Low-Level Cloud Variability Over the Equatorial Cold Tongue in Observations and GCMs

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Outline

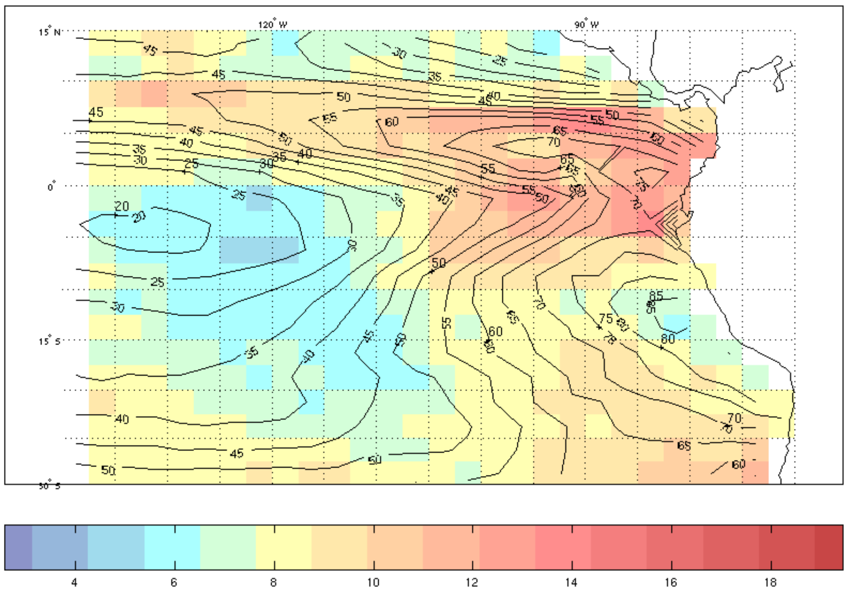
- Large interannual low-level cloud variability occurs over the equatorial cold tongue.
- Advection over an SST gradient is a dominant factor controlling low-level cloud (e.g., Deser et al. 1993).
- The advection effect opposes the SST/LTS effect on cloudiness over the southern side of the cold tongue.
- The differing influence of advection and SST/LTS on low-level cloudiness provides a good opportunity to evaluate GCM boundary layer cloud simulations.

Observational Data and Methods

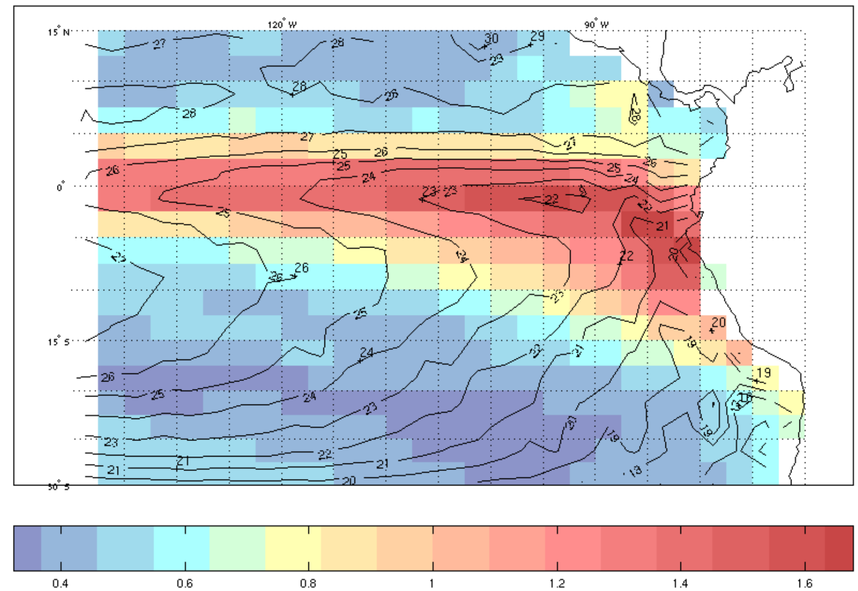
- Monthly mean daytime low-level cloud amount from ISCCP D2 adjusted for overlap by higher clouds
- Meteorological parameters from NCEP/NCAR reanalysis
- Ship synoptic reports from Hahn and Warren Extended Edited Cloud Report Archive (EECRA)
- Soundings from EPIC transects in 1999 and 2001

- Examine June-November cool season during 1983-2001
- Define “SST advection” as $-V_{1000} \cdot \nabla SST$

Climatology and Interannual Variability

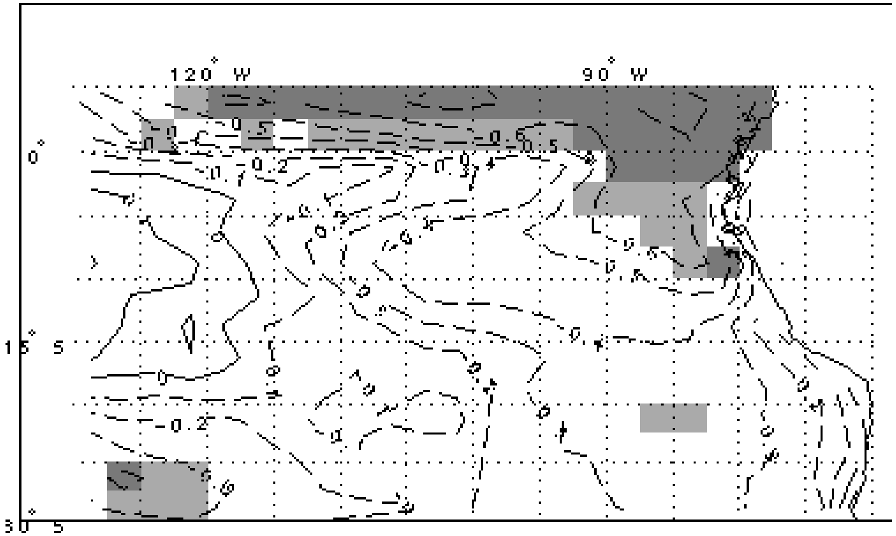


ISCCP low-level cloud amount mean (lines) and standard deviation of monthly anomalies (color)

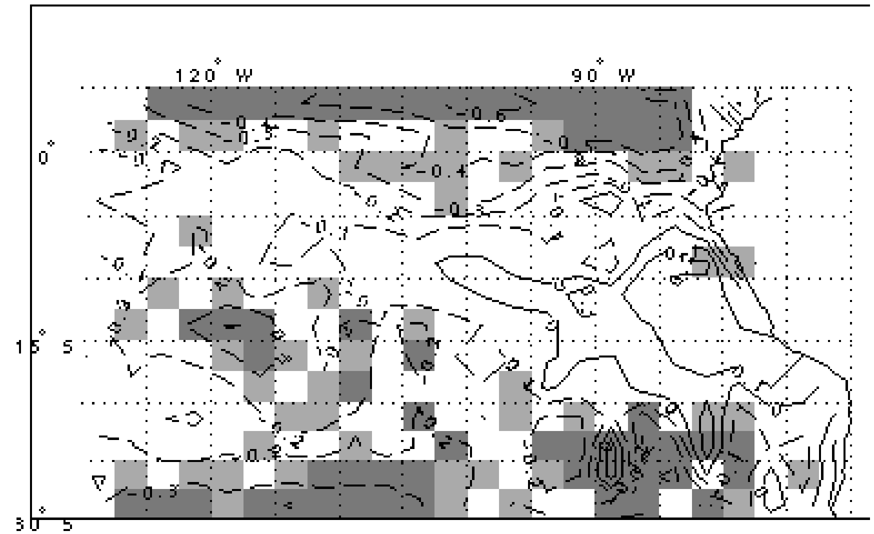


SST mean (lines) and standard deviation of monthly anomalies (color)

Relationships with Low-Level Cloud



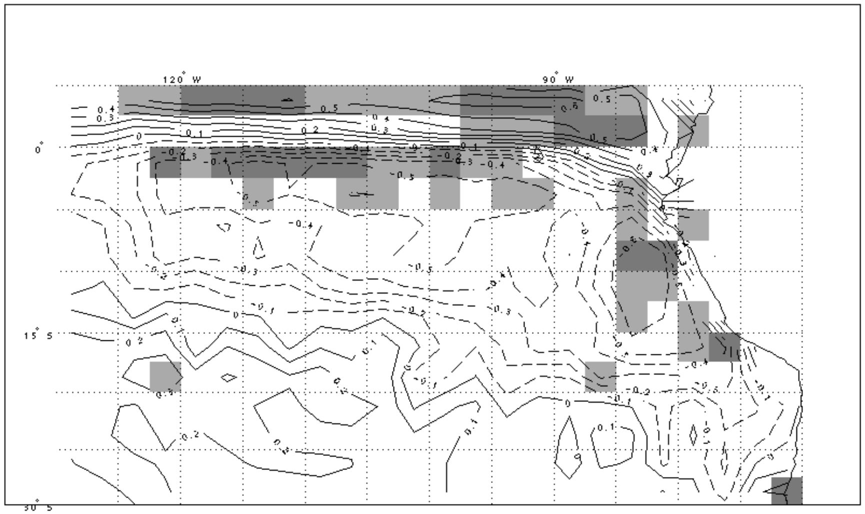
cloud and SST correlation

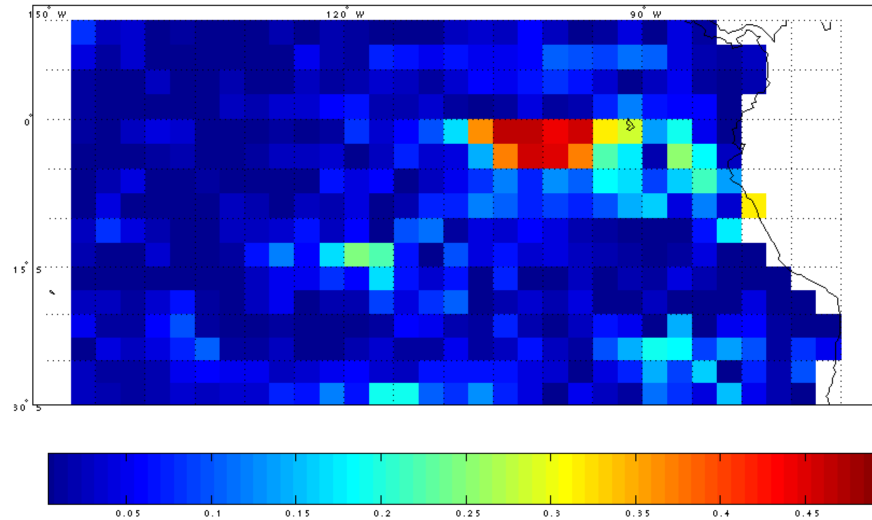


cloud and SST advection correlation

light gray = 95% significant
dark gray = 99% significant

Relationships with Low-Level Cloud



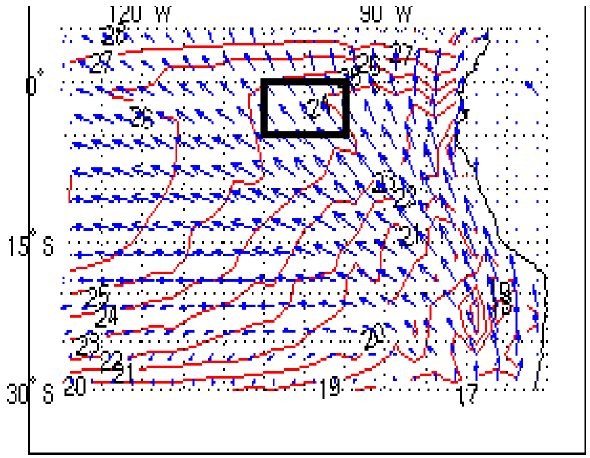


SST and SST advection correlation

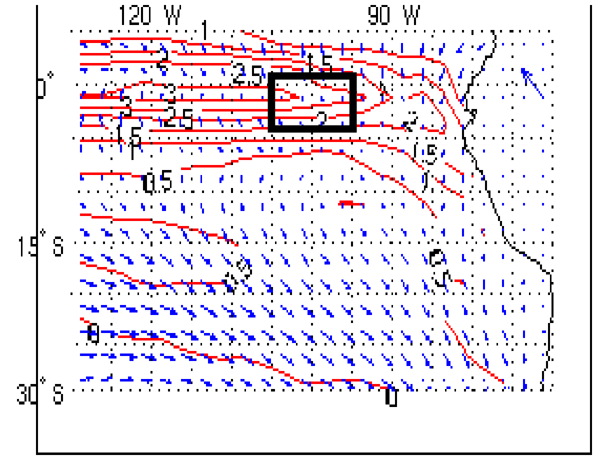
Additional variance explained by regressing on SST advection in addition to SST

Warm and Cold Advection Composites

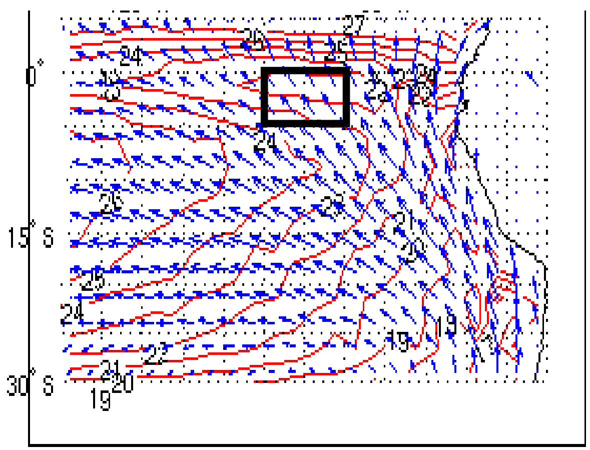
ANOMALOUSLY COLD ADVECTION



COLD MINUS WARM ANOMALY FIELDS



ANOMALOUSLY WARM ADVECTION



Plots are averaged over lower and upper terciles of monthly anomalies of SST advection in the designated region.

Warm and Cold Advection Zonal Means

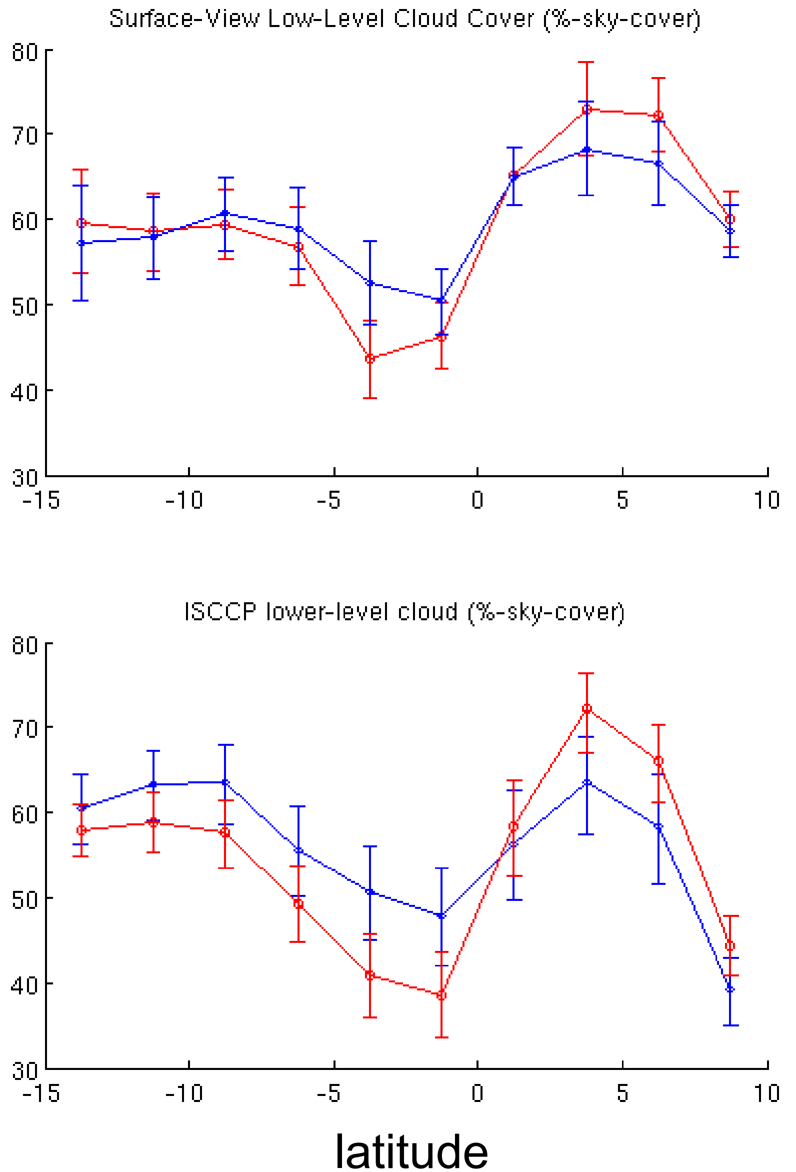
averaged over 95-105°W

red = warm anomalous SST advection tercile

blue = cold anomalous SST advection tercile

less cloud amount on southern side of cold tongue for warm SST advection

opposite response on northern side of cold tongue



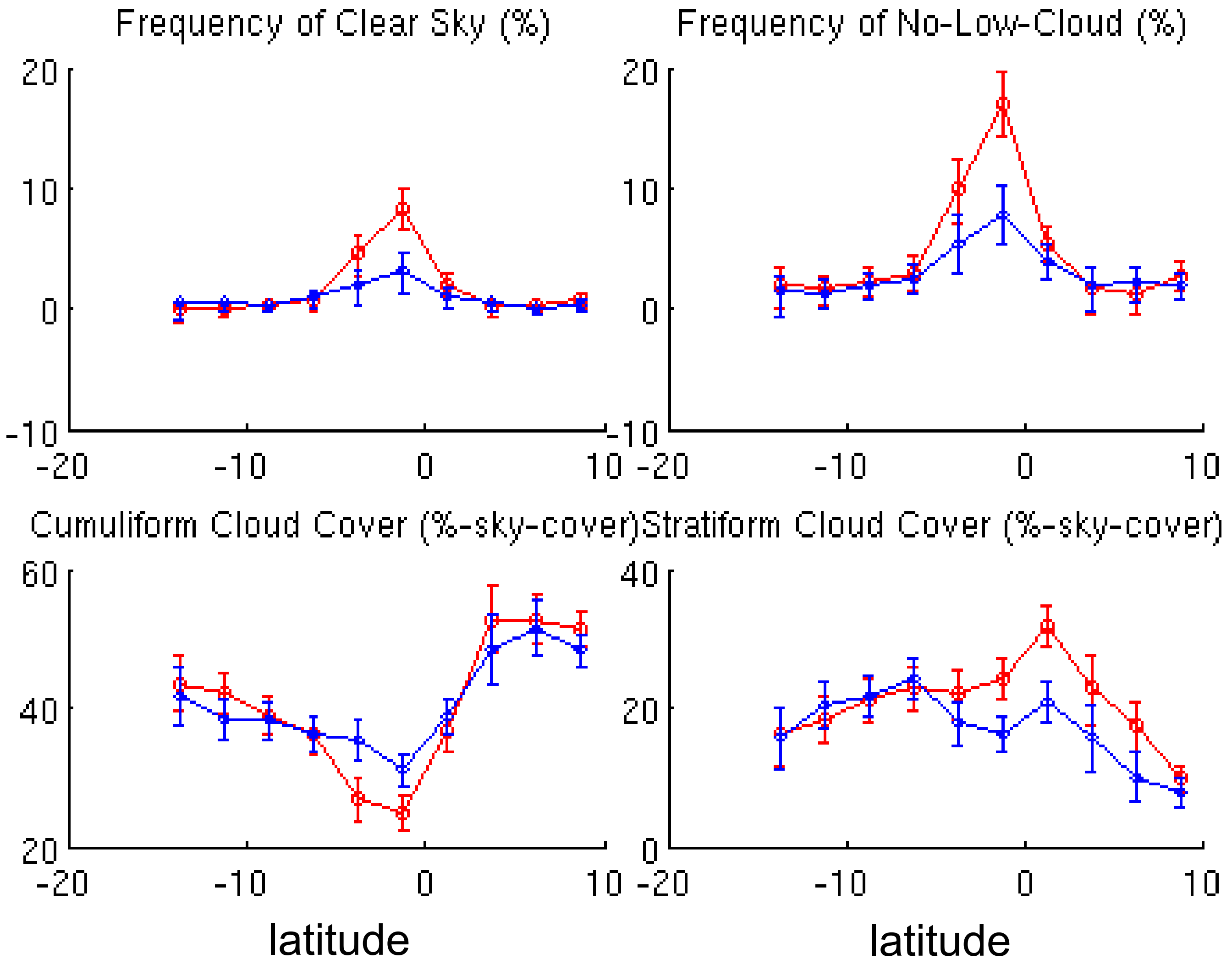
Warm and Cold Advection Zonal Means

on southern side of cold tongue, warm SST advection is related to:

more clear sky

more Sc, St

less Cu, Cu/Sc



Warm and Cold Advection Zonal Means

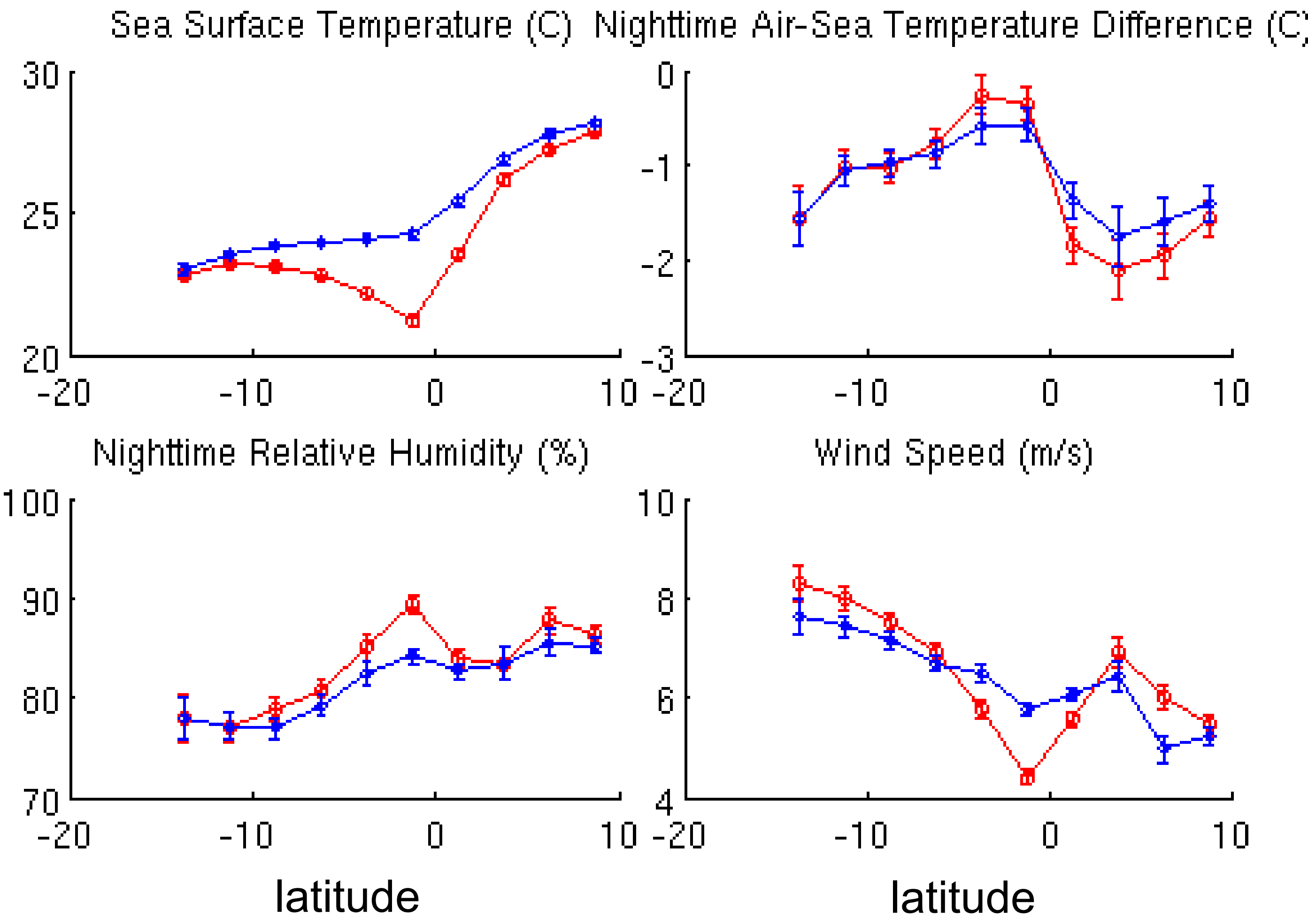
on southern side of cold tongue, warm SST advection is related to:

colder SST

higher RH_{sfc}

weaker $wind_{sfc}$

less negative air-sea T diff

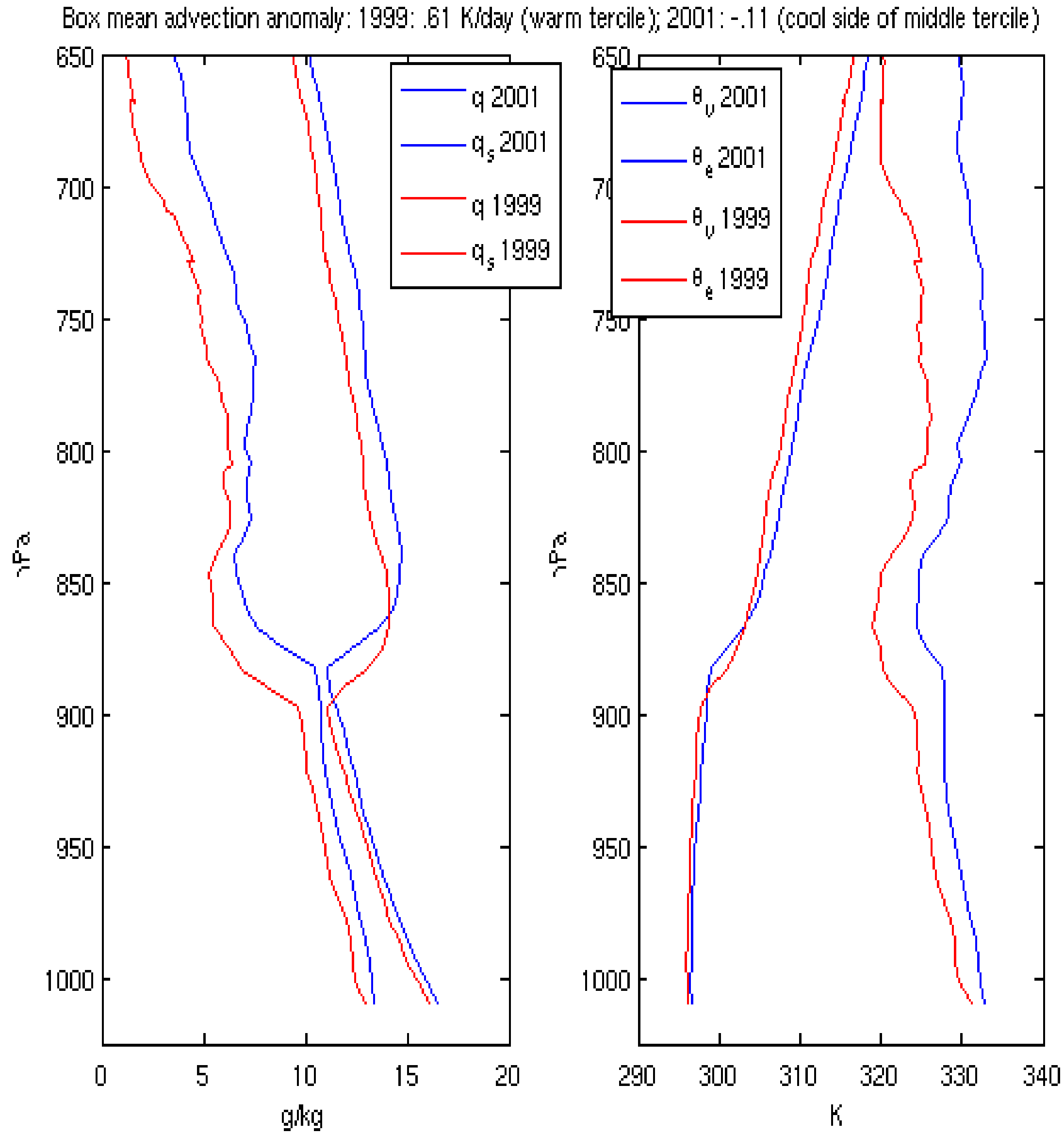


Warm and Cold Advection Soundings

on southern side of cold tongue, warm SST advection is related to:

shallower atmospheric boundary layer

lower RH near boundary layer top



Observational Summary

South of the Equator

strong cold tongue ➔ air flows over relatively colder water ➔ surface layer becomes stratified ➔ upward mixing of moisture is inhibited ➔ cloudiness is not sustained against subsidence and entrainment warming

weak cold tongue ➔ air flows over water of similar temperature ➔ surface layer not stratified ➔ upward mixing of moisture is not inhibited ➔ cloudiness is sustained against subsidence and entrainment warming

North of the Equator

strong cold tongue ➔ air flows over much warmer water ➔ surface layer becomes very destabilized ➔ much cloudiness is generated

weak cold tongue ➔ air flows over warmer water ➔ surface layer becomes destabilized ➔ some cloudiness is generated

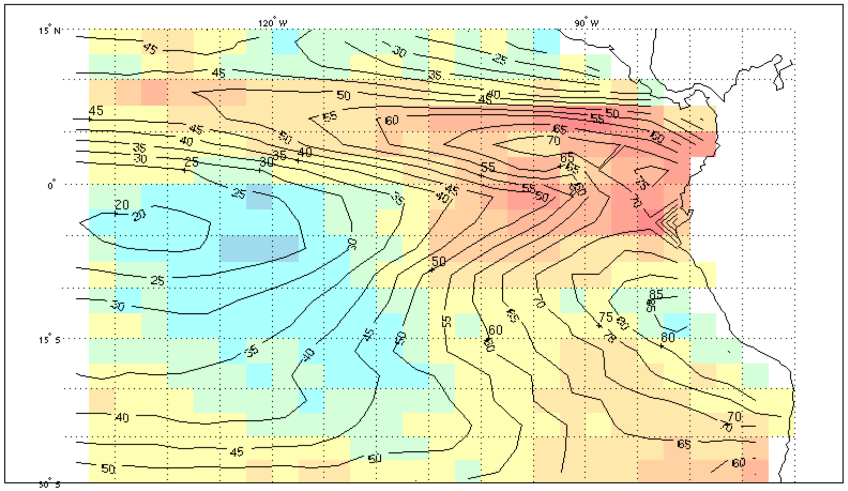
Evaluation of GCM output

- Atmosphere-only AMIP runs with prescribed historical SST for NCAR CAM3 and GFDL AM2
- Coupled atmosphere-ocean runs from NCAR CCSM3 and GFDL CM2.0, CM2.1

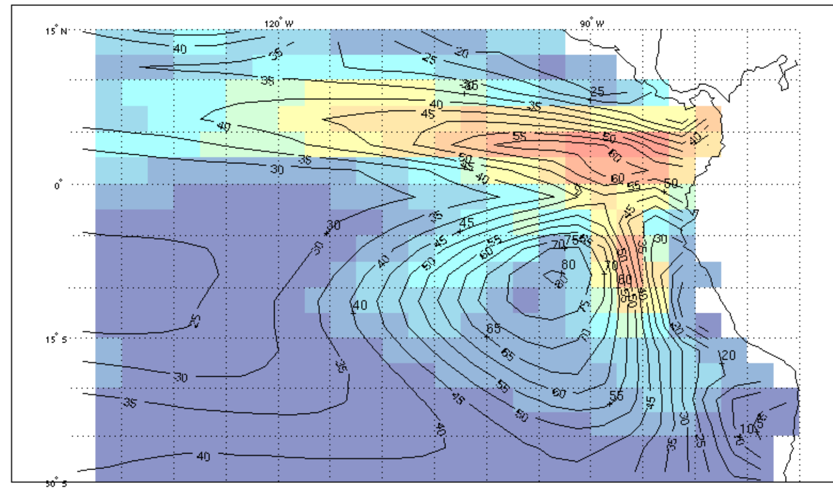
- Coupled model output is difficult to evaluate since cloud, SST, and wind distributions substantially differ from the observed distributions

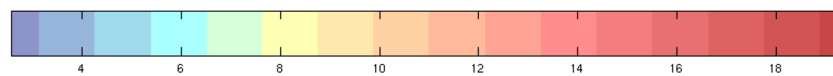
Climatology and Interannual Variability

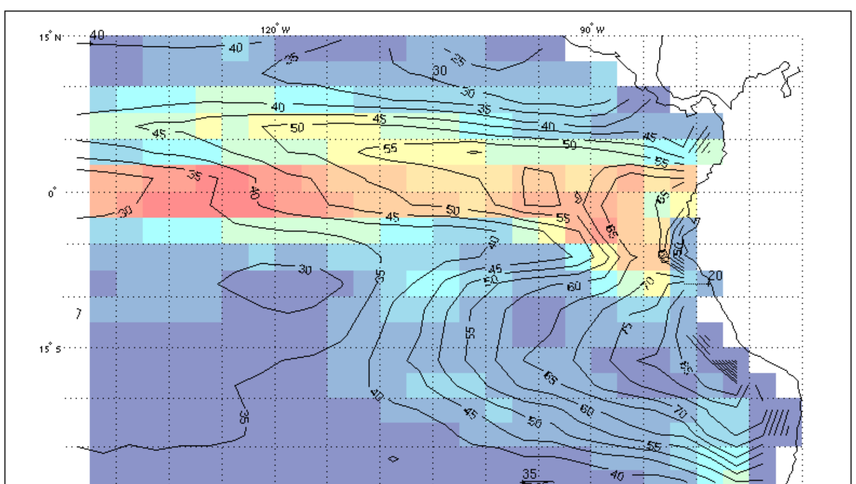
Observed



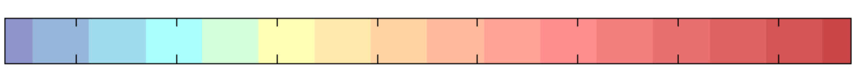
GFDL AM2





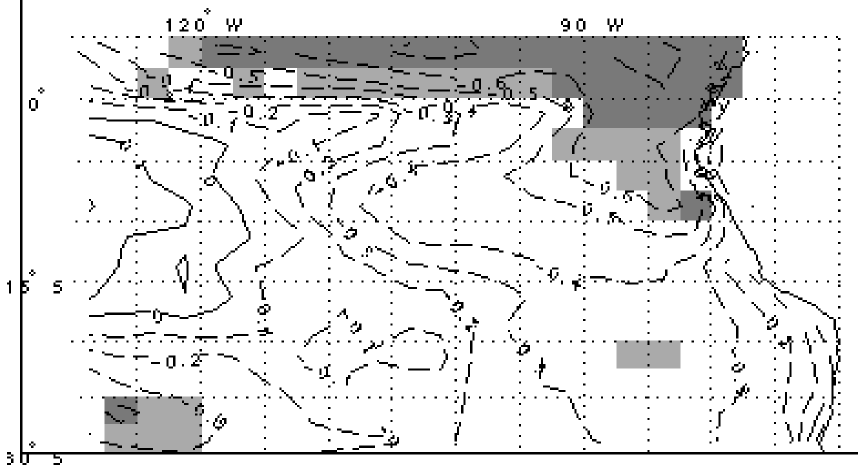


NCAR CAM3

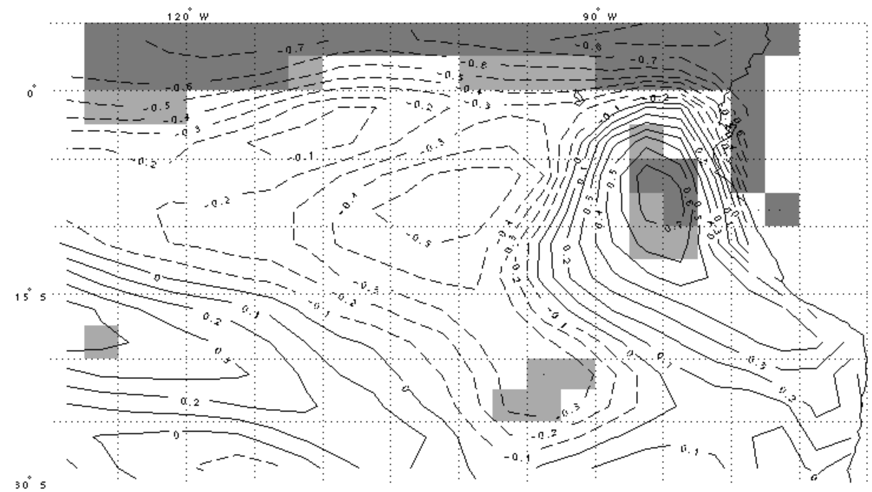


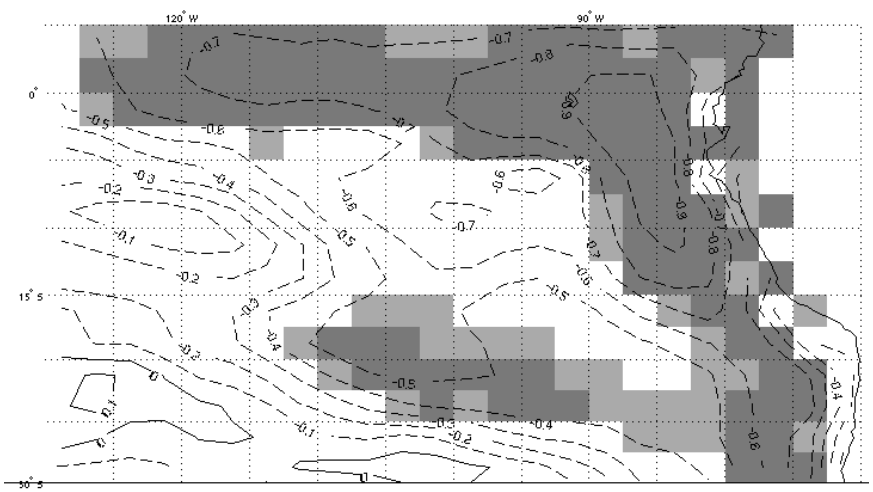
Low-Level Cloud – SST Correlation

Observed



GFDL AM2

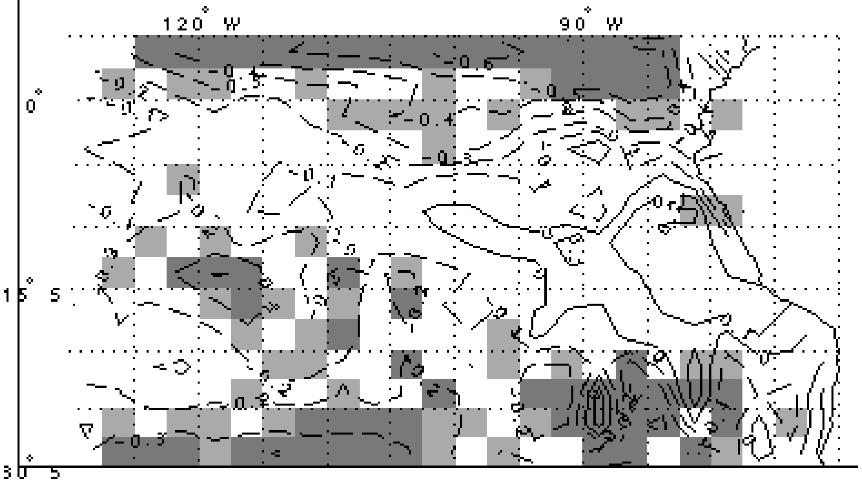




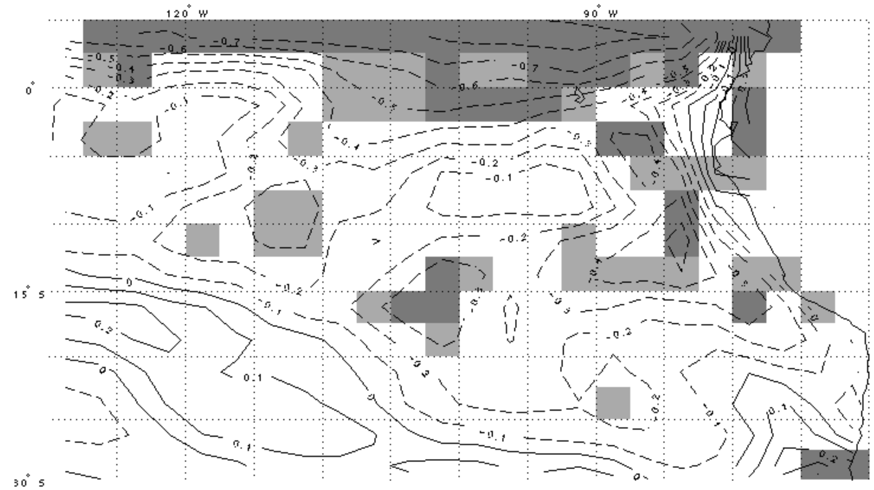
NCAR CAM3

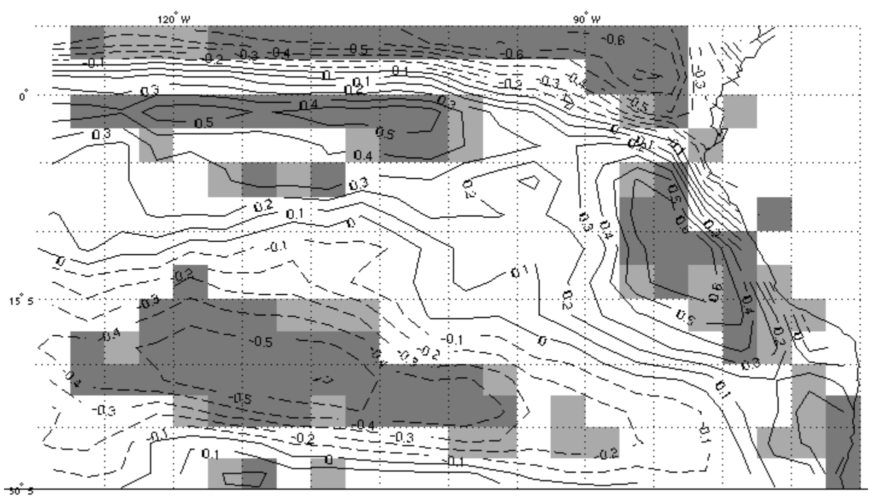
Cloud - SST Advection Correlation

Observed



GFDL AM2

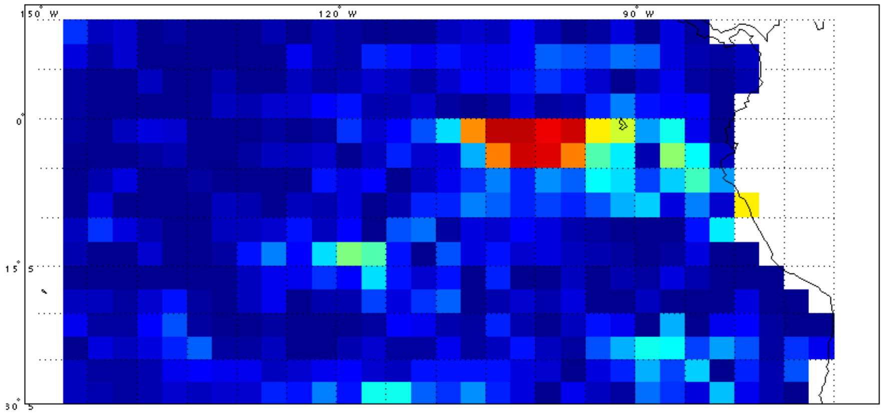




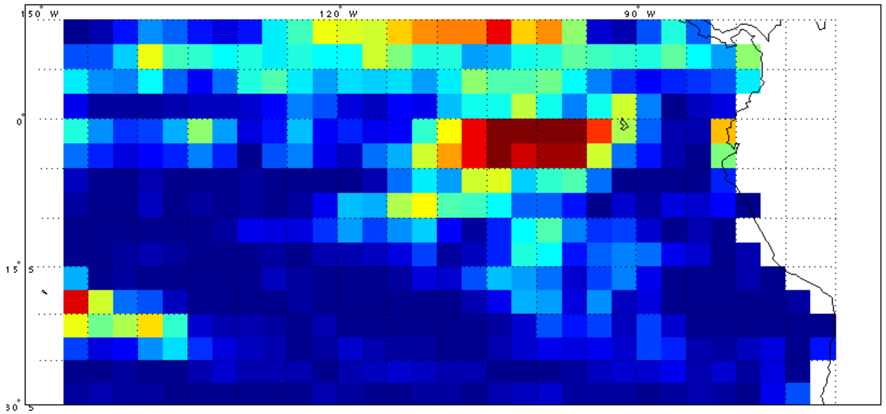
NCAR CAM3

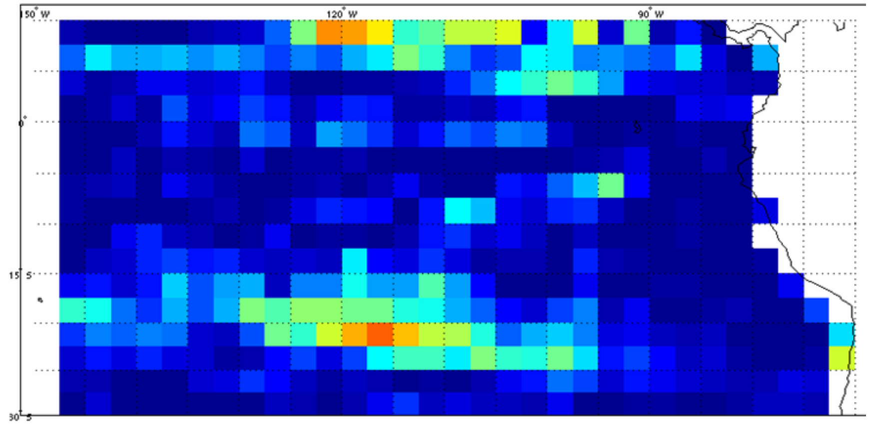
Additional Variance due to SST Advection

Observed



GFDL AM2





NCAR CAM3

Dataset and Longitude range		Mean temperature advection anomaly (K/day)			Mean low cloud anomaly (%)	
		Anomalously cool advection S of Eq	Anomalously warm advection S of Eq		Anomalously cool advection S of Eq	Anomalously warm advection S of Eq
ISCCP + reanalysis, 110-90W	Eq-5N	0.76	-0.53		-3.9	0.8
	5S-Eq	-0.59	0.56		3.3	-5.1
GFDL AM2 110-90W	Eq-5N	0.65	-0.44		-4.6	1.1
	5S-Eq	-0.37	0.35		1.8	-3.4
NCAR CAM3 110-90W	Eq-5N	0.88	-0.62		-5.4	3.7
	5S-Eq	-0.47	0.45		-5.5	4.3
CCSM3 130-110W	Eq-5N	0.54	-0.52		11.1	-14.2
	5S-Eq	-1.32	1.40		10.5	-11.9
GFDL CM2.0 105-125W	Eq-6N	0.13	-0.05		5.6	-5.7
	6S-Eq	-0.51	0.43		-1.1	1.3
GFDL CM2.1 130-90W	Eq-6N	0.23	-0.22		16.4	-11.0
	6S-Eq	-0.92	0.77		3.2	-2.2
CCSM3 110-90W	Eq-5N	0.18	-0.13		2.8	-4.3
	5S-Eq	-0.19	0.18		2.6	-4.0
GFDL CM2.0 110-90W	Eq-6N	0.00	0.02		2.3	-2.7
	6S-Eq	-0.21	0.18		0.5	0.3
GFDL CM2.1 110-90W	Eq-6N	-0.19	0.44		7.5	-10.1
	6S-Eq	-0.29	0.28		2.8	-3.0

Conclusions

- The GFDL AM2 reproduces the observed cloud-advection relationship when provided with prescribed historical SST, but the NCAR CAM3 does not.
- The GFDL and NCAR coupled atmosphere-ocean models do not reproduce the observed cloud-advection relationship, perhaps because the simulated eastern equatorial Pacific is too unrealistic.
- The cloud-advection relationship on the southern side of the cold tongue is a good diagnostic for GCM boundary layer cloudiness since it opposes the SST/LTS-cloud relationship.