Model Circulation Biases with Ties to Dynamics

Kidston & Gerber, 2010

Intermodel variability of the poleward shift of the austral jet stream in the CMIP3 integrations linked to biases in 20th century climatology. GRL.

Barnes & Hartmann, 2010

Testing a theory for the effect of latitude on the persistence of eddy-driven jets using CMIP3 simulations. GRL.

Ceppi *et al.*, 2012

Southern hemisphere jet latitude biases in CMIP5 models linked to shortwave cloud forcing. GRL.

Chang *et al.*, 2012

CMIP5 multimodel ensemble projection of storm track change under global warming. JGR.

Bracegirdle *et al.*, 2013

Assessment of surface winds over the Atlantic, Indian, and Pacific Ocean sectors of the Southern Ocean in CMIP5 models: historical bias, forcing response, and state dependence. JGR.

Grise & Polvani, 2014

Southern hemisphere cloud-dynamics biases in CMIP5 models and their implications for climate projections. JCLI.

Presented by Todd R. Jones

December 2, 2014

AT780 - Atmosphere's Response to Climate Change

Overview

Annular modes
Storm tracks
Jet streams
Position, variability, strength

What are the model biases, and how are they related?

Do model parameters correlate with their biases?

Do the model biases point to dynamical processes?

What implications do the biases have for climate projection?

Kidston & Gerber, 2010

Intermodel variability of the poleward shift of the austral jet stream in the CMIP3 integrations linked to biases in 20th century climatology

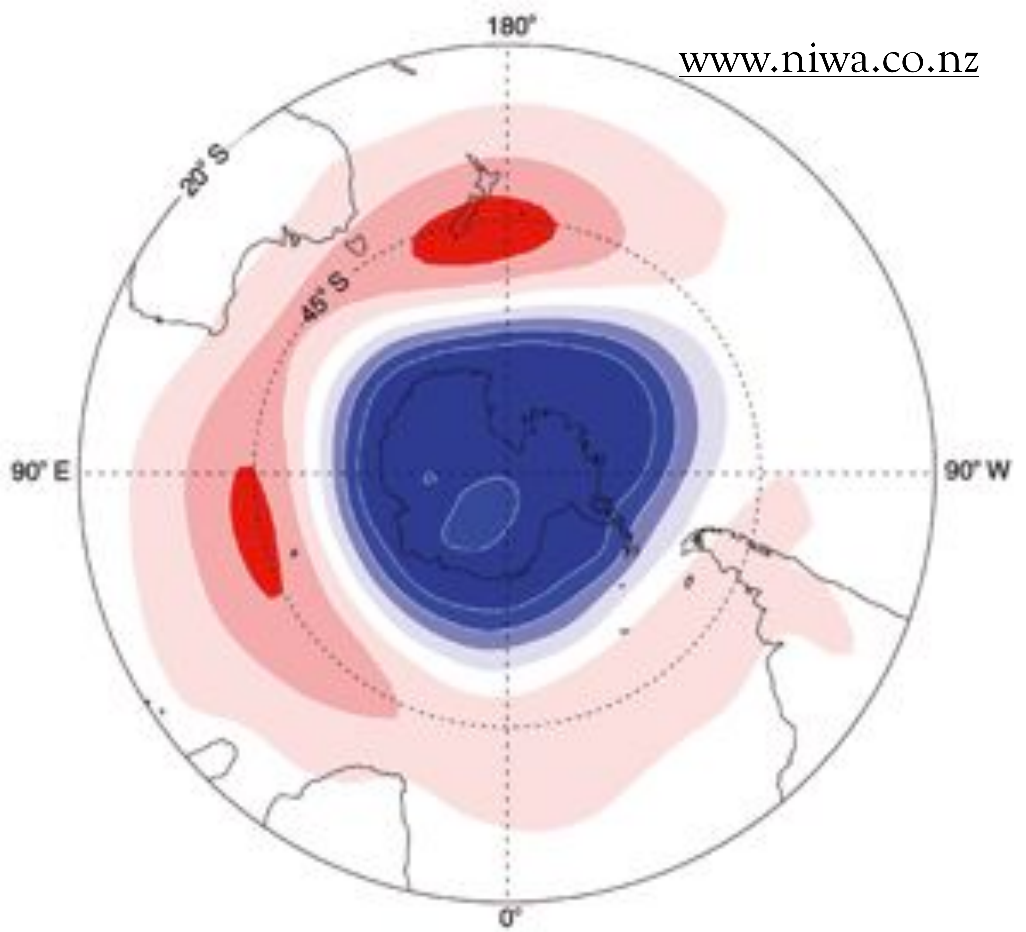
J. Kidston[1] and E. P. Gerber[2]

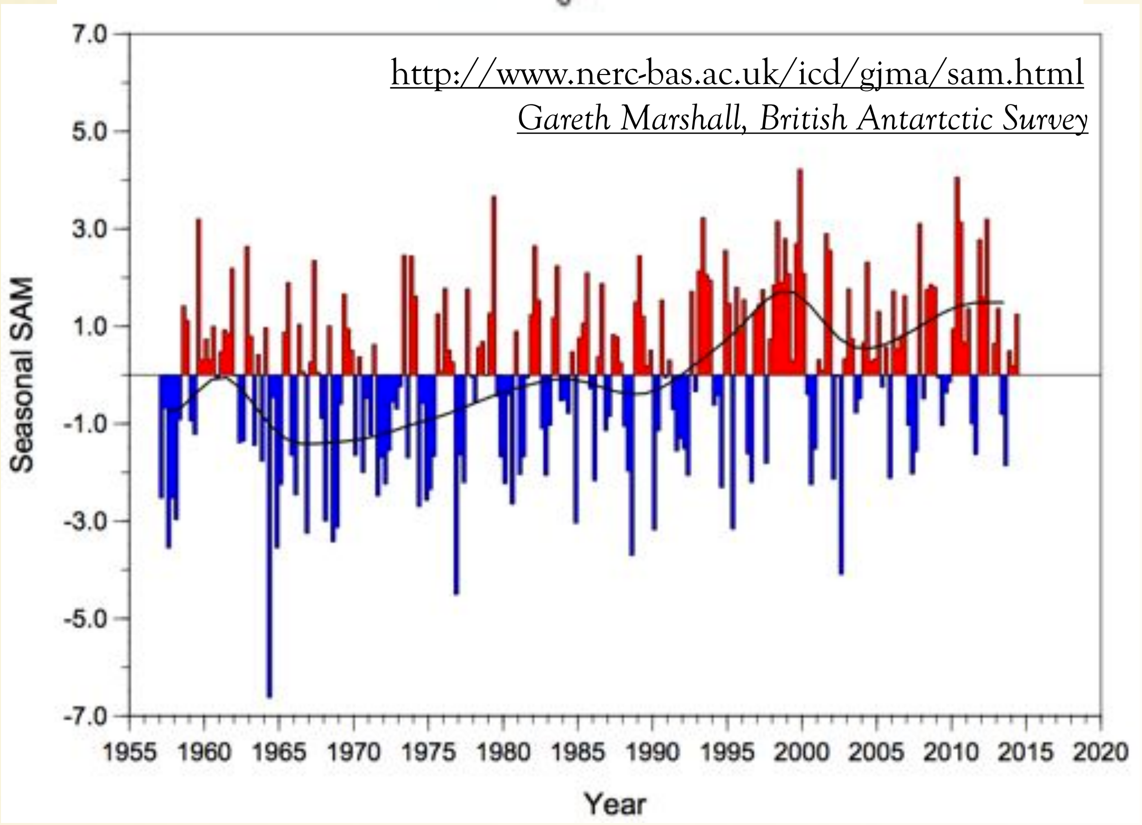
Received 9 February 2010; revised 11 March 2010; accepted 2 April 2010; published 15 May 2010.

- Consider poleward shift of SH eddy-driven jets in 11 CMIP3 models under increasing GHGs
  - Substantial disagreement as to the trend's strength.
  - Correlations with jet position biases and biases in the jet's internal variability (how it simulates the SAM's persistence).
- Model's ability to simulate the 20th century may indicate fitness for climate prediction.

Southern Annular Mode

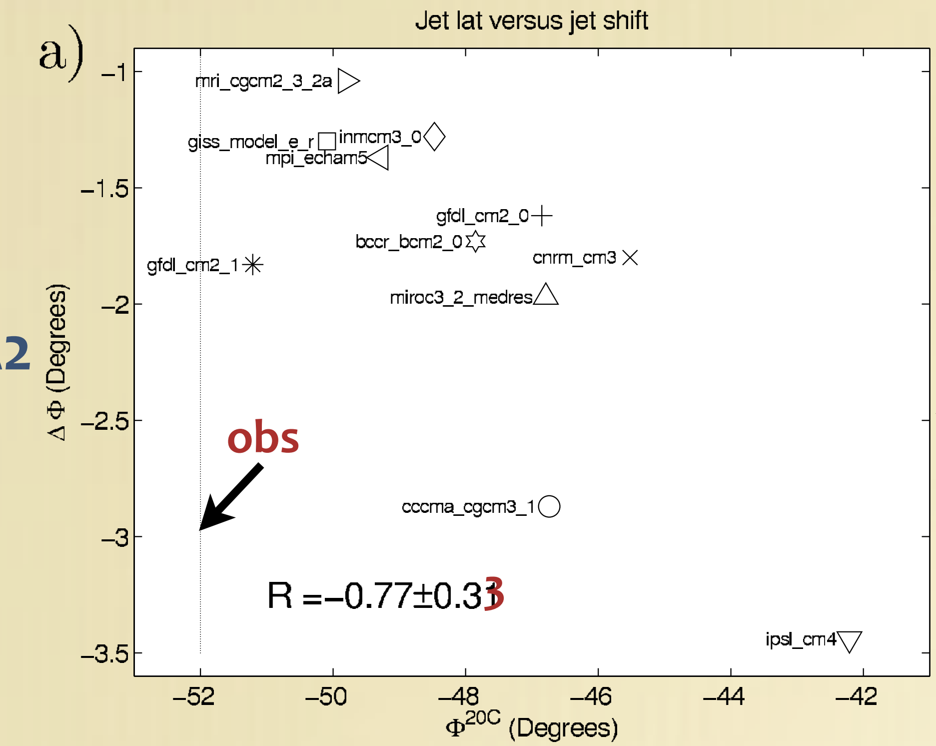
- Principal mode (20-30%) of intraseasonal variability in the anomalous circulation of the SH extratropics and high latitudes.
- Synchronous pressure anomalies of opposite signs in Antarctica and the midlatitudes.
- Historical and projected increasing trend

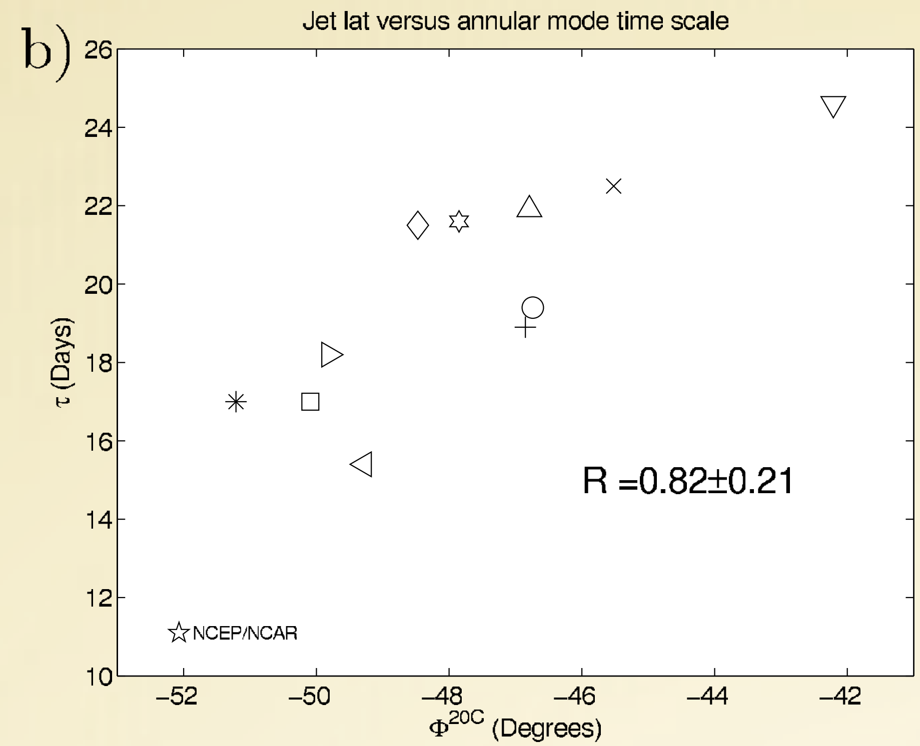




SH Jet Shift and Relation to SAM

20c --> A2 Shift





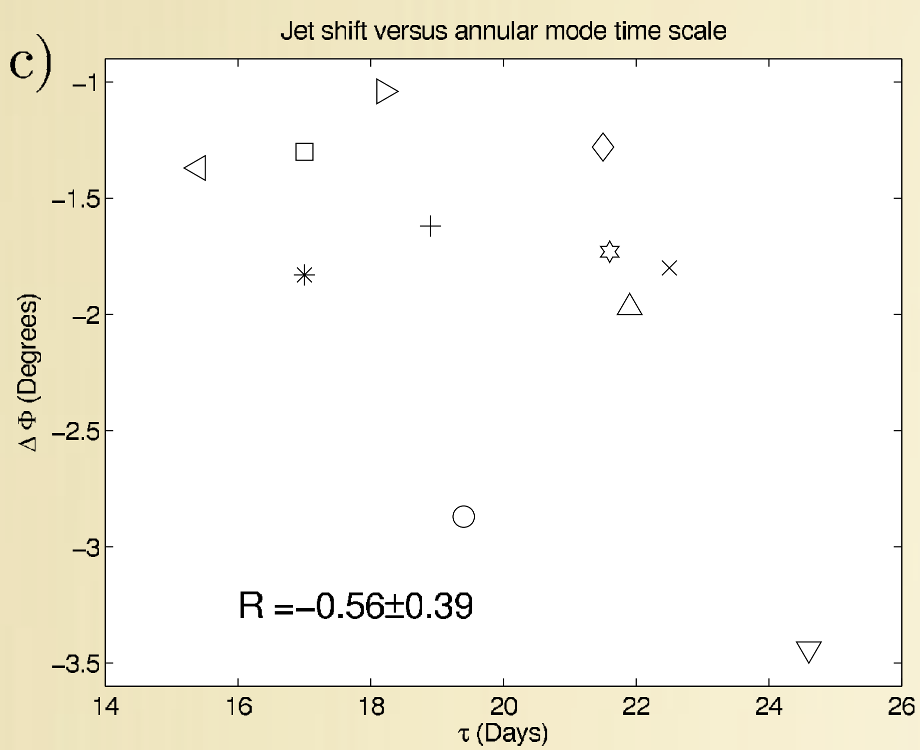
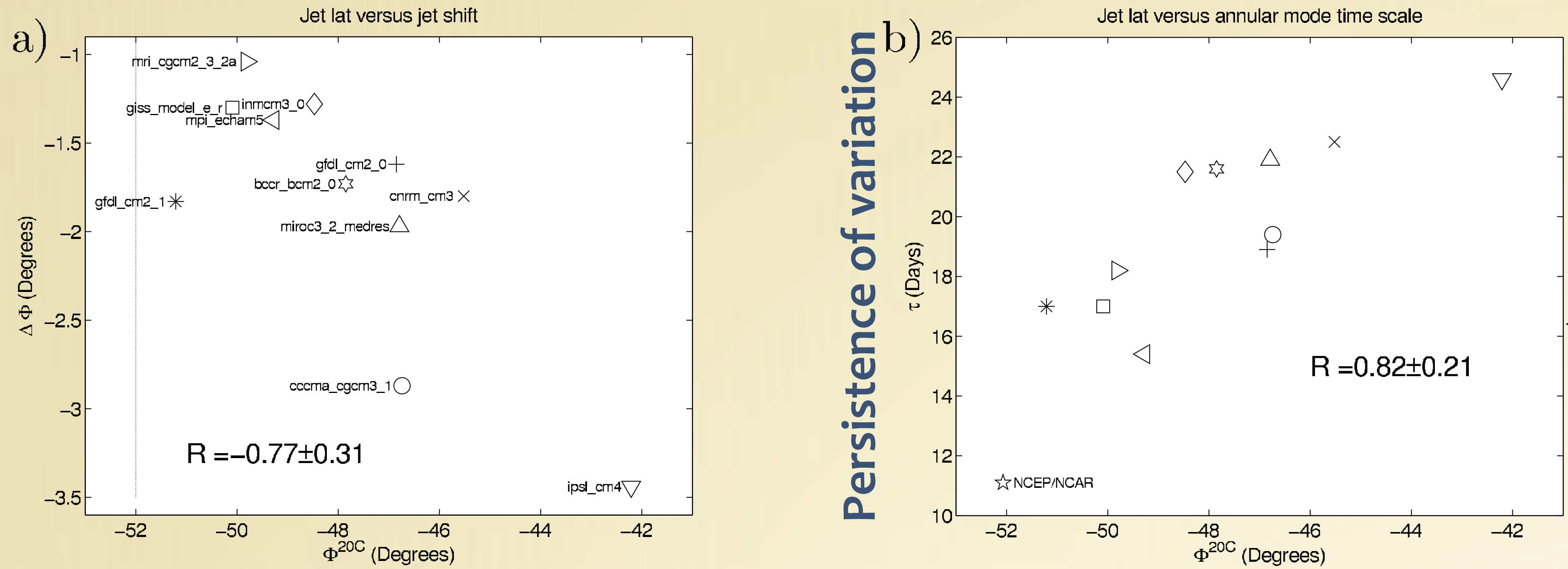


Figure 1. (a) The latitude of the Southern Hemisphere eddy-driven jet stream in the CMIP3 global circulation models 20C3M control simulations from 1960–2000, Φ^{20C}, versus the difference between Φ^{20C} and the latitude of the jet in the future A2 simulation during 2060–2100, $\Delta\Phi$. The shift in jet position $\Delta\Phi$ quantifies the respond of the circulation to climate forcing. The model name is to the right of each datum. (b) Φ^{20C} versus the e-folding time scale of the Southern Annular Mode, τ, which quantifies the persistence of the models internal variability. The NCEP/NCAR reanalysis datum was not included in the computation of the correlation coefficient. (c) τ versus $\Delta\Phi$. The uncertainty associated with the correlation coefficient in each figure corresponds to the 90% confidence interval.

Kidston & Gerber, 2010

SH Jet Shift and Relation to SAM



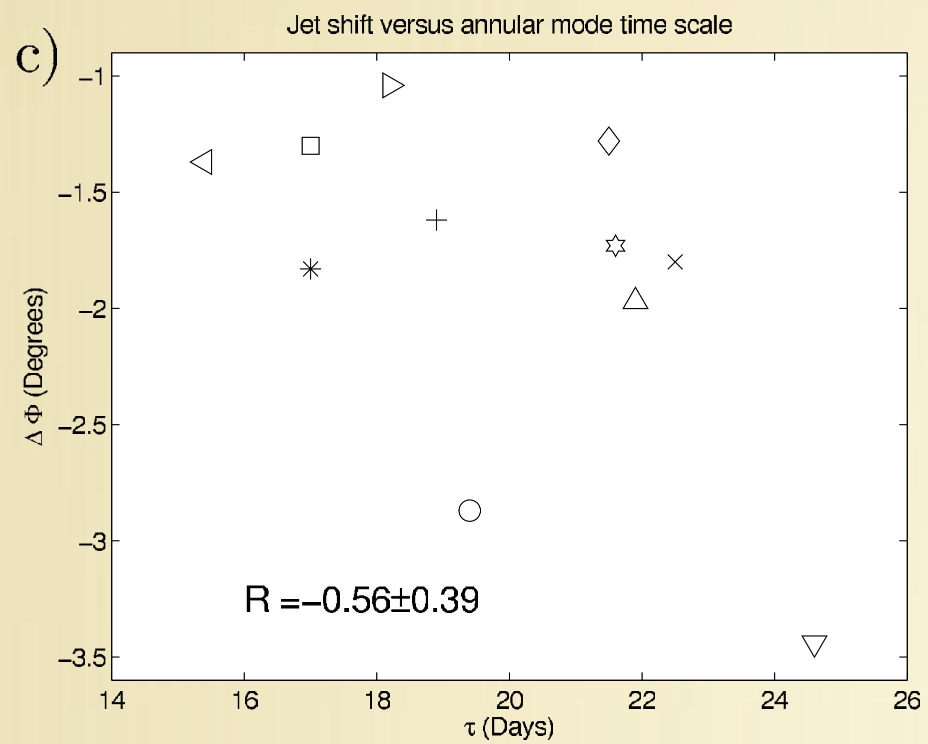
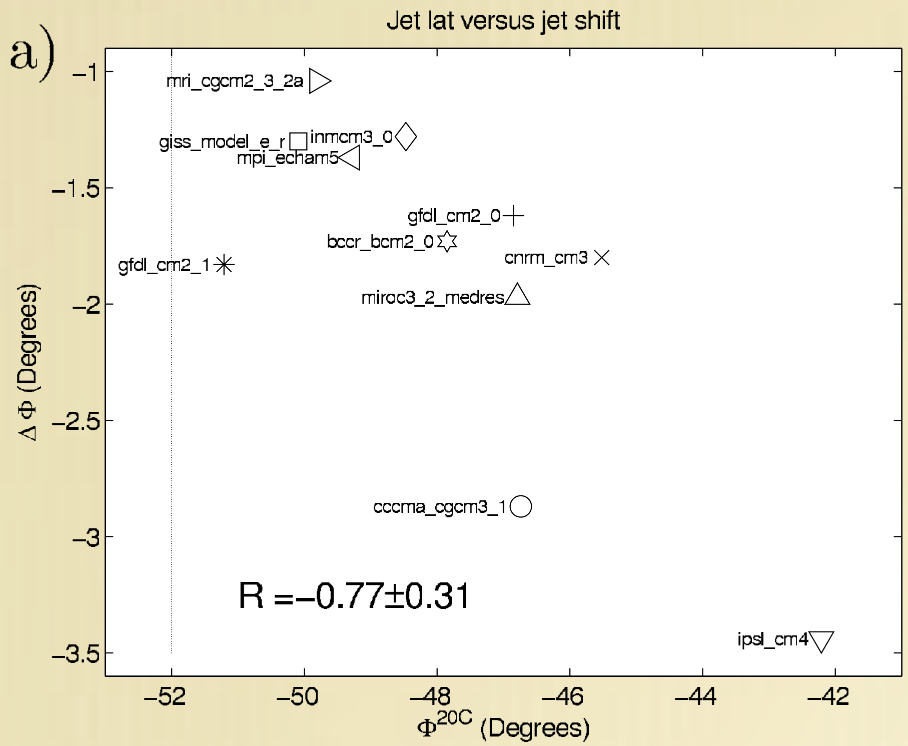
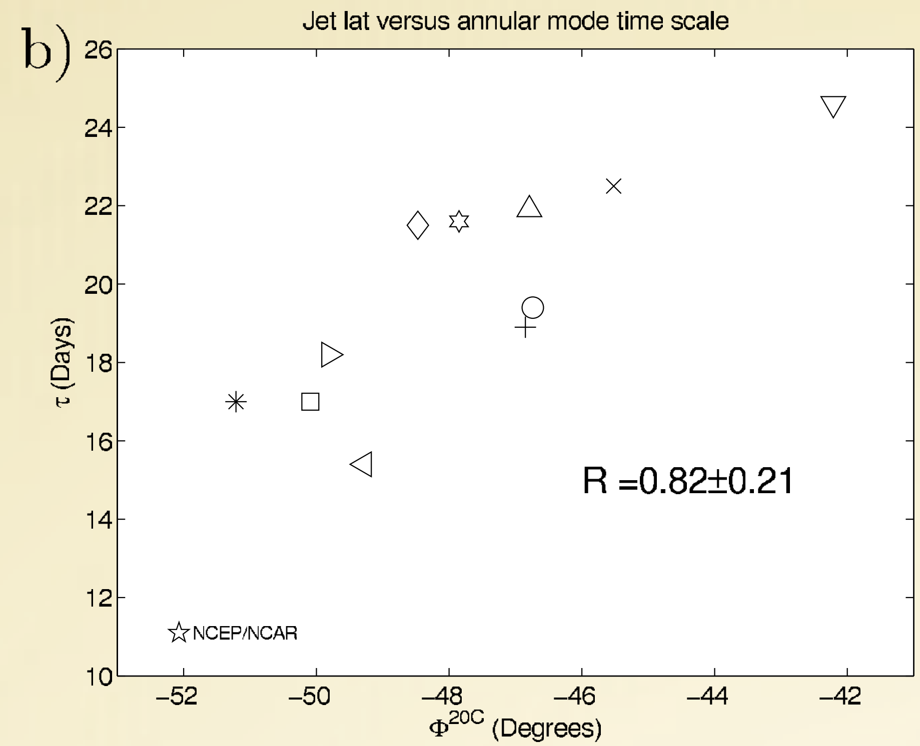


Figure 1. (a) The latitude of the Southern Hemisphere eddy-driven jet stream in the CMIP3 global circulation models 20C3M control simulations from 1960–2000, Φ^{20C}, versus the difference between Φ^{20C} and the latitude of the jet in the future A2 simulation during 2060–2100, $\Delta\Phi$. The shift in jet position $\Delta\Phi$ quantifies the respond of the circulation to climate forcing. The model name is to the right of each datum. (b) Φ^{20C} versus the *e*-folding time scale of the Southern Annular Mode, τ, which quantifies the persistence of the models internal variability. The NCEP/NCAR reanalysis datum was not included in the computation of the correlation coefficient. (c) τ versus $\Delta\Phi$. The uncertainty associated with the correlation coefficient in each figure corresponds to the 90% confidence interval.

Kidston & Gerber, 2010

SH Jet Shift and Relation to SAM





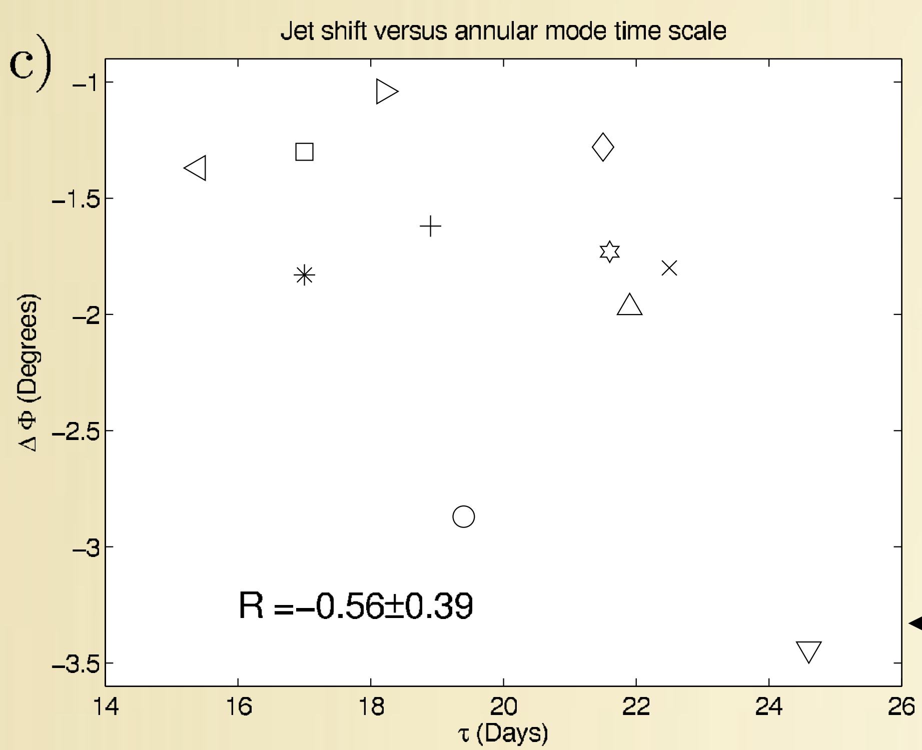


Figure 1. (a) The latitude of the Southern Hemisphere eddy-driven jet stream in the CMIP3 global circulation models 20C3M control simulations from 1960–2000, Φ^{20C}, versus the difference between Φ^{20C} and the latitude of the jet in the future A2 simulation during 2060–2100, $\Delta\Phi$. The shift in jet position $\Delta\Phi$ quantifies the respond of the circulation to climate forcing. The model name is to the right of each datum. (b) Φ^{20C} versus the *e*-folding time scale of the Southern Annular Mode, τ, which quantifies the persistence of the models internal variability. The NCEP/NCAR reanalysis datum was not included in the computation of the correlation coefficient. (c) τ versus $\Delta\Phi$. The uncertainty associated with the correlation coefficient in each figure corresponds to the 90% confidence interval.

Kidston & Gerber, 2010

SH Jet Shift and Relation to SAM

Table 1. Correlation Between Jet Position Φ^{20C}, Shift $\Delta\Phi$, and Time Scale τ as a Function of Season

	SON	DJF	MAM	JJA	Annual[a]
corr(Φ^{20C}, $\Delta\Phi$)	−0.61	−0.08	−0.76	−0.81	−0.77
corr(Φ^{20C}, τ)	0.80	0.39	0.48	0.60	0.82
corr(τ, $\Delta\Phi$)	−0.31	−0.03	−0.21	−0.31	−0.56

[a]The annual mean correlations shown in Figure 1 are listed for reference.

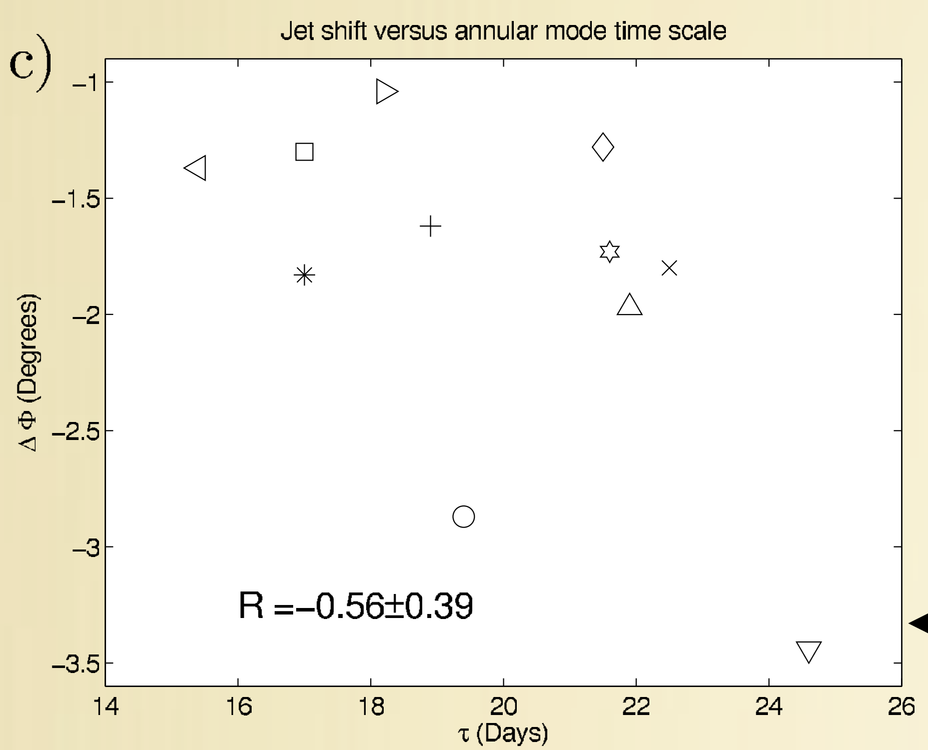


Figure 1. (a) The latitude of the Southern Hemisphere eddy-driven jet stream in the CMIP3 global circulation models 20C3M control simulations from 1960–2000, Φ^{20C}, versus the difference between Φ^{20C} and the latitude of the jet in the future A2 simulation during 2060–2100, $\Delta\Phi$. The shift in jet position $\Delta\Phi$ quantifies the respond of the circulation to climate forcing. The model name is to the right of each datum. (b) Φ^{20C} versus the *e*-folding time scale of the Southern Annular Mode, τ, which quantifies the persistence of the models internal variability. The NCEP/NCAR reanalysis datum was not included in the computation of the correlation coefficient. (c) τ versus $\Delta\Phi$. The uncertainty associated with the correlation coefficient in each figure corresponds to the 90% confidence interval.

Kidston & Gerber, 2010

Kidston & Gerber, 2010

- Strength of the shift trend is correlated with position biases in the 20th century control.
  - Basic geometry?
    - More room to shift poleward, appears more sensitive as the jet moves to some high-latitude limit
- SAM variability timescale is associated with 20th century position biases.
  - Interaction with the subtropical jet?
  - Ability to maintain itself?
    - Eddy genesis region closer to equator: narrower source region and greater momentum flux convergence
- Model's ability to simulate the 20th century may indicate fitness for climate prediction.
  - Observed position is more poleward, and persistence timescale is much shorter.
  - **Applied to regressions:** 0.6-0.9°(using obs position) vs 1.8° MMM

Review Overview

Paper	Variables	Notes
Kidston and Gerber	Jet position Jet internal variability (SAM)	20th Century position biases are correlated with position and variability changes

Barnes and Hartmann (2010)

- Noting *Kidston and Gerber, Son et al. (2010)*'s similar results in 17 chemistry-climate GCMs, and *Barnes et al. (2010)*'s insights into the reasons for the SAM's persistence decrease as the jet shifts poleward:
  - Investigate the effect of latitude on persistence in 37 CMIP3 integrations.
  - Demonstrate a mechanism explaining why models with equatorward jet biases have unrealistic persistence timescales and large poleward shifts under global warming.
    - A turning latitude near the pole inhibits wave breaking on the poleward side of the jet and increases equatorward wave breaking.
    - This reduces the positive feedback between the eddies and the mean flow and reduces persistence as the jet moves poleward.

Testing a theory for the effect of latitude on the persistence of eddy-driven jets using CMIP3 simulations

Elizabeth A. Barnes[1] and Dennis L. Hartmann[1]

Received 28 May 2010; revised 24 June 2010; accepted 28 June 2010; published 3 August 2010.

Persistence and Mean Jet Position

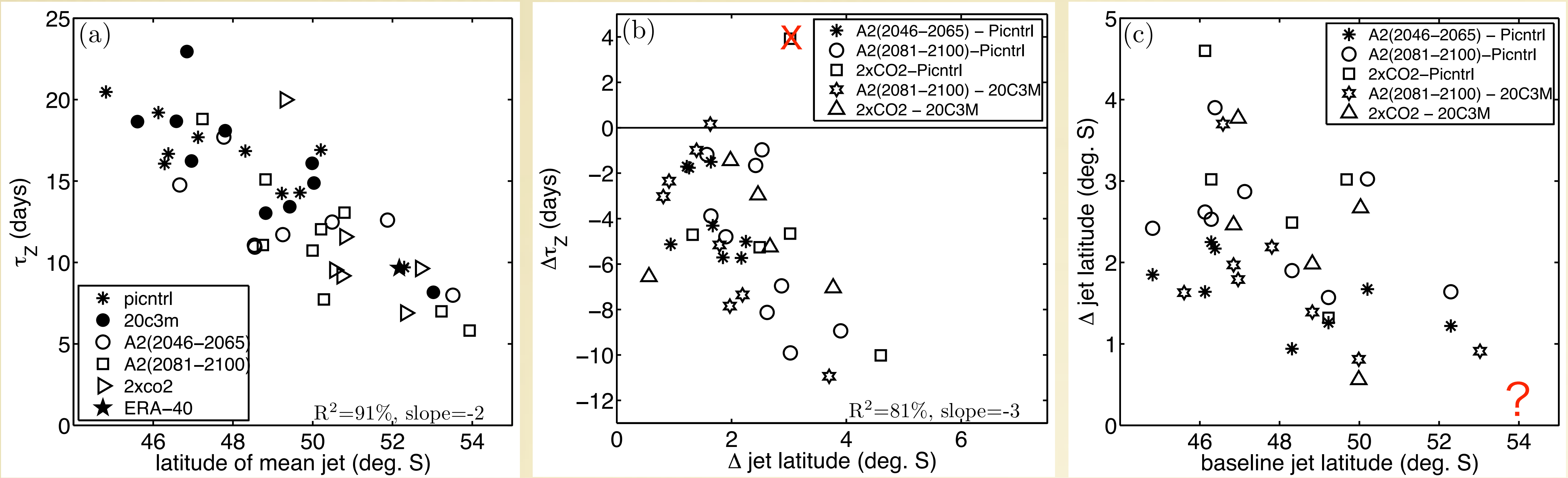


Figure 1. (a) The e-folding time of Z versus the latitude of the mean jet across scenarios and models. (b) The difference between scenarios of the e-folding time of Z ($\Delta\tau_Z$) versus the poleward shift of the latitude of the mean jet (Δ jet latitude). (c) Δ jet latitude between global warming and baseline scenarios versus the latitude of the jet in the baseline scenario.

- Similar persistence/mean position relationship between models, integrations, and K&G
- Consistent intramodel decrease in persistence with climate change.
- Jets shift less under warming when initially nearer the pole.

Persistence and Mean Jet Position

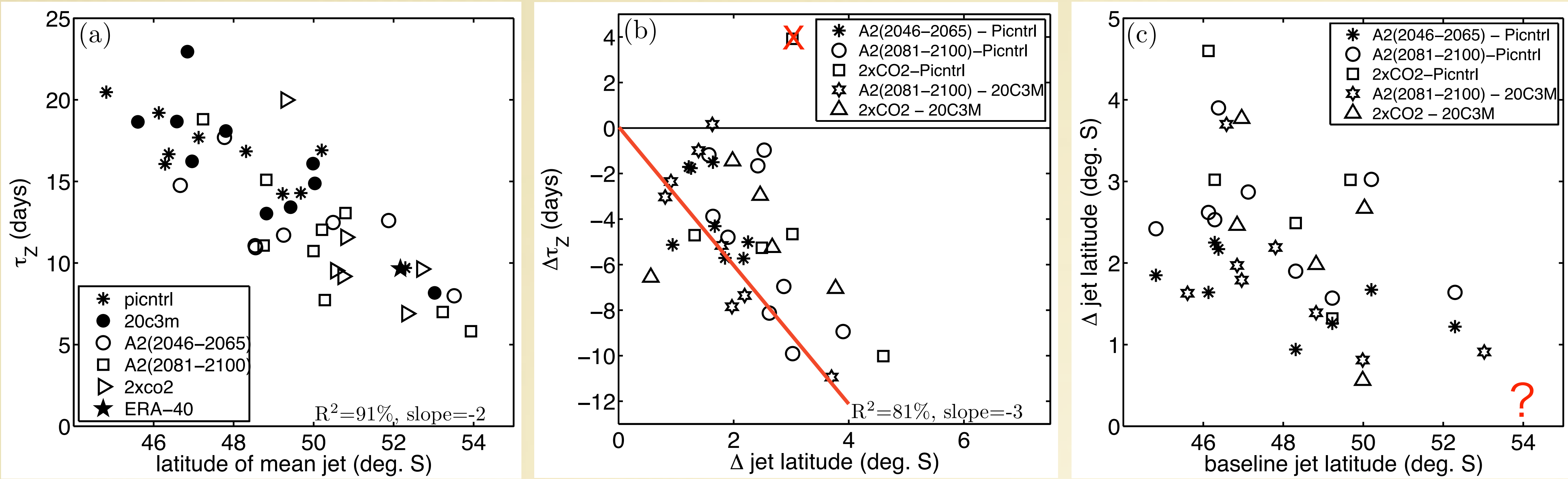


Figure 1. (a) The e-folding time of Z versus the latitude of the mean jet across scenarios and models. (b) The difference between scenarios of the e-folding time of Z ($\Delta\tau_Z$) versus the poleward shift of the latitude of the mean jet (Δ jet latitude). (c) Δ jet latitude between global warming and baseline scenarios versus the latitude of the jet in the baseline scenario.

- Similar persistence/mean position relationship between models, integrations, and K&G
- Consistent intramodel decrease in persistence with climate change.
- Jets shift less under warming when initially nearer the pole.

Persistence and Mean Jet Position

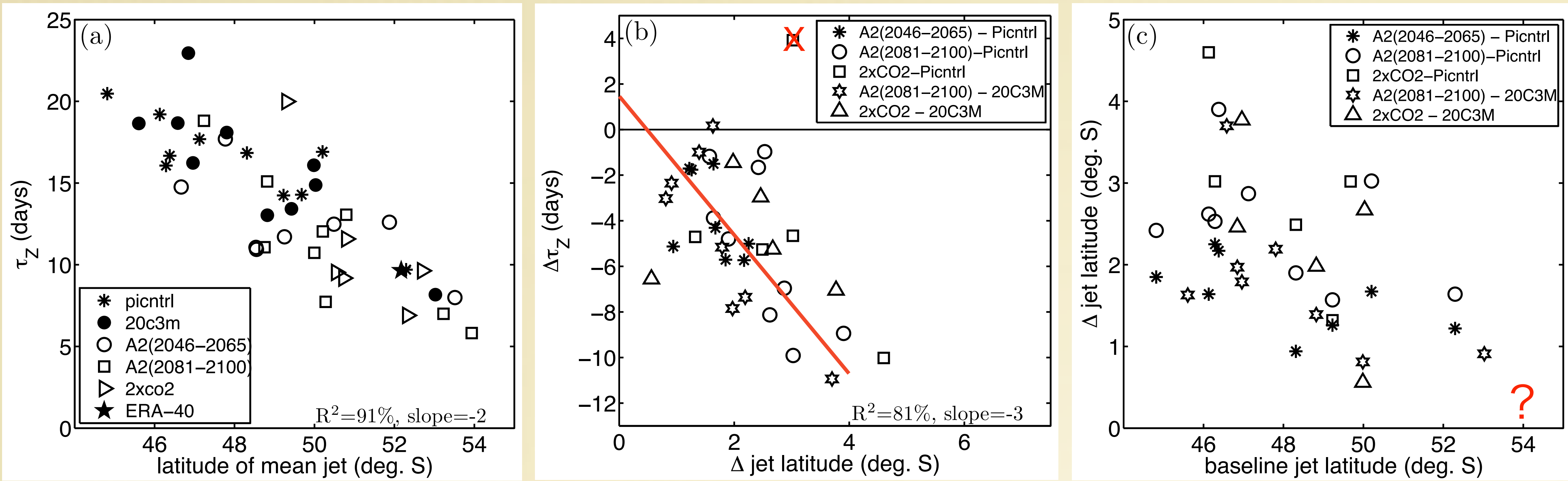
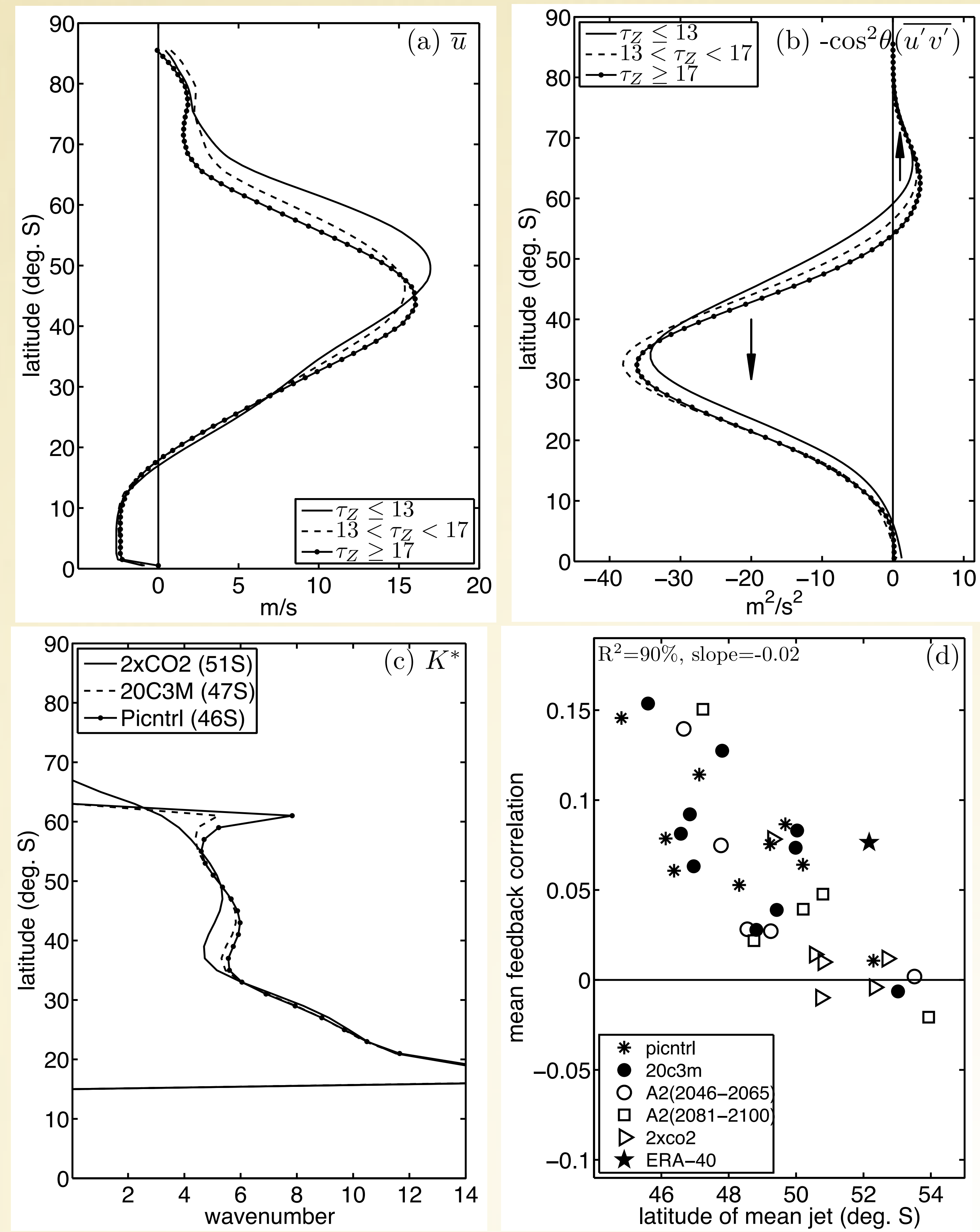


Figure 1. (a) The e-folding time of Z versus the latitude of the mean jet across scenarios and models. (b) The difference between scenarios of the e-folding time of Z ($\Delta\tau_Z$) versus the poleward shift of the latitude of the mean jet (Δ jet latitude). (c) Δ jet latitude between global warming and baseline scenarios versus the latitude of the jet in the baseline scenario.

- Similar persistence/mean position relationship between models, integrations, and K&G
- Consistent intramodel decrease in persistence with climate change.
- Jets shift less under warming when initially nearer the pole.

Persistence and Mean Jet Position

- For poleward jet:
  - Broader profile
  - Stronger pole-side westerlies
  - Less poleward propagation
  - More equatorward propagation
- Wavenumber *k* turns when it reaches the latitude where *K**= *k* and propagates toward larger *K**, breaking near its critical latitude.
  - For a jet at 51°S, waves reach a turning latitude before a critical latitude.
    - Turning > propagation/breaking
  - Spreads eddy forcing region and lessens the likelihood of persistence.



Barnes and Hartmann (2010)

- Very similar results when comparing high (poleward, wider, short-lived) and low (equatorward, narrower, persistent) phase SAM events in GCM integrations and reanalysis.
- Models agree on persistence/location relationship, and now you know a plausible explanation for that relationship.
- Why the jets shift under climate change and why the models are mostly wrong and differ about the location (and therefore persistence) are different issues, covered previously and in a bit.

Review Overview

Paper	Variables	Notes
Kidston and Gerber (2010)	Jet position Jet internal variability (SAM)	Position biases are correlated with position and variability changes
Barnes and Hartmann (2010)	Jet position Jet internal variability (SAM) Wave propagation	Position biases are correlated with position and variability changes; Physical explanations

Ceppi et al. (2012)

Southern Hemisphere jet latitude biases in CMIP5 models linked to shortwave cloud forcing

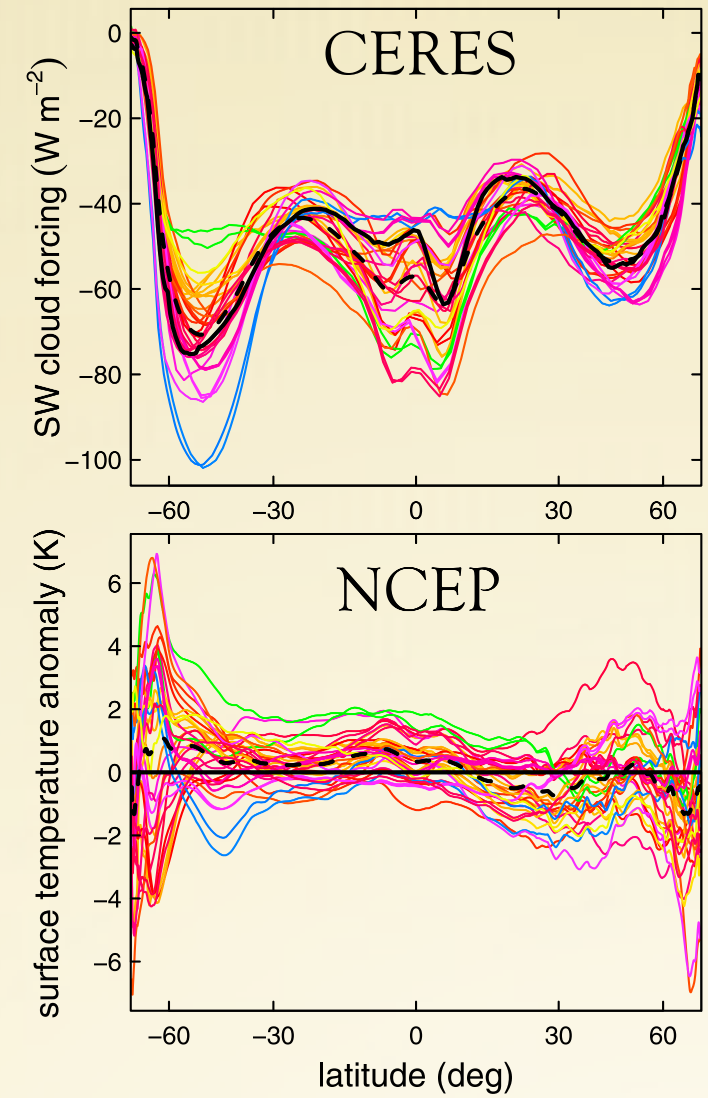
Paulo Ceppi,[1] Yen-Ting Hwang,[1] Dargan M. W. Frierson,[1] and Dennis L. Hartmann[1]

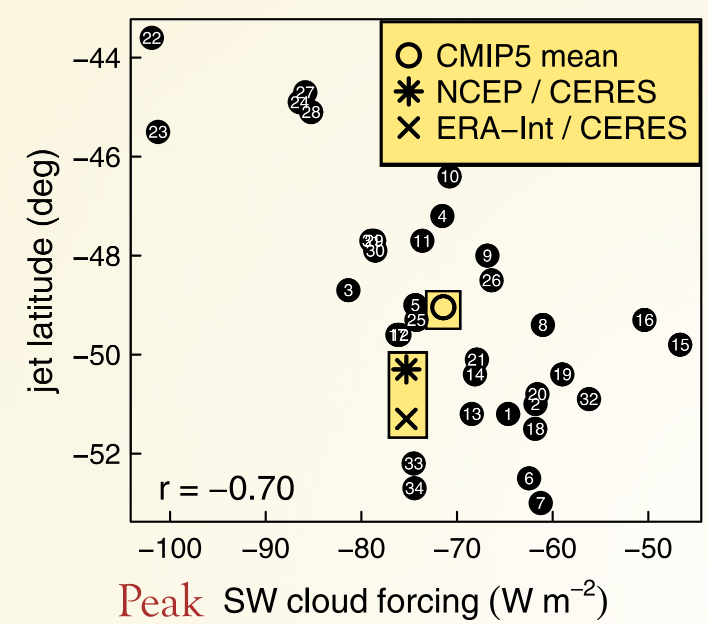
Received 13 July 2012; revised 4 September 2012; accepted 4 September 2012; published 5 October 2012.

- Sharp local maxima of precipitation and surface wind stress are found near the jet streams.
- Need for accurate representation of jet strength and position.
  - Affects frequency of blocking, wind stress impacts on ocean currents, persistence of annular modes
- Analyze jet biases in 34 CMIP5 models and provide a comparison to aquaplanet simulations.
  - 1979-2005
  - Link biases to midlatitude shortwave cloud forcing (SWCF) anomalies and related changes in meridional surface temperature gradients and baroclinicity.

Biases in CMIP5 CGCMs

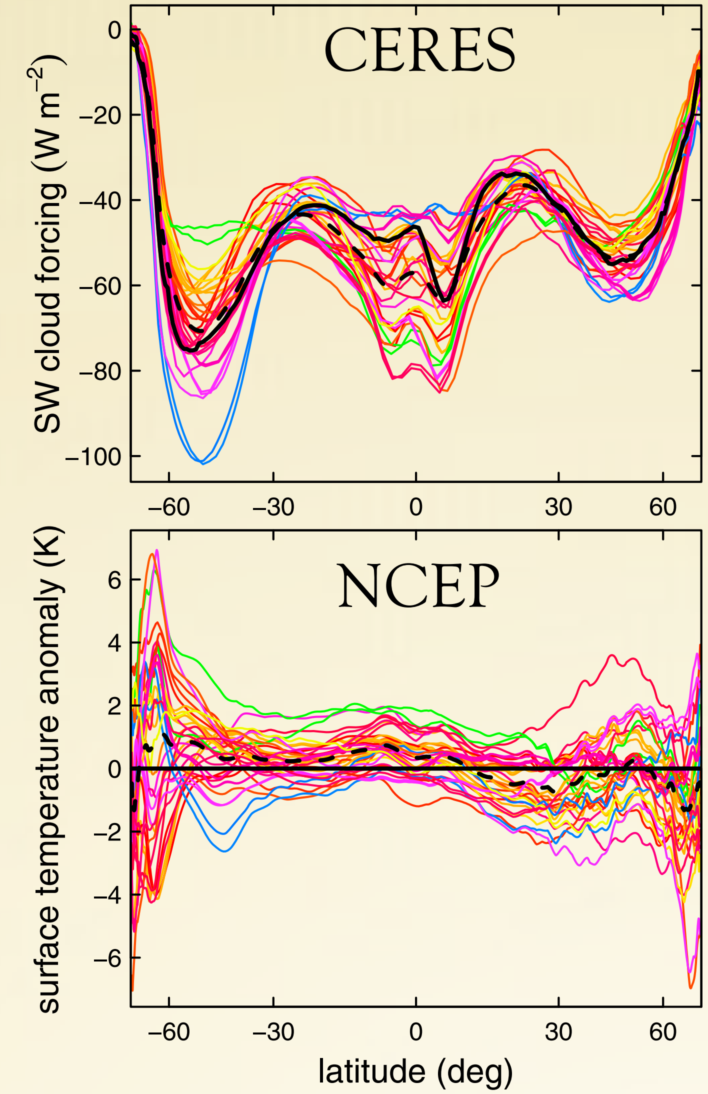
- Large SWCF spread in SH M-L and Tr.
- Large spread in mean surface temps.
- Color coding shows correlating influence of SWCF on surface temps.
  - $r = 0.63$
  - Sign of SWCF anomalies are often the same in both hemispheres, but relationships are much weaker in the NH.
- Jet position & strength respond to global, hemispheric, and local thermal forcings.
  - Is it those from SWCF?
  - Those with cold M-Ls have an equatorward jet position bias -- 49% variance explained.
    - 26% without IPSL and MIROC outliers
- Variations in jet within each model change SWCF by small amount (<models)
  - Unlikely: other forcing --> jet --> SWCF

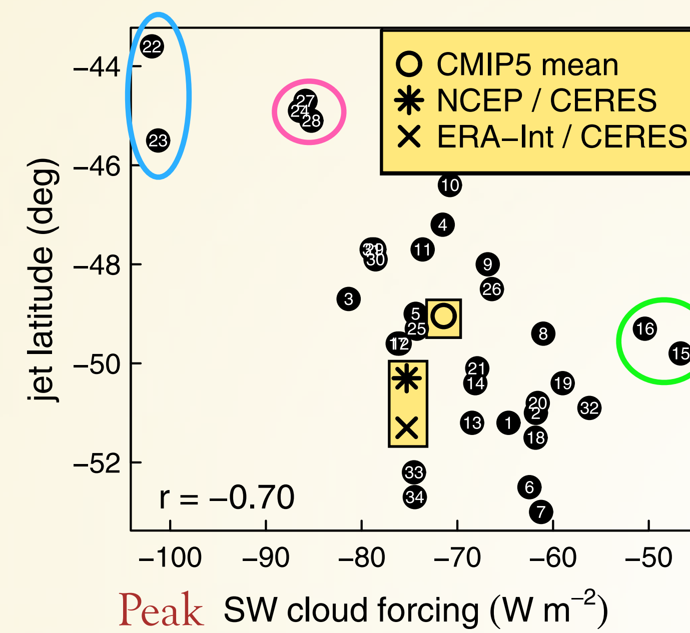




Biases in CMIP5 CGCMs

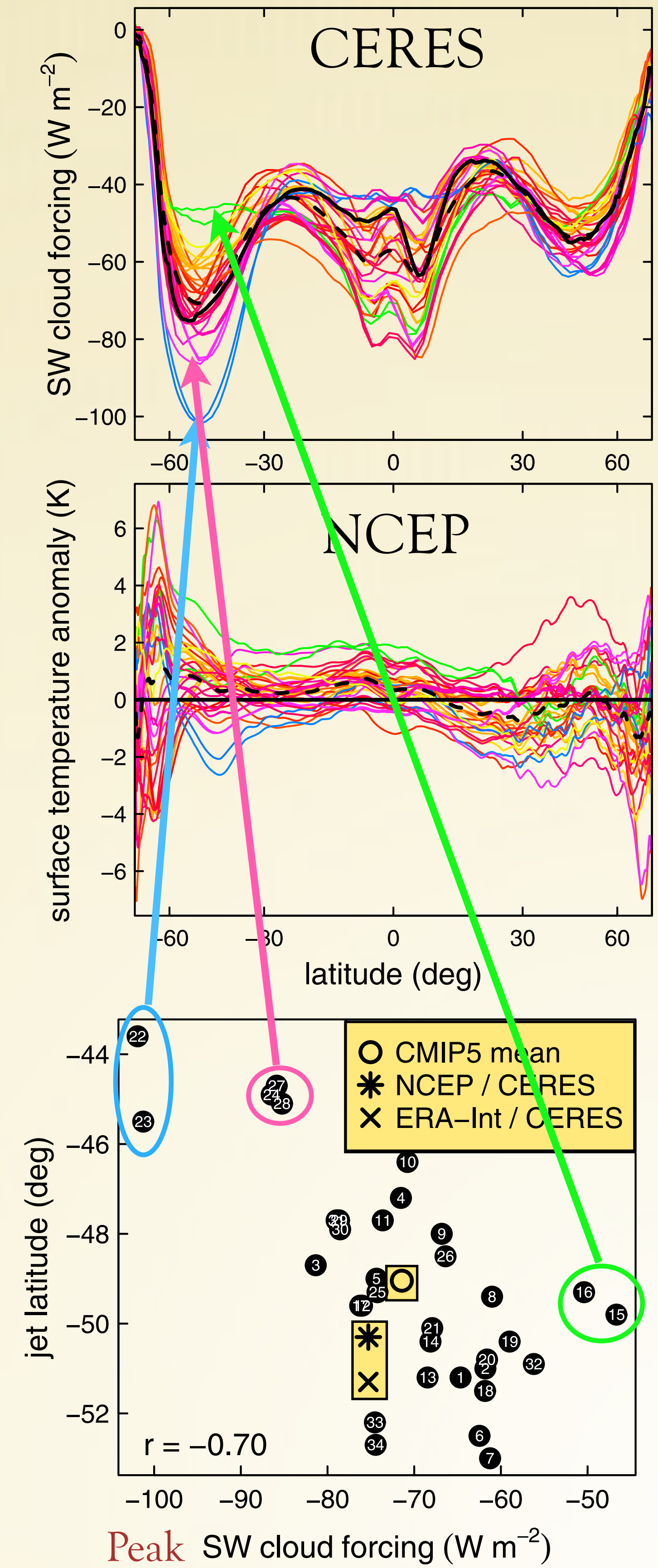
- Large SWCF spread in SH M-L and Tr.
- Large spread in mean surface temps.
- Color coding shows correlating influence of SWCF on surface temps.
  - $r = 0.63$
  - Sign of SWCF anomalies are often the same in both hemispheres, but relationships are much weaker in the NH.
- Jet position & strength respond to global, hemispheric, and local thermal forcings.
  - Is it those from SWCF?
  - Those with cold M-Ls have an equatorward jet position bias -- 49% variance explained.
    - 26% without IPSL and MIROC outliers
- Variations in jet within each model change SWCF by small amount (<models)
  - Unlikely: other forcing --> jet --> SWCF





Biases in CMIP5 CGCMs

- Large SWCF spread in SH M-L and Tr.
- Large spread in mean surface temps.
- Color coding shows correlating influence of SWCF on surface temps.
  - $r = 0.63$
  - Sign of SWCF anomalies are often the same in both hemispheres, but relationships are much weaker in the NH.
- Jet position & strength respond to global, hemispheric, and local thermal forcings.
  - Is it those from SWCF?
  - Those with cold M-Ls have an equatorward jet position bias -- 49% variance explained.
    - 26% without IPSL and MIROC outliers
- Variations in jet within each model change SWCF by small amount (<models)
  - Unlikely: other forcing --> jet --> SWCF

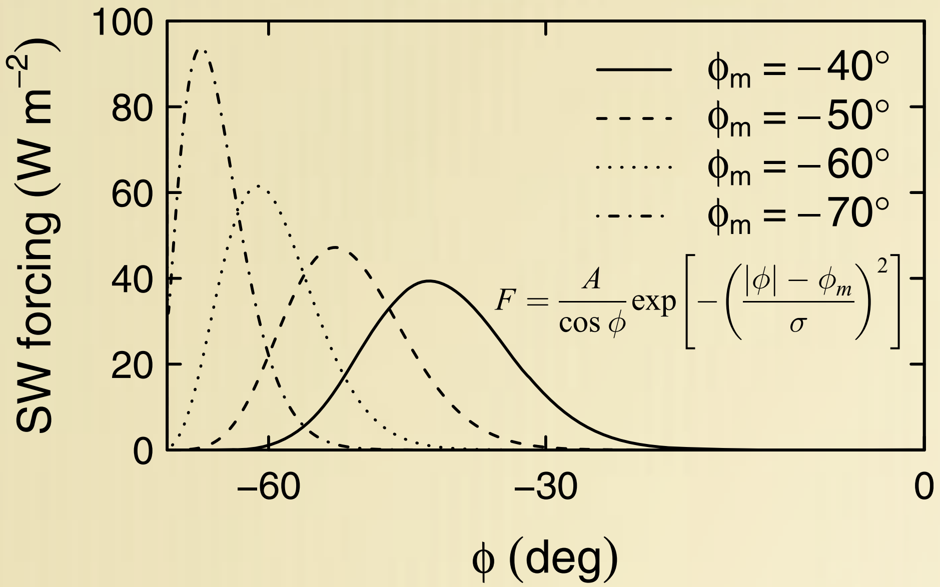


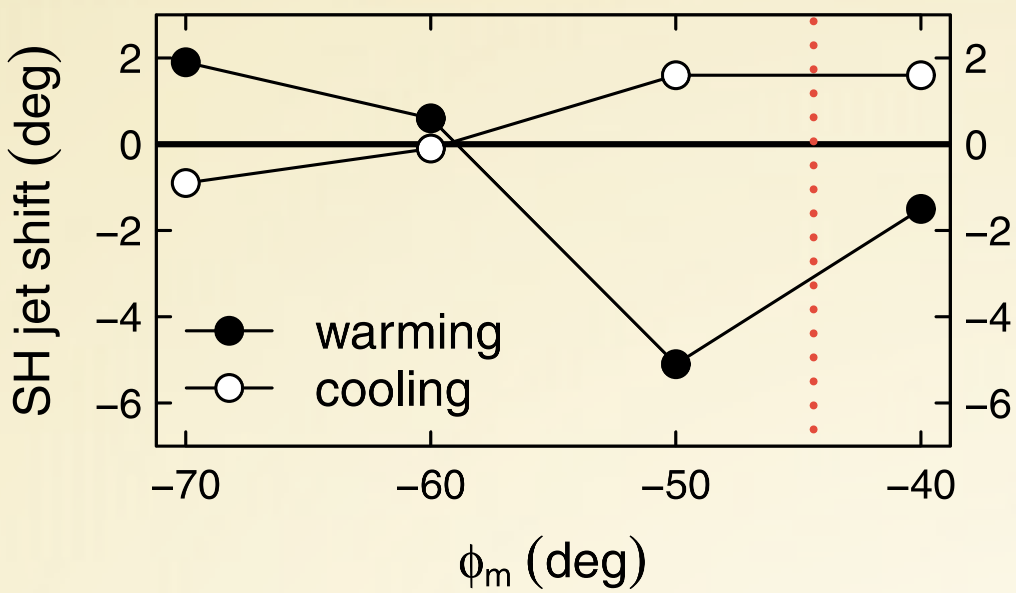
Cloud Influences on Jet Latitude

- Positive SWCF anomaly:
  - Causes a net warming of the hemisphere
  - Shifts strongest meridional temperature gradient poleward

Cloud Influences on Jet Latitude

- **Positive SWCF anomaly:**
  - Causes a net warming of the hemisphere
  - Shifts strongest meridional temperature gradient poleward





- **Mid-latitude warming:**
  - SST gradient increases poleward of jet, decreases equatorward
  - Jet moves poleward
    - Strongest response at 50°S, ~near model jet position (44°S)
- **High-latitude warming:**
  - Mid-latitude SST gradient weakens
  - Jet moves equatorward

Review Overview

Paper	Variables	Notes
Kidston and Gerber (2010)	Jet position Jet internal variability (SAM)	Position biases are correlated with position and variability changes
Barnes and Hartmann (2010)	Jet position Jet internal variability (SAM) Wave propagation	Position biases are correlated with position and variability changes; Physical explanations
Ceppi et al. (2012)	Jet position SWCF Surface temperature	Position biases are correlated with SWCF biases; Points to local cloud biases.

Chang et al. (2012)

CMIP5 multimodel ensemble projection of storm track change under global warming

Edmund K. M. Chang,[1] Yanjuan Guo,[2] and Xiaoming Xia[1]

Received 27 July 2012; revised 19 October 2012; accepted 21 October 2012; published 15 December 2012.

- Examine CMIP5 ensemble storm track changes
  - Historical: 1980-1999
  - RCP: 4.5, 8.5; 2041-2060, 2081-2100
  - Variance statistics
    - Meridional wind
    - Sea level pressure
  - Cyclone track statistics
    - Negative sea level pressure center tracking
      - Between 20-70° latitude
      - Lasting over 2 days
      - Moving over 1000 km
  - Comparison to CMIP3: SRES A2, 2100
  - Relationships between biases and projections
    - Different time periods, scenarios, hemispheres
    - Changes in extreme cyclones
  - ERA-Interim

"24-hour difference filter"

$$vv = \overline{\{v(t+24hr) - v(t)\}^2}$$

Storm Track Climatology: vv

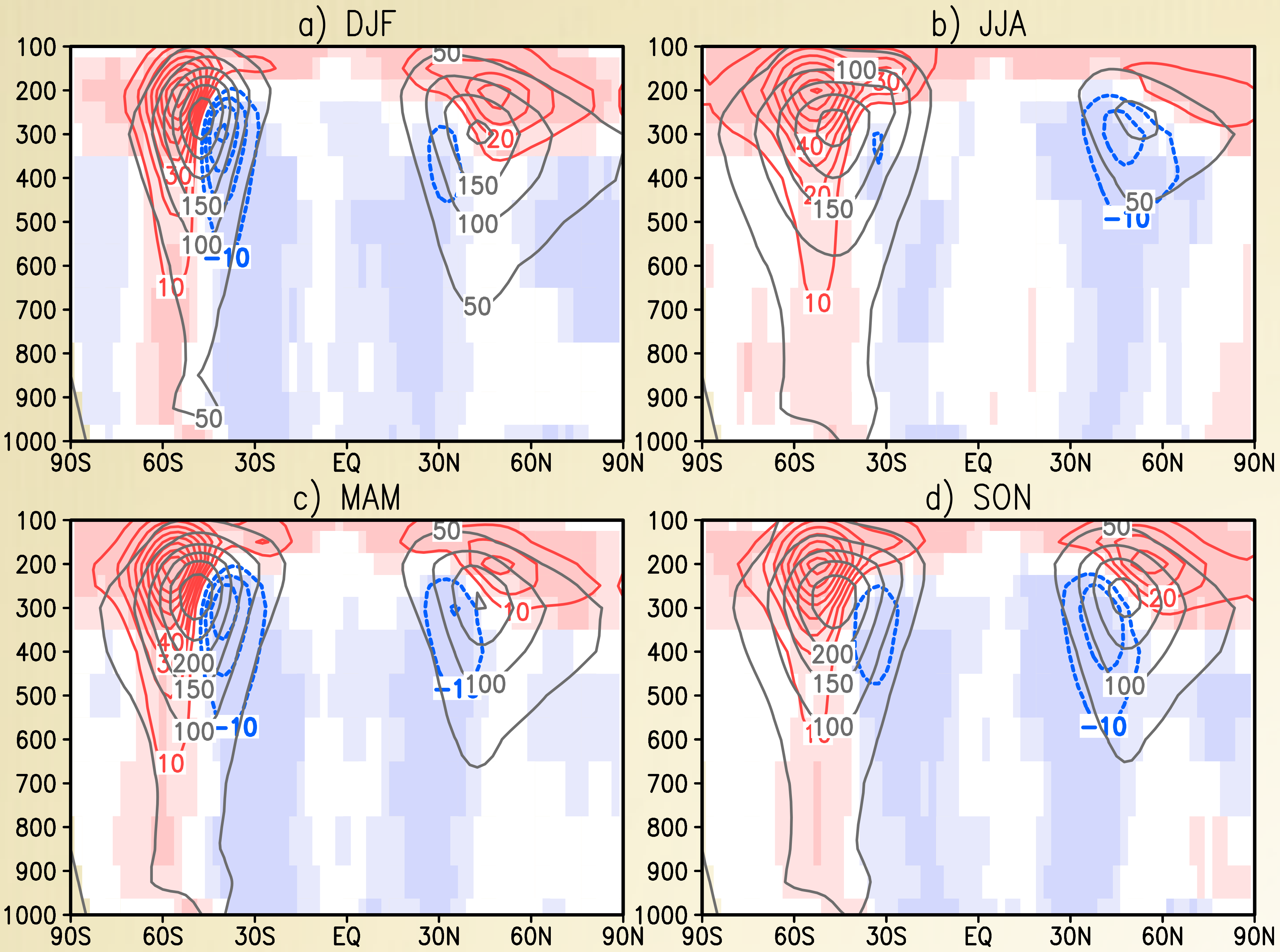
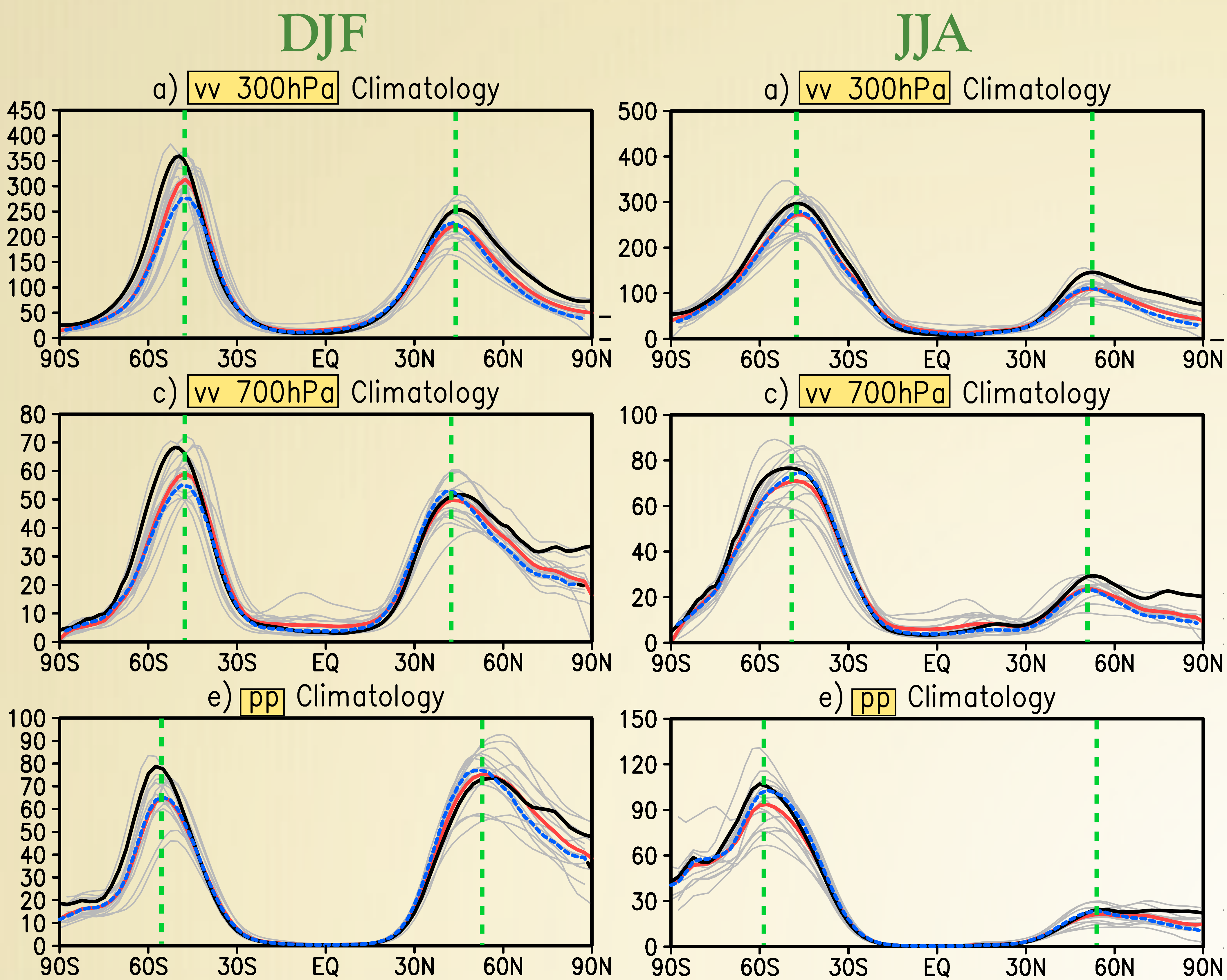


Figure 1. Projected changes from 1980 to 1999 to 2081–2100 in zonal mean vv by CMIP5 multimodel ensemble based on RCP8.5 scenario, as a function of latitude and pressure. (a) DJF; (b) JJA; (c) MAM; (d) SON. Black contours indicate model climatology (contour interval 50 $m^2\ s^{-2}$). Red and blue contours indicate projected changes (contour interval 10 $m^2\ s^{-2}$). Shadings indicate regions over which ≥80% (light) or 100% (dark) of the models agree on the sign of the change.

Climatology: Zonal Mean



Projected Changes: RCP8.5

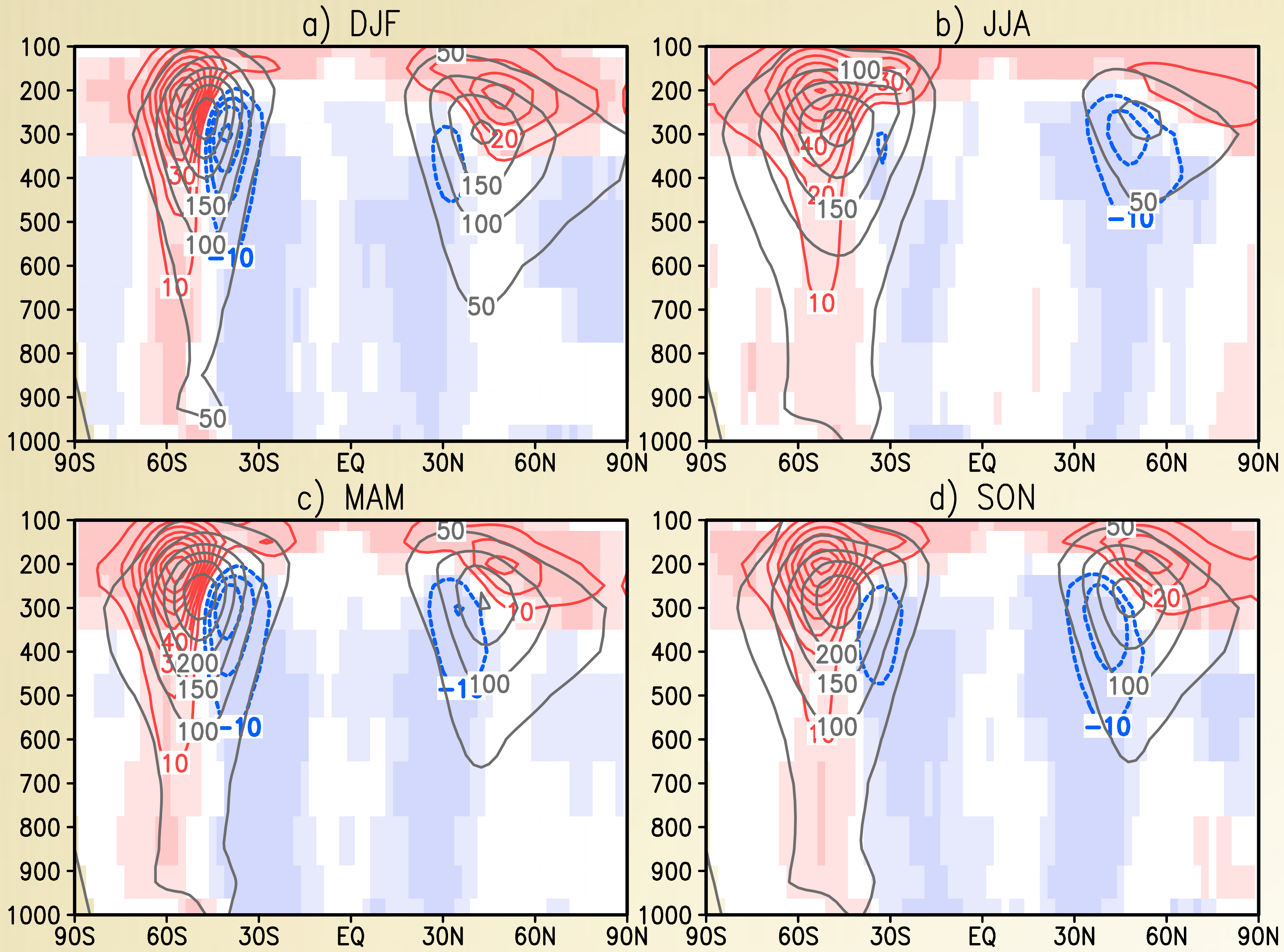
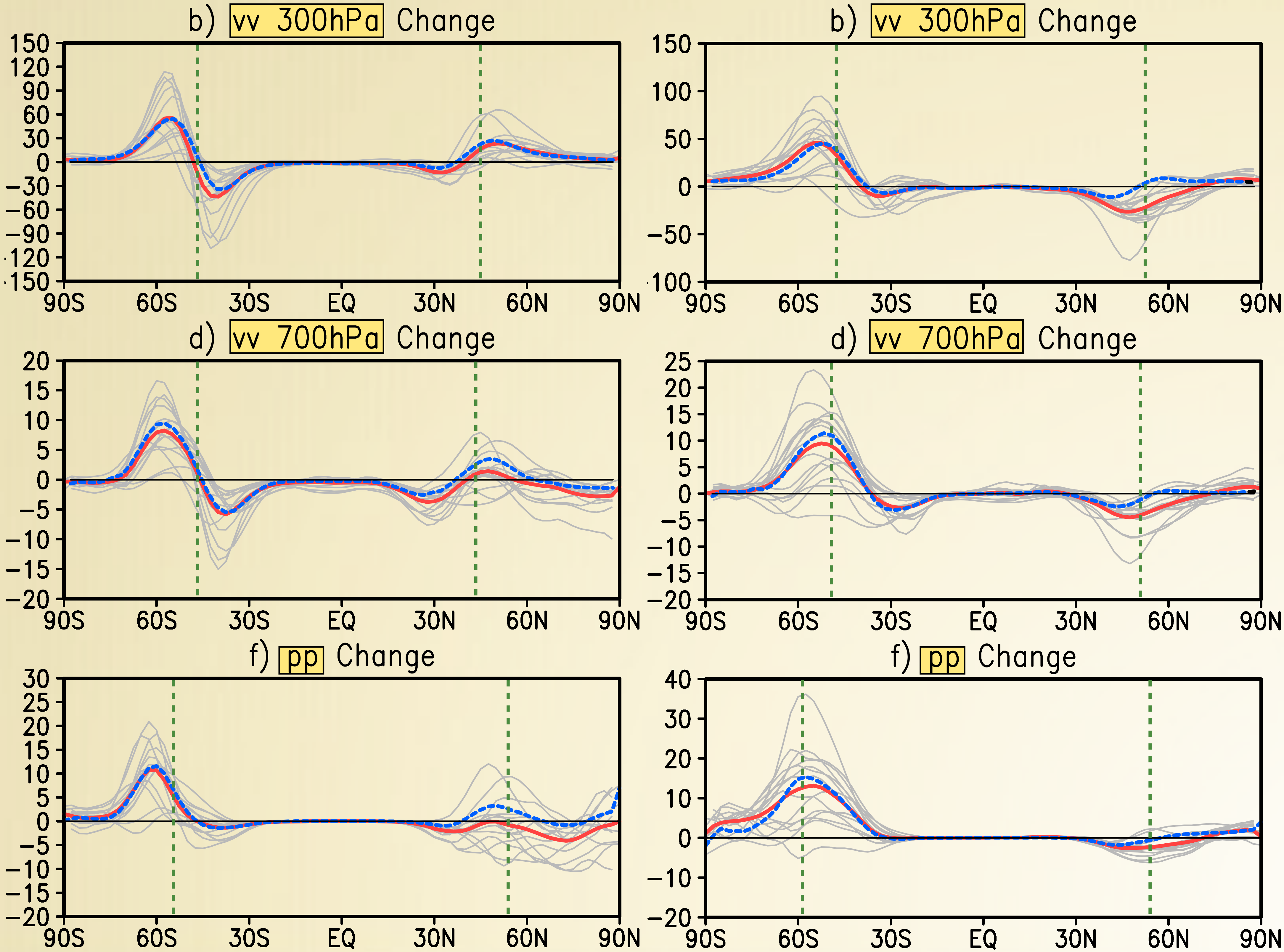


Figure 1. Projected changes from 1980 to 1999 to 2081–2100 in zonal mean vv by CMIP5 multimodel ensemble based on RCP8.5 scenario, as a function of latitude and pressure. (a) DJF; (b) JJA; (c) MAM; (d) SON. Black contours indicate model climatology (contour interval 50 $m^2\ s^{-2}$). Red and blue contours indicate projected changes (contour interval 10 $m^2\ s^{-2}$). Shadings indicate regions over which ≥80% (light) or 100% (dark) of the models agree on the sign of the change.

Projected Changes: RCP8.5

DJF   JJA



Projected Changes: Geographical Distribution, 300 hPa

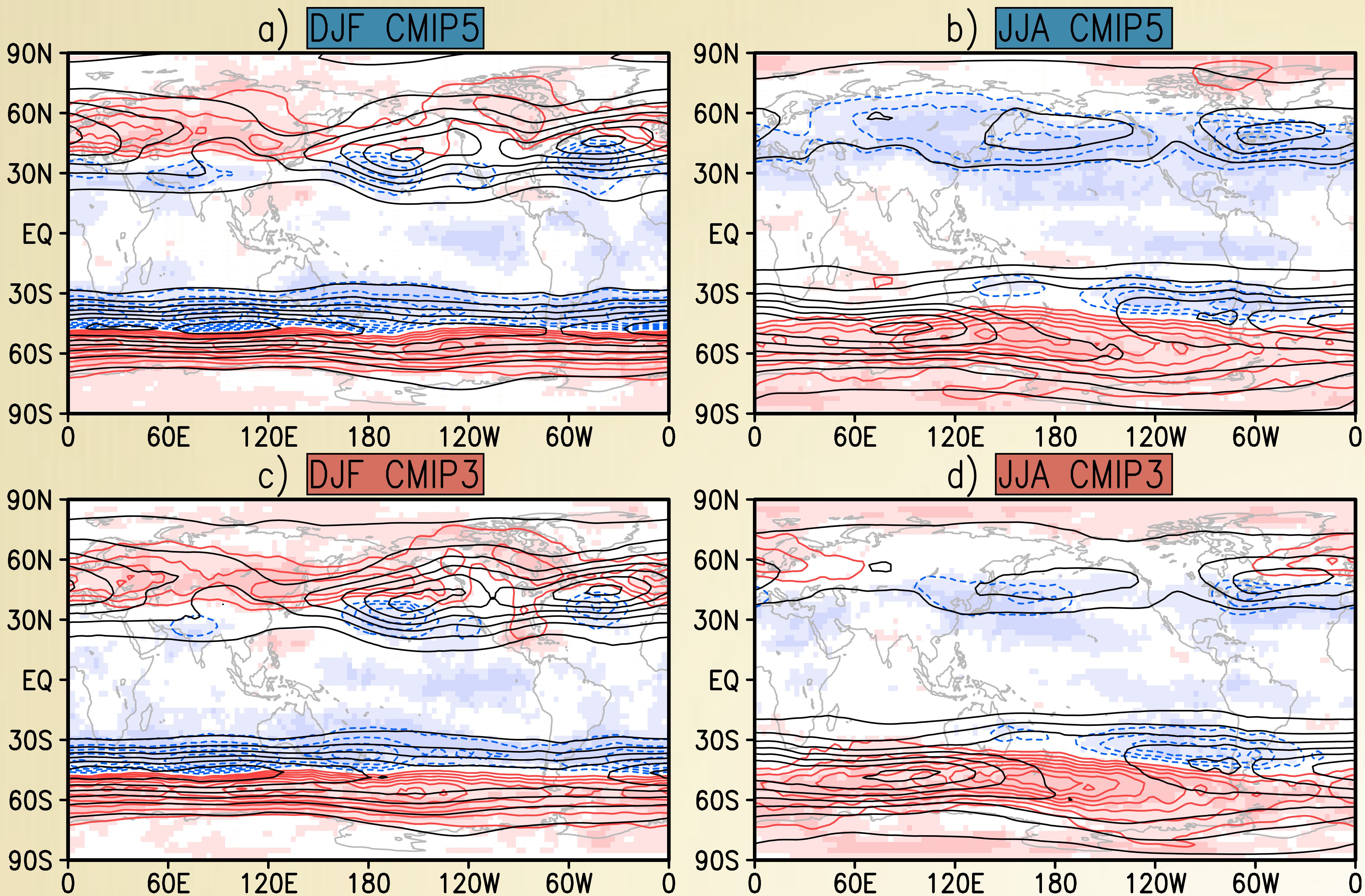


Figure 4. Projected changes from 1980 to 1999 to 2081–2100 in vv at 300 hPa. (a) DJF CMIP5 RCP8.5; (b) JJA CMIP5 RCP8.5; (c) DJF CMIP3 SRES A2; (d) JJA CMIP3 SRES A2. Black contours indicate model climatology (contour interval 50 m^2 s^{-2}). Red and blue contours indicate projected changes (contour interval 10 m^2 s^{-2}). Shadings indicate regions over which ≥80% (light) or 100% (dark) of the models agree on the sign of the change.

Projected Changes: Geographical Distribution, 700 hPa

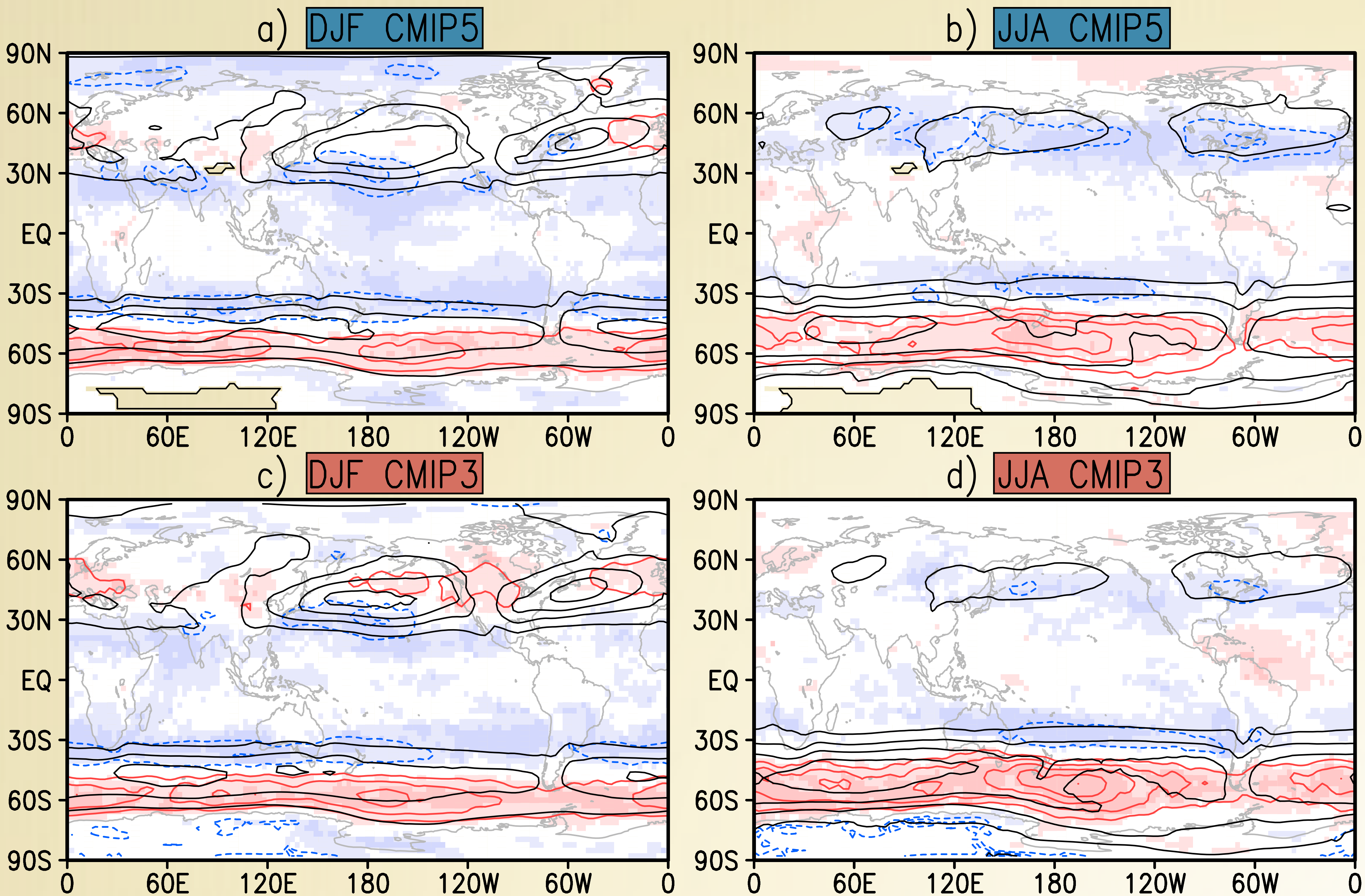


Figure 5. Same as Figure 4, but for vv at 700 hPa. Contour intervals are 20 $m^2\ s^{-2}$ for climatology and 4 $m^2\ s^{-2}$ for projected changes, respectively.

Projected Changes: Geographical Distribution, Surface

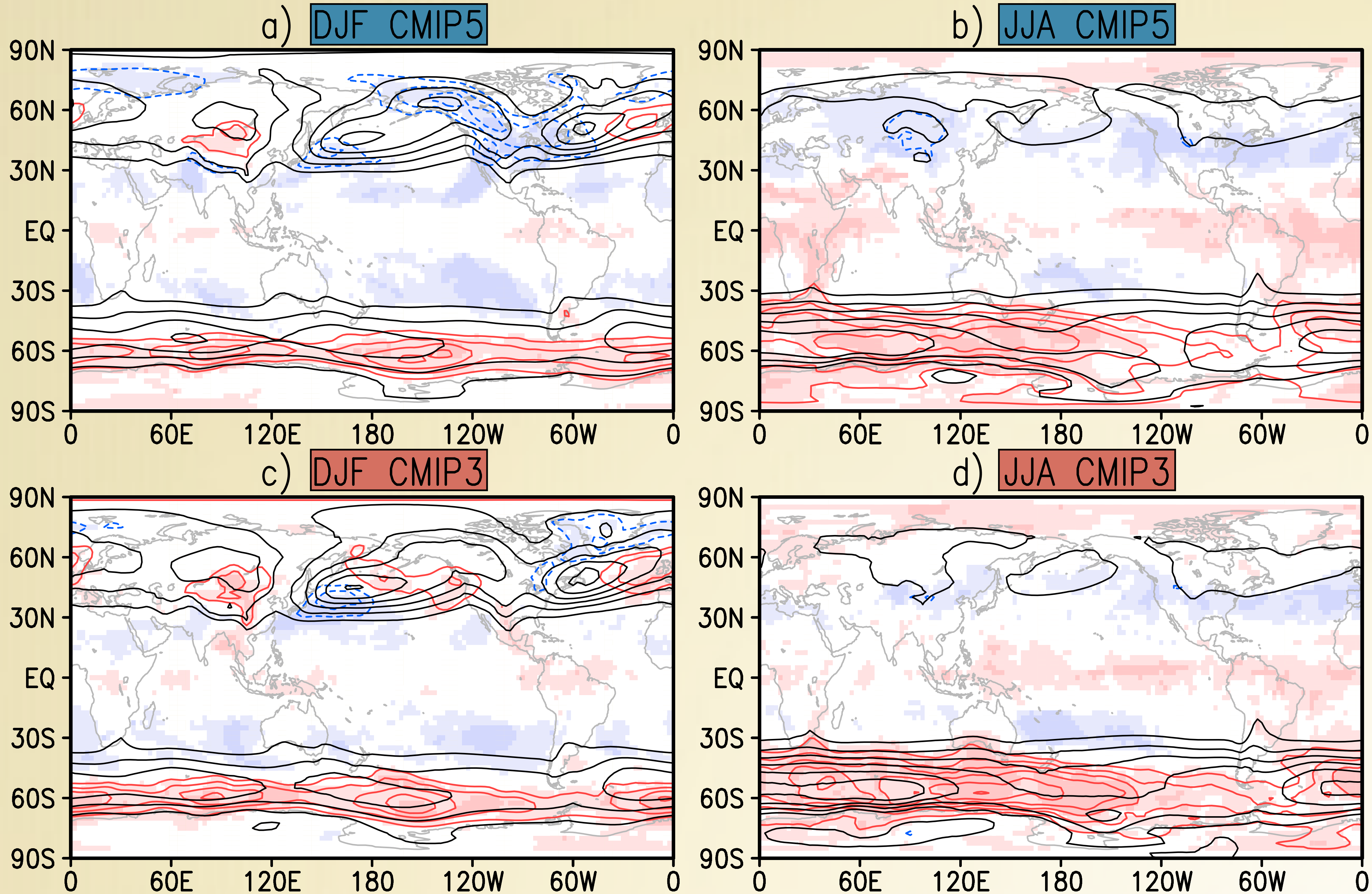
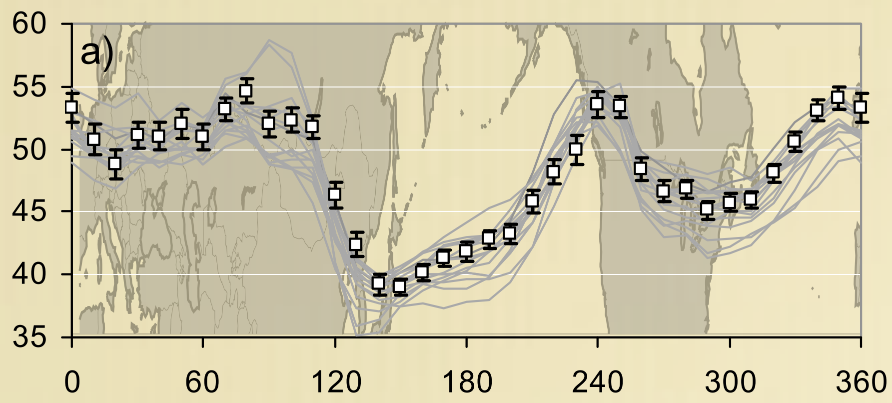
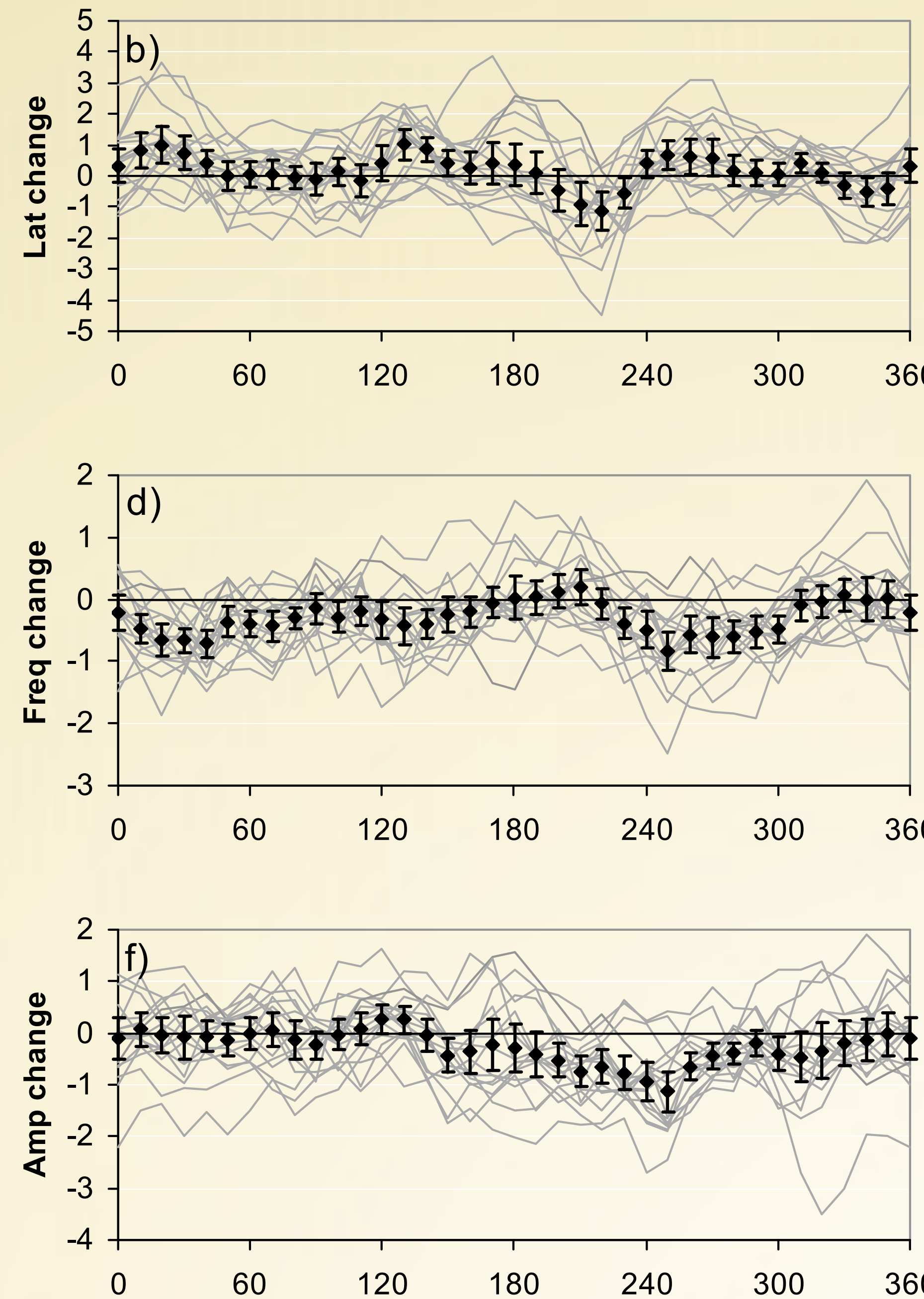


Figure 6. Same as Figure 4, but for pp at sea level. Contour intervals are 20 hPa^2 for climatology and 4 hPa^2 for projected changes, respectively.

Cyclone Tracking Projections

NH DJF



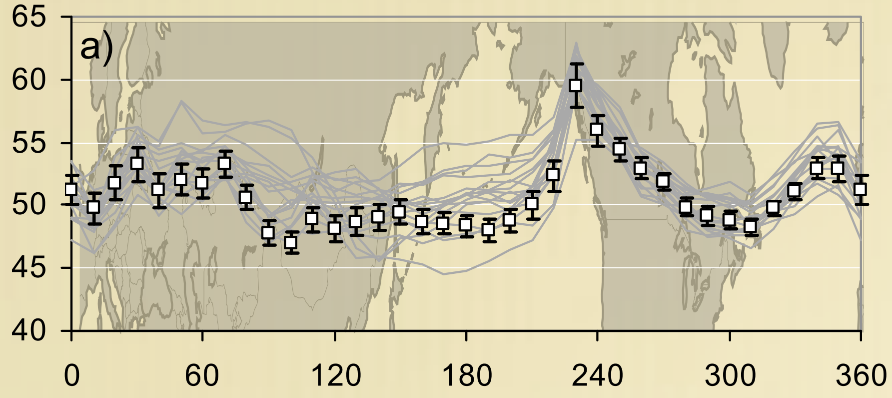


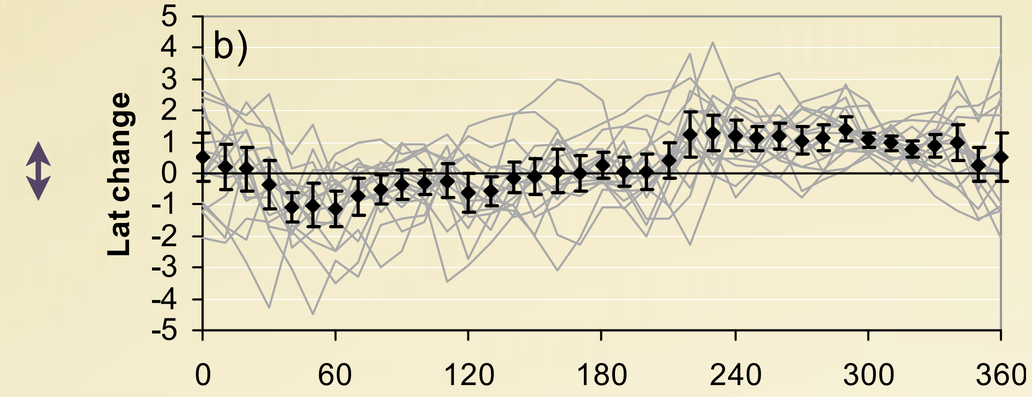
#/month

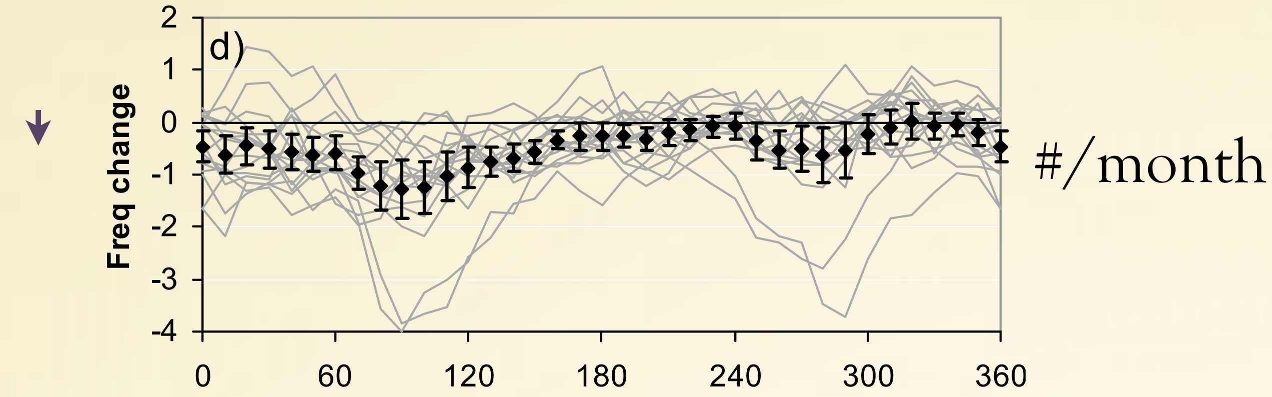
hPa

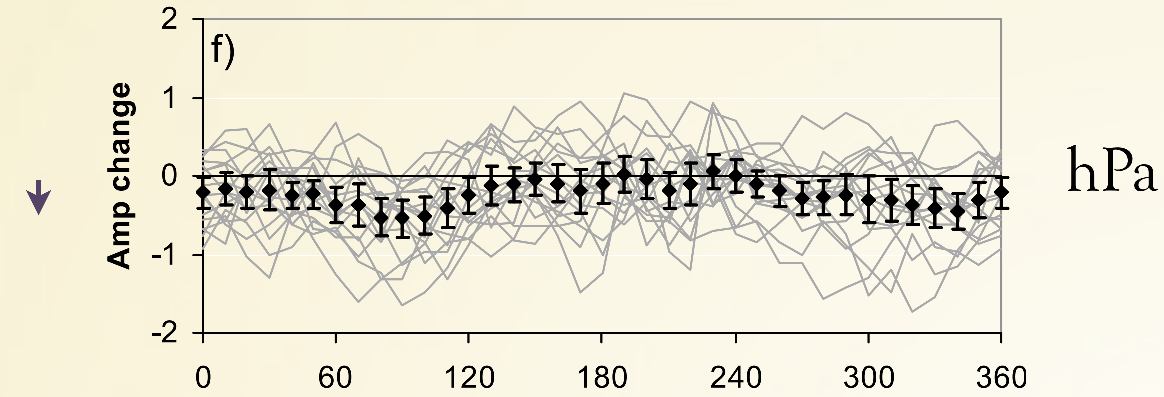
Cyclone Tracking Projections

NH JJA



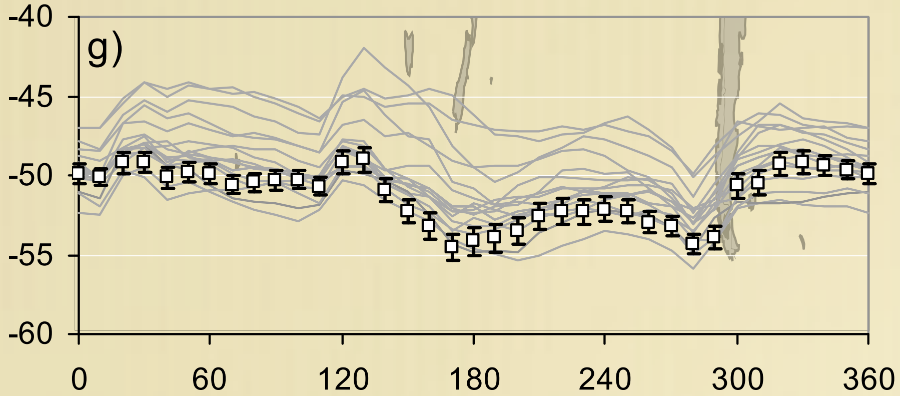


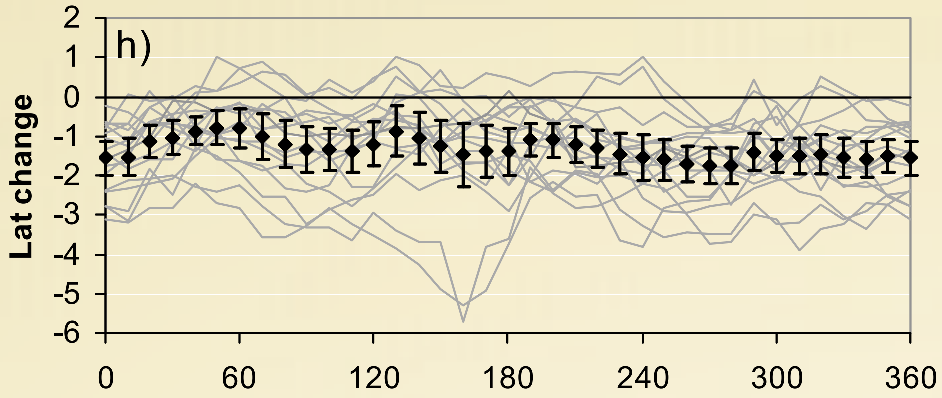


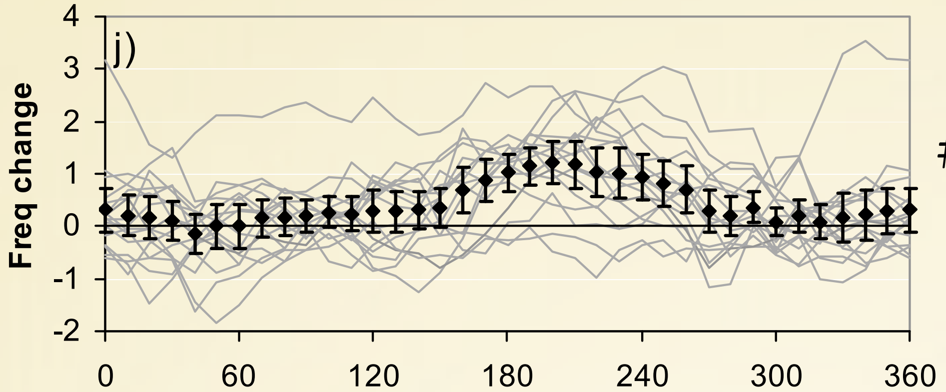


Cyclone Tracking Projections

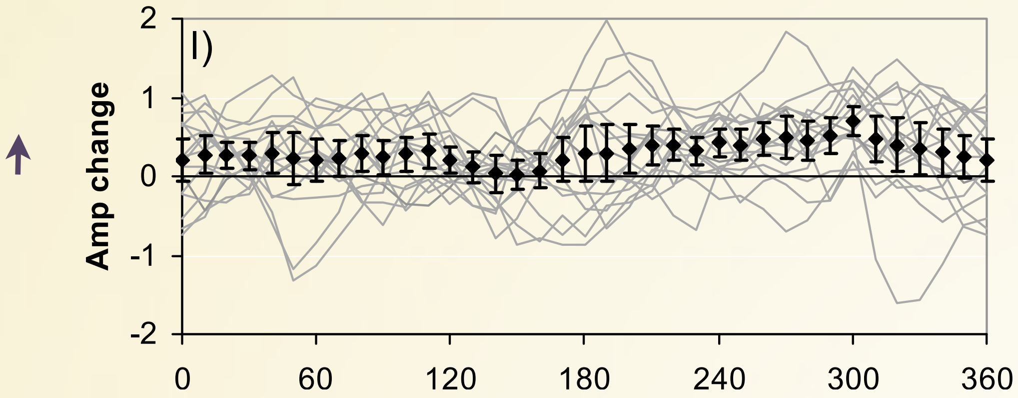
SH DJF







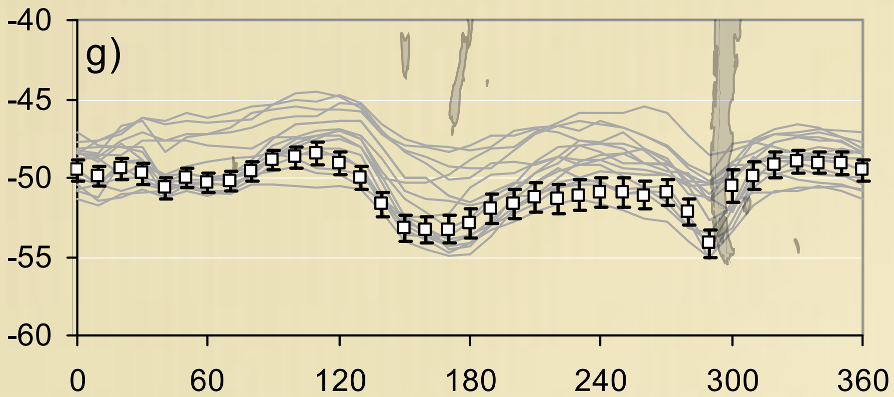
#/month

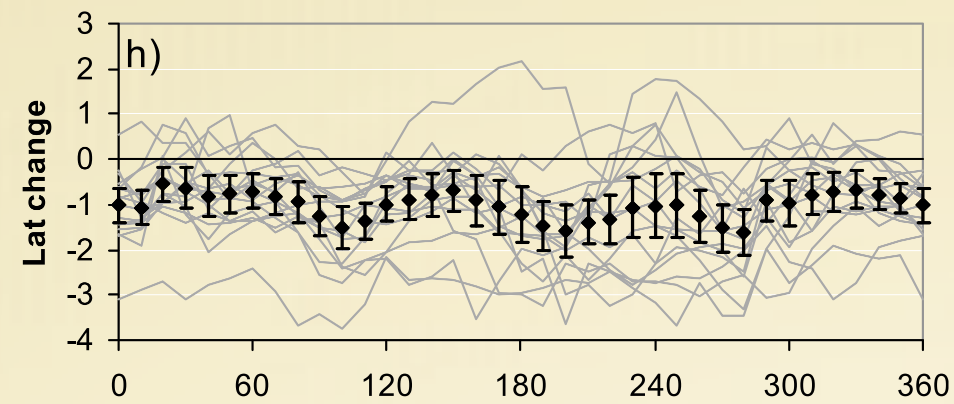


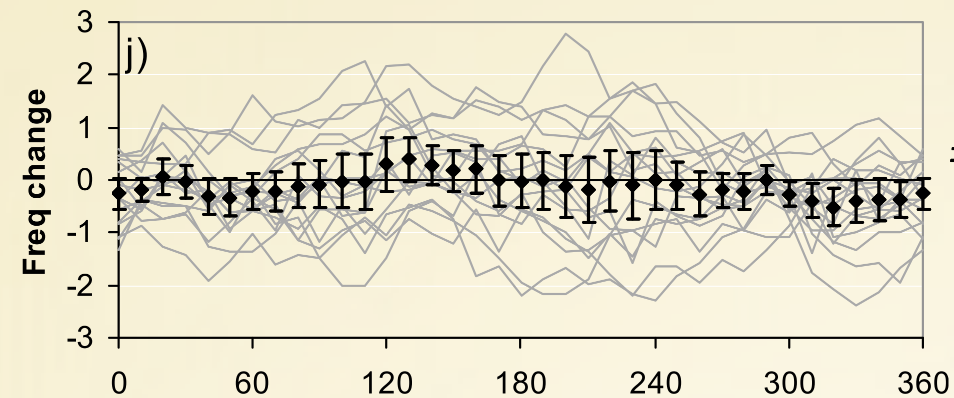
hPa

Cyclone Tracking Projections

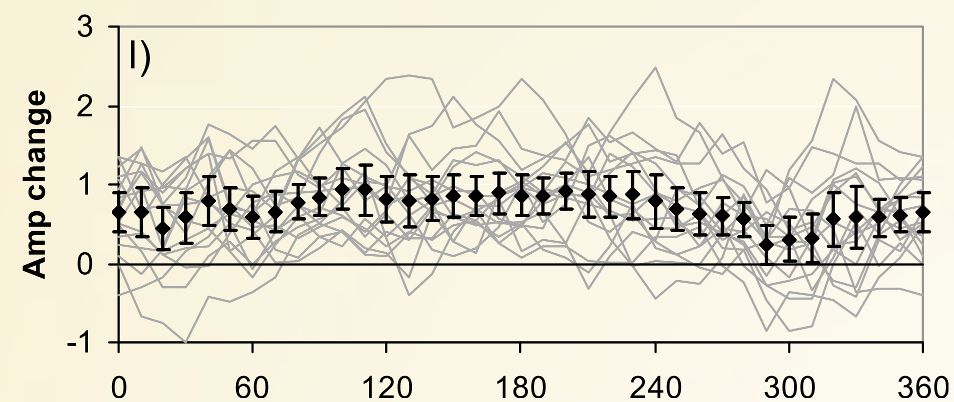
SH JJA







#/month



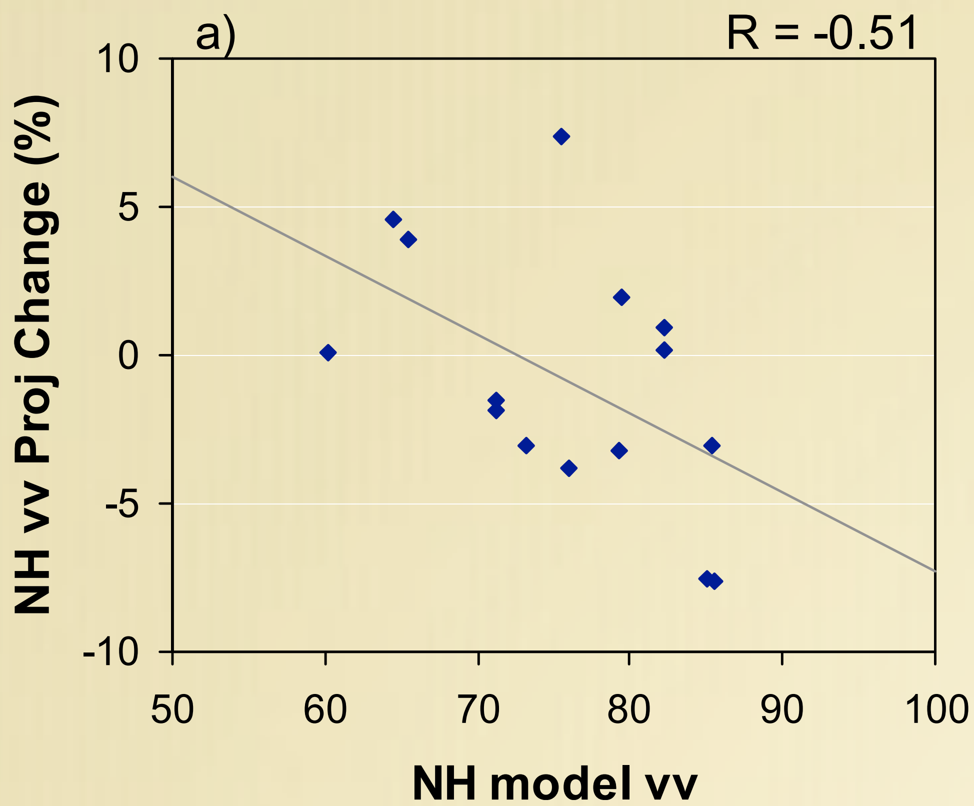
hPa

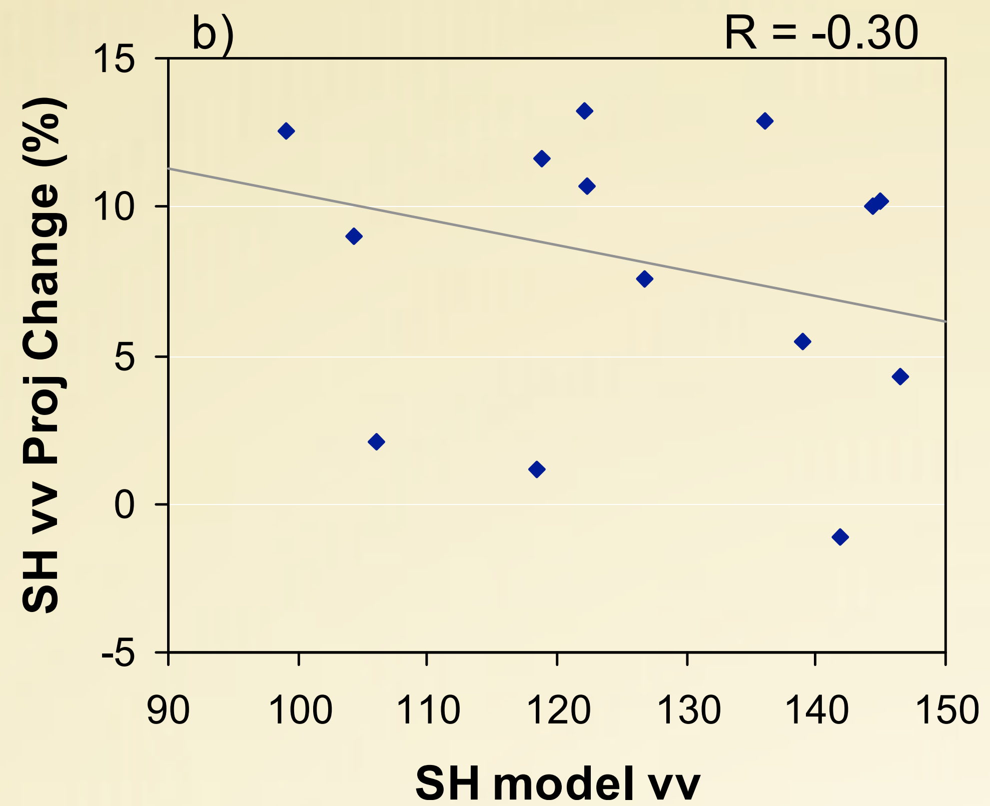
Other Interesting Things...

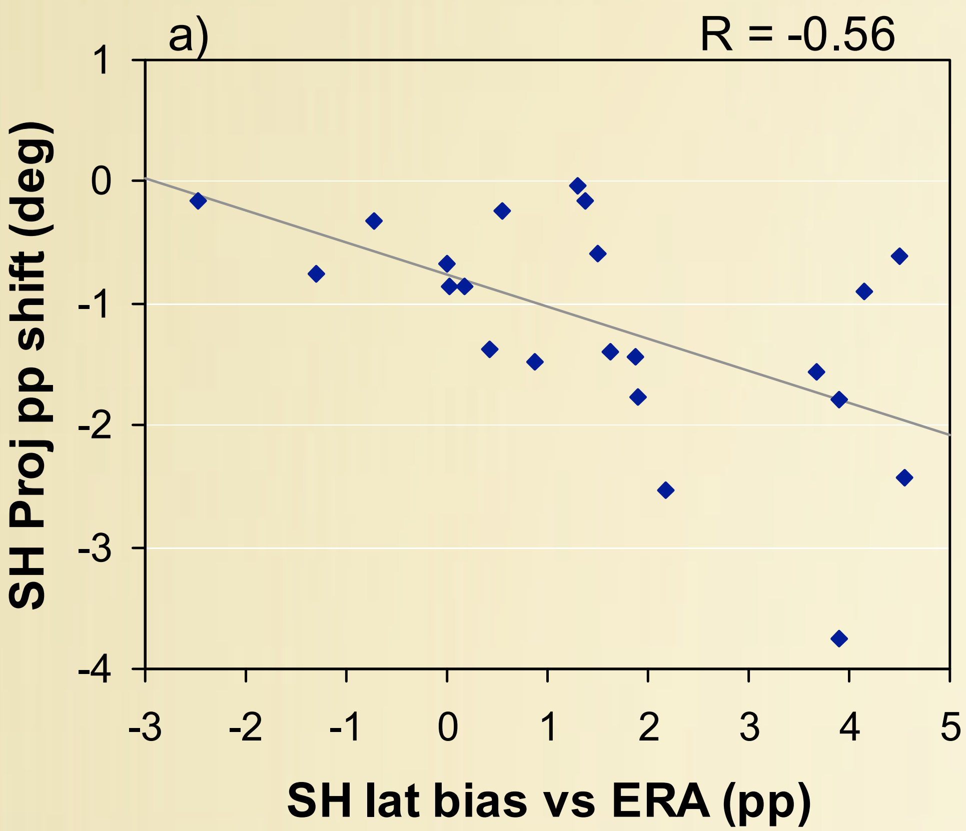
- Comparisons with CMIP3
  - Different models with different forcings, but...
  - DJF: Improved SH amplitude, NH position, projections very similar except for amplitude reduction over NA at surface
  - JJA: Improved NH amplitude (poleward), worse SH amplitude (even weaker), NH projections are for greater strength reductions, displaced further poleward, especially aloft
- Mid 21st Century & RCP4.5
  - Results indicate continuous, gradual shift through century
  - 4.5 end of century shift is not far from that of mid century
- Extreme Cyclones (<-40) & Bombs (-12 hPa in 12 h)
  - Models produce fewer in climatology
  - Extreme - NH: 15% decrease (.1-.5); SH: 12% increase (.1-.7)
  - Bombs - NH: 23% decrease (.4-1); SH: 13% increase, spring (.1)

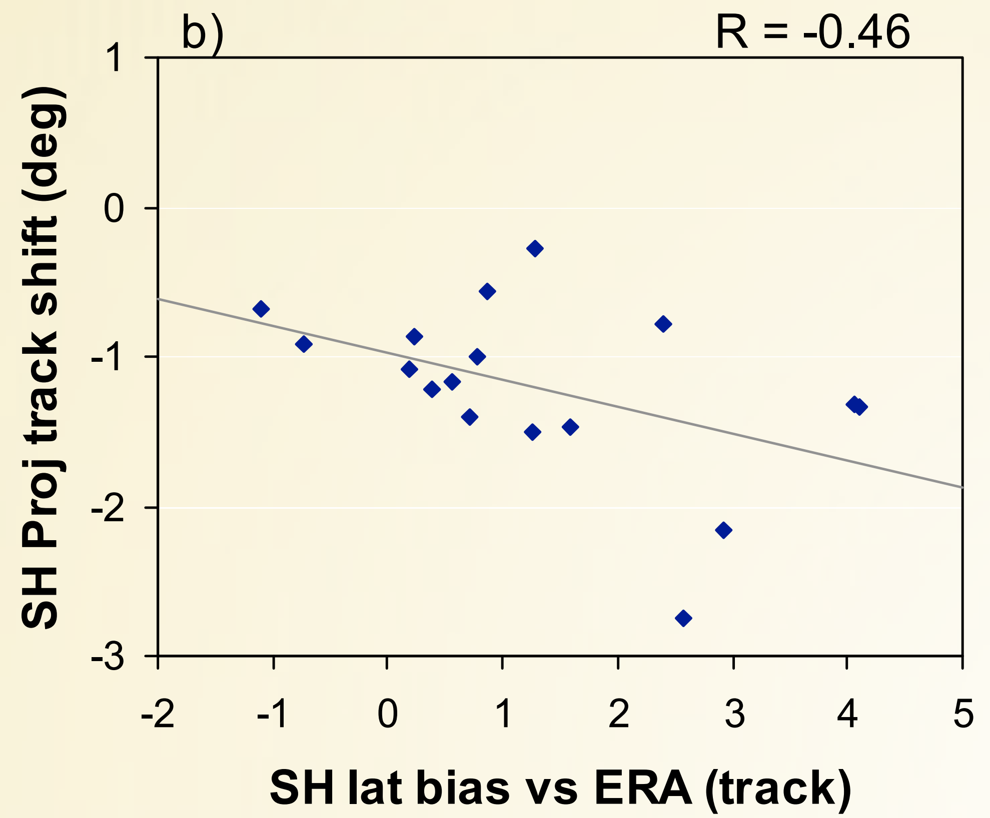
Biases and Their Implications

RCP8.5









Review Overview

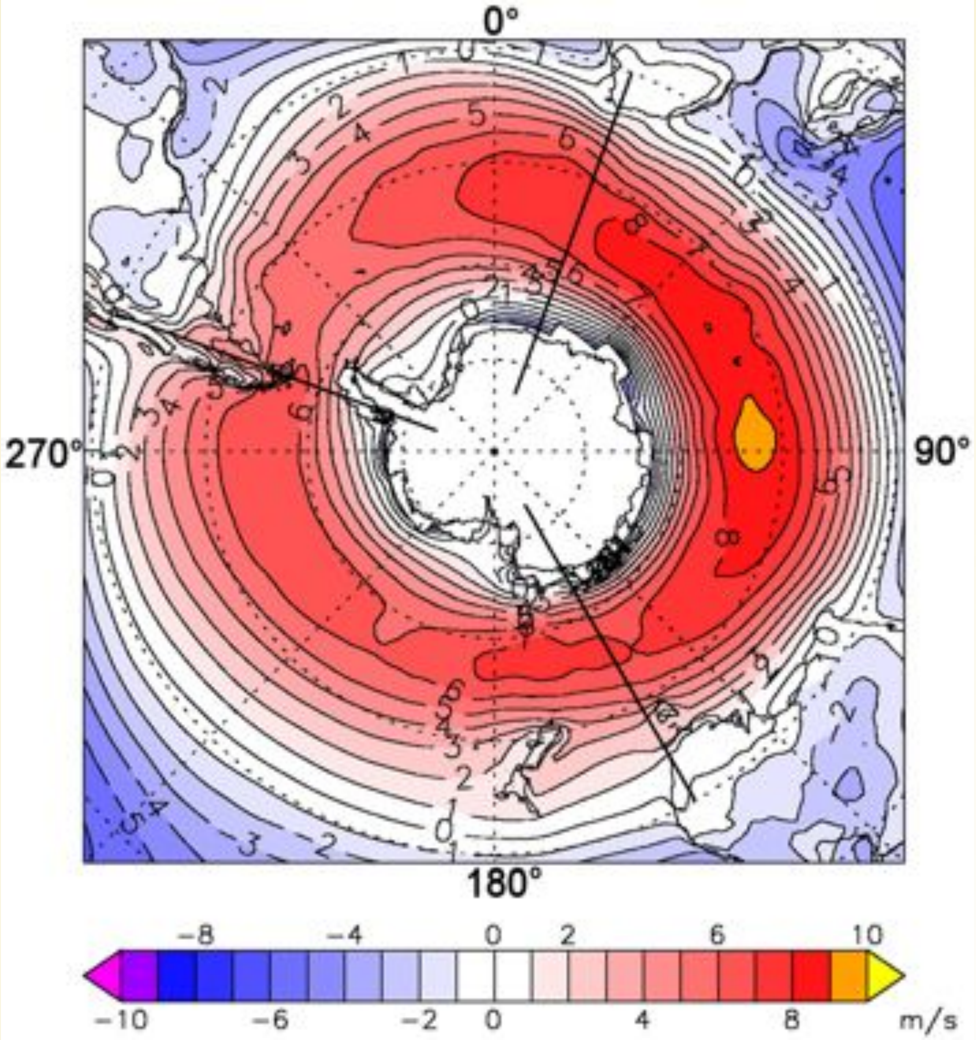
Paper	Variables	Notes
Kidston and Gerber (2010)	Jet position Jet internal variability (SAM)	Position biases are correlated with position and variability changes
Barnes and Hartmann (2010)	Jet position Jet internal variability (SAM) Wave propagation	Position biases are correlated with position and variability changes; Physical explanations
Ceppi et al. (2012)	Jet position SWCF Surface temperature	Position biases are correlated with SWCF biases; Points to local cloud biases.
Chang et al. (2012)	v-wind and SPL variance Cyclone track statistics	Correlations between historical biases and projected shifts in position and strength

Bracegirdle et al. (2013)

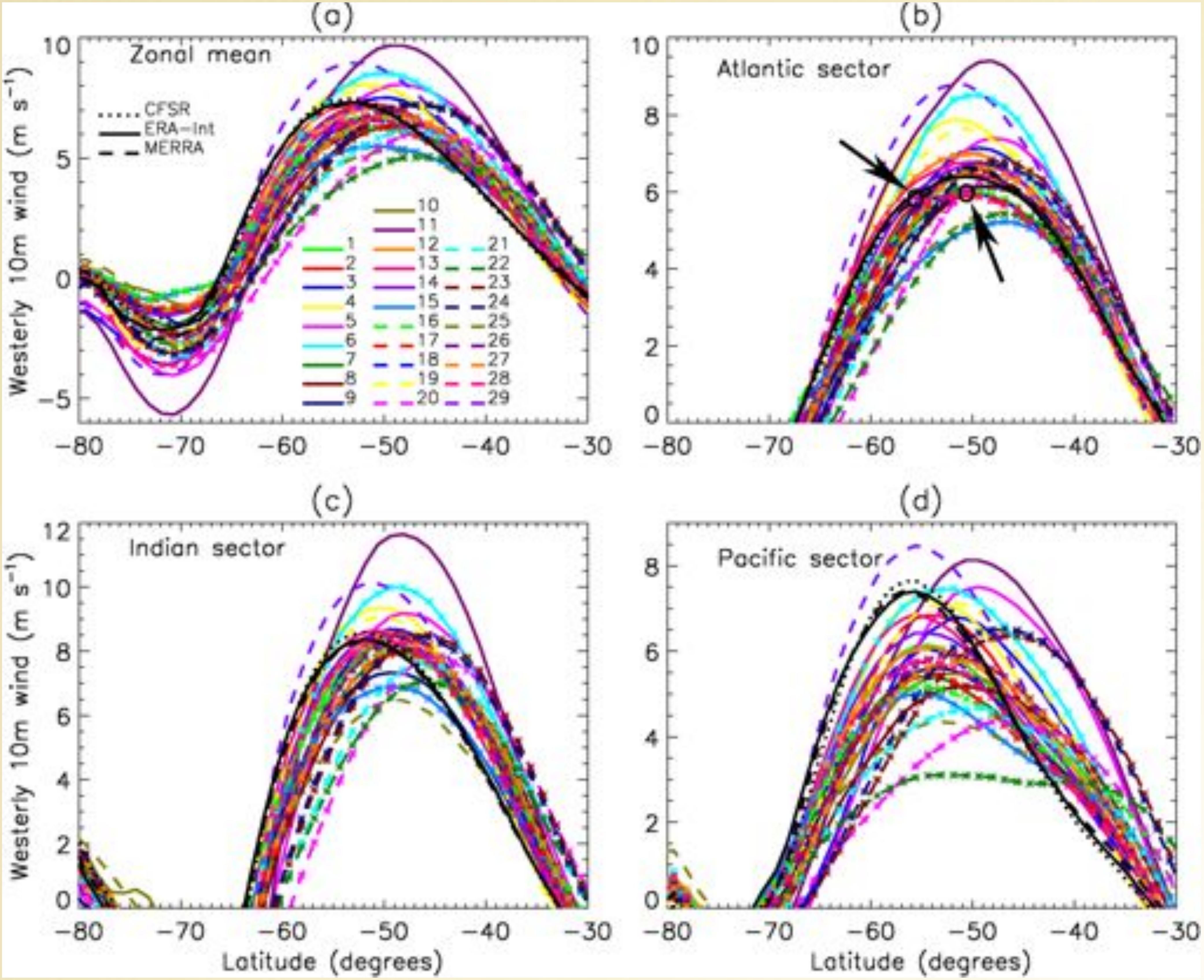
Assessment of surface winds over the Atlantic, Indian, and Pacific Ocean sectors of the Southern Ocean in CMIP5 models: historical bias, forcing response, and state dependence

Thomas J. Bracegirdle,[1] Emily Shuckburgh,[1] Jean-Baptiste Sallee,[1] Zhaomin Wang,[2] Andrew J. S. Meijers,[1] Nicolas Bruneau,[1] Tony Phillips,[1] and Laura J. Wilcox[3]

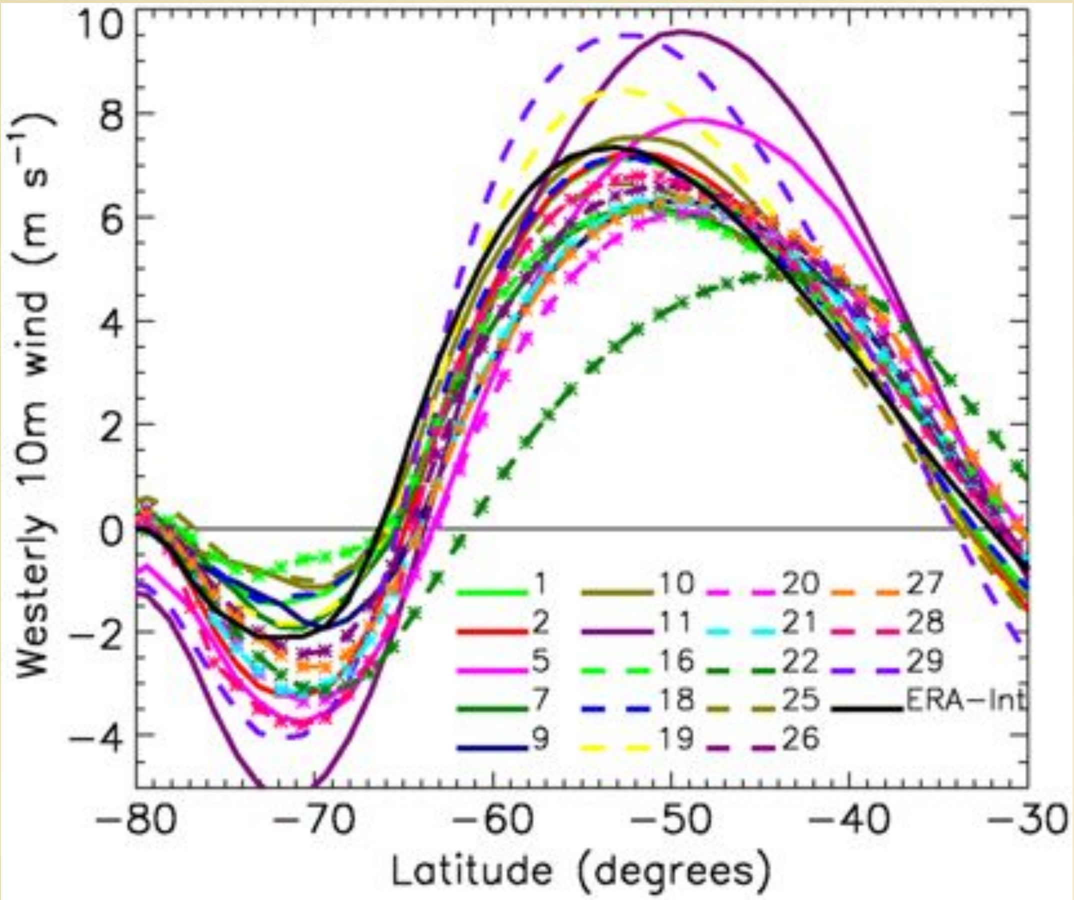
- Examine surface winds over Southern Ocean in CMIP5
  - Focus on understanding ocean impacts and interactions
  - Atlantic, Indian, Pacific
    - Assess longitudinal differences in carbon uptake via local wind
    - Different mechanisms in different locations
  - 29 models in various combinations
  - Jet strength: zonal mean 10m zonal wind
  - Present day skill: 20th century
  - Future change: RCP4.5 & 8.5
  - Analysis by model attributes
    - Coupled v. AMIP
    - High v. Low top
  - Jet shift and state dependence

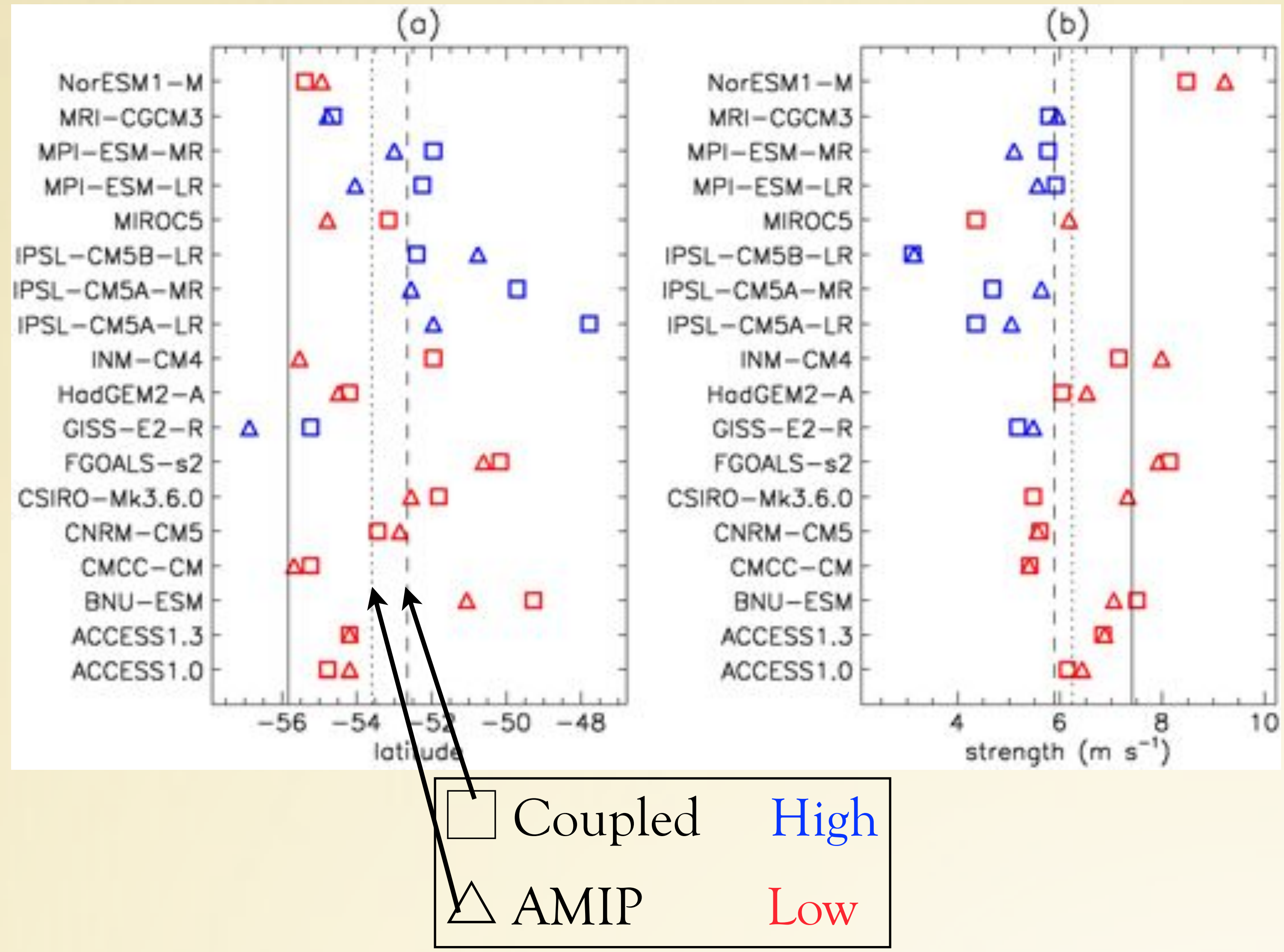


Mean State Skill (1985-2004)



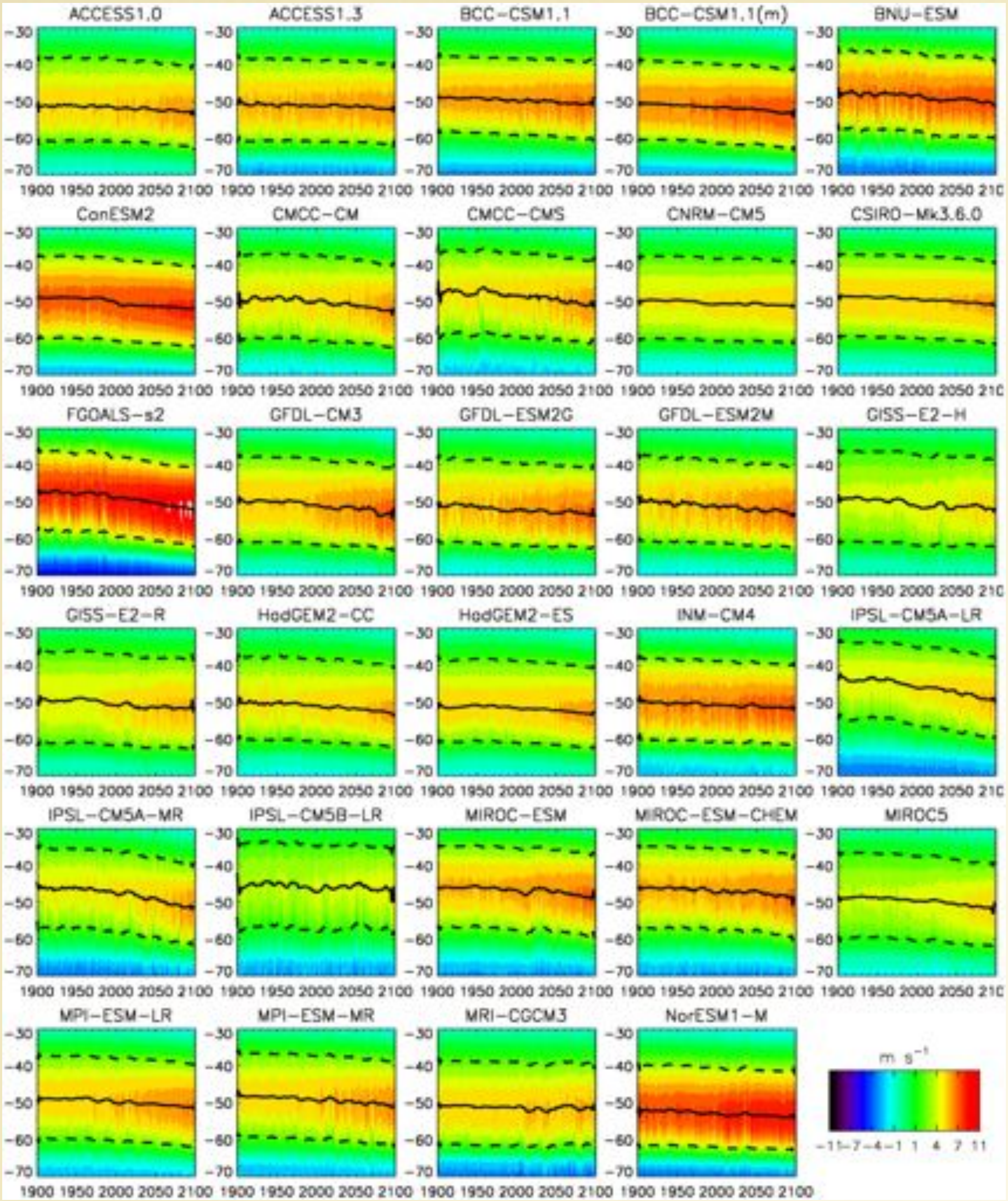
18 AMIP Runs





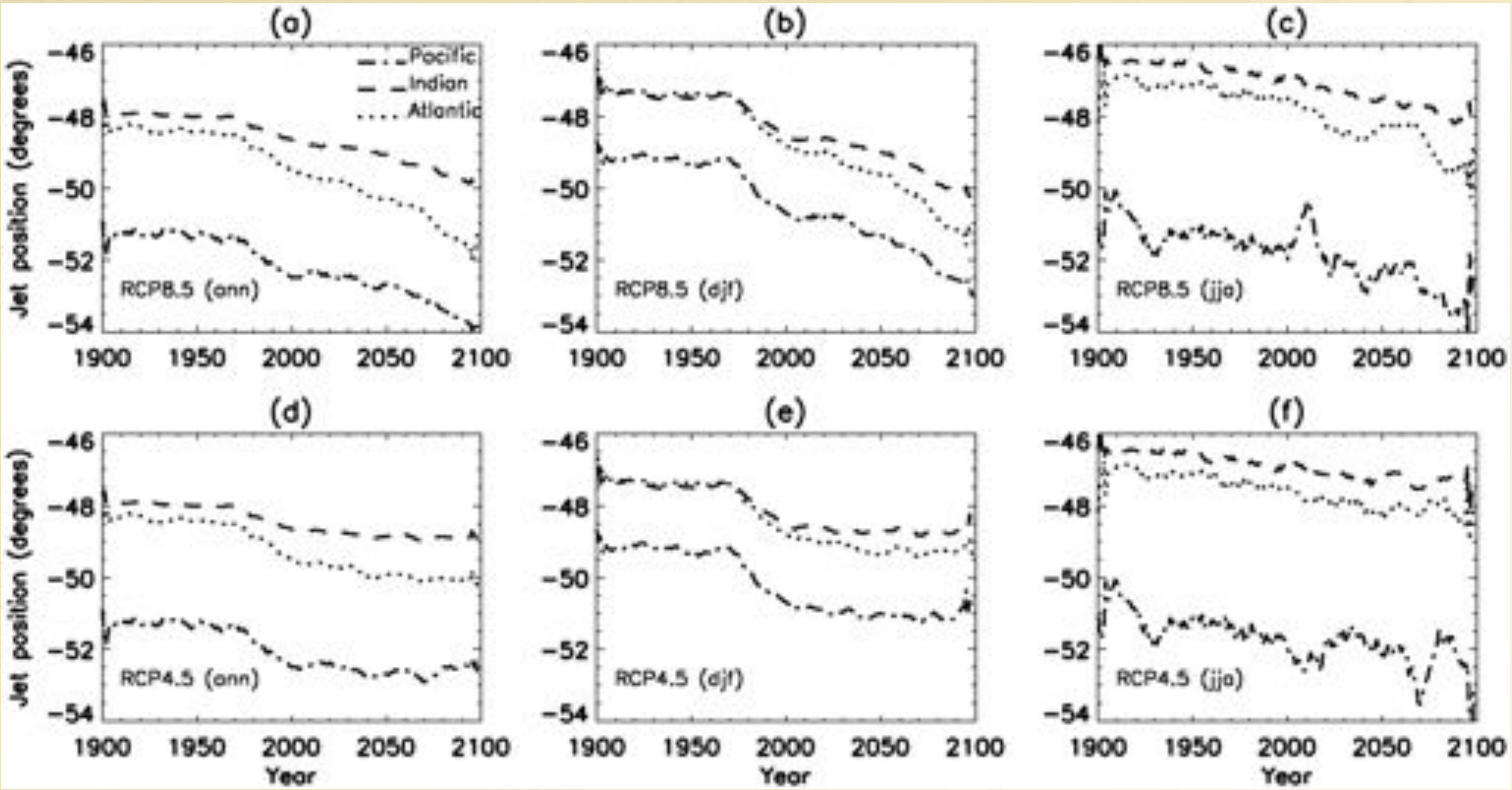
	Zonal Mean	Atlantic Sector	Indian Sector	Pacific Sector
Historical position bias (degrees)	3.4 ± 1.9	1.4 ± 1.6	3.3 ± 1.6	3.2 ± 2.3
	$[3.3 \pm 1.9]$	$[1.4 \pm 1.5]$	$[3.4 \pm 1.6]$	$[3.3 \pm 2.7]$
AMIP position bias (degrees)	2.4 ± 2.2	0.7 ± 2.3	2.6 ± 2.3	2.2 ± 1.8
Historical strength bias ($\mathrm{m\,s^{-1}}$)	-0.5 ± 1.2	0.3 ± 1.1	0.0 ± 1.2	-1.5 ± 1.4
	$[-0.4 \pm 1.0]$	$[0.3 \pm 1.0]$	$[0.1 \pm 1.0]$	$[-1.4 \pm 1.2]$
AMIP strength bias ($\mathrm{m\,s^{-1}}$)	-0.3 ± 1.2	0.4 ± 1.1	0.1 ± 1.1	-1.2 ± 1.4

Temporal Changes, 1900-2100



10-m westerly wind
Annual/zonal mean

Changes by Basin & Scenario



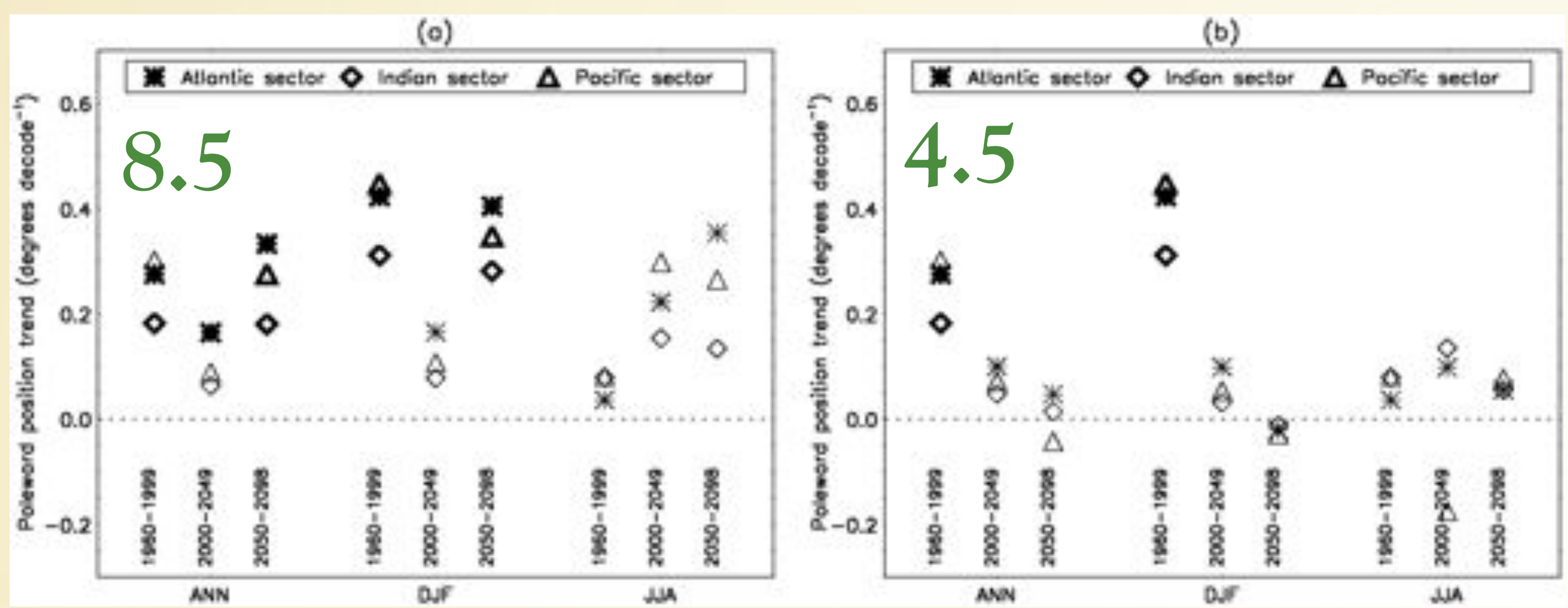
RCP8.5

RCP4.5

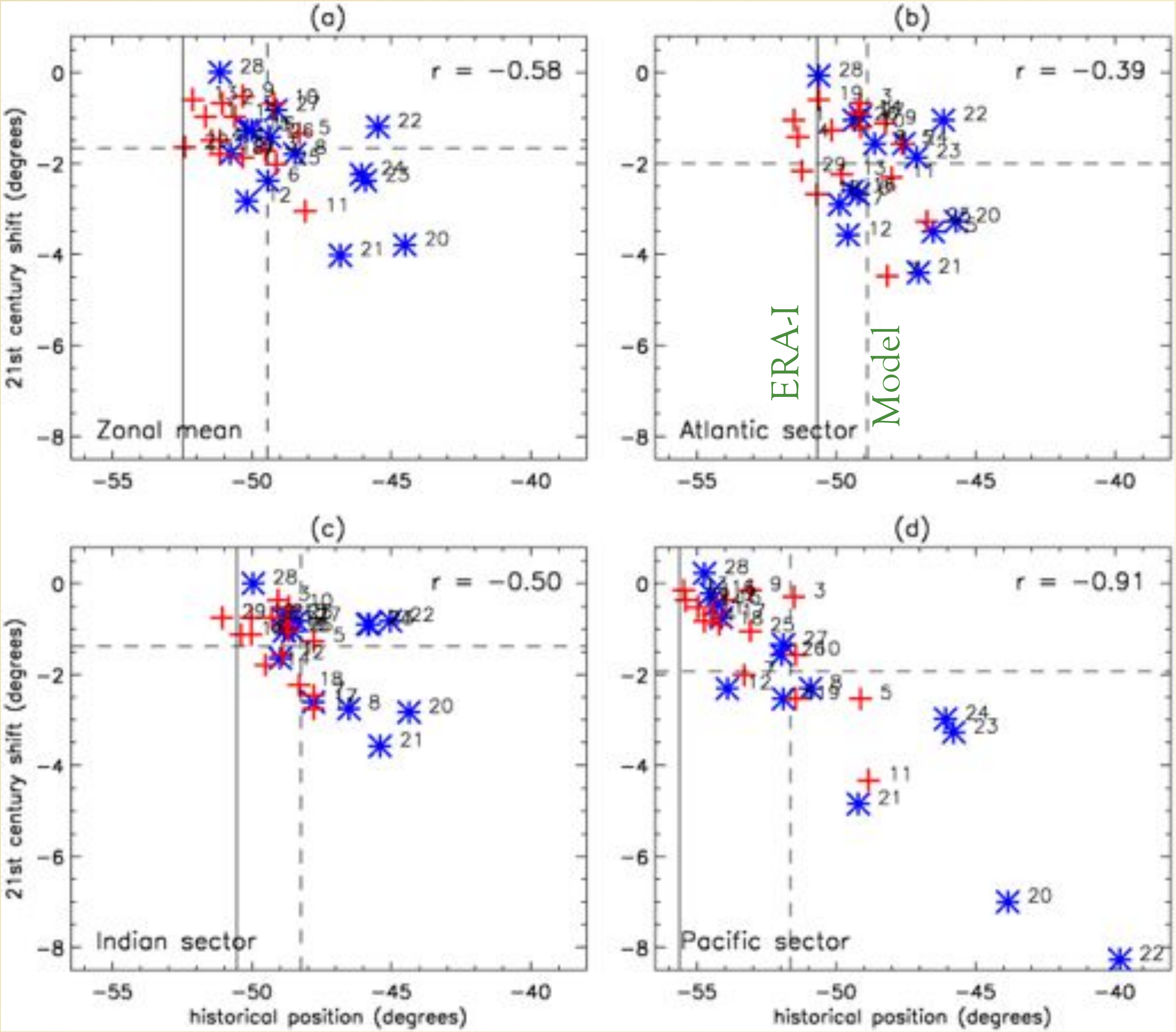
Annual

DJF

JJA



High and Low Top Models



1960-1999

v.

2059-2098

(RCP8.5)

✲ High

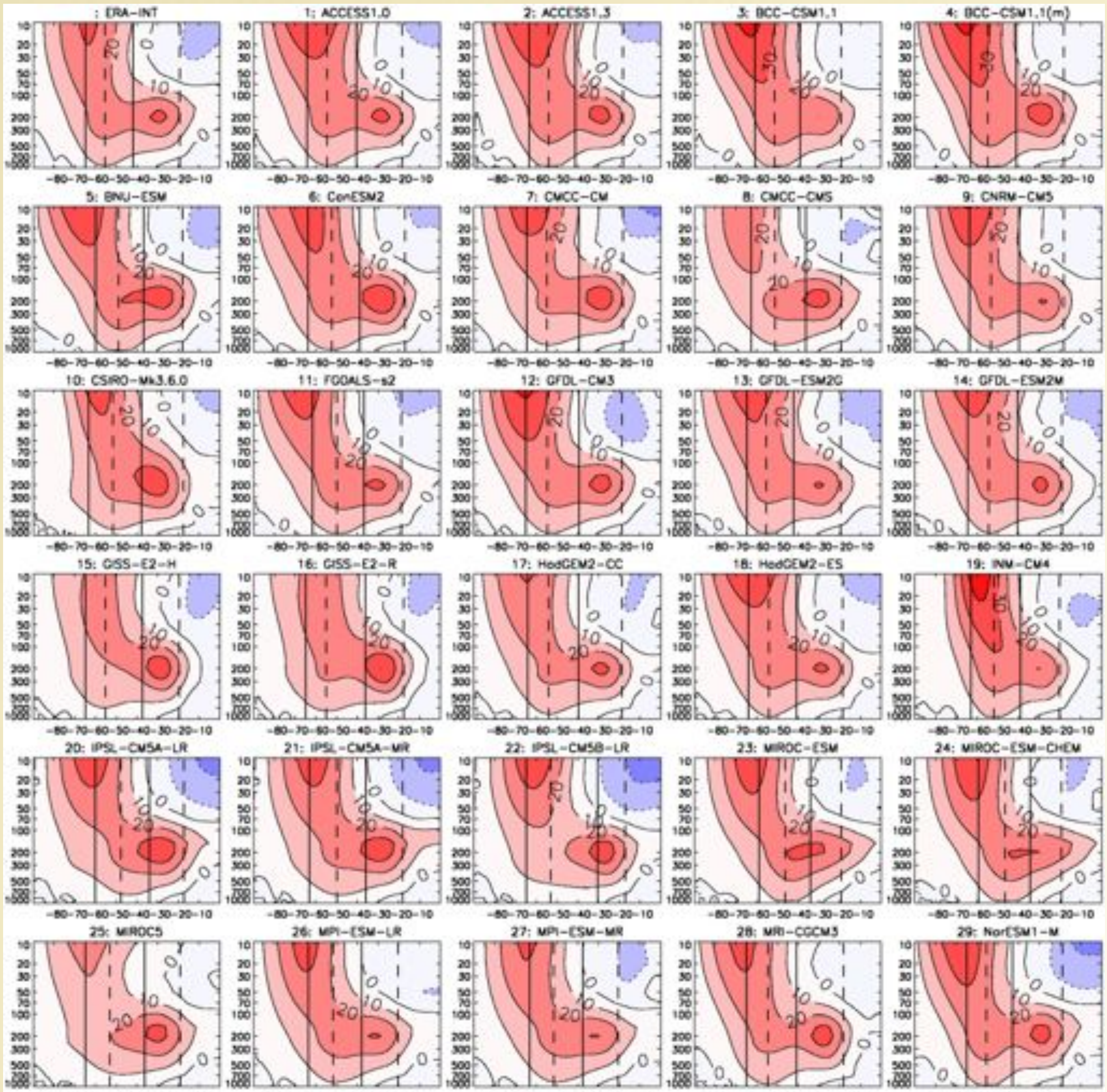
+ Low

Jet Shift and State Dependence

- Investigate 2 mechanisms that relate shifts in the jet to tropospheric eddy feedbacks that depend on the time mean jet structure:
  - Barnes and Hartmann (2010)
    - Differences in eddy feedback could originate in differences in wave breaking on the poleward side of the sub-polar jet, when poleward breaking is suppressed and a wider jet extends to higher latitudes.
    - Models that already do that show smaller shifts in projections
  - Simpson *et al.* (2012)
    - Tropospheric eddy feedback and poleward shift is stronger when the distance between the sub-polar eddy-driven jet and the sub-tropical critical line is smaller.
    - Higher latitude jets with a larger distance exhibit a weaker poleward jet shift.
  - PT-Distance: Sub-polar jet to sub-tropical critical line (kinda)
  - *P*-width: Width of sub-polar jet

Jet Shift and State Dependence

Pacific

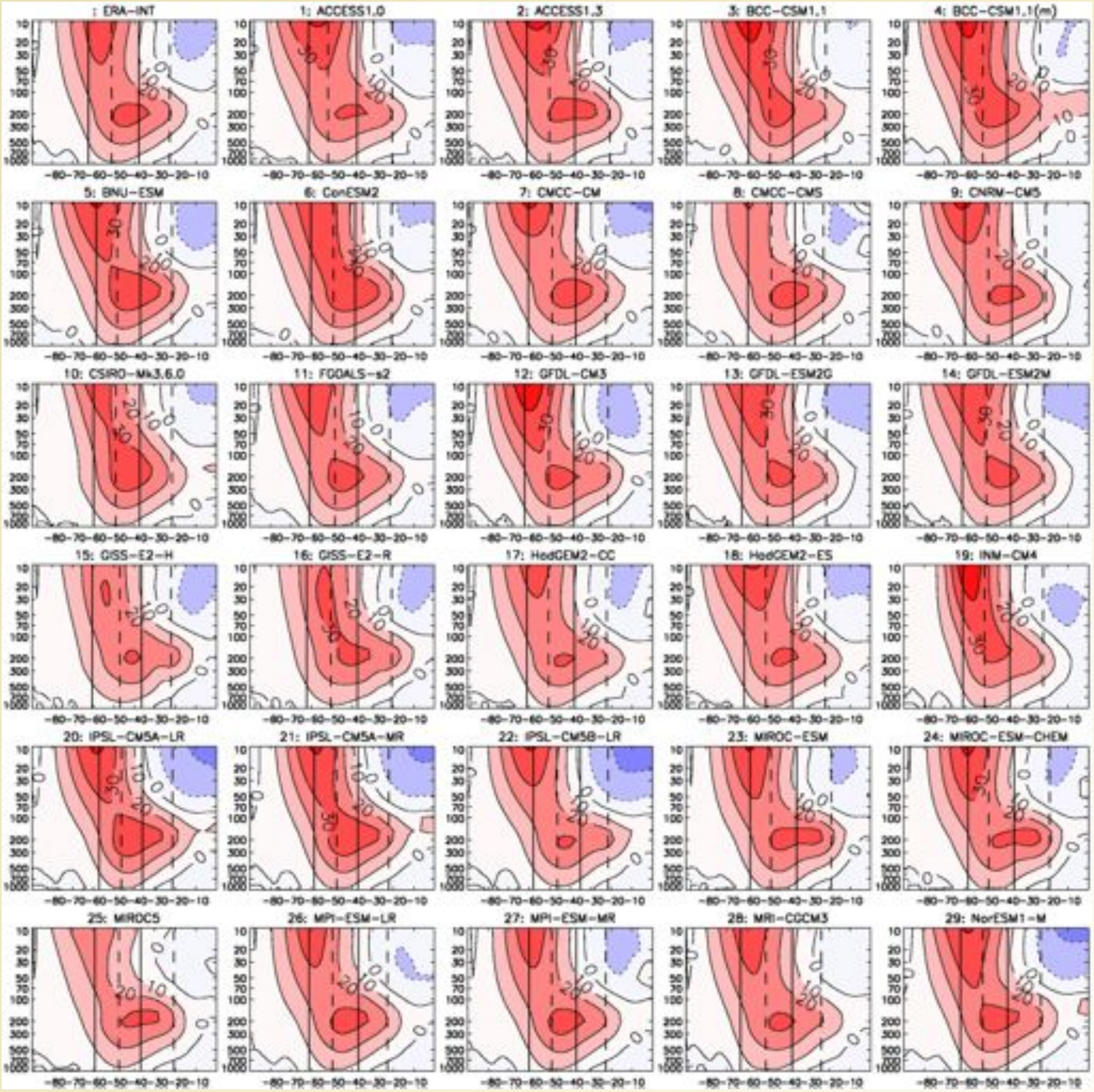


P-width

PT-distance

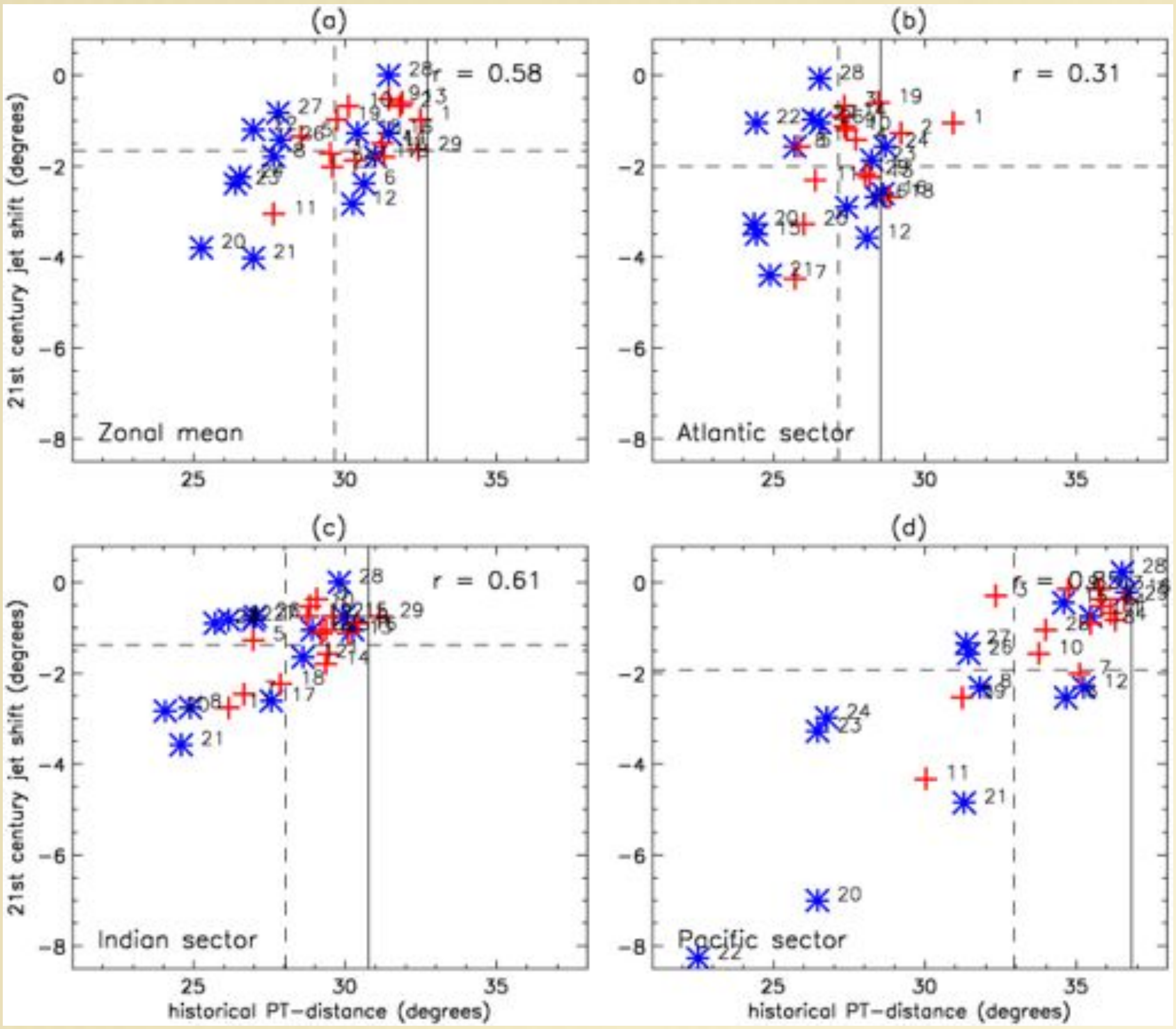
Jet Shift and State Dependence

Atlantic

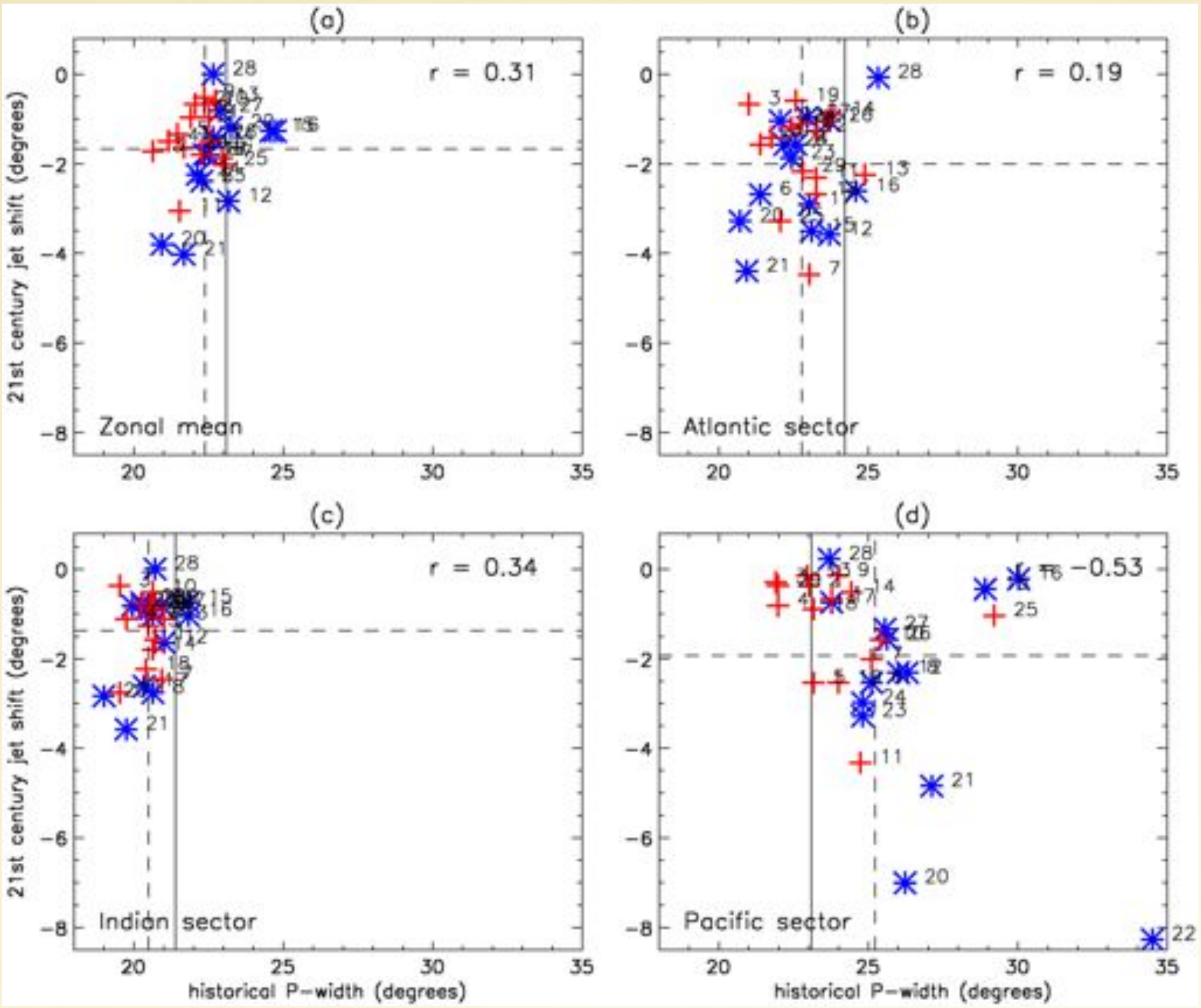


Jet Shift and State Dependence

PT-Distance



P-Width



- The dynamical response differs across sectors.
- Both mechanisms appear to be factors in the Indian and Atlantic sectors.
- Only the PT mechanism seems to hold in the Pacific.

Review Overview

Paper	Variables	Notes
Kidston and Gerber (2010)	Jet position Jet internal variability (SAM)	Position biases are correlated with position and variability changes
Barnes and Hartmann (2010)	Jet position Jet internal variability (SAM) Wave propagation	Position biases are correlated with position and variability changes; Physical explanations
Ceppi et al. (2012)	Jet position SWCF Surface temperature	Position biases are correlated with SWCF biases; Points to local cloud biases.
Chang et al. (2012)	v-wind and SPL variance Cyclone track statistics	Correlations between historical biases and projected shifts in position and strength
Bracegirdle et al. (2013)	Jet position Jet strength Jet width/distance to C.L.	PT-distance and jet width correlate with jet shift; Dependent on basin

Grise & Polvani (2014)

- Noting that:
  - Feedbacks involving clouds are responsible for most of the spread in climate sensitivity,
  - The Southern Ocean is almost entirely covered by clouds in climatology,
  - Southern clouds are related to the position of storm tracks and jets that is projected to change,
  - And the relationship between SH jet variability and cloud radiative processes is model dependent,
- The goal is to clarify the connections among jet variability, cloud radiative processes, and model sensitivity.
  - 20 CMIP5 models with equilibrium climate sensitivity values
  - Preindustrial, historical, 4xCO_2, 30-year fixed SST/SI (PI & 4x)

Southern Hemisphere Cloud–Dynamics Biases in CMIP5 Models and Their Implications for Climate Projections

KEVIN M. GRISE

Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York

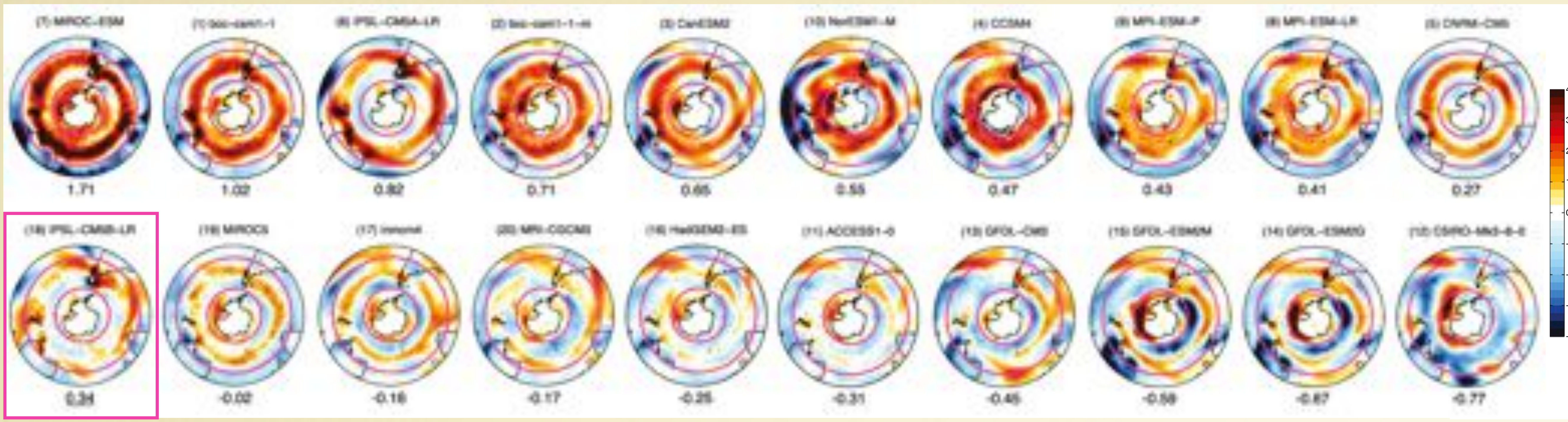
LORENZO M. POLVANI

Lamont-Doherty Earth Observatory, Department of Applied Physics and Applied Mathematics, and Department of Earth and Environmental Sciences, Columbia University, New York, New York

Shortwave CRE Anomalies Regressed on SH Jet Latitude Time Series, DJF, PI

$$R_{\text{jet–CRE}_{i,j}} = \frac{\overline{R'_{\text{CRE}_{i,j}} \phi'_{\text{u850}}}}{\overline{\phi'^2_{\text{u850}}}}.$$

$$R_{\text{CRE}} = R_{\text{clear}} - R$$



- Shortwave jet-CRE: ΔCRE per 1° poleward jet bias [Wm^{-2}]
- Separated visually into Type I and Type II.
- Averaging 30°-60° yields jet-CRE indices.
- Type I: Reduction in midlatitude total cloud fraction.

Longwave CRE Anomalies Regressed on SH Jet Latitude Time Series, DJF, PI

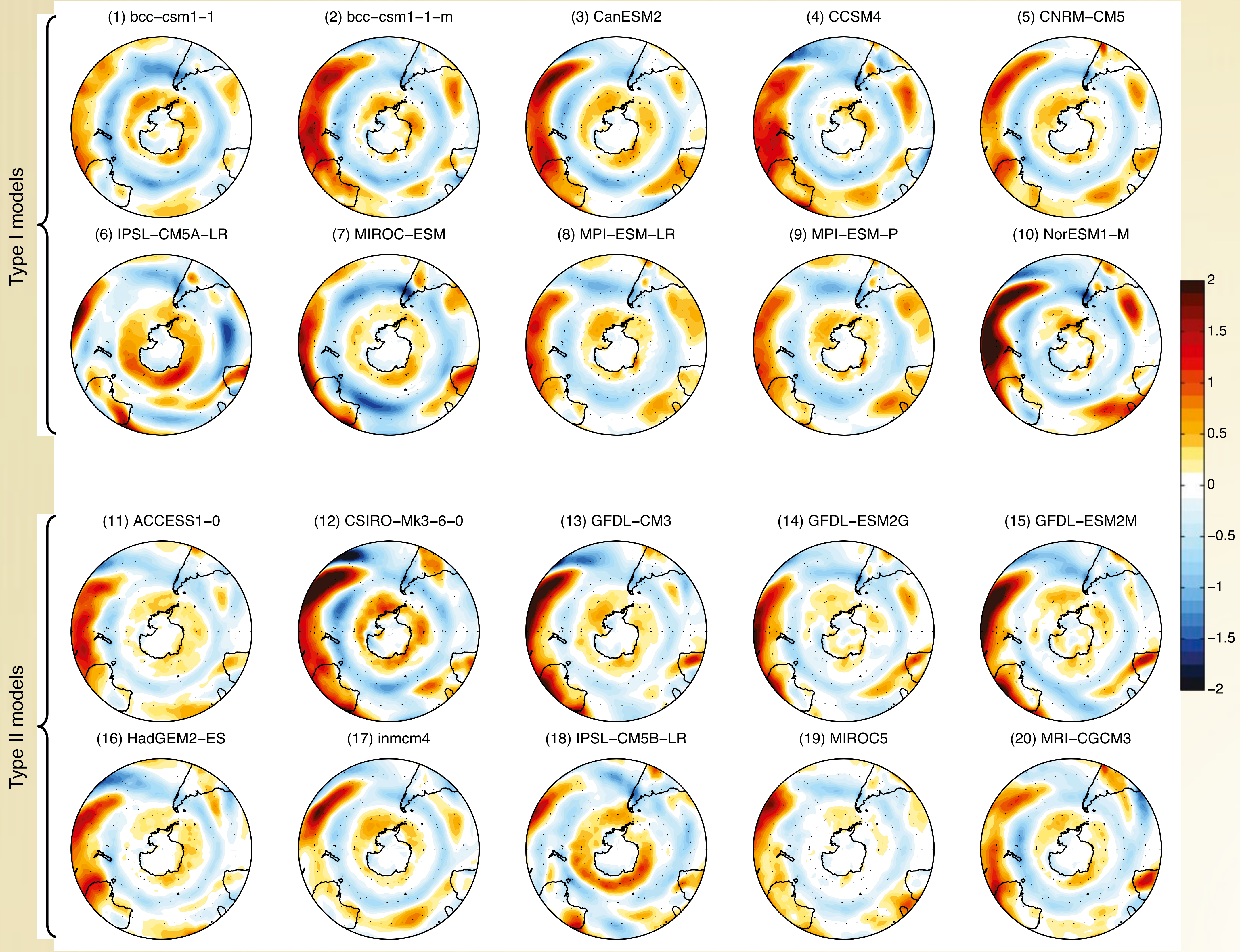
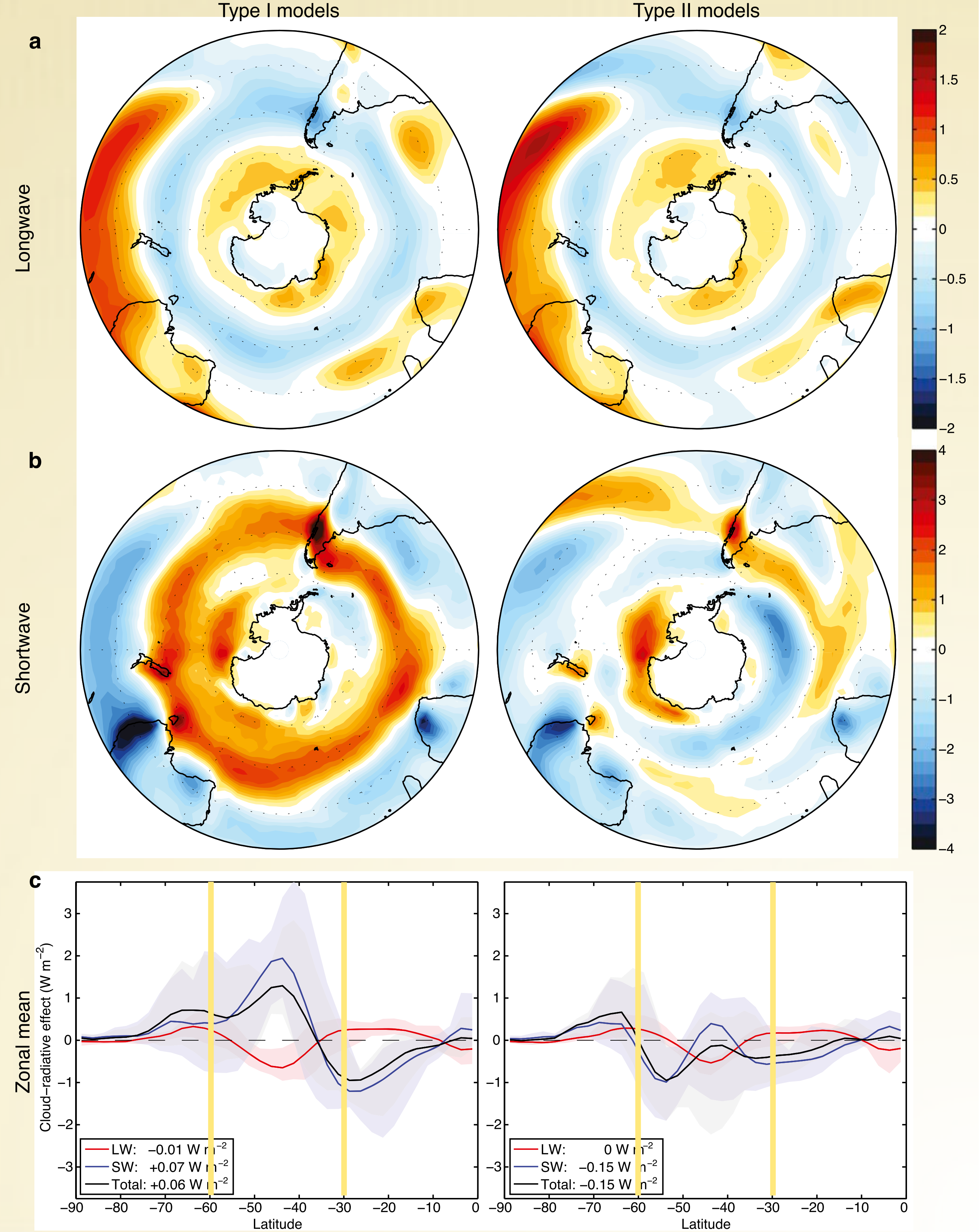


FIG. 2. As in Fig. 1, but for the longwave jet–CRE patterns. The contour interval is 0.125 W m^{-2}.

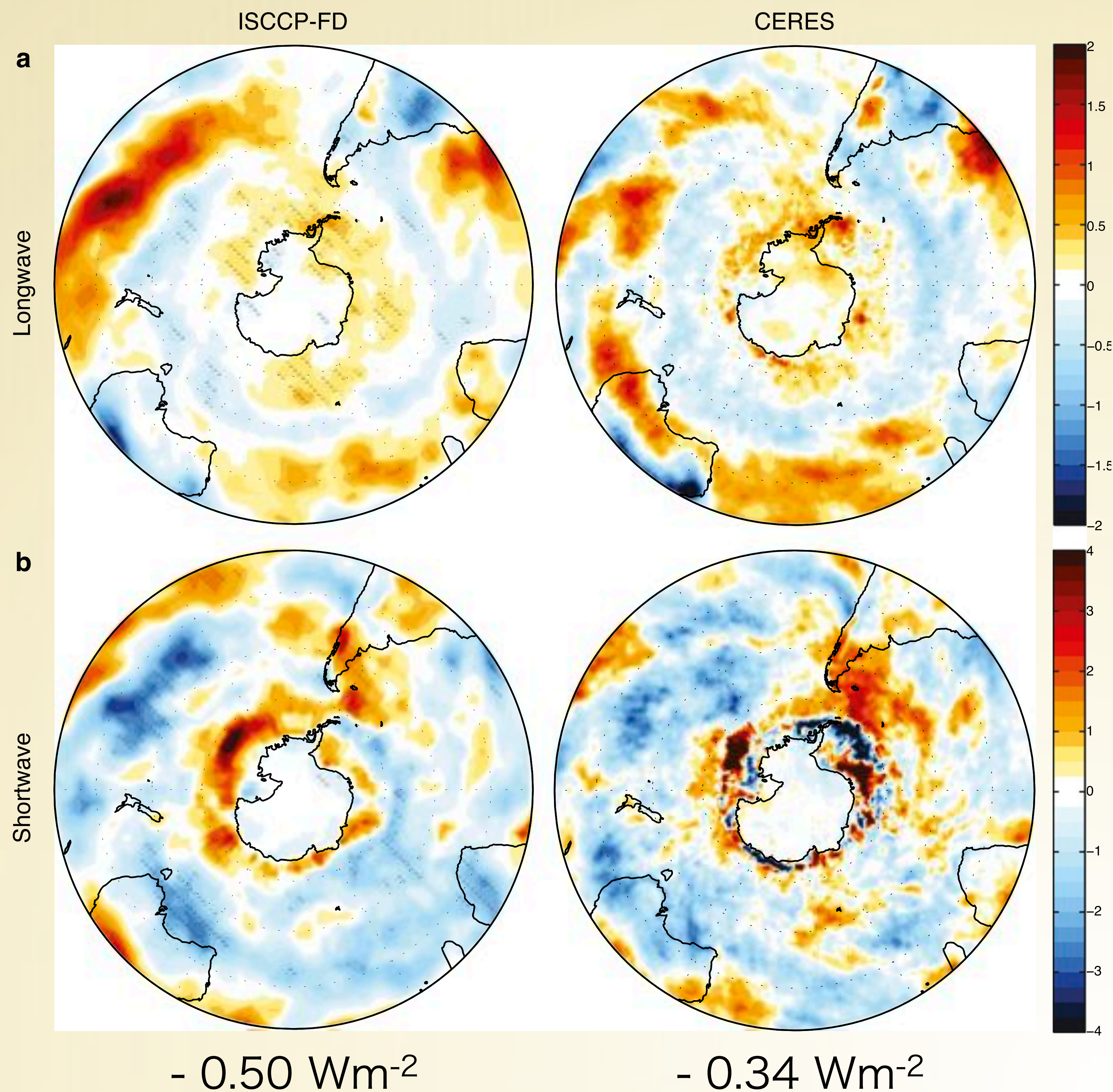
Composite jet-CRE Patterns

- Composite longwave pattern nearly identical for both types
- Clear composite shortwave differences
- Hemispherically averaged heating for Type I; cooling for Type II
- Likely to have implications under climate change

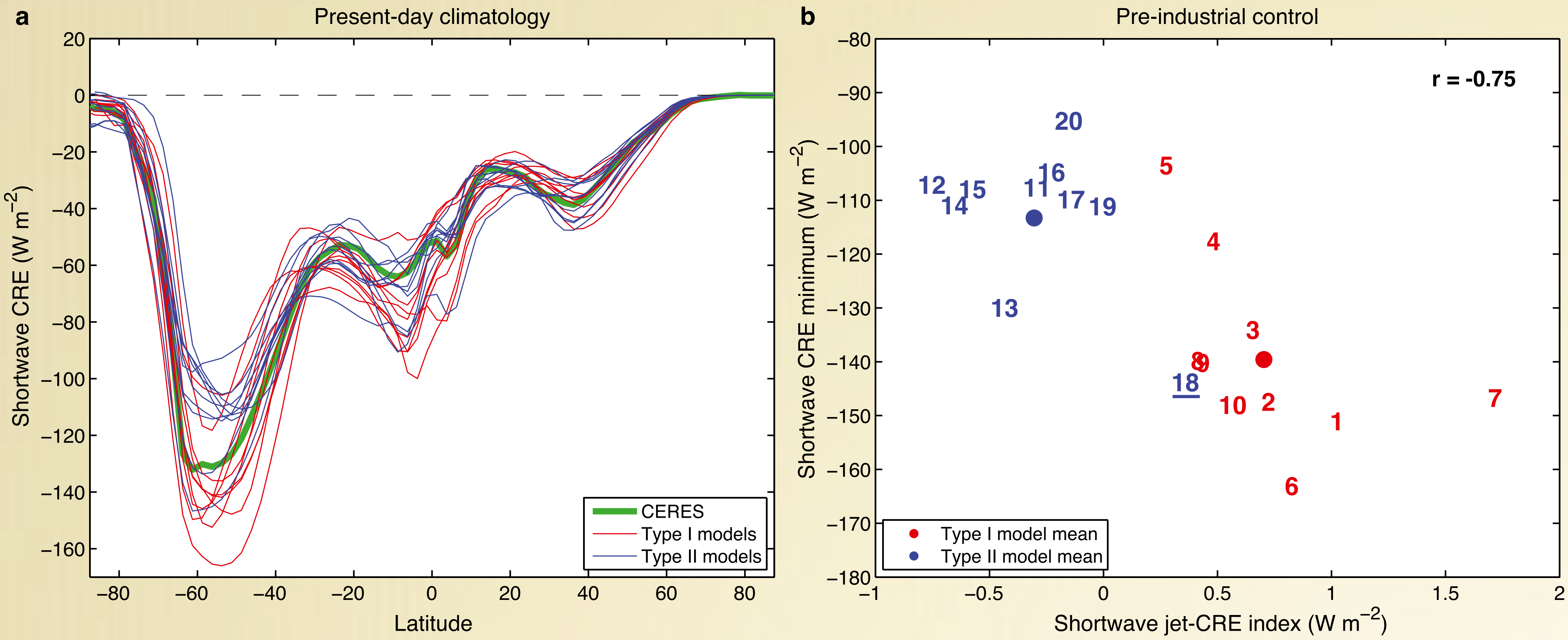


Comparison with Observations

- Longwave pattern is similar to models.
- Shortwave pattern is like a noisy Type II.
- Previous study of a Type I model showed good match to cloud fraction data.
  - Only shows up in jet-CRE

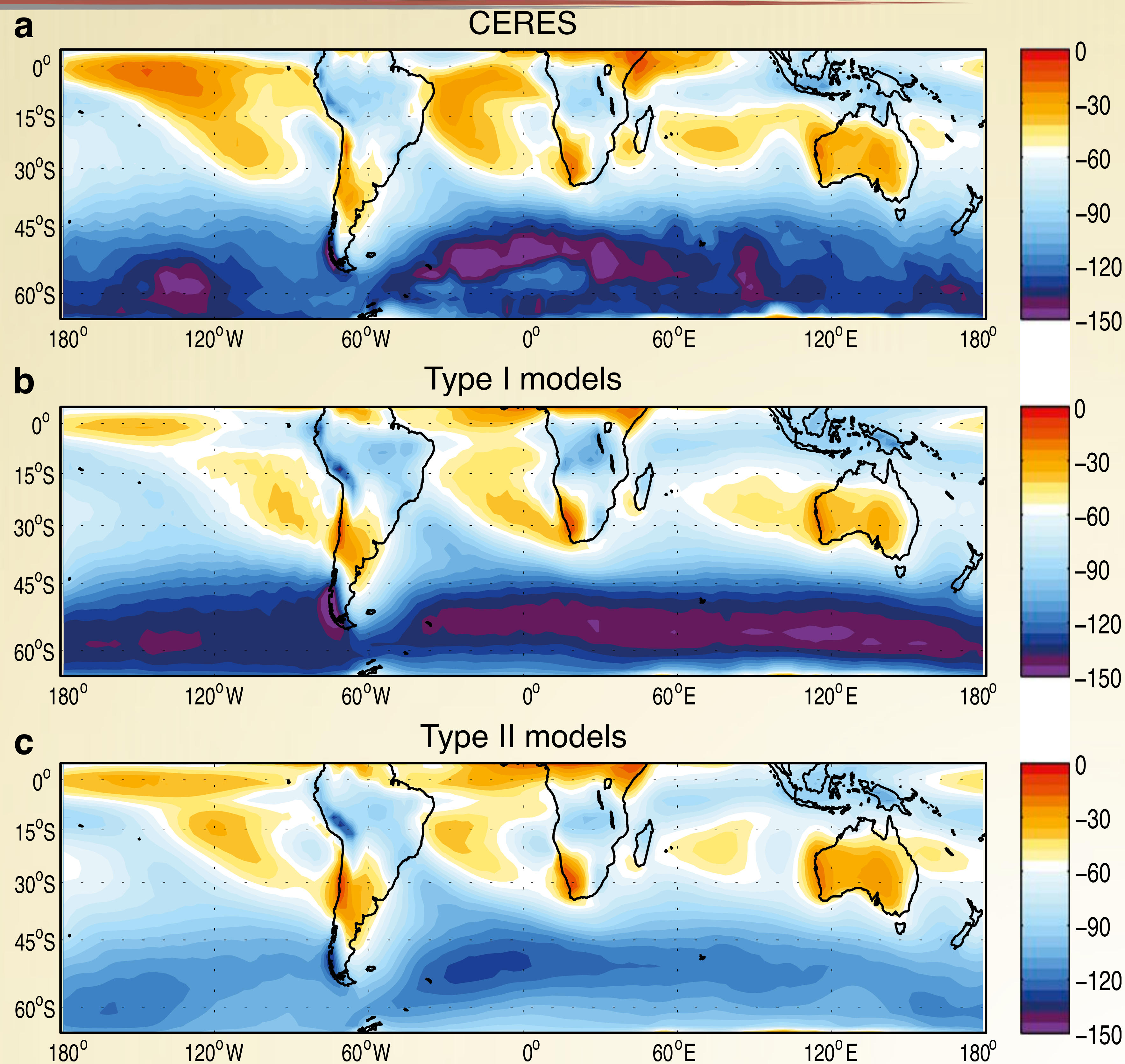


Zonally Averaged CRE Climatology (DJF)



- **Widely differing SW CRE minima**
  - **Maximum in cloud reflection of insolation**
    - **Type I:** -140 Wm^{-2}; **Type II:** -110 Wm^{-2}
- **Models with greater climatological reflection of incident SW also have greater SW jet-CRE indices.**

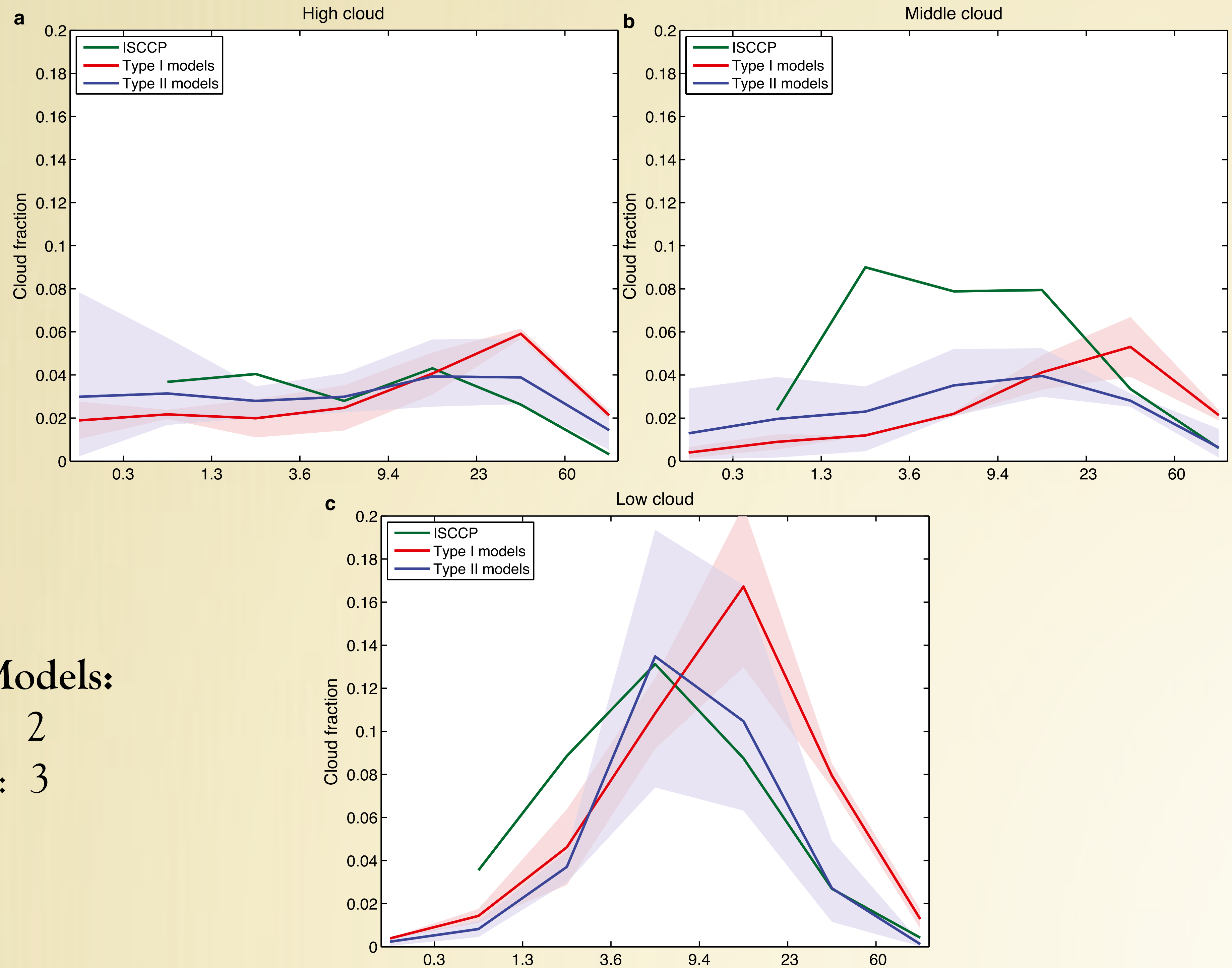
Spatial CRE Climatology (DJF)



- Type I magnitudes are, again, close to observations.
- Type I structure is too widespread and zonally symmetric.
- Type II still underestimates magnitude.
- Type II structure is a better match.

Confirming Structural Similarities

- Cloud Optical Depth 40°-60°S (ISCCP Simulator)

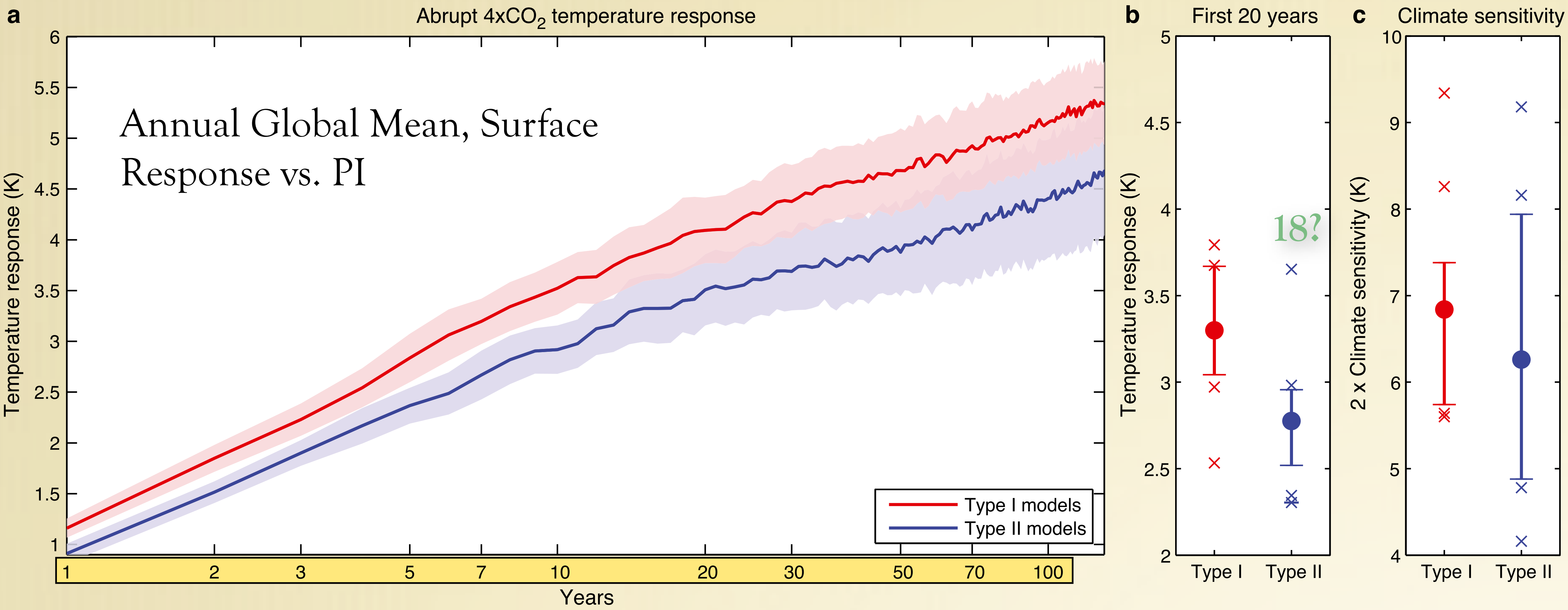


No. of Models:

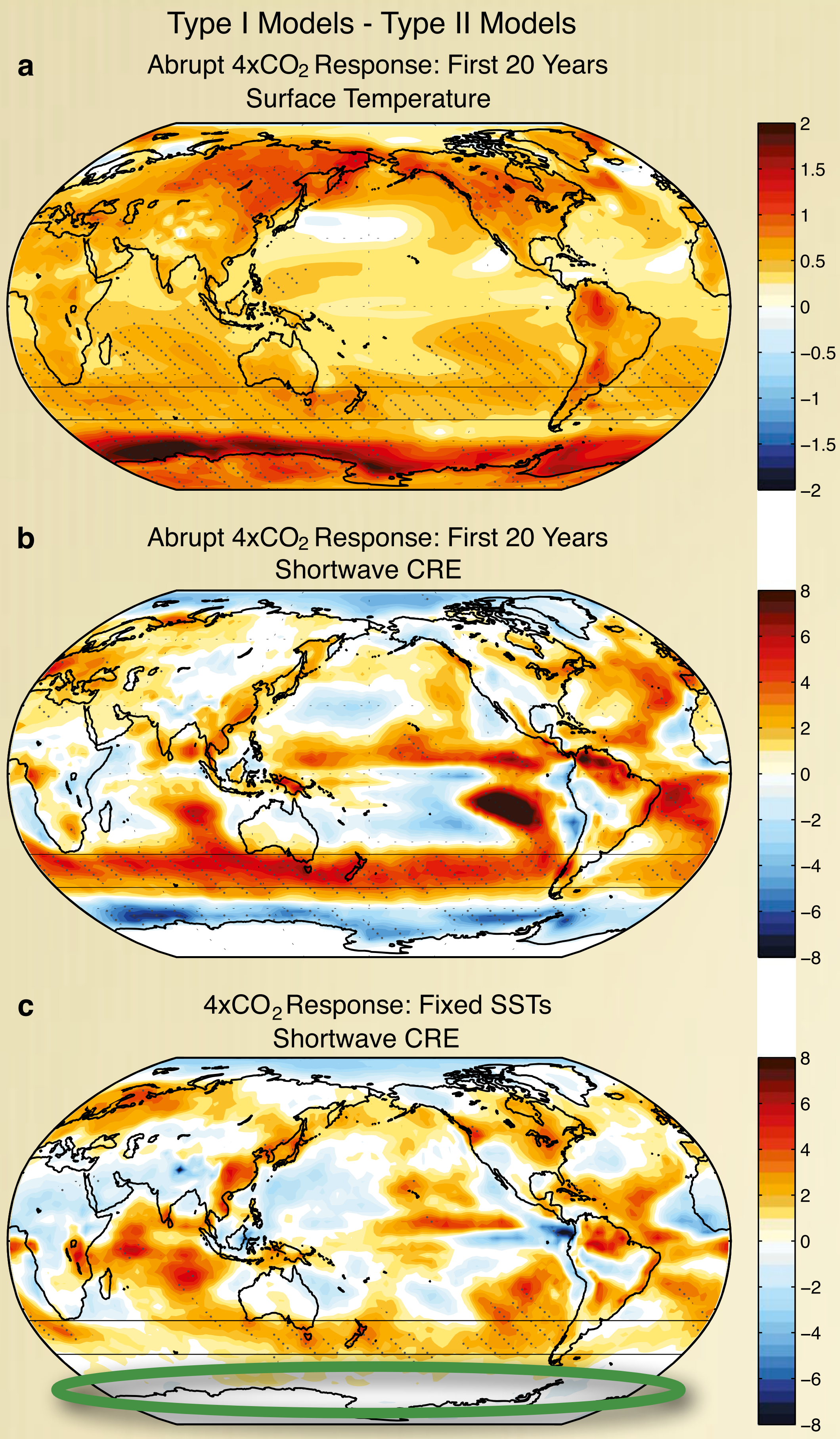
Type I: 2

Type II: 3

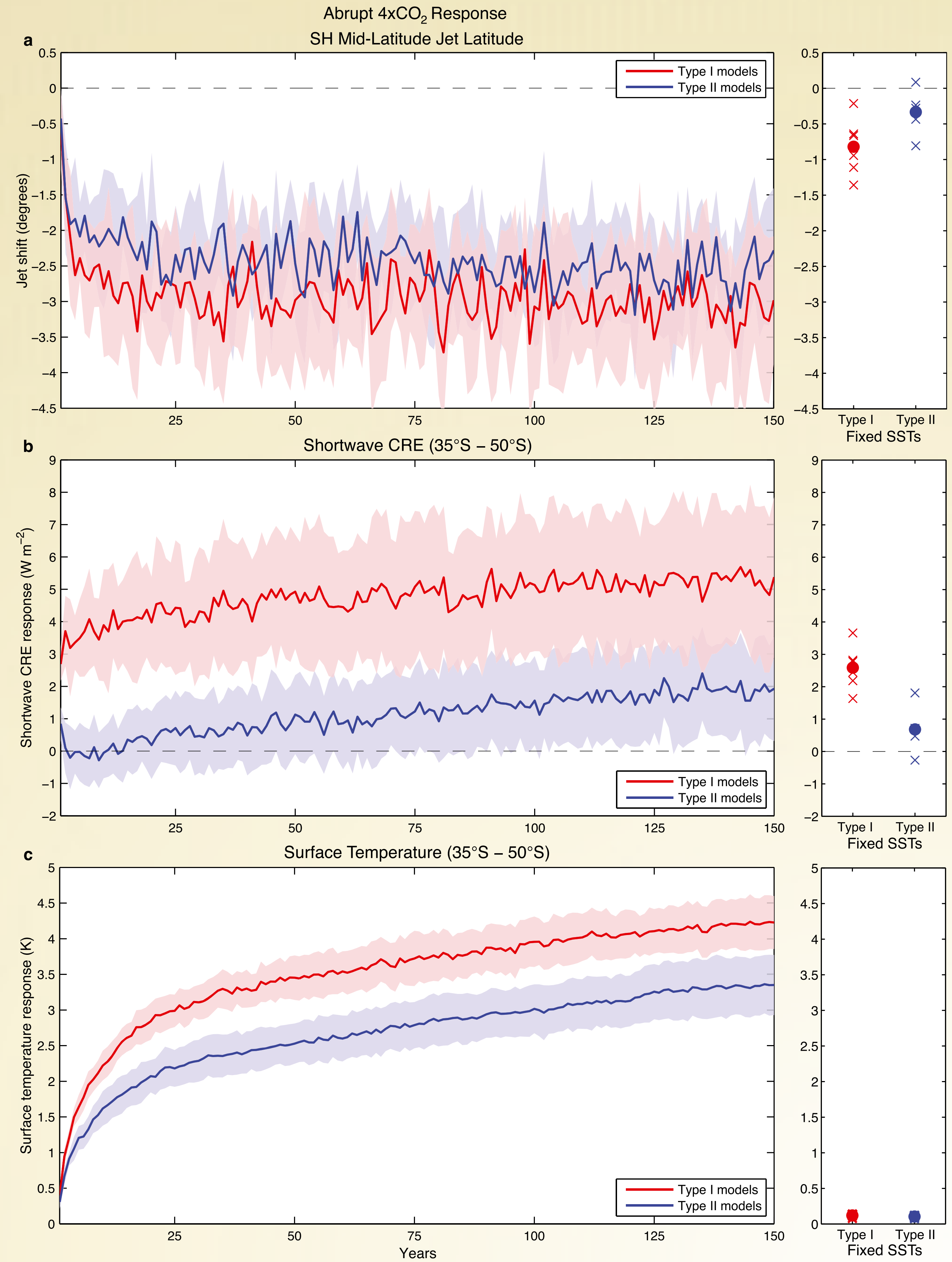
Future Climate Projections: $4xCO_2$



- Type I models warm faster in the first 20 years.
- Slow convergence noted.
  - Little difference in climate sensitivity.
- Agrees with other studies showing cloud-induced SW warming as largely responsible for rapid adjustment.

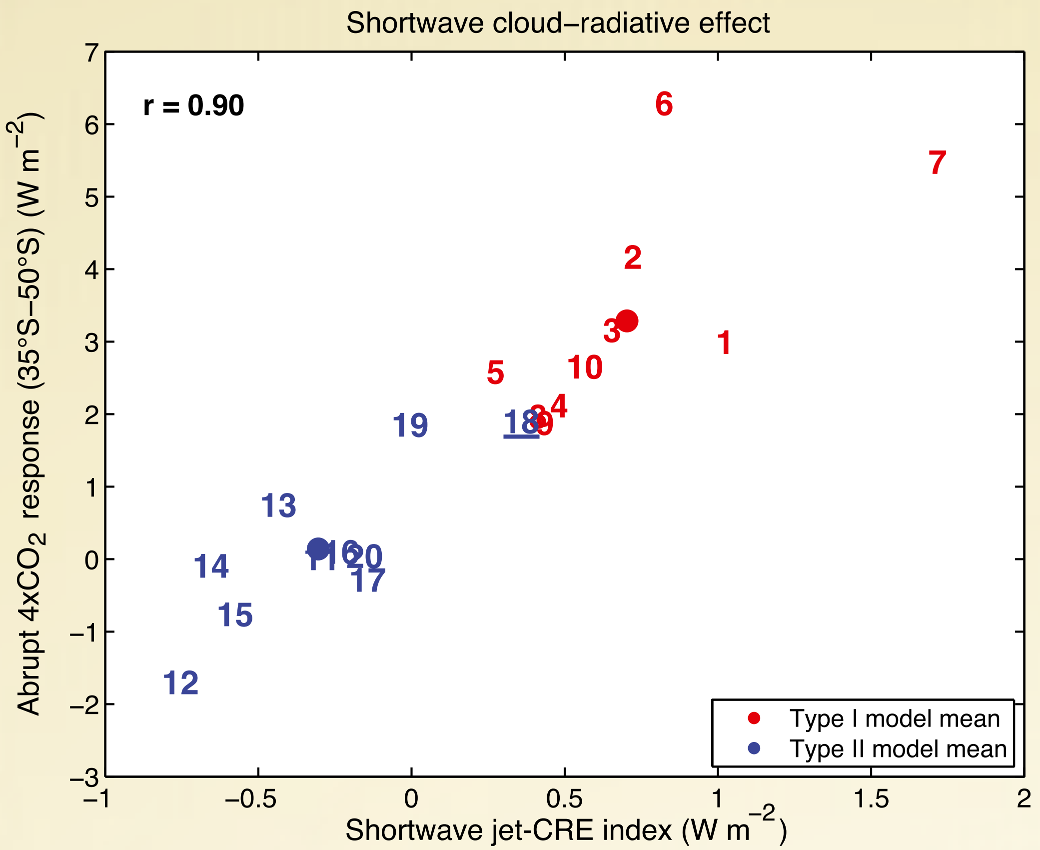


Type I Models - Type II Models
a
Abrupt 4xCO2 Response: First 20 Years
Surface Temperature
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
b
Abrupt 4xCO2 Response: First 20 Years
Shortwave CRE
8
6
4
2
0
−2
−4
−6
−8
c
4xCO2 Response: Fixed SSTs
Shortwave CRE
8
6
4
2
0
−2
−4
−6
−8



Abrupt 4xCO2 Response
SH Mid-Latitude Jet Latitude
a
Jet shift (degrees)
Type I models
Type II models
Type I
Type II
Fixed SSTs
b
Shortwave CRE (35°S – 50°S)
Shortwave CRE response (W m−2)
Type I models
Type II models
Type I
Type II
Fixed SSTs
c
Surface Temperature (35°S – 50°S)
Surface temperature response (K)
Type I models
Type II models
Years
Type I
Type II
Fixed SSTs

Grise & Polvani Summary



- While the jets shift in both Types, only those that produce SW CRE warming in response to unforced jet shifts also produce it in the forced case.
- The additional warming may bias Type I model projections.
- Type II models may be underestimating warming.
- No evidence of a statistical difference in equilibrium climate sensitivity, as warming converges.
- The significant difference is in the rapid response to CO_2.

Review Overview

Paper	Variables	Notes
Kidston and Gerber (2010)	Jet position Jet internal variability	Position biases are correlated with position and variability changes
Barnes and Hartmann (2010)	Jet position Jet internal variability Wave propagation	Position biases are correlated with position and variability changes; Physical explanations
Ceppi et al. (2012)	Jet position SWCF Surface temperature	Position biases are correlated with SWCF biases; Points to local cloud biases.
Chang et al. (2012)	v-wind and SPL variance Cyclone track statistics	Correlations between historical biases and projected shifts in position and strength
Bracegirdle et al. (2013)	Jet position Jet strength	PT-distance and jet width correlate with jet shift; Dependent on basin
Grise and Polvani (2014)	Cloud radiative effect Jet position Cloud optical depth Surface temperature	Position biases are not well correlated with SWCRE; Contrary indications are due to Type-I models' rapid response.