Ten-years progress and development in seismic remote sensing monitoring technology

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2013-10-25
Outline

1. Main requirements of satellite technique for earthquake monitoring

2. Framework of application system for seismic satellite monitoring

3. Main developments of seismic satellite monitoring
M>7: 2 in every 3 years in mainland, 18 per year in the earth
M>6: 4 per year in mainland China, 150 in the earth
Earth observation from spatial technology provide new opportunities for improving the ability of earthquake prevent and disaster reduction.

- Large-scale
- Highly dynamic
- Multi-parameters
- All-weather

Seeing the Earth with new eyes.
### Emergency Defense System

**Visible light**
- Seismic structure survey

**Infrared**
- Blind structure survey
- Brightness temperature, radiation flux, infrared image

**Radar**
- Blind structure survey
- Defacement monitoring

**Hyperspectrum**
- Deep structural inversion

**Electromagnetism**
- Low frequency EM and ionospheric perturbation

**Acoustic gravity wave**
- Infrasound and AGW disturbance

**Gravity field**
- Microgravity disturbance

**Navigation**
- Deformation monitoring and navigation
- Deformation observation, TEC inversion, navigation and positioning

### Monitoring and Forecasting System

- Strain accumulation line
- Medium and long-term; long term
- Strain recovery line

### Emergency Rescue System

- Disaster monitoring, damage assessment, recovery and reconstruction work monitoring, emergency preparedness

### Remote Sensing Seismic Structural Survey and Earthquake Damage Prediction

- Remote sensing earthquake monitoring (Geophysical and geochemical remote sensing inversion)

### Remote Sensing Earthquake Damage Prediction and Emergency
Outline

1. Main requirements of satellite technique for earthquake monitoring

2. Framework of application system for seismic satellite monitoring

3. Main developments of seismic satellite monitoring
Conceptual diagram of China earthquake monitoring system from Space

- **IR sat**
- **EM wave, Plasma, Particles**
- **TEC/f_oF_2**
- **OLR/TBB& SHF**
- **EM field and wave/TBB**
- **CSES Mission**
- **SIGN mission**
- **GPS/BD-2**
- **EM station**
- **FOCUS**
Space segment of the three-dimensional seismic monitoring

- Long-term and mid-term seismic precursors monitoring system: GPS-BD, D-InSAR, gravity, etc.
- Mid-term and short-term seismic precursors monitoring system: Infrared, hyperspectral, etc.
- Short-term and impending seismic precursors monitoring system: Seismo-Ionosphere, etc.
- Emergency response and dynamic monitoring system: optical, radar, etc.
- Independent support system: communication satellite, navigation, etc.
Key Projects

- Geophysical remote sensing satellite: Electromagnetic Satellite, gravity satellite
- High-resolution optical and radar satellite in geostationary orbit
- Reformation of crustal movement observation network platform: GPS - BD
- Integrated satellite application system for earthquake: RS+BD+ communication Satellite
- Key theories and technologies for seismic satellite monitoring and applications
Infrastructure of applications system for earthquake prevent and disaster reduction
Technical flow of long-term and mid-term earthquake prediction

Seismotectonics analysis and determination of potential seismic zone

GPS/BD
D-InSAR
Field investigation
Field gravite observation

Data processing and data fusion
Inversion

Fault geometry and slip rate
3D deep structure of lithosphere

Long-term and mid-term earthquake prediction
Spatotemporal evolution process of crustal deformation field

ZY-2C/3, HJ, GF-1/2/3, etc

Field gravite observation
Technical flow of short-term and impending earthquake prediction
Outline

1. Main requirements of satellite technique for earthquake monitoring
2. Framework of application system for seismic satellite monitoring
3. Main developments of seismic satellite monitoring
Framework of multi-source seismic information processing system
Technical flow on electromagnetic satellite data-processing

Satellite data

Data classification

Different grade data (0, 1, 2)

Background and anomalies

Data processing methods

Earthquake predictive index from the ground to the ionosphere

Satellite data

Data classification

Different grade data (0, 1, 2)

Background and anomalies

Data processing methods

Earthquake predictive index from the ground to the ionosphere

1. Background: different magnetic, frequency, season space background
2. Disturbance: magnetic, seismic, pulse, thunder, lightning, artificial emission

1. Background and abnormal event features
2. Earthquake information extraction method
3. Earthquake case study and statistical analysis
4. Earthquake prediction index from the ground to the ionosphere

1. Time: residual vector, extremum, analysis
2. Frequency: dynamic, components, analysis
3. Space: dynamic, image, evolution
4. Location:反向追踪、波源定位

1. Earthquake case study and statistical analysis
2. Earthquake predictive index from the ground to the ionosphere

Data processing methods

Earthquake predictive index from the ground to the ionosphere

1. 地面数据、资料、震例、指标
2. 地面数据、资料、震例、指标
3. 地面数据、资料、震例、指标
4. 地面数据、资料、震例、指标
GPS TEC
Electron density (Ne) before M8.0 Wenchuan earthquake
In-situ Ionic H+ and O+ content recorded by DEMETER satellite
Case studies after the Wenchuan event (O+).
Main features of ionospheric anomalies related with earthquake

- **Main physics parameters**
  - Electromagnetic fields: VLF, ELF, ULF, etc;
  - Plasma: TEC; $f_0F_2$; Electron / ion concentration and temperature; Ionic components, etc;
  - Energetic particles: particle flux.

- **Time**
  - Plasma Disturbances 1-5 days before earthquake, duration 4 to 6 hours;
  - Electromagnetic field and energetic particle Disturbances: 1-5 hours before earthquake;
  - Disturbances often come in the afternoon.

- **Spatial scale**
  - about 10° around, epicenter a certain shift relative to the epicenter, magnetic conjugate zone may also occur

- **Intensity**
  - magnetic: nT;
  - Electronic field: uV/m;
  - Energetic particles and Plasma: more than 20-30%.
Technique flow of Infrared radiation anomaly processing

Infrared radiation anomaly study

Background of multi-parameter

Multi-parameter background study

Infrared information related to earthquake

Infrared information extraction

Comprehensive analysis of multi-parameters

Spatial variation

Temporal variation

Different space scale background characteristics

Change analysis

Earthquake infrared information characteristics (time, space, intensity, and relationship with construction)

Inner correlation

Anomaly change synchronization

Chongqing Earthquake

Shaanxi Earthquake

Yushu Earthquake

Wenchuan Earthquake

Wu'an Earthquake

Yuanli Earthquake
Infrared radiation anomaly related with the M8.0 Wenchuan earthquake

**Brightness Temperature**

- **2008**
  The obvious Brightness Temperature anomalies (May 7 and 8) may be have relationship with this event.

- **2007**
  The anomalies (May 10, 21 and 29) may be have relationship with wenchuan earthquake. Another possibility is M6.4 Ninger earthquake occurred on Jun 6, 2007.

- **2006**
  No obvious anomalies.
Infrared radiation anomaly related with the M8.0 Wenchuan earthquake

Outgoing Longwave Radiation

- The obvious OLR anomaly appeared 13 days (April 29, 2008) before this event in the epicenter.
- This kind of anomaly appeared frequently in the epicenter region until the day before this earthquake (May 11, 2008), and the scale decreased gradually. Then the anomalies disappeared completely after the earthquake.
- The anomaly covers an area of approximately 20,000 square kilometers and was distributed along the Longmenshan fault zone, which is the seismogenic structure of this earthquake.

The OLR anomaly evolution before Wenchuan Ms 8.0 earthquake on May 12, 2008
(Epicenter is marked with red star, active faults with red lines)
Infrared radiation anomaly related with the M8.0 Wenchuan earthquake

Surface Latent Heat Flux

- Obvious SLHF anomalies before this earthquake over the epicenter area.
- The scale of anomalies decreased gradually and disappeared completely after the earthquake.

The SLHF anomaly evolution before Wenchuan Ms 8.0 earthquake on May 12, 2008
The NCEP air temperature anomalies of this event start from 5 May and the highest anomalies appear on 6 May.

The NCEP air temperature anomalies disappeared completely after 7 May.
## Comprehensive forecast

### Synchronism Features of Infrared Multi-parameter

<table>
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<td></td>
<td></td>
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<td>time</td>
</tr>
<tr>
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<td>no abnormal</td>
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<td></td>
<td></td>
<td></td>
<td>isolated</td>
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<td></td>
<td></td>
<td></td>
<td>1-3 (STD threshold)</td>
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<td></td>
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<td>&gt;M6.0 for better</td>
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The anomalies appeared about two weeks prior to earthquakes.

The location of seismic anomalies were usually isolated and near the epicenter.

The infrared anomalies are possible to be detected in several earthquakes, especially greater magnitude (Ms>6.0) events.
Successful case

Wenchuan earthquake—2008.5.12

Mid-term prediction
Crustal deformation measurement by InSAR

CR/PS-InSAR Joint algorithm flowchart

Constrained by the deformation rate of CR point and the elevation solved by the GPS receivers, it can improve the square error of the baseline network of PS point and in the final solved out the unknown parameters.

This can effectively combine the CRInSAR with PSInSAR to improve the accuracy of calculation.
Mean slip rate (mm/yr): Left 2003-2008; Right: 2008-2010

Slip profiles, left: 2003-2008年, right: 2008-2010
3D deformation field produced by the Yutian earthquake

\[
\begin{pmatrix}
  d_U \\
  d_E
\end{pmatrix} =
\begin{pmatrix}
  0.554895 & 0.516508 \\
  -1.415460 & 1.430564
\end{pmatrix}
\begin{pmatrix}
  d_1 + d_n \cdot 0.071996 \\
  d_2 + d_n \cdot 0.077346
\end{pmatrix}
\] (4-6)
Gravity satellite
D-InSAR Satellite constellation
SAR satellite in high orbit
Multi-angle infrared

Electromagnetic satellite

Gravity satellite

National civil space infrastructure

Optical satellite
Radar satellite
Infrared and hyperspectral satellite in high orbit

Optical satellite in high orbit

Electromagnetic satellite

2020 2025 2030

BD navigation system
Follow-up plan of BD

Satellite communication system
Follow-up plan of satellite communication system

Application projections

BD navigation system
Follow-up plan of BD

Satellite communication system
Follow-up plan of satellite communication system

2020
2025
2030

Bussiness RS satellite
New-type probe satellite
Ground ancillary facilities
Thanks for Your Attention
Infrared multi-parameter and earthquakes

- SLHF
- NCEP
- TBB
- OLR

internal relationship?

abnormal synchronism?

earthquake