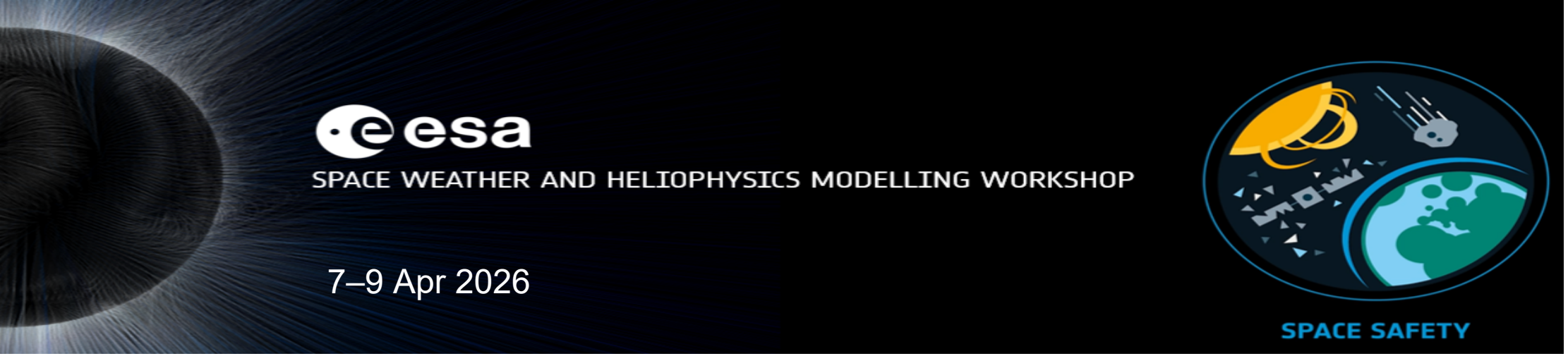

THERION Retrieve Thermospheric parameters at mid and equatorial latitudes

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OUTLINE

- Monitoring the thermosphere
- State of the art: models and observations
- THERION
- Mid latitude
- Equatorial latitude
- Future developments
- Conclusion

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Thousands of satellites (communication, military, navigation) are orbiting around the Earth, their orbiting characteristics being dependent on neutral density.

Therefore the development of methods to nowcast and forecast atmospheric drag effects on satellites is a very actual problem

Direct observations of Thermosphere parameters are technically complicated, very expensive and cannot be conducted on the regular basis

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Thermosphere: Current Observational and Models Capabilities and Limitations

- **LEO satellite accelerometers (SWARM, GRACE/GRACE-FO)**
  - Thermospheric density inferred at **~500 km altitude and above**
- **GNSS-based density retrievals**
  - Complementary estimates at similar orbital altitudes
- **Optical observations**
  - Large-scale thermospheric signatures
  - Limited real-time availability
- **Key limitation**:
  - **Lack of routine observations in the thermosphere (~200–400 km)**
  - Critical region for ionosphere–thermosphere coupling and satellite drag

Most thermospheric observations are limited to altitudes of ~500 km and above, leaving the 200–400 km region largely unobserved

Ionospheric-Thermospheric models

Physics-based Model

(TIGCM, CTIPe, WAM-IPE, GAIA)

Empirical Models

(IRI, MSISE, DTM, JB

Because the thermosphere is poorly observed, models are not optional but essential for storm-time monitoring and early-warning applications.

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A new approach to monitor the thermosphere based on routine ionosonde observations and when available neutral density observations from satellite

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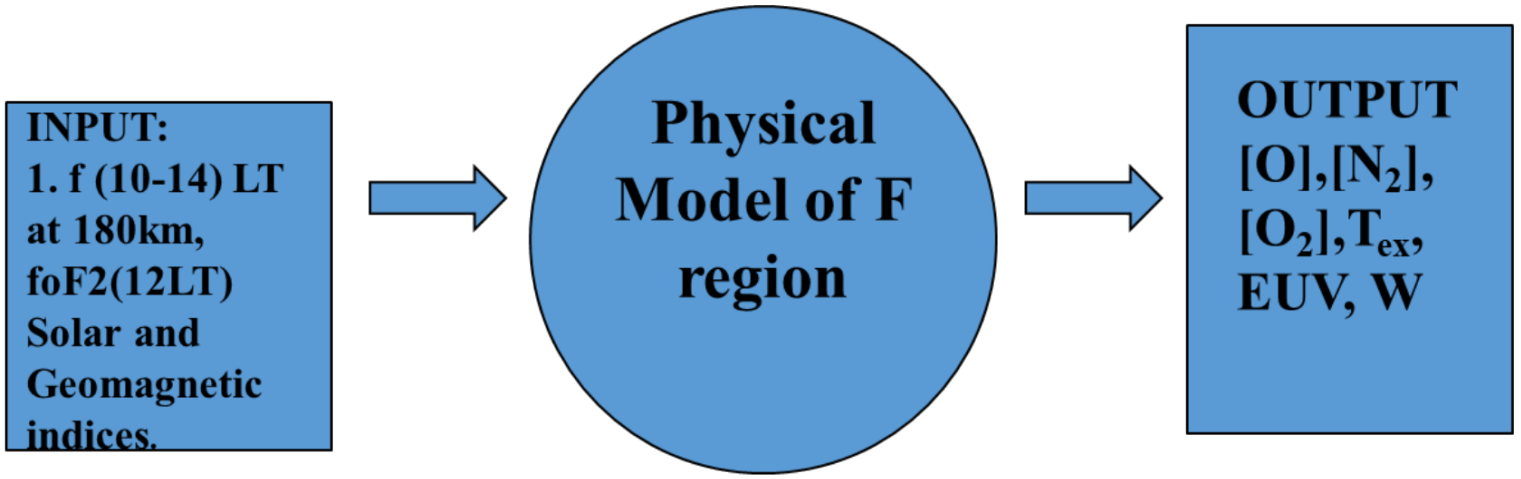
METHOD TO RETRIEVE THERMOSPHERIC PARAMETERS

(Perrone,Mikhailov, JGR, 2018;Space Weather,2025)

THERION retrieves thermospheric parameters from ionospheric observations at mid and equatorial region at 12LT



*Others input that are used when available: neutral density observations from satellite

THERION is currently at research stage but shows strong potential for operational applications

THERION is inserted in SPACE IT UP project funded by ASI

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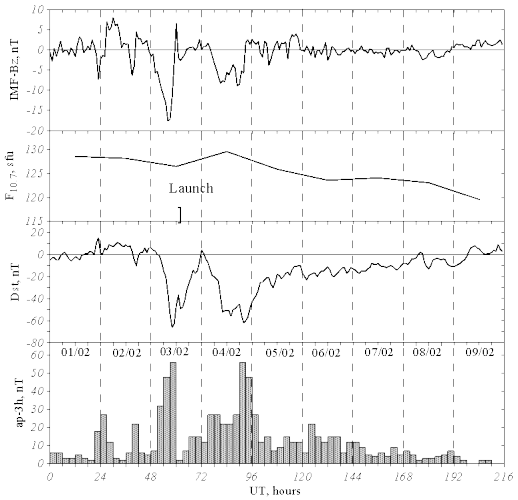
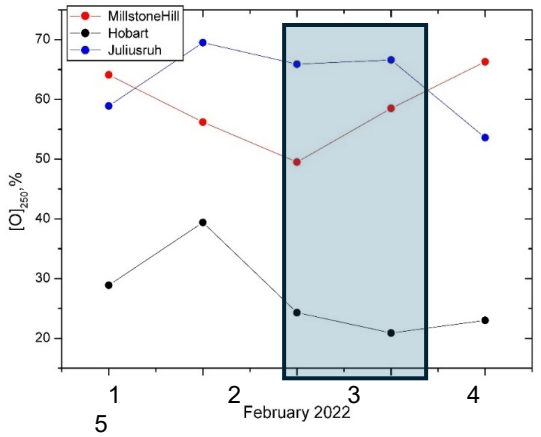
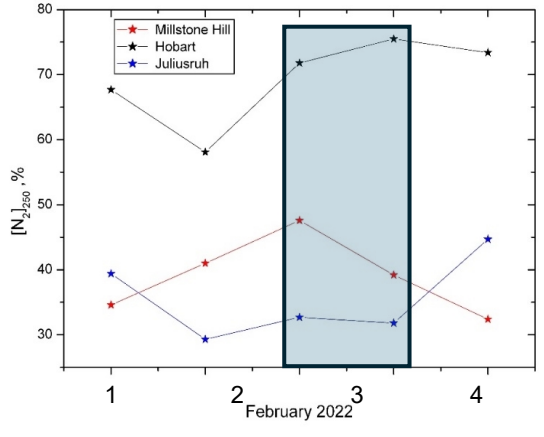
Mid Latitude: The state of thermosphere, using ionosonde and Swarm C observations, during the storm of February 3, 2022 resulted in the loss of 38 SpaceX Starlink satellites.



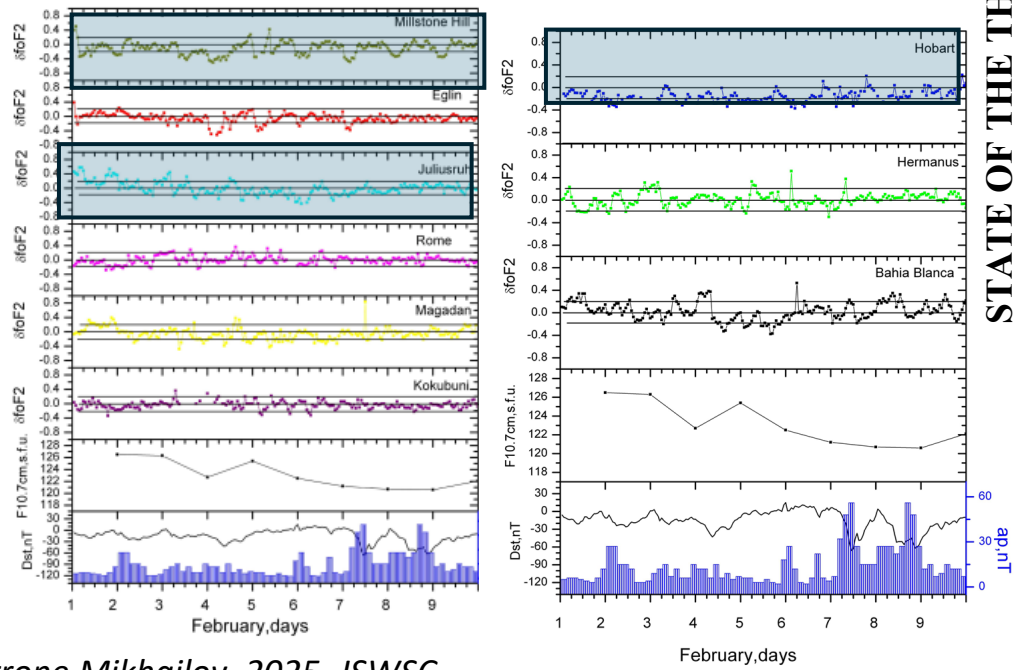
On 3 February 2022, SpaceX Starlink launching 49 satellites 38 have been lost due to enhanced neutral density associated with two moderate geomagnetic storms



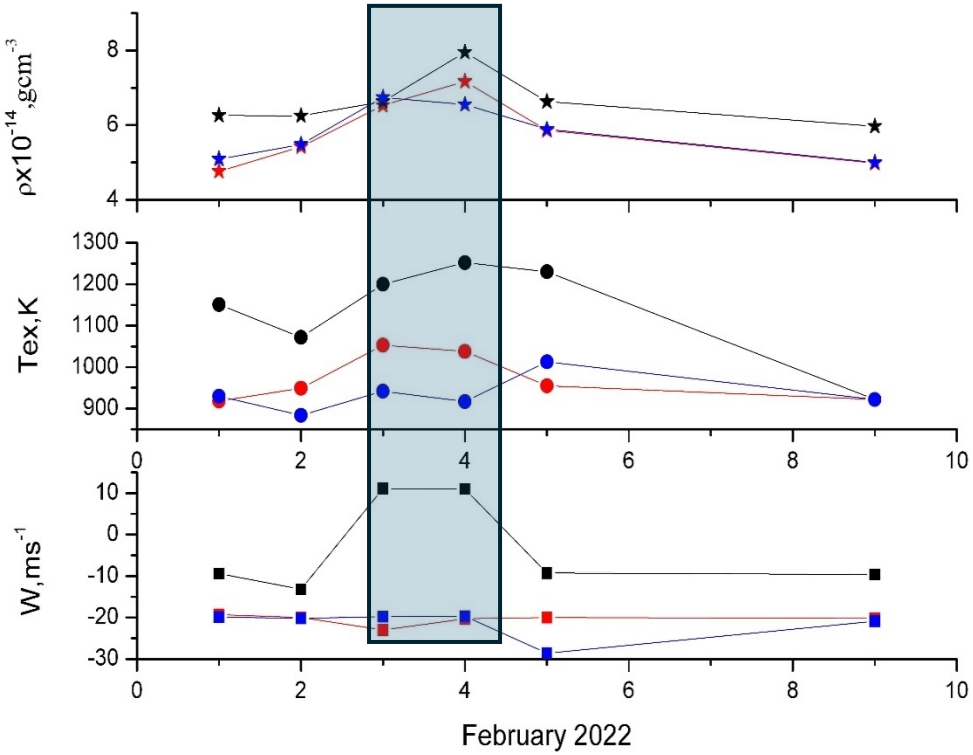


STATE OF THE IONOSPHERE

Northern Hemisphere Southern Hemisphere



STATE OF THE THERMOSPHERE



Due to the 3 February storm the max increase of neutral density at 12LT is seen in Hobart

Perrone,Mikhailov, 2025, JSWSC

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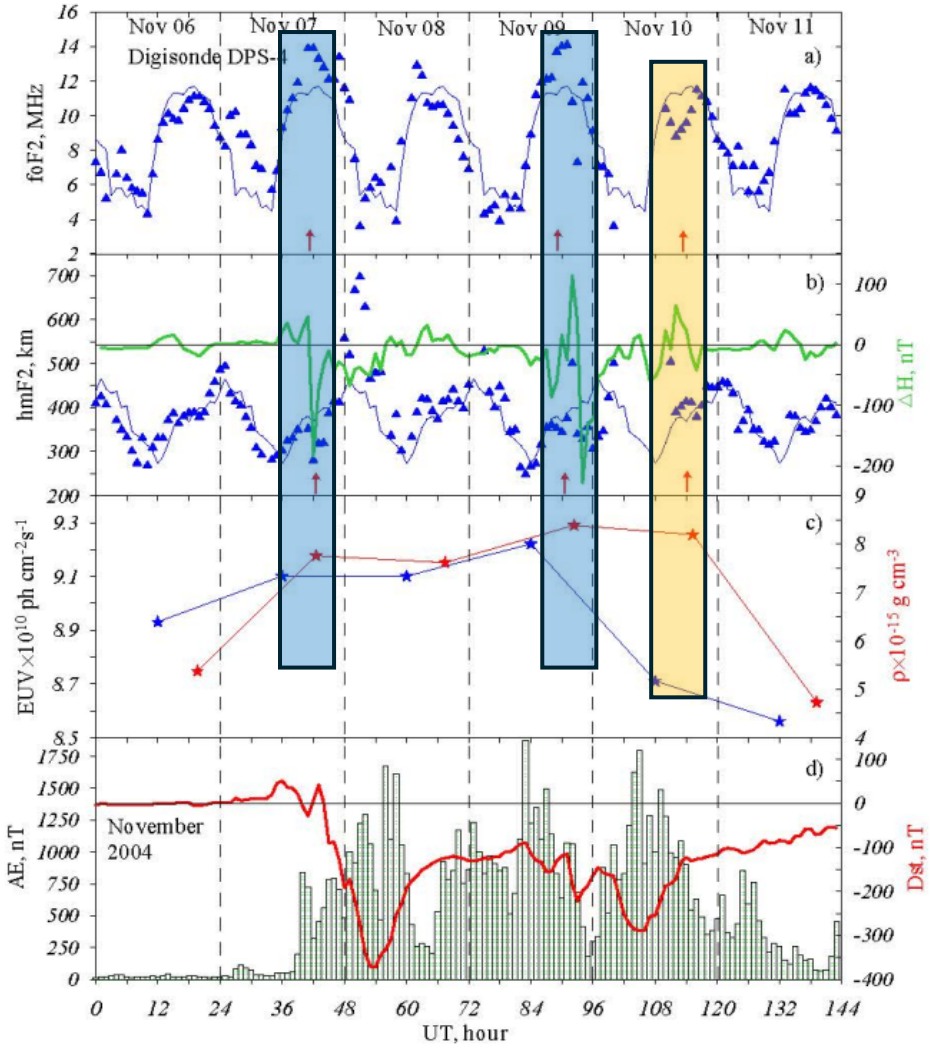
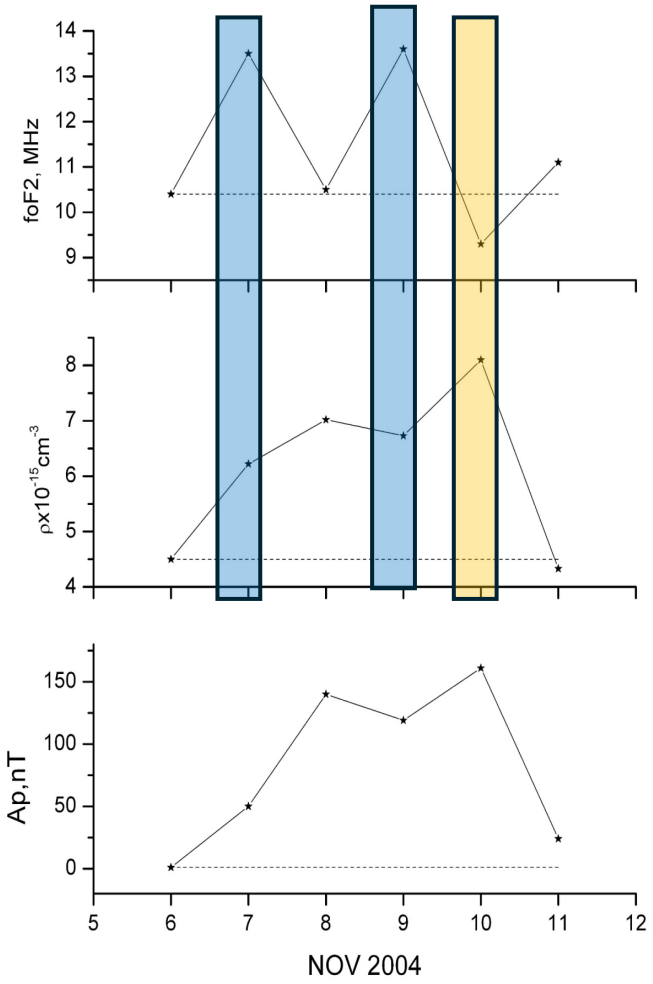
Equatorial Latitude:Retrieved parameters for a severe geomagnetic storm in November 2004

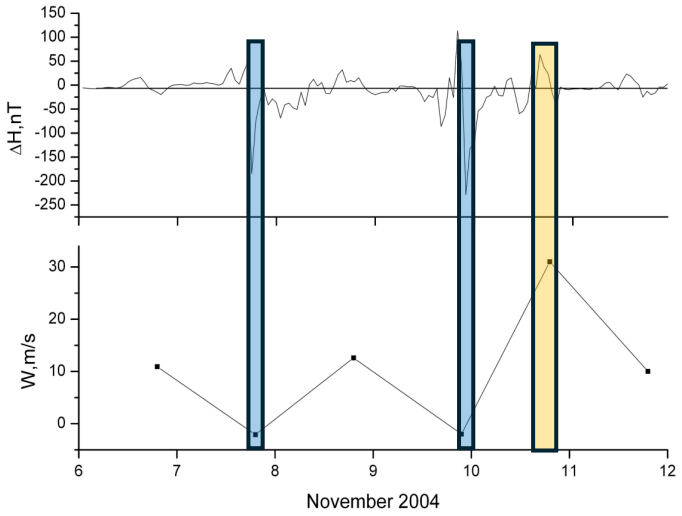


Perrone,Mikhailov, Space Weather, 2025



The deviation of the H-component from the nighttime (00-04 LT) level for the two stations and the difference

ΔH(Huancayo) - ΔH(Fuquene) were calculated.



The H-component of magnetic field ground observations may be used to check the retrieved vertical drifts.

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FUTURE DEVELOPMENTS

Potential to monitor the thermosphere using worldwide ionosonde observations, towards a practical tool .

Integration of THERION in the INGV ionosonde network including the new INGV European oblique ionosonde infrastructure

IonoNet.ingv.it

Potential integration with EUROMAP for thermospheric parameter prediction based on ionospheric forecasts

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CONCLUSIONS

THERION provides a novel approach to retrieve thermospheric parameters from ionospheric observation at mid and equatorial region

Addresses the lack of observations in the 200–400 km region, critical for ionosphere–thermosphere coupling

Shows strong potential for future operational applications in space weather services

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