



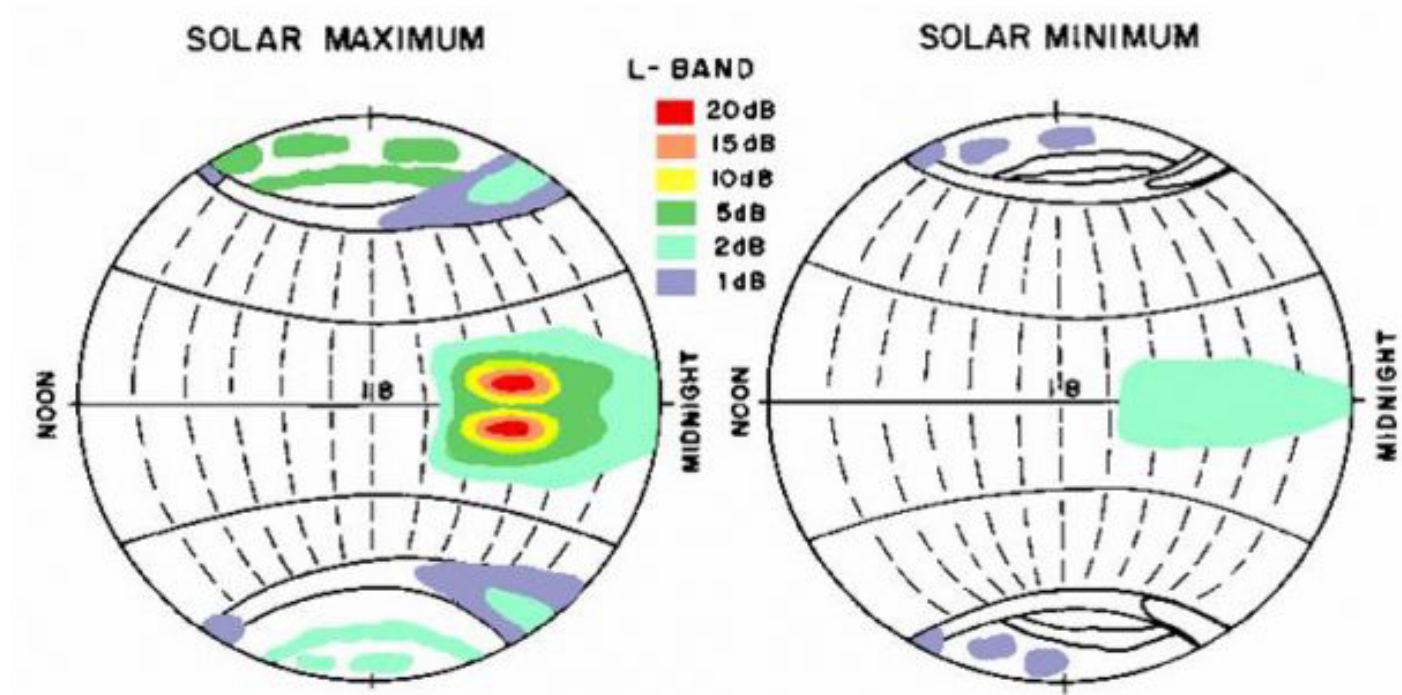
**Beacon Satellite**  
SYMPOSIUM 2016

# **Dynamics of the ionospheric irregularities during severe geomagnetic storms in 2015 by GPS measurements**

**Iurii Cherniak<sup>1</sup>, Irina Zakharenkova<sup>2</sup>**

<sup>1</sup>SRRC UWM, <sup>2</sup>IPGP

# Occurrence of L band scintillation during high and low solar activity



(Basu. et al., J. Atmos. Terr. Phys, 2002)

# GPS ROT/ROTI data

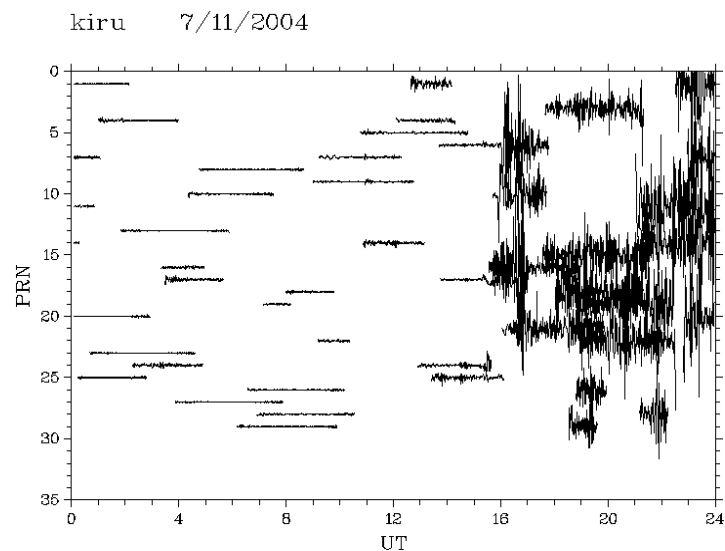
Ionospheric irregularities can be characterized by measuring its impact on amplitude and phase of the received GPS signal.

**ROT** (rate of TEC change, dTEC/dt) as a measure of phase fluctuation activity (Wanninger, 1993):

$$ROT = \frac{sTEC_k^i - sTEC_{k-1}^i}{(t_k - t_{k-1})}$$

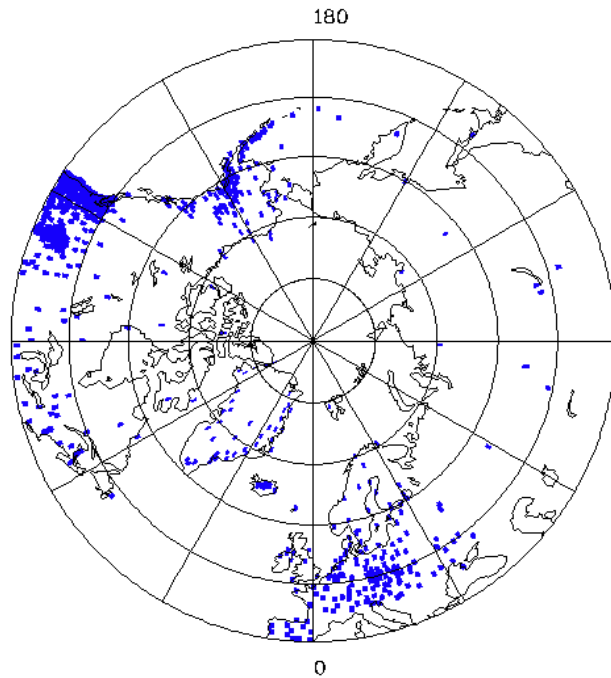
Rate of TEC Index (**ROTI**) as a GPS-based index that characterizes the severity of the GPS phase fluctuations and detects the presence of ionospheric irregularities. Proposed by Pi et al., 1997.

$$ROTI = \sqrt{\langle ROT^2 \rangle - \langle ROT \rangle^2}$$



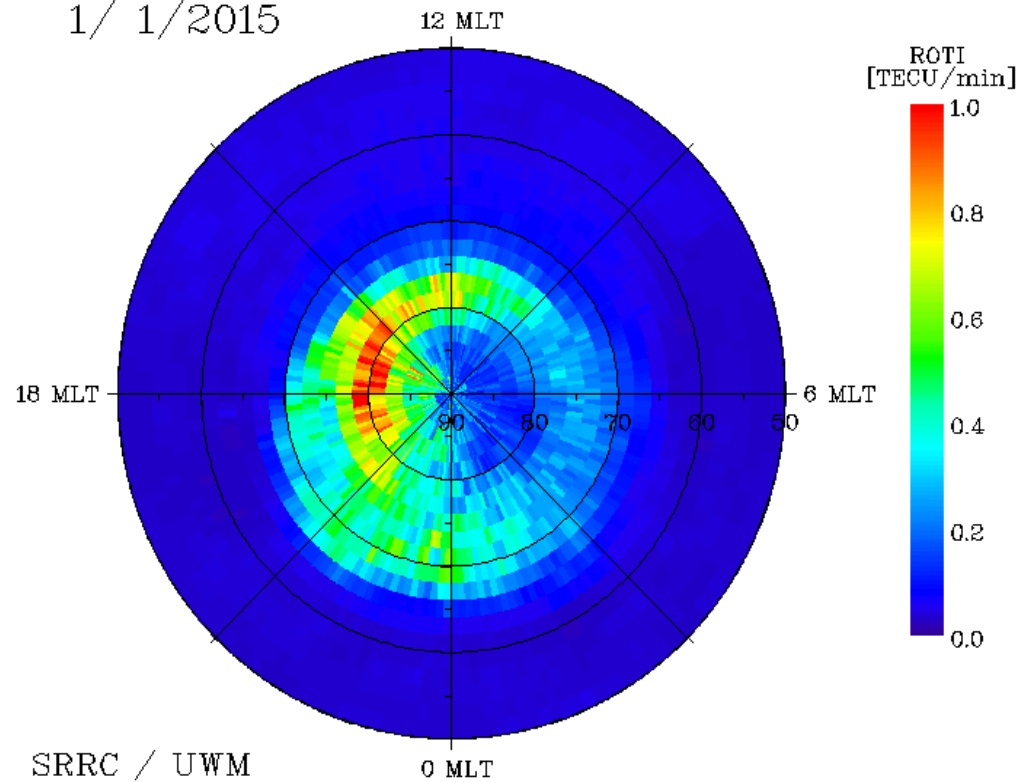
# GPS ROTI maps

Phase fluctuation occurrence is represented as a function of magnetic local time (MLT) and corrected magnetic latitude (MLAT).

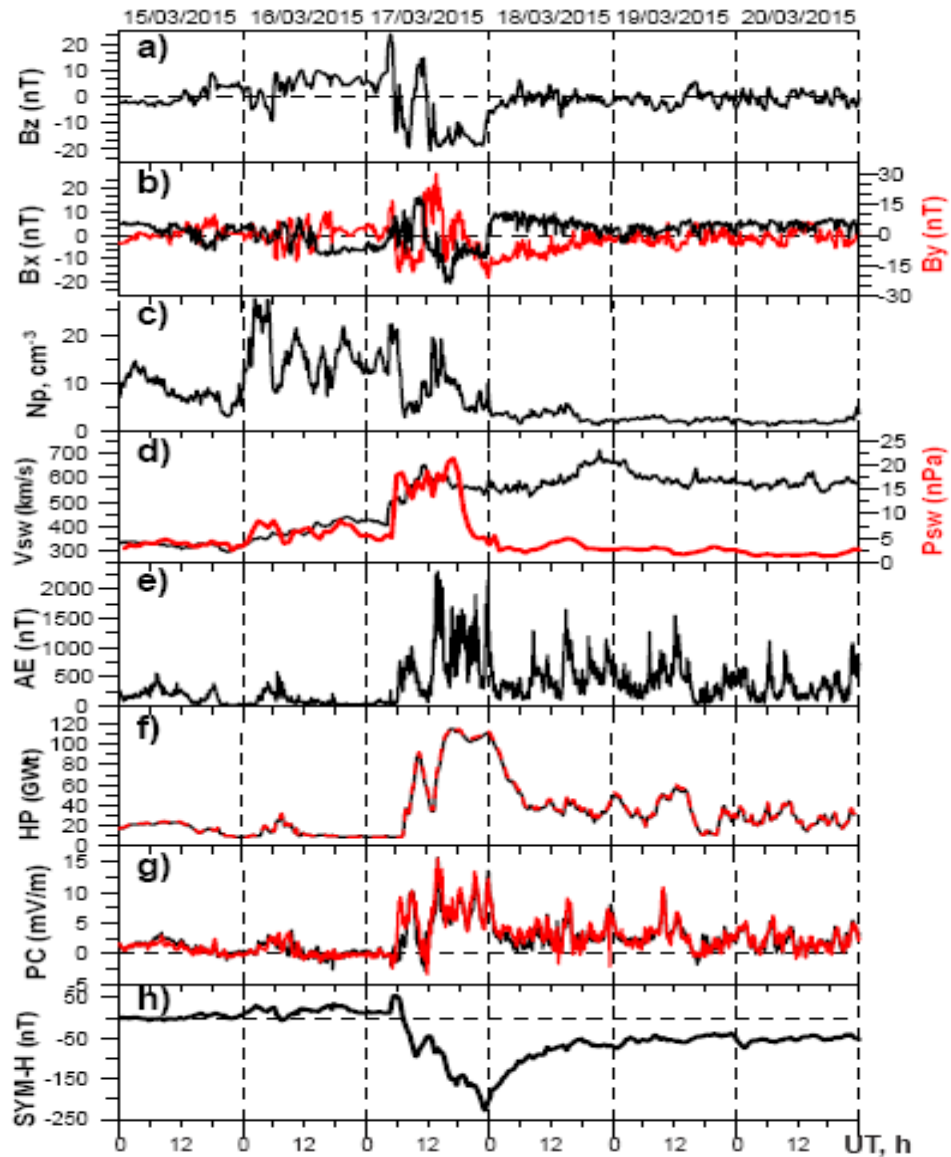


Grid: 2° MLAT by 8 min MLT.

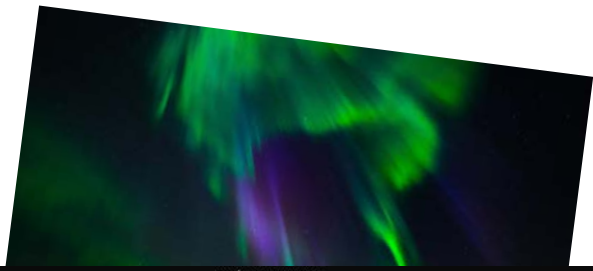
1/ 1/2015



# 2015 St. Patrick's Day Storm



- Largest storm for last 10 years
- Intense particle precipitation
- Aurora was registered at mid-latitudes



The Washington Post

Capital Weather Gang

### Photos: Spectacular aurora from severe solar storm light up northern skies

By Jason Samenow March 18, 2015



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Forecast

Fri.	Set.
60° / 87°	60° / 84°
60%	



B. Wanner, WAAS Technical Report: "Iono activity affected WAAS performance in Canada, Alaska, and CONUS on March 17 and March 18"

*WAAS Technical Report  
William J. Hughes Technical Center  
Atlantic City International Airport, NJ  
March 19, 2015*

*Author(s): Bill Wanner*

*DR #127: Effect on WAAS  
from Iono Activity on  
March 17-18, 2015*

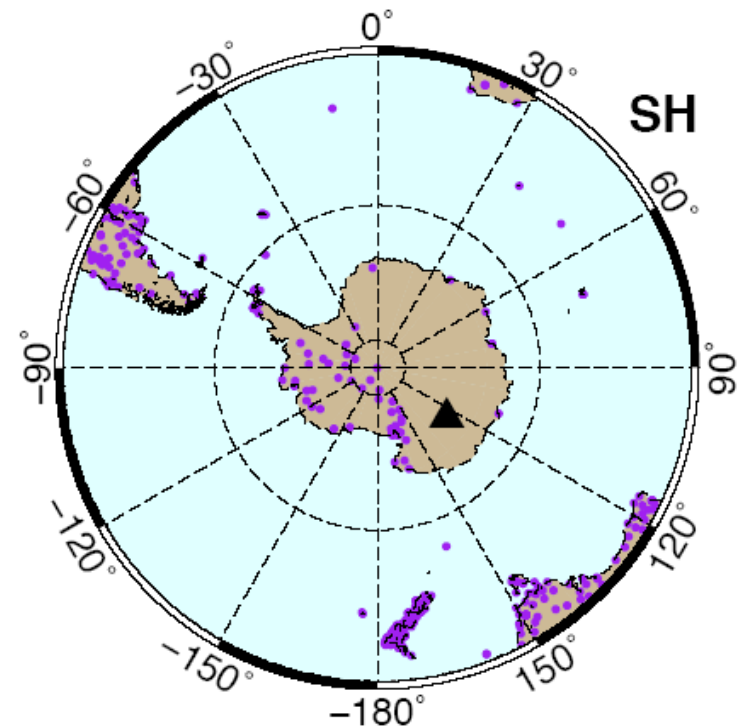
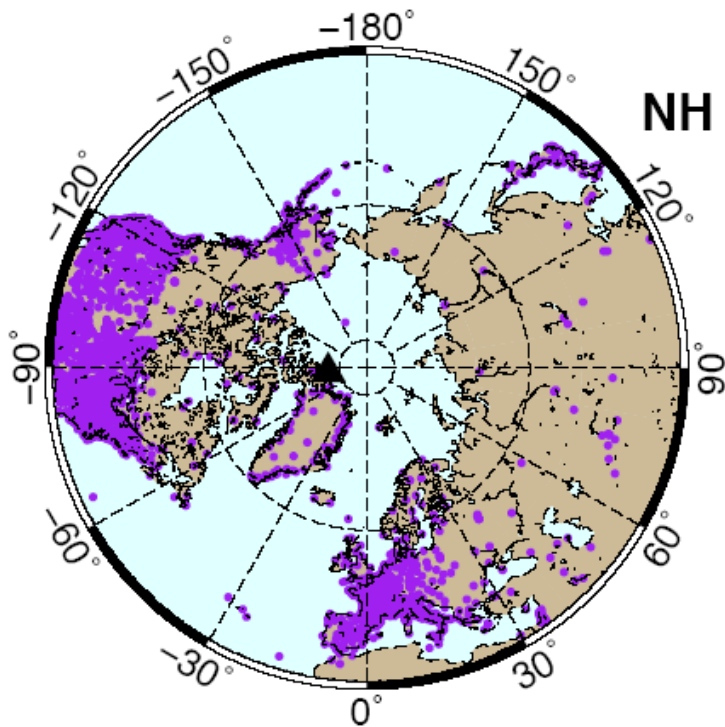


*GPS Week/Day: Week 1836 Day 2  
(03/17/2015)*

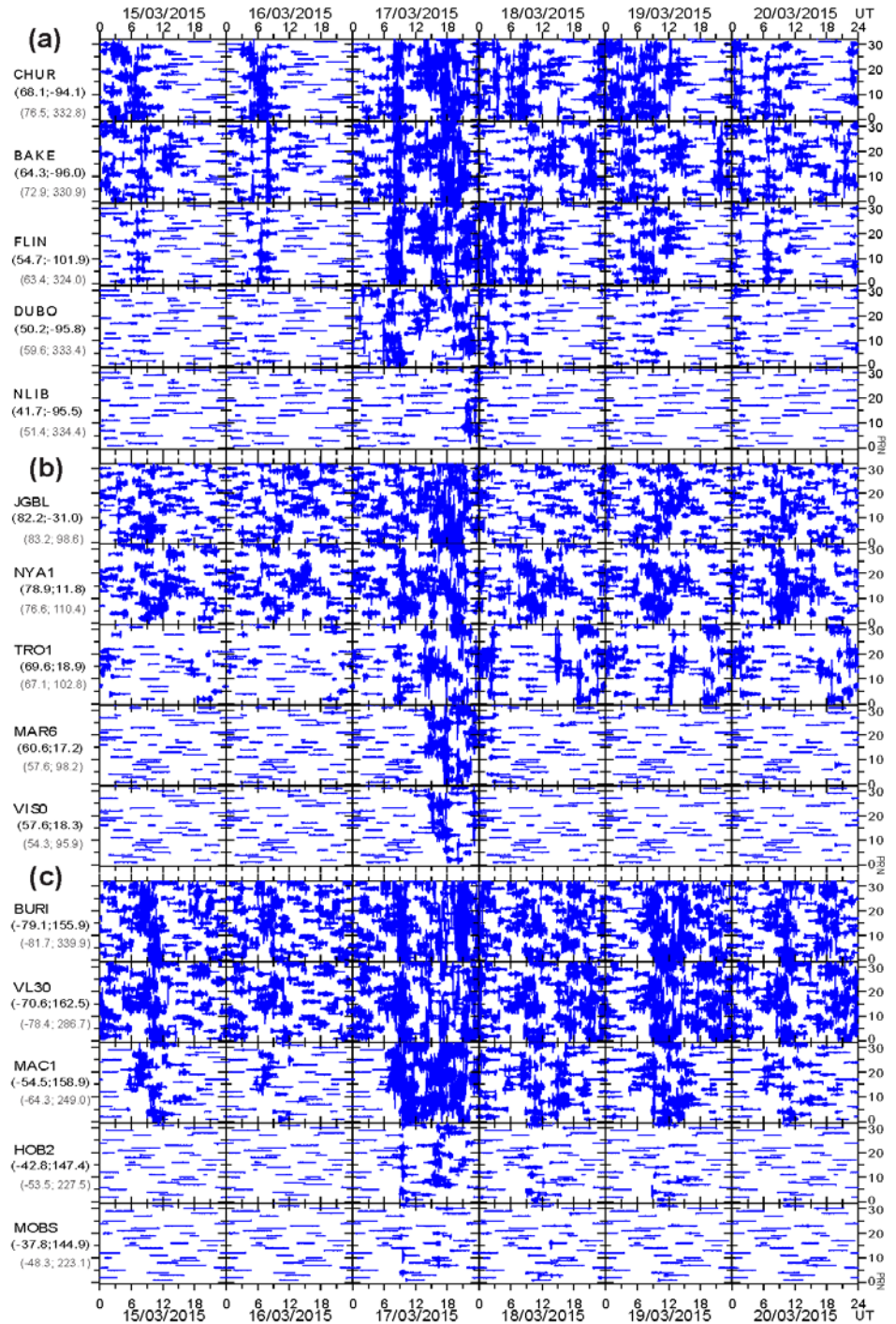
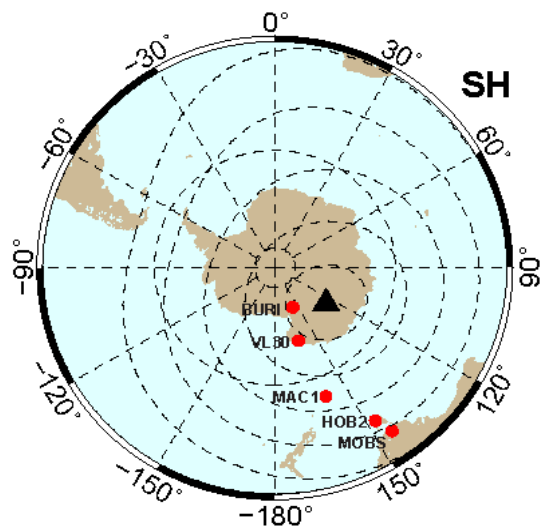
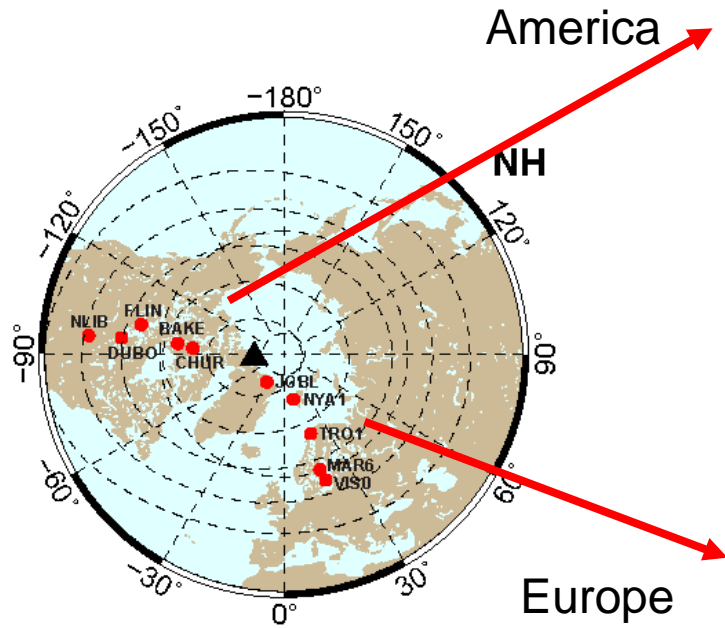


# GPS Database

From more than 5000 available permanent worldwide stations we excluded the equatorial and low-latitude stations (30° S - 30° N) to yield ~2500 and ~200 stations for the Northern and Southern Hemispheres respectively.



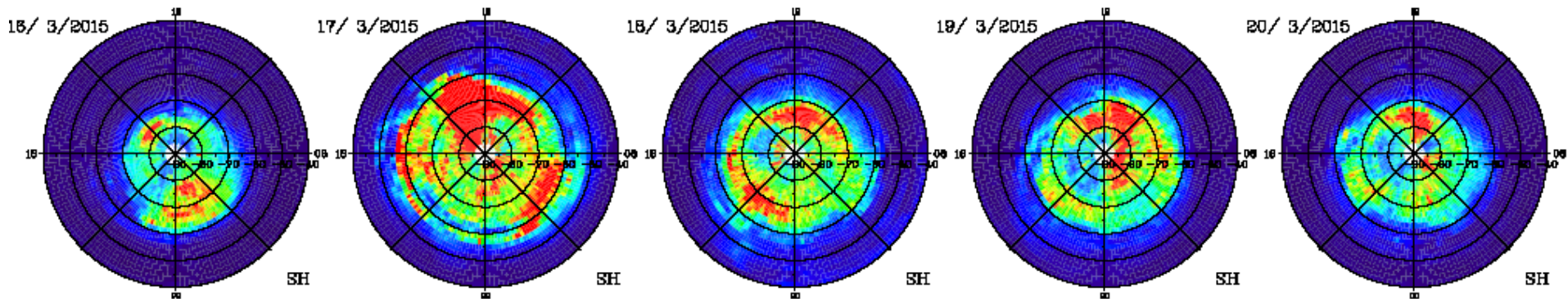
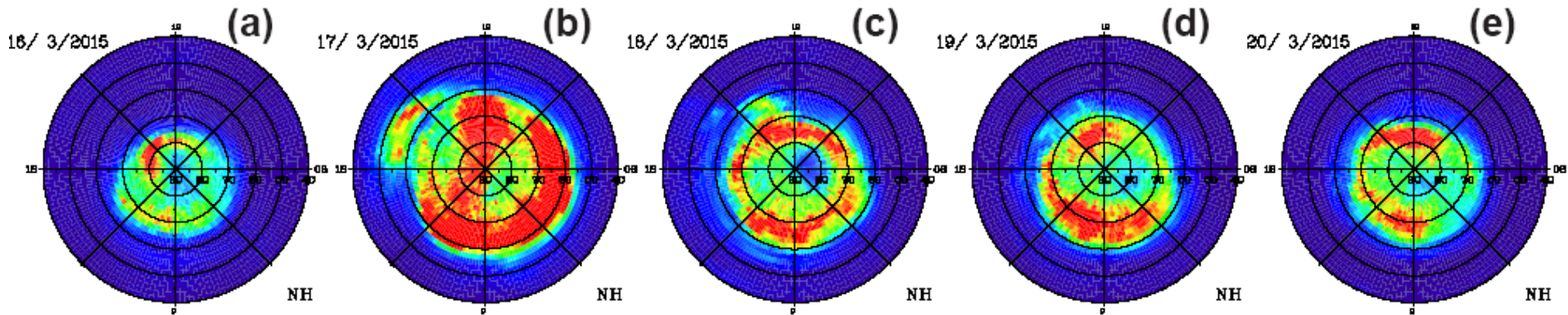
# ROT variability



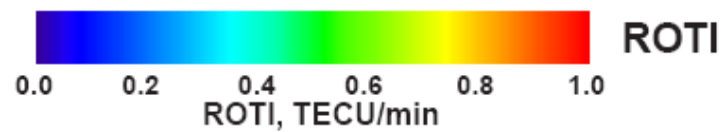


# Diurnal ROTI maps

Northern Hemisphere



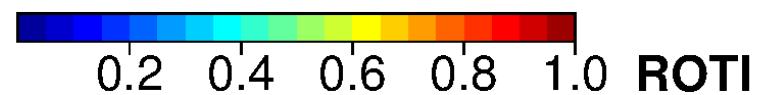
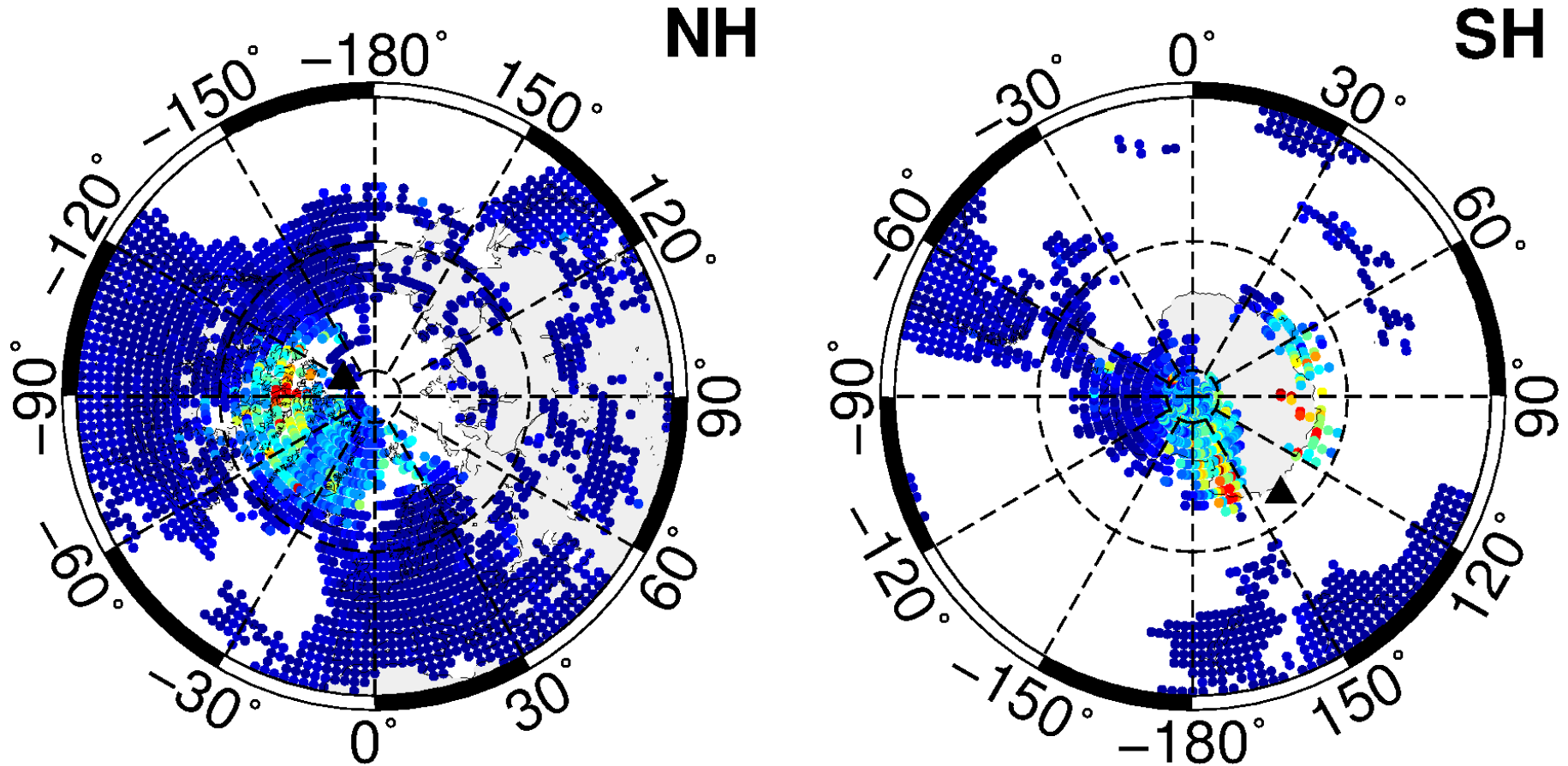
Southern Hemisphere



# Dynamics of ionospheric irregularities: Hourly ROTI maps

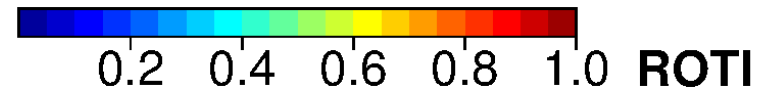
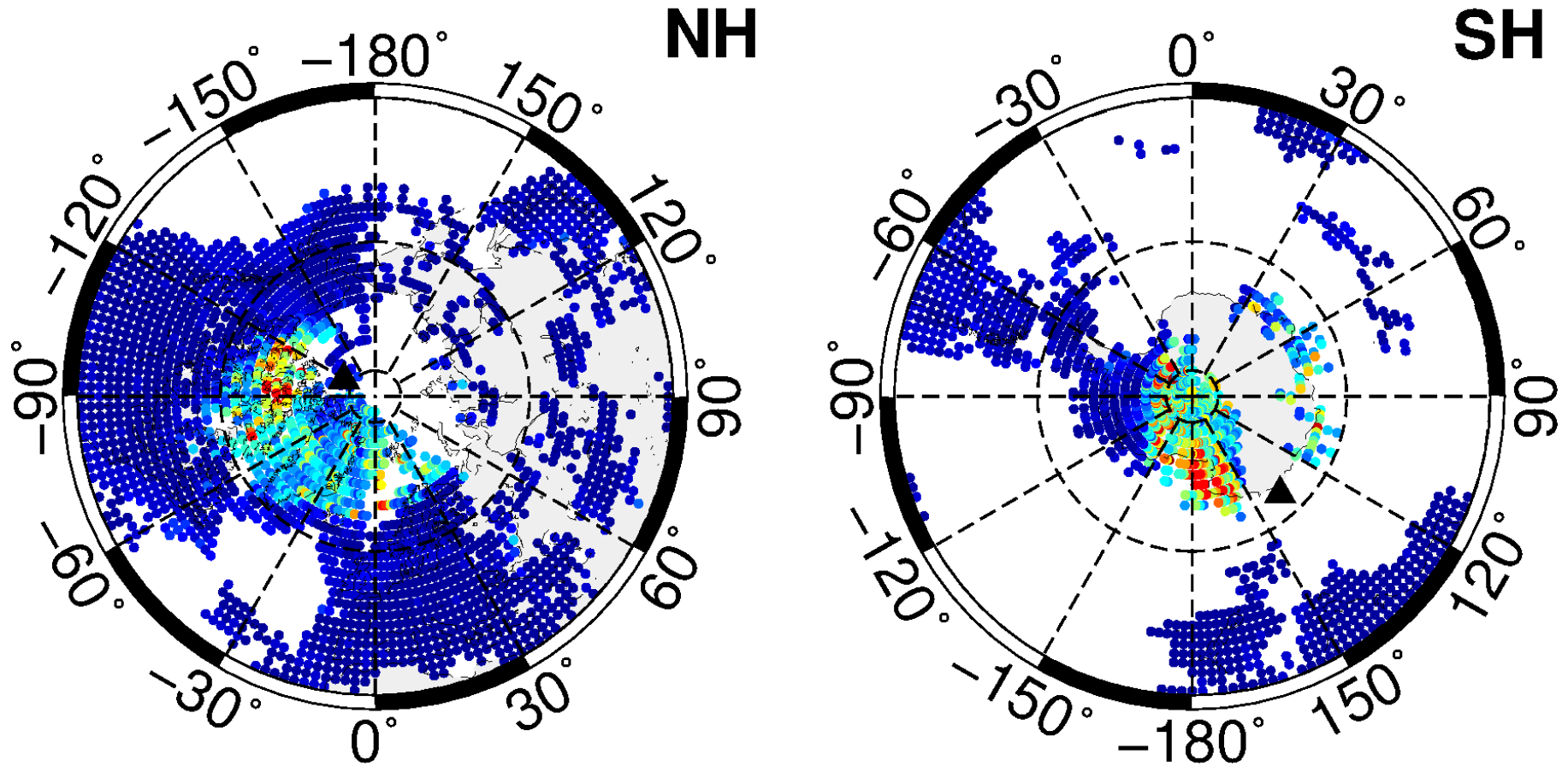
Quiet Day

## 16/03/2015 00 UT

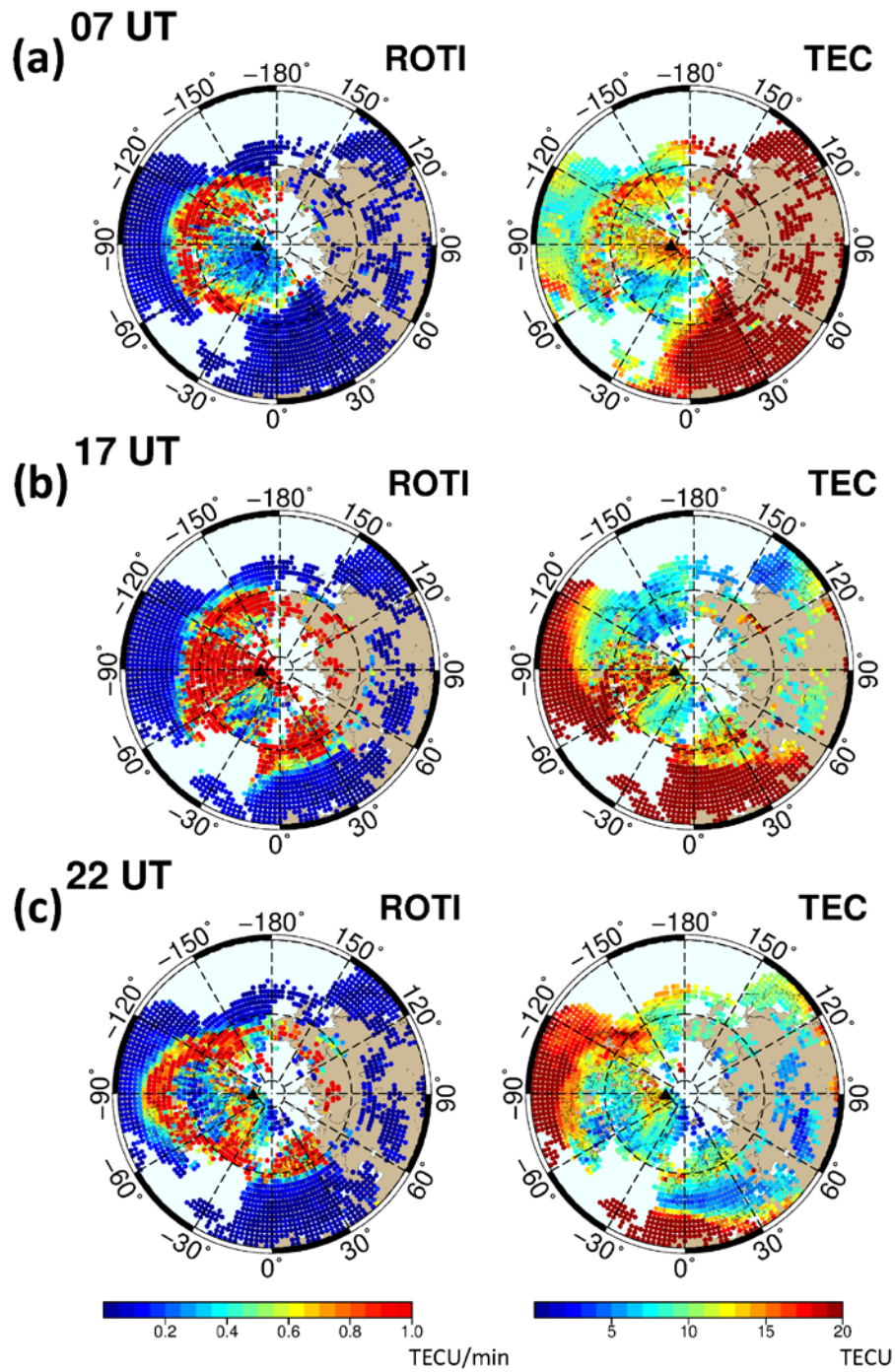


# Dynamics of ionospheric irregularities: Storm day

## 17/03/2015 00 UT

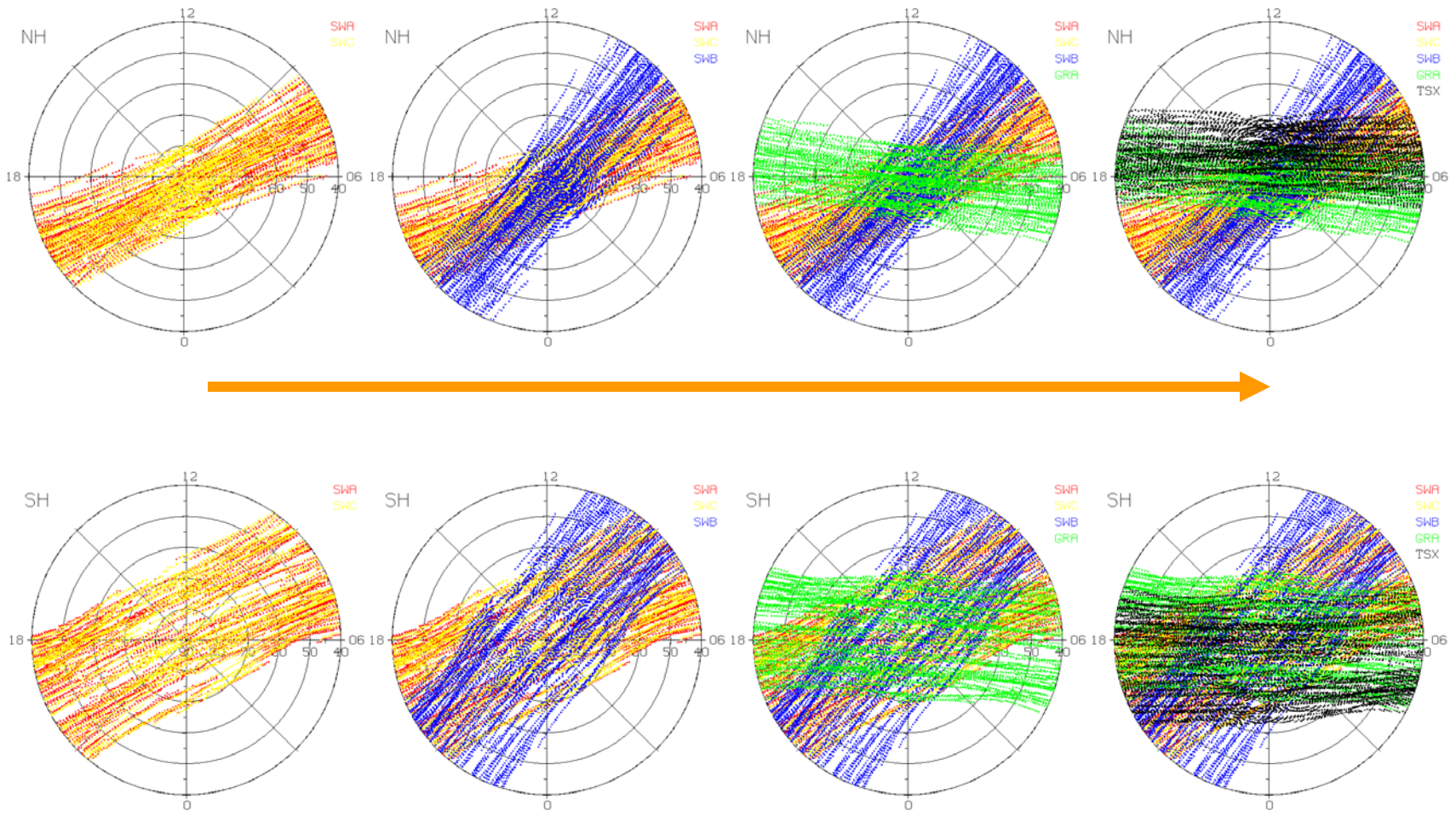


# SED/TOI



# LEO GPS data – new possibilities for topside irregularities study

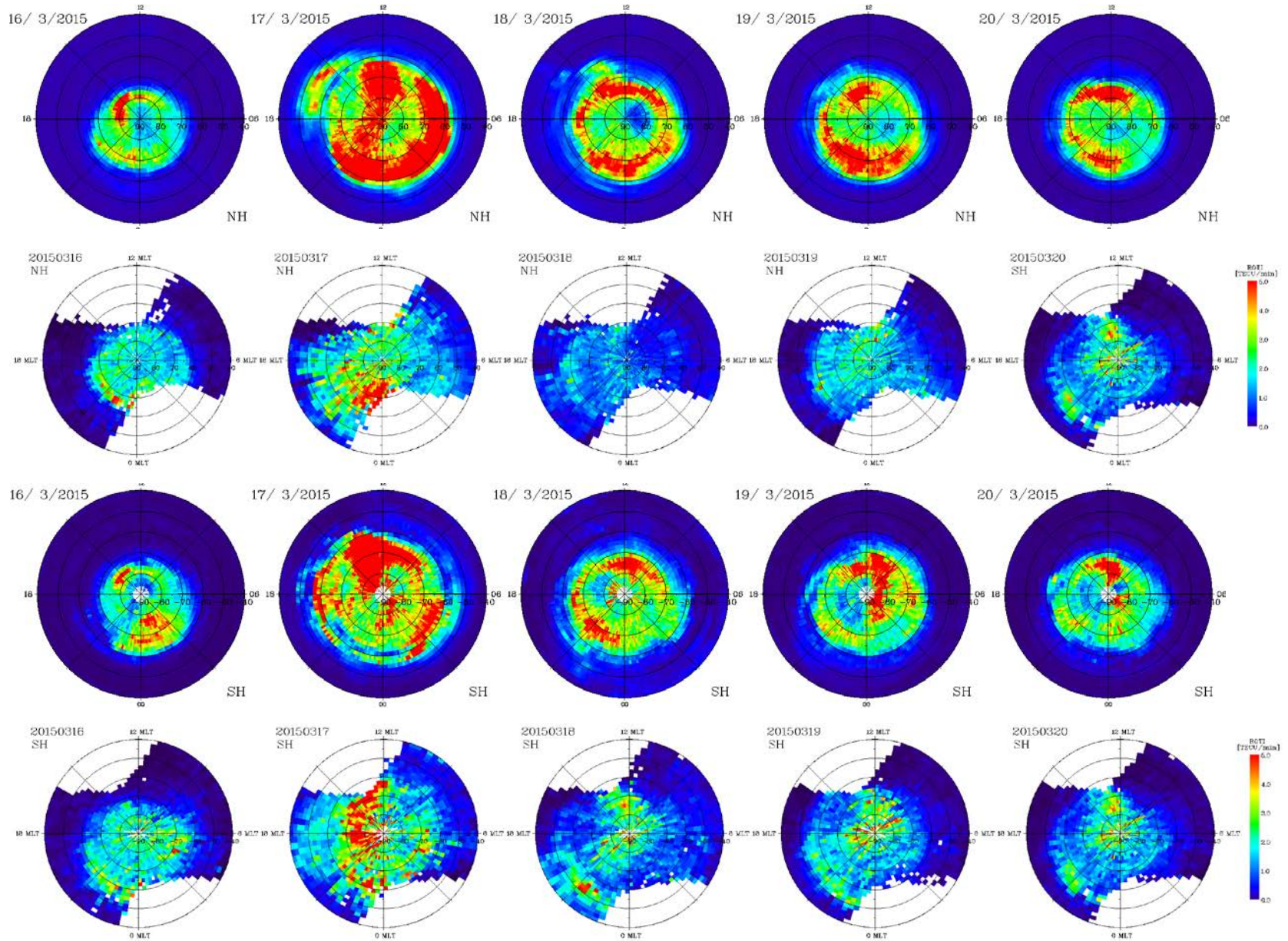
Covers polar regions of both hemispheres.



Advantages of multi-satellite observations:

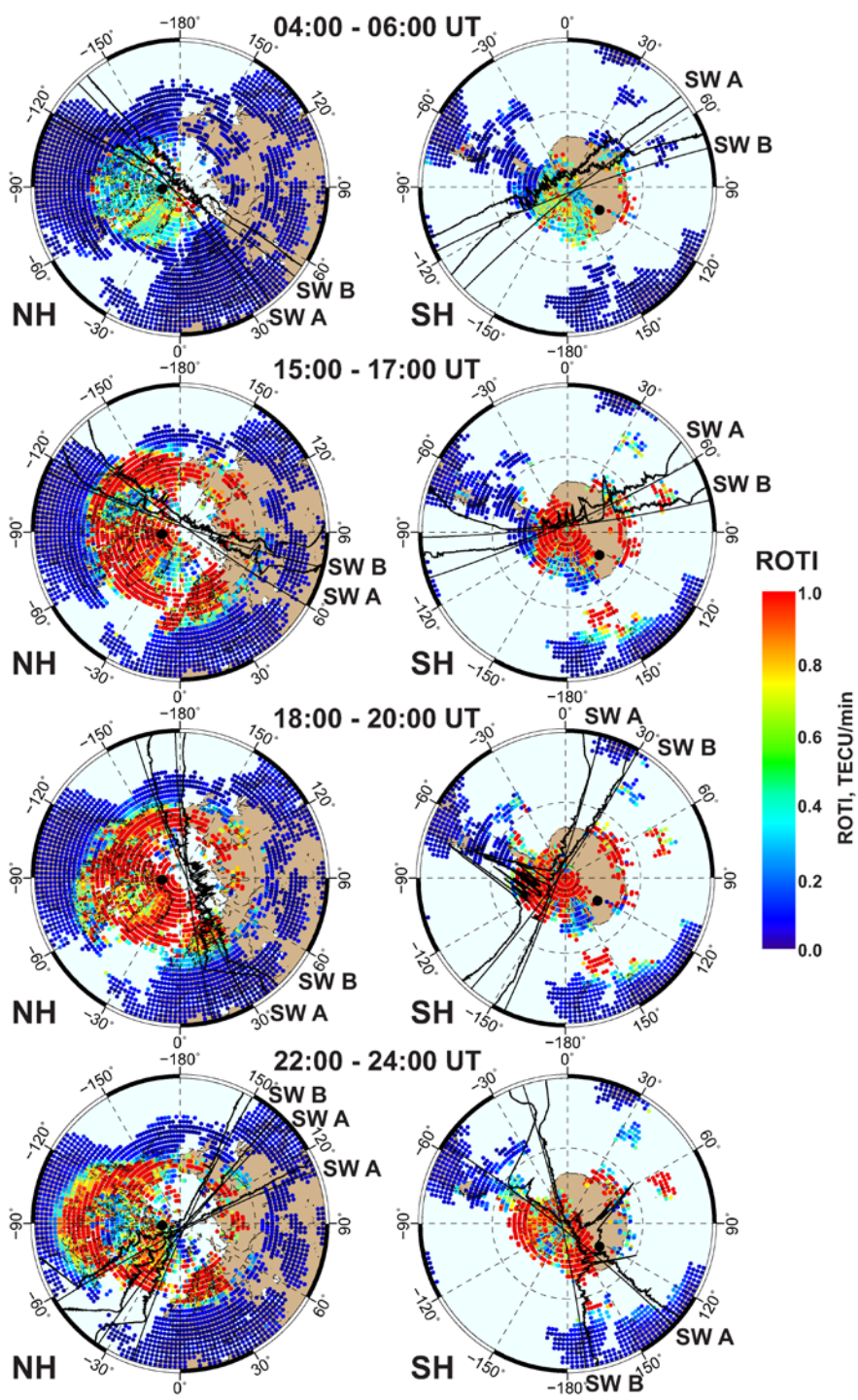
Swarm A, Swarm C, Swarm B, GRACE, TerraSAR-X

# Duurnal ROTI maps: Ground GPS vs LEO GPS



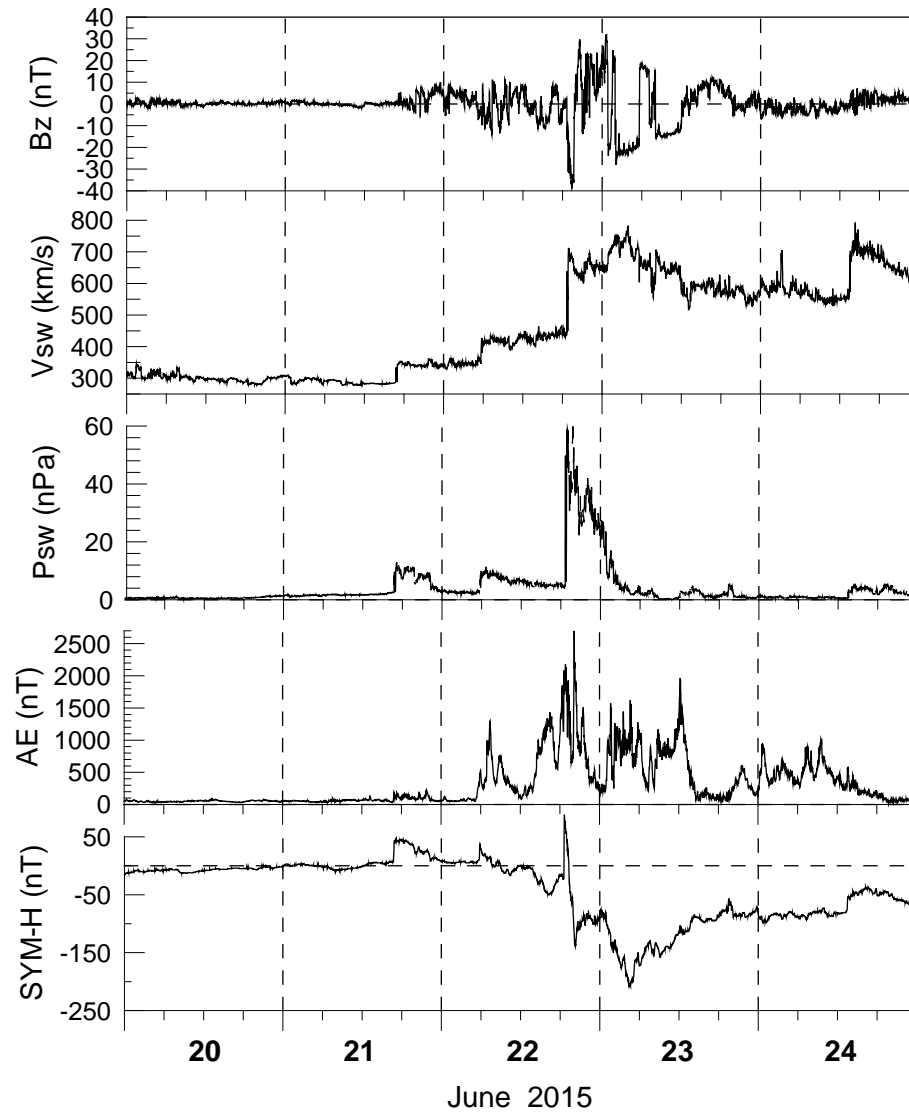
Application of ROTI mapping technique to LEO GPS measurements.

# Swarm plasma density probe



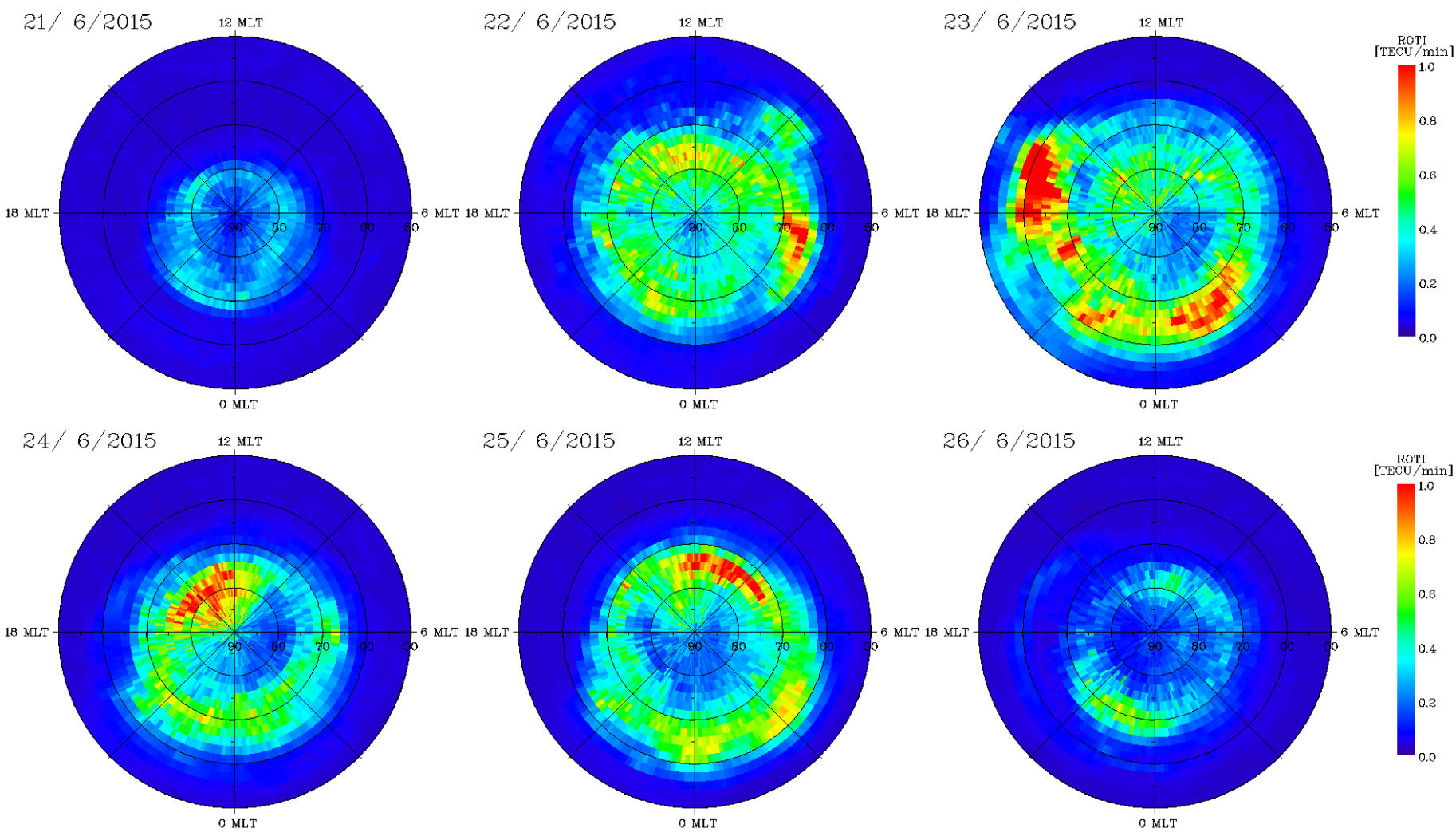
Swarm LP data confirm electron density enhancement in SED/TOI and ionospheric irregularities structure.

# June 2015 Storm





# Diurnal ROTI maps

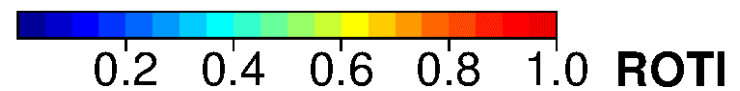
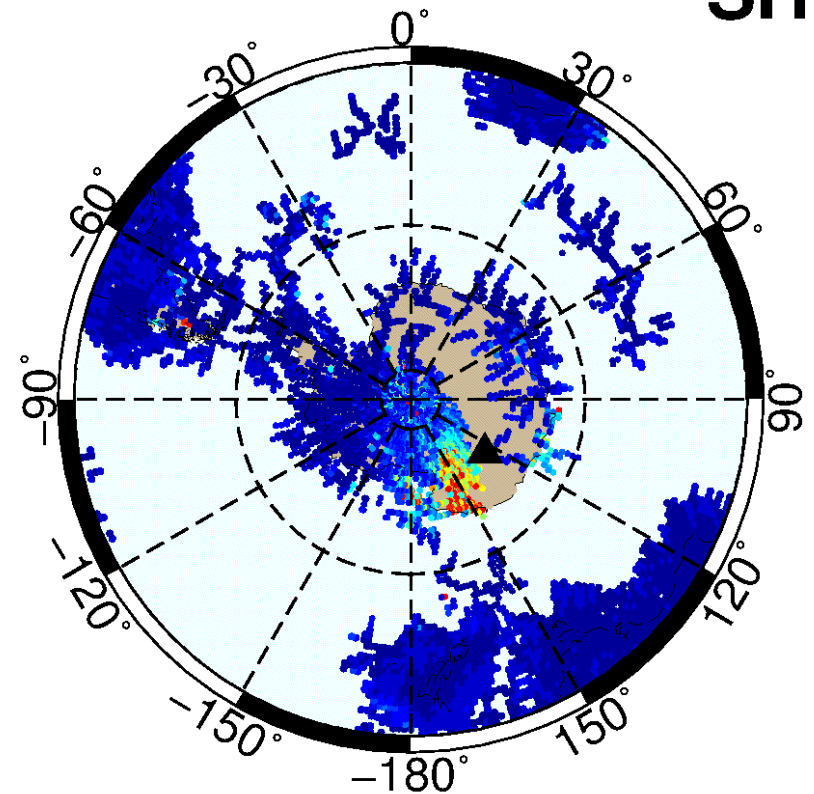
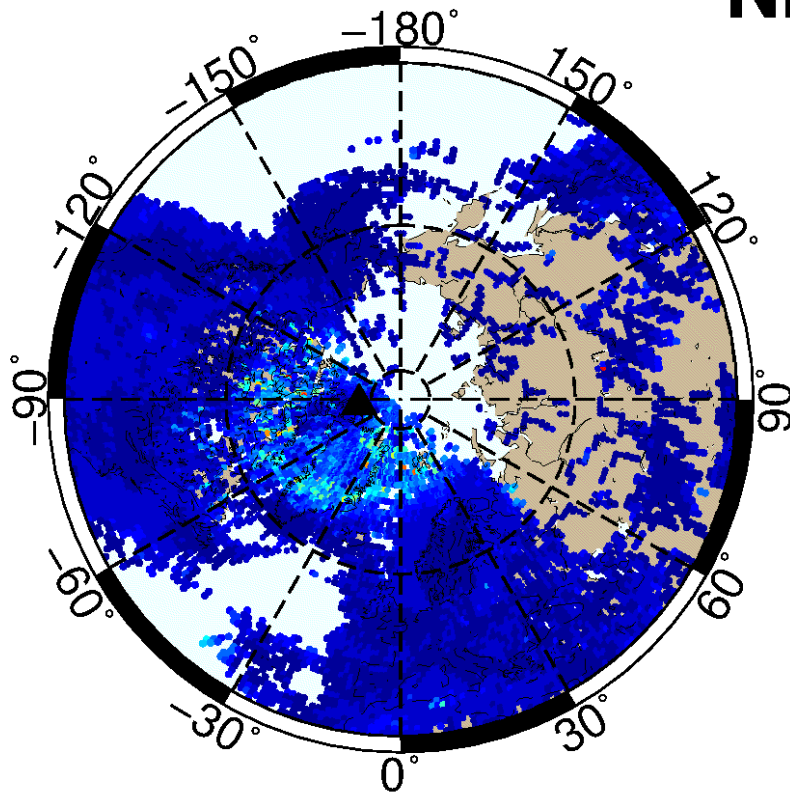


# Dynamics of ionospheric irregularities: Quiet day

**20/06/2015 01:00**

**NH**

**SH**

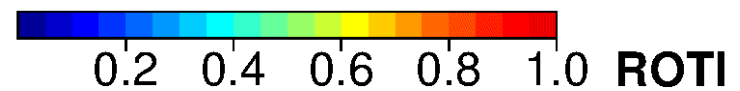
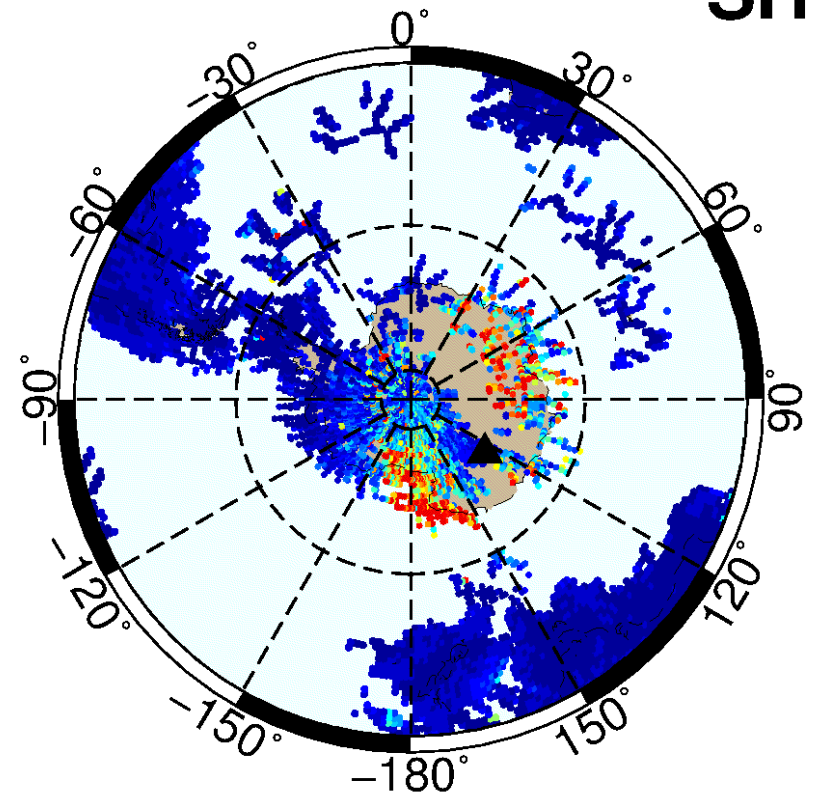
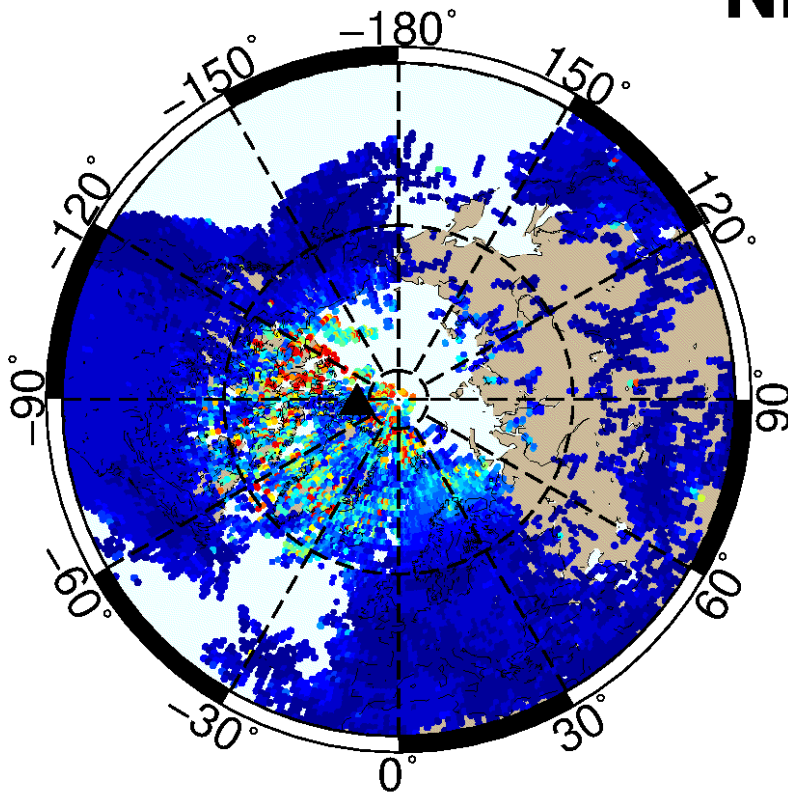


# Dynamics of ionospheric irregularities: Storm day

**23/06/2015 23:00**

**NH**

**SH**



**Thank you for your attention!**

## Acknowledgements

- ✓ IGS (<ftp://cddis.gsfc.nasa.gov>),
- ✓ UNAVCO (<ftp://data-out.unavco.org>),
- ✓ NOAA CORS (<ftp://geodesy.noaa.gov/cors>),
- ✓ EUREF (<ftp://rgpdata.ign.fr>),
- ✓ Natural Resources Canada ([webapp.geod.nrcan.gc.ca](http://webapp.geod.nrcan.gc.ca)),
- ✓ RAMSAC CORS of NGI of Argentina  
([www.igm.gov.ar/NuestrasActividades/Geodesia/Ramsac/](http://www.igm.gov.ar/NuestrasActividades/Geodesia/Ramsac/)),
- ✓ Australian (<ftp://ftp.ga.gov.au>),
- ✓ New Zealand (<ftp://geonet.org.nz>) GNSS networks.

We also thank IGS and CODE for providing GPS products (orbits, biases).

The authors thank the NASA/GSFC's Space Physics Data Facility's OMNIWeb service, for providing OMNI data (<ftp://spdf.gsfc.nasa.gov/pub/data/omni>) and the program code for CGM coordinates calculation.

The AE data are provided by the World Data Center for Geomagnetism, Kyoto University ([wdc.kugi.kyoto-u.ac.jp](http://wdc.kugi.kyoto-u.ac.jp)).

The HP data were provided by the Space Weather Prediction Center (SWPC) of NOAA (<http://www.swpc.noaa.gov/>).