Fluvial Seismology
Case study 1

Presenting study from -

- Burtin, A., Bollinger, L., Vergne, J., Cattin, R., and Nábělek, J. L. (2008), Spectral analysis of seismic noise induced by rivers: A new tool to monitor spatiotemporal changes in stream hydrodynamics, *J. Geophys. Res.*, 113, B05301, doi:10.1029/2007JB005034.

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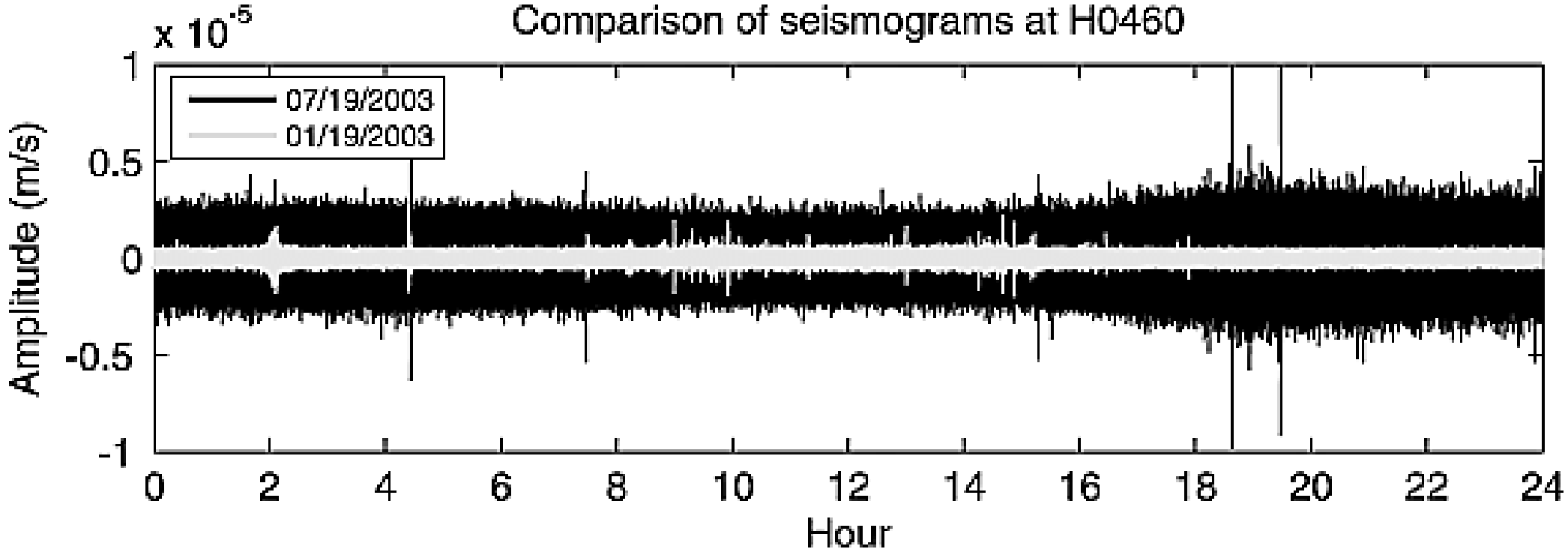
Indian Institute of Science, Bengaluru

Analysis of seismic noise induced by rivers

A. Burtin et al. 2008

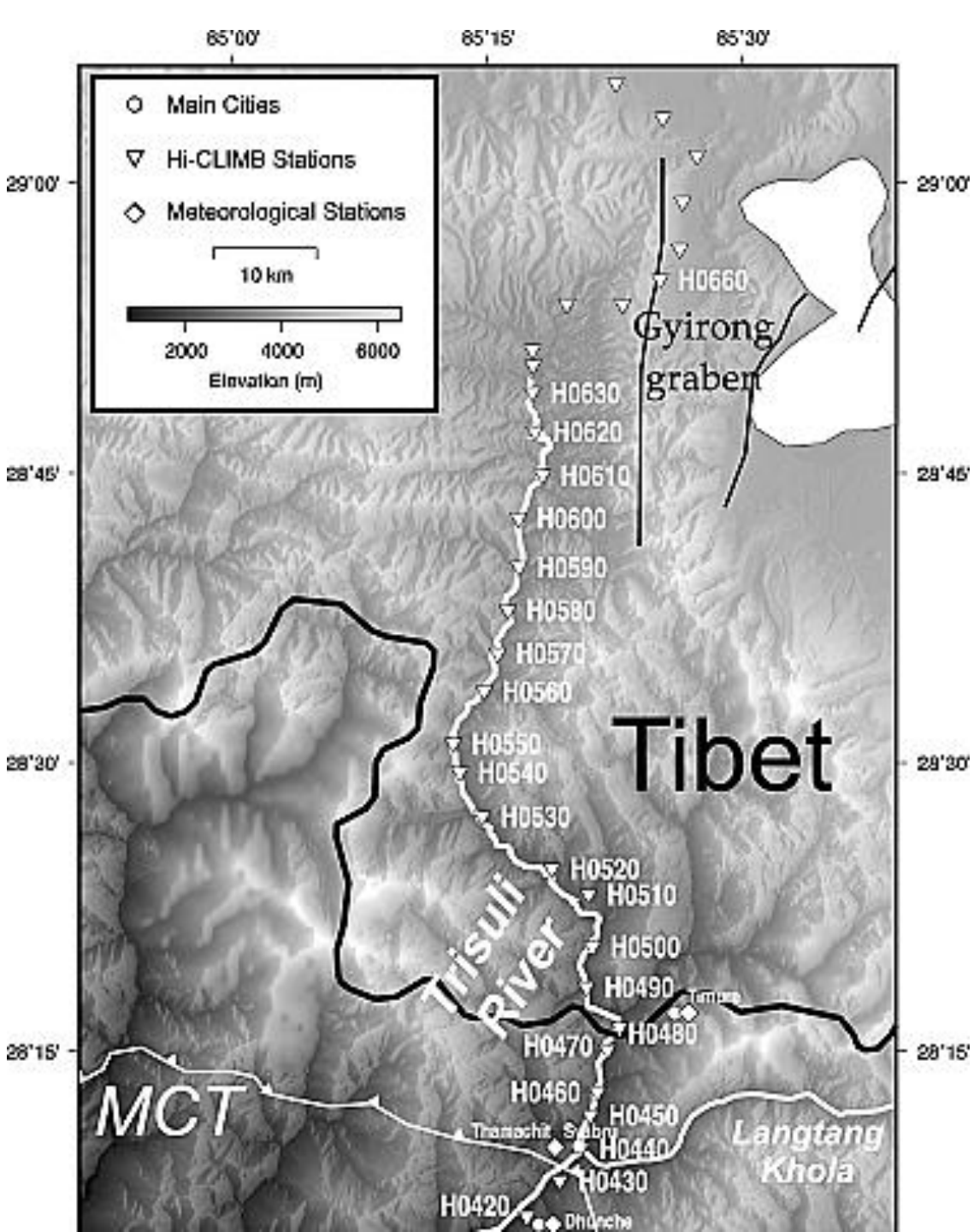
Aim of the analysis:
To found out the potential of using background seismic noise to quantify in continuous river bed load and monitor its spatial variations.

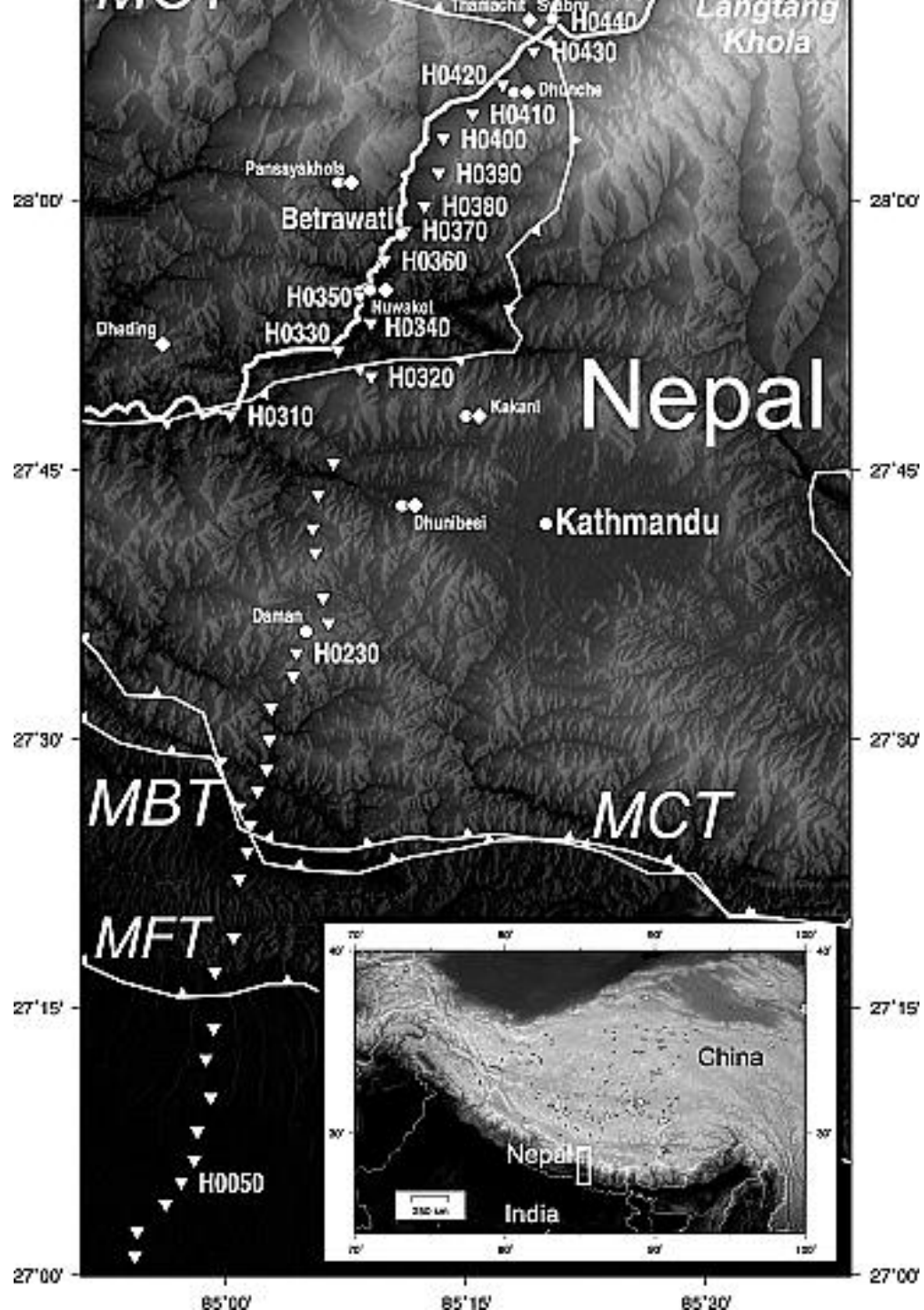
The data was used from Himalayan Tibetan Continental Lithosphere during Mountain Building experiment (Hi-CLIMB), a project designed to image the lithospheric structures across the Himalayan collision zone. During this 3-year experiment, 115 broadband seismometers were deployed from southern Nepal to the Bang-gong suture in central Tibet along the Trisuli River.



Comparison of two 1-d-long vertical seismograms recorded at station H0460. A full day of January (19 January 2003) and July (19 July 2003) are represented in white and black, respectively.

- During summer, high-frequency noise is one order larger than during winter.
- Daily variation of the noise during summer is also noticed, with larger noise amplitude at night than during the day.


Main Cities
Hi-CLIMB Stations
Meteorological Stations
10 km
2000
4000
6000
Elevation (m)
85°00'
85°15'
85°30'
29°00'
28°45'
28°30'
28°15'
H0660
Gyirong graben
H0630
H0620
H0610
H0600
H0590
H0580
H0570
H0560
H0550
H0540
H0530
H0520
H0510
H0500
H0490
H0480
H0470
H0460
H0450
H0440
H0430
H0420
Tibet
Trisuli River
Timure
Thanachit
Syabru
Dhunche
MCT
Langtang Khola


MCT
Thanachit
Syabru
H0440
H0430
H0420
Dhunche
H0410
H0400
H0390
H0380
H0370
H0360
H0350
Nuwakot
H0340
H0330
H0320
H0310
Kakani
Panasyakhola
Betrawati
Dhading
Langtang Khola
Nepal
Dhunibeesi
Kathmandu
Daman
H0230
MBT
MCT
MFT
H0050
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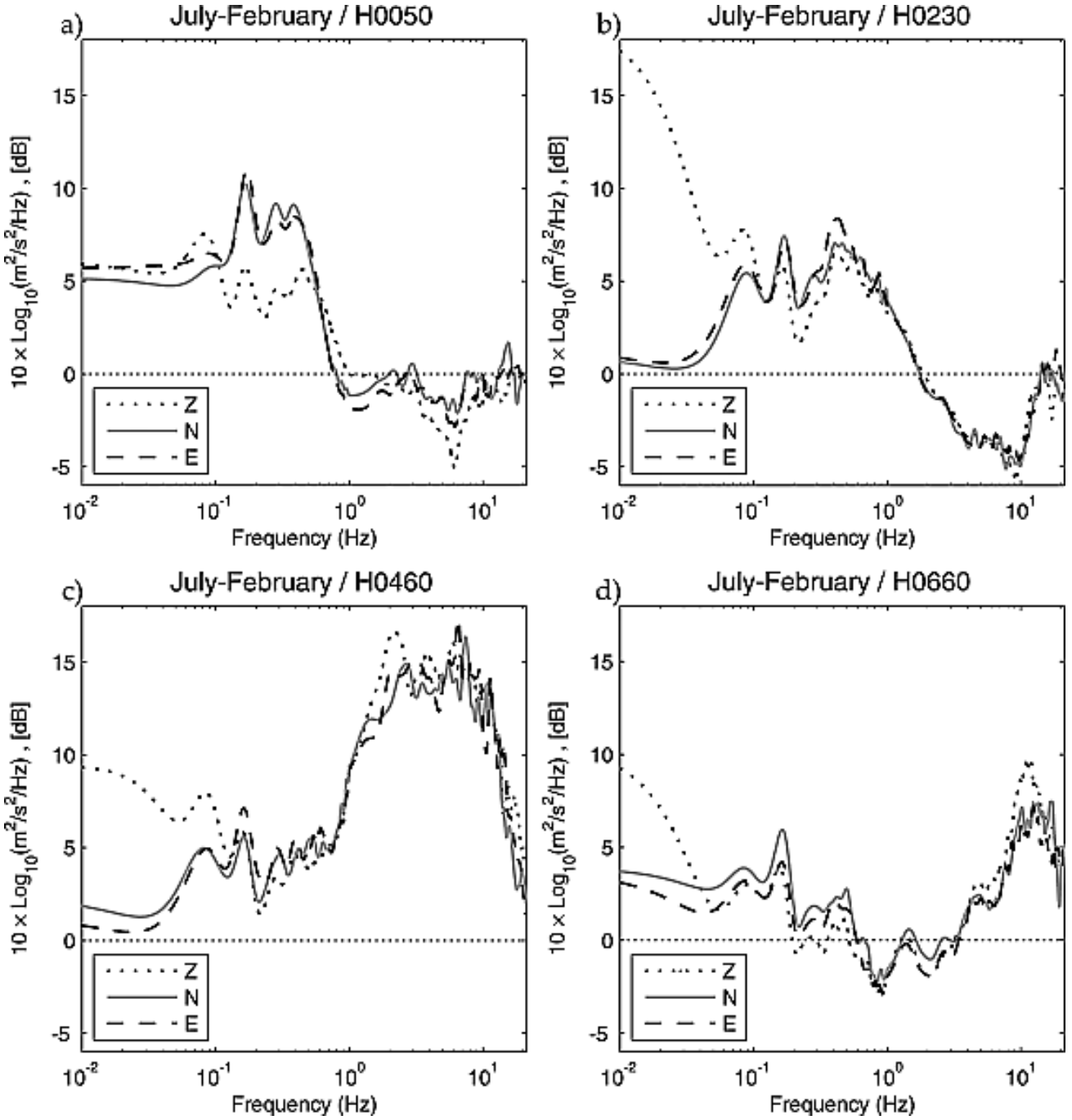


Seasonal Fluctuations

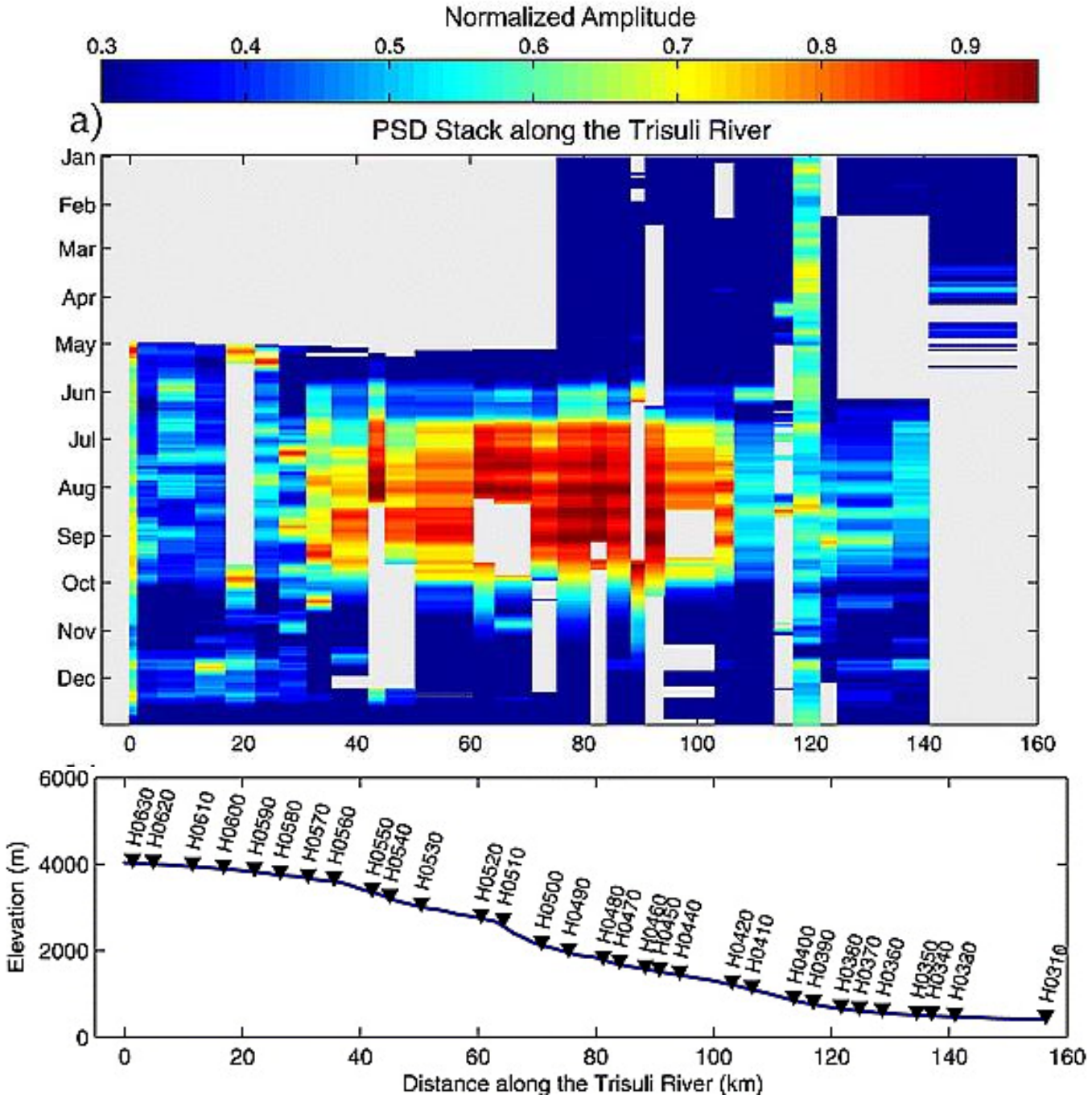
In the microseism band (0.1–1 Hz), stations H0050, H0230, and H0460 record larger energy amplitudes in July by about 5 to 10 dB .

Possible explanation: The appearance of oceanic depressions localized over the Gulf of Bengal during the summer monsoon period could explain the enhancement of oceanic swell.

H0460 : (nearest to trisuli river) The noise amplitudes on the seismograms from station **H0460** are then 6 times larger at high frequency during the monsoon period than during the dry season. A similar observation was made at most stations located along the Trisuli River.

Possible explanation: ??

Seasonal fluctuation of seismic noise: obtained by subtracting the average July PSD to the average February PSD for 2003 at stations (a) H0050, (b) H0230, (c) H0460, and (d) H0660.



- The daily noise levels at stations close to the Trisuli River, reveals a strong increase of the high- frequency energy (>1 Hz), from stations H0410 to H0560 from June to September.
- For these stations, the level of noise shows a first increase at the end of May lasting until mid-June.
- Then, the energy reveals a second increase and reaches an almost constant level until the end of September with intermittent peaks that are well correlated between stations.
- The time period of energy enhancement coincides with the summer monsoon period in Nepal.

Steep local gradient

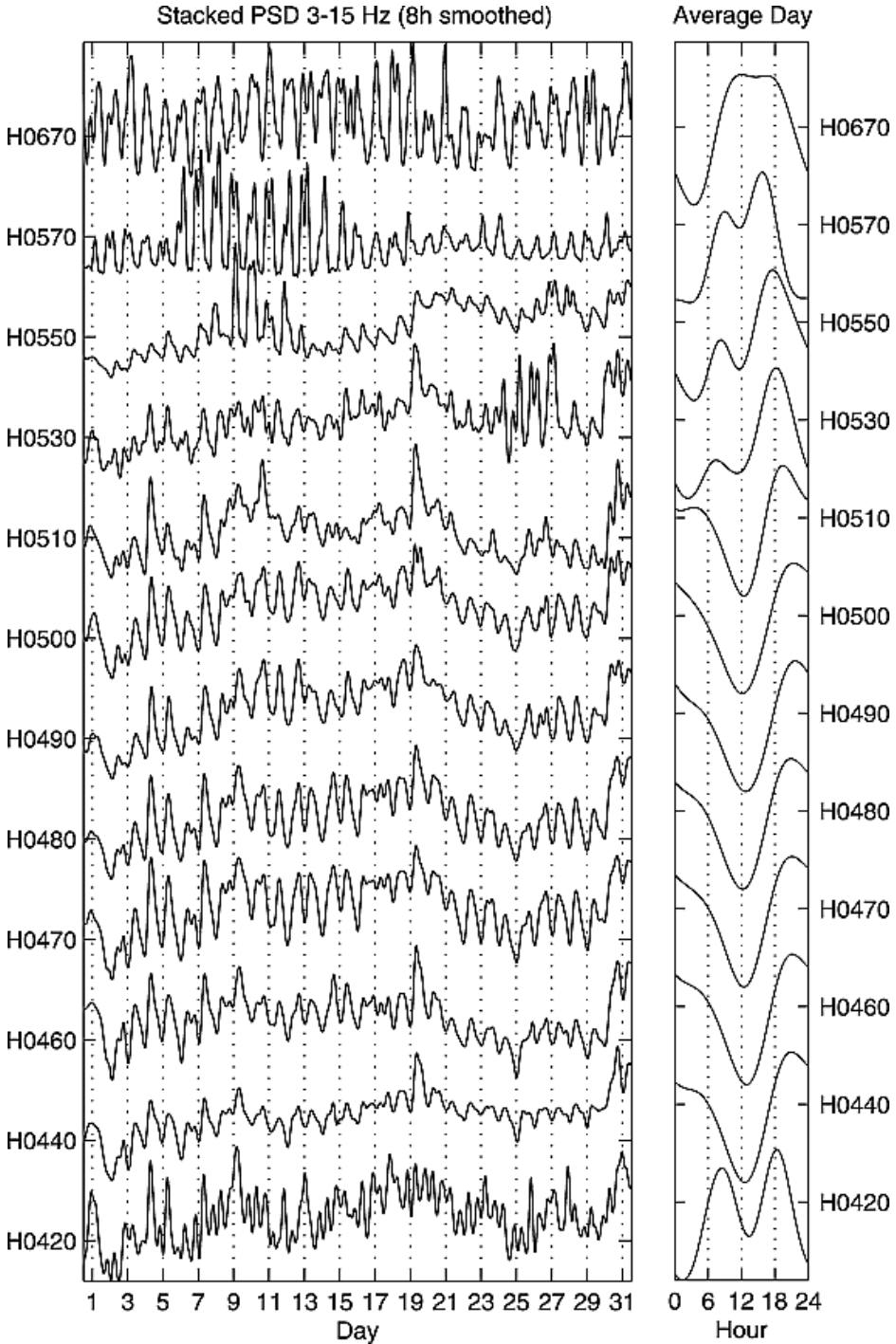
Mean vertical PSDs at Hi-CLIMB stations along the Trisuli River.
Location of the Hi-CLIMB stations (downward black triangles) projected on the elevation profile of the Trisuli river.

What do you think could be the possible explanation for this type of seismicity?

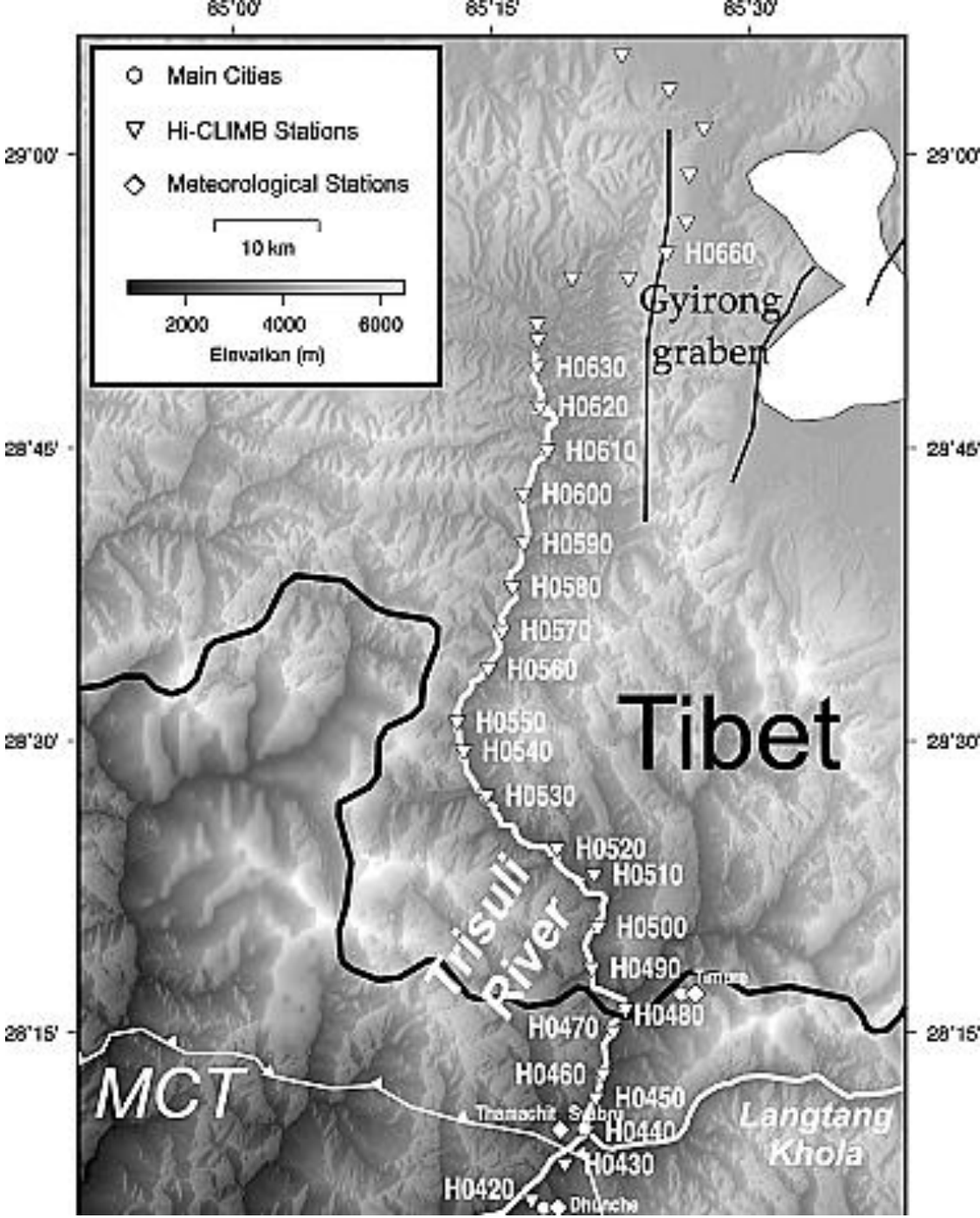
a) More amp during July at seismometer near river?
b) High seismicity during night than day?
c) High PSD at seismic stations along Trisuli river?

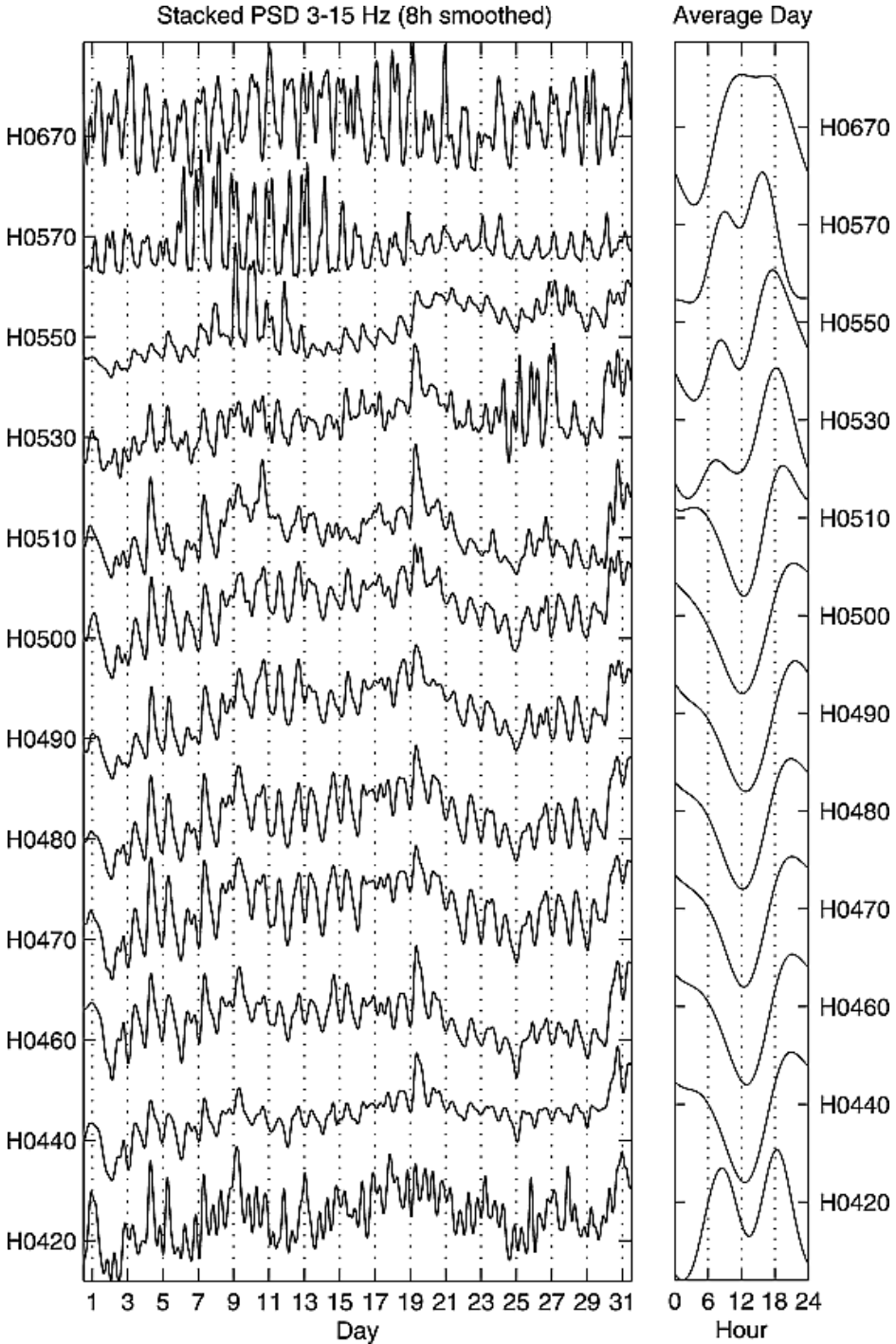
- Anthropogenic source ??
- Glacial melt (seasonal fluctuation) ??
- Precipitation ??
- Water level of river ??
- Bed-load transport ??
- Any other idea??

Let's see which one or more may be the possible reason...



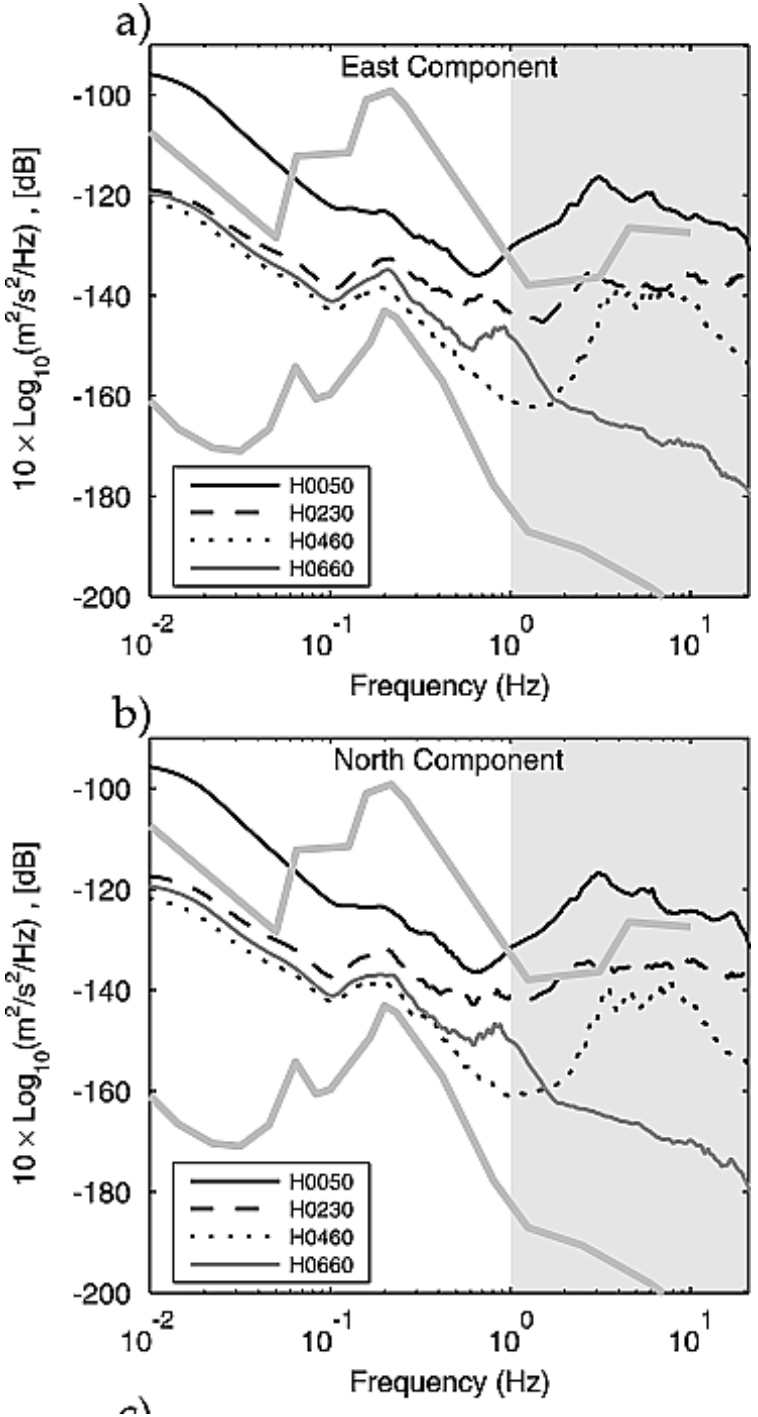
(a) PSDs stacked over a frequency band of 3–15 Hz for July 2003.





- The hourly fluctuation of the summer high-frequency energy is shown in Figure.
- This 24-h cycle has a minimum amplitude reached at 01 pm and a maximum amplitude late in the evening.
- This suggests that the source responsible for this seismic noise is anticorrelated with the possible sources of anthropogenic noise, which has a minimum at night.
- This 24-h periodic signal is observed from stations H0440 to H0510 covering about 30 km along the Trisuli River.
- South of station H0420 and north of H0510, the diurnal modulation of the summer seismic noise at high frequencies is not present.
- These ‘‘low-noise’’ regions coincide with areas where the gradient of the river stream is small.

(a) PSDs stacked over a frequency band of 3–15 Hz for July 2003 and for a set of Hi-CLIMB stations from north to south, top to bottom, respectively. (b) Corresponding mean daily noise level variations calculated by summing 24-h-long segments of the curves



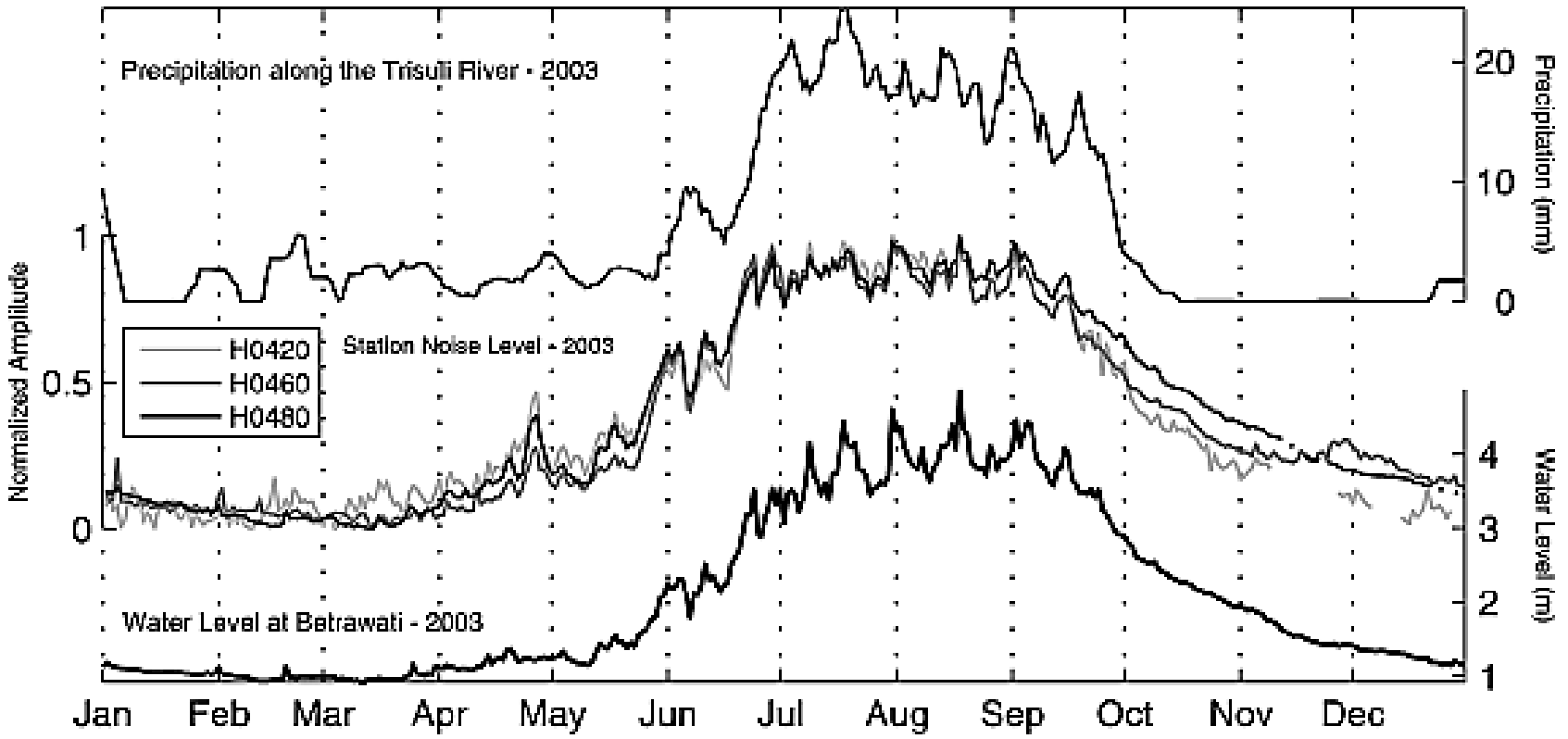
Mean annual (2003) PSDs.

The large gray lines are the new high noise model (NHNM) and the new low noise model (NLNM) of Peterson [1993].

- In the high-frequency band (>1 Hz), the energy decreases up to 50 dB from south (station H0050) to north (station H0660).
- This noise decrease is consistent with a northward decrease in population density from Nepal to Tibet.
- Station H0460 have a similar noise level energy at high frequencies as H0230. And almost all stations from H0410 to H0570 exhibit a similar noise level energy, in the frequency band 2–12 Hz.
- <u>These stations are located far from any major cities</u> and high traffic roads, thus the origin of this seismic noise, in this frequency band, **<u>cannot be linked to anthropogenic sources</u>** and is rather related to natural sources.

Stations near Trisuli river shows seasonal variations of energy at high frequencies, this suggests an interaction between the source of noise and the river discharge.

To test this hypothesis we compare local meteorological and hydrological data with the noise level curves obtained from the seismic stations installed along the river.



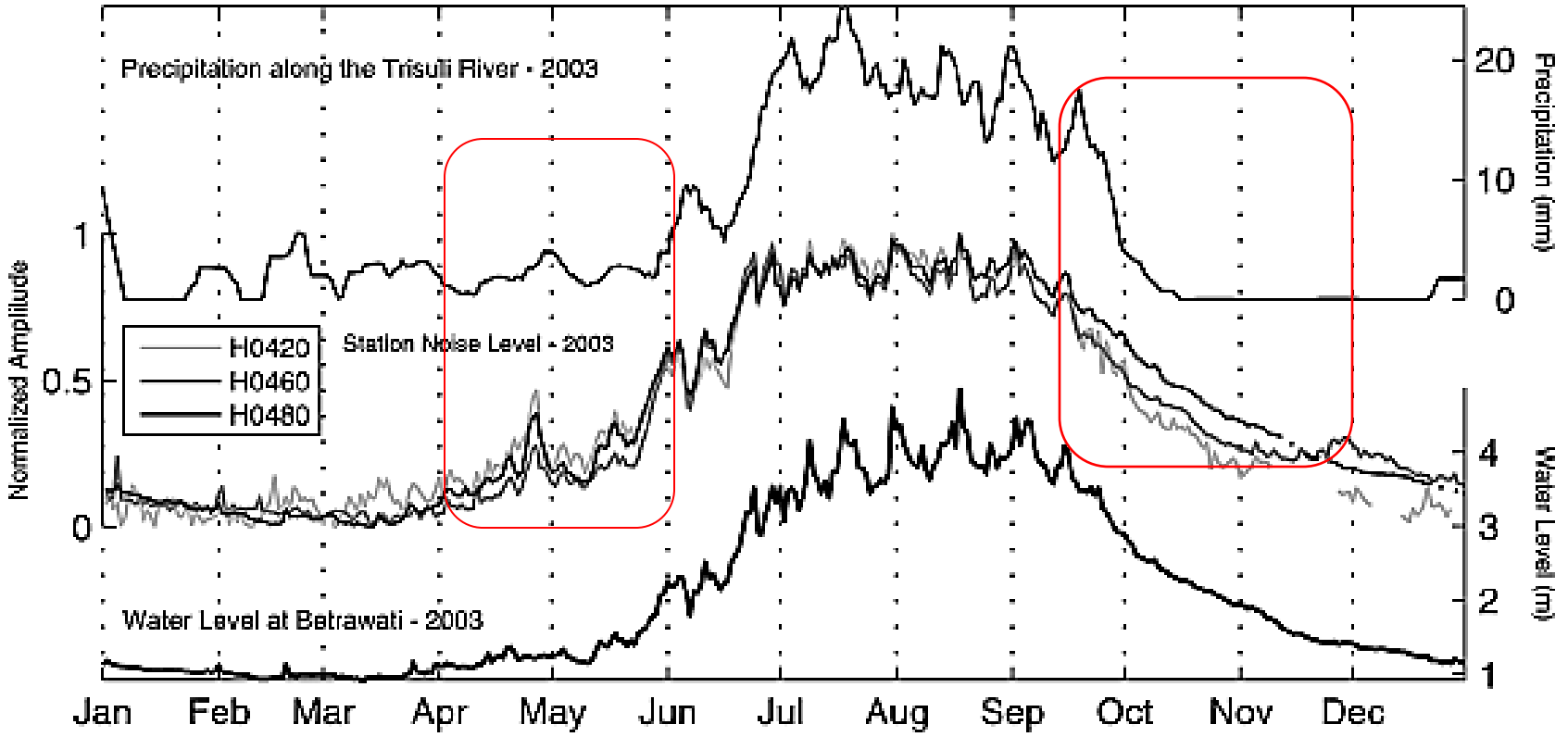
Top curve is the 10-d centered moving average of the daily precipitation rate in mm for year 2003 at 8 meteorological stations from the Department of Hydrology and Meteorology of Nepal (DHM) located along the valley of the Trisuli River.

Middle curves are the high-frequency noise level (averaged over the three components and the frequency band 3–15 Hz for year 2003) at stations H0420, H0460, and H0480.

Bottom curve is the Trisuli water level in meters measured at the town of Betrawati near station H0370 during year 2003.

From January to May the precipitation in the region are rare and weak meanwhile the noise level is low. However, the noise level time series does not correlate with the rare local rainfall.

In June at the onset of the monsoon season, the precipitation rate increases and remains at the highest levels of the year until the end of September. In June, seismic noise at the observed stations increases rapidly, reaching an amplitude threshold for the following three months.

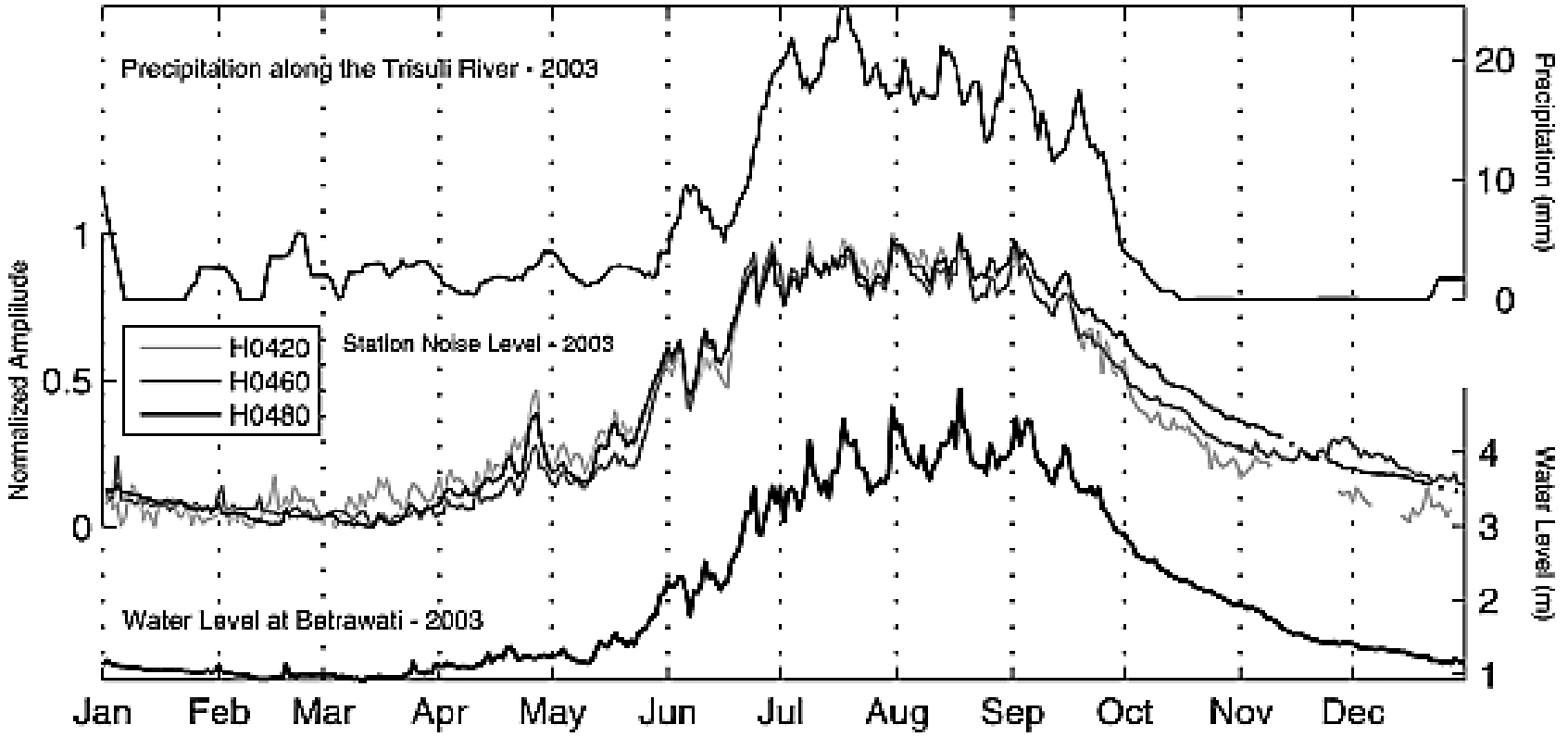


At the end of September, the precipitation rates depict a sudden decrease whereas the recession of ambient noise is gentler.

- Peaks of noise level during the monsoon period are not well in phase with peaks of precipitation.
- Correlation coefficient between noise amplitude at H0460 with precipitation is 0.61.

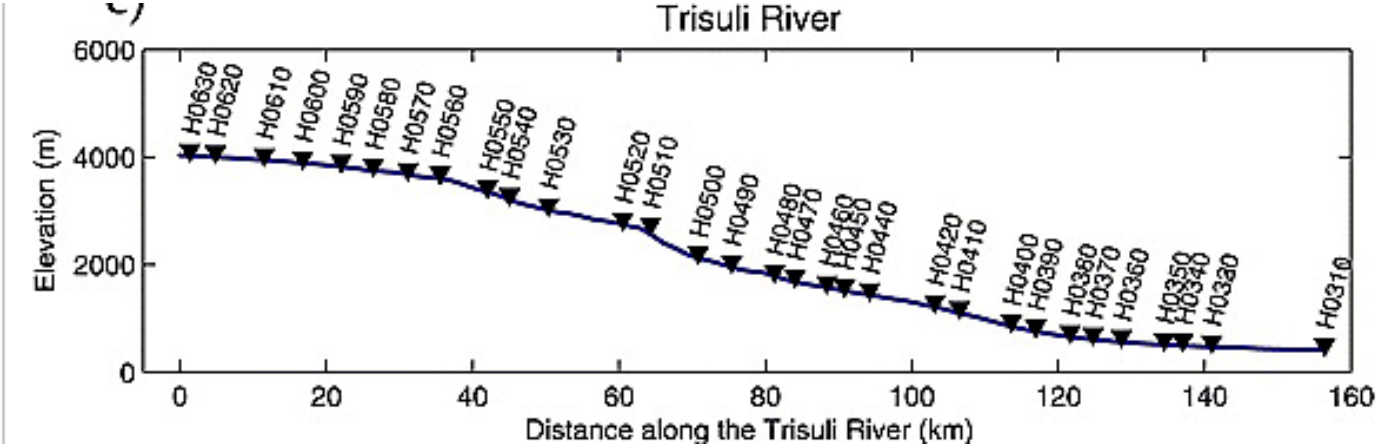
Water discharge through Trisuli river was continuously monitored and we find-

1. Gentle increase of discharge from April to May. 2. Rapid augmentation in June due to the fast melting of snow and ice in glaciers in response to increased air temperature. 3. In July and August, discharge rates reach the largest values. 4. September to October- period of rapid discharge recession. 5. Whereas from November to March the discharge decreases only slightly.

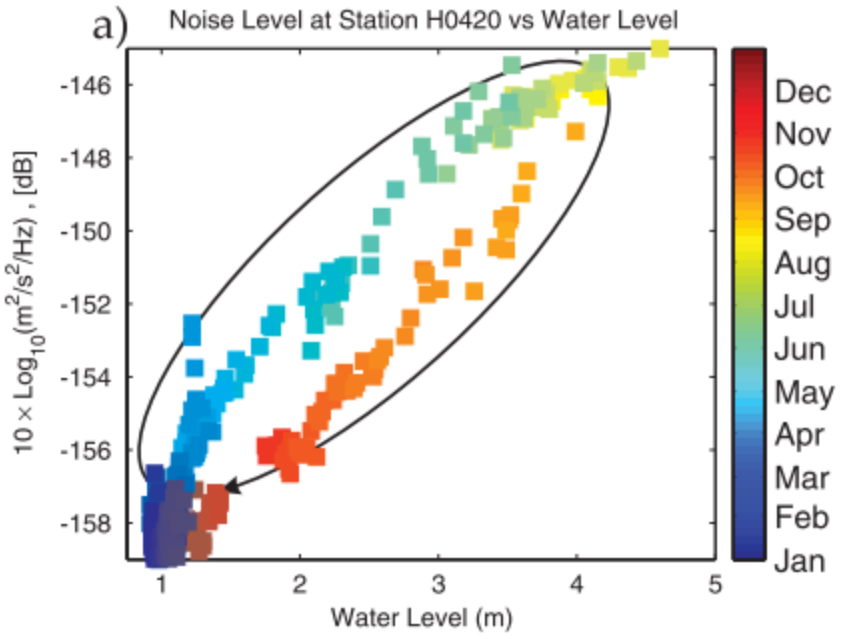


- During the monsoon period, the time series of both data sets is well correlated.
- The correlation coefficient between H0460 seismic noise and water level is 0.86, whereas it is only 0.61 with precipitation.

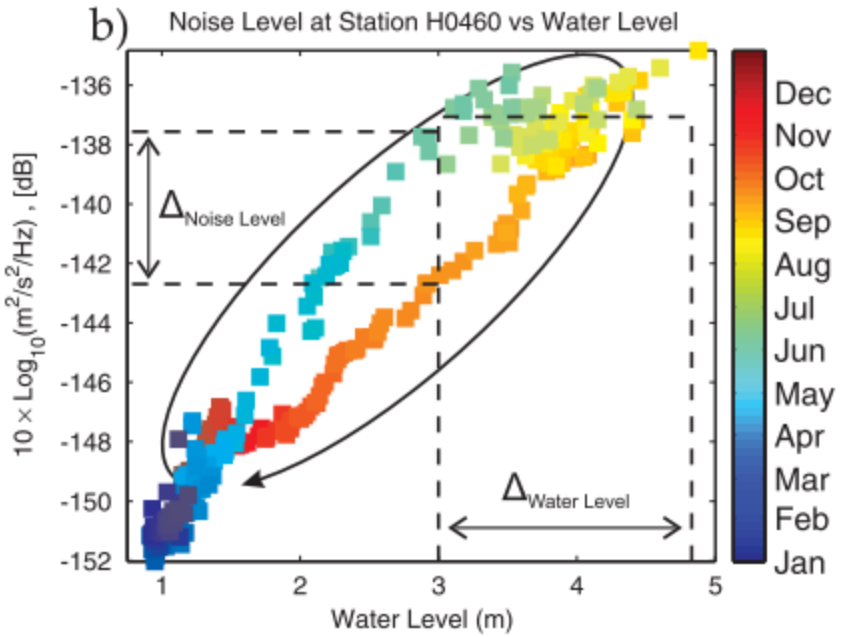
- South of station H0370- weak gradient and a wide channel, up to 100 m during the monsoon, and the supply of water is mainly accommodated by an increase of the width.
- Through the High Himalayan range- strong gradient and the channel is narrow, around 10 m. Flanked by steep slopes, the large amount of water supplied by the monsoon is mainly balanced by an increase of the water level, which enhances the basal shear stress of the Trisuli River.

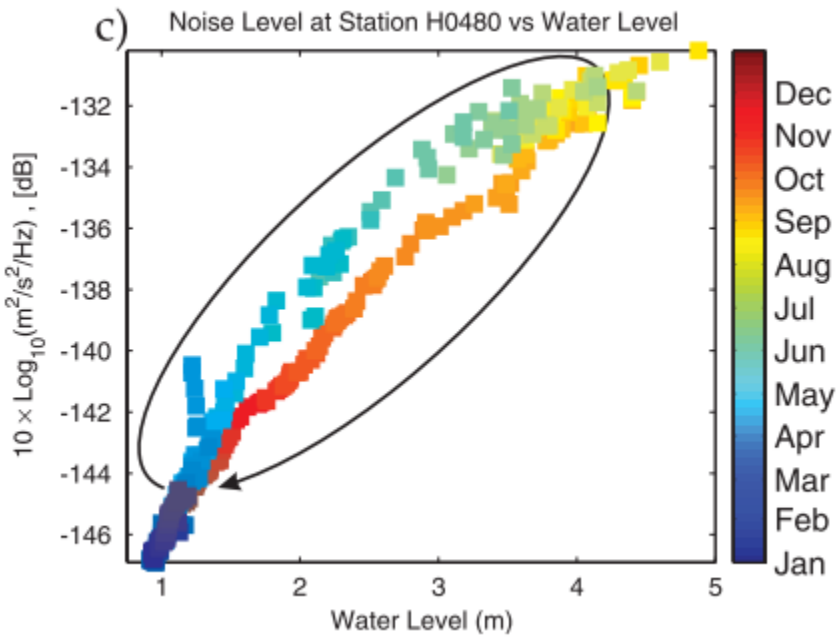


- Effect of the increase in the basal shear stress is the initiation of the bed load motion.
- The correlation of the integrated seismic noise with the water level of the river reveals that the hydrodynamics is a possible source of seismic noise.
- Because of a larger river discharge during the monsoon, the turbulence induced by the stream is probably at the origin of the observed seismic noise.



- For equivalent water level the amplitude of noise recorded at the beginning of the monsoon (June to July) is larger than the one recorded at the end of the rain season (September to October).
- part of the available bed load at the beginning of the rainfall season have been used or removed at the end of the monsoon, which leads to a decrease in the river- generated seismic noise, since only the largest boulders remain available to produce noise
- From July to August, despite a constant increase in water level (from 3.25 to 5 m), the amplitude of the noise remains almost constant (<2 dB). {classical concept of critical shear stress can be used to describe the river transport capacity}



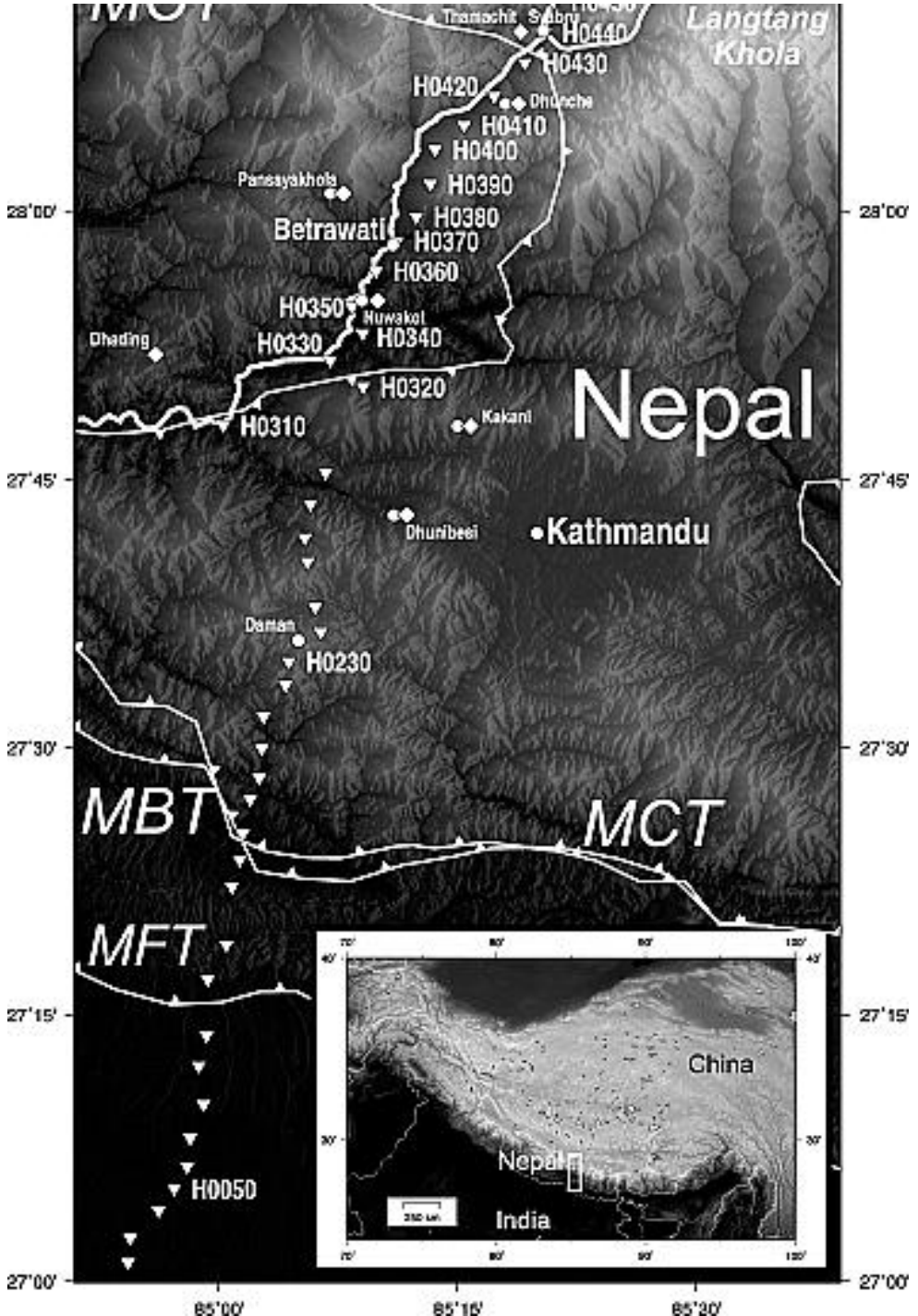


Mean daily noise level amplitudes at station (a) H0420, (b) H0460, and (c) H0480 compared to the daily water level of the Trisuli River measured at Betrawati during year 2003. Each square represents 1 d, and its color indicates month of the year. The observed hysteresis progression is indicated by the black arrow curve.

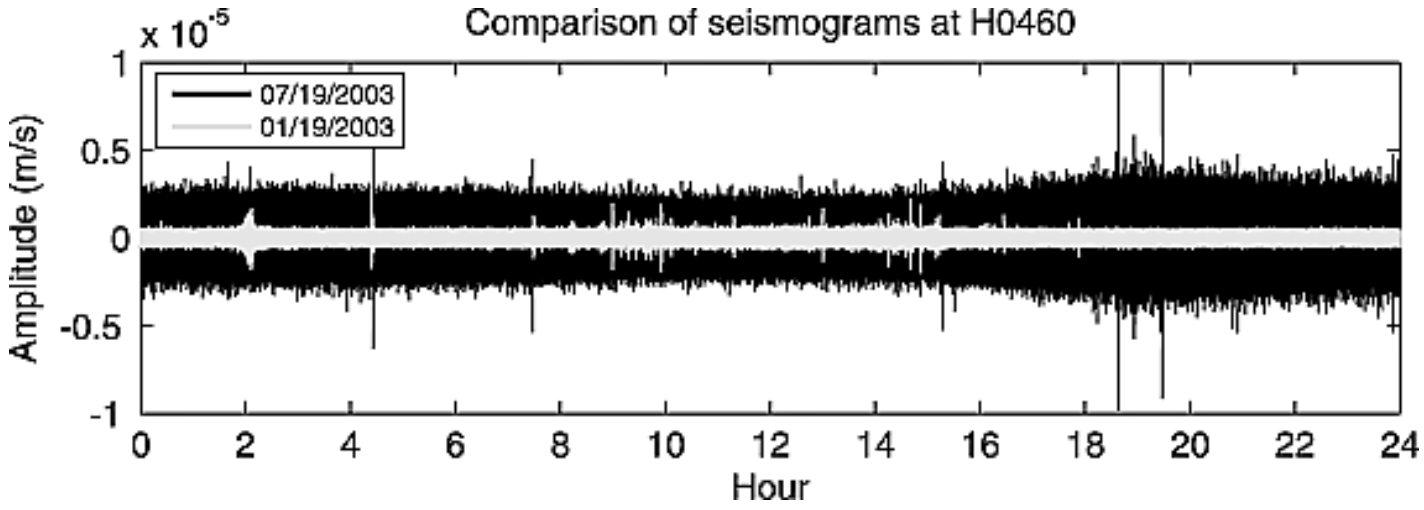
- Despite of the major effect of monsoon rainfall in the water supply south of Betrawati, we do not have significant seasonal changes in the amplitude of noise.

- Stations in the southern part of the river are located in the vicinity of river segments for which the bed load characteristics are not efficient to produce seismic noise either due to a missing large fraction of the bed load or variations of the basal shear stress.

- All these observations point the influence of the different mechanisms of bed load transport on the recorded seismic noise. The motion of blocks within the river should produce seismic waves since this solid fraction is coupled to the ground.



Explanation for High seismicity at night



- These seasonal and daily variation of discharge measurements seem to be well correlated with our observations of noise levels at seismic stations close to the Trisuli River.

- Ueno et al. [2001] show a remarkably periodic diurnal cycle during the summer monsoon. The total amount of precipitation from 04 pm to 06 am corresponds to 88% of the daily total amount.

- Fukushima et al., [1987] also observe a daily fluctuation of discharge during July and August. According to them, the hourly discharge rate is the largest from 09 pm to midnight in the Langtang Khola watershed.

THANK YOU

These slides are only for educational purpose and all the content in them are taken from some research papers.
This literature review was done as a part of internship.