Exploring Stormtime Ionosphere-Thermosphere Dynamics With the Multiscale Atmosphere-Geospace Environment (MAGE) Model

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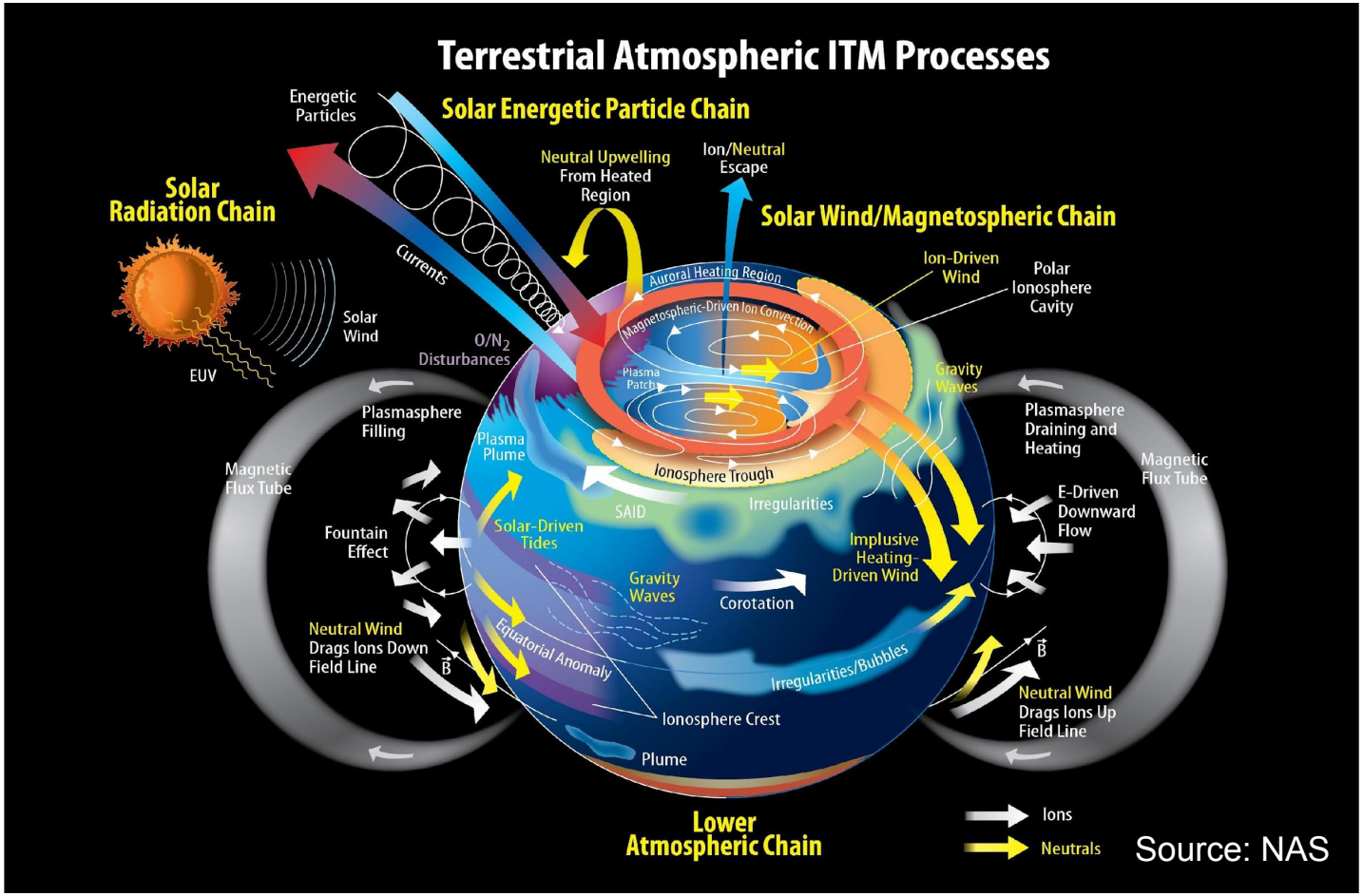
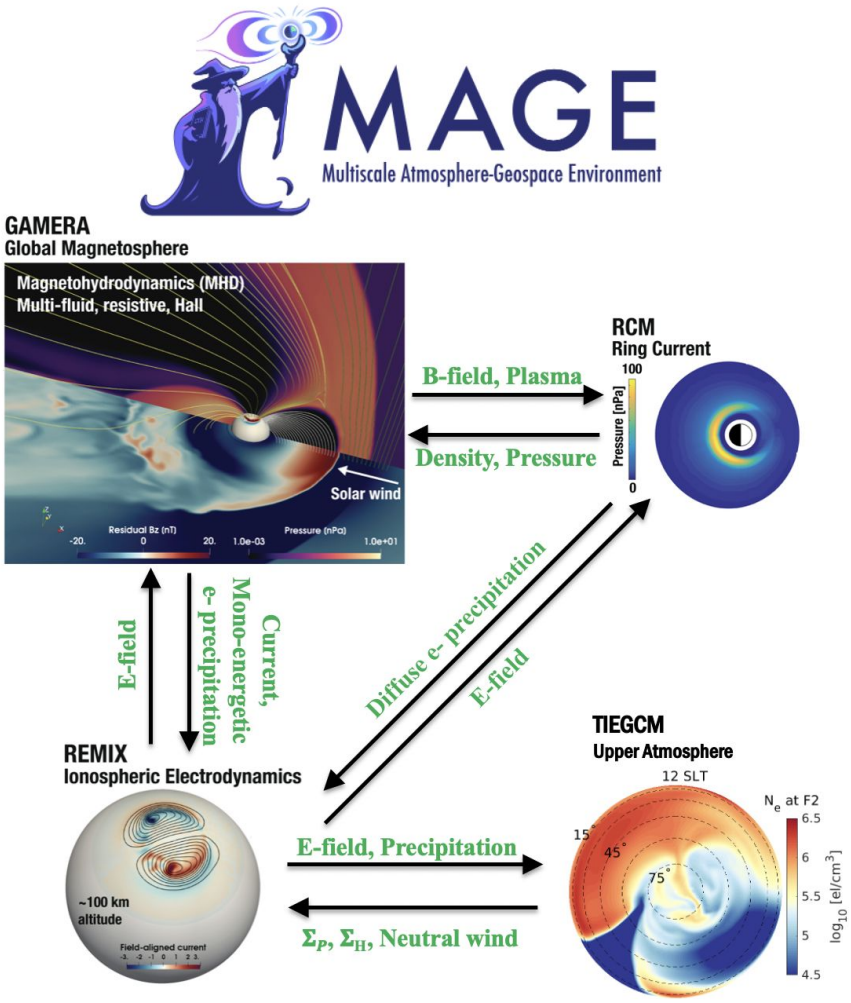
The Ionosphere-Thermosphere System



- The IT system is characterized by multiple spatial-temporal scales and driven by forcings from the magnetosphere and the lower atmosphere.

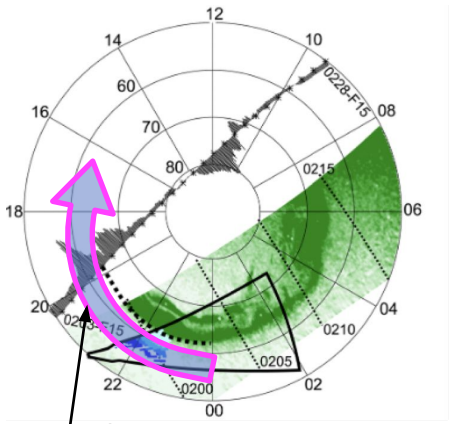
MAGE Model

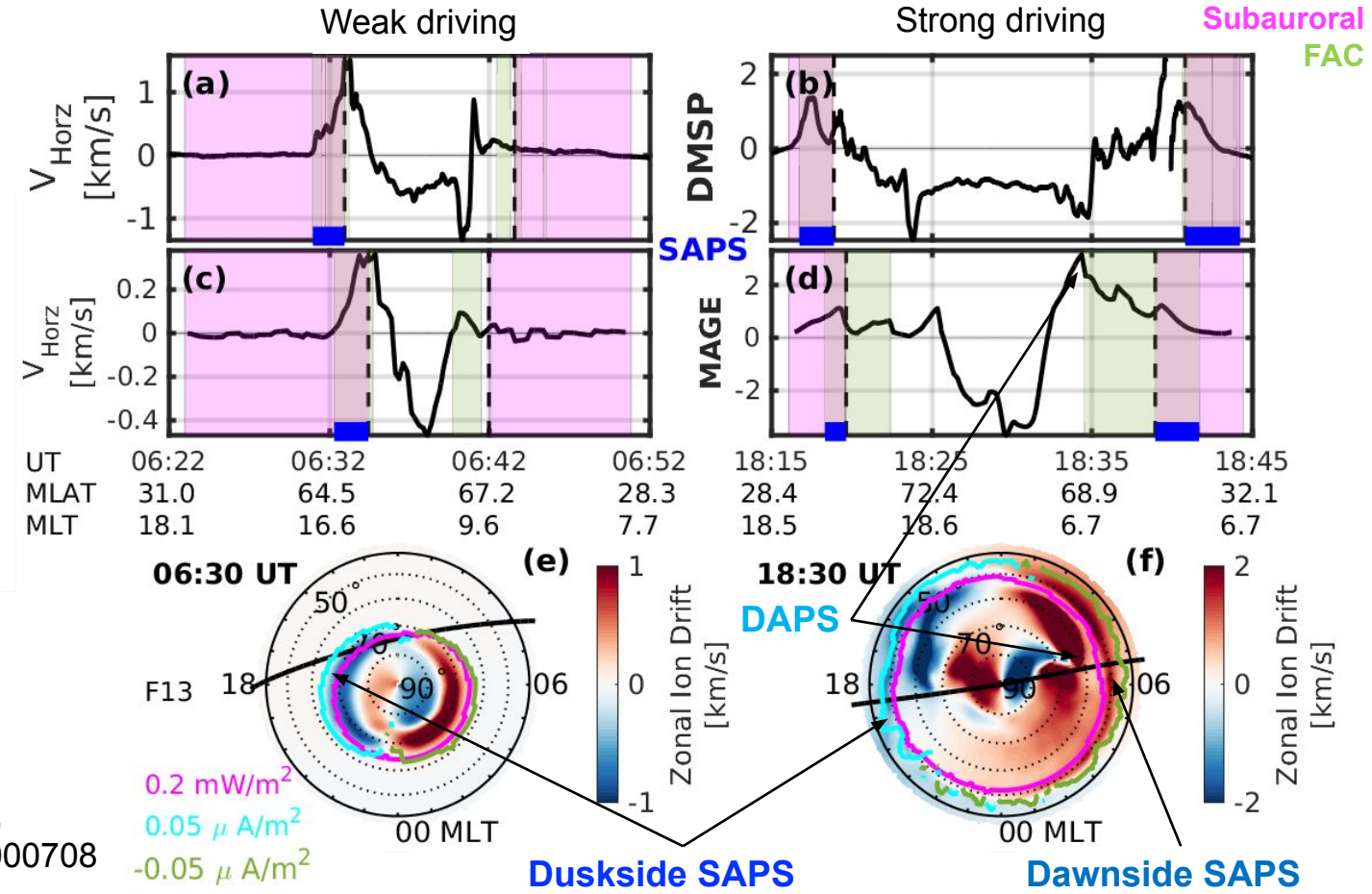


Lin et al., 2021; Pham et al. 2022

- The Multiscale Atmosphere-Geospace Environment (MAGE) model is a whole geospace model under development at the NASA DRIVE Science Center for Geospace Storms (CGS).
- The current version 1.0 of MAGE consists of two-way coupled GAMERA, RCM, and TIEGCM model for the magnetosphere-ionosphere-thermosphere (MIT).
- MAGE has been widely used in multiscale MIT dynamics during storm time.

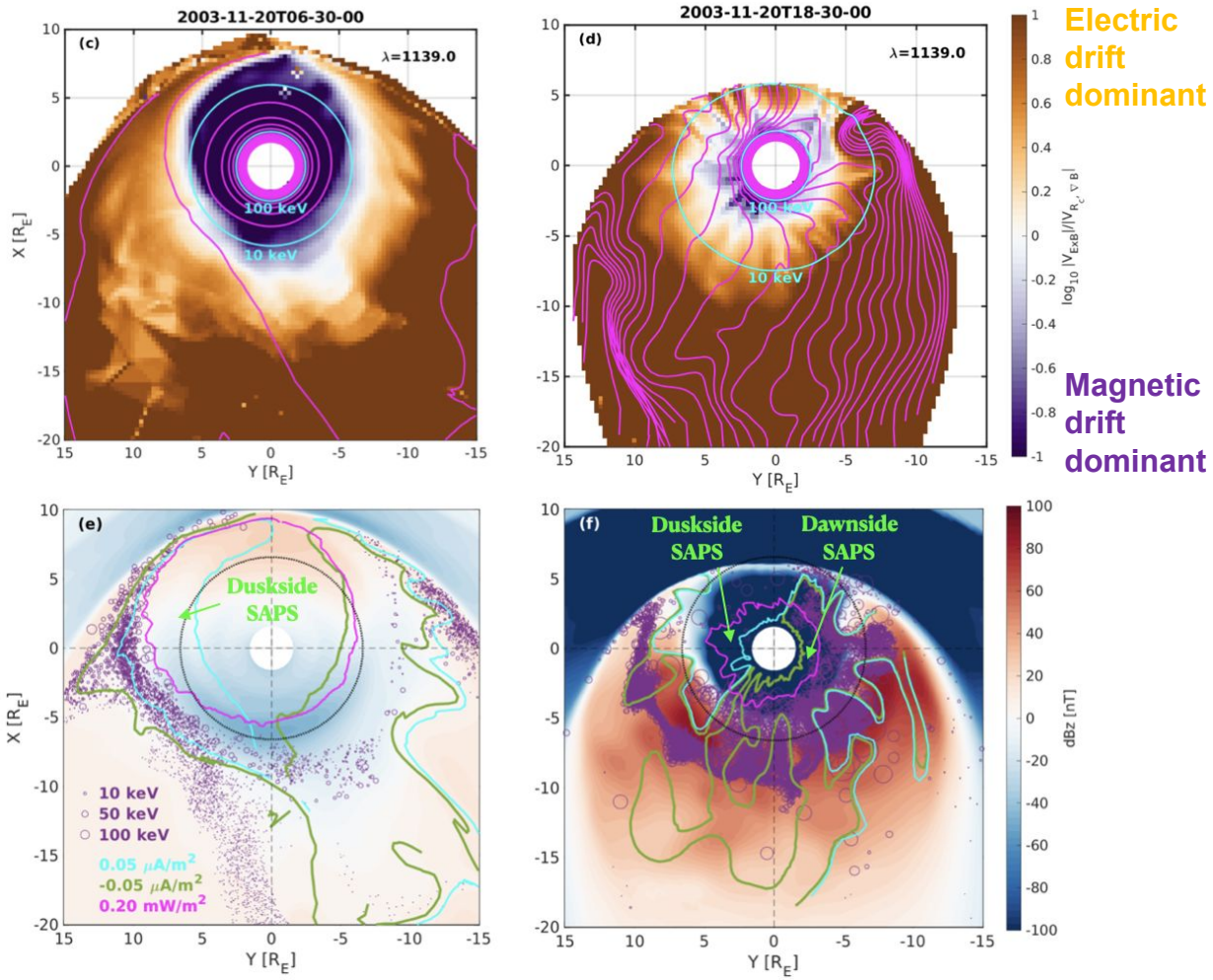
Dawnside Subauroral Polarization Streams (SAPS)





- SAPS are a common mesoscale ionospheric structure (100s km) that result from MIT coupling and can have significant space weather effects.
- Dawnside SAPS were found during the main phase of a major geomagnetic storm on 20 November 2003.

Magnetospheric equatorial plane

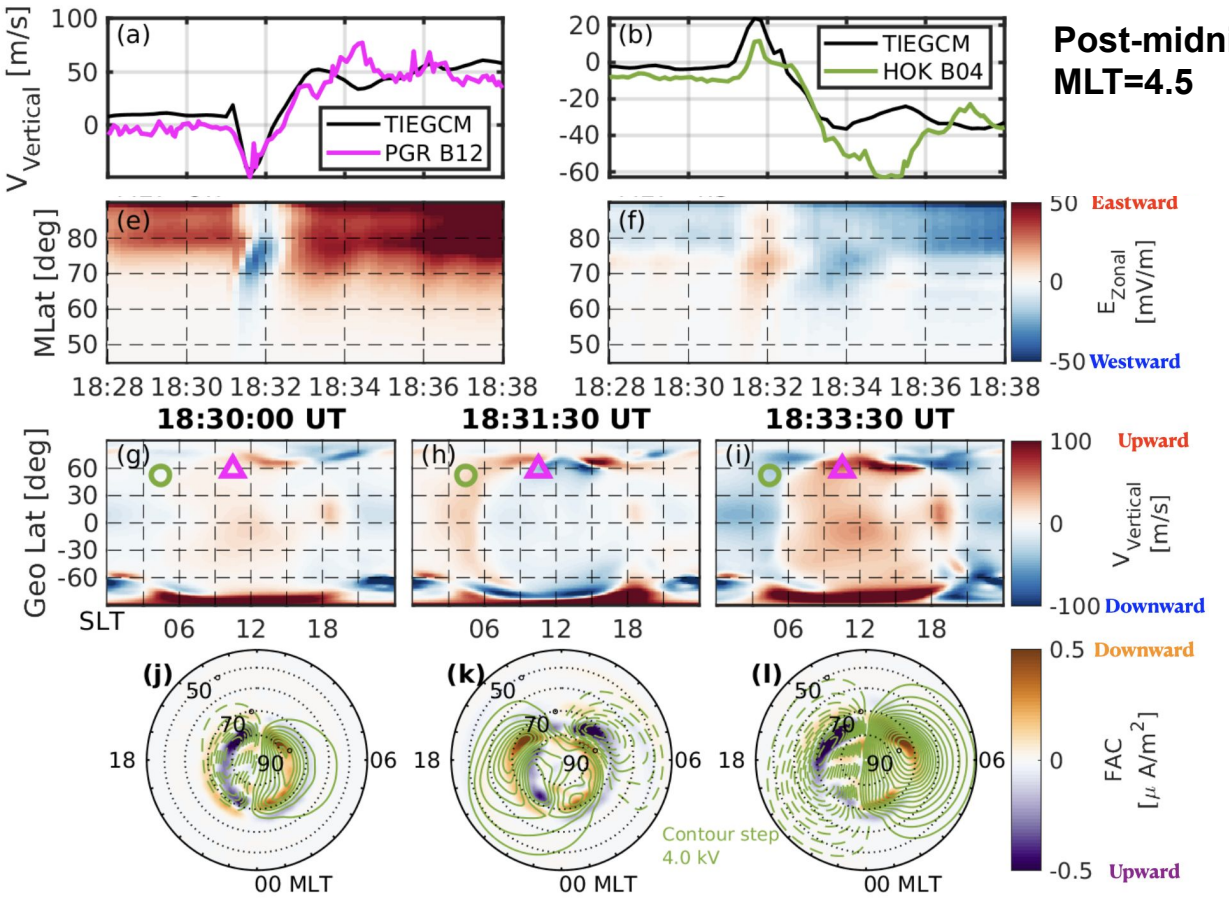


- **Competition between electric drift and magnetic drift**: energetic ions can only access the dawnside when convection is strong enough to overcome the westward B drift.
- Ions penetrate deeper than electrons on the dawnside to form a gap between auroral boundary and upward R2 FAC boundary to form the eastward SAPS.

Geospace Concussion

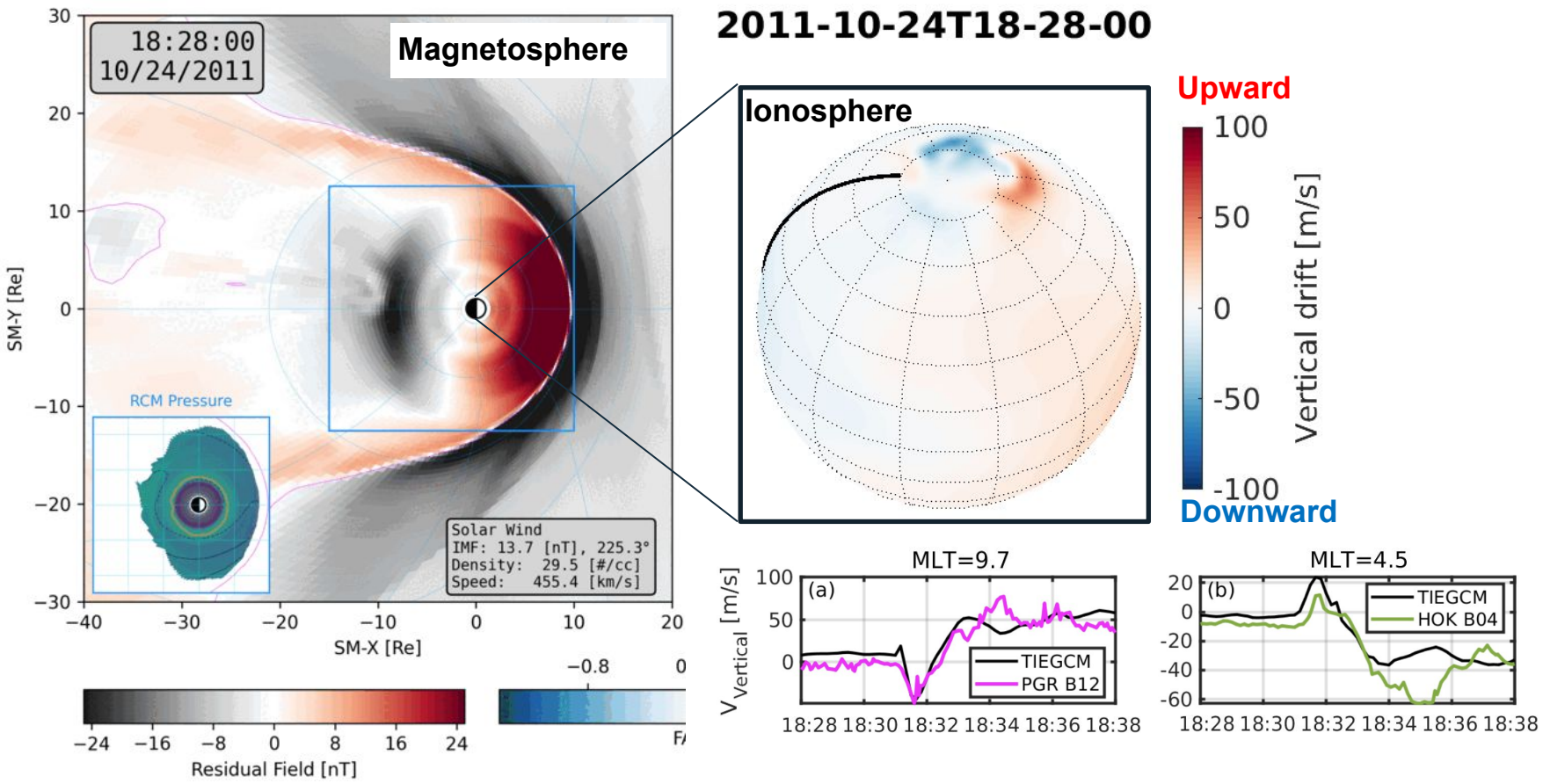
Dayside MLT=9.7

Post-midnight MLT=4.5



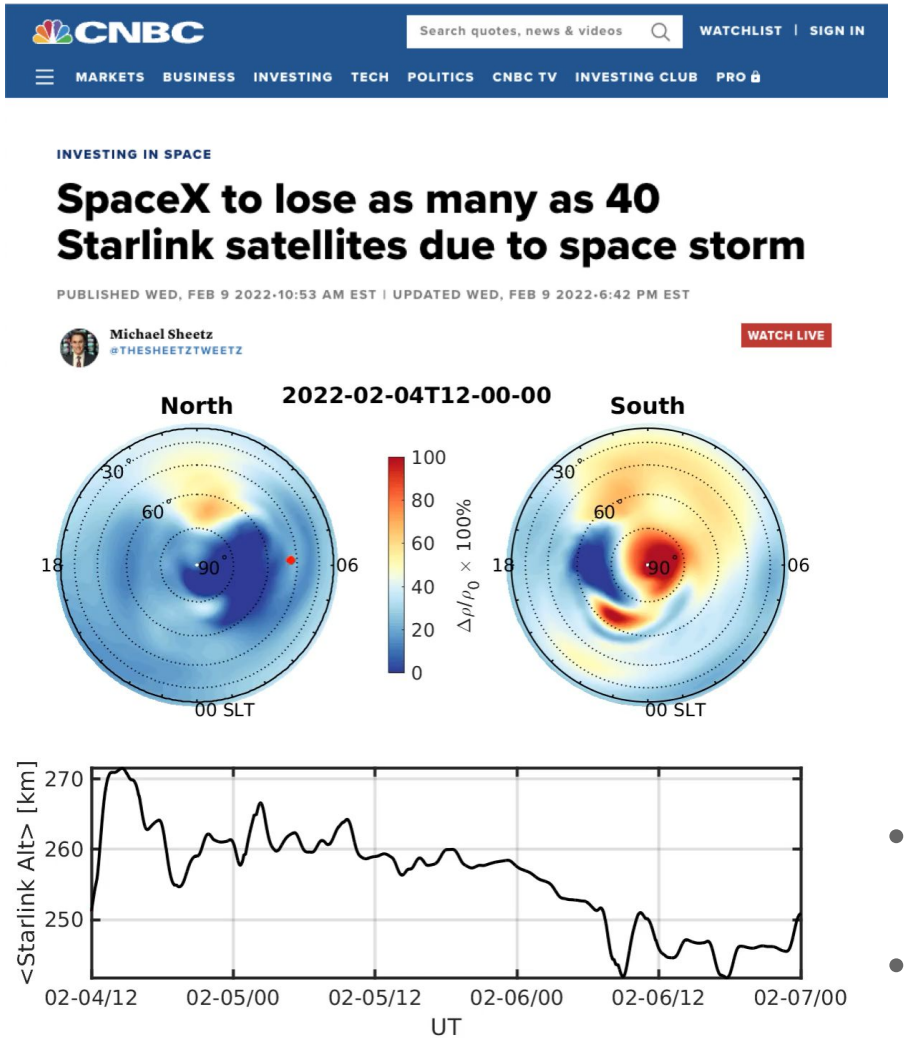
Shi, Lin et al., 2022GL100014

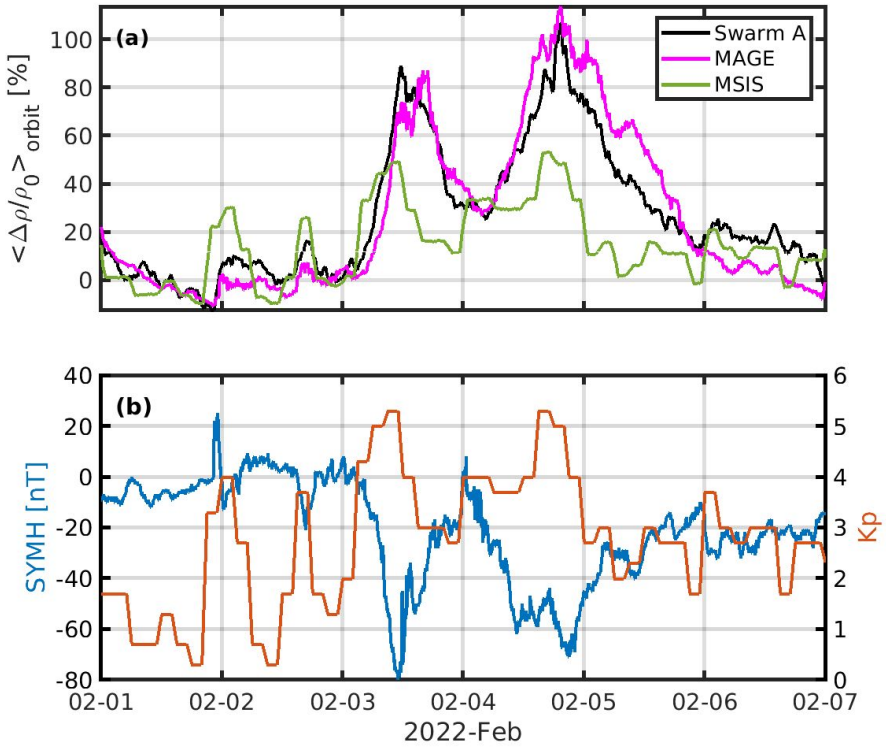
- Geospace concussion refers to a transient (~1 min) global reversal of ionospheric vertical drift during sudden storm commencement.
- The ion drift reversal is explained by the reversal of zonal E field when an opposite pair of field-aligned current is produced by the sudden compression of dayside magnetosphere.



- Geospace concussion viewed from the perspective of coupled magnetosphere-ionosphere.

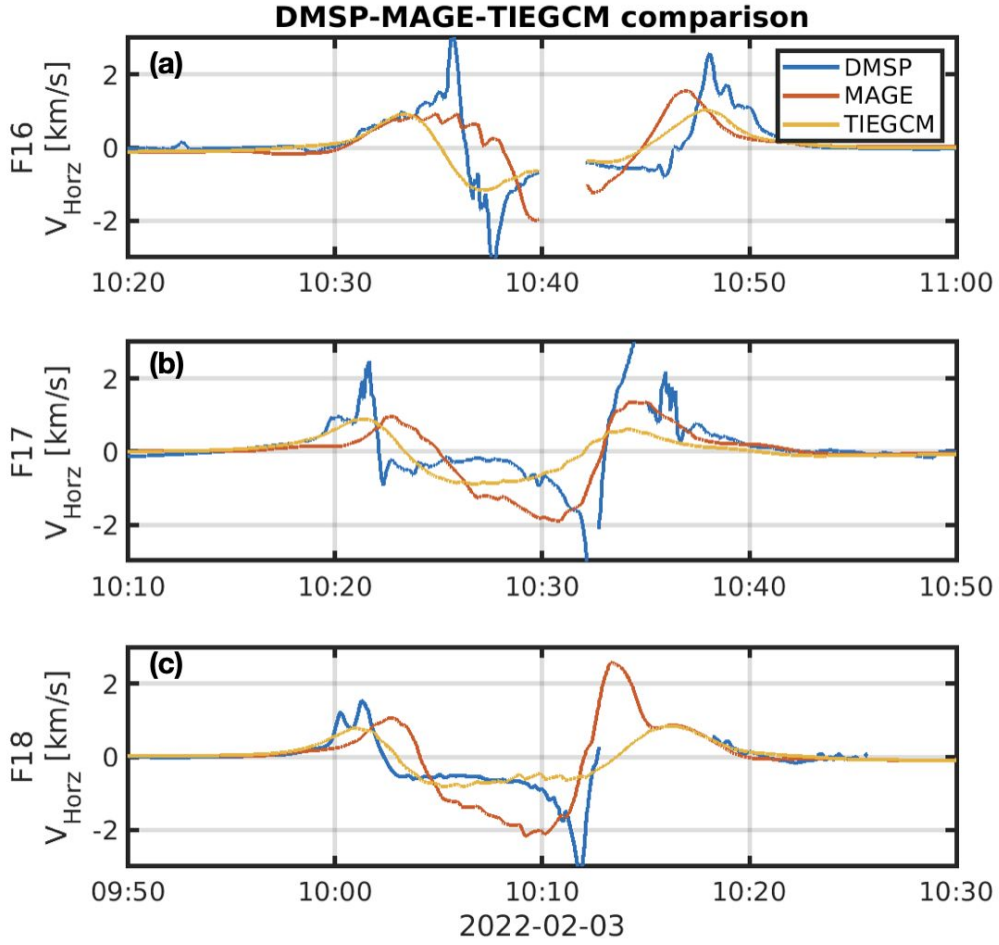
Neutral density variation during the “SpaceX” storm

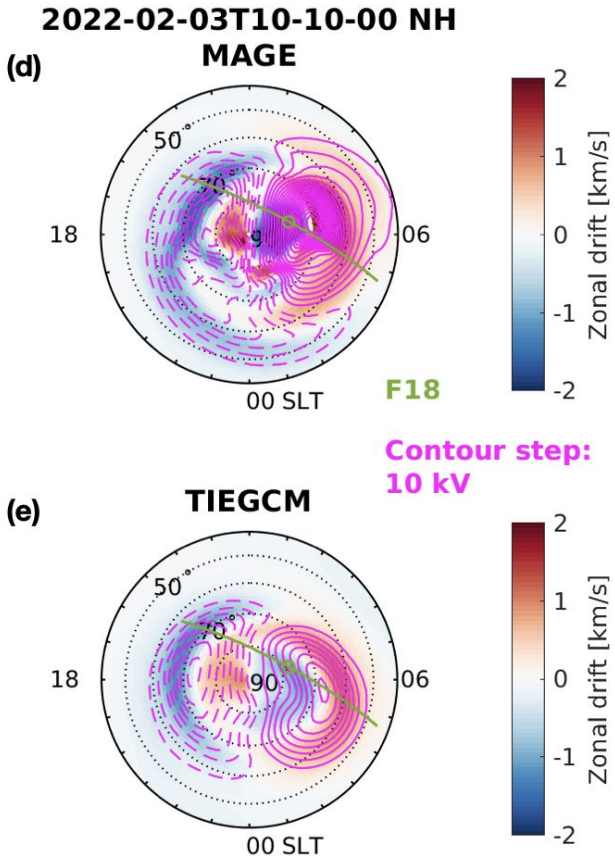




- SpaceX lost ~40 satellites during a moderate geomagnetic storm on 3-4 Feb 2022.
- Stormtime neutral density variation is reproduced by MAGE with a better agreement than by empirical models.

Lin et al., 2022SW003254





- The better performance of MAGE is attributed to a more accurate specification of magnetospheric forcing, e.g., convection, precipitation, which are more dynamic and intense during storm time than statistical average pattern.

Summary

- The MAGE model has been widely used in the study of storm time mesoscale and transient IT dynamics and space weather effects:

1. Dawnside SAPS are formed during strong geomagnetic storms.
2. Geospace concussion occurs as a transient response (~1 min) to sudden commencements.
3. First-principles specification of magnetospheric forcing is needed to reproduce the thermospheric neutral density variation.

- **These studies highlight the importance of treating the geospace as a coupled system in s dies.**