Evaluation of modelled clouds using passive satellite imagery (AVHRR/SEVIRI/MODIS) and active sensors from the A-Train satellites (CloudSat/CALIPSO)

Karl-Göran Karlsson, SMHI
Workshop on Moist Processes in models
SMHI, Norrköping June 15-17, 2009

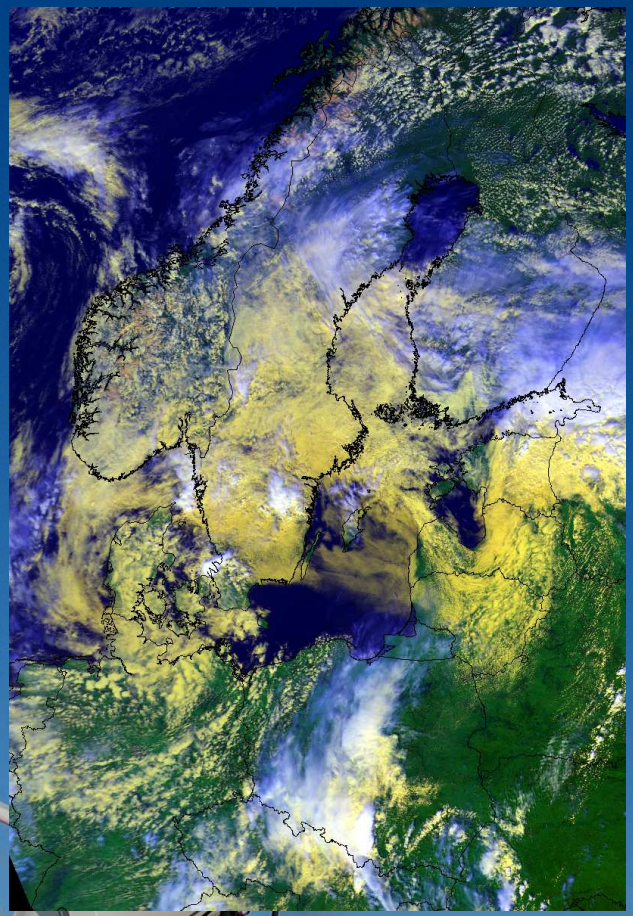
- CONTENT:
  - Introduction to image datasets and processing efforts
  - Previous model evaluation work
  - CloudSat/CALIPSO datasets
  - Model evaluation concept: Dataset Simulator approach
  - Future plans

‘Traditional’ passive satellite imagery for multispectral cloud analysis and cloud property retrievals

POLAR
Sensors: AVHRR (5 spectral chanels)
MODIS (36 spectral channels)

GEOSTATIONARY
Sensor: SEVIRI (12 spectral channels)

Satellites:
NOAA
METOP
EOS



Satellites:
METEOSAT
(GOES
GMS
FYI)

Spatial resolution: 1 km
Obs. frequency:
2-14 obs/day

Spatial resolution: 3 km
Obs. frequency:
96 obs/day

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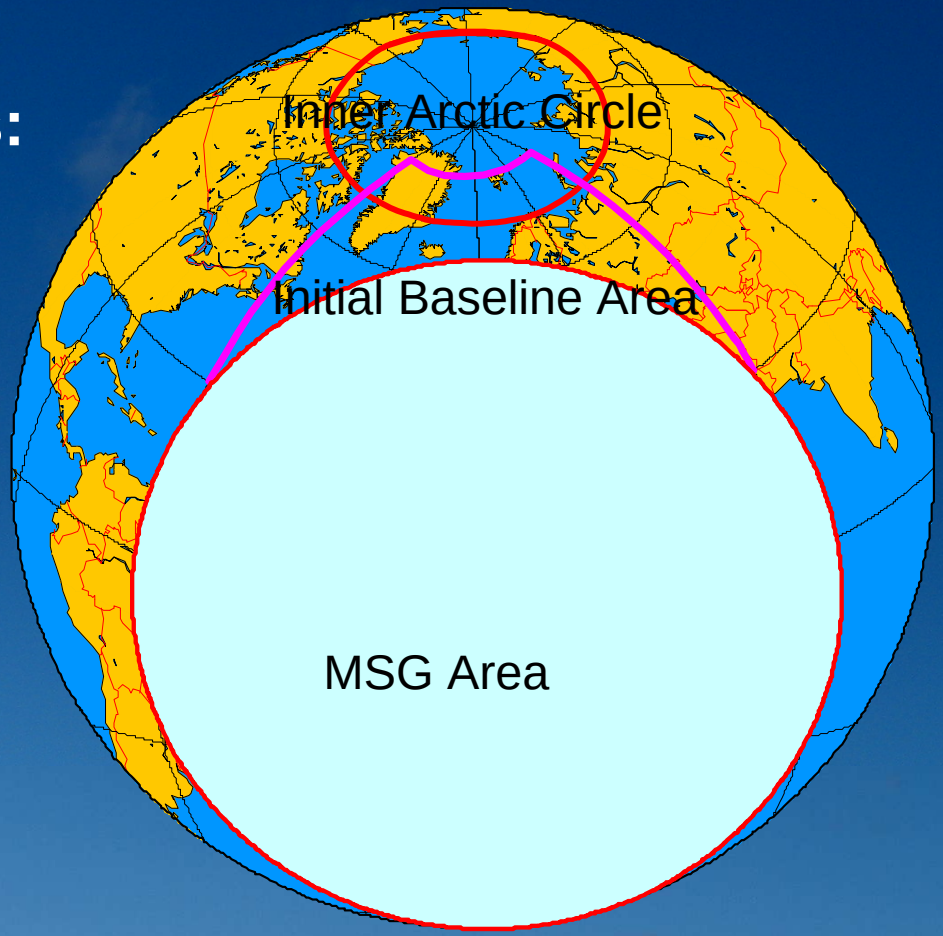
Cloud datasets produced by the EUMETSAT Climate Monitoring Satellite Application Facility (CM SAF) project

Cloud products:

- Cloud fraction
- Cloud type
- Cloud top
- Cloud phase
- Cloud optical thickness
- Cloud liquid water path



Three processing areas

(More info at www.cmsaf.eu)

Daily and monthly means for polar and geostationary data (+ diurnal cycle for the latter) since January 2005

Long term global datasets (1982-2010) under preparation

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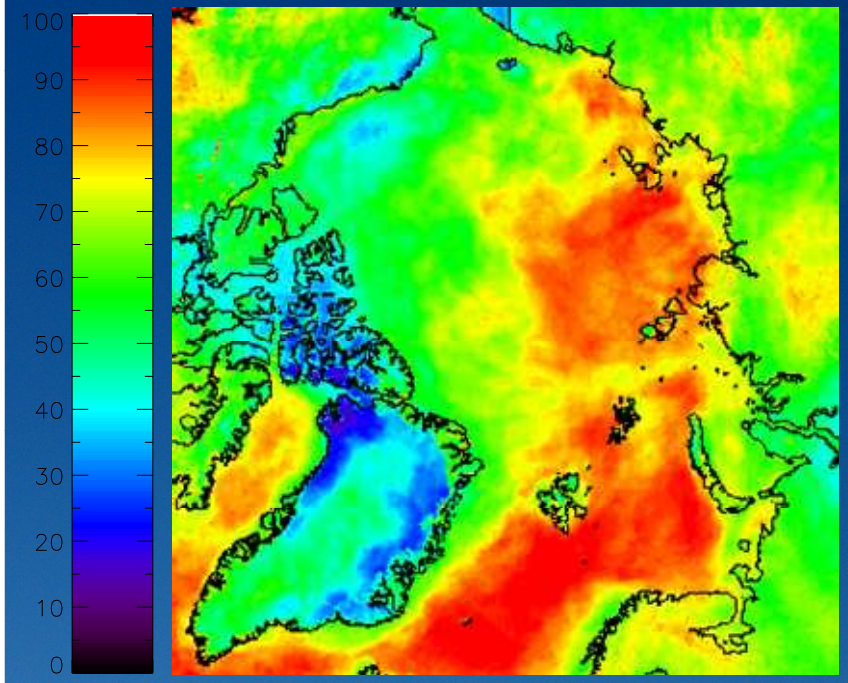
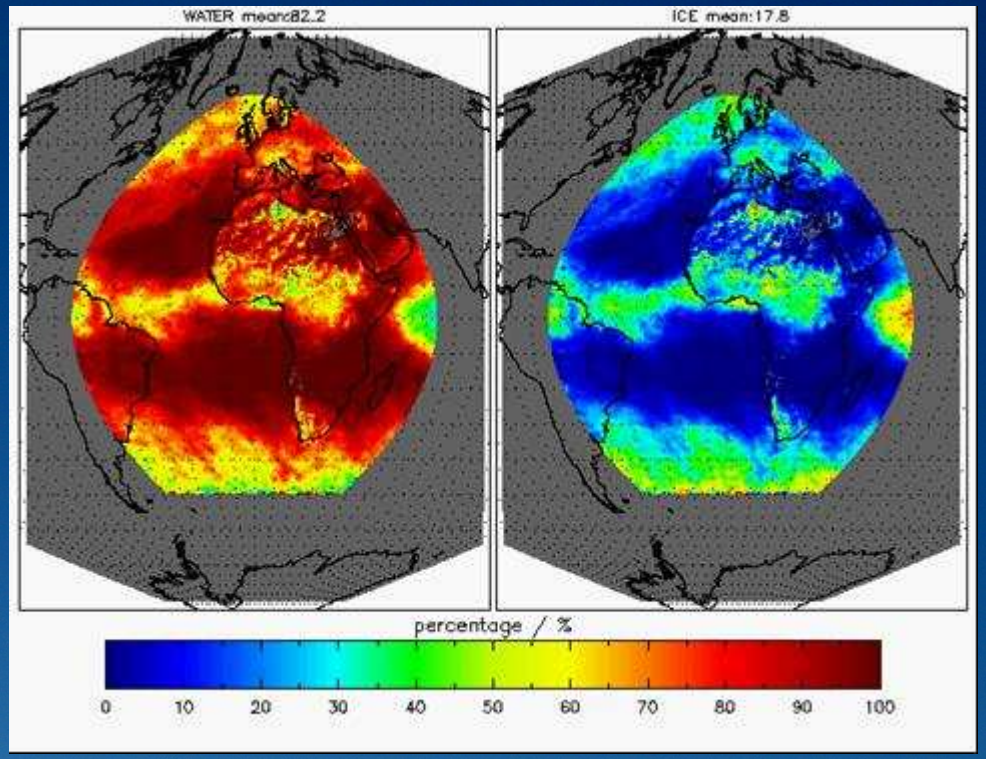
Examples of CM SAF cloud fraction and cloud phase products



Mean monthly cloud amount in the Arctic in July 2007



Mean monthly cloud phase contributions (water + ice) over the MSG disk

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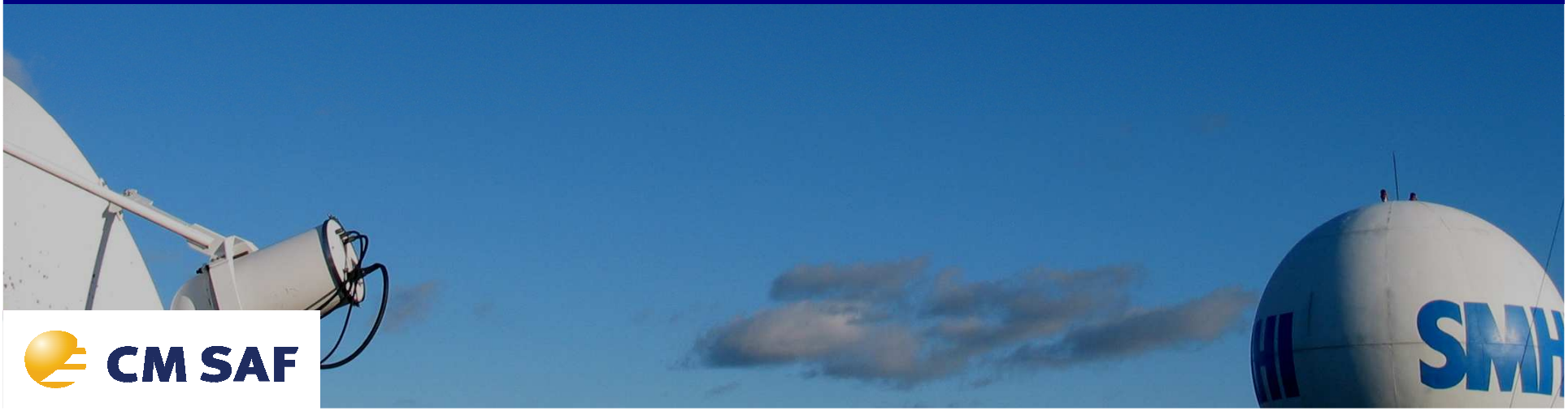
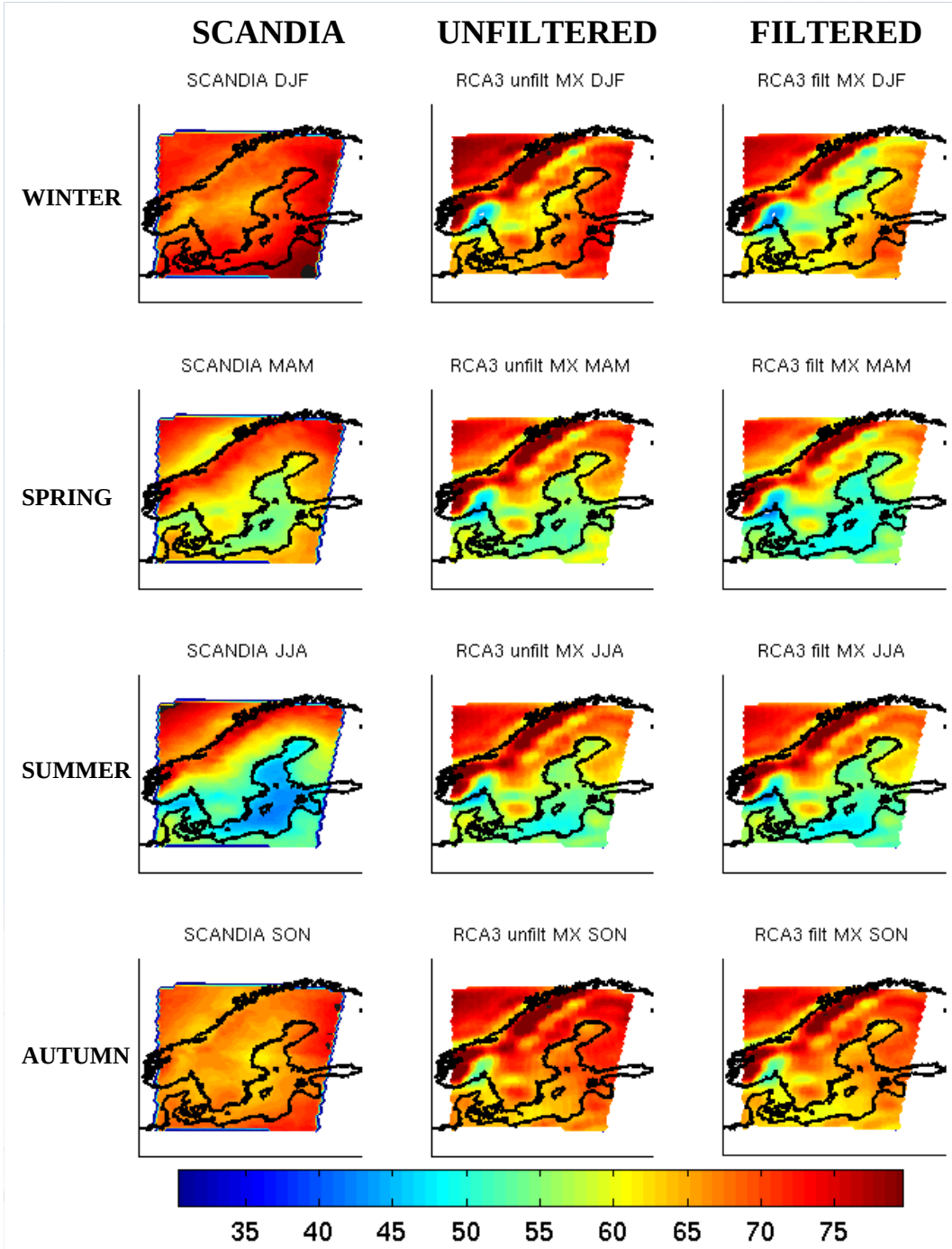
Previous work on model evaluation based on satellite data at SMHI – Evaluating RCA3 with SCANDIA climatologies

- **Based on the SCANDIA 1991-2000 cloud climatology over Scandinavia** *(Karlsson, 2003, Int. J. Climatol.)*
- **Included several model data adjustments to satellite dataset (e.g., exact time matching and filtering of thinnest clouds)**
- **Included tests of various cloud overlap**
- **Evaluated fractional cloud cover and vertical distribution of clouds (cloud top/optical thickness histograms)**





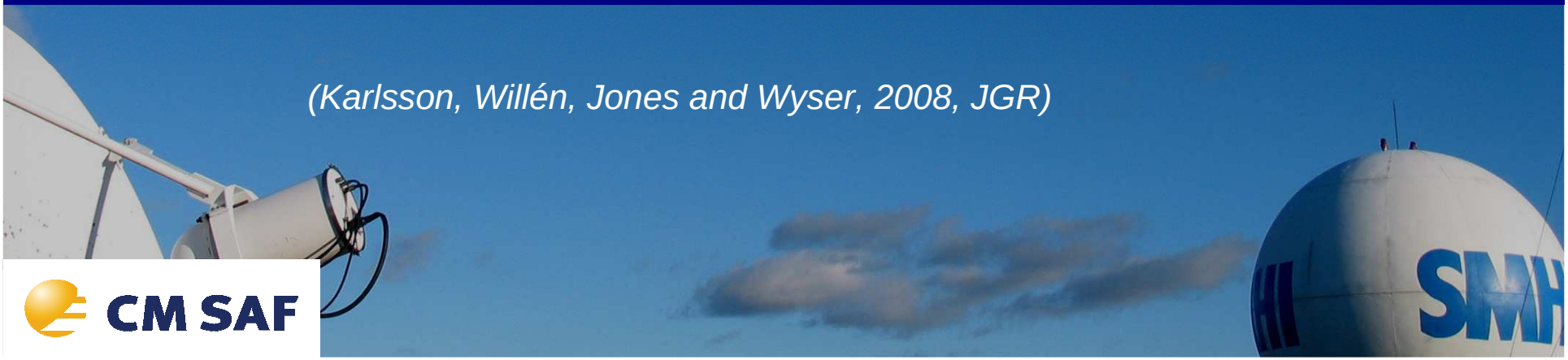
SEASONAL TOTAL CLOUD COVER (%) – Comparison between unfiltered and filtered RCA3 results for Maximum cloud overlap

- Unfiltered RCA3 results higher
- After filtering deviations are smaller and for some seasons changed into deficit
- Cloud amounts for summer still higher than SCANDIA for all cloud overlaps
- Two distinct geographical features:
  1. Higher cloud amounts over Scandinavian mountains for all seasons
  2. Substantial minimum over south-eastern Norway (vicinity of Oslo)

Summary of results of SCANDIA-RCA3 evaluation:

- Fairly good agreement (a few % underestimation) of overall total cloud cover
- Unrealistic high cloud amounts in Scandinavian mountain range
- Lack of mid-level clouds (-5 %) compensated by some excess of high-level and low-level clouds
- Cloud height/Cloud optical thickness histograms indicated too much cloud condensate in all height levels but especially for low-level clouds in summer

(Karlsson, Willén, Jones and Wyser, 2008, JGR)



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RACMO model evaluation at KNMI using SEVIRI cloud products

Objective

- Evaluate diurnal cycles of Cloud Properties from the Regional Atmospheric Climate Model (RACMO) with corresponding cycles derived from SEVIRI.

RACMO (version 3)

- Limited area hydrostatic model
- Physics based on ECMWF
- HIRLAM forecast component

Method

- Hourly RACMO and SEVIRI data over Europe (May – Sep 2004)
- Comparison to Cloudnet ground-based observations
- Evaluation of daylight cycles for four climate regions

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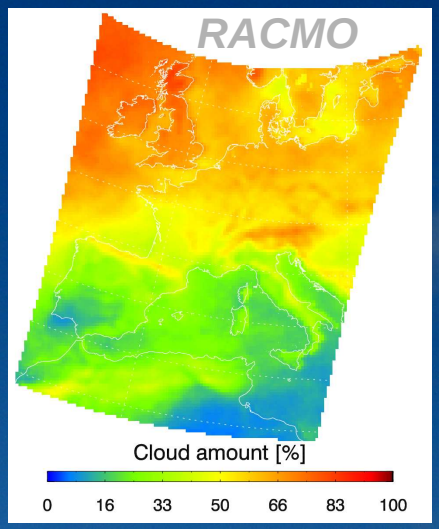
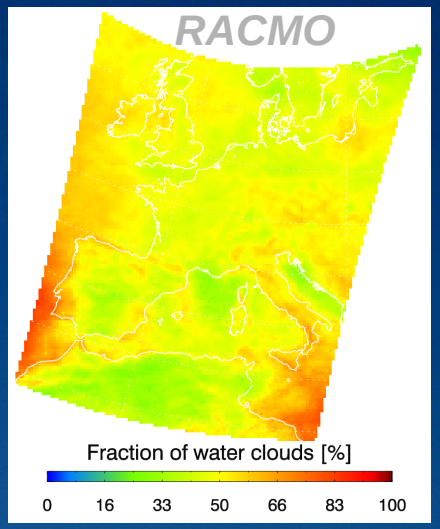
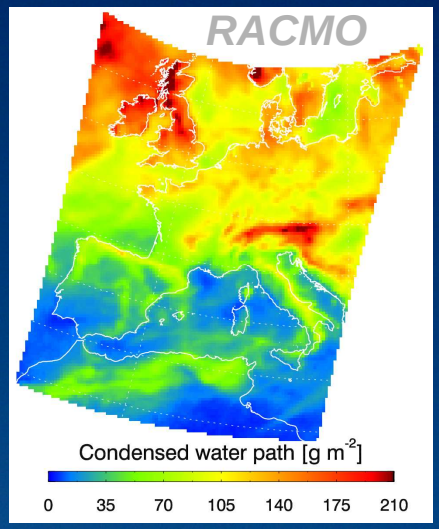
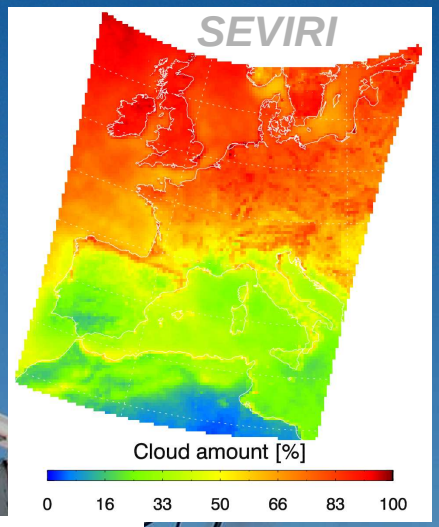
(Courtesy of Rob Roebeling, KNMI)

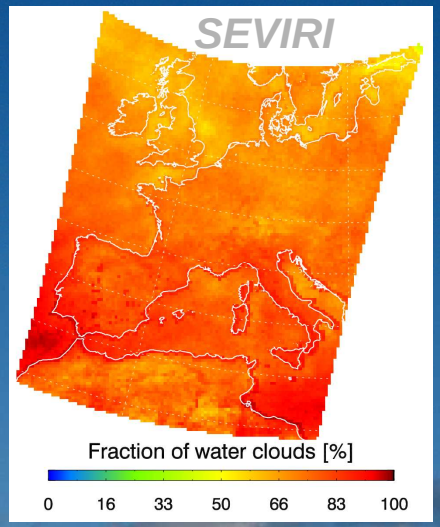
RACMO evaluation: Spatial variations over Europe (average values May-Sep 2004)

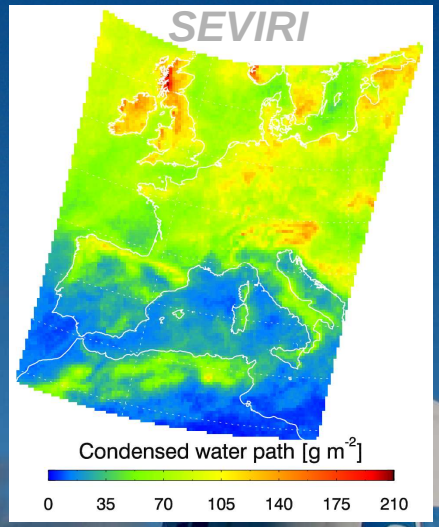












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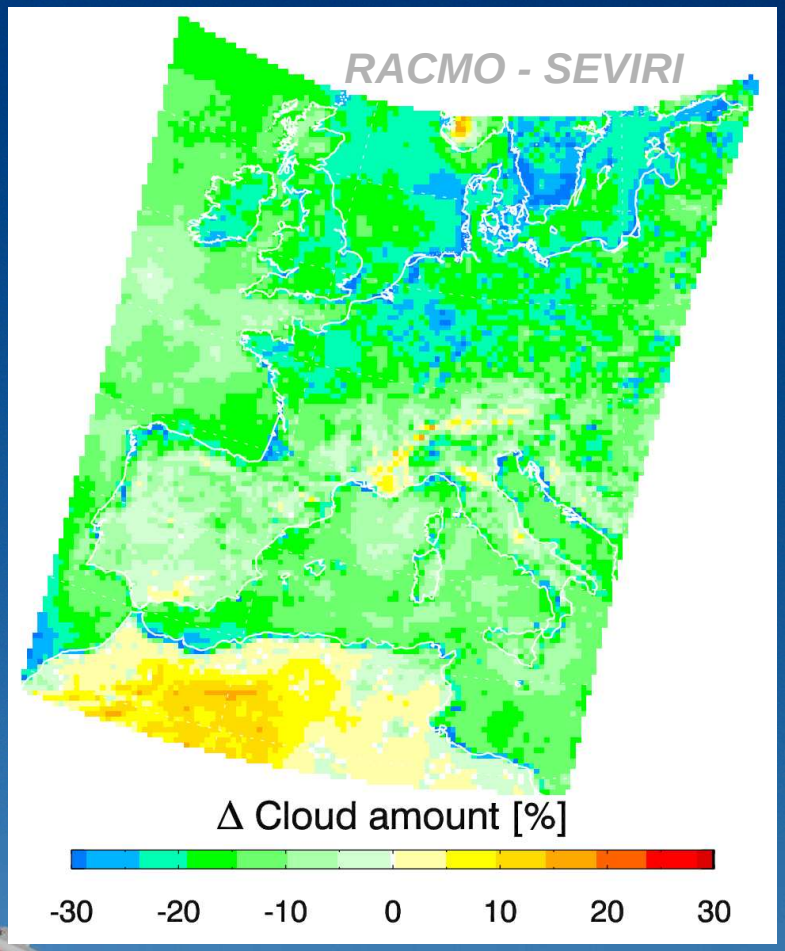
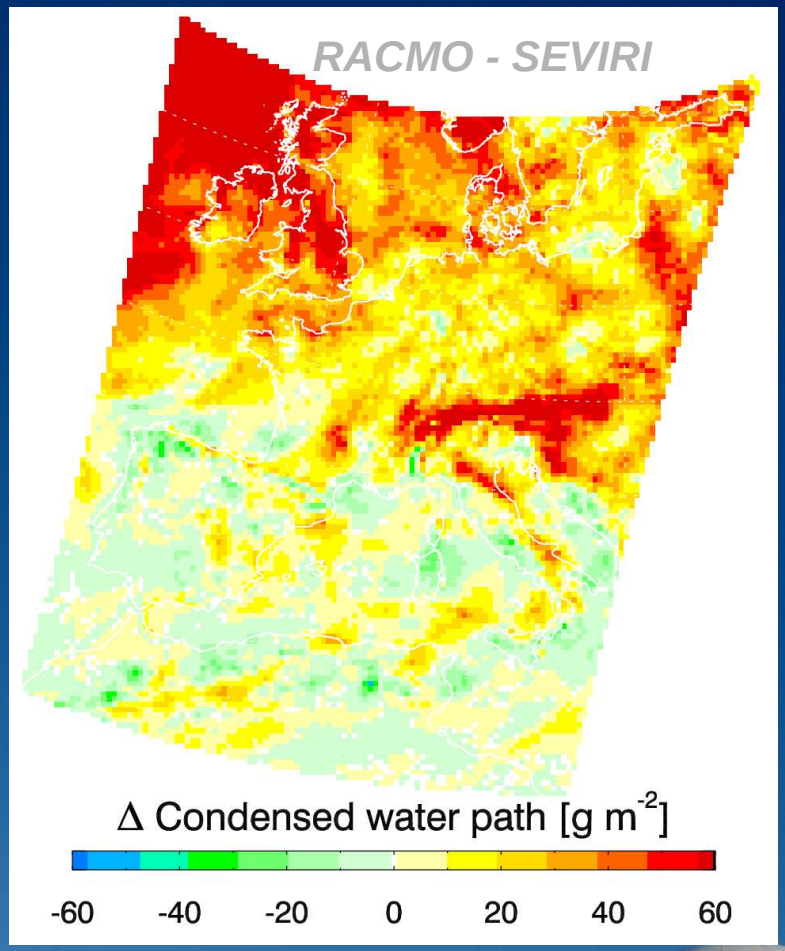
(Courtesy of Rob Roebeling, KNMI)

RACMO evaluation: Spatial variations over Europe (average values May-Sep 2004)



Difference between RACMO and SEVIRI Cloud Amounts



Difference between RACMO and SEVIRI Condensed Water Path

(Courtesy of Rob Roebeling, KNMI)

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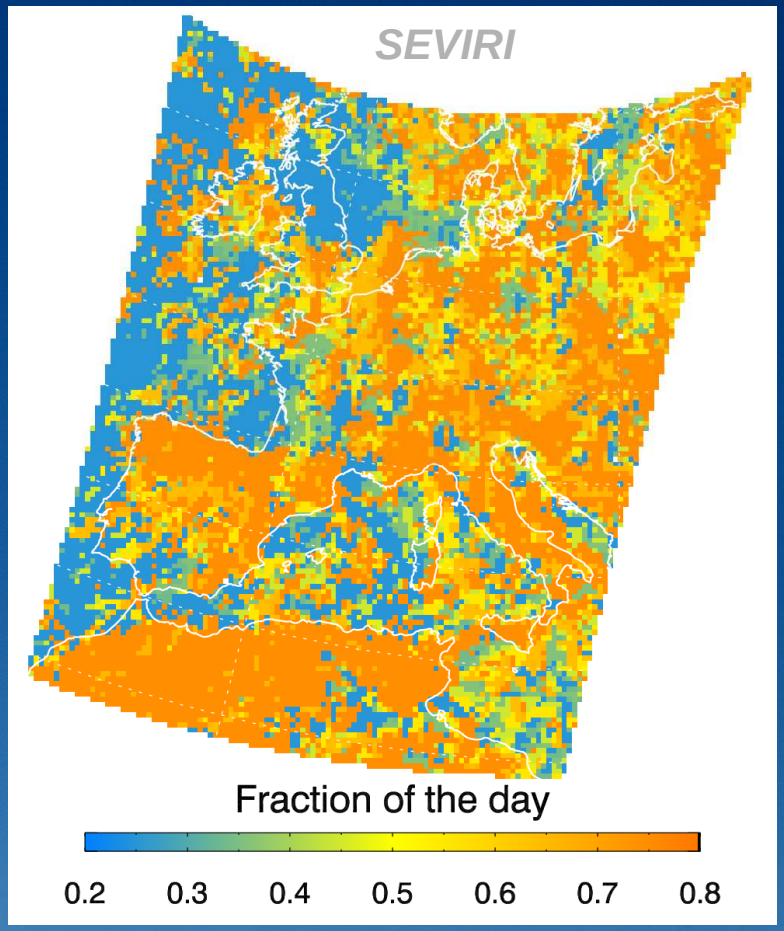
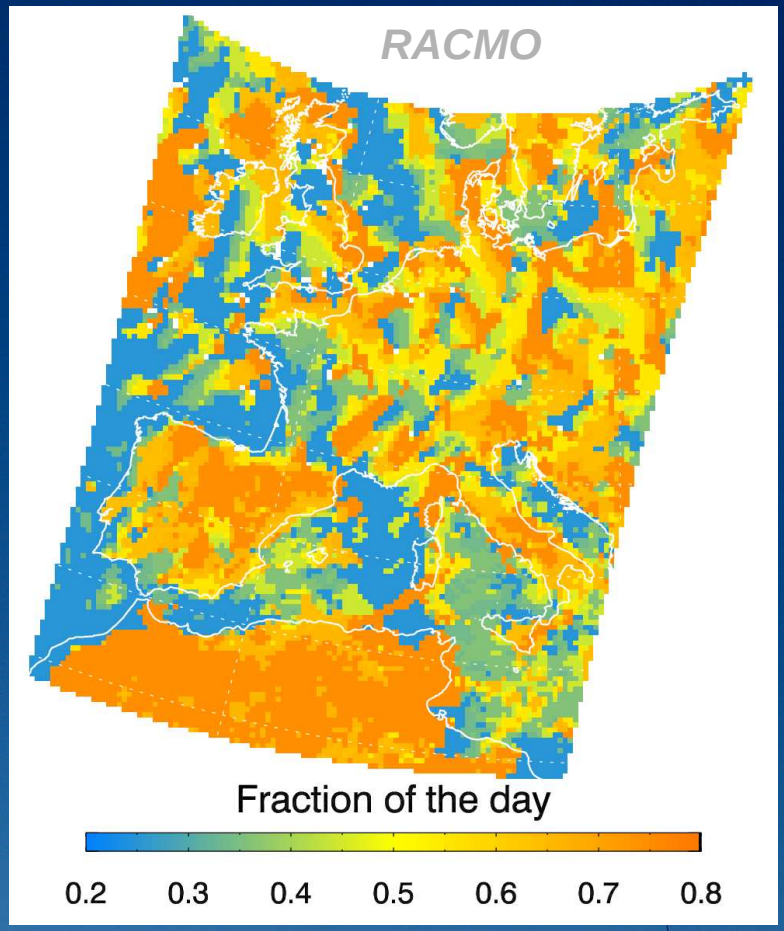
RACMO evaluation: Diurnal cycle of clouds



Daytime fraction of SEVIRI maximum CWP during May – Sept. 2004



Daytime fraction of RACMO maximum CWP during May – Sept. 2004

(Courtesy of Rob Roebeling, KNMI

Paper by Roebeling and Meijgaard, 2009, J. Climate)

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A-Train satellites with CloudSat/CALIPSO

Notice observation sequence in the Aqua train orbit:

- First comes Aqua (MODIS) (FOV resolution 1 km main channels)
- CloudSat passes 1 minute later (FOV resolution about 1.7 km)
- CALIPSO passes 1 minute and 15 seconds later (FOV resolution 1 km)

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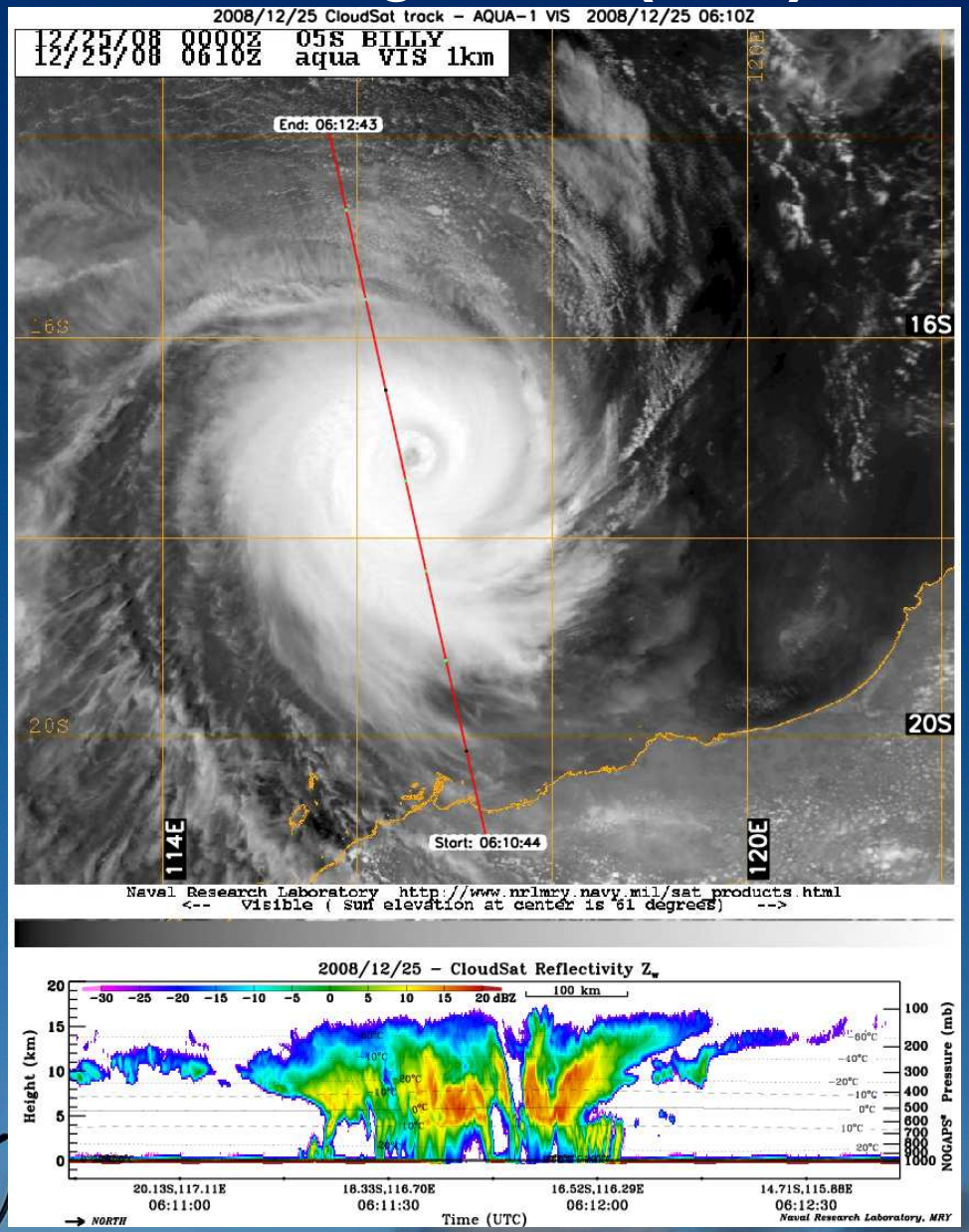
CloudSat Cloud Profiling Radar (CPR) datasets

Tropical hurricane Billy

25 Dec 2008

Location: North of Australia



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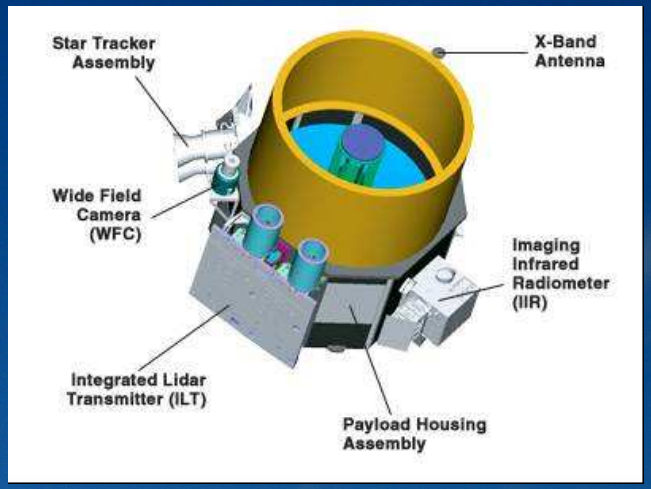
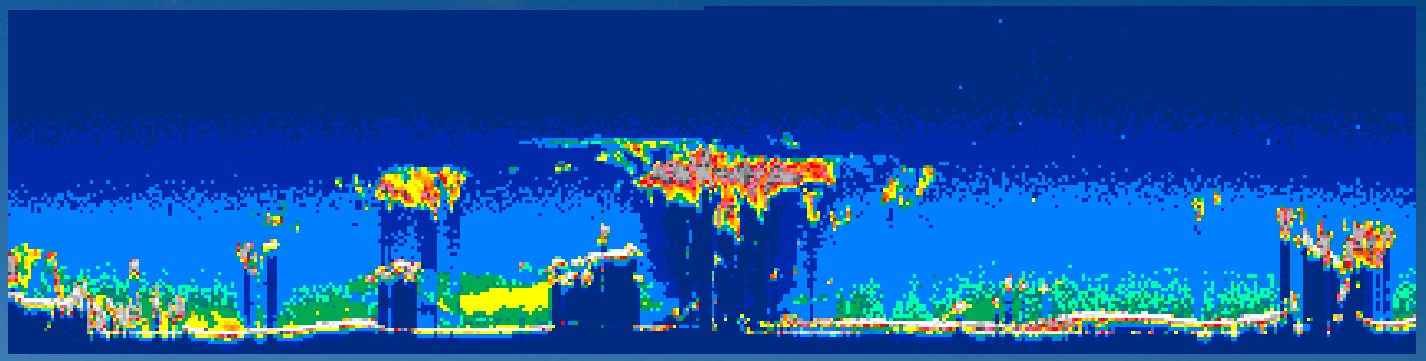
CALIPSO Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) datasets

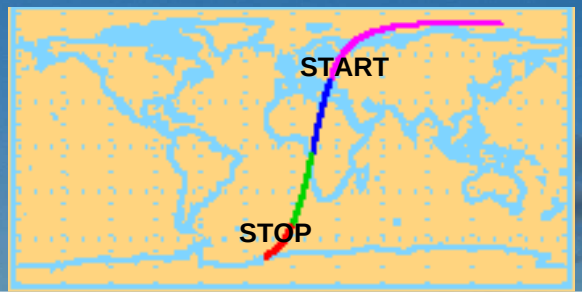


Example below from 16 March 2009



START

STOP



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How can we best use CloudSat/CALIPSO datasets for model evaluation?

Limitation: Exclusively nadir view in a polar orbit means repeat cycle of 15 days

(AVHRR/MODIS: 50 min at poles and 6 hours at Equator)

(SEVIRI=15 minutes)

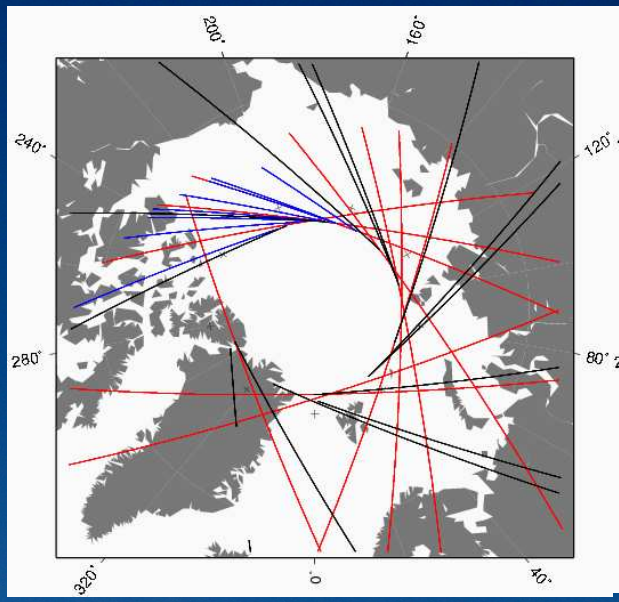
1. **Detailed process studies on case-by-case basis (cross-sections)**

2. **Examining global mean conditions (evaluating climate models) using CloudSat/CALIPSO datasets compiled over several years**

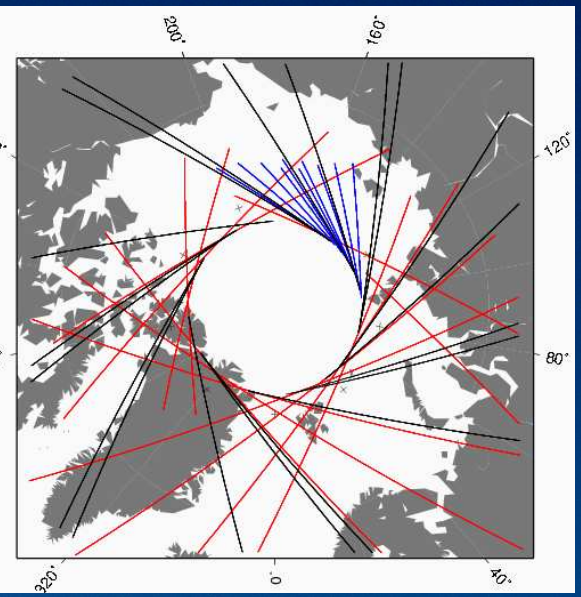
3. **In depth evaluation of “traditional” image-based cloud datasets to increase confidence**

CALIPSO evaluation of CM SAF cloud products in the Arctic

Overview of realised matchup tracks (within 2 minutes)



June 2007

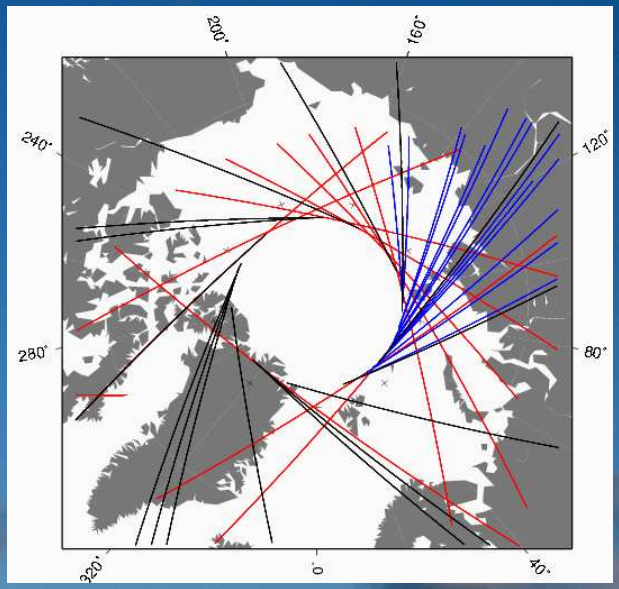


July 2007

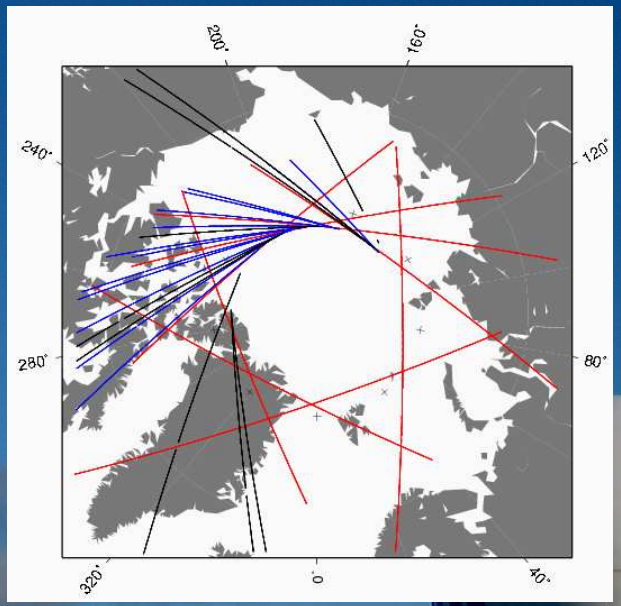
Red: NOAA-18

Black: METOP-2

Blue: NOAA-17



August 2007



December 2007

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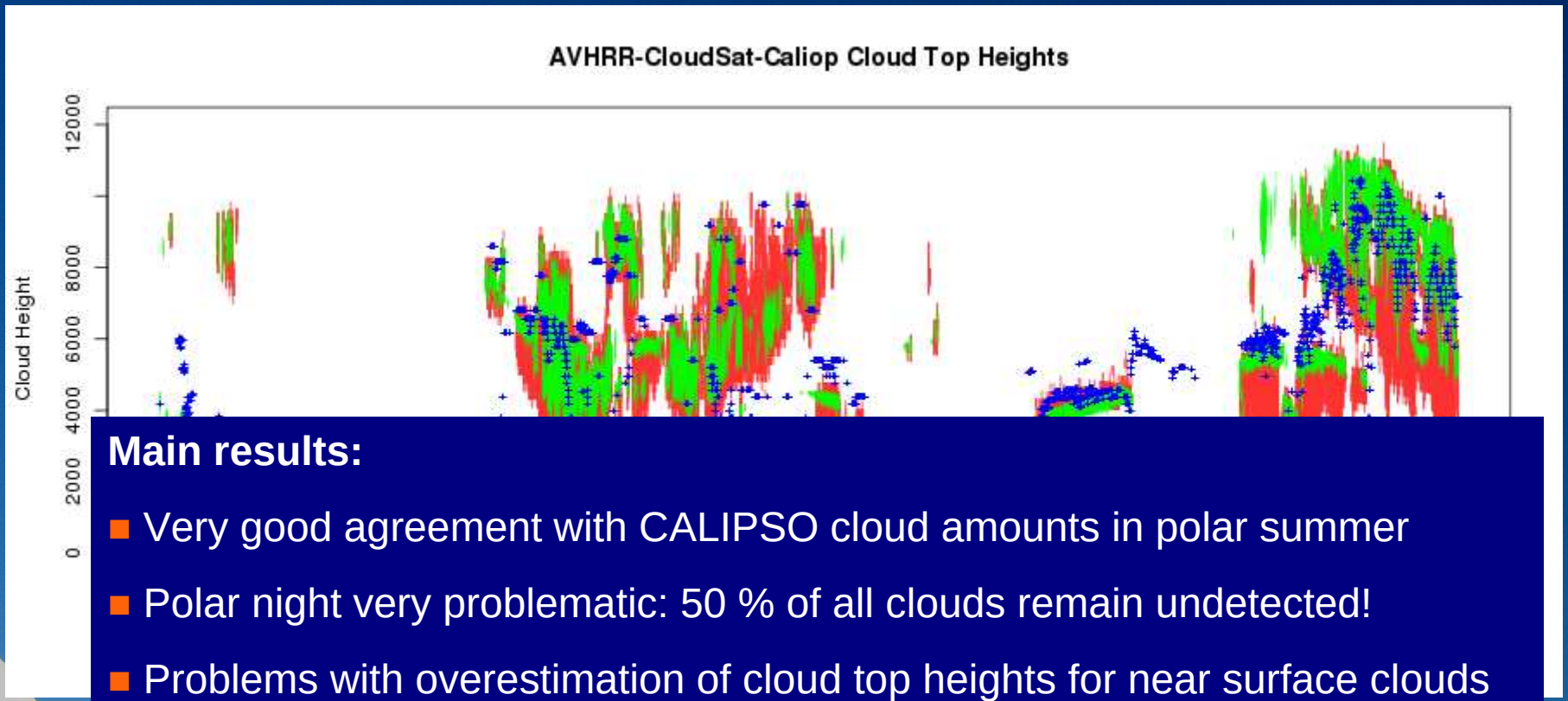
Cross section with AVHRR, CloudSat and CALIPSO results – Example of NOAA-18 along-track 27 July 06:12



Main results:

- Very good agreement with CALIPSO cloud amounts in polar summer
- Polar night very problematic: 50 % of all clouds remain undetected!
- Problems with overestimation of cloud top heights for near surface clouds

(Paper submitted to Atmos. Chem. Phys).

Green: CALIOP

Blue: AVHRR Cloud Top Height

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The Simulator approach – a way to optimise the use of satellite data and satellite-derived products for model evaluation

Purpose: Remove (mitigate) existing differences between satellite and model datasets to enable meaningful comparisons

Historic background: Increasing frustration over the fact that different satellite-derived datasets often give entirely differerent results!

Main driver: Cloud Feedback Model Intercomparison Project (CFMIP)
Developing the CFMIP Observational Simulation Package (COSP)

(Contacts: Johannes Quaas, MPI-M
Mark Webb, UKMO
Sandrine Bony, LMD)

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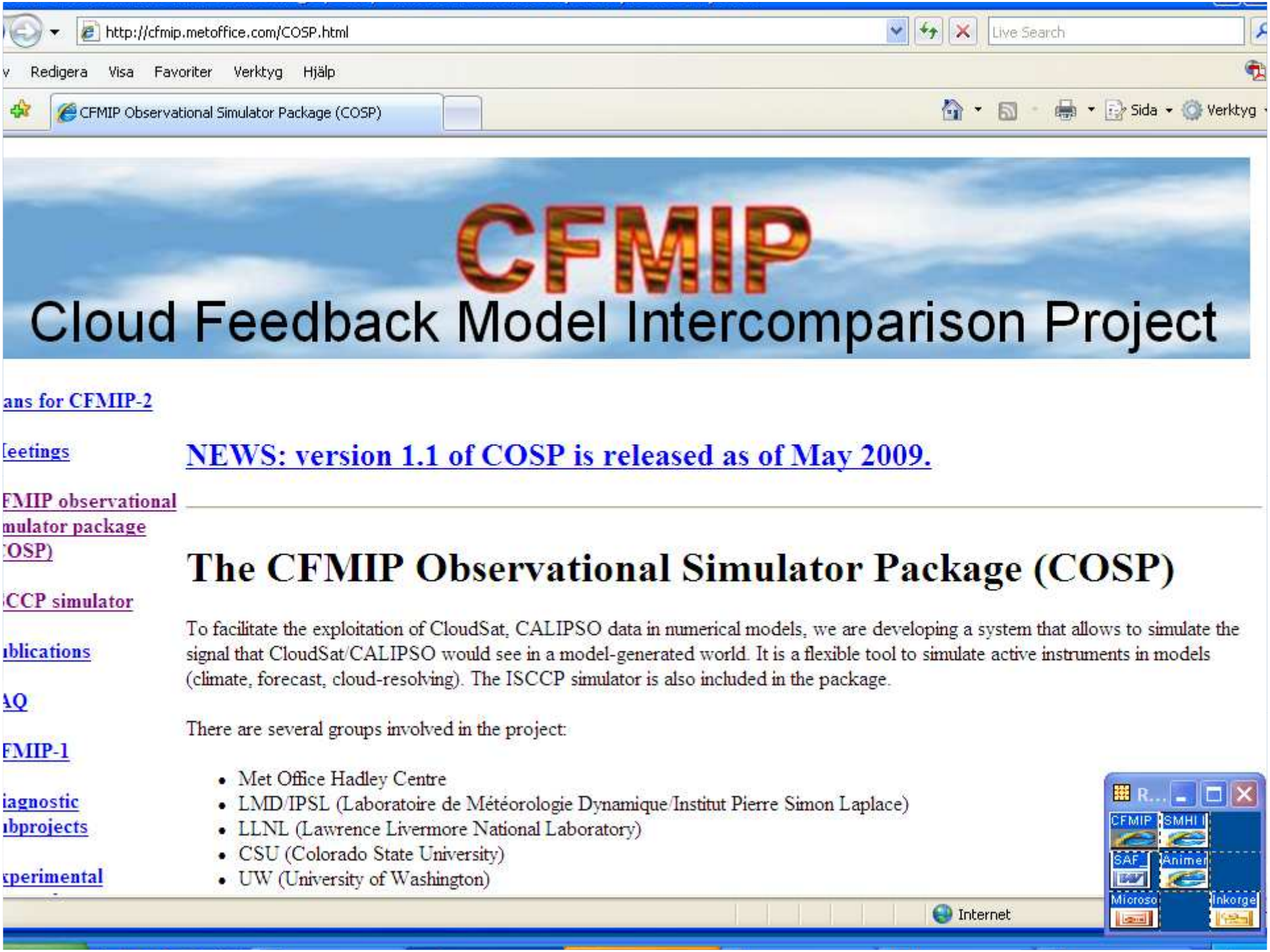
http://cfmip.metoffice.com/COSP.html
Live Search
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CFMIP Observational Simulator Package (COSP)
Sida Verktyg
CFMIP
Cloud Feedback Model Intercomparison Project
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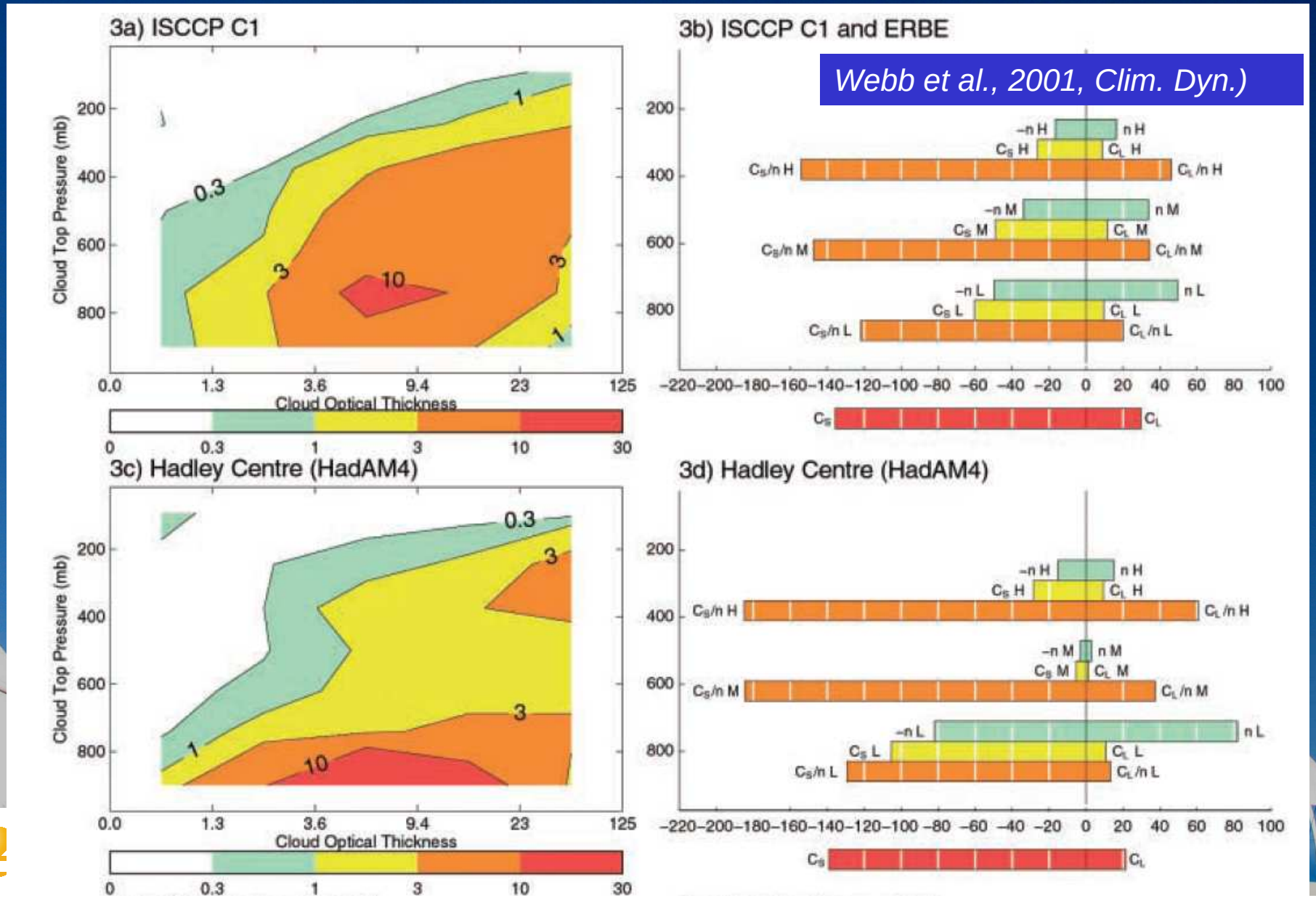
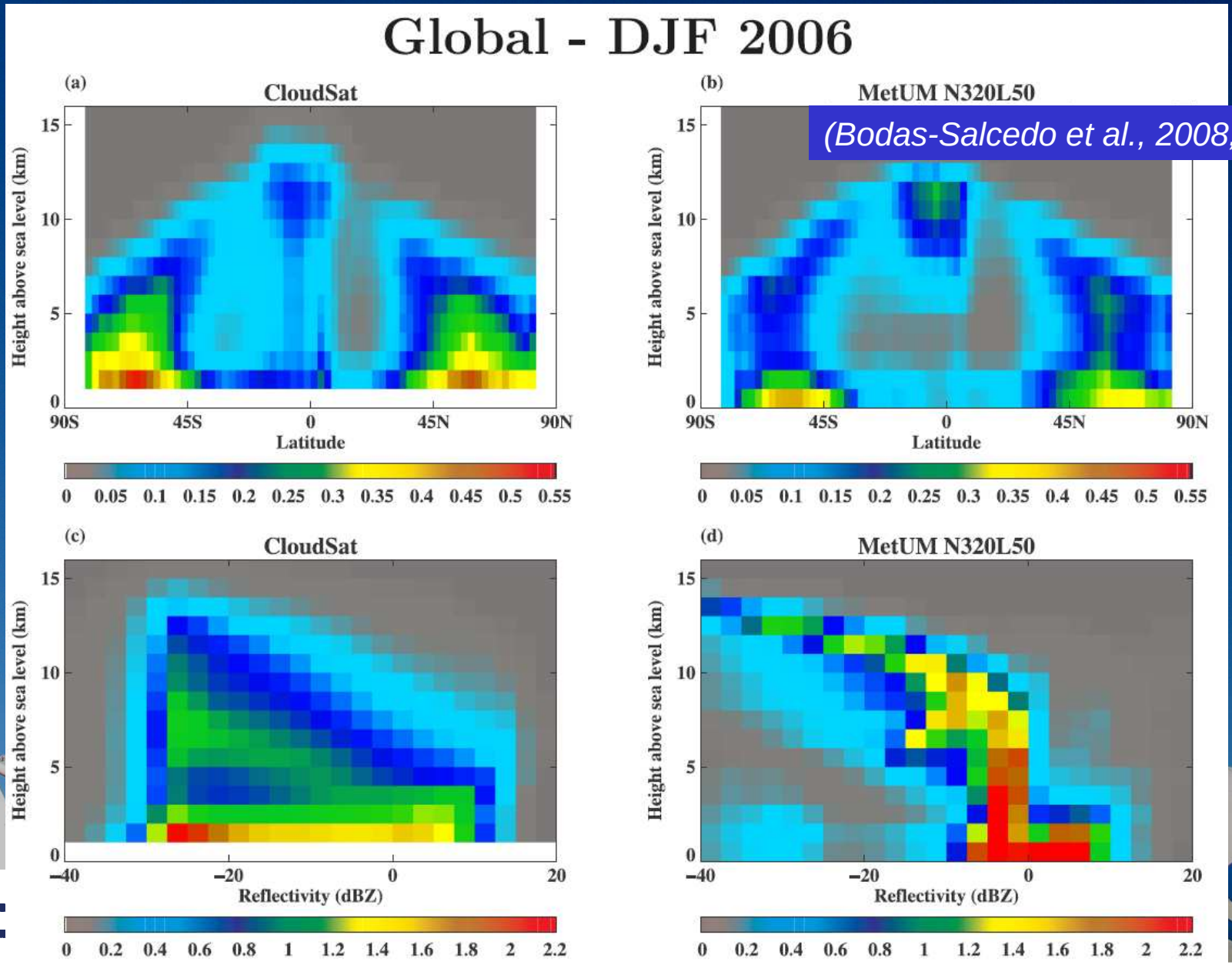
NEWS: version 1.1 of COSP is released as of May 2009.
The CFMIP Observational Simulator Package (COSP)
To facilitate the exploitation of CloudSat, CALIPSO data in numerical models, we are developing a system that allows to simulate the signal that CloudSat/CALIPSO would see in a model-generated world. It is a flexible tool to simulate active instruments in models (climate, forecast, cloud-resolving). The ISCCP simulator is also included in the package.
There are several groups involved in the project:
Met Office Hadley Centre
LMD/IPSL (Laboratoire de Météorologie Dynamique/Institut Pierre Simon Laplace)
LLNL (Lawrence Livermore National Laboratory)
CSU (Colorado State University)
UW (University of Washington)
Internet
CFMIP
SMHI
SAF
Animer
Microso
Inkorge

Example use of ISCCP simulator: Evaluating cloudtop/optical thickness distributions (left) and cloud forcing (right)

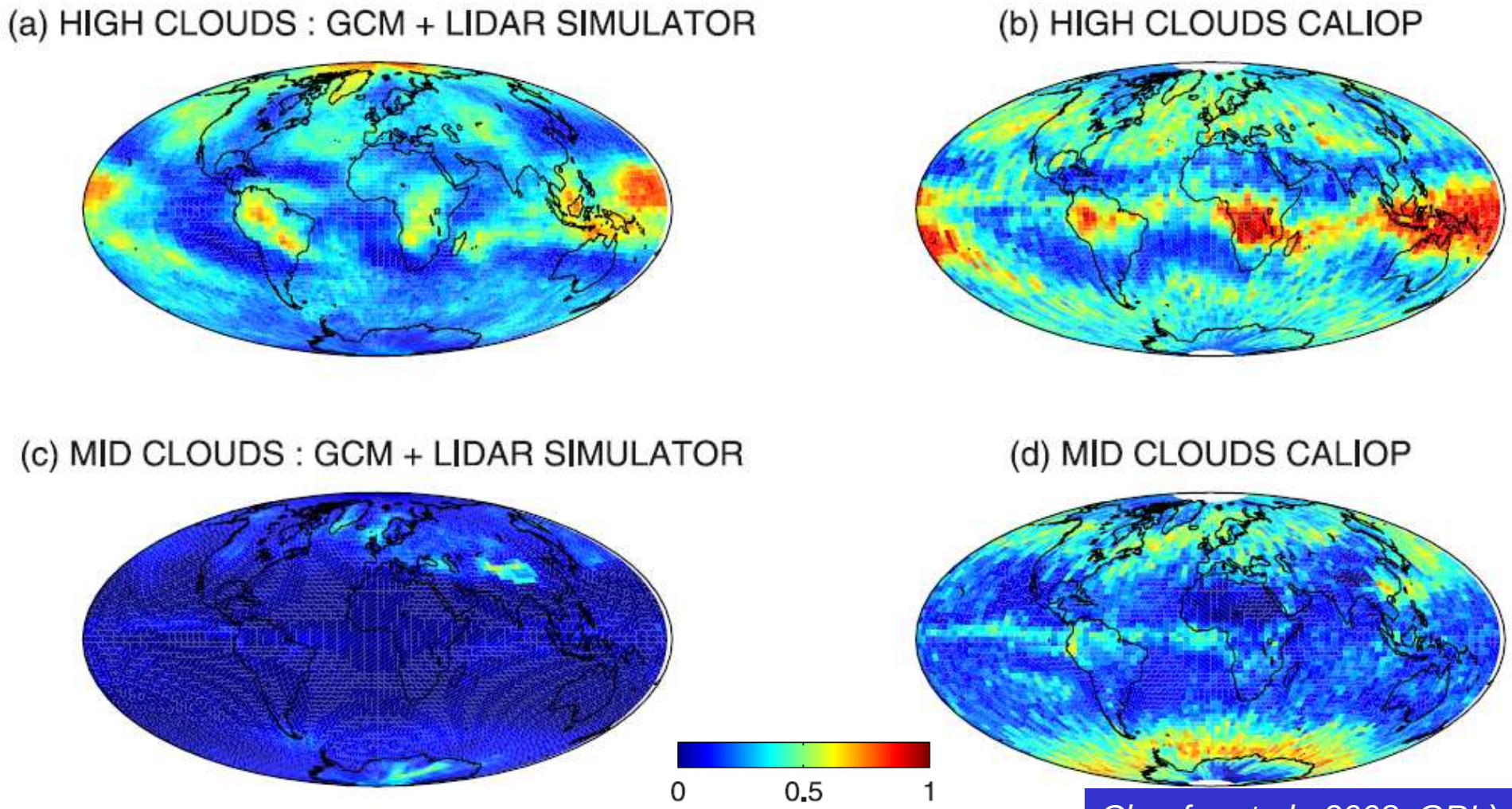


Example CloudSat simulator: Evaluating hydrometeor occurrence (top) and height/reflectivity histograms (bottom)



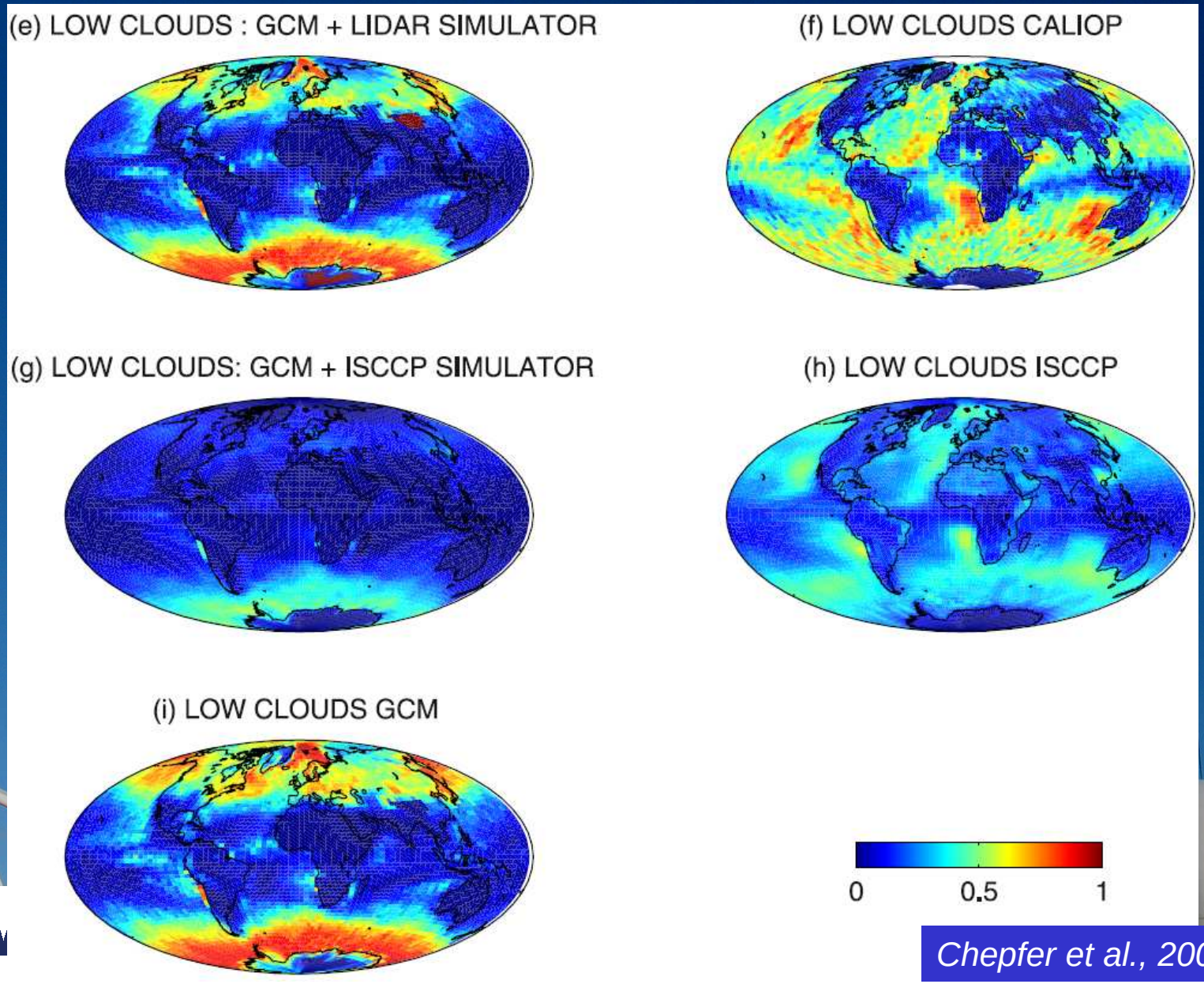
(Bodas-Salcedo et al., 2008, JGR)

Example CALIPSO simulator: Evaluating HIGH (top) and MID (bottom) cloud occurrence for climate model LMDZ4 (*Hourdin et al., 2006, Clim. Dyn.)*



Chepfer et al., 2008, GRL)

Example CALIPSO + ISCCP simulator: Evaluating LOW cloud occurrence for climate model LMDZ4



Chepfer et al., 2008, GRL)

Conclusions and future plans

Use of Dataset Simulators appears to be a promising approach for a more efficient model evaluation based on satellite data comparisons

CM SAF/SMHI plans:

- **Attempt to use the CM SAF global cloud and radiation dataset from NOAA/AVHRR in the period 1982-2010 to evaluate EC-Earth/RCAO simulations (in particular in the Arctic region)**
- **Ambition to be involved in the development of a CM SAF dataset simulator**


THE END
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SMH