Cloud, radiation, and precipitation changes with midlatitude storm strength and frequency and the resulting climate feedbacks

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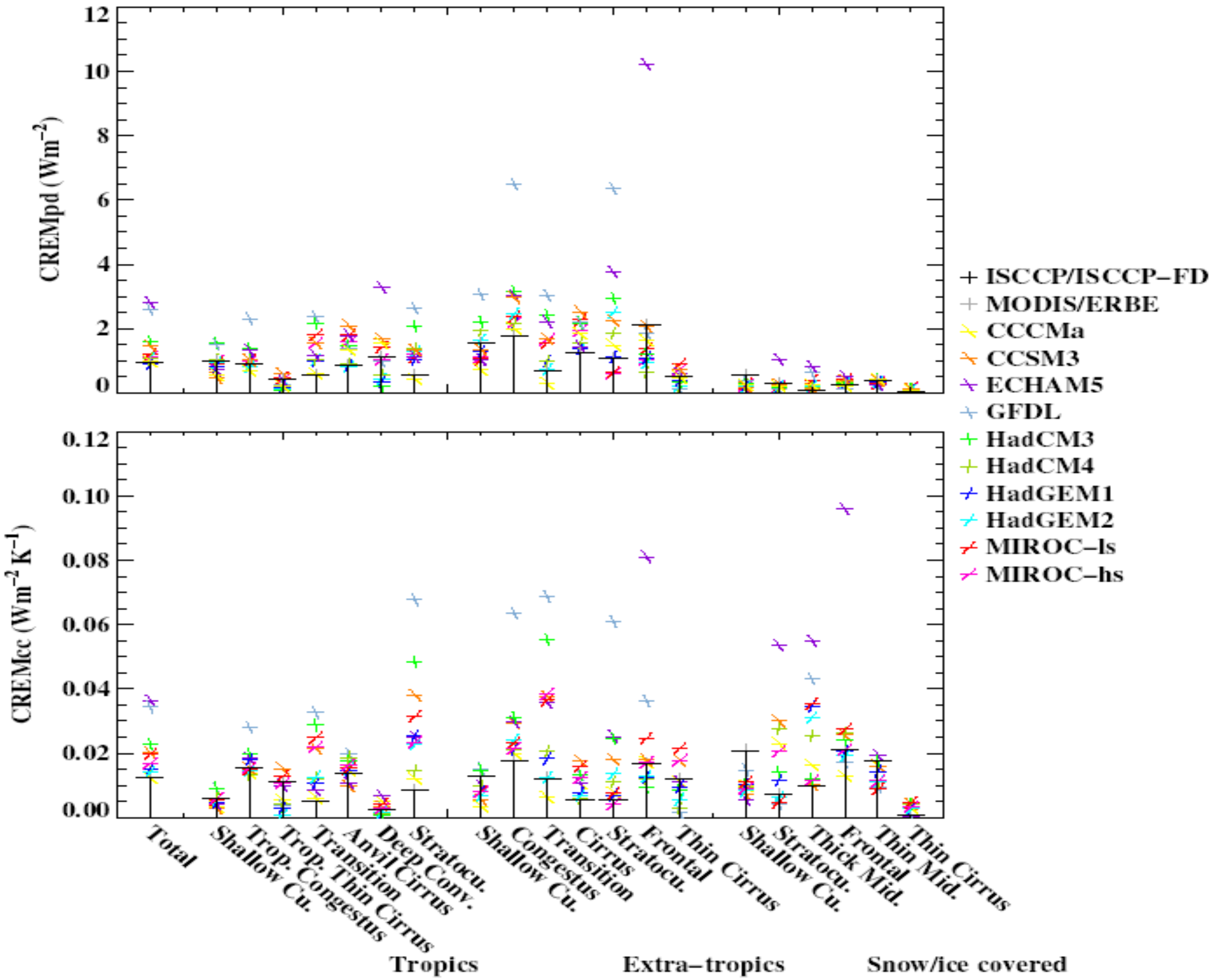
Cloud-type contributions to model spread in TOA radiation/feedbacks (Williams and Webb 2008)



Extratropical clouds, contrary to popular belief, produce the largest spread among GCM cloud radiative signatures

ACCUMULATED KNOWLEDGE ON MIDLATITUDE STORMS AND CLIMATE

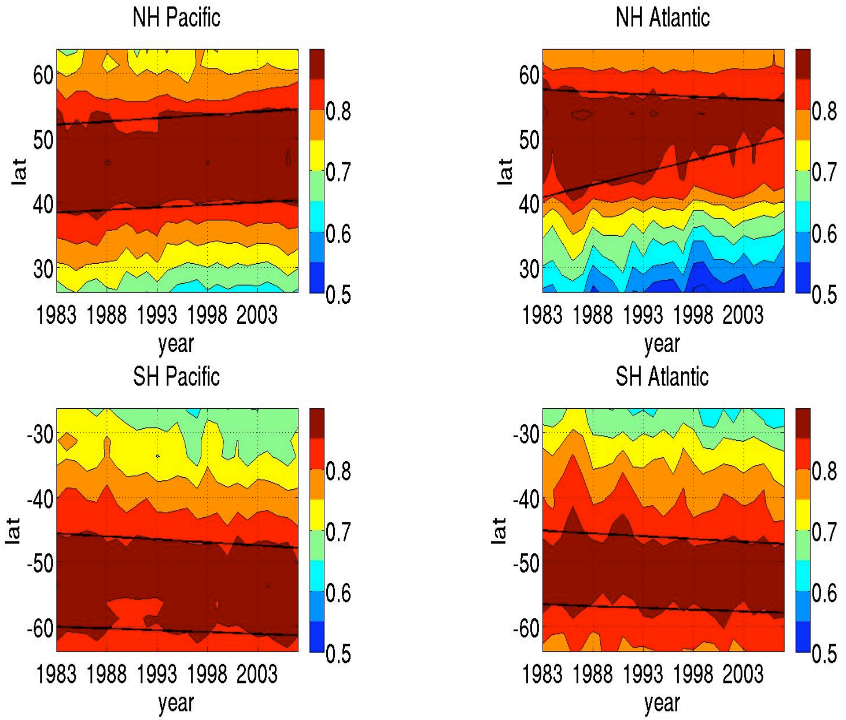
OBSERVATIONAL EVIDENCE:

- POLEWARD STORM TRACK SHIFT
- INCREASE IN STORM STRENGTH

MODEL CLIMATE PROJECTIONS:

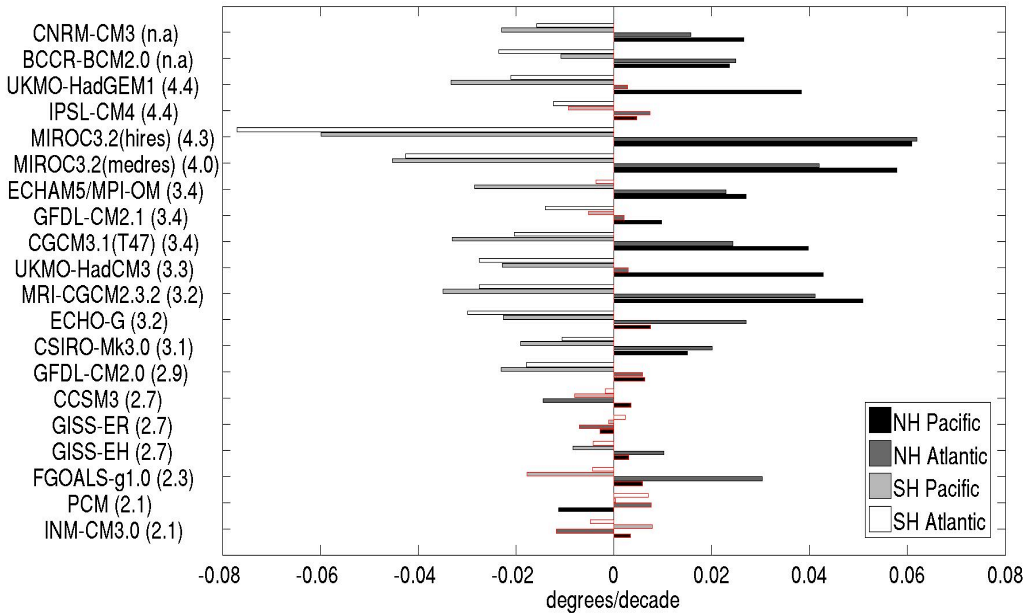
- POLEWARD STORM TRACK SHIFT
- INCREASE IN STORM STRENGTH
- DECREASE IN STORM FREQUENCY

- ANALYSES FOCUSED ON CHANGES IN DYNAMICS
- CLOUD CHANGES AND RADIATION EFFECTS HAVE NOT BEEN EXTENSIVELY STUDIED



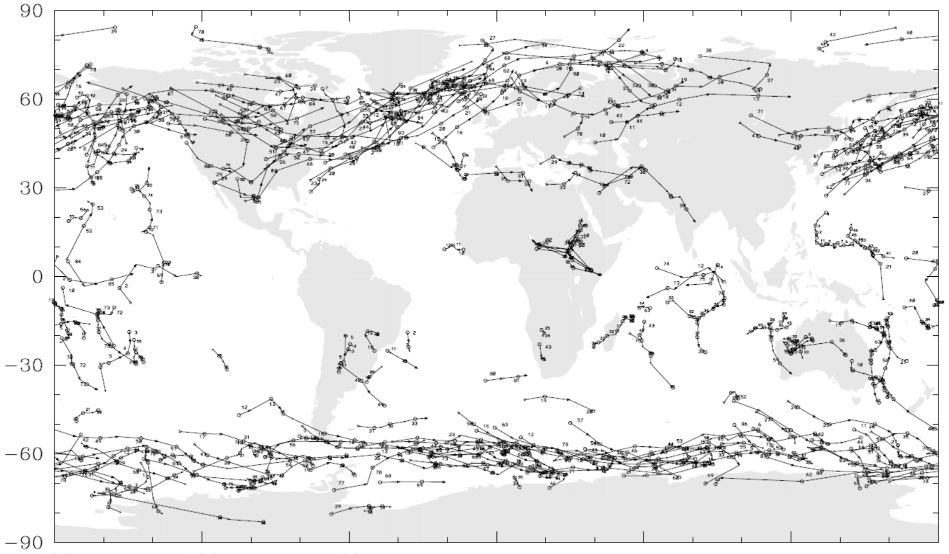
Midlatitude cloud changes in the last 30 years:

- ISCCP retrievals show a poleward shift of the cloud field over midlatitude oceans
- Assuming an 1% ~ 1W/m2 relationship, the shifts produce warming that ranges between 1W/m2 and 5W/m2 in the different basins



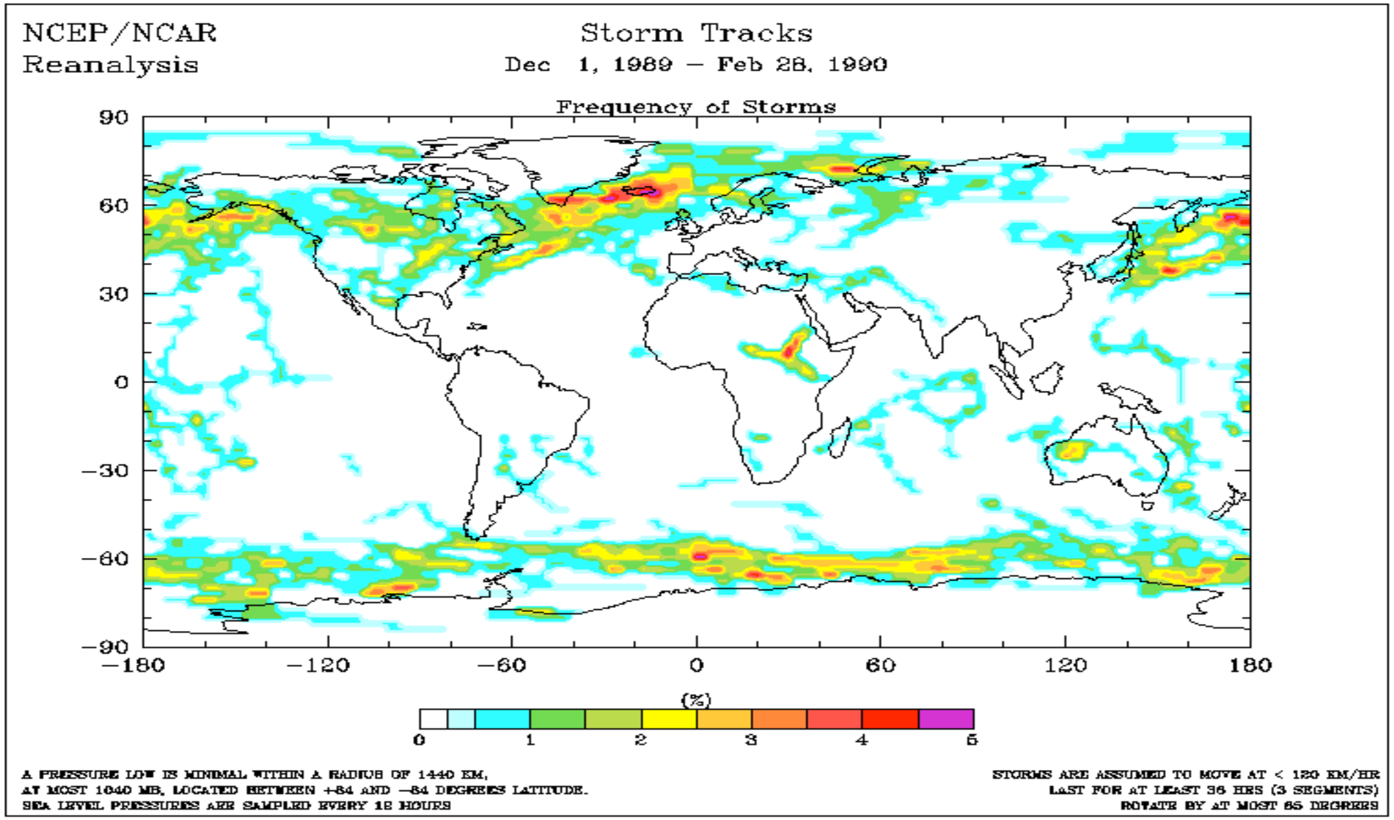
Climate models, for the most part, produce similar midlatitude cloud shifts in climate change simulations

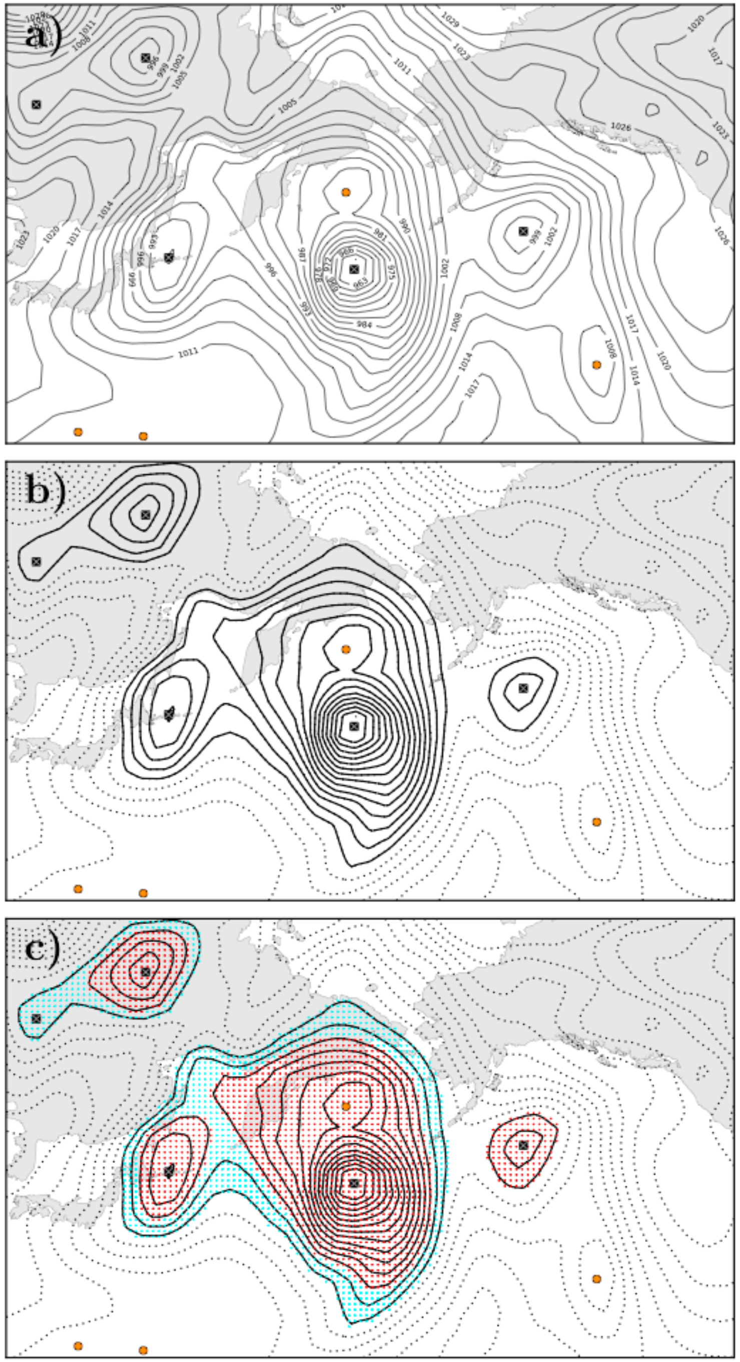
Bender, Ramanathan, and Tselioudis 2011



Connecting storm tracks to clouds and radiation:

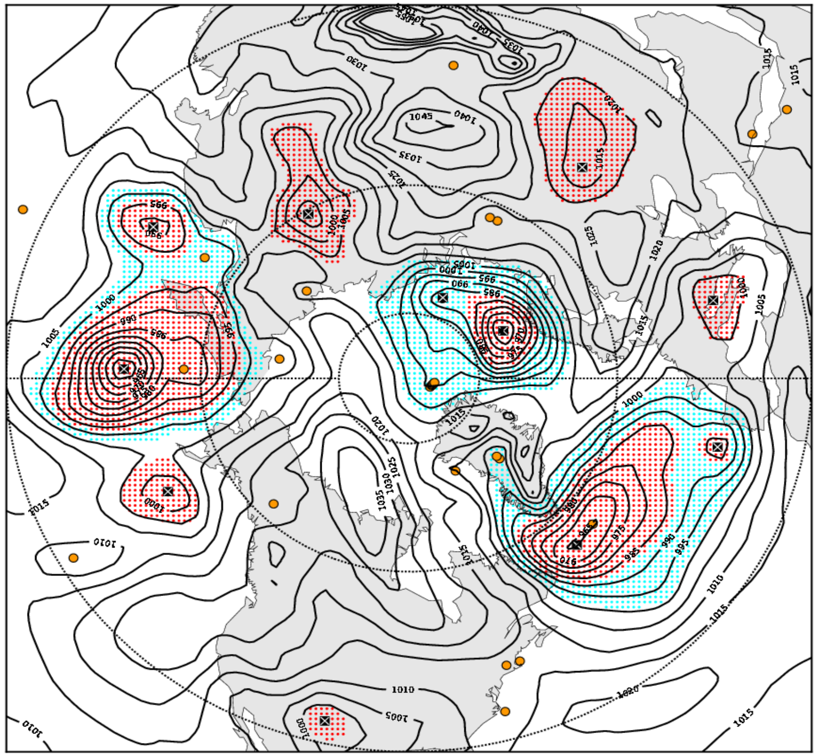
Traditional methods track the position of the low pressure center and do not provide information on the storm area





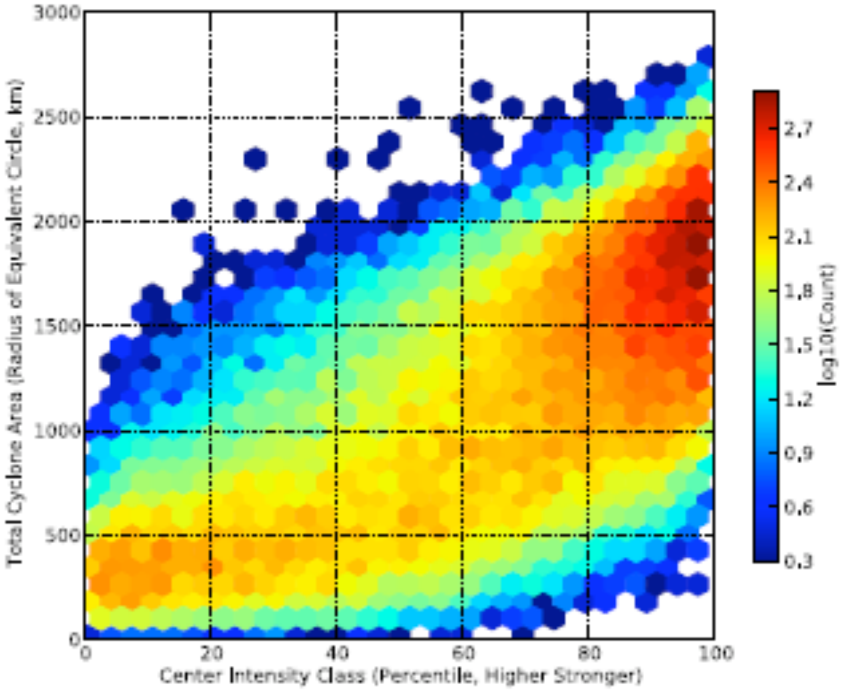
Dynamic definition of the storm area of influence:

Provides the full extent (coverage) of the baroclinic storm track and facilitates the study of storm effects on clouds and radiation



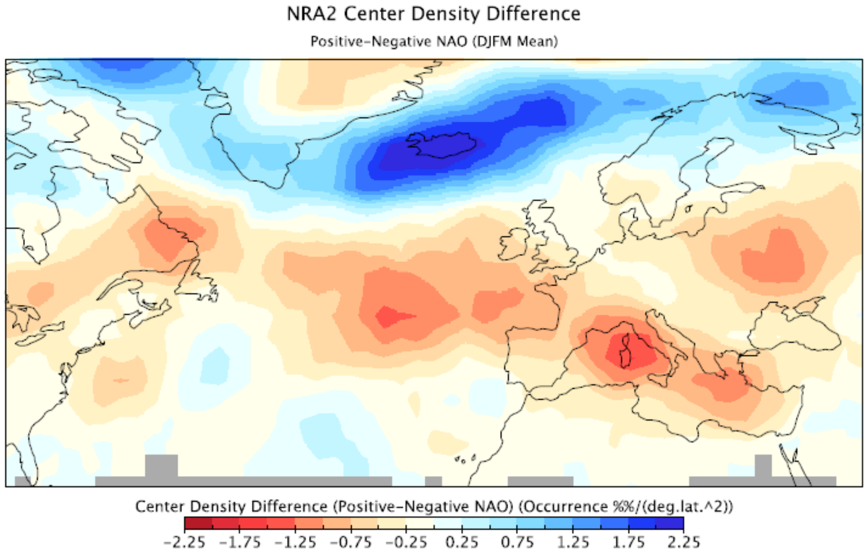
Bauer, Tselioudis, and Rossow 2011

Storm area vs. storm strength



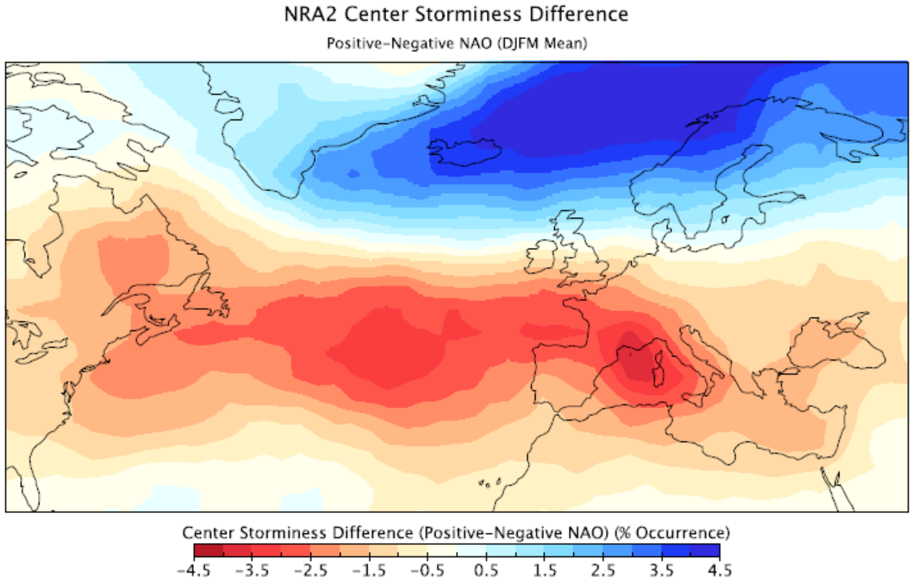
The strong relationship between storm area and strength implies that area variability is a factor in storm cloud and radiation feedbacks.

A paradigm of poleward stork track shift: the two phases of the NAO


NRA2 Center Density Difference

Positive–Negative NAO (DJFM Mean)

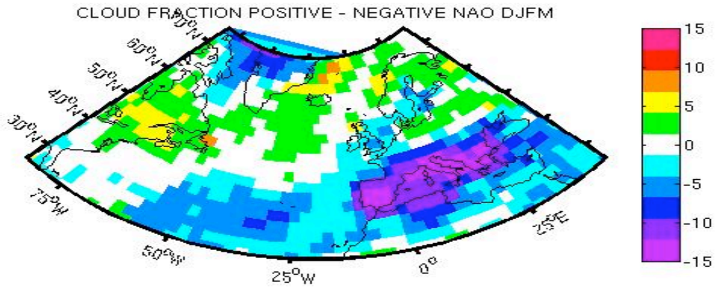
Changes in storm center density between positive and negative NAO winters

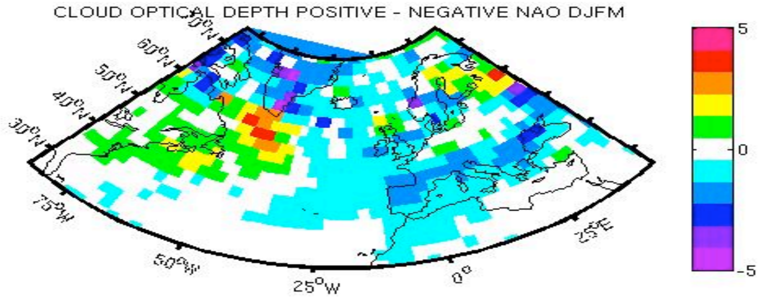

NRA2 Center Storminess Difference

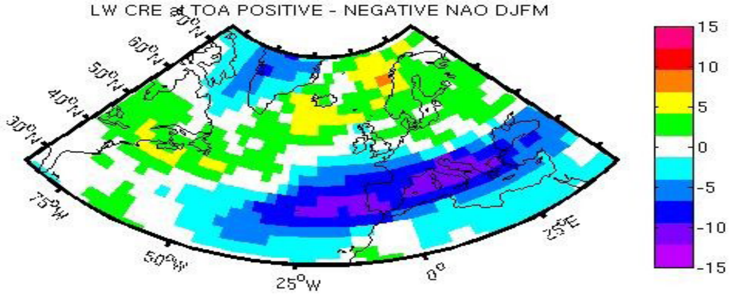
Positive–Negative NAO (DJFM Mean)

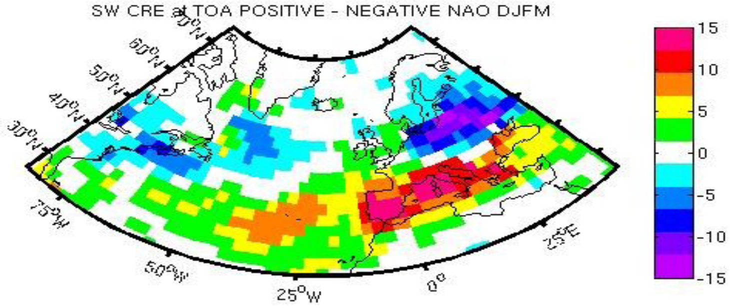
Changes in storm area of influence between positive and negative NAO winters

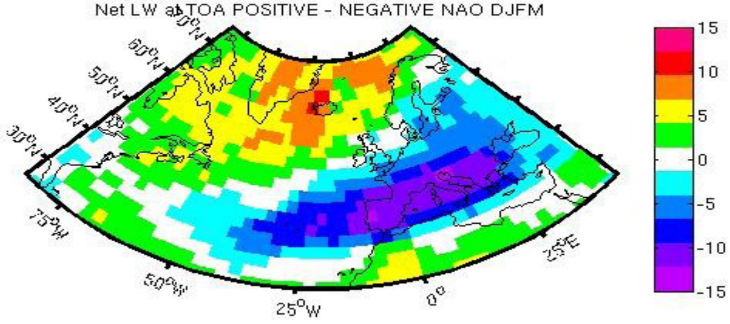
Cloud and radiation changes with NAO phase

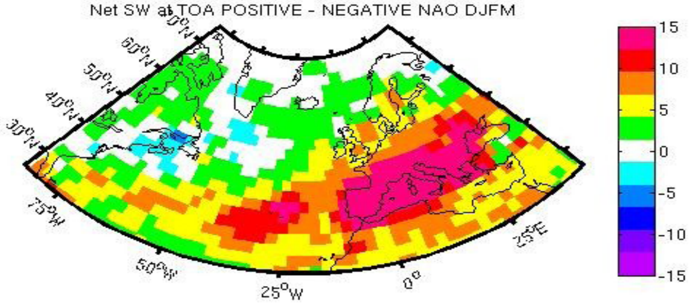

CLOUD FRACTION POSITIVE - NEGATIVE NAO DJFM


CLOUD OPTICAL DEPTH POSITIVE - NEGATIVE NAO DJFM

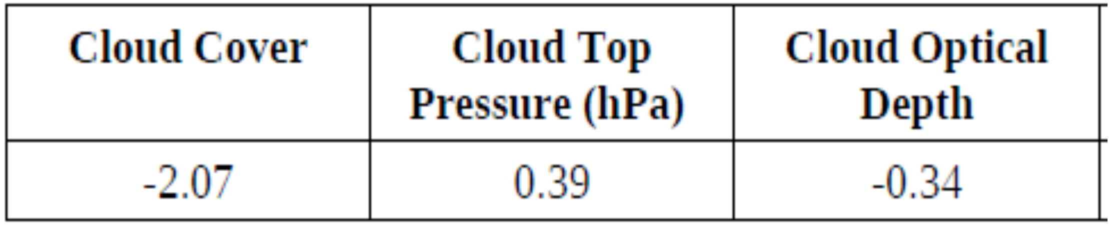

LW CRE at TOA POSITIVE - NEGATIVE NAO DJFM


SW CRE at TOA POSITIVE - NEGATIVE NAO DJFM

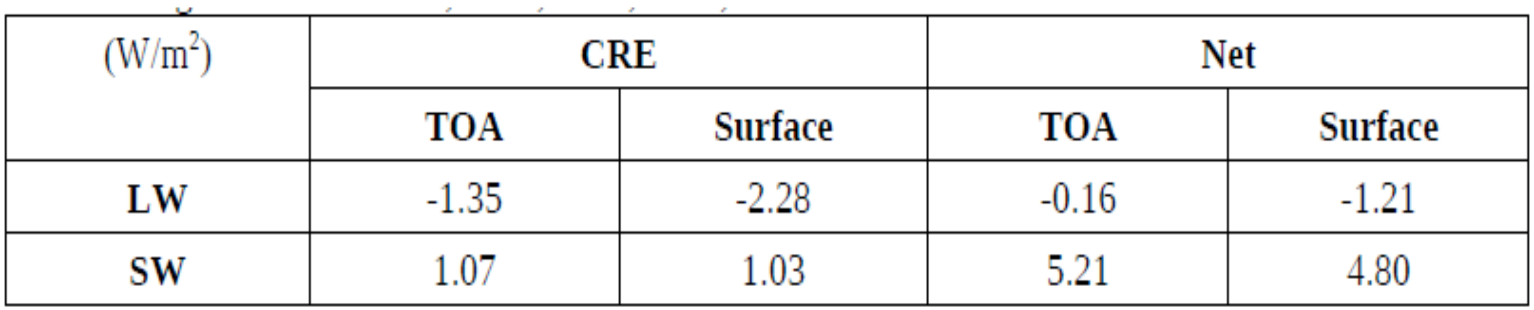

Net LW at TOA POSITIVE - NEGATIVE NAO DJFM


Net SW at TOA POSITIVE - NEGATIVE NAO DJFM

Cloud and radiation cumulative changes over the domain



Cloud Cover	Cloud Top Pressure (hPa)	Cloud Optical Depth
-2.07	0.39	-0.34



(W/m²)	CRE		Net	
	TOA	Surface	TOA	Surface
LW	-1.35	-2.28	-0.16	-1.21
SW	1.07	1.03	5.21	4.80

- Poleward storm shift produces decreases in cloud cover and cloud optical depth

- CRE changes by ~1W/m2, producing compensating SW warming and LW cooling effects

- Net TOA radiation changes are dominated by SW warming of ~5W/m2, resulting from warming in the southern regions and little change in the northern regions were incoming SW amount is small in the winter months

Concluding thoughts:

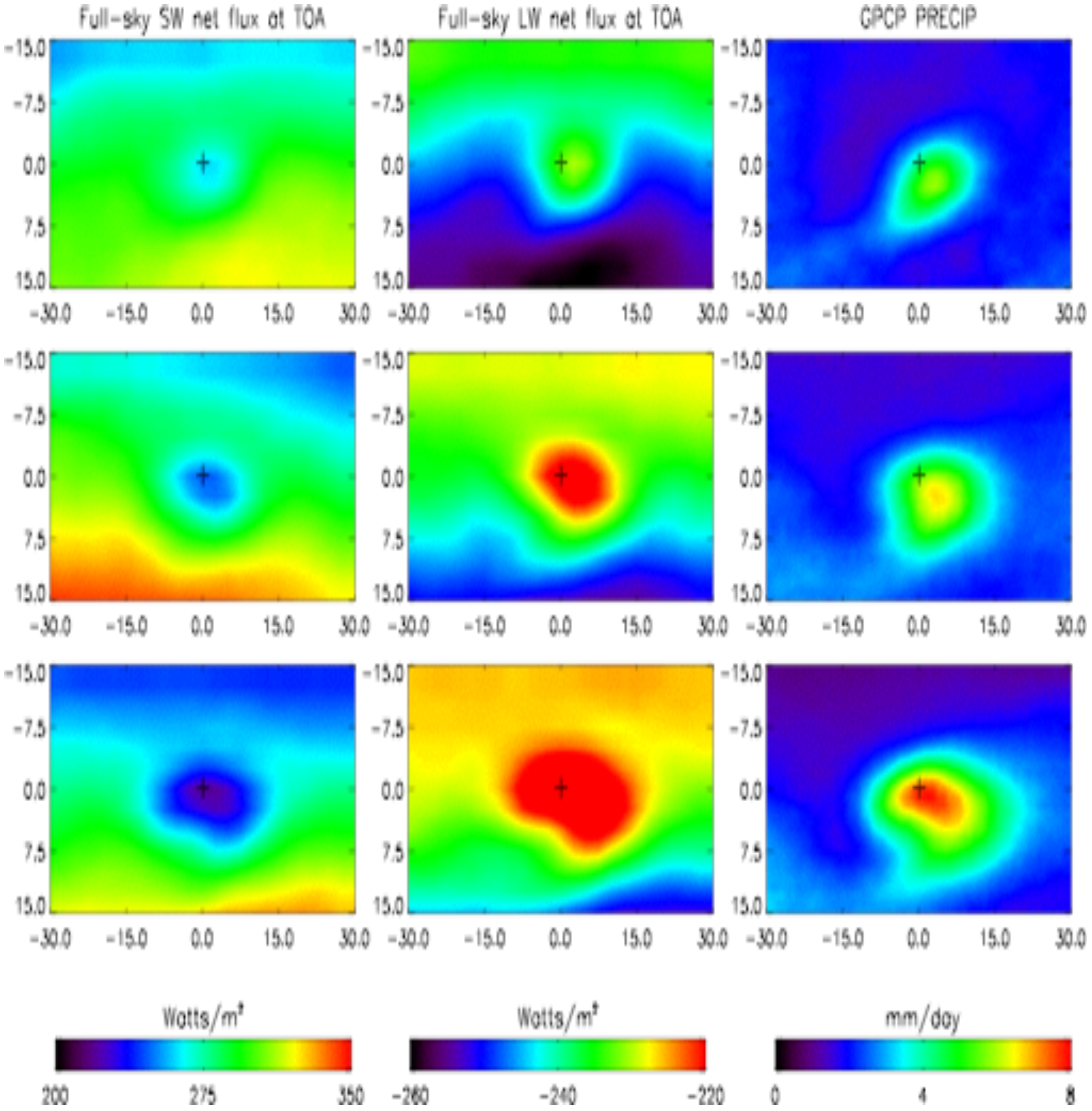
•Poleward storm track shifts are derived in observational analyses and are simulated in climate warming runs

•The short record of available satellite observations begins to show poleward shifts in midlatitude cloud amounts

•Analysis of a storm track shift paradigm shows that it produces radiative effects dominated by a SW warming at the equatoward part of the domain

•Scaled over an annual, global domain the effect of the pulling of the '*storm track curtain*' implies a cloud feedback of about 1W/m2

How do radiation and precipitation fields change with storm strength and frequency?



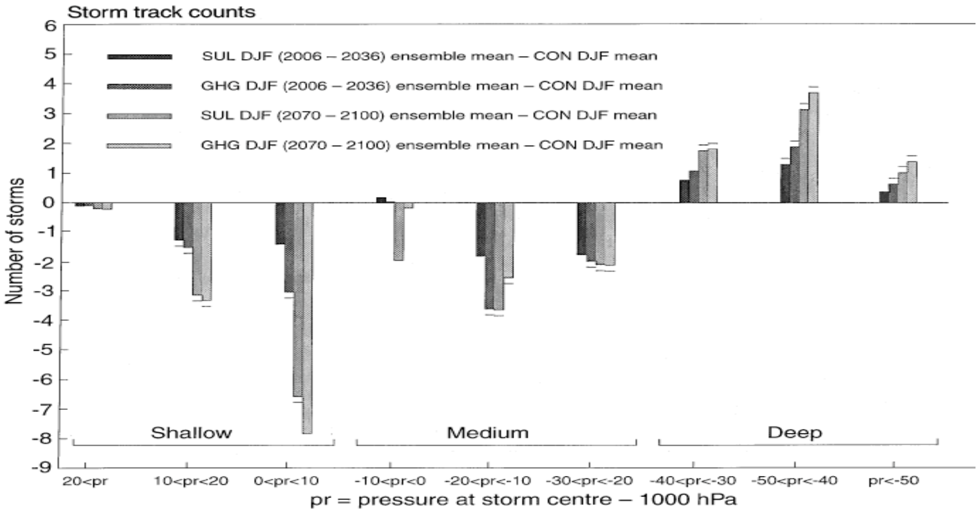
Weak

Medium

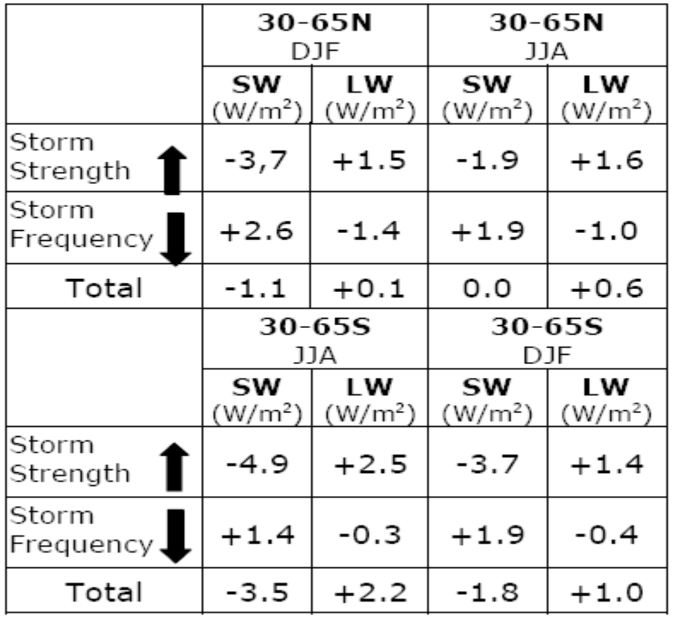
Strong

Tselioudis and Rossow 2007

UKMO prediction for 2XCO2 storm changes (Carnell and Senior 1998)

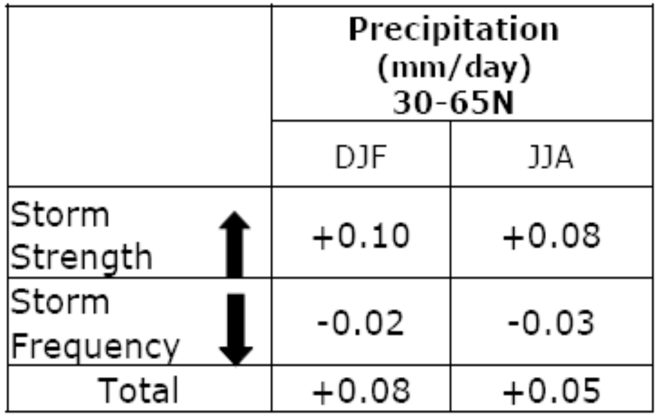


What if the UKMO prediction materialized?



	30-65N DJF		30-65N JJA	
	SW (W/m²)	LW (W/m²)	SW (W/m²)	LW (W/m²)
Storm Strength ⬆	-3,7	+1.5	-1.9	+1.6
Storm Frequency ⬇	+2.6	-1.4	+1.9	-1.0
Total	-1.1	+0.1	0.0	+0.6
	30-65S JJA		30-65S DJF	
	SW (W/m²)	LW (W/m²)	SW (W/m²)	LW (W/m²)
Storm Strength ⬆	-4.9	+2.5	-3.7	+1.4
Storm Frequency ⬇	+1.4	-0.3	+1.9	-0.4
Total	-3.5	+2.2	-1.8	+1.0

Table 1: Net TOA shortwave and longwave flux changes with storm strength and frequency



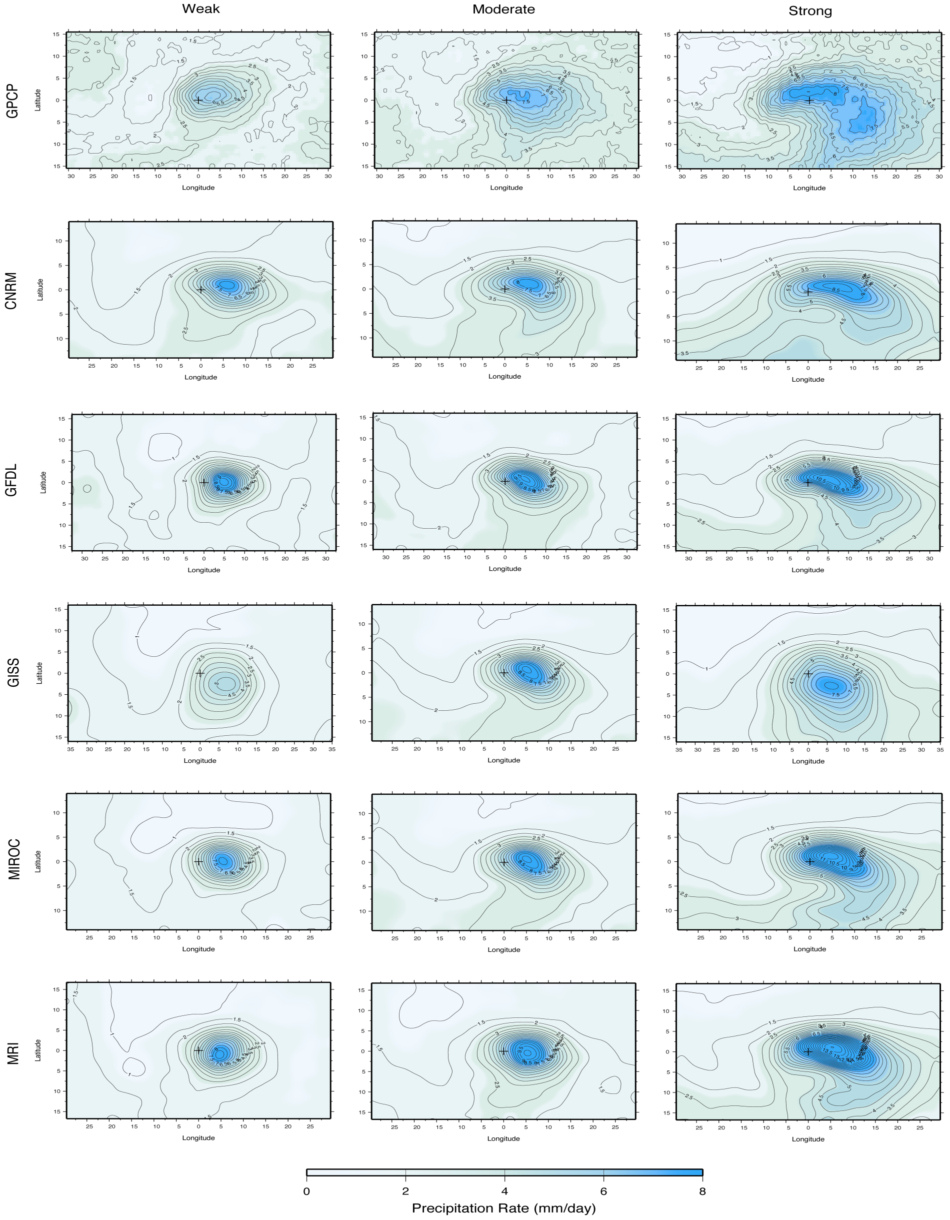
	Precipitation (mm/day) 30-65N	
	DJF	JJA
Storm Strength ⬆	+0.10	+0.08
Storm Frequency ⬇	-0.02	-0.03
Total	+0.08	+0.05

Table 1: Net precipitation changes with storm strength and frequency

Tselioudis and Rossow 2007

Storm Composites in Model Evaluation

Precipitation Changes with Storm Strength in Observations and in IPCC Models



Calculation of midlatitude precipitation changes with climate assuming UKMO-predicted storm changes

	Storm Strength	Storm Frequency	Total
GPCP	+0.1 (mm/day)	-0.02 (mm/day)	+0.08 (mm/day)
CNRM	+0.08	-0.14	-0.06
GFDL	+0.08	-0.11	-0.03
GISS	+0.05	-0.10	-0.05
MIROC	+0.08	-0.11	-0.03
MRI	+0.10	-0.11	-0.01

- All models estimate correctly the increase in precipitation due to increasing storm strength but overestimate the decrease in precipitation due to decreasing storm frequency. This is because all models produce very little midlatitude precipitation outside storm events. As a result, models produce a negative rather than a positive precipitation feedback when the two UKMO-predicted storm changes are applied together

Tselioudis et al. 2011