Clouds and the general circulation: Poleward cloud shifts and the role of the Hadley cell and the baroclinic storm track

George Tselioudis, Dimitra Konsta, Costas Douvis, Mike Bauer

- Observational and modeling evidence for systematic circulation shifts with climate warming relate primarily to Hadley cell expansion (tropical widening) and to storm track poleward shifts

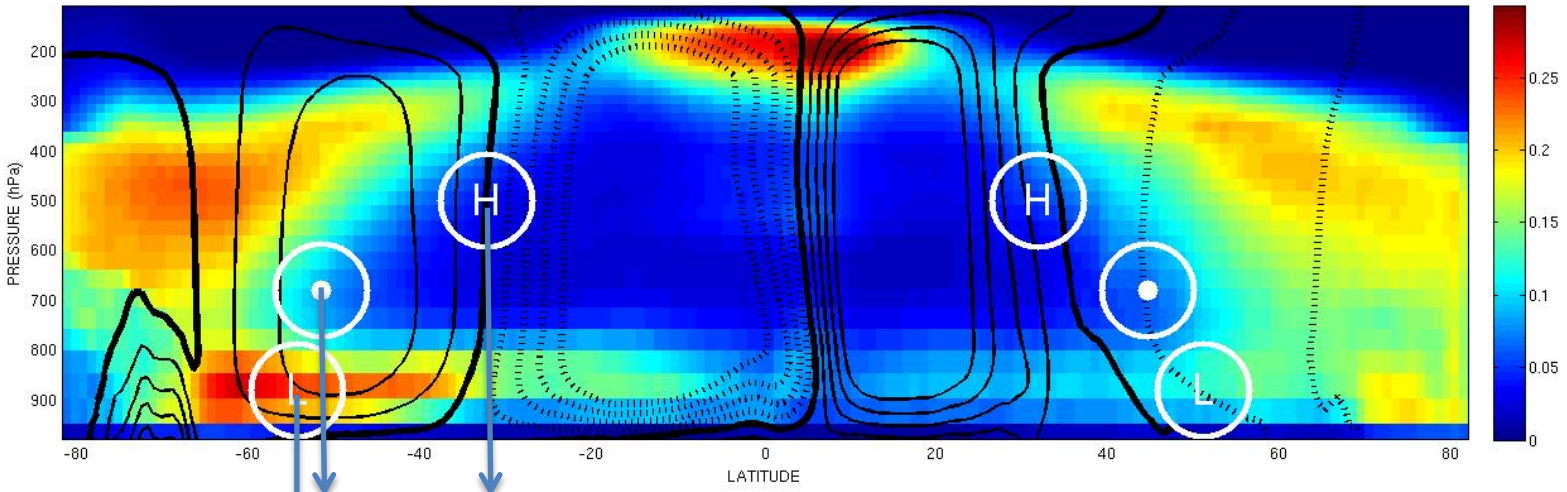
- Observational analyses find poleward cloud shifts in satellite retrievals over the last 30 years

- Modeling results show strong relationships between poleward cloud shifts and model climate sensitivity

- All this makes it crucial to understand and quantify relationships between dynamics and cloud latitudinal shifts

Cloud field and dynamic indices

CloudSat/CALIPSO cloud vertical profile



U850 max

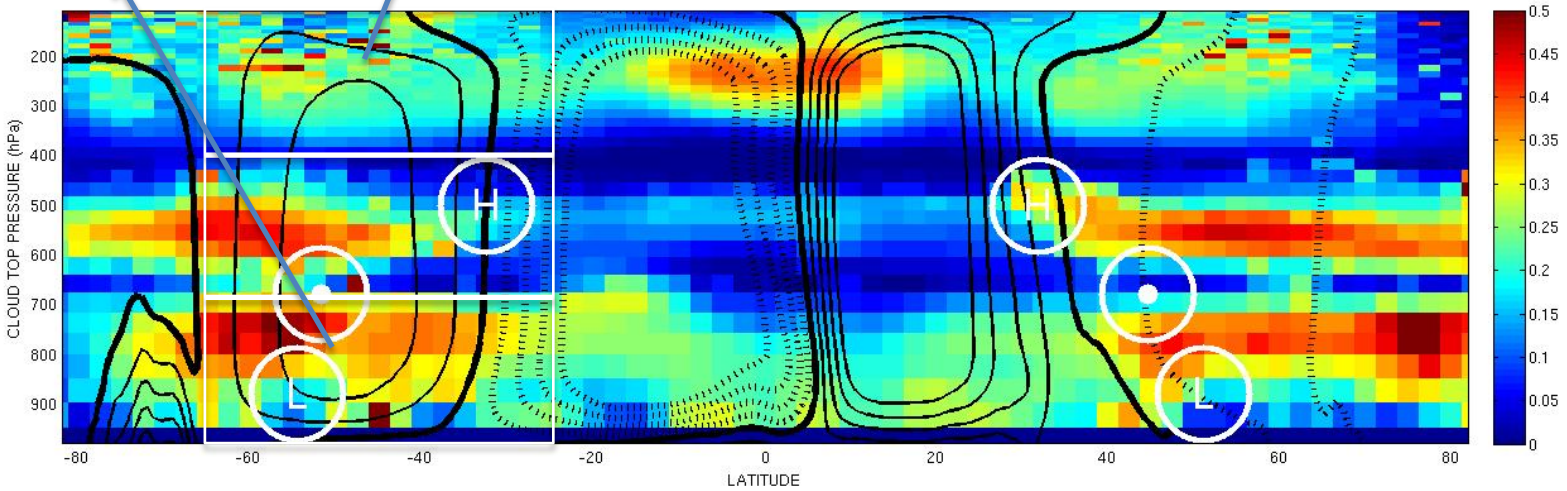
Hadley cell edge

Storm track

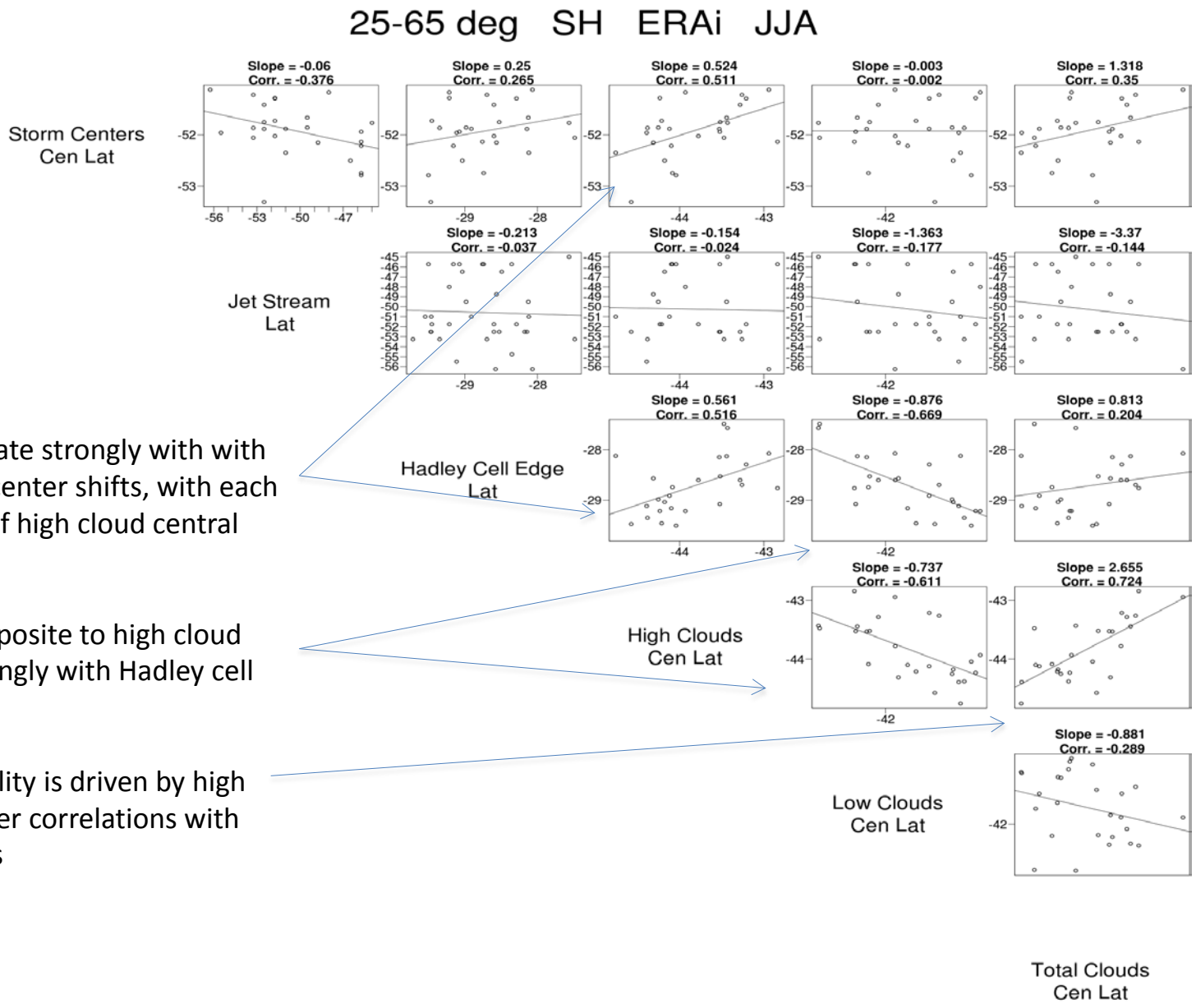
Low cloud Central latitude

High cloud Central latitude

ISCCP cloud top profile



Relationships between seasonal interannual cloud and dynamics shifts



- High cloud shifts correlate strongly with with Hadley cell and Storm center shifts, with each explaining about 25% of high cloud central latitude variability
- Low cloud shifts are opposite to high cloud ones and correlate strongly with Hadley cell shifts
- Total cloud shift variability is driven by high clouds but shows weaker correlations with Hadley and storm shifts

Summary of relationships between cloud and dynamics shifts

DJF – S.Hem. – 25-65°

	Storm Centers	Jet Stream	Hadley Cell
High Clouds	0.101	0.188	0.386
Low Clouds	0.194	-0.256	-0.339
Total Cloud	-0.032	-0.049	0.208

JJA – S.Hem. – 25-65°

	Storm Centers	Jet Stream	Hadley Cell
High Clouds	**0.511**	-0.024	**0.516**
Low Clouds	-0.002	-0.177	**-0.669**
Total Cloud	0.350	-0.144	0.204

MAM – S.Hem. – 25-65°

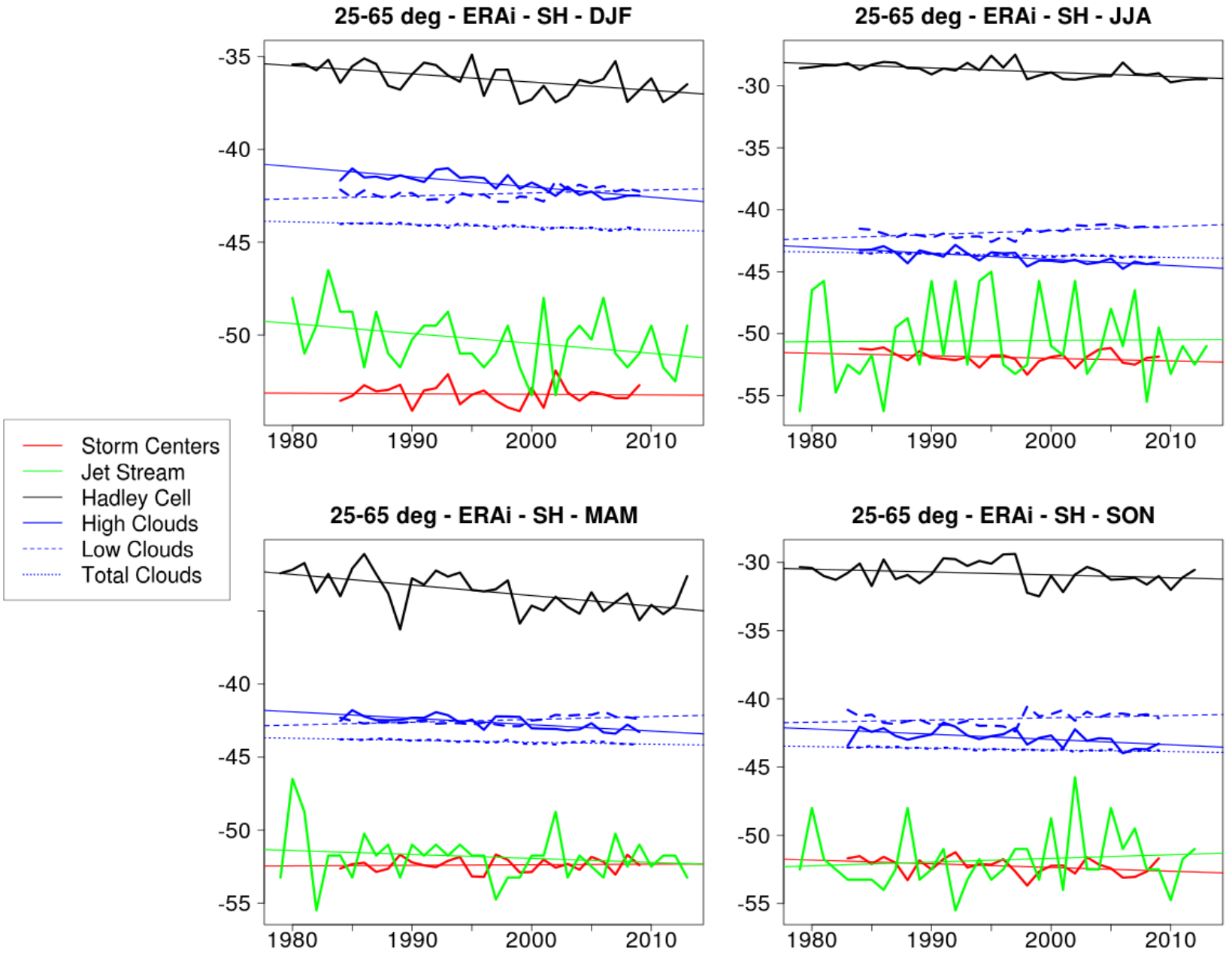
	Storm Centers	Jet Stream	Hadley Cell
High Clouds	0.215	-0.240	**0.599**
Low Clouds	0.051	0.147	-0.360
Total Cloud	0.045	-0.156	**0.503**

SON – S.Hem. – 25-65°

	Storm Centers	Jet Stream	Hadley Cell
High Clouds	0.463	-0.059	**0.583**
Low Clouds	-0.246	0.063	**-0.699**
Total Cloud	0.464	-0.453	0.078

- High clouds correlate with Hadley cell extent in all seasons and with storm centers in winter and spring
- Low clouds correlate with Hadley cell extent in all seasons
- Total cloud correlates with storm centers in the winter and spring, with Jet stream in the spring, and with Hadley cell extent in the fall

Trends in cloud and dynamics central atitudes in the last 29 years



Summary of trends in cloud and dynamics central latitudes in the last 29 years

	S.Hem.			
Deg. / decade	**DJF**	**MAM**	**JJA**	**SON**
Storm Centers	-0.030	0.037	-0.208	-0.273
Jet Stream	-0.533	-0.273	0.055	0.269
Hadley Cell	**-0.442**	**-0.724**	**-0.347**	-0.210
High Clouds	**-0.546**	**-0.438**	**-0.496**	**-0.388**
Low Clouds	0.156	**0.192**	**0.325**	0.162
Total Cloud	**-0.143**	**-0.134**	**-0.146**	**-0.123**

- Hadley cell and high clouds have been shifting consistently poleward at rates of 0.35-0.72 degrees/decade or about 1.5 degrees in the last 30 years

- Total cloud has been shifting poleward at rates of 0.12-0.15 degrees/decade or about 0.4 degrees in the last 30 years

What is the radiative effect of a 1-degree poleward cloud shift?

DCRE(W/m^2) for 1 degree poleward shift	ISCCP-FD	ERBE	CERES
S. Hem	0.84	1.44	1.50

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

A shift of 0.4 degrees in total cloud in the last 30 years implies a radiative warming of about 0.5W/m2

Discussion

- Hadley cell extent correlates with SH high and low cloud shifts in all seasons, while storm track location correlates with high and total cloud shifts in winter and spring
- The SH high and total cloud poleward shift observed in ISCCP in the last 30 years can be attributed to Hadley cell expansion
- Relative role of climate warming and ozone depletion/recovery processes is the SH need to be investigated
- NH cloud-dynamics relationships harder to examine in zonal mean sense, but basin-wide results point to stronger role of storm track on cloud shifts

25-65 deg SH ERAi SON