The Nonlinear Northern Hemisphere Stratospheric Temperature Response to External Radiative Forcing in Decadal Climate Simulations

Abdullah A. Fahad[1], Andrea Molod[1], Dimitris Menemenlis[2], Patrick Heimbach[3], Atanas Trayanov[1], Ehud Strobach[4], Lawrence Coy[1], Krzysztof Wargan[1]
[1]NASA, GMAO, Goddard Space Flight Center, MD, US; [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, US
[3]University of Texas at Austin, USA; [4]Agricultural Research Organization, Israel;

GMAO
Global Modeling & Assimilation Office

1. Introduction

The ability to understand and predict how the changing CO_2 and Ozone in the atmosphere drive the climate versus the internal forcing on seasonal to decadal timescales is critical for seasonal to decadal prediction.

2. Methods & Experiments

In this study, we used a 1-degree configuration of the GEOS-MITgcm coupled ocean-atmosphere general circulation model. A series of 30-year simulations were performed wherein the external forcing (solar, CO_2, aerosol emissions, ozone) was repeated from a single year. The 30 years from such a simulation are regarded here as a 30-member ensemble. The suite of such simulations include forcing from 1992 (P1992), 2000 (P2000), and 2020 (P2020). In addition to the "perpetual year" simulations, a 10-member ensemble of 1992-2020 "transient" simulations were performed, wherein the external forcing was as in observations.

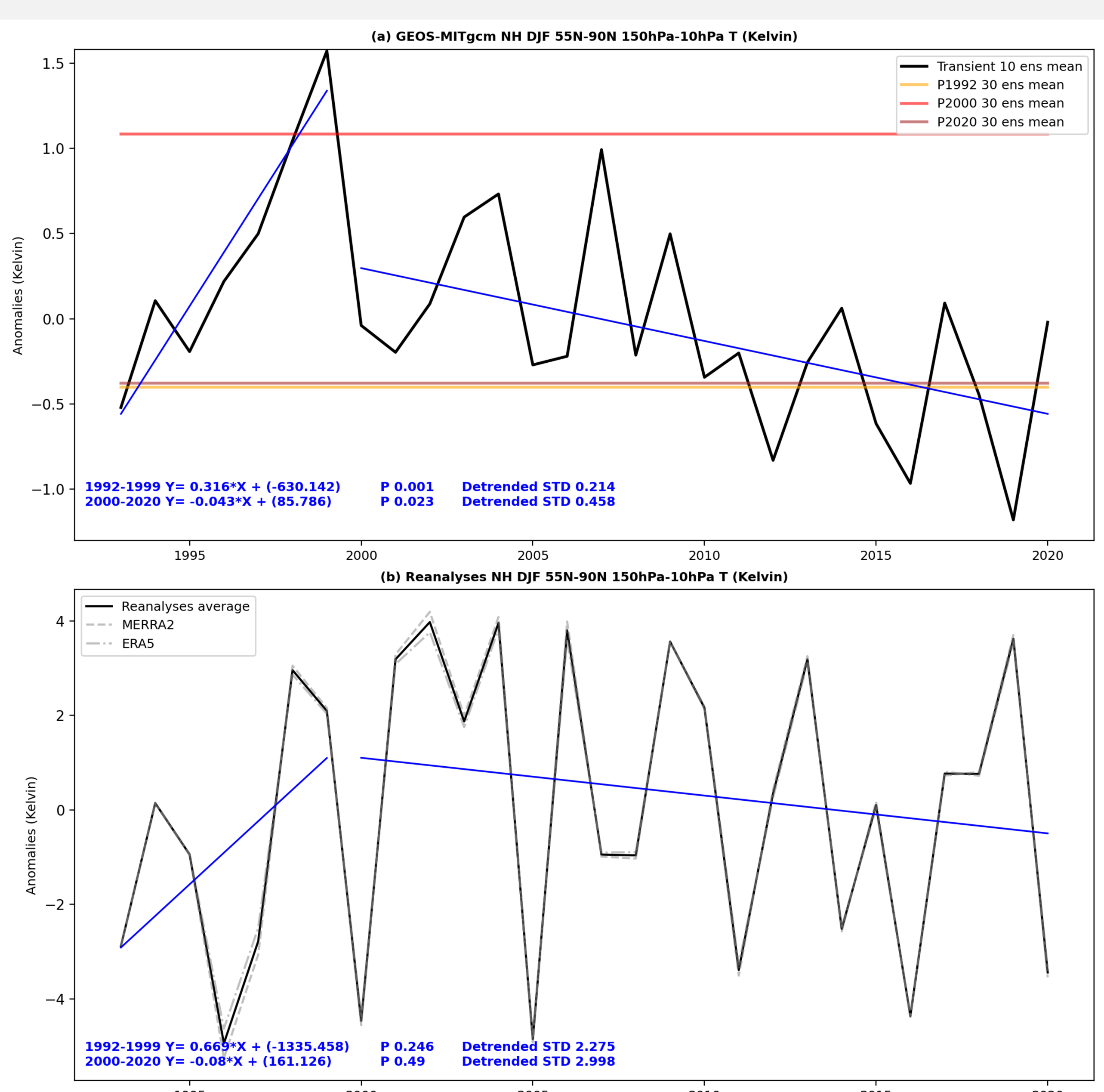

Fig. 1 (a) GEOS-MIT, & (b) (a) Reanalysis DJF NH air temperature 150-10hPa 55N-90N mean

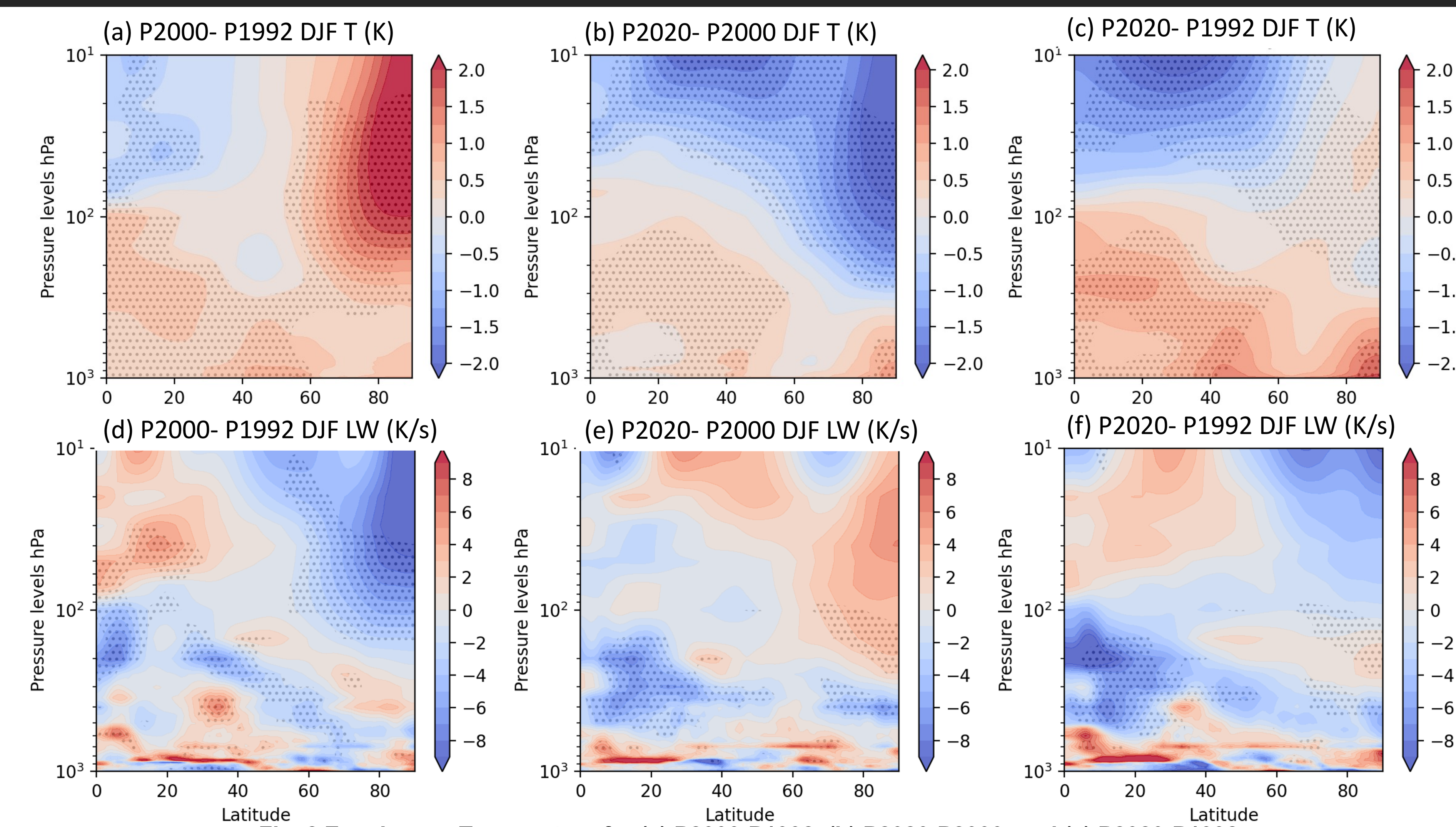

Fig. 2 Zonal mean Temperature for (a) P2000-P1992, (b) P2020-P2000, and (c) P2020-P1992. Similarly, for longwave, (d) P2000-P1992, (e) P2020-P2000, and (f) P2020-P1992

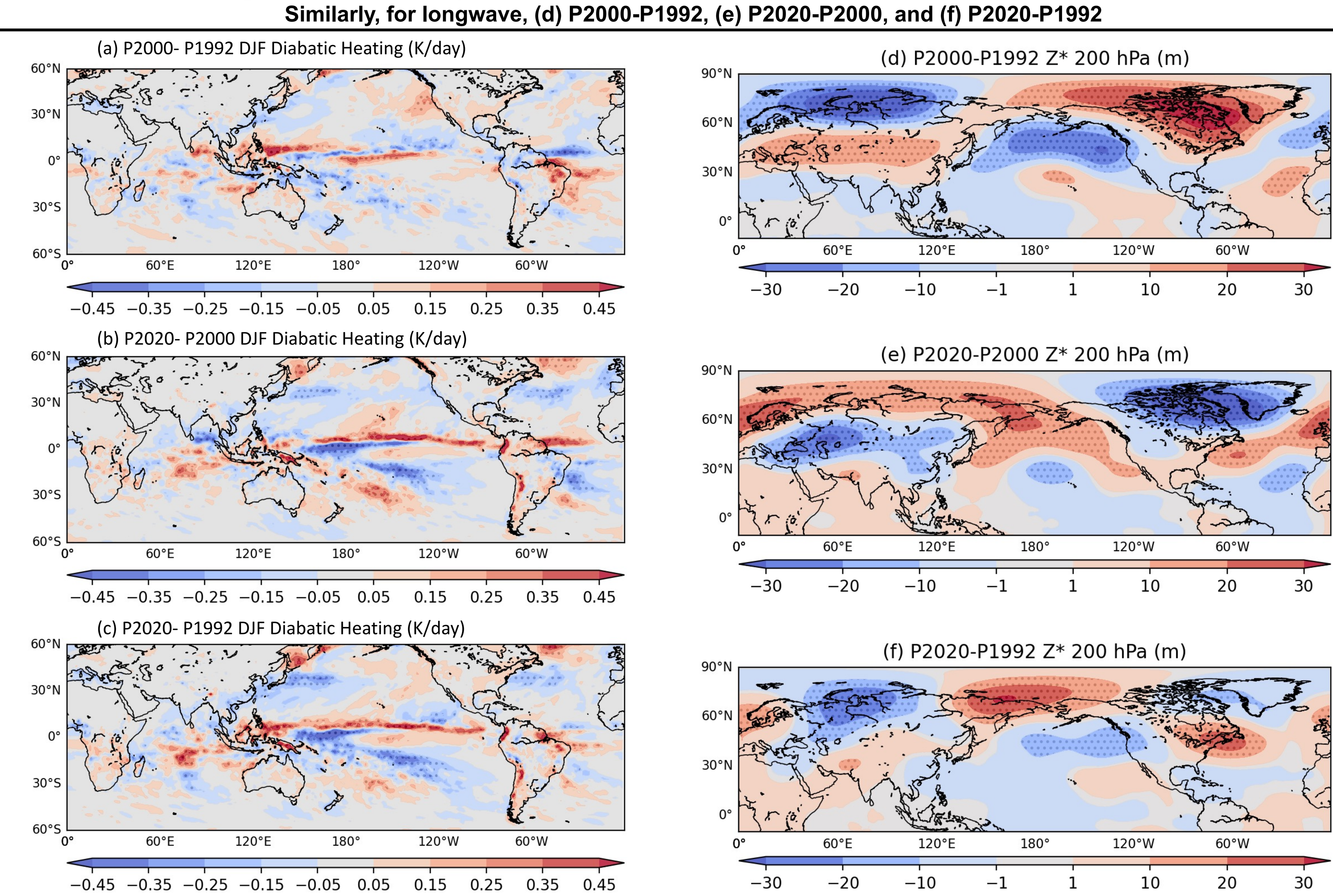

Fig. 3 Vertically integrated Diabatic heating for (a) P2000-P1992, (b) P2020-P2000, and (c) P2020-P1992. Similarly, for eddy height Z*, (d) P2000-P1992, (e) P2020-P2000, and (f) P2020-P1992

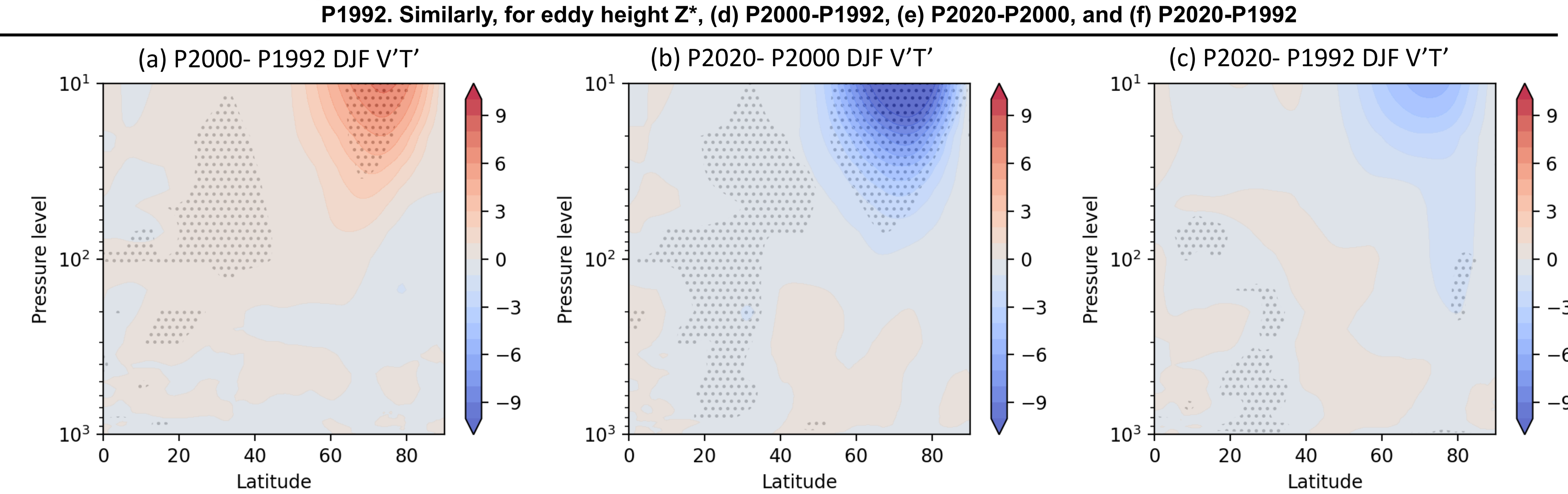

Fig. 4 Meridional heat transport due to transient wave activity V'T' for (a) P2000-P1992, (b) P2020-P2000, and (c) P2020-P1992.

4. Results

Our Perpetual run and transient run experiments show that the DJF Northern Hemisphere (NH) polar stratosphere temperature increases during 1992-2000 and decreases during 2000-2020 (Figs.1&2). The general expectation is that the stratospheric temperature decreases with CO_2 increase in the atmosphere. Despite running with repeating Ozone levels and volcanic emissions from specific years, the difference between perpetual experiments produces a NH temperature response similar to the transient run and reanalysis, which suggests that it is the low frequency (e.g. ENSO, IPO, PDO, & NAO) variability is not responsible for this phenomenon.

The vertically integrated tropical diabatic heating change from the P1992 to the P2000 perpetual experiment showed a pattern that results in a strengthened stationary Rossby wave response over the Pacific-North American (PNA) region (Figs. 3a,d, & 4a), and an increase in poleward meridional heat transport due to stationary and transient wave activity. In contrast, the pattern of vertically integrated diabatic heating change from the P2000 to the P2020 experiment resulted in a weakened PNA stationary wave response and a weakened heat transfer from NH high-latitude upper troposphere to lower polar stratosphere, especially due to the transient wave activity (Figs. 3b,e, & 4b).

5. Discussion

The aerosol content is initialized from a spun-up initial condition and the emissions supplied to the GOCART model do not contain explosive volcanics, so the stratospheric aerosol can't be the driver of decadal variability in our simulations.

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E-mail: a.fahad@nasa.gov | *Web:* www.afahadabdullah.com

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