Externally forced patterns of multidecadal cloud change in observations and models

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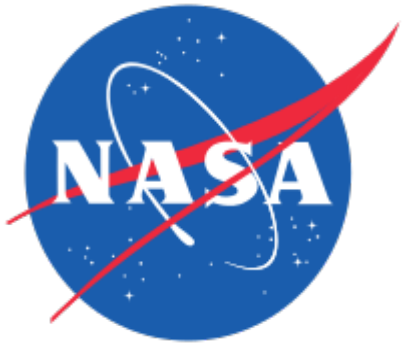
A Little Help from My Friends

Collaborators:

- Bob Allen (UCR)
- Amato Evan (SIO)
- Mark Zelinka and Steve Klein (LLNL)
- Michael Olheiser (Winona State)

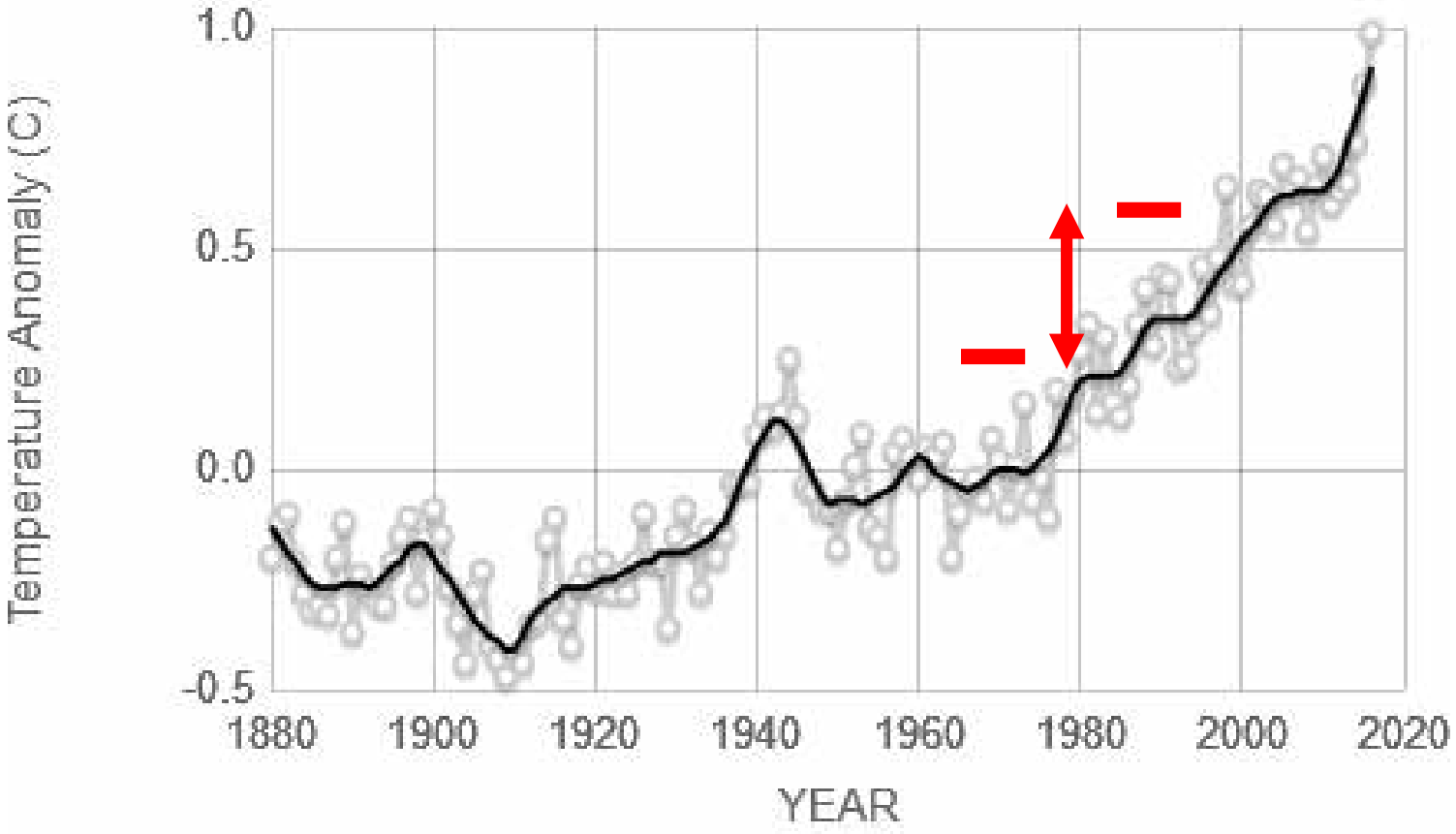
Funders:



Substantial Global Warming from 1980s to 2000s

What is the cloud change pattern during the satellite era?

Is the cloud change pattern partially a response to anthropogenic forcing?

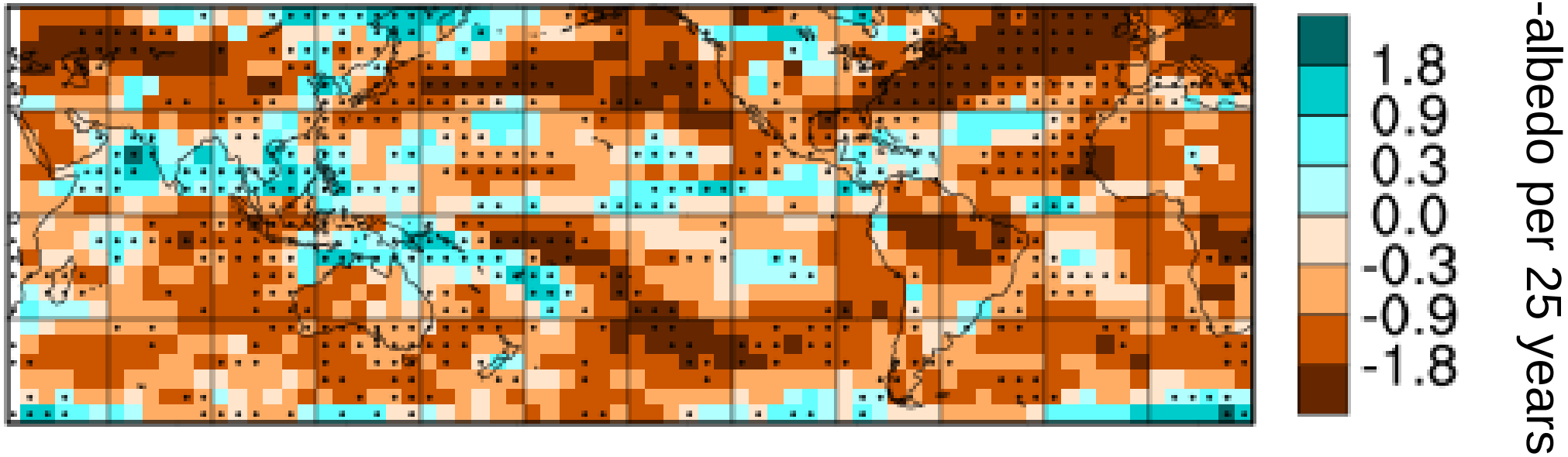


Source: climate.nasa.gov

CERES-ERBS Albedo Change Pattern

Subtract ERBS 1985-1989 mean from CERES 2002-2014 mean

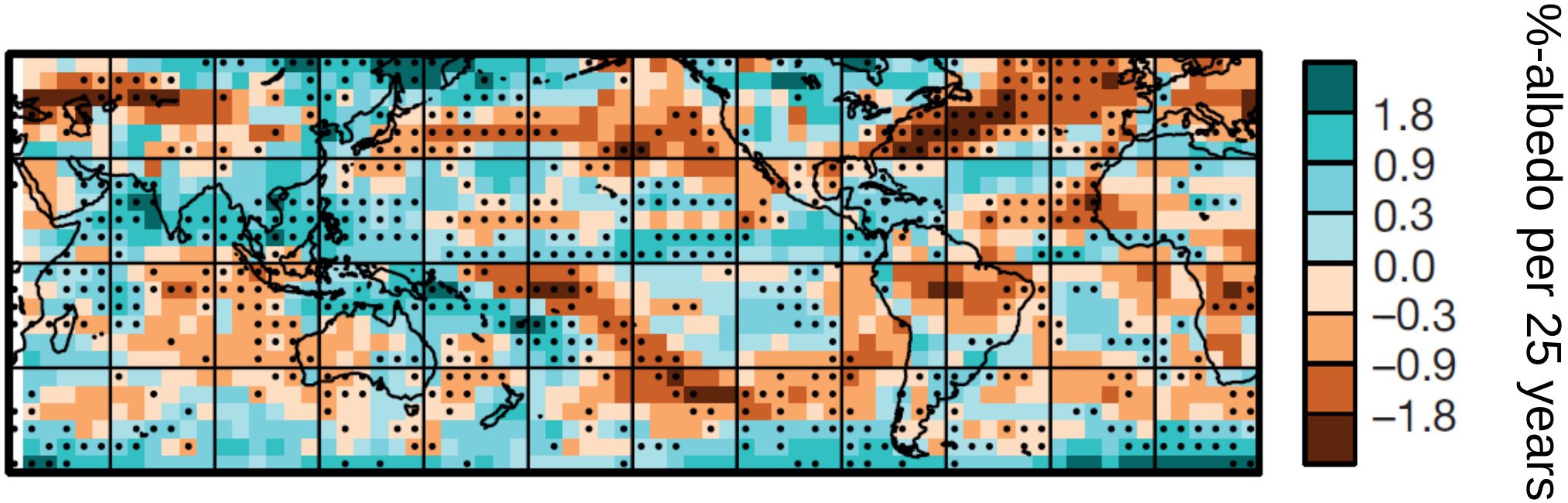
Decreasing albedo over most of globe due to lack of calibration between satellites



CERES-ERBS Albedo Change Pattern

Subtract ERBS 1985-1989 mean from CERES 2002-2014 mean

But first multiply ERBS albedo values by constant factor so ERBS global mean albedo matches CERES global mean albedo

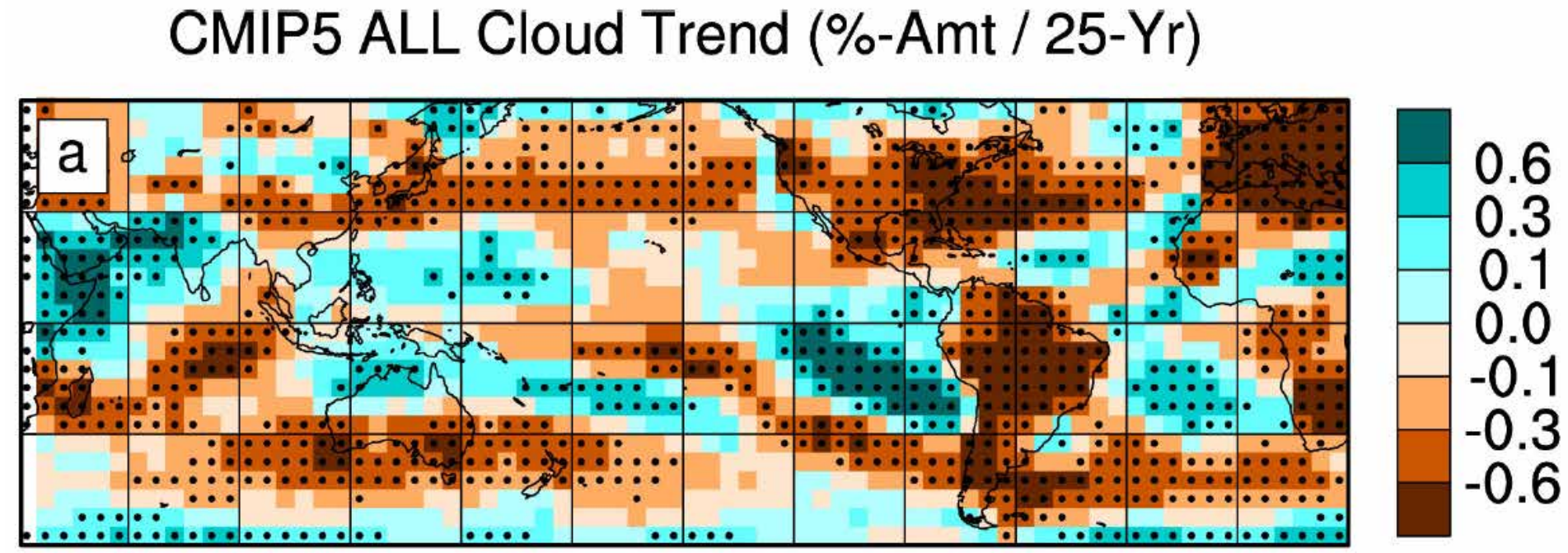


Correction of Satellite Data

- All multidecadal satellite cloud and albedo records suffer from lack of calibration and other artifacts
- These may be empirically removed by assuming no change in global mean cloud and albedo (Norris and Evan 2015)
- The correction procedure has small impact on the regional pattern of cloud and albedo change

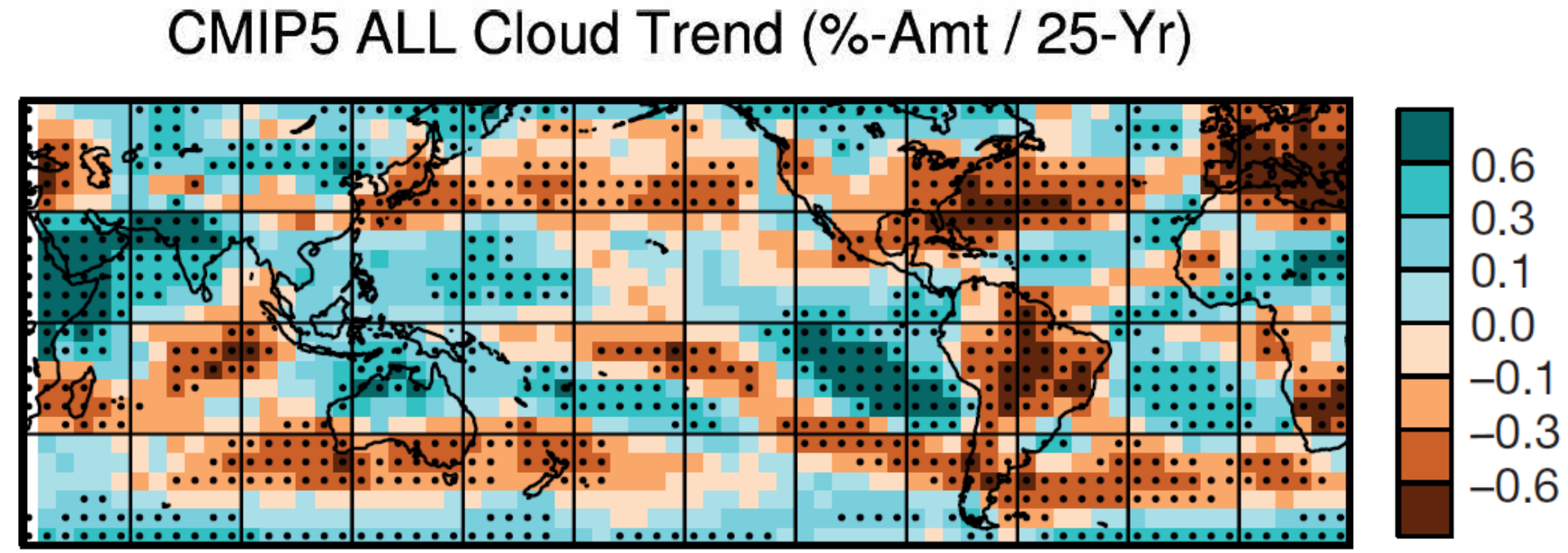
Is the observed spatial pattern of cloud change (relative to the global mean) similar to that simulated by models with external radiative forcing?

Model Cloud Change due to Historical Forcing



Ensemble mean cloud change between 1983 and 2009 for simulations with historical changes in greenhouse gases, anthropogenic aerosol, ozone, and volcanic aerosol (33 models and 107 realizations)

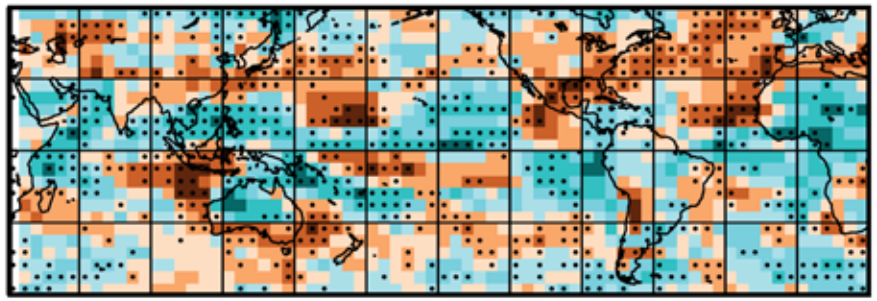
Model Cloud Change due to Historical Forcing

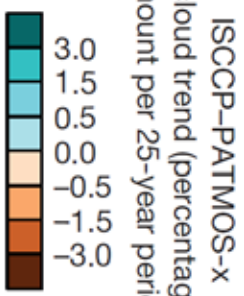


After subtracting a global mean cloud trend of
0.13%-amount per 25 years from every grid box

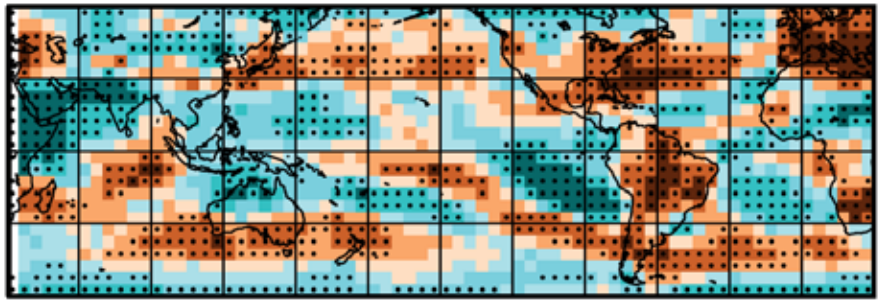
Agreement Between Models and Observations

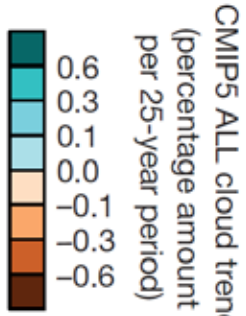
ISCCP+PATMOS-x Cloud Trend



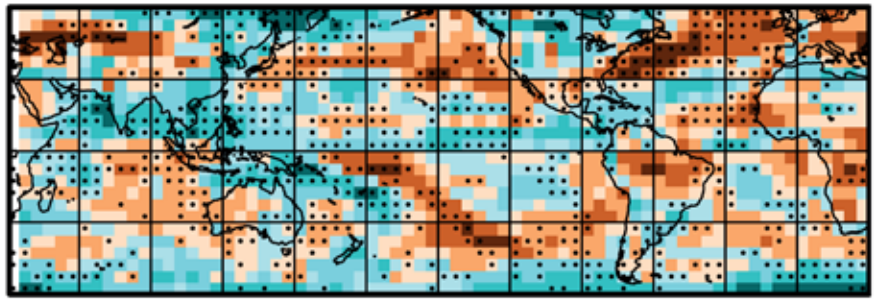


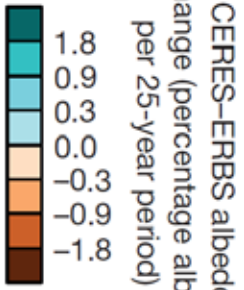
Ensemble Mean Historical Simulated Trend



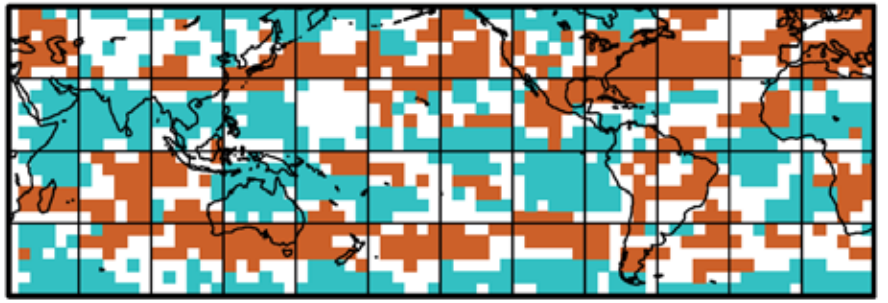


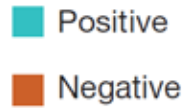
CERES-ERBS Albedo Difference





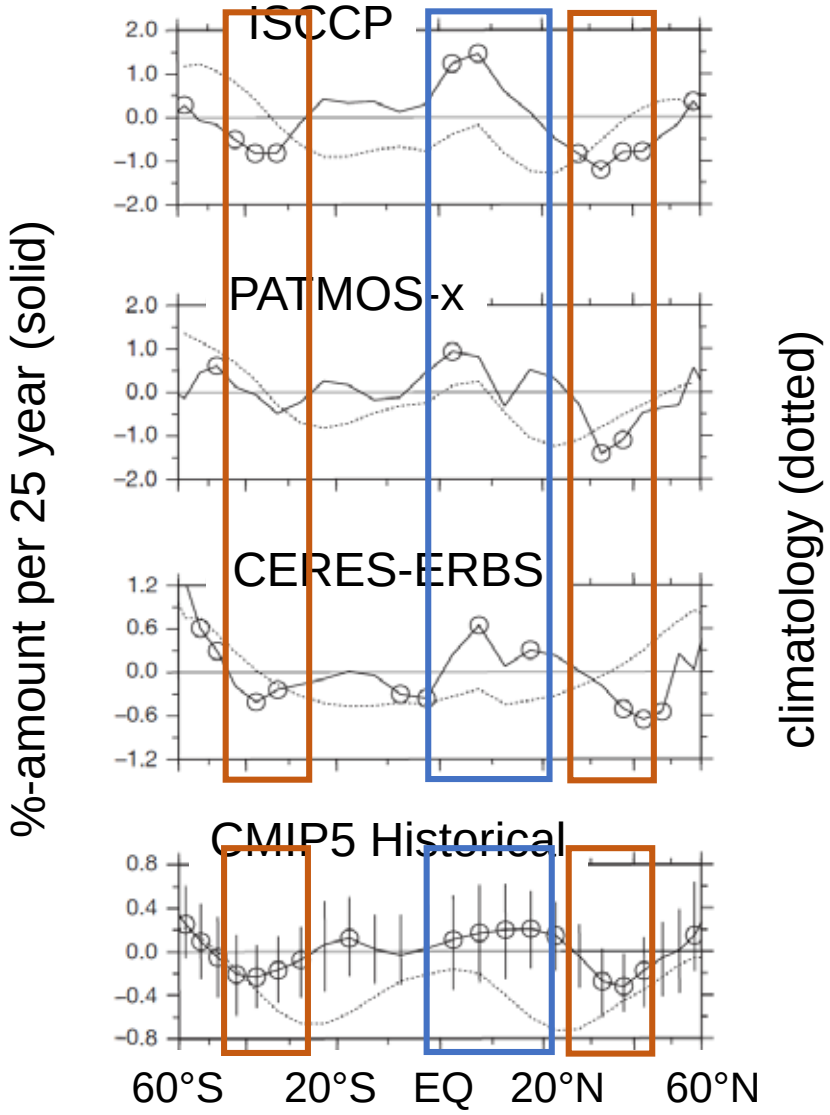
Majority of Models and Satellite Records Agree





Pattern of cloud change from the 1980s to the 2000s
(relative to global mean cloud change)

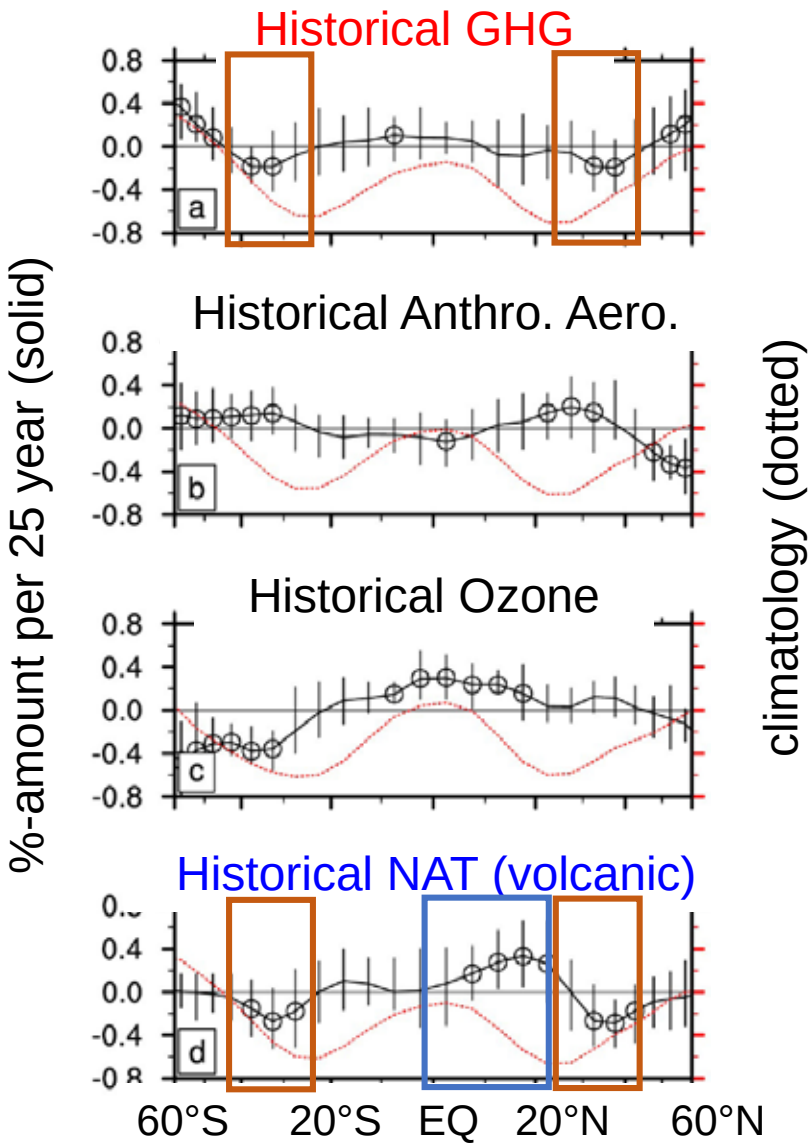
Zonal Mean Total Cloud and Albedo Change



Three independent satellite datasets exhibit reduced cloud and albedo around 30-40°N and 30-40°S and enhanced cloud and albedo around 0-20°N between the 1980s and 2000s *relative to an unknown global mean change*

Similar cloud changes are present in the ensemble mean historical simulation with all external anthropogenic and natural radiative forcings (greenhouse gas, aerosol, ozone, etc.)

Attribution to Individual External Radiative Forcings

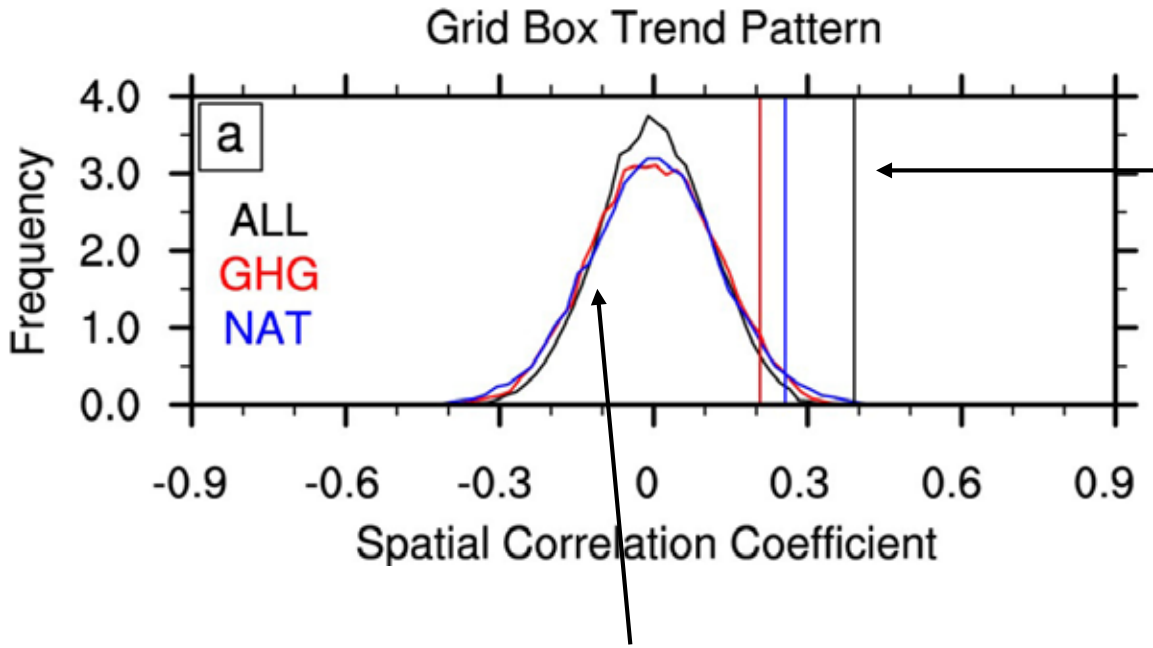


Only anthropogenic greenhouse gases (GHG) and natural volcanic (NAT) radiative forcings reproduce the observed* reduction in cloud around 30-40°N and 30-40°S

Only natural volcanic (NAT) radiative forcing additionally reproduces the observed* enhancement in cloud around 0-20°N

** relative to an unknown global mean change*

Could Internal Variability Produce the Trend Patterns?



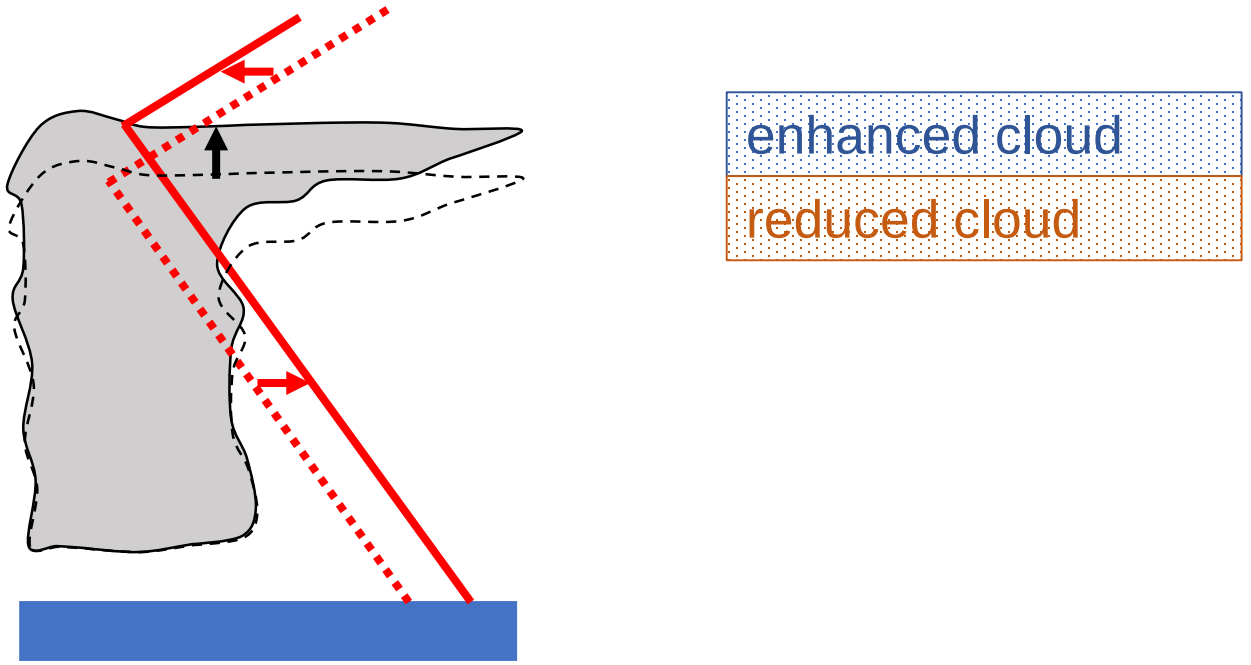
Frequency distribution of the spatial correlation between externally forced 27-year cloud trend pattern and 27-year cloud trend patterns from internal atmosphere-ocean variability (PI control)

Correlation between externally forced cloud trend pattern and observed cloud trend pattern

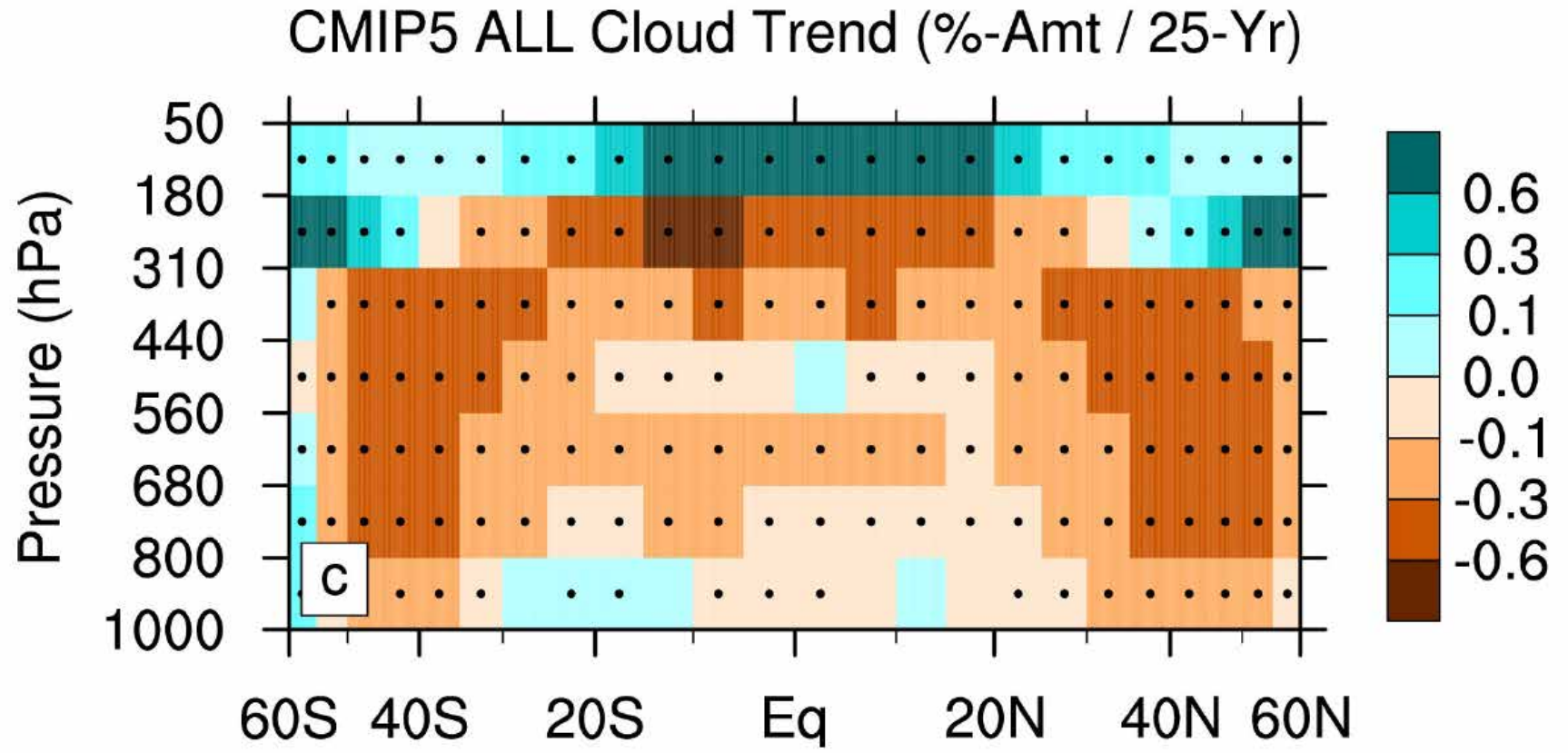
It is extremely unlikely that the observed cloud change pattern from the 1980s to the 2000s could result from unforced internal variability

High-Level Cloud Top Rise

- Increased greenhouse gas concentration (and recovery from volcanic aerosol) warms troposphere but cools stratosphere
- Fixed Anvil Temperature hypothesis (Hartmann and Larson 2002)



Model Cloud Change due to Historical Forcing



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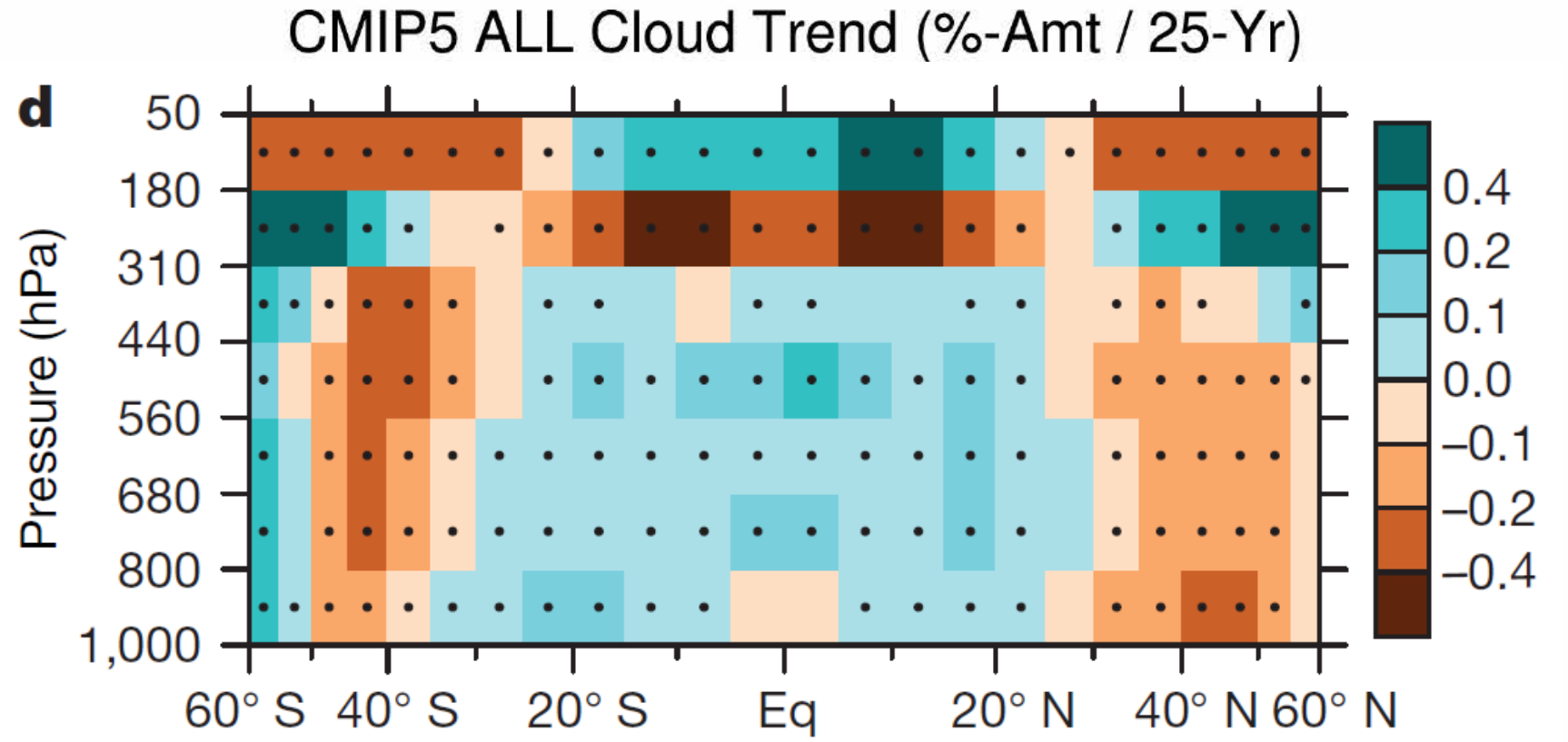
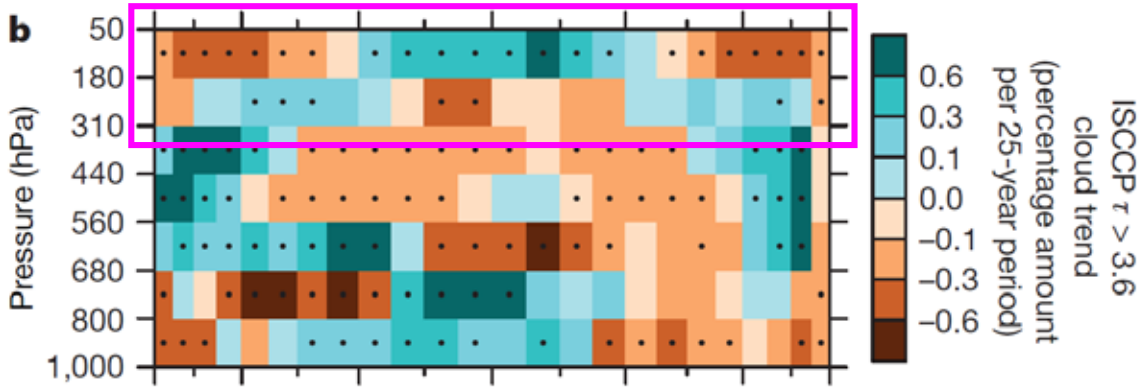


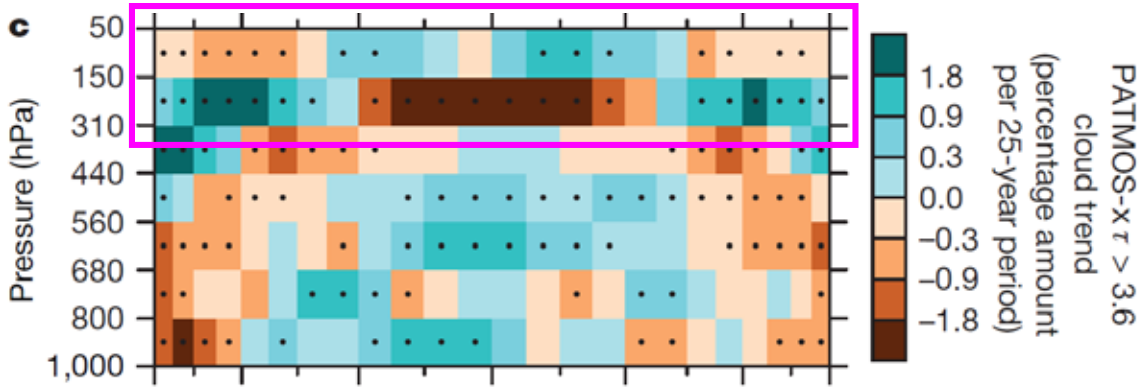
After subtracting global mean cloud trend at each pressure level

Agreement Between Models and Observations

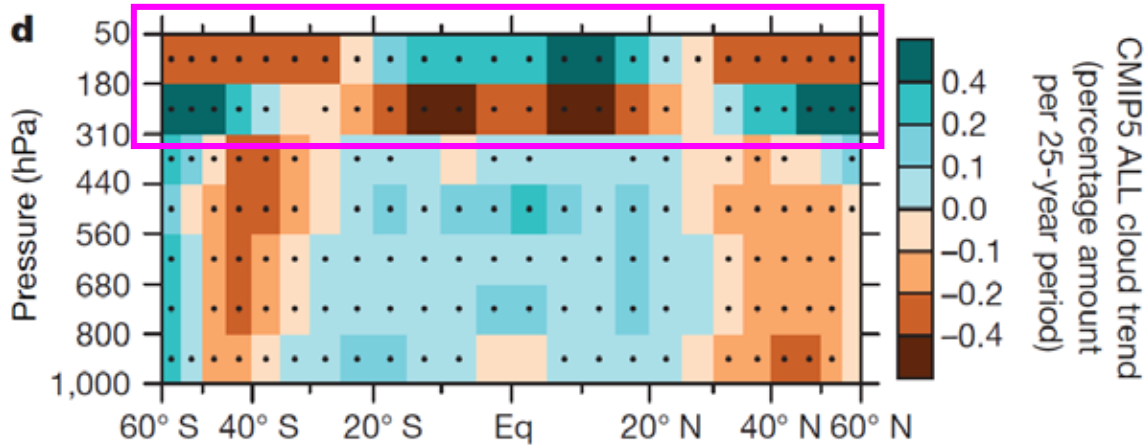
ISCCP Cloud Trend



PATMOS-x Cloud Trend



Ensemble Mean Historical Simulated Trend



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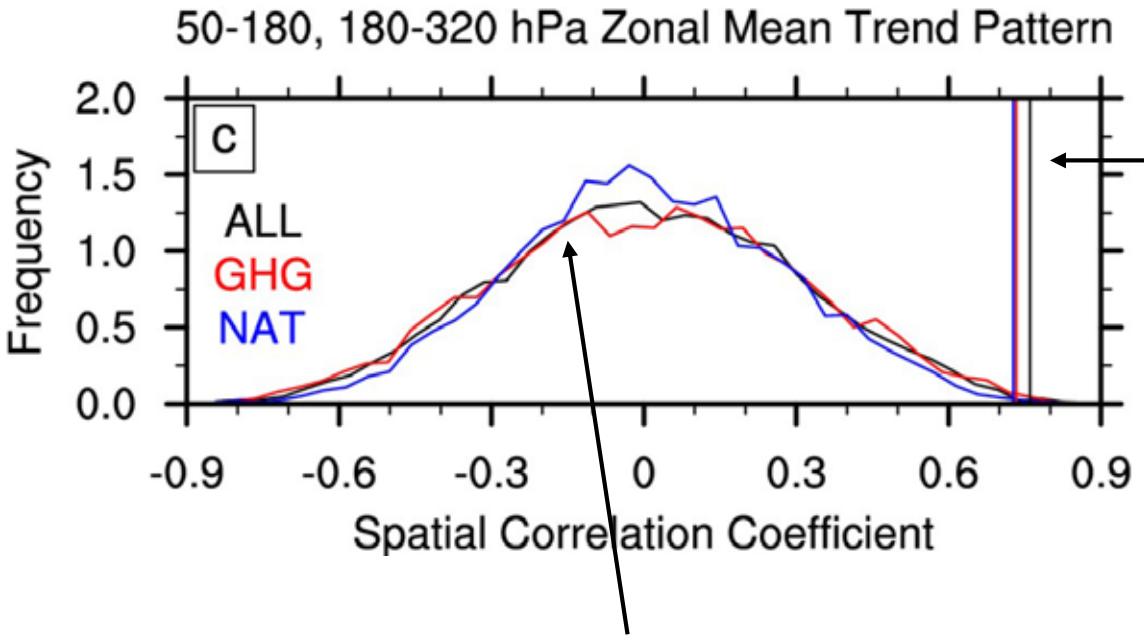
Could Internal Variability Produce the Trend Patterns?



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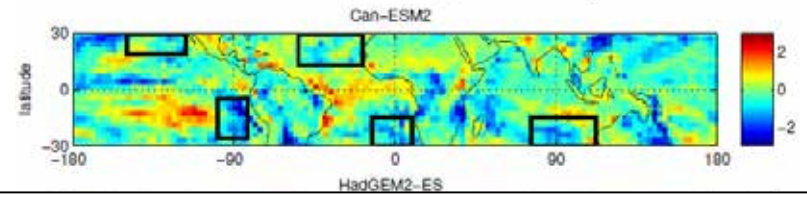
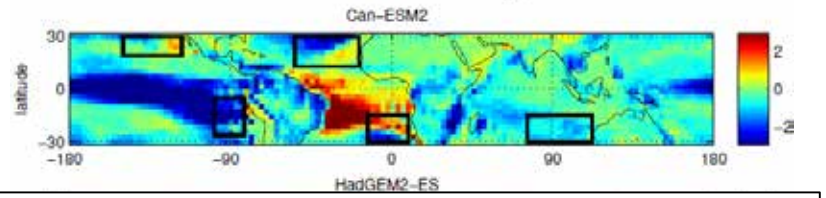
Historical and 4xCO_2 Low Cloud Change Patterns

1980s to 2000s Low-Level Cloud Change



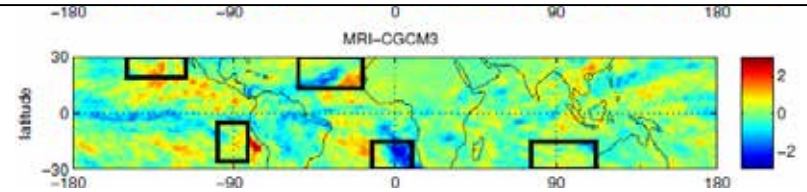
4xCO_2 Equilibrium Low-Level Cloud Change

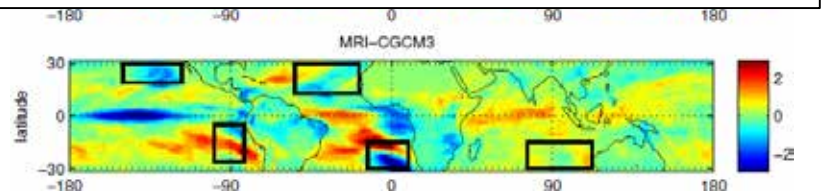


No agreement between models for low-level cloud change pattern from 1980s to 2000s

Simulated low-level cloud change pattern from 1980s to 2000s does not resemble 4xCO_2 equilibrium pattern for same model

Observed low-level cloud change pattern from 1980s to 2000s likely results from internal atmosphere-ocean variability





Summary

Observations and simulations with historical external radiative forcing exhibit spatial patterns of cloud change from 1980s to 2000s consistent with:*

- Reduced cloudiness around 30-40ºN and 30-40ºS
- A rise in the highest cloud tops at tropical and middle latitudes
- Cloud changes attributed to anthropogenic greenhouse gases and recovery from volcanic cooling
- Observational confirmation for two positive cloud feedbacks associated with global warming

** Relative to an unknown global mean cloud change*

Summary (continued)

- No consistency for low-level cloud changes, which are attributed to internal atmosphere-ocean variability

  (but there is still other evidence for a positive feedback, see my poster with Tim Myers in the early afternoon today)

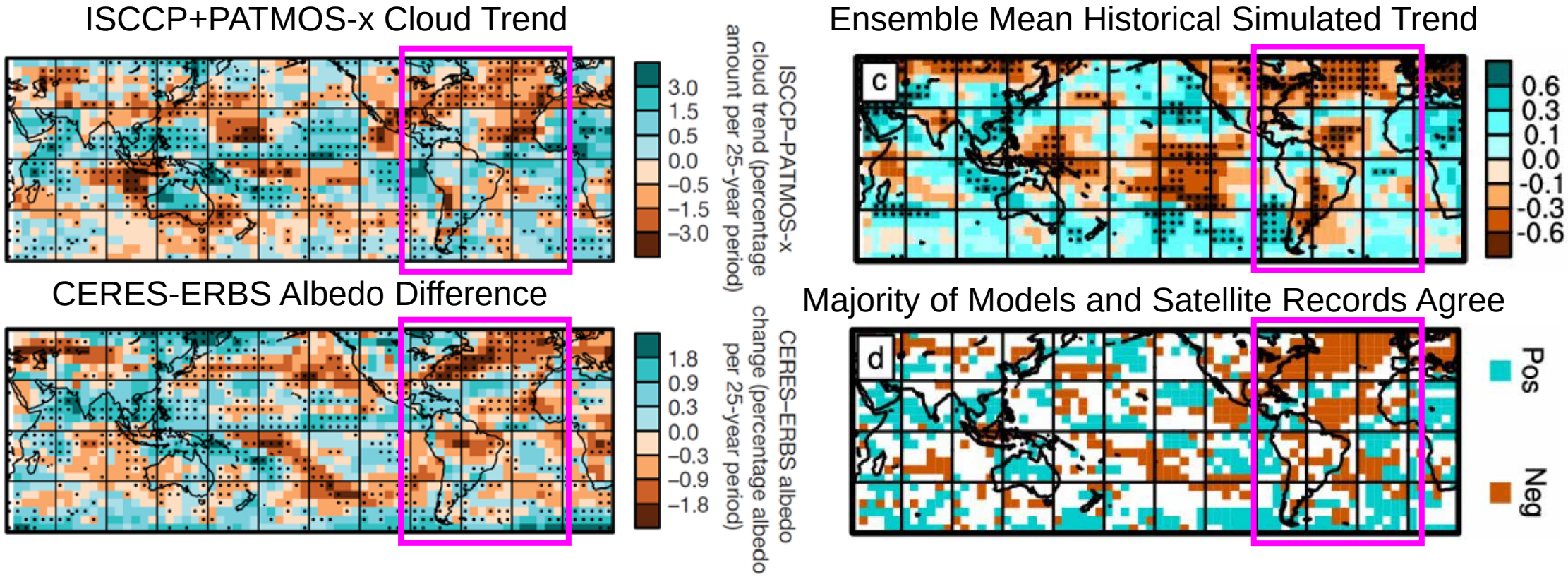
Not Mentioned for Reasons of Time

- *Beyond zonal means* -- cloud changes in certain regions appear to be externally forced
- Anthropogenic aerosol may be driving cloud changes over the whole Atlantic Ocean

Thank You!

Extra Slides

Only Anthropgenic Aerosol Radiative Forcing



Observed trend pattern resembles model trend pattern for simulations with only anthropogenic aerosol forcing over the Atlantic Ocean