The Origin of the Hum

Toshiro Tanimoto
Visiting Fellow, CAS, LMU
UCSB

Menu

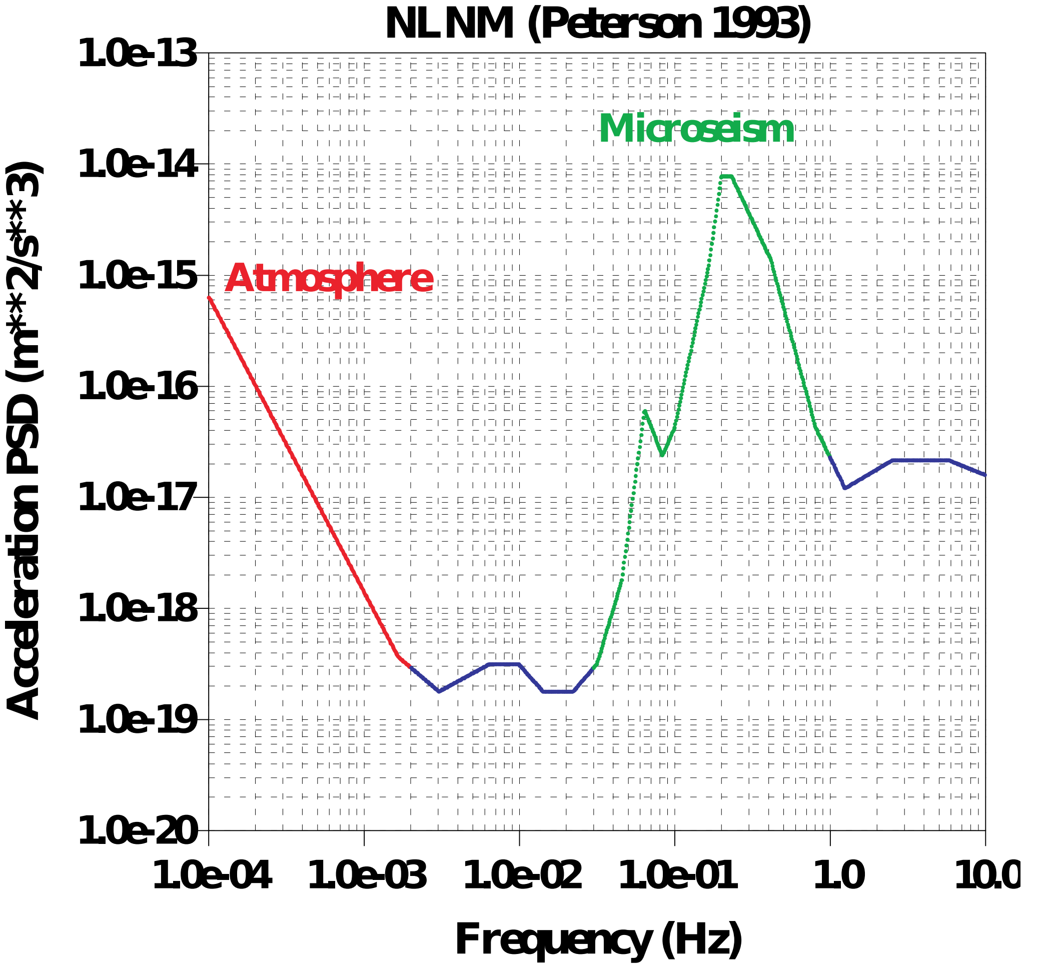
1. The (Historical) Origin of the Hum (Study)

2. Development of our understanding

3. Questions

Background

Towards Understanding Seismic Noise



Symposium on Microseisms

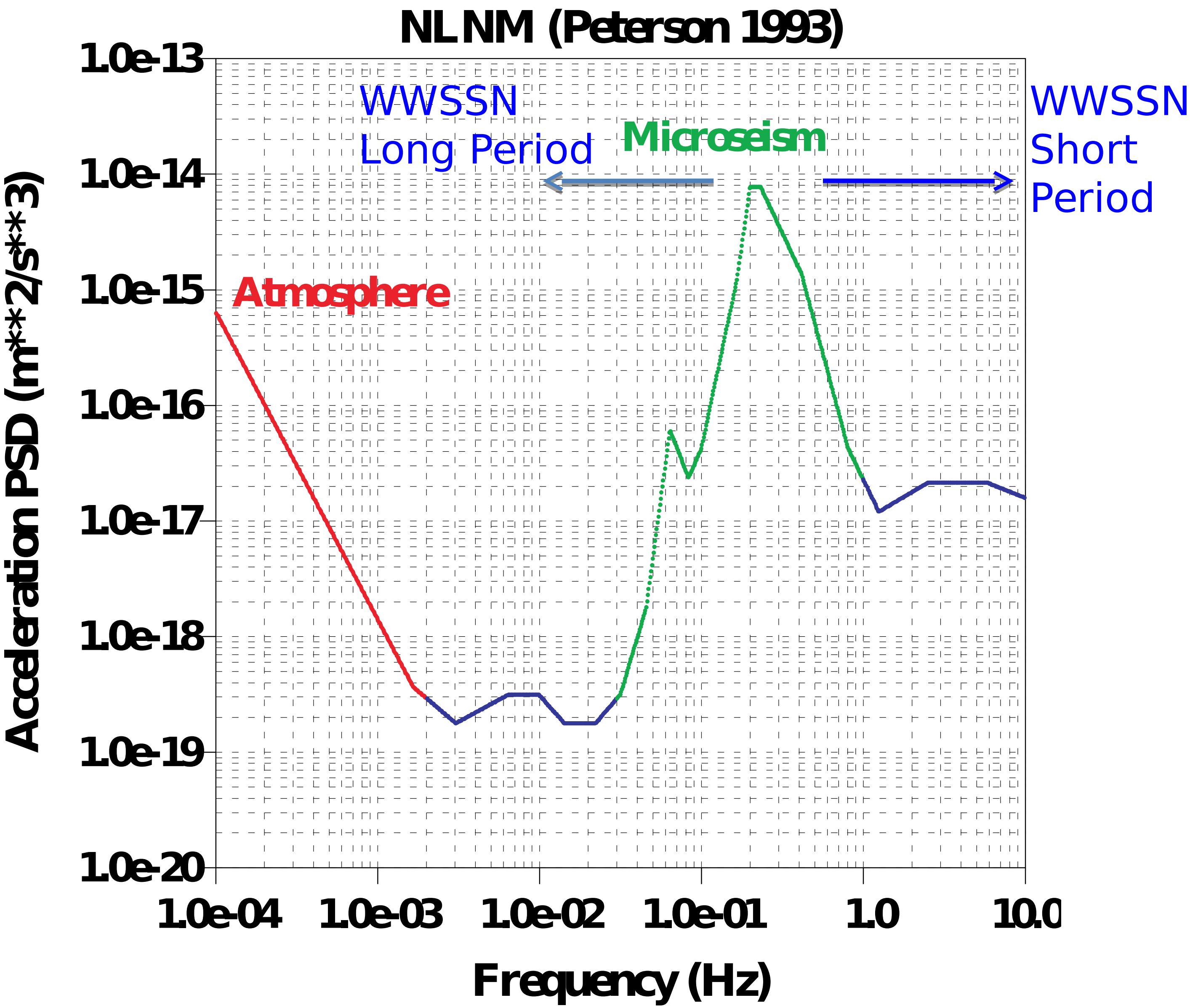
Held at Arden House
Harriman, N. Y.
4-6 September 1952

SPONSORED BY THE OFFICE OF NAVAL RESEARCH, AND THE GEOPHYSICAL RESEARCH DIRECTORATE OF THE U. S. AIR FORCE

Attendants at SYMPOSIUM ON MICROSEISMS held at Arden House, Harriman, New York, September 4-6, 1952

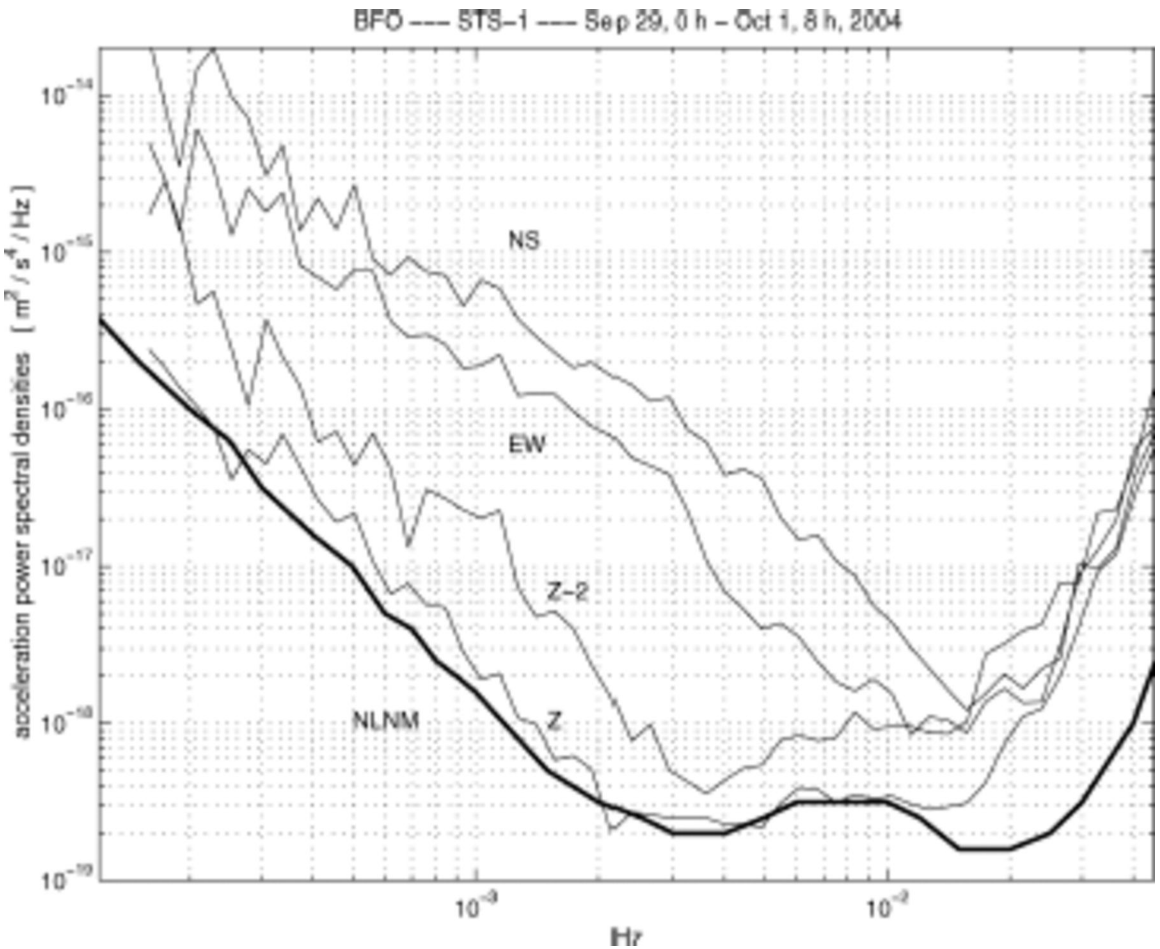
(front, left to right)	
Dr. Perry Byerly	University of California, Berkeley, Calif.
Dr. Florence Van Straten	Navy Department, Washington, D. C.
Mr. William Donn	Brooklyn College, Brooklyn, N. Y.
Dr. J. E. Dinger	Naval Research Laboratory, Washington, D. C.
Dr. James T. Wilson	University of Michigan, Ann Arbor, Michigan
Dr. John N. Adkins	Office of Naval Research, Washington, D. C.
Dr. W. S. Jardetzky	Lamont Geological Observatory, Palisades, N. Y.
Dr. M. S. Longuet-Higgins	Trinity College, Cambridge, England
Dr. J. G. Scholte	Meterologisch Instituut, The Netherlands
Dr. Norman A. Haskell	Air Force Cambridge Research Center, Mass.
Dr. Beno Gutenberg	Seismological Laboratory, Pasadena, Calif.
Dr. R. C. Gibbs	National Research Ccuncil, Washington, D. C.
Dr. Carl F. Romney	Geotechnical Corporation, Troy, N. Y.
Dr. Jack E. Oliver	Lamont Geological Laboratory, Palisades, N. Y.
Mr. Frank Crowley	Air Force Cambridge Research Center, Mass.
(back row, left to right)	
Dr. Marcus Bath	Meteorological Institute, Uppsala, Sweden
Dr. Ben S. Melton	Air Force Headquarters, Washington, D. C.
Rev. James B. Macelwane, S. J.	St. Louis University, St. Louis, Mo.
Dr. G. E. R. Deacon	Natl. Institute of Oceanography, Teddington, England
Dr. Marion H. Gilmore	U. S. Naval Air Station, Miami, Florida
Dr. John J. Lynch, S. J.	Fordham University, New York, N. Y.
Dr. Frank Press	Lamont Geological Observatory, Palisades, N. Y.
Dr. J. A. Peoples	Air Force Cambridge Research Center, Mass.
Dr. Dean S. Carder	U. S. Coast and Geodetic Survey, Washington, D. C.
Dr. J. E. Ramirez, S. J.	Estacion Sismologica, Bogota, Colombia

From Google Books



NLNM (Peterson 1993)
1.0e-13
1.0e-14
1.0e-15
1.0e-16
1.0e-17
1.0e-18
1.0e-19
1.0e-20
Acceleration PSD (m**2/s**3)
WWSSN
Long Period
Microseism
WWSSN
Short
Period
Atmosphere
1.0e-04
1.0e-03
1.0e-02
1.0e-01
1.0
10.0
Frequency (Hz)

Acceleration power spectral densities for 56 h long records of the STS-1 seismometers at station BFO. Solid lines labelled Z, EW and NS are from the corresponding components for the very quiet 56 h interval starting 2004 September 29, 0:00:00 GMT. Note the large difference between the vertical and horizontal components.



Zürn W , and Wielandt E Geophys. J. Int. 2007;168:647-658

Geophysical Journal International

Four Papers in 1998

1. Nawa et al., Earth, Planets and Space, 1998
   Superconducting gravimeter at Showa Station in Antarctica
2. Suda, Nawa, and Fukao, Science, 1998
   IDA (gravimeter)
3. Kobayashi and Nishida, Nature, 1998
   Theory (planetary applications)
4. Tanimoto, Um, Kobayashi, Nishida, GRL, 1998
   IDA

Nawa et al. (1998)
Superconducting gravimeter in Antarctica

Earth Planets Space, **50**, 3–8, 1998

Incessant excitation of the Earth's free oscillations

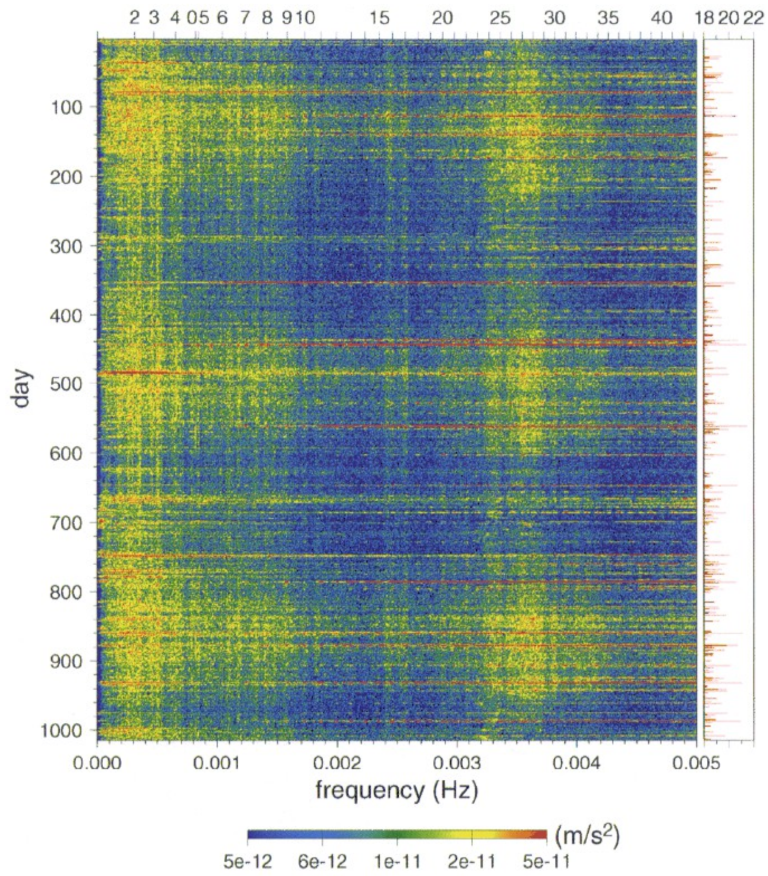
Kazunari Nawa[1], Naoki Suda[1], Yoshio Fukao[2], Tadahiro Sato[3],
Yuichi Aoyama[4], and Kazuo Shibuya[5]

[1]*Department of Earth and Planetary Sciences, Nagoya University, Furo, Chikusa-ku, Nagoya 464-8602, Japan*
[2]*Earthquake Research Institute, University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan*
[3]*National Astronomical Observatory, Mizusawa, 2-12 Hoshigaoka, Mizusawa, Iwate 023-0861, Japan*
[4]*The Graduate University for Advanced Studies, 2-12 Hoshigaoka, Mizusawa, Iwate 023-0861, Japan*
[5]*National Institute of Polar Research, 1-9-10 Kaga, Itabashi-ku, Tokyo 173-0003, Japan*

(Received November 5, 1997; Revised December 10, 1997; Accepted December 10, 1997)

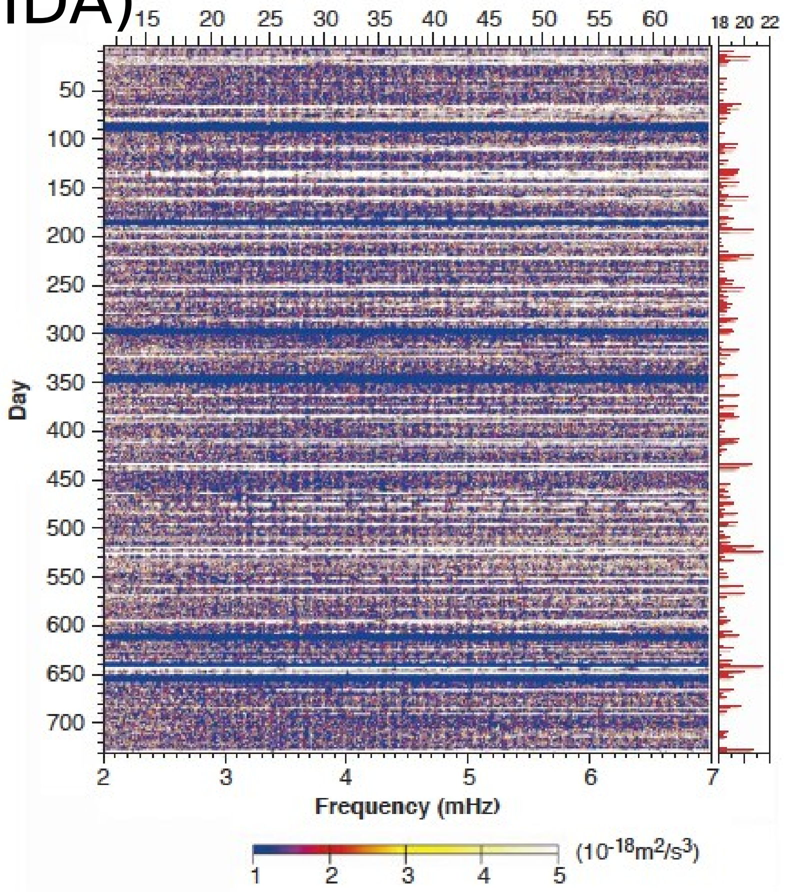
Nawa et al. (1998)
Superconducting gravimeter at Showa, Antarctica

K. NAWA *et al.*: INCESSANT EXCITATION OF THE EARTH'S FREE OSCILLATIONS



Suda, Nawa, Fukao (1998)

Data
(IDA)



Dat
a

Synthet
ic

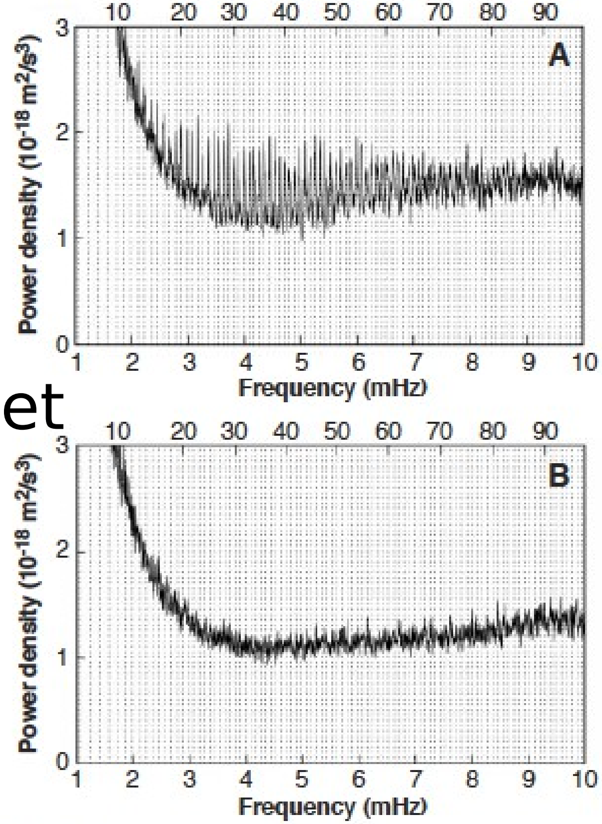


Fig. 3. Comparison of the averaged power spectral density at SUR between (**A**) the observed and (**B**) synthetic spectrograms for the seismically inactive periods, which are 437 days (12% of the total record) selected from the 10-year period.

3

Continuous excitation of planetary free oscillations by atmospheric disturbances

Naoki Kobayashi* & Kiwamu Nishida*†

* *Earth and Planetary Sciences, Tokyo Institute of Technology, Meguro, Tokyo 152, Japan*

Seismology provides a powerful tool for probing planetary interiors[1,2], but it has been considered inapplicable to tectonically inactive planets where earthquakes are absent. Here, however, we show that the atmospheres of solid planets are capable of exerting dynamic pressure on their surfaces, thereby exciting free oscillations with amplitudes large enough to be detected by modern broad-band seismographs. Order-of-magnitude estimates of these forces give similar amplitudes of a few nanogals for the Earth, Venus and Mars despite widely varying atmospheric and ambient conditions. The amplitudes are also predicted to have a weak frequency dependence. Our analysis of seismograms,

Excitation by Random Pressure Source

Key : the correlation length (λ) in pressure

This nature paper assumed that

$\lambda \sim$ Scale height of atmosphere (8.7km)

Observation indicates $\lambda \sim$ 1 km or less,

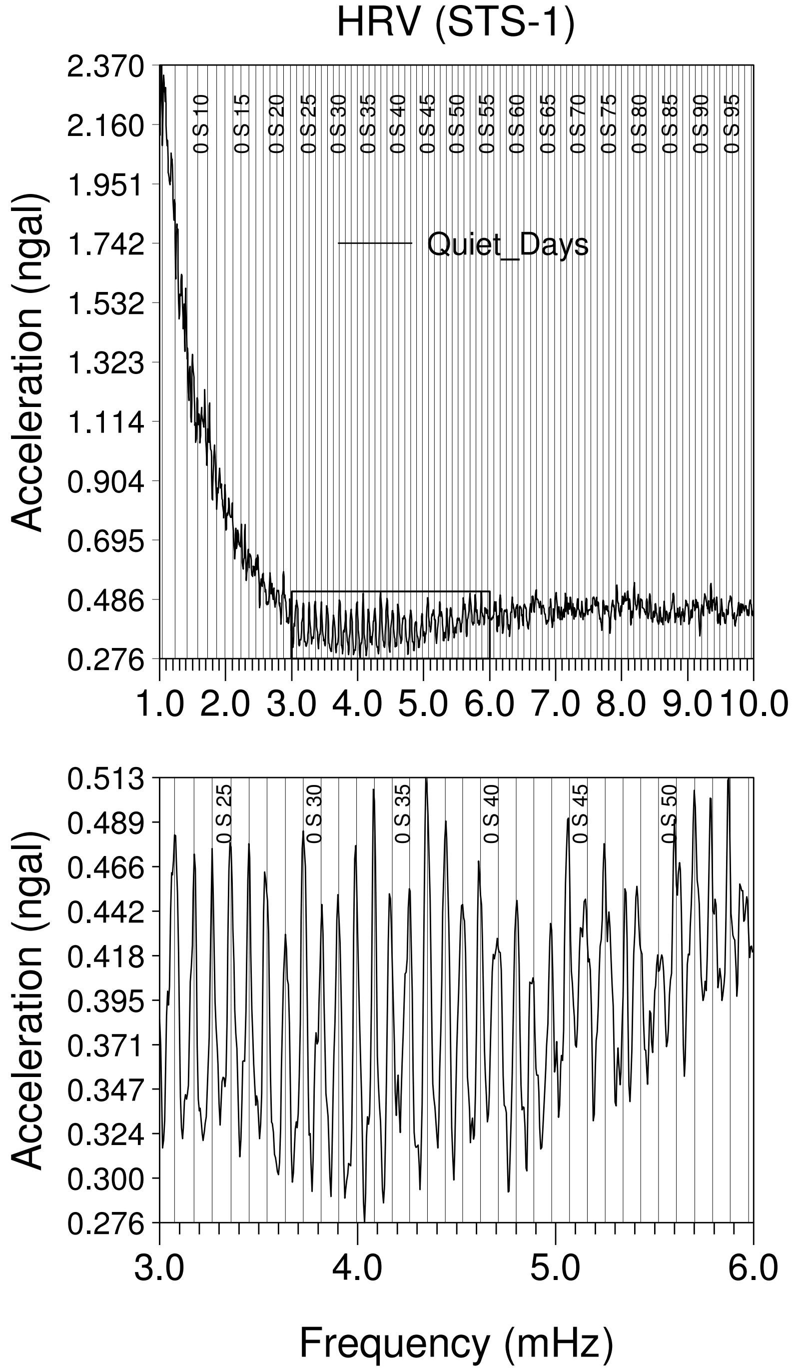
thus the estimates were too large.

GEOPHYSICAL RESEARCH LETTERS, VOL. 25, NO.10, PAGES 1553-1556, MAY 15, 1998

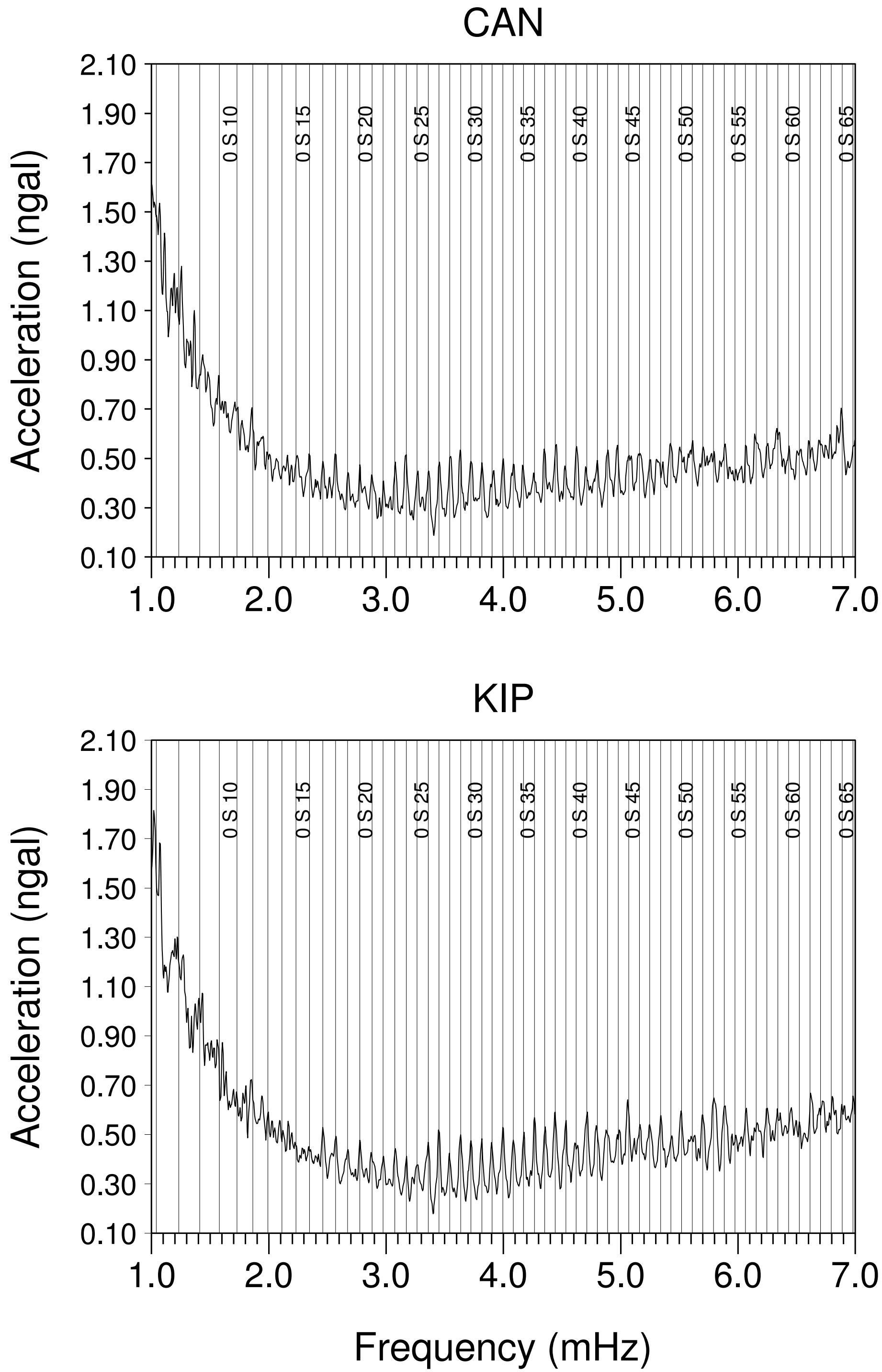
Earth's continuous oscillations observed on seismically quiet days

Toshiro Tanimoto and Junho Um
Department of Geological Sciences and Institute of Crustal Studies, University of California, Santa Barbara

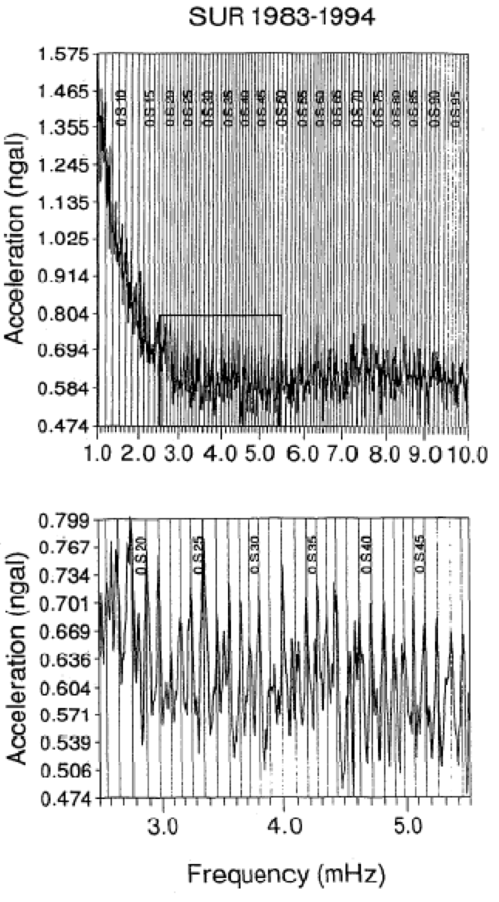
Kiwamu Nishida and Naoki Kobayashi
Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Tokyo, Japan



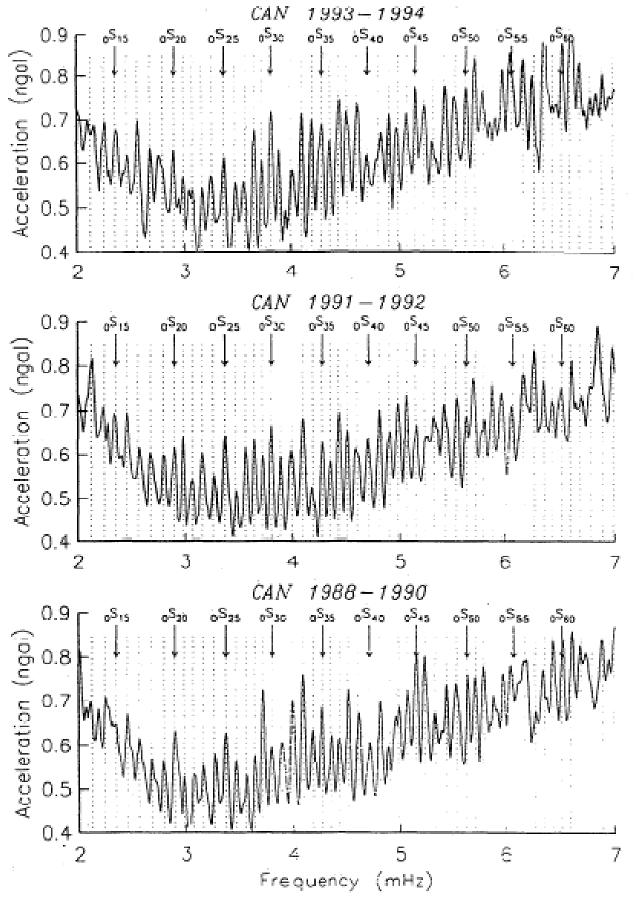
HRV (STS-1)
Acceleration (ngal)
2.370
2.160
1.951
1.742
1.532
1.323
1.114
0.904
0.695
0.486
0.276
0 S 10
0 S 15
0 S 20
0 S 25
0 S 30
0 S 35
0 S 40
0 S 45
0 S 50
0 S 55
0 S 60
0 S 65
0 S 70
0 S 75
0 S 80
0 S 85
0 S 90
0 S 95
Quiet_Days
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Acceleration (ngal)
0.513
0.489
0.466
0.442
0.418
0.395
0.371
0.347
0.324
0.300
0.276
0 S 25
0 S 30
0 S 35
0 S 40
0 S 45
0 S 50
3.0
4.0
5.0
6.0
Frequency (mHz)

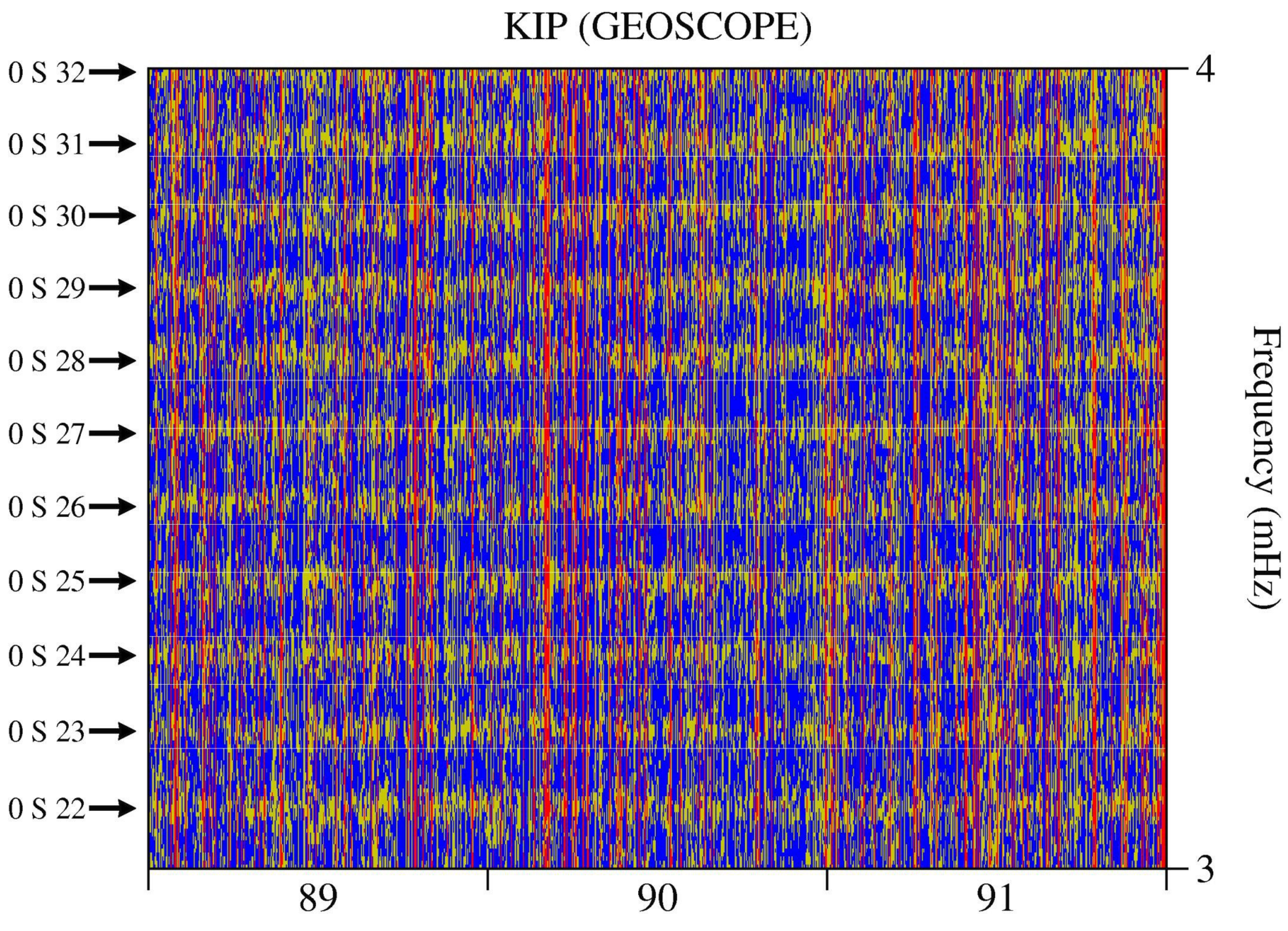

CAN
KIP
Acceleration (ngal)
Frequency (mHz)
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
1.0
2.0
3.0
4.0
5.0
6.0
7.0
0 S 10
0 S 15
0 S 20
0 S 25
0 S 30
0 S 35
0 S 40
0 S 45
0 S 50
0 S 55
0 S 60
0 S 65

IDA



Geoscope

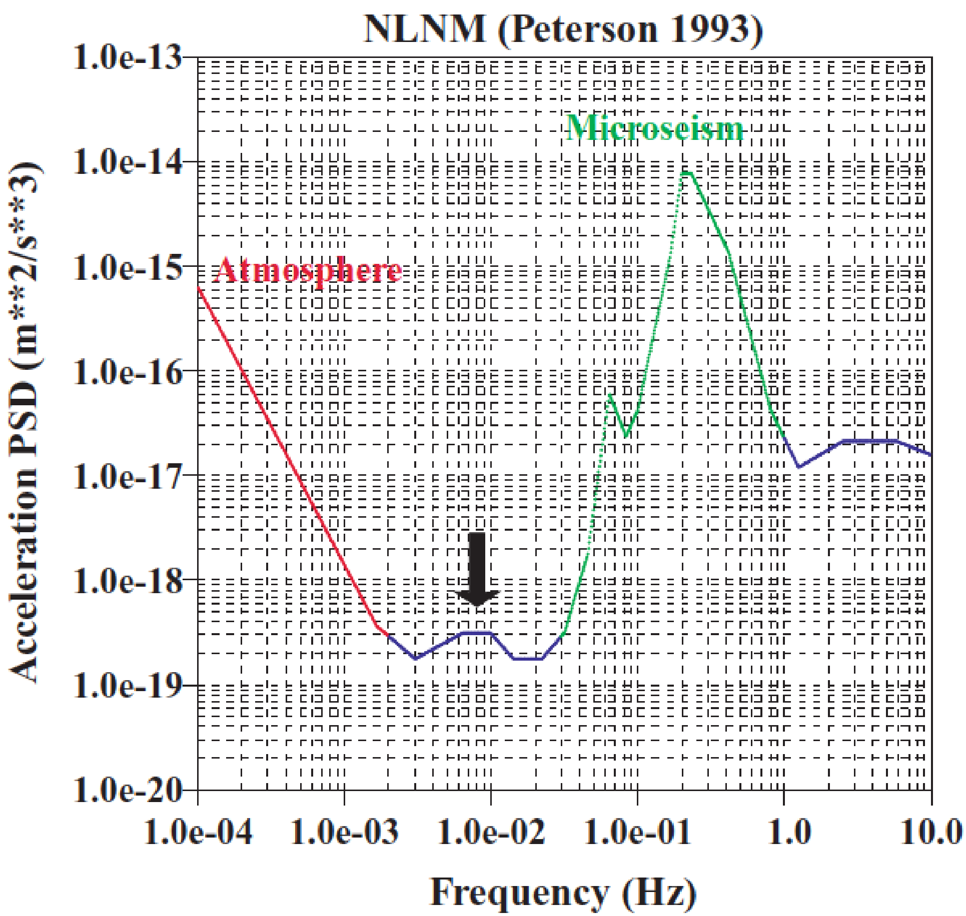


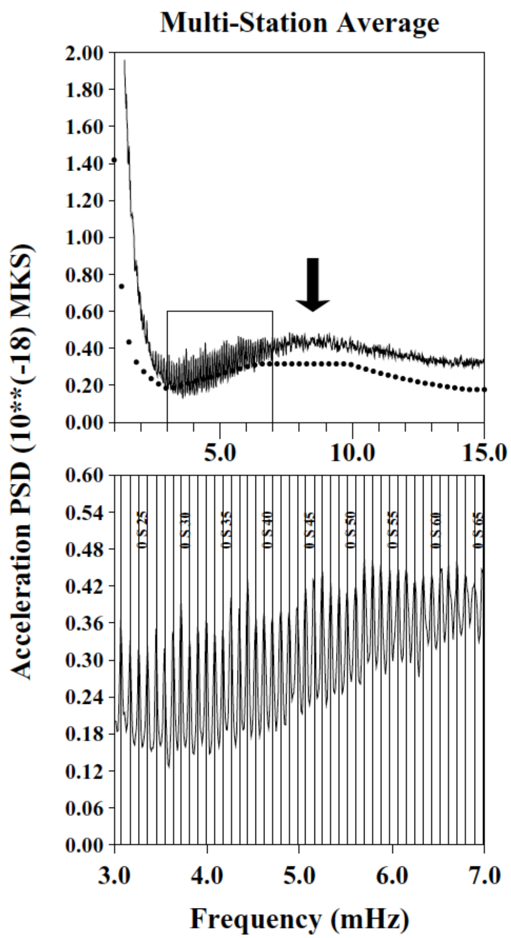

KIP (GEOSCOPE)
0 S 32
0 S 31
0 S 30
0 S 29
0 S 28
0 S 27
0 S 26
0 S 25
0 S 24
0 S 23
0 S 22
4
3
Frequency (mHz)
89
90
91

We started to work on the hum because

1. Justify the installment of a superconducting gravimeter in Antarctica. They needed (wanted) to justify their big investiment.

2. Dream for planetary applications
    Get planetary interior of a
non-tectonic
    planet.

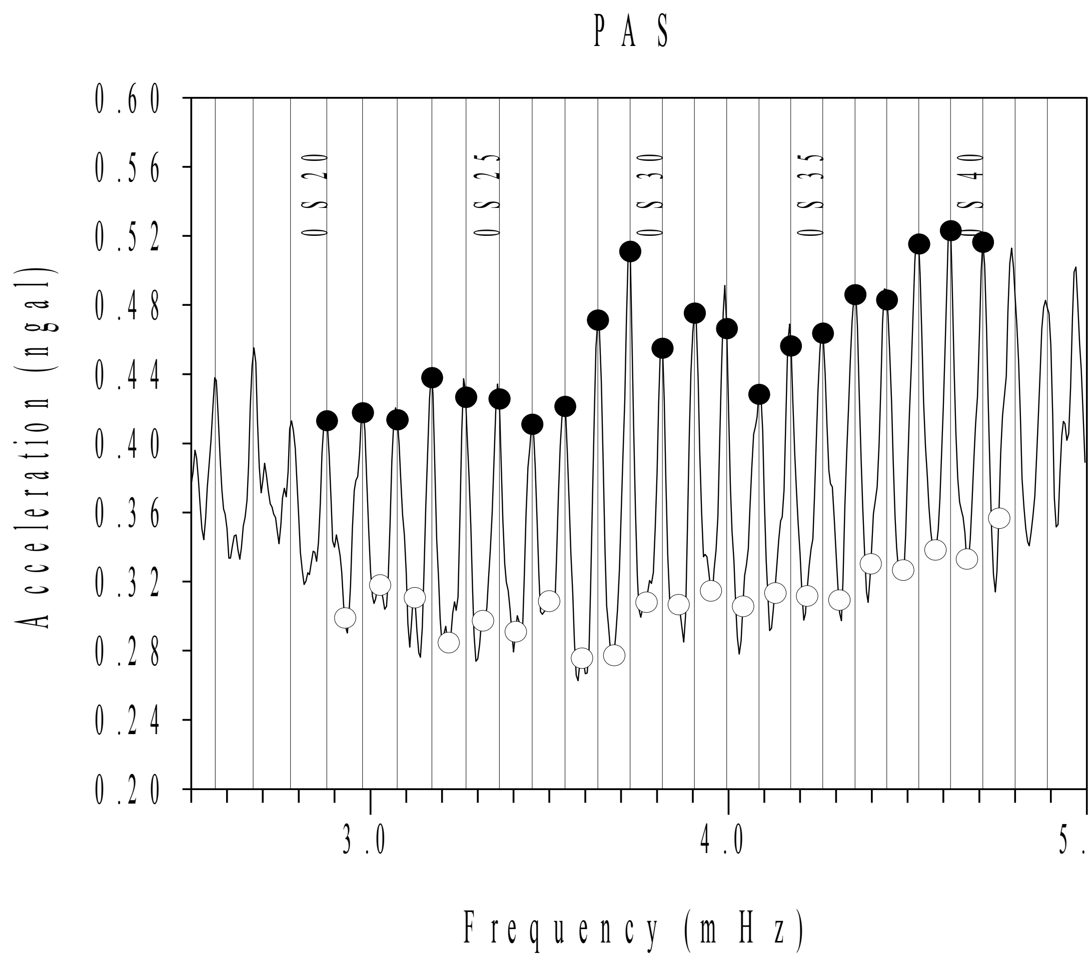

NLNM (Peterson 1993)
Acceleration PSD (m**2/s**3)
1.0e-13
1.0e-14
1.0e-15
1.0e-16
1.0e-17
1.0e-18
1.0e-19
1.0e-20
Microseism
Atmosphere
1.0e-04
1.0e-03
1.0e-02
1.0e-01
1.0
10.0
Frequency (Hz)

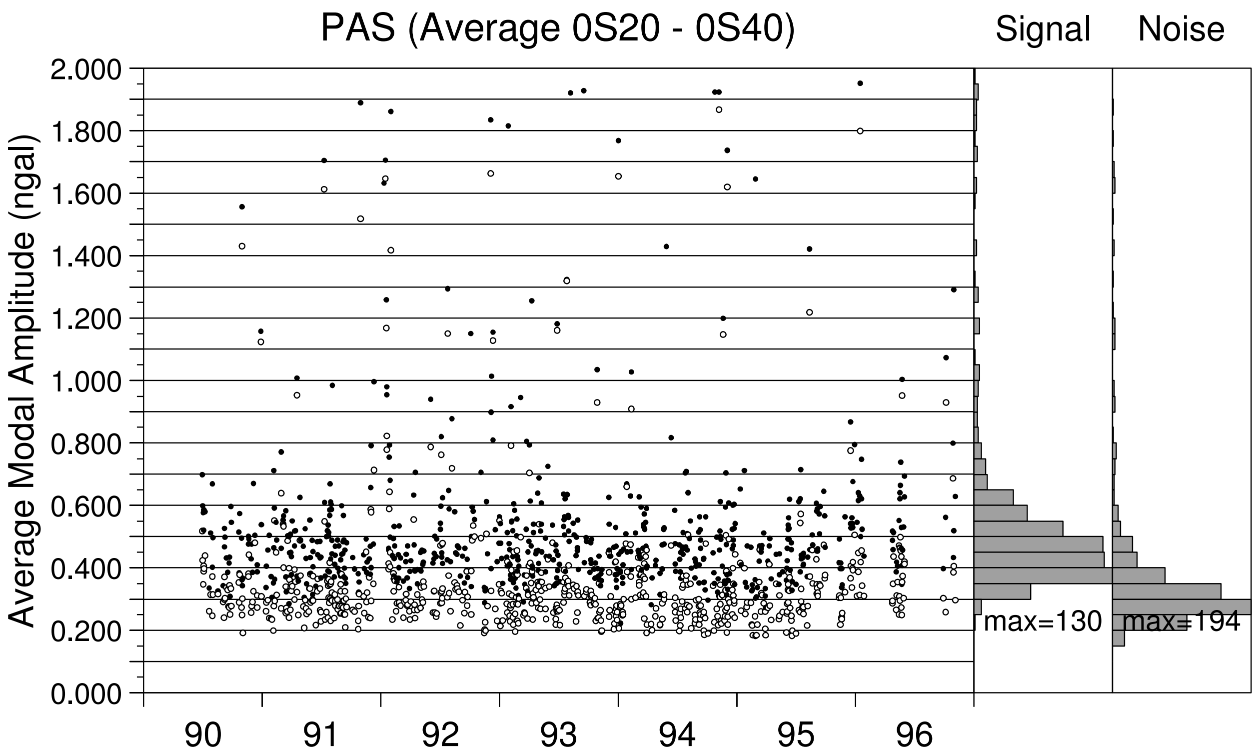


Multi-Station Average
Acceleration PSD (10**(-18) MKS)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
5.0
10.0
15.0
0.60
0.54
0.48
0.42
0.36
0.30
0.24
0.18
0.12
0.06
0.00
0 S 25
0 S 30
0 S 35
0 S 40
0 S 45
0 S 50
0 S 55
0 S 60
0 S 65
3.0
4.0
5.0
6.0
7.0
Frequency (mHz)

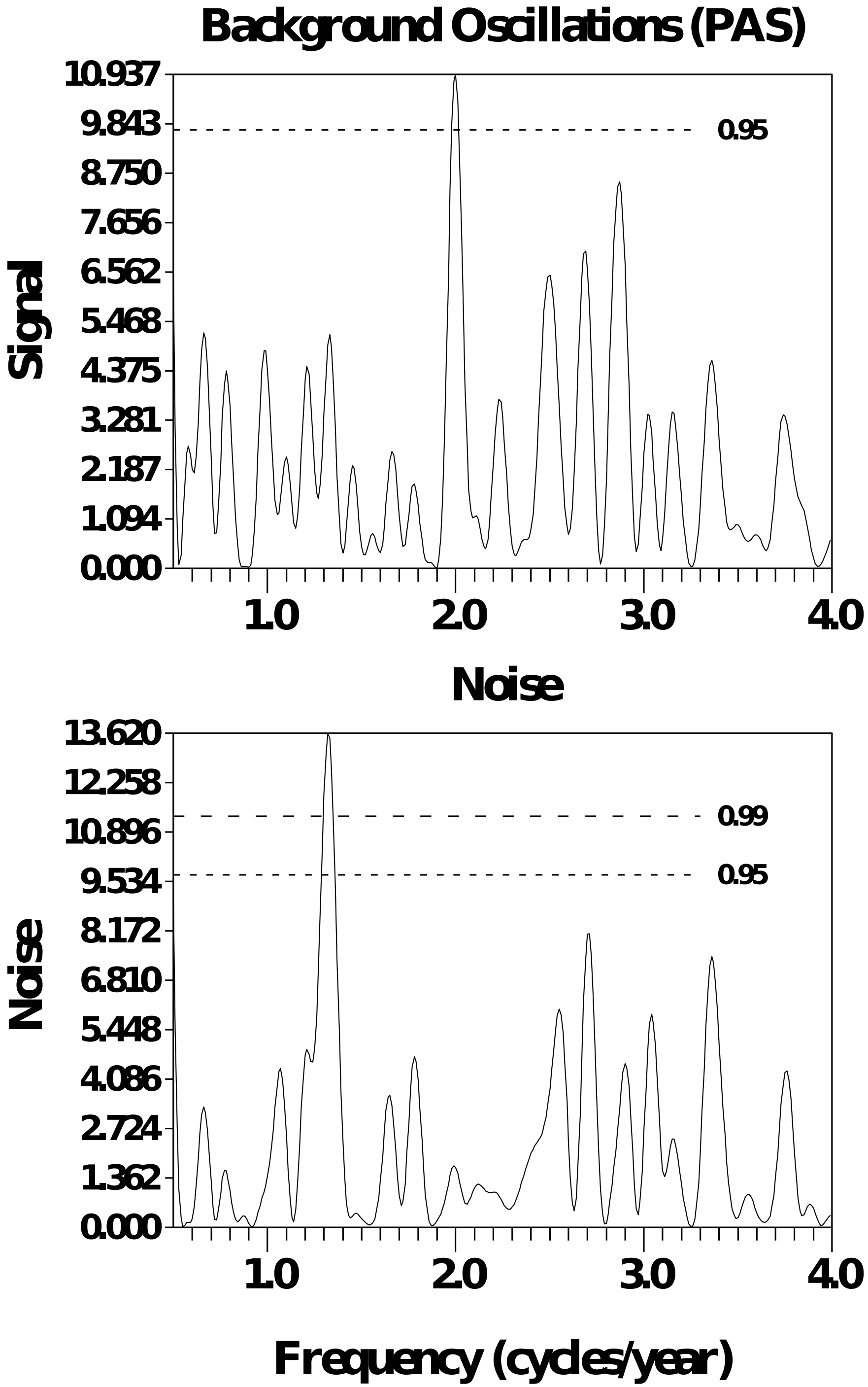
Is the excitation source in the solid earth or in the atmosphere/ocean ?

- Claims of slow earthquakes (e.g., Beroza and Jordan, 1990).
- Something like tremor may excite them.
- The key is in detection of seasonality.


PAS
0.60
0.56
0.52
0.48
0.44
0.40
0.36
0.32
0.28
0.24
0.20
Acceleration (ngal)
0S20
0S25
0S30
0S35
0S40
3.0
4.0
5.0
Frequency (mHz)

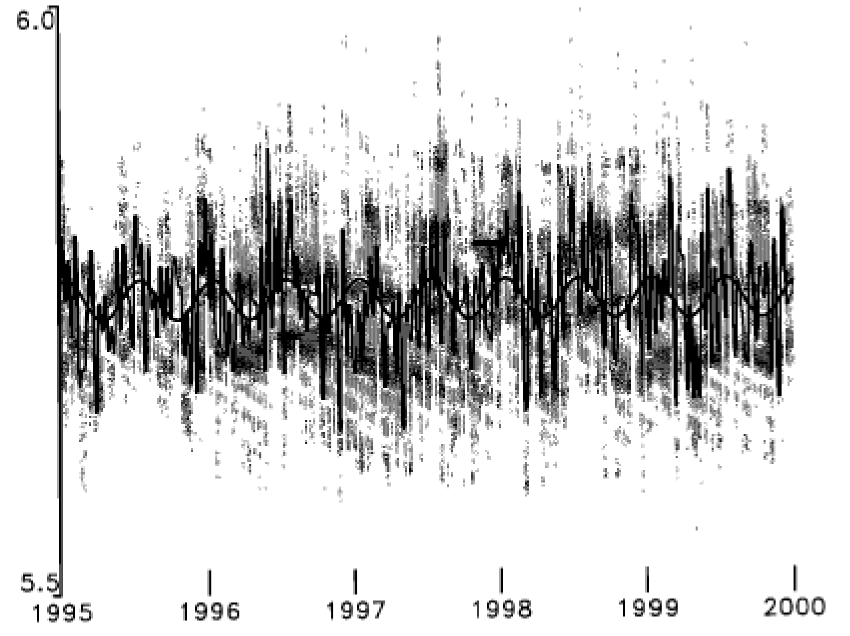


PAS (Average 0S20 - 0S40)
Signal
Noise
Average Modal Amplitude (ngal)
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
90
91
92
93
94
95
96
max=130
max=194

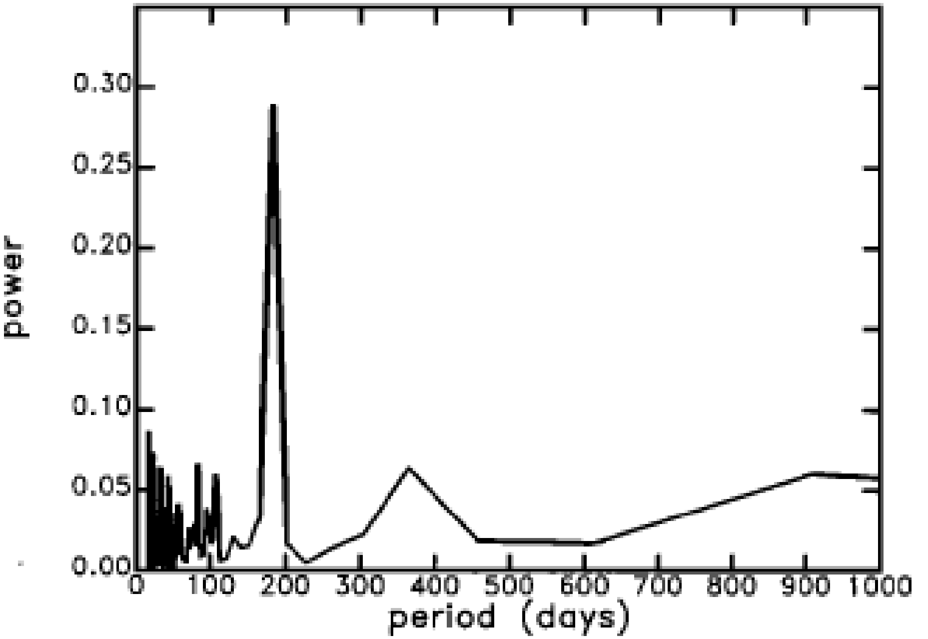

Background Oscillations (PAS)
Signal
10.937
9.843
8.750
7.656
6.562
5.468
4.375
3.281
2.187
1.094
0.000
0.95
1.0
2.0
3.0
4.0
Noise
Noise
13.620
12.258
10.896
9.534
8.172
6.810
5.448
4.086
2.724
1.362
0.000
0.99
0.95
1.0
2.0
3.0
4.0
Frequency (cycles/year)

Ekstrom, JGR, 2001

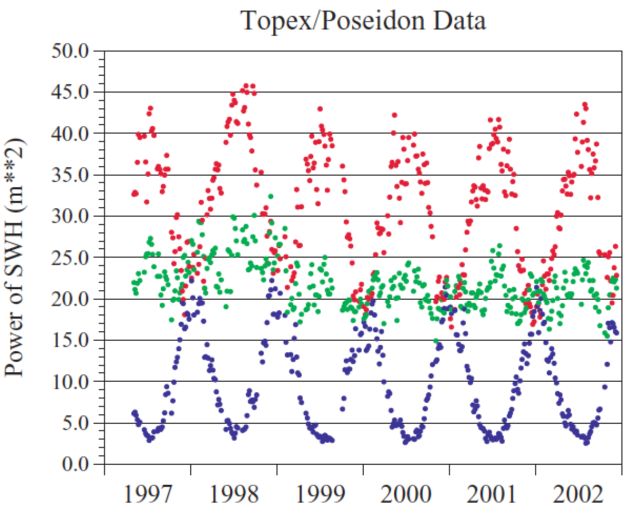
On seismically quiet days, equivalent Rayleigh-waves for M~5.8 are circulating around the globe.

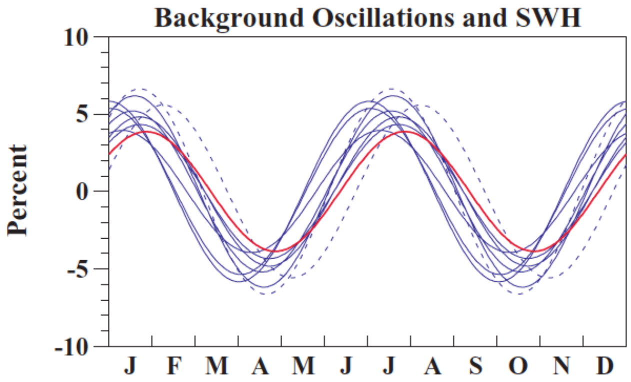


Periodicity in the stack is dominated by 6-months periodicity



Seismic Data and SWH





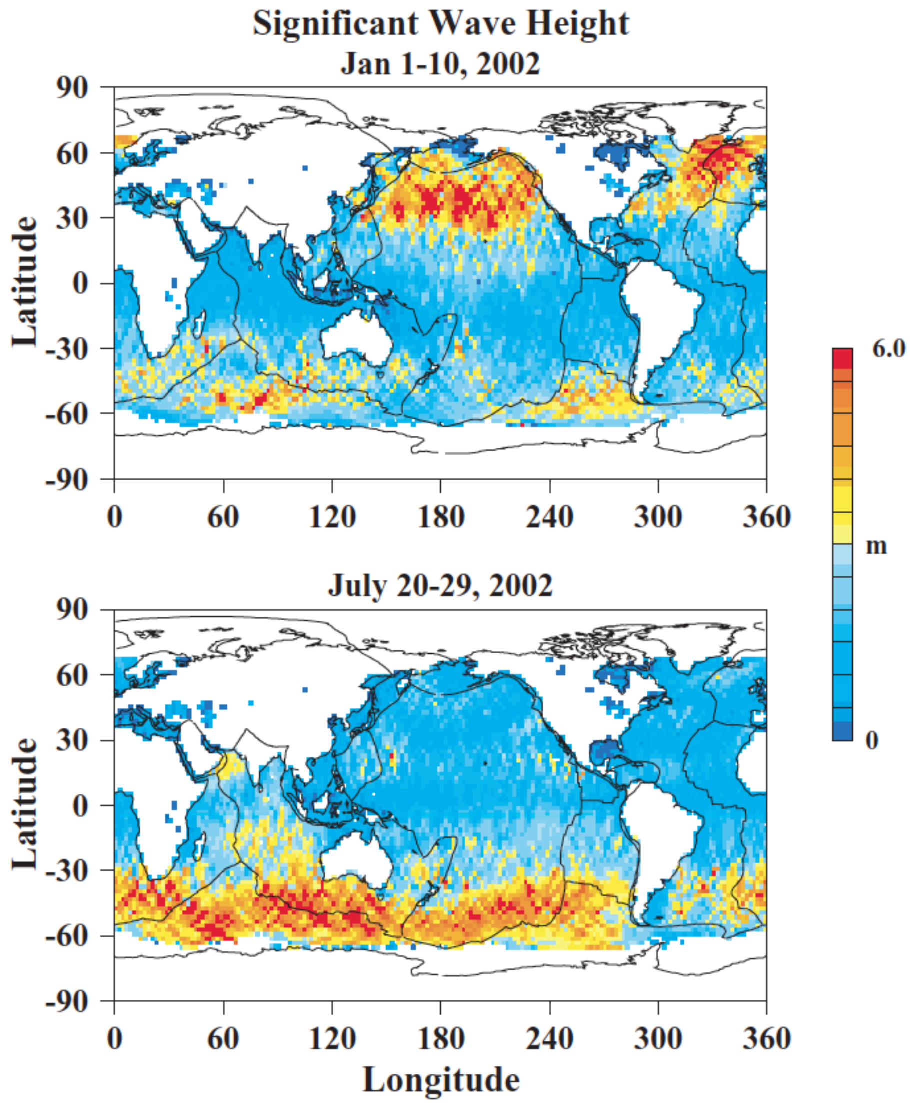
What would create 6-months periodicity?

Obviously both atmosphere and ocean could.

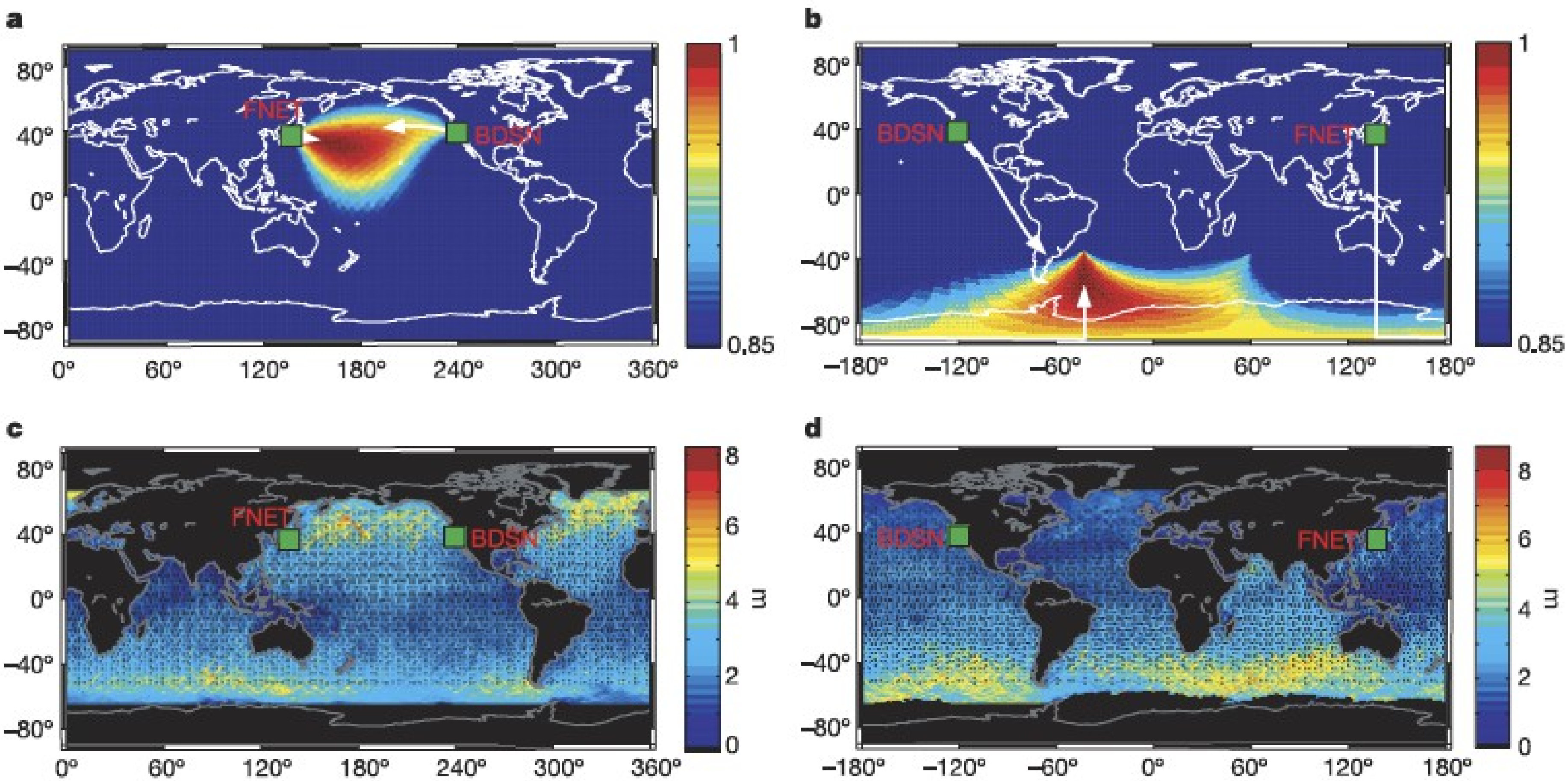
My eureka moment was

1. The oceans can cause large pressure changes.
2. The atmosphere : pressure change is < 10% The correlation length is small.

My eureka moment



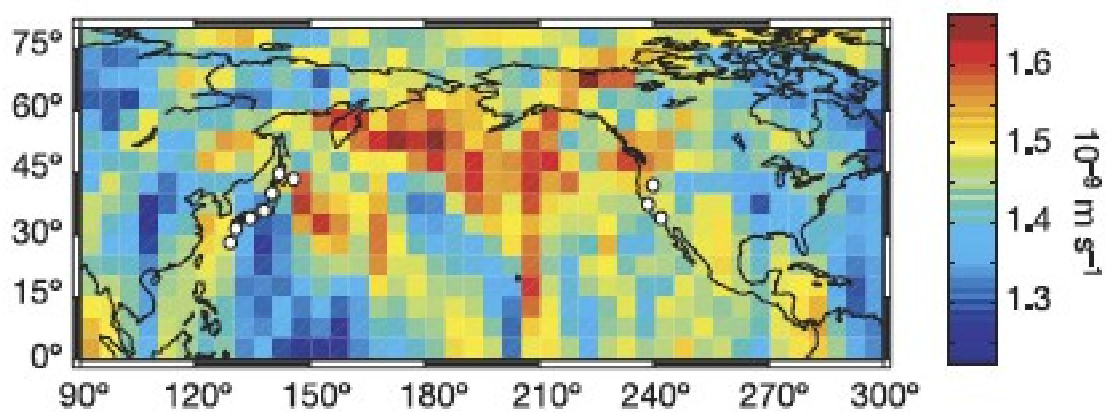
Rhie and Romanowicz, Nature, 2004



Excitation of Earth's continuous free oscillations by atmosphere–ocean–seafloor coupling

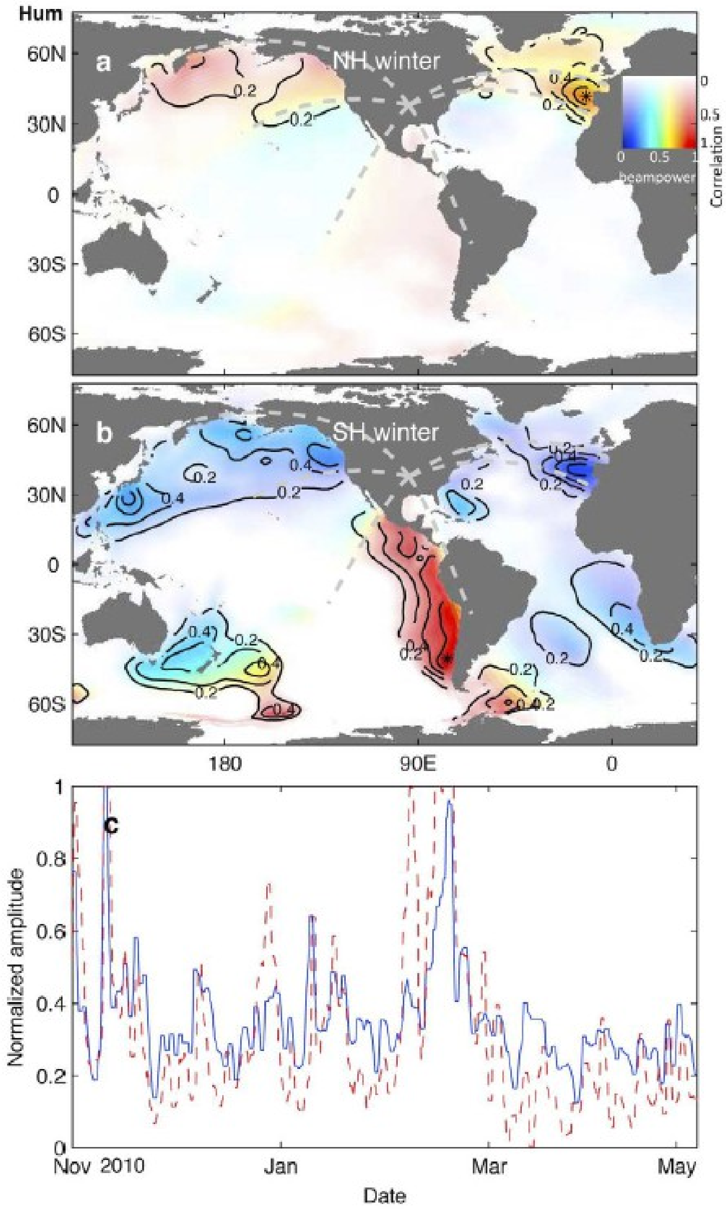
Junkee Rhie & Barbara Romanowicz

Berkeley Seismological Laboratory and Department of Earth and Planetary Science, University of California, Berkeley, California 94720, USA



Traer, Gerstoft, Bromirski & Shearer, JGR 2014

Beam azimuth and SWH Correlation



NH Winter

SH Winter

Interactions of Ocean Waves with Sea Bottom (Scattering of Ocean Waves into Love Waves)

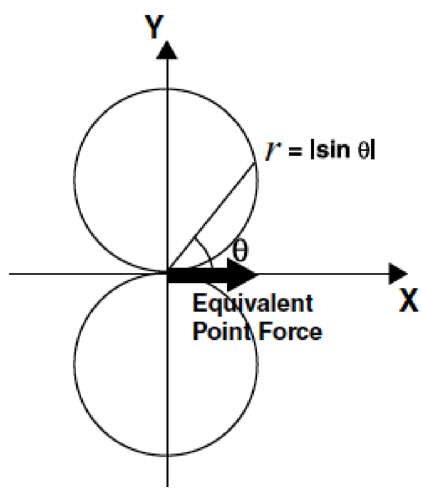
Geophysical Journal International

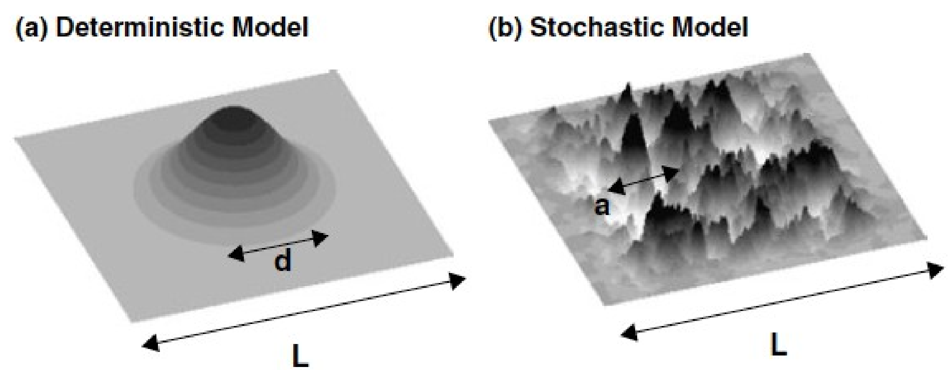
Geophys. J. Int. (2010) **182,** 1515–1523 doi: 10.1111/j.1365-246X.2010.04695.x

Love-wave excitation due to the interaction between a propagating ocean wave and the sea-bottom topography

Tatsuhiko Saito

National Research Institute for Earth Science and Disaster Prevention, Tsukuba, Ibaraki, Japan. E-mail: saito-ta@bosai.go.jp





Questions

1. Where are the sources?

2. What is the mechanism of excitation (hum) ?
   Is it the same with the primary microseism ?

3. How are Love waves excited? (hum and microseisms)
   Is the scattering hypothesis the answer ?
   Question on (i) Generation of Love waves
   vs. (ii) Rayleigh to Love conversion

4. How are the ~100 sec infragravity waves excited first of all ?

Geochemistry
Geophysics
Geosystems
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Published by AGU and the Geochemical Society

Article
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Q05007, doi:10.1029/2008GC001942
ISSN: 1525-2027

Observations of infragravity waves at the ocean-bottom broadband seismic stations Endeavour (KEBB) and Explorer (KXBB)

David Dolenc

Seismological Laboratory, University of California, Berkeley, McCone Hall 215, Berkeley, California 94720, USA

Now at Large Lakes Observatory, University of Minnesota, 109 RLB, 2205 East 5th Street, Duluth, Minnesota 55812, USA (ddolenc@d.umn.edu)

Barbara Romanowicz

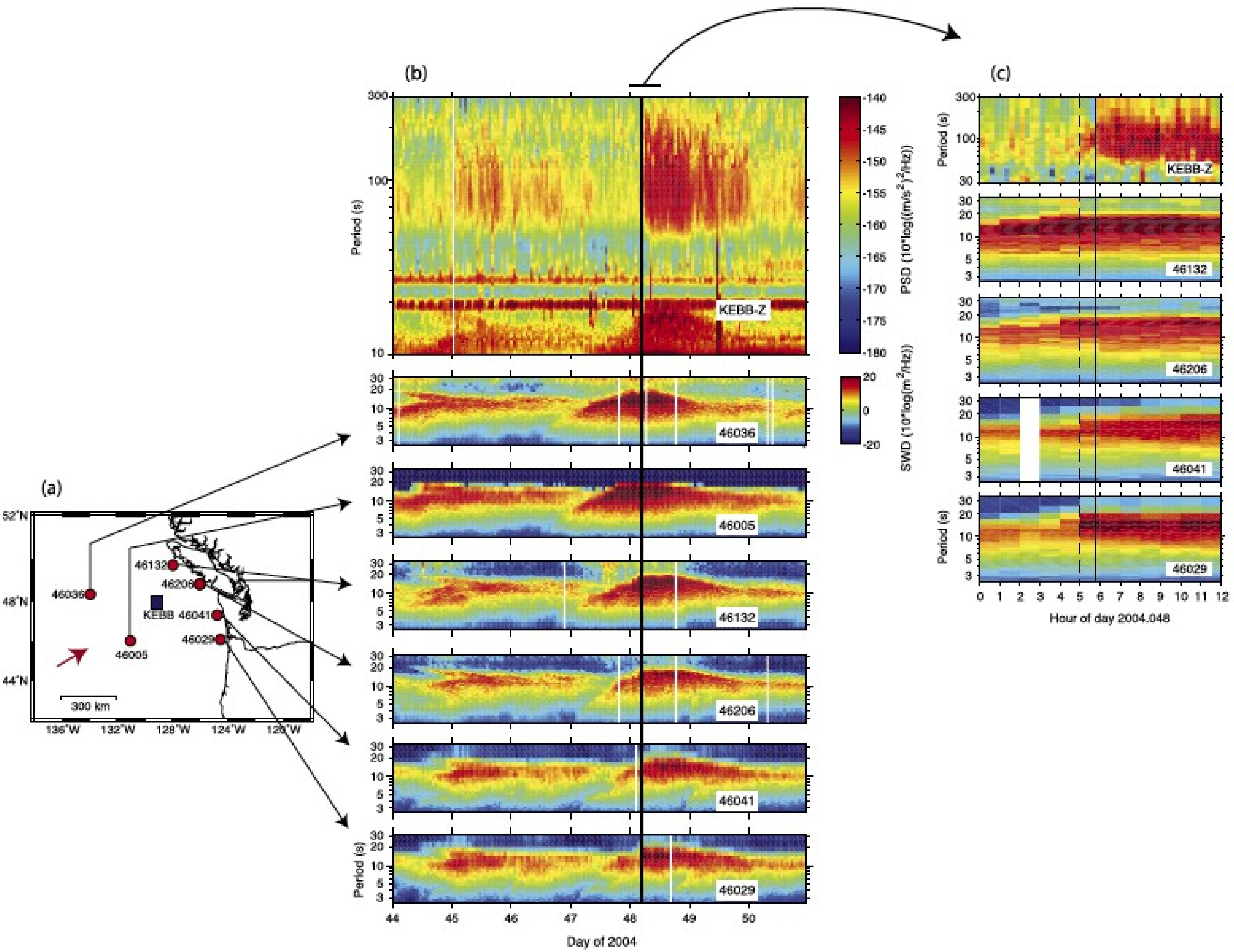
Seismological Laboratory, University of California, Berkeley, McCone Hall 215, Berkeley, California 94720, USA

Paul McGill

Monterey Bay Aquarium Research Institute, 7700 Sandholdt Road, Moss Landing, California 95039, USA

William Wilcock

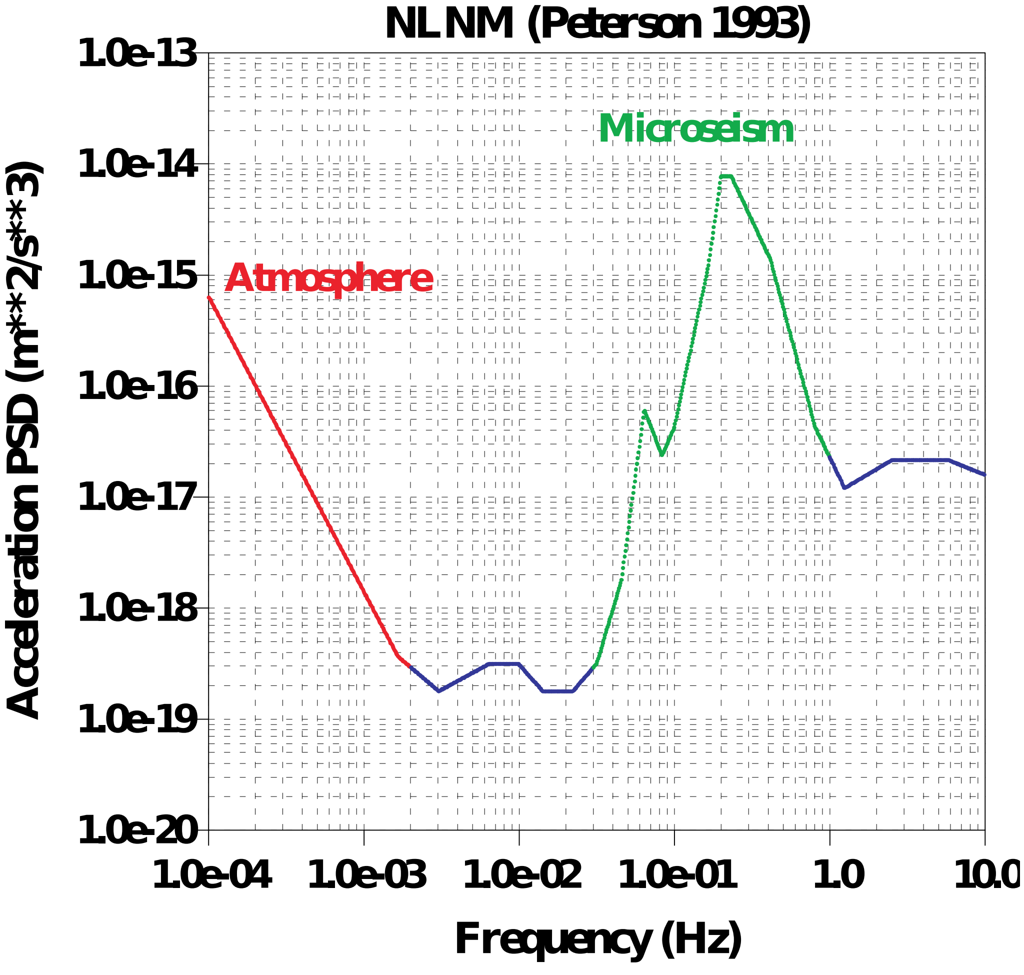
School of Oceanography, University of Washington, Box 357940, Seattle, Washington 98195, USA



(a)
(b)
(c)
52°N
48°N
44°N
136°W
132°W
128°W
124°W
120°W
300 km
46036
46005
46132
46206
KEBB
46041
46029
KEBB-Z
Period (s)
Day of 2004
PSD (10*log((m/s^2)^2/Hz))
SWD (10*log(m^2/Hz))
Hour of day 2004.048

Notion :

Rayleigh waves are constantly circulating the Earth.



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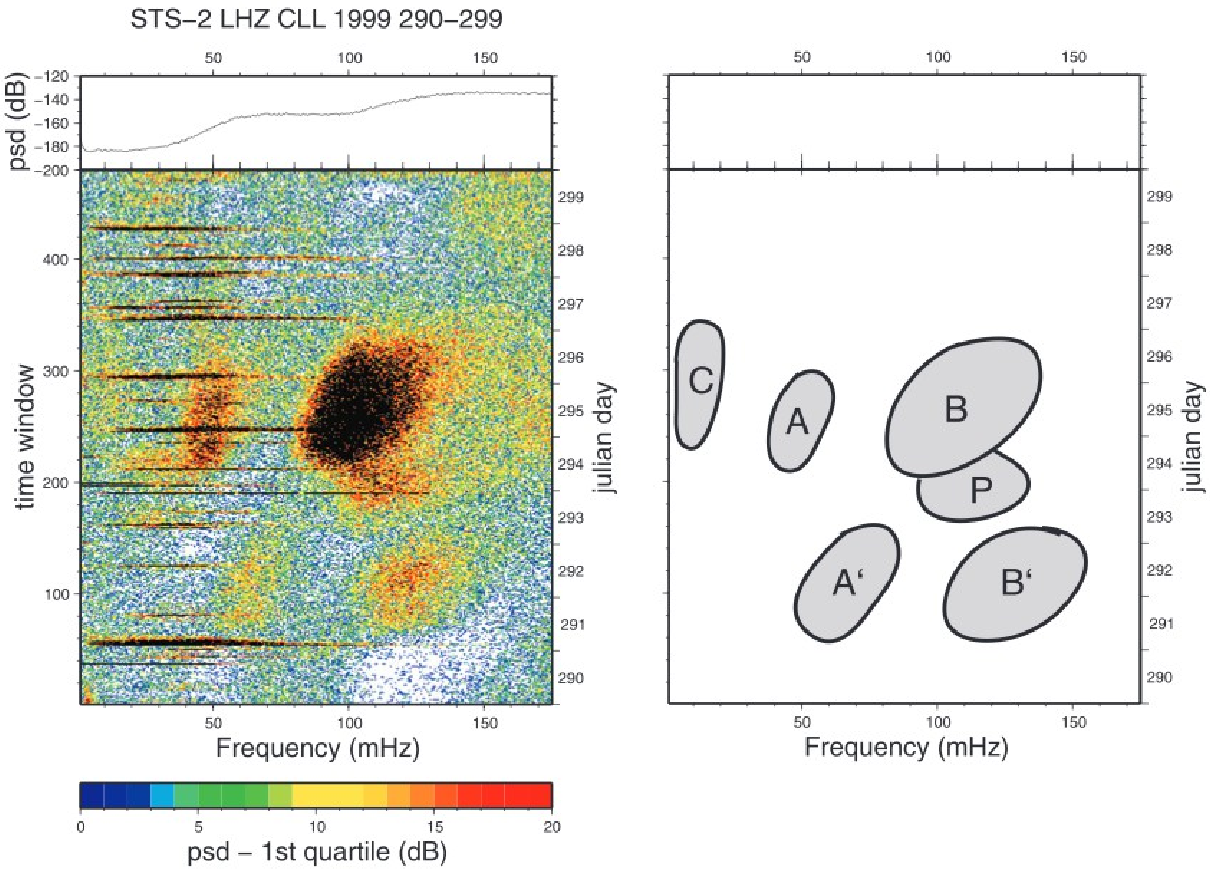
Geophys. J. Int. (2010) **183**, 330–338 doi: 10.1111/j.1365-246X.2010.04723.x

Excitation of long-period Rayleigh waves by large storms over the North Atlantic Ocean

Dieter Kurrle[1]* and Rudolf Widmer-Schnidrig[2]

[1] *Institute of Geophysics, University of Stuttgart, Azenbergstr.* 16, D-70174 *Stuttgart, Germany. E-mail: Dieter.Kurrle@lgrb.uni-freiburg.de*

[2] *Black Forest Observatory (BFO), Heubach* 206, D-77709 *Wolfach, Germany*



Hurricane Sandy (October, 2012)