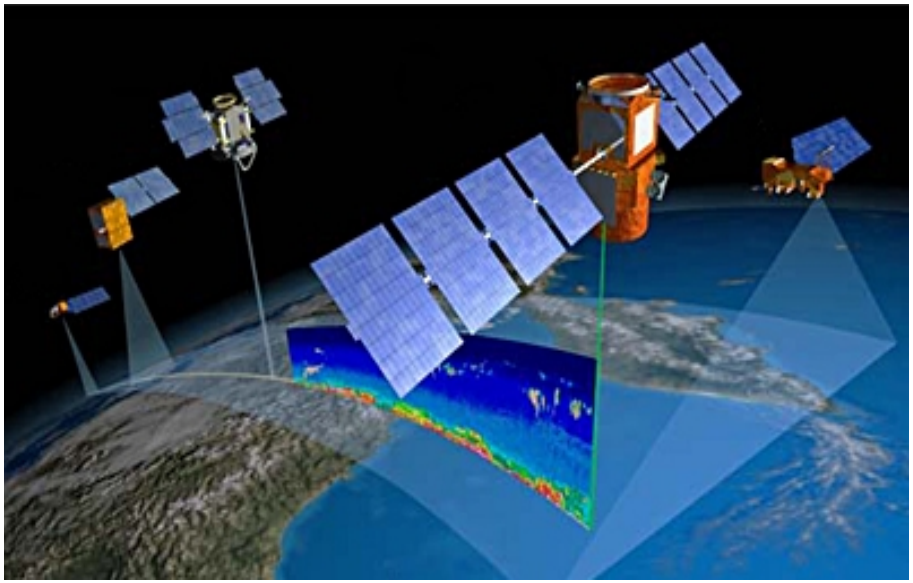
A sneak peak at compensating errors in the vertical distribution and optical properties of clouds in several CMIP5 models.



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Laboratoire de Météorologie Dynamique

Structure

Overview of models, satellites, data sets and simulators used.

Comparison of observations and CMIP5 model output:

- cloud radiative forcing
- vertical distribution of low-level clouds
- cloud optical properties
- large-scale environment.

Conclusions

Identify systematic compensating errors and areas of inter-model spread amongst the vertical representations of clouds and their optical properties using satellite retrievals.

CMIP5 Models & Observations

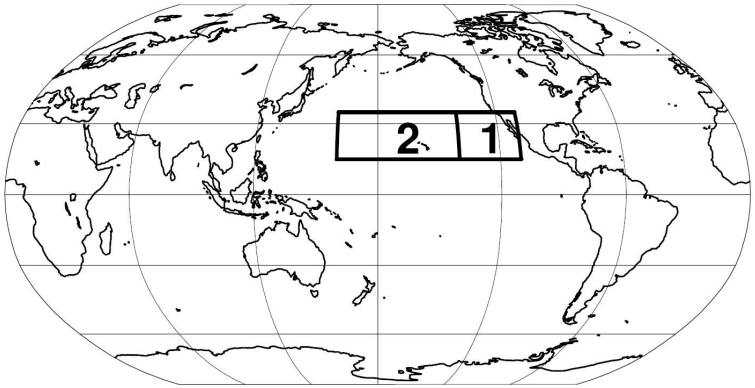
- CMIP5: AMIP experiments from 06/2006 – 12/2008.
  - IPSL: IPSL-CM5A-LR
  - IPSL: IPSL-CM5A-LR
  - CNRM: CNRM-CM5
  - MPI-M: MPI-ESM-LR
  - MOHC: HadGEM2-A
  - CCCma: CanAM4

  } With COSP* CALIPSO and Parasol satellite simulators.

- Observations: Combine active and passive satellite instruments to understand the vertical structure of multi-layered clouds.
  - CALIPSO (GOCCP): Total/High/Mid/Low & 3D cloud fraction.
  - Parasol: Reflectance
  - CERES (EBAF): Cloud Radiative Forcing
  - ERA-Interim: Large scale environmental properties.

First Study:

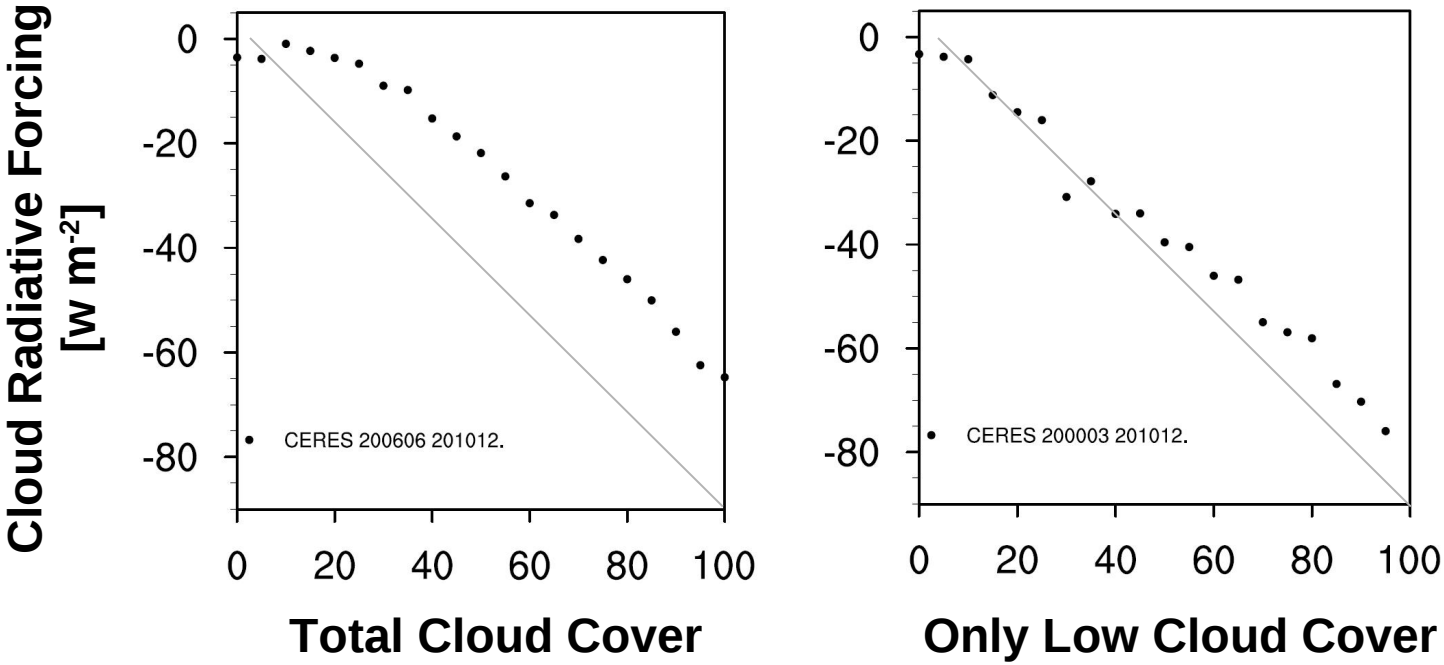
- Cloud Radiative Forcing (CRF) above two geographical regions, representing low-level clouds:
  - Californian Stratocumulus
  - Hawaiian Shallow Cumulus.



Tropical, marine boundary layer clouds identified as primary cause for inter-model differences, in particular trade cumulus clouds and stratocumulus-to-cumulus transitions*.

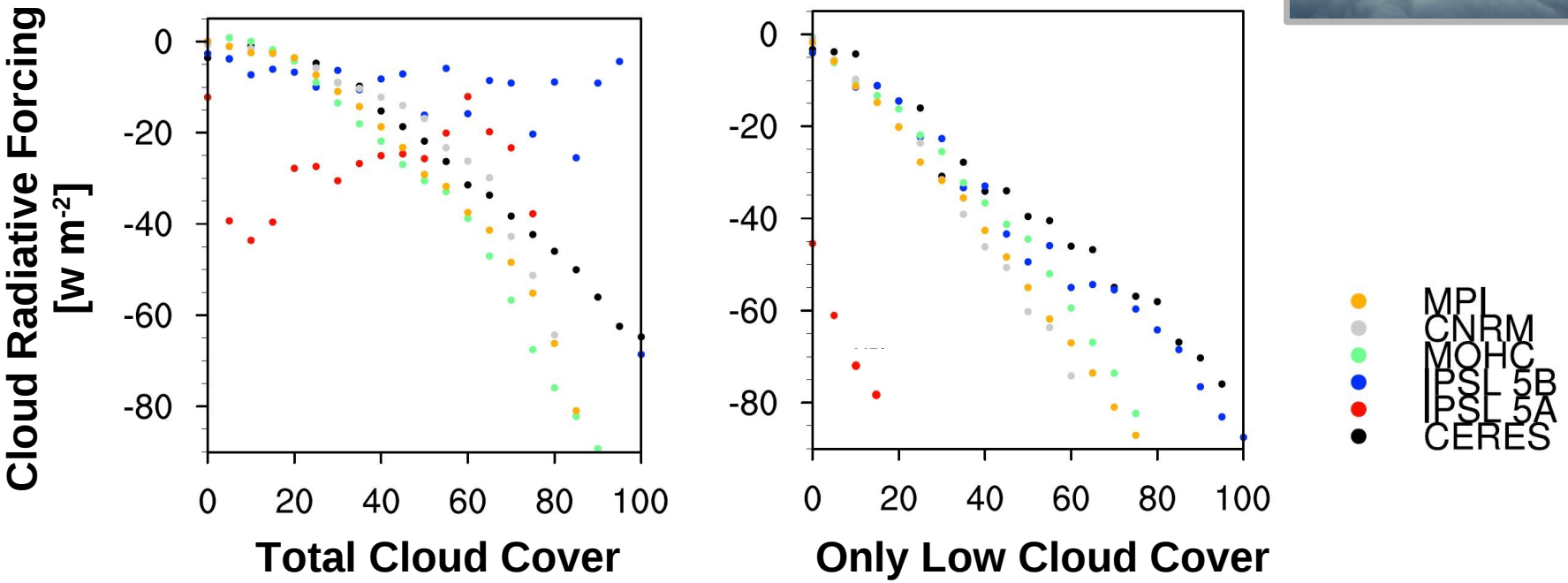
* Bony and Dufresne, 2005

Californian Stratocumulus



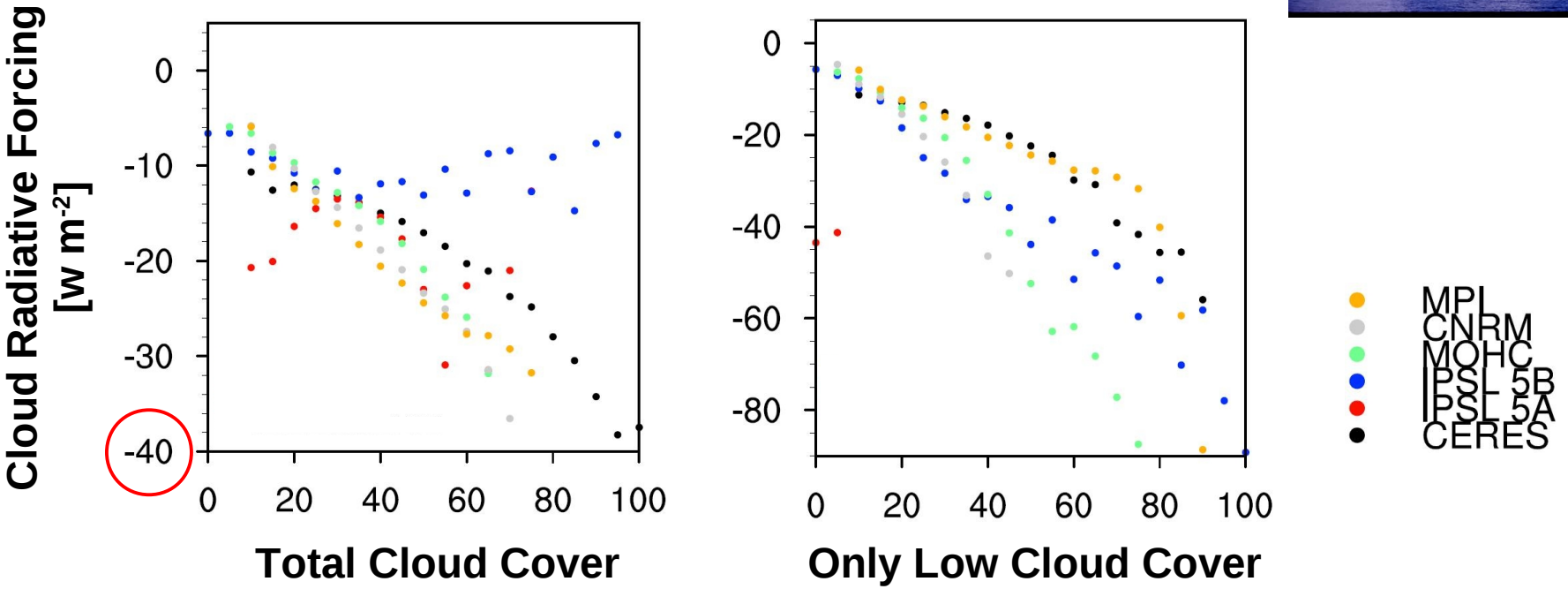
- 'Only' Low-level cloud conditions occur when high- and mid-level clouds, as defined by CALIPSO, are less than 5%.
- High- and mid-level clouds act to dampening CRF.

Californian stratocumulus



- Models show large inter-model spread in CRF due to varying amounts of high- and mid-level clouds.
- CRF under 'Only Low-level' clouds conditions, very similar, though too reflective.

Hawaiian Shallow Cumulus

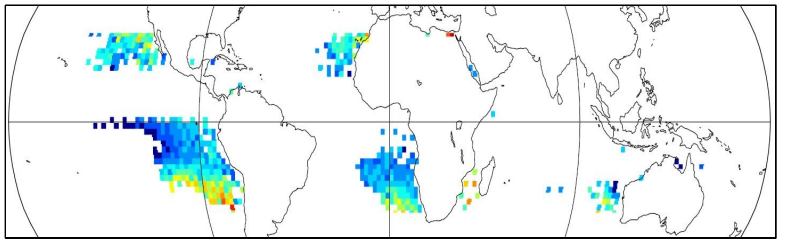


- Models show similar CRF under total cloud conditions due to compensating errors.
- CRF under 'Only Low' cloud conditions show clouds too reflective. Large inter-model spread amongst low-level clouds.

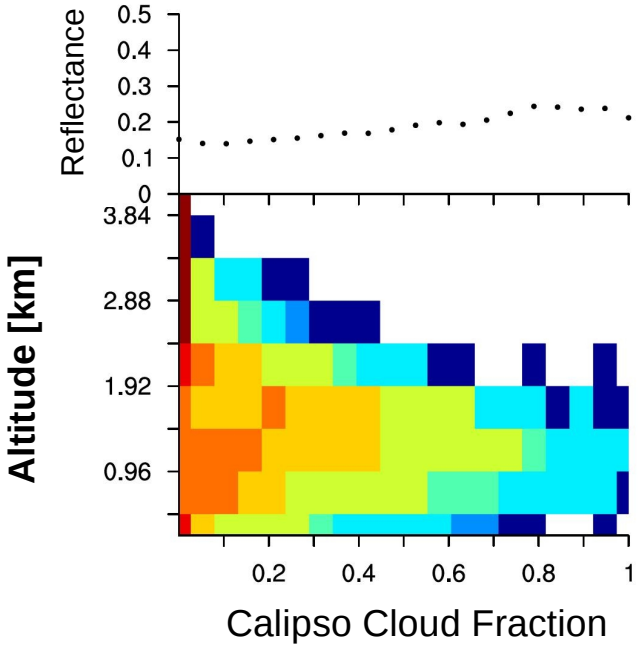
Second Study:

- Expanded study area to 30N/30S.
- Identified only low-level clouds (H,M<5%) under large-scale subsidence (w_{500hPa},w_{700hPa}<10hPa day^{-1}).
- Use LTS determine stratocumulus and shallow cumulus regimes.

Dynamical Stratocumulus

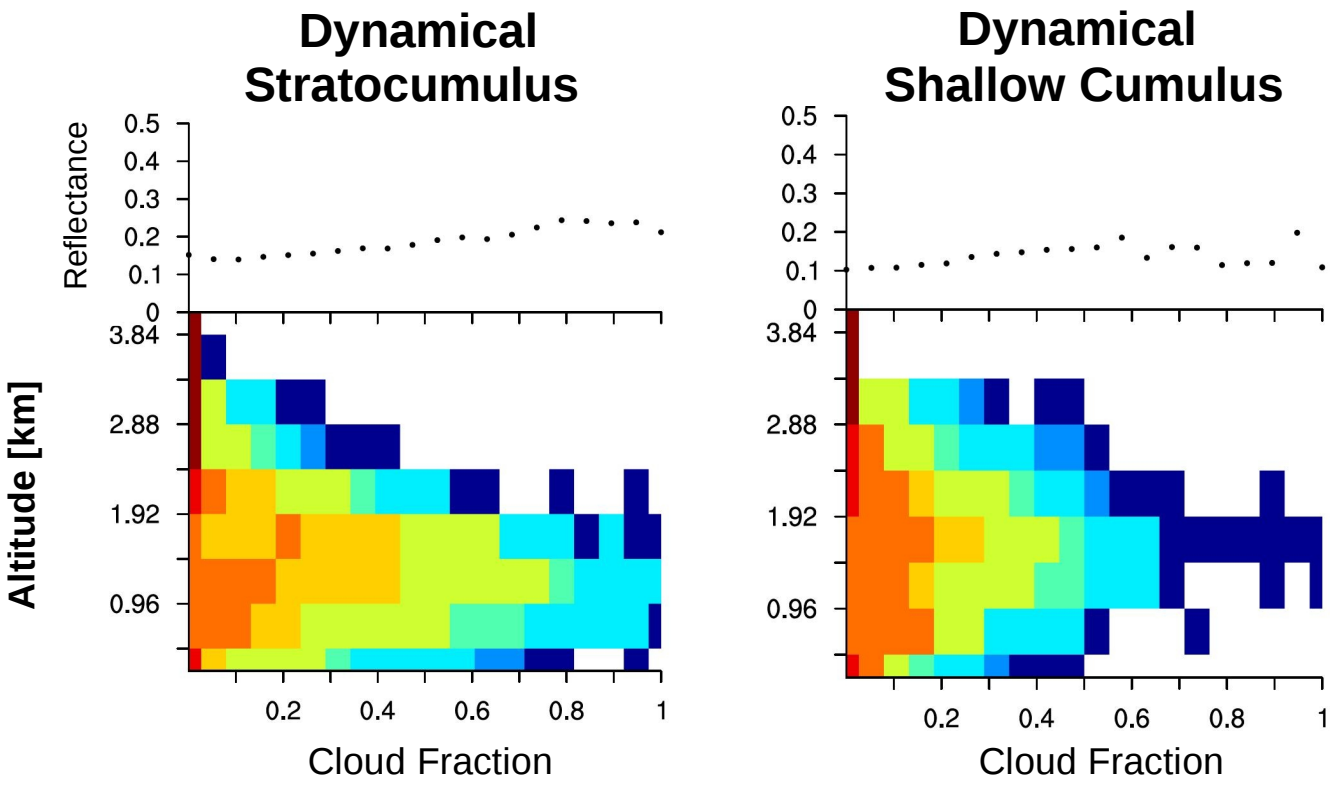


- Determine frequency of clouds of a given fraction at a given altitude in the lowest 4km of atmosphere.
- Determine average Parasol reflectance of clouds for a given cloud fraction.



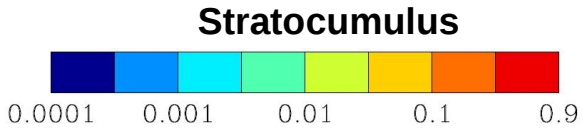
Cloud Optical Properties

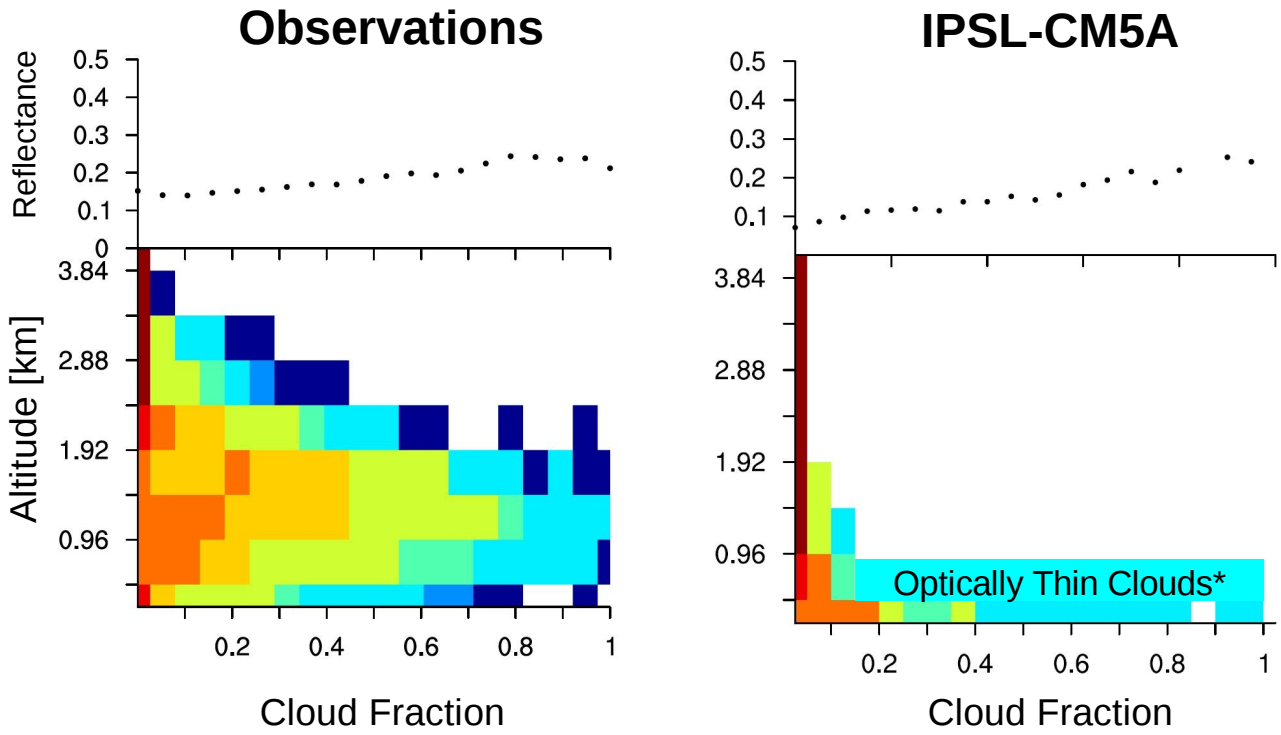
CALIPSO/ Parasol Observations



- Stratocumulus regime has a greater frequency of clouds with large fractions lower in the atmosphere than shallow cumulus regime.

Cloud Optical Properties

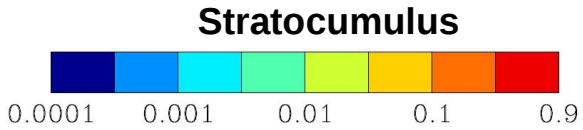


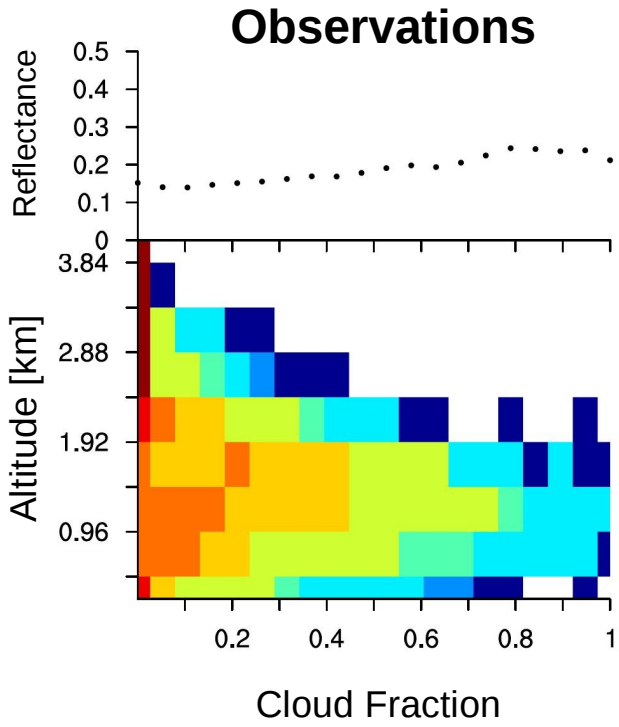


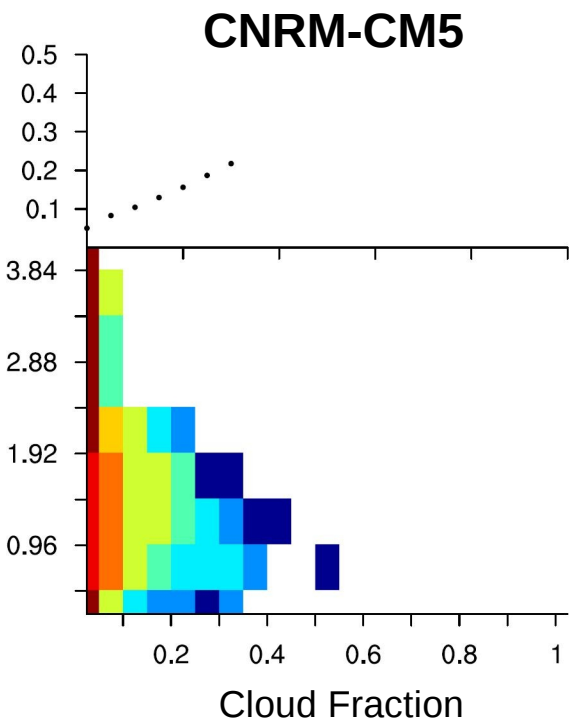
- Despite different vertical distribution of low-level clouds, reflectance is similar to observations.

*Lidar 3<SR<5: Undefined

Cloud Optical Properties

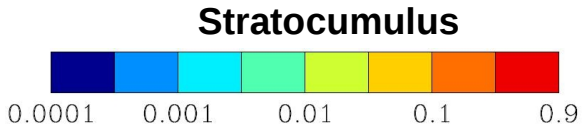


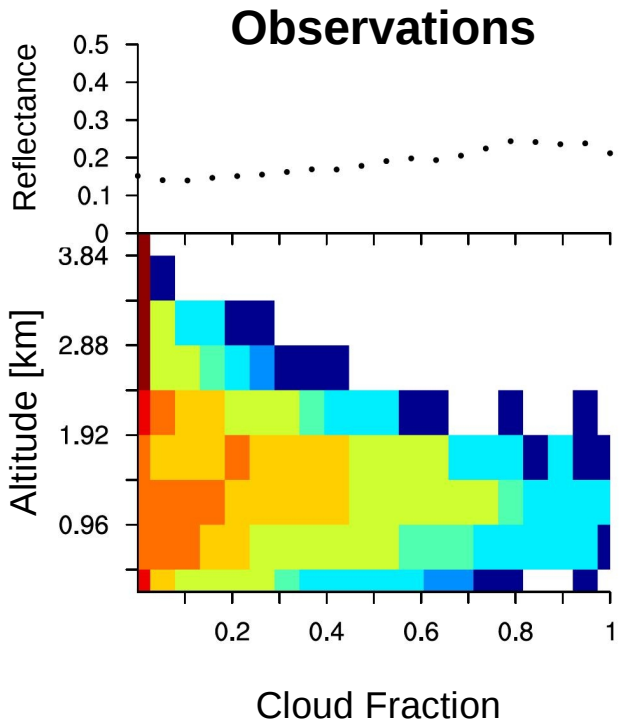


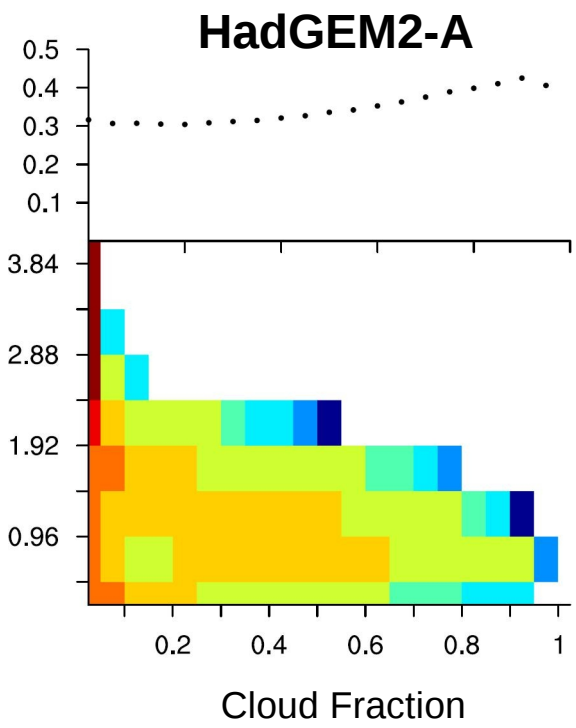


- Greater amount of clouds distributed vertically.
- Lacks presence of clouds with large fractions.
- Clouds with fractions >0.3 are optically bright.

Cloud Optical Properties

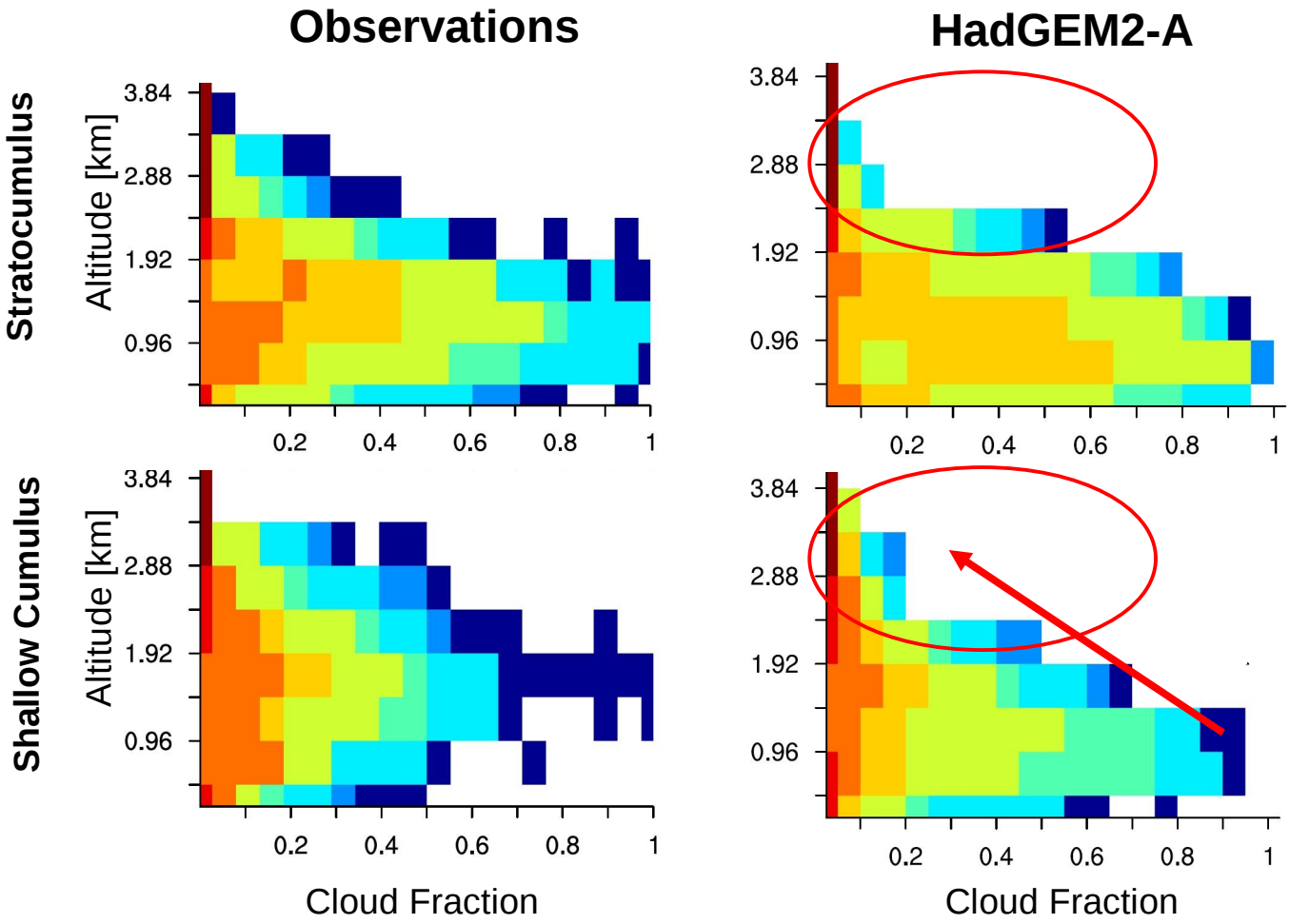






- HadGEM2-A best captures the vertical distribution of clouds.
- Frequency of clouds with fractions >0.6 overestimated.
- Reflectance overestimated for all fractions.

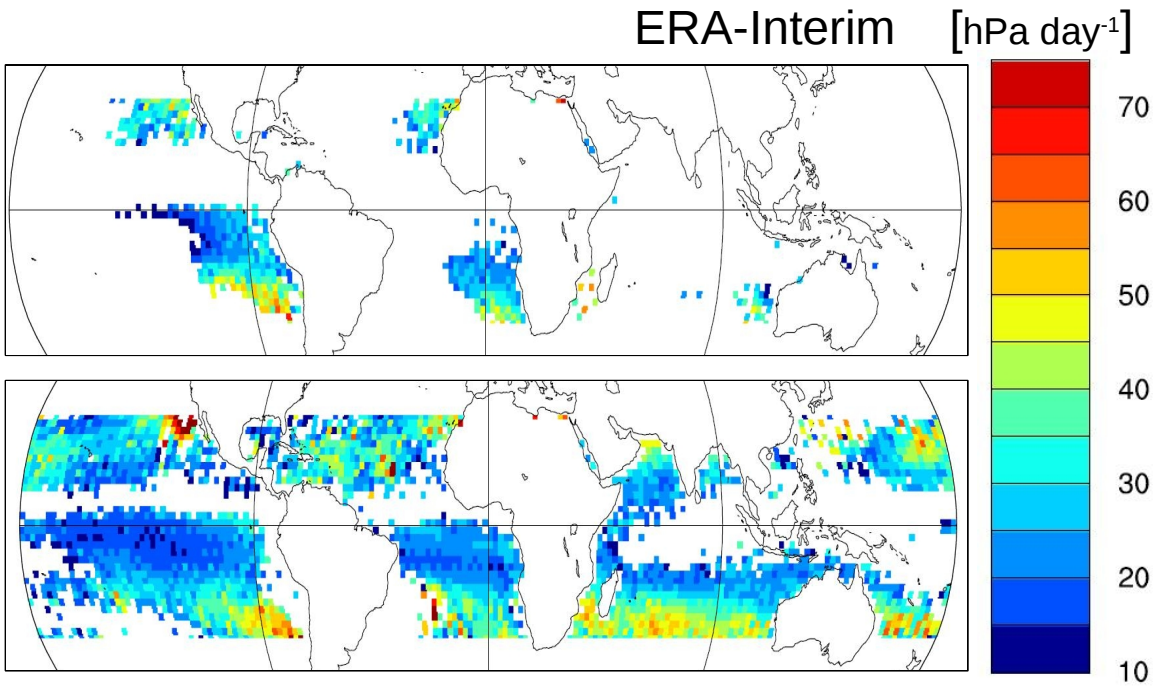
Cloud Optical Properties



- Stratocumulus and shallow cumulus in model(s) are very similar.
- Modelled clouds appear bounded to surface.

Third Study

- Study large-scale environmental properties: omega and surface fluxes of each only low-level cloud regime.



- Frequency
- Area
- **Strength**

Omega and Surface Flux

Stratocumulus

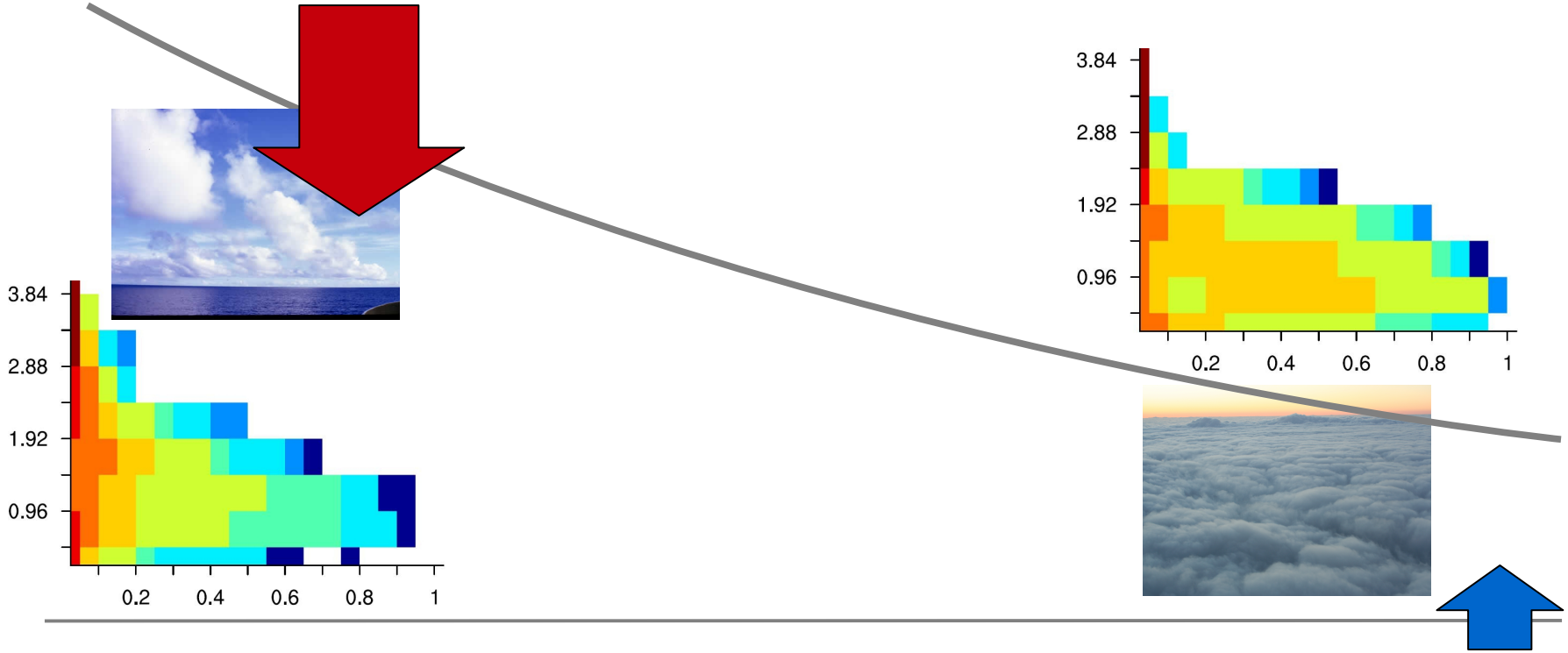
	ERA-Int	IPSL-5A	IPSL-5B	CNRM	MPI	CCCma	MOHC
Omega (hPa day^{-1})	**29.65**	1.00	N/A	1.53	1.17	1.02	1.03
Surface Flux (W m^{-2})	**120.77**	0.85	N/A	0.84	0.80	0.88	1.00

Shallow Cumulus

	ERA-Int	IPSL-5A	IPSL-5B	CNRM	MPI	CCCma	MOHC
Omega (hPa day^{-1})	**28.45**	1.08	N/A	1.53	1.36	1.10	1.21
Surface Flux (W m^{-2})	**159.38**	0.96	N/A	0.98	1.00	1.03	1.03

- Stratocumulus: Underestimate strength of surface flux.
- Shallow Cumulus: Overestimate strength of omega.

Omega and Surface Flux



- Underestimate of surface heat flux implies PBL does not warm or moisten sufficiently. The PBL will be shallower due to less positively buoyant parcels.
- Overestimate of subsidence strength suppresses transport of moisture and energy. (By strengthening inversion?)
- If transport of moisture b/w levels too weak -> greater frequency of clds -> artificially 'jucier' clds (weaker turbulence) -> optically thicker clds + combined with overlap -> yielding too reflective clds?)

Conclusions

Where do CMIP5 models show systematic errors or diverge in their representation of the vertical distribution of clouds and their optical properties?

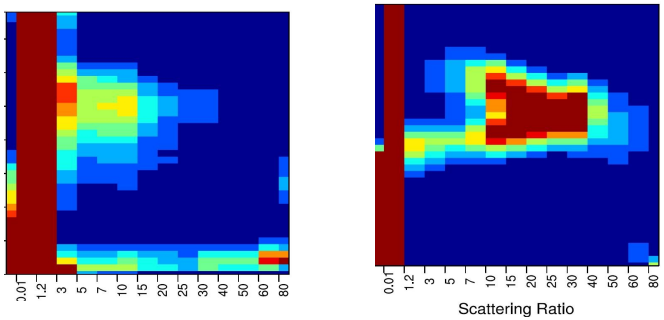
- Models systematically overestimate CRF when only low-level clouds are present.
- In Hawaiian shallow cumulus regions, overestimate of CRF in low-level clouds compensated by presence of high- and mid-level clouds.
- 3D distribution: Frequency of clouds are greatest at lowest levels. Models show lack of clouds between 2-3km; particularly in shallow cumulus regime.
- Models systematically overestimate strength of large-scale subsidence in regions of shallow cumulus clouds.
- Models systematically underestimate strength of surface fluxes in regions of stratocumulus clouds.

Outlook

- Look at parasol reflectance of single layer clouds.
- Understand influence of large-scale environment on boundary layer depth and transfer of moist static energy in models.
- Frequency & intensity of precipitation in CMIP5 models.
- Include comparison with other satellites simulator products:
  - CloudSat and CALIPSO simulator:

Hawaiian Trade Cumulus

Lidar Scattering Ratio Histogram



Radar Reflectivity Histograms