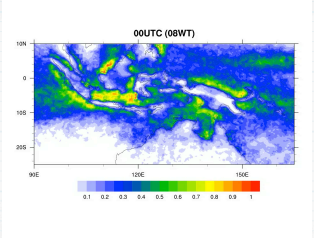


Evaluation of clouds in large-scale models

What? Why? How?
Part 2

Christian Jakob & Jean-Louis Dufresne

What is fit for purpose?

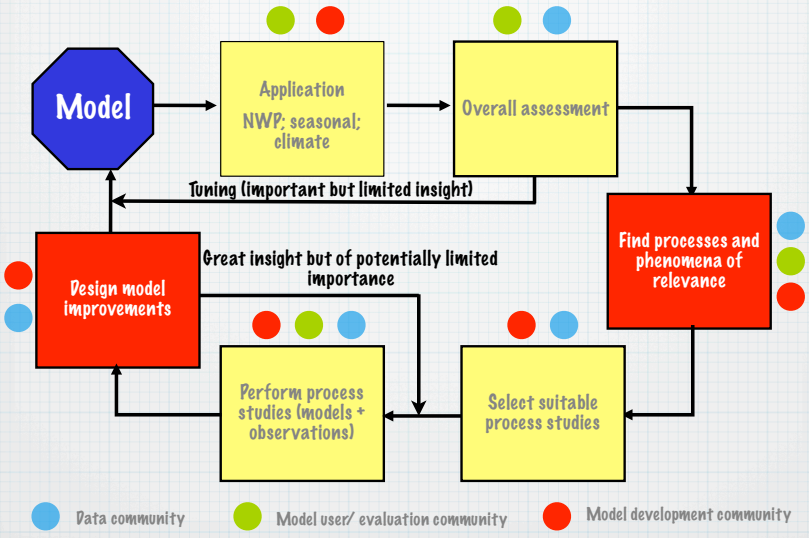




What is the truth?

* Model evaluation usually **needs an estimate of the "truth"...**

Approaches to model evaluation



Weather vs Climate model evaluation

* Recall: One main role of evaluation -> fit for purpose test
* **Weather Prediction:** This is relatively easy as the predicted weather will occur in a few days and we can compare the model forecast to observations at that point.
* **Climate:** It will be decades before we can judge the success of our projections. We can only evaluate model performance for current and past climates.

Weather vs Climate model evaluation

* A close connection of **success** in simulating aspects of **current climate** to model **behaviour in future projections** has not been established!
* Therefore, evaluation of current climate is - at best - a **necessary condition** for model quality.
* This also implies that our **reliance on understanding** is of much greater significance for climate than weather models.

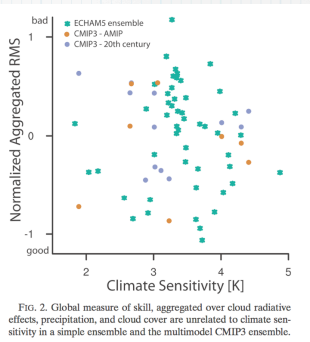
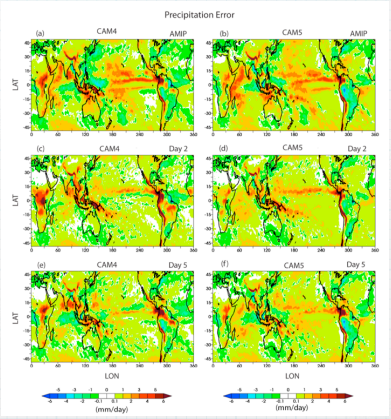


FIG. 2. Global measure of skill, aggregated over cloud radiative effects, precipitation, and cloud cover are unrelated to climate sensitivity in a simple ensemble and the multimodel CMIP3 ensemble.

Klocke et al., JCl, 2012

Running climate models in weather mode

- In theory we can run **climate models initialized** - in practice this may be hard.
- The main reason for doing so is to **constrain the circulation** closer to the truth, so that error in clouds/precipitation can more easily be assigned to parametrization issues.
- There is an **international** project doing this - **Transpose AMIP**



Climate

2-d FC

5-d FC

Xie et al., JCL, 2013

Evaluating clouds and precipitation

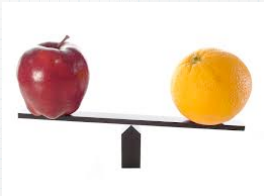
... is a tricky business!

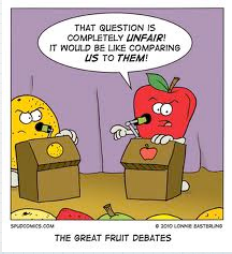
What are we interested in?

- **Radiative effects** of clouds
- **Heating** in clouds and precipitation and its effects in interactions with circulations
- Determined by **cloud properties**, such as cloud fraction, cloud water/ice content, cloud particle characteristics

Some issues specific to cloud evaluation

- Clouds and precipitation are **difficult to observe** (see observations lectures).
- Clouds and precipitation in models are represented by **parametrization** through a few variables, such as **cloud fraction, cloud water and ice content, rainfall rate** (see model lectures).
- This leads to **many potential issues in comparing** the two.





Two approaches to reconciliation

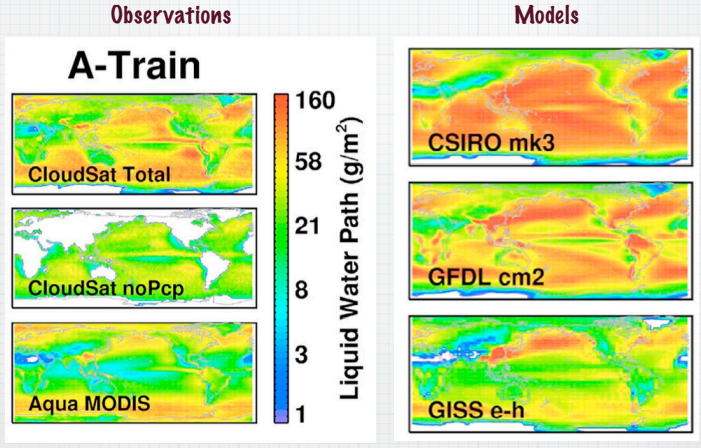
Derive model variables from observed quantities
Retrievals

Model cloud
usually fraction, water and ice

Observed cloud
usually a measurement of radiation

Simulate observed quantities from the model fields
Instrument simulators

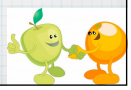
Retrieval example



Jiang et al., JGR 2012

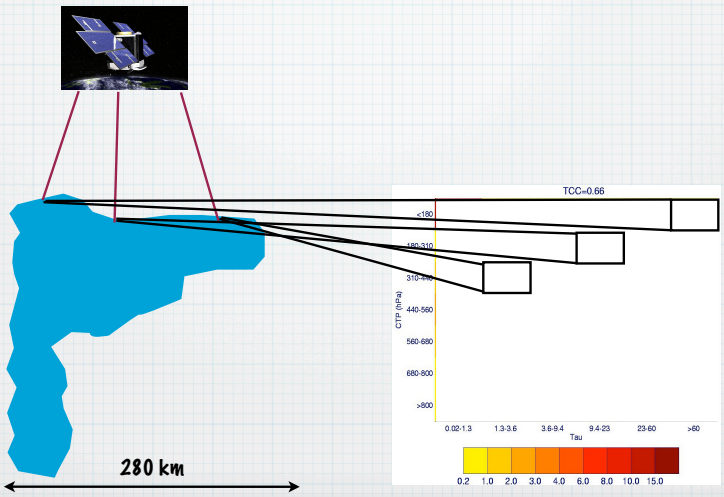
Instrument simulators

- **Basic idea:**
  - Derive observed quantities from model fields
  - These include radiances, radar reflectivity, depolarization ratio etc.
- Two key steps:
  - **Match spatial scales**
  - **Match the observable**



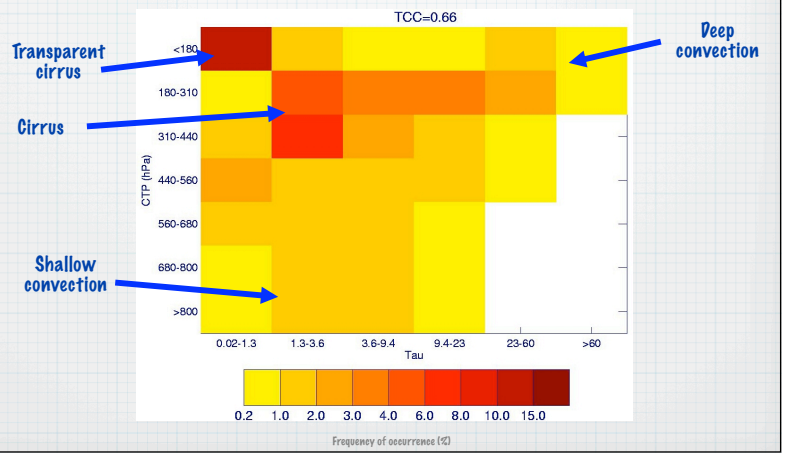
The ISCCP simulator

ISCCP data in CTP-τ diagrams



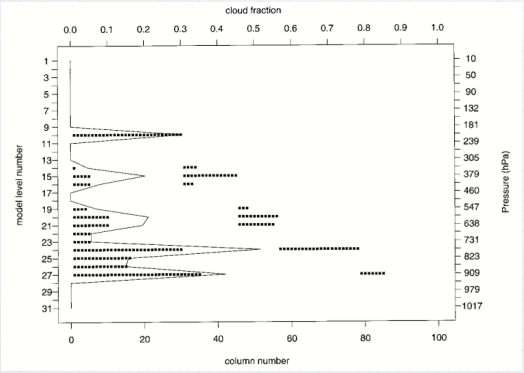
The ISCCP simulator

The ISCCP D1 data set provides **joint histograms of the frequency of occurrence of clouds with a certain cloud top-pressure and optical thickness in grid boxes of ca. 280x280km.** These histograms have a strong relationship to cloud types (e.g., Rossow and Schiffer, 1999). The example below shows the mean histogram for 1999-2000 averaged over an area in the Western Pacific (130-170 E, 10 N-10 S).



The ISCCP simulator

Step 1: Scale matching

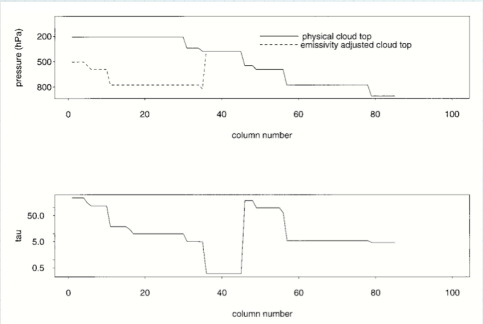


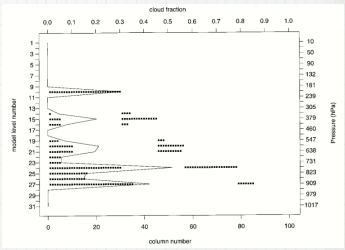
* Model cloud fraction profile
* Apply overlap assumption
* Divide grid-box into sub-boxes
* Treat each box as a satellite pixel

Klein and Jakob, MWR, 1999

The ISCCP simulator

Step 2: Radiative adjustment of cloud top





* Calculate 11 μm radiance for each sub-column
* Mimic IPCC procedure to find cloud top by assuming single layer cloud moving it vertically until the radiances match.

Klein and Jakob, MWR, 1999

A radar simulator

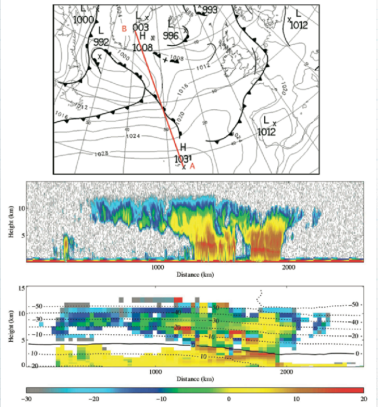
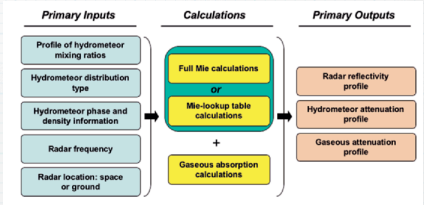


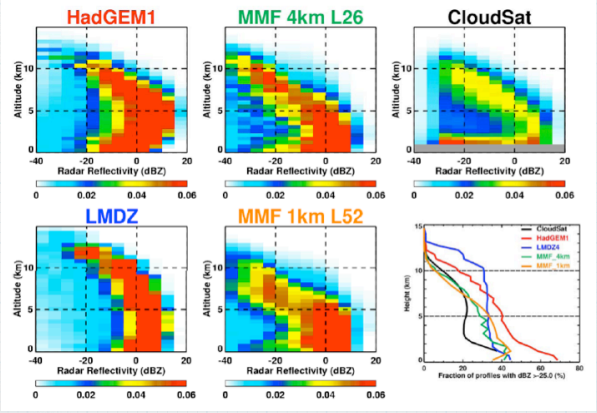
FIG. 4. Example of simulated midlatitude system in the Met Office global forecast model. The upper panel is the North Atlantic analysis chart at 1800 UTC on 7 July 2006. The red line shows the *CloudSat* track, from A to B. The middle panel shows the radar reflectivity (in dBZ) observed by *CloudSat*. The lower panel is the simulated reflectivity from the model outputs. Isotherms (°C) are contoured, the solid line denoting the freezing level.

Haynes et al., BAMS, 2007

QuickBeam



A radar simulator



CloudSat Simulator

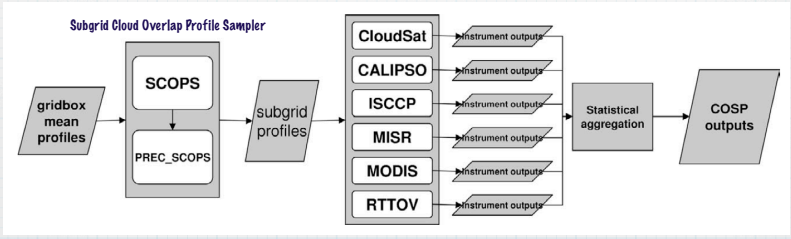
Cloud-Frequency with Altitude Diagram

North Pacific region

Bodas-Salcedo et al., BAMS, 2011

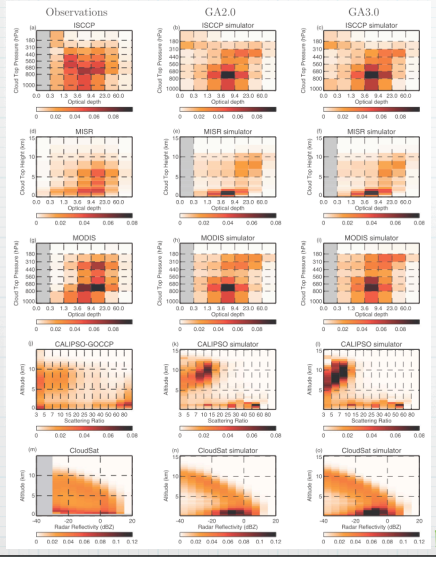
The COSP simulator

* Simulators can be built for other instruments/collection of instruments.
* The Cloud Feedback Model Intercomparison Project (CFMIP) Observation Simulator Package combines a number of them in one software package.



Bodas-Salcedo et al., BAMS, 2011

The COSP simulator



* Test of two model versions over the Southern Ocean in DJF
* Model lacks mid-level clouds (ISCCP, MISR, MODIS)
* CALIPSO -> lack of mid-level clouds with large scattering ratio (liquid).
* Lack of bi-modality in CloudSat simulated histograms -> too much drizzle

Bodas-Salcedo et al., JCL, 2012

Simulator limitations

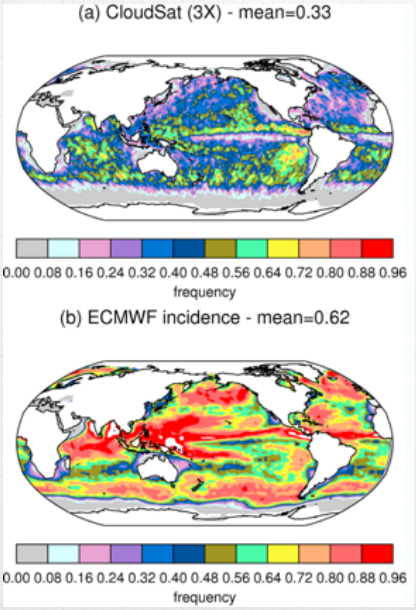
- Can be a **misnomer** to begin with.
- Can **obscure model error** (e.g., ISCCP high over low cloud)
- Observational artifacts might be missing.
- Ancillary data might not be the same (e.g., surface albedo).
- Different assumptions (e.g., partly cloudy pixels in the real world) skew the results

Basic weather and climate model evaluation

Frequently used data sets

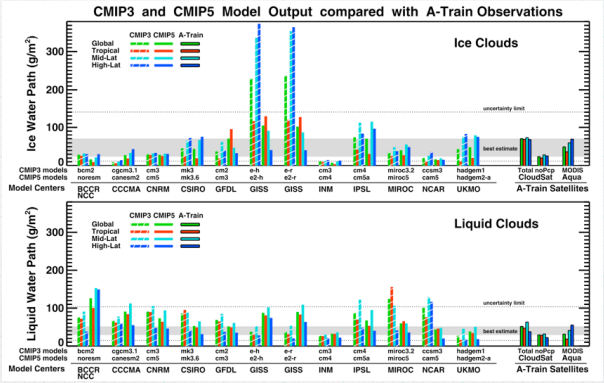
- Some commonly used data sets are:
  - Reanalyses by NCEP, ECMWF (ERA40, ERA-I), NASA (MERRA) and JMA
  - Radiation: CERES (Clouds And The Earth's Radiant Energy System) and previously ERBE (Earth Radiation Budget Experiment)
  - Precipitation: GPCP (Global Precipitation Climatology Project), CMAP (Climate Prediction Centre Merged Analysis of Precipitation), TRMM (Tropical Rainfall Measurement Mission), CloudSat, CMORPH (Climate Prediction Center Morphing technique)
  - Cloud properties: ISCCP (International Satellite Cloud Climatology Project), MODIS (Moderate Resolution Imaging Spectroradiometer) cloud products, CloudSat (Cloud radar), CALIPSO (Lidar, especially GOCCP - GCM-oriented CALIPSO Cloud Product)

The "drizzle" problem



Stephens et al., JGR, 2010

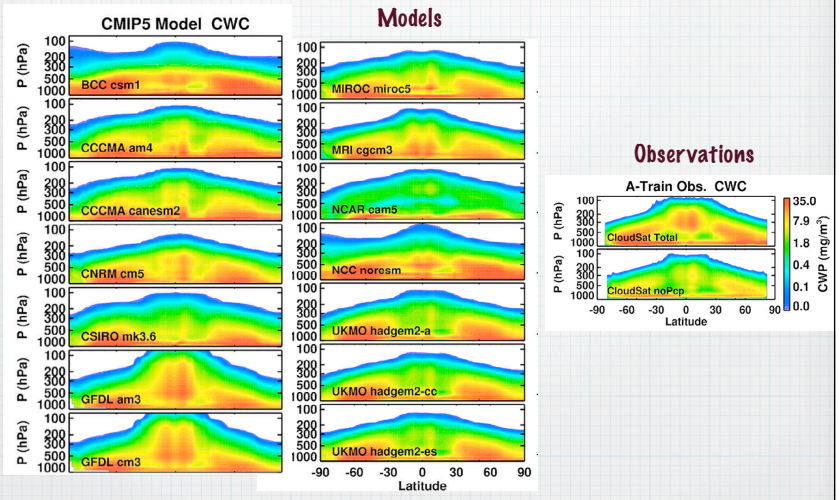
Liquid and Ice water path



- Wide range of simulated IWP and LWP, especially IWP
- Some moderate improvement in newer models

Jiang et al., JGR 2012

Vertical cloud structure



Jiang et al., JGR 2012