

**ICG-5 WG-B, Turino**

# **Ionospheric Monitoring in China**

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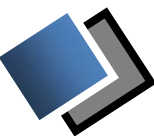


# Outline

**1. Introduction**

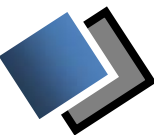
**2. Ionosphere monitoring in China**

**3. Summary**



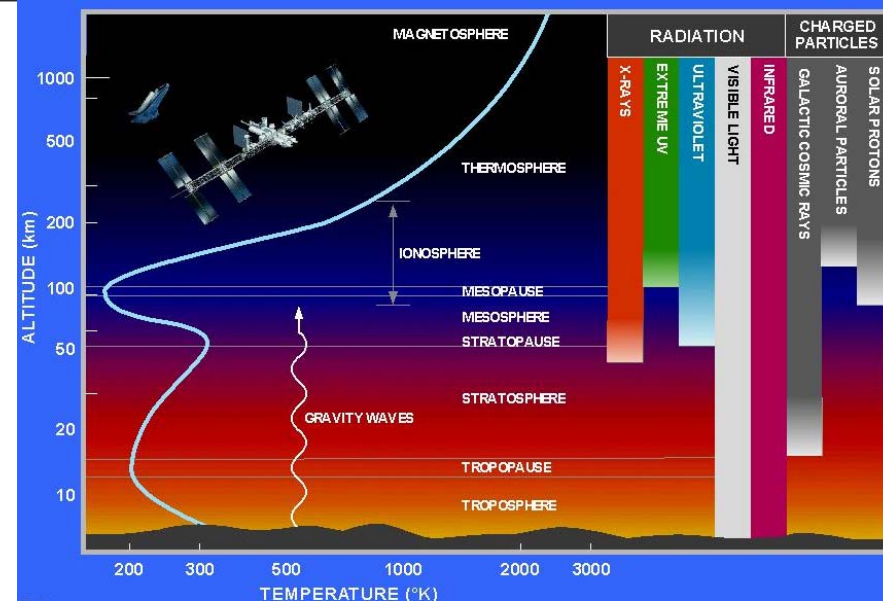
# 1. Introduction

- **GNSS performance is influenced by the ionosphere, its monitoring is quite important for the system performance.**
- **There exist many ionospheric monitoring network in some countries, like USA, Russian, Japan and European area.**
- **The Ionospheric monitoring network could be used for many different applications.**



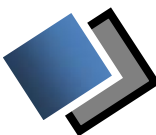
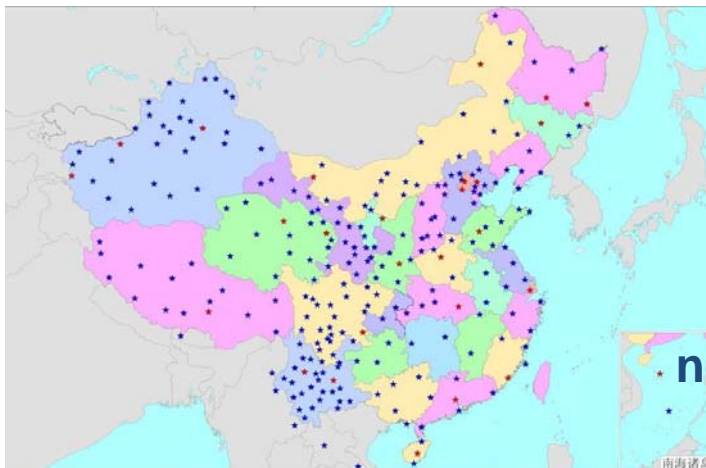
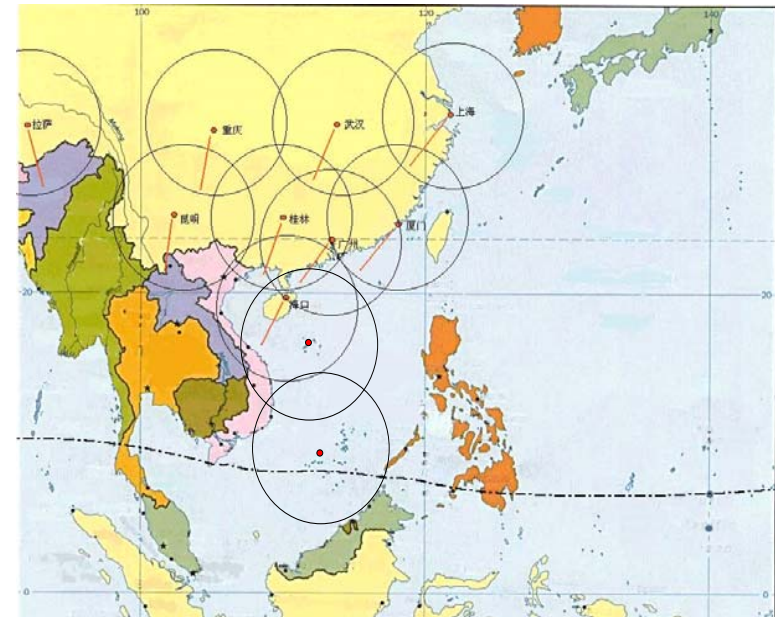
## 2. Ionosphere Monitoring in China

- ◆ Chinese Ionosphere Monitoring Network
- ◆ Global Ionospheric Modeling
- ◆ Regional Ionospheric Modeling
  - ◆ Ionospheric Physics
  - ◆ Regional precise ionospheric correction models
  - ◆ New technologies application in ionosphere detection
- ◆ Ionospheric threat models for SBAS
- ◆ Ionospheric Disturbance Effects on GNSS



# 2.1 Chinese Ionosphere Monitoring network

- ◆ Ionospheric monitoring network
  - ◆ Cover most of the subcontinent.
  - ◆ Real time monitoring.
- ◆ Monitoring methods:
  - ◆ GPS- for TEC and Scintillation.
  - ◆ Tri-band satellite beacons
  - ◆ Ionosondes
  - ◆ Oblique sounders
  - ◆ VLF device
  - Radar
  - ◆ .....

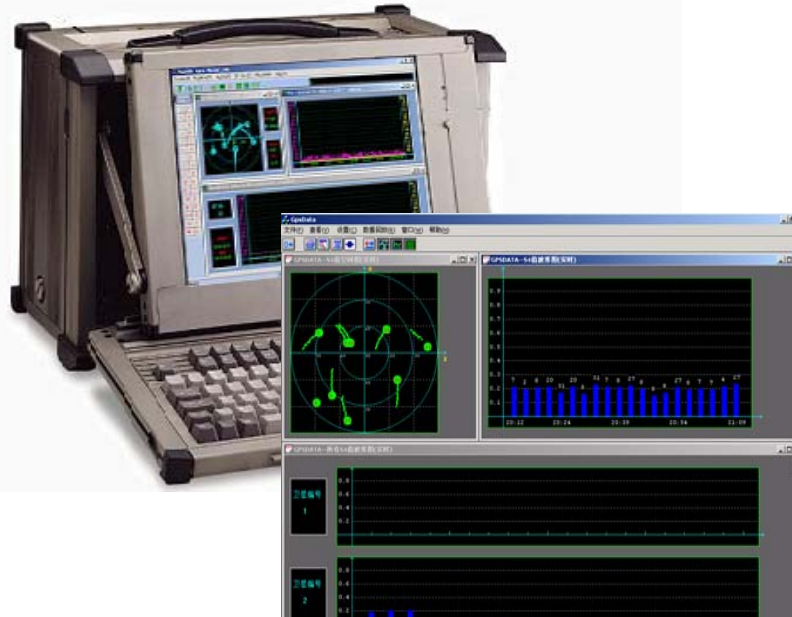




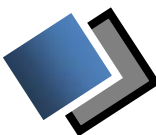
**Antenna of Ionosonde**



**Ionosonde**

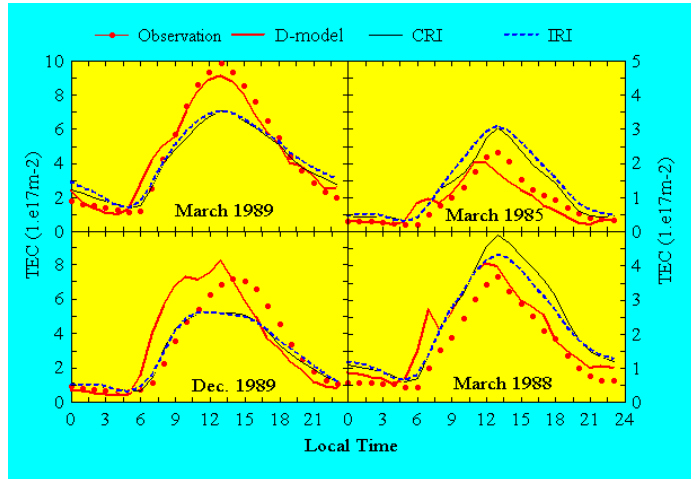


**Ionospheric  
scintillation  
monitor with GPS**

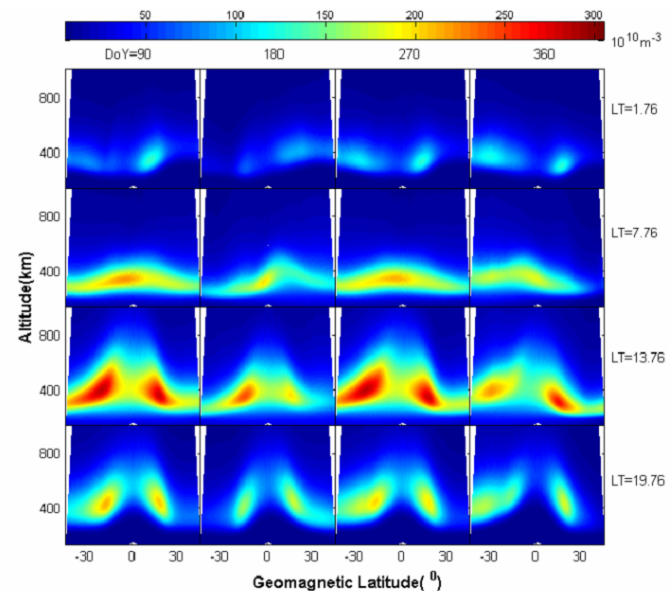


## 2.2 Global Ionospheric Modeling

- ◆ A correction model Chinese Reference Ionosphere (CRI) is developed;
- ◆ Middle and low latitude theoretical Ionospheric model-Theoretical Ionospheric Model of the Earth in Institute of Geology and Geophysics, Chinese Academy of Sciences (TIME-IGGCAS);



Ionospheric TEC comparison between CRI ,IRI and observations

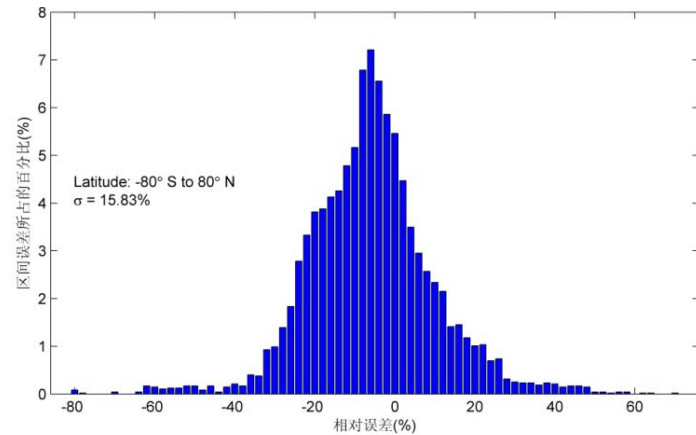
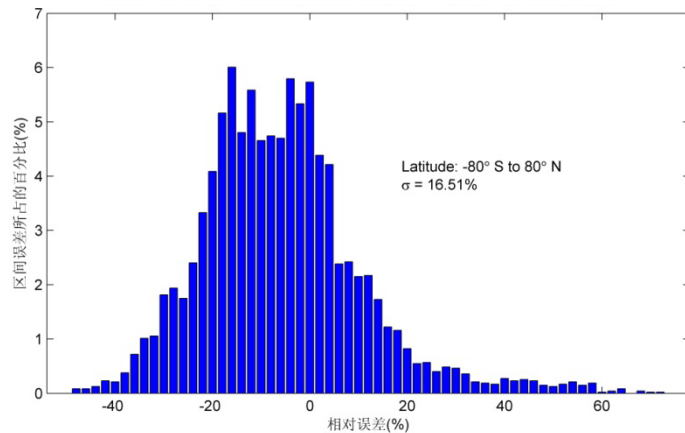


Ionospheric Electron Density by TIME-IGGCAS



## ◆ Ionospheric Modeling for GNSS

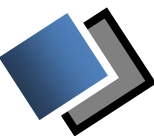
- Based on CRI and NeQuick model, a modified model is under development to satisfying GNSS use
- Ionospheric Eclipse Factor Method for Single-frequency GNSS User
- Modified Klobuchar Model for China Regional GNSS



Error distribution of the original model (IRI)

Error distribution of modified model

Performance comparison between the original model and the modified model for GNSS

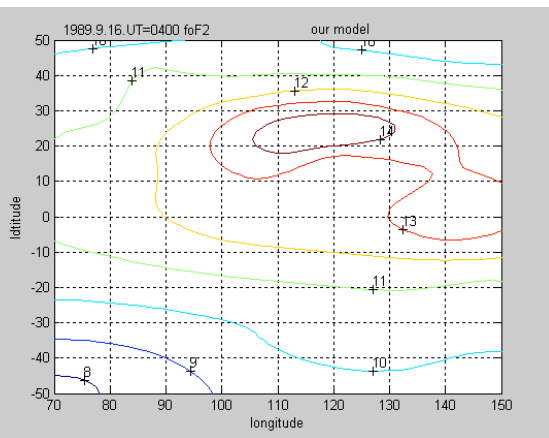




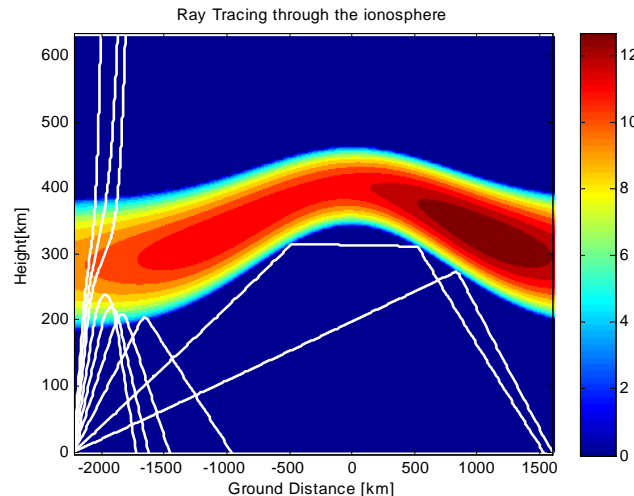
## 2.3 Regional Ionospheric Model

### a) Ionospheric Physics

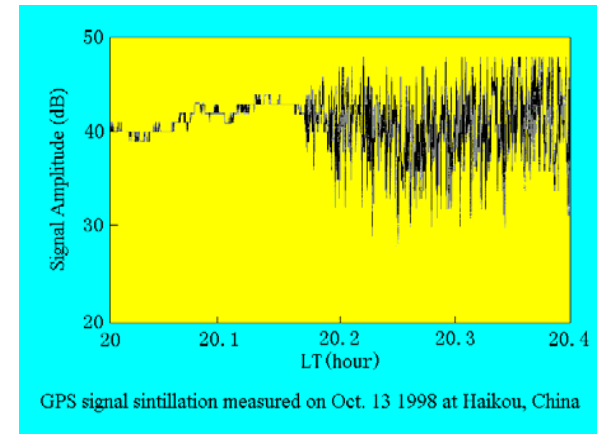
- ◆ Long-term trends of the ionosphere variations;
- ◆ Ionospheric disturbances studies;
- ◆ Characters of ionospheric scintillations in low-latitude area of China;
- ◆ Character of ionosphere in polar region.



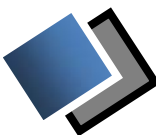
**Ionospheric long-term forecasting (foF2)**



**Ray tracing for ionospheric disturbances detection**

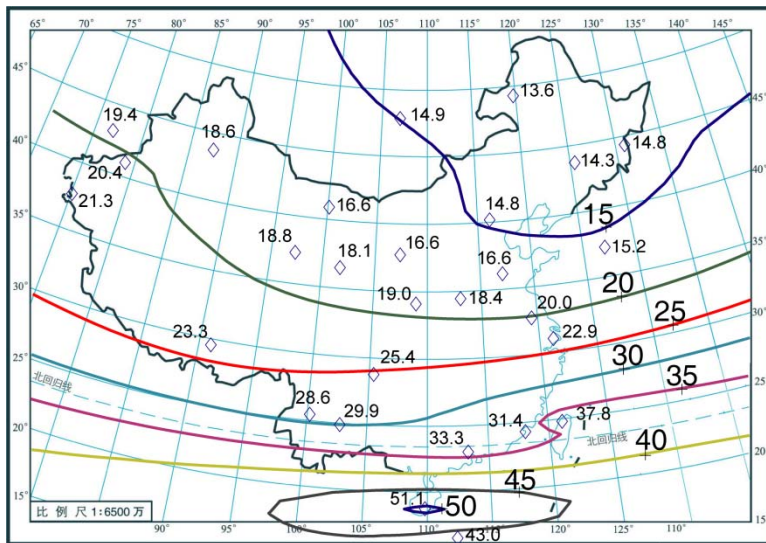


**Ionospheric scintillations**

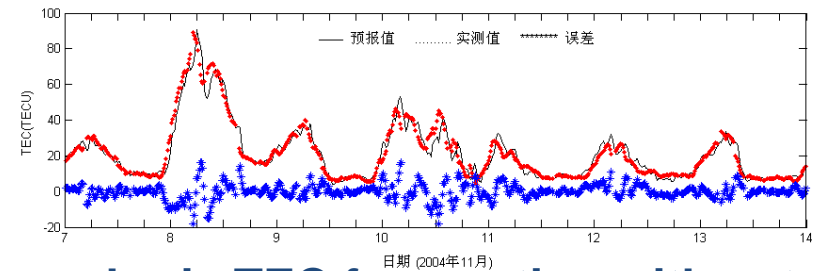
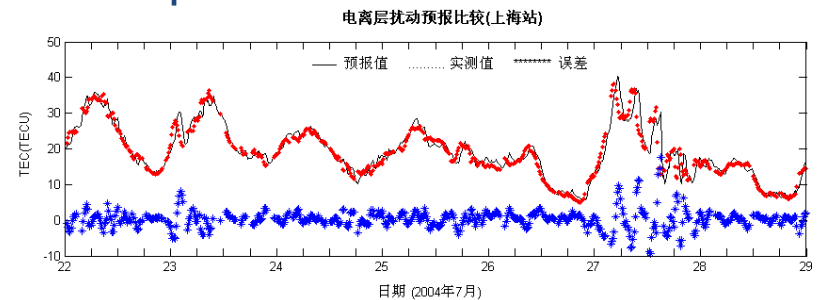


## b) Regional precise Ionospheric correction models

- ◆ Spatial and temporal correlation studies conducted to look for a better way for ionospheric TEC map reconstruction and prediction.
- ◆ The presented TEC mapping system has been used for estimate the ionospheric TEC over China.
- ◆ Realization of a suitable regional ionospheric model for augmentation system.



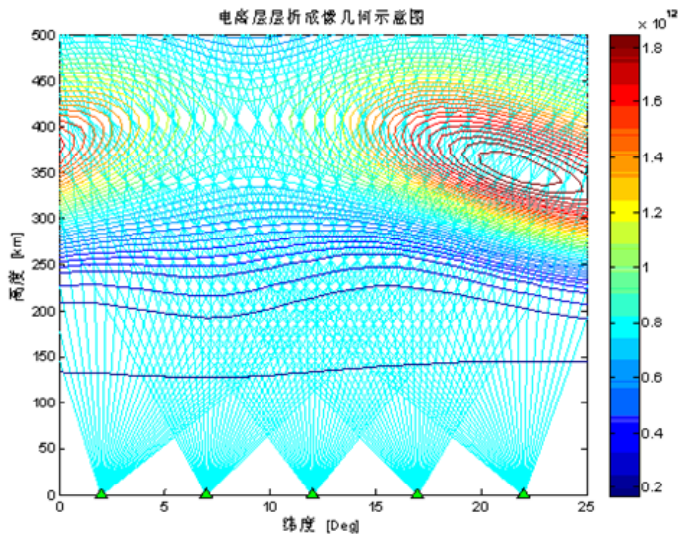
**Ionospheric TEC mapping with Kriging technique**



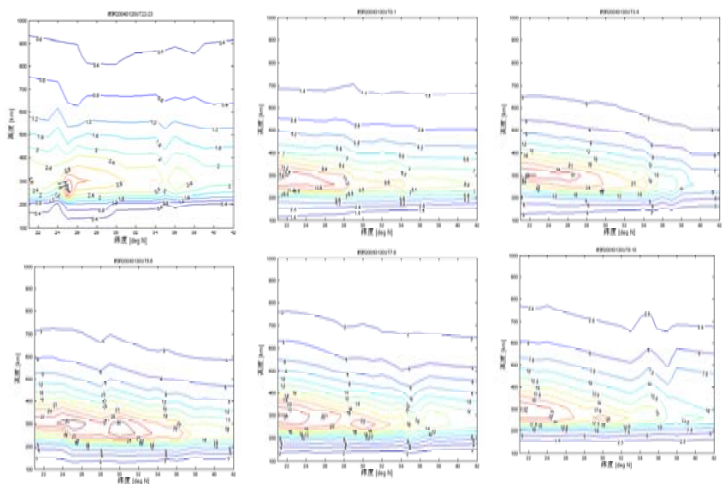
**Ionospheric TEC forecasting with auto-correlation method**  
(Black: measured TEC; Red: Forecasted TEC; Blue: Error of forecasted TEC)

# c) New technologies in the ionosphere detection

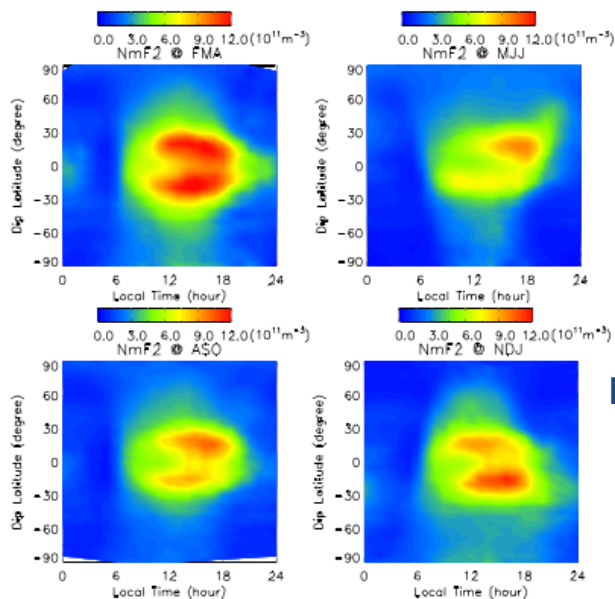
- ◆ CIT, Computerized Ionospheric Tomography, used for fine Ionospheric parameters reconstruction.
- ◆ GNSS occultation for global Ionospheric weather research.
- ◆ CIT for GNSS Augmentation application.



Ground based ionospheric tomography



CIT for geomagnetic storm imaging

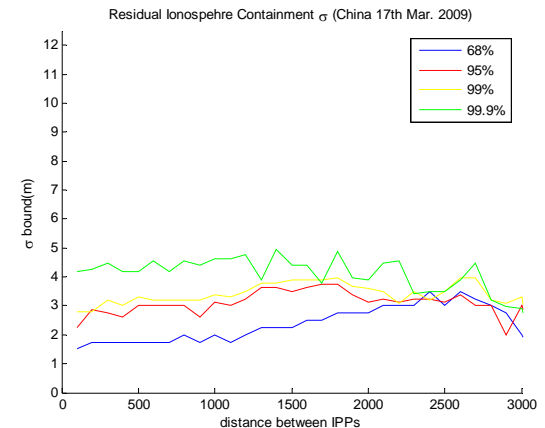
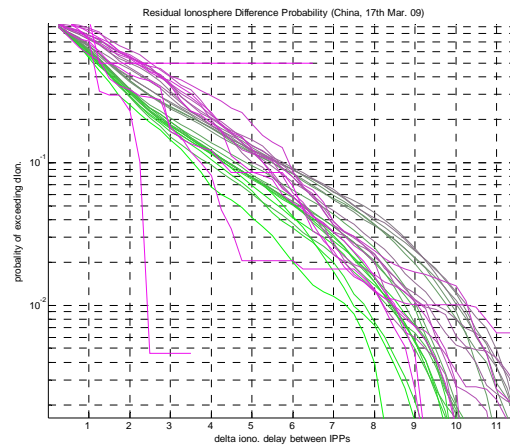
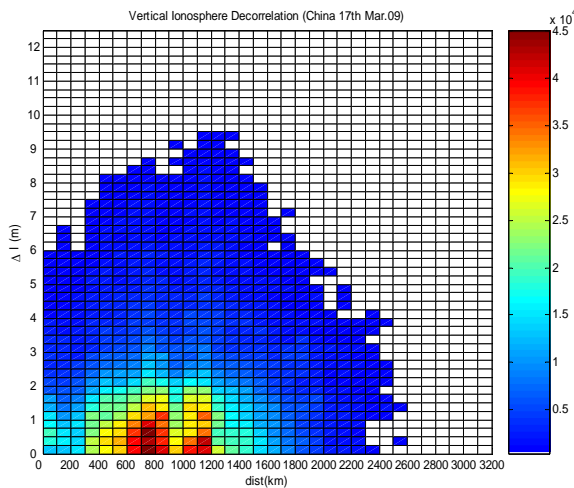


GNSS occultation in the global ionospheric NmF2 detection

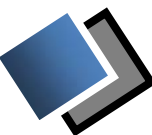


## 2.4 Ionospheric threat models for SBAS

- A Ionospheric threat model has been developed to over-bound the ionospheric delay errors. Thus the performance of ionosphere related integrity is improved.

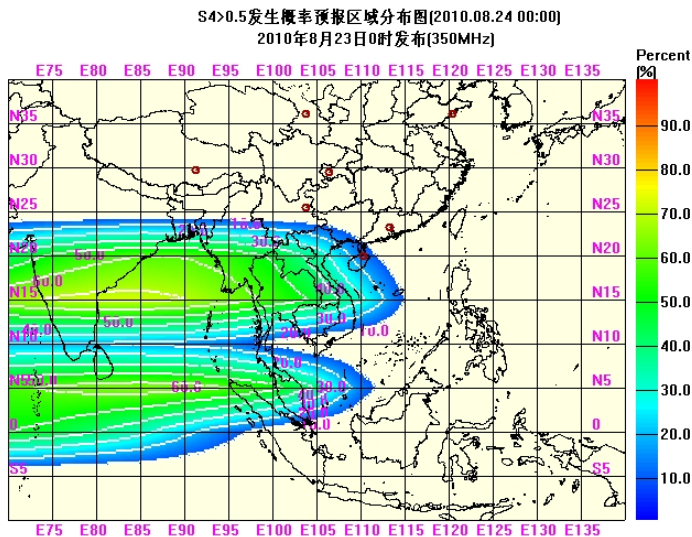


**Research of Regional Ionospheric Characters in China**

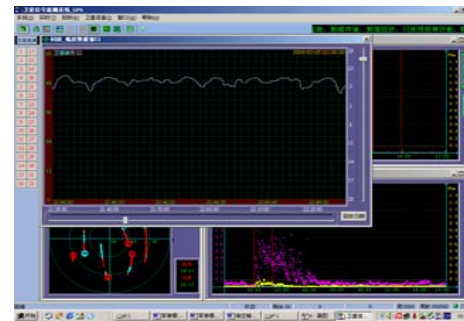


# 2.5 Ionospheric Disturbance Effects on GNSS

- ◆ Ionospheric scintillation monitoring and forecasting in low-latitude areas in China.
- ◆ Impacts analysis of ionospheric scintillation on the GNSS.



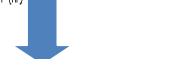
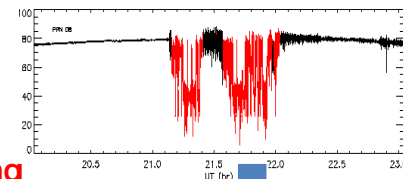
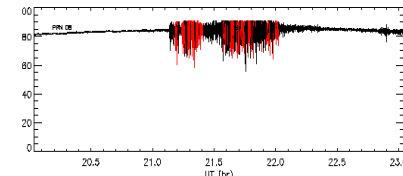
**Ionosphere scintillation distribution over China.**  
(made by CRIRP)



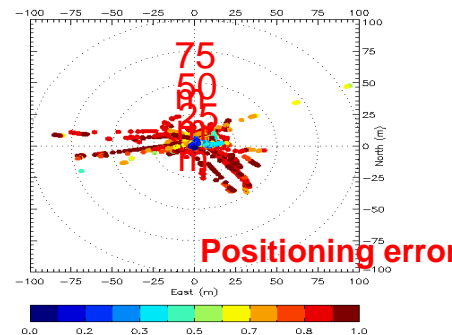
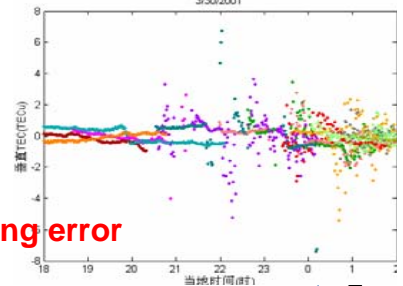
Signal fading



C/N0 fluctuating



Tracking error



Positioning error

**Ionosphere scintillation impacts on GPS positioning**



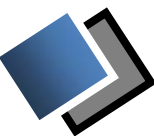
## ***2.6 Improvements for GNSS in China***

### **◆ Ionospheric scintillation model**

- **Studies are carried out on ionospheric scintillation model which could be used to current and short-term forecasting in China sub-continent.**

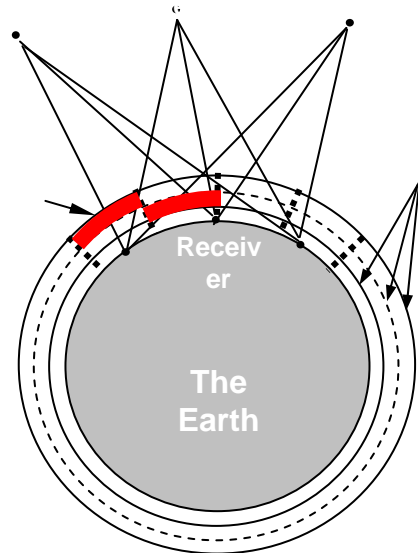
### **◆ Ionospheric models for GNSS Regional Augmentation system**

- **New single frequency correction algorithms**
- **Ionospheric threat models**
- **Detecting methods for ionospheric irregularity**

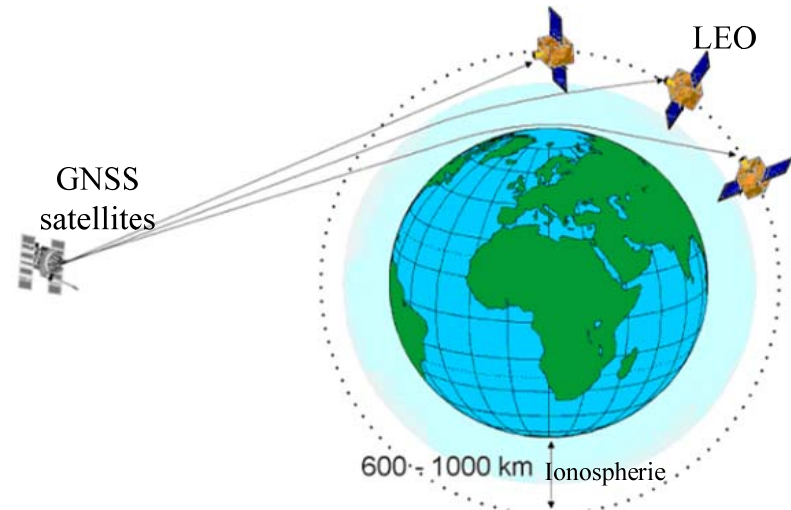


## 2.7 Further Works

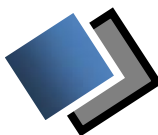
- ◆ Global Ionospheric Models optimization for GNSS Modernization
- ◆ Improvement of Ionospheric threat models for SBAS
- ◆ New technologies application in the SBAS Ionospheric correction modeling, for example, the Computerize Ionospheric Tomography, GNSS occultation, etc.



Computerize Ionospheric Tomography

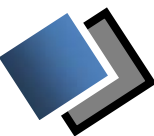


GNSS occultation



### 3. Summary

- **Ionospheric is quite important for GNSS applications**
- **China has established an Ionosphere monitoring network and provide data for GNSS service**
- **The current monitoring network could be updated and expanded on demand**
- **China is open for the international cooperation in this area.**





**Thanks for your attention!**

