Observing and modeling seismic noise

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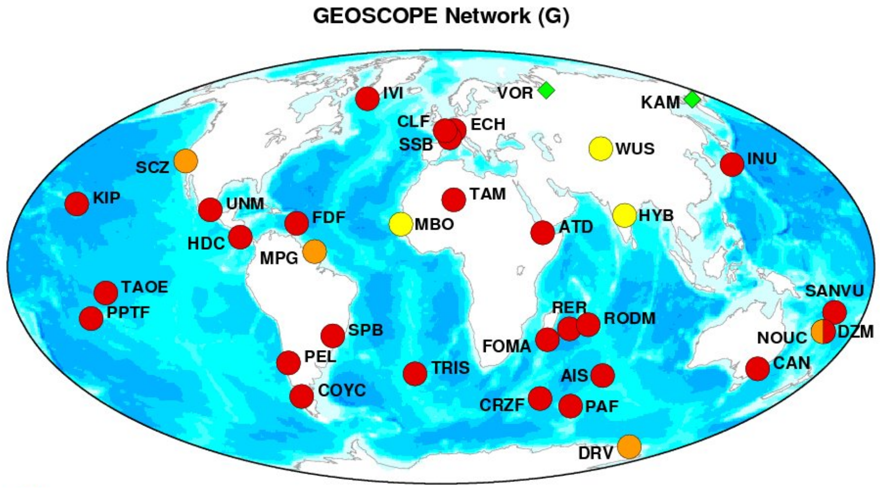
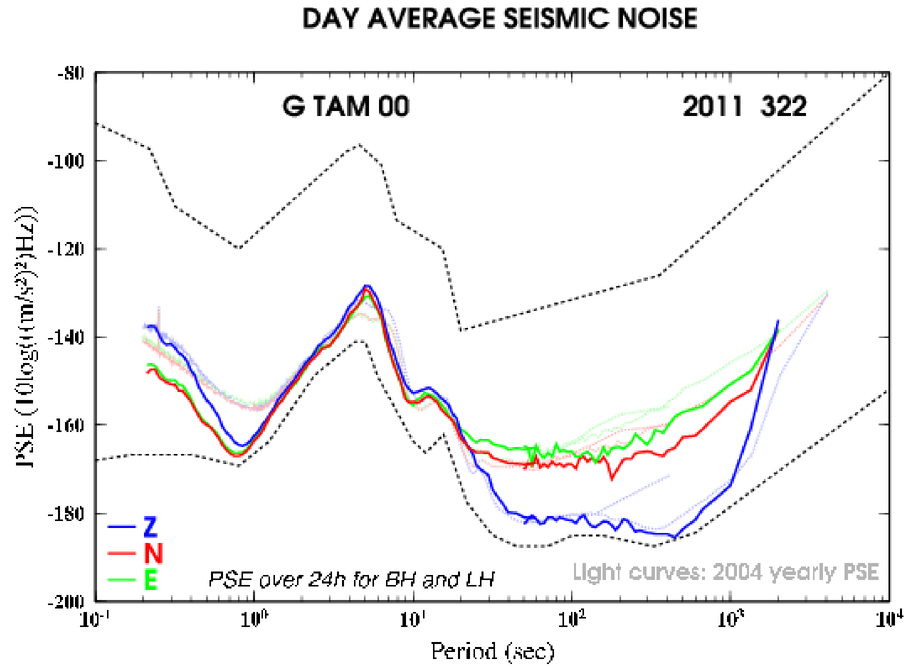
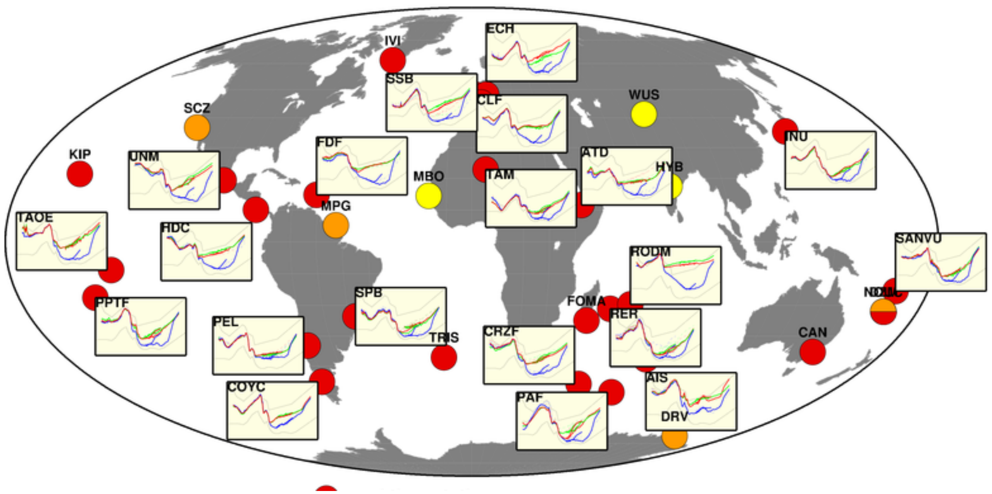
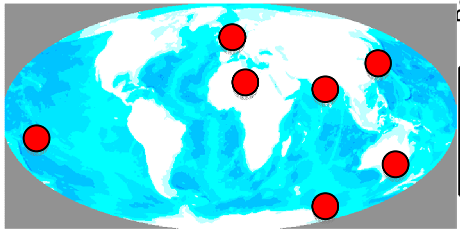
GEOSCOPE network

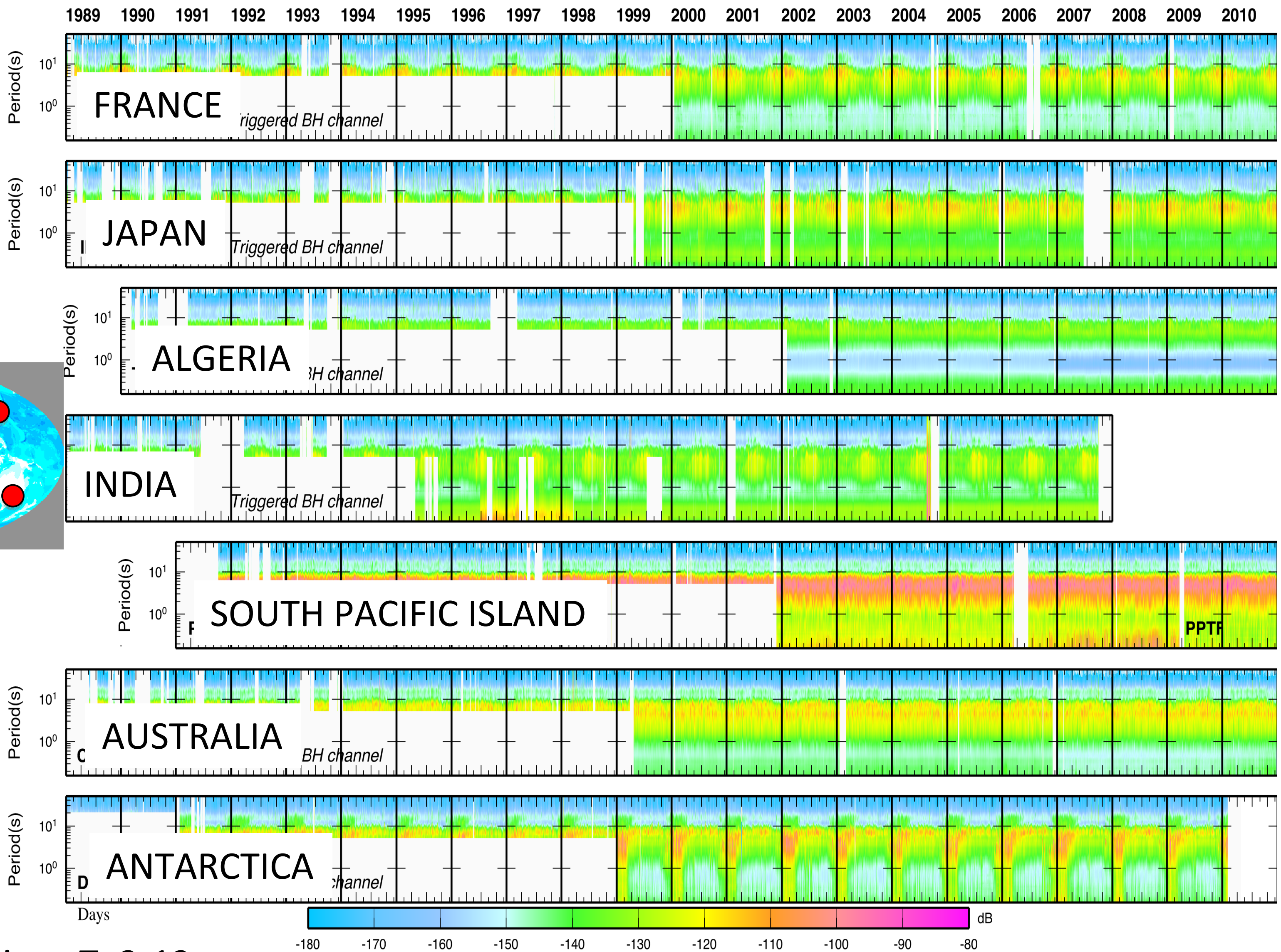






SEISMIC NOISE RECORDED OVER 20 YEARS
by the GEOSCOPE network





Secondary microseism: T=3-12sec

Secondary microseism sources

<u>Secondary microseism theory</u>

(T=3-12sec)

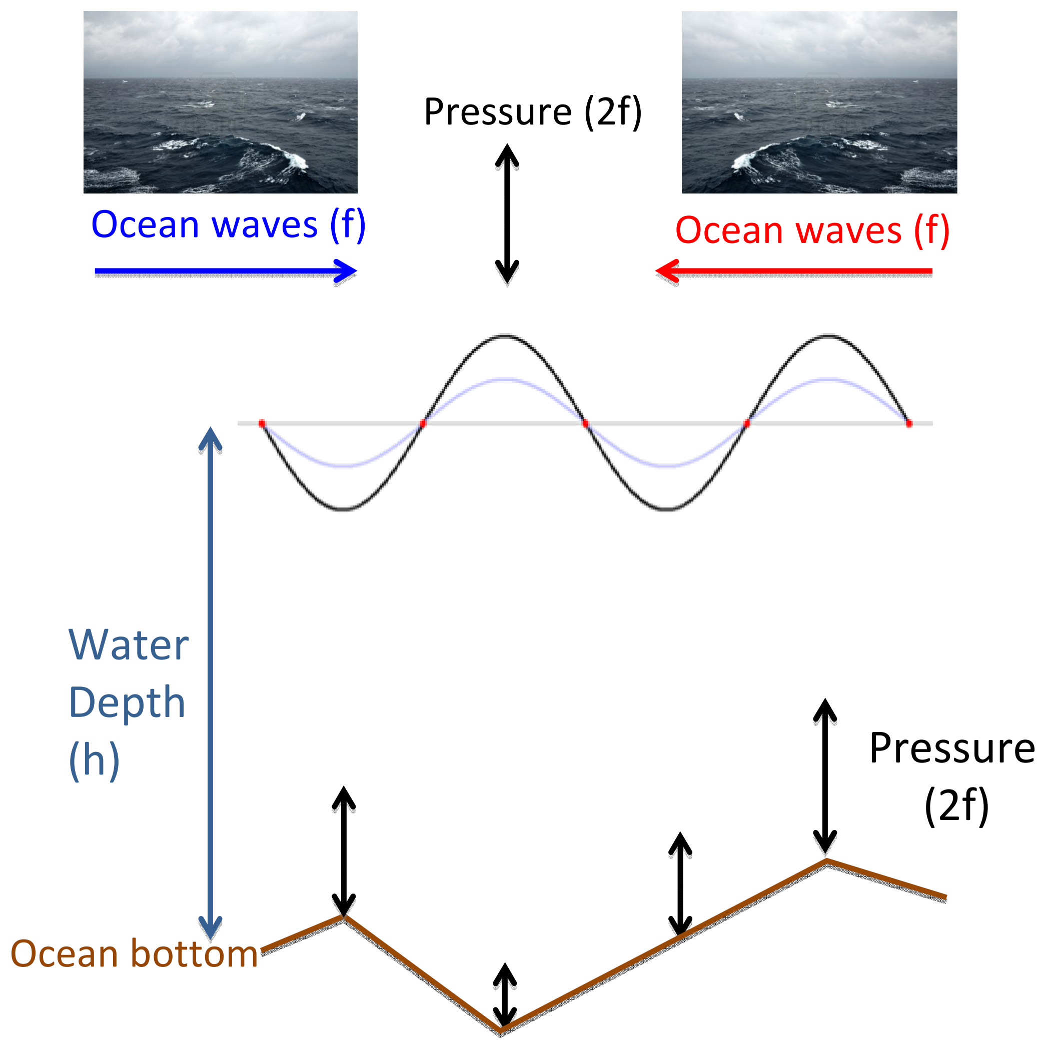
Longuet-Higgins (1950), Hasselman (1963)

Ocean waves of frequency f vanish below the water base

Pressure at the ocean bottom:
- frequency 2f
- no attenuation with depth
- the amplitude modulated by:

$$\frac{2 \quad .2f.h}{Vs}$$

h: water depth
f: seismic frequency
Vs: crust S-wave velocity

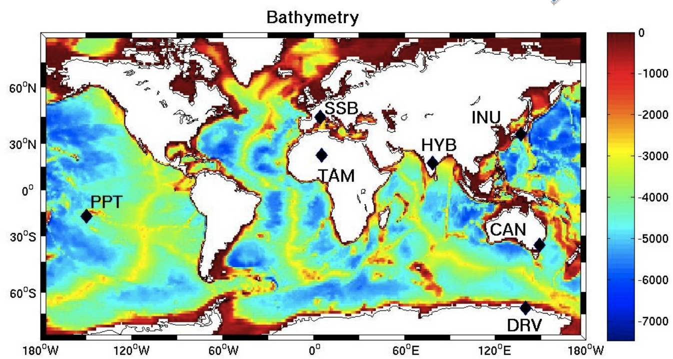


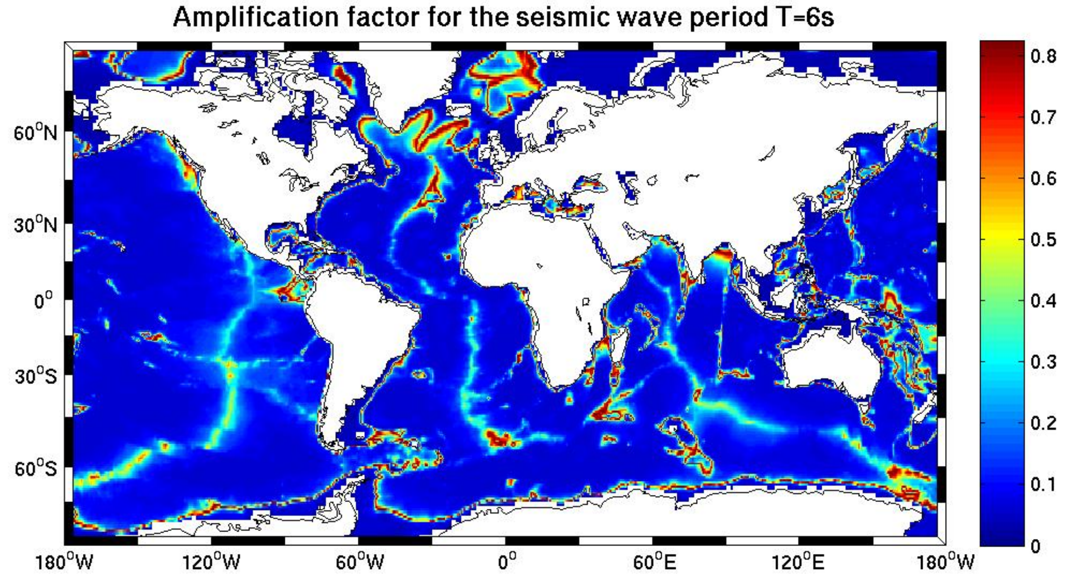
Secondary microseism amplification

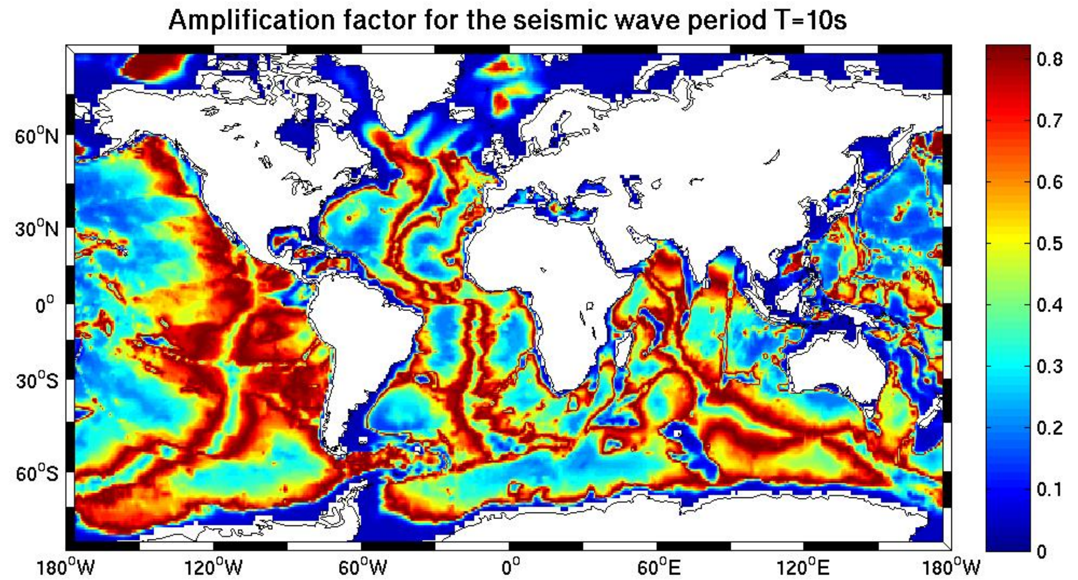
Ocean bottom pressure fluctuations
Depnds on the water depth
and period

Period=6s

Period=10s



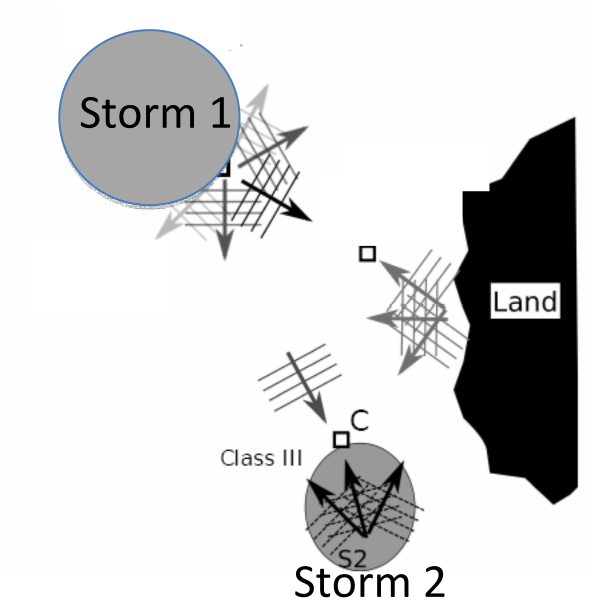


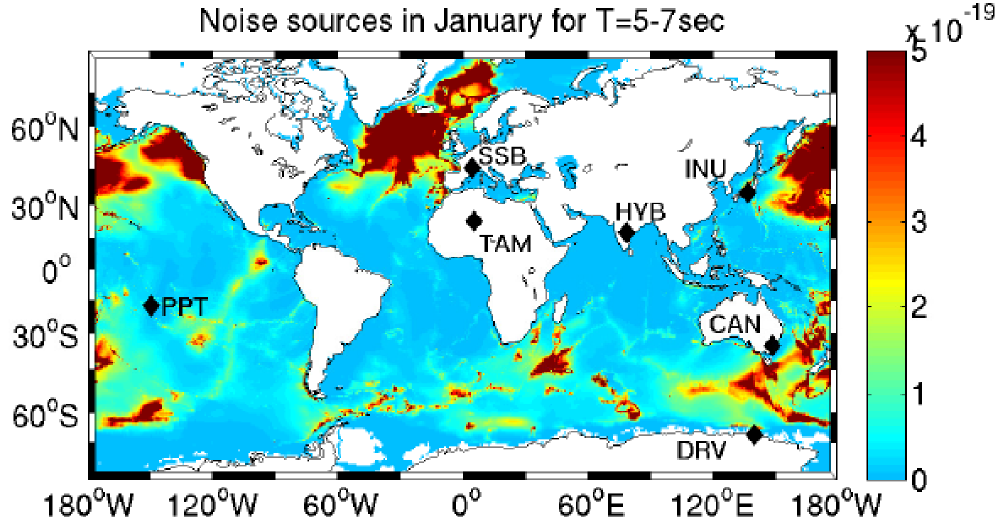


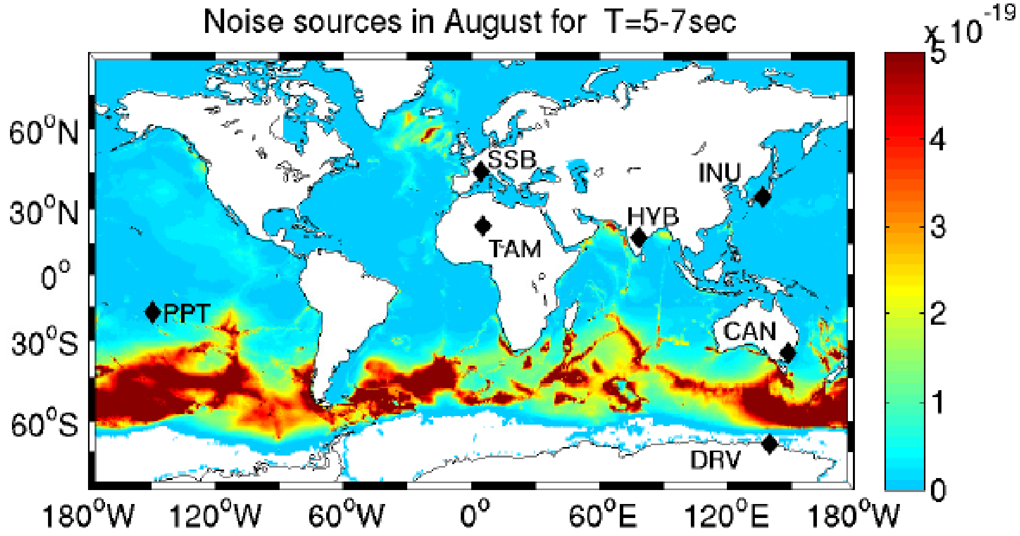
Secondary microseism sources

Noise sources are generated when there is interaction of ocean waves:

- within a storm
- between storms
- by reflection at the coast



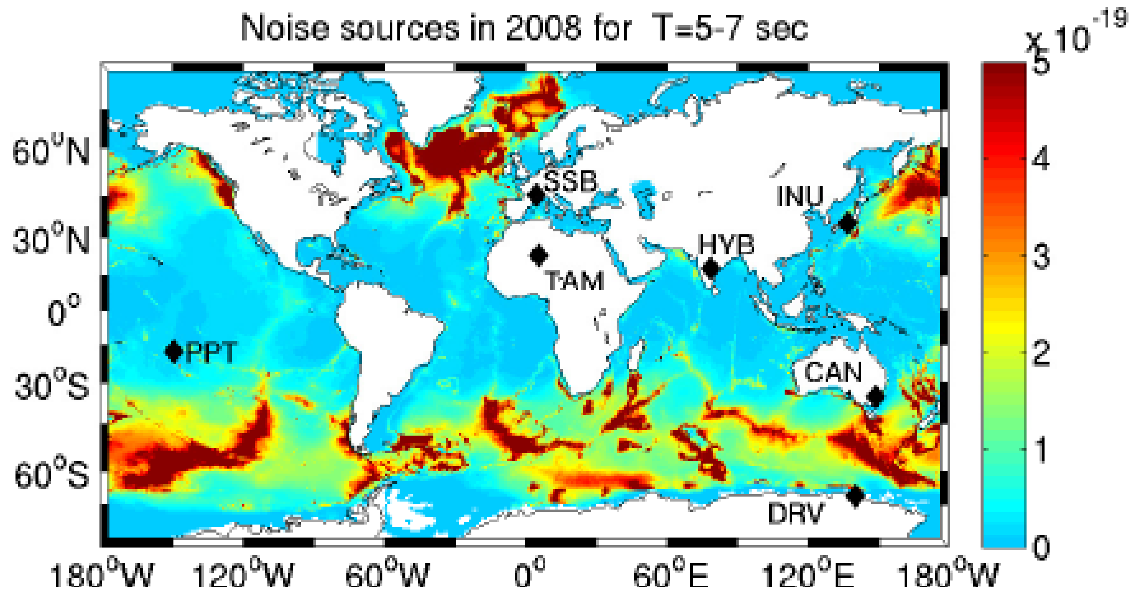




Our source model (IOWAGA, Ardhuin et al.2011),
Is computed with the code WAVEWATCH III (version 3.14)
using 6-hourly wind analysis from ECMWF
It is the first model that takes into account coastal reflection

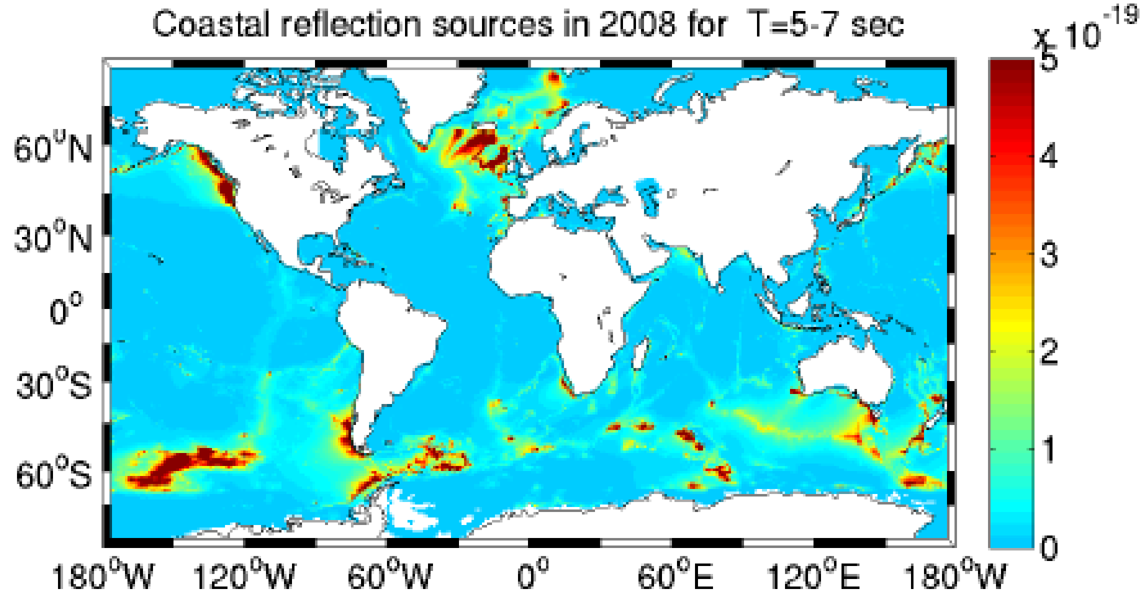
Secondary microseism sources

All noise sources in 2008



Sources generated by coastal reflection:

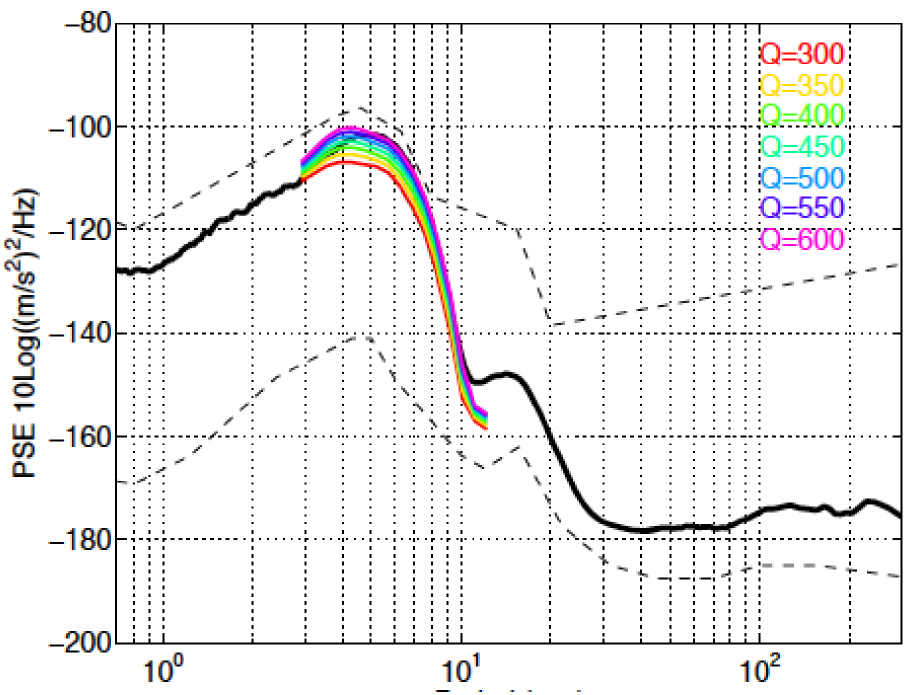
between 30˚ -60˚ along west coasts



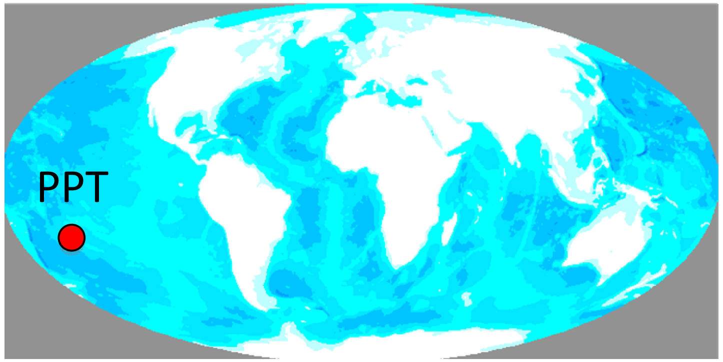
Modeling noise spectra

Synthetic spectrum:

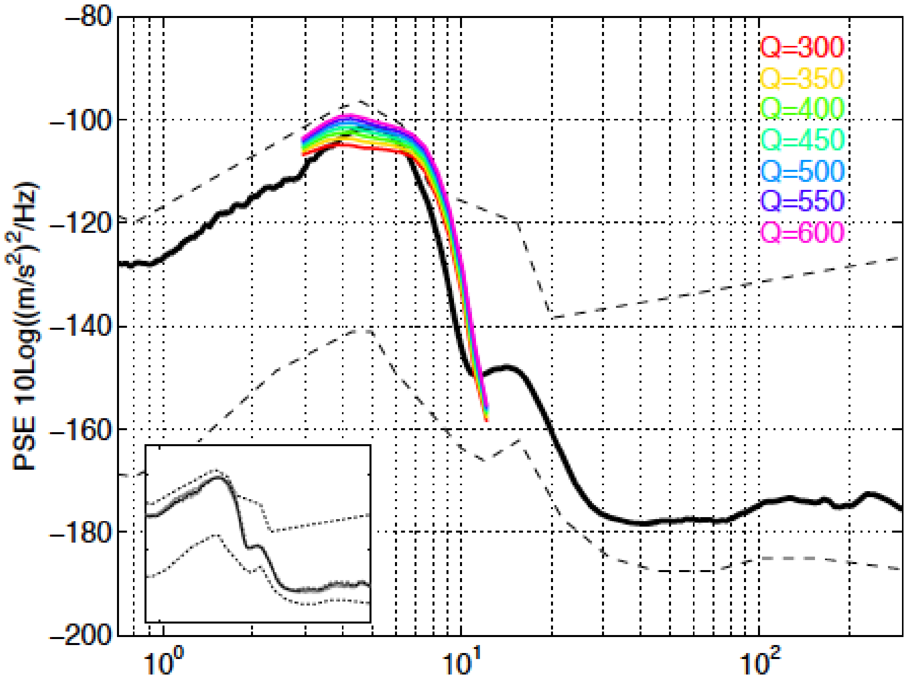
$$F_\delta(\lambda,\phi,f_s) = \underbrace{\int_0^{2\pi}\int_0^{\pi} S_{DF}(f_s)}_{\text{source}} \underbrace{\frac{1}{a\sin(\alpha)}\exp(\frac{-2\pi f_s a\alpha}{QU})}_{\text{propagation}} \underbrace{a^2 sin(\phi')d\lambda' d\phi'}_{\text{elementary surface}}$$



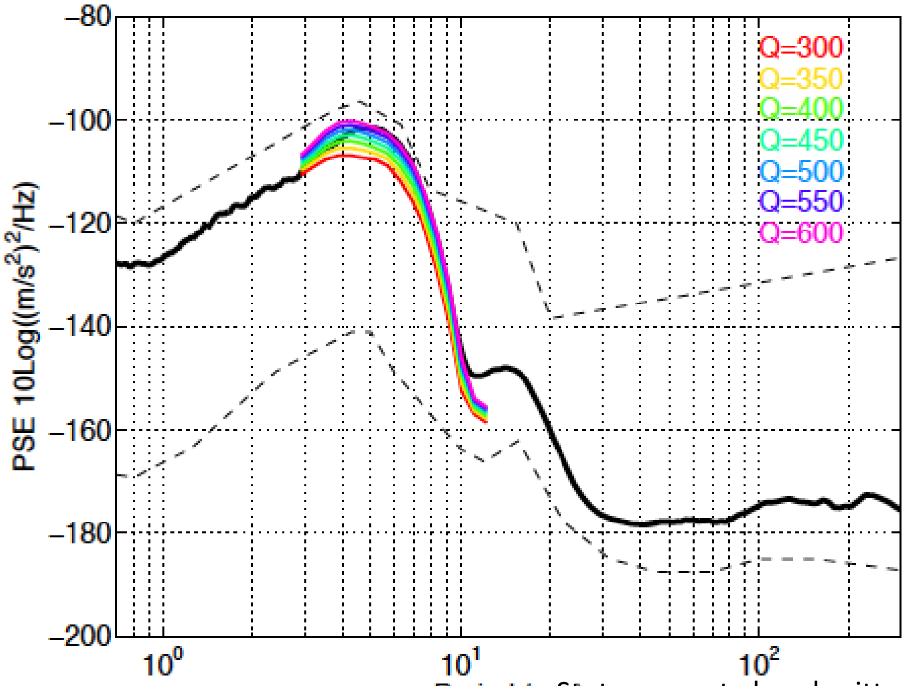
Modeling noise spectra



With 10% coastal reflection

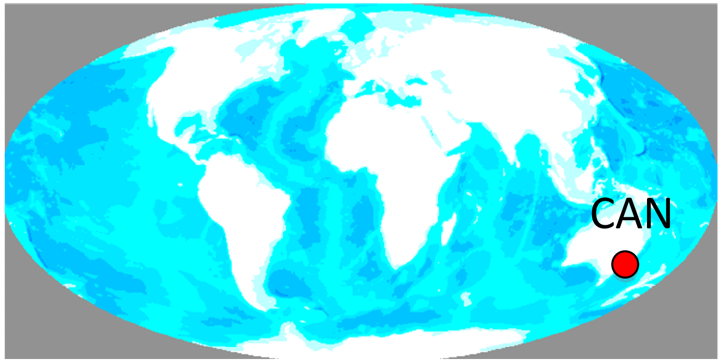


Without coastal reflection

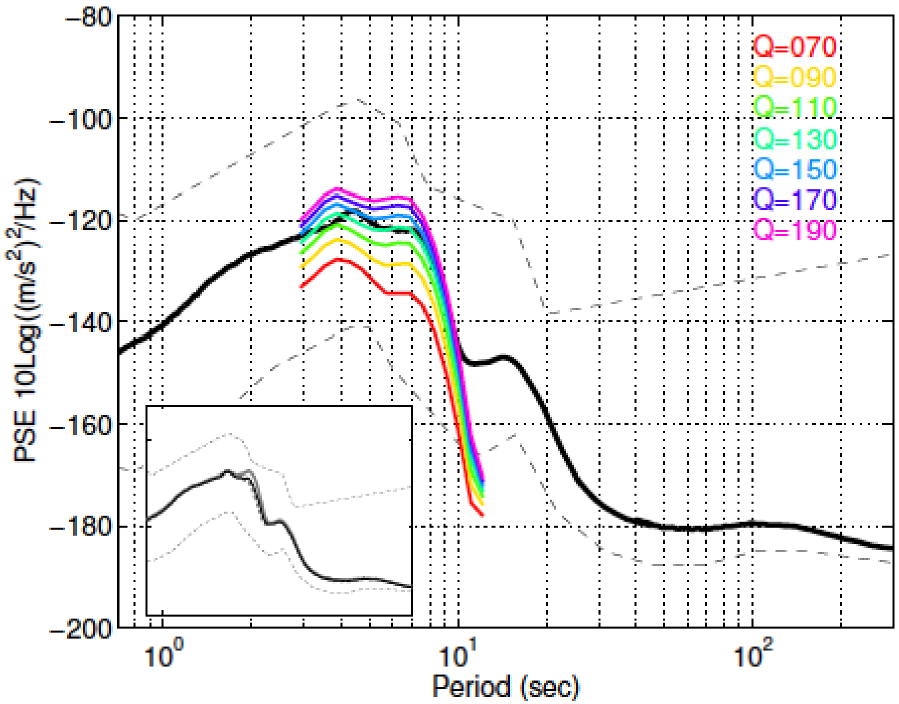


Stutzmann et al., submitted

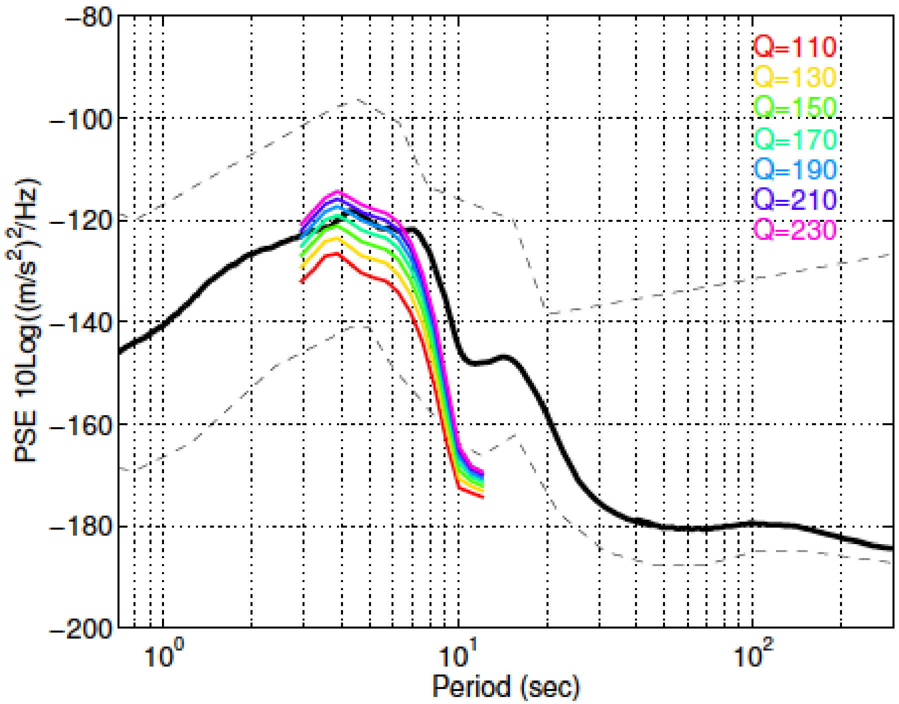
Modeling noise spectra



With 10% coastal reflection



Without coastal reflection

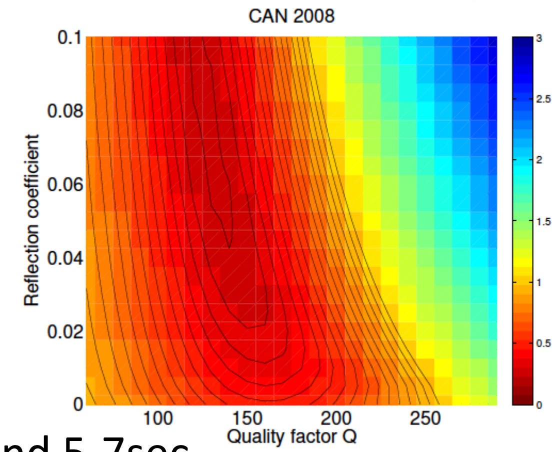


Stutzmann et al., submitted

Modeling seismic noise

Parameters not well constained:

- seismic attenuation
- ocean wave reflection coefficient

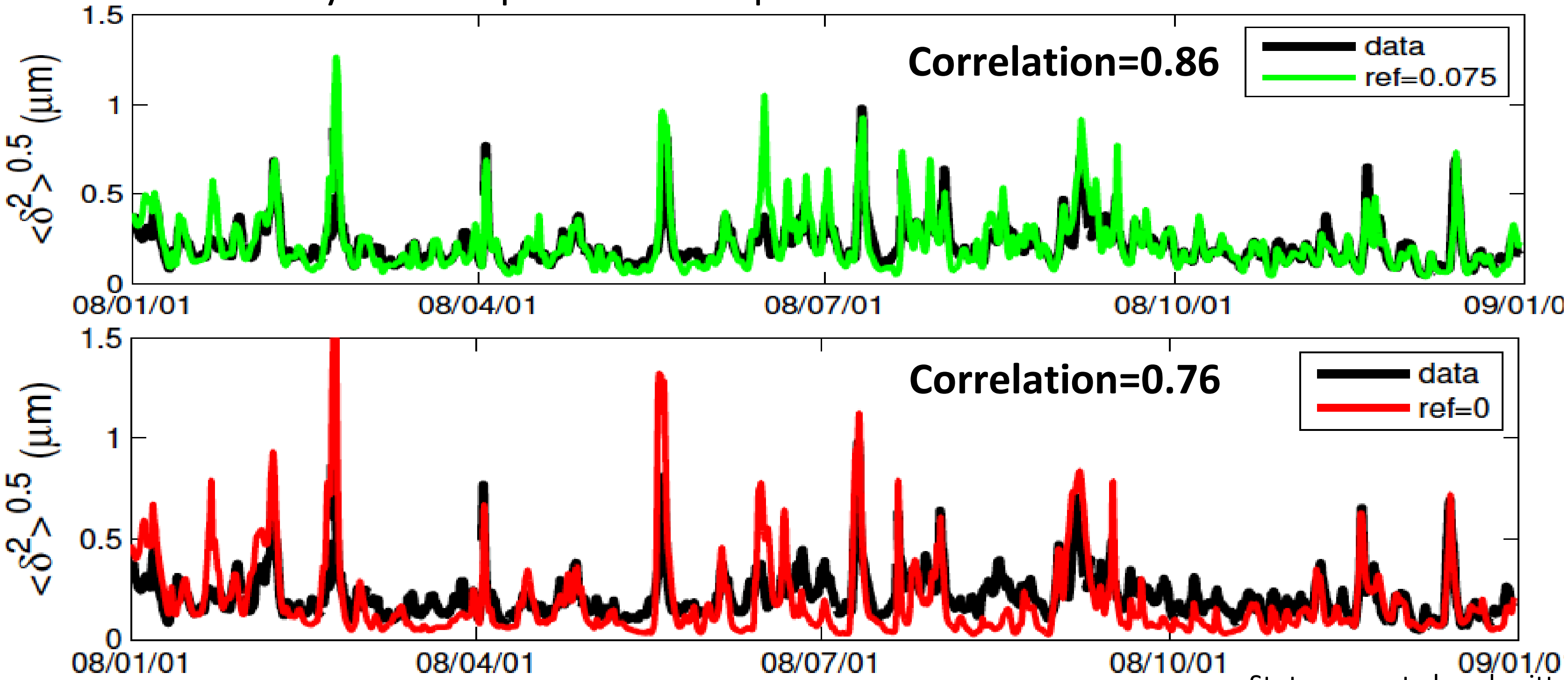


Misfit

Real and synthetic spectra in the period band 5-7sec

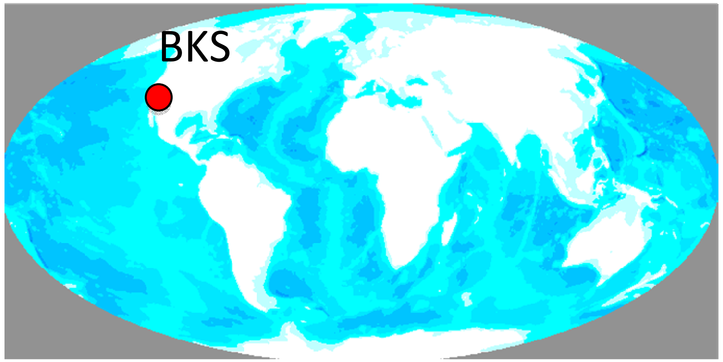
With coastal reflection

Without coastal reflection



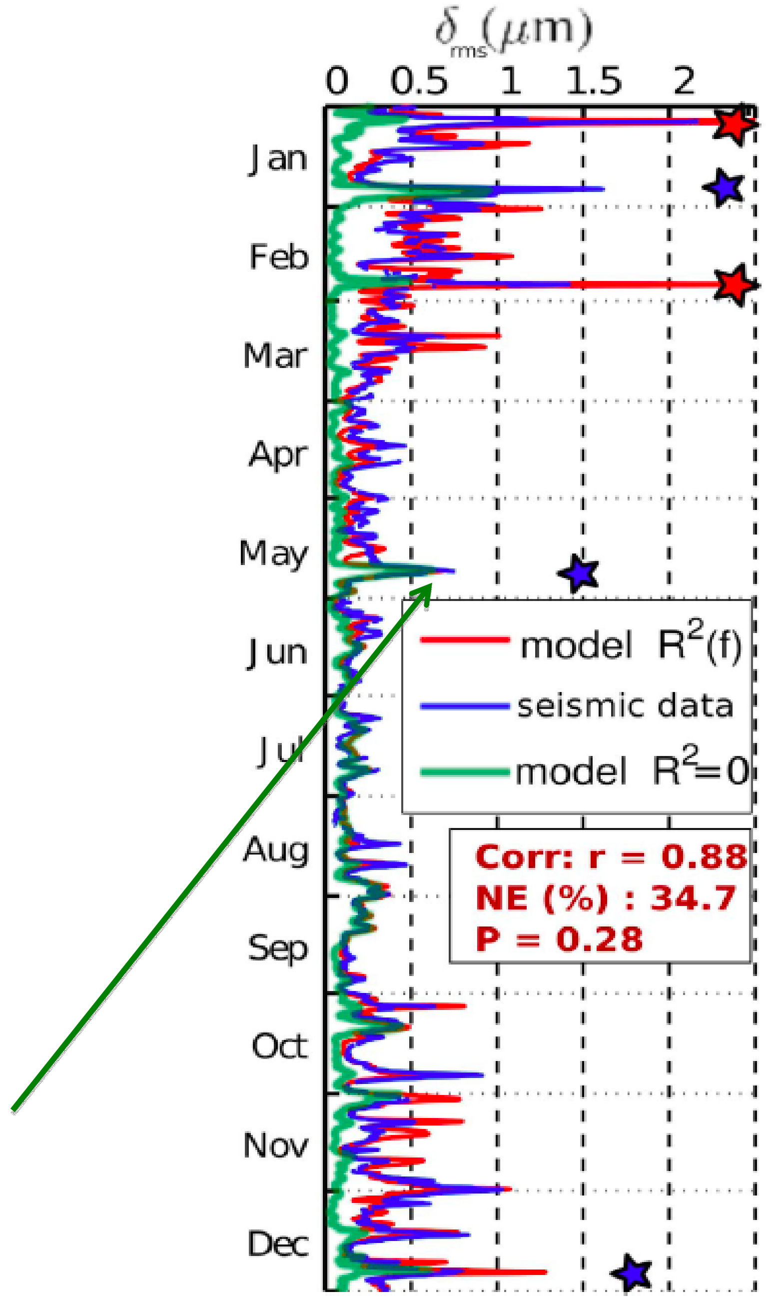
Stutzmann et al., submitte

Coastal station: BKS



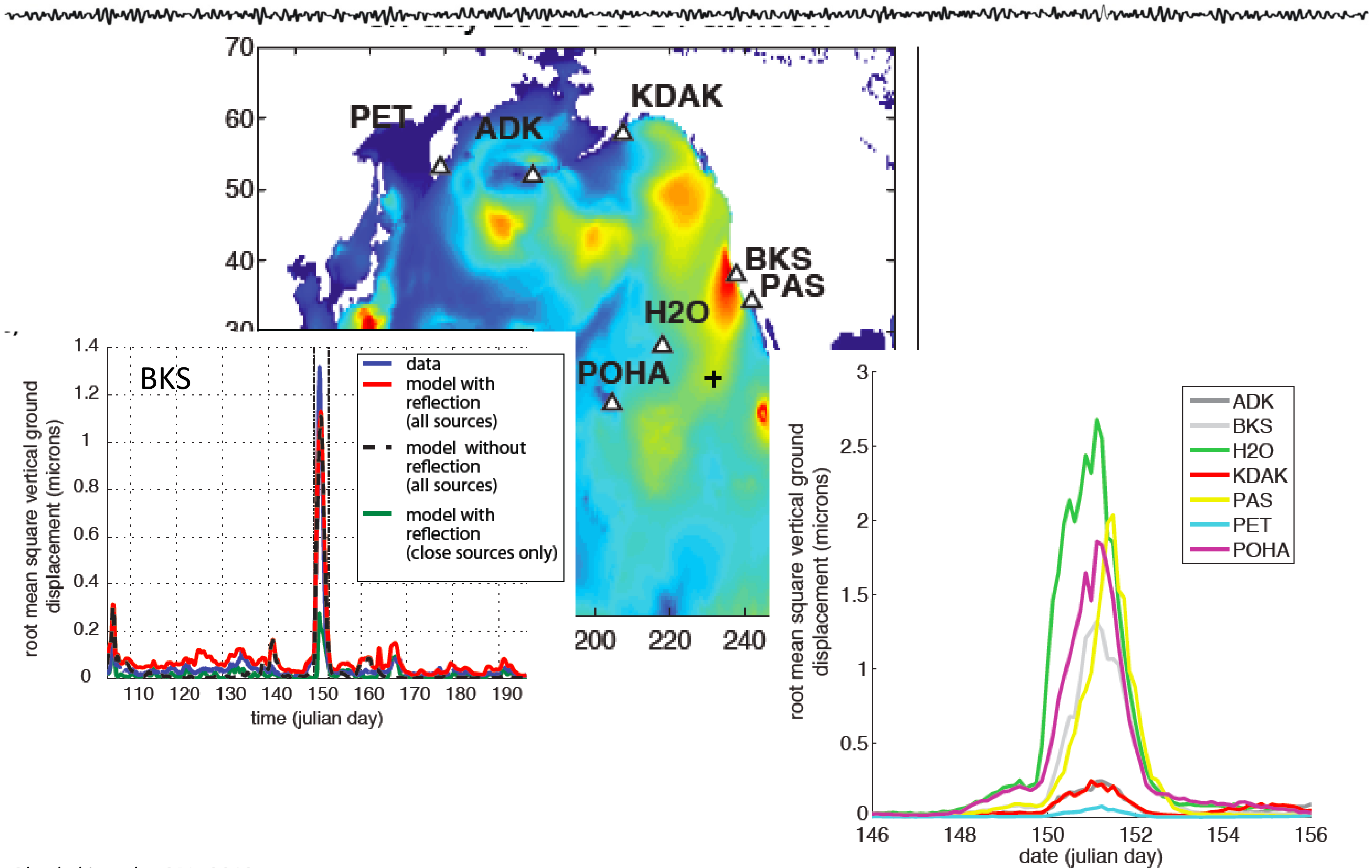
-Coastal reflection is strong and BKS mostly records noise generated by local sea state

-BKS also records some strong deep ocean sources

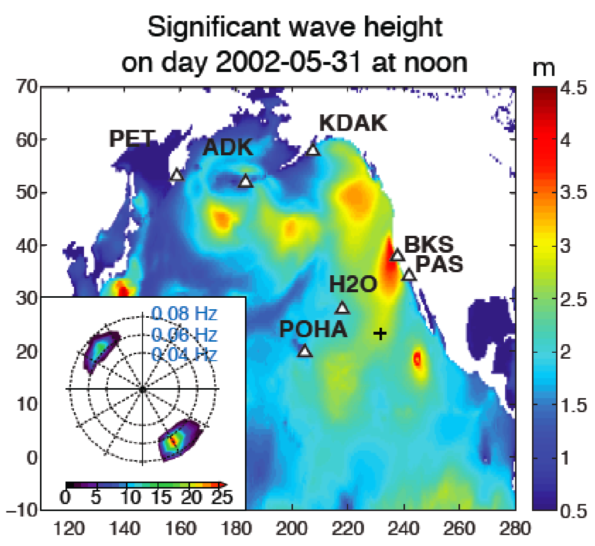


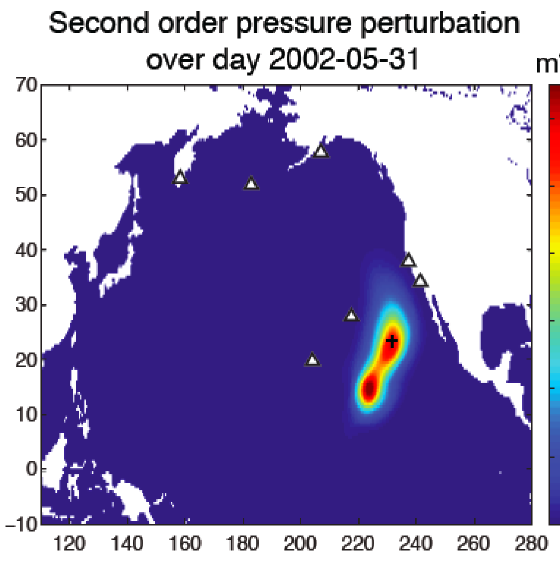
Ardhuin et al. 2012

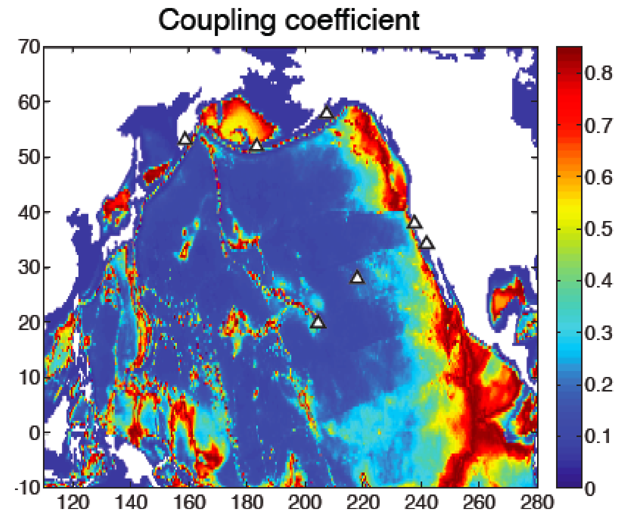
A strong source are in deep ocean

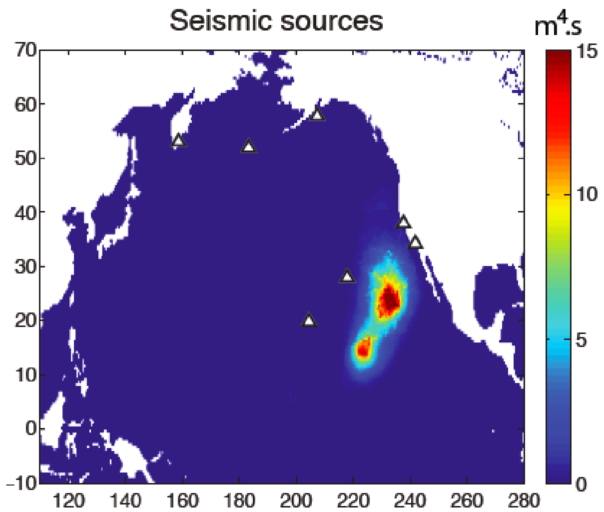


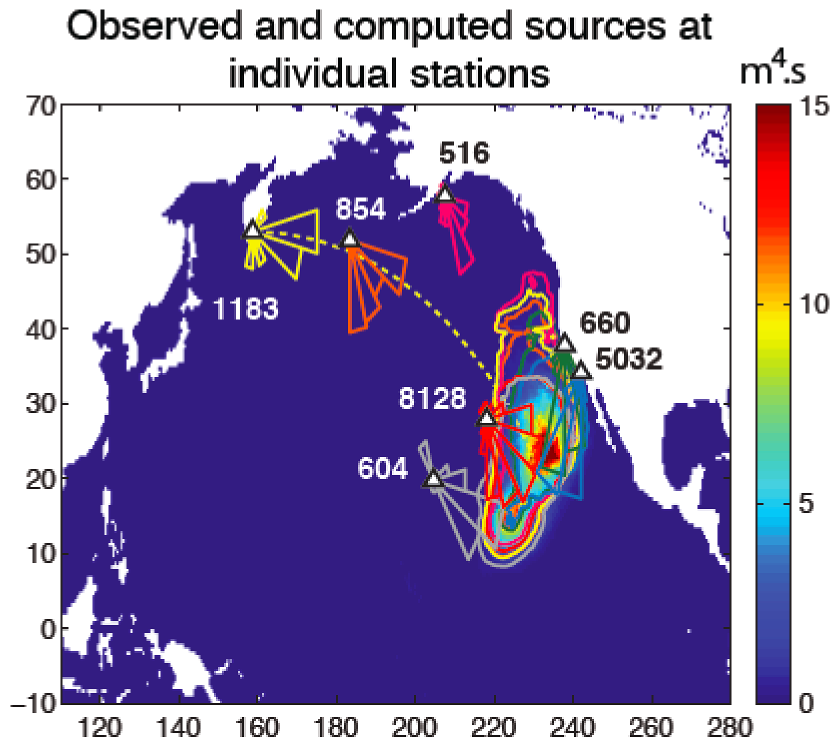
Obrebski et al.,, GRL, 2012







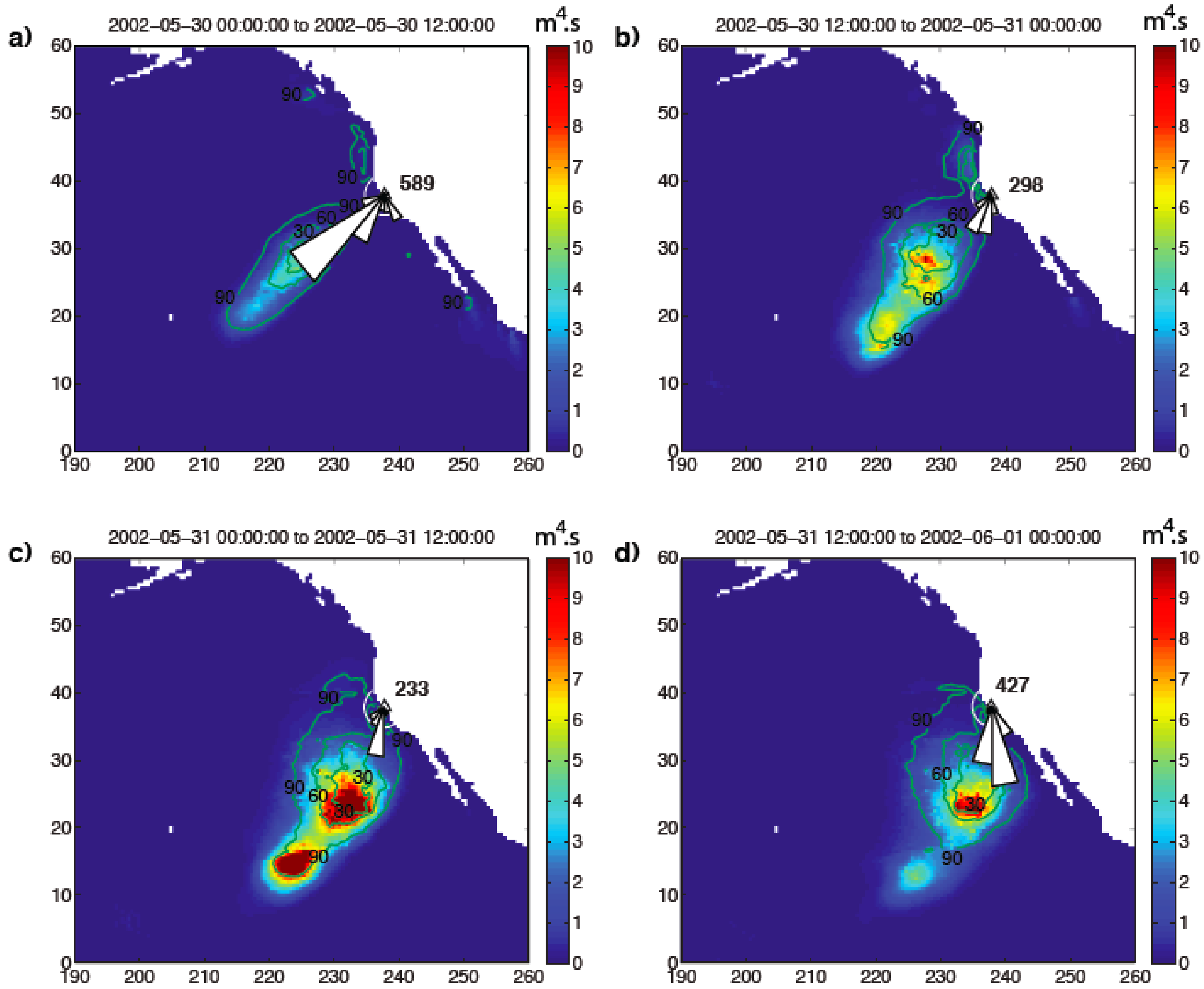




Moderate sea state generates strong sources in deep ocean

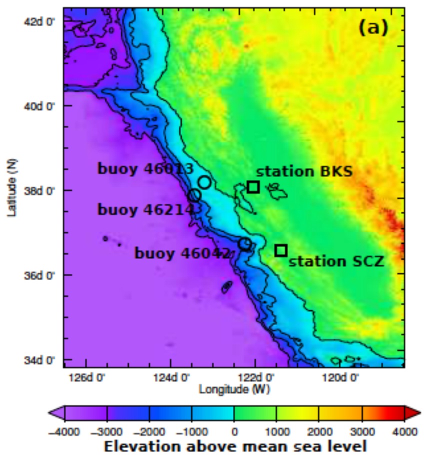
Obrebski et al. 2012. Polarization analysis: Schimmel et al. 2011

Time evolution of the source



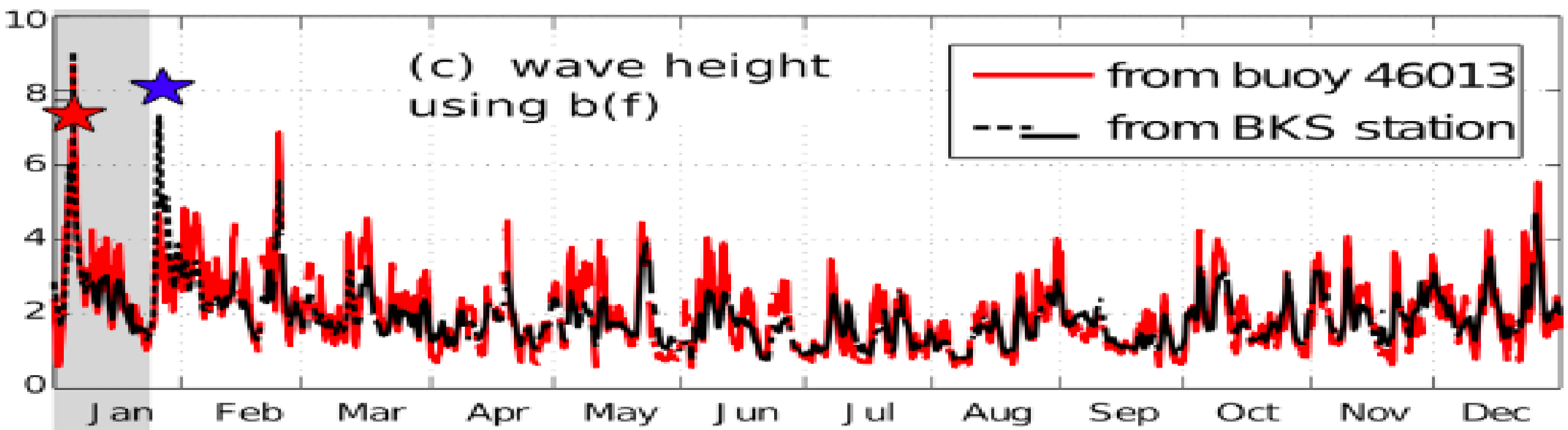
Obrebski et al. 2012

When coastal reflection is dominant



When coastal reflection sources are dominant,
seismic signal is mainly sensitive to local sea
and can be used as a proxi of the ocean significant wave height

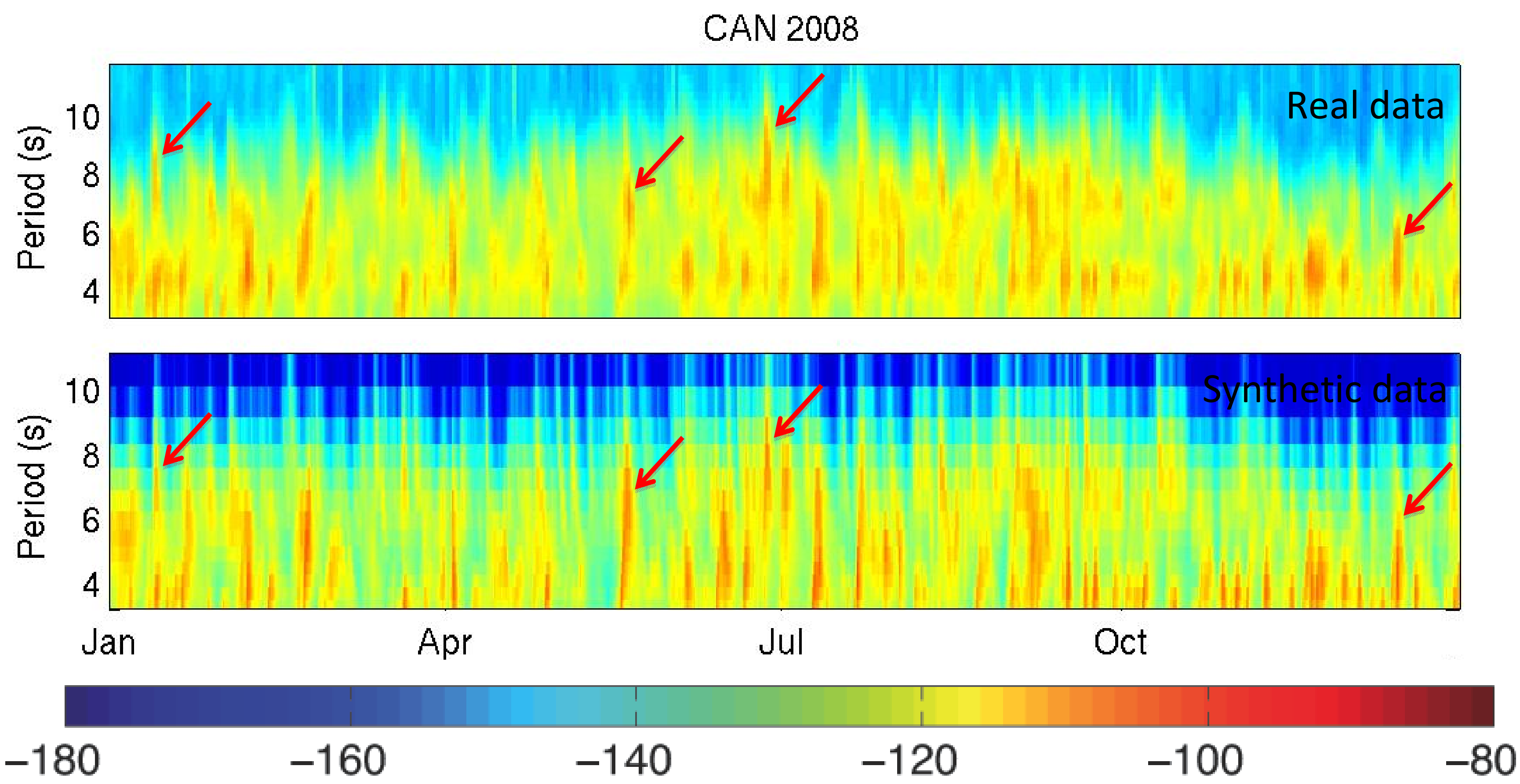
$$H_{s,eq} = 4\sqrt{\int_{f_{\min}}^{f_{\max}} a(f)[F_\delta(f_s, t+\tau)]^{b(f)} \mathrm{d}f}.$$



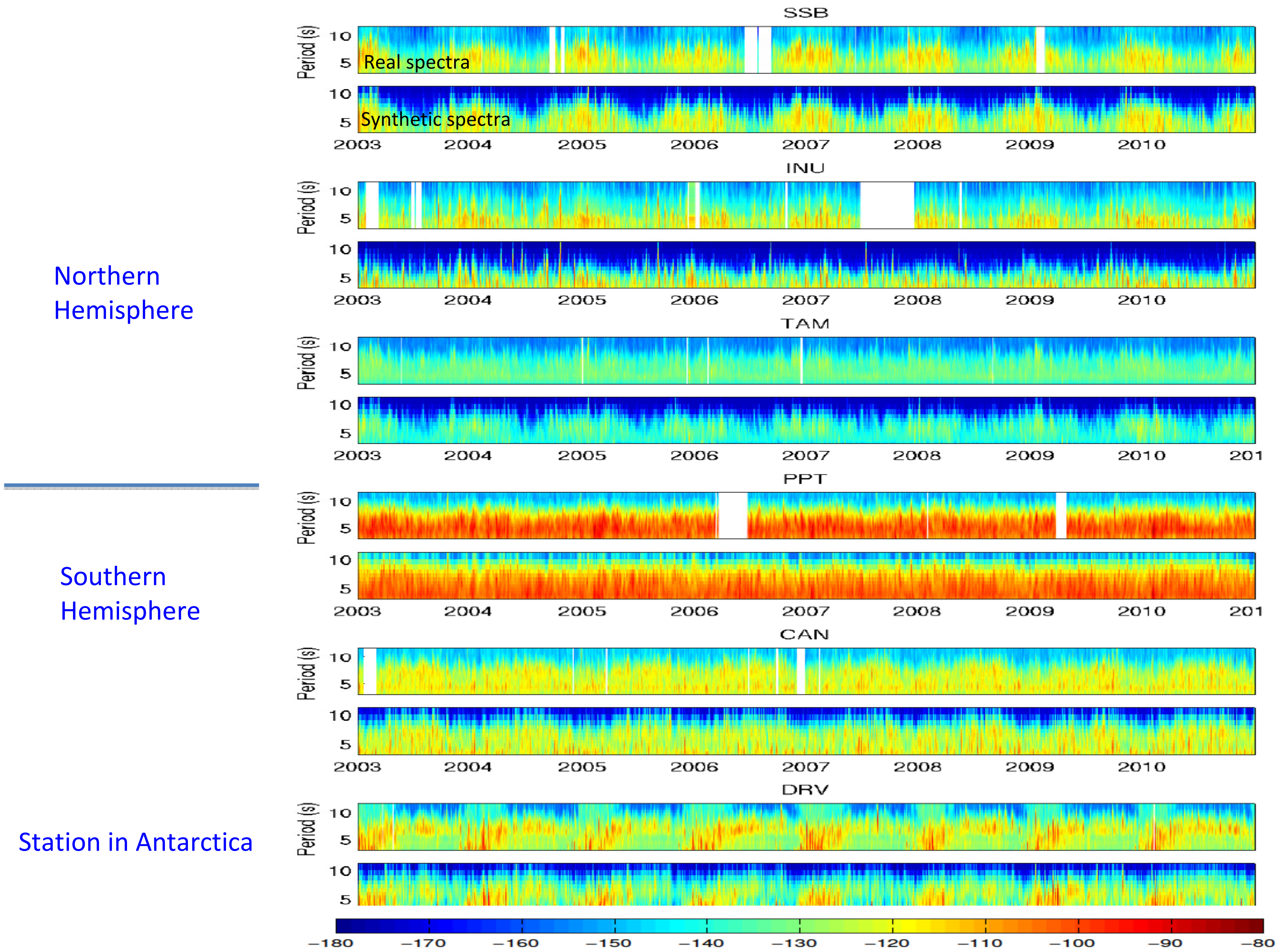
Distant sources have been removed

Ardhuin et al. 2012

Modeling seismic noise

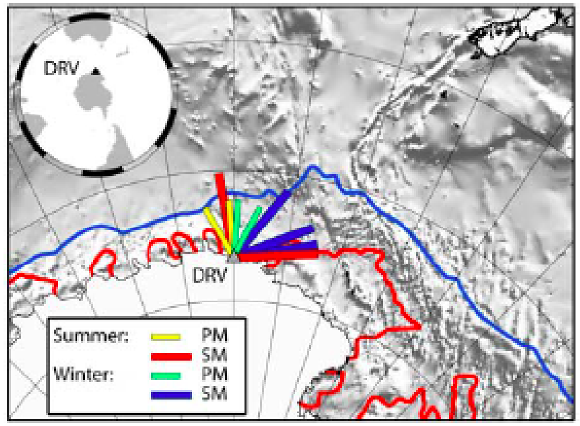


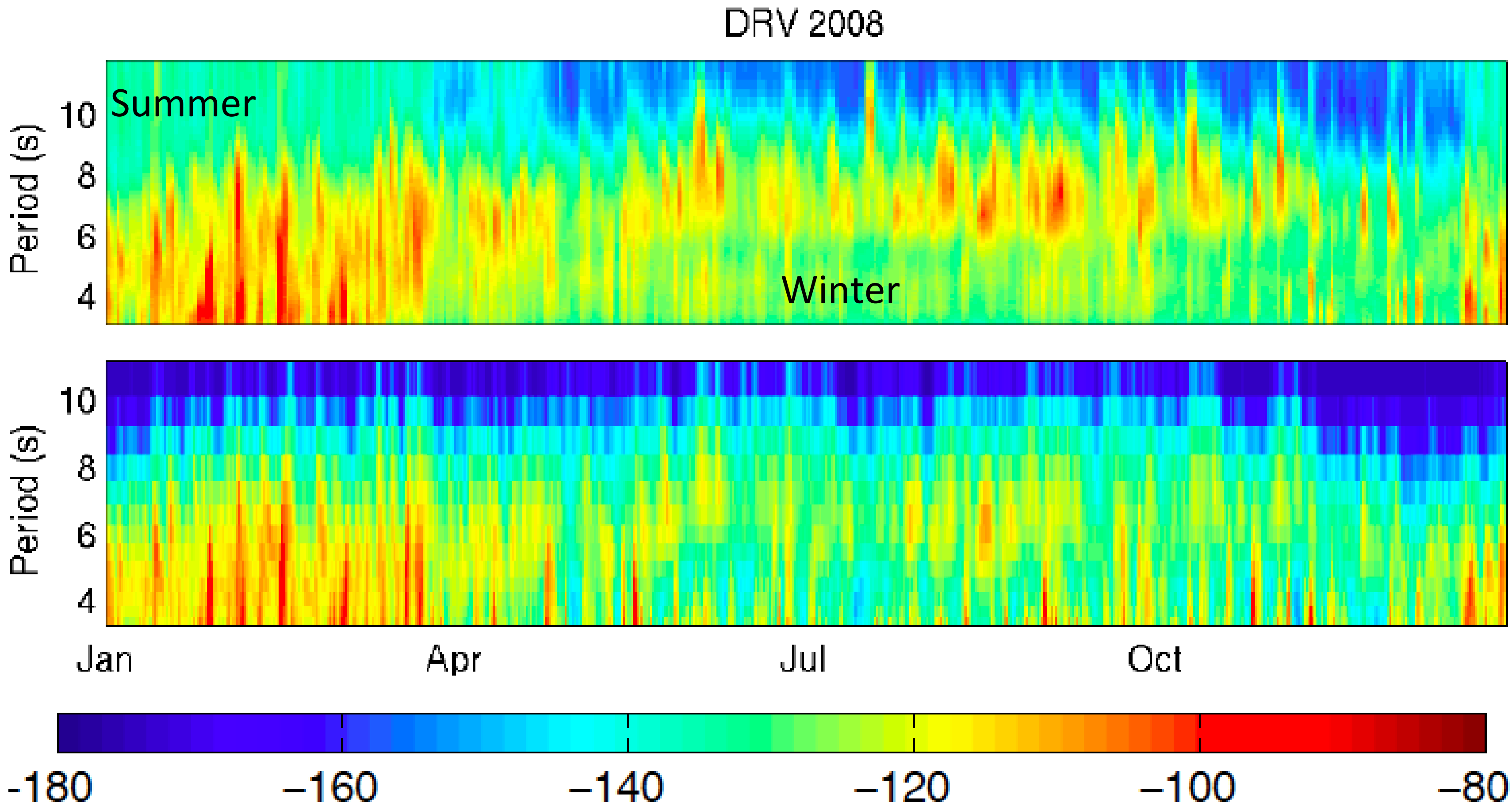
Good agreement between observed and synthetic spectra:
correct dates, amplitudes and frequency content

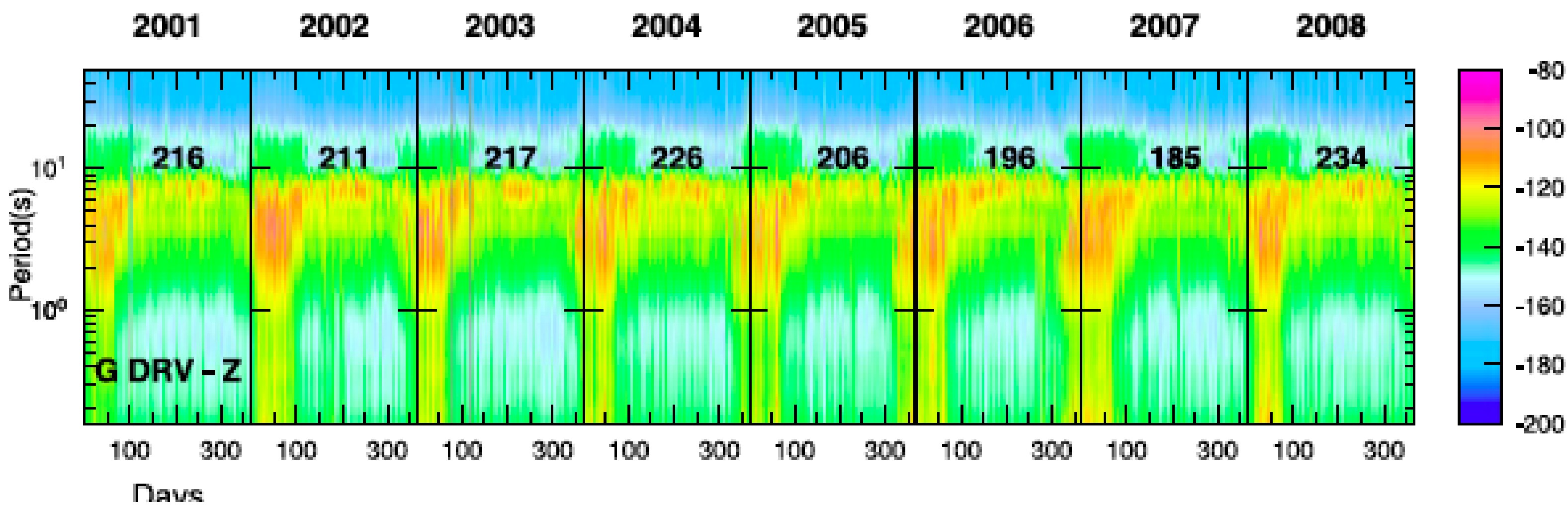

Northern Hemisphere
Southern Hemisphere
Station in Antarctica
SSB
INU
TAM
PPT
CAN
DRV
Real spectra
Synthetic spectra
Period (s)
10
5
2003
2004
2005
2006
2007
2008
2009
2010
201
−180
−170
−160
−150
−140
−130
−120
−110
−100
−90
−80

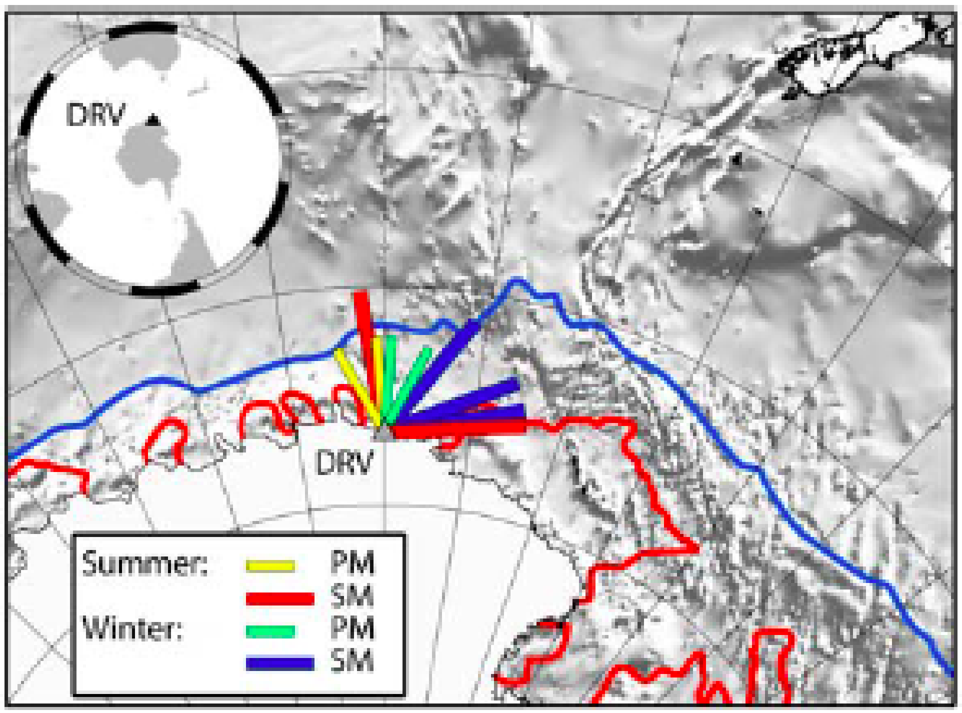
Effect of the variation of the sea ice

In Antarctica:



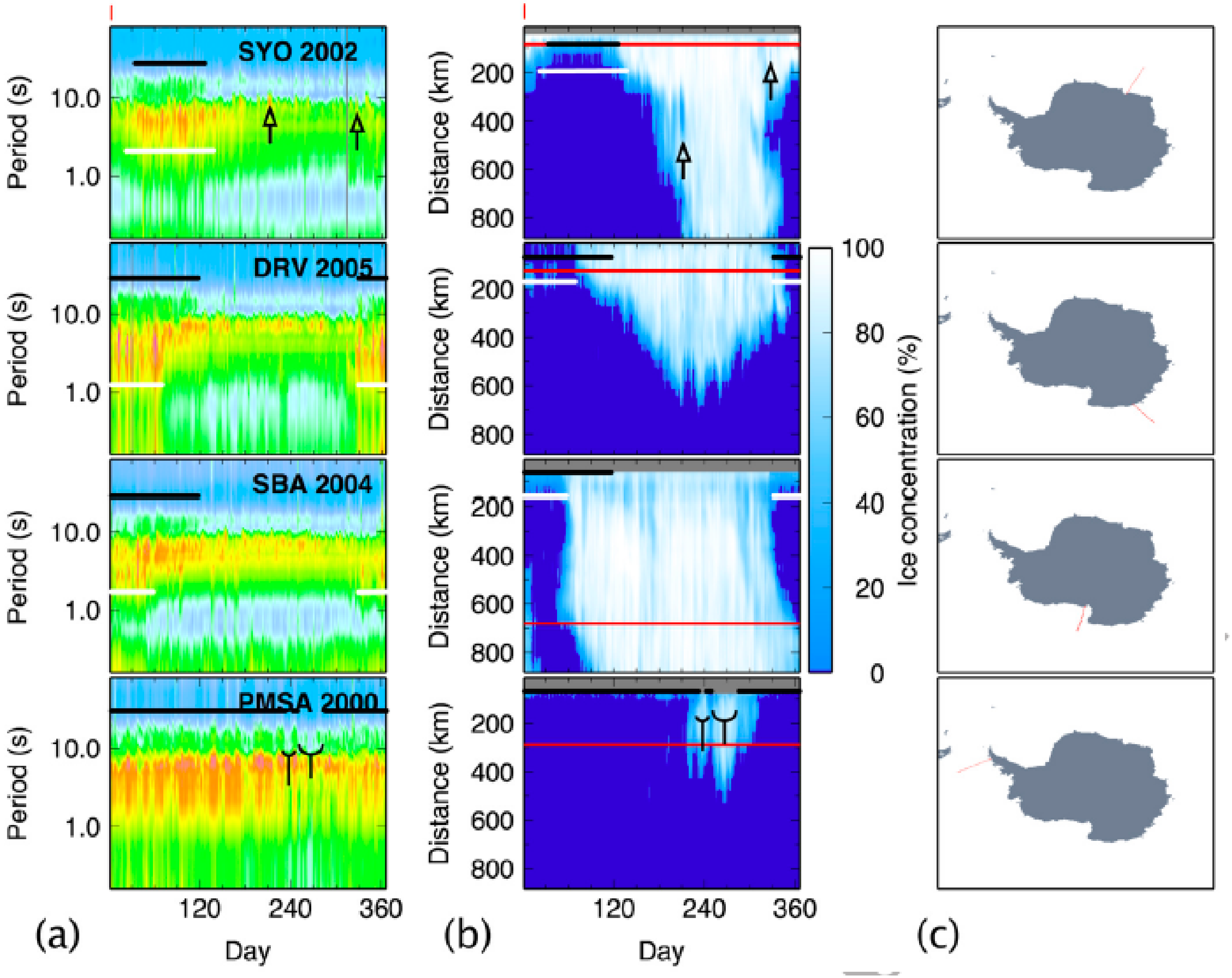






In winter, decrease of the amplitude of
- the primary microseism (10-15sec)
- the short period secondary microseism

Stutzmann et al., G3, 2009



Decrease of the noise associated with the primary microseism
and with the short period secondary microseism
is correlated with the ice concentration

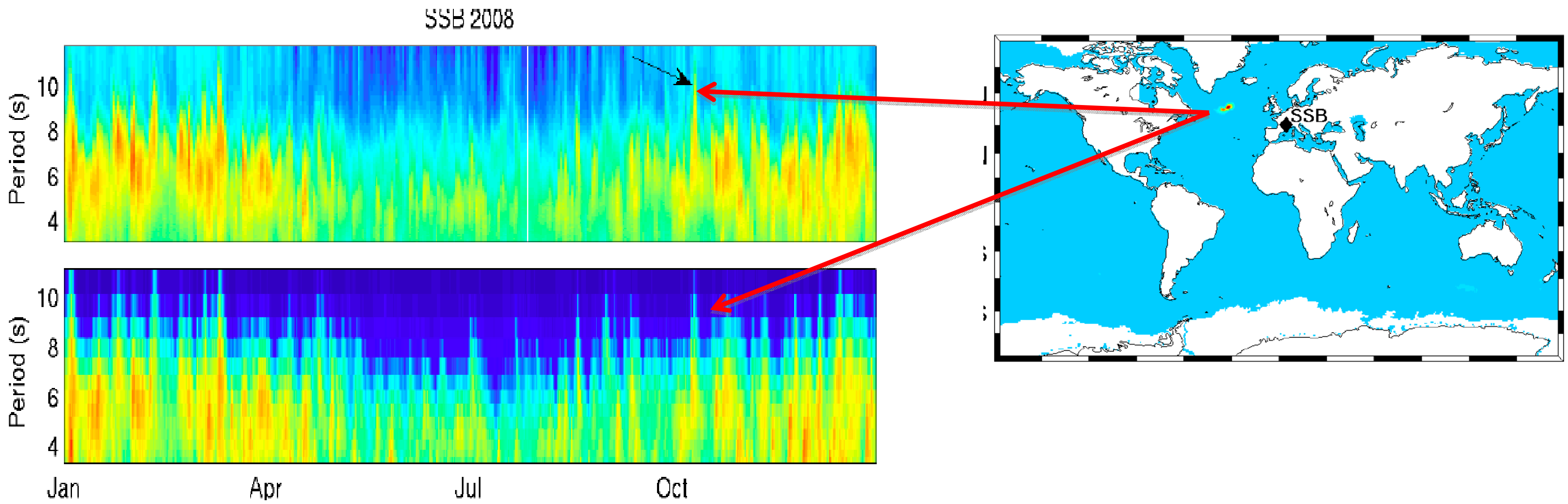
Grob et al., 2011

Conclusions

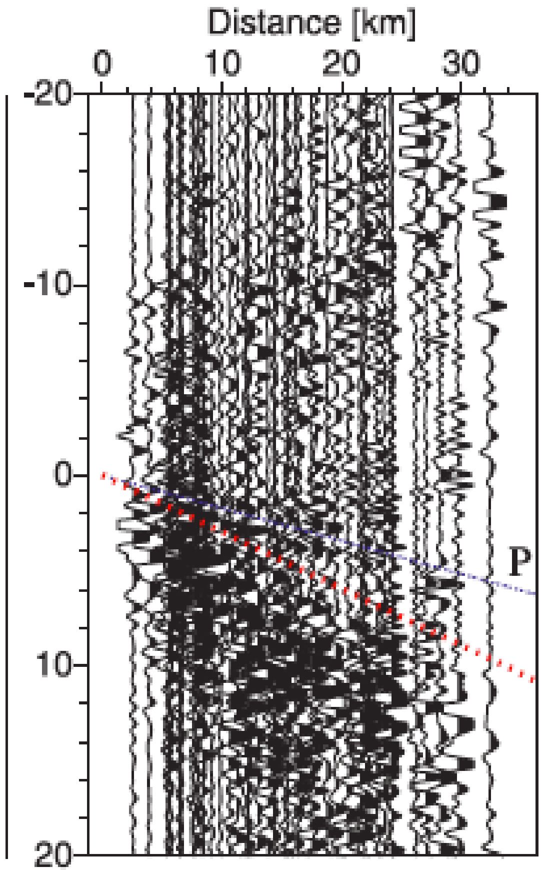
- Good agreement between observed and modeled seismic noise for stations in various environment

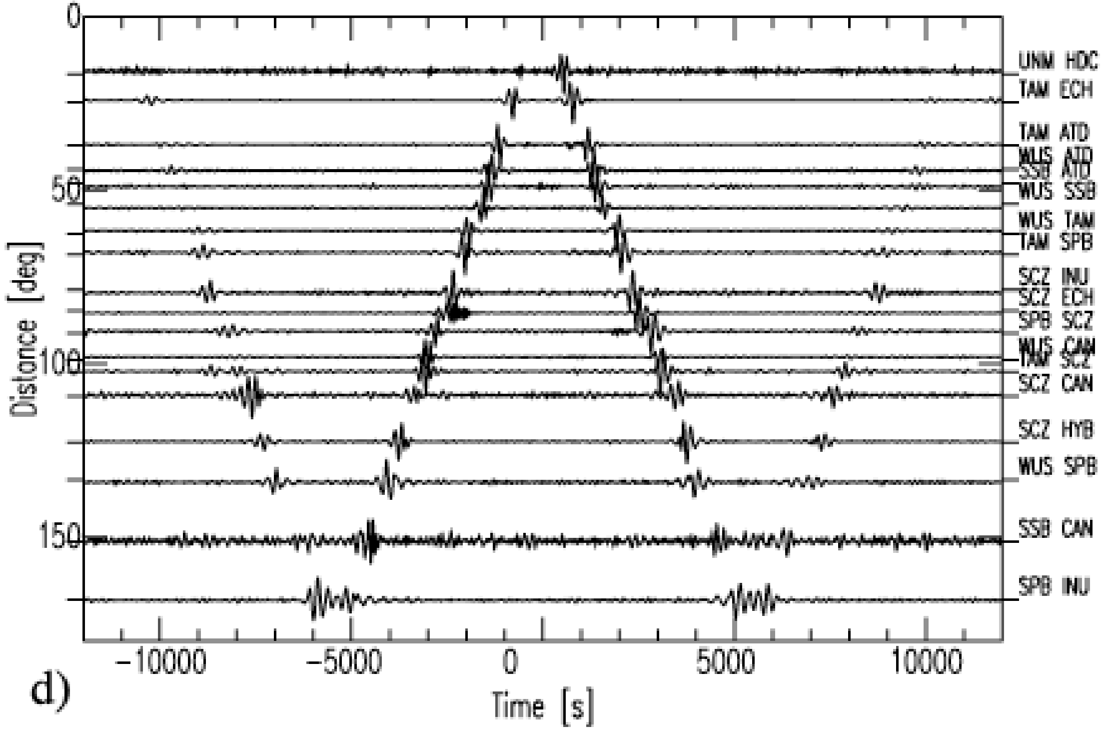
- Ocean wave coastal reflections generate noise sources along west coasts

- The largest noise peaks are generated in deep oceans
- Coastal reflections generate numerous smaller sources



Extraction of body waves and surface waves from noise





Schimmel et al., 2010