Nonvolcanic Tremor in Denali Surface Waves at Broadband Stations in Northern California: Instrumental Causes?

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Abstract: The surface waves from the Denali earthquake (03 Nov 2002) are among the largest teleseismic surface wave signals, in counts, to pass across Northern California since high dynamic range, broadband sensors and digitizers were installed at the stations of the BK network. In 2002, data from the broadband sensors were recorded continuously at 20 sps from all sites, and continuously at 80 Hz or 100 Hz at some of those sites. In the data from the BK stations, we find the same evidence of nonvolcanic tremor (NVT) at all sites as was shown for the station PKD by Peng et al (2007). Looking more closely, we find that the surface wave amplitudes are greater than 1e6 counts on all components, while the amplitudes of the "NVT" are between 100 and 1000 counts, and exceed the upper corner of sensitivity to high frequency ground motion of the STS1 sensors (5 Hz or 10 Hz) located at some sites. We investigate a number of possible explanations for the high frequency signals in the seismometers and in the dataloggers. Two potential problems are that large long-period ground motions can cause saturation of the seismometer feedback electronics and they can cause numerical problems in the digital anti-aliasing filters. Either of these conditions could produce signal-generated high-frequency noise within the broadband seismometer/high-resolution digitizer system.

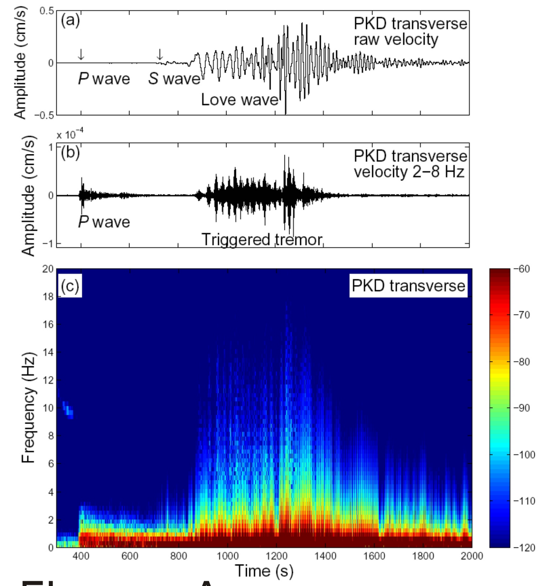


Figure A

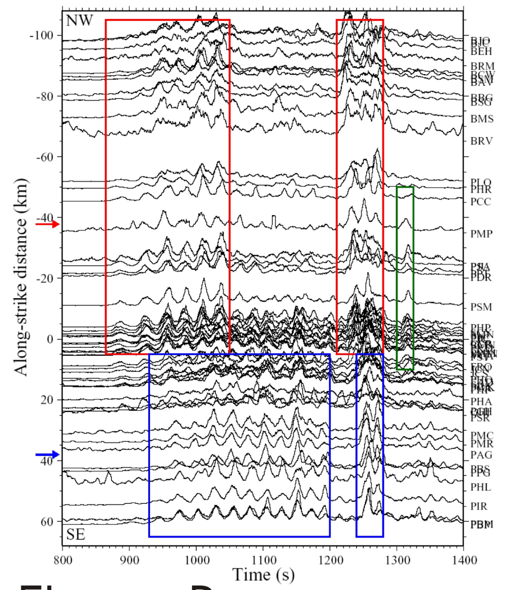


Figure B

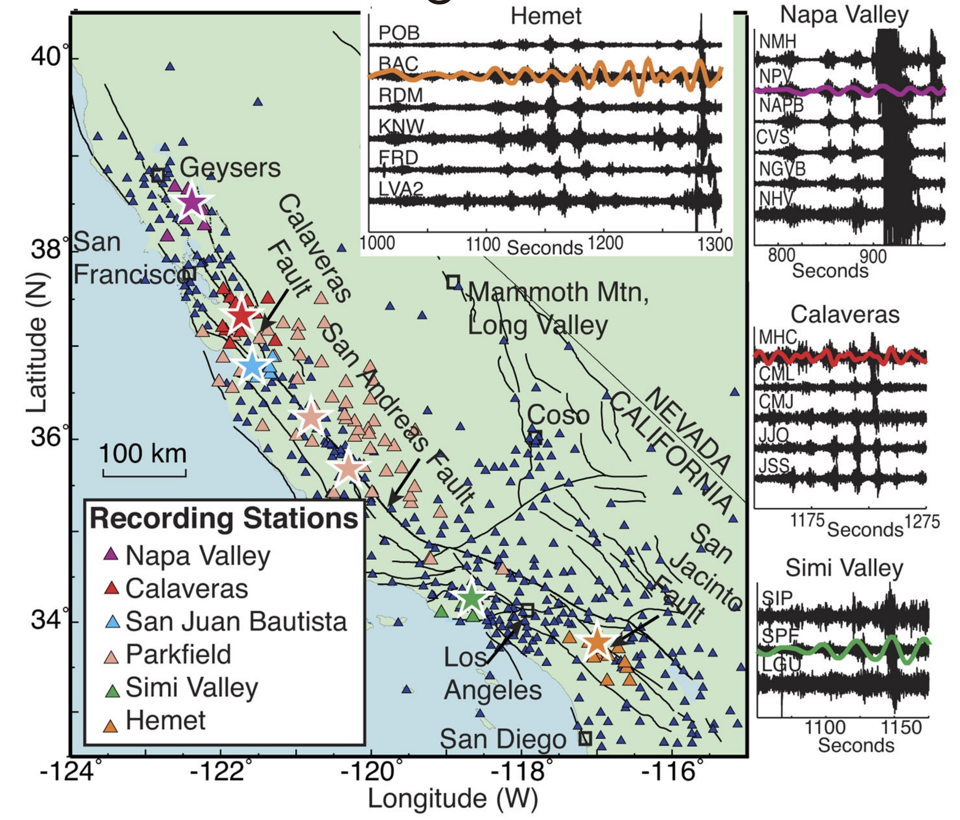
Observations of Nonvolcanic Tremor in California during Surface Waves from the 2002 Denali Earthquake

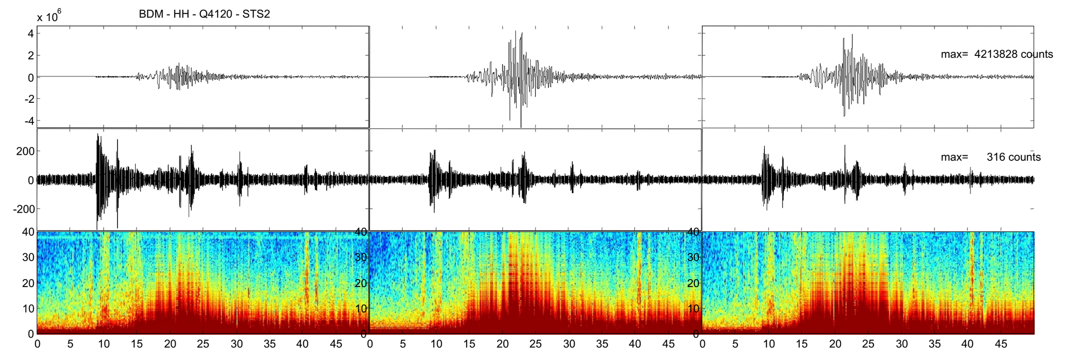
At the 2007 Fall AGU meeting (Peng et al, 2007) and in a ScienceExpress paper (Gomberg et al, 2007) showed observations of nonvolcanic tremor (NVT) in the surface waves of the Denali Earthquake (2002) at a variety of stations in Northern California (see Figures A, B and C).

In particular, the figure showing the NVT at the broadband BK station PKD caught our attention (Figure A). It shows that the absolute velocity amplitude on the transverse component at PKD exceeds 0.5 cm/s, while the amplitude of the associated tremor in the band between 2 and 8 Hz is on the order of $5x10^{-5}$ cm/s. Thus, the tremor amplitude at PKD is $\sim 10^{-4}$ of the amplitude of the surface waves (and in Figure A of the P-waves also).

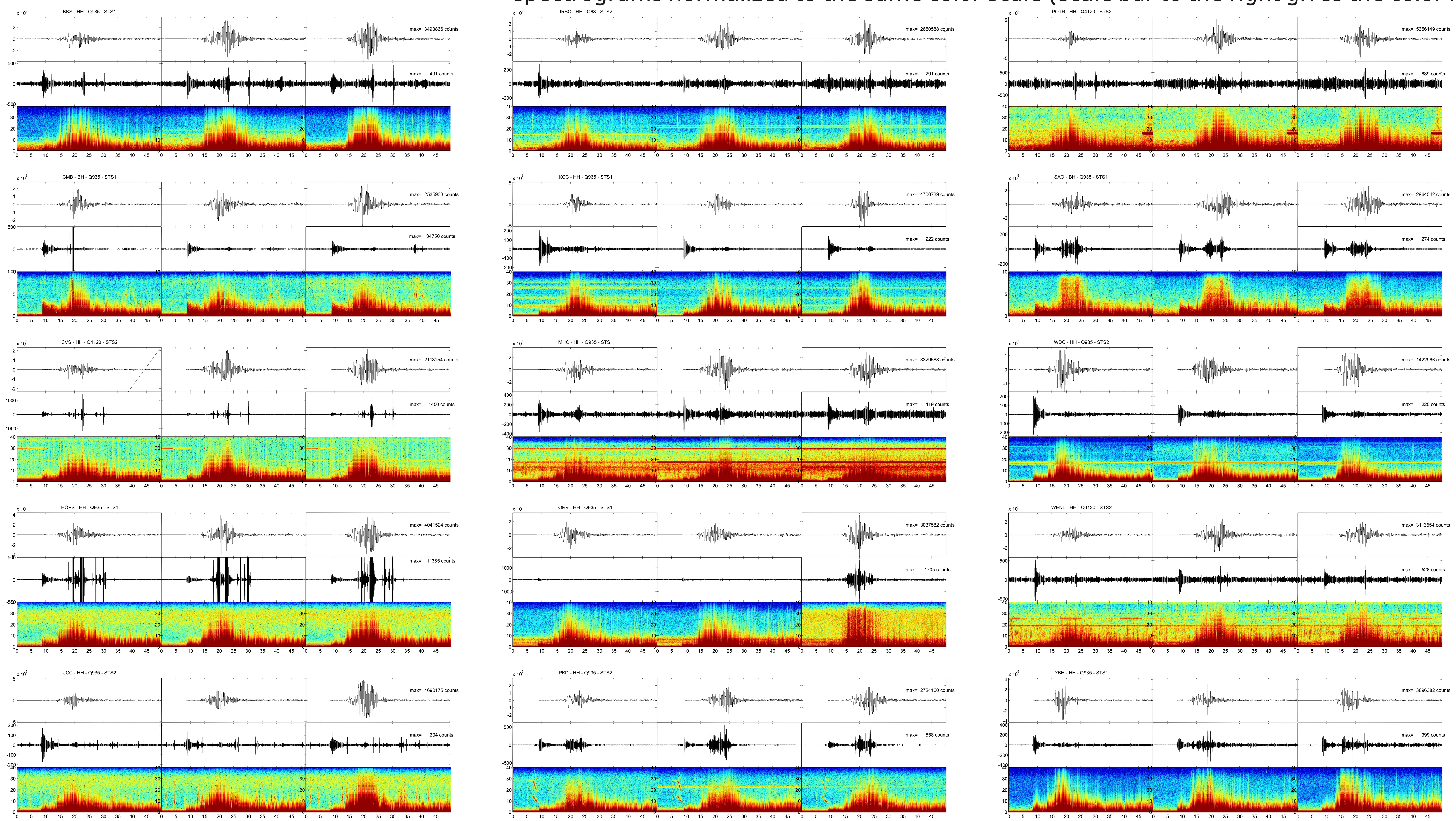
We also found the spectrogram in Figure A disturbing. If the tremor is generated by a "different source" than the surface waves (i.e. NVT), why do the lines in the spectra extend through all frequencies with continuously decreasing amplitude, from the maxima of the surface waves at .015-.05 Hz (corresponding to periods of 60 through 20 s) to the frequencies of the tremor in the band, 2-8 Hz? In our experience, signals from different sources (i.e. wind, microseisms, tremor) generally appear as separated peaks in the spectrum.

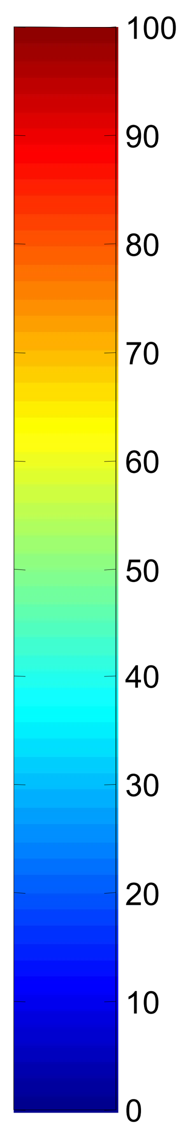
Figure C





These plots show the data from the HH channels of the BK network stations where available. Data from CMB and SAO are from the BH channels, while BRIB and FARB are not shown (clipped). The upper traces are the raw, unprocessed data in counts. Middle traces are bandpass filtered data, also in "counts", and the lower traces show the spectrograms normalized to the same color scale (scale bar to the right gives the color in





Summary

The "tremor" observed on ORV-HHE is clearly anomalous (none on HHZ or HHN. It appears to be due to sensor saturation, which can result in high frequency non-linearity. Similar effects are visible at YBH on the two horizontal components. We continue to research possible causes within the digitzer relating to the behavior of the antialiasing filters and the digital signal processing when the input signals exceed the input range.

While we do not have conclusive evidence that the "tremor" observed at the broadband stations of the BK network have instrumental cause, we have no firm evidence that it has its source outside the instruments.