

Relative Role of Geomagnetic Forcing and Solar EUV on the Thermospheric Temperature During the April 2023 Geomagnetic Storm using

GOLD and GITM

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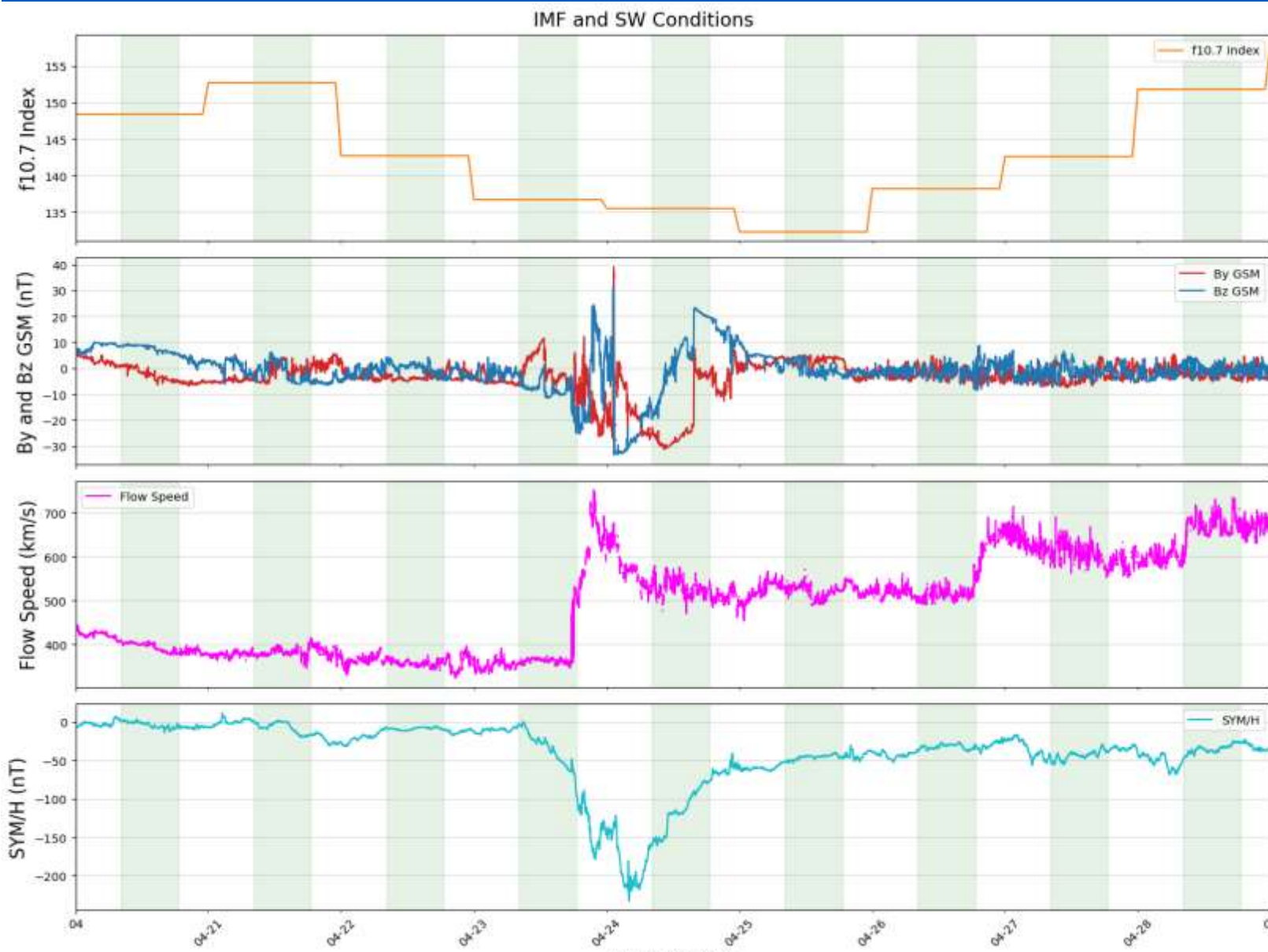
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[1] Introduction and Motivation

- Motivation:** Investigate how geomagnetic forcing versus solar EUV variability drive thermospheric temperature changes during geomagnetic storm recovery.
- Global-Scale Observations of the Limb and Disk (GOLD)'s two-dimensional thermospheric temperature observations capture the storm-time response at 160 km.
- Two Global Ionosphere-Thermosphere Model (GITM) simulations—(1) a standard run with time-varying EUV and Assimilative Mapping of Ionospheric Electrodynamics (AMIE)-driven high-latitude geomagnetic inputs, (2) a controlled run with fixed pre-storm EUV and AMIE-driven geomagnetic inputs—separate geomagnetic versus solar EUV effects studied at 160 km altitude.
- Comparison of GOLD observations with GITM runs quantifies the relative contributions of geomagnetic forcing and solar EUV to post-storm thermospheric cooling

[2] Event Overview



- Min SYM/H index: ~-230 nT around 06 UT
- Green shades represent GOLD coverage of each day
- Solar radiation (F10.7) changes from 144 sfu on 04/22 to 132 sfu on 04/25.
- IMF B_z was mostly southward (-30 nT) after 02 UT on 04/24 and turned northward after 12 UT and remained northward until 12:30 UT on 04/25.
- ΔT_{disk} obtained by subtracting temperature from 04/22 (quiet).

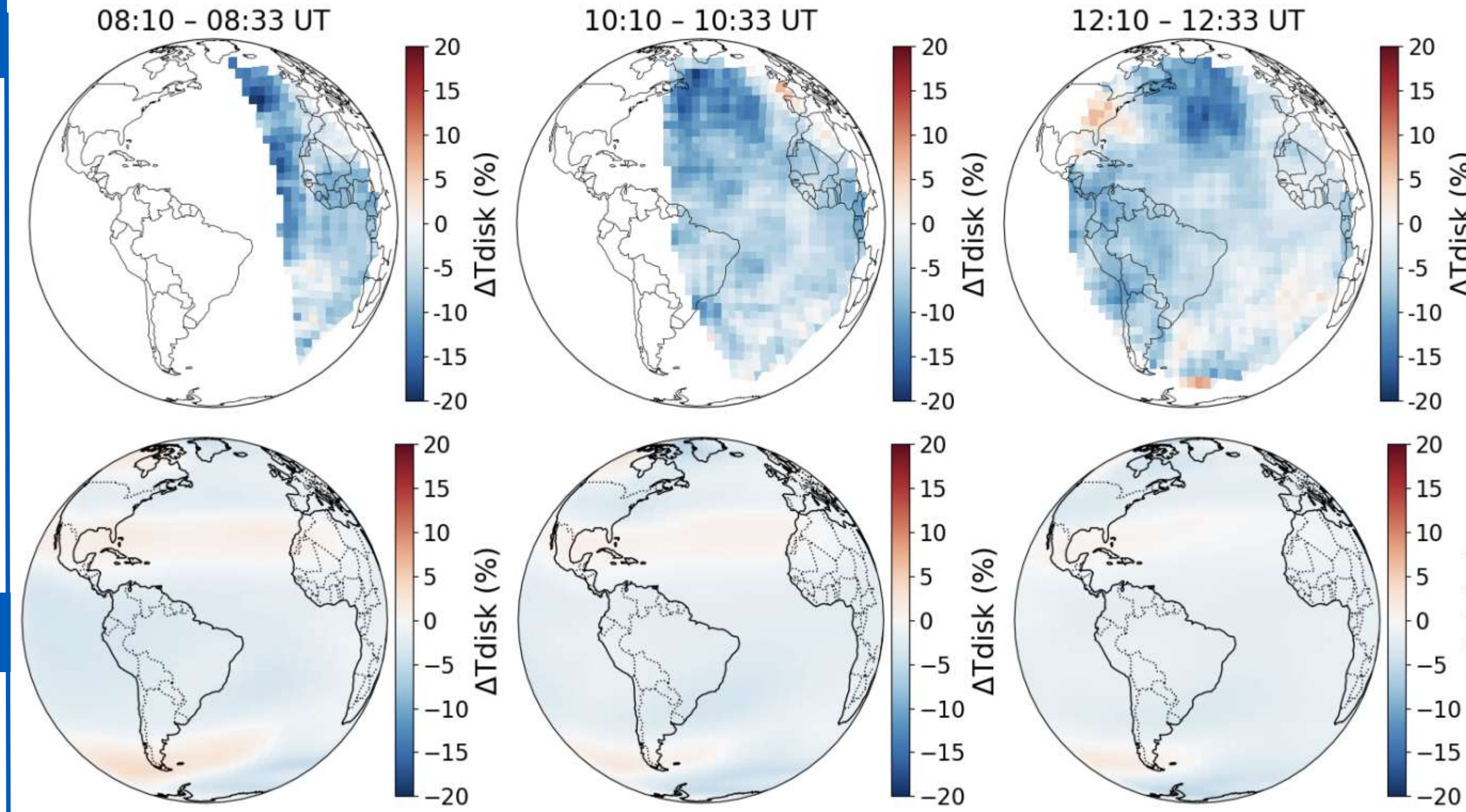


Fig 3: Same as Fig 1 above but for (04/25). GOLD (top) and GITM (bottom).

- GOLD shows immediate widespread cooling on 04/25 ($\Delta T_{\text{disk}} < 0\%$) across most of the observed disk at all UTs with temperature reduction almost reaching ~-18 % in Northern hemisphere high-latitude regions at 10-12 UT.
- GITM also shows return towards baseline, with subtle cooling (-5 % to 0%) mostly in Southern hemisphere high-latitudes.
- Both GOLD and GITM show localized ~10-15% enhancement patch near east American and region extending into Caribbean sectors at 12:10-12:33 UT. Such signatures are seen in GITM around 30° - 40° N and 60° S at earlier UTs but not in GOLD due to lack of coverage.
- Temperature Reduction continues throughout the day and most regions show temperature significantly less than pre-storm condition.

[4] Travelling Atmospheric Disturbances from GITM

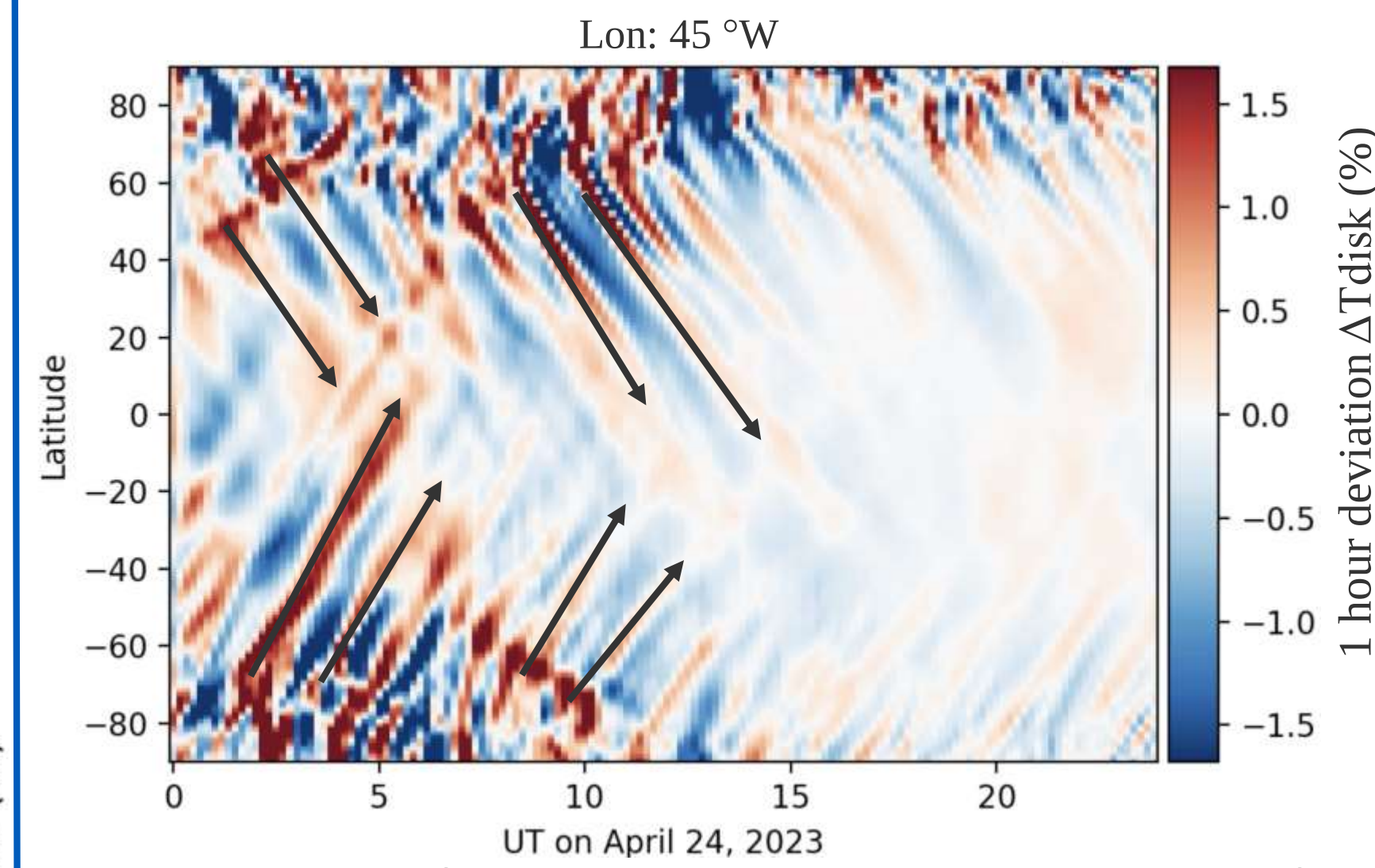


Fig 4: Deviation from 1 hour average in Temperature from GITM simulation on April 24, 2023 shows Travelling Atmospheric Disturbances (TADs) signatures within $\pm 2\%$ range.

- TADs seen as early as 02 UT propagating equatorward from both hemispheres until 15 UT with speeds ranging from ~385 m/s to ~667 m/s. After 15 UT, the TAD signals become weaker but still visible with $\pm 0.5\%$ intensity

[5.1] Relative Importance of Solar EUV & Storm Forcing using GITM

Case A: Apr 22 F10.7 + Apr 22 Storm Forcing Case B: Apr 24 F10.7 + Apr 24 Storm Forcing Case C: Apr 22 F10.7 + Apr 24 Storm Forcing

Solar EUV contribution relative to baseline = $(B - C) / A * 100\%$

Geomagnetic Storm Forcing contribution relative to baseline = $(C - A) / A * 100\%$

Apr 24 2023 @ 160 km: EUV Contribution on Temperature Relative to Quiet Day

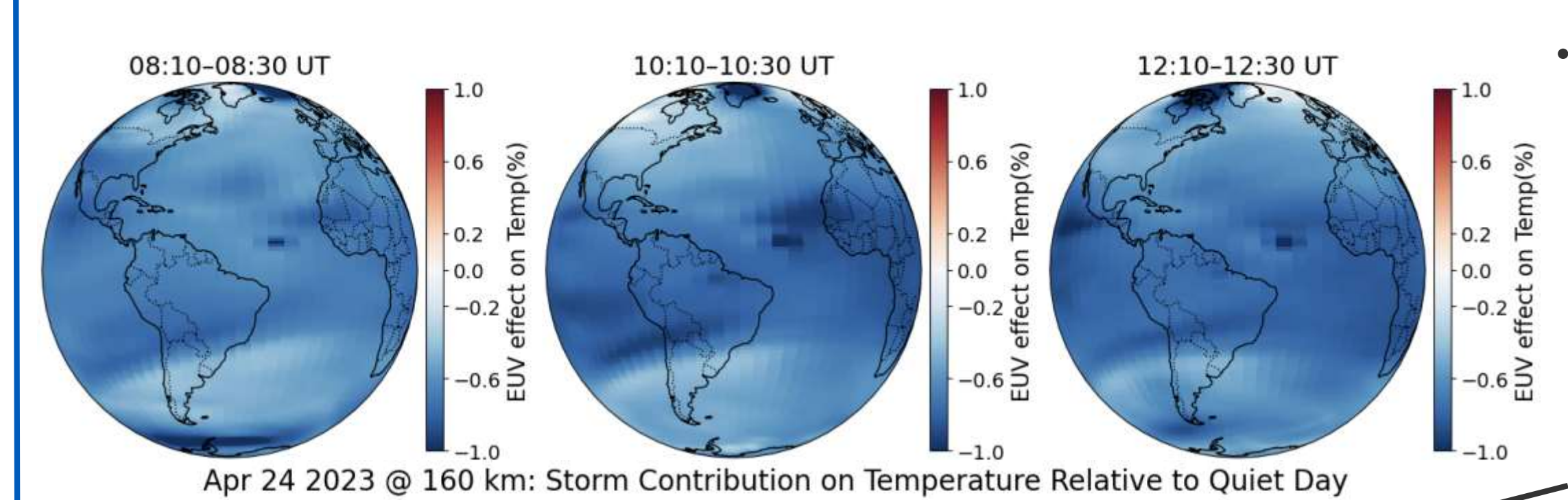


Fig 5: Contribution of Solar EUV (top) and Storm forcing (bottom) seen on temperature perturbation on Apr 24 relative to Apr 22 (quiet day). Storm forcing seen as dominant driver enhancing temperature at 160 km altitude.

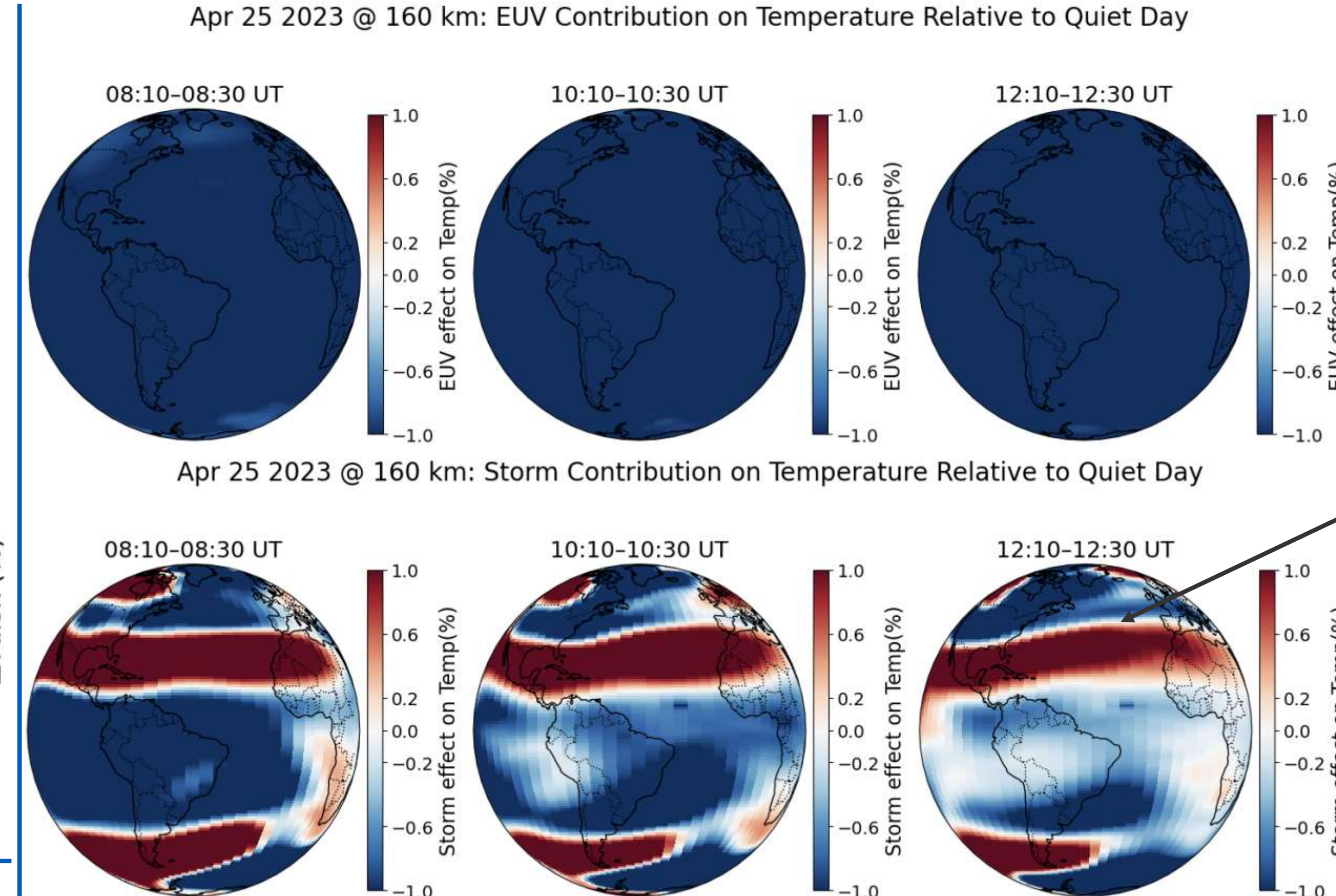


Fig 6: Same as Fig 5 but for Apr 25, 2023. Geomagnetic forcing effect is significantly reduced whereas Solar EUV has enhanced cooling effect following the recovery phase on Apr 24 as seen in same colorbar range compared to Fig 5 top row.

[5.2] Relative Importance of Solar EUV & Storm Forcing: Spatio-temporal evolution

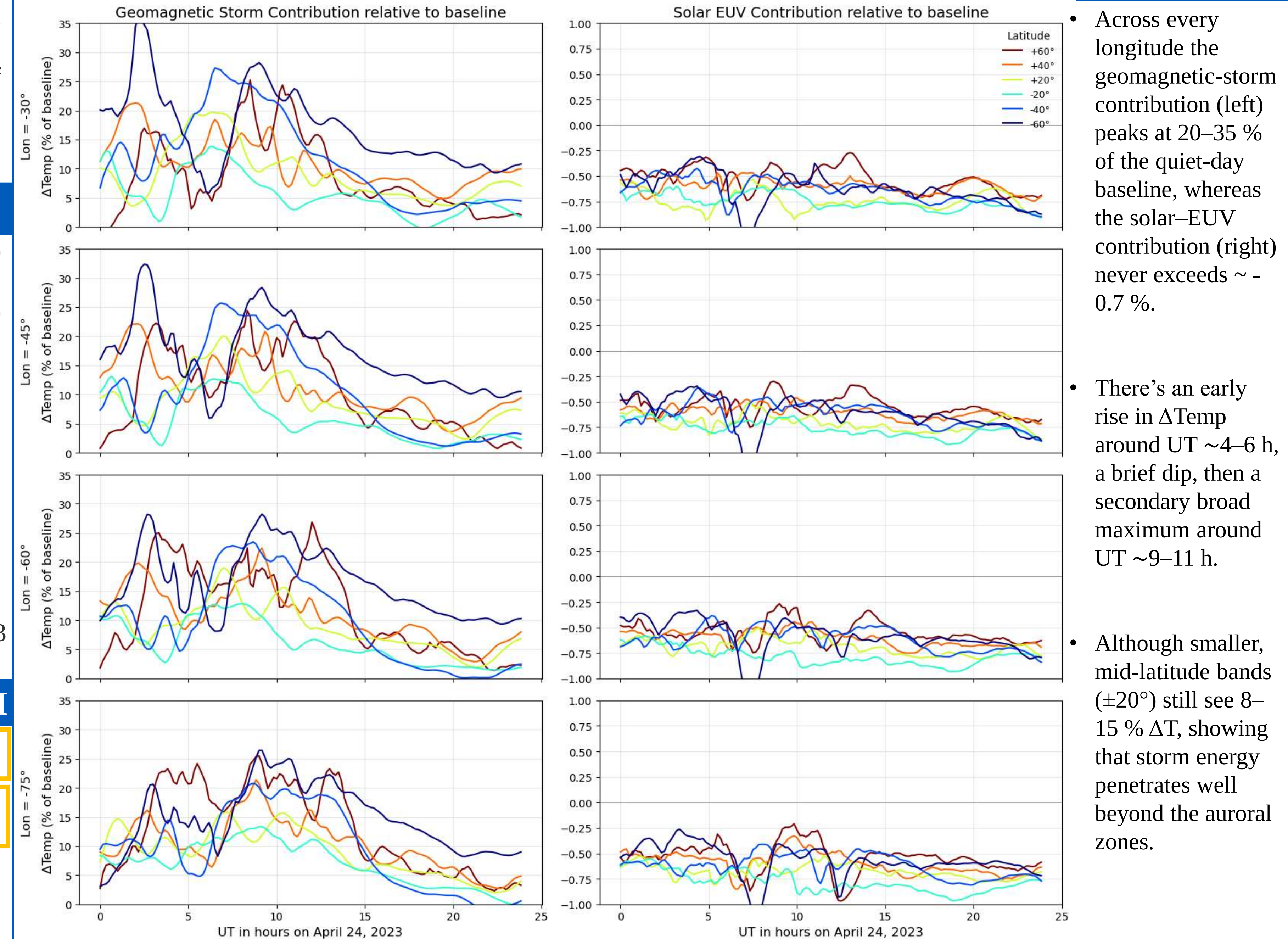


Fig 7: Time series of relative thermospheric temperature perturbations at 160 km on April 24 2023 (percent of quiet-day baseline), showing geomagnetic-storm forcing (left) versus solar EUV forcing (right). Each row is a fixed longitude (-30°, -45°, -60°, -75°), and colored lines denote latitude bands from +60° (red) to -60° (blue).

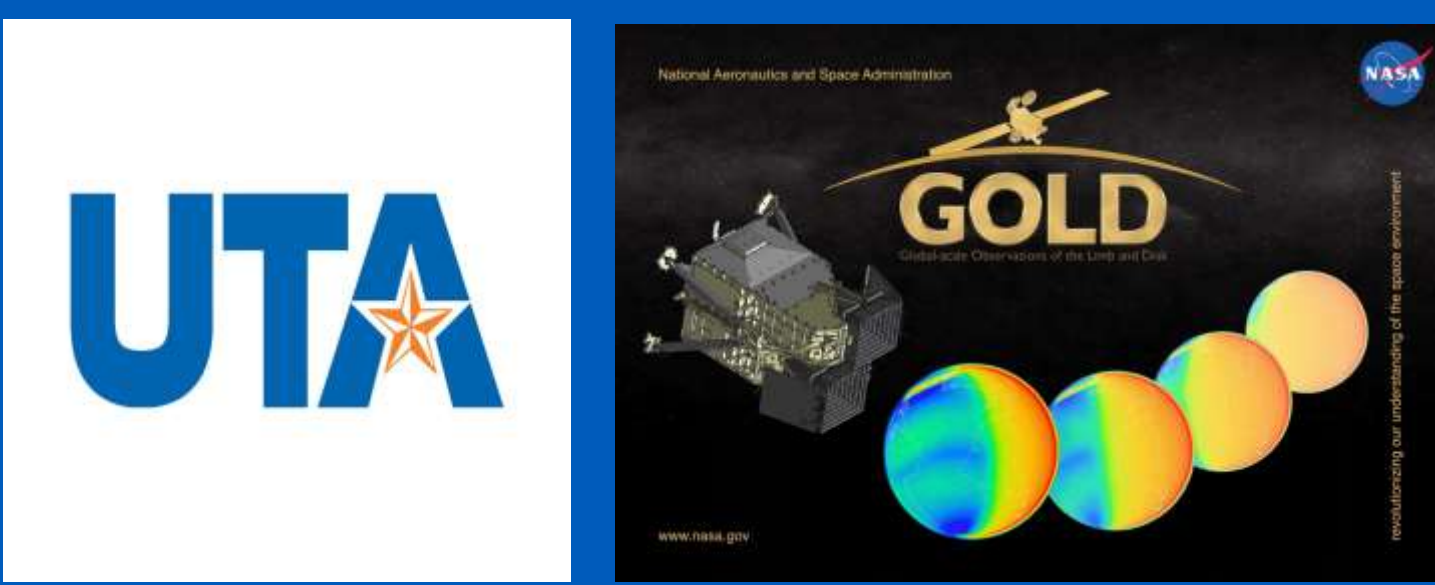
[6] Summary

- On April 24, (~8 sfu) solar EUV change produced <1 % temperature change, whereas storm forcing drove large high-latitude heating (20-30% of baseline).
- TADs seen from GITM simulated temperature perturbation propagate equatorward at 385-667 m/s during recovery.
- By April 25, storm-driven enhancement subsides to $\pm 3\%$ and decreasing solar EUV becomes main contributor to widespread cooling (up to ~-1.8 % compared to ~-1% on April 24).
- We combine GOLD's 2D neutral temperature observations with multiple GITM simulations to separate relative roles of EUV & Storm forcing.

[7] Future Work & Acknowledgment

- Quantify NO cooling impacts to study the reason behind significant cooling on April 25 (<0 %) using GITM simulated NO cooling rates.
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[3] Temperature Perturbation: GOLD & GITM Comparison

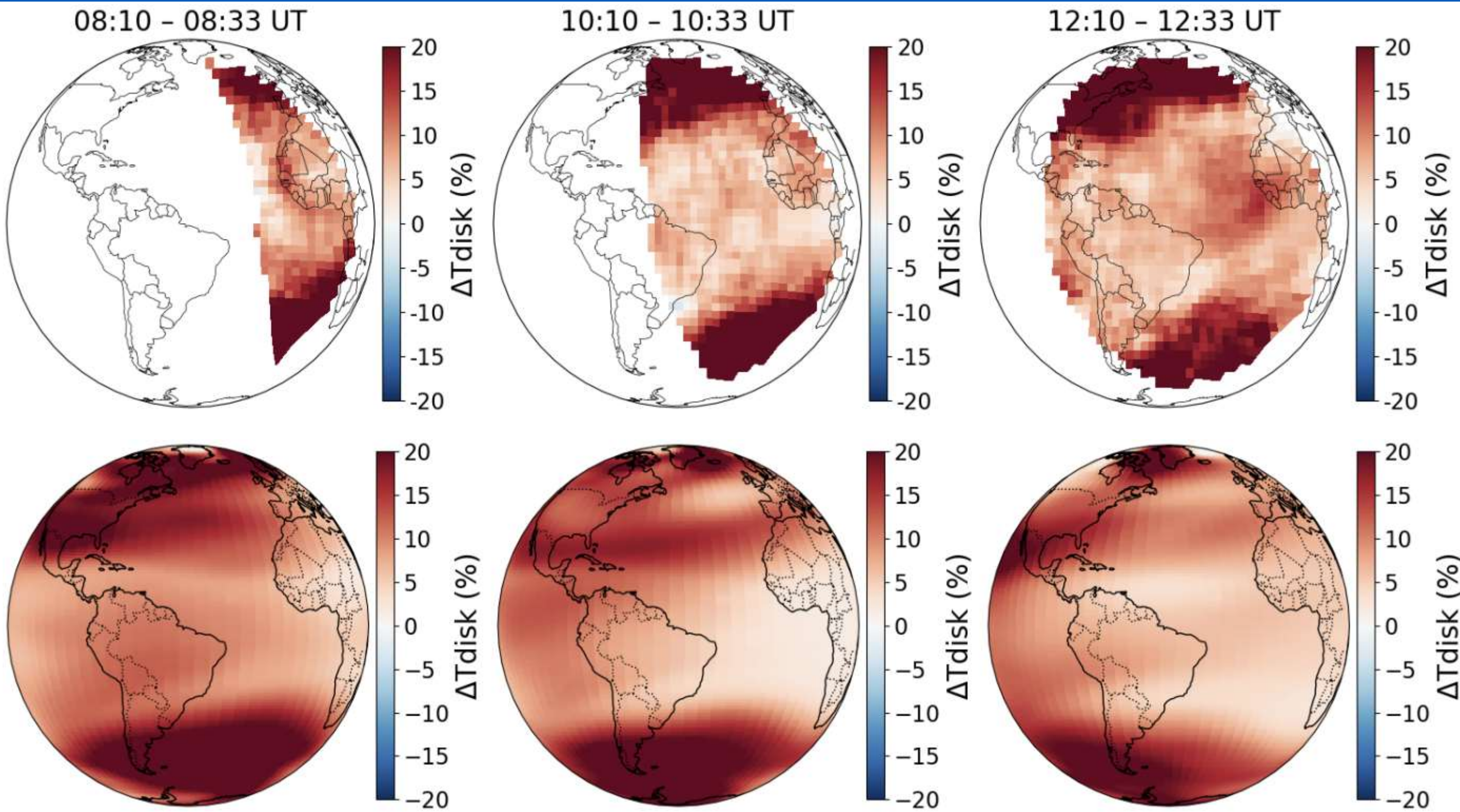


Fig 1: Difference in neutral temperature variation at times of selected GOLD coverages from GOLD (top row) and GITM (bottom row) on 04/24: recovery phase started around 06 UT.

- GOLD peaks at ~+20 % in auroral regions in both hemisphere around 10 UT with initial mid-latitude enhancement (~+8 %), whereas GITM's shows maximum enhancement in southern hemisphere with ~+16 % in northern hemisphere.
- GOLD transitions to widespread enhancement (~+10%) across 20°N - 40°S at 12:10-12:33 UT whereas GITM still maintains high-latitude enhancement (~+15 %) but underestimates mid to low latitude response (<8 %).
- GITM clearly shows the spatial pattern of temperature enhancement expands westward with time.
- GOLD shows a pronounced hotspot with enhancement >15-20% near the low-latitude west African region whereas GITM lacks such sharp low-latitude peak.

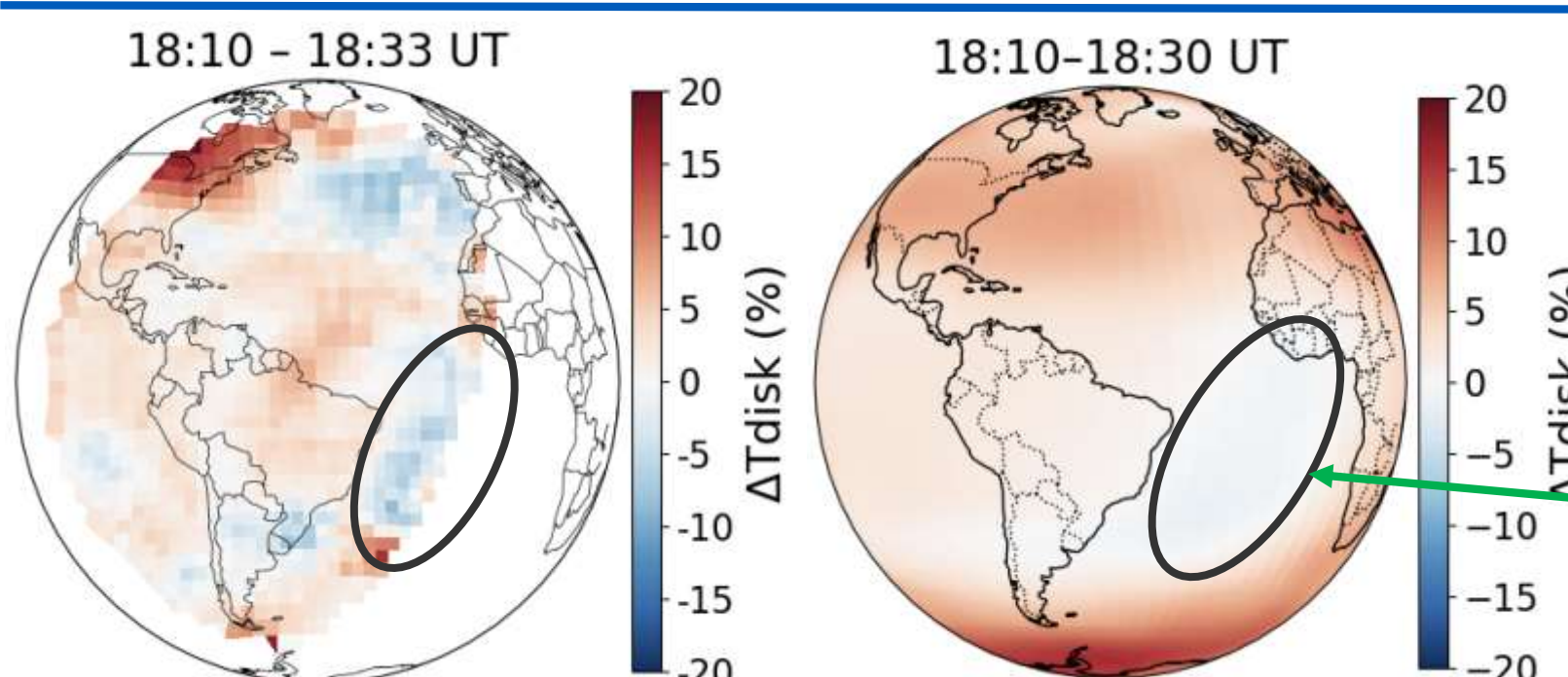


Fig 2: (a) GOLD (b) GITM

- By 18:10 - 18:33 UT, both GOLD and GITM show significant reduction with magnitudes mostly within $\pm 5-10\%$ with <0 % near South Atlantic region.
- GOLD still shows ~+15 % enhancement near North American sector.