

Uncertainties in Climate Change Projections of Tropical Circulation

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INTRODUCTION

- Three main sources of uncertainty (Deser et al. 2010)
 1. forcing
 - incomplete knowledge of external factors
 2. model response
 - differences in physical and numerical formulations
 3. internal variability
 - natural variability in the absence of external forcing
- Estimation of uncertainty
 1. CMIP3 multi-model archive (e.g. Hegerl et al. 2007)
 2. large ensemble with a single model
(Selten et al. 2004, Deser et al. 2010)

INTRODUCTION

- CCSM3 40-member ensemble for 2000-2060 (Deser et al. 2010)
 - AIB scenario
 - trend = (2051-2060) – (2005-2014)
- Variables of interest
 - surface air temp, precip, and SLP (Deser et al. 2010)
 - mean circulation (this work)
 - HC weakening (e.g. Lu et al. 2007)
 - HC widening (e.g. Seidel et al. 2007)
 - Tropopause rise (e.g. Lorenz and DeWeaver 2007)

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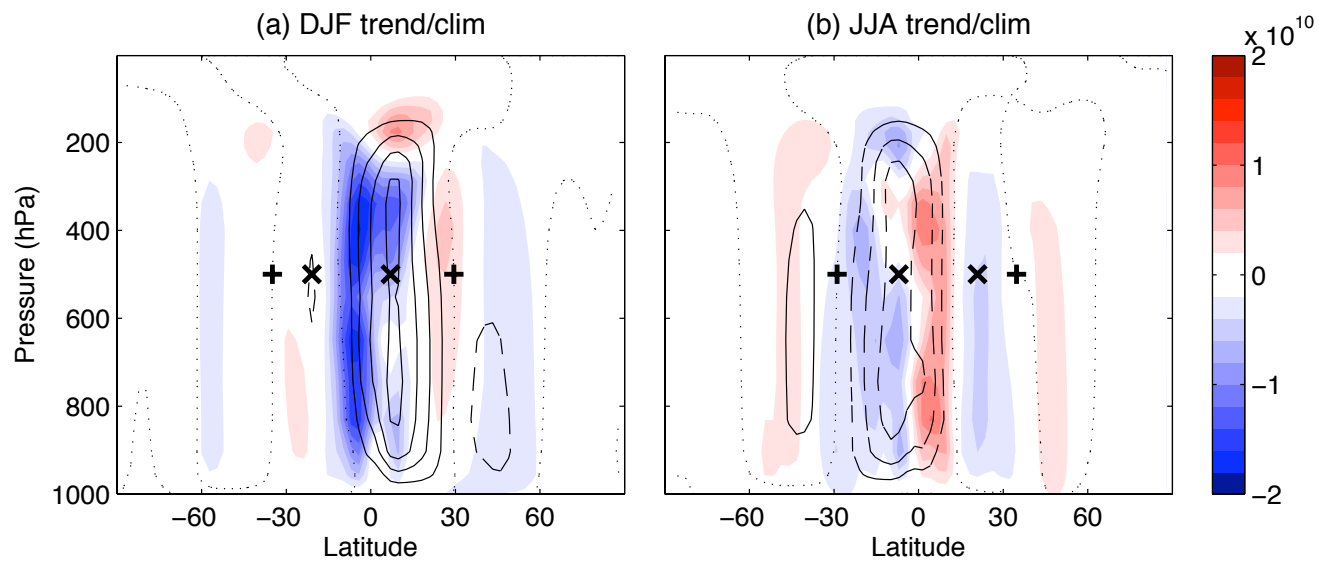
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3. Is there a relationship between the patterns of the forced response and the leading patterns of internal variability?
 - EOF analysis on the set of 40 trend maps after removing the ensemble mean trends

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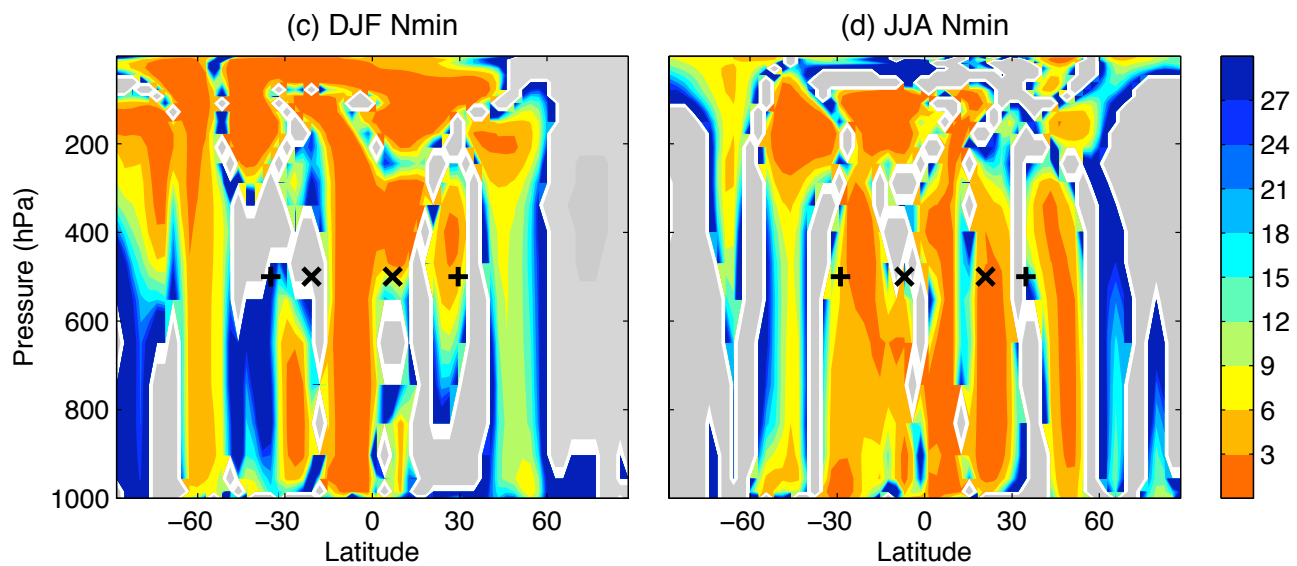
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 - EOF analysis on the set of 40 trend maps after removing the ensemble mean trends
4. How is EOF1 of circulation trends associated with precipitation?
 - precip regressions associated with EOF1 ψ trends

STREAMFUNCTION Ψ

Shading: trend
Contours: climatology

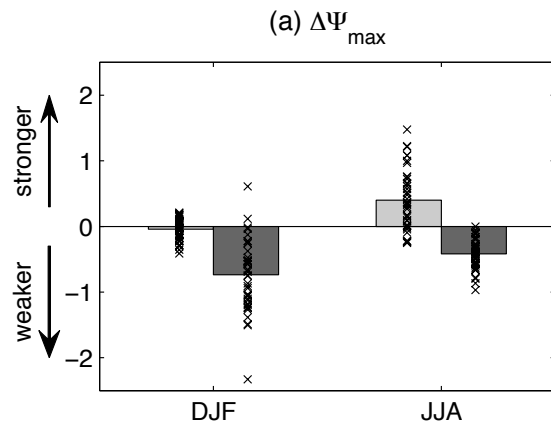


Nmin to detect
significant trends

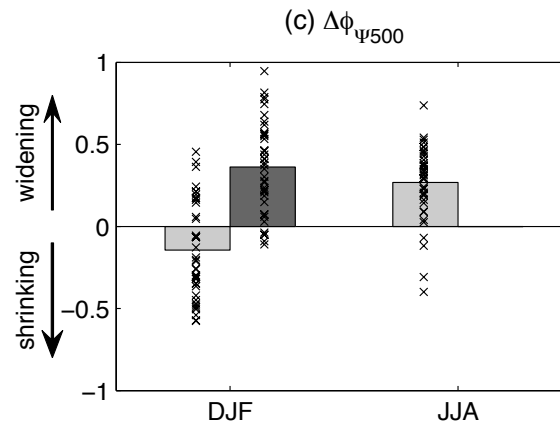


HADLEY CELL METRICS

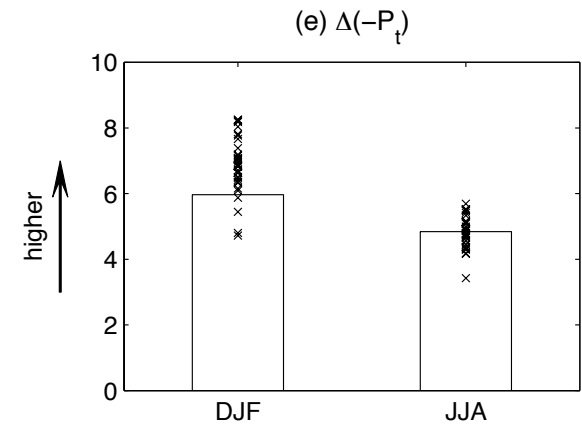
HC strength (10^{10}kg s^{-1})



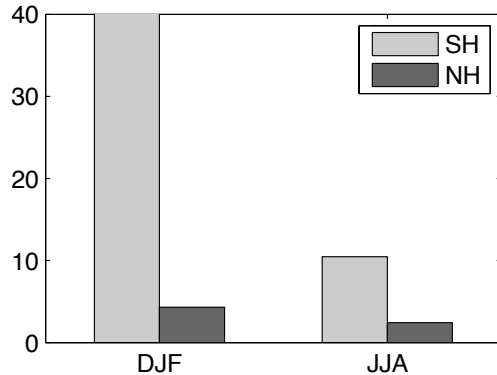
HC edge ($^{\circ}$)



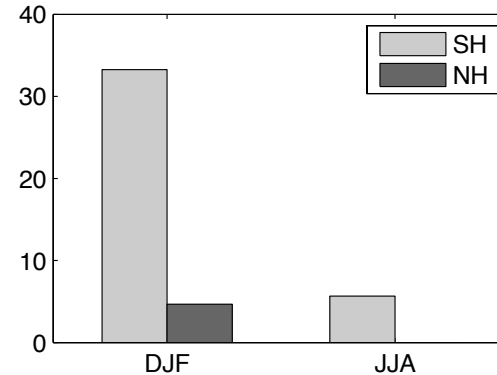
HC height (mb)



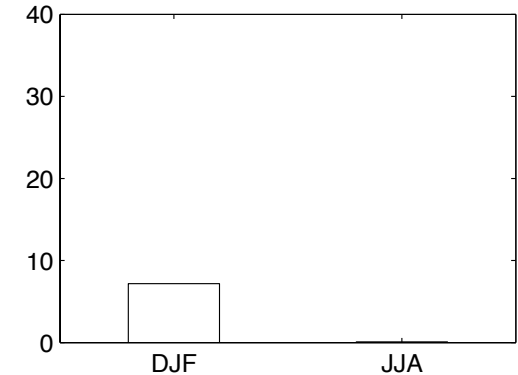
(b) $\Delta\Psi_{\text{max}}$ Nmin



(d) $\Delta\phi_{\psi 500}$ Nmin

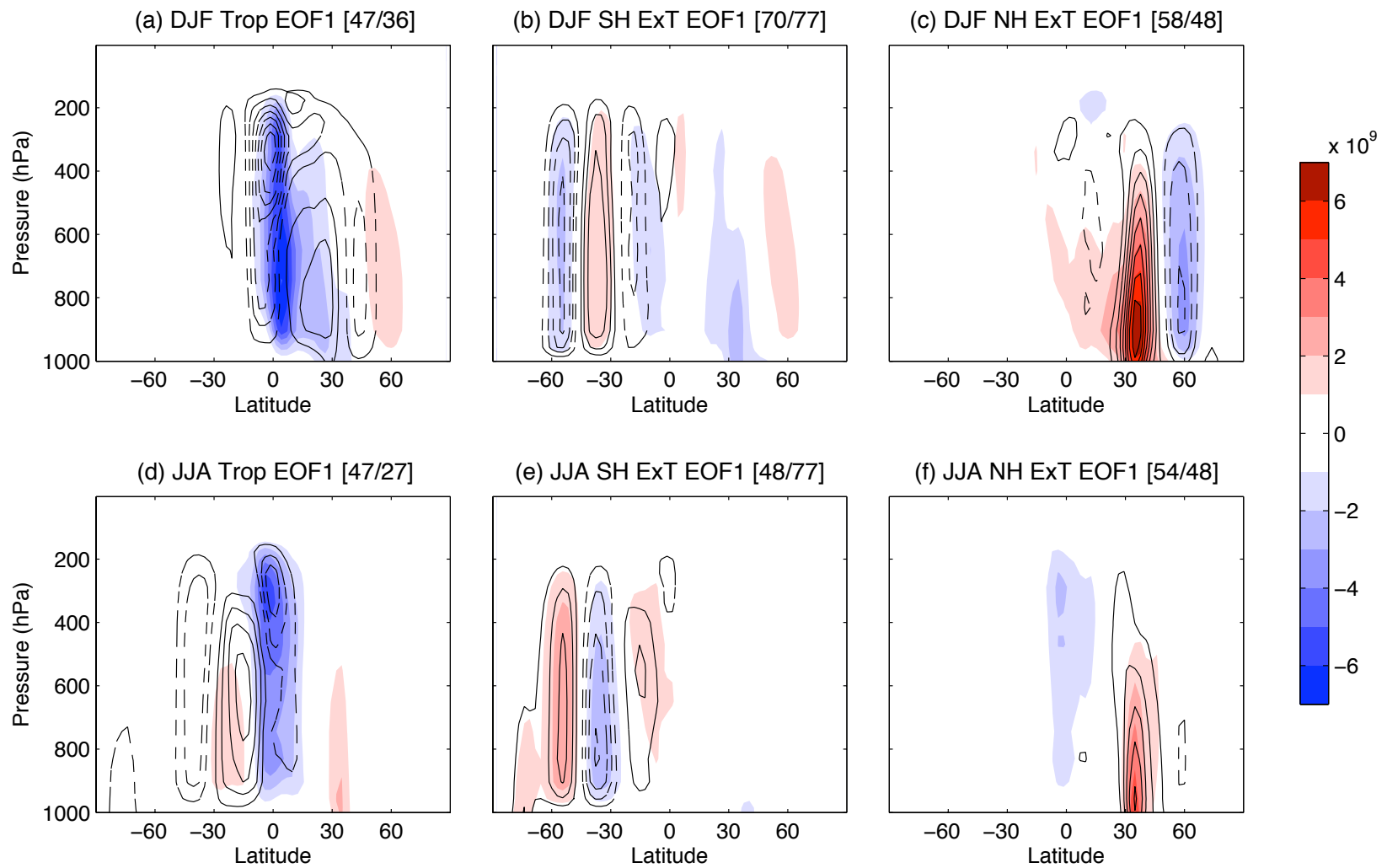


(f) $\Delta(-P_t)$ Nmin



Ψ EOF1

Shading: CCSM3 40 members \blacklozenge Contours: CAM3 100 members



Ψ EOF1 AND HC METRICS

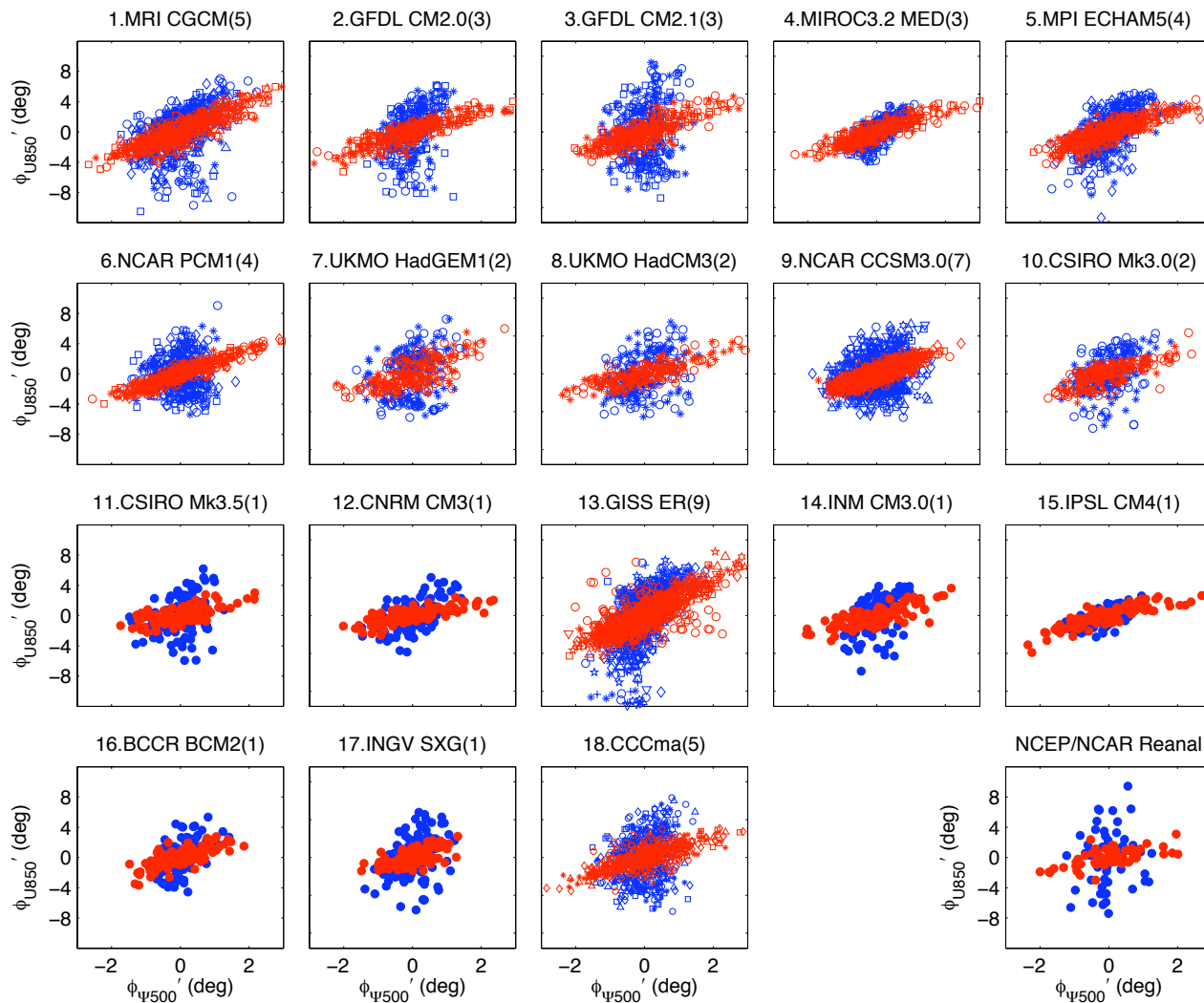
Correlation
(DJF/JJA)

PC1 \ HC metrics	Trop	SH ExT	NH ExT
Ψ_{max}	0.91/0.71	0.35/0.35	0.31/0.01
SH $\phi_{\Psi500}$	0.01/0.40	0.93/0.67	.
NH $\phi_{\Psi500}$	0.22/N.A.	.	0.37/N.A.

EXTRATROPICAL JET LATITUDE AND HC EDGE

20C3M 18 models

SH Jet latitude

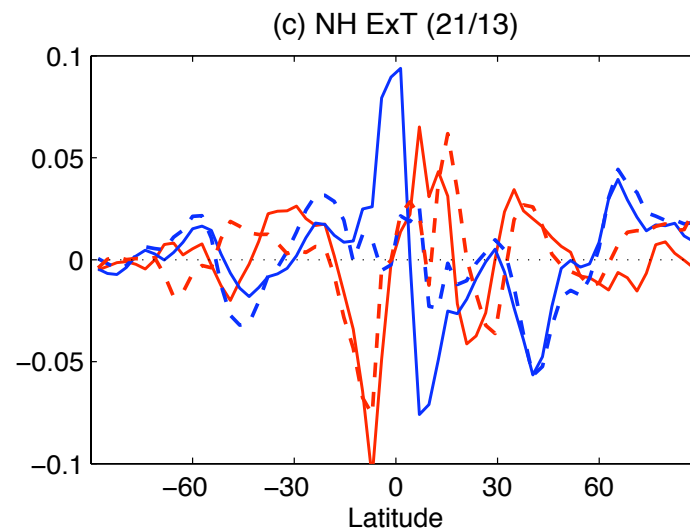
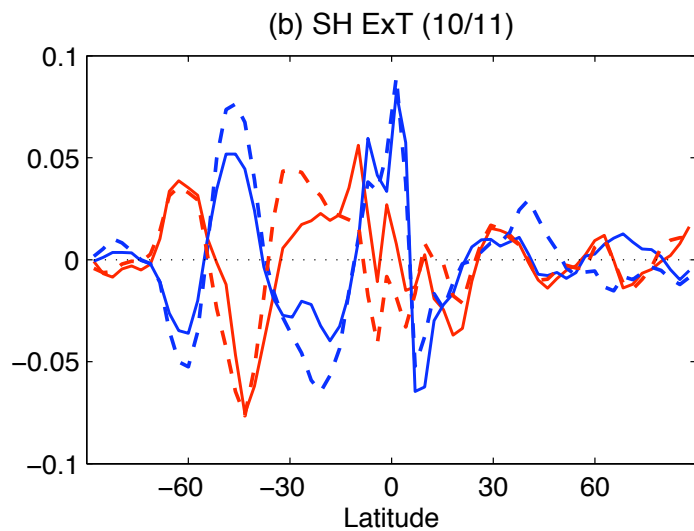
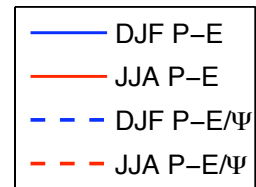
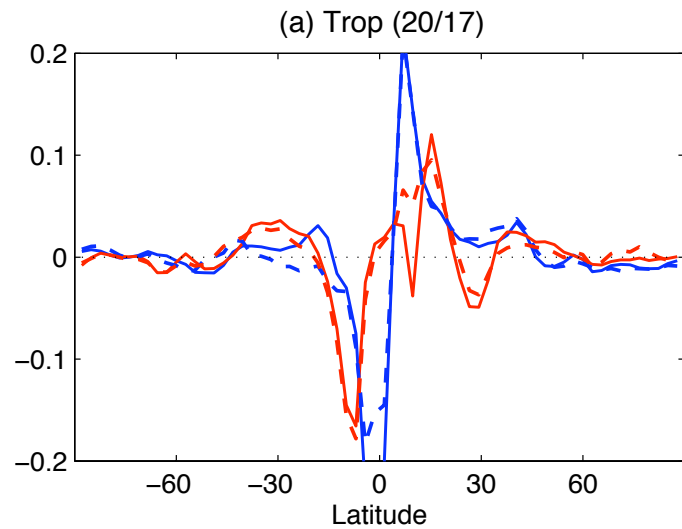


Corr:
0.82 in SH DJF
0.40 in SH JJA

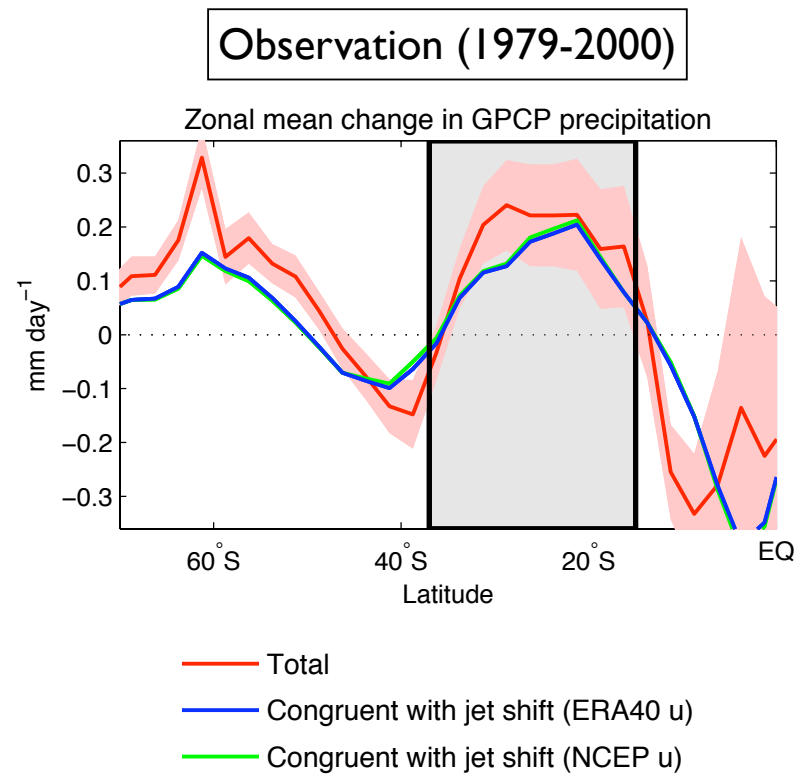
SH HC edge

Kang and Polvani, *J. Clim.* 2011

ASSOCIATION WITH P-E



JET SHIFT AND PRECIPITATION

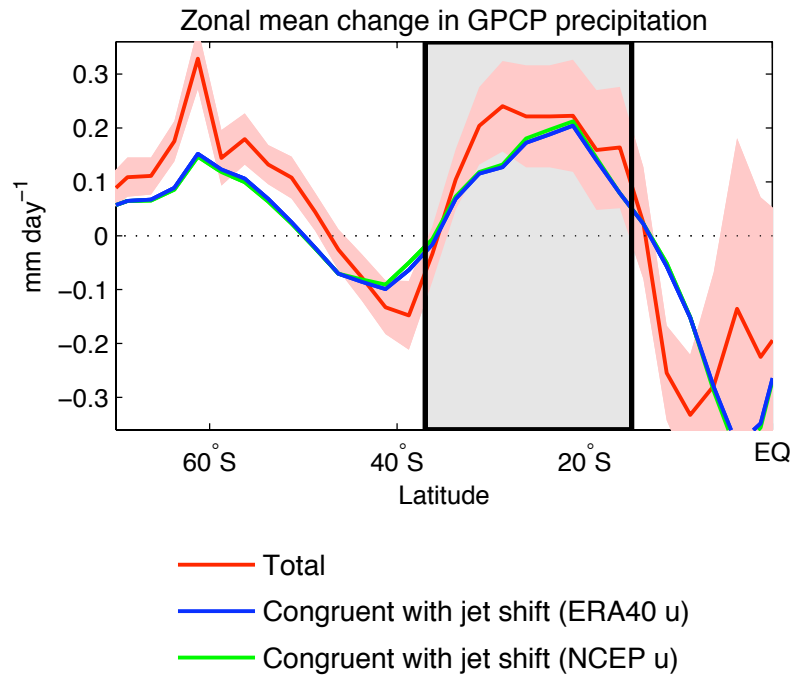


Kang et al. *Science*, 2011

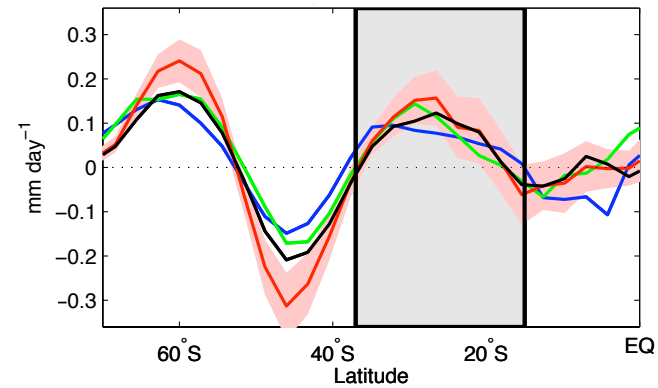
JET SHIFT AND PRECIPITATION

Models

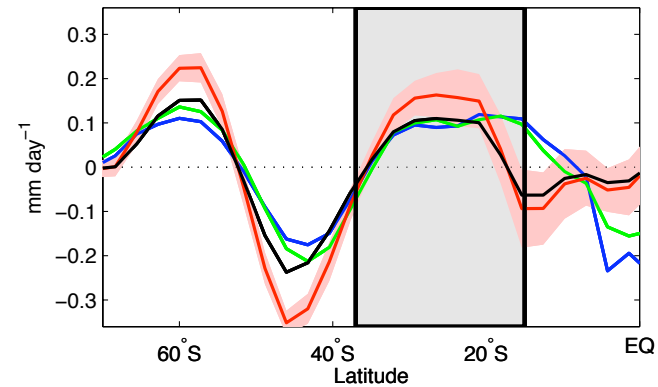
Observation (1979-2000)



Change in precipitation



Change in precip congruent with jet shift



- Coupled CMAM
- Uncoupled CMAM
- Uncoupled CAM3
- Uncoupled CAM3 only SH polar O₃

Kang et al. *Science*, 2011

SUMMARY

- One needs to be careful when using the predefined HC metrics because the HC trend accompanies complex 2D structure.
- The pattern of uncertainty (leading EOF) is characterized by
 - tropics: a modulation of the HC strength
 - extratropics: annular modes
 - ▶ well correlated with the HC edge and the eddy-driven jet
 - ▶ characterizes the tripole pattern of precipitation changes