Trends in Austral jet position in high- and low-top CMIP5 models

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Project aims

How does an improved representation of the lower stratosphere change our understanding of past tropospheric climate and future climate projections?

Three specific questions:

1. Do 'high-top' models better represent past climatology and trends than those with a 'low-top'?
2. What are the anticipated future changes in Austral jet position?
3. What are the mechanisms for changes in jet position, and how do they relate to the differences between high- and low-top models?

Motivation

- Past changes in jet position have been shown to result from concomitant GHG and stratospheric ozone forcing
  - Model studies suggest that ozone depletion is the primary driver
  - Expect cancellation or reversal of trends in near future as ozone recovers
- Low-tops have cold-bias and underestimate variability
- CMIP5 gives unprecedented availability of high-top models and comparable ozone scenarios

Jet position

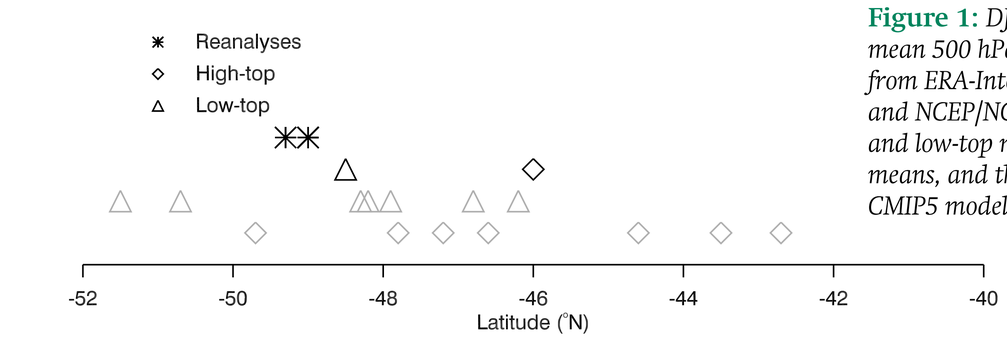


Figure 1: *DJF (1979-2006) mean 500 hPa jet position from ERA-Interim, CFSR, and NCEP/NCAR, the high- and low-top multi-model means, and the individual CMIP5 models considered.*

- Wide range of climatological jet position, mostly Equatorward of the reanalyses
- High-top multi-model mean has a greater Equatorward bias

Change in jet position and temperatures

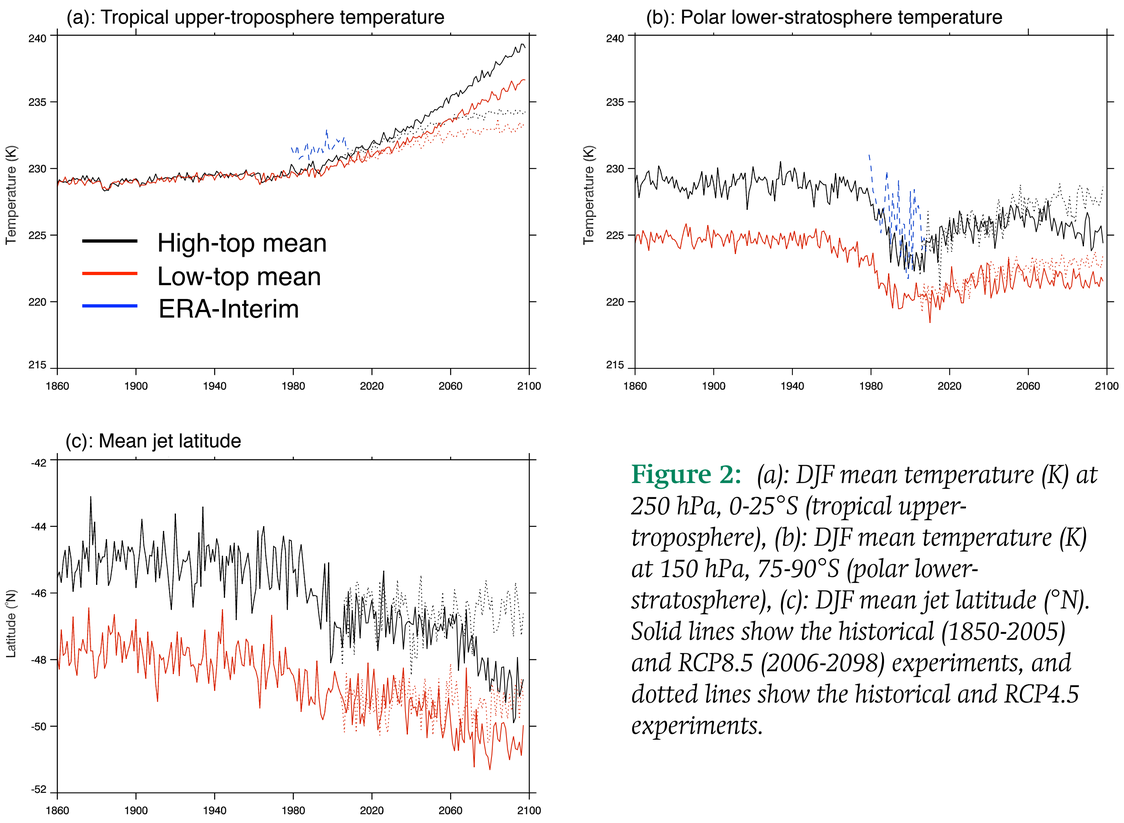


Figure 2: *(a): DJF mean temperature (K) at 250 hPa, 0-25°S (tropical upper-troposphere), (b): DJF mean temperature (K) at 150 hPa, 75-90°S (polar lower-stratosphere), (c): DJF mean jet latitude (°N). Solid lines show the historical (1850-2005) and RCP8.5 (2006-2098) experiments, and dotted lines show the historical and RCP4.5 experiments.*

- Low-top models have a pronounced cold bias in the polar lower stratosphere
- Reversal in polar lower stratospheric temperature trends in ozone recovery period
  - High-top models show greater warming in response to ozone recovery
- Reduced rate of poleward jet shift in ozone recovery period
  - Particularly pronounced in the high-top mean

Influence of position bias?

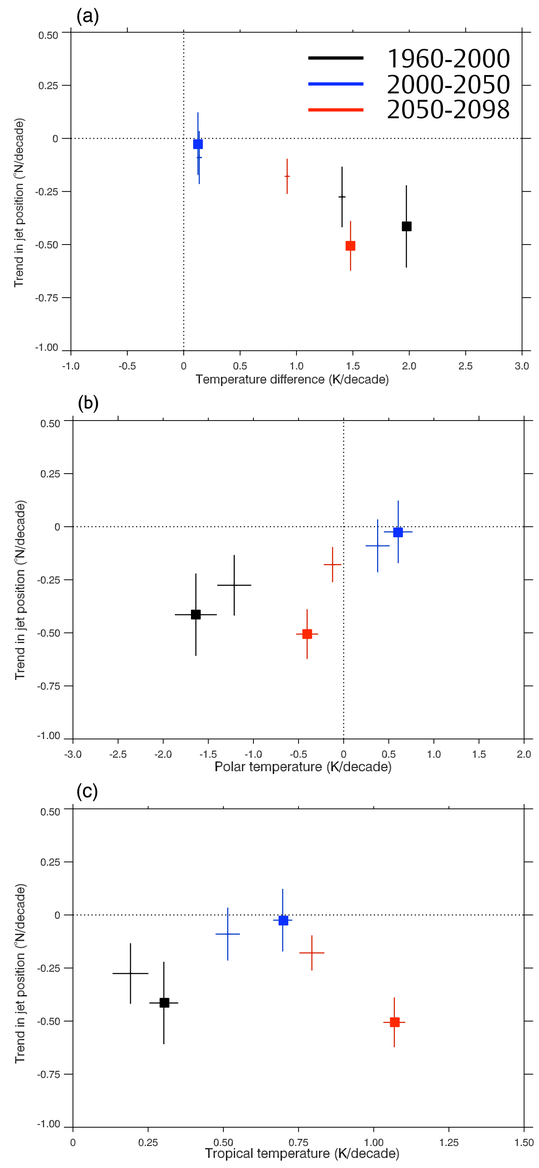
	SON	DJF	MAM	JJA	Ann
KG [1]	-0.61	-0.08	-0.76	-0.81	-0.77
This work	-0.30	-0.37	-0.74	-0.53	-0.64

Table 1: *Correlation between jet position and shift*

- Kidston and Gerber (2010) [1] showed a strong relationship between jet position and jet shift in CMIP3 models
  - Equatorward biases in position resulted in larger shifts
- Similar relationship exists for CMIP5 models
  - Stronger, but not significant, relationship identified in DJF

Temperature gradient as a driver

Meridional temperature gradient: difference between polar lower-stratospheric and tropical upper-tropospheric temperatures



- Trend in temperature gradient is larger in the high-top mean
- Trend in jet position not significantly different from zero corresponds to near zero temperature gradient
- Near zero trend in temperature gradient in 2000-2050 due to warming polar lower stratosphere
- Large difference in temperature gradient between high- and low-top mean in 2050-2098 due to greater tropical warming in the high tops
  - High-tops show greater magnitude temperature trends in all periods

Figure 3: *(a): Meridional temperature gradient (K/decade) and 500 hPa jet position (°N/decade) trends for the low- and high-top multi-model mean for the historical and RCP8.5 experiments. (b): Polar lower-stratospheric temperature and 500 hPa jet position. (c): Tropical upper-tropospheric temperature and jet position. Squares indicate high-top models. Error bars are two standard errors.*

Linear response to temperature changes?

- Sensitivity = $\frac{\Delta \text{ jet position}}{\Delta \text{ temperature}}$
- Sensitivity is invariant across all time periods and scenarios
- Hints of deviation from a linear response in some models under strong forcing

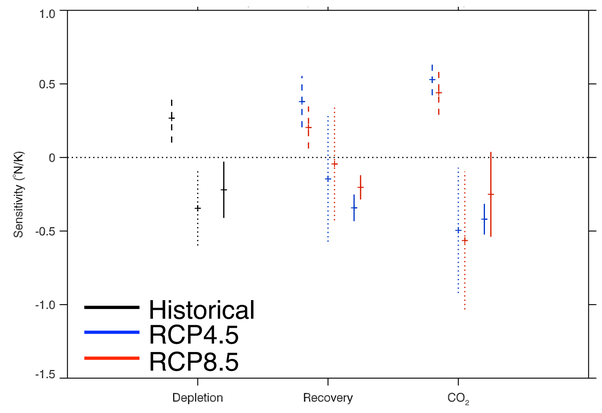


Figure 4: *Sensitivity (°N/K) of the position of the 500 hPa jet to trends in polar lower-stratosphere temperature (dashed), tropical upper-troposphere temperature (dotted), and meridional temperature gradient (solid), in the ozone depletion (1960-2000), ozone recovery (2000-2050), and GHG dominated (2050-2098) periods. Historical data are shown in black, RCP4.5 in blue, and RCP8.5 in red. Error bars are two standard errors.*

- High-top models have larger temperature and jet position responses to forcing
- High-top models have a better representation of historical temperature, but a larger Equatorward jet bias
- Cancellation between the effects of ozone recovery and increasing greenhouse gases is particularly apparent in the high-top models

References

[1] Kidston, J., and Gerber, E. P. (2010). *GRL*, **37**, L09708.

Learn more: Wilcox, L. J., Charlton-Perez, A. J., and Gray, L. J., (2012). *J. Geophys. Res.*, **117,** D13115