

MITC-15

Sudden Global Ionospheric Disturbances driven by Field-Aligned Currents

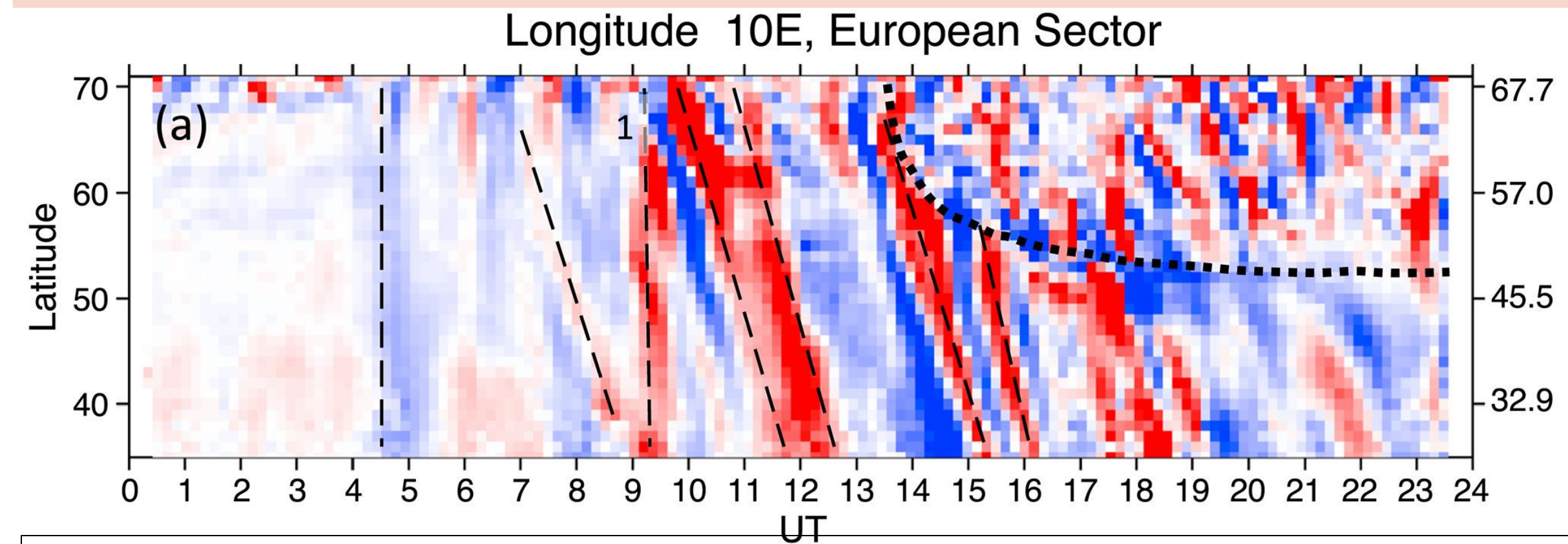
A New Basis for Understanding Prompt Penetration Electric Field (PPEF) using Total Electron Content

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Background and Motivation

Prompt Penetration Electric Field (PPEF) occurs when solar wind IMF orientation changes abruptly causing a fraction of the high-latitude electric fields to penetrate spontaneously to the middle and low-latitude ionosphere (Tsurutani et al., 2008). PPEFs can also occur during compression, substorms, and Region 1 (R1) – Region 2 (R2) Field Aligned Currents (FACs). FACs are a dominant process by which energy and momentum are transported from the magnetosphere to the ionosphere. Waghule et al. (2023) investigated some extreme geomagnetic storms which compressed the magnetopause to within the geosynchronous orbit, and identified that during such extreme forcing conditions, large-scale R1 FACs appear to extend to lower latitudes.

Traveling ionospheric disturbances (TIDs) and storm-enhanced density (SED) were investigated by Borries et al. (2016) and Lu et al. (2020) for the March 17, 2015, St. Patrick's Day storm - which is one of the storms under our investigation. TIDs are often characterized as diagonal line in the Total Electron Content TEC perturbation (dTEC) keogram as shown in figure below. Borries et al. (2016) identified a rapid propagation of dTEC (see vertical blue and red streaks at 04:45 UT and 09:30 UT) in their investigation. They noted that such a perturbation can only be caused by a perturbed electric field which can propagate essentially with the speed of light – hence associated with PPEF.



To further understand the drivers of PPEFs we...

1. Identify instances when R1/R2 FAC imbalance is driving PPEFs
2. Explore if PPEFs caused by R1/R2 FAC occur only at certain longitudes/Local times or globally?

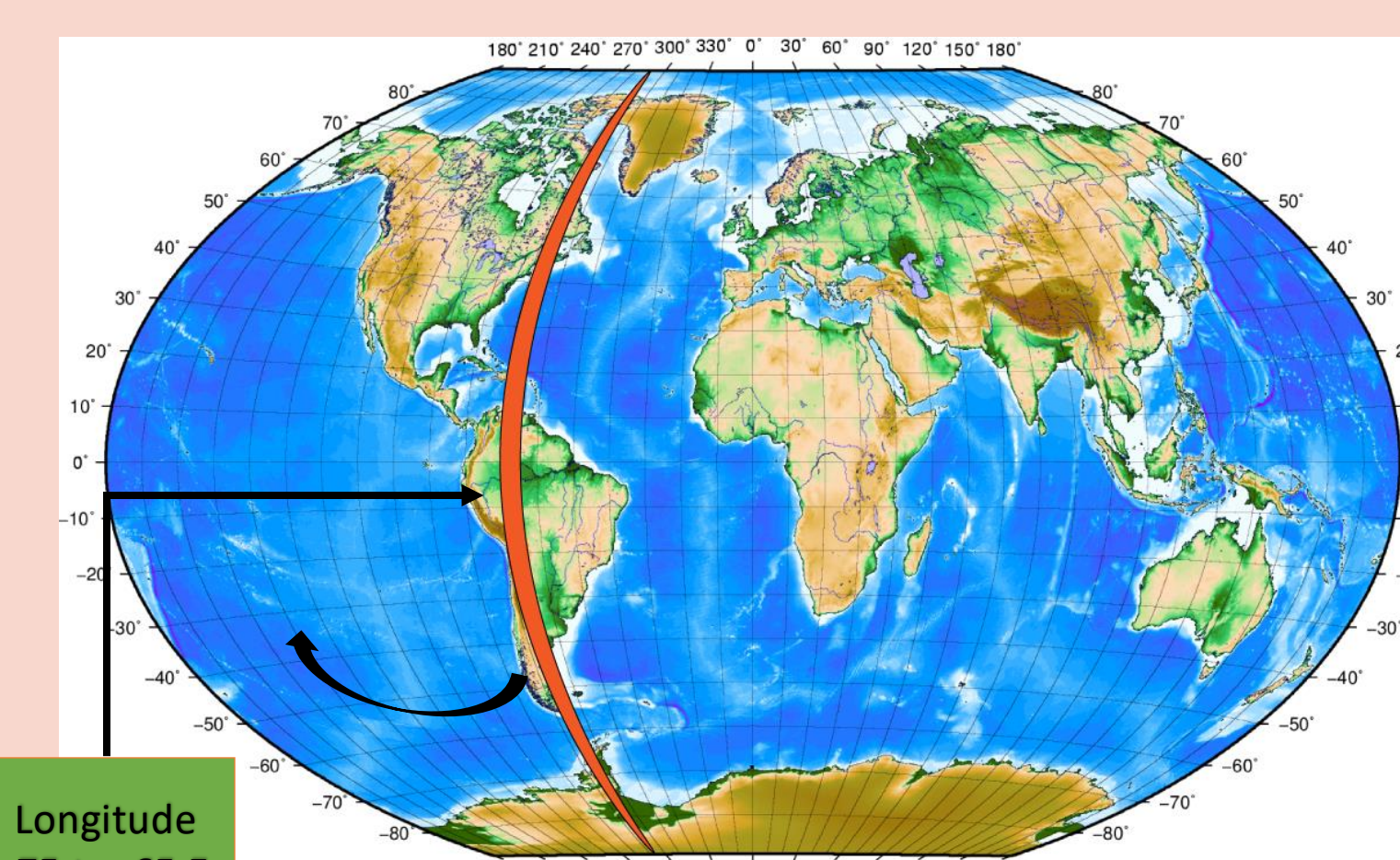
Data Analysis

Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) Data

Global FAC patterns in Magnetic Coordinates and FAC Keograms at dawn (6 MLT) for Northern Hemisphere are derived from using Optimal Interpolation (OI) method (Shi et al., 2020; Waghule & Knipp, 2022).

Global Navigation Satellite System (GNSS) Data

Spatial Slice used for TEC perturbation keogram



TEC perturbation (dTEC) Keogram maps were created in Geographic Coordinates for selected latitudes and longitudes (as shown in figure on the left) obtained by detrending TEC with a 30-min running mean- for all links between a ground-based GNSS receiver and visible navigation satellites. (Lu et al., 2020)

Global dTEC polar maps were created in Geographic Coordinates using dTEC data from Madrigal Website available every 5 minutes.

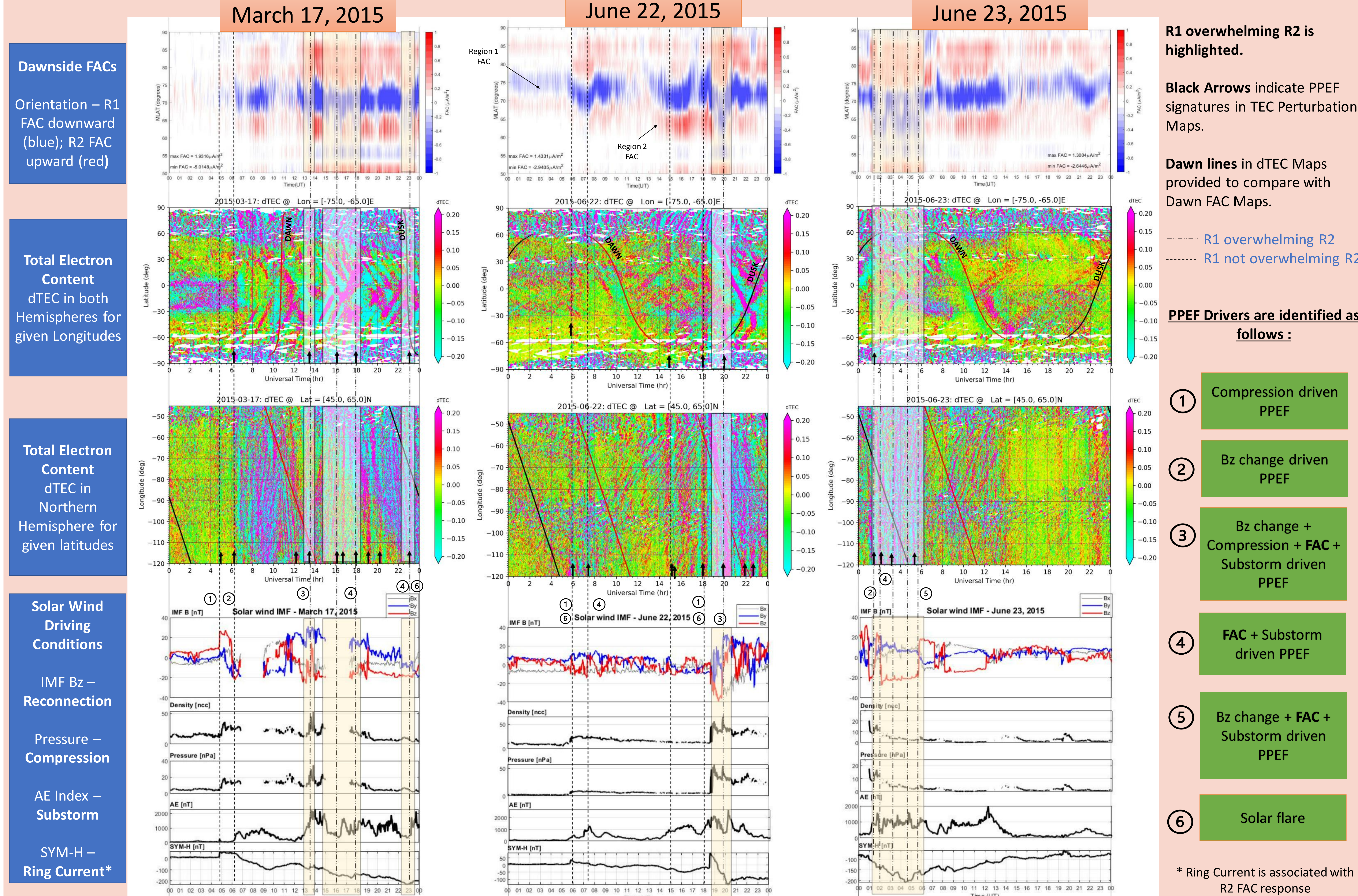
OMNIwebdata

Solar wind parameters - Interplanetary Magnetic Field (IMF) Bz - along with derived parameters of flow pressure, Auroral Electrojet index (AE), and Sym-H index.

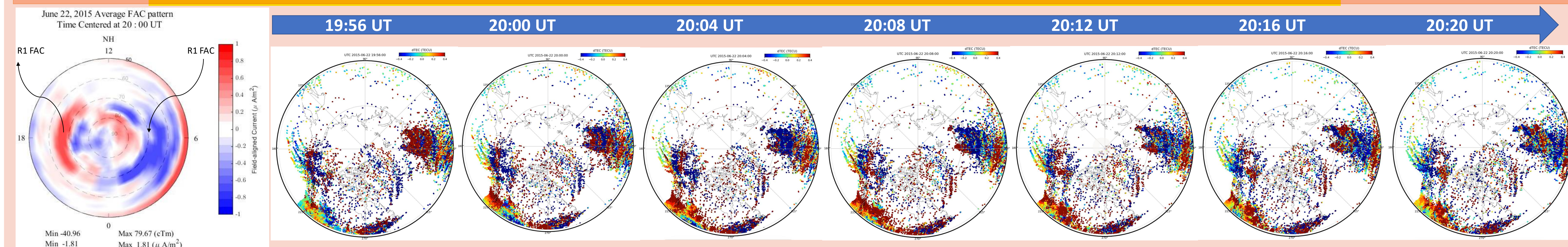
Since we are interested in exploring large scale FACs as one of the PPEF drivers, comparing results in different coordinate systems (although not ideal) can be insightful.



Results



June 22, 2015 - Global FAC and differential TEC Distribution for R1 FAC overwhelming R2 FAC



Evolution of dTEC – Positive differential Total Electron Content (Red region) over the United States sector stays in the same/similar location starting from 19:56 – 20:20 UT while evolution of TIDs is obvious in the European sector between 50-70 Glat. The positive dTEC seems to persist in the 60-50 Glat European Sector for the entire duration.

Discussion and Questions

PPEFs have been studied using Equatorial Electrojet (EEJ) as proxy. Recently, it has been identified that dTEC maps can help identify PPEF signatures. For the three superstorms, the PPEF signatures appear in both latitude and longitude TEC perturbation keograms, some at the same time (implying global PPEF) and some at different times (regional PPEF). These signatures have been identified as Sudden Global Ionospheric Disturbances (SGD) as described in Zhang et al. (2023) [Submitted].

At the time instances of Region 1 FAC overwhelming Region 2 FACs, also known as under-shielding (marked with dashed lines inside the yellow highlighted region), dTEC PPEF signature appear in both latitude and longitude dTEC keograms indicating instances of under-shielding (R1 FAC > R2 FAC) are consistent with global PPEF!

Future Work

- Prepare dTEC keograms in magnetic coordinate system for better comparison with keograms. We suspect that even in magnetic coordinates, the PPEF signatures will exist.
- Use techniques to improve dTEC spatial coverage
- Are these identified drivers working to cause PPEFs separately or in tandem?

References And Acknowledgements

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