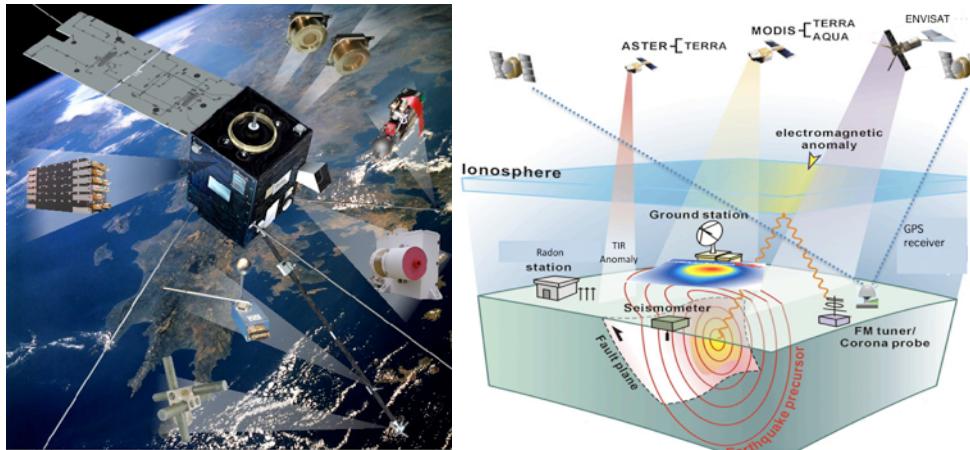


# *Space-borne and Ground Observations of Ionospheric/ Atmospheric Signals Associated with Major Earthquakes*

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<sup>4</sup>*Institute of Applied Geophysics, Rostokinskaya str., 9, Moscow, 129128, Russia*

<sup>5</sup>*National Central University, Chung-Li, Taiwan*

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<sup>7</sup>*Democritus University of Thrace, Greece*

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2. Statistical studies of atmospheric earthquake precursors-Greece, Taiwan and Japan
3. Case studies
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  - M6.7, L'Aquila, April 6<sup>th</sup>, 2009, Italy
  - M9.0, Great Tohoku Earthquake, March 11<sup>th</sup>, 2011, Japan
5. Summary

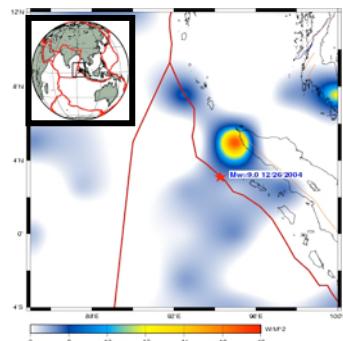
# Where we are now

*Methodology of the precursory signals we are investigating*

*Understanding the relationship ship between several Geophysical signature*

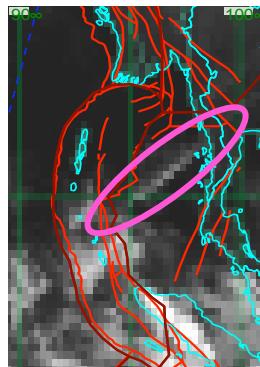
## Thermal infrared

NOAA/AVHRR,AQUA/AIRS OLR



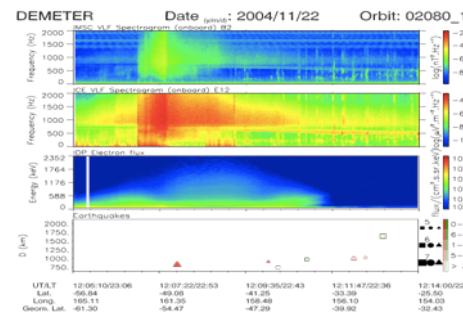
## Clouds information

MODIS, GOES, METEOSAT

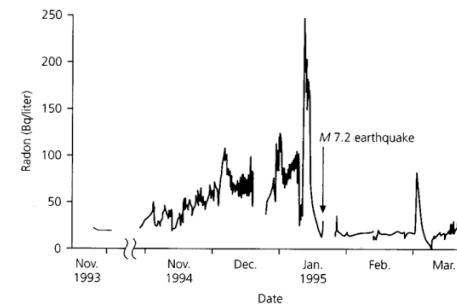


## Ionospheric variability

DMSP,DEMETER

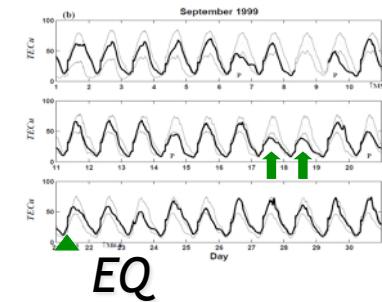


## Radon/ Gas variations



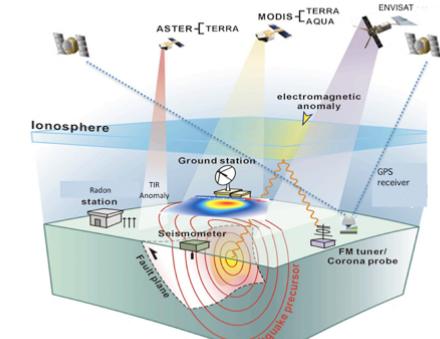
## Total Electron Content

GPS, COSMIC

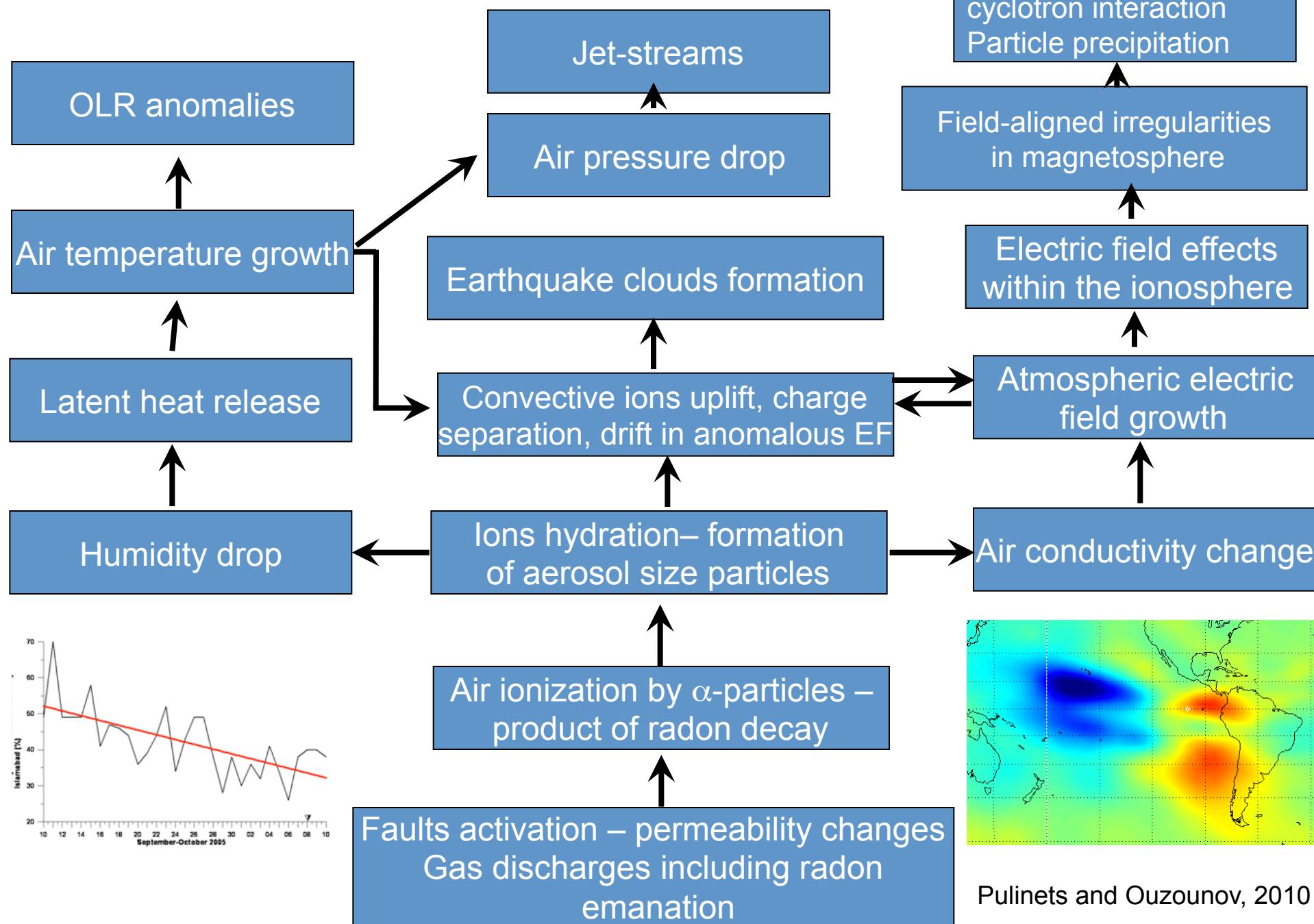


## Data Integration

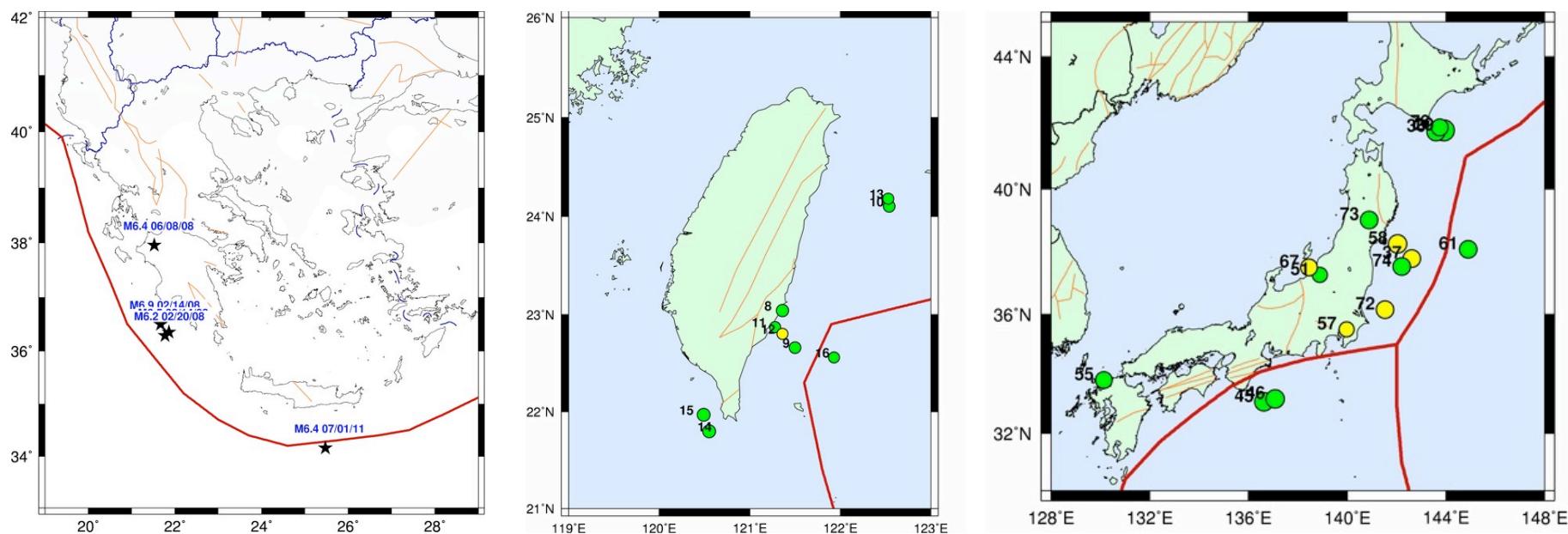
Sensor Web



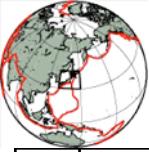
# Schematic presentation of the LAIC model



# *Statistical studies of Atmospheric precursors. Data Selection Greece, Taiwan and Japan*

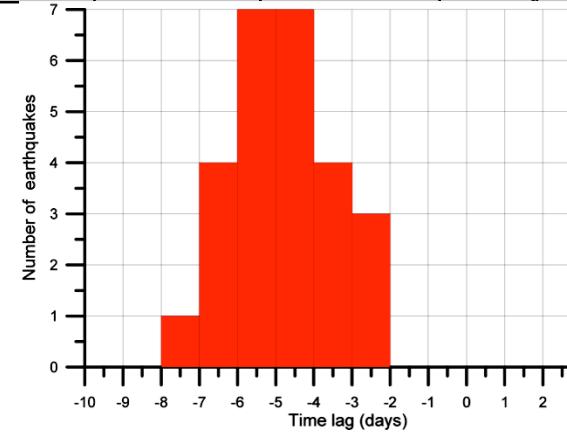
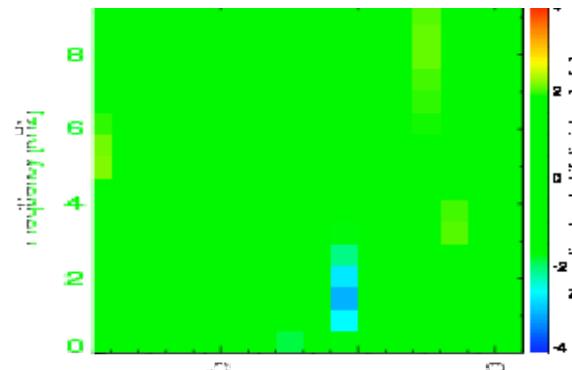
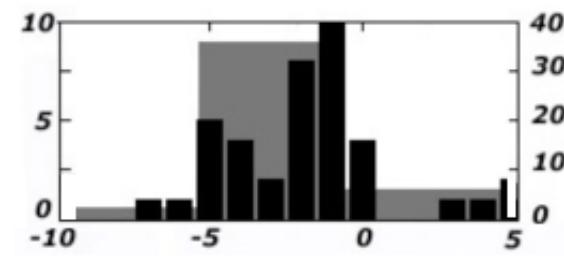


*2003-2009 – 6 major events in Greece, 9 in Taiwan, 15 in Japan and most recent 2009-2010 earthquakes been selected - total of 30 earthquakes (M>5.9)*



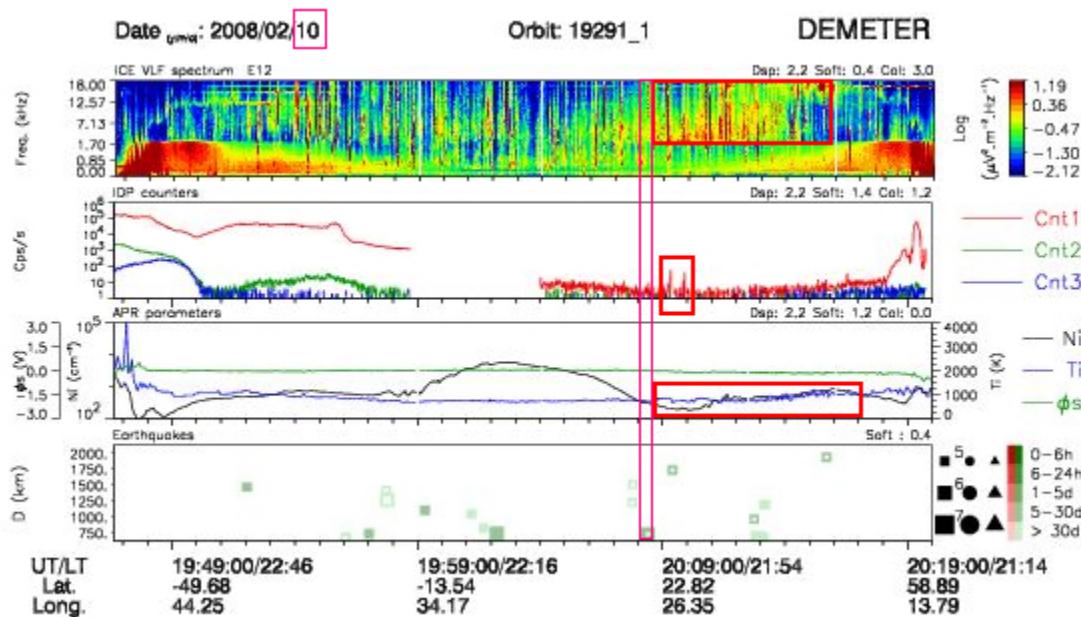
# Cross-validation of earthquake related signals

#	Catalog #	Region	Date	Lat	Lon	M	Depth	L/W	OLR [days]	Rn [days]	AirTemp [days]	GPS/TEC [days]	DEMETER
1	47	Japan	2004/9/5	33.18	137.07	7.4	10	Water	-4	-4		-3	
2	51	Japan	2004/10/27	37.28	138.88	6	14	Land	-3	-3		-2	
3	56	Japan	2005/3/20	33.81	130.13	6.6	10	Water	-5	-5		-4	
4	58	Japan	2005/7/23	35.5	139.98	5.9	61	Water	-4	-4		-4	
5	68	Japan	2007/7/16	37.53	138.45	6.6	12	Water	-4	-4		-4	- 12 hours
6	14	Taiwan	2006/12/26	21.8	120.55	7.1	10	Water	-5			-2	- 10 hours
7	15	Taiwan	2006/12/26	21.97	120.49	6.9	10	Water	-5			-2	- 10 hours
8	1	Italy	2009/04/06	42.42	13.39	6.3	10	Land	-3	-7/-1	-3/-1	-1	
9	2	Samoa	2009/09/29	-15.5	172.0	8	18	Water	-4		-	-4	-4, 3, 1 days
10		Haiti	2010/01/12	18.5	-72.5	7.0	13	Land	-4			-1	-3 days

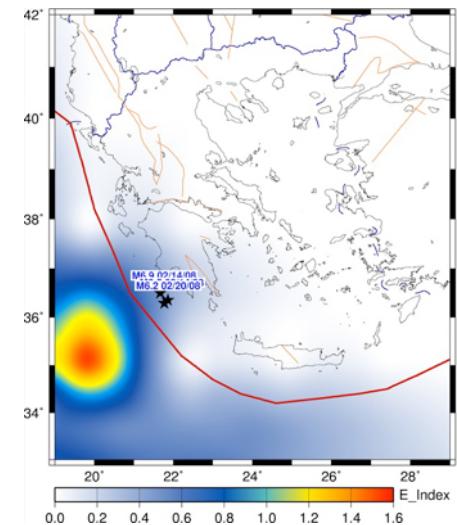


A. GPS/TEC over Taiwan (1996-2000) show a systematic TEC enhancement 2-5 days in advance (Liu et al., 2003); B. DEMETER data electric field in the VLF range (1-10 KHz) showing a systematic decrease of the intensity during nighttime, 4-6 hours prior to 9000 earthquakes of ( $M > 5$ ) for period 2004-2011, (Pisa et al, 2011); and C. Thermal radiation for  $M > 5.9$  (2003-2008) over Japan and Taiwan. (Ouzounov et al., 2009)

# Atmospheric Processes Associated with some of Greece Earthquakes

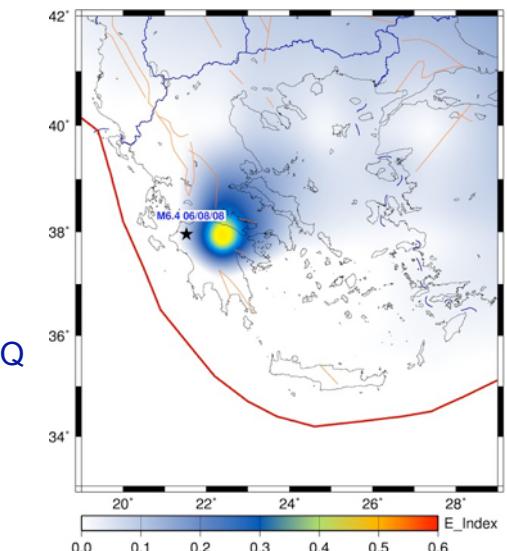
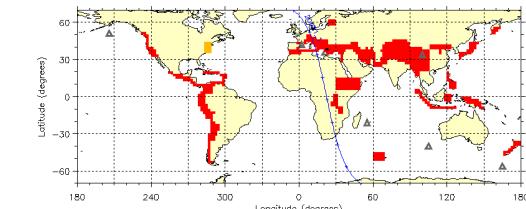
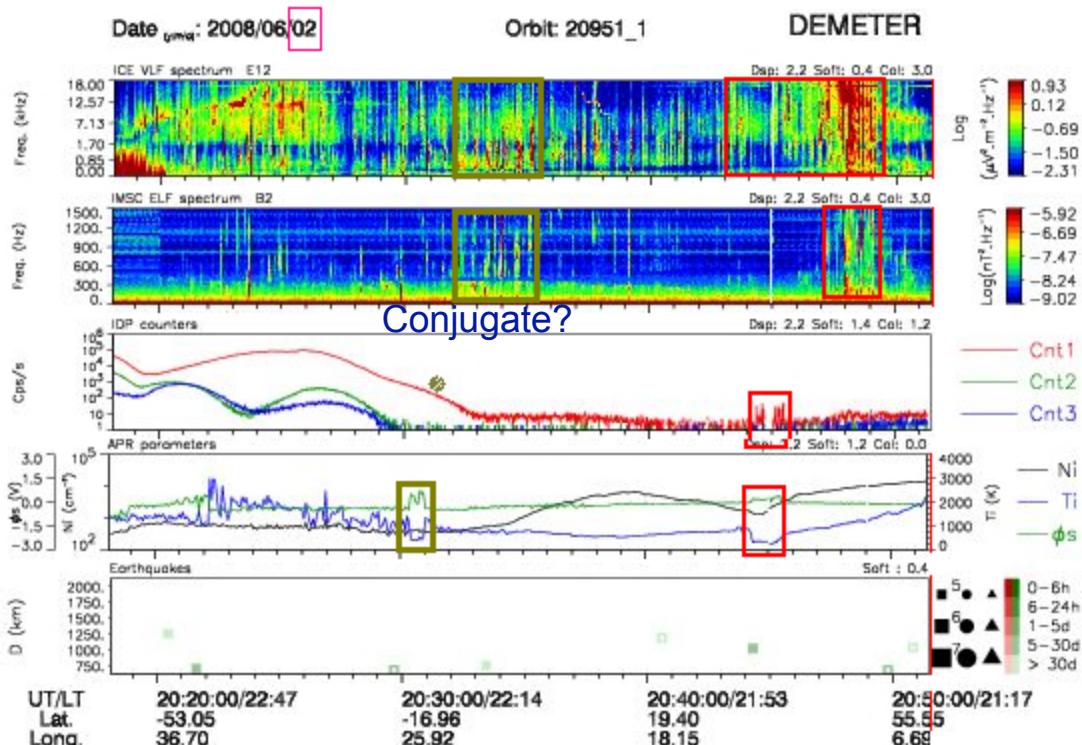


OLR anomaly  
-2 days



- |                                    |                    |             |                  |
|------------------------------------|--------------------|-------------|------------------|
| <b>1. Methoni</b>                  | <b>2008-02-14,</b> | <b>6.7,</b> | <b>(Med.Sea)</b> |
| <b>2. Andravida (Peloponnisos)</b> | <b>2008-06-08,</b> | <b>6.5,</b> | <b>(Land)</b>    |
| <b>3. Kythira</b>                  | <b>2006-01-08,</b> | <b>6.8,</b> | <b>(Med.Sea)</b> |

# Atmospheric Processes Associated with some of Greece Earthquakes



1. Methoni

2008-02-14,

6.7,

(Med.Sea) OLR anomaly  
-3 days

2. Andravida (Peloponnisos)

2008-06-08,

6.5,

(Land)

3. Kythira

2006-01-08,

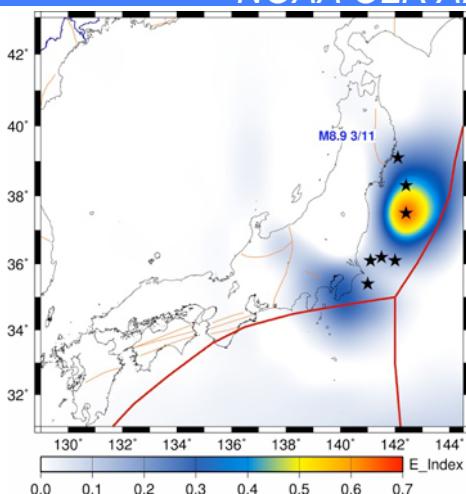
6.8,

(Med.Sea)

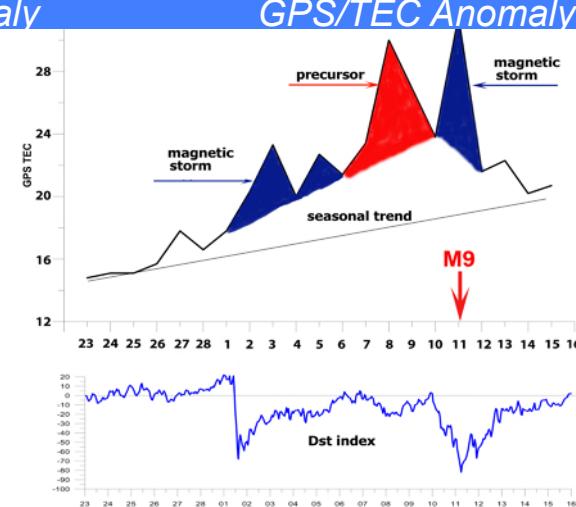


# The Atmospheric-Ionospheric Response to M9 Tohoku Earthquake Revealed by Joined Satellite and Ground Observations

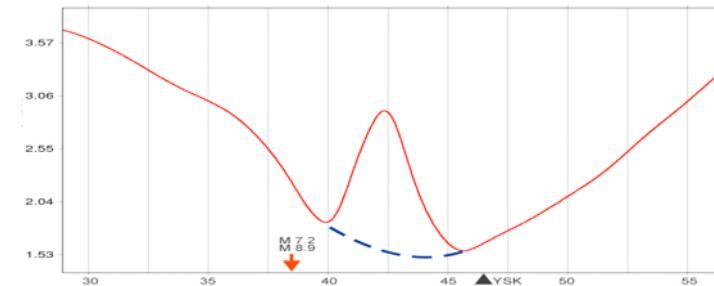
NOAA OLR Anomaly



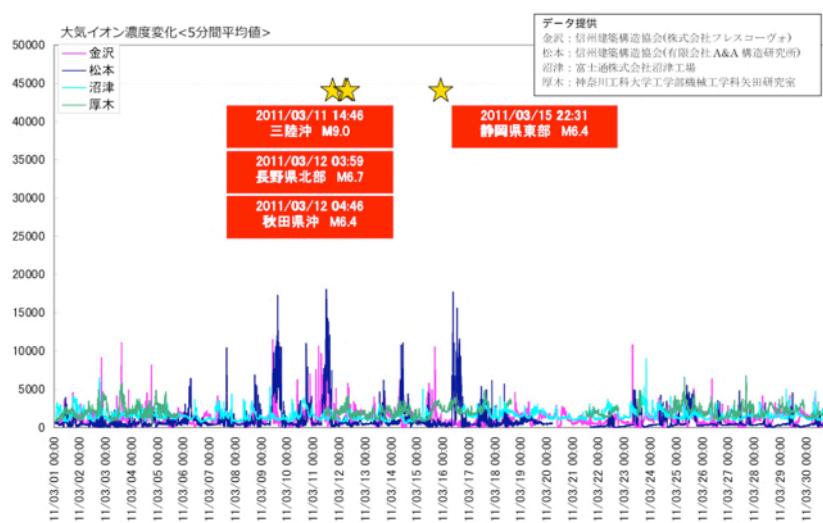
GPS/TEC Anomaly



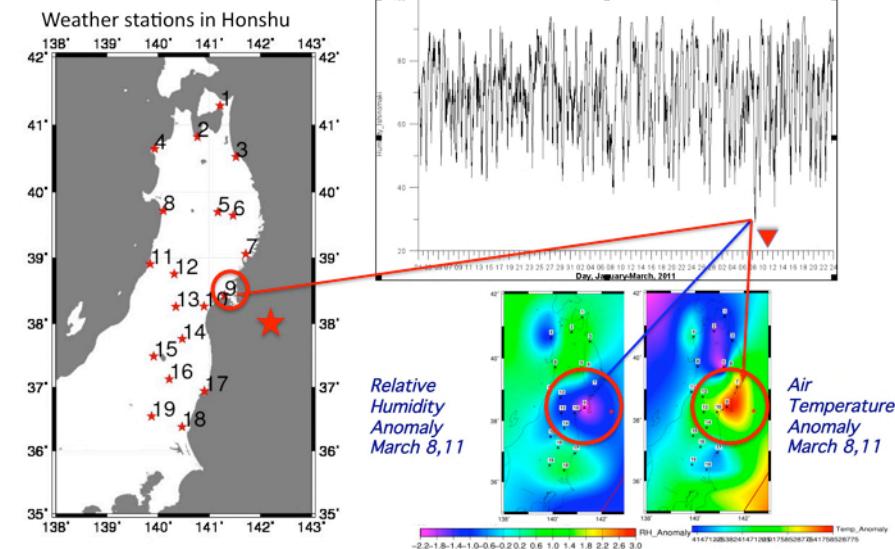
LEO tomography



Ion Content (E-Pisco)

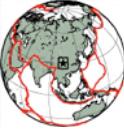


Air Temperature/Humidity Ouzounov et al, 2011



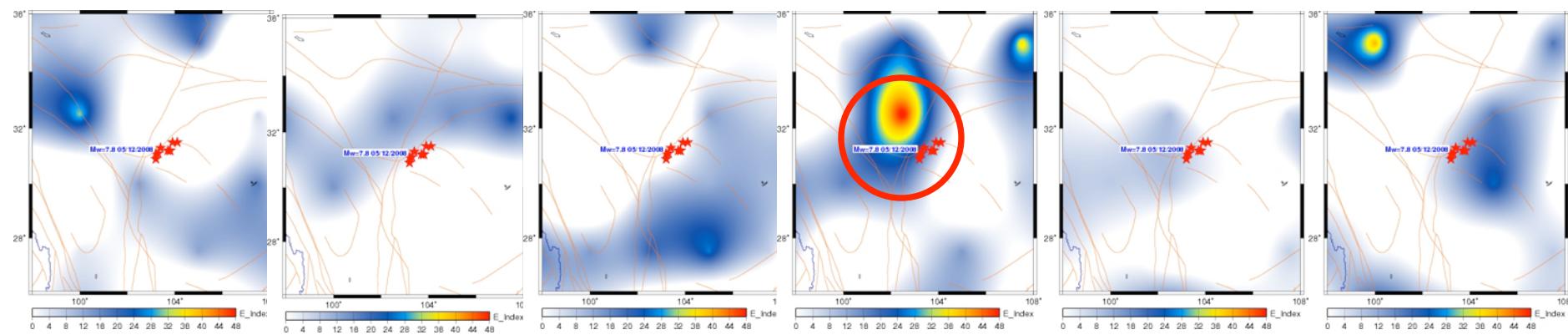
2<sup>nd</sup> DEMETER workshop, Oct 10-12, 2011, Paris



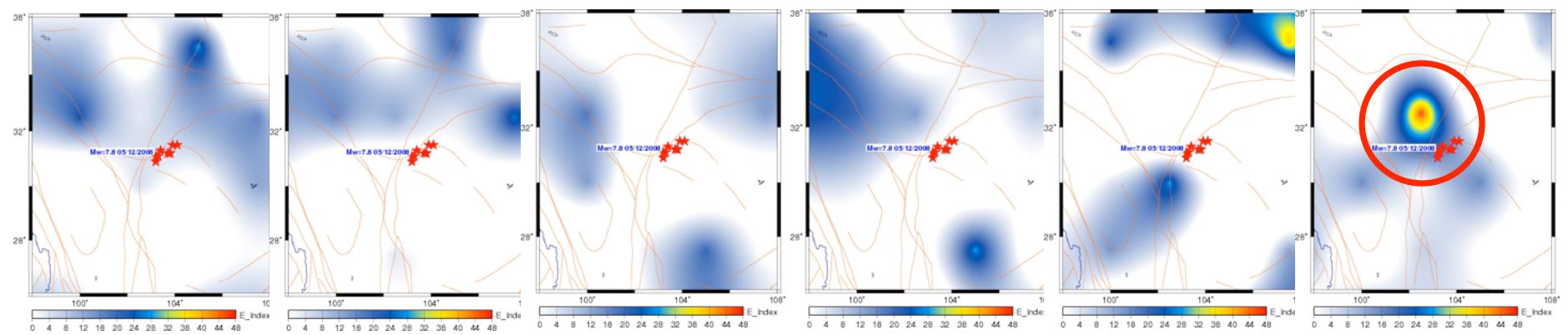


# M7.9 Wenchuan Earthquake, China 2008 Hot-spot alerts around M7.9 Thermal Infrared maps of daily night-time earth outgoing radiation over epicenter of M7.8 Eastern Sichuan, China May 3- May 14, 2008,

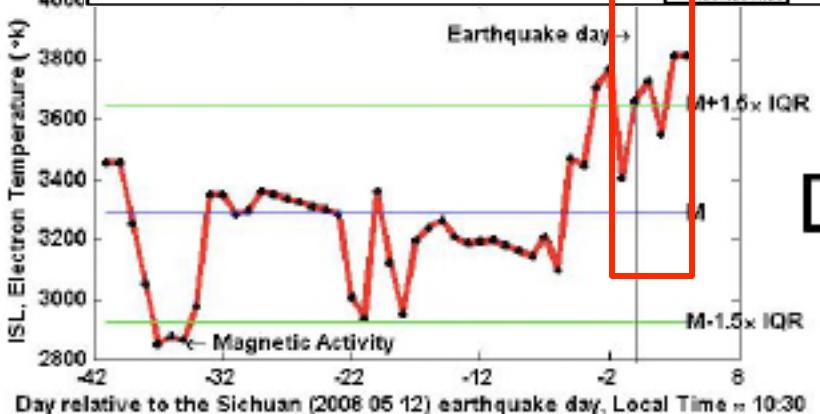
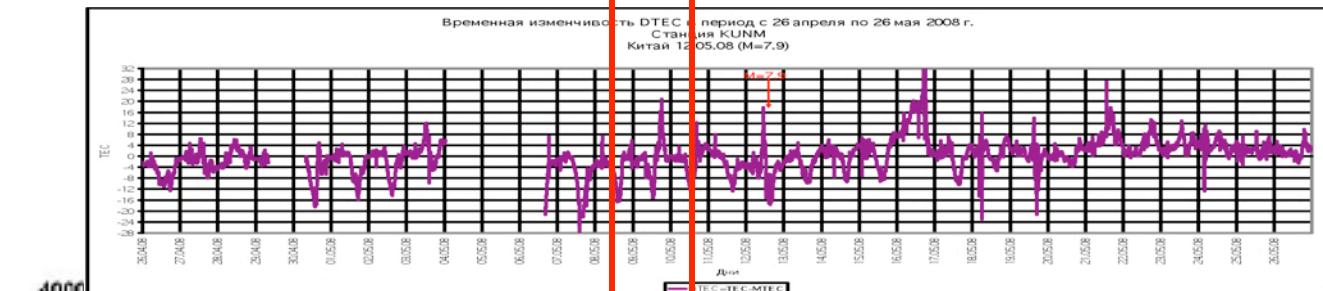
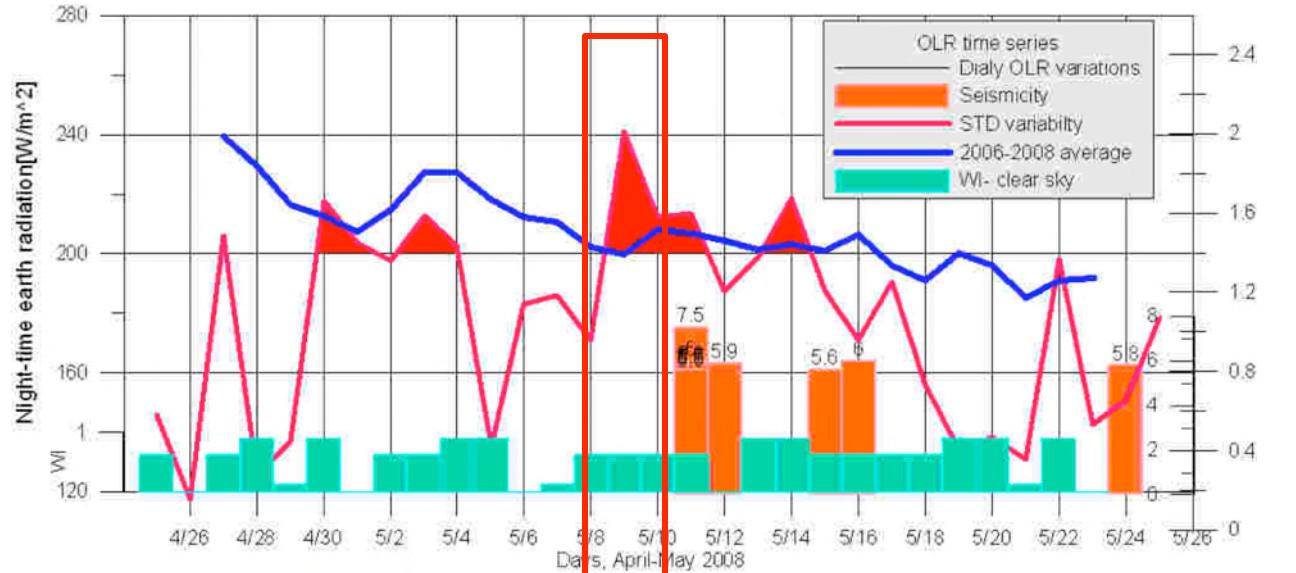
03 May            04 May            05 May            06 May            07 May            08 May



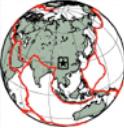
09 May            10 May            11 May            12 May            13 May            14 May



# OLR Time series, GPS/TEC and DEMETER electron density profile

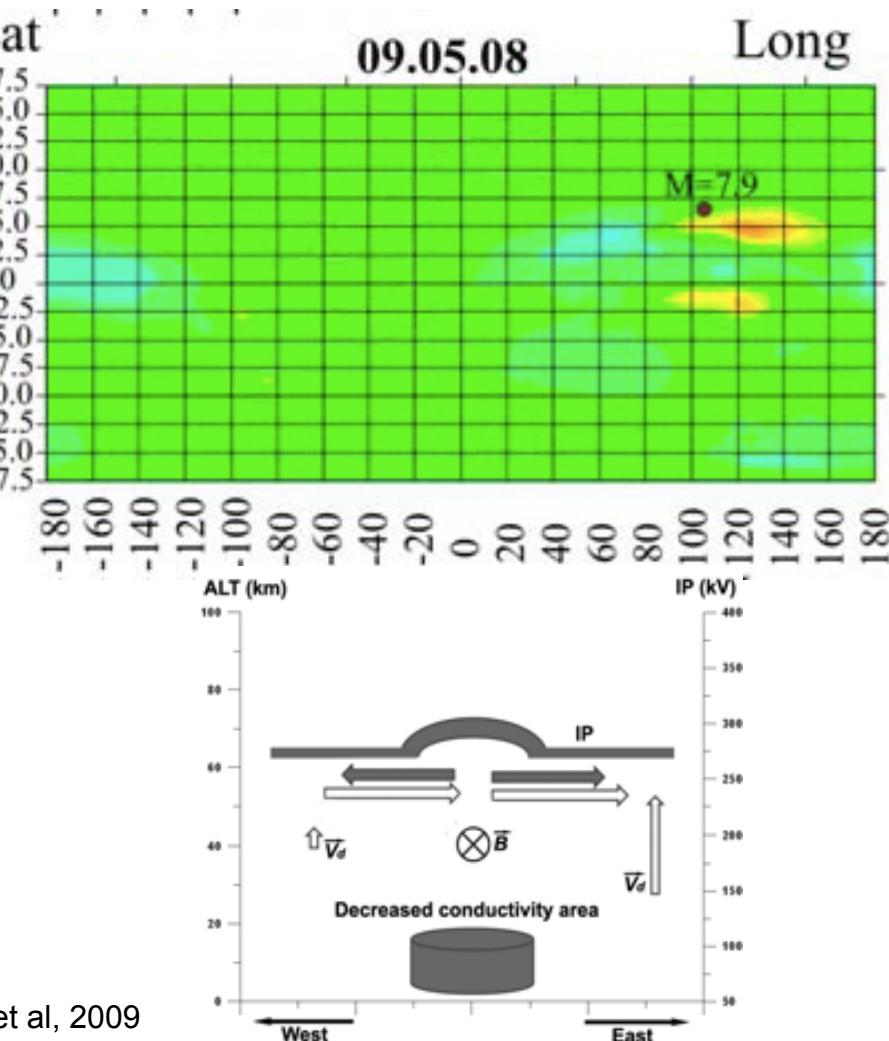
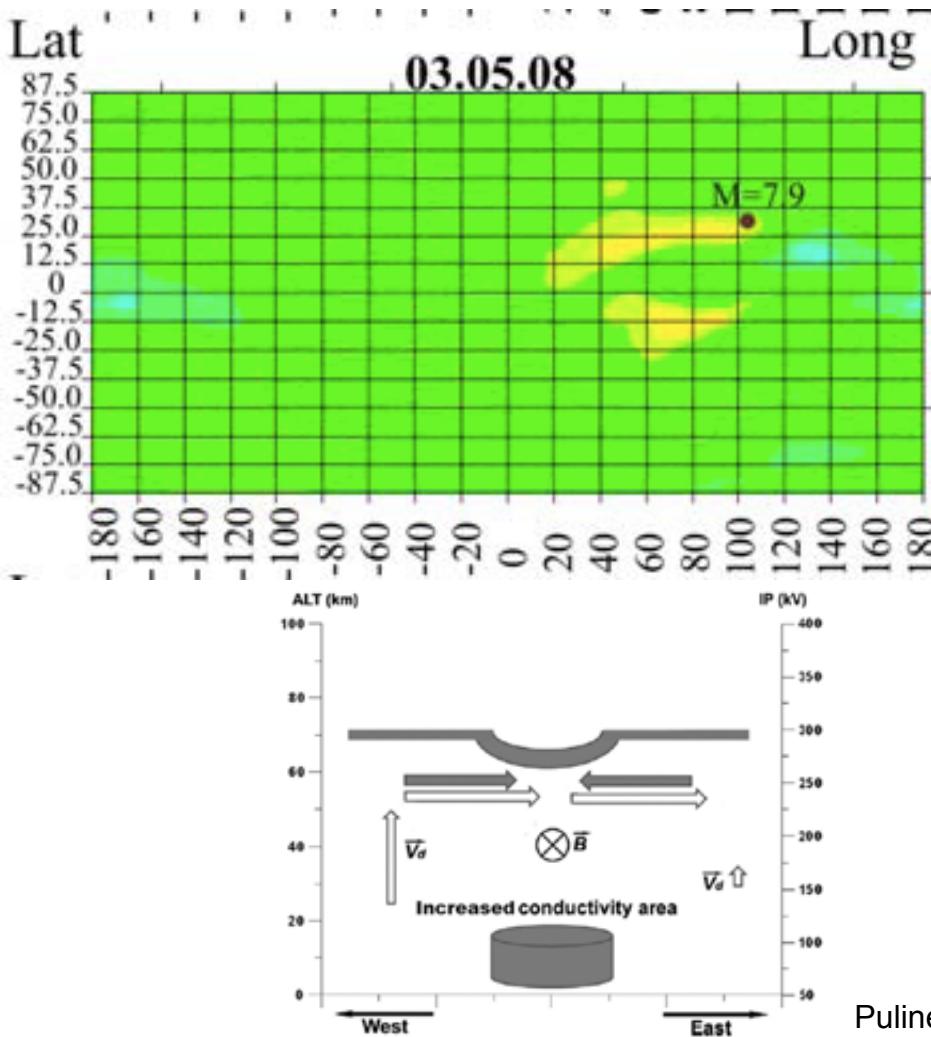


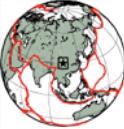
Akhoondzadeh, et al., 2010



# GPS/TEC

## M7.9 Wenchuan Earthquake, China 2008

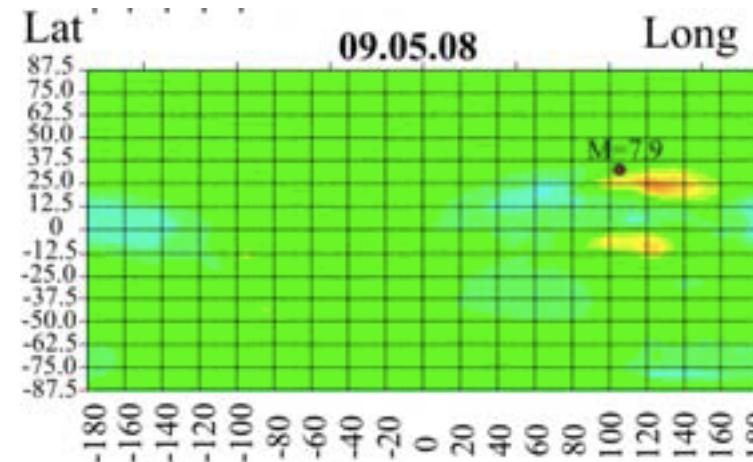




# GPS/TEC and DEMETER

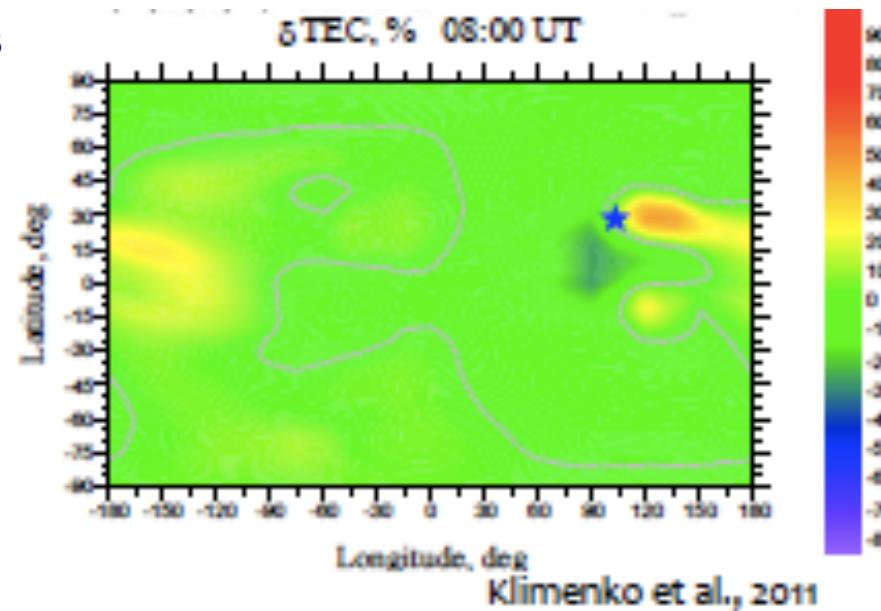
## M7.9 Wenchuan Earthquake, China 2008

GPS/TEC data



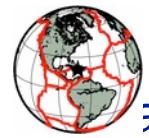
Pulinets et al, 2009

Modeling EQ effects  
by generating  
Electrical field



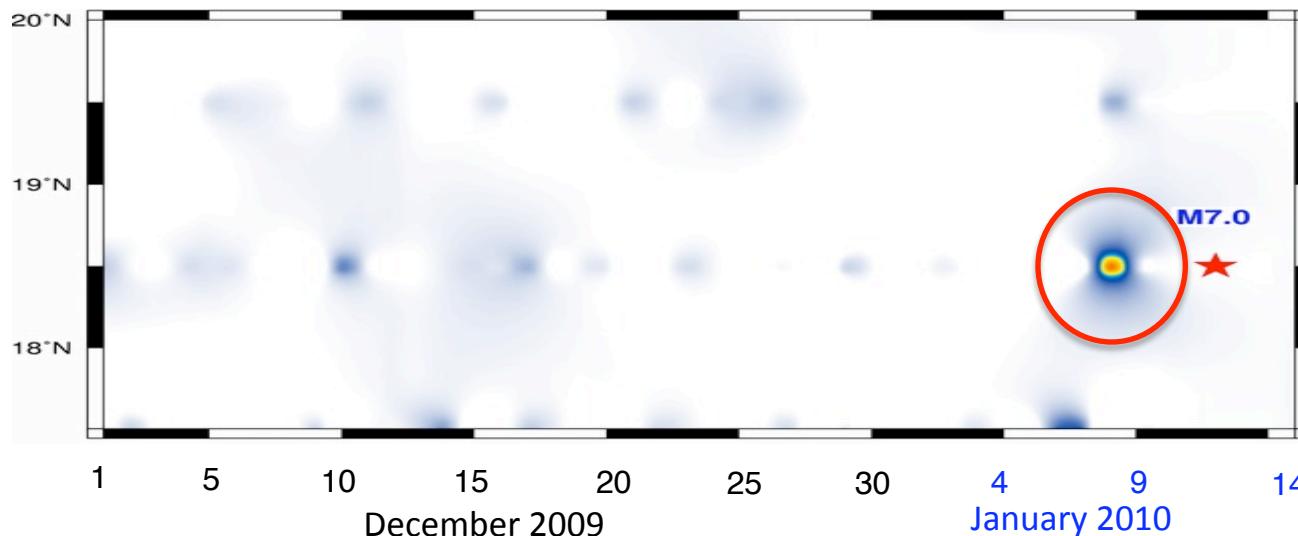
DEMETER meeting, Oct 10-12, 2011, Paris



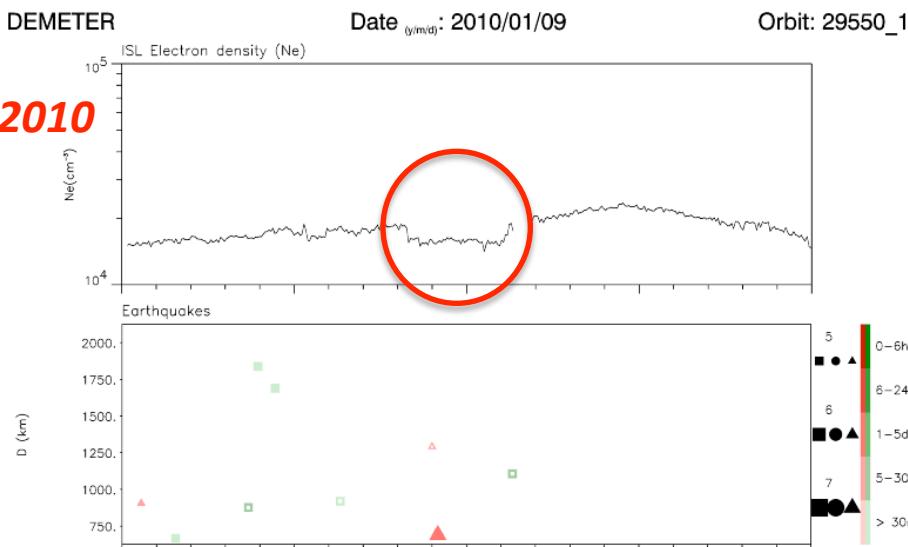


# Time-Latitude diagram for night-time of OLR hot spots

and DEMETER electron density over the epicenter of M7.0 Haiti earthquake



M7.0 Haiti of January 12<sup>th</sup>, 2010



Parrot, 2010

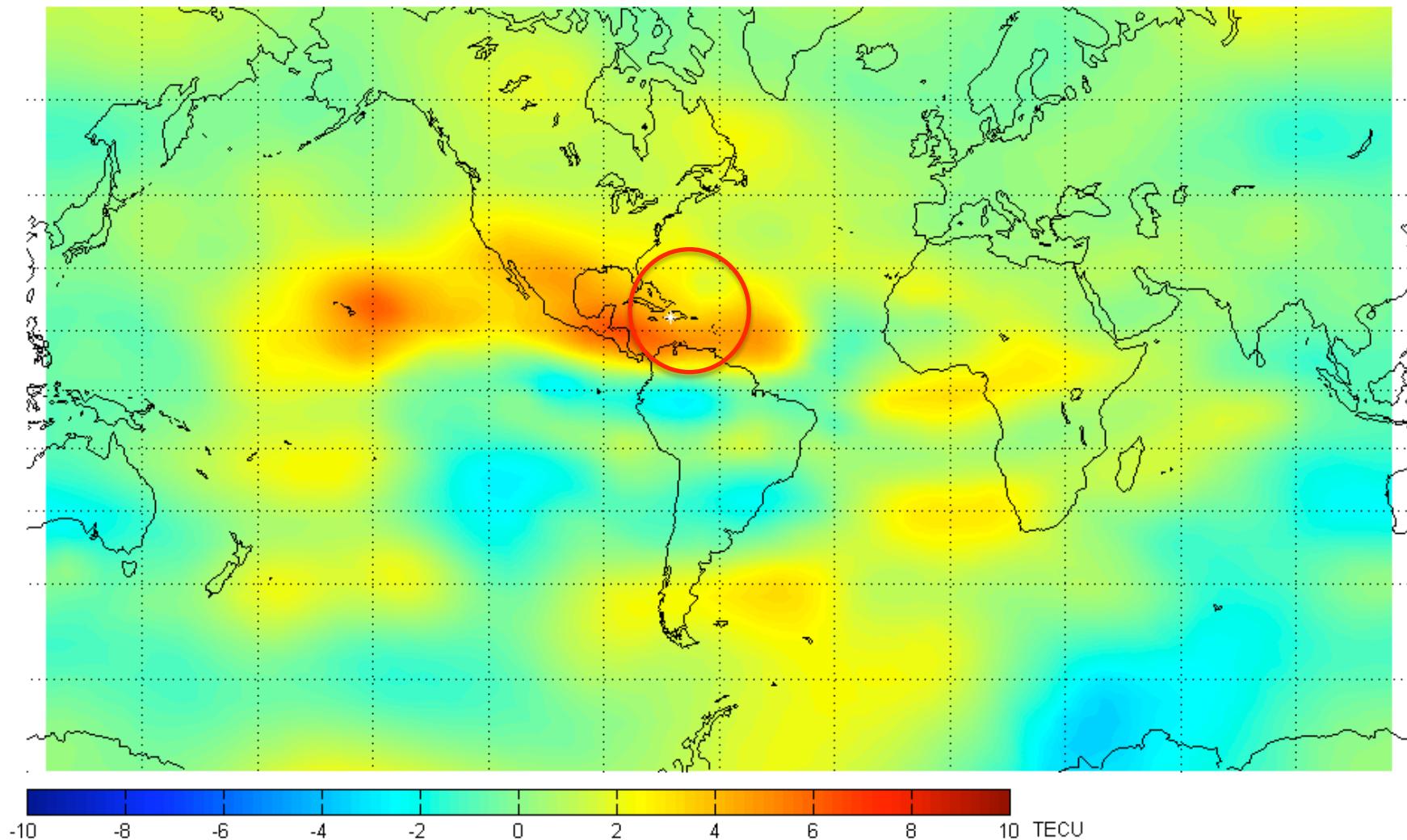


# IGR GPS/TEC, JAN 11, 2010

**M7.0 Haiti of January 12<sup>th</sup>, 2010**

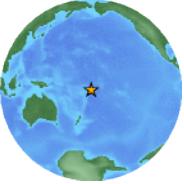
TEC difference with previous 10-days mean

Source: IGR Center: Haiti Date: 2010.01.11 UT: 20:00:00



2<sup>nd</sup> DEMETER workshop, Oct 10-12, 2011, Paris



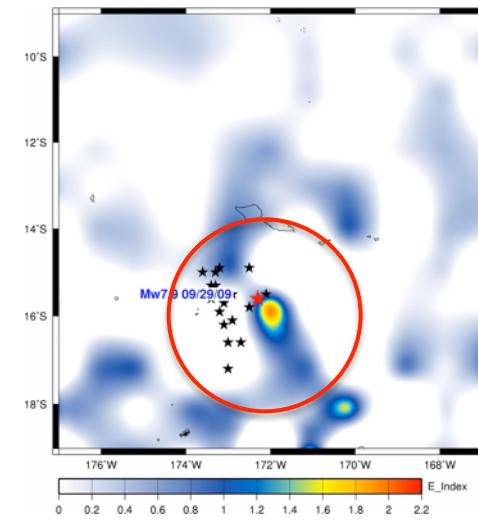
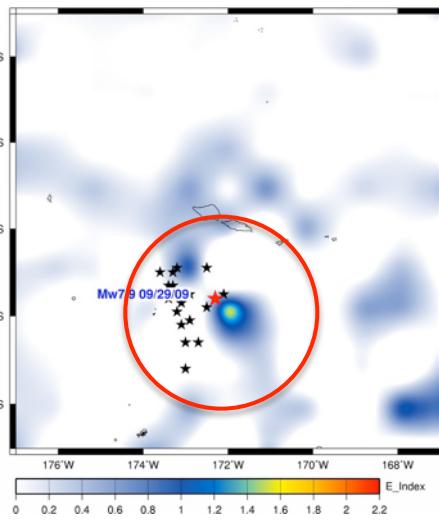
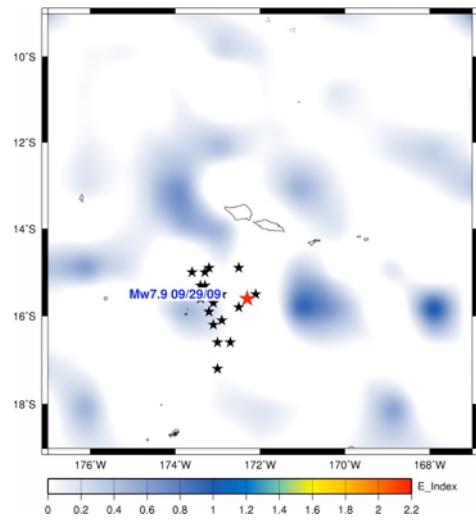


# Atmospheric Processes Associated with the M8.0 Samoan EQ September 29, 2009. OLR hotspots night-time maps

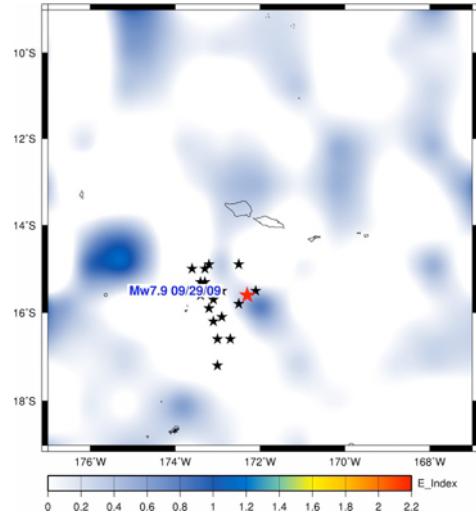
09.24.2009

09.25.2009

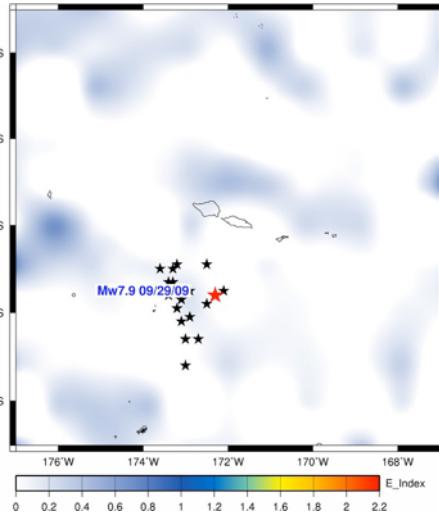
09.26.2009



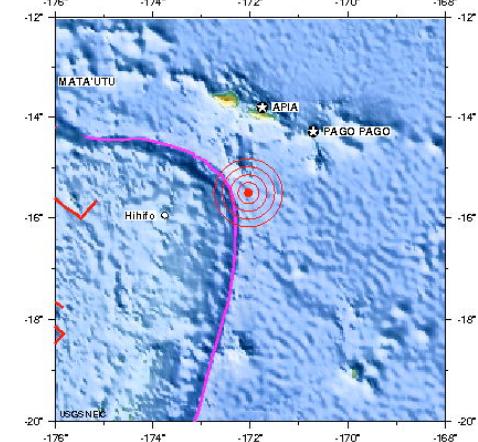
09.27.2009



09.28.2009



09.29.2009

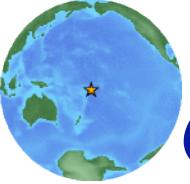


SAMOA ISLANDS REGION

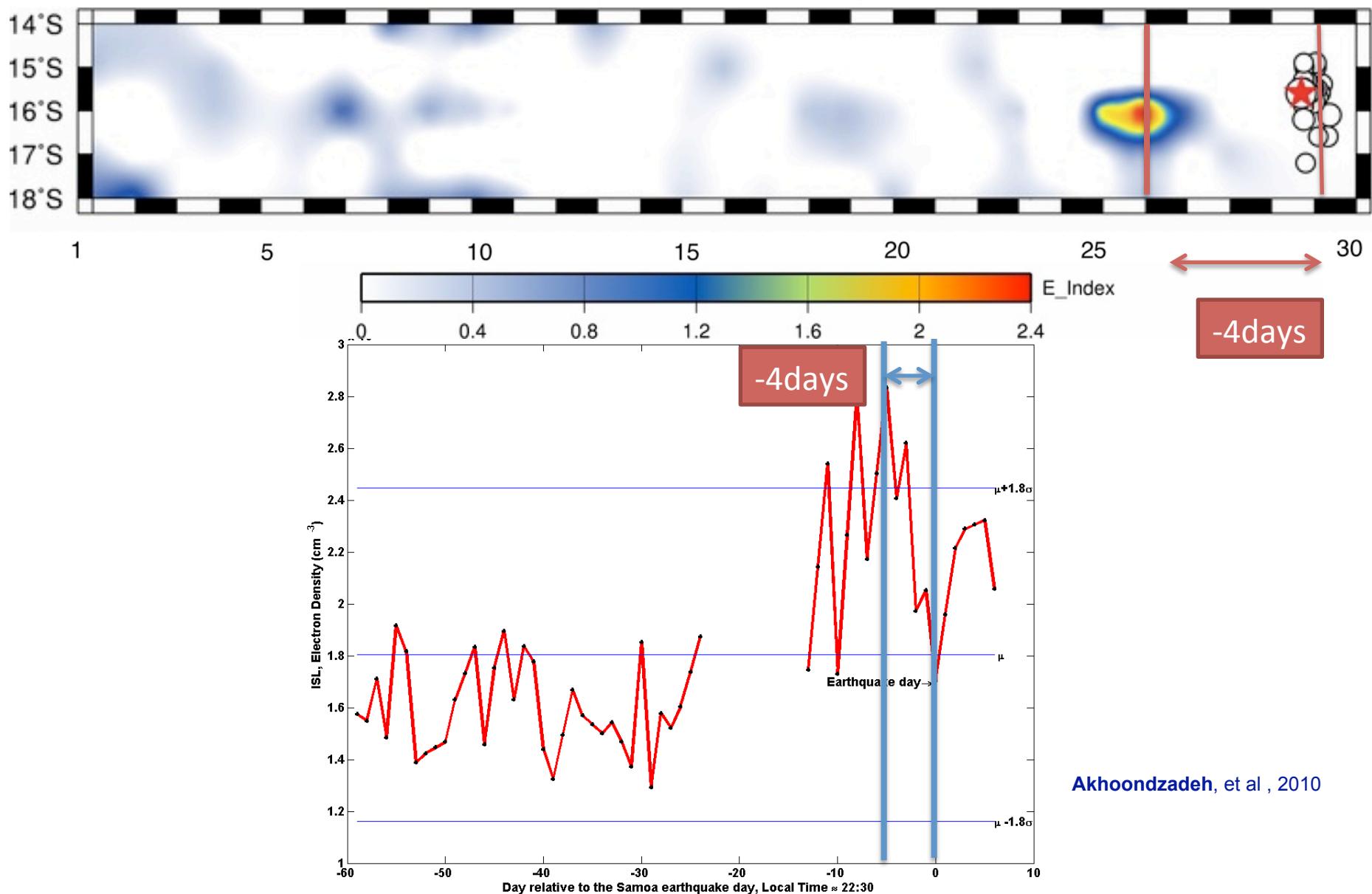
2009 09 29 17:48:10 UTC 15.51S 172.03W Depth: 18.0 km, Magnitude: 8.0  
Earthquake Location

2<sup>nd</sup> DEMETER workshop, Oct 10-12, 2011, Paris





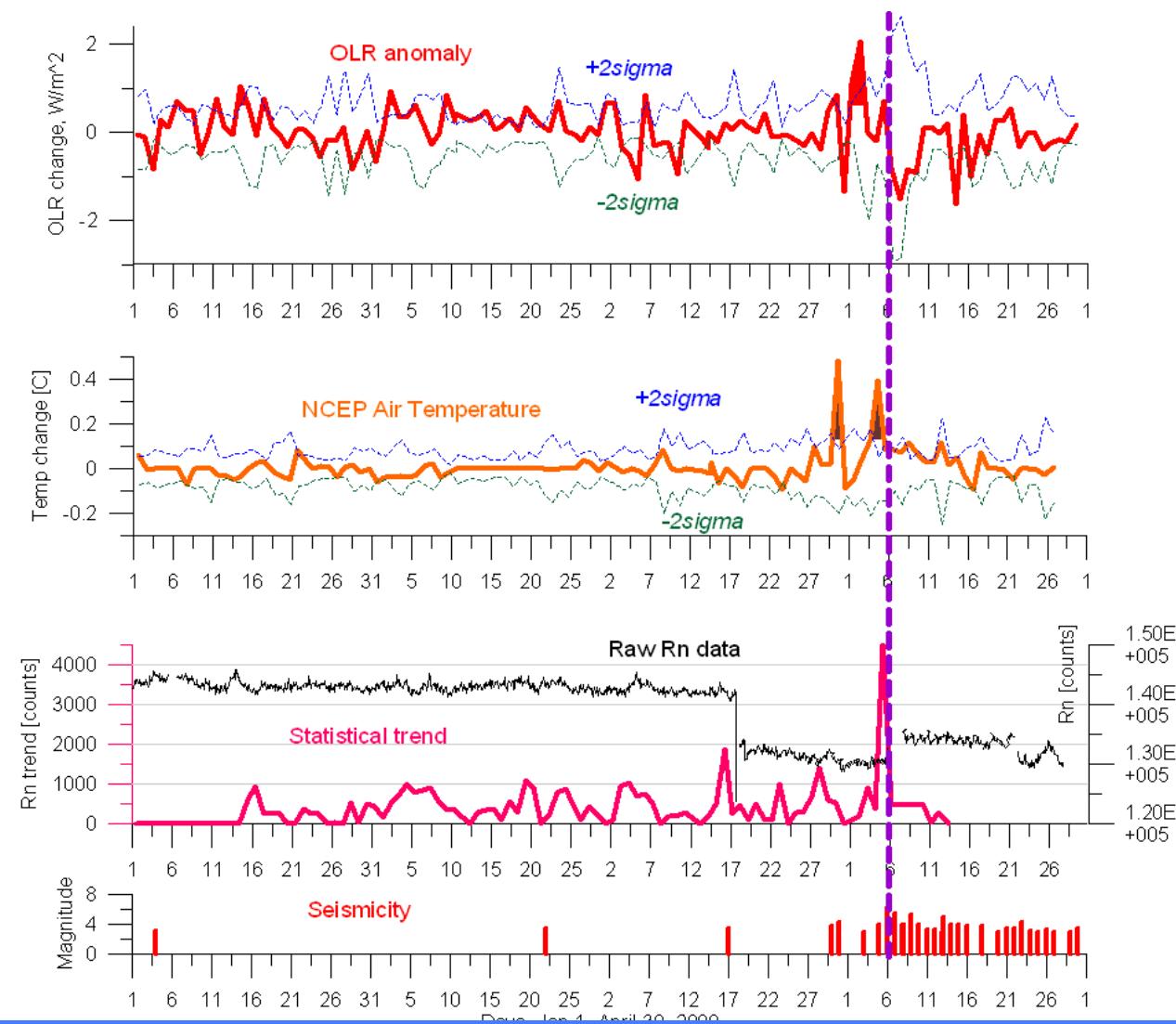
*Time-Latitude diagram for night-time of OLR hot spots  
(NASA Aqua/AIRS) over the M7.9 Samoa earthquake of Sept 2009  
with start -M7.9, circles- aftershocks for 09.29-09.30.2009*





# What we have learned from L'Aquila EQ?

Time series atmospheric variability observed from  
January 1- April 30, 2009 within a 100 km radius of the L'Aquila  
earthquake (top to bottom)



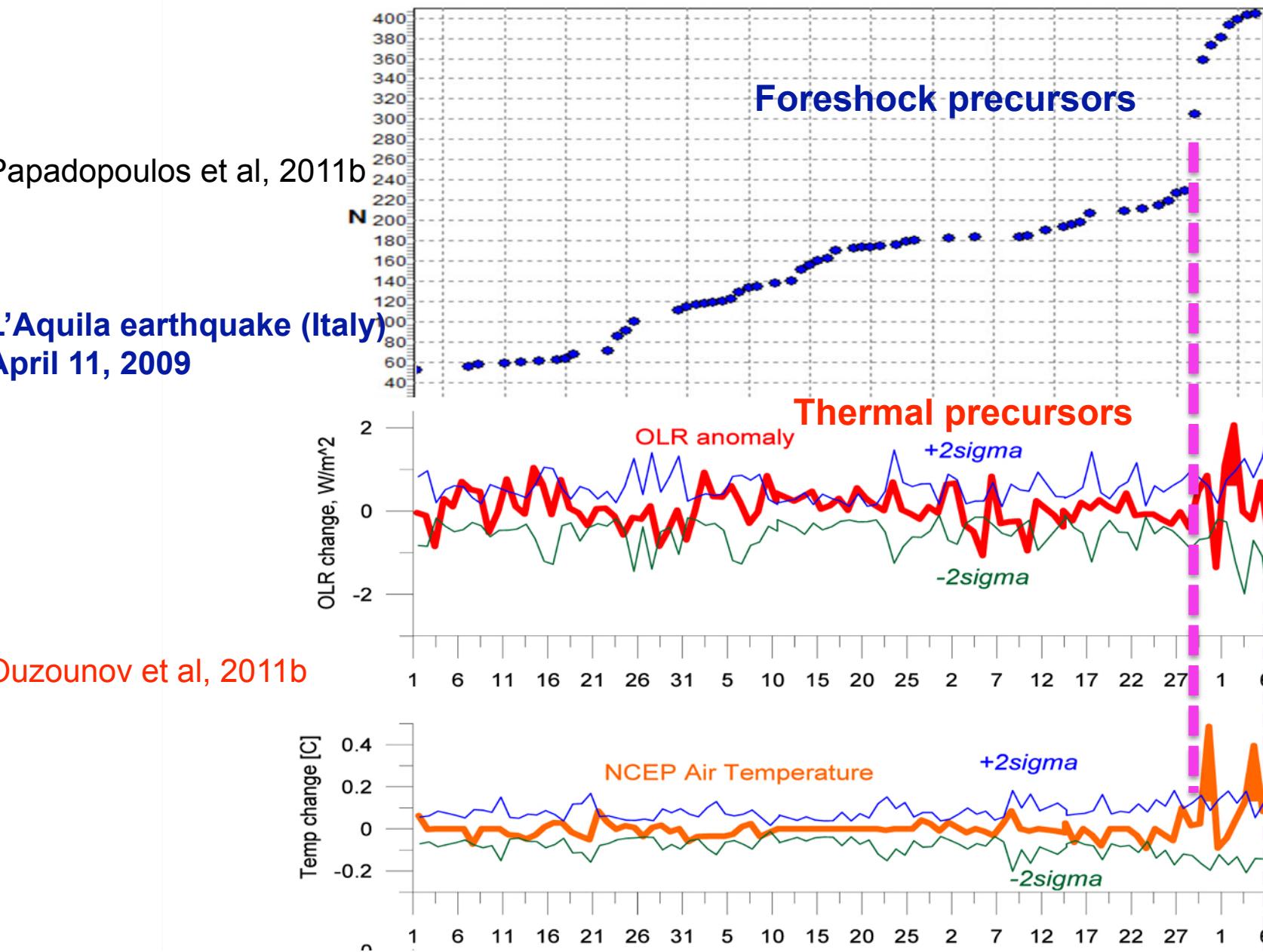
2<sup>nd</sup> DEMETER workshop, Oct 10-12, 2011, Paris



*Foreshocks period  $\Leftrightarrow$  short-term earthquake atmospheric precursors – are they represent the same physical process?*

Papadopoulos et al, 2011b

L'Aquila earthquake (Italy)  
April 11, 2009



Ouzounov et al, 2011b

# Points to take home

1. DEMETER plasma data have shown a unique support in order to explain the most of the observed atmospheric variations observed before the earthquakes
2. We use Multi sensor data to study earthquake. The primary reason the complex and dynamic nature of the earthquake hazard risk on global scale requires spatial, spectral, and temporal coverage **that is far beyond any single satellite mission.**
3. We have systematically analyzed the transient features of thermal atmospheric field associated **with 30 major earthquakes ( $M>5.9$ )** in Greece, Taiwan, Japan, Italy and Samoa by using NOAA POES,DEMETER and NASA EOS Aqua..
4. Our findings demonstrate the presence of related variations of these parameters implying their connection **with the earthquake preparation process**
5. **Sensor Web approach** was used to start automatic identification of earthquake precursors

# References

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- Pulinets S., **D. Ouzounov**, L. Ciraolo, R. Singh, G. Cervone, A. Leyva, M.Dunajecka, Karelina, K. Boyarchuk, (2006), Thermal, Atmospheric and Ionospheric Anomalies Around the time of Colima M7.8 Earthquake of January 21, 2003, *Annales Geophysicale*, 24, 835-849
- **Ouzounov D.**, N. Bryant, T. Logan, S. Pulinets, P.Taylor, (2006), Satellite thermal IR phenomena associated with some of the major earthquakes in 1999-2004, *Physics and Chemistry of the Earth*, 31,154-163



*Thank you!*

*Questions?*

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