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

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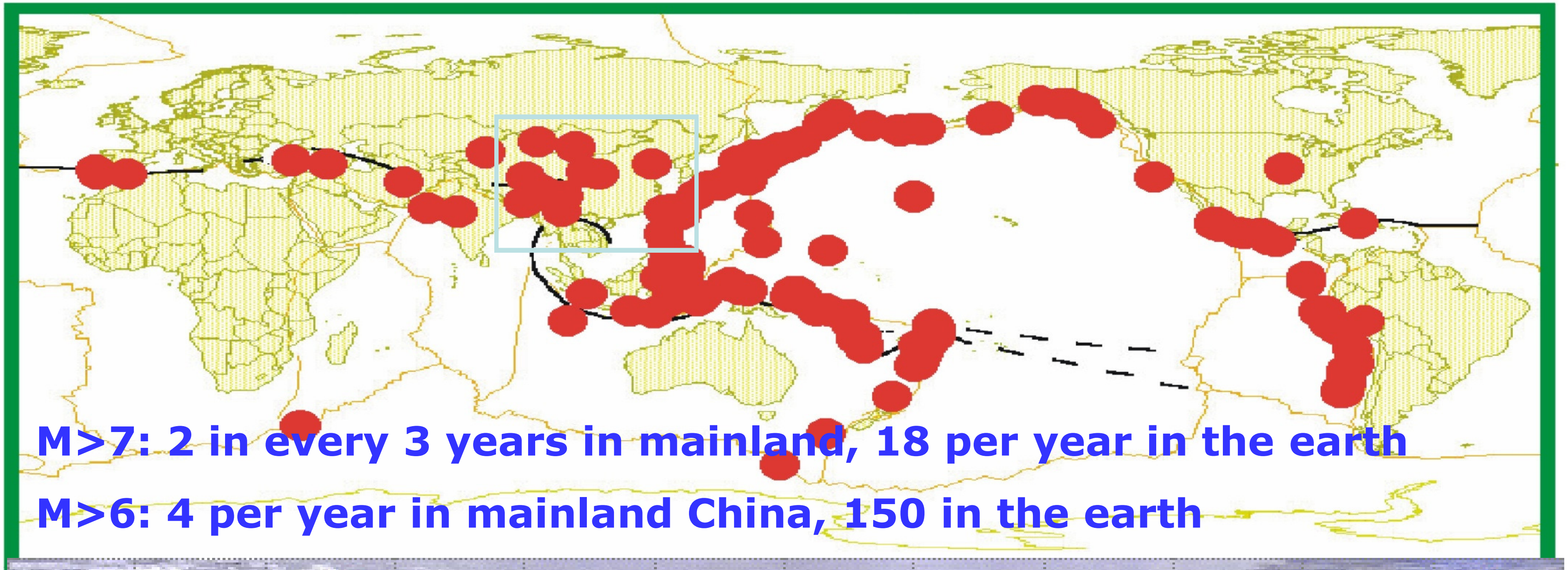
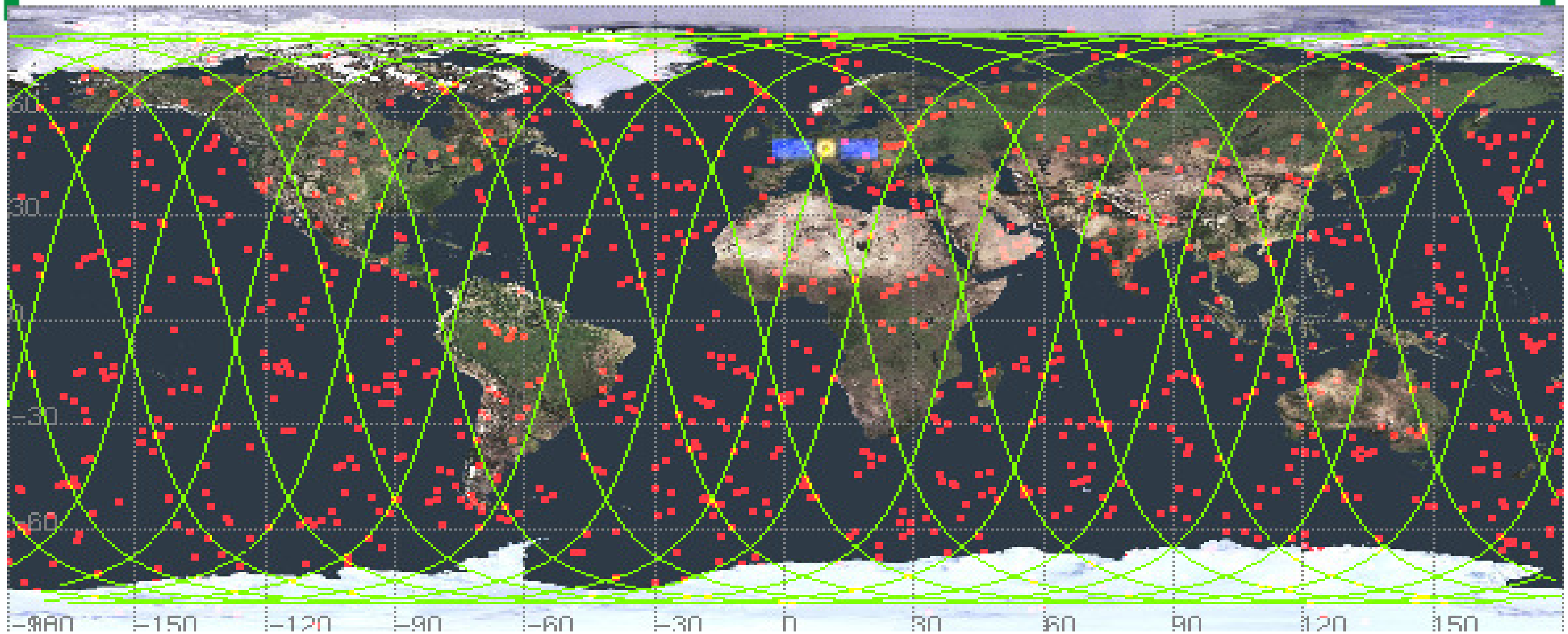
Outline

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


60
30
0
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-180
-150
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-60
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0
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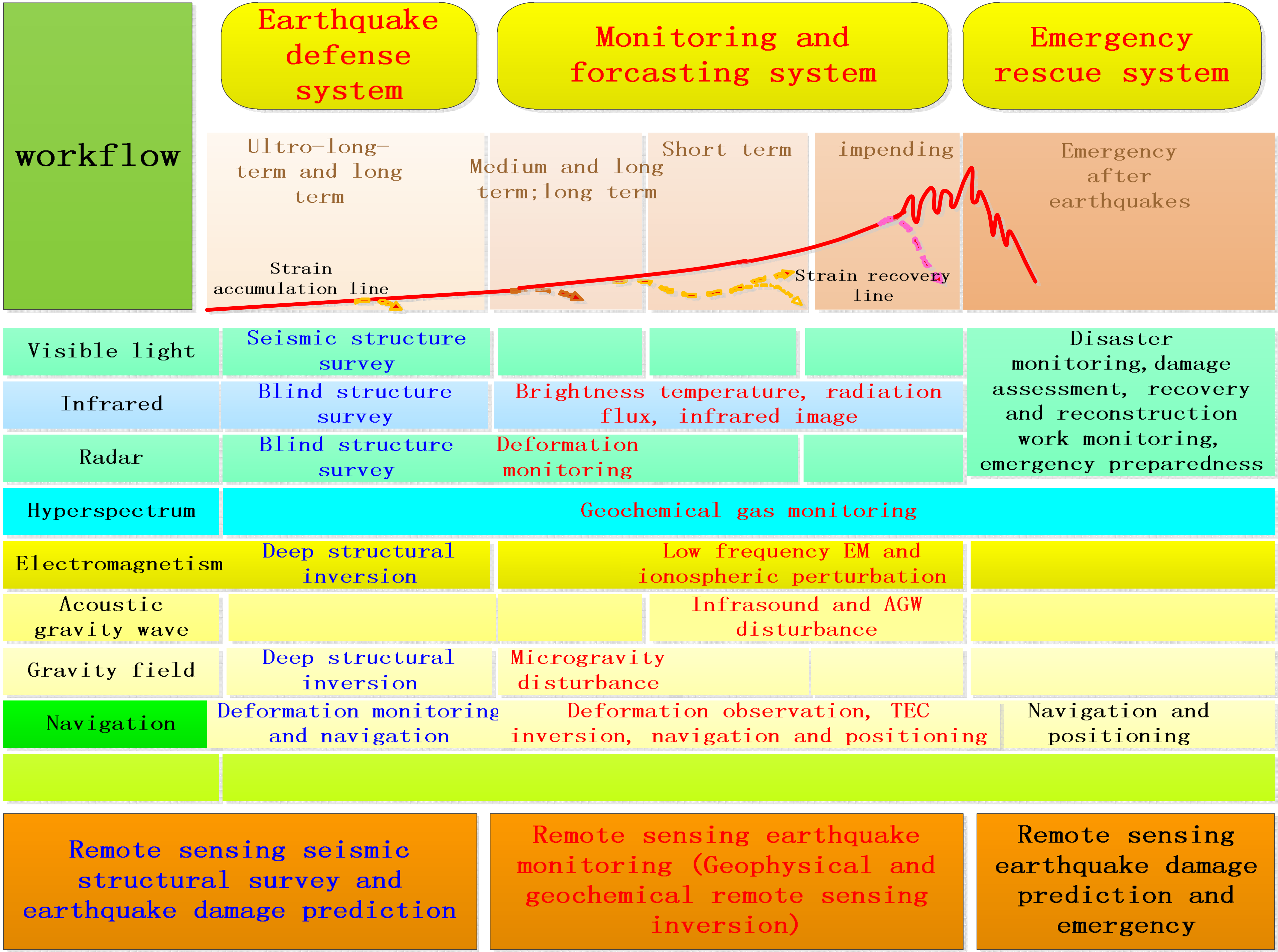
90
120
150

Earth observation from spatial technology provide new opportunities for improving of the ability of earthquake prevent and disaster reduction

- **Large-scale**
  - **highly dynamic**
    - **multi-parameters**
      - **all-weather**

Seeing the Earth with new eyes


workflow
Earthquake defense system
Monitoring and forcasting system
Emergency rescue system
Ultro-long-term and long term
Medium and long term;long term
Short term
impending
Emergency after earthquakes
Strain accumulation line
Strain recovery line
Visible light
Seismic structure survey
Disaster monitoring, damage assessment, recovery and reconstruction work monitoring, emergency preparedness
Infrared
Blind structure survey
Brightness temperature, radiation flux, infrared image
Radar
Blind structure survey
Deformation monitoring
Hyperspectrum
Geochemical gas monitoring
Electromagnetism
Deep structural inversion
Low frequency EM and ionospheric perturbation
Acoustic gravity wave
Infrasound and AGW disturbance
Gravity field
Deep structural inversion
Microgravity disturbance
Navigation
Deformation monitoring and navigation
Deformation observation, TEC inversion, navigation and positioning
Navigation and positioning
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

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1. **Main requirements of satellite technique for earthquake monitoring**
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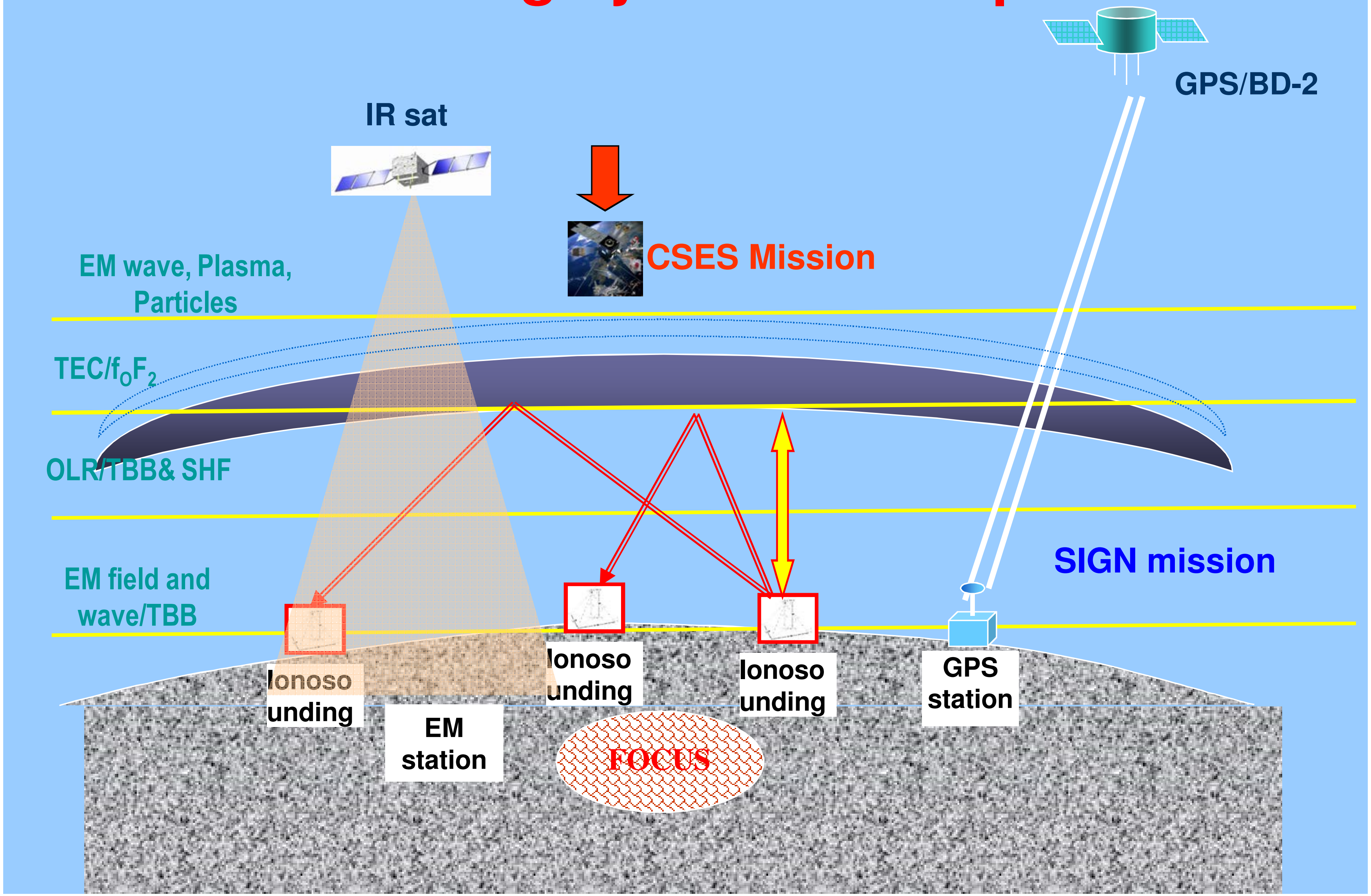
Conceptual diagram of China earthquake monitoring system from Space



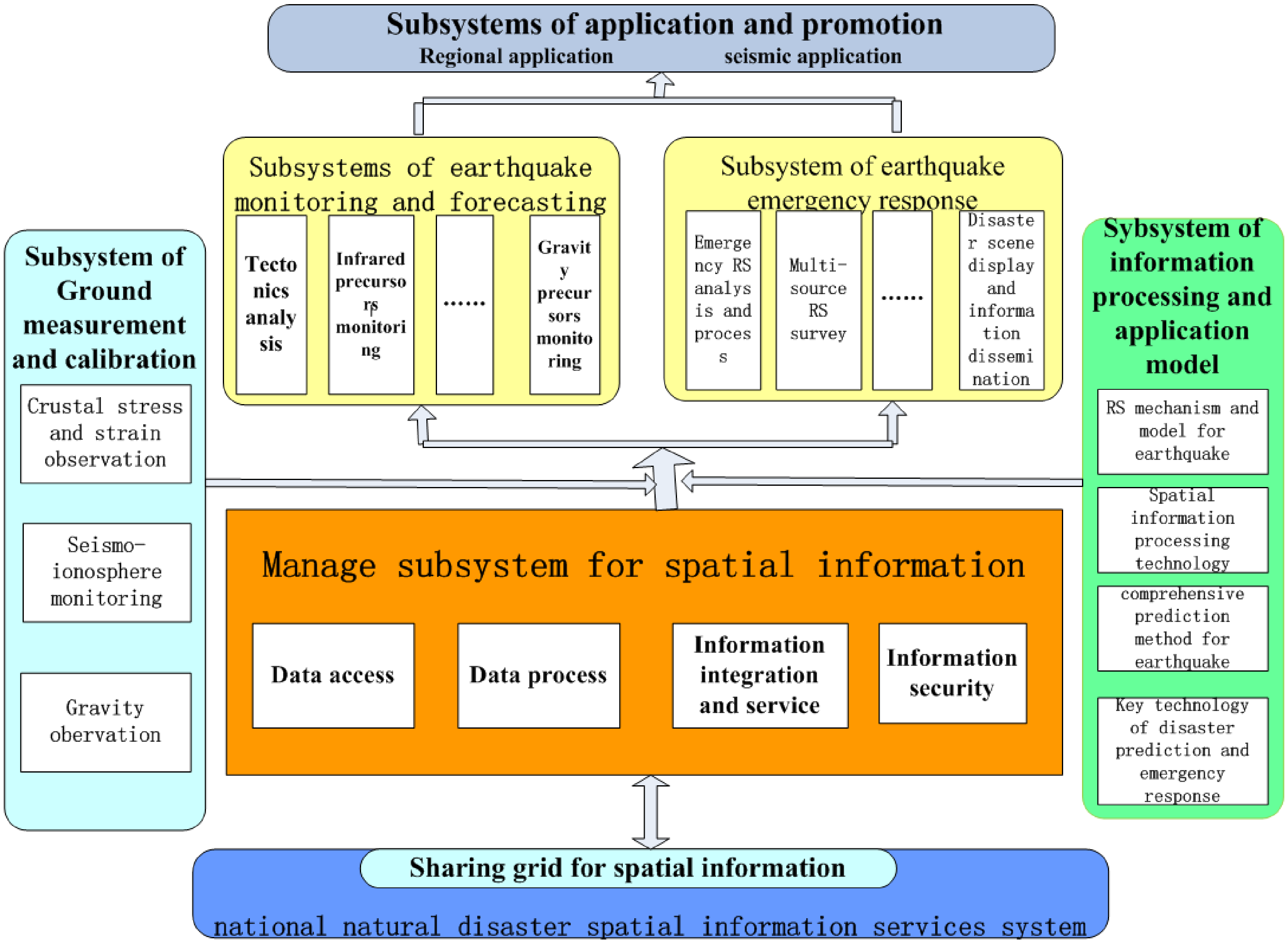
Space segment of the three-dimensional seismic monitoring

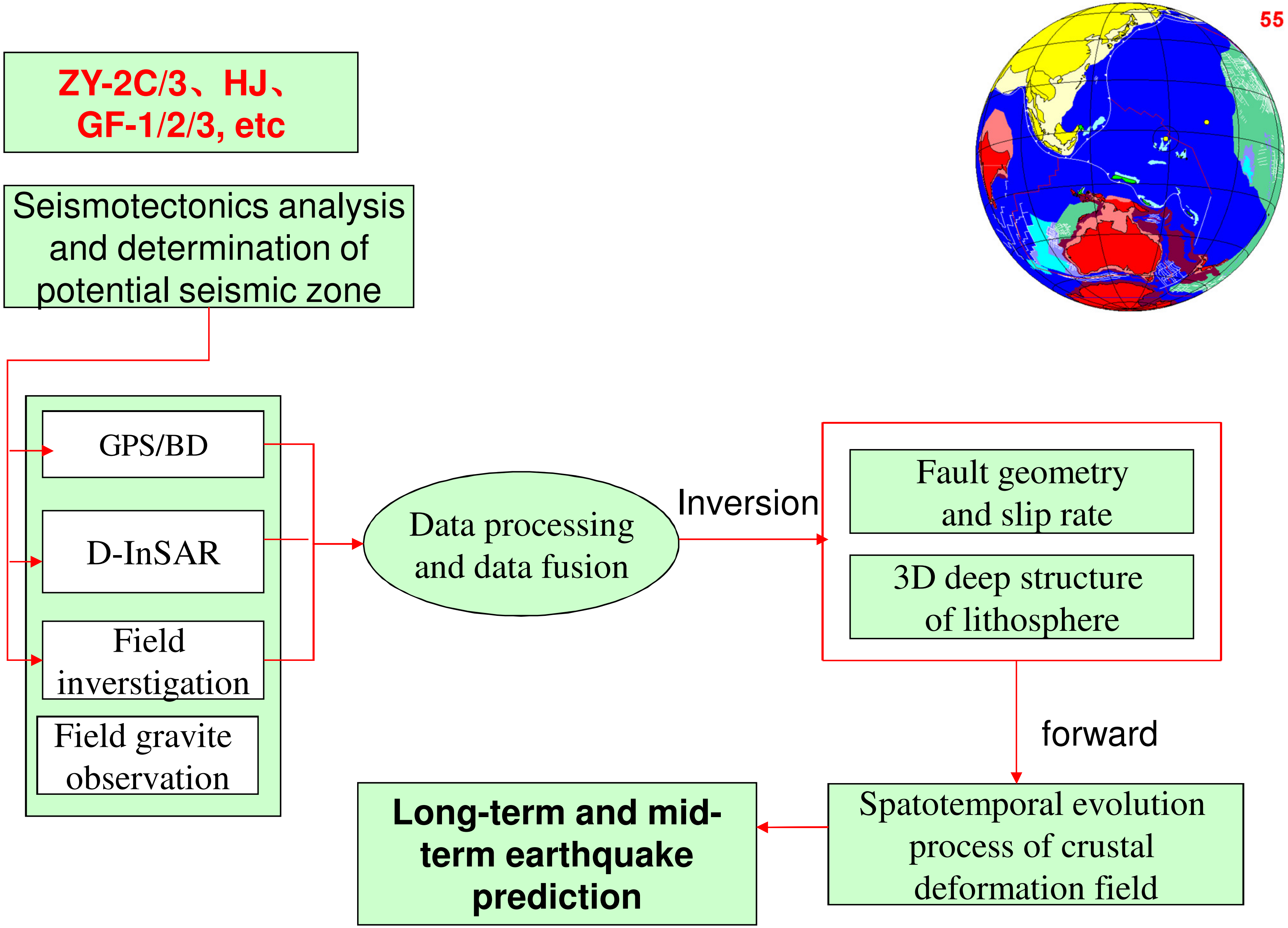
- Long-term and mid-term seismic precursors monitoring system: GPS-BD, D-InSAR, gravity, etc.
- Mid-term and short-term seismic precursors monitoring system: Infrared, hyperspectral, etc.
- Short-term and impending seismic precursors monitoring system: Seismo-Ionosphere, etc.
- Emergency response and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

Key Projects

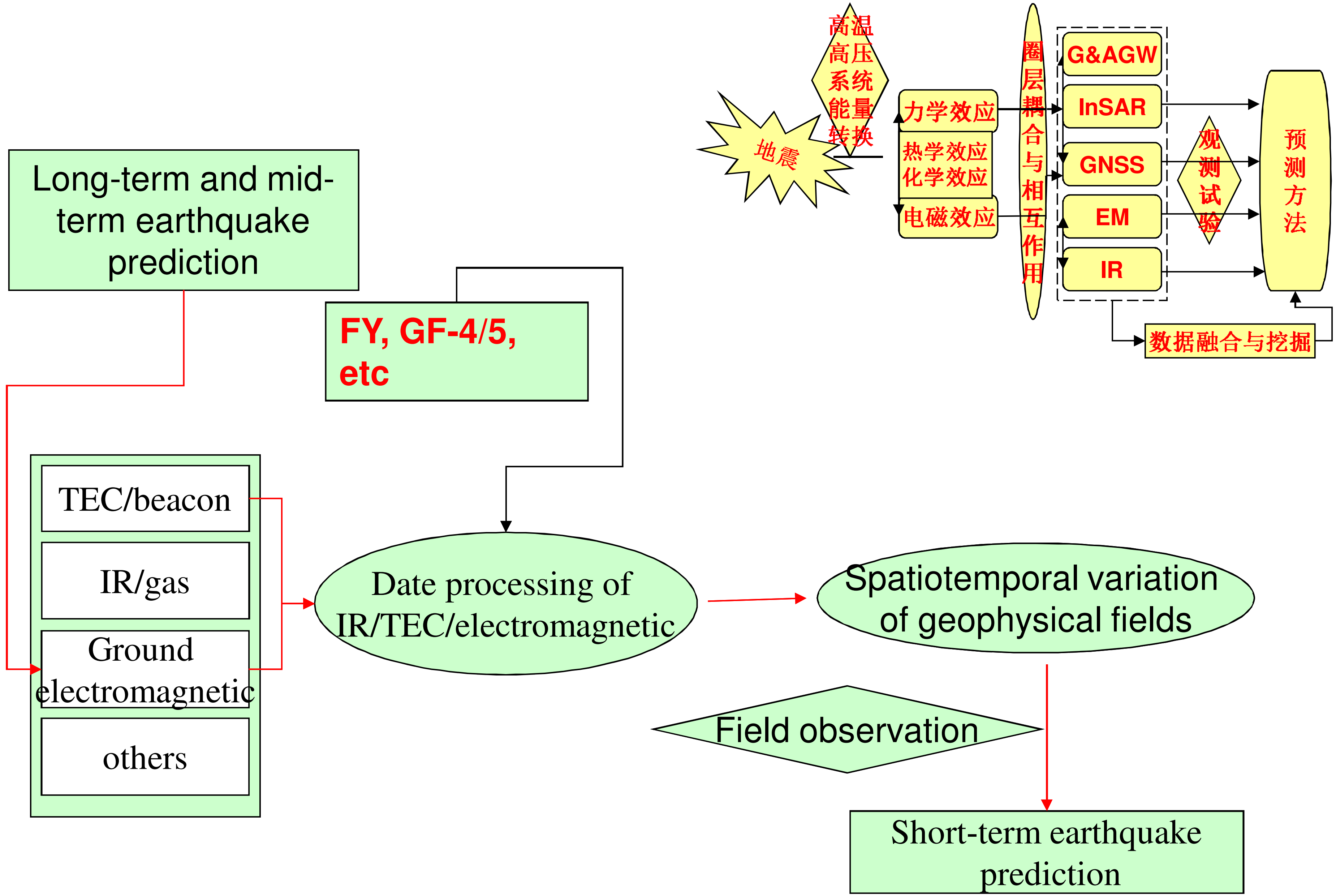
- Geophysical remote sensing satellite: Electromagnetic Satellite, gravity satellite
- High-resolution optical and radar satellite in geostationary orbit
- Reformation of crustal movement observation network platform: GPS - BD
- Integrated satellite application system for earthquake: RS+BD+ communication 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



Technical flow of short-term and impending earthquake prediction

Outline

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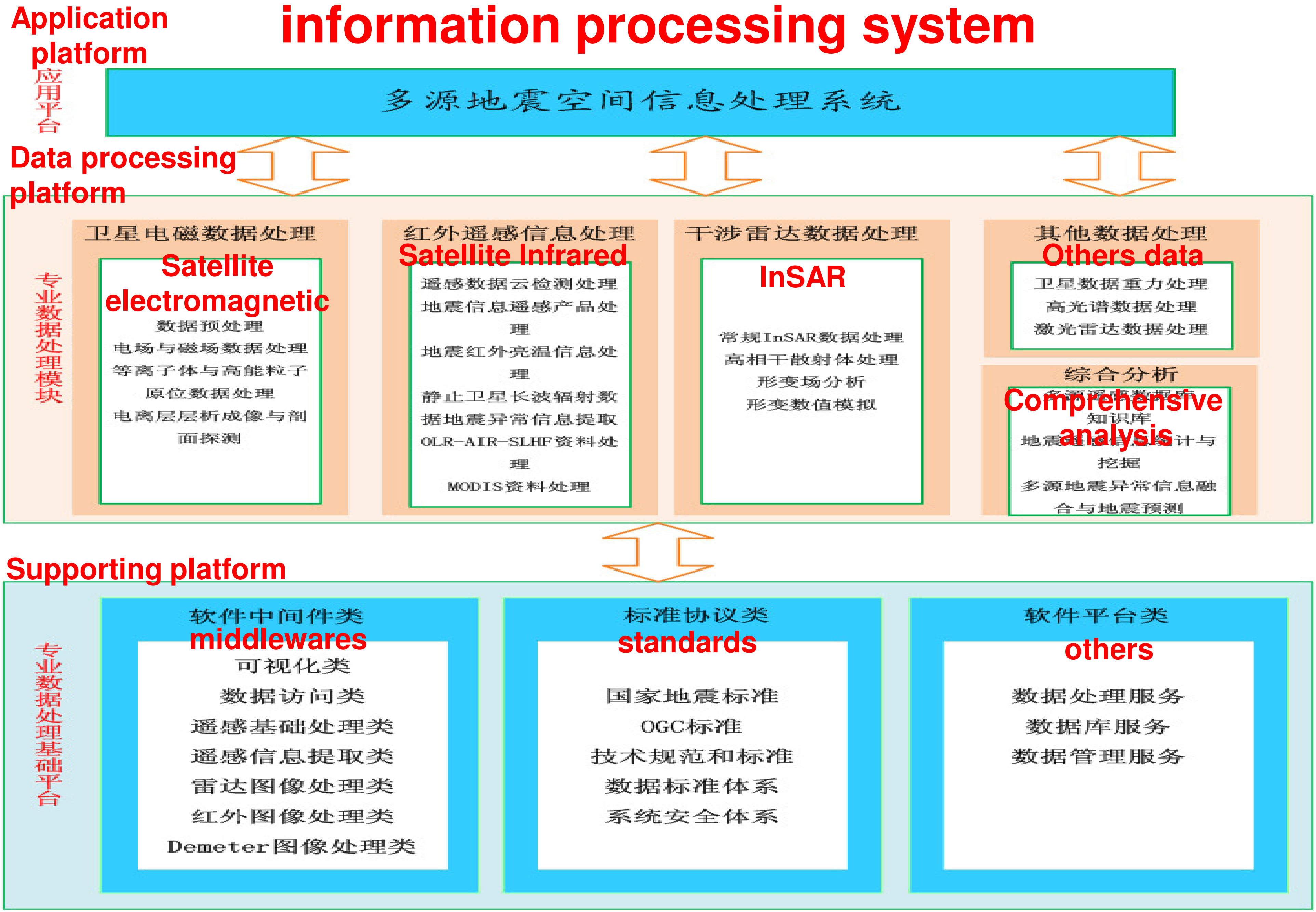
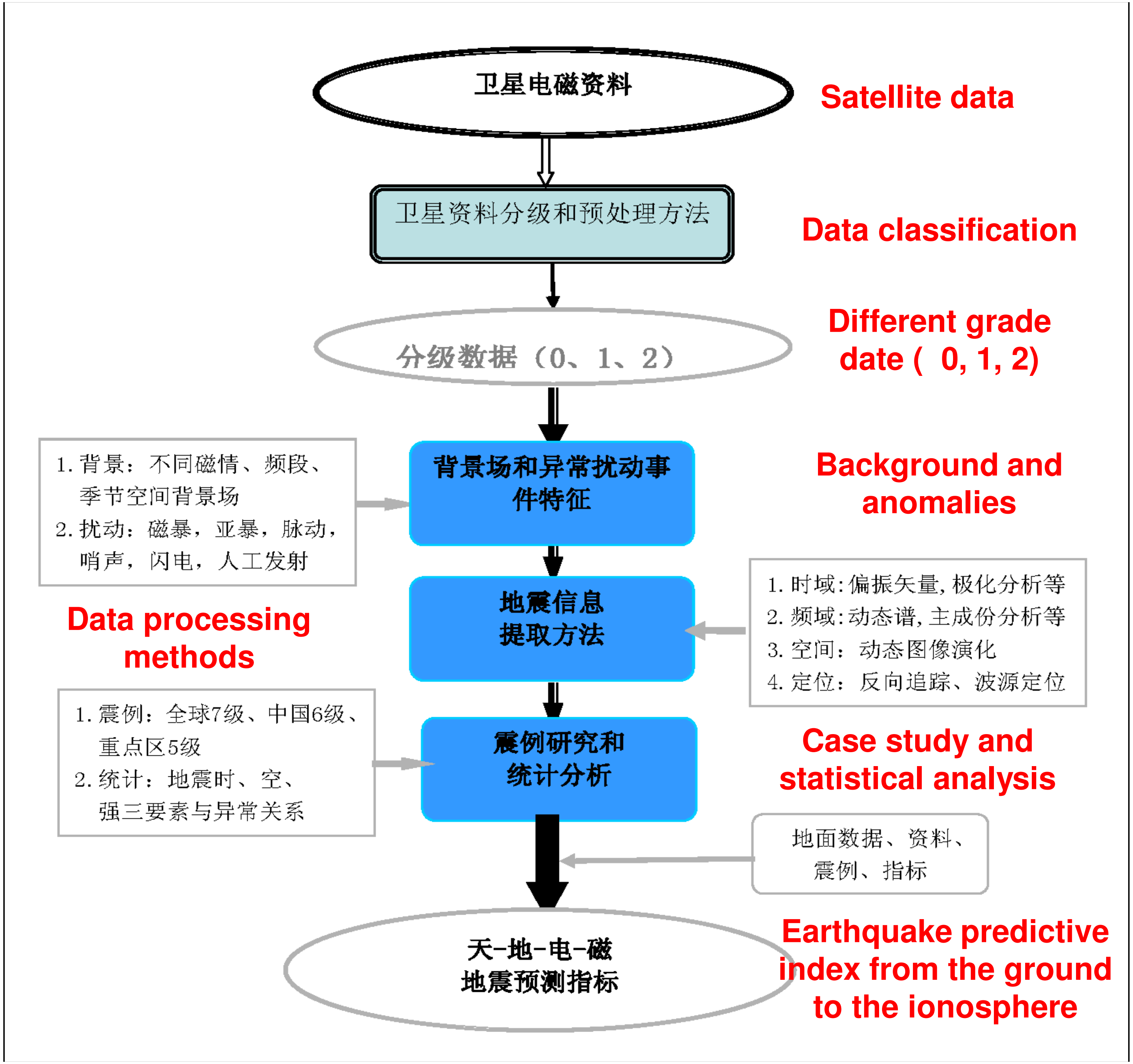
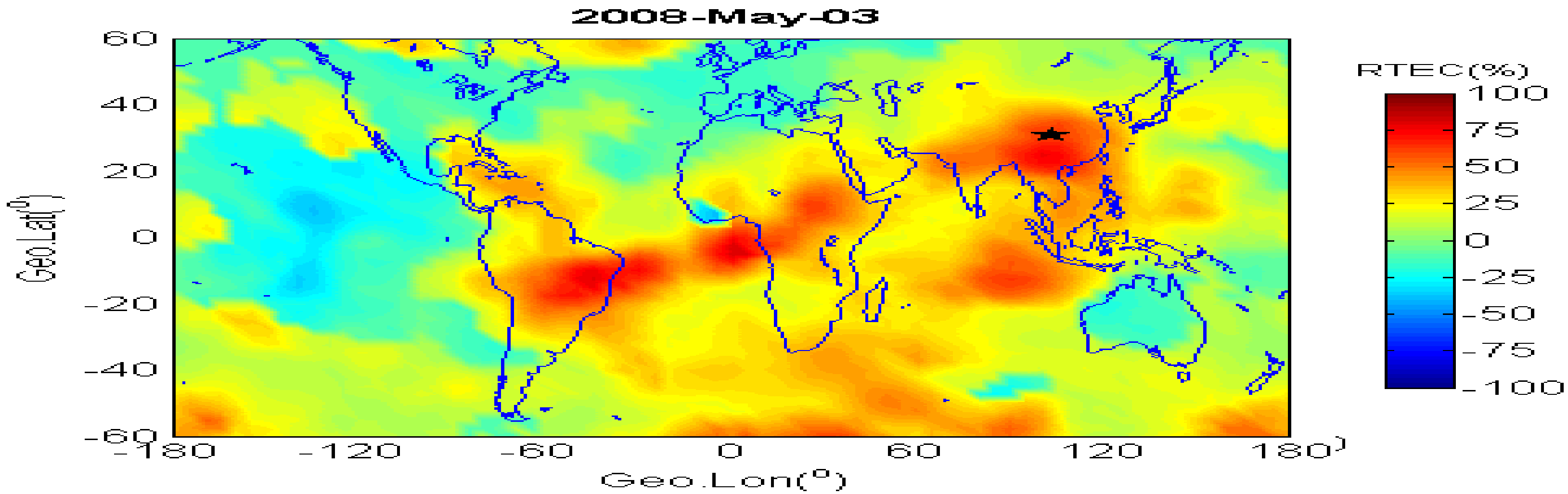
Framework of multi-source seismic information processing system



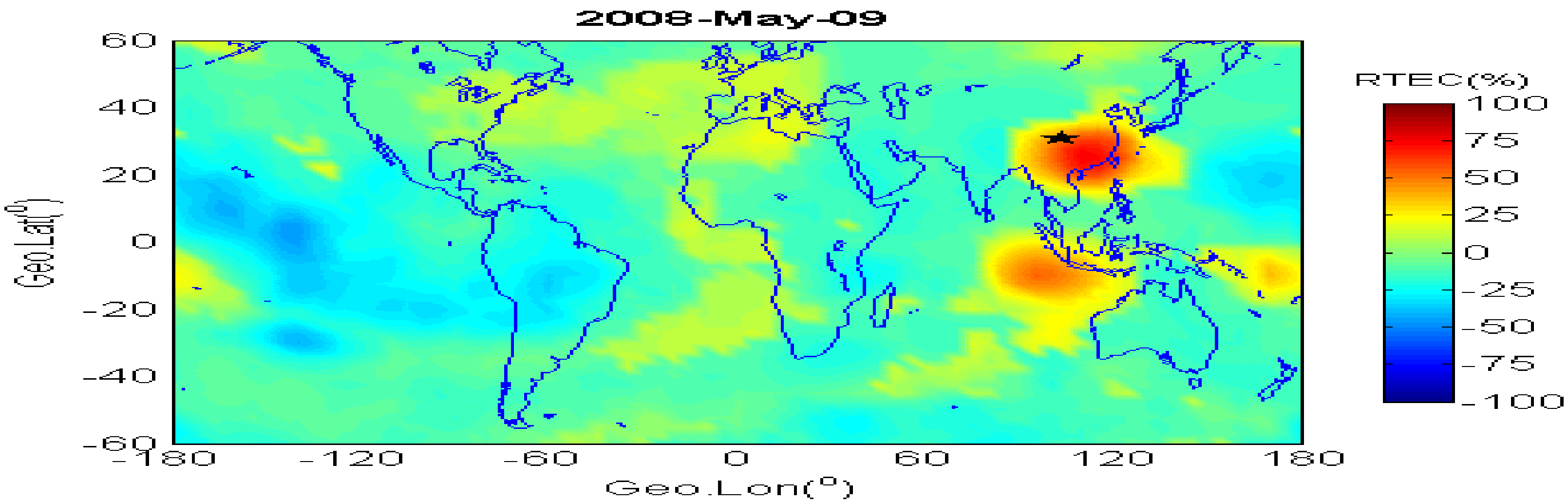
Technical flow on electromagnetic satellite data-processing



GPS TEC

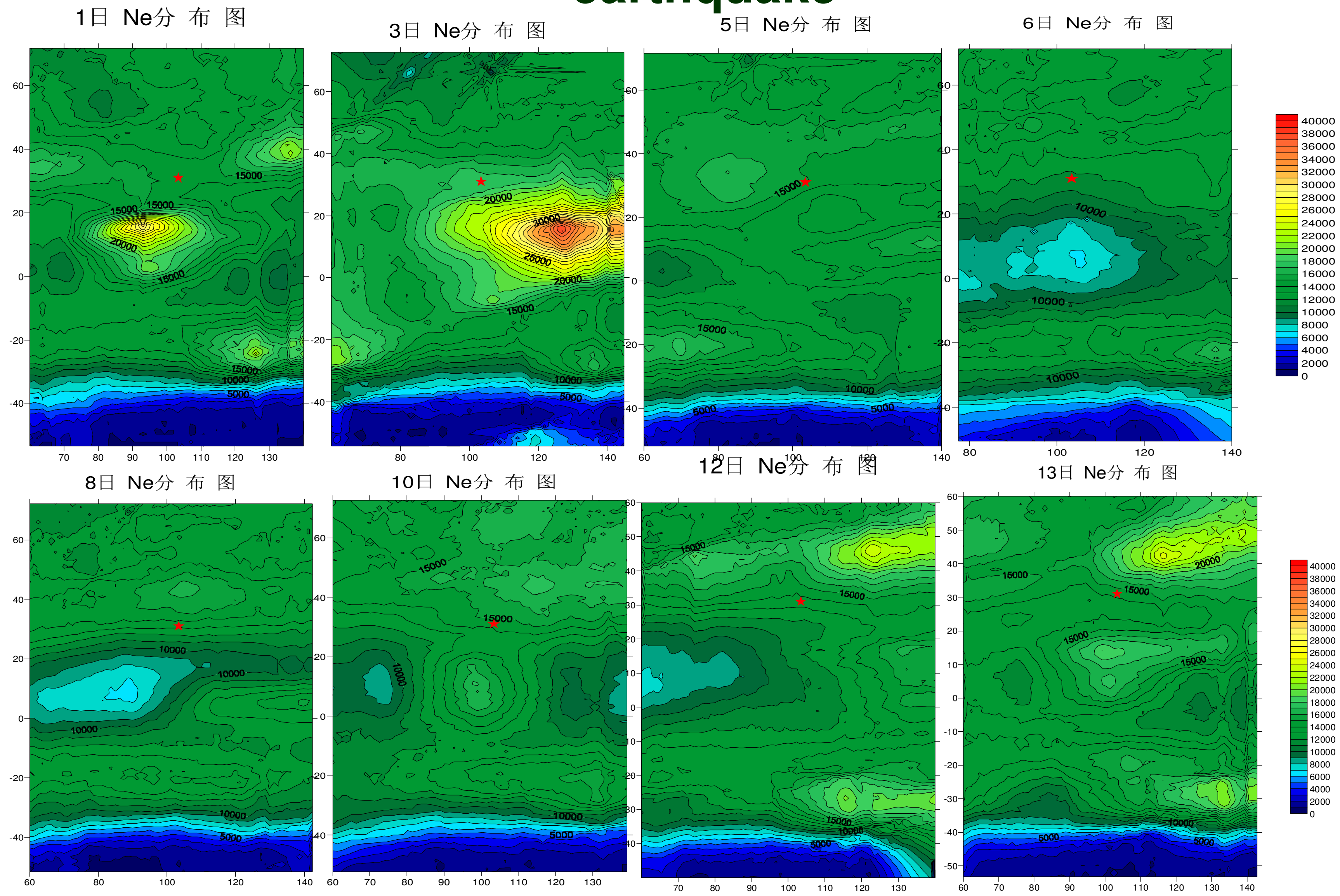


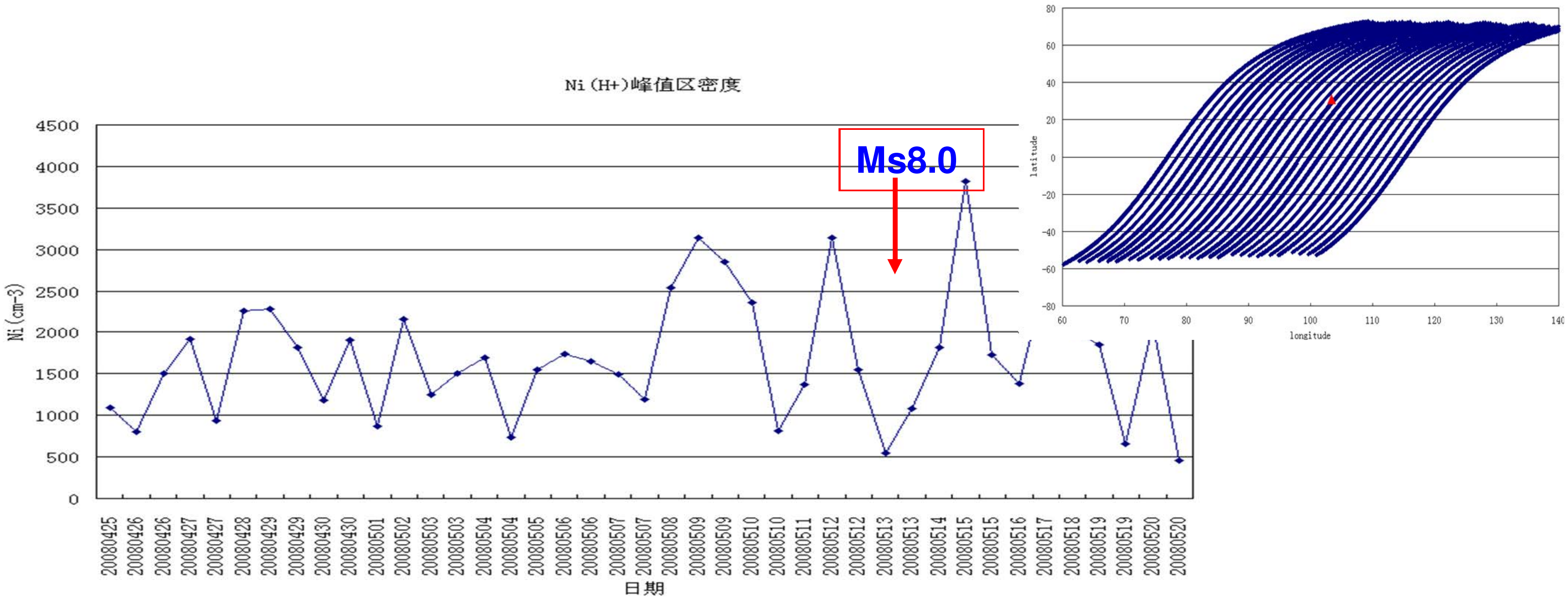
2008-May-03
60
40
20
0
-20
-40
-60
Geo.Lat(°)
-180
-120
-60
0
60
120
180
Geo.Lon(°)
RTEC(%)
100
75
50
25
0
-25
-50
-75
-100

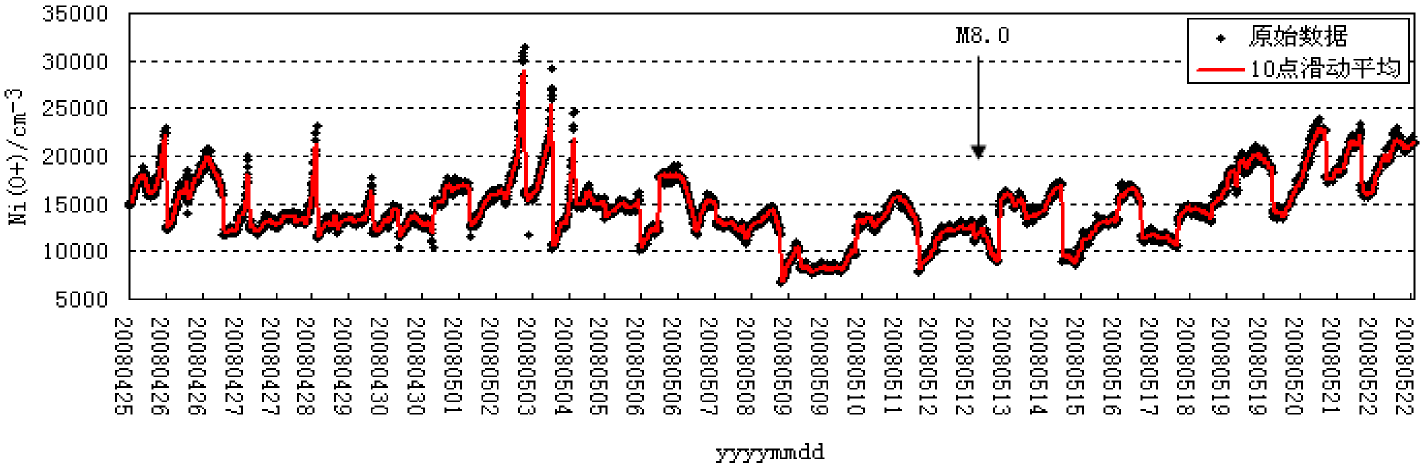


2008-May-09
60
40
20
0
-20
-40
-60
Geo.Lat(°)
-180
-120
-60
0
60
120
180
Geo.Lon(°)
RTEC(%)
100
75
50
25
0
-25
-50
-75
-100

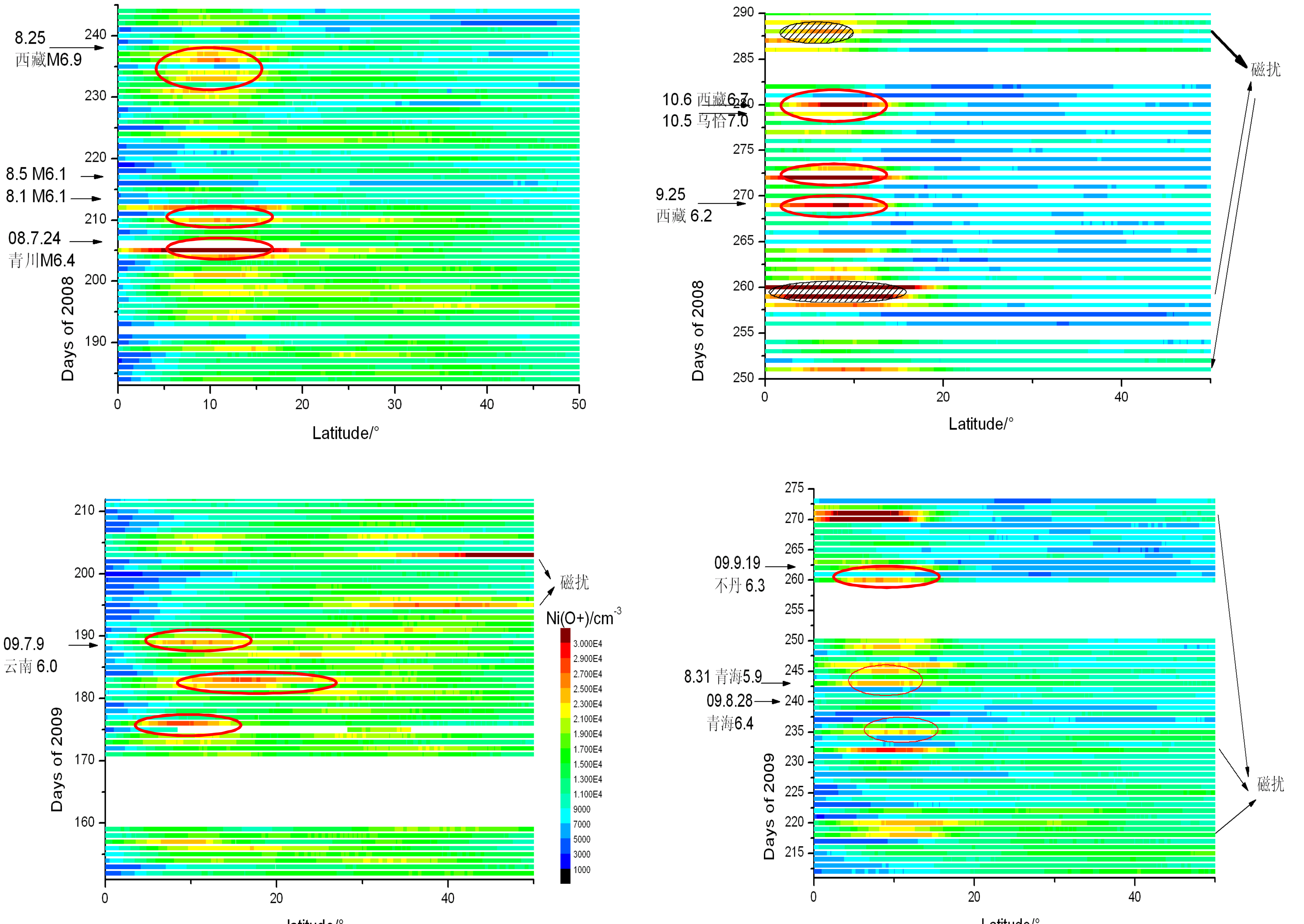
Electron density(Ne) before M8.0 Wenchuan earthquake







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

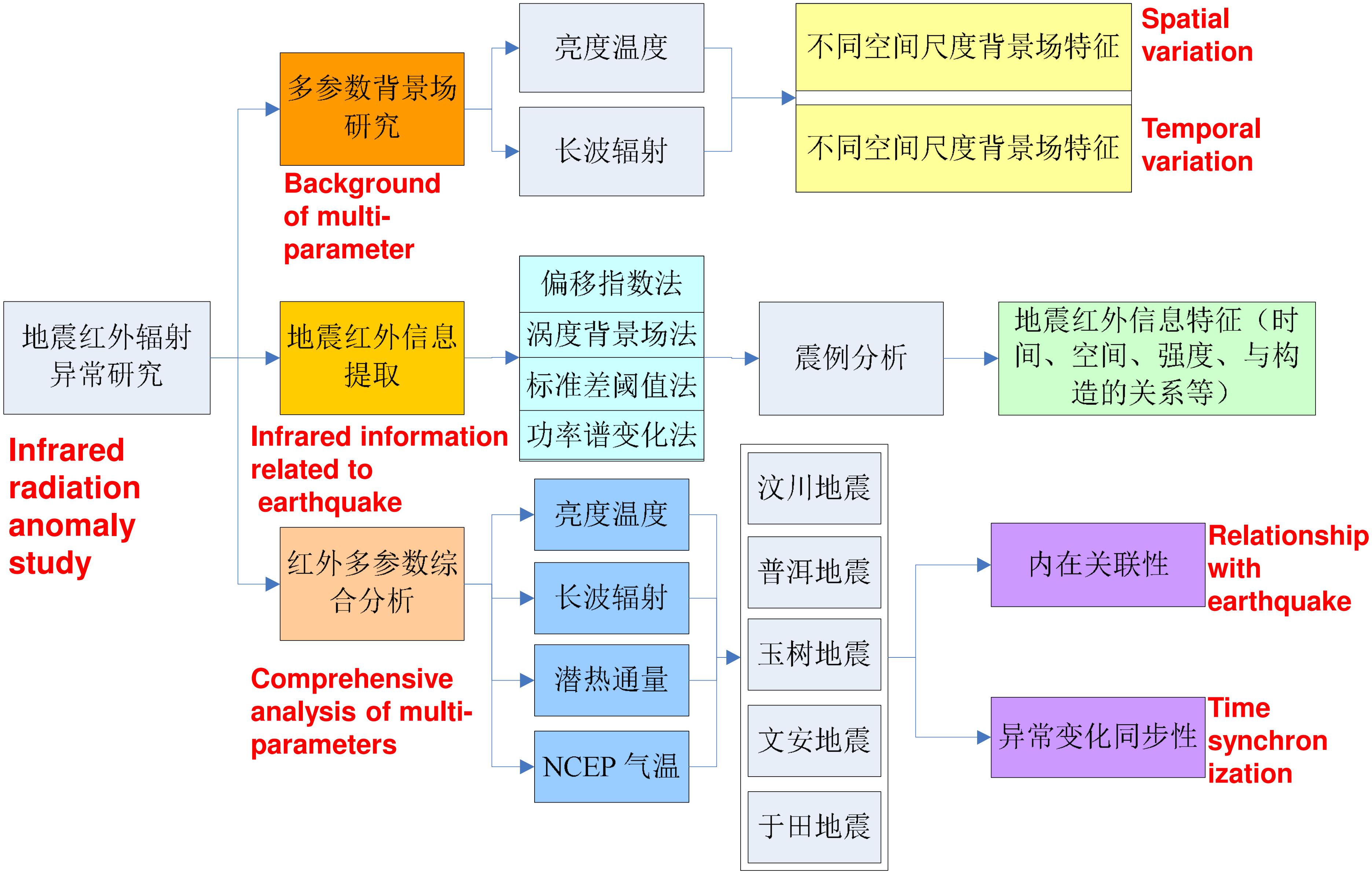
- intensity

  magnetic: nT;

  Electronic field: uV/m;

  Energetic particles and Plasma: more than 20-30%.

Technique flow of Infrared radiation anomaly processing



Infrared radiation anomaly related with the M8.0 Wenchuan earthquake

Brightness Temperature

➢2008

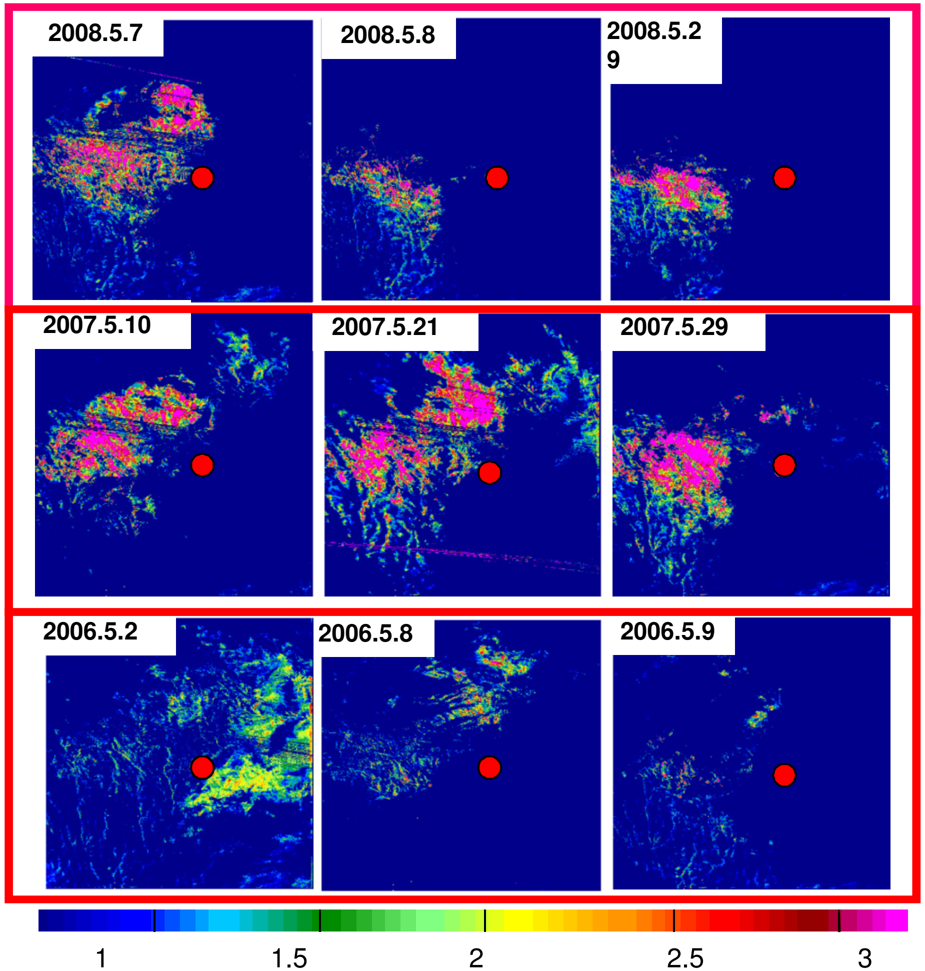
The obvious Brightness Temperature anomalies(May 7 and 8) may be have relationship with this event.

➢ 2007

The anomalies(May10，21and 29） may be have relationship with wenchuan earthquake. Another possibility is M6.4 Ninger earthquake occurred on Jun 6, 2007 .

➢2006

No obvious anomalies.



the TBB anomaly evolution before Wenchuan Ms 8.0 earthquake on May 12, 2008

● epicenter

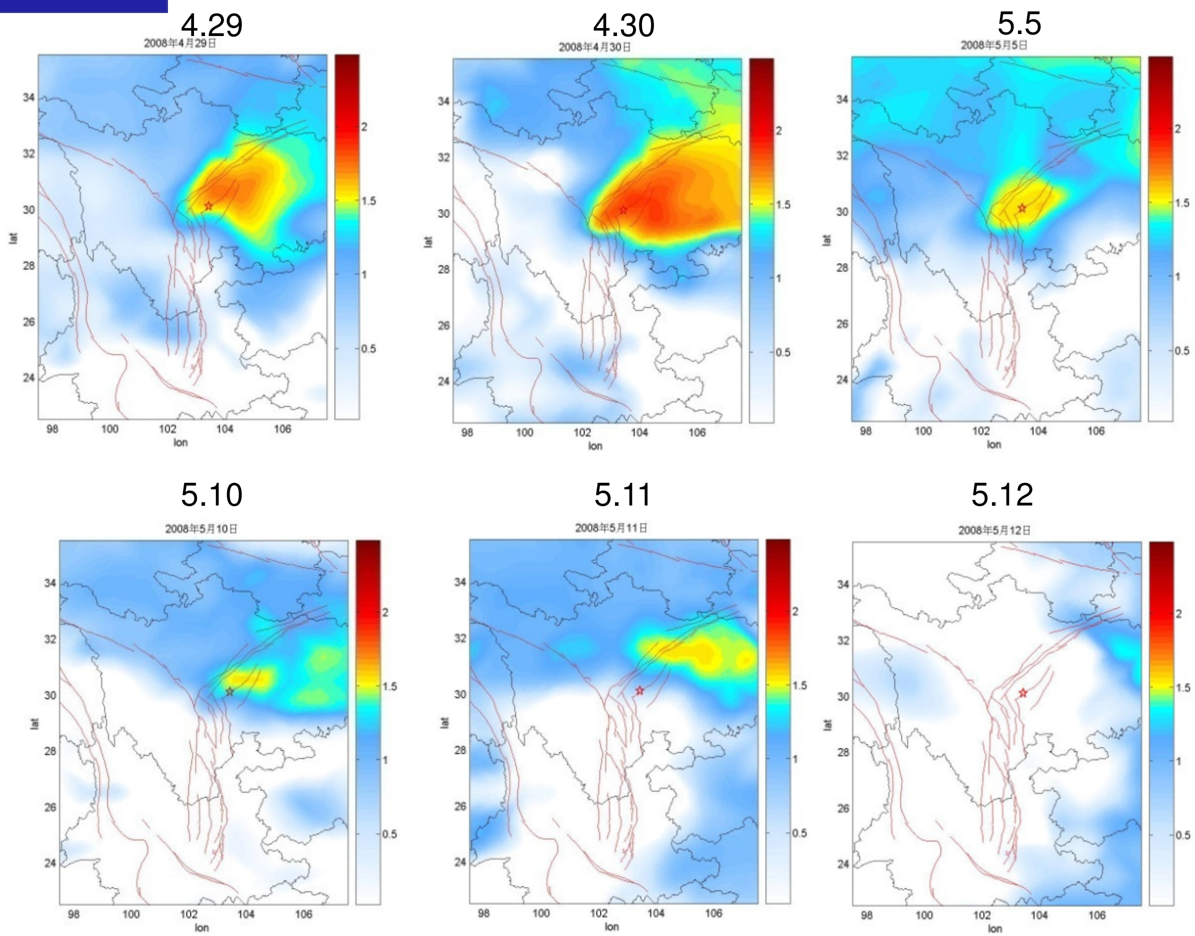
Infrared radiation anomaly related with the M8.0 Wenchuan earthquake

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.

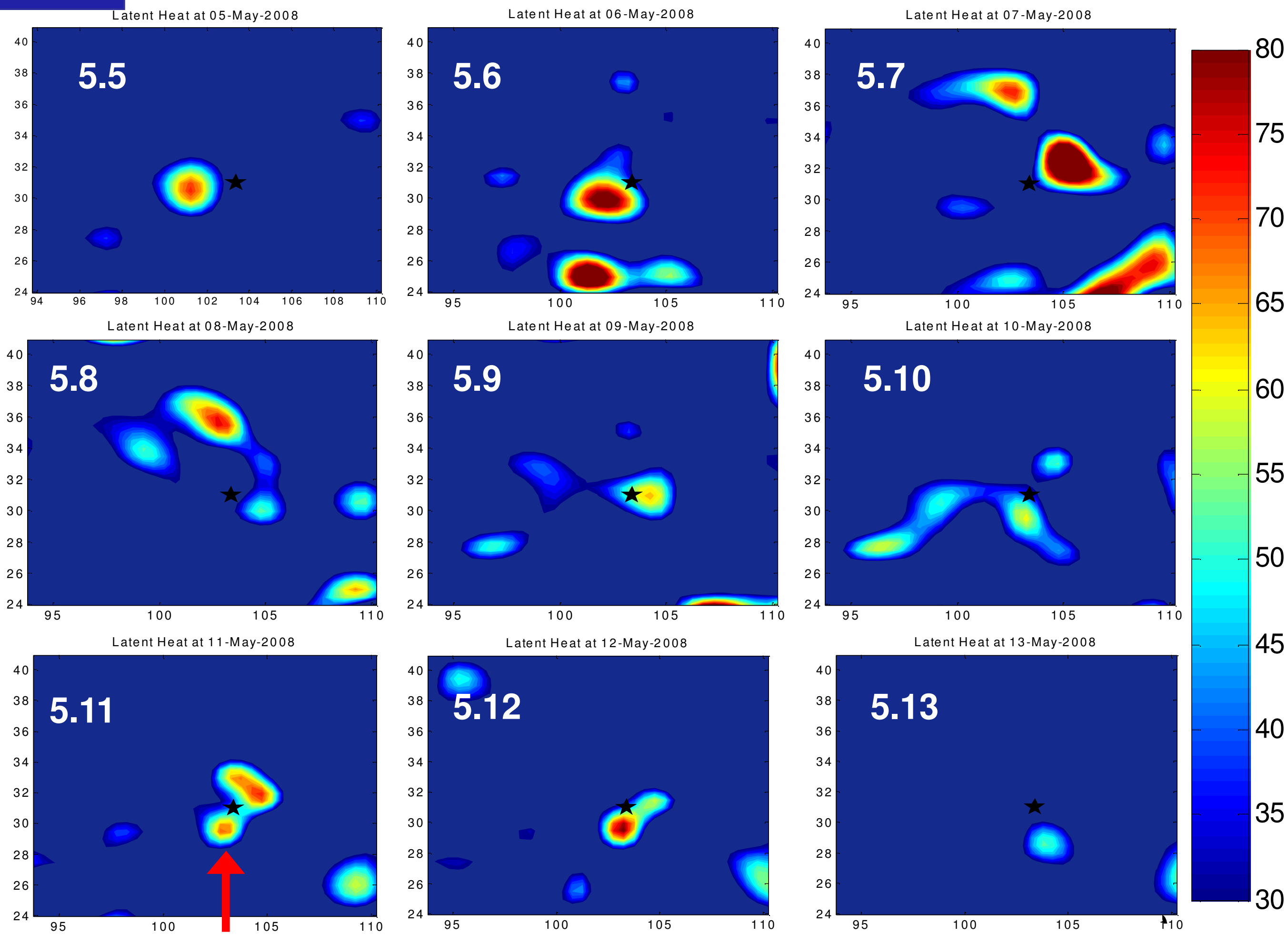


the OLR anomaly evolution before Wenchuan Ms 8.0 earthquake on May 12, 2008
(Epicenter is marked with red star, active faults with red lines)

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.



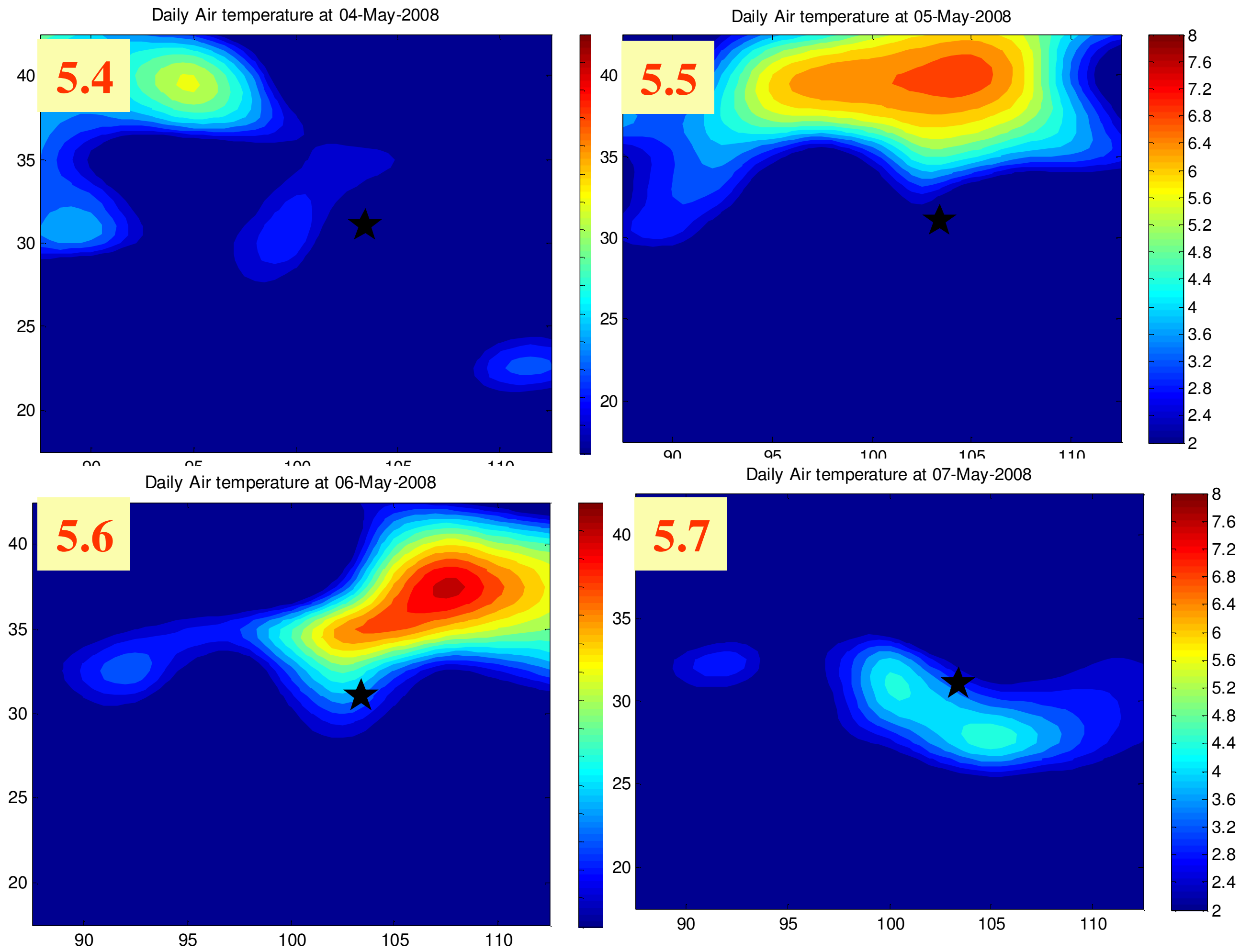
the SLHF anomaly evolution before Wenchuan Ms 8.0 earthquake on May 12, 2008

Infrared radiation anomaly related with the M8.0 Wenchuan earthquake

NCEP Air Temperature

•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.



the NCEP anomaly evolution before Wenchuan Ms 8.0 earthquake on May 12, 2008

Comprehensive forecast

Synchronism Features of Infrared Multi-parameter

No	TYPE	Case study			characteristics			reflect capacity
		total	abnormal	no abnormal	time	space	magnitude	
						isolated	1-3（STD threshold）	>M6.0 for better
2	*TBB*	23	15	8	several days to	Near the fault	>3(threshold)	Most of the earthquakes
3	*SLHF*	95	73 (77%)	22（23%）	2 weeks	Moving toward to the epicenter	About 90W/m^2 (difference from background)	>M6.0 for better
4	*NC EP*		(62%)	(38%)		in the highest region	5-11.2° (difference from background)	Most of the earthquakes

The anomalies appeared about two weeks prior to earthquakes.

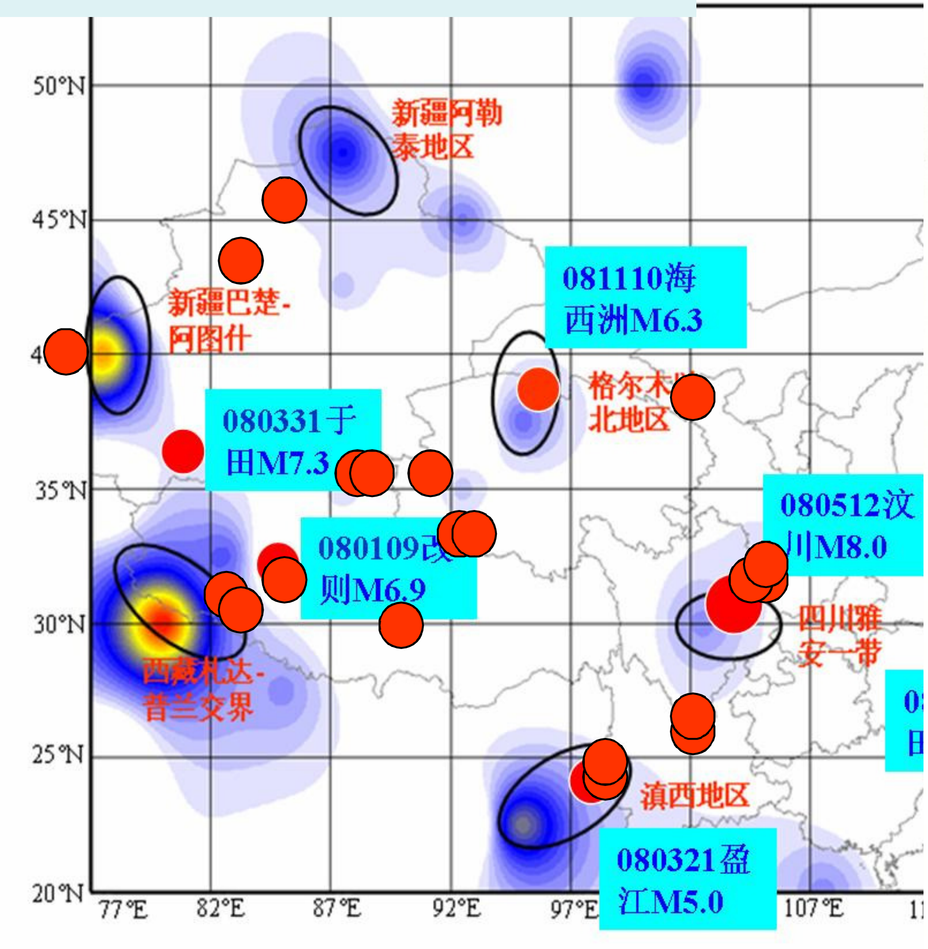
The location of seismic anomalies were usually isolated and near the epicenter.

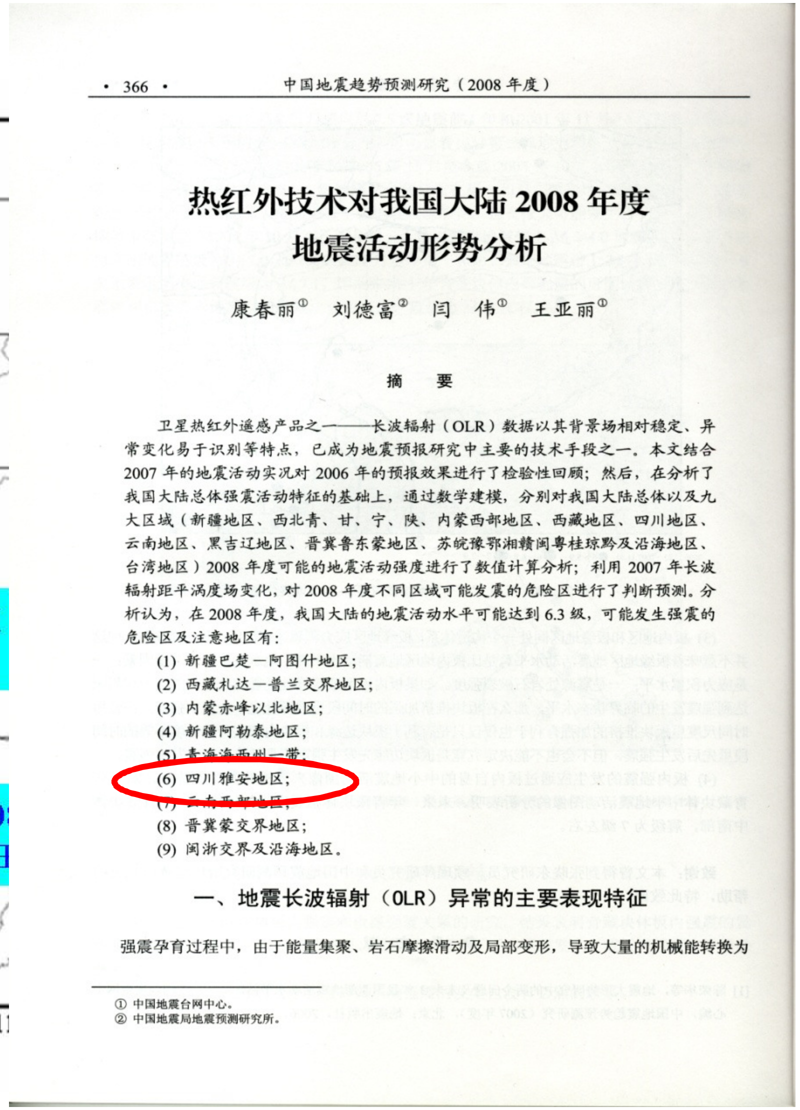
The infrared anomalies are possible to be detected in several earthquakes， especially greater magnitude (Ms>6.0) events.

Successful case

Mid-term prediction

Wenchuan earthquake-2008.5.12





热红外技术对我国大陆 2008 年度地震活动形势分析

康春丽[①] 刘德富[②] 闫 伟[①] 王亚丽[①]

摘　要

卫星热红外遥感产品之一——长波辐射（OLR）数据以其背景场相对稳定、异常变化易于识别等特点，已成为地震预报研究中主要的技术手段之一。本文结合 2007 年的地震活动实况对 2006 年的预报效果进行了检验性回顾；然后，在分析了我国大陆总体强震活动特征的基础上，通过数学建模，分别对我国大陆总体以及九大区域（新疆地区、西北青、甘、宁、陕、内蒙西部地区、西藏地区、四川地区、云南地区、黑吉辽地区、晋冀鲁东蒙地区、苏皖豫鄂湘赣闽粤桂琼黔及沿海地区、台湾地区）2008 年度可能的地震活动强度进行了数值计算分析；利用 2007 年长波辐射距平涡度场变化，对 2008 年度不同区域可能发震的危险区进行了判断预测。分析认为，在 2008 年度，我国大陆的地震活动水平可能达到 6.3 级，可能发生强震的危险区及注意地区有：

(1) 新疆巴楚—阿图什地区；
(2) 西藏札达—普兰交界地区；
(3) 内蒙赤峰以北地区；
(4) 新疆阿勒泰地区；
(5) 青海海西州一带；
(6) 四川雅安地区；
(7) 云南西部地区；
(8) 晋冀蒙交界地区；
(9) 闽浙交界及沿海地区。

一、地震长波辐射（OLR）异常的主要表现特征

强震孕育过程中，由于能量集聚、岩石摩擦滑动及局部变形，导致大量的机械能转换为

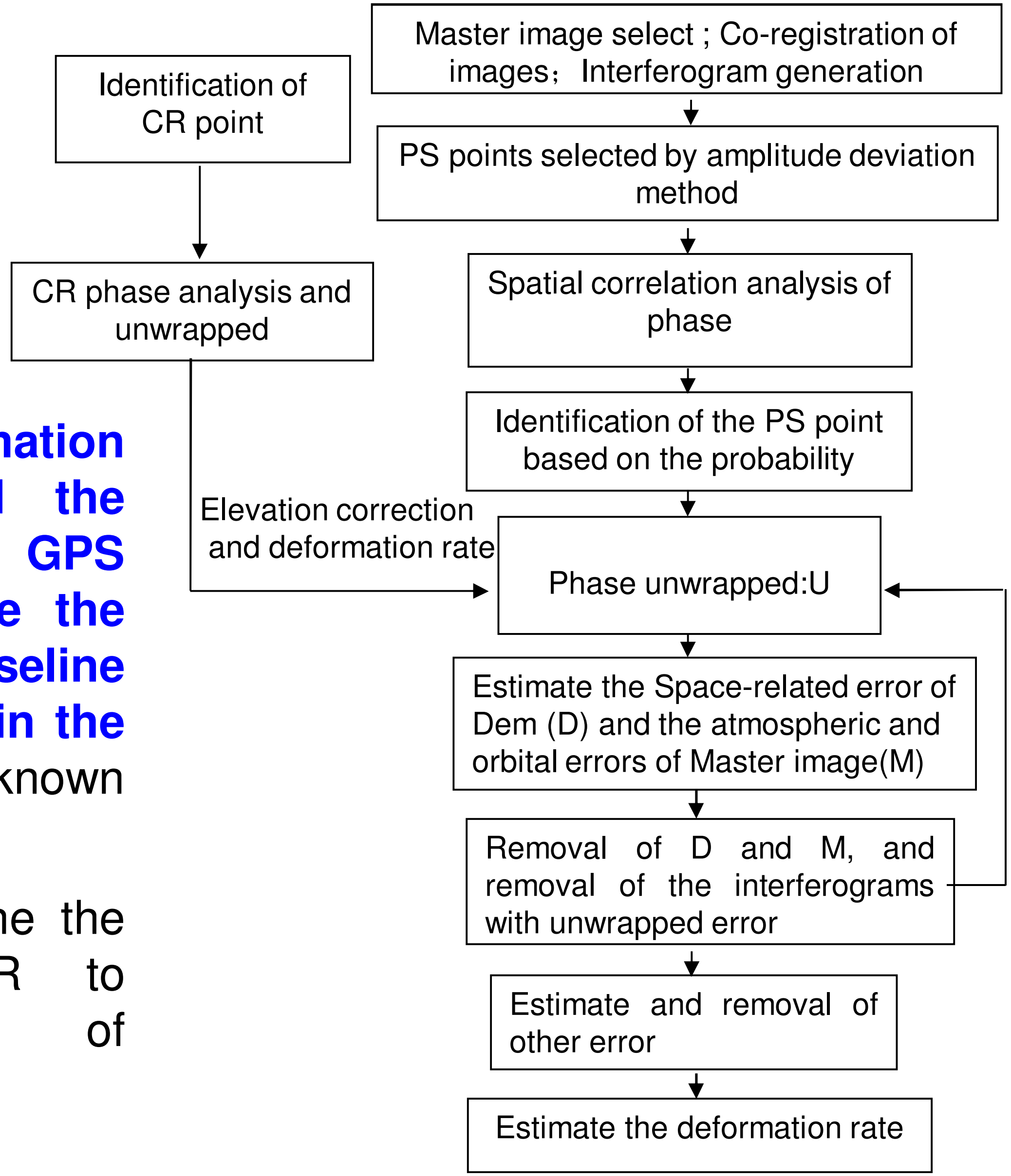
① 中国地震台网中心。
② 中国地震局地震预测研究所。

Crustal deformation measurement by InSAR

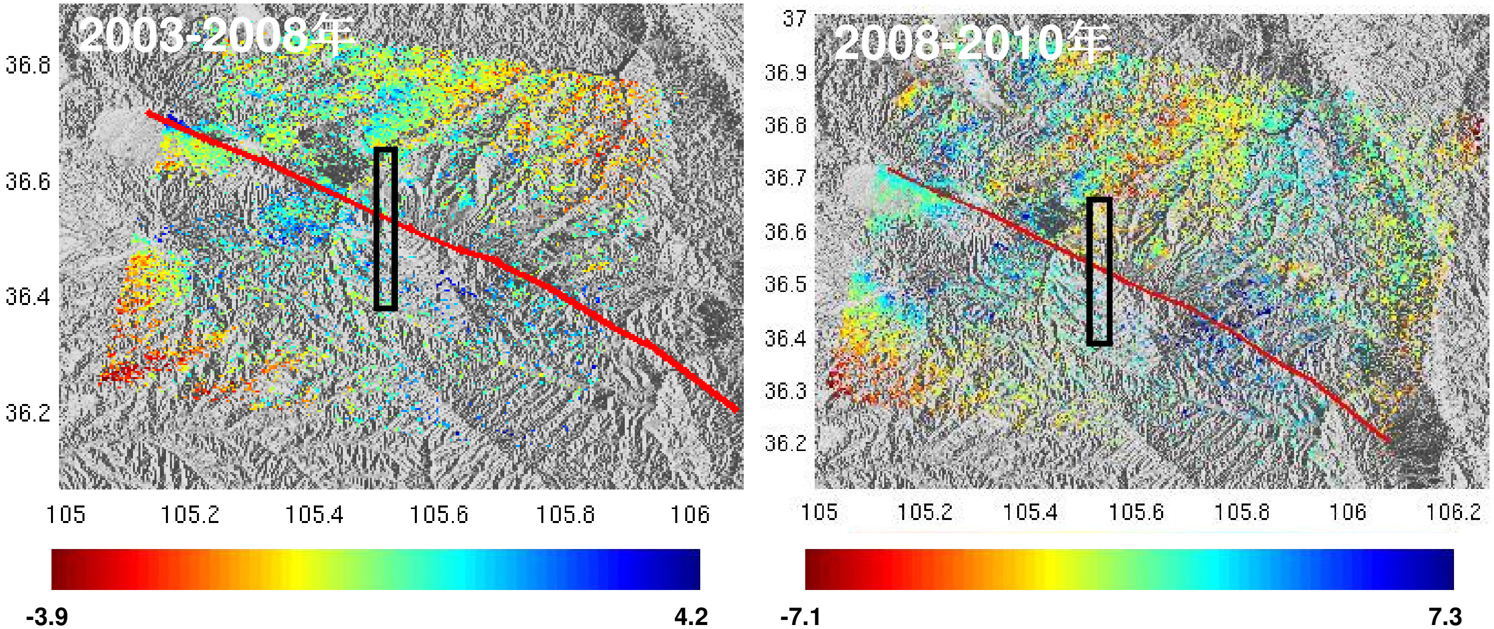
- **CR/PS-InSAR** Joint algorithm flowchart

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.

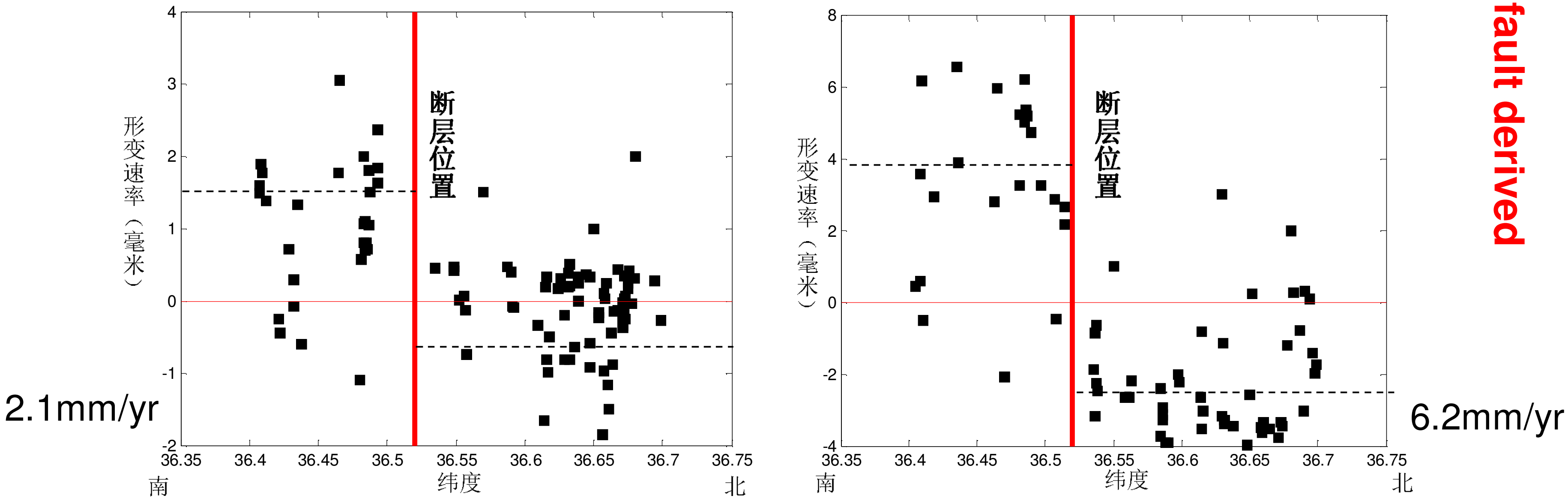
This can effectively combine the CRInSAR with PSInSAR to improve the accuracy of calculation.



Slip rates on the Haiyuan fault derived from PS/CR InSAR



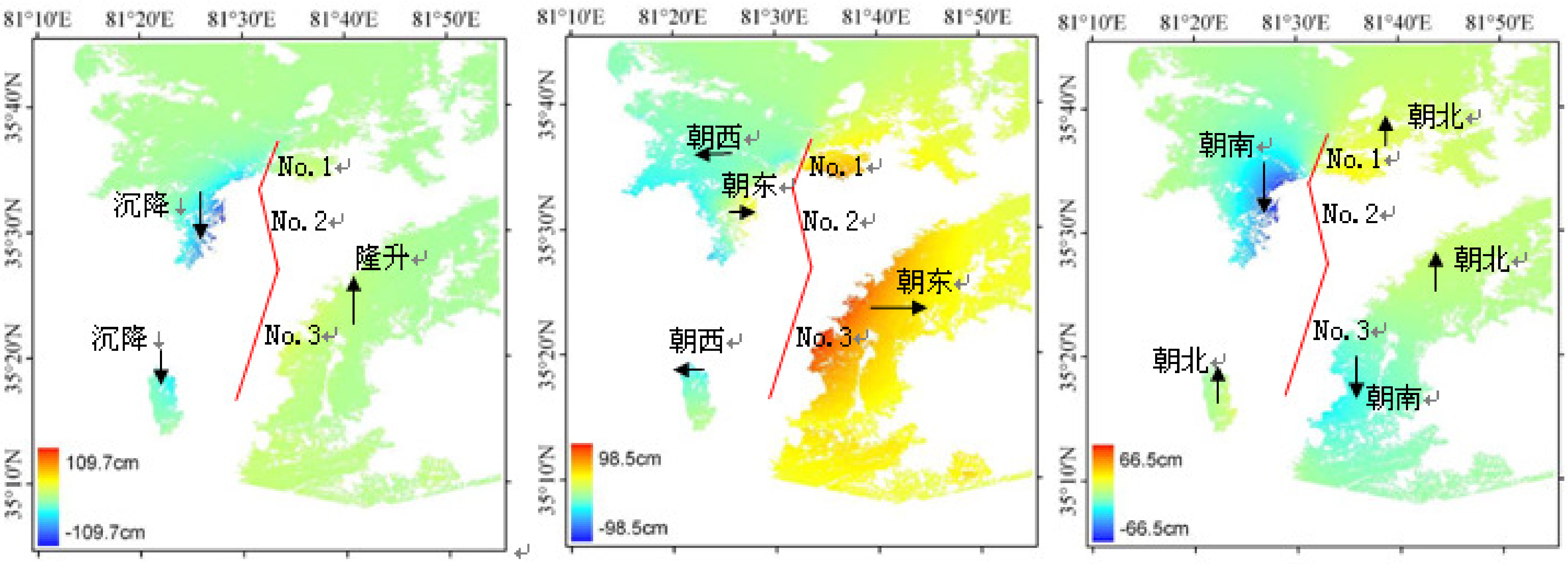
Mean slip rate（mm/yr): Left 2003-2008; Right: 2008-2010



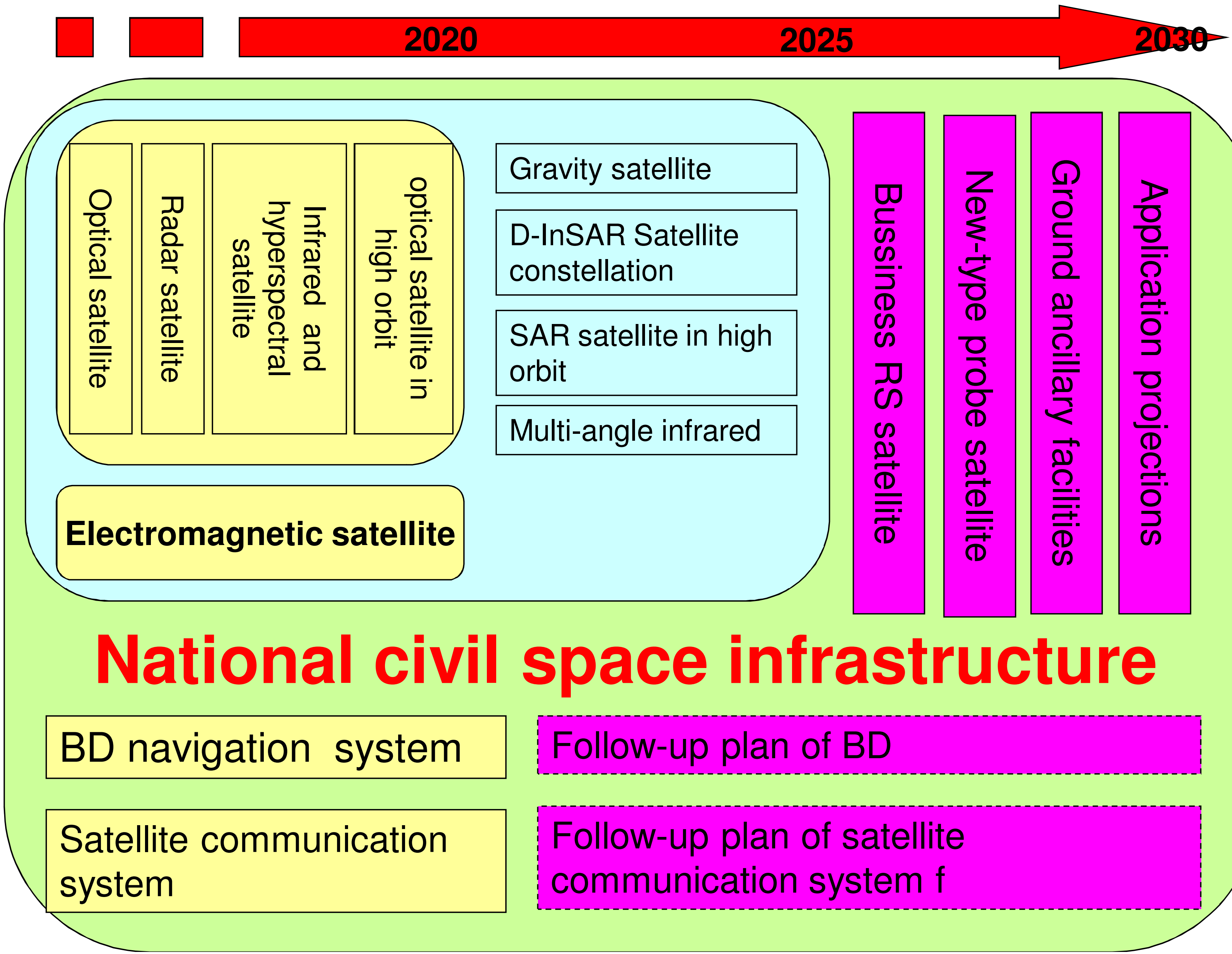
Slip profiles, left: 2003-2008年, right: 2008-2010

3D deformation field produced by the Yutian earthquake

$$\begin{pmatrix} d_U \\ d_E \end{pmatrix} = \begin{pmatrix} 0.554895 & 0.516508 \\ -1.415460 & 1.430564 \end{pmatrix} \begin{pmatrix} d_1 + d_n \cdot 0.071996 \\ d_2 + d_n \cdot 0.077346 \end{pmatrix} \qquad (4-6)$$



（a） dU （-109.7cm至19.2cm） （b） dE （-51.4cm至98.5cm） （c） dN （-66.5cm至25.8cm）


2020
2025
2030
Optical satellite
Radar satellite
Infrared and hyperspectral satellite
optical satellite in high orbit
Gravity satellite
D-InSAR Satellite constellation
SAR satellite in high orbit
Multi-angle infrared
Electromagnetic satellite
Bussiness RS satellite
New-type probe satellite
Ground ancillary facilities
Application projections
National civil space infrastructure
BD navigation system
Follow-up plan of BD
Satellite communication system
Follow-up plan of satellite communication system f

Thanks for Your Attention

Infrared multi-parameter and earthquakes