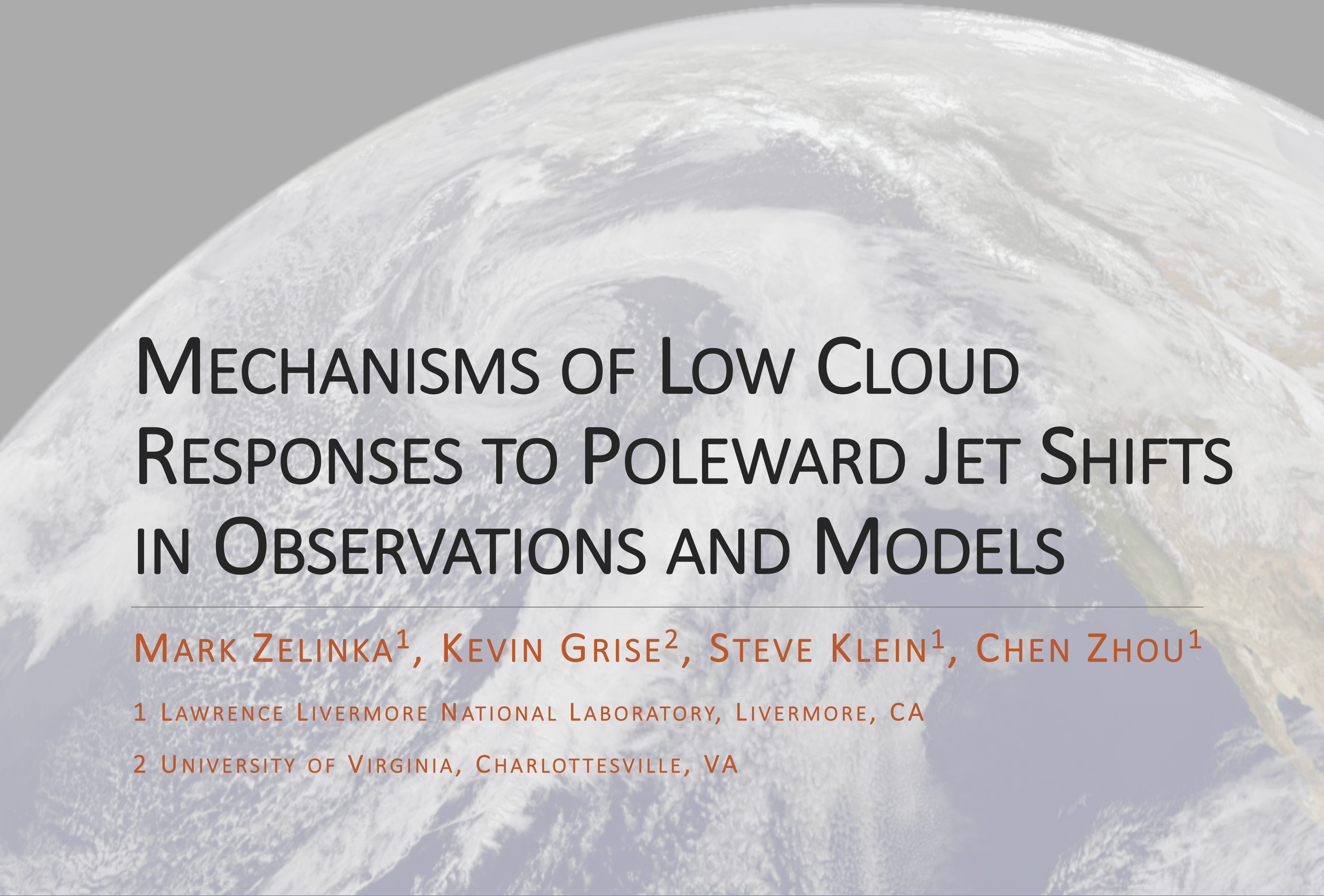

Mechanisms of Low Cloud Responses to Poleward Jet Shifts in Observations and Models

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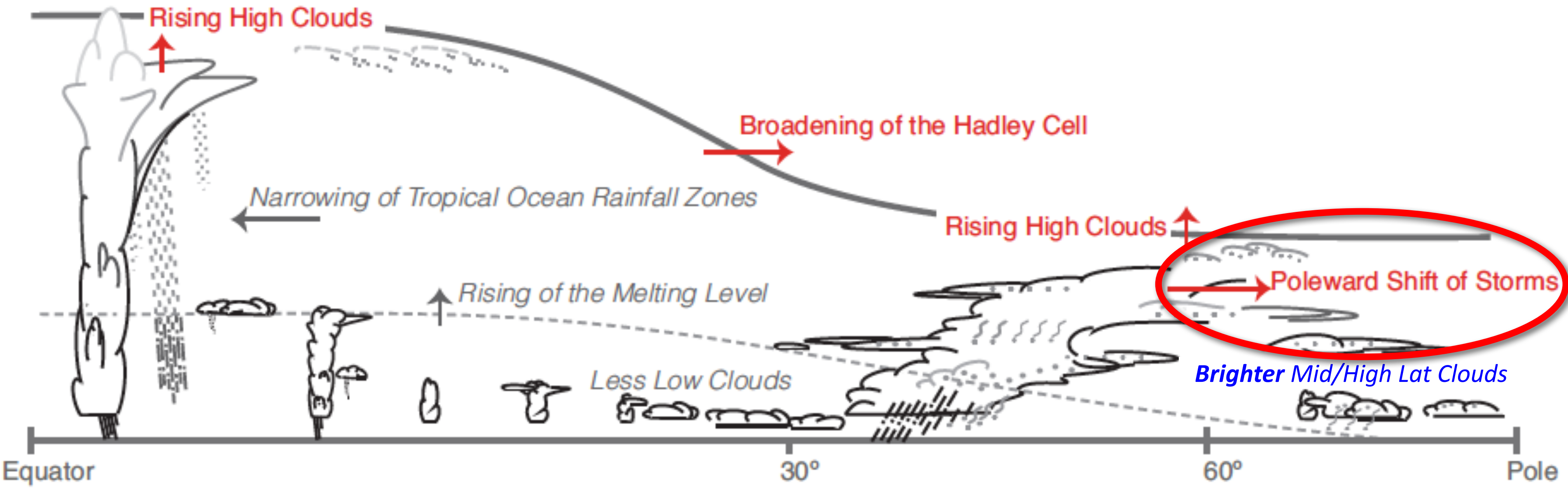
The effort of MDZ was supported by the NASA New Investigator Program (NNH14AX83I) and was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. IM-Release: LLNL-716519

"The true amount of ***positive feedback*** *coming from poleward shifts therefore remains highly uncertain…"*
--AR5



Modified from IPCC AR5, Figure 7.11

Background

The long-standing expectation that poleward shifts of the midlatitude jet will lead to poleward shifts of clouds and a net warming effect on the climate system has been shown to be misguided by several recent studies:

- *Kay et al. (2014); Grise & Polvani (2014); Ceppi et al. (2014); Wall & Hartmann (2015); Ceppi & Hartmann (2015); Tselioudis et al. (2016); Grise & Medeiros (2016)*

Notably, inter-annual jet latitude variations have small impacts on TOA radiation that do not resemble the response to long-term warming.

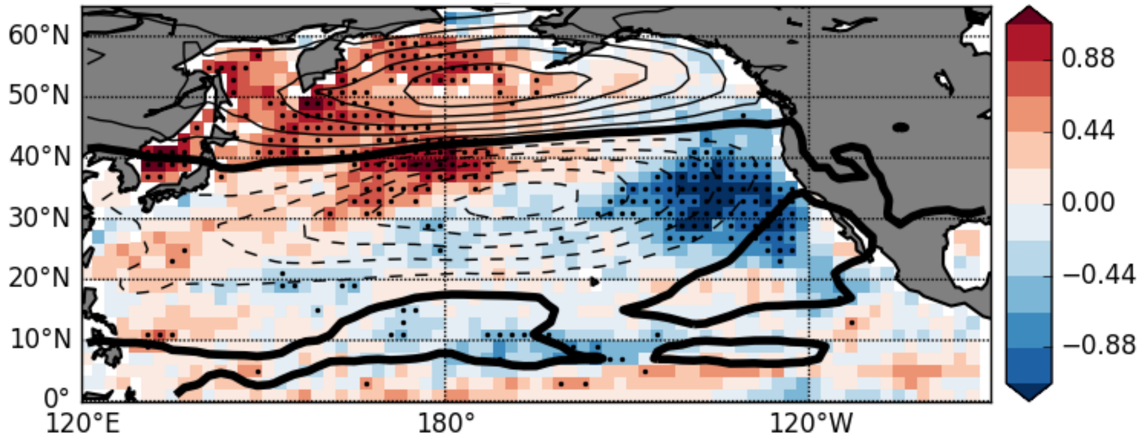
Here we ask why that is, and assess models' ability to capture it.

Data & Methodology

We regress interannual anomalies in radiation, clouds, and relevant meteorological fields against interannual anomalies in jet latitude.

- Meteorological data (ω, T, u, v) come from ERA-Interim reanalysis (Dee et al. 2011).
- To compute jet latitude, we find the latitude of maximum zonal mean U_{850} within each ocean basin following Barnes & Polvani (2013).
- Low clouds defined as CTP>680hPa. For passive sensors, LCC = lo/(1-mid-hi) following the random overlap assumption of Morcrette & Fouquart (1986).
- Tadv is computed as -udSST/dx – vdSST/dy, where u & v are the zonal & meridional wind at 1000 hPa, following Norris & Iacobellis (2005). We use NOAA Optimum Interpolation SST v2 (Reynolds et al. 2002).
- The annual cycle and any long-term trend are removed from all datasets.
- We consider only oceanic locations. Here I'll present N. Pacific results.
- We do the same analysis in CMIP5 GCMs, using piControl runs from 21 models. LCC in models is approximated as the maximum cloud fraction between 1000 and 680 hPa.

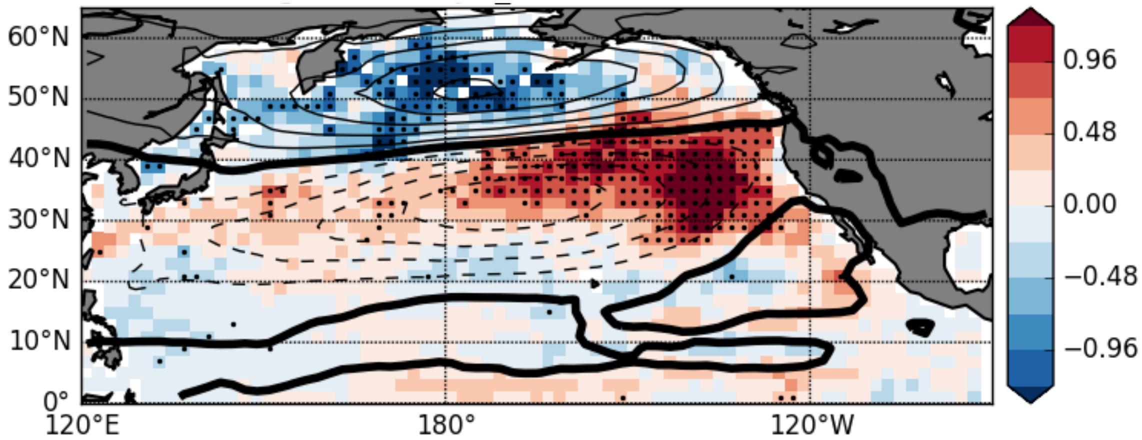
Response of CRE & LCC to Jet Shift



ΔNet CRE (CERES) [W/m^2]

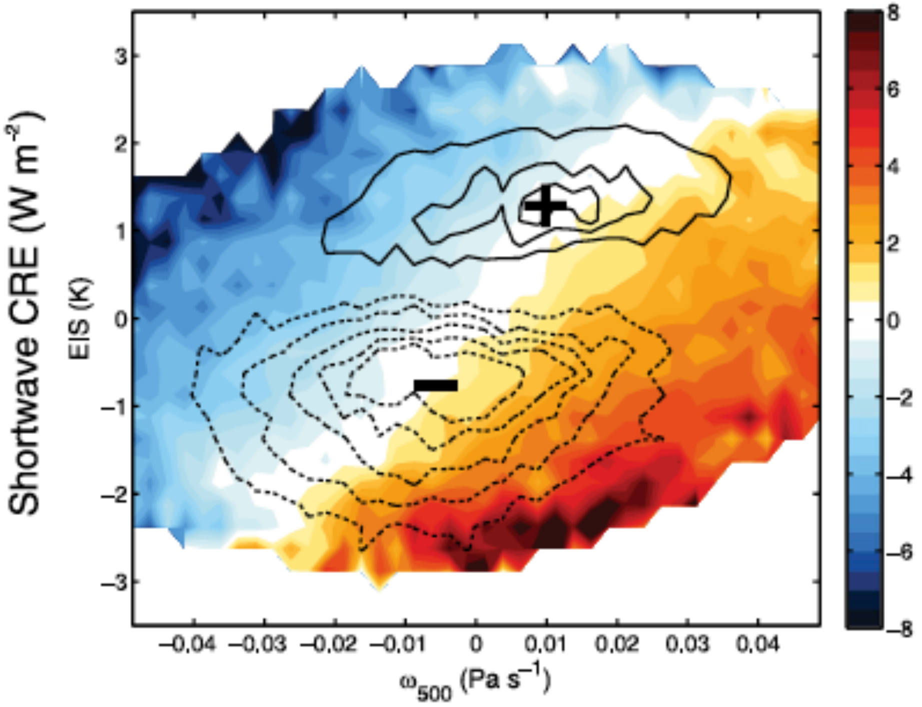
b/w contours: ΔU_{850}

Contour interval = 0.2 m/s



ΔLCC (MODIS) [%]

Cloud- & CRE-Controlling Factors

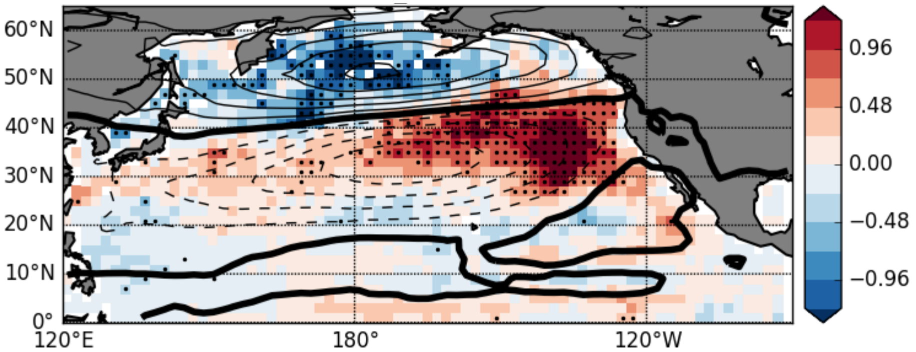


Grise and Medeiros (2016)

Composites of ISCCP LCC anomalies at all oceanic grid points over the Southern Ocean (40°–50°S) as a function of the coinciding vertical velocity and EIS anomalies.

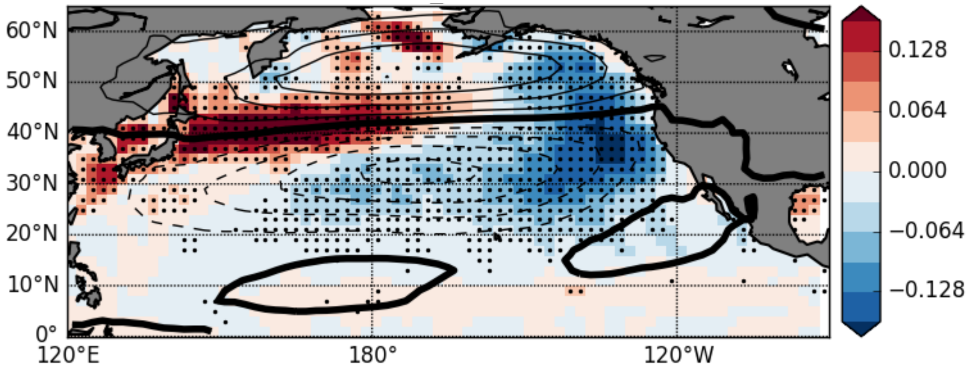
Response of Meteorology to Jet Shift

ΔLCC (MODIS) [%]

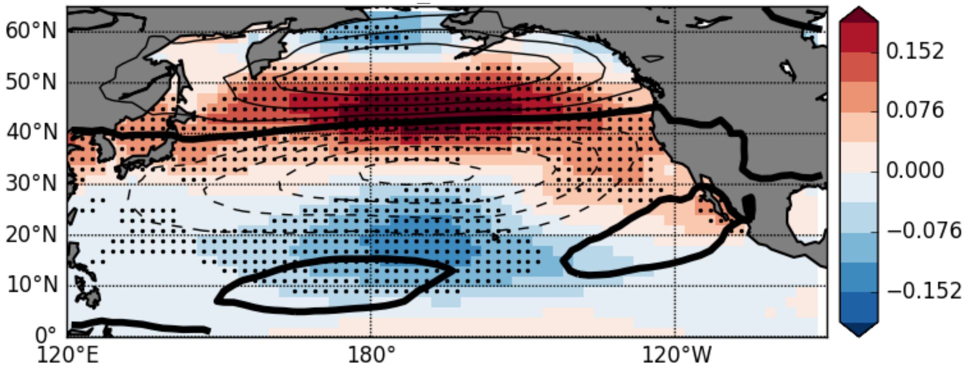


b/w contours: ΔU_{850}
Contour interval = 0.2 m/s

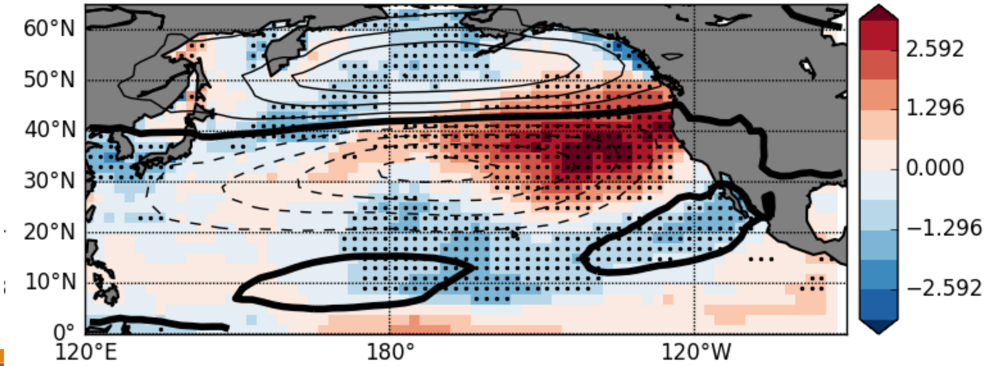
ΔTadv [K/dy]



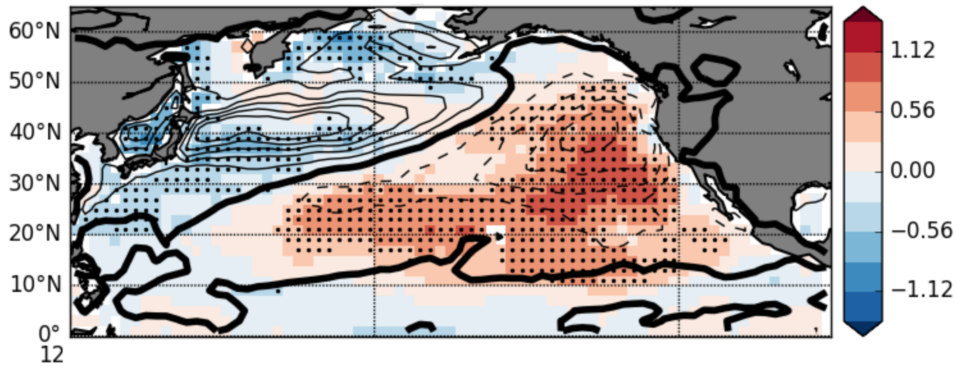
ΔEIS [K]



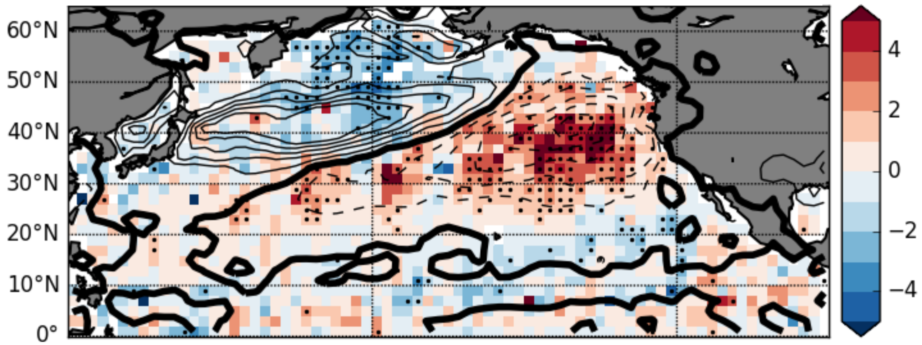
$\Delta\omega_{500}$ [hPa/dy]



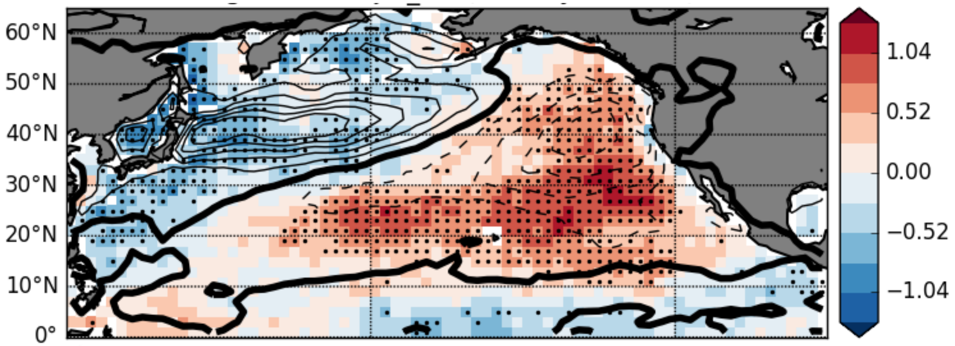
ISCCP



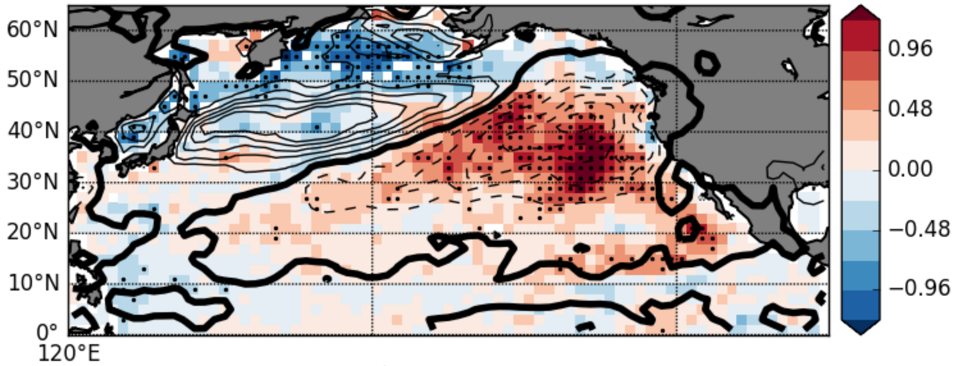
MISR



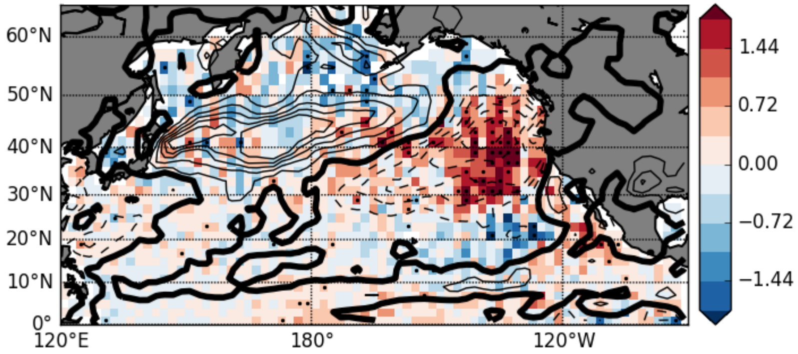
PATMOS-x



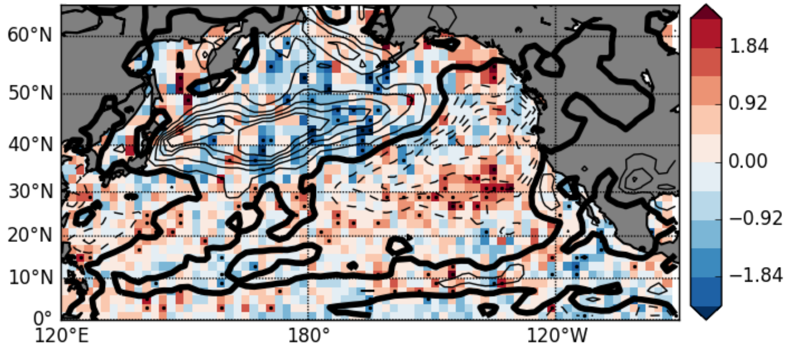
MODIS



Calipso (GOCCP)



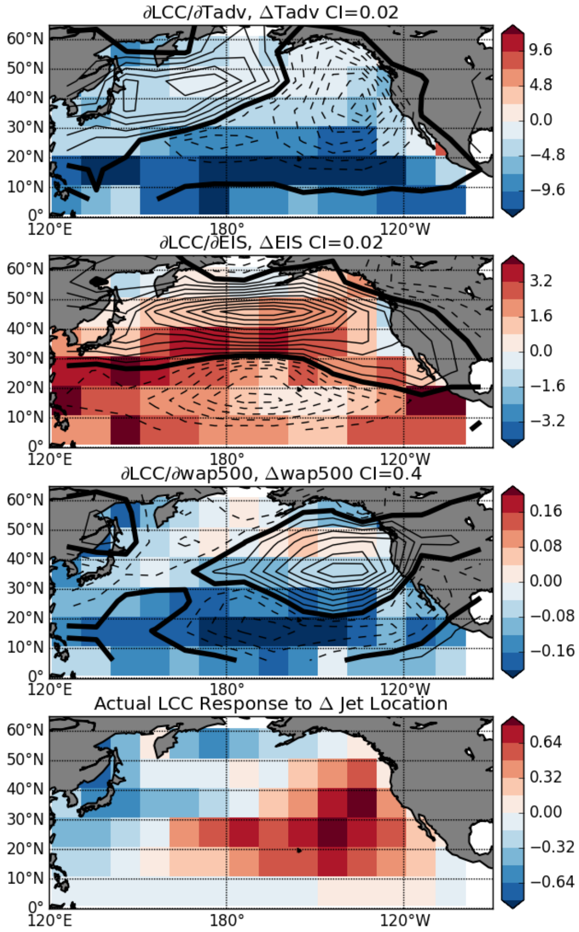
CloudSat



Passive LCC = lo/(1-mid-hi) **colors: ΔLCC [%] | contours: $\Delta Tadv_{N\text{-}S}$ [K/dy]**

$$\Delta LCC = \left(\frac{\partial LCC}{\partial Tadv}\right)\Delta Tadv + \left(\frac{\partial LCC}{\partial EIS}\right)\Delta EIS + \left(\frac{\partial LCC}{\partial \omega_{500}}\right)\Delta\omega_{500}$$

$\partial LCC/\partial x$



Tadv

EIS

ω_{500}

ISCCP (Jul 1983 – Dec 2009)

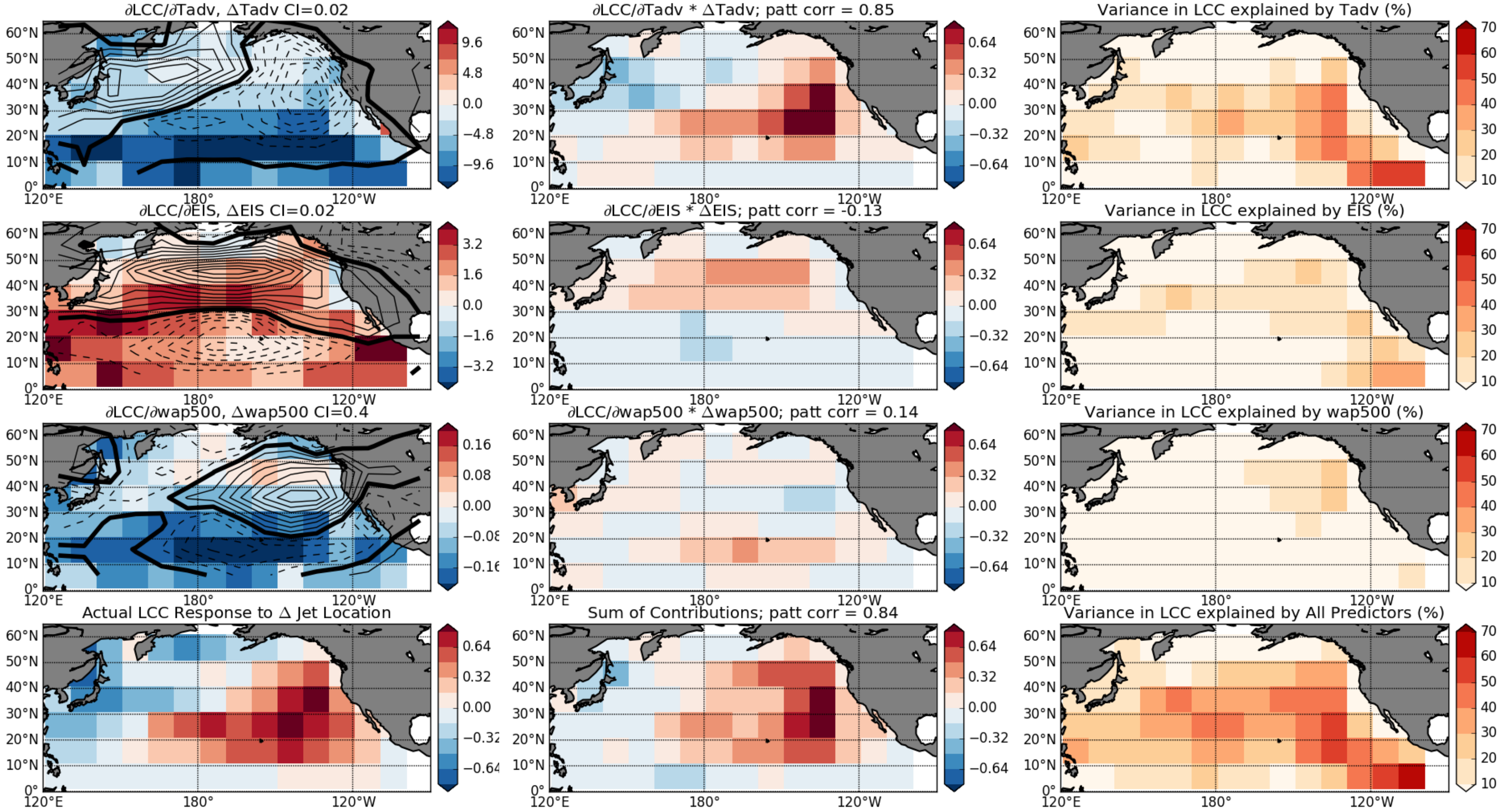
$$\Delta LCC = \left(\frac{\partial LCC}{\partial Tadv}\right)\Delta Tadv + \left(\frac{\partial LCC}{\partial EIS}\right)\Delta EIS + \left(\frac{\partial LCC}{\partial \omega_{500}}\right)\Delta\omega_{500}$$

$\partial LCC/\partial x$ | $(\partial LCC/\partial x)\Delta x$ | var(LCC) explained by x

Tadv

EIS

ω_{500}



ISCCP (Jul 1983 – Dec 2009)

$$\Delta LCC = \left(\frac{\partial LCC}{\partial Tadv}\right)\Delta Tadv + \left(\frac{\partial LCC}{\partial EIS}\right)\Delta EIS + \left(\frac{\partial LCC}{\partial \omega_{500}}\right)\Delta \omega_{500}$$

$\partial LCC/\partial x$

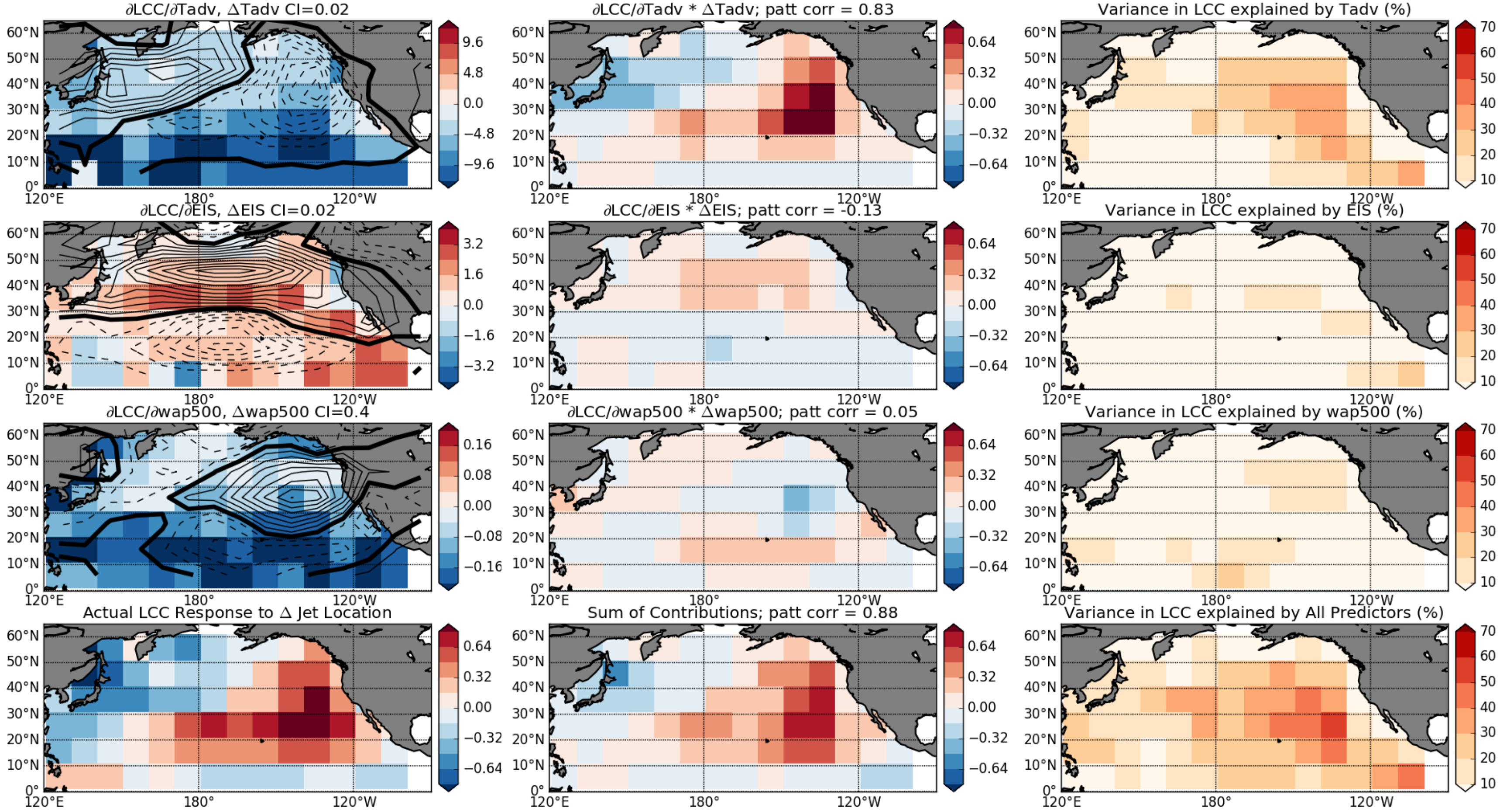
$(\partial LCC/\partial x)\Delta x$

var(LCC) explained by x

Tadv

EIS

ω_{500}



PATMOS-x (Jan 1982 – Dec 2009)

Surface Cold Advection has been Highlighted in the Literature

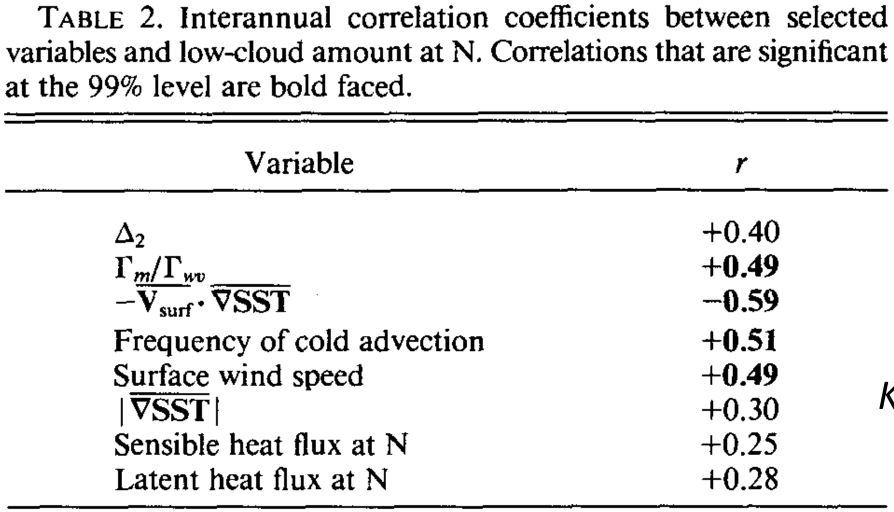


TABLE 2. Interannual correlation coefficients between selected variables and low-cloud amount at N. Correlations that are significant at the 99% level are bold faced.

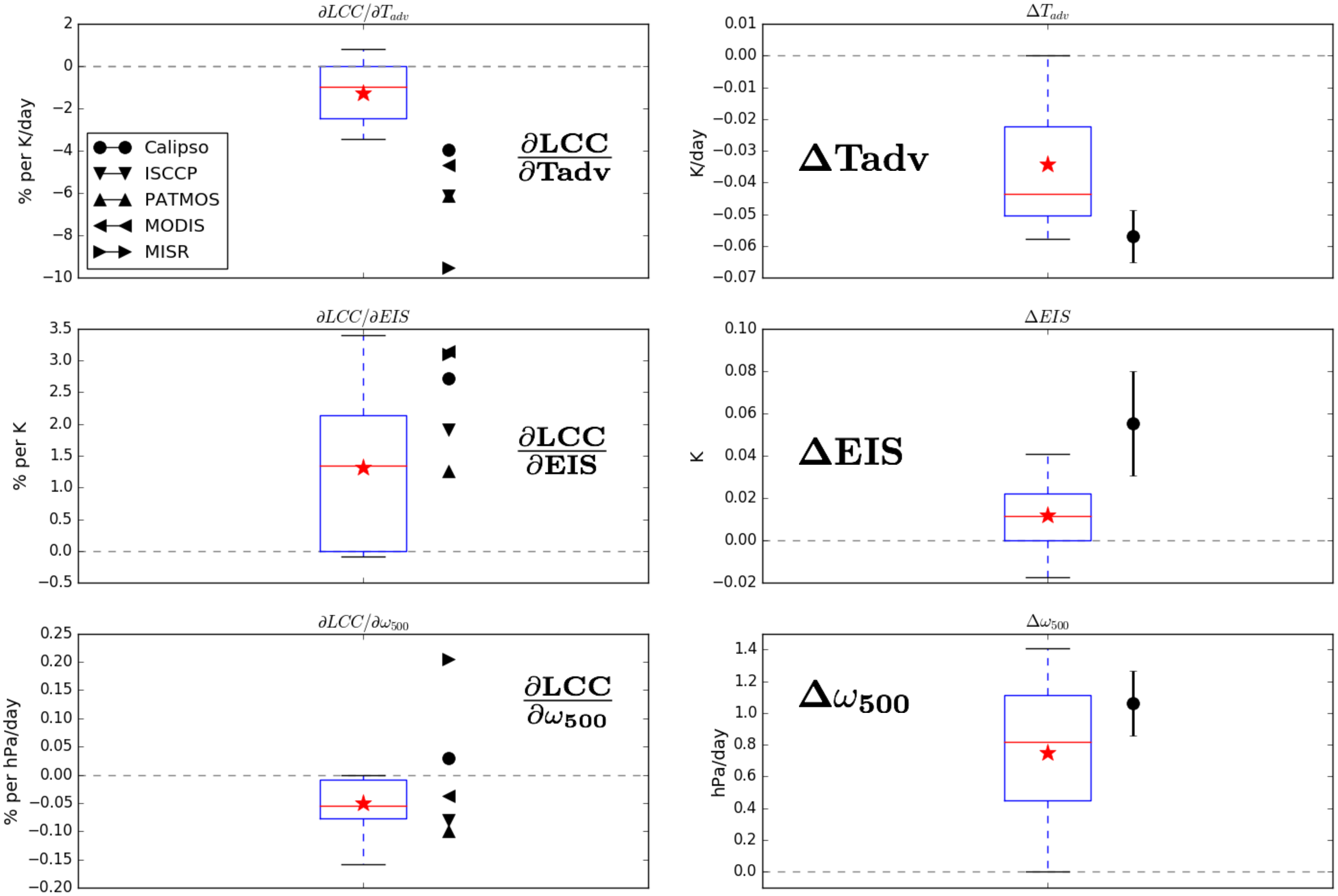
Variable	r
Δ_2	+0.40
Γ_m/Γ_{wv}	**+0.49**
$-\overline{\mathbf{V}}_{\mathrm{surf}}\cdot\overline{\nabla \mathrm{SST}}$	**−0.59**
Frequency of cold advection	**+0.51**
Surface wind speed	**+0.49**
$\lvert\overline{\nabla \mathrm{SST}}\rvert$	+0.30
Sensible heat flux at N	+0.25
Latent heat flux at N	+0.28

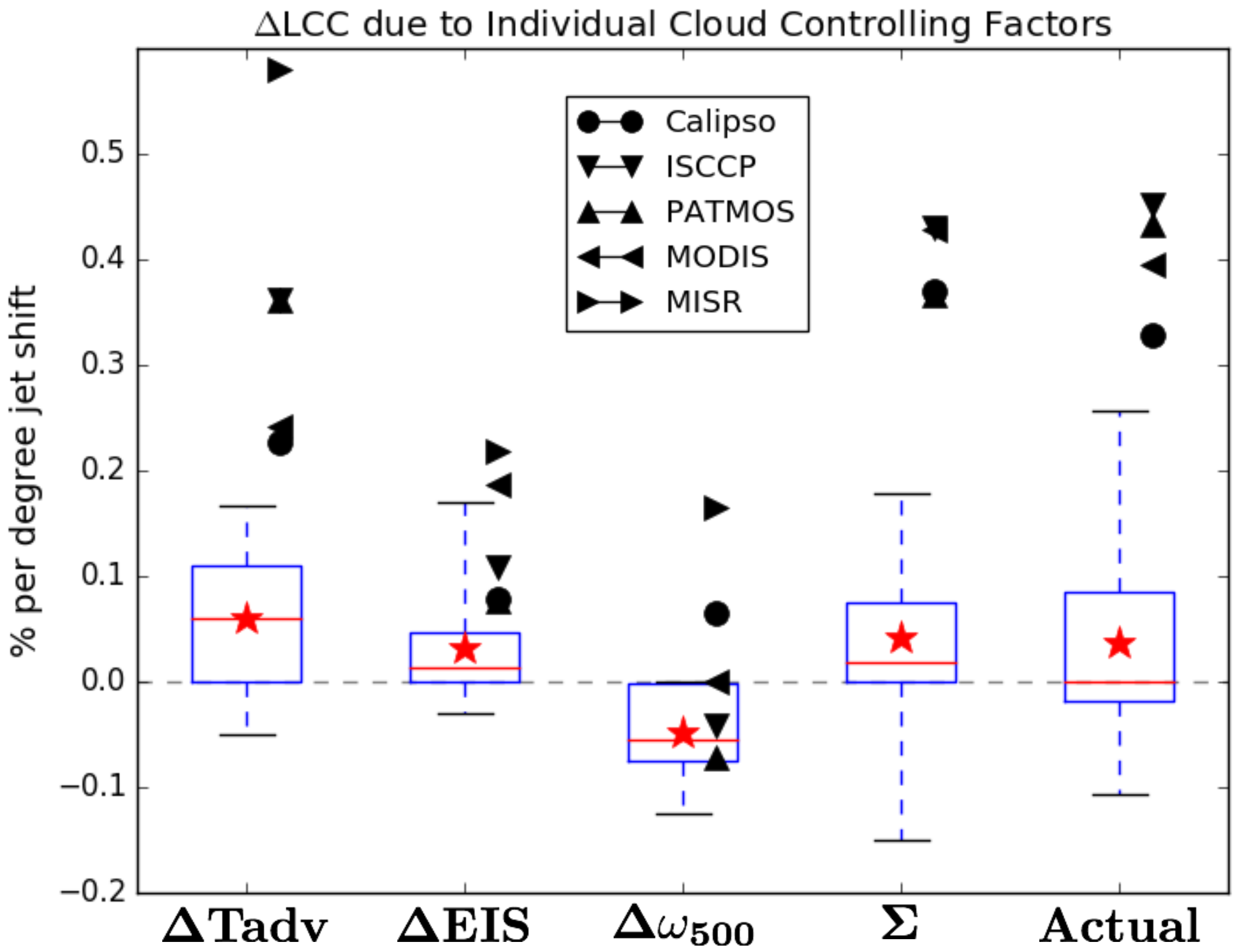
Weather Ship N @ 30N 140W

Klein et al. (1995)

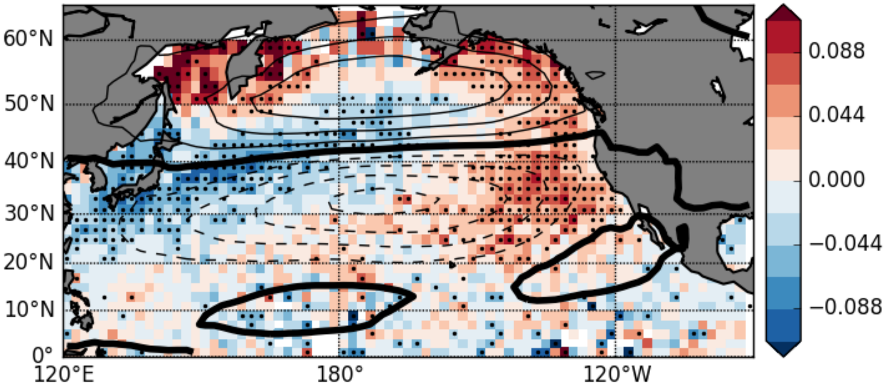
see also *Deser et al. (1993), Norris (1998a,b), Myers and Norris (2015), Seethala et al. (2015), Fletcher et al. (2016)*

Model Evaluation of Low Cloud Controlling Factors over the NE Pacific



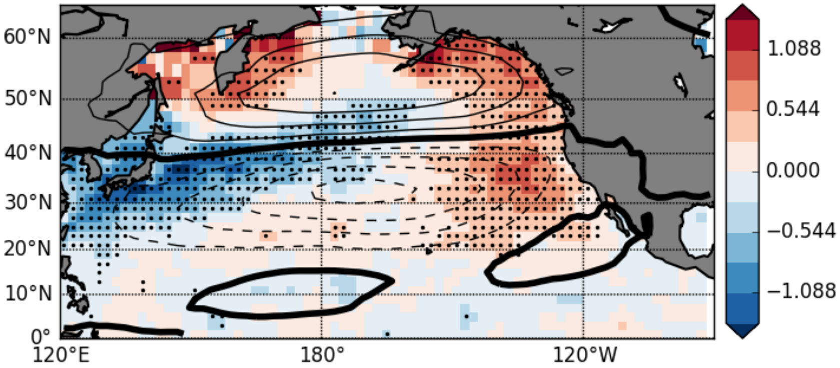

ΔLCC due to Individual Cloud Controlling Factors
% per degree jet shift
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
Calipso
ISCCP
PATMOS
MODIS
MISR
ΔTadv
ΔEIS
$\Delta\omega_{500}$
Σ
Actual

Surface Cold Advection: A proxy for surface fluxes

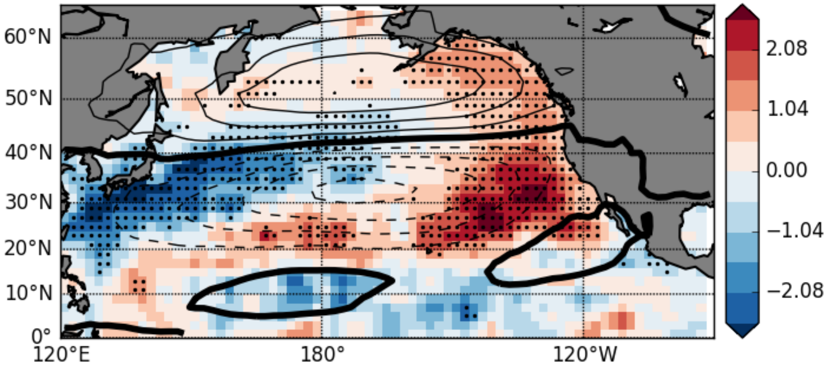


$T_{sea} - T_{air}$ [K]

ICOADS 3.0
(Jan 1982 – Dec 2012)



Sensible Heat Flux [W/m^2]



Latent Heat Flux [W/m^2]

NOCS Surface Flux Dataset v2.0
(Jan 1982 – Dec 2006)

Conclusions

On interannual timescales, **poleward jet shifts do not lead to large positive radiative heating anomalies** from clouds shifting to latitudes with less insolation.

This is because total cloud cover does not respond strongly to poleward jet shifts, as **low clouds increase in broad regions, including those vacated by high clouds**.

Over the NE Pacific, both passive and active satellite sensors observe **large increases in low cloud cover** in response to poleward jet shifts.

This increase of low clouds is **mostly due to enhanced surface cold air advection**.

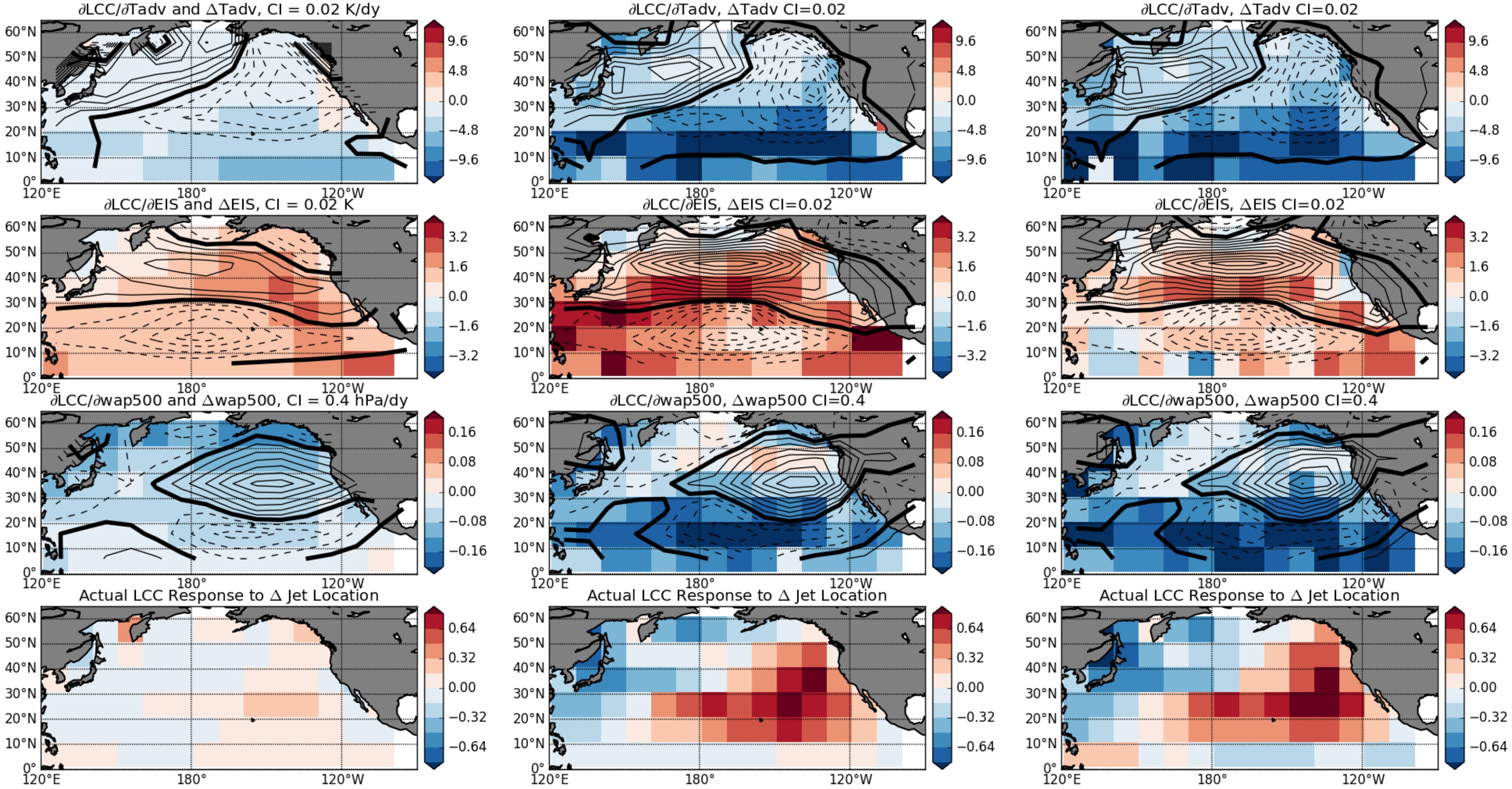
GCMs **systematically underestimate** the increase of low cloud cover with surface cold advection & hence **systematically underestimate** the increase in low cloud cover in the NE Pacific in response to interannual poleward jet shifts.

Results depend somewhat on basin/season/sensor/time period.

Thank you!

AND THANKS, ESPECIALLY, TO BILL

Ensemble Mean **ISCCP** **PATMOS-x**



Response of NPAC Clouds to Jet Shift

CloudSat

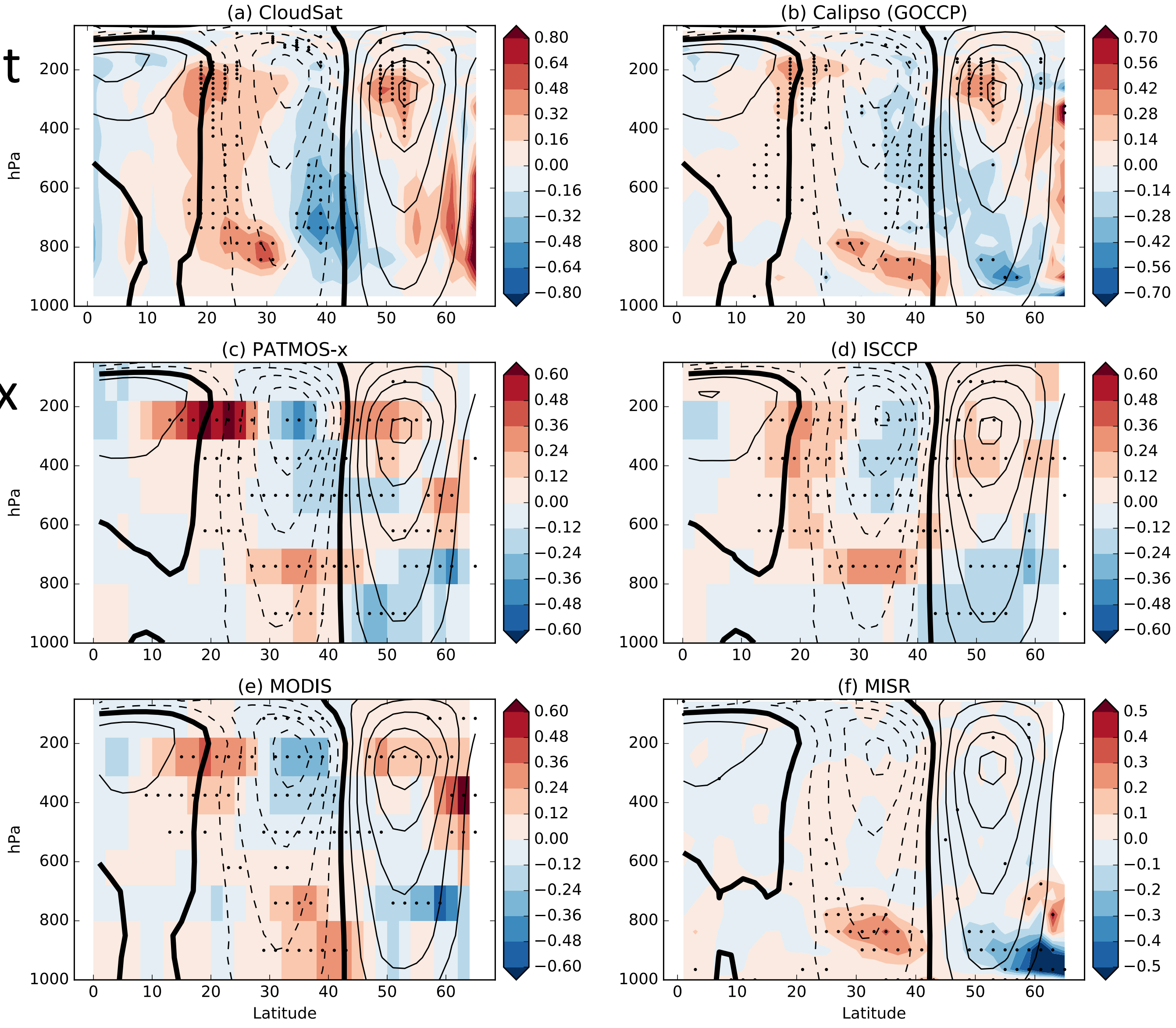
Calipso

PATMOS-x

ISCCP

MODIS

MISR



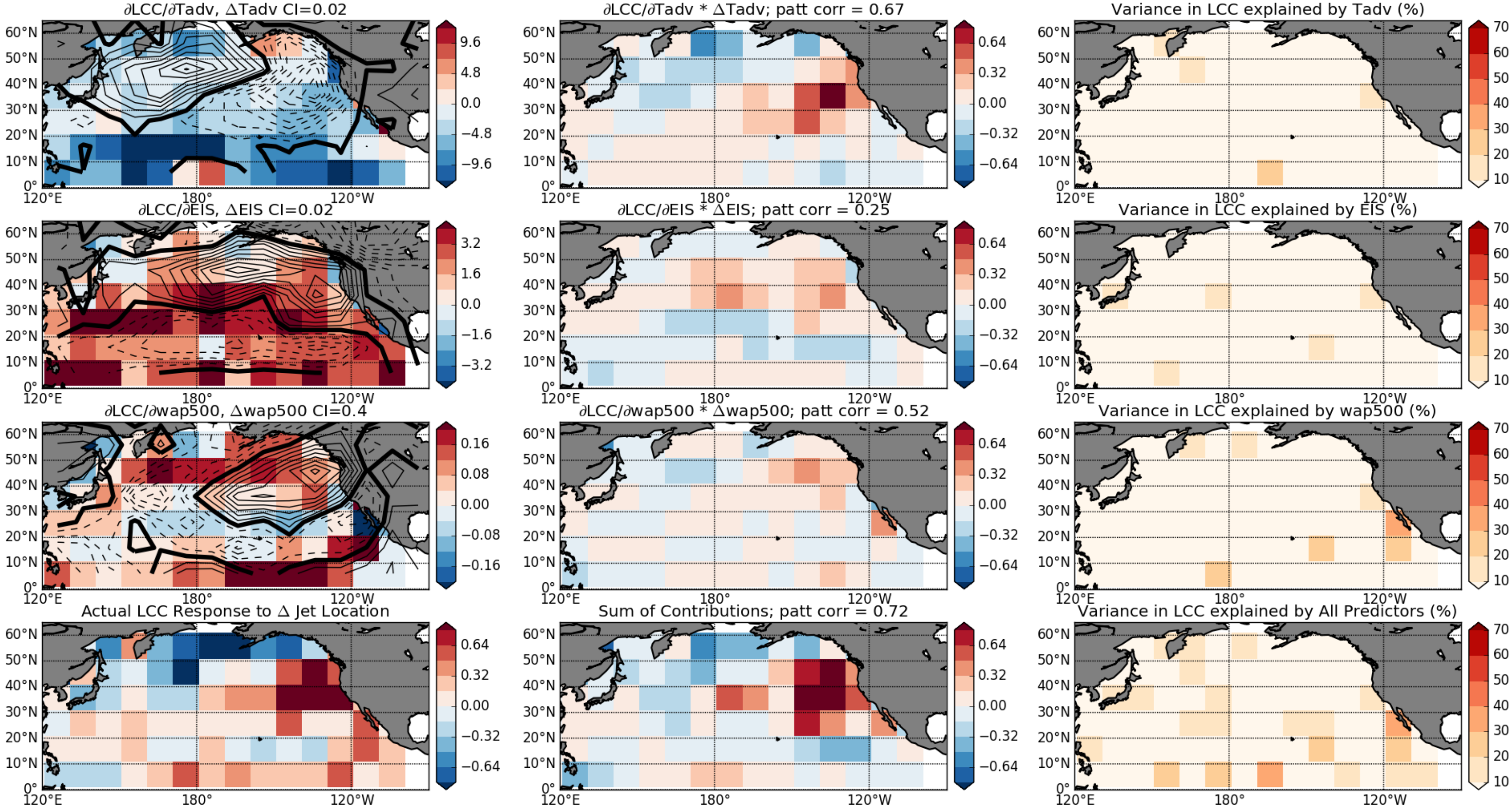
$$\Delta LCC = \left(\frac{\partial LCC}{\partial Tadv}\right)\Delta Tadv + \left(\frac{\partial LCC}{\partial EIS}\right)\Delta EIS + \left(\frac{\partial LCC}{\partial \omega_{500}}\right)\Delta \omega_{500}$$

$\partial LCC/\partial x$ | $(\partial LCC/\partial x)\Delta x$ | var(LCC) explained by x

Tadv

EIS

ω_{500}



∂LCC/∂Tadv, ΔTadv CI=0.02

∂LCC/∂Tadv * ΔTadv; patt corr = 0.67

Variance in LCC explained by Tadv (%)

∂LCC/∂EIS, ΔEIS CI=0.02

∂LCC/∂EIS * ΔEIS; patt corr = 0.25

Variance in LCC explained by EIS (%)

∂LCC/∂wap500, Δwap500 CI=0.4

∂LCC/∂wap500 * Δwap500; patt corr = 0.52

Variance in LCC explained by wap500 (%)

Actual LCC Response to Δ Jet Location

Sum of Contributions; patt corr = 0.72

Variance in LCC explained by All Predictors (%)

Calipso (Jun 2006 – Dec 2010)

$$\Delta LCC = \left(\frac{\partial LCC}{\partial Tadv}\right)\Delta Tadv + \left(\frac{\partial LCC}{\partial EIS}\right)\Delta EIS + \left(\frac{\partial LCC}{\partial \omega_{500}}\right)\Delta\omega_{500}$$

$\partial LCC/\partial x$

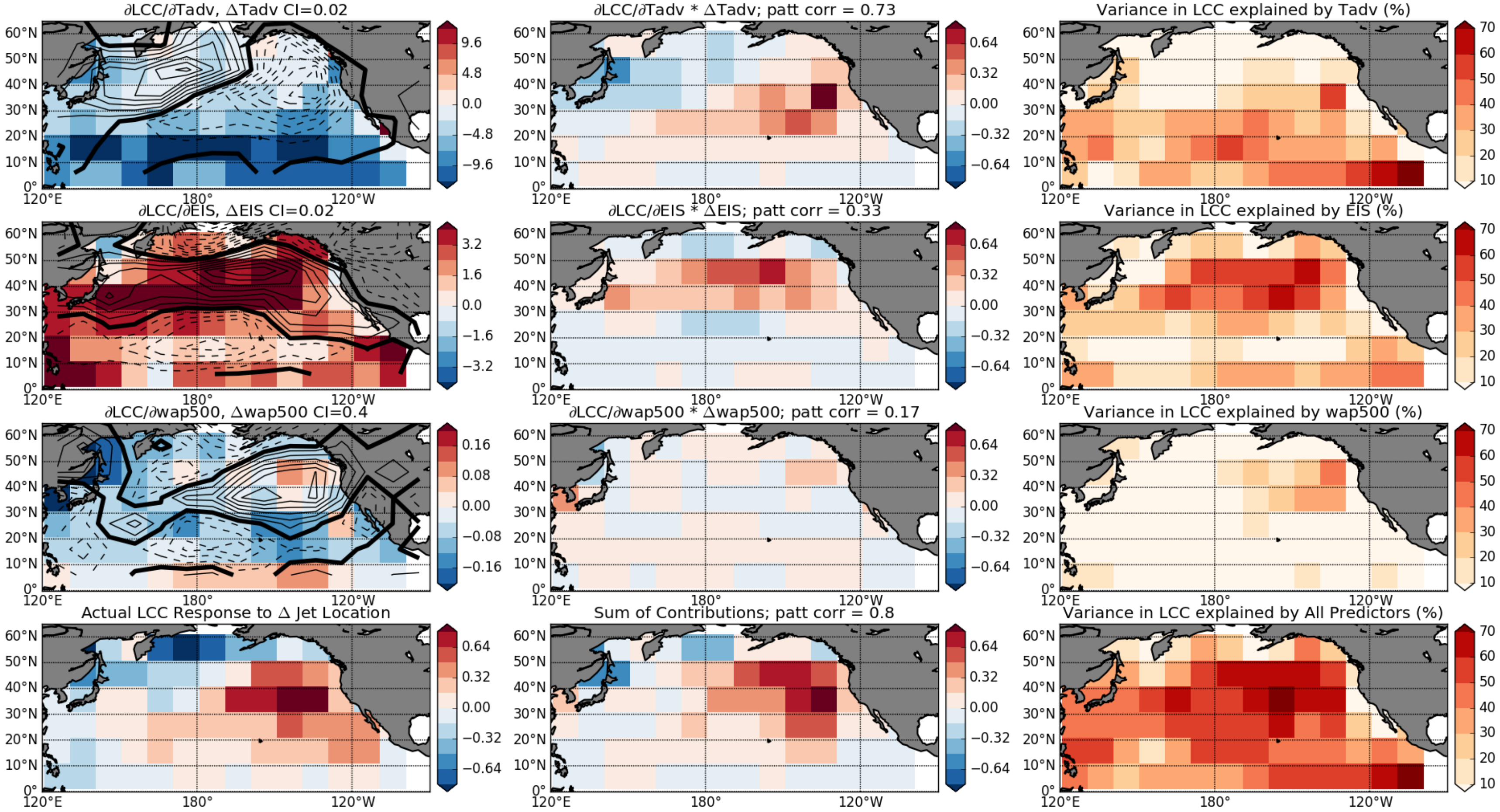
$(\partial LCC/\partial x)\Delta x$

var(LCC) explained by x

Tadv

EIS

ω_{500}



∂LCC/∂Tadv, ΔTadv CI=0.02

∂LCC/∂Tadv * ΔTadv; patt corr = 0.73

Variance in LCC explained by Tadv (%)

∂LCC/∂EIS, ΔEIS CI=0.02

∂LCC/∂EIS * ΔEIS; patt corr = 0.33

Variance in LCC explained by EIS (%)

∂LCC/∂wap500, Δwap500 CI=0.4

∂LCC/∂wap500 * Δwap500; patt corr = 0.17

Variance in LCC explained by wap500 (%)

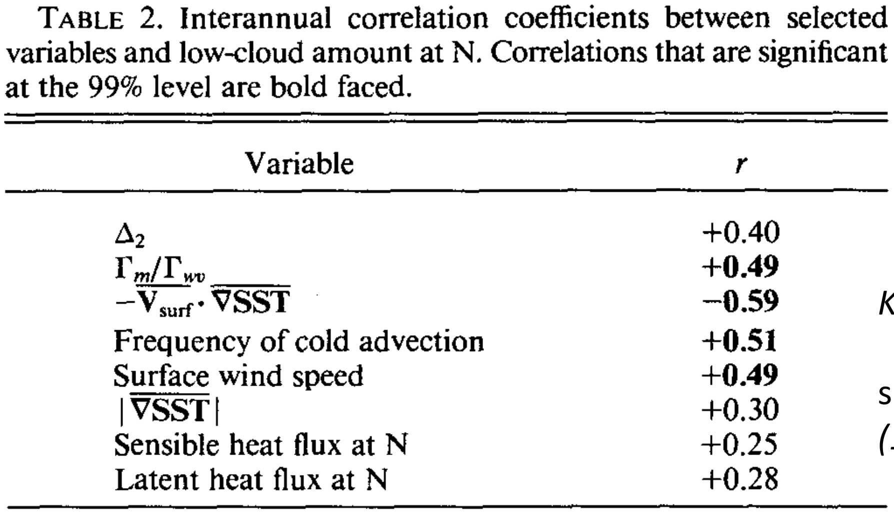
Actual LCC Response to Δ Jet Location

Sum of Contributions; patt corr = 0.8

Variance in LCC explained by All Predictors (%)

MODIS (Jul 2002 – Apr 2011)

Surface Cold Advection has been highlighted previously



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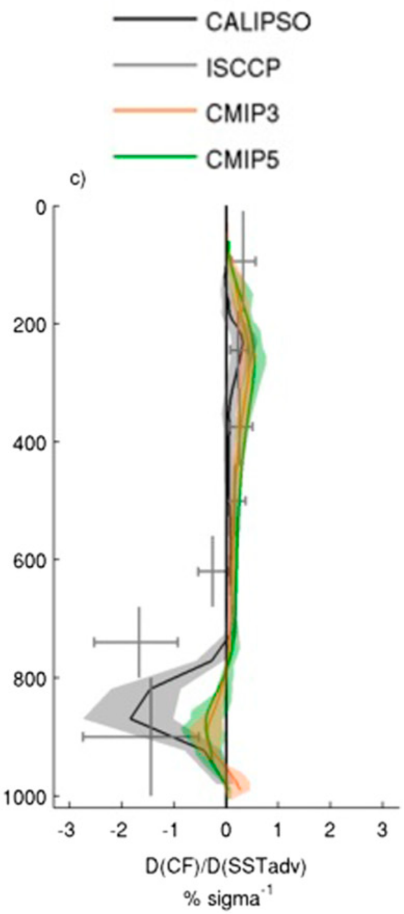
Weather Ship N: 30N 140W

Klein et al. (1995)

see also *Deser et al. (1993), Norris (1998a,b), Fletcher et al (2016)*



←Models do not handle this well.

"In contrast to observations, the multimodel means simulate no change in SW CRE when SSTadv is anomalously cold, physically consistent with producing too little increase in low-level CF for this condition. This indicates that the SW-CRE–SSTadv relationship is on average poorly simulated by the models."

-- *Myers and Norris (2015)*