

Geospace Integration of Satellite and Ground Observations for Alerting of Large Earthquakes

Dimitar Ouzounov

Chapman University Center of Excellence in Earth Systems Modeling & Observations, CA USA

With cooperati on of
Katsumi Hattori², Sergey Pulnits³, Tiger Liu⁴
² Departments of Earth Sciences, Chiba University, Chiba, Japan
³ Space Research Institute, Russian Academy of Sciences, Moscow, Russia
⁴ Institute of Space science, National Central University, Zhongli City, Taiwan
ouzounov@chapman.edu

CEReS 2015, Chiba, Nov 30, 2015, Japan

Outline

1. Geo space approach to study Earth processes
2. Nature of pre-earthquake effects in atmosphere-Lithosphere-Atmosphere coupling
3. Sensor Web approach to study pre-earthquake phenomena
4. Concept of Multi Sensor Observations - Joint analysis of satellite and ground observation
5. Retrospective/prospective tests
6. Summary

CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

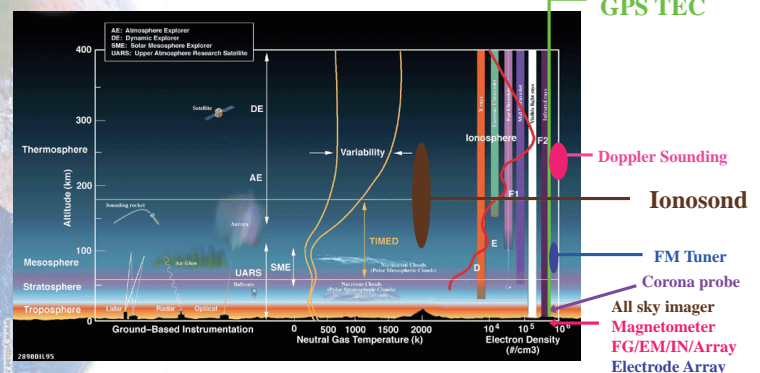
Who are we?



Center of Excellence in Earth Systems Modeling & Observations- Orange, California

CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Geospace Observation Networks



CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Who are we?

International LAIC team

ISSI-Bern, Switzerland
 ISSI-Beijing, China

- ²Space Research Inst., Russian Acad. of Sci, 84/32 Profsoyuznaya, Moscow, 117997, Russia
- ³University of Basilicata, Via dell'Ateneo Lucano, 10 85100 - Potenza, Italy,
- ⁴Institute of Space science, National Central University, Chung-Li 320, Taiwan
- ⁵Department of Earth Sciences, Chiba University, Inage, Chiba, 263-8522, Japan
- ⁶LPC2E/CNRS, 3A, Avenue de la Recherche Scientifique 45071 Orléans cedex 2, France
- ⁷Murmansk State Technical University, Sportivnaya St., 13, 183010, Murmansk, Russia
- ⁸Central Aerological Obsr., Pervomayskaya str. 3, Dolgoprudny, Moscow reg., Russia

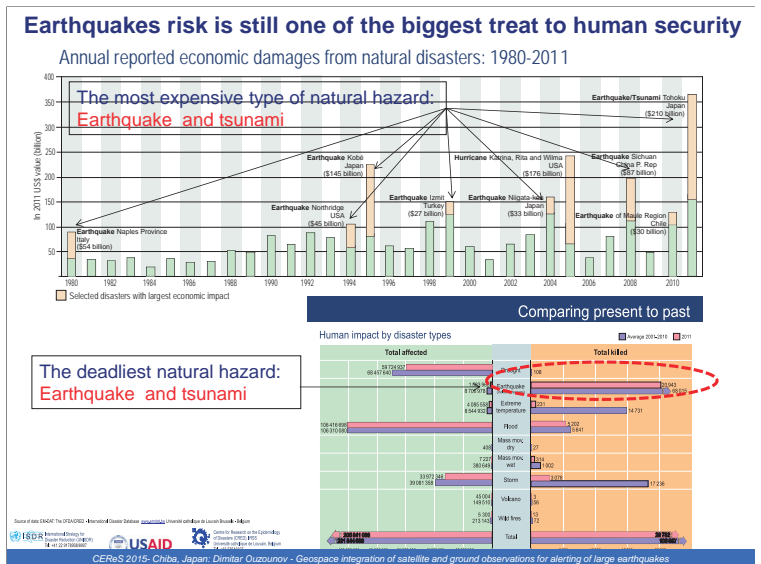
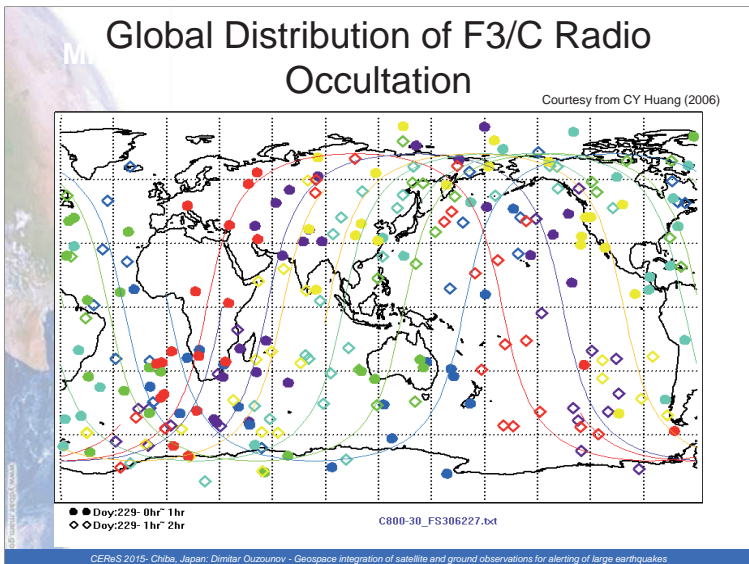
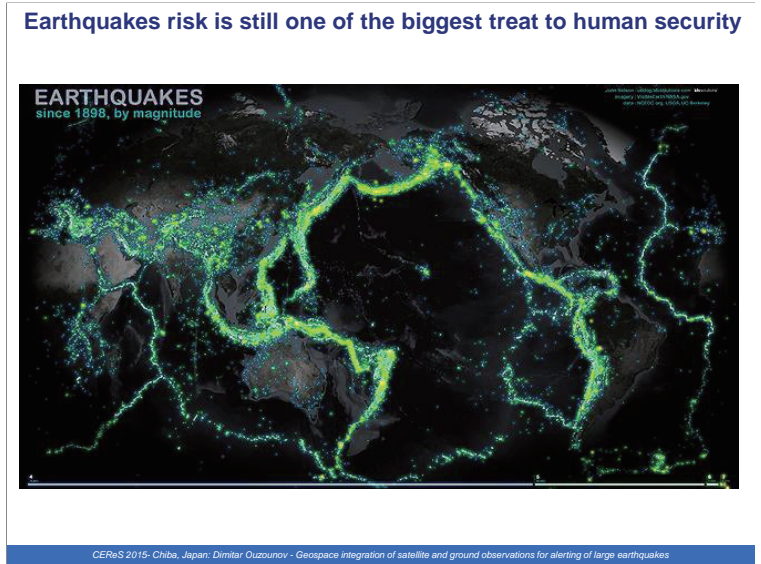
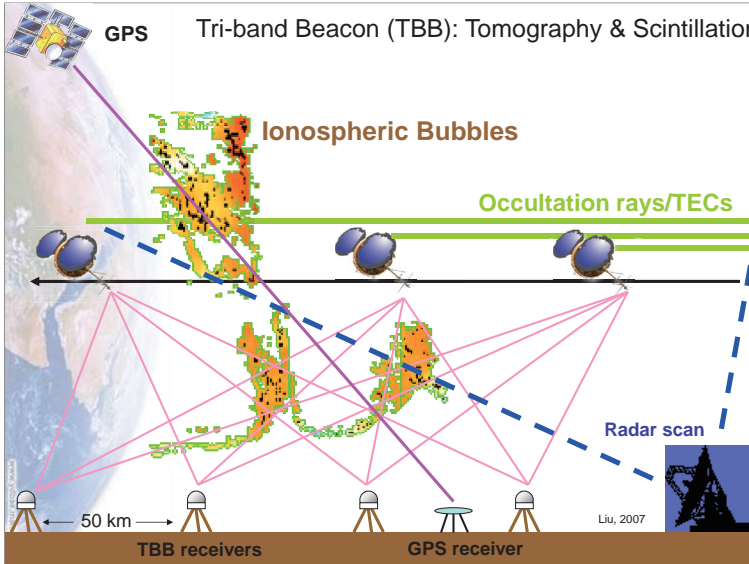
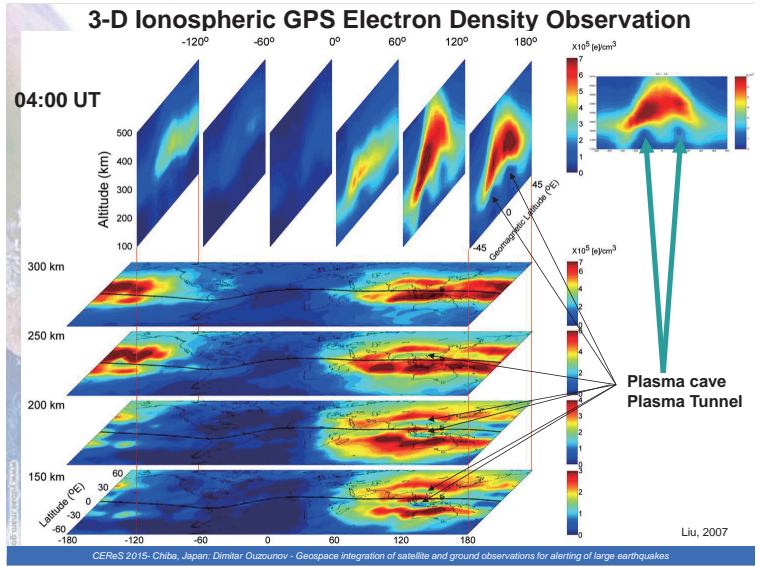
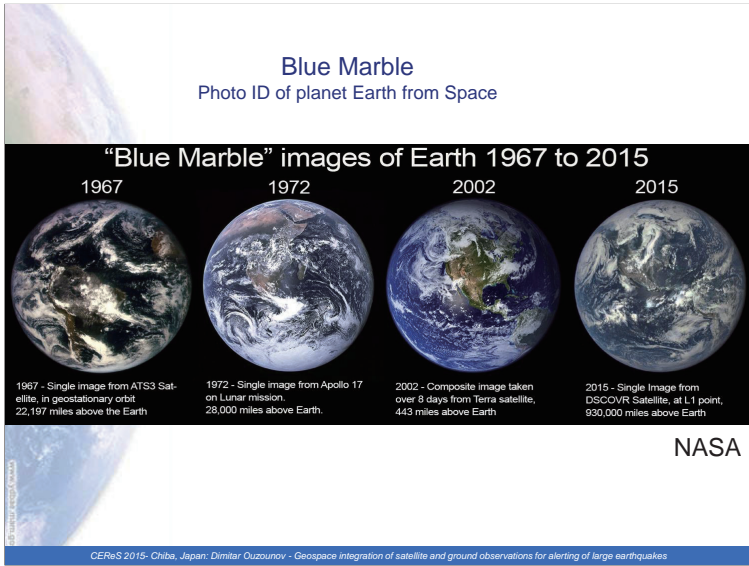


CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

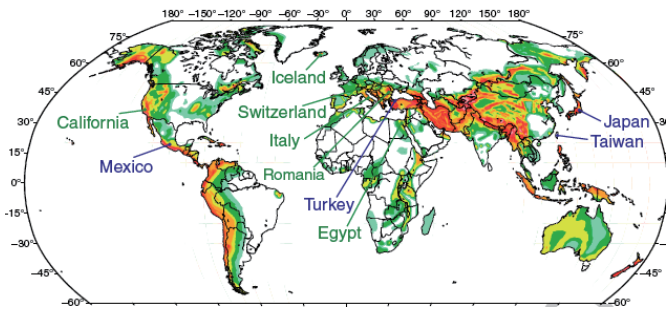
What is the name of this image?



CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes



Map of earthquake early-warning systems



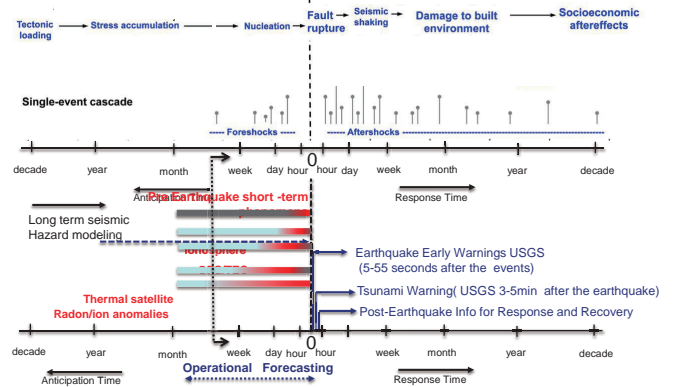
Map showing the locations of earthquake early-warning systems currently in operation (blue) or development (green) around the world. Operational systems include Japan, Taiwan, Mexico, and Turkey. Systems are in development for California, Egypt, Greece, Iceland, Italy, Romania, and Switzerland. The locations are overlaid on the GSHAP global seismichazard map (Giardini et al., 1999). (After Allen, 2007)

CEReS 2015- Chiba, Japan; Dimitar Ouzourov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Introduction Observations Model Validation Results

Earthquakes progress as chain reactions

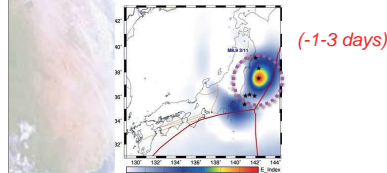
After Tom Jordan (SCEC, Monterey CA, 2011)



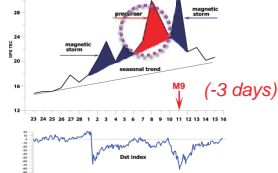
CEReS 2015- Chiba, Japan; Dimitar Ouzourov - Geospace integration of satellite and ground observations for alerting of large earthquakes

2013: What have we learned from the 2011 M9 Tohoku Earthquake? Multi-parameter pre-earthquake panel

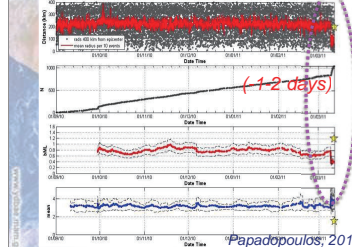
NOAA Thermal Anomaly



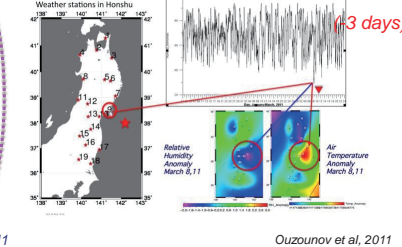
GPS/TEC Anomaly



Foreshock analysis



Air Temperature/Humidity



Papadopoulos, 2011

Ouzourov et al, 2011

CEReS 2015- Chiba, Japan; Dimitar Ouzourov - Geospace integration of satellite and ground observations for alerting of large earthquakes

International Collaborative Framework

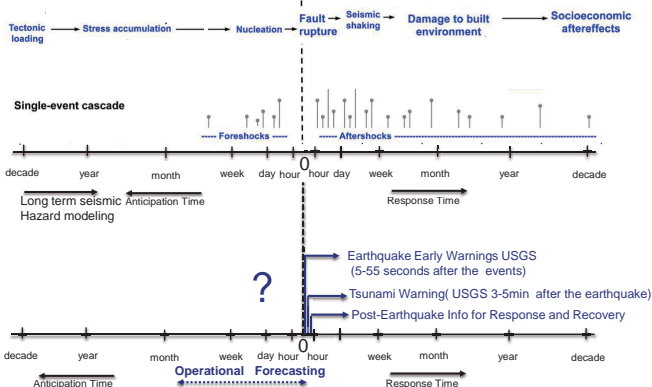


CEReS 2015- Chiba, Japan; Dimitar Ouzourov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Introduction Observations Model Validation Results

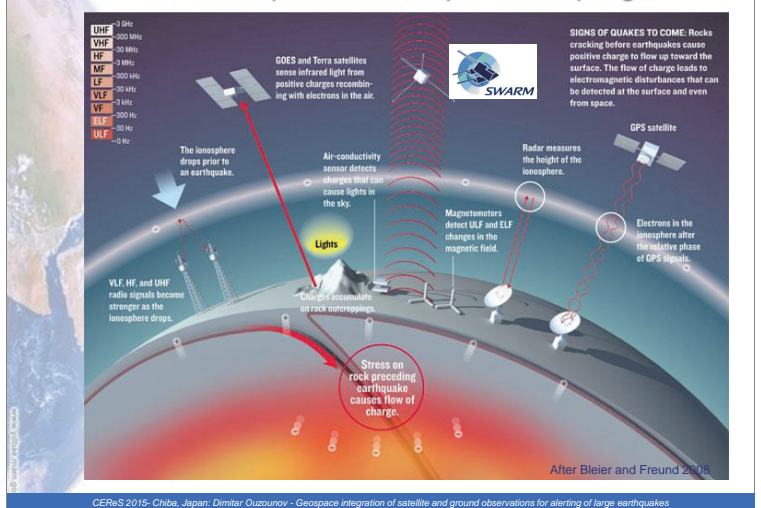
Earthquakes progress as chain reactions

After Tom Jordan (SCEC, Monterey CA, 2011)

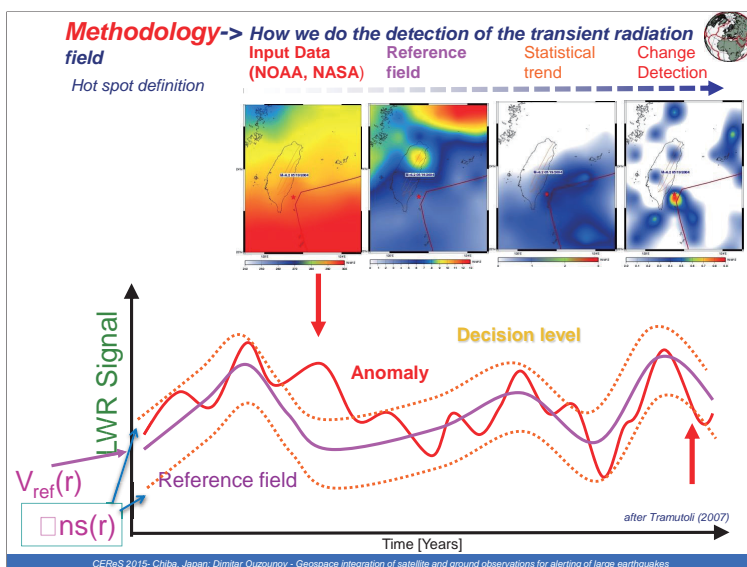
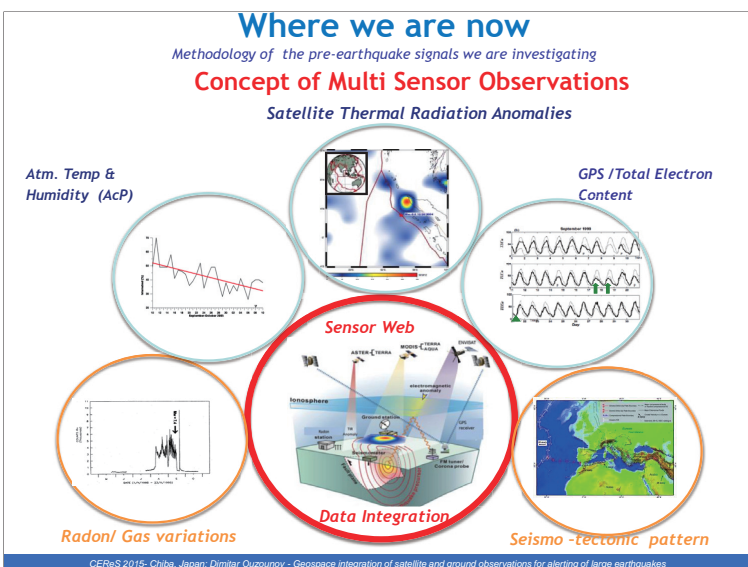
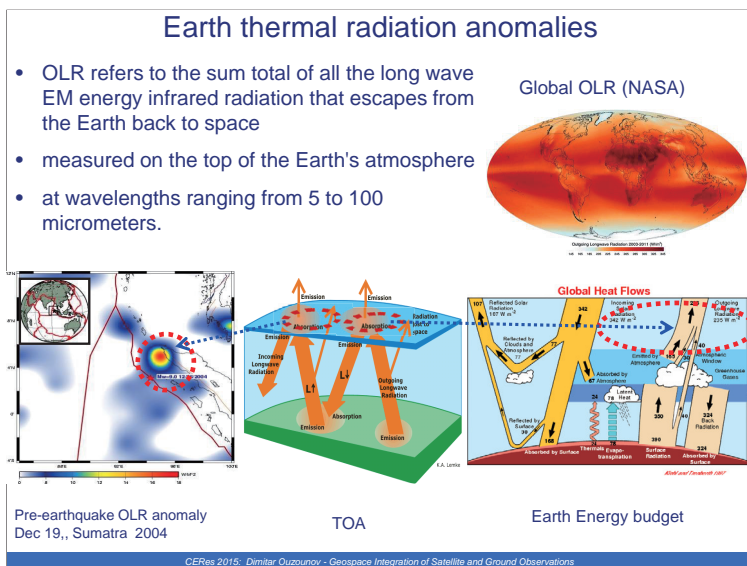
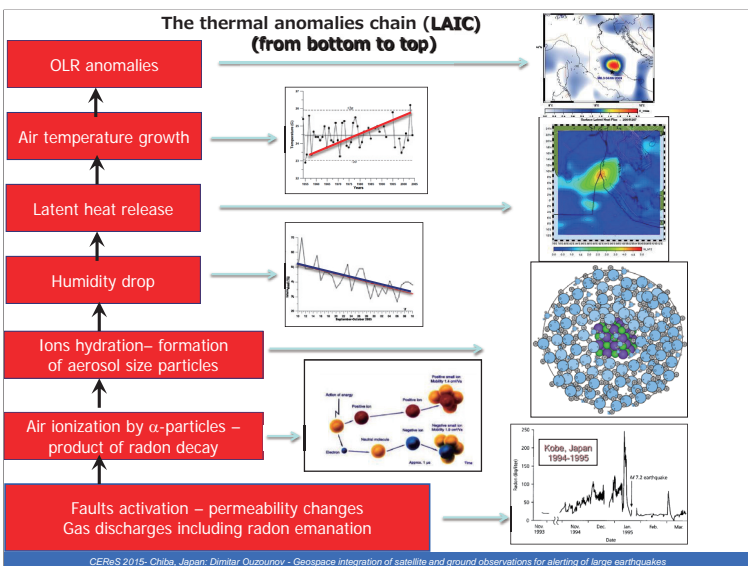
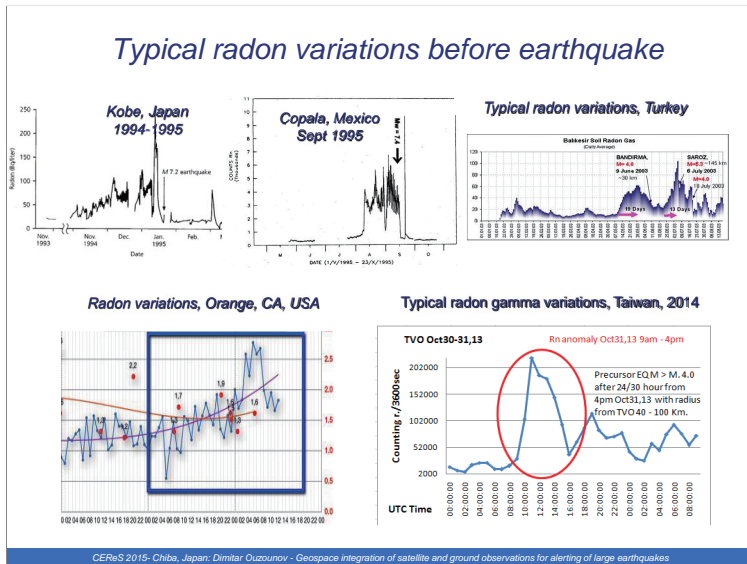
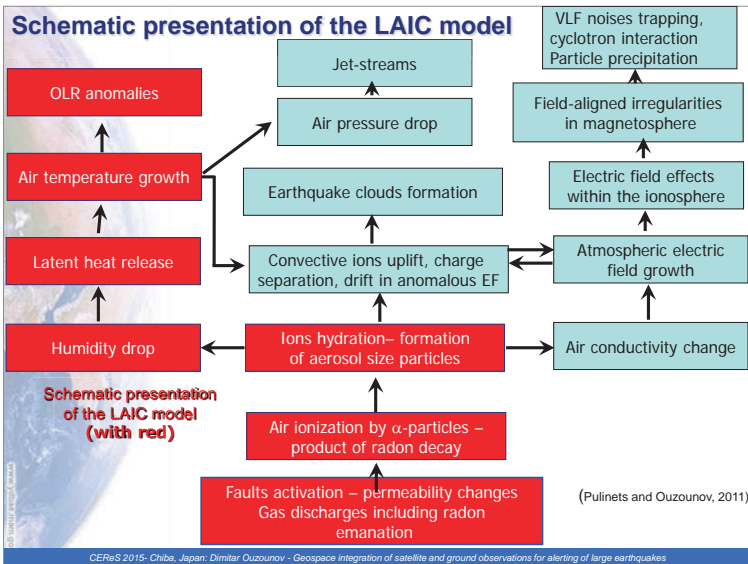


CEReS 2015- Chiba, Japan; Dimitar Ouzourov - Geospace integration of satellite and ground observations for alerting of large earthquakes

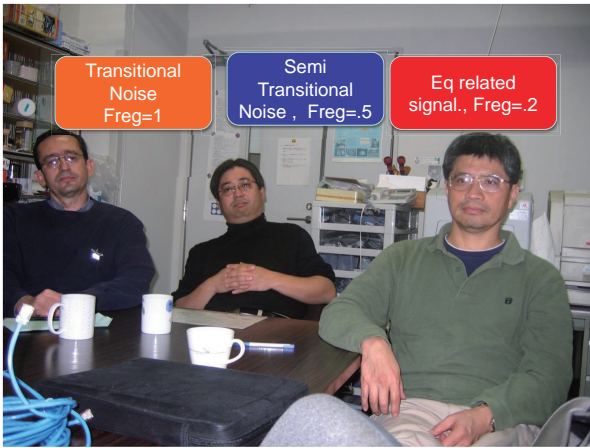
The Lithosphere -Atmosphere coupling



CEReS 2015- Chiba, Japan; Dimitar Ouzourov - Geospace integration of satellite and ground observations for alerting of large earthquakes



Demo: Signal/Noise detection theory.

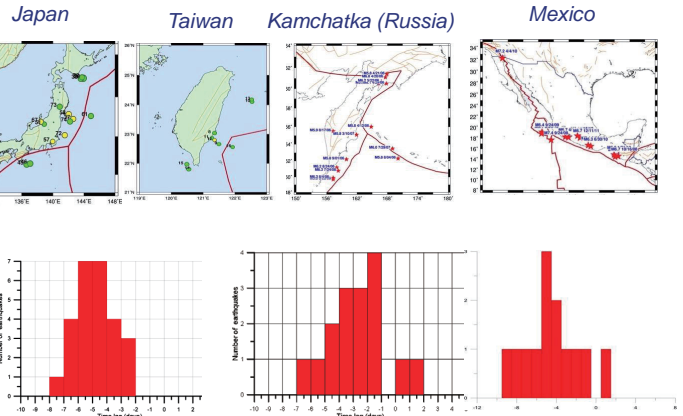


Chiba University, Japan, 2009

CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

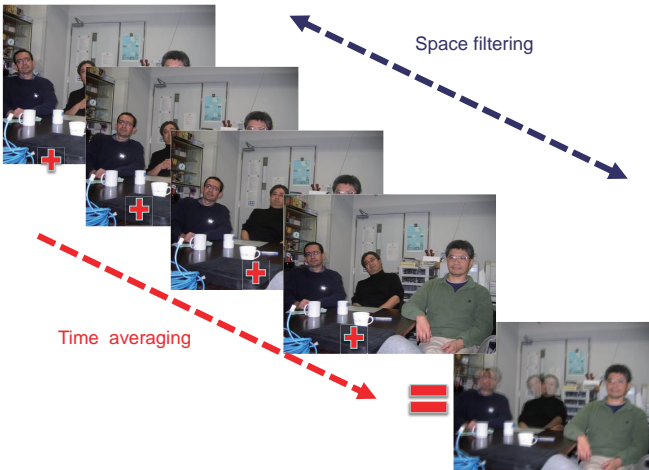
Retrospective statistical studies of TIR signals

Japan, Taiwan - 24 major events (2004-2009, M>5.8)
 Kamchatka(Russia) 14, major events (2006-2008, M>5.8)
 Mexico - 13 major events (2004-2009, M>6)



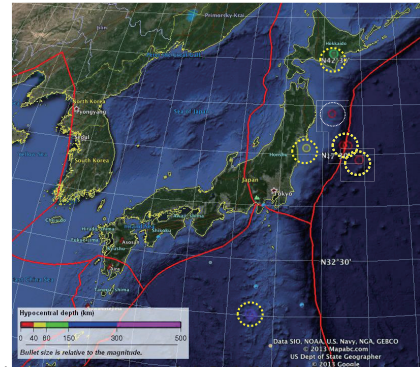
CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Demo: Signal/Noise detection theory.



CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Prospective Testing - Japan M6+ (Dec 2012-Dec, 2013)- 8 major earthquakes



With yellow are marked the alerted events

| Date | Time UTC | Latitude | Longitude | Depth | Magnitude | RegionName |
|----------|----------|----------|-----------|-------|-----------|-----------------------|
| 10/25/13 | 17:10:17 | 37.22 | 144.69 | 10 | 7.1 | OFFEASTCOASTJFHONSHU |
| 9/4/13 | 0:18:25 | 30.04 | 138.8 | 419 | 6.5 | IZUISLANDS |
| 5/18/13 | 5:48:01 | 37.79 | 141.51 | 52 | 6 | NEAREASTCOASTJFHONSHU |
| 4/21/13 | 3:22:17 | 29.96 | 138.96 | 435 | 6.2 | IZUISLANDS |
| 4/1/13 | 18:53:17 | 39.58 | 143.1 | 10 | 6 | OFFEASTCOASTJFHONSHU |
| 2/2/13 | 14:17:34 | 42.79 | 143.17 | 100 | 6.9 | HOKKAIDO |
| 12/7/12 | 8:31:14 | 37.95 | 143.75 | 30 | 6.2 | OFFEASTCOASTJFHONSHU |
| 12/7/12 | 8:18:23 | 37.92 | 144.02 | 30 | 7.3 | OFFEASTCOASTJFHONSHU |

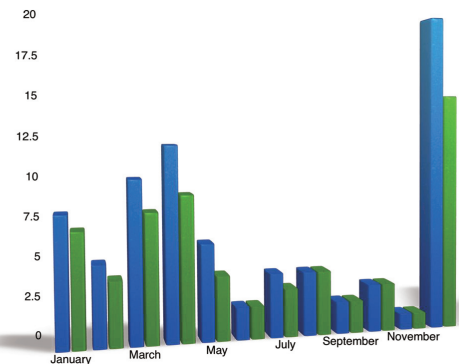
CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Demo: Signal/Noise detection theory.



CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Prospective tests for Japan
 Dec 2012-Dec 2013, for M>5.5 (Stage 1)
 Total alerts: 75 : Earthquake occurrence: 51



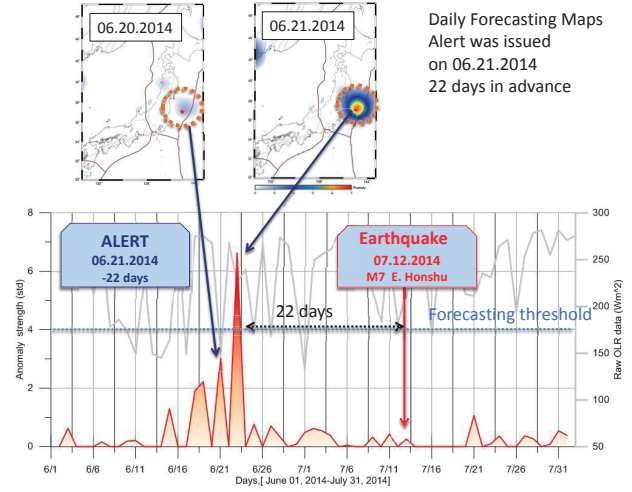
CEReS 2015- Chiba, Japan: Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Prospective tests for Japan (Stage 2)
Dec 2014-Dec 2015, for M>6

| Citizen Response | Date & Time UTC | Latitude degrees | Longitude degrees | Depth km | Mag [+] | Region name [+] |
|------------------|------------------------------|------------------|-------------------|-----------|------------|---|
| | | | | | | 1 |
| 1 | 2015-02-16 23:06:27.4 | 39.87 N | 142.94 E | 15 | 6.8 | NEAR EAST COAST OF HONSHU, JAPAN |
| 7 | 2014-07-11 19:21:59.7 | 37.06 N | 142.54 E | 10 | 6.5 | OFF EAST COAST OF HONSHU, JAPAN |

CEReS 2015- Chiba, Japan; Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

M7 of July 12, 2014 Eastern Honshu, Japan

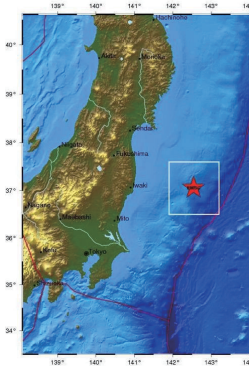


34

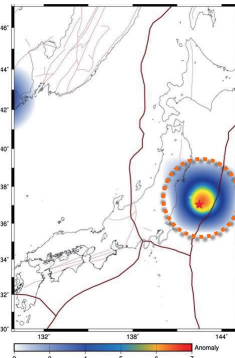
CEReS 2015- Chiba, Japan; Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

M7 of July 12, 2014 Eastern Honshu, Japan

Epicentral map (EMSC)



Alert was issued on June 21, 2014,
21 days in advance



With red star – epicenter of M7 07.12.2014,
Red solid lines – plate boundaries,
Brown lines – fault systems,
orange dash circle – estimated region for the future epicenter

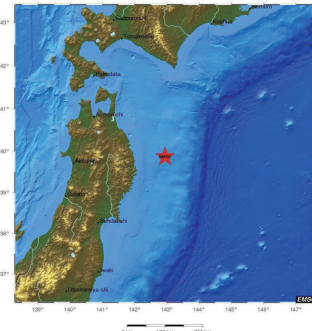
2014-07-11 19:21:59.7 **37.06 N** **142.54 E** **10** **6.5** **OFF EAST COAST OF HONSHU, JAPAN**

32

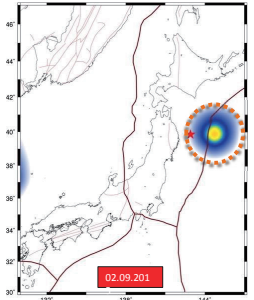
CEReS 2015- Chiba, Japan; Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

M6.8 of Feb 16, 2015 Eastern Honshu, Japan

| | | | | | | |
|----------|------------------------------|----------------|-----------------|-----------|------------|---|
| 1 | 2015-02-16 23:06:27.4 | 39.87 N | 142.94 E | 15 | 6.8 | NEAR EAST COAST OF HONSHU, JAPAN |
|----------|------------------------------|----------------|-----------------|-----------|------------|---|

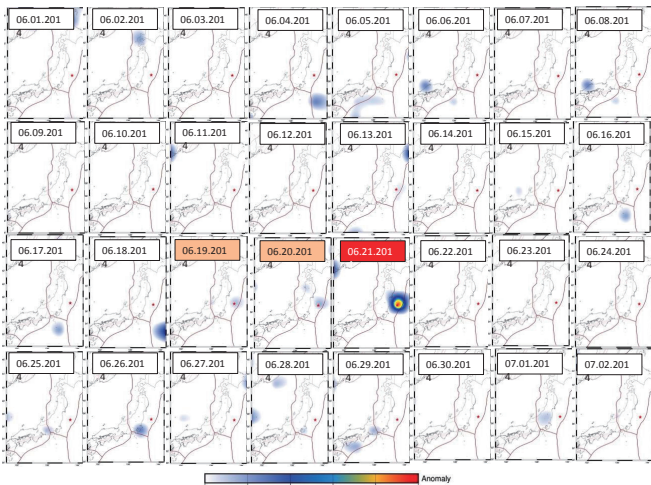


Alert was issued on Feb 9, 2015
7 days in advance



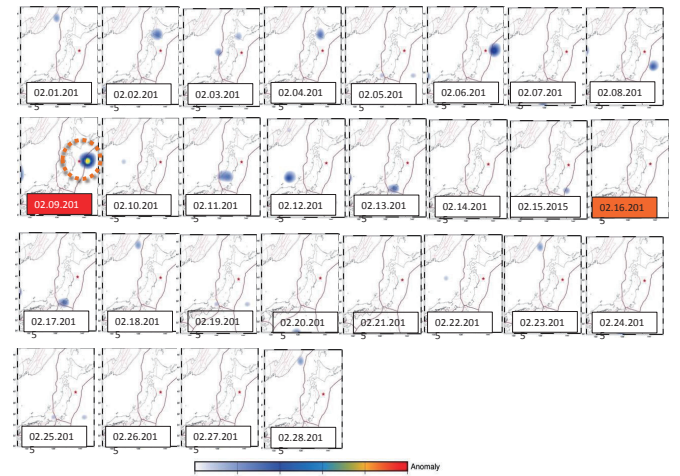
CEReS 2015- Chiba, Japan; Dimitar Ouzounov - Geospace Integration of Satellite and Ground Observations

Daily TIR detection maps, NPOES, night time



CEReS 2015- Chiba, Japan; Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Daily TIR detection maps, NPOES, night time
Feb 1-Feb 28 2015



CEReS 2015- Chiba, Japan; Dimitar Ouzounov - Geospace integration of satellite and ground observations for alerting of large earthquakes

Points to take home

1. Using the fundamental principles of atmospheric physics the updated **Lithosphere-Atmosphere –Ionosphere Coupling concept** can explain the most of the observed atmospheric/ionospheric variations observed before the earthquakes.
2. **The Geospace Sensor Web** of using different satellite sensors and different geophysical fields strongly support the LAIC estimates. Our Initial results show that this approach used as integrated web, could provide an **earthquake early-warning capabilities**(from hours to several days);
4. The lead time for thermal anomalous signals before the earthquake occurrence varies between **2 and 7 days, for GPS/TEC 1-3 days;**
5. Our findings demonstrate the presence of related variations of these parameters implying **their connection** with the earthquake preparation process .
4. **Next is to Test, Improve and Test again...**

CERes 2015: Dimitar Ouzounov - Geospace Integration of Satellite and Ground Observations