Evaluation of clouds simulated by the LMDZ5 GCM using A-train satellite observations (CALIPSO-PARASOL-CERES)

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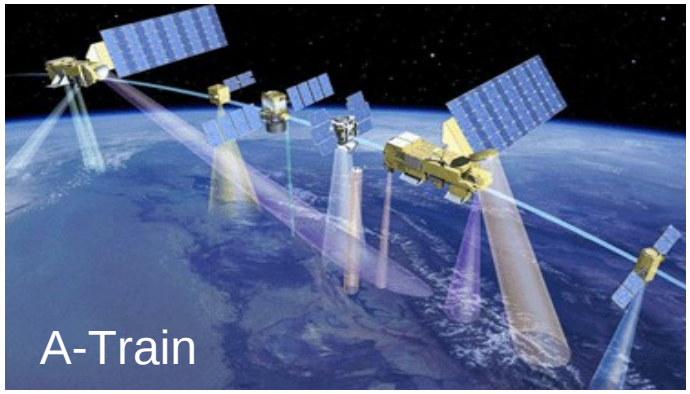
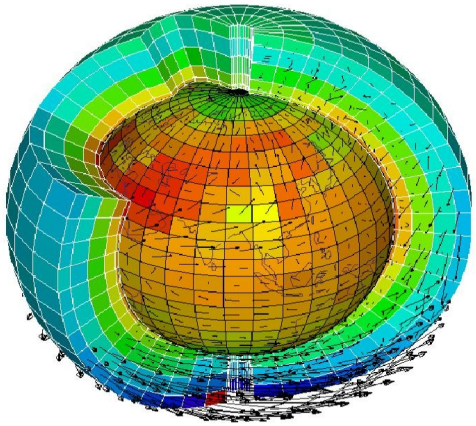
Concluding EUCLIPSE/CFMIP meeting, 8-11 July 2014, Egmond aan zee

Method of comparing A-train observations with climate models





Radiometer CERES
→ Cloud Radiative Forcing

Radiometer PARASOL
→ Cloud Optical Depth (cloud reflectance 6km, in 1 constant direction: θv=30°, φv=320°)

Lidar CALIPSO *[Chepfer et al., 2010]*
→ Cloud Fraction (330m), Cloud Vertical Distribution (30m)

LMDZ5A :
standard version of IPSL coupled model

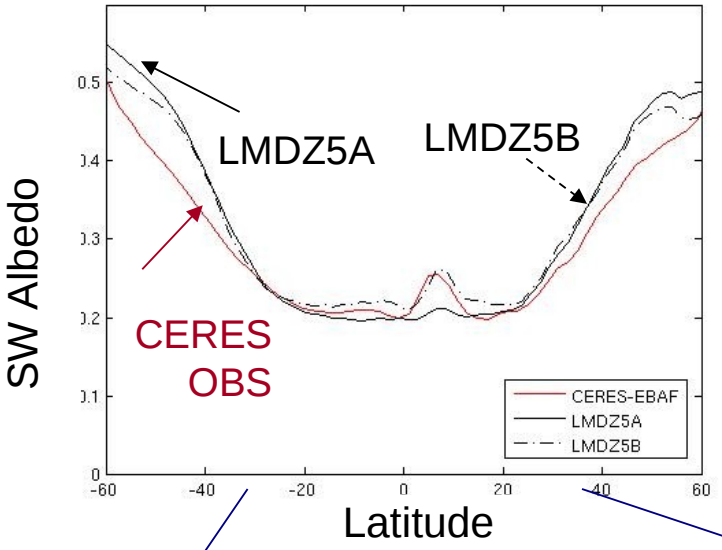
LMDZ5B :
- New boundary layer and low level cloud scheme
- Modified version of the convective scheme of Emanuel
- Wakes created from reevaporation or convective rainstorms

+ COSP simulator

Objective
→ Use the A-Train observations to better assess the cloud description simulated by GCMs

➔ **Monthly mean evaluation of cloud properties**

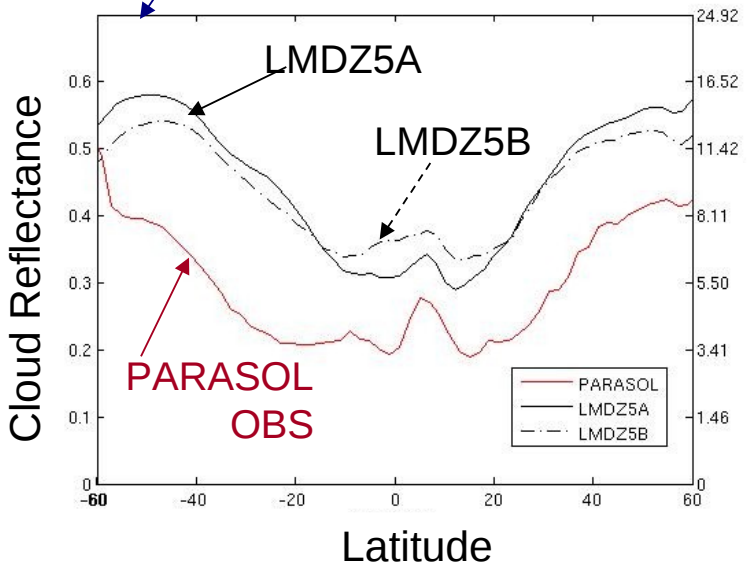
Monthly mean evaluation of cloud properties
Zonal Mean Cloud Properties

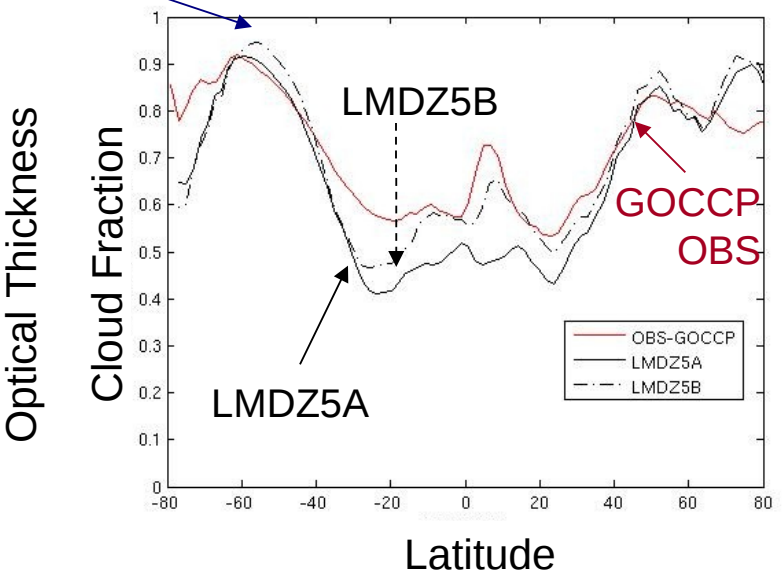


The general structure of Monthly Mean TOA Fluxes is well simulated

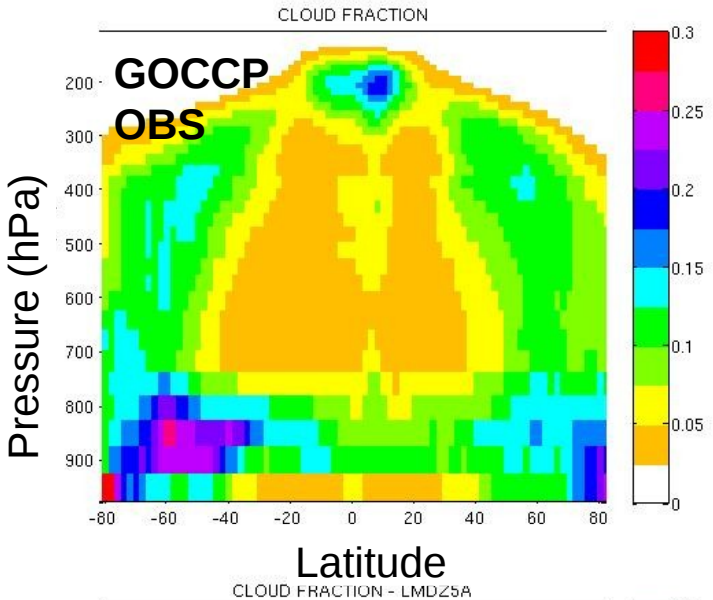
→ Error compensation between the monthly mean vertically integrated values of cloud cover and cloud optical depth

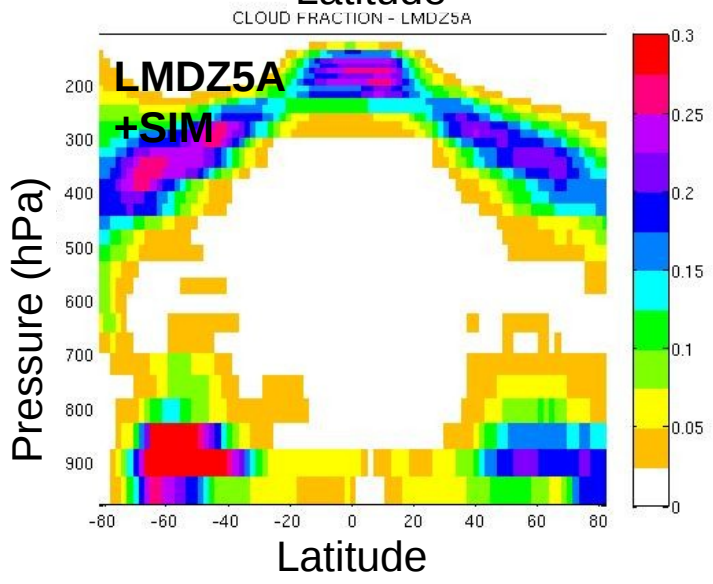
Cloud Radiative Forcing depends on the Reflectance and the Cloud Fraction

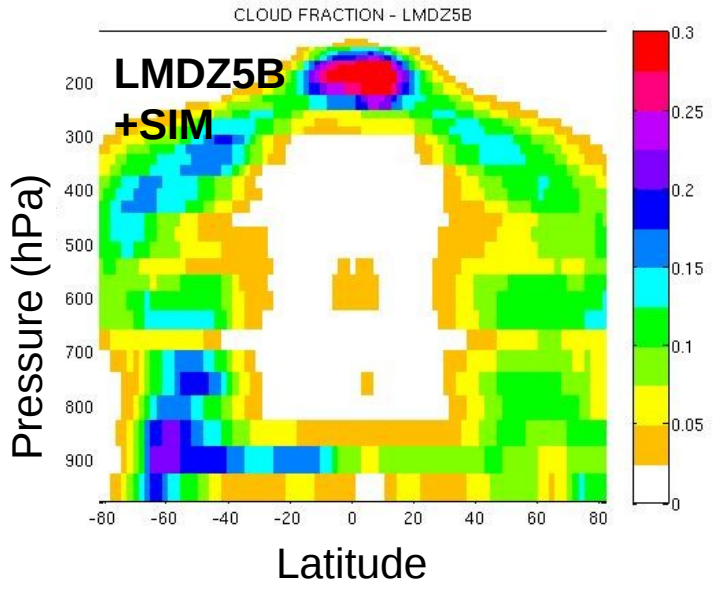




Monthly mean evaluation of cloud properties
Cloud Vertical Structure







→ Error compensations in Cloud Vertical Distribution between :

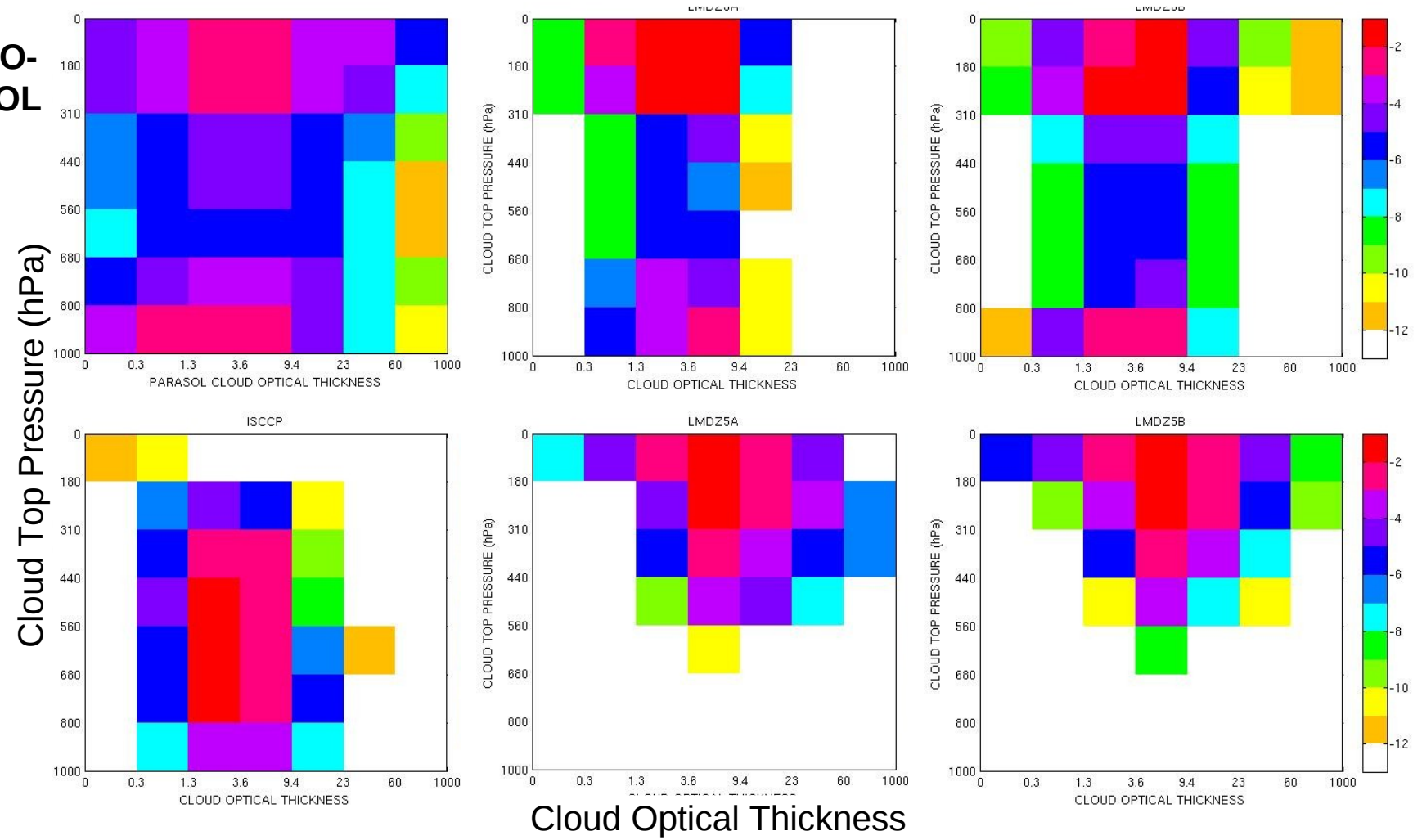
Overestimated:

- High clouds

Underestimated:

- Tropical low clouds
- Congestus
- Mid level mid lat

Monthly mean evaluation of cloud properties
Cloud Top Pressure – Cloud Optical Thickness



→ The two distinct populations of high and low clouds observed and simulated by CALIPSO-PARASOL are replaced by one cluster in the middle of the atmosphere for ISCCP obs and in high altitudes for the model.

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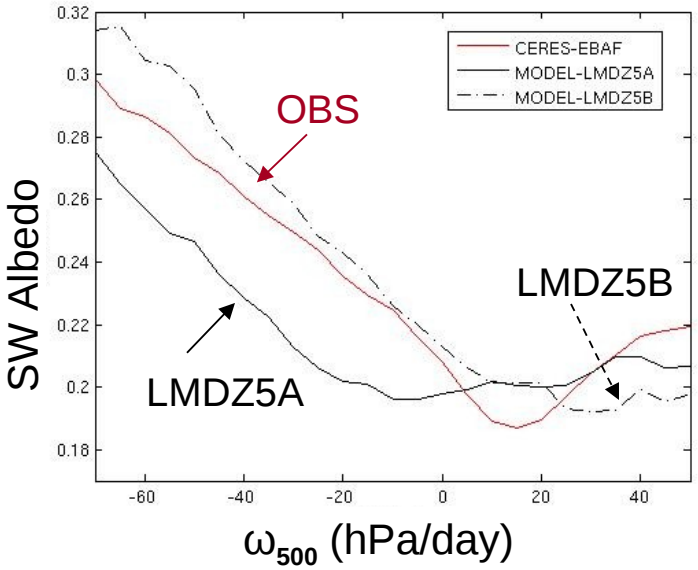
Monthly mean evaluation of cloud properties
Dynamical Regimes

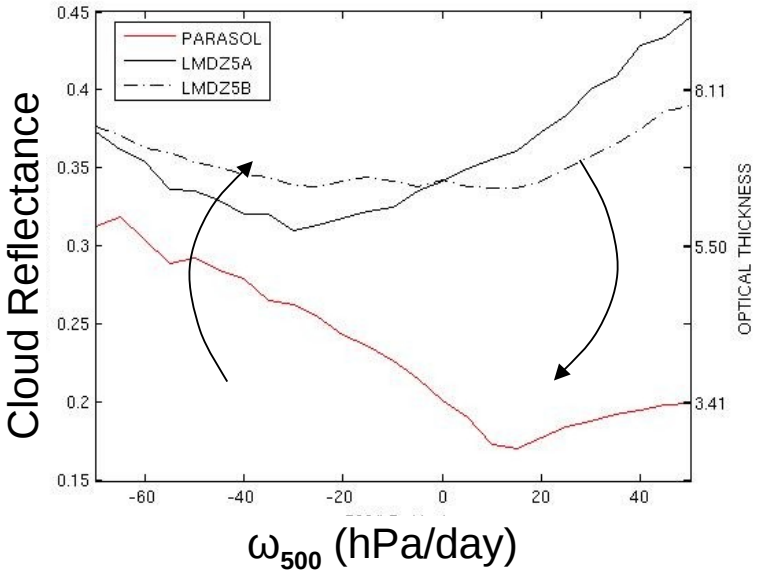


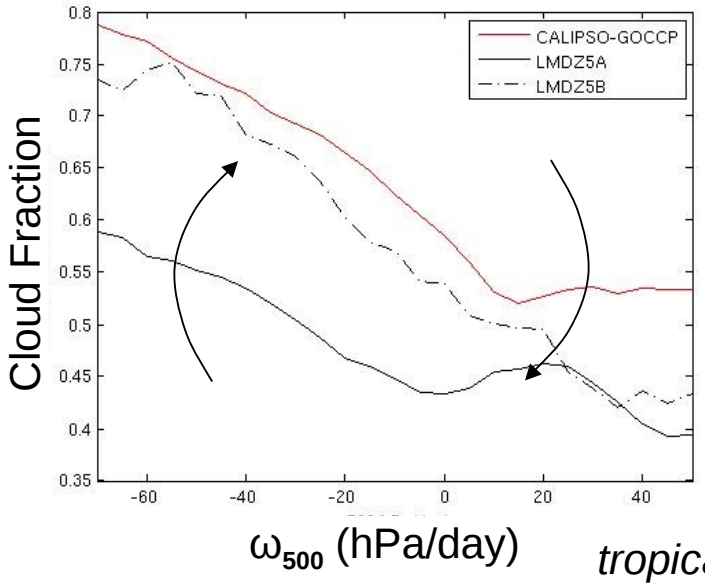
→ Subsidence regions

models simulate well the albedo as a result of two combined errors : models create clouds optically too thick but they are too few.

→ Convective regions

underestimation of cloud fraction (more from LMDZ5A), slight overestimation of cloud reflectance : underestimation of cloud albedo by LMDZ5A and overstimation by LMDZ5B





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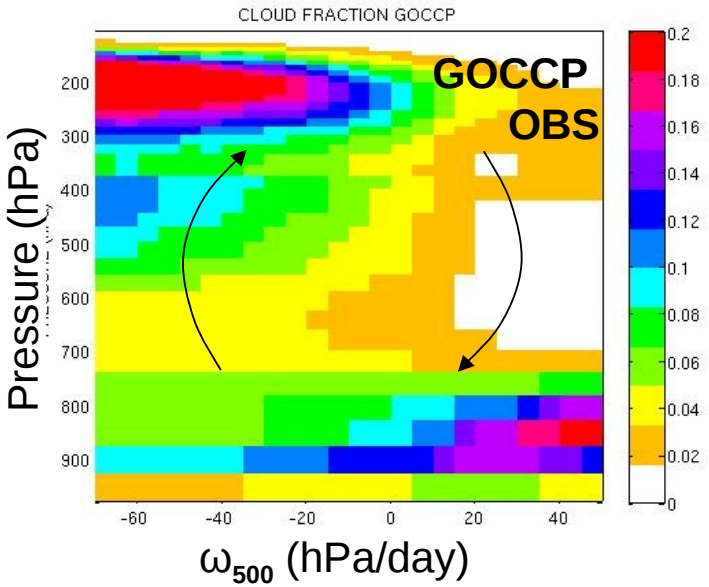
Monthly mean evaluation of cloud properties
Dynamical Regimes

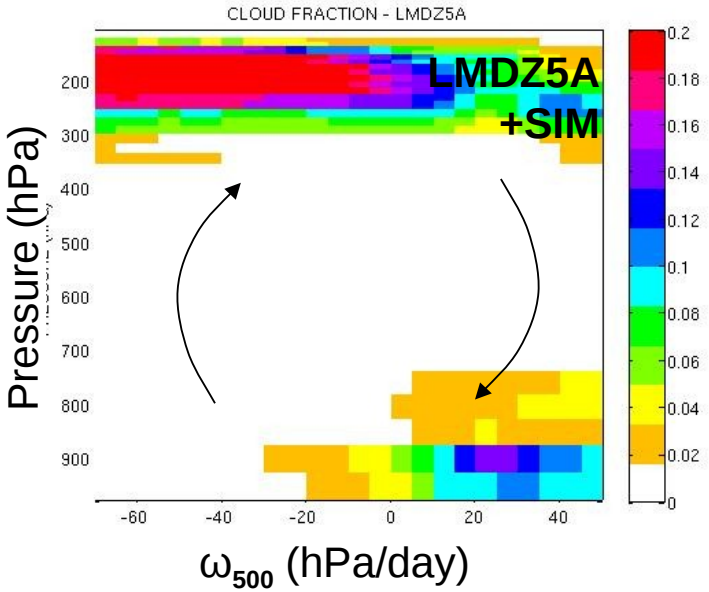


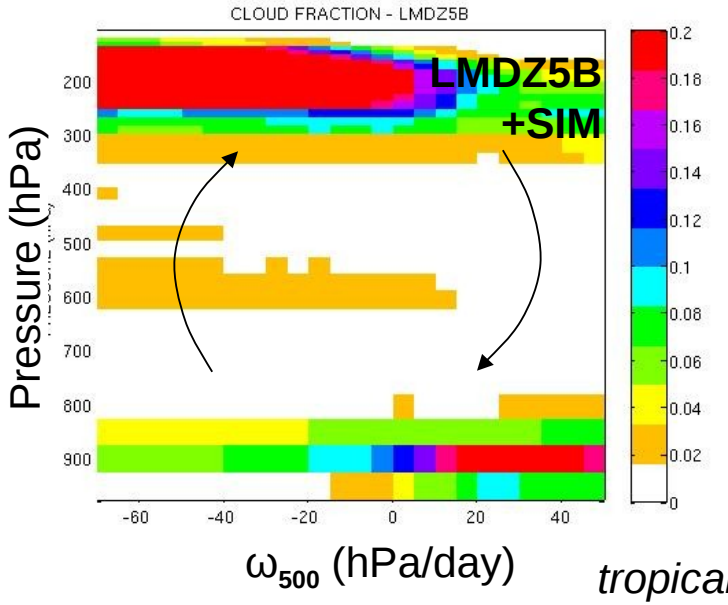
→ LMDZ5A

underestimates significantly low and mid level clouds

→ LMDZ5B

- new boundary layer and low level cloud scheme improve boundary layer clouds
- modified version of convective scheme impoves the properties of high level clouds and simulates some mid-level clouds in tropics





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➔ **Instantaneous evaluation of cloud properties**

↳ **Hereafter**

cloud processes = the instantaneous relationship between cloud properties (CF, z, τ_{cloud})

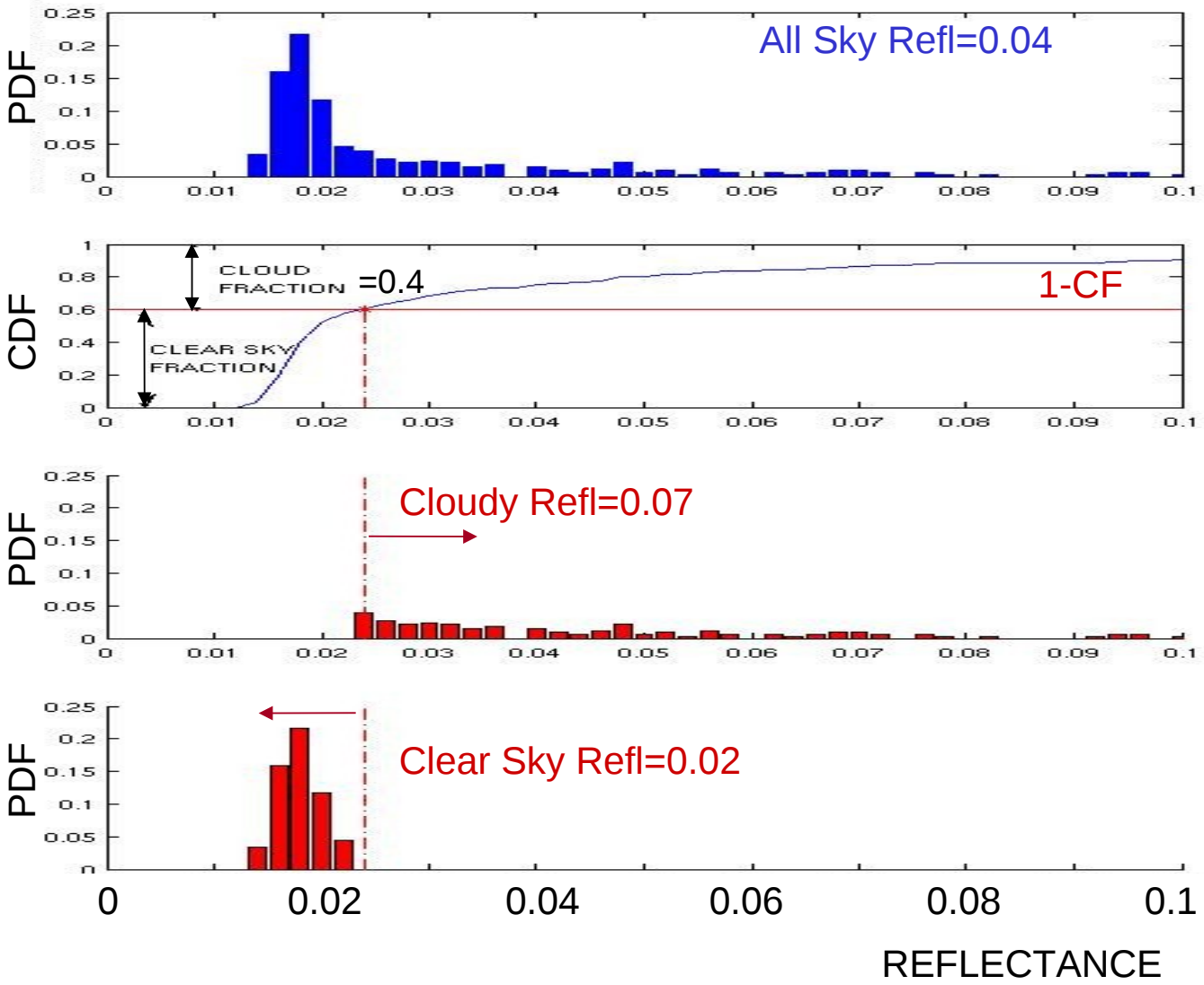
(or between them and the cloud environment)

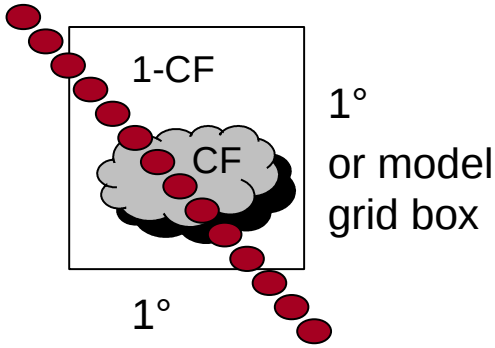
1) Statistical description of the relationship between cloud properties increases our confidence in the ability of models to simulate cloud variations

2) Instantaneous variables facilitate the link between observations and model parametrisations.

↳ **How do Cloud Fraction and Cloud Reflectance vary instantaneously?**

Use of high resolution data - Methodology

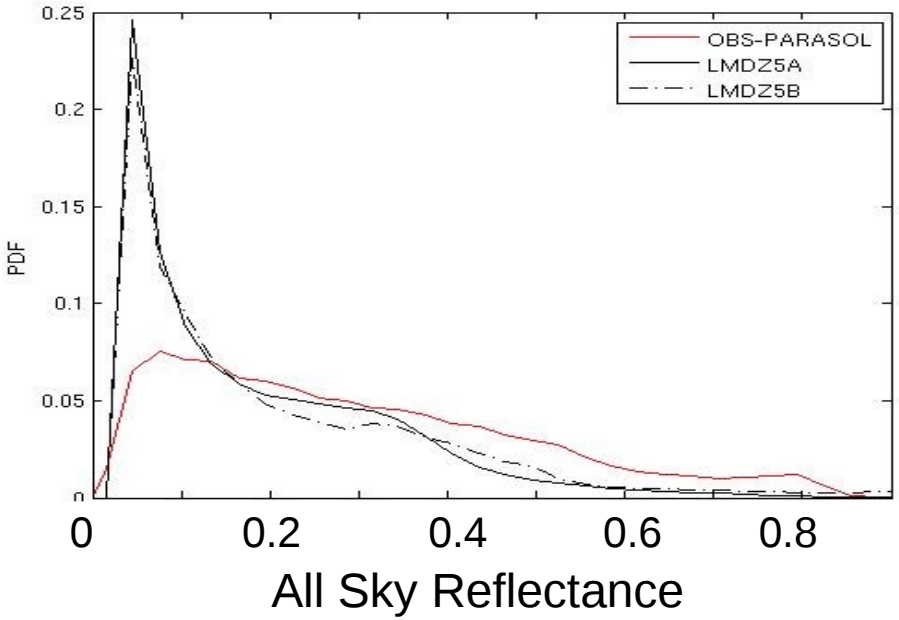




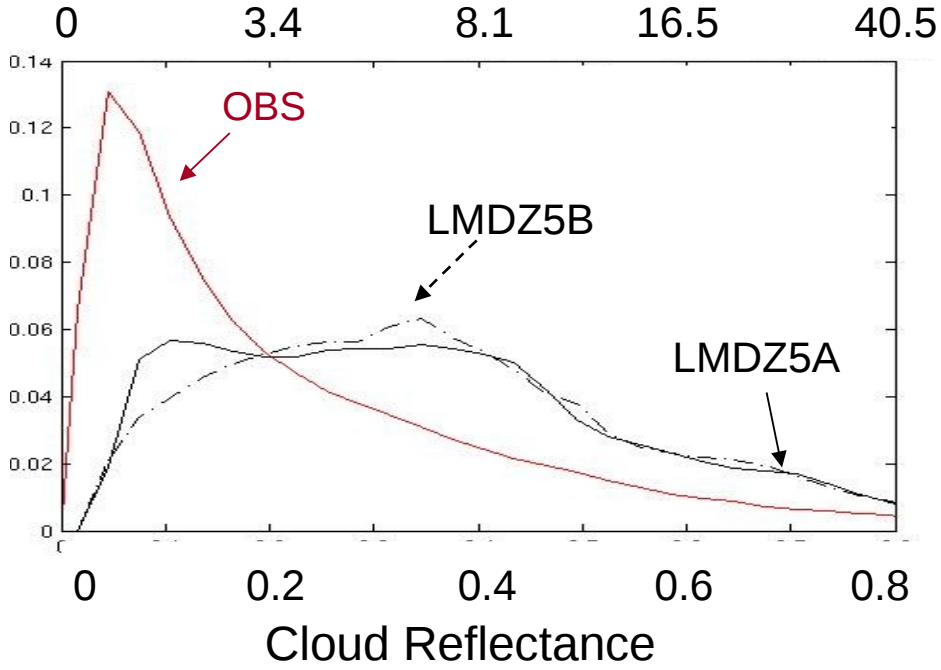
Same methodology for simulator's outputs
⇒ In each grid box (obs/mod): Cloud Fraction and Cloud Reflectance

Cloud Optical Depth
Evaluation of the model at high resolution

PDF



Optical thickness (spherical particles and θ_s=30°)



→ overestimation of low values of All-Sky Reflectance and underestimation of high values.

BUT for cloud reflectance (no clear sky contribution):

→ more optically thick clouds and less optically thin clouds simulated.

Corresponding CDF: 50% of the clouds: Obs cloud optical depth < 2.5
Model's cloud optical depth < 6

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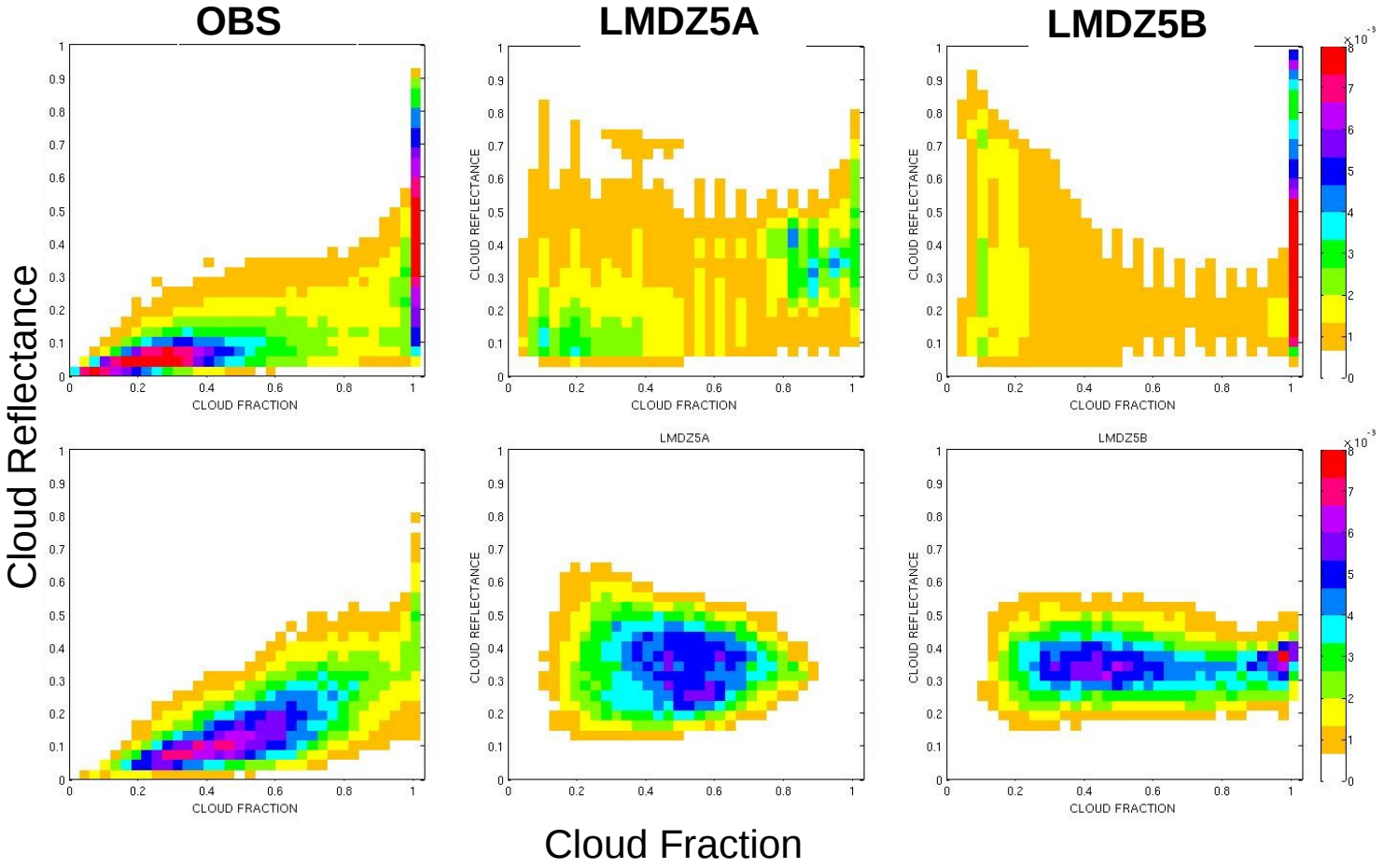
Instantaneous evaluation of cloud properties
Relationship between Cloud Fraction and Cloud Optical Depth



The relationship between Cloud Fraction and Cloud Optical Depth is significantly dependent on the spatio-temporal resolution in observations and in the model

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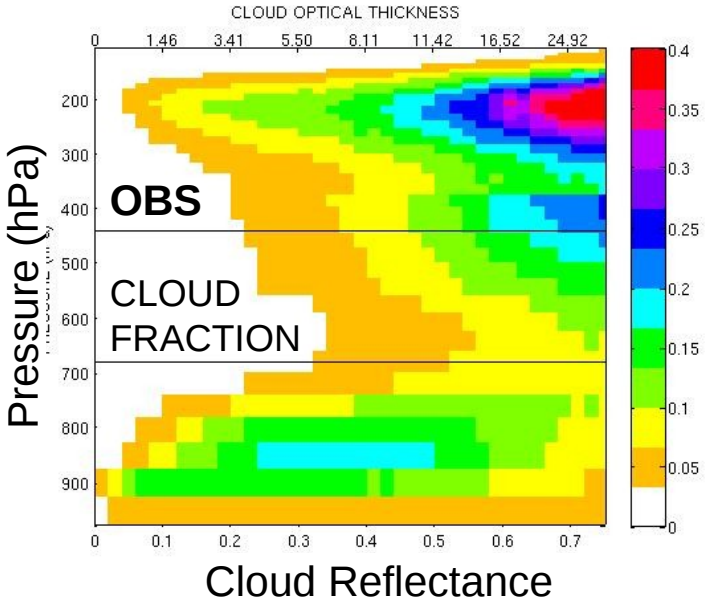
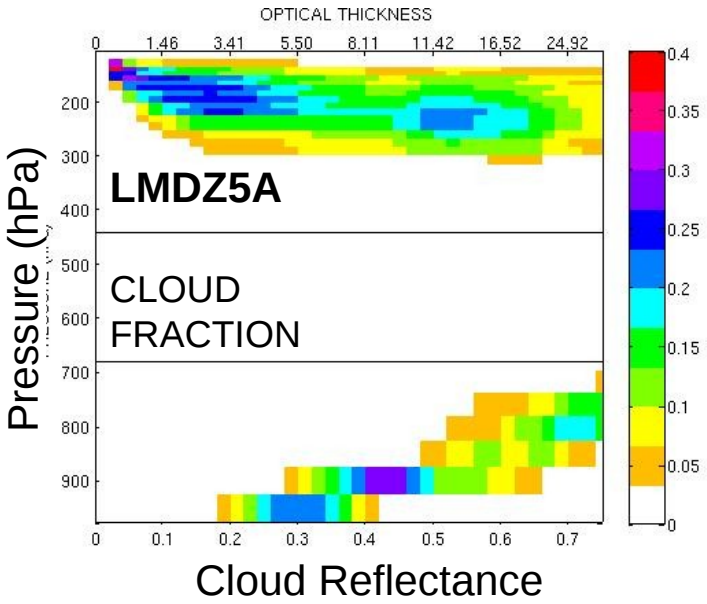
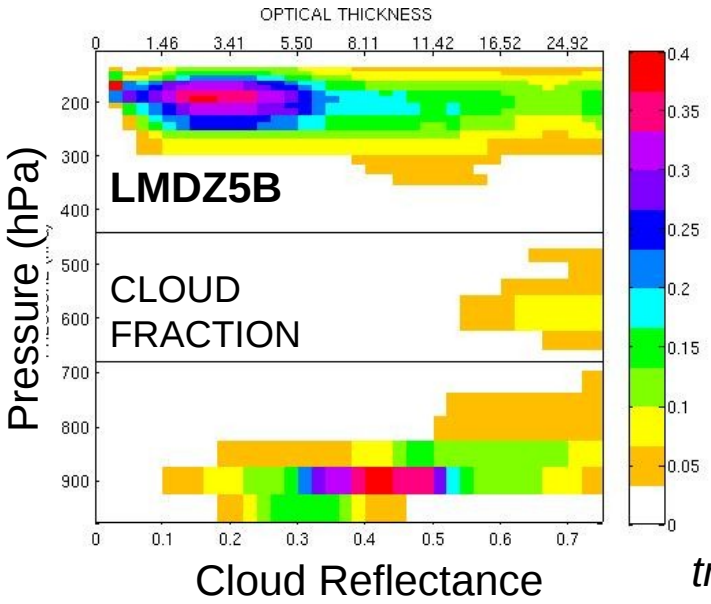
Instantaneous evaluation of cloud properties
Vertical distribution of clouds according to their optical thickness



Models biases :

- more optically thin high clouds
- few optically thick high clouds
- no mid level clouds (or not well simulated)
- overestimation of optically thick low clouds





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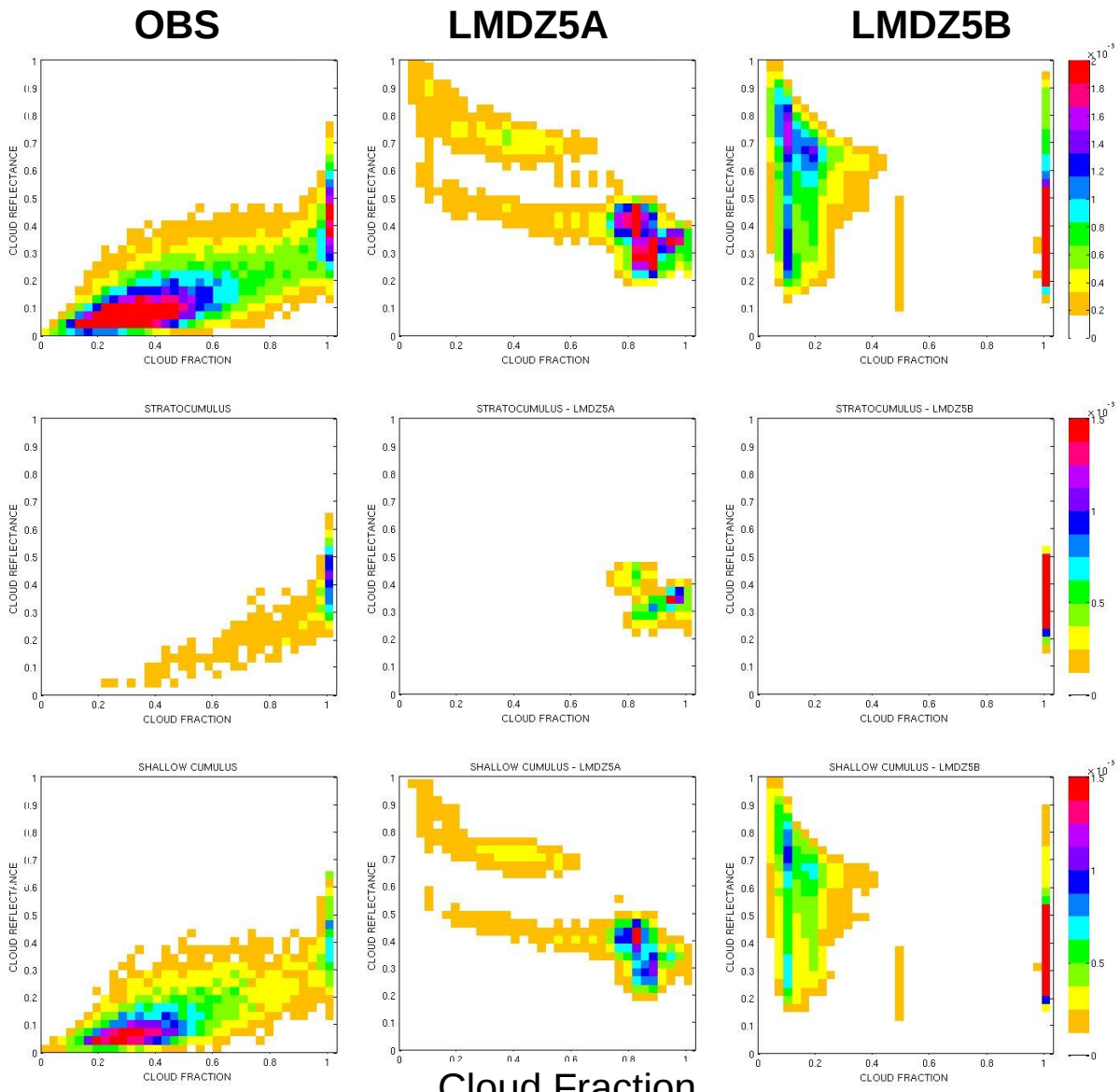
Instantaneous evaluation of cloud properties
Focus on boundary layer clouds



Biases:

- underestimation of CF and overestimation of τ_{cloud}
- simulation of a significantly different relation between CF and τ_{cloud}

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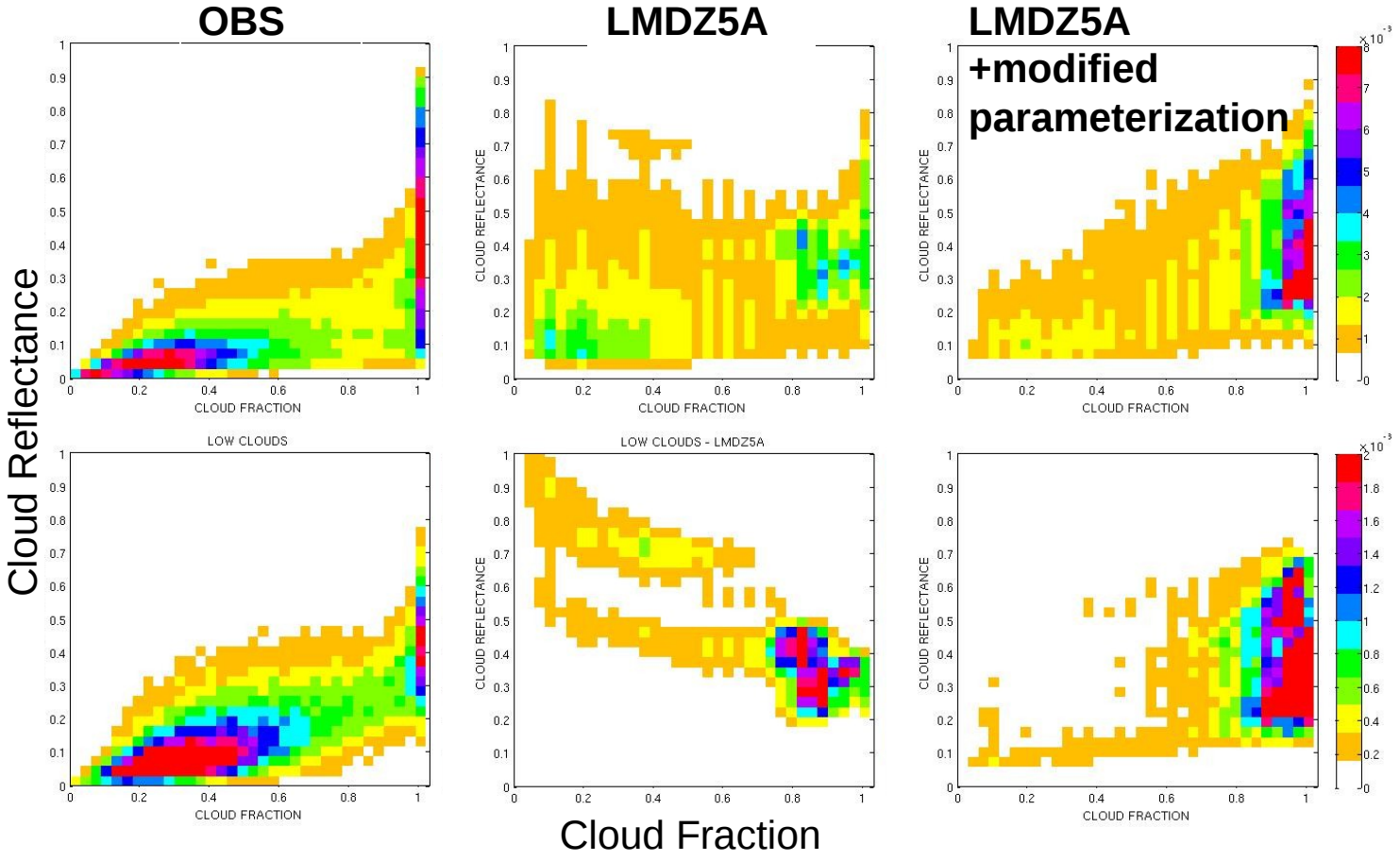
From instantaneous evaluation of cloud properties to model improvement

All clouds

Low clouds mainly



→Modified parameterization (considering the horizontal heterogeneity of cloud layers, talk J.L. Dufresne) leads to the cloud reflectance increasing with cloud fraction : consistent with observations

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Conclusion

→ **A-train observations allow to build pictures of cloud properties containing information at the cloud scale. It shows how the cloud properties (cloud cover, cloud optical depth and cloud vertical distribution) vary together under a same change of environment around the cloud**

cloud optical depth increases with the cloud horizontal extent

→ **The evaluation of the instantaneous cloud properties reveals models biases:**

- cloud optical depth decreases when the cloud extends horizontally (CF increases), contrary to what is observed

- error compensations in the model are identified: underestimation of high optically thin clouds and overestimation of high thin clouds, the model simulates too few low clouds but they are optically too thick

⇩

The study of cloud properties at high spatial and temporal resolution enables to evaluate the ability of models to reproduce the instantaneous relation between cloud properties and thus allows process oriented evaluation, may guide improving model parametrization and may help to bridge the gap between model evaluation and model development.


Thank you !