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Low-level marine tropical clouds in six CMIP6 models are too few, too bright but also too compact and too homogenous ⁽¹⁾



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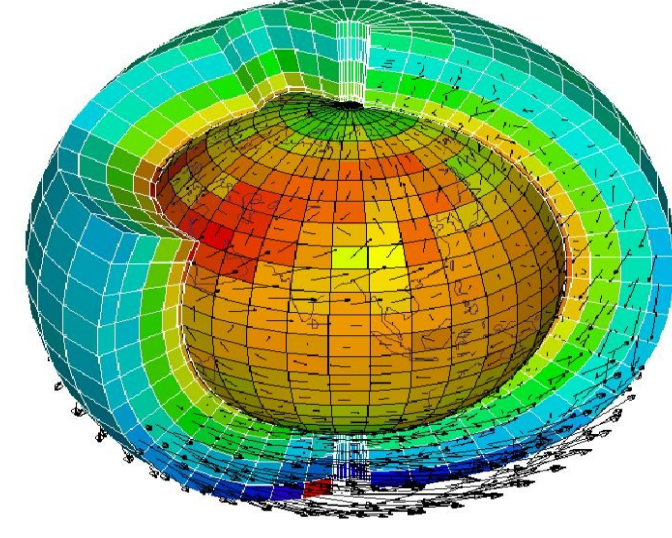
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Abstract

Several studies have shown that most climate models underestimate cloud cover and overestimate cloud reflectivity, particularly for the tropical low-level clouds. Here we analyze the characteristics of low-level tropical marine clouds simulated by six climate models, which provided COSP output within the CMIP6 project. CALIPSO lidar observations and PARASOL mono-directional reflectance are used for model evaluation. It is found that the 'too few, too bright' bias is still present for these models. The reflectance is particularly overestimated when cloud cover is low. Models do not simulate any optically thin clouds. They fail to reproduce the increasing cloud optical depth with increasing lower tropospheric stability as observed. These results suggest that most models do not sufficiently account for the effect of the small-scale spatial heterogeneity in cloud properties or the variety of cloud types at the grid scale that is observed.

Methodology of evaluating clouds in climate models



Radiometer PARASOL

→ Cloud Optical Depth (cloud reflectance 6km, in 1 constant direction: $\theta_v=30^\circ$, $\phi_v=320^\circ$)

Lidar CALIPSO – GOCCP ⁽¹⁾

→ Cloud Fraction (330m), Cloud Vertical Distribution (30m)

Objective

→ is the too few too bright bias still present in CMIP6 models?
→ is there a common origin of this bias?

CMIP6 models :

- IPSL-CM6A
- CNRM-CM6
- HadGEM3
- MRI
- MIROC6
- GFDL

+ COSP simulator

Variables under study ^(2,3)

Cloud Cover and Cloud Reflectance (a proxy of Cloud Albedo)

Region of study

Tropical Oceans ($30^\circ S - 30^\circ N$)

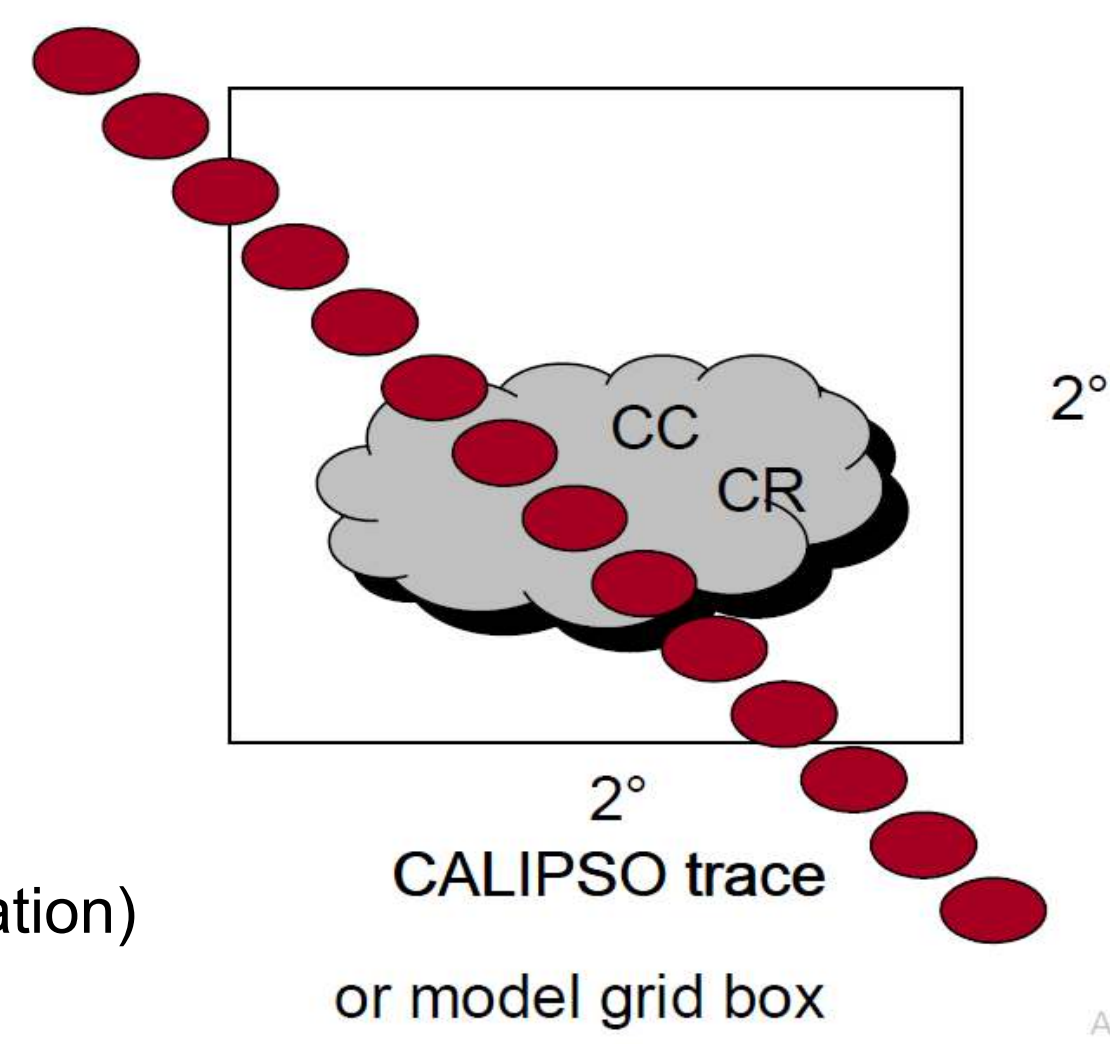
Situations of dominant low-level clouds

Criterion : $CC_{low} > 0.9 * CC$

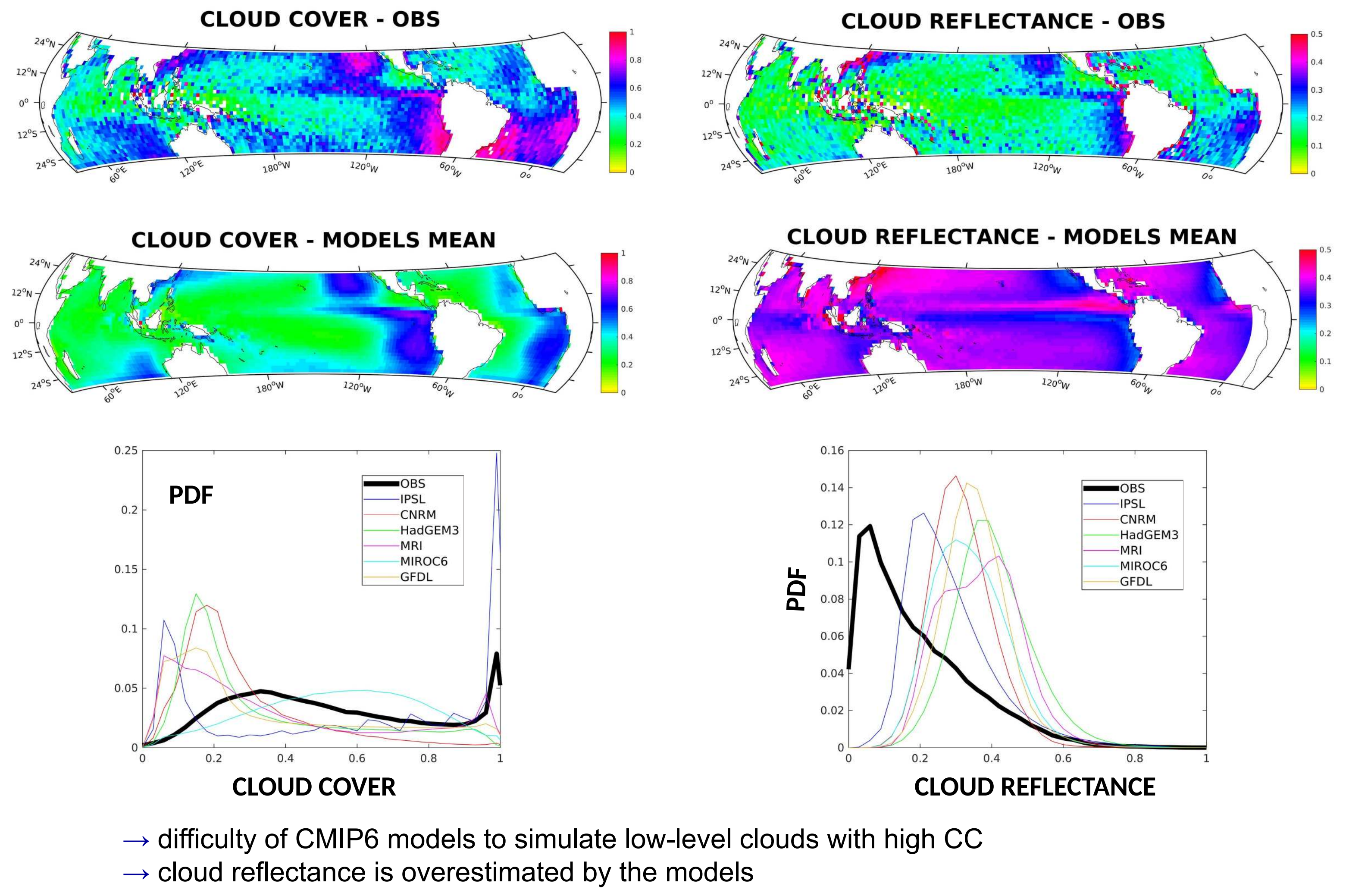
Temporal resolution

Daily (the highest possible giving a view of models' parameterization)

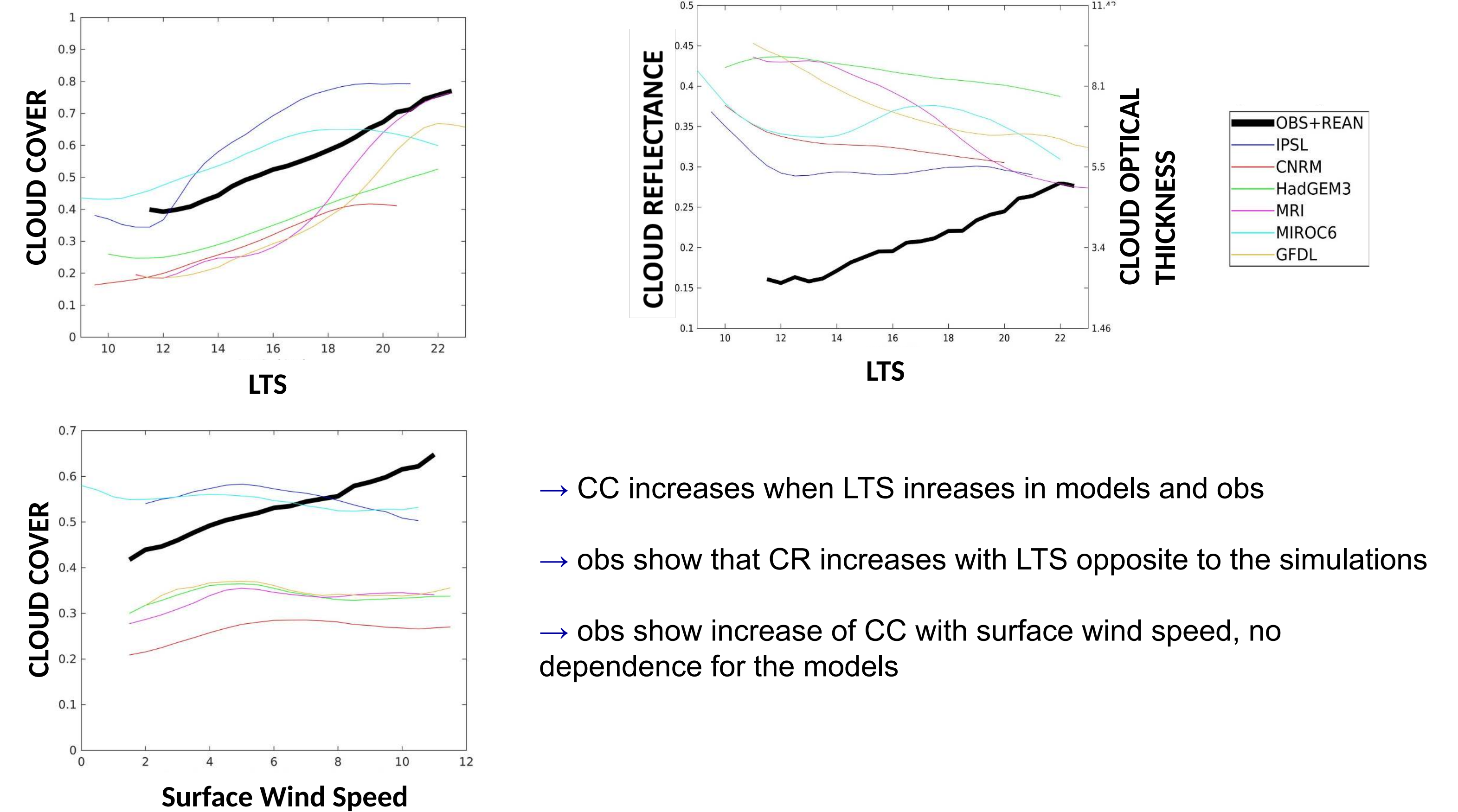
4 years climatology (2007 – 2010)



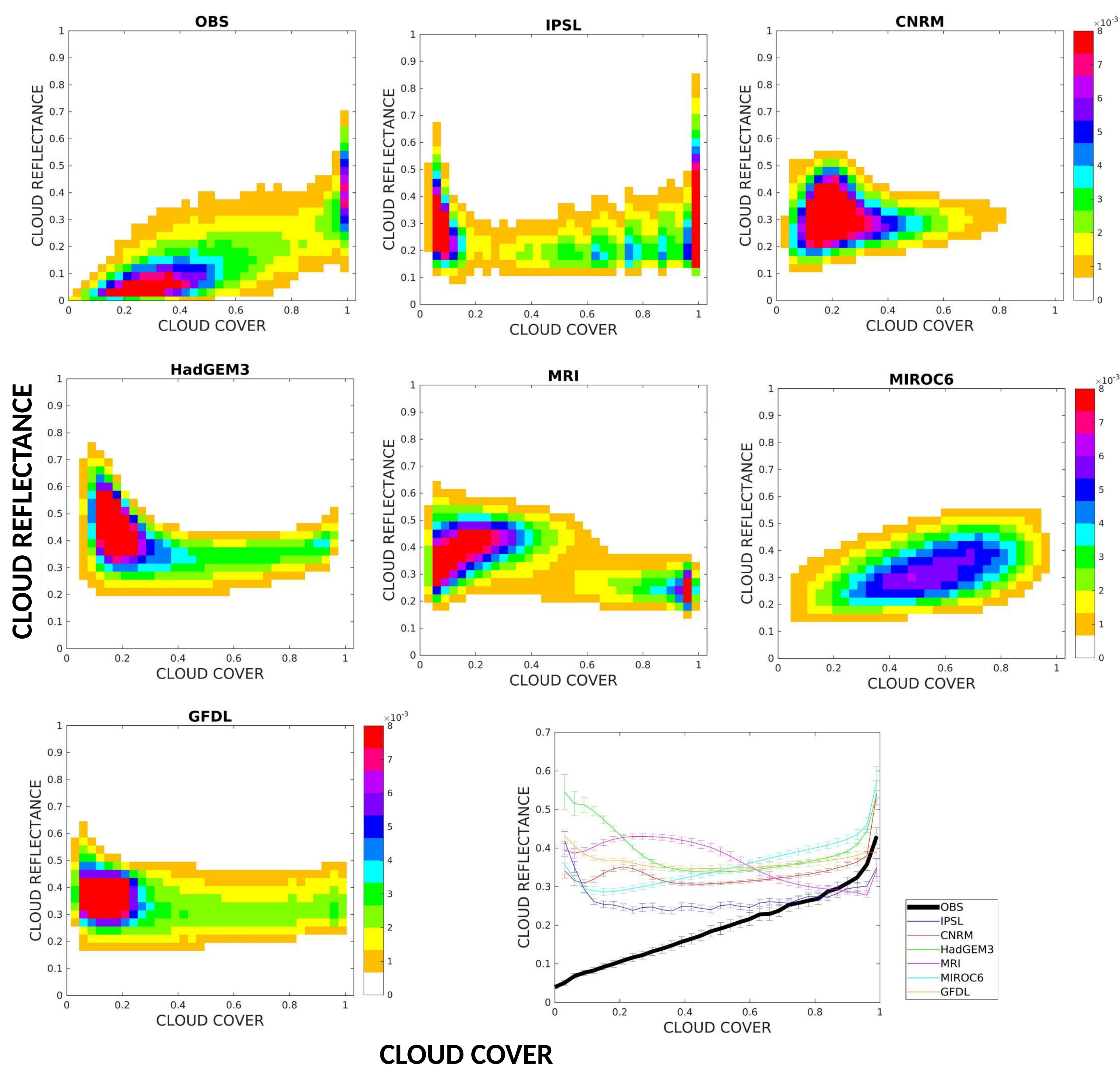
The too few too bright bias in CMIP6 models



Variation with the environment



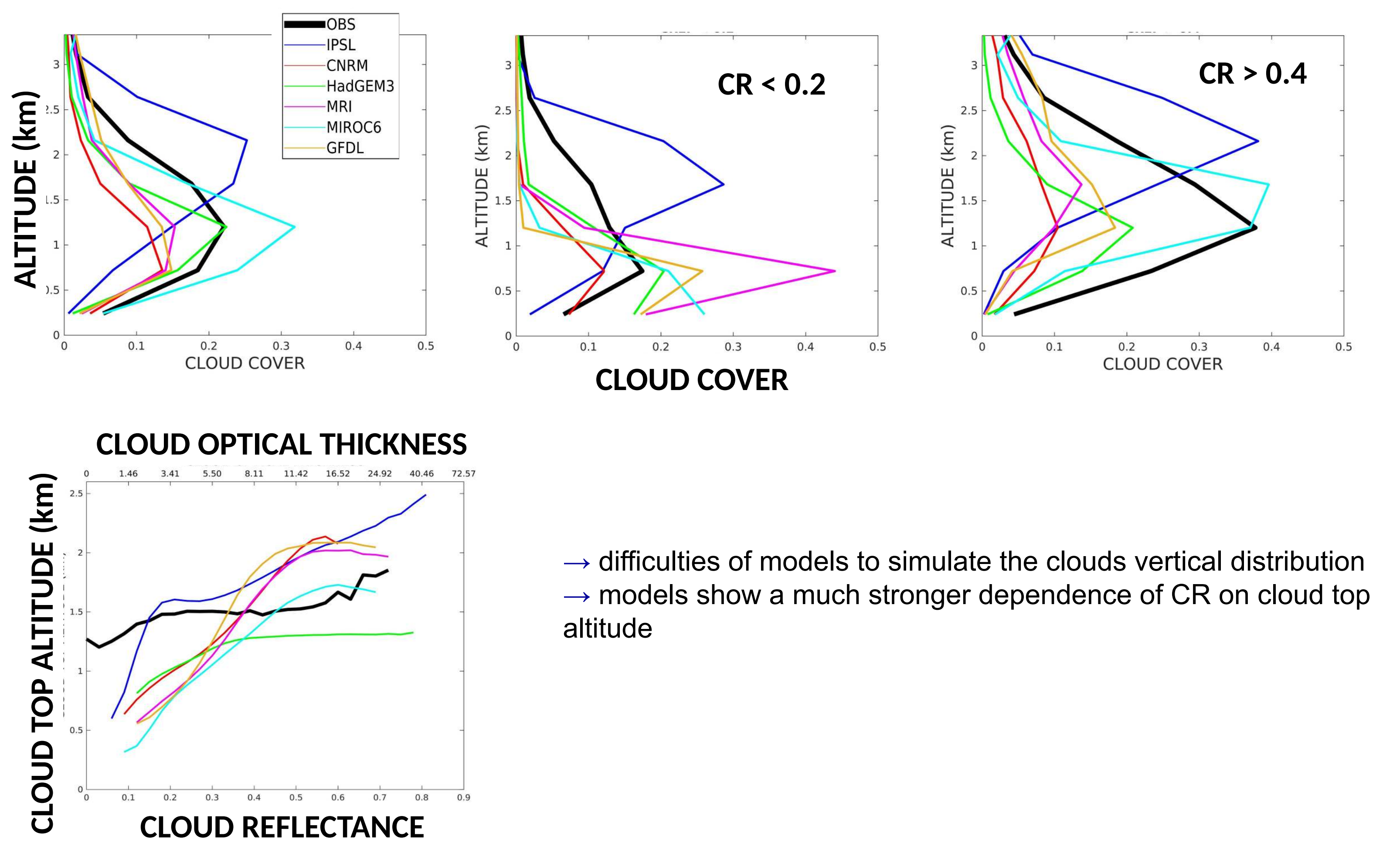
Relationship between low cloud cover and brightness



Obs
→ two clouds populations: cumulus and stratocumulus type clouds
→ cloud reflectance increases with increasing cloud cover

Models
→ inability to simulate the two distinct cloud populations
→ difficulty to simulate the increase on cloud reflectance with cloud cover

Vertical distribution



Conclusions

→ The too few too bright bias is still present in CMIP6 models for low level clouds

Biases in the simulation of cloud properties:

- Stratocumulus clouds on the eastern coast of the oceans are absent or underestimated in many models
- CR decreases with CC in obs, models show inverse or no dependence
- CR increases with LTS in obs but not in models
- CTH is too low for optically thin clouds and increases with CR much faster in models than in obs

→ Can we infer some common origin of this bias among the different climate models?

Hypotheses:

- Models simulate too often small cumulus clouds (low CC and high CR) and lack of a variety of low-level cloud types.
- Lack of taking into account the sub-grid heterogeneity of cloud properties in the models.

References :

- (1) Konsta, D., J-L. Dufresne, H. Chepfer, J. Vial, T. Koshiro, H. Kawai, A. Bodas-Salcedo, R. Roehrig, M. Watanabe, T. Ogura, 2022: Low-level marine tropical clouds in six CMIP6 models are too few, too bright but also too compact and too homogenous, *Geophys. Res. Lett.* (Accepted)
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- (3) Konsta D., et al., 2012 : A process oriented characterization of tropical oceanic clouds for climate model evaluation, based on a statistical analysis of daytime A-train observations. *Clim Dyn*, 39, 2091–2108, doi:10.1007/s00382-012-1533-7.
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