Robustness of the simulated tropospheric response to ozone depletion.*

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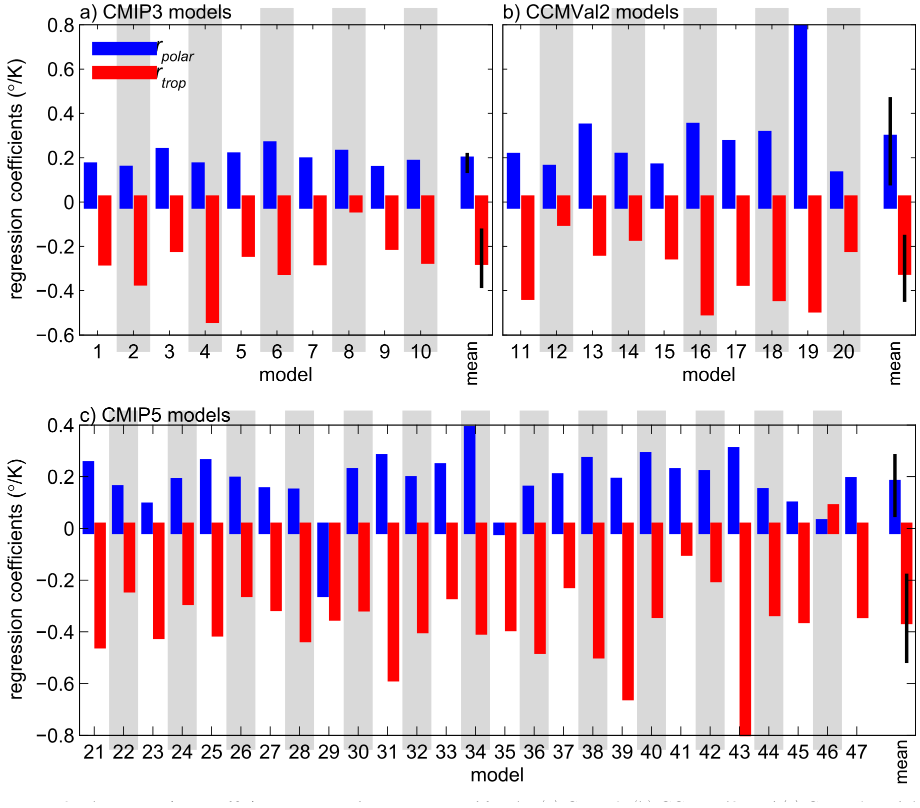
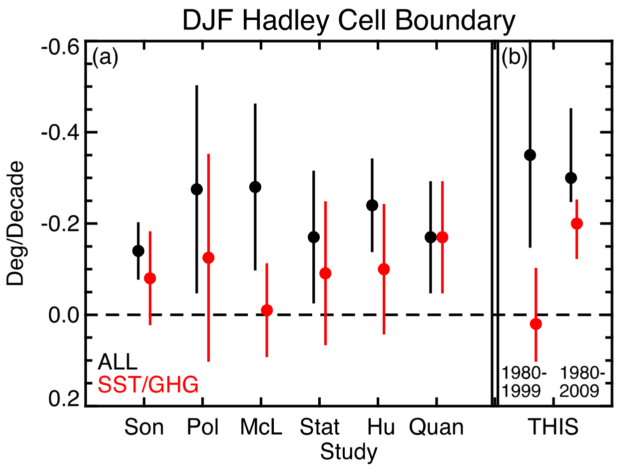
Introduction

Recent modeling studies have differed as to the magnitude of the response of the SH tropospheric circulation to ozone depletion.





[Waugh et al. 2015]

[Gerber & Son 2015]

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Introduction

Are these differences due to differences in model dynamics?

We examine tropospheric response across a hierarchy of models, ranging from

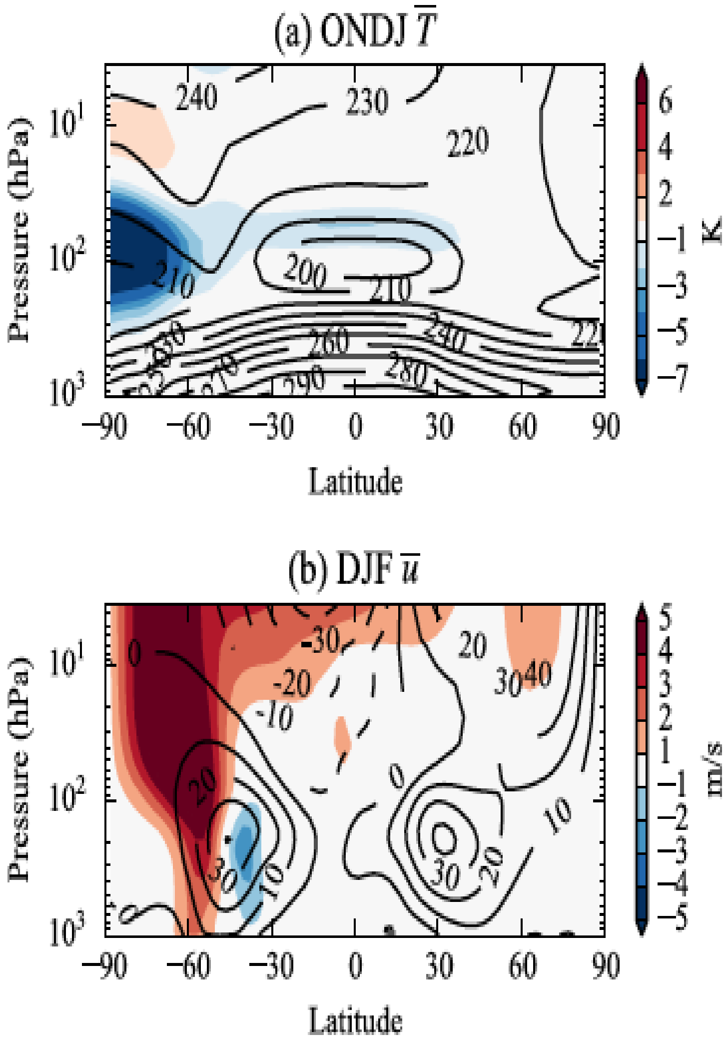
atmosphere-only models with prescribed O_3,

to

coupled atmosphere-ocean models with interactive stratospheric chemistry.

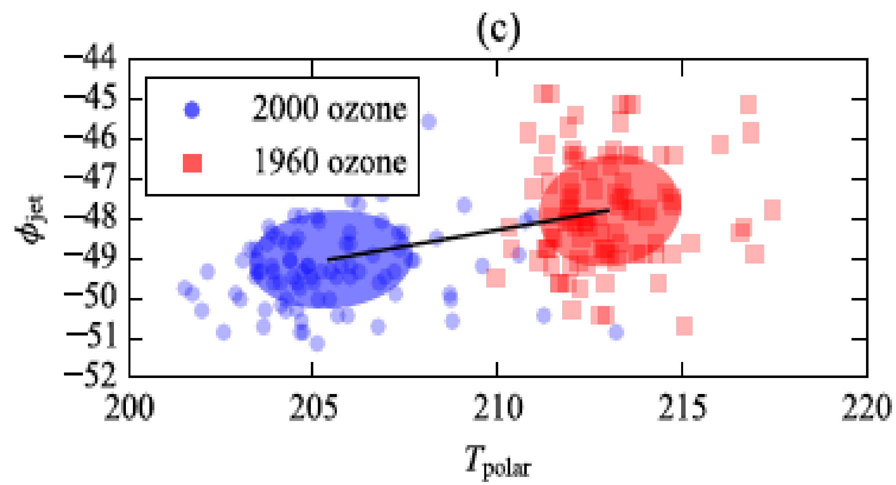
Follow approach of Polvani et al. (2011) …

Polvani et al. (2011)



Performed pairs of CAM3 time-slice integrations that differ only in stratospheric O_3 (1960 or 2000).

Difference shows cooling in polar lower stratosphere and poleward movement of jet latitude.



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Model Integrations

atmosphere-only models
with prescribed O_3

Pair name	Model	Ozone	GHG	SST	Length
CAM-2000	CAM3	SPARC (1960/2000)	2000 (SRES-A1b)	HadISST (2000)	100 years
CAM-1960	CAM3	SPARC (1960/2000)	1960 (SRES-A1b)	HadISST (1960)	100 years
CAM-1870	CAM3	SPARC (1960/2000)	1870	HadISST(1870)	50 years
CAM-1870CM2	CAM3	SPARC (1960/2000)	1870	CM2.1 control	50 years
GFDL-A	ESM2Mc atmos	SPARC (1960/2000)	1860	ESM2Mc control	100 years
GFDL-O	ESM2Mc	SPARC (1960/2000)	1860	Coupled	100 years
GEOSCCM-A	GEOSCCM	Interactive chemistry	Transient	HadISST/Reynolds	3x16 years
GEOSCCM-O	GEOSCCM	Interactive chemistry	Transient	Coupled	4x16 years
CMAM	CMAM	Interactive chemistry	1960	Coupled	3x16 years

coupled atmosphere-ocean
models with interactive
stratospheric chemistry.

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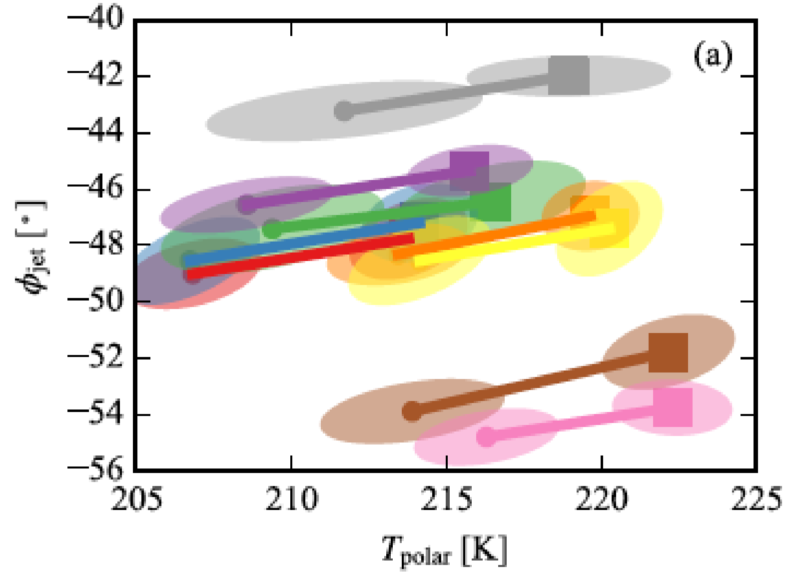
Polar T – tropospheric circulation

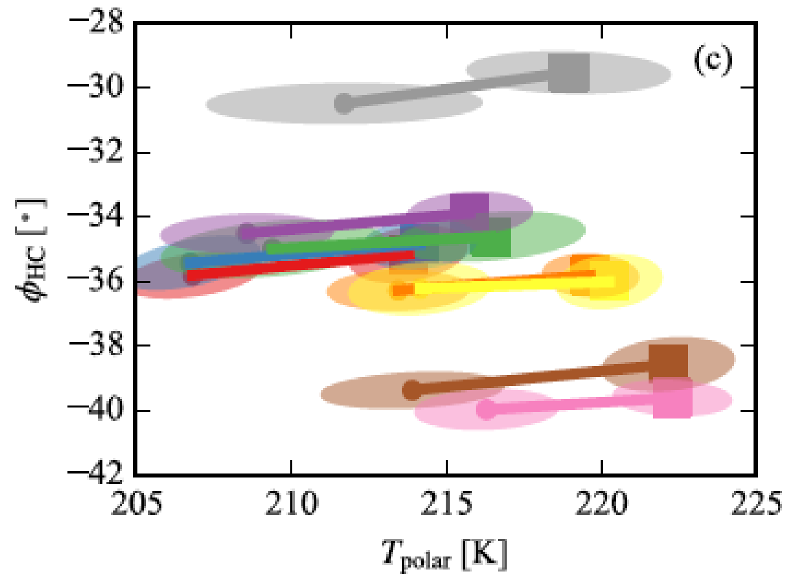
Wide range of climatological mean

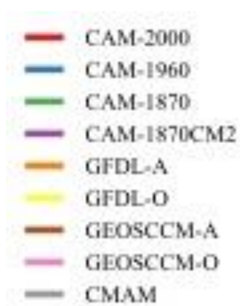
- polar 100hPa T,
- jet latitude ϕ_{jet}, and
- Hadley Cell edge ϕ_{HC}

among the models.

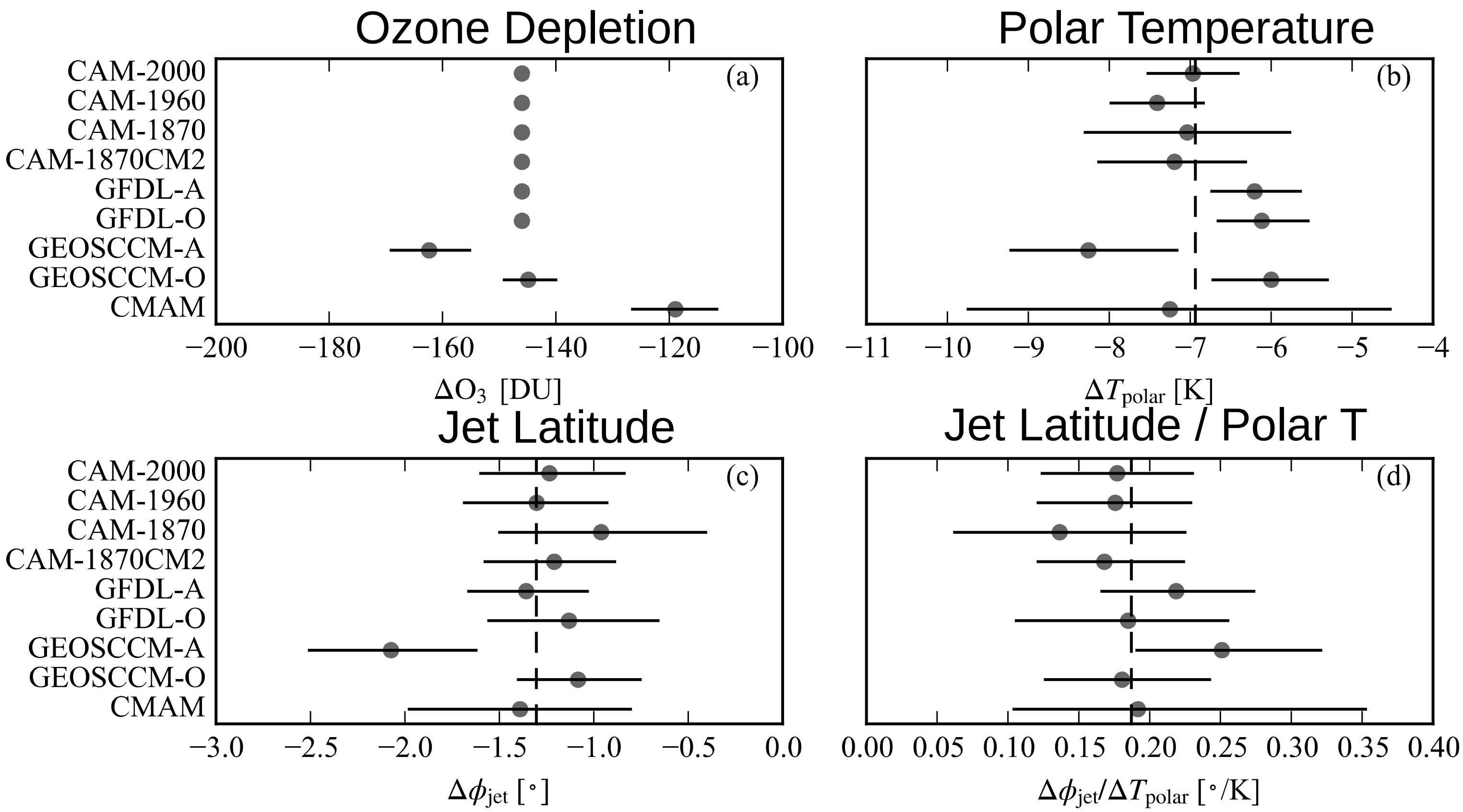
But in all models, the jet latitude and HC edge are further poleward when colder pole (ozone depletion).







Response of jet to Ozone Hole



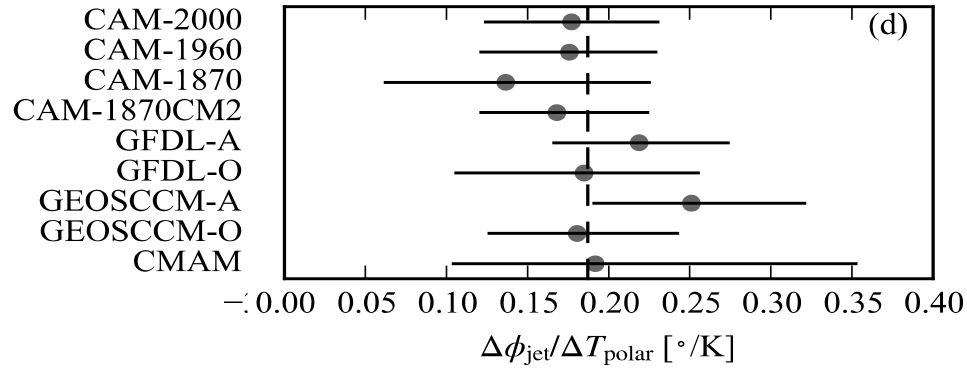
- Consistent jet latitude response among the models (esp. when normalized by stratospheric ΔT).
- Large uncertainty in response (due to large interannual variability in models).

Jet Latitude & Strength, HC edge

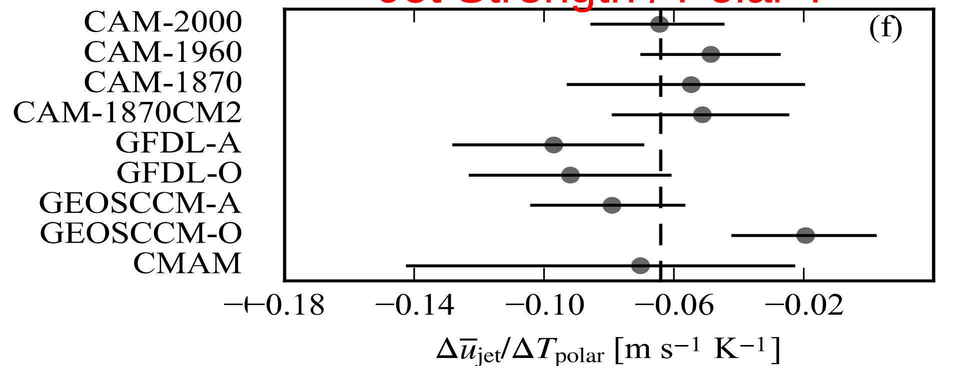
There is less consistency in the HC edge and (especially) jet strength response.

There do not appear to be any consistent differences between different types of model

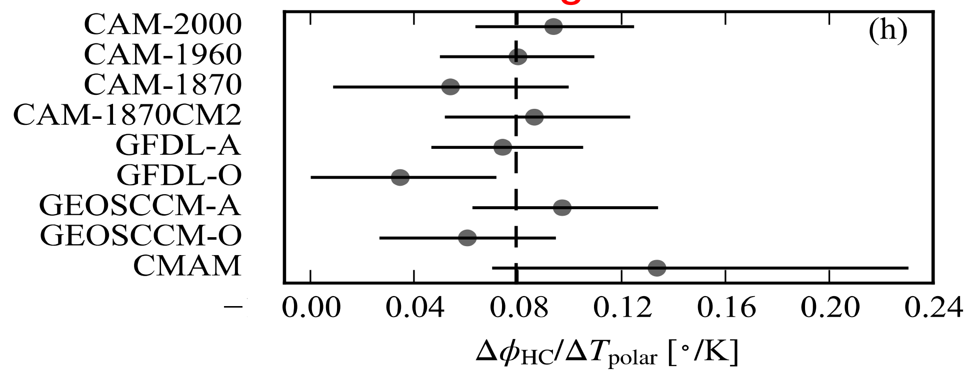
Jet Latitude / Polar T



Jet Strength / Polar T



HC edge / Polar T



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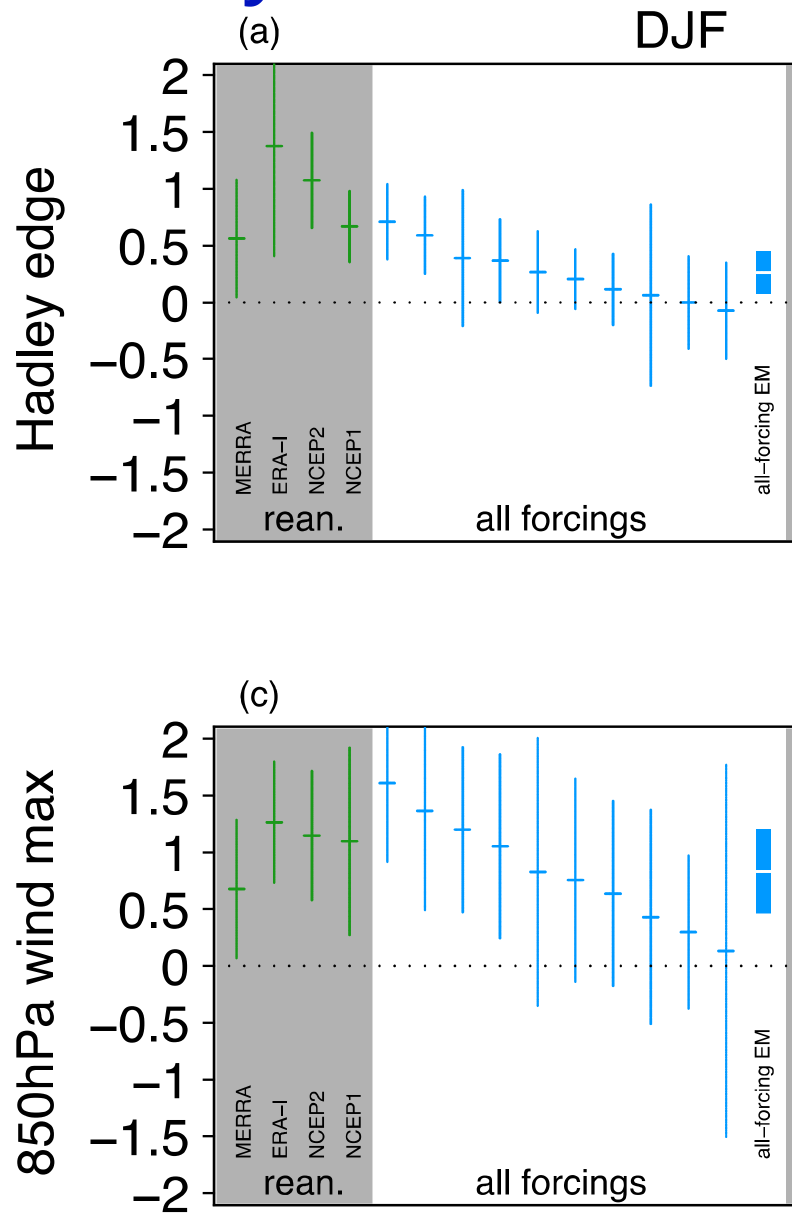
Internal Variability

Large internal variability illustrated by 1980-2000 trends from 10-member ensemble of GEOSCCM transient runs (Garfinkel et al 2015).



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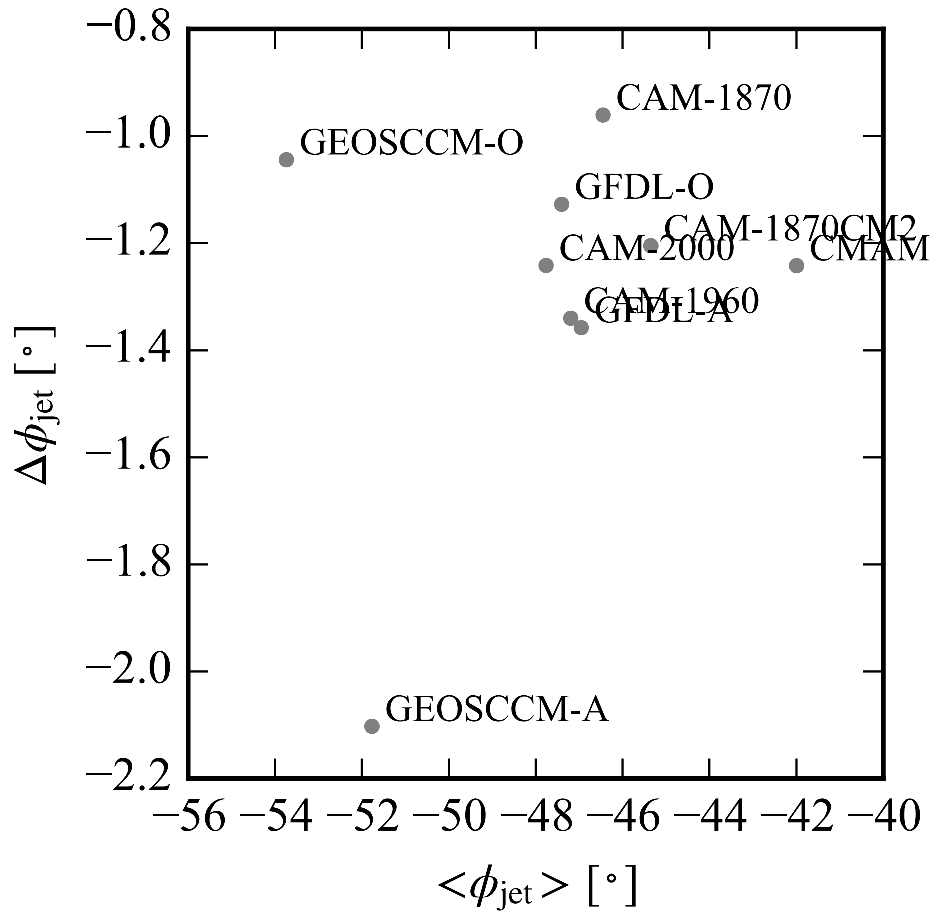
Impact of bias in mean state

Previous studies have suggested magnitude of jet response may be linked to biases in mean position.

However, there is no correlation between the climatological jet latitude and the ozone depletion-induced summertime jet shift.

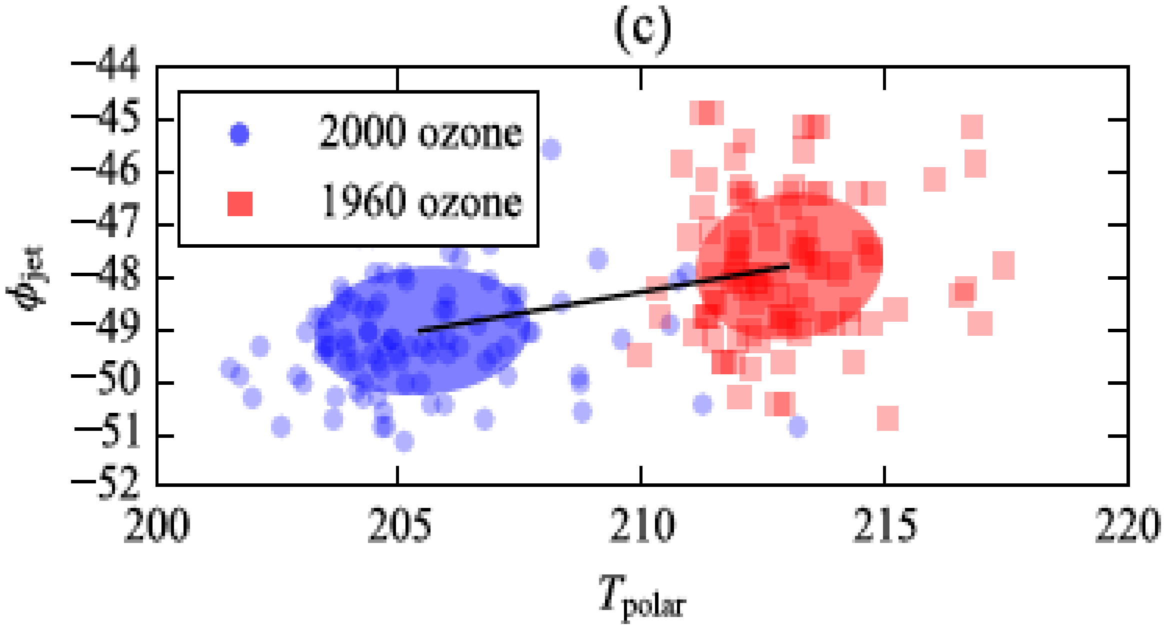
[Consistent with Simpson and Polvani (2016) CMIP5 analysis.]



Long-Term vrs Interannual Variability

Polvani et al. (2011) noted apparent difference between interannual variability and long-term trends.

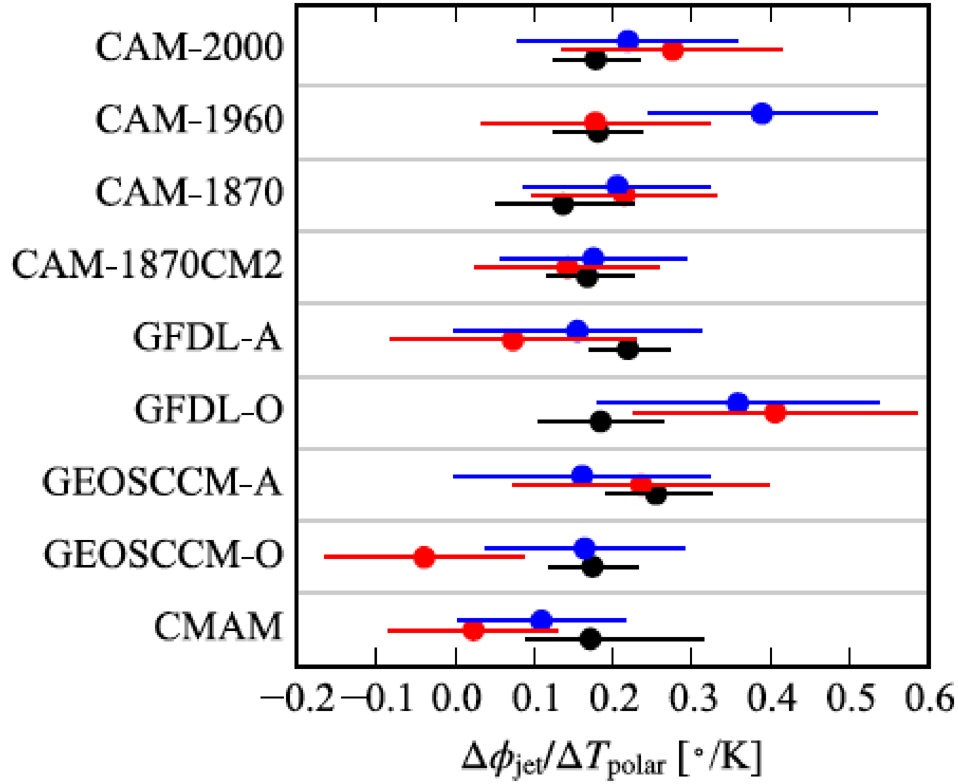
Suggested different mechanisms may be operating for different time scales.



Long-Term vrs Interannual Variability

Compare the interannual linear regression coefficient of ϕ_{jet} and T_{polar} for each simulation (1960 and 2000) with the ratio of $\Delta\phi_{jet}$ to ΔT_{polar} for each pair.

In nearly all cases we find consistent values
=>
Same mechanisms operating on short and long time scales.



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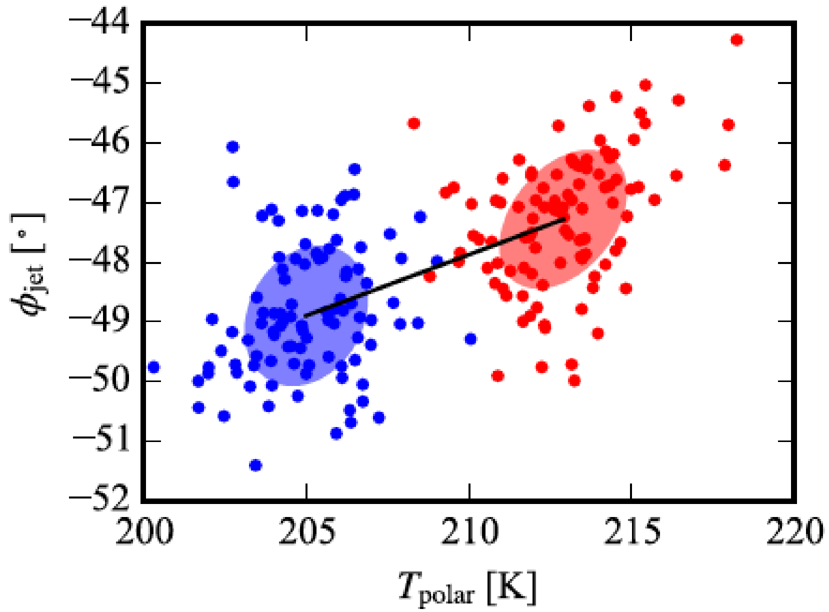
Long-Term vrs Interannual Variability

Appearance of small interannual correlation relative to ozone induced change comes from large internal variability (noise).

Consider simple linear model

$$\phi_{\text{jet}} = a + b(T_{\text{polar}} - T_0) + cN(0,1),$$

with A=-49°, b=0.2°/K, c=1°, and T_0=205K (blue) or 213K (red)



As with climate models appearance of low correlation within each cloud, but correlation same as long term shift.

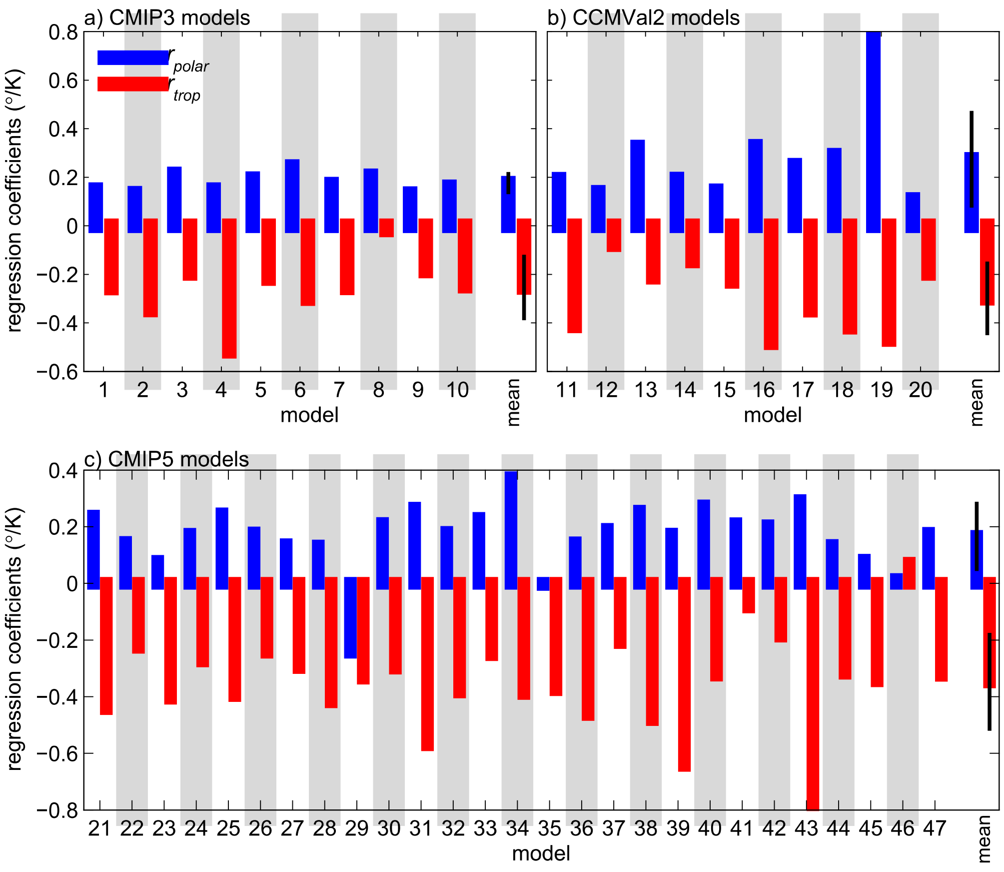
Conclusions.

1. “Controlled” experiments show consistent response of jet and HC to ozone depletion across a wide range of models.

2. Large internal variability leads to significant uncertainties in response. Need long time-slice runs or large number of transient runs.

3. A significant fraction of inter-model differences could be attributed to interannual variability (and lack of large ensembles).

Gerber and Son (2015)



Multi-model mean

$r_{polar} \sim \Delta\phi_{jet} / \Delta T_{polar}$
$=0.2^{o}/K$,

consistent with results here, but large spread amongst model.

Possibly due to only single ensembles for most models.

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