

Fusing Ground-Based TEC and GOLD Inferred TEC Using Statistical Calibration

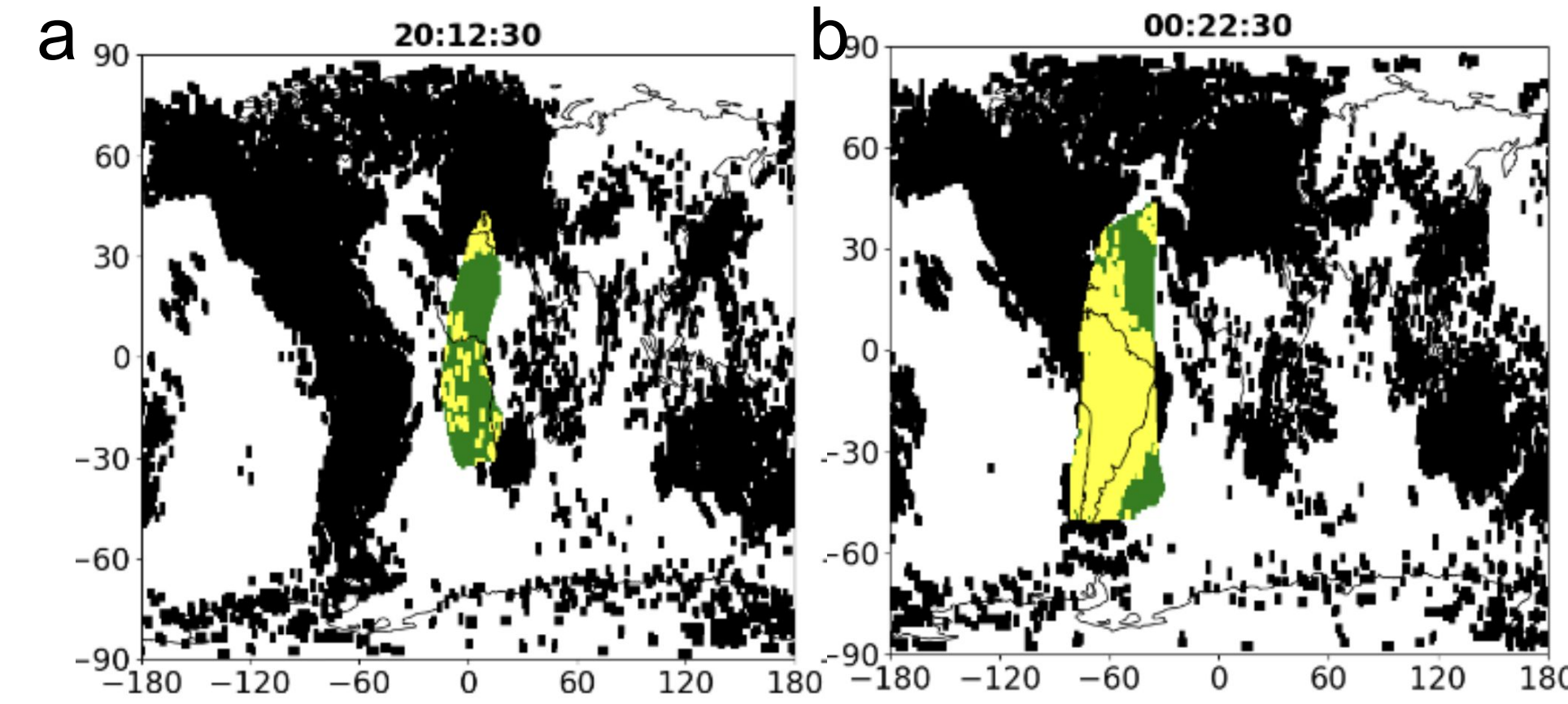
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Introduction

- Currently, TEC is mostly calculated using ground based receivers, which leads to **sparse data over oceanic regions** as well as Asia and Africa.
- This project infers **TEC values from the GOLD oxygen emission 135.6 nm radiance** as a supplement to the existing Madrigal TEC database.
- After the initial combination, a **calibration technique is utilized** to achieve better consistency when merging the datasets.
- The effect of this additional data on the VISTA algorithm is assessed.

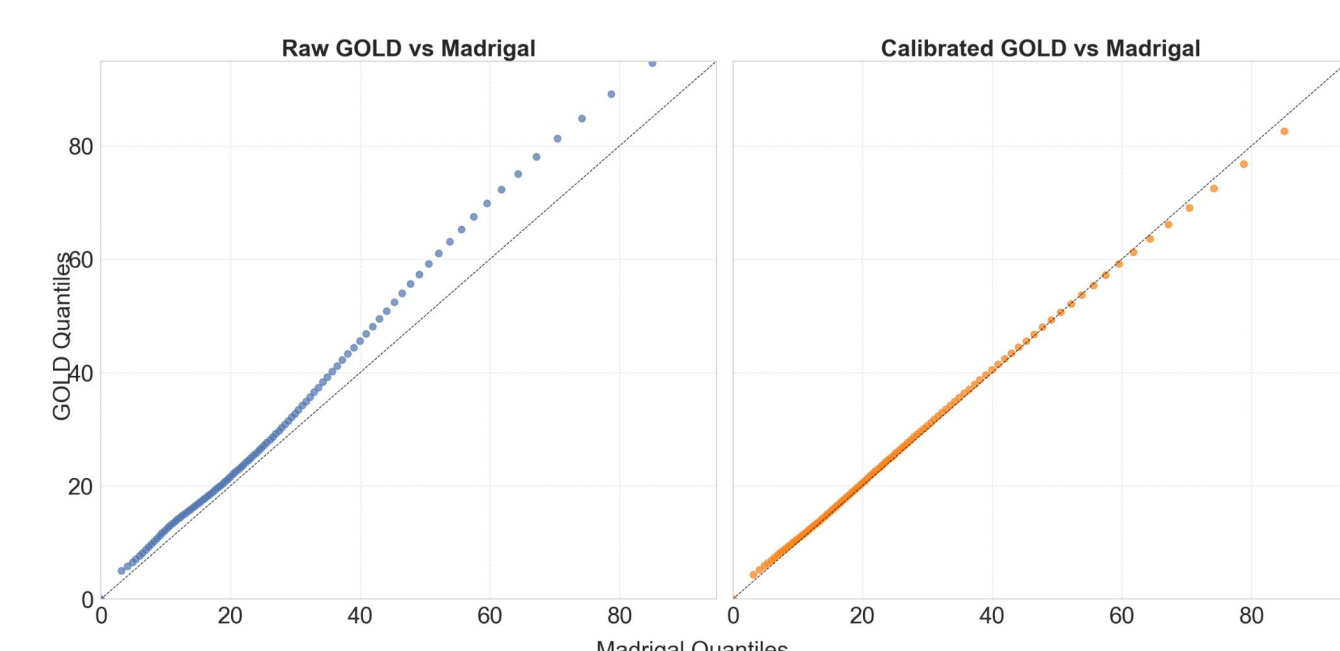
Methods



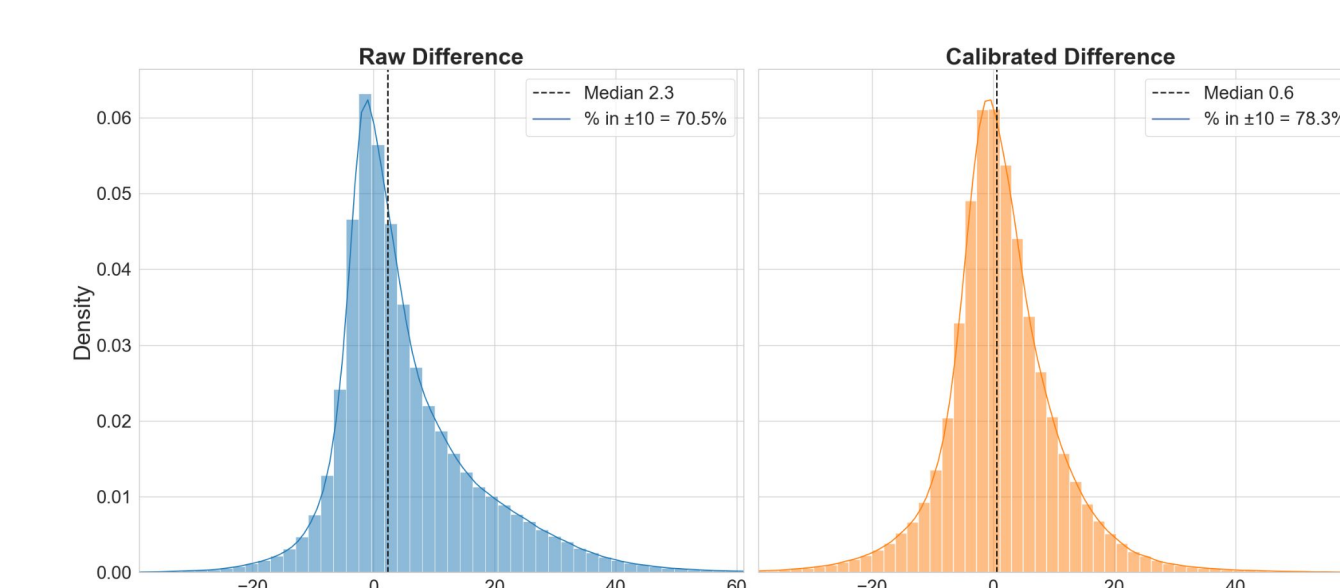
Coverage of GOLD data throughout its daily observation period 20:00(a)-00:30(b) UT. Black: Madrigal. Green: GOLD. Yellow: Both.

Combining and Calibrating Algorithm

- Using Qin et al. (2023) algorithm, preliminary TEC values are calculated based on OI GOLD observations.
- GOLD's resolution is decreased to a $1^\circ \times 1^\circ$ geographic grid for compatibility with the Madrigal TEC data.
- A median filter is applied to both datasets and overlapping data points are identified.
- To avoid solar and auroral contaminations, observations below 110 SZA and above a certain magnetic latitude are also eliminated.
- A target Empirical Cumulative Distribution Function (ECDF) is created from an hour of Madrigal values at common locations.
- An inverse CDF transforms all GOLD data to match the target distribution.



QQ plots before and after calibration



Distribution of difference between GOLD and Madrigal TEC for March 2024. Up to **7.8% increase in data with difference under 10 TECU**.

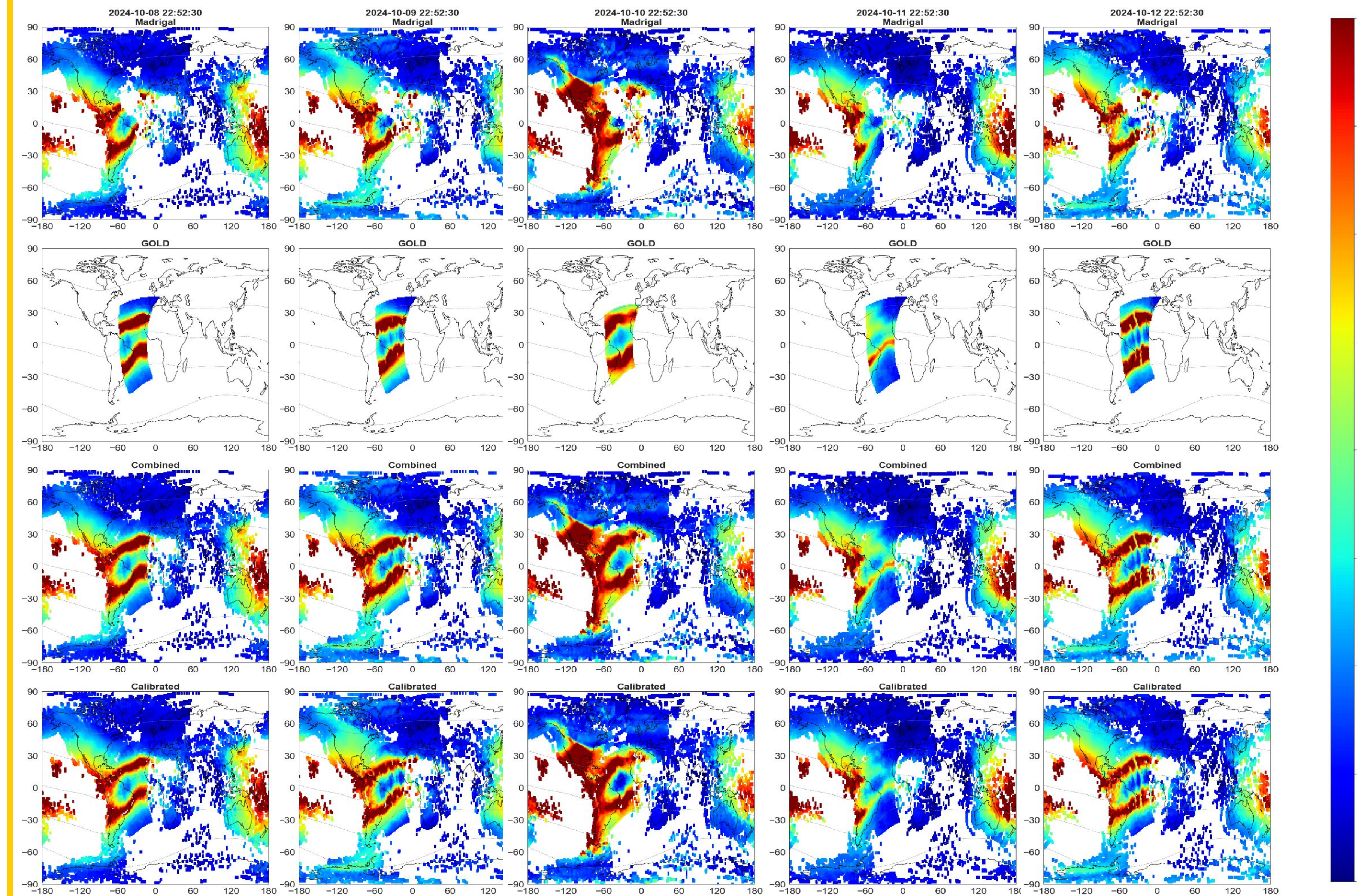
Metric	Raw	Calibrated
Accuracy (RMSE)	10.56	4.44
Bias (Mean Error)	3.82	0.42
Association (Pearson R)	0.9	0.98
Skill Score	0.48	0.78

* $\sigma \approx 20$ for all datasets

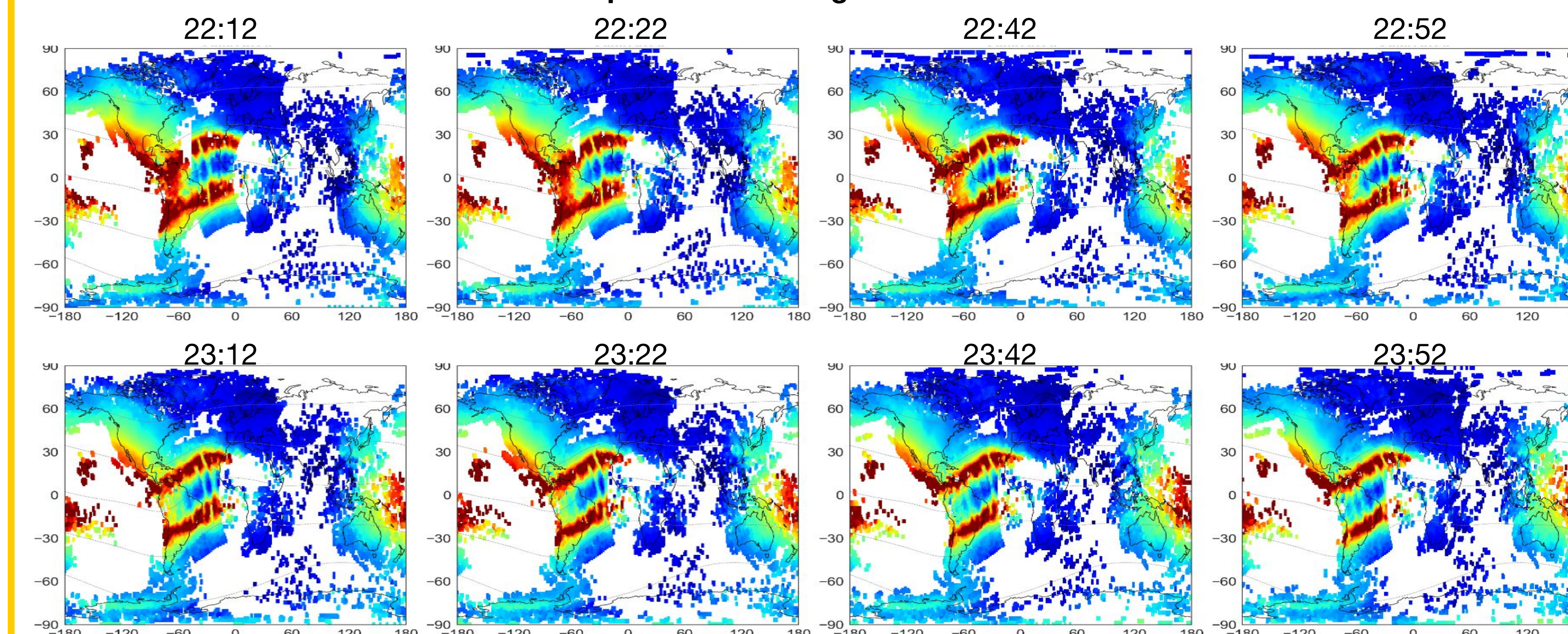
Metrics assessment of GOLD values vs. Madrigal observations in overlapping regions for the whole year of 2024

Gallery of Revealed Low Latitude Structures

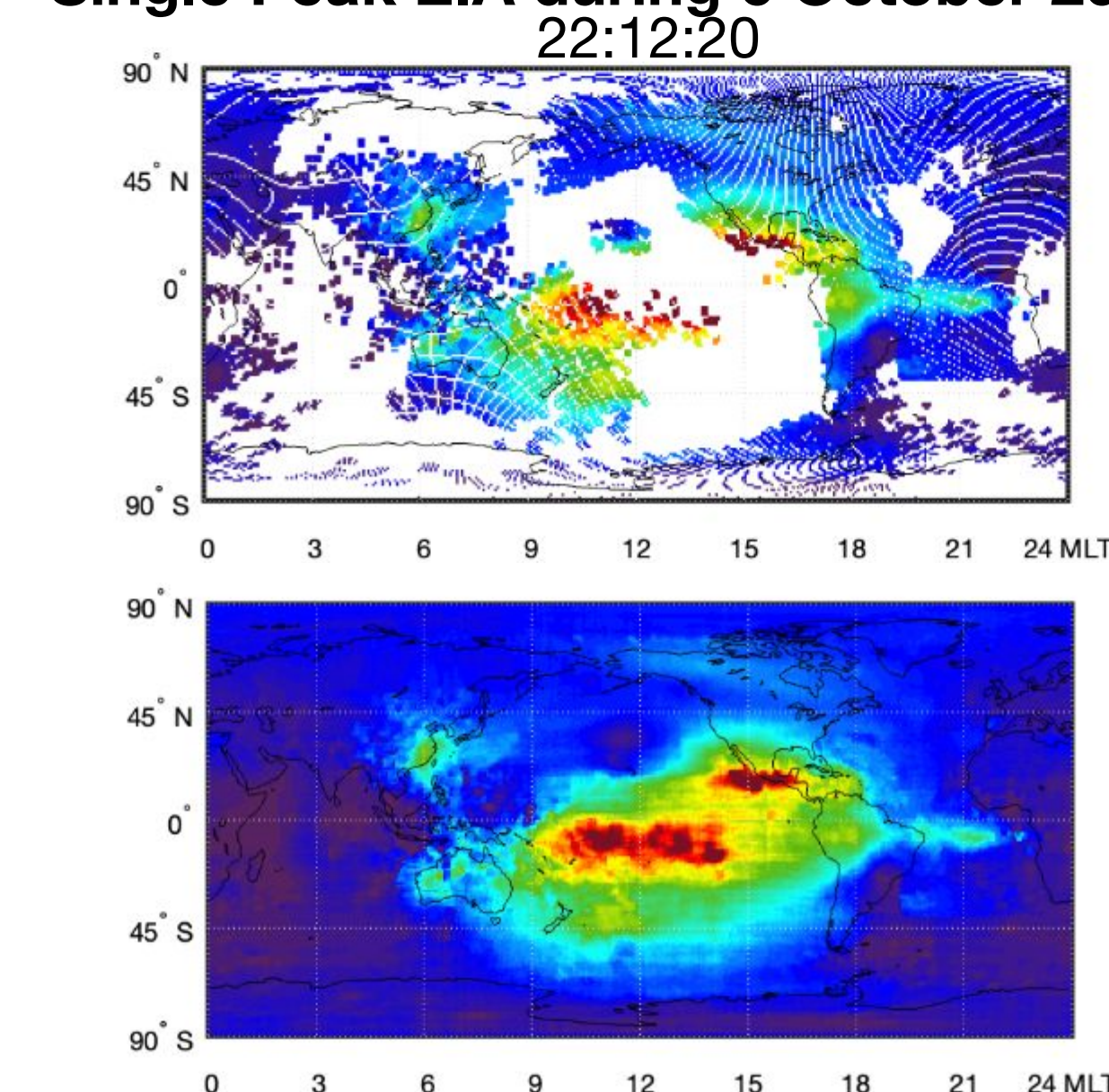
Storm-time EIA Morphology during 8-12 October 2024



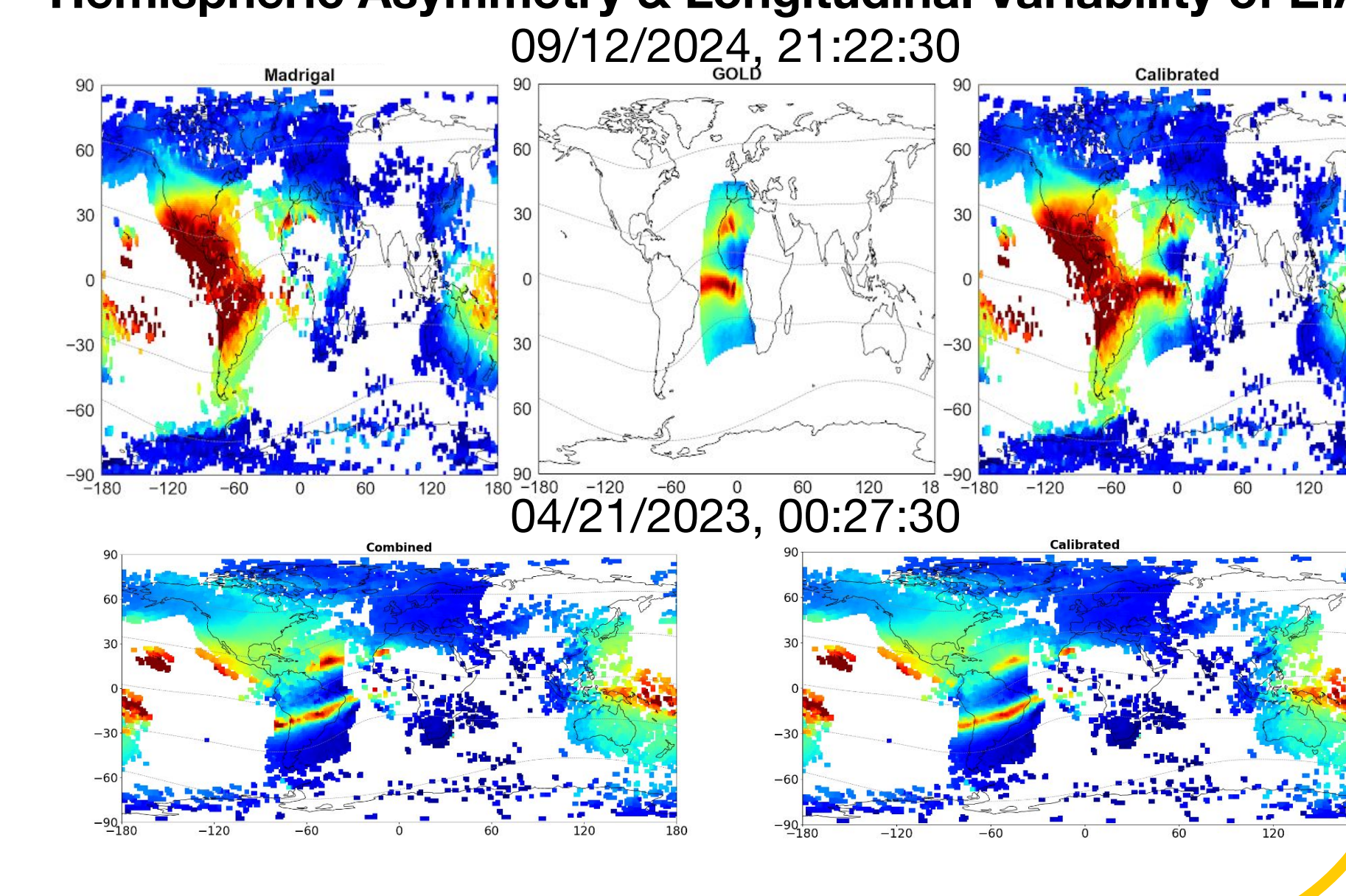
Evolution of Superbubble during the 12 October 2024 Storm



Single Peak EIA during 6 October 2024

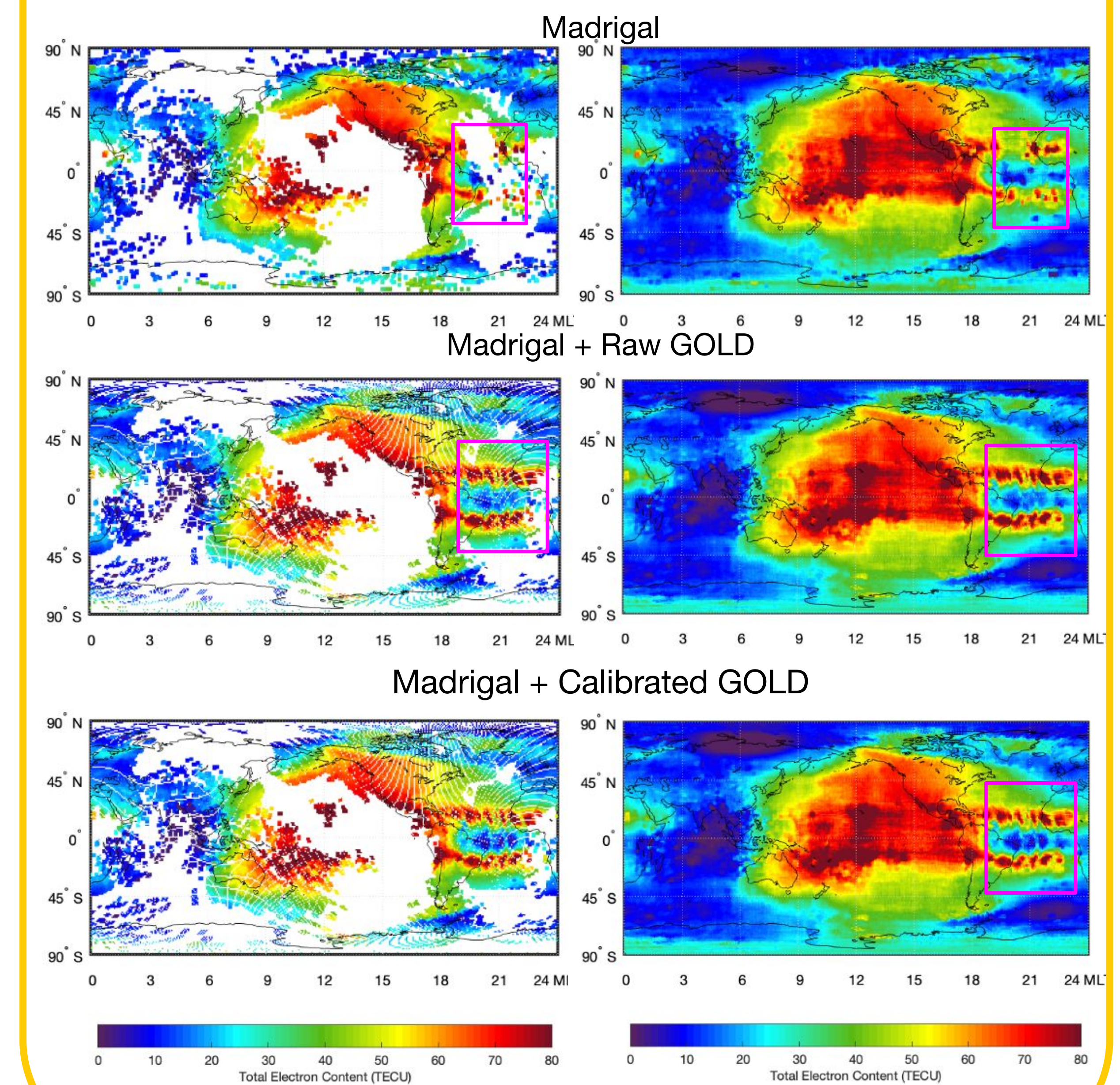


Hemispheric Asymmetry & Longitudinal Variability of EIAs



Impact on VISTA Ionosphere Specification

6 October 2024, 22:42:30 UT



Conclusions

- GOLD data provides a valuable resource for low latitude studies, both as a TEC model supplement and a EIA/EPB information resource, tapping into a previously undersampled oceanic region.
- The statistical analysis confirms the validity of calibration and allows us to rely on the calibrated GOLD database as an accurate TEC data source.
- We ingested the combined GOLD and Madrigal TEC into the VISTA algorithm and found that the GOLD data improved the specification of the low latitude ionosphere, including EIA and EPB structures

References

- Qin, J., Liu, H., Yin, X., Liu, M., Wang, J., Mao, T., et al. (2023). Inferring the ionospheric state with the far ultraviolet imager on the Fengyun-4C geostationary satellite: Retrieval algorithm and verification
- Hu Sun, Zhijun Hua, Jiaen Ren, Shasha Zou, Yuekai Sun, Yang Chen. "Matrix completion methods for the total electron content video reconstruction." Ann. Appl. Stat. 16 (3) 1333 – 1358, September 2022. <https://doi.org/10.1214/21-AOAS1541>

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The University of Michigan is located on the traditional territory of the Anishinaabe people. In 1817, the Ojibwe, Odawa, and Bodewadami Nations made the largest single land transfer to the University of Michigan. This was offered ceremonially as a gift through the Treaty at the Foot of the Rapids so that their children could be educated. Through these words of acknowledgment, their contemporary and ancestral ties to the land and their contributions to the university are renewed and reaffirmed.