# Multidecadal Tropical Cloud Variability in Observations and GCMs

Joel Norris
Scripps Institution of Oceanography

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# Observations

- upper-level (mid+high) cloud cover obtained from surface synoptic cloud reports in EECRA/COADS
- wind components from COADS corrected for linear increase in tropical mean scalar wind speed
- wind components estimated from Smith and Reynolds reconstructed SLP
- Hulme precipitation (continents and islands only)
- Kaplan SST

*all data are averaged to seasonal 5°$\times$10° means*

# NCAR CCSM3 Simulations

- 10-member AMIP ensemble (historical SST boundary condition with and without historical radiative forcing)
- 5-member IPCC “$20^{th}$ century” ensemble (coupled model with historical radiative forcing)
- 520-year control run (coupled model with 1990 radiative forcing)

*high-level cloud amount and lowest layer wind components are converted to seasonal 5°×10° means*

# GFDL CM2.0 and CM2.1 Simulations

- 3-member IPCC "20th century" ensemble for CM2.0 and for CM2.1
- 480-year control run (1860 radiative forcing) for CM2.0 and for CM2.1

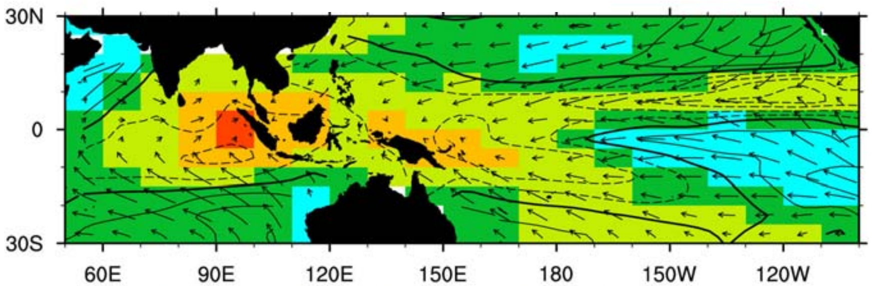
*high-level cloud amount and lowest layer wind components are converted to seasonal 5°$\times$10° means*

# CM2.0 and CM2.1 Differences

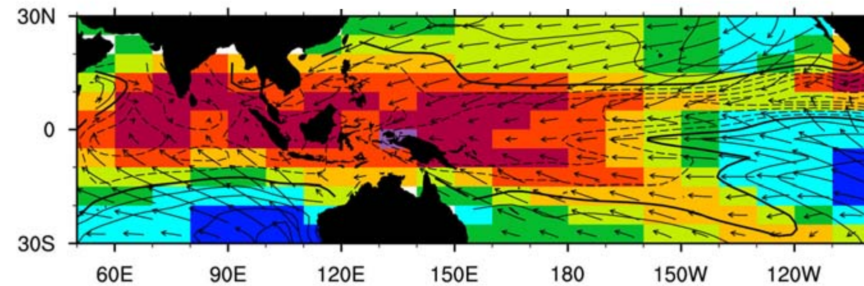
- Atmospheric dynamical core is B-grid for CM2.0 and finite volume for CM2.1
- CM2.1 has a 25% smaller cloud droplet radius threshold for raindrop formation
- CM2.1 has an 18% faster rate of cloud erosion in convective conditions

# Cloud Climatologies

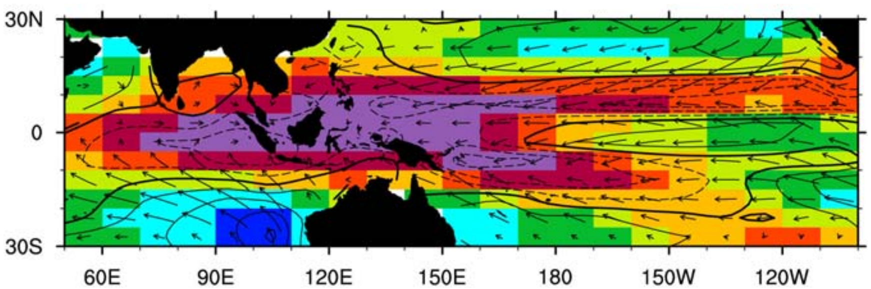
Observations



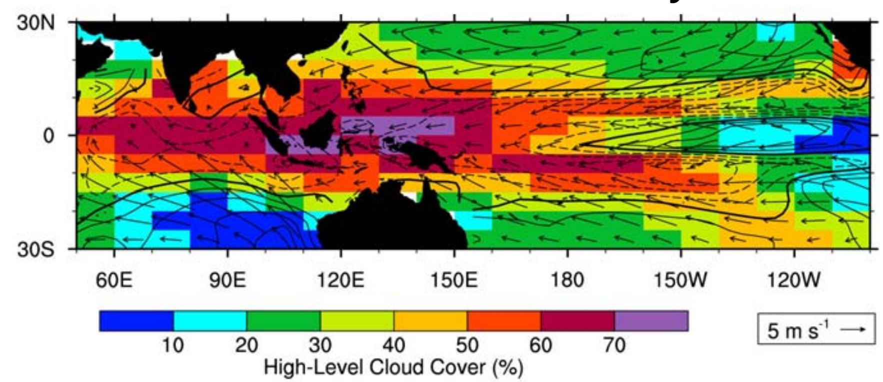

CCSM3 AMIP



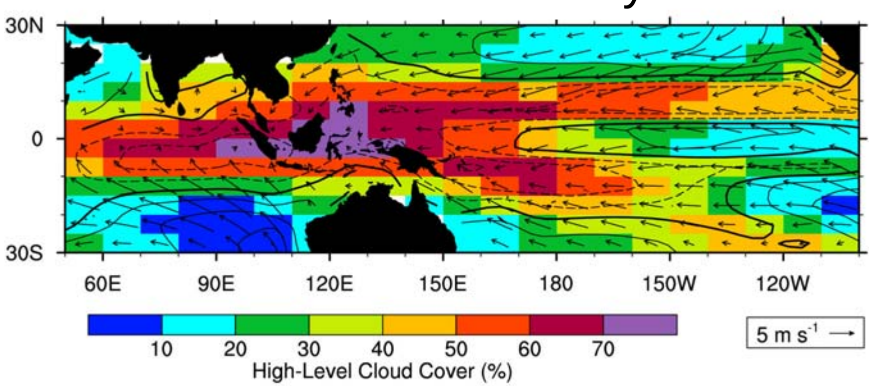

CM2.0 20th Century




CCSM3 20th Century




CM2.1 20th Century




color = cloud cover
arrows = near-surface wind
lines = divergence (every $1 \times 10^{-6}$ $s^{-1}$)

# Analysis Method

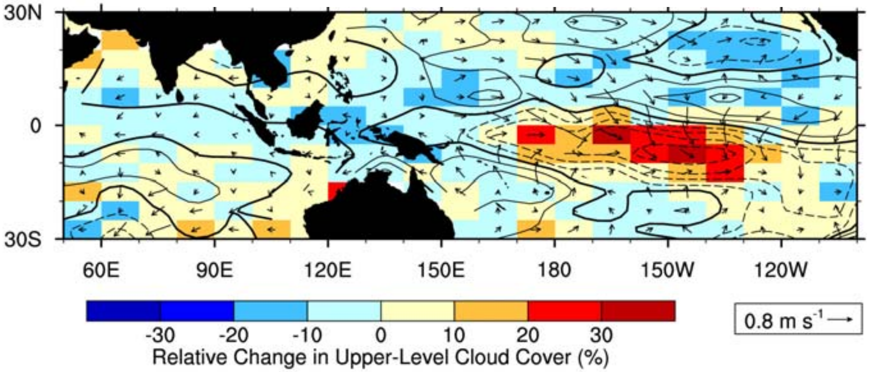
- Relative changes in cloud cover are compared since climatological cloud cover substantially differs between observations and simulations.
- The 1957-1976 average is subtracted from the 1977-1996 average for observations, AMIP, and IPCC 20$^{th}$ century simulations.

  *Do the GCMs reproduce the observed pattern and magnitude of change?*
- Running differences between 20-year running averages are calculated for the control runs.

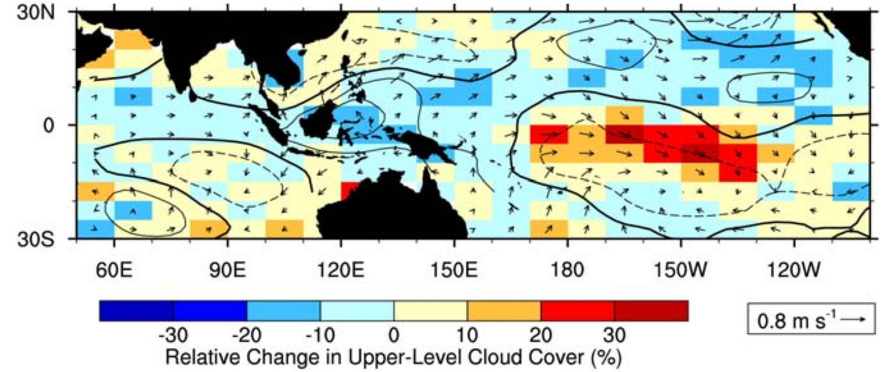
  *Is natural variability in the GCMs as large as the observed change?*

# Observed Interdecadal Change

Cloud and COADS Divergence

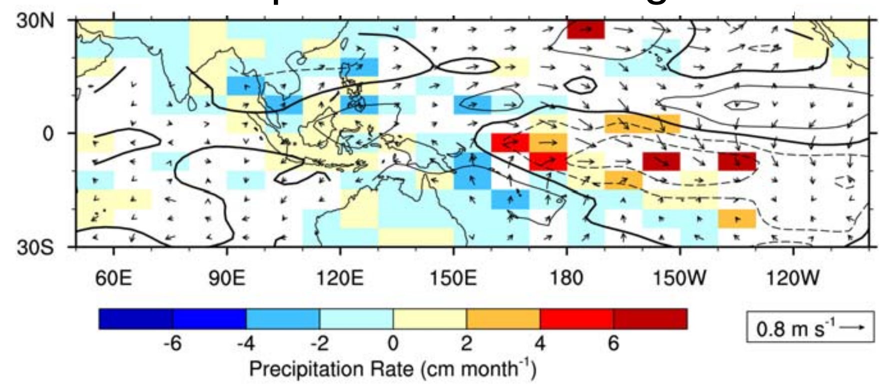



Cloud and SLP-derived Divergence



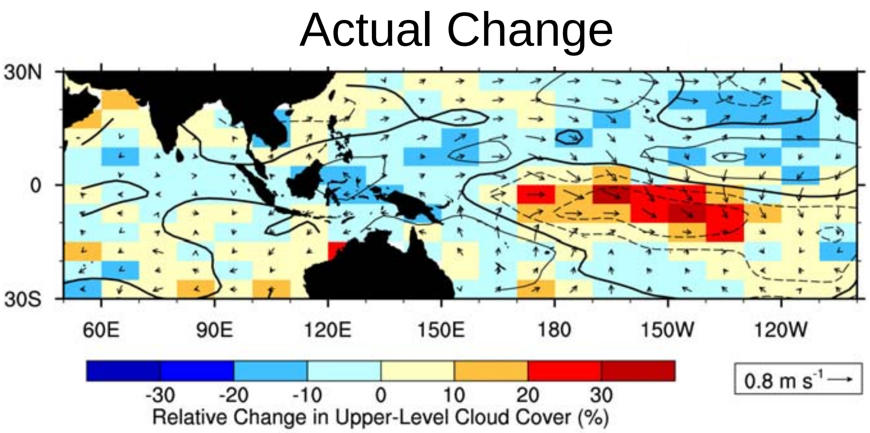

color = cloud cover or precipitation rate
arrows = near-surface wind
lines = divergence (every $0.15\times10^{-6}\ s^{-1}$)

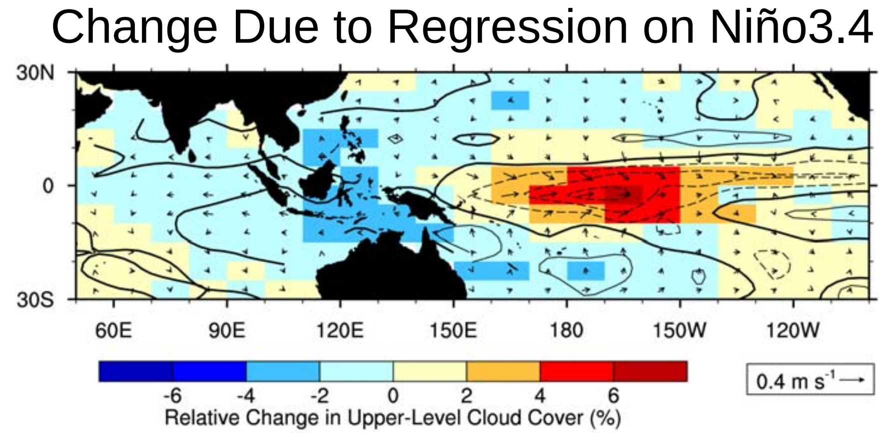
Precipitation and Divergence




*upper-level cloud cover and precipitation have generally increased where there is more convergence and decreased where there is more divergence*

# Not Merely Due to Interannual El Niño



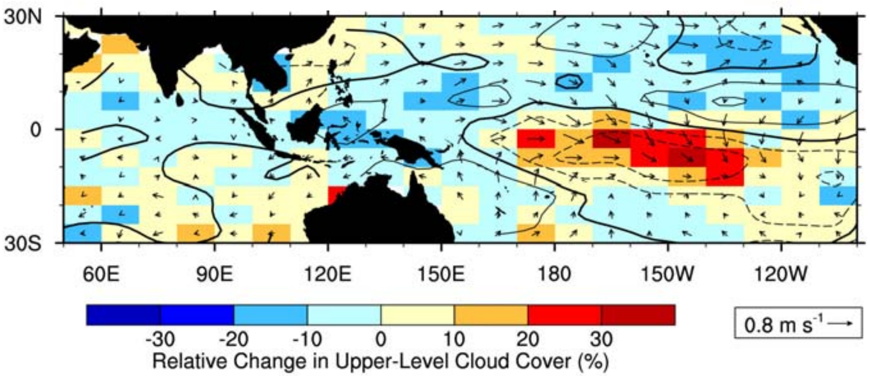

color = cloud cover (every 10%)
arrows = near-surface wind (0.8 m $s^{-1}$)
lines = divergence (every $0.15\times10^{-6}$ $s^{-1}$)

color = cloud cover (every 2%)
arrows = near-surface wind (0.4 m $s^{-1}$)
lines = divergence (every $0.08\times10^{-6}$ $s^{-1}$)

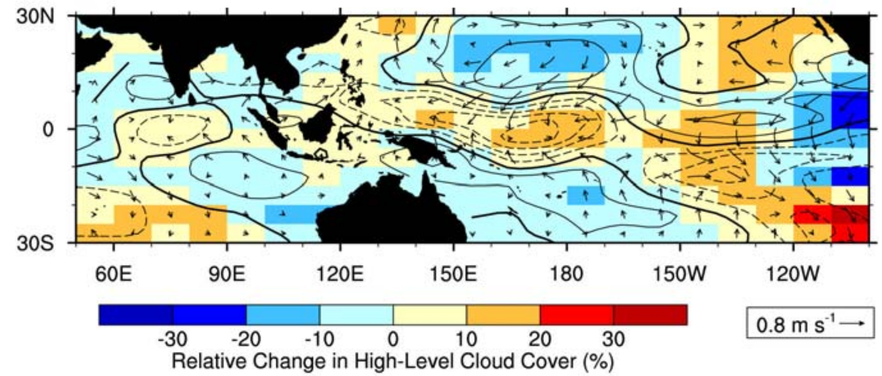
*the cloud cover change accounted for by a linear relationship to interannual El Niño variations has a similar pattern but much smaller magnitude than the interdecadal change*

# AMIP Comparison

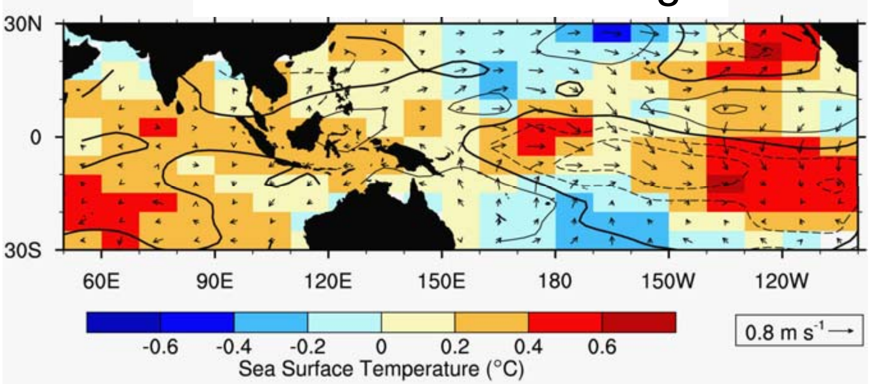
Observed Cloud Change



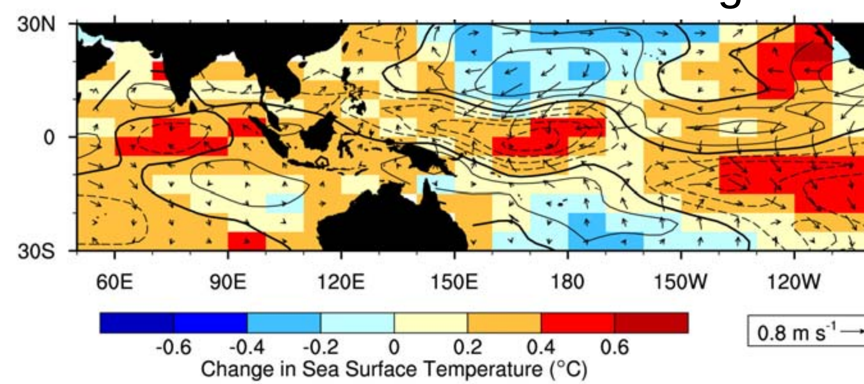

CCSM3 AMIP Cloud Change




Observed SST Change



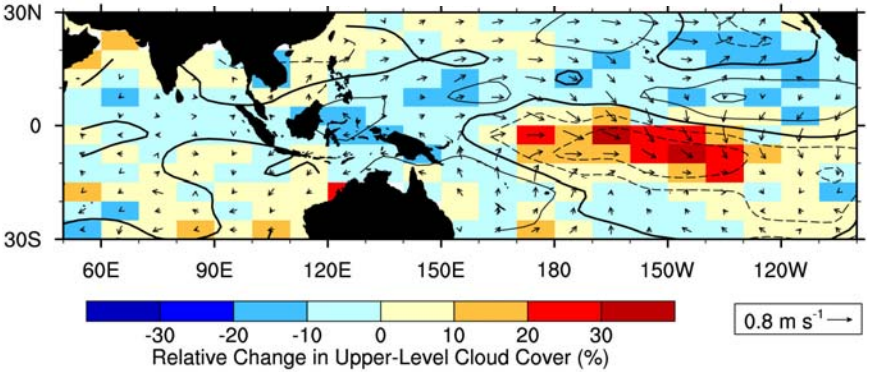

CCSM3 AMIP SST Change



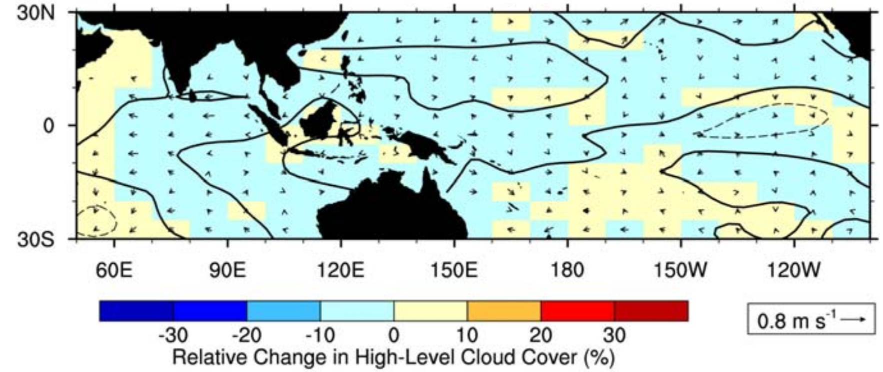

*upper-level cloud cover changes in AMIP runs are weaker than observed changes and have a generally similar pattern, albeit more localized on SST anomalies*

# 20th Century Run Comparison

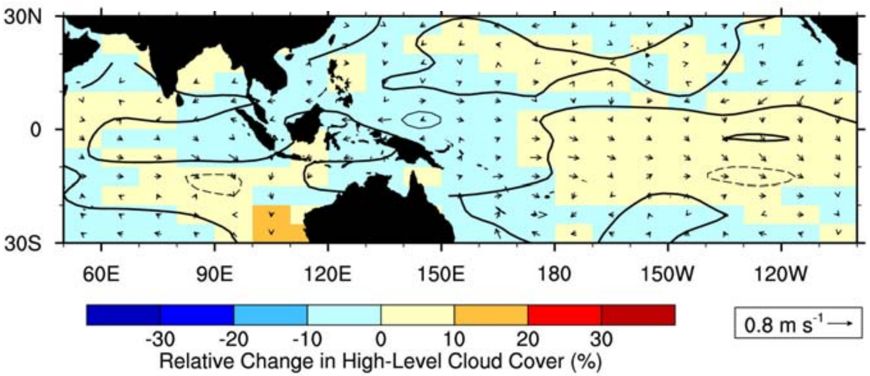
Observed Cloud Change



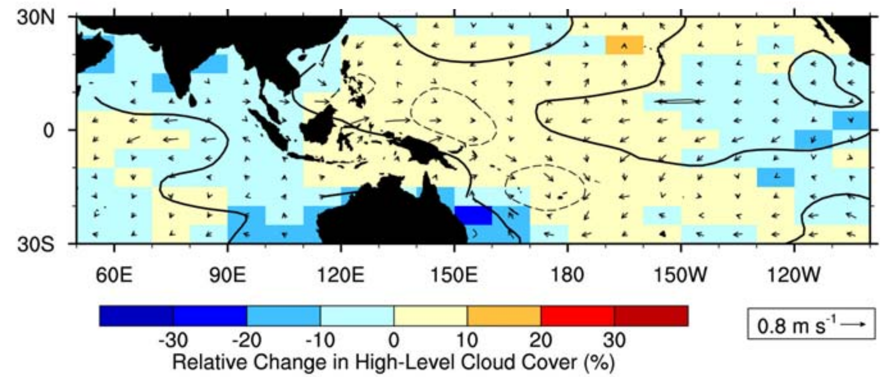

CCSM3 Cloud Change




CM2.0 Cloud Change



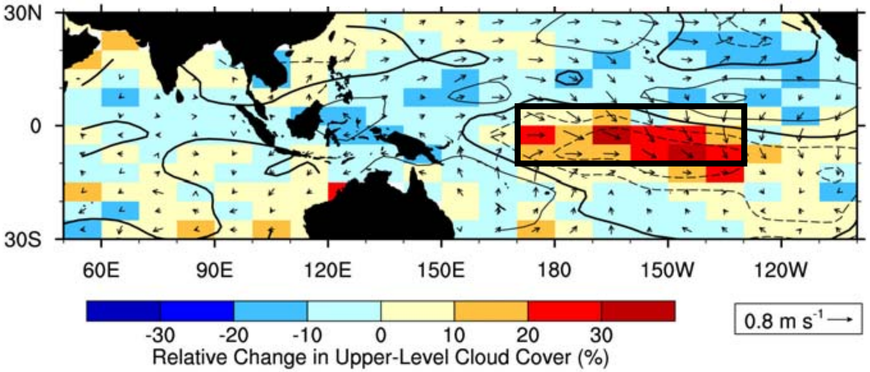

CM2.1 Cloud Change



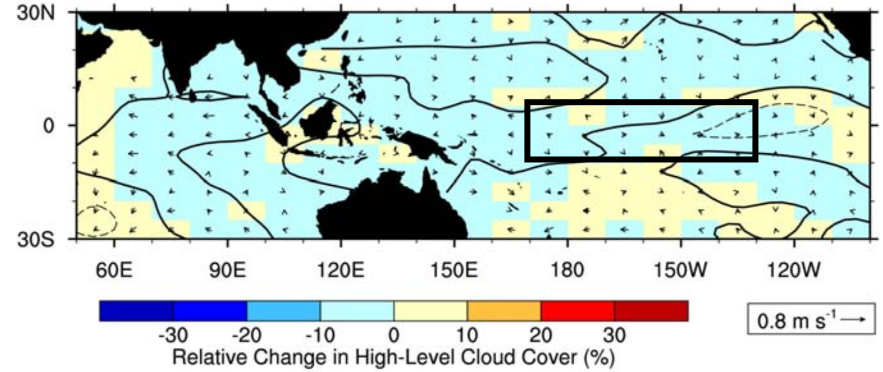

*upper-level cloud cover changes in the 20th Century runs do not resemble the observed changes because the evolution of the coupled atmosphere-ocean model is different from what happened in the real world*

# Averaging Region for Control Comparison

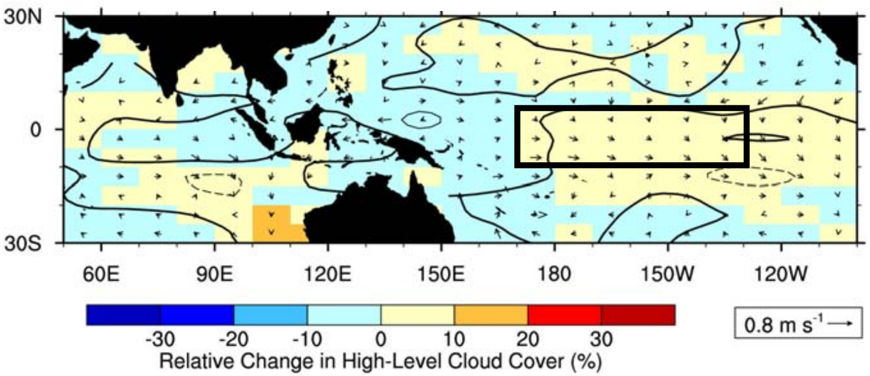
Observed Cloud Change



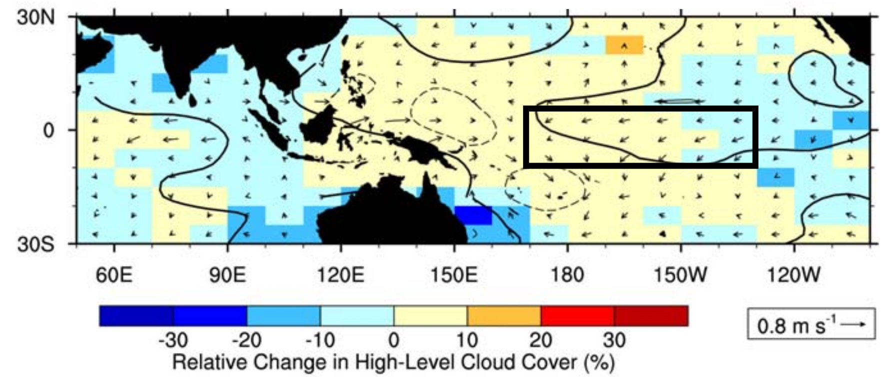

CCSM3 Cloud Change




CM2.0 Cloud Change



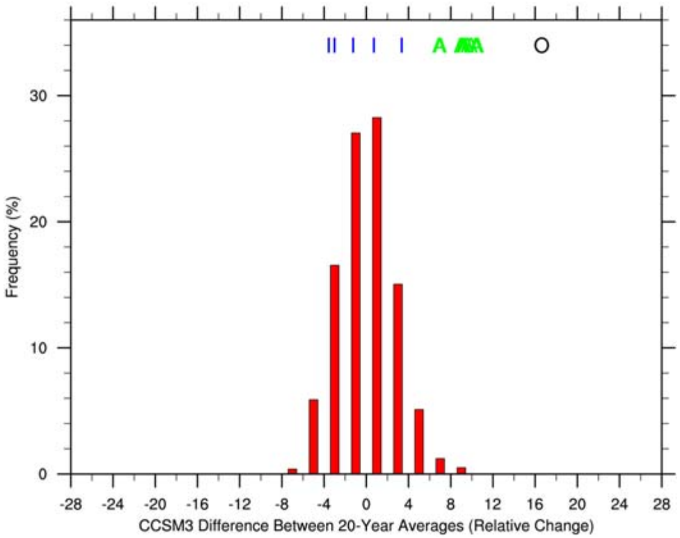

CM2.1 Cloud Change



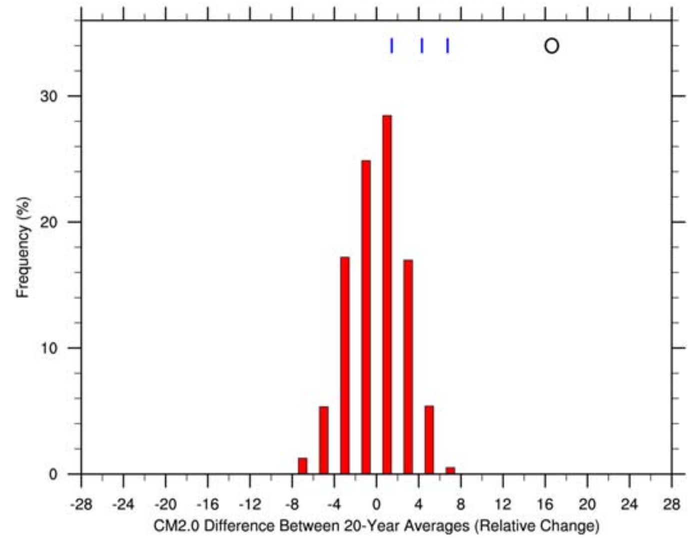

*the frequency distribution of interdecadal cloud change in the coupled control runs will be examined in the specified region to determine if it is comparable to the observed upper-level cloud change*

# Central Eq. Pacific Control Comparison

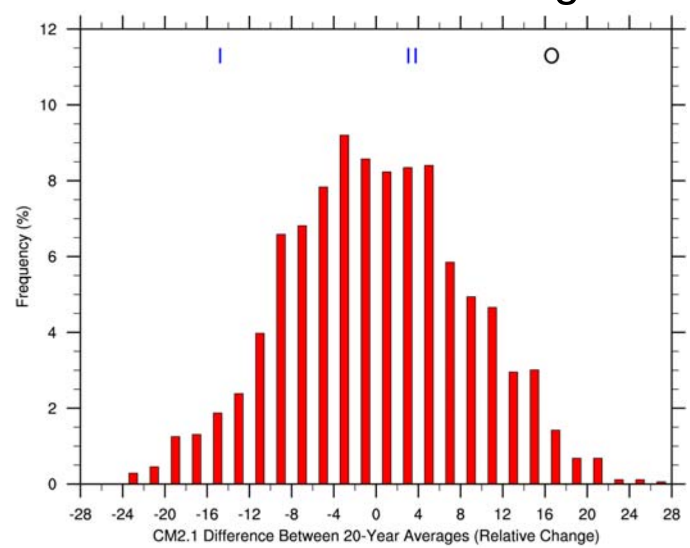
CCSM3 Cloud Change




CM2.0 Cloud Change




CM2.1 Cloud Change




red = control run histogram

blue = IPCC 20th Century runs

green = AMIP runs

black = observed

# Conclusions

- Between 1957-1976 and 1977-1996…

  *observed upper-level cloud cover increased over the central equatorial Pacific*

  *decreased over the adjacent subtropics*

  *decreased over the western tropical Pacific*
- Physically consistent changes occur in precipitation and surface atmospheric circulation.
- These changes are much larger than the expected linear response to the observed increase in Niño3.4 SST.

# Conclusions

- CCSM3 AMIP simulations largely reproduce the observed central Pacific upper-level cloud changes, albeit with relatively weaker magnitude.
- CCSM3, CM2.0, and CM2.1 IPCC 20$^{th}$ Century runs do not reproduce the observed cloud changes.
- Interdecadal cloud variability in the CCSM3 and CM2.0 control runs is much weaker than the observed interdecadal cloud change.
- Interdecadal cloud variability in the CM2.1 control run has more realistic amplitude *(but interannual SST variability is too high)*.

# Conclusions

- The CCSM3, CM2.0, and CM2.1 20$^{th}$ Century simulations (if believable) suggest that the observed tropical cloud changes are not a climate response to anthropogenic forcing.
- Multidecadal tropical cloud variability is too weak in CCSM3 and CM2.0.