Improving Low-Cloud Simulation with an Upgraded Multiscale Modeling Framework

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Motivation and outline of this talk

From Teixeira et al. (2011):

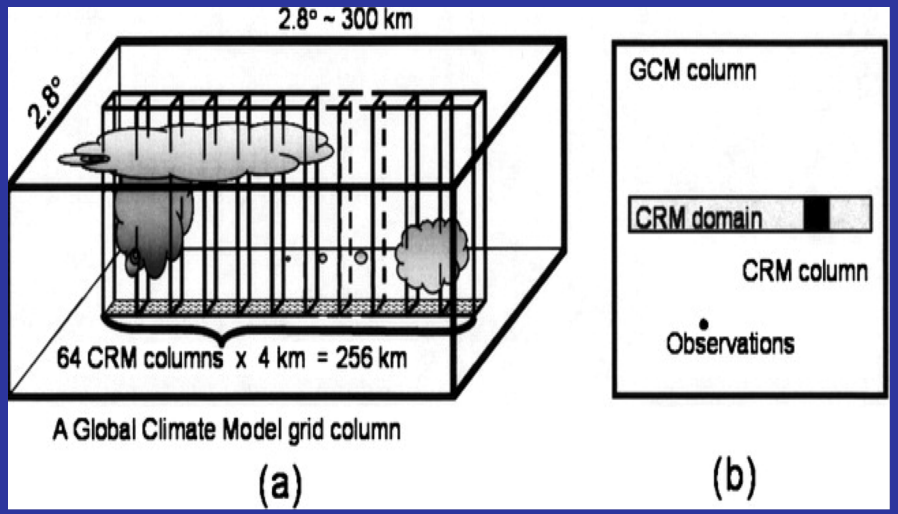
Unfortunately, many of the important characteristics of these (low) cloud regimes are not realistically represented in weather and climate prediction models.

This is in spite of some promising advances in the development of cloud and cloudy boundary layer parameterizations during the last several years.

1. Global distribution of low clouds
2. Tropical/subtropical cloud regime transition
3. Seasonal variations of low clouds in the eastern Pacific
4. Relationships between low cloud and large-scale variables

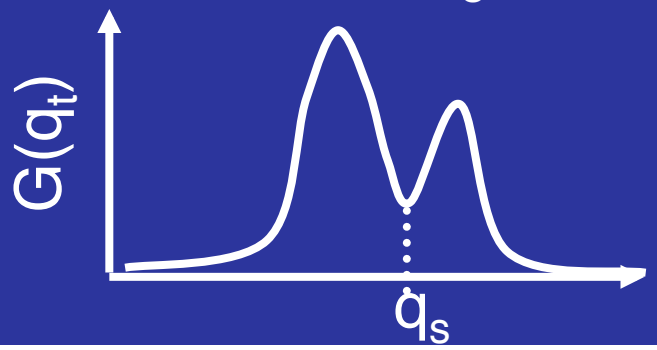
Multiscale Modeling Framework (MMF)
(Grabowski 2001; Khairoutdinov and Randall 2001)

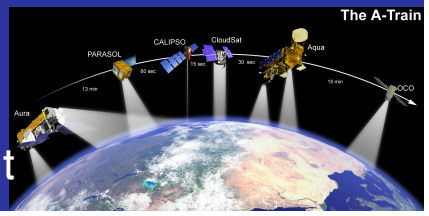
- A CRM is embedded at each grid column (~100s km) of the host GCM to represent cloud physical processes
- The CRM explicitly simulates cloud-scale dynamics (~1s km) and processes
- Periodic lateral boundary condition for CRM (not extend to the edges)



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



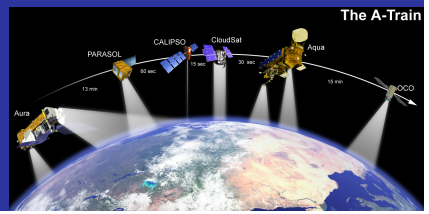


Objectives for MMF climate simulation

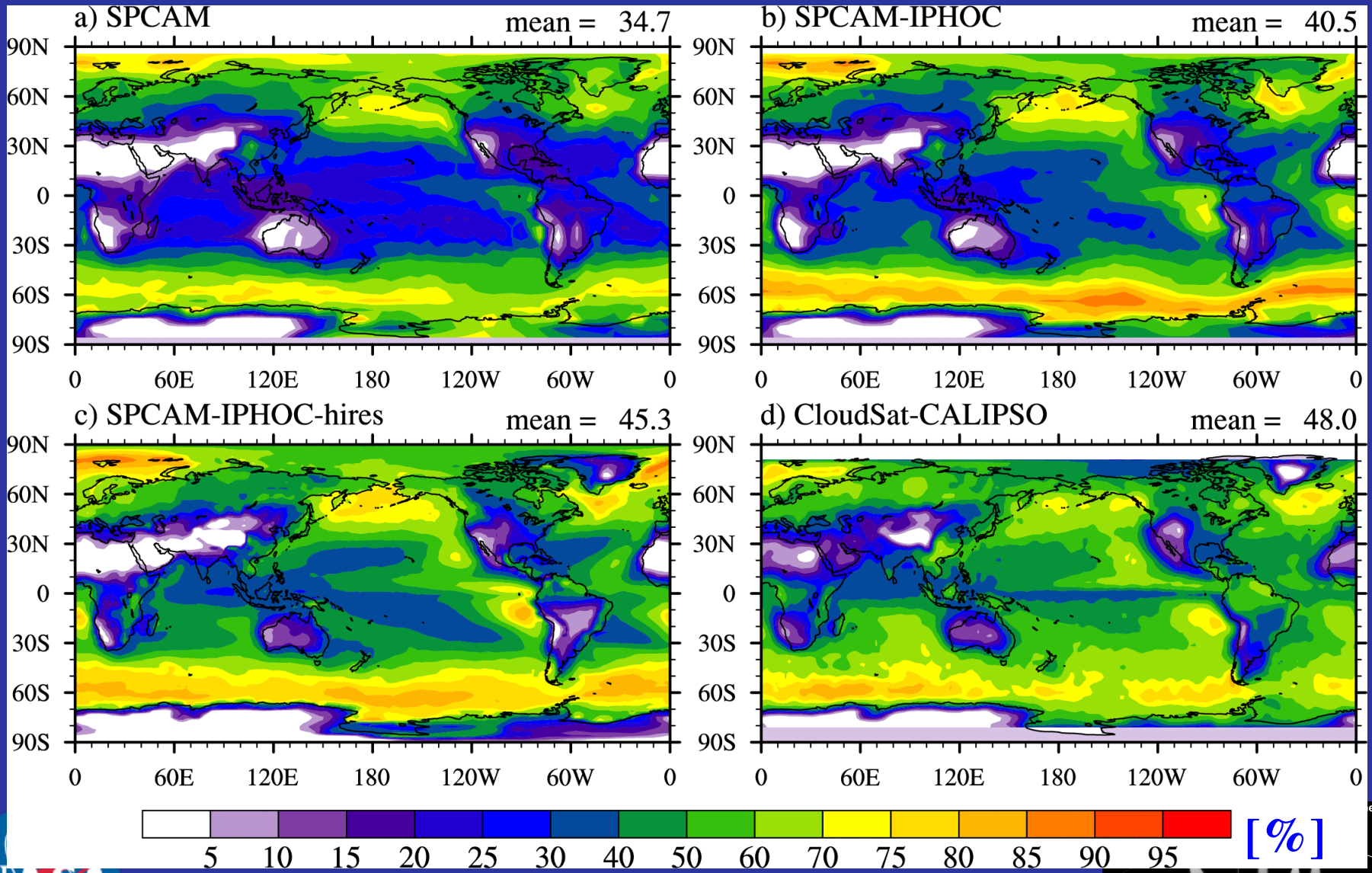
- to improve the simulation of low-level clouds in the SPCAM MMF
- to evaluate and compare the performance of MMF simulations against state-of-the-art observations

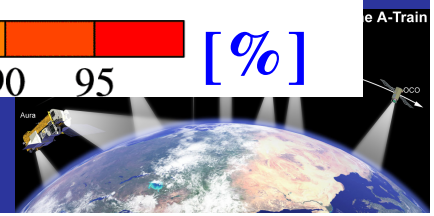
MMF models and observational data

- Standard *SPCAM*, at T21 resolution, 2-yr run (semi-Lagrangian)
- Upgraded SPCAM, called *SPCAM-IPHOC*, at T21 resolution (with semi-Lagrangian dynamic core); 2-yr run
- *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, ERA40, ERAI and NCEP reanalyses

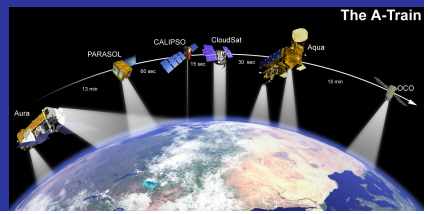


Low-level (sfc - 700 hPa) cloud amount (%)

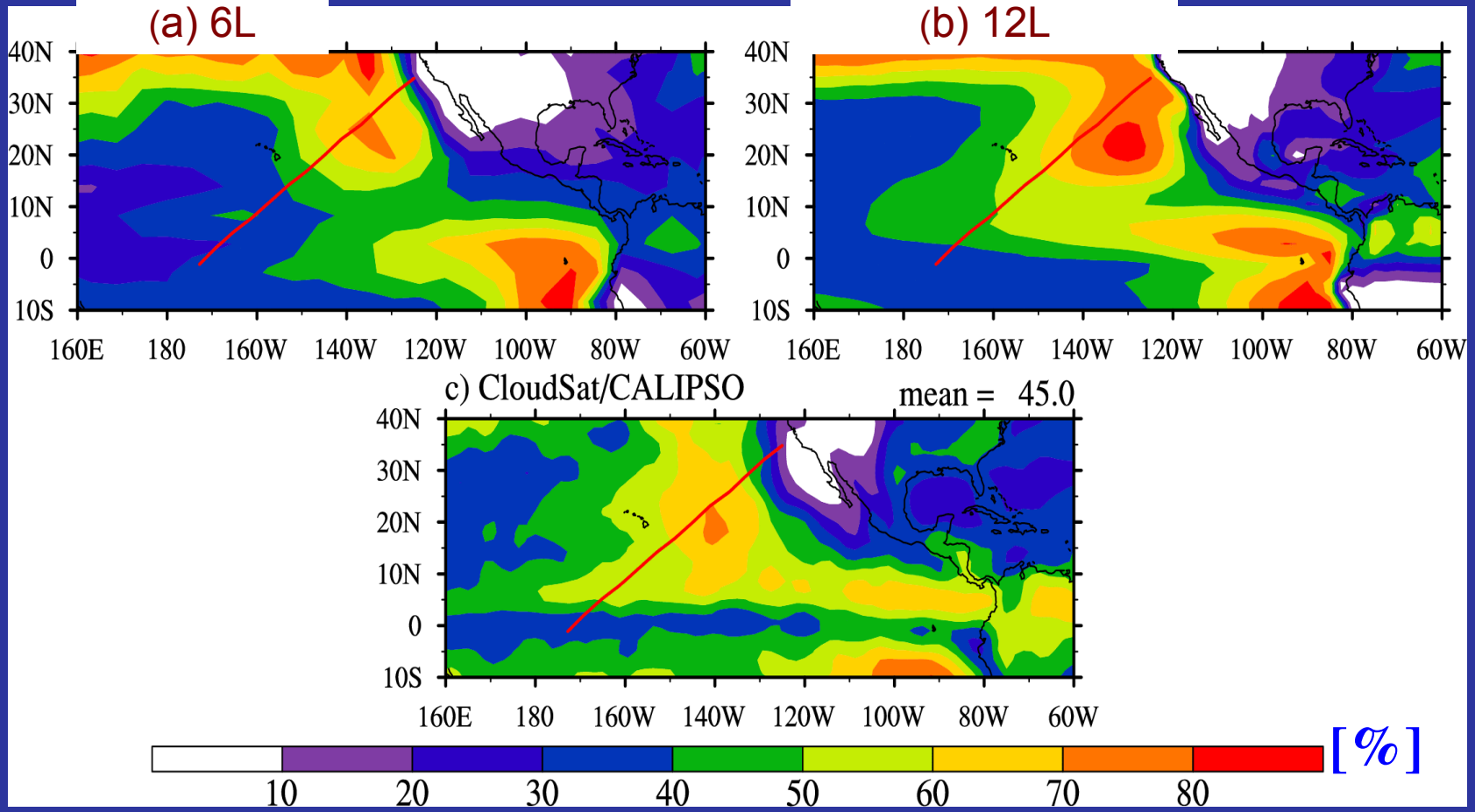


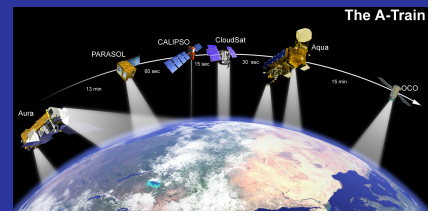


Tropical/subtropical cloud regime transition

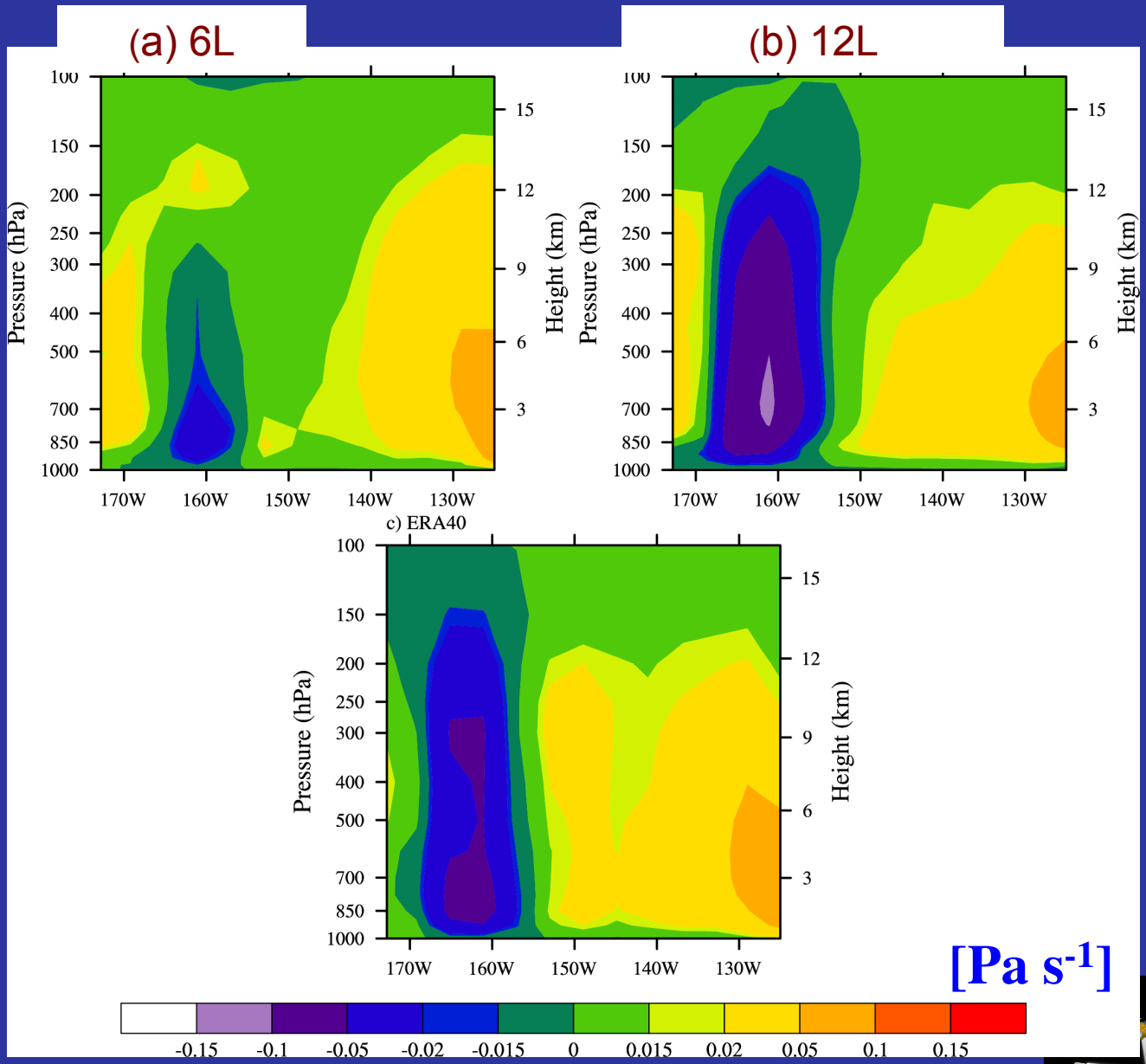


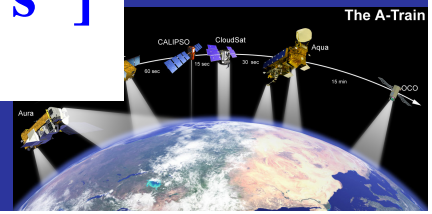
Northeastern (NE) Pacific transect: Low-level cloud amount



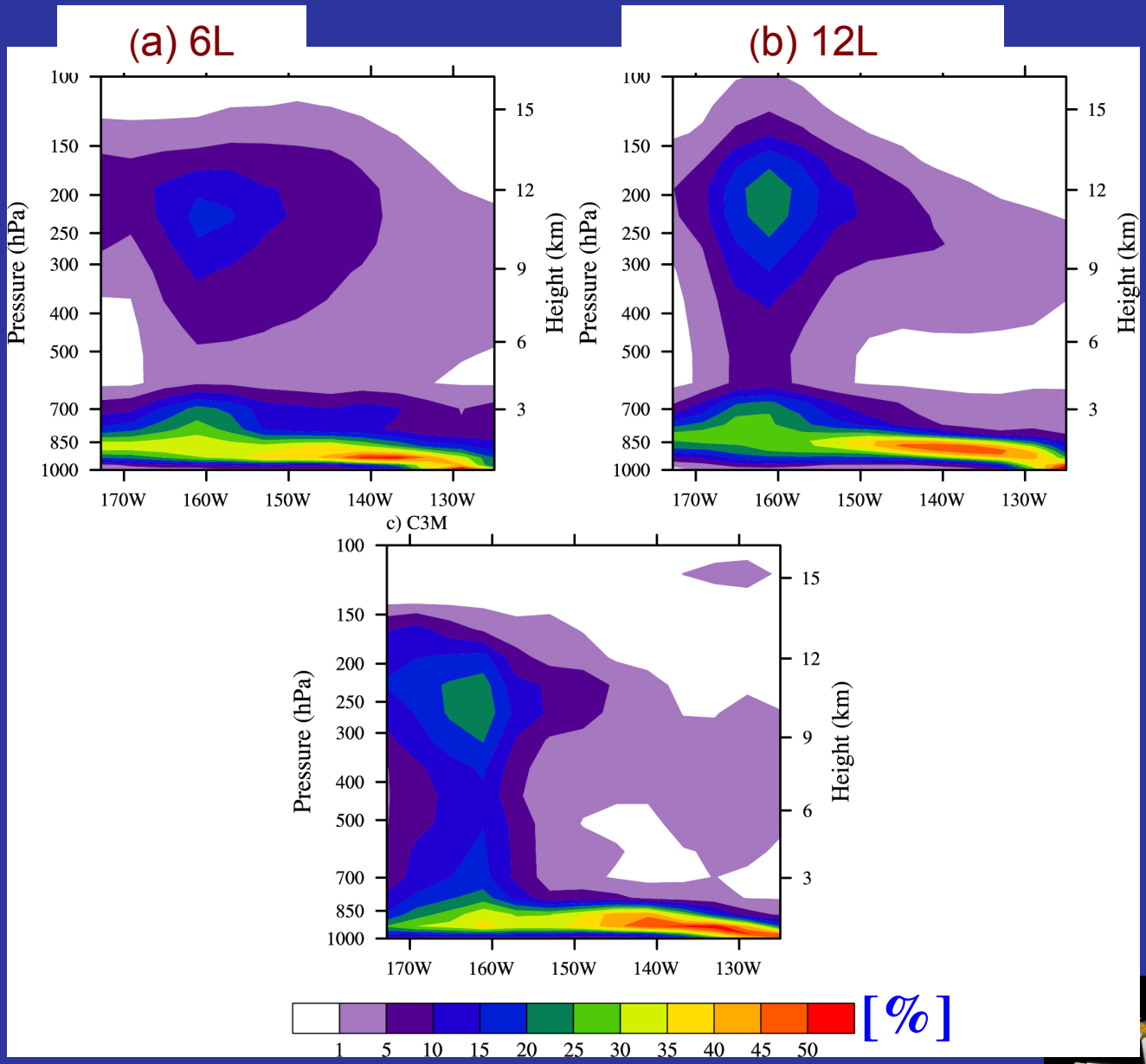


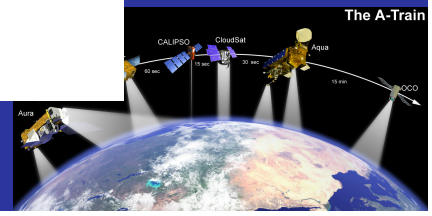
NE Pacific transect: L-S vertical velocity



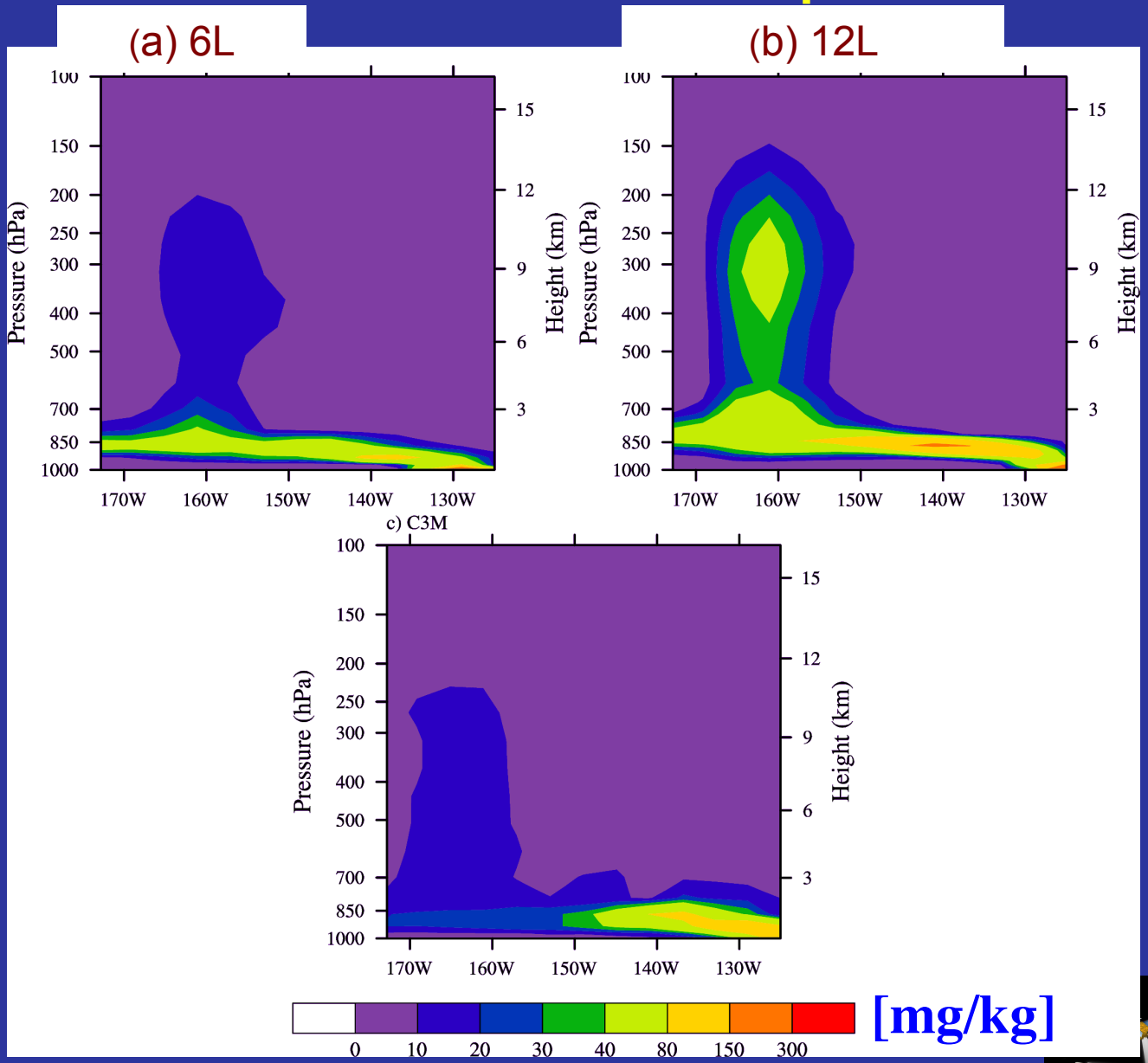


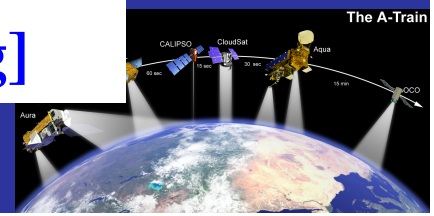
NE Pacific transect: Cloud fraction



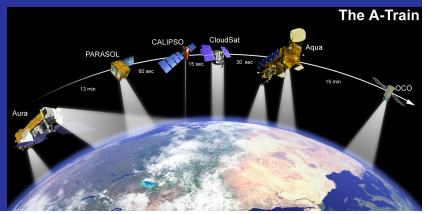


NE Pacific transect:Cloud liquid+ice content

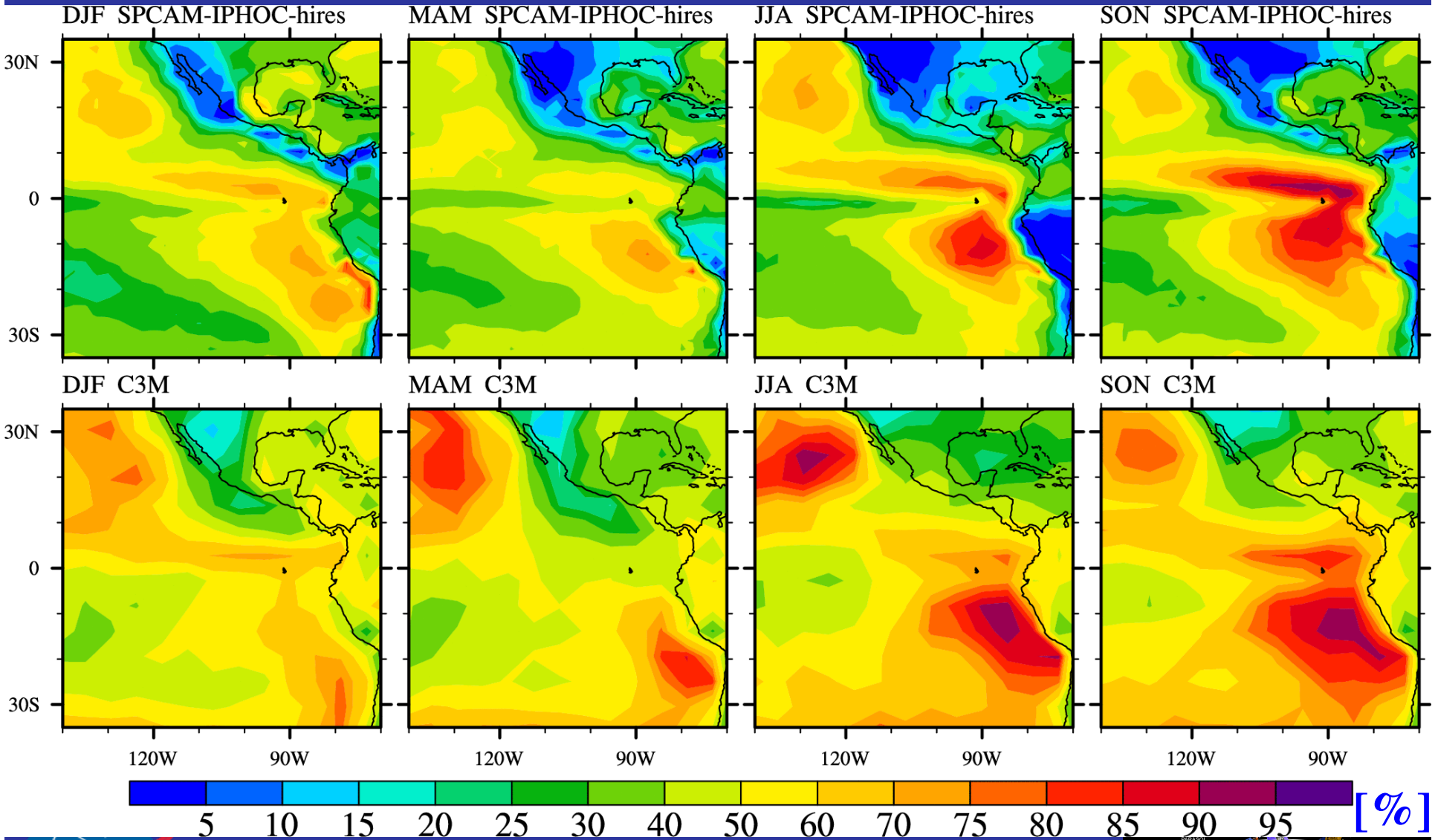




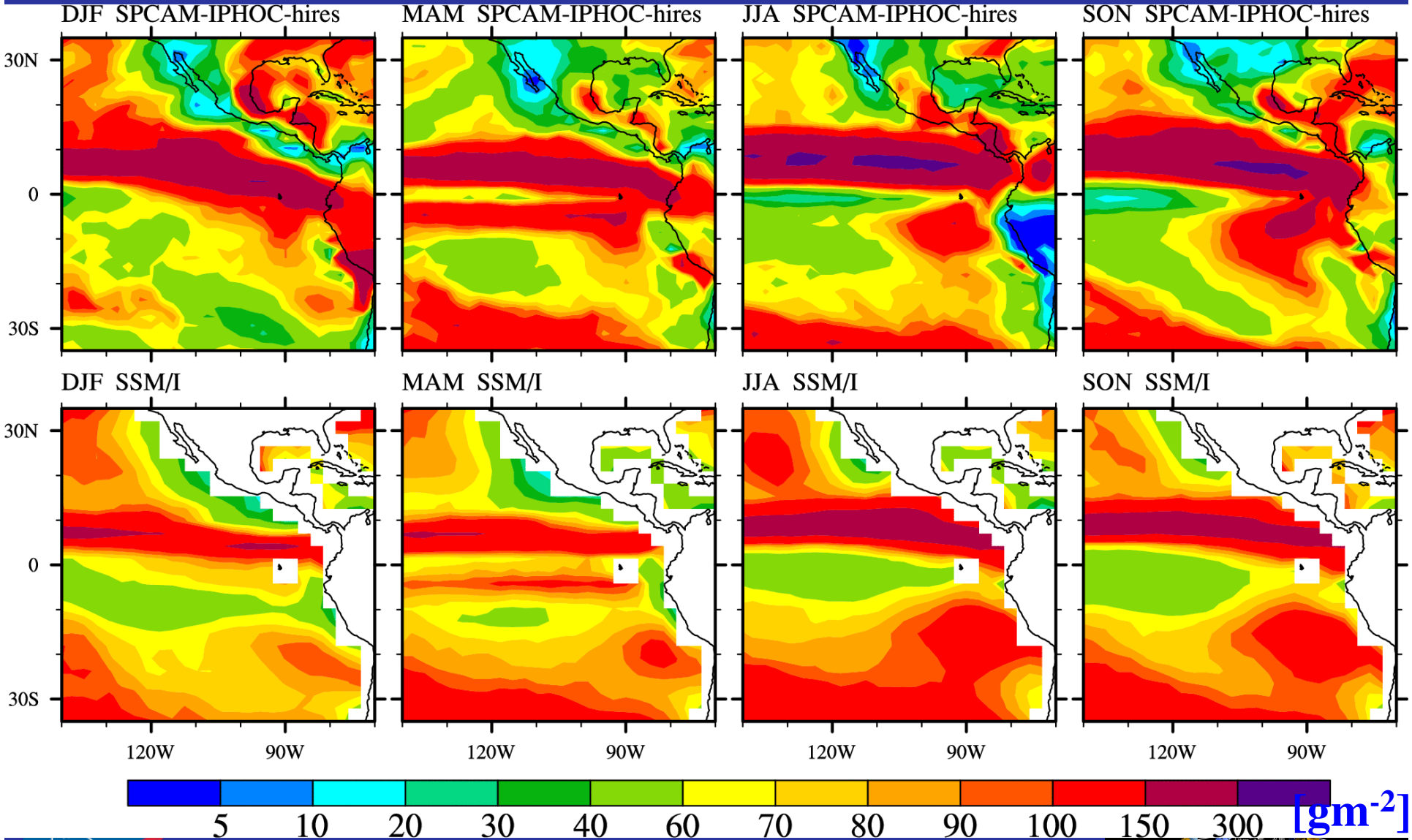
Seasonal variations of low clouds in the eastern Pacific



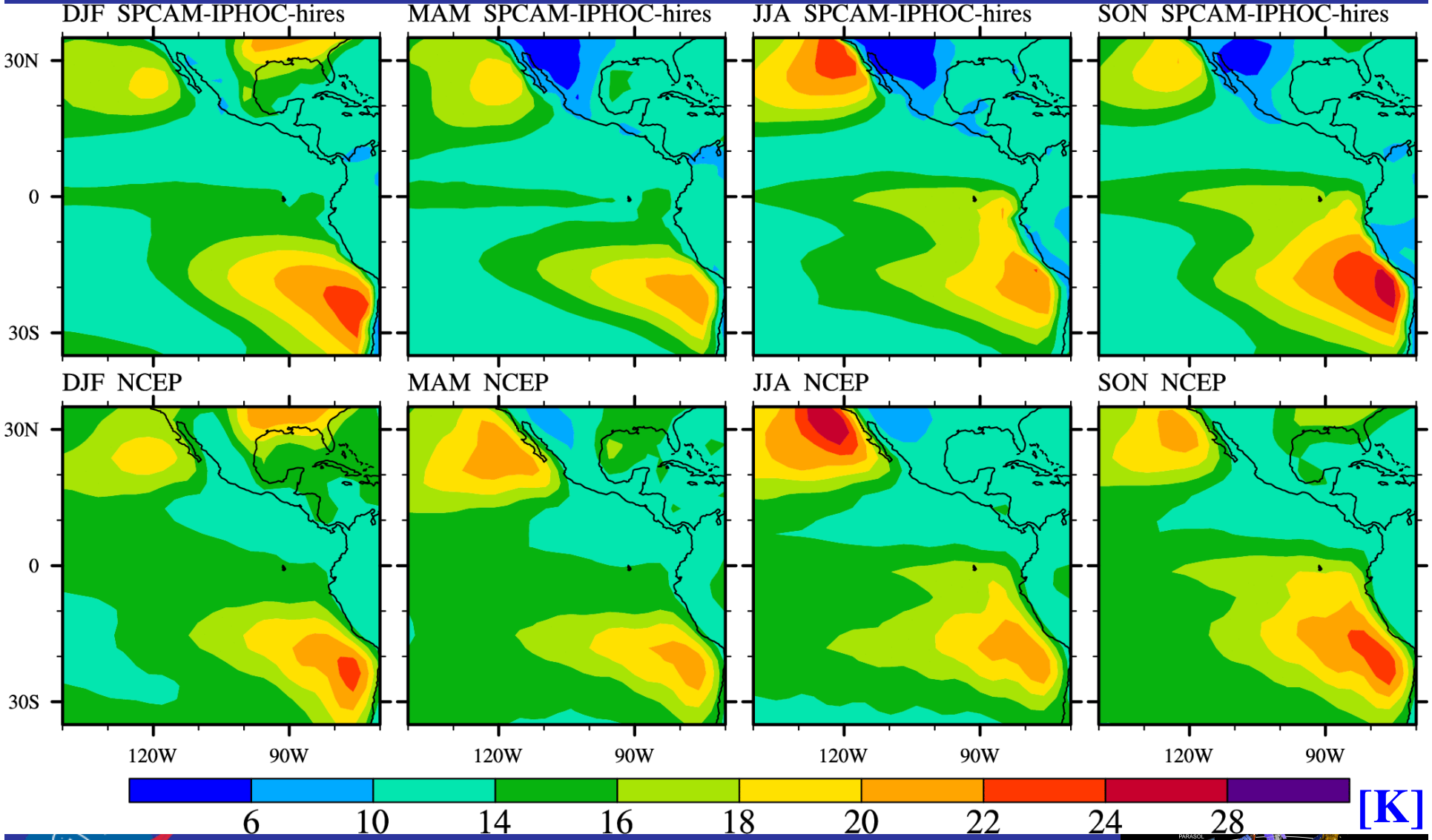
Seasonal variations: Low-level cloud amount



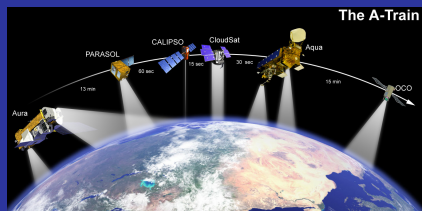
Seasonal variations: Liquid water path



Seasonal variations: Low tropospheric stability

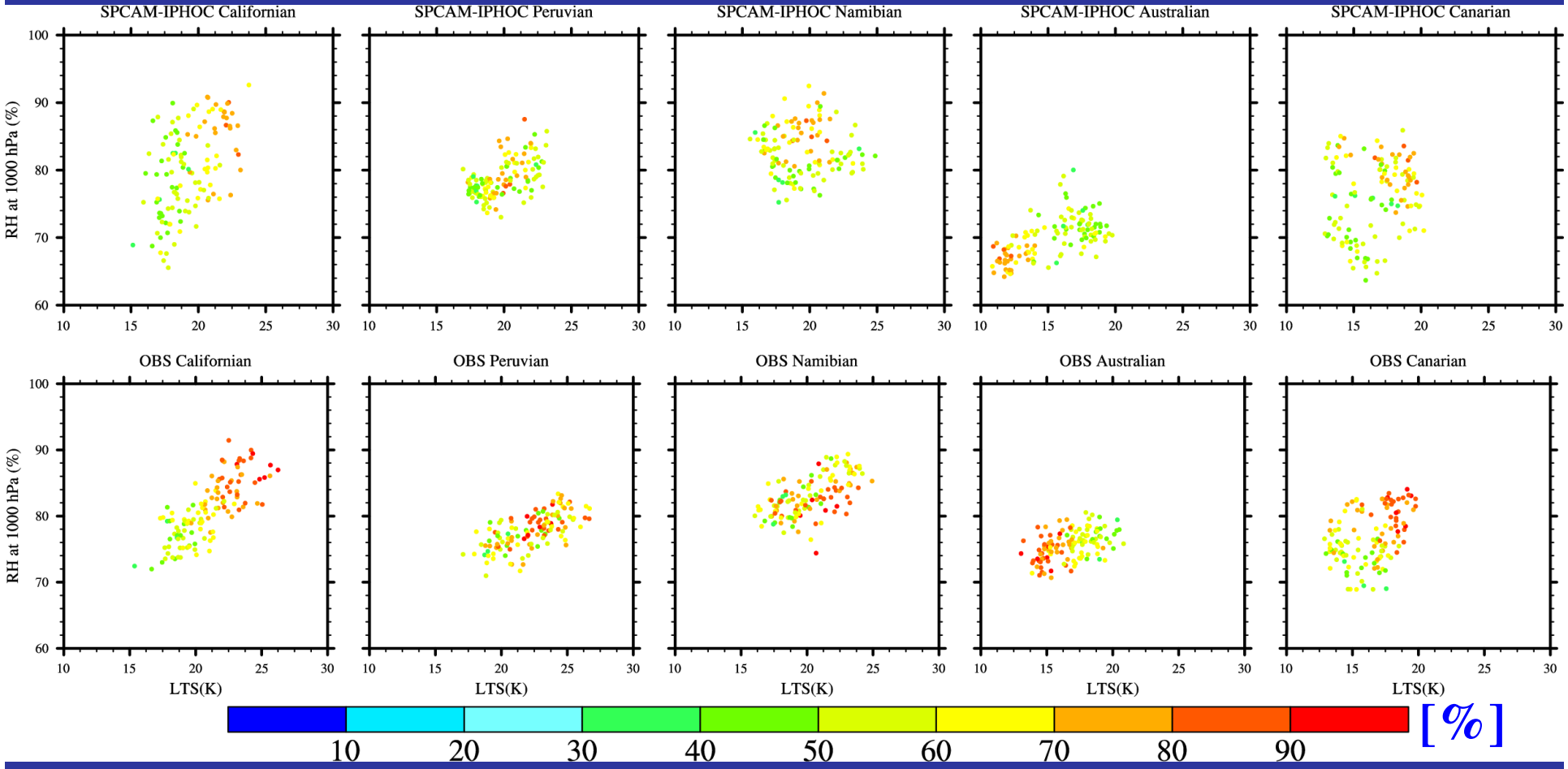


Relationships between low cloud and large-scale variables

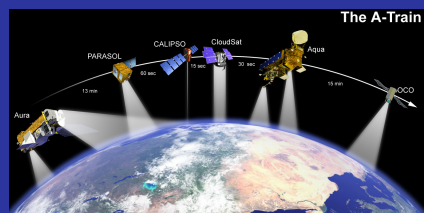


Relationships with RH (@1000 hPa) and LTS

SPCAM-IPHOC-hires (top row), Obs. (bottom row)

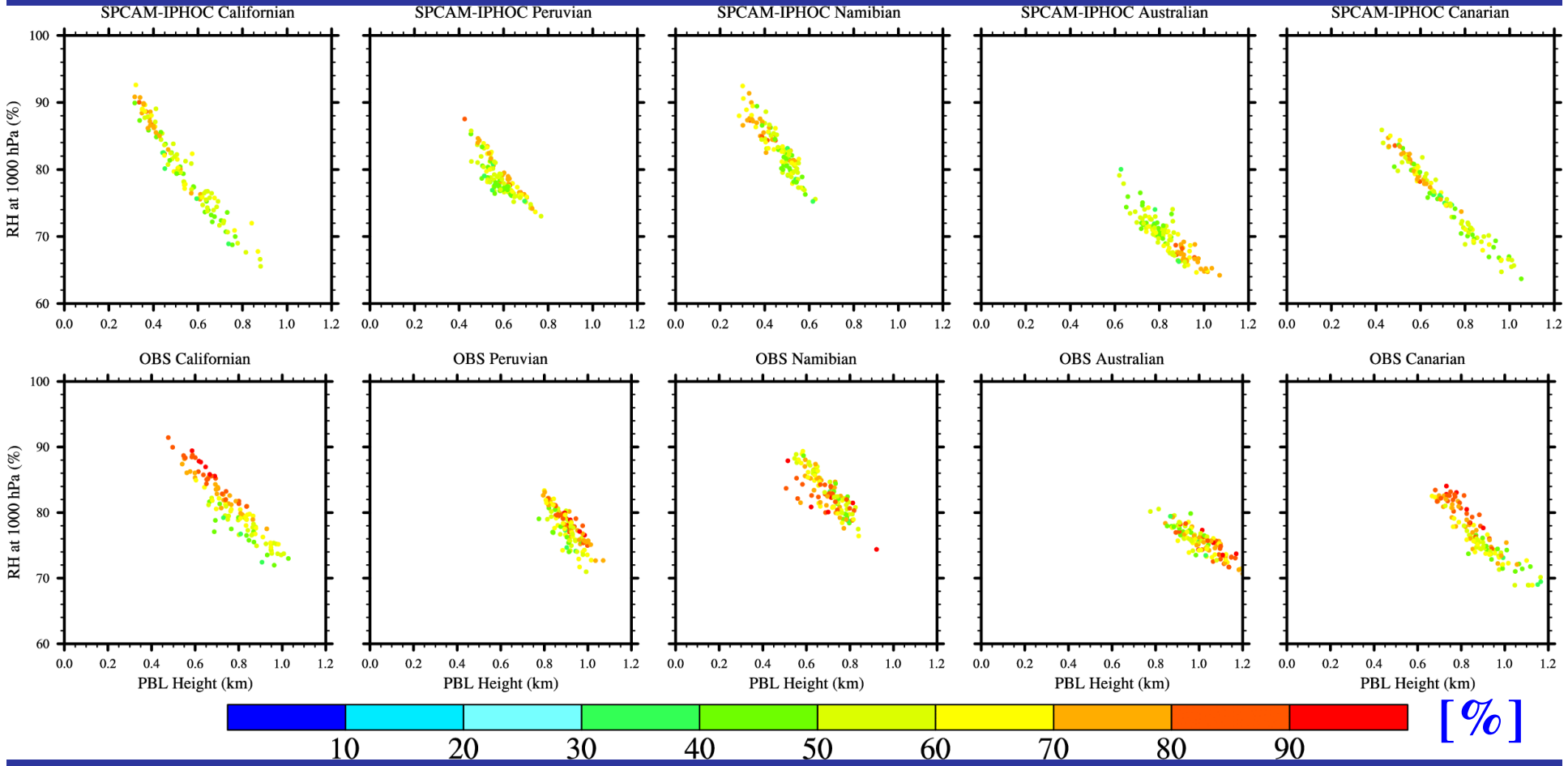


Obs: ISCCP D2 low+mid cld; ERA Interim

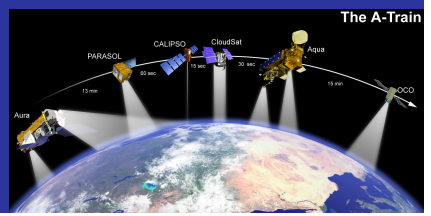


Relationships with RH (@1000 hPa) and PBL Hgt

SPCAM-IPHOC-hires (top row), Obs. (bottom row)

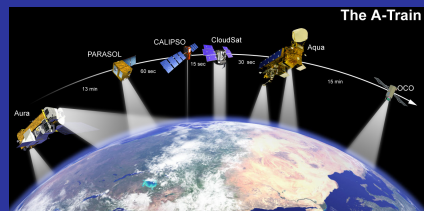


Obs: ISCCP D2 low+mid cld; ERA Interim

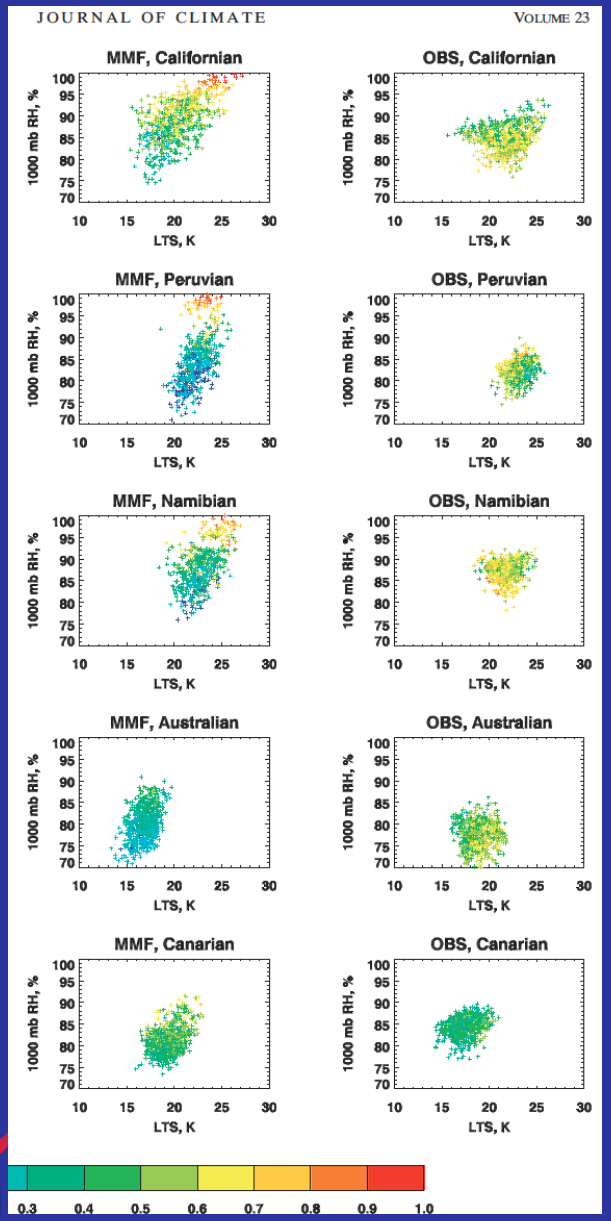


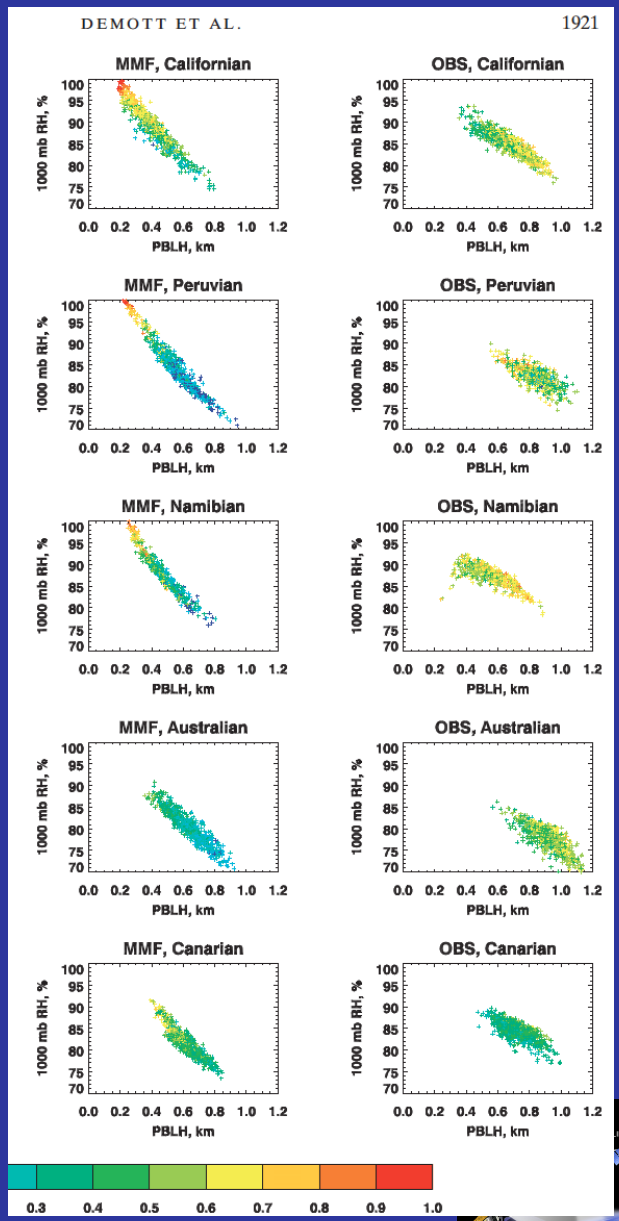
Summary

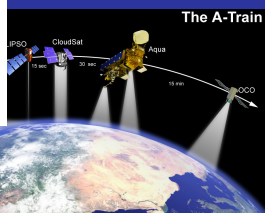
- Both upgraded MMF simulations show improved representation of the global distributions of low-level clouds and the amounts of low-level clouds in the subtropics
- The additional resolution in the lower troposphere (from 6 levels to 12 levels below 700 hPa) greatly improves the simulation
- The tropical/subtropical cloud regime transition is realistically simulated, especially for the low clouds
- The seasonal variations in the eastern Pacific are realistically simulated to a great extent
- 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



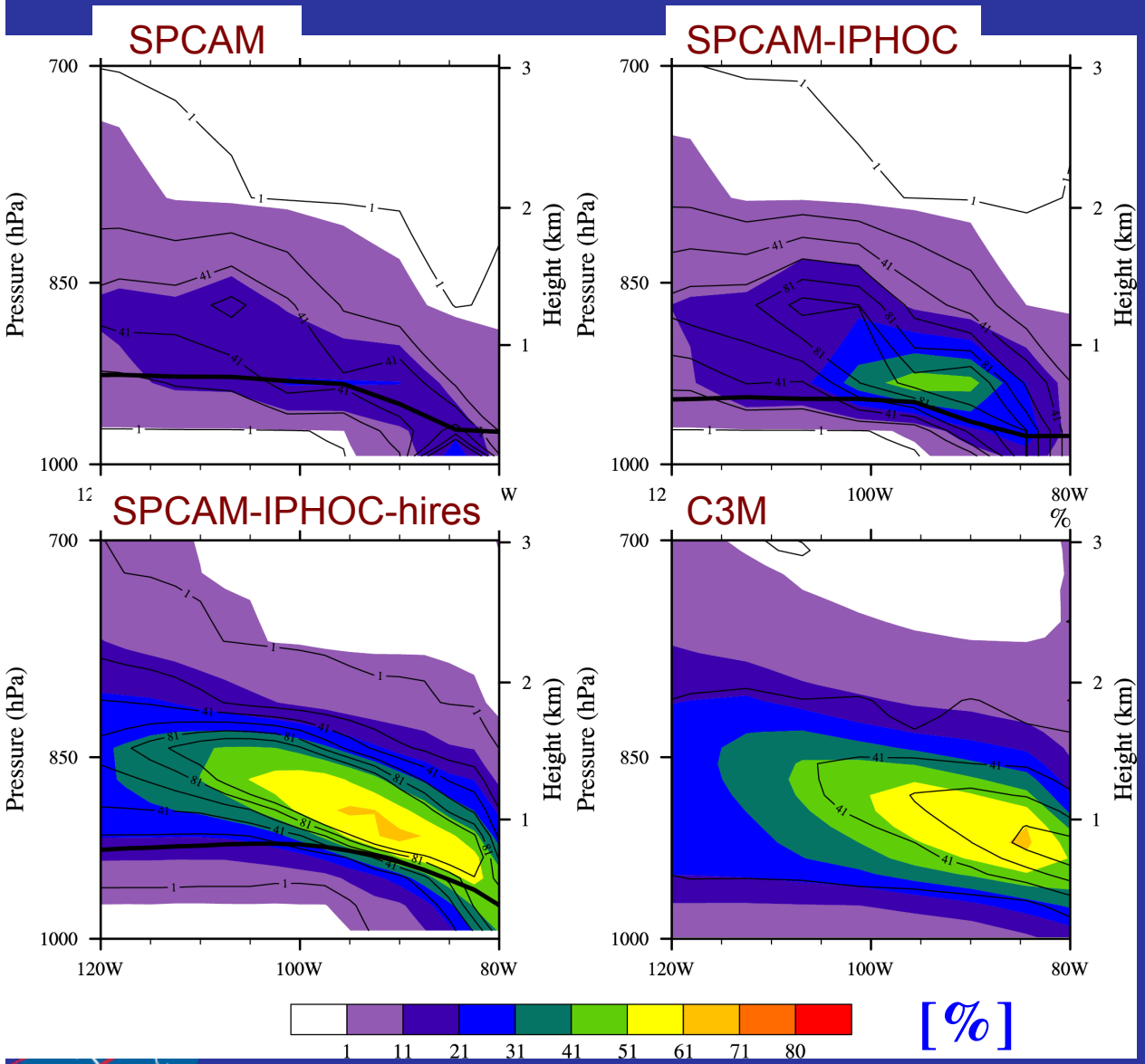
Relationships w/ RH, LTS and PBL Hgt in SPCAM



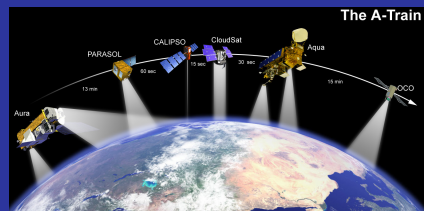




Annual mean cloud fraction (color) and cloud liquid water (contour) west of South America (15°S)



Cheng, A. and K.-M. Xu, 2011: Improved low-cloud simulation from a multiscale modeling framework with a third-order turbulence closure in its cloud-resolving model component. *J. Geophys. Res.*, **116,** D14101, doi: 10.1029/2010JD015362.



Seasonal variations: SST and wind