Lamont-Doherty Earth Observatory
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The Antarctic Dipole and its Stratospheric Connection

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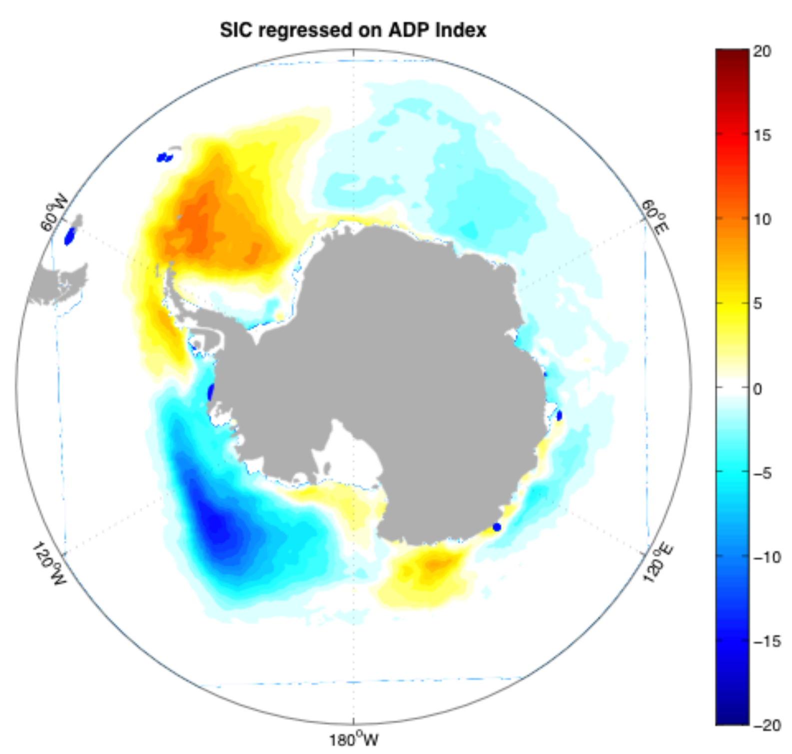
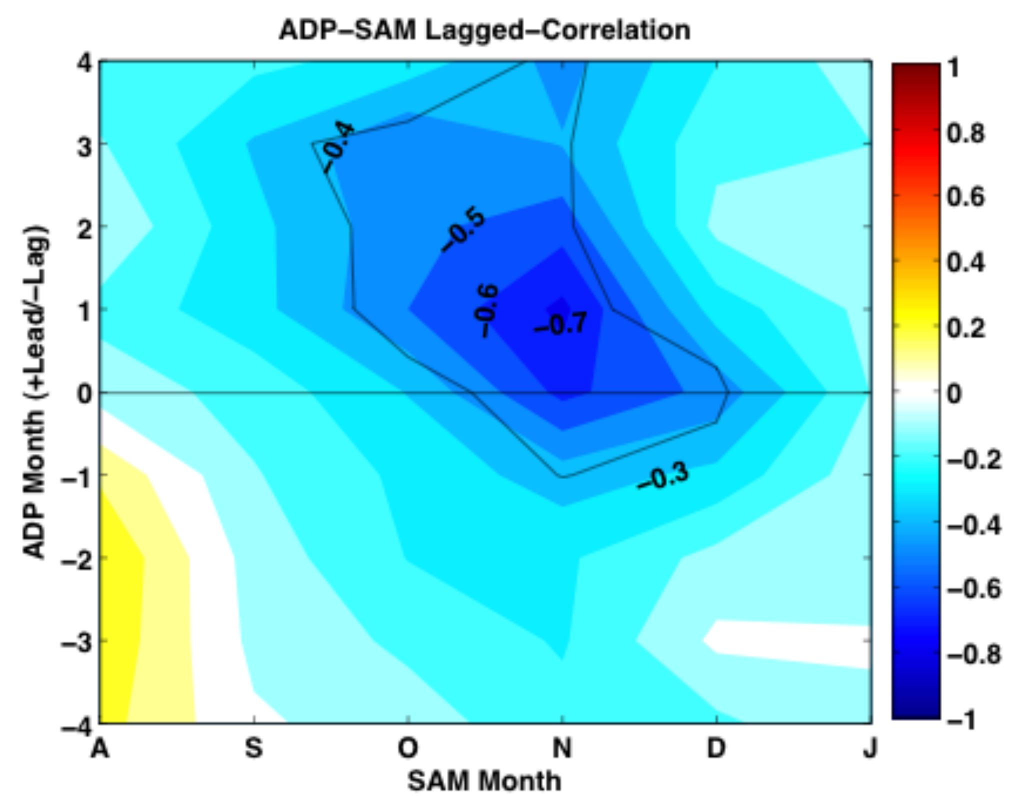
Introduction

The leading mode of Antarctic sea ice variability is characterized by the Antarctic Dipole Pattern (ADP), a pattern of opposing sea ice anomalies in the central/eastern Pacific and Atlantic sectors of the Southern Ocean (Yuan and Martinson 2001). Several studies have shown a strong correlation between tropical variability, such as ENSO, and the ADP and suggest that variability at low latitudes drives variability in the Southern Ocean region. (Yuan and Martinson 2000; Holland et al. 2005). Other studies have also shown a strong correlations between sea ice variability and other large-scale modes of climate variability such as the Southern Annular Mode (SAM; Stammerjohn et al. 2008).

Here we seek to examine whether the ADP itself can drive remote changes in the atmospheric circulation. We find that the ADP can potentially influence mid-latitude variability via a stratosphere-troposphere coupled response that projects onto the SAM.

Figure 1 shows sea ice concentration (SIC) regressed on the ADP index. The ADP index is defined as the difference between the mean sea ice edge anomaly in the Pacific sector (150°W-120°W) and the Atlantic sector (50°W-20°W). The ADP corresponds to a dipole in SIC anomalies about the Antarctic Peninsula. Data are the NSIDC/NASA Bootstrap monthly SIC (Fetterer et al. 2002).





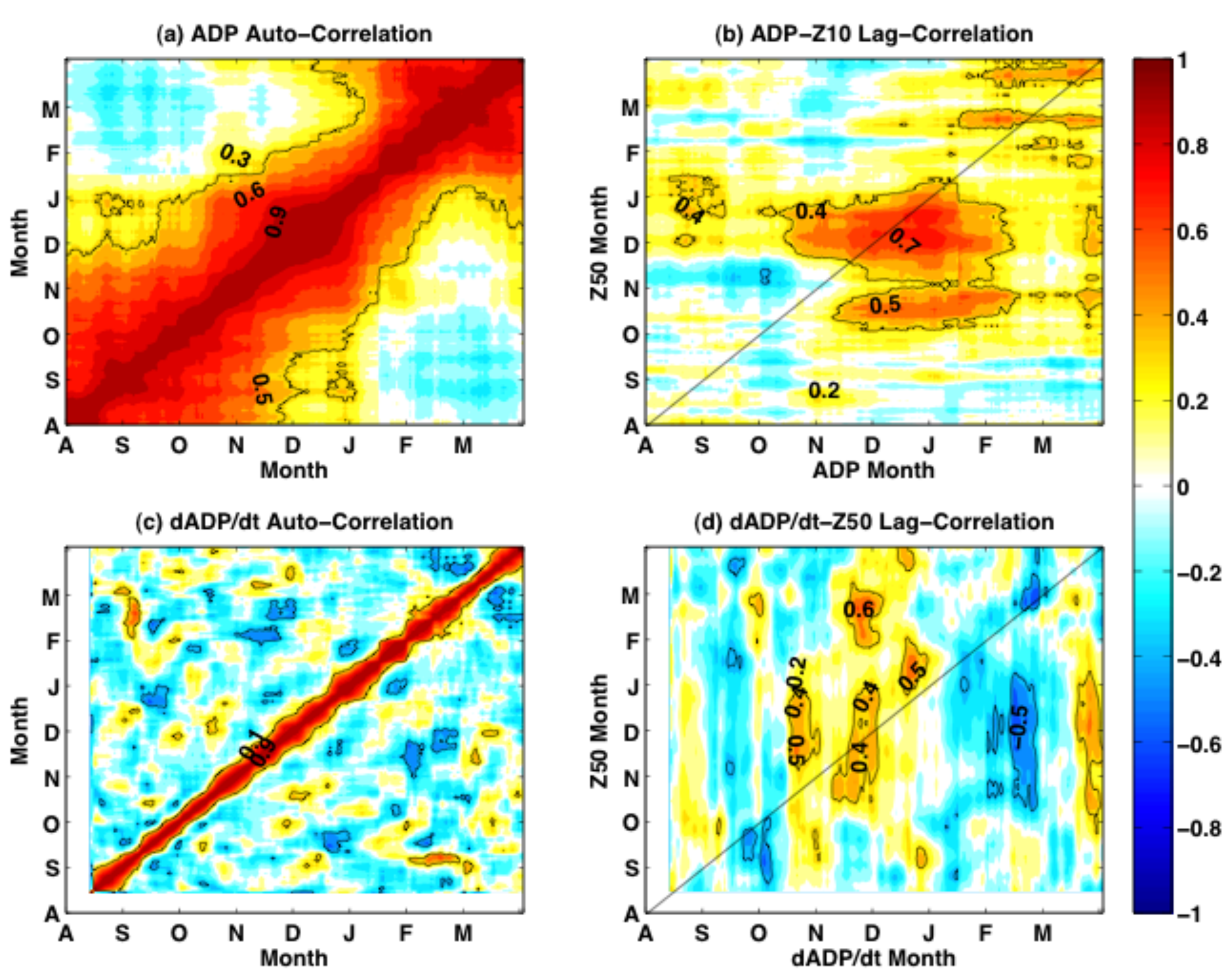


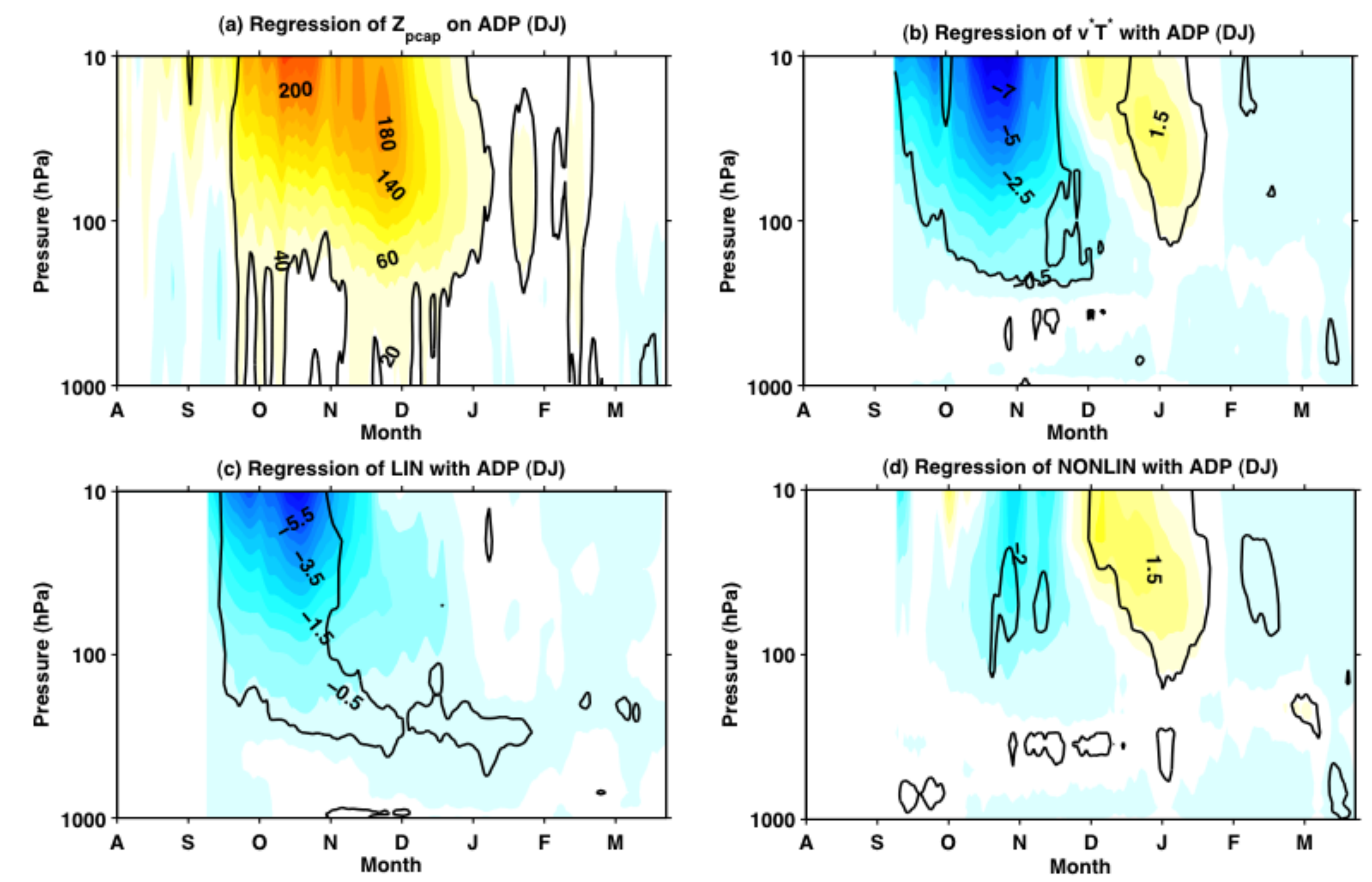
Figure 2 illustrates the lag-correlation between the ADP and the SAM. There is a strong correlation between the ADP and SAM in the austral spring and summer. Although the SAM tends to lead the ADP most of the time, there is also evidence that the ADP may lead the SAM.

This result lead us to examine the vertical structure of the ADP-SAM correlation. We found that the strong correlation between the ADP and SAM in spring/summer extends into the stratosphere.

This is illustrated in **Figure 3**. Here we show the (a) auto-correlation of the ADP itself, and (b) the lag- correlation between the ADP and the polar cap-averaged GPH at 50 hPa. Data are ERA-Interim (Dee et al. 2011) for 1979-2011 (excluding the year 2002).

The correlation between the ADP and Z50 also indicates that there are times when the ADP leads the stratosphere.

Because ADP anomalies are quite persistent (Fig. 3a), we also examined the correlations between the ADP tendency and Z50 (Fig. 3c), to avoid eliminate any artifacts associated with the ADP persistence. Again we find that the ADP tendency in spring leads the stratosphere.

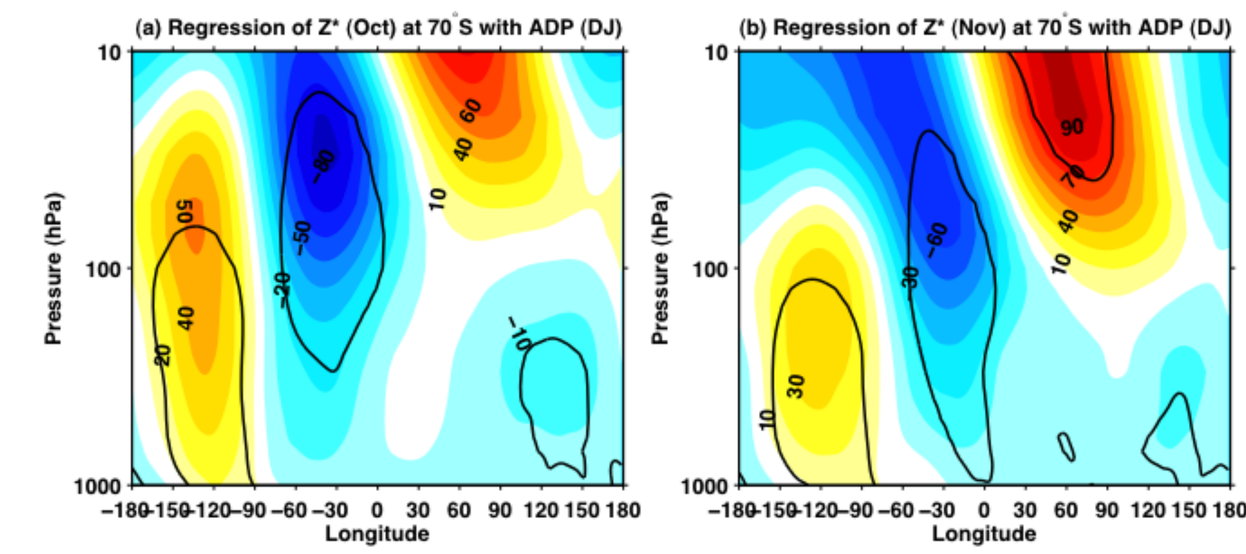


Focusing on the summer correlations in **Figure 3**, **Figure 4** shows regressions of (a) polar cap-averaged GPH (Z_{pcap}), (b) 40-80°S averaged meridional eddy heat flux, v*T*, (c) the linear interference component of v*T*, LIN and (d) the nonlinear component, NONLIN, on the December-January (DJ) ADP.

We find a very distinct stratosphere-troposphere coupled response driven by constructively interfering vertically propagating planetary waves (see below, **Figure 5**).

Regressions with the October-November ADP show similar results but with a slightly weaker magnitude.

Figure 5 shows the eddy GPH at 70°S regressed on the DJ ADP. We find a clear signal of a vertically propagating planetary wave. Again we see a very similar wave pattern for October-November ADP regressions. We also find that this wave pattern remains when we remove ENSO from the ADP time series, suggesting that this is wave forced locally by sea ice anomalies.



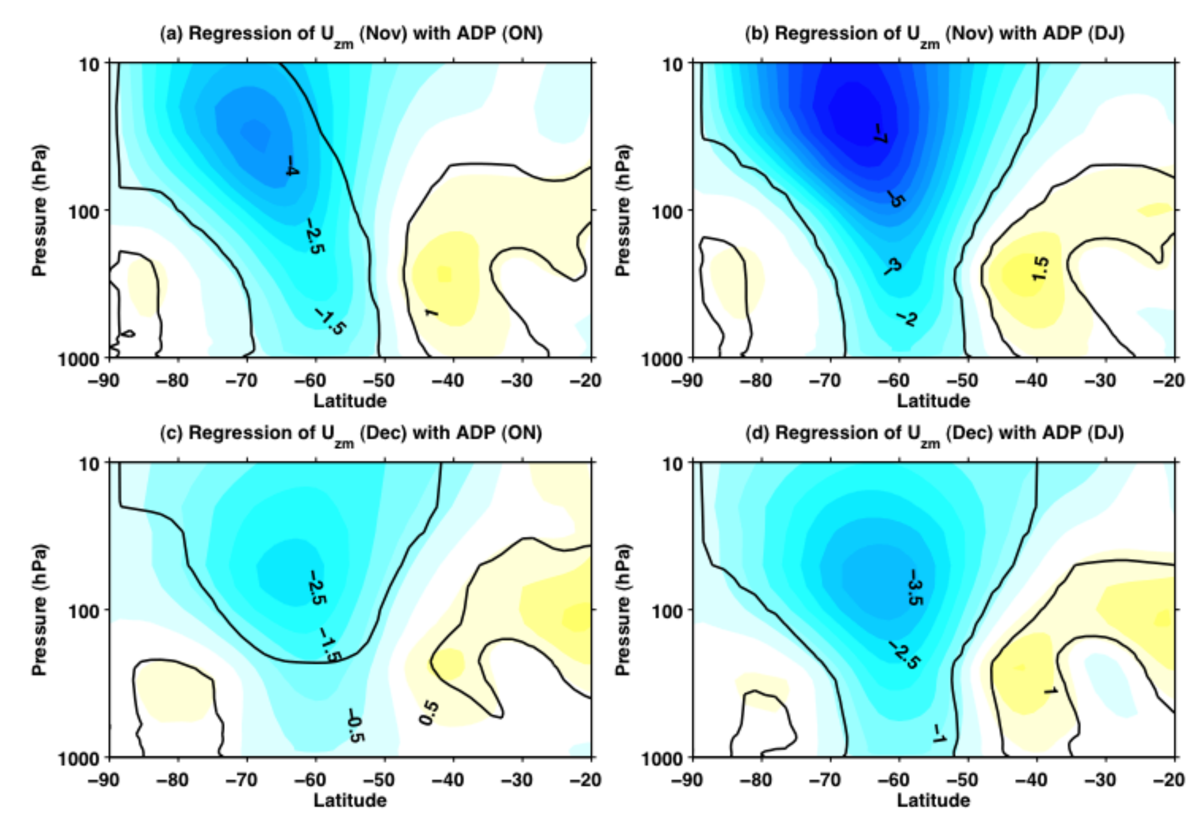
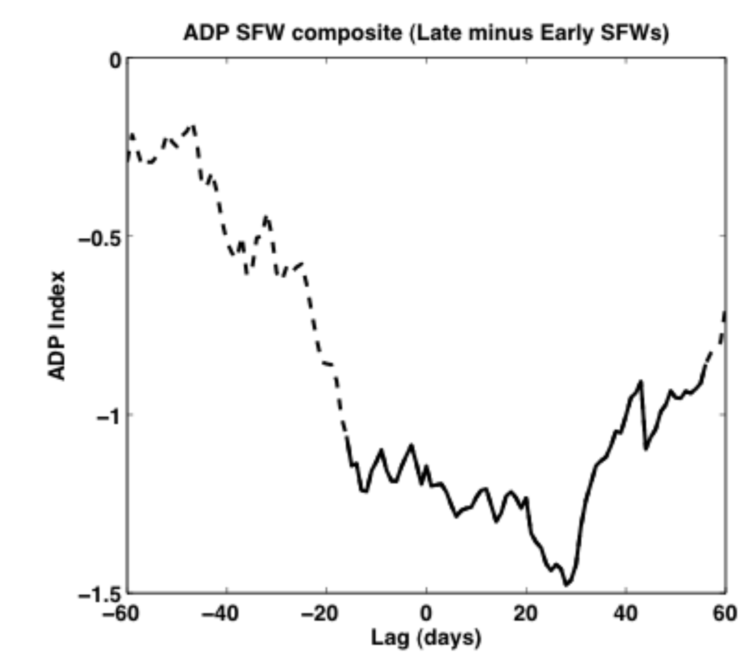


Figure 6 shows regressions of November (top row) and December (bottom row) zonal mean zonal wind on the ON ADP (left column) and the DJ ADP (right column). We find the signature of the SAM, extending up to the stratosphere and into the mid-latitudes in the troposphere.

Finally, to demonstrate that there is both a lead and lag component to the ADP-stratospheric circulation relationship, **Figure 7** shows the difference in the daily ADP index between late and early stratospheric final warmings (SFW). The composite difference is centered about the SFW central date.

We find a significant difference in the ADP Index between late and early SFW years up to 20 days before the central date and extending up to 40 days after.



Conclusions

Using satellite and reanalysis data, we find a strong relationship between the timing of the breakdown of the Southern Hemisphere stratospheric polar vortex and the Antarctic Dipole Index. Determining whether the ADP leads or lags the stratosphere or both, via a positive feedback process, is challenging. However, we find a clear signal of an upward propagating wave pattern emanating from the central/eastern Pacific sector of the ADP suggesting that the ADP is driving changes in the stratospheric circulation.

Future work will emphasize disentangling the lead-lag relationship as well as performing sea ice perturbation model simulations to explore the dynamics in detail.

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