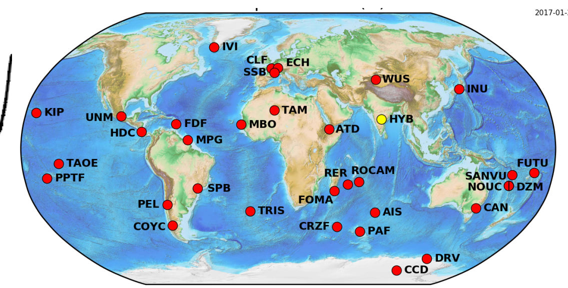
Toward monitoring ocean wave activity using seismic stations

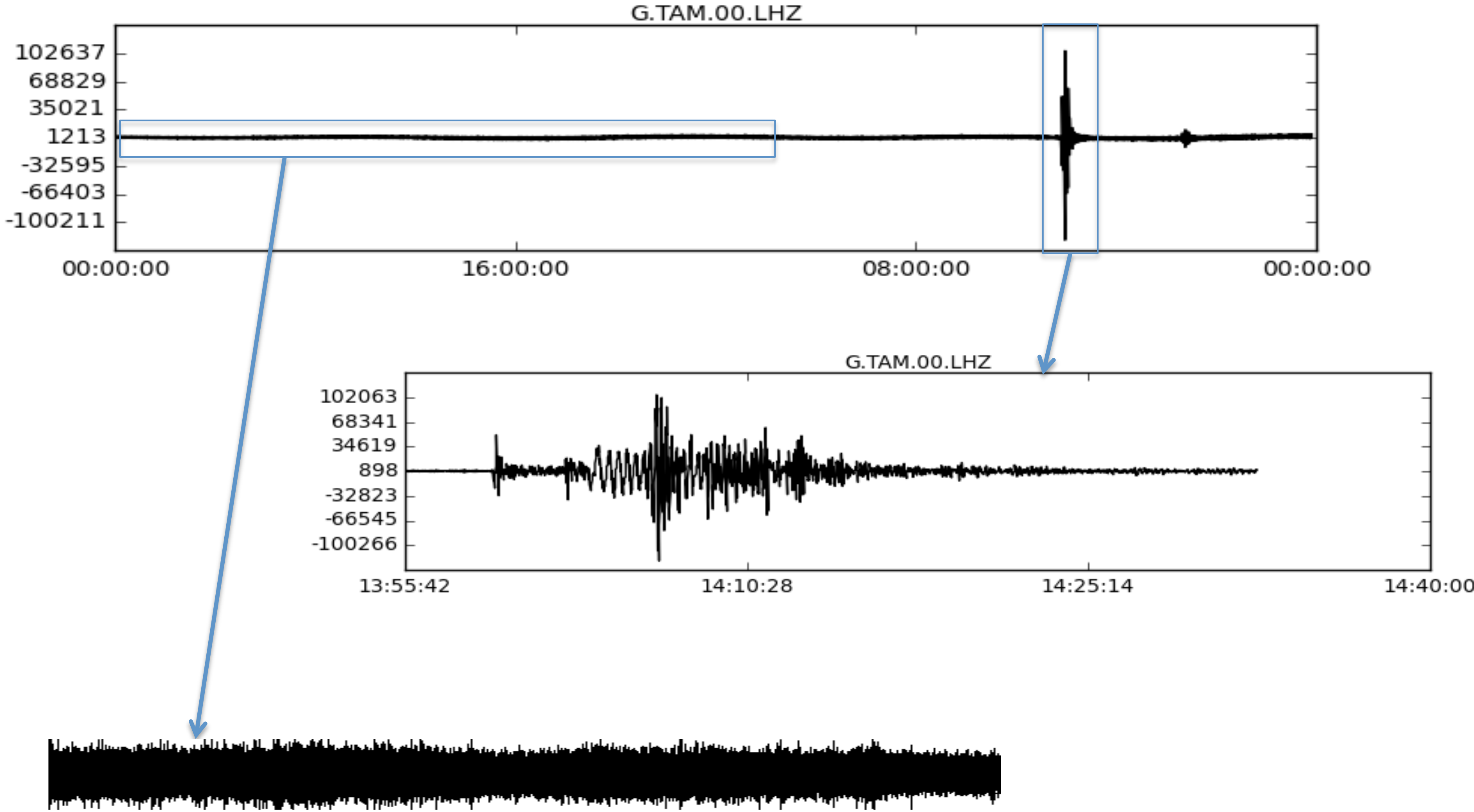


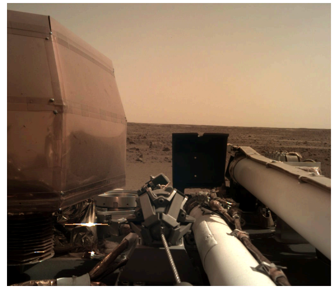
E. Stutzmann[1]

M. Schimmel[2] , F. Ardhuin[3], M. Meschede[1], V. Farra[1],

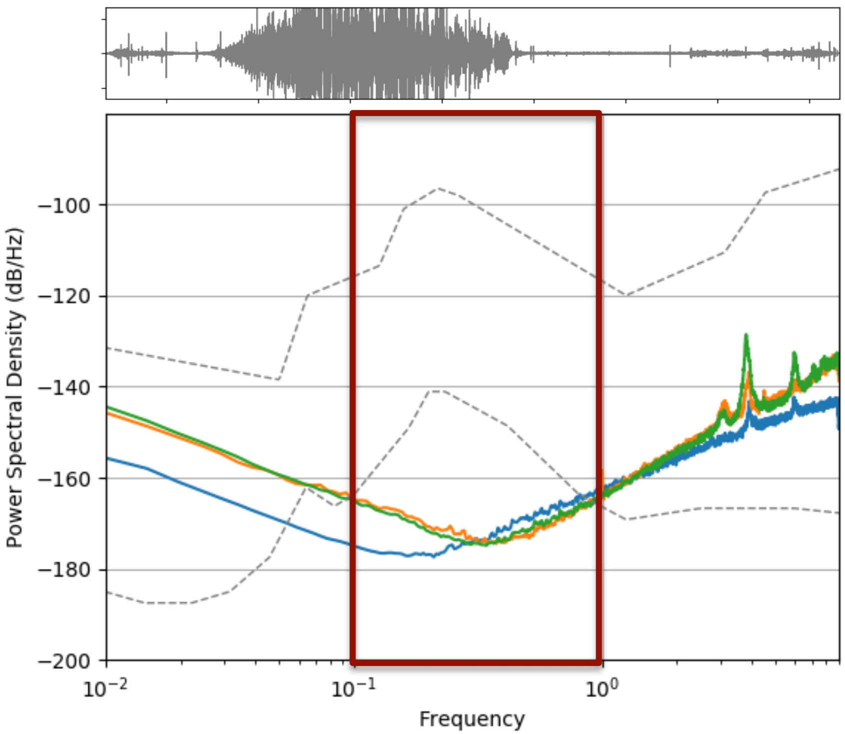
1. Institut de Physique du Globe de Paris, France
2. CSIC-ICTJA, Barcelona
3. IFREMER

Greece - Magnitude:6.1

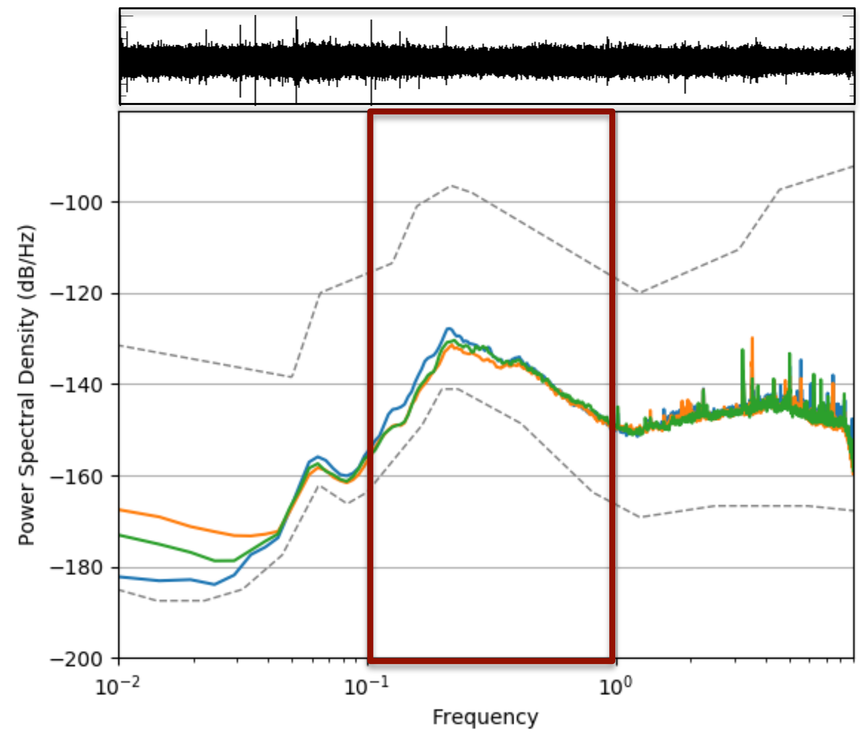




MARS

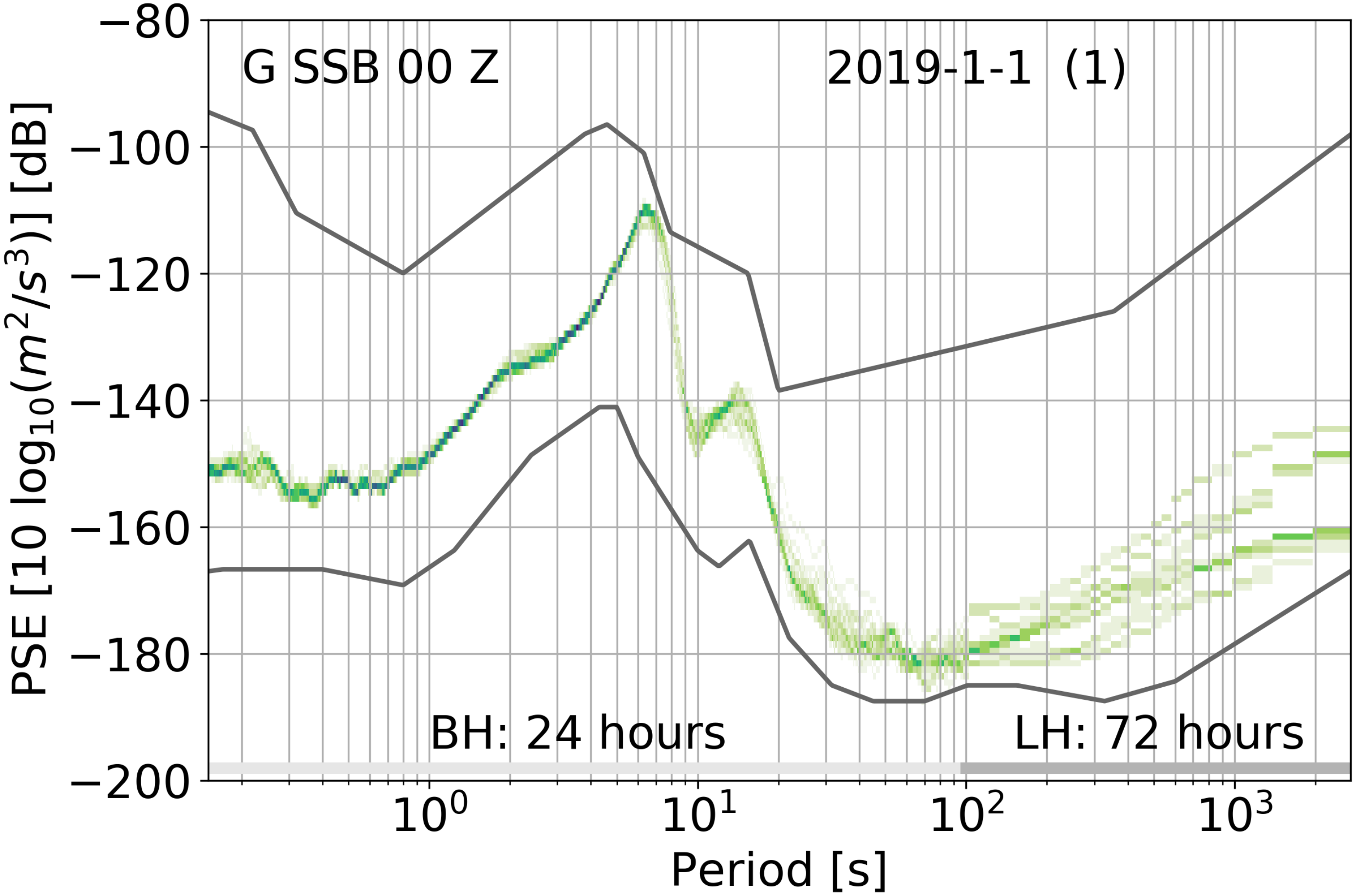


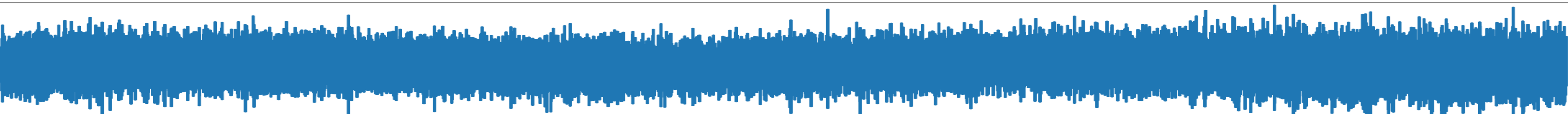
EARTH



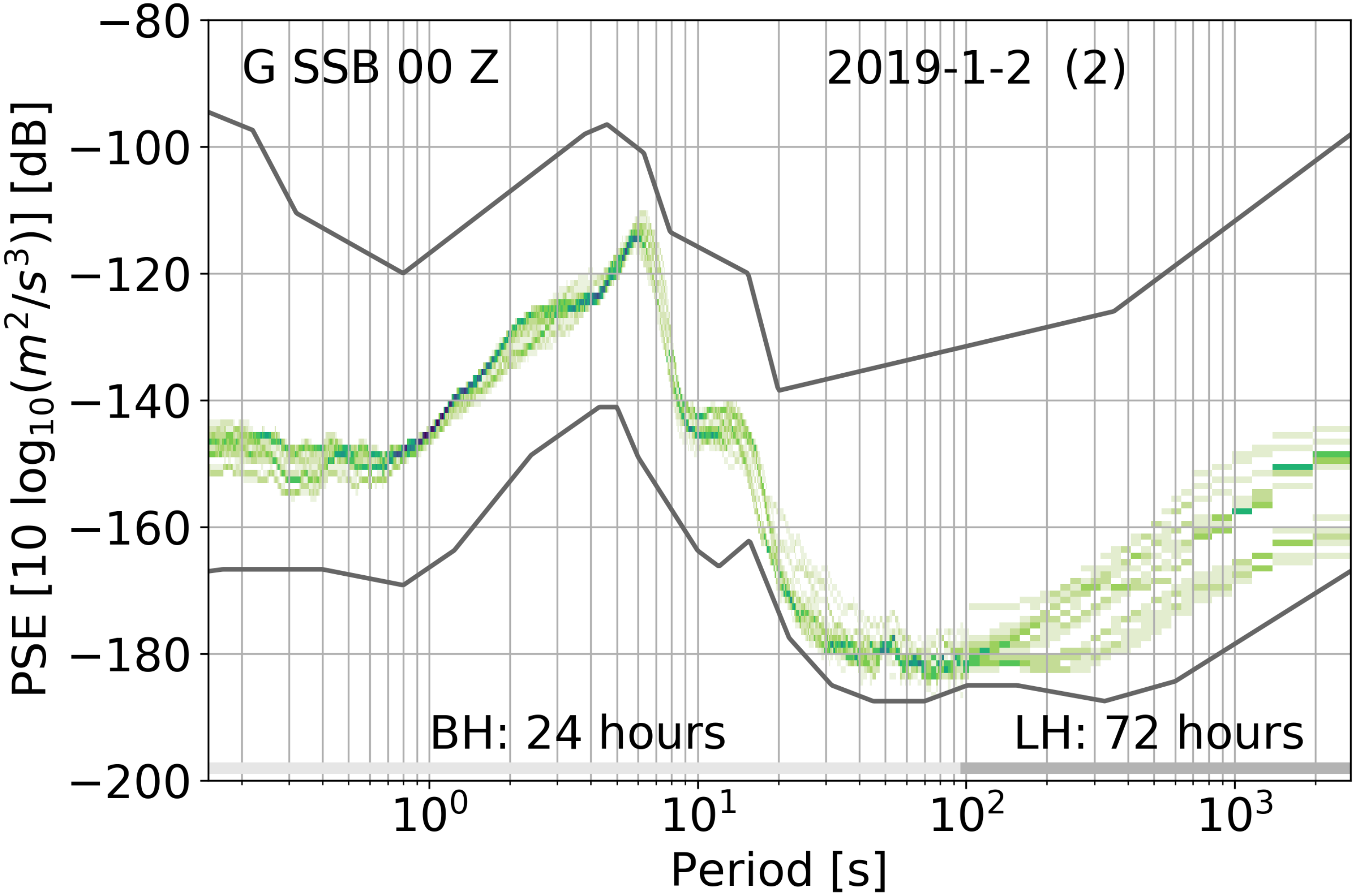
No ocean on Mars→ No microseisms→ Noise level 1000 lower between 0.1-1 Hz

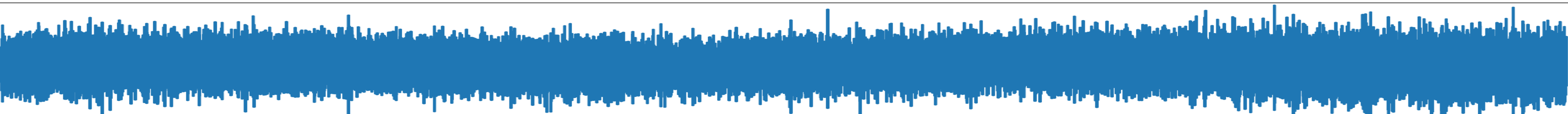
Noise spectrum



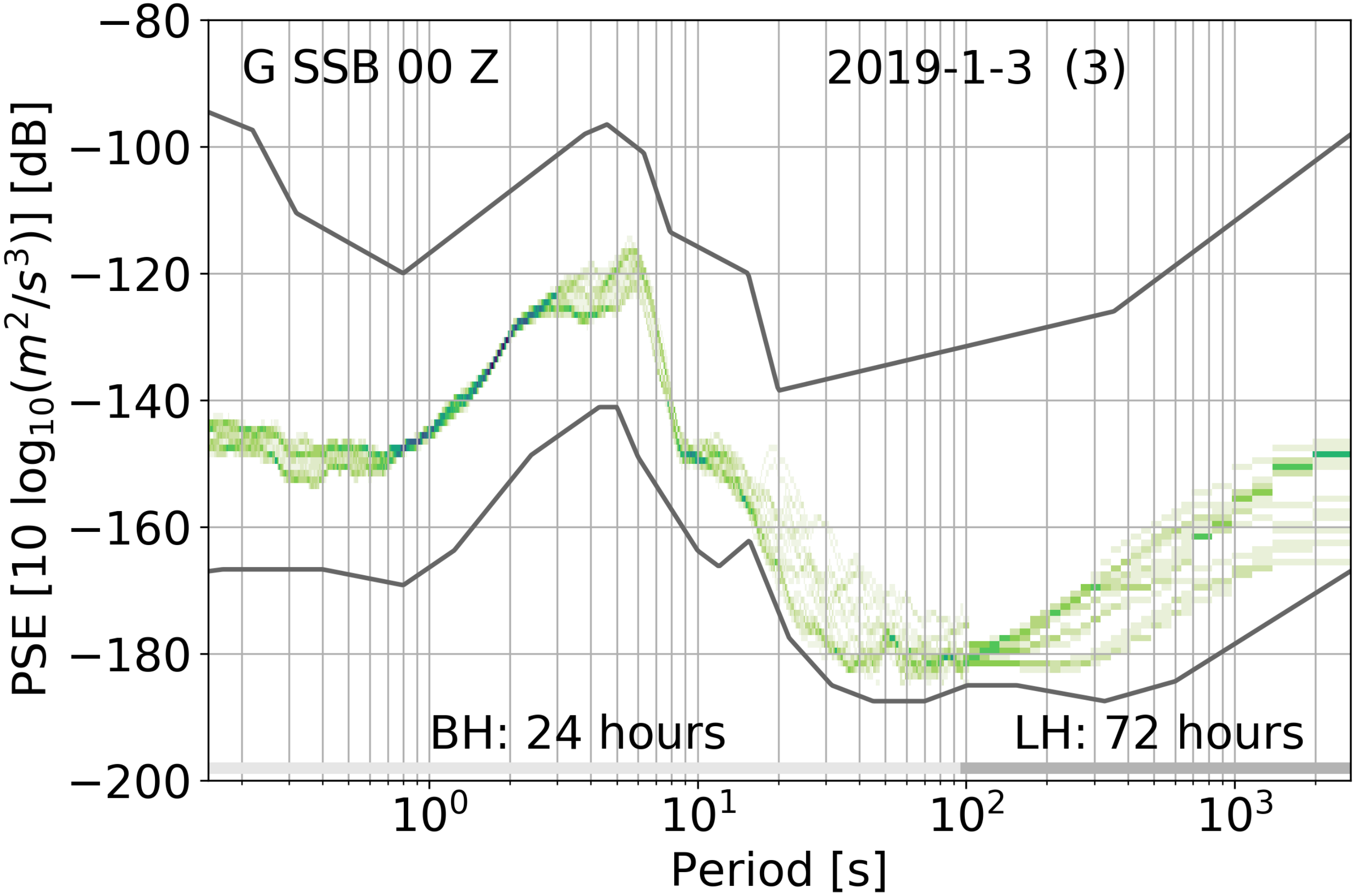


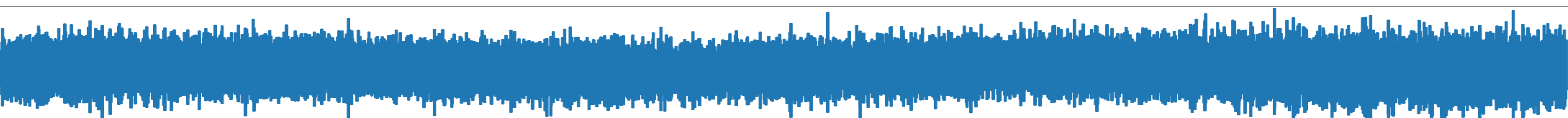
Noise spectrum



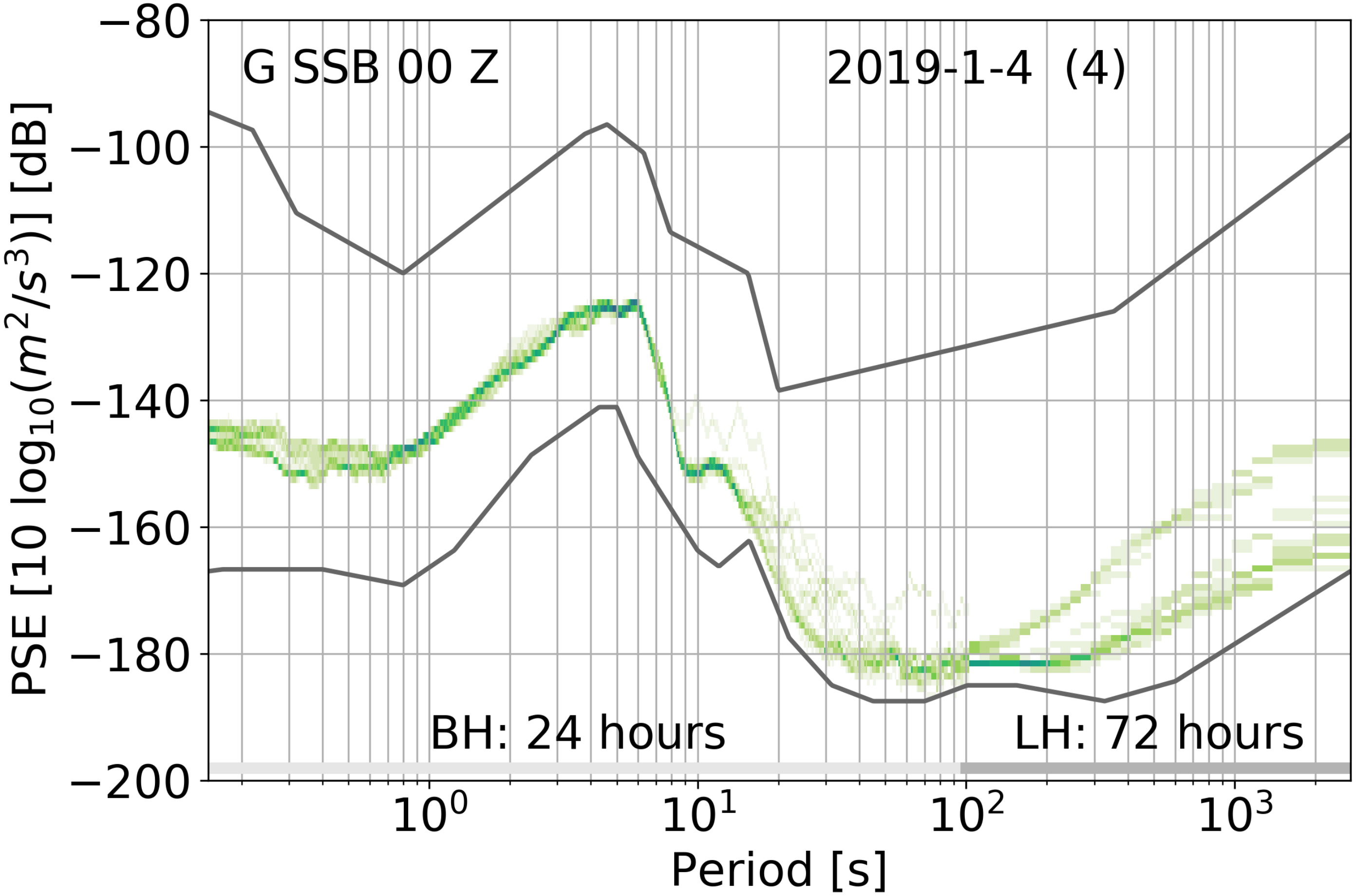


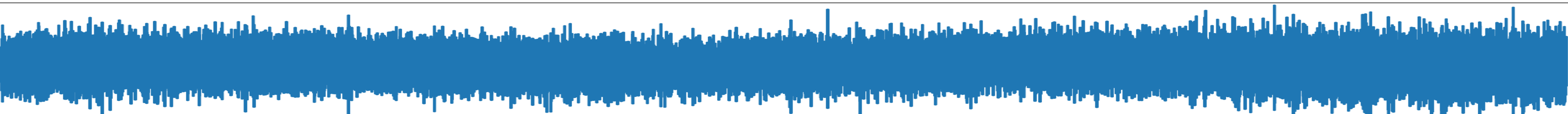
Noise spectrum



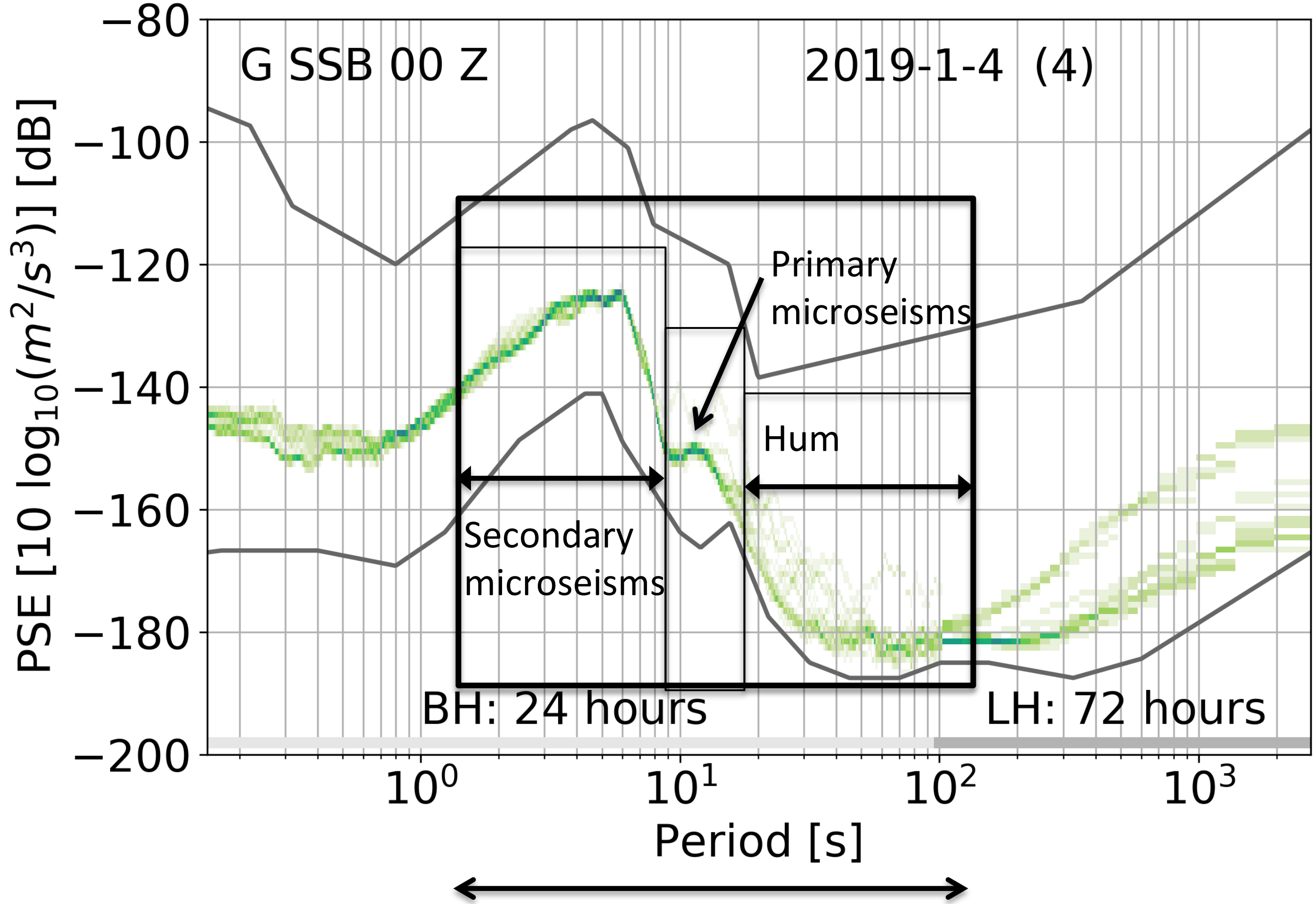


Noise spectrum



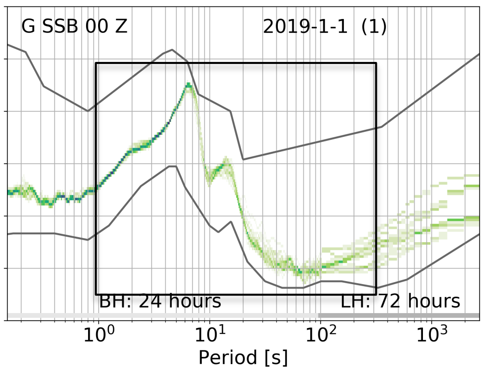


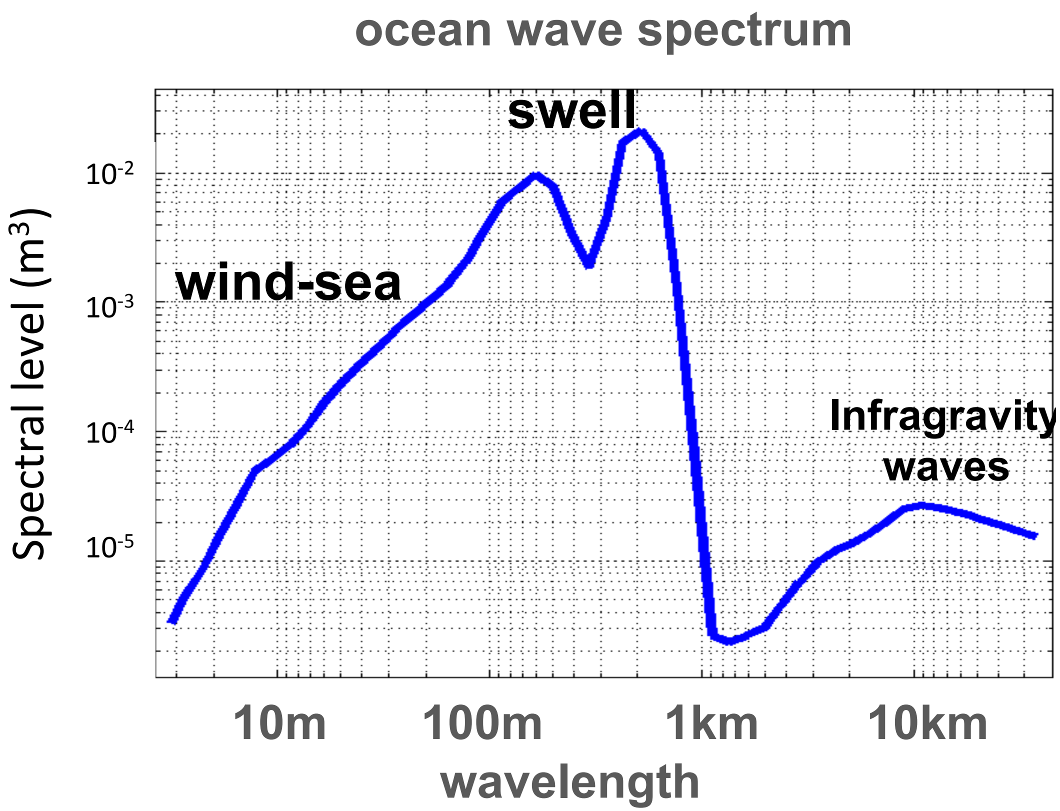
Noise spectrum



Noise with periods between 1 and 500 sec are generated by oceans waves

Ocean wave spectrum

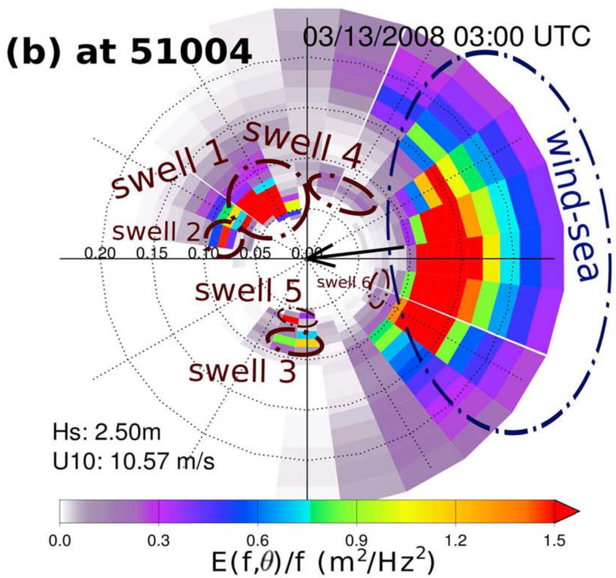


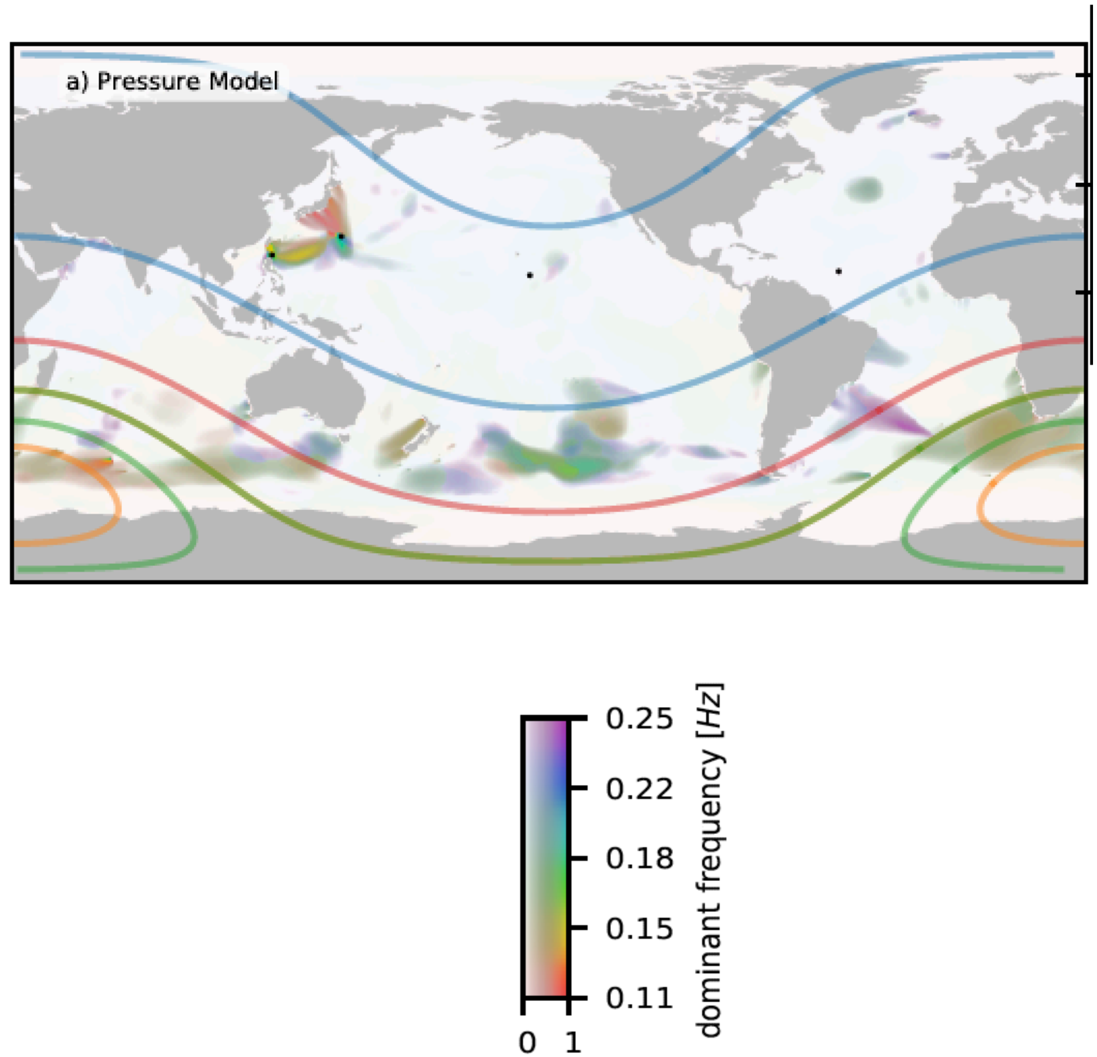


Wind sea and swell→ primary and secondary microseisms
Infragravity waves → hum

Longuet Higgins, 1950
Hassselman 1963
Ardhuin, Gualtieri, Stutzmann, 2015

Secondary microseisms (period 1-10 s)



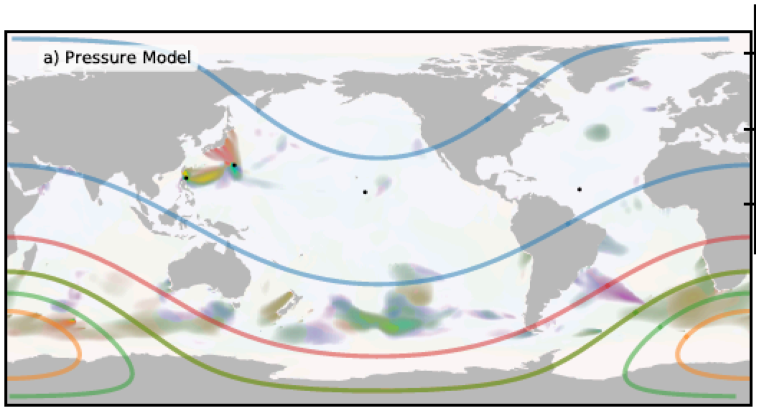


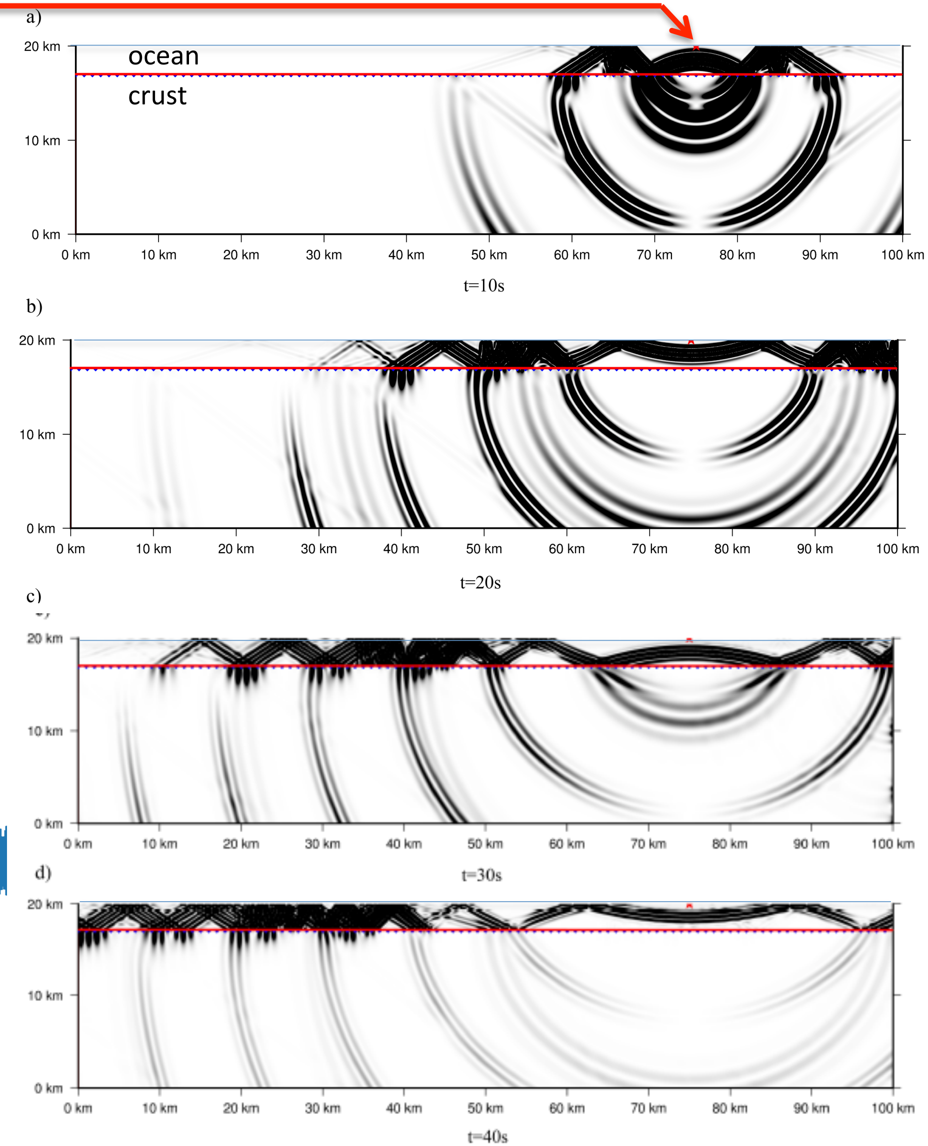
Waves are computed every 6 hours
Code WAVEWATCH III
6-hourly wind analysis from ECMWF

Ardhuin et al., 2011

Secondary microseisms (period 1-10 s)

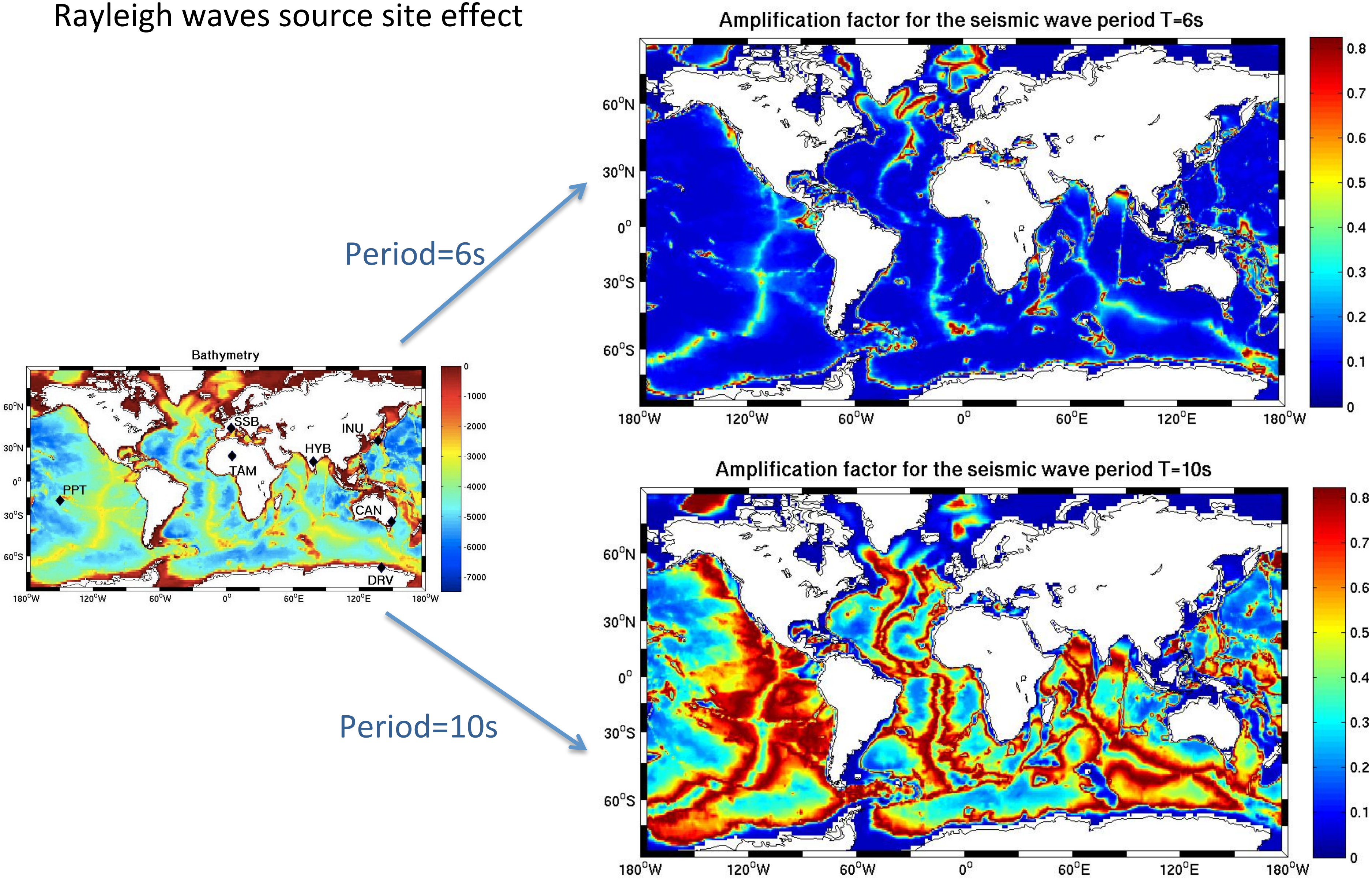
Pressure sources every 3 hours (IFREMER model)





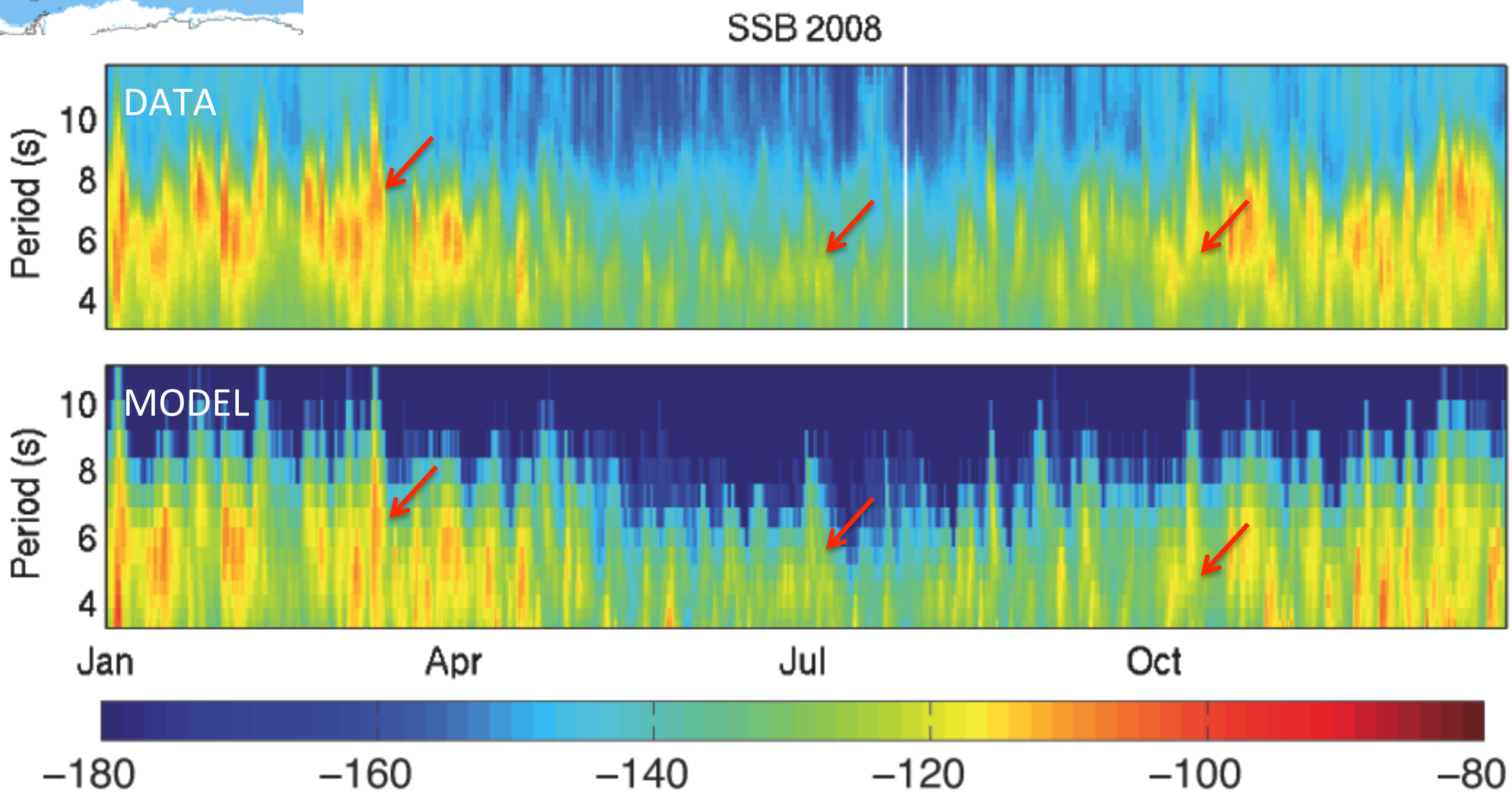
large amplitude surface waves and tiny body waves

Surface waves:
Rayleigh waves source site effect



Longuet Higgins, 1950, Kedar et al., 2007, Ardhuin et al., 2011, Stutzmann et al., 2012

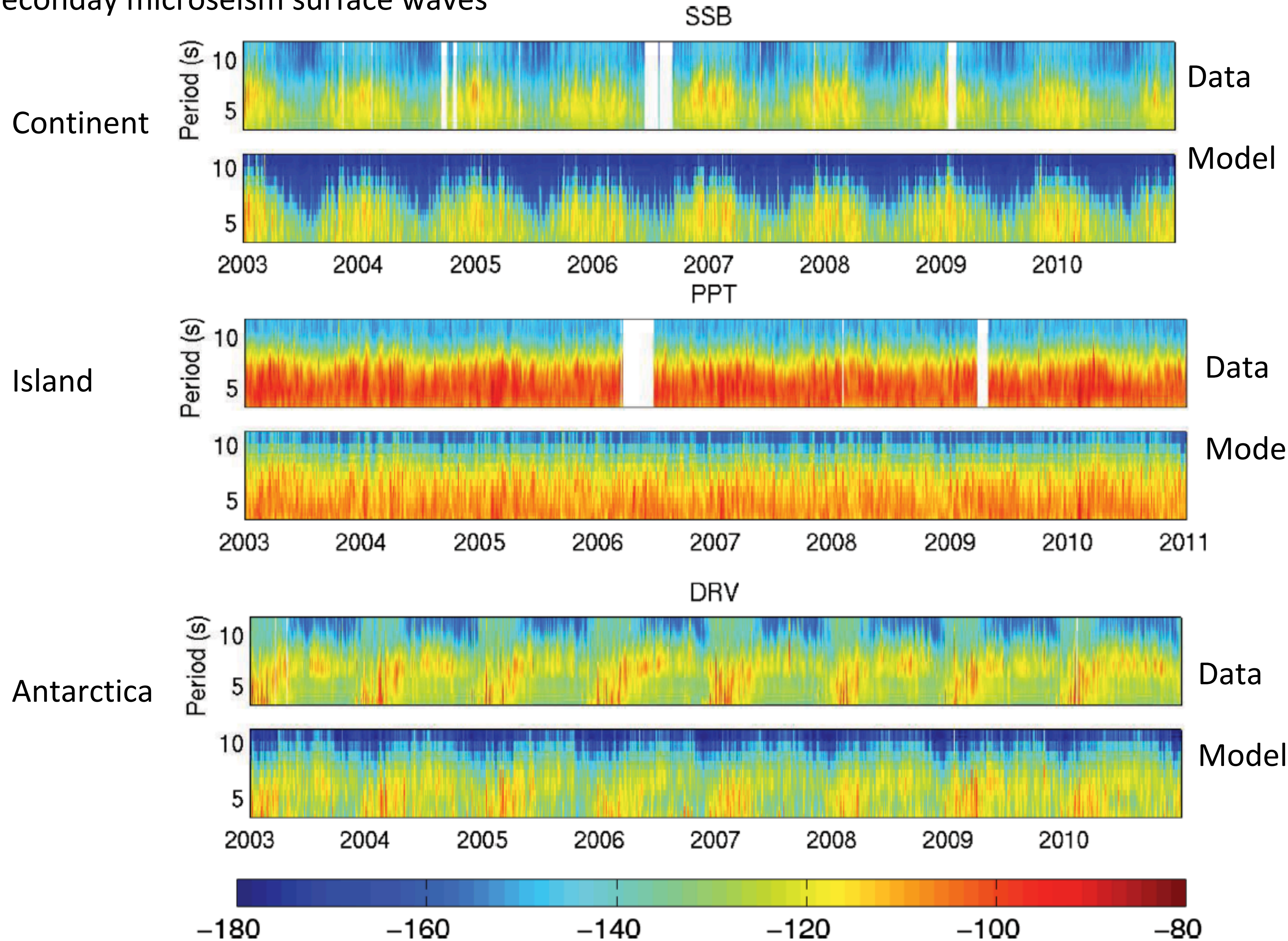
Seconday microseisms surface waves



Spectrogram are well modelled (frequency content and amplitudes)
Strongest PSD are due to large storms
Weaker PSD is due to coastal sources related to ocean wave coastal reflection

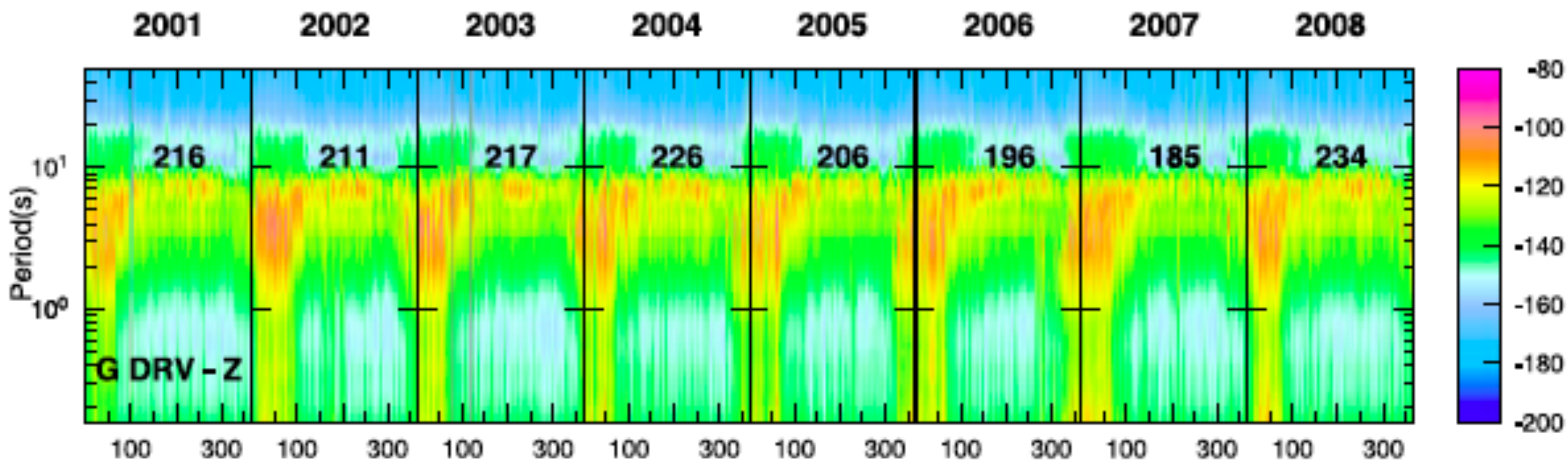
Stutzmann, Ardhuin et al., GJI, 2012

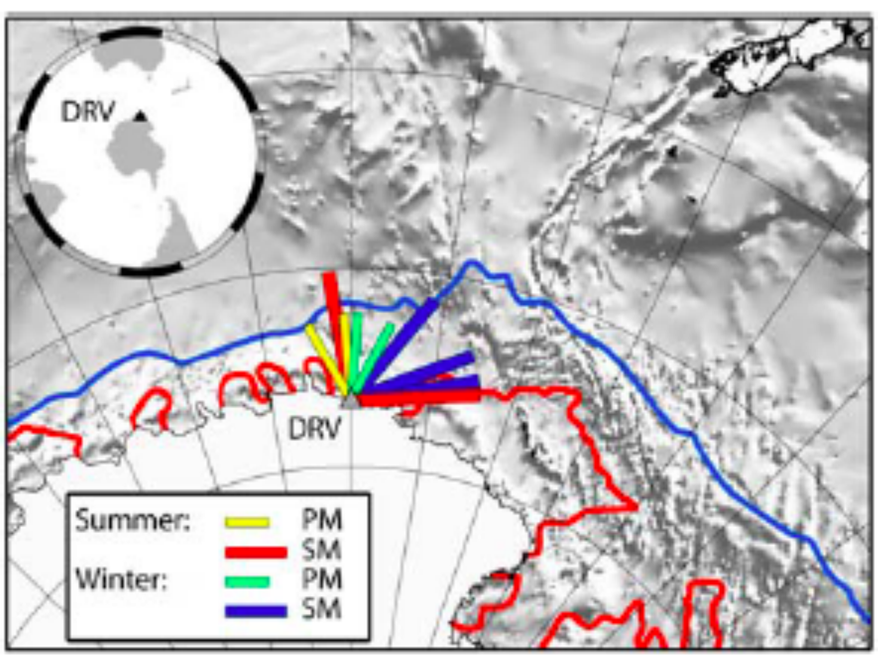
Seconday microseism surface waves



Stutzmann, Ardhuin, et al., GJI, 2012

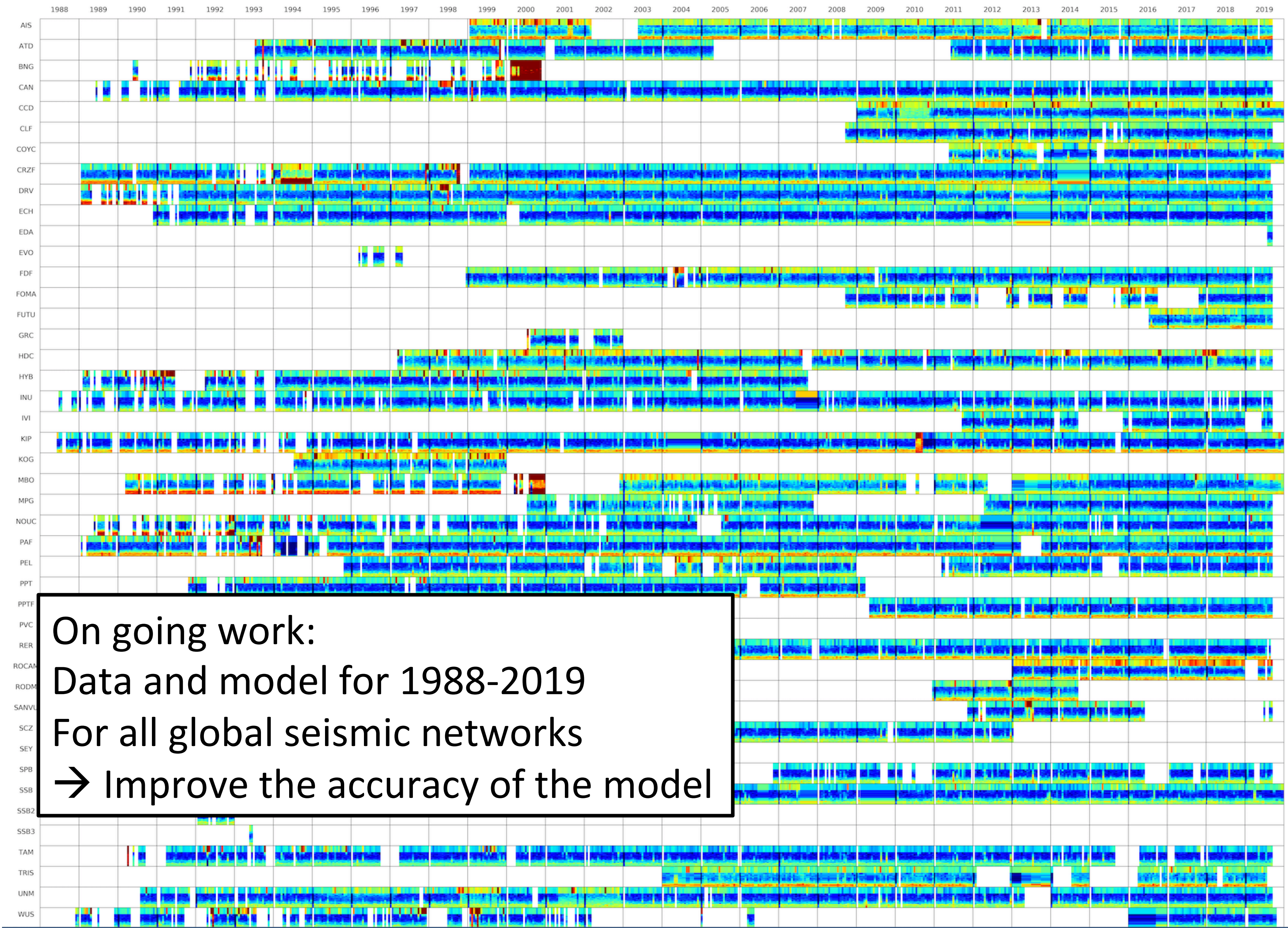
Sea ice effect on seismic noise





In winter, decrease of the amplitude of
- the primary microseism (10-15sec)
- the short period secondary microseism

Stutzmann, Schimmel et al., 2009 ;
Grob et al., 2011



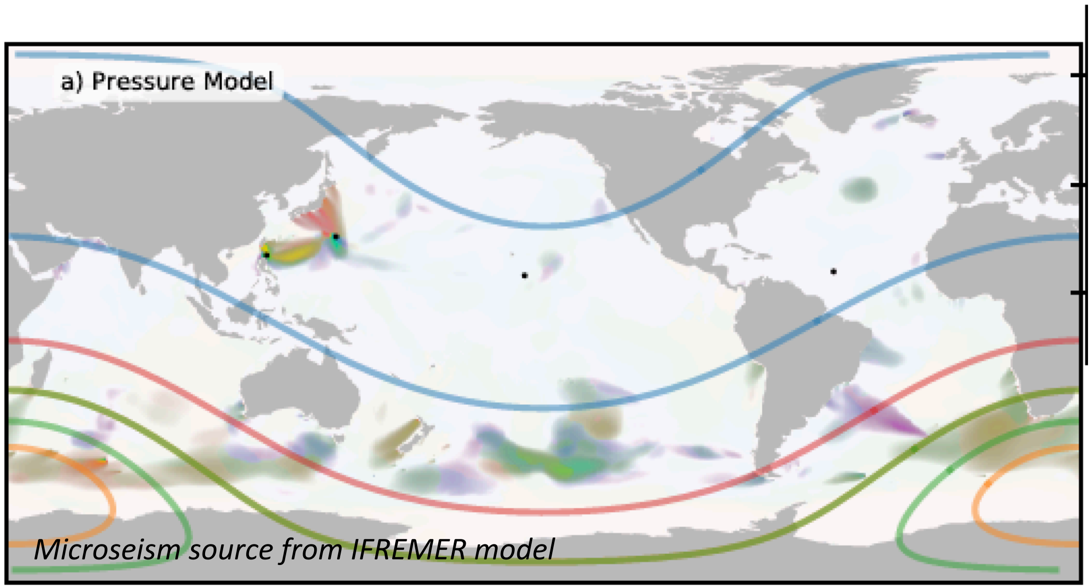
On going work:

Data and model for 1988-2019

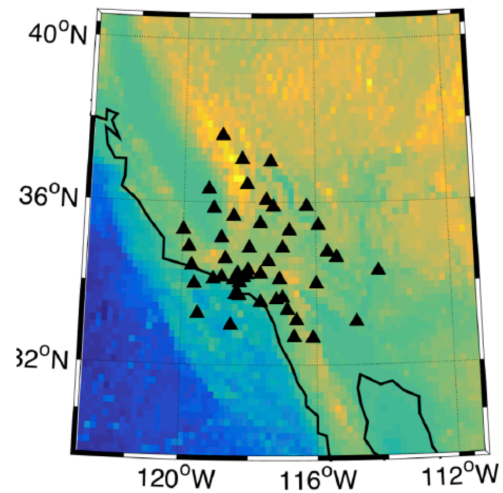
For all global seismic networks

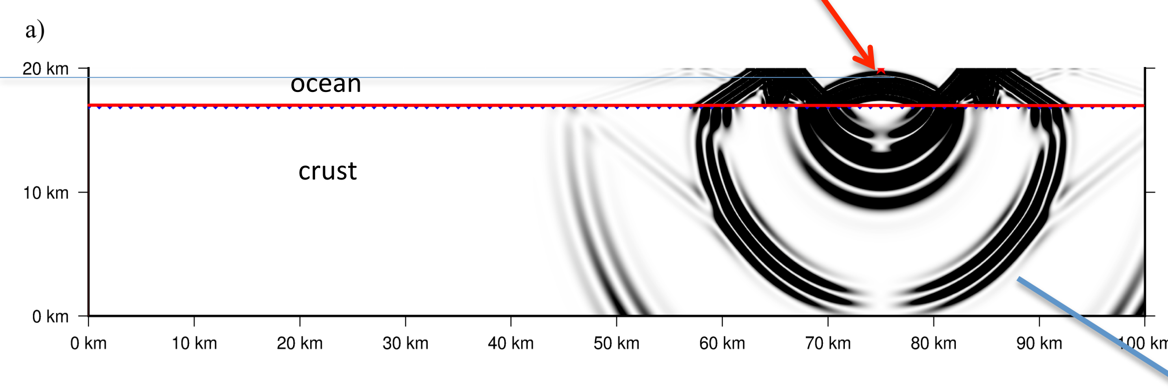
→ Improve the accuracy of the model

Secondary microseism body waves

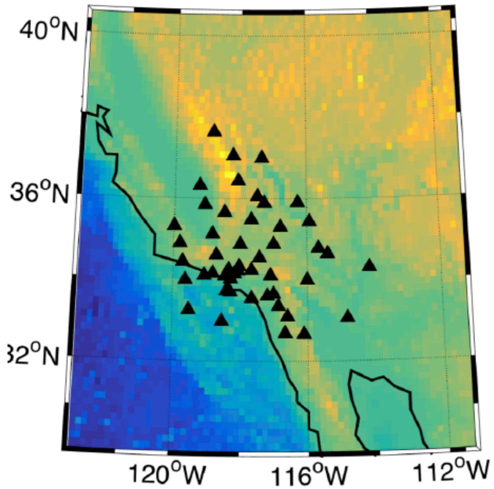


Seismic network





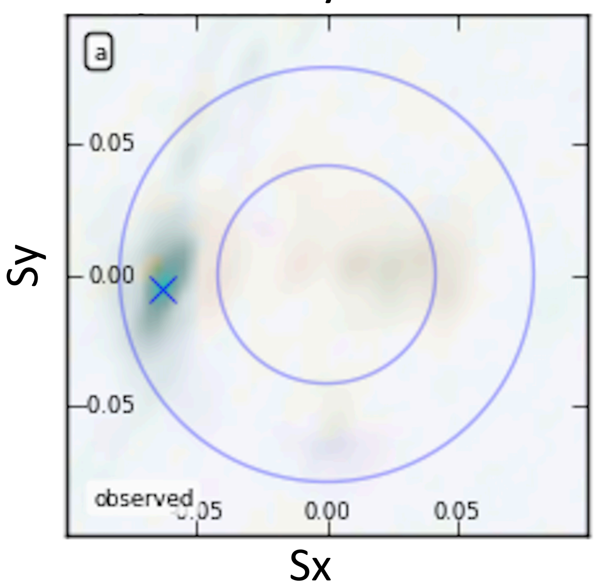
Secondary microseisms body waves detection

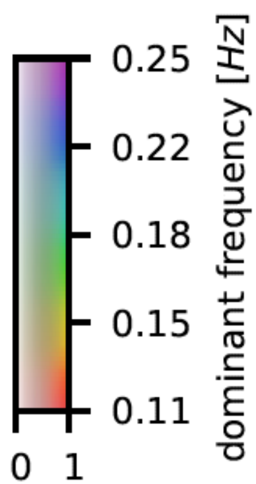


The array record P-waves
from multiple sources

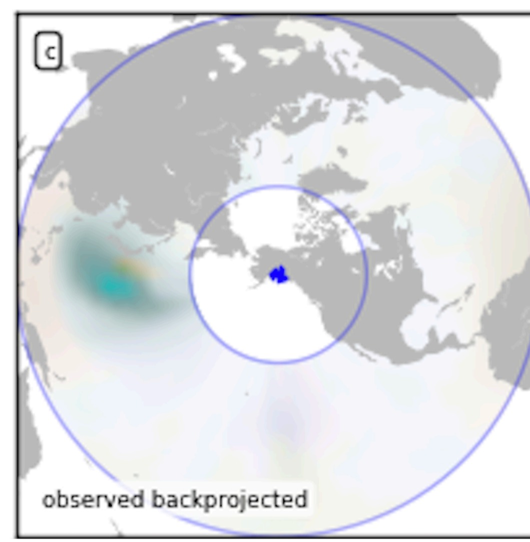
Each source is defined by its location,
corresponding to a P-wave slowness: $\boldsymbol{s} = (s_x, s_y)$
and its dominant frequency f

Beam averaged
over 1 day of data



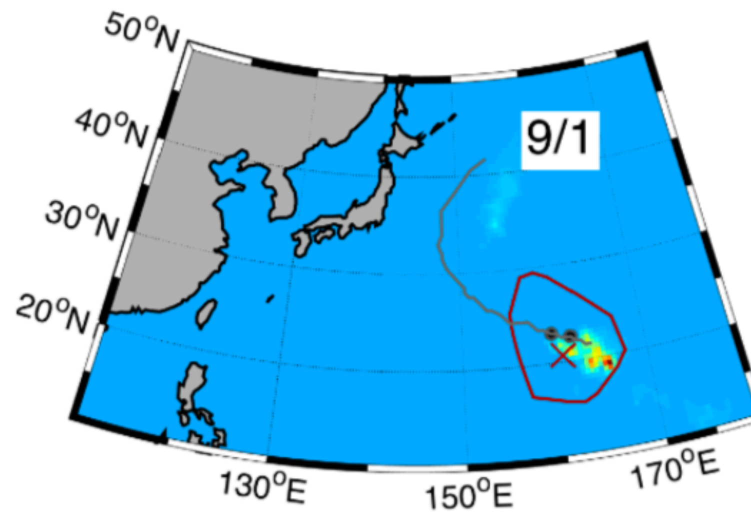


Back projection

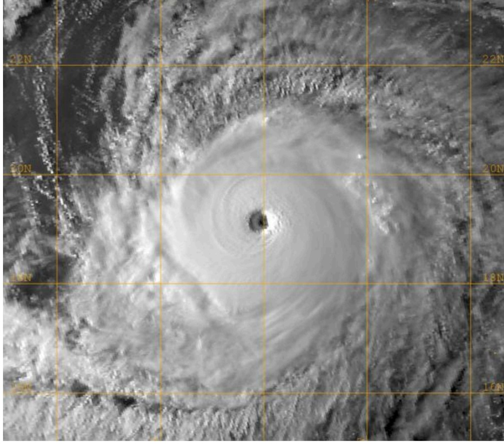


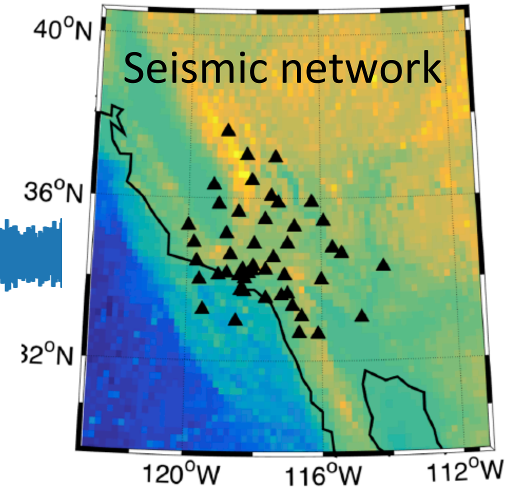
Beamforming using the seismic array in California

→Location and amplitude of the source



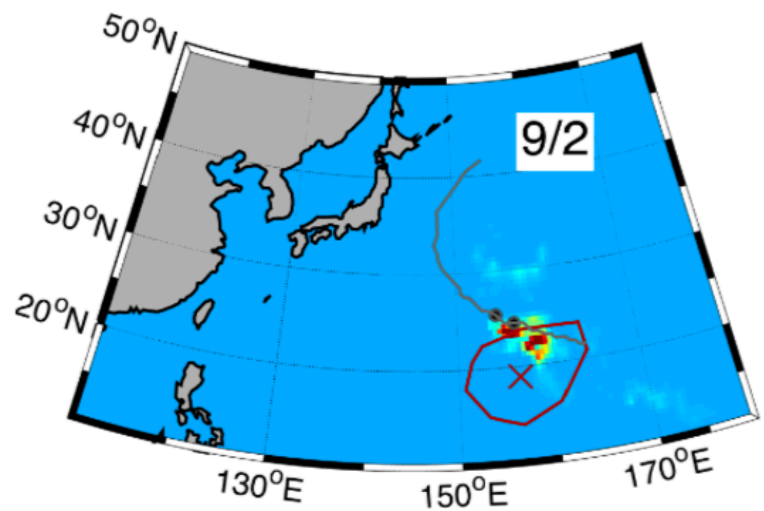
Farra, Stutzmann et al., 2017



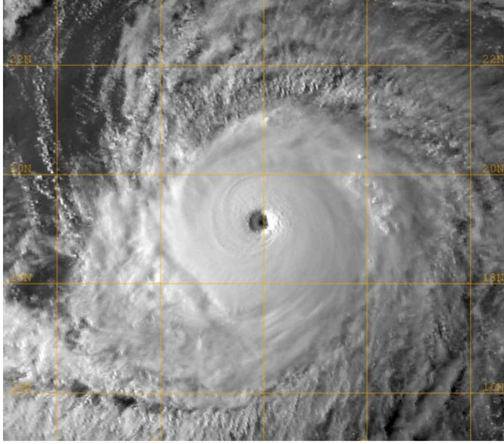


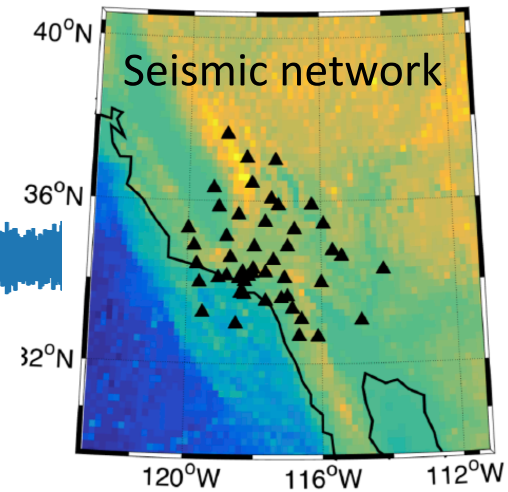
Beamforming using the
seismic array in California

→Location and amplitude of the source



Farra, Stutzmann et al., 2017





Beamforming using the
seismic array in California

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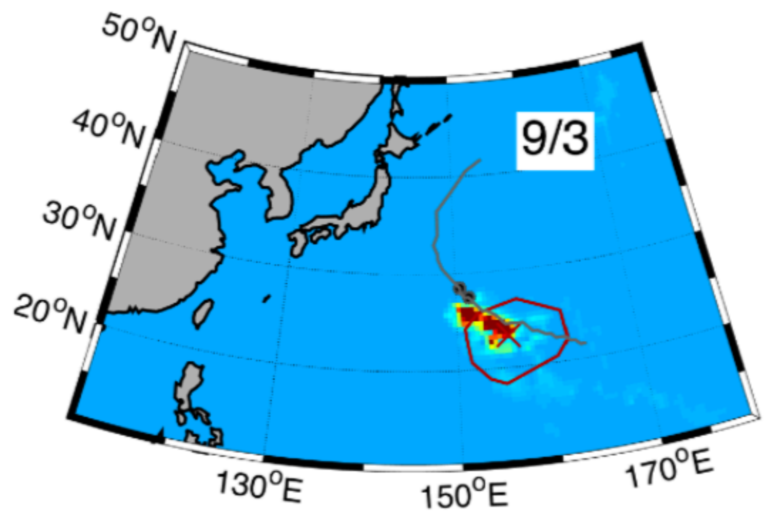
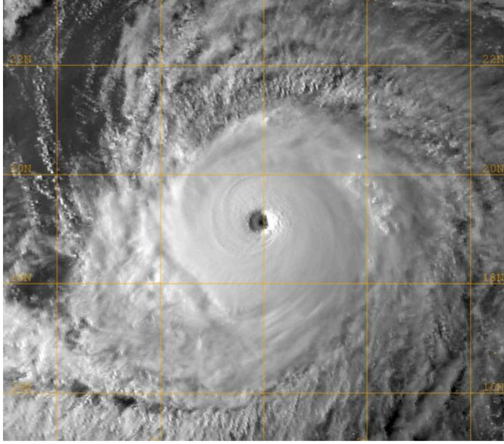
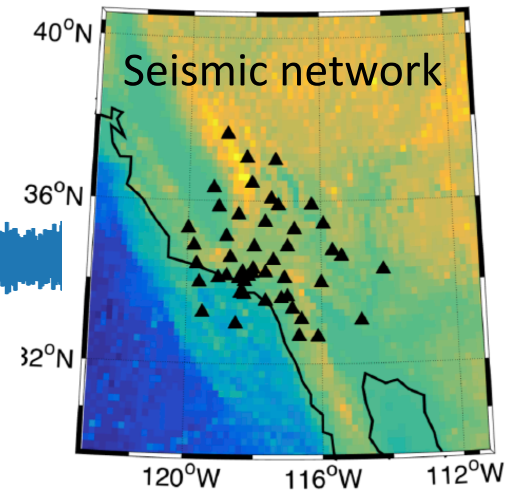


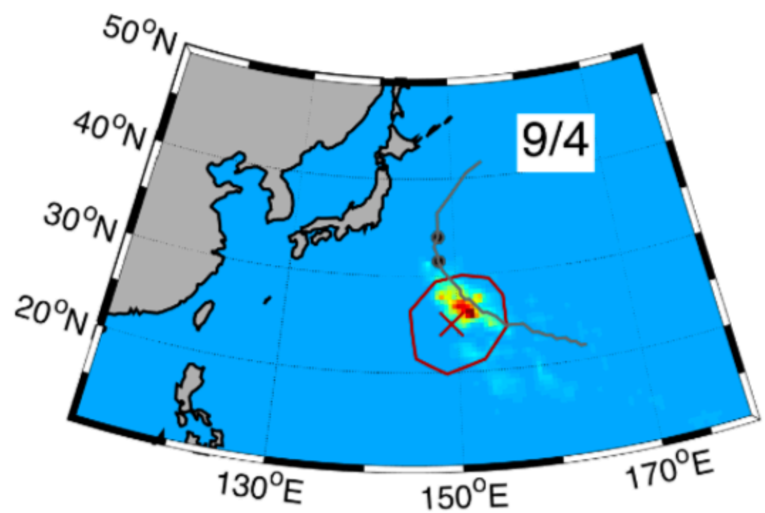
Farra, Stutzmann et al., 2017



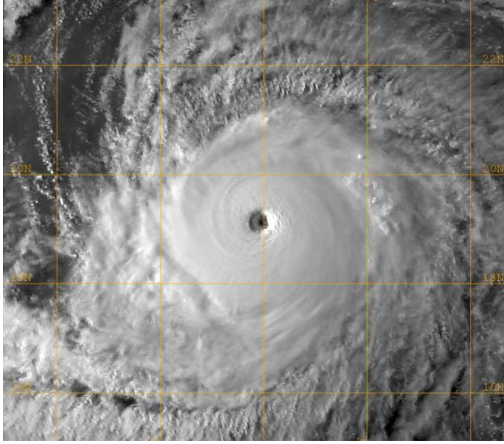
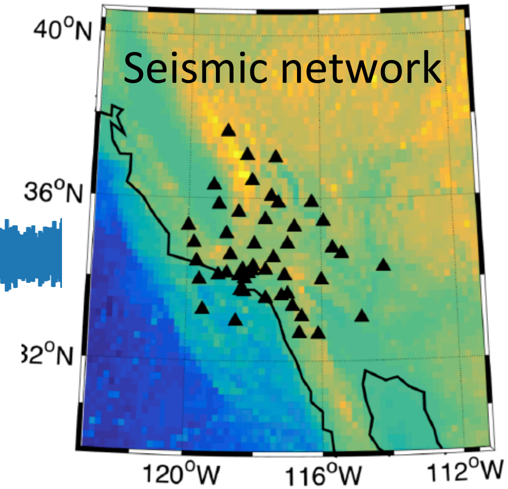


Beamforming using the seismic array in California

→Location and amplitude of the source

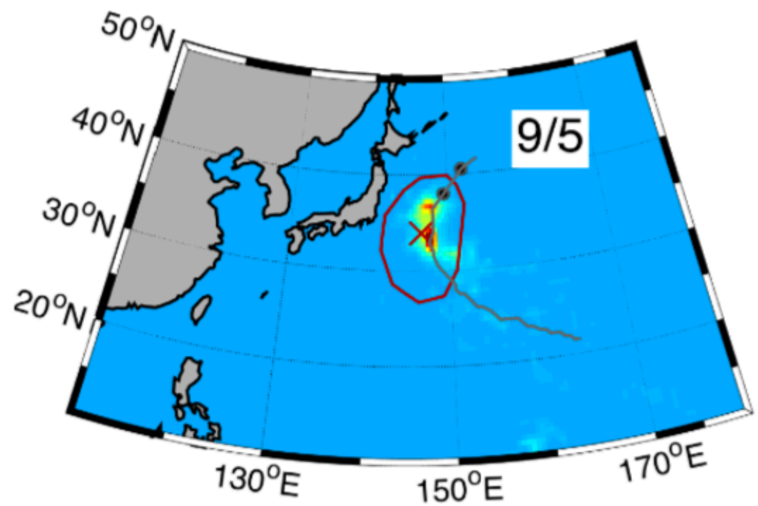


Farra, Stutzmann et al., 2017

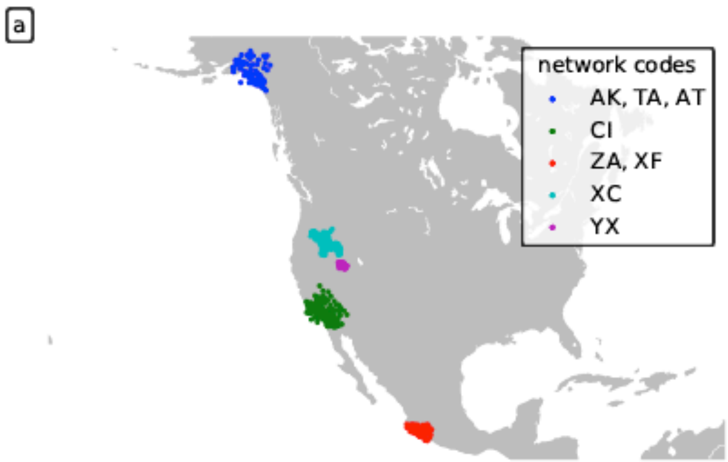
Beamforming using the
seismic array in California

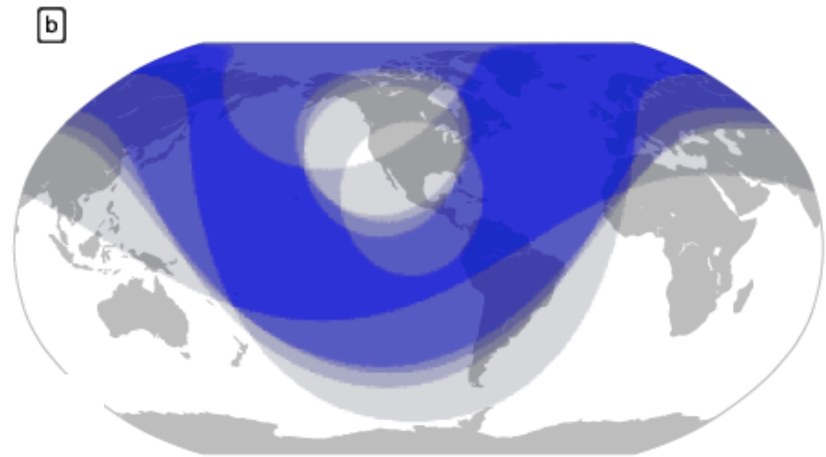
→Location and amplitude of the source



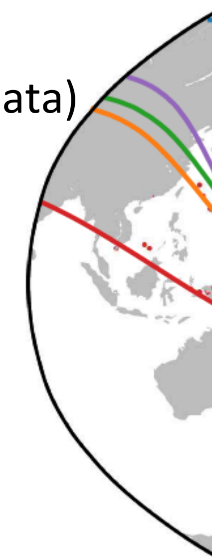
Farra, Stutzmann et al., 2017

Secondary microseism sources at global scale

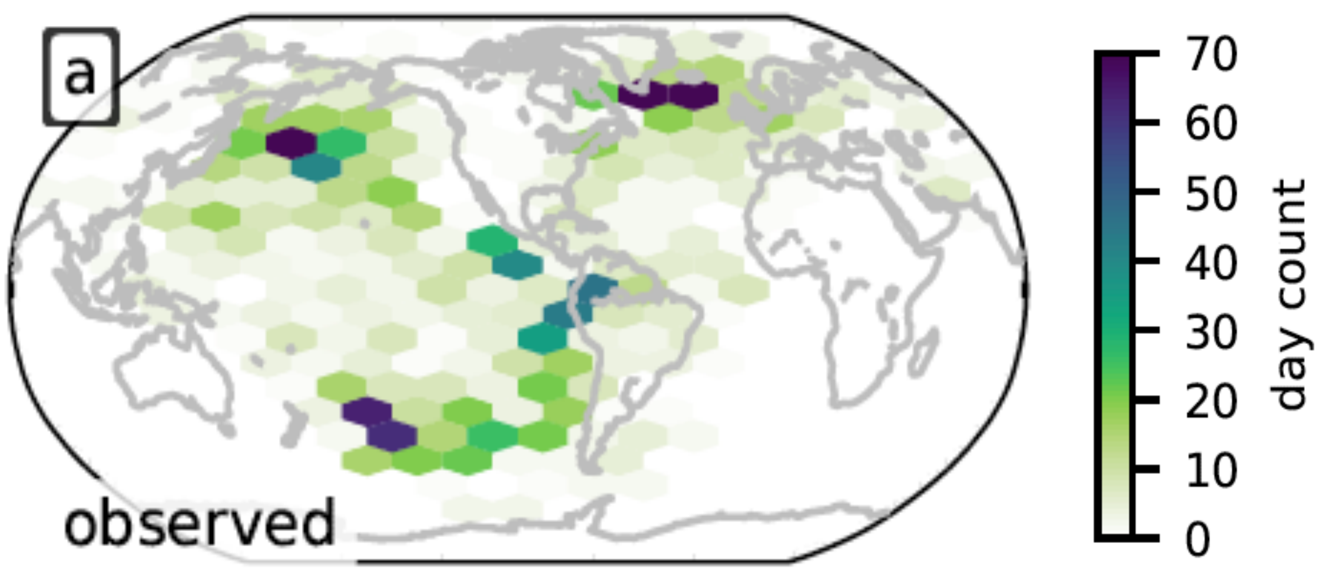




Strongest sources
per day
(5 years of data)

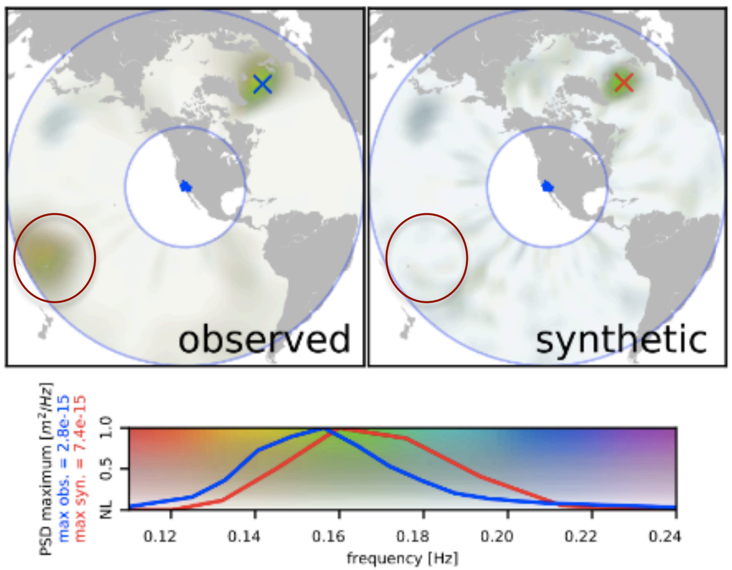


Histograms of the sources

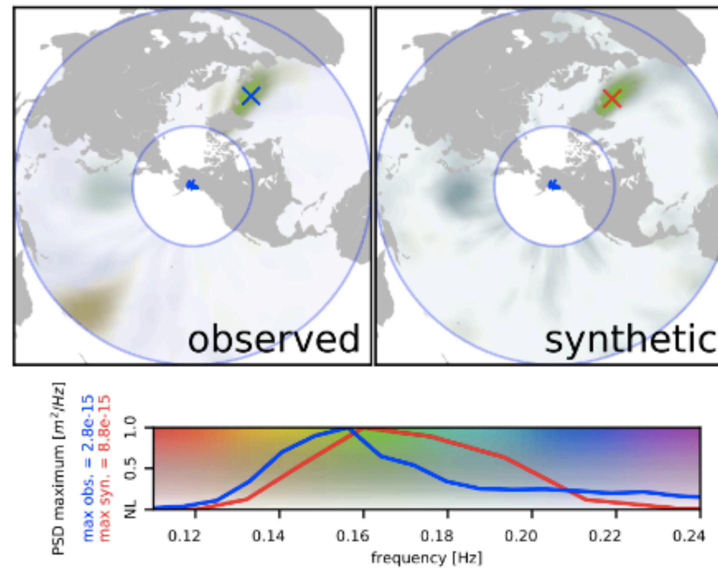


Meschede, Stutzmann et al., JGR, 2017

Comparison of back projected sources

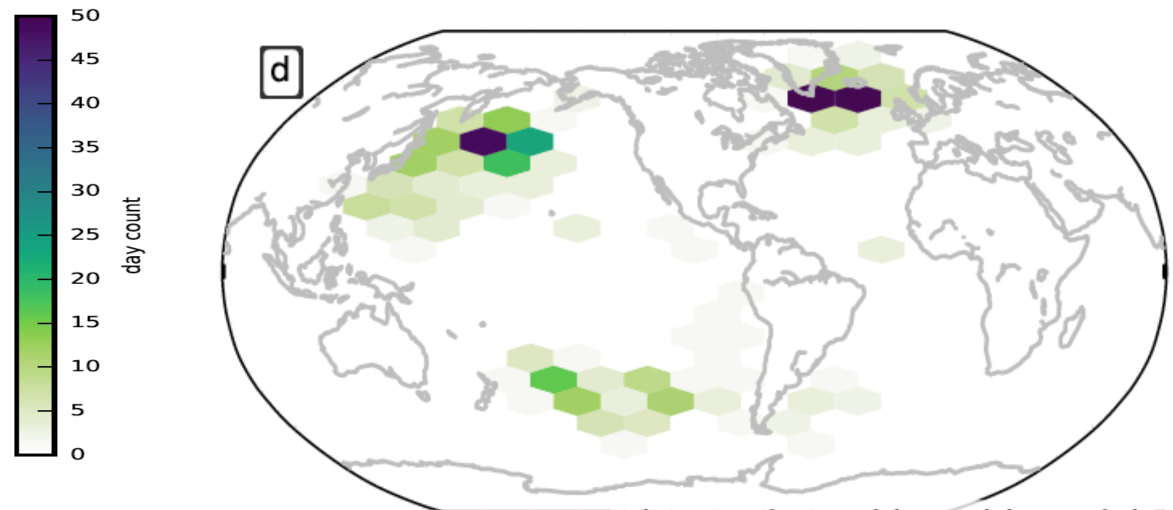


California array

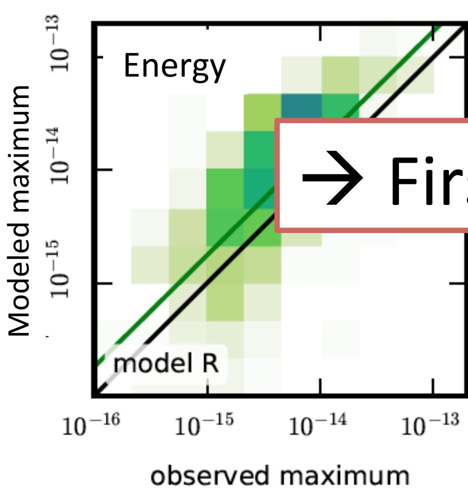


Alaska array

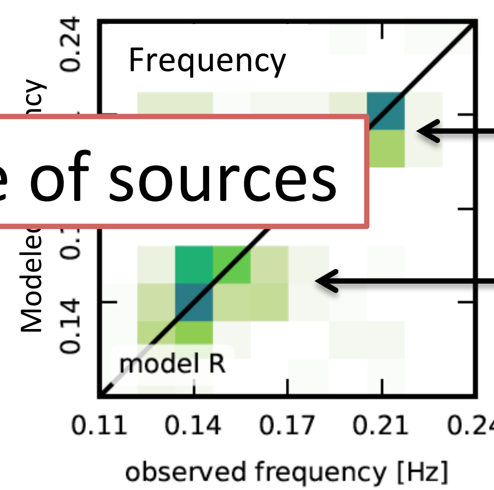
Matching sources



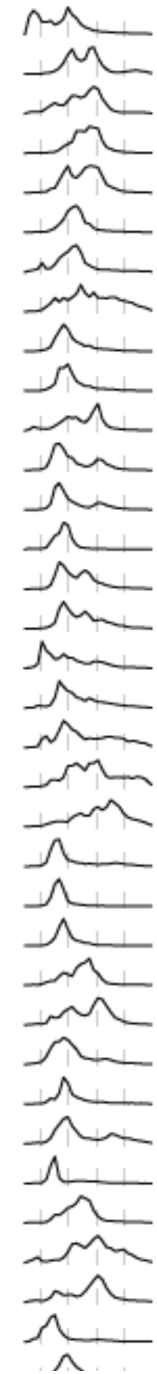
observed matching with model R



→ First catalogue of sources



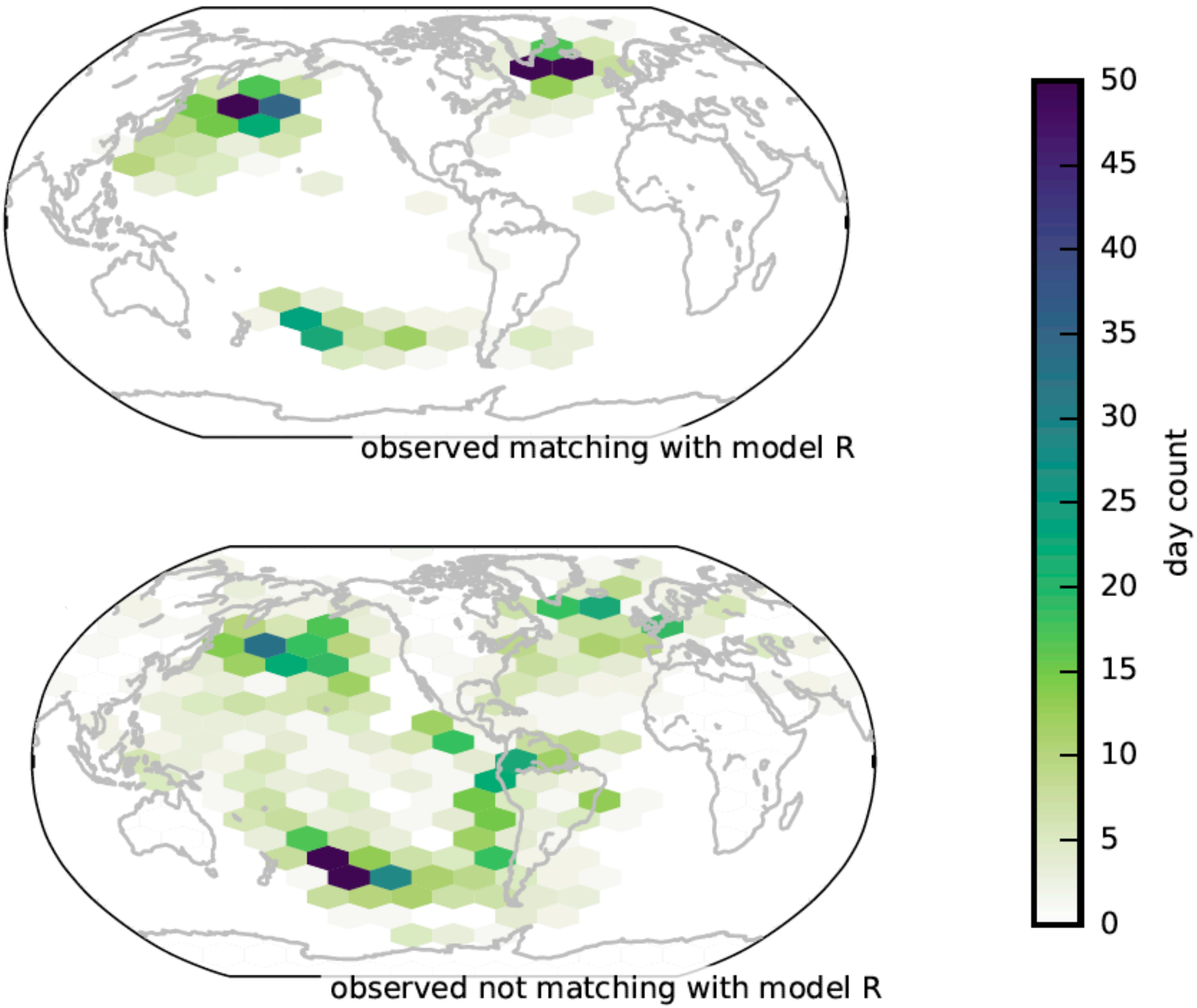
2 pics:
Strongest
water
colum
resonance



Energy and dominant frequency are accurately modeled

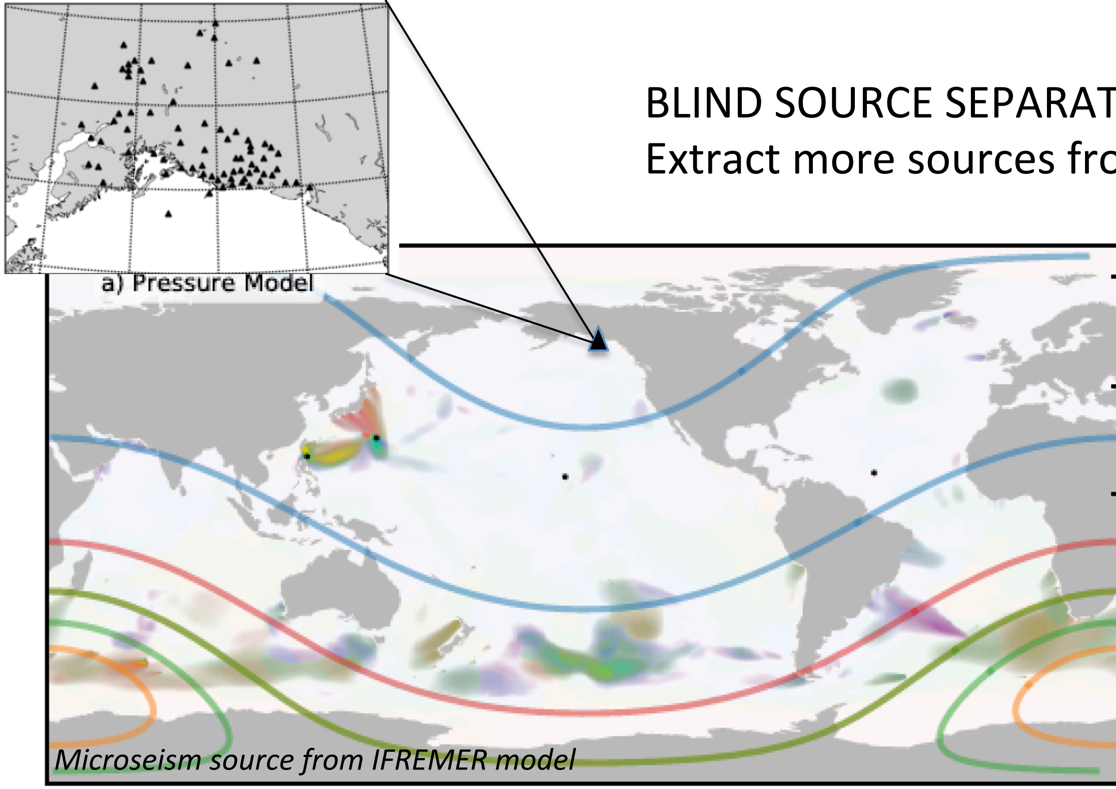
Meschede, Stutzmann et al., JGR, 2017

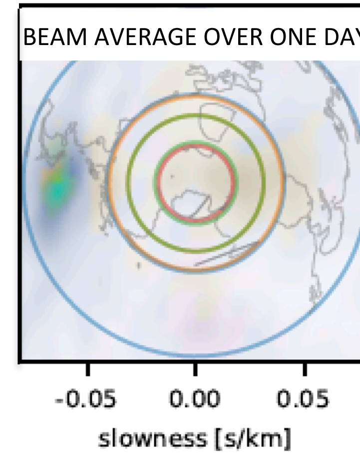
All sources

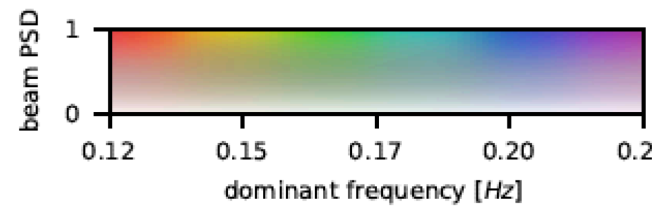


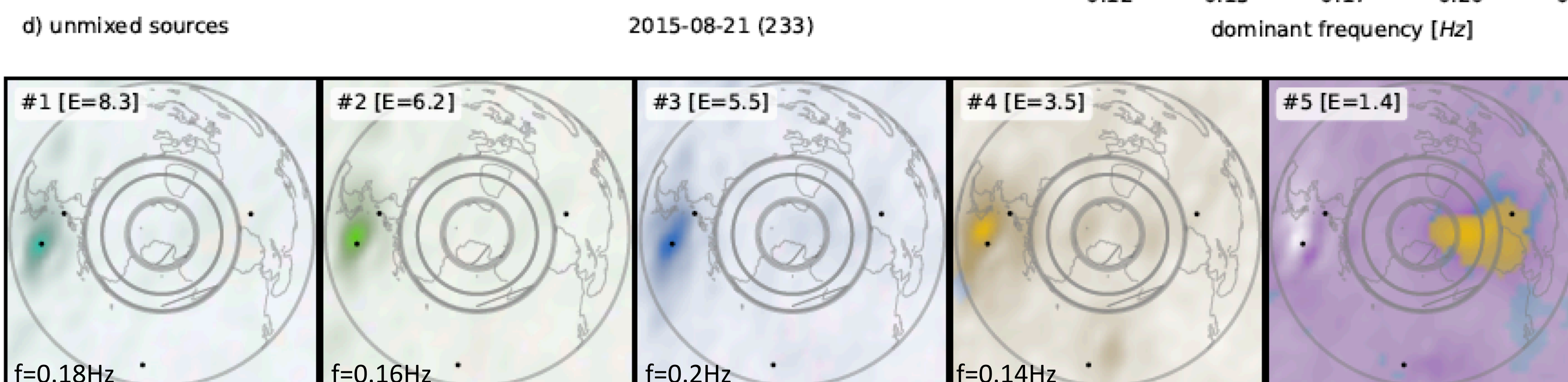
Meschede, Stutzmann et al., JGR, 2017

BLIND SOURCE SEPARATION:
Extract more sources from the seismic signal



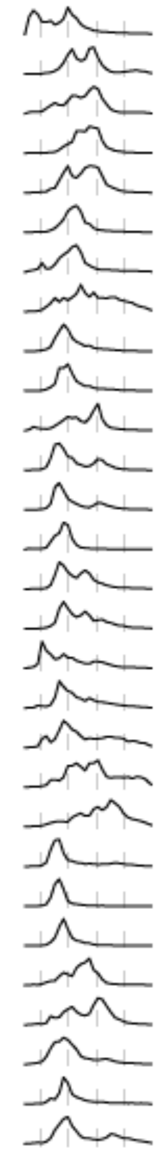






Meschede, Stutzmann, Schimmel, 2019

Conclusions



- Seismic data provide long time series that can be accurately modeled using sources from oceanographic models
- Body waves enables to extract individual sources
- Seismic data are very sensitive to the wave coastal reflection coefficient

On going work:

- Analysis of longer time series
- Machine learning for building new catalogue of sources
- Improve the modeling of noise