Early Career Science Highlight I:

Interactions between Geomagnetic Activity and Sudden Stratosphere Warming

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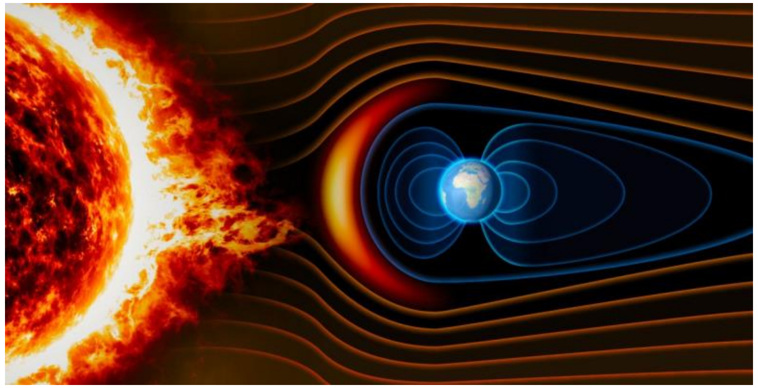
Forcing from Above and Below to Space Weather

Geomagnetic Storm



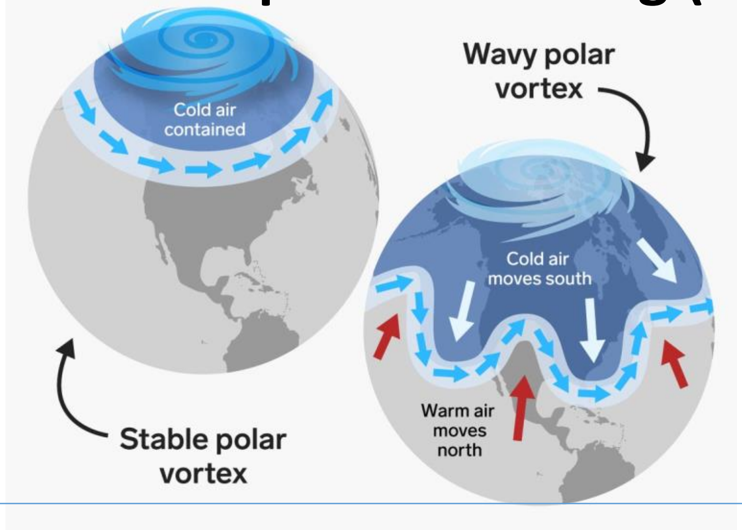
Storms are typically triggered from the Sun interacting with the Earth's magnetosphere. (Kp index >5)

Key Effects of a Geomagnetic Storm:

1. Col. O/N_2 decrease at mid-to-high latitudes and increase at low latitudes

2. Positive and negative **TEC** anomalies

Sudden Stratosphere Warming (SSW)



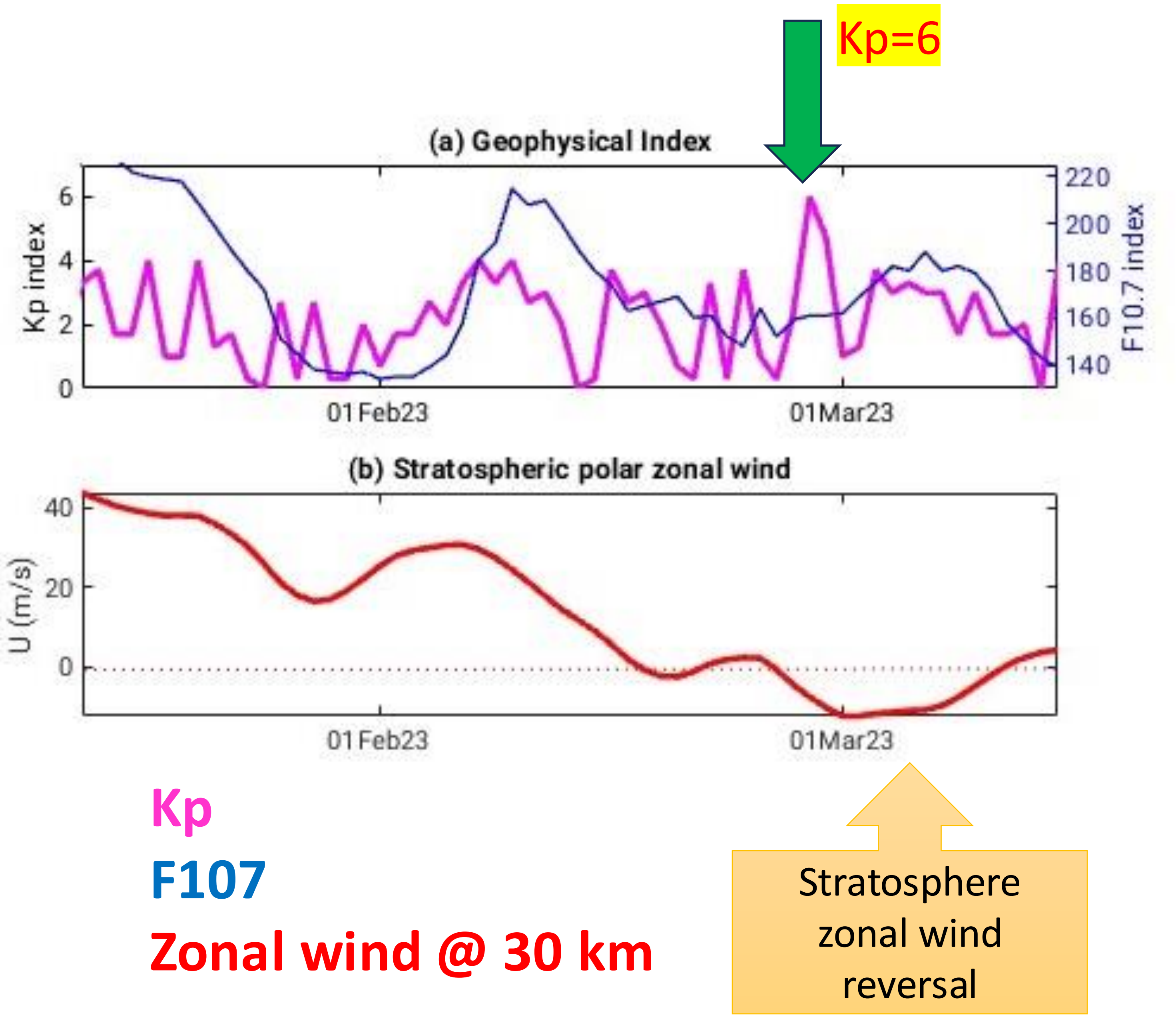
Rapid warming of the polar stratosphere & reversal of zonal winds, during northern winter, enhanced global-scale wave driving.

Key Effects of a Sudden Stratospheric Warming:

1. Decrease in the **Col. O/N_2** at low latitudes

2. Enhanced **TEC** in morning and reduced **TEC** in afternoon.

A Case Study: 27th February 2023 Storm



Kp

F107

Zonal wind @ 30 km

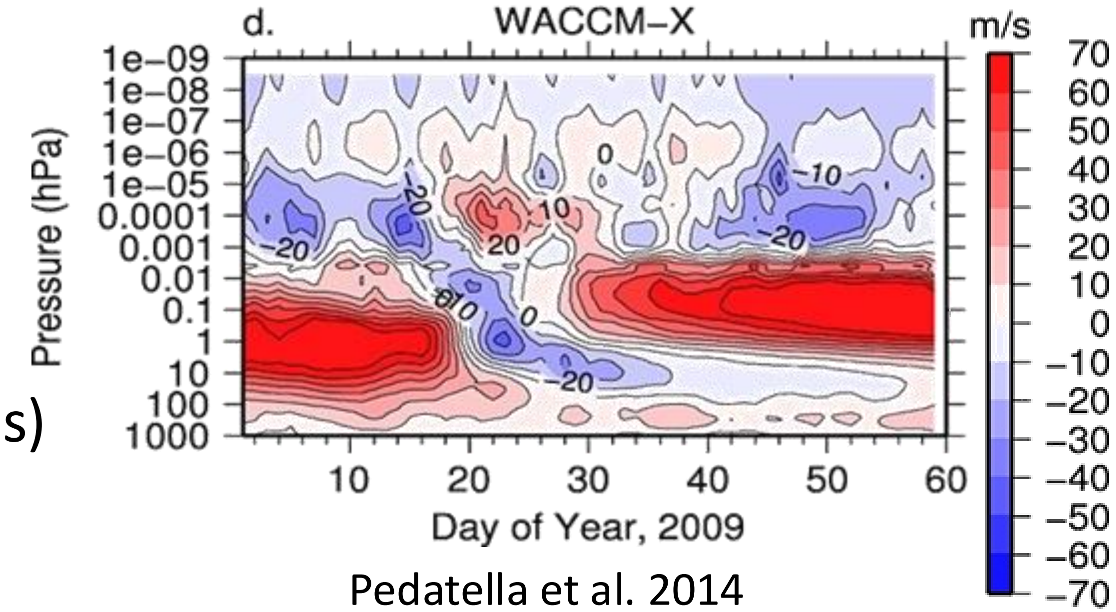
Simultaneous strong forcing from above and below: The storm occurs during the SSW event/ stratospheric zonal wind reversal

Objective: Highlight the importance of **SSW preconditioning (due to lower atmosphere forcing) to storm** impact on space weather

Analysis Tools: SD-WACCM-X Runs

❑**Run1**: With SSW + Storm

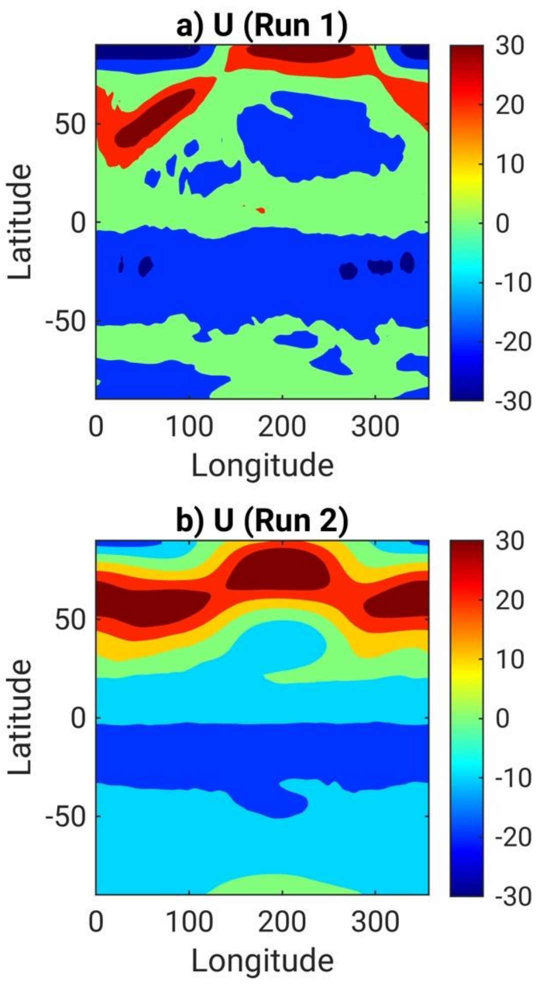
- Hourly MERRA-2 (reanalysis dataset based on assimilated meteorological observations)



Pedatella et al. 2014

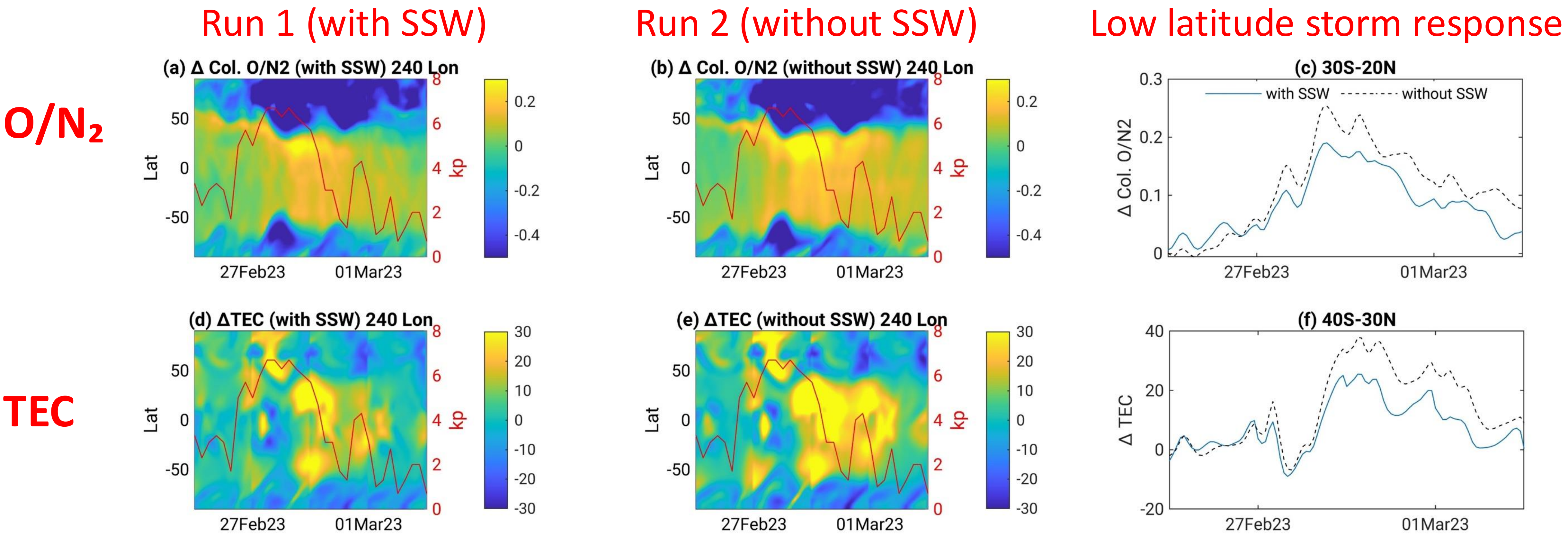
❑**Run2**: No SSW + Storm

- 40-years MERRA-2 climatology
- Removes day-to-day and SSW induced variability



- **Analysis**: Storm response= storm (27th Feb; kp=6) – quiet (24th, 25th Feb; kp<3)

Storm Response: TEC, Col. O/N2 @ 240 Longitude (Temporal Effects)

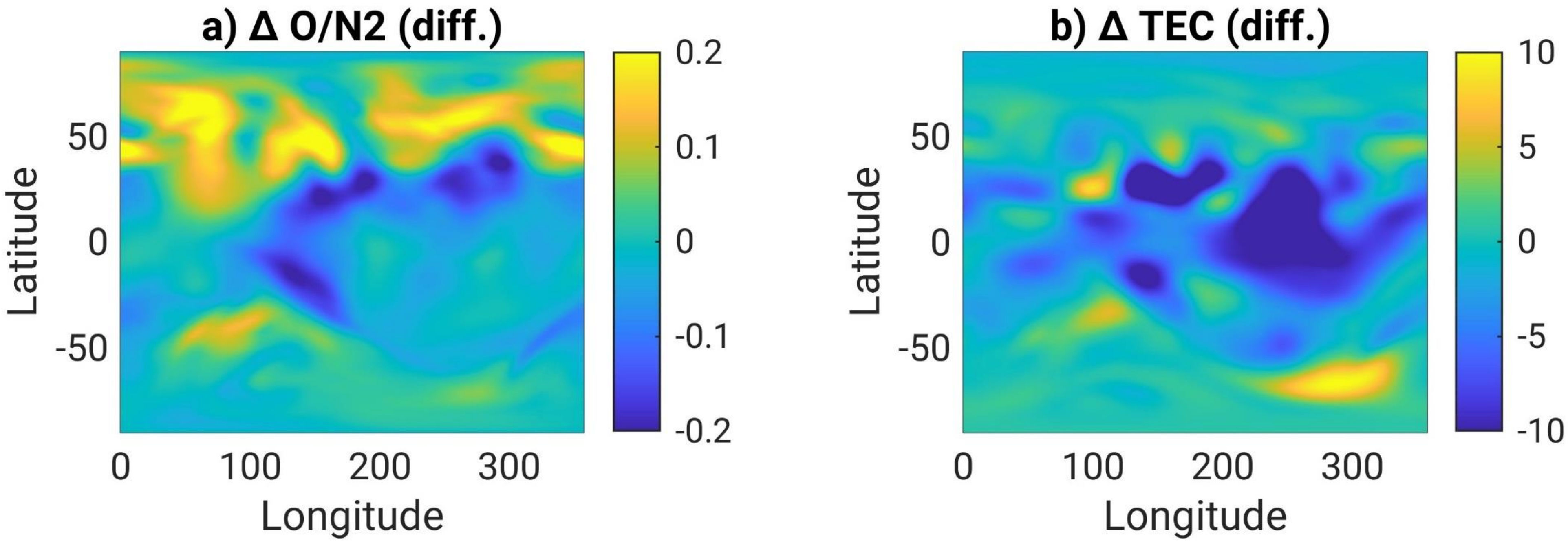


Storm-impacted **TEC** and **Col. O/N_2** exhibit **20-50% changes and faster storm recovery** driven by lower atmosphere preconditioning during SSW.

Next-> Lower atmosphere preconditioning due to SSW -> Relative storm response (Run1 - Run2)

Lower Atmosphere SSW Preconditioning on Storm Response (Spatial Effects

Diurnal mean or mean state changes during storm recovery (28th Feb):

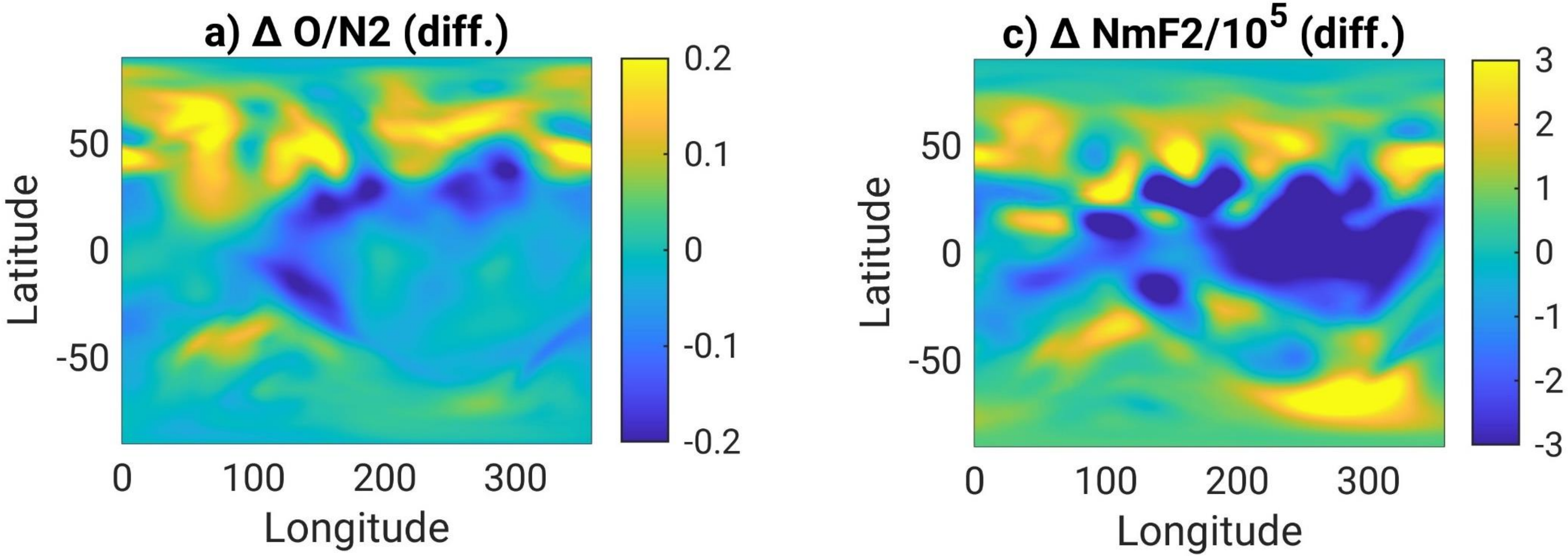


Col. O/N_2 changes predominately at **mid-latitudes**, while **TEC** changes over **low latitudes**.

Why don't the O/N_2 changes appear to correlate with the TEC variations?

Lower Atmosphere SSW Preconditioning on Storm Response (Spatial Effects

Diurnal mean or mean state changes during storm recovery (28th Feb):



1. **Col. O/N_2** changes correlate to peak electron density **NmF2** changes over **mid latitudes**
2. **Low latitudes** mean changes driven by **dynamic transport.**

$$\frac{\partial N_{O^+}}{\partial t} = \underbrace{production - loss}_{O/N_2 \text{ related chemistry}} + \underbrace{trans_{EXB} + trans_{wind}}_{\text{Plasma transport}} + amb_{diff}$$

Conclusions

- **SSW preconditioning** leads to **20–50% variation** in **storm-time electron density and O/N_2** and **accelerates post-storm recovery**.

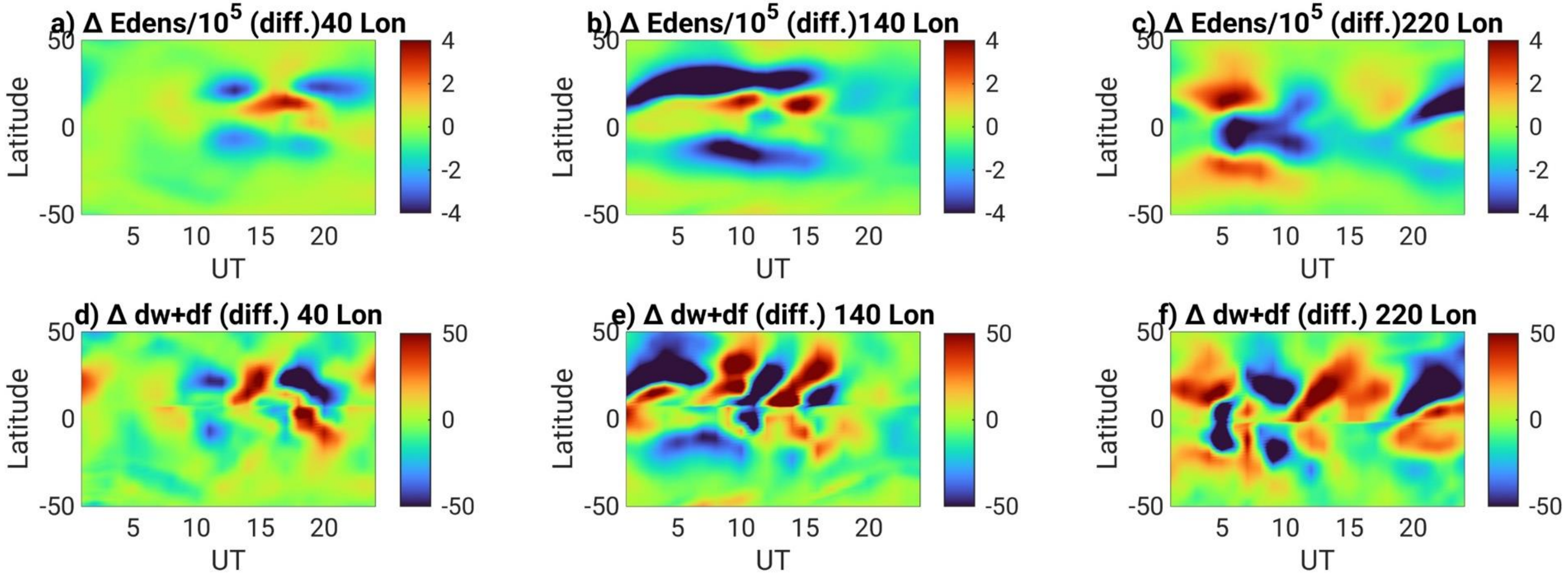
- **O/N_2 changes** during recovery are most **prominent at mid-latitudes**.
- **Electron density changes** occur **mainly at low-to-mid latitudes**:
  - *Mid-latitudes:* Driven by thermospheric composition and ion-neutral chemistry.
  - *Low-latitudes:* Governed by dynamic transport (electric fields, field-aligned winds)

Mechanism study key conclusions *(can be found in our upcoming paper)*

- ***Electron density Local time variability at low latitudes*** *likely due to* ***terdiurnal and semidiurnal tidal*** *influence during nighttime hours.*

- ***Col. O/N_2*** *is preconditioned* ***by storm interacting with altered thermosphere background introduced during SSW event.***

Mechanism Study Key Conclusions



Local time variability in TEC seems to be primarily influenced by **terdiurnal (8 hr) and semidiurnal (12 hr) tidal** components similar to **wind transport** local time variations of O+.

The preconditioning effects due to terdiurnal tides are more pronounced during **nighttime hours**.