Evaluation of the clouds description in climate models using CALIPSO

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Contributors :

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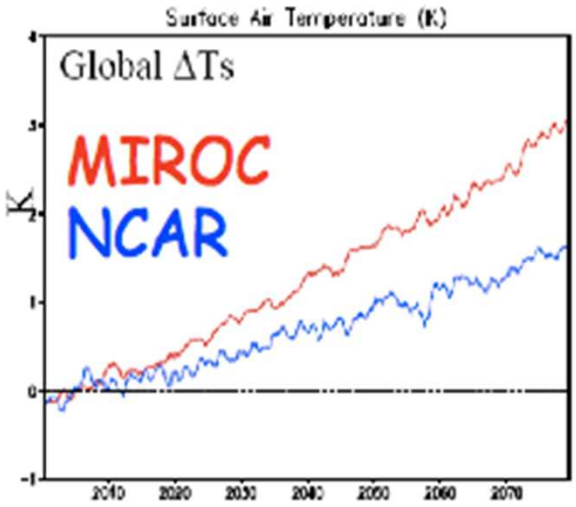
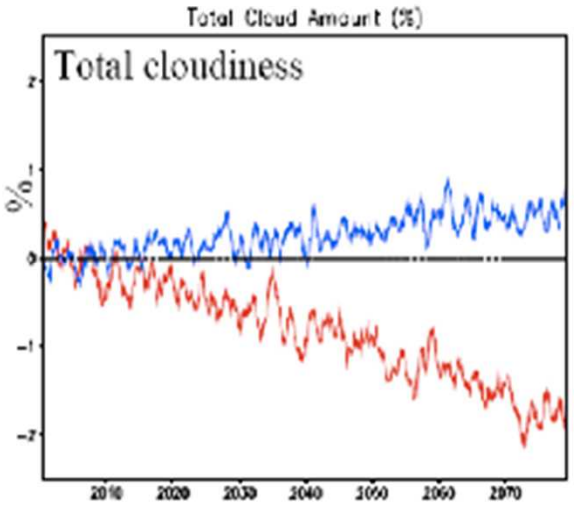
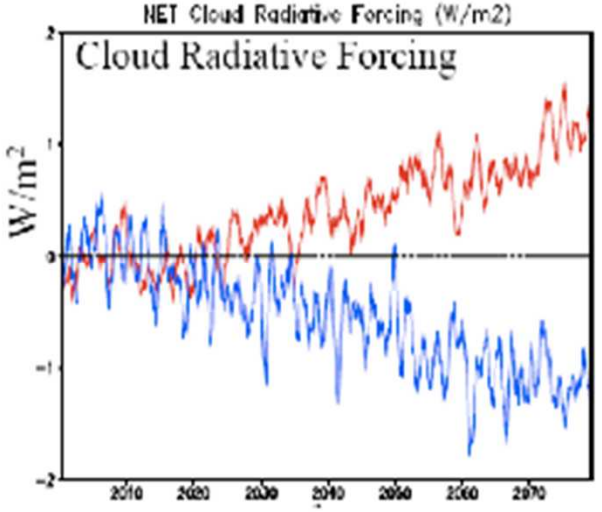
Clouds & Climate Change

Projections of future climate for 2 different climate models







Courtesy S. Bony

Clouds : a key uncertainty for model-based estimate of future climate evolution

i.e., Randall et al. 2007, Dufresne and Bony, 2009, Soden et Held, 2006, Webb et al., 2006, Ringer et al. 2006

⬇

Need a thorough evaluation of cloud description in climate models

(even if a more realistic description of cloud processes in a model in the current climate does not necessarily imply a more realistic prediction of the cloud response in a warming climate !)

Objective: evaluate cloud description in climate model

⇒Global scale, not only regional studies
⇒Statistically significant, no case studies alone
⇒Identify if systematic defaults are shared by different climate models
⇒Be as close as possible to the parameterization scale:
instantaneous cloud variables at *high spatial resolution*

Objective: evaluate cloud description in climate model

⇒ Global scale, not only regional studies
⇒ Statistically significant, no case studies alone
⇒ Identify systematic defaults shared by different climate models
⇒ Be as close as possible to the parameterization:
instantaneous correlation between different cloud variables at *high spatial resolution*

A methodology :

CALIPSO/COSP simulator http://www.cfmip.net
CALIPSO-GOCCP and CFMIP-OBS observations http://www.polytechnique.ipsl.fr/cfmip-obs

⇒ a consistent definition of clouds in « model+simulator » outputs and in observations :
differences can be attributed to model defaults.

Refs: Klein and Jakob 1999, Chiriaco et al. 2005, Chepfer et al. 2007, 2008, 2010, 2012, Bodas et al 2011, Konsta el al. 2012

In this talk, we use « CMIP5 models + COSP/CALIPSO » outputs (available on the ESG)

Background

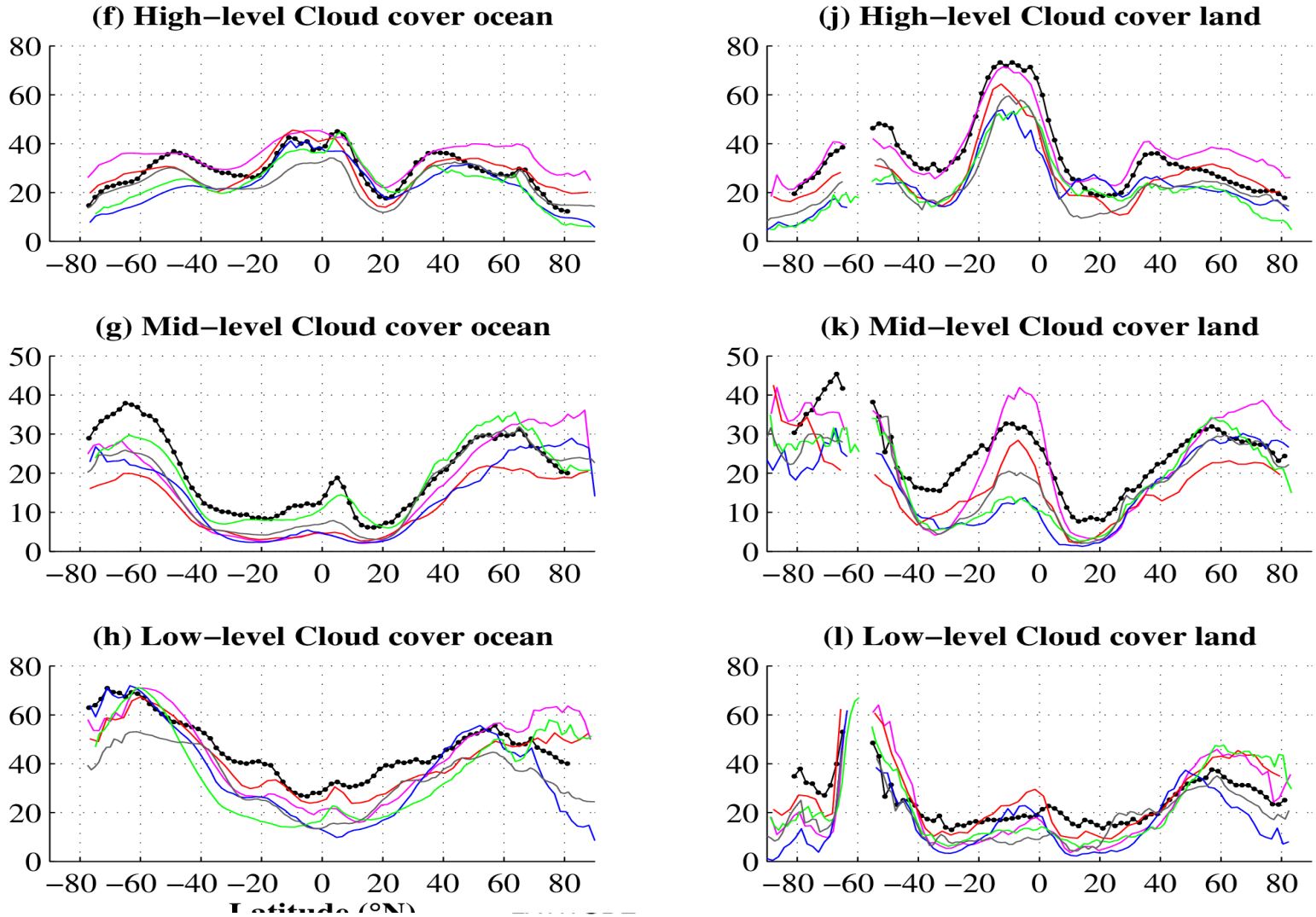
New information provided by CALIPSO at global scale over 6+ years:

- Cloud cover of optical thin clouds
- Cloud cover of highly fractionnated clouds
- Detailed vertical cloud structure
- Cloud water phase determination independent of the temperature
- Cloud detection above reflecting surfaces and close to the surface
- Instantaneous colocated observations with passive A-train sensors and with CloudSat radar

Main Limitations for clouds : Attenuation , Heliosynchroneous orbit

Clouds at global scale

Cloud covers: CMIP5+COSP models vs CALIPSO-GOCCP

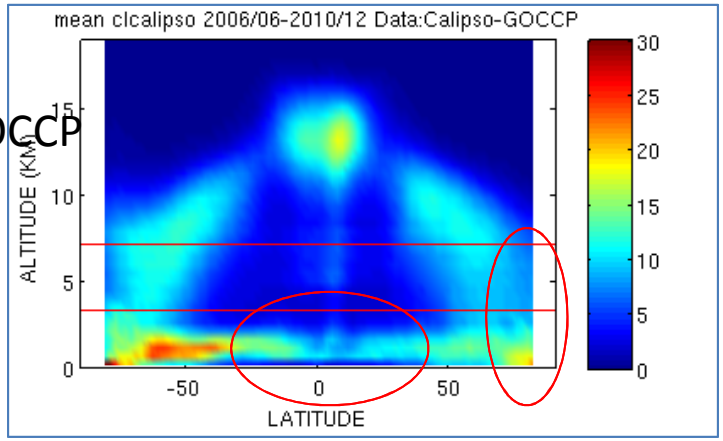


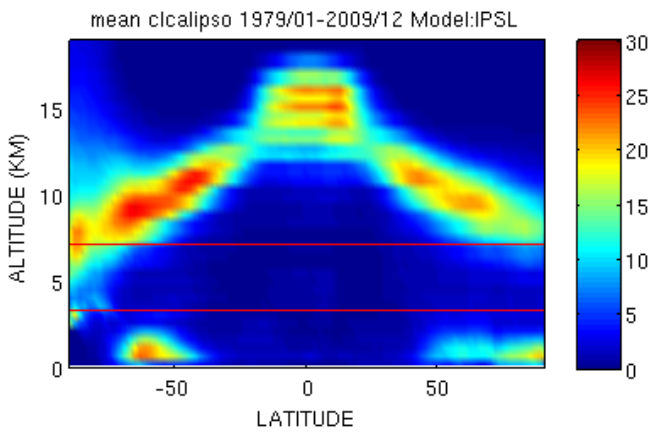
Cesana and Chepfer, GRL, 2012

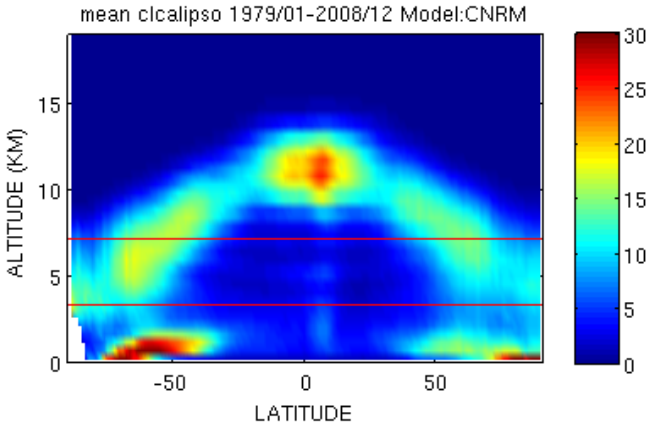
Compared to passive remote sensing evaluation of CMIP3 models done by Zhang et al. [2005], the CALIPSO evaluation of CMIP5 models suggests that
- the inter-model spread in low, mid, high cloud cover is reduced,
- the underestimate of mid-level clouds by all models is confirmed,
- and the high latitude clouds are significantly different than the ones seen by passive remote sensing.

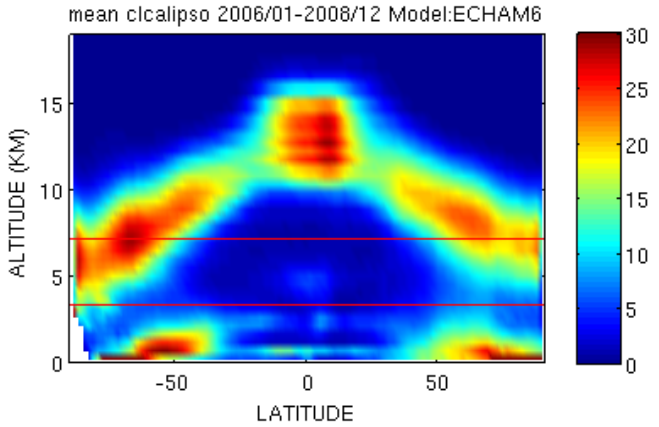
Cloud vertical structure: CMIP5+COSP models vs CALIPSO-GOCCP

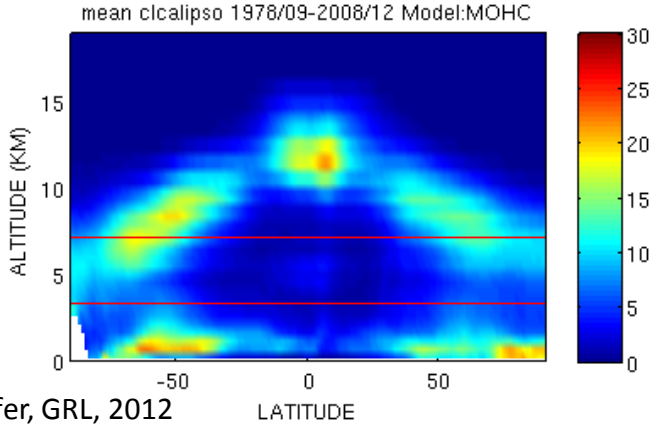
Obs
CALIPSO-GOCCP

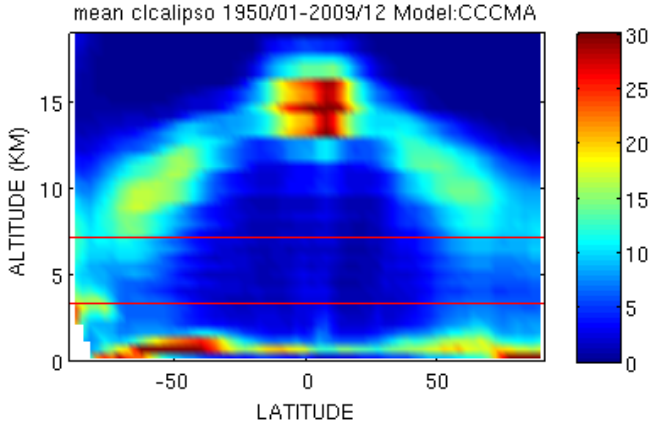












Cesana and Chepfer, GRL, 2012

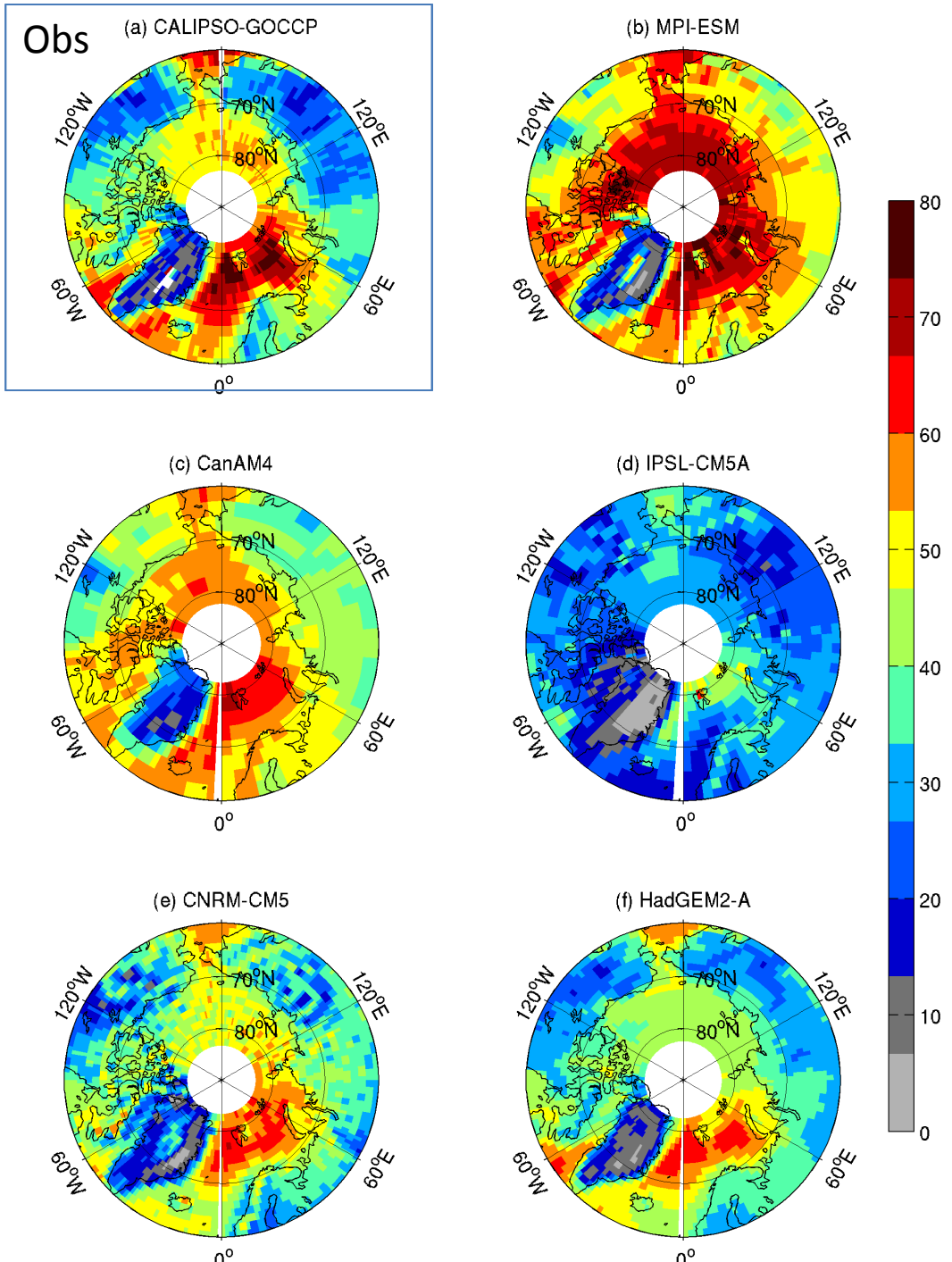
Arctic clouds

Arctic Low level Clouds cover

(annual mean)

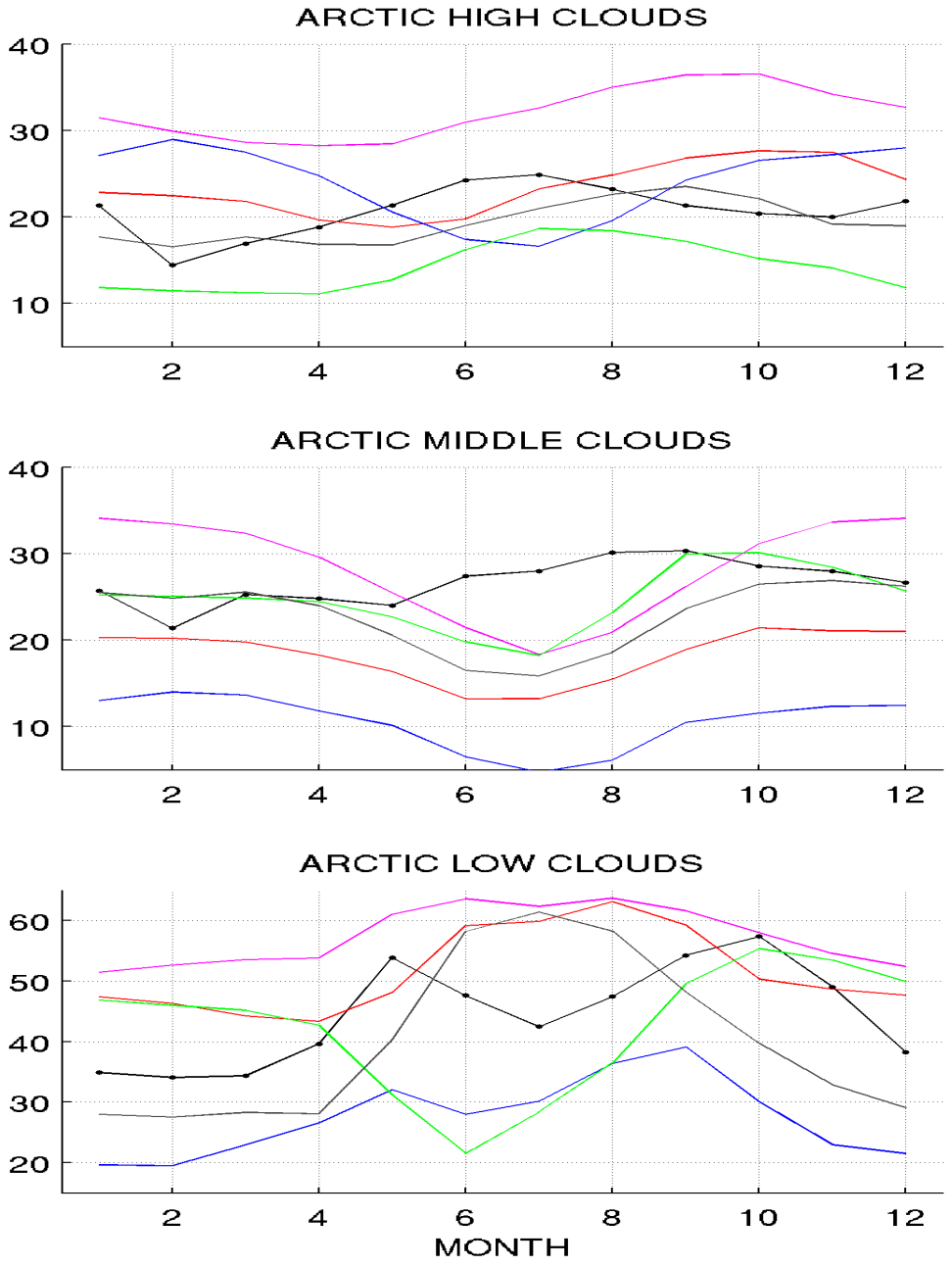
Models:
CMIP5 +COSP

Obs:
CALIPSO-GOCCP



Cesana and Chepfer, GRL, 2012

Arctic Cloud cover Seasonal variation



Obs:
CALIPSO-GOCCP

Models:
CMIP5- +COSP

Cesana and Chepfer, GRL, 2012

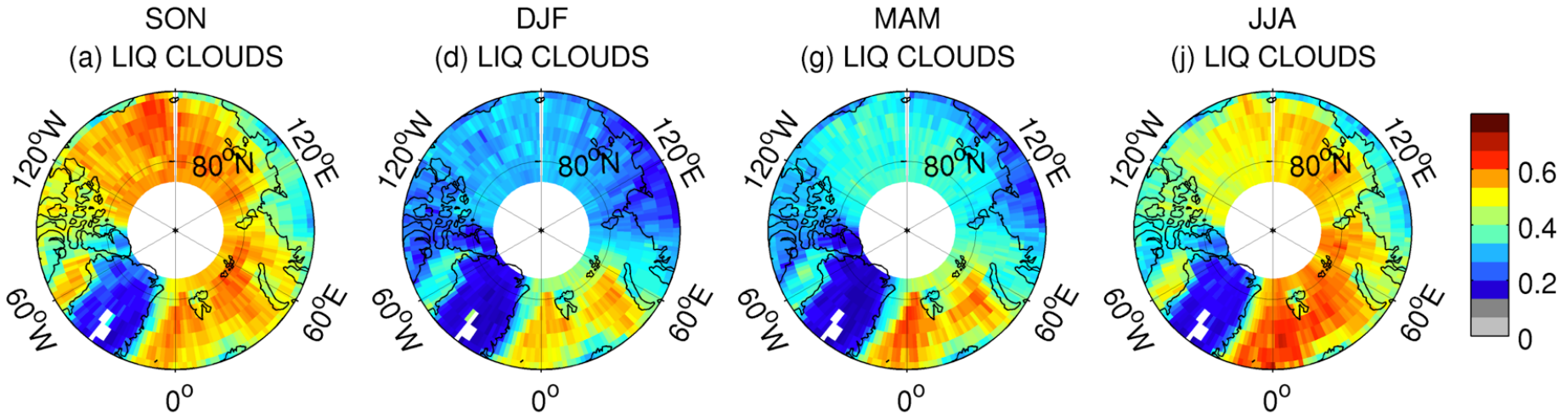
About the Arctic cloud phase

Ground-based observations (1 year at SHEBA) show that persistent liquid- containing Arctic clouds occur frequently and have a dominant influence on Arctic surface radiative fluxes. (ie. Shupe et al. 2004, Morrison et al. 2011)

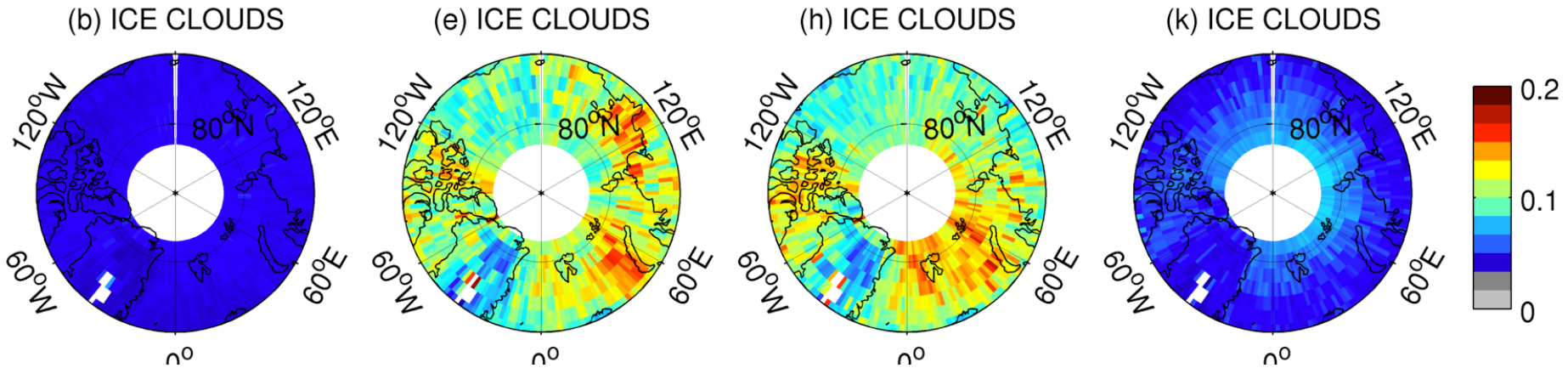
Yet, without a hemispheric multi-year perspective, the climate relevance of these intriguing Arctic cloud observations was unknown.

Arctic Low Clouds Phase: Observed Seasonal Variation

LIQUID LOW CLOUDS –OBS CALIPSO-GOCCP



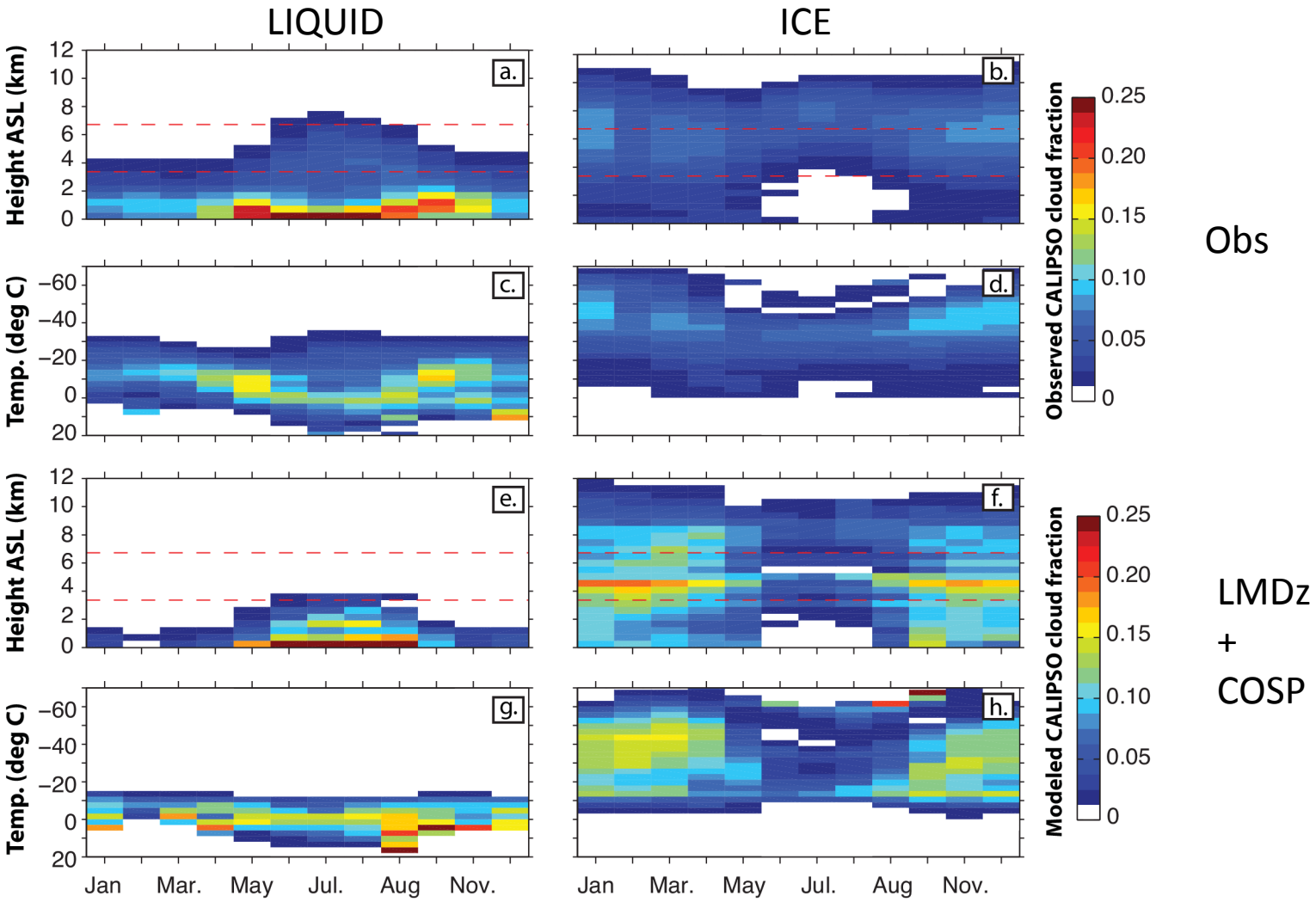
ICE LOW CLOUDS –OBS CALIPSO-GOCCP



⇒Over Arctic ocean-covered areas, low-level liquid-containing clouds are prevalent in all seasons, especially in Fall

Cesana, Kay, Chepfer, English, de Boer, GRL, 2012

Seasonal variation of open ocean Arctic cloud phase
LMDz+COSP vs CALIPSO-GOCCP

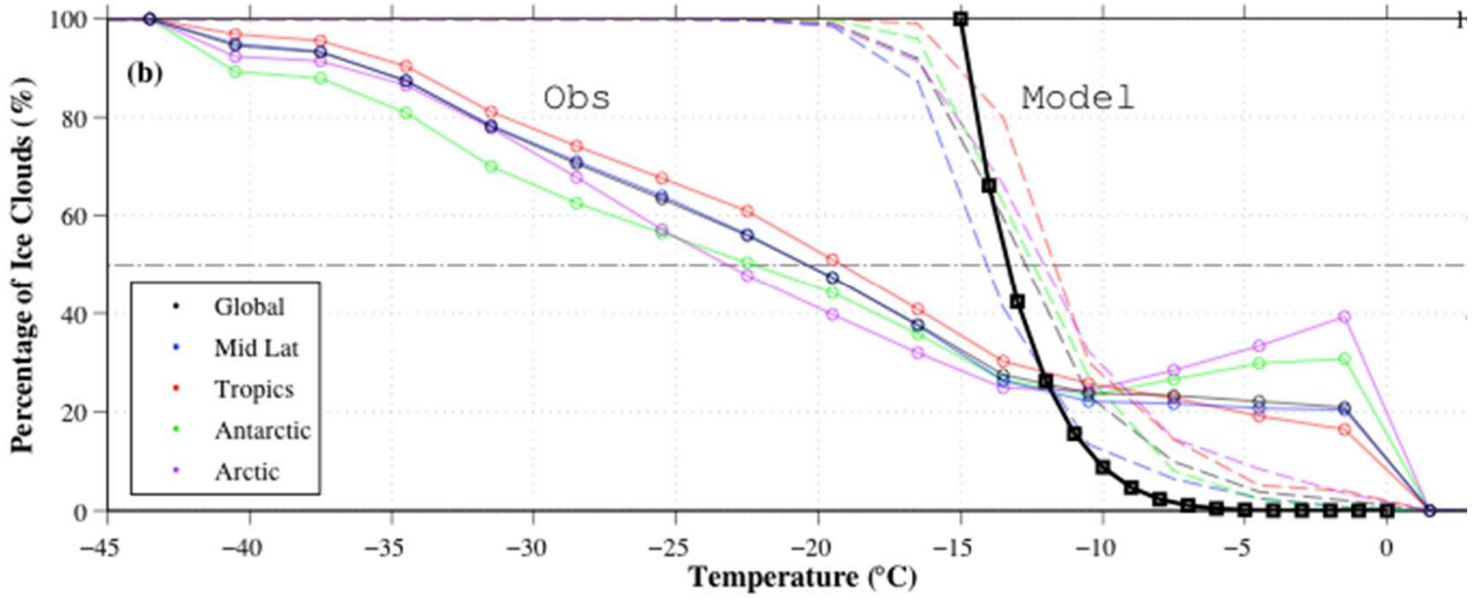


=> A lack of liquid- containing Arctic clouds in LMDZ

Cesana, Kay, Chepfer, English, de Boer, GRL, 2012

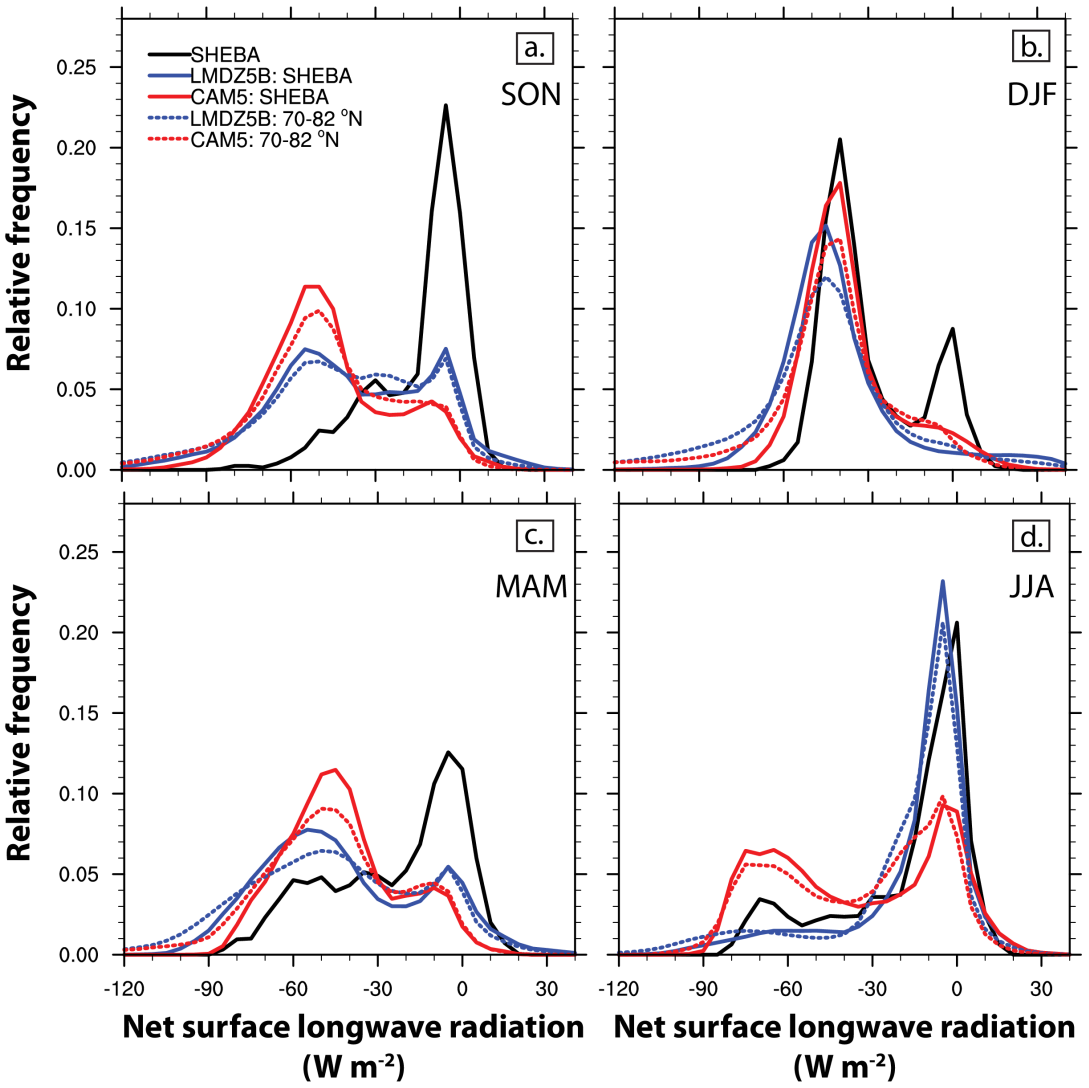
Cloud water phase:

LMDZ+COSP models vs CALIPSO-GOCCP



Cesana and Chepfer, submitted to JGR

Seasonal variation of Arctic Surface Fluxes



« Radiatively Opaque » state
NetLW =0

(Down minus up)

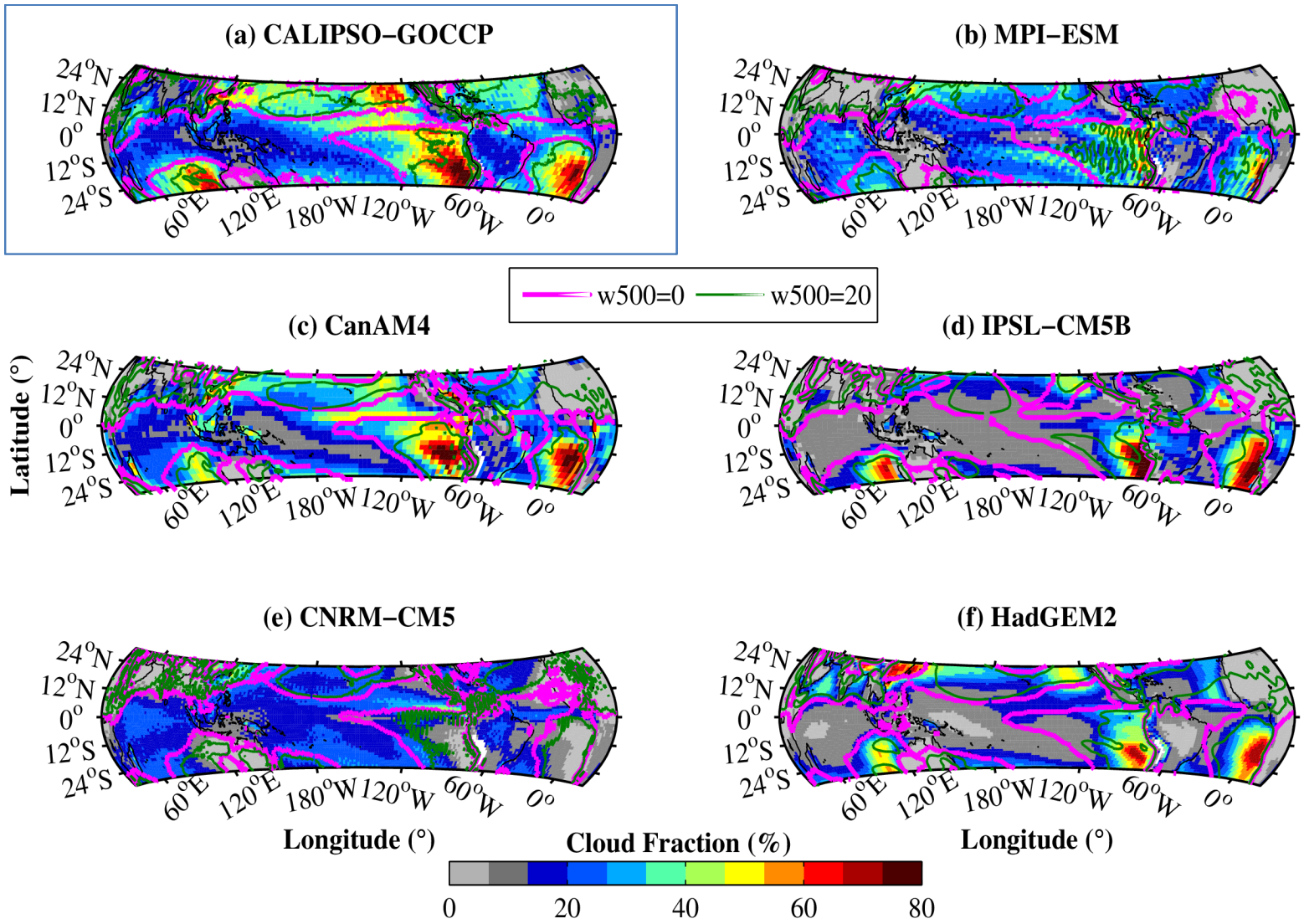
The lack of liquid- containing Arctic clouds contributes to a lack of “radiatively opaque” states.
The surface radiation biases found in LMDZ5B and CAM5 is found in others CMIP5 models

Cesana, Kay, Chepfer, English, de Boer, GRL, 2012

Tropical clouds

The low level clouds in subsidence regions :
at the heart of tropical cloud feedback uncertainties
in climate models (*Bony and Dufresne, 2005*)

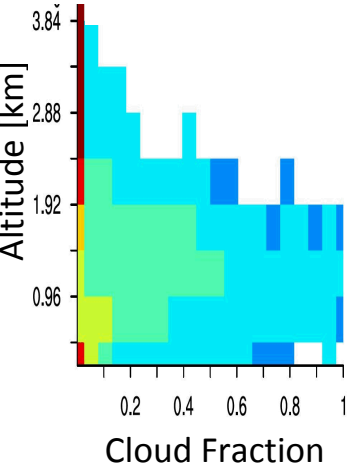
Low level Tropical Clouds : CMIP5+COSP models vs CALIPSO-GOCCP



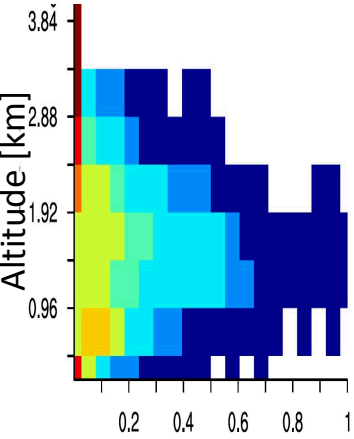
Cesana and Chepfer, GRL, 2012

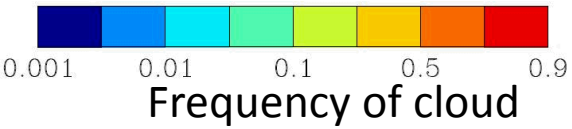
Observations
CALIPSO-GOCCP

Stratocumulus

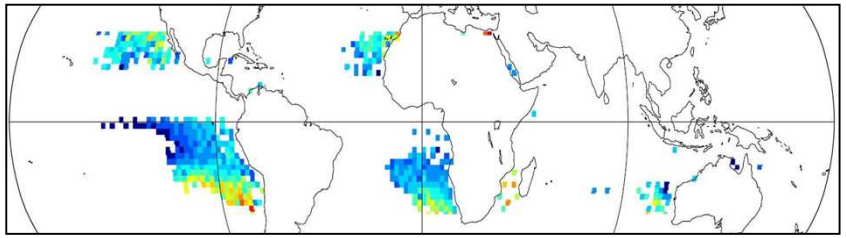


Shallow Cumulus





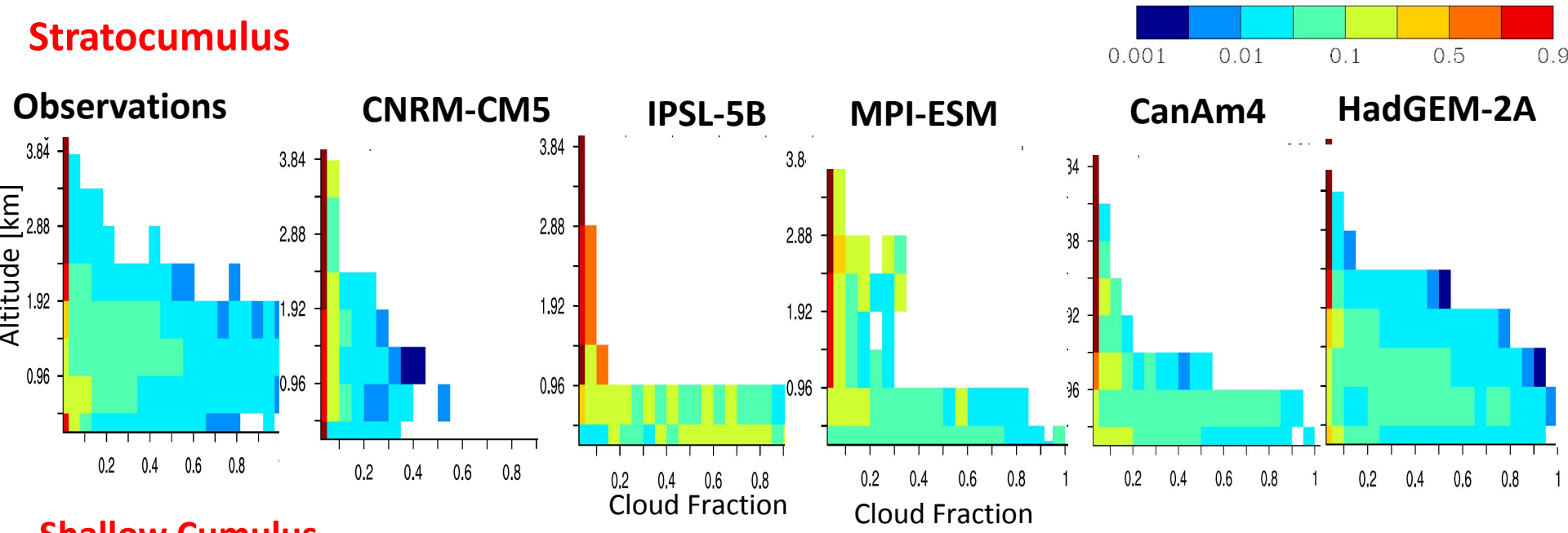
Dynamical Stratocumulus



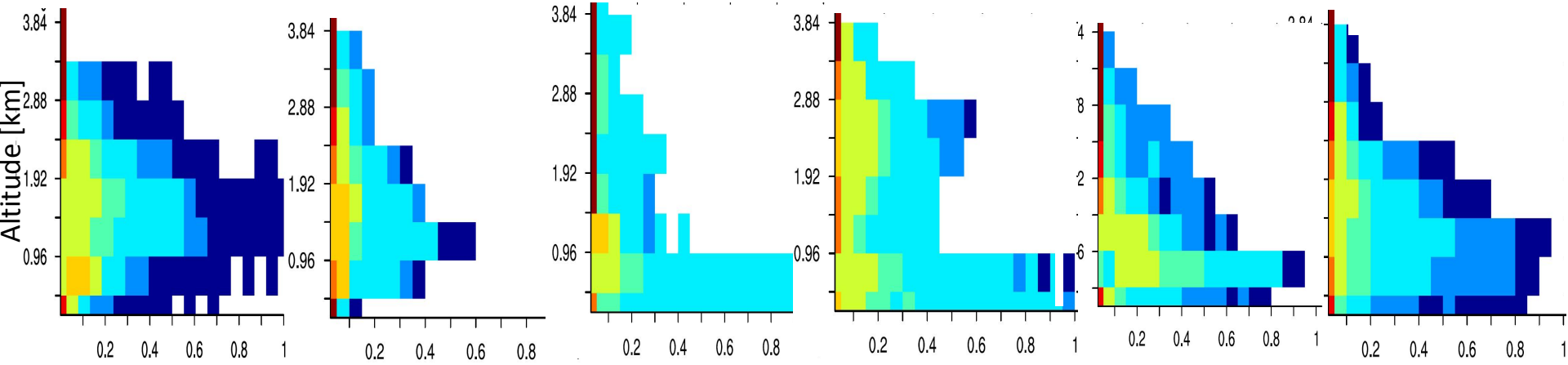
- Expanded study area to 30N/30S.
- Identified only low-level clouds (H,M<5%) under large-scale subsidence (w500hPa,w700hPa<10hPa day-1).
- Use LTS determine stratocumulus and shallow cumulus regimes.

C. Nam, S. Bony, JL Dufresne, H. Chepfer, GRL, 2012

Stratocumulus



Shallow Cumulus



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

C. Nam, S. Bony, JL Dufresne, H.Chepfer; GRL, 2012

Closer to the cloud process scale … and to the *parameterization*:

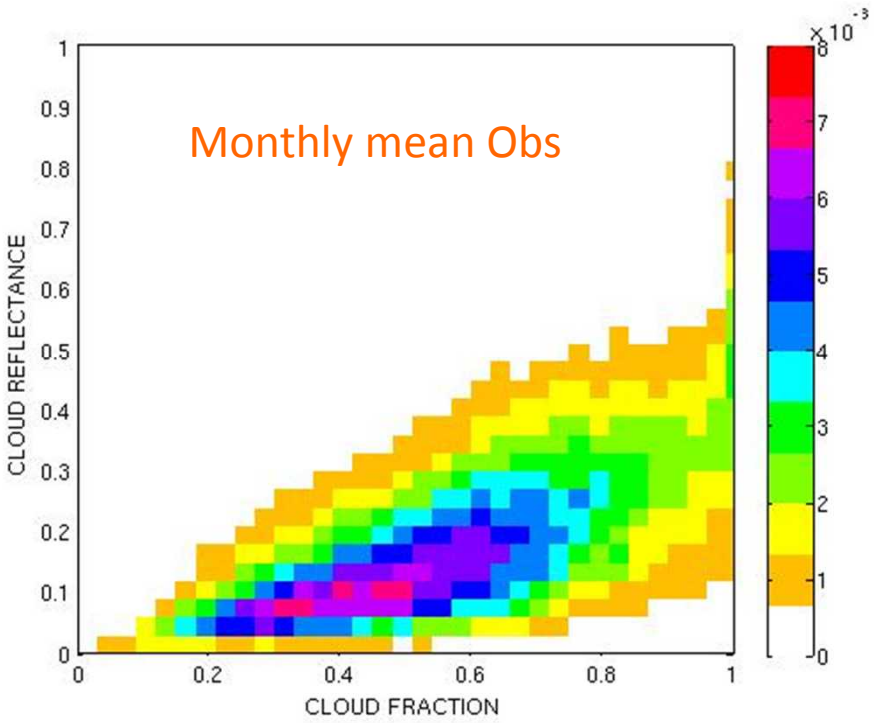
1) Observe relationships
between *instantaneous* (instead of monthly) cloud variables
at *high spatial resolution*

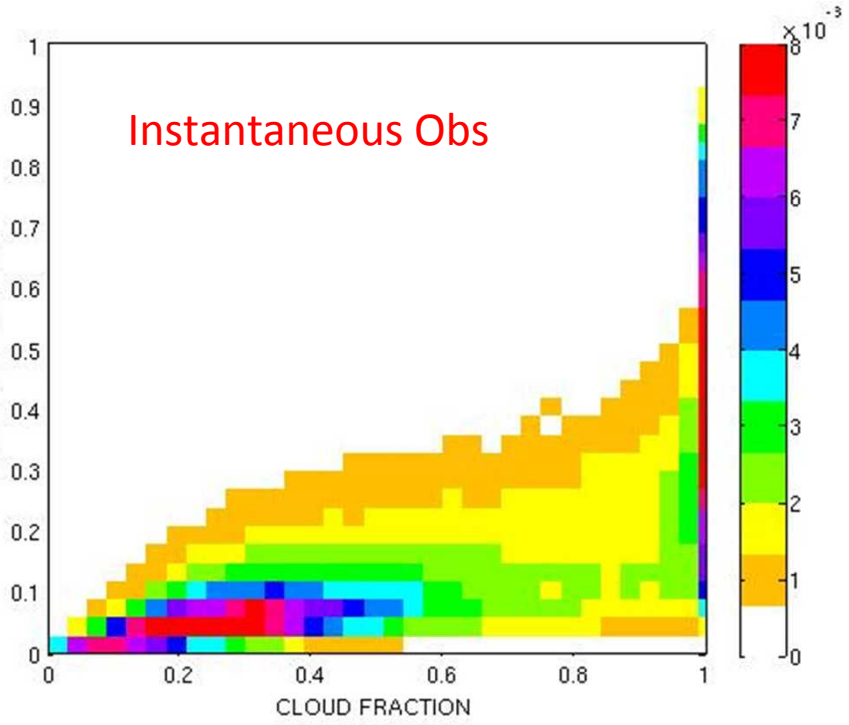
2) Evaluate the capability of the model to reproduce these correlations

Relationships

between the observed Cloud Fraction (Calipso) and Cloudy reflectance (Parasol)

- a drop for the optical depth

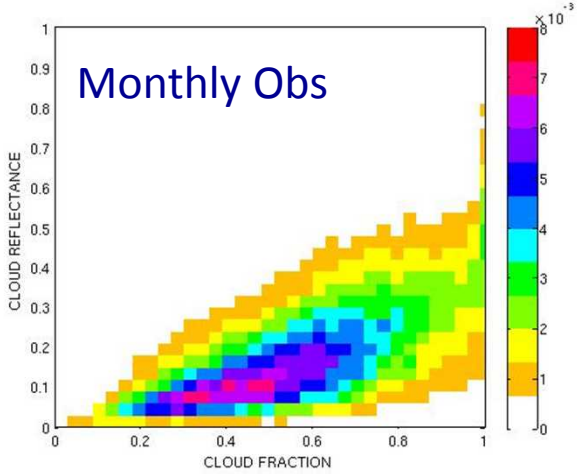


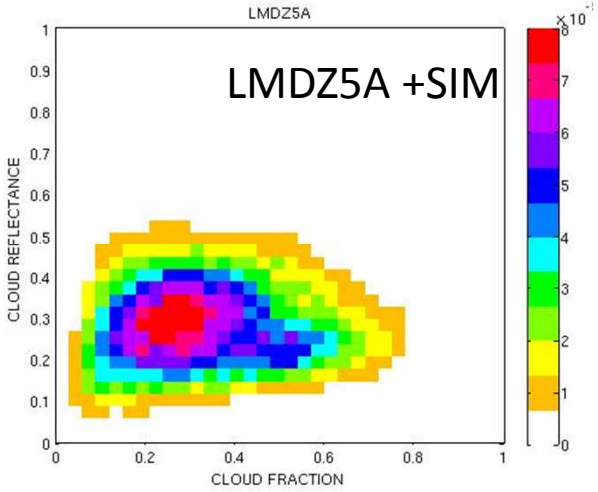


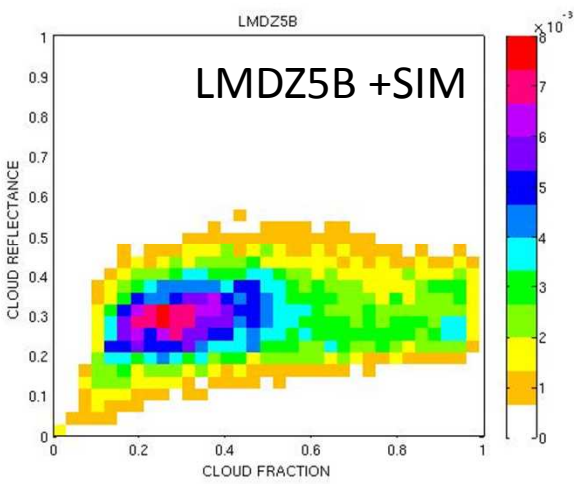
Konsta, Chepfer, Dufresne, Climate Dynamics, 2012

Relationships
between the observed Cloud Fraction (Calipso) and Cloudy reflectance (Parasol)

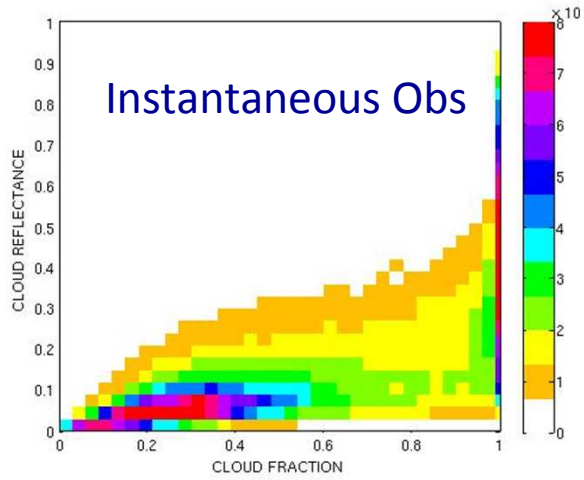
Monthly

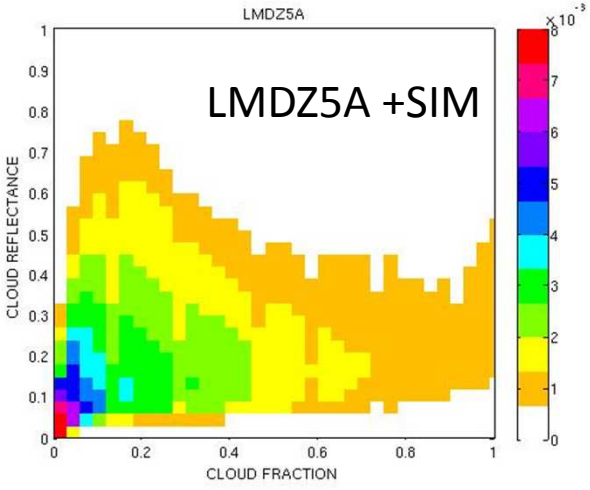


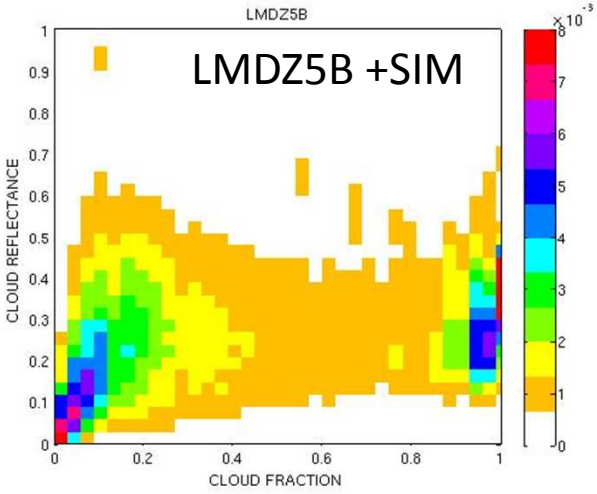




Instantaneous







Konsta et al., submitted

Concluding remarks

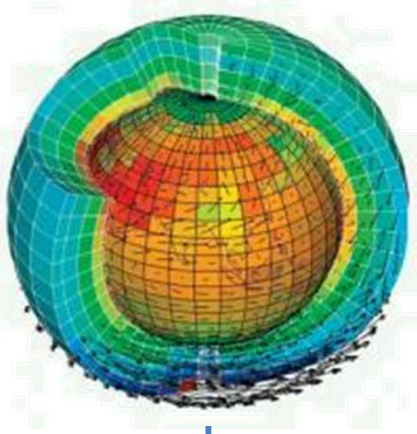
- CALIPSO observations (and COSP/Lidar) are now largely used
  - for evaluating the cloud description in climate models within CMIP5/CFMIP2
  - for identifying systematic models defaults
  - for helping proposing leads for parameterization development (instantaneous obs)

- CALIPSO provides clear cutting edge information in (at least) two climate sensitive regions:
  the Tropical clouds (and particularly shallow cumulus)
  the Polar regions
  through… clouds vertical structure, detection, phase, …

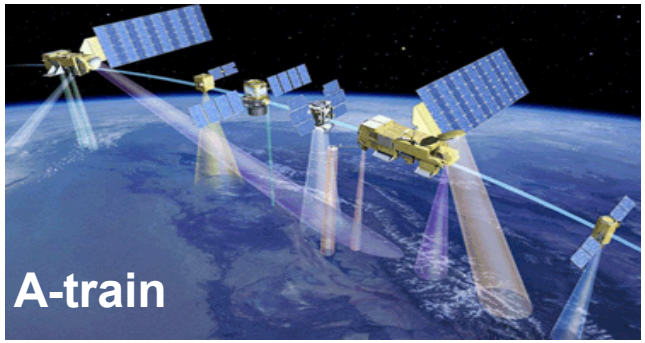
- CALIPSO/Cloudsat obs analysis for natural large scale, interannual variability (in link with model)… not so much yet

- Plans for EarthCare:
  - Merge CALIPSO-GOCCP with ATLID-GOECP (FOV, wvlgth, …)
    to capture interannual variability of cloud vertical structure, phase etc… and link with atmospheric circulation anomalies (ENSO, …)

Clouds in climate models & Clouds seen by satellites



not consistent



Simulators COSP

CFMIP-OBS

Simulated dataset

consistent

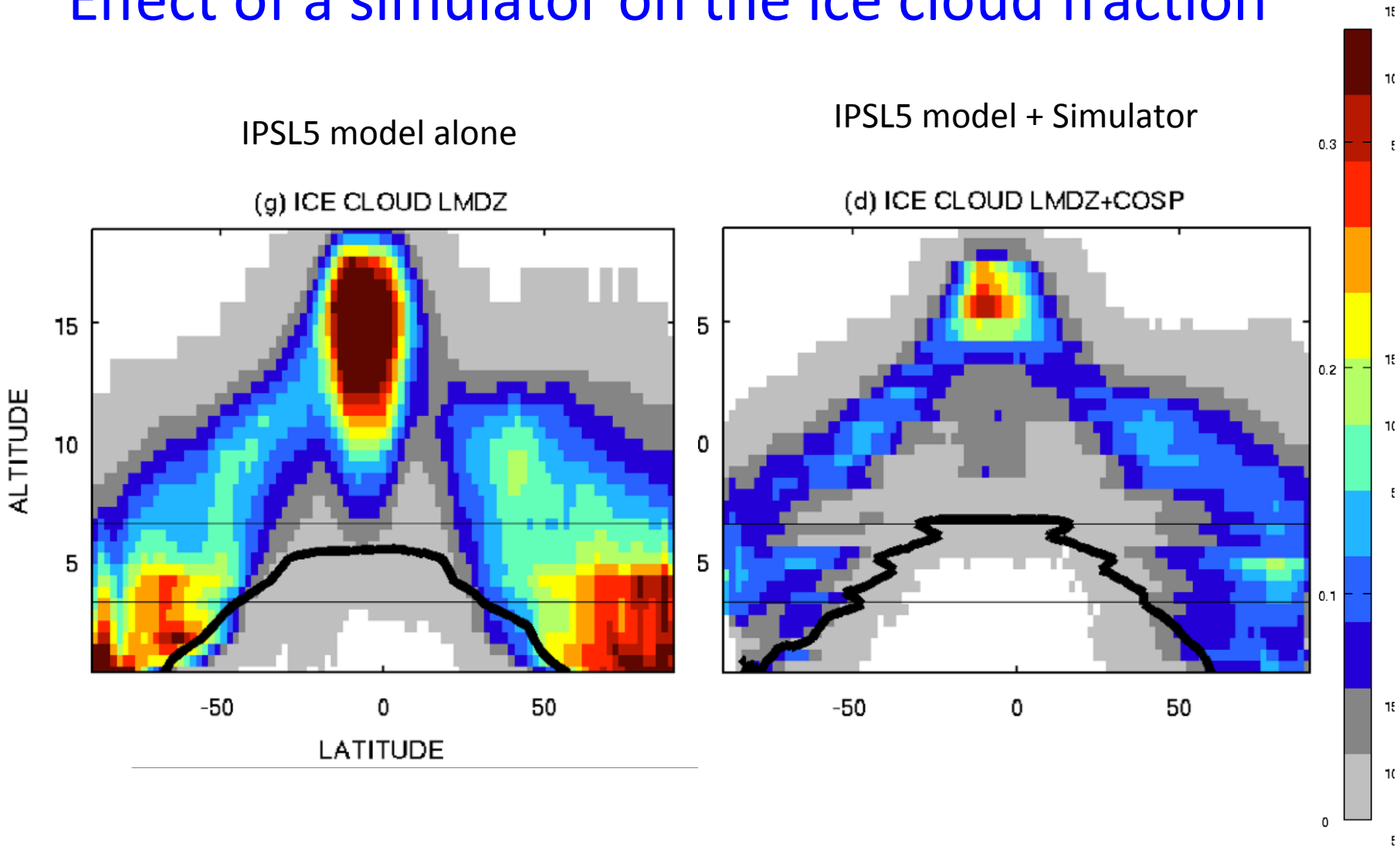
Observed dataset

Ensure that model/obs are due to model defaults

Background : « models & simulators » side
Effect of a simulator on the ice cloud fraction

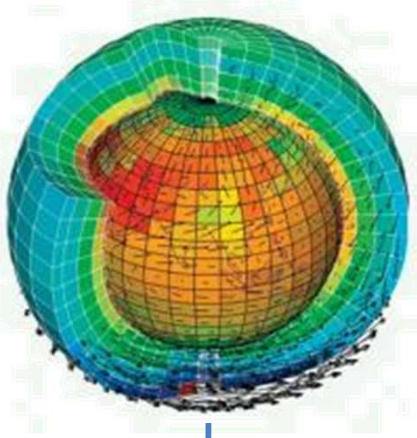
IPSL5 model alone

IPSL5 model + Simulator



Cesana and Chepfer, submitted JGR

Background : « models & simulators » side



COSP: CFMIP Observations Simulator Package
http://www.cfmip.net

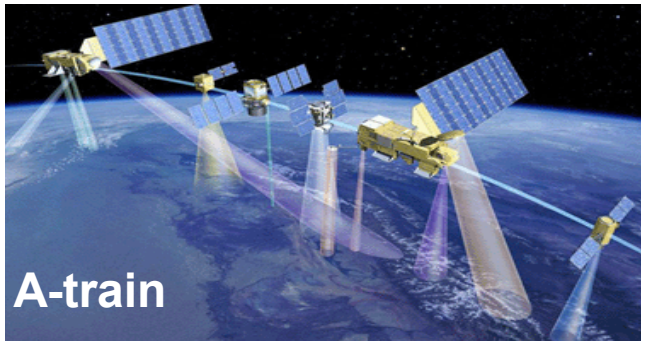
SCOPS subgrid : Klein and Jakob 1999
ISCCP simulator : Webb and Klein, 2001
CALIPSO simulator: Chepfer et al. 2007, 2008
CloudSat simulator : Haynes et al. 2007
MODIS simulator : Pincus et al. 2012
MISR simulator: Marchand et al. 2009
COSP infrastructure: Bodas et al 2011
PARASOL: Konsta el al. 2012
…

2008
WGCM recommended the use of COSP in CMIP5 climate model simulations

2008
CFMIP recommended the use of all COSP modules for current climate simulations CFMIP-2 (2007)

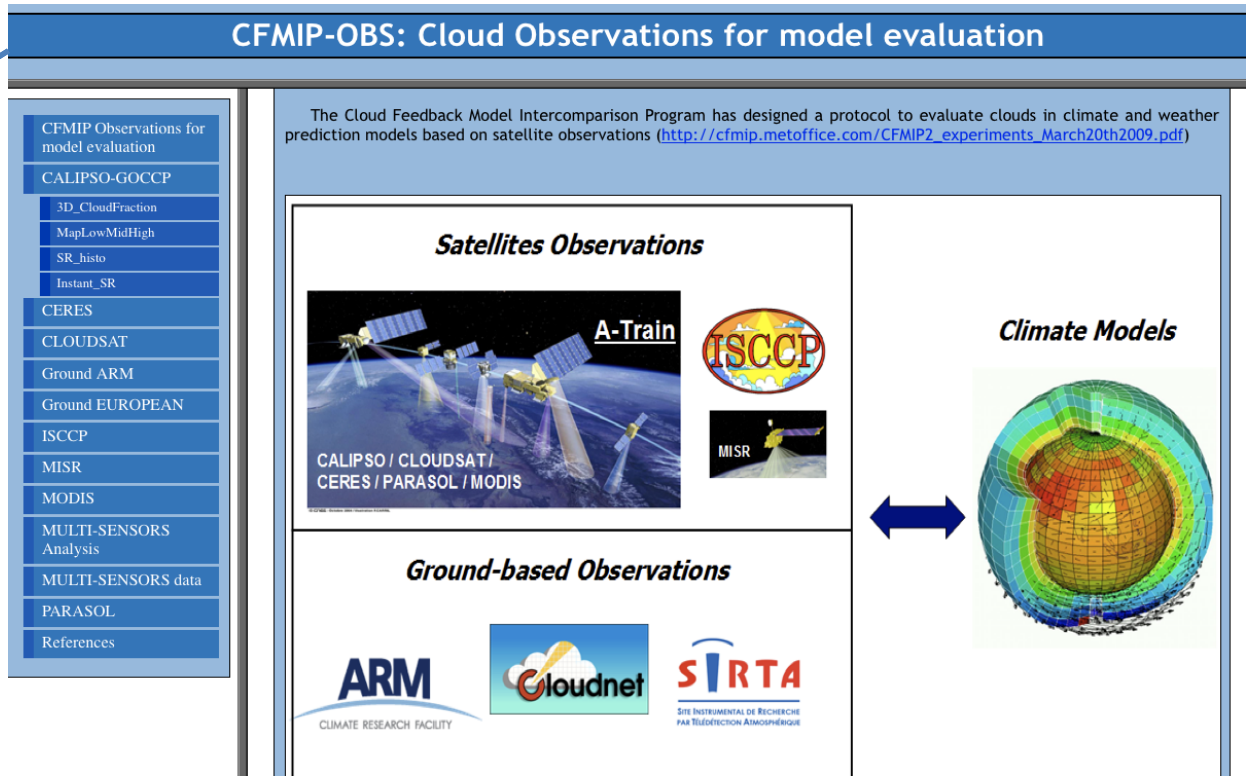
2012 : CMIP-5 and CFMIP2 ouputs with Climate models + COSP simulators for: IPSL, CCCMA, CAM, ECHAM, MIROC,HAGEM, …

Background: observations side



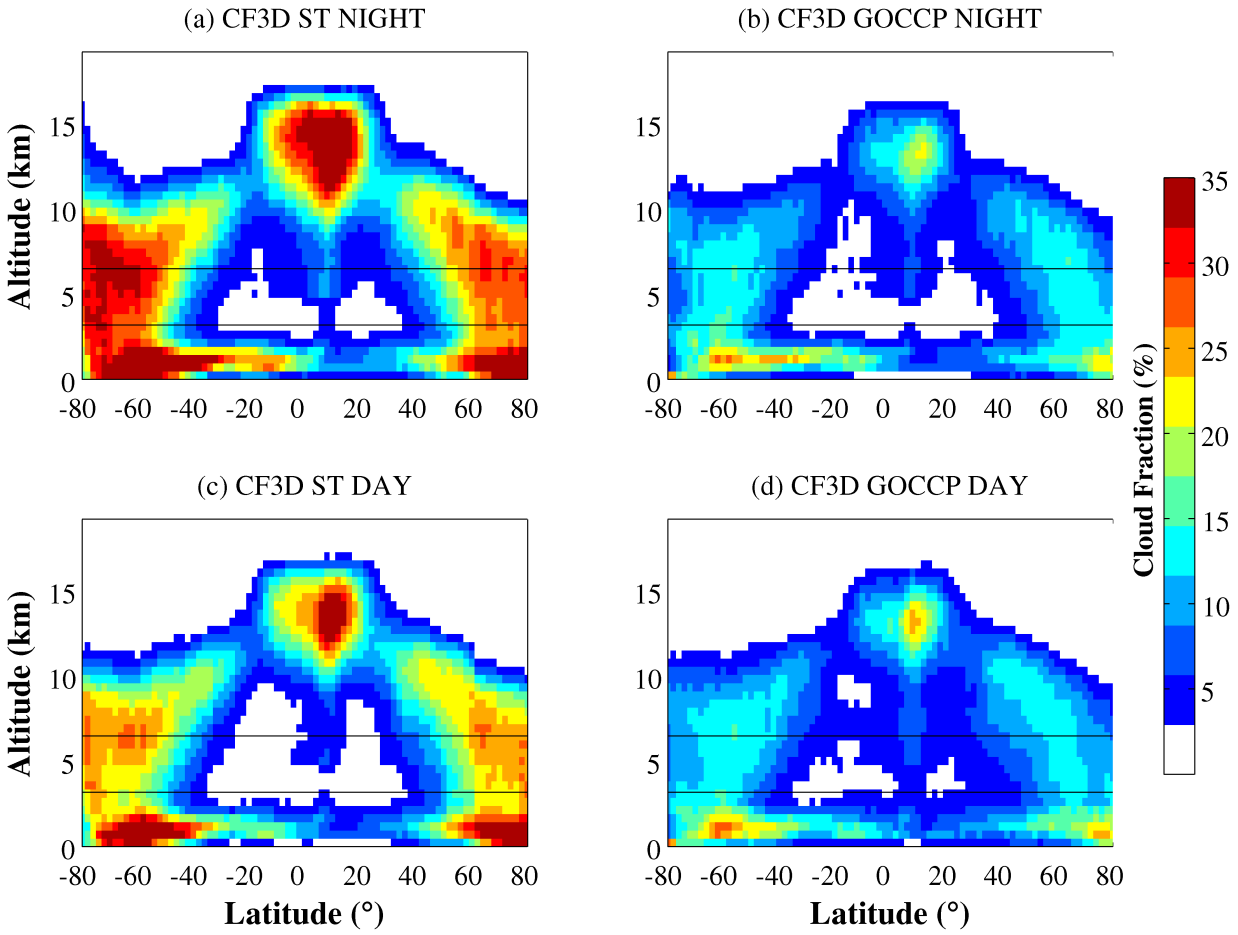
2008
Development of
CFMIP-OBS

2012 :
CFMIP-OBS on the
Earth System Grid



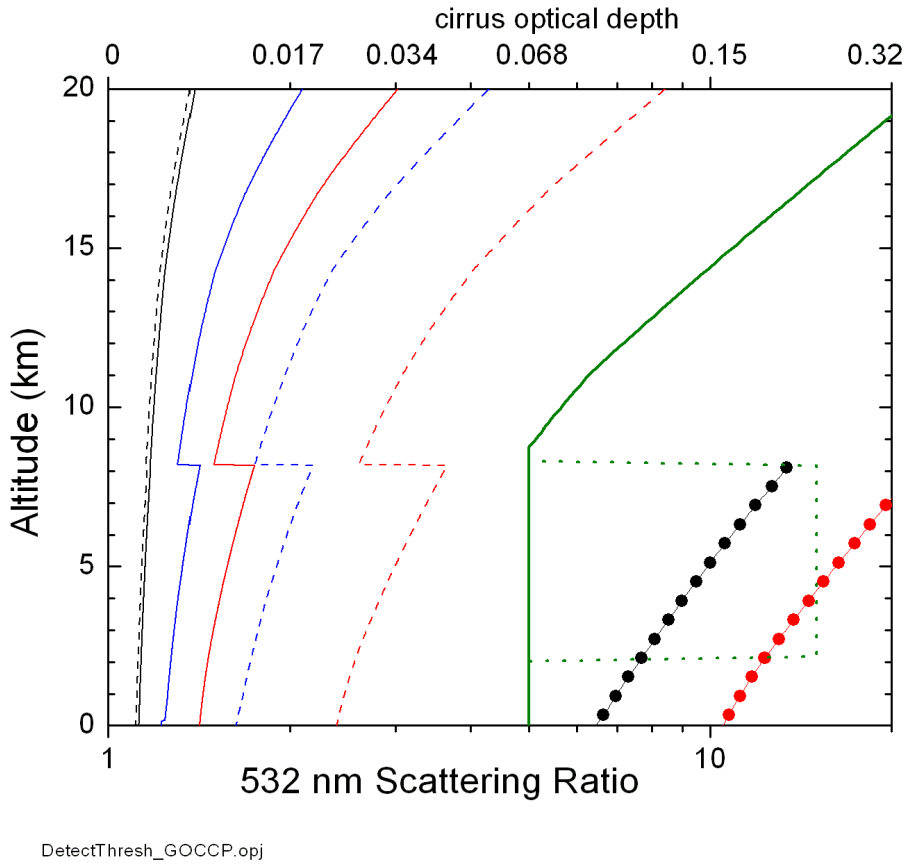
http://climserv.ipsl.polytechnique.fr/cfmip-obs/

Background : « observations » side
Effect of resolution and cloud detection threshold on the cloud fraction



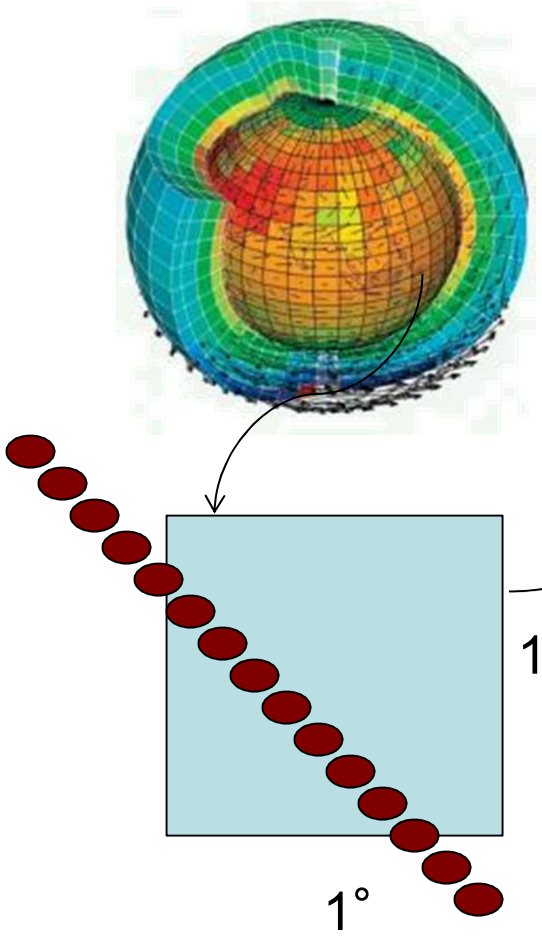
Chepfer, Cesana, Winker, Getzewitch, Vaughan, Liu 2012, JAOT

Background : « observations » side
Effect of resolution and cloud detection threshold on the cloud fraction

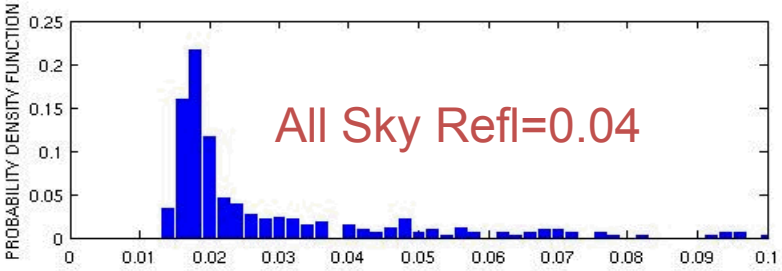


Chepfer, Cesana, Winker, Getzewitch, Vaughan, Liu 2012, JAOT

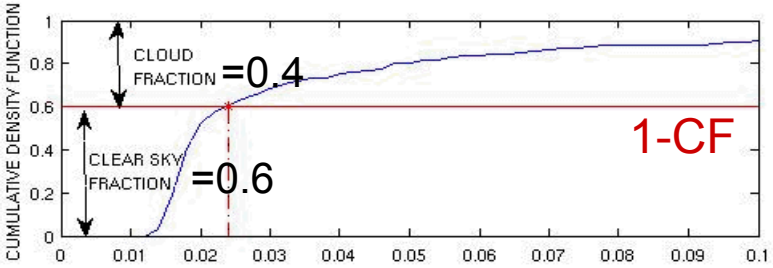
A methodology: from the case study to global statistics using high spatial resolution data

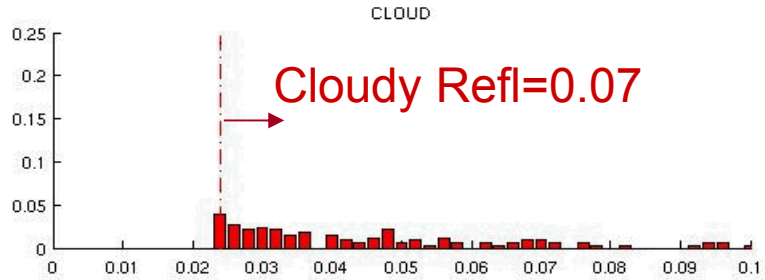


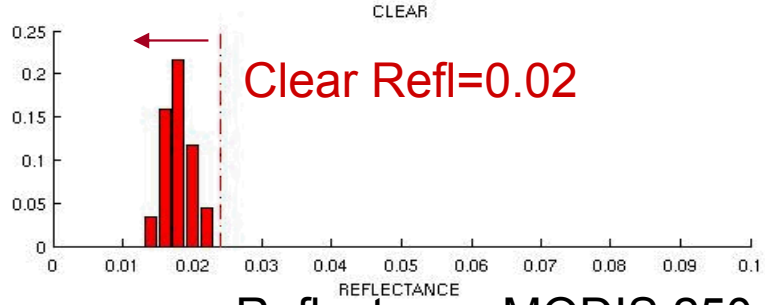
PDF



CDF



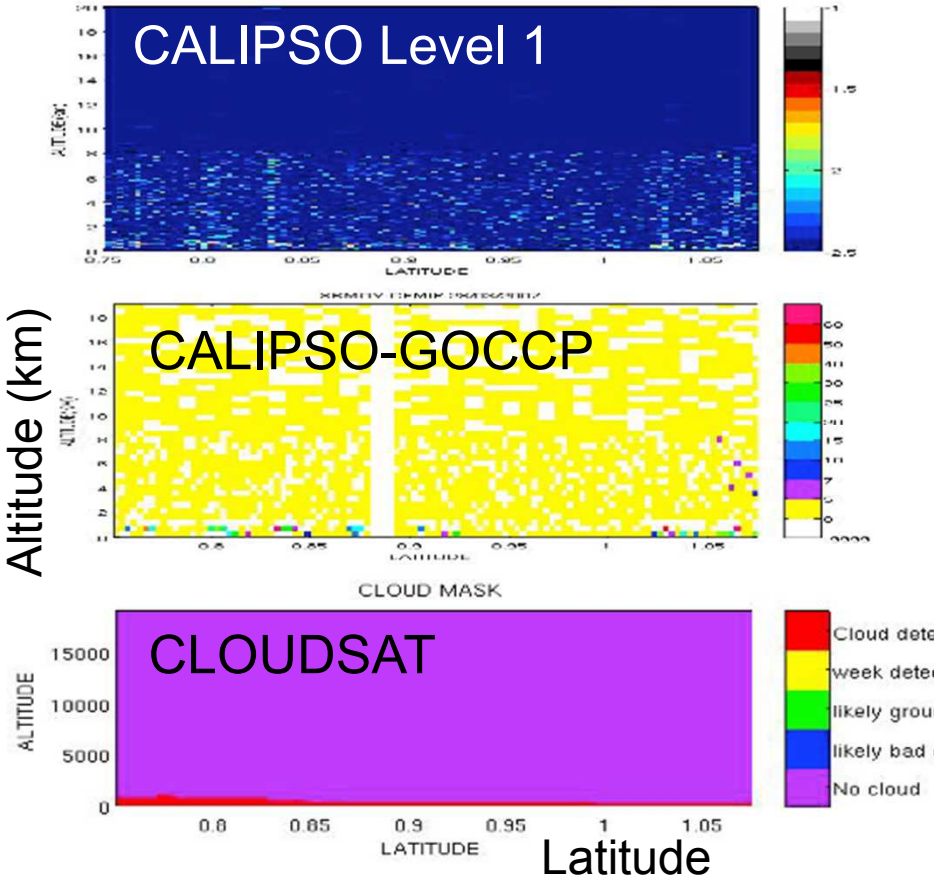


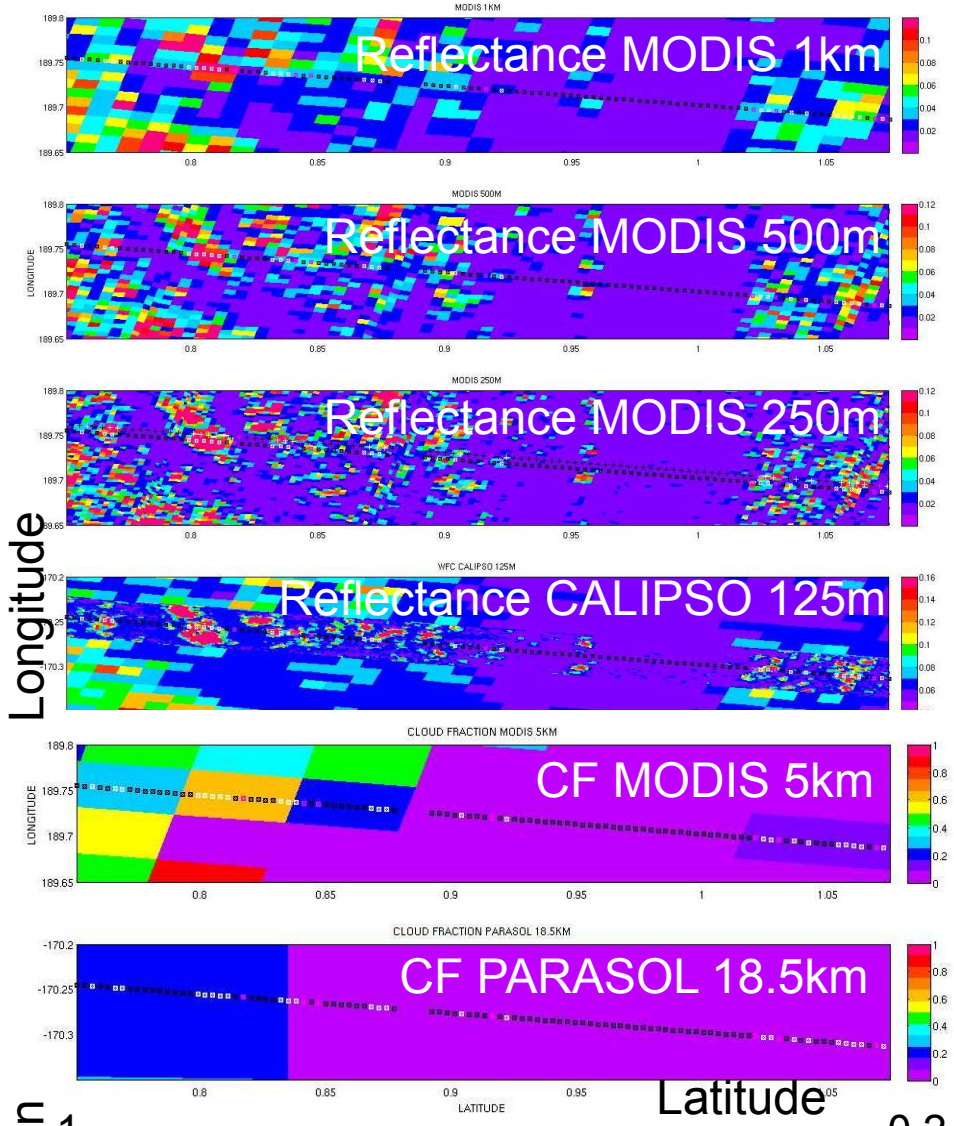


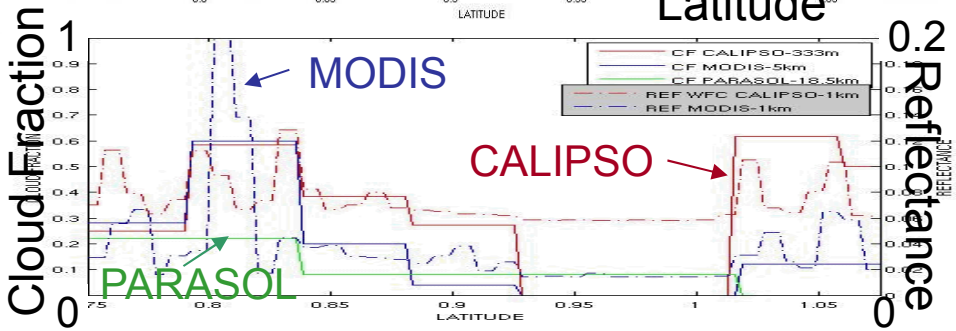
Same methodology for simulator's outputs
⇒In each grid box (obs/mod):
Cloud Fraction and Cloudy Refl

Reflectance MODIS 250m

A case study: low tropical boundary layer clouds - high resolution obs -







Impact of the spatial resolution of the sensors
Need a clean separation clear/cloudy
Need colocated and simultaneous observations