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SUPPLEMENTARY MATERIALS

The following pages contain supplementary information and materials related to my application package for the for the Earth Science Tenure Track Assistant Professor in the Department of Environmental and Ocean Sciences at the University of San Diego:

- Copy of Official Graduate Transcripts from the University of California, Berkeley

- Sample lecture/lab slides from courses taught at MIT, the University of California, Berkeley, and at a Summer School on Water Research

- Copy of student teaching evaluations from two courses taught at the University of California, Berkeley in 2011 and 2009

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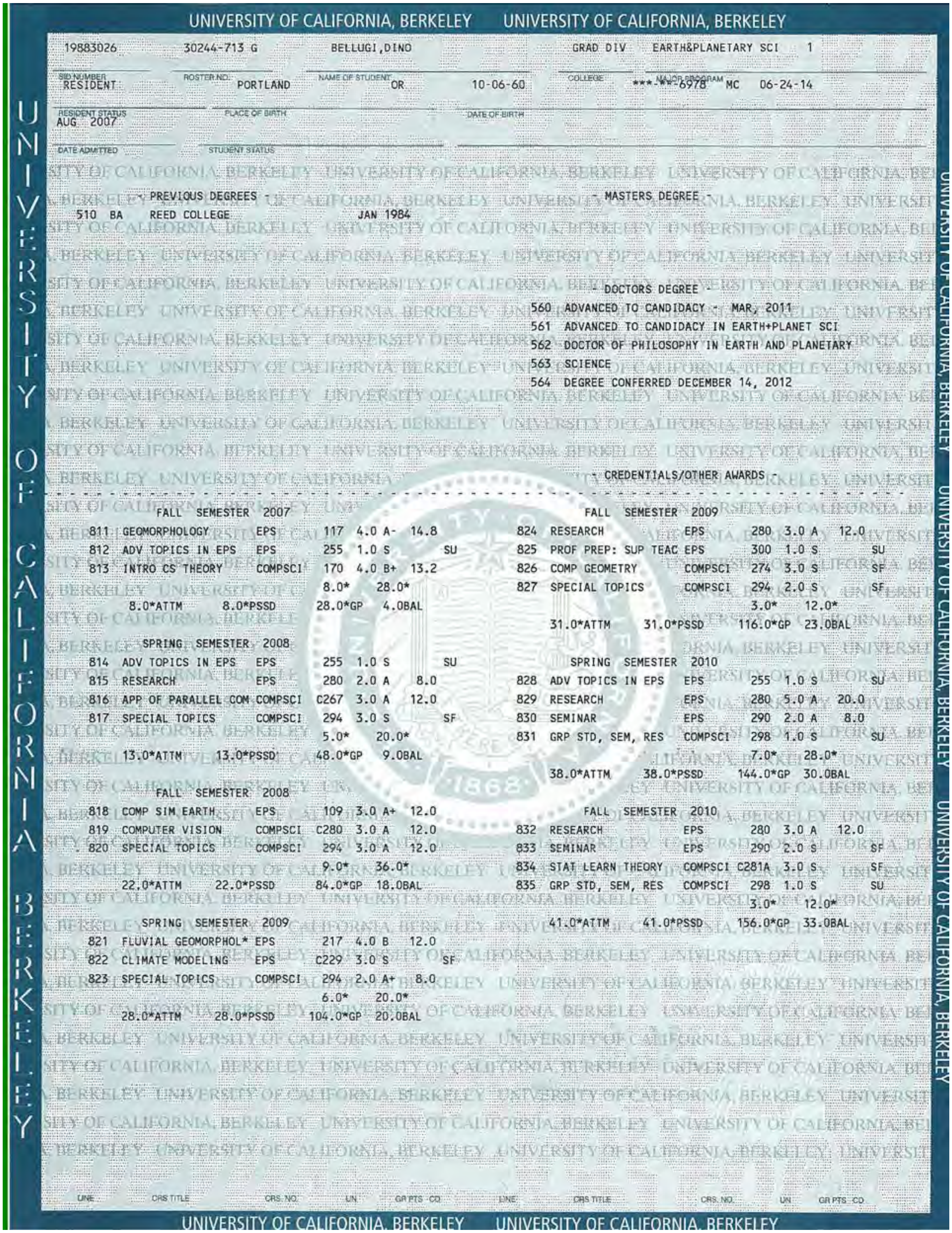
GRADUATE TRANSCRIPT



UNIVERSITY OF CALIFORNIA, BERKELEY UNIVERSITY OF CALIFORNIA, BERKELEY

SID NUMBER: 19883026	ROSTER NO.: 30244-713 G	NAME OF STUDENT: BELLUGI,DINO	COLLEGE: GRAD DIV	MAJOR PROGRAM: EARTH&PLANETARY SCI 1
RESIDENT STATUS: RESIDENT	PLACE OF BIRTH: PORTLAND OR	DATE OF BIRTH: 10-06-60	***-**-6978 MC 06-24-14	
DATE ADMITTED: AUG 2007	STUDENT STATUS:			

\- PREVIOUS DEGREES -
510 BA REED COLLEGE JAN 1984

\- MASTERS DEGREE -

\- DOCTORS DEGREE -
560 ADVANCED TO CANDIDACY - MAR, 2011
561 ADVANCED TO CANDIDACY IN EARTH+PLANET SCI
562 DOCTOR OF PHILOSOPHY IN EARTH AND PLANETARY
563 SCIENCE
564 DEGREE CONFERRED DECEMBER 14, 2012

\- CREDENTIALS/OTHER AWARDS -

FALL SEMESTER 2007
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812 ADV TOPICS IN EPS EPS 255 1.0 S SU
813 INTRO CS THEORY COMPSCI 170 4.0 B+ 13.2
8.0* 28.0*
8.0*ATTM 8.0*PSSD 28.0*GP 4.0BAL

SPRING SEMESTER 2008
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815 RESEARCH EPS 280 2.0 A 8.0
816 APP OF PARALLEL COM COMPSCI C267 3.0 A 12.0
817 SPECIAL TOPICS COMPSCI 294 3.0 S SF
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827 SPECIAL TOPICS COMPSCI 294 2.0 S SF
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831 GRP STD, SEM, RES COMPSCI 298 1.0 S SU
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FALL SEMESTER 2010
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3.0* 12.0*
41.0*ATTM 41.0*PSSD 156.0*GP 33.0BAL

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SAMPLE LECTURE SLIDES

The following pages contain sample lecture/lab slides from courses taught at the Massachusetts Institute of Technology, the University of California, Berkeley, and from one of three shourt courses given at a Summer School on Water Research:

- Guest lecturer, MIT, Fall 2013, EAPS 12.163 "Geomorphology". Instructor: Prof. Taylor Perron. Lecture on shallow landslide prediction.

- Instructor, UCB, Spring 2011, EPS209 "Matlab Applications in Earth Science", co-developed and co-taught with Prof. Burkhard Militzer. Lecture and lab on image segmentation, lecture and lab on GIS, Mapping Toolbox, and WMS.

- Lecturer, 2nd International Summer School on Water Research, "Landslide modeling and Early Warning Systems", Summer 2013. Lecture on support Vector Machine Classification for Earth Science applications.

Shallow landslides

Outline:

Slope stability
  - Mohr-Coulomb failure
  - Simple theory
  - Implications for failure

Hydrological model
  - Darcy's law
  - Simple model for wetness

Shalstab
  - Theory
  - Application

If we have time:

- Debris flows potential
- Landslide size
  - 3-D stability model
  - Search algorithm

[Photo: Bill Dietrich]

Shallow landslides

[Photo: Bill Dietrich]

Shallow landslides

[Photo: John Stock]

Shallow landslides

Near Rio de Janeiro, Brasil, January 2011, ~1500 casualties

[Photo: Bill Dietrich]

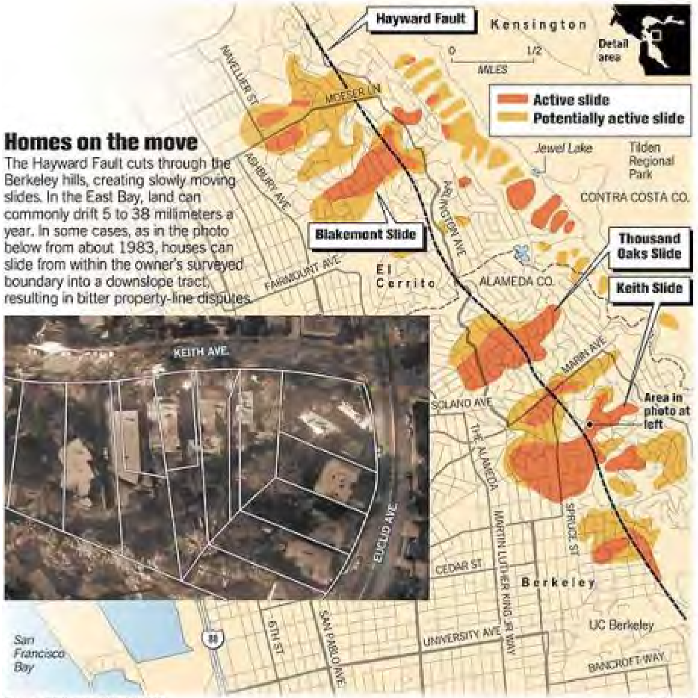
Shallow landslides

168号線地すべり

Marin Co., CA 1998

Marin Co., CA 1998

Deep seated landslides



Homes on the move

The Hayward Fault cuts through the Berkeley hills, creating slowly moving slides. In the East Bay, land can commonly drift 5 to 38 millimeters a year. In some cases, as in the photo below from about 1983, houses can slide from within the owner's surveyed boundary into a downslope tract, resulting in bitter property-line disputes.

Source: ESRI, GDT, USGS, FEMA

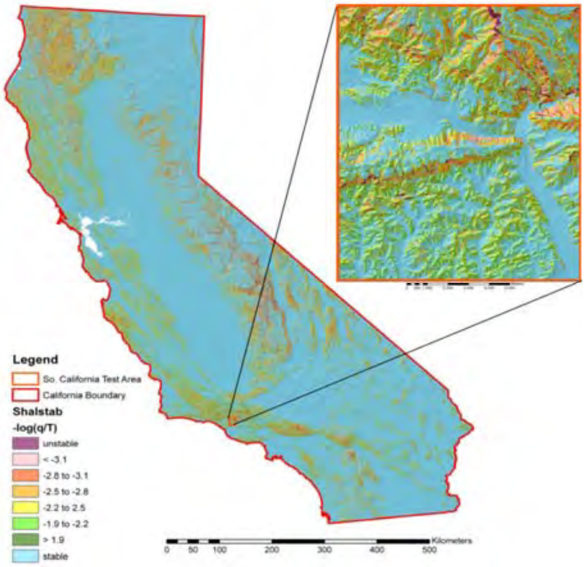
The Chronicle

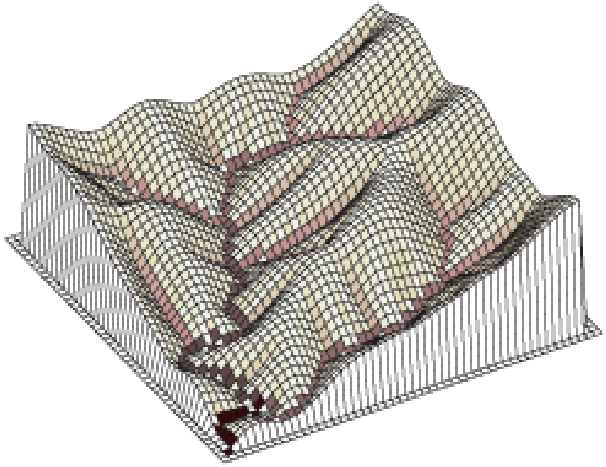
Laguna Beach 2005

La Jolla 2007

Risk Prediction

Landscape Evolution





[Dietrich & Montgomery, 1998; Bellugi, et al., 2011; Stock & Bellugi, 2011]

[Tucker and Bras, 1998]

Ridge and valley topography In the Oregon Coast Range

5 Key Questions

Where?

When?

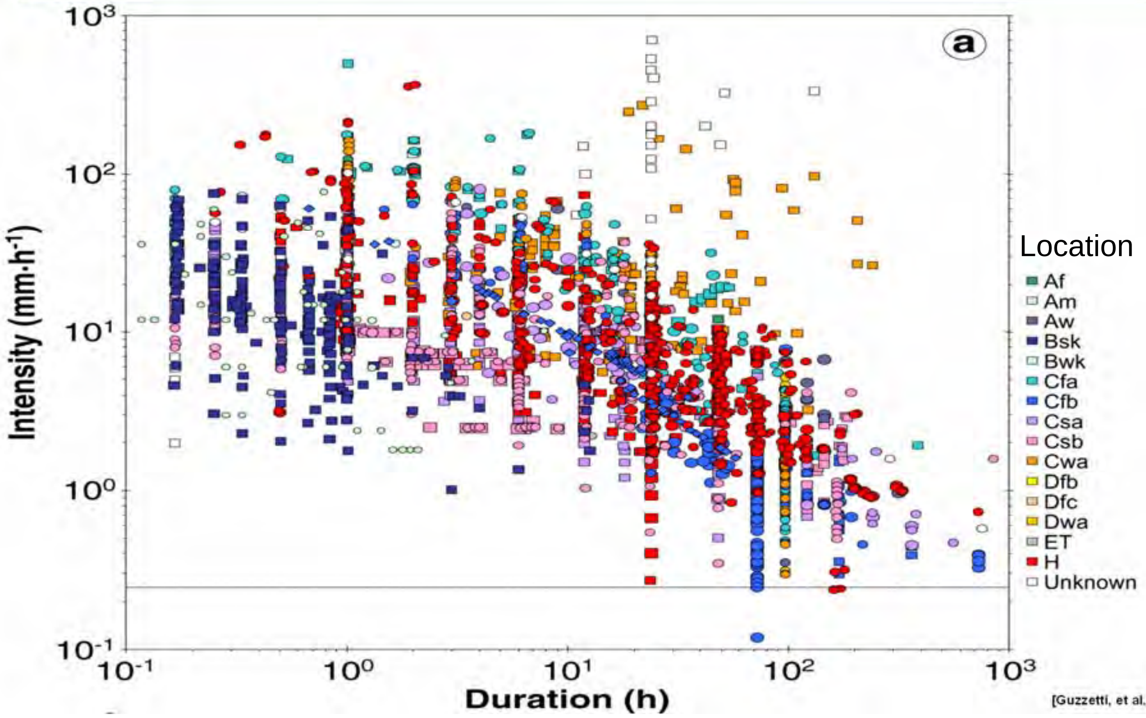
How big?

How far?

Mass gain or loss?

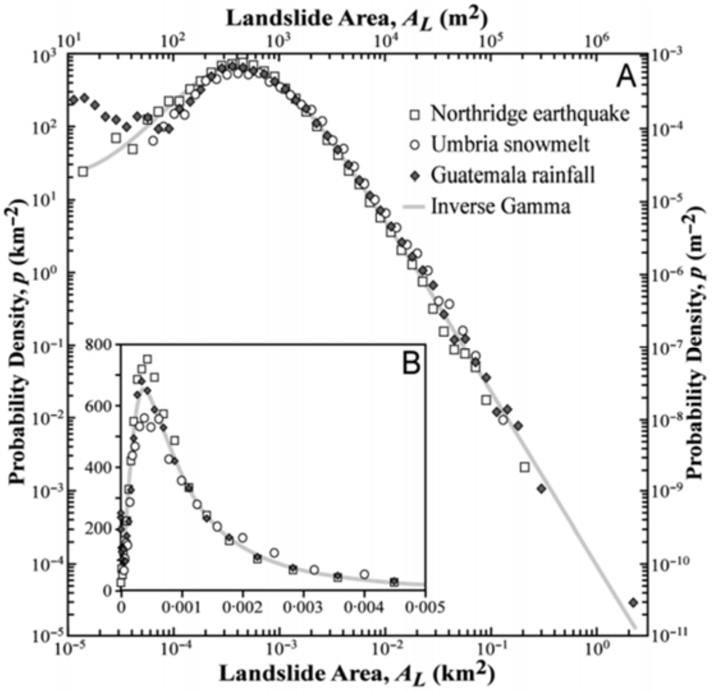
Laguna Beach, California, 1998

What we know: when?



[Guzzetti, et al., 2008]

What we know: how big?



Malamud, et al., 2005]

5 Key Questions

Where?

When?

How big?

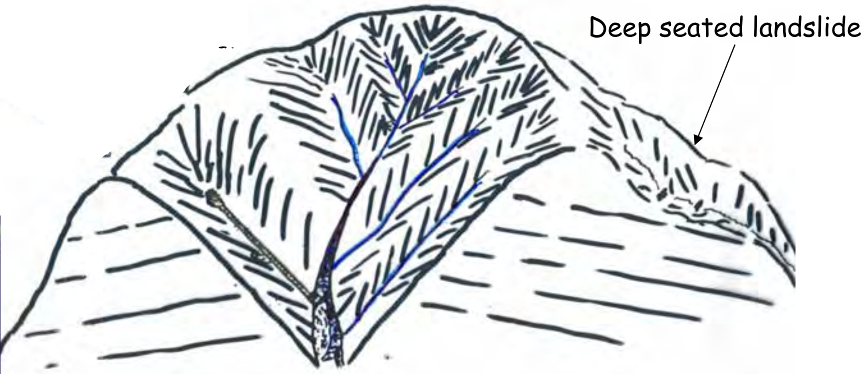
How far?

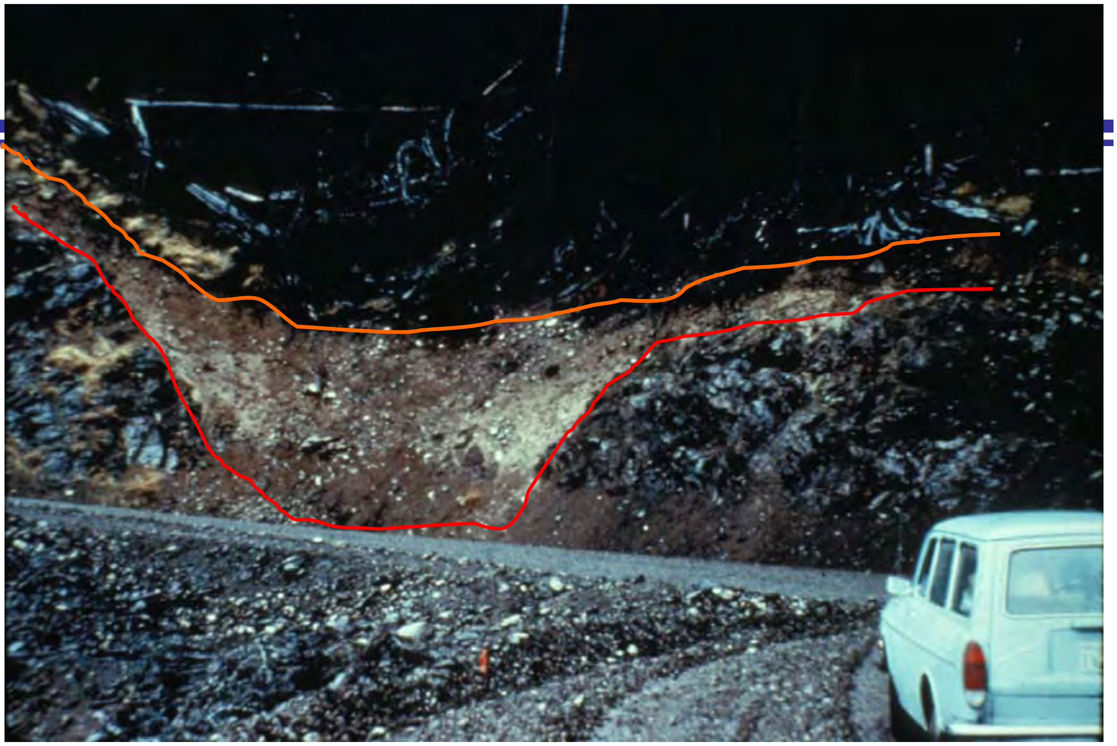
Mass gain or loss?

Laguna Beach, California, 1998

Ridge and valley topography In the Oregon Coast Range

Example: processes shaping the Oregon Coast Range





Shallow Landslides

[Dietrich]

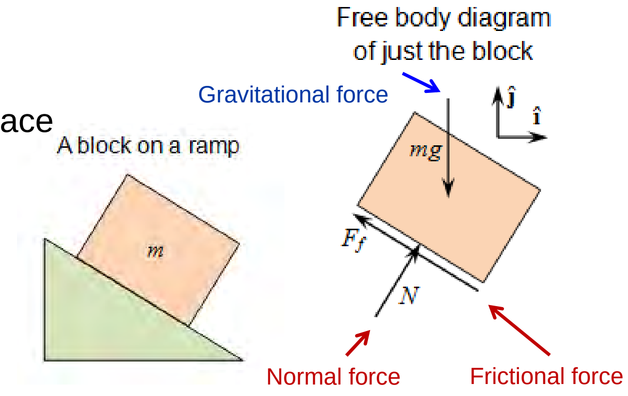
Mohr-Coulomb Failure

$$\tau = \sigma' \tan\phi + C$$

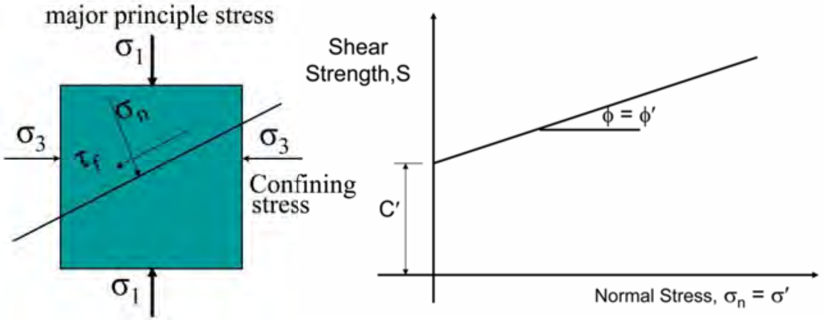
Shear strength Normal stress (effective) Friction angle Cohesion

Assumptions:
- Brittle materials
- Contact area << total contact surface
- Normal force ∝ contact area

Questions:
- When not applicable?
- How is it parameterized?



Mohr-Coulomb Failure



$$\tau = \sigma' \tan\phi + C$$

Assumptions and limitations:
- Shear is the failure mechanism, occurring at peak strength
- Other mechanisms: strain-induced liquefaction
- Direction of failure doesn’t always agree with observations
- Friction and cohesion act in unison
- Strength-stress relationship often not linear

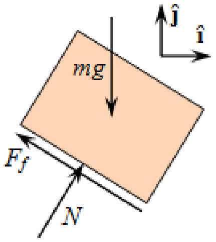
Mohr-Coulomb for Landslides

$$\tau = C + (\sigma - u)\tan\phi$$

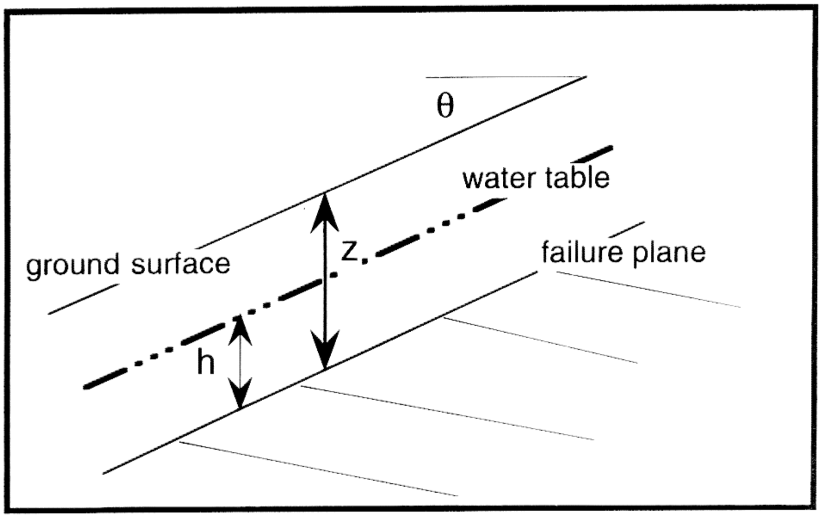
- τ: Downslope Soil weight
- C: Cohesion (soil and roots)
- σ: Normal stress (increases friction)
- u: Pore pressure (reduces friction)
- ϕ: Friction angle (angle of repose)

Valid immediately before failure

A simple implementation:
- Ignore cohesion for now
- Pore pressure ≈ normal component of the weight of the water present in the soil
- Compute the down-slope and slope-normal forces
- Use a typical value for phi (e.g. 30-45 degrees)



Infinite Slope Framework



Key assumptions:

- Infinite inclined plane with angle θ
- Failure plane parallel to the surface
- Failure occurs at soil/bedrock boundary
- Flow parallel to the failure boundary

Infinite Slope

$$\tau = \cancel{C} + (\sigma - u)\tan\phi$$

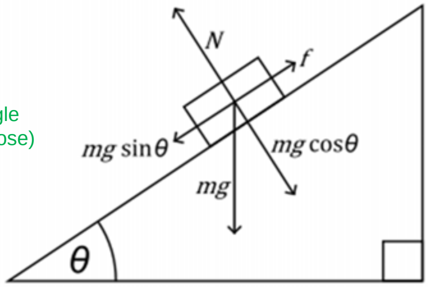
Downslope Soil weight

Cohesion (soil and roots)

Normal stress (increases friction)

Pore pressure (reduces friction)

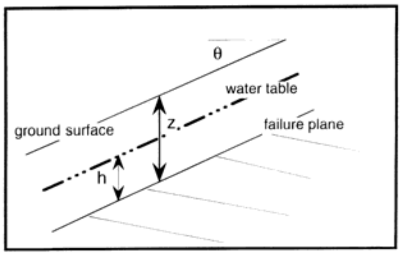
Friction angle (angle of repose)



Add force decomposition (sinθ and cosθ):

- Downslope weight = $\rho_s gz\cos\theta\sin\theta$
- Normal stress = $\rho_s gz\cos^2\theta$
- Pore pressure = $\rho_w gh\cos^2\theta$

Where ρ_s and ρ_w are soil and water bulk density.



We get:

$$\boxed{\rho_s gz\cos\theta\sin\theta = (\rho_s gz\cos^2\theta \ - \rho_w gh\cos^2\theta)\tan\phi}$$

[Dietrich et al., 1994, 1995, 2001, etc.]

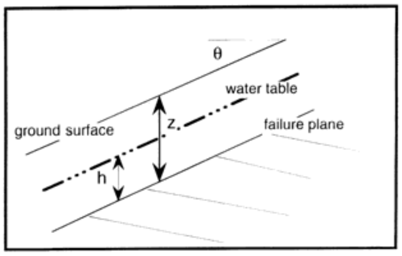
Instability Condition

$$\boxed{\rho_s gz\cos\theta\sin\theta = (\rho_s gz\cos^2\theta \ - \rho_w gh\cos^2\theta)\tan\phi}$$

$$\boxed{\frac{h}{z} = \frac{\rho_s}{\rho_w}\left(1 - \frac{\tan\theta}{\tan\phi}\right)}$$

Note: $\boxed{0 \le \frac{h}{z} \le 1}$

(when stress=strength)

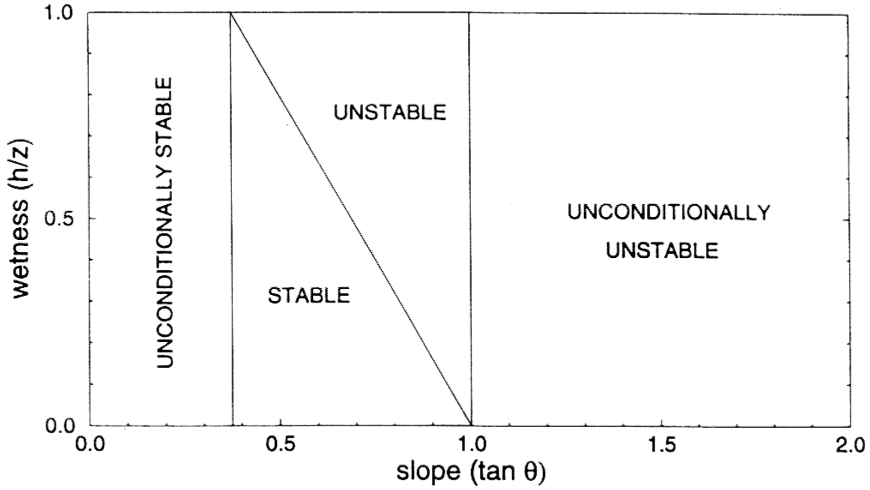


Implications:

- Soil does not need to be fully saturated for failure!
- Four cases:
  - "Unconditionally stable": failure requires h/z > 1, i.e.: $\boxed{\tan\theta \le \tan\phi(1 - (\rho_s - \rho_w))}$
  - "Unconditionally unstable": slope > than friction angle (h/z < 0)
  - "Stable": h/z < *R.H.S.*
  - "Unstable": h/z > *R.H.S.*

[Montgomery and Dietrich, 1994]

Instability Condition



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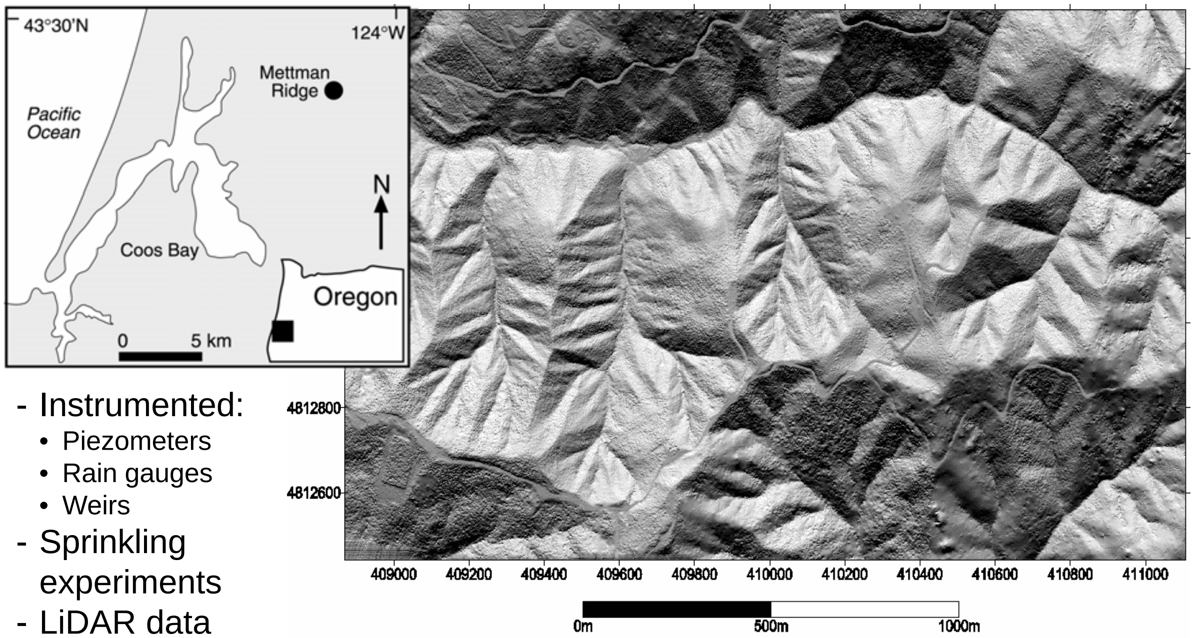
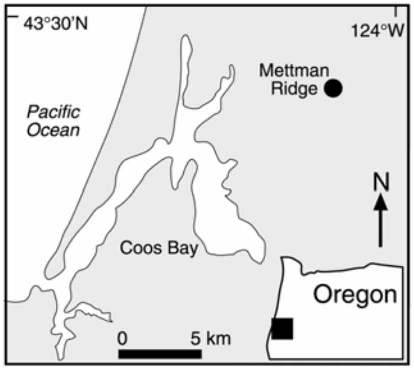
[Montgomery and Dietrich, 1994]

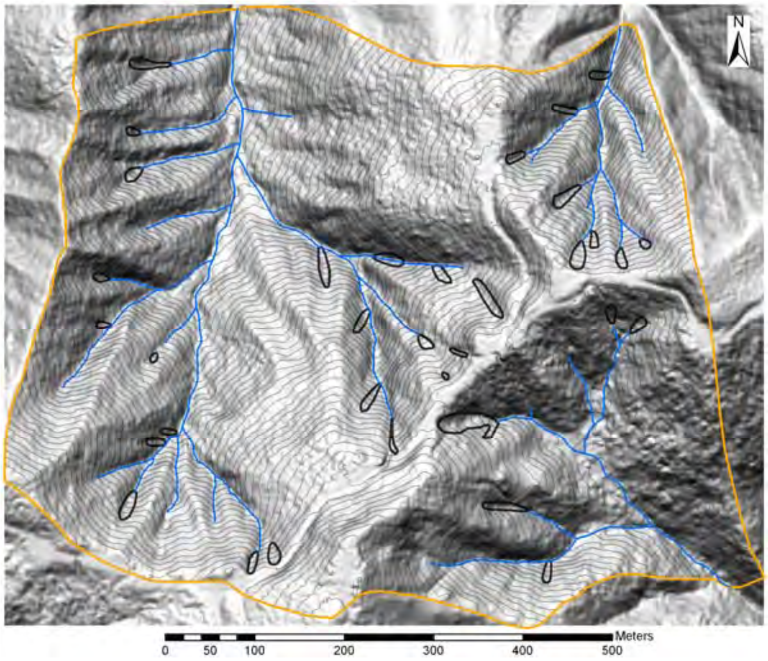
Coos Bay Field Site



- Instrumented:
  - Piezometers
  - Rain gauges
  - Weirs
- Sprinkling experiments
- LiDAR data
- Mapped landslides

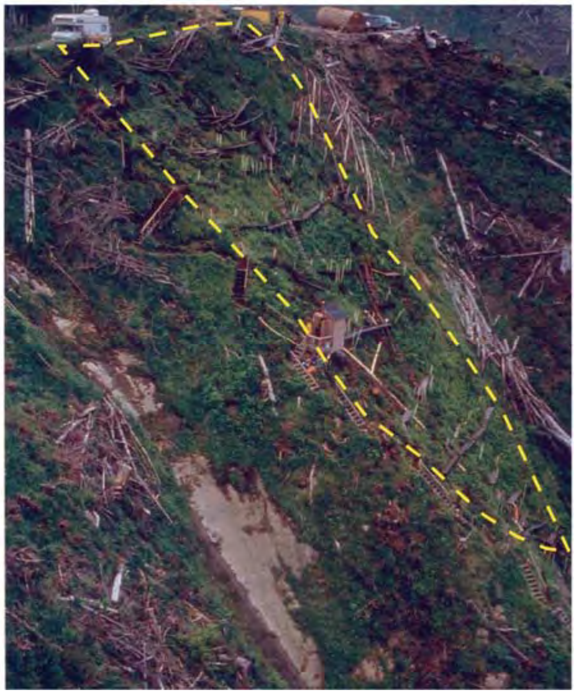
Coos Bay Field Site

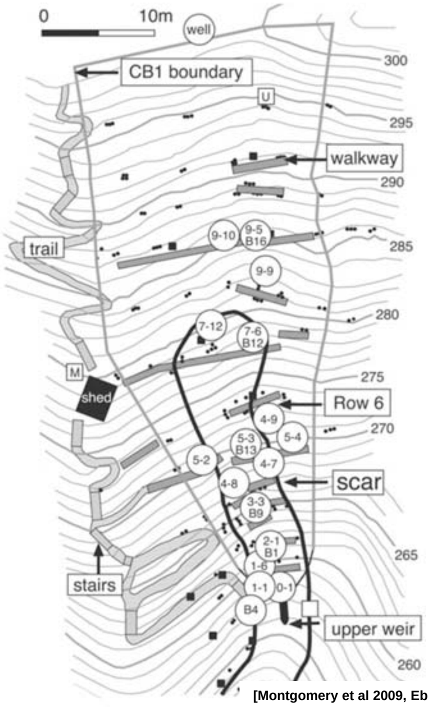




- Instrumented:
  - Piezometers
  - Rain gauges
  - Weirs
- Sprinkling experiments
- LiDAR data
- Mapped landslides

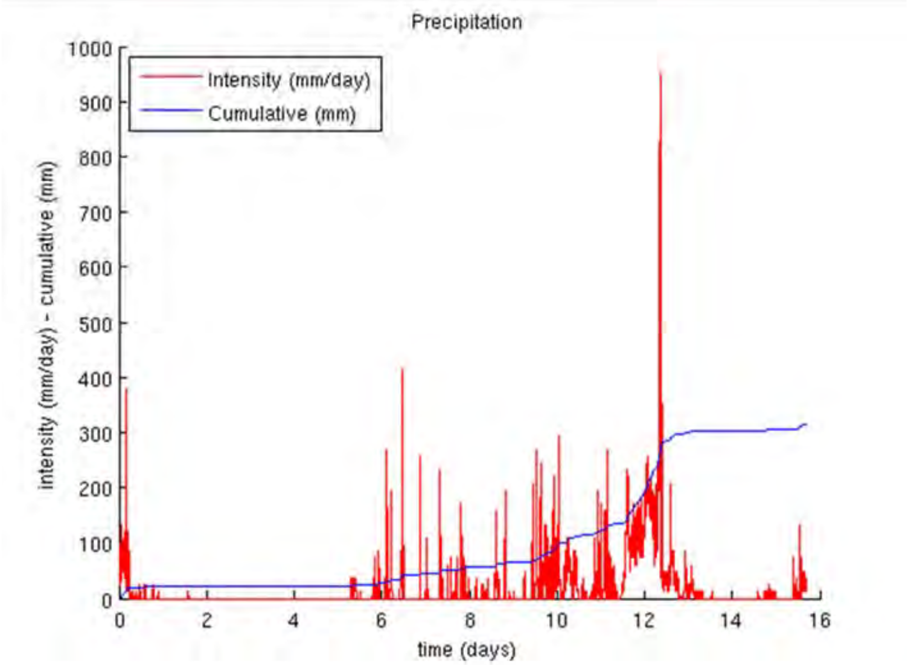
Coos Bay Instrumentation





[Montgomery et al 2009, Ebel et al 2007]

Coos Bay Rain



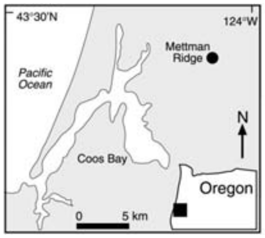
November 12-20, 1996

[Montgomery et al., 2009]

Coos Bay Before and After

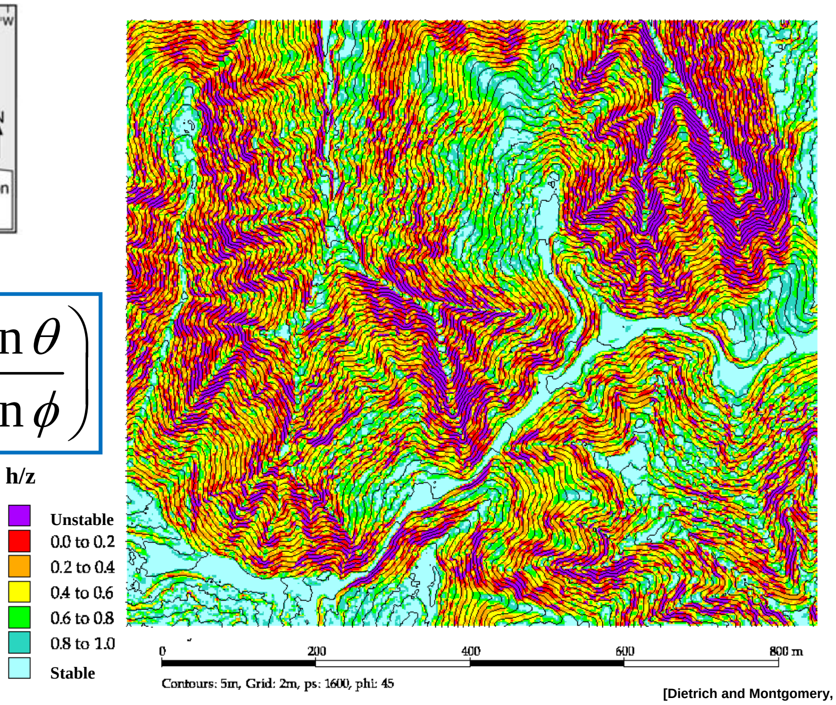
[Photos: Dietrich]

h/z for Slope Instability



Coos Bay field site

$$\frac{h}{z} = \frac{\rho_s}{\rho_w}\left(1 - \frac{\tan\theta}{\tan\phi}\right)$$

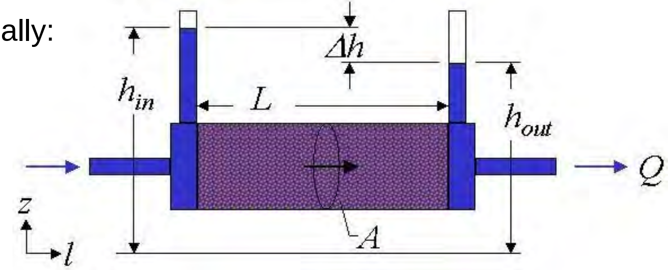


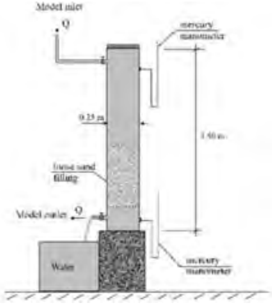
[Dietrich and Montgomery, 1998]

How do we compute h/z?

Hydrology: Darcy's Law

Empirically:





Discharge [L^3/T]:

$$Q \propto A\frac{h_1 - h_2}{L}$$

Velocity [L/T]:

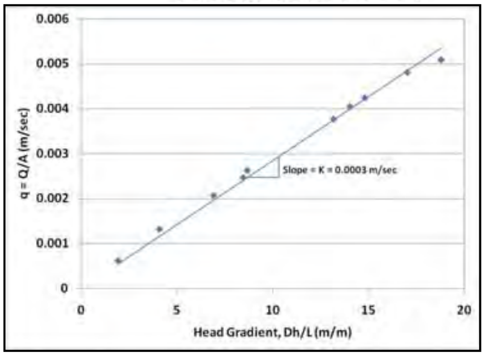
$$V = \frac{Q}{A} = K_s\frac{\Delta h}{L}$$

Velocity:

$$V = \frac{Q}{A} = K_s\left(\frac{\partial\psi}{\partial l} + \frac{\partial z}{\partial l}\right)$$

If flow is uniform:

$$V = K_s\frac{\partial z}{\partial l} = K_s \sin\theta$$



Assumptions:

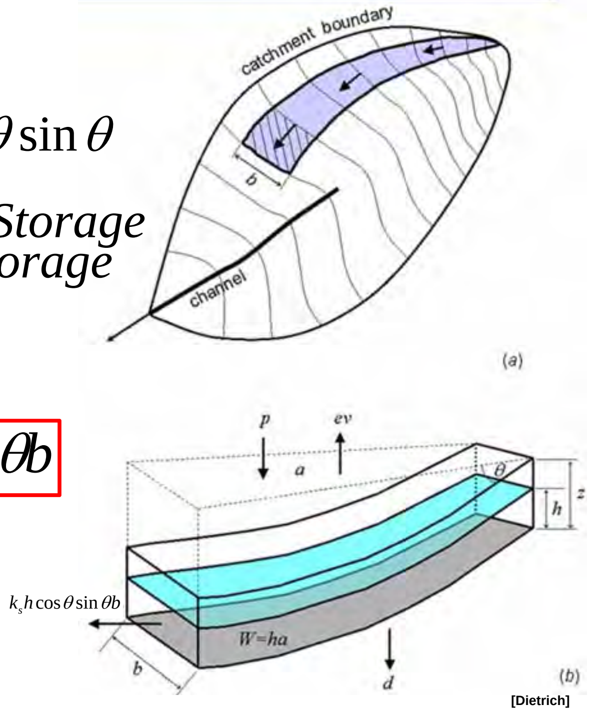
- Laminar flow (non-turbulent, kinetic energy ignored)
- Over areas much larger than pore sizes (~ 10x)
- Constant fluid properties (temperature, density, etc.)

θ: slope angle [L/L]

k$_s$: the hydraulic conductivity [L/T]

http://biosystems.okstate.edu/Darcy

Hydrology: Darcy's Law



[Dietrich]

Velocity of fluid: $V = k_s \sin\theta$

Flux (per unit width): $Vh\cos\theta = k_s h \cos\theta \sin\theta$

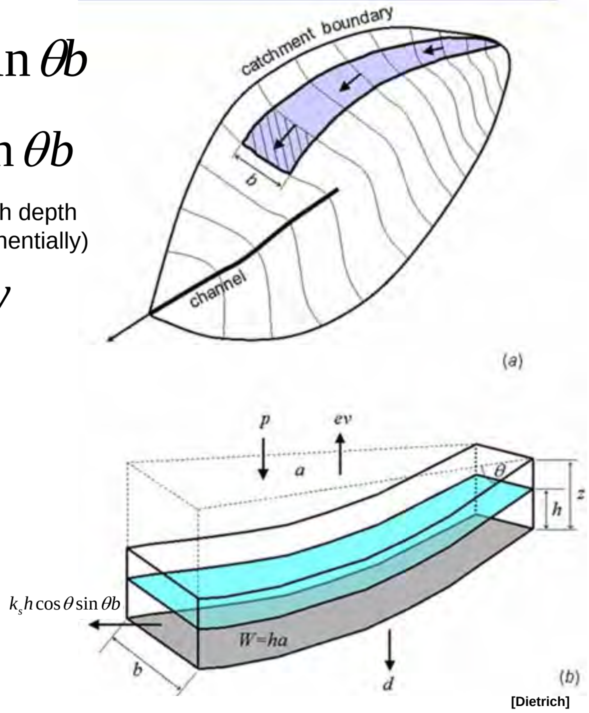
Conservation of mass:
$$Input - Output = \Delta Storage$$
$$qa - Output = \Delta Storage$$

At steady state:
$$qa - Output = 0$$
$$qa = Output$$

$$\Rightarrow \quad \boxed{qa = k_s h \cos\theta \sin\theta b}$$

sinθ: the head gradient [L/L]
k_s: the saturated conductivity [L/T]
hcosθ: the (normal) saturated thickness [L]
q: effective precipitation (p-ev-d) [L/T]
a: horizontal surface area [L^2]

Steady State Subsurface Flow



[Dietrich]

Steady state subsurface flow: $qa = k_s h \cos\theta \sin\theta b$

At saturation (h=z): $qa = k_s z \cos\theta \sin\theta b$

Note that: $k_s = f(y)$ declines with depth (often exponentially)

Let: $T = \int k_s \cos\theta dy$

Approximation: $T \approx k_s z \cos\theta$

$$\Rightarrow \quad \boxed{qa = T \sin\theta b}$$

q: effective precipitation (p-ev-d) [L/T]
sinθ: the head gradient [L/L]
k_s: the saturated conductivity [L/T]
T: the transmissivity [L^2/T]
zcosθ: the (normal) soil thickness [L]
hcosθ: the (normal) saturated thickness [L]

Saturation Subsurface Flow

Steady state subsurface flow:

$$qa = T\sin\theta b$$

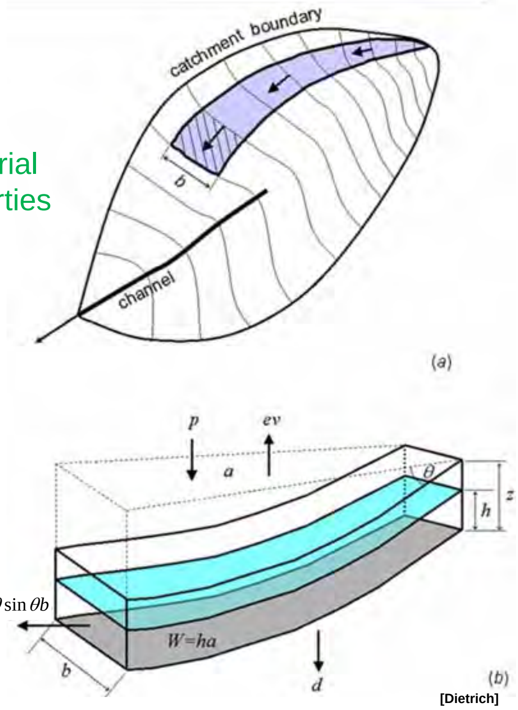
At saturation:

$$\frac{a}{b\sin\theta} = \frac{T}{q}$$

Material properties

Topographic index

Effective precipitation



[Dietrich]

q: effective precipitation (p-ev-d) [L/T]
sinθ: the head gradient [L/L]
k_s: the saturated conductivity [L/T]
T: the transmissivity [L^2/T]
zcosθ: the (normal) soil thickness [L]
hcosθ: the (normal) saturated thickness [L]

Topographic Index

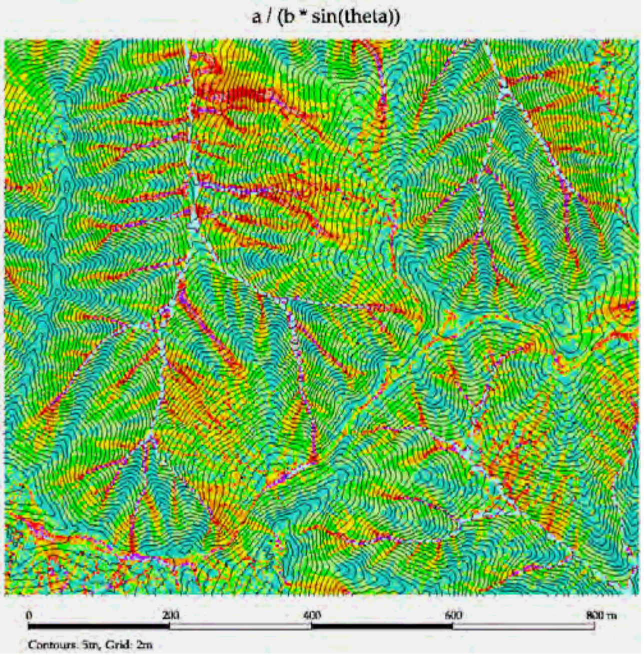
$$\frac{a}{b\sin\theta} = \frac{T}{q}$$

Material properties

Topographic index

Effective precipitation

a/(b*sin(theta)) (m)
- 🟦 Above 4000
- 🟪 2000 - 4000
- 🟧 1000 - 2000
- 🟥 500 - 1000
- 🟧 250 - 500
- 🟨 100 - 250
- 🟩 50 - 100
- 🟩 25 - 50
- 🟦 0 - 25



[Dietrich and Montgomery, 1998]

Drainage Area

$$\frac{a}{b\sin\theta}=\frac{T}{q}$$

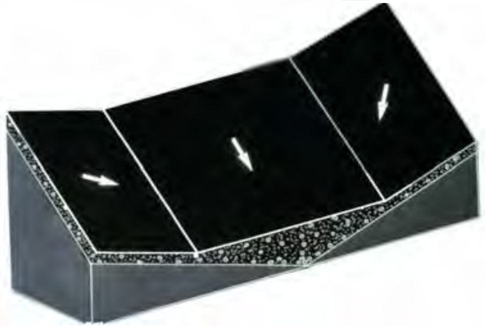
Material properties

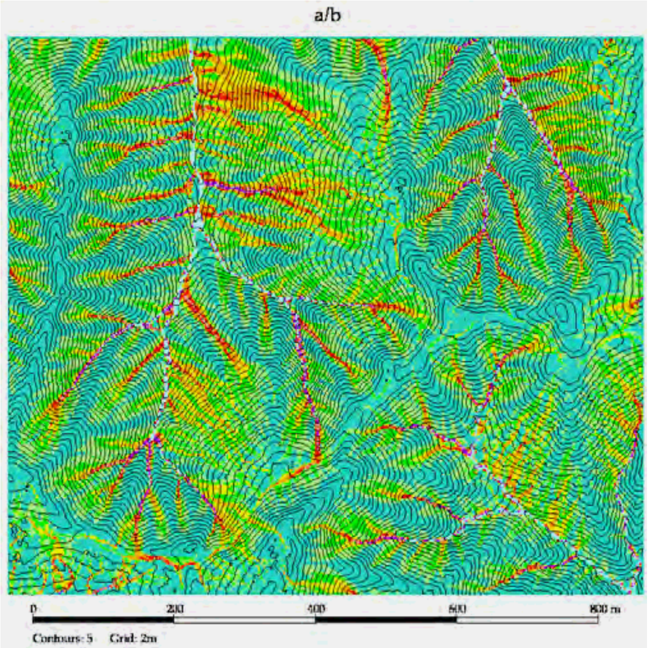
Topographic index

Effective precipitation

a/b (m)

🟦	Above 4000
🟪	2000 - 4000
🟧	1000 - 2000
🟥	500 - 1000
🟧	250 - 500
🟨	100 - 250
🟩	50 - 100
🟩	25 - 50
🟦	0 - 25





[Dietrich and Montgomery, 1998]

Simple model for relative saturation

At saturation:

Topographic index

$$\frac{a}{b\sin\theta}=\frac{T}{q}$$

Material properties

Effective precipitation

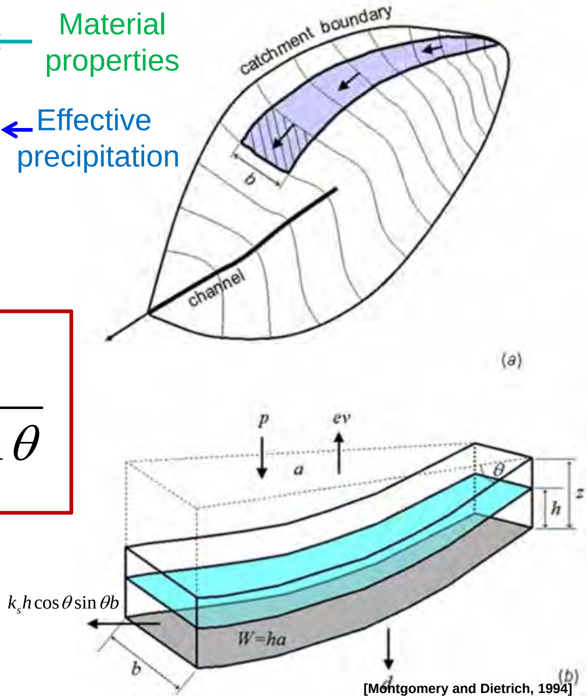
In general:

$$\frac{a}{b\sin\theta}=\frac{T}{q}\frac{h}{z}$$

Relative saturation ("wetness")

$$\frac{h}{z}=\frac{q}{T}\frac{a}{b\sin\theta}$$

a/b: drainage area per cell width [L]
h/z: relative saturation [L/L]
q: effective precipitation (p-ev-d) [L/T]
sinθ: the head gradient [L/L]
T: the transmissivity [L^2/T]



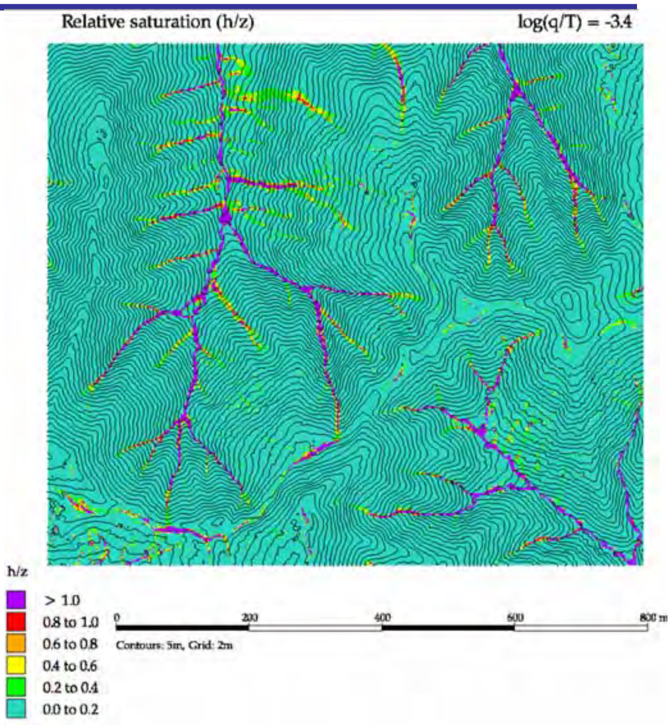
[Montgomery and Dietrich, 1994]

Relative Saturation

$$\frac{h}{z}=\frac{q}{T}\frac{a}{b\sin\theta}$$

log (q/T) (1/m)	q/T (1/m)	q (m/day) (for T=65m^2/day)
-3.4	0.00040	0.026
-3.1	0.00079	0.05135
-2.8	0.00158	0.1027
-2.5	0.00316	0.2054
-2.2	0.00633	0.41145
-1.9	0.01266	0.818

Steady state precipitation (generally not reached!)



Shalstab

Slope stability model: $$\frac{h}{z}=\frac{\rho_s}{\rho_w}\left(1-\frac{\tan\theta}{\tan\phi}\right)$$ ← Instability condition

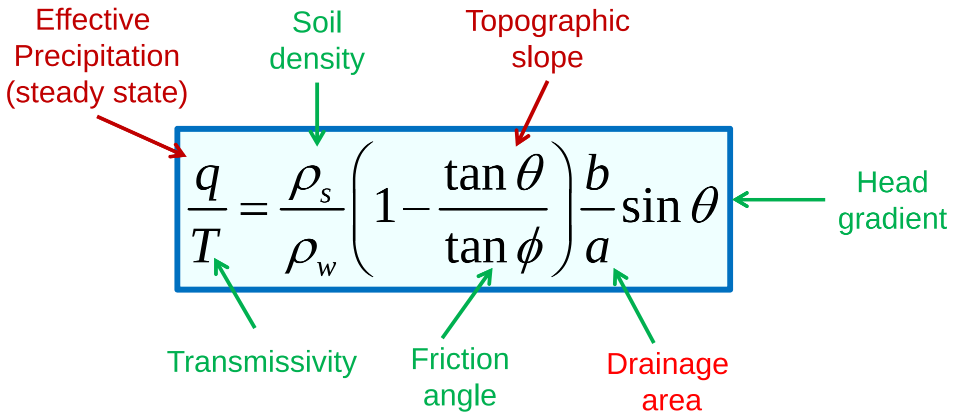
Hydrological model: $$\frac{h}{z}=\frac{q}{T}\frac{a}{b\sin\theta}$$ ← Relative saturation

Couple the models: $$\frac{q}{T}\frac{a}{b\sin\theta}=\frac{\rho_s}{\rho_w}\left(1-\frac{\tan\theta}{\tan\phi}\right)$$

Shalstab: $$\frac{q}{T}=\frac{\rho_s}{\rho_w}\left(1-\frac{\tan\theta}{\tan\phi}\right)\frac{b}{a}\sin\theta$$

[Montgomery and Dietrich, 1994]

Shalstab: a compact simple model



Effective Precipitation (steady state)

Soil density

Topographic slope

$$\frac{q}{T} = \frac{\rho_s}{\rho_w}\left(1-\frac{\tan\theta}{\tan\phi}\right)\frac{b}{a}\sin\theta$$

Head gradient

Transmissivity

Friction angle

Drainage area

🟩 : Increasing these values increases stability

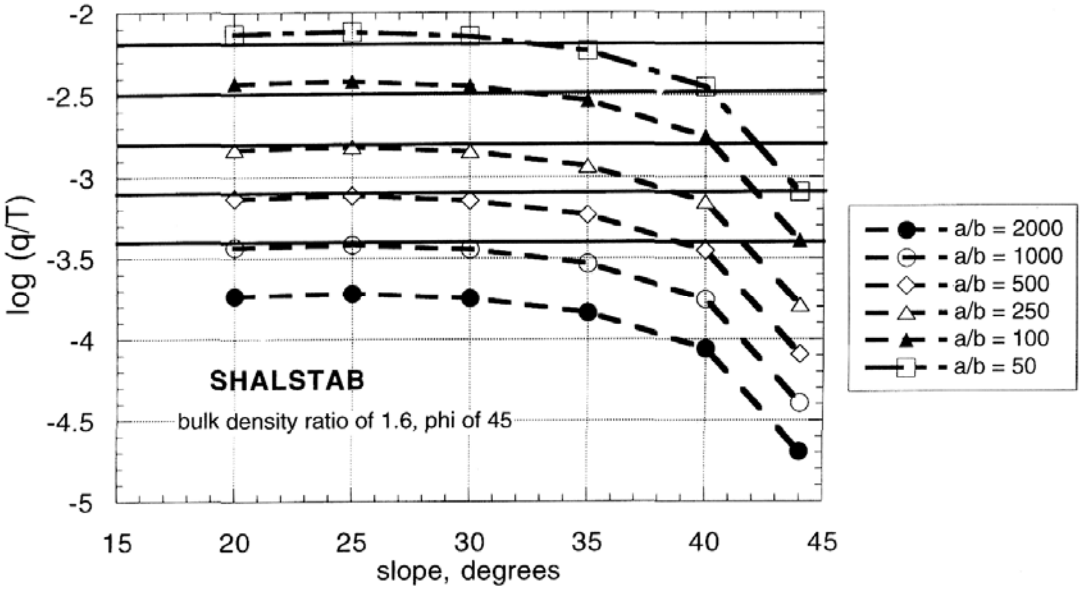
🟥 : Increasing these values increases instability

Questions:
- What is the role of slope?
- What can Shalstab tell us?

For documentation and software go to:
http://calm.geo.berkeley.edu/~geomorph

[Montgomery and Dietrich, 1994]

Controls on instability: Slope vs. Area

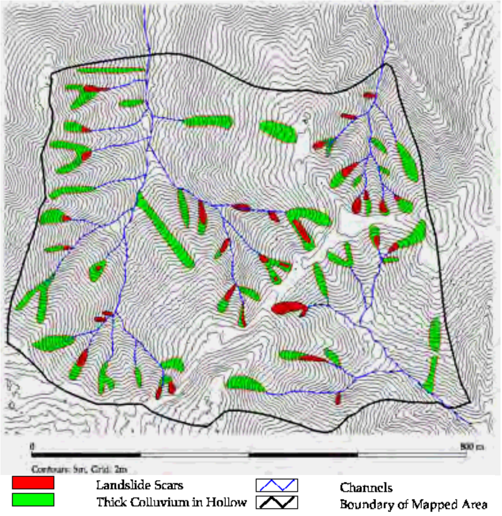


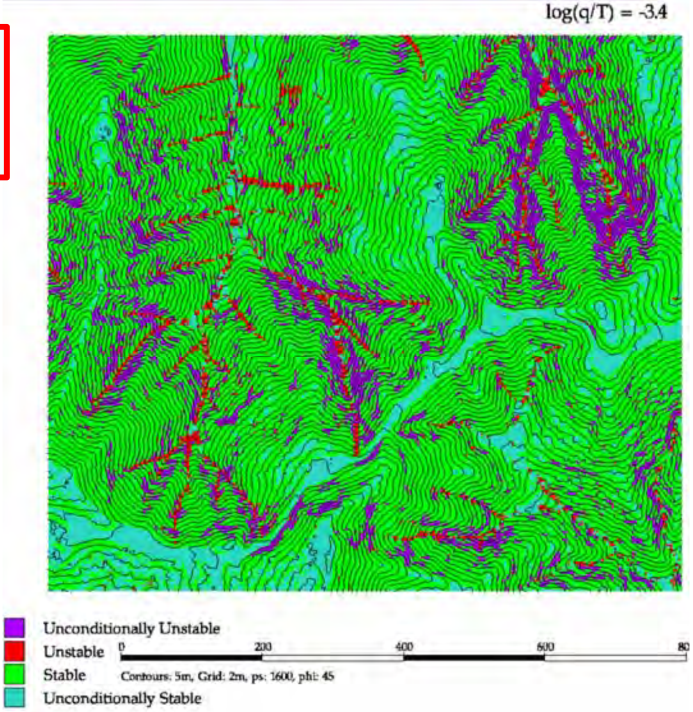
- Below 30 degrees area controls instability
- Slope becomes important above 30 degrees

[Dietrich and Montgomery, 1998]

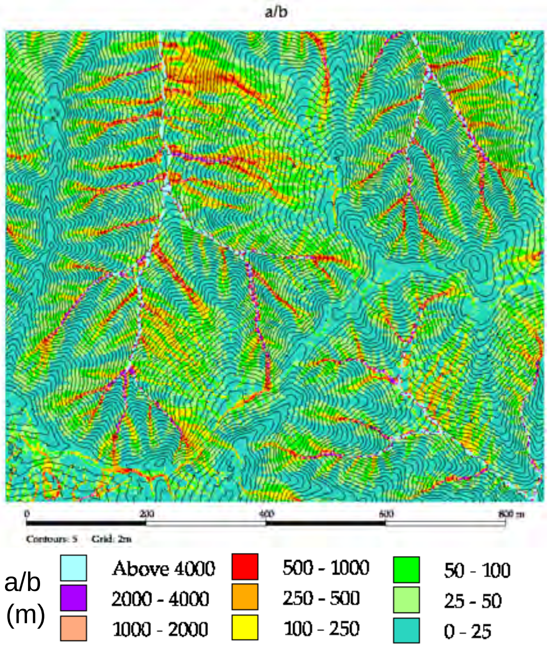
Relative instability potential

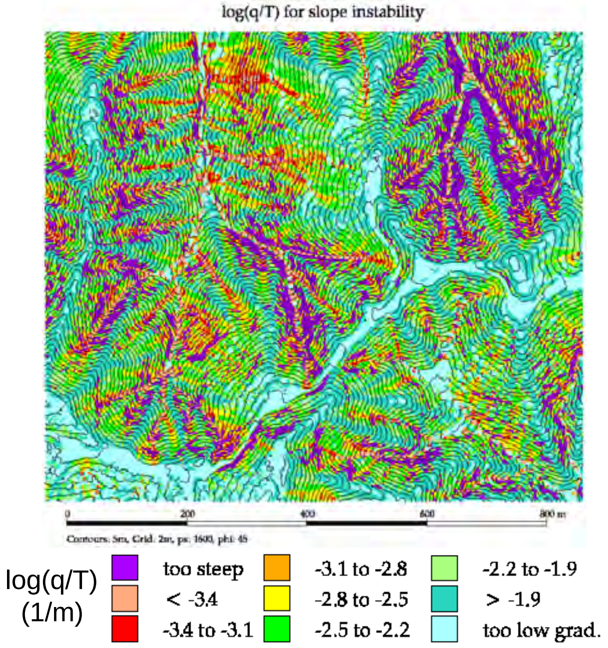
$$\frac{q}{T}=\frac{\rho_s}{\rho_w}\left(1-\frac{\tan\theta}{\tan\phi}\right)\frac{b}{a}\sin\theta$$





Controls on instability: Slope vs. Area

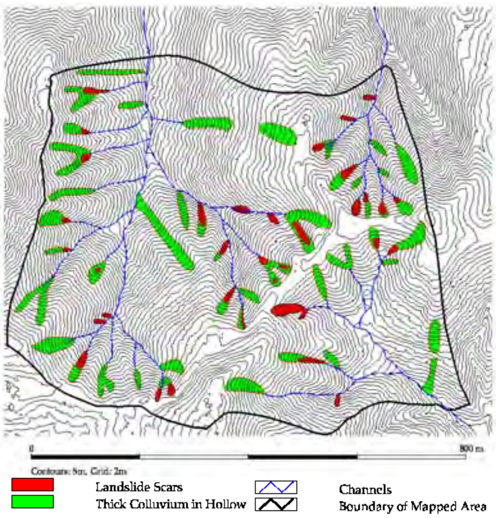


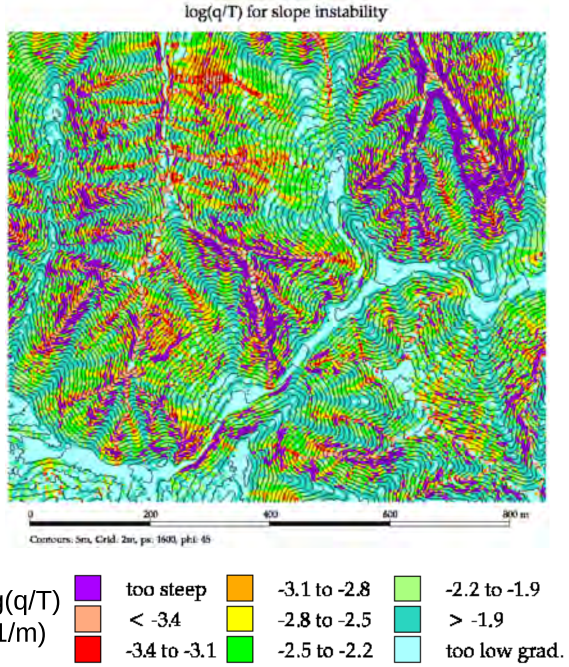


- Drainage area dominates, until the slopes become steep!

[Dietrich and Montgomery, 1998]

Shalstab: Performance





Parameters:

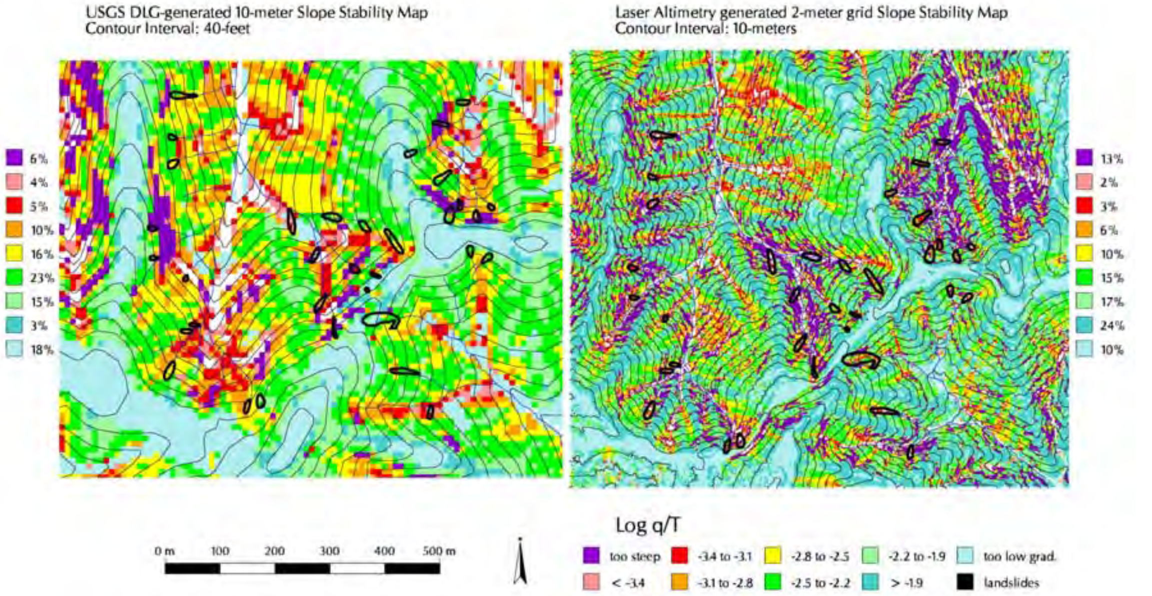
- ρ_s/ρ_w = 1.6
- ϕ = 45°

log(q/T)
(1/m)

- No soil depth
- No cohesion
- Over prediction!

[Dietrich and Montgomery, 1998]

Controls on instability: Resolution



High resolution vs.
low resolution data:

- Number of captured landslides
- Percent of landscape affected

[Dietrich et al., 2001]

5 Key Questions

Where?

How big?

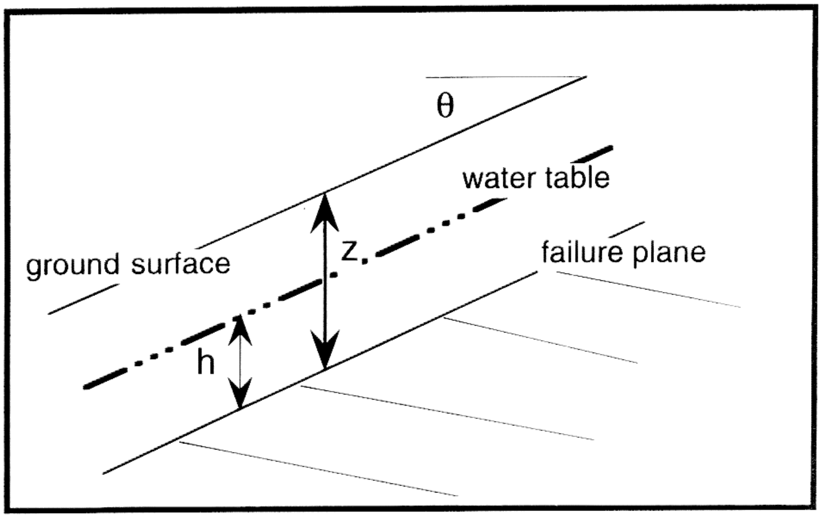
How far?

When?

Mass gain or loss?

Laguna Beach, California, 1998

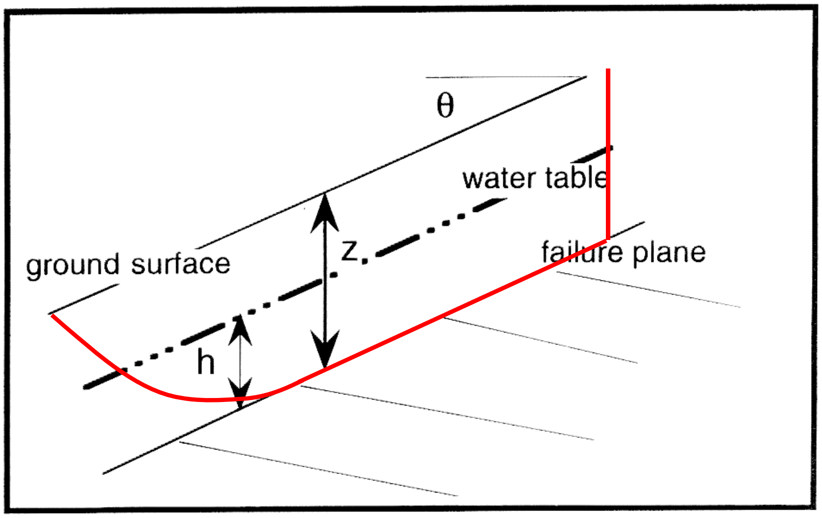
Infinite Slope Framework



Key assumptions:

- Infinite inclined plane with angle θ
- Failure plane parallel to the surface
- Failure occurs at soil/bedrock boundary
- Flow parallel to the failure boundary

Infinite Slope Framework



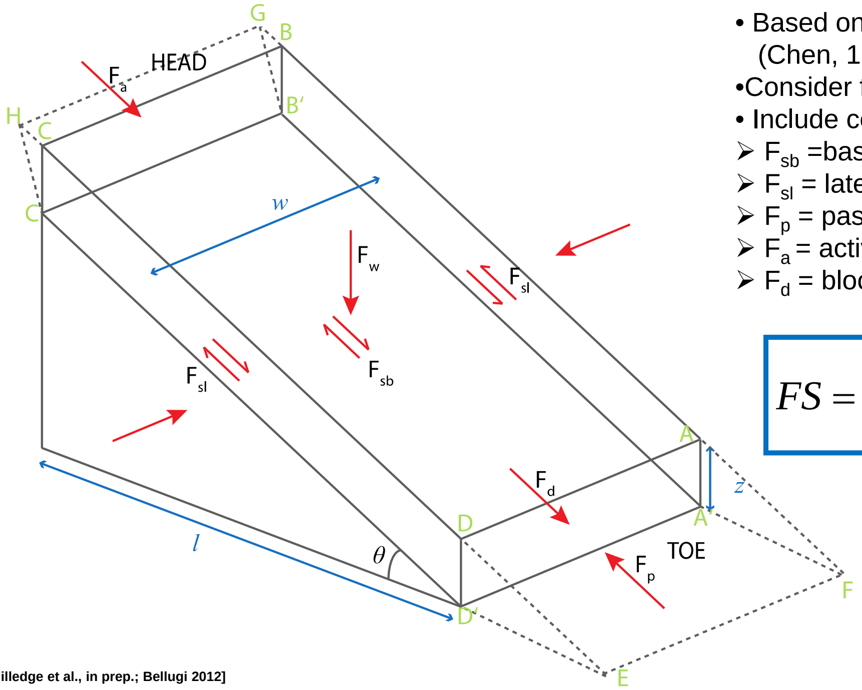
Neglects:
- Normal forces from upslope and downslope boundaries
- Sidewall friction
- Cohesion on the lateral boundaries

Landslide Size

[Schmidt, et al., 2001]

Lateral reinforcement matters

3-D Slope stability model



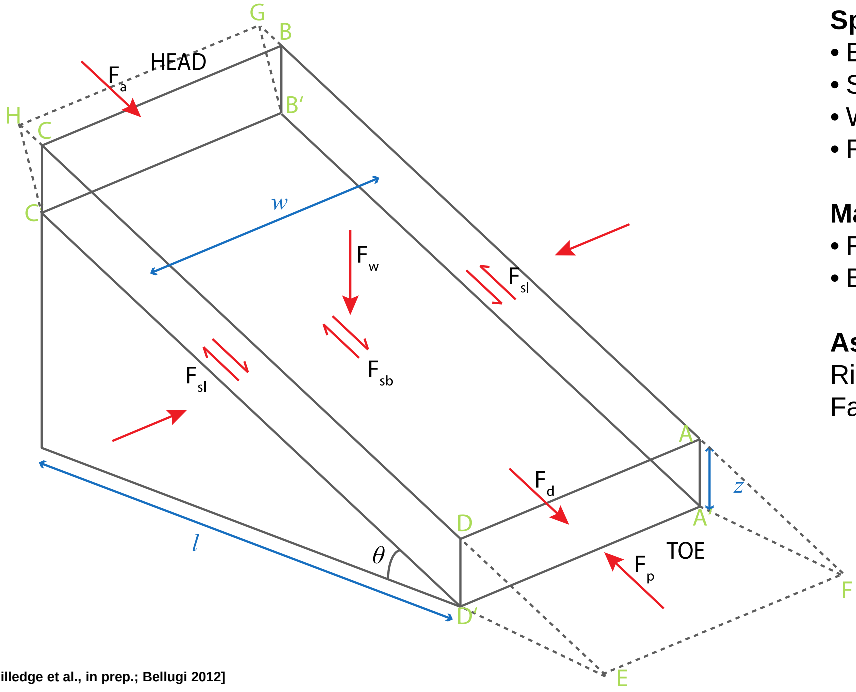
- Based on Wedge Method (Chen, 1981)
- Consider forces on all 5 boundaries
- Include cohesion & friction
  - ➢ F_{sb} =basal shear resistance
  - ➢ F_{sl} = lateral shear resistance
  - ➢ F_p = passive wedge resistance
  - ➢ F_a = active wedge driving force
  - ➢ F_d = block driving force

$$\boxed{FS = \frac{F_{sb} + F_{sl} + F_p - F_a}{F_d}}$$

l = block length
w = block width
z = failure plane depth
θ = failure plane slope

[Milledge et al., in prep.; Bellugi 2012]

3-D Slope stability model



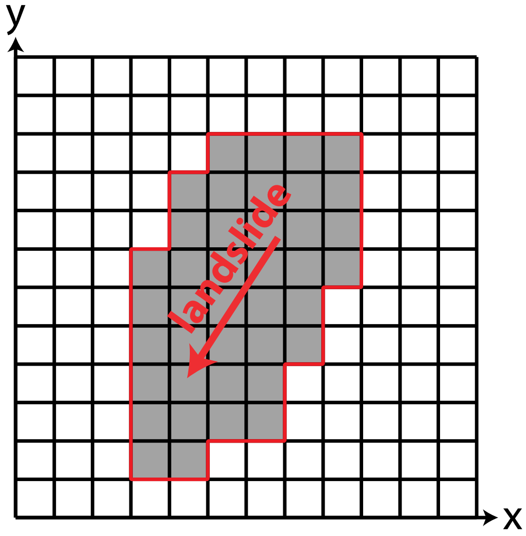
[Milledge et al., in prep.; Bellugi 2012]

Spatial Data:
- Elevation
- Soil depth
- Water table height
- Root strength field

Material Properties:
- Friction angle
- Bulk density

Assumptions:
Rigid block
Failure plane location

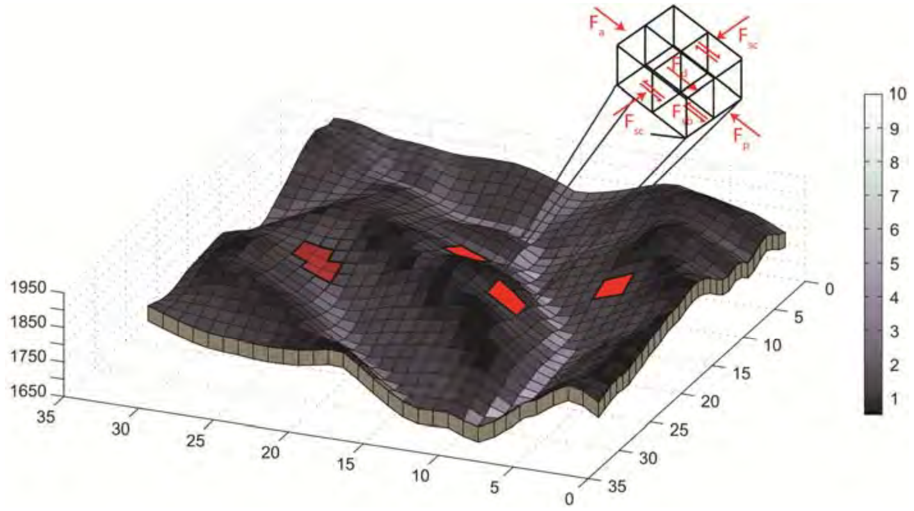
3-D Slope stability model



- Grid application based on Hovland's method of columns
  - i.e. ratio of the sum of driving and resisting forces
- But include new treatment of boundaries

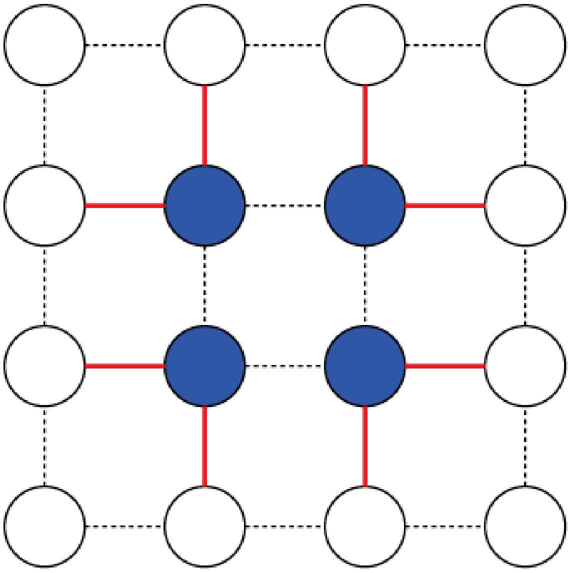
[Hovland 1977]

A discrete landscape model

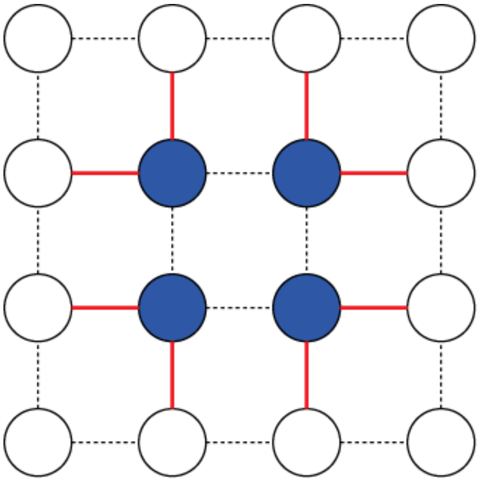


- Discretize landscape into *grid* of cells
- Associate each cell with a node in a *graph*

A discrete landscape model



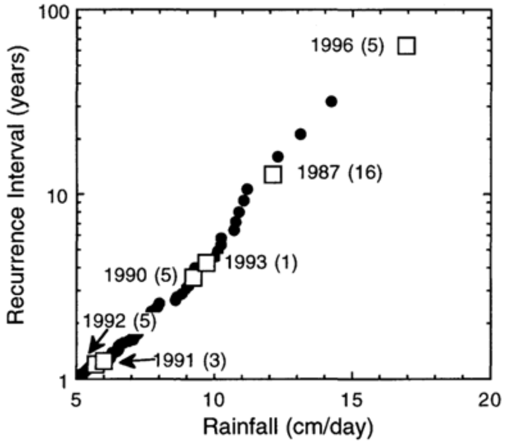
A discrete landscape model



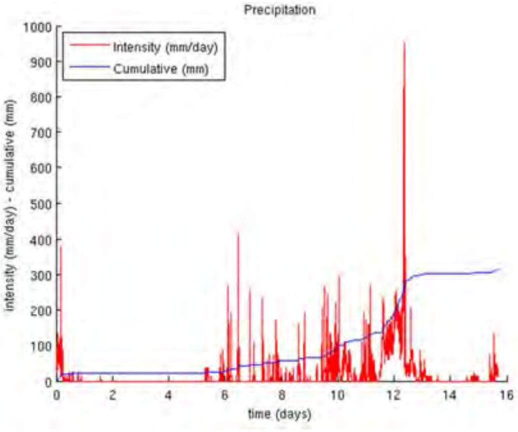
- Discretize landscape into *grid* of cells
- Associate each cell with a node in a *graph*
- *Nodes:* landscape cells annotated by driving forces
- *Edges:* resistive forces between neighboring grid cells

Storms

Composite (6 24-hour storms):



1996 storm 10-minute time series:

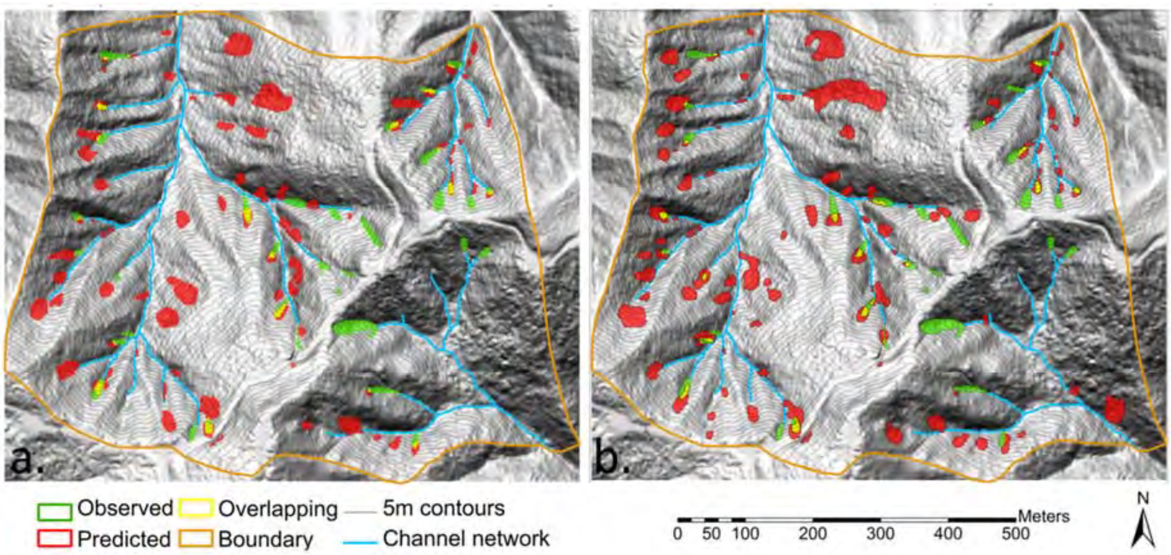


November 12-20, 1996

Results

Composite (6 24-hour storms):

1996 storm 10-minute time series:

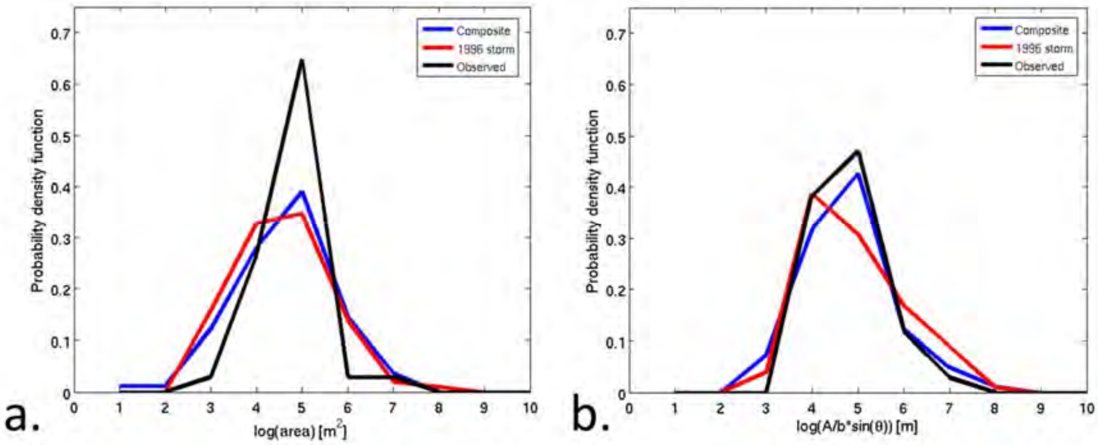


Still much over prediction!

Results

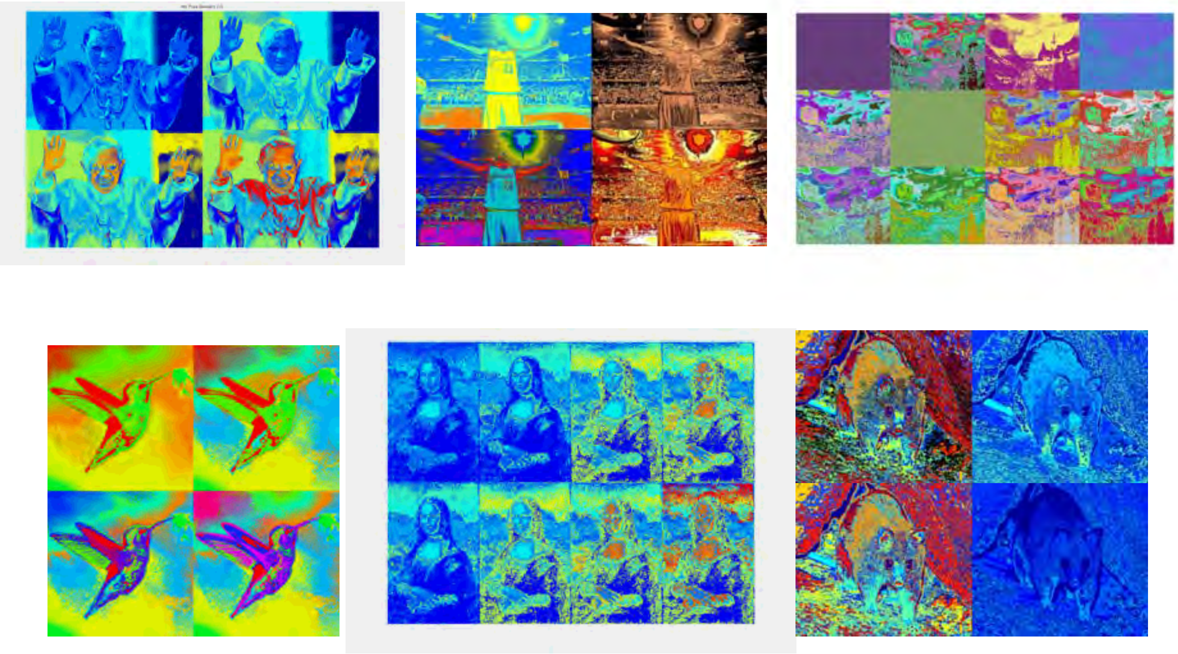
Landslide size:

Location (topographic index):



Captures observed distributions!

Homework



Final Project

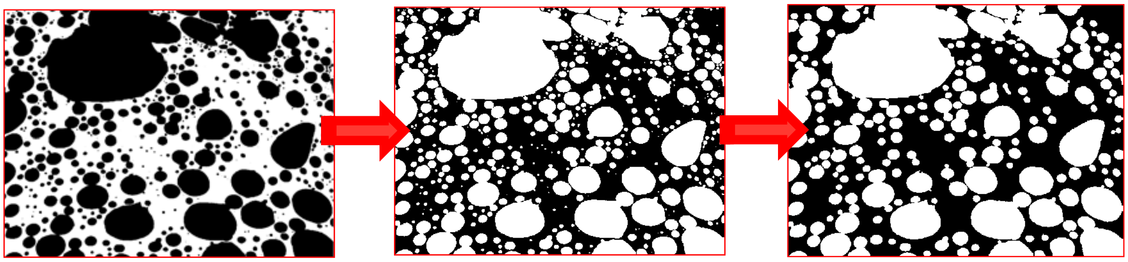
Think about it soon:
- It will help us fine-tune the class
- We can point you towards useful resources
- You will run out of time

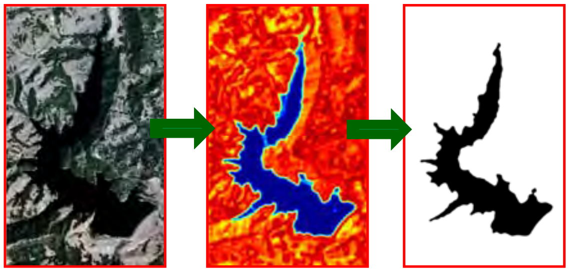
Individual:
- Exception: collaboration (2 people max) for a harder problem
- Proposal (< 1 page) stating objectives and methods by March 9th
- 10 minute presentation (plus questions) on April 13th
- Note: a little more expected from a group effort

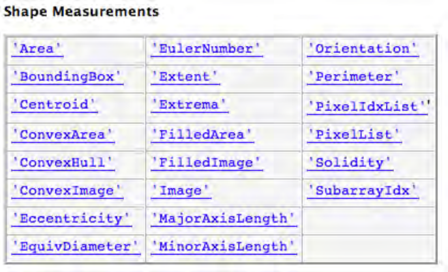
Current proposals:
- Quantify constituents in concrete from electron microscopy images
- Extract vegetation characteristics from satellite imagery
- Model hillslope hydrology

Review

- Transforming images to binary (thresholding, indexing, filtering)
- Regions from binary images (`bwconncomp()`)
- Measuring regions (`regionprops()`)







Shape Measurements

'Area'	'EulerNumber'	'Orientation'
'BoundingBox'	'Extent'	'Perimeter'
'Centroid'	'Extrema'	'PixelIdxList''
'ConvexArea'	'FilledArea'	'PixelList'
'ConvexHull'	'FilledImage'	'Solidity'
'ConvexImage'	'Image'	'SubarrayIdx'
'Eccentricity'	'MajorAxisLength'	
'EquivDiameter'	'MinorAxisLength'	

Today: Image Segmentation (part 1)

Algae Patches:

- Selecting a Region of Interest (ROI) in an image
- Alternative metric for measuring similarity
- Pixel-based segmentation

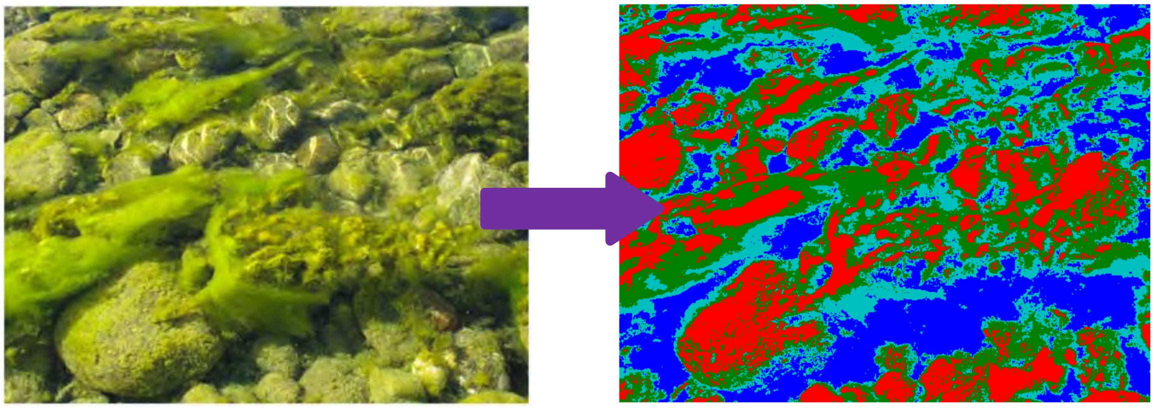
Victoria Crater (Mars):

- Images as watersheds
- The Watershed Transform
- Median filtering

San Pablo Reservoir:

- “Texture” Filters
- Morphological operations

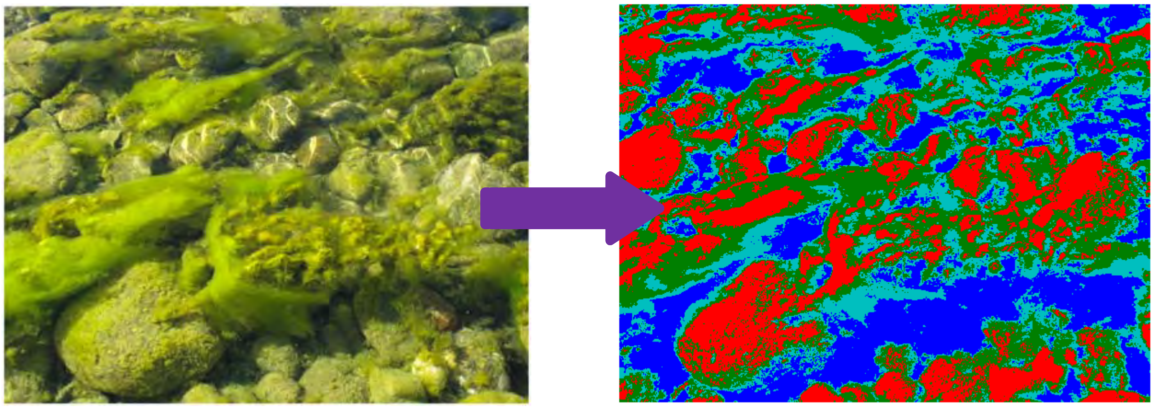
Algae Identification and rgb2ind()



- Using `rgb2ind()` with 4 colors (recolored for more contrast)

- Our task: we only want to label *coherent* regions that are *similar* to a few user-defined algae types and discard the rest.

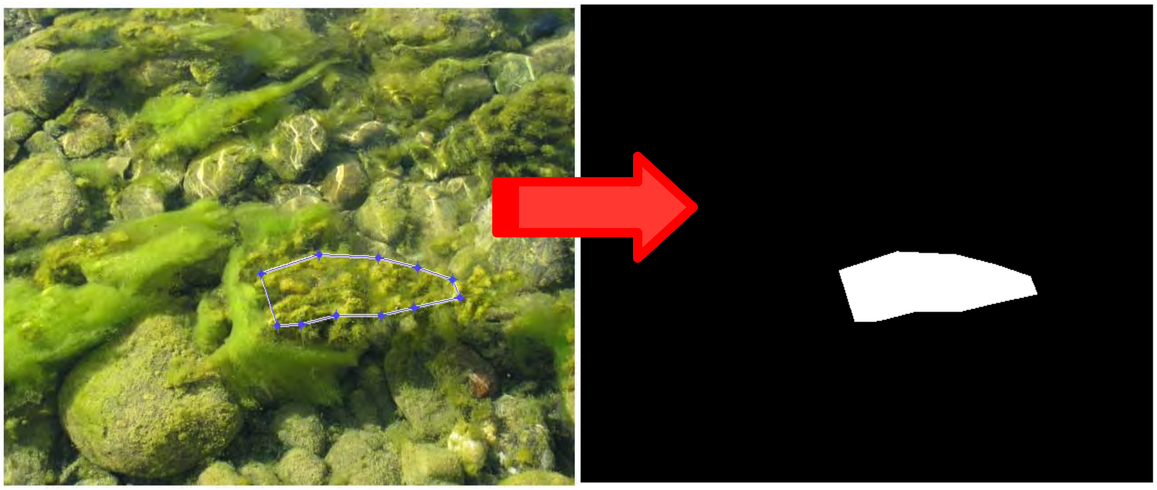
Algae Identification and rgb2ind()



- Note: `rgb2ind()` assigns *every* pixel to one of *n* colors
- Our task: we only want to label *coherent* regions that are *similar* to a few user-defined algae types and discard the rest.

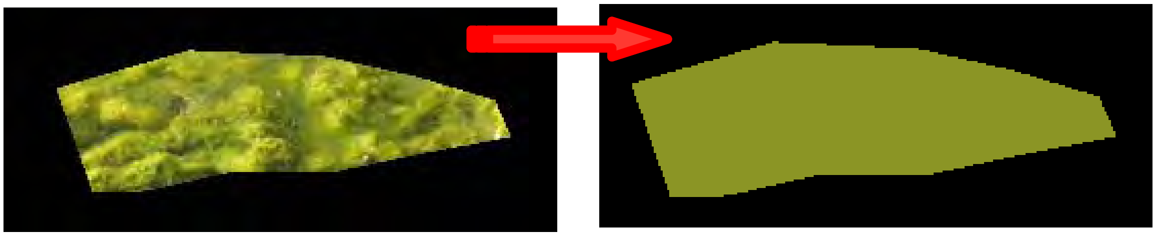
- How do we *define* “similar”?
- How do we *select* a “color representation” for each type?

Selecting a Region of Interest (ROI)

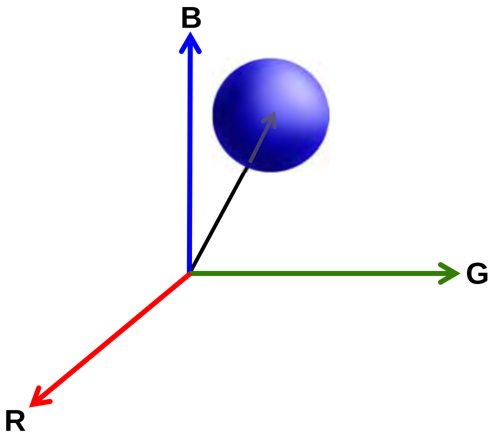


- The function `roipoly()` allows for manual region selection
- It returns a mask containing 1 inside the region and 0 outside
- How do we describe this region?
- What is representative of this region?

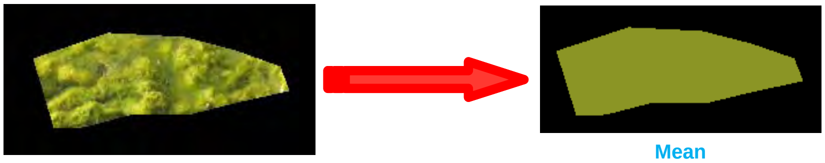
Picking a Representative Color



- Simplest: pick the *mean* color
- Then *similarity* implies being within a certain (Euclidean) distance in RGB space
- The pixels that are within a sphere centered at the mean color are *similar*
- Is this too simplified?



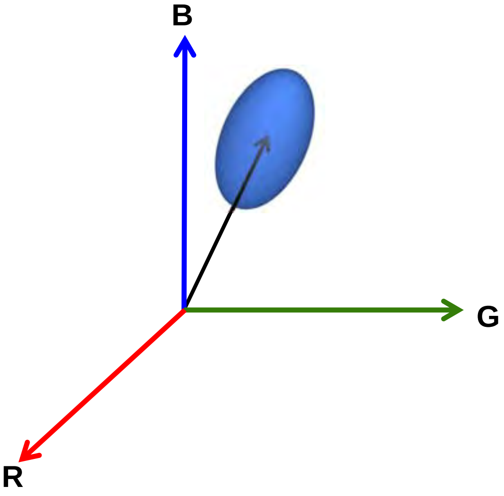
Picking a Representative Color



Mean

$$+\begin{pmatrix} 1135.9 & 1072.1 & 380.2 \\ 1072.1 & 1031.7 & 364.7 \\ 380.2 & 364.7 & 335.6 \end{pmatrix}$$

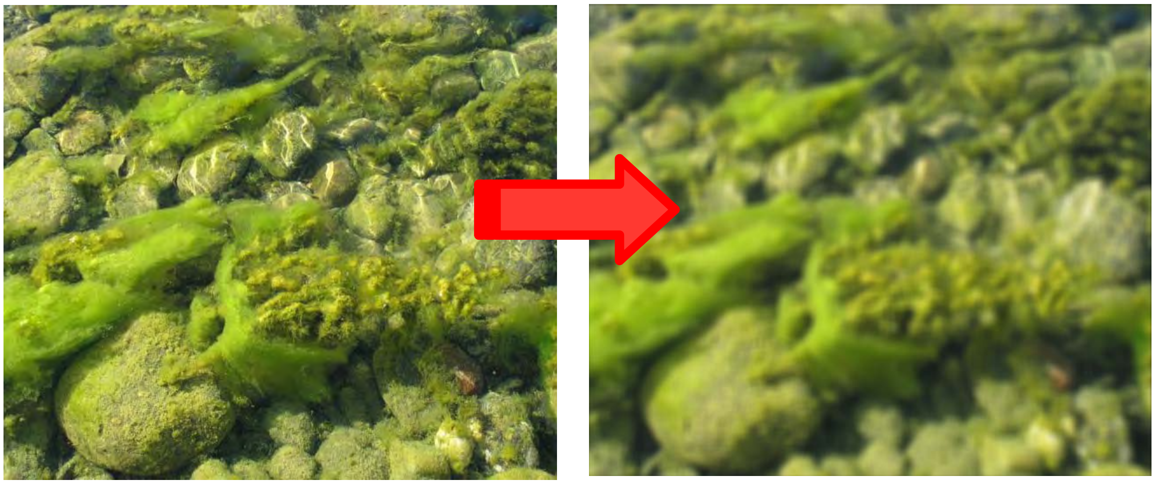
Covariance Matrix



- Compute the *mean* and the *covariance* matrix
- Then *similarity* implies being within a *weighted* distance
- The pixels that are within an *ellipsoid* centered at the mean color are *similar*
- Known as the *Mahalanobis distance*
- In Matlab:

  functions `mahal(), cov()`

Smoothing

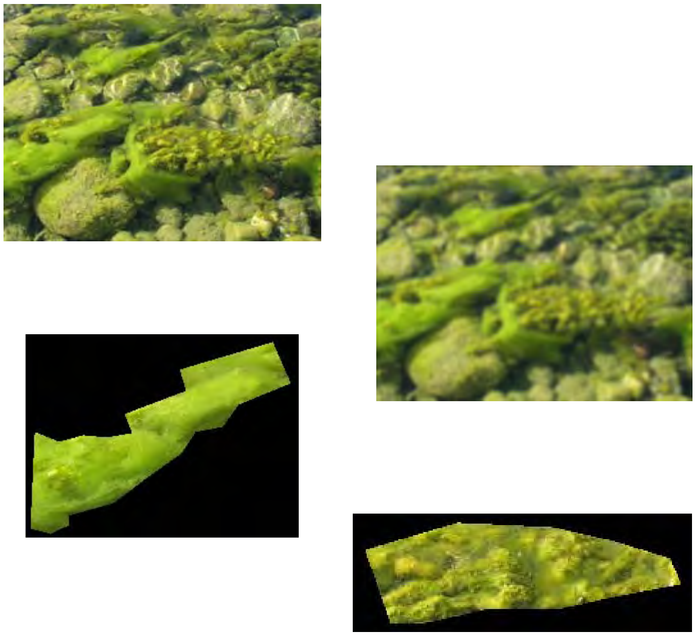


- Some of the variance is noise, and we'd like coherent regions
- We can remove it by averaging neighboring pixels:

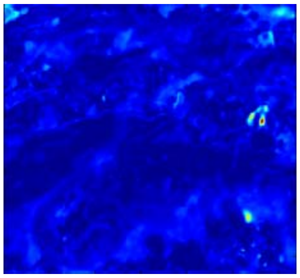
```
myFilter = fspecial('average', 10);
smoothImg = imfilter(myImage, myFilter);
```

Simple Supervised Learning Algorithm

- Read the image
- Smooth the image
- Pick the representative color patches
- Learn mean and covariance for each patch

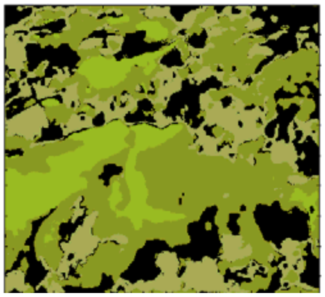


Simple Supervised Learning Algorithm



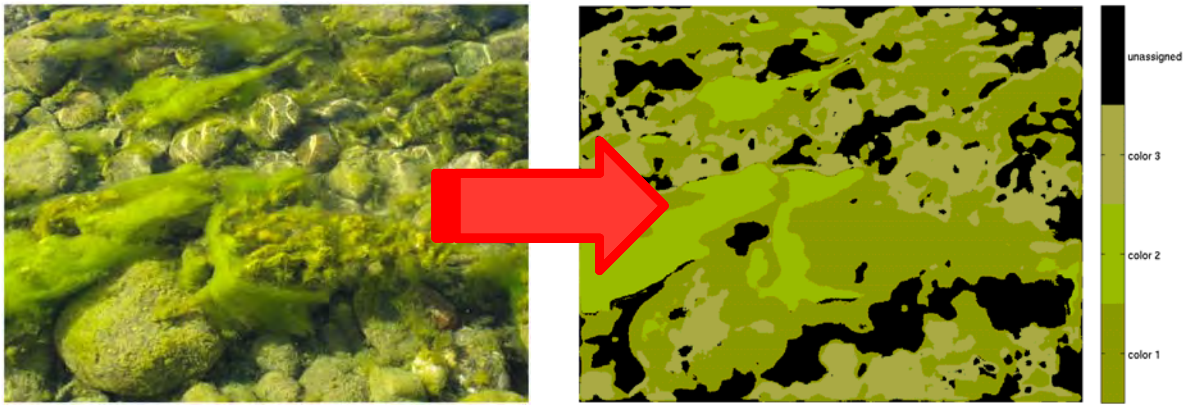
- Compute the mininum *Mahalanobis distance* of all pixels to any *mean* color

- Assign each pixel to index of closest color



- Label each pixel that is too distant as belonging to no class (index = 0)
- Function of two or three parameters:
  - Number of colors
  - Threshold of distance
  - Filter size (optional)

Result



- A reasonable and simple start, but still very crude
- How could we improve the procedure?

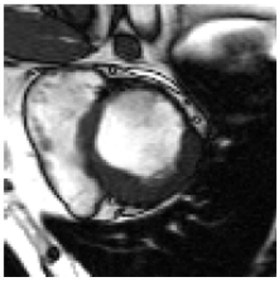
Regions from “continuous” images

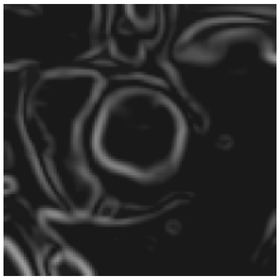
So far:

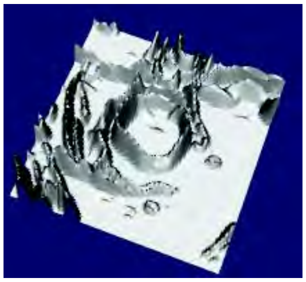
- Pixel-based segmentation methods

Other approaches:

- Global:
  “Topography”
  “Morphology”
- Local:
  Edge detection
  Topology

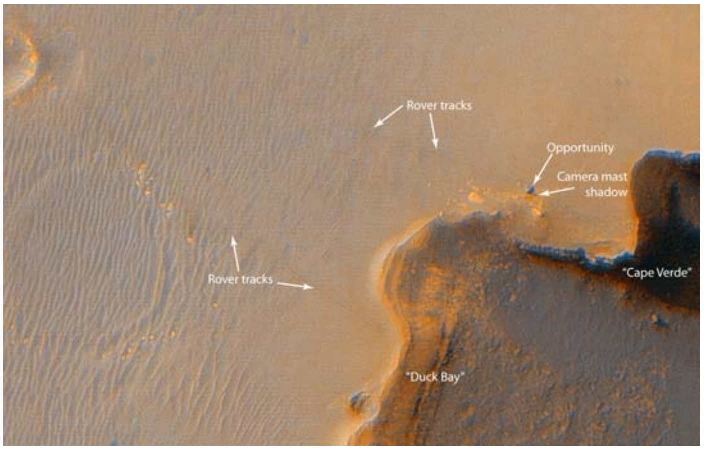

Cardiac MRI image


Gradient image


Topography


Edges

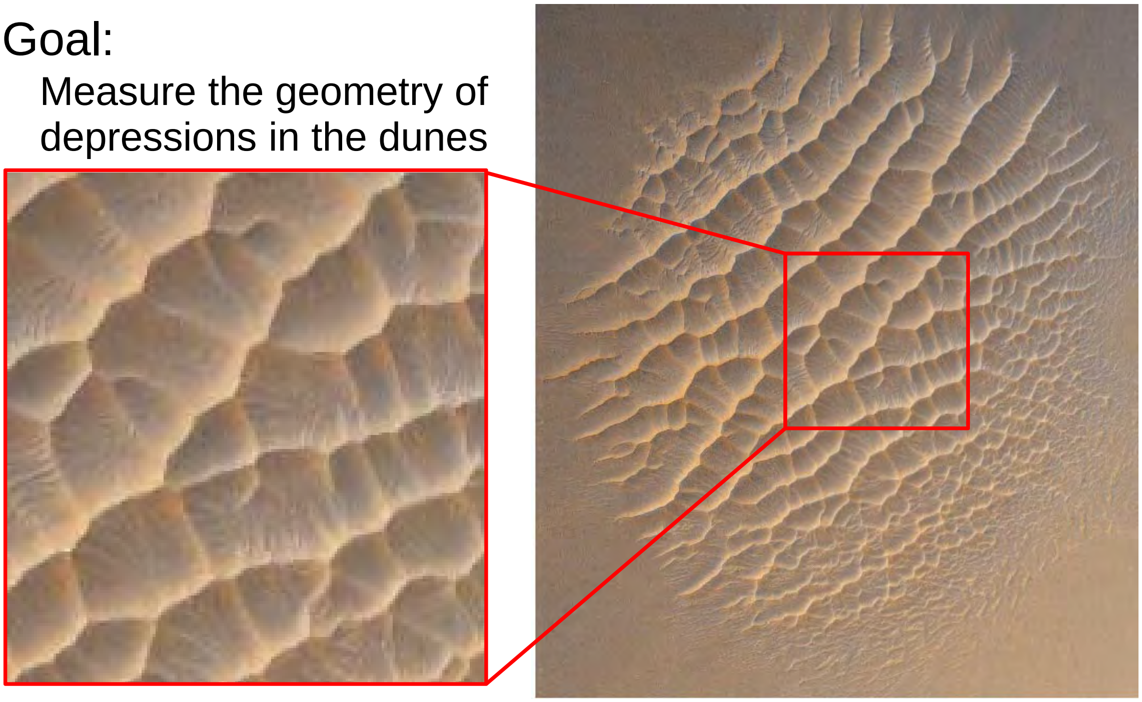
Victoria Crater (Mars)



Dunes in Victoria Crater

Goal:

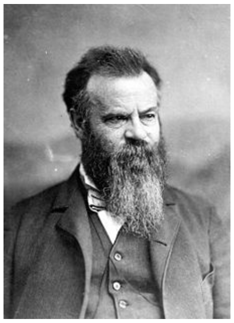
- Measure the geometry of depressions in the dunes



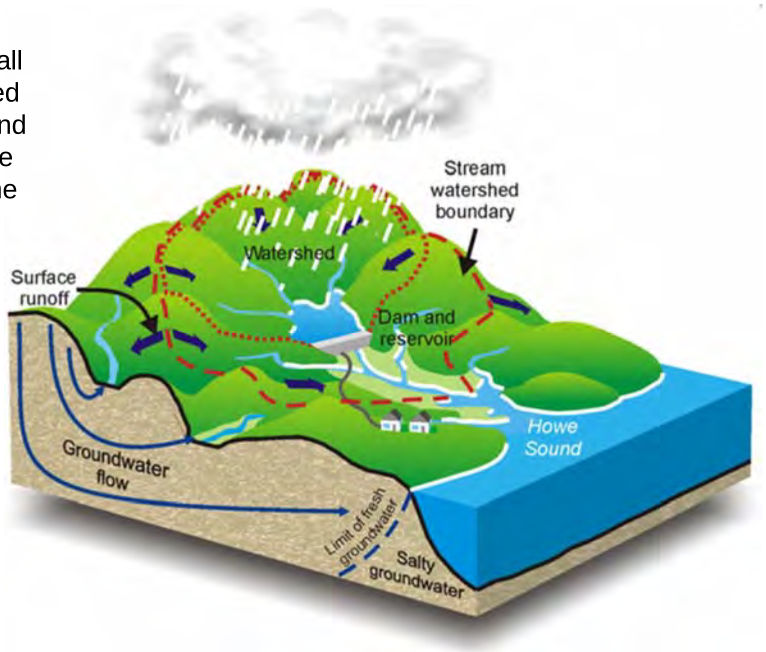
Watersheds

“That area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community."

John Wesley Powell

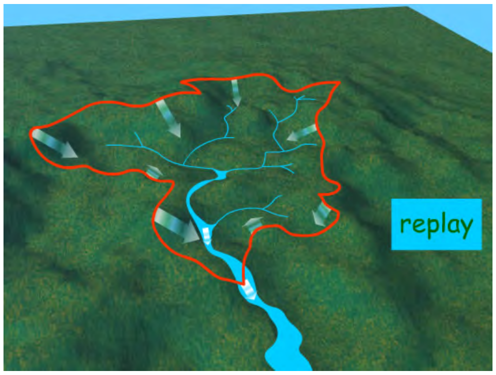


Director of the USGS
(1881-1894)



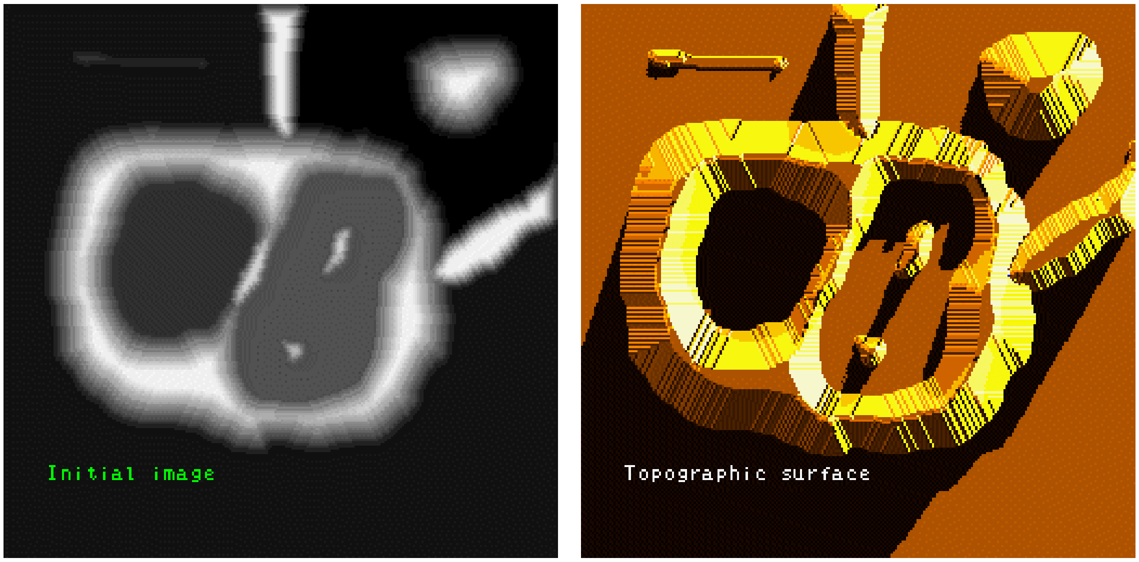
Watershed Transformation to Group Pixels into Regions

- **Interpret grey level as elevation**
- **Decide which pixels are connected**
- **Drop water on every pixel and see which local minimum it drains to**
- **Identify regions that drain to the same minimum, identify borders also**

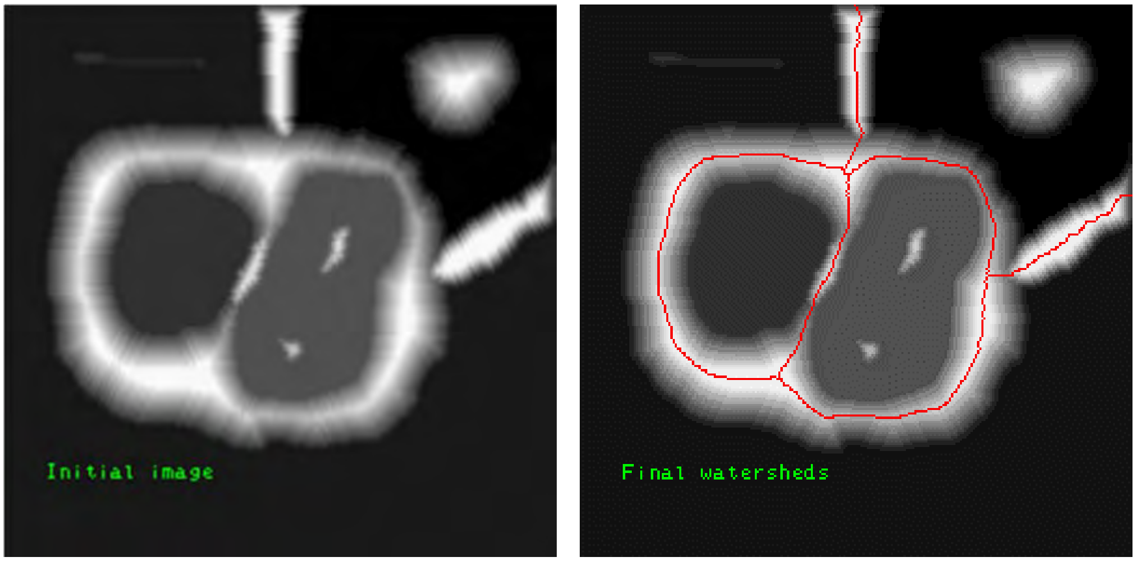


Images and Watershed Transformation

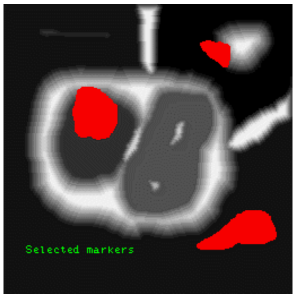
Intensity as elevation:

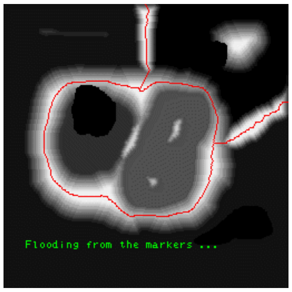


Watershed Transform



Marker-Controlled Watershed Transform



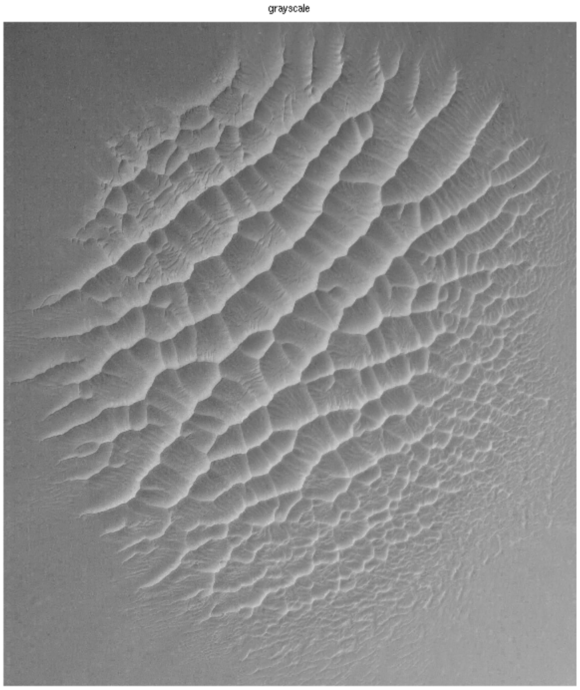


Dunes in Victoria Crater

```
% clear and close all
clear all;
close all

% read image
I =
imread('victoria_crater4.png');
imshow(I);
title('original image');
```

Grayscale

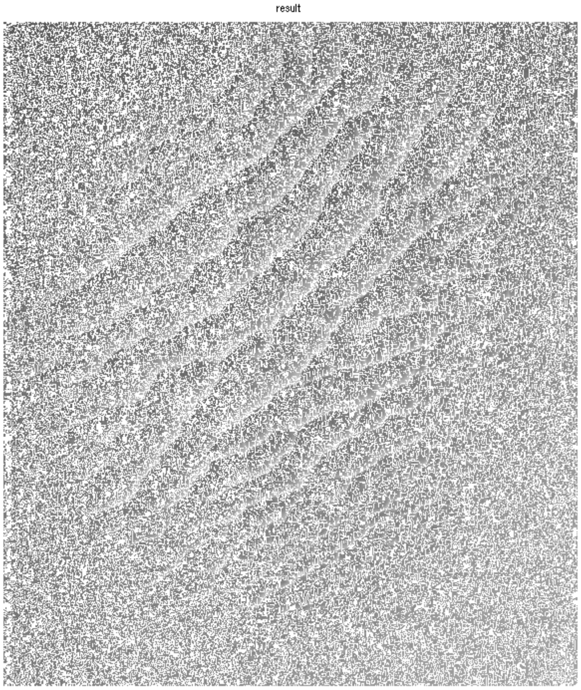
```
% grayscale image
G = rgb2gray(I);
figure; imshow(G);
title('grayscale');
```



Watershed

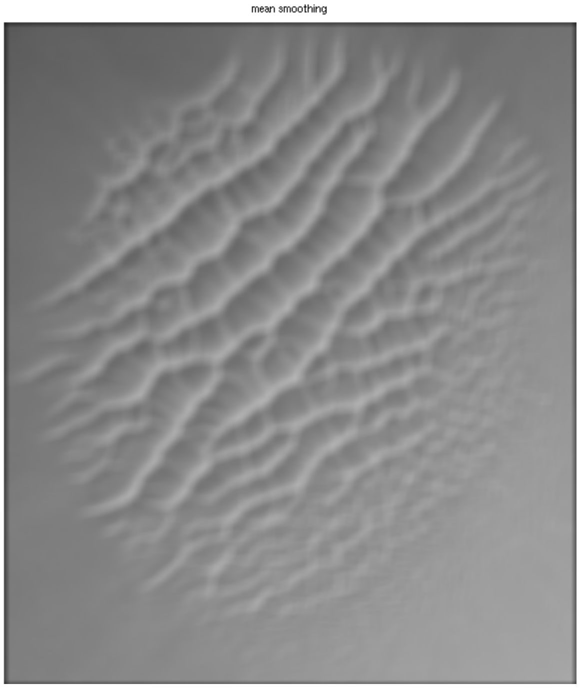
```
% now the watershed
L = watershed(G);
G2 = G;
G2(L == 0) = 255;
figure; imshow(G2);
title('result');
impixelinfo
```

What happened?



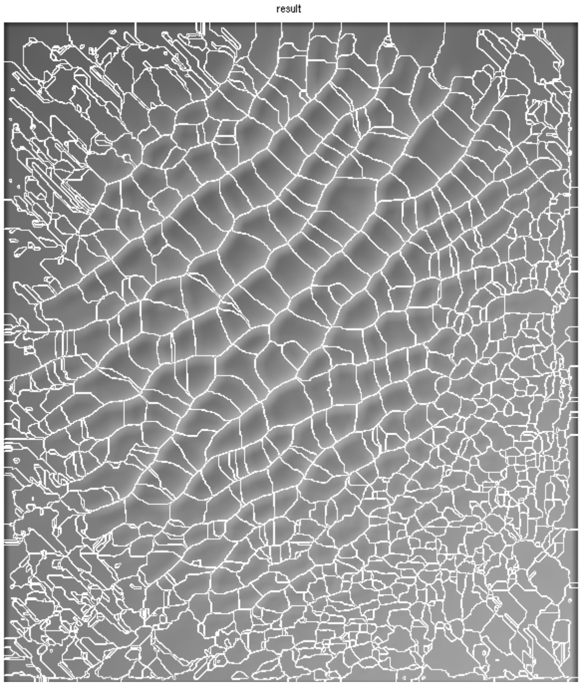
Smoothed (Mean)

```
% smooth a little
fSize = 24;
h = ones(fSize,fSize) / fSize^2;
Sm = imfilter(G, h);
figure; imshow(Sm);
title('mean smoothing');
```



Watershed on Smoothed Image

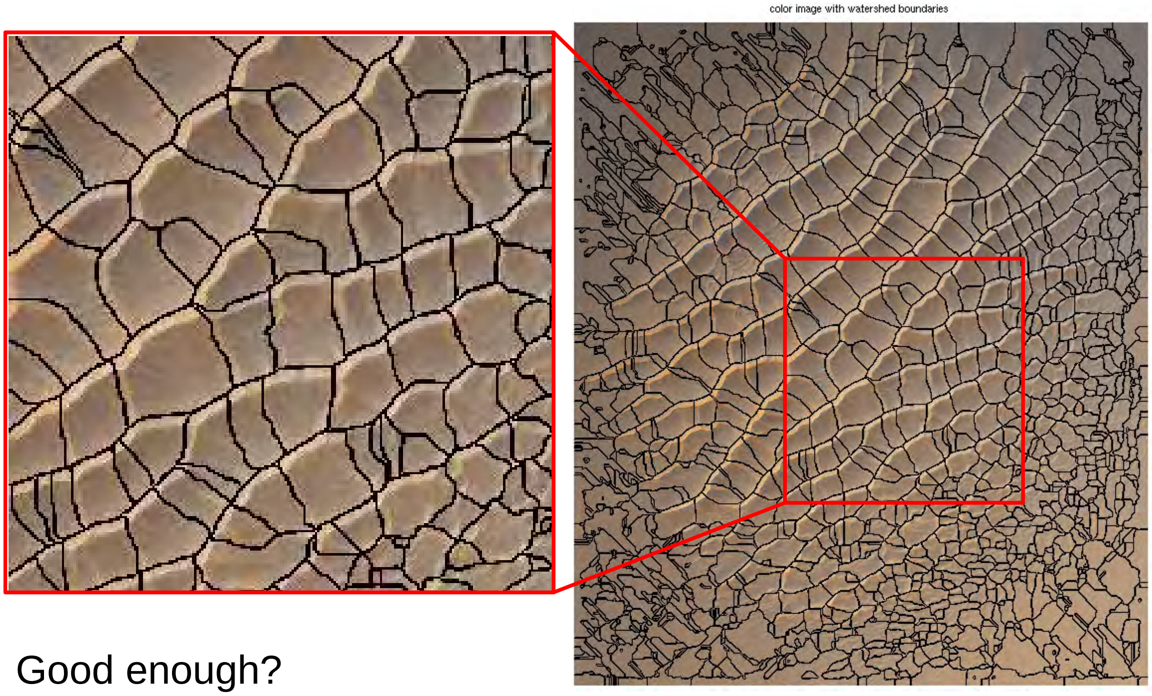
```
% now the watershed
L = watershed(Sm);
L0 = (L==0);
G2 = Sm;
G2(L0) = 255;
figure; imshow(G2);
title('result');
```



Overlay Watershed Boundaries and Original Color Image

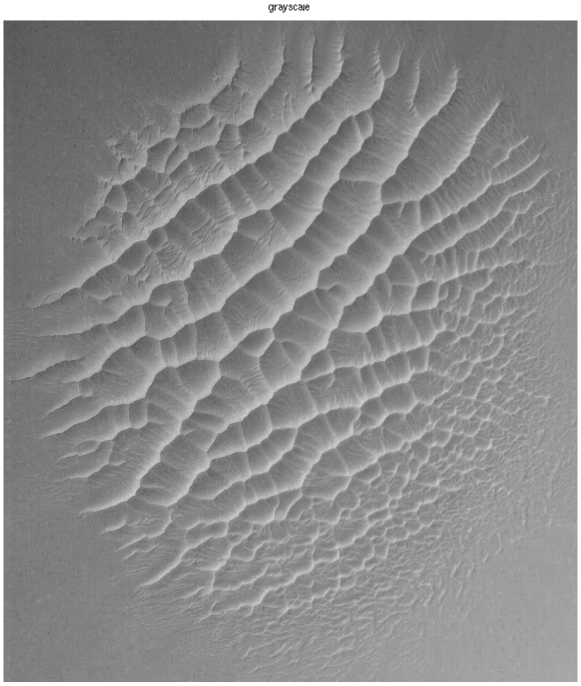
```
% color image
I1=I(:,:,1); I1(L0)=0;  % red
I2=I(:,:,2); I2(L0)=0;  % green
I3=I(:,:,3); I3(L0)=0;  % blue
II=cat(3, I1, I2, I3);  % rgb
figure; imshow(II);
title('color image with
watershed boundaries');
```

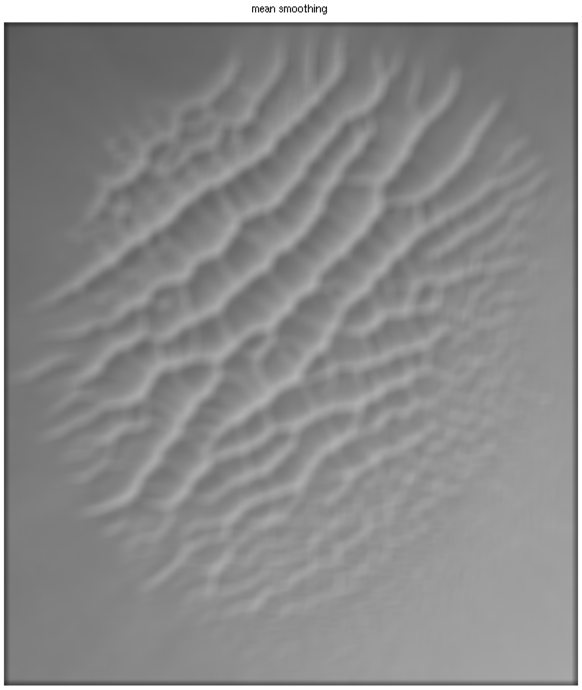
Detail View



Good enough?

Grayscale Image vs. Smoothed (Mean)

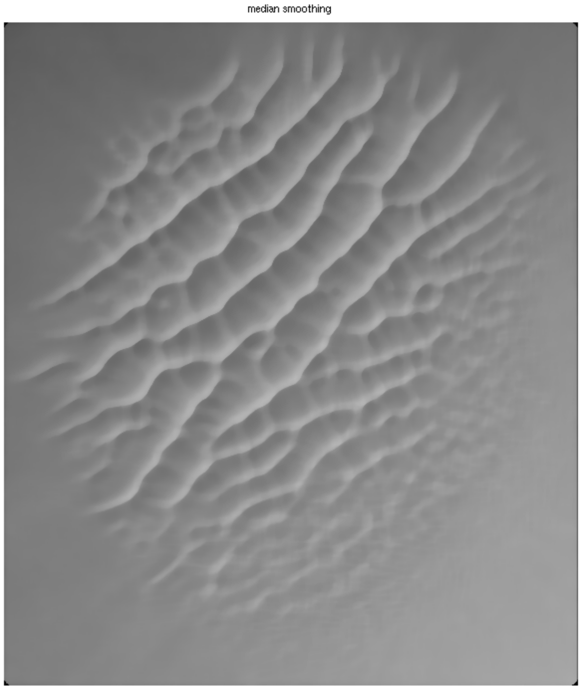




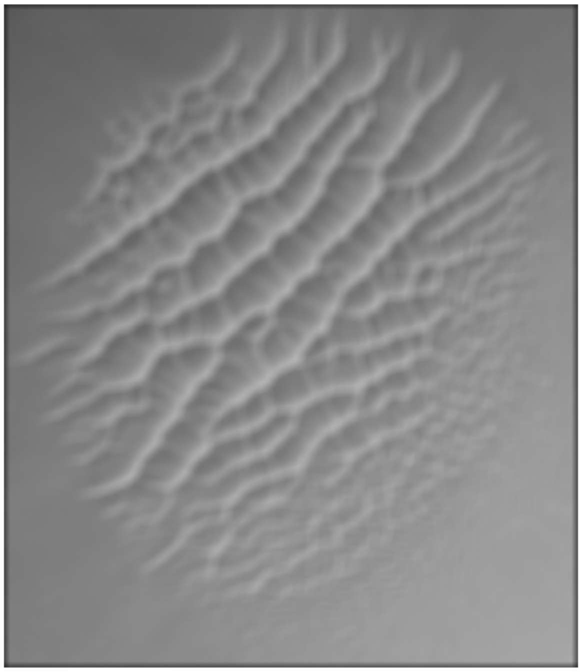
A Different Way to Smooth: Median Filter

- Removes “salt and pepper” noise
- Preserves edges

```
% smooth a little (median)
fSize = 24;
Sm = medfilt2(G, [fSize fSize]);
figure; imshow(Sm);
title('median smoothing');
```



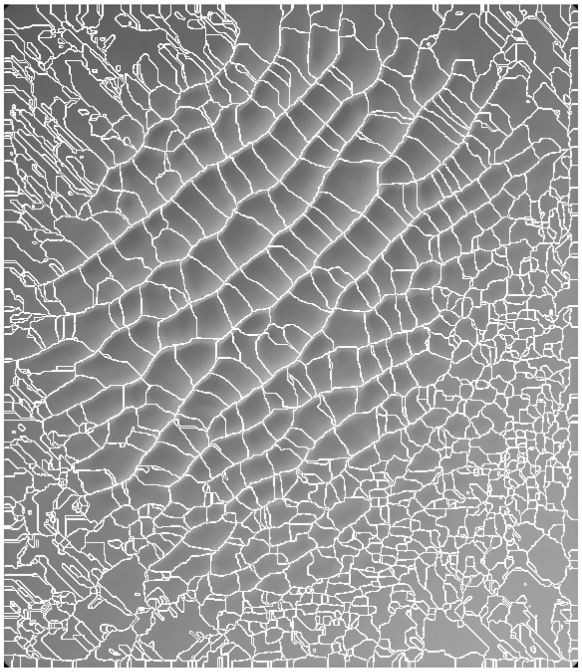
Smoothed Image: Mean vs. Median


mean smoothing


median smoothing

Watershed and Median Smoothing

```
% now the watershed
L = watershed(Sm);
L0 = (L==0);
G2 = Sm;
G2(L0) = 255;
figure; imshow(G2);
title('result');
```


result

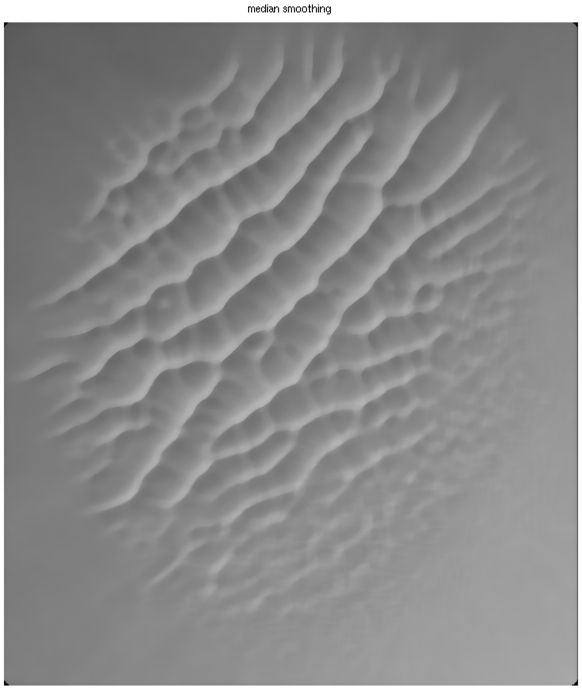
Overlay Watershed Boundaries and Original Color Image

```
% color image
I1=I(:,:,1); I1(L0)=0;  % red
I2=I(:,:,2); I2(L0)=0;  % green
I3=I(:,:,3); I3(L0)=0;  % blue
II=cat(3, I1, I2, I3);  % rgb
figure; imshow(II);
title('color image with
watershed boundaries');
```

Comments, ideas?

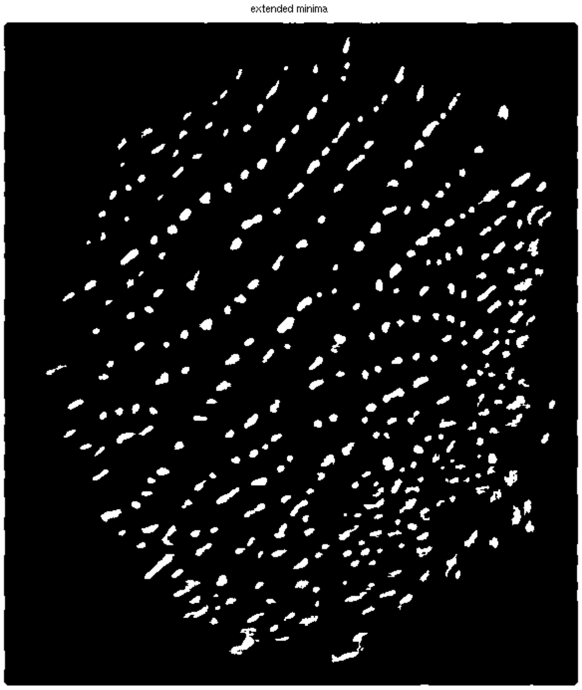
Guiding the Watershed Transform

- What do the depressions have in common?
- Can we inform the watershed transform?



Regional Extended Minima

```
% get regional minima "deeper"
% than a specified threshold
thresh = 3;
Imin = imextendedmin(Sm,thresh);
figure; imshow(Imin);
title('extended minima');
```

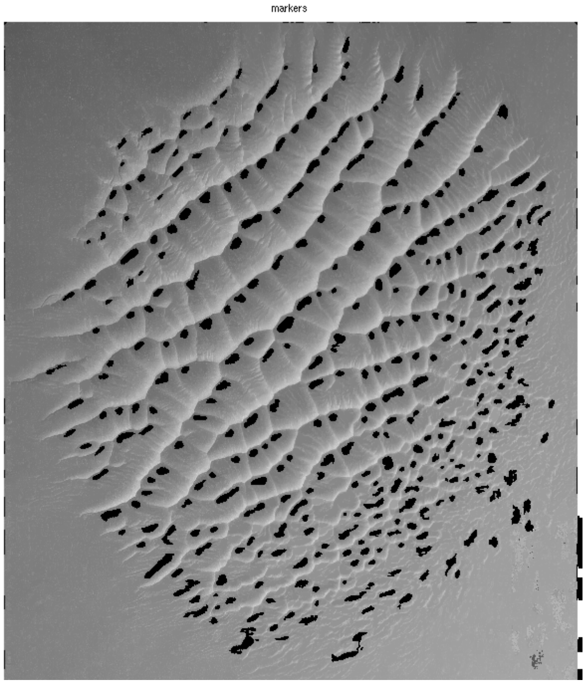


Note: similar function for maxima: `imextendedmax()`

Imposed Extended Minima

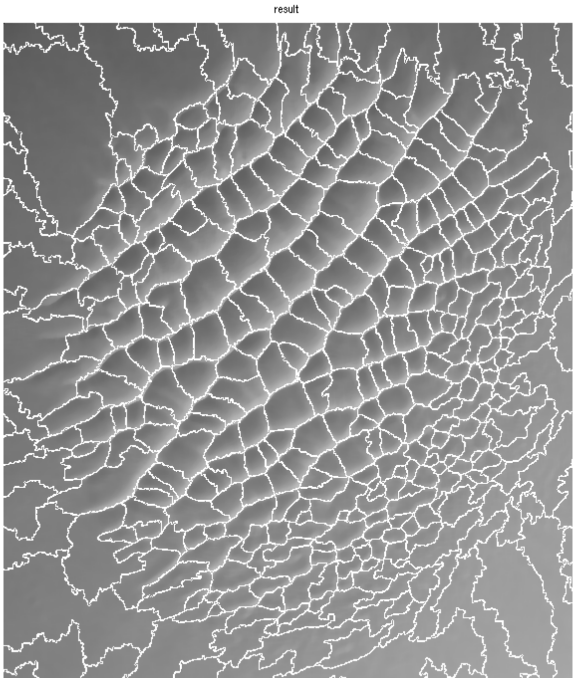
- Impose regional minima on the original grayscale image
- The function `imimposemin(I, BW)` modifies an intensity image I so that it only has the regional minima contained in BW

```
% now we have internal markers,
% impose them on original image:
G2 = imimposemin(G, Imin);
figure; imshow(G2);
title('markers');
```



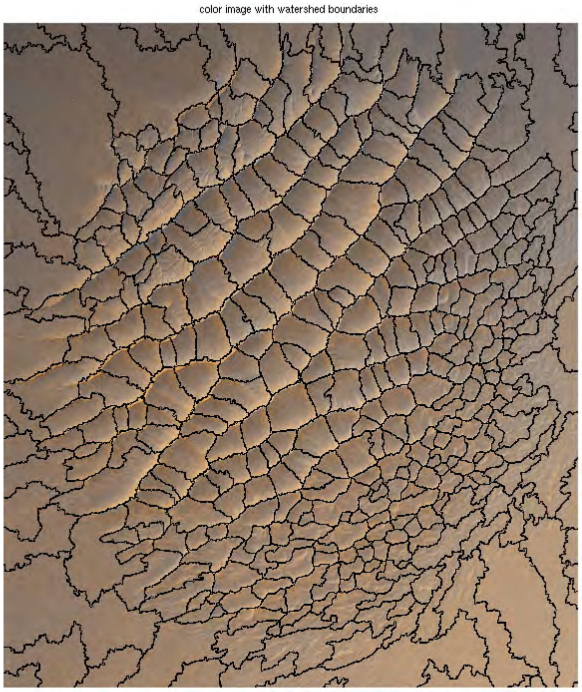
Marker-Controlled Watershed

```
% now the watershed
L2 = watershed(G2);
L0 = (L2==0);
G3 = Sm;
G3(L0) = 255;
figure; imshow(G3./255);
title('result');
```



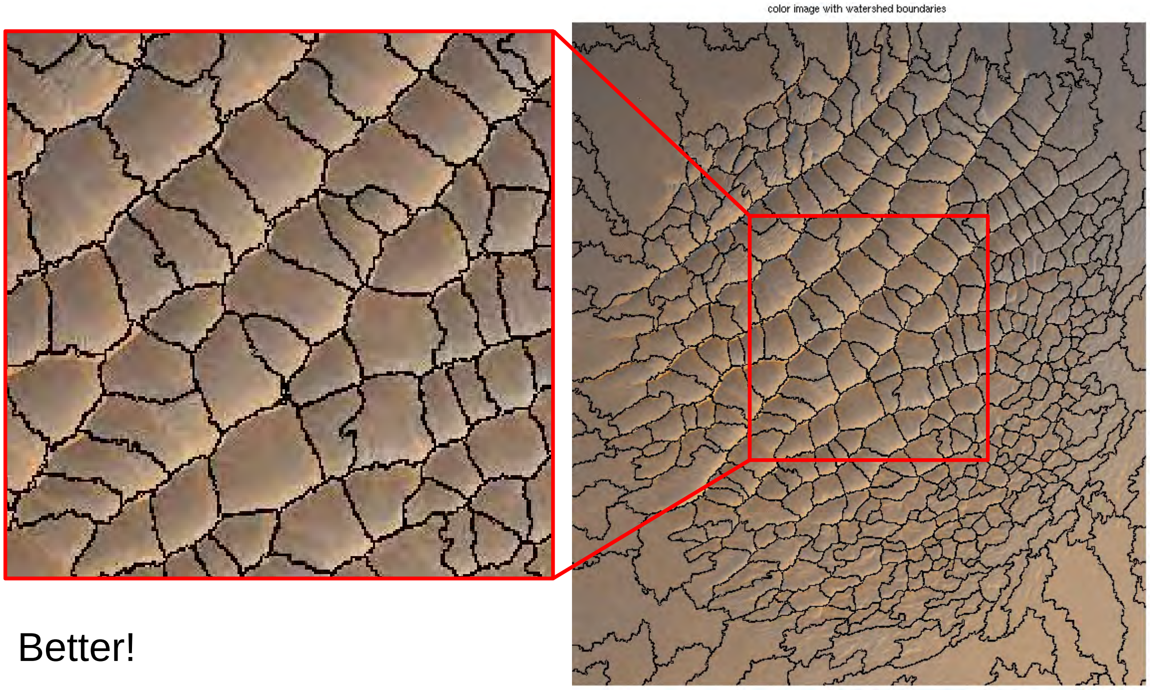
Overlay Watershed Boundaries and Original Color Image

```
% color image
I1=I(:,:,1); I1(L0)=0;  % red
I2=I(:,:,2); I2(L0)=0;  % green
I3=I(:,:,3); I3(L0)=0;  % blue
II=cat(3, I1, I2, I3);  % rgb
figure; imshow(II);
title('color image with
watershed boundaries');
```



Better!

Detail View


color image with watershed boundaries

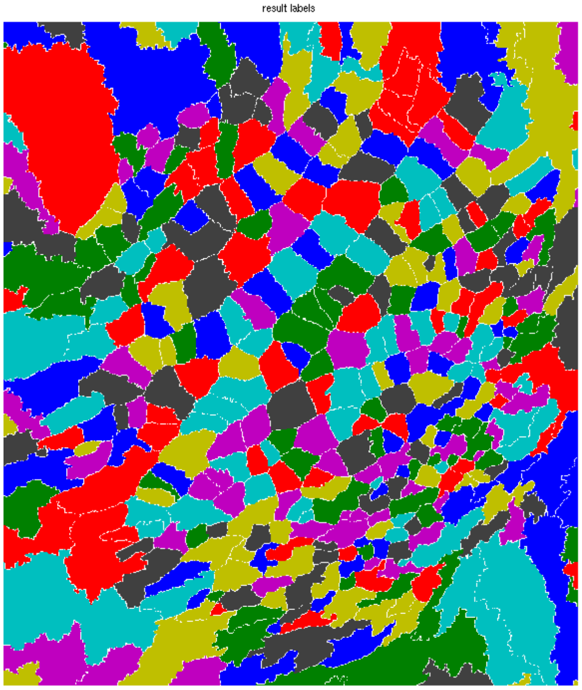
Better!

Watershed Function also Outputs Labels

Output of Watershed function:

- Matrix the size of the image
- Zero on the boundaries
- Region number inside the regions

```
% label and show
map = lines(max(L2(:)));
G4 = label2rgb(L2, map);
figure; imshow(G4);
title('result labels');
```


result labels

Applications of Watershed Transform

- Directly on an image
- On the gradient of the image
- On the Distance Transform

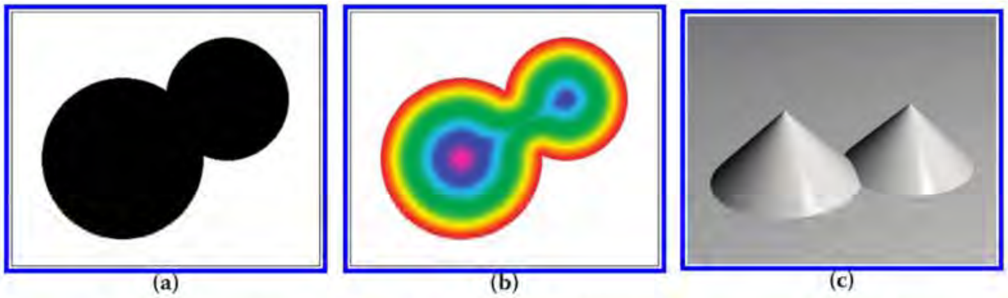


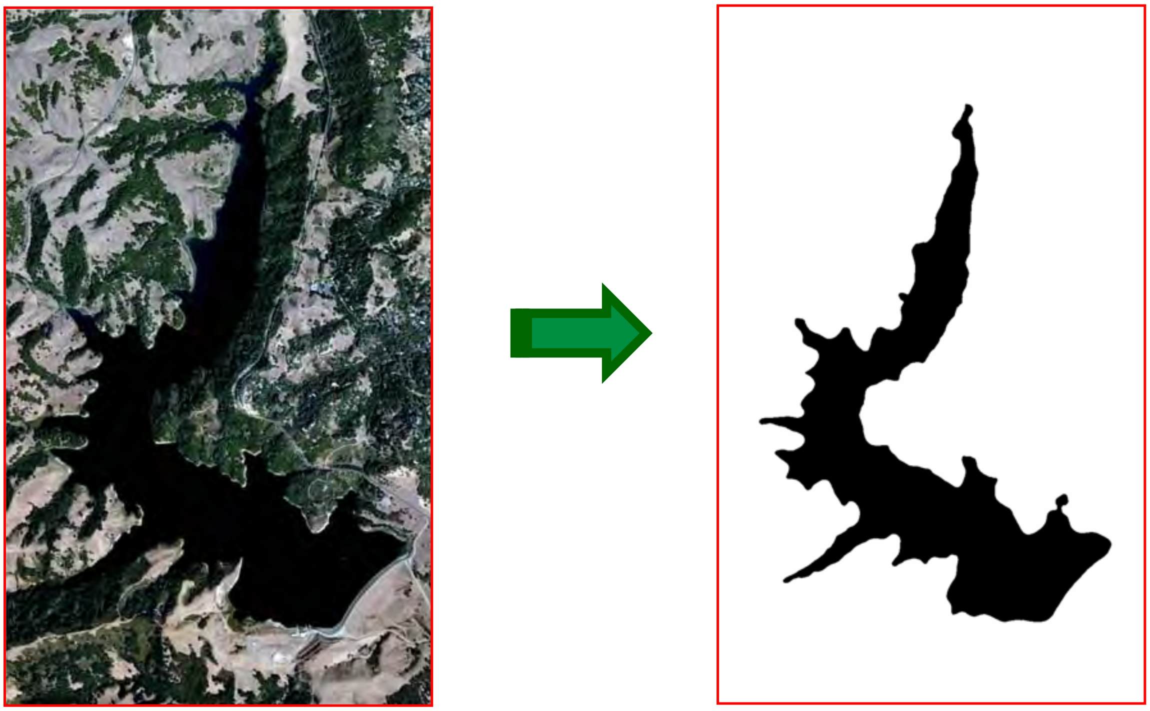
Figure 8.63 *EDM for touching features:* ***(a)*** *binary image of two touching circular features;* ***(b)*** *EDM with pixels color-coded to show distance from boundary;* ***(c)*** *rendered display showing pixel heights. Note the boundary between the two cones.*

From: "The Image Processing Handbook"

In Matlab: `bwdist()`

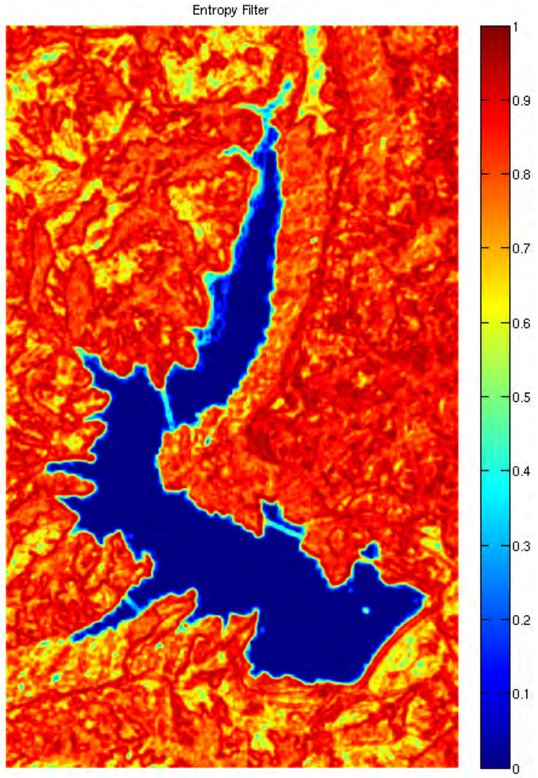
Also called: the Euclidean Distance Map (EDM)

San Pablo Reservoir



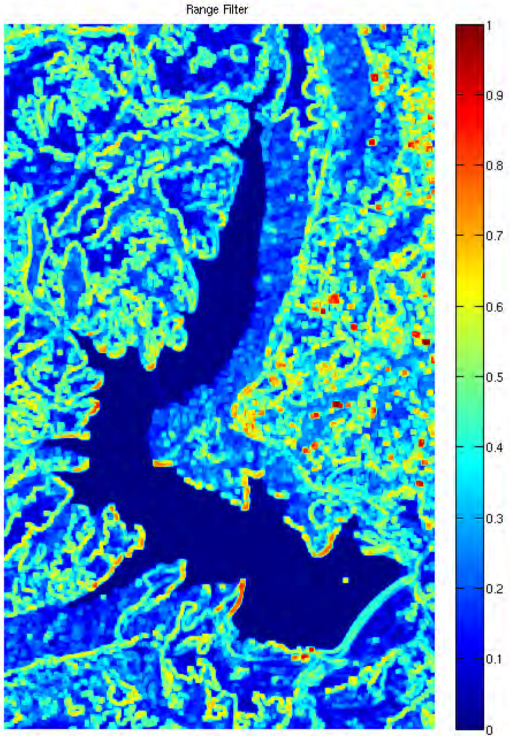
Identified lake area: 190146 pixels (last lecture)

Review: Entropy Filter



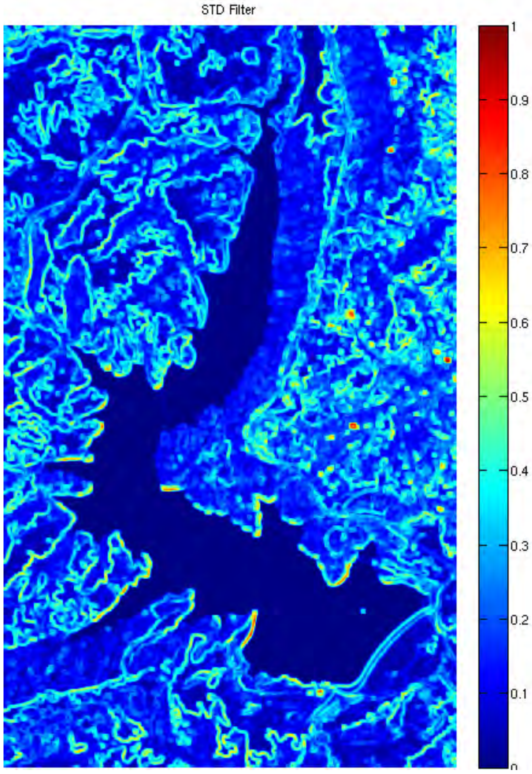
```
fSize = 9; nHood = true(fSize);
E = entropyfilt(G,nhood);
figure; imshow(E);
```

New: Range Filter



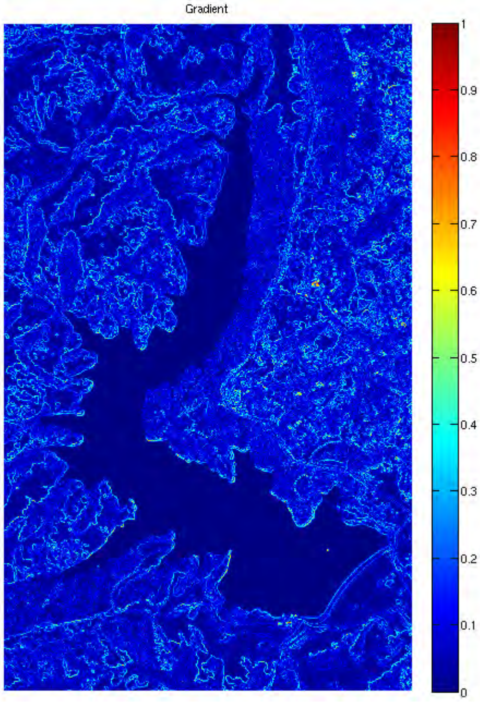
```
fSize = 9; nHood = true(fSize);
E = rangefilt(G,nhood);
figure; imshow(E);
```

New: Standard Deviation Filter



```
fSize = 9; nHood = true(fSize);
E = stdfilt(G,nhood);
figure; imshow(E);
```

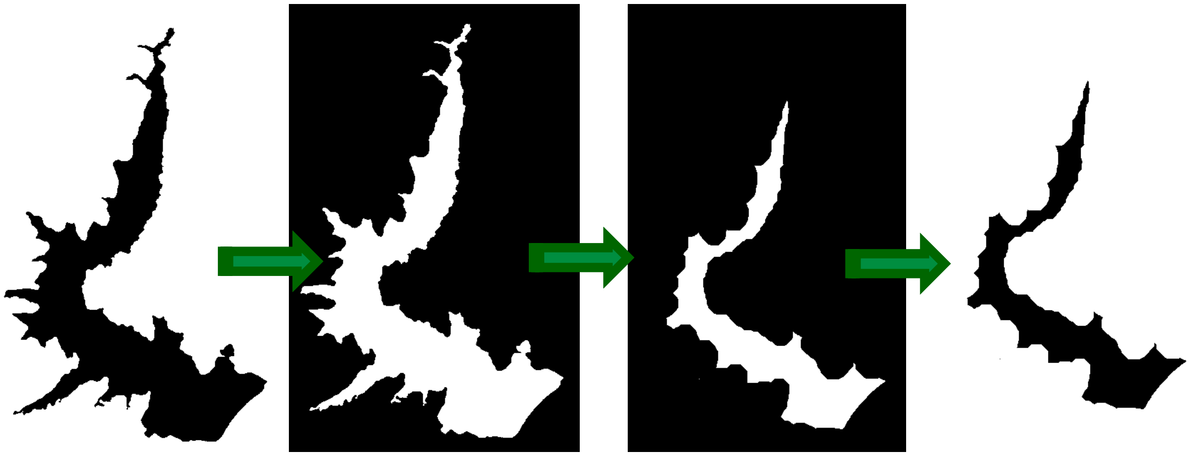
New: Gradients



```
[Gx Gy] = gradient(double(G));
Gr = sqrt(Gx.^2 + Gy.^2);
figure; imshow(Gr);
```

Also: `diff(), del2()`

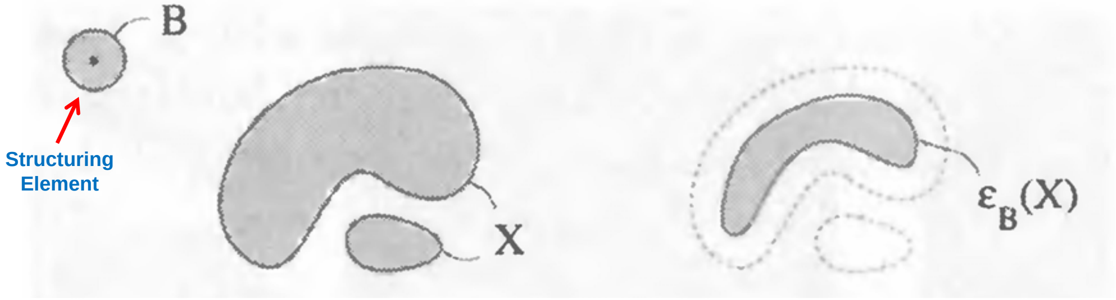
Morphological operations: Erosion, Dilation, Opening Closing



Example of Erosion

Note: Matlab likes to operate on foreground objects!

Image Erosion

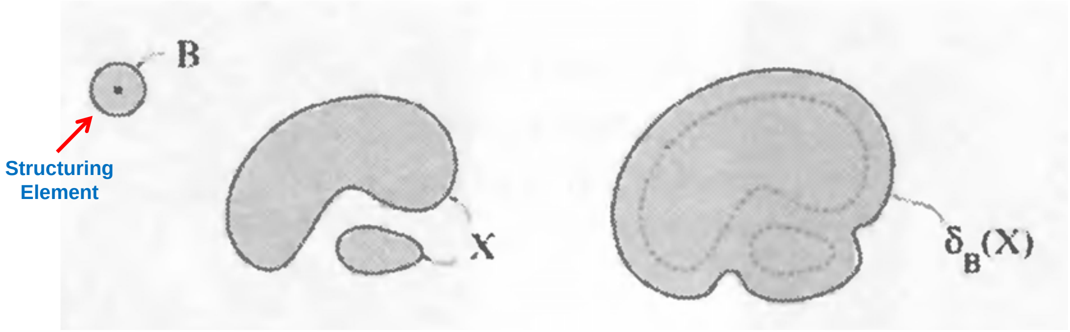


- Does B “fit” in the set X?
- Retain all points (i,j) in X such that when B is centered at (i,j), B is contained in X
- Mathematically:

$$\varepsilon_B(X) = \{\mathbf{x} \mid B_{\mathbf{x}} \subseteq X\}$$

- In Matlab: `imerode(Img,Elt)`

Image Dilation

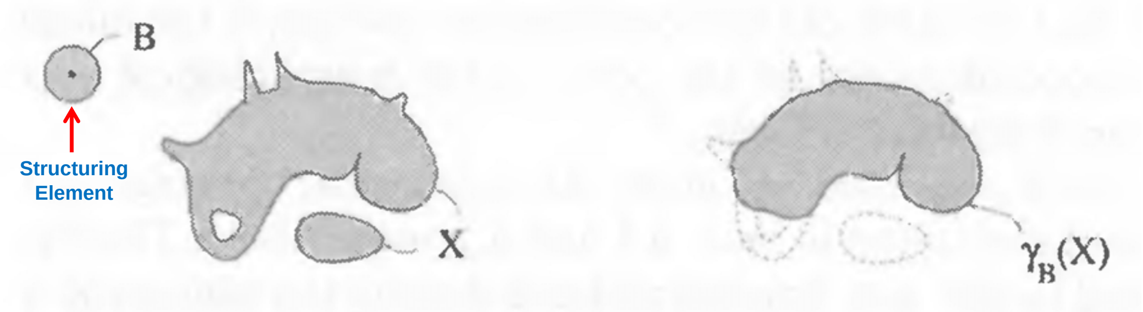


- Does B “touch” the set X?
- Add to X all points (i,j) in B such that when B is centered at (i,j), B is overlapping with X
- Mathematically:

$$\delta_B(X) = \bigcup_{\mathbf{b}\in B} X_{-\mathbf{b}}$$

- In Matlab: `imdilate(Img,Elt)`

Image Opening



- Does B “fit” in the set X?
- Like with erosion, retain all points (i,j) in X such that when B is centered at (i,j), B is contained in X
- When the previous is true, also keep all of B
- Mathematically:

$$\gamma_B(X) = \bigcup_{\mathbf{x}} \{B_{\mathbf{x}} \mid B_{\mathbf{x}} \subseteq X\}$$

- In Matlab: `imopen(Img,Elt)`

Image Closing

- Does B “fit” in the background of the set X?
- When the previous is true, all of B belongs to the background
- The complement of the new background define X
- Mathematically:

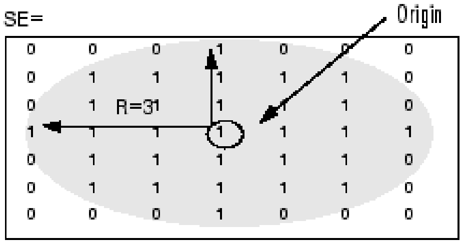
$$\phi_B(X) = \left[\bigcup_{\mathbf{x}}\{B_{\mathbf{x}} \mid B_{\mathbf{x}} \subseteq X^c\}\right]^c$$

- In Matlab: `imclose(Img,Elt)`

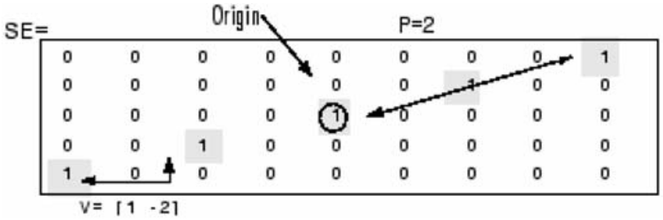
Structuring Elements

Many shapes:

Structuring Elements	
'arbitrary'	'pair'
'diamond'	'periodicline'
'disk'	'rectangle'
'line'	'square'
'octagon'	

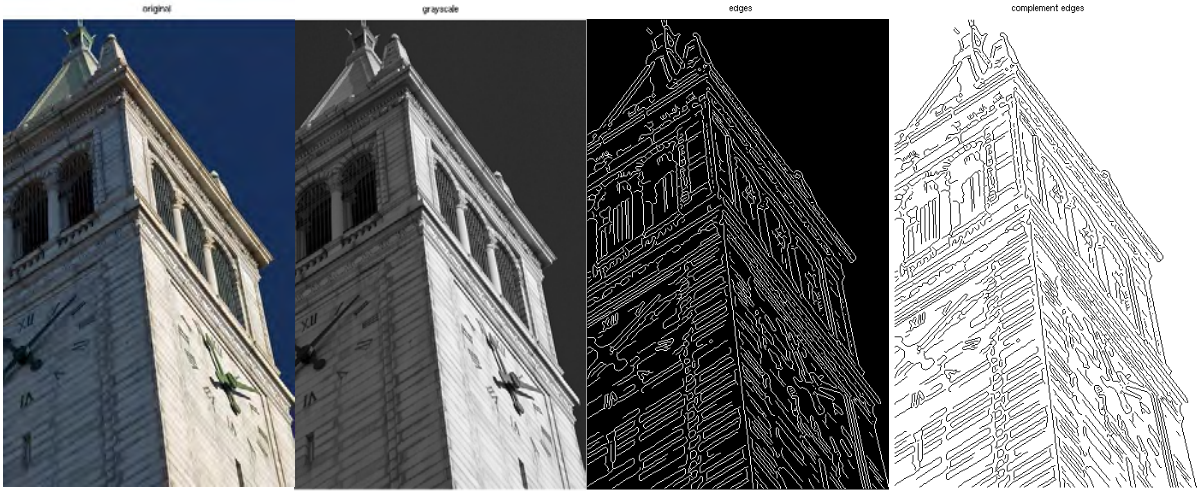


0	0	0	1	0	0	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
1	1	1	1	1	1	1
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	0	0	1	0	0	0



0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0
0	0	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0

Next time: Segmentation from Edges



The Covariance Matrix (Review)

- Consider a 6-sided *fair* die where *outcomes* all have probability 1/6
- The *mean* (the expected value) is:

$$\mu = E(X) = \sum XP(X) = \sum_{i=1}^{6} x_i p_i = \frac{1}{6}\sum_{i=1}^{6} x_i = (1+2+3+4+5+6)/6 = 3.5$$

- The *variance* is the squared deviation from the mean:

$$\sigma^2 = Var(X) = E\left[\left(X-\mu\right)^2\right] = \sum_{i=1}^{6} p_i\left(x_i-\mu\right)^2 = = \frac{1}{6}\sum_{i=1}^{6}\left(i-3.5\right)^2 \approx 2.9$$

- The *covariance matrix* is a generalization of the variance:

$$\Sigma = Cov(X) = E\left[\left(X-E\left[X\right]\right)\ \left(X-E\left[X\right]\right)^T\right]$$

- i.e., the matrix whose *(i,j)* entry is:

$$\Sigma_{ij} = Cov(x_i, x_j) = E\left[\left(x_i-\mu_i\right)\ \left(x_j-\mu_j\right)^T\right]$$

In Matlab:
function **`cov()`**

- For the die this is an identical definition to the variance:

$$\left(\begin{bmatrix}-2.5 & -1.5 & -0.5 & 0.5 & 1.5 & 2.5\end{bmatrix}\begin{bmatrix}-2.5 & -1.5 & -0.5 & 0.5 & 1.5 & 2.5\end{bmatrix}^T\right)/6 \approx 2.9$$

- But for the color pixels it is a 3x3 matrix

Computer Lab Assignment 3

Image Segmentation 1

This lab has two parts. First we will apply the *watershed transform* to identify dune regions on Mars. This is an application of the *region-based image segmentation methods* that were discussed in the lecture. In the second part, we will learn how to use the *pixel-based image segmentation* and the *Mahalanobis* distance measure. We will apply this approach to aerial imagery of Marin County, CA and measure the extent of forestation.

Part 1 – Dunes in Craters on Mars

Here we will apply the *watershed* transformation to identify dune regions on Mars. Different filtering techniques will be discussed to obtain good results.

1) Download the file craterdunes2.jpg from bSpace. Then start writing a new Matlab script that displays it.

```
clf ; clear ; close all
I = imread('craterdunes2.jpg');
G = rgb2gray(I);
figure; imshow(G);title('grey scale image'); impixelinfo
```

Apply the *watershed* transformation

```
L = watershed(G, 8);
figure, imshow(L); title('watershed');
```

and superimpose the region boundaries on the original image

```
I1=I(:,:,1); I1(L==0)=255;
I2=I(:,:,2); I2(L==0)=0;
I3=I(:,:,3); I3(L==0)=0;
II=I; II(:,:,1)=I1; II(:,:,2)=I2; II(:,:,3)=I3;
imshow(II); title('color image with watershed boundaries');
```

You obtain an over-segmented image that we shall now improve upon.

2) Smooth the image before the *watershed* transform by applying an averaging filter. Insert the following lines into your code:

```
n=3; h = ones(n,n) / (n*n);
G = imfilter(G,h);
figure, imshow(G); title('filtered image (averaged)');
```

Increase the filter size *n* until you obtain the best result. You should now have obtained an image with region of reasonable size but with boundaries shifted towards the setting sun.

3) Rather than applying an averaging, or *mean*, filter, try a *median* filter:

```
 G2 = double(G);
G3 = medfilt2(G2, [n n]) ./ 255;
figure; imshow(G3);title('median smoothing');impixelinfo
```

Are the results any better? Decide for yourself and keep using your preferred filtering technique with the optimal filter size for part 4.

4) Now we want to apply the *marker controlled watershed transform* where we first identify the shadiest regions in the filtered image that are darker then their surrounding by a certain threshold. Then we use the Matlab command `imimposemin` to manipulate the original image in such a way that it only has minima where `GMin` has been set to zero by the `imextendedmin` command.

```
 % get regional minima "deeper" than a threshold
min_thresh = 3/255;
GMin = imextendedmin(G3, min_thresh);
figure; imshow(GMin);title('extended minima');

% now we have “markers”, impose them on original image
G4 = imimposemin(G, GMin);
figure; imshow(G4);
title('original grey scale with minima imposed (markers for watershed)');impixelinfo

L = watershed(G4, 8);
```

Try this method for different threshold values. You should see how the minima identified by `imextendedmin` grow or shrink. Characterize how this affects the resulting dune region. Determine the best threshold value and save your final code. Well done!!

Part 2 – Telling the Forest from the Trees

For this part, we will use images from the National Agriculture Imagery Program (NAIP).
NAIP acquires aerial imagery during the agricultural growing seasons in the continental U.S.A. and makes digital ortho-photography available to the public through their web site:
http://www.fsa.usda.gov/FSA/apfoapp?area=home&subject=prog&topic=landing
For California, these and other geo-spatial data are available at http://www.atlas.ca.gov.
These images have a spatial resolution of 1m, meaning that each pixel corresponds to 1 m^2.
For use in our lab, these images were converted to PNG format, hopefully preserving this resolution.

1) Download the two images available on bSpace, named *naip1.png* and *naip2.png*:

Our goal will be to select a sample forest patch and automatically classify all the forest pixels in these images.

Sample code will be provided for you to cut and paste into your Matlab session.

As the size of these images is rather large, some operations such as smoothing might be slow. For this reason, we recommend you save the code samples in separate files so that you don't have to repeat unnecessary operations and only execute those that you will be modifying. Also, you will need most of this code for your next homework assignment.

2) Read one of the two images into Matlab and display it:

```
% set image name
imName = 'naip1.png';

% read and check image, get size
rgbImg = imread(imName);
[nRows nCols nLyrs] = size(rgbImg);
if (nLyrs ~= 3)
error('Image is not RGB!');
end
nPix = nRows * nCols;

% display original image
figure;
imshow(rgbImg);
title(['RGB image ' imName]);
```

Note how in the last line the string 'RGB image' is concatenated with the variable "imName".

If you wish you could save this section as readNaip.m

3) Smooth the image you selected and display it:

```
% set filter size
filtSize = 25;

% smooth image
fprintf('Smoothing image ...\n');
myFilt = ones(filtSize) ./ filtSize^2;
smoothImg = imfilter(rgbImg, myFilt);

% display smoothed image
figure;
imshow(smoothImg);
title('smoothed RGB image');
```

Keep in mind that results may be dependent on the filter size chosen here, you may decide to vary the filter size after you see the results. Again, you may wish to save this code in a file such as smoothNaip.m

Region selection is performed with the function roipoly(). This function enables the user to click around a region and create a polygon. To complete the function, right click on the polygon and select the option "Create Mask". The process should look something like this:

4) Select a representative sample forest patch and display it:

```
% print some instructions with the function fprintf()
fprintf('Use mouse to delineate region for color sample\n');
fprintf('Click to place a vertex\n');
fprintf('Right-click and select Create Mask to close polygon\n');

% open a new figure for the region selection and call roipoly()
figure;
title('Select region');
roiMask = roipoly(rgbImg);

% display the mask
figure;
imshow(roiMask);
title('Mask');

% use the mask to extract the color region
fprintf('Masking region ...\n');
red = immultiply(roiMask, smoothImg(:,:,1));
green = immultiply(roiMask, smoothImg(:,:,2));
blue = immultiply(roiMask, smoothImg(:,:,3));
roiImg = cat(3, red, green, blue);

% display the color region
figure;
imshow(roiImg);
title('Color sample');
```

You may want to save this code in a separate file (such as selectNaip.m) in order to easily repeat the selection process roipoly() produces a black and white mask. The color region is extracted from the smoothed image using this mask: multiplying the image’s individual color planes by this mask preserves only the pixels which correspond to the value of 1 in the mask. The function cat() can then concatenate the resulting color planes back together into a new image. The result should look something like this:

To compute statistics and distances, we need to reshape both the image and the color patch into vectors. This is done by using the function reshape(), you are encouraged to look it up in the help. Also note that these vectors are converted from integers to doubles.

5) Compute mean patch color and standard deviation, and print their values:

```
% reshape image into vector of size nPix by 3
imgPix = double(reshape(smoothImg, nPix, 3));

% reshape roi region into vector of size nPix by 3
roiPix = double(reshape(roiImg, nPix, 3));

% find the nonzero entries in the mask
roiIdx = find(roiMask);

% keep only the RGB pixels corresponding to the mask
roiPix = roiPix(roiIdx, 1:3);

% get statistics
fprintf('Computing region statistics ...\n');

% mean color (could be used for drawing the forest in a "truer" color)
myMean = mean(roiPix)
% standard deviation (use the max value for R, G, or B)
myStd = max(std(roiPix))
```

Don't forget to save your code. Note that printing the mean and std can be done by simply omitting the semi-colon at the end of the line. Also note the above code only stores the maximum standard deviation (from red, green, or blue). Finally, notice the use of the function find() which returns the indices of the nonzero values. These indices are then used to select the masked color information. Look at the help for this function.

The Mahalanobis distance (see lecture notes) is computed using the function mahal(). This function computes the distance for each row of a (large) vector to a smaller sample, by considering the covariance of the smaller sample. The resulting distance needs to then be reshaped into the size of the image.

6) Compute Mahalanobis distance from all image pixels to region pixels:

```
% compute distance vector
mahDist = mahal(imgPix, roiPix);

% reshape distance and store in matrix
myDist = reshape(mahDist, nRows, nCols);

% display the distance
figure;
imagesc(myDist);
title('Mahalanobis distance from region color');
colorbar;
impixelinfo
```

What are the sizes of imgPix, roiPix, and mahDist? What is the size of myDist after the reshaping?

Enlarge the figure with the Mahalanobis distance and hover over it with your cursor (use the command impixelinfo if you didn't include it in the code). What value ranges do you see? Can you use them to discriminate forest from non-forest?

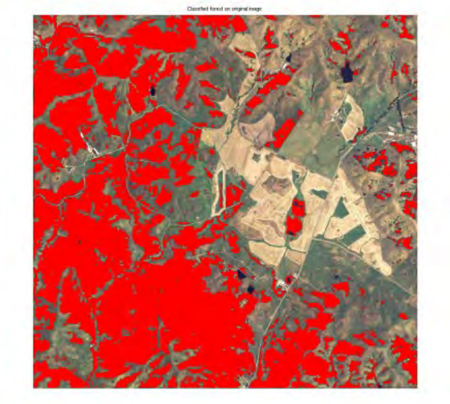
Segmentation is performed by assigning each pixel to either forest or not forest, based on this distance. Rather than picking a completely arbitrary value, we will use the region's standard deviation value as a threshold of distance. If the distance is less than one or two standard deviations (you get to play with these values), then the pixel is classified as forest.

7) Segment the image based on the Mahalanobis distance and display the result:

```
% define how many standard deviations are allowed
kThresh = 1;
% myDist contains the distances of each pixel to mean color
% if minimum is more than k*std label it 0, else label 1
fprintf('Thresholding pixels with distance from region color ...\n');
mySegm = false(nRows, nCols);
mySegm(myDist <= kThresh * myStd) = true;

% get the red, green and blue parts of the image
Ir = rgbImg(:,:,1);
Ig = rgbImg(:,:,2);
Ib = rgbImg(:,:,3);

% label the segmented pixels in red
Ir(mySegm==1) = 255;
Ib(mySegm==1) = 0;
Ig(mySegm==1) = 0;

% put the red, green, and blue parts back together
I = cat(3,Ir,Ig,Ib);

% display the labeled image
figure; imshow(I);
title('Classified forest on original image');
```

Look at the line `mySegm(myDist <= kThresh * myStd) = true;` What does it do? How many operations is it performing? Can you think of a way to do the same using loops? Replacing loops in this fashion is called "code vectorization".

Your result should look something like this:



Compare the original image (the very first figure) with your result. Are you identifying most of the forested areas? Are you getting too much or too little forest? Which parameters affect this outcome?

8) As the region you selected is rather small compared to the entire image, one standard deviation might not be sufficient to accommodate the variation in the forest colors. In your homework you will learn how to sample from several regions, but for now we can simply relax the distance threshold. Increase the standard deviation threshold (kThresh) to another value (perhaps to 1.5 or 2) and re-run the code from section 7. Again, compare with the original image. Are you getting too much or too little forest? How does the smoothing affect this result?

In this exercise we restricted classification to separating forest from not-forest. In general, more land cover classes may be desirable. One way to visualize such results may be with the use of a normalized histogram.

9) Build a normalized histogram of the forest and non-forest pixel counts:

```
% count the foreground pixels
myCount = sum(mySegm(:));

% make a normalized distribution
myDistr = [myCount nPix-myCount] ./ nPix;

% display histogram
figure;
bar(myDistr);
axis([0.5 2.5 0 1]);
set(gca, 'XTickLabel', {'Forest', 'Other'});
title('Forest percentage');
```

Note that because mySegm contained only 0 and 1 values, it was sufficient to sum the mySegm matrix to count the forest pixels. This will not be true in general, you will have to select the specific class values and count how many times they occur. You have done a similar operation in previous exercises using loops. This operation can also be done in a "vectorized fashion". For example, consider these two statements: class2 = (mySegm == 2); class2count = sum(class2(:)); What do they do? Also note in the above code how one can set axis labels on a figure by using the functions set() and gca() (get current axis).

Perhaps the forest was not our only interest, and we wished to also measure how much plowed land we see in the image. We can select a different patch and run the code again without any changes. Note that you only have to start from step 4), no need to run from the beginning unless you wish to use a different smoothing filter.

10) Sample a patch from the image that looks like it has been plowed or farmed (like in the example below) and re-run the code starting from step 4.

How does your code perform in identifying the farmed pixels? Did you have to change the standard deviation threshold or the smoothing filter size? How different are the distance values from the ones you examined during the forest exercise? Your result should look something like this (except perhaps better!):

Today: GIS and the Mapping Toolbox

Geographic Information Systems
- Data abstraction and data types
- Datums and projections
- Data sources
- LiDAR data
- Web Map Service

GIS and Mapping Toolbox
- Features
- Data
- Analysis
- Pros and Cons

Course Evaluations
- Fill out forms
- Deliver to McCone

Lab Exercise
- Making a map
- Retrieving Web-based data
- Real-time weather
- Ortho-photos
- Digital Elevation Model

“Blue Marble Earth”, NASA

Geographic Information Systems

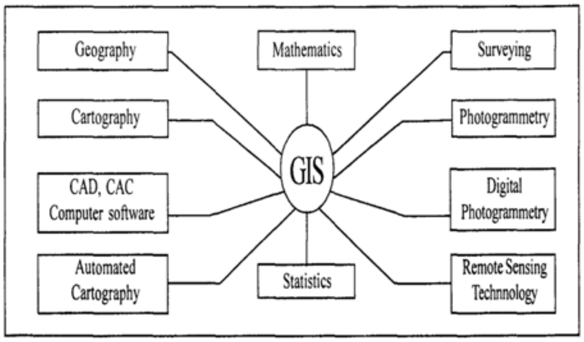


Figure: Reddy, "Remote Sensing, and Geographical Information Systems"

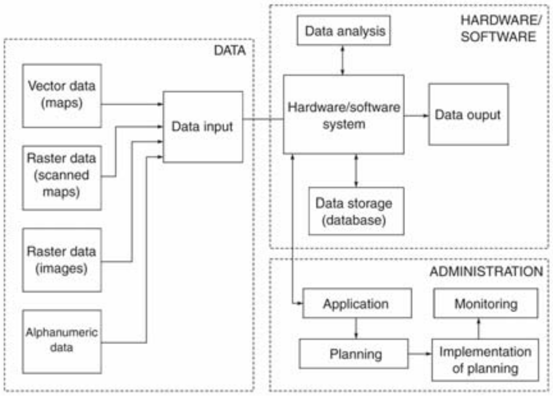


Figure: Konecny, "Geoinformation: Remote Sensing, Photogrammetry and Geographical Information Systems"

A *geographic information system*, as defined in the Environmental Systems Research Institute’s (ESRI’s) *Dictionary of GIS Terminology*, is a collection of computer hardware, software, and geographic data for capturing, storing, updating, manipulating, analyzing, and displaying all forms of geographically referenced information.

Common GIS Systems

Commercial

State of the art: ESRI ArcGIS

Knocking on the door: MATLAB

The future (?): Google earth engine a google.org project

Open-Source

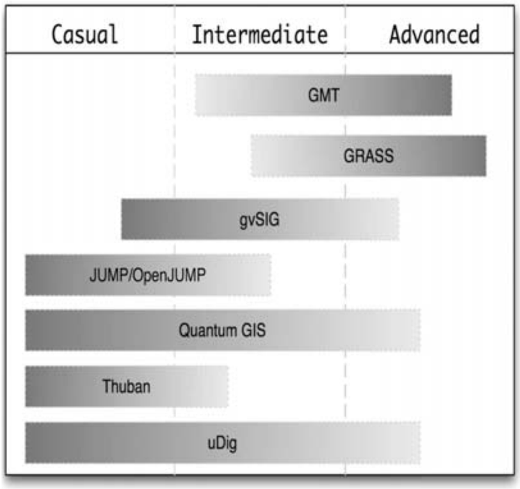


Figure: Sherman, “Desktop GIS”

GIS Data Abstraction

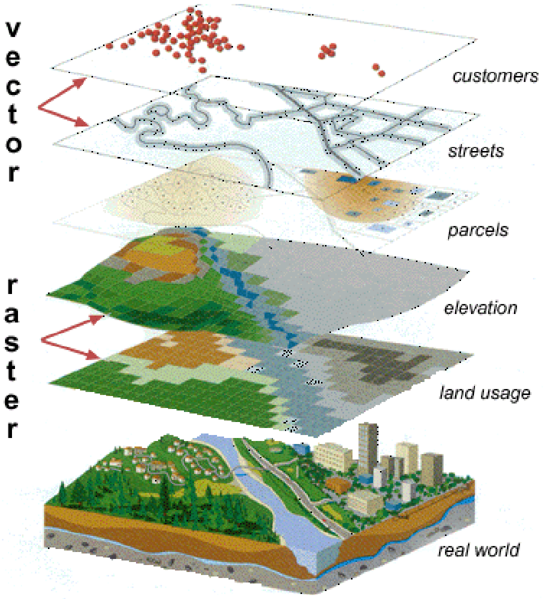


Figure: NCDDC/NOAA

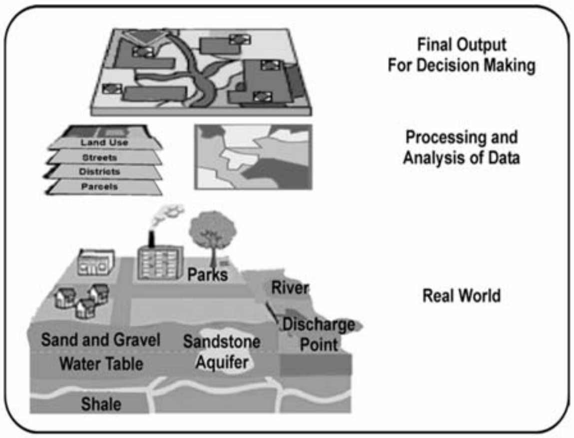
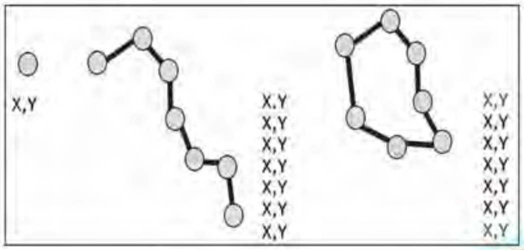


Figure: Fazal, “GIS Basics”

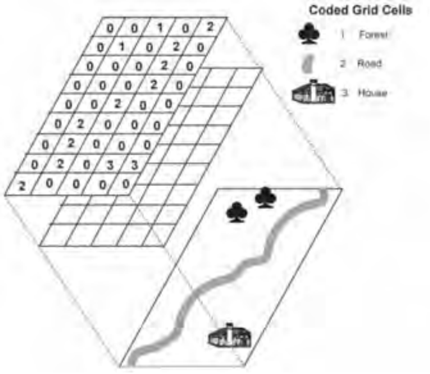
Layer cake model

GIS Data Types

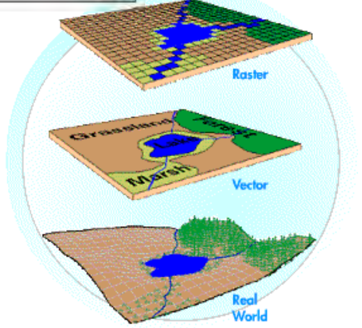
Vector



Raster



0	0	1	0	2	
0	1	0	2	0	
0	0	0	2	0	
0	0	0	2	0	
0	0	2	0	0	
0	2	0	0	0	
0	2	0	0	0	
0	2	0	3	3	
2	0	0	0	0	



Common formats:

- ESRI Shapefiles
- CAD files
- Digital Line Graph

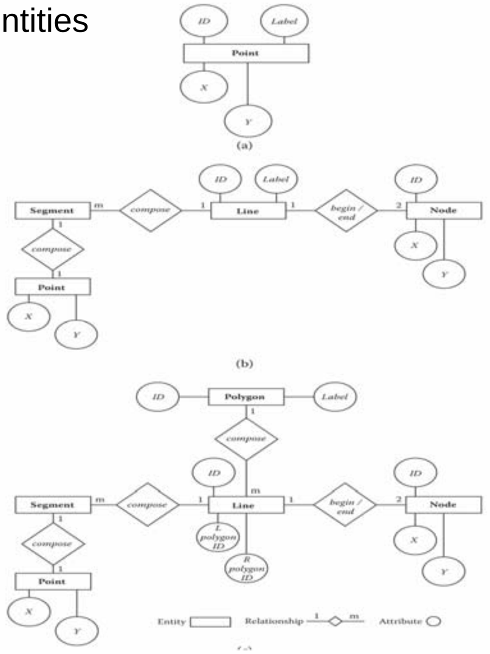
Common formats:

- ESRI grid
- USGS dem
- geoTIFF

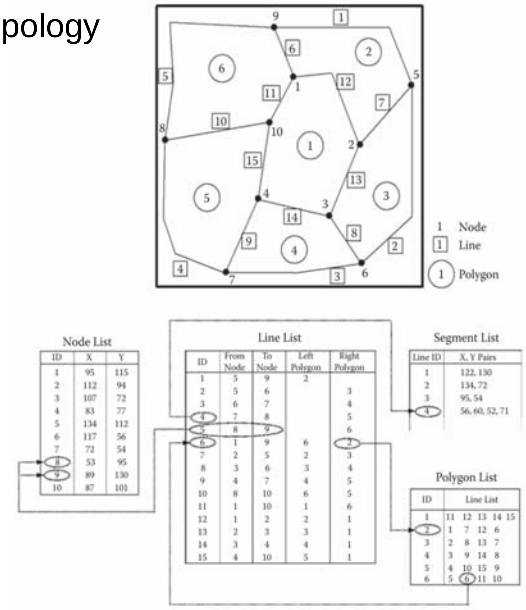
Figures: Fazal, “GIS Basics"

Vector Data

Entities



Topology



Node List

ID	X	Y
1	95	115
2	112	94
3	107	72
4	83	77
5	134	112
6	117	56
7	72	54
8	53	95
9	89	130
10	87	101

Line List

ID	From Node	To Node	Left Polygon	Right Polygon
1	5	9	2	
2	5	6		3
3	6	7		4
4	7	8		5
5	8	9		6
6	1	9	6	2
7	2	5	2	3
8	3	6	3	4
9	4	7	4	5
10	8	10	6	5
11	1	10	1	6
12	1	2	2	1
13	2	3	3	1
14	3	4	4	1
15	4	10	5	1

Segment List

Line ID	X, Y Pairs
1	122, 130
2	134, 72
3	95, 54
4	56, 60, 52, 71

Polygon List

ID	Line List
1	11 12 13 14 15
2	1 7 12 6
3	2 8 13 7
4	3 9 14 8
5	4 10 15 9
6	5 6 11 10

Figures: Brimicombe, “GIS, environmental modeling and engineering"

Raster Data

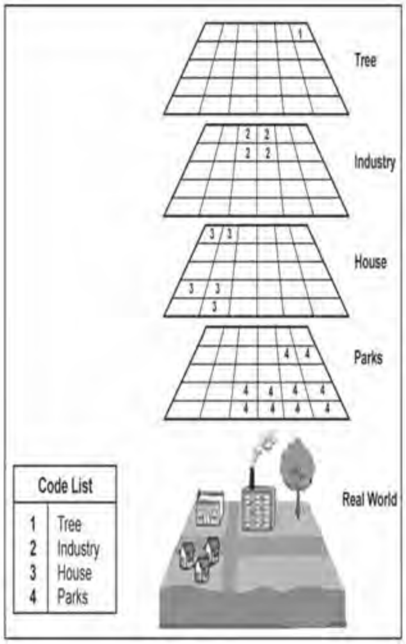
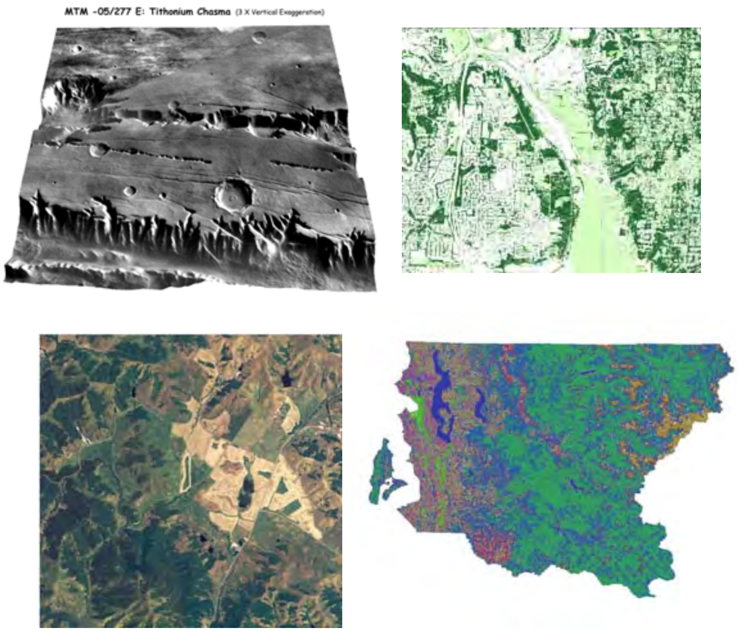


Figure: Fazal, “GIS Basics"



Figures: Wikipedia and other internet resources

Vector vs. Raster Example

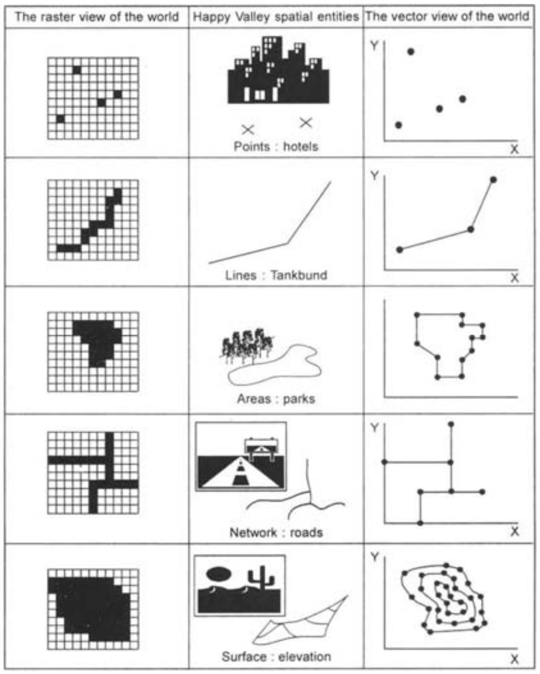


Figure: Reddy, "Remote Sensing, and Geographical Information Systems"

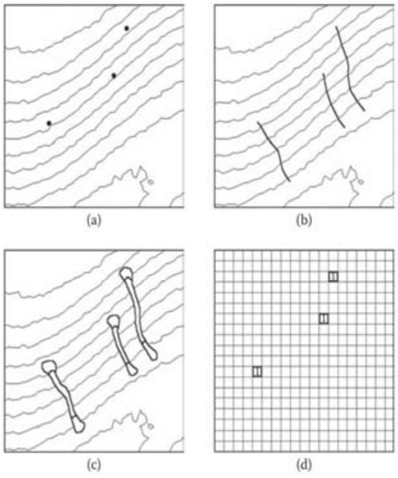
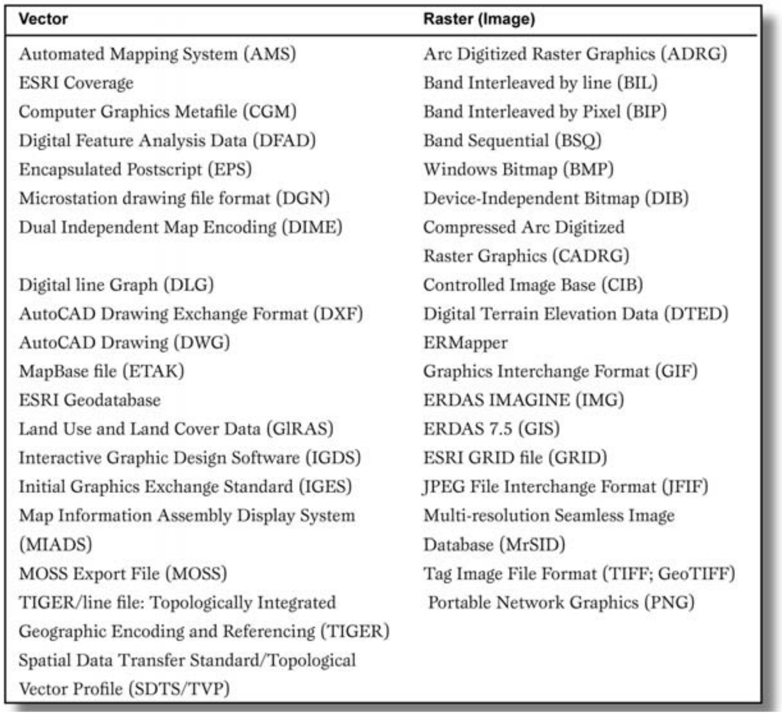


FIGURE 2.6
Four possible methods of representing landslides in GIS: (a) as points, (b) as lines, (c) as polygons, (d) as a tessellation (raster).

Figure: Brimicombe, “GIS, environmental modeling and engineering"

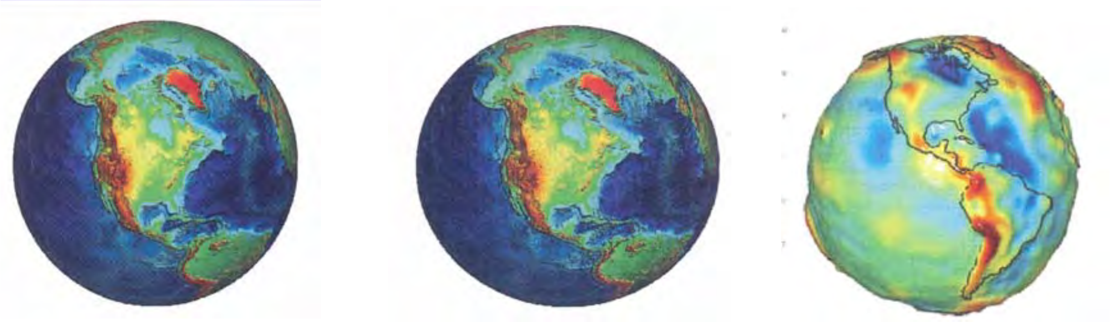
Vector and Raster Formats



Vector	Raster (Image)
Automated Mapping System (AMS)	Arc Digitized Raster Graphics (ADRG)
ESRI Coverage	Band Interleaved by line (BIL)
Computer Graphics Metafile (CGM)	Band Interleaved by Pixel (BIP)
Digital Feature Analysis Data (DFAD)	Band Sequential (BSQ)
Encapsulated Postscript (EPS)	Windows Bitmap (BMP)
Microstation drawing file format (DGN)	Device-Independent Bitmap (DIB)
Dual Independent Map Encoding (DIME)	Compressed Arc Digitized Raster Graphics (CADRG)
Digital line Graph (DLG)	Controlled Image Base (CIB)
AutoCAD Drawing Exchange Format (DXF)	Digital Terrain Elevation Data (DTED)
AutoCAD Drawing (DWG)	ERMapper
MapBase file (ETAK)	Graphics Interchange Format (GIF)
ESRI Geodatabase	ERDAS IMAGINE (IMG)
Land Use and Land Cover Data (GIRAS)	ERDAS 7.5 (GIS)
Interactive Graphic Design Software (IGDS)	ESRI GRID file (GRID)
Initial Graphics Exchange Standard (IGES)	JPEG File Interchange Format (JFIF)
Map Information Assembly Display System (MIADS)	Multi-resolution Seamless Image Database (MrSID)
MOSS Export File (MOSS)	Tag Image File Format (TIFF; GeoTIFF)
TIGER/line file: Topologically Integrated Geographic Encoding and Referencing (TIGER)	Portable Network Graphics (PNG)
Spatial Data Transfer Standard/Topological Vector Profile (SDTS/TVP)	

Figure: Fazal, "GIS Basics"

Georeferencing: Datums



Figures: Clarke, "Getting Started with GIS"

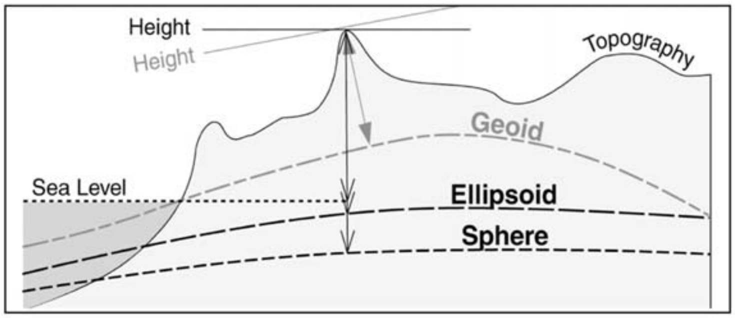
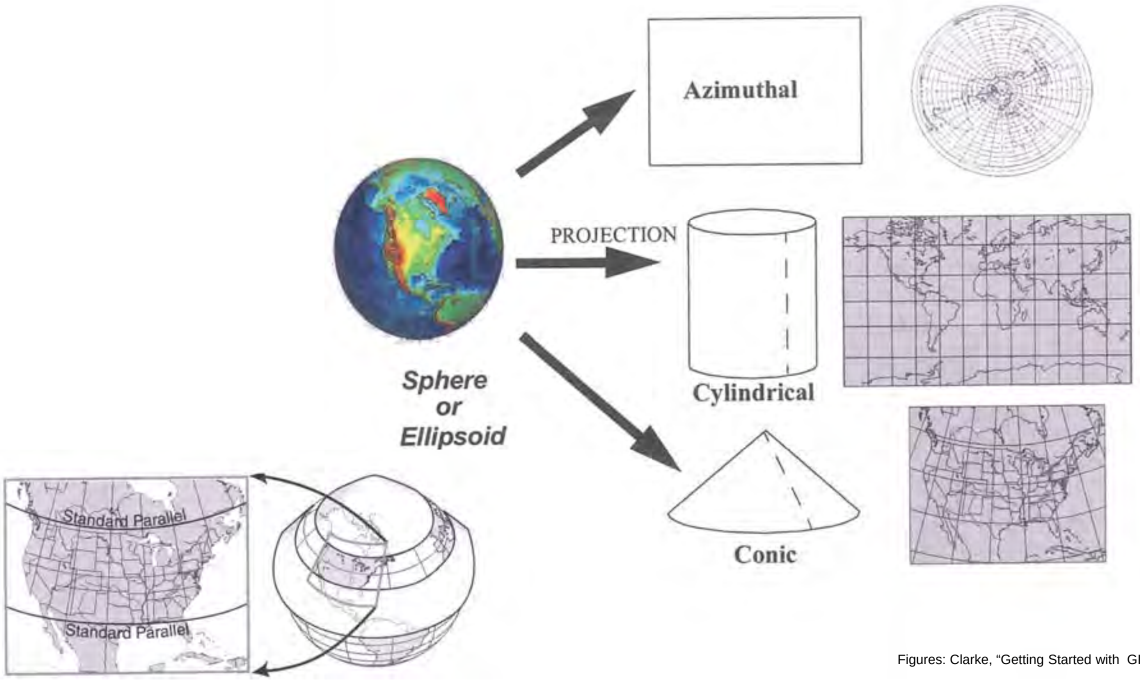


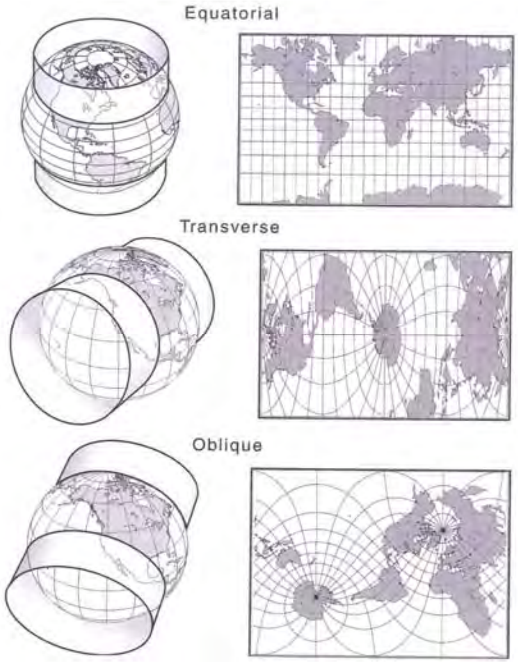
Figure: Fazal, "GIS Basics"

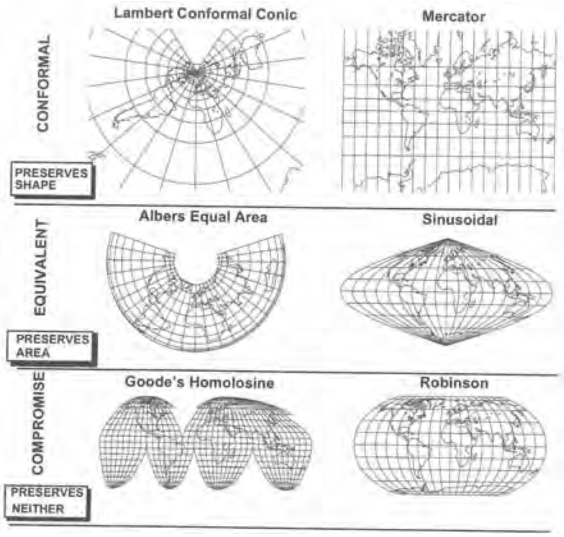
Georeferencing: Projections



Figures: Clarke, "Getting Started with GIS"

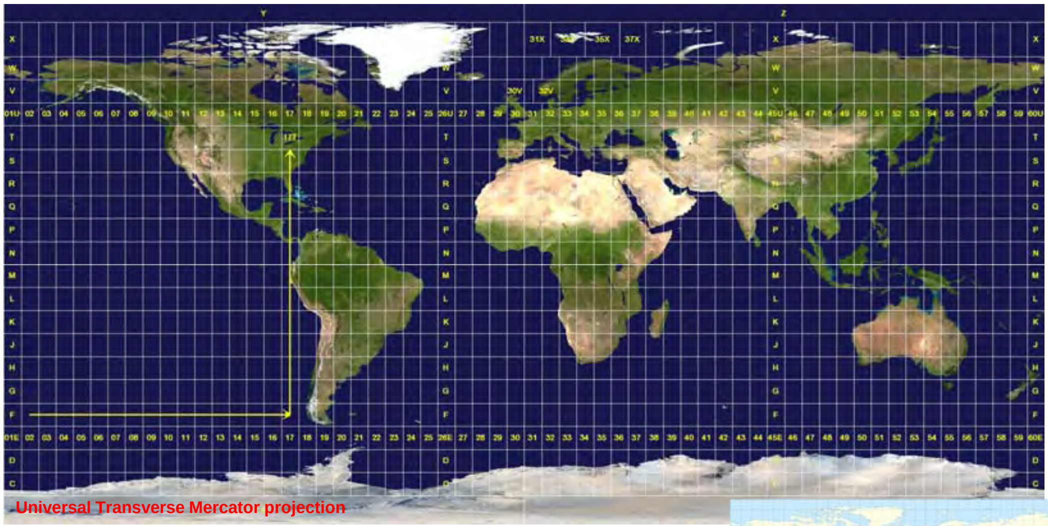
Georeferencing: Projections





Figures: Clarke, "Getting Started with GIS"

UTM Projection



Universal Transverse Mercator projection

Conformal:

- Preserves angles and shapes
- Distorts areas and distances (~1/1000)
- 60 zones of 6 degrees longitude
- Units of meters

Geographic projection

Figures: Wikipedia

GIS Operations

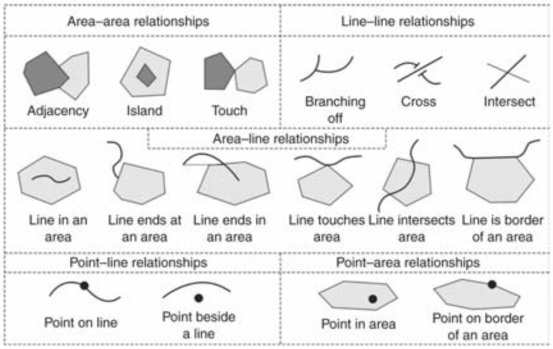
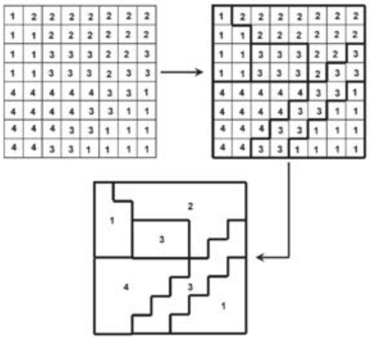


Figure: Fazal, "GIS Basics"

Topology



1	2	2	2	2	2	2	2
1	1	2	2	2	2	2	2
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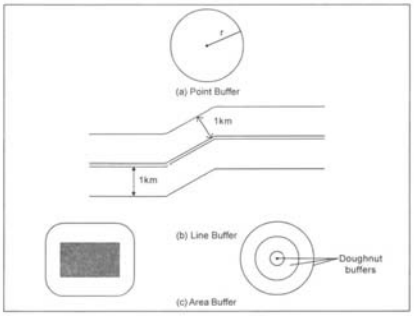
1	1	3	3	3	2	3	3
4	4	4	4	4	3	3	1
4	4	4	4	3	3	1	1
4	4	4	3	3	1	1	1
4	4	3	3	1	1	1	1

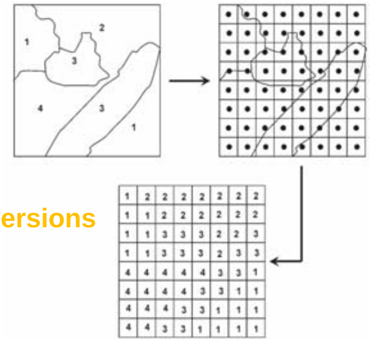
1	2	2	2	2	2	2	2
1	1	2	2	2	2	2	2
1	1	3	3	3	2	2	3
1	1	3	3	3	2	3	3
4	4	4	4	4	3	3	1
4	4	4	4	3	3	1	1
4	4	4	3	3	1	1	1
4	4	3	3	1	1	1	1



Buffers

Figure: Reddy, "Remote Sensing, and Geographical Information Systems"

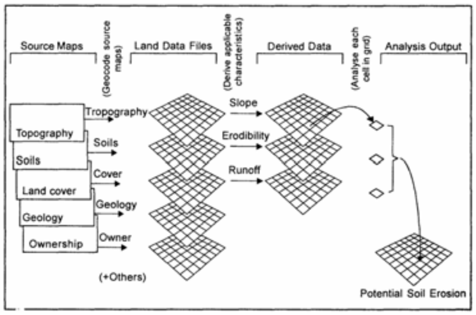
Conversions



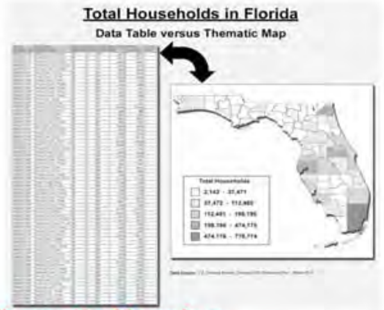
1	2	2	2	2	2	2	2
1	1	2	2	2	2	2	2
1	1	3	3	3	2	2	3
1	1	3	3	3	2	3	3
4	4	4	4	4	3	3	1
4	4	4	4	3	3	1	1
4	4	4	3	3	1	1	1
4	4	3	3	1	1	1	1

Figure: Fazal, "GIS Basics"

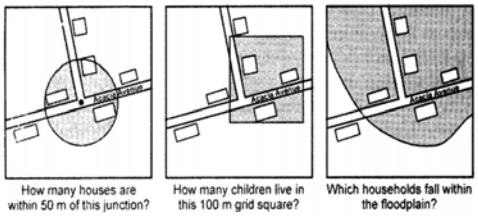
GIS Operations



Map Algebra Figure: Reddy, "Remote Sensing, and GIS"



Thematic Mapping Figure: Galati, "GIS Demistified"



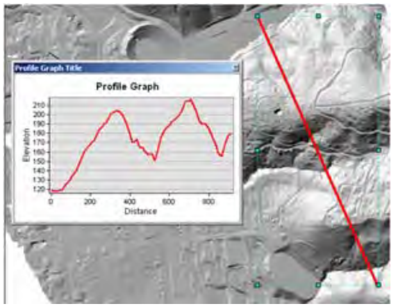
How many houses are within 50 m of this junction?

How many children live in this 100 m grid square?

Which households fall within the floodplain?

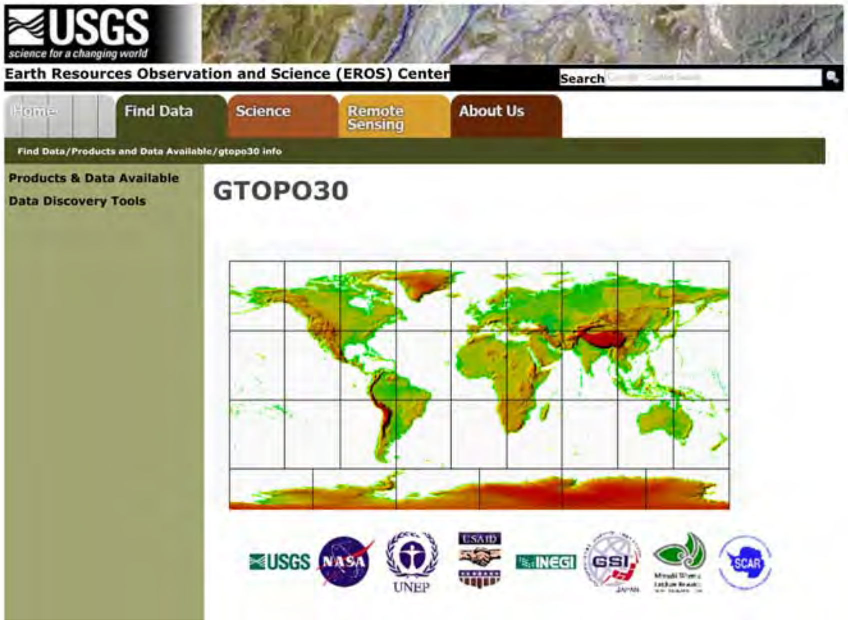
Database Queries
(by location and/or attribute)

Figure: Fazal, "GIS Basics"



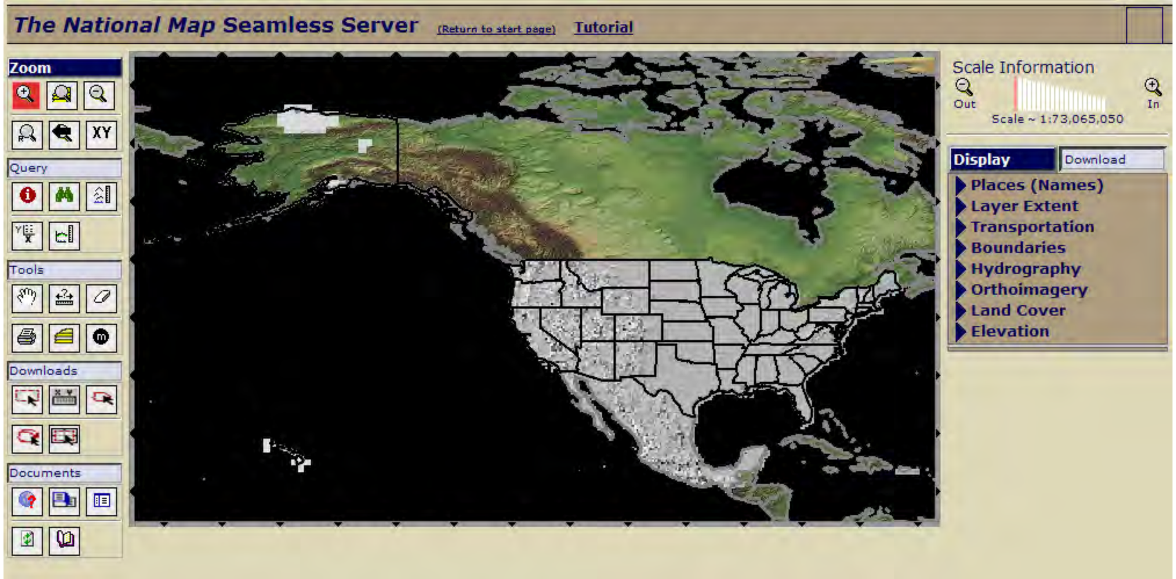
Measurements

GIS Data Sources: GTOPO30

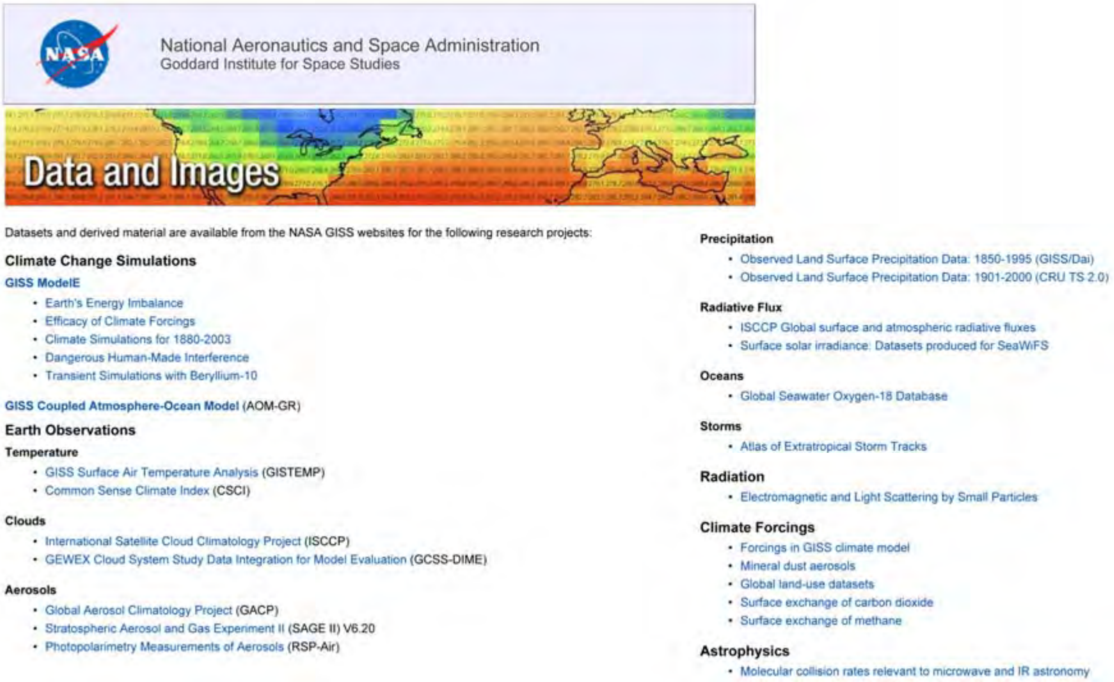


Entire world at 30 arc seconds (~1km) resolution

GIS Data Sources: USGS



GIS Data Sources: NASA



National Aeronautics and Space Administration
Goddard Institute for Space Studies

Data and Images

Datasets and derived material are available from the NASA GISS websites for the following research projects:

Climate Change Simulations

GISS ModelE

- Earth's Energy Imbalance
- Efficacy of Climate Forcings
- Climate Simulations for 1880-2003
- Dangerous Human-Made Interference
- Transient Simulations with Beryllium-10

GISS Coupled Atmosphere-Ocean Model (AOM-GR)

Earth Observations

Temperature

- GISS Surface Air Temperature Analysis (GISTEMP)
- Common Sense Climate Index (CSCI)

Clouds

- International Satellite Cloud Climatology Project (ISCCP)
- GEWEX Cloud System Study Data Integration for Model Evaluation (GCSS-DIME)

Aerosols

- Global Aerosol Climatology Project (GACP)
- Stratospheric Aerosol and Gas Experiment II (SAGE II) V6.20
- Photopolarimetry Measurements of Aerosols (RSP-Air)

Precipitation

- Observed Land Surface Precipitation Data: 1850-1995 (GISS/Dai)
- Observed Land Surface Precipitation Data: 1901-2000 (CRU TS 2.0)

Radiative Flux

- ISCCP Global surface and atmospheric radiative fluxes
- Surface solar irradiance: Datasets produced for SeaWiFS

Oceans

- Global Seawater Oxygen-18 Database

Storms

- Atlas of Extratropical Storm Tracks

Radiation

- Electromagnetic and Light Scattering by Small Particles

Climate Forcings

- Forcings in GISS climate model
- Mineral dust aerosols
- Global land-use datasets
- Surface exchange of carbon dioxide
- Surface exchange of methane

Astrophysics

- Molecular collision rates relevant to microwave and IR astronomy

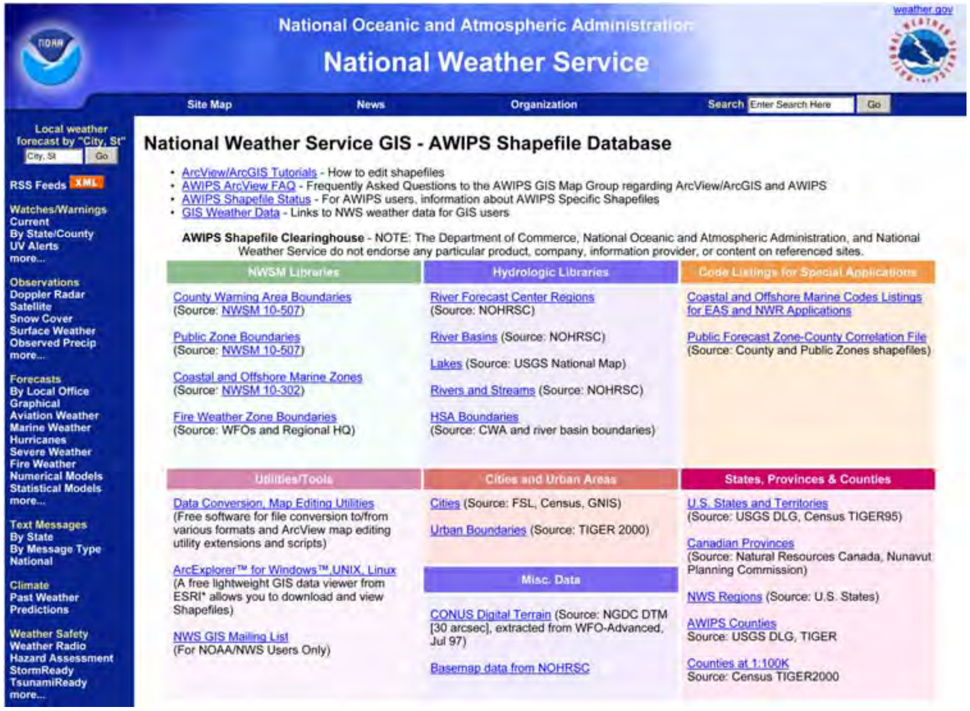
GIS Data Sources: NOAA

In the Spotlight: March 11, 2011 Honshu, Japan Tsunami

NOAA's National Geophysical Data Center (NGDC) provides scientific stewardship, products, and services for geophysical data from the Sun to the Earth and Earth's sea floor and solid earth environment, including Earth observations from space.

Learn more about NGDC activities, mission, and organizational structure or read the latest news.

GIS Data Sources: NWS



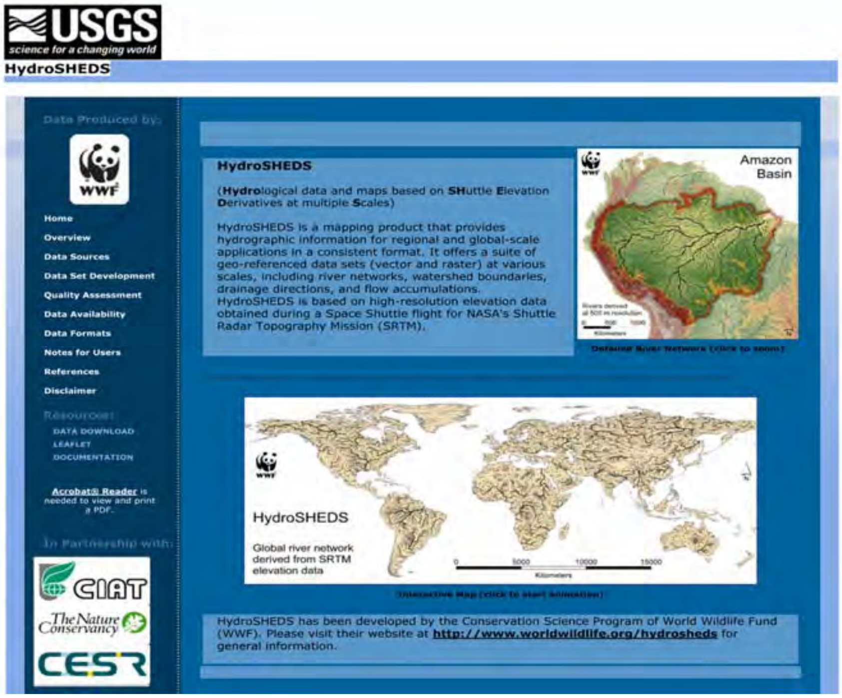
National Weather Service GIS - AWIPS Shapefile Database

- ArcView/ArcGIS Tutorials - How to edit shapefiles
- AWIPS ArcView FAQ - Frequently Asked Questions to the AWIPS GIS Map Group regarding ArcView/ArcGIS and AWIPS
- AWIPS Shapefile Status - For AWIPS users, information about AWIPS Specific Shapefiles
- GIS Weather Data - Links to NWS weather data for GIS users

AWIPS Shapefile Clearinghouse - NOTE: The Department of Commerce, National Oceanic and Atmospheric Administration, and National Weather Service do not endorse any particular product, company, information provider, or content on referenced sites.

NWSM Libraries	Hydrologic Libraries	Code Listings for Special Applications
County Warning Area Boundaries (Source: NWSM 10-507) Public Zone Boundaries (Source: NWSM 10-507) Coastal and Offshore Marine Zones (Source: NWSM 10-302) Fire Weather Zone Boundaries (Source: WFOs and Regional HQ)	River Forecast Center Regions (Source: NOHRSC) River Basins (Source: NOHRSC) Lakes (Source: USGS National Map) Rivers and Streams (Source: NOHRSC) HSA Boundaries (Source: CWA and river basin boundaries)	Coastal and Offshore Marine Codes Listings for EAS and NWR Applications Public Forecast Zone-County Correlation File (Source: County and Public Zones shapefiles)
Utilities/Tools	**Cities and Urban Areas**	**States, Provinces & Counties**
Data Conversion, Map Editing Utilities (Free software for file conversion to/from various formats and ArcView map editing utility extensions and scripts) ArcExplorer™ for Windows™,UNIX, Linux (A free lightweight GIS data viewer from ESRI* allows you to download and view Shapefiles) NWS GIS Mailing List (For NOAA/NWS Users Only)	Cities (Source: FSL, Census, GNIS) Urban Boundaries (Source: TIGER 2000) **Misc. Data** CONUS Digital Terrain (Source: NGDC DTM [30 arcsec], extracted from WFO-Advanced, Jul 97) Basemap data from NOHRSC	U.S. States and Territories (Source: USGS DLG, Census TIGER95) Canadian Provinces (Source: Natural Resources Canada, Nunavut Planning Commission) NWS Regions (Source: U.S. States) AWIPS Counties Source: USGS DLG, TIGER Counties at 1:100K Source: Census TIGER2000

GIS Data Sources: HydroSHEDS



HydroSHEDS

(**Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives at multiple **S**cales)

HydroSHEDS is a mapping product that provides hydrographic information for regional and global-scale applications in a consistent format. It offers a suite of geo-referenced data sets (vector and raster) at various scales, including river networks, watershed boundaries, drainage directions, and flow accumulations. HydroSHEDS is based on high-resolution elevation data obtained during a Space Shuttle flight for NASA's Shuttle Radar Topography Mission (SRTM).

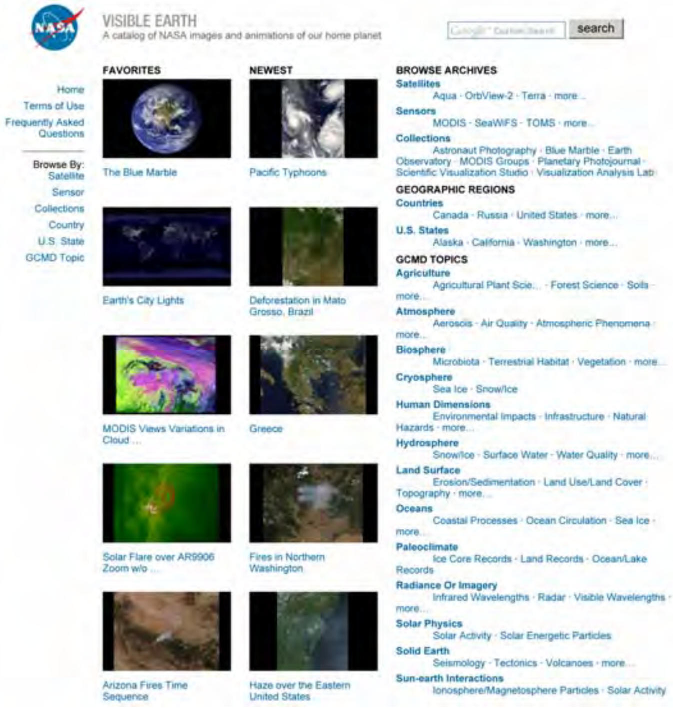
Detailed River Network (click to zoom)

Interactive Map (click to start animation)

HydroSHEDS has been developed by the Conservation Science Program of World Wildlife Fund (WWF). Please visit their website at **http://www.worldwildlife.org/hydrosheds** for general information.

Acrobat® Reader is needed to view and print a PDF.

GIS Data Sources: Visible Earth



BROWSE ARCHIVES

Satellites
Aqua · OrbView-2 · Terra · more...

Sensors
MODIS · SeaWiFS · TOMS · more...

Collections
Astronaut Photography · Blue Marble · Earth Observatory · MODIS Groups · Planetary Photojournal · Scientific Visualization Studio · Visualization Analysis Lab

GEOGRAPHIC REGIONS

Countries
Canada · Russia · United States · more...

U.S. States
Alaska · California · Washington · more...

GCMD TOPICS

Agriculture
Agricultural Plant Scie... · Forest Science · Soils · more...

Atmosphere
Aerosols · Air Quality · Atmospheric Phenomena · more...

Biosphere
Microbiota · Terrestrial Habitat · Vegetation · more...

Cryosphere
Sea Ice · Snow/Ice

Human Dimensions
Environmental Impacts · Infrastructure · Natural Hazards · more...

Hydrosphere
Snow/Ice · Surface Water · Water Quality · more...

Land Surface
Erosion/Sedimentation · Land Use/Land Cover · Topography · more...

Oceans
Coastal Processes · Ocean Circulation · Sea Ice · more...

Paleoclimate
Ice Core Records · Land Records · Ocean/Lake Records

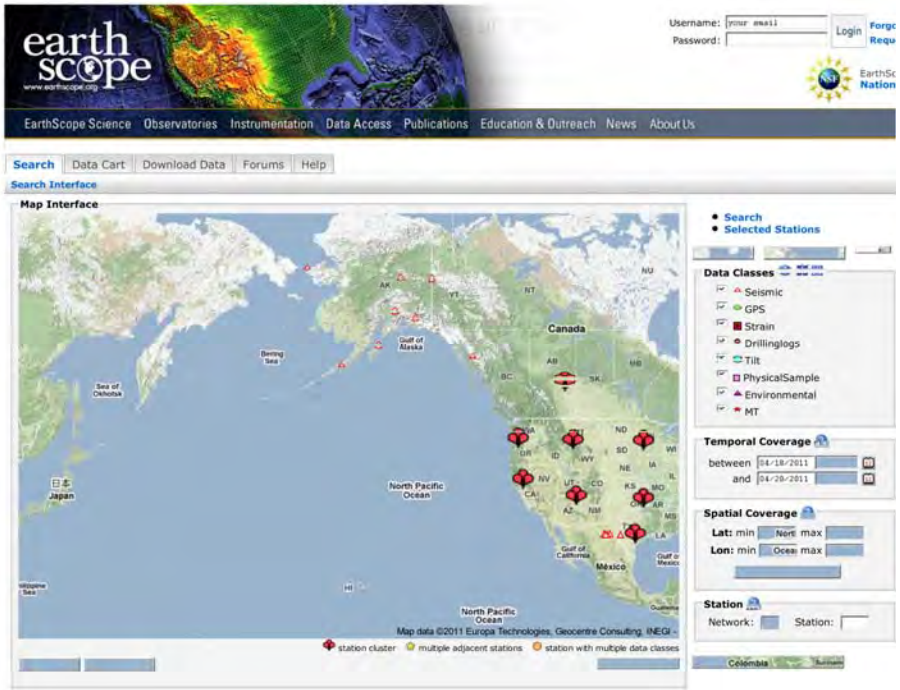
Radiance Or Imagery
Infrared Wavelengths · Radar · Visible Wavelengths · more...

Solar Physics
Solar Activity · Solar Energetic Particles

Solid Earth
Seismology · Tectonics · Volcanoes · more...

Sun-earth Interactions
Ionosphere/Magnetosphere Particles · Solar Activity

GIS Data Sources: EarthScope



Username: your email

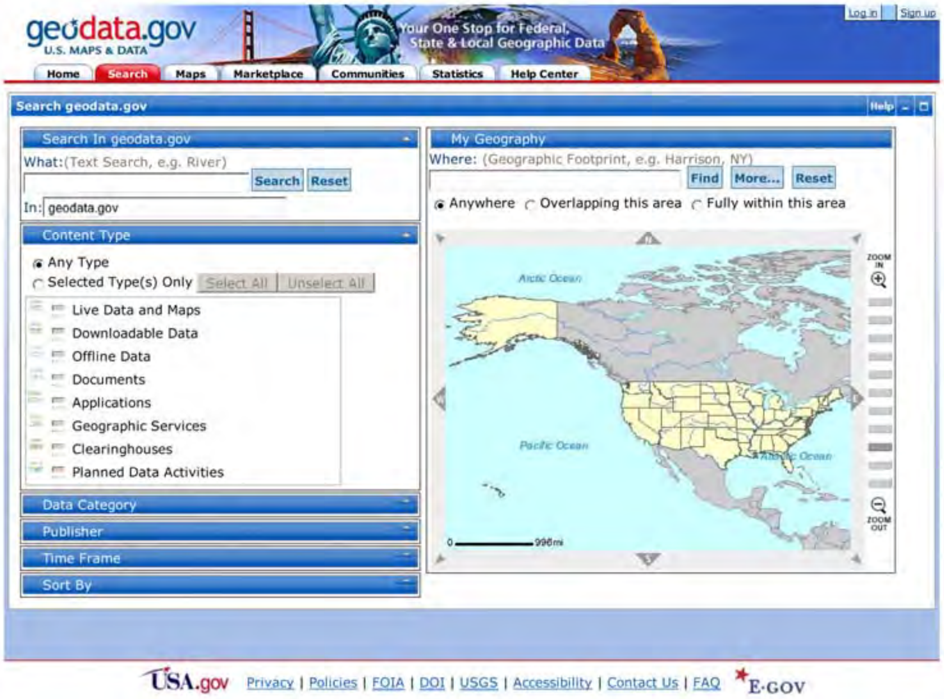
Password:

Temporal Coverage: between 04/18/2011 and 04/20/2011

Spatial Coverage: Lat: min max; Lon: min max

Station: Network: Station:

GIS Data Sources: geodata.gov



What: (Text Search, e.g. River)

In: geodata.gov

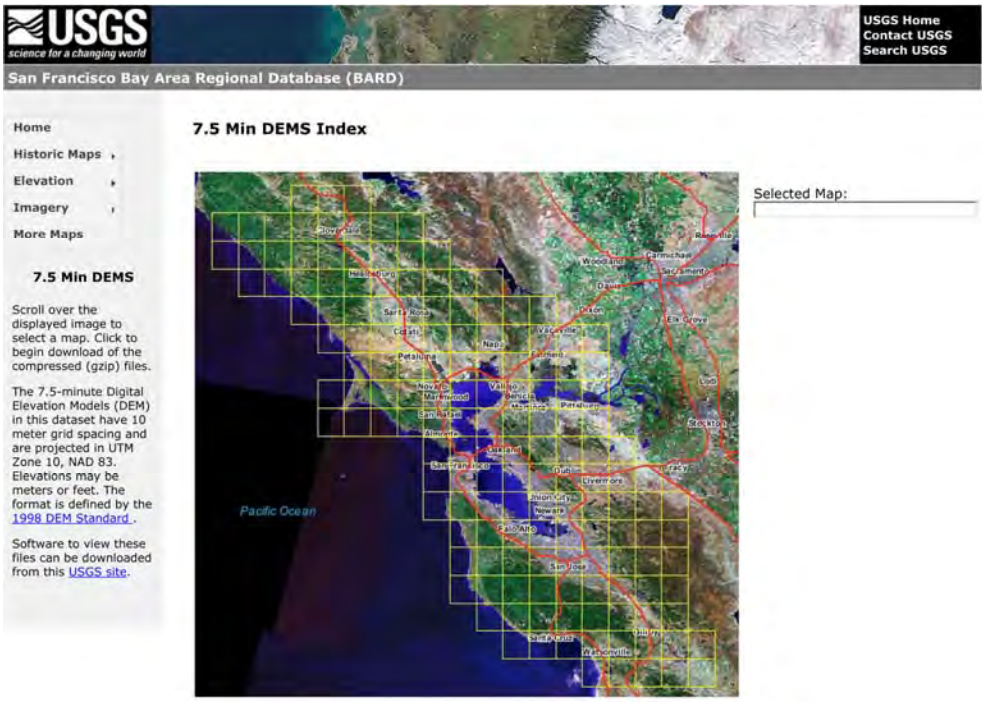
● Any Type
○ Selected Type(s) Only

- ☐ Live Data and Maps
- ☐ Downloadable Data
- ☐ Offline Data
- ☐ Documents
- ☐ Applications
- ☐ Geographic Services
- ☐ Clearinghouses
- ☐ Planned Data Activities

Where: (Geographic Footprint, e.g. Harrison, NY)

● Anywhere ○ Overlapping this area ○ Fully within this area

GIS Data Sources: BARD



San Francisco Bay Area Regional Database (BARD)

- Home
- Historic Maps ▸
- Elevation ▸
- Imagery ▸
- More Maps

7.5 Min DEMS

Scroll over the displayed image to select a map. Click to begin download of the compressed (gzip) files.

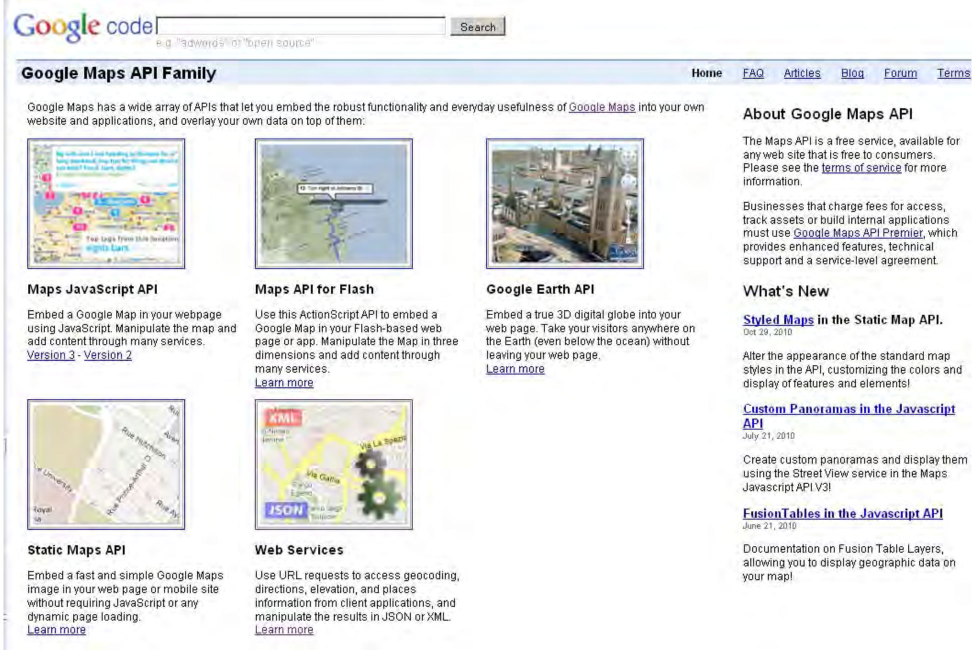
The 7.5-minute Digital Elevation Models (DEM) in this dataset have 10 meter grid spacing and are projected in UTM Zone 10, NAD 83. Elevations may be meters or feet. The format is defined by the 1998 DEM Standard .

Software to view these files can be downloaded from this USGS site.

7.5 Min DEMS Index

Selected Map:

GIS Data Sources: Google



Google Maps API Family

Google Maps has a wide array of APIs that let you embed the robust functionality and everyday usefulness of Google Maps into your own website and applications, and overlay your own data on top of them:

Maps JavaScript API

Embed a Google Map in your webpage using JavaScript. Manipulate the map and add content through many services.
Version 3 - Version 2

Maps API for Flash

Use this ActionScript API to embed a Google Map in your Flash-based web page or app. Manipulate the Map in three dimensions and add content through many services.
Learn more

Google Earth API

Embed a true 3D digital globe into your web page. Take your visitors anywhere on the Earth (even below the ocean) without leaving your web page.
Learn more

Static Maps API

Embed a fast and simple Google Maps image in your web page or mobile site without requiring JavaScript or any dynamic page loading.
Learn more

Web Services

Use URL requests to access geocoding, directions, elevation, and places information from client applications, and manipulate the results in JSON or XML.
Learn more

About Google Maps API

The Maps API is a free service, available for any web site that is free to consumers. Please see the terms of service for more information.

Businesses that charge fees for access, track assets or build internal applications must use Google Maps API Premier, which provides enhanced features, technical support and a service-level agreement.

What's New

Styled Maps in the Static Map API.
Oct 29, 2010

Alter the appearance of the standard map styles in the API, customizing the colors and display of features and elements!

Custom Panoramas in the Javascript API
July 21, 2010

Create custom panoramas and display them using the Street View service in the Maps Javascript API V3!

FusionTables in the Javascript API
June 21, 2010

Documentation on Fusion Table Layers, allowing you to display geographic data on your map!

GIS Data Sources: Microsoft

Click the green areas to zoom-in on the map.

© 2010 Microsoft Corporation. | Terms of Use | Privacy Statement | Sponsored By USGS Microsoft Research bing

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GIS Data Sources: Canada

Natural Resources Canada > Earth Sciences Sector > GeoGratis

Welcome to GeoGratis

Geospatial data available online at no cost and without restrictions!

GeoGratis is a portal provided by the Earth Sciences Sector (ESS) of Natural Resources Canada (NRCan) which provides geospatial data at no cost and without restrictions via your Web browser.

The data will be useful whether you're a novice who needs a geographic map for a presentation, or an expert who wants to overlay a vector layer of digital data on a classified multiband image, with a digital elevation model as a backdrop.

The geospatial data are grouped in collections and are compatible with the most popular geographic information systems (GIS), with image analysis systems and the graphics applications of editing software.

Register to users list

Natural Resources Canada encourages you to register, on a voluntary basis, to the GeoGratis' users list. This will allow NRCan to better know its users and to increase the quality of products and services offered on GeoGratis.

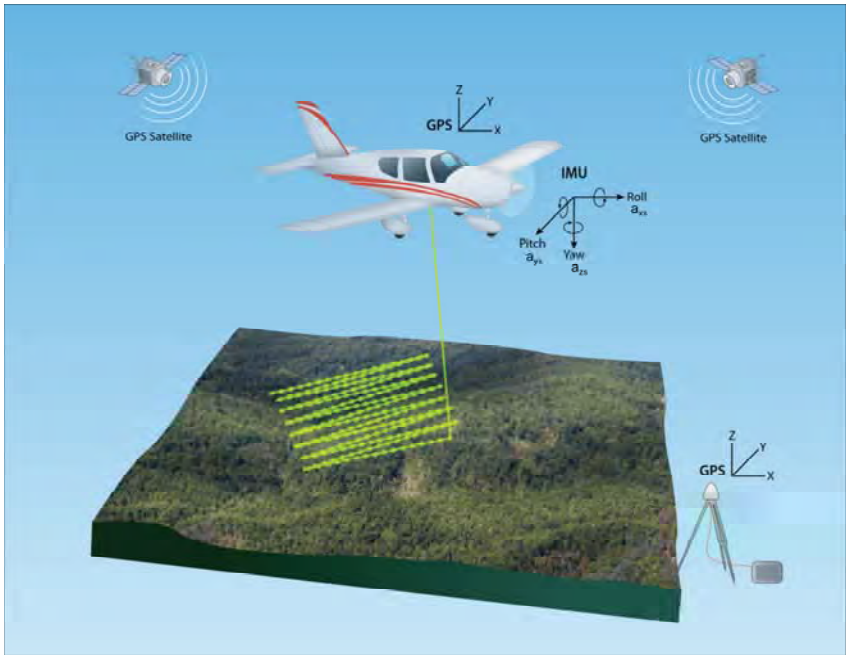
All the submitted information will be kept strictly confidential. Please, see also Natural Resources Canada Privacy Policy for more details.

Use and Restrictions

What's new?

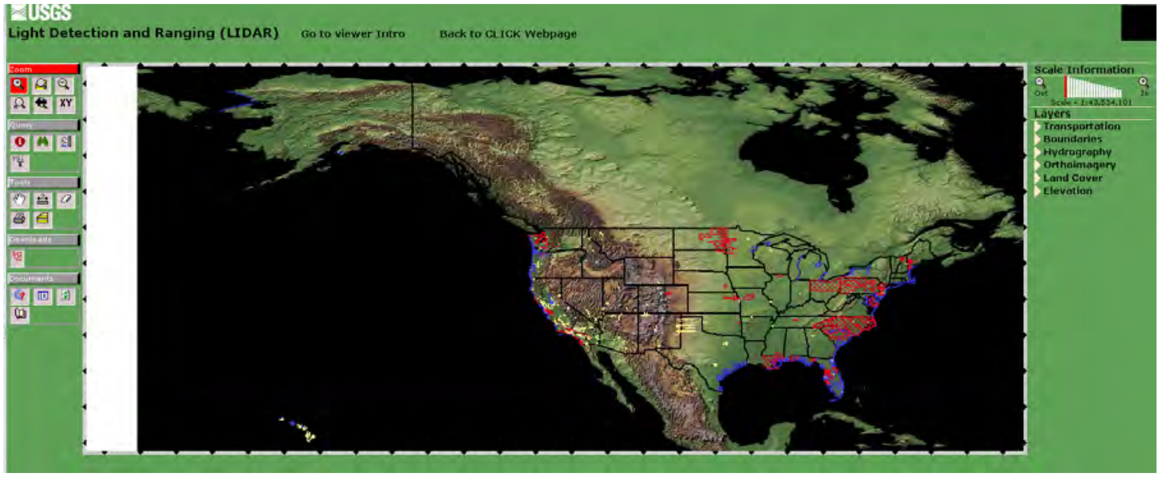
- New Canadian Topographic Maps
- New Release: Toporama, now available!
- New CanVec data now available
- Advisory to CanVec Users
- Distribution discrepancies - CanVec version 6 release - April 14th 2010
- New identifiers for GeoGratis Collection

LiDAR Data



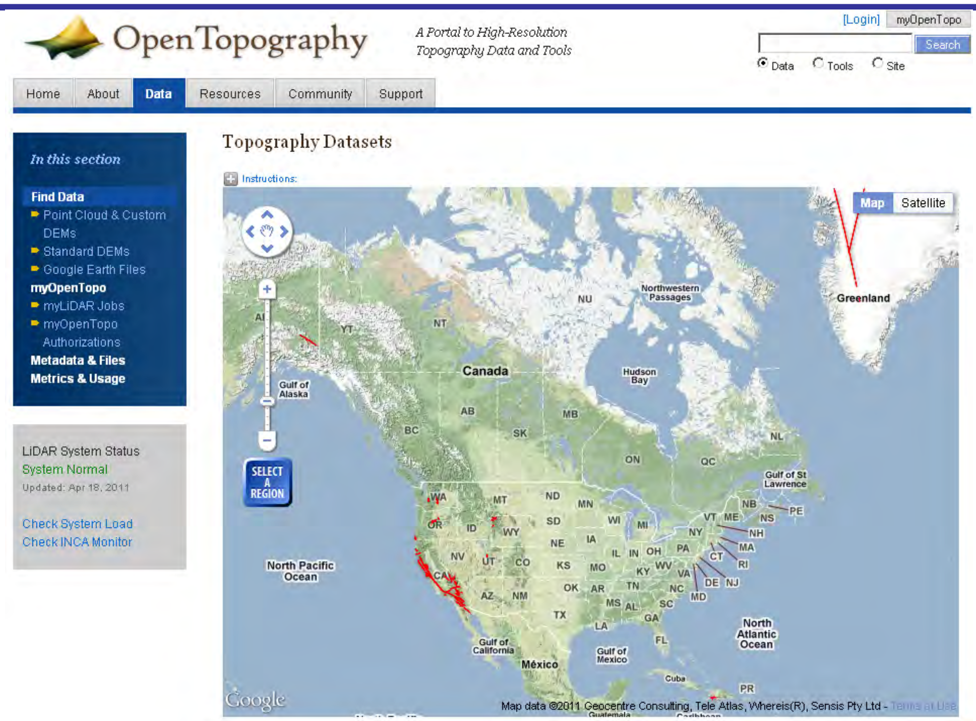
LiDAR Data Sources: NCALM

LiDAR Data Sources: USGS



Various states and local governments (via USGS portal)

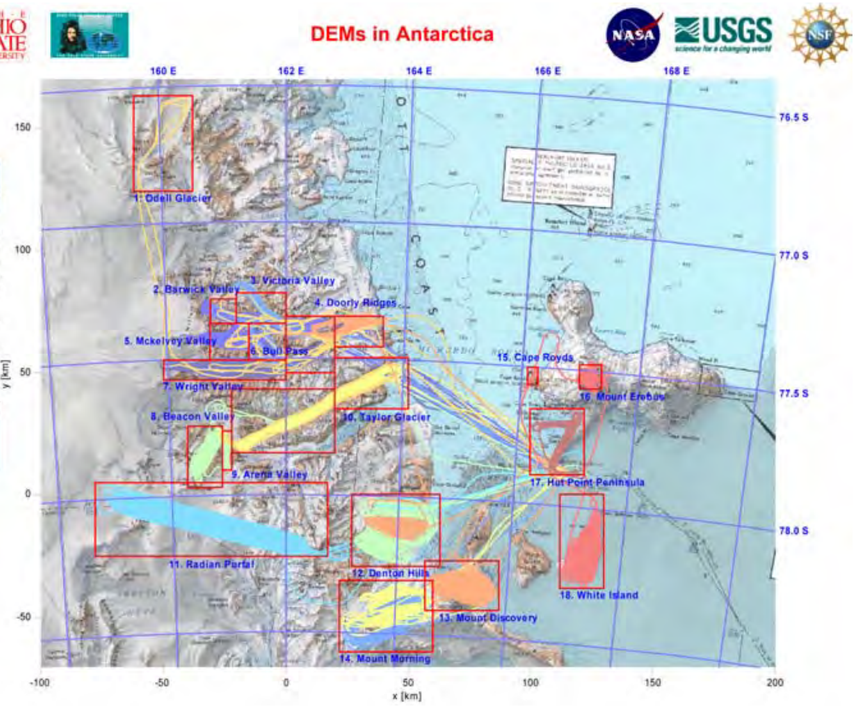
LiDAR Data Sources: OpenTopography



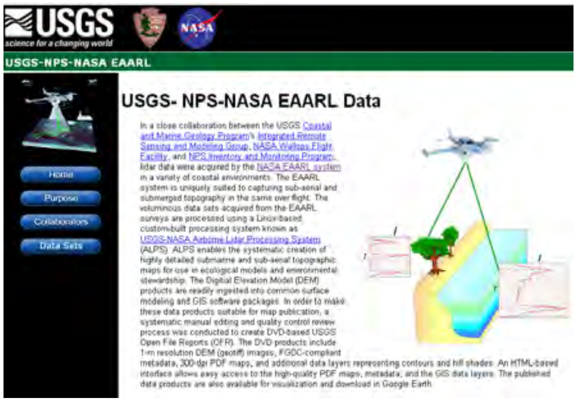
LiDAR Data Sources: Antartica

United States Antarctic Resource Center

LiDAR High-resolution DEMFinal D4

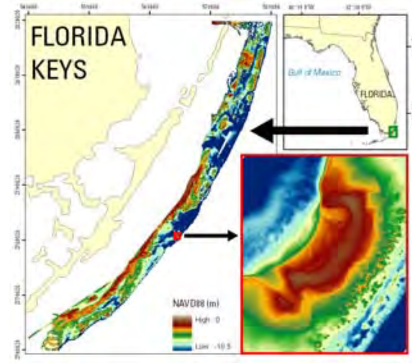


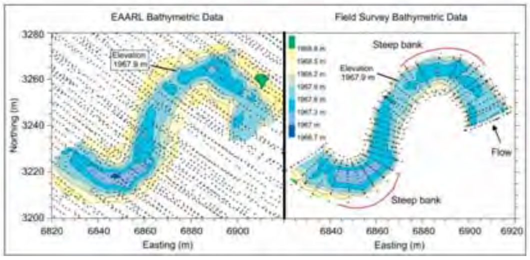
LiDAR Data Sources: Bathimetry



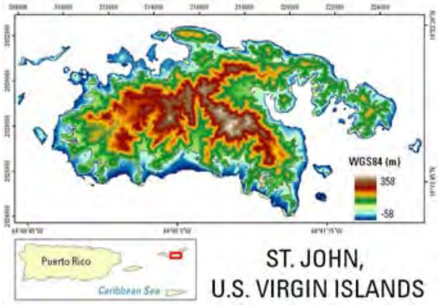
USGS- NPS-NASA EAARL Data

In a close collaboration between the USGS Coastal and Marine Geology Program's Integrated Remote Sensing and Modeling Group, NASA Wallops Flight Facility, and NPS Inventory and Monitoring Program, lidar data were acquired by the NASA EAARL system in a variety of coastal environments. The EAARL system is uniquely suited to capturing sub-aerial and submerged topography in the same over flight. The voluminous data sets acquired from the EAARL surveys are processed using a Linux-based custom-built processing system known as USGS-NASA Airborne Lidar Processing System (ALPS). ALPS enables the systematic creation of highly detailed submarine and sub-aerial topographic maps for use in ecological models and environmental stewardship. The Digital Elevation Model (DEM) products are readily ingested into common surface modeling and GIS software packages. In order to make these data products suitable for map publication, a systematic manual editing and quality control review process was conducted to create DVD-based USGS Open File Reports (OFR). The DVD products include 1-m resolution DEM (geotiff) images, FGDC-compliant metadata, 300-dpi PDF maps, and additional data layers representing contours and hill shades. An HTML-based interface allows easy access to the high-quality PDF maps, metadata, and the GIS data layers. The published data products are also available for visualization and download in Google Earth.



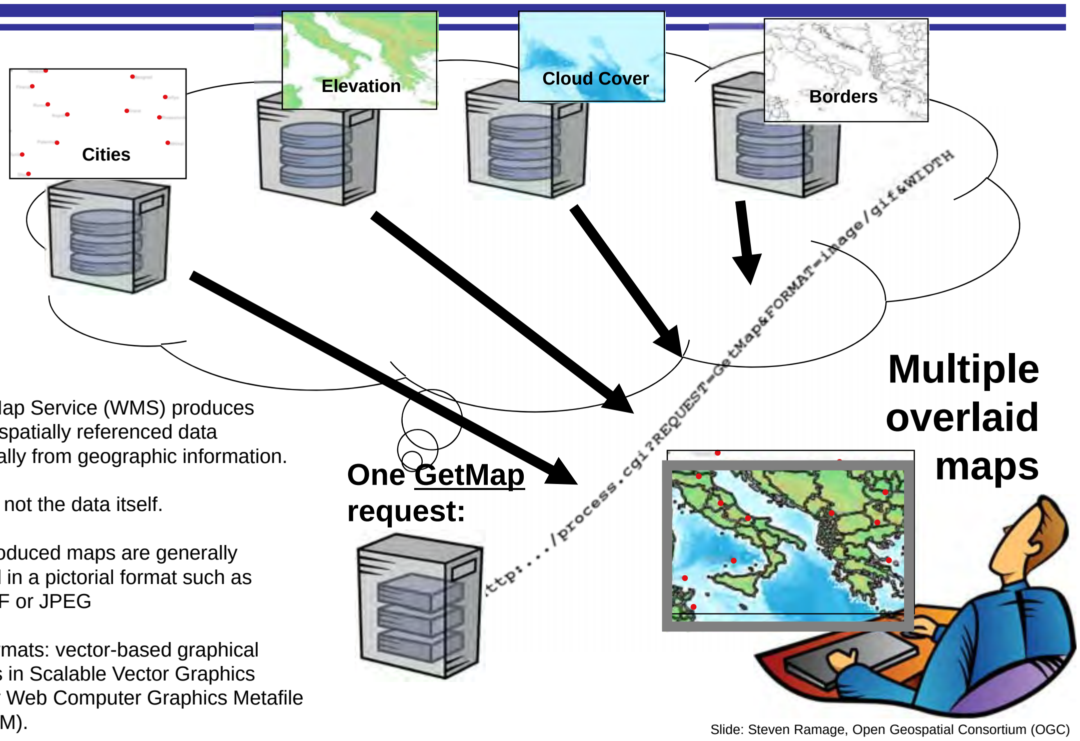


McKean et al., 2009



ST. JOHN,
U.S. VIRGIN ISLANDS

Web Map Service (WMS)



One GetMap request:

Multiple overlaid maps

A Web Map Service (WMS) produces maps of spatially referenced data dynamically from geographic information.

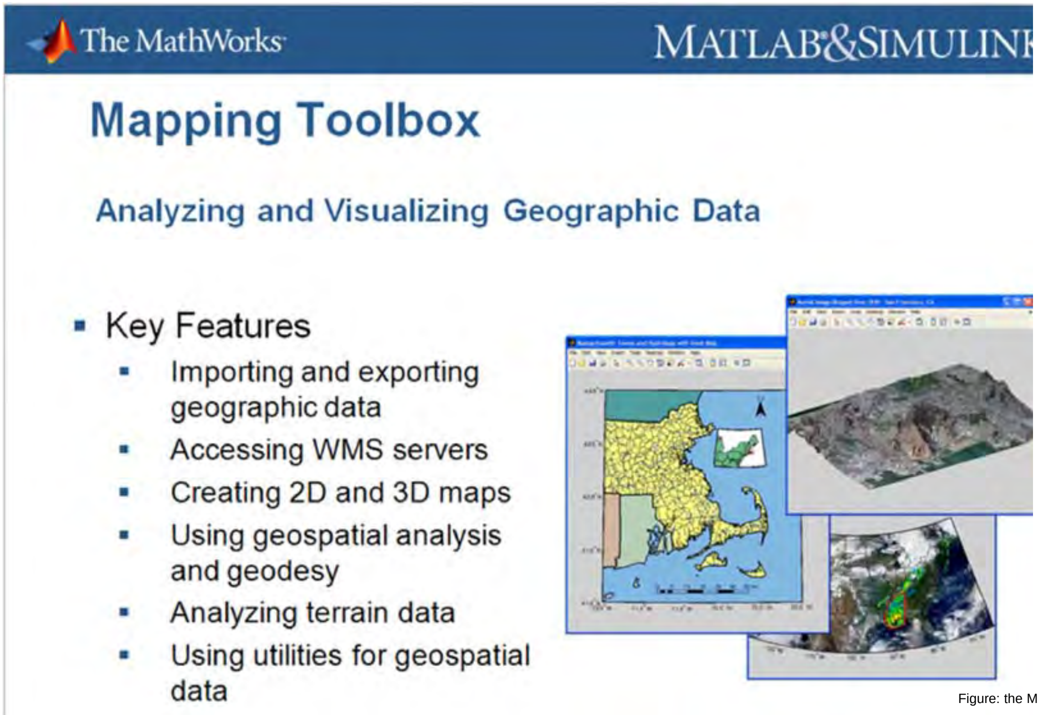
A map is not the data itself.

WMS-produced maps are generally rendered in a pictorial format such as PNG, GIF or JPEG

Other formats: vector-based graphical elements in Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (WebCGM).

Slide: Steven Ramage, Open Geospatial Consortium (OGC)

Mapping Toolbox: Features



The MathWorks MATLAB&SIMULIN

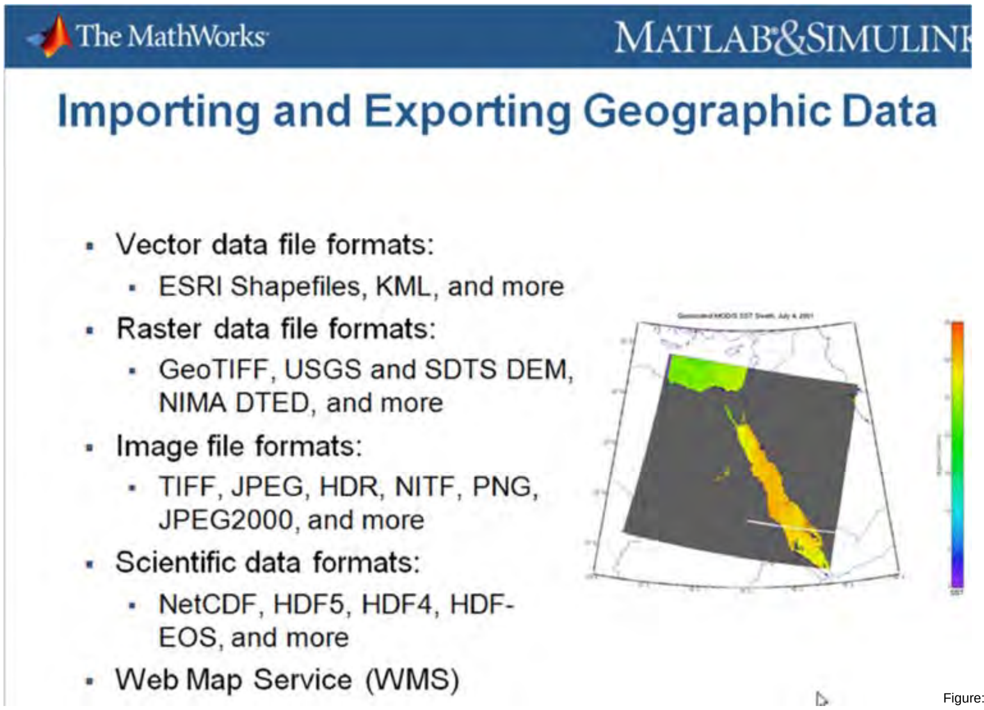
Mapping Toolbox

Analyzing and Visualizing Geographic Data

- Key Features
  - Importing and exporting geographic data
  - Accessing WMS servers
  - Creating 2D and 3D maps
  - Using geospatial analysis and geodesy
  - Analyzing terrain data
  - Using utilities for geospatial data

Figure: the Mathworks

Mapping Toolbox: Data

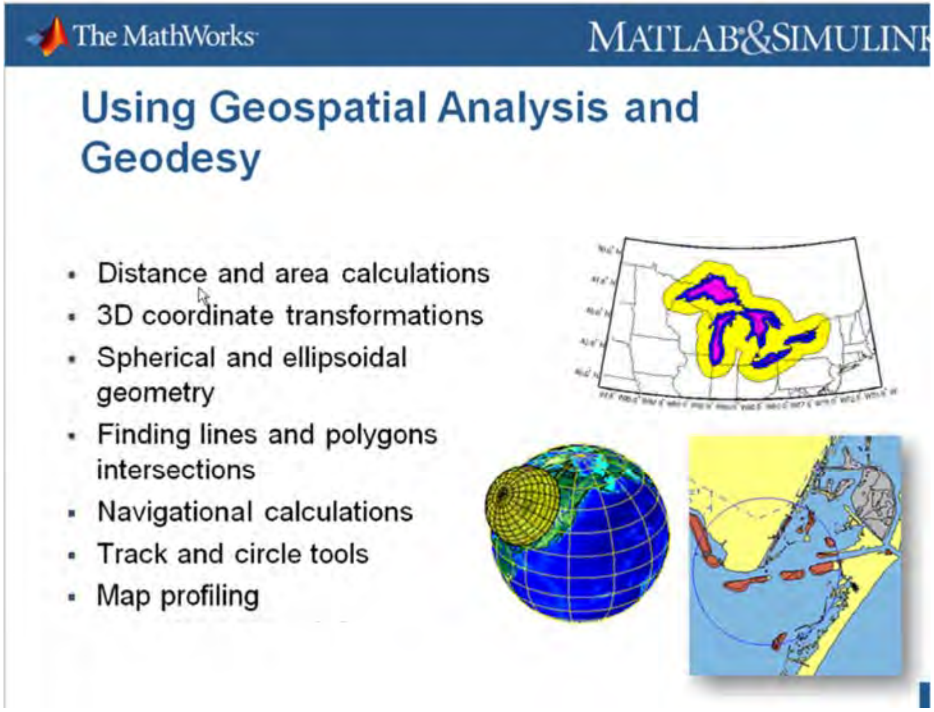


Importing and Exporting Geographic Data

- Vector data file formats:
  - ESRI Shapefiles, KML, and more
- Raster data file formats:
  - GeoTIFF, USGS and SDTS DEM, NIMA DTED, and more
- Image file formats:
  - TIFF, JPEG, HDR, NITF, PNG, JPEG2000, and more
- Scientific data formats:
  - NetCDF, HDF5, HDF4, HDF-EOS, and more
- Web Map Service (WMS)

Figure: the Mathworks

Mapping Toolbox: Analysis

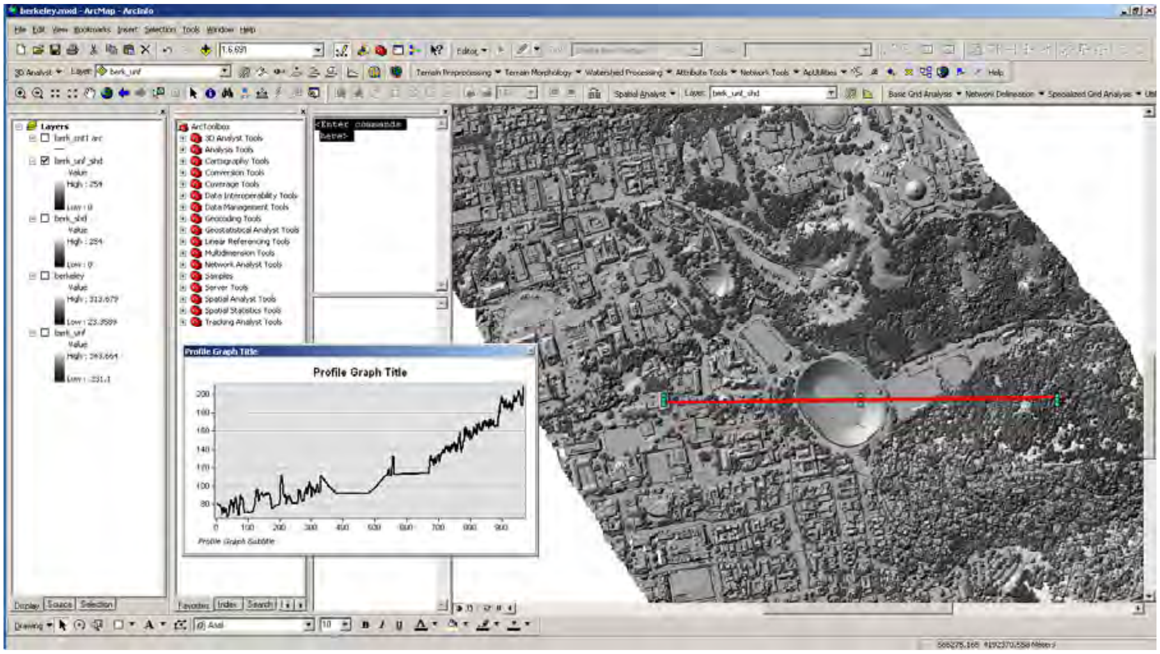


Using Geospatial Analysis and Geodesy

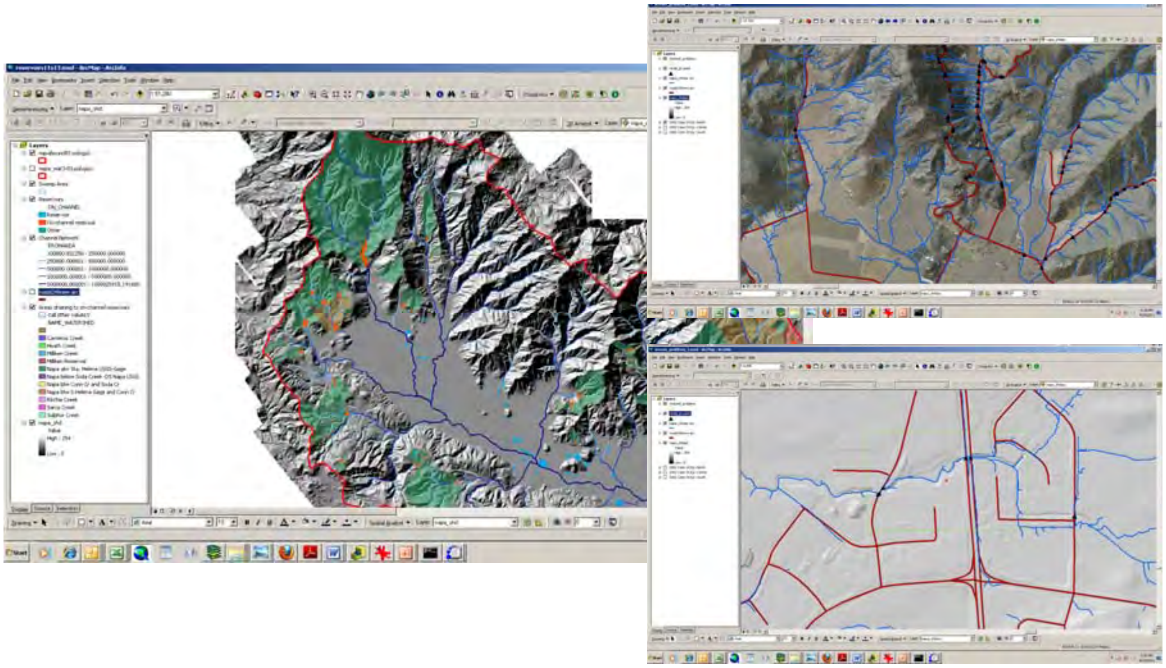
- Distance and area calculations
- 3D coordinate transformations
- Spherical and ellipsoidal geometry
- Finding lines and polygons intersections
- Navigational calculations
- Track and circle tools
- Map profiling

Figure: the Mathworks

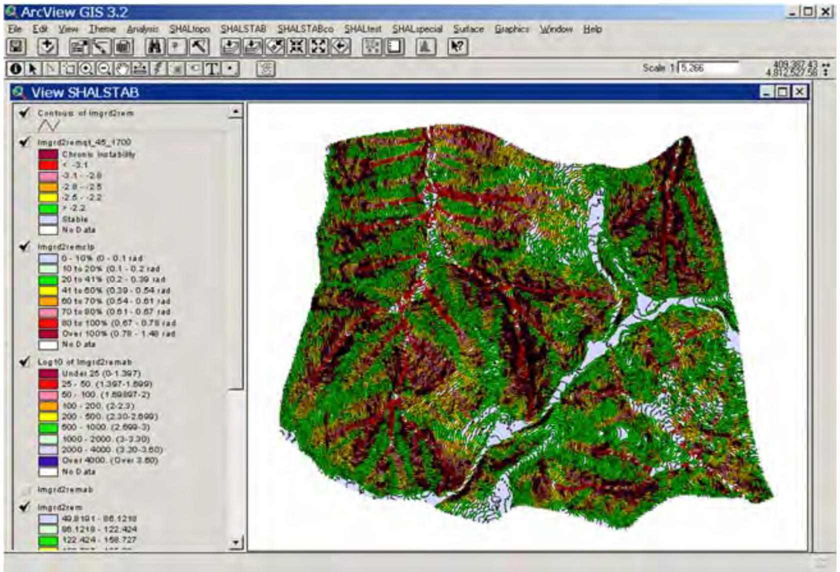
ESRI ArcGIS



ESRI ArcGIS



ESRI ArcView: SHALSTAB



Relative potential for shallow landsliding

Montgomery and Dietrich,1994

Dietrich, Bellugi, de Asua, 2001

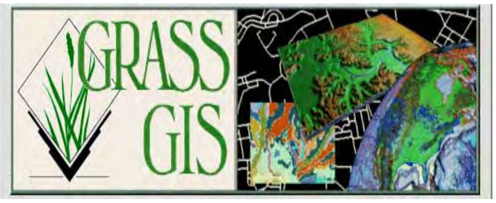
Also available in Matlab

$$\frac{q}{T} = \frac{\rho_s}{\rho_w}(1 - \frac{\tan\theta}{\tan\phi})\frac{b}{a}\sin\theta$$

Which GIS to use?

Arc ESRI GIS

MATLAB®
The Language of Technical Computing
Copyright 1984-2004, The MathWorks, Inc.



Google earth engine
a google.org project
earthengine.googlelabs.com

EPS 209 Course Evaluations

Fill out two forms:

- Instructor (Burkhard Militzer)
- GSI (Dino Bellugi)

Need a volunteer:

- Collect the forms
- Deliver them to McCone Hall
  - ✓ Gretchen vonDuering (371)
  - ✓ Margie Winn (398)
  - ✓ Main office (307)

Lab Exercise in 15 minutes:

- Making a map
- Retrieving Web-based data
- Real-time weather
- Ortho-photos
- Digital Elevation Model

Computer Lab Assignment 7

Maps and Web Map Service (WMS) Data

This lab has three parts. In the first part, we learn to make a simple map. In the second part, we retrieve a satellite image and weather data from a WMS and we add it to the map, to simulate a cross country flight. In the third part we load a digital elevation model (DEM) and display it. Then we will retrieve aerial imagery and drape it on the DEM. As you learn new Matlab functions, look them up in the help for examples of their usage.

This spectacular "blue marble" image is the most detailed true-color image of the entire Earth to date. Using a collection of satellite-based observations, scientists and visualizers stitched together months of observations of the land surface, oceans, sea ice, and clouds into a seamless, true-color mosaic of every square kilometer (.386 square mile) of our planet. These images are freely available to educators, scientists, museums, and the public from NASA web site and WMS servers.

Part 1 – My first Matlab map

Here we make a very simple map of the United States to familiarize ourselves with some functionalities of the Mapping Toolbox.

(1) Let's start by making a blank map of the Continental US. Type the following commands in your editor and execute them:

```
figure;
usamap('conus');
```

(2) Now let's load a shapefile (a common file format for vector data) with the borders of the states. This file is called `'usastatehi.shp'` and it comes packaged with the Mapping Tollbox: Type the following commands in your editor window and execute them:

```
states = shaperead('usastatehi.shp', 'UseGeoCoords', true);
```

(3) The variable 'states' is an array of structures. Type states(1) into the command window. You will get a description of the data structure:

```
       Geometry: 'Polygon'

    BoundingBox: [2x2 double]
```

```
             Lon: [1x521 double]

             Lat: [1x521 double]

            Name: 'Alabama'

        LabelLat: 32.2827

        LabelLon: -86.9206
```

Notice the variables present in this structure. In particular, note the two arrays ‘Lon’ and ‘Lat’, as there are what are used by Matlab to draw the shape of the state.

(3) Now let’s load a shapefile (a common file format for vector data) with the location and names of major world cities. This file is called `'worldcities.shp'`and it also comes packaged with the Mapping Tollbox: Type the following commands in your editor window and execute them:

```
cities = shaperead('worldcities.shp', 'UseGeoCoords', true);
```

Again, type cities(1) in the command window. Note that since the geometry is now a point, Lat and Lon now have only a single value.

(4) Now let’s display the map: type the following commands in your editor window and execute them:

```
geoshow(states);
```

(5) Now let’s add the names of the states to the map. Note that the structure in the shapefile also contained fields called ‘LabelLat’ and ‘LabelLon’. We will use these coordinates to place our labels. Type the following commands in your editor window and execute them:

```
textm([states.LabelLat], [states.LabelLon], {states.Name},
'HorizontalAlignment', 'center', 'FontSize', 6);
```

(6) Now let’s plot the cities to the map. Type the following commands in your editor window and execute them:

```
plotm([cities.Lat], [cities.Lon], '.r');
```

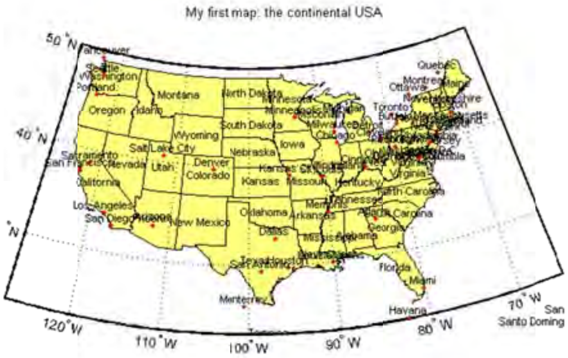
(7) Now let’s add the names of the cities to the map. Note that the cities structure did not contain label coordinates. We will thus use the city coordinates but place our labels right above the city. Type the following commands in your editor window and execute them:

```
textm([cities.Lat], [cities.Lon], {cities.Name}, 'HorizontalAlignment',
'center', 'VerticalAlignment', 'bottom', 'FontSize', 5);
```

(8) Finally, add a title to the map:

```
title('My first map: the continental USA');
```

You made your first Matlab geographic map! It should look something like this:



Save your code as you will be adding to it in the next part.

Part 2 – Flying across the USA

In this part we will update the previous map with images and real-time information.

(1) Let’s start again by making a blank map of the Continental US and reading the states boundaries and the major cities:

```
figure;
usamap('conus');
states = shaperead('usastatehi.shp', 'UseGeoCoords', true);
cities = shaperead('worldcities.shp', 'UseGeoCoords', true);
```

(2) As we will be retrieving data for this map, we will need to define what the latitude and longitude limits are. We can do this by retrieving the map structure of the current blank map:

```
mstruct = gcm;
```

The command ‘gcm’ means “get current map”, and its output is assigned to the map structure mstruct. Type ‘mstruct’ in the command window to see its contents. In particular, note the fields ‘maplatlimit’ and ‘maplonlimit’. These are the bounding box of your map. Assign them to your latlim and lonlim variables:

```
latlim = mstruct.maplatlimit;
lonlim = mstruct.maplonlimit;
```

(3) Now we will retrieve the part of the “Blue Marble Earth” image (seen in the lecture) that fits into this map. The first step is finding the correct WMS server. We know the image is from NASA, so we will search for servers that have the word NASA in their URL:

```
nasa = wmsfind('NASA', 'SearchField', 'serverurl');
```

In the variable editor, explore the WMS layer array 'nasa', and note the diverse nature of its contents. Now we can refine the search to look for the words 'blue marble':

```
nasa = nasa.refine('blue marble');
```

The command 'refine' is an object function of the layer structure. Again, in the variable editor explore the WMS layer array 'nasa', and note the much reduced nature of its contents.

(4) Now we are ready to retrieve the image using the bounding box of our map:

```
[BM,  R]  =  wmsread(nasa(1),  'ImageFormat',  'image/png',  'Latlim',  latlim,
'Lonlim', lonlim, 'CellSize', 0.1);
```

In the variable editor, look at the variables BM and R. The former is the RGB image, and the latter is a geo-referencing matrix used for drawing the image onto the map.

(5) Now we are ready to display the image and the state boundaries on our map:

```
figure(gcf);
geoshow(BM, R);
hold on
geoshow(states, 'FaceColor', 'none', 'EdgeColor', 'w');
geoshow(cities, 'Color', 'r', 'Marker', '.');
```

Note how BM and R are passed to 'geoshow'. Also note that to overlay the multiple layers one has to use "hold on" just like with regular Matlab figures.

(6) Let's pretend that we are about to fly between two of these cities. Let's trace our route by inputting the start and end points directly on the map:

```
figure(gcf);
disp('Input start and end points')
[lat lon] = inputm(2);
start = [lat(1) lon(1)];
dest = [lat(2) lon(2)];
```

The function 'inputm' takes the number of desired points as a parameter. Click on the start and end city.

(7) The next step is to construct a great circle (the shortest distance on the surface of a sphere) between the two cities and to display it on the map. This is done with the navigation functions 'gcwaypts' and 'track', and the usual 'geoshow':

```
[lat_gc,lon_gc] = gcwaypts(start(1),start(2),dest(1),dest(2));
[lattrk_gc lontrk_gc] = track('gc', lat_gc, lon_gc, 'degrees');
figure(gcf);
geoshow(lattrk_gc, lontrk_gc, 'DisplayType', 'line', 'Color', 'r');
```

(8) One can measure the length of this path using the navigation function 'legs' which returns the bearing and the distance along the way:

```
[course_gc dist_gc] = legs(lat_gc, lon_gc, 'gc');
```

```
disp(['Great circle path length: ' num2str(sum(dist_gc))]);
```

(9) We now have our course, but it would be nice to check the weather along the way. We can look up the radar data, much like we did for the blue marble image. Search for ‘nexrad’ among the WMS servers:

```
nexrad = wmsfind('nexrad', 'SearchField', 'serverurl');
```

In the variable editor, explore the WMS layer array ‘nexrad, and note its contents. Now we can refine the search to look for the words ‘current’:

```
nexrad = nexrad.refine('current');
```

(10) Retrieve the weather data and display it on the map:

```
[W, R2] = wmsread(nexrad(1), 'ImageFormat', 'image/png', 'Latlim', latlim,
'Lonlim', lonlim, 'ImageHeight', size(BM,1), 'ImageWidth', size(BM,2),
'BackgroundColor', [0 0 0]);
figure(gcf);
geoshow(W, R2);
```

Note how various parameters of ‘wmsread’ were used to get an image of the same size as the blue marble image and with a transparent background color. Note however, that when we show this image, we erase the blue marble image. We can fix this by adding the pixels showing precipitation to the blue marble image:

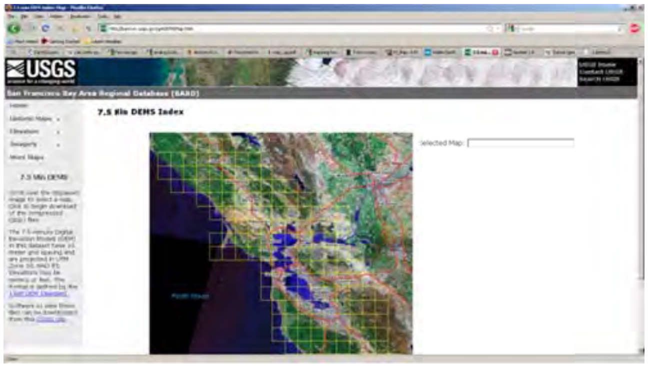
```
windex = any(W > 0, 3);
windex = cat(3, windex, windex, windex);
WBM = BM;
WBM(windex) = uint8(W(windex).*255);
figure(gcf);
geoshow(WBM, R2);
```

Your map should now look something like this:

How is the weather along the route? If you were trying to plot a route that is less direct but avoids the bad weather, you’d probably want to look not just at the current radar image, but also at a sequence of images prior to the current one to see where the storm is going. Nexrad offers these data on the WMS server as well.

Part 3 – Retrieving elevation data and aerial imagery for the San Francisco Bay Area

Among the data repositories we saw in the lecture there was the San Francisco Bay Area Regional Database (BARD). Open a browser and go to this URL: http://bard.wr.usgs.gov/getDEMSMap.html. Here you will see an index map with the USGS 7.5-minute Digital Elevation Models (DEM). The tiles in this dataset have 10 meter grid spacing and units of (hopefully) meters.



Matlab has functions to read data directly from web sites such as this one, we will use them to download and display a DEM of your choice.

(1) Let's start by picking a DEM to explore. On the BARD web page hover with the cursor over the desired quadrangle to obtain its name. In the example listed below I use the 'sf_north' DEM, but feel free to change it to one of your choice:

```
demFilename = 'sf_north.dem';
demExt = '.gz';
dataServerURL = 'http://bard.wr.usgs.gov/bard/elevation/';
```

(2) Now we can use the Matlab function 'urlwrite' to write the file from the URL to the current directory, and the function 'gunzip' to uncompress it:

```
URL = [dataServerURL demFilename demExt];
urlwrite(URL, [demFilename demExt]);
gunzip([demFilename demExt]);
```

(3) Use the mapping toolbox function 'usgs24kdem' to import the elevation data:

```
[Lat, Lon, Elv, Header] = usgs24kdem(demFilename);
```

Note that this function returns matrices for latitude, longitude and elevation, as well as a header structure with the DEM info. Type 'Header' in the command window to explore its contents. Then get the bounding box of the DEM from the Lat and Lon matrices:

```
latlim = [min(Lat(:)) max(Lat(:))];
lonlim = [min(Lon(:)) max(Lon(:))];
```

(4) Display the elevation data using 'usamap' and 'geoshow':

```
figure;
usamap(latlim, lonlim);
geoshow(Lat, Lon, Elv, 'DisplayType','surface');
title(demFilename, 'Interpreter', 'none');
```

Note that Matlab used the standard color map (jet) to display the elevation. Generate a more topographic colormap by using the function ‘demcmap’:

```
demcmap(Elv);
```

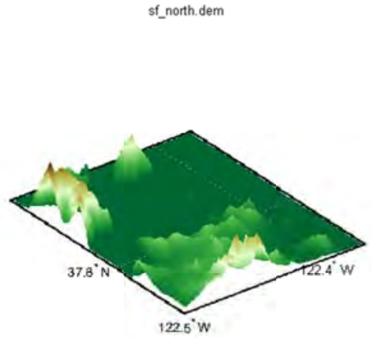
Want a 3-D view? It’s simple with the ‘view’ function:

```
view(3);
```

Perhaps we would like to exaggerate the vertical axis for a more 3-D effect. This can be done with the ‘daspectm’ function:

```
daspectm('m',1.5)
```

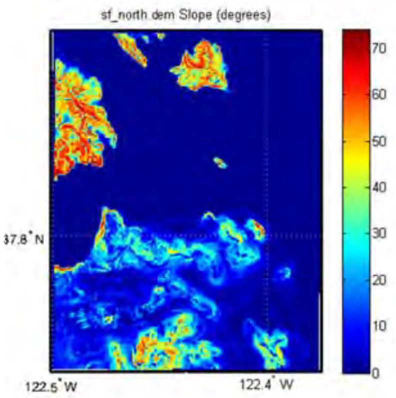
Your map should now look something like this:



(5) Lets make and display a slope map, using Matlab’s ‘gradientm’ function:

```
[aspect, slope, gradN, gradE] = gradientm(Lat, Lon, Elv);
figure;
usamap(latlim, lonlim);
geoshow(Lat, Lon, slope, 'DisplayType', 'texturemap');
colorbar
title([demFilename ' Slope (degrees)'], 'Interpreter', 'none');
```

Does your map look like this?



(6) Now let's search for an aerial image to drape over our DEM. We can get one from WMS, much like we did for the radar data. Search for 'usgs' and 'california' among the WMS servers:

```
ortho = wmsfind('usgs*california', 'SearchField', 'serverurl', 'Latlim',
latlim, 'Lonlim', lonlim);
```

Note the use of the wildcard '*' in the search. In the variable editor, explore the WMS layer array 'ortho', and note its contents. We know we want the high-resolution (0.3m) color image, so we can refine the search to look for the words '0.3m' and 'color':

```
ortho = ortho.refine('0.3m*color', 'SearchField', 'LayerTitle');
```

In the variable editor one can see that some of the fields of the individual layers say '<Update using WMSUPDATE>'. One can update the information with the function 'wmsupdate':

```
ortho = wmsupdate(ortho(1));
```

(7) Now we are ready to retrieve the image. As you have already done it twice, offered here is an alternative method to create the request:

```
% create a WMS request structure
server = WebMapServer(ortho.ServerURL);
request = WMSMapRequest(ortho, server);

% modify map request for the desired limits, format and size
request.Latlim = latlim;
request.Lonlim = lonlim;
request.ImageFormat = 'image/png';
request.ImageHeight = size(Elv,1);
request.ImageWidth = size(Elv,2);

% Request the map
Map = server.getMap(request.RequestURL);
Ref = request.RasterRef;
```

(8) Let's display the DEM again, but with the elevation draped on it:

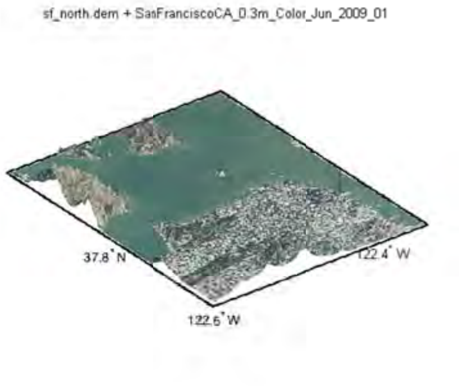
```
figure;
```

```
usamap(latlim, lonlim);
geoshow(Lat, Lon, Elv, 'DisplayType', 'surface', 'CData', Map);
title([demFilename ' + ' ortho.LayerName], 'Interpreter', 'none');
```

Exaggerate and switch to 3-D view:

```
daspectm('m',1.5)
view(3)
```

Isn’t WMS groovy? Your map should look something like this:



See you next week for final project presentations!

Support Vector Machine Classification

2nd International Summer School on Water Research

Landslide modeling and Early Warning Systems
8 July 2013

Dino Bellugi
Massachusetts Institute of Technology

Support Vector Machine Classification

SVM-based Classification
- Classification
- Object representation
- Training and validation
- Linearly separable data
- Linearly non-separable data
- Non-linearly separable data
- The SVM formulation
- The Kernel trick

Rock Classification
- Rock image database
- Rock characteristics
- Creating a rock descriptor
- SVM Software
- SVM Cookbook
- Training an SVM
- A test
- Results

Landslide Identification
- Deep seated landslides

Landslide Prediction
- Landslide database
- Landslide characteristics
- Creating the descriptor
- Training the SVM
- A preliminary test

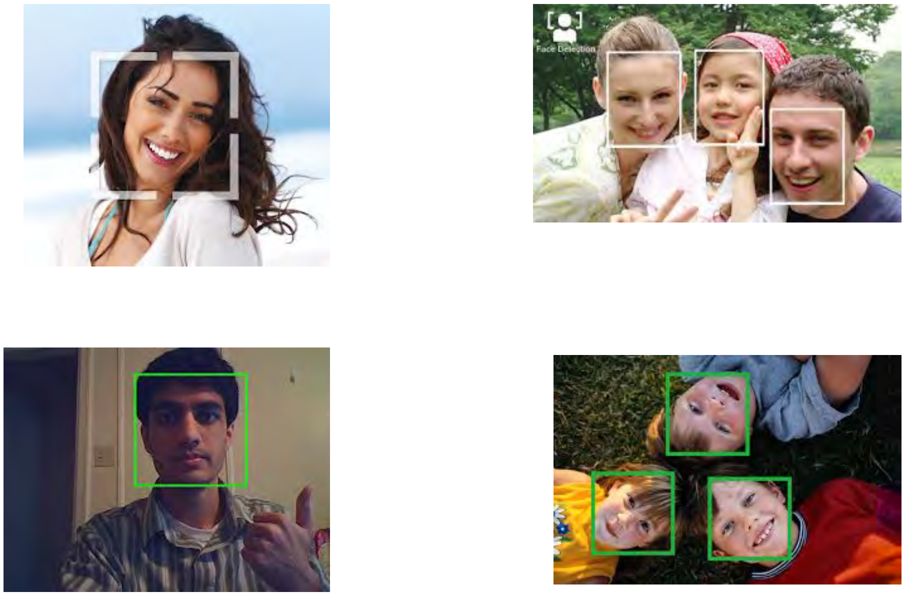
Discussion
- Storm classification
- A real application (Luigi!)

Some slides adapted from:
Dino Bellugi - EPS 209:
"Matlab Applications in Earth Science"
Michael Jordan - CS 294:
"Practical Machine Learning"
University of California, Berkeley

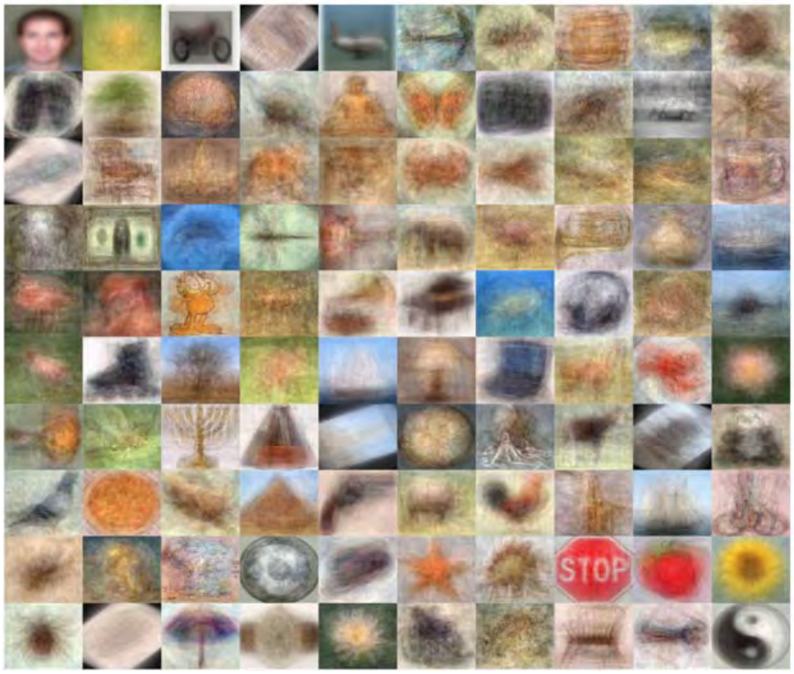
Classification

- In classification problems, each entity in some domain can be placed in one of a discrete set of categories: yes/no, friend/foe, good/bad/indifferent, etc.
- Given a training set of labeled entities, develop a rule for assigning labels to entities in a test set
- For example:
  - Observe whether a given medication affects various patients positively or negatively over several years (the training set).
  - Given this data, extract a rule allowing us to predict whether or not any new patient will respond positively or negatively to the medication.
- Many variations on this theme:
  - binary classification
  - multi-category classification
  - non-exclusive categories

Example: face detection



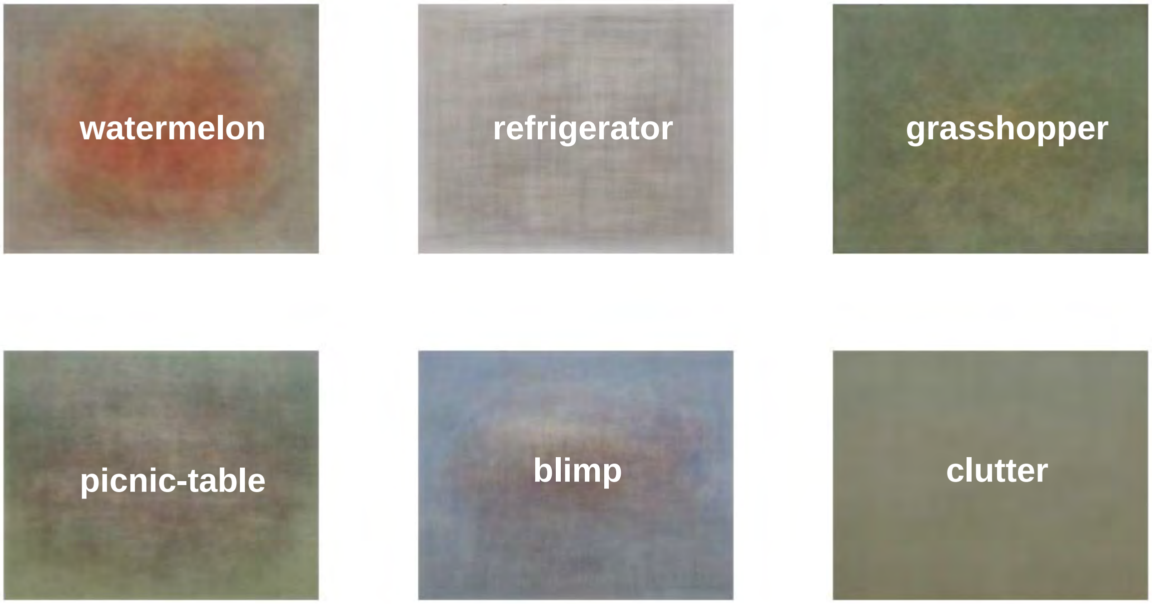
Example: object recognition



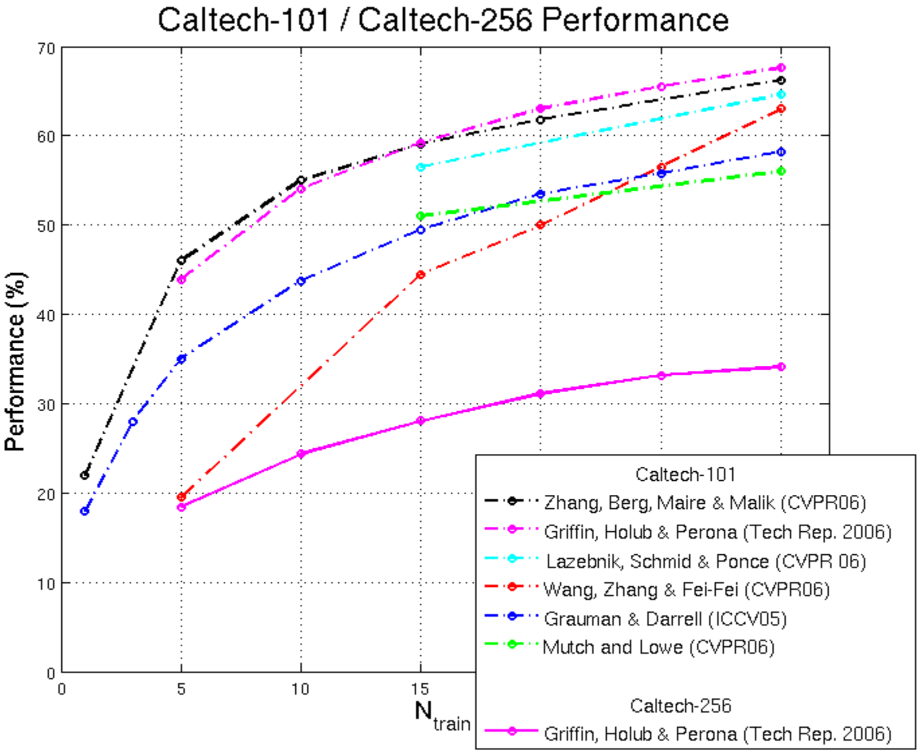
Example: object recognition

Try to find: blimp, clutter, grasshopper, picnic-table, refrigerator, watermelon

Example: object recognition

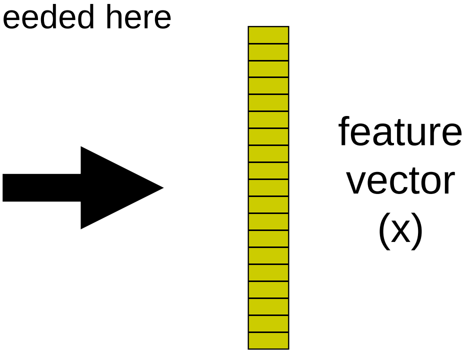


Example: object recognition



Object Representation

- Each object to be classified is represented as a pair (x, y):
  - x is a description of the object (see examples of data types in the following slides)
  - y is a label (assumed binary for now: 1 or -1)
- Success or failure of a machine learning classifier often depends on choosing good descriptions of objects
  - the choice of description can also be viewed as a learning problem
  - but good human intuitions are often needed here
- Vectorial data:
  - physical attributes
  - textual attributes
  - context
  - history



Example: Spam Filter

- Input: email
- Output: spam/ham
- Setup:
  - Get a large collection of example emails, each labeled “spam” or “ham”
  - Note: someone has to hand label all this data
  - Want to learn to predict labels of new, future emails
- Features: The attributes used to make the ham / spam decision
  - Words: FREE!
  - Text Patterns: $dd, CAPS
  - Non-text: SenderInContacts
  - …

✗

Dear Sir.

First, I must solicit your confidence in this transaction, this is by virtue of its nature as being utterly confidencial and top secret. …

✗

TO BE REMOVED FROM FUTURE MAILINGS, SIMPLY REPLY TO THIS MESSAGE AND PUT "REMOVE" IN THE SUBJECT.

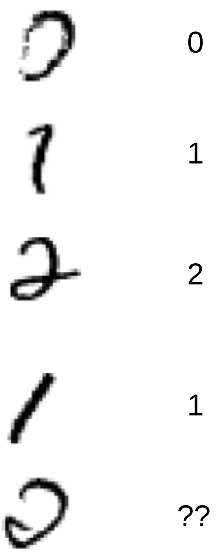
99 MILLION EMAIL ADDRESSES
FOR ONLY $99

✓

Ok, Iknow this is blatantly OT but I'm beginning to go insane. Had an old Dell Dimension XPS sitting in the corner and decided to put it to use, I know it was working pre being stuck in the corner, but when I plugged it in, hit the power nothing happened.

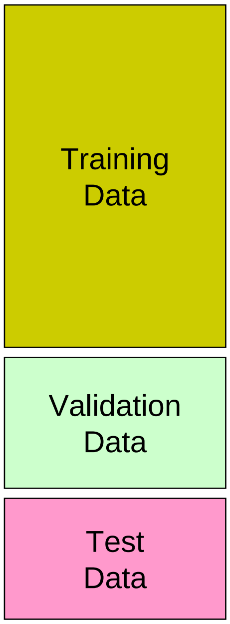
Example: Digit Recognition

- Input: images / pixel grids
- Output: a digit 0-9
- Setup:
  - Get a large collection of example images, each labeled with a digit
  - Note: someone has to hand label all this data
  - Want to learn to predict labels of new, future digit images
- Features: The attributes used to make the digit decision
  - Pixels: (6,8)=ON
  - Shape Patterns: NumComponents, AspectRatio, NumLoops
  - …
- Current state-of-the-art: Human-level performance



Training and Validation

- Data: labeled instances, e.g. emails marked spam/ham
  - Training set
  - Validation set
  - Test set
- Training
  - Estimate parameters on training set
  - Tune hyperparameters on validation set
  - Report results on test set
  - Anything short of this yields over-optimistic claims
- Evaluation
  - Many different metrics
  - Ideally, the criteria used to train the classifier should be closely related to those used to evaluate the classifier
- Statistical issues
  - Want a classifier which does well on *test* data
  - Overfitting: fitting the training data very closely, but not generalizing well
  - Error bars: want realistic (conservative) estimates of accuracy



Training Data

Validation Data

Test Data

Some State of the Art Classifiers

- **Support vector machines (SVMs)**
- Decision trees
- Random forests
- Kernelized logistic regression
- Kernelized discriminant analysis
- Kernelized perceptron
- Bayesian classifiers
- Boosting and other ensemble methods

Some Resources

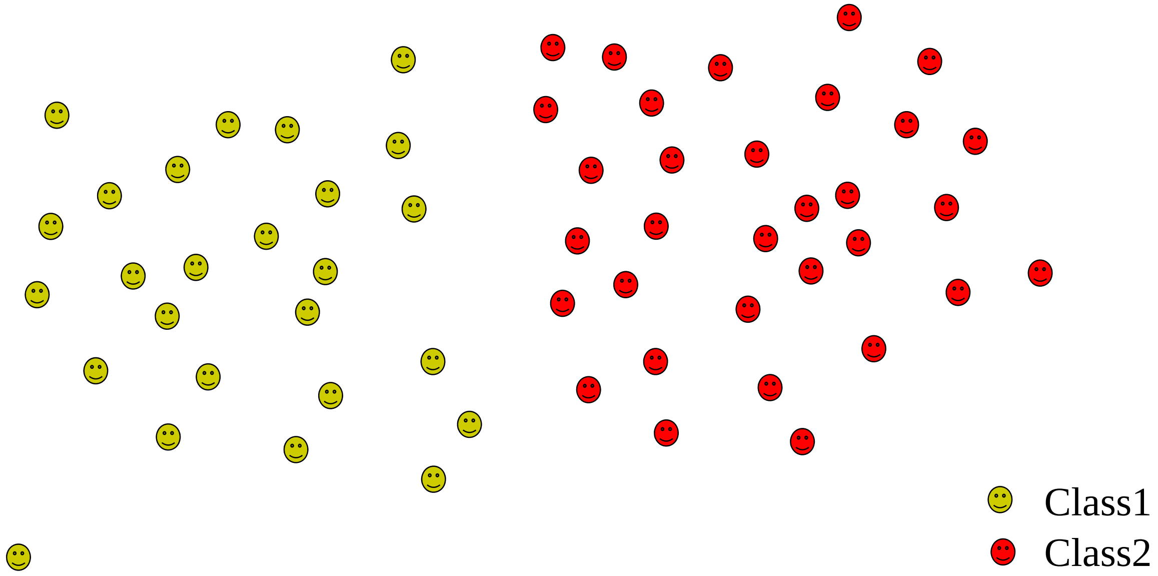
- Google ‘Berkeley practical machine learning’ for more information

- Trevor Hastie’s “The elements of statistical learning: data mining, inference, and prediction.” Springer. 2001

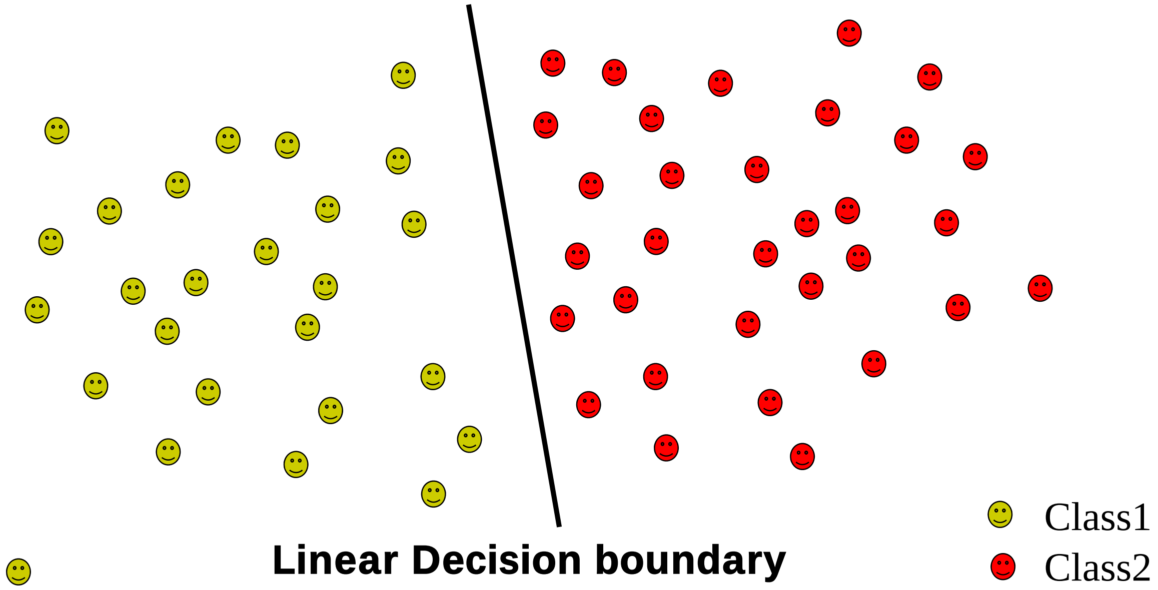
- Nello Cristianini’s web page:

  http://www.support-vector.net/

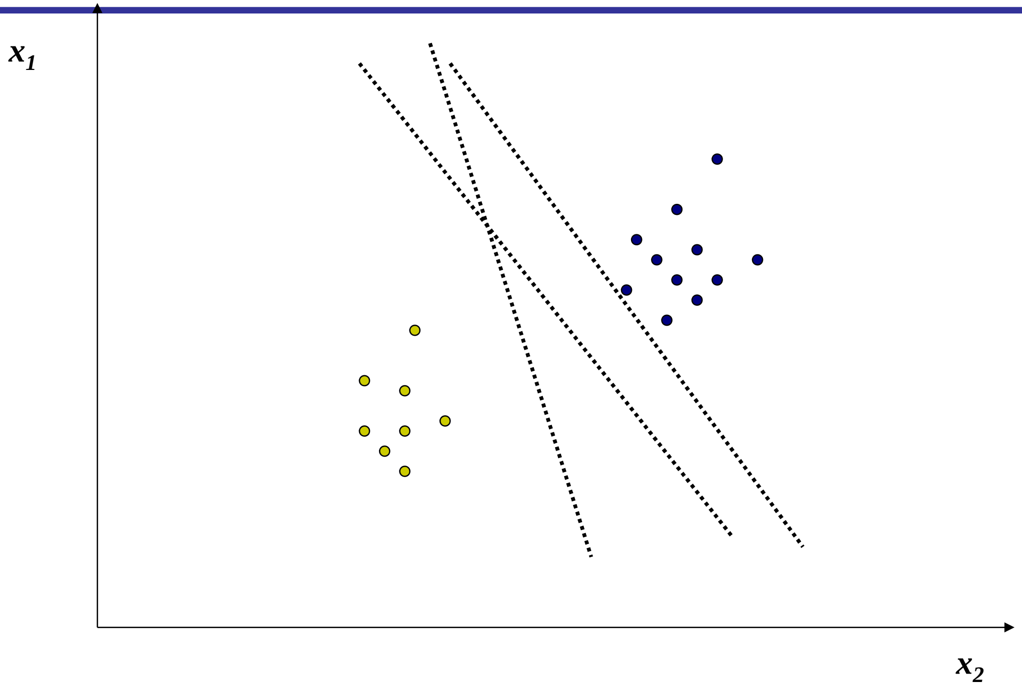
Intuitive Picture of the Problem



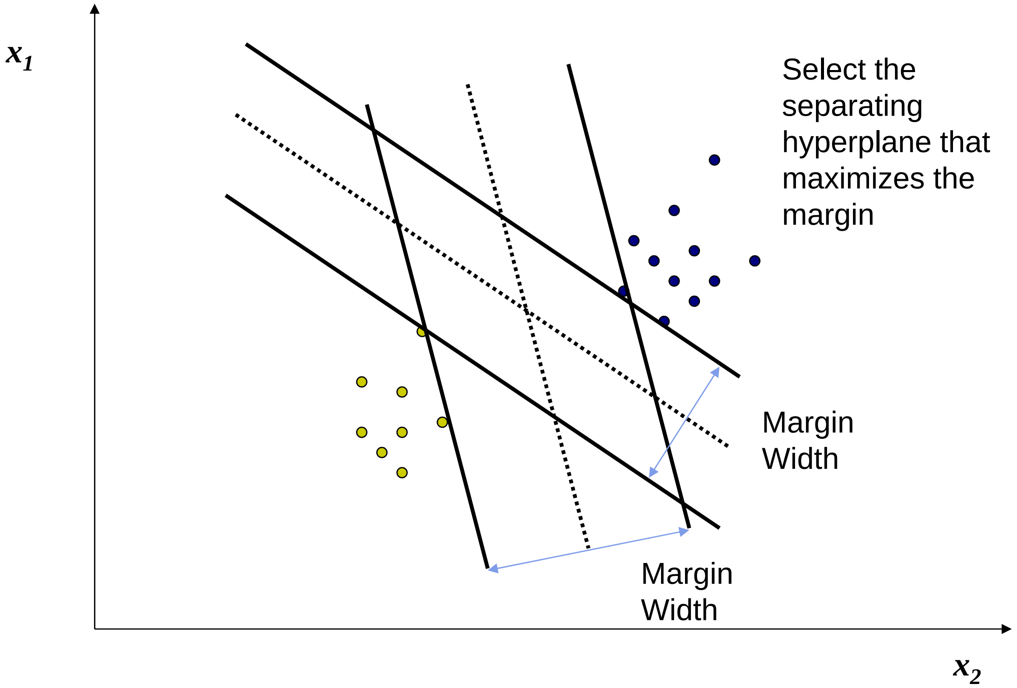
Linearly Separable Data



Which Hyper-plane to Use?

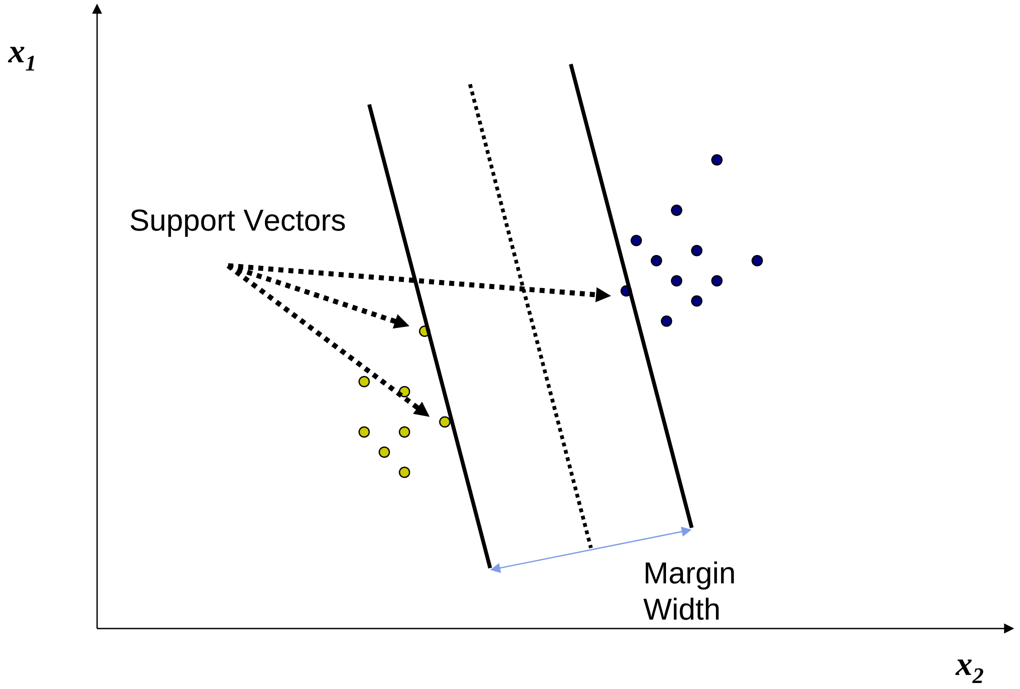


Maximizing the Margin



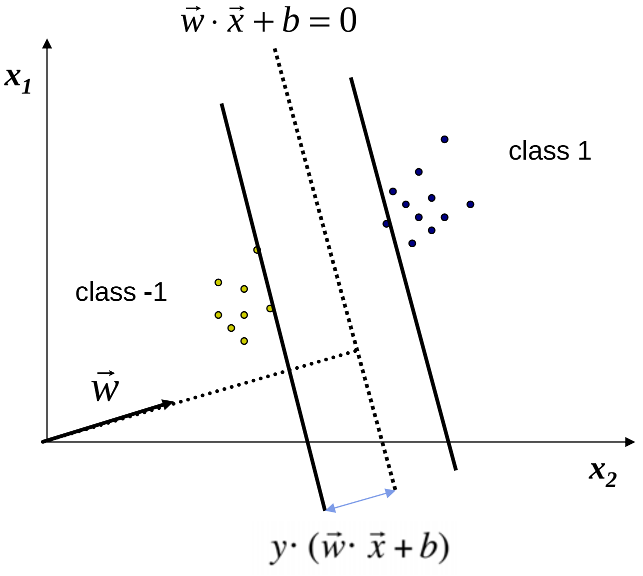
Select the separating hyperplane that maximizes the margin

Support Vectors



Setting up the Optimization Problem

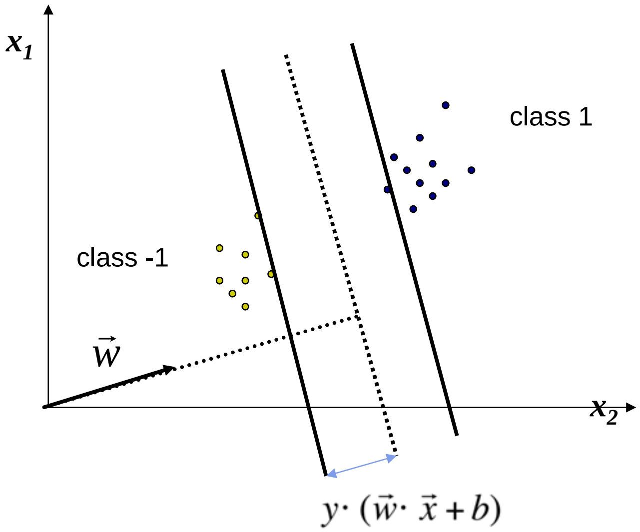
Linear decision boundary: $f(\vec{x}) = \mathrm{sgn}(\vec{w}\cdot \vec{x}+b) = \begin{cases} 1, & if\ \ \vec{w}\cdot \vec{x}+b \geq 0 \\ -1, & otherwise \end{cases}$



The Optimization Problem

The maximum margin can be characterized as a solution to an optimization problem:

$$\begin{aligned} &\max\ \gamma \\ &s.t.\quad y\cdot(\vec{w}\cdot\vec{x}+b)\geq\gamma, \forall(x,y)\ in\ training\ set \\ &\qquad \|\vec{w}\|^2 = 1 \end{aligned}$$



Linear Hard-Margin SVM Formulation

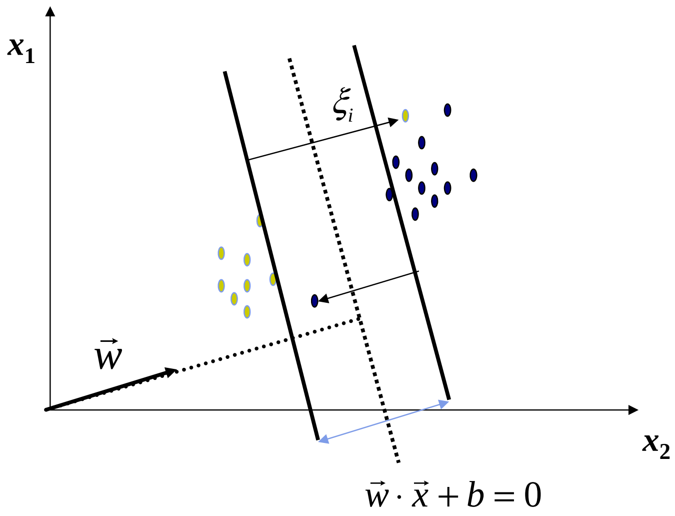
- Simple manipulation yields an equivalent problem: find *w,b* that solves

$$\min \frac{1}{2}\|w\|^2$$

$$s.t.\ y_i(w\cdot x_i+b)\geq 1,\ \ \forall x_i$$

- Problem is convex, so there is a unique global minimum value (when feasible).
- There is also a unique minimizer, i.e. *w* and *b* value that provides the minimum.
- Quadratic Programming
  - very efficient computationally with procedures that take advantage of the special structure

Linear Non-Separable Case

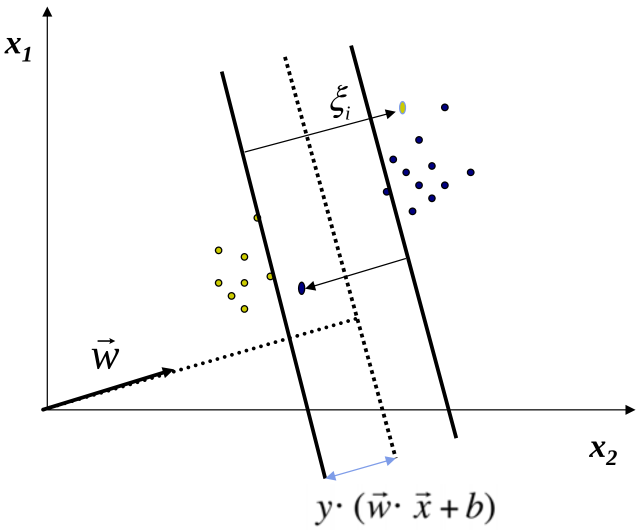


Allow some instances to fall within the margin, but penalize them.

Introduce slack variables ξ_i

Formulating the Optimization Problem

$$\begin{aligned}
&\max \ \gamma - C\sum \xi_i \\
&s.t. \ \ y_i \cdot (\vec{w}\cdot \vec{x}_i + b) \geq \gamma - \xi_i, \ \forall i \\
&\qquad \xi_i \geq 0, \ \forall i \\
&\qquad \|\vec{w}\|^2 = 1
\end{aligned}$$



Objective function penalizes for misclassified instances and those within the margin

C trades-off margin width and misclassifications

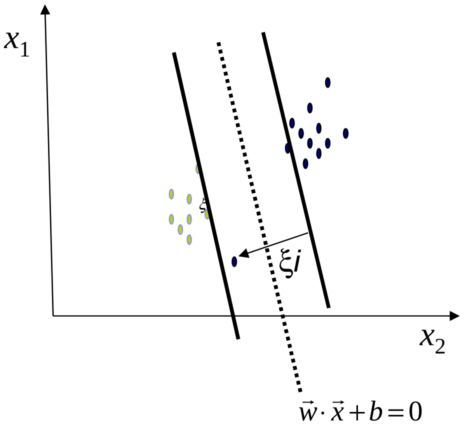
Linear Soft-Margin SVM's

- Equivalent problem:

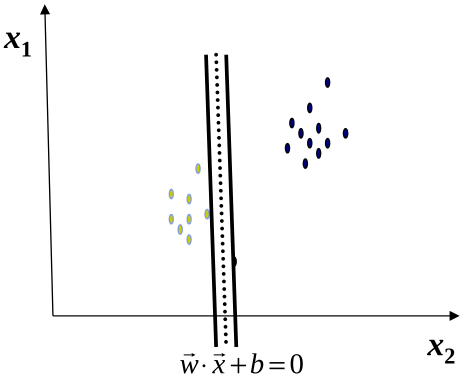
$$\min \frac{1}{2}\|w\|^2 + C\sum_i \xi_i \qquad \begin{array}{l} y_i(w\cdot x_i + b) \geq 1-\xi_i,\ \forall x_i \\ \xi_i \geq 0 \end{array}$$

- Algorithm tries to push ξ_i to zero while maximizing margin
- As $C \to 0$, we get the hard-margin solution
- Notice: algorithm does not minimize the *number* of misclassifications (NP-complete problem) but the sum of distances from the margin hyperplanes
- Other formulations can use ξ_i^2 instead

Robustness of Hard vs. Soft Margin SVM's

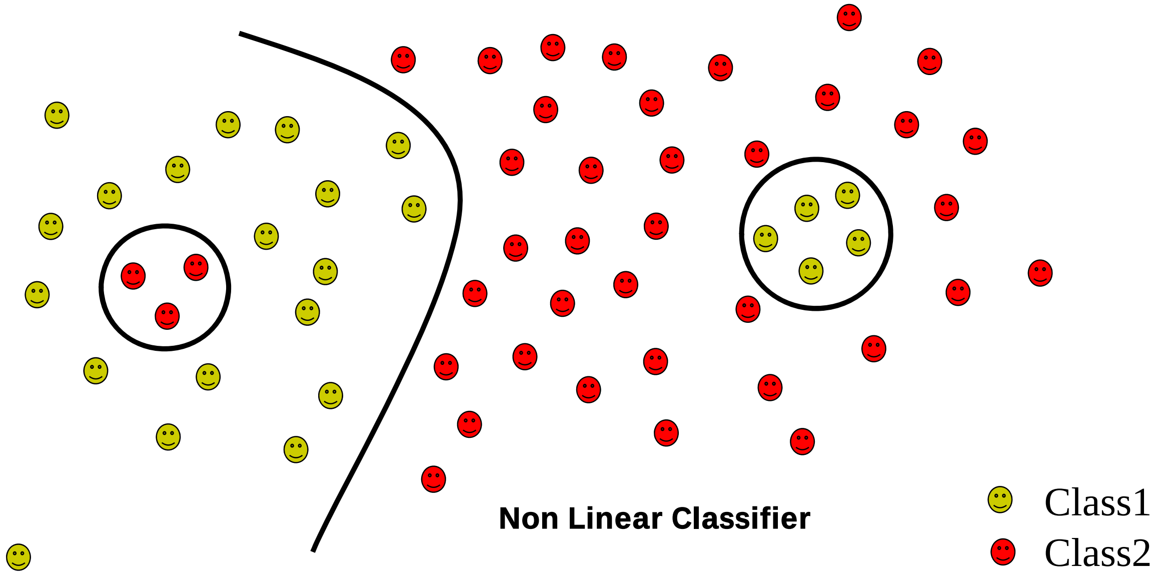


Soft Margin SVM

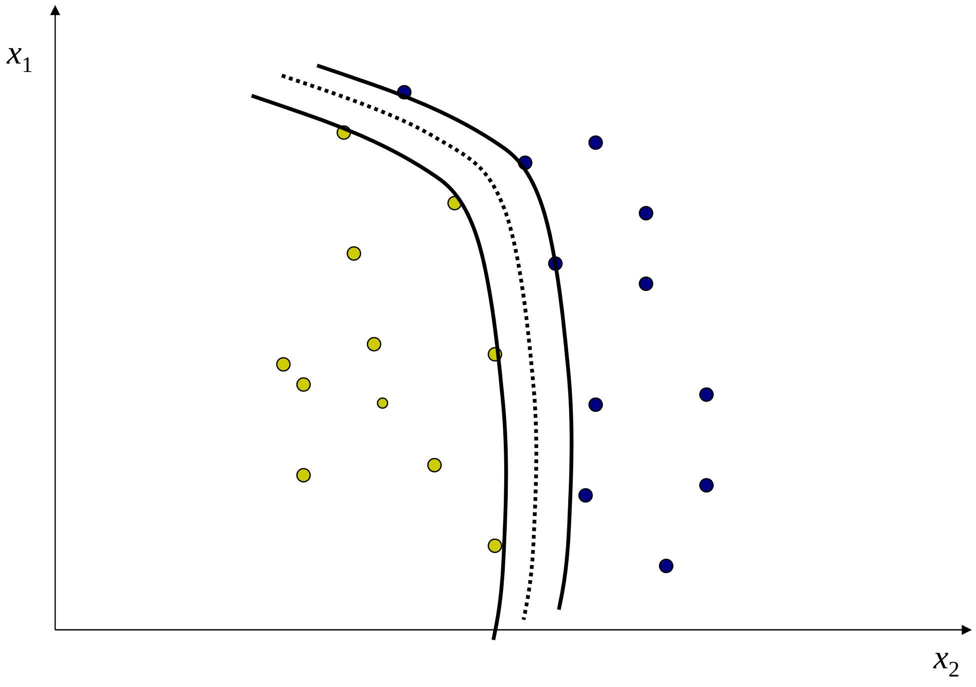


Hard Margin SVM

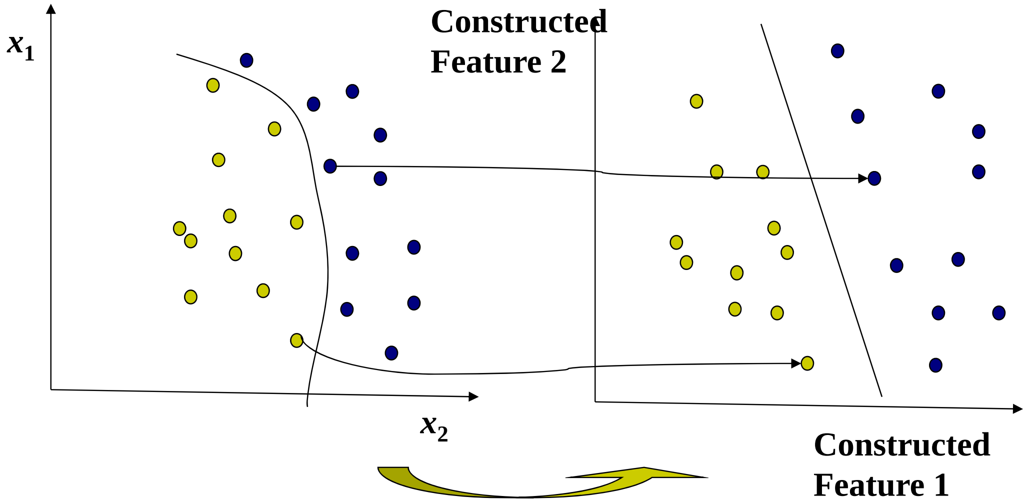
Non-Linearly Separable Data



Advantages of Non-Linear Surfaces

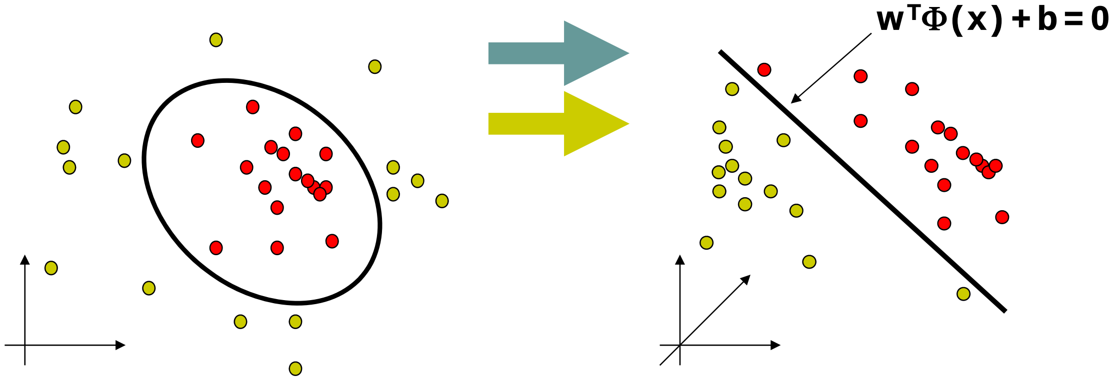


Linear Classifiers in High-Dimensional Spaces



Find function Φ(x) to map to a different space

Example



$X=[x\ \ z]$

$\Phi(X)=[x^2\ \ z^2\ \ xz]$

$$f(x) = \text{sign}(w_1x^2 + w_2z^2 + w_3xz + b)$$

Mapping Data to High-Dimensional Spaces

- Find function $\Phi(x)$ to map to a different space, then SVM formulation becomes:

$$\min \frac{1}{2}\|w\|^2 + C\sum_i \xi_i \qquad s.t.\ \ y_i(w \cdot \Phi(x) + b) \geq 1 - \xi_i, \forall x_i$$
$$\xi_i \geq 0$$

- Data appear as $\Phi(x)$, weights *w* are now weights in the new space
- Explicit mapping expensive if $\Phi(x)$ is very high dimensional
- Solving the problem without explicitly mapping the data is desirable

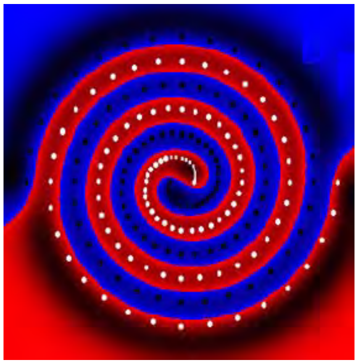
The Kernel Trick

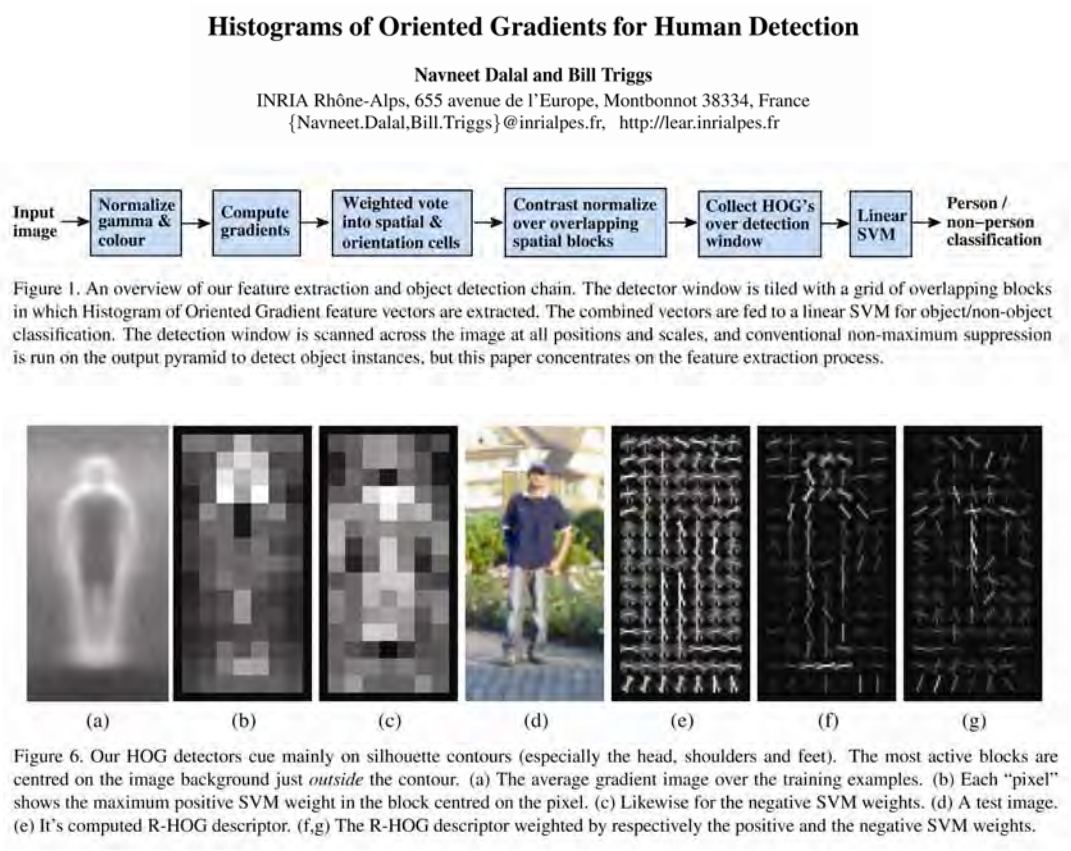
- $\Phi(x_i) \cdot \Phi(x_j)$: means map data into new space, then take the inner product of the new vectors
- We can instead simply find a function such that: $K(x_i \cdot x_j) = \Phi(x_i) \cdot \Phi(x_j)$, i.e., the image of the inner product of the data is the inner product of the images of the data
- Then, we do not need to explicitly map the data into the high-dimensional space to solve the optimization problem

Kernels

- Some common kernels
  - Linear kernel: $k(x,z) = x^T z$
    → equivalent to linear algorithm
  - Polynomial kernel: $k(x,z) = (1+x^T z)^d$
    → polynomial decision rules
  - RBF kernel: $k(x,z) = \exp(-||x-z||^2/2\sigma)$
    → highly nonlinear decisions

A hyperplane in some space





Histograms of Oriented Gradients for Human Detection

Navneet Dalal and Bill Triggs
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{Navneet.Dalal,Bill.Triggs}@inrialpes.fr, http://lear.inrialpes.fr

Figure 1. An overview of our feature extraction and object detection chain. The detector window is tiled with a grid of overlapping blocks in which Histogram of Oriented Gradient feature vectors are extracted. The combined vectors are fed to a linear SVM for object/non-object classification. The detection window is scanned across the image at all positions and scales, and conventional non-maximum suppression is run on the output pyramid to detect object instances, but this paper concentrates on the feature extraction process.

Figure 6. Our HOG detectors cue mainly on silhouette contours (especially the head, shoulders and feet). The most active blocks are centred on the image background just *outside* the contour. (a) The average gradient image over the training examples. (b) Each "pixel" shows the maximum positive SVM weight in the block centred on the pixel. (c) Likewise for the negative SVM weights. (d) A test image. (e) It's computed R-HOG descriptor. (f,g) The R-HOG descriptor weighted by respectively the positive and the negative SVM weights.

CVPR 2005

Representing shape with a spatial pyramid kernel

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- Implements HOG on a quad-tree
- Canny edges, Sobel gradients
- No smoothing
- Gradients transferred to edges
- Binned for orientation
- Weighted by their strength

- PHOG descriptor:
  Concatenation of HOG descriptors for each level of pyramid (BFS)

- Matlab code available from the Robotics Research Group (Visual Geometry), University of Oxford:
  www.robots.ox.ac.uk/~vgg

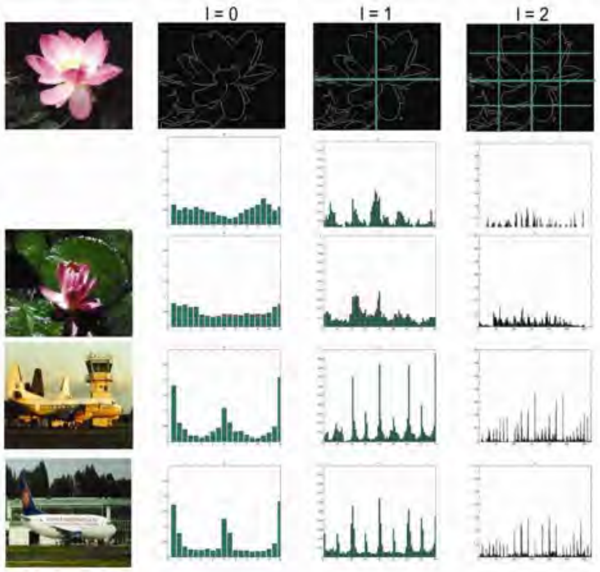
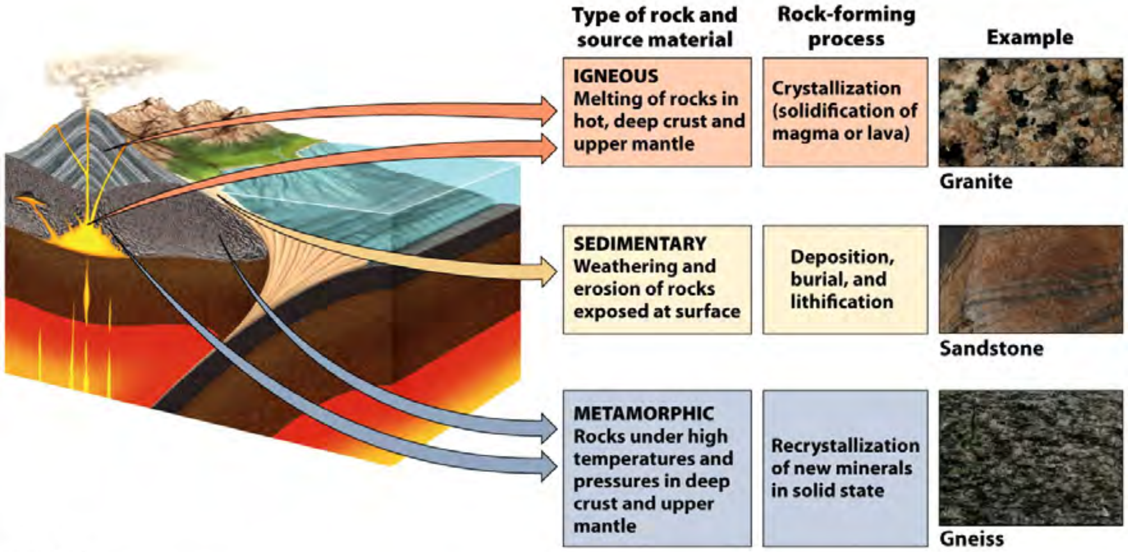


Figure 1: Shape spatial pyramid representation. Top row: an image and grids for levels $l = 0$ to $l = 2$; Below: histogram representations corresponding to each level. The final PHOG vector is a weighted concatenation of vectors (histograms) for all levels. Remaining rows: images from the same and from different categories, together with their histogram representations.

CIVR 2007

Rock Classification



Type of rock and source material	Rock-forming process	Example
IGNEOUS Melting of rocks in hot, deep crust and upper mantle	Crystallization (solidification of magma or lava)	Granite
SEDIMENTARY Weathering and erosion of rocks exposed at surface	Deposition, burial, and lithification	Sandstone
METAMORPHIC Rocks under high temperatures and pressures in deep crust and upper mantle	Recrystallization of new minerals in solid state	Gneiss

Figure 3.24
Understanding Earth, Sixth Edition
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Rock Classification: Igneous

Chapter 4 Opener
Understanding Earth, Sixth Edition
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Extrusive pyroclasts form in violent eruptions from lava thrown high in the air.

Extrusive igneous rocks cool rapidly on Earth's surface and are fine-grained.

Intrusive igneous rocks cool slowly in Earth's interior, allowing large, coarse crystals to form.

Porphyritic crystals start to grow beneath Earth's surface. Some crystals grow large, but the remaining melt cools faster, forming smaller crystals, either because it is erupted to the surface or because it is intruded close to Earth's surface.

Figure 4.3
Understanding Earth, Sixth Edition
© 2010 W. H. Freeman and Company

Rock Classification: Sedimentary

Figure 5.10
Understanding Earth, Sixth Edition
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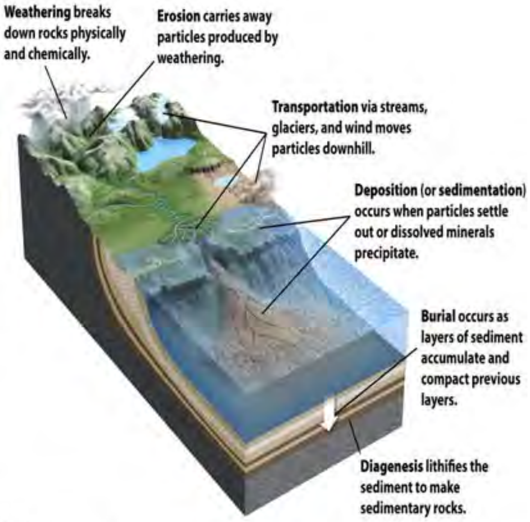

Weathering breaks down rocks physically and chemically.

Erosion carries away particles produced by weathering.

Transportation via streams, glaciers, and wind moves particles downhill.

Deposition (or sedimentation) occurs when particles settle out or dissolved minerals precipitate.

Burial occurs as layers of sediment accumulate and compact previous layers.

Diagenesis lithifies the sediment to make sedimentary rocks.

Figure 5.1
Understanding Earth, Sixth Edition
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Rock Classification: Metamorphic

Figure 6.3
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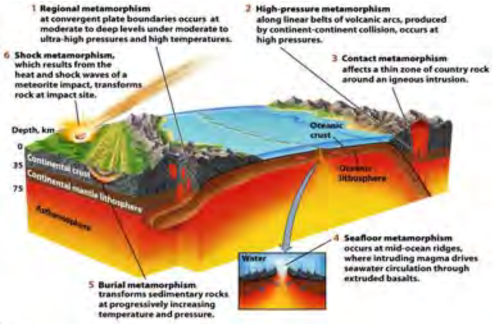

Figure [illegible]
Understanding Earth, Sixth Edition
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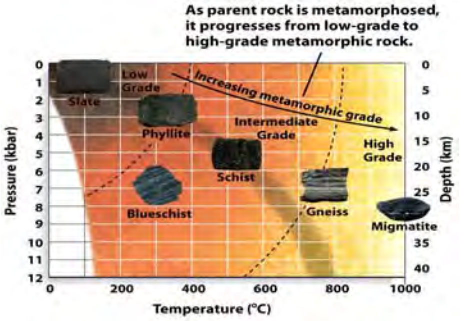

Figure 6.9b
Understanding Earth, Sixth Edition
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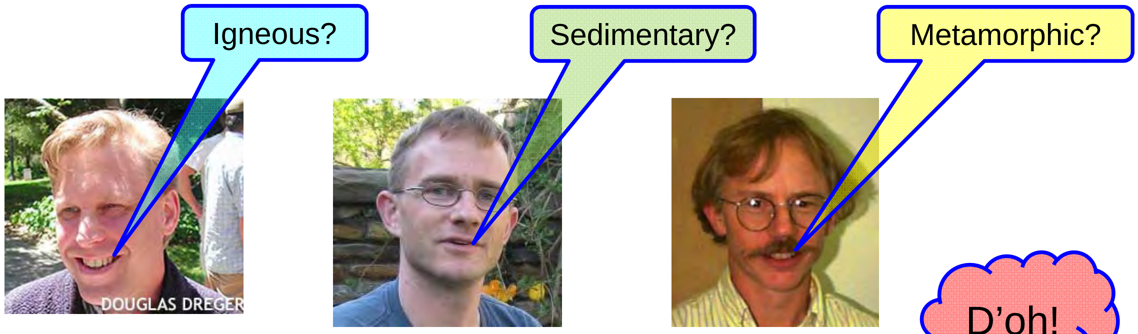
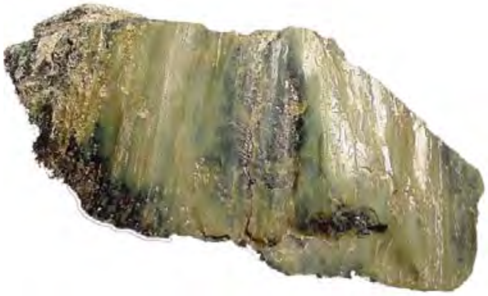
Rock Classification: my Exams





Rock Database

Virtual Geology Museum

sponsored by Cochise College

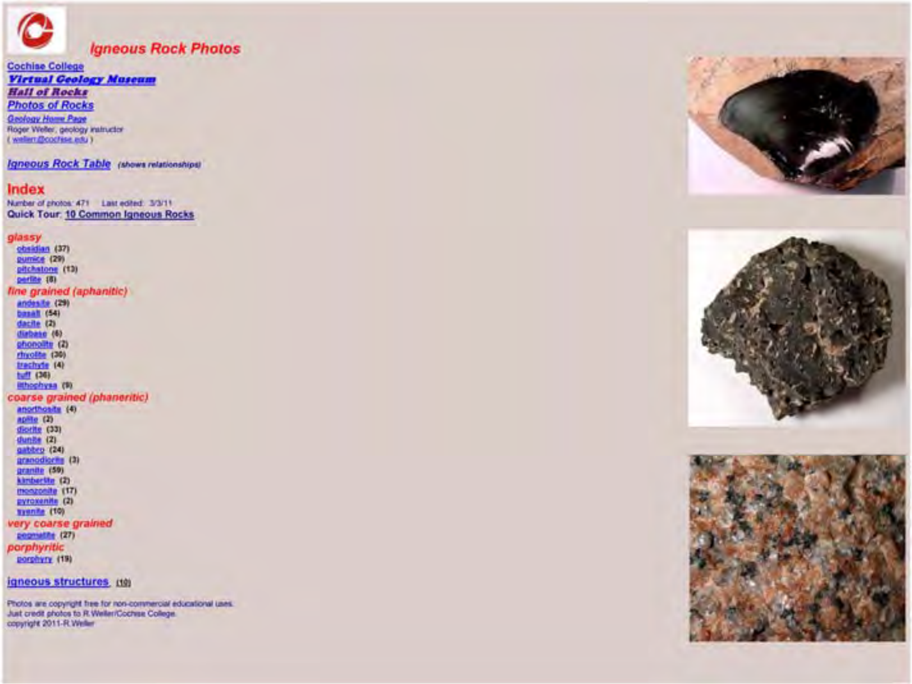
Hall of Rocks -introduction by Opal's Pals

Attractions:

- Igneous Rock Photos
- Sedimentary Rock Photos
- Metamorphic Rock Photos
- Rocks Used in Building
- Quick Tours of Rock Types

Roger Weller, curator (wellerr@cochise.edu)

Igneous Rocks



Igneous Rock Photos

Cochise College

Virtual Geology Museum

Hall of Rocks

Photos of Rocks

Geology Home Page

Roger Weller, geology instructor

(wellerr@cochise.edu)

Igneous Rock Table *(shows relationships)*

Index

Number of photos: 471 Last edited: 3/3/11

Quick Tour: 10 Common Igneous Rocks

glassy
- obsidian (37)
- pumice (29)
- pitchstone (13)
- perlite (8)

fine grained (aphanitic)
- andesite (29)
- basalt (54)
- dacite (2)
- diabase (6)
- phonolite (2)
- rhyolite (30)
- trachyte (4)
- tuff (36)
- lithophysa (9)

coarse grained (phaneritic)
- anorthosite (4)
- aplite (2)
- diorite (33)
- dunite (2)
- gabbro (24)
- granodiorite (3)
- granite (59)
- kimberlite (2)
- monzonite (17)
- pyroxenite (2)
- syenite (10)

very coarse grained
- pegmatite (27)

porphyritic
- porphyry (19)

igneous structures (10)

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Sedimentary Rocks

Sedimentary Rocks

Cochise College
Virtual Geology Museum
Hall of Rocks
Photos of Rocks
Geology Home Page
Roger Weller, geology instructor (wellerr@cochise.edu)

List
last edited: 2/9/11 number of photos: 322
Quick Tour: 12 Common Sedimentary Rocks

clastic sedimentary rocks
- breccia (16)
- conglomerate (29)
- sandstone (47)
- siltstone (3)
- shale (29)

chemical sedimentary rocks
- limestone (52)
- travertine (18)
- dolomite (2)
- gypsum (14)
- anhydrite (5)
- salt (8)
- chert (7)
- flint (6)
- jasper (4)
- oolite (5)
- diatomaceous earth (2)
- misc. evaporites (4)
- taconite (3)

biological sedimentary rocks
- coal (19)
- amber (8)

sedimentary features
- septarian nodules (3)

sedimentary structures (36)
- cave formations (1)
- chert nodues (2)
- concretions (1)
- cross bedding (9)
- mud cracks (6)
- ripple marks (5)
- raindrop imprints (4)
- liesegang rings (5)
- tool marks (2)
- cone-in-cone structures (2)

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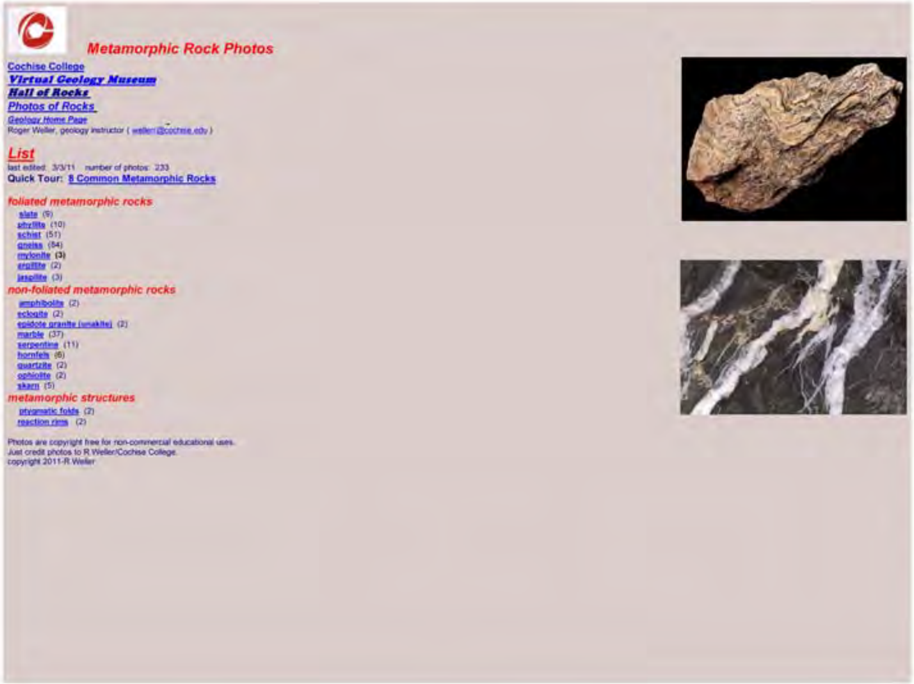
Metamorphic Rocks



Metamorphic Rock Photos

Cochise College
Virtual Geology Museum
Hall of Rocks
Photos of Rocks
Geology Home Page
Roger Weller, geology instructor (wellerr@cochise.edu)

List
last edited: 3/3/11 number of photos: 233
Quick Tour: 8 Common Metamorphic Rocks

foliated metamorphic rocks
- slate (9)
- phyllite (10)
- schist (51)
- gneiss (54)
- mylonite (3)
- argillite (2)
- jaspilite (3)

non-foliated metamorphic rocks
- amphibolite (2)
- eclogite (2)
- epidote granite (unakite) (2)
- marble (37)
- serpentine (11)
- hornfels (6)
- quartzite (2)
- ophiolite (2)
- skarn (5)

metamorphic structures
- ptygmatic folds (2)
- reaction rims (2)

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Training Set: Igneous Rocks
(85 samples)

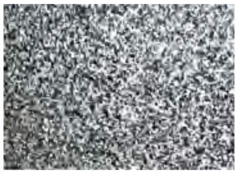
Training Set: Metamorphic Rocks
(56 samples)

Training Set: Sedimentary Rocks (70 samples)

Rock Descriptor

Igneous


Andesite


Diorite


Granite


Obsidian

Sedimentary

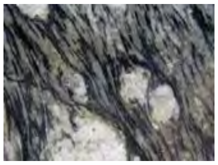

Travertine


Sandstone


Shale


Conglomerate

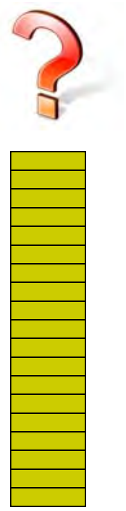
Metamorphic


Gneiss


Slate

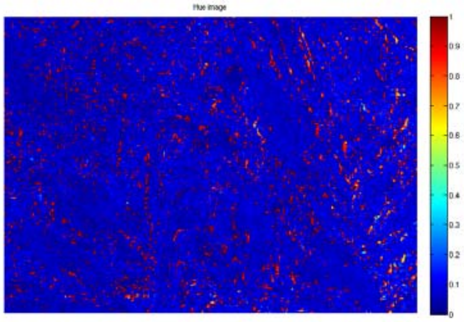

Marble


Schist



Feature Vector

Color Spaces



```
% convert image to R, G, B, HSV and to Gray
G = double(rgb2gray(I))./255;
HSV = rgb2hsv(I);
H = HSV(:,:,1);
R = I(:,:,1);
Gr = I(:,:,2);
B = I(:,:,3);
```

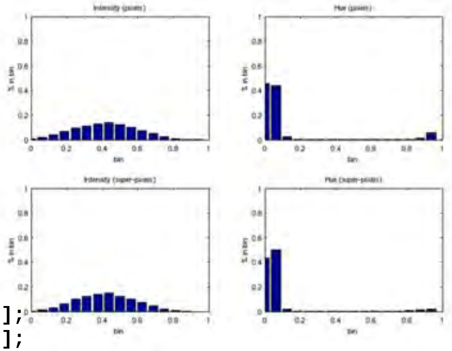
Multiple Scales (Spatial Pyramid)

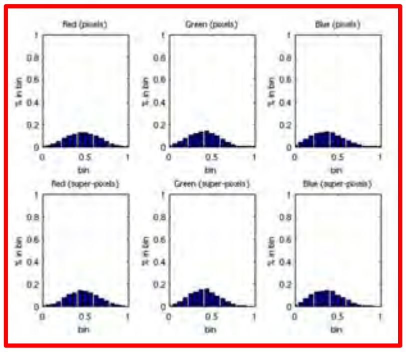
```
function [distrG bSeps]= …
   makeHistograms(G, nBins, imScale, noZero, doCat, opts)
% makes normalized histograms
% with nBins bins at scale imScale
% if doCat is false:
%    returns a matrix nBins by nBlocks
% if doCat is true:
%    returns a vector of length nBins x nBlocks
% if noZero is true:
%    only nonzero elements are considered
```

Rock Color

```
% number of pyramid levels and histogram bins
nLevs = 3;
nBins = 16;

% initialize distributions
GDis = []; HDis = [];
RDis = []; GrDis = []; BDis = [];
sGDis = []; sHDis = [];
sRDis = []; sGrDis = []; sBDis = [];

% make histogram at all levels and concatenate
for n = 1:nLevs
   GDis = [GDis; makeHistograms(G, nBins, n, 0, 1, opts)];
   HDis = [HDis; makeHistograms(H, nBins, n, 0, 1, opts)];
   RDis = [RDis; makeHistograms(R, nBins, n, 0, 1, opts)];
   GrDis = [GrDis; makeHistograms(Gr, nBins, n, 0, 1, opts)];
   BDis = [BDis; makeHistograms(B, nBins, n, 0, 1, op opts)];
   sGDis = [sGDis; makeHistograms(sG, nBins, n, 0, 1, opts)];
   sHDis = [sHDis; makeHistograms(sH, nBins, n, 0, 1, opts)];
   sRDis = [sRDis; makeHistograms(sR, nBins, n, 0, 1, opts)];
   sBDis = [sBDis; makeHistograms(sB, nBins, n, 0, 1, opts)];
end
```

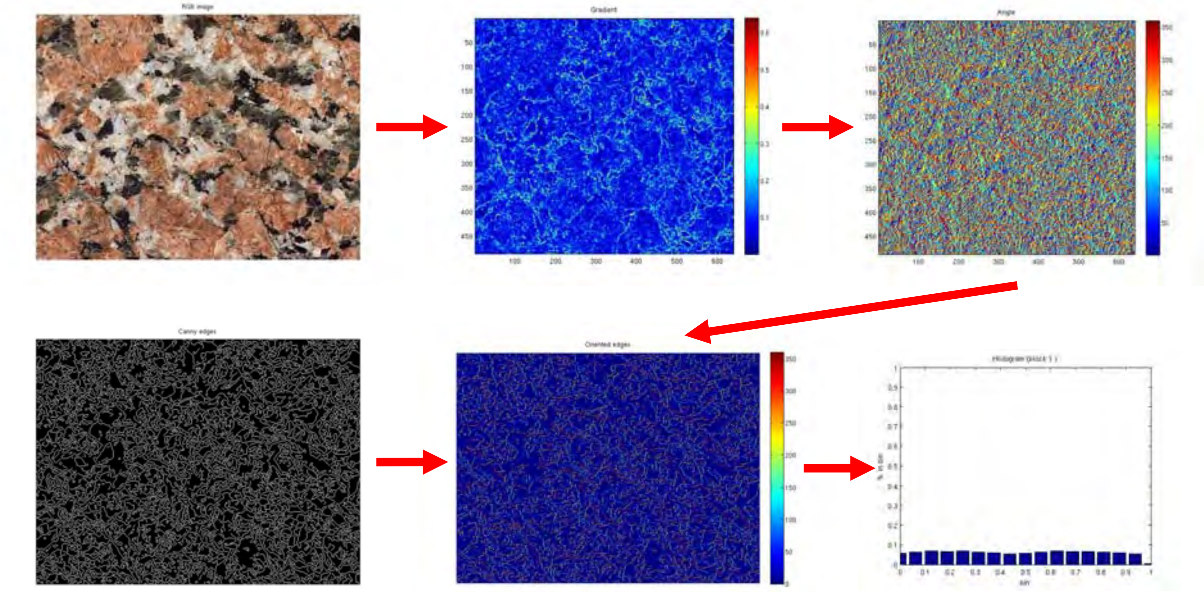
Parameters





A lot more histograms than what is shown:
at 3 scales there are 25 histograms per image

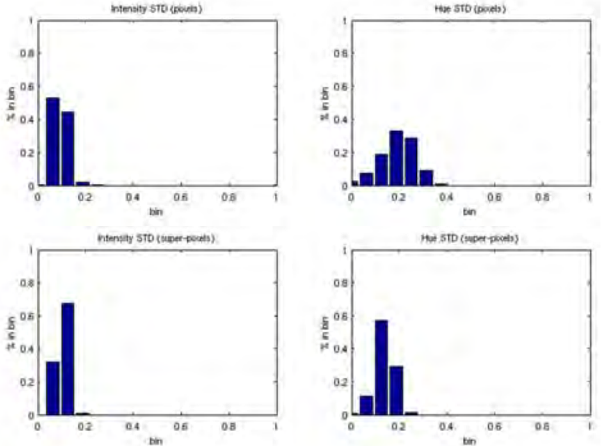
Grain Contours: Oriented Edges



A lot more histograms !

```
function [OE E A Gx Gy]= getOrEdges(G, options)
% creates a matrix of oriented edges:
%   each canny edge pixel contains the angle of the gradient direction
```

Rock Texture: Local Standard Deviation

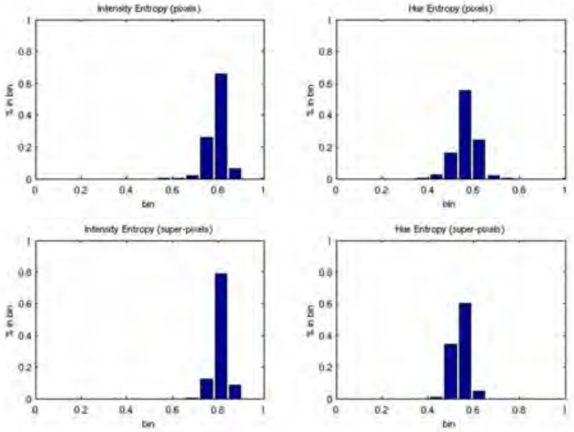


```
% apply std filter
fSize = 21;
dG = stdfilt(G, ones(fSize));
dH = stdfilt(H, ones(fSize));
sdG = stdfilt(sG, ones(fSize));
sdH = stdfilt(sH, ones(fSize));

% initialize distributions
dGDis = [];
dHDis = [];
sdGDis = [];
sdHDis = [];

% make histogram at all scales
for n = 1:nLevs
   dGDis = [dGDis; makeHistograms(dG, nBins, n, false, true, options)];
   dHDis = [dGDis; makeHistograms(dH, nBins, n, false, true, options)];
   sdGDis = [sdGDis; makeHistograms(sdG, nBins, n, false, true, options)];
   sdHDis = [sdHDis; makeHistograms(sdH, nBins, n, false, true, options)];
end
```

Parameter

A lot more histograms than what is shown:
at 3 scales there are 25 histograms per image

Rock Texture: Local Entropy



```
% apply entropy filter
fSize = 21;
eG = entropyfilt(G, ones(fSize));
eH = entropyfilt(H, ones(fSize));
seG = entropyfilt(sG, ones(fSize));
seH = entropyfilt(sH, ones(fSize));

% initialize distributions
eGDis = [];
eHDis = [];
seGDis = [];
seHDis = [];

% make histogram at all scales
for n = 1:nLevs
   eGDis = [eGDis; makeHistograms(eG, nBins, n, false, true, options)];
   eHDis = [eGDis; makeHistograms(eH, nBins, n, false, true, options)];
   seGDis = [seGDis; makeHistograms(seG, nBins, n, false, true, options)];
   seHDis = [seHDis; makeHistograms(seH, nBins, n, false, true, options)];
end
```

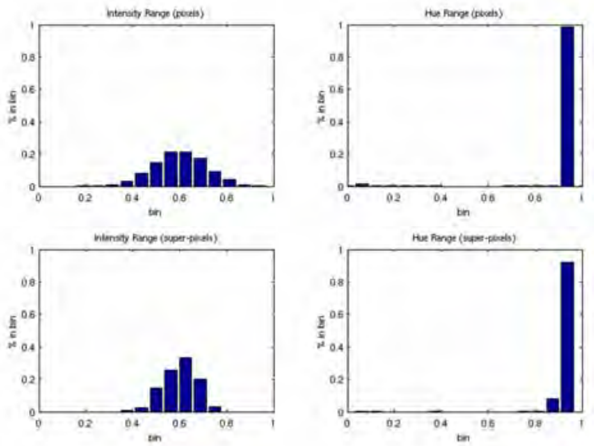
Parameter

A lot more histograms than what is shown:
at 3 scales there are 25 histograms per image

Rock Texture: Local Range

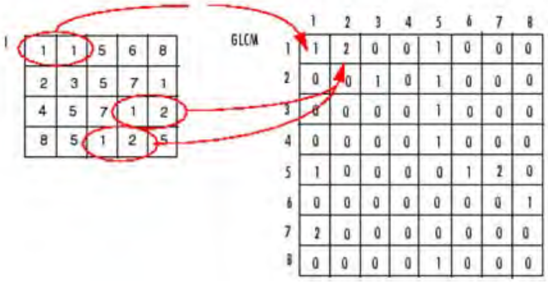
```
% apply range filter
fSize = 21;
rG = rangefilt(G, ones(fSize));
rH = rangefilt(H, ones(fSize));
srG = rangefilt(sG, ones(fSize));
srH = rangefilt(sH, ones(fSize));

% initialize distributions
rGDis = [];
rHDis = [];
srGDis = [];
srHDis = [];

% make histogram at all scales
for n = 1:nLevs
   rGDis = [rGDis; makeHistograms(rG, nBins, n, false, true, options)];
   rHDis = [rGDis; makeHistograms(rH, nBins, n, false, true, options)];
   srGDis = [srGDis; makeHistograms(srG, nBins, n, false, true, options)];
   srHDis = [srHDis; makeHistograms(srH, nBins, n, false, true, options)];
end
```

Parameter



**A lot more histograms than what is shown:
at 3 scales there are 25 histograms per image**

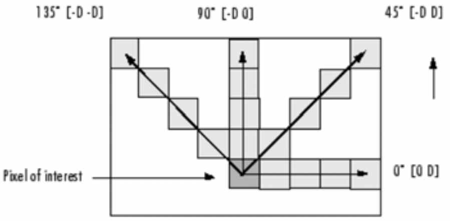
Co-Occurrence Matrix



1	1	1	5	6	8
	2	3	5	7	1
	4	5	7	1	2
	8	5	1	2	5

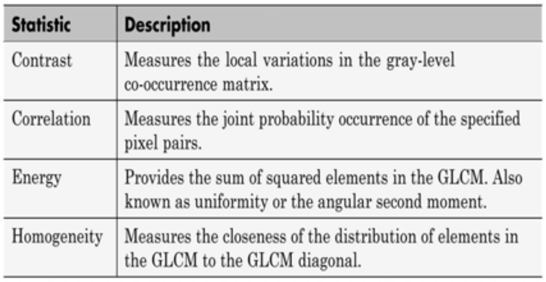
	1	2	3	4	5	6	7	8
1	1	2	0	0	1	0	0	0
2	0	0	1	0	1	0	0	0
3	0	0	0	0	1	0	0	0
4	0	0	0	0	1	0	0	0
5	1	0	0	0	0	1	2	0
6	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0
8	0	0	0	0	1	0	0	0

```
offsets = [ 0 1; 0 2; 0 3; 0 4;...
           -1 1; -2 2; -3 3; -4 4;...
           -1 0; -2 0; -3 0; -4 0;...
           -1 -1; -2 -2; -3 -3; -4 -4];
```



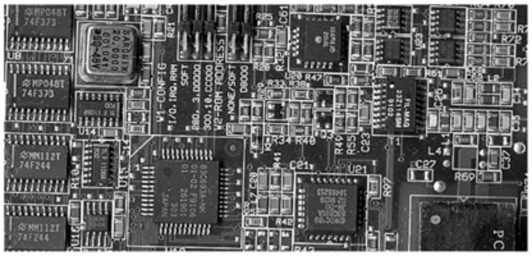
Gray Level Co-Occurrence Matrix (GLCM)

- GLCM functions characterize texture
- Calculate how often pairs of pixels with specific values and in a specified spatial relationship occur in an image
- Function of angle and distance
- Various properties can be extracted
- In Matlab: graycomatrix() and graycoprops()

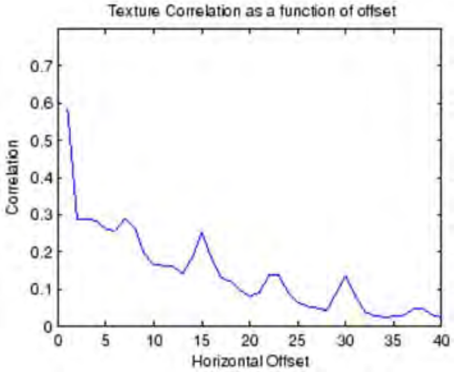


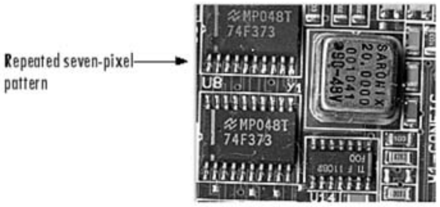
Statistic	Description
Contrast	Measures the local variations in the gray-level co-occurrence matrix.
Correlation	Measures the joint probability occurrence of the specified pixel pairs.
Energy	Provides the sum of squared elements in the GLCM. Also known as uniformity or the angular second moment.
Homogeneity	Measures the closeness of the distribution of elements in the GLCM to the GLCM diagonal.

Co-Occurrence Matrix



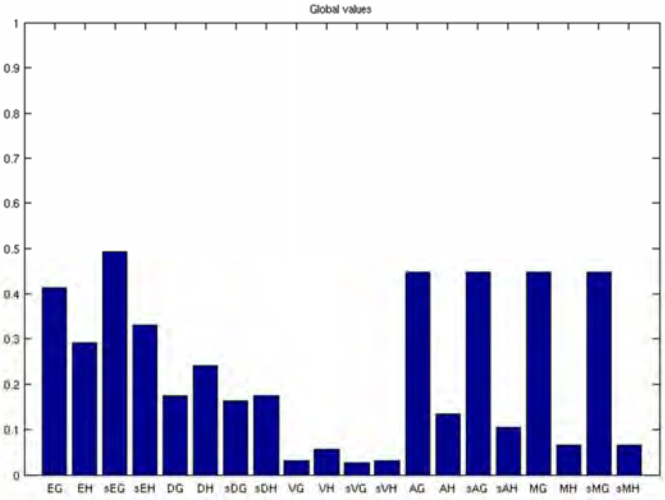
```
% read image and convert to grayscale
circuitBoard = rgb2gray(imread('board.tif'));
imshow(circuitBoard);

% create horizontal offsets
offsets0 = [zeros(40,1) (1:40)'];

% get GLCM and stats
glcms = graycomatrix(circuitBoard,'Offset',offsets0);
stats = graycoprops(glcms,'Contrast Correlation');

% plot correlation
figure, plot([stats.Correlation]);
title('Texture Correlation as a function of offset');
xlabel('Horizontal Offset');
ylabel('Correlation');
```





Global Values

```
% compute normalized entropy at all levels
EG = []; EH = []; sEG = []; sEH = [];
for n = 1:nLevs
   EG = [EG; getNEntrs(G, n, opts)];
   EH = [EH; getNEntrs(H, n, opts)];
   sEG = [sEG; getNEntrs(sG, n, opts)];
   sEH = [sEH; getNEntrs(sH, n, opts)];
end
% compute standard deviation at all levels
DG = []; DH = []; sDG = []; sDH = [];
for n = 1:nLevs
   DG = [DG; getStddevs(G, n, opts)];
   DH = [DH; getStddevs(H, n, opts)];
   sDG = [sDG; getStddevs(sG, n, opts)];
   sDH = [sDH; getStddevs(sH, n, opts)];
end
% compute variance at all levels
VG = []; VH = []; sVG = []; sVH = [];
for n = 1:nLevs
   VG = [VG; getVariances(G, n, opts)];
   VH = [VH; getVariances(H, n, opts)];
   sVG = [sVG; getVariances(sG, n, opts)];
   sVH = [sVH; getVariances(sH, n, opts)];
end
% compute mean at all levels
AG = []; AH = []; sAG = []; sAH = [];
for n = 1:nLevs
   AG = [AG; getMeans(G, n, options)];
   AH = [AH; getMeans(H, n, options)];
   sAG = [sAG; getMeans(sG, n, options)];
   sAH = [sAH; getMeans(sH, n, options)];
end
% compute median at all levels
MG = []; MH = []; sMG = []; sMH = [];
for n = 1:nLevs
   MG = [MG; getMedians(G, n, options)];
   MH = [MH; getMedians(H, n, options)];
   sMG = [sMG; getMedians(sG, n, options)];
   sMH = [sMH; getMedians(sH, n, options)];
end
```

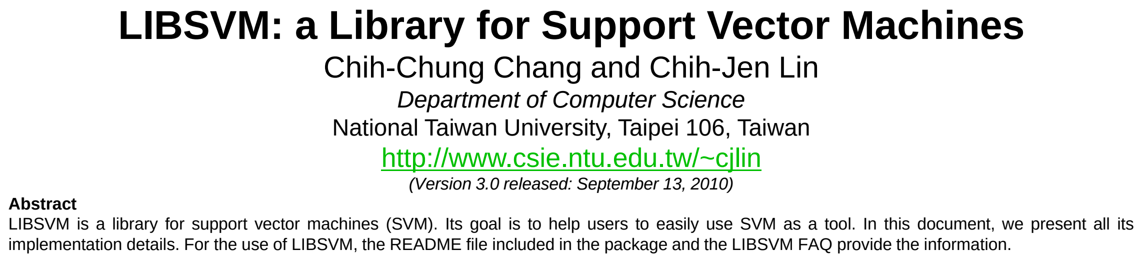


**A lot more values than what is shown:
at 3 scales there are 25 values per field**

The Descriptor
(22,052 Dimensions)

```
% concatenate descriptor
descriptor = [ ...

GDis; HDis; sGDis; sHDis; ...                   % intensity, hue histogram
RDis; GrDis; BDis; sRDis; sGrDis; sBDis; ...    % RGB histogram
rGDis; rHDis; srGDis; srHDis; ...               % local range histogram
eGDis; eHDis; seGDis; seHDis; ...               % local entropy histogram
dGDis; dHDis; sdGDis; sdHDis; ...               % local std histogram

statsG.Correlation'; sstatsG.Correlation'; ...  % intensity correlation
statsH.Correlation'; sstatsH.Correlation'; ...  % hue correlation

statsG.Contrast'; sstatsG.Contrast'; ...        % intensity contrast
statsH.Contrast'; sstatsH.Contrast'; ...        % hue contrast

statsG.Energy'; sstatsG.Energy'; ...            % intensity energy
statsH.Energy'; sstatsH.Energy'; ...            % hue energy

statsG.Homogeneity'; sstatsG.Homogeneity'; ...  % intensity homogeneity
statsH.Homogeneity'; sstatsH.Homogeneity'; ...  % hue homogeneity

EG; EH; sEG; sEH; ...                           % global entropy
VG; VH; sVG; sVH; ...                           % global variance
DG; DH; sDG; sDH; ...                           % global std
AG; AH; sAG; sAH; ...                           % global mean
MG; MH; sMG; sMH; ...                           % global median

];
```

SVM Software



LIBSVM: a Library for Support Vector Machines

Chih-Chung Chang and Chih-Jen Lin

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http://www.csie.ntu.edu.tw/~cjlin

(Version 3.0 released: September 13, 2010)

Abstract

LIBSVM is a library for support vector machines (SVM). Its goal is to help users to easily use SVM as a tool. In this document, we present all its implementation details. For the use of LIBSVM, the README file included in the package and the LIBSVM FAQ provide the information.

Different SVM formulations
Efficient multi-class classification
Cross validation for model selection
Probability estimates
Various kernels (including precomputed kernel matrix)
Weighted SVM for unbalanced data
Both C++ and Java sources
GUI demonstrating SVM classification and regression
Python, R, MATLAB, Perl, Ruby, Weka, Common LISP, CLISP, Haskell, and LabVIEW, interfaces.
C# .NET code and CUDA extension is available.
It's also included in some data mining environments: RapidMiner and PCP.
Automatic model selection which can generate contour of cross validation accuracy.

SVM Cookbook

A Practical Guide to Support Vector Classication

Chih-Wei Hsu, Chih-Chung Chang, and Chih-Jen Lin
Department of Computer Science
National Taiwan University, Taipei 106, Taiwan
http://www.csie.ntu.edu.tw/~cjlin

(Initial version: 2003 Last updated: April 15, 2010)

Abstract
The support vector machine (SVM) is a popular classification technique. However, beginners who are not familiar with SVM often get unsatisfactory results since they miss some easy but significant steps. In this guide, we propose a simple procedure which usually gives reasonable results.

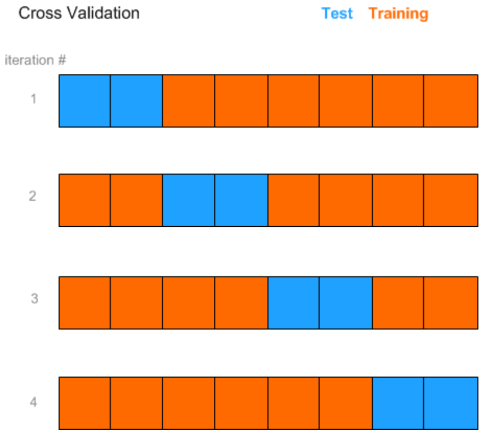
We propose that beginners try the following procedure first:

- Transform data to the format of an SVM package
- Conduct simple scaling on the data
- Consider the RBF kernel $K(x; y) = e^{-\gamma||x-y||^2}$
- Use grid search and cross-validation to find the best parameters C and γ
- Use the best parameters C and to train the whole training set
- Test

SVM Type and Cross Validation

Defined in training arguments:

- Kernel type
- Cross validation subsets
- Cost and Gamma parameters



Ex.: 4-fold cross validation

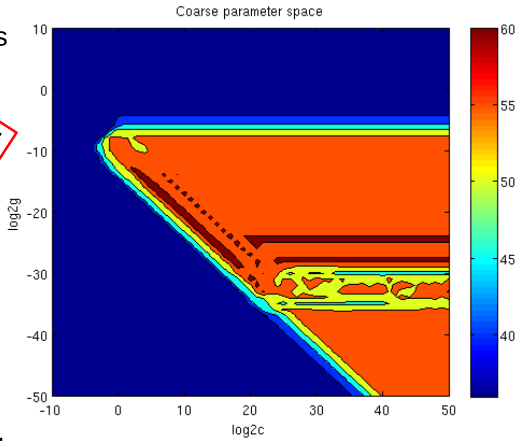
Example:

```
% svm type (RBF)
svm_type = ' -t 2 ';

% svm command (cross-validation and parameters)
svm_cmd = ['-v ', num2str(num_folds), ...
     ' -c ',num2str(C_param), ...
     ' -g ', num2str(G_param)];

% get cross-validation value
result = svmtrain(trainLabels, trainDescriptors, [svm_cmd svm_type]);
```

Parameter Search: Coarse

Finding Cost and Gamma parameters:

- Search a large grid space using coarse steps
- Use cross validation to find region with good results



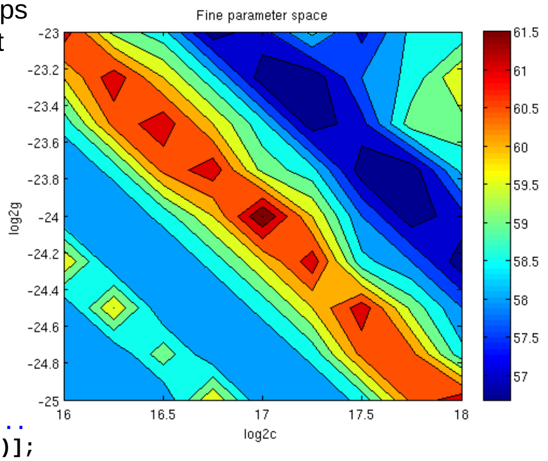
```
% initialize variables
cv = zeros(ceil(numGIters), ceil(numCIters));
xvec = min_csearch:coarse_step:max_csearch;
yvec = min_gsearch:coarse_step:max_gsearch;
[xcv,ycv] = meshgrid(xvec, yvec);

% loop over cost parameter
for indlog2c = 1:numel(xvec)
    log2c = xvec(indlog2c);

    % loop over gamma parameter
    for indlog2g = 1:numel(yvec)
        log2g = yvec(indlog2g);

        % store all cross-validation results
        svm_cmd = ['-v ', num2str(sub_num), ' -c ', ...
            num2str(2^log2c), ' -g ', num2str(2^log2g)];
        cv(indlog2g, indlog2c) = ...
            svmtrain(trainLabels, trainDescriptors, [svm_cmd svm_type svm_opts]);

        % update best result
        if (cv(indlog2g, indlog2c) > bestcv)
            bestcv = cv(indlog2g, indlog2c); bestc = 2^log2c; bestg = 2^log2g;
        end
    end
end
```

Parameter

Parameter Search: Fine

Finding Cost and Gamma parameters:

- Repeat procedure on smaller space with fine steps
- Use cross validation to find region the best result



```
% initialize variables
cv = zeros(ceil(numGIters), ceil(numCIters));
xvec = min_csearch:fine_step:max_csearch;
yvec = min_gsearch:fine_step:max_gsearch;
[xcv,ycv] = meshgrid(xvec, yvec);

% loop over cost parameter
for indlog2c = 1:numel(xvec)
    log2c = xvec(indlog2c);

    % loop over gamma parameter
    for indlog2g = 1:numel(yvec)
        log2g = yvec(indlog2g);

        % store all cross-validation results
        svm_cmd = ['-v ', num2str(sub_num), ' -c ', ...
            num2str(2^log2c), ' -g ', num2str(2^log2g)];
        cv(indlog2g, indlog2c) = ...
            svmtrain(trainLabels, trainDescriptors, [svm_cmd svm_type svm_opts]);

        % update best result
        if (cv(indlog2g, indlog2c) > bestcv)
            bestcv = cv(indlog2g, indlog2c); bestc = 2^log2c; bestg = 2^log2g;
        end
    end
end
```

Training the SVM

Training:

- Use the best discovered parameters
- Train on the entire training data (no cross-validation)

Check:

- Use the trained model on the training data
- Ideally you should get 100% accuracy

```
% use best parameters
svm_params = [' -c ', num2str(bestc), ' -g ', num2str(bestg) ' '];

% train
svm_model = svmtrain(trainLabels, trainDescriptors, [svm_type svm_params]);

% test
[labels, accuracy, value] =  ...
   svmpredict(trainLabels, trainDescriptors, svm_model, svm_opts);
```

Classifying with the SVM

Validating:

- Use the trained model on the separate testing data with labels (same as on previous slide but on data that was not part of the training)
- Decide if your accuracy is good enough

```
% test on separate labeled data
[labels, accuracy, value] =  ...
   svmpredict(testLabels, testDescriptors, svm_model, svm_opts);
```

Predicting:

- Use the trained model on new data with unknown labels

```
% generate random labels (2-class in this example)
randLabels = double(round(rand(numInstances, 1)));

% predict on new data
[labels, accuracy, value] =  ...
   svmpredict(randLabels, neDescriptors, svm_model, svm_opts);
```

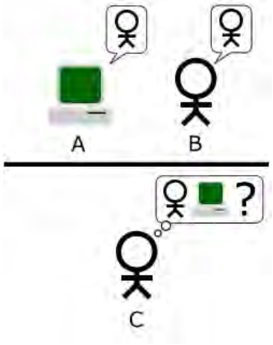
iRock: Results

How well did it do?

Note: the selection of the training and testing images was entirely random
(and no rocks were harmed in the process)

Man vs. Machine: the Turing Test

Alan Mathison Turing, 1912-1954



Turing, A.M. (1950). Mind, 59, 433-460.

COMPUTING MACHINERY AND INTELLIGENCE

By A. M. Turing

I propose to consider the question, **"Can machines think?"**
This should begin with definitions of the meaning of the terms "machine" and "think." The definitions might be framed so as to reflect so far as possible the normal use of the words, but this attitude is dangerous, If the meaning of the words "machine" and "think" are to be found by examining how they are commonly used it is difficult to escape the conclusion that the meaning and the answer to the question, "Can machines think?" is to be sought in a statistical survey such as a Gallup poll. But this is absurd. Instead of attempting such a definition I shall replace the question by another, which is closely related to it and is expressed in relatively unambiguous words.

The new form of the problem can be described in terms of a game which we call the 'imitation game." It is played with three people, a man (A), a woman (B), and an interrogator (C) who may be of either sex. The interrogator stays in a room apart front the other two. The object of the game for the interrogator is to determine which of the other two is the man and which is the woman. He knows them by labels X and Y, and at the end of the game he says either "X is A and Y is B" or "X is B and Y is A." The interrogator is allowed to put questions to A and B thus:

C: Will X please tell me the length of his or her hair?

Now suppose X is actually A, then A must answer. It is A's object in the game to try and cause C to make the wrong identification. His answer might therefore be:

"My hair is shingled, and the longest strands are about nine inches long."

In order that tones of voice may not help the interrogator the answers should be written, or better still, typewritten. The ideal arrangement is to have a tele-printer communicating between the two rooms. Alternatively the question and answers can be repeated by an intermediary. The object of the game for the third player (B) is to help the interrogator. The best strategy for her is probably to give truthful answers. She can add such things as "I am the woman, don't listen to him!" to her answers, but it will avail nothing as the man can make similar remarks.

We now ask the question, "What will happen when a machine takes the part of A in this game?" Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman? These questions replace our original, "Can machines think?"

Man vs. Machine: Deep Blue

HOME PAGE TODAY'S PAPER VIDEO MOST POPULAR TIMES TOPICS

The New York Times

N.Y. / Region

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION

Swift and Slashing, Computer Topples Kasparov

In brisk and brutal fashion, the I.B.M. computer Deep Blue unseated humanity, at least temporarily, as the finest chess playing entity on the planet yesterday, when Garry Kasparov, the world chess champion, resigned the sixth and final game of the match after just 19 moves, saying, "I lost my fighting spirit."

The unexpectedly swift denouement to the bitterly fought contest came as a surprise, because until yesterday Mr. Kasparov had been able to summon the wherewithal to match Deep Blue gambit for gambit.

The manner of the conclusion overshadowed the debate over the meaning of the computer's success. Grandmasters and computer experts alike went from praising the match as a great experiment, invaluable to both science and chess (if a temporary blow to the collective ego of the human race) to smacking their foreheads in amazement at the champion's abrupt crumpling.

"It had the impact of a Greek tragedy," said Monty Newborn, chairman of the chess committee for the Association for Computing, which was responsible for officiating the match.

It was the second victory of the match for the computer -- there were three draws -- making the final score 3 1/2 to 2 1/2, the first time any chess champion has been beaten by a machine in a traditional match. Mr. Kasparov, 34, retains his title, which he has held since 1985, but the loss was nonetheless unprecedented in his career; he has never before lost a multigame match against an individual opponent.

Garry Kimovich Kasparov
World Chess Champion 1985-2000

Man vs. Machine: Watson

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The New York Times

Science

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION A

ENVIRONMENT SPACE & COSMOS

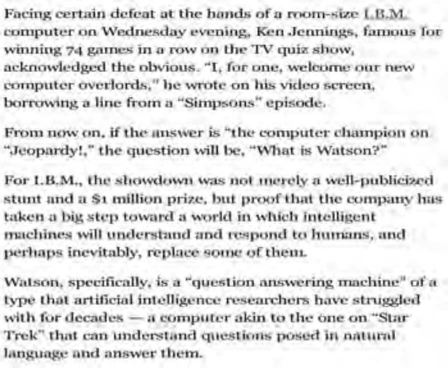
Computer Wins on 'Jeopardy!': Trivial, It's Not

Carol Kaelson/Jeopardy Productions Inc., via Associated Press

Two "Jeopardy!" champions, Ken Jennings, left, and Brad Rutter, competed against a computer named Watson, which proved adept at buzzing in quickly.

By JOHN MARKOFF
Published: February 16, 2011

YORKTOWN HEIGHTS, N.Y. — In the end, the humans on "Jeopardy!" surrendered meekly.



Facing certain defeat at the hands of a room-size I.B.M. computer on Wednesday evening, Ken Jennings, famous for winning 74 games in a row on the TV quiz show, acknowledged the obvious. "I, for one, welcome our new computer overlords," he wrote on his video screen, borrowing a line from a "Simpsons" episode.

From now on, if the answer is "the computer champion on "Jeopardy!," the question will be, "What is Watson?"

For I.B.M., the showdown was not merely a well-publicized stunt and a $1 million prize, but proof that the company has taken a big step toward a world in which intelligent machines will understand and respond to humans, and perhaps inevitably, replace some of them.

Watson, specifically, is a "question answering machine" of a type that artificial intelligence researchers have struggled with for decades — a computer akin to the one on "Star Trek" that can understand questions posed in natural language and answer them.

Man vs. Machine: ISSWR Students & iRock

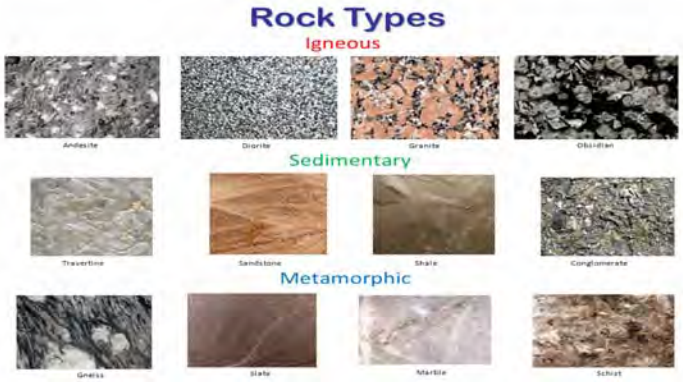
ISSWR Students

iRock

Man vs. Machine: ISSWR Students & iRock

- Take one picture card and three colored voting cards
- Study the picture card while we get ready
- A random sequence of 26 images will be shown
- Vote quickly by raising one of the colored cards
- One volunteer to call the vote
- Another volunteer to tally the counts on the board

Ready?



Igneous

Sedimentary

Metamorphic

ISSWR vs. iRock: Image 1

ISSWR vs. iRock: Image 1

Truth: Limestone – Sedimentary

iRock: Sedimentary

✓

ISSWR vs. iRock: Image 2

ISSWR vs. iRock: Image 2

Truth: **Schist – Metamorphic**
iRock: **Metamorphic**

ISSWR vs. iRock: Image 3

ISSWR vs. iRock: Image 3

Truth: **Shale – Sedimentary**
iRock: **Sedimentary**

ISSWR vs. iRock: Image 4

ISSWR vs. iRock: Image 4

Truth: **Diorite – Igneous**
iRock: **Igneous** ✓

ISSWR vs. iRock: Image 5

ISSWR vs. iRock: Image 5

Truth: Andesite – Igneous
iRock: Igneous

ISSWR vs. iRock: Image 6

ISSWR vs. iRock: Image 6

Truth: **Conglomerate – Sedimentary**
iRock: **Sedimentary**

✓

ISSWR vs. iRock: Image 7

ISSWR vs. iRock: Image 7

Truth: Gypsum – Sedimentary
iRock: Sedimentary

ISSWR vs. iRock: Image 8

ISSWR vs. iRock: Image 8

Truth: **Marble – Metamorphic**
iRock: **Metamorphic** ✓

ISSWR vs. iRock: Image 9

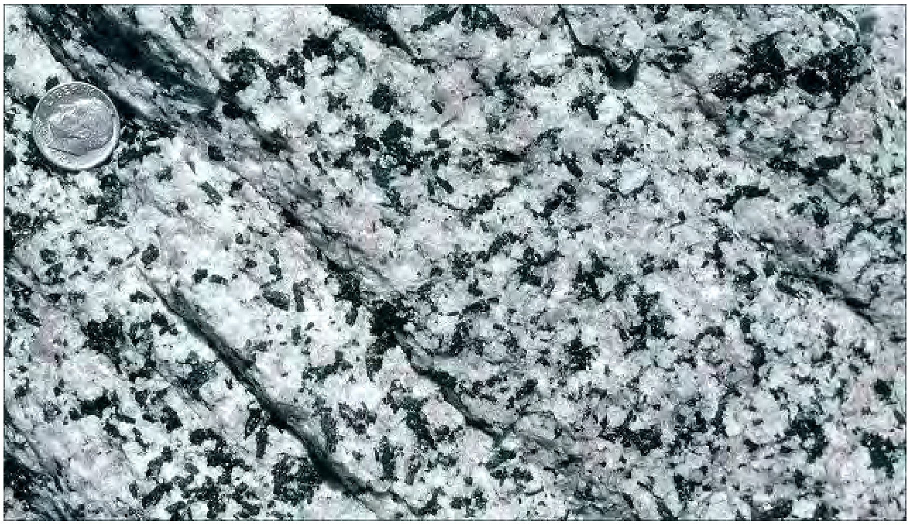
ISSWR vs. iRock: Image 9

Truth: **Shale – Sedimentary**
iRock: **Sedimentary**

✓

ISSWR vs. iRock: Image 10

ISSWR vs. iRock: Image 10



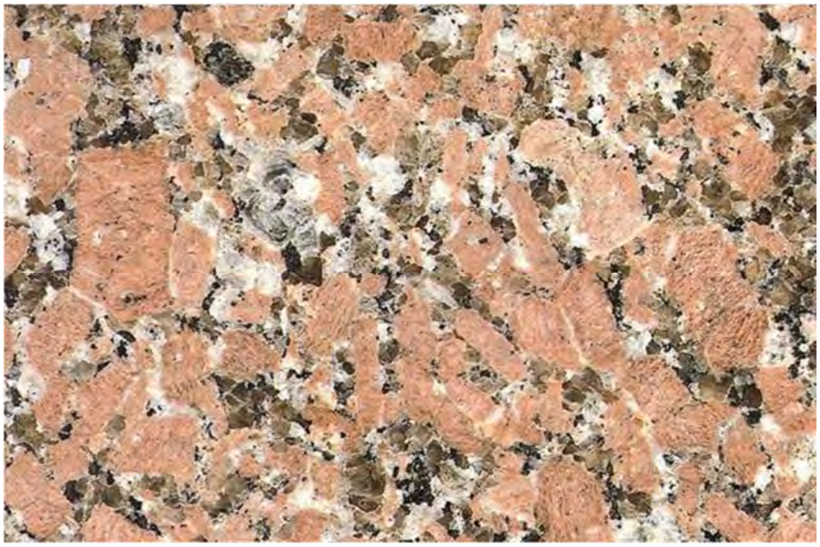
Truth: Granodiorite – Igneous
iRock: Igneous ✓

ISSWR vs. iRock: Image 11

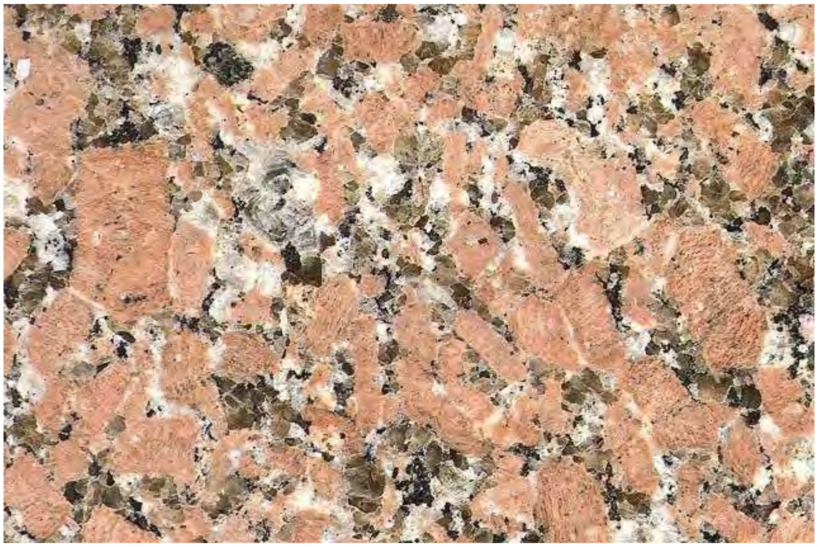
ISSWR vs. iRock: Image 11

Truth: Anhydrite – Sedimentary
iRock: Sedimentary ✗

ISSWR vs. iRock: Image 12



ISSWR vs. iRock: Image 12



Truth: Granite – Igneous
iRock: Igneous

✓

ISSWR vs. iRock: Image 13

ISSWR vs. iRock: Image 13

Truth: **Marble – Metamorphic**
iRock: **Metamorphic**

✓

ISSWR vs. iRock: Image 14

ISSWR vs. iRock: Image 14

Truth: Rhyolite – Igneous
iRock: Metamorphic

ISSWR vs. iRock: Image 15

ISSWR vs. iRock: Image 15

Truth: **Skarn – Metamorphic**
iRock: **Metamorphic**

ISSWR vs. iRock: Image 16

ISSWR vs. iRock: Image 16

Truth: **Limestone – Sedimentary**
iRock: **Sedimentary** ✓

ISSWR vs. iRock: Image 17

ISSWR vs. iRock: Image 17

Truth: Schist – Metamorphic
iRock: Metamorphic ✓

ISSWR vs. iRock: Image 18

ISSWR vs. iRock: Image 18

Truth: **Syenite – Igneous**
iRock: **Igneous**

ISSWR vs. iRock: Image 19

ISSWR vs. iRock: Image 19

Truth: Sandstone – Sedimentary
iRock: Sedimentary ✓

ISSWR vs. iRock: Image 20

ISSWR vs. iRock: Image 20

Truth: Schist – Metamorphic
iRock: Metamorphic

✓

ISSWR vs. iRock: Image 21

ISSWR vs. iRock: Image 21

Truth: **Conglomerate – Sedimentary**
iRock: **Sedimentary**

✓

ISSWR vs. iRock: Image 22

ISSWR vs. iRock: Image 22

Truth: Diabase – Igneous
iRock: Igneous

ISSWR vs. iRock: Image 23

ISSWR vs. iRock: Image 21

Truth: Limestone – Sedimentary
iRock: Sedimentary

✓

ISSWR vs. iRock: Image 24

ISSWR vs. iRock: Image 24

Truth: Siltstone – Sedimentary
iRock: Sedimentary

✓

ISSWR vs. iRock: Image 25

ISSWR vs. iRock: Image 25

Truth: Schist – Metamorphic
iRock: Metamorphic

✓

ISSWR vs. iRock: Image 26

ISSWR vs. iRock: Image 26

Truth: Volcanic Sandstone – Igneous
iRock: Igneous

✓

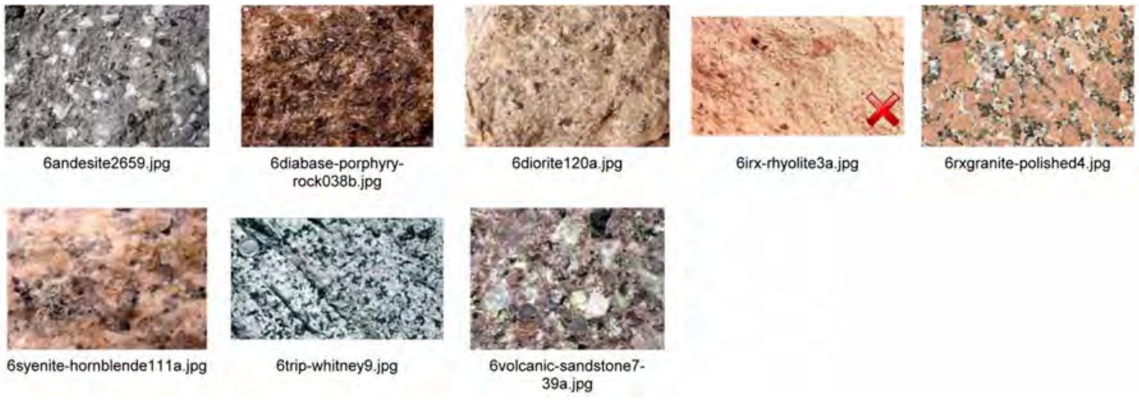
Man vs. Machine: ISSWR Students & iRock

… out of 26 correct

24 out of 26 correct

---

iRock: Recap



Truth: Igneous

iRock: Igneous (87.5%), Sedimentary (12.5%), Metamorphic (0%)

iRock: Recap

Truth: Sedimentary
iRock: Sedimentary (91%), Igneous (0%), Metamorphic (9%)

---

iRock: Recap

Truth: Metamorphic
iRock: Metamorphic (100%), Igneous (0%), Sedimentary (0%)

iRock: Another Test (after re-training)


6andesite2662.jpg


6diorite120a.jpg


6diorite1877a.jpg


6granite-hornblende-rock014b.jpg


6irx-diorite-polished1.jpg


6obsidian7-02b.jpg


6pyroxenite-harzburgite-rock043b.jpg


6trip-whitney9.jpg

Truth: Igneous
iRock: Igneous (87.5%), Metamorphic (12.5%), Sedimentary (0%)

---

iRock: Another Test (after re-training)


6breccia-chert133a.jpg


6limestone-lithographic150b.jpg


6sandstone-crossbedding44.jpg


6shale-argillaceous-rock52b.jpg


6shale-oil-rock55b.jpg


6srx-conglomerate9b.jpg


6srx-sandstone-coarse1.jpg


6srx-siltstone2.jpg


6taconite159a.jpg


6travertine155c.jpg

Truth: Sedimentary
iRock: Sedimentary (80%), Igneous (0%), Metamorphic (20%)

iRock: Another Test (after re-training)


6gneiss1850a.jpg


6gneiss-biotite-rock79b.jpg


6gneiss-corundum191b.jpg


6marble1900.jpg


6marble-tobermorite180b.jpg


6mrx-gneiss-flat1.jpg


6mrx-marble-polished-breccia5.jpg

Not so lucky this time!

Truth: **Metamorphic**
iRock: **Metamorphic (42.9%), Igneous (57.1%), Sedimentary (0%)**

---

iRock: Discussion

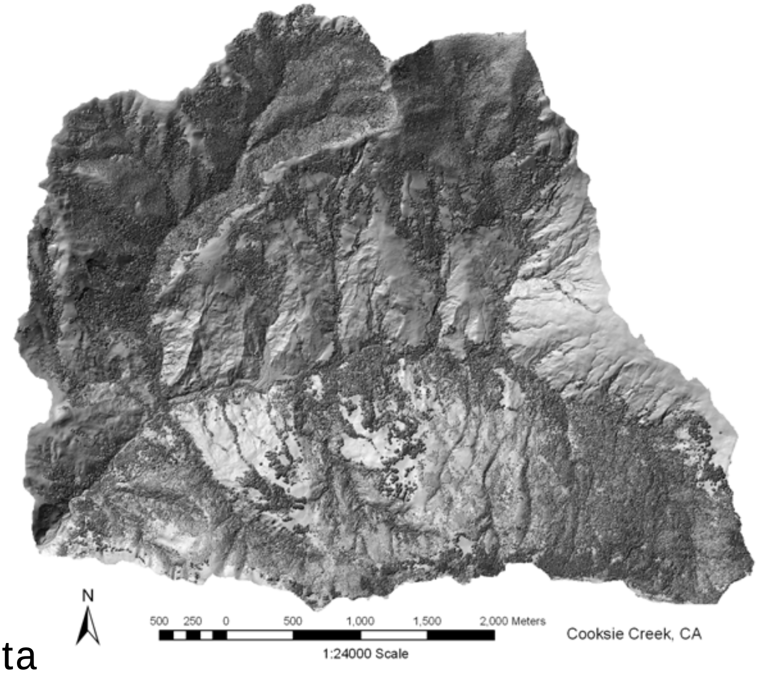
What happened and why?

How many features?
Which features?

How much training?
How much testing?

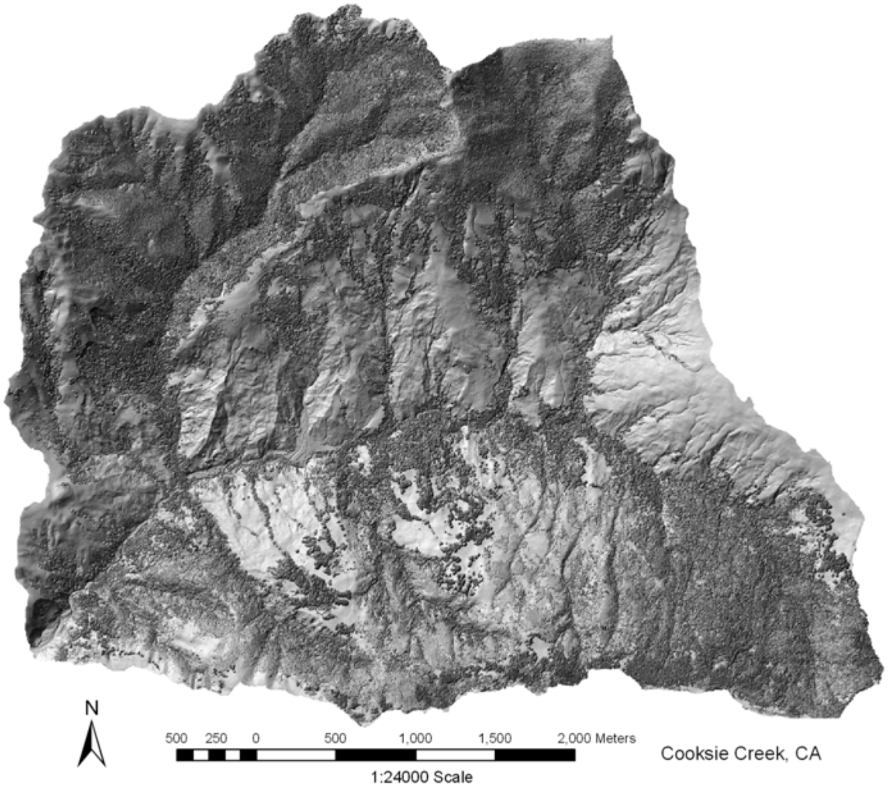
Can we take better advantage of prior knowledge?
How could we apply this technique to landslide identification?
How could we apply this technique to landslide prediction?

Landslide (deep) identification



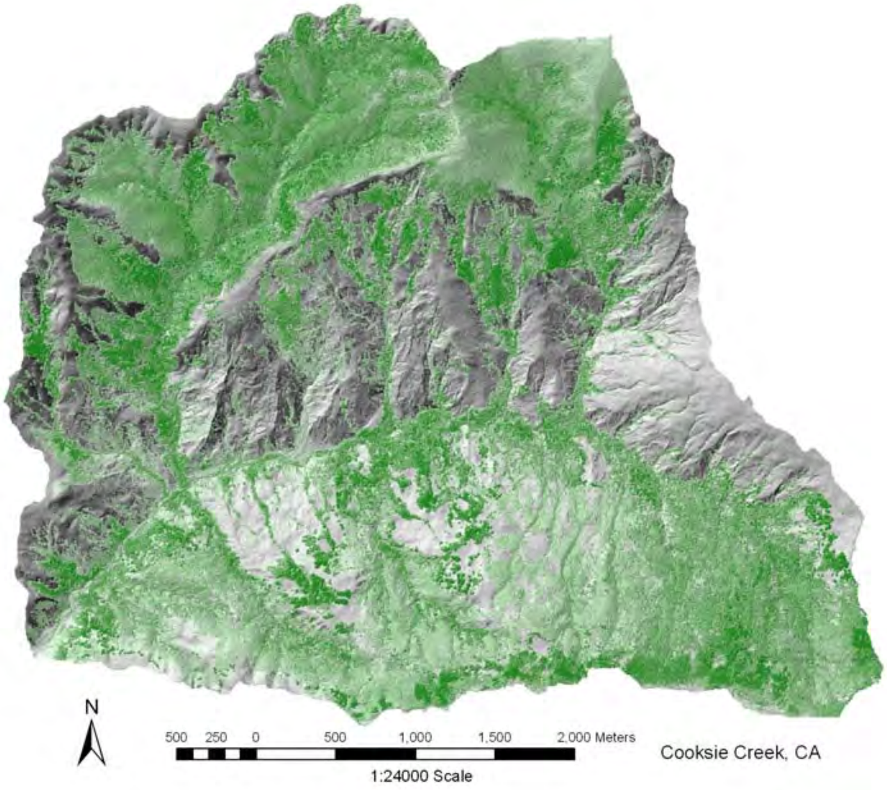
LiDAR 1m data

LiDAR 1m data

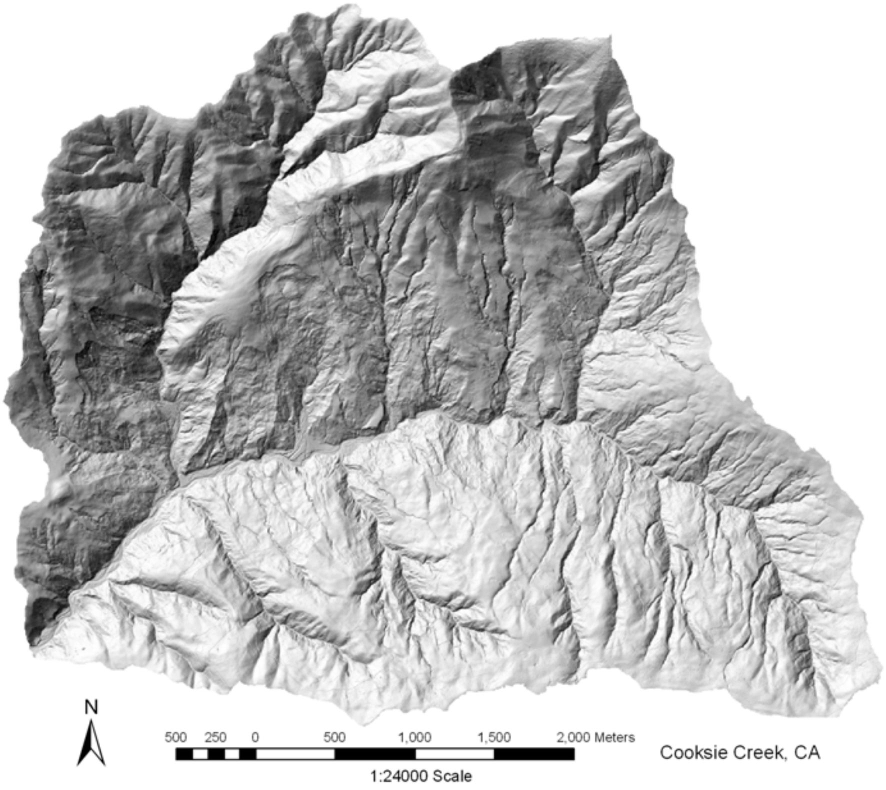


Yay NCALM!

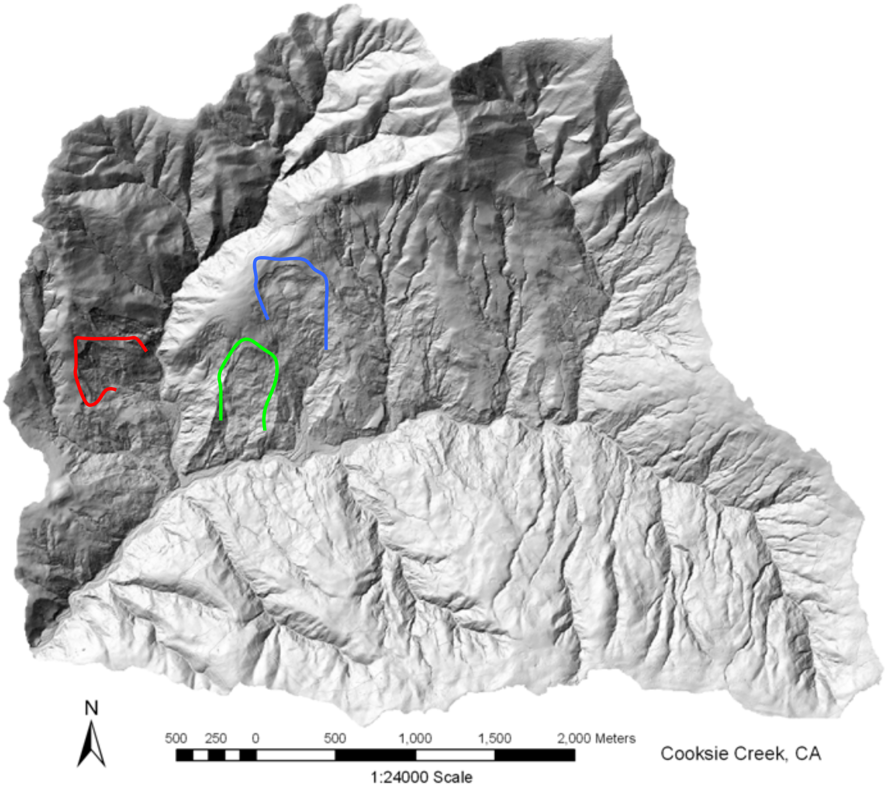
Filter vegetation



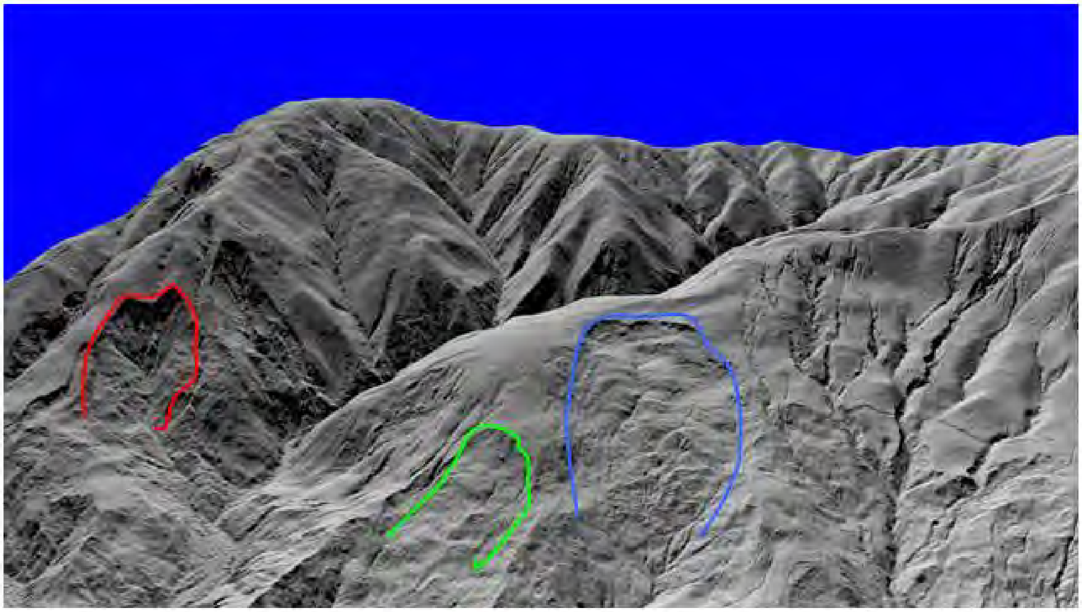
Bare earth



Landslides



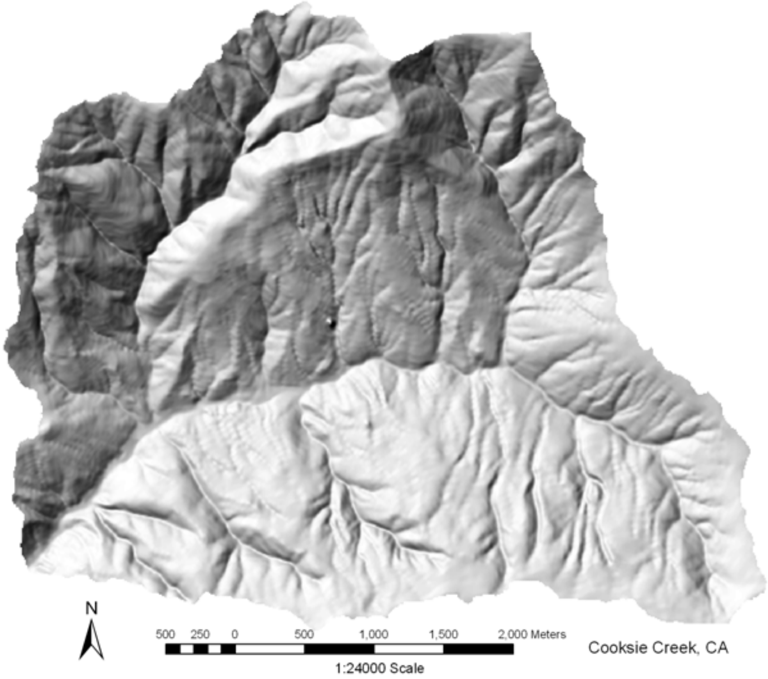
Landslides
(3-D, vertical
exaggeration)



Signature:

- Rougher texture
- Edges around scarp
- Differently dissected
- Differently sloping

USGS 10m data

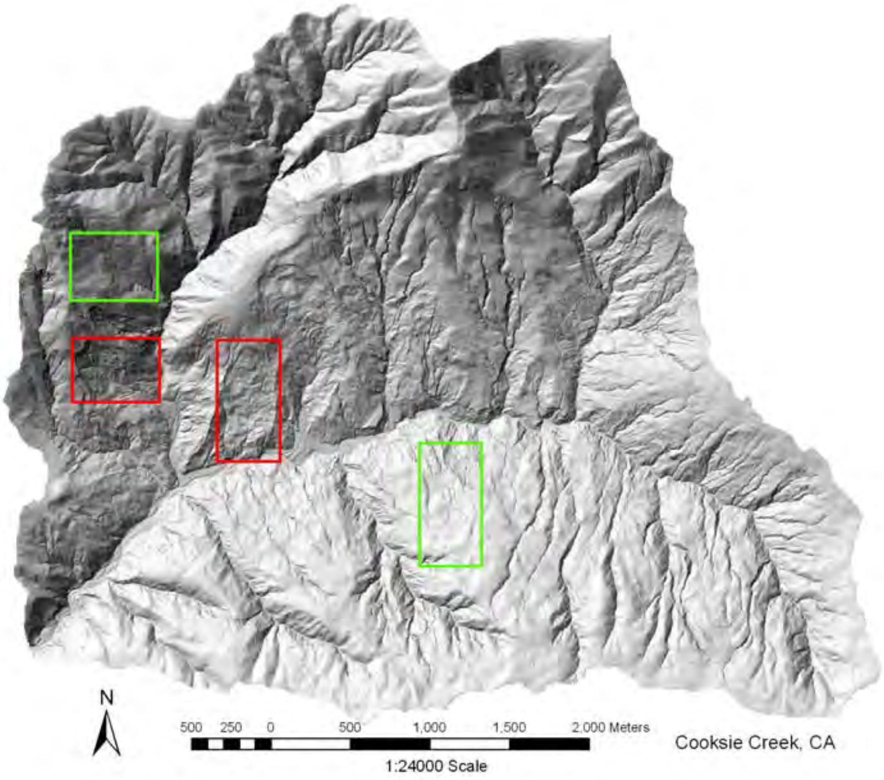


Signature:

- Smoother texture
- Less defined edges
- Flatter slopes
- More uniform slope direction

Can we learn the signature independently of the type of data?

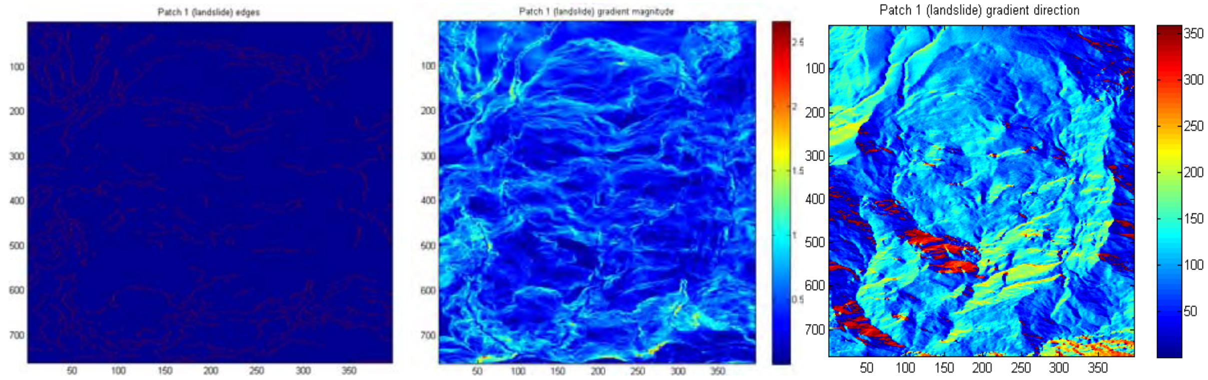
Test patches



P-HOG

Gradients

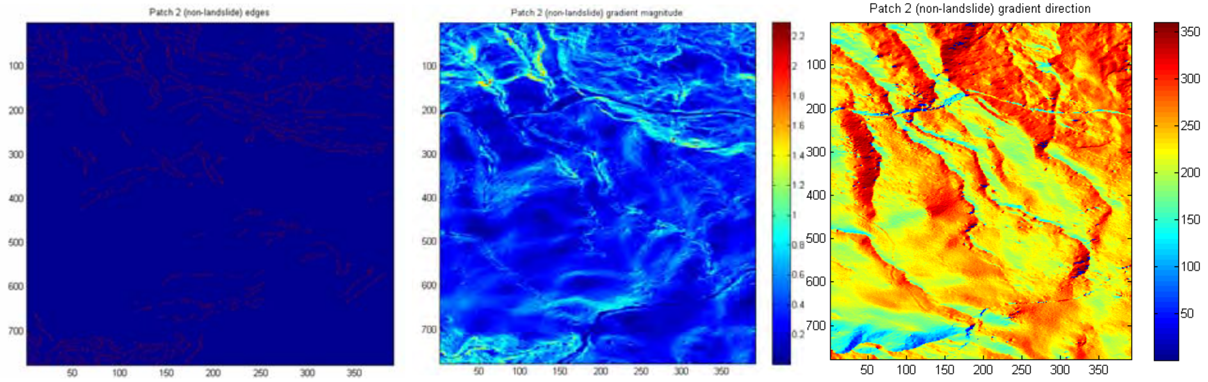
Landslide (patch 1)


Patch 1 (landslide) edges

Patch 1 (landslide) gradient magnitude

Patch 1 (landslide) gradient direction

Non-landslide (patch 2)


Patch 2 (non-landslide) edges

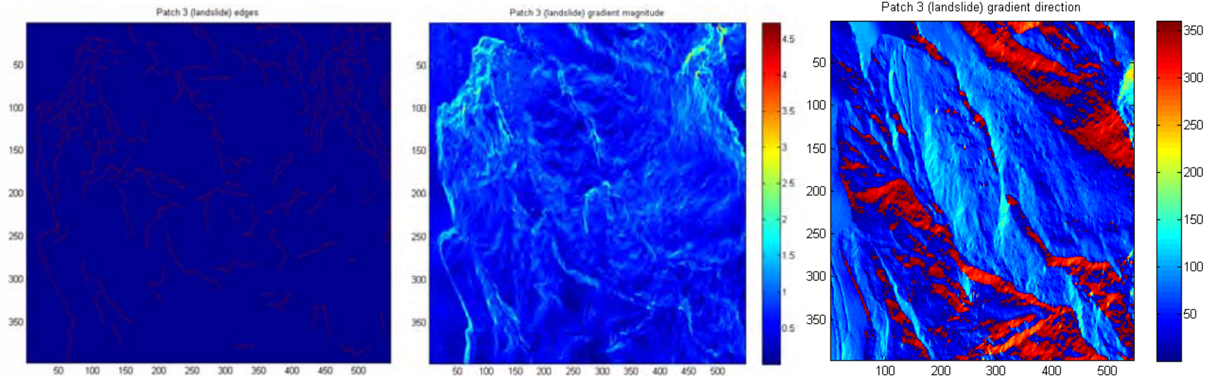
Patch 2 (non-landslide) gradient magnitude

Patch 2 (non-landslide) gradient direction

P-HOG

Gradients

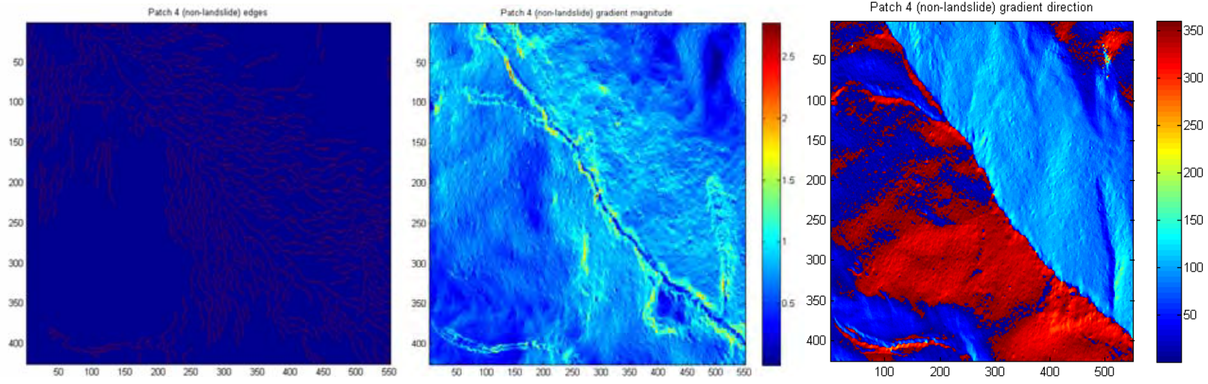
Landslide (patch 3)


Patch 3 (landslide) edges

Patch 3 (landslide) gradient magnitude

Patch 3 (landslide) gradient direction

Not landslide (patch 4)


Patch 4 (non-landslide) edges

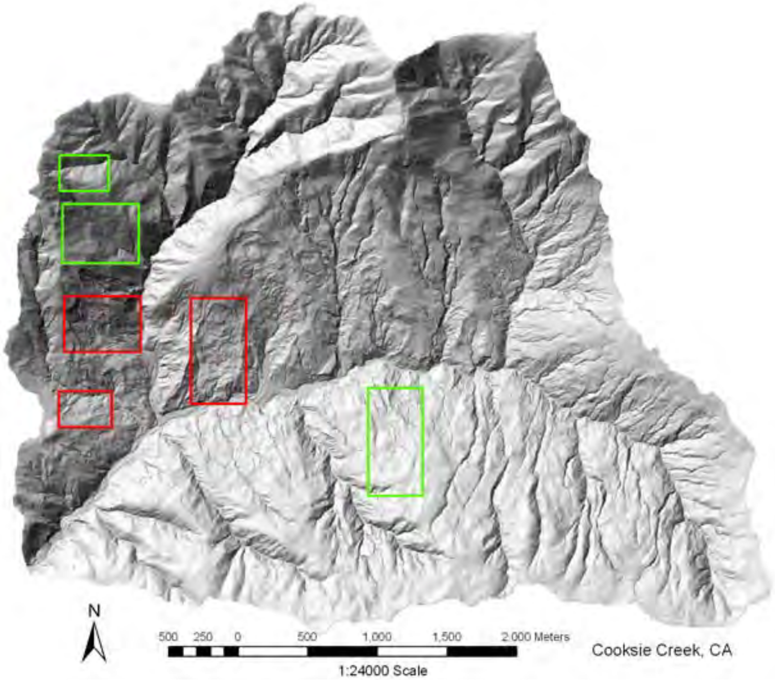
Patch 4 (non-landslide) gradient magnitude

Patch 4 (non-landslide) gradient direction

Lib-SVM

(thanks Subhransu!)

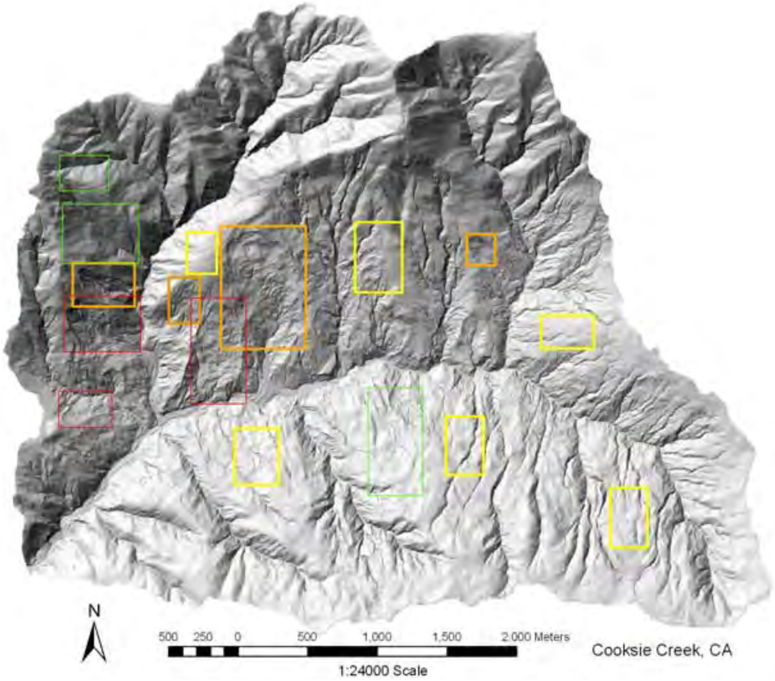
- Matlab implementation:
  - LibSVM
  - Training, test, and classify routines
  - Linear, Radial Basis, or Sigmoid Kernels
- Learning:
  - 6 training patches (red – landslide, green – non landslide)



Lib-SVM

(thanks Subhransu!)

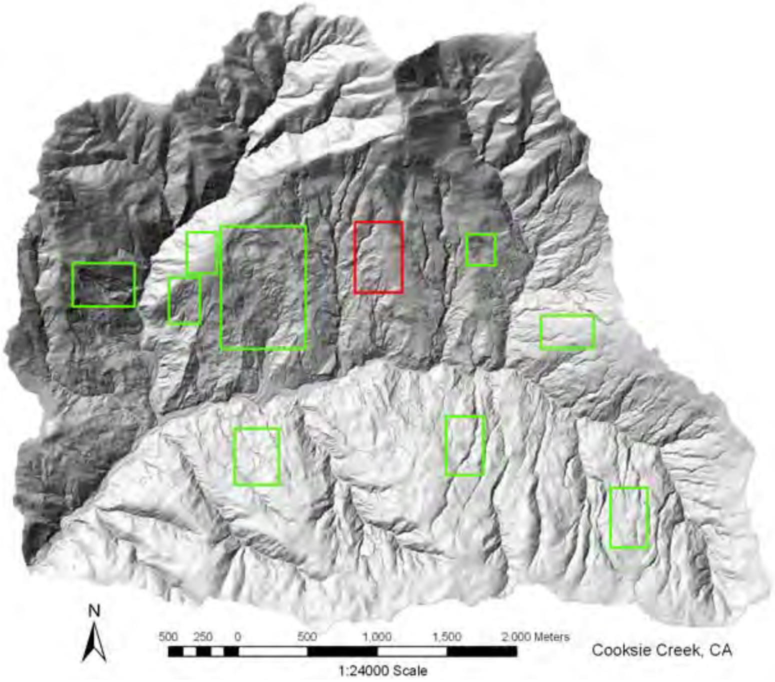
- Matlab implementation:
  - LibSVM
  - Training, test, and classify routines
  - Linear, Radial Basis, or Sigmoid Kernels
- Learning:
  - 6 training patches (red – landslide, green – non landslide)
- Testing:
  - 10 new patches (orange – landslide, yellow – non landslide)



Lib-SVM

Results

- Much to my surprise:
  Nine out of ten correct!
  (correct – green,
  incorrect - red)

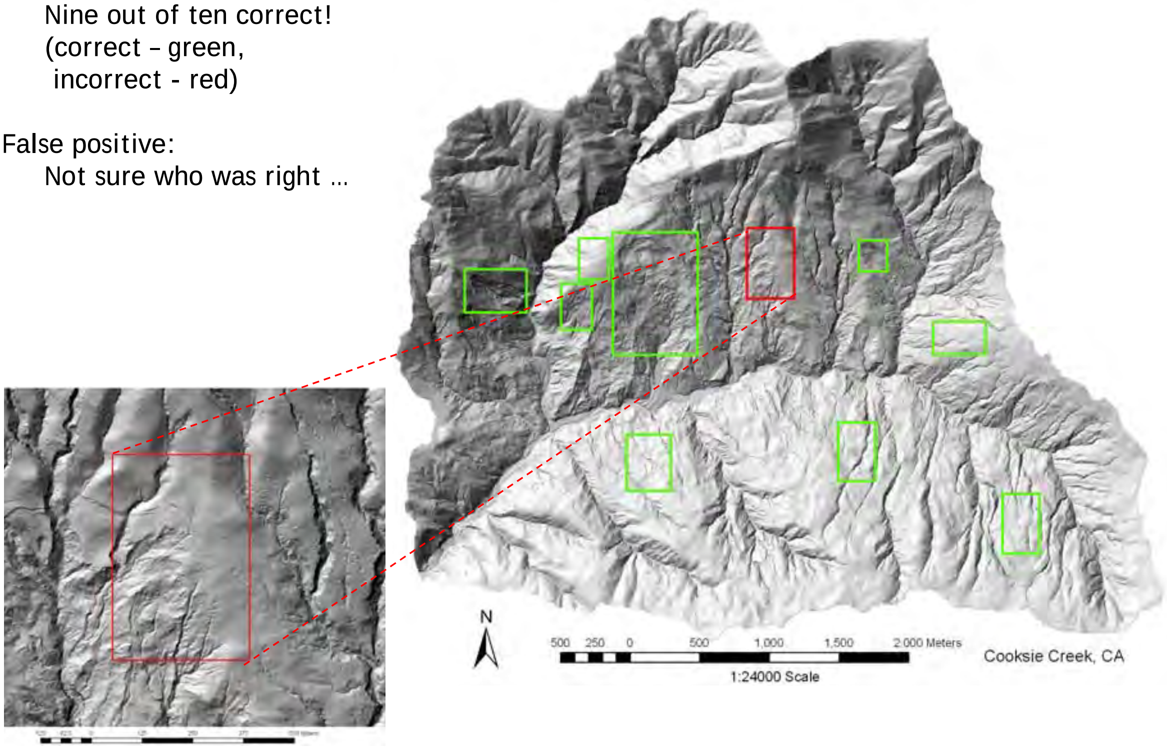


Lib-SVM

Results

- Much to my surprise:
  Nine out of ten correct!
  (correct – green,
  incorrect - red)

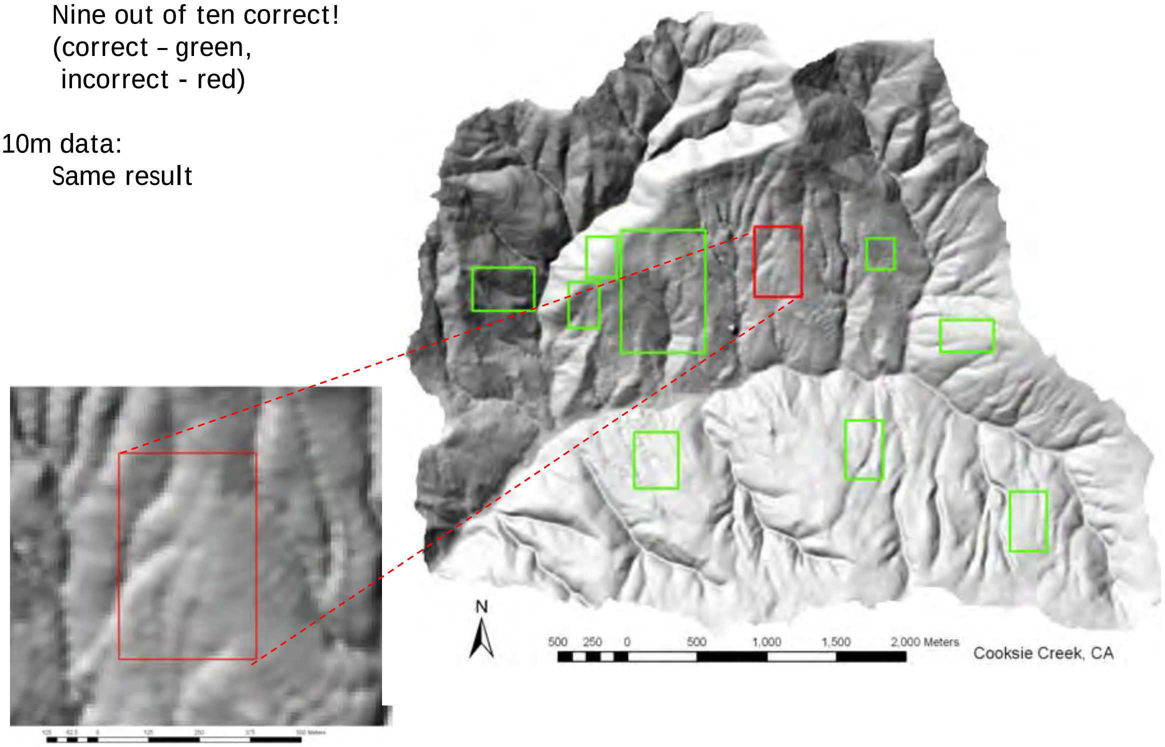
- False positive:
  Not sure who was right …



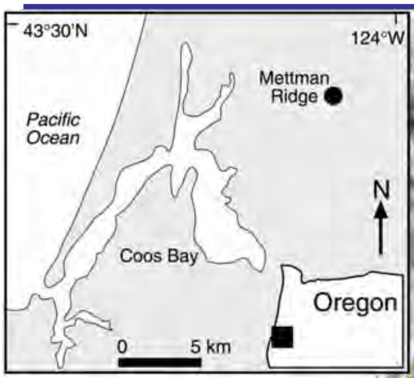
Lib-SVM Results

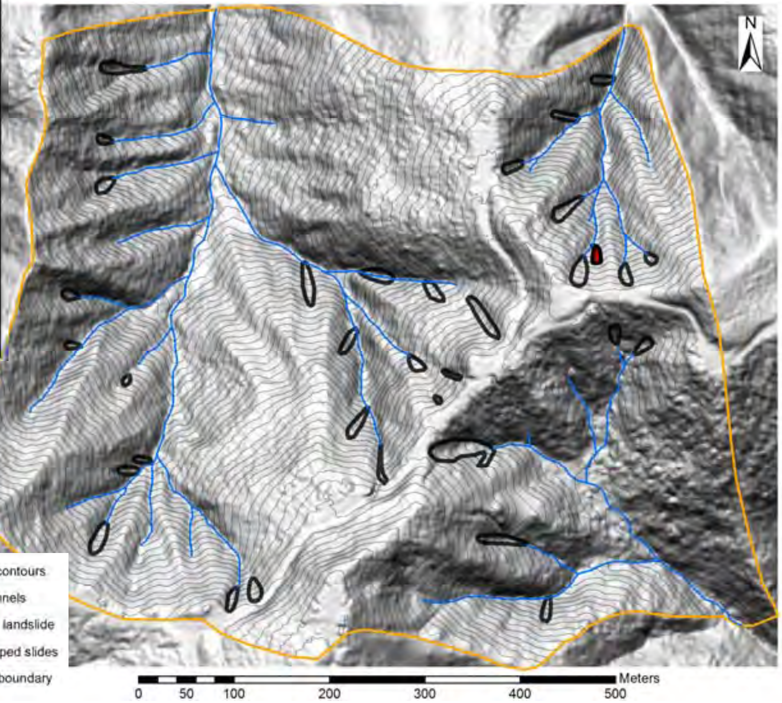
- Much to my surprise:
  Nine out of ten correct!
  (correct – green,
  incorrect - red)

-10m data:
  Same result



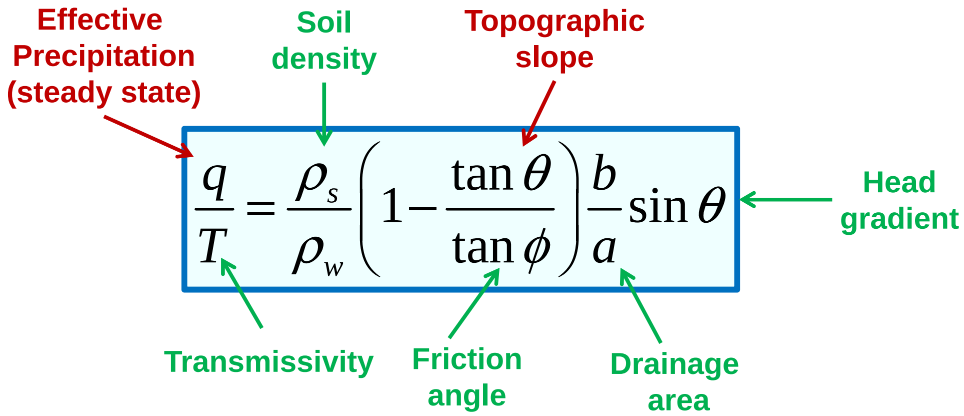
Landslide (shallow) prediction





- **Instrumented:**
  - **Piezometers**
  - **Rain gauges**
  - **Weirs**
- **Sprinkling experiments**
- **LiDAR data**
- **Mapped landslides**

Shalstab: a compact simple model



Effective Precipitation (steady state)

Soil density

Topographic slope

$$\frac{q}{T} = \frac{\rho_s}{\rho_w}\left(1 - \frac{\tan\theta}{\tan\phi}\right)\frac{b}{a}\sin\theta$$

Head gradient

Transmissivity

Friction angle

Drainage area

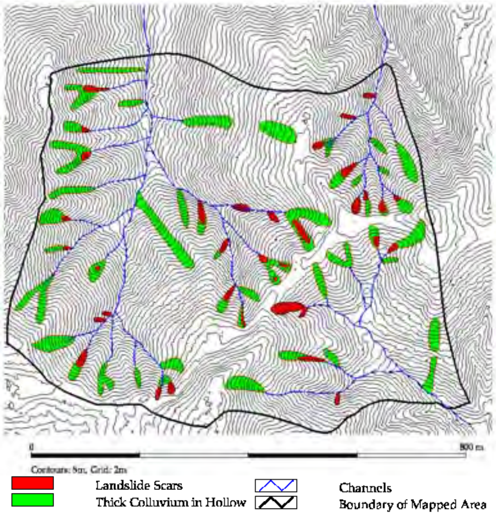
🟩 **: Increasing these values increases stability**

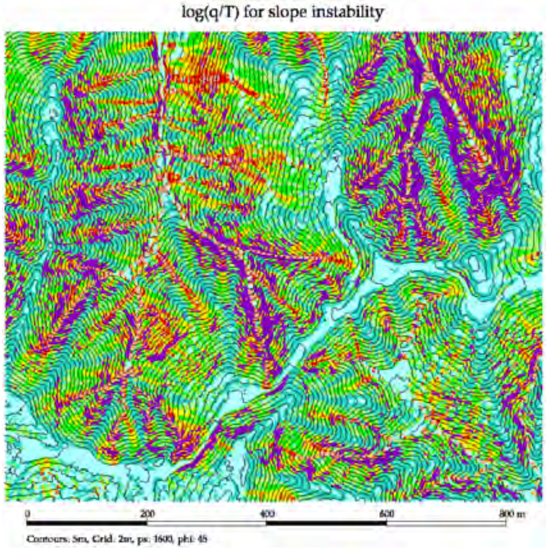
🟥 **: Increasing these values increases instability**

For documentation and software go to:
http://calm.geo.berkeley.edu/~geomorph

[Montgomery and Dietrich, 1994]

Shalstab: Performance (over-prediction)





Parameters:

- $\rho_s/\rho_w = 1.6$
- $\phi = 45°$

log(q/T) (1/m)	🟪	too steep	🟧	-3.1 to -2.8	🟩	-2.2 to -1.9
	🟧	< -3.4	🟨	-2.8 to -2.5	🟦	> -1.9
	🟥	-3.4 to -3.1	🟩	-2.5 to -2.2	🟦	too low grad.

- No soil depth
- No cohesion

[Dietrich and Montgomery, 1998]

Soil depth

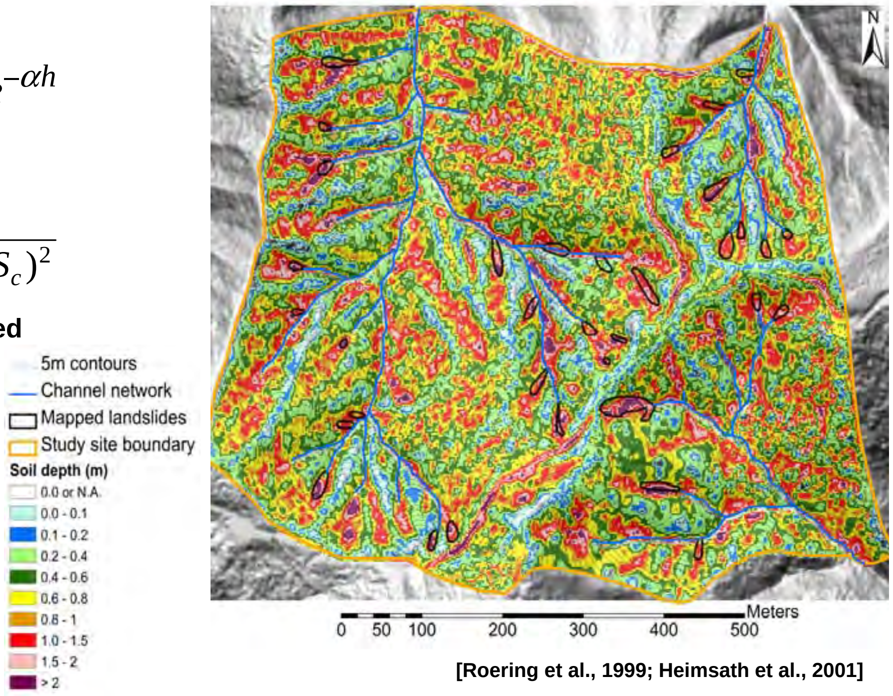
- Soil production:

$$-\frac{\partial z_b}{\partial t} = \varepsilon e^{-\alpha h}$$

- Soil transport:

$$\tilde{q} = \frac{K\nabla z}{1-(|\nabla z|/S_c)^2}$$

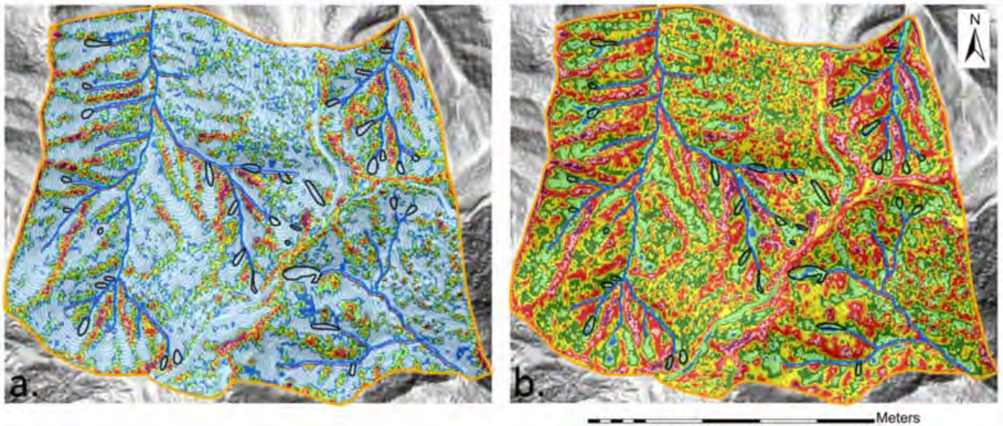
- Regionally calibrated
- No landsliding in this realization!



Observation: landslides in thick soils

[Roering et al., 1999; Heimsath et al., 2001]

Root Strength



a: basal, b: lateral

- **Exponential:** $C_{rz} = C_{r0}e^{-zj}$
- **Total:** $R_{rl} = \int_0^z C_{r0}e^{-zj}\,dz$
- **Lateral:** $C_l = \frac{R_{rl}}{z}$
- **Basal** $C_b = C_{rz}$

From CB-1 data

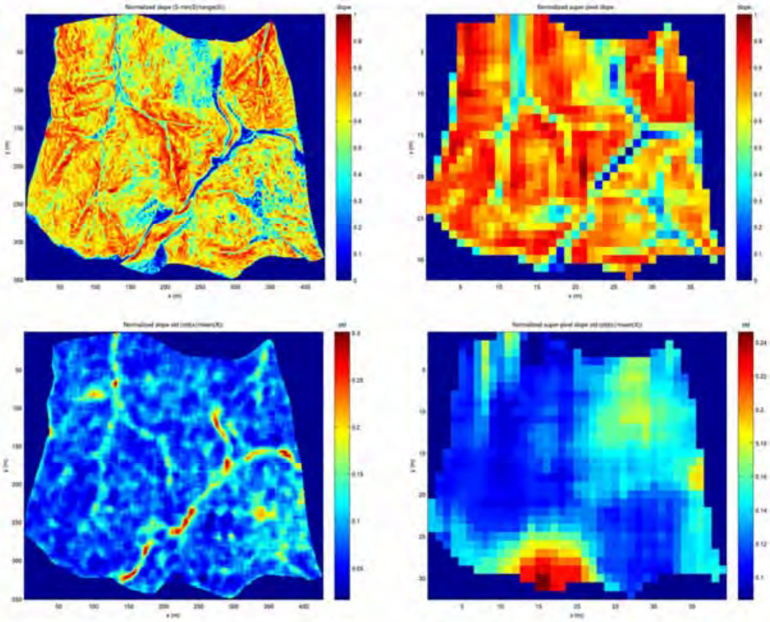
$C_{r0} = 21666\ Pa$
$j = 4.96\ m^{-1}$

Observation: landslides in low root strength

[Benda & Dunne, 1997; Schmidt et al., 1999; Montgomery et al., 2009]

The descriptor

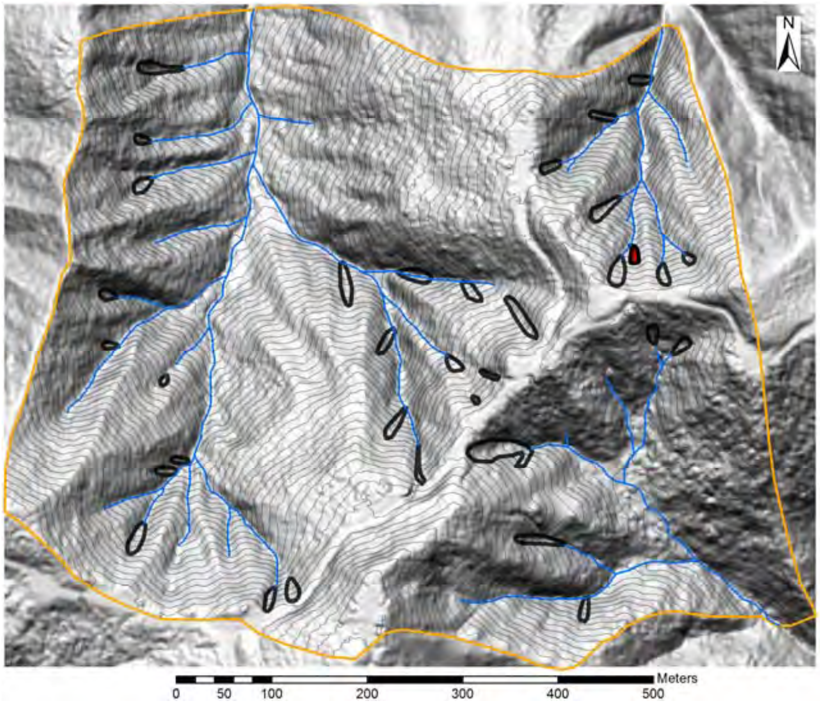
- Topographic attributes:
  - Elevation
  - Slope
  - Curvature
  - Drainage area
  - Soil thickness
  - Orientations
- Regional attributes:
  - Vegetation
  - Lithology
  - Landuse
- Textural properties:
  - Local MAD
  - Local Entropy
  - Local Range
- Multiple scales
  - Spatial pyramid



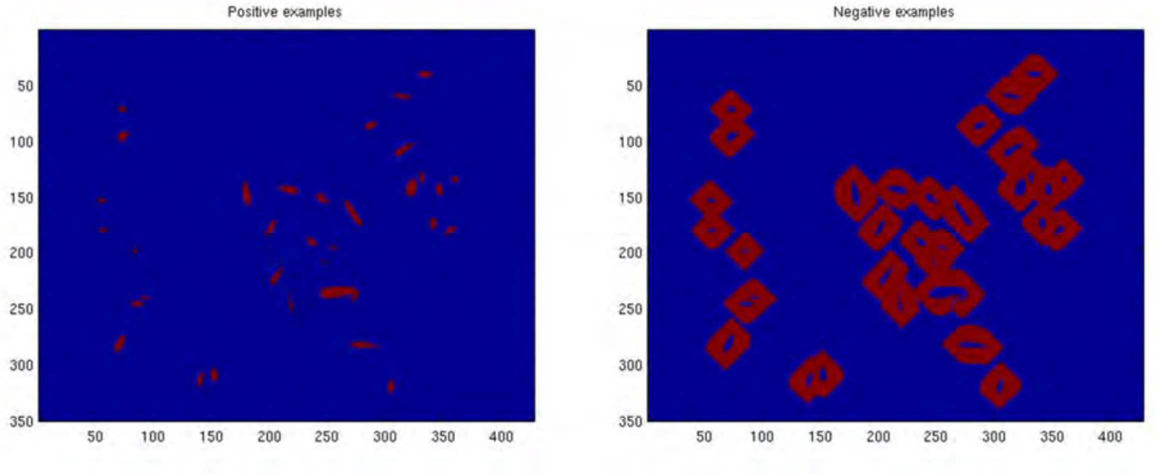
~ 100 dimensions

Example: slope and std(slope)
at the fine and coarse scales

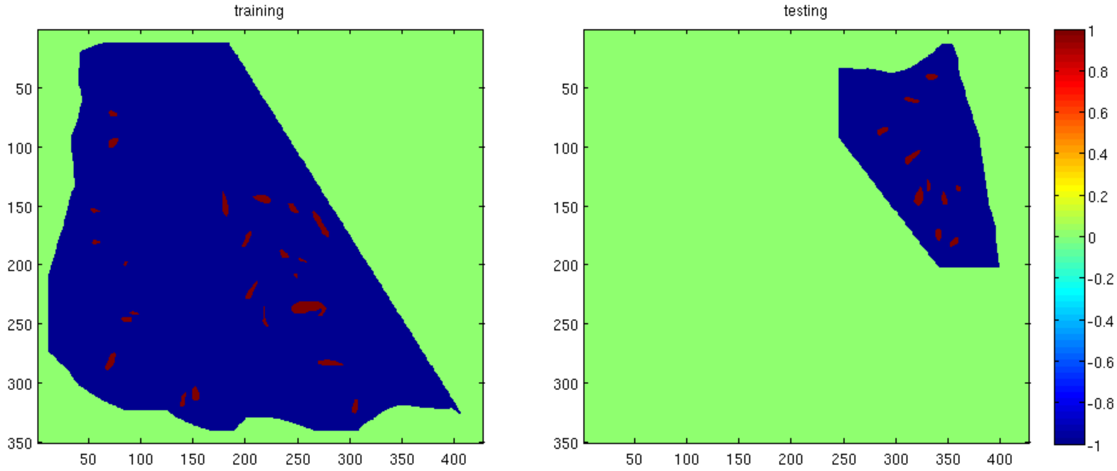
True positives and true negatives?



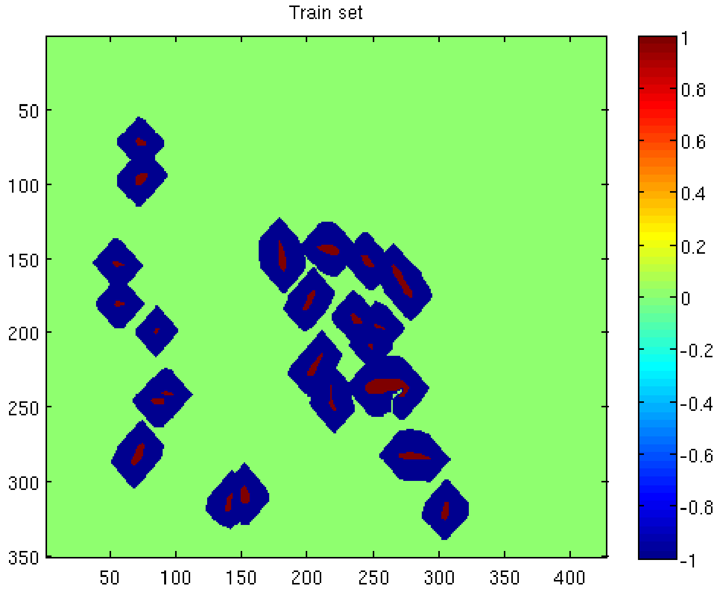
True positives and true negatives?



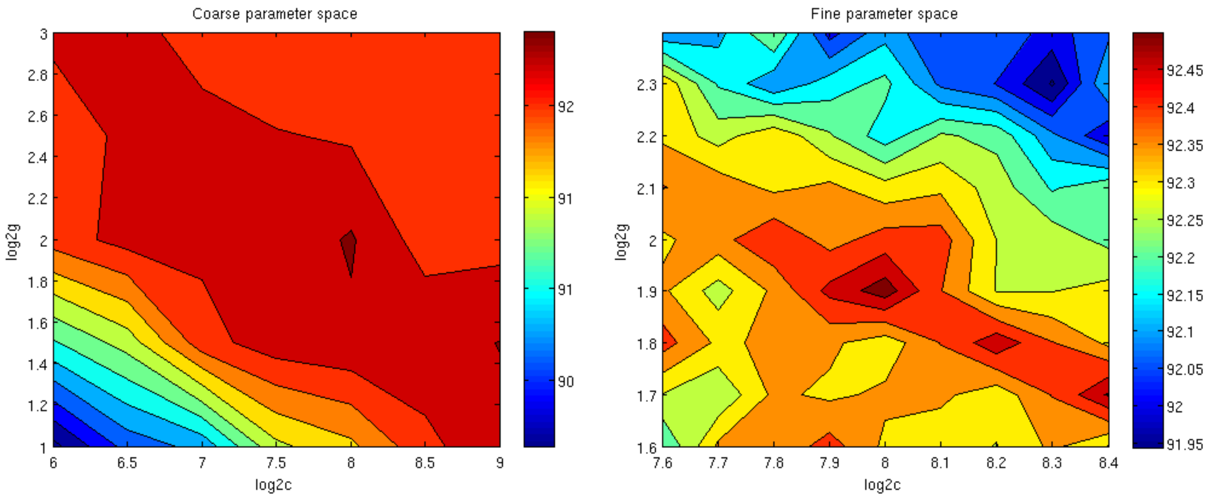
Training and testing



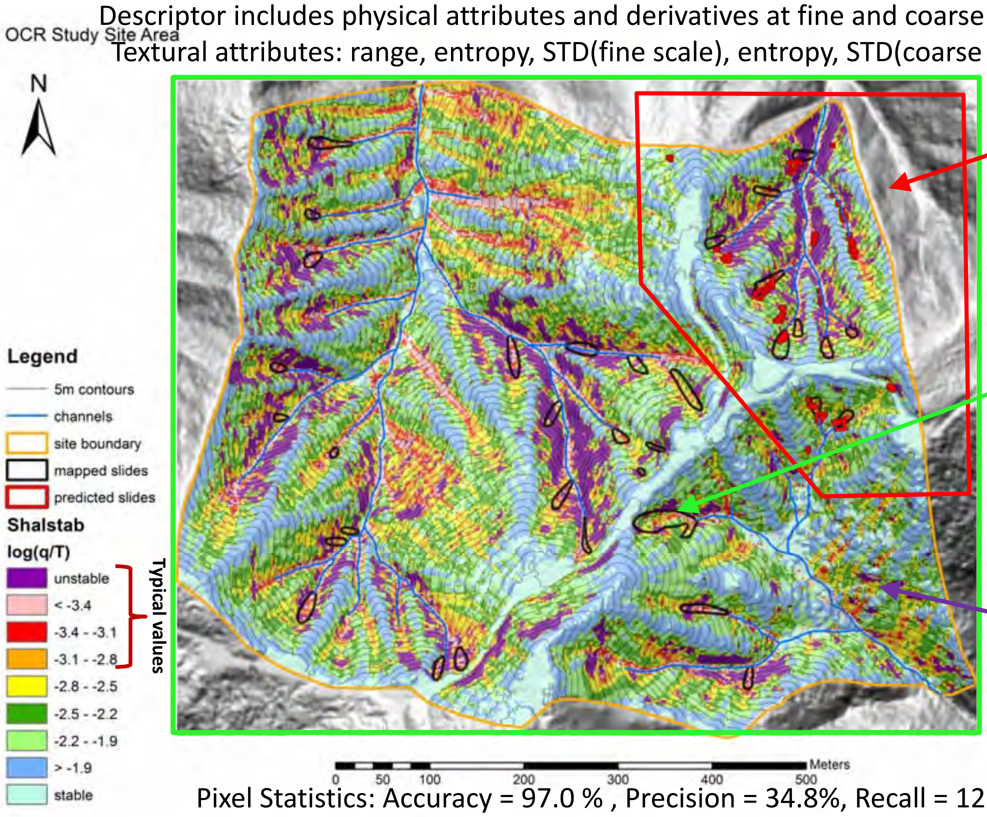
Training and testing



Parameter search (radial basis function)



Descriptor includes physical attributes and derivatives at fine and coarse scales.
Textural attributes: range, entropy, STD(fine scale), entropy, STD(coarse scale)



Test area:
all data pixels
in red polygon
(not seen in
training phase)

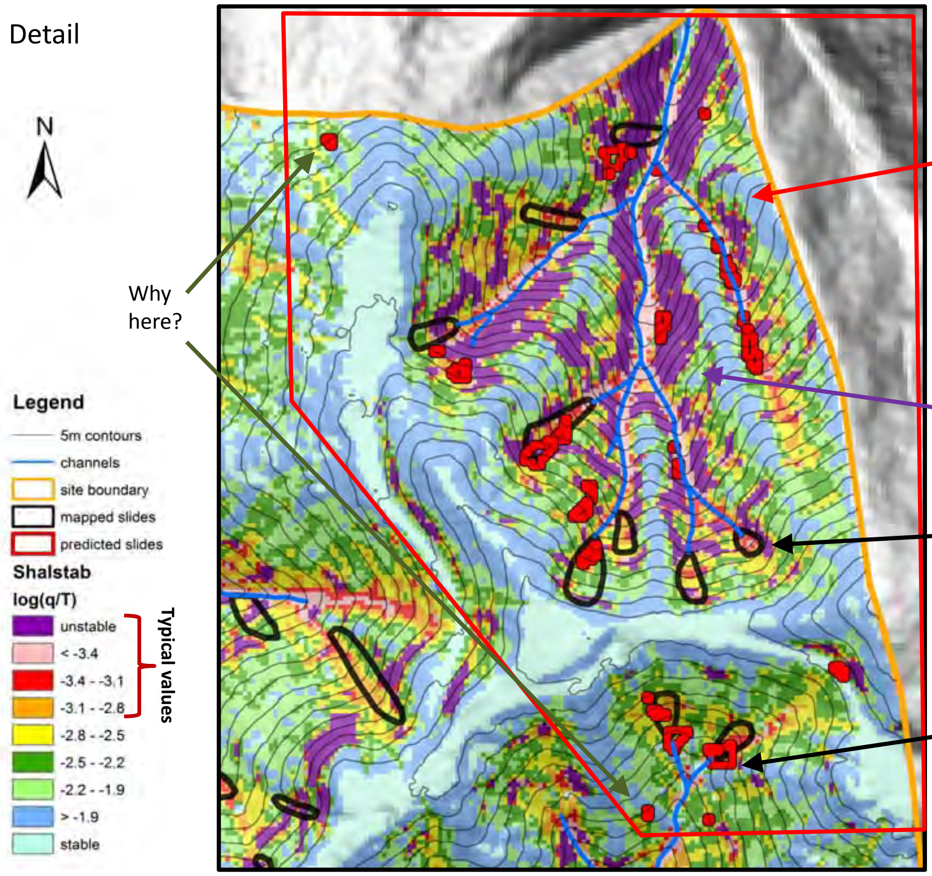
Training area:
(+) all pixels inside
mapped slides
(not in test area),
and (-) a **4-pixel**
buffer around them

Smoothing:
None

Background:
Shalstab draped
on shaded relief

Pixel Statistics: Accuracy = 97.0 % , Precision = 34.8%, Recall = 12.9%,
F-Score: 18.9%, True Positive Rate = 12.9%, False Positive Rate = 0.7%

Detail



Why
here?

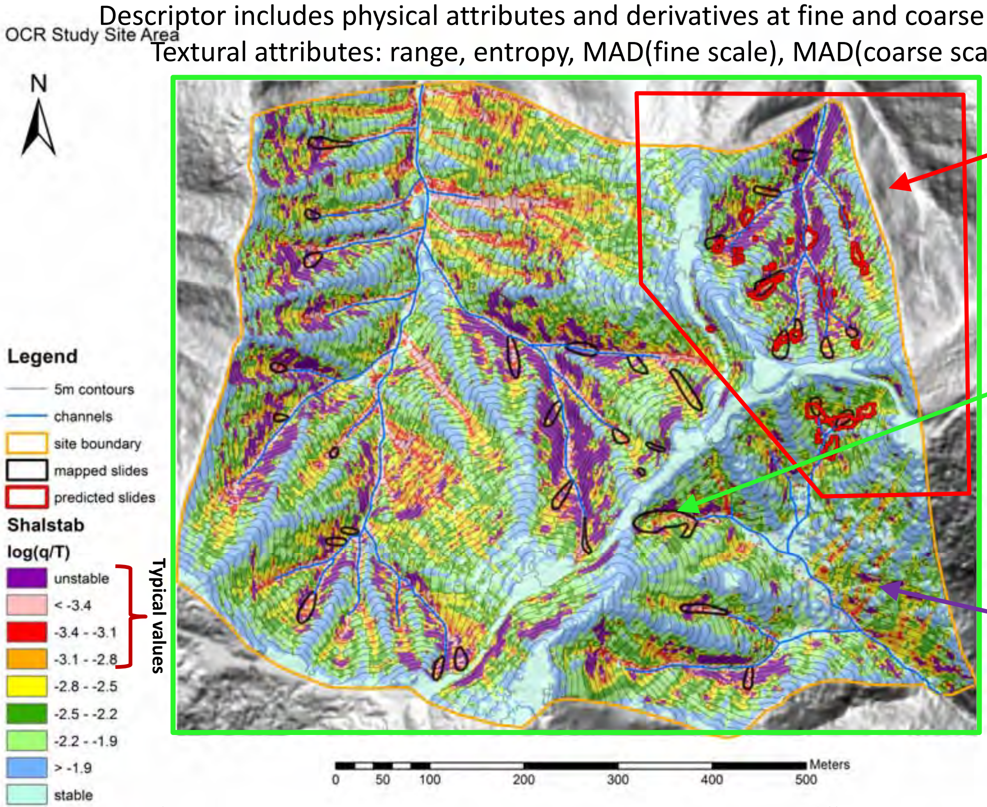
Test area:
All data pixels
In red polygon
(not seen in
training phase)

Background:
Shalstab draped
on shaded relief

Actual
landslides

Predicted
landslides

Descriptor includes physical attributes and derivatives at fine and coarse scales.
Textural attributes: range, entropy, MAD(fine scale), MAD(coarse scale)



Test area:
all data pixels
in red polygon
(not seen in
training phase)

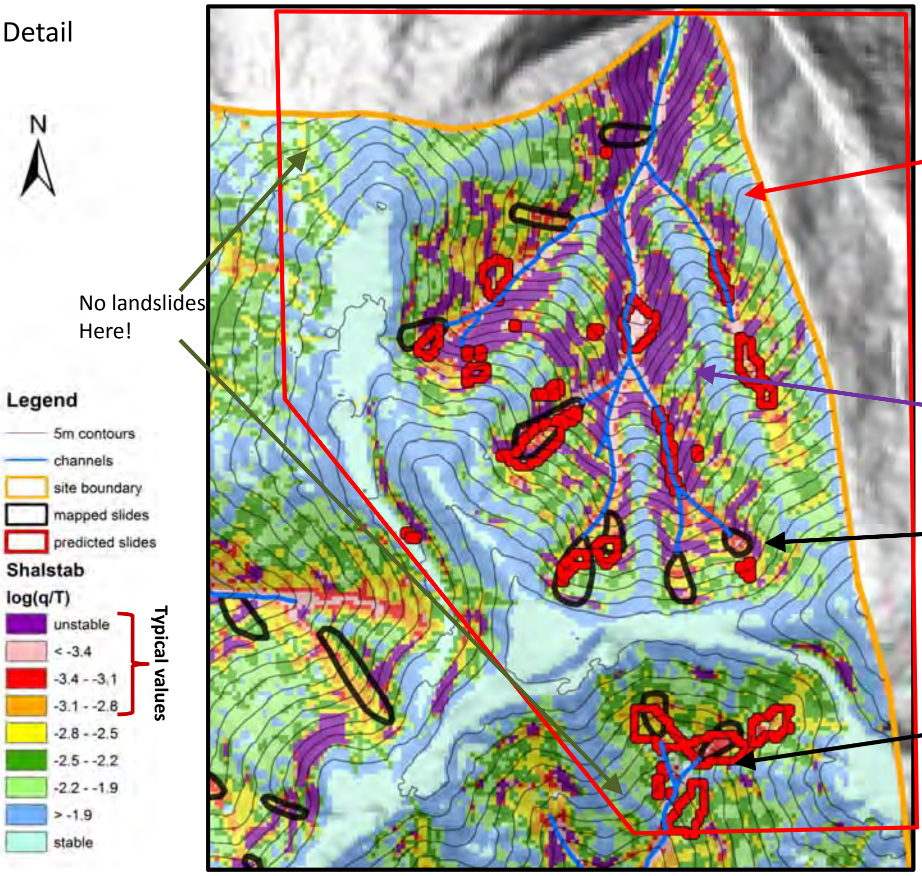
Training area:
(+) all pixels inside
mapped slides
(not in test area),
and (-) a **4-pixel**
buffer around them

Smoothing:
5-pixel Gaussian

Background:
Shalstab (relative
potential for
instability) draped
on shaded relief

Pixel Statistics: Accuracy = 95.8 % , Precision = 28.8%, Recall = 35.2%,
F-Score: 31.7%, True Positive Rate = 35.2%, False Positive Rate = 2.4%

Detail



No landslides
Here!

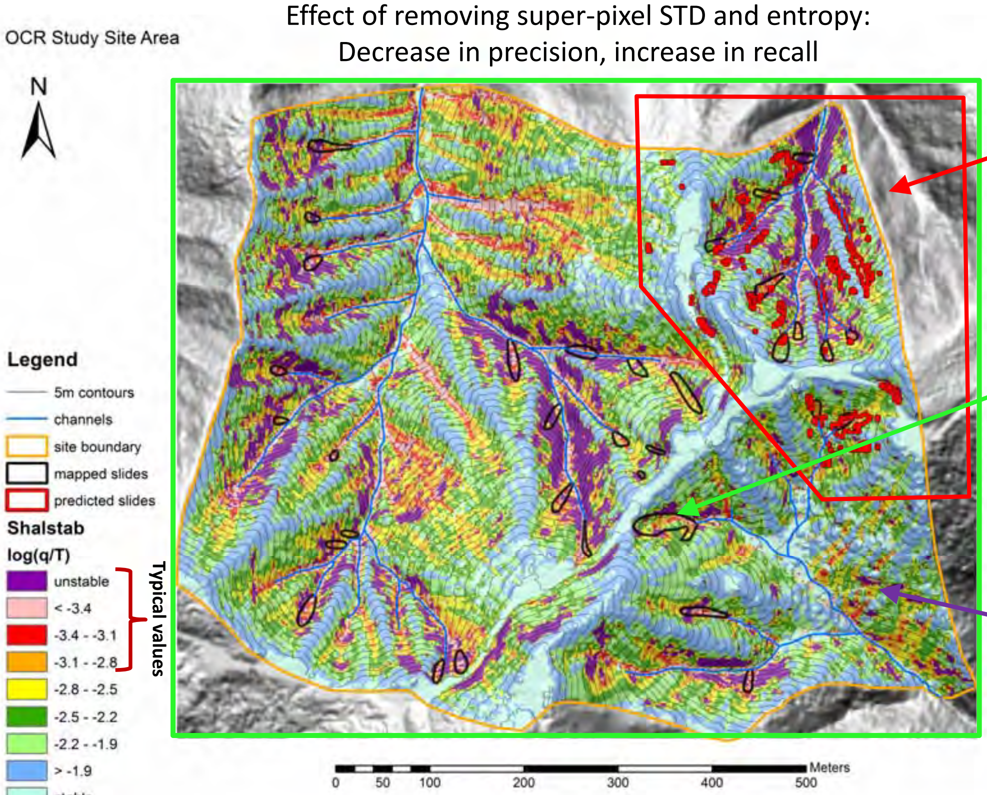
Test area:
All data pixels
In red polygon
(not seen in
training phase)

Background:
Shalstab draped
on shaded relief

Actual
landslides

Predicted
landslides

Effect of removing super-pixel STD and entropy: Decrease in precision, increase in recall



Test area:
all data pixels
in red polygon
(not seen in
training phase)

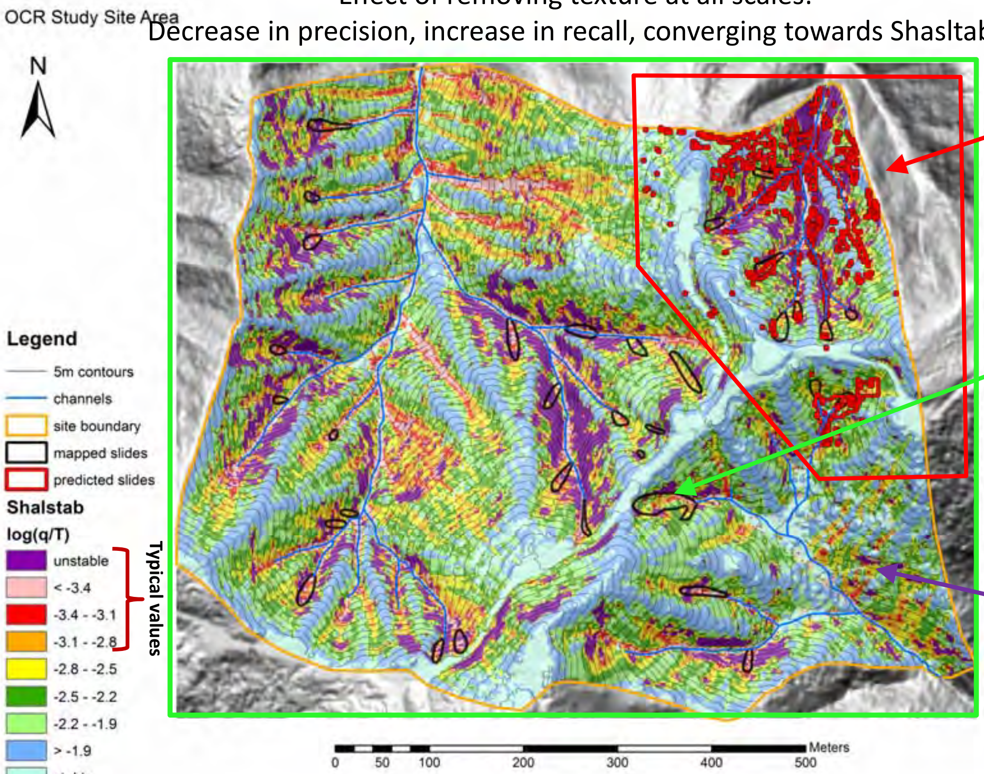
Training area:
(+) all pixels inside
mapped slides
(not in test area),
and (-) a **4-pixel**
buffer around them

Smoothing:
None

Background:
Shalstab draped
on shaded relief

Pixel Statistics: Accuracy = 94.2 % , Precision = 10.8%, Recall = 15.4%,
F-Score: 12.7%, True Positive Rate = 15.4%, False Positive Rate = 3.5%

Effect of removing texture at all scales: Decrease in precision, increase in recall, converging towards Shasltab!



Test area:
all data pixels
in red polygon
(not seen in
training phase)

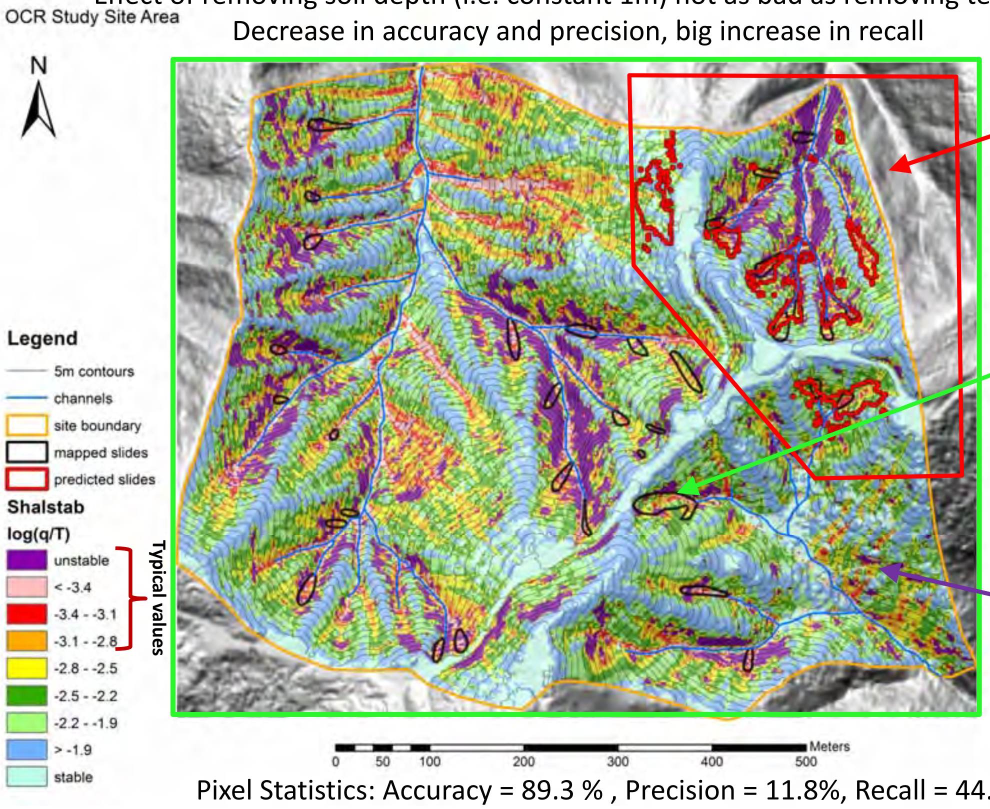
Training area:
(+) all pixels inside
mapped slides
(not in test area),
and (-) a **4-pixel**
buffer around them

Smoothing:
None

Background:
Shalstab draped
on shaded relief

Pixel Statistics: Accuracy = 90.0 % , Precision = 8.1%, Recall = 25.7%,
F-Score: 12.3%, True Positive Rate = 25.7%, False Positive Rate = 8.2%

Effect of removing soil depth (i.e. constant 1m) not as bad as removing texture: Decrease in accuracy and precision, big increase in recall



Test area:
all data pixels
in red polygon
(not seen in
training phase)

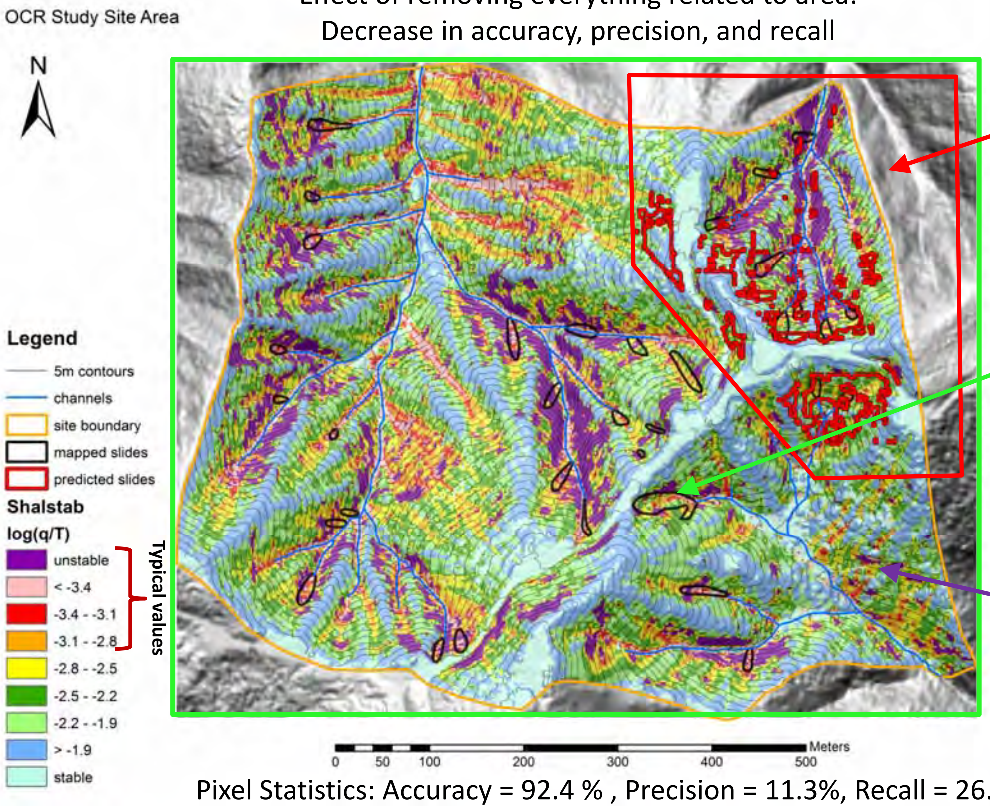
Training area:
(+) all pixels inside
mapped slides
(not in test area),
and (-) a **4-pixel**
buffer around them

Smoothing:
5-pixel Gaussian
Morphing:
Majority

Background:
Shalstab draped
on shaded relief

Pixel Statistics: Accuracy = 89.3 % , Precision = 11.8%, Recall = 44.6%,
F-Score: 18.6%, True Positive Rate = 44.6%, False Positive Rate = 9.4%

Effect of removing everything related to area: Decrease in accuracy, precision, and recall



Test area:
all data pixels
in red polygon
(not seen in
training phase)

Training area:
(+) all pixels inside
mapped slides
(not in test area),
and (-) a **4-pixel**
buffer around them

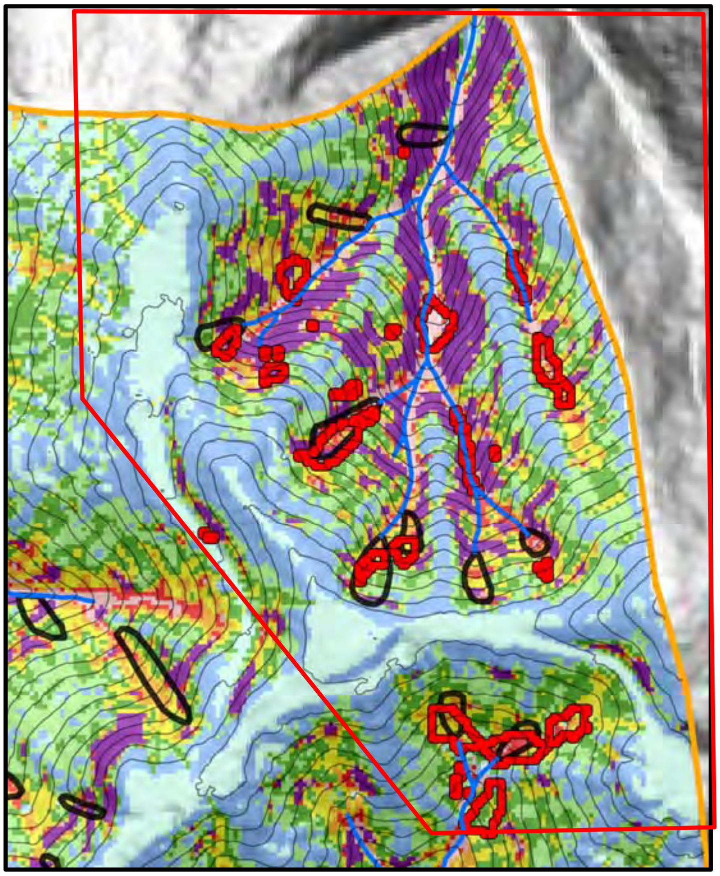
Smoothing:
5-pixel Gaussian
Morphing:
Majority

Background:
Shalstab draped
on shaded relief

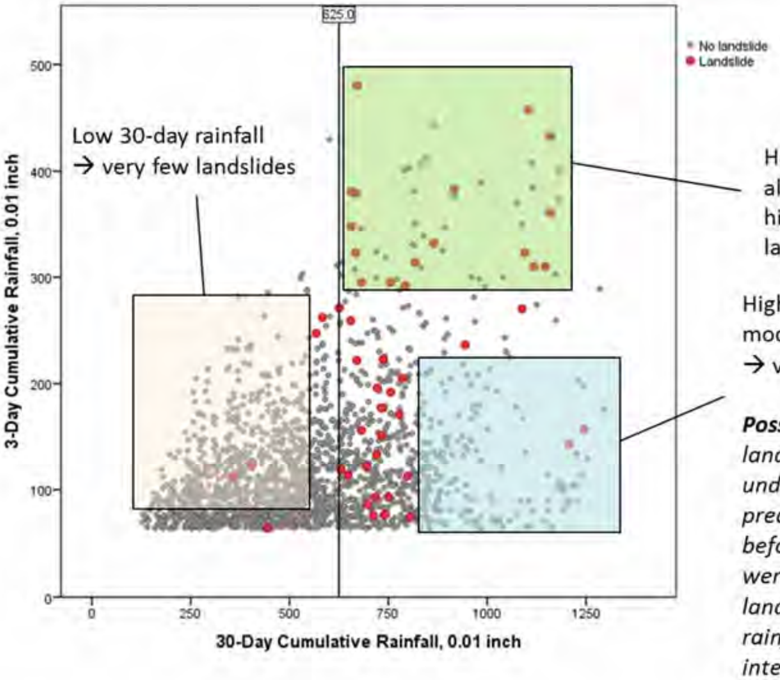
Pixel Statistics: Accuracy = 92.4 % , Precision = 11.3%, Recall = 26.1%,
F-Score: 15.8%, True Positive Rate = 26.1%, False Positive Rate = 13.7%

Results are encouraging:

- Implicitly figured out a Shalstab-like rule
- Reduced over-prediction
- Couple physical and empirical models?
- Need landslide databases with long term observations!
- Can we apply to the temporal domain?



Application to storms: Seattle landslides



Low 30-day rainfall → very few landslides

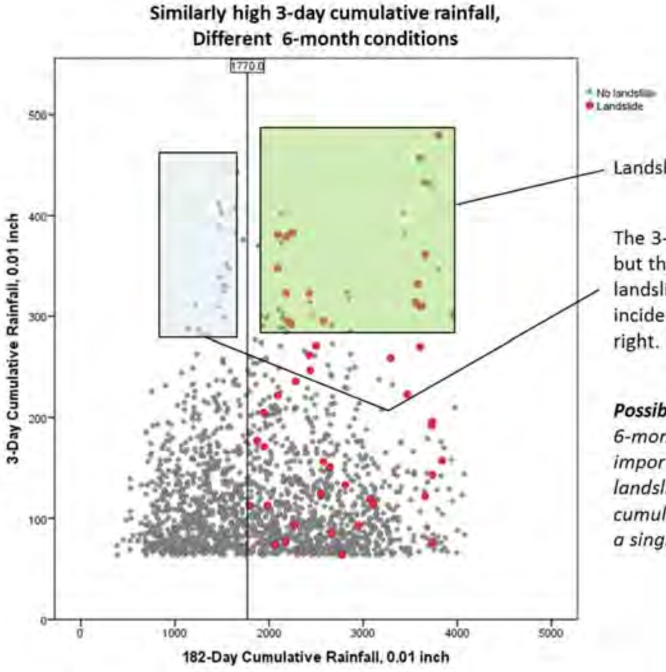
Heavy short-term rainfall + already saturated soil → high probability of landslides

High 30-day rainfall with moderate 3-day precipitation → very few landslides

Possible explanation:
landslides which could fail under moderate precipitations failed well before cumulative maxima were reached. Additional landslides can fail only if rainfall becomes more intense

[Markuzon et al. 2012]

Application to storms: Seattle landslides



Landslide incidence is high

The 3-day precipitation is high, but there are no observed landslides. Compare the incidence to the blue box on the right. No landslides observed

Possible explanation:
6-month cumulative rainfall is an important factor in triggering landslides even in a high 3-day cumulative rainfall conditions → a single big storm isn't enough?

[Markuzon et al. 2012]

Summary

- Data-driven approaches are easy to implement given good training data
- They can be used to identify geomorphological features in a landscape
- Such methods also have good predictive potential
- Coupling mechanistic and empirical slope stability models can help reduce over-prediction
- Similar approach can be used to improve the prediction of landslide-triggering storms

We need large, detailed, accurate, and long-term landslide datasets!

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Postdoctoral Scholar
Perron Surface Processes Group
O'Gorman Atmospheric and Hydrological Processes Group
Department of Earth, Atmospheric and Planetary Sciences

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Email: dinob@mit.edu
http://eapsweb.mit.edu/people/dinob

TEACHING EVALUATIONS

The following pages contain student teaching evaluations two courses at the University of California, Berkeley:

- Instructor, Spring 2011, EPS209 "Matlab Applications in Earth Science". New graduate course offering a practical toolbox for analyzing Earth science data, and to explore selected problems in earth and environmental sciences, with particular focus on image processing and machine learning techniques. Responsible for curriculum, lectures, and labs development, grades, and office hours. Co-developed and co-taught with Prof. Burkhard Militzer.

- Graduate Student Instructor, Fall 2009, EPS50 "The Planet Earth". Instructors: Prof. Michael Manga and Prof. Doug Dreger. Undergraduate introductory course on geology and geophysics. Gave lectures, guided labs and field trips, advised students, graded assignments, and held office hours.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Sprg 2011

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	5	( )
14. provides useful feedback on exams and assignments	1	2	3	4	5	( )
15. seems to enjoy teaching	1	2	3	4	5	( )
16. is available to students outside of class	1	2	3	4	5	( )
17. is enthusiastic about the subject	1	2	3	4	5	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	5
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** 209 EPS **Semester/Year:** Spring 2011

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	5	(✓)
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5] very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Again, I just wish the labs & HW were:

a) less complex & shorter

b) Offer the class for optional 3 units and have a lab every week to get through the material.

* Im maybe a different case b/c I have no programming skills.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Spring/2011

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	[✓ 4]	5	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	[✓ 4]	5
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

It's really cool, just sometimes the homework assignments are not very clear so I need to read a couple times to understand. I really like the class.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Sp 11

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	[✓ 4]	5	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	[✓ 3]	4	5	( )
9. presents clear summaries or reviews of the material covered	1	2	[✓ 3]	4	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	[✓ 1]	2	3	4	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	[✓ 4]	5 very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** 209 **Semester/Year:** Spr 2011

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	[✓ 3]	4	5	( )
9. presents clear summaries or reviews of the material covered	1	2	[✓ 3]	4	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	[✓ 3]	4	5	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

thanks for the hard work Dino!

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: ____________ **Course/Section:** ____________ **Semester/Year:** ________

Please circle the number that indicates the degree to which these statements describe your GSI.

	In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1.	appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2.	is well prepared	1	2	3	4	[✓ 5]	( )
3.	uses class time effectively	1	2	3	[✓ 4]	5	( )
4.	explains new material clearly	1	2	3	4	[✓ 5]	( )
5.	has clear objectives for each class session	1	2	3	[✓ 4]	5	( )
6.	is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7.	raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	[✓ 5]	( )
8.	knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9.	presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10.	makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11.	is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12.	helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Very good class

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Spr '11

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive			very descriptive		n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	[✓ 4]	5	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	[✓ 3]	4	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi Course/Section: EPS 207 Semester/Year: S11

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	5	[✓ ( )]
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Fantastic class! I really appreciate all of the hard work that you put in.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: DINO BELLUGI **Course/Section:** EPS 209 **Semester/Year:** SPR 11

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know	
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )	
2. is well prepared	1	2	3	4	[✓ 5]	( )	
3. uses class time effectively	1	2	3	4	[✓ 5]	( )	← !!!
4. explains new material clearly	1	2	3	4	[✓ 5]	( )	
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )	
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )	
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )	
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )	
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )	
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )	← !!!
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )	
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )	

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	5	[✓ ( )]
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5 very effective]

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DINO IS A VERY TALENTED EDUCATOR. HIS LECTURES AND LABS WERE VERY EFFECTIVE AND WILL SERVE AS THOROUGH RESOURCES FOR MY RESEARCH IN THE FUTURE. DINO IS VERY APPROACHABLE AND EXTREMELY KNOWLEDGABLE ABOUT THE SUBJECT.

I WOULD DEFINITELY TAKE A CLASS FROM DINO AGAIN.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Bino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Sp 2011

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	[✓ 3]	4	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	[✓ 1]	2	3	4	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Evaluate and return the homework!

We got 0 Feedback during the whole class!

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Sp 209

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Great job on lectures

Quality of HW and lab is outstanding.

Really cares about teaching

Excited about subject

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Spring 2011

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	5	[✓ ( )]
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** 209 **Semester/Year:** Spring 2011

Please circle the number that indicates the degree to which these statements describe your GSI.

	In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1.	appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2.	is well prepared	1	2	3	4	[✓ 5]	( )
3.	uses class time effectively	1	2	3	4	[✓ 5]	( )
4.	explains new material clearly	1	2	3	4	[✓ 5]	( )
5.	has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6.	is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7.	raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8.	knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9.	presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10.	makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11.	is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12.	helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5] very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Best GSI ever.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 203 **Semester/Year:** Spring 11

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Dino has been a great GSI and clearly put a lot of effort into making this class both useful & interesting. I can't really think of any things that might need to be improved on his part.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** EPS 209 **Semester/Year:** Spring/2011

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— *Continued on reverse* —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5] very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

I know it is hard to achieve in "2 unit" class, but it will be much nicer if you could explain more about theory behind image segmentation.

In addition, solution m-files for both lab and homework will be necessary to develop more efficient coding skill.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Course/Section: EPS 50 Semester/Year: Fall 09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	3	[✓ 4]	5	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	[✓ 4]	5	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	3	4	5	[✓ ( )]
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	[✓ 4]	5	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Office hours were very useful. Dino was always willing to help explain things when I didn't understand.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** 50 **Semester/Year:** Fall 2009

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive			very descriptive		n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	[✓ 3]	4	5	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	[✓ 4]	5 very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Course/Section: ______ Semester/Year: Fall 09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	[✓ 4]	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5 very effective]

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Very good, takes time to explain.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: DINO BONUCCI Course/Section: GPS 50 Semester/Year: FALL 2005

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	5	(X)
17. is enthusiastic about the subject	1	2	3	[✓ 4]	5	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5] very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

-DINO IS AWESOME! VERY HELPFUL, ALWAYS UNDERSTANDING,
I FEEL LIKE HE UNDERSTANDS WHAT WE ARE GOING THROUGH.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dave Bellag

Course/Section: EPS 520/Tues. 1-4

Semester/Year: Fall/09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	[✓ 3]	[✓ 4]	5	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	3	[✓ 4]	5	( )
4. explains new material clearly	1	2	[✓ 3]	4	5	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	[✓ 4]	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	[✓ 3]	4	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	[✓ 3]	4	5	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	[✓ 4]	5 very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi Course/Section: 50 Semester/Year: F09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	[✓ 4]	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	[✓ 3]	4	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5 very effective]

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi Course/Section: W 10-1 Semester/Year: F 09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive			very descriptive		n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	4	5	( )
6. is concerned that students learn the material	1	2	3	[✓ 4]	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	[✓ 3]	4	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	[✓ 4]	5
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

Dino is a great GSI, the only minor problem is he occasionally gets mixed up with the subject material, he seems to need to review it a little more before section

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino **Course/Section:** EPS 50 **Semester/Year:** Fall 09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	4	[✓ 5]	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	[✓ 4]	5	( )
6. is concerned that students learn the material	1	2	[✓ 3]	4	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	[✓ 4]	5	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	4	[✓ 5]
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi Course/Section: EPS 050, section 1 Semester/Year: Fall 2009

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	[✓ 4]	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	[✓ 4]	5	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	[✓ 1]	2	3	4	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	[✓ 4]	5
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

no comments,

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Course/Section: EPS 50 Semester/Year: Fall 09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	4	[✓ 5]	( )
5. has clear objectives for each class session	1	2	3	[✓ 4]	5	( )
6. is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	[✓ 3]	4	5	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	[✓ 4]	5	( )
17. is enthusiastic about the subject	1	2	3	[✓ 4]	5	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	3	[✓ 4]	5
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi Course/Section: EPS 50 / 102 Semester/Year: Fall 09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	3	4	[✓ 5]	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	[✓ 4]	5	( )
6. is concerned that students learn the material	1	2	[✓ 3]	4	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	[✓ 3]	4	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	[✓ 4]	5	( )
11. is thoughtful and precise when answering questions	1	2	[✓ 3]	4	5	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	[✓ 4]	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	[✓ 4]	5 very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

I wish he could provide better explanations in reviews before lab. He goes really fast through the review.

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi Course/Section: EPS 50 W-10 Semester/Year: fall '09

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	3	[✓ 4]	5	( )
2. is well prepared	1	2	3	[✓ 4]	5	( )
3. uses class time effectively	1	2	3	[✓ 4]	5	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	[✓ 4]	5	( )
6. is concerned that students learn the material	1	2	3	[✓ 4]	5	( )
7. raises challenging questions or reviews of the material covered	1	2	[✓ 3]	4	5	( )
8. knows if the class is understanding him/her	1	2	3	[✓ 4]	5	( )
9. presents clear summaries or reviews of the material covered	1	2	3	[✓ 4]	5	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	[✓ 4]	5	( )
12. helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	[✓ 3]	4	5	( )
15. seems to enjoy teaching	1	2	3	[✓ 4]	5	( )
16. is available to students outside of class	1	2	3	[✓ 4]	5	( )
17. is enthusiastic about the subject	1	2	3	[✓ 4]	5	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1	2	[✓ 3]	4	5
not effective at all		moderately effective		very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi Course/Section: 1 Semester/Year: Fall 2009

Please circle the number that indicates the degree to which these statements describe your GSI.

In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1. appears to have a good knowledge of the subject	1	2	[✓ 3]	4	5	( )
2. is well prepared	1	2	[✓ 3]	4	5	( )
3. uses class time effectively	1	2	[✓ 3]	4	5	( )
4. explains new material clearly	1	2	3	[✓ 4]	5	( )
5. has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6. is concerned that students learn the material	1	2	3	[✓ 4]	5	( )
7. raises challenging questions or reviews of the material covered	1	2	3	[✓ 4]	5	( )
8. knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9. presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10. makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11. is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12. helps clarify points not understood in lecture	1	2	3	[✓ 4]	5	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	[✓ 4]	5	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject very!	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	[✓ 4]	5 very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).

I think Dino is sometimes ~~confused by~~ not sure of the course material, especially the rocks and minerals section

DEPARTMENT OF EARTH AND PLANETARY SCIENCE

GRADUATE STUDENT INSTRUCTOR EVALUATION

GSI: Dino Bellugi **Course/Section:** ERS 50 [illegible] **Semester/Year:** Fall 09

Please circle the number that indicates the degree to which these statements describe your GSI.

	In general, your GSI:	not at all descriptive				very descriptive	n.a./ don't know
1.	appears to have a good knowledge of the subject	1	2	3	4	[✓ 5]	( )
2.	is well prepared	1	2	3	4	[✓ 5]	( )
3.	uses class time effectively	1	2	3	4	[✓ 5]	( )
4.	explains new material clearly	1	2	3	4	[✓ 5]	( )
5.	has clear objectives for each class session	1	2	3	4	[✓ 5]	( )
6.	is concerned that students learn the material	1	2	3	4	[✓ 5]	( )
7.	raises challenging questions or reviews of the material covered	1	2	3	4	[✓ 5]	( )
8.	knows if the class is understanding him/her	1	2	3	4	[✓ 5]	( )
9.	presents clear summaries or reviews of the material covered	1	2	3	4	[✓ 5]	( )
10.	makes you feel comfortable about asking questions or expressing ideas	1	2	3	4	[✓ 5]	( )
11.	is thoughtful and precise when answering questions	1	2	3	4	[✓ 5]	( )
12.	helps clarify points not understood in lecture	1	2	3	4	[✓ 5]	( )

— Continued on reverse —

GRADUATE STUDENT INSTRUCTOR EVALUATION, Continued

13. is helpful and supportive when you are having difficulty	1	2	3	4	[✓ 5]	( )
14. provides useful feedback on exams and assignments	1	2	3	4	[✓ 5]	( )
15. seems to enjoy teaching	1	2	3	4	[✓ 5]	( )
16. is available to students outside of class	1	2	3	4	[✓ 5]	( )
17. is enthusiastic about the subject	1	2	3	4	[✓ 5]	( )

Considering both the limitations and the possibilities of the subject matter and the course, how would you rate the overall teaching effectiveness of this graduate student instructor?

1 not effective at all	2	3 moderately effective	4	[✓ 5] very effective

What comments or suggestions do you have regarding the teaching effectiveness of this GSI? (Please feel free to use the other side of this page if you need to).