Early Warning of Earthquakes Using Earth, Ocean and Atmospheric Parameters Observed From Satellite Data

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Guido Cervone and Menas Kafatos

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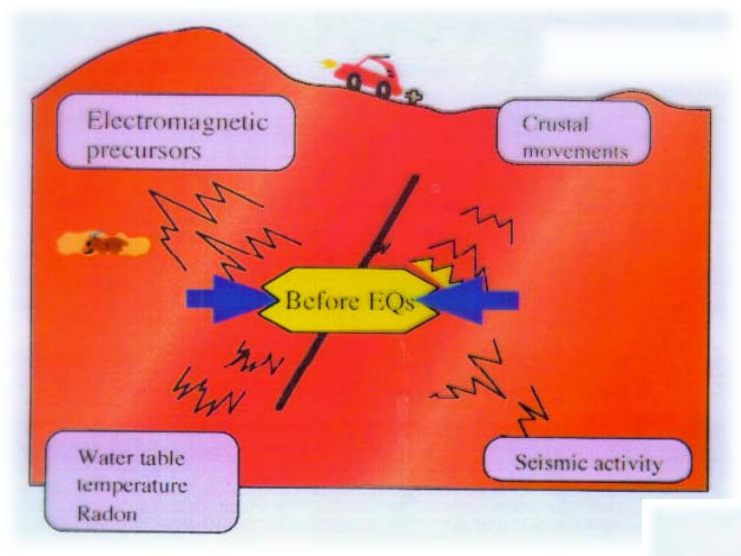
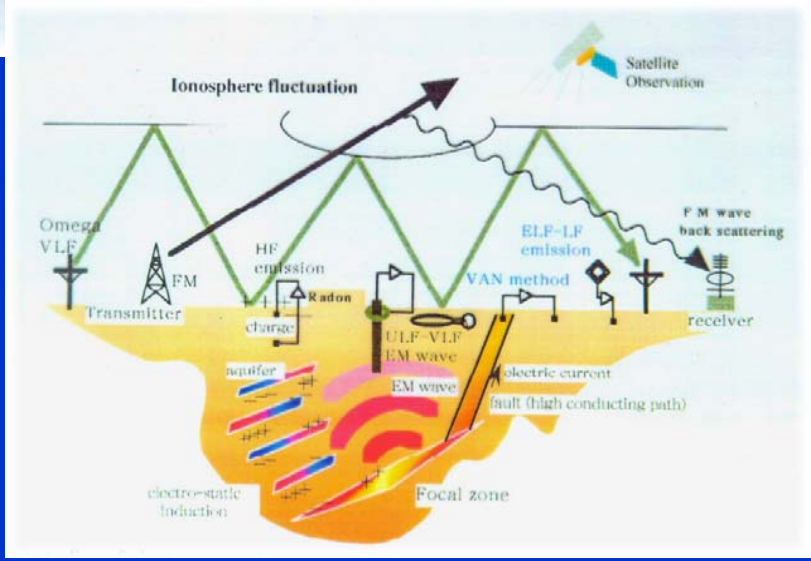




Land-Ocean-Atmosphere-Ionosphere coupling

Globe - Land, Ocean and Atmosphere

Land - 30% and Ocean 70%,

(atmosphere is linkage between land and Ocean)

Earthquakes – Land and Ocean

Effect can be seen on the earth, ocean and atmosphere

Ground monitoring – using Geophysical methods

It was difficult to find complementary behavior

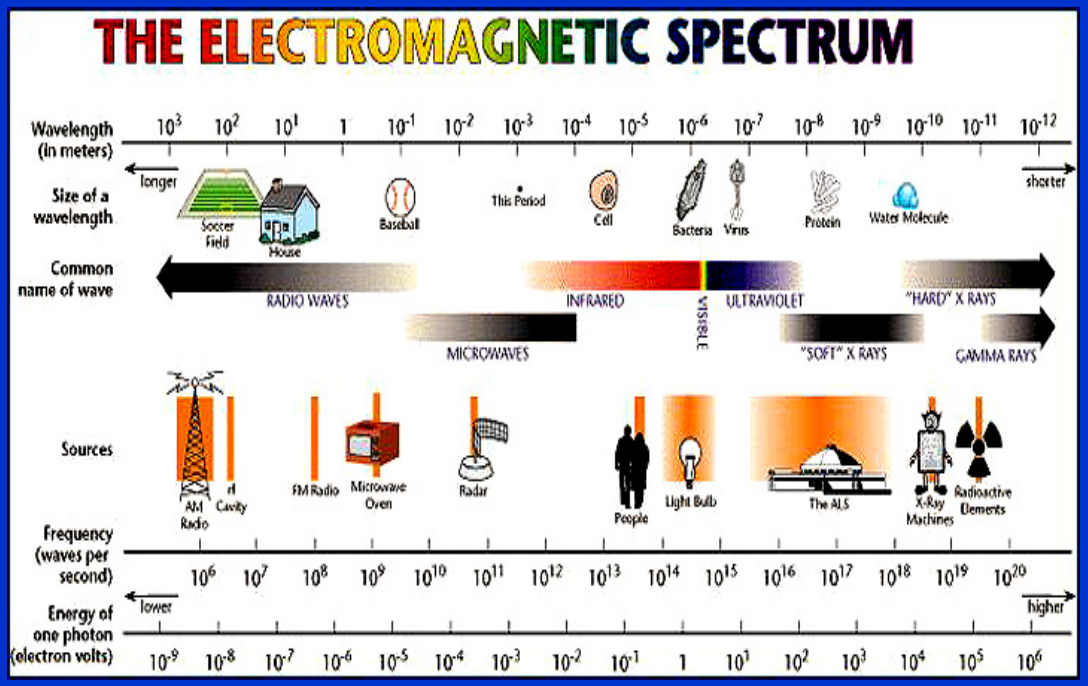
- It is now believed that strong coupling exists between Land-Ocean-Atmosphere-Ionosphere

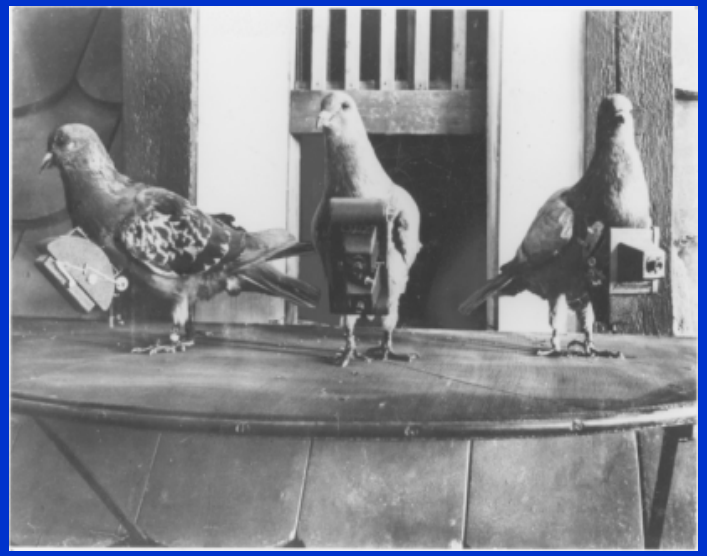
- Here, we want to show complementary behavior of land, ocean, atmosphere and ionosphere parameters prior to the earthquake events.

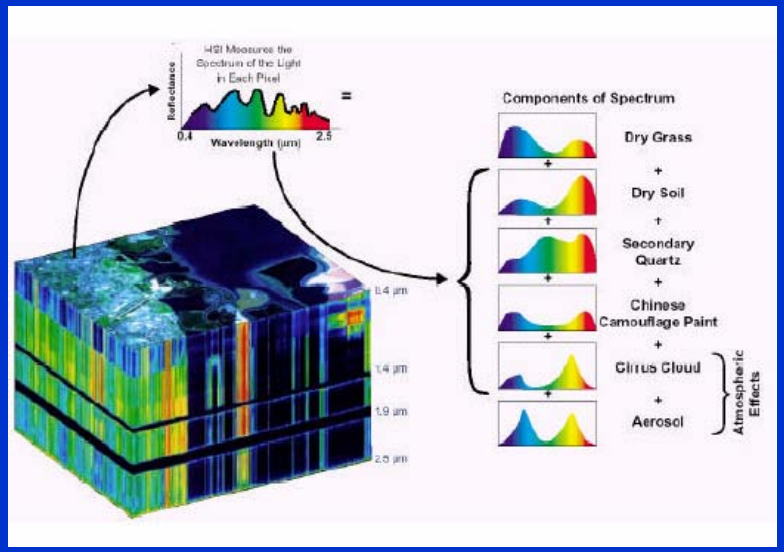
- All these parameters are deduced from satellite remote sensing data.

Remote Sensing

Monitoring – using optical and microwave sensors
It is now easy to study complementary behavior



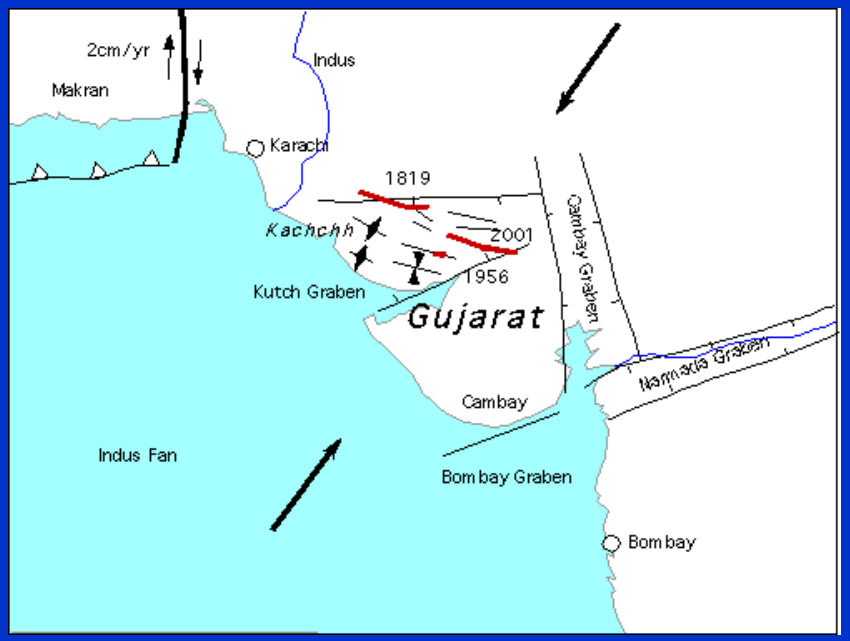




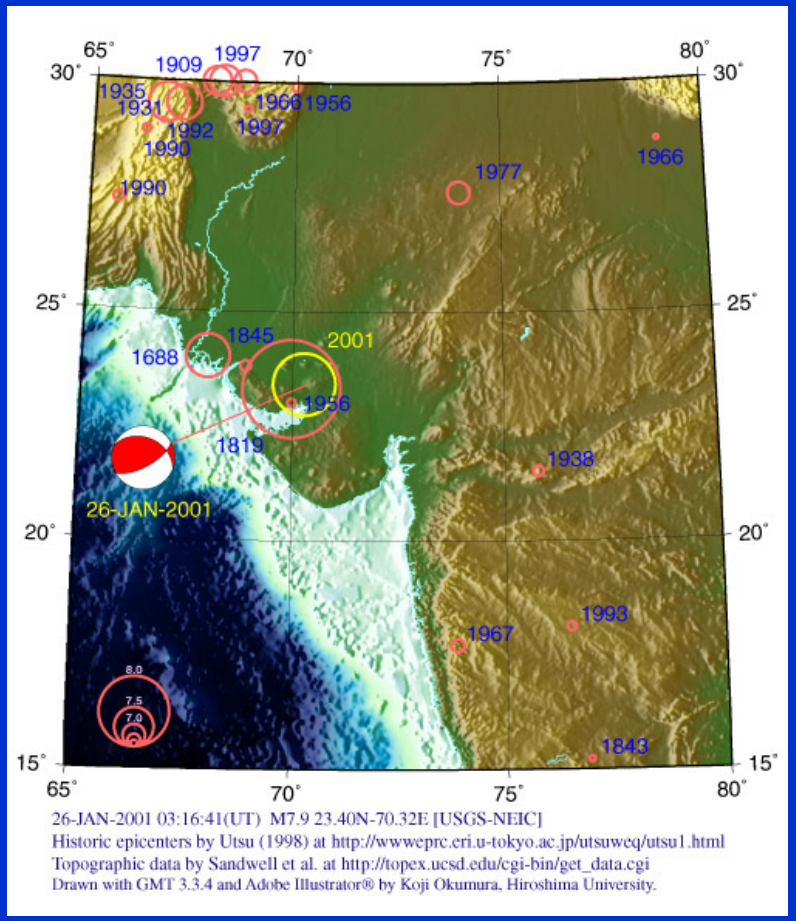
Land, Ocean and atmospheric Parameters

- ♣Surface Latent Heat Flux
- ♣ Water Vapor
- ♣ Cloud cover
- ♣ Chlorophyll Concentration (MODIS)
- ♣ Sea Surface Temperature (TMI satellite)
- ♣ Total Electron Content (using GPS and TOPEX satellite)
- ♣Land Skin Temperature
- ♣ Moisture content

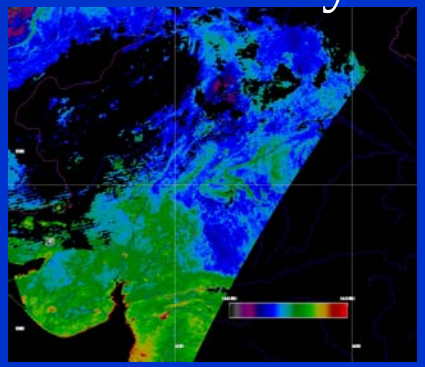
Gujarat Earthquake (India) Region WESTERN INDIA; Date-Time 2001 01 26 23:40:30 UTC, Location 23.40N 70.32E; Depth 23.6.0 Km; Magnitude 7.7 ; Source USGS NEIC



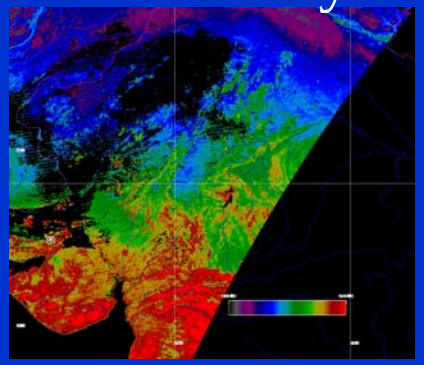
(R.P.Singh WWW source)



January 01



January 20



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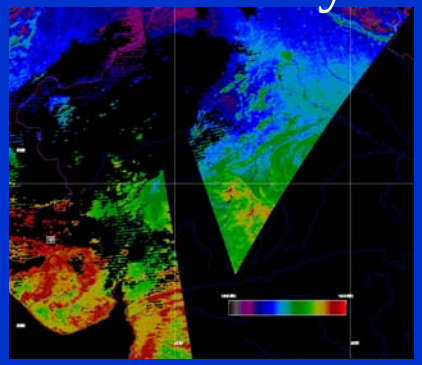
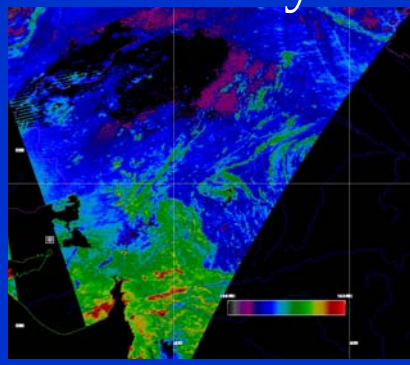
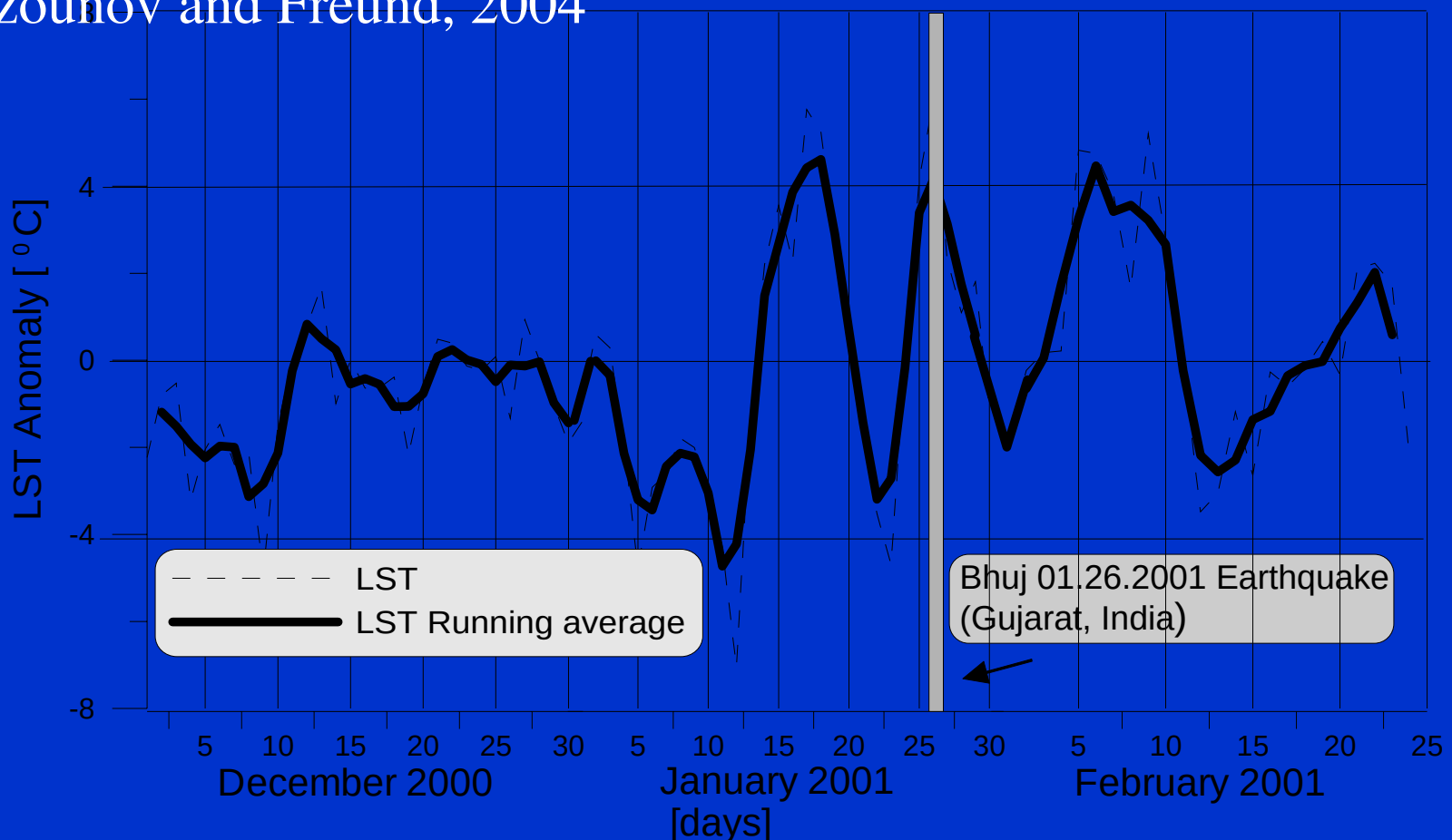


January 26

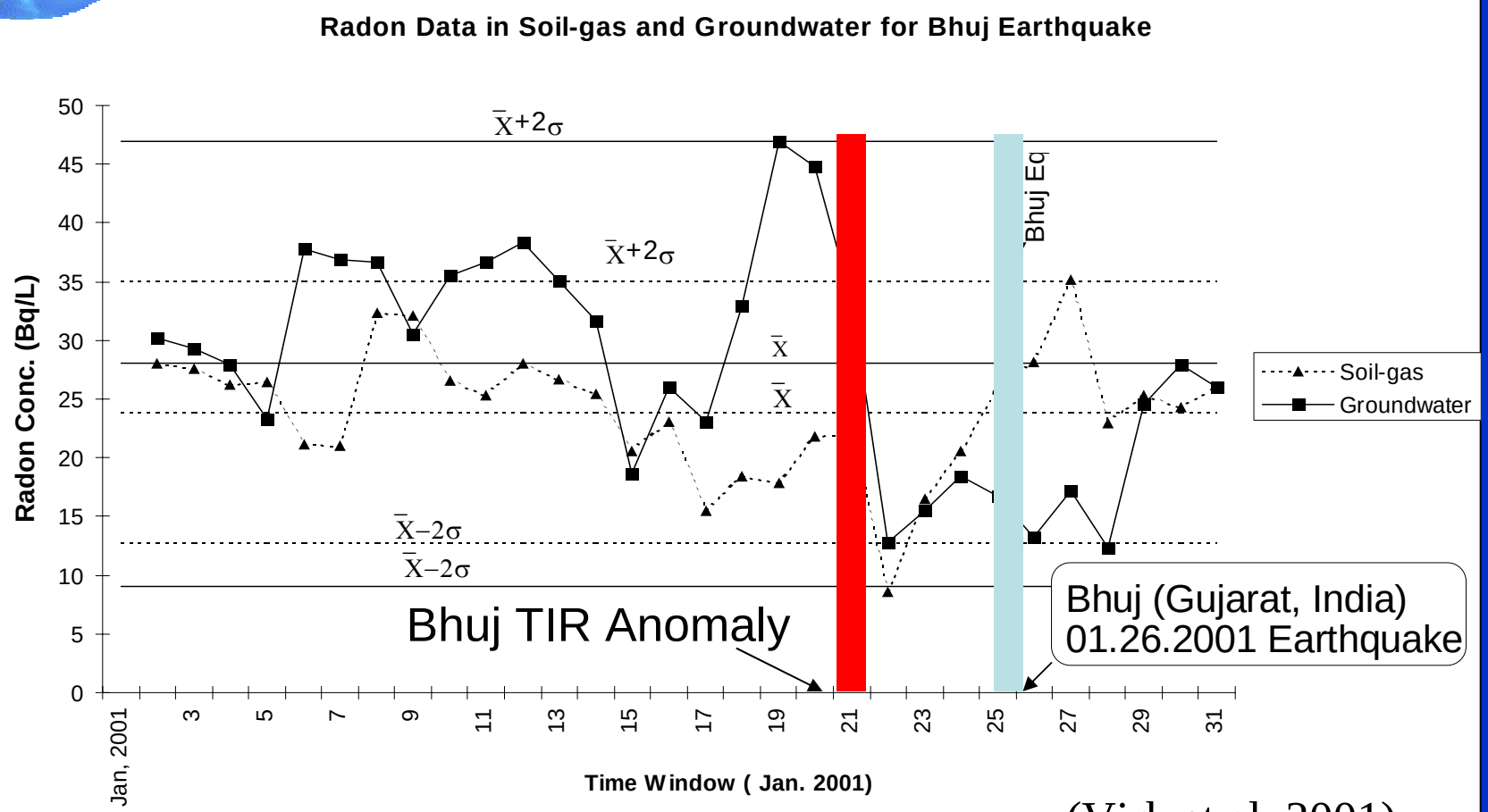


Ouzounov and Freund, 2004



TIR anomalies <-> Rn monitoring

Gujarat Earthquake (India); Date-Time 2001 01 26 23:40:30 UTC,
Location 23.40N 70.32E; Depth 23.6.0 Km; Magnitude 7.7 ; (USGS NEIC)

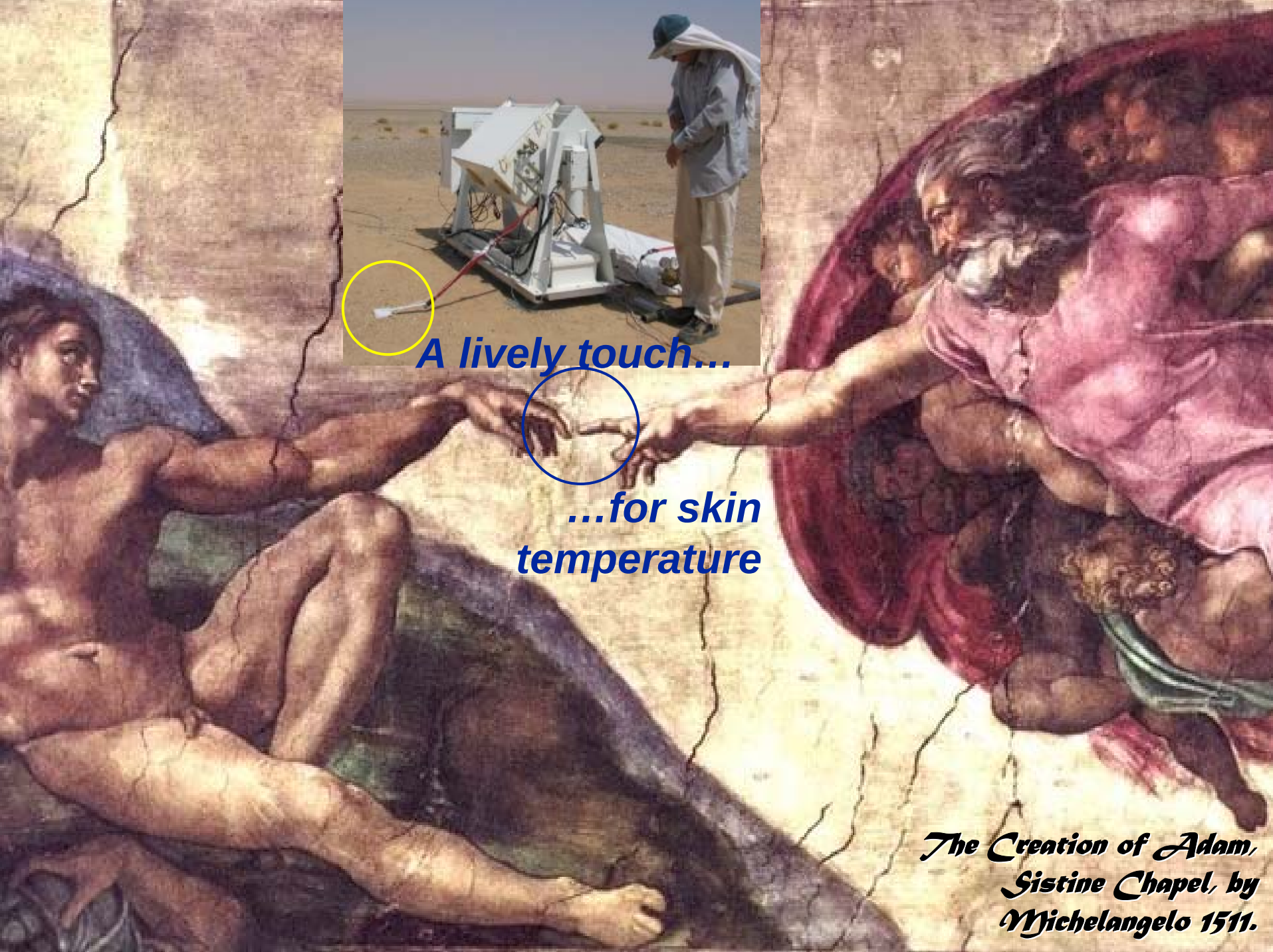


(Virk et al. 2001)

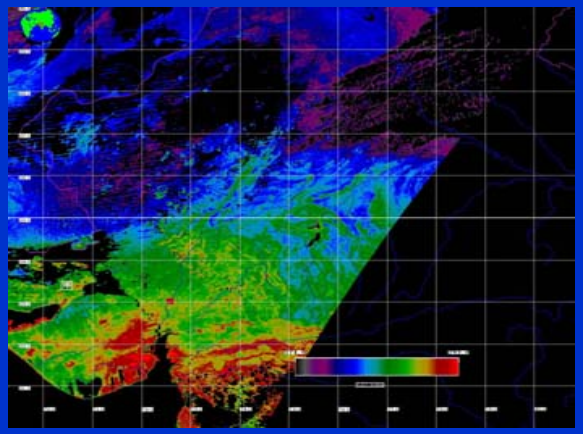
- **Skin temperature of the Earth change significantly**

- **Seismologists do not believe since no thermal anomaly is found at the focal region and in surrounding region**

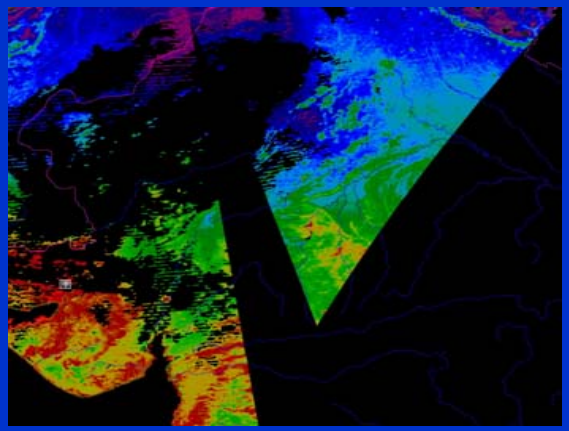
- **Cause??**


A lively touch…
…for skin temperature
The Creation of Adam, Sistine Chapel, by Michelangelo 1511.

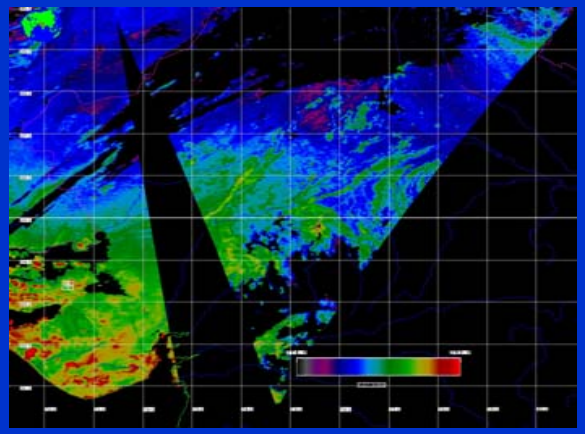
Complementary Parameters



Jan 6, 2001

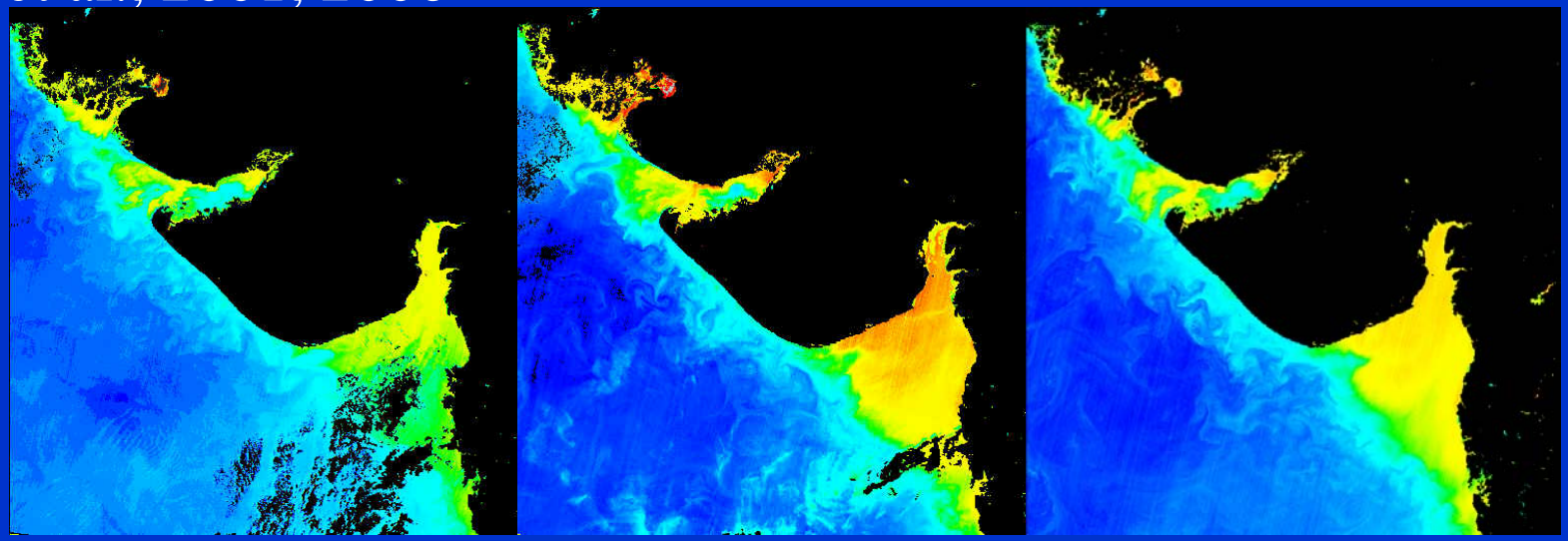


Jan 21, 2001



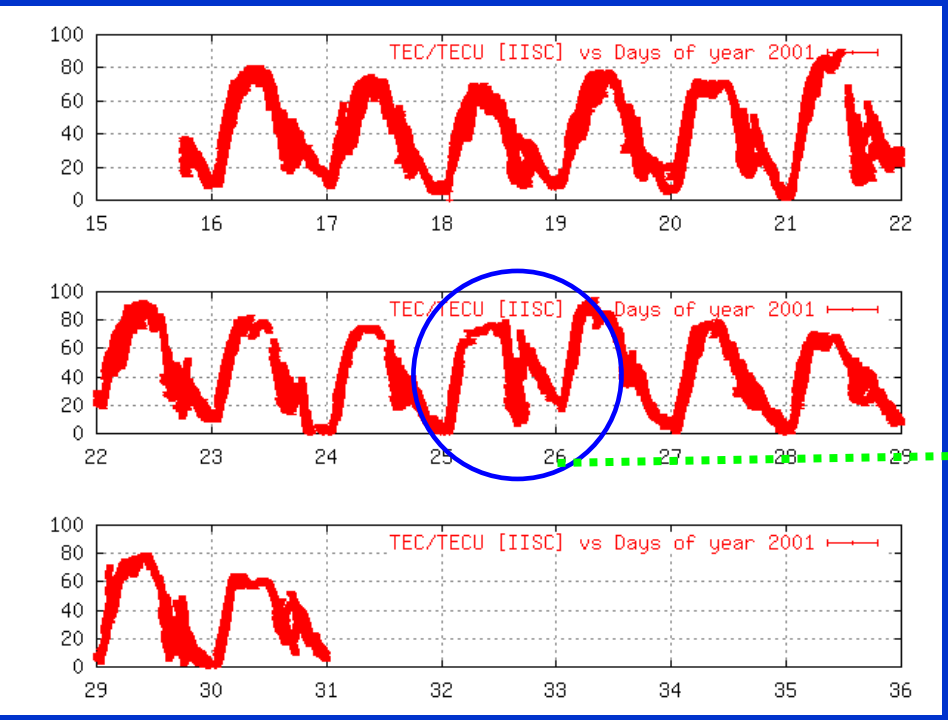
Jan 28, 2001

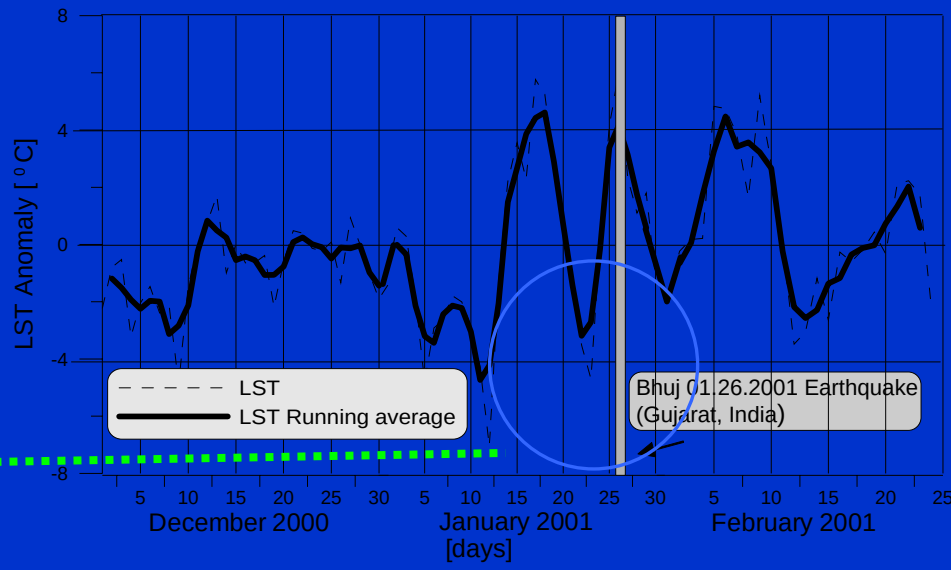
Singh et al., 2001, 2006



(a) January 18, 2001 **(b) January 26, 2001** **(c) February 3, 2001**

TEC GPS data and MODIS LST for Gujarat, Jan 2001

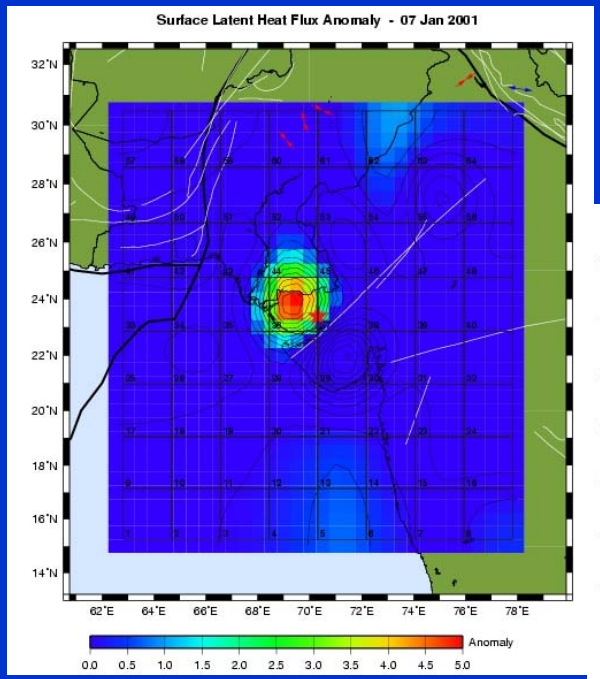


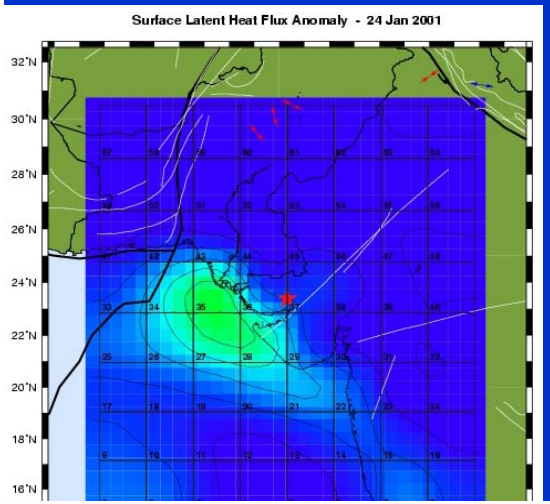


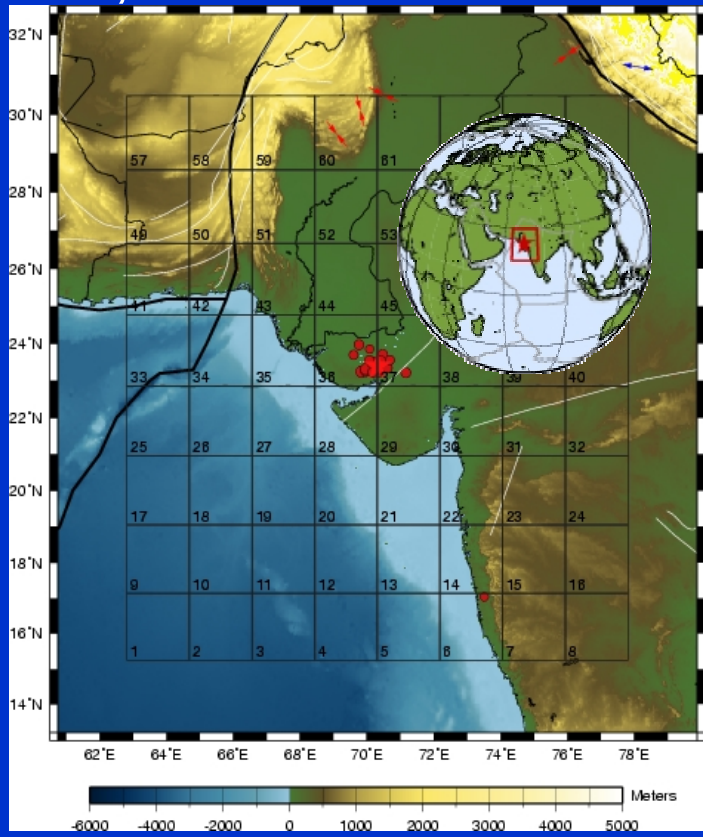
MODIS Night time LST

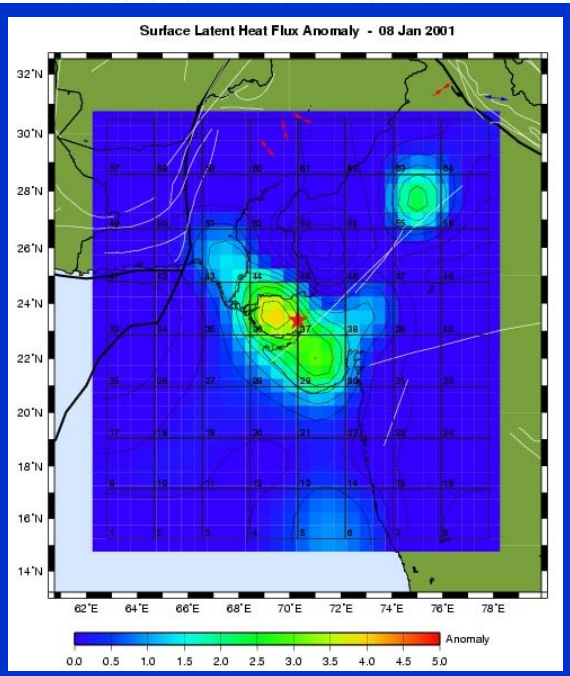
ISSC GPS Receiver Lat 13°, Long 76° [Pulinets et al, 2003}

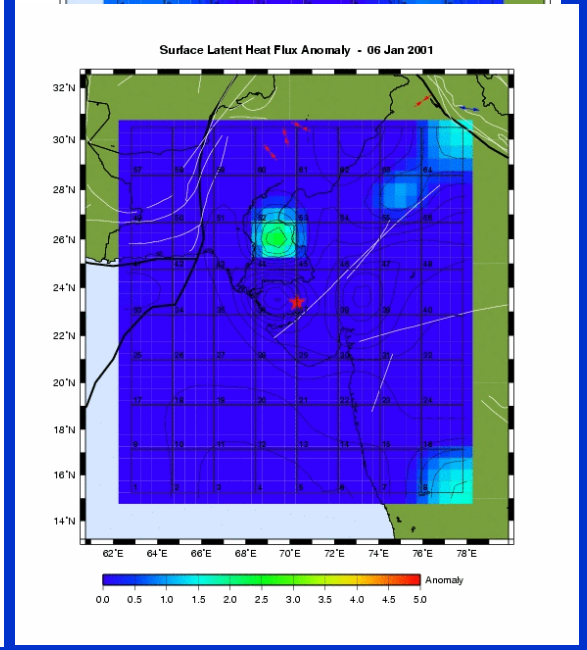
26 Jan 2001 23.399N 70.316E Mw=7.6 17 Km GUJARAT, INDIA







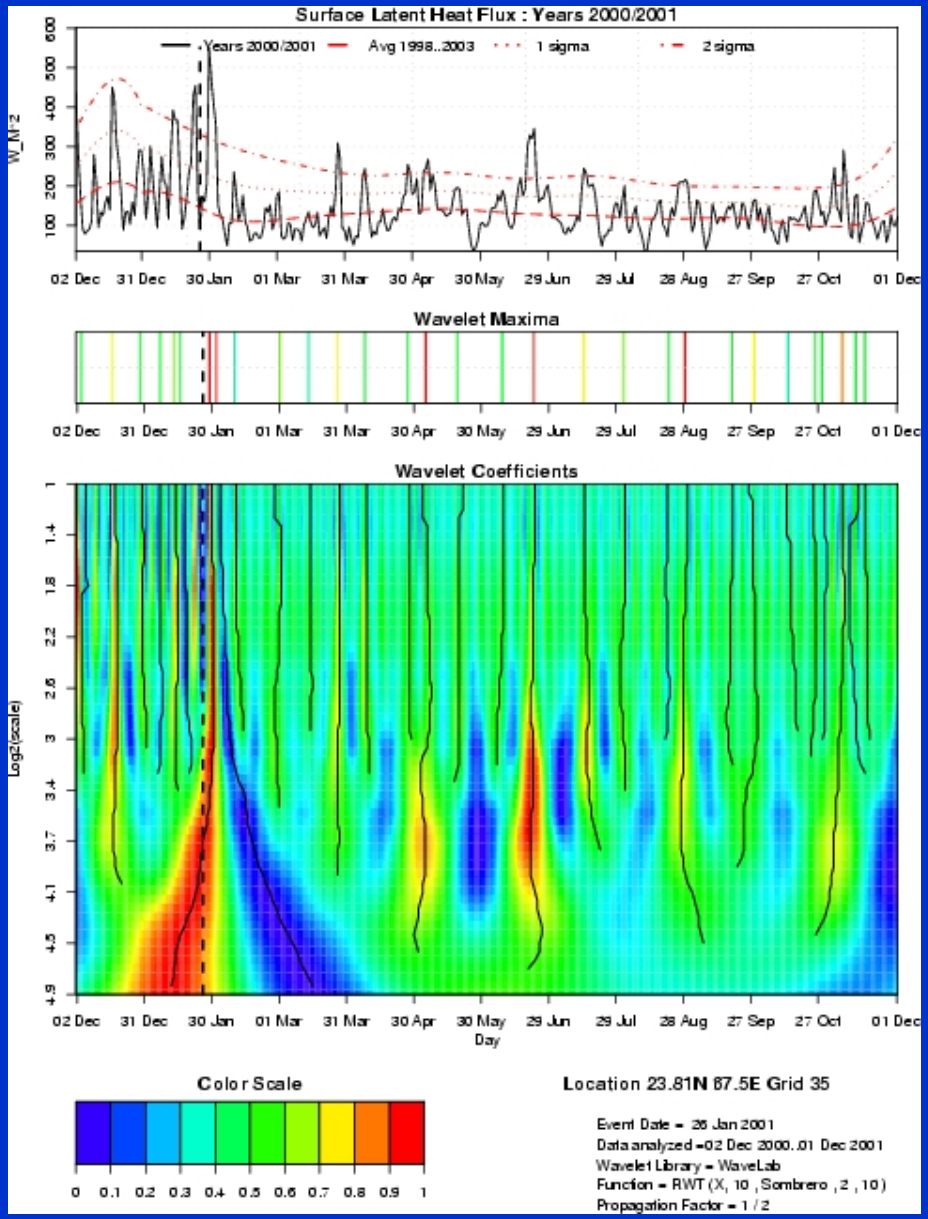


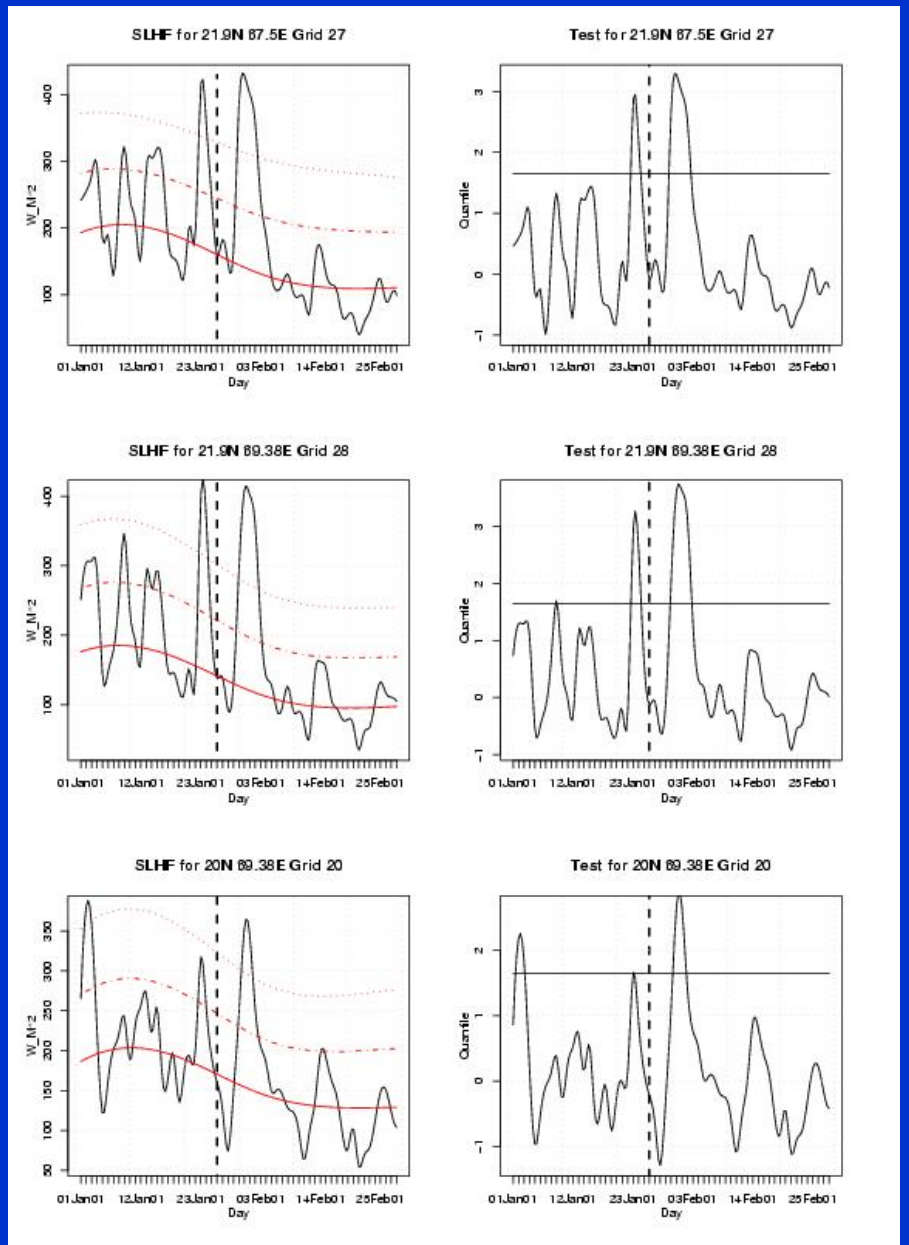


Cervone et al., 2005

SLHF Anomalies

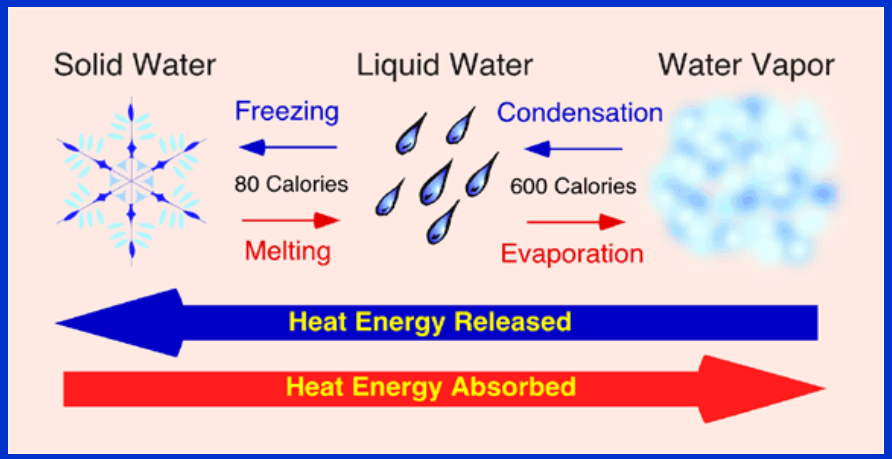
Cervone et al. 2005



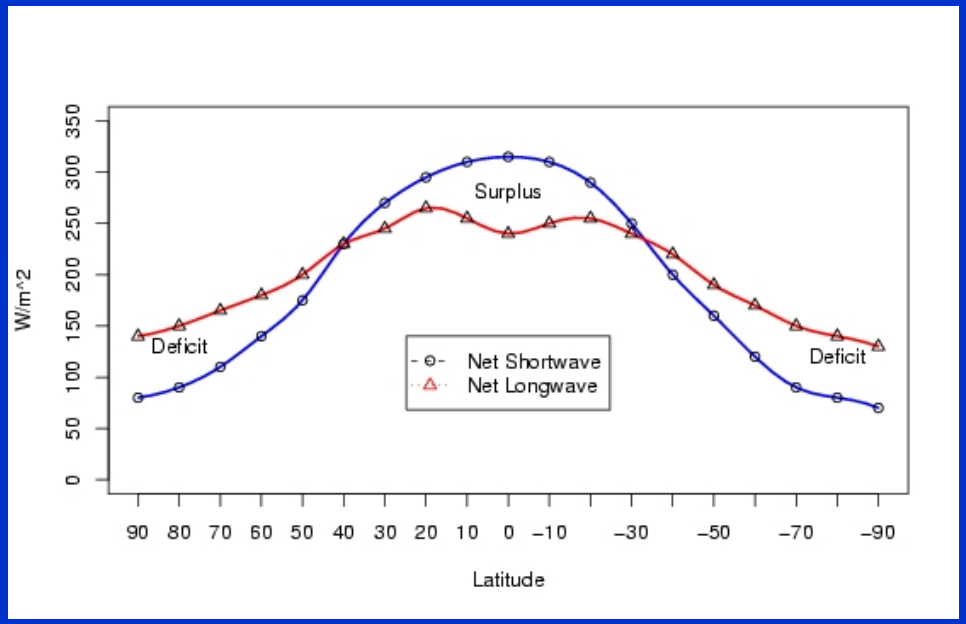


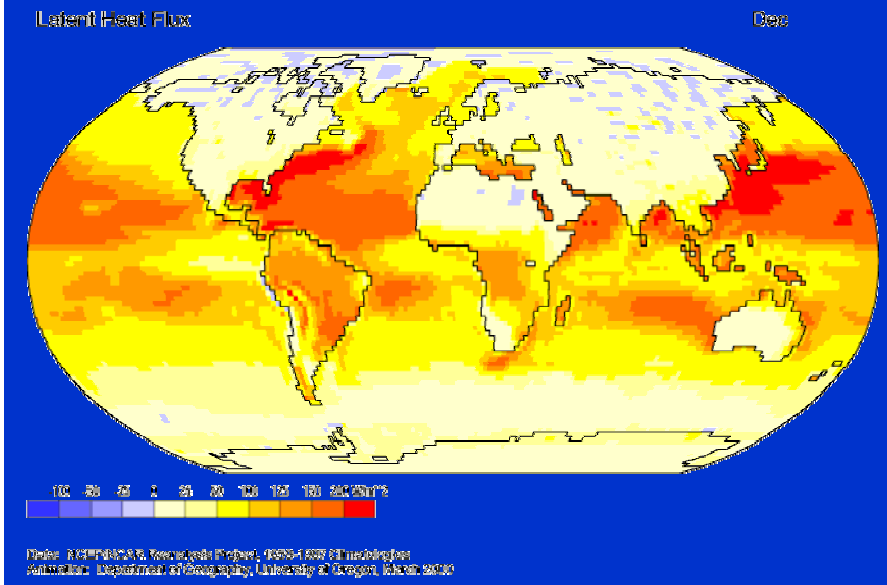
Surface Latent Heat Flux (SLHF) Data

- LH: Energy required to change to a different state of matter
- SLHF: Global movement of latent heat energy through circulations of air and water
- SLHF: possible earthquake precursor (Dey and Singh, 2004, Cervone et al, 2004,2005)



http://www.physicalgeography.net/fundamentals/6c.html



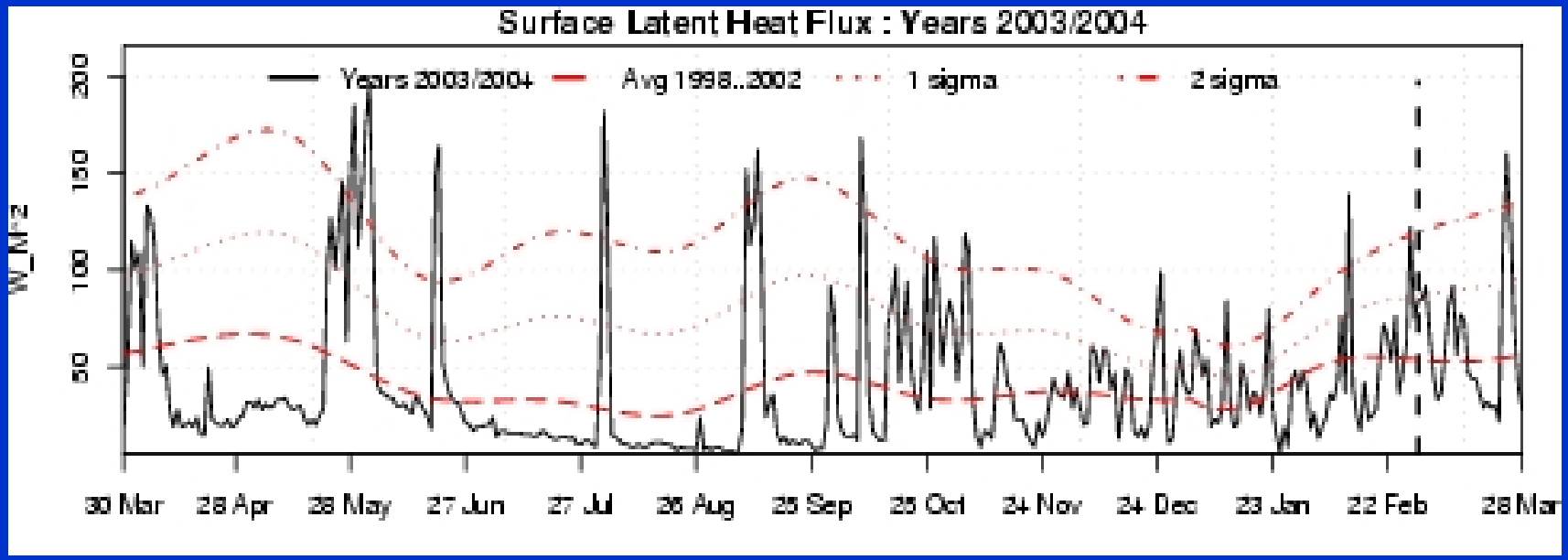


SLHF Data Anomalies

The origin of the anomalous SLHF is likely to be related with increase of the surface temperature caused by:

- Crustal deformation
- Release of gases
- Increase in humidity and pressure
- Local greenhouse

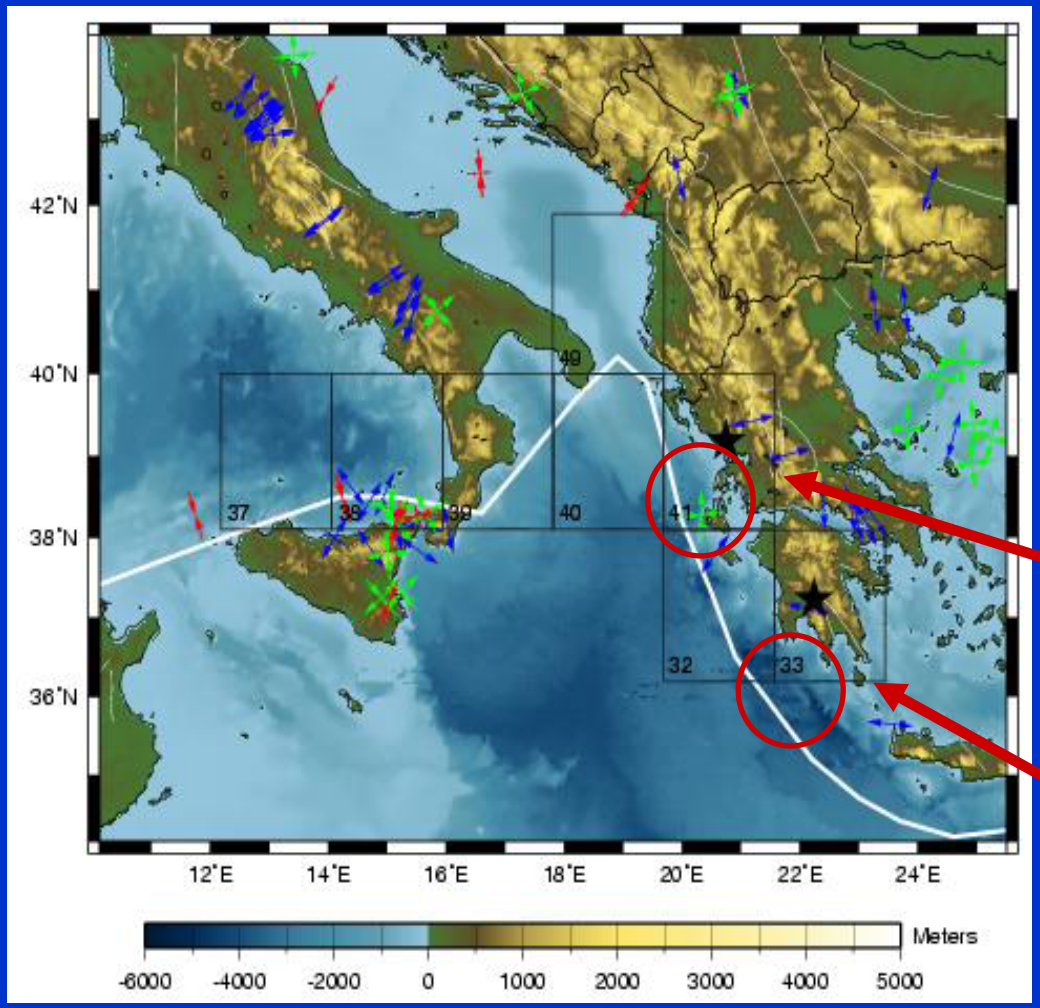
Identification of Anomalous Peaks



- Which are the anomalous peaks?
- How are they distributed in the space?
- Which peaks are associated with earthquakes?

- SLHF anomalies are characterized with the earthquakes of
- Magnitude more than 5.5
- Focal depth less than 30 km
- Close to the coasts and also near the areas surrounded by snow cover

2 Greek Earthquakes

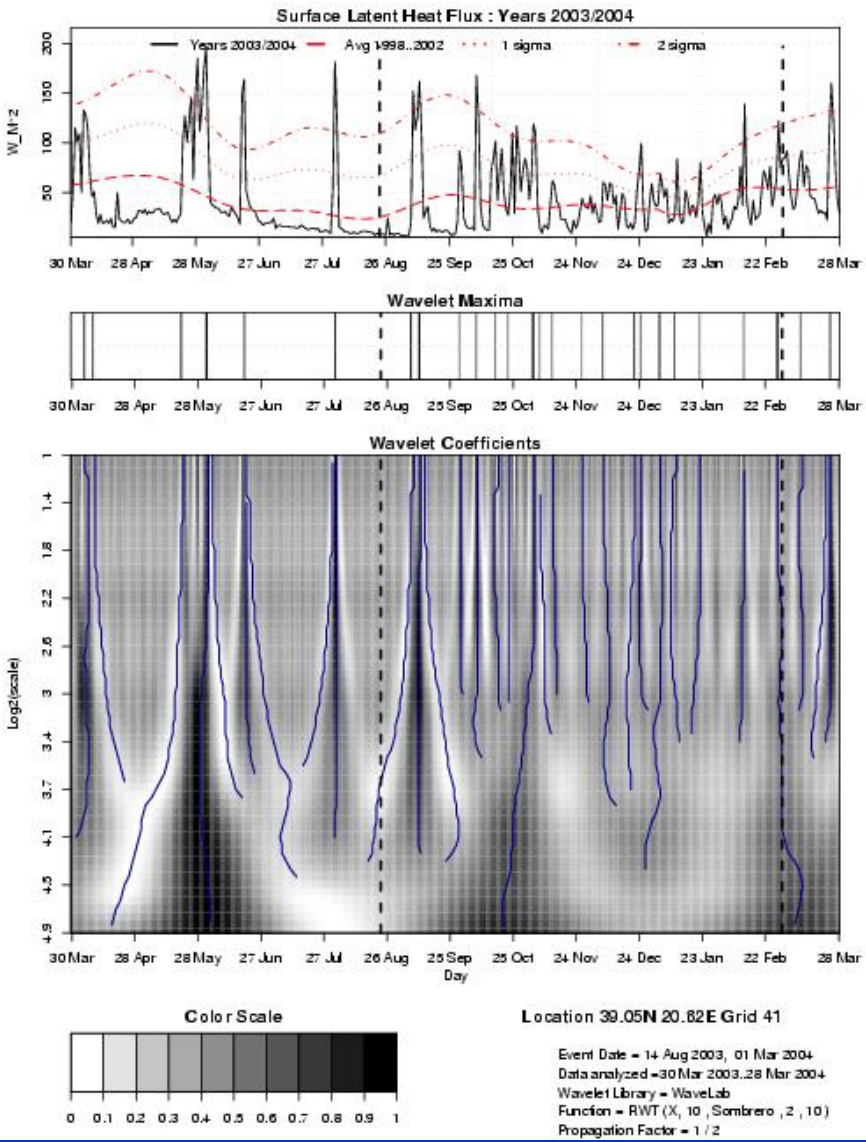


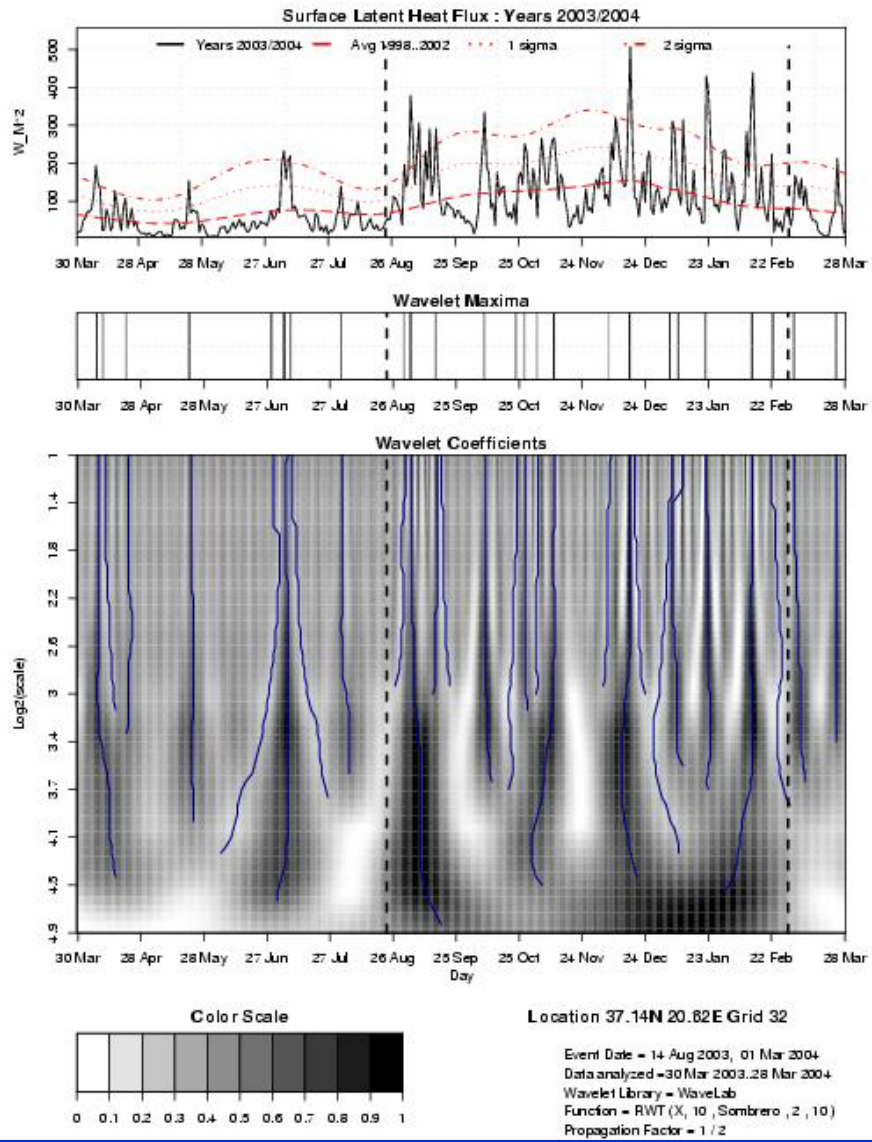
- 8 Aug 2003 Mw=6.7

1 Mar 2004 Mw=5.7

G. Cervone et al., 2004
Wavelet maxima curves of surface latent heat flux associated with two recent Greek earthquakes
Natural Hazards and Earth System Science, Vol. 4, pp 359-374, 28-5-2004

SLHF Over the Epicenters

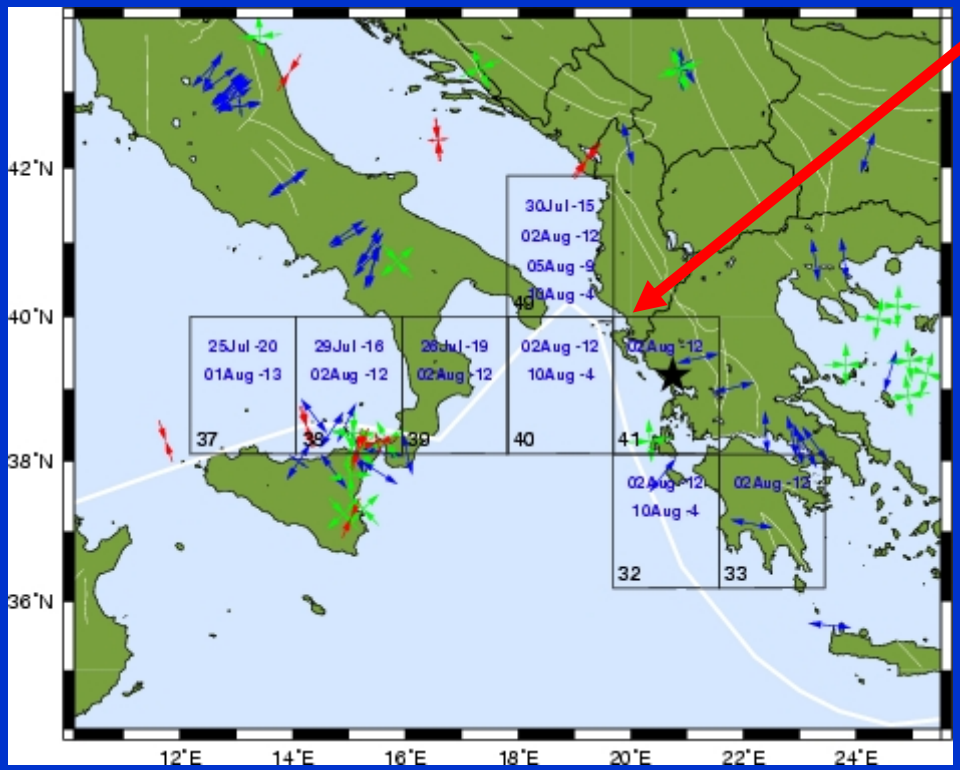




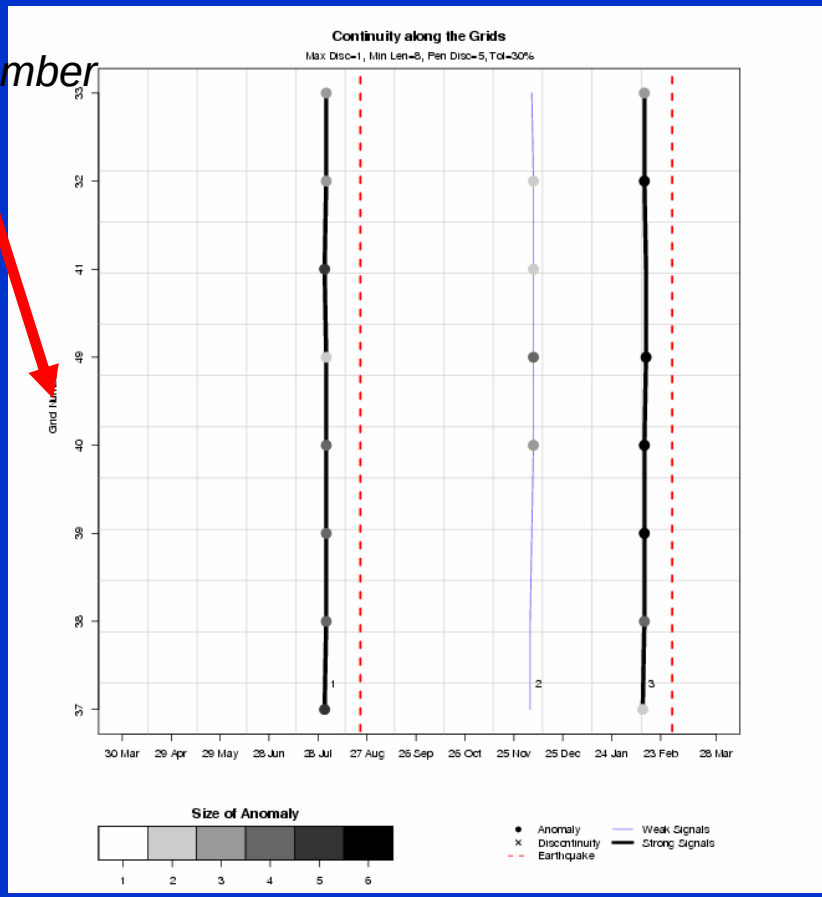
Spatial and Temporal Continuity

- Spatial Continuity: Precise geometrical continuity

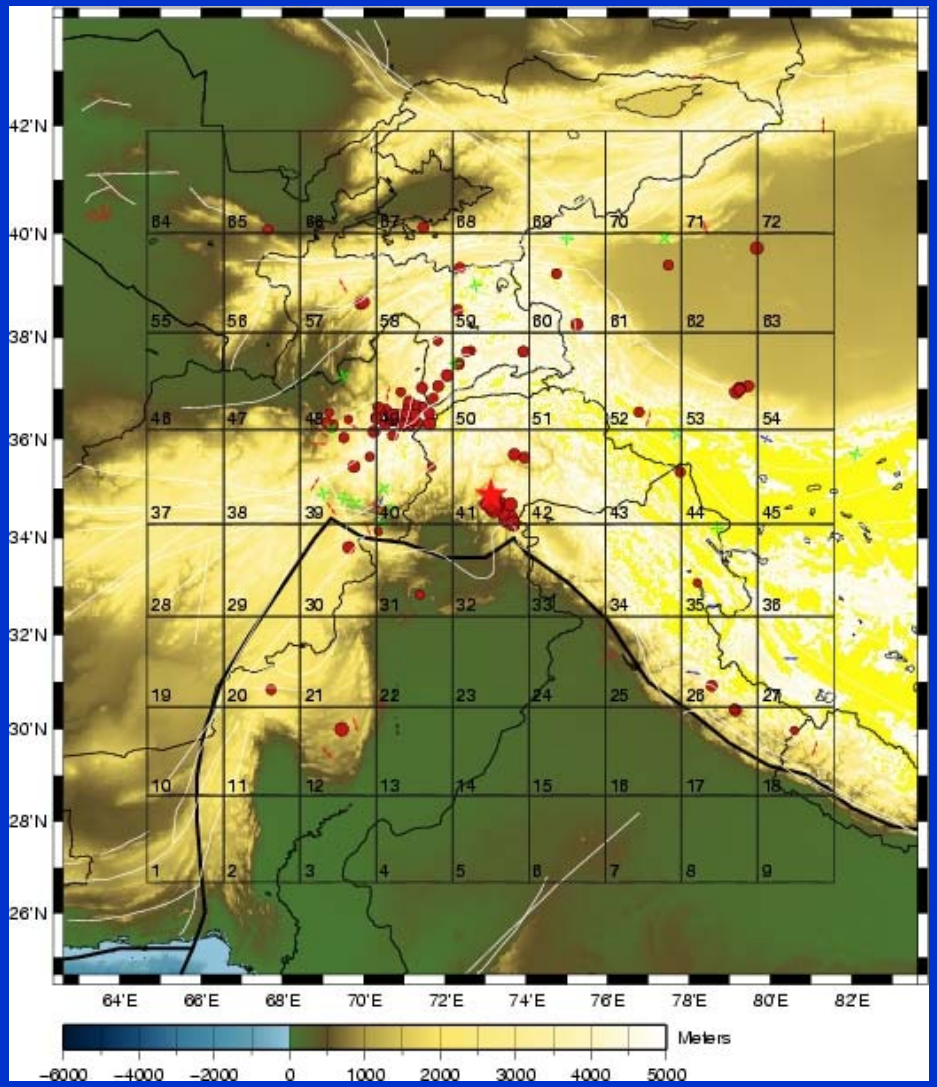
Cervone et al. (2004)

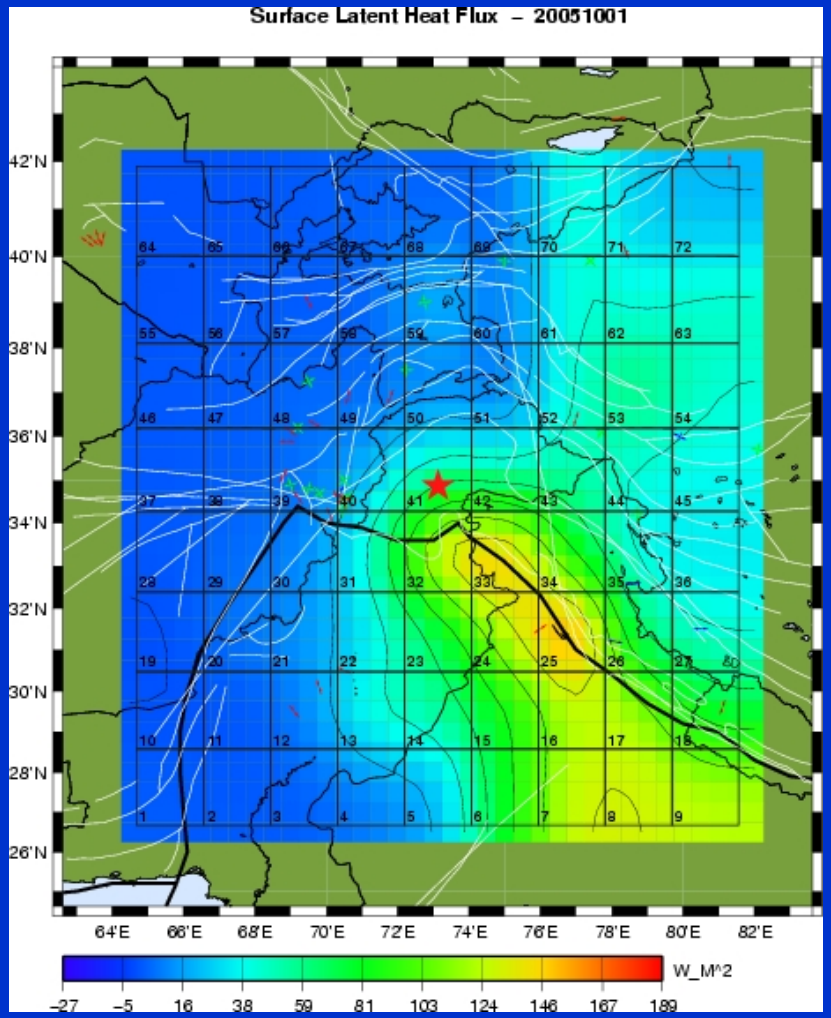


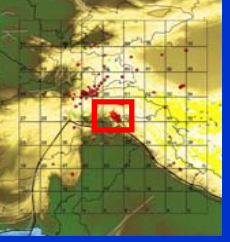
Grid Number



Pakistan Earthquake

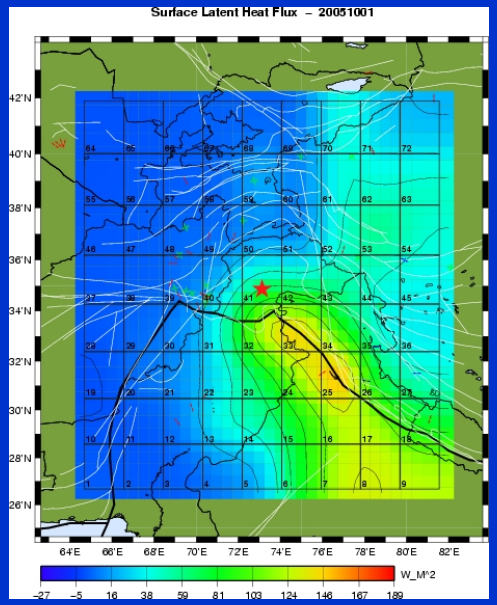


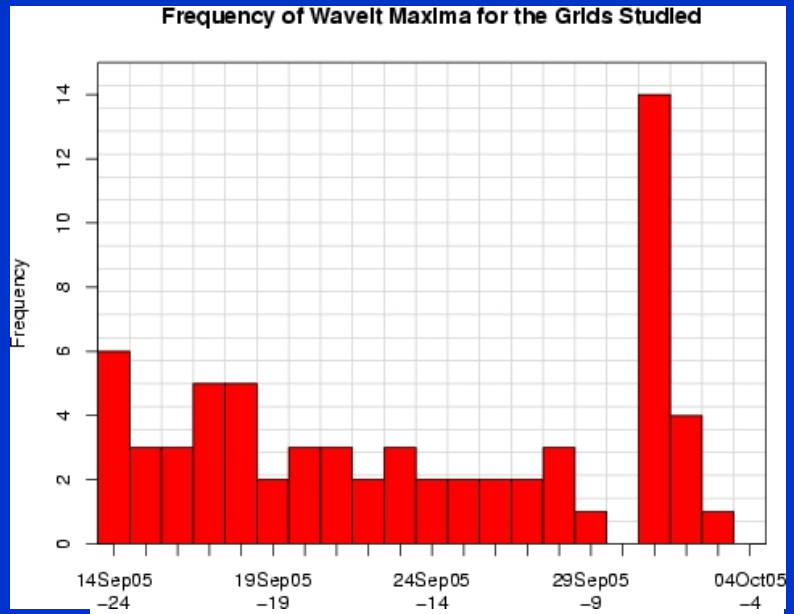




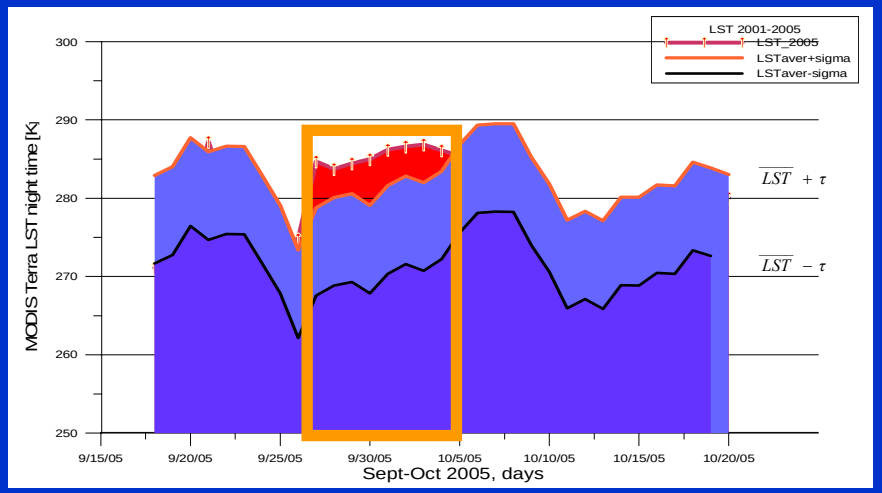
M 7.6 – Kashmir /PAKISTAN, 2005, October 8 03:50:40 UTC

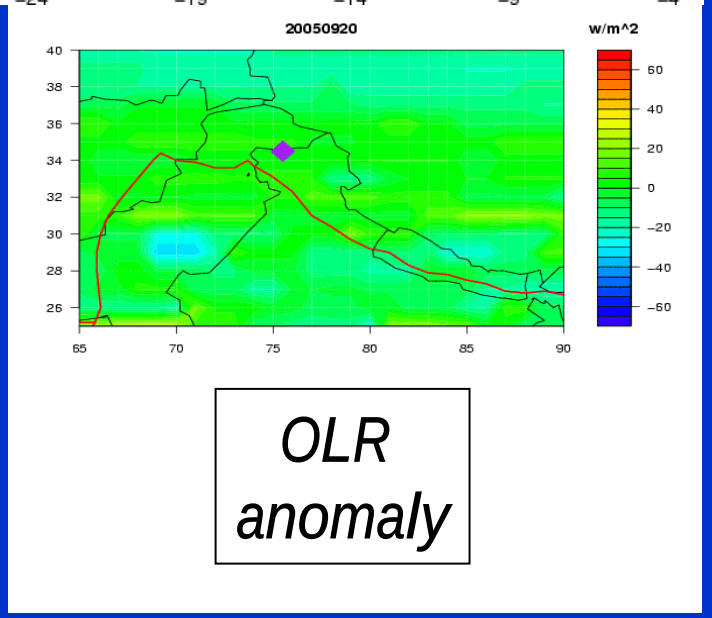
SLHF anomaly





TIR anomaly



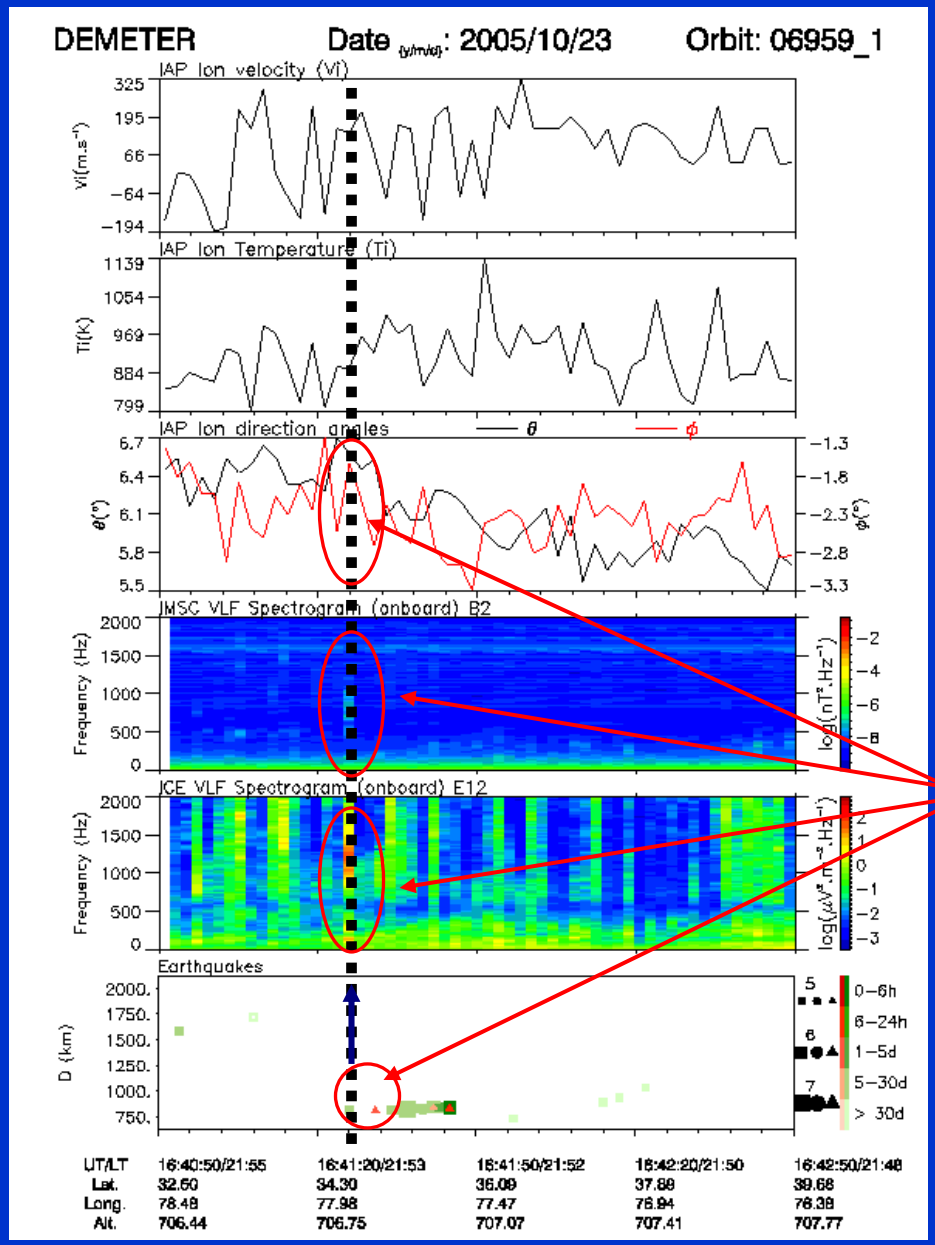


OLR anomaly

Examples of ionospheric perturbations in possible correlation with Kashmir earthquake , 10.23.2005, M6.0

DEMETER

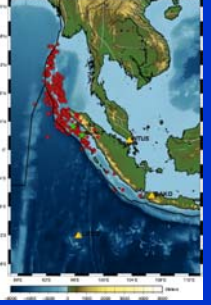
Kashmir,
Oct 23, 2005
M=6.0
Lat=34.88N
Lon=73.4E
15:04 GMT

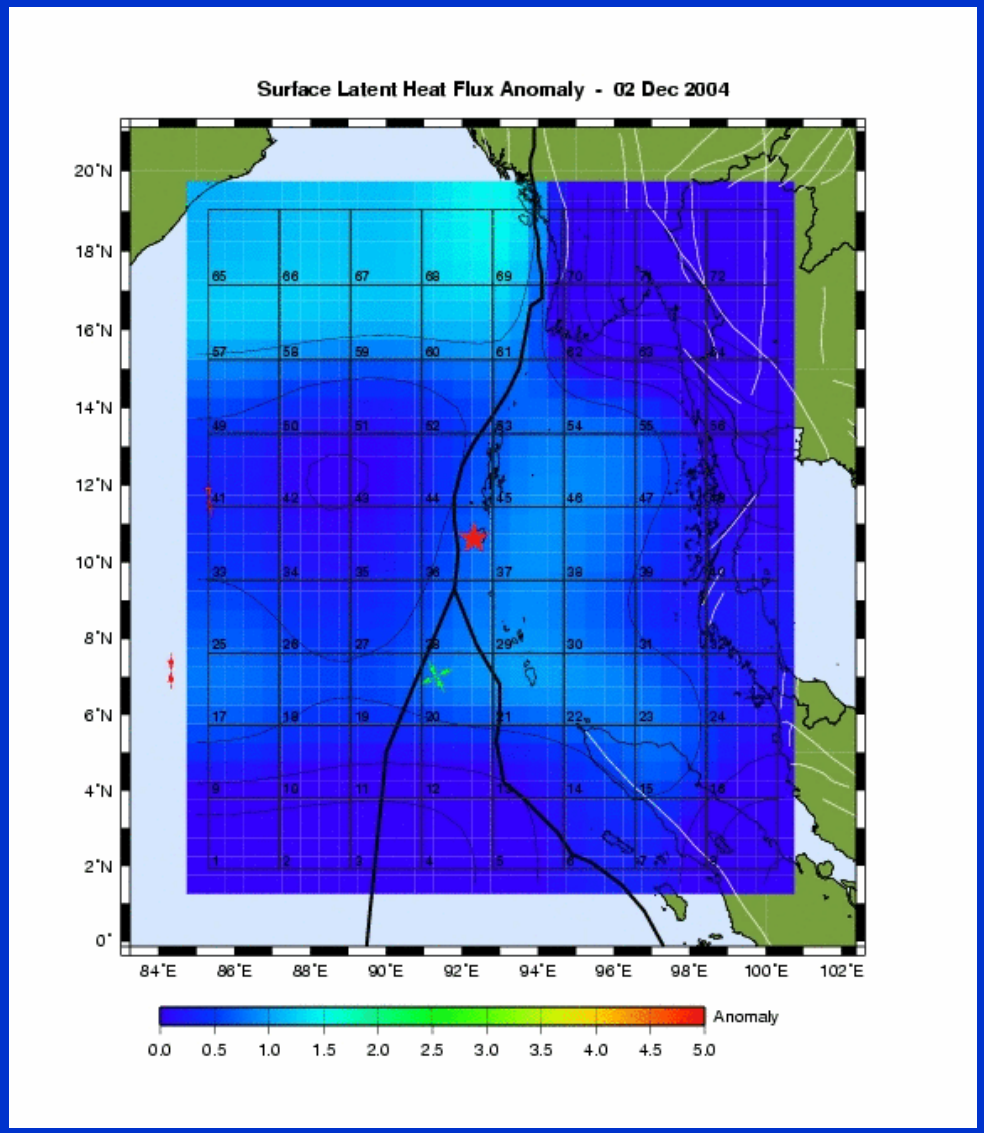


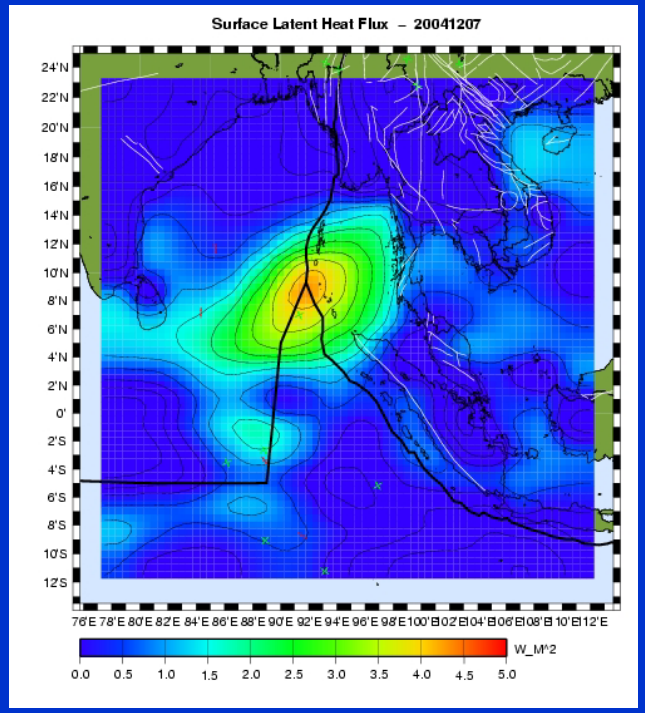
One hour before the quake

Ouzounov et al. 2006

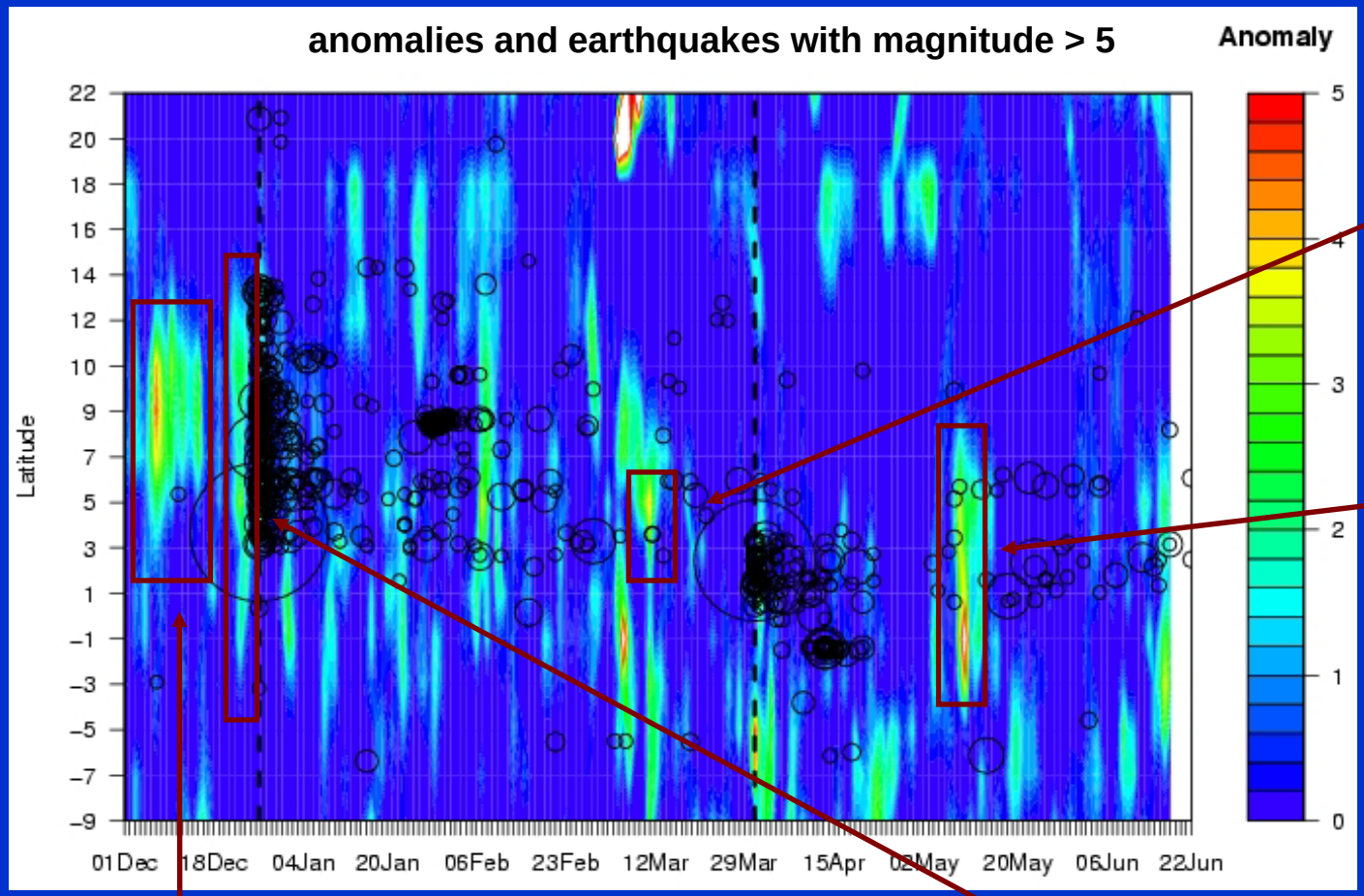
Northern Sumatra, Dec 26, 2004







Joint EM Analysis



- Large Anomaly
- ~ 4 Days from 3-7-05

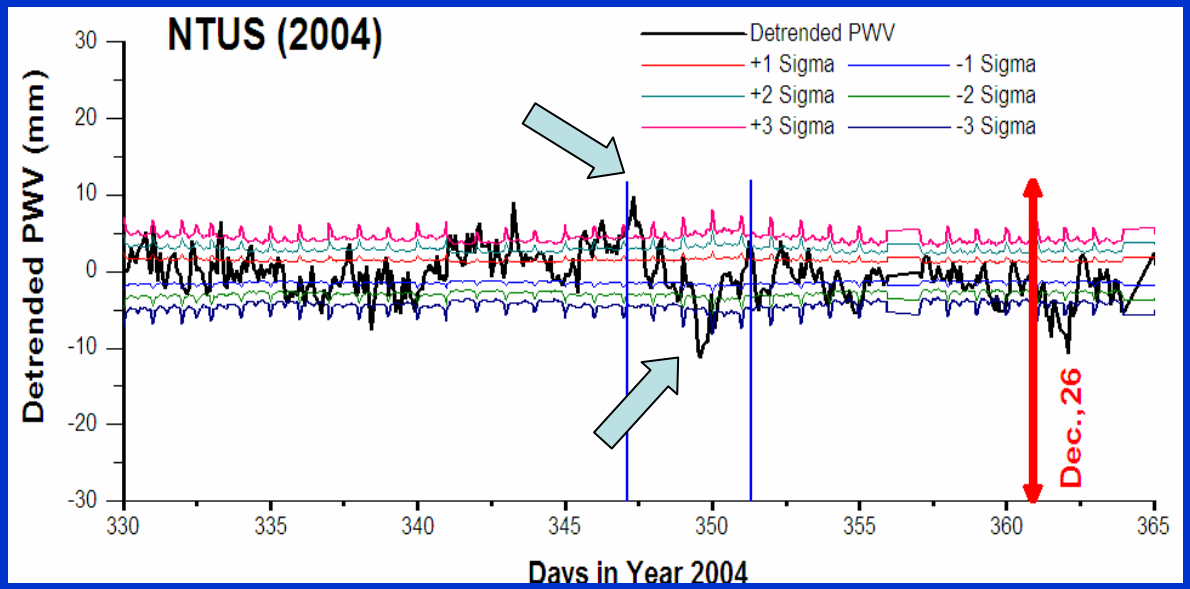
- Large Anomaly
- ~ 3 Days from 5-9-05

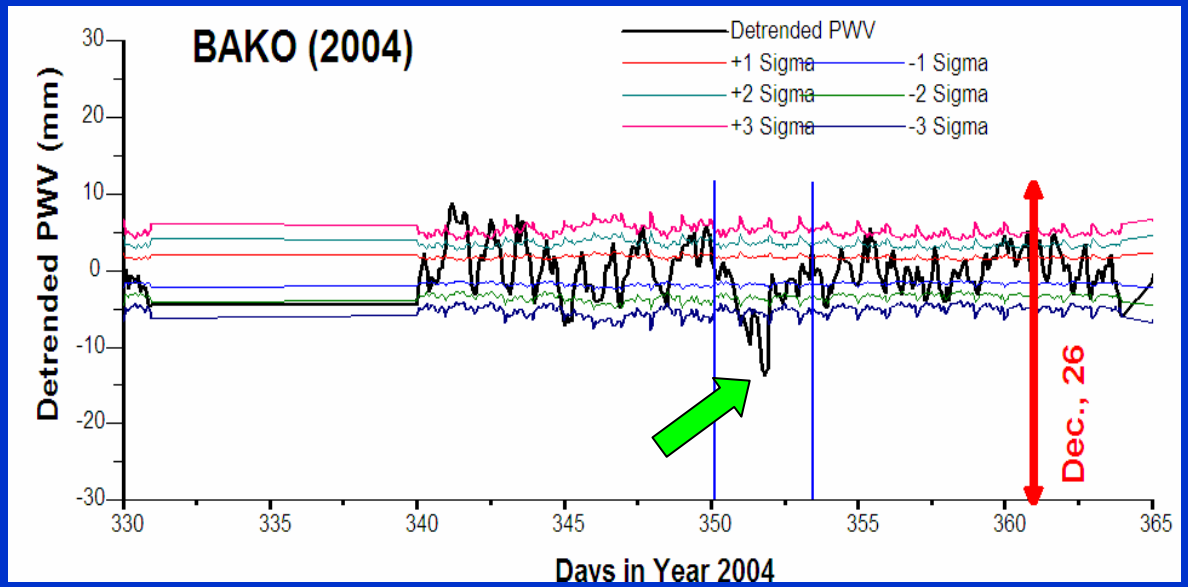
- Largest Anomaly
- Highest Value Center of Fracture Zone
- ~ 14 Days From 12-07-04

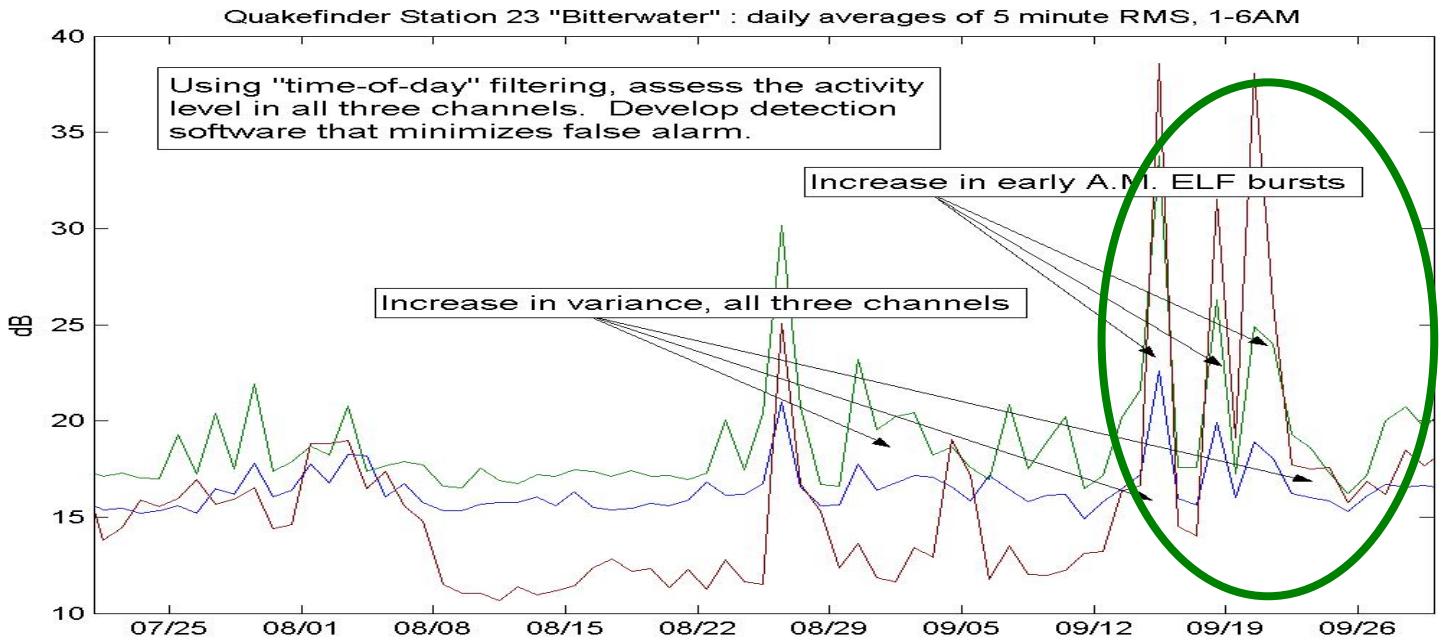
- Smaller Anomaly
- Highest Value at Epicenter
- ~ 2 Days from 12-22-04

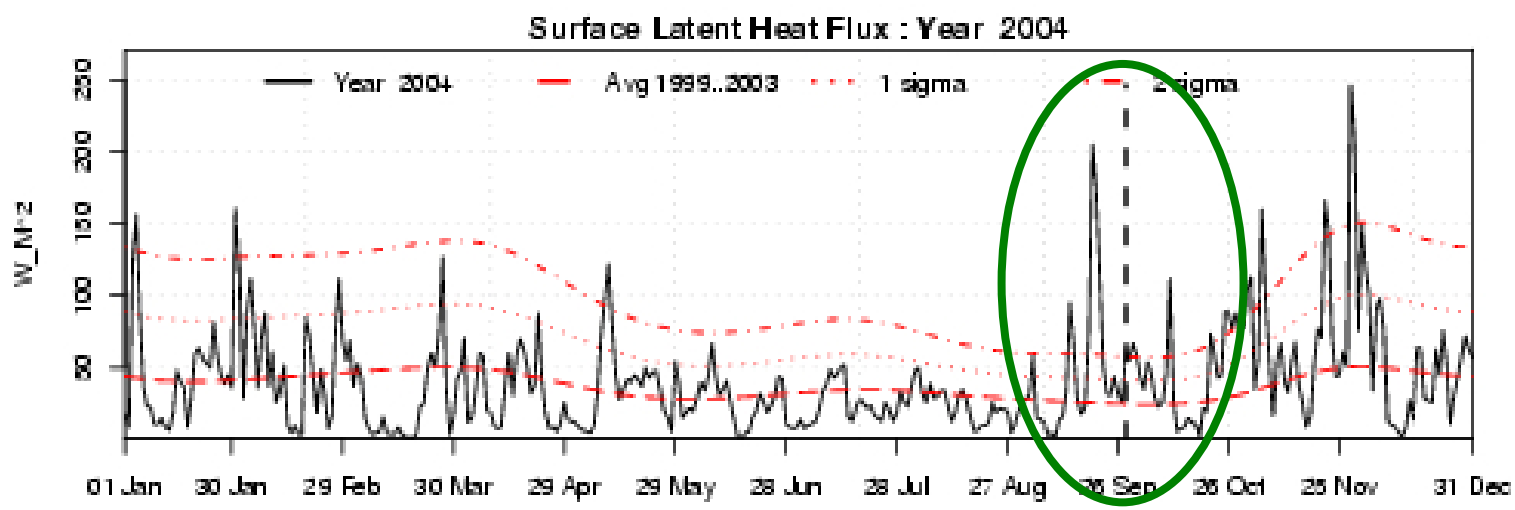
Sumatra Earthquake: Dec. 26, 2004

GPS Precipitable Water Vapor (mm): hourly

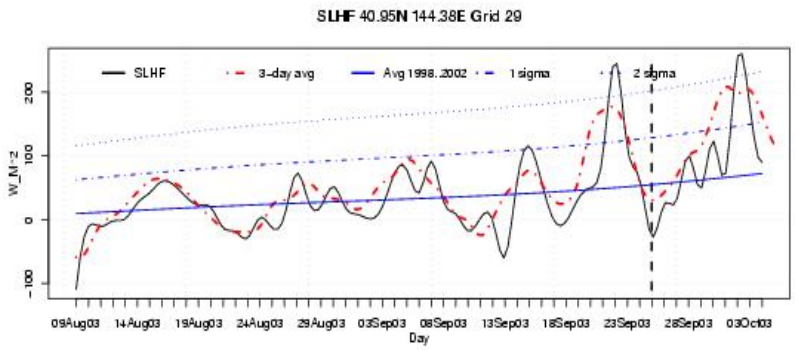




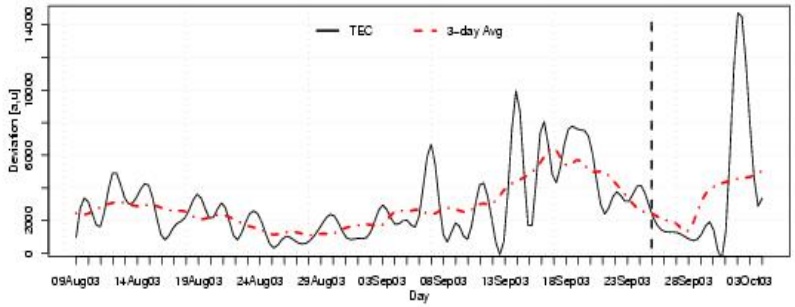

Quakefinder Station 23 "Bitterwater" : daily averages of 5 minute RMS, 1-6AM
Using "time-of-day" filtering, assess the activity level in all three channels. Develop detection software that minimizes false alarm.
Increase in early A.M. ELF bursts
Increase in variance, all three channels
dB
40
35
30
25
20
15
10
07/25
08/01
08/08
08/15
08/22
08/29
09/05
09/12
09/19
09/26


Surface Latent Heat Flux : Year 2004
Year 2004
Avg 1999..2003
1 sigma
2 sigma
W_M^2
250
200
150
100
50
01 Jan
30 Jan
29 Feb
30 Mar
29 Apr
29 May
28 Jun
28 Jul
27 Aug
26 Sep
26 Oct
25 Nov
31 Dec

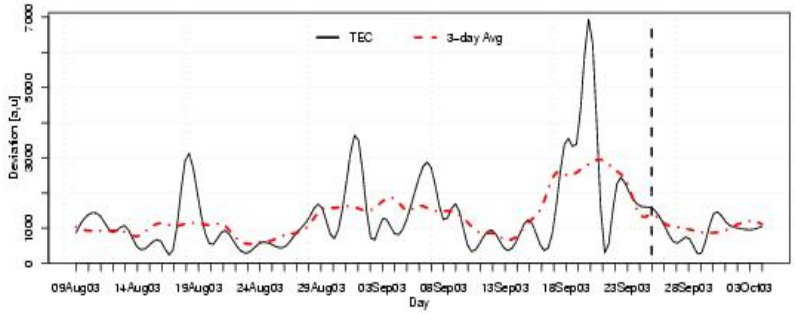
25 Sep 2003 41.815N 143.910E Mw=8.3 27 TOKACHI, JAPAN

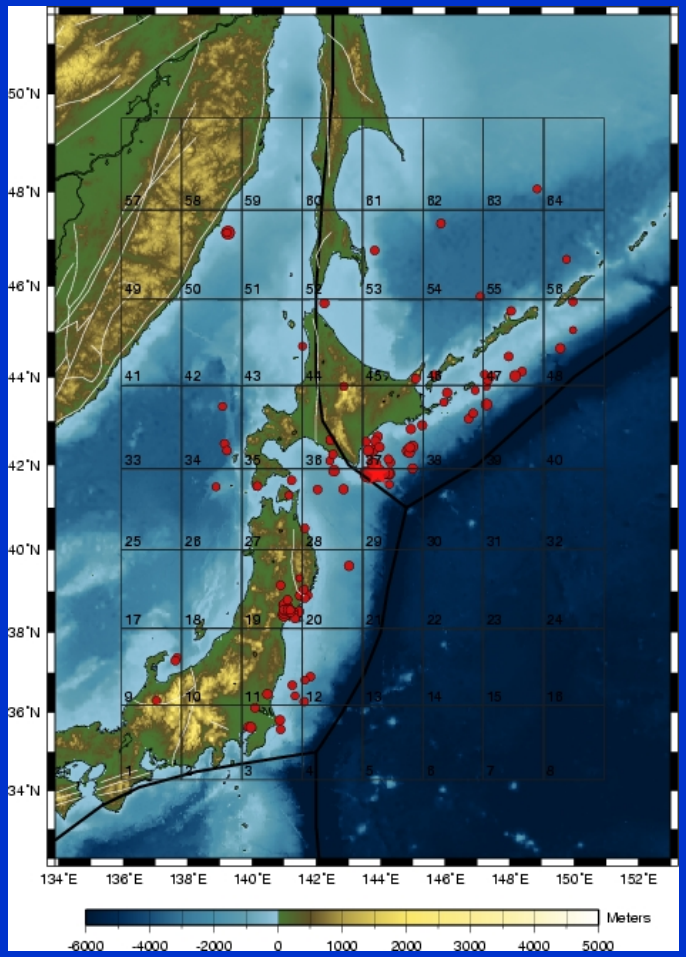


Night Time EM Variations Hokkaido



Night Time EM Variations Kamchatka





Cervone et al., 2006

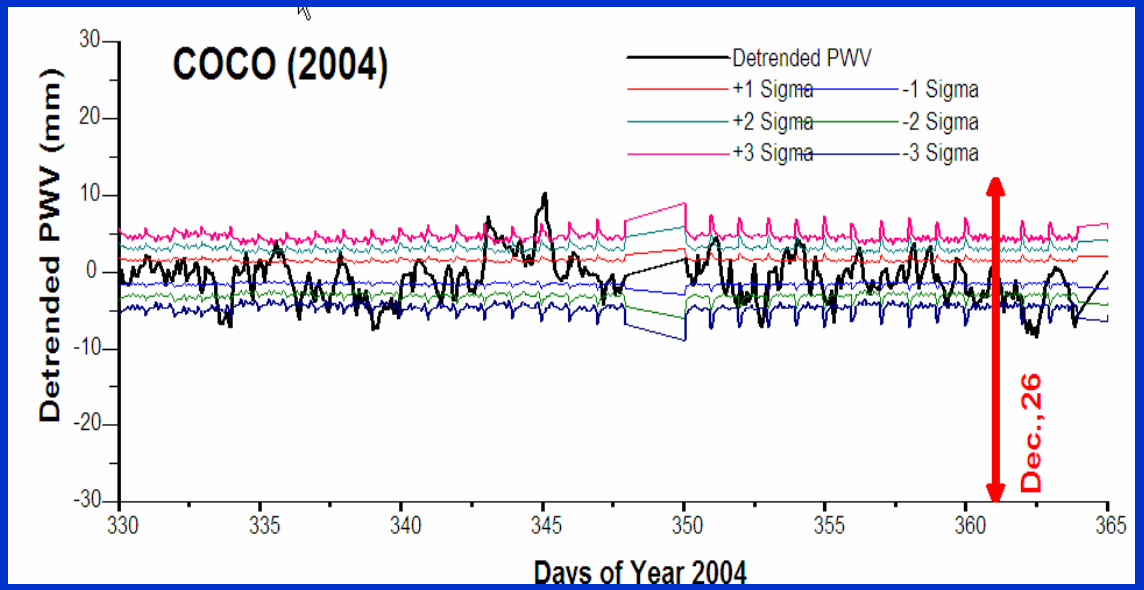
CQuake

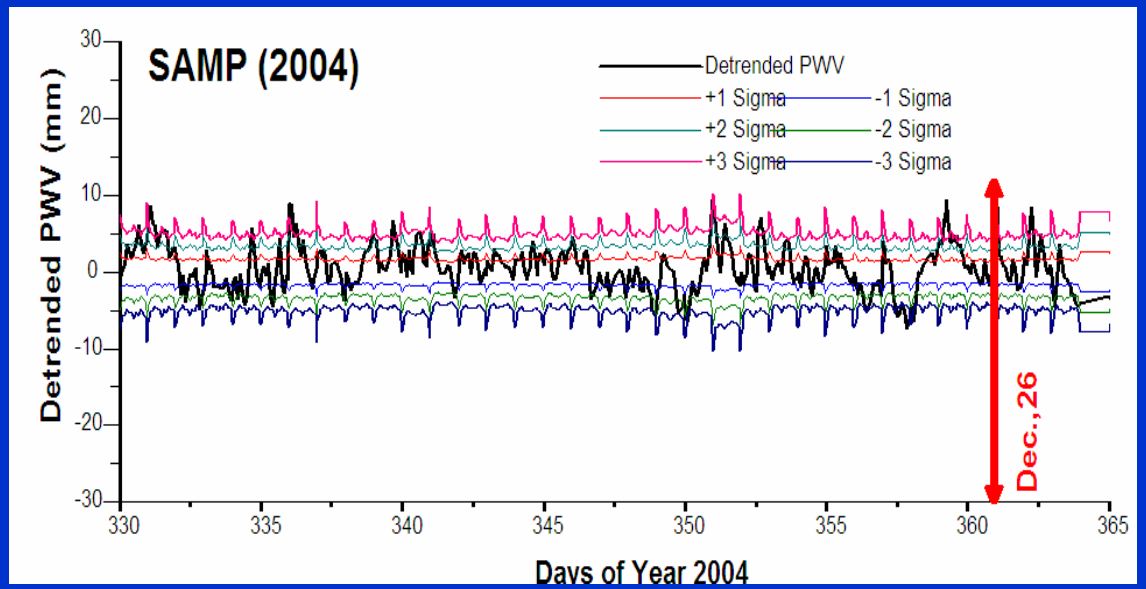
- http://crete.gmu.edu/cquake
- 3000 earthquakes analized since November 2004
- Results usually available 30 minutes after each event

Conclusion

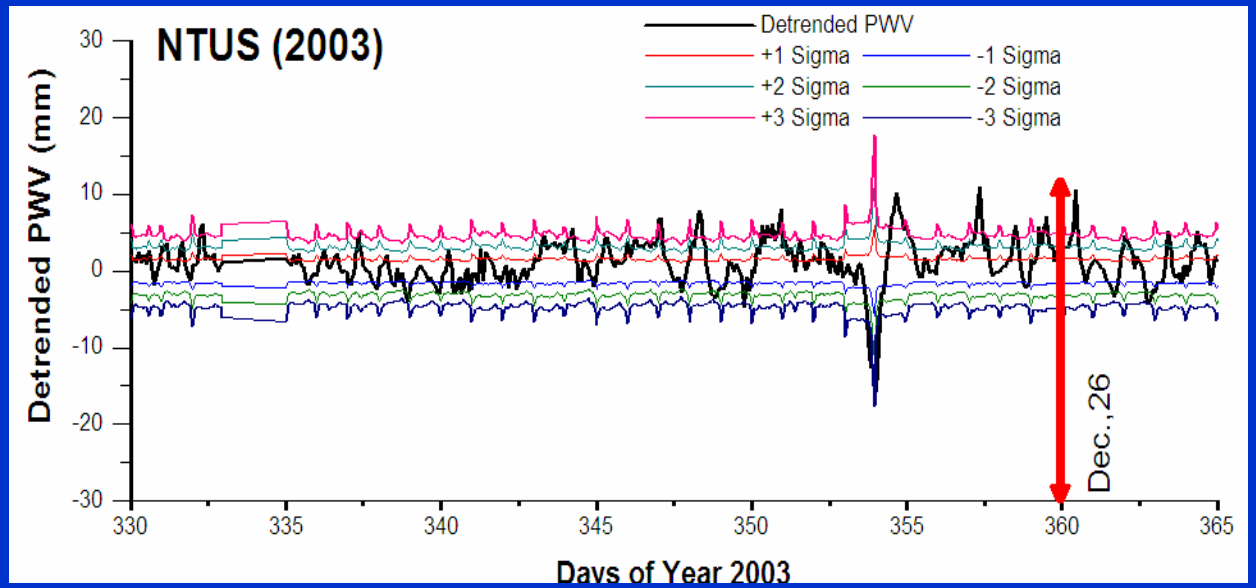
- **Satellite data shows promising results for Earthquake Precursors, in spite of numerous limitations.**

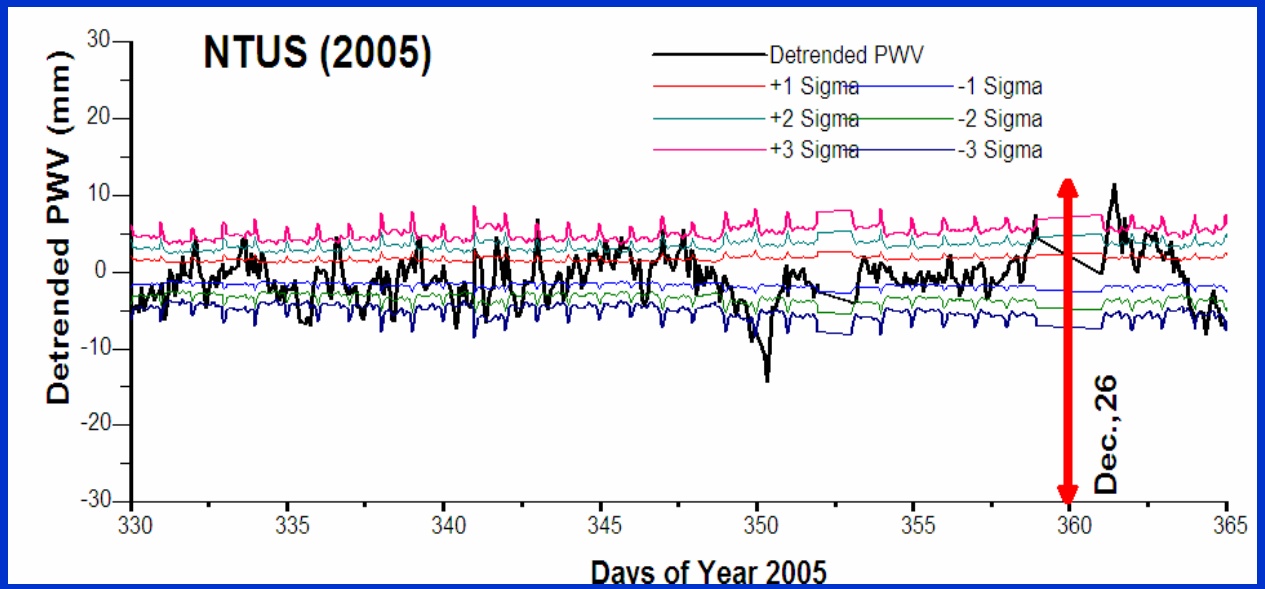
- **It is believed that with the GEOSS (Global Earth Observation System of Systems will provide a new insights in Early Warning to Earthquake community**


COCO (2004)
Detrended PWV
+1 Sigma
-1 Sigma
+2 Sigma
-2 Sigma
+3 Sigma
-3 Sigma
Dec.,26
Detrended PWV (mm)
Days of Year 2004
30
20
10
0
-10
-20
-30
330
335
340
345
350
355
360
365

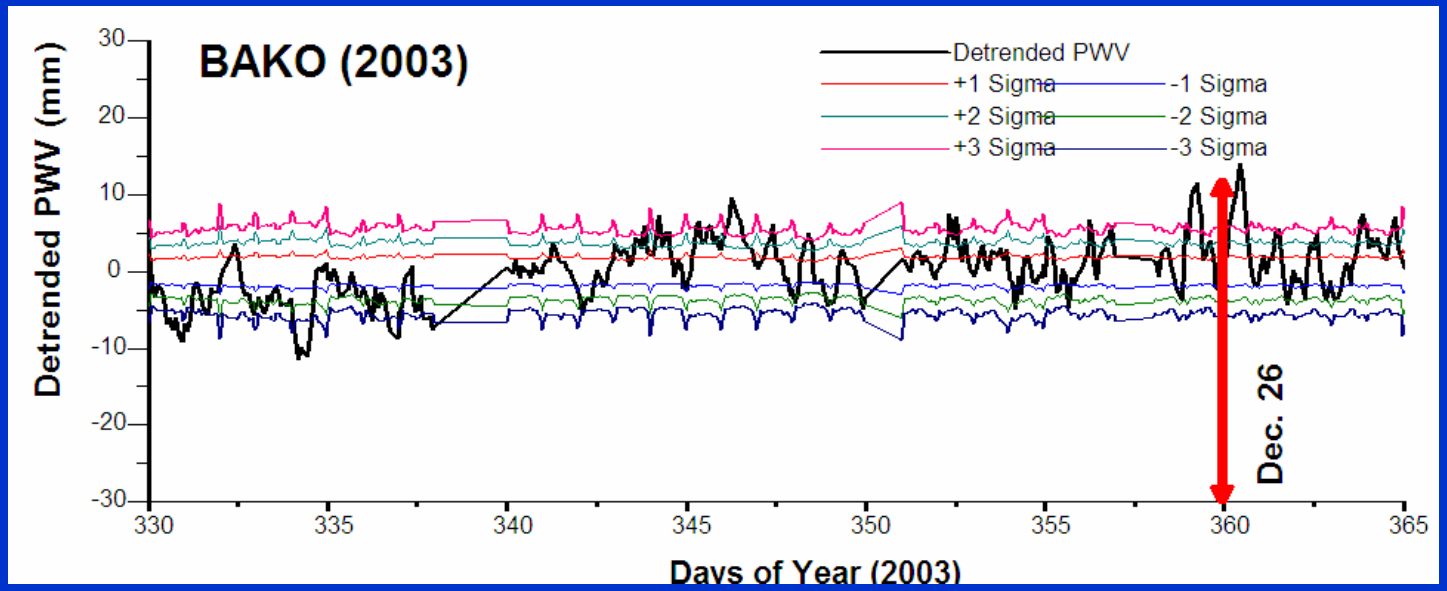

SAMP (2004)
Detrended PWV
+1 Sigma
-1 Sigma
+2 Sigma
-2 Sigma
+3 Sigma
-3 Sigma
Dec.,26
Detrended PWV (mm)
Days of Year 2004
30
20
10
0
-10
-20
-30
330
335
340
345
350
355
360
365

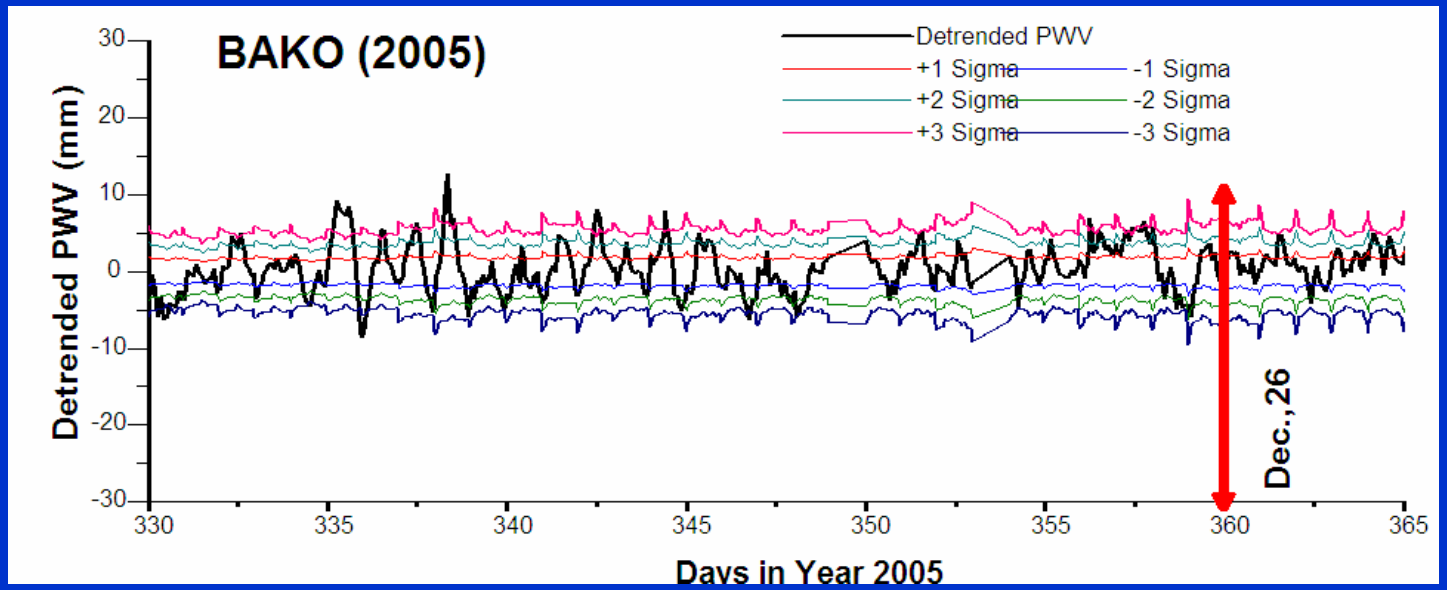
Comparison with other years, NTUS (2003 and 2004)

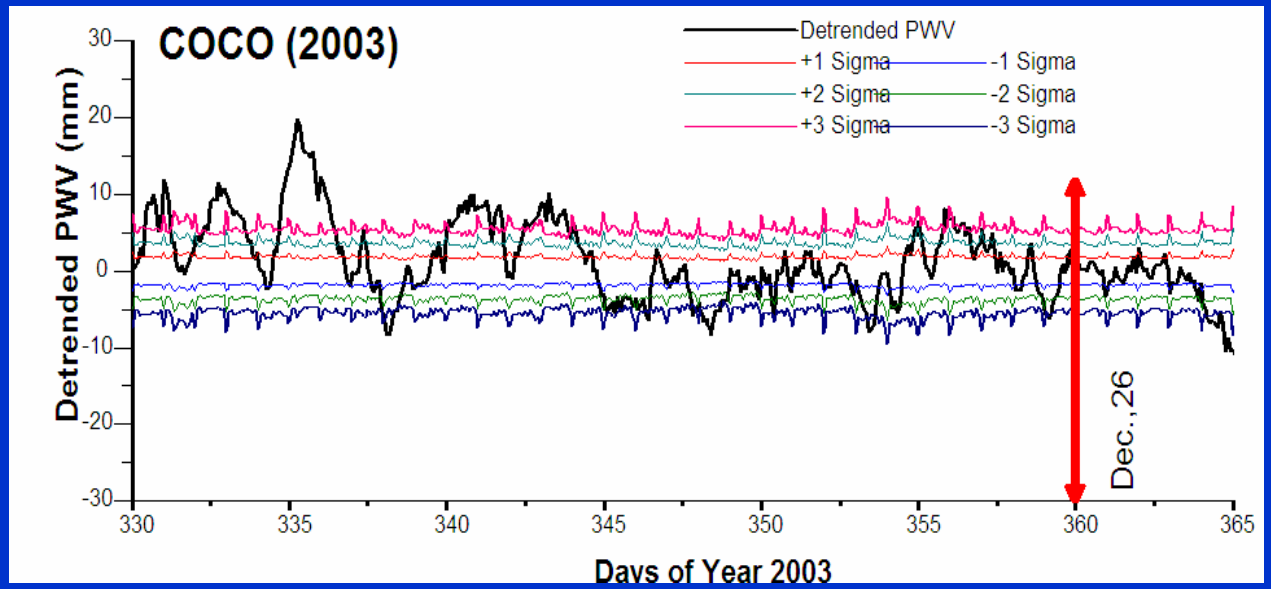


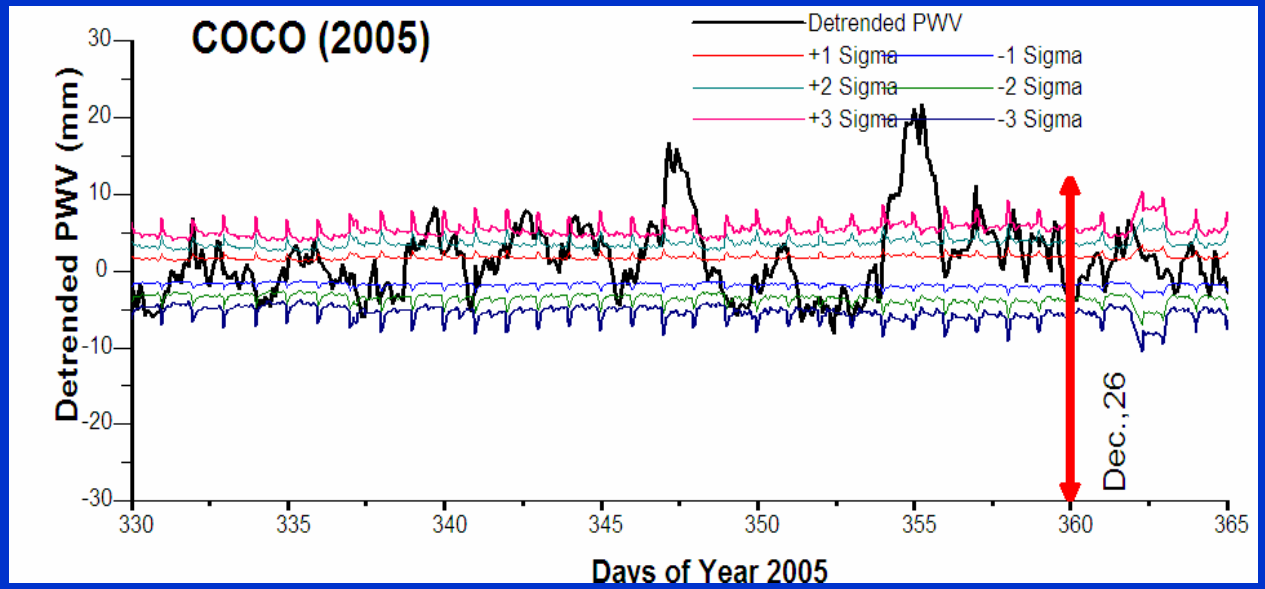


Comparison with other years BAKO (2003 and 2004)






COCO (2003)
Detrended PWV
+1 Sigma
-1 Sigma
+2 Sigma
-2 Sigma
+3 Sigma
-3 Sigma
Detrended PWV (mm)
30
20
10
0
-10
-20
-30
330
335
340
345
350
355
360
365
Dec.,26
Days of Year 2003


COCO (2005)
Detrended PWV
+1 Sigma
-1 Sigma
+2 Sigma
-2 Sigma
+3 Sigma
-3 Sigma
Detrended PWV (mm)
30
20
10
0
-10
-20
-30
330
335
340
345
350
355
360
365
Dec.,26
Days of Year 2005