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Bipolar climatology of GNSS ionospheric scintillation under quiet geomagnetic conditions

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Outline

- *Introduction*
- *Data*
- *Method*
- *Results and discussion*
- *Remarks*
- *Next steps*

Introduction

AIM

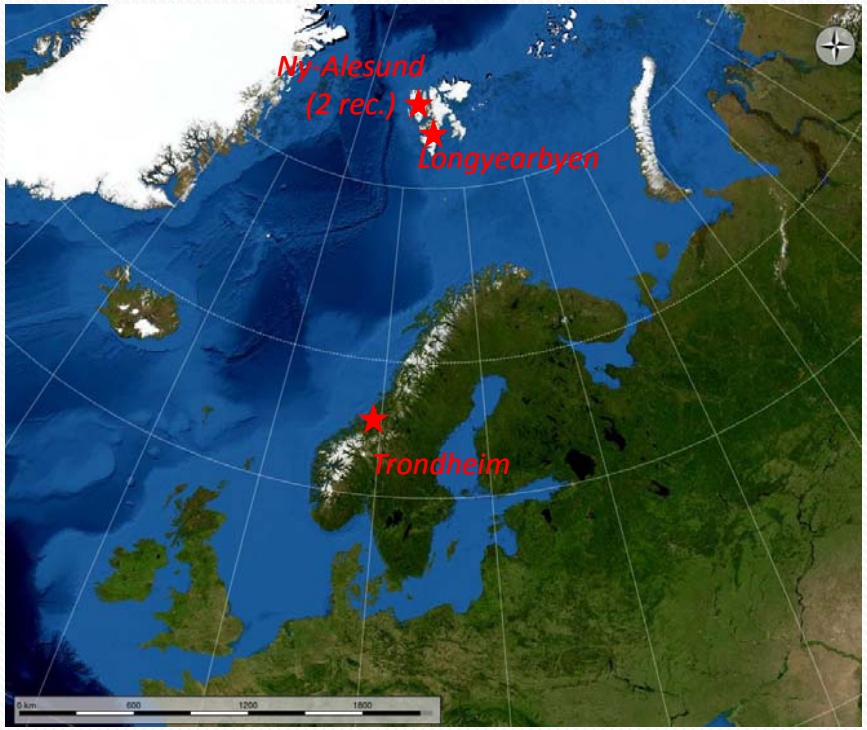
Develop a "scintillation climatology" over both polar areas

- Forecast of Space Weather events

DATA

Scintillation data from *INGV-IESSG-UoB network of GISTM* (GPS Ionospheric Scintillation and TEC Monitor) receivers

- NovAtel OEM4 dual-frequency
- 50 Hz



WHERE

Receivers in Antarctica (2) and Northern Europe (4)

- Cusp/cap and auroral latitudes

WHEN

Year 2008 data

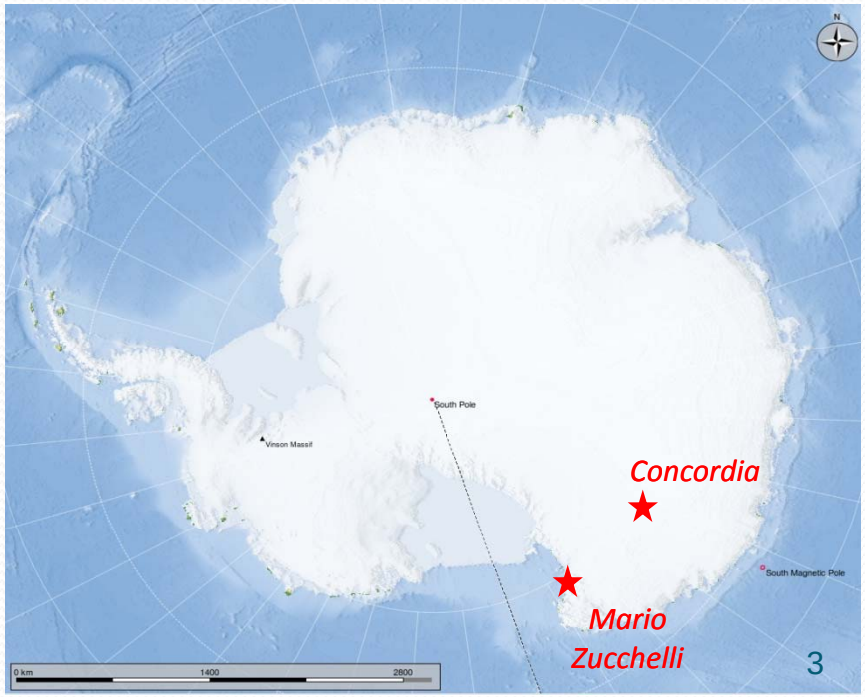
-Very quiet period

-Useful for climatology

METHOD

Scintillation occurrence maps

ROT (Rate of TEC) maps



Data

- Scintillation indices computed over 60 seconds from L1 (1.57 GHz)
  - ***Phase σ_φ*** $\sigma_\phi^2 = \langle \phi^2 \rangle - \langle \phi \rangle^2$
  - ***Amplitude S_4*** $S_4^2 = \left(\langle I^2 \rangle - \langle I \rangle^2 \right) / \langle I \rangle^2.$
- Reducing tracking errors
  - α_{elev} > 20° for both indices.
- Vertical quantities

ID	Location	Latitude	Longitude	CGLat	CGLon	Hemisphere	Days of data	%
NYA0	Ny-Ålesund	78.9°N	11.9°E	76.0°N	112.3°E	North	192	52.5
NYA1	Ny-Ålesund	78.9°N	11.9°E	76.0°N	112.3°E	North	317	86.6
LYB0	Longyearbyen	78.2°N	16.0°E	74.7°N	129.2°N	North	295	80.6
NSF1	Trondheim	63.4°N	10.4°E	63.0°N	103.2°E	North	295	80.6
DMC0	Concordia Station	75.1°S	123.2°E	84.4°S	222.6°E	South	356	97.3
BTN0	Mario Zucchelli Station	74.7°S	164.1°E	77.1°S	275.9°E	South	333	91.0

Method

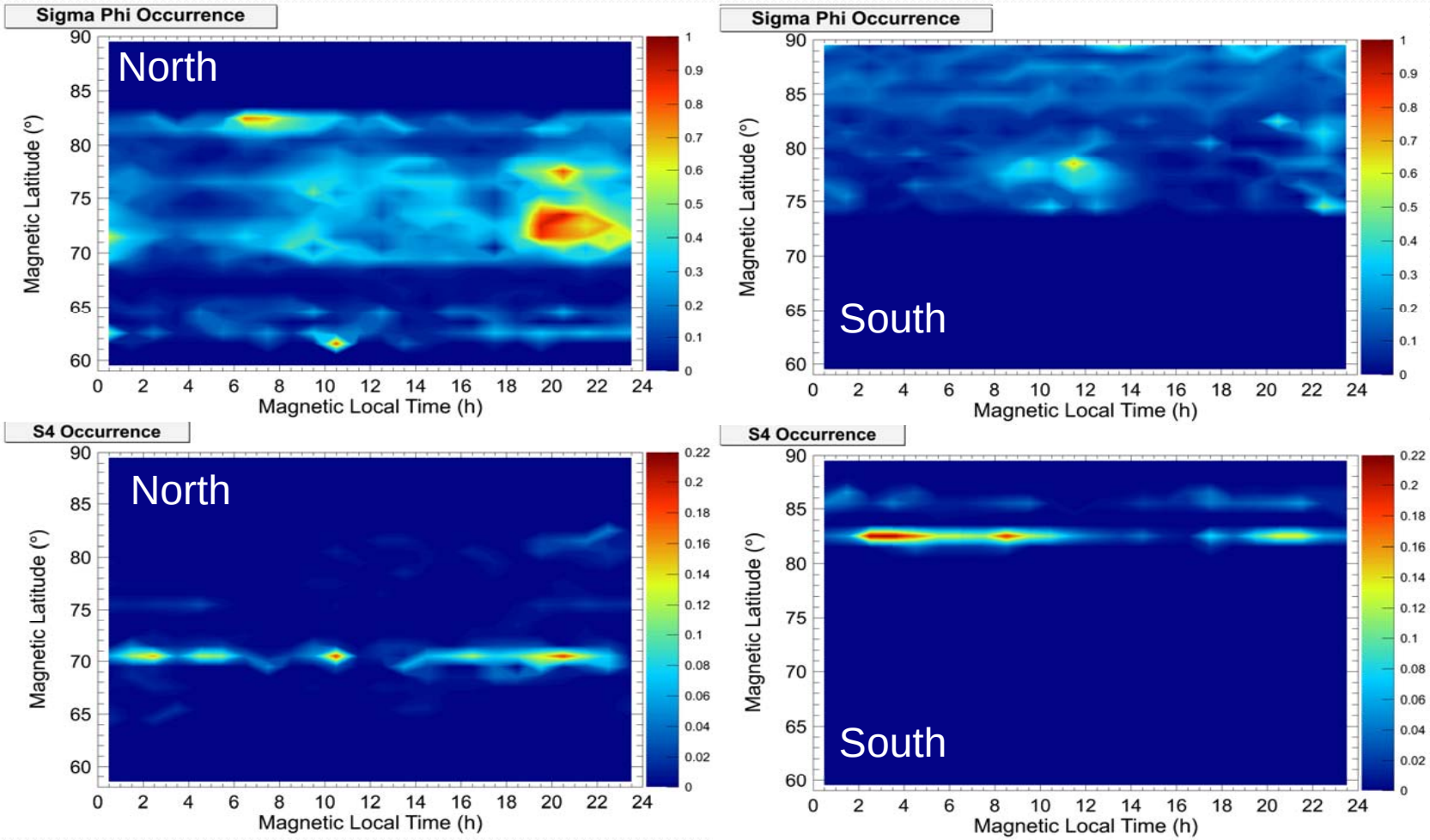
- **Maps of percentage occurrence**
  - M_{lat} vs MLT
- **Percentage occurrence**
  - 1 bin = 1h MLT x 1° M_{lat}
- **Thresholds:**
  - 0.25 radians for σ_ϕ
  - 0.25 for S_4
- **Accuracy < 2.5 %**
  - Avoid low statistics bins
- **Feldstein auroral oval superimposed**
  - Different geomagnetic activity
    - Quiet period IQ=0 to 3
  - Electron density gradients on the boundaries

$$\frac{N(S_4 or \sigma_\varphi > threshold)}{N_{tot}}$$

Distinguish moderate/strong scintillation

$$R_{\%} = 100 \cdot \frac{\sigma(N_{tot})}{N_{tot}} = \frac{100}{\sqrt{N_{tot}}}$$

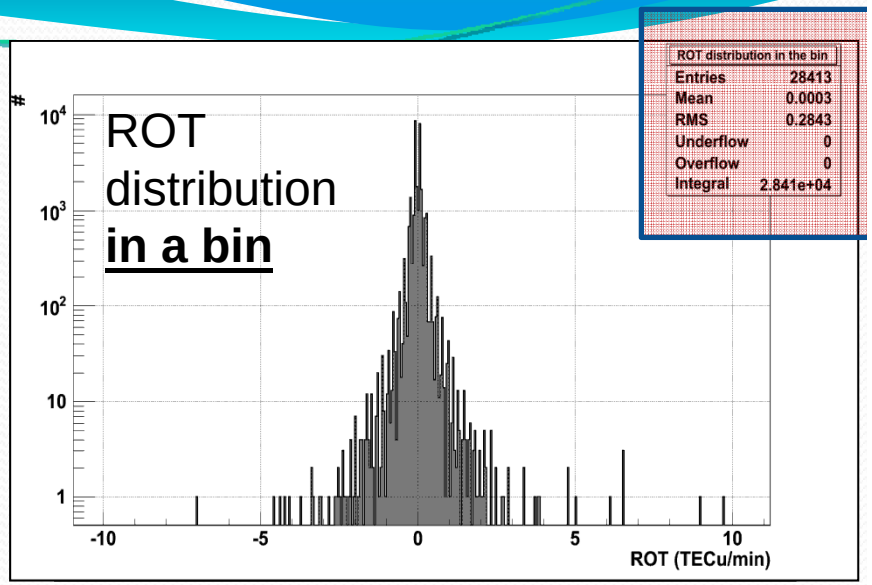
Results and discussion



- **Superposition of 3 effects (mainly Phase scintillation):**
  - Auroral oval boundaries
  - Ionospheric through walls
  - Polar cap patches

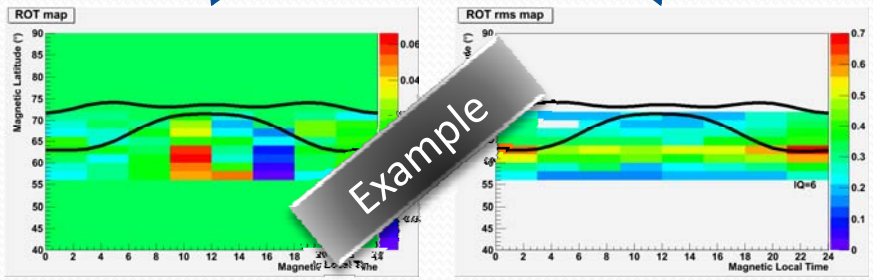
ROT maps

- ROT helps in identification of regions with intense TEC gradients
  - Maps ROT and ROTrms
- ROT 1-min distribution of the whole period (ex. South Hemisphere)
- Extract sub-distribution in each bin (same segmentation of percentage occurrence)
  - Get Mean
  - Get Root Mean Square
- Fill ROT and ROTrms maps

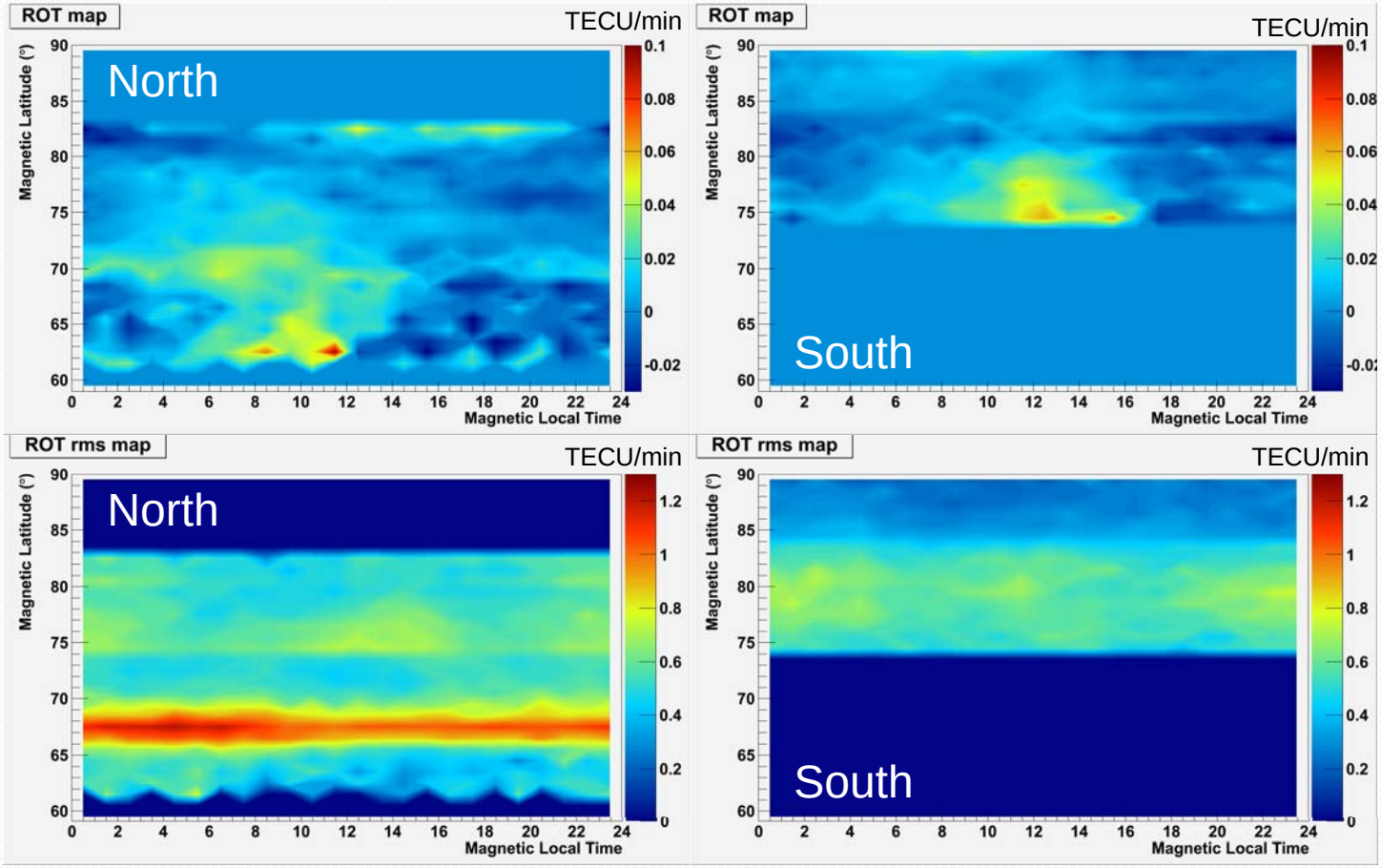


GetMean() - GetRMS()

Fill maps with Mean values and RMS's



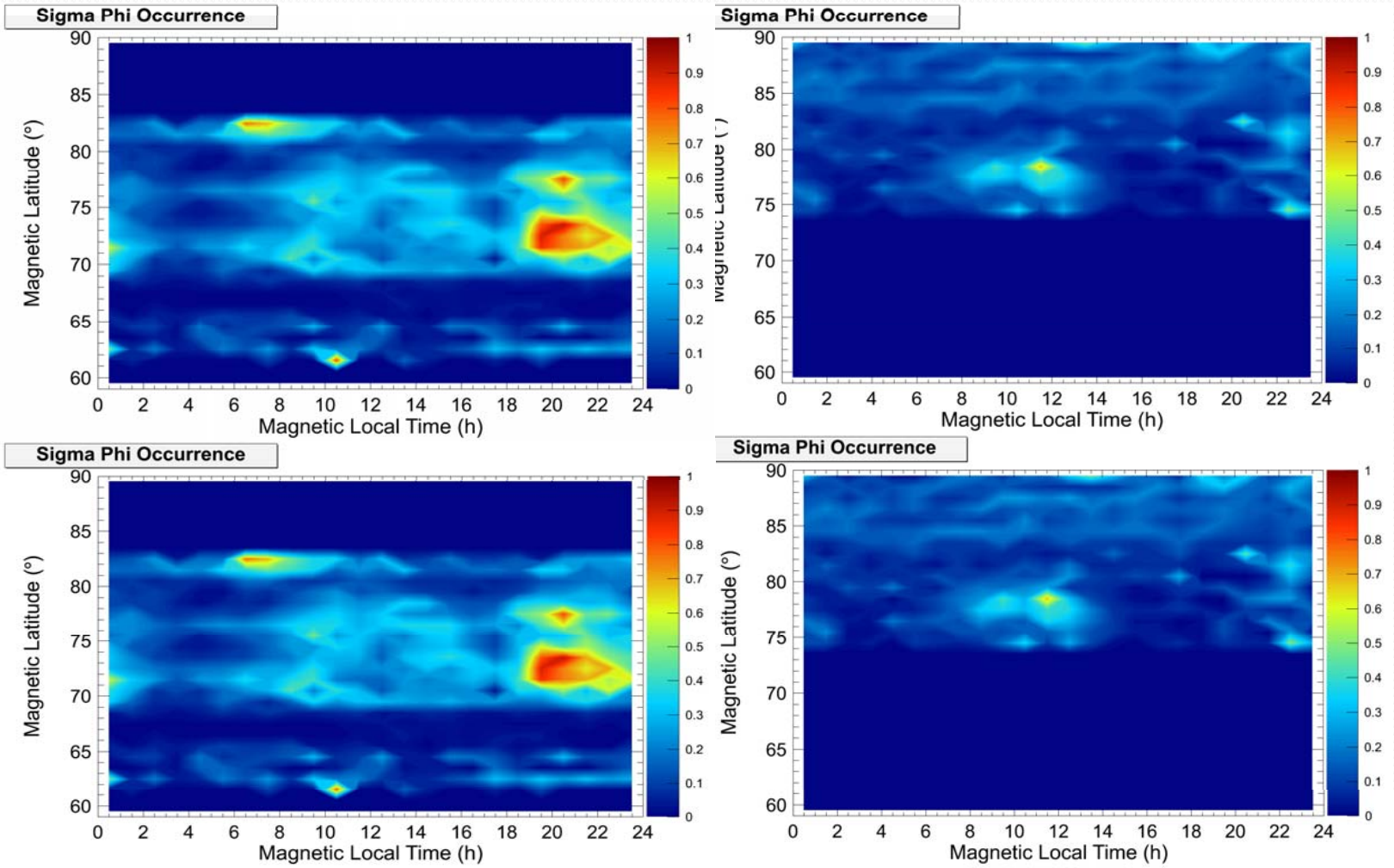
ROT and ROTrms



- Identification of polar cap patches
- Cusp region well drawn especially over south hemisphere
- ROTrms almost identical between 74° and 84° MLAT
- Interesting ROT feature around MLT noon over north hemisphere (?)

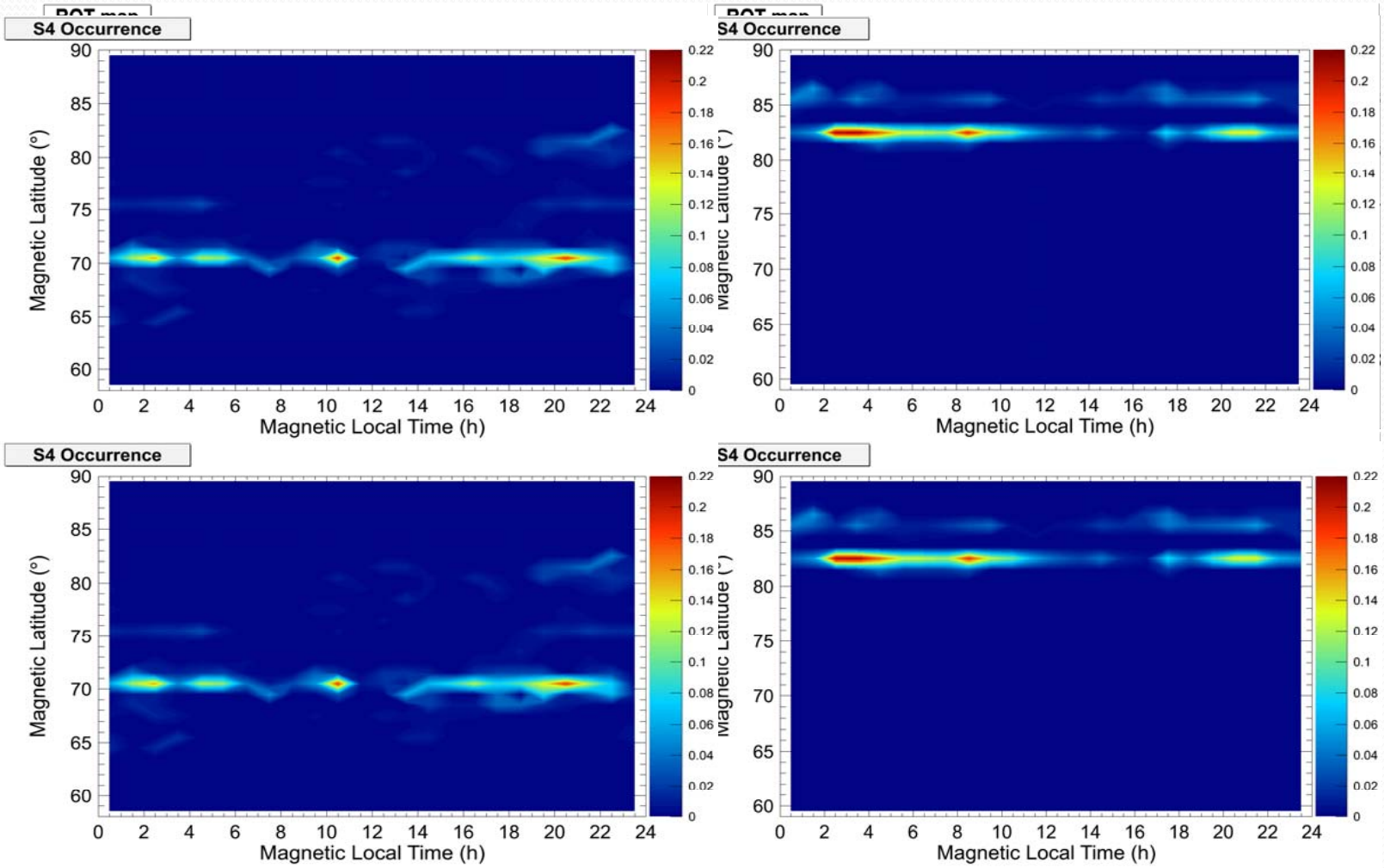
Correspondences (1/2)

Phase & ROT



Correspondences (2/2)

Amplitude & ROT



Remarks

- Scintillation data from GISTMs located over a wide range of latitudes in both hemispheres
- Scintillation occurrences map for a long quiet period (2008) has been produced
  - Auroral oval boundaries, trough walls and polar cap patches host scintillation
- ROT and ROTrms maps are useful to identify TEC structures
  - SigmaPhi seems to be more related to ROT
  - S4 seems to be more related to ROTrms
    - ROTrms is a sort of numerical second derivative of TEC → DROTI(?!)
    - DROTI (TECU/min^{-2})=$8.5 \cdot 10^3 \nu_F^2 S4$ (single phase screen assumption)

Next steps

- Enlarge the statistics to consider a significant variety of ionospheric conditions
- Seasonal variation of the scintillation occurrence
- Extend the climatology to equatorial latitudes
- Change thresholds in the scintillation occurrence definition
- Compare the maps with tomographic reconstructions by MIDAS
- Explore the information theory approach to understand ROT and ROTrms.

INGV scintillation and TEC data at: **www.eswua.ingv.it**

Thanks for your attention!

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