

# Variations of total electron content with solar wind parameters at high-latitude ionosphere

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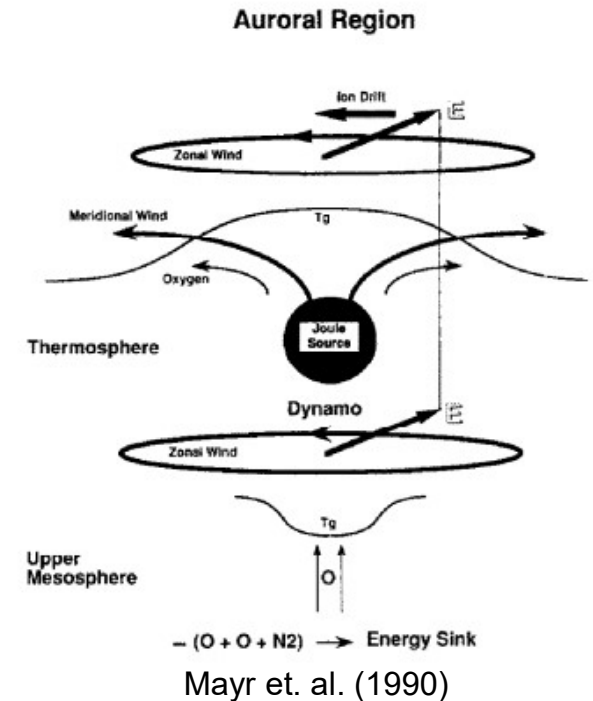
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Knowledge for Tomorrow

## Solar wind impact on high-latitude ionosphere

- Interaction between solar wind and magnetosphere drives the upper atmosphere.
- Changes in solar radiation, geomagnetic disturbances, and lower atmosphere forcing can all contribute to variability of maximum electron density of the F2 layer and the **total electron content (TEC)**. (Cai et. al., 2021)
- Intense **Joule heating** in thermosphere results in upwelling of nitrogen-rich or oxygen-depleted air. Depleted **O/N<sub>2</sub>** air causing a decrease in electron density in **polar regions** due to a higher recombination process through ion-molecule exchange reaction with **N<sub>2</sub>** molecules (Ranjan et. al., 2023).
- There exist positive storm effects (electron density enhancements) and negative effects (electron density depletion) in the ionosphere (Borries et. al., 2015)



- How does the thermosphere-ionosphere system respond to solar wind variation and how it changes with season and local time?

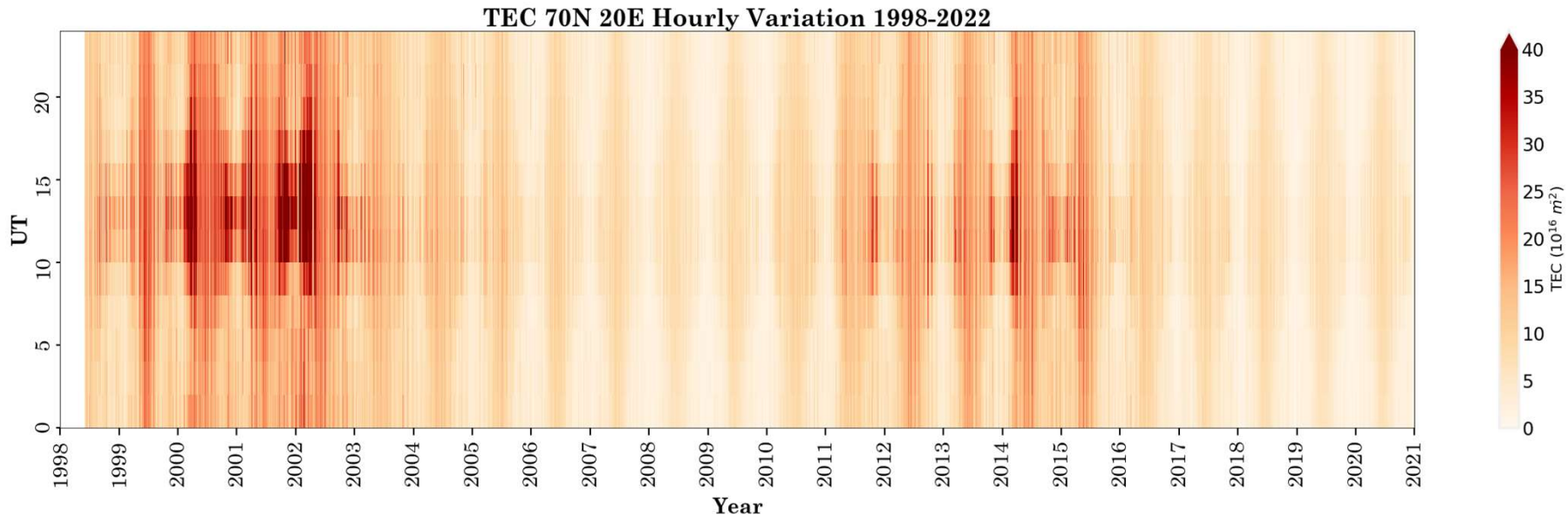


## Objectives

- Study the impact of solar wind on high-latitude ionospheric total electron content (TEC) on time scales of hours, seasons, years, and solar cycles.
- Reveal the differences in TEC and solar wind correlations.
- Study the response time of the ionosphere to solar wind variations.
- Explain the possible reasons and mechanisms behind the correlations.



# Total Electron Content (TEC) and Daily Sunspot Number (SSN) Data

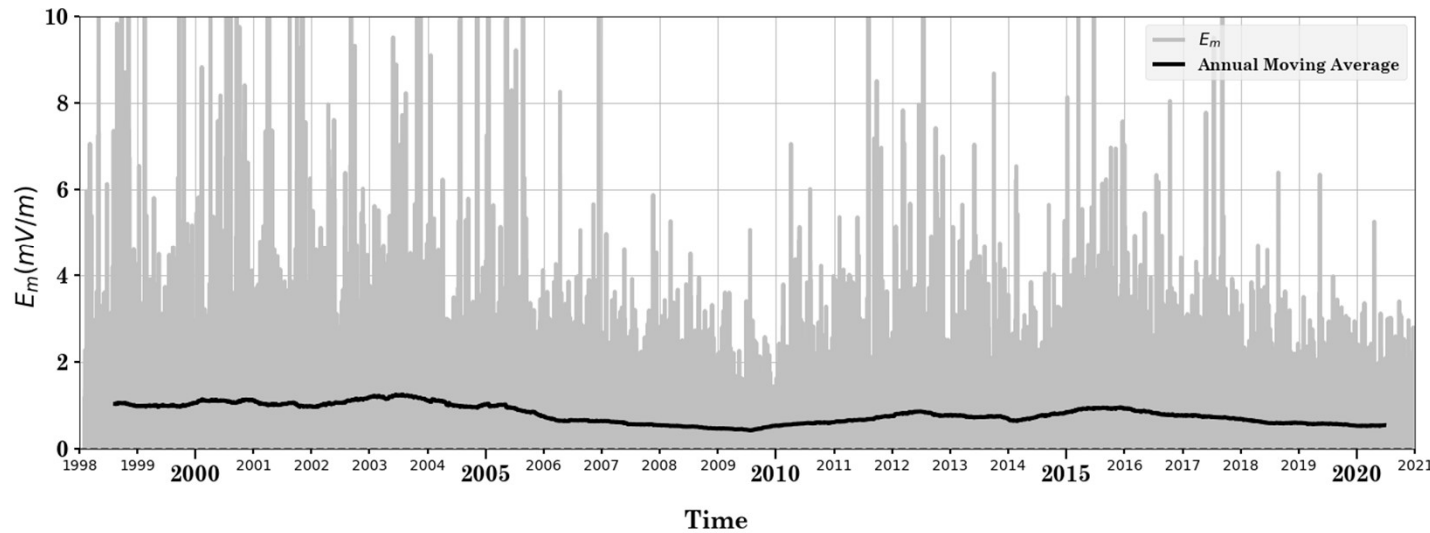


**Data:** 2 hours resolution IGS TEC Map  
**Location:** Near Tromsø/Norway, 70N 20E  
**Time span:** 23 years (1998-2021)  
**Local time:** UTC+1 (+2 daylight savings)



# Merging Electric Field as Solar Wind Coupling Function

2-Hour Resampled ACE SWE Data



**Data:** 2 hours resampled ACE SWE data  
**Time span:** 23 years (1998-2021)

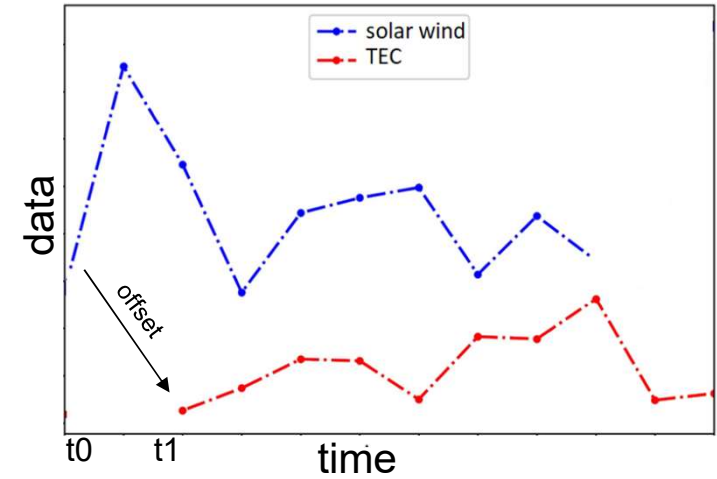
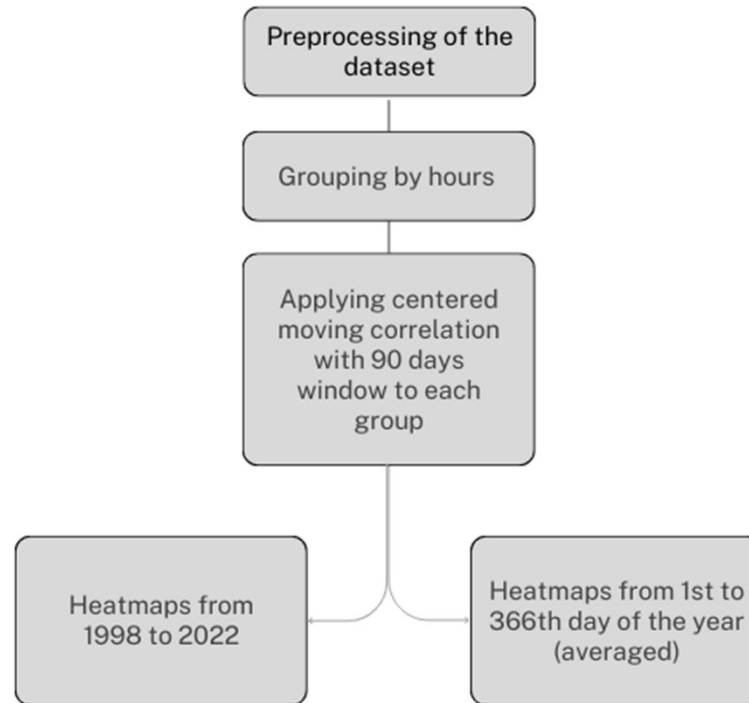
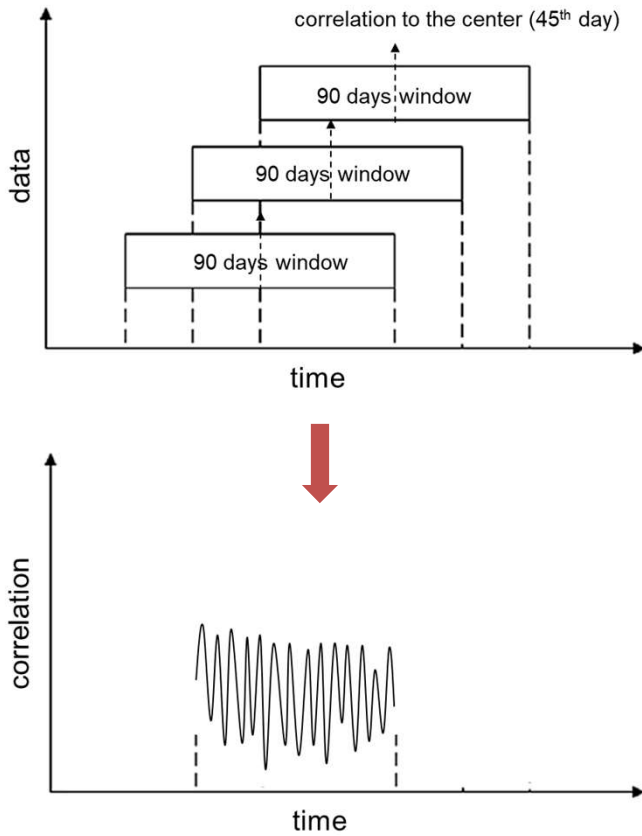
$$E_m = v_{sw} B_t \sin^2 \left( \frac{\theta}{2} \right)$$

Kan & Lee (1979)

$B_T = \sqrt{B_y^2 + B_z^2}$  Magnitude of IMF in yz plane  
 $V_{sw}$  = solar wind speed  
 $\Theta$  = Angle between z direction and projection of IMF in yz-plane

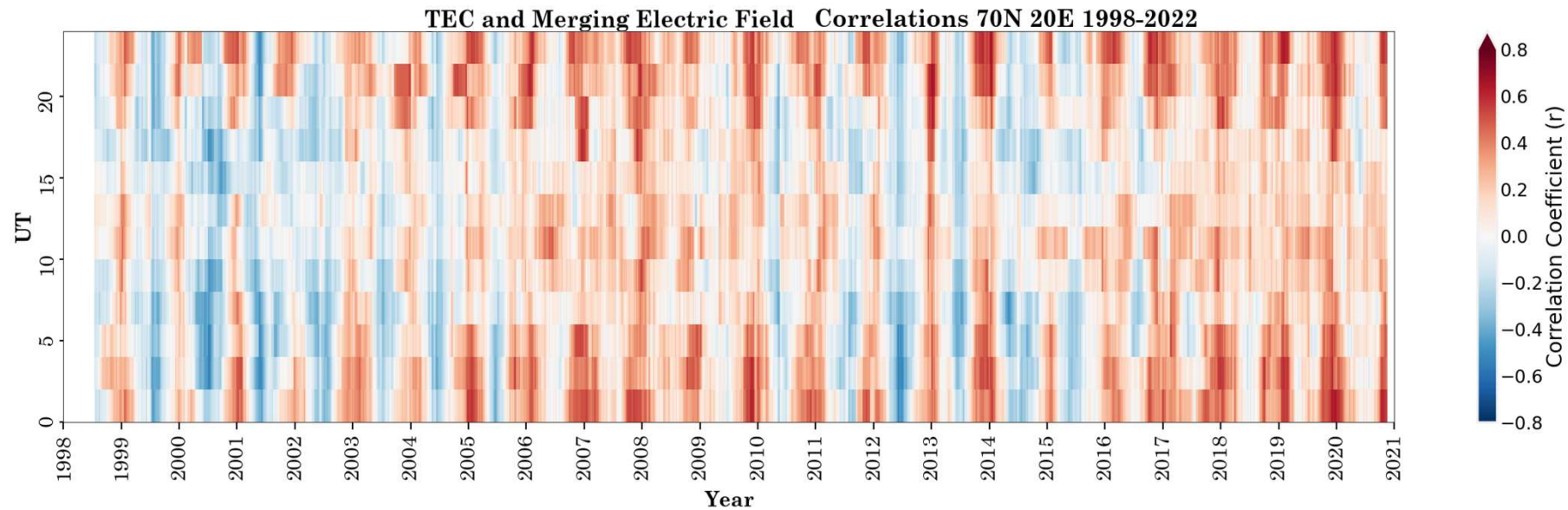


# Method: Centered Moving Correlation with 90 Days Window and Delay





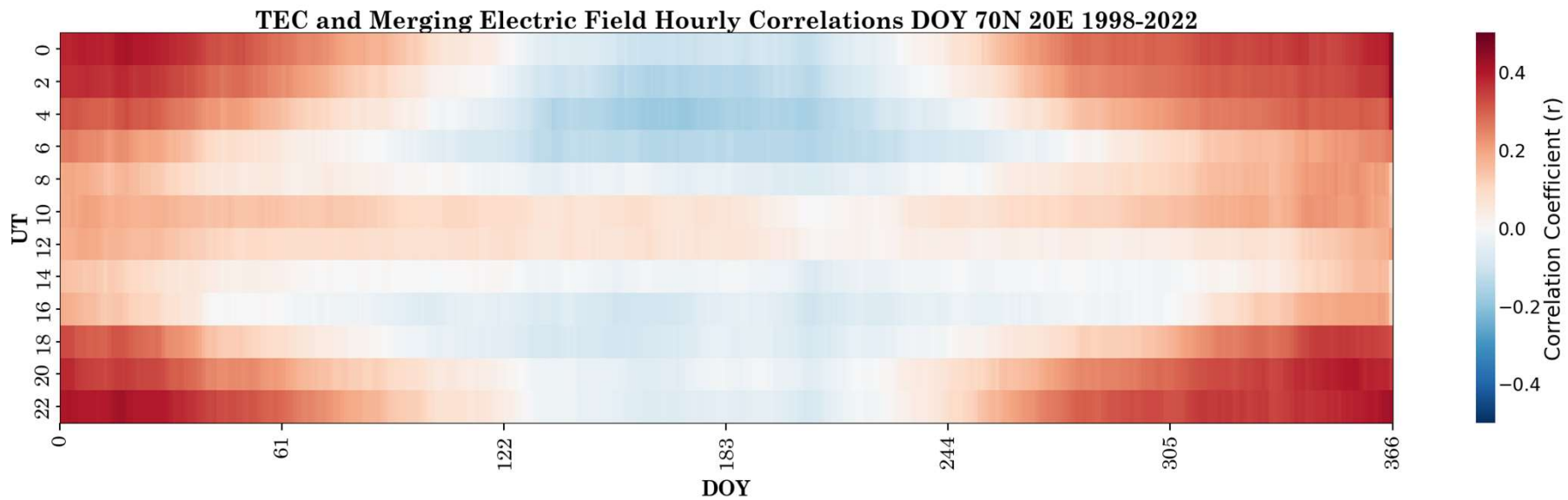
# Temporal Evolution of the TEC and $E_m$ Correlations



- Positive correlations during winter nighttime
- Negative correlations during summer daytime solar max



## Average Annual Variation of TEC and $E_m$ Correlations



Positive-negative correlation effect

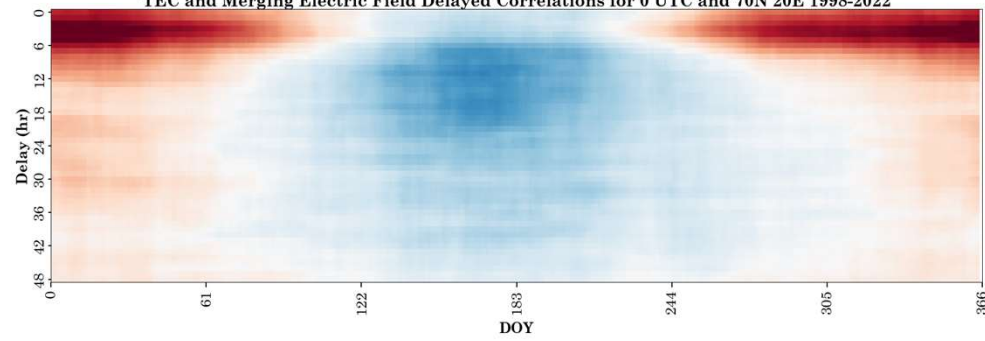
- Convection (winter-transport of plasma)
- Recombination (summer-reduction of plasma)



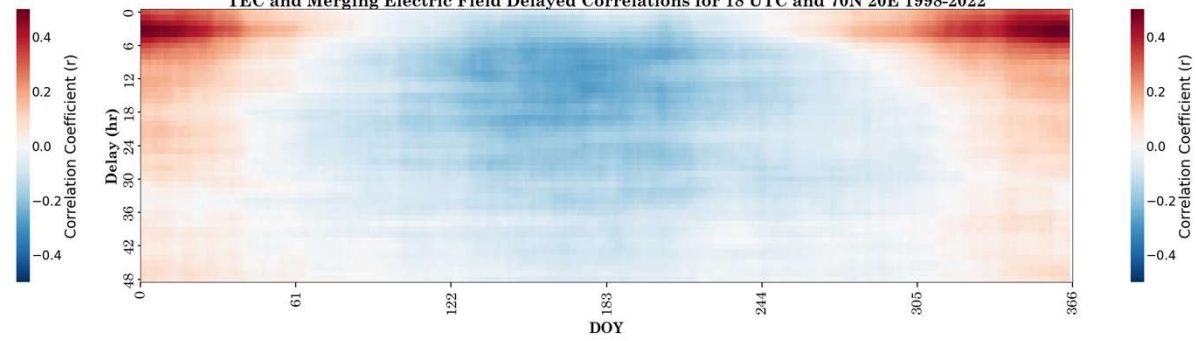


# Response Time of TEC to Solar Wind ( $E_m$ )

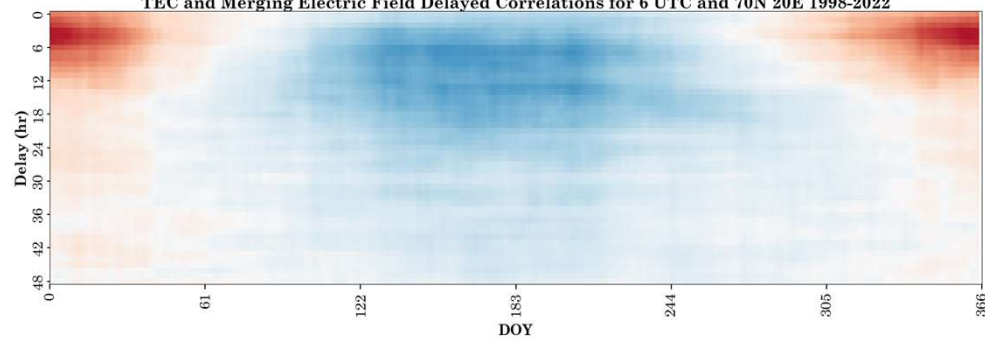
TEC and Merging Electric Field Delayed Correlations for 0 UTC and 70N 20E 1998-2022



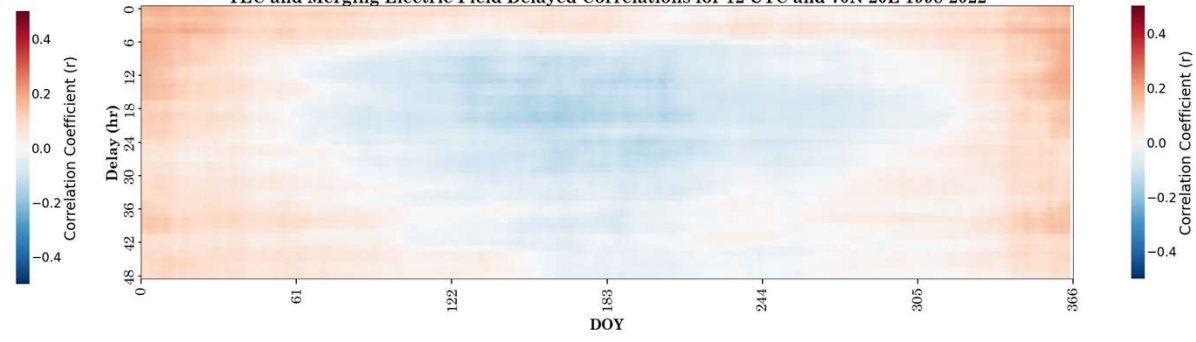
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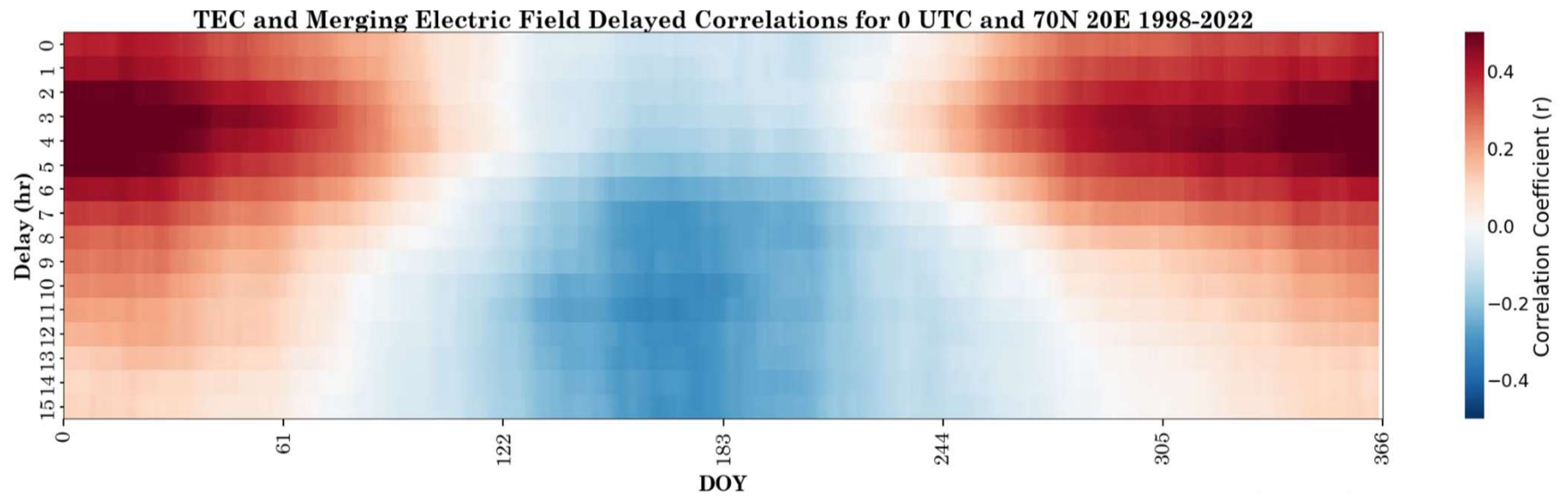


TEC and Merging Electric Field Delayed Correlations for 6 UTC and 70N 20E 1998-2022



TEC and Merging Electric Field Delayed Correlations for 12 UTC and 70N 20E 1998-2022





## Summary

- Seasonal and local time dependency of solar wind in high latitude ionosphere
- Merging electric field correlation analysis with Total Electron Content
  1. During winter (summer) it is strongly positive (mostly negative during daytime)
  2. Positive winter effect – plasma transport (convection)
  3. Negative summer effect – recombination (upwelling of molecules and more intense heating)
- Response of ionospheric TEC to solar wind:
  1. Shorter– positive winter effect
  2. Longer– negative summer effect



## References

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Thanks!



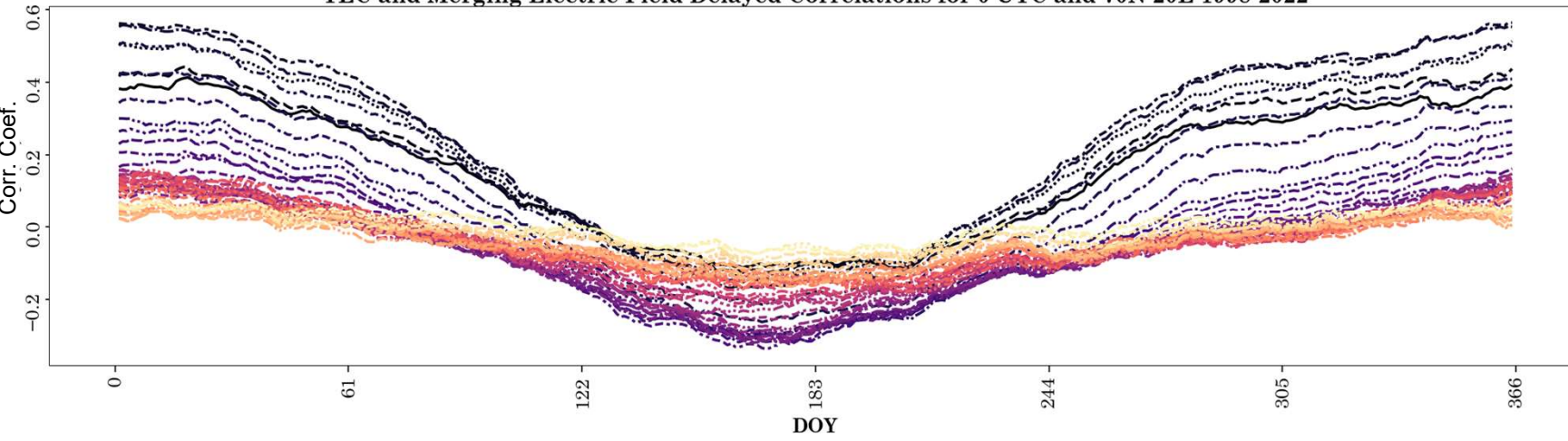


## Sources for negative/positive effect on ionosphere

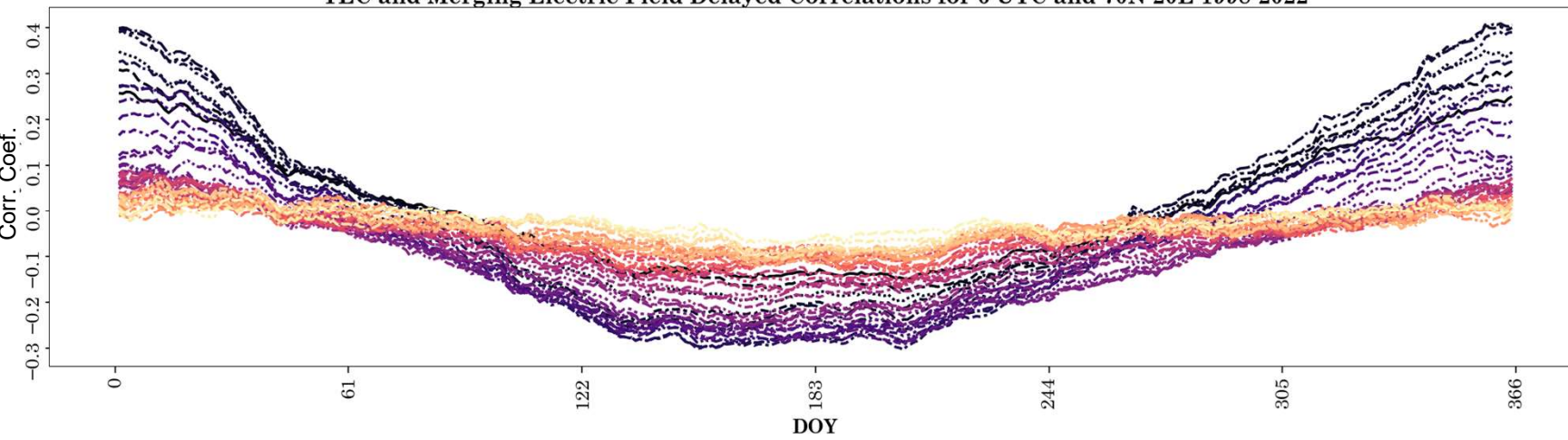
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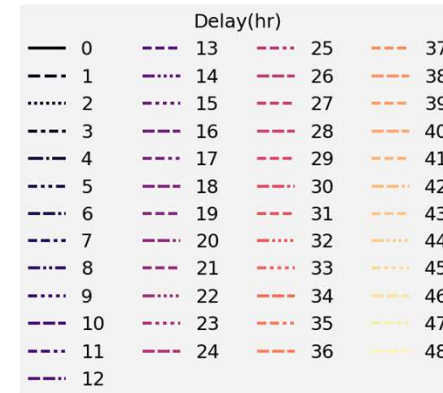
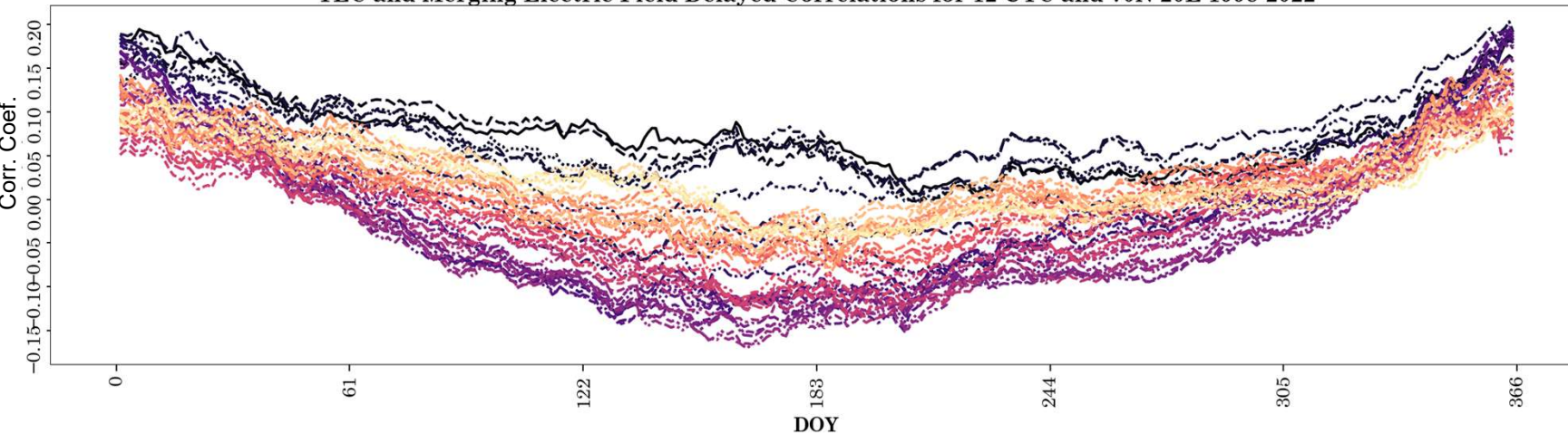
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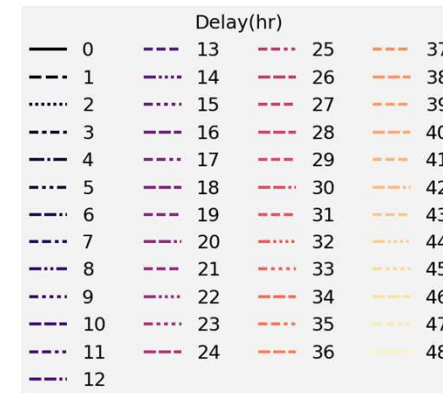
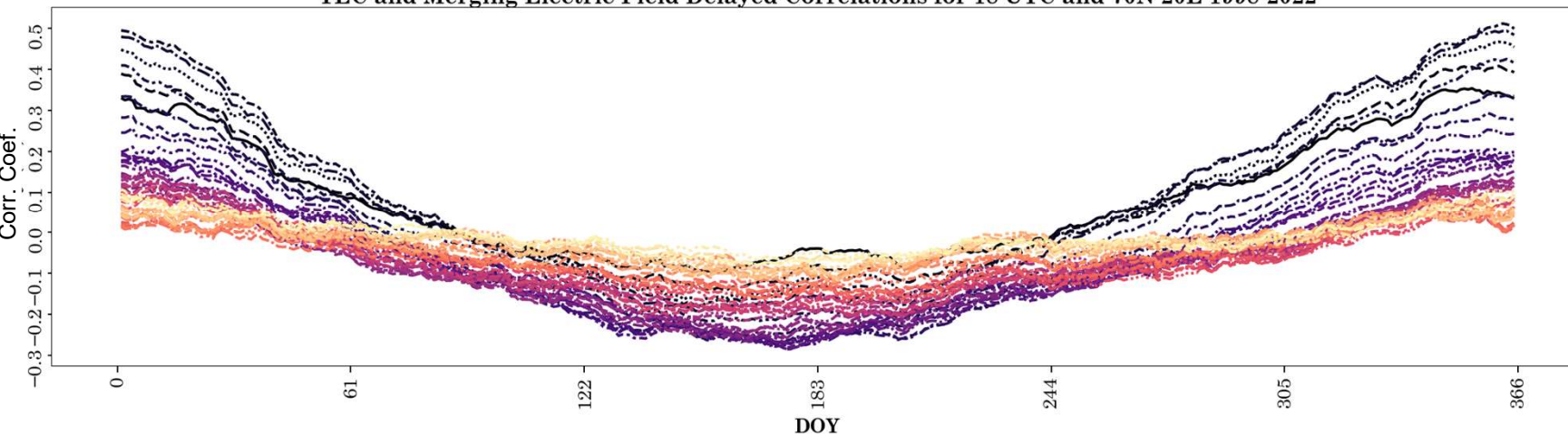
TEC and Merging Electric Field Delayed Correlations for 6 UTC and 70N 20E 1998-2022



TEC and Merging Electric Field Delayed Correlations for 12 UTC and 70N 20E 1998-2022

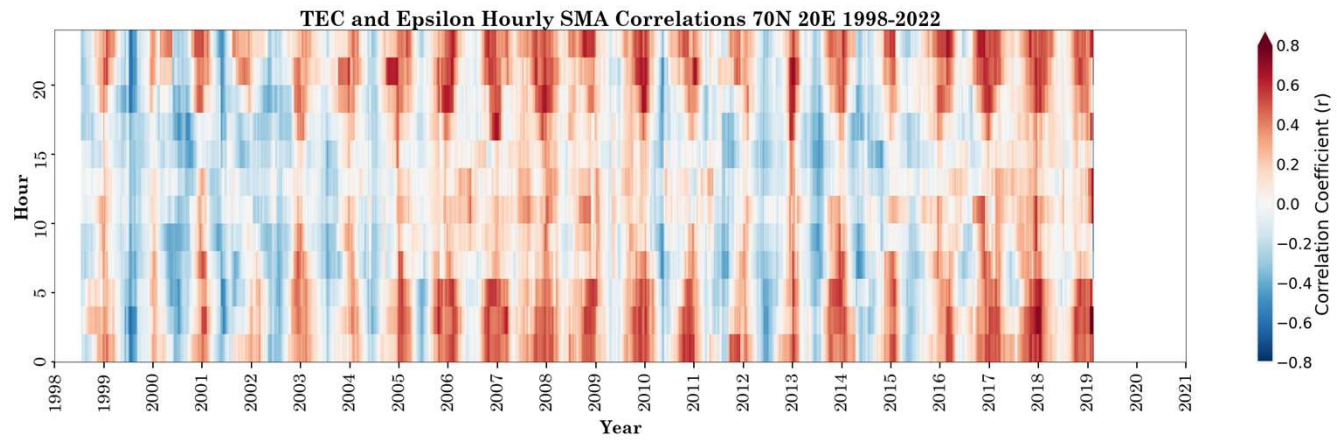
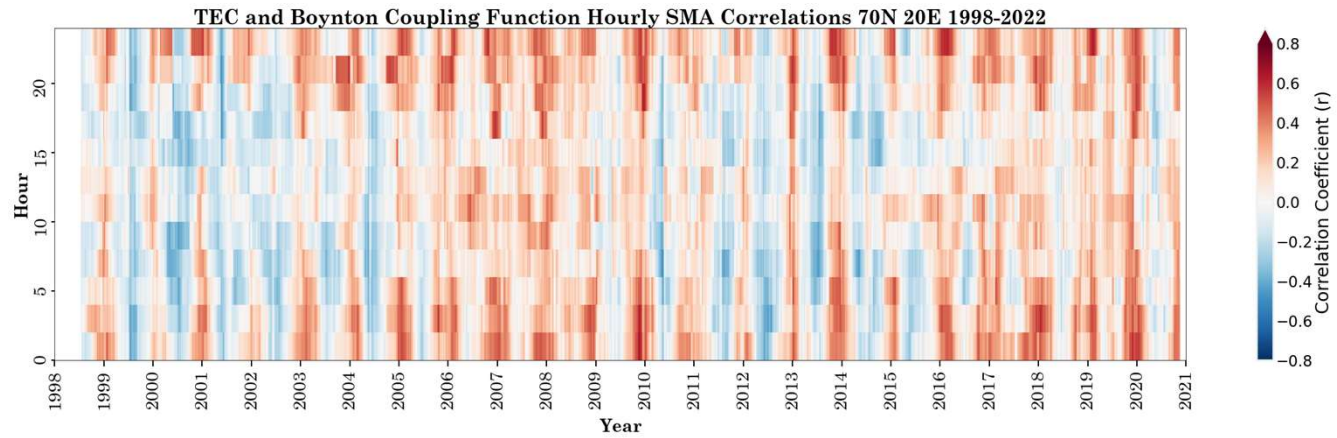


TEC and Merging Electric Field Delayed Correlations for 18 UTC and 70N 20E 1998-2022

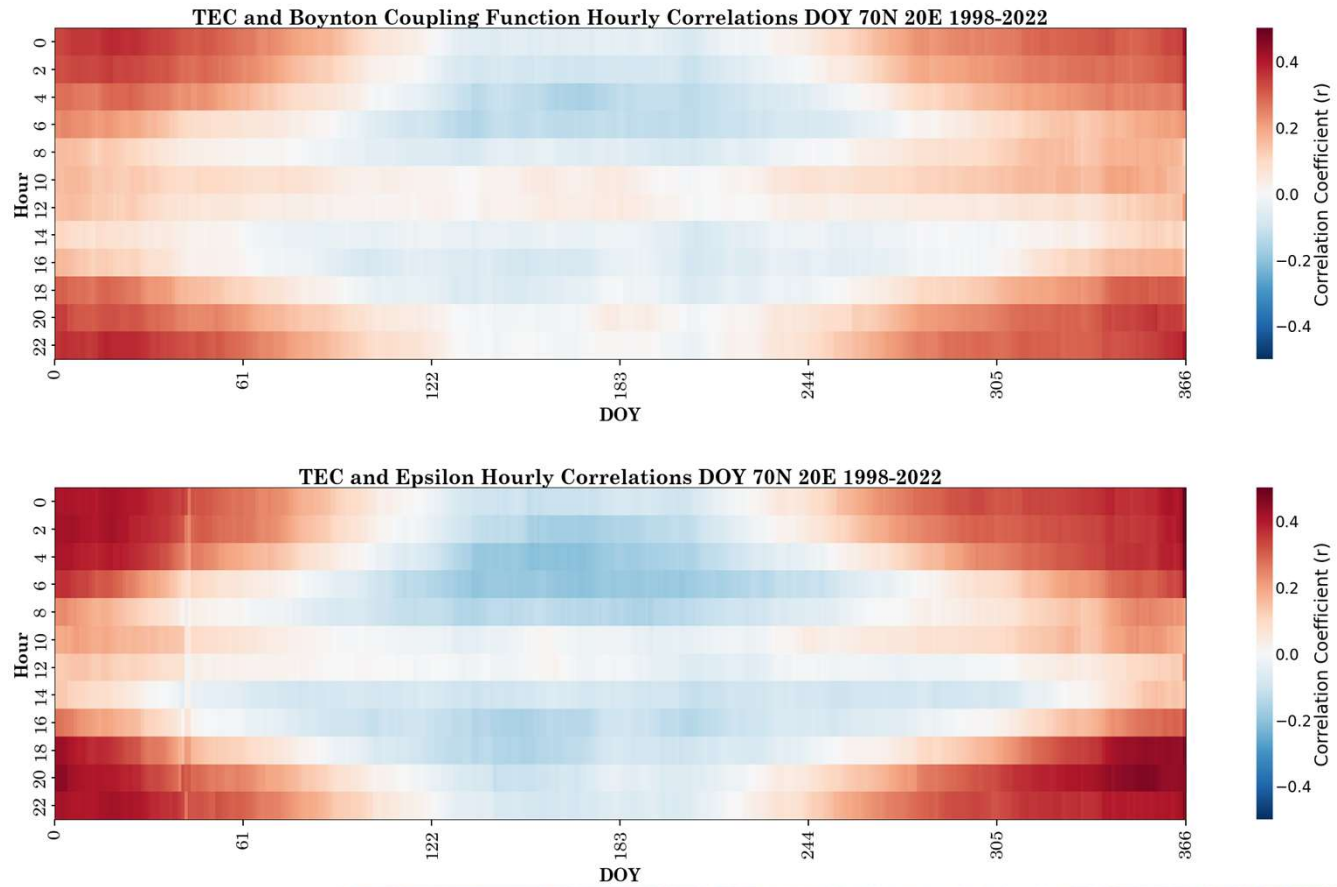




# Temporal Evolution of the TEC and Other Coupling Parameters Correlations

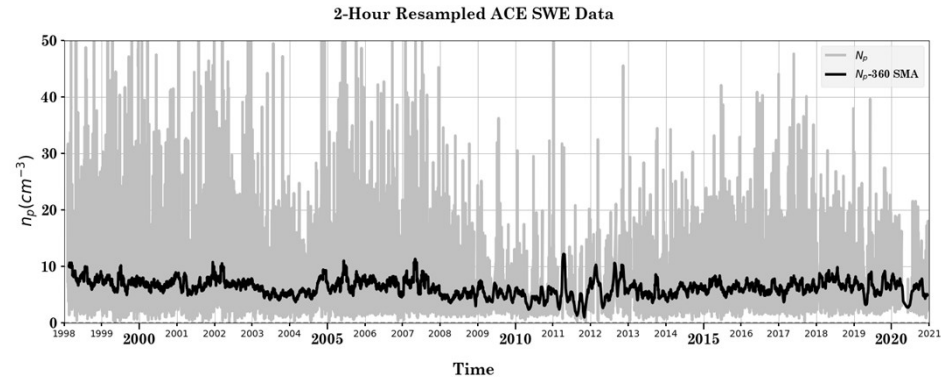
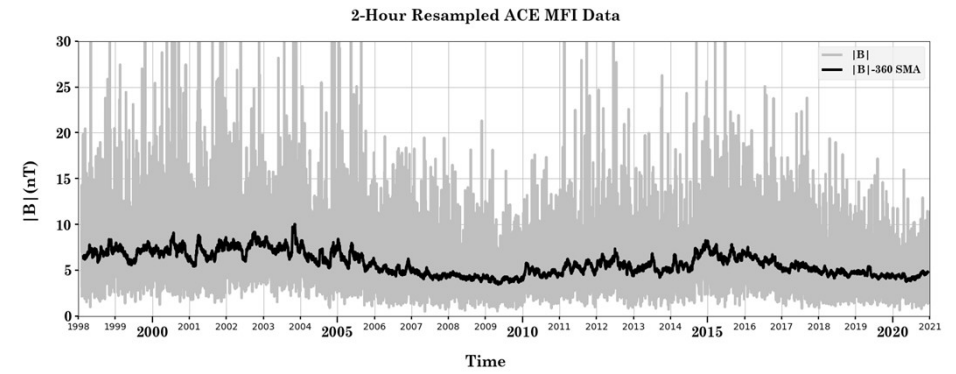
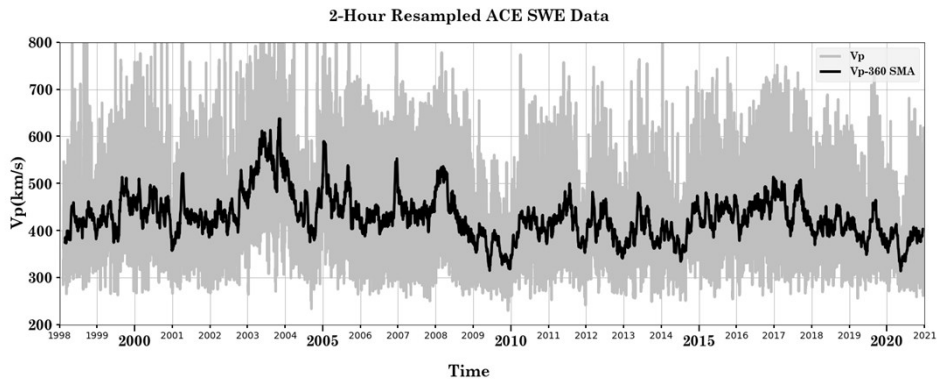


# Average Annual Variation of TEC and Other Coupling Parameters Correlations





## Solar Wind Parameters



## Geomagnetic Activity Parameters

