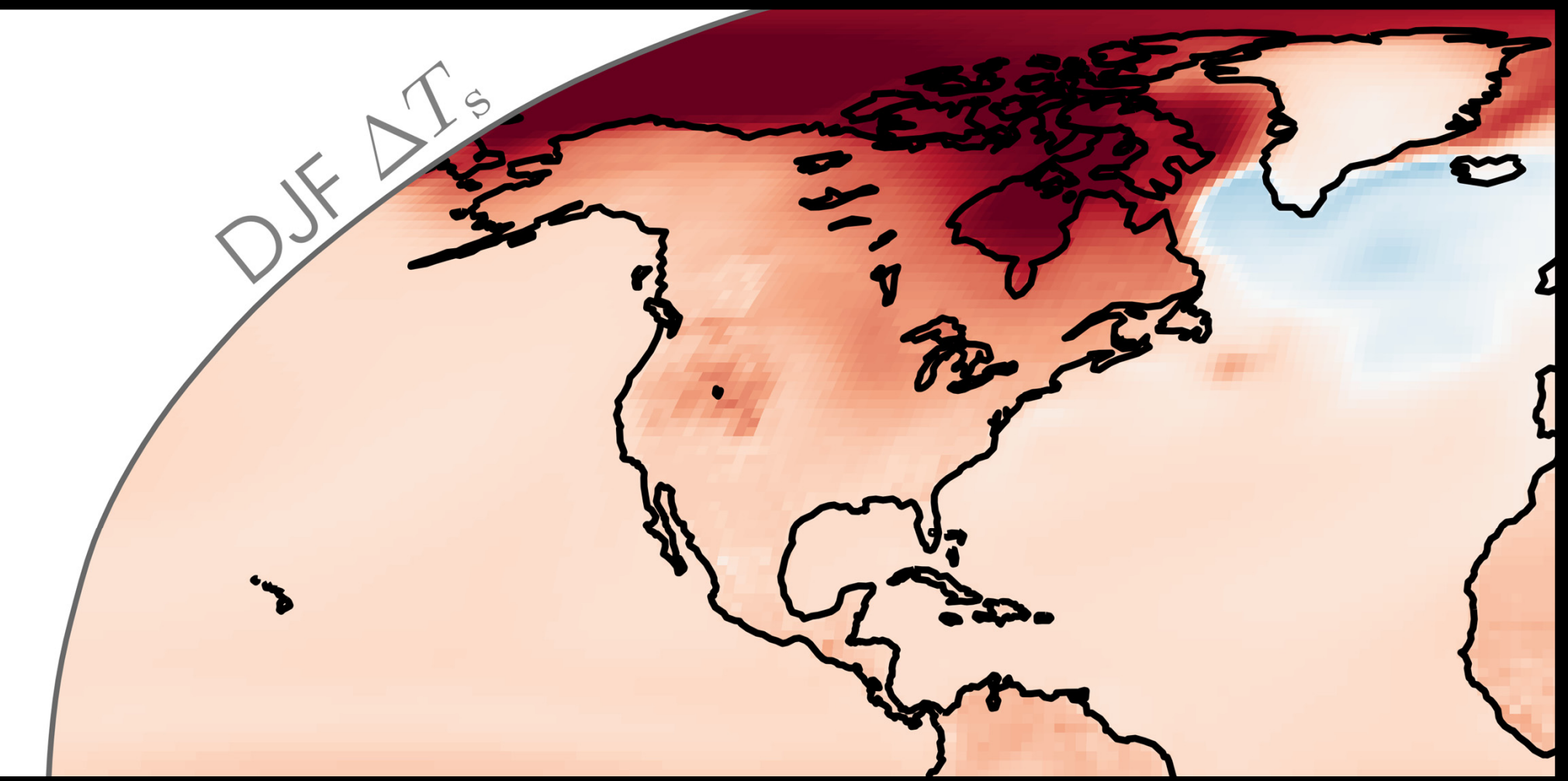


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# Mid-Tropospheric Arctic De-Amplification in Version 2 of the CESM Large Ensemble

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## OBSERVED WARMING.

Prominent Arctic warming relative to other latitudes and the global mean (Arctic Amplification; AA) is a defining feature of ongoing climate change. Observations reveal the greatest rates of warming arising from the Arctic near-surface and extending through the Arctic's atmospheric column (Fig 1).

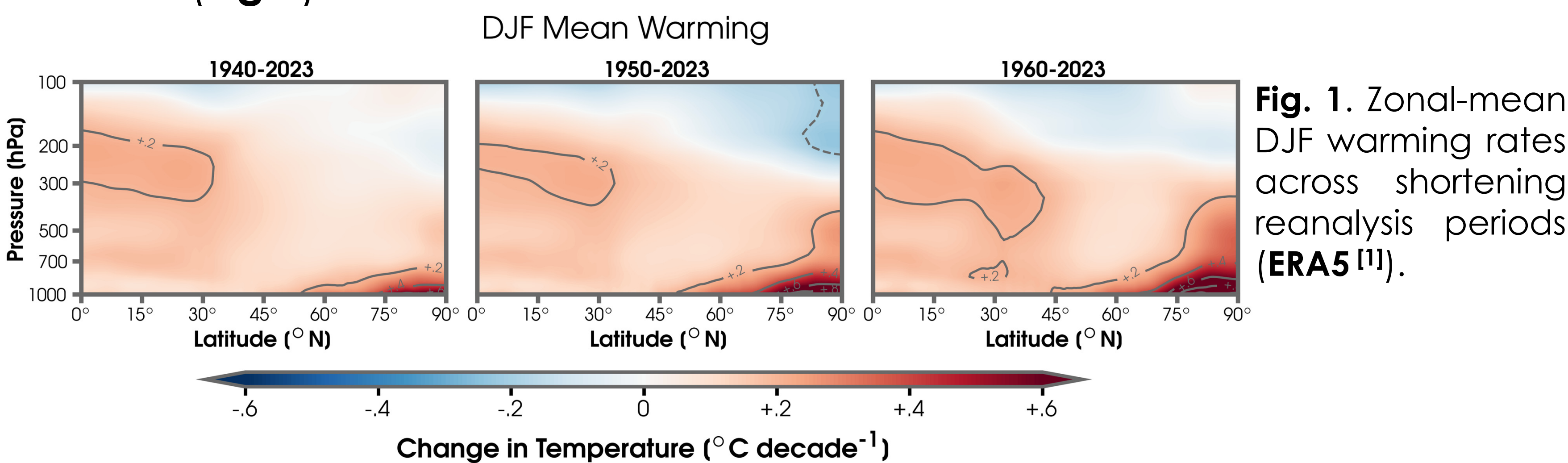


Fig. 1. Zonal-mean DJF warming rates across shortening reanalysis periods (ERA5 [1]).

## MODELED WARMING.

Large ensembles like that from the Community Earth System Model (CESM), CESM1-LE [2] (LENS1), generate numerous realizations of the climate system to portray the range of internal variability among the multi-decadal warming signal.

The latest CESM2-LE [5] (LENS2) produces a more drastic slowdown of the Atlantic Meridional Overturning Circulation (AMOC) and a warming pattern in the zonal-mean atmospheric profile led by upper-tropospheric tropical warming (UTW) (Fig 2).

## MODELED DYNAMICS.

Dynamical indices [3,4] characterize mid-latitude atmospheric circulation from daily fields.

The **zonal index (ZON)** is computed as the difference in 500 hPa geopotential height (Z500) between the 60°-90°N and 20°-50°N latitude bands.

The **sinuosity index (SIN)** measures the length of the precise Z500 isohypse (normalized by a straight line) that is equivalent to the 30°-70°N spatial mean.

The **blocking index (BLO)** uses requirements in the meridional Z500 gradient under a 5-day persistence criteria to identify prolonged reversals of flow.

The **jet variability index (JVI)** reuses the SIN to obtain a distribution across latitudes of grid points  $\leq 5$  gpm from the previously used Z500 isohypse, calculating the span of the middle 90% for each month.

## CONCLUSIONS.

LENS2 projects dominant upper-tropospheric tropical warming over Arctic amplification, supporting winters with reinforced westerlies, reduced sinuosity and blocking, and a narrower, poleward-shifted jet consistent with the "tug-of-war" mechanism.

Note: The 21<sup>st</sup> century response is defined as the difference between the projected periods of LENS1 [2057-2086] or LENS2 [2071-2100] and their respected historical periods [1981-2010] to convey a high emissions change in radiative forcing of  $\sim +4.7 \text{ W m}^{-2}$ .

## REFERENCES.

- [1] Hersbach et al. 2020. Q. J. R. Meteorol. Soc.
- [2] Kay et al. 2015. Bull. Am. Meteorol. Soc.
- [3] Peings et al. 2017. J. Clim.
- [4] Peings et al. 2018. Environ. Res. Lett.
- [5] Rodgers et al. 2021. Earth Syst. Dyn.

## 21<sup>st</sup> Century $T$ Amplification & $\Delta U$ for DJF Atlantic Sector (50°W - 40°E)

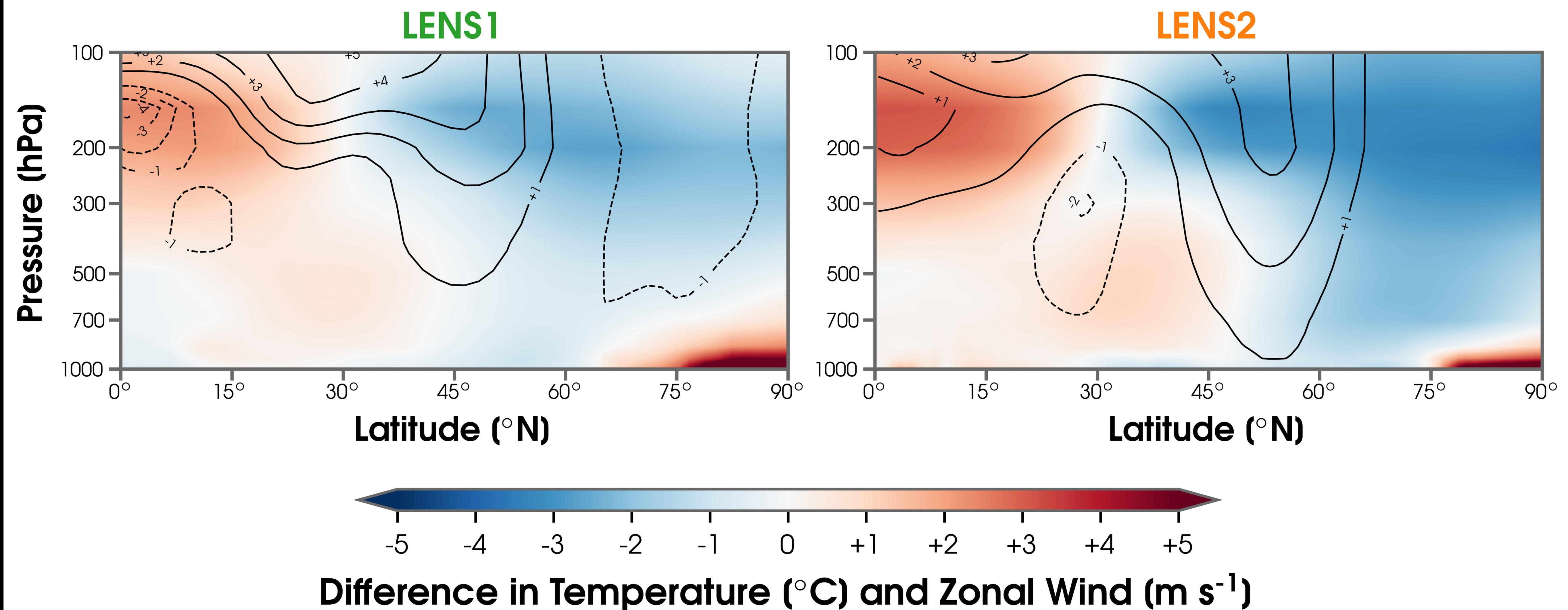


Fig 2. Ensemble mean, zonal-mean temperature change in the boreal winter (DJF) Atlantic sector (50°W - 40°E) between early and late 21<sup>st</sup> century periods minus the all-latitude mean temperature change by pressure height. Black contours depict the change in the zonal-mean wind over the same period.

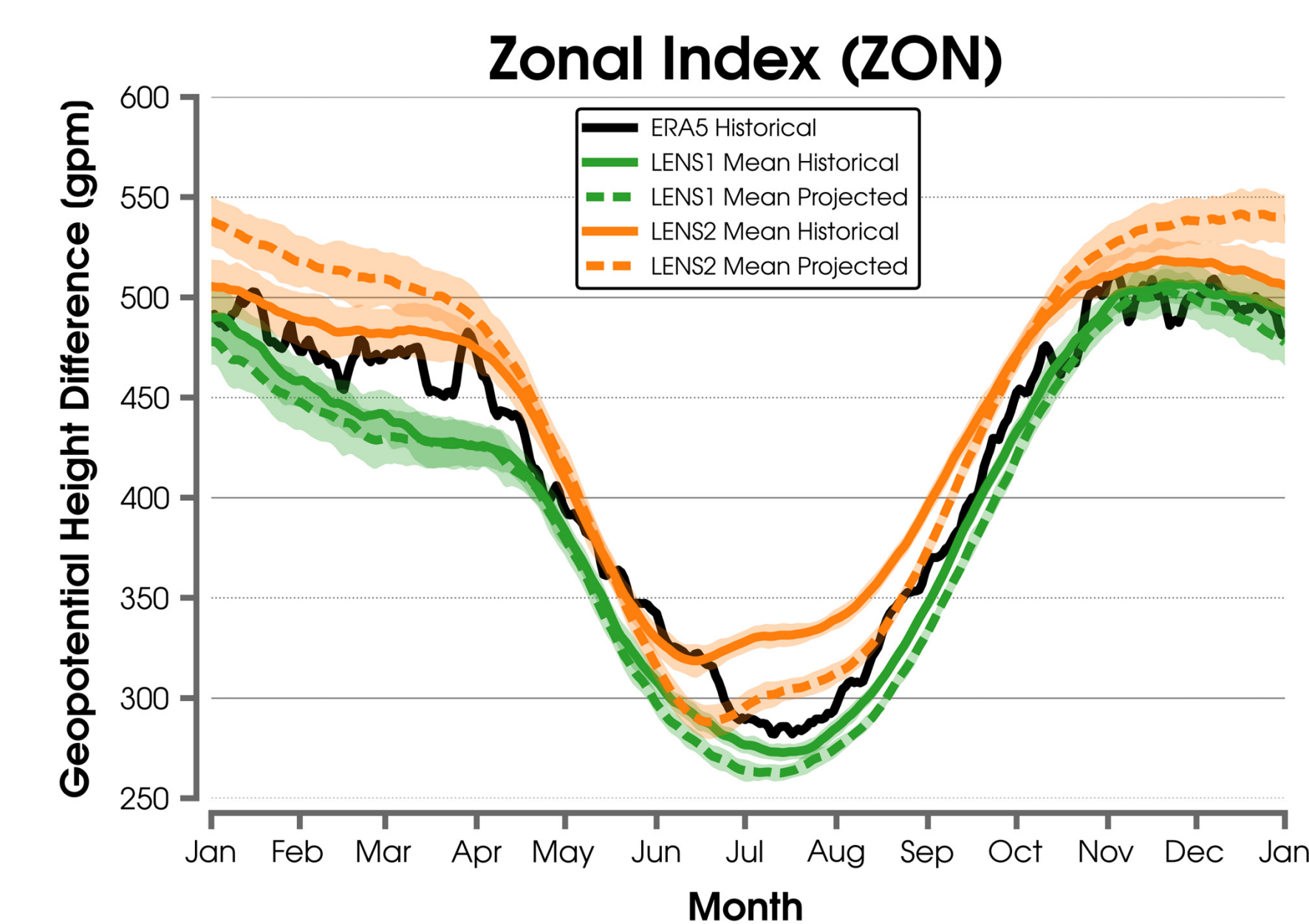


Fig 3.

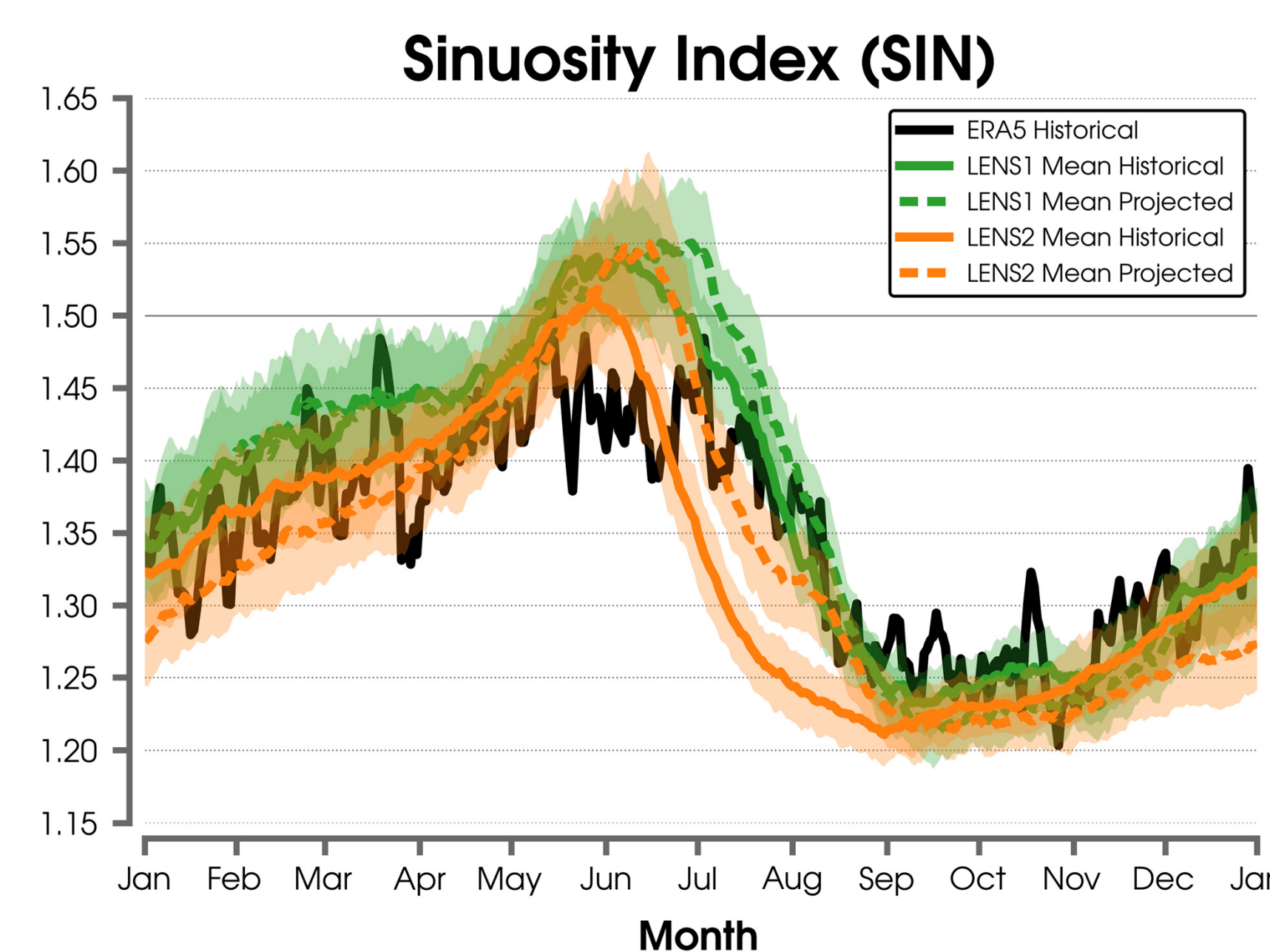


Fig 4. Same as Fig 3 but for SIN.

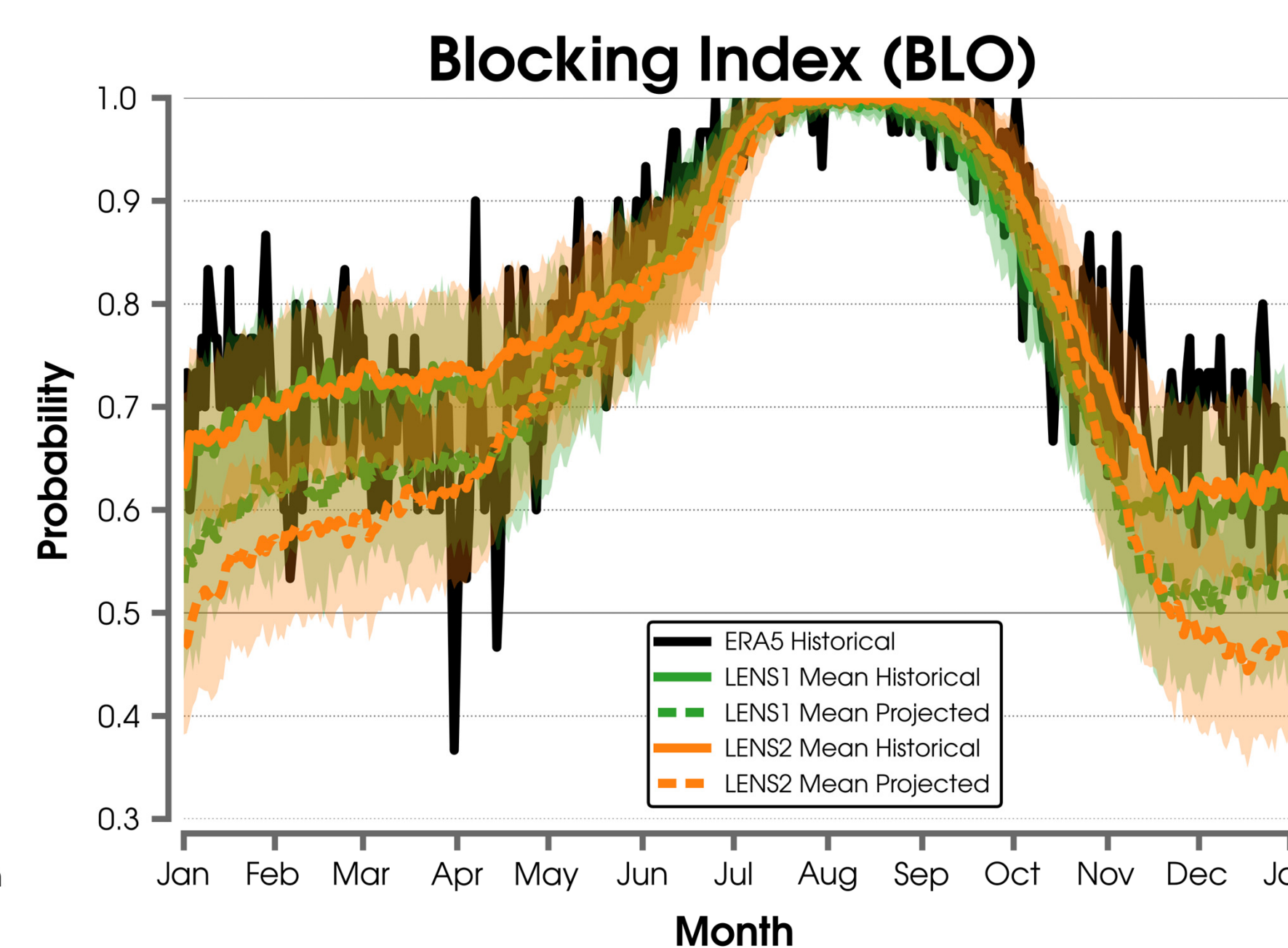


Fig 5. Same as Fig 3 but for BLO.

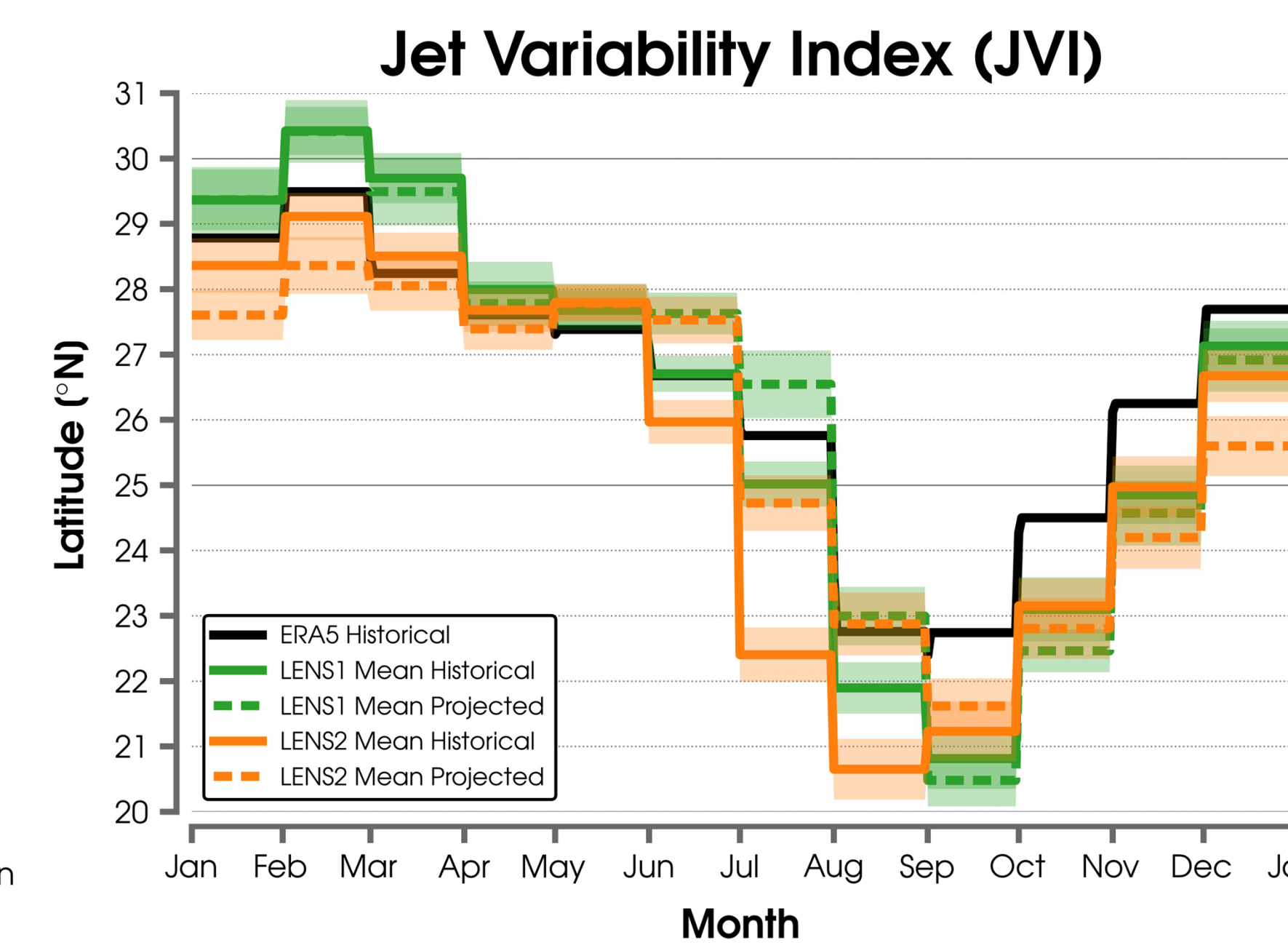


Fig 6. Same as Fig 3 but for JVI.

ZON climatography in the historical (solid line) and projected (dashed line) periods for LENS1 (green) and LENS2 (orange) ensemble means, overlaid on ERA5 [1] (black). Shading on model data indicates  $\pm 1$  standard deviation of ensemble members.