Seasonal variations of low clouds simulated by an upgraded multiscale modeling framework model

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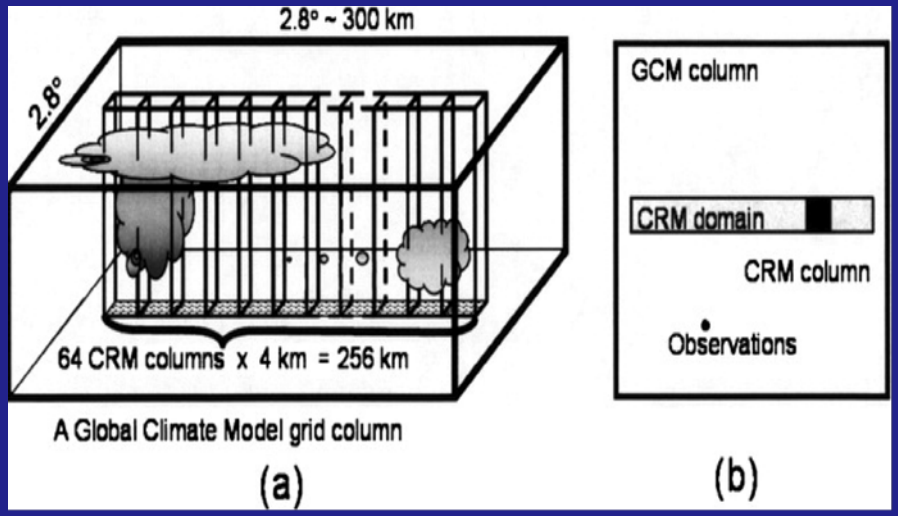
Multiscale Modeling Framework (MMF)

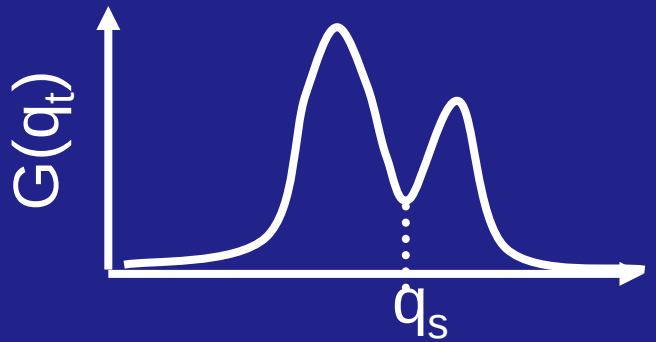
(Grabowski 2001; Khairoutdinov and Randall 2001)

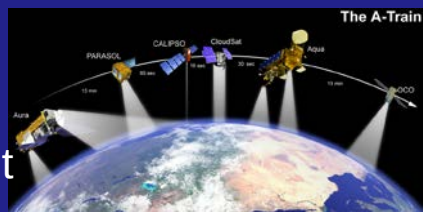
- A CRM is embedded at each grid column (~100s km) of the host GCM to represent cloud physical processes
- The CRM explicitly simulates cloud-scale dynamics (~1s km) and processes
- Periodic lateral boundary condition for CRM (not extend to the edges)



An upgraded CRM with a third-order turbulence closure (IPHOC):

- Double-Gaussian distribution of liquid-water potential temperature, total water mixing ratio and vertical velocity
- Skewnesses, i.e., the three third-order moments, predicted
- All first-, second-, third- and fourth-order moments, subgrid-scale condensation and buoyancy based on the same PDF



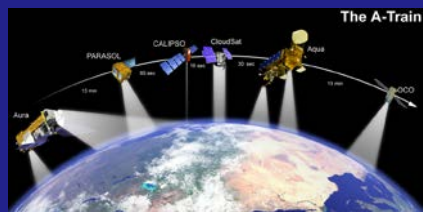


Objectives for MMF climate simulation

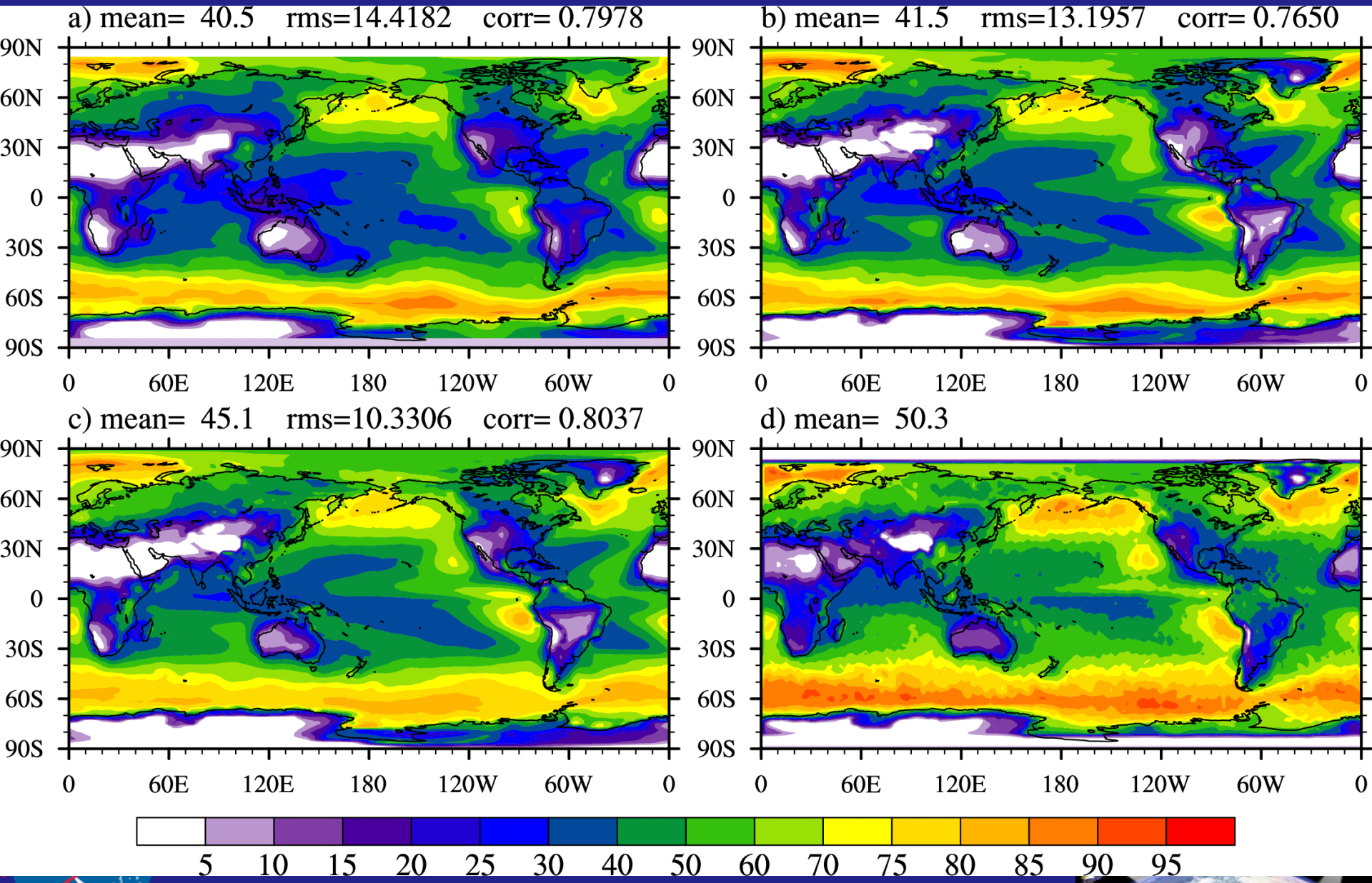
- to improve the simulation of low-level clouds in the SPCAM MMF
- to evaluate and compare the performance of MMF simulations against state-of-the-art observations

MMF models and observational data

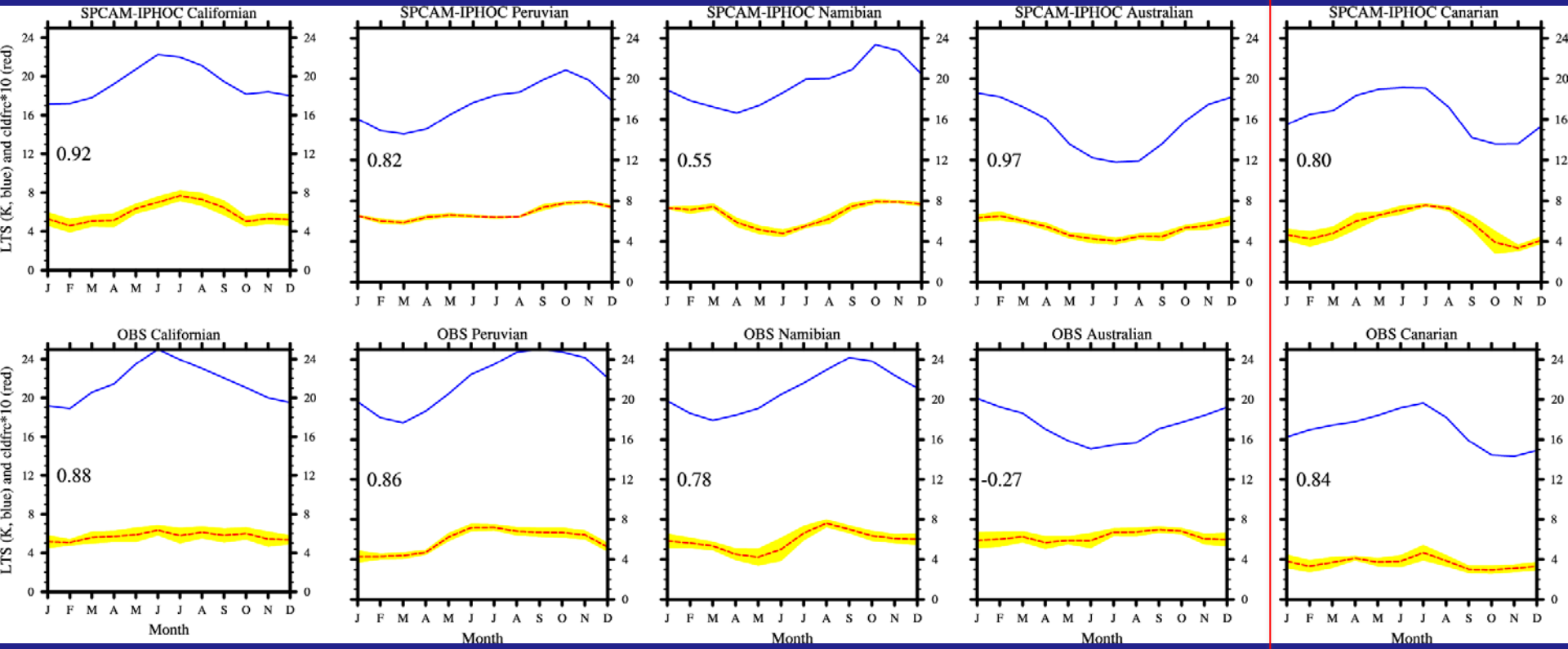
- *SPCAM-IPHOC-hires* with finite-volume dynamic core (1.9°x2.5°); doubling the number of levels below 700 hPa (6 to 12); 10-yr run
- C3M (CloudSat, CALIPSO, CERES, MODIS) observations
- SSM/I observations, ERA Interim reanalysis
- GPCP
- CERES EBAF (Energy balanced and filled) TOA & surface fluxes

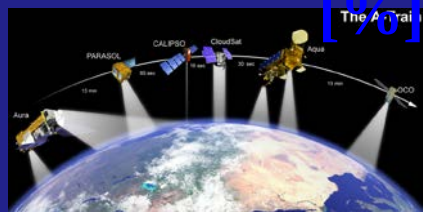


Low-level Cloud Amount from SPCAM-IPHOC

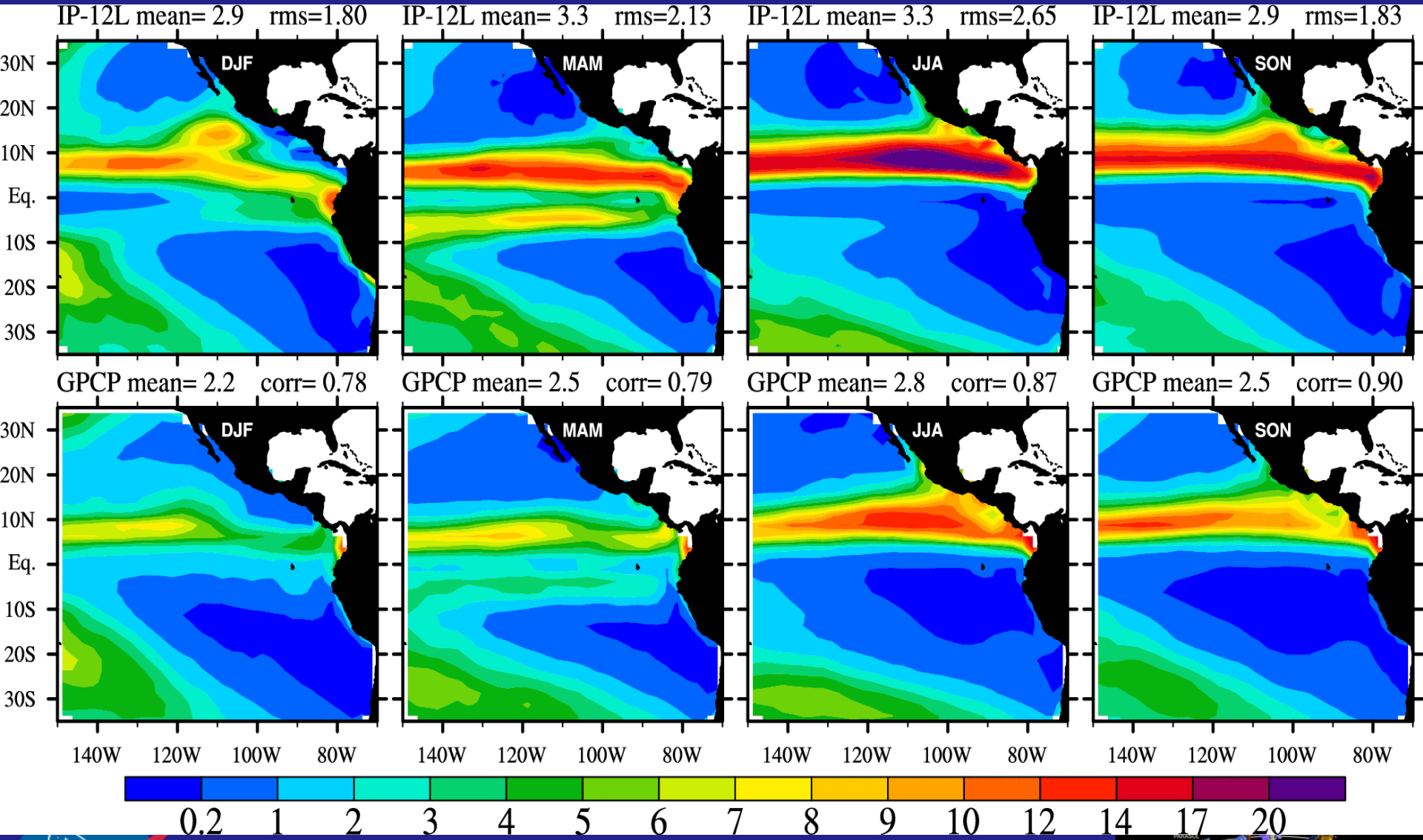


Annual cycle of Low-level Cloud Amount and LTS from SPCAM-IPHOC and ISCCP

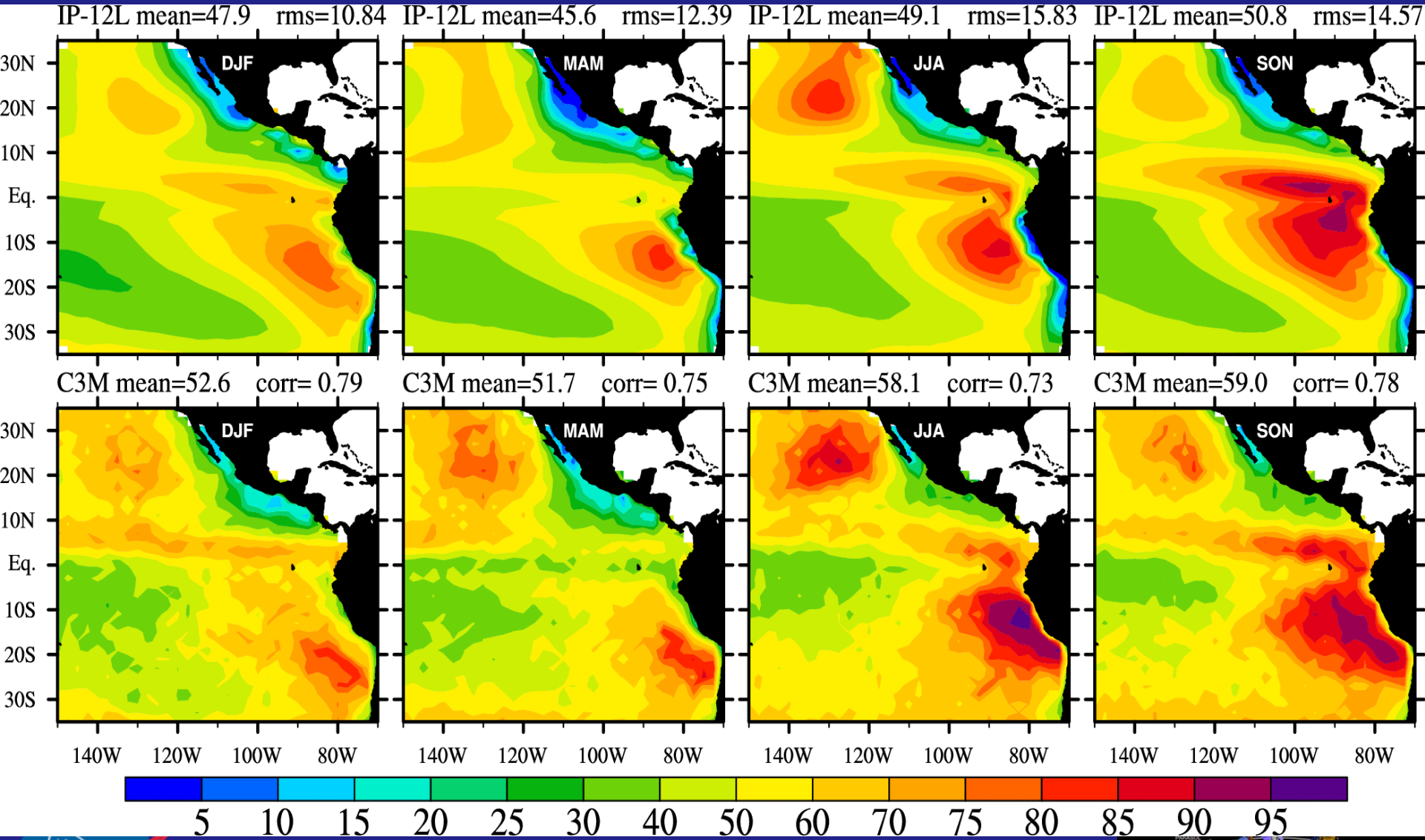




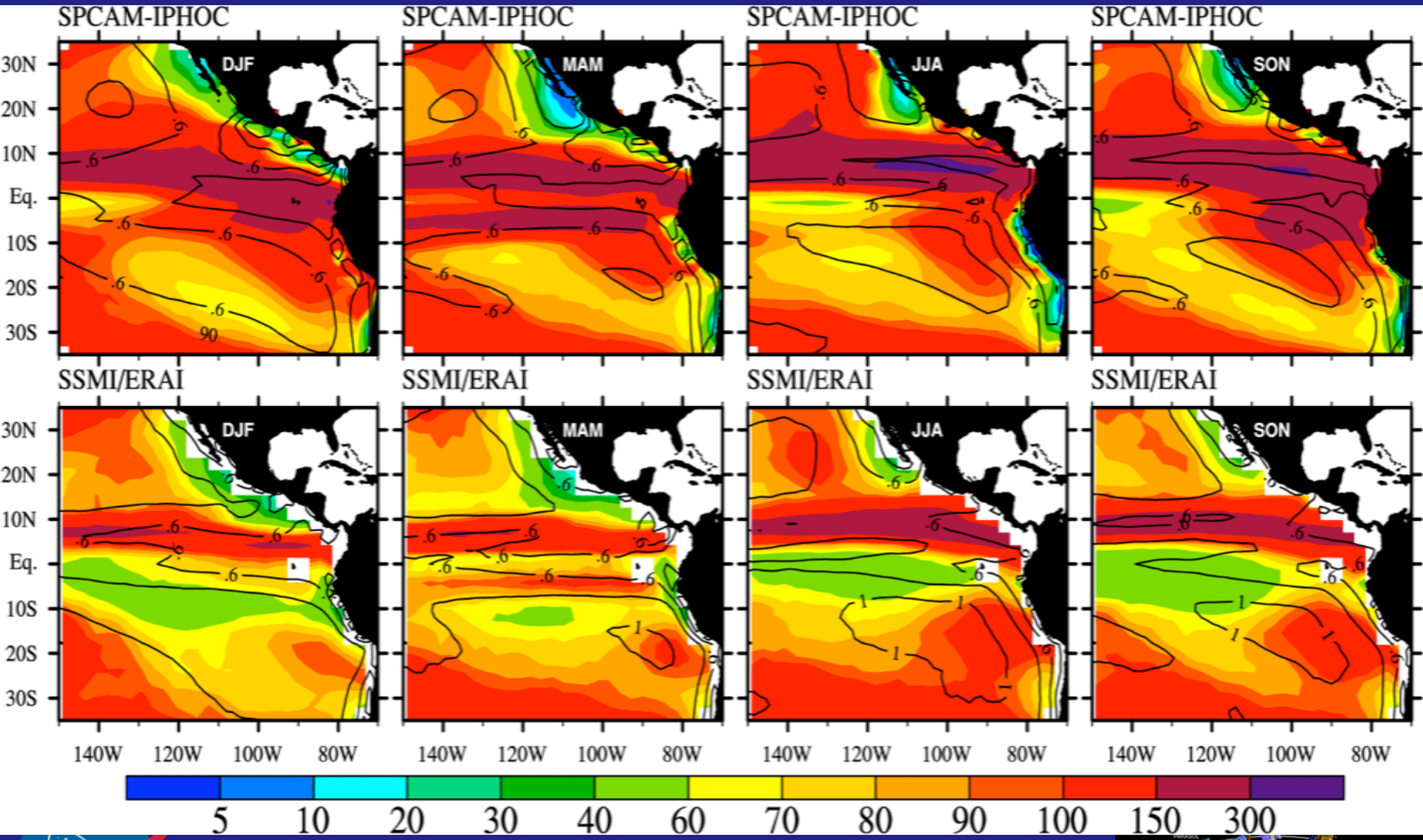
Surface precipitation rate (Obs.: GPCP)



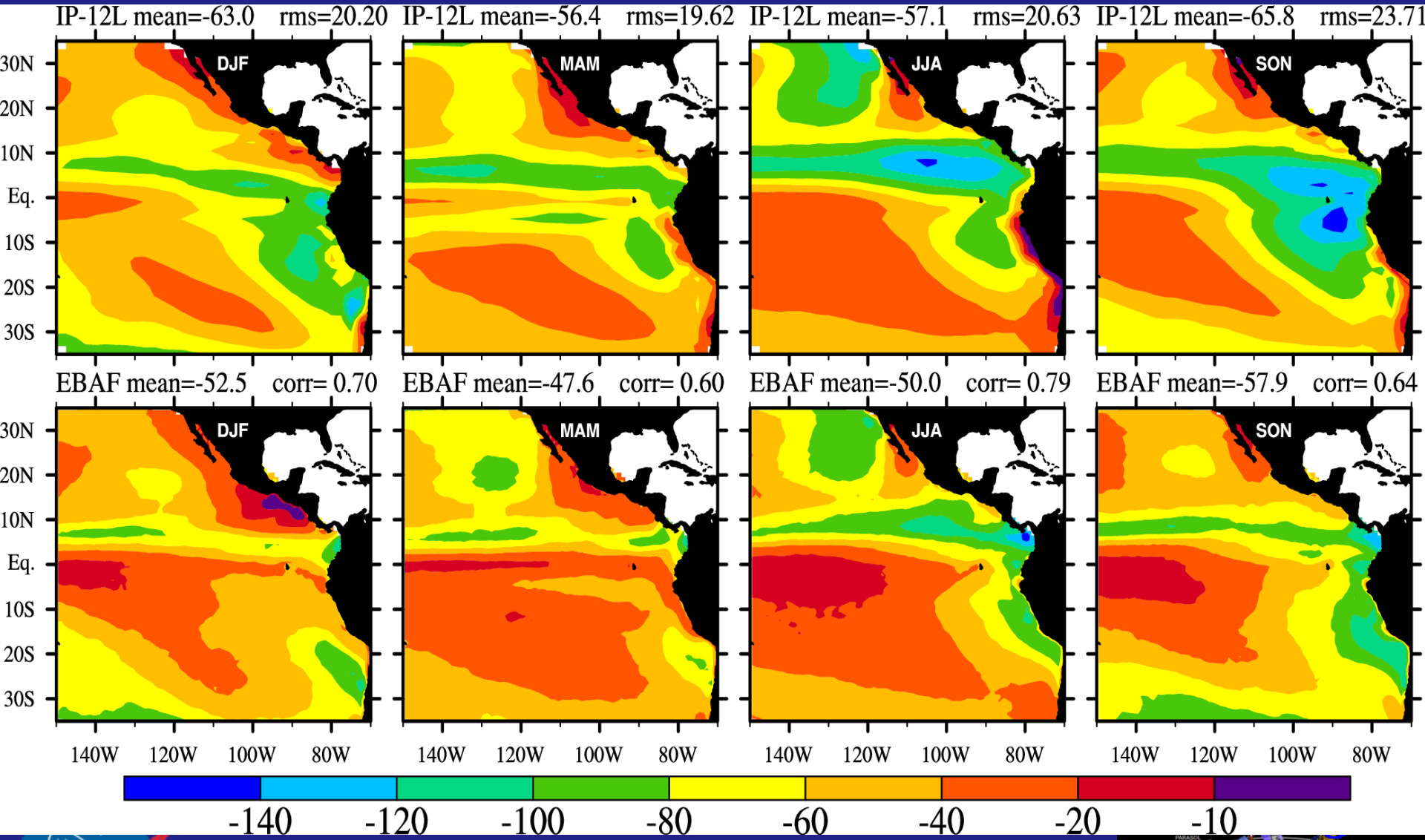
Low Cloud Amount (Obs.: Cloudsat/CALIPSO)



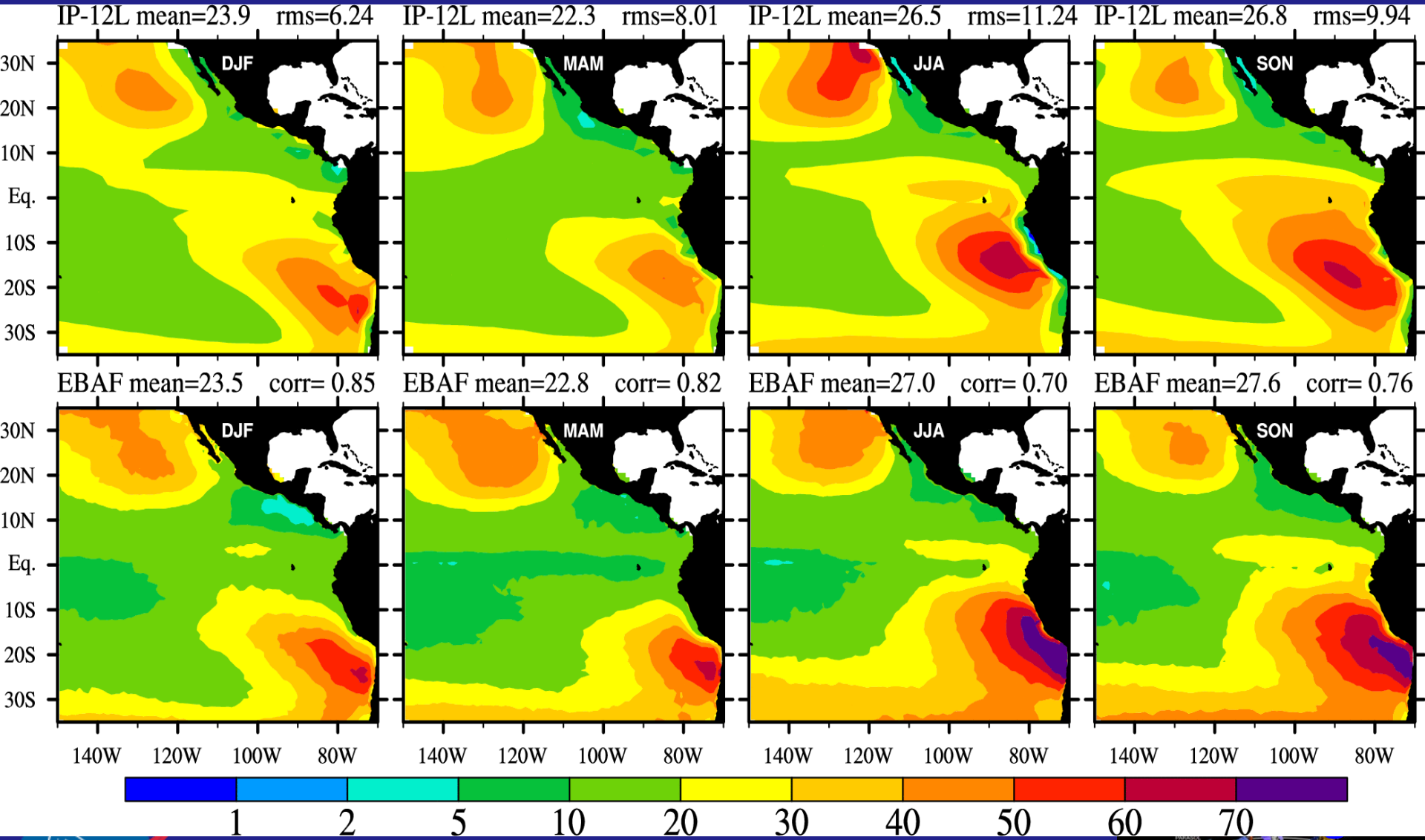
LWP & PBL depth (Obs.: SSM/I & ERA Interim)



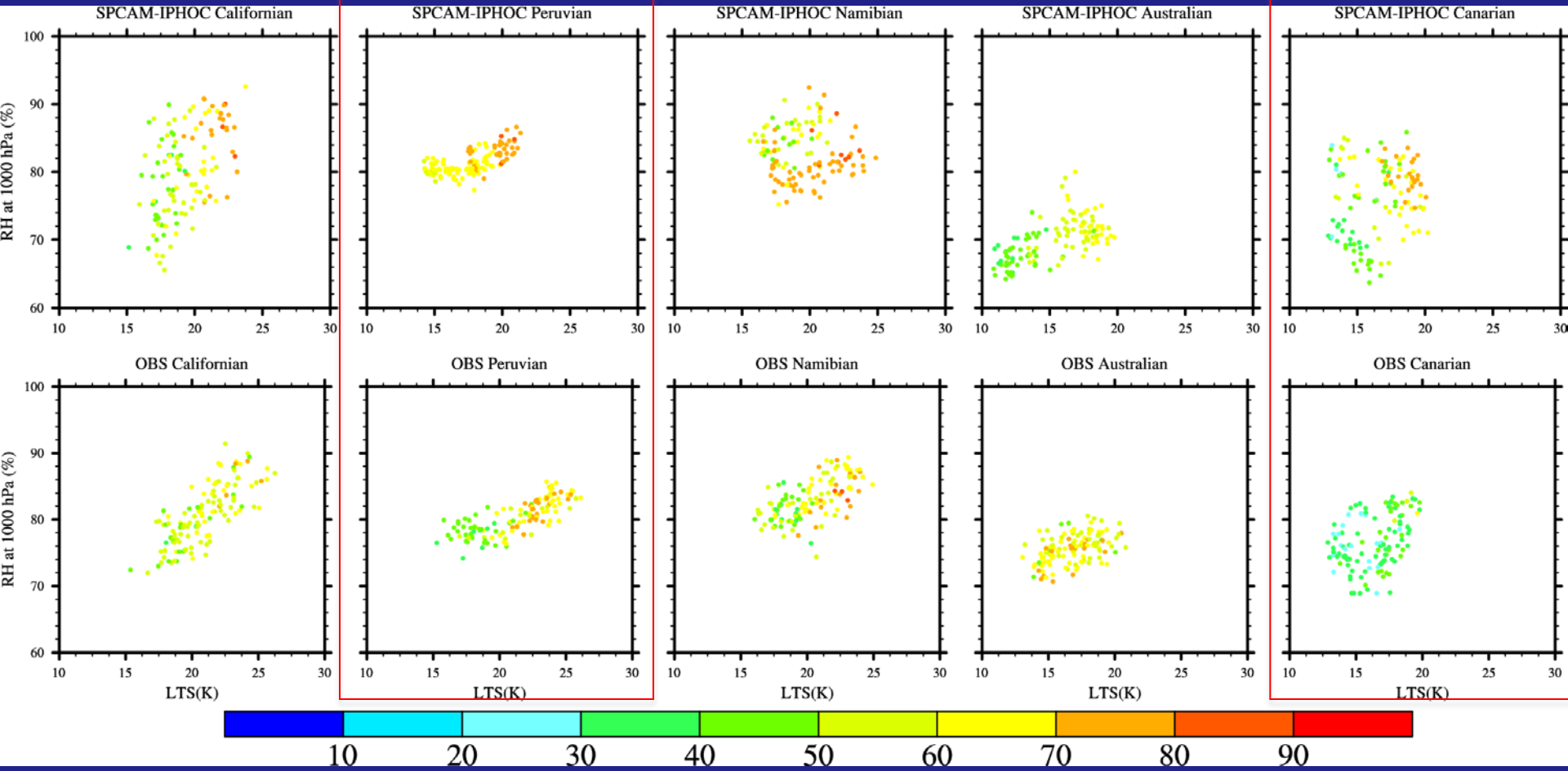
TOA SW cloud radiative effects (Obs.: CERES)

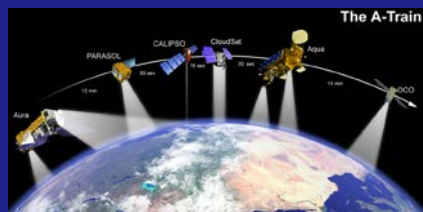


Sfc LW cloud radiative effects (Obs.: CERES)

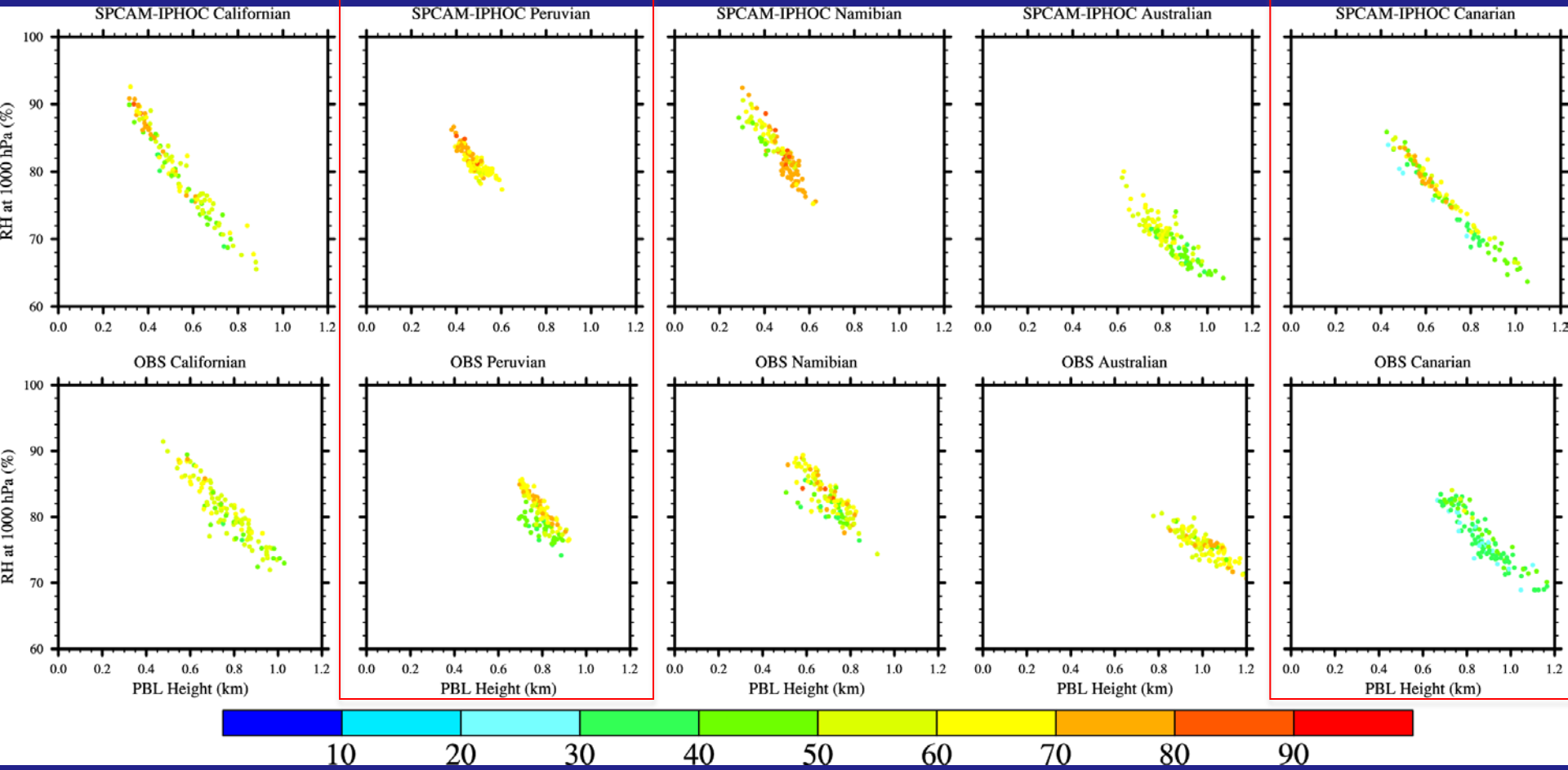


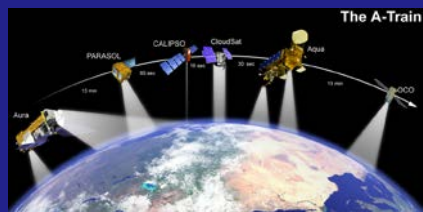
Relationships with RH (@1000 hPa) and LTS





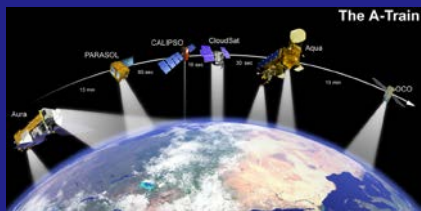
Relationships with RH (@1000 hPa) and PBL Hgt



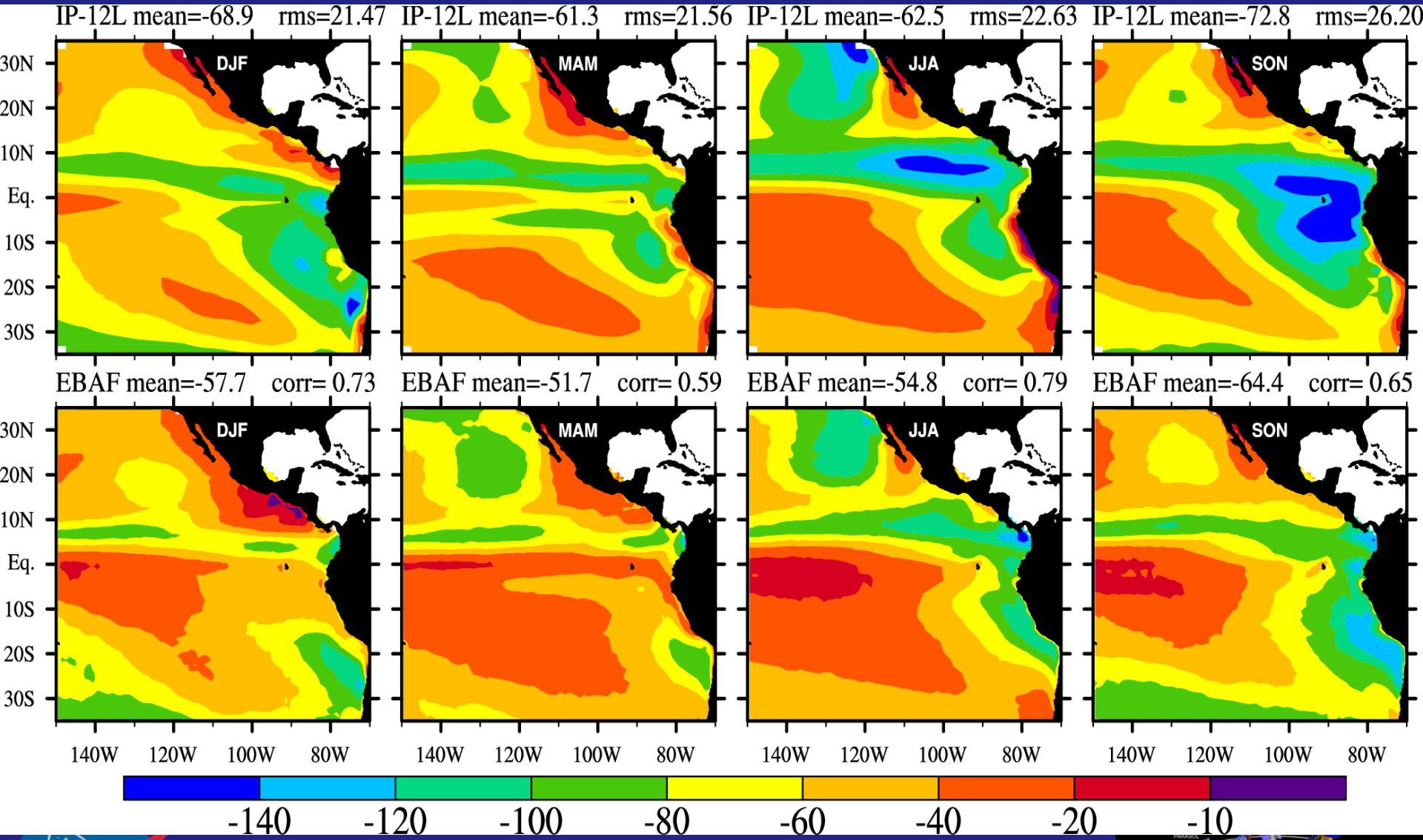


Summary

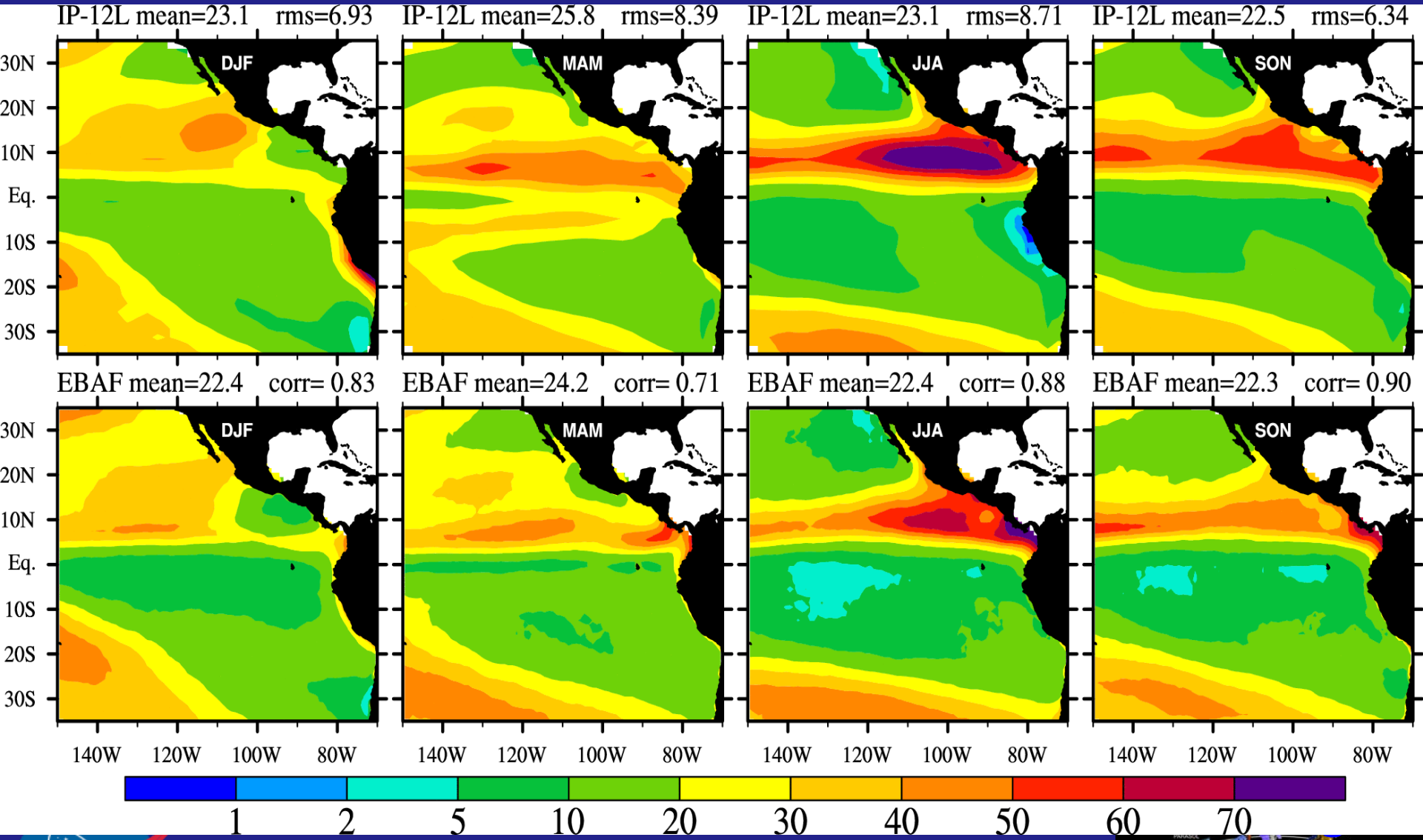
- The seasonal variations in the eastern Pacific are realistically simulated to a great extent, but the locations of maximum cloud centers are more equatorward than in observations
- The relationships of low clouds with large-scale variables (RH at 1000 hPa, LTS and PBL height) agree with the observations in the low cloud deck regions



Sfc SW cloud radiative effects (Obs.: CERES)



TOA LW cloud radiative effects (Obs.: CERES)



Low Cloud Amount & LTS (ERA Interim)