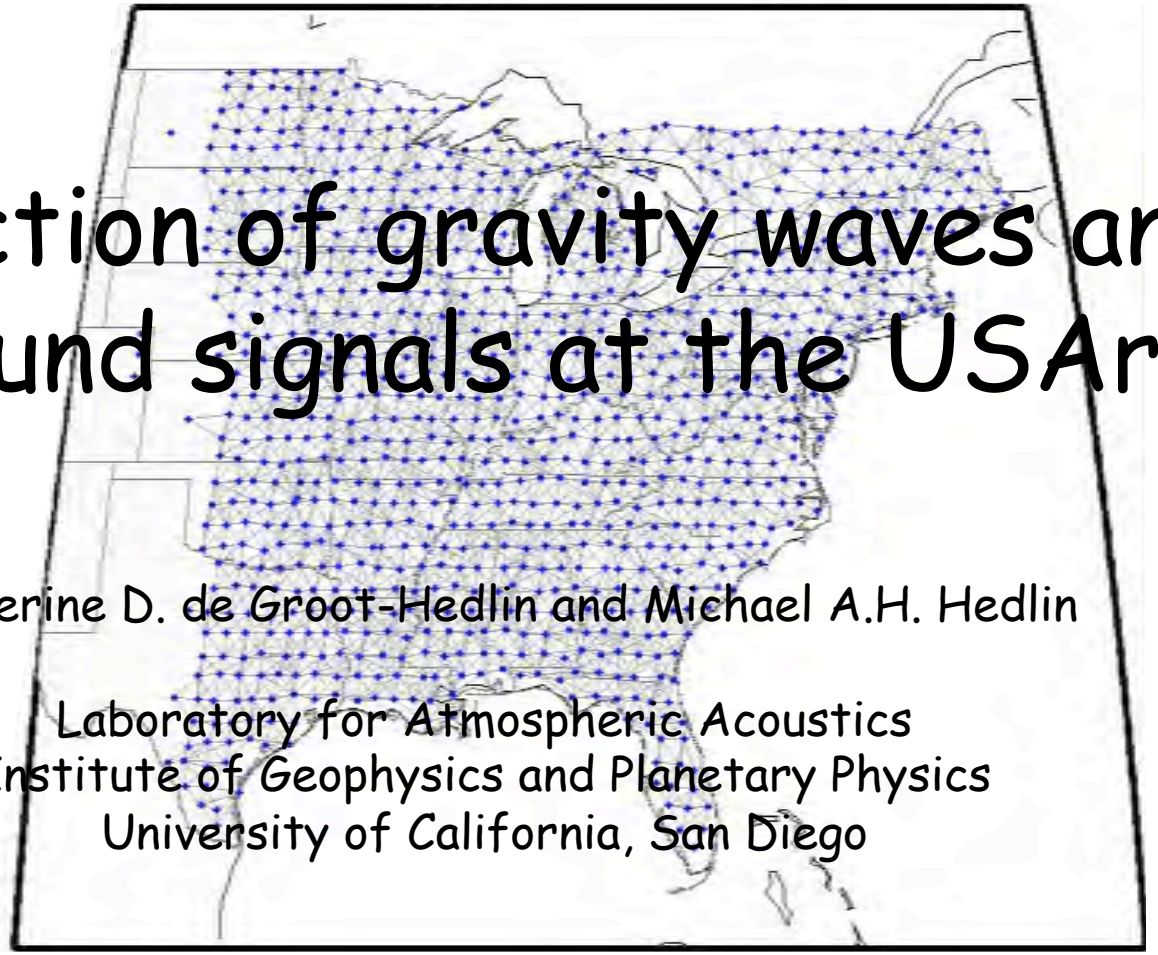
Detection of gravity waves and infrasound signals at the USArray



Catherine D. de Groot-Hedlin and Michael A.H. Hedlin

Laboratory for Atmospheric Acoustics
Institute of Geophysics and Planetary Physics
University of California, San Diego

Outline

① The USArray Transportable Array (TA)
② GW Detection method
③ Case studies of atmospheric gravity waves
④ Infrasound event detection
   a) A new detection method

US Transportable Array
February, 2006

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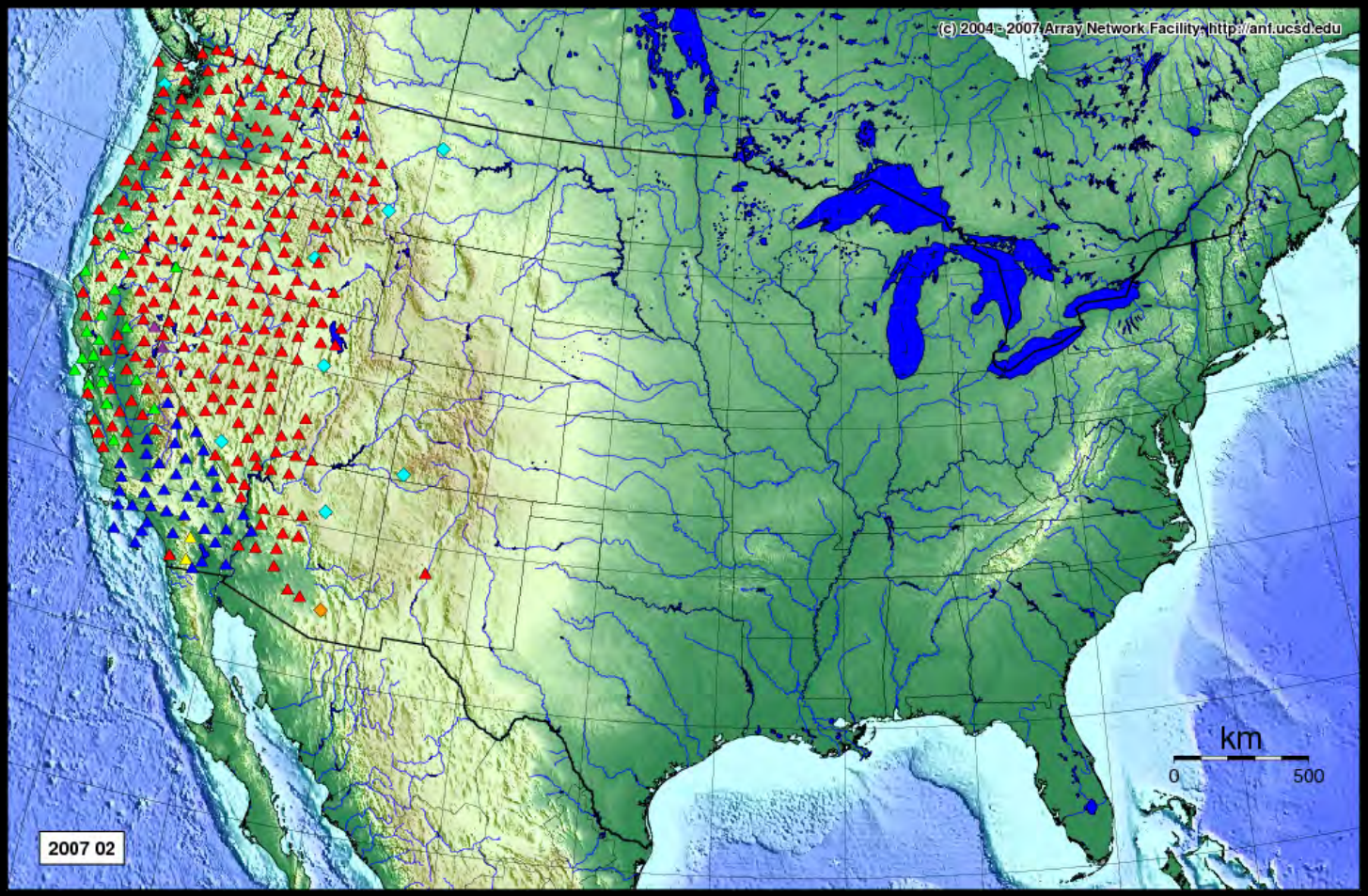
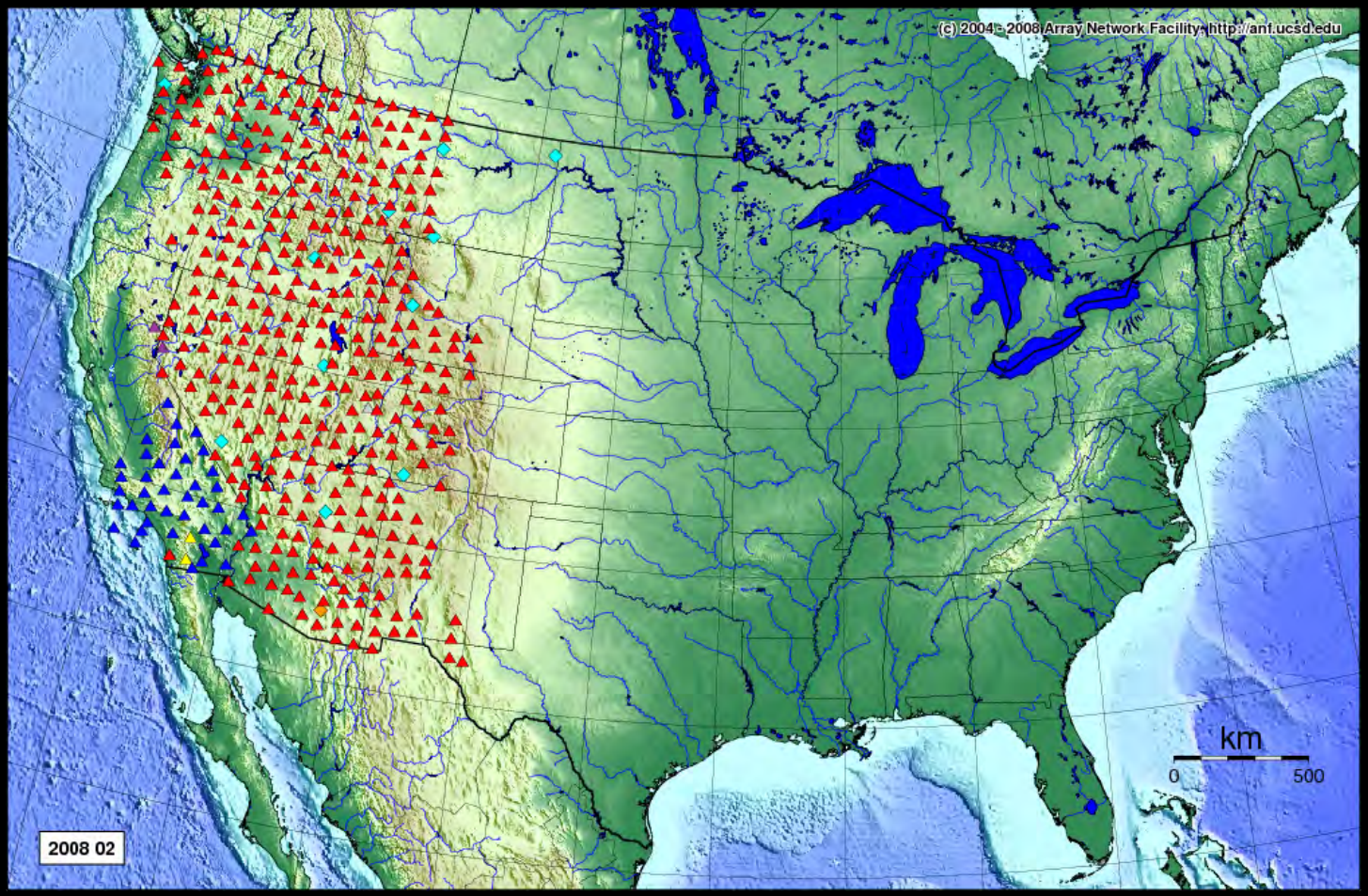
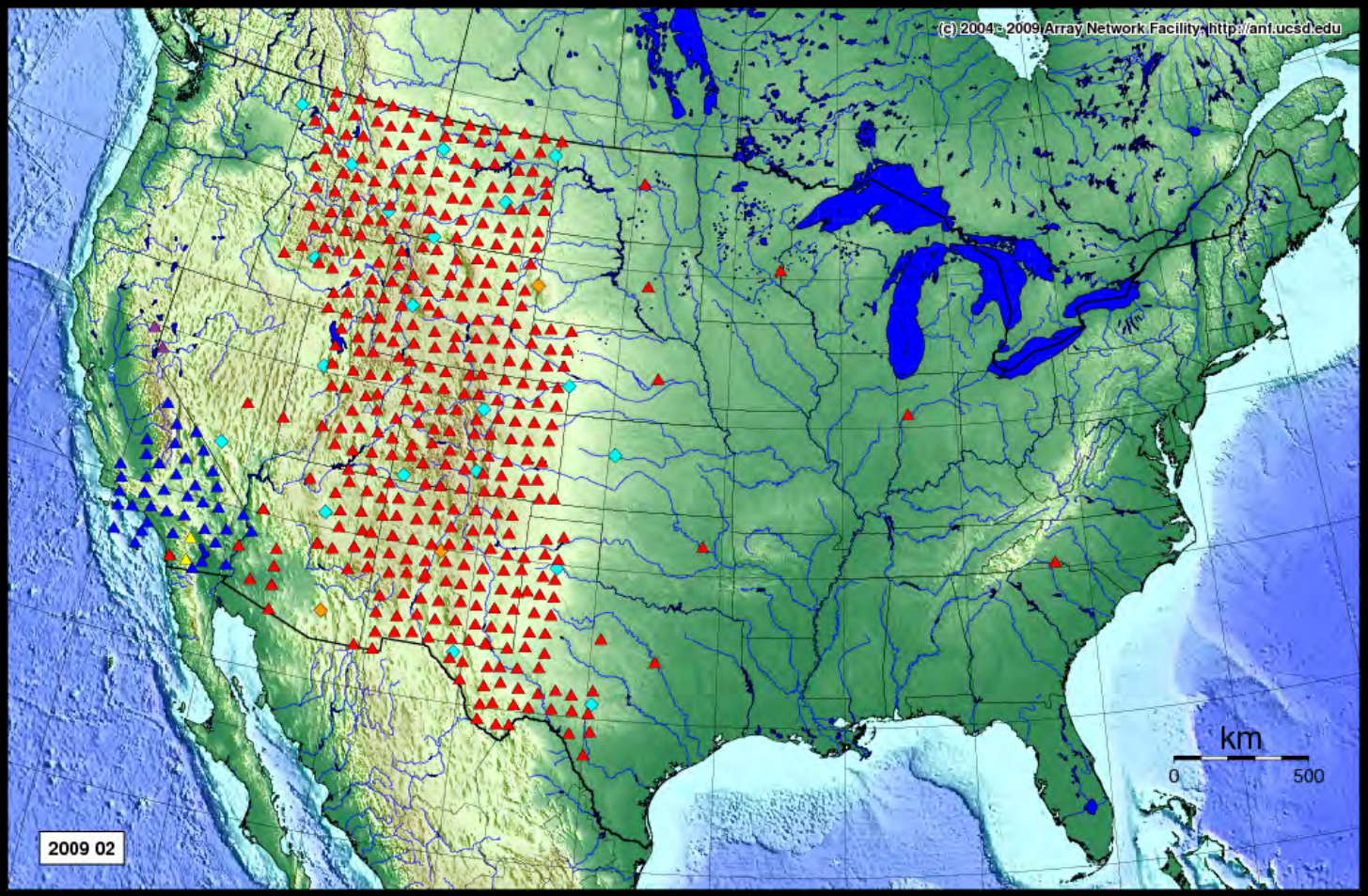
February, 2007



February, 2008



February, 2009



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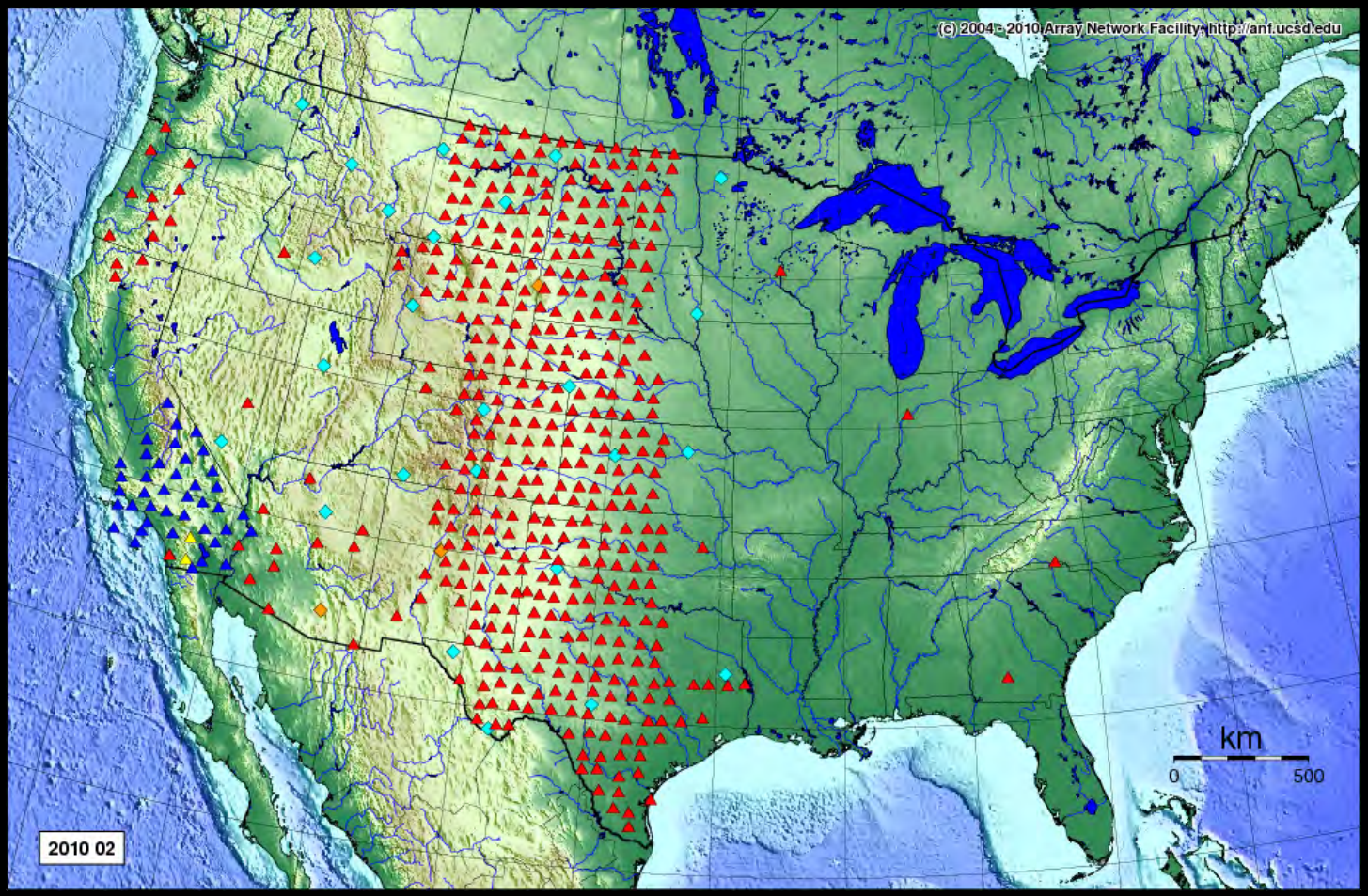
February, 2010 barometers were added



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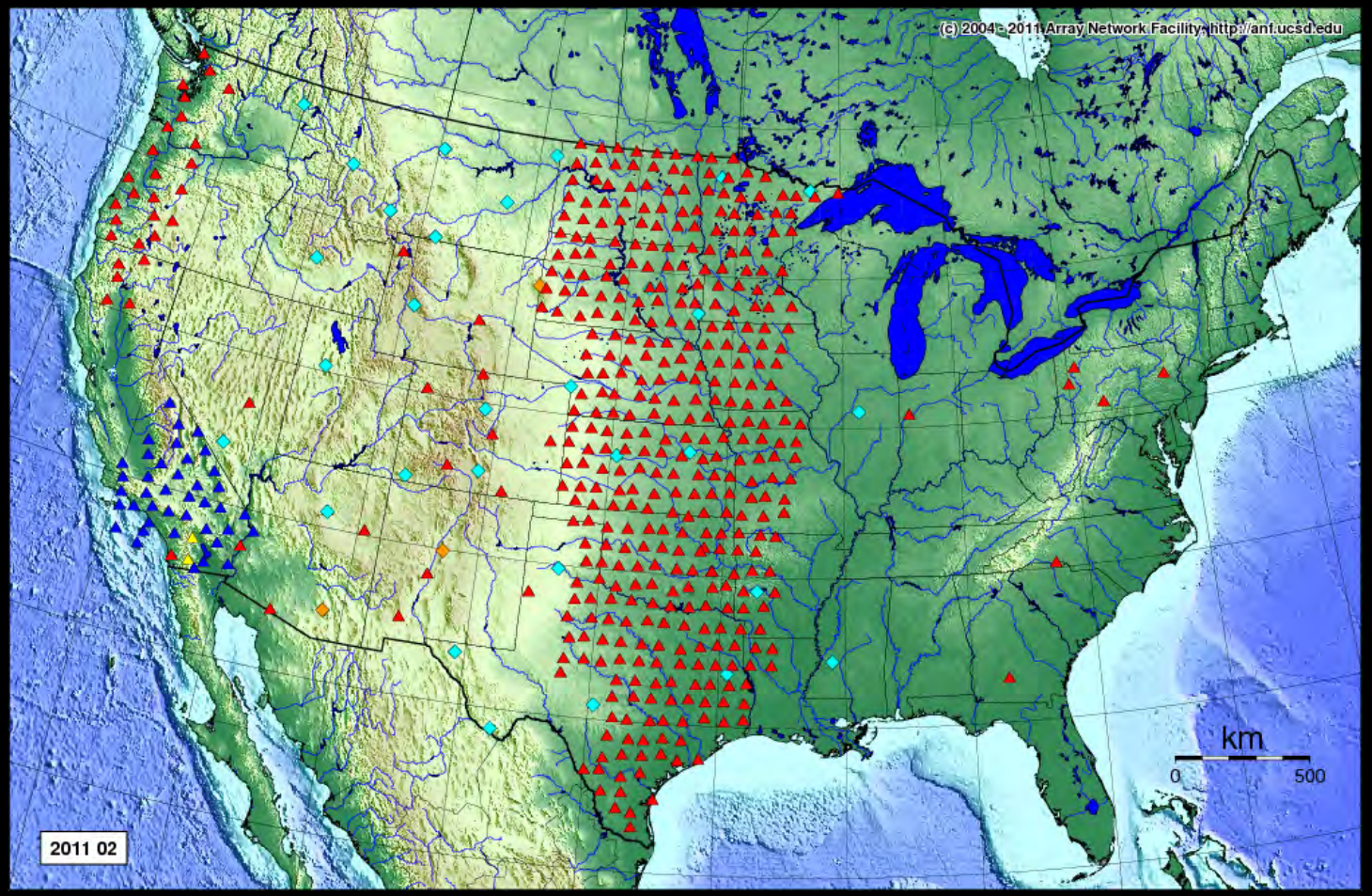
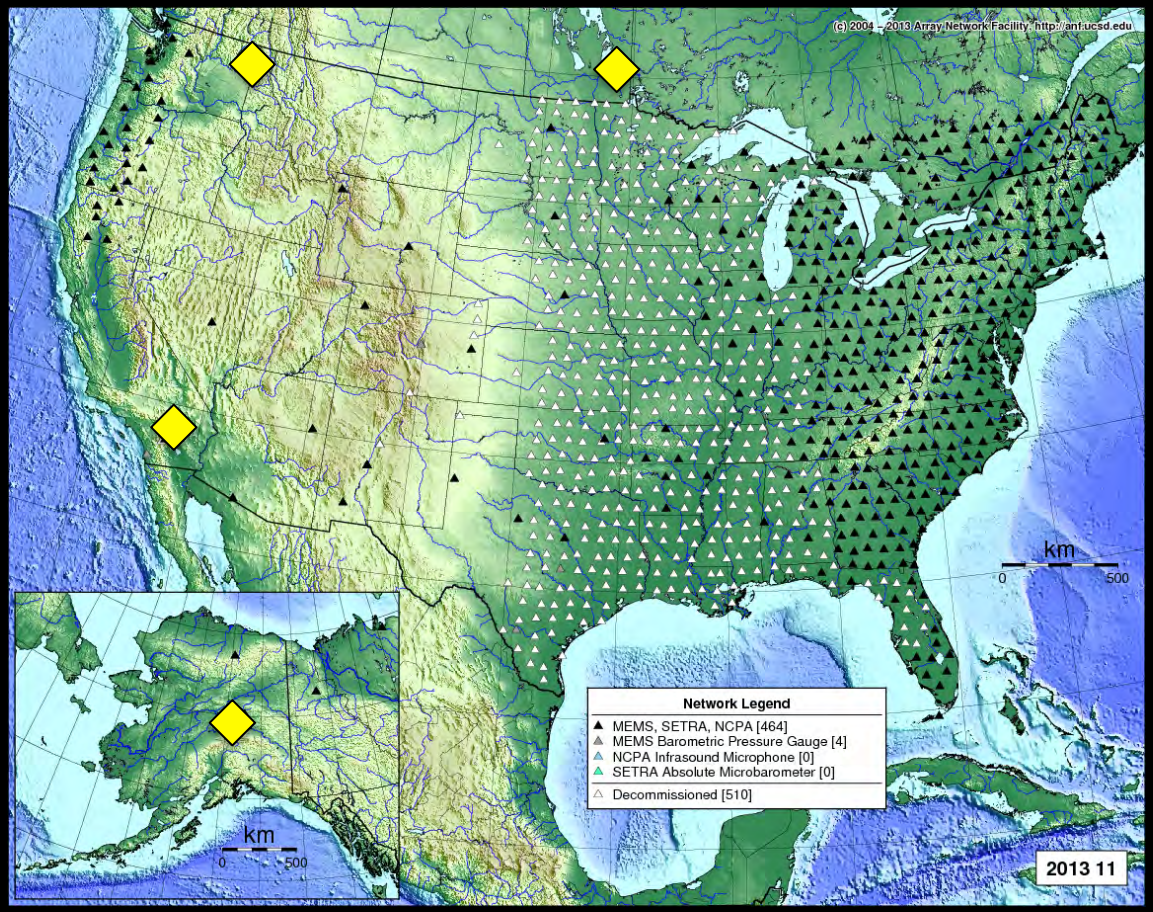
February, 2011



USArray Transportable Array & IMS infrasound arrays



Three atmospheric sensors at each site

- MEMS: D.C. – 100 s
- Setra: D.C. – 1 Hz
- NCPA infrasound microphone: 200 s – Nyquist

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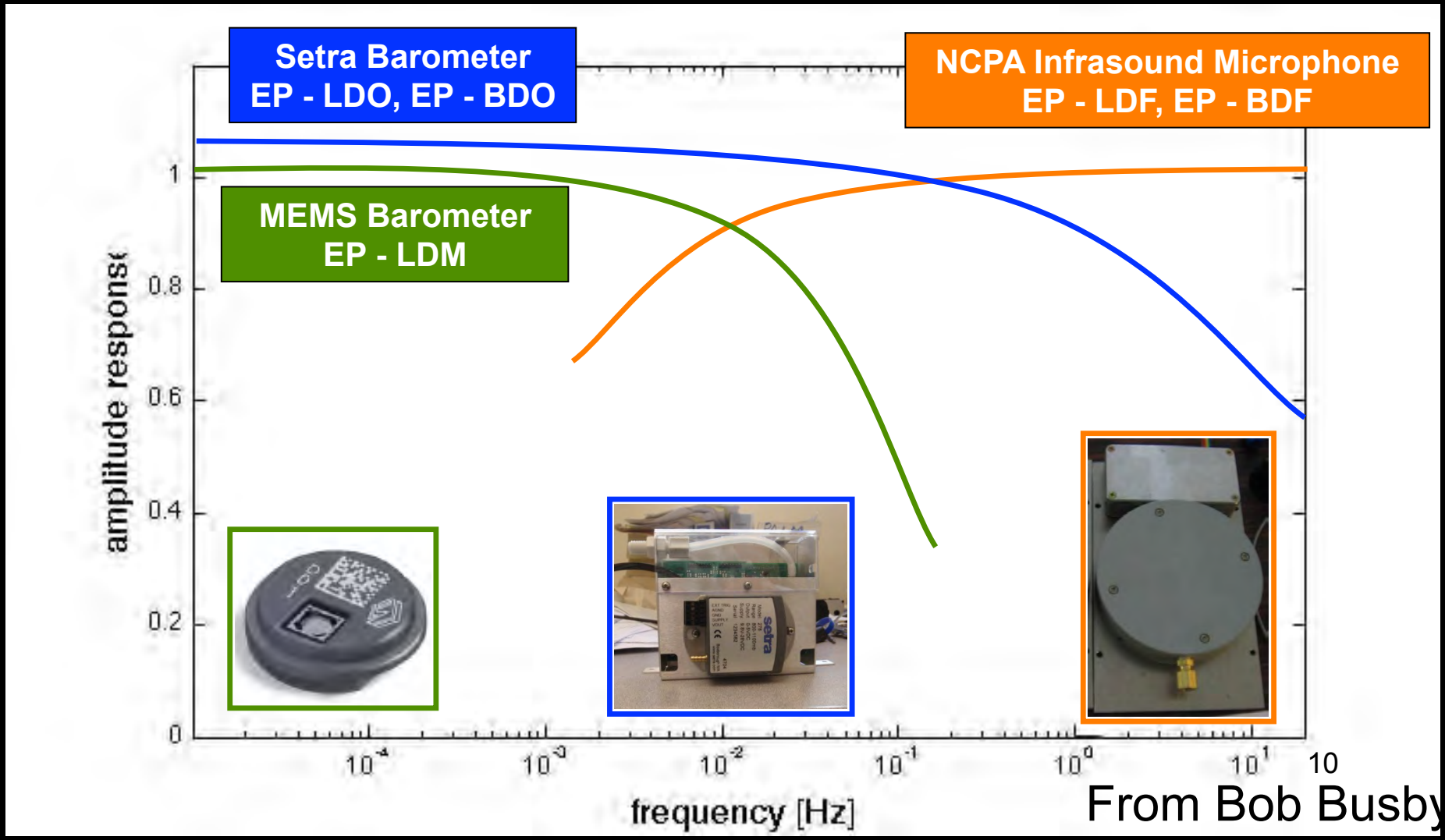
Pressure sensor response

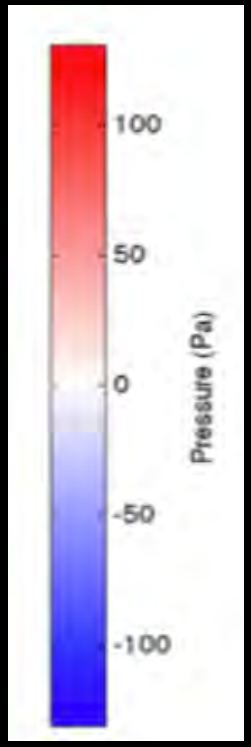
- Overlapping pass-bands provides continuous coverage from DC to 20 Hz

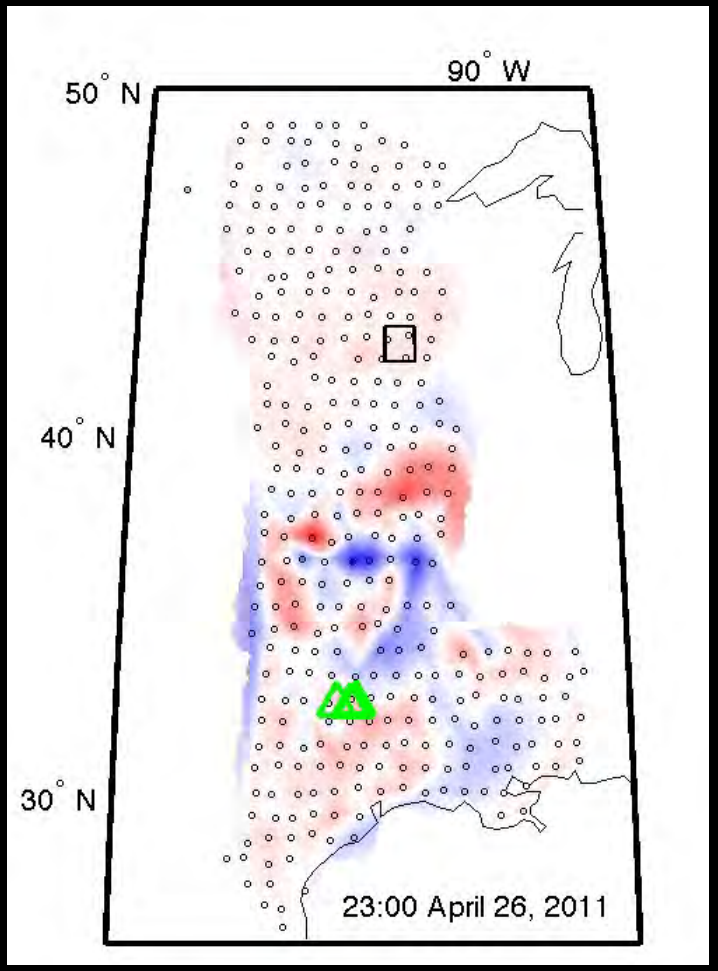


From Bob Busby

Atmospheric gravity waves

Example event: April, 2011





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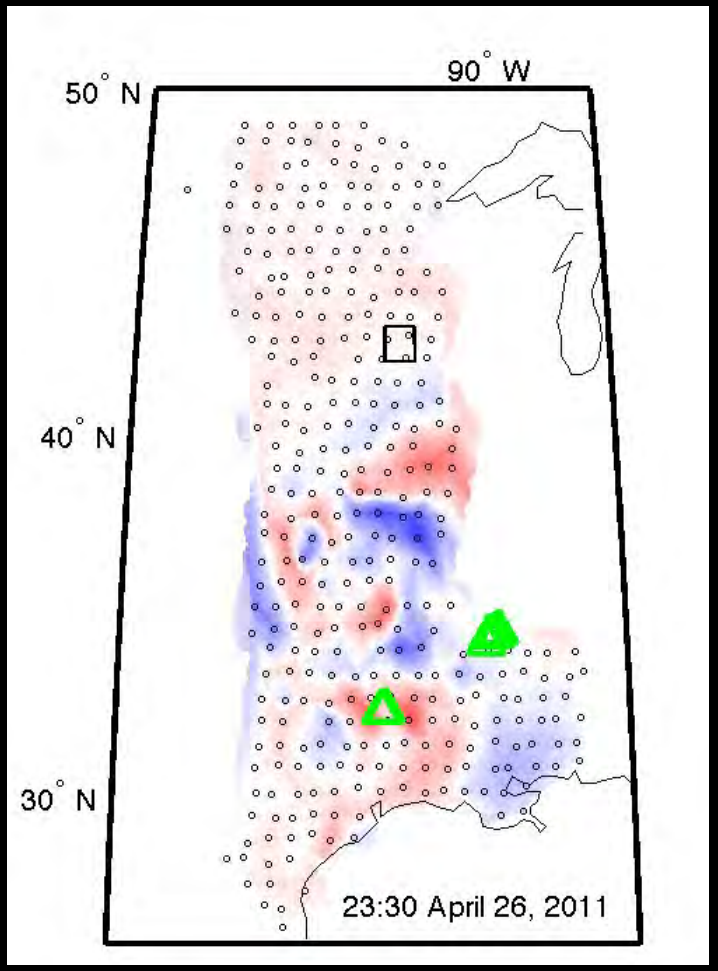
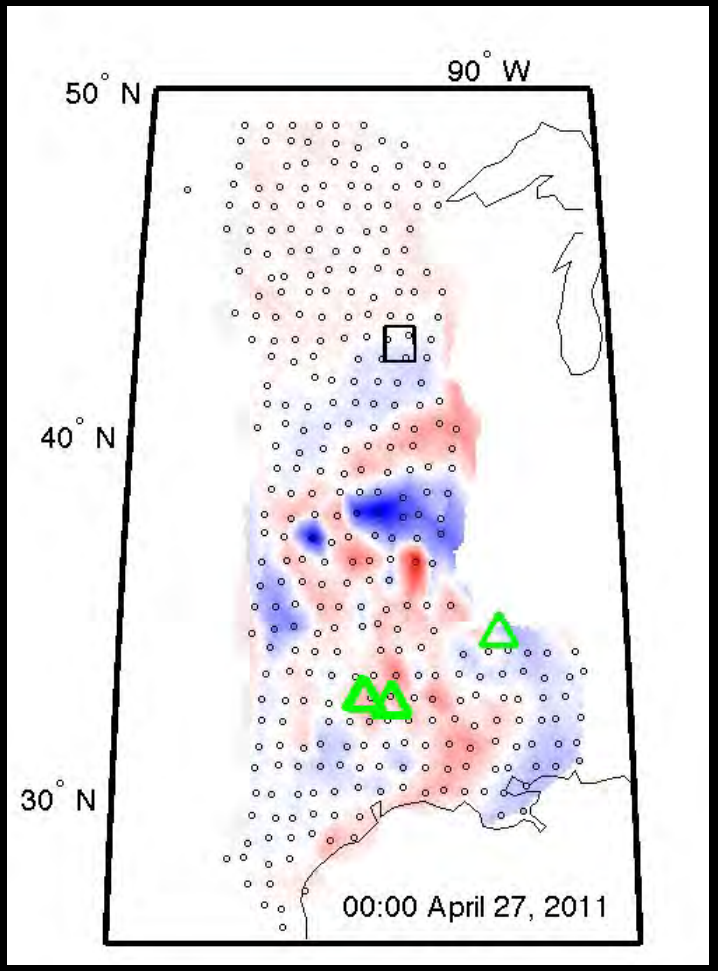

50° N
90° W
40° N
30° N
23:30 April 26, 2011



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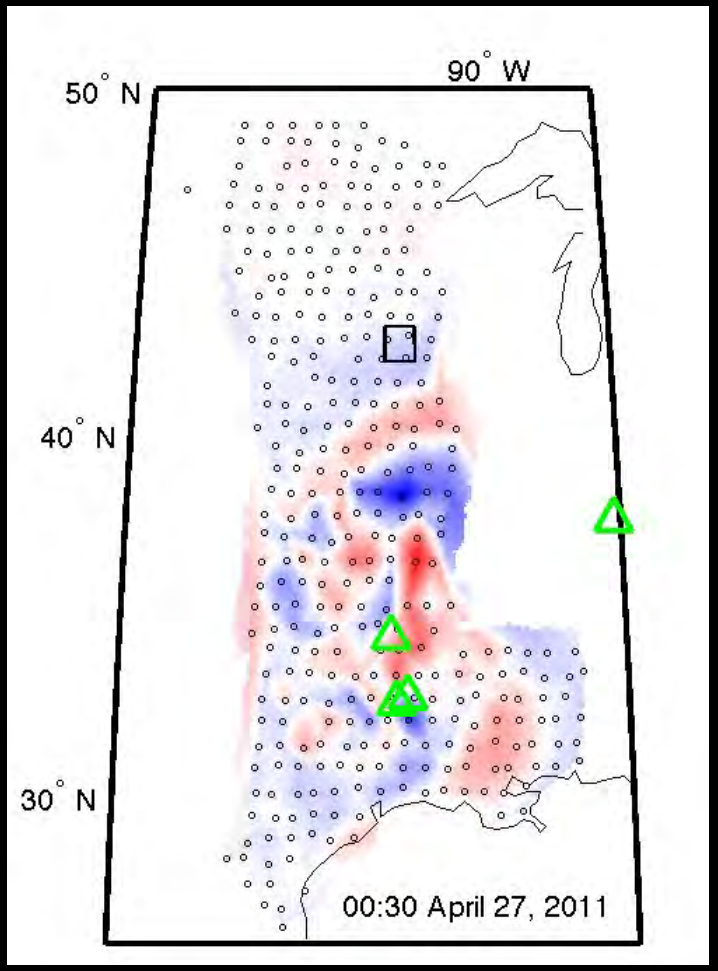

LABORATORY FOR ATMOSPHERIC ACOUSTICS
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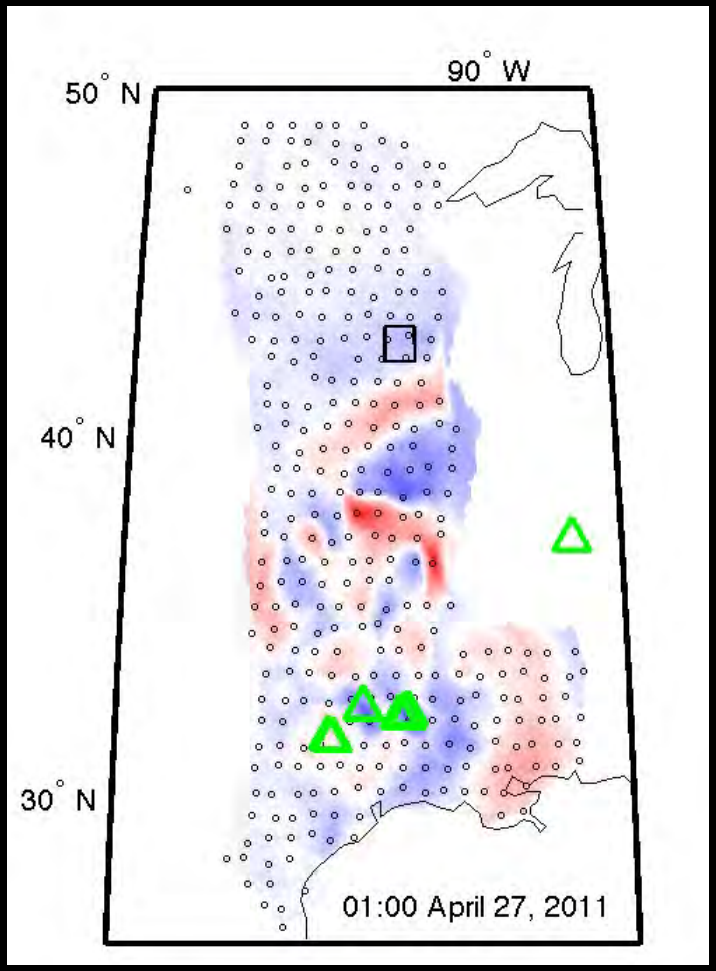

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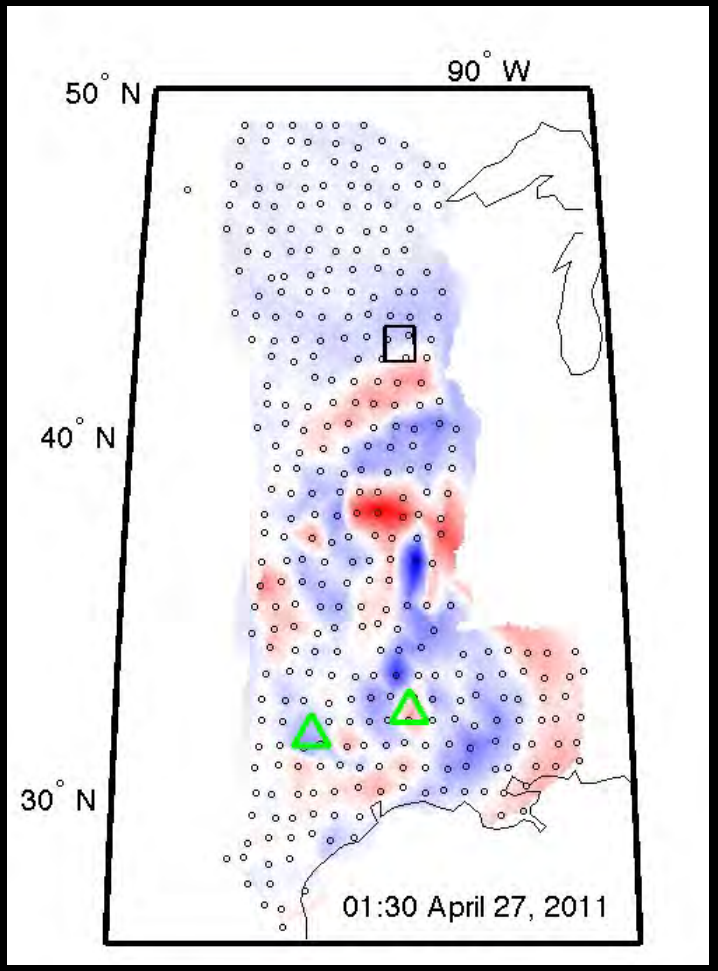

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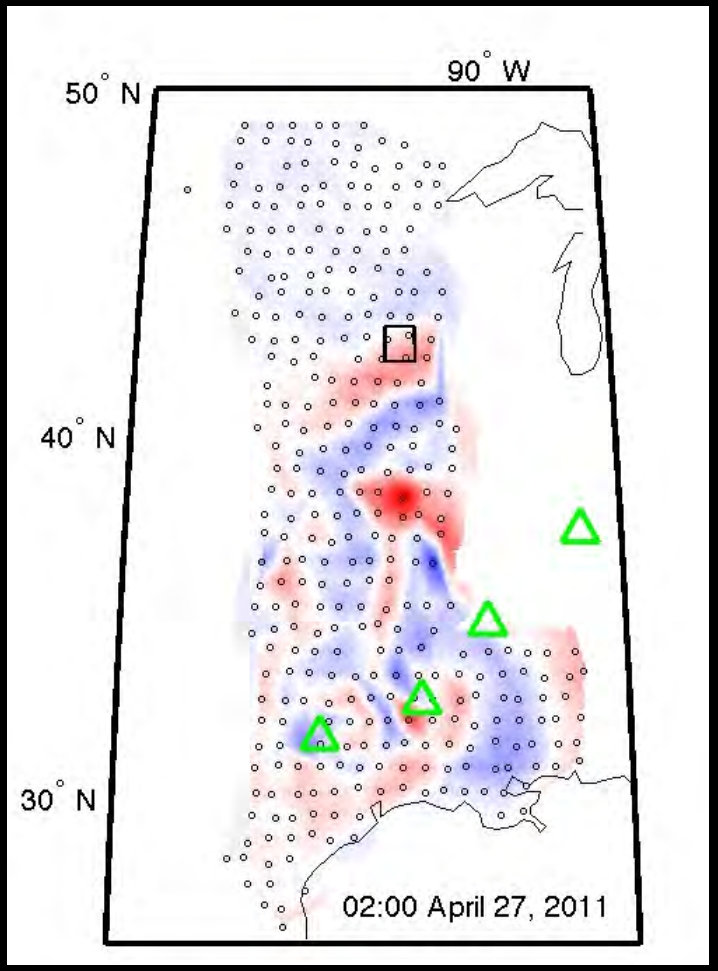
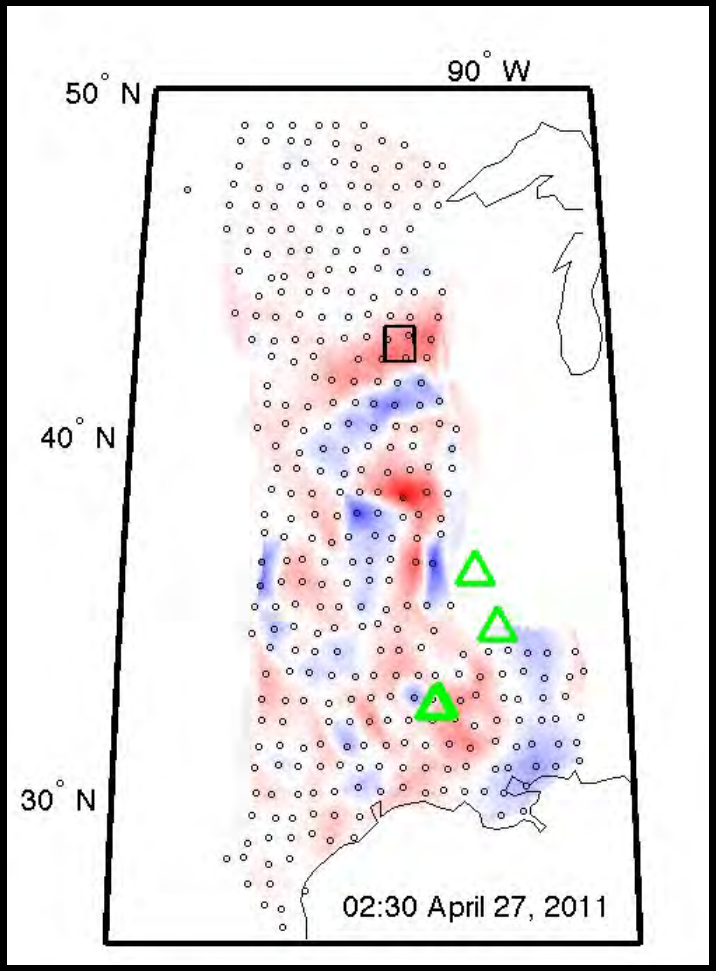

50° N
90° W
40° N
30° N
02:00 April 27, 2011



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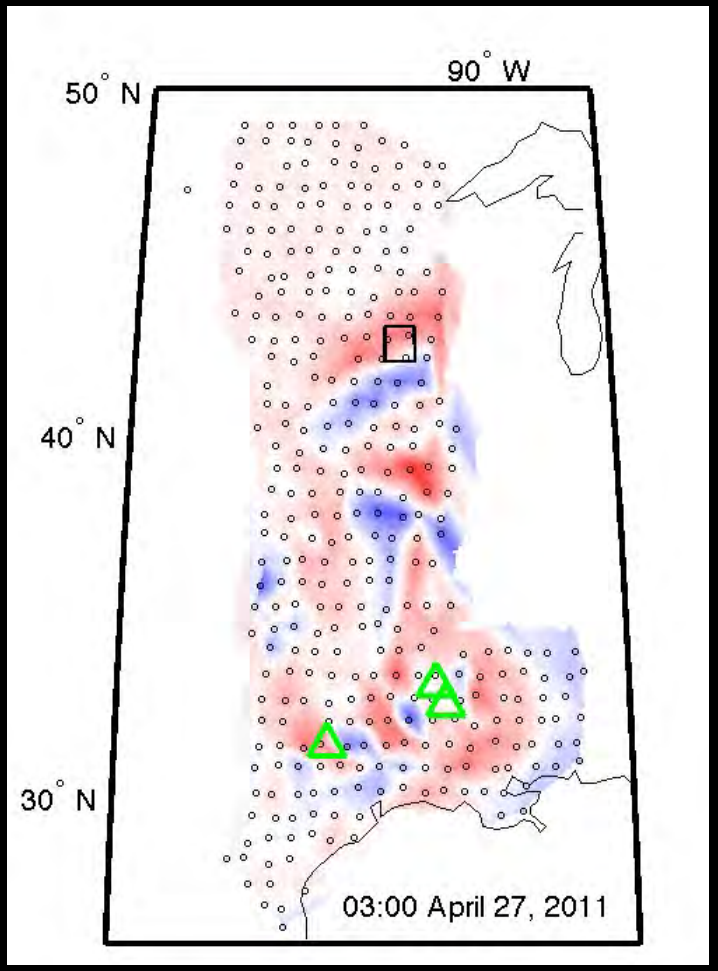
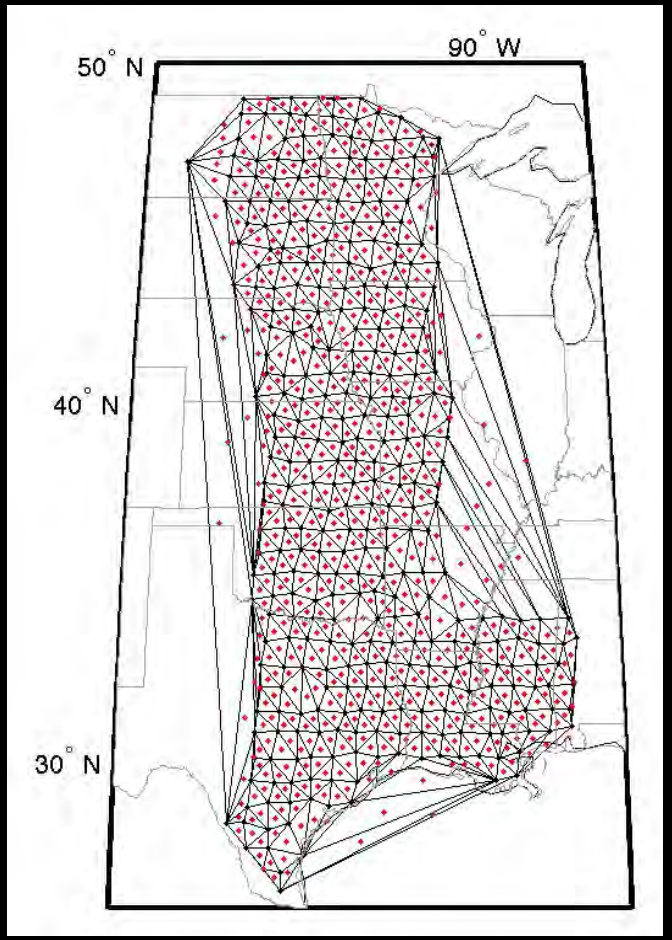

50° N
90° W
40° N
30° N
03:00 April 27, 2011

Recast TA as massive collection of arrays

Use Delauney triangulation



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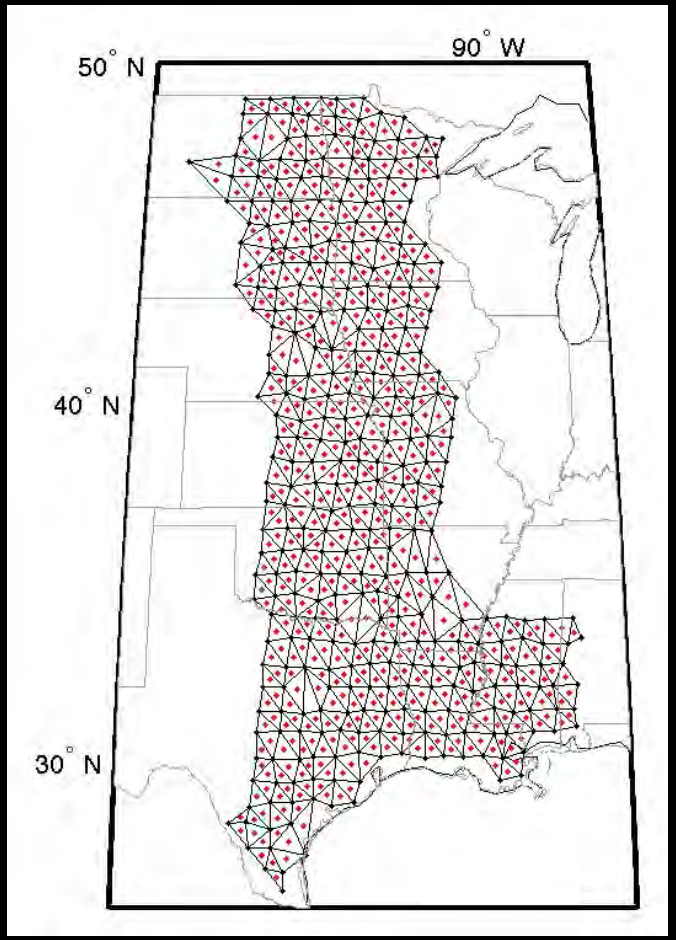
Remove oddly shaped arrays

Are left with 580 triads



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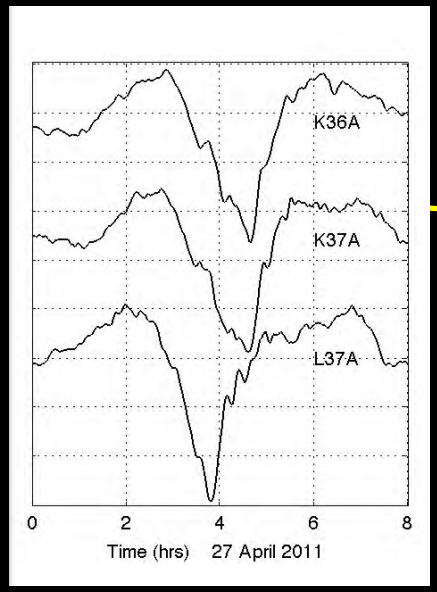

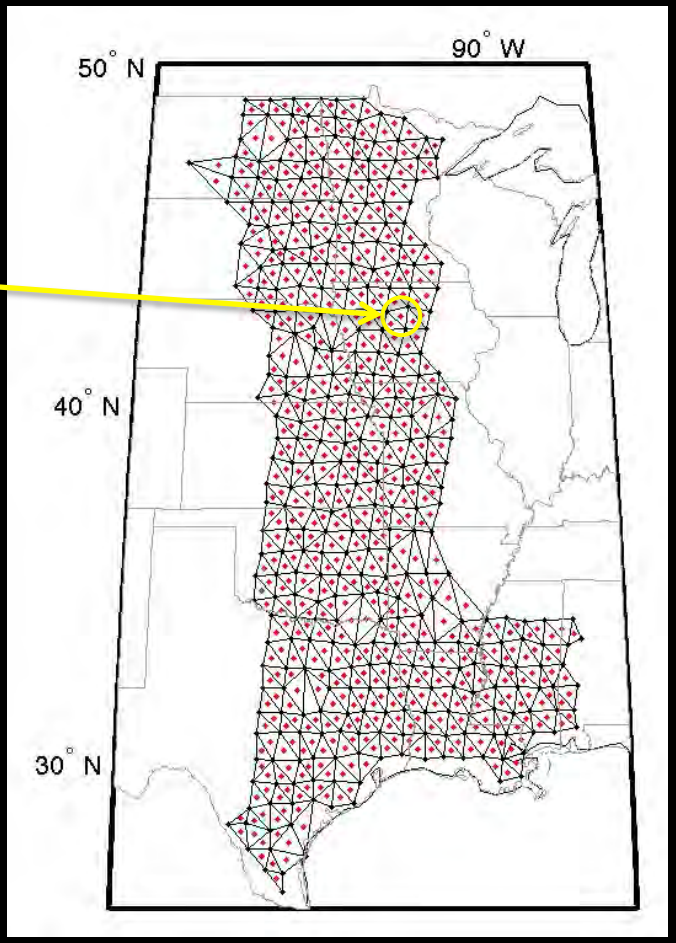

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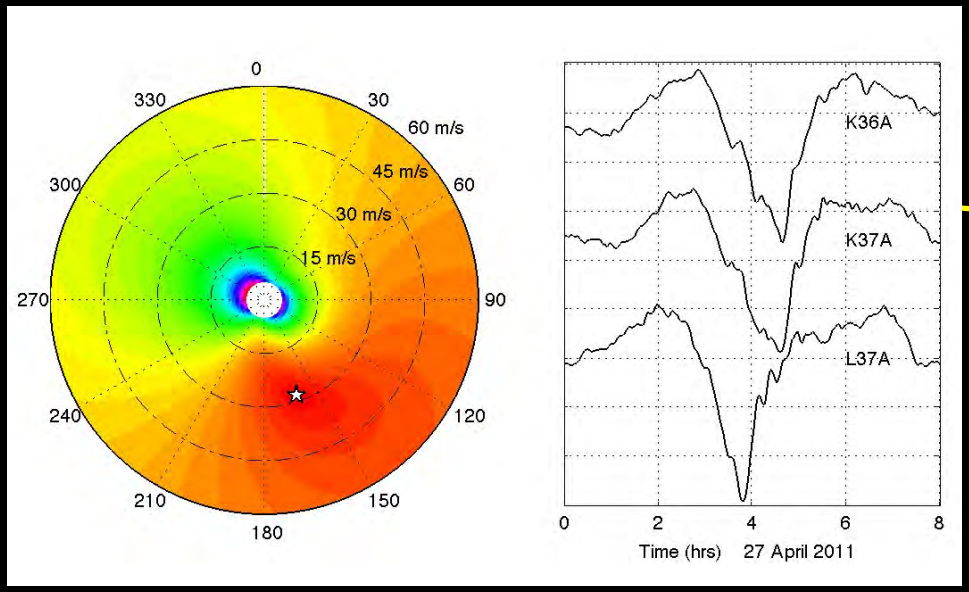
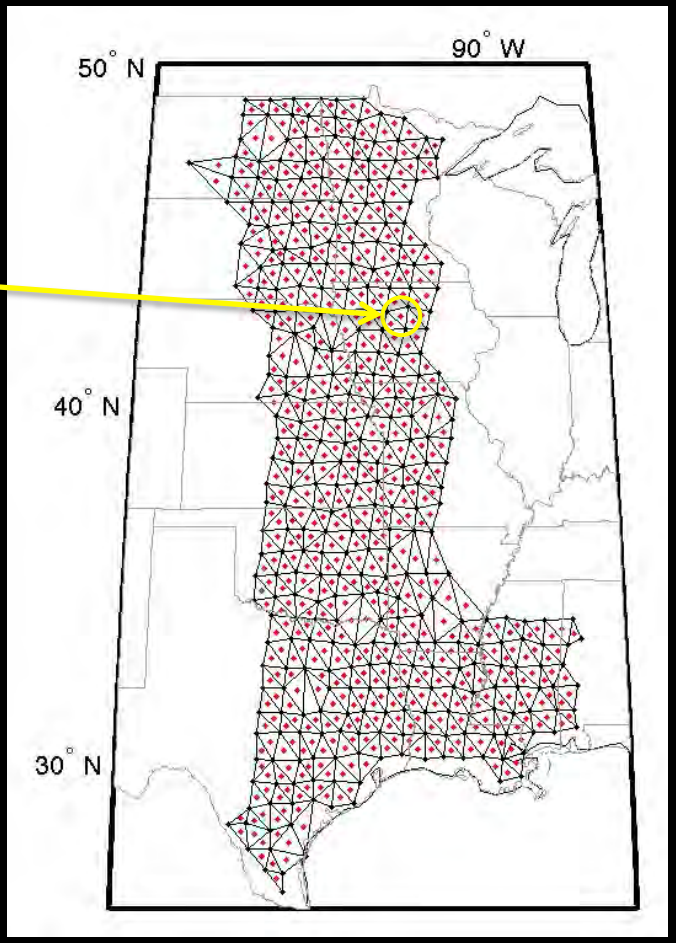
Filter & cross-correlate to detect coherent signals





$$t_{ij} + t_{jk} + t_{ki} < tcut$$

Consistency criterion, Cansi, 1995

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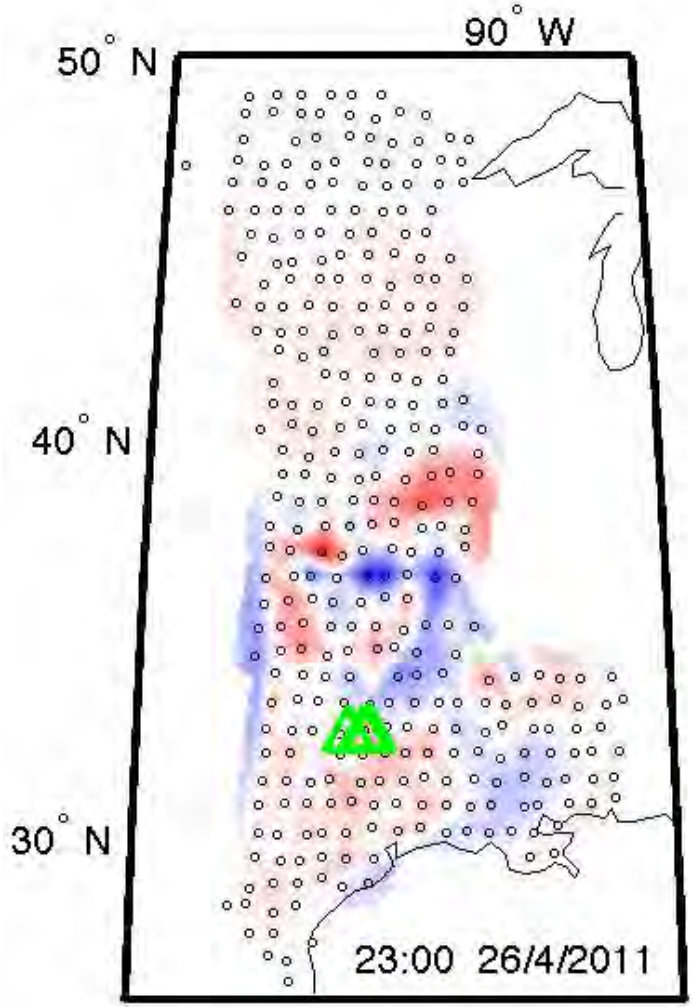
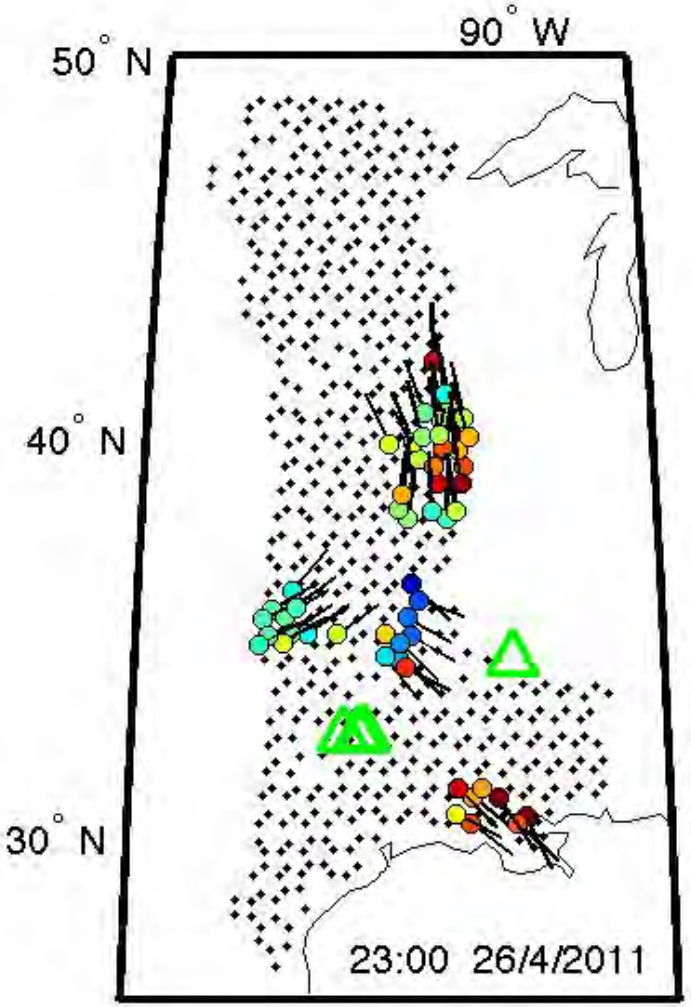
Three steps

- Divide TA into non-overlapping triads
- Process, looking for arrivals consistent with gravity wave phase velocities
- Find groups of neighboring triads with consistent detections





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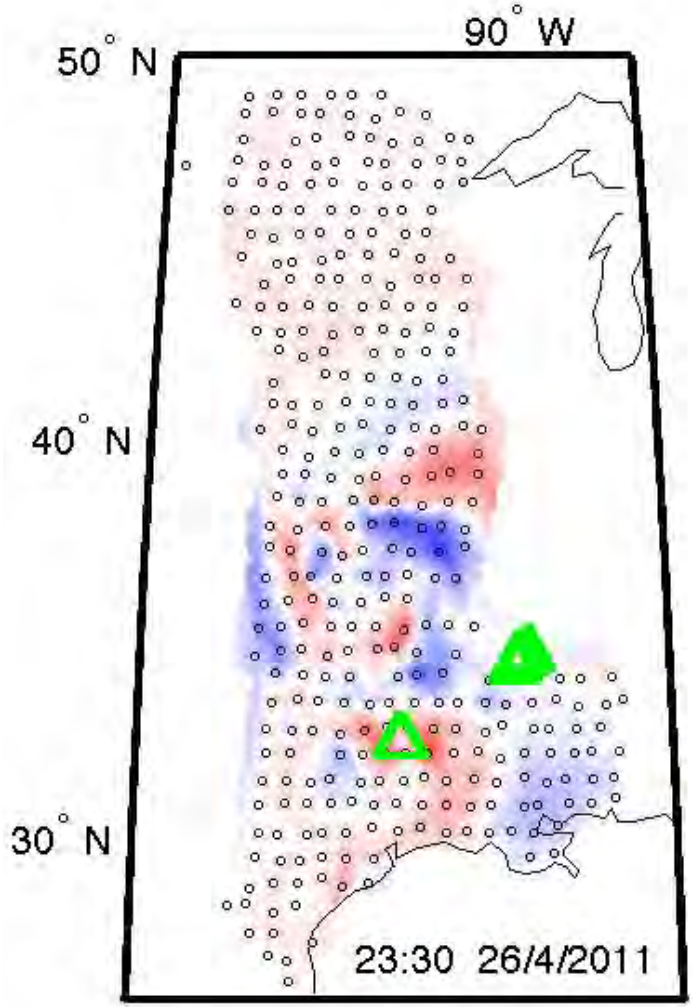

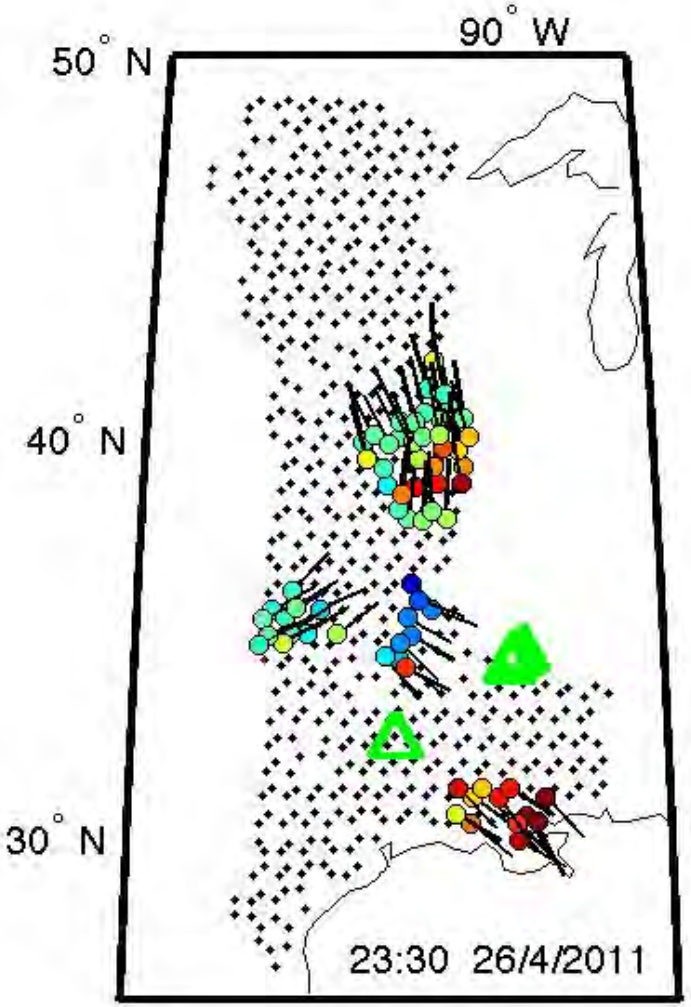

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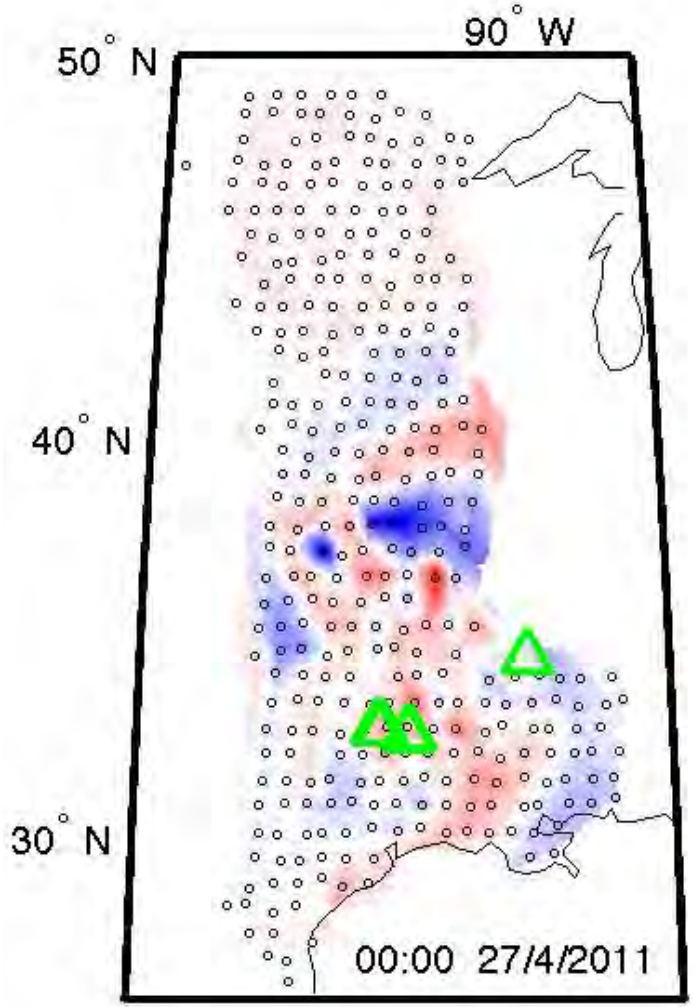

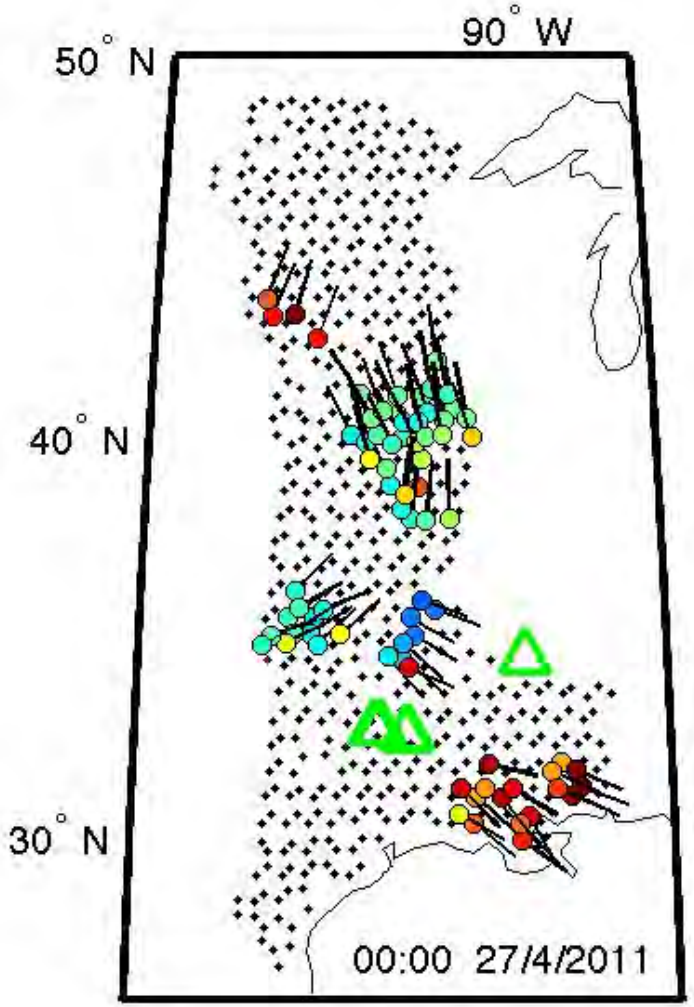

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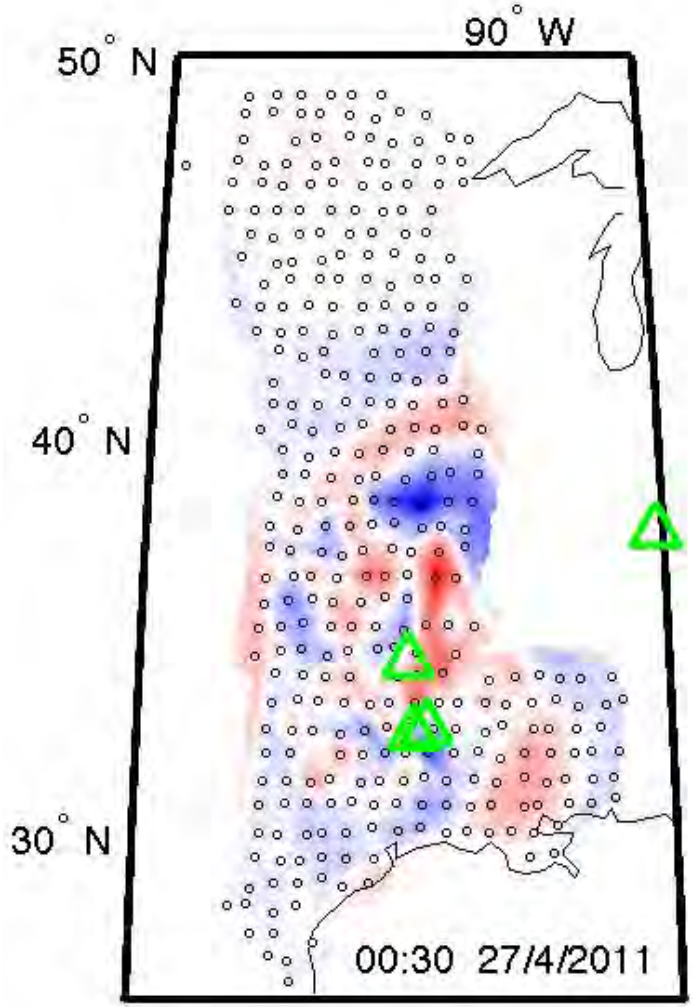

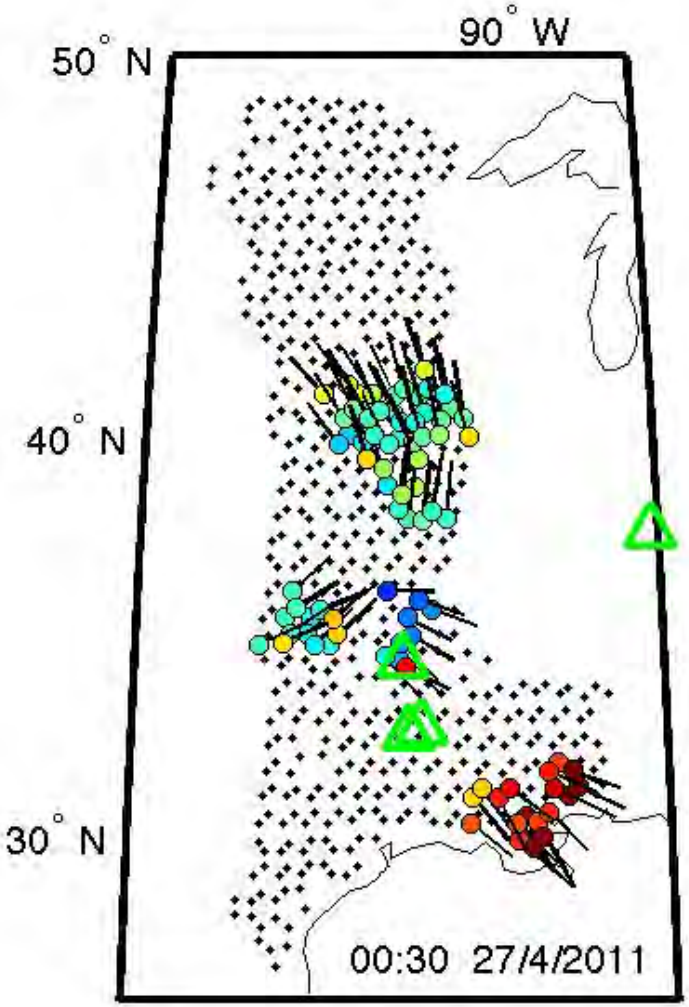

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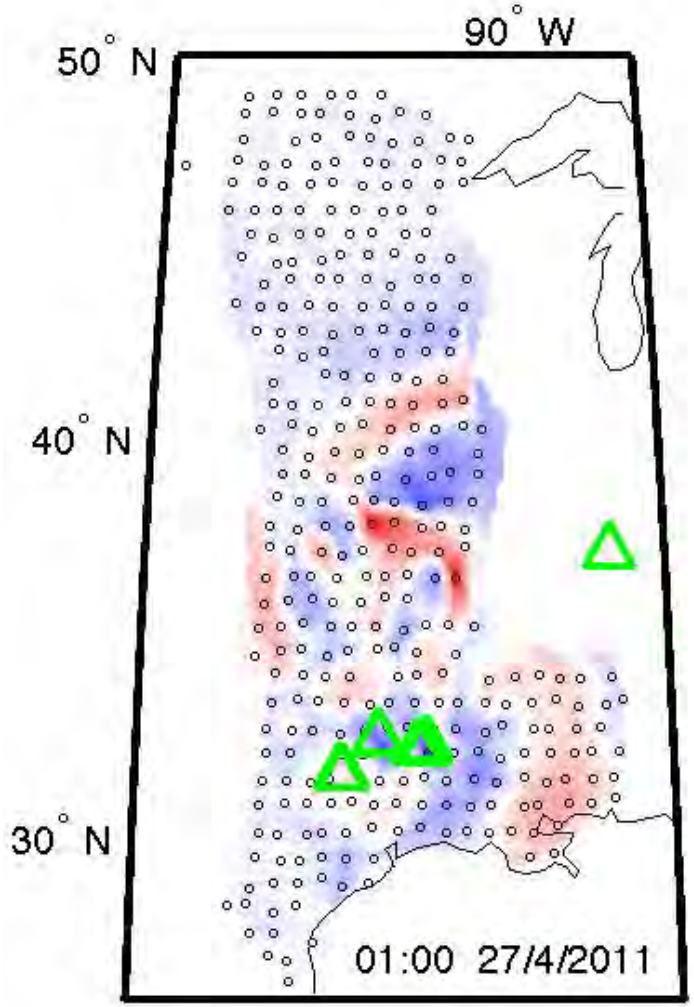

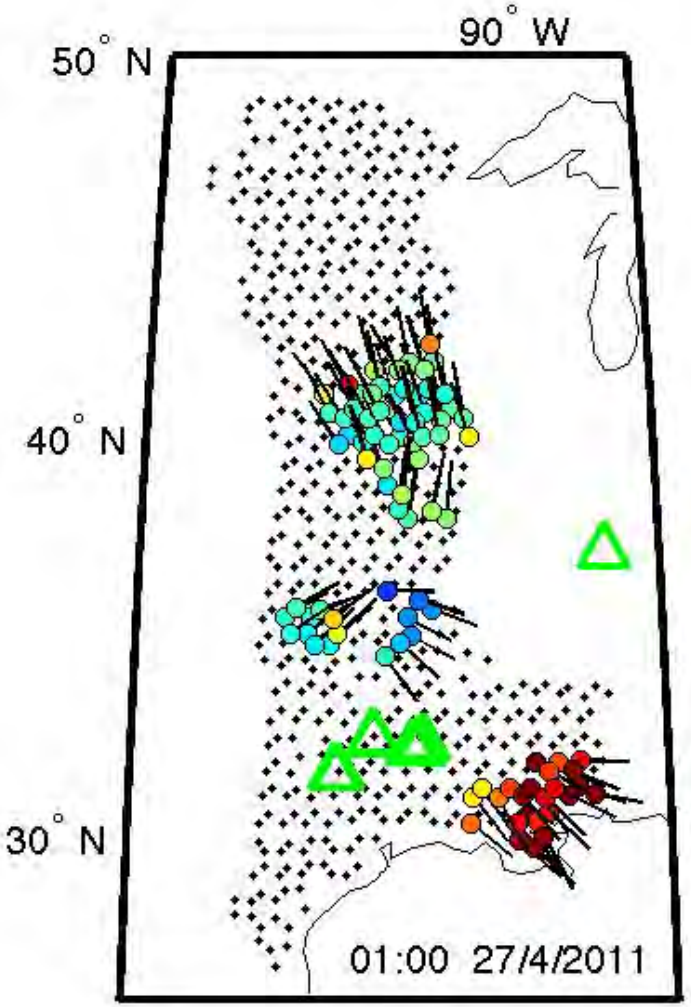

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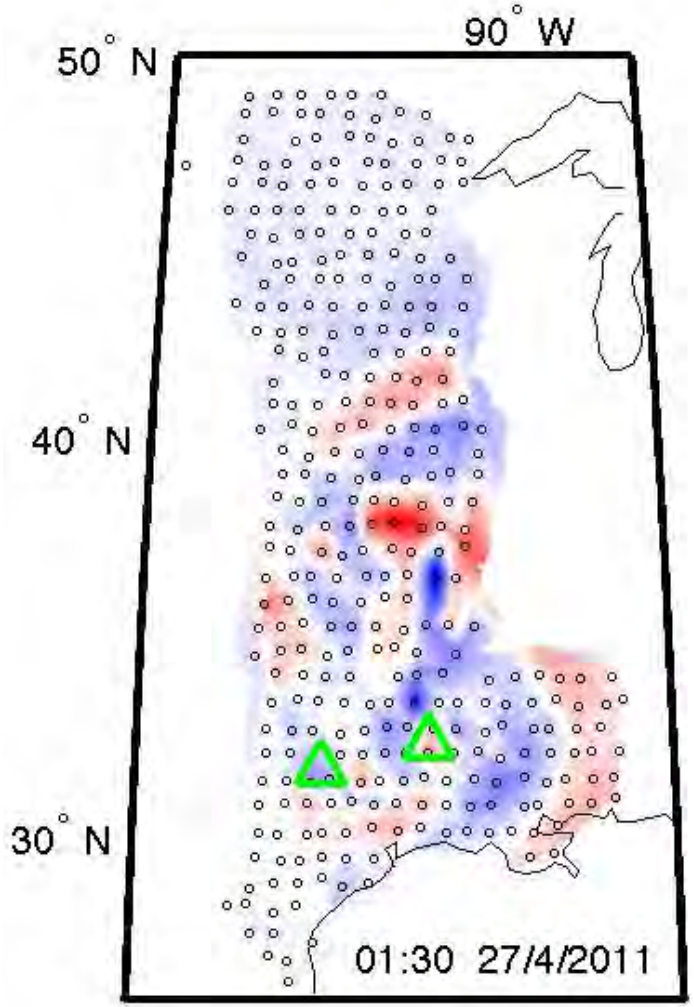

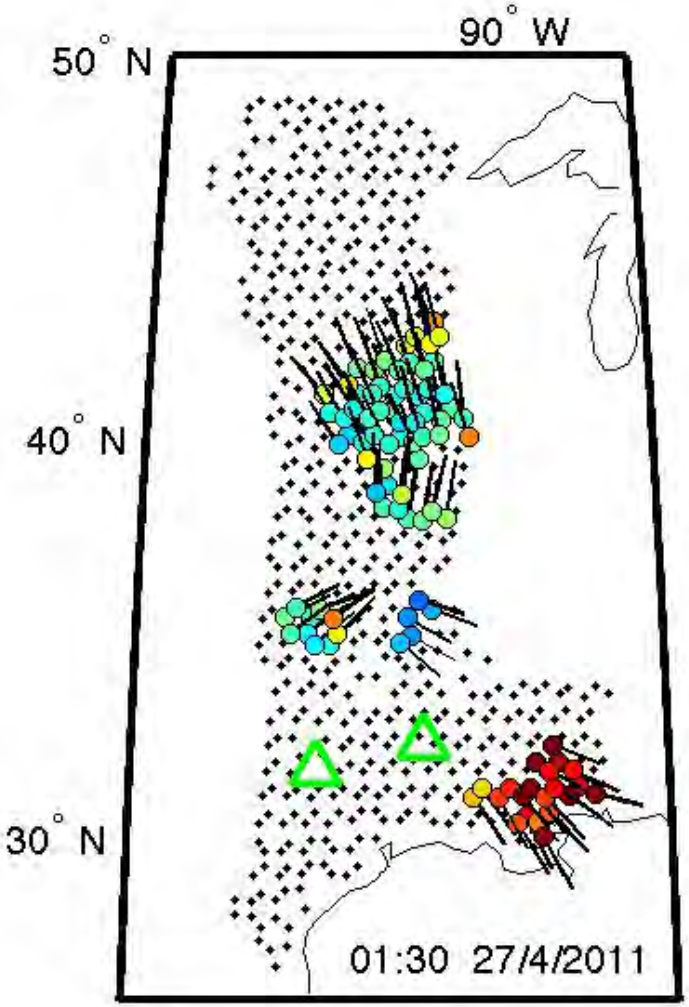

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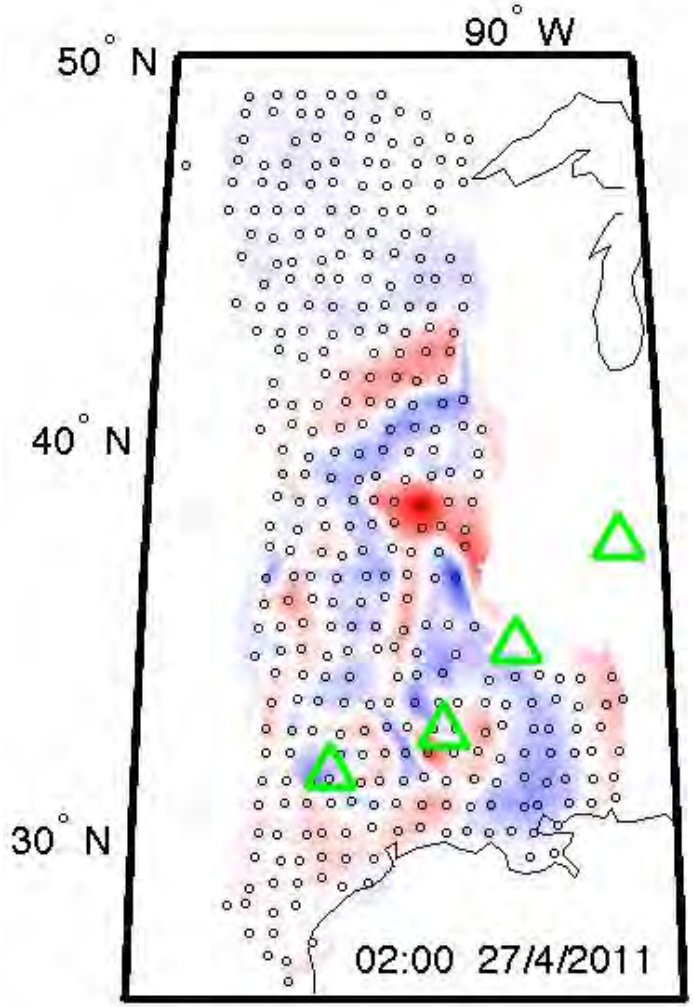

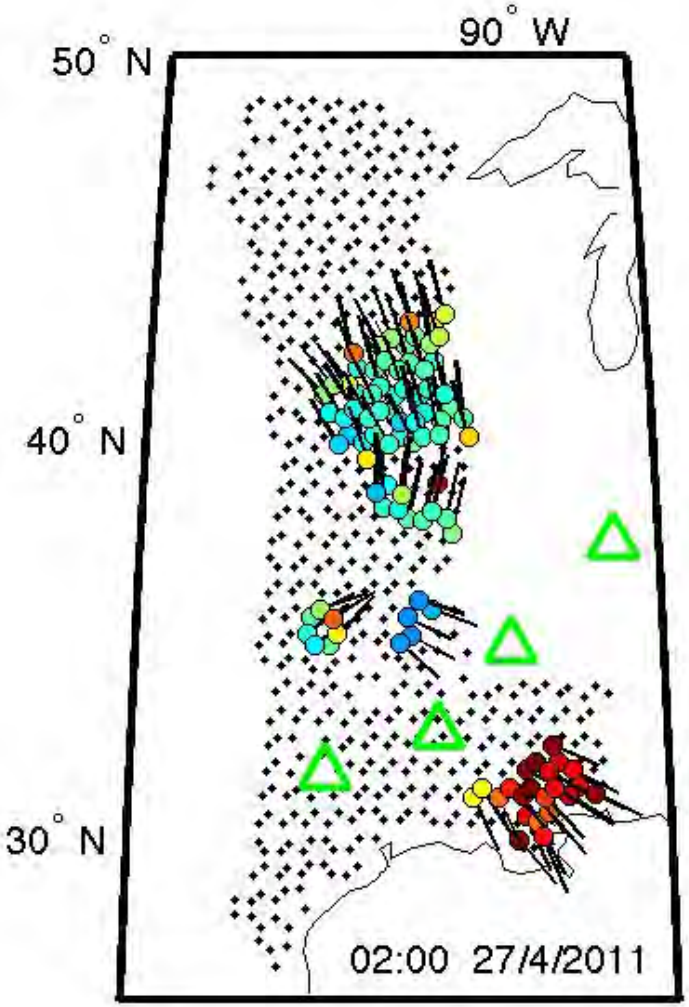

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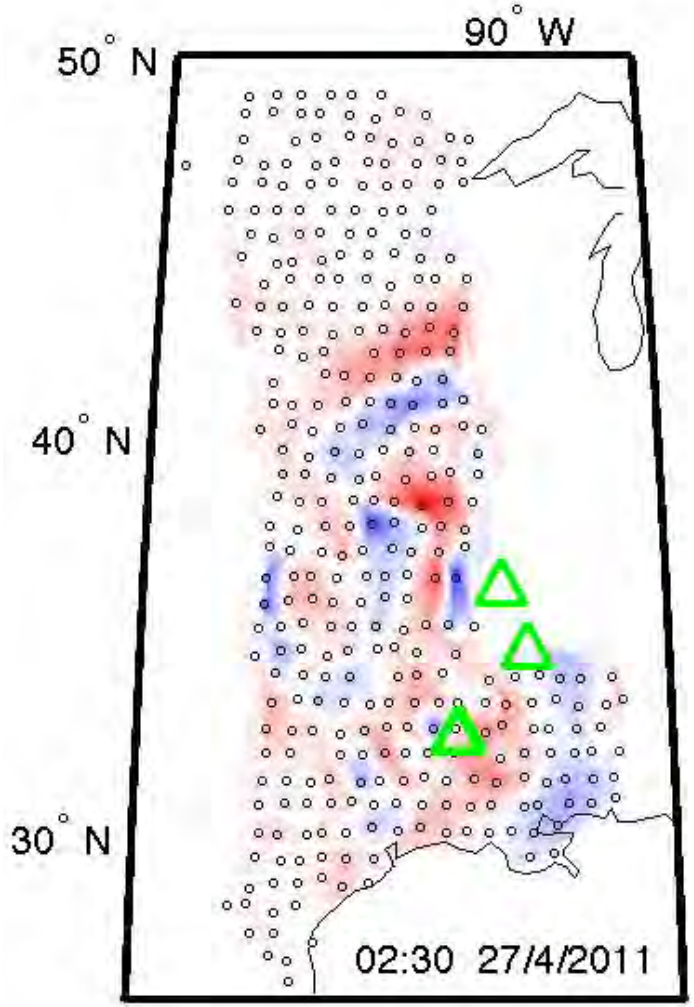

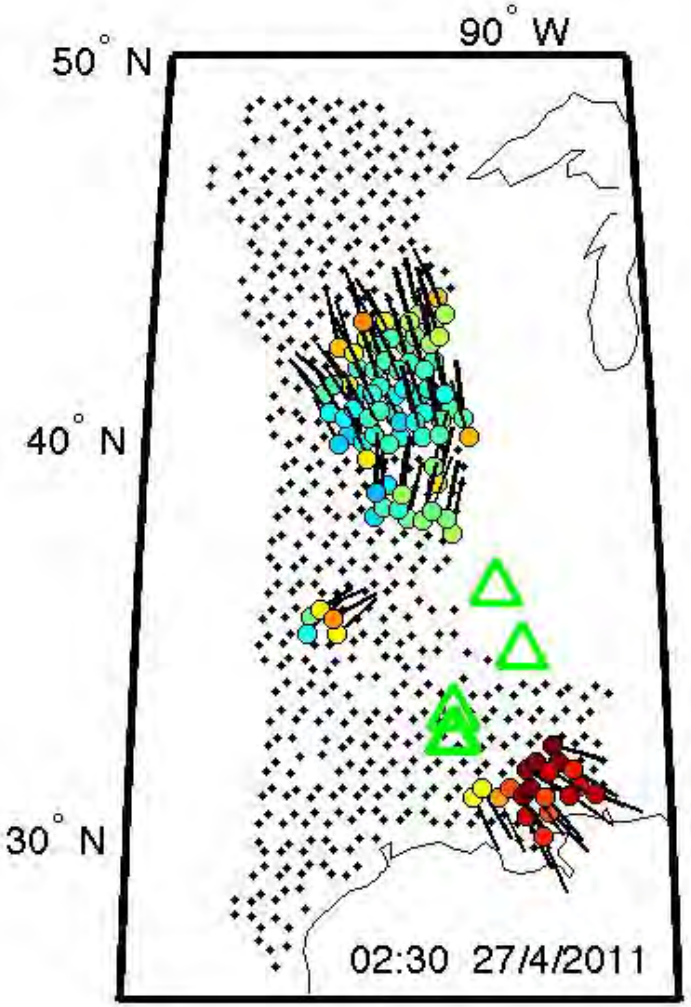

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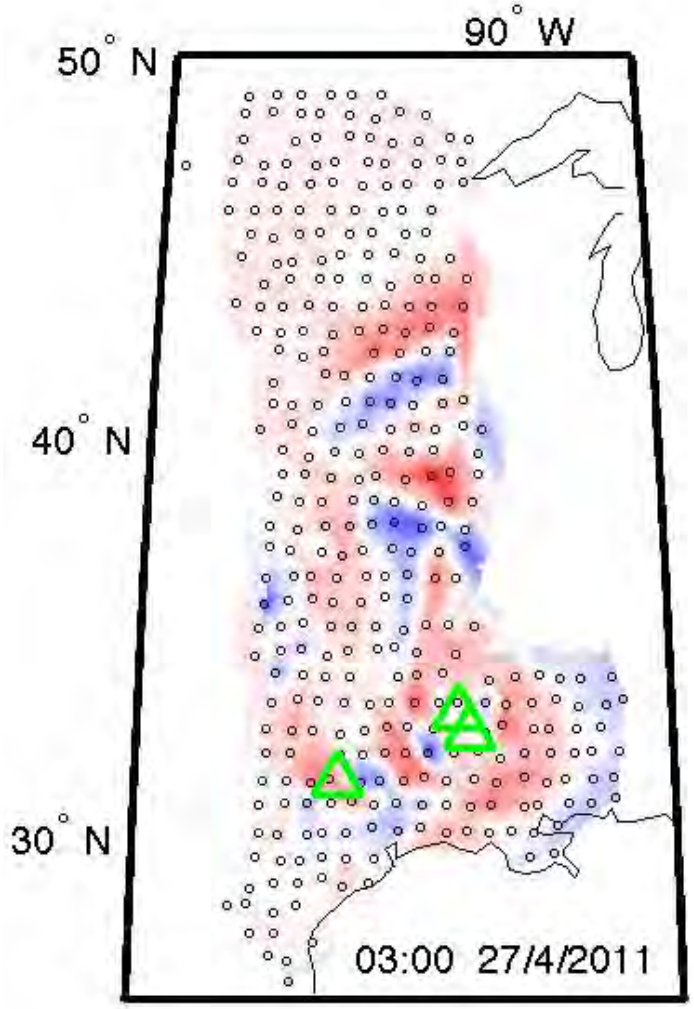

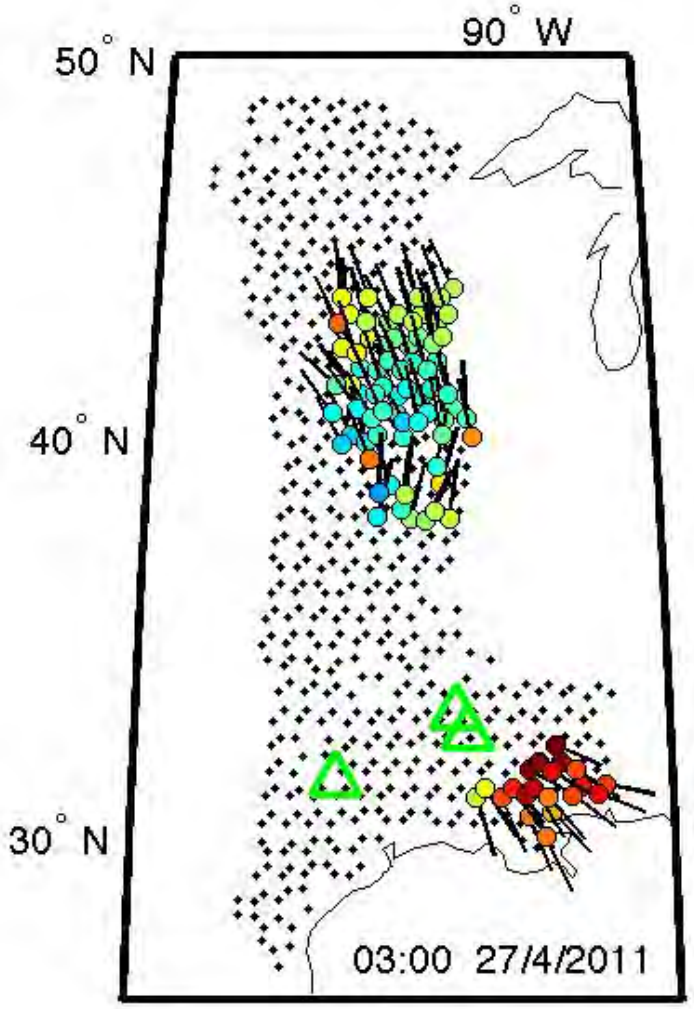

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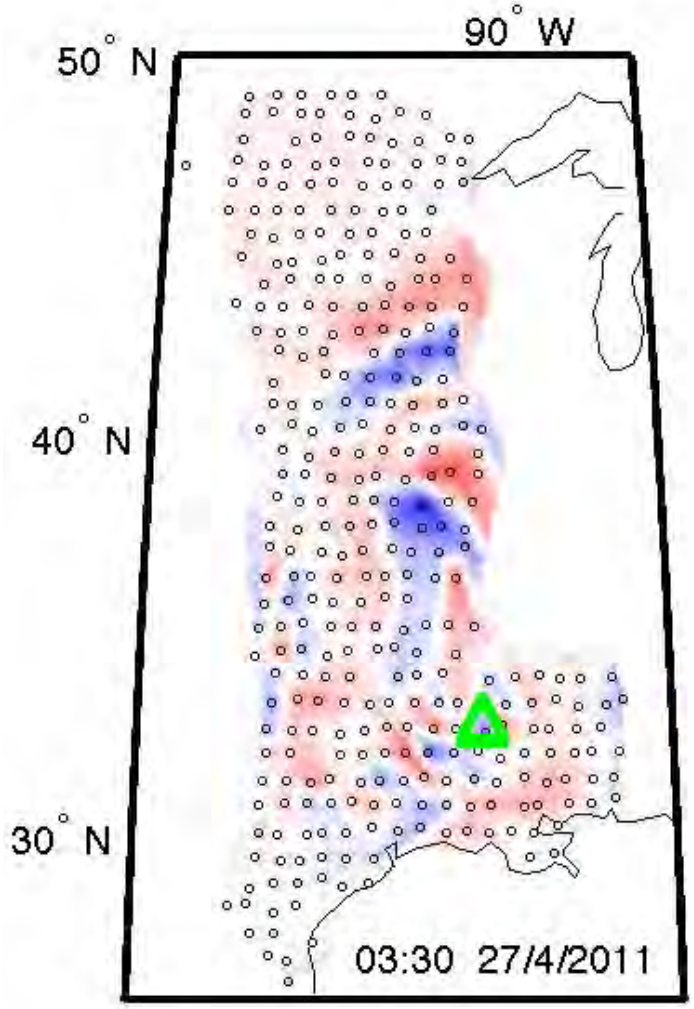

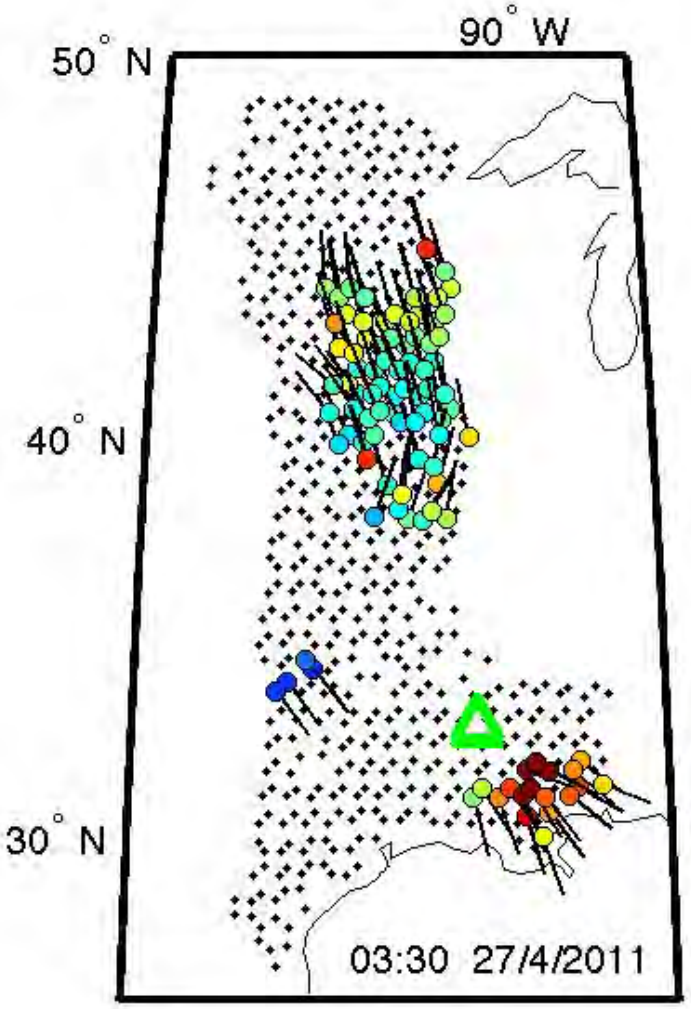

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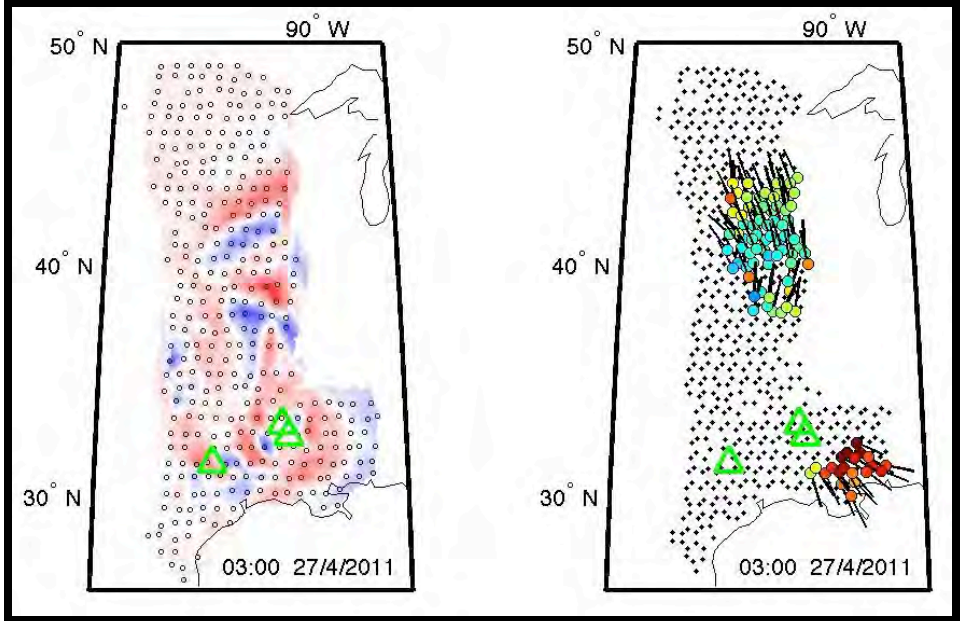
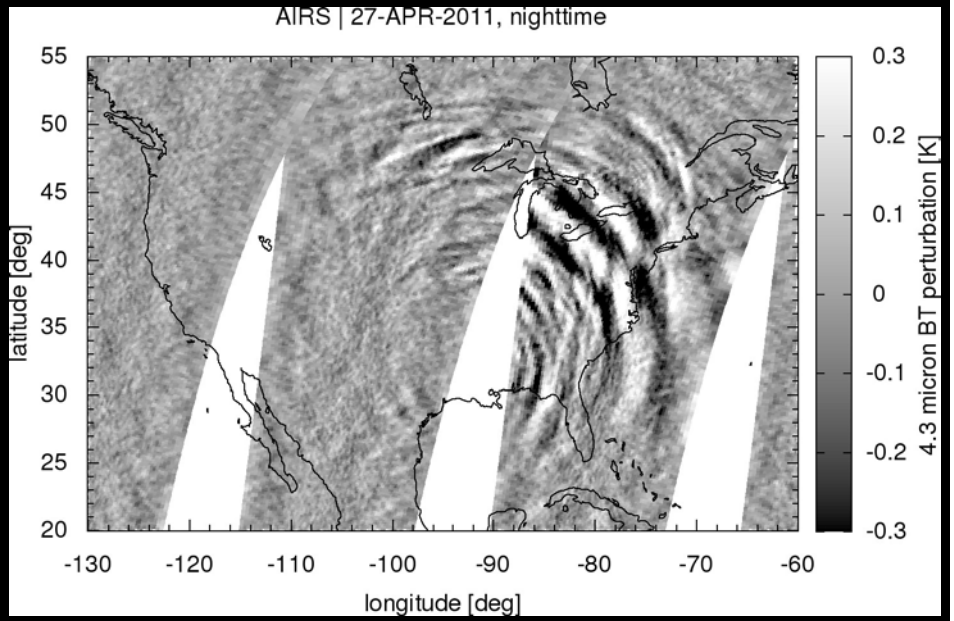
Comparison with satellite observations

Gravity waves detected at Earth's surface on MEMS sensor data

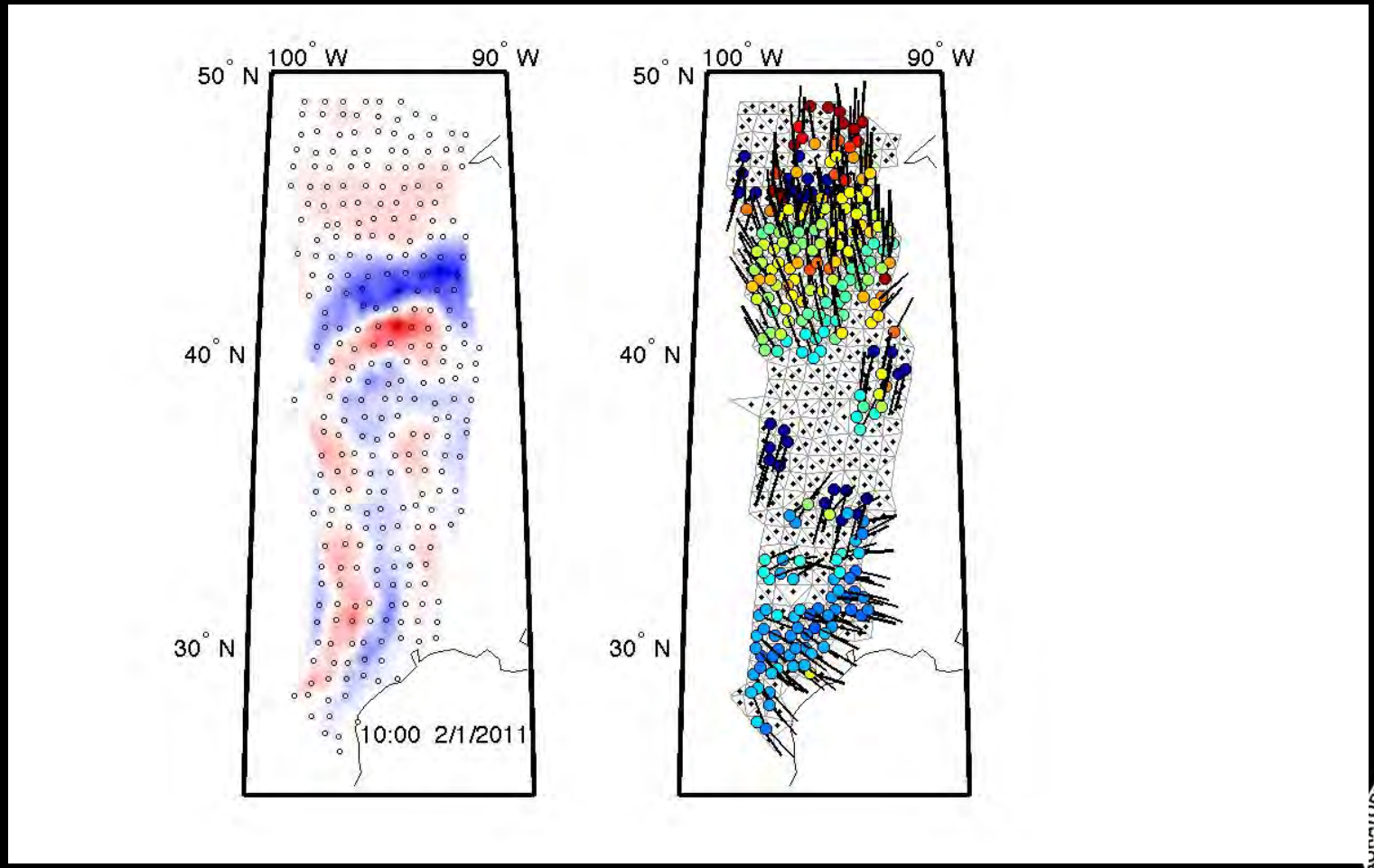
Stratospheric Gravity waves detected by the Atmospheric Infrared Sounder (AIRS) satellite

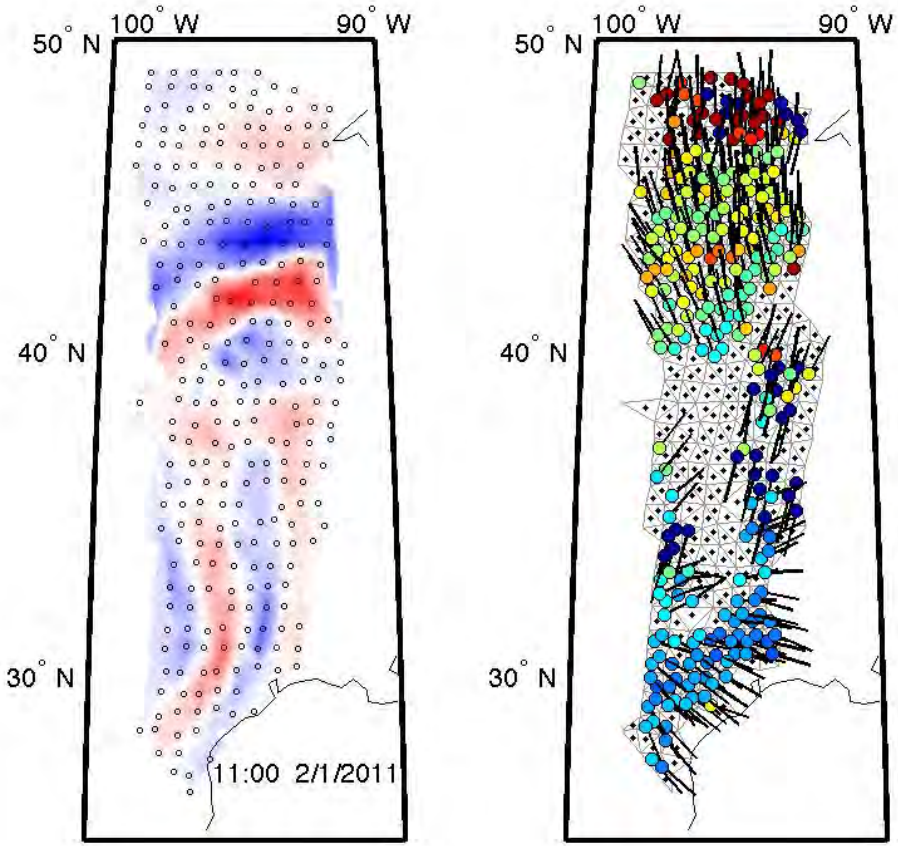


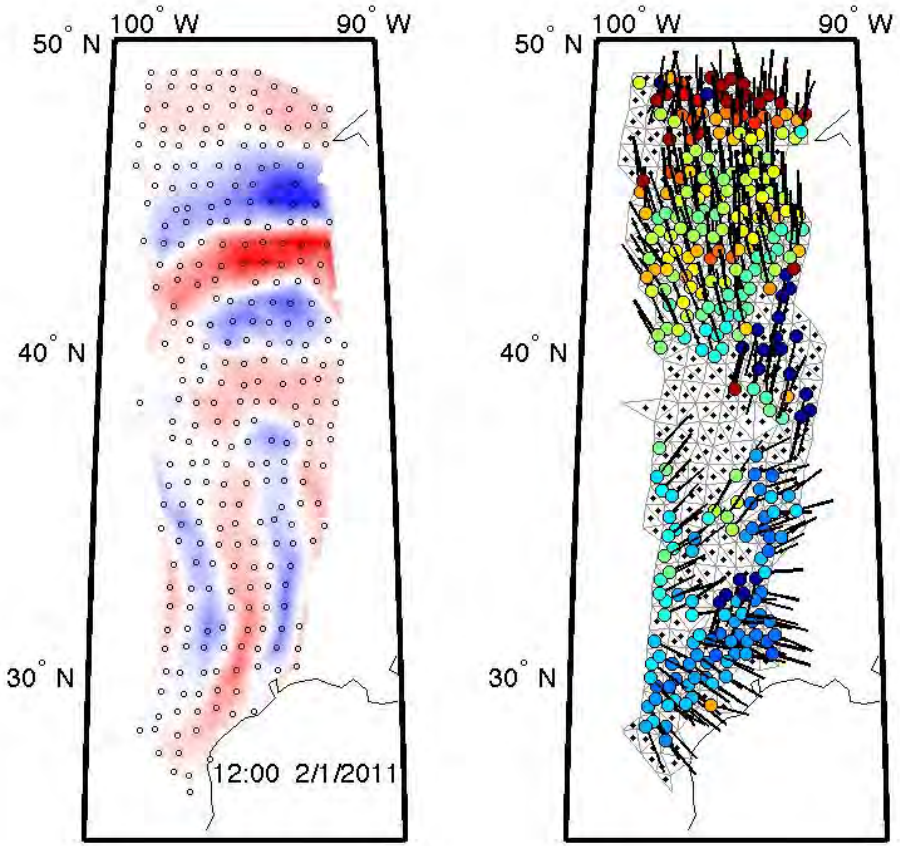


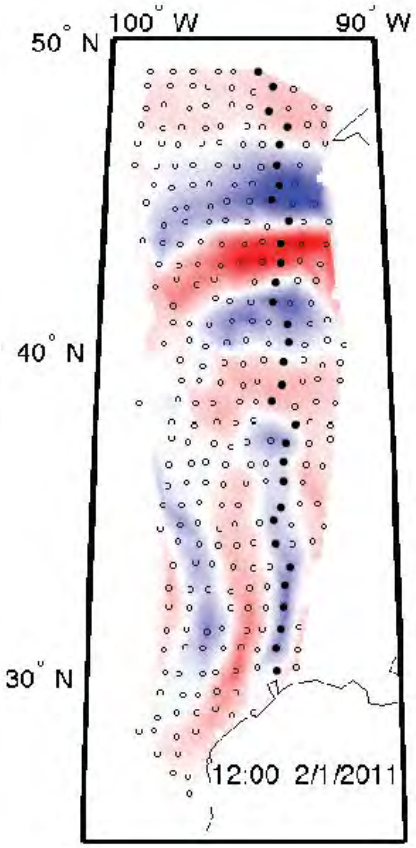
From Lars Hoffmann

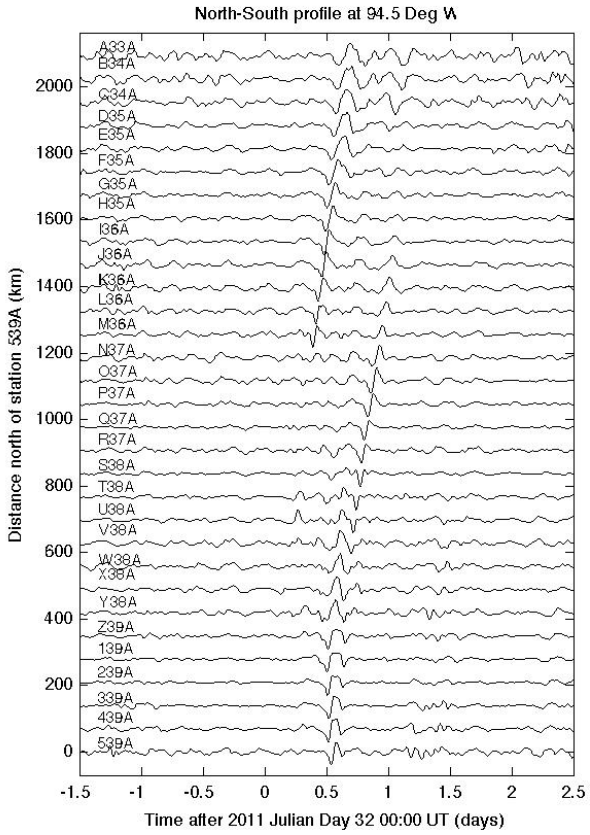
Second example: Largest Event of 2011



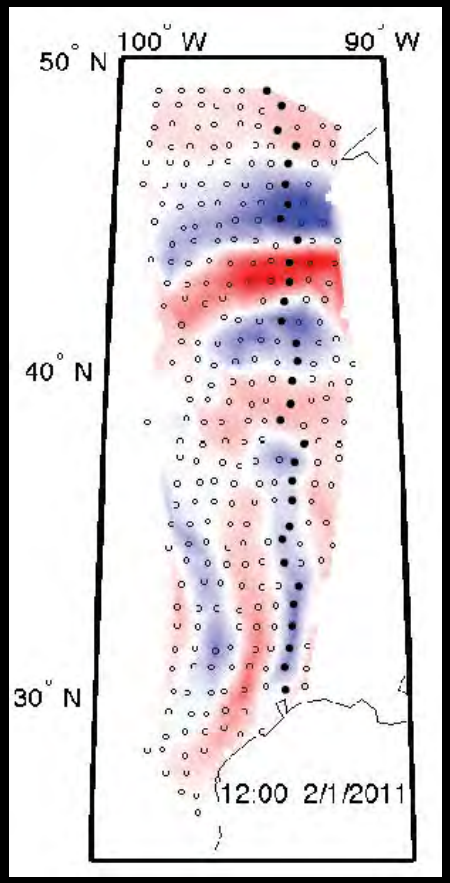

50° N
100° W
90° W
40° N
30° N
11:00 2/1/2011
50° N
100° W
90° W
40° N
30° N

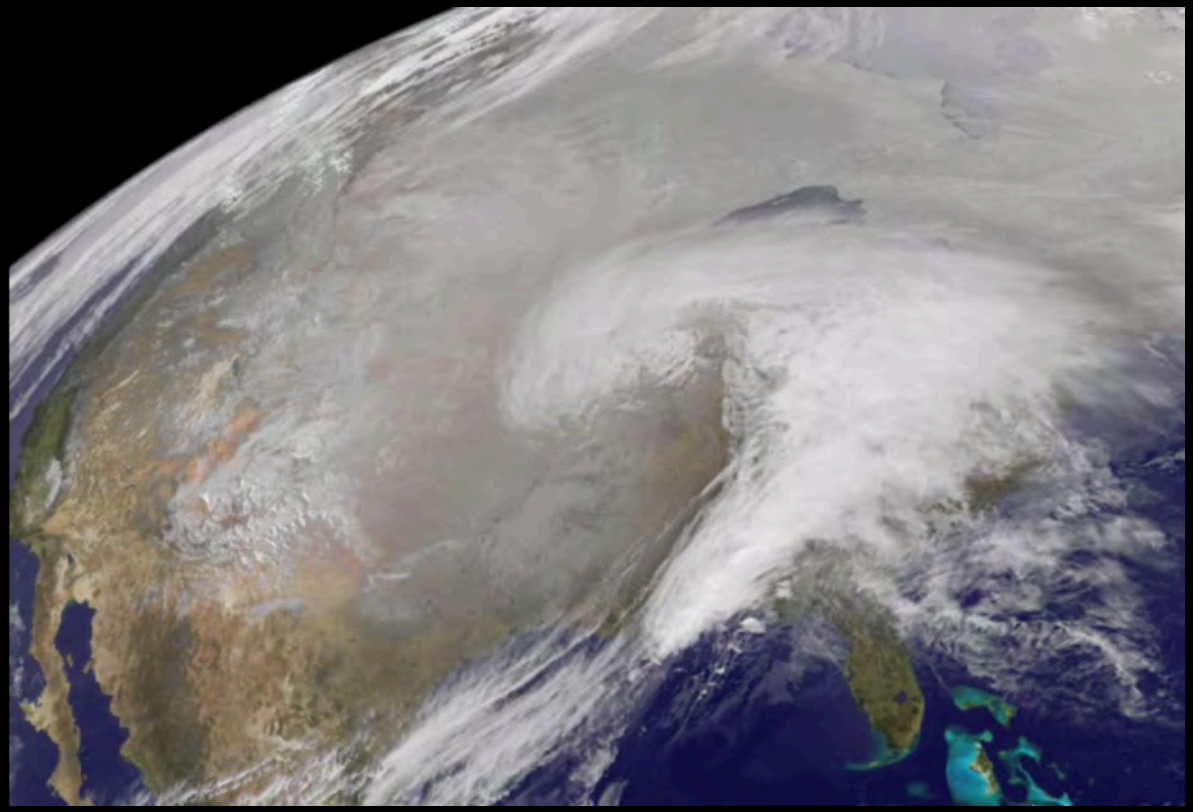

50° N
100° W
90° W
40° N
30° N
12:00 2/1/2011
50° N
100° W
90° W
40° N
30° N


50° N
100° W
90° W
40° N
30° N
12:00 2/1/2011


North-South profile at 94.5 Deg W
Distance north of station 539A (km)
Time after 2011 Julian Day 32 00:00 UT (days)
A33A
B34A
C34A
D35A
E35A
F35A
G35A
H35A
I36A
J36A
K36A
L36A
M36A
N37A
O37A
P37A
Q37A
R37A
S38A
T38A
U38A
V38A
W38A
X38A
Y38A
Z39A
139A
239A
339A
439A
539A

Pressure pattern & cloud pattern





Gravity waves are generated by convective activity

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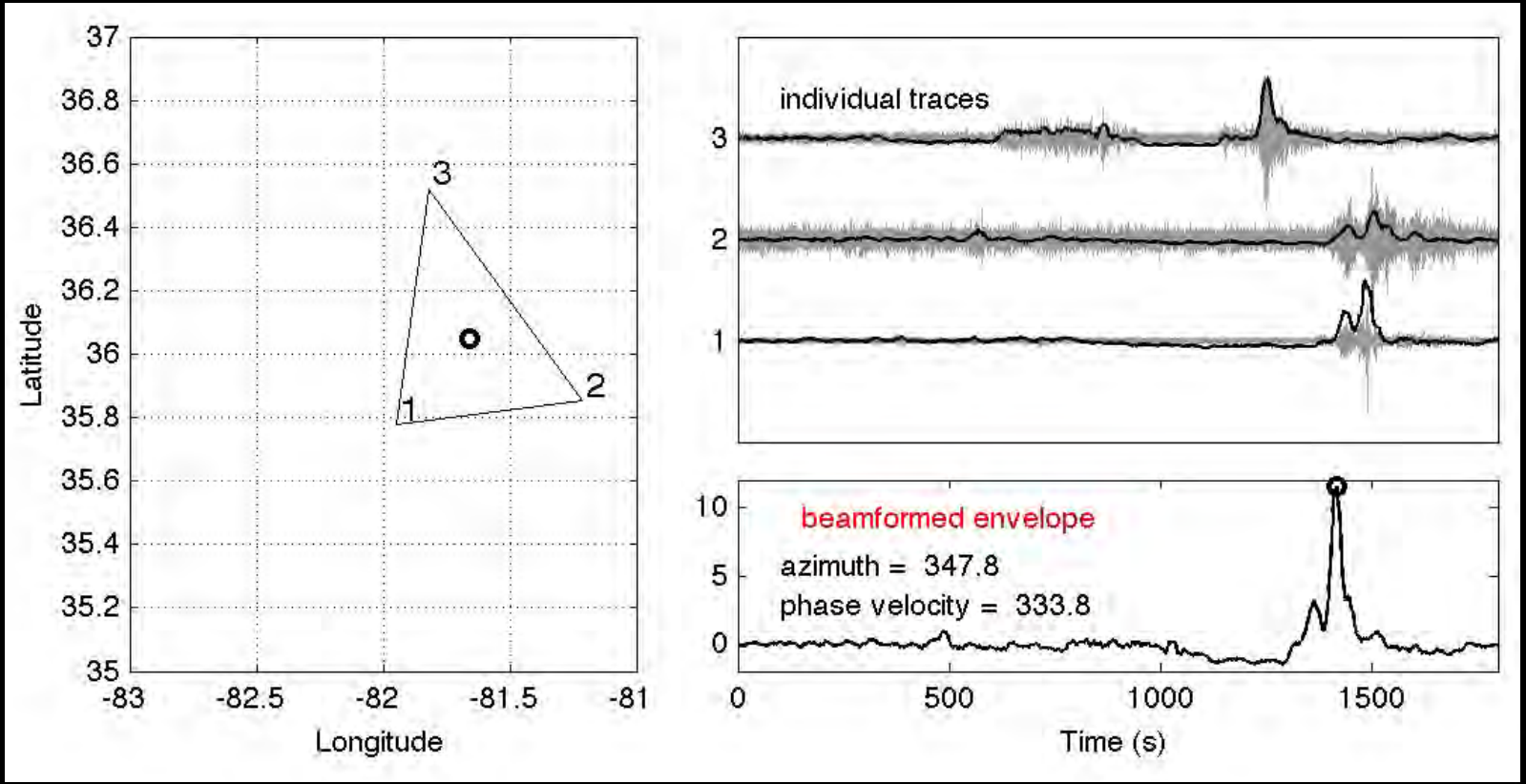
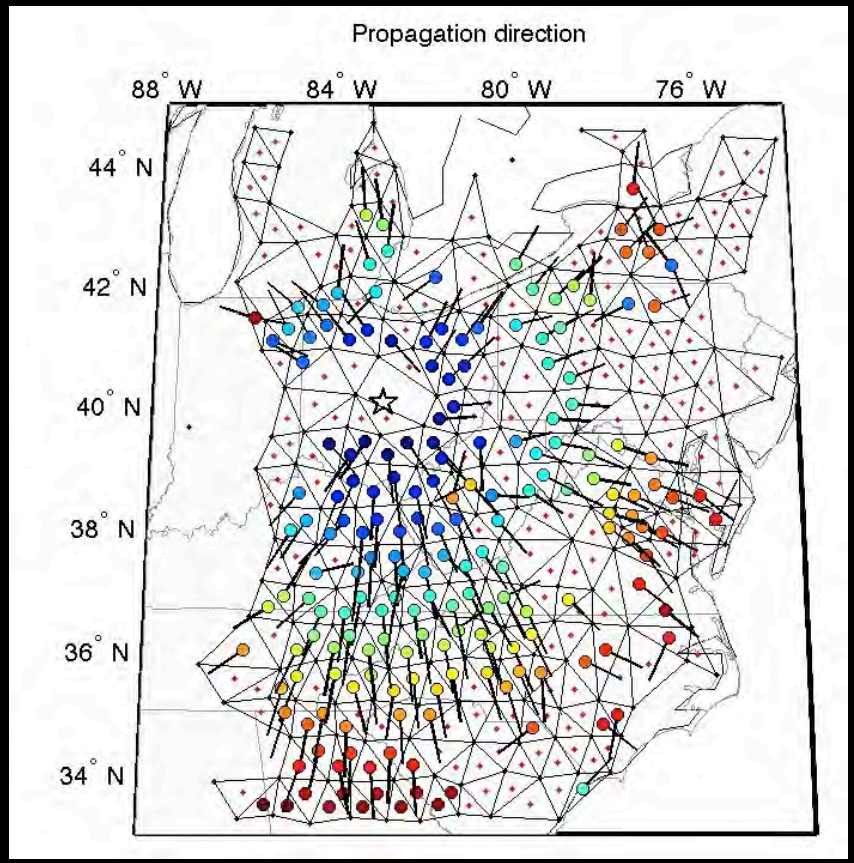
Application to infrasound

Application to infrasound detections – incoherent processing

- Infrasound signals are incoherent between stations.
- Signal envelopes are x-correlated → signal speed & direction

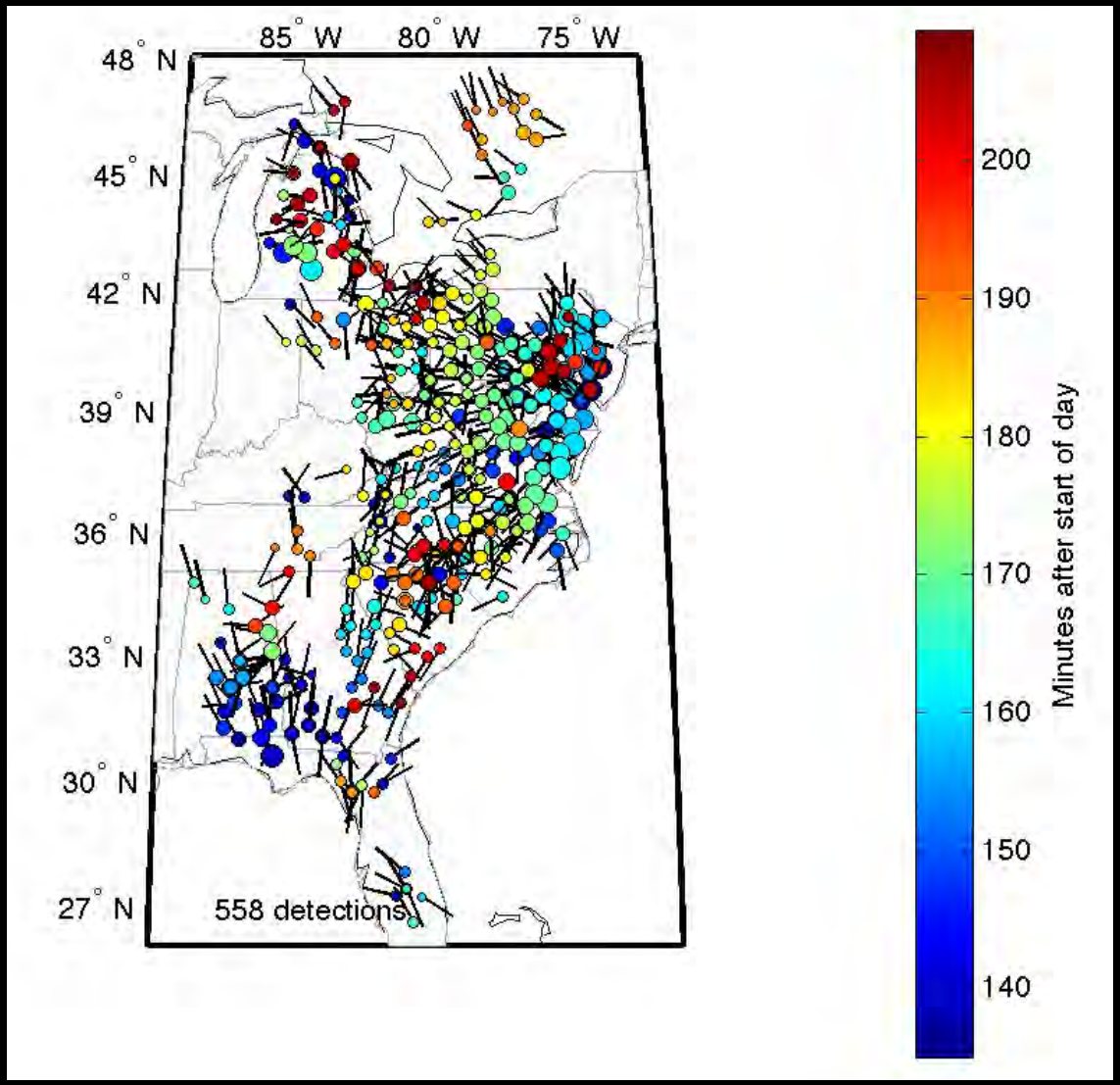


Ohio meteoroid

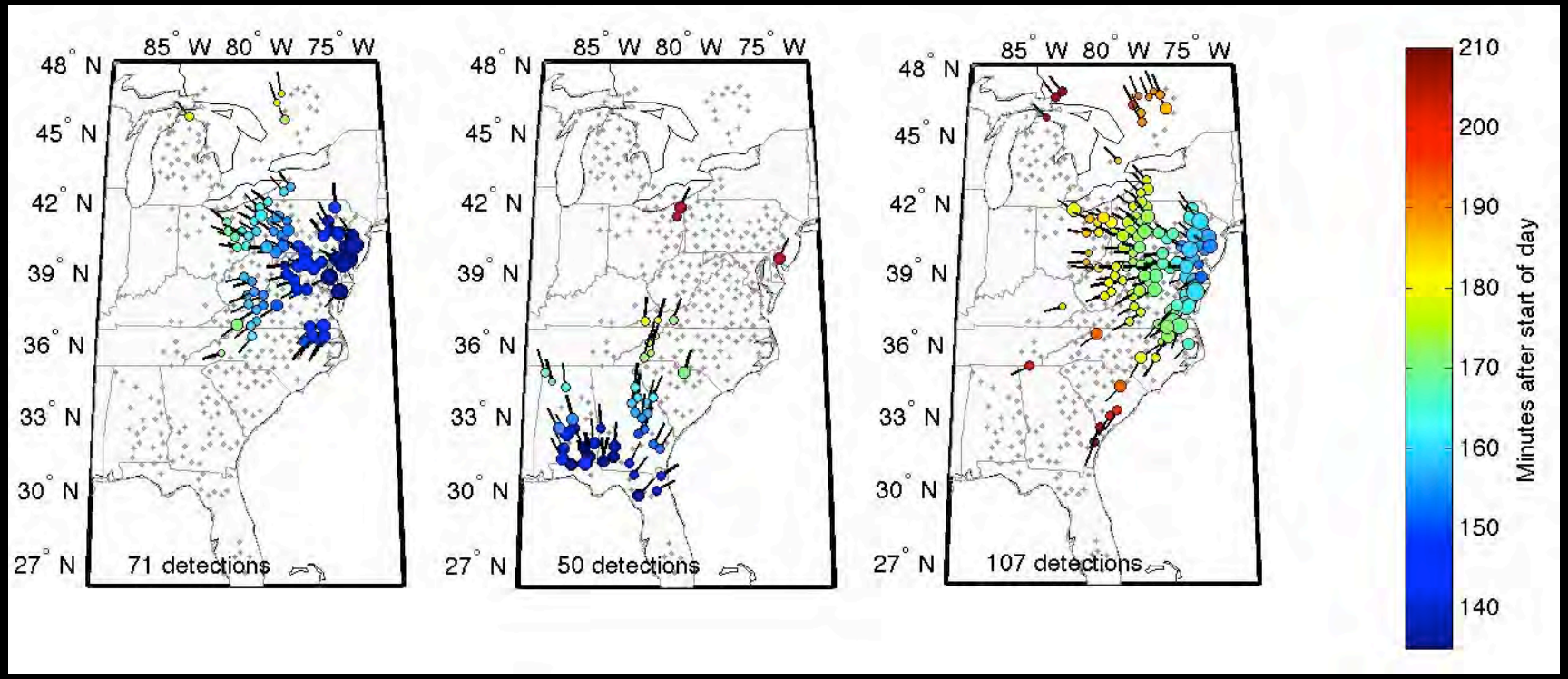


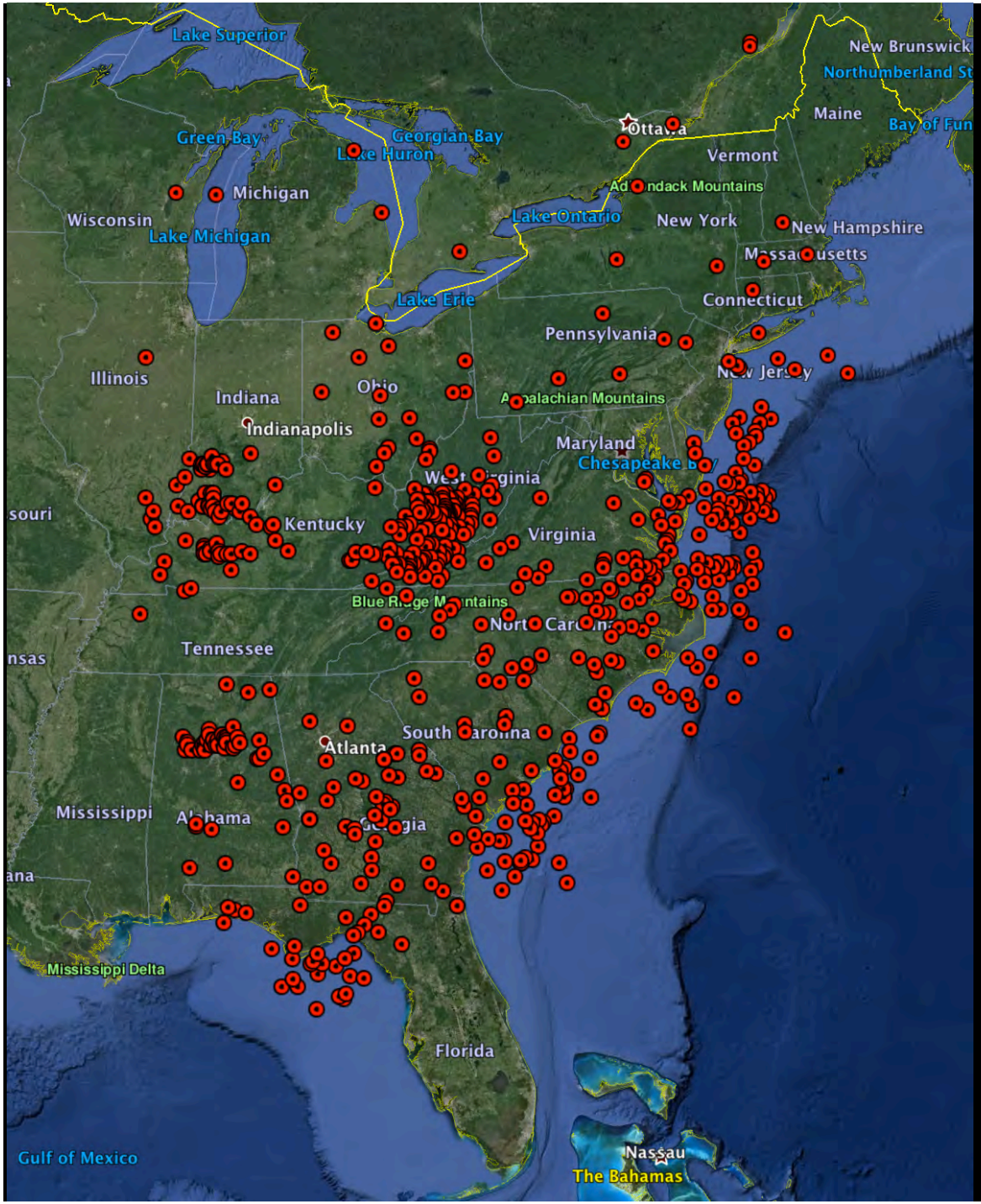
Detections at a quiet time of day

Detections over a noisy 75 minute period – day 213, 2013



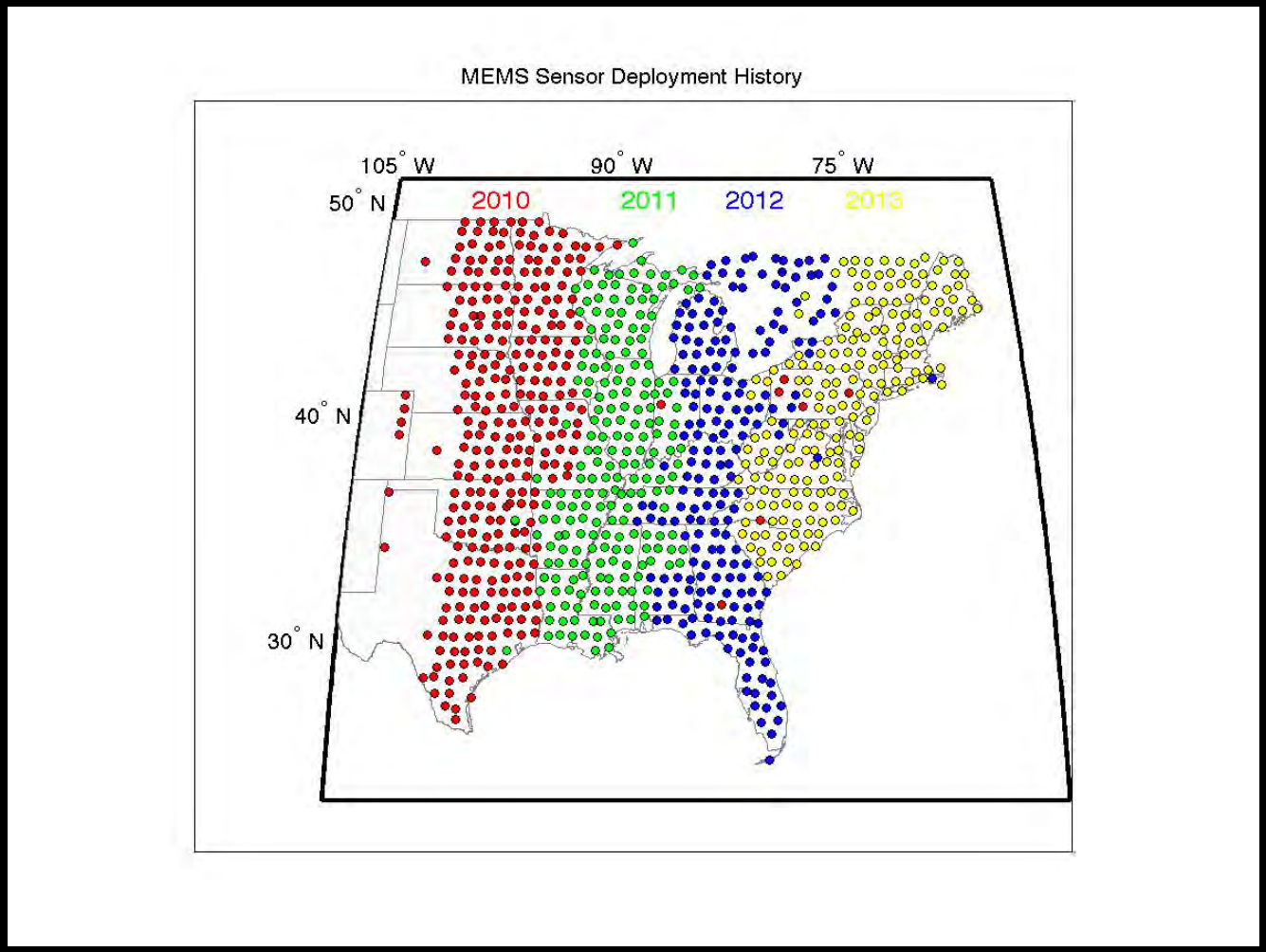
Separation into clusters



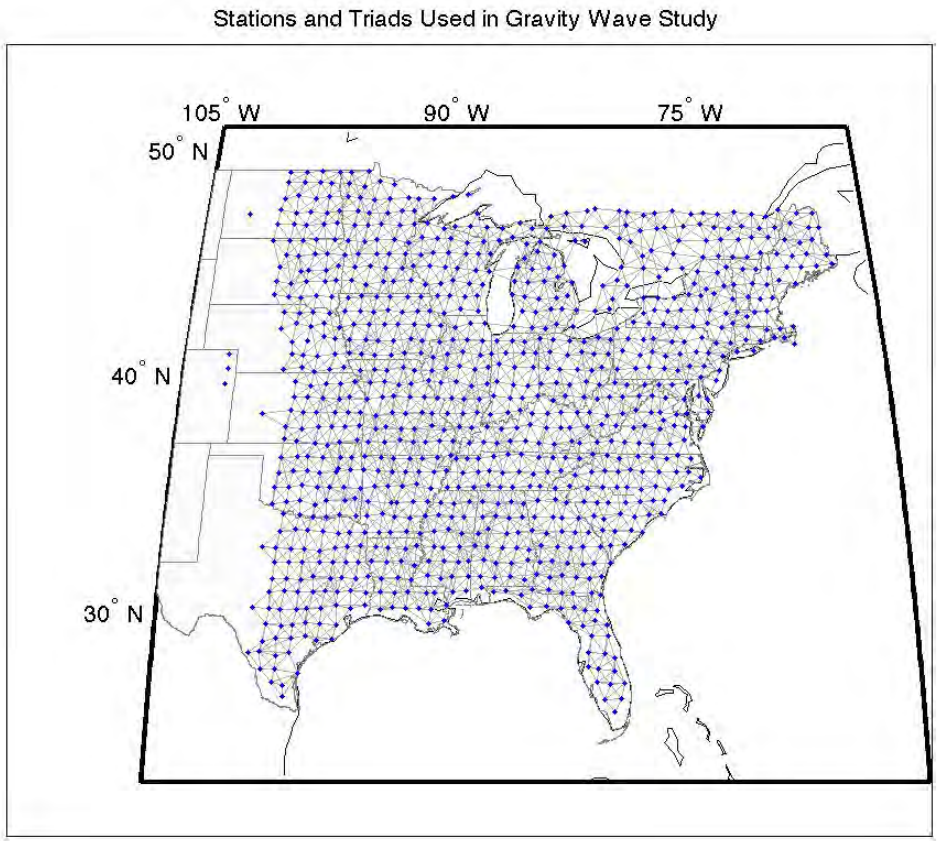


- Event Catalog
- Over 5 months

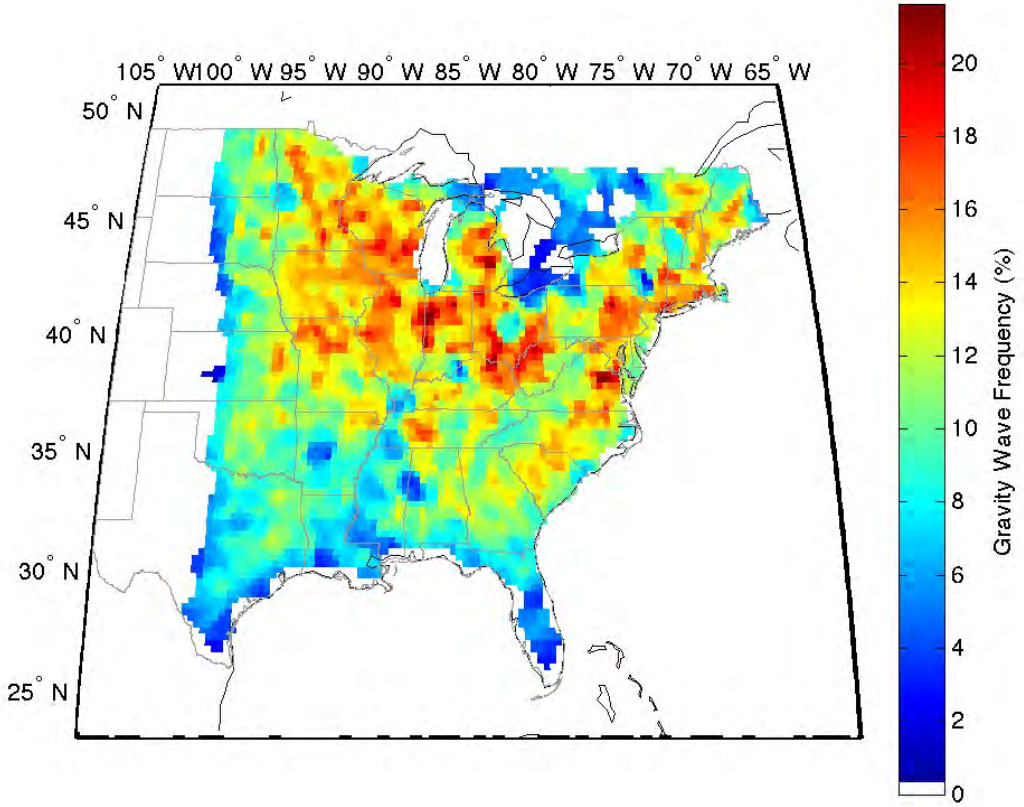
Next stage of gravity wave analysis



2010-2014 TA contains ~ 3,600 triads



Gravity wave occurrence 2010-2014



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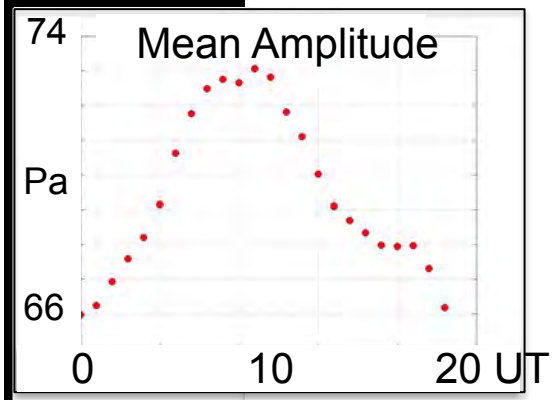
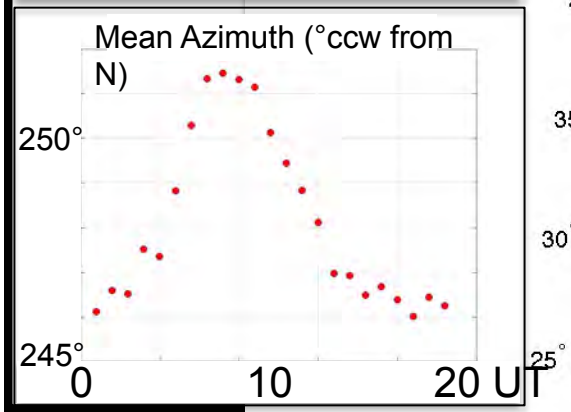
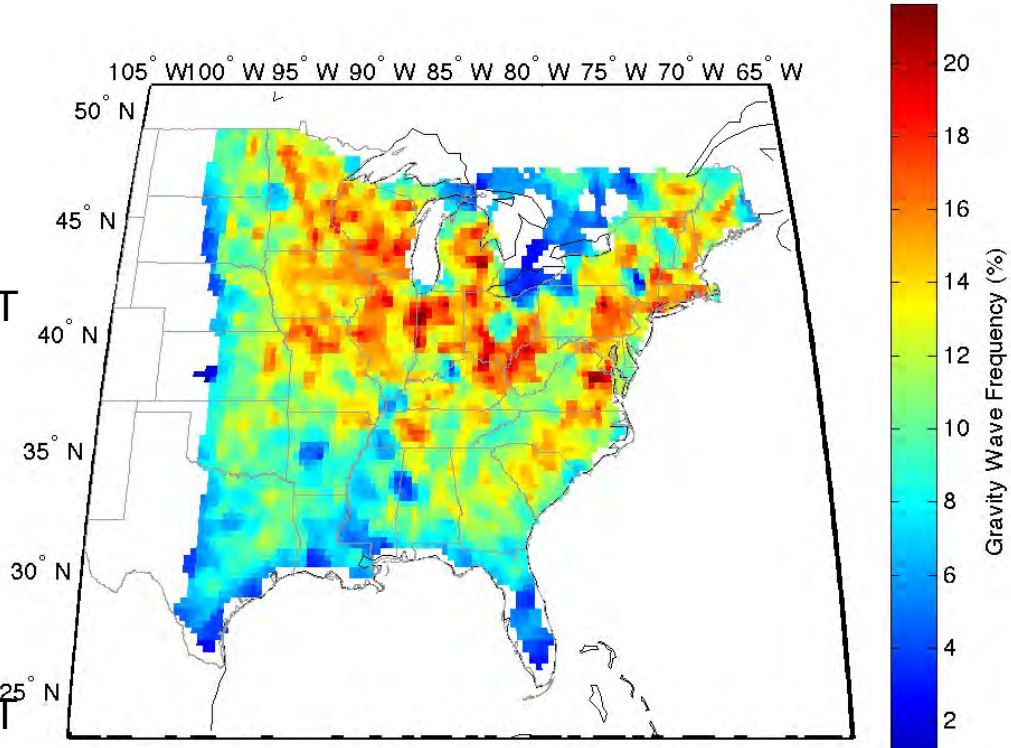
Gravity wave occurrence 2010-2014







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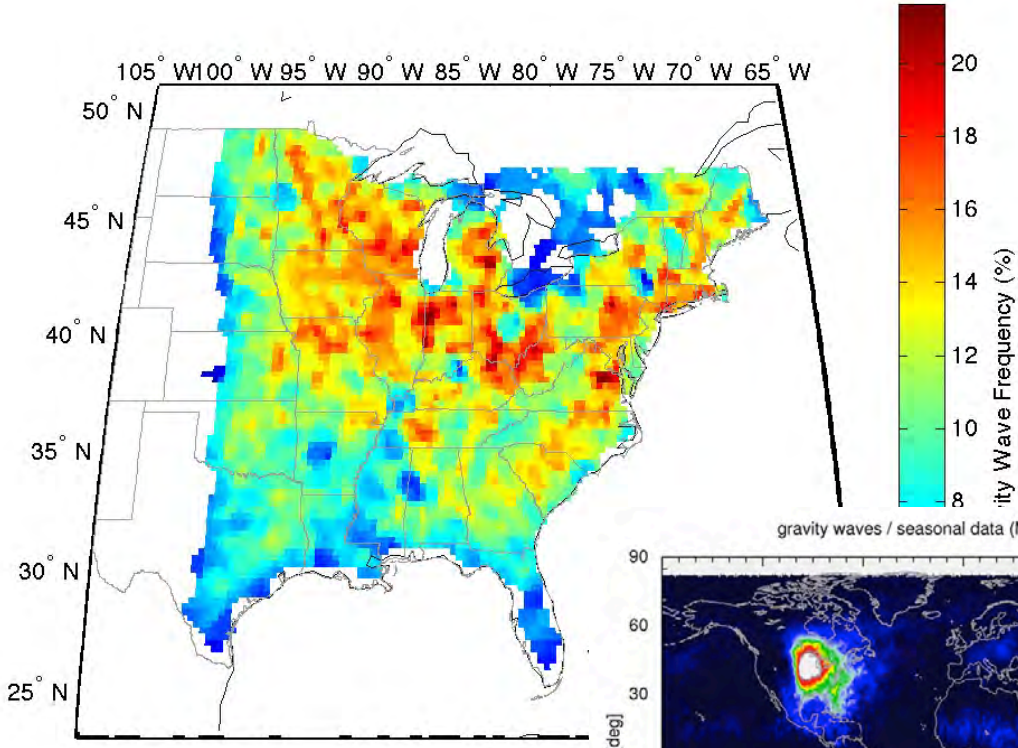
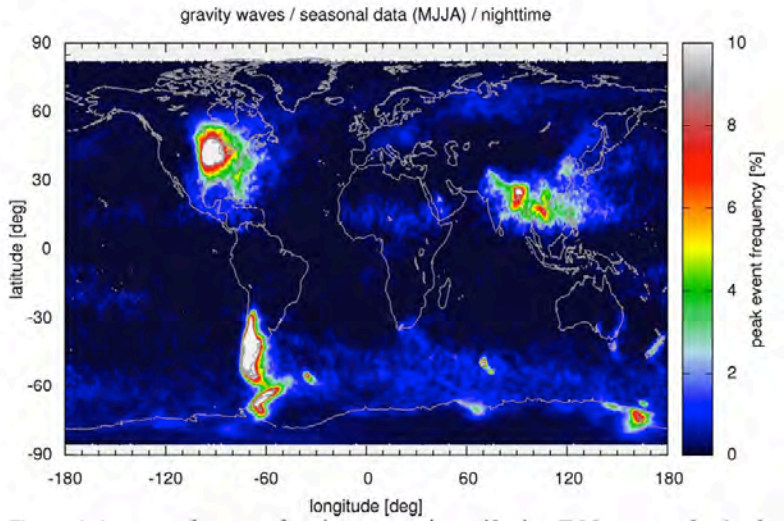
Gravity wave occurrence 2010-2014





From Lars Hoffman

Summary

Automated gravity wave detector:

- Gravity waves are coherent over much smaller scales than the entire TA
- Divide the TA into many sub-arrays to track the wavefield motion → USArray has characteristics of both array and network
- Yields a discretized view of the wave field
- Gravity waves observed at the surface are also observed by satellite

Automated infrasound detector:

- Uses GW detector method, except on infrasound envelopes
- Separation of detections into clusters is key

Other possible applications:

- Aid atmospheric scientists in GW detection

Project was supported by NSF Earthscope EAR-1358520

Concluding remarks

- Seismometers readily record atmospheric events
- The TA has provided a large catalog of events for study of infrasound propagation/atmospheric structure
- The upgraded TA is a new, large, observatory for study of the Earth's interior, atmosphere and interaction between the two