GBAS Brazilian Ionospheric Threat Model Project

New Verification Methodology of Ionospheric Gradients Observed in the Brazilian Region

ICAO ISTF/5

16 – 18 February, 2015

Motivation and Goal

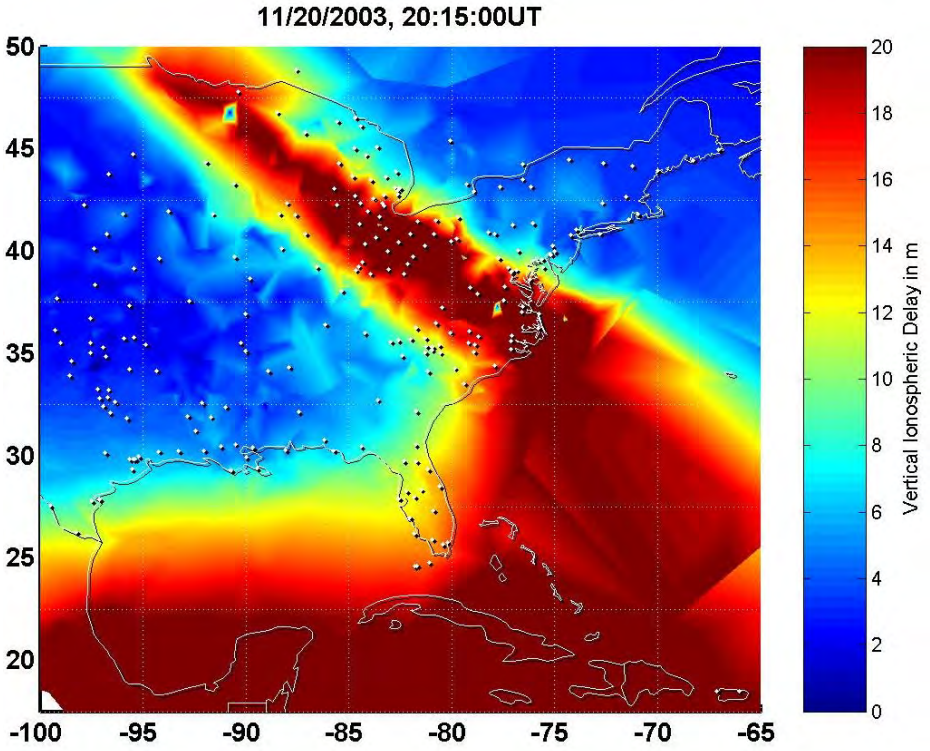
- **A Honeywell SLS-4000 GBAS ground facility installed at the Galeão International Airport in Brazil is configured with the Conterminous U.S (CONUS) threat model.**

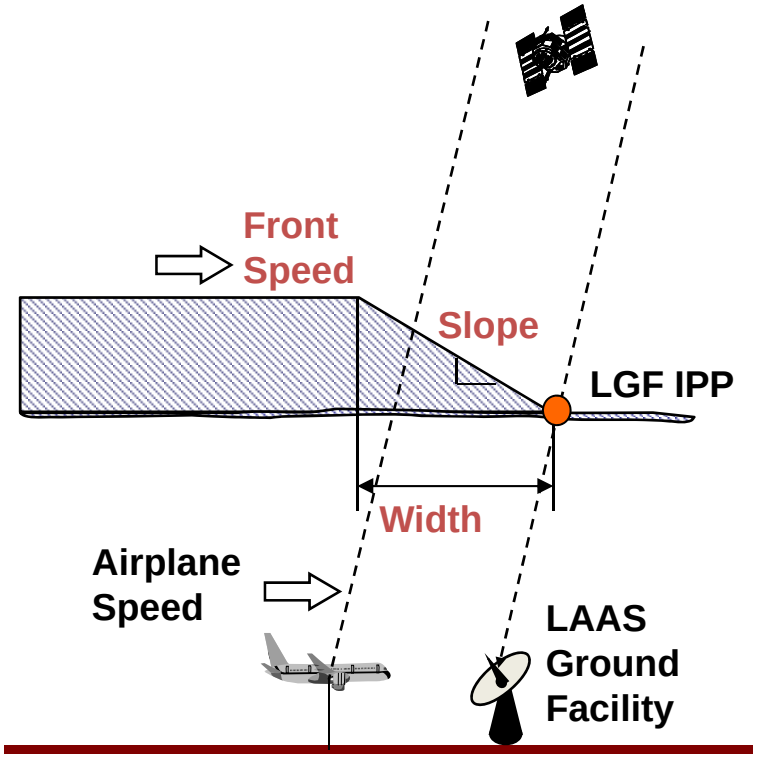
- **Ionospheric activity in equatorial regions (within 25 degrees latitude of the geomagnetic equator) is known to be significantly more variable and more intense than what is encountered in mid-latitude regions such as CONUS.**

- **Goal: Develop a new model for Brazil**

CONUS Threat Model

Max. Front slope (mm/km)	Low elevation (<15°)	375
	Medium elevation (15° <el<65°)	375+50(el-15)/50
	High elevation (>65°)	425
Front width (km)	25 – 200	
Front speed (m/s)	0 – 750	
Max. differential delay (m)	50	





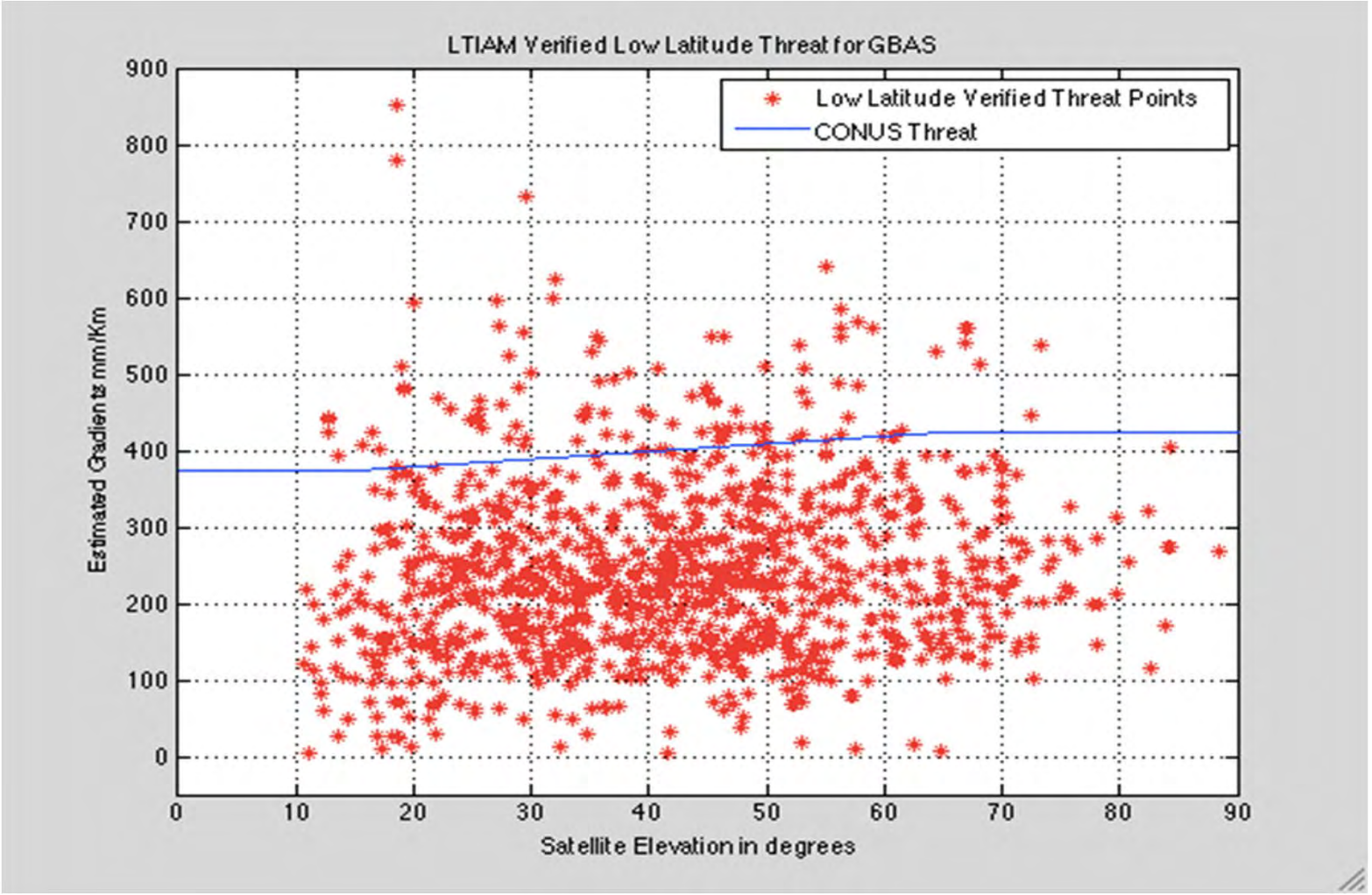
Data Processing Efforts and Findings

- **Government/Industry Project**
  - **Project conducted as an international, interagency effort with a variety of funding sources**
  - **Team – DECEA, ICEA, INPE, FAA Tech Center, Stanford, Boston College, NAVTAC, Mirus, KAIST.**

- **Identified 120+ active ionosphere days during the peak of the current solar cycle (March 2011 – April 2014) .**
  - **85 scintillating, 8 non-scintillating, 7 storm days (based on Kp), 27 days identified by INPE (based on Dst)**

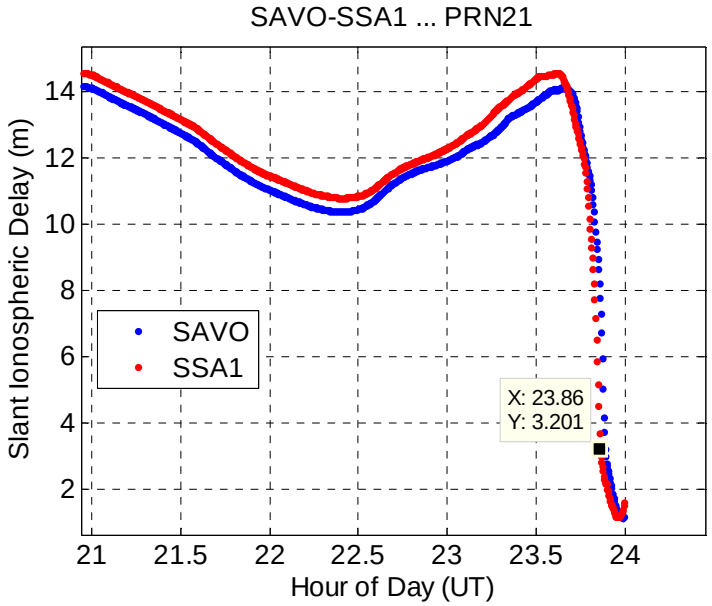
- **Threat points generated from LTIAM processing**
  - **35 points > 500 mm/km, 5 points > 600 mm/km**
  - **Max. gradient > 800 mm/km**

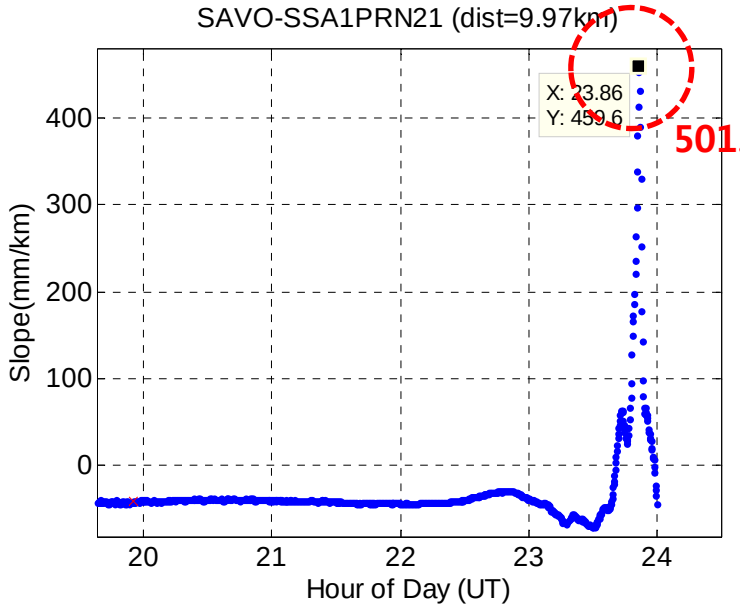
Preliminary Results: Brazilian Threat Model

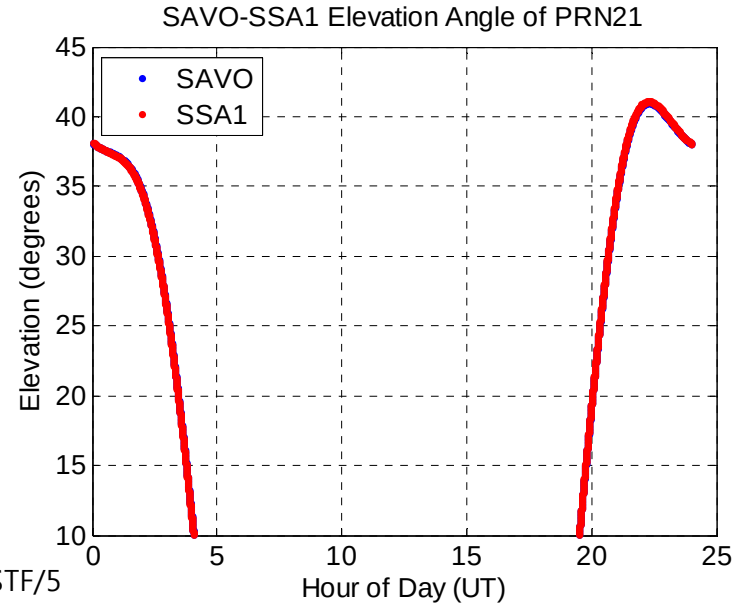


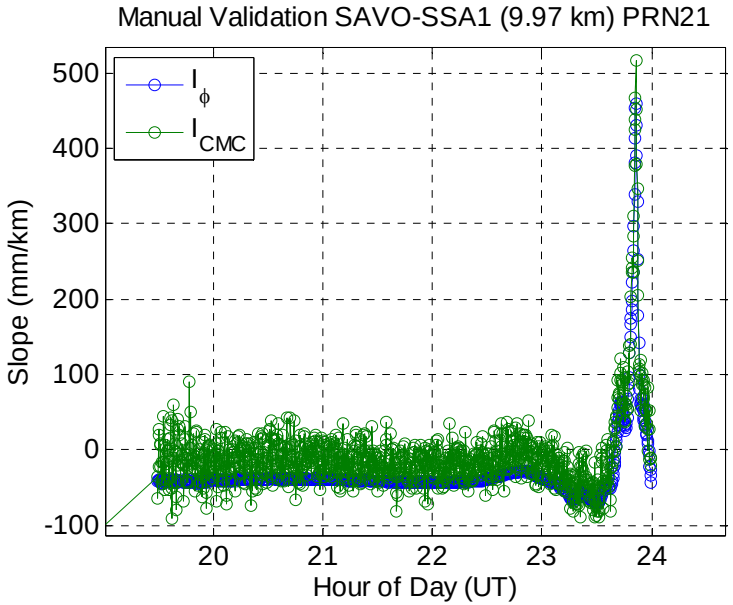
The threat points are verified through the normal LTAIM procedure. However, the second phase of validation is required to confirm those are actual ionospheric events

SAVO-SSA1 PRN 21



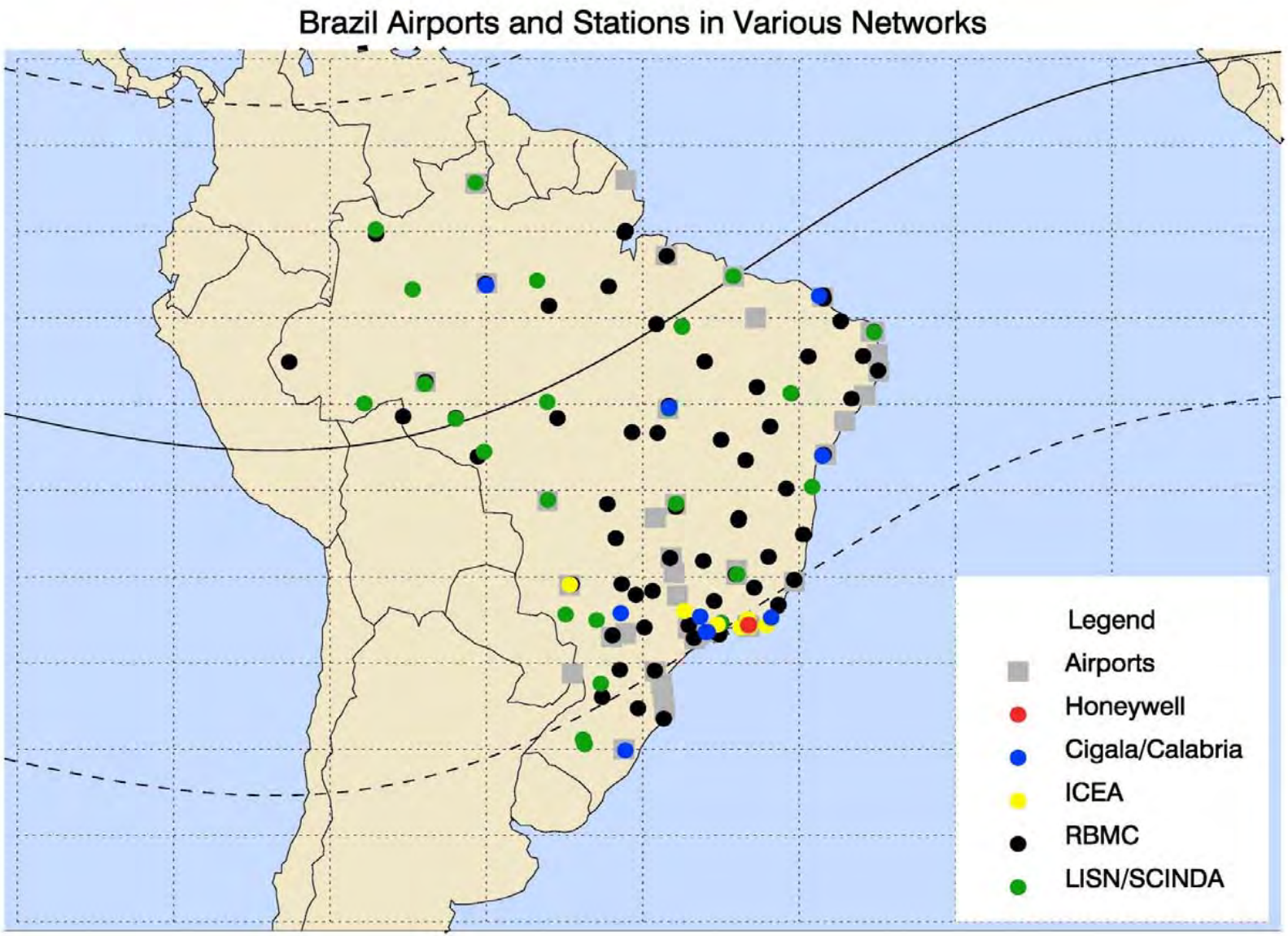






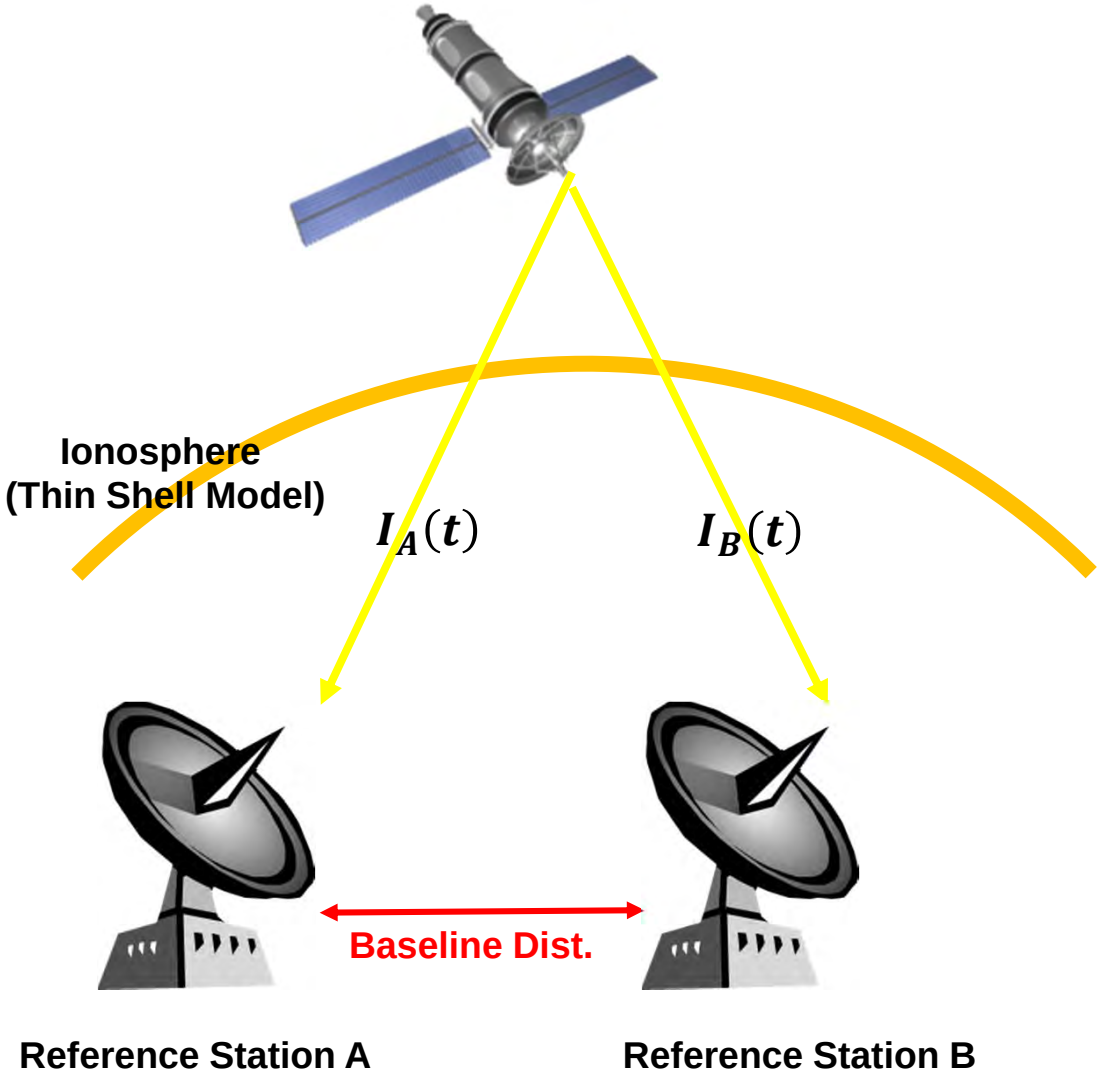
Second-phase Validation Methods

- **Station-wide Validation**
  - **Requires nearby stations**
  - **The sparse network stations in Brazil limits the use of this method**
- **Satellite-wide Validation**
  - **Required other satellites**
- **Time-step method (New)**
  - **Does not need additional stations or satellites**
  - **Spatial gradients and Temporal gradients are mixed together**


Brazil Airports and Stations in Various Networks
Legend
Airports
Honeywell
Cigala/Calabria
ICEA
RBMC
LISN/SCINDA

Station-Wide Validation

Station-pair method

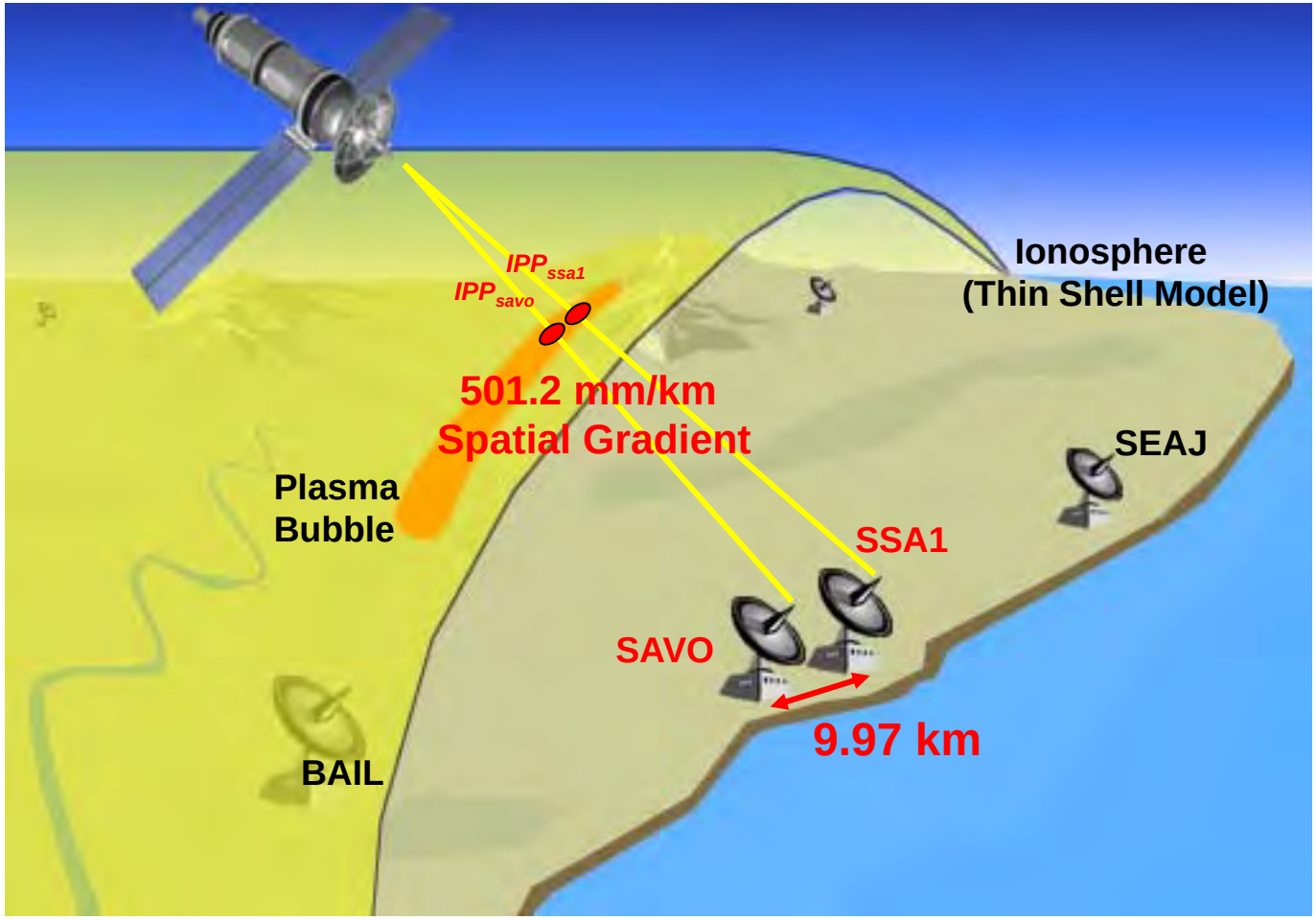


$$Gradient = \frac{|I_A(t) - I_B(t)|}{Baseline\ Distance}$$

Station-Wide Validation

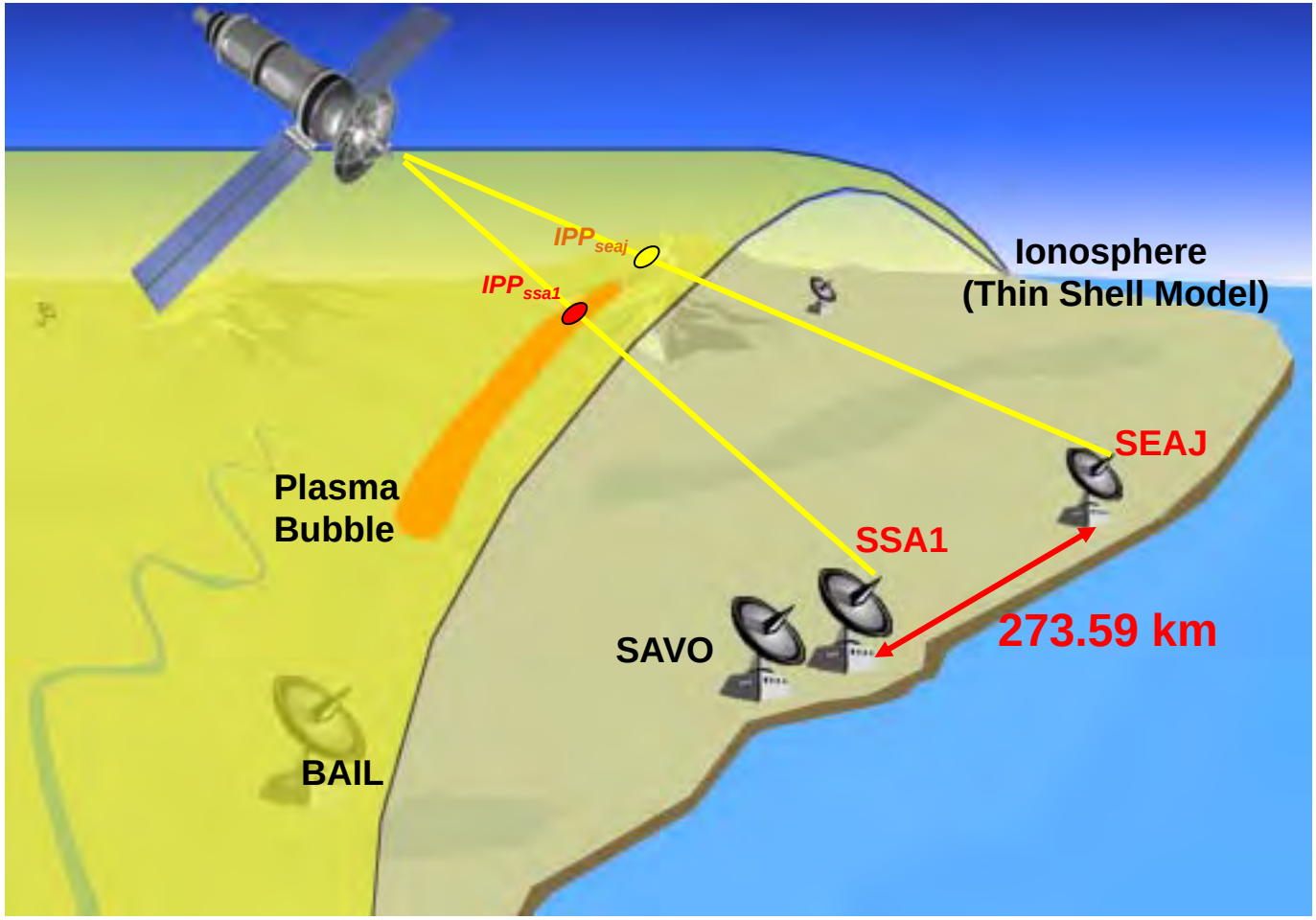
Limitation in the Brazilian region

- **A spatial gradient of 501.2 mm/km was observed from the station pair, SAVO-SSA1, tracking PRN 21.**



Station-Wide Validation

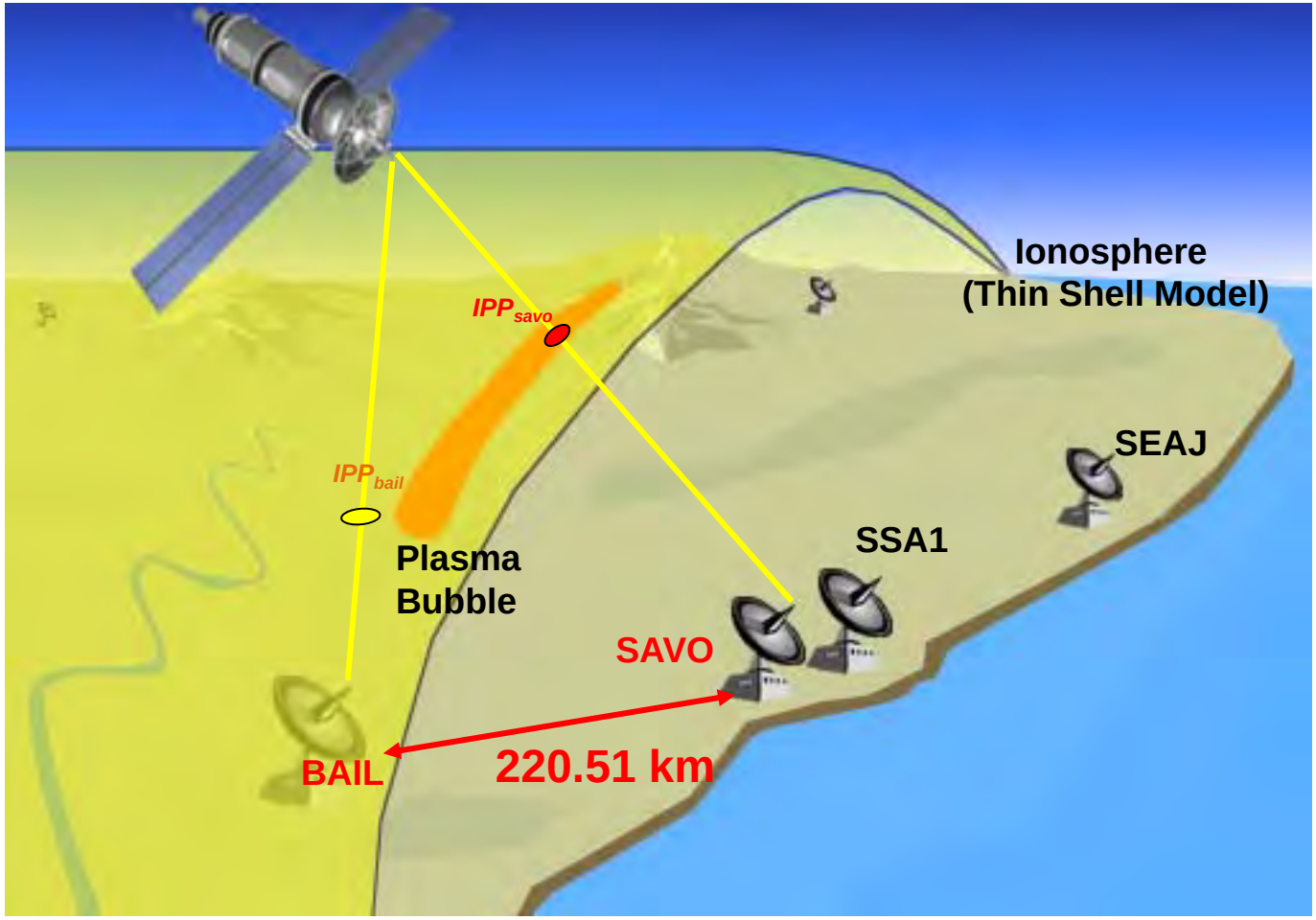
Limitation in the Brazilian region



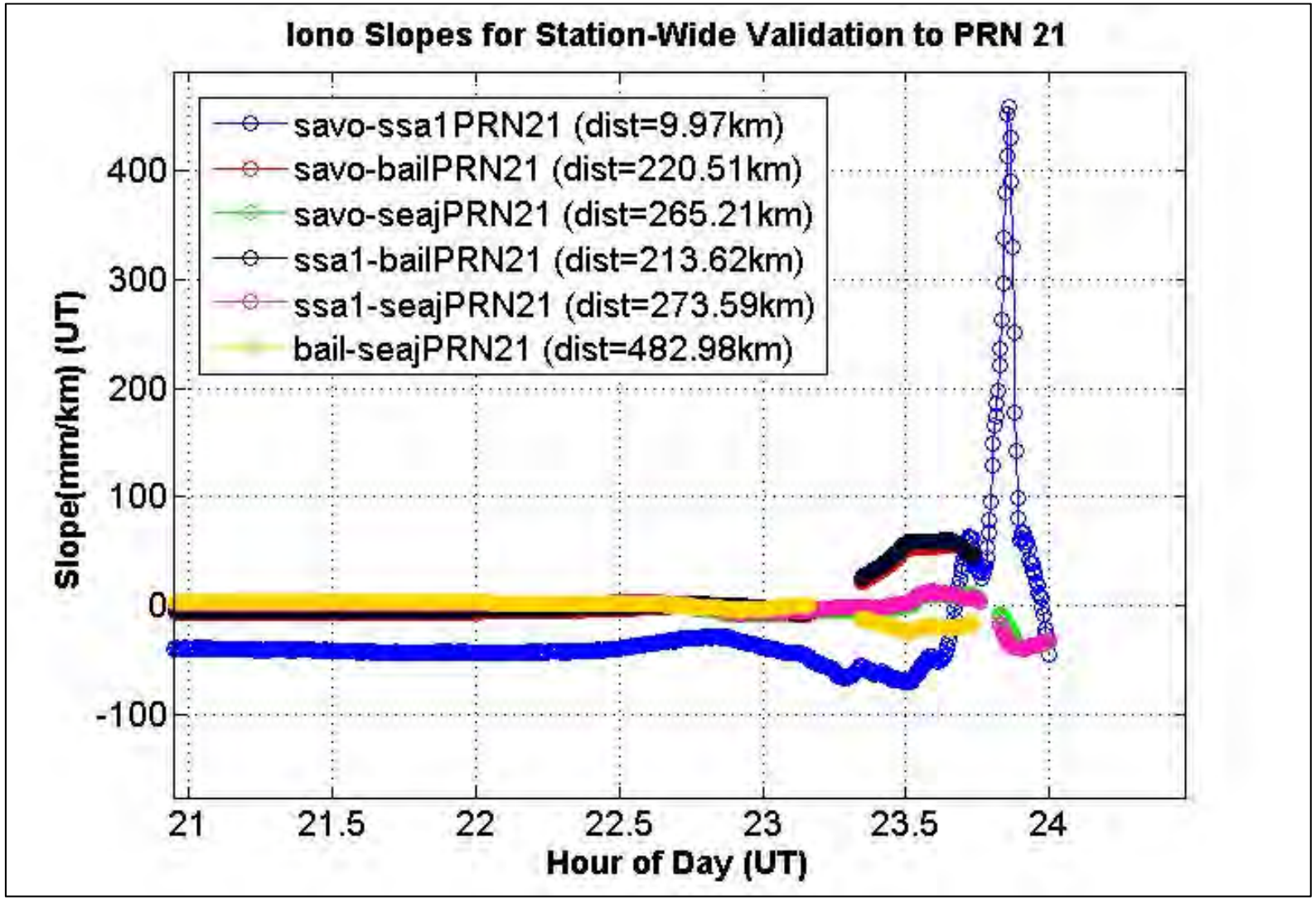
Station-Wide Validation

Limitation in the Brazilian region

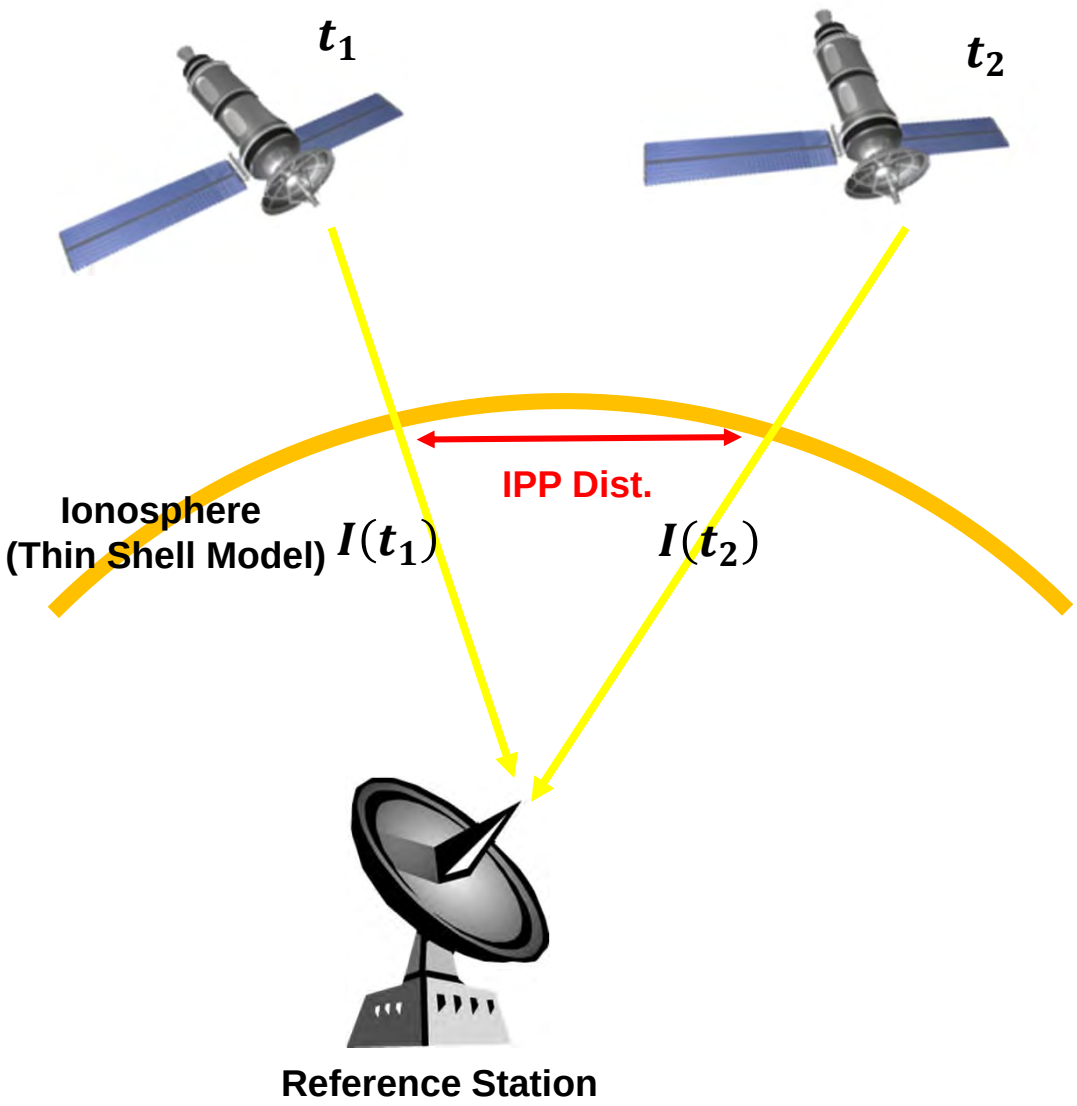
- **Nearby stations in Brazil are not close enough to validate small-scale (in width) ionospheric anomaly (*e.g.* EPBs)**



Station-wide Validation

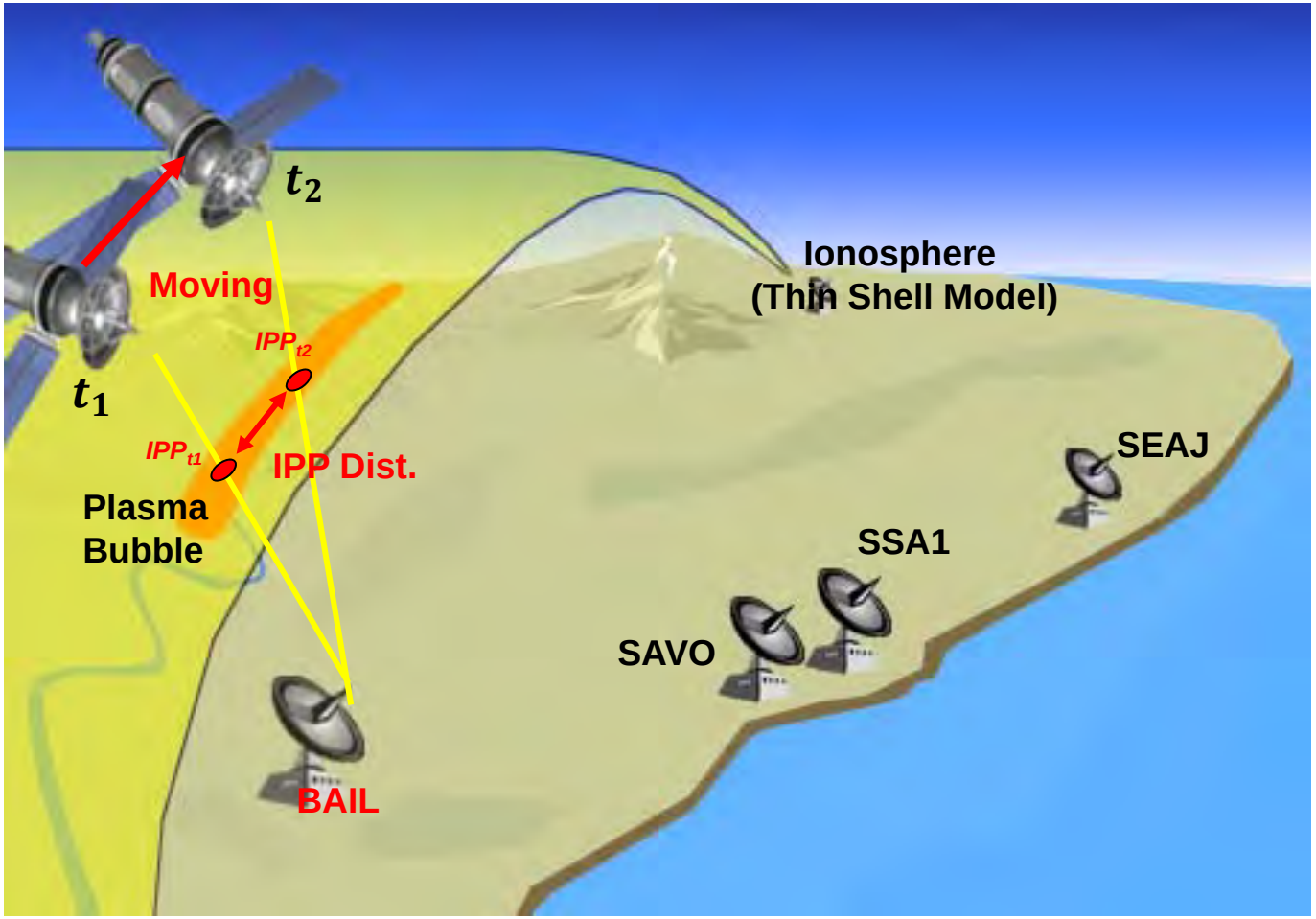


Time-Step Method



$$Gradient = \frac{|I(t_1) - I(t_2)|}{IPP\ Distance}$$

Time-Step Validation



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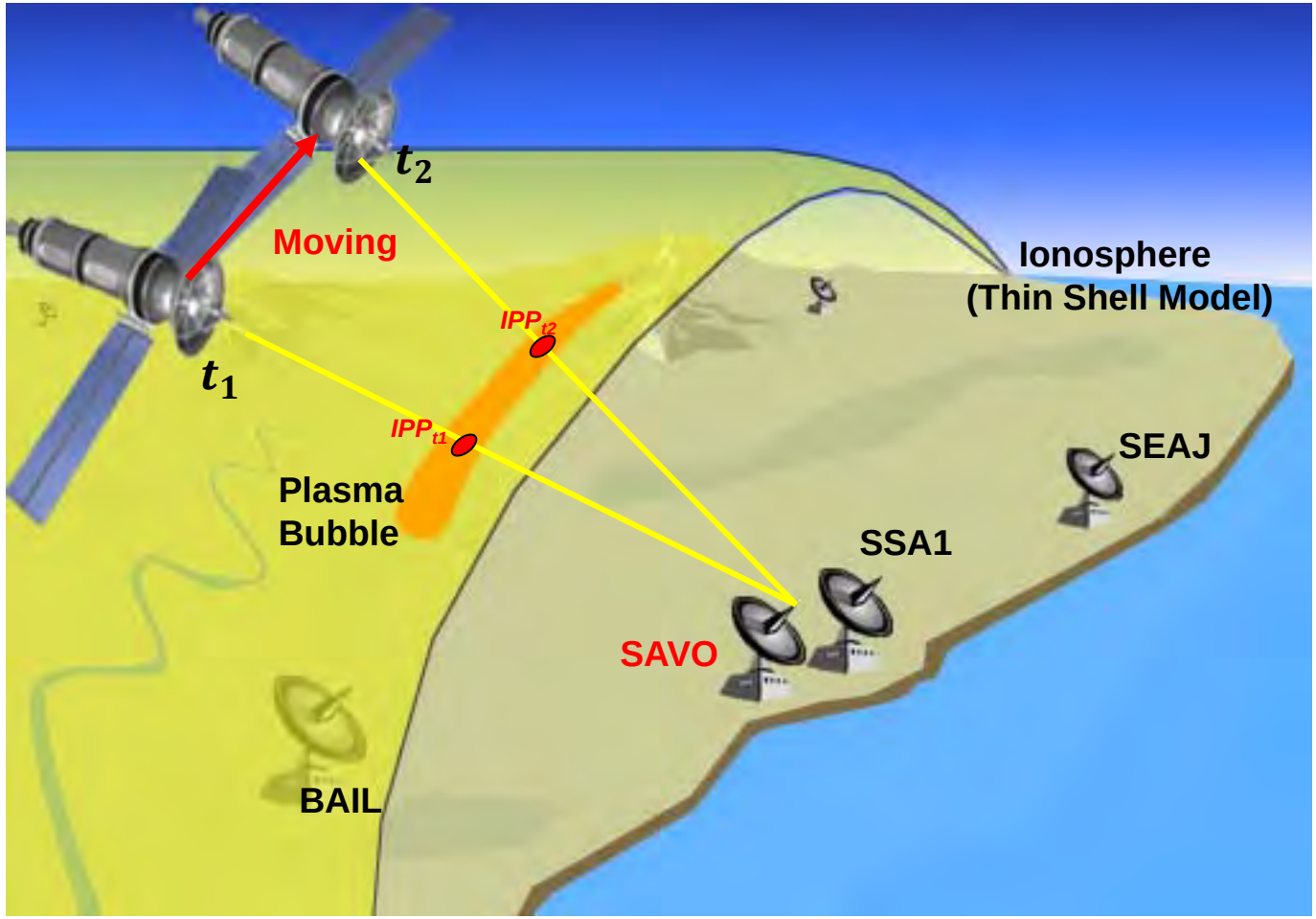
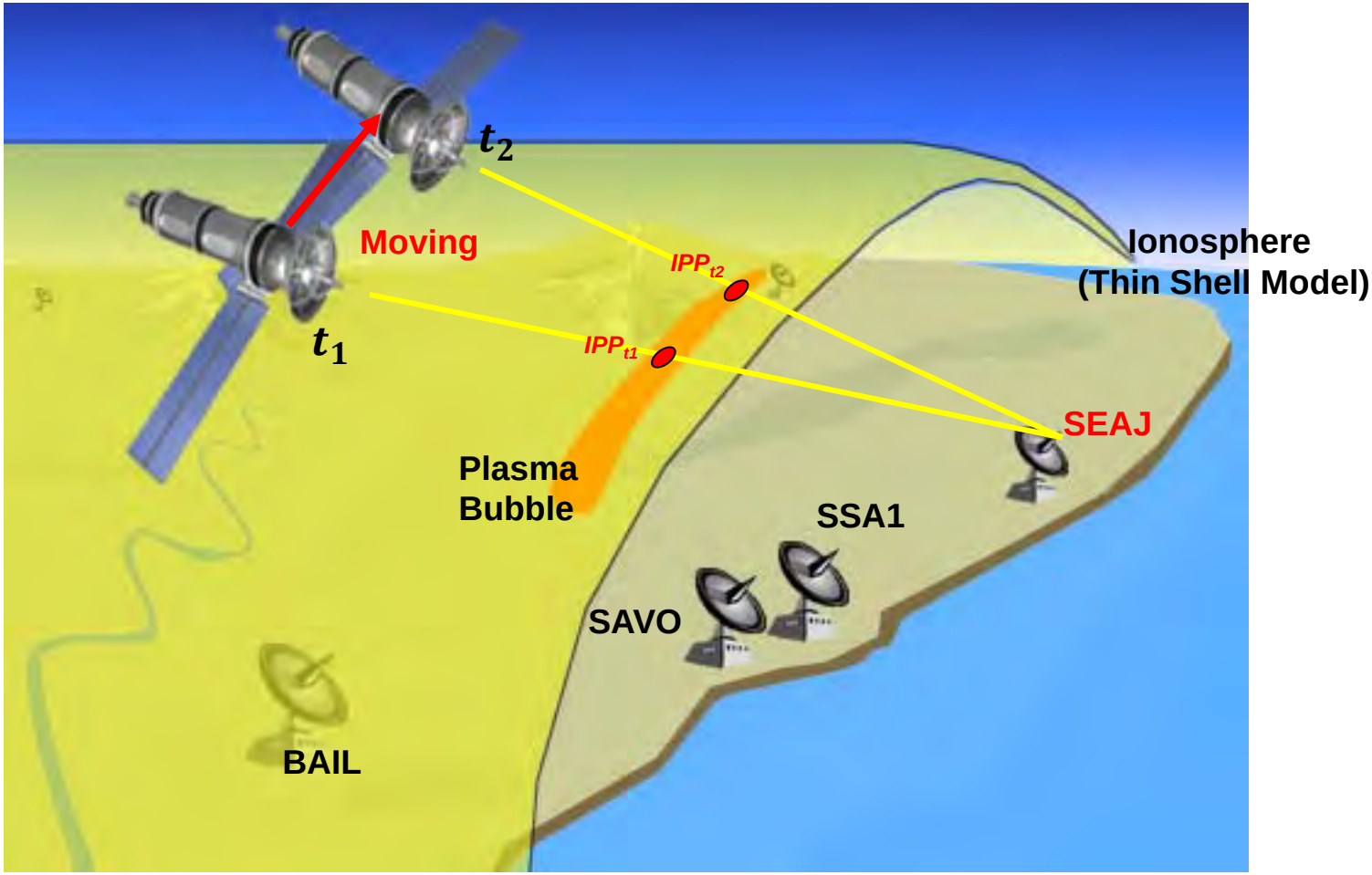
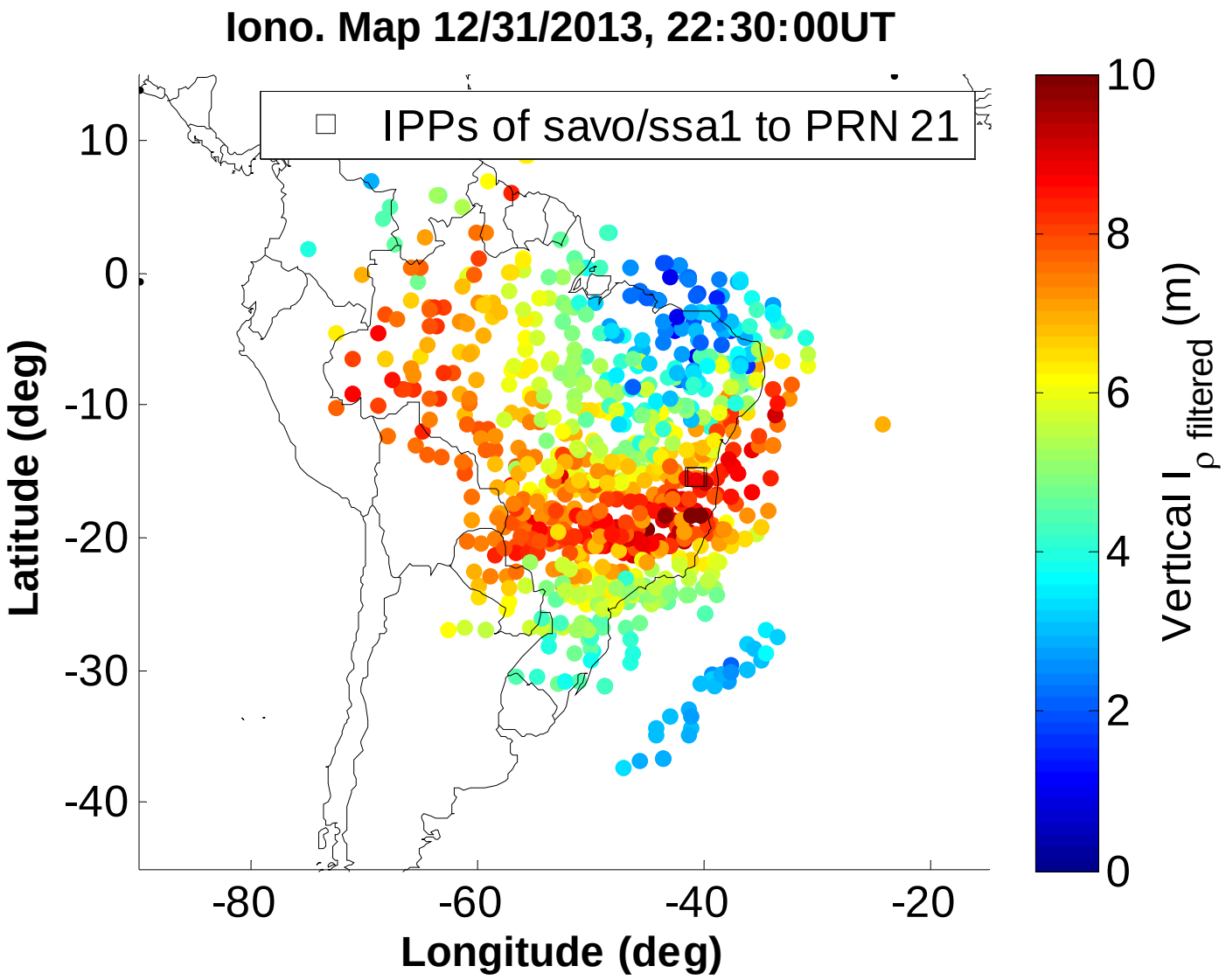


Time-Step Validation



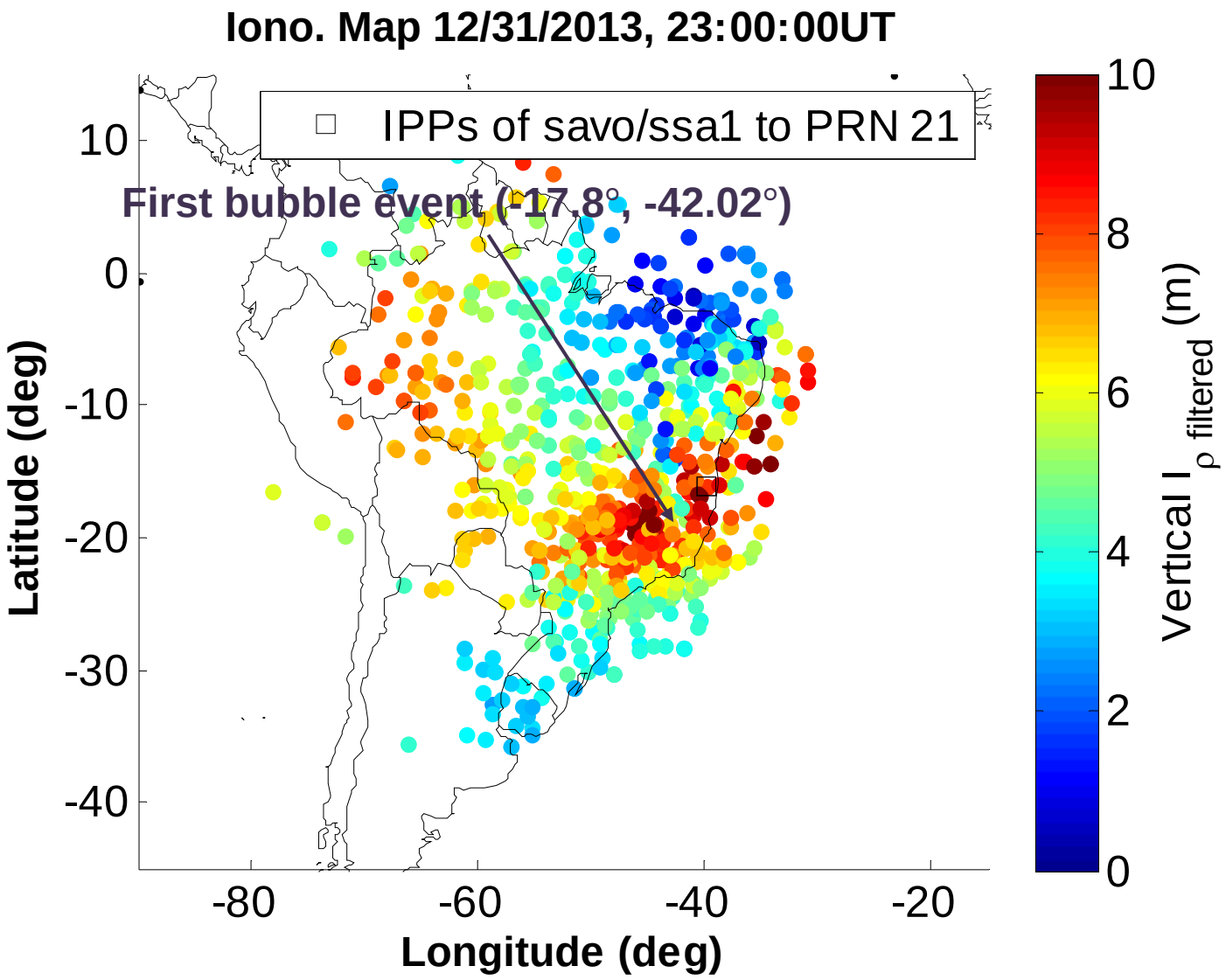
Regional Ionospheric Map

22:30:00 UT



Regional Ionospheric Map

23:00:00 UT



Regional Ionospheric Map

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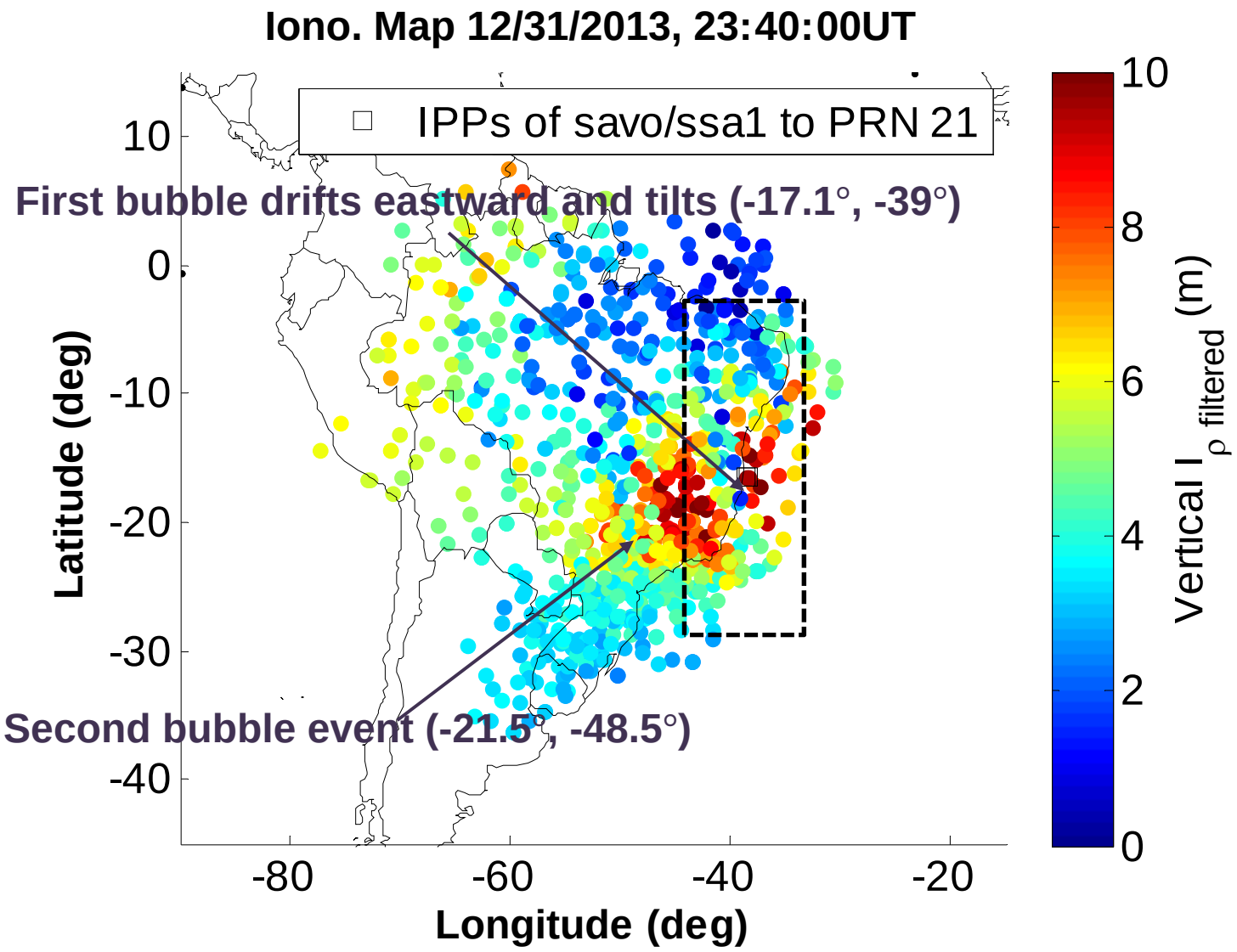
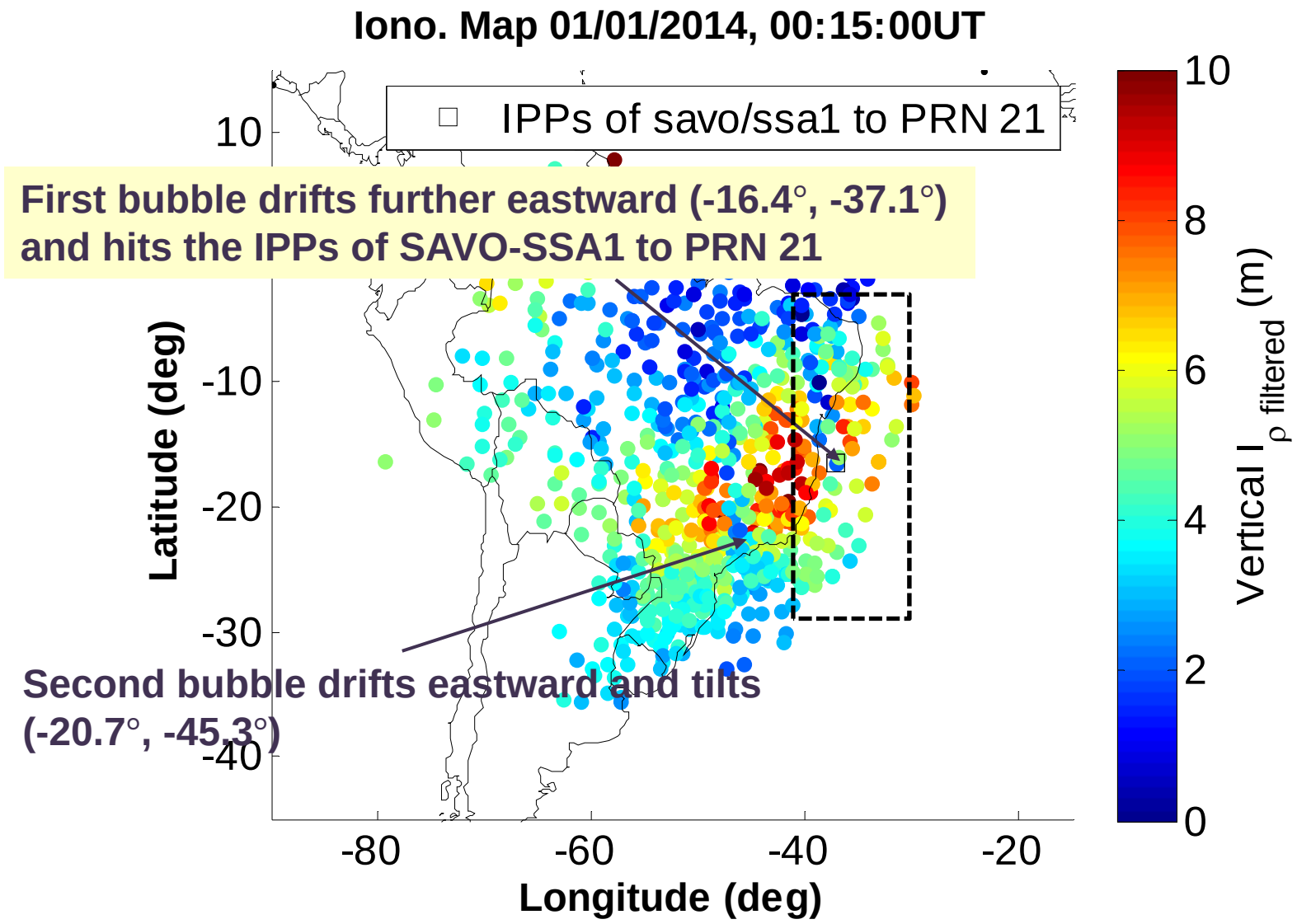
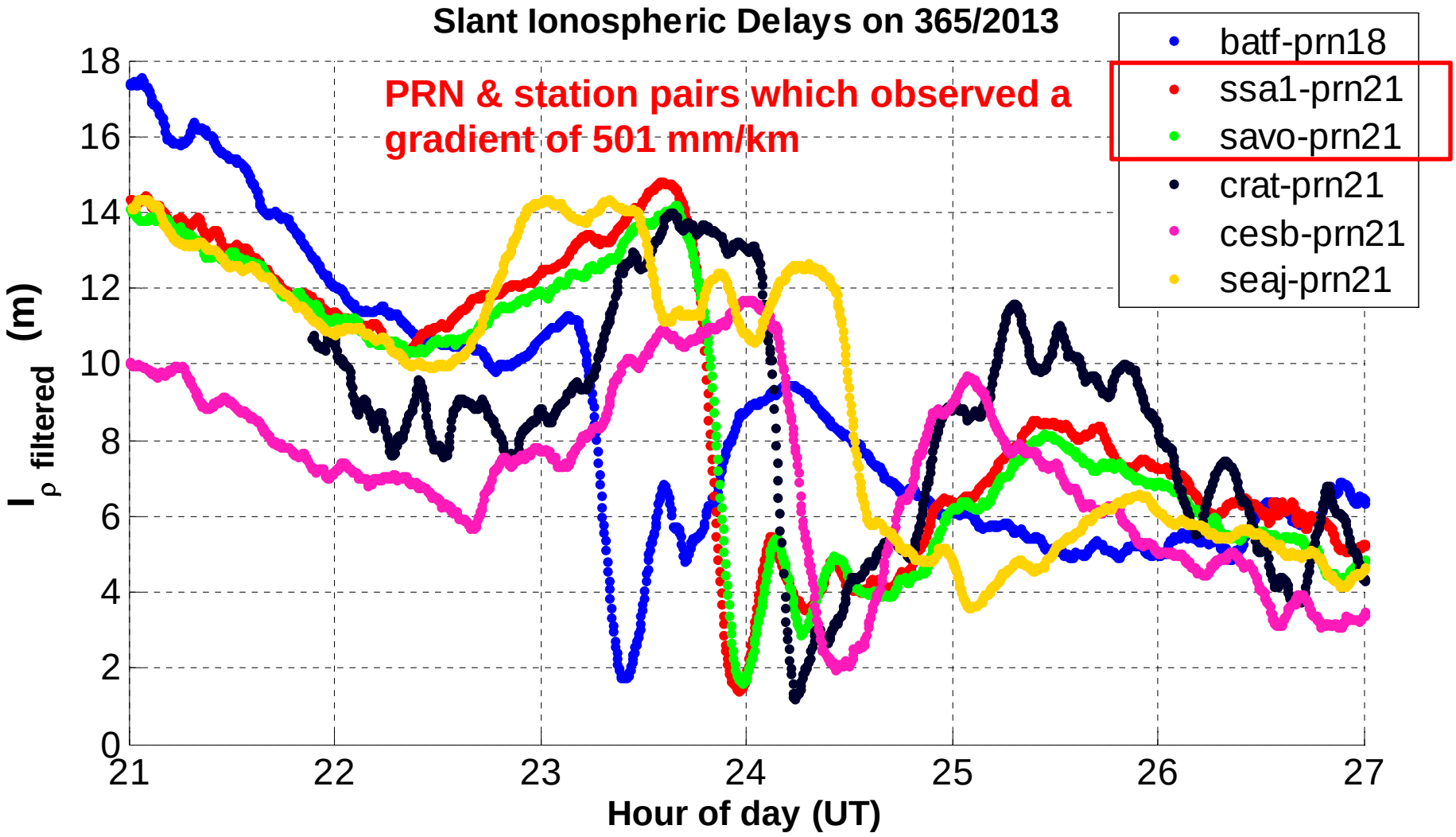


Regional Ionospheric Map

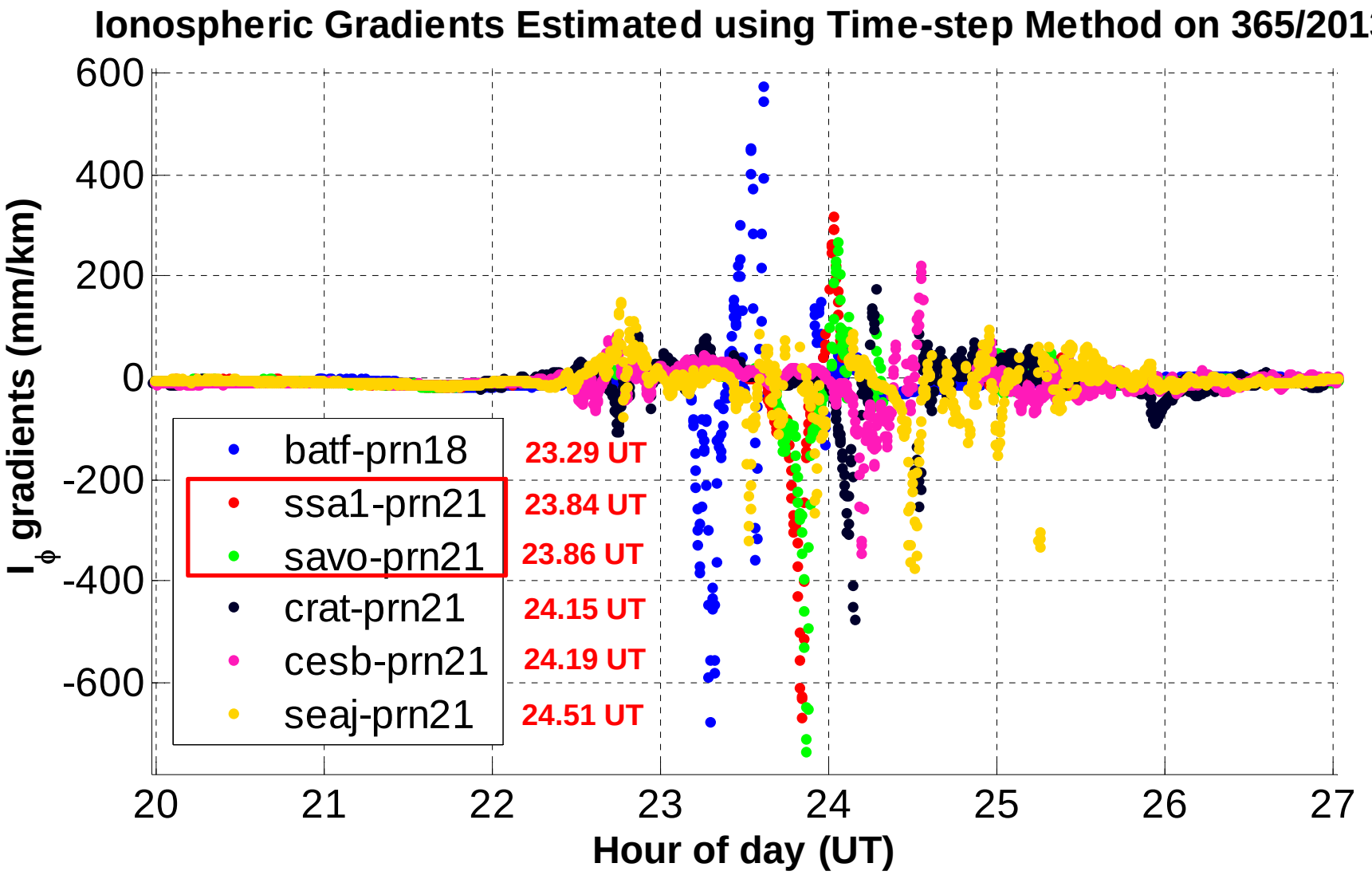
00:15:00 UT (001/2014)



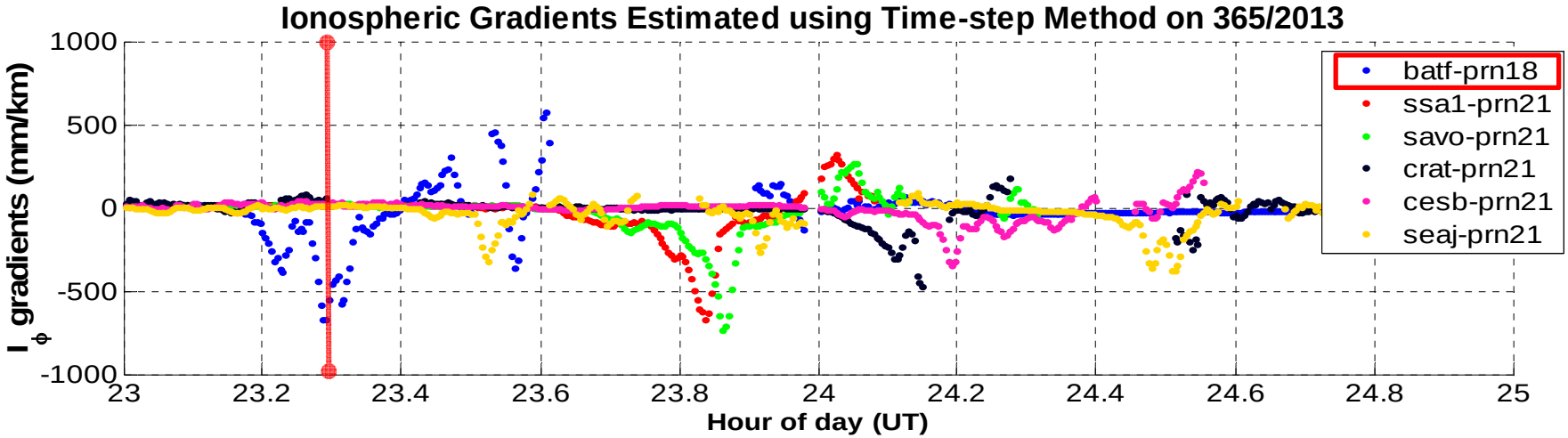
Filtered Code-based Ionospheric Delay Estimates

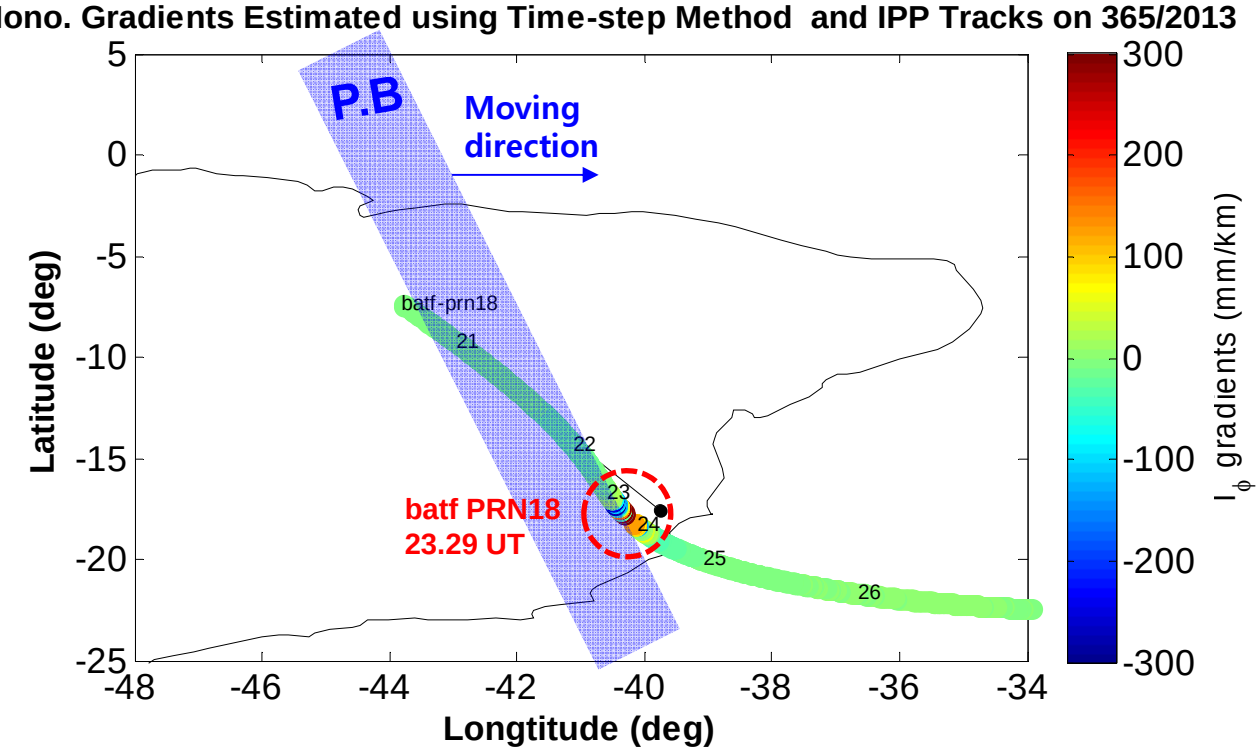


Time-Step-Method-Based Ionospheric Slopes



Time-Step-Based Slopes vs IPP Tracks





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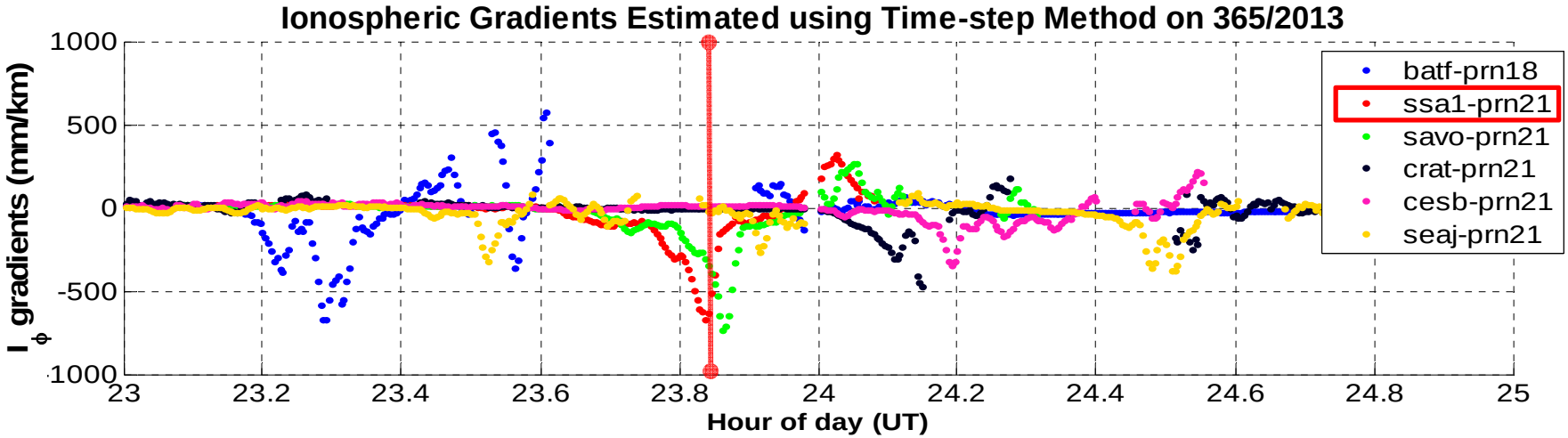

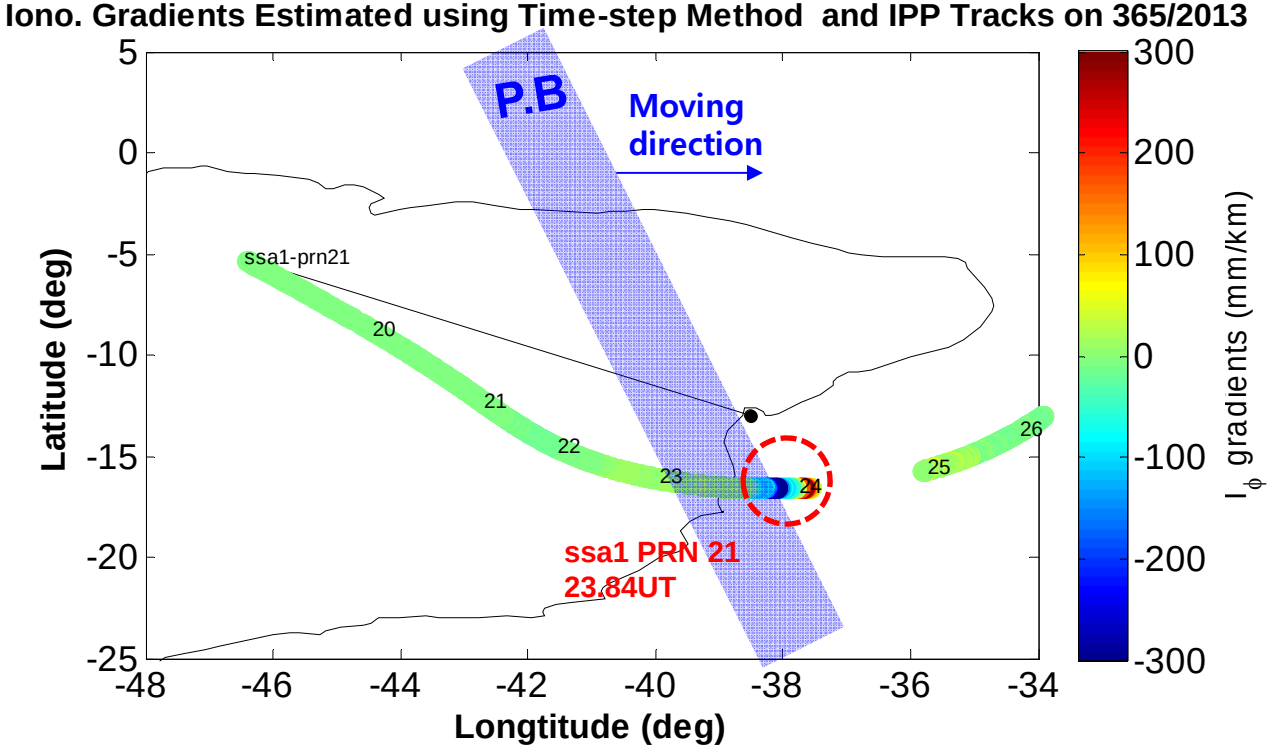

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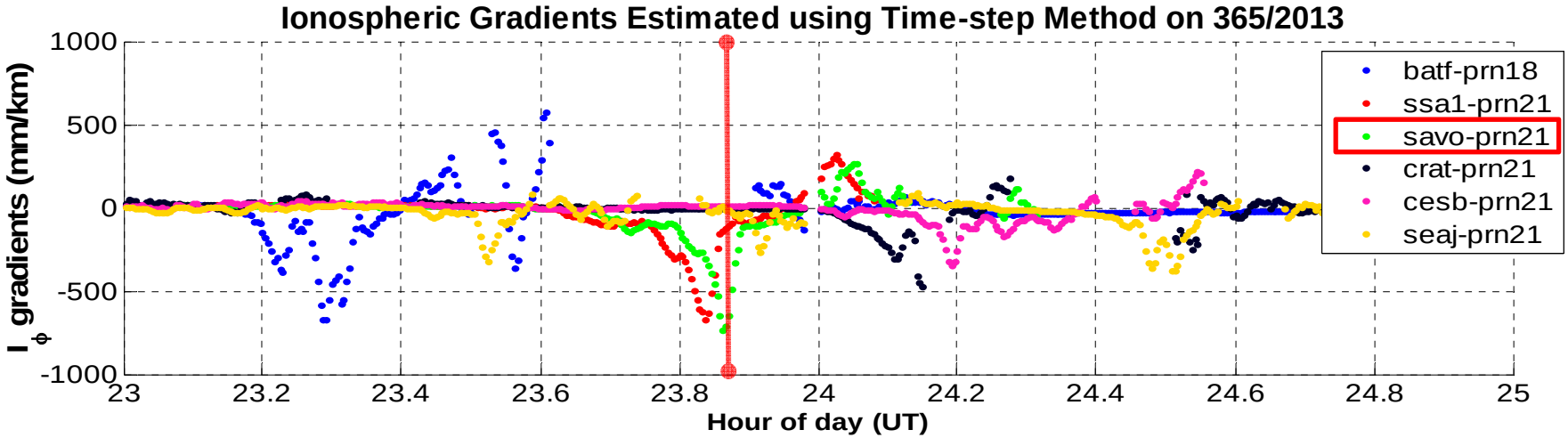

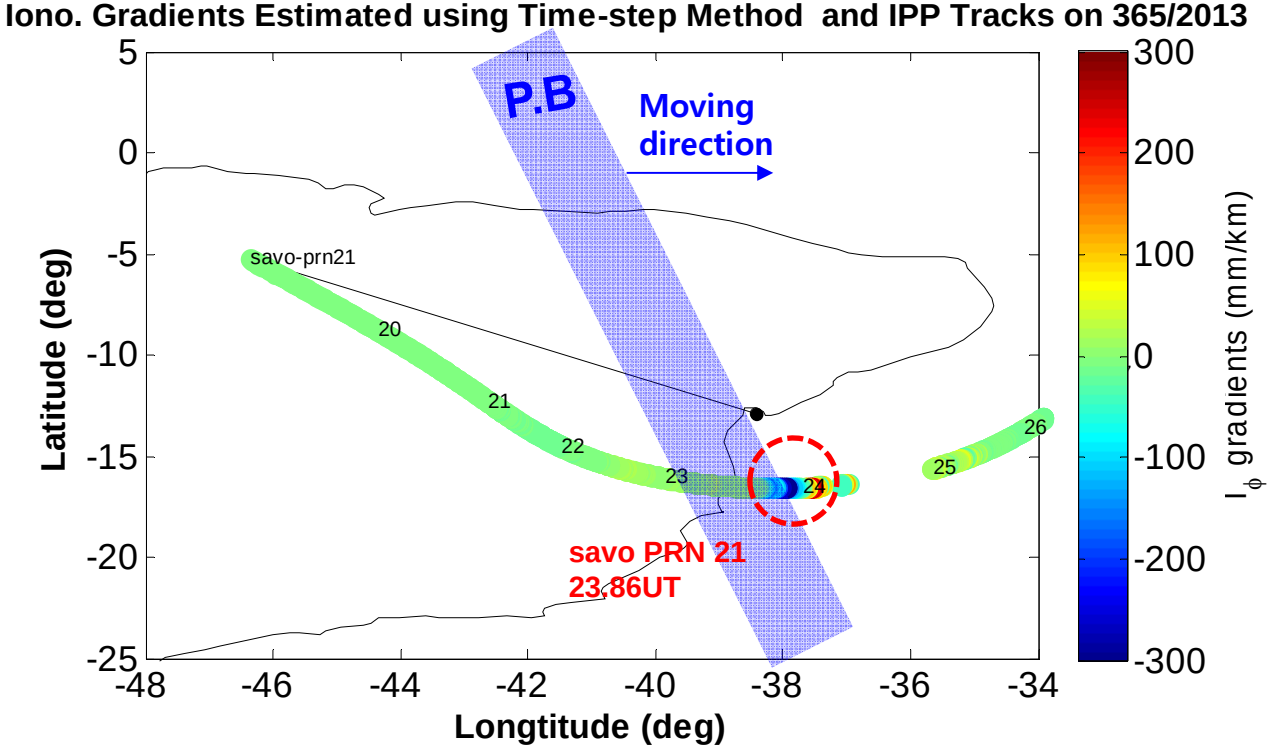

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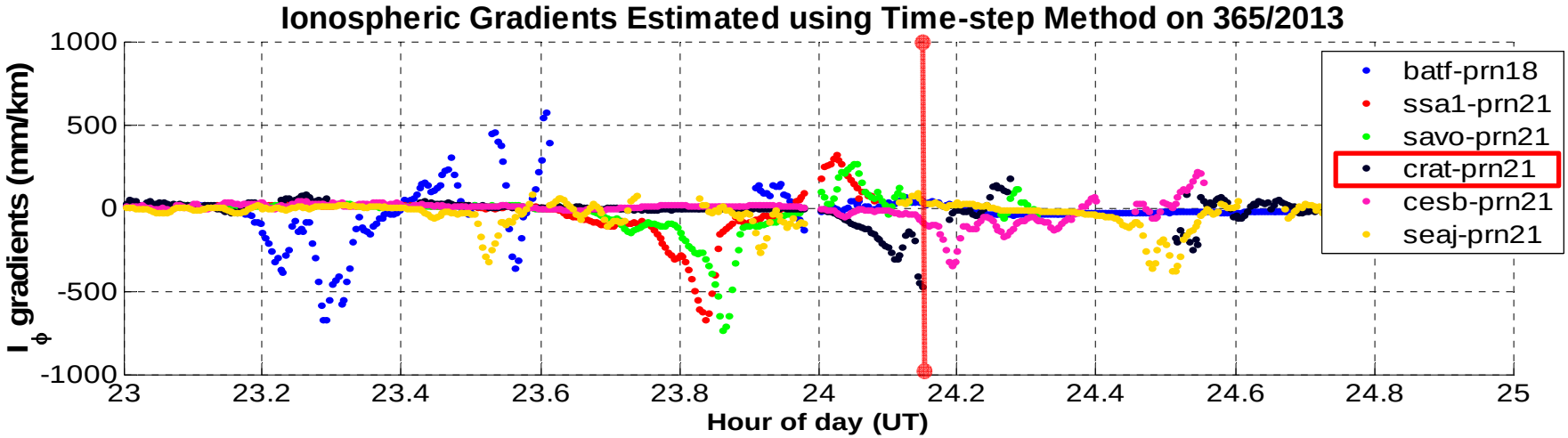

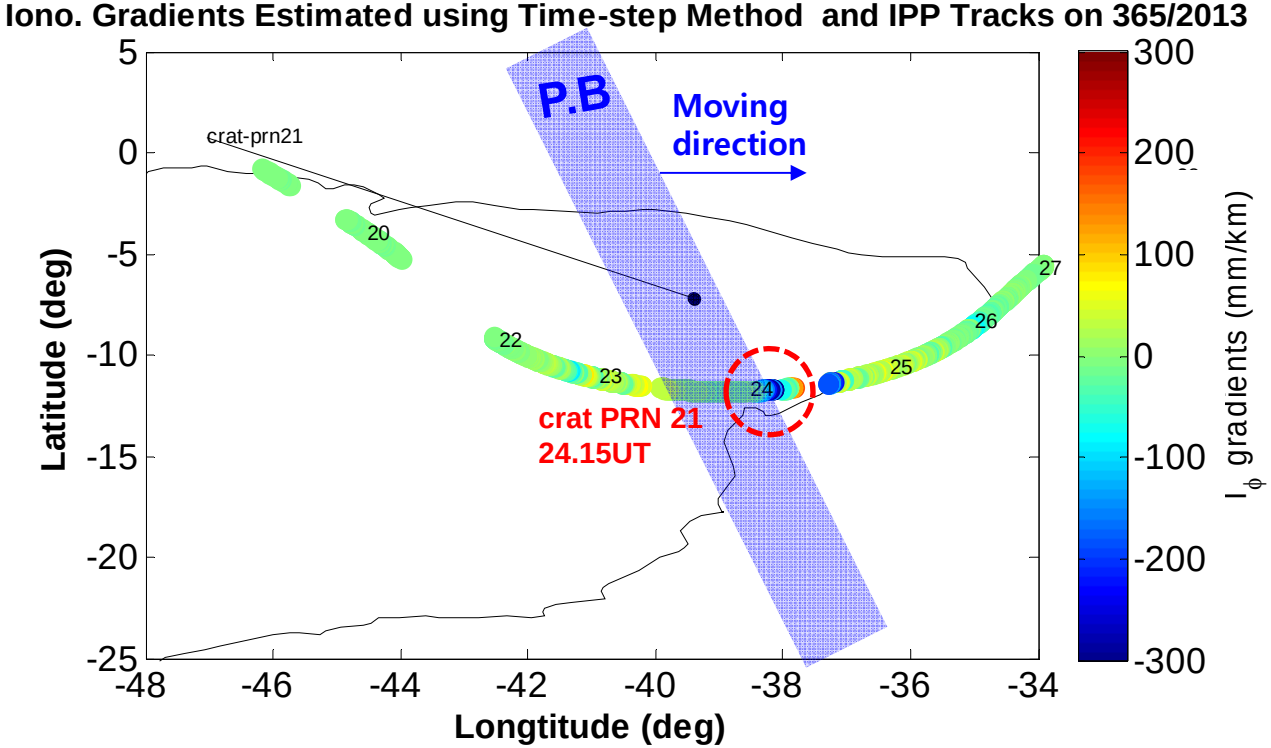

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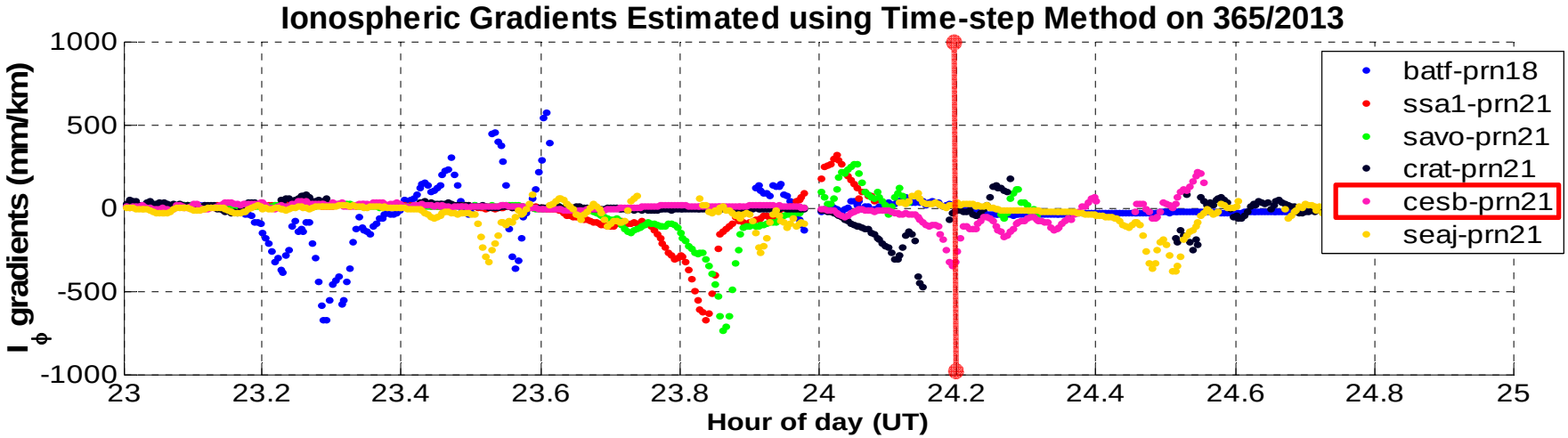

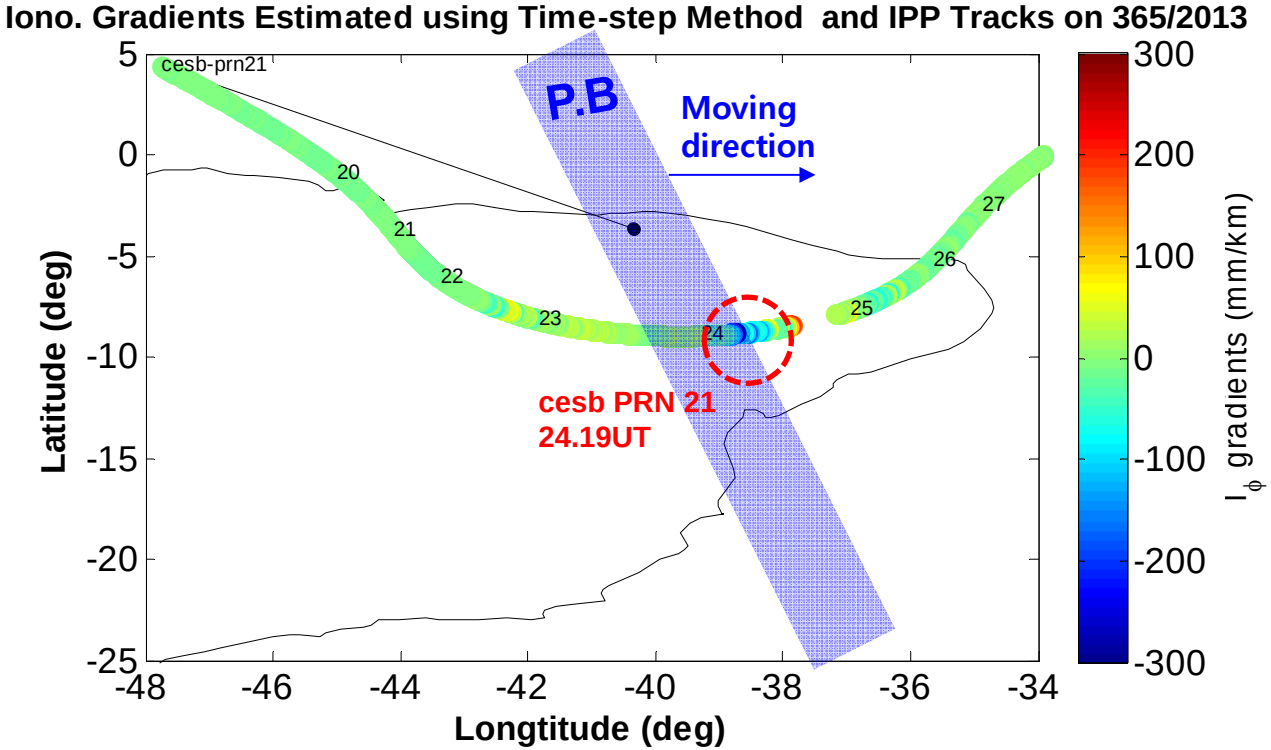

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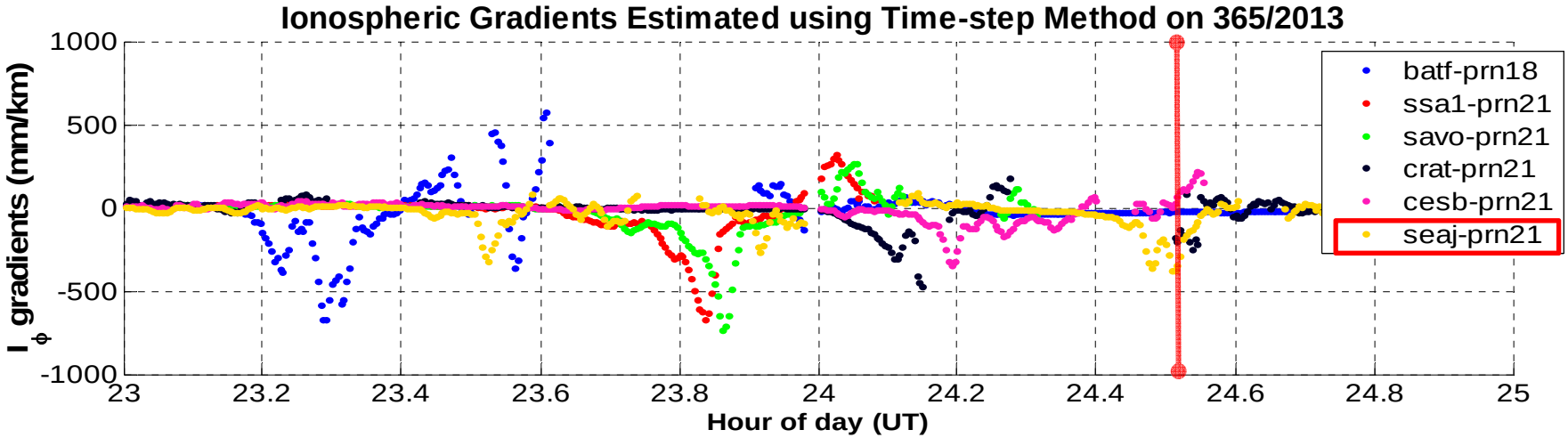

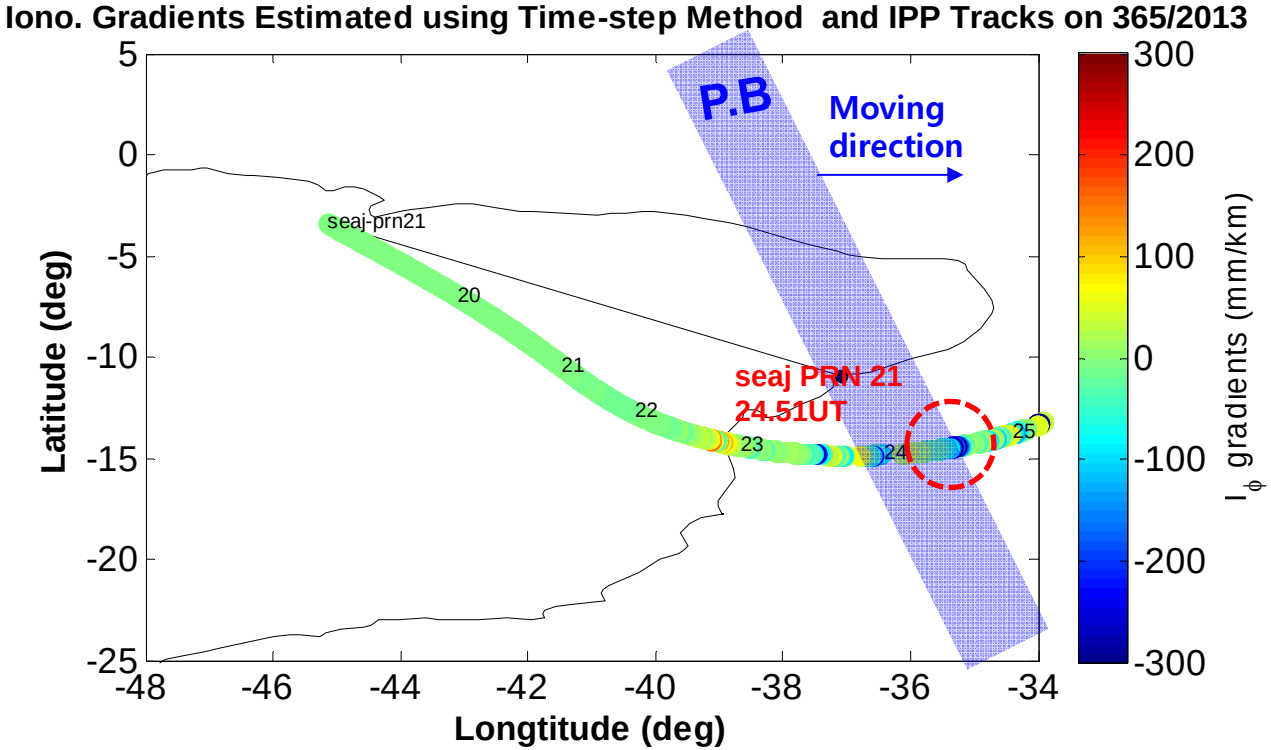

Summary

- **The comprehensive analysis supports that multiple satellite-station pairs were impacted by the same EPB in different times and locations**
  - **visualize the severe gradient events in time series in conjunction with the IPP tracks, the motion of EPB, and the location of stations**
  - **the extreme ionospheric gradient candidate of our interest is finally validated to be real**

- **Gradients above 500 mm/km should be validated using the proposed methodology while developing an ionospheric anomaly threat model for GBAS operation in the Brazilian region**