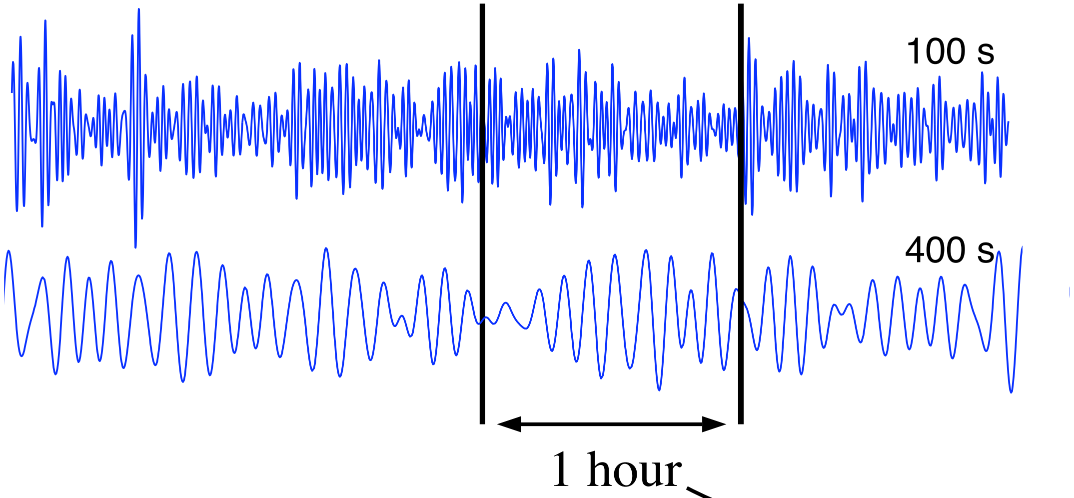
5. Data quality control using noise

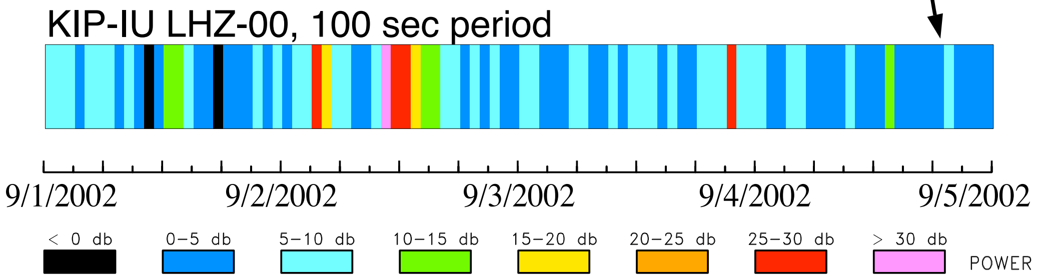
6. Finding interesting things in the noise

Calculation of signal power of long-period GSN data

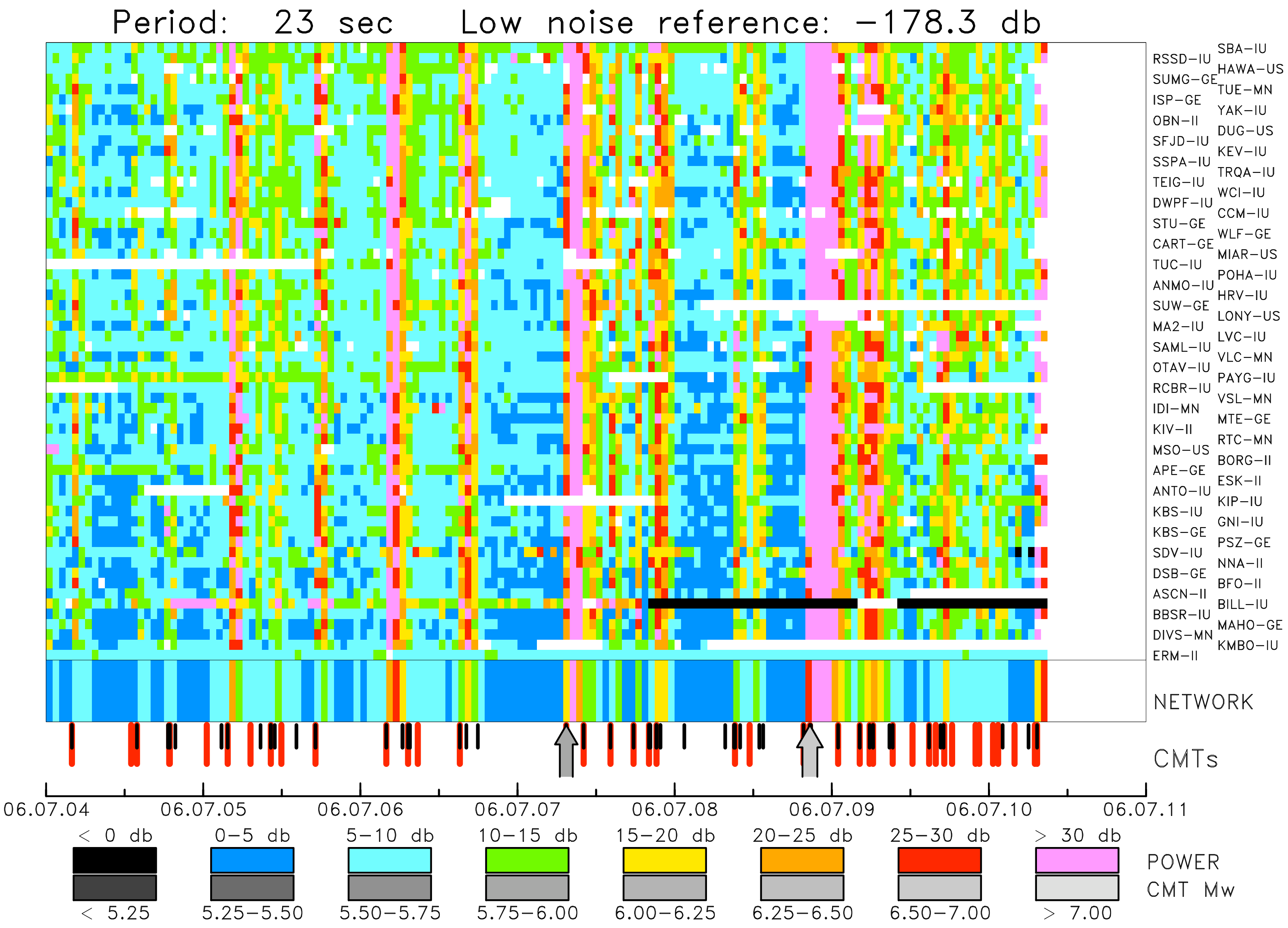
continuous filtered time series:



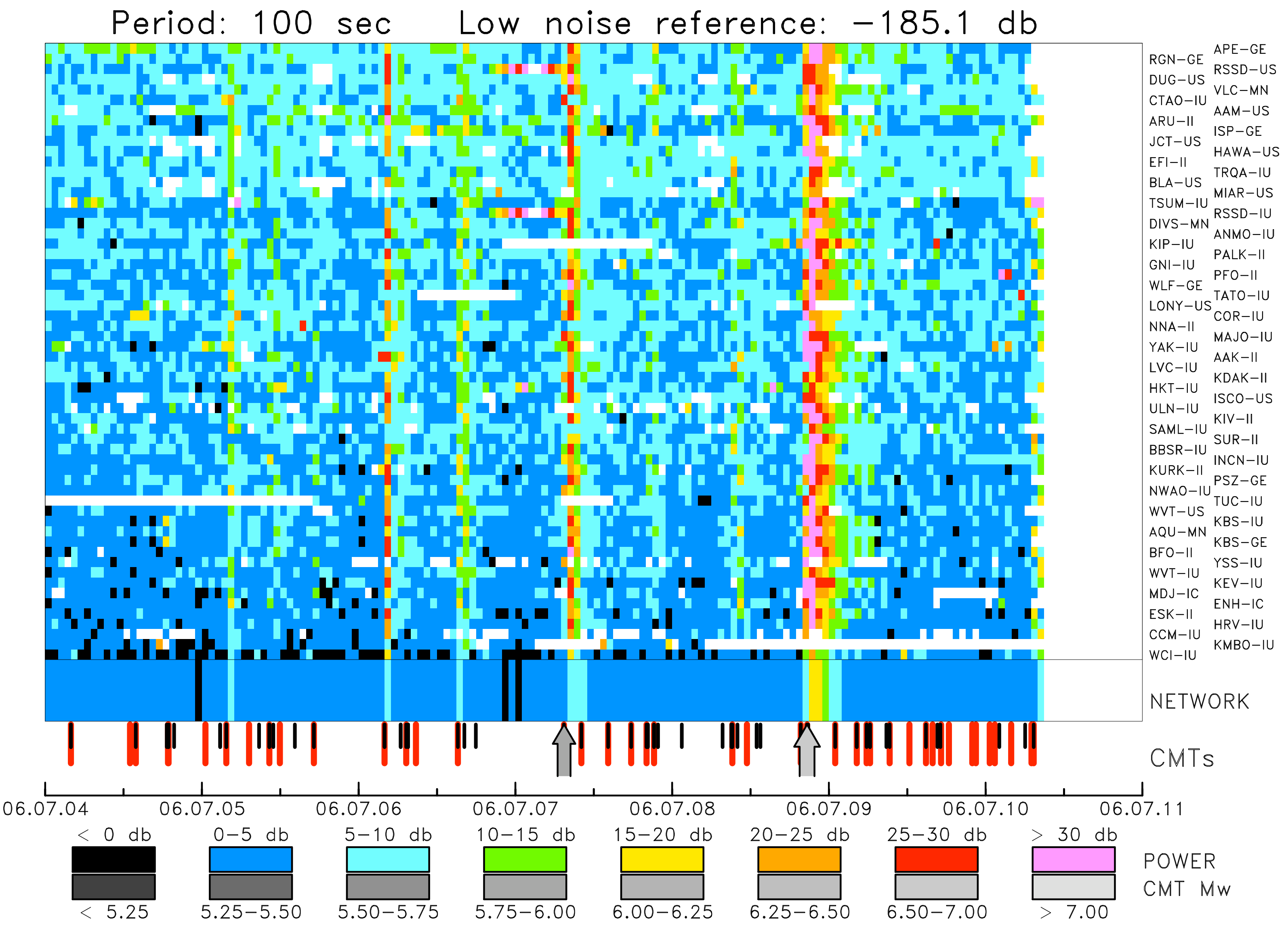
1. calculate rms
2. convert to power spectral density
3. store as hourly samples of signal level



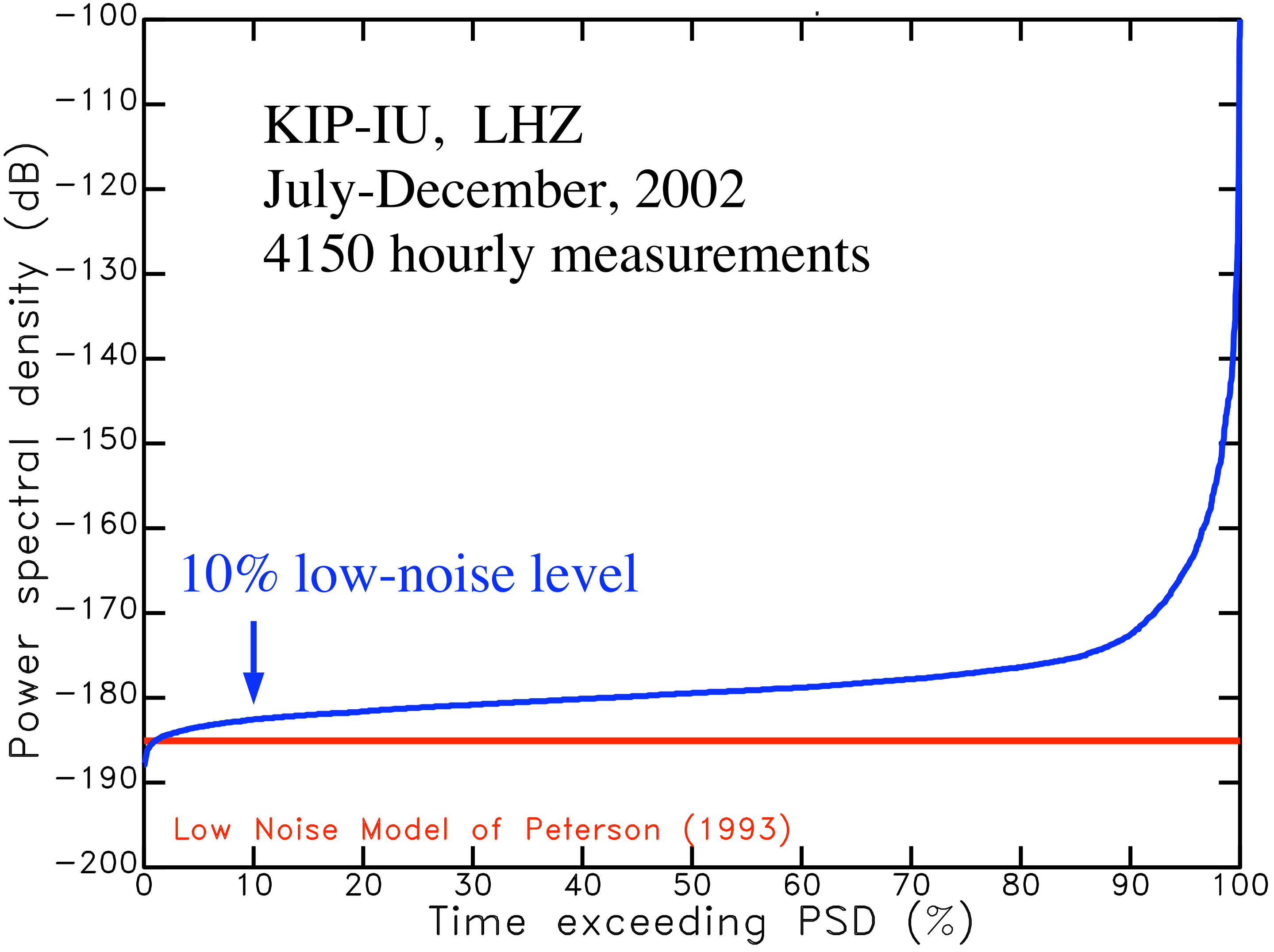
One week of noise at 23 seconds period



One week of noise at 100 seconds period



100 sec period - distribution of PSD

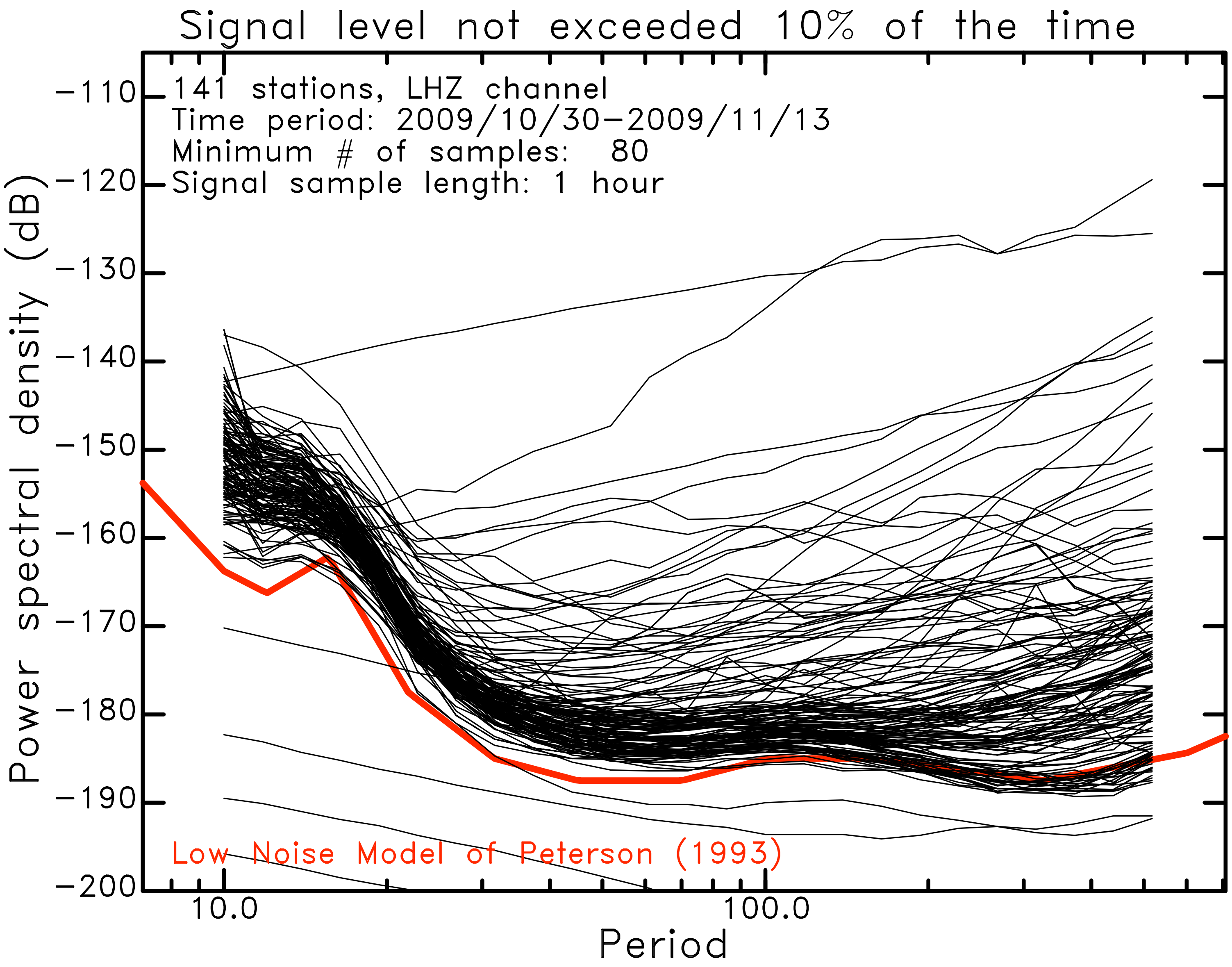


KIP-IU, LHZ
July-December, 2002
4150 hourly measurements

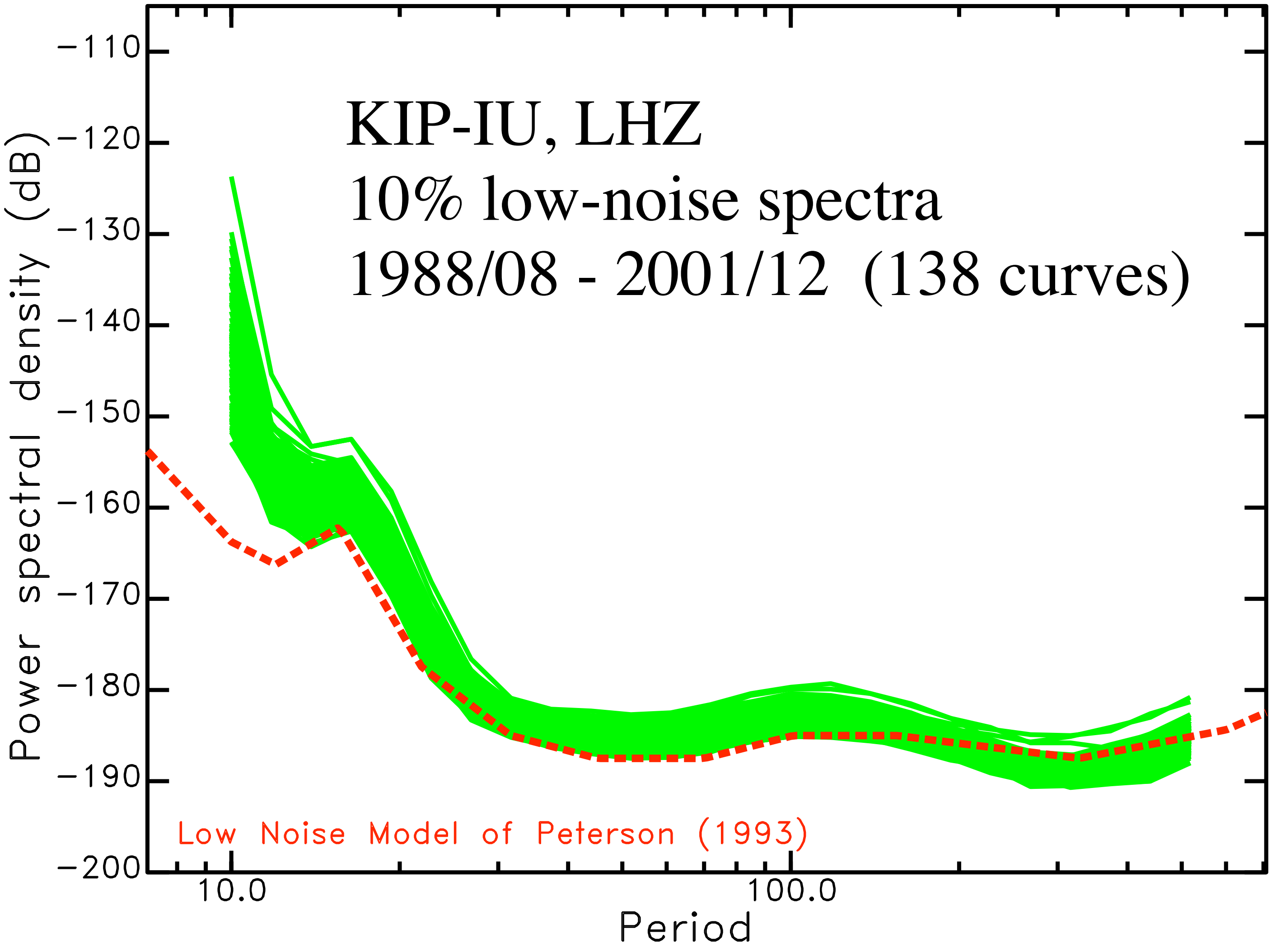
10% low-noise level

Low Noise Model of Peterson (1993)

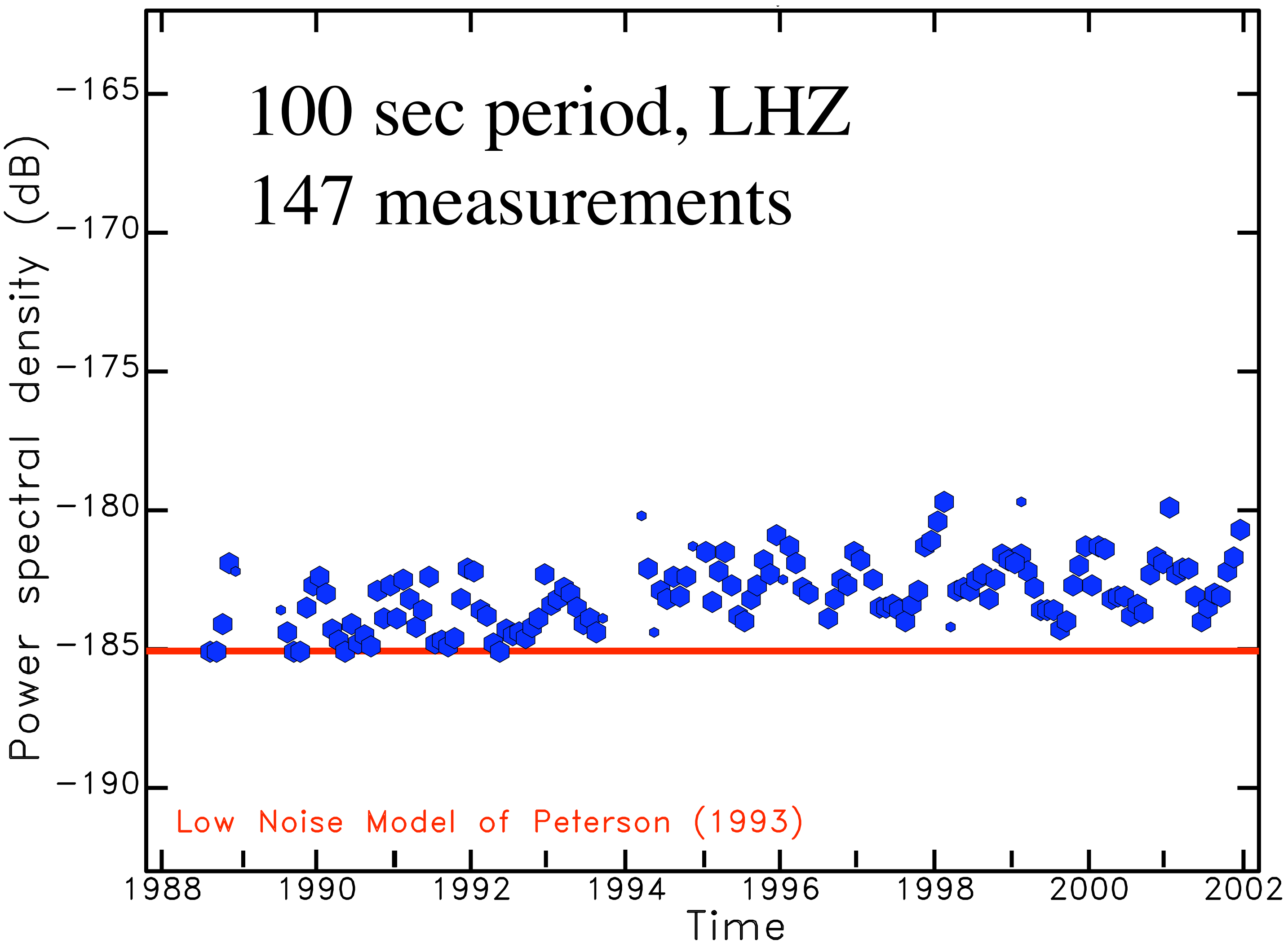
Noise spectra from the Global Seismic Network

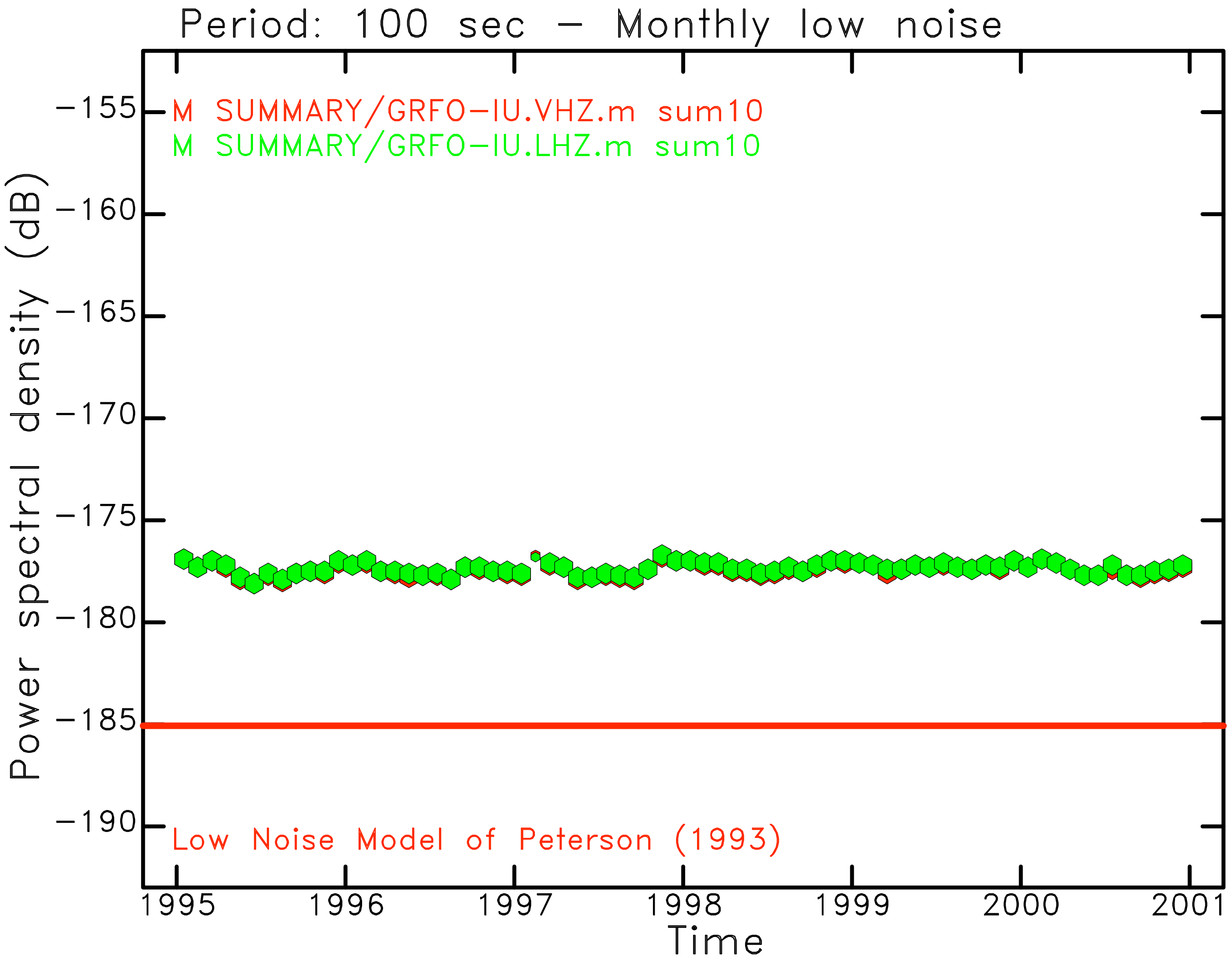


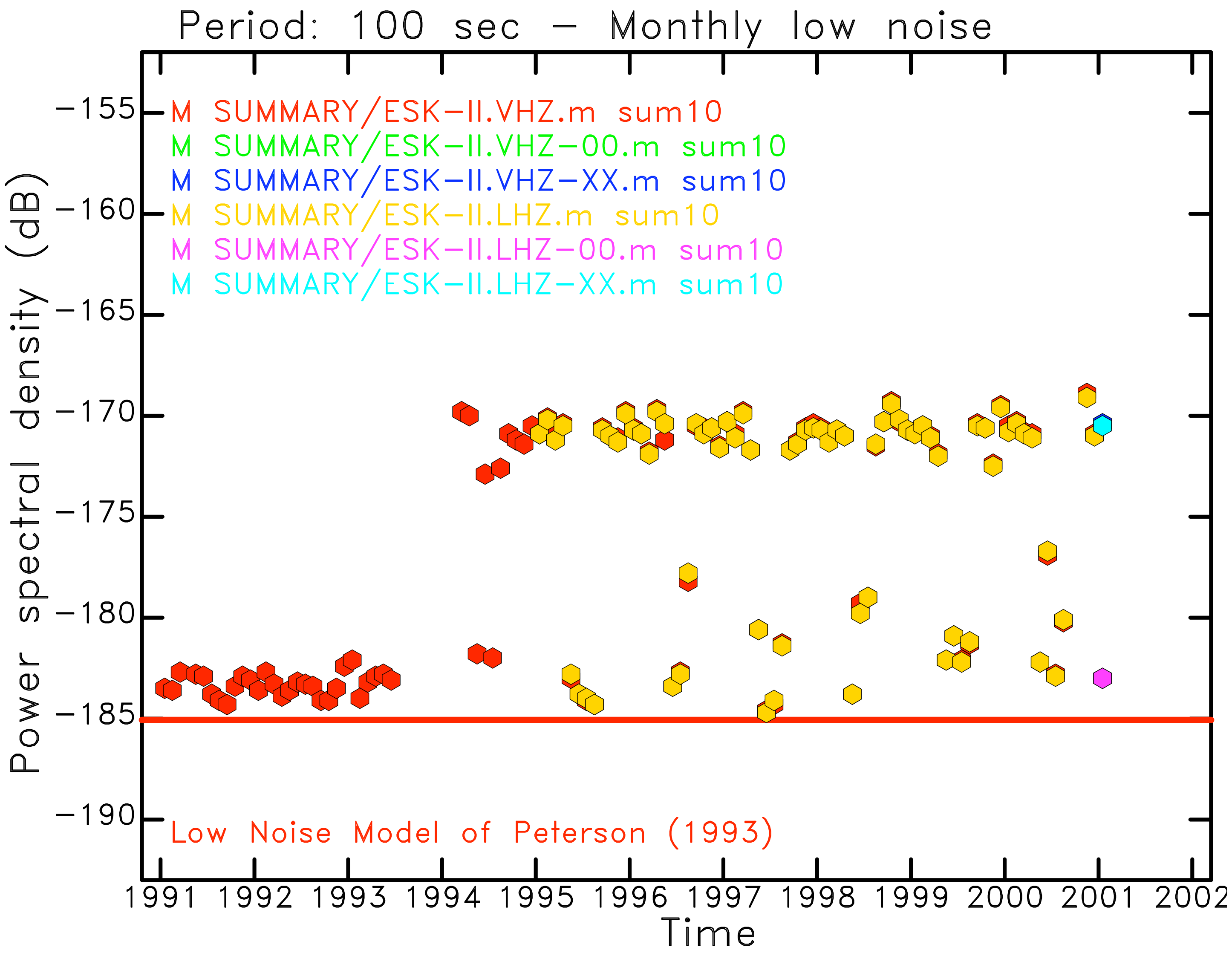
Stability of low-noise spectra



10% low-noise level at KIP since 1988



Period: 100 sec – Monthly low noise
M SUMMARY/GRFO-IU.VHZ.m sum10
M SUMMARY/GRFO-IU.LHZ.m sum10
Low Noise Model of Peterson (1993)
Power spectral density (dB)
−155
−160
−165
−170
−175
−180
−185
−190
1995
1996
1997
1998
1999
2000
2001
Time



Period: 100 sec – Monthly low noise
M SUMMARY/ESK-II.VHZ.m sum10
M SUMMARY/ESK-II.VHZ-00.m sum10
M SUMMARY/ESK-II.VHZ-XX.m sum10
M SUMMARY/ESK-II.LHZ.m sum10
M SUMMARY/ESK-II.LHZ-00.m sum10
M SUMMARY/ESK-II.LHZ-XX.m sum10
Power spectral density (dB)
−155
−160
−165
−170
−175
−180
−185
−190
Low Noise Model of Peterson (1993)
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
Time

6. Finding interesting things in the noise

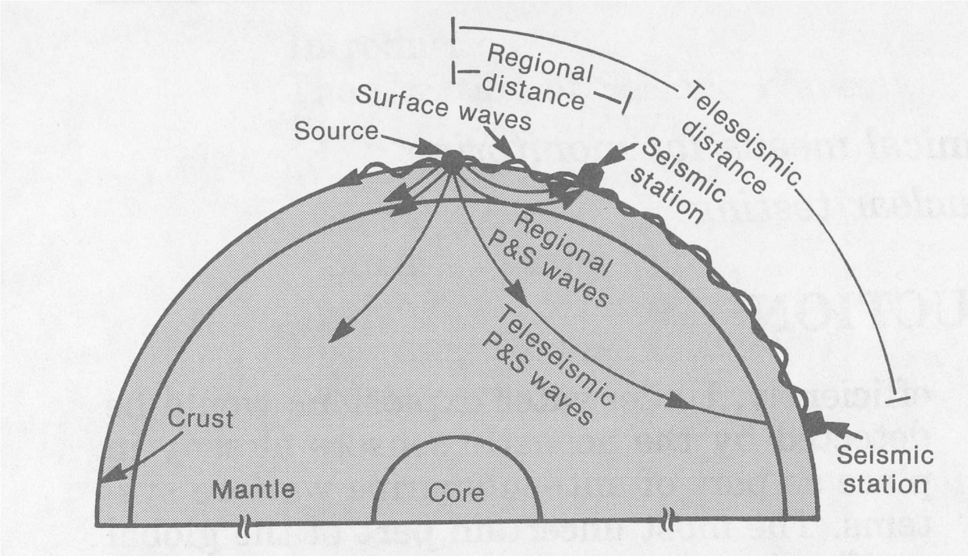
Seismographs record signals with frequencies between ~10 Hz to 1000 seconds.

Earthquakes are detected and located using high-frequency signals (around 1 Hz).

Are there short-lived geophysical phenomena that generate seismic waves at long periods but that are not detected at short periods?

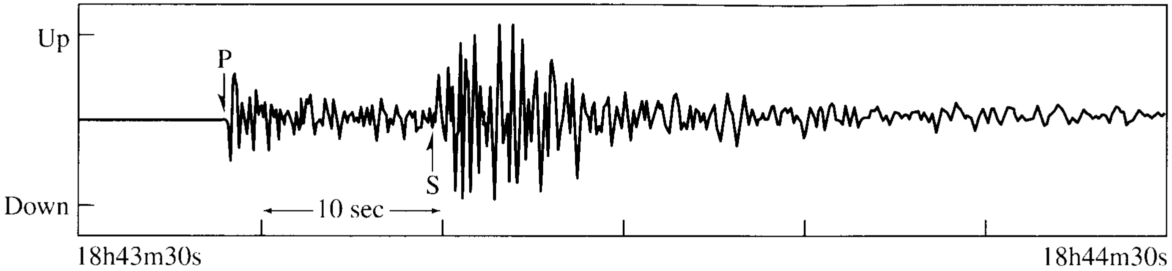
Locating Earthquakes (1)

wave propagation through the Earth



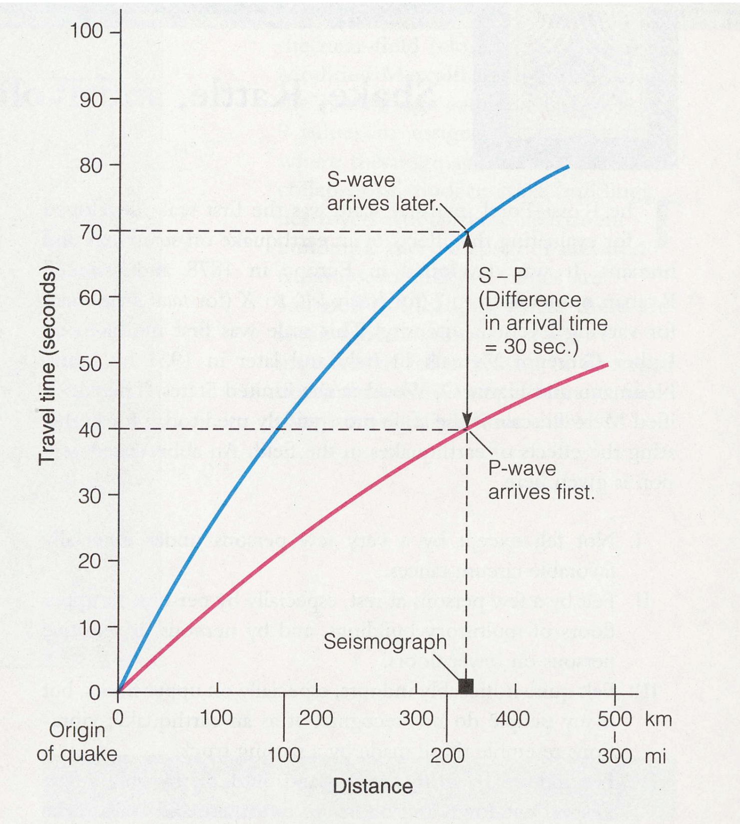
An earthquake or underground explosion generates seismic waves that propagate through the Earth.

seismogram

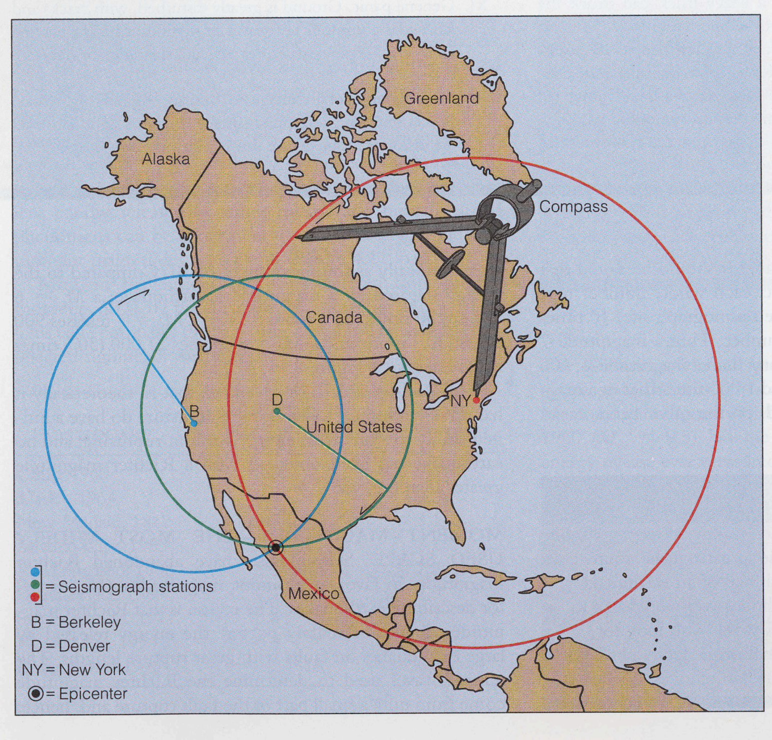


Locating earthquakes (2)

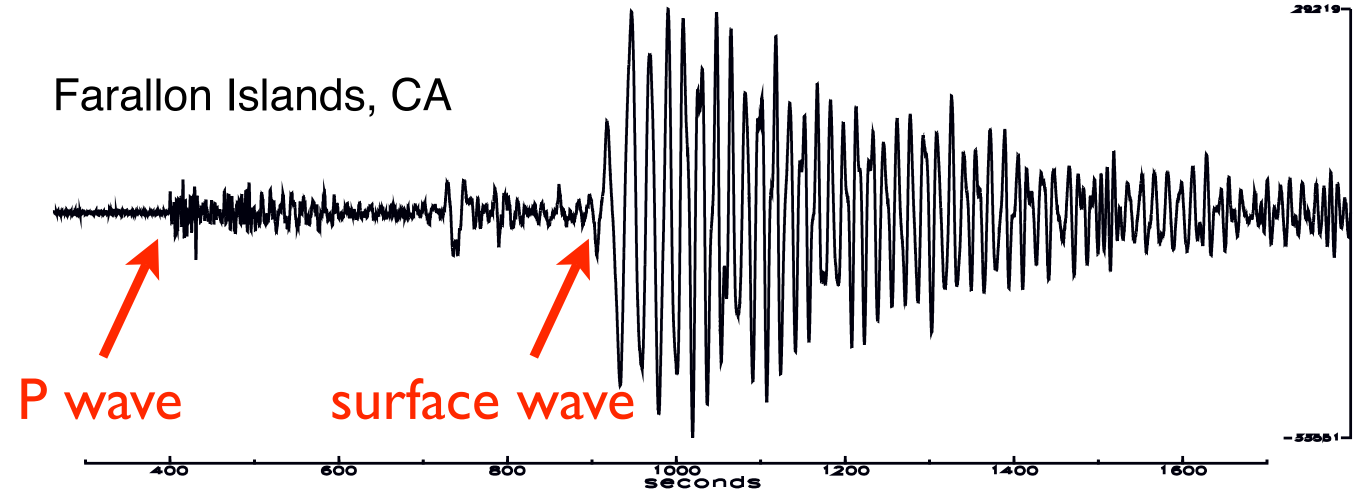
travel-time curves

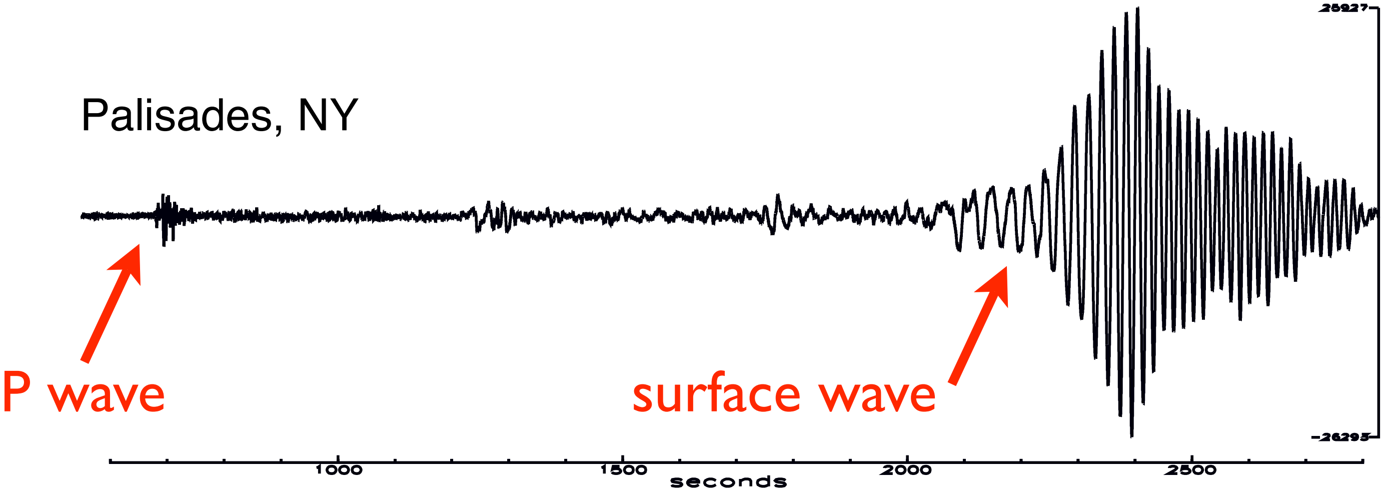


triangulation



October 15, 2006, Hawaii earthquake, M=6.7

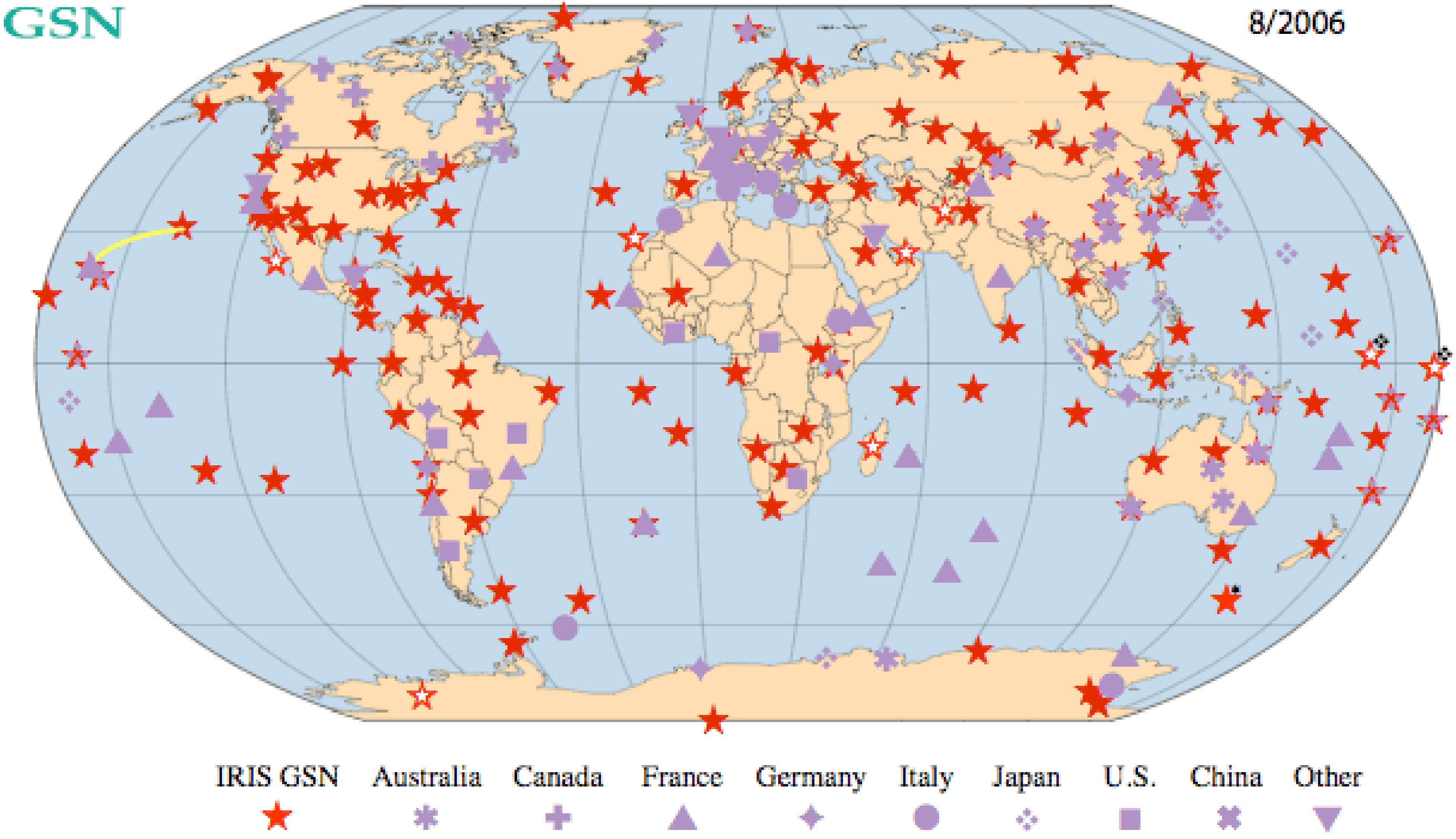




GSN

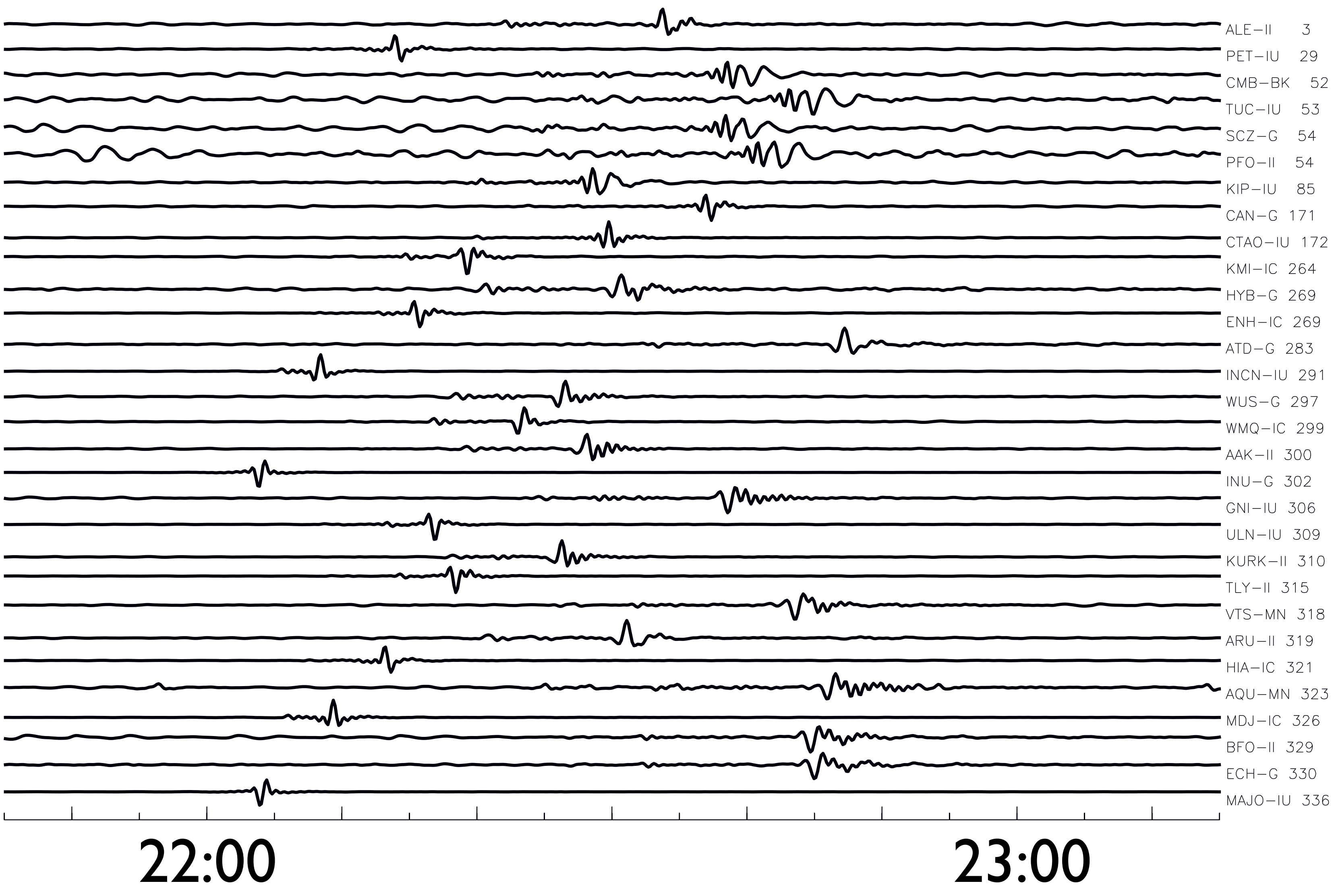
GLOBAL SEISMOGRAPHIC NETWORK

& INTERNATIONAL FEDERATION OF DIGITAL SEISMIC NETWORKS

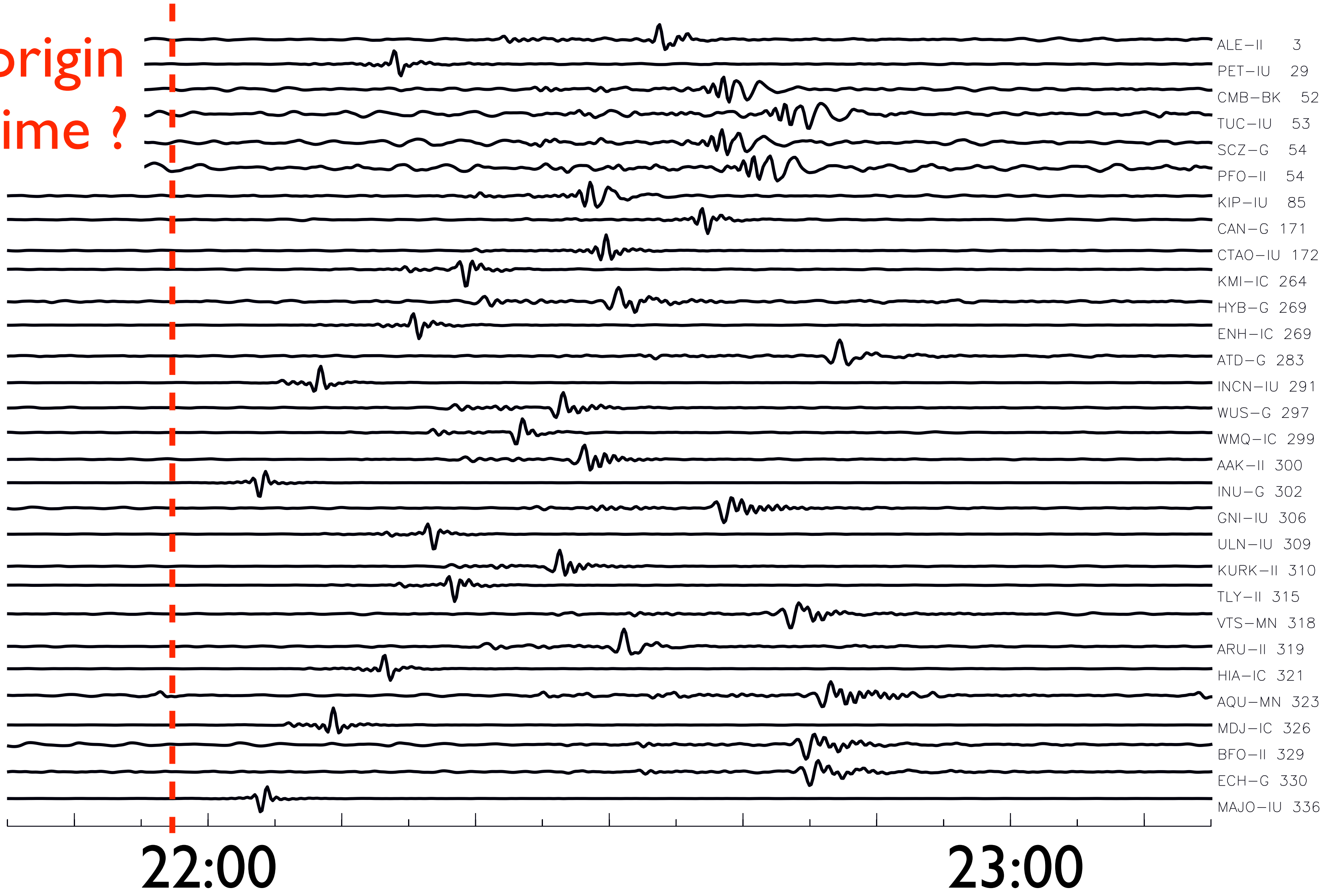


8/2006

1. Collect data from the GSN
2. Filter in period range 35- 250 seconds



1. Collect data from the GSN
2. Filter in period range 35- 250 seconds


origin time ?

Surface-wave dispersion

Seismic surface waves are dispersive, $c = c(\omega)$, where $\omega = \frac{2\pi}{T}$ and T is the period of the waves.

Travel time τ is therefore dependent on frequency, $\tau(\omega)$.

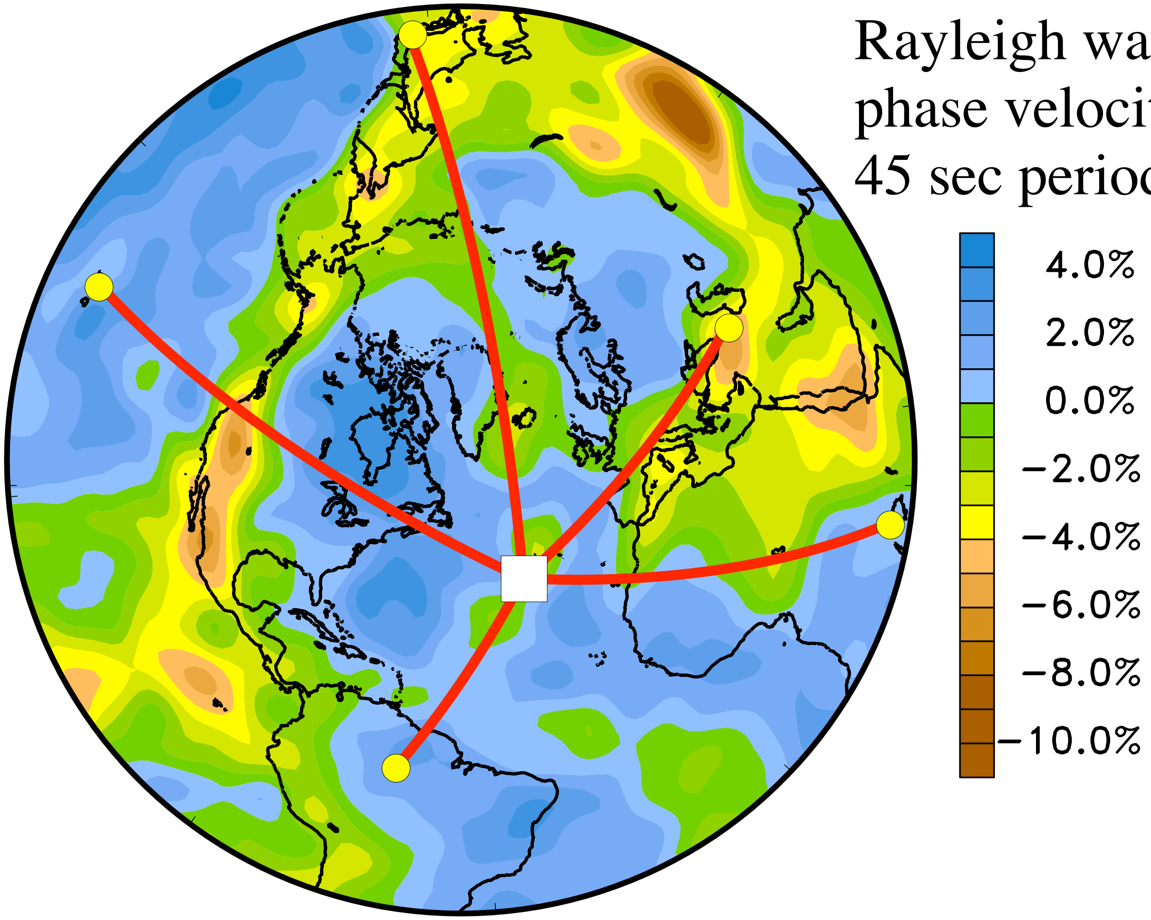
Propagation phase $\Phi(\omega) = \omega \cdot \tau(\omega) = \frac{\tau(\omega) \cdot 2\pi}{T}$.

For the propagation phase from point (θ_A, φ_A) to point (θ_B, φ_B) we write,

$$\Phi(\omega) = \int_A^B \frac{\omega}{c(\theta, \varphi; \omega)} ds$$

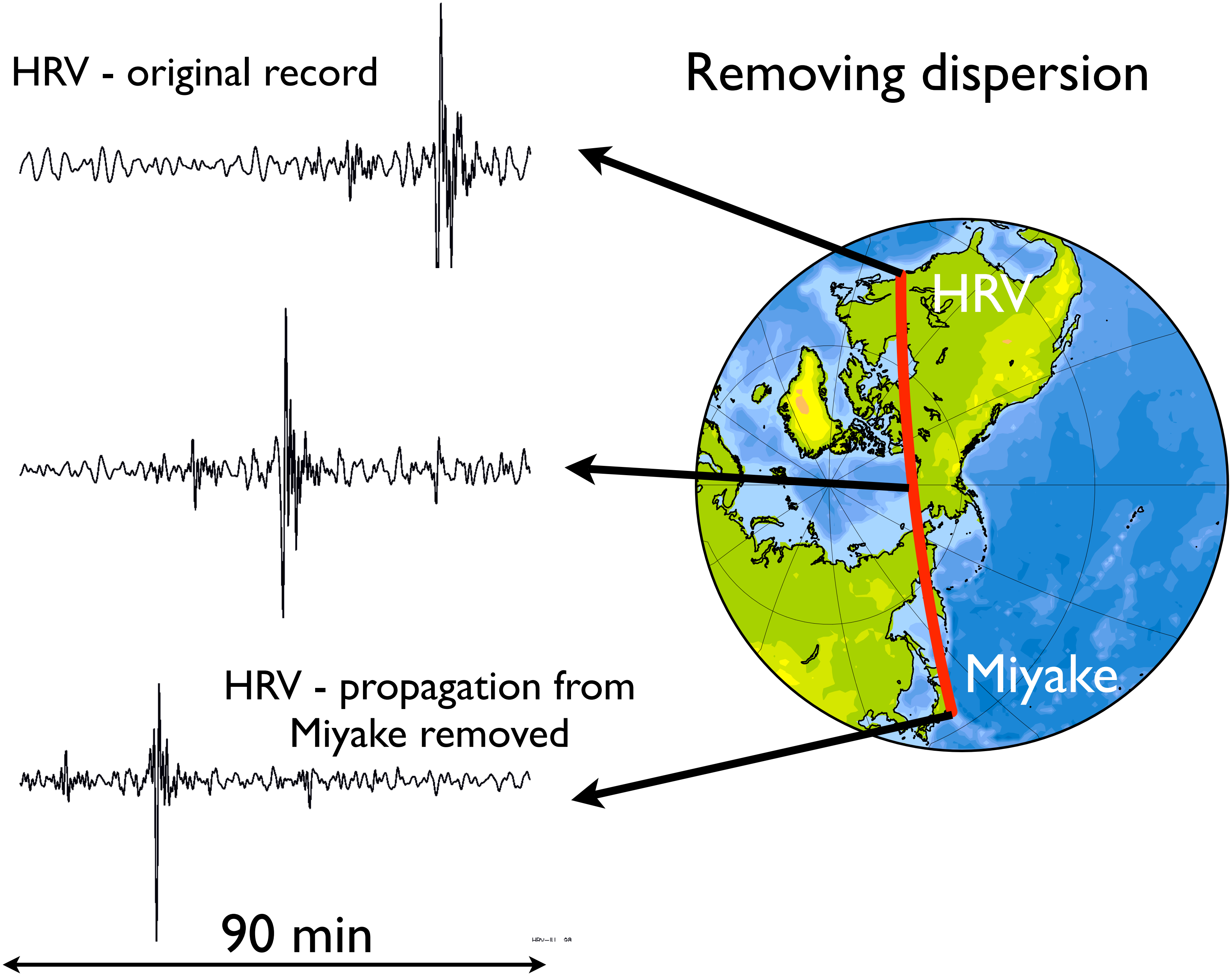
with velocity depending on position, $c(\theta, \varphi)$.

3. Select a target location

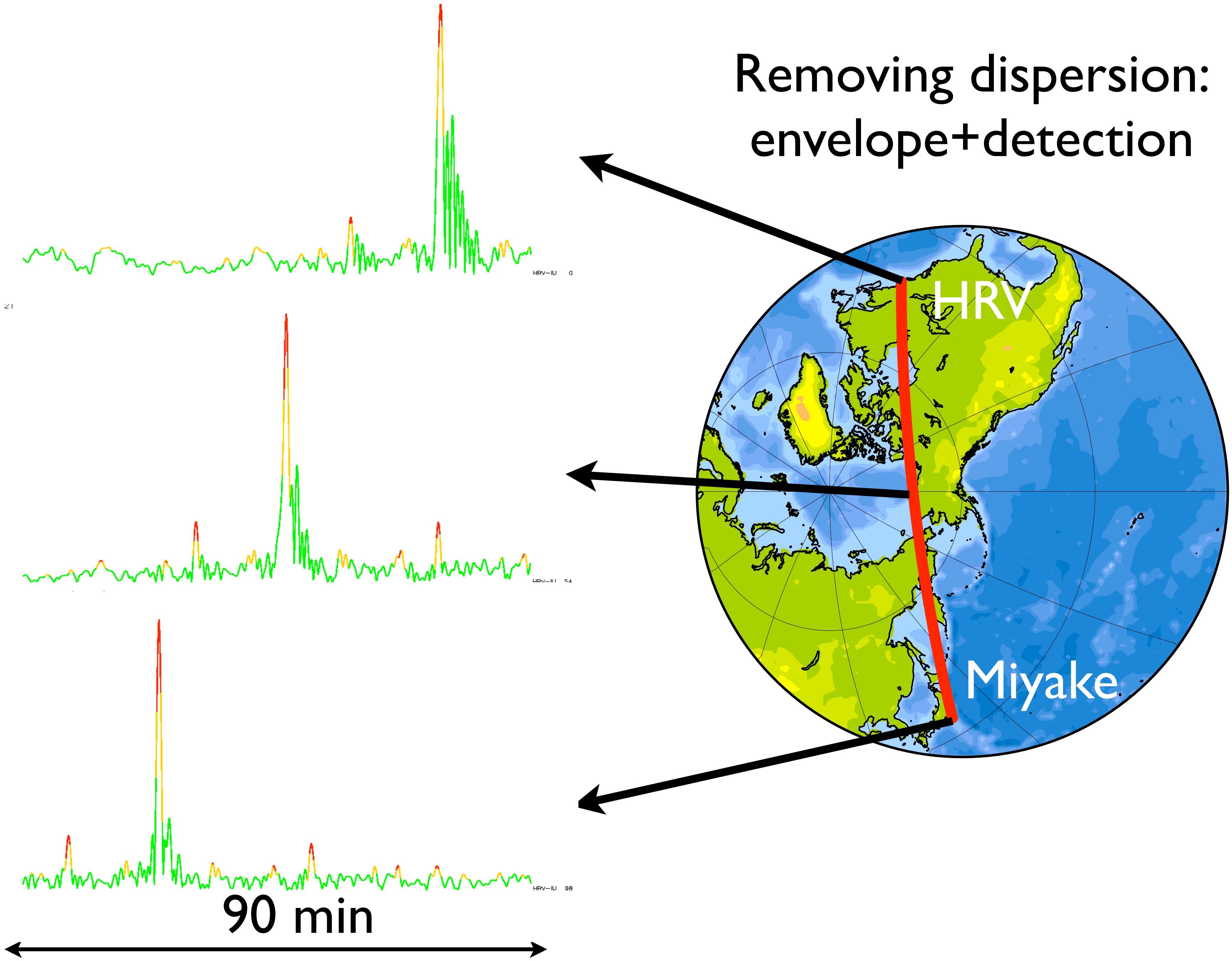


4. Calculate and remove dispersion from each station to the target

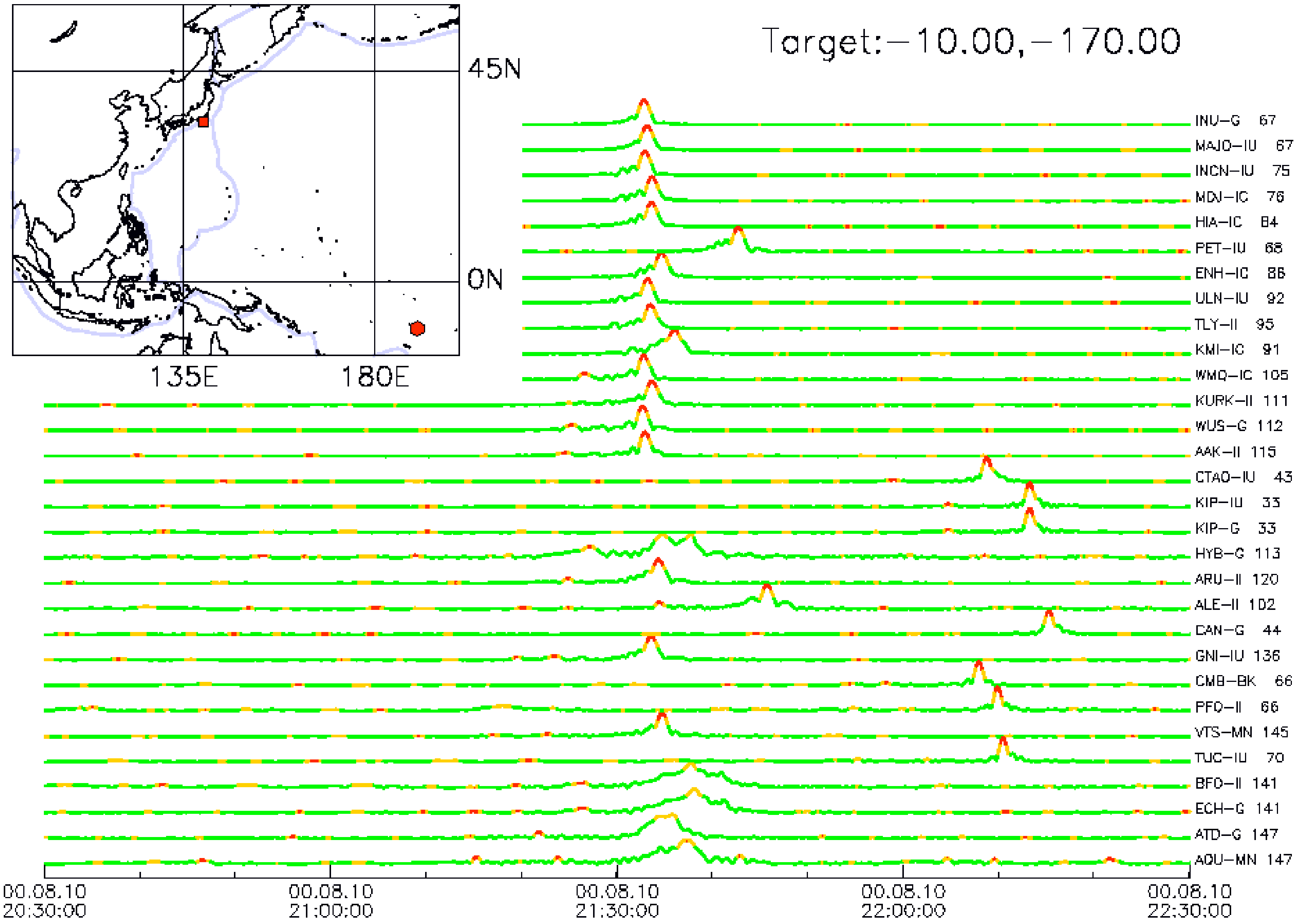
Removing dispersion



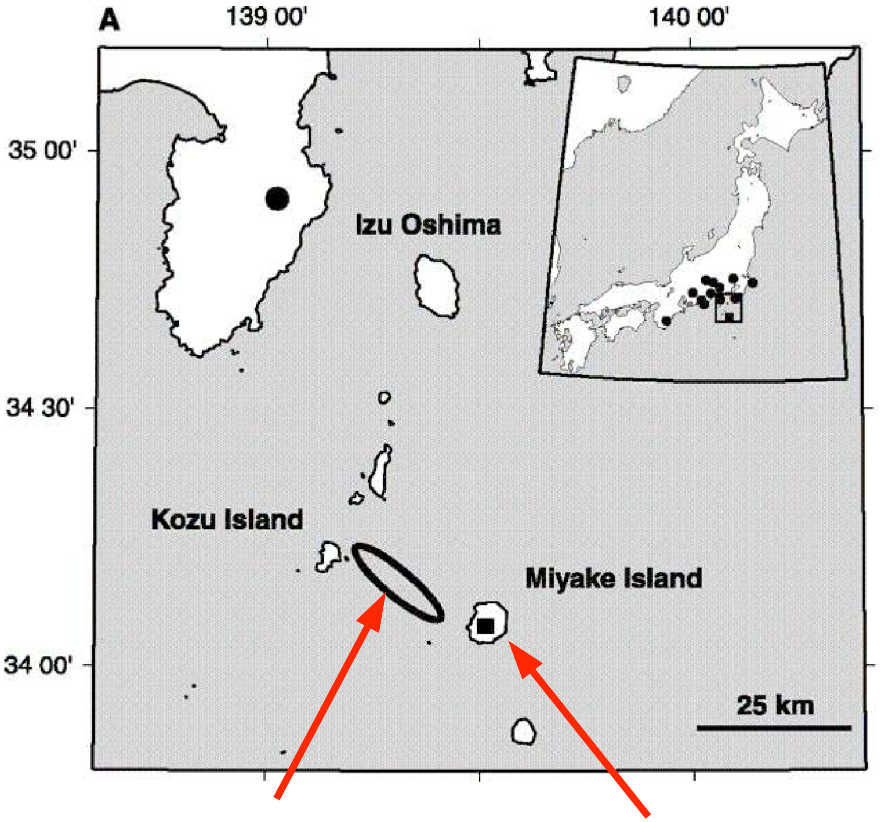
Removing dispersion: envelope+detection



Miyake Island, 2000/08/10



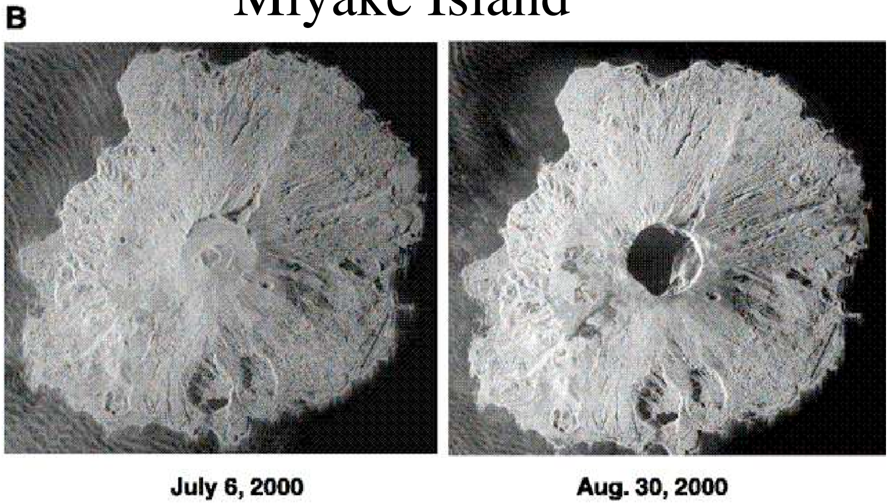
Caldera formation on Miyake Island associated with magma migration in the Izu Islands, June-September, 2000



dike injection, earthquakes

caldera formation

Miyake Island



before

after

(Figure adapted from Kumagai et al., Science, 2001)

Systematic global search:

4050 points on the Earth's surface
100-200 stations
15 years
365 days/year
6 4-hour seismograms/day

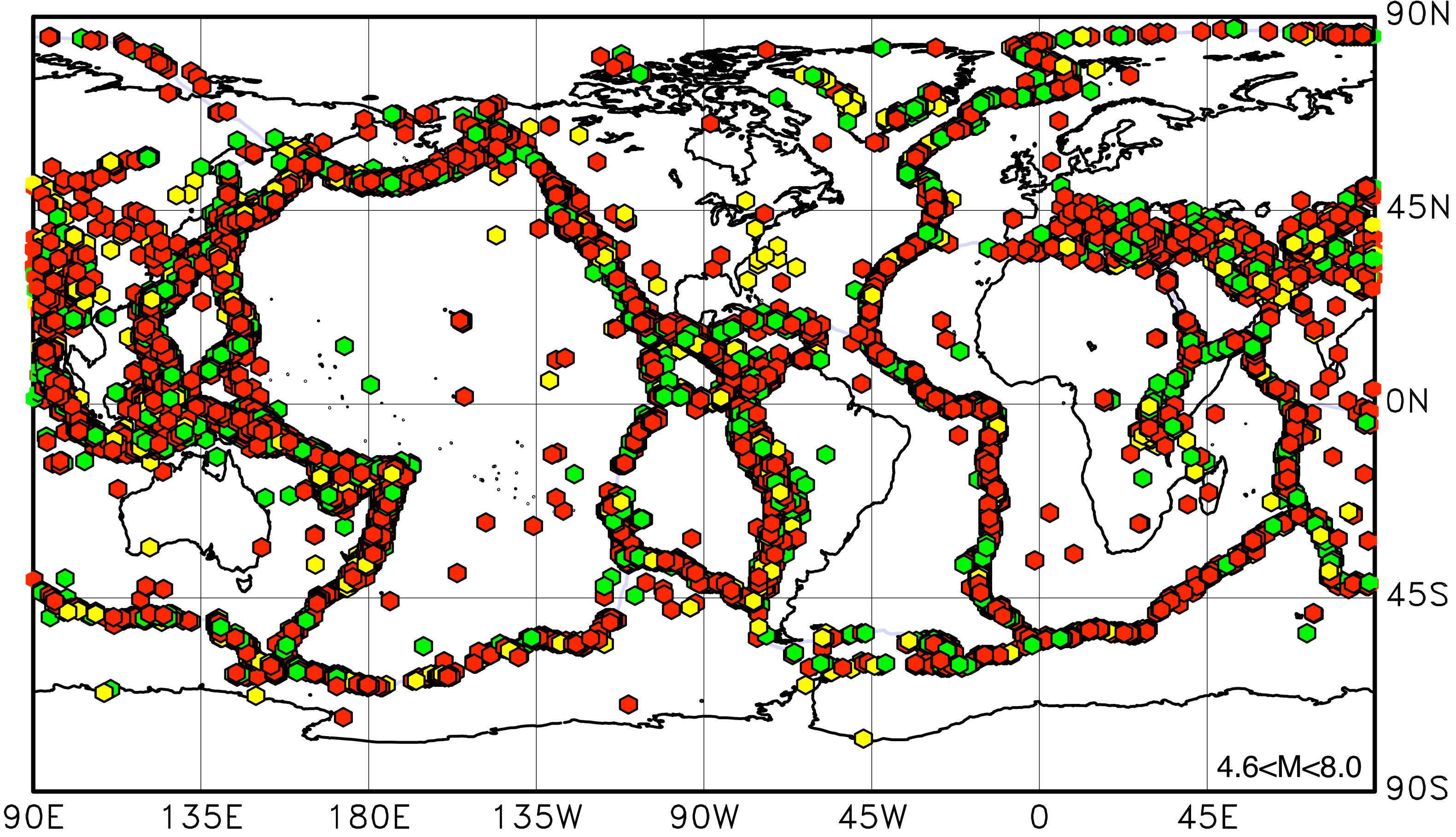
20,000,000,000 4-hour event stacks

check for event every 4 seconds:

80,000,000,000,000 detection tests

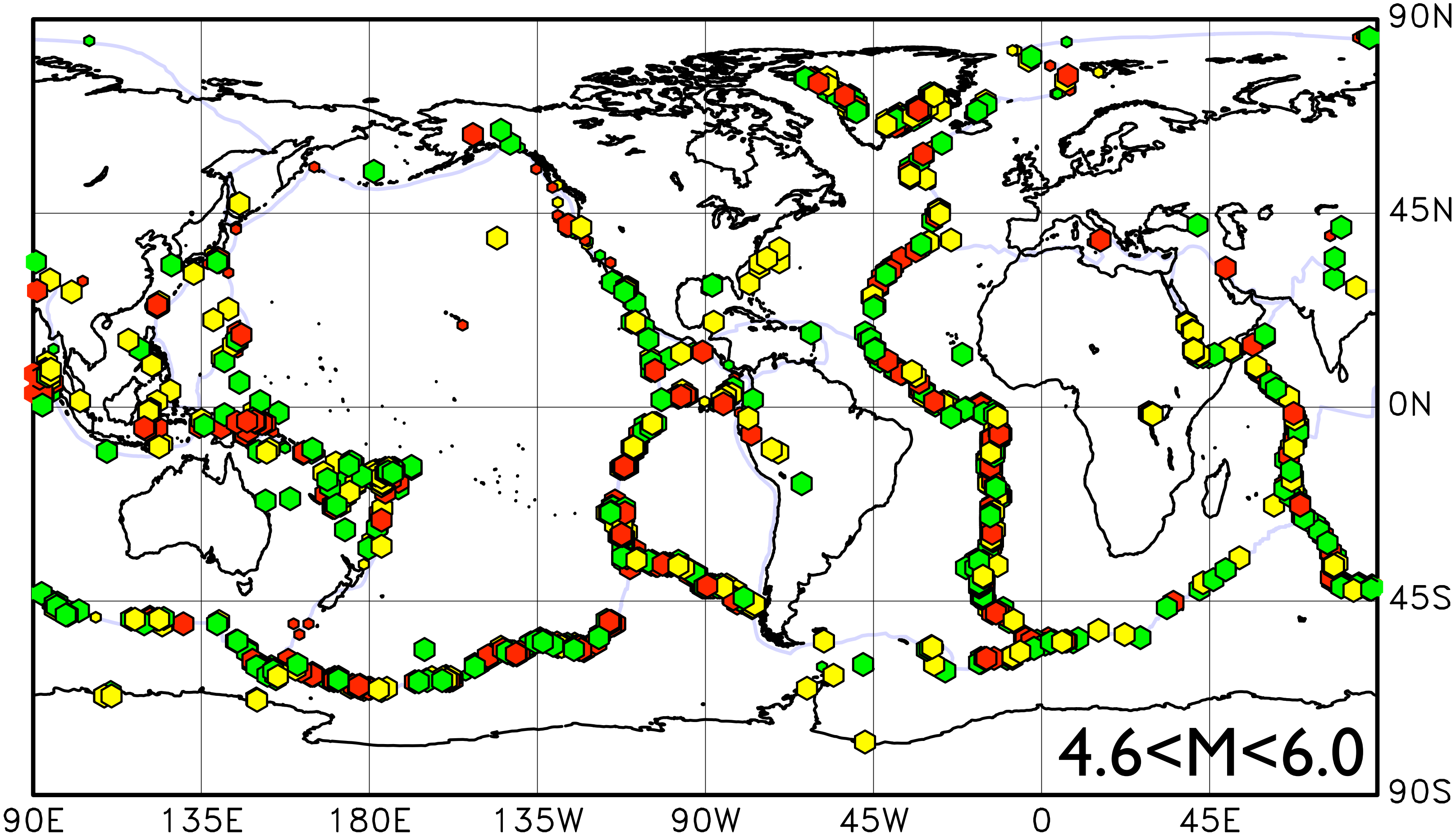
24,412 detected seismic events
1993-2003

- 🟥 best detection
- 🟩 very good detection
- 🟨 good detection

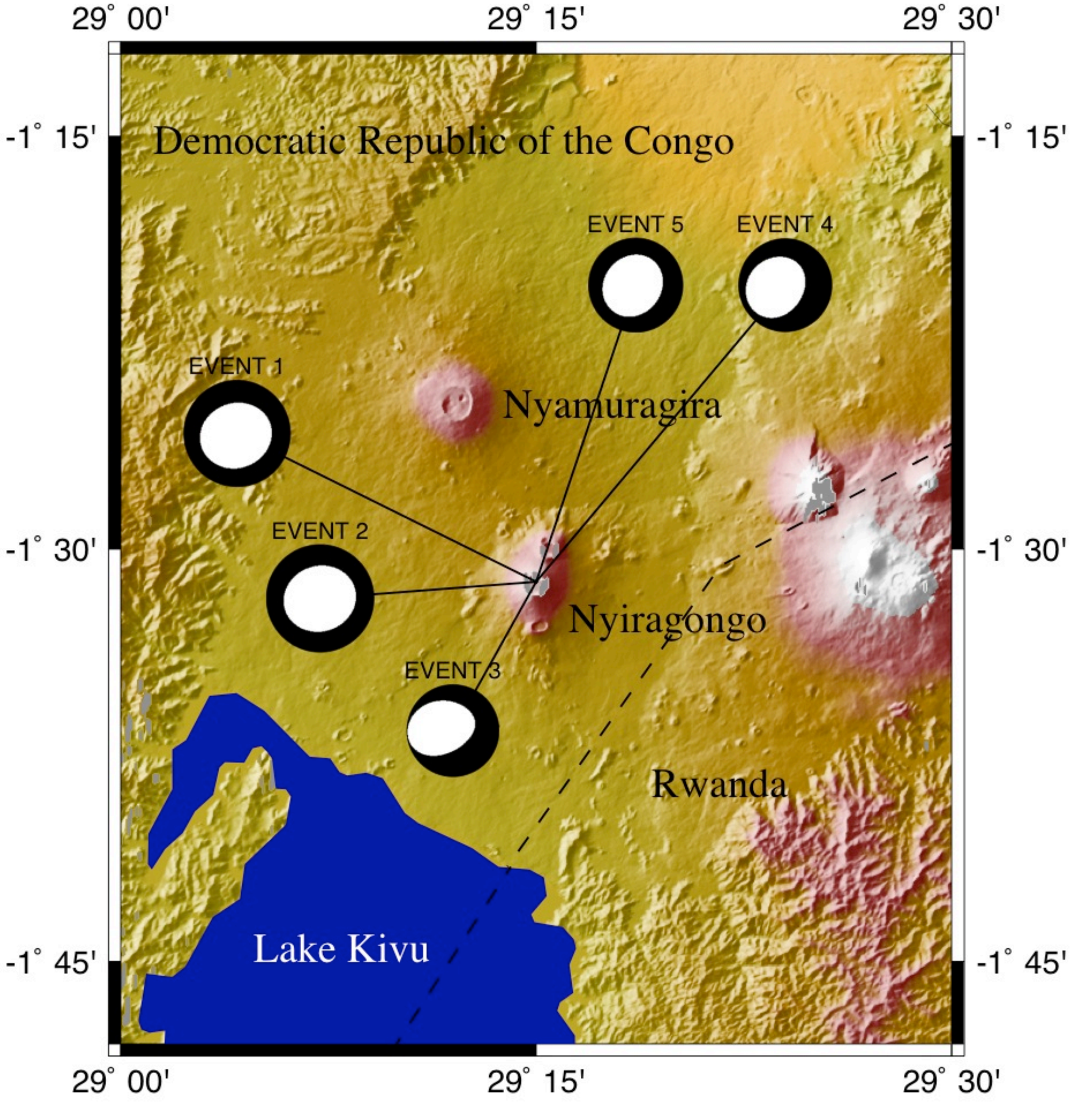


Previously undetected earthquakes since 1993

Best
Very good
Good



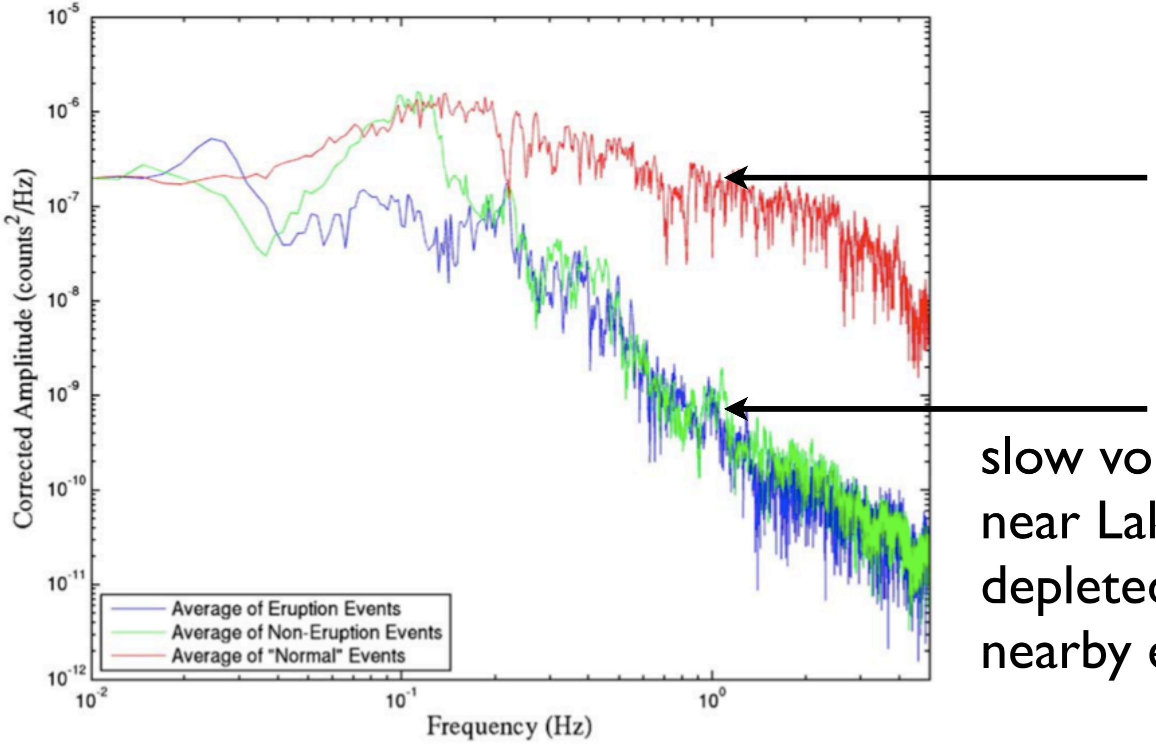
Slow earthquakes at Nyiragongo Volcano



Shuler and Ekstrom, 2007

Detection and analysis of events with little high-frequency energy

(courtesy A. Shuler)

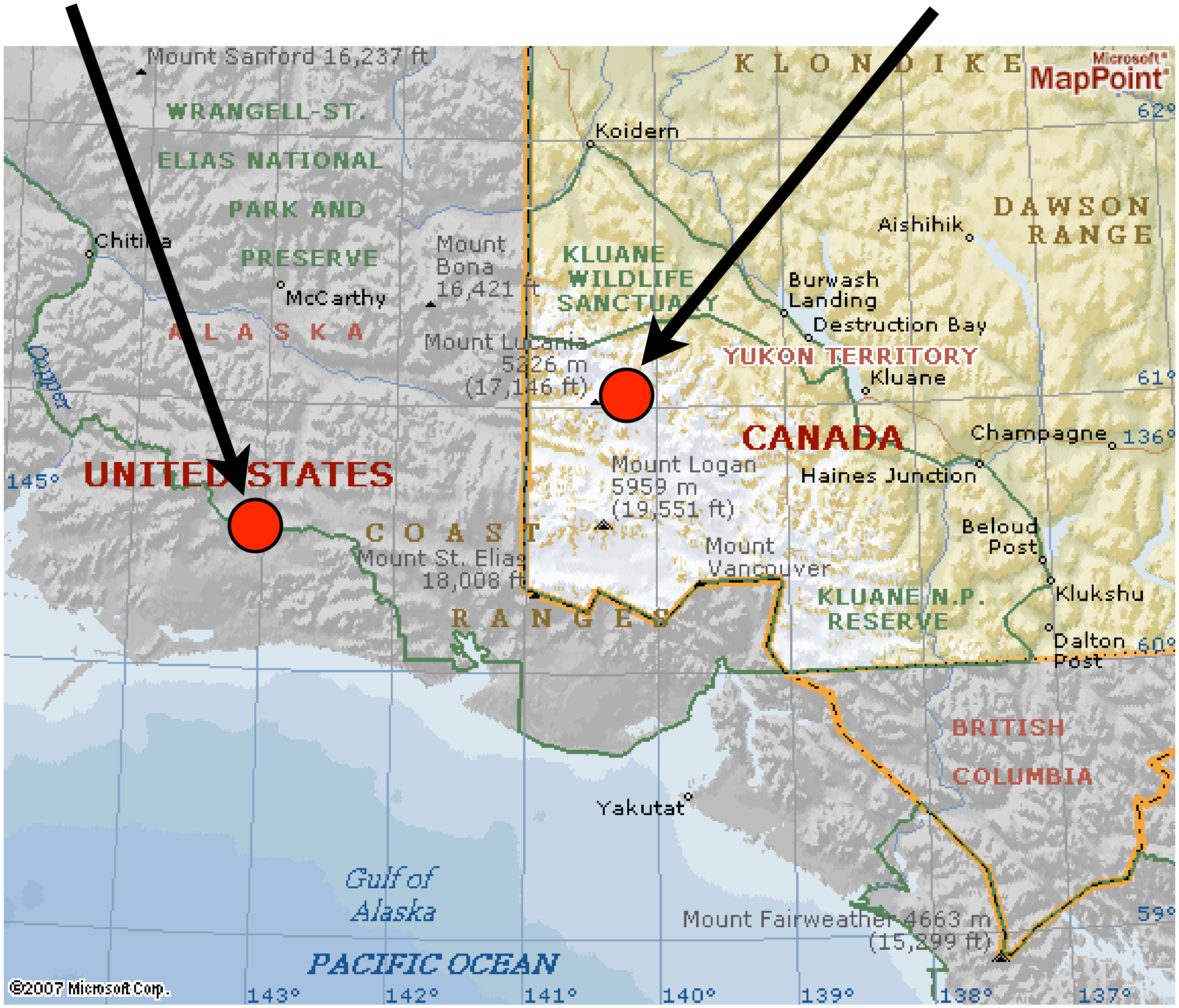


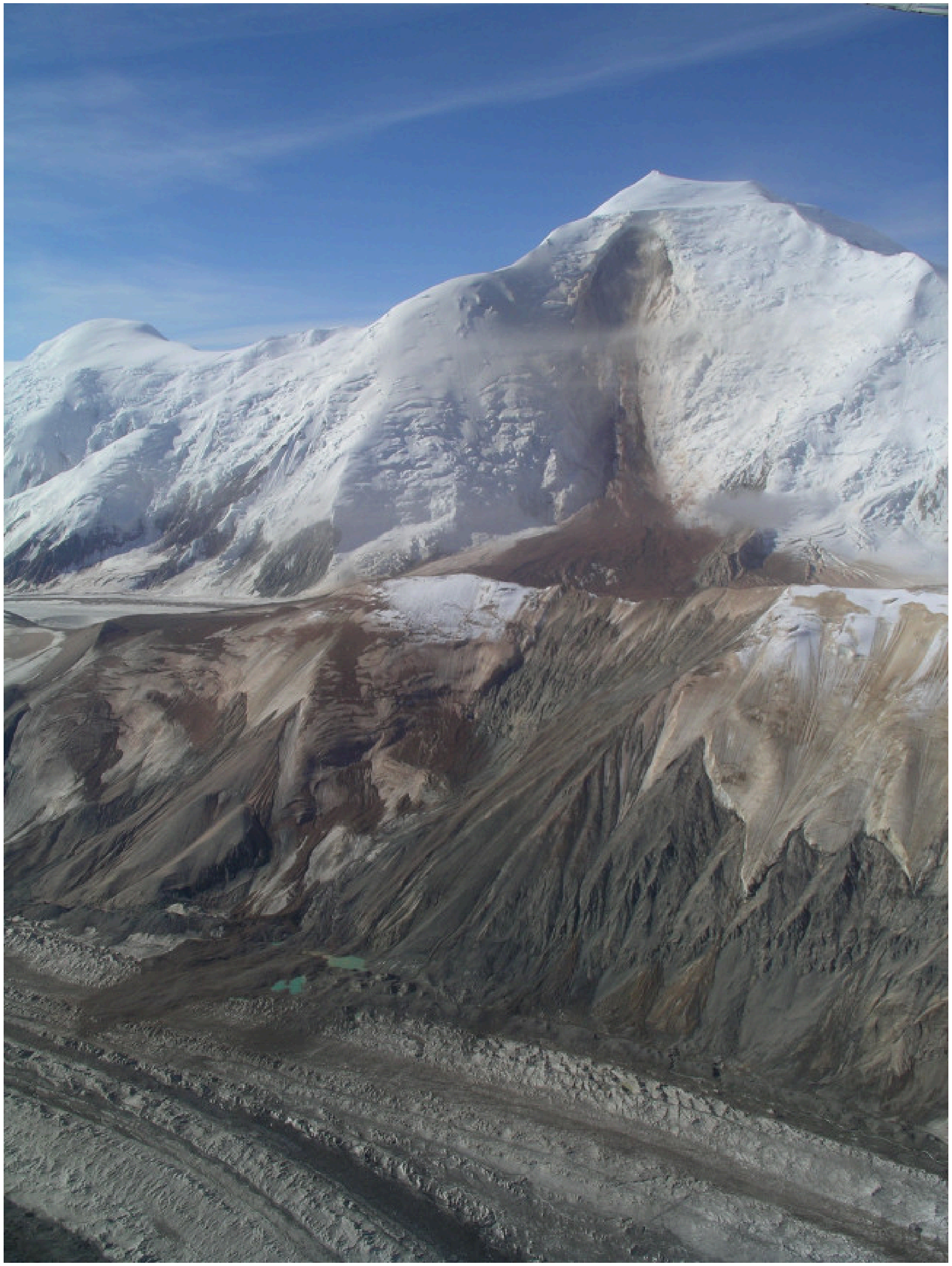
slow volcano-tectonic earthquakes near Lake Kivu have 1-Hz energy depleted by more than 10^2 wrt nearby earthquakes

Two strange M=5.2 earthquakes

9/14/2005

7/25/2007

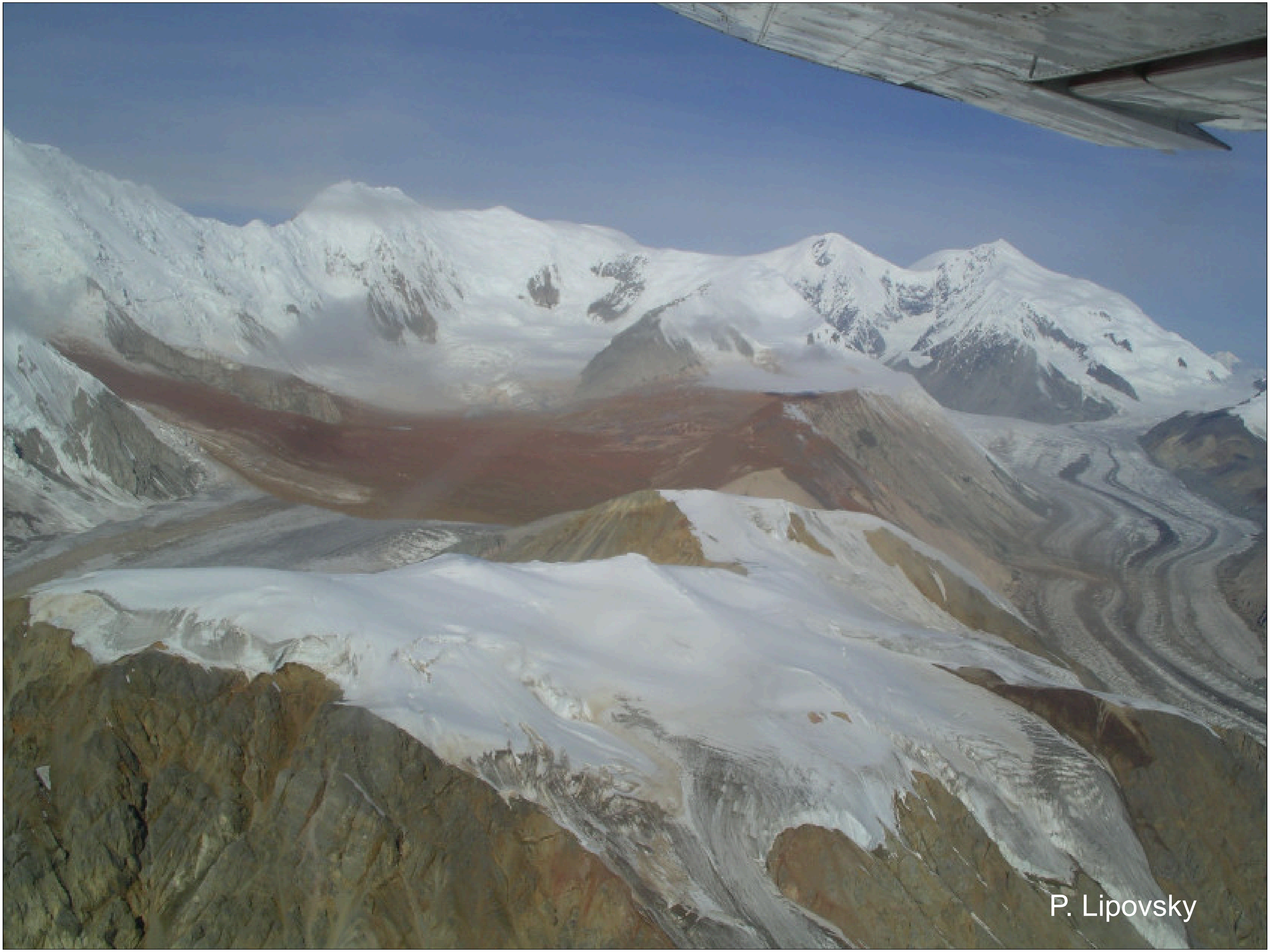




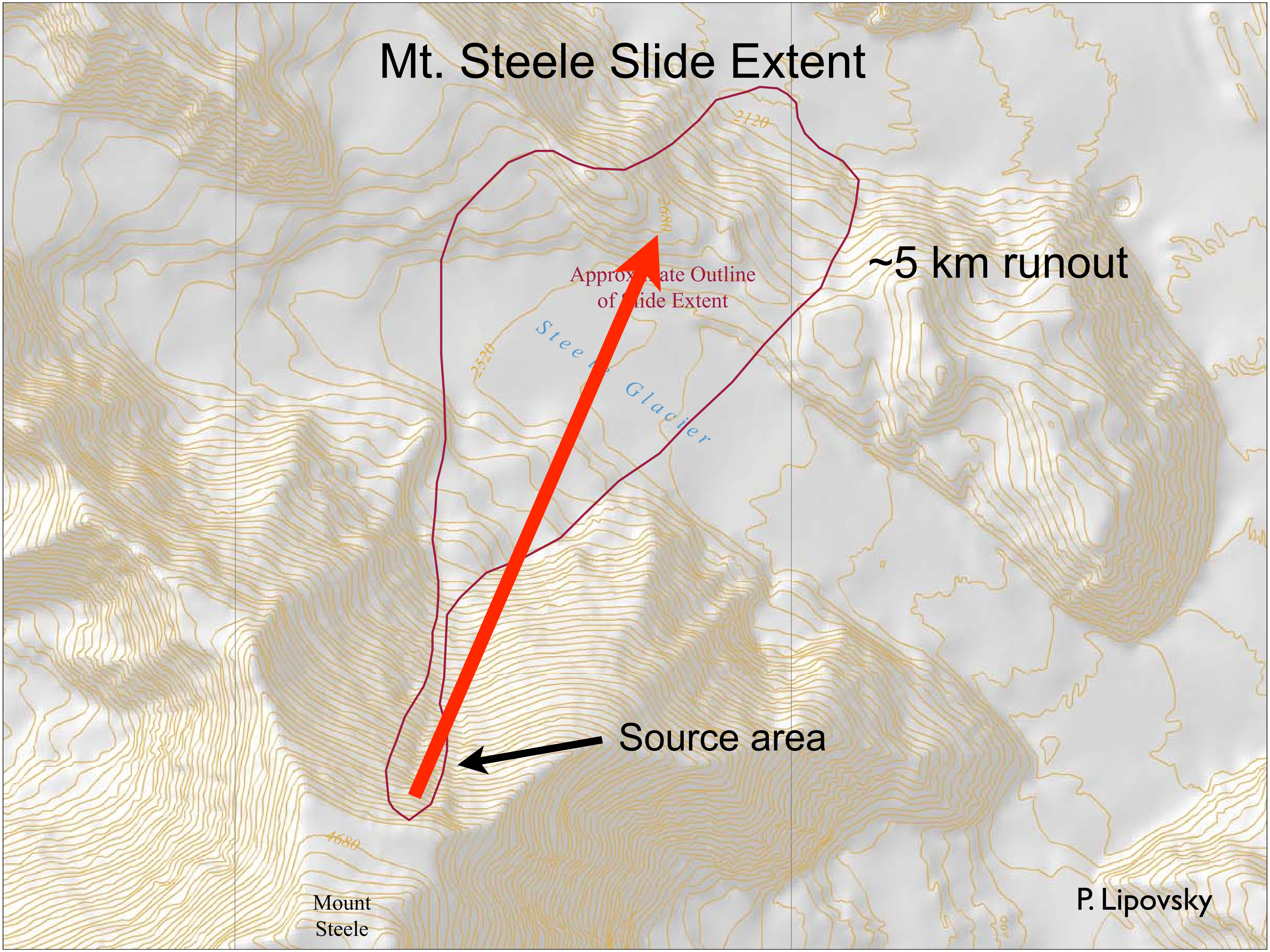
Mount Steele rock avalanche 7/25/2007

~50 million cubic meters of rock and ice

photo: P. Lipovsky


P. Lipovsky

Mt. Steele Slide Extent

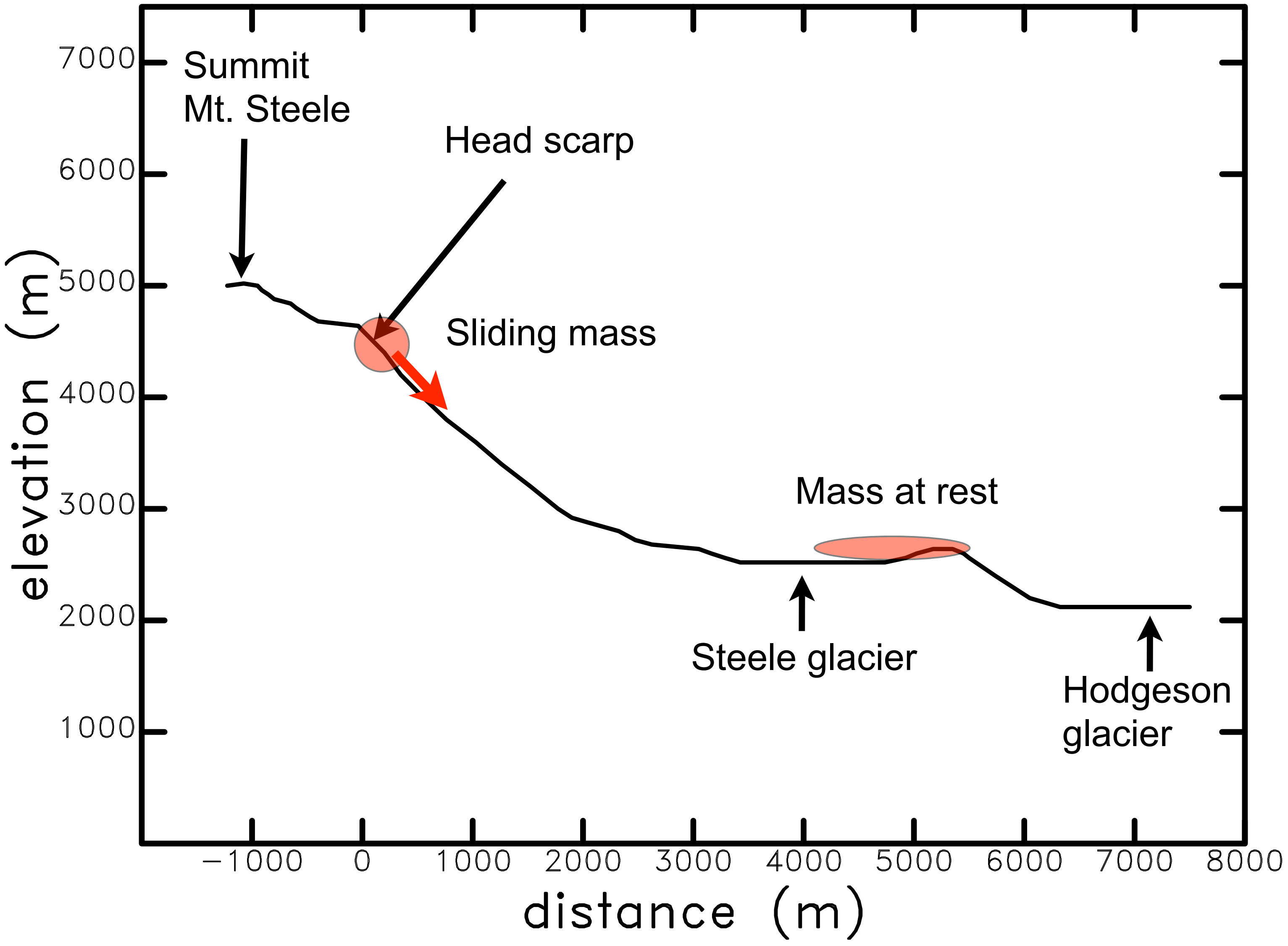


~5 km runout

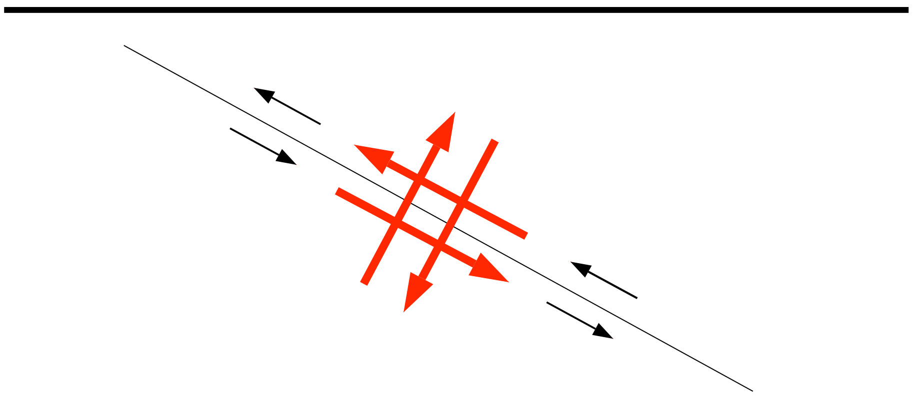
Source area

P. Lipovsky

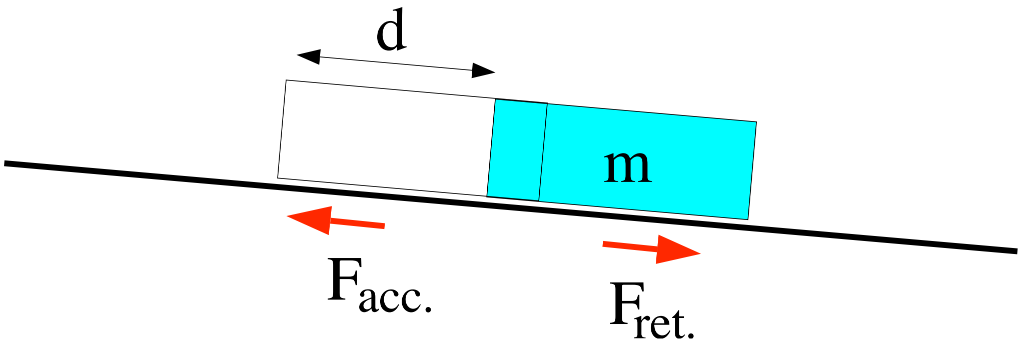
Mt. Steele rock avalanche, 7/25/2007



Faulting force model



Landslide force model

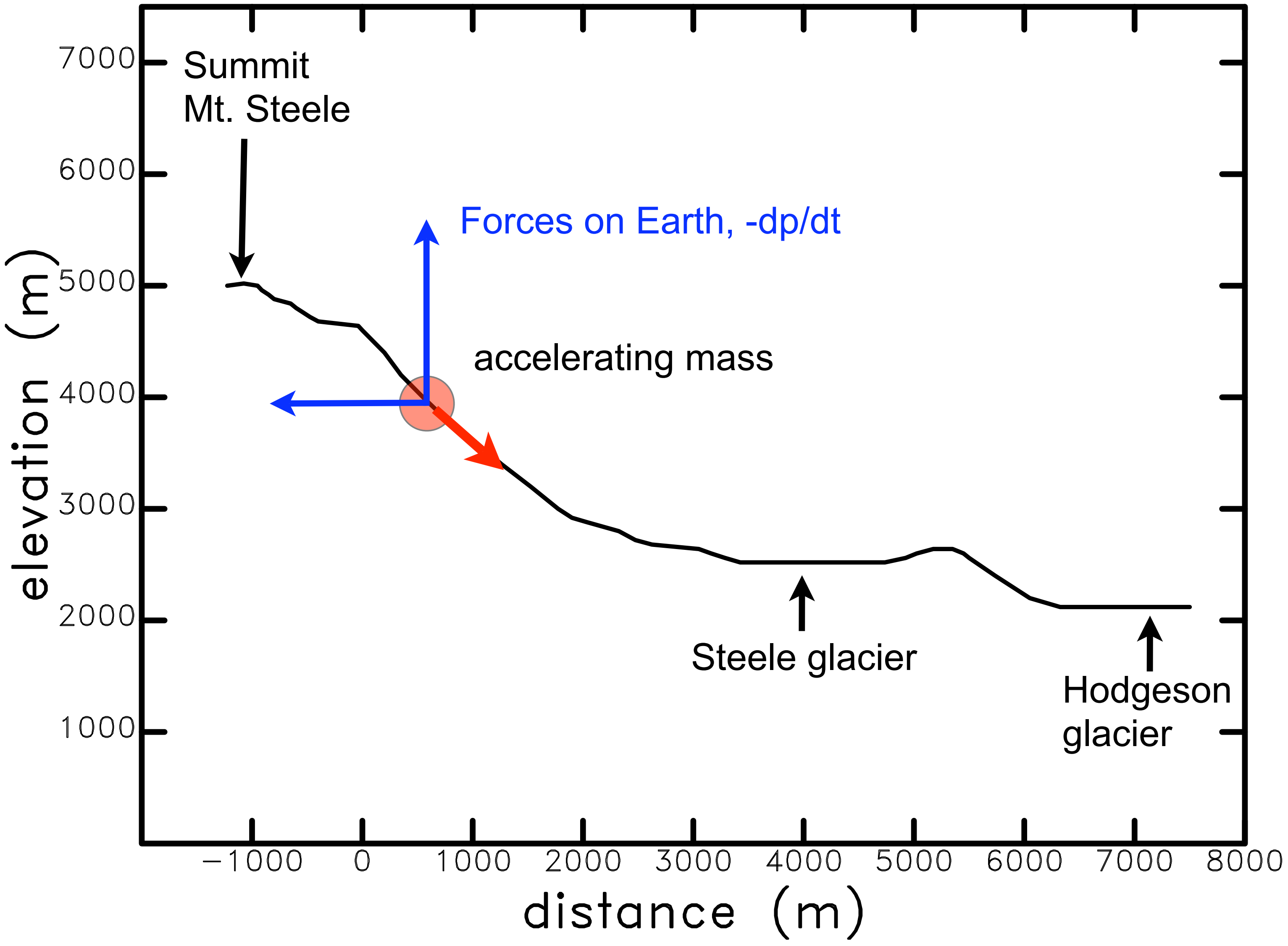


Mount Steele

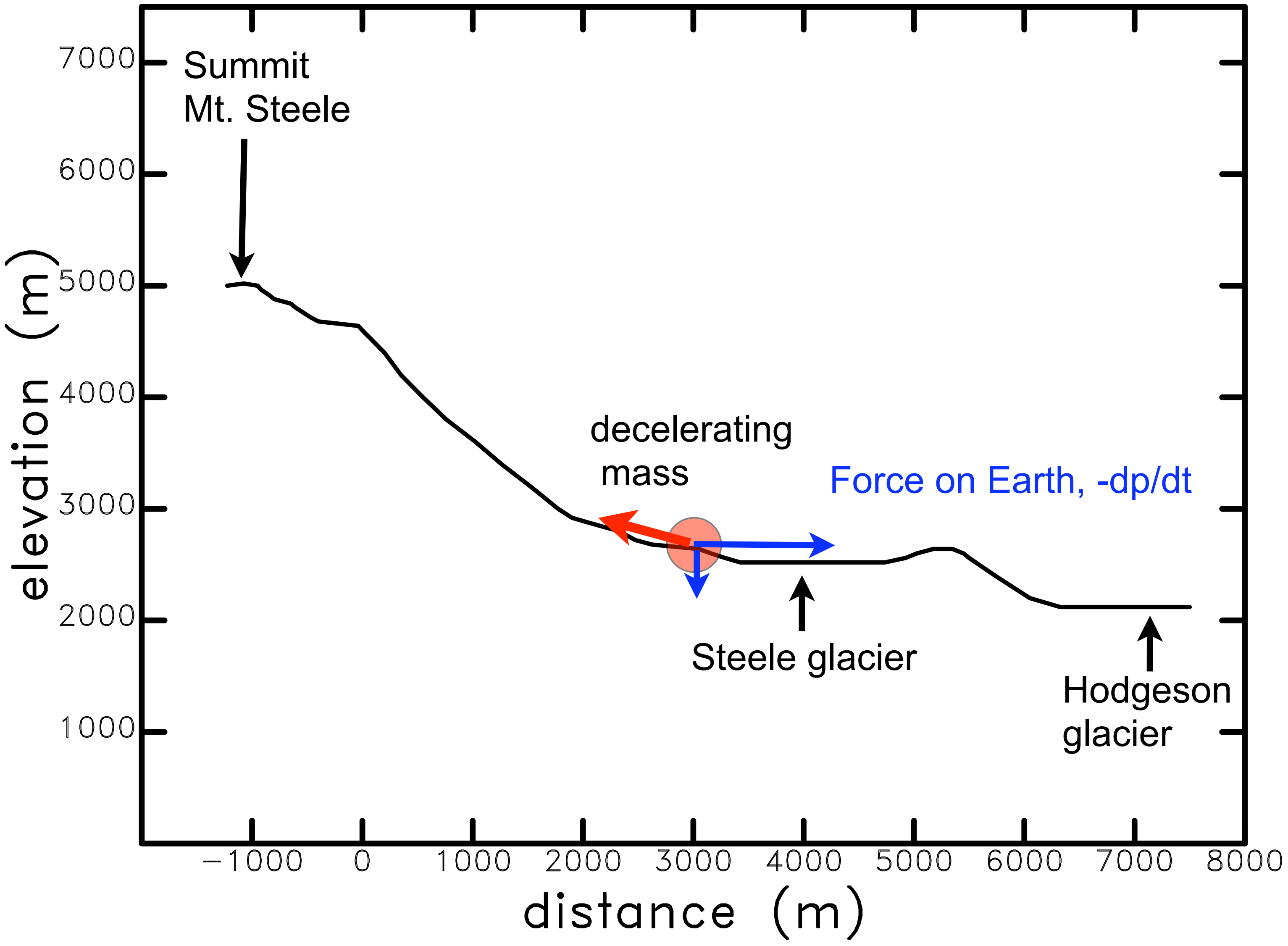
SI: DSCN0396.JPG

P. Lipovsky

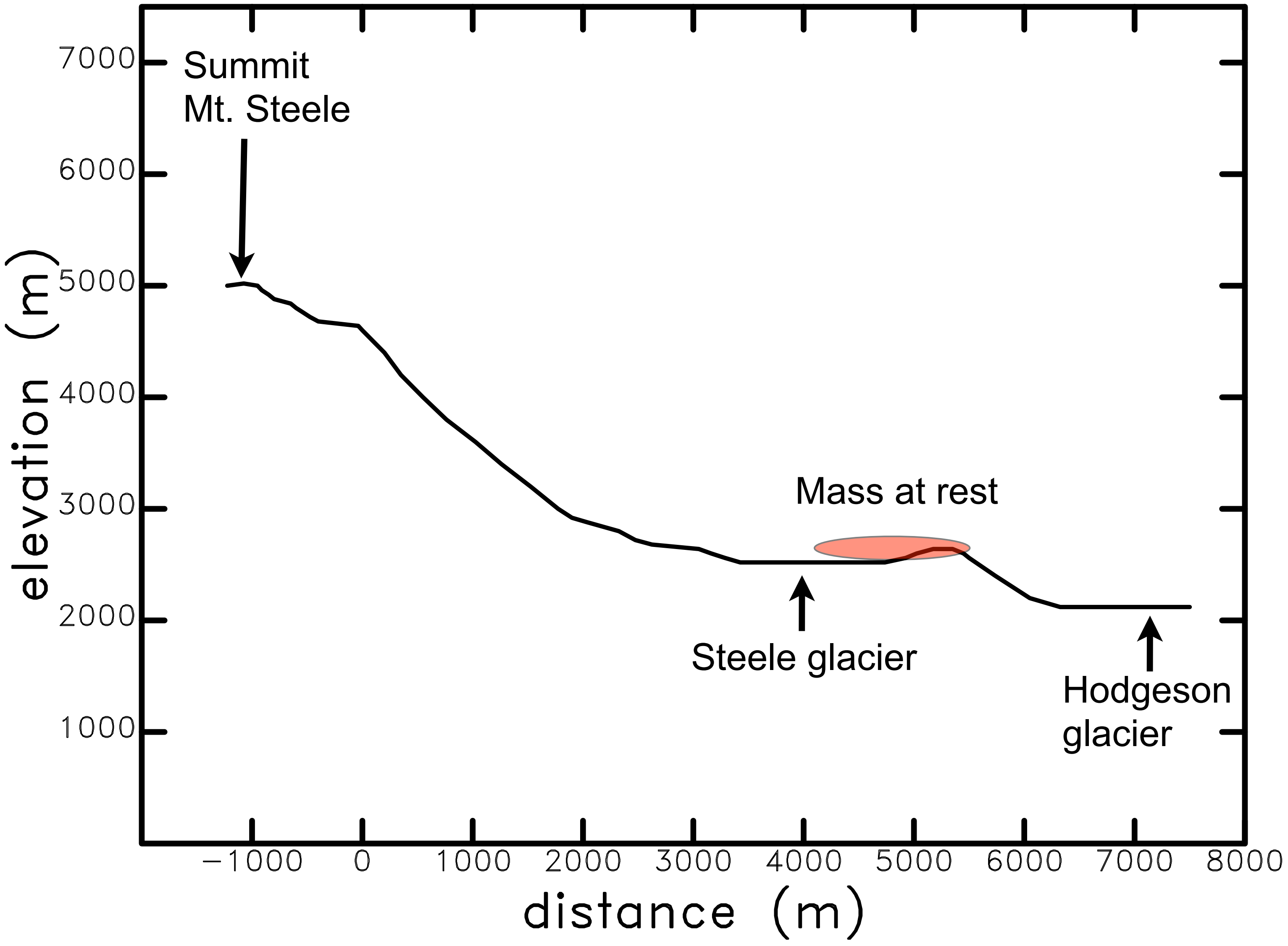
Mt. Steele rock avalanche, 7/25/2007



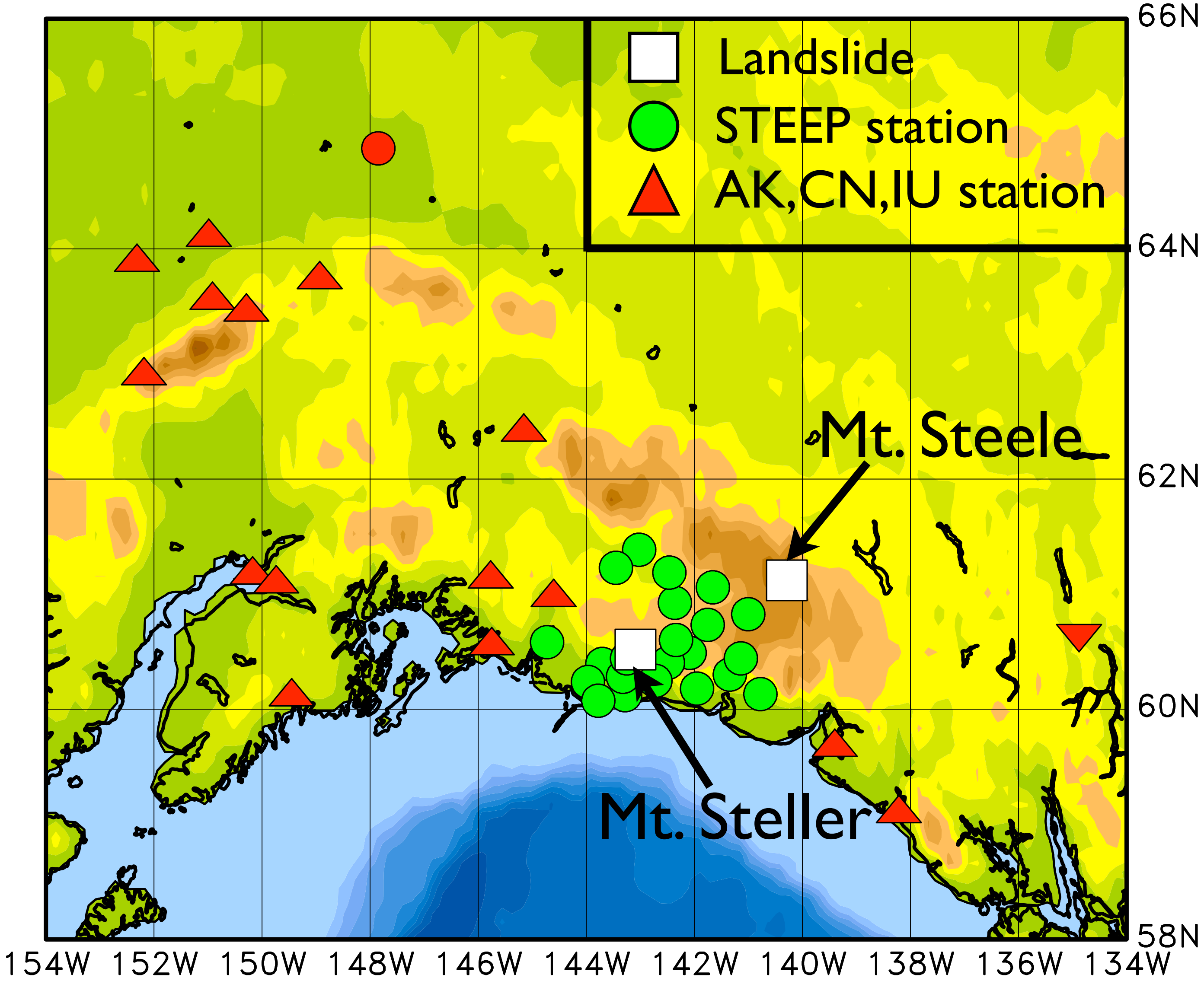
Mt. Steele rock avalanche, 7/25/2007



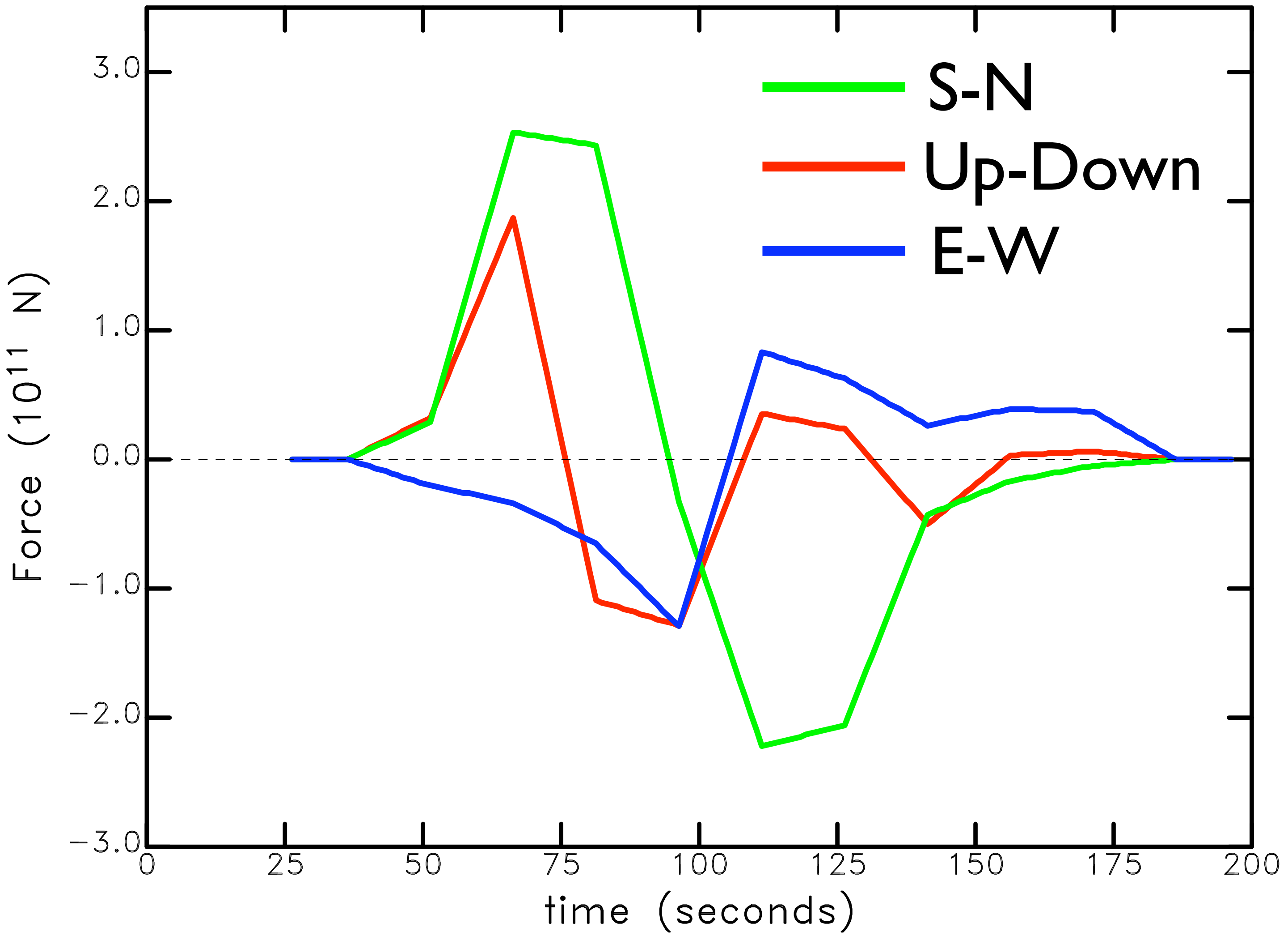
Mt. Steele rock avalanche, 7/25/2007



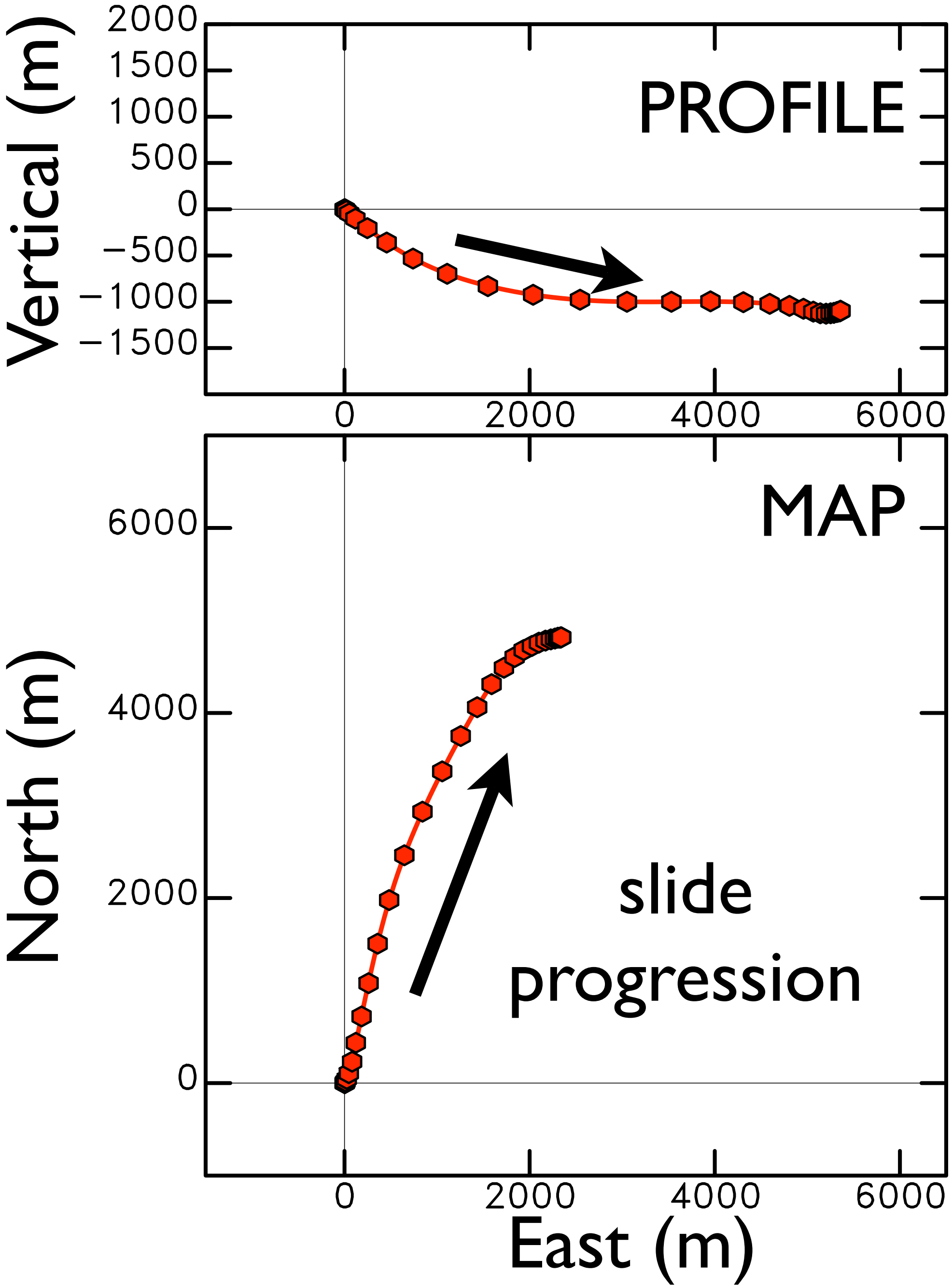
Seismographic stations near Mt. Steele and Mt. Steller



Result from inversion: forces acting on the Earth



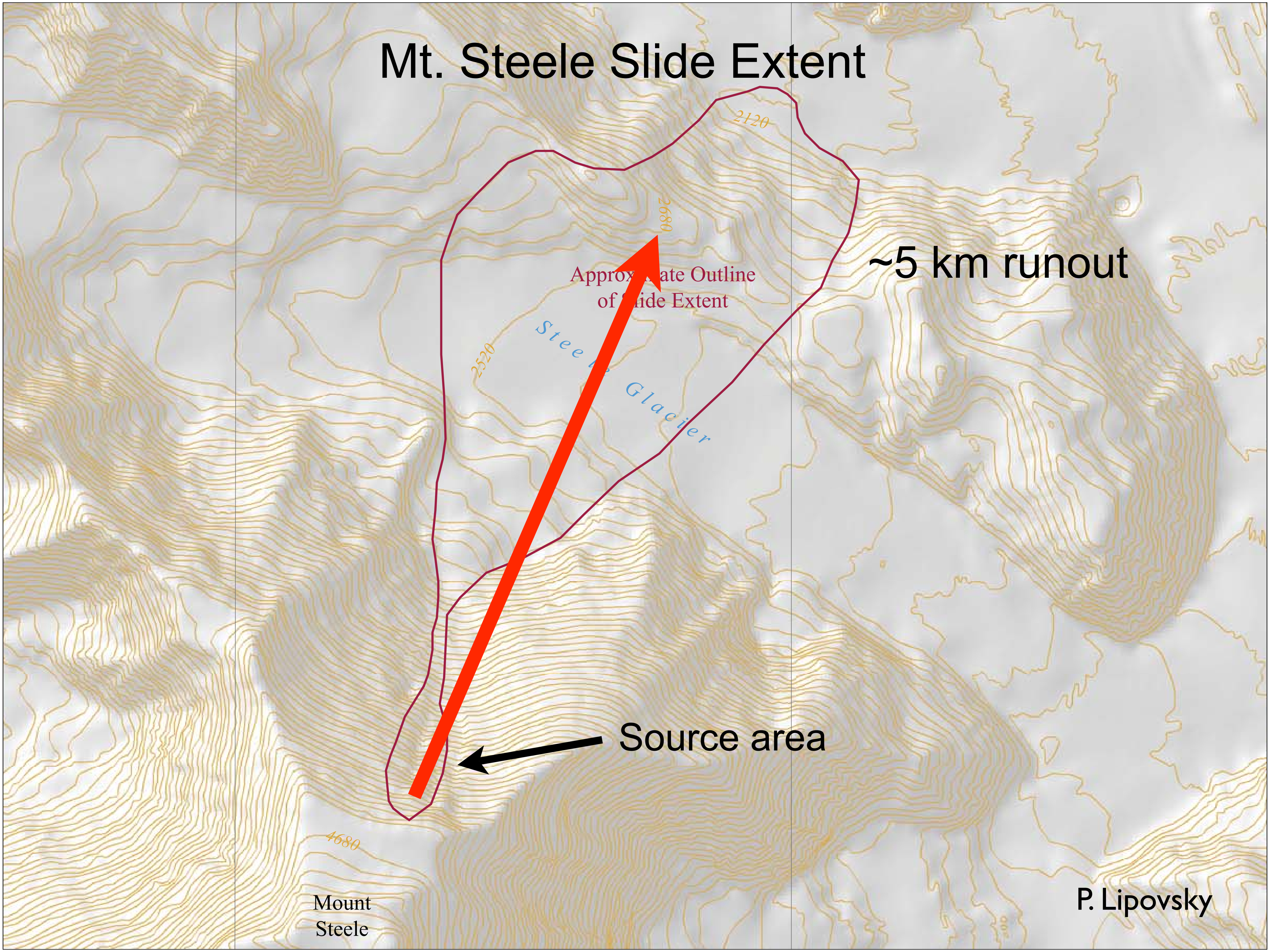
Mass runout and drop



mass:
8×10^{10} kg

(5 sec time step between symbols)

Mt. Steele Slide Extent



~5 km runout

Source area

P. Lipovsky

Preliminary conclusions:

1. Landslides can be detected and located using long-period seismograms

2. Details of the landslide source, in particular the mass, duration, vertical drop and runout, can be constrained by broadband seismology

3. The sliding mass for Mt. Steele is ~10^{11} kg

4. Other unassociated long-period events may be landslide earthquakes

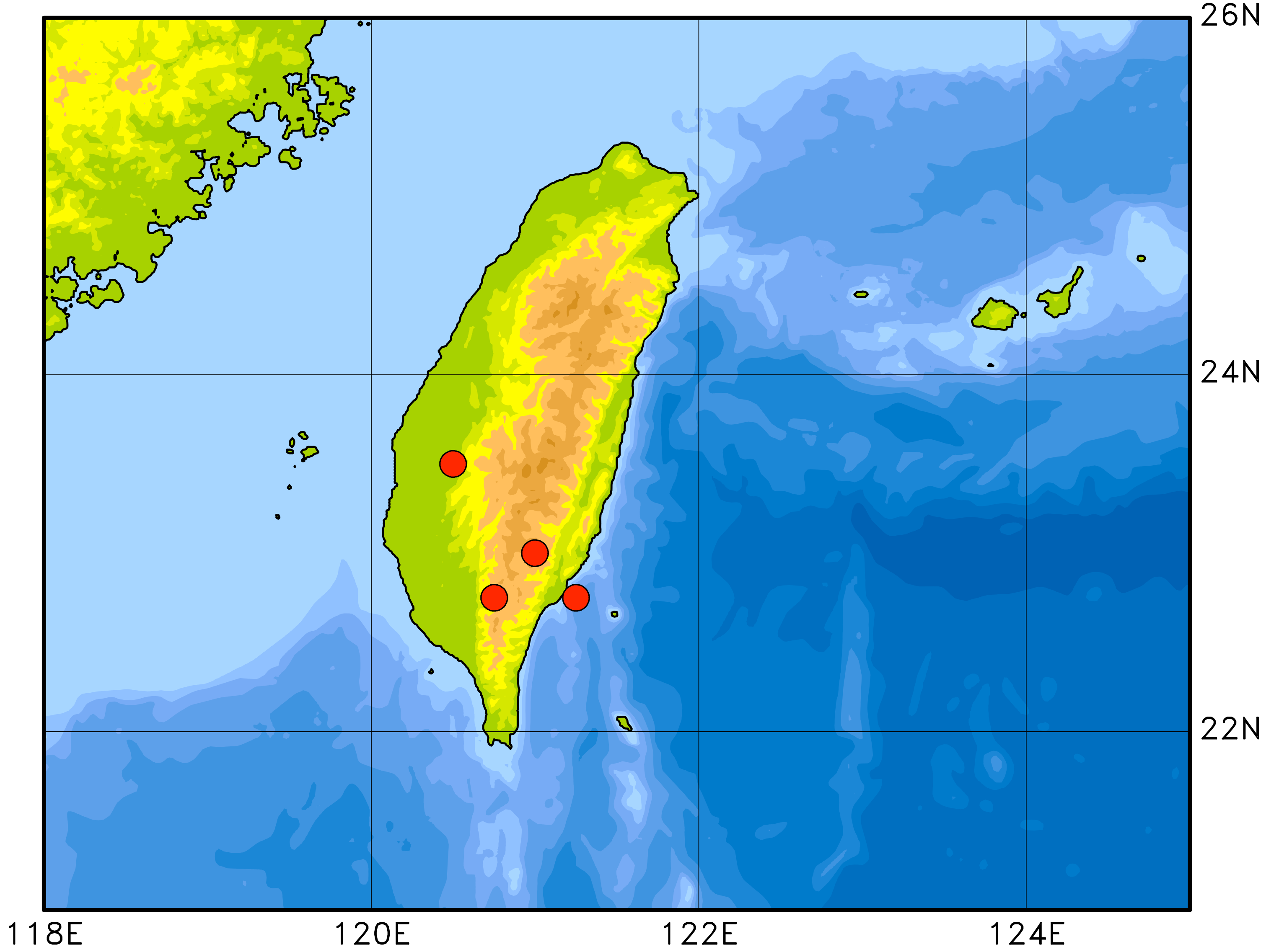
Source zone of Mt. Steller slide, 9/14/2005

R. Homberger, Ultima Thule

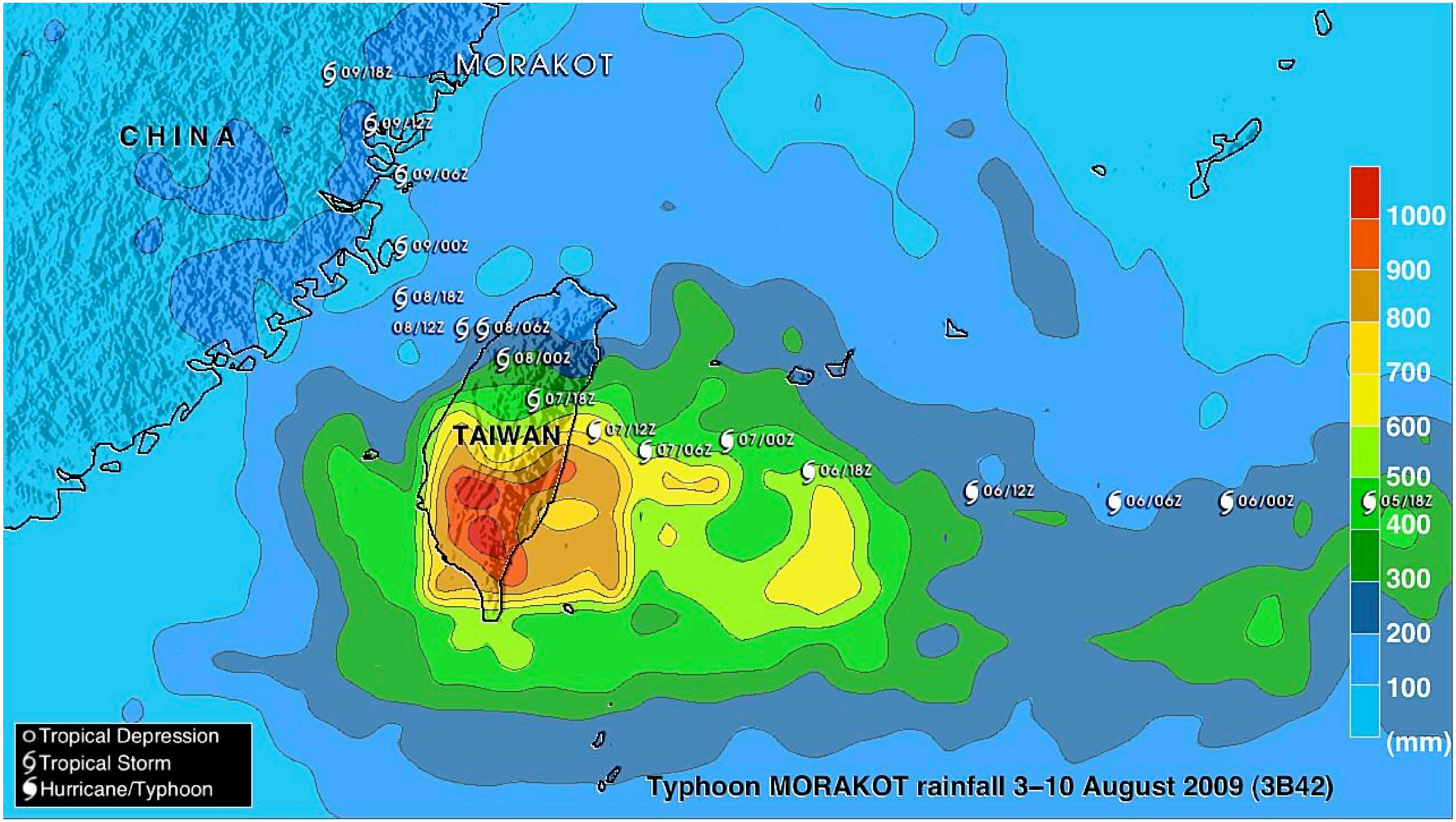
Val Pola landslide, 1987 (Italy)

Randa rockslides, 1991 (Switzerland)

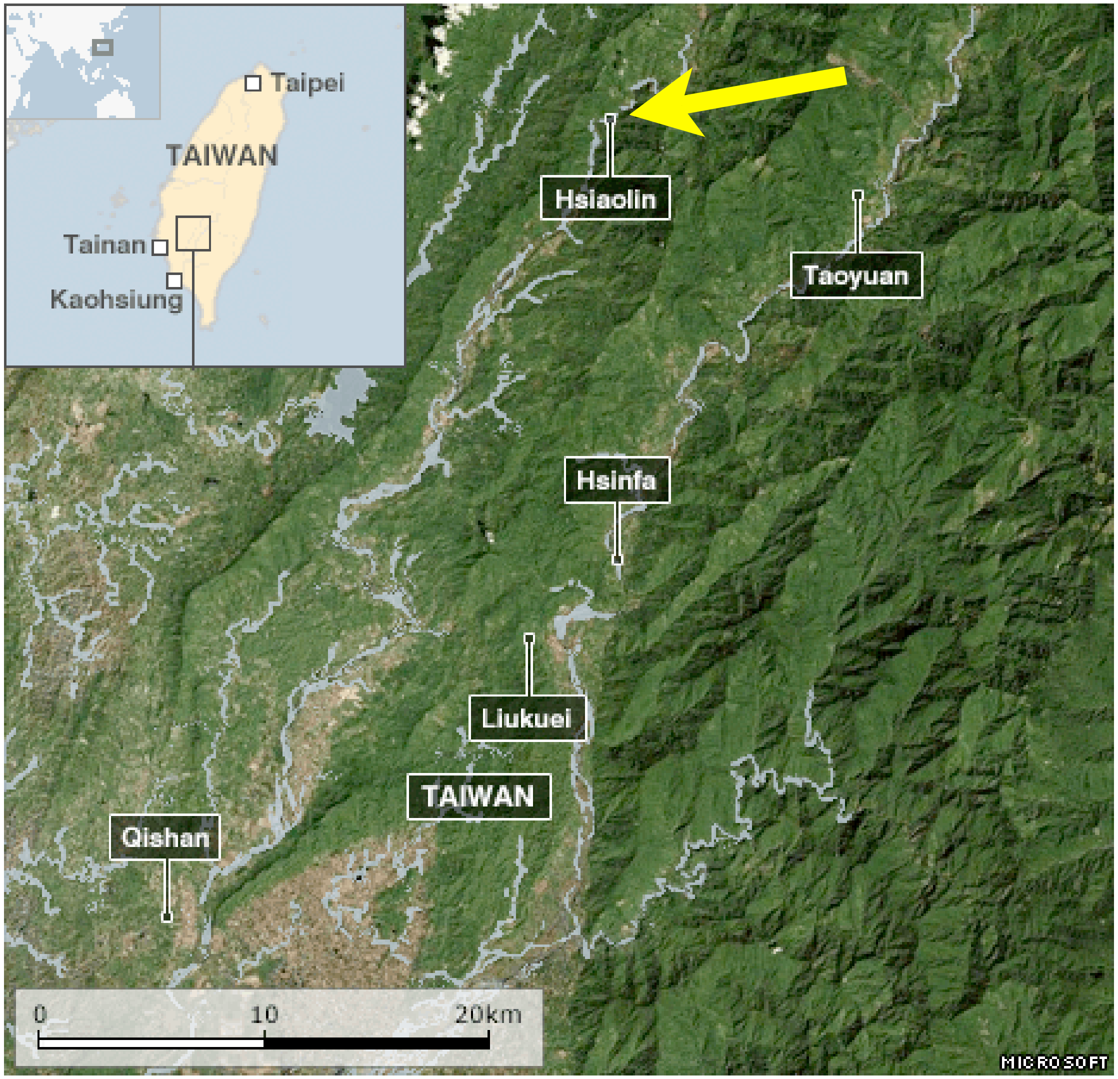
Four new M=5 events on Taiwan, Aug 8-10, 2009



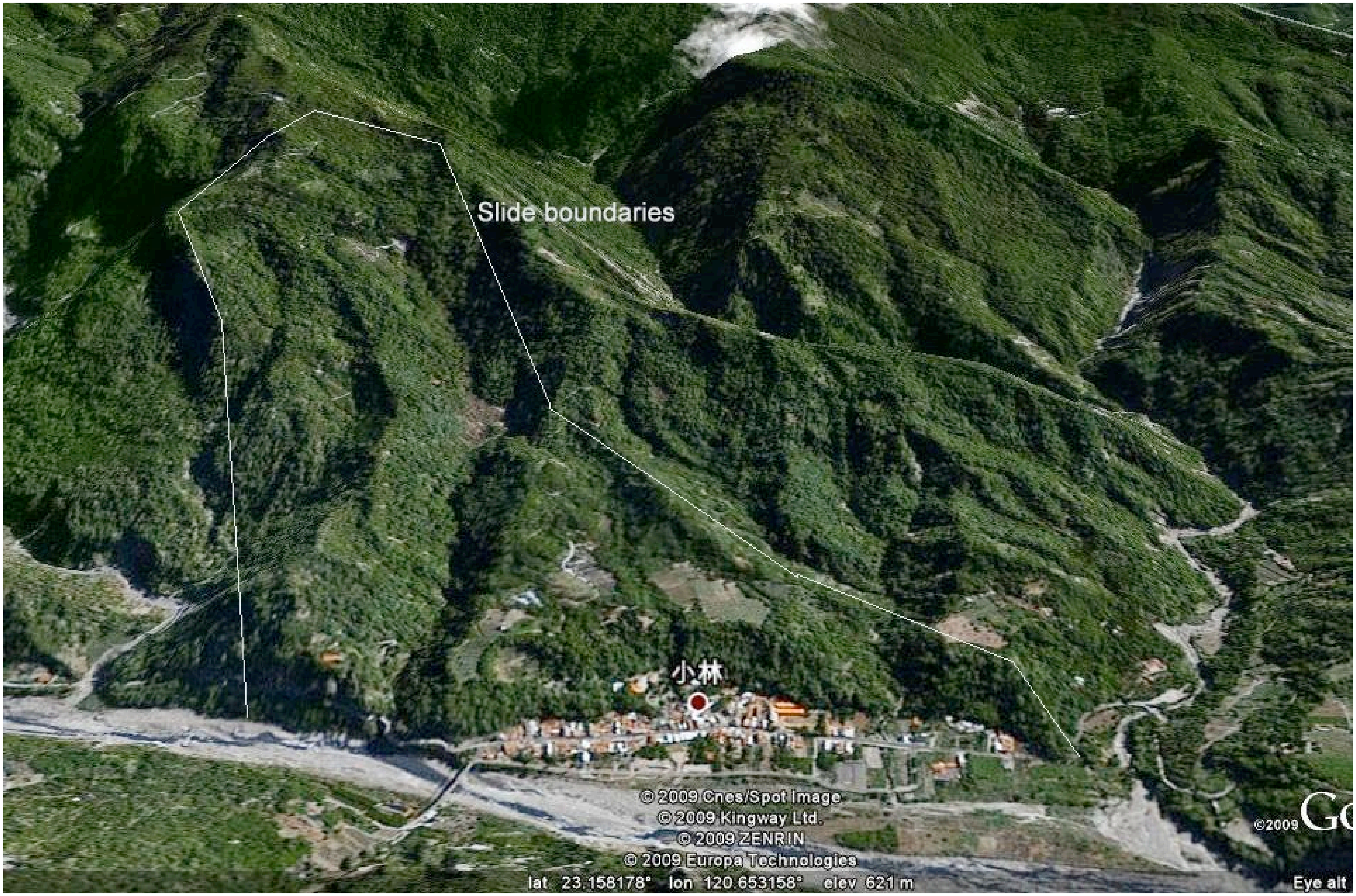
Rainfall associated with typhoon Morakot, 08/2009



Taiwan - area of massive landslides



Village of Hsiaolin and slide outline



Hsiaolin slide

before

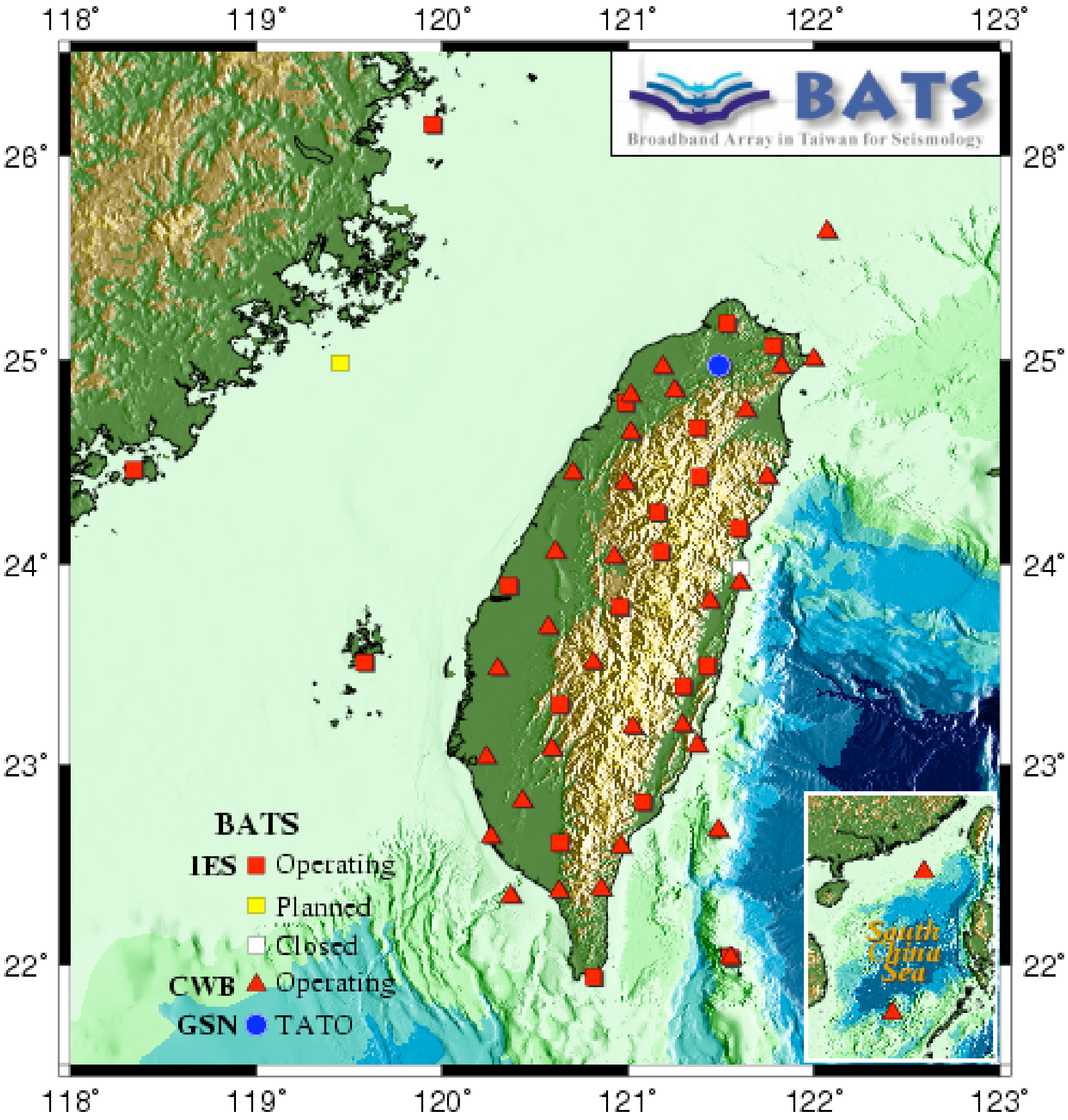
after

Some research questions:

1. How much information about individual landslides can be extracted from seismic observations?

2. How can seismology contribute to the monitoring of large mass-wasting events?

Ex-Premier Liu Chao-shiuan



Data Management Center, Institute of Earth Sciences, Academia Sinica

http://dmc.earth.sinica.edu.tw **http://bats.earth.sinica.edu.tw**

Main points

1. Noise can be very interesting

2. There are many geophysical phenomena that produce seismic signals (other than earthquakes):
    volcanos, landslides, cavity collapses,
    glaciers, asteroids, storms, waves, ...

3. Seismology can be used to investigate and monitor events other than earthquakes