The 'storm curtain' effect: poleward shift of storm clouds and the radiative consequences

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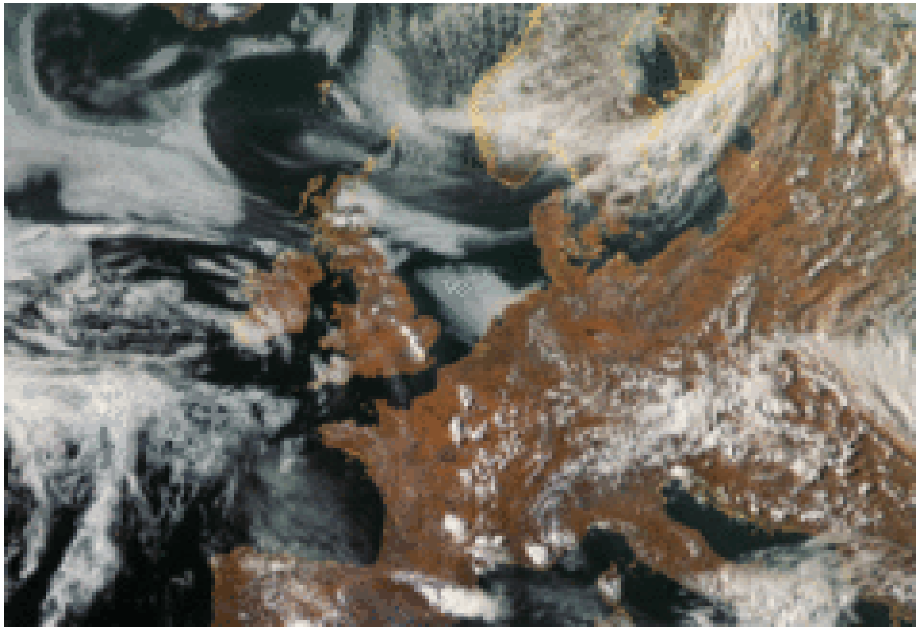


EUCLIPSE - CFMIP meeting, May 29 to June 1st 2012, Paris, France.

Sources of storm cloud radiative feedbacks on climate

1. Changes in storm strength and frequency

- Increases in storm strength and decreases in frequency have been found in reanalysis results and are present in many model projections.

- Increases in midlatitude storm intensity produce shortwave cooling and longwave warming while decreases in storm frequency produce the opposite effects. When the two changes are added together the increase in storm strength dominates producing a shortwave cooling effect of 0–3.5 W/m^2 and a longwave warming effect of 0.1–2.2 W/m^2. (Tselioudis and Rossow 2006, based on UKMO 2xCO2 storm change projection).

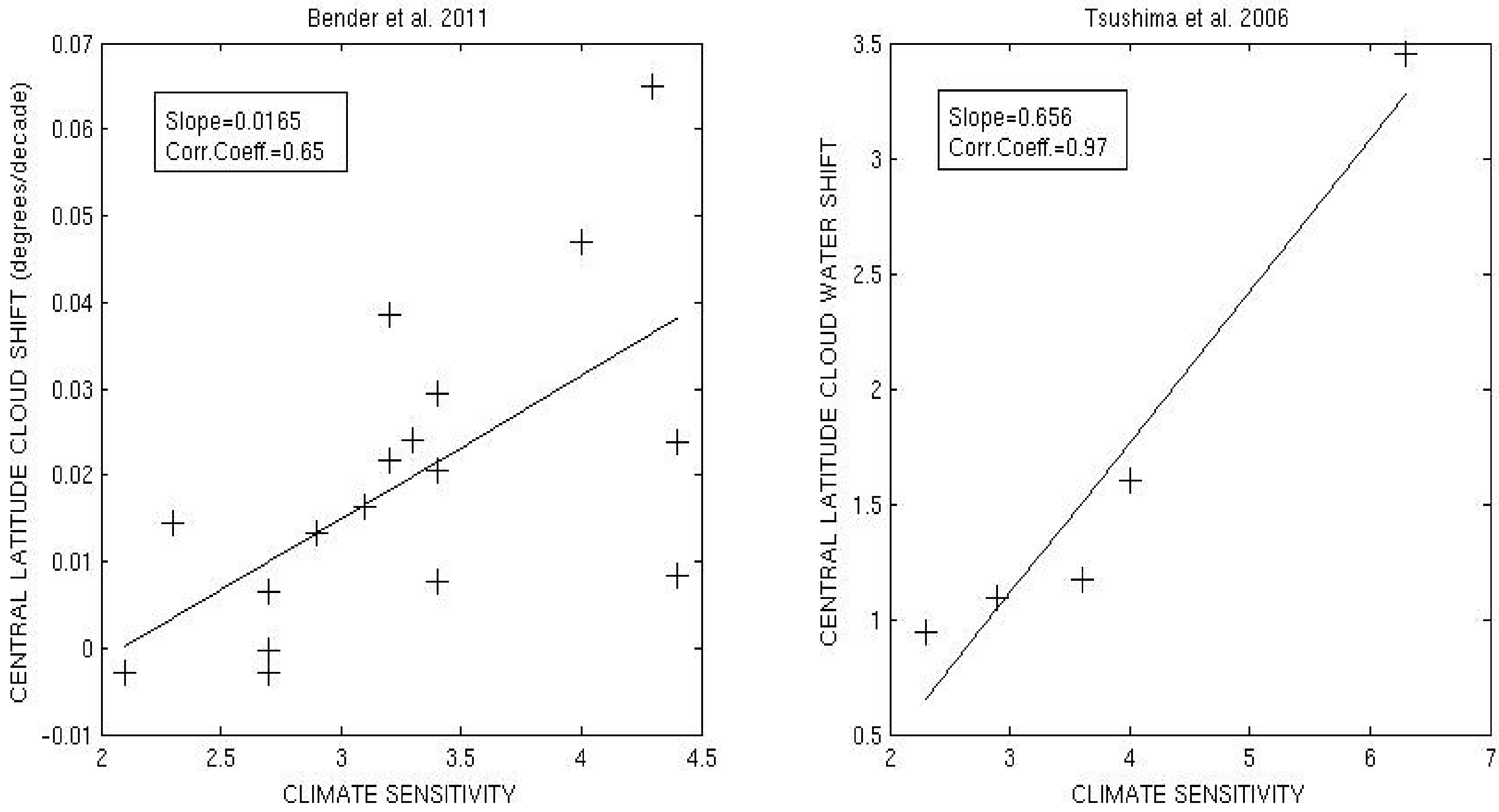
2. Poleward shift of midlatitude storm track

- Such shifts have been found in reanalysis results (when 50+ year records are examined) and are present in most model projections.

- Shifts in midlatitude cloudiness was found in last 25-years analysis of ISCCP observations (Bender et al. 2012).

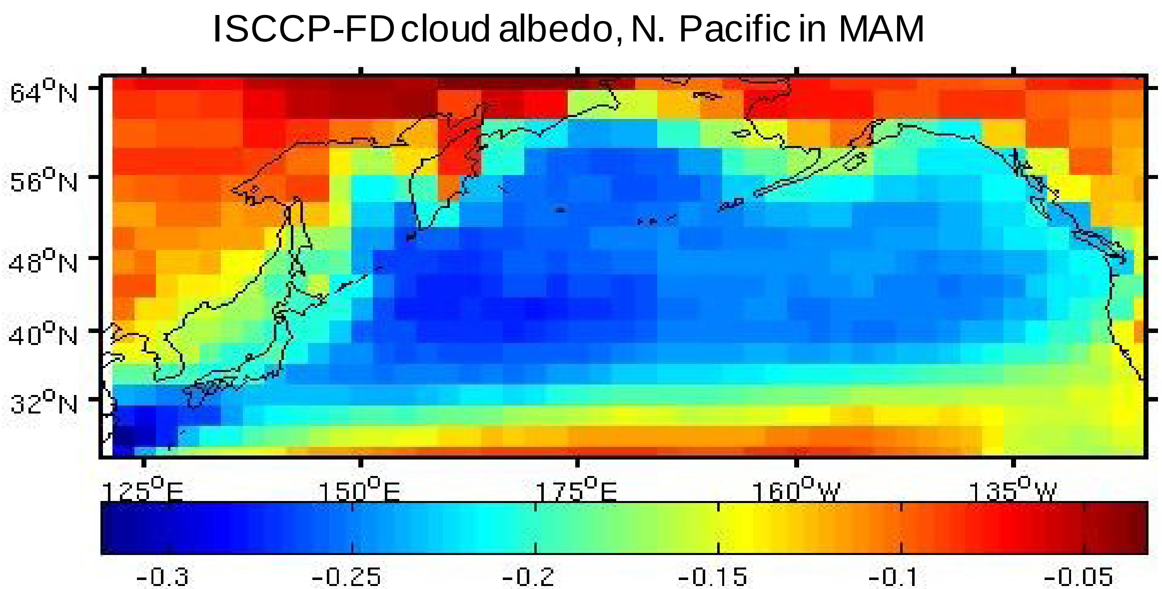
- Potential positive SW feedback from shifting cloud shield to regions of lower insolation, found in Tsushima et al. (2006) to have magnitude similar to total cloud response to 2xCO2 warming,

Storm cloud poleward shift and climate sensitivity



How can observations be used to constrain model sensitivity related to shift of clouds to poleward regions of lower insolation?

Radiative response to 1-degree poleward cloud shift can be calculated from observations by taking the cloud albedo field from satellite retrievals.........

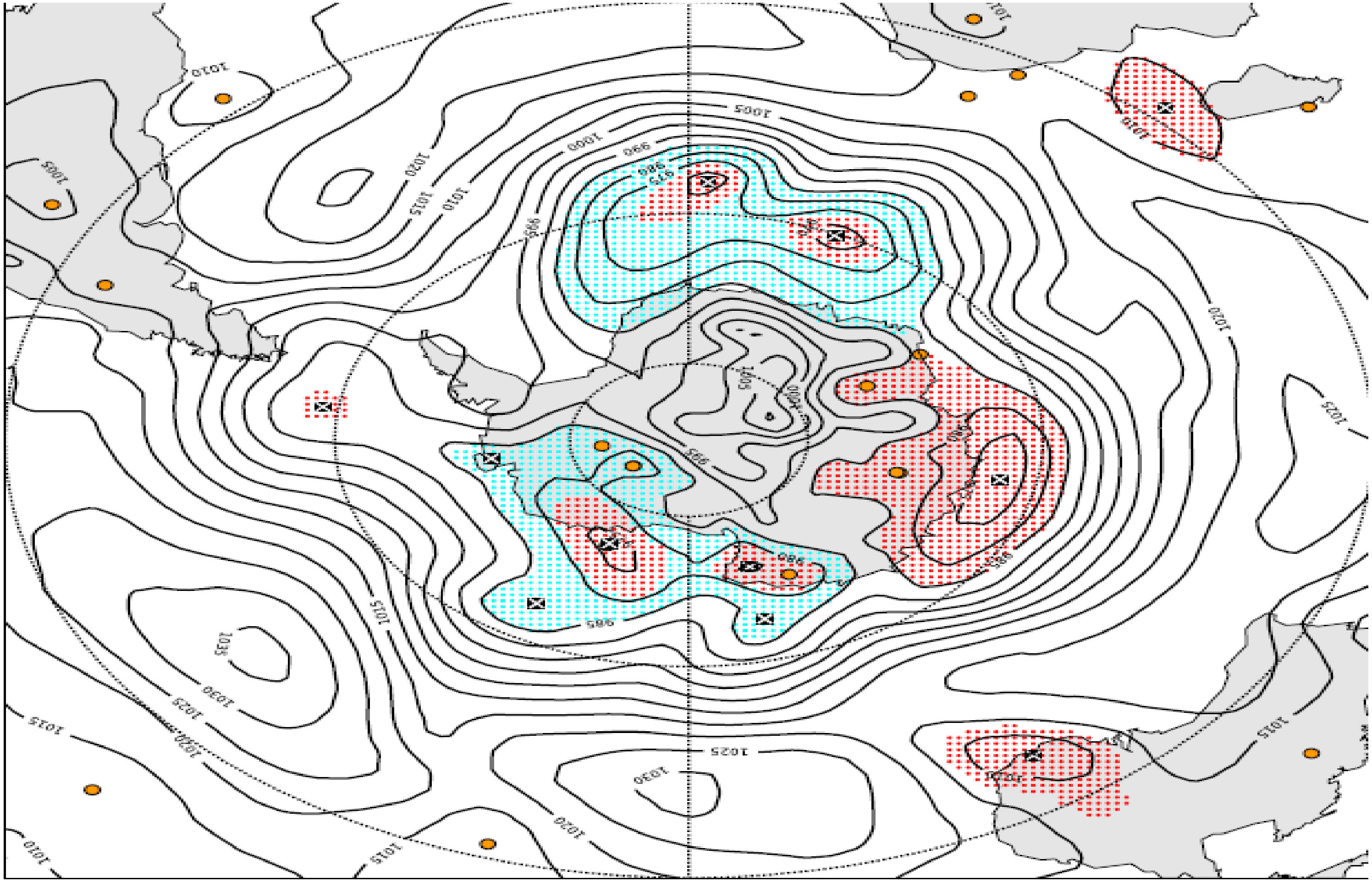


....shifting it poleward by 1 degree, calculating the new SW CRE, and differencing it from the observed one. The resulting SW warming using three major radiative flux datasets ranges between 0.75 and 1.95 W/m^2 (1.4±0.6W/m^2) per degree of albedo shift

DCRE(W/m^2) for 1 degree poleward shift	ISCCP-FD	ERBE	CERES
N. Atlantic	1.49	1.76	1.74
N. Pacific	0.96	1.95	1.20
S. Atlantic	0.75	1.53	1.56
S. Pacific	0.93	1.35	1.44

ISCCP-FD 1984-2009, ERBE 1985-1989, CERES 2001-2009

MCMS: Storminess a better tool to study storm cloud shifts



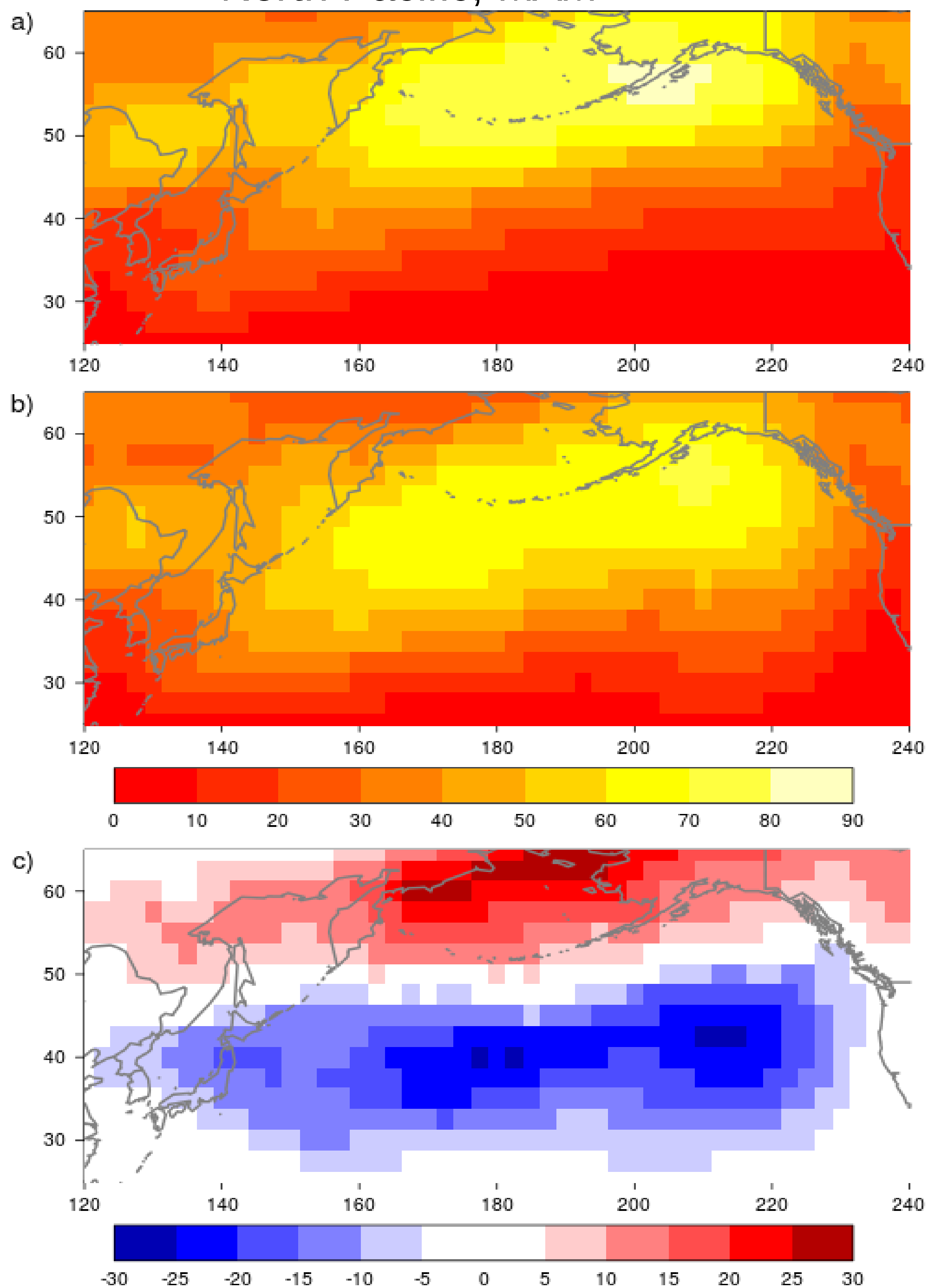
- Storminess represents a storm alley that encompasses the major storm cloud structures rather than just a storm path focused on the movement of the storm centers
- The central latitude of those storm alleys is used to separate years of poleward and equatoward storm tracks

Storminess in five most poleward years

Storminess in five most equatoward years

Storminess difference between poleward and equatoward 5-year sets

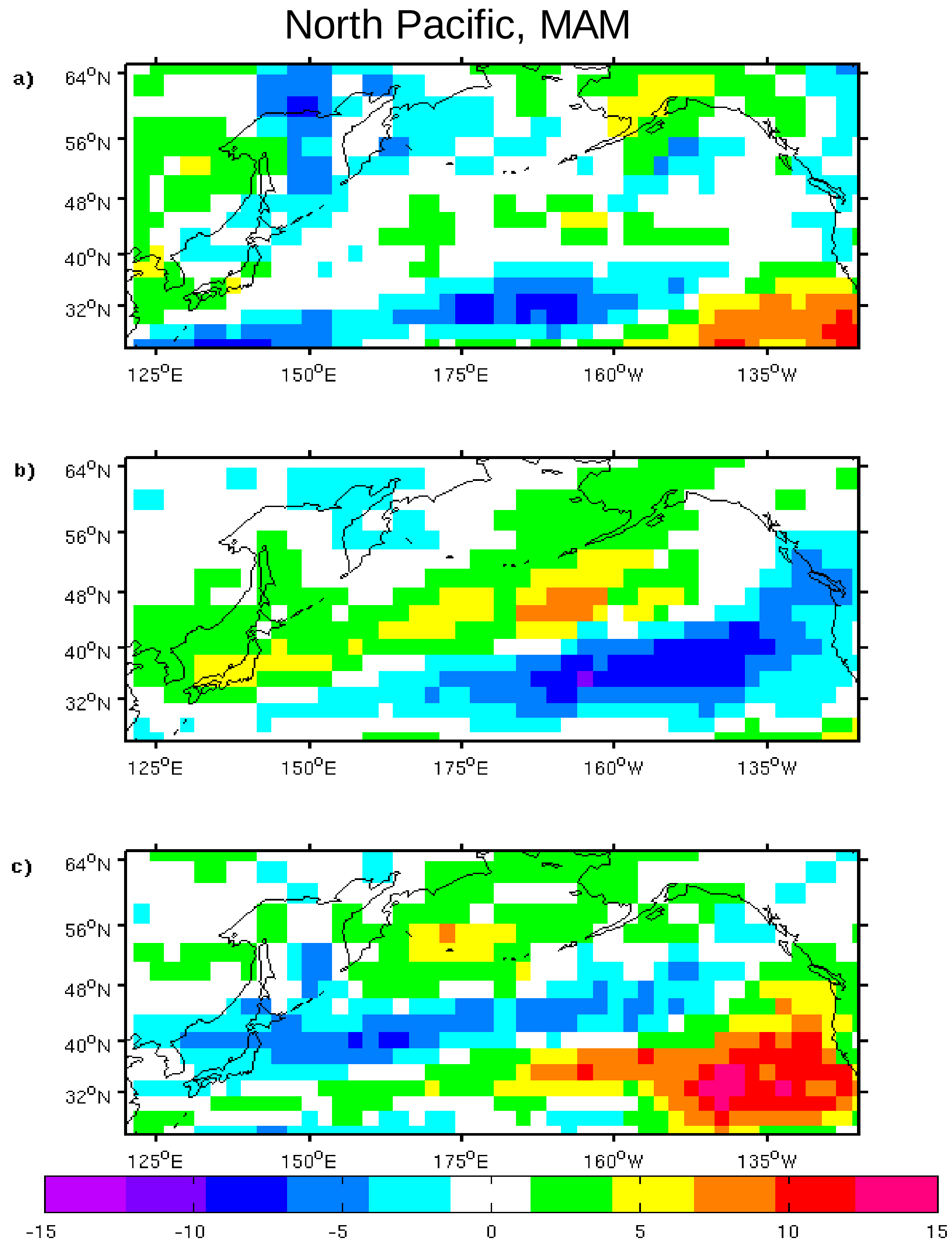
North Pacific, MAM

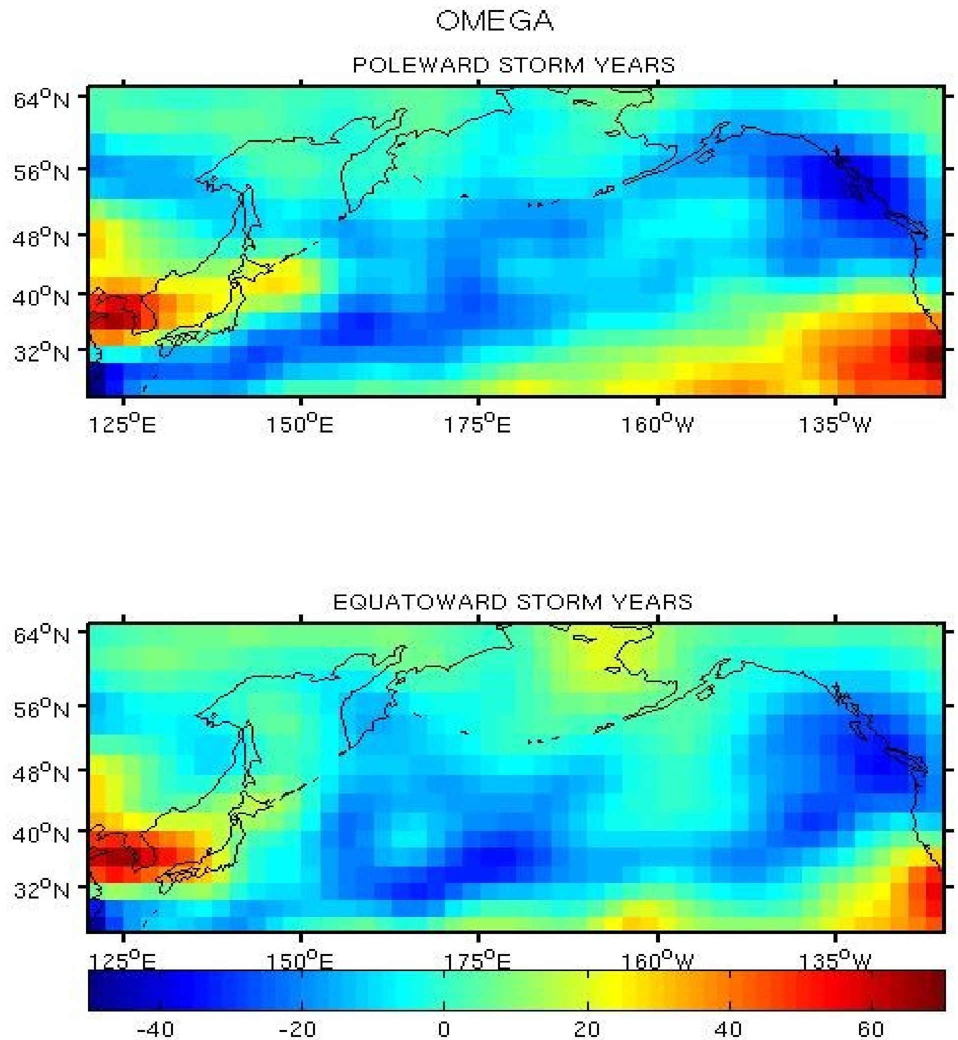


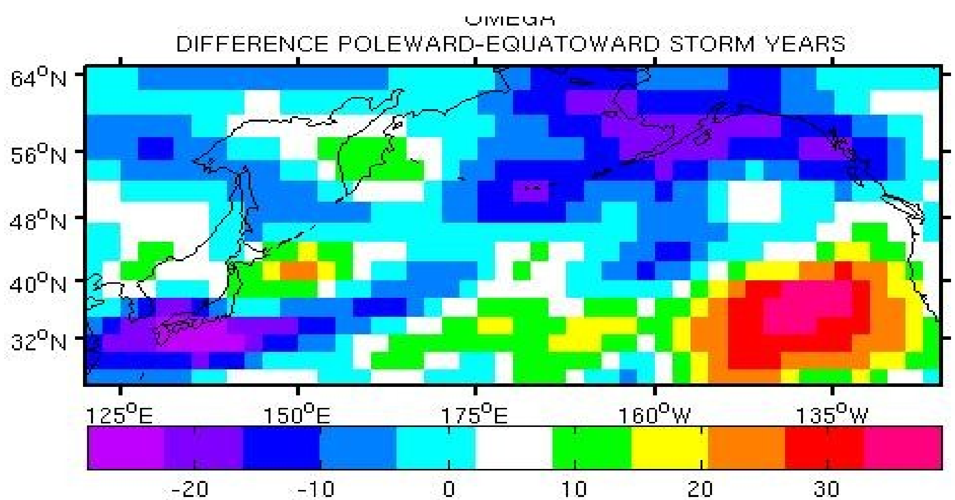
Total cloud difference between poleward and equatoward 5-year sets

High cloud difference between poleward and equatoward 5-year sets

Low cloud difference between poleward and equatoward 5-year sets

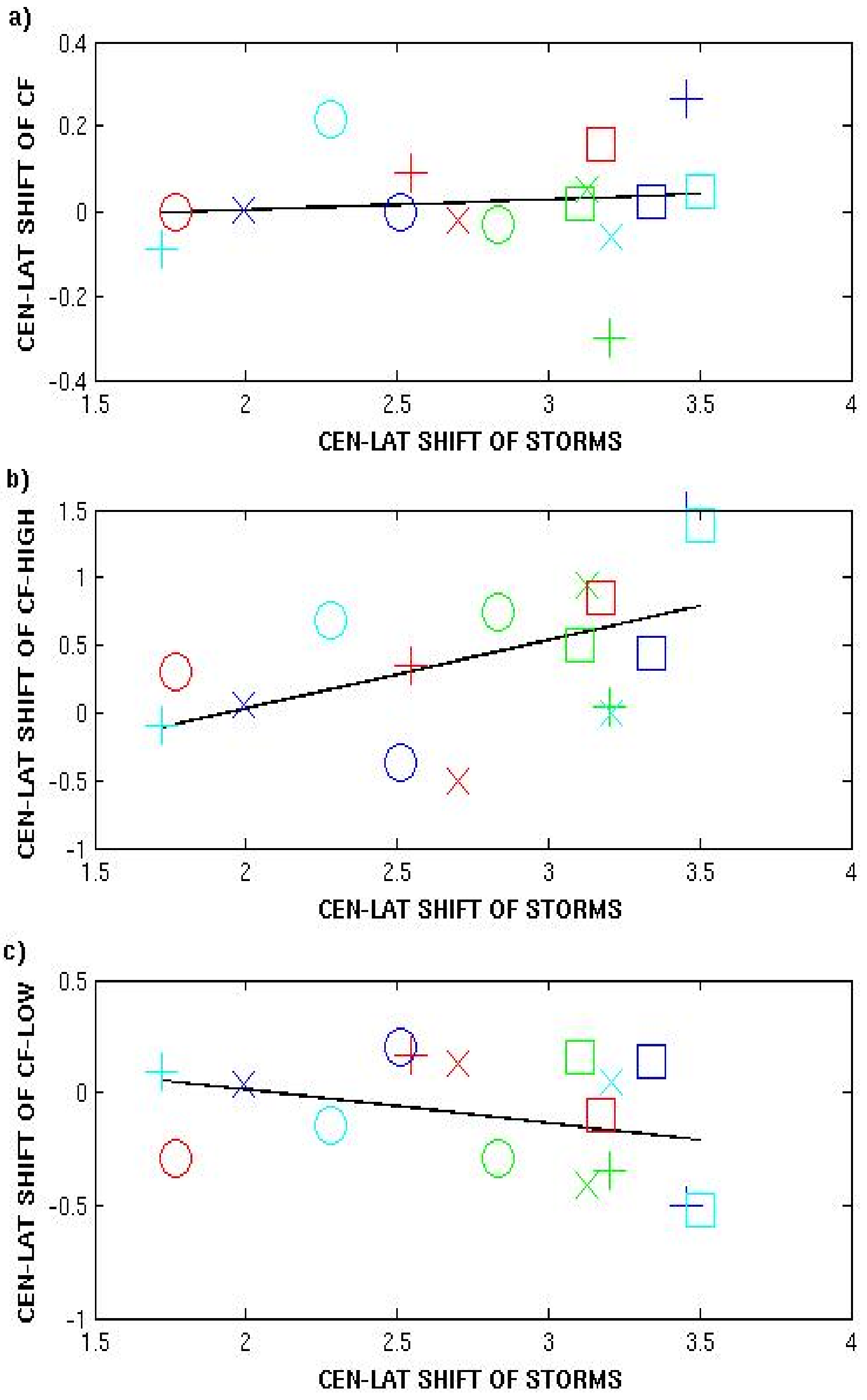






Changes in 500mb Omega between poleward and equatoward 5-year sets:

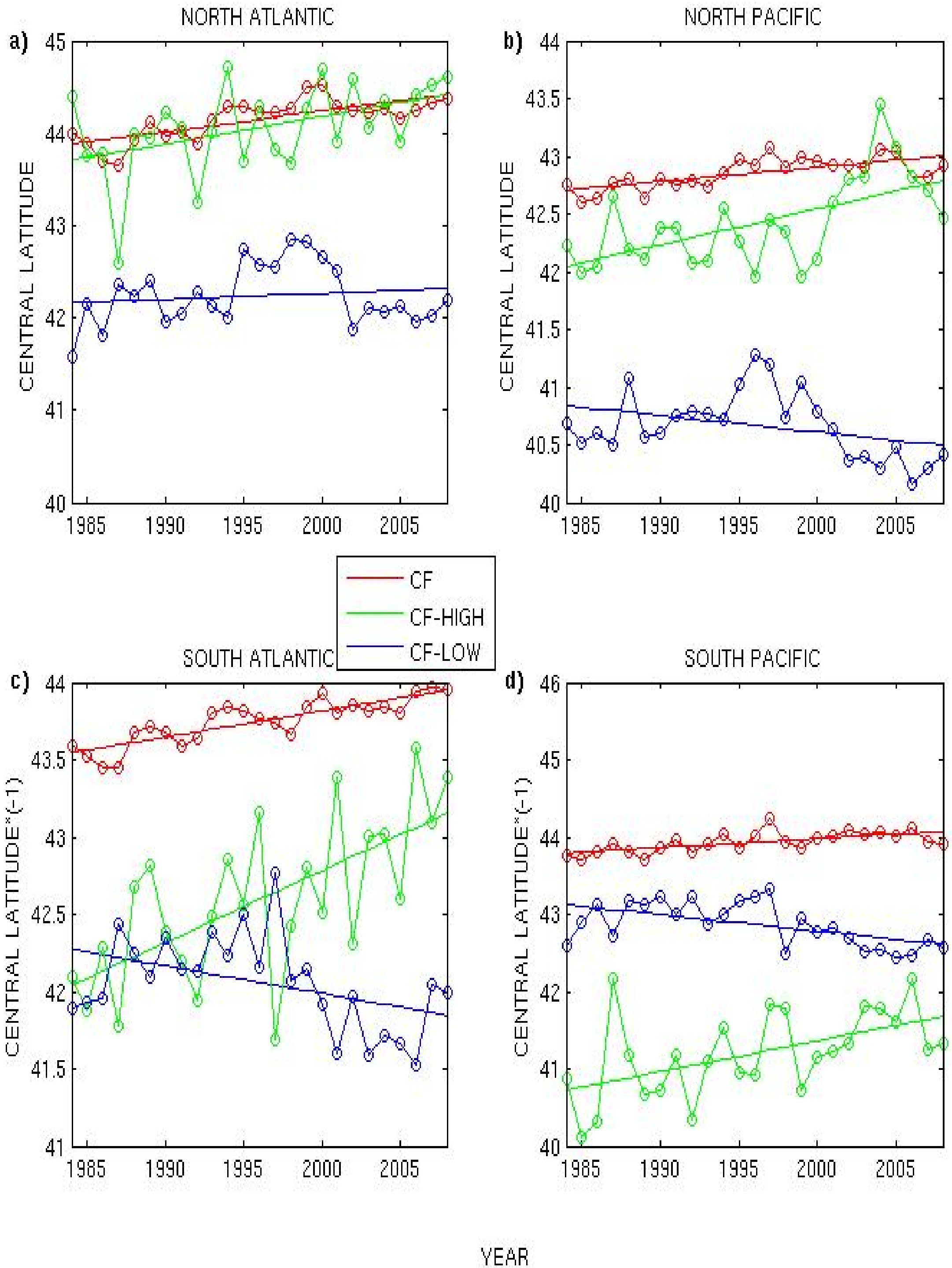
Subsidence zone strengthens and moves poleward – poleward extension of the subsiding Hadley cell branch



Linear correlations between storminess shifts and shifts in cloud and radiation properties

Cor. vs. storminess	*Slope*	*Corr. Coeff.*
Cftot	0.025	0.113
Cfhigh	0.503	**0.516**
Cflow	-0.150	**-0.342**
CTP	-0.008	-0.035
CWP	0.255	**0.509**
LW CRE	0.152	**0.373**
SW CRE	0.045	0.144

- High clouds are the best tracers of storminess shifts
- Low clouds show negative and weaker correlations with storminess



25-year linear trend of cloud and radiation parameters

Time Series Slope(degrees/decade)	*N. ATL*	*N. PAC.*	*S. ATL.*	*S. PAC.*
Cftot	**0.23**	**0.12**	**0.17**	**0.12**
Cfhigh	**0.30**	**0.31**	**0.46**	**0.40**
Cflow	0.07	**-0.14**	**-0.18**	**-0.21**
CTP	0.02	-0.02	**-0.15**	**-0.12**
CWP	0.02	0.06	**0.46**	**0.36**
LW CRE	0.11	**0.12**	**0.21**	0.08
SW CRE	**0.22**	**0.18**	**0.13**	**0.14**

- High clouds shift poleward at ~0.4^{o}/decade
- Total cloud and SW CRE shift poleward at ~0.2^{o}/decade
- Low clouds 'shift' equatoward at ~0.2^{o}/decade except in the N. Atlantic

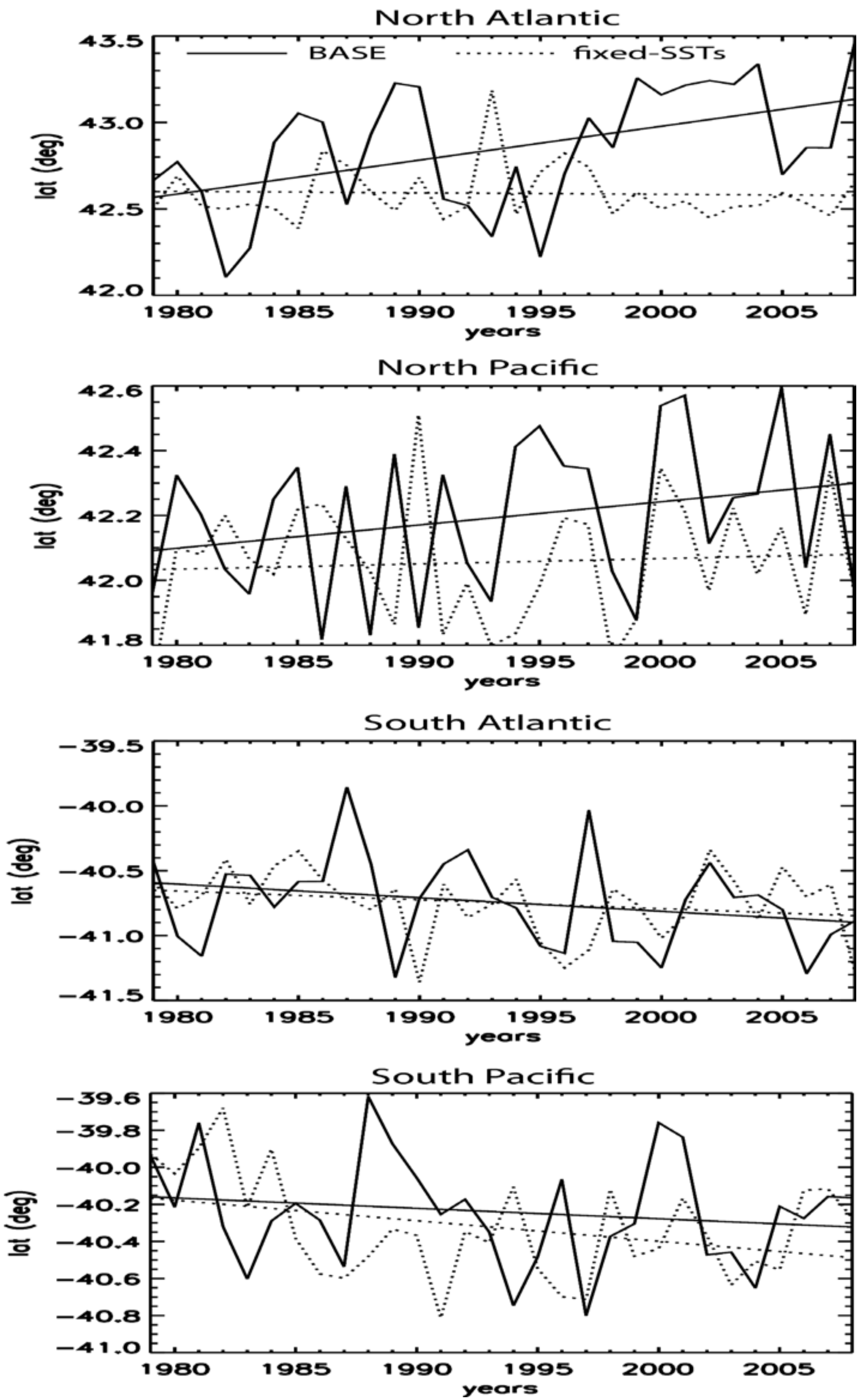
Model constraints for current climate runs

- High clouds shift poleward at ~0.4^o/decade or 1 degree in last 25 years
- Total cloud and SW CRE shift poleward at ~0.2^o/decade or 0.5 degree in last 25 years
- Low clouds 'shift' equatoward at ~0.2^o/decade except in the N. Atlantic
- 1-degree poleward SW CRE shift produces 1.4±0.6W/m^2 radiative warming

Radiative implications of poleward storm shifts

- Current climate: Half-degree poleward SW CRE shift implies ~0.75W/m^2 radiative warming in last 25 years
- Projected over 100 years (1980s-2070s) a constant ~0.2^o/decade SW CRE poleward shift produces a 2.5W/m^2 radiative warming (impressive but to be taken with a grain of salt....)

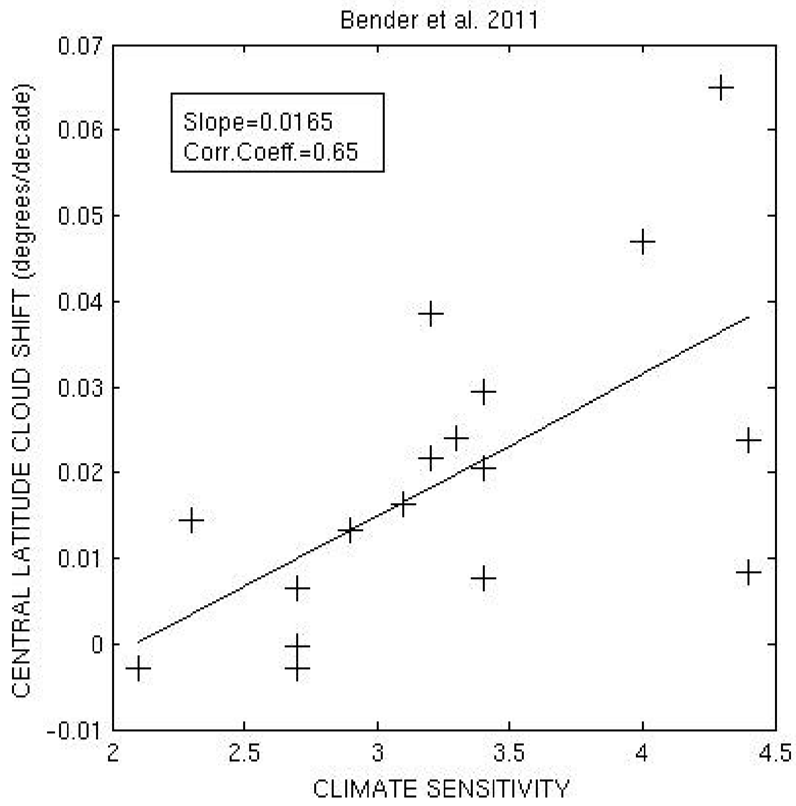
GISS GCM High Cloud Shift

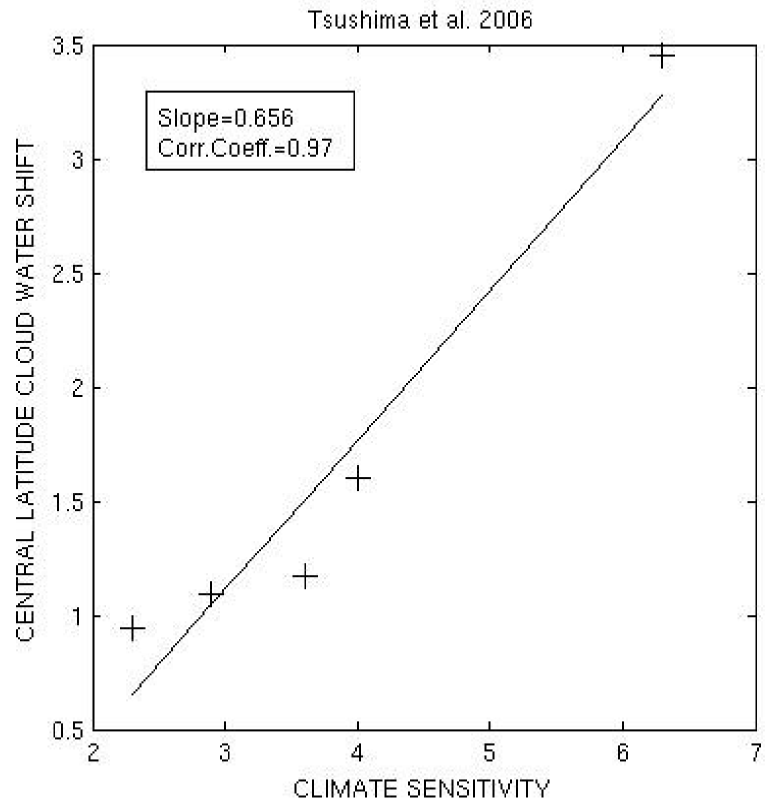


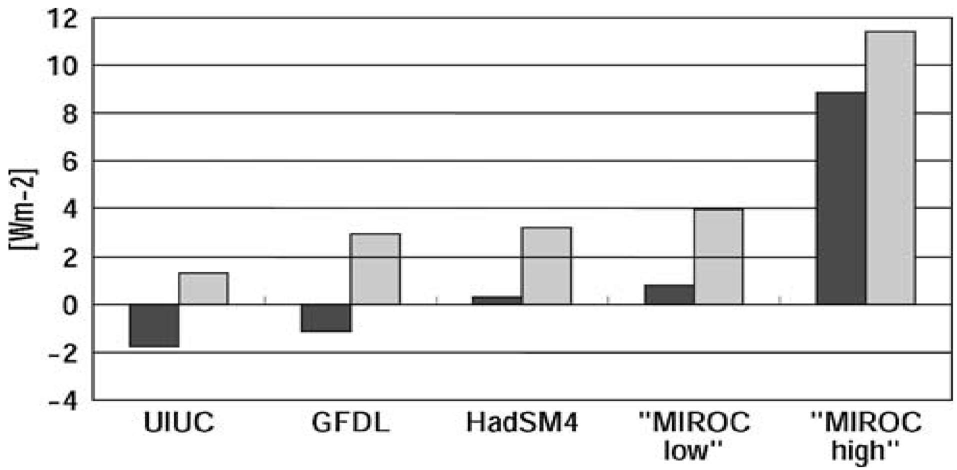
Constraining the GISS GCM

- Two current climate (1979-2008) runs, one with climatological SSTs (BASE) and one with fixed SSTs at 1979 values
- In the N.H. High clouds shift poleward only in the BASE run (surface SST gradients important in storm shift?)
- In the S.H. high clouds shift poleward in both runs (other mechanisms important in storm shifts?)
- In all cases, high cloud shifts are about 0.5 degree in the 25 years, half the observed magnitude (50% score).

Storm cloud poleward shift and climate sensitivity







The change in the annually averaged solar cloud forcing averaged over 60S to 30S for 2xCO2 climate (black bars) and for the polar shift of cloud albedo forcing from 1·CO2 climate (grey bars). Tsushima et al. 2006