Seismo-acoustic studies at the Earth's surface and in the atmosphere

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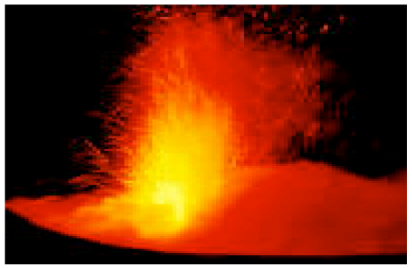
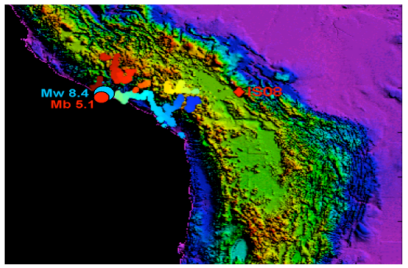
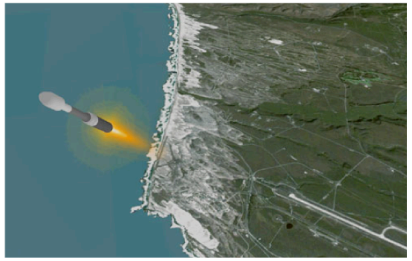
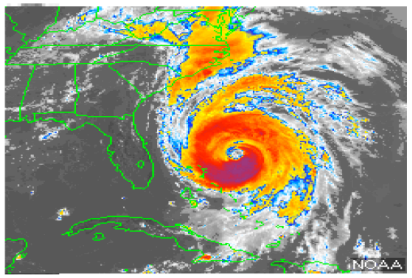
Content

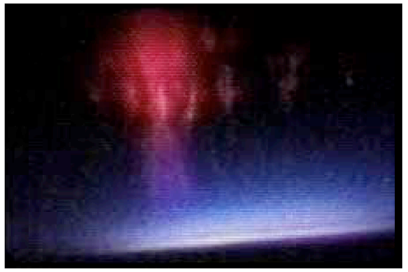
- Brief review of infrasound
- Societal relevance of infrasound today
  - e.g nuclear and hazard monitoring
- Recent studies
  - Common ground with seismology
- Grand challenges
  - How cooperation with seismic community can help

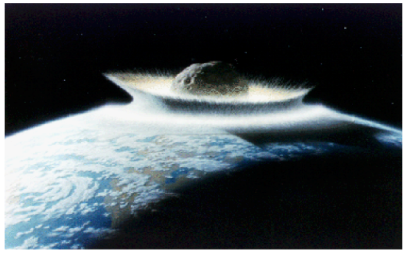
Some Infrasound Sources

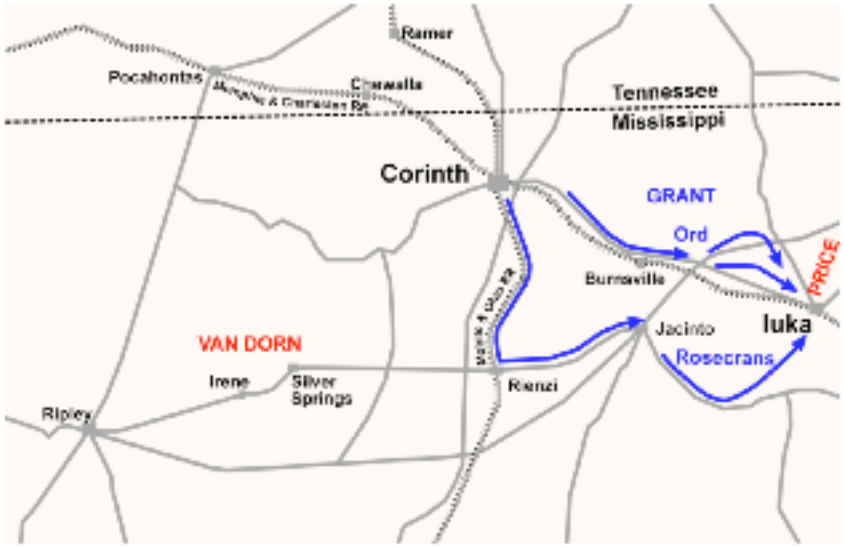



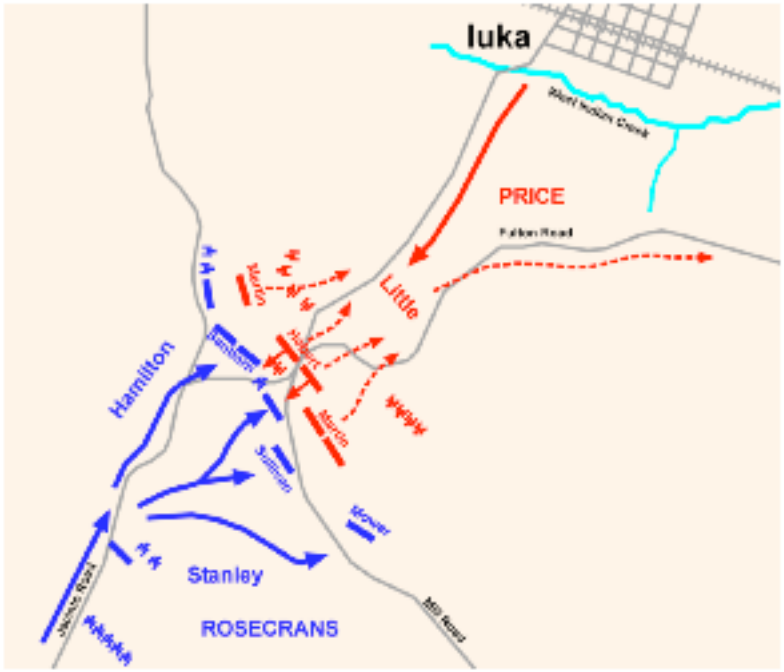


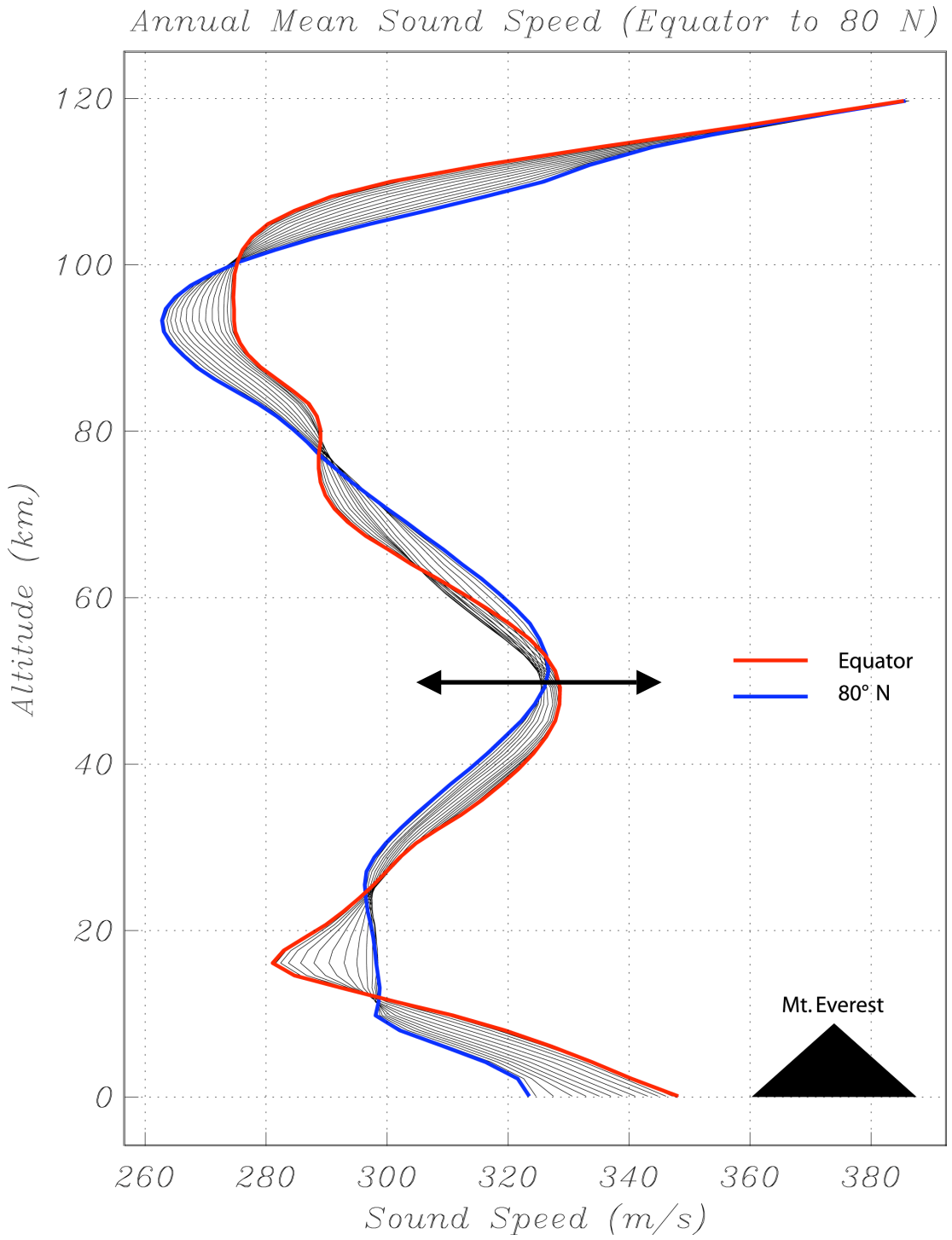




Sound Propagation

- Battle of Luca, September 19, 1862







- Propagation through unsteady atmosphere is known to be complex

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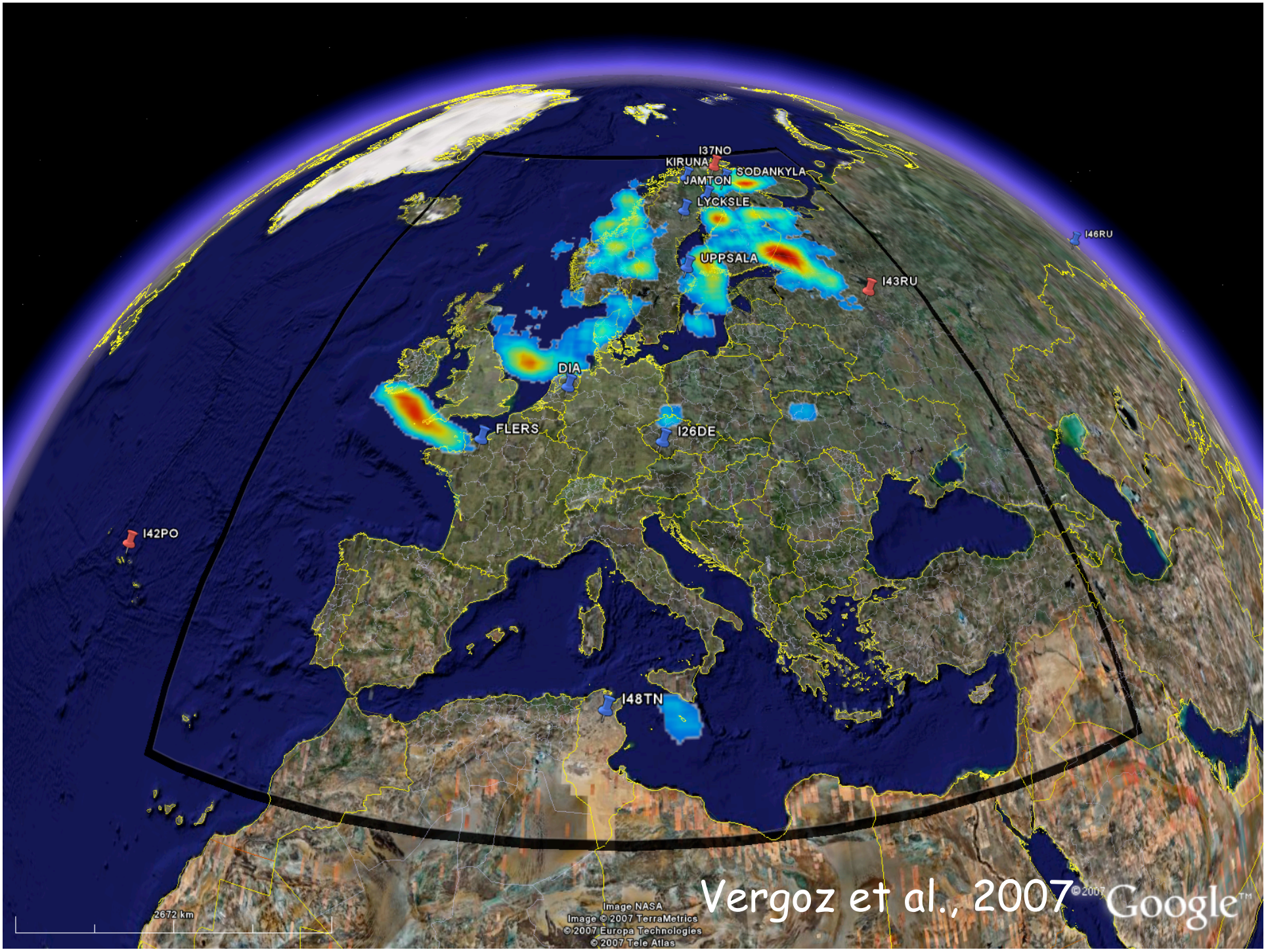
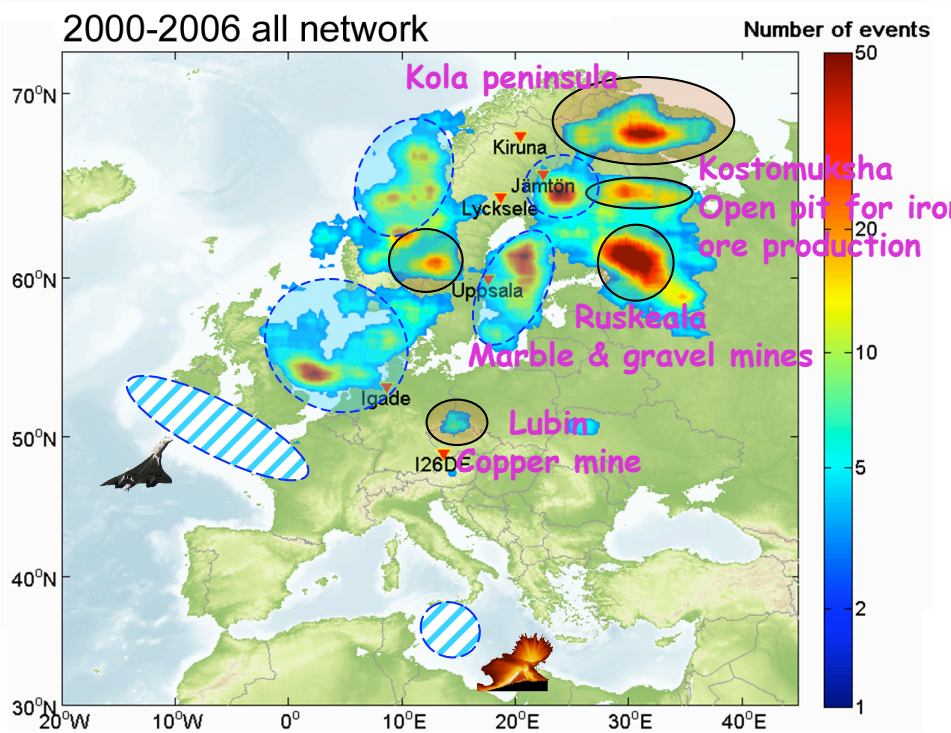
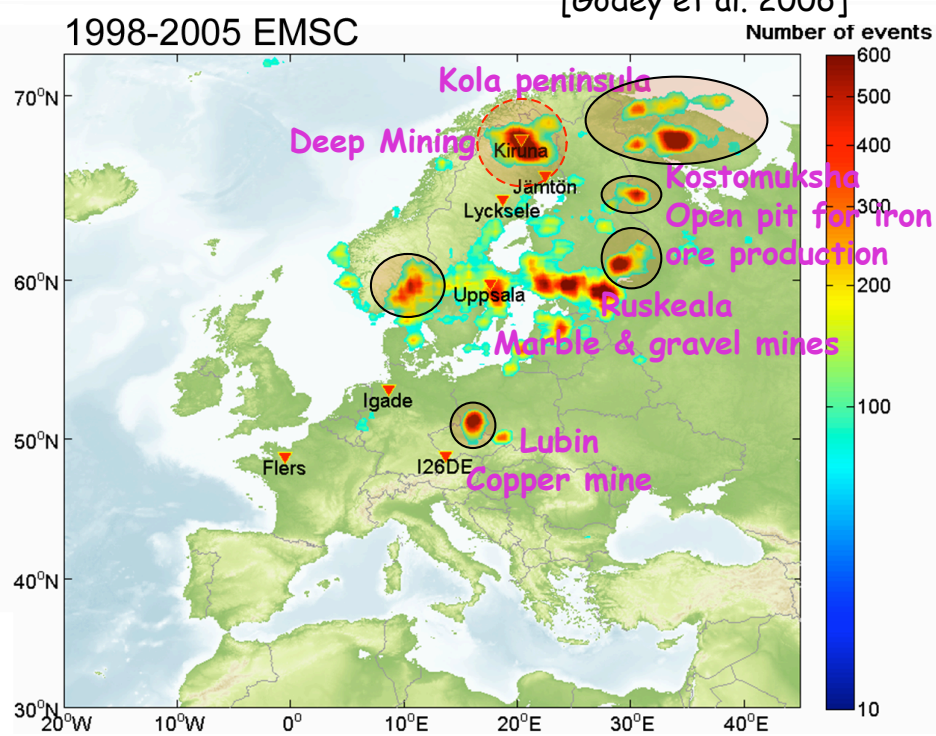

I37NO
KIRUNA
SODANKYLA
JAMTON
LYCKSLE
I46RU
UPPSALA
I43RU
DIA
FLERS
I26DE
I42PO
I48TN
2672 km
Image NASA
Image © 2007 TerraMetrics
© 2007 Europa Technologies
© 2007 Tele Atlas
Vergoz et al., 2007
© 2007 Google™

Infrasound and Seismic Event Catalogs

[Godey et al. 2006]





IS bulletin
(2000-2007)

4 874 events

EMSC bulletin
Non-earthquakes reported events
(1998-2005)

18 160 events

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Vergoz et al., 2007

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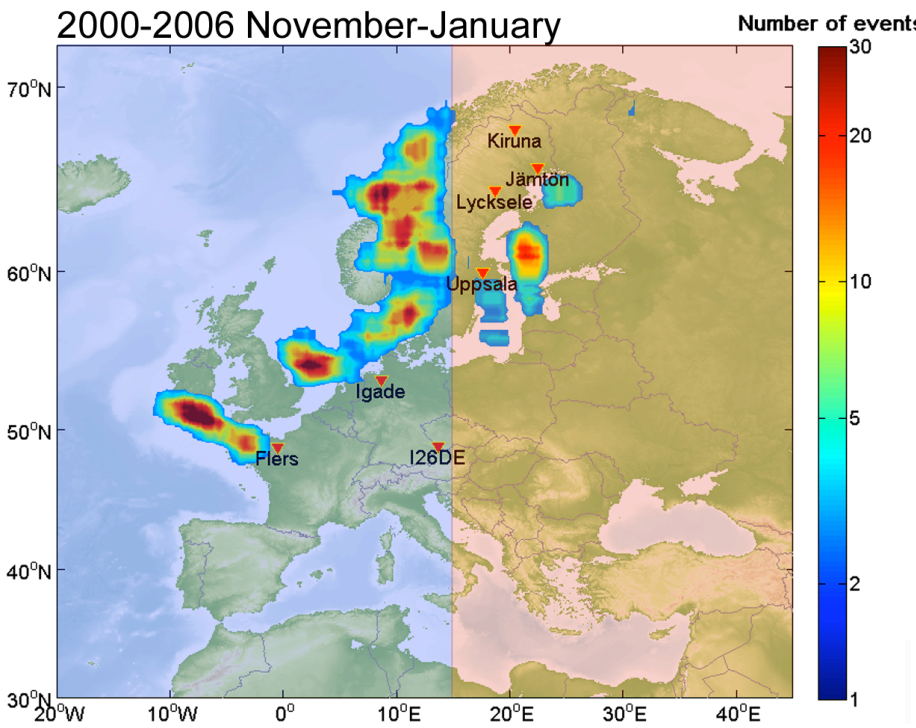
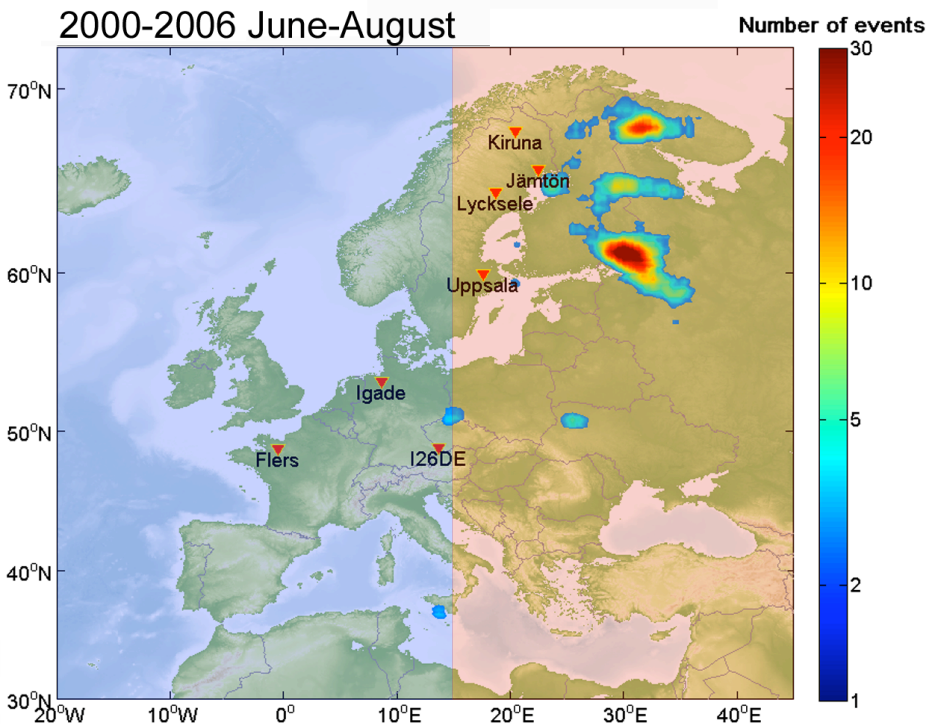
Observed performances : Seasonal effects





Winter

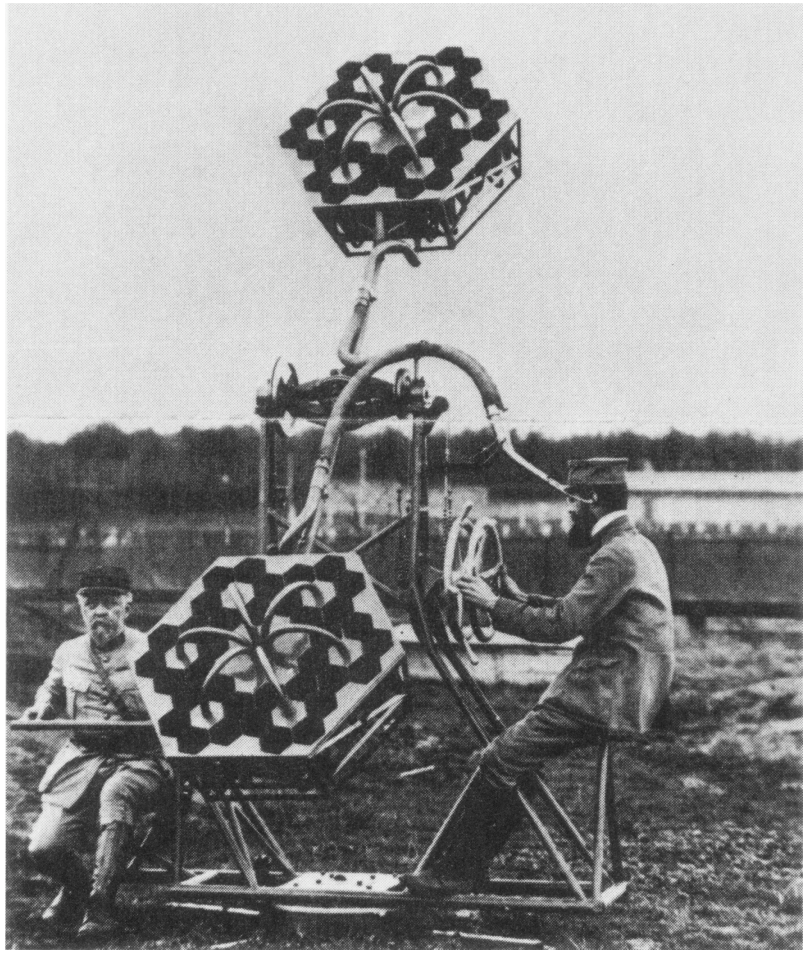
75% 25%

Summer

15% 85%

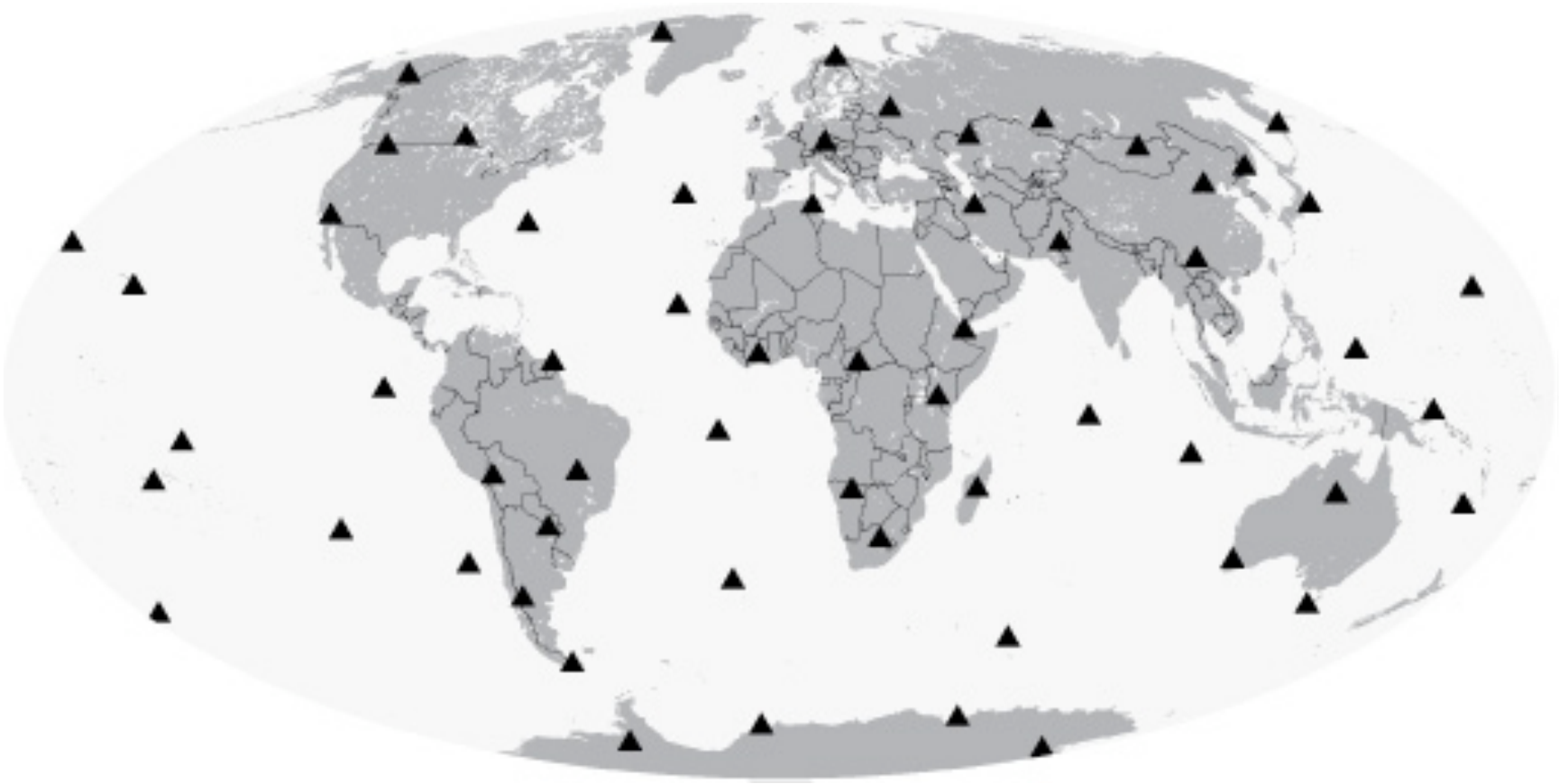
Vergoz et al., 2007

Infrasound Detection



Wind noise key

IMS Infrasound Network



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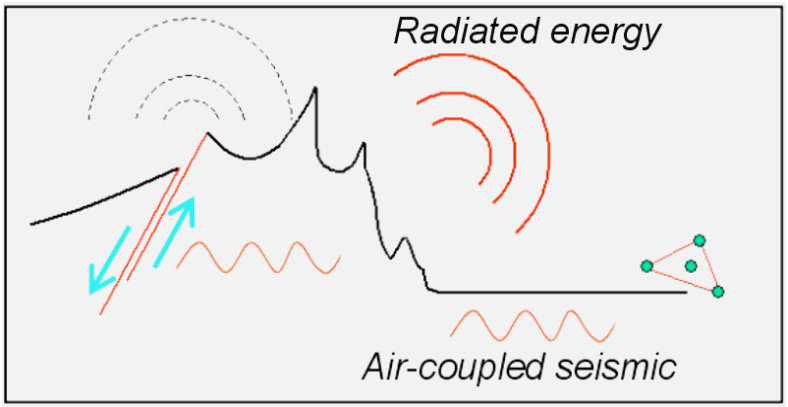
Societal relevance

- Societal relevance of infrasound today
  - Nuclear monitoring
  - Hazard monitoring
    - Volcanoes
    - Storms
    - Avalanches
    - Tsunamis
    - Wildfires
  - Tragic events - e.g. Columbia
  - Basic research

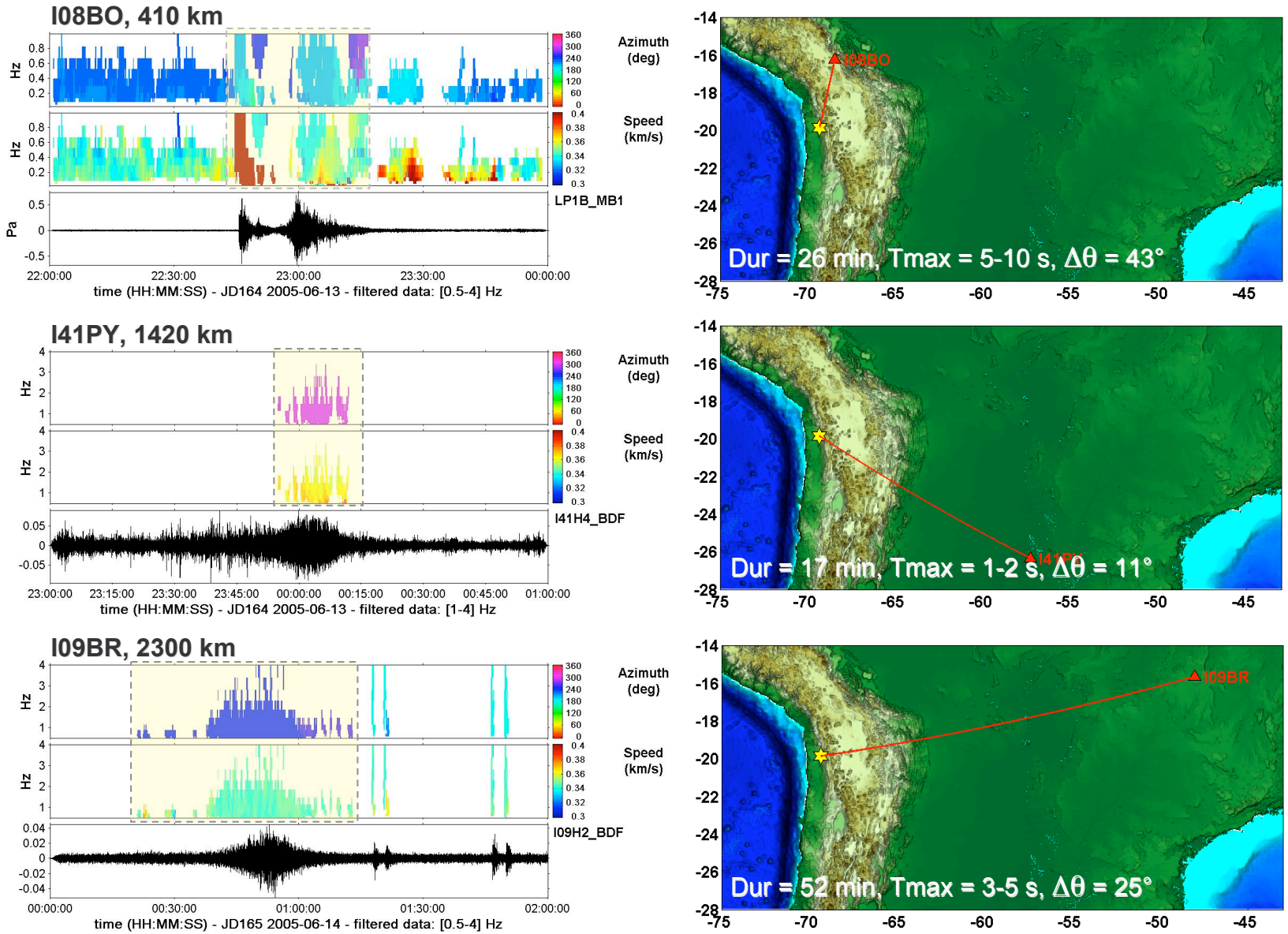
Some recent studies

Earthquake studies

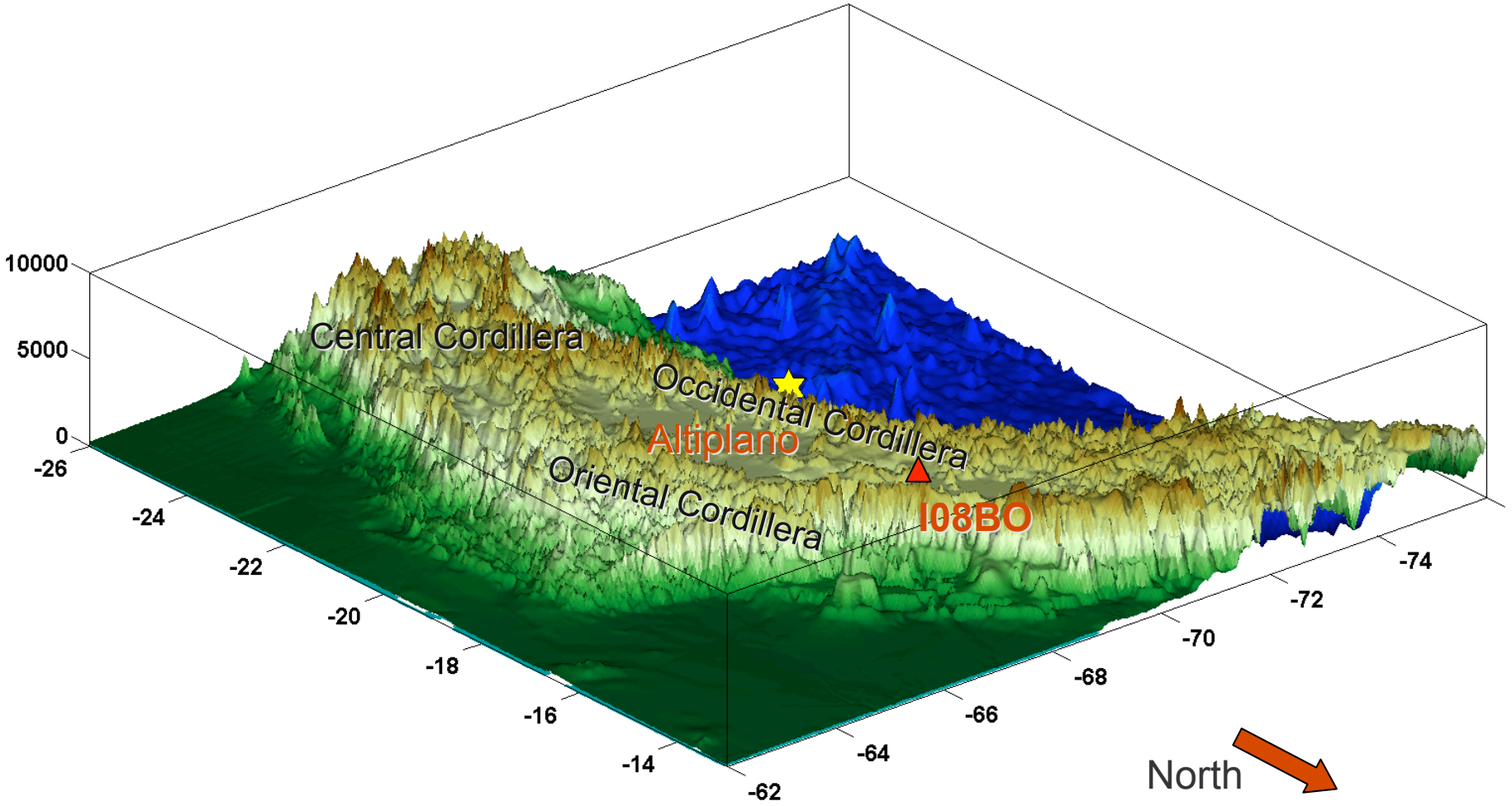


Le Pichon, 2005

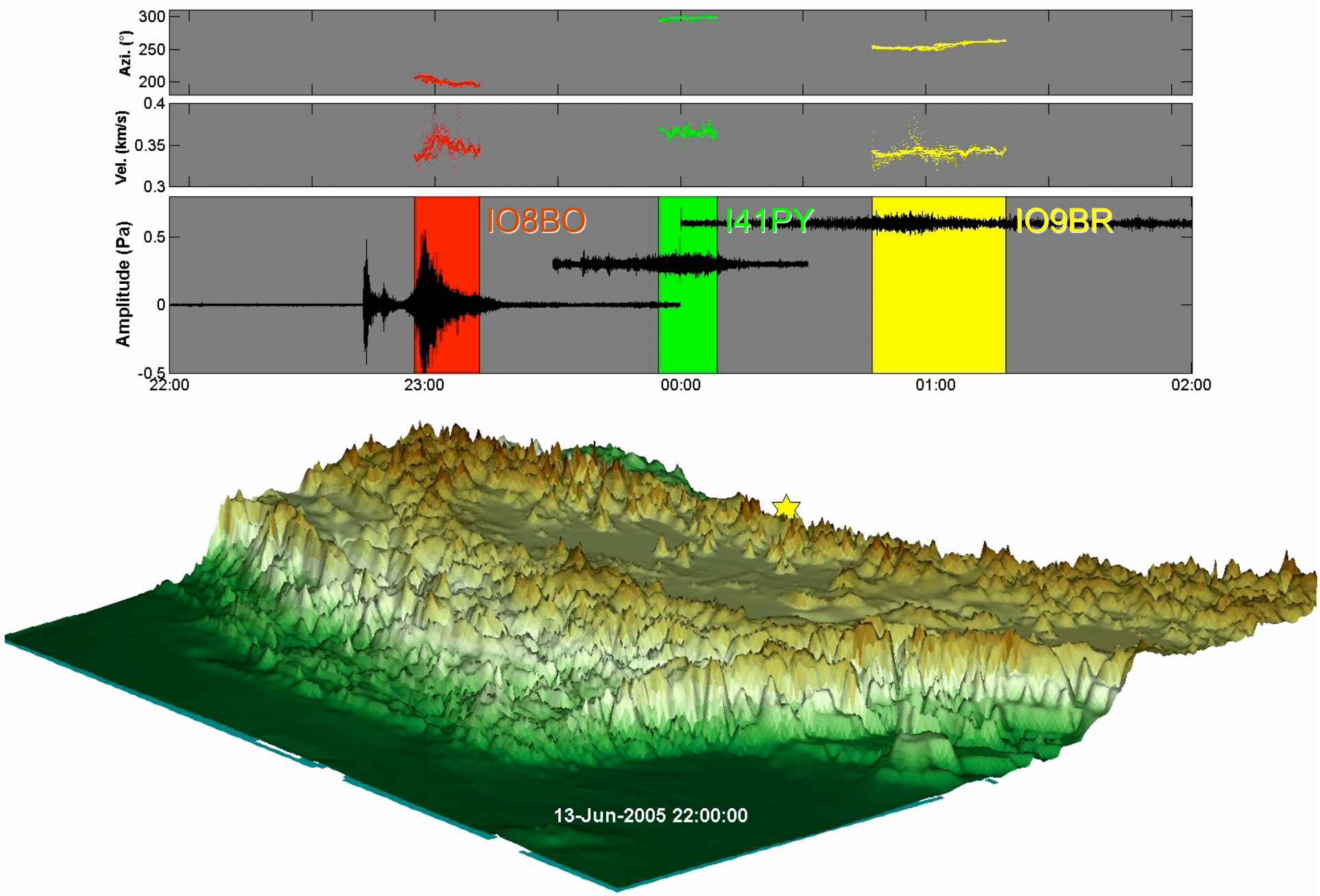
Infrasound measurements at I08BO, I09BR and I41PY



Le Pichon, 2008---M7.8 Northern Chile, June 13, 2005

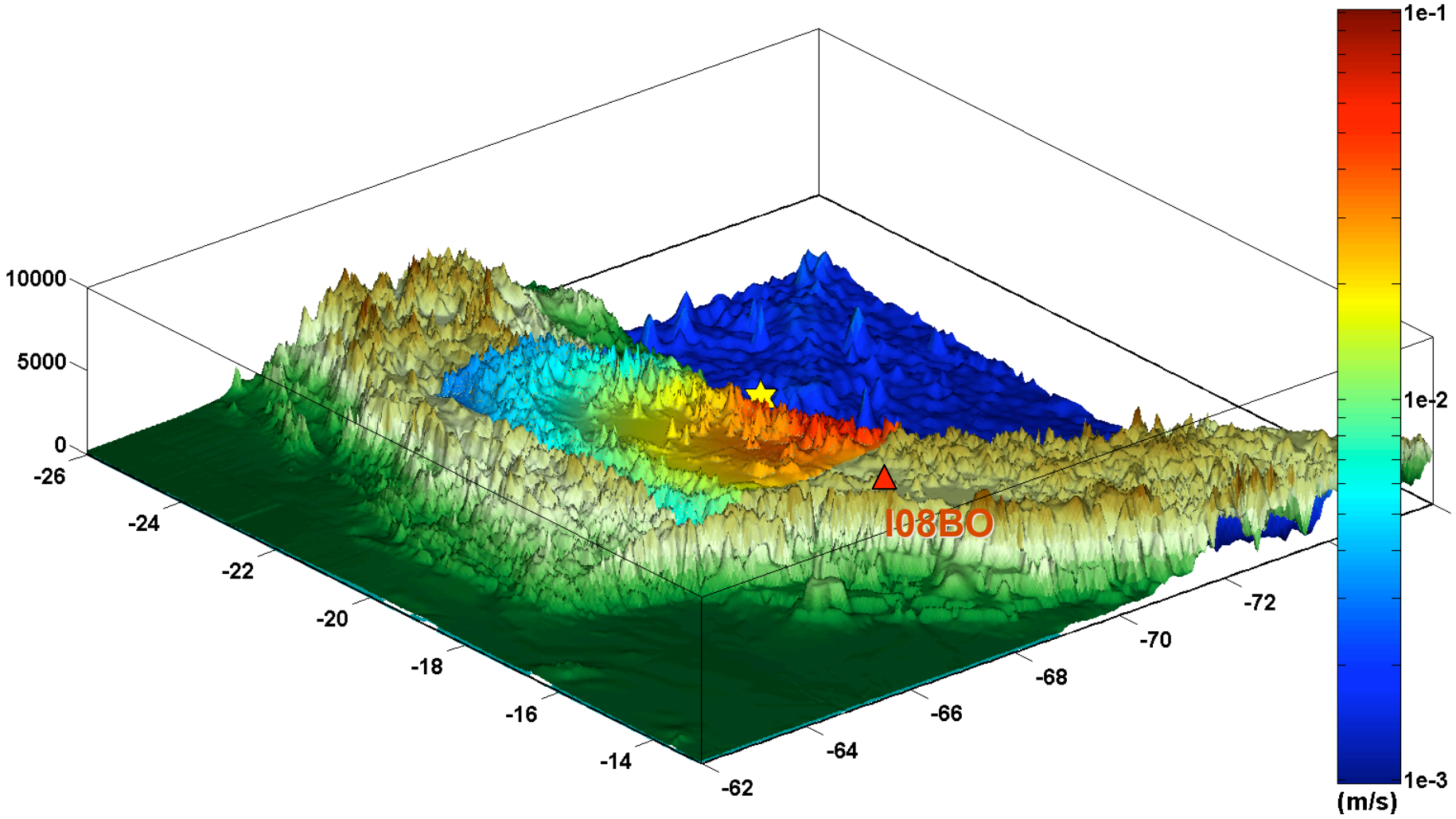


Le Pichon, 2008



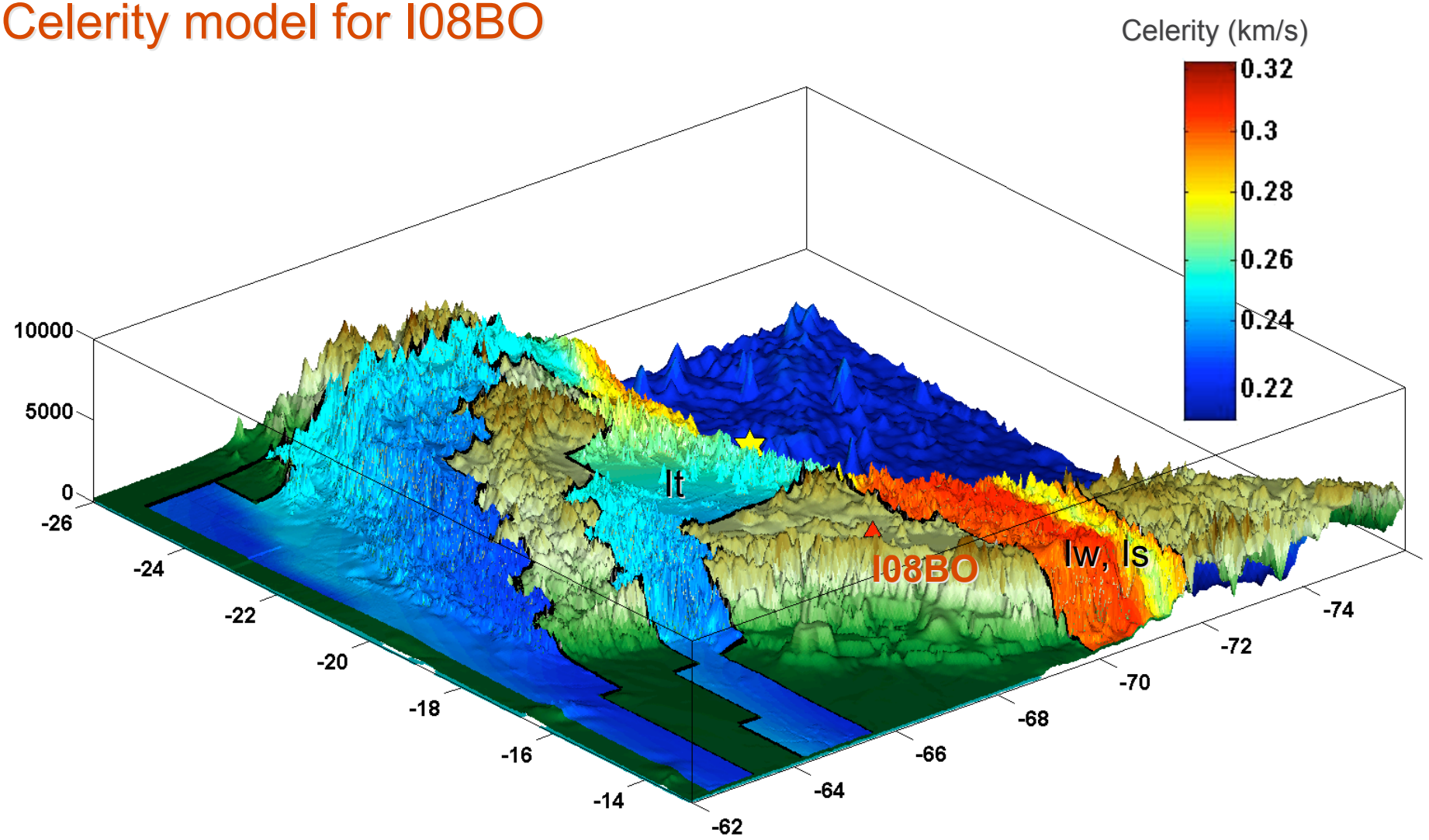
Le Pichon, 2008

Amplitude of the simulated ground velocity



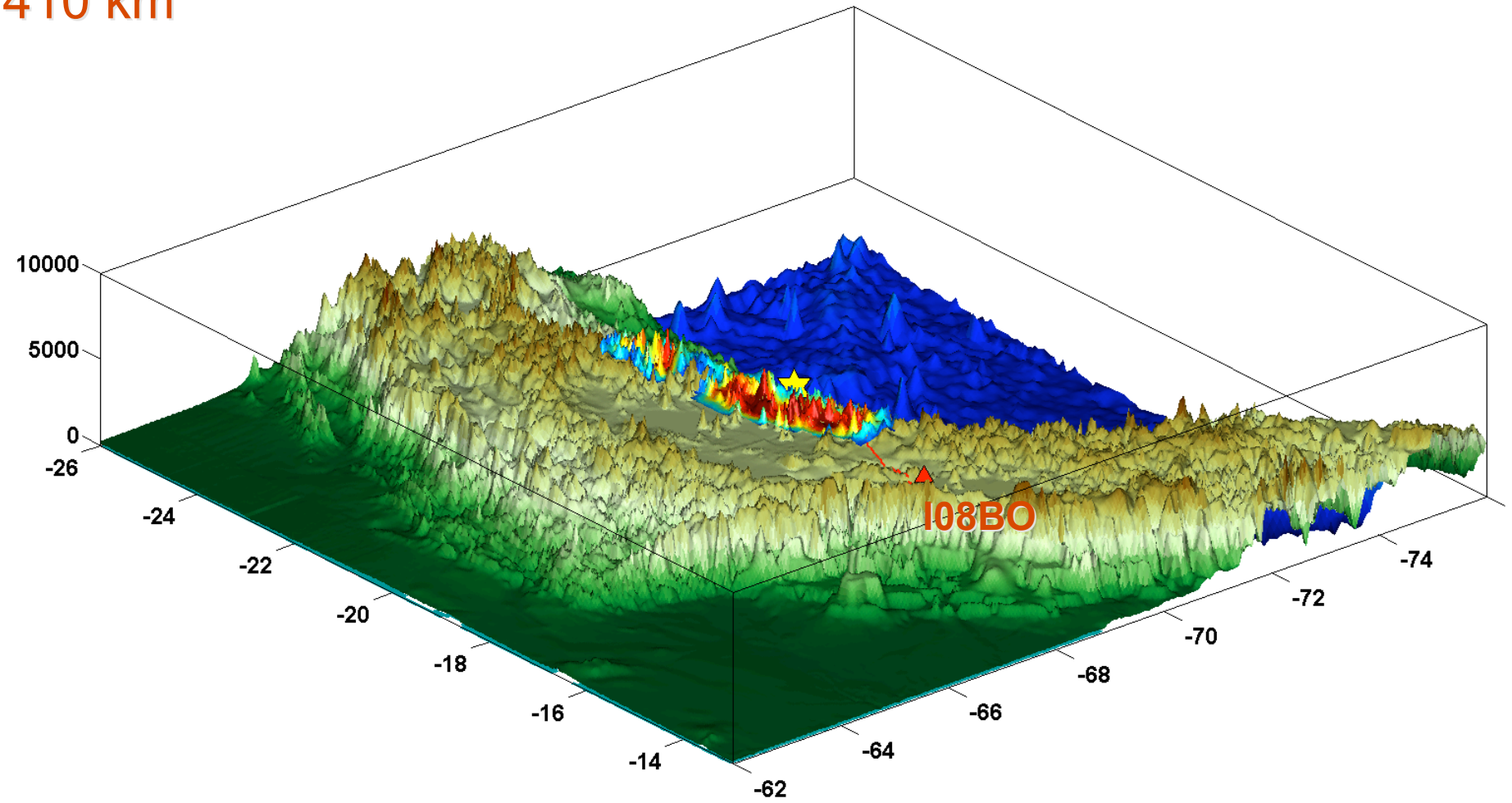
Le Pichon, 2008

Celerity model for I08BO



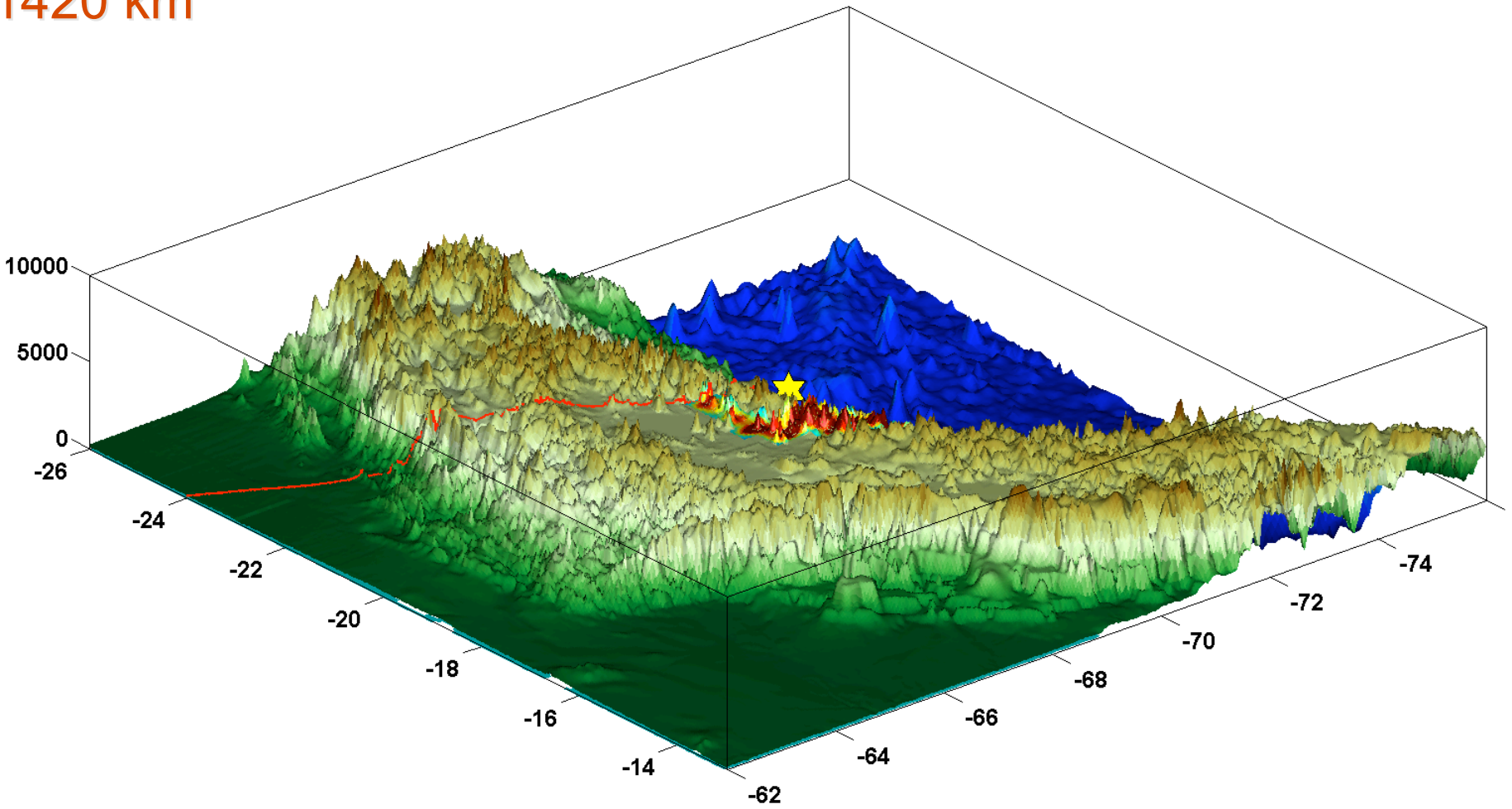
Le Pichon, 2008

Infrasound source regions from I08BO
410 km



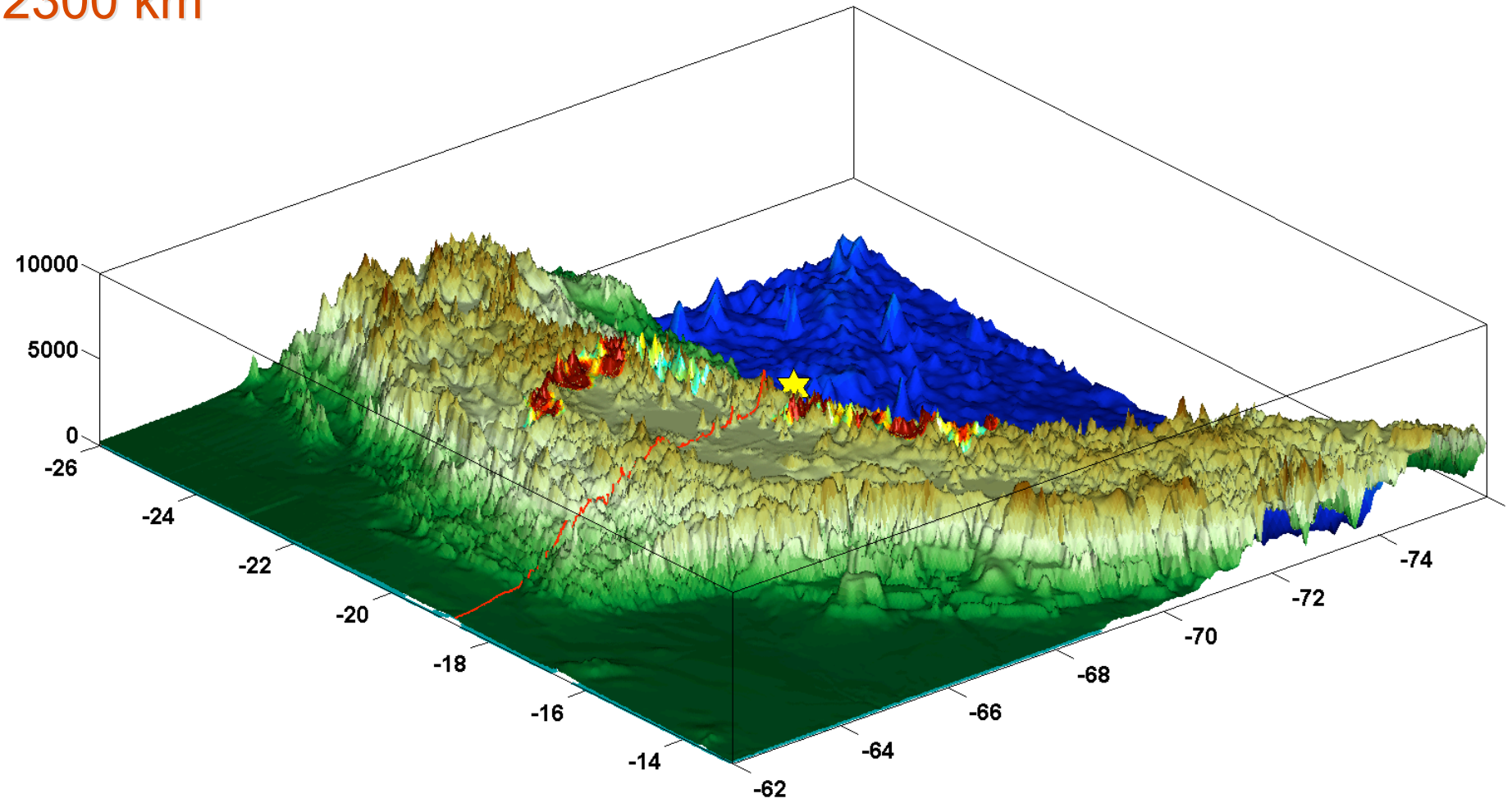
Le Pichon, 2008

Infrasound source regions from I41PY
1420 km



Le Pichon, 2008

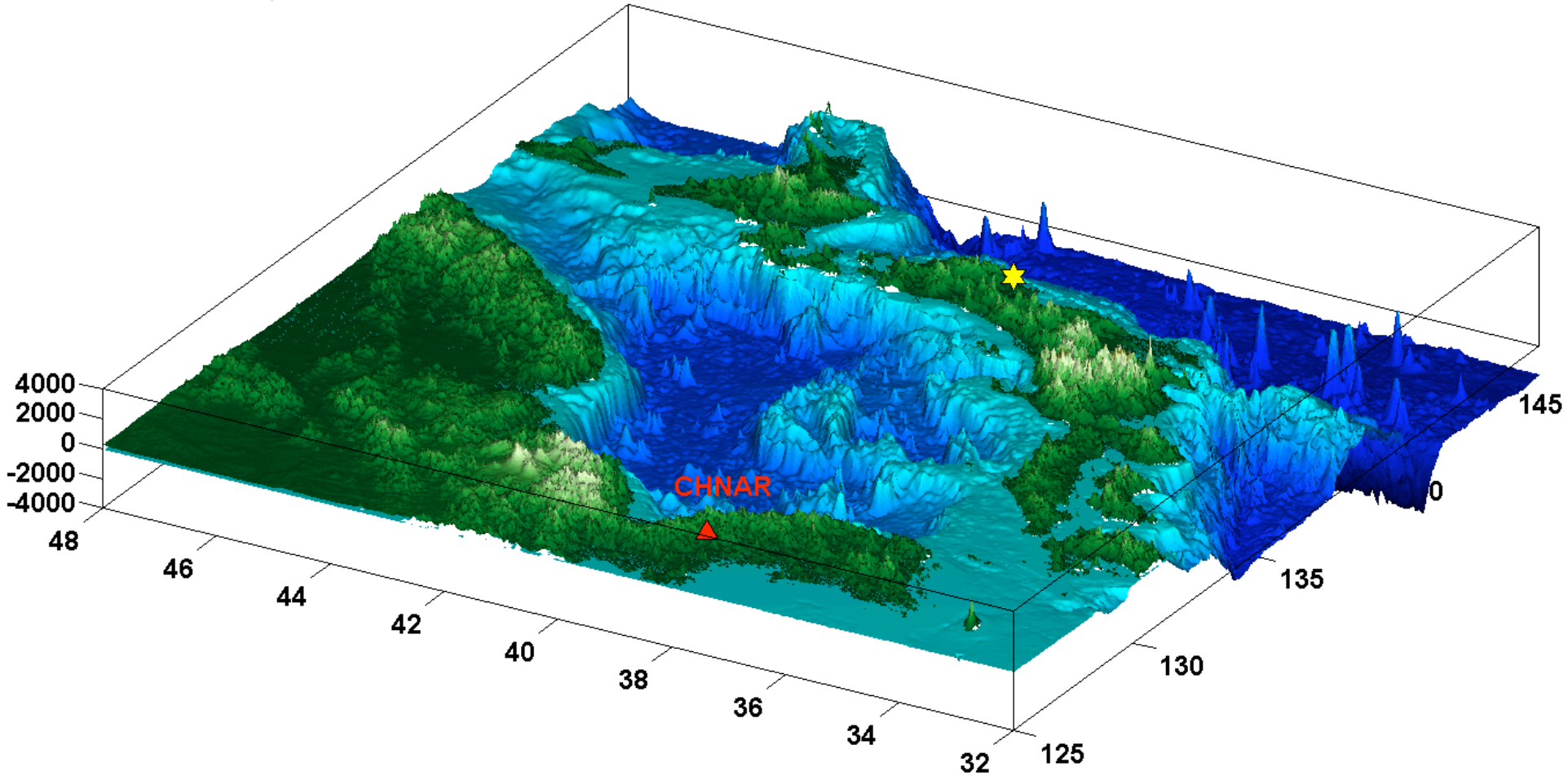
Infrasound source regions from I09BR
2300 km



Le Pichon, 2008

M7.0 East Coast of Honshu, Japan
May 26, 2003
Depth: 70 km

CHNAR: 1300 km



[Lee et al., 2004]

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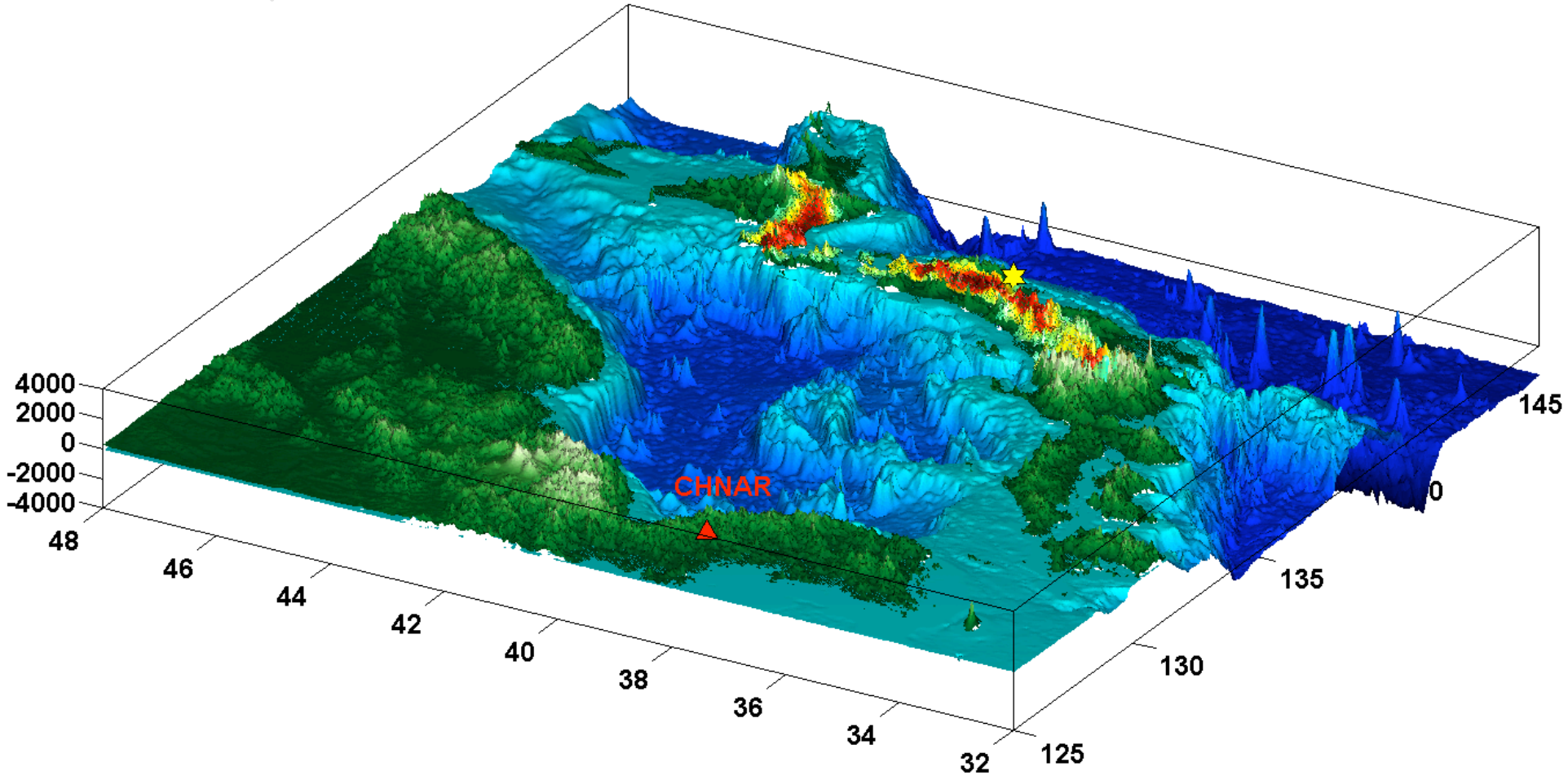


Duration: ~40 min
Radiating zone: ~1200 km

[Lee et al., 2004]

Monitoring and Studying Volcanoes

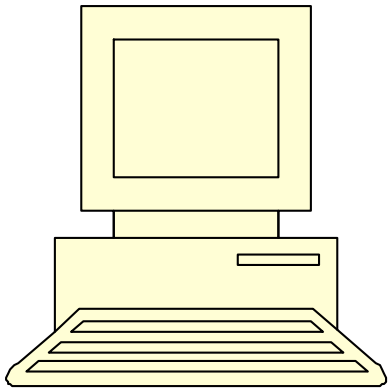
Acoustic Surveillance of Hazardous Eruptions (ASHE)

Operational Concept

4-element array

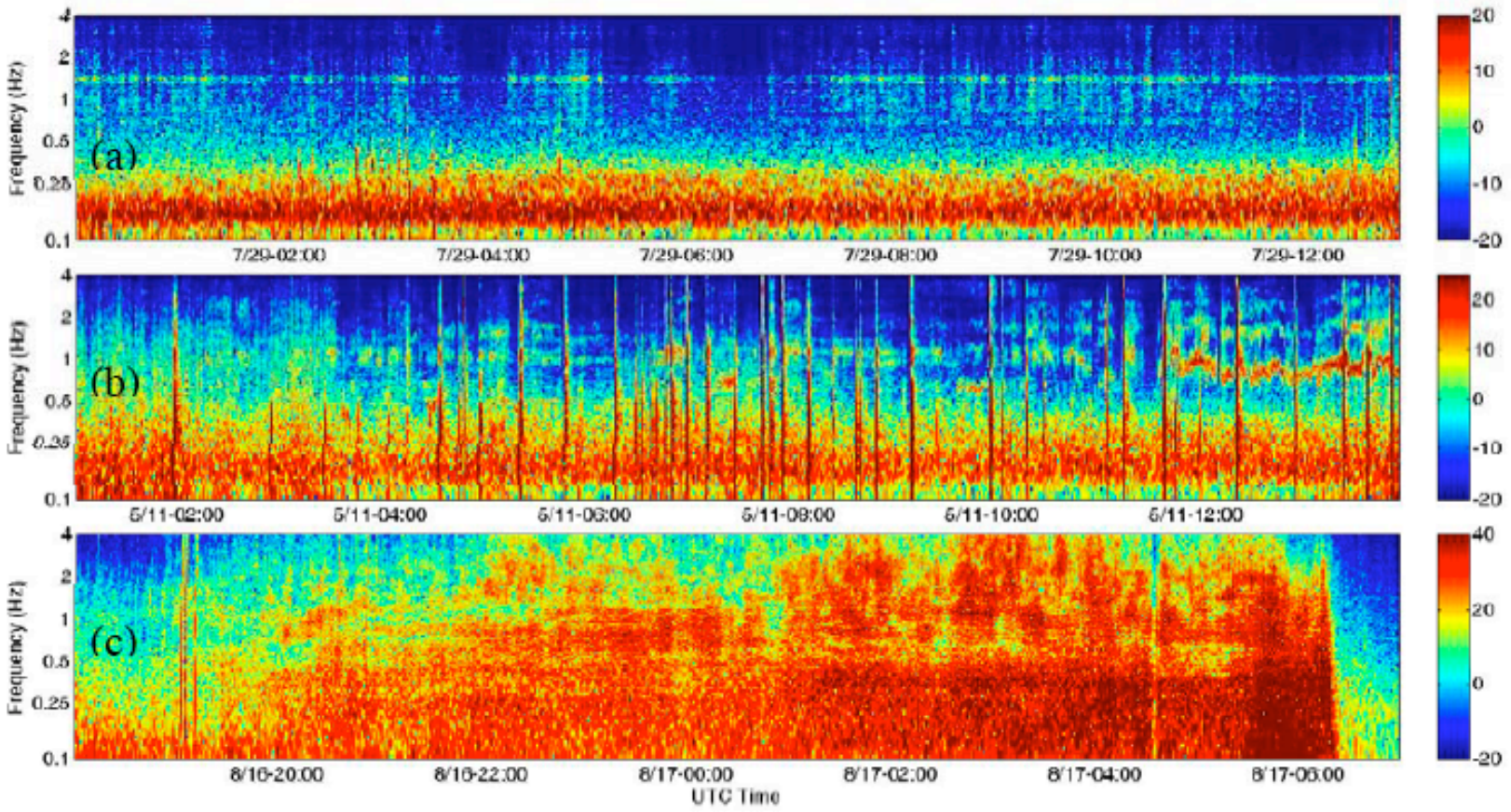
Analysis centre

VAAC



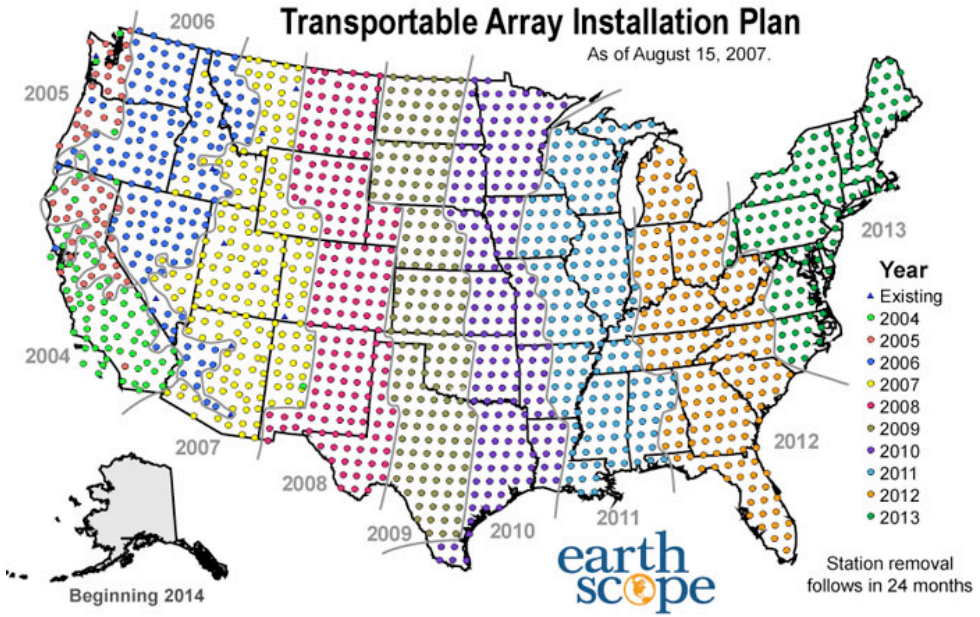
Bass et al., 2007

Tungurahua 2006 Garces et al., 2008



Low-level tremor (top), explosions and tremor (middle), Vulcanian->Plinian (bottom)

Studies of Atmospheric Events using the USArray



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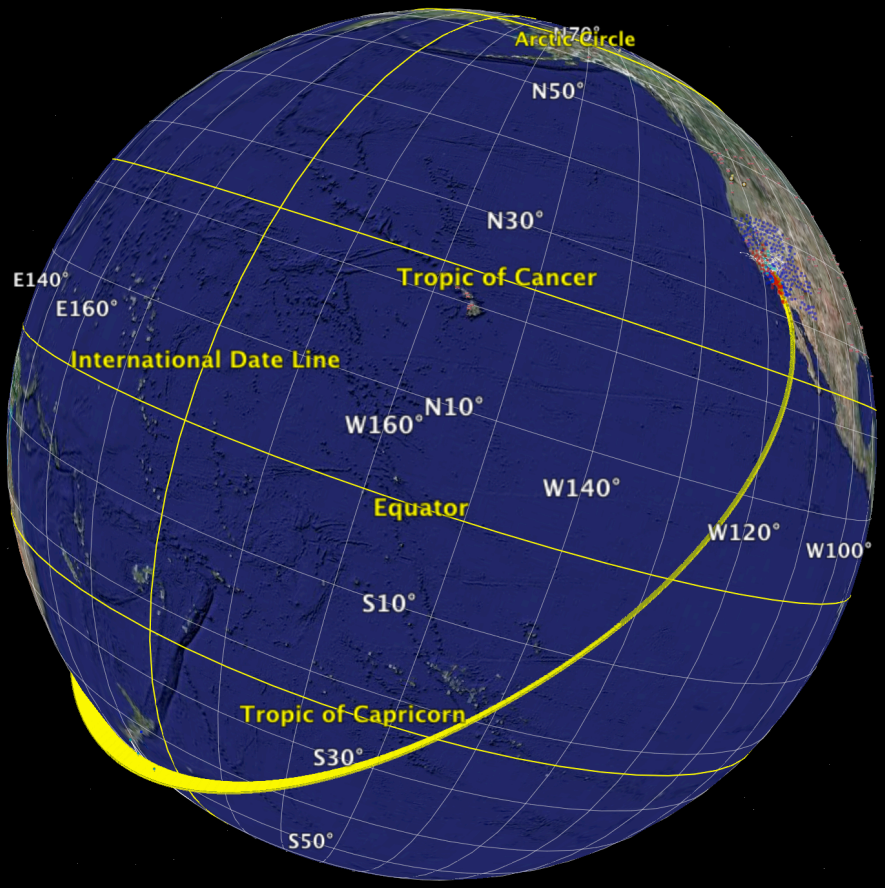
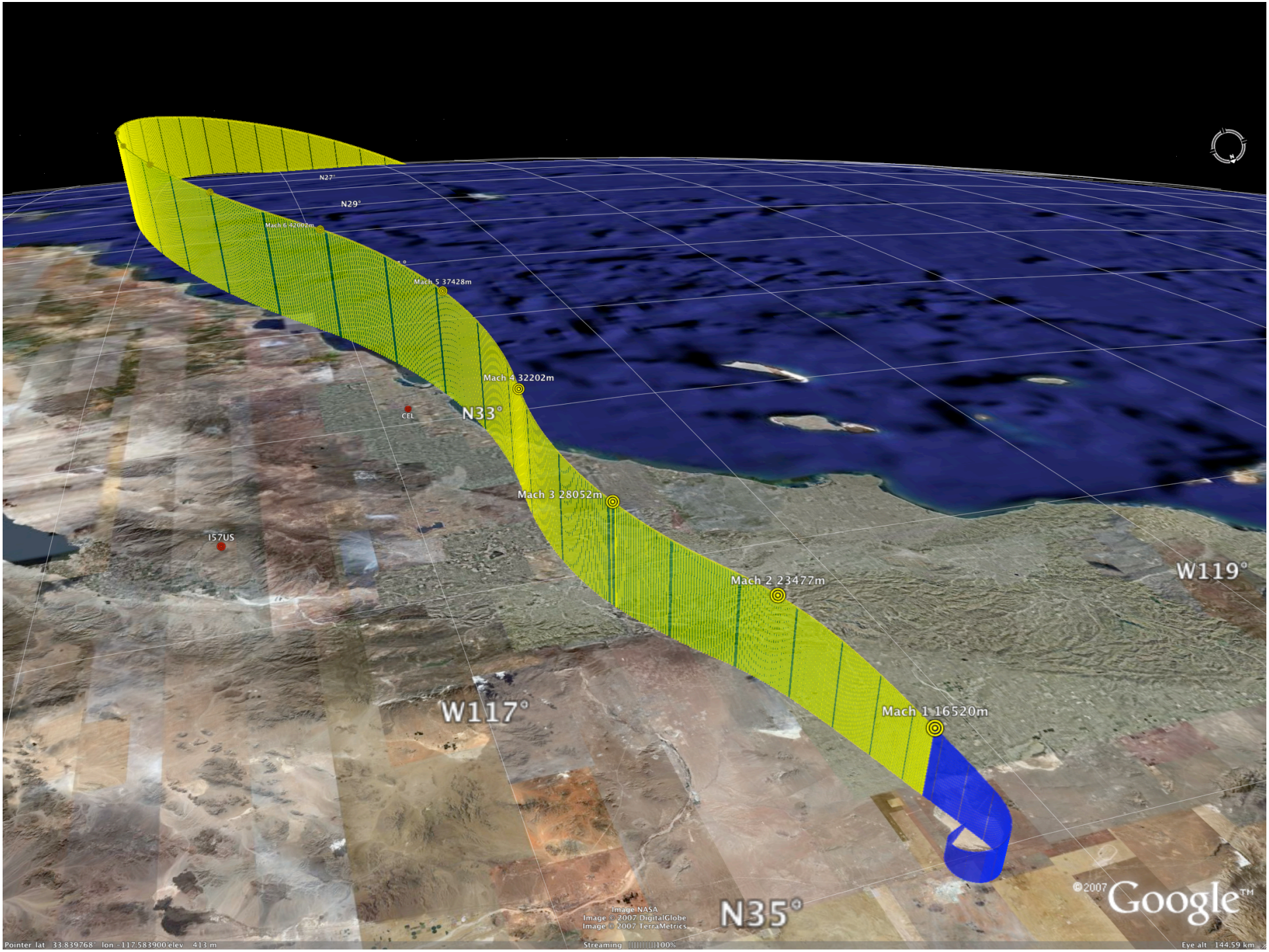
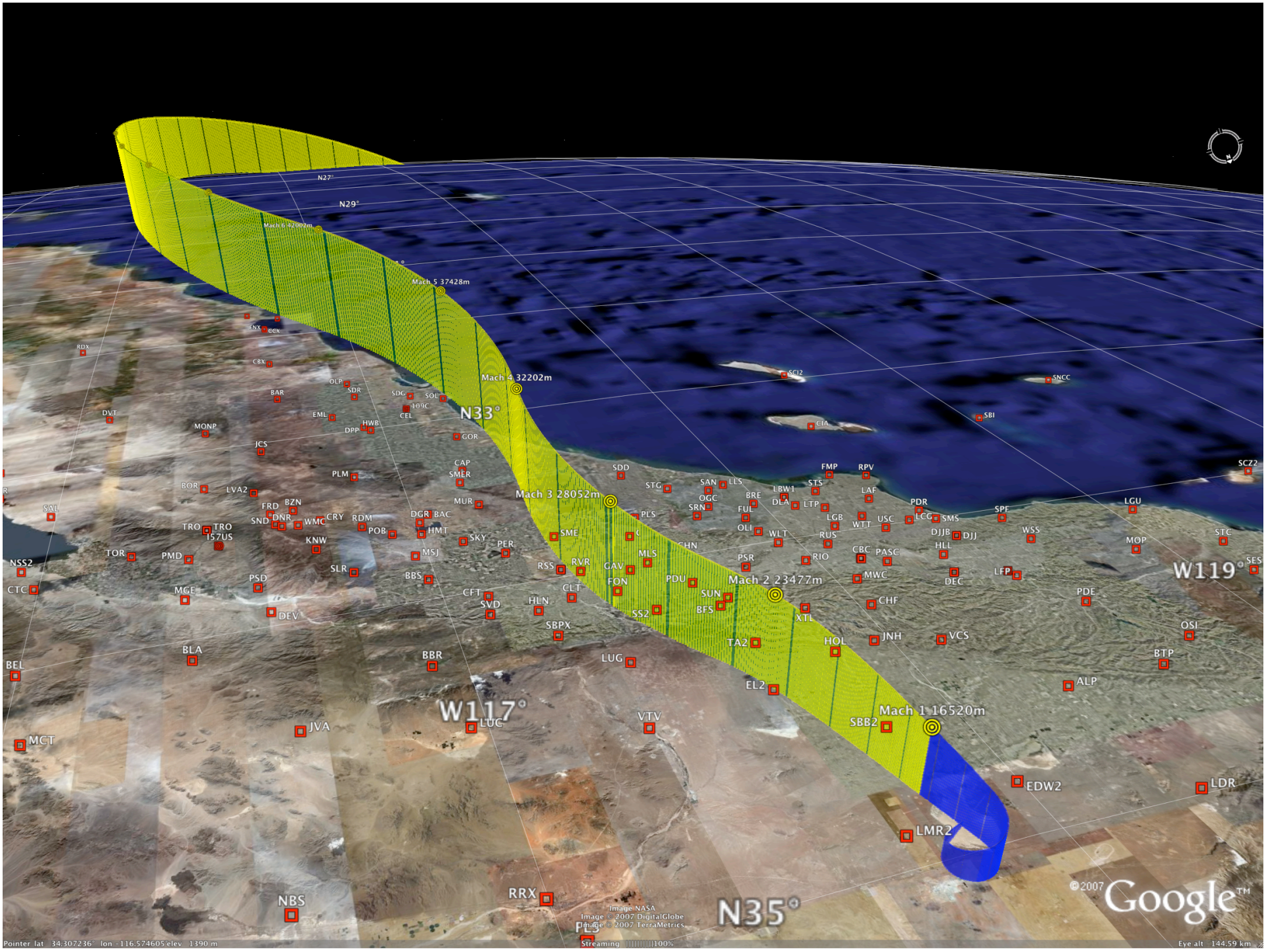
Atlantis


N70°
Arctic Circle
N50°
N30°
Tropic of Cancer
E140°
E160°
International Date Line
N10°
W160°
W140°
Equator
W120°
W100°
S10°
Tropic of Capricorn
S30°
S50°


N27°
N29°
Mach 6 42002m
Mach 5 37428m
Mach 4 32202m
CEL
N33°
Mach 3 28052m
I57US
Mach 2 23477m
W119°
W117°
Mach 1 16520m
N35°
Image NASA
Image © 2007 DigitalGlobe
Image © 2007 TerraMetrics
©2007 Google™
Pointer lat 33.839768° lon -117.583900 elev 413 m
Streaming 100%
Eye alt 144.59 km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W117°
W119°
N35°
RDX
CBX
ENX
CCX
OLP
SDR
BAR
SDC
SOL
109C
CEL
DVT
EML
DPP
HWB
MONP
JCS
GOR
CAP
SMER
PLM
BOR
LVA2
SAL
FRD
BZN
DNR
SND
WMC
CRY
RDM
TRO
157US
KNW
POB
DGR
BAC
HMT
MUR
SKY
PER
MSJ
TOR
PMD
NSS2
CTC
SLR
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MGE
DEV
BBS
CFT
SVD
HLN
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BLA
BEL
BBR
LUG
MCT
JVA
LUC
VTV
RRX
NBS
SCI2
SNCC
SBI
CIA
SCZ2
SDD
STG
SME
PLS
RSS
RVR
GAV
FON
CLT
MLS
PDU
SUN
BFS
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JNH
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LDR
LMR2
SAN
LLS
OGC
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FUL
OLI
DLA
LBW1
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LTP
FMP
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LAF
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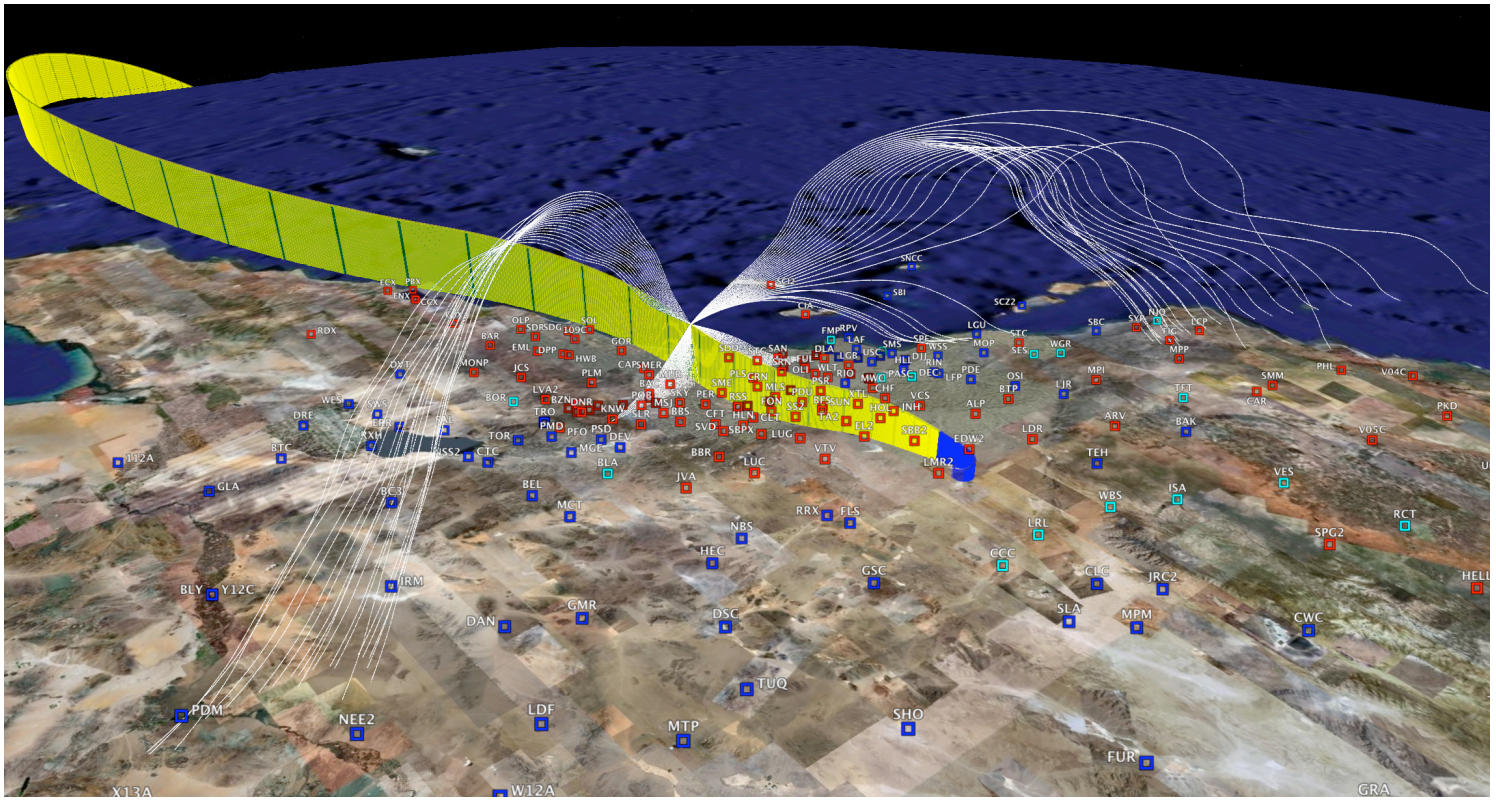
LCG
SMS
SPF
LGB
WTT
USC
WLT
RUS
RIO
PSC
CBC
DJJB
DJJ
HLL
WSS
LGU
STC
MOP
SES
Image NASA
Image © 2007 DigitalGlobe
Image © 2007 TerraMetrics
© 2007 Google™
Pointer lat 34.307236° lon -116.574605 elev 1390 m
Streaming 100%
Eye alt 144.59 km

Propagation



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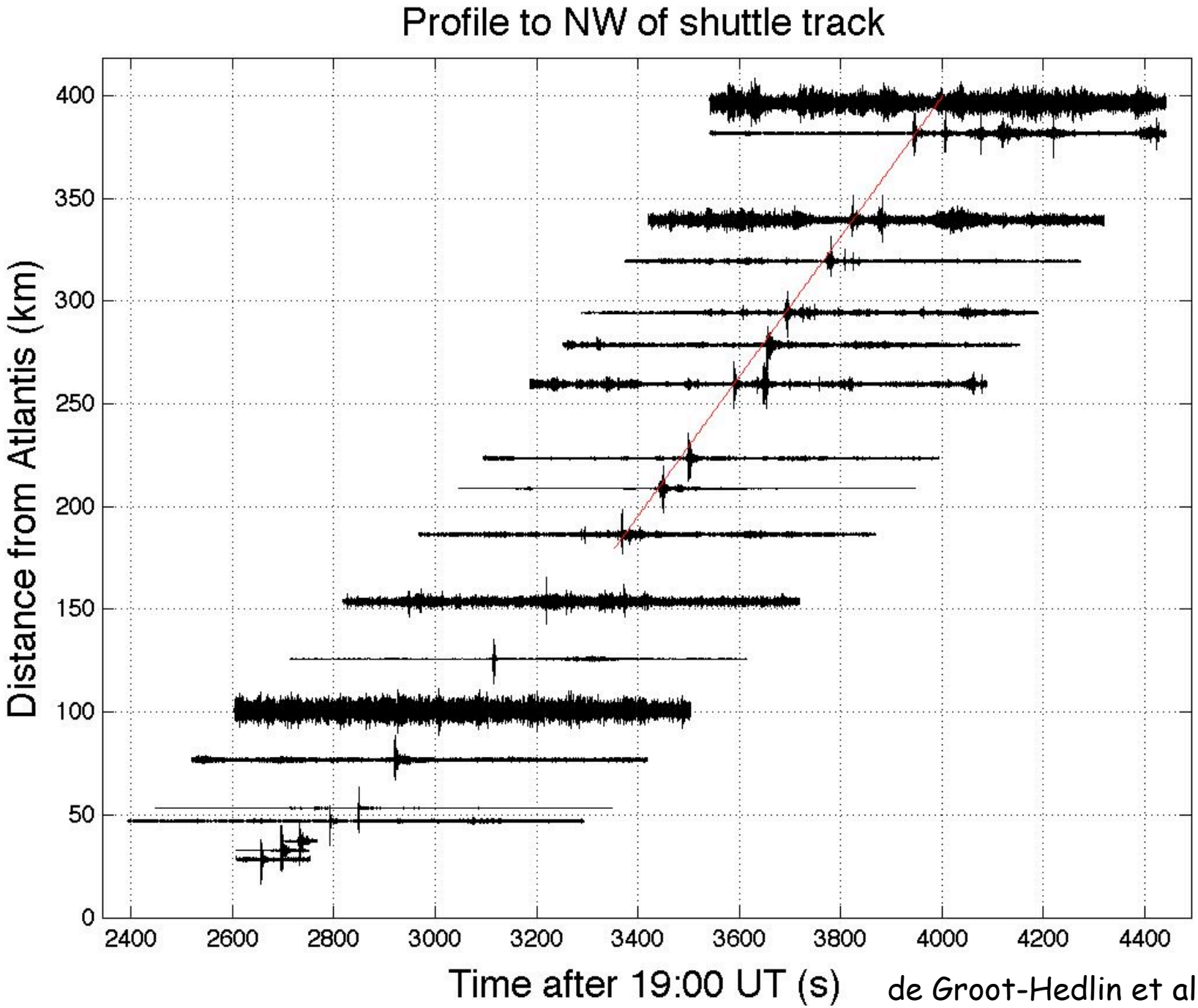
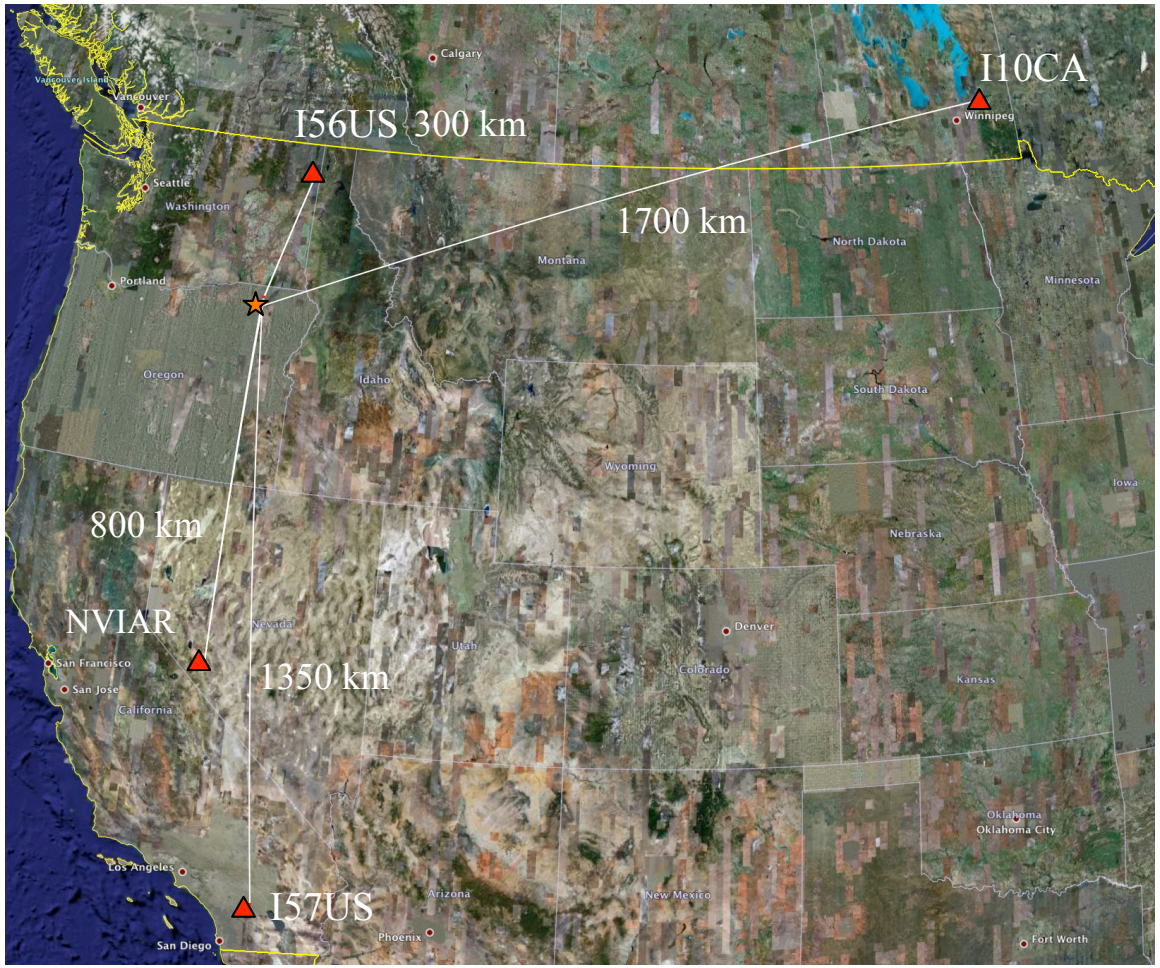


de Groot-Hedlin et al., 2008

The USArray and the Oregon bolide



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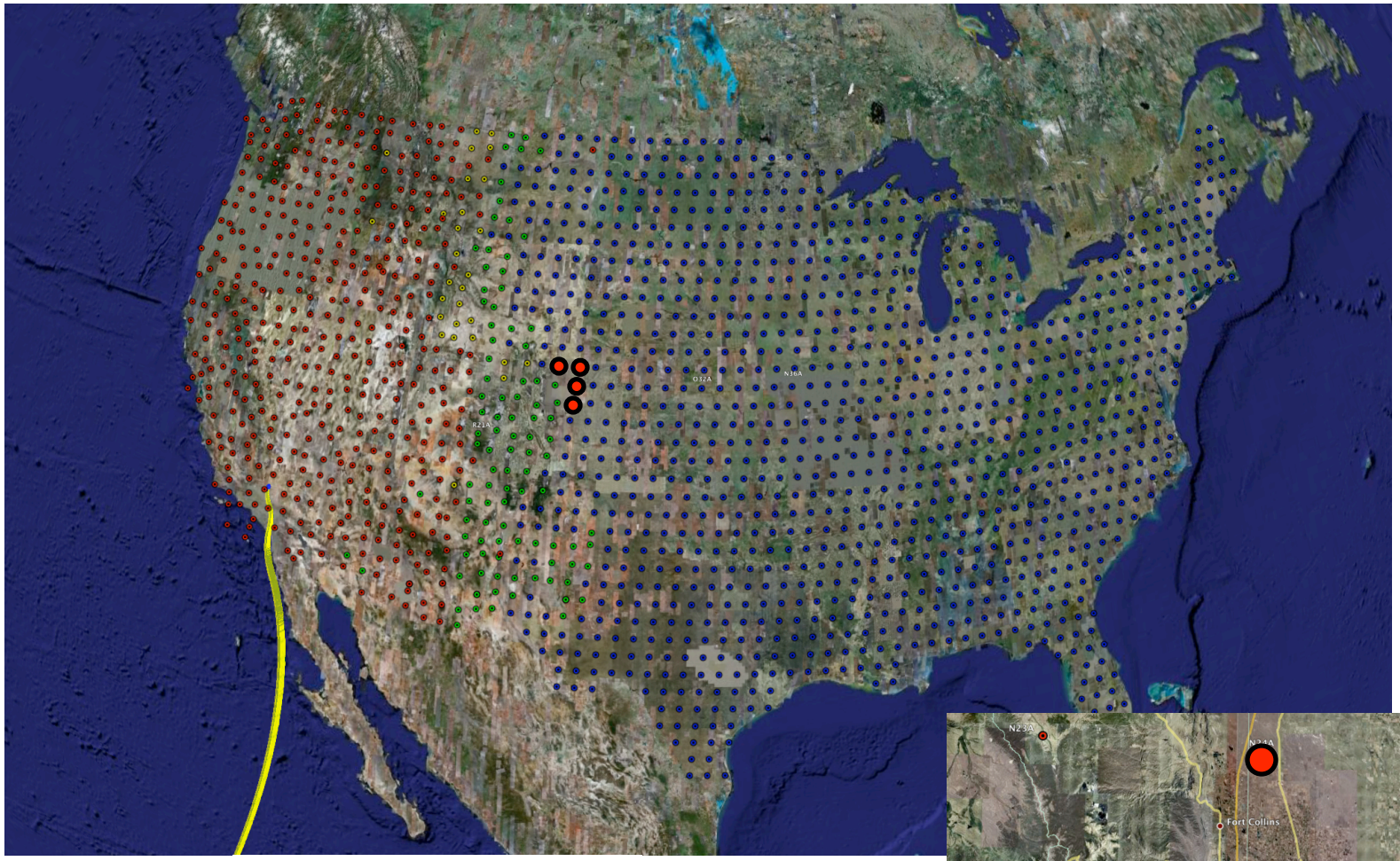
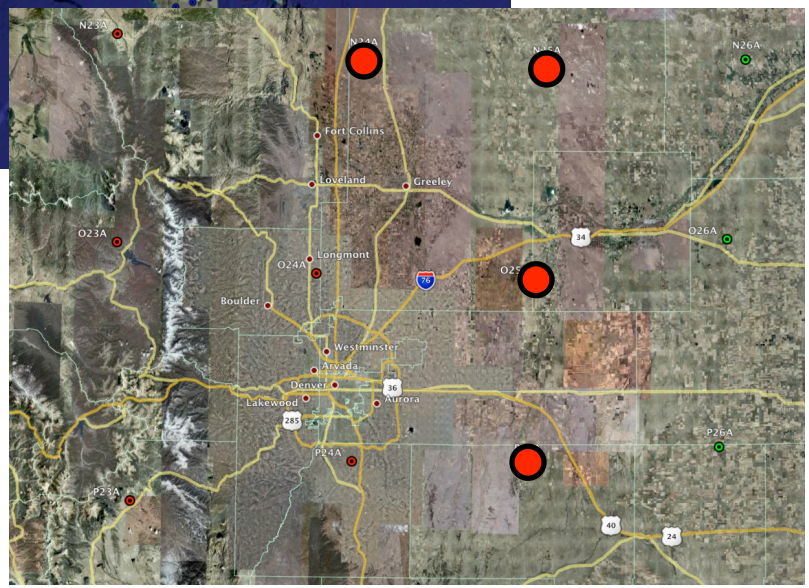
Grand challenges (part 1)

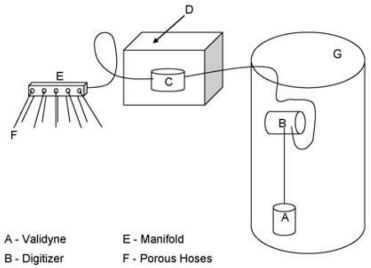
- Test and refine our models of atmospheric structure
  - Increase station density
  - Ground-truth more sources
  - Co-locate atmospheric pressure sensors with seismic stations
  - Would help in many other areas (e.g. mechanical coupling between atmosphere and solid Earth, nature of acoustic noise, infrasound propagation modeling

More seismo-acoustic networks?

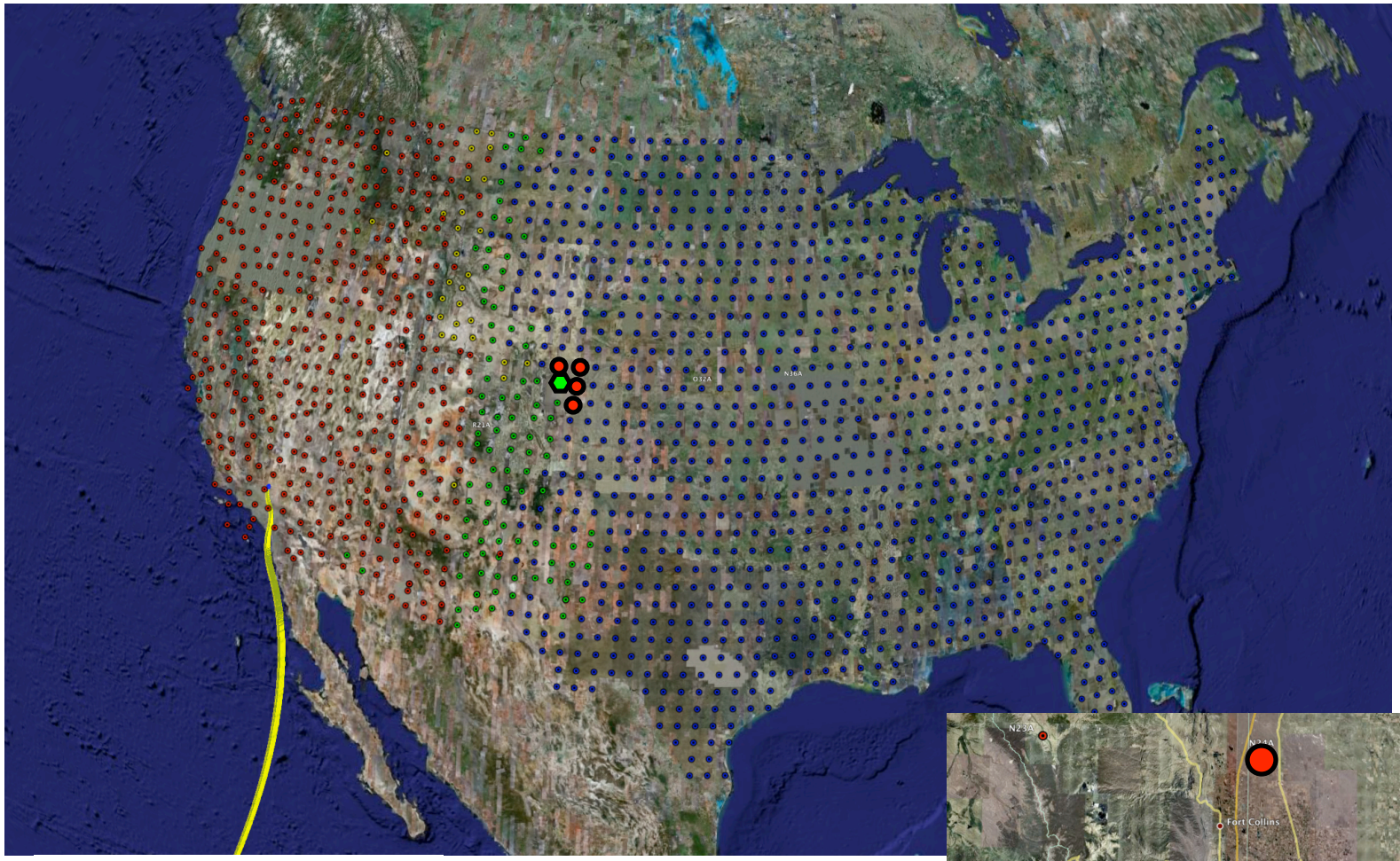
- e.g. SMU/IRIS effort underway

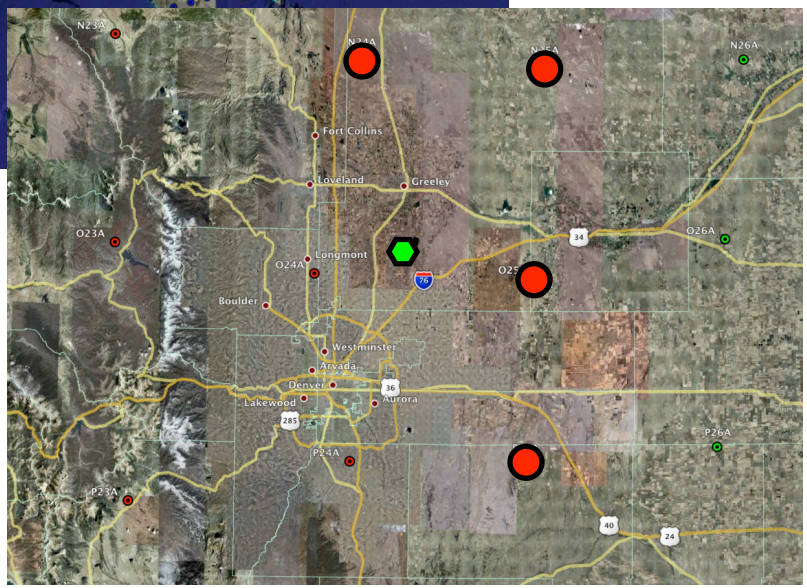


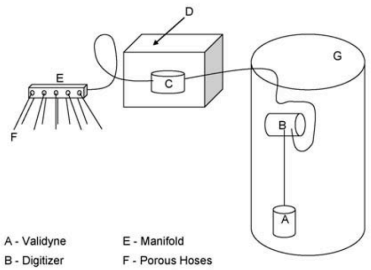




A - Validyne
B - Digitizer
C - Chaparral
D - Chaparral Enclosure
E - Manifold
F - Porous Hoses
G – Seismic Vault







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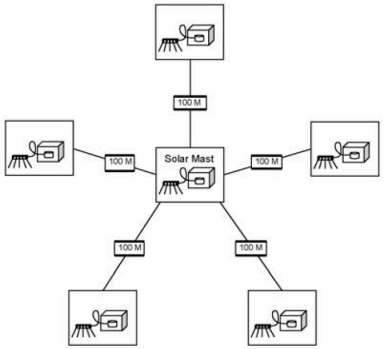

LR
De

More seismo-acoustic networks?

- e.g. SMU/IRIS effort underway
- Can we do this on a larger scale?
  - Single sensors with interspersed arrays?
  - Begin at a "modest" scale?
  - Still time to begin with the USArray?

Grand challenges (pt. 2)

- Improve our ability to characterize near-surface and atmospheric processes using infrasound and infrasound with seismic
  - There is a rich interface between infrasound and seismic
    - e.g. the study and monitoring of volcanoes

AtmoScope - A. Muschinski

- GPS meteorology
- Atmospheric tides
- Free oscillations
- NWP
- Mesoscale meteorology and regional climate
- Limnology, hydrology, gravimetry and geodesy
- Adaptive seismometry
- Natural Hazards
- Meteor physics and CTBT monitoring

Concluding comments

- Information about seismic events can be carried by atmospheric signals and vice versa
  - Much common ground between the two disciplines
- Grand challenges
  - Many scientific issues could be addressed by increasing acoustic station density & co-locating these stns with seismic
    - e.g. atmospheric structure -> atmospheric propagation
    - e.g. hazard monitoring
    - e.g. mitigating seismic noise from atmosphere