Multi-Index Analysis of Ionospheric Disturbances Driven by Internal and External Physical Mechanisms During Space Weather Events

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ISWI 2024 - SESSION 7, 11/06/2024 (14:00 - 14:15)

Ionospheric Indices (DIX & ROTI)

$$DIX_k(t) = \left| \frac{\alpha_k \left(\Delta TEC_k(t) / TEC_k^{Qd}(t) \right) + \Delta TEC_k(t)}{\beta} \right|$$

where: $\Delta TEC_k(t) = TEC_k(t) - qTEC_k(t)$

First version by Jakowski et al. (2006)
Current version:
Picanço (2019), Denardini et al. (2020a)

- Geomagnetic Storms (Denardini et al., 2020)
- Disturbed Electric Fields (Picanço et al., 2021)
- Equatorial Plasma Bubbles (Picanço et al., 2022, 2024)
- Latitudinal TEC gradients (Barbosa-Neto et al., 2023)

$$ROTI_k(t) = \sqrt{\langle ROT^2 \rangle - \langle ROT \rangle^2}$$

where: $ROT_k(t) = \frac{TEC_k(t2) - TEC_k(t1)}{t2 - t1}$

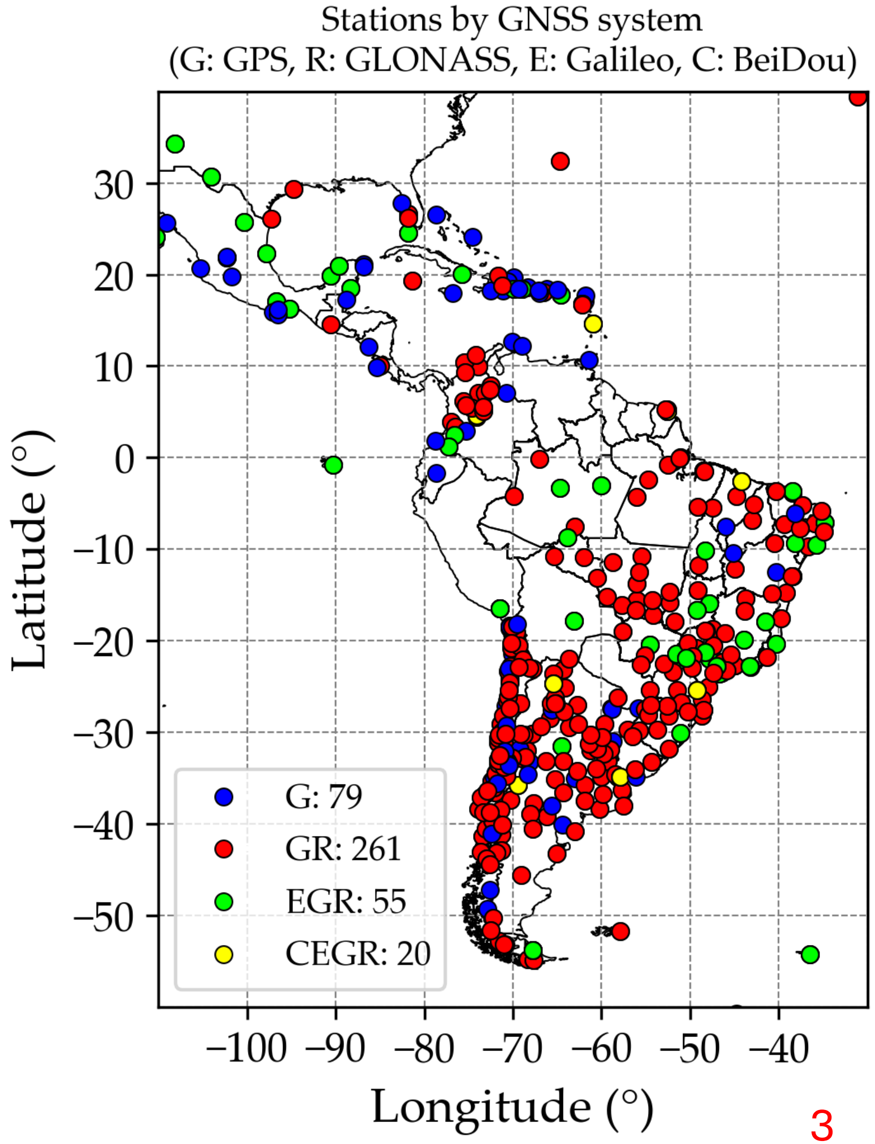
Proposed by Pi et al. (1997)

- MSTIDs (Nishioka et al., 2009)
- Polar-region irregularities (Kotulak et al., 2009)
- Equatorial Plasma Bubbles (Carmo et al., 2021)

Methodology – GNSS Stations

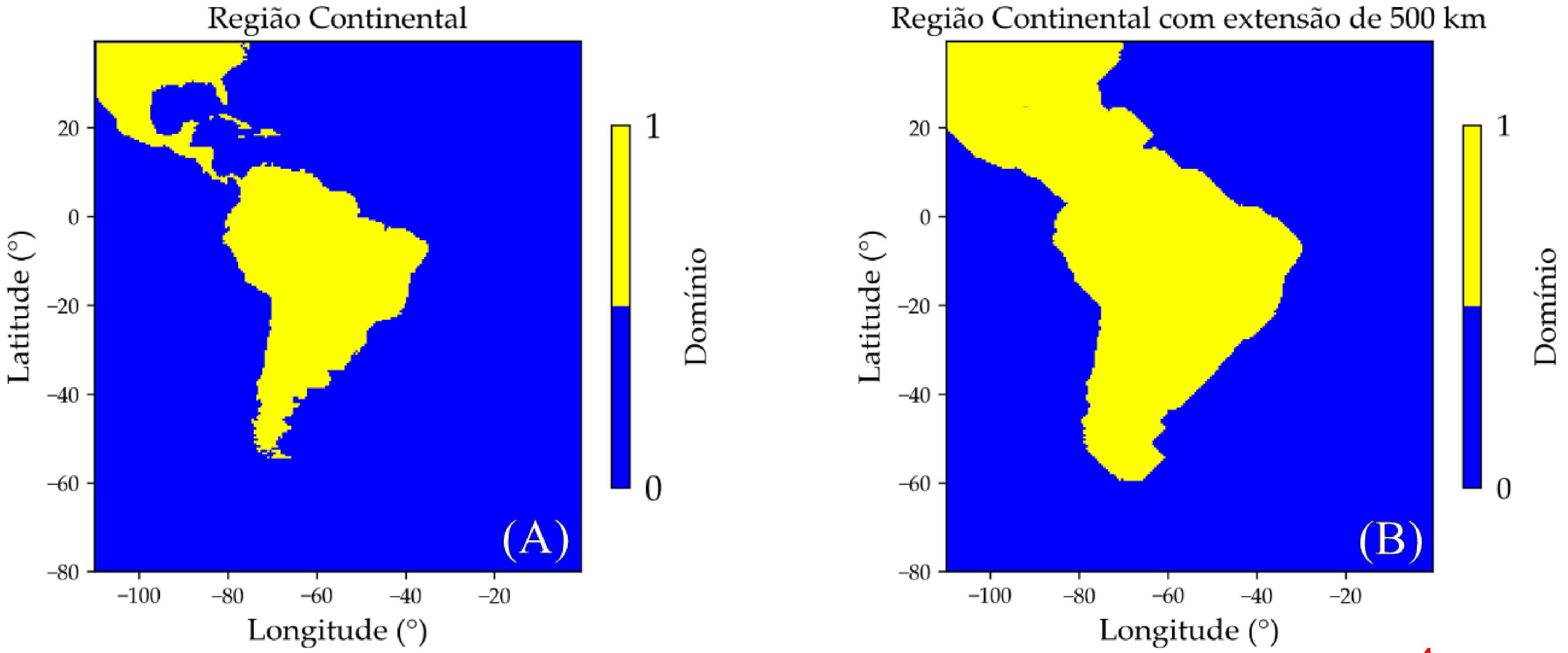
~ **450** GNSS ground stations
TEC calculation: Mendoza et al. (2019)
Constellations:
GPS, GLONASS, Galileo and BeiDou
Number of frequency combinations:17
GNSS Networks:

RBMC (Brazil)
RAMSAC (Argentina)
LISN (Peru)
UNAVCO (USA)
SGM (Uruguay)
IGS (International)
(among others)

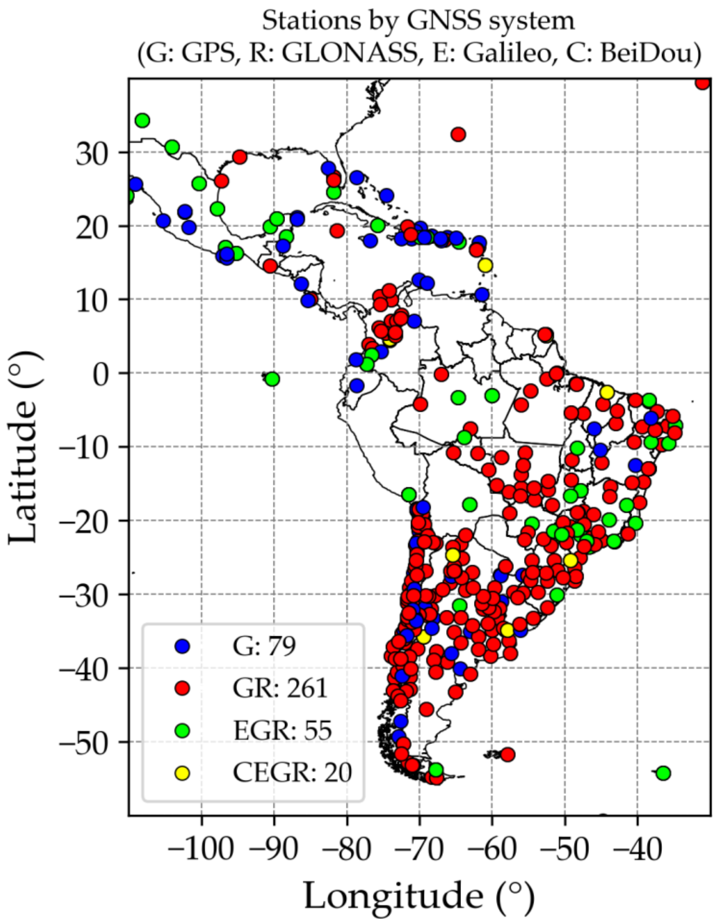


Methodology (DIX and ROTI maps)

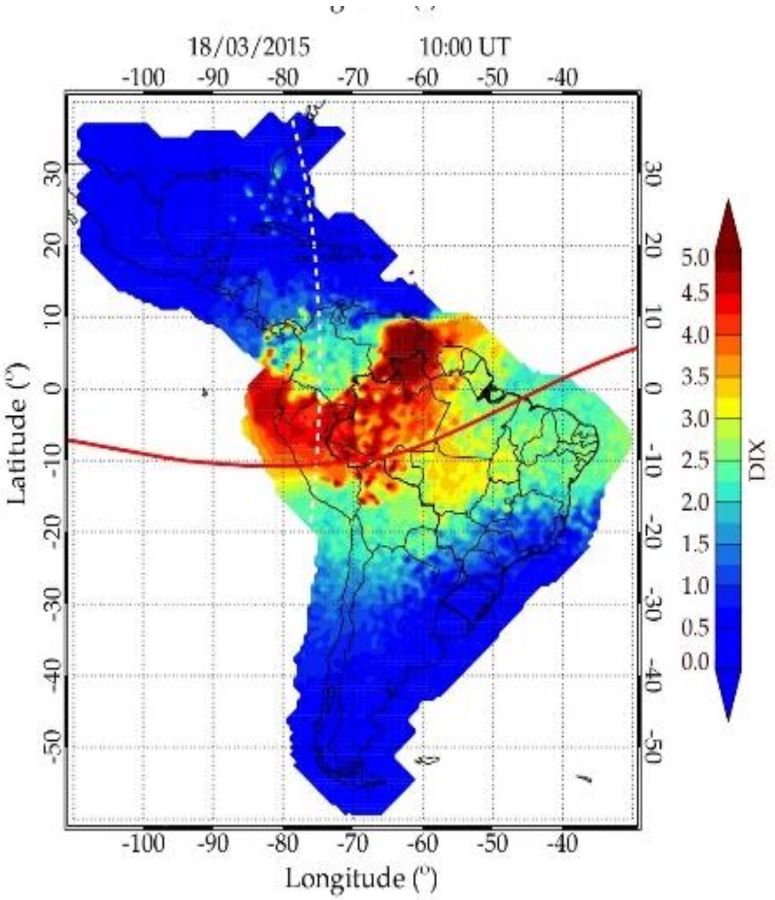
Interpolation: Takahashi et al. (2016)
Domain: Latin America with 500km extension
DIX and ROTI maps for every 10 min (with c. data)



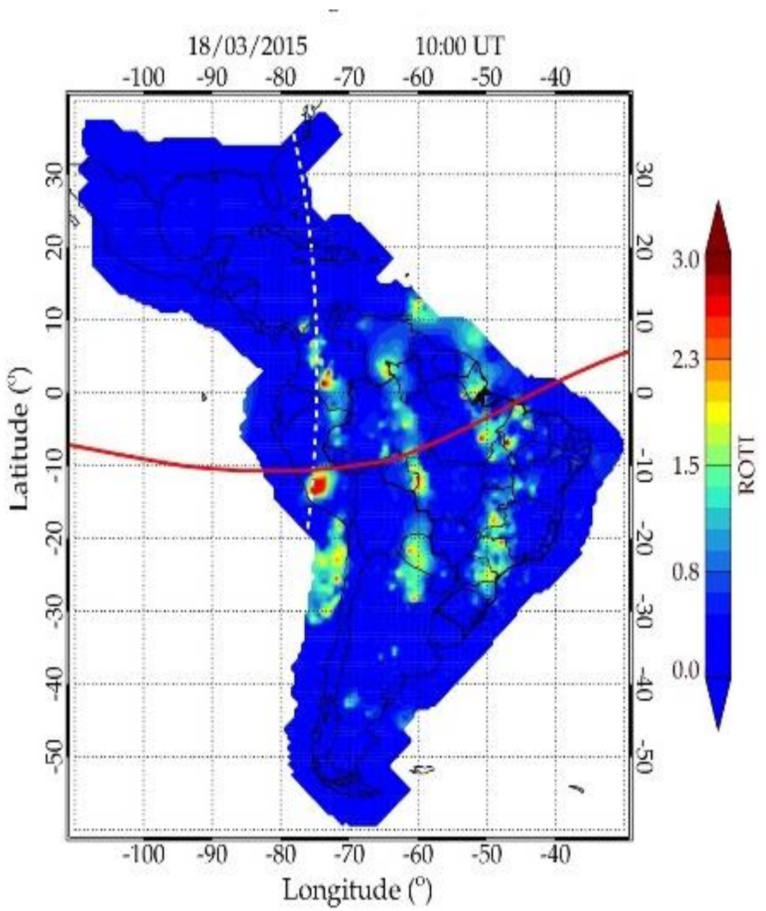
Methodology - DIX and ROTI maps



Multi-GNSS ground stations

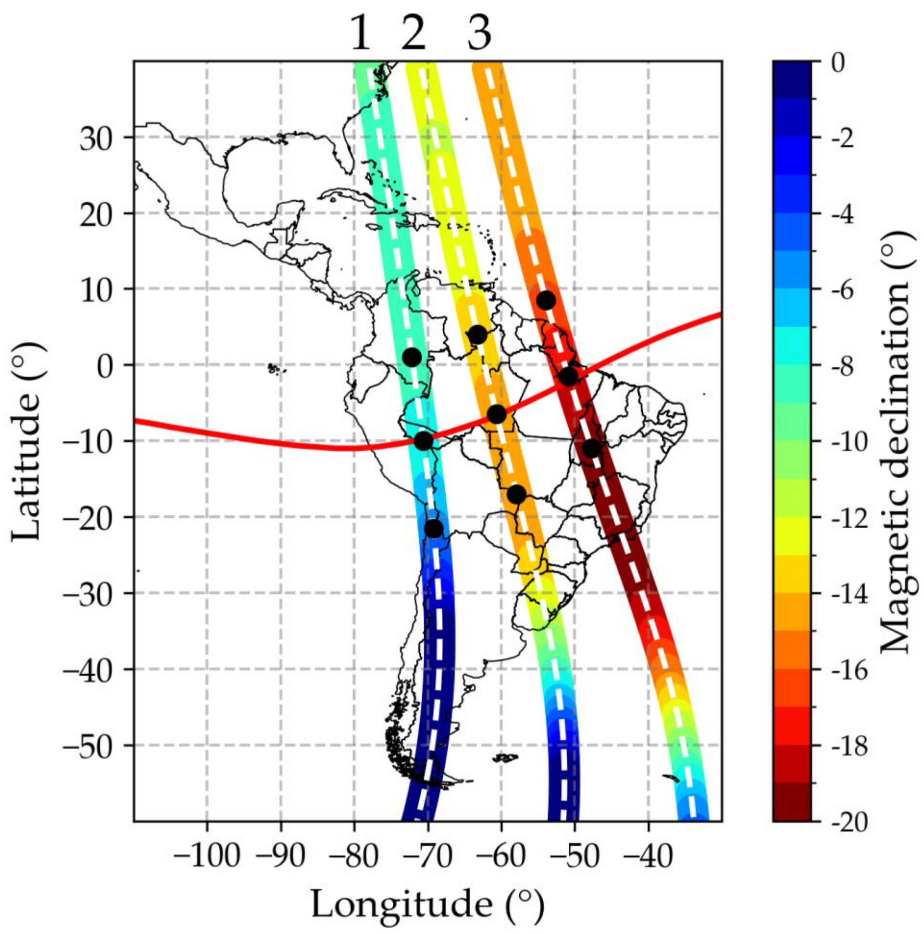


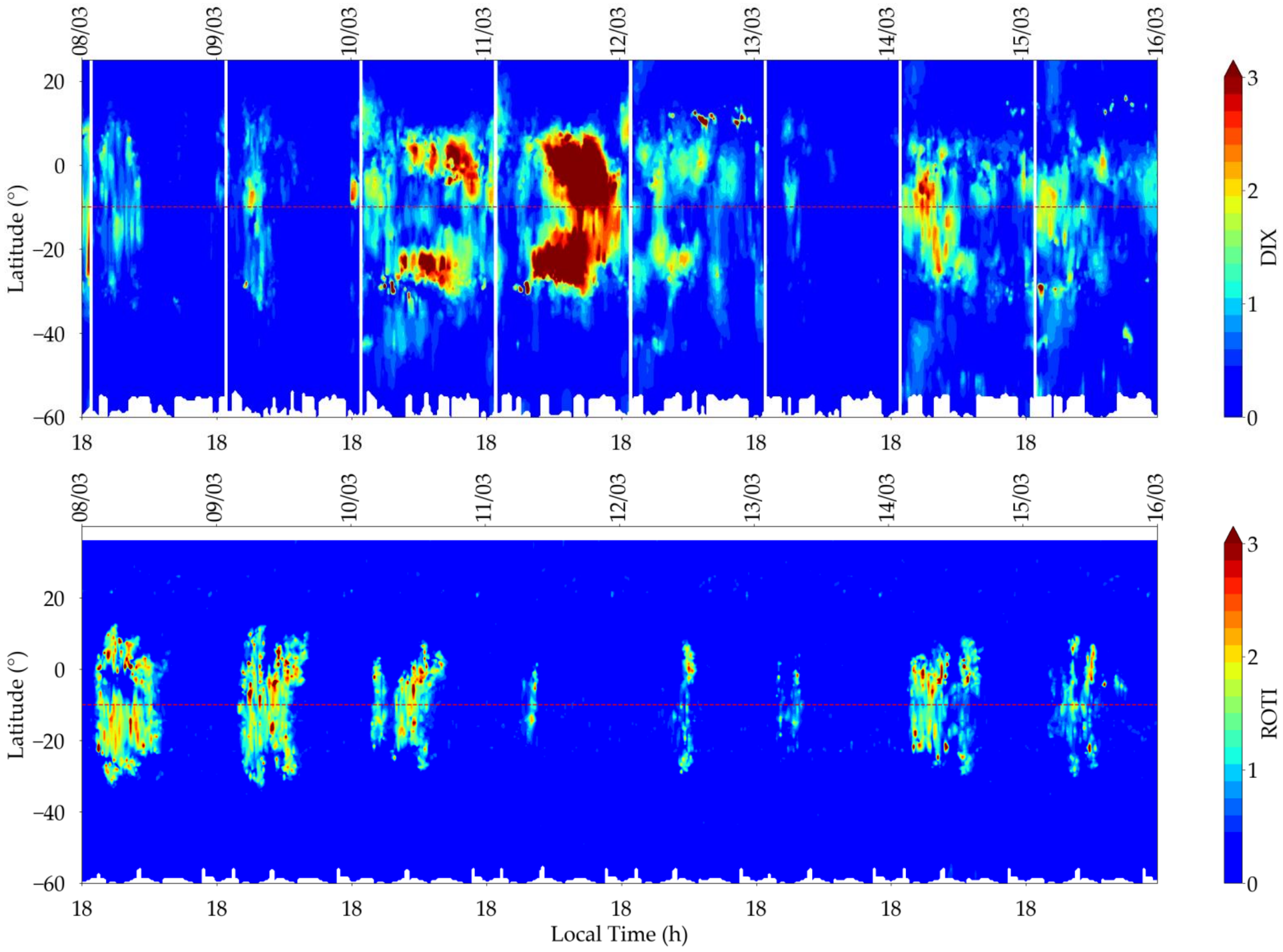
DIX maps



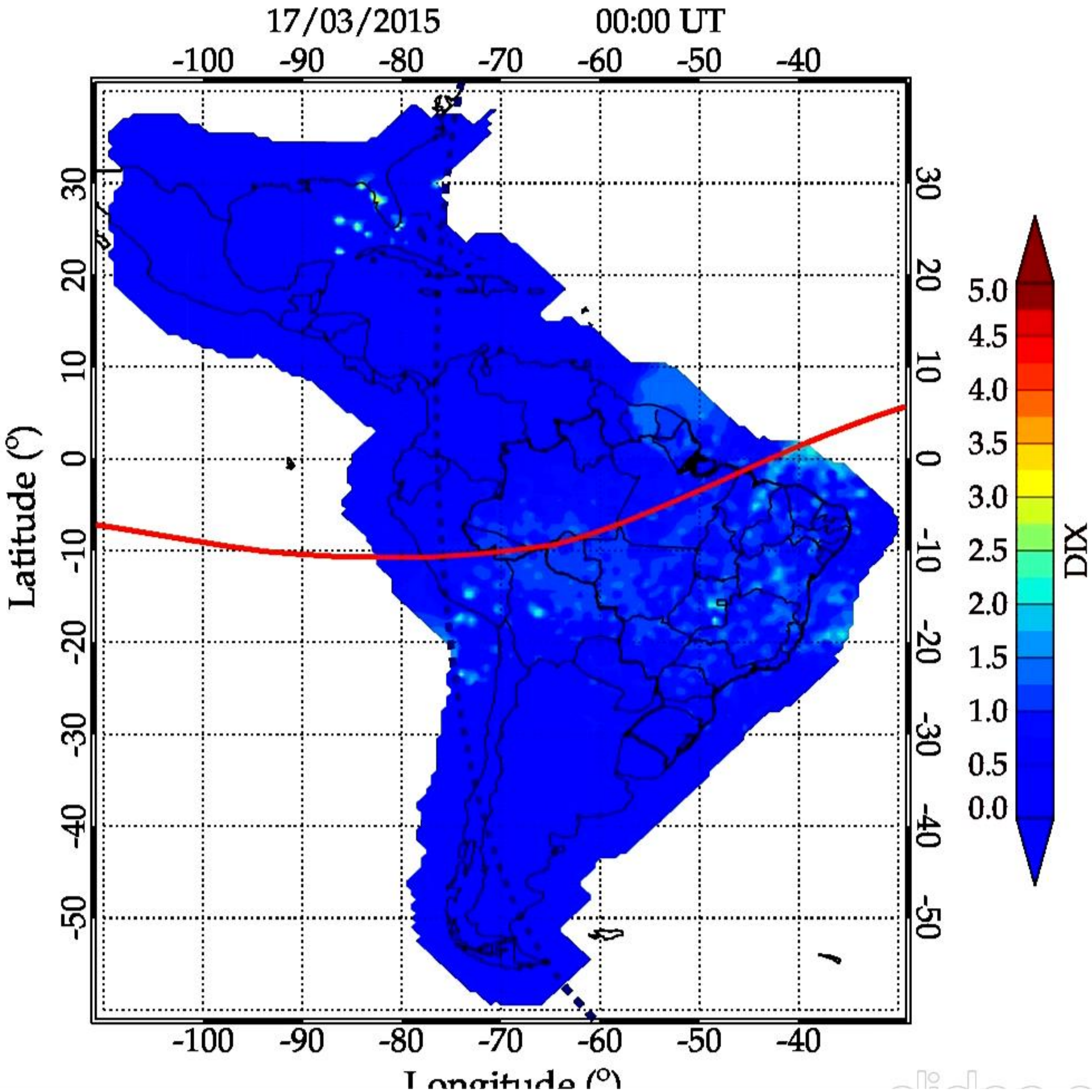
ROTI maps

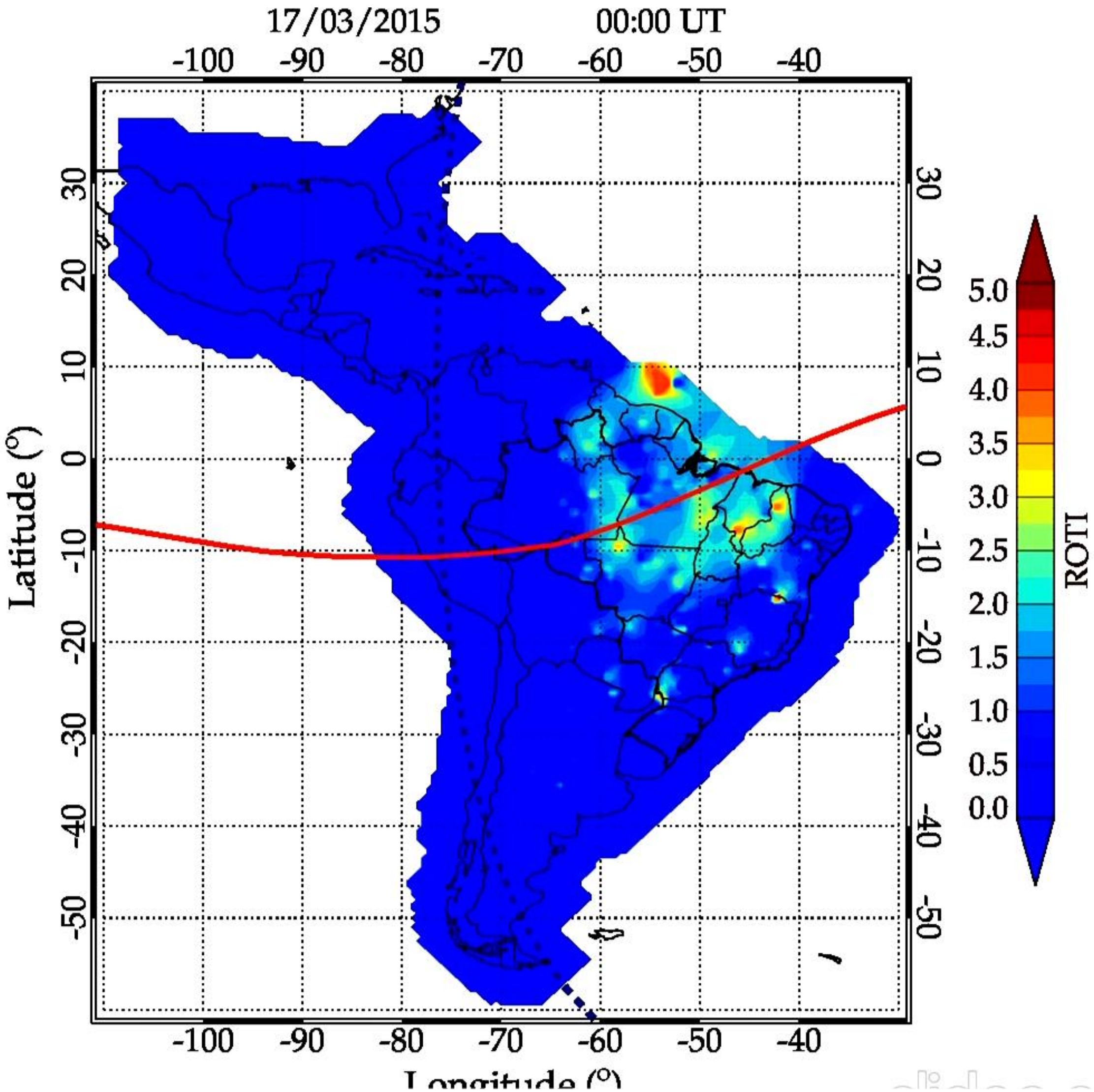
Methodology - Keograms





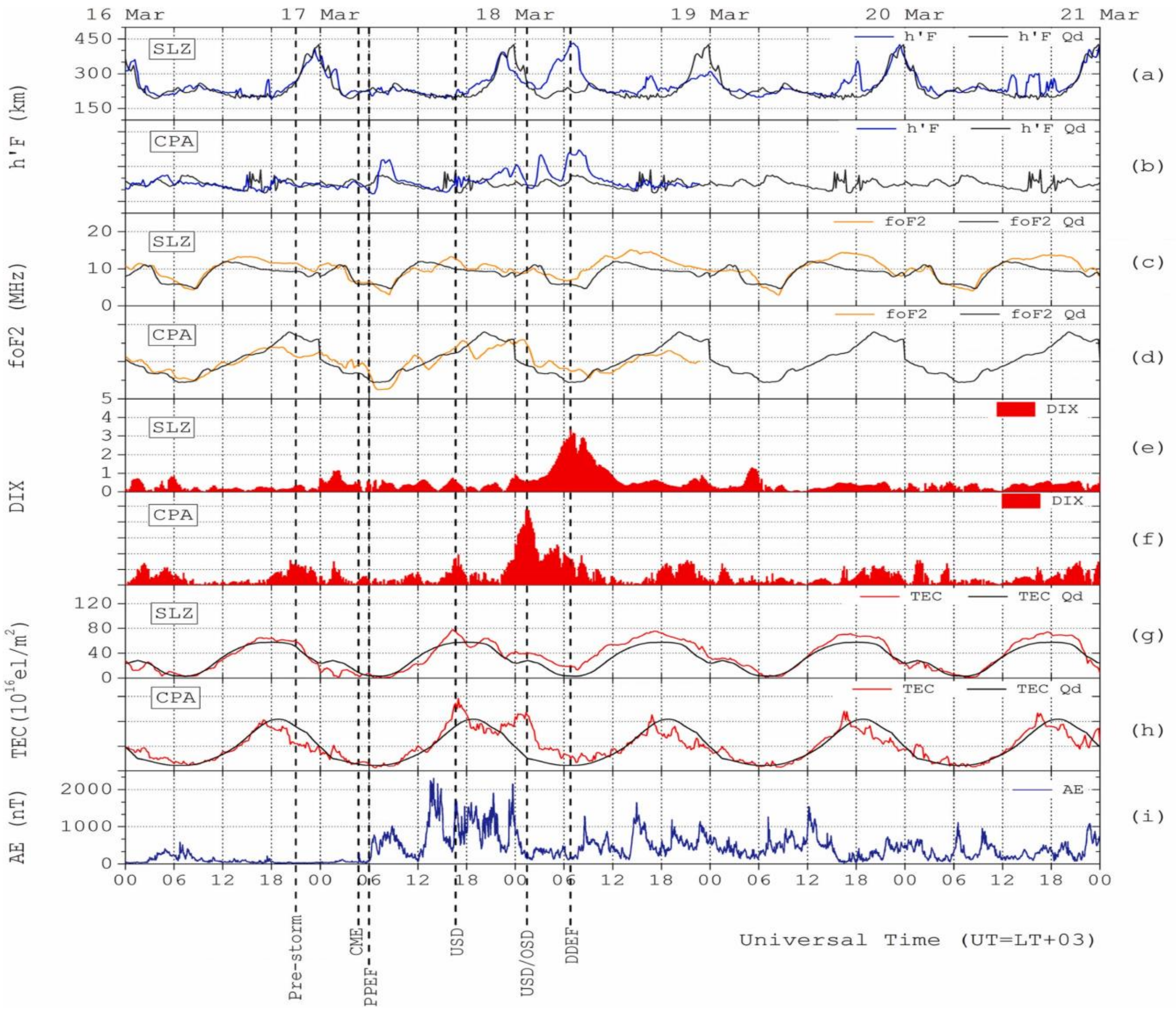
Results (St. Patrick's Day Geomagnetic Storm)



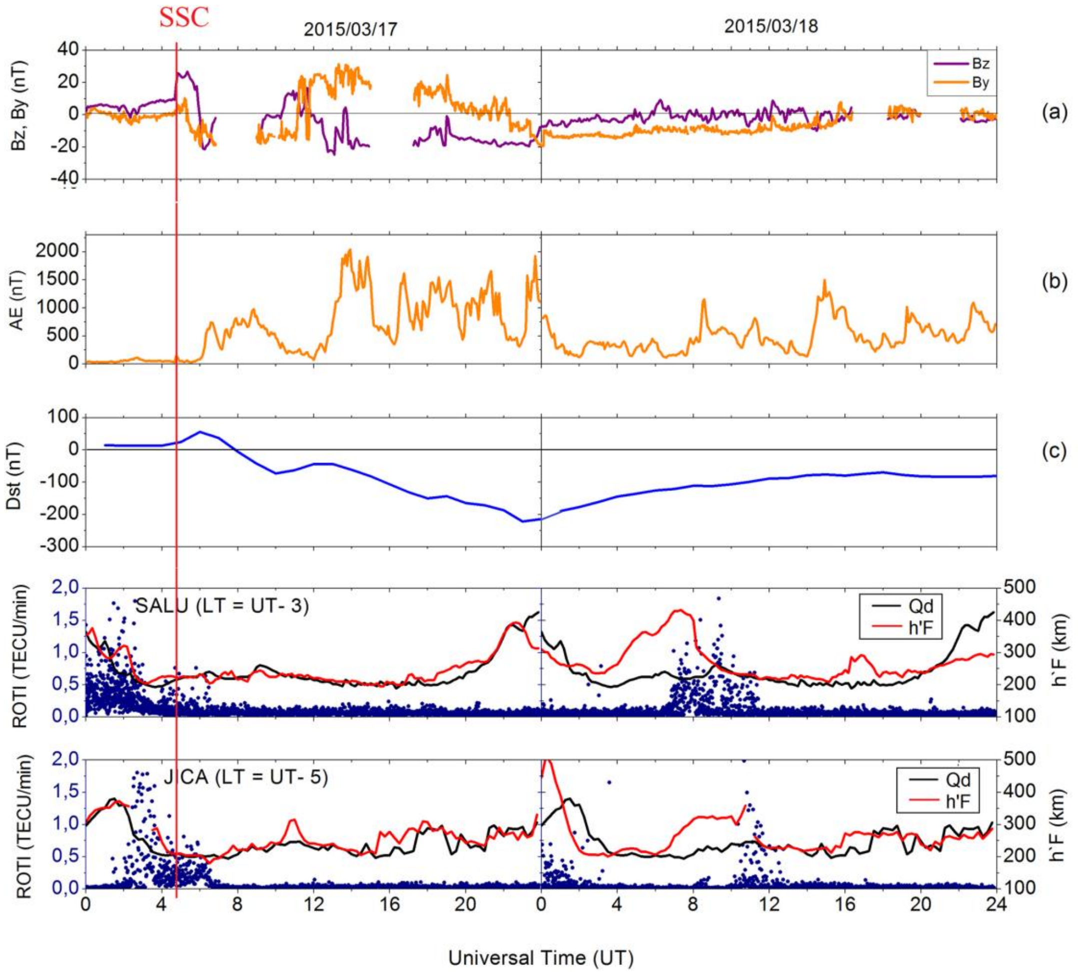


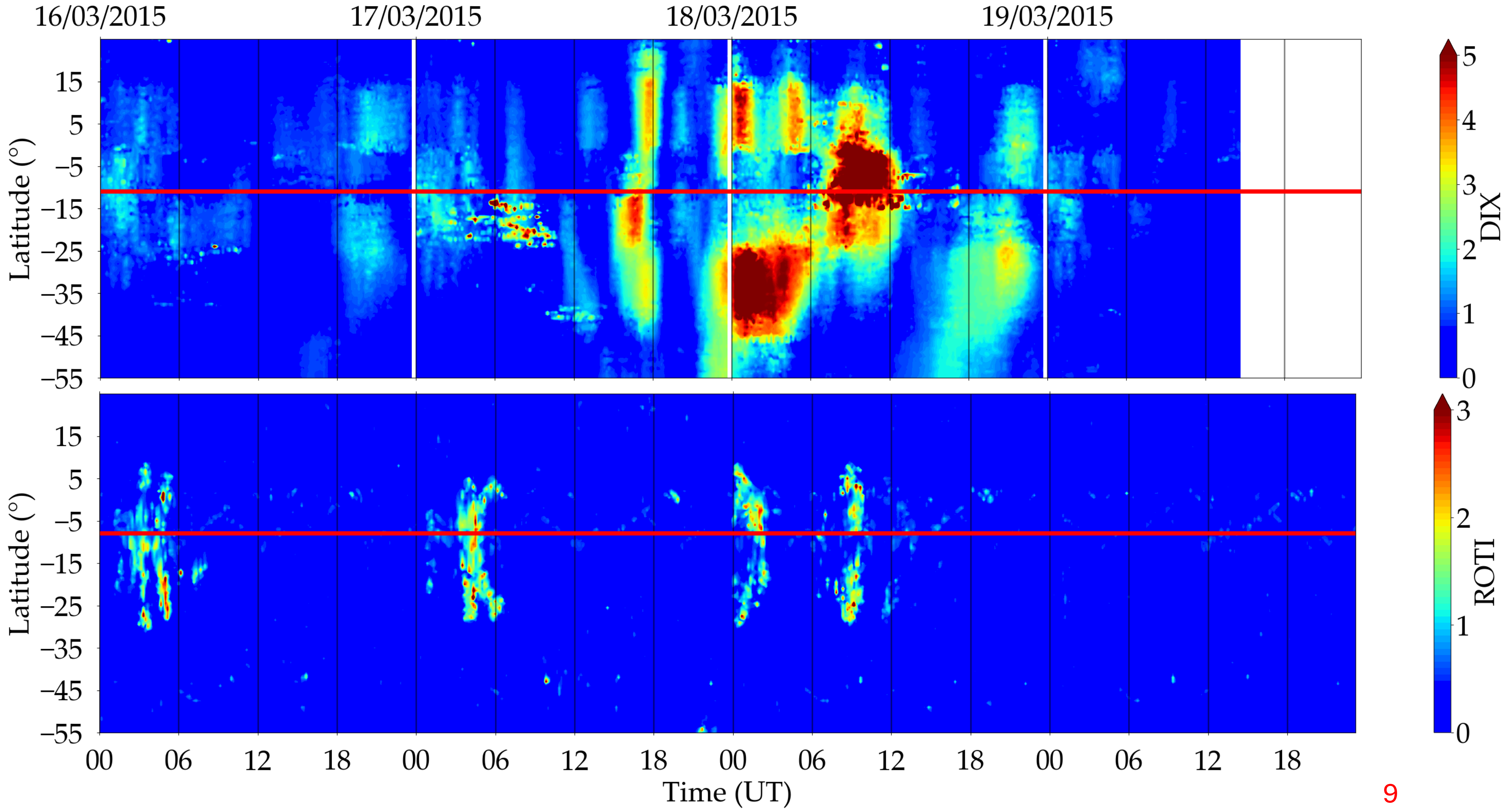
Results (St. Patrick’s Day Geomagnetic Storm)

Picanço et al. (2021)



Carmo et al. (2022)

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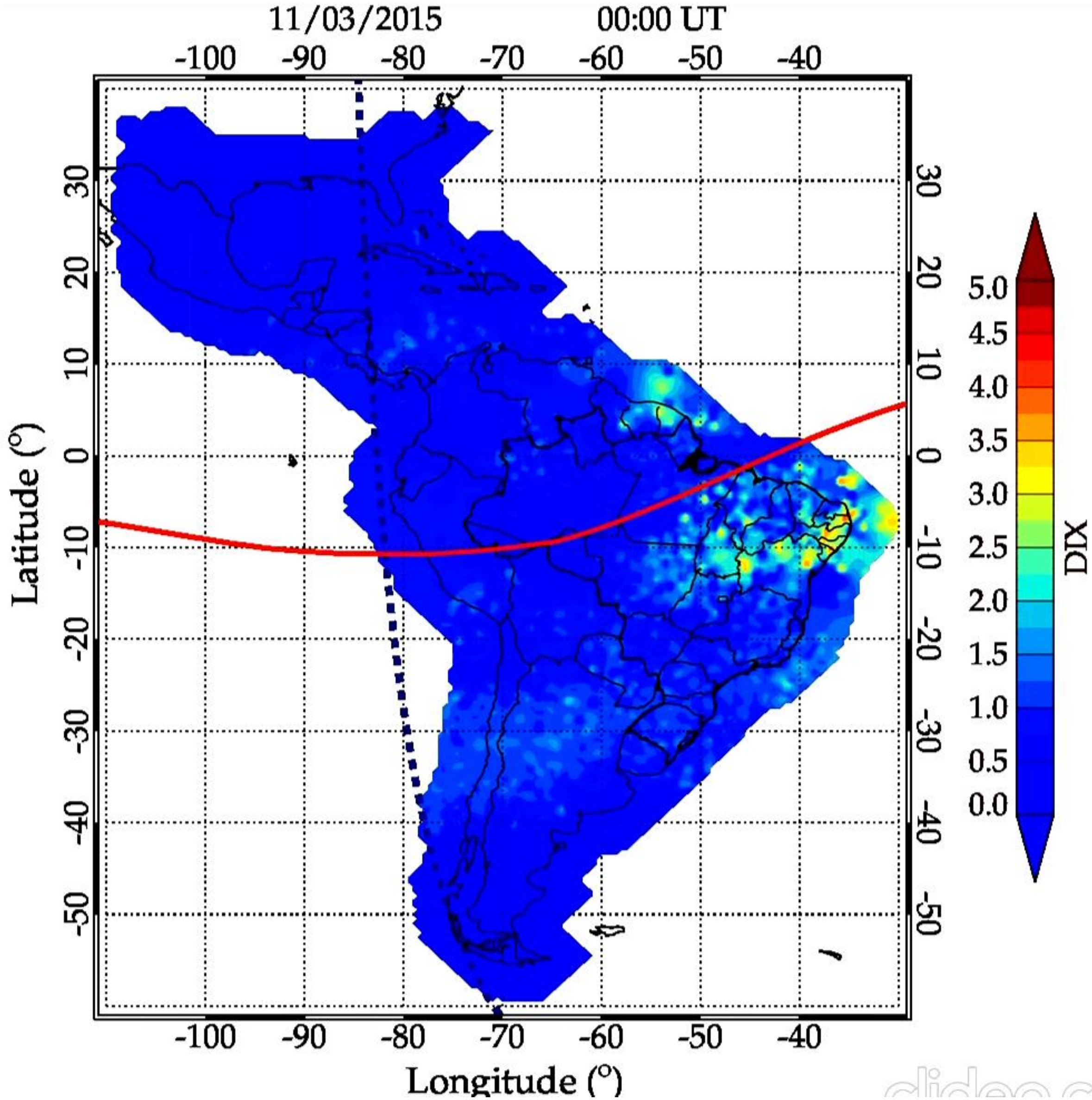
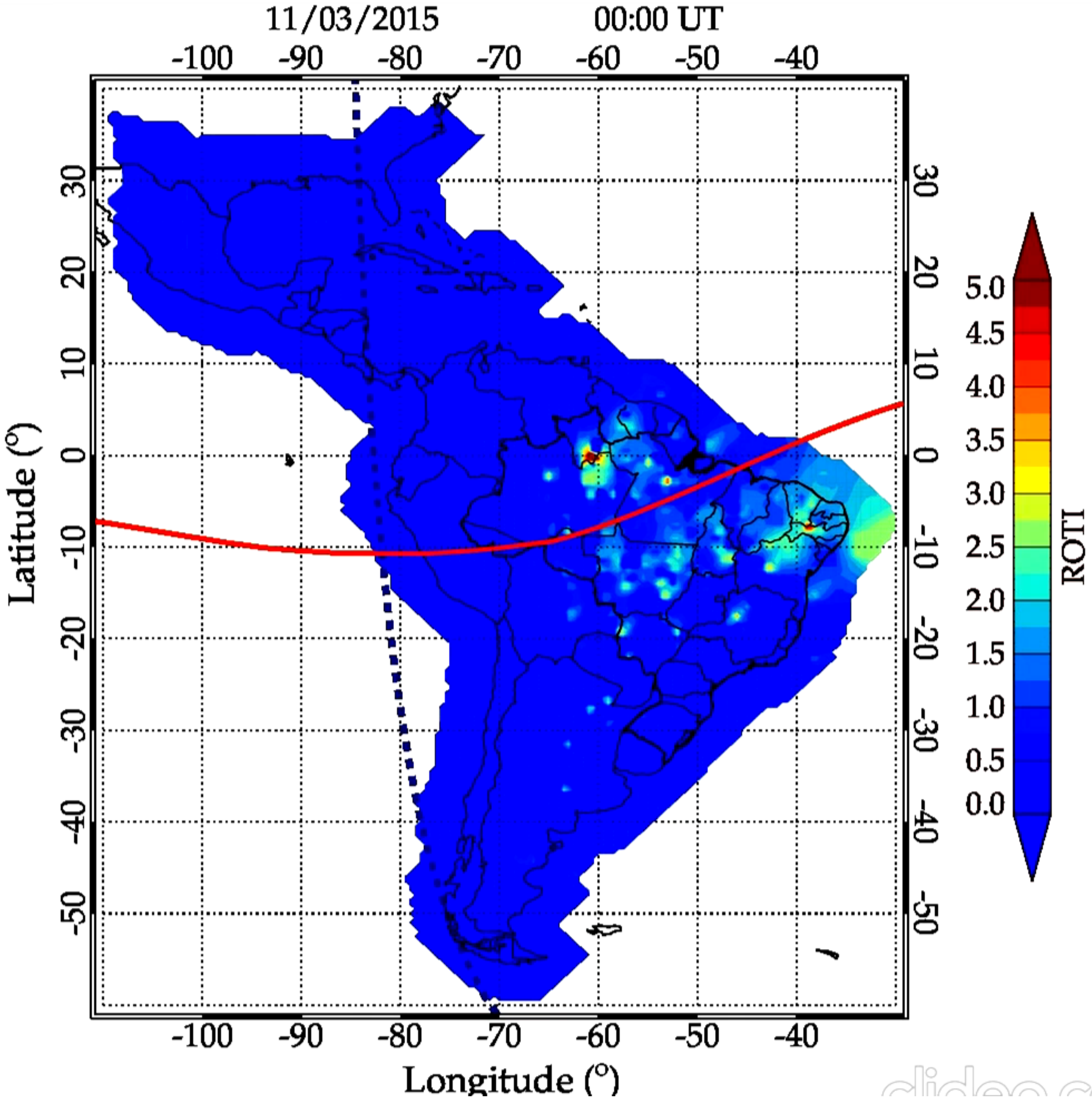
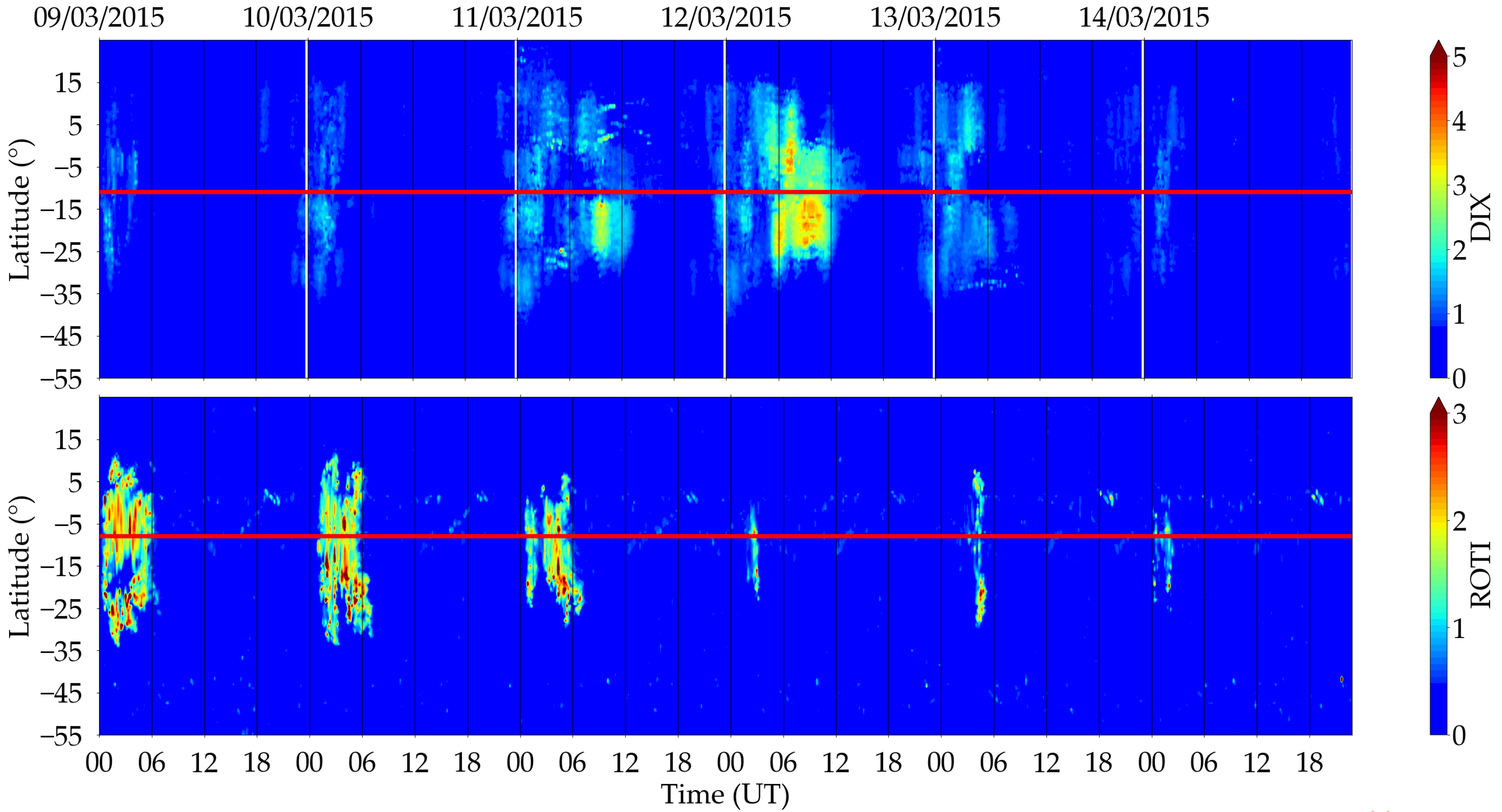
Results (Pre-storm period)







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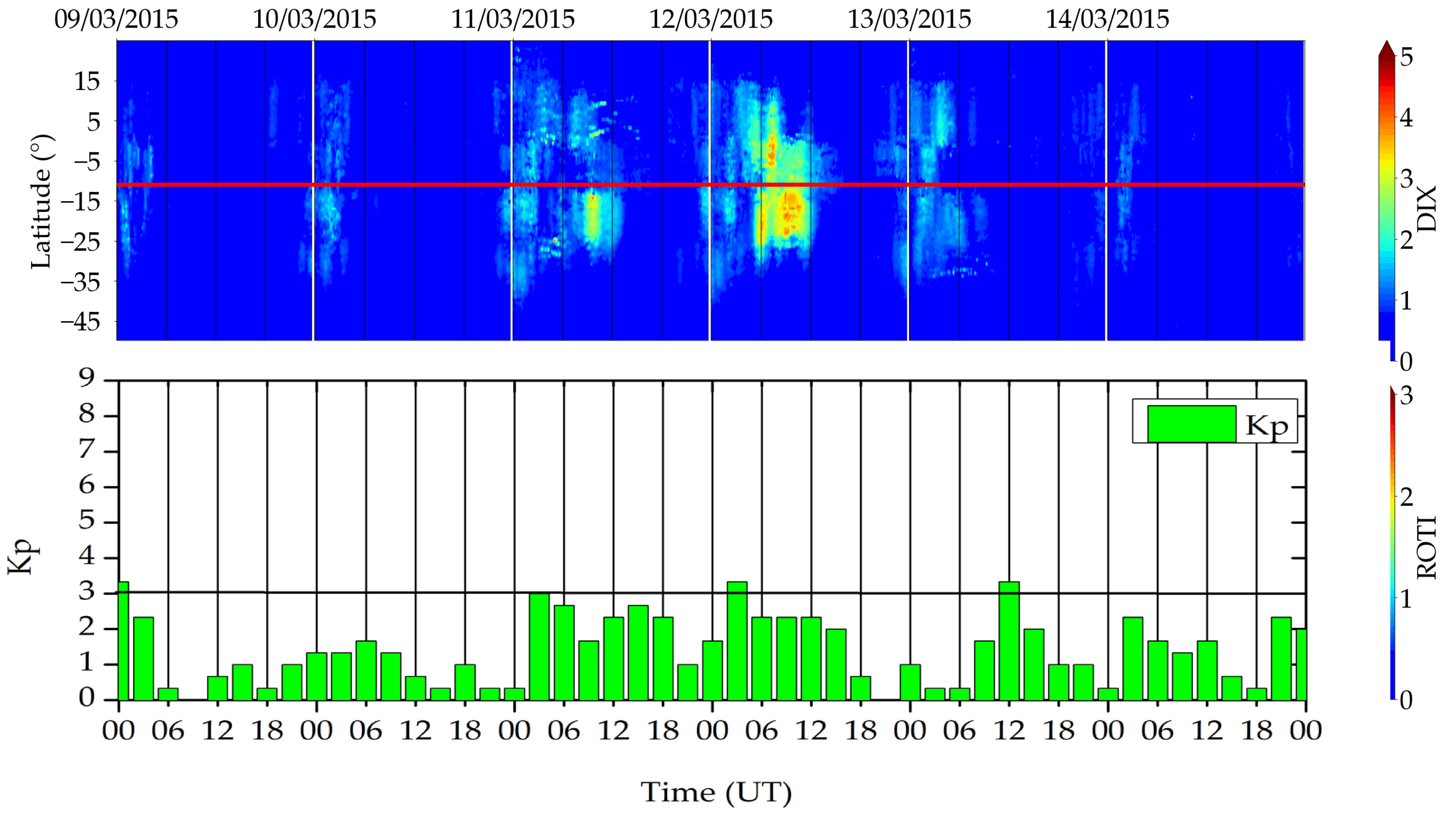
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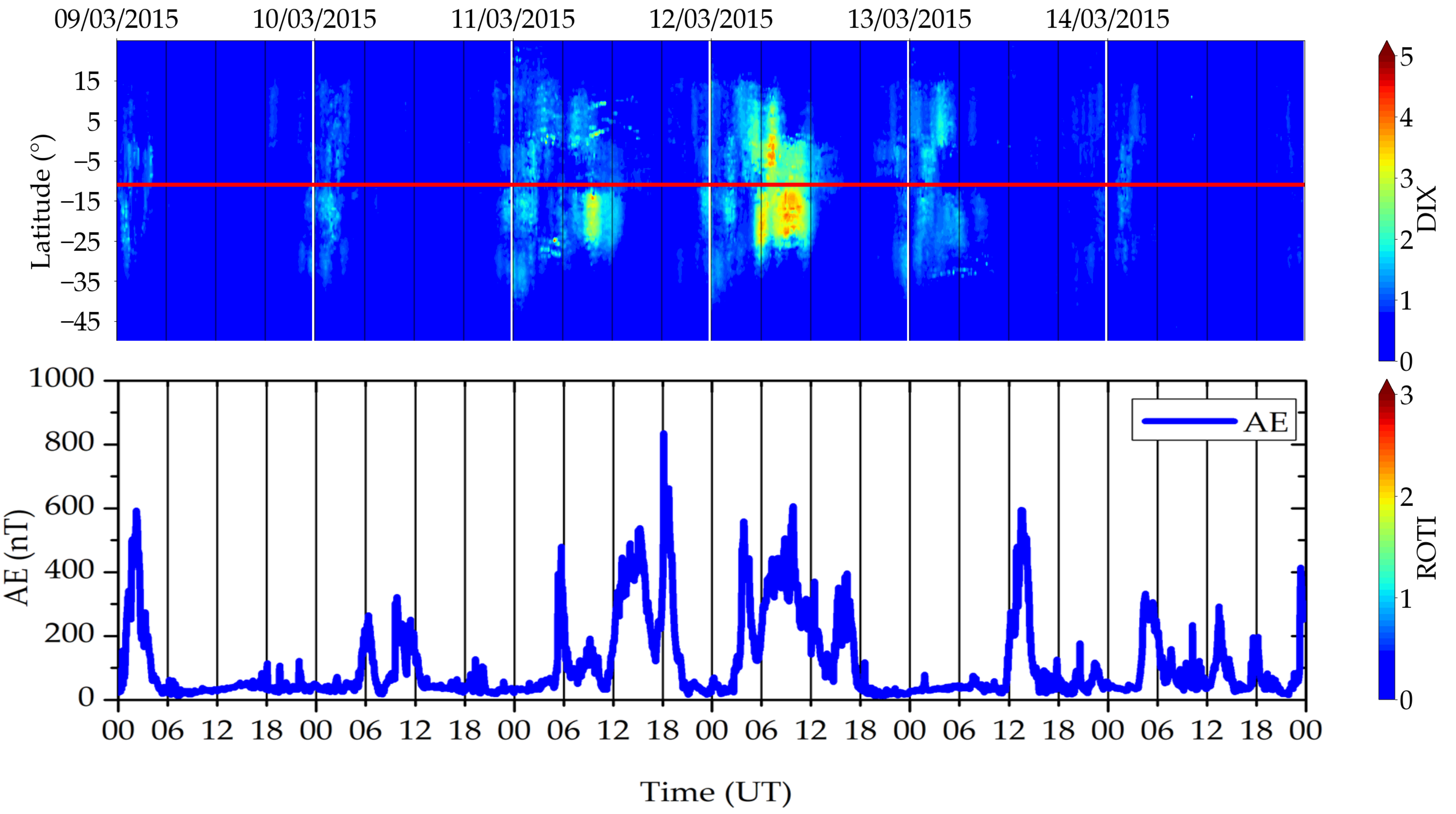

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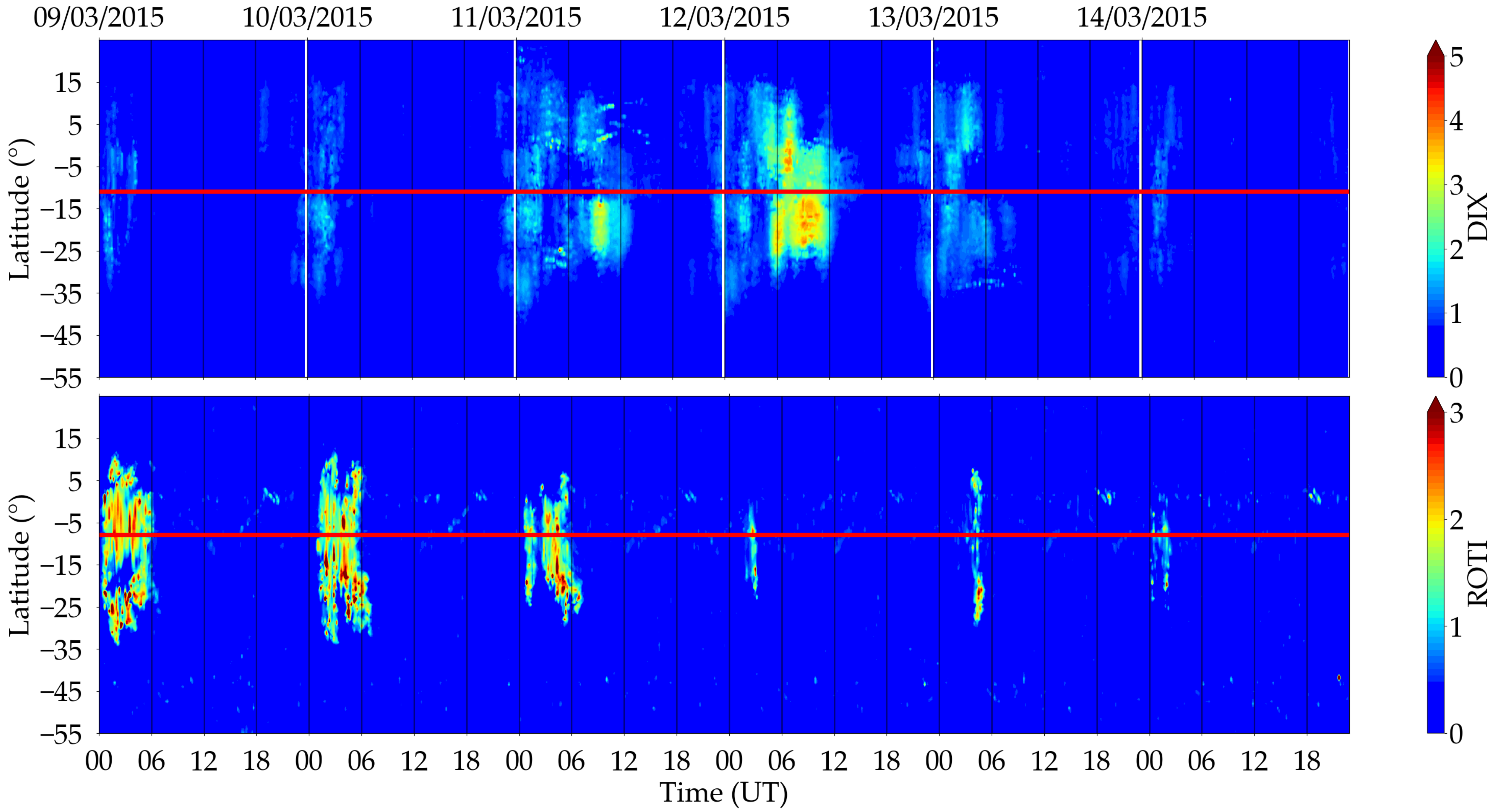

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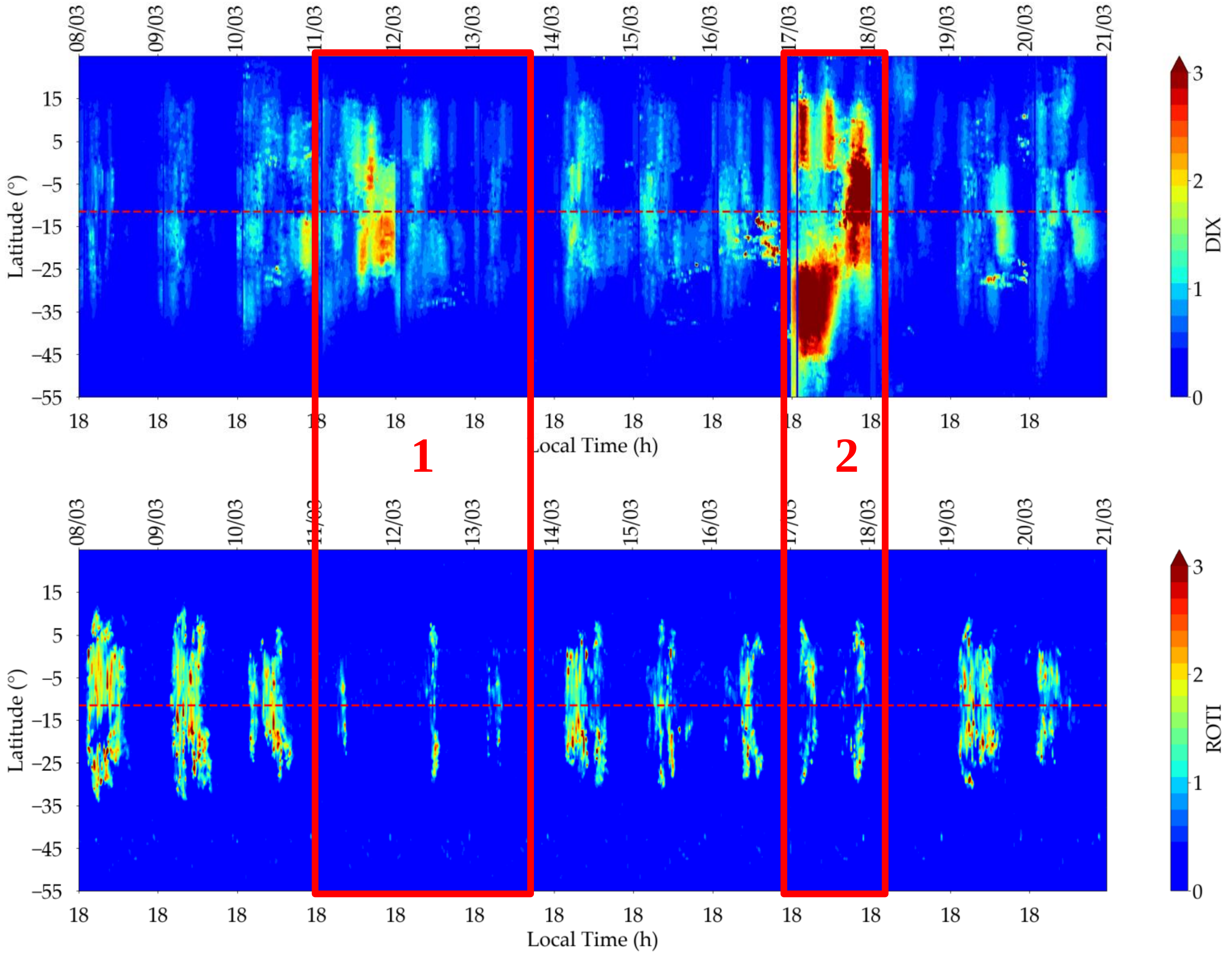
Results (Summary)

1 - Shortening of plasma bubble duration during the occurrence of a substorm as seen by DIX and ROTI keograms

2 – Plasma Bubble occurrence during an intense geomagnetic storm (17-18 March, 2015)



Conclusions

1. We have developed a **methodology to assess the morphological and physical characteristics of ionospheric disturbances** using multi-GNSS DIX and ROTI maps over South America. Thus, we have studied two space weather events: the St. Patrick's Day geomagnetic storm and the pre-storm period.

2. Our findings indicate that the ionosphere **is primarily affected by disturbances in plasma drift** behavior during periods of **magnetic storms and substorms**.

3. In this regard, we present a multi-index analysis showing that the time of occurrence of Equatorial Plasma Bubbles (EPB) can be **a proxy for the vertical plasma drift in the ionosphere**. This drift is closely linked to the **relation between thermospheric winds and disturbed electric fields** during magnetic storms and substorms.

4. In conclusion, our findings suggest that, even though each index only reveals "**when/where**" these disturbances occur, it can also offer insights into "**why**" the ionosphere experiences such disturbances.

References

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