



# Thermospheric Neutral Density Scorecard

Joe Sypal,<sup>1</sup> Jack Wang,<sup>1,2</sup> Jia Yue,<sup>1,2</sup> Paul DiMarzio,<sup>1</sup> Sean Bruinsma,<sup>3</sup> Min-Yang Chou,<sup>1,2</sup> Chiu Wiegand,<sup>2</sup> Masha Kuznetsova,<sup>2</sup> Leila Mays<sup>2</sup>

Catholic University of America<sup>1</sup> CCMC, NASA GSFC<sup>2</sup> GET-CNES, Space Geodesy Office,<sup>3</sup> France

## Problem Statement

In the validation of thermospheric neutral density models, there are still several challenges.

- **Widening validation scope.**
- **Managing model versions**
- **Creating an online platform to track validation progress.**

This validation campaign aims to alleviate these challenges by creating an online platform that can be used to track the validation progress of different models of thermospheric neutral density across time.

## Methodology

This project uses the metric that was proposed in the validation project Sutton, 2018; Bruinsma et al., 2021; Bruinsma and Laurens, 2024. When validating model output for a single peak storm, we analyze four phases of the geomagnetic storm.

- **Phase 1 (Pre-storm):** 30 hours before until 18 hours before  $t_0$
- **Phase 2 (Onset):** 18 hours before  $t_0$  until  $t_0$
- **Phase 3 (Main and Recovery):**  $t_0$  until 36 hours after  $t_0$
- **Phase 4 (Post storm):** 36 hours after  $t_0$  until 48 hours after  $t_0$

Where  $t_0$  is determined by the first time that the ap index reaches 80.

In order to reduce the effect of non storm related model errors, the pre-storm phase is used to de-bias the models using a scaling factor which is applied to the model densities in all four phases.

When validating output for a multiple peak storm, the phases analyzed are similar to those of a single peak storm with one modification: the third phase is extended due to another occurrence of the ap index reaching 80.

## An Interactive Visual Platform

- This scorecard provides a unified, user friendly frontend to explore and compare model validation results.
- It provides the capabilities to trace progress over time by incorporating newer model versions, run settings, and the latest events.



<https://ccmc.gsfc.nasa.gov/itmap/>

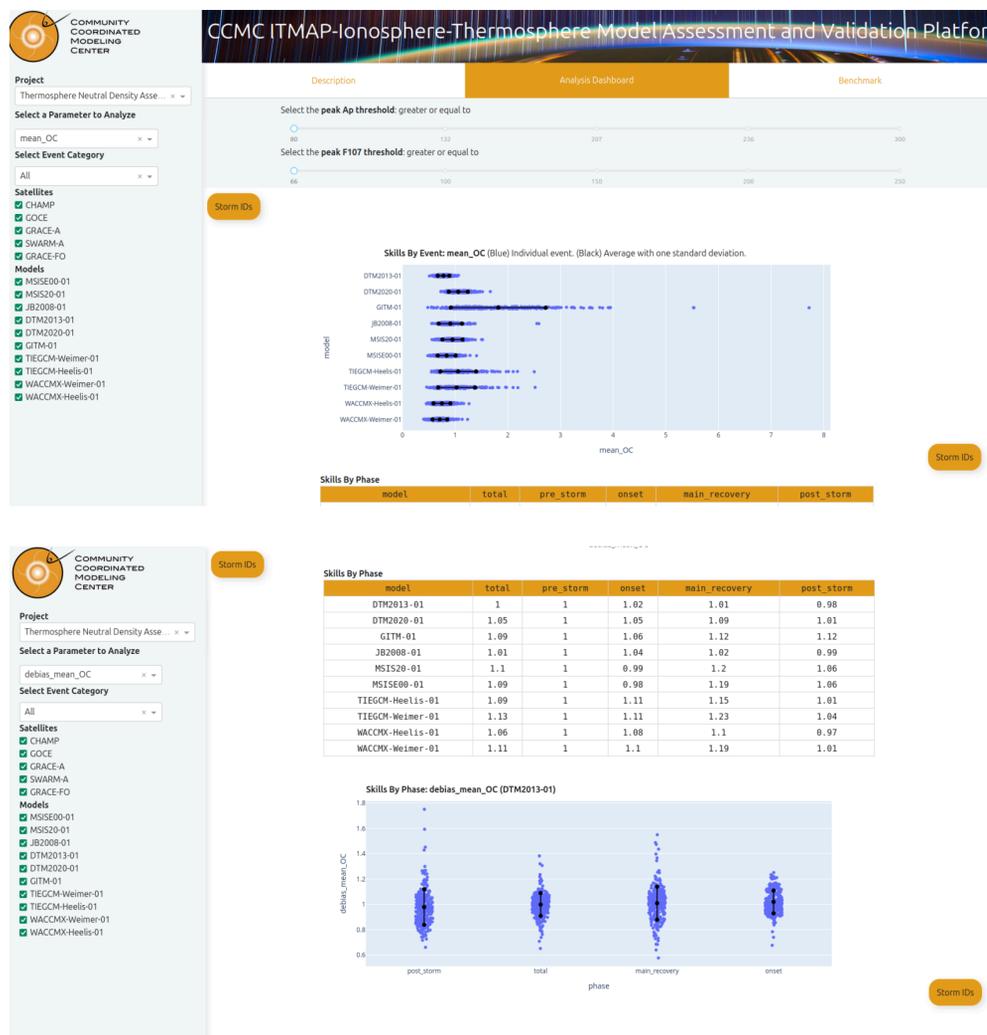


Figure 1: The main page of the Thermospheric Neutral Density Scorecard.

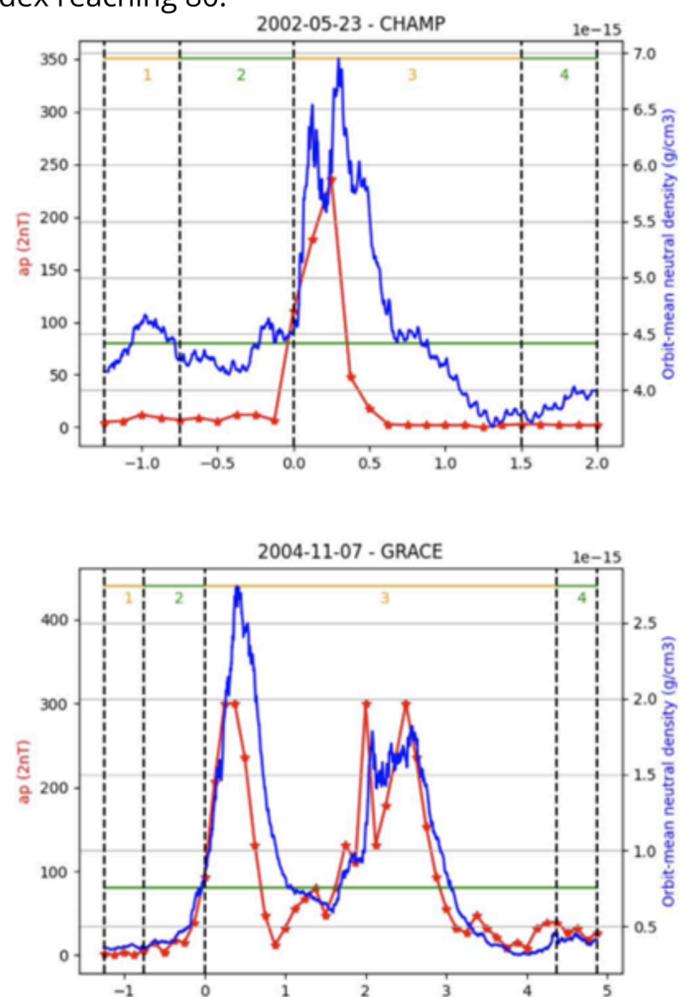


Figure 2: The four phases (Phases 1–4) of the assessment interval for single-peak (top) and multiple-peak (bottom) storms, with  $t_0$  centered on the time of the first peak in ap with a minimum of 80 (horizontal green line). The X-axis represents the day relative to  $t_0$ . (Red) Ap index. (Blue) Orbit-mean neutral density. Adapted from Bruinsma and Laurens (2024).

## References

- Sutton EK. DOI: [10.1002/2017SW00178](https://doi.org/10.1002/2017SW00178).
- Bruinsma S, Boniface C, Sutton EK & Fedrizzi M, DOI: [10.1051/swsc/2021002](https://doi.org/10.1051/swsc/2021002).
- Bruinsma S & Laurens S. DOI: [10.1051/swsc/2024027](https://doi.org/10.1051/swsc/2024027).