CALIPSO and the clouds

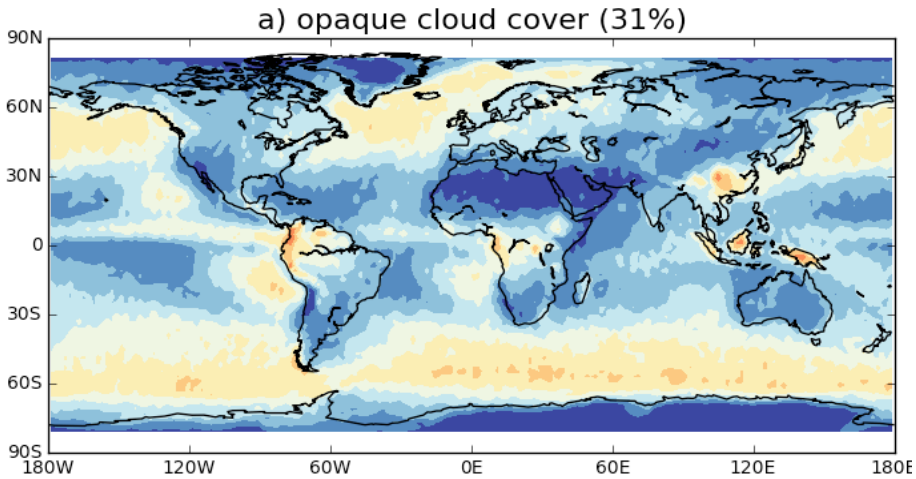
Hélène Chepfer
LMD/IPSL, University Pierre and Marie Curie

Outline

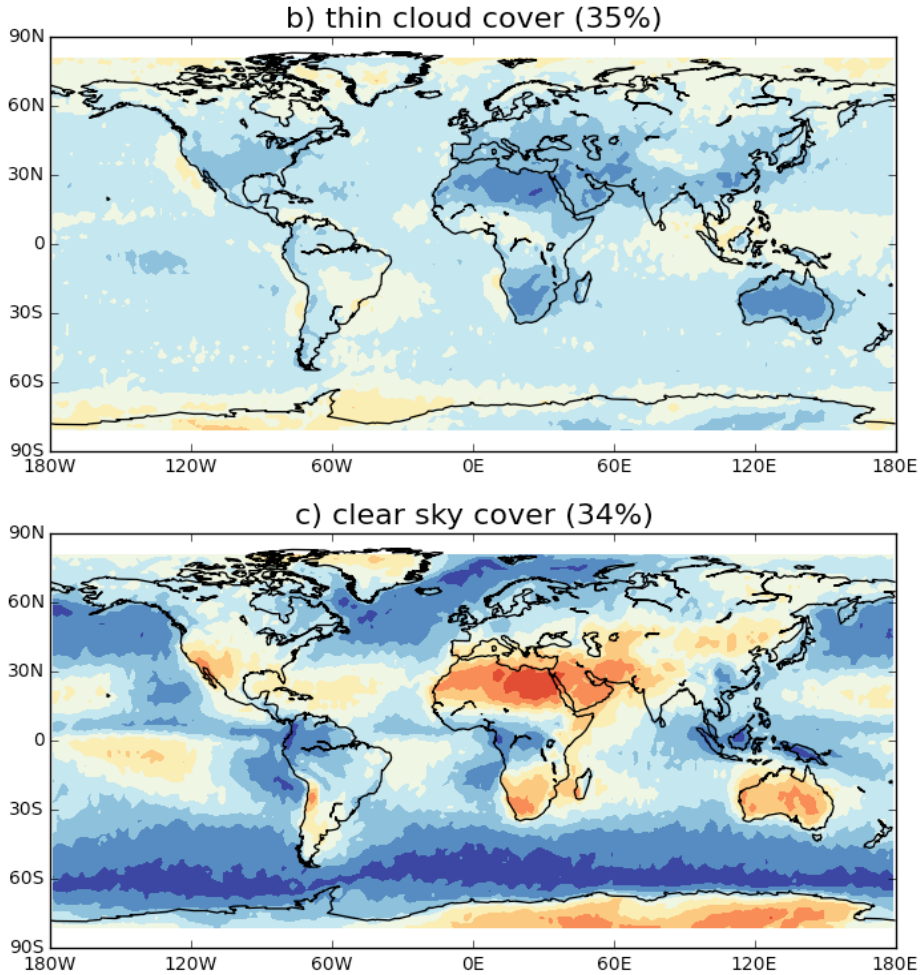
- On the use of Calipso to evaluate climate models (GOCCP and COSP/lidar)
- Low level tropical clouds
- Deep convective tropical clouds

Calipso observes entirely the atmosphere down to the surface in 69% of the profiles

Opaque clouds



Thin clouds



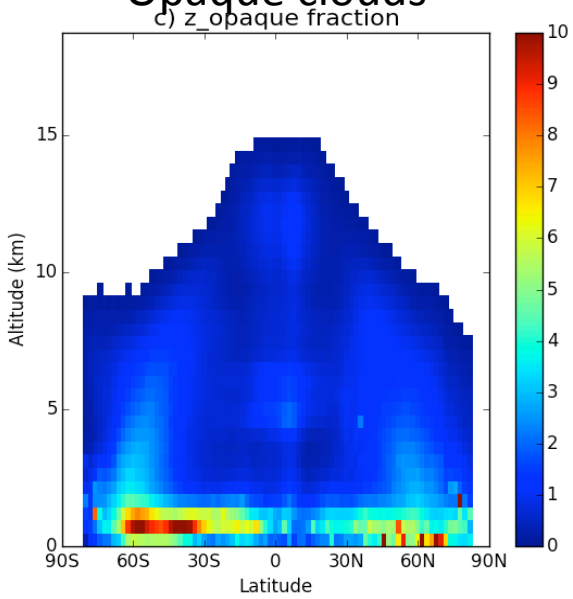
Clear sky

Whereas 31% of the profiles sound partially atmosphere

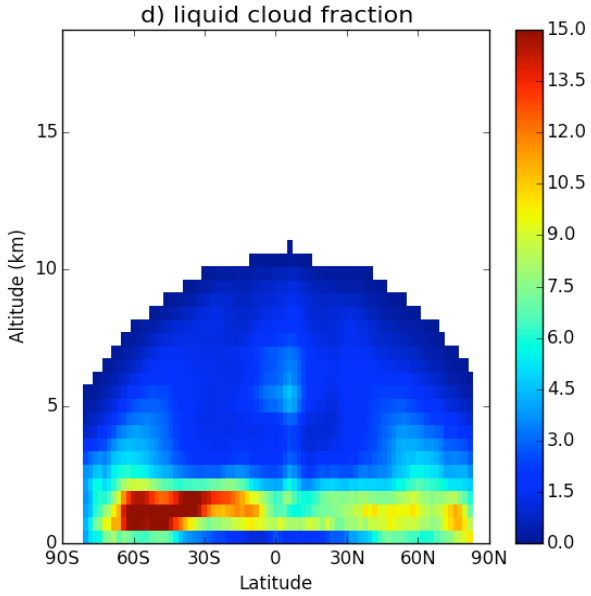
Guzman, R., et al. , 2016, JGR-Atm, Submitted

A majority of the opaque clouds are below 4 km of altitude and are composed of liquid water

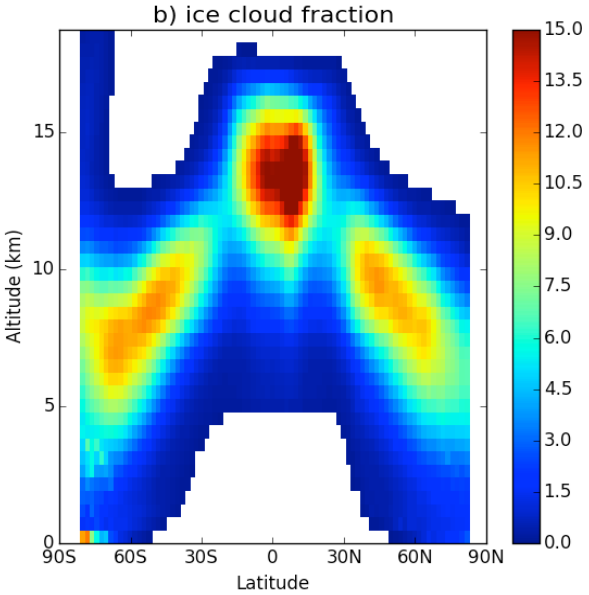
Opaque clouds



Liquid clouds



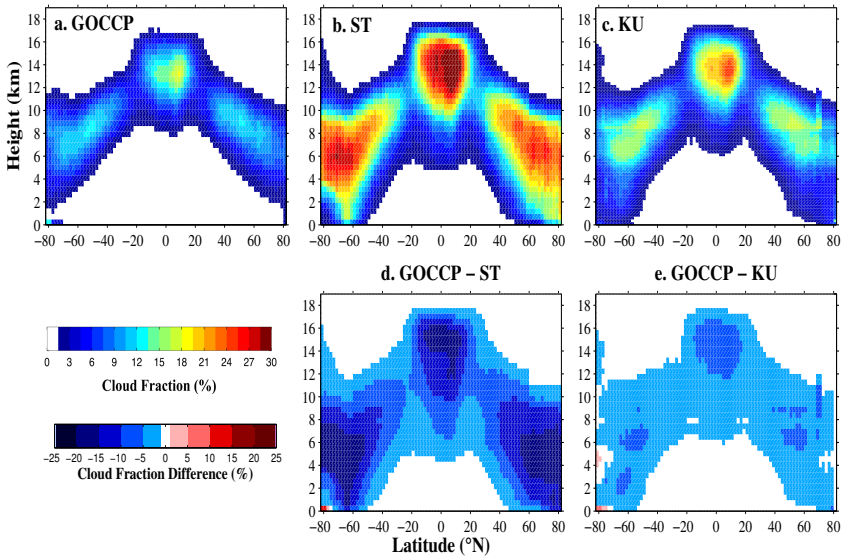
Ice clouds



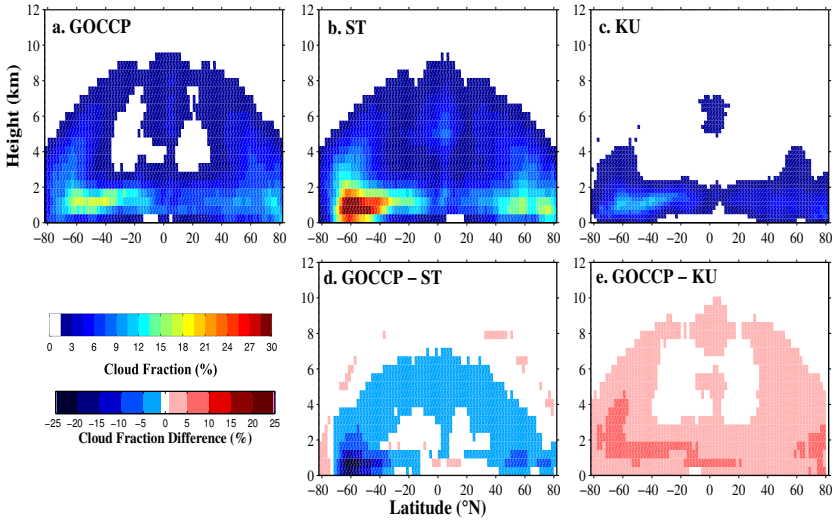
Guzman, R., et al. , JGR-Atm, Submitted

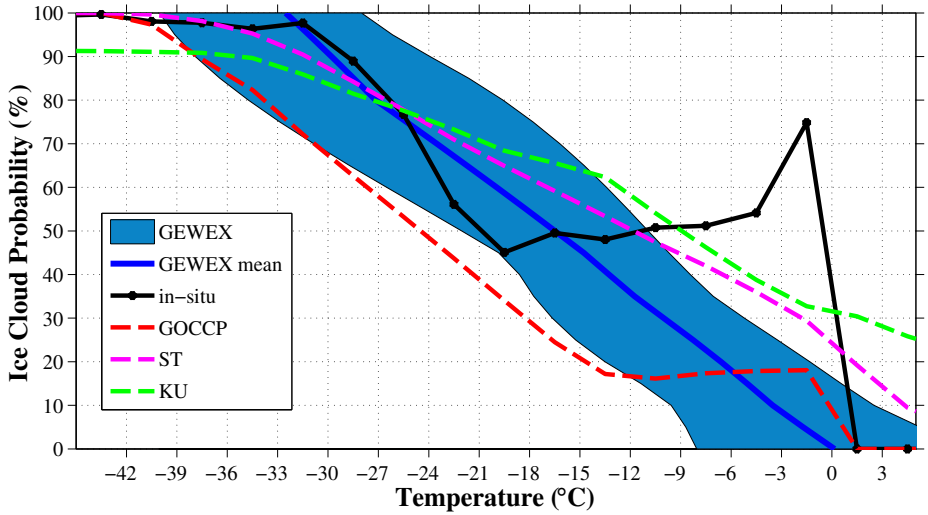
Clouds climatologies derived from the same Level1 Caliso dataset are different depending on the resolution (vertical/**horizontal**) and the associated detection threshold (constrained by SNR)

Ice clouds



Liquid clouds





Cesana et al. 2016, JGR
Chepfer et al. 2013, JAOT

Acknowledging the significant impact of the differences in the cloud definition between observational products (cloud opacity, cloud masking, resolutions, detection thresholds, etc…) and also between models

the Cloud Feedback Model Intercomparison Program (CFMIP) developed :

The simulator COSP/lidar (Chepfer et al. 2008, GRL, Cesana et al. 2013, JGR, Bodas et al.)

The GCM Oriented Cloud Product GOCCP(Chepfer et et al: 2010, JGR, Cesana et al. 2013, JGR)

Recommended to use COSP/lidar and GOCCP for evaluating the description of clouds in climate models

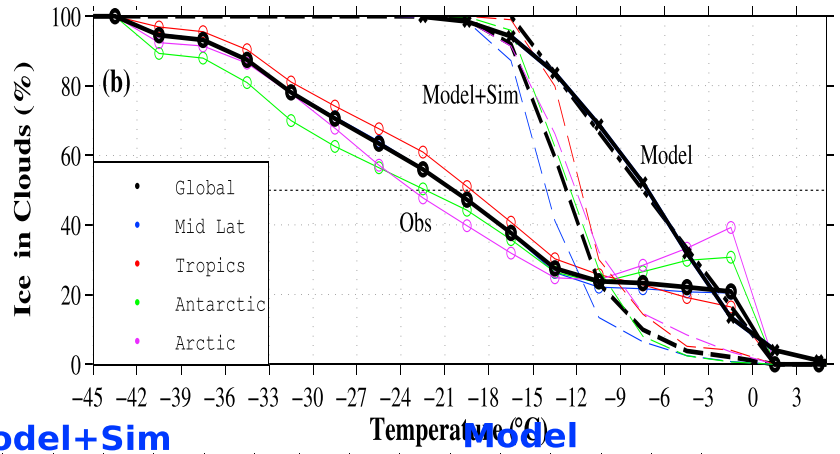
in CFMIP2 (Bony et al.) ,

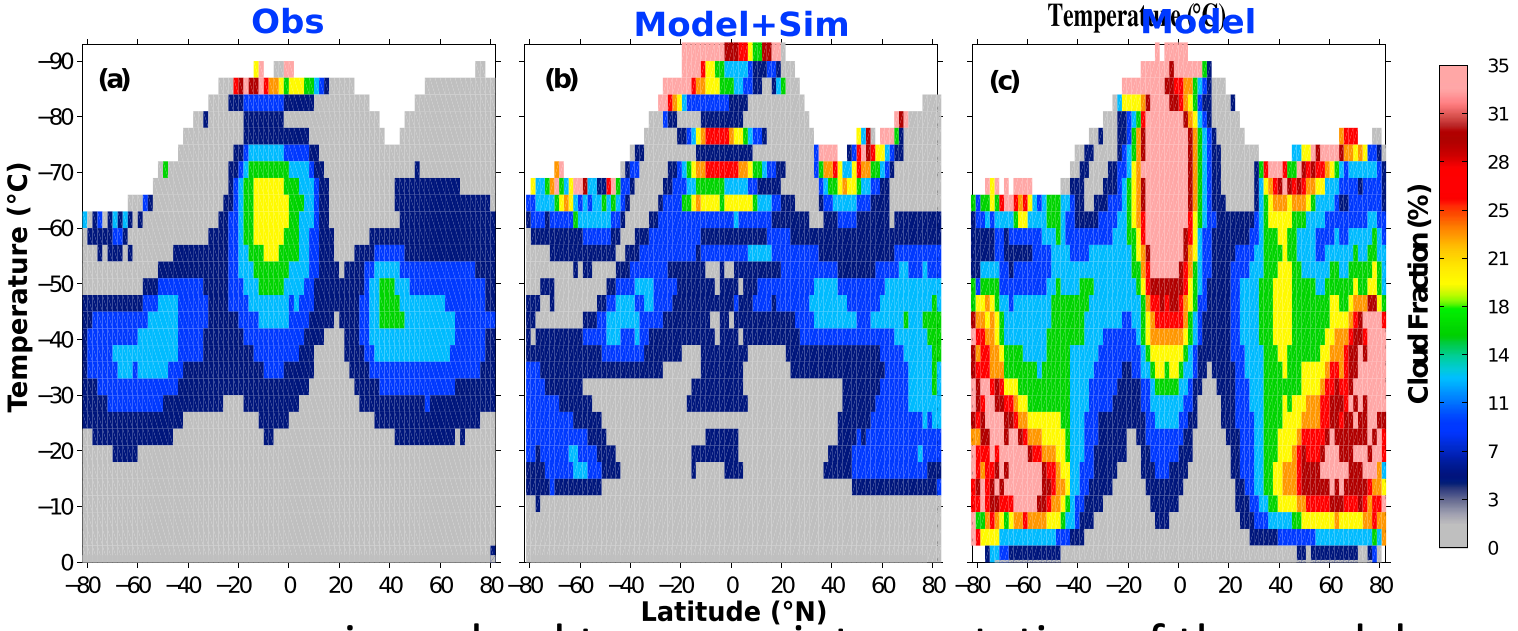
in CMIP5 (Taylor et al.)

in CMIP6 (Webb et al, GMD, 2016, submitted)

Cloud phase observed by CALIPSO is a new a strong constrain for climate models,

Cesana et al. 2015, JGR-Atm, 2012, GRL, 2013 JGR
Bodas et al. 2014
Kay et al. 2016
McCoy et al. 2016
Hawcroft et al. 2016a and 2016b J Clim.
Storelvmo et al. 2016





But apple to orange comparisons lead to wrong interpretation of the model-obs differences, and contribute (among others things) to different conclusions regarding the sensitivity of the climate to the cloud phase change

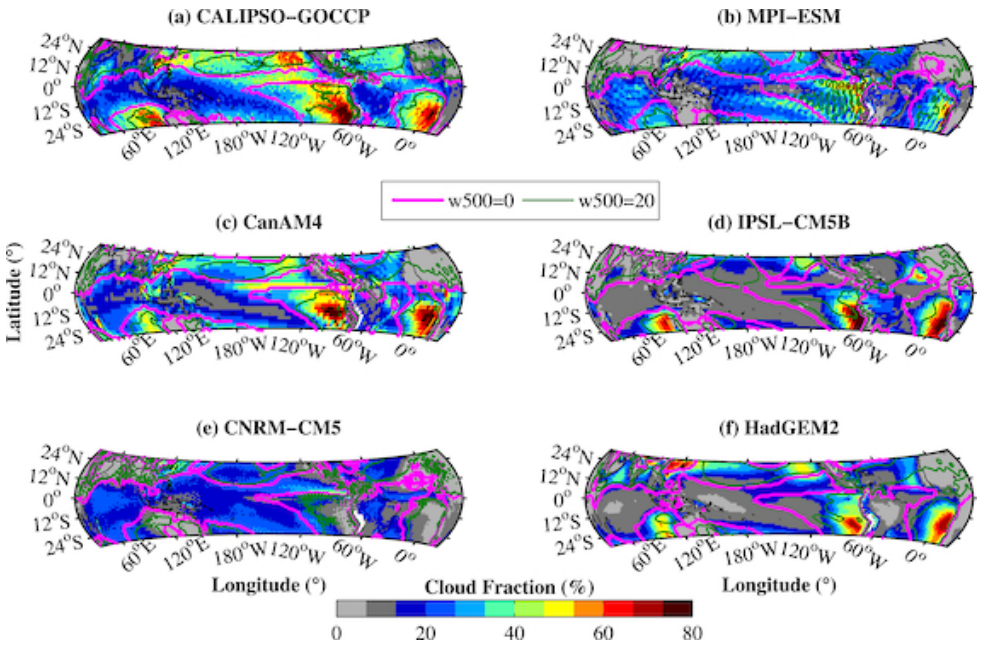
Low level clouds (z < 4km) in Tropical subsidence regions (w500>0)

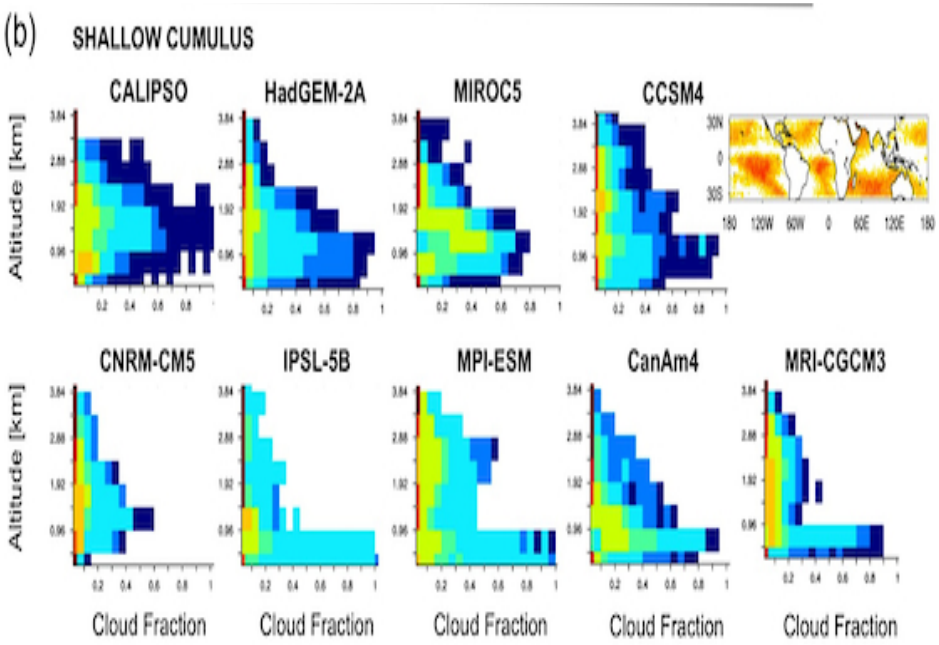
Expected Cloud Feedback mechanism :

Subtropic marine low level cloud cover decreases when the sea surface temperature increases => Positive ?? SW cloud feedback

Qu et al. 2014
Klein and Hall 2015
Bretherton 2015
…

The too few too bright low level cloud problem in CMIP5 models





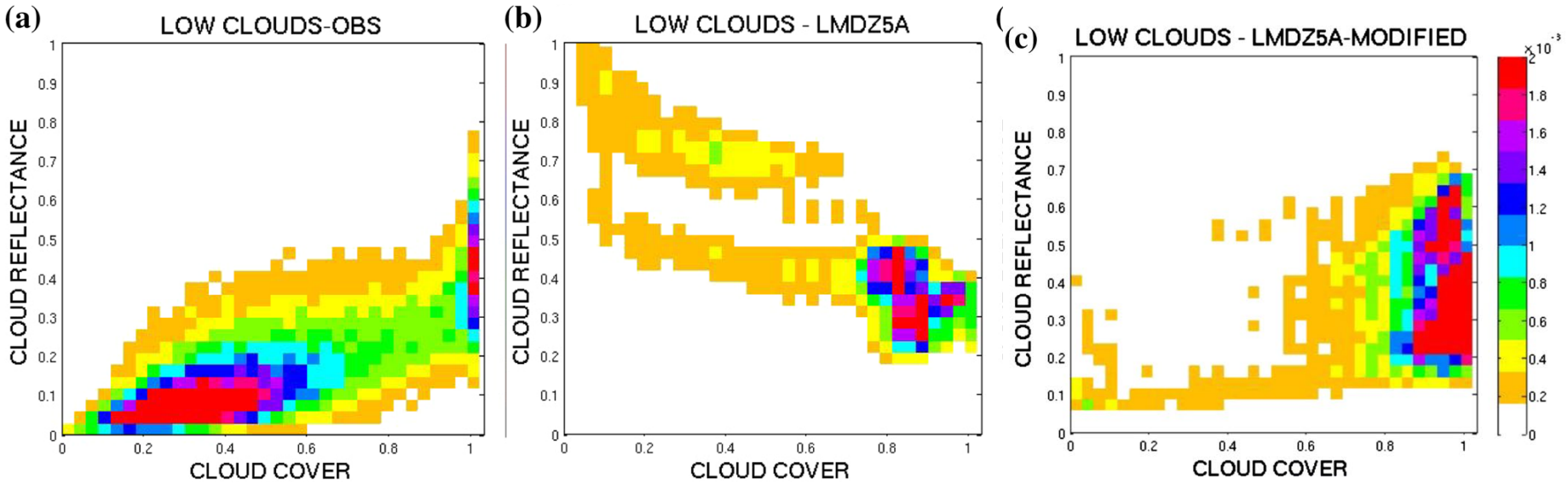
Nam et al., 2012, GRL
Cesana and Chepfer, 2012, GRL

Instantaneous Calipso/A-train correlation between variables at high spatial resolution guide parameterization development in climate models

Observations
CALIPSO/PARASOL

Model
+ simulators

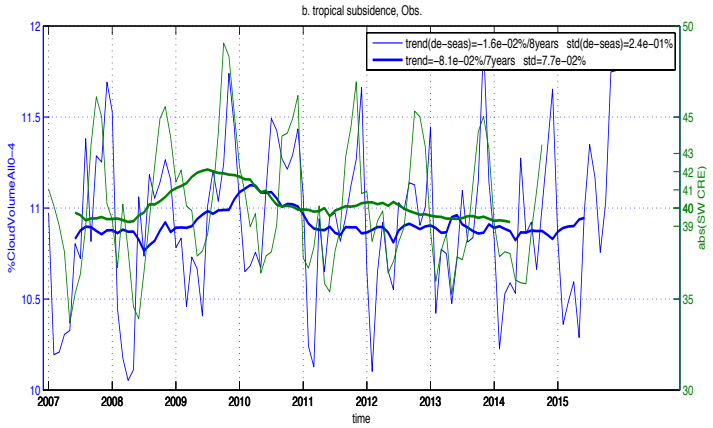
Model-modified
+ simulators



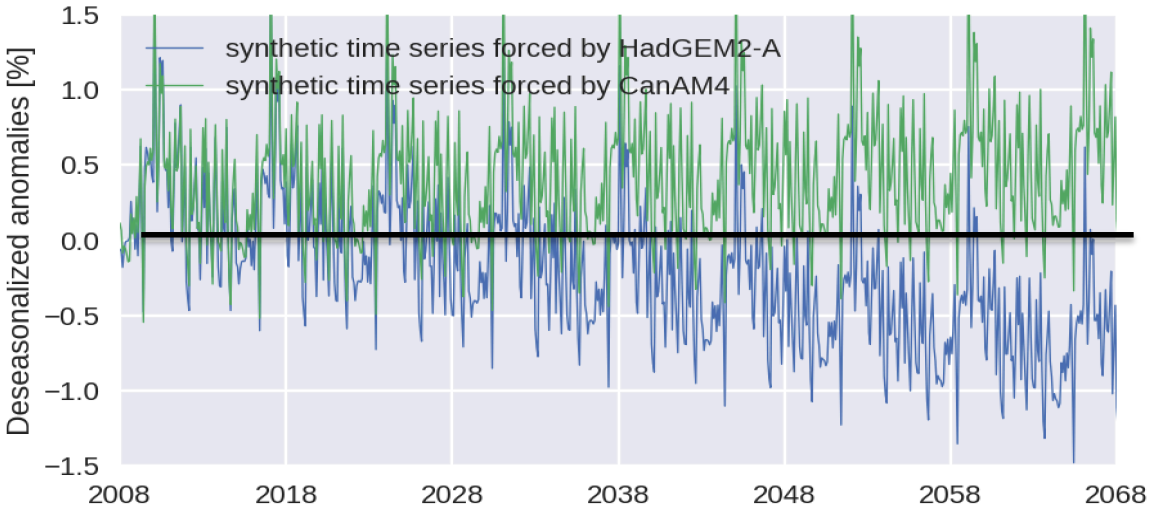
Model-modified includes a new parameterization of the vertical subgrid cloud distribution deduced from Calipso obs

Konsta, Dufresne, Chepfer, et al., 2015, Climate Dynamics
Konsta, Chepfer, Dufresne, et al., 2012, Climate Dynamics

A lidar 25+ years record to constrain the SW cloud feedback, and climate sensitivity



Calipso low cloud volume drives the CRE-SW



Lidar in space record would allow observing the sign of the SW feedback
model predicting >0 SW feedback
model predicting <0 SW feedback

And also the magntiude of the SW tropical feedback

Chepfer et al, in prep

Opaque Tropical clouds in convective regions (w500<0)

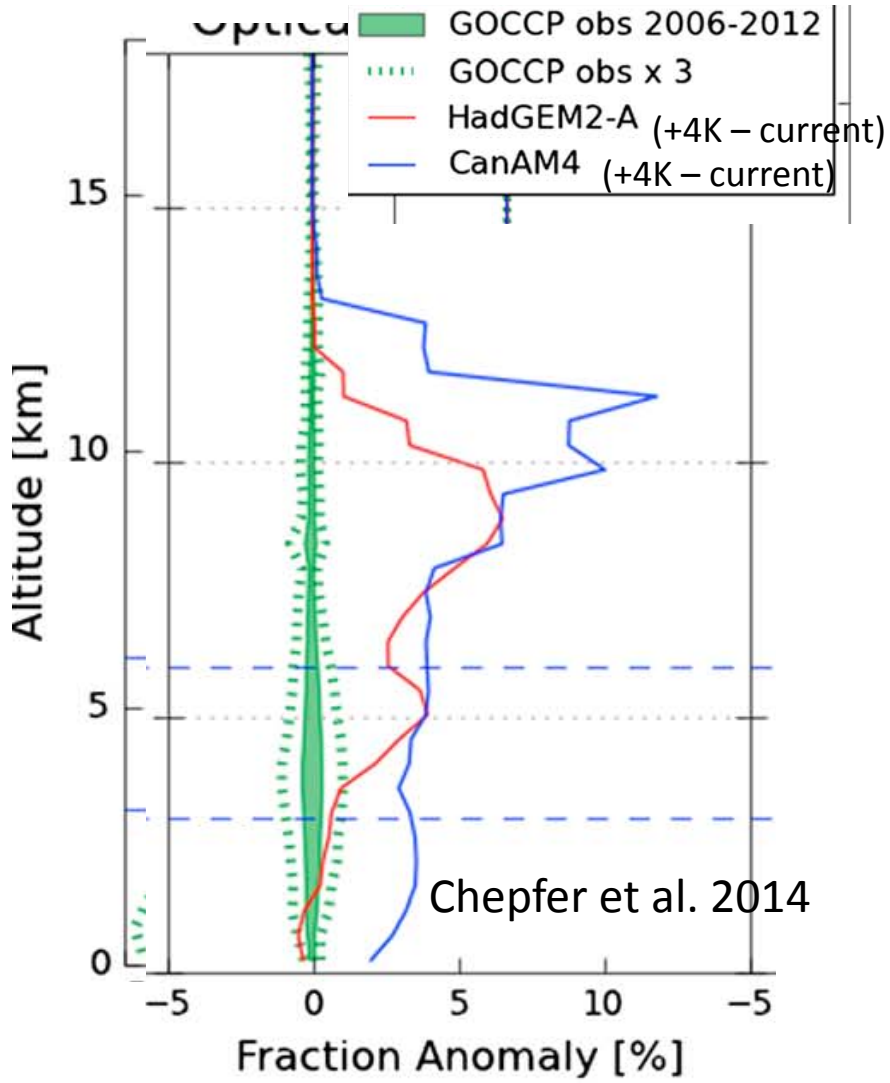
Expected Cloud Feedback mechanism :

Opaque tropical clouds are expected to rise up as surface temperature increases => Is the dominant Positive LW cloud feedback term , … how much ? Depends on models

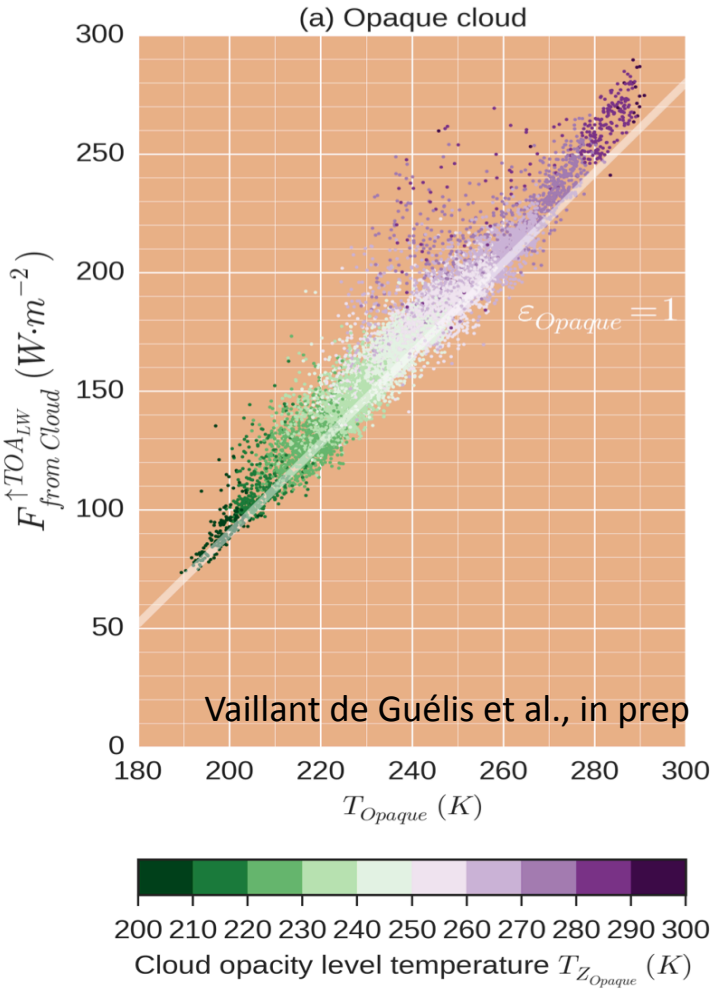
Hartmann et al. 2002
Zelinka et al. 2012
Wang et al. 2002
O'Gorman et al. 2013
Chepfer et al. 2014, GRL
…

…

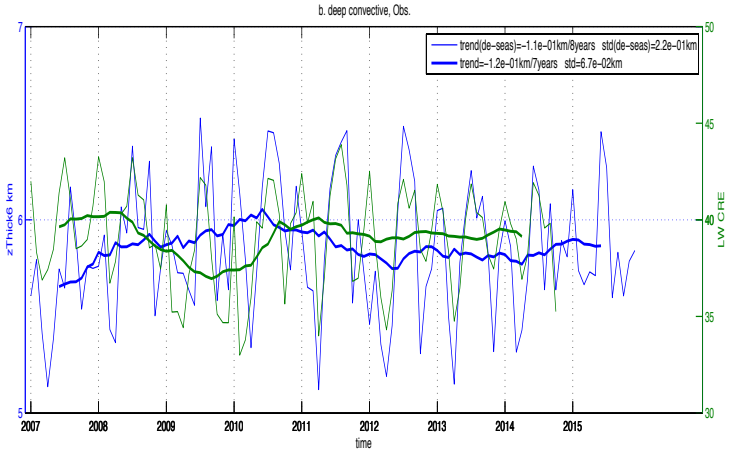
The altitude of opaque clouds is expected to rise up quickly when climate warms, the altitude of opaque clouds is the main driver of the CRE LW => a direct observable of LW tropical feedback



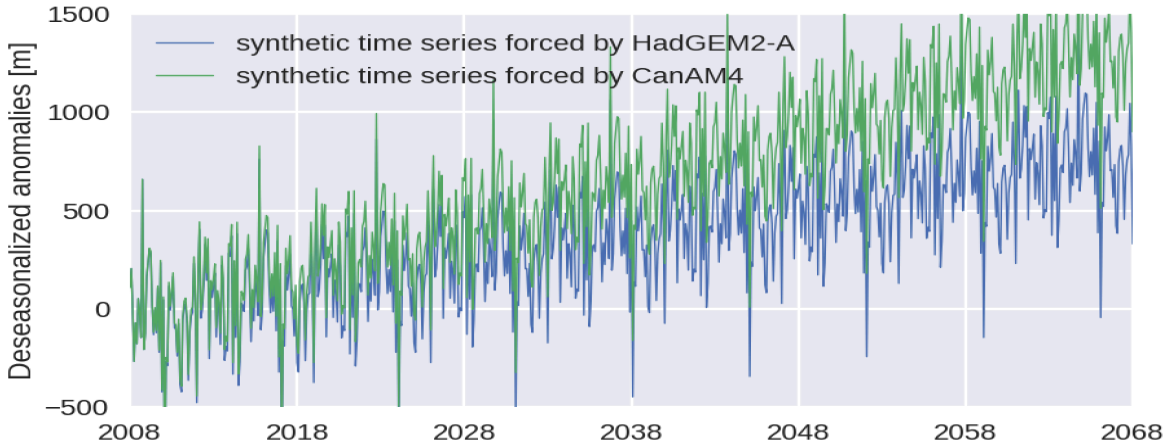
CERES & CALIOP observations:
part of the TOA outgoing LW flux that comes from cloud
over CERES footprints collocated with CALIOP lidar profiles



A lidar 25+ years record constrains the LW cloud feedback, and climate sensitivity



The altitude of opacity drives the LW CRE



The lidar opaque altitude increases for both models, but with different amplitude

Model with large positive feedback,

Model with moderate positive feedback

If the models predictions were right, the cloud rise up would be observable soon, which doesn't seem to be the case=> models overestimate the LW cloud feedback

Conclusion

- Developing/tuning climate models directly against observations without taking into account resolutions and cloud masking effect (simulator), would likely lead to erroneous conclusions and model developments

- CALIPSO/A-train cloud observations and COSP:
  - have allowed numerous model evaluations
    (see CFMIP webpage list of references),
  - are currently allowing improvement/leads for cloud description/ parameterization in climate models
    (eg. low level shallow tropical clouds, cloud phase)
    when used at high spatio-temporal resolution with simulators

- Vertically resolved observations collected by active sensors are able to constrain the longstanding question of cloud feedback sign and amplitude in different regions, if the record is long enough
  => need for another Calipso/CloudSat after EarthCare with no gap
  (any gap delay the capability to constrain cloud feedback and climate sensitivity)