Topic #3: Variability of Clouds and Precipitation

- Clouds have compensating cooling and warming radiative effects and whether cloud effects increase or decrease with global warming is uncertain => cloud feedback is one of the primary contributors to climate sensitivity.

- Precipitation is vital to life on Earth and latent heating associated with precipitation drives global atmospheric circulation; however, climate simulations of precipitation and its change have large discrepancies.

- Variabilities of clouds and precipitation are closely coupled.

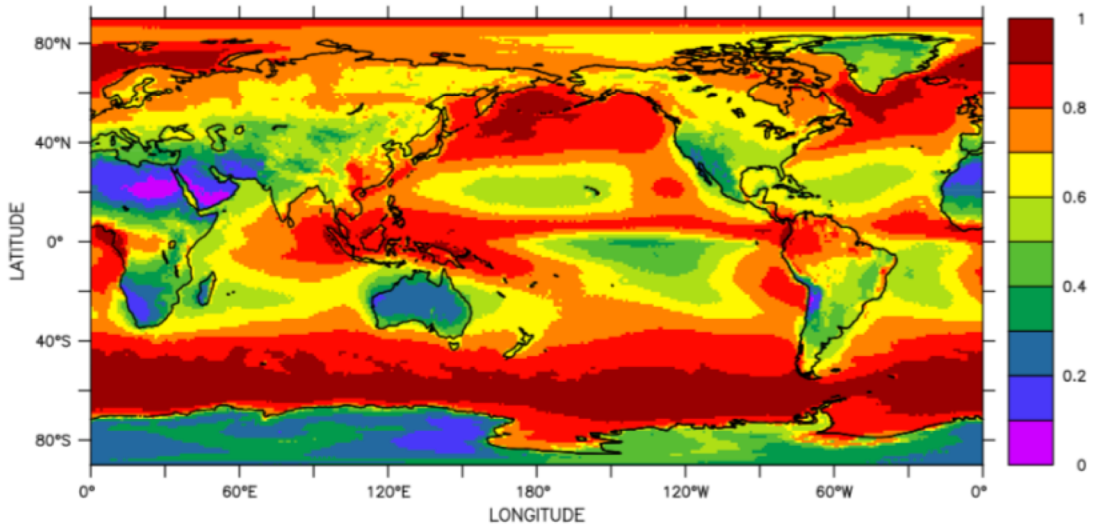
Questions to Answer

- Q1: What are the spatial distributions of clouds, cloud radiative effects and precipitation? (2-D maps; zonal-mean plots)
- Q2: How are clouds and precipitation distributions related to large-scale circulation, SST and other quantities (PW, RH, LTS, CAPE etc)? (correlation maps, scatter plots, conditions sampling)
- Q3: What are the seasonal and interannual variations of clouds, cloud radiative effects and precipitation? Are there detectable trends? (time series, EOF analysis)
- Q4: How do climate models simulate the spatial and temporal variabilities of clouds and precipitation?
- Q5: What are the “emergent constraints” for climate sensitivity and hydrological sensitivity?

Examples: Q1

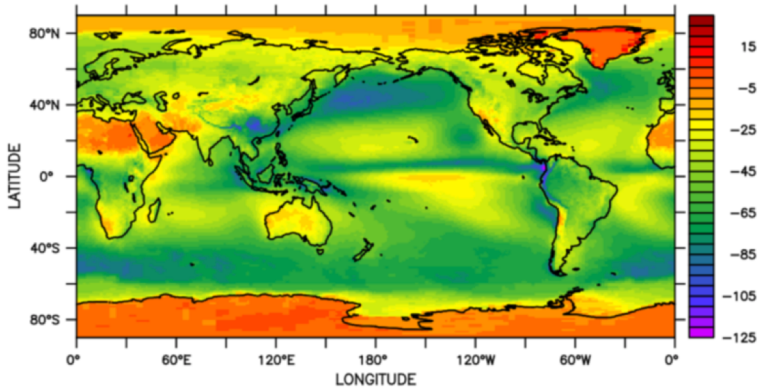
- Q1: What are the spatial distributions of clouds, cloud radiative effects and precipitation? (2-D maps; zonal-mean plots)

MODIS Daytime total cloud fraction



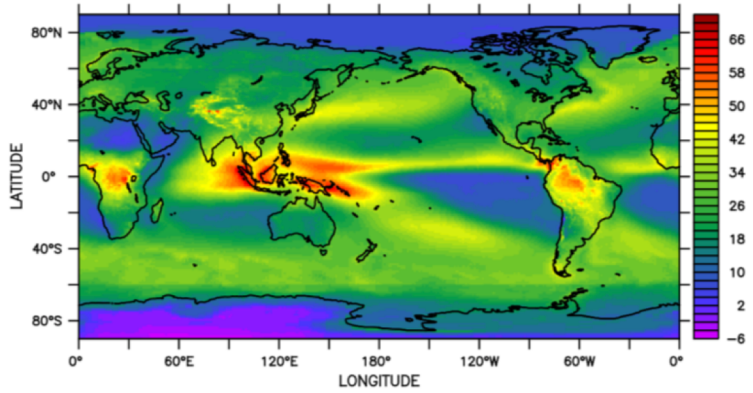
CF_DAY_MEAN_MONTHLY_GLOBAL (1)

SWCRF $= F^{\uparrow}_{SW,clear}(TOA) - F^{\uparrow}_{SW,cloudy}(TOA)$



the difference: (nasa_ceres:rsutcs) − (nasa_ceres:rsut)

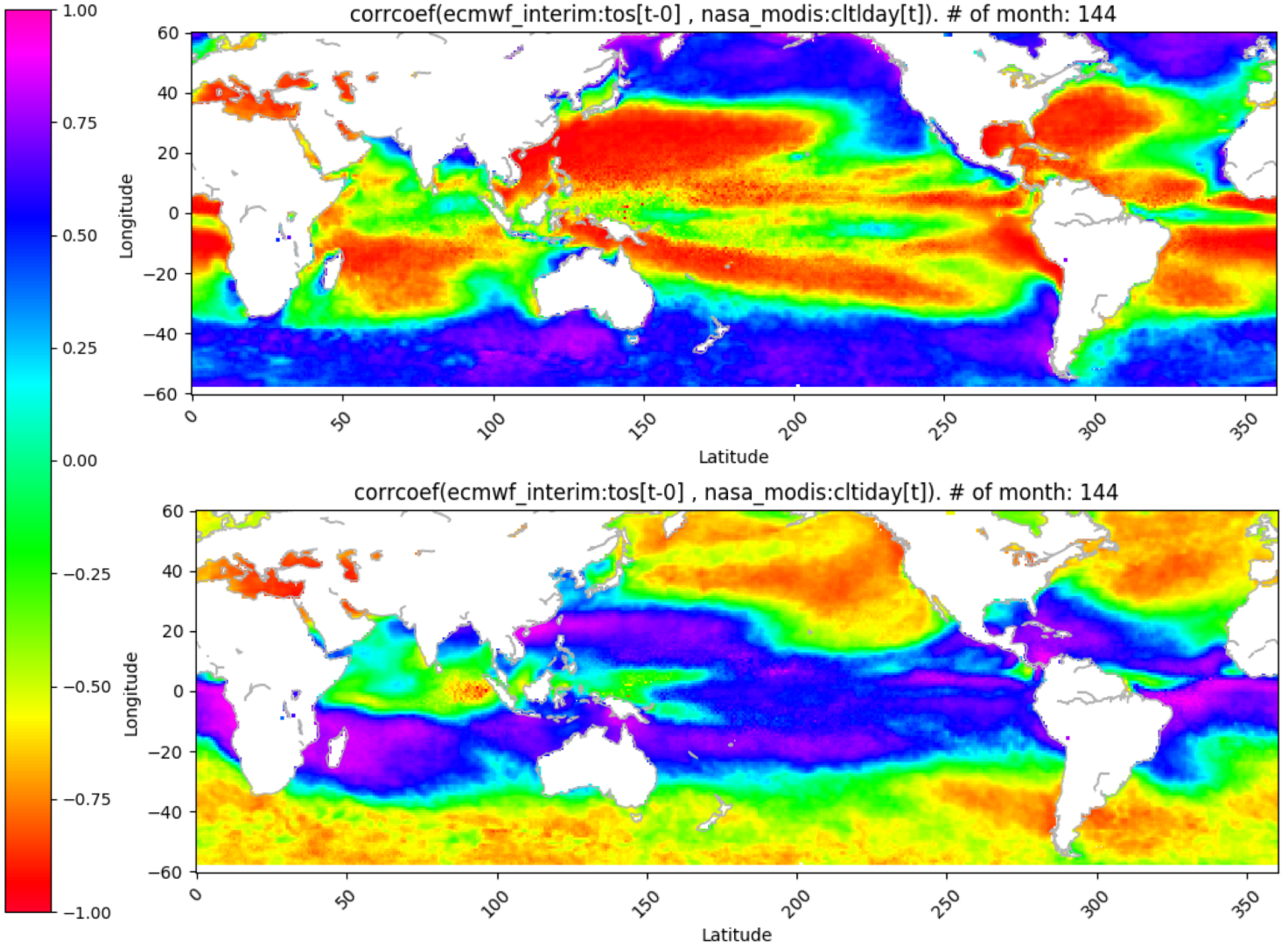
LWCRF $= F^{\uparrow}_{LW,clear}(TOA) - F^{\uparrow}_{LW,cloudy}(TOA)$



the difference: (nasa_ceres:rlutcs) − (nasa_ceres:rlut)

Examples: Q2

Q2: How clouds and precipitation distributions related to large-scale circulation, SST and other quantities (PW, RH, LTS, CAPE etc)? (correlation maps, scatter plots, conditions sampling)



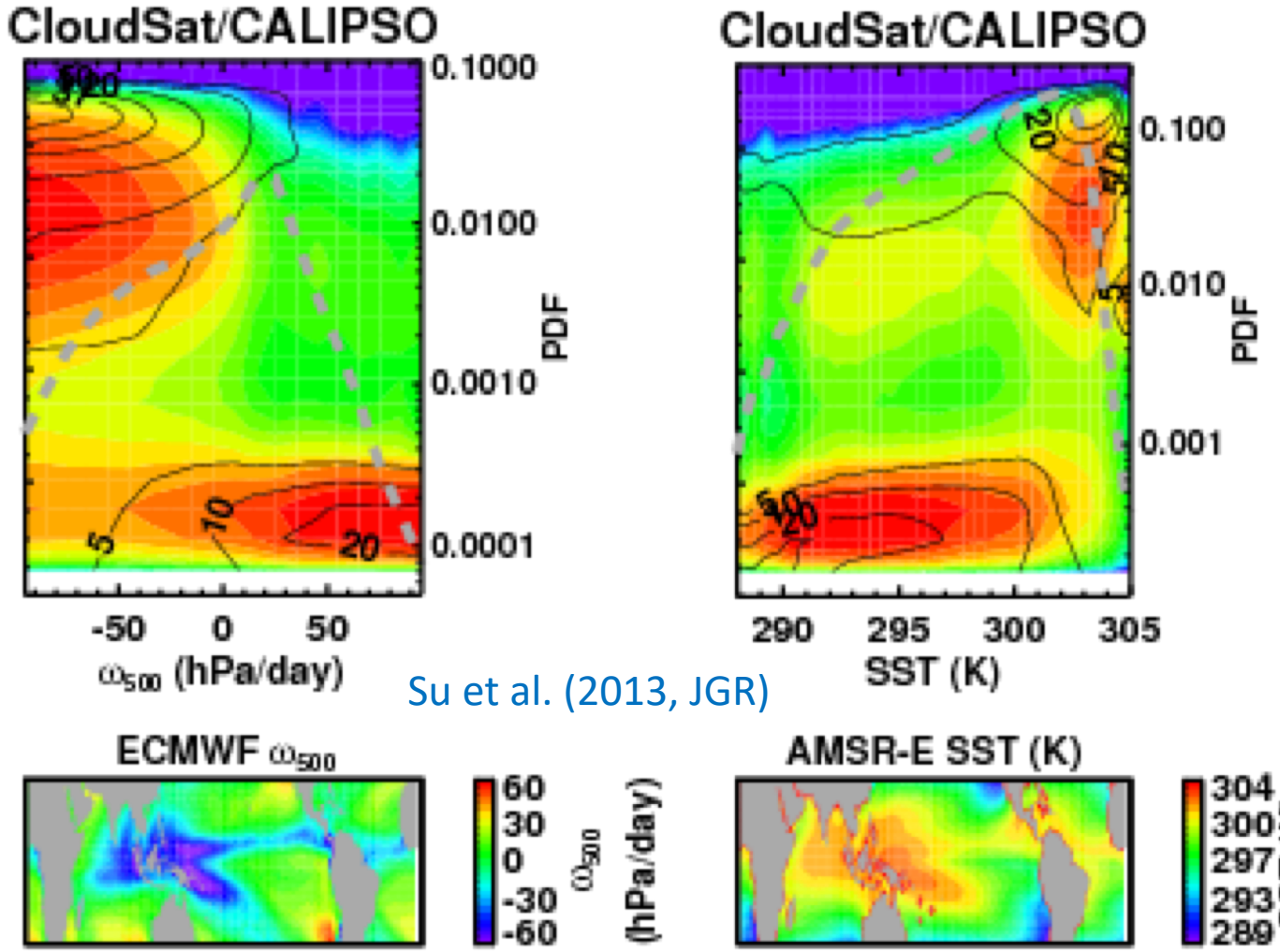
In the low-latitudes, and in the margins of the tropics, SST is strongly ***anticorrelated*** with MODIS liquid cloud fraction.
Over the mid-latitudes, and even off the coast of California, low clouds are ***positively*** correlated with SST, suggesting that maximum low clouds occur during the warm season (summer)

Ice cloud fraction is ***positively*** correlated with SST over the low-latitudes, suggesting that more convection happens when SSTs are higher.
Over the mid-latitudes, high ice clouds are predominant during the winter (e.g. when SSTs are lower)

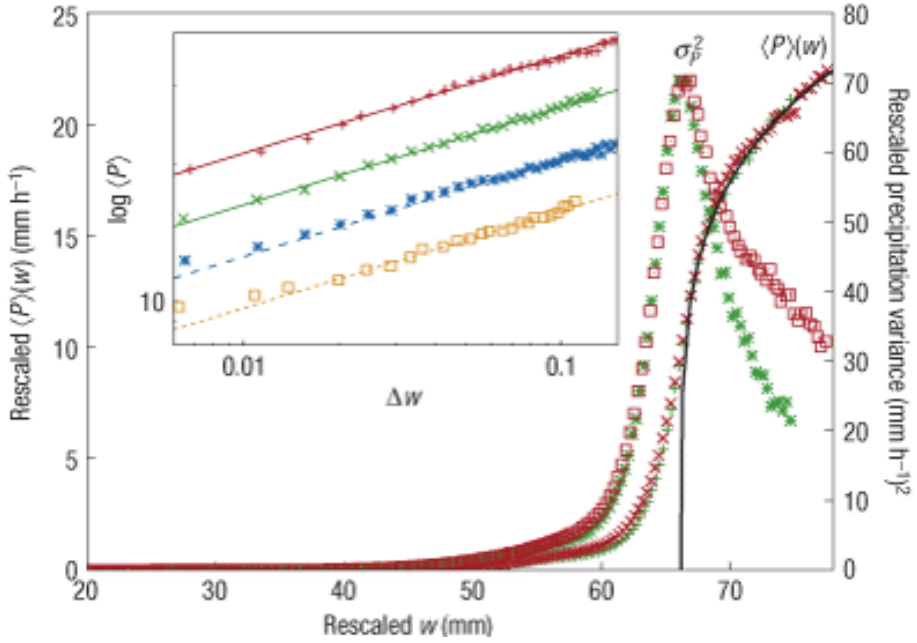
Examples: Q2

Q2: How are clouds and precipitation distributions related to large-scale circulation, SST and other quantities (PW, RH, LTS, CAPE etc)? (scatter plots, conditions sampling)

Observations



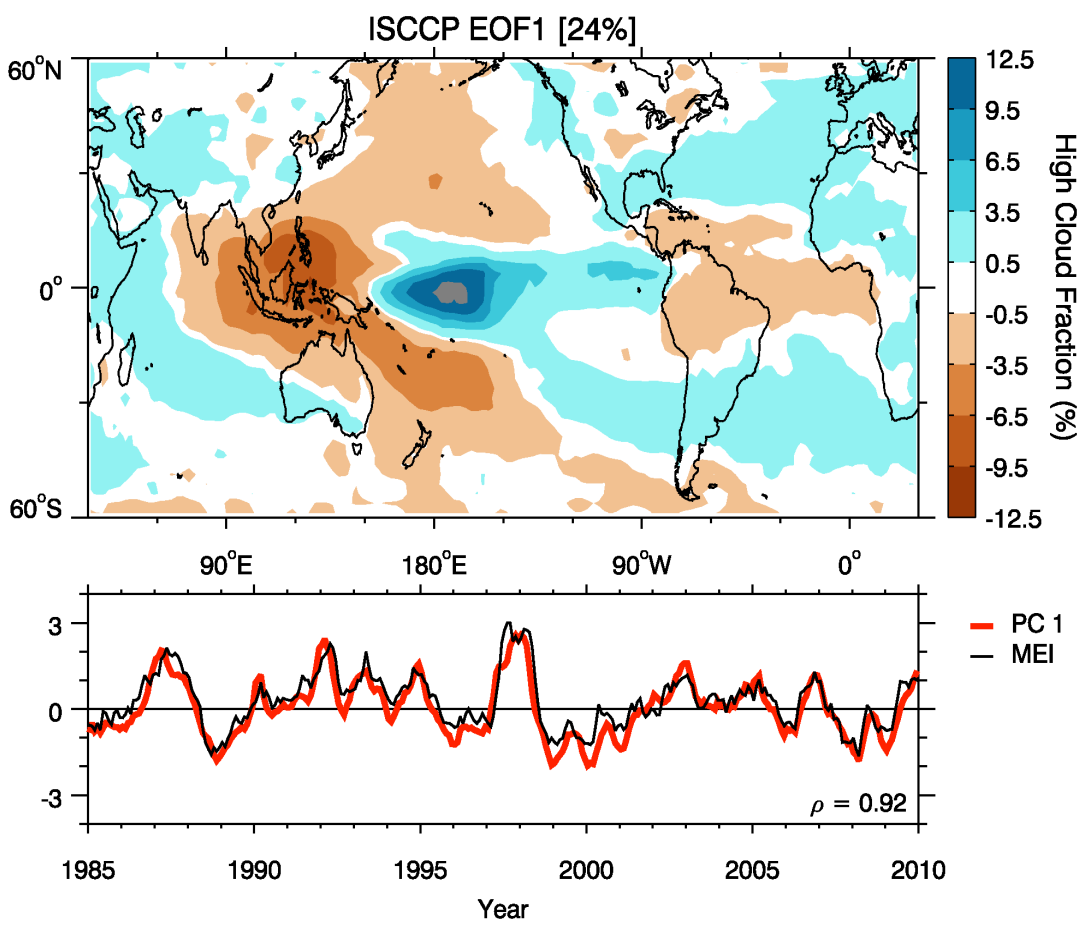
Su et al. (2013, JGR)

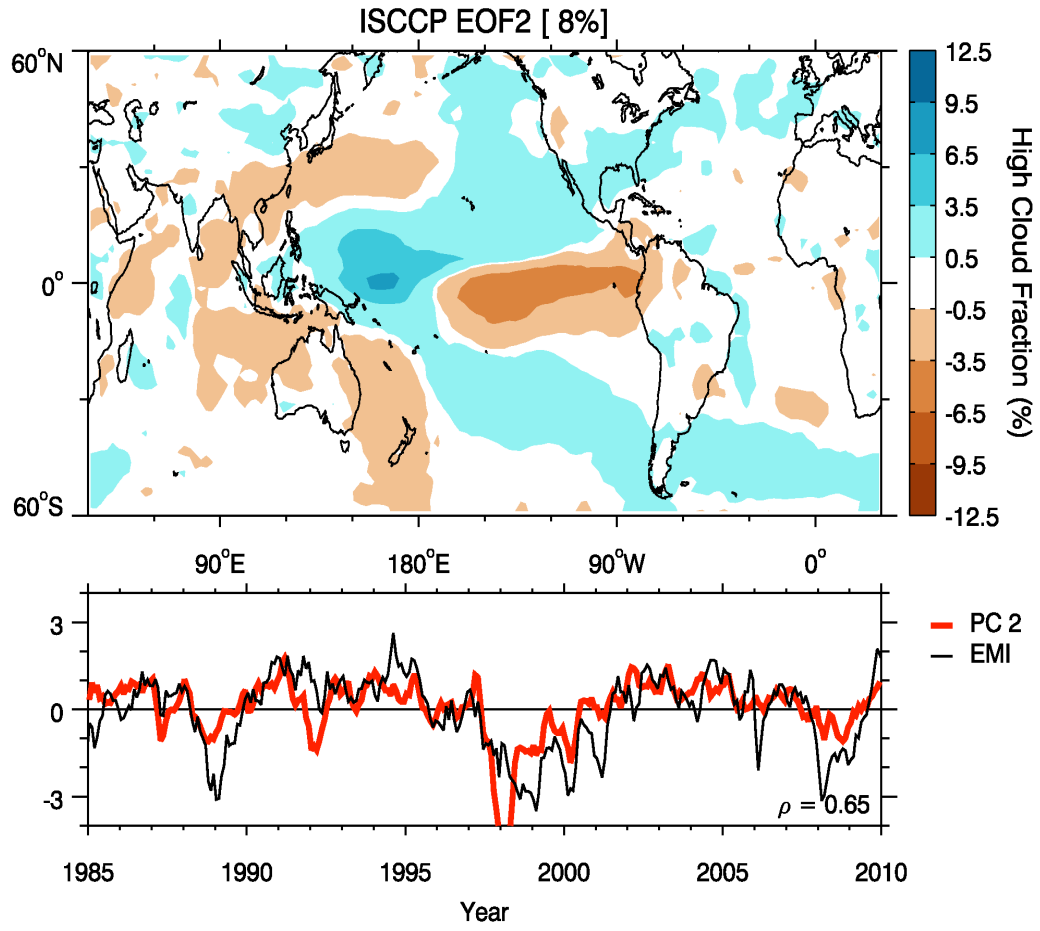


Peters and Neelin (2006, Nat. Phys.)

Examples: Q3

- Q3: What are the seasonal and interannual variations of clouds, cloud radiative effects and precipitation? Are there detectable trends? (time series, EOF analysis)

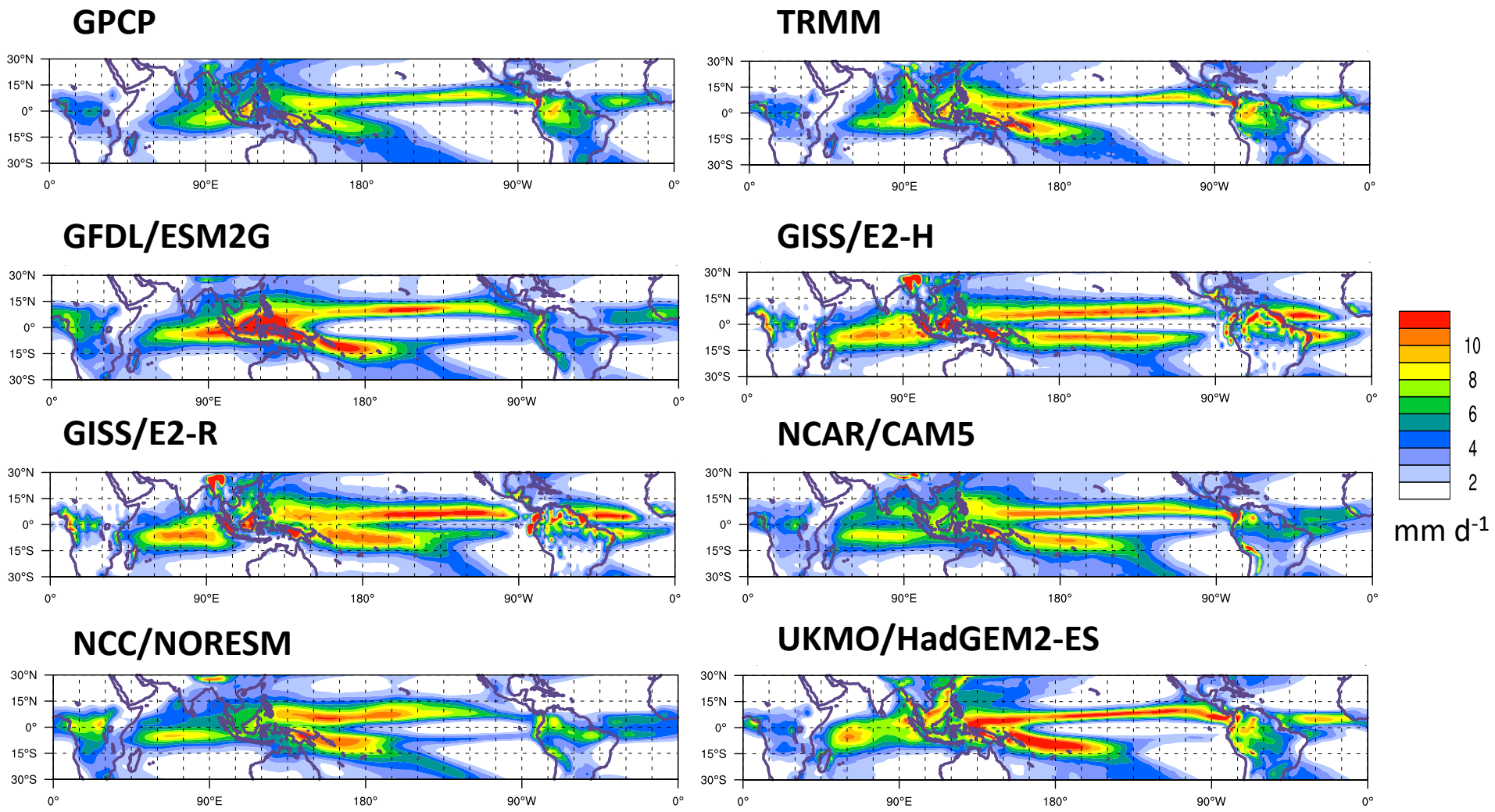




Li et al. (2017, Clim. Dyn.)

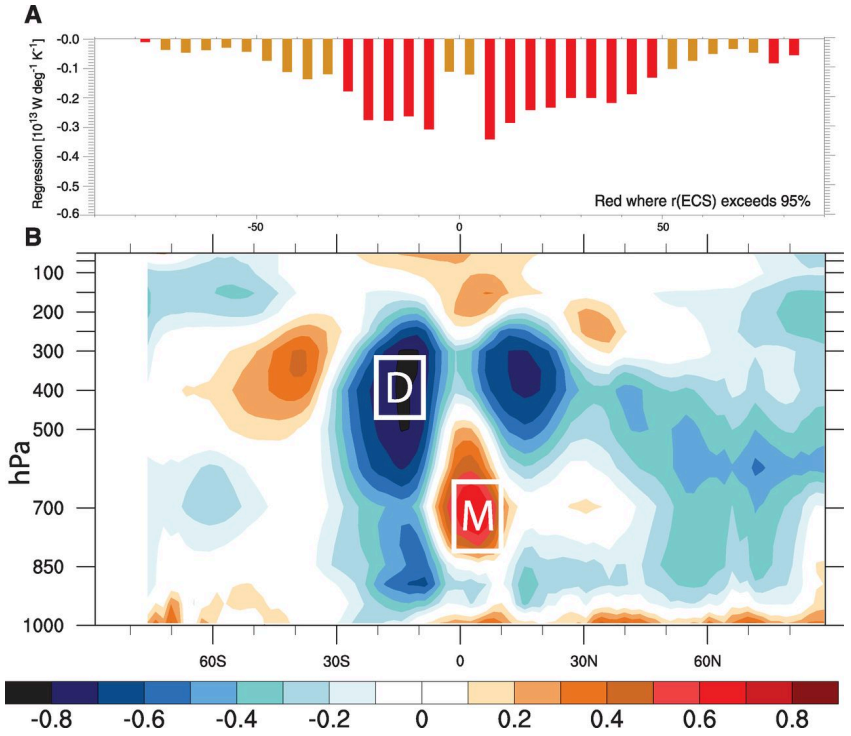
Examples: Q4

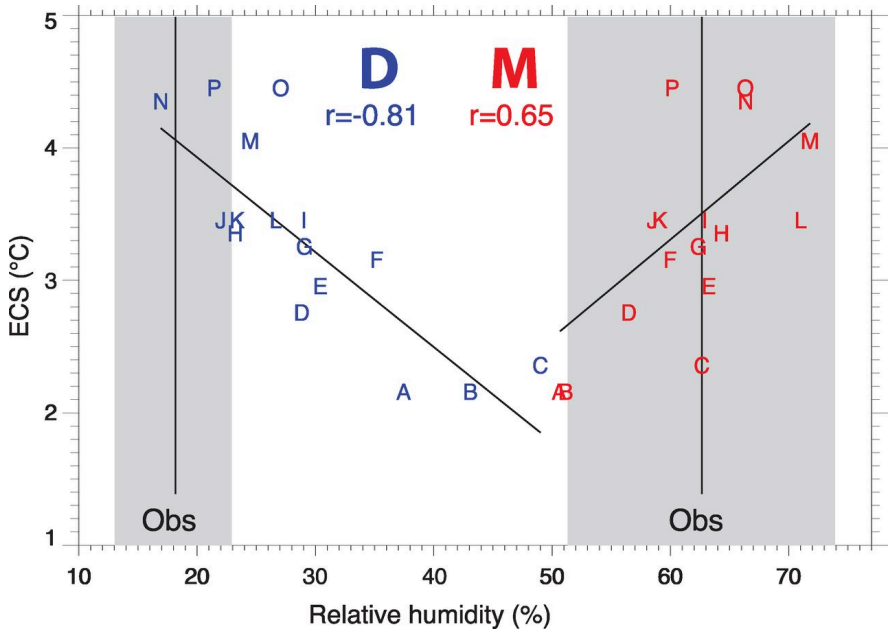
- Q4: How do climate models simulate the spatial and temporal variabilities of clouds and precipitation?



Examples: Q5

- Q5: What are the “emergent constraints” of climate sensitivity and hydrological sensitivity?





- Subtropical free-tropospheric relative humidity (RH) bears a strong negative correlation with ECS.
- Models that are close to the observed RH have relatively high ECS.

Fasullo and Trenberth (2012, Science)

Topic #3: Variability of Clouds and Precipitation

- Datasets: MODIS cloud fraction (including liquid and ice cloud fraction), GPCP/TRMM precipitation, AMSR-E sea surface temperature (and optional ECMWF-Interim), CERES longwave and shortwave radiative fluxes, CMIP5 simulations of cloud fraction, precipitation and radiative fluxes

- Geographic foci: global, tropics (15S-15N), subtropics (15-30S/N), mid-latitude (30-60S/N) and selected regions (ITCZ, northeast Pacific and southeast Pacific, etc)

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