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

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Possible earthquake precursors

Current studies of electromagnetic methods for short-term EQ prediction.

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)
Ouzounov and Freund, 2004

LST Anomaly [°C]

LST
LST Running average

Bhuj 01.26.2001 Earthquake (Gujarat, India)
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)

Radon Data in Soil-gas and Groundwater for Bhuj Earthquake

(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

Singh et al., 2001, 2006


Jan 18, 2001, Jan 26, 2001, Feb 3, 2001
TEC GPS data and MODIS LST for Gujarat, Jan 2001

December 2000 - January 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
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
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)*
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

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

Ouzounov et al. 2006
Northern Sumatra, Dec 26, 2004

Surface Latent Heat Flux Anomaly - 02 Dec 2004

Anomaly

0.0  0.5  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0
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

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

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

Joint EM Analysis
Sumatra Earthquake: Dec. 26, 2004

GPS Precipitable Water Vapor (mm): hourly
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
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 analyzed 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
Comparison with other years, NTUS (2003 and 2004)
Comparison with other years BAKO (2003 and 2004)