REACTION OF THE UPPER ATMOSPHERE TO THE 27-D SOLAR CYCLE

Comparison of CTIPe and TIE-GCM Simulations to Observations

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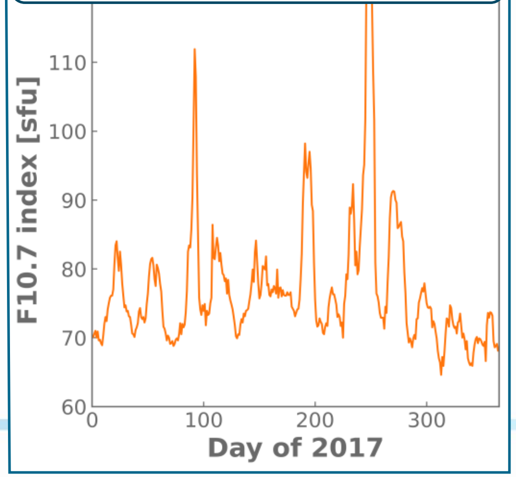
Effect of Solar Radiation on the Upper Atmosphere

27-day solar rotation period

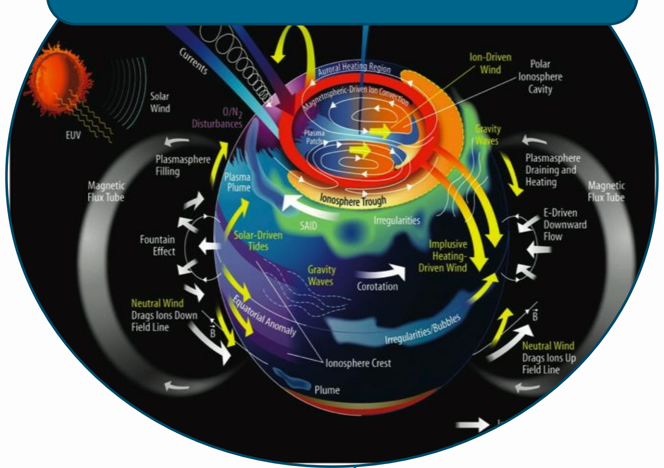
27-day signature in solar radiation



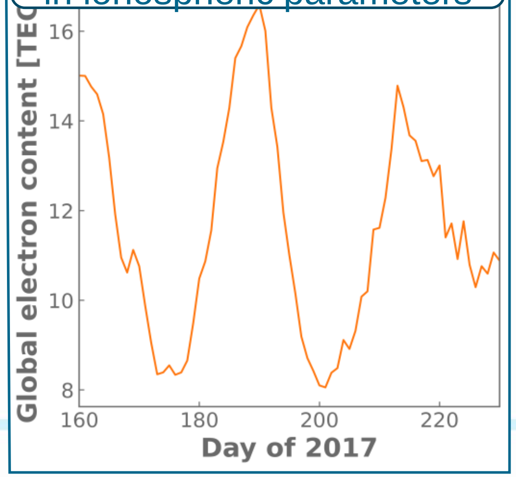
Solar EUV radiation

- Absorption
- Chemical processes
- Physical processes
- …

Atmospheric response

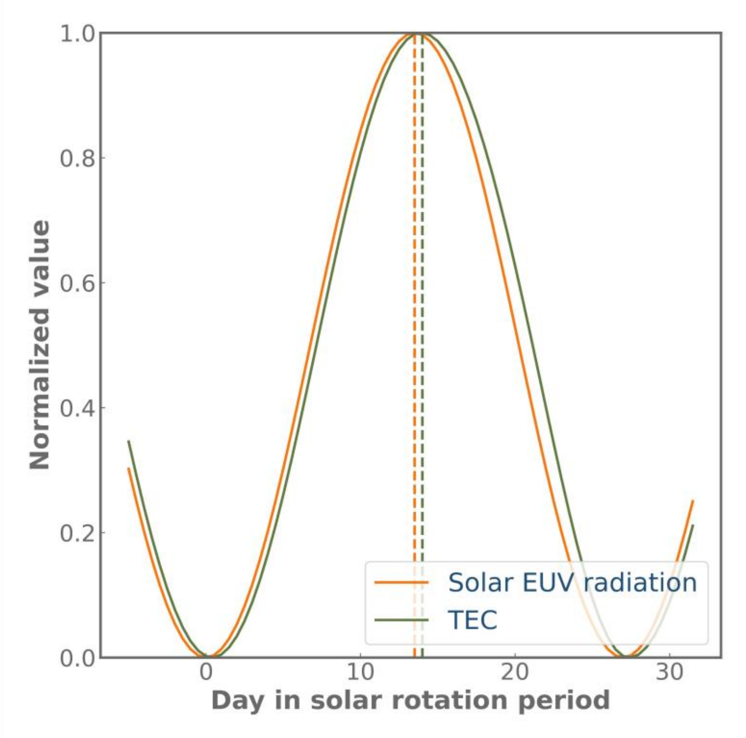


Delayed 27-day signature in ionospheric parameters



Key Findings in Previous Studies

Ionospheric Delay



Underlying processes, e.g.:

- Absorption
- Ionization
- Recombination
- Transport

Photodissociation causes an accumulation of O_2 which influences ion loss and production (Risbeth et al. 1998, Ren et al. 2018)

Delay dependent on solar and geomagnetic activity (Schmölter et al. 2020)

Studying the delay with physical models (CTIPe) shows altitude dependence (Vaishnav et al. 2021)

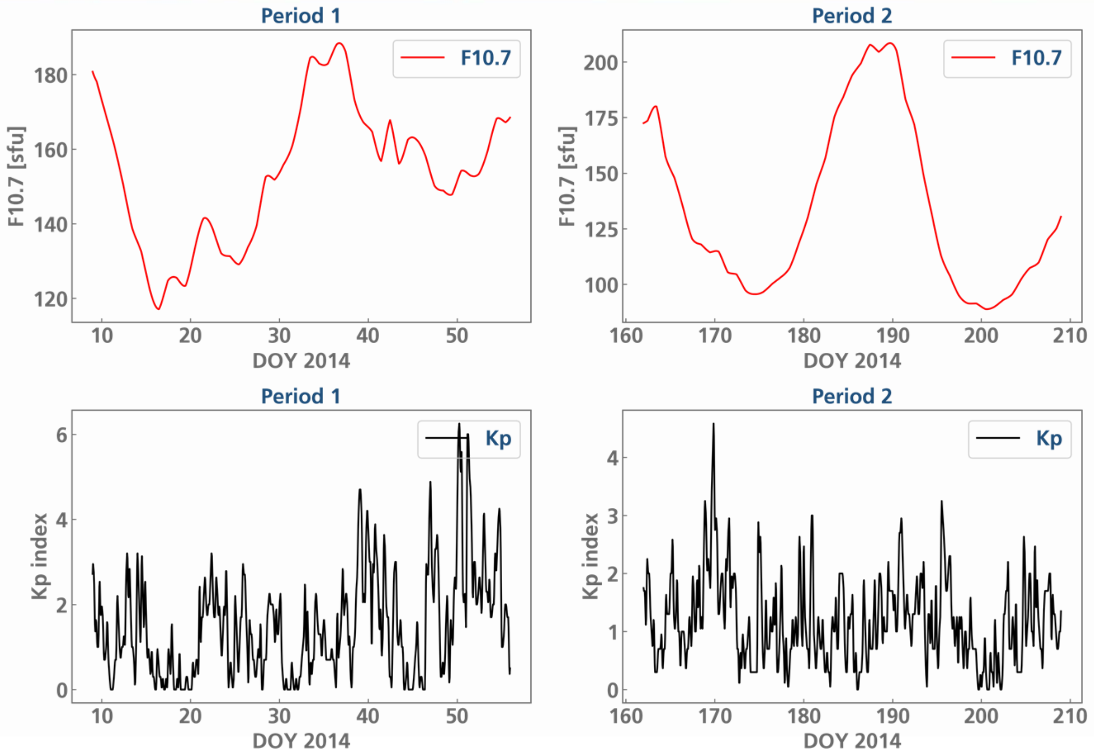
Physical models allow for detailed analysis of ionospheric constituents where observations are not possible

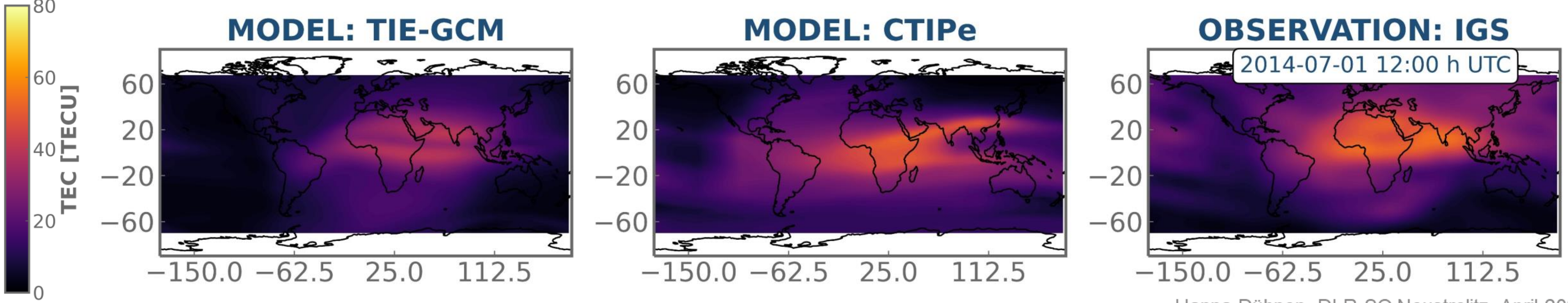
1. How do plasma- and neutral dynamics influence the global distribution of the delay?
2. Can we use the understanding of processes underlying the delay to improve future modelling?

Solar Rotation Periods

Approach

- Case study for two time intervals with different solar rotation characteristics in F10.7
- Comparison based on different numerical model runs (TIE-GCM and CTIPe)
- Comparison of numerical results with observational data (IGS)

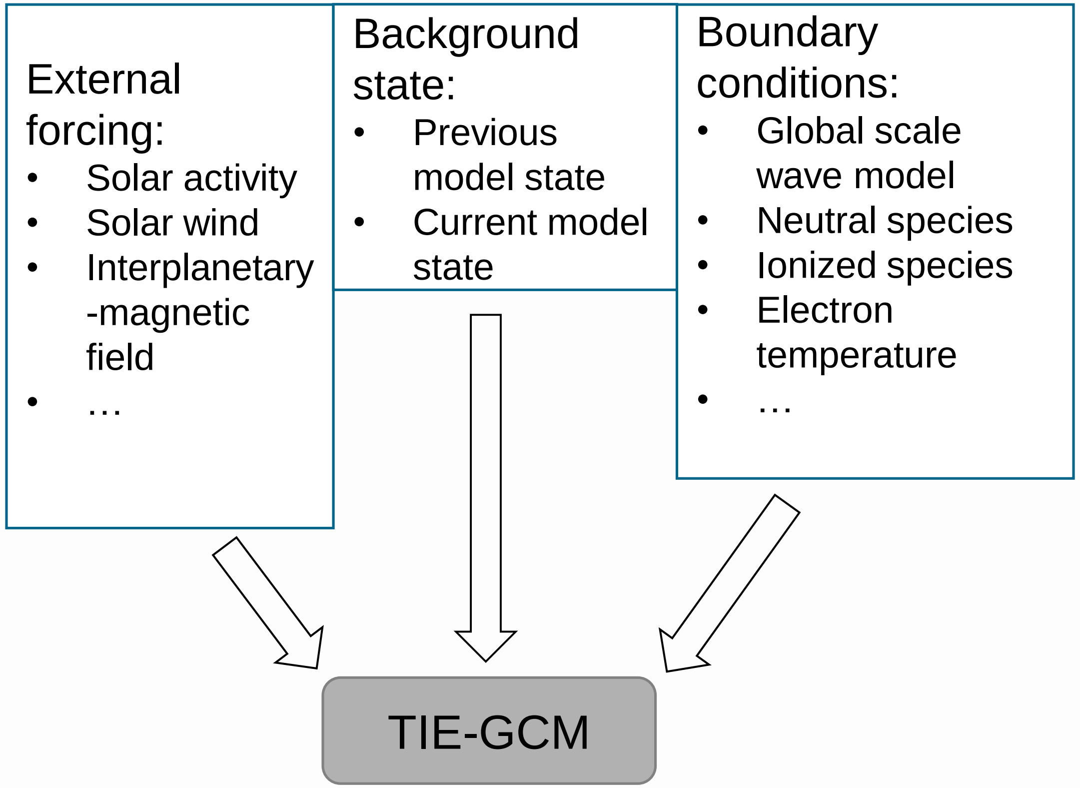




Physical Upper Atmosphere Models

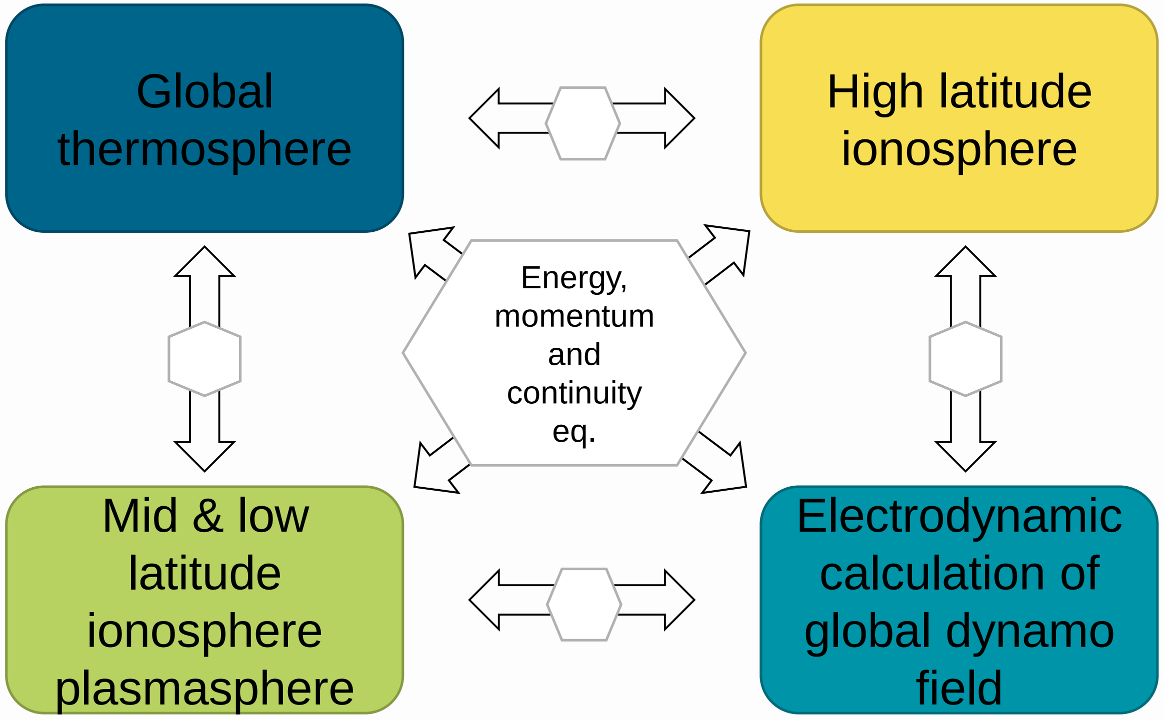
TIE-GCM[1]

Thermosphere Ionosphere Electrodynamics – General Circulation Model



CTIPe[2]

Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics model



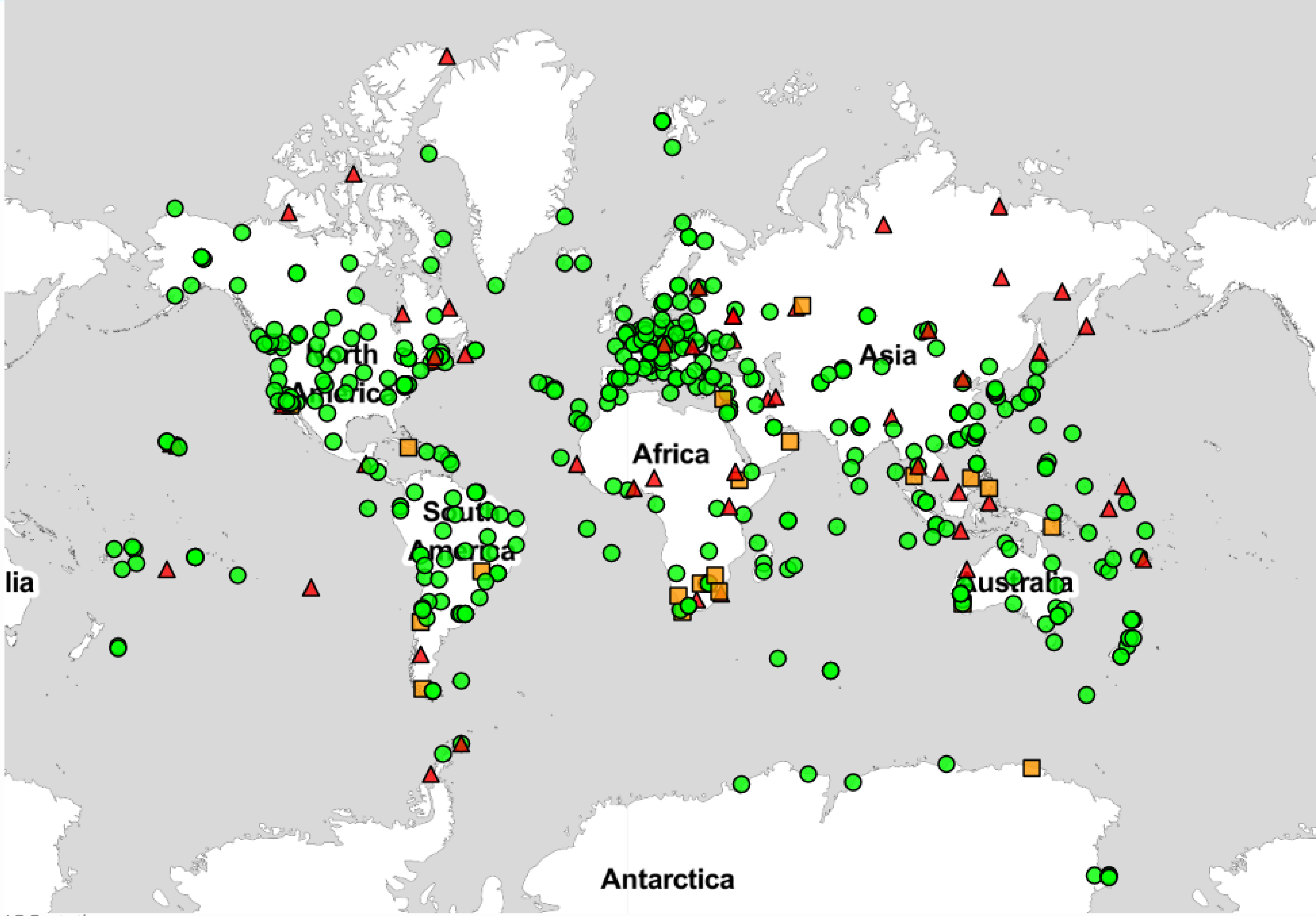
[1]Qian, L., A. G, et al. The NCAR TIE-GCM: A community model of the coupled thermosphere/ionosphere system, 2014

[2]Milward et al. An investigation into the influence of tidal forcing on F region equatorial vertical ion drift using a global ionosphere-thermosphere model with coupled electrodynamics, 2001

Observational Data

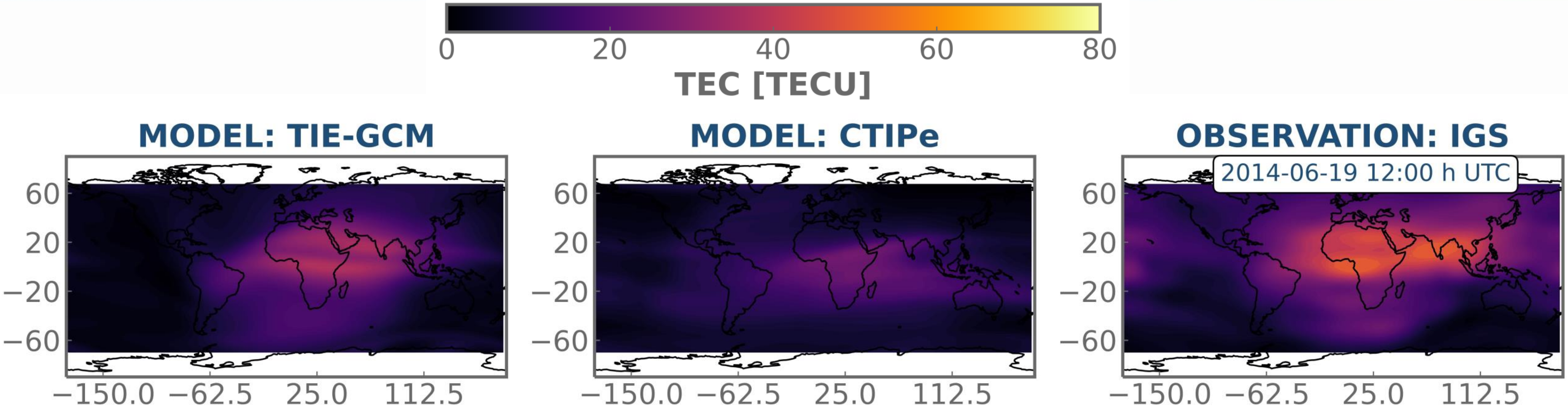
IGS
International GNSS Service

- Extensive network of GNSS measurement stations
- Ground based TEC measurements
- Provide global ionosphere maps



IGS stations,
Image source: https://igs.org
Johnston, G., Riddell, A., Hausler, G. (2017). The International GNSS Service. Teunissen, Peter J.G., & Montenbruck, O. (Eds.), Springer Handbook of Global Navigation Satellite Systems (1st ed., pp. 967-982). Cham, Switzerland: Springer International Publishing. DOI: 10.1007/978-3-319-42928-1.

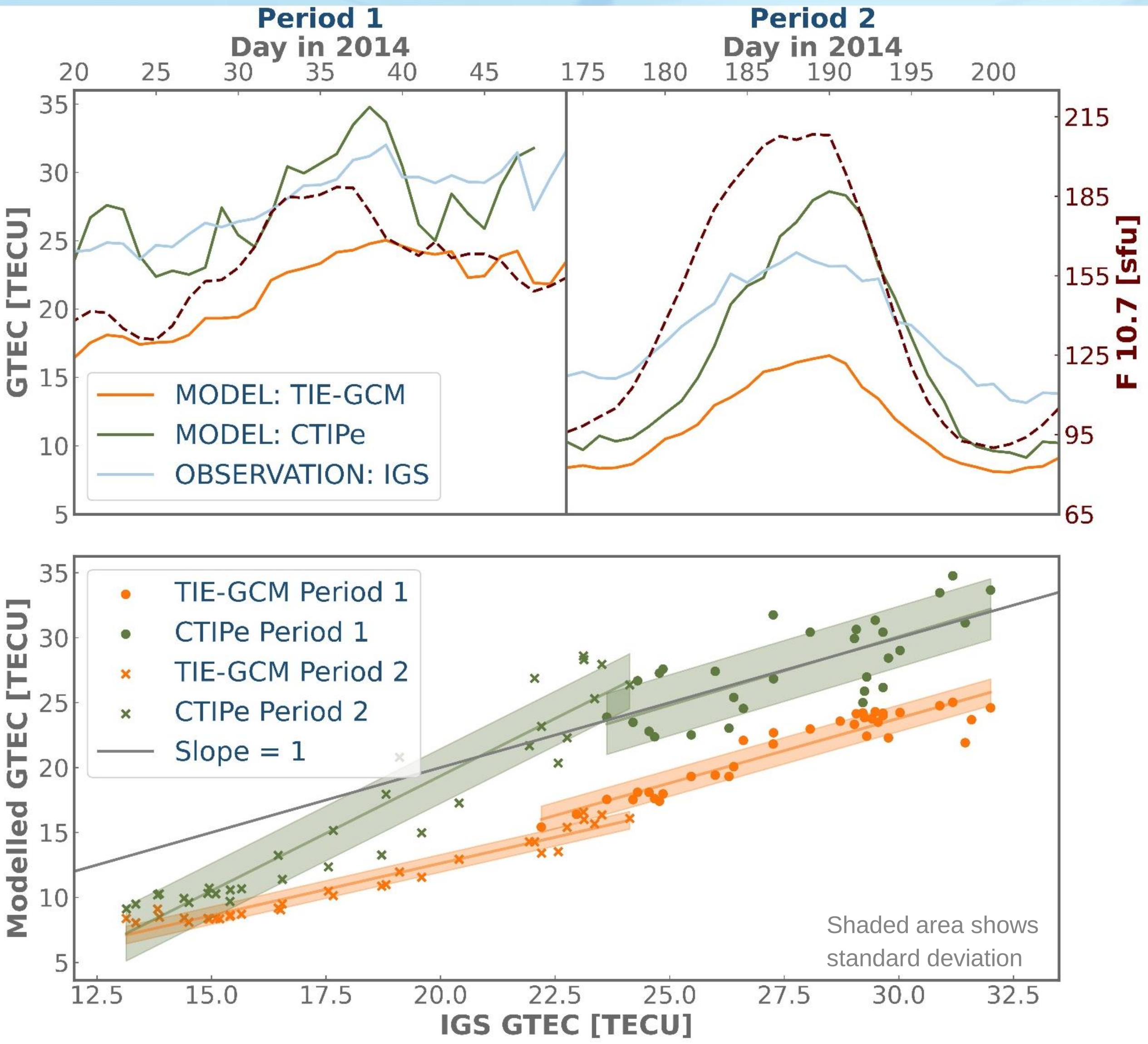
Comparison of TEC Maps



Comparison of models with obs. data:

Phenomena	TIE-GCM	CTIPe
Equatorial Anomaly	Overestimated	Underestimated
Latitude dependent TEC	Localized deviations	Well correlated

Comparison of GTEC



- TIE GCM results show constant offset to observational data
- CTIPe shows too strong TEC response to changes in F10.7

Correlation coefficients to IGS data:

Period	TIE GCM	CTIPe
1	0.93	0.74
2	0.97	0.95

Delay Analysis

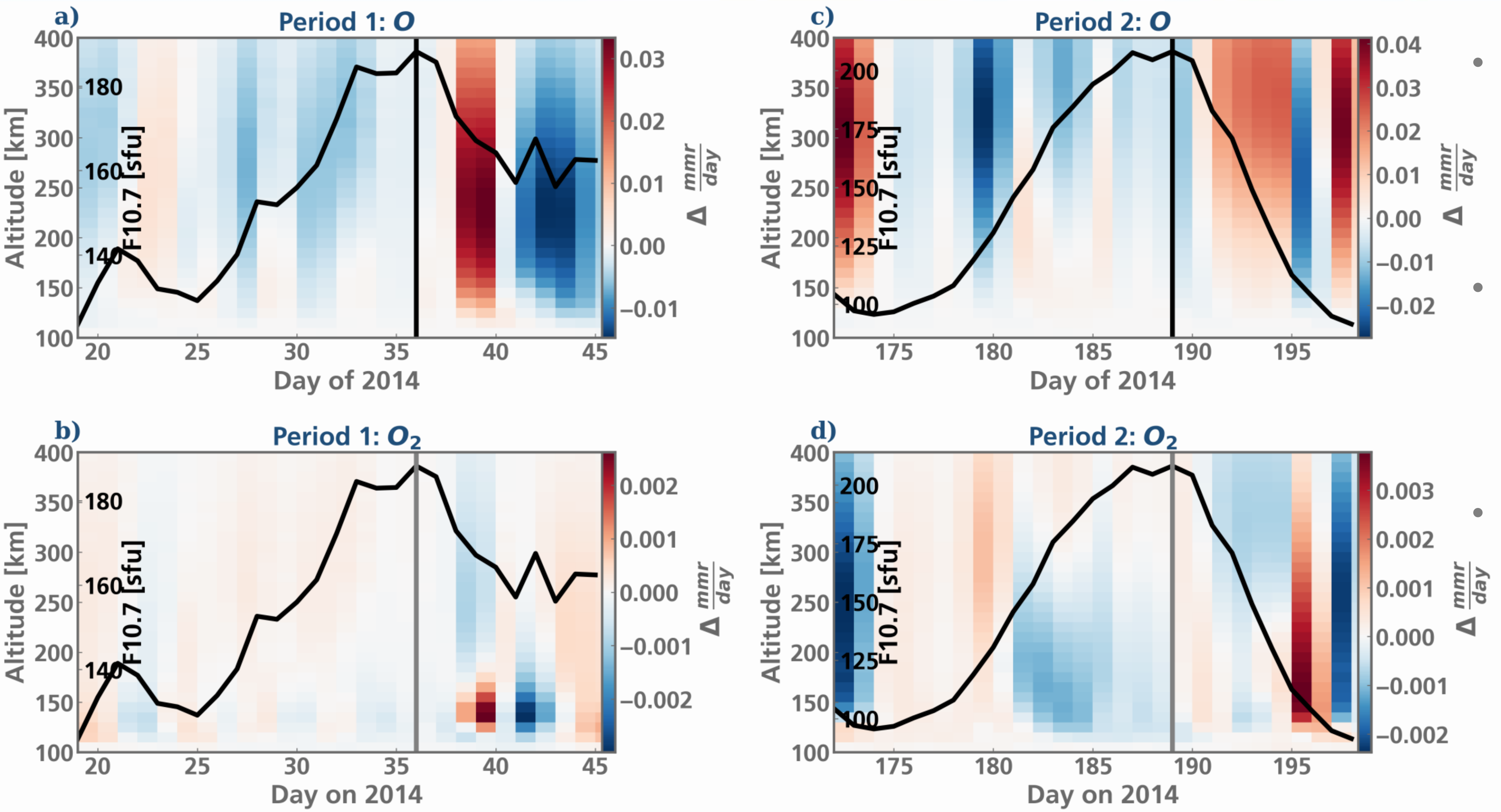


Figure: Day to day changes in concentrations of neutral species per altitude at 51.5° N, 0°W, and 12:00 h UTC. Gray vertical line marks the maximum solar activity. Modelled with TIE-GCM.

- Underlying trend in solar activity dominates 27-day pattern in Period 1
- Accumulation of O_2 and loss of O delayed to solar activity maximum by 1-3 days
- Decreased delay at higher altitudes

Conclusion

Model comparison:

- Good agreement with observational data
- Both models show systematic differences to observational data

Delay analysis:

- Agreement with previous studies based on idealized solar EUV radiation, especially for Period 2
- Altitude dependent delay for O_2 decreasing with height

1. Which processes are significant for the difference in ionospheric response between the idealized and non-idealized solar EUV signature?
2. How are the underlying processes modelled differently to cause systematic differences to the observational data?

Thank You!

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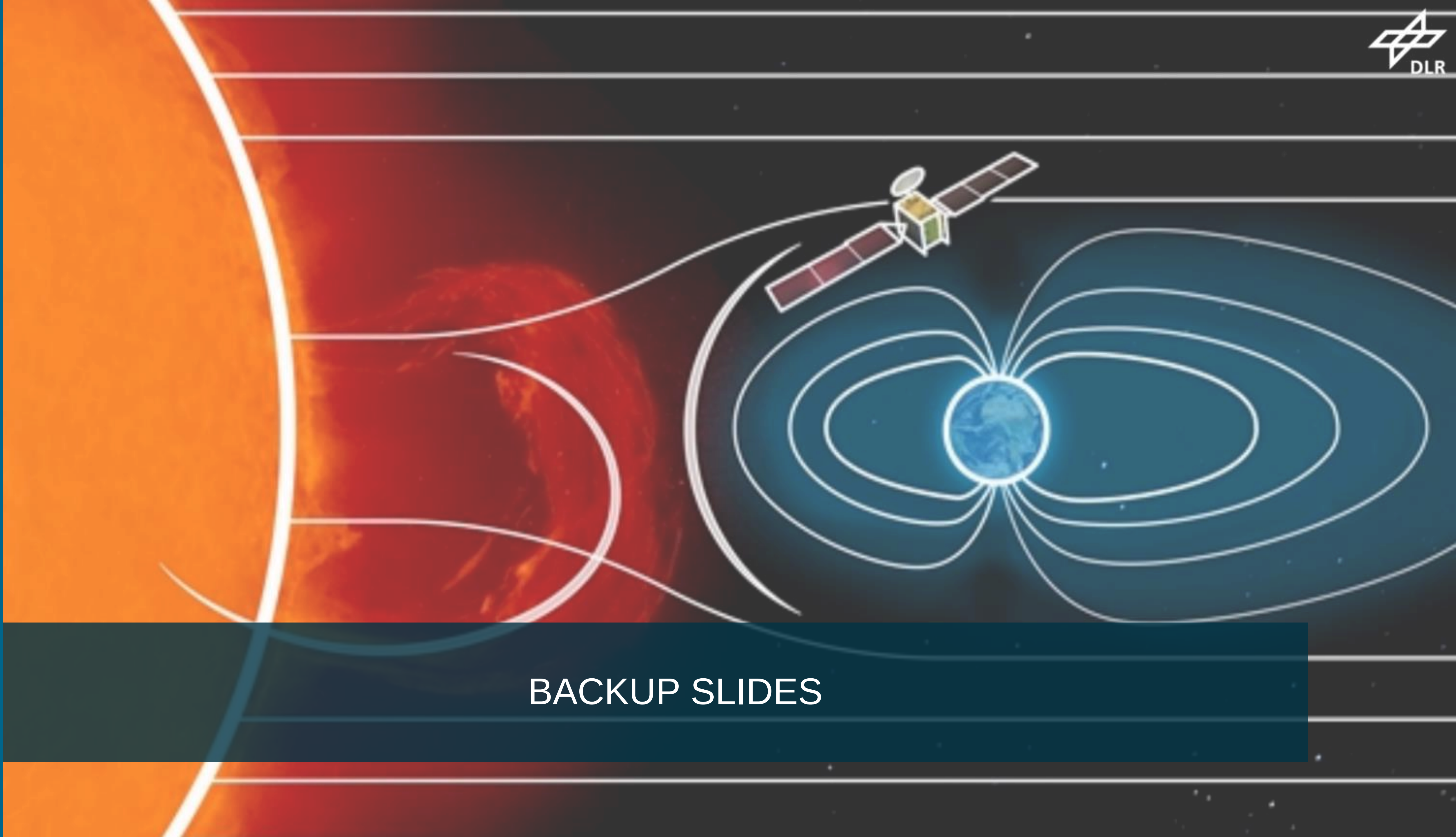

BACKUP SLIDES

Ionized components