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Using satellite cloud observations in the development, evaluation & application of climate models

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GlobCloud Workshop, Berlin, 25th - 27th March 2009

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Outline

- Focus on work at the Met Office – the Unified Model is used for climate prediction, short-range NWP, seasonal & decadal forecasting
- Why do we use satellite data?
- Use of ISCCP & CloudSat data for model evaluation and development
- Application of these techniques to studying cloud feedbacks under climate change
- Brief concluding remarks
  - COSP – simulating satellite measurements in models
  - Current developments in climate modelling
  - What do modellers require?

Why do we use satellite data?

- Evaluate the physical processes most relevant to reducing uncertainty in climate predictions
- Inform & prioritise key areas for developing and improving climate models
- Constrain climate change predictions – or at least try and determine if this is possible
- Detection & attribution of observed variations to natural and anthropogenic forcings
- Initialisation of models used for seasonal-to-decadal prediction

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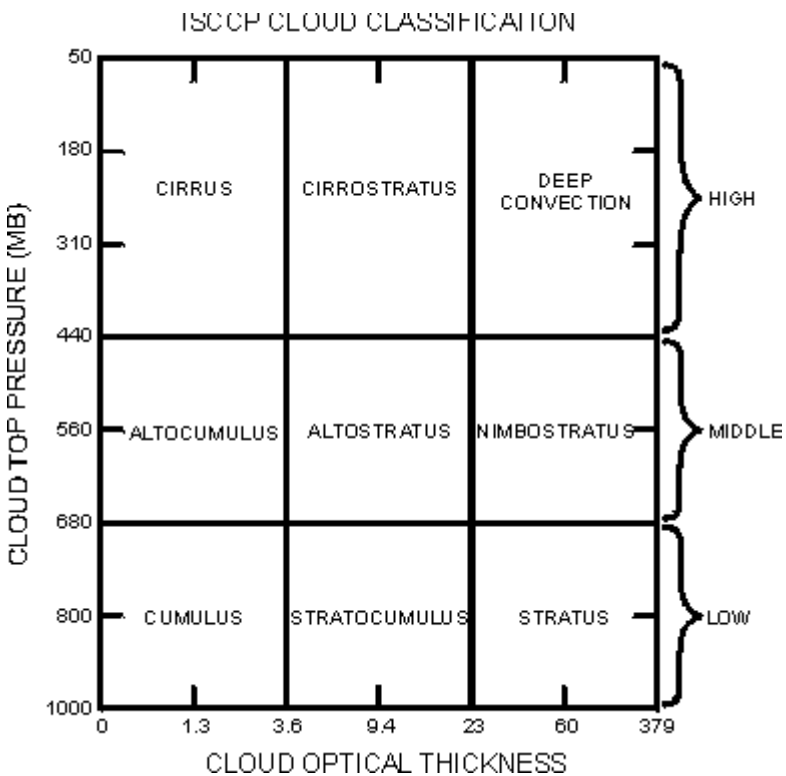
ISCCP histograms & the ISCCP simulator



Apparently limited information content (VIS + IR radiance) but in a climatological histogram format which is invaluable to modellers

Use of ISCCP by modellers has been become widespread due to availability of the ISCCP simulator

MODIS and CERES are producing ISCCP-like statistical summaries

First major result was identification of compensating errors – correct radiation budget, incorrect clouds

Data have since been used in process studies and attempts to constrain cloud feedbacks

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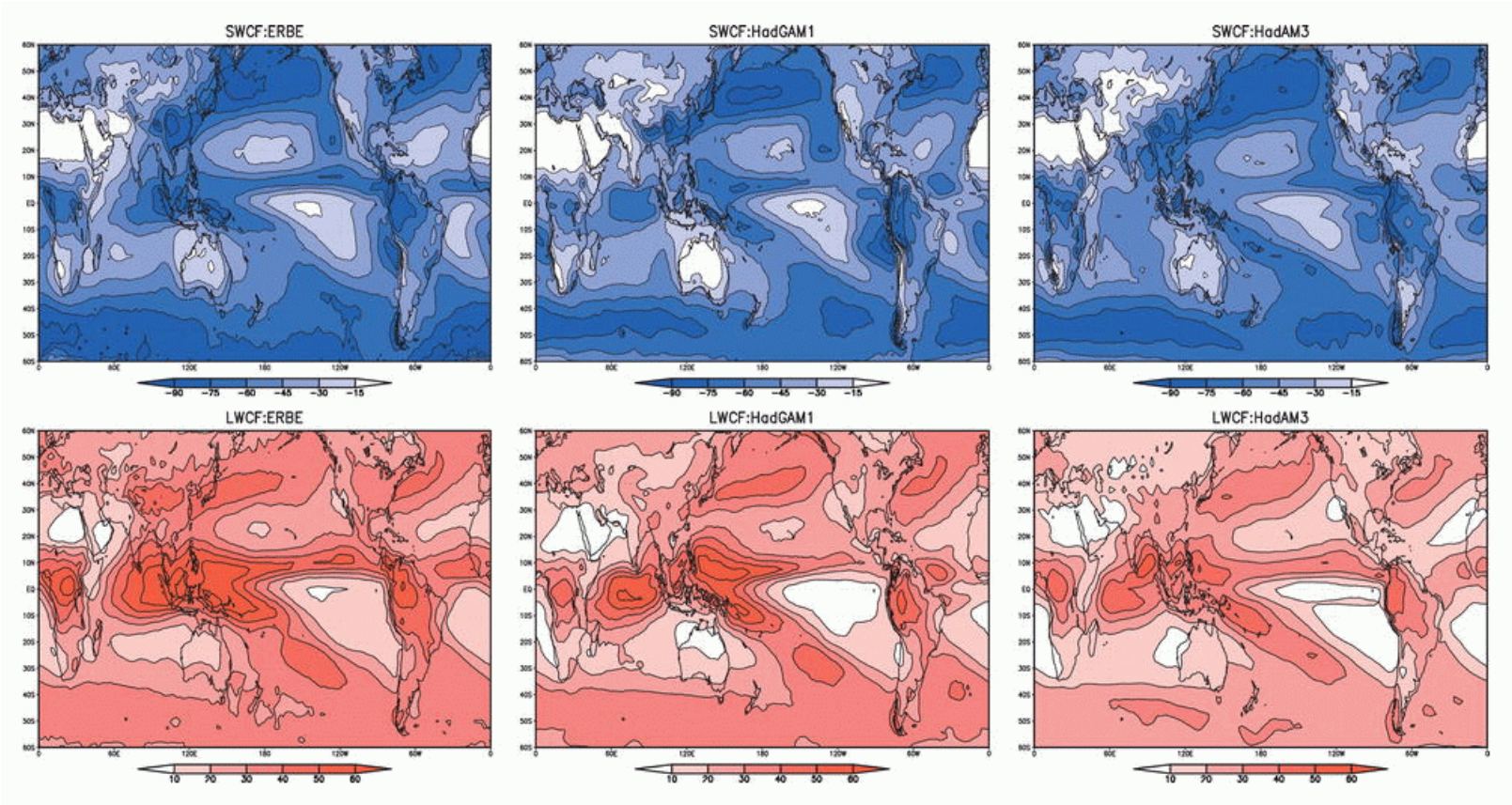
Compensation of errors: Cloud radiative effects look similar in the two models…

ERBE HadGEM1 HadCM3

SW cloud forcing

LW cloud forcing



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Martin et al. (2006)

However, the cloud fields certainly do not.

Low level cloud: CTP < 680 hPa

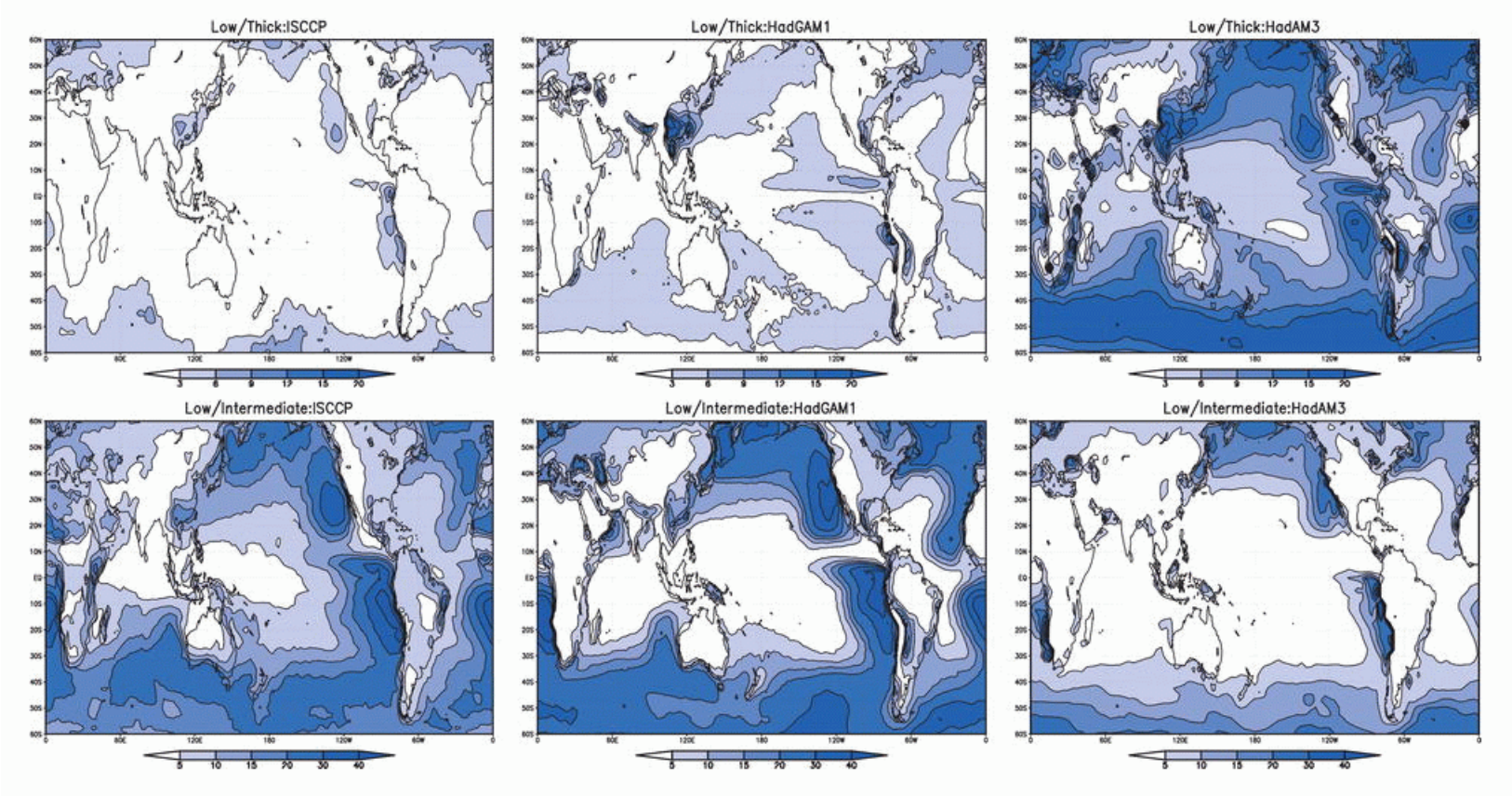
ISCCP HadGEM1 HadCM3

Thick "Stratus"

OD > 23

Medium "Stratocu"

3<OD<23



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Martin et al. (2006)

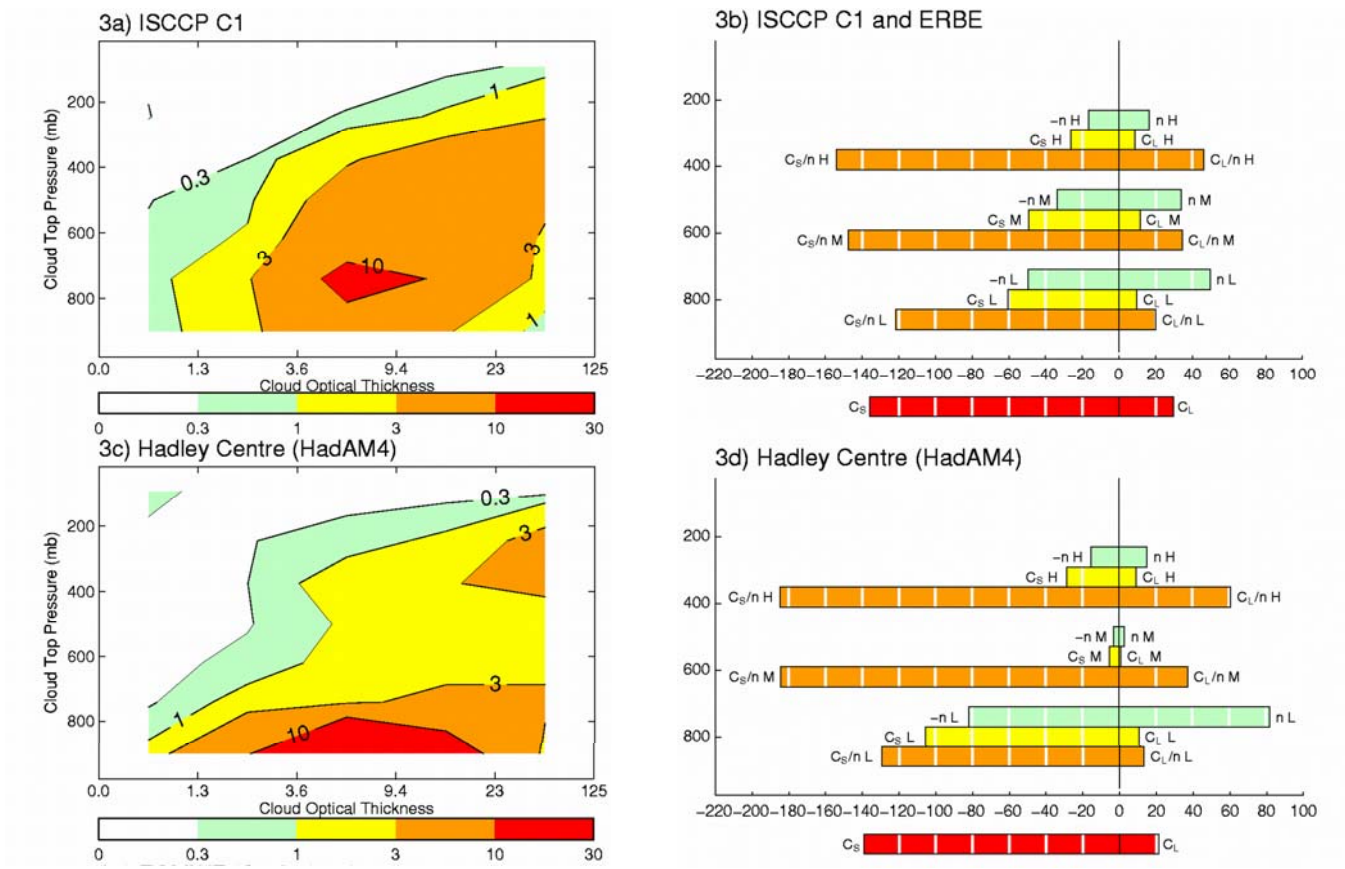
More detailed analysis shows how this operates in specific regions – Northern Pacific, July

Observations

(ISCCP+ERBE)

Climate model

(HadCM4)



The radiative effects of the excessive boundary layer cloud compensate for the lack of cloud at mid levels of the troposphere

Webb et al. (2001)

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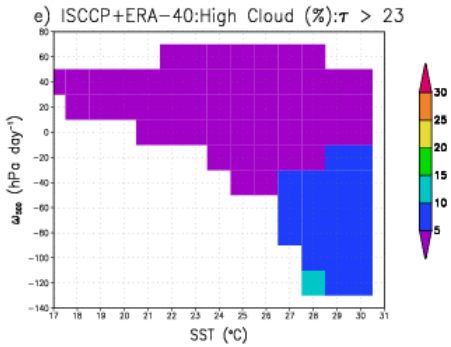
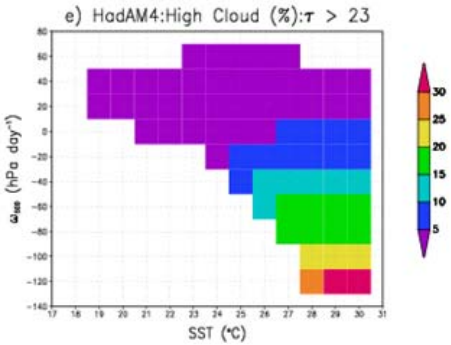
Analysis in terms of dynamical regimes: high/thick cloud over tropical oceans

ISCCP+ERA40



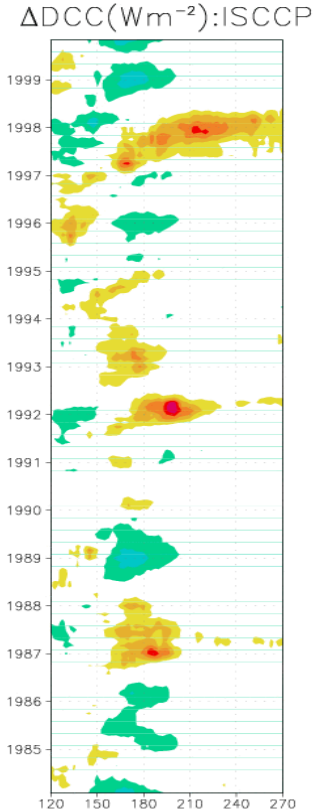
Increasing ascent at 500 hPa

Climate Model

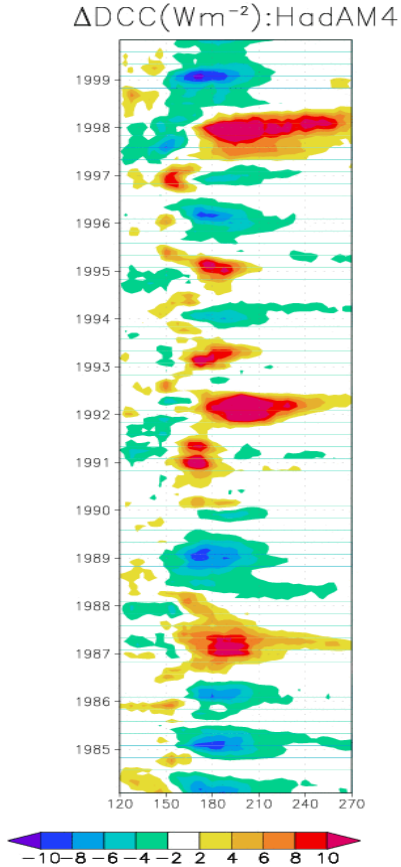


Increasing SST

ISCCP



Model



Anomalies in high/thick cloud along the Equatorial Pacific 1984 – 2000

Ringer & Allan (2004)

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Cloud clustering using observed and simulated ISCCP data

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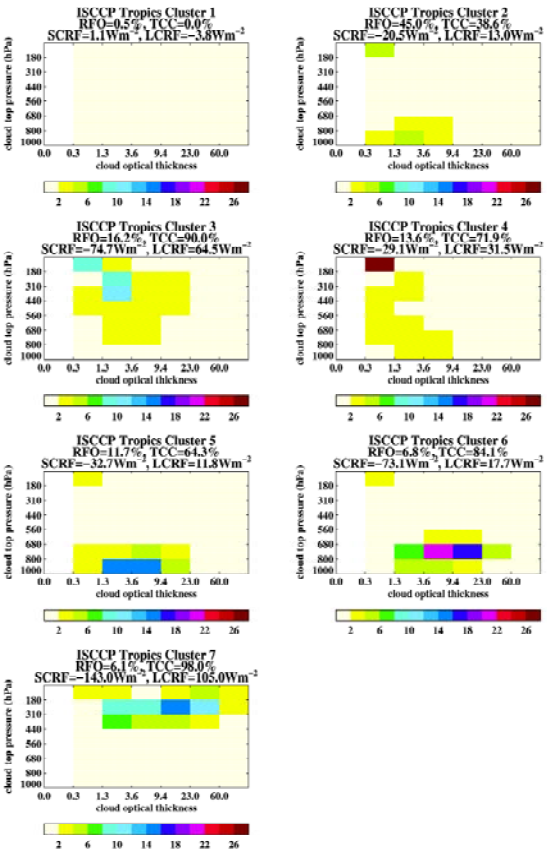
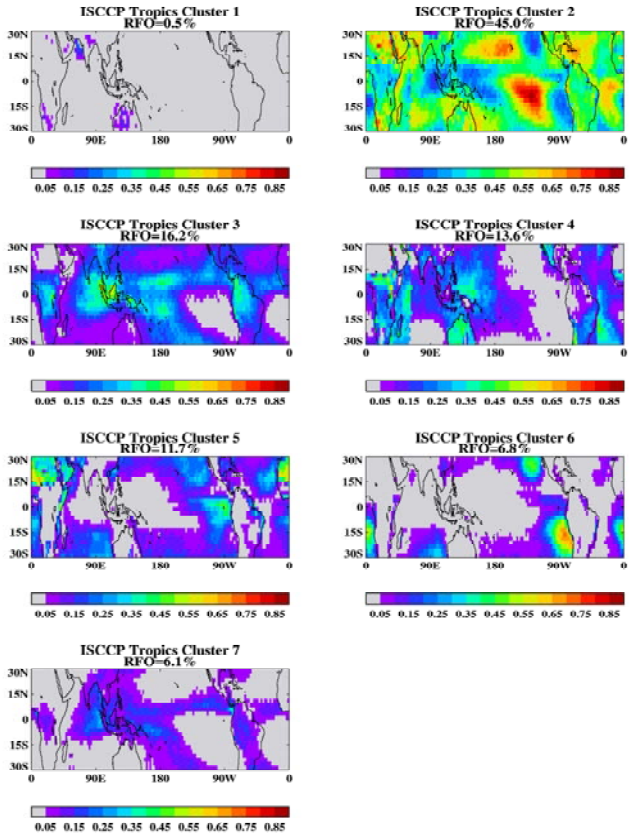
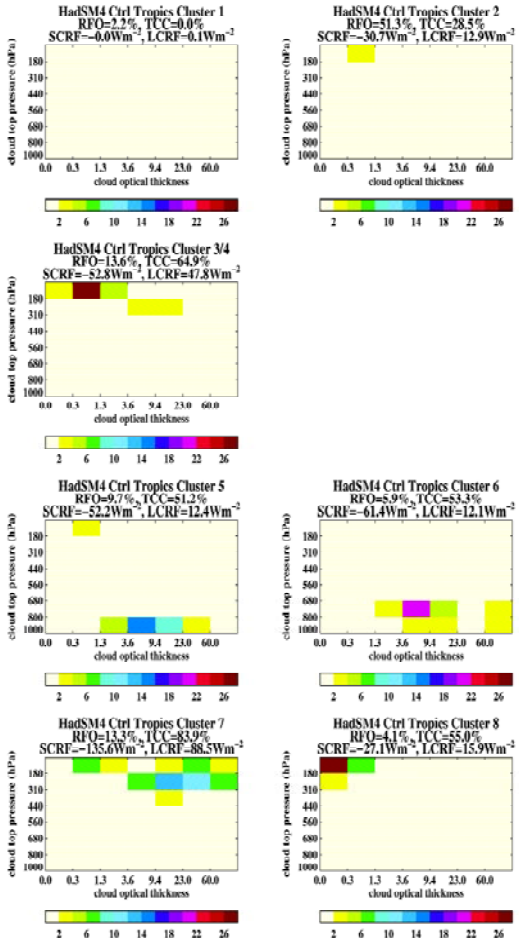
Observed clusters



Geographical location



Simulated clusters



Williams et al. (2005)

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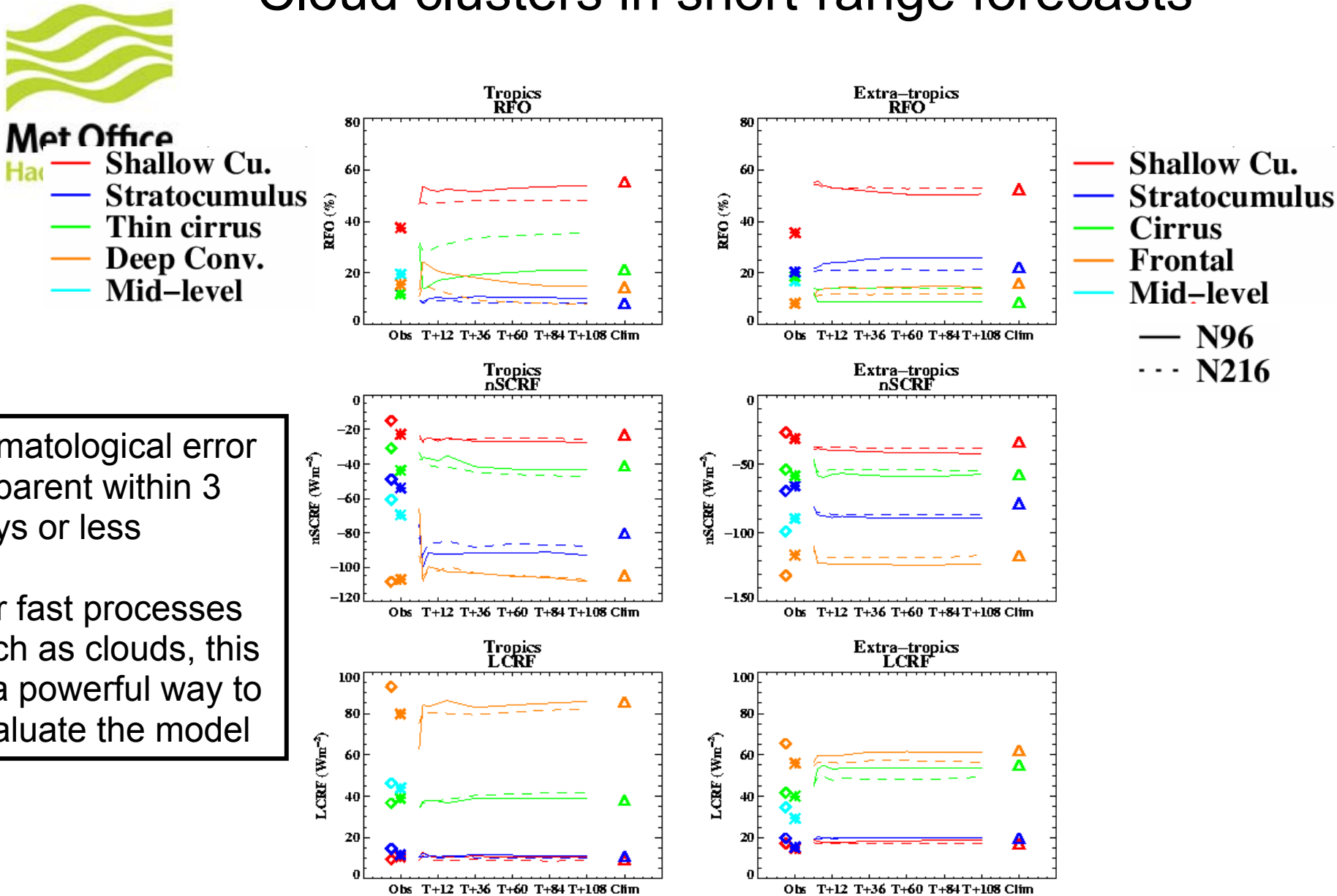
Cloud clusters in short-range forecasts



Climatological error apparent within 3 days or less

For fast processes such as clouds, this is a powerful way to evaluate the model

Williams & Brooks (2008)

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Evaluation of the Met Office global forecast model using CloudSat

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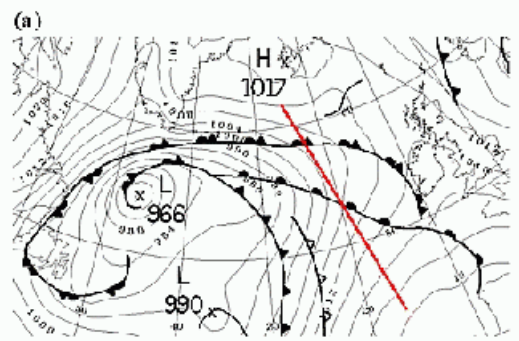
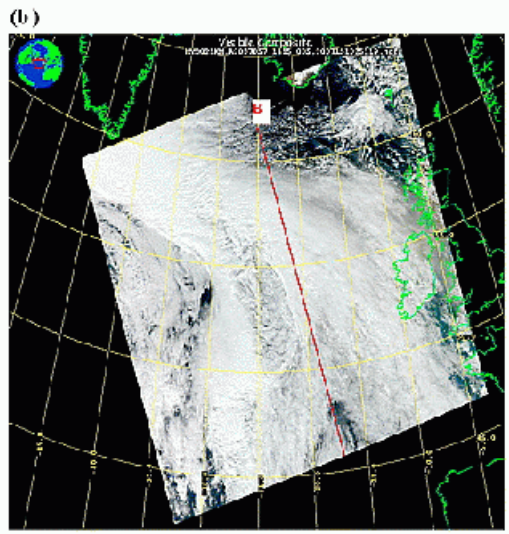
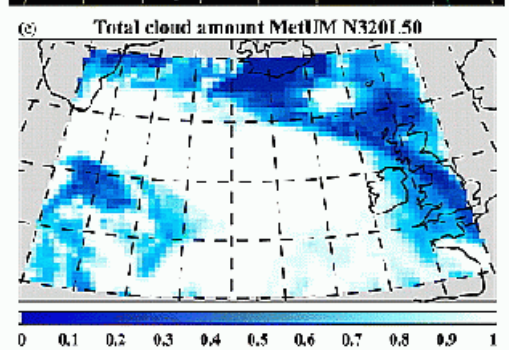
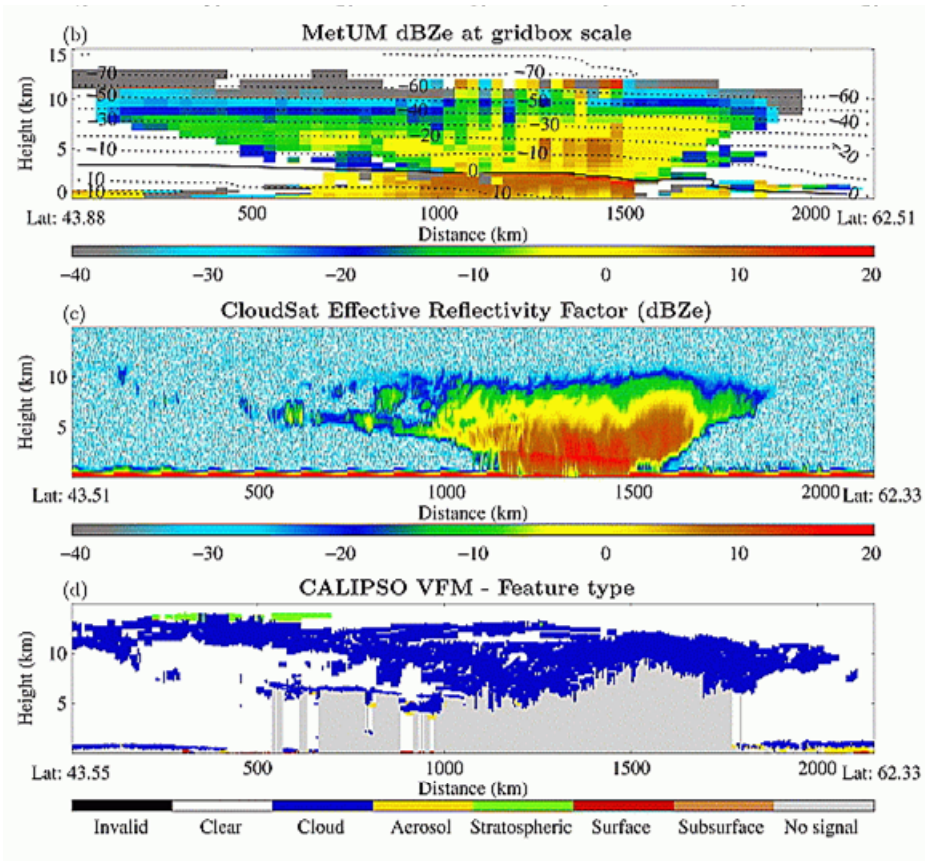




MODIS



Model cloud amount



South → North

Bodas-Salcedo et al. (2008)

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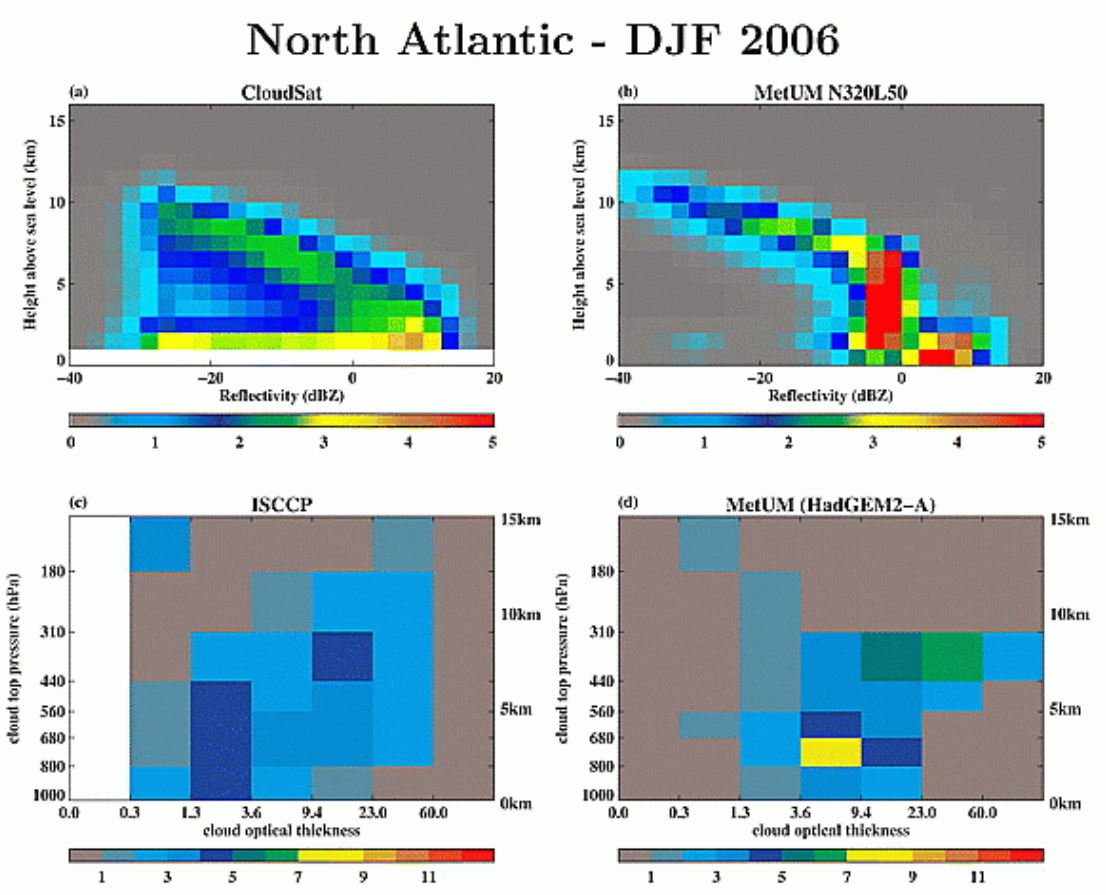
Statistical analysis: North Atlantic

Observations Model

CloudSat:
Reflectivity – height, frequency of hydrometeor occurrence

ISCCP:
optical thickness – height



Bodas-Salcedo et al. (2008)

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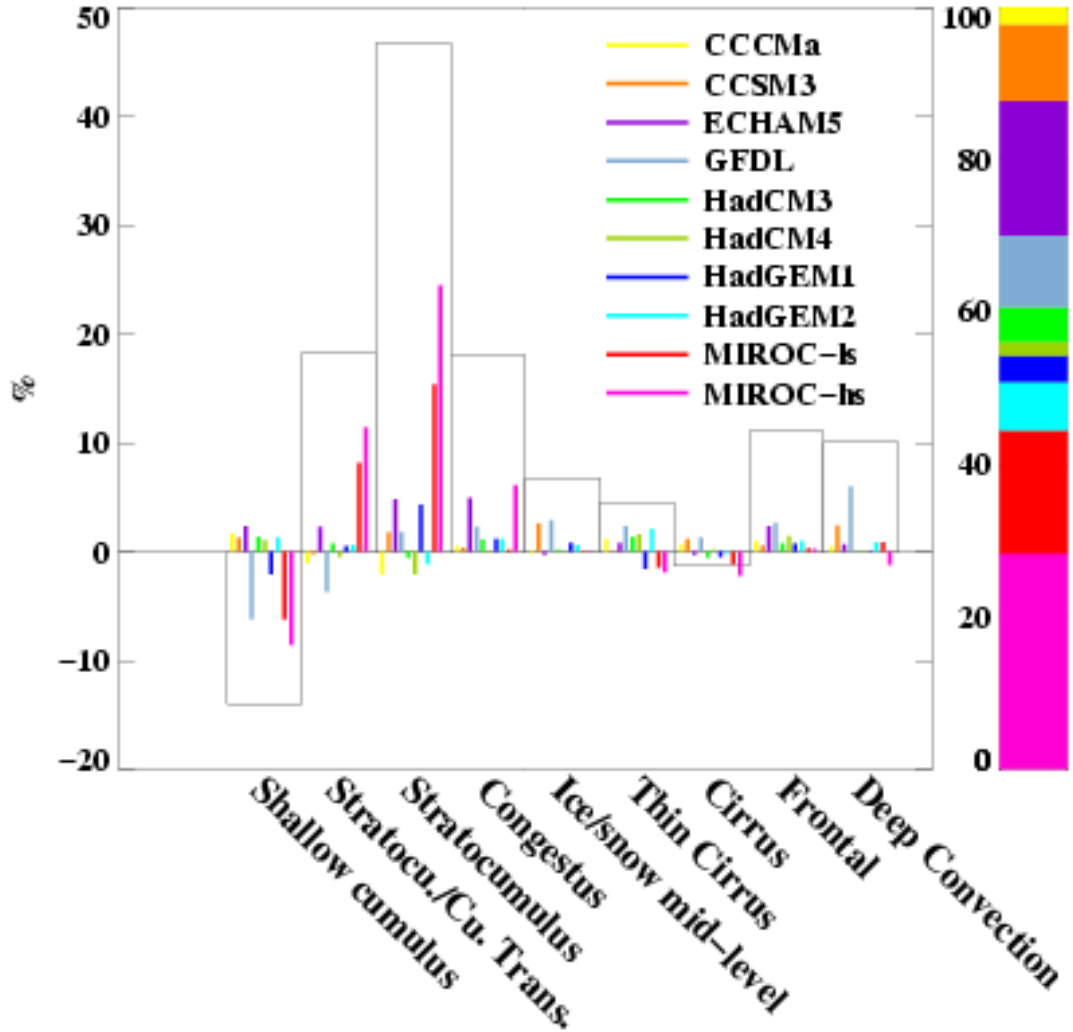
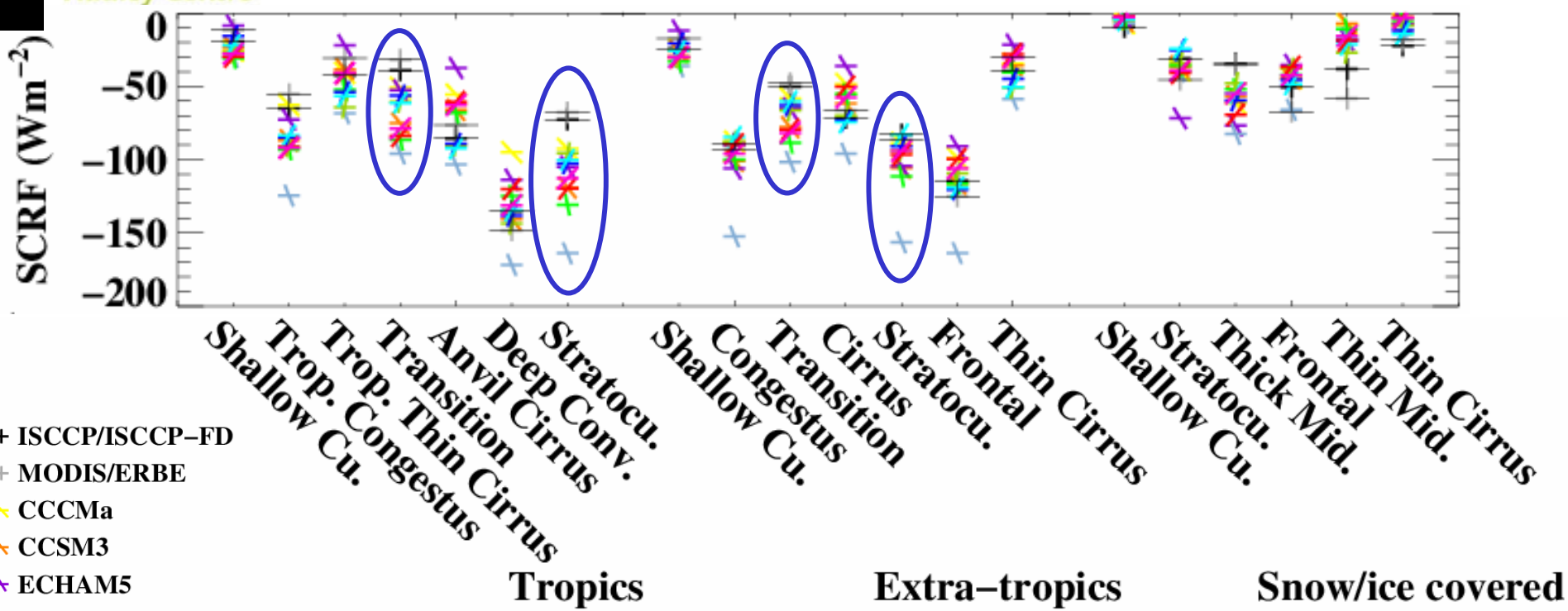
Application to cloud feedbacks: cloud clustering, uncertainty in the radiative response under climate change



Contribution of each regime to the inter-model variance in the change in net cloud forcing.

Williams & Webb (2008)

Evaluation of regime properties
(shortwave cloud radiative forcing)



Stratocumulus and cloud undergoing transition from stratocumulus to shallow cumulus is too bright in these models.

Williams & Webb (2008)

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COSP: The CFMIP Observational Simulator Package
See: **www.cfmip.net**

- Designed to facilitate the exploitation of satellite data in numerical models – climate, global NWP, mesoscale / regional, CRMs, etc
- Developed through international collaboration: Met Office, LMD/IPSL, PCMDI, Colorado State Univ., Univ. of Washington
- Flexible tool that currently enables simulation of:
    - CloudSat, CALIPSO, ISCCP, PARASOL, MISR
- ISCCP diagnostics are "strongly recommended" for CFMIP/AR5 experiments; use of COSP is recommended in a subset of experiments
- 22 institutions have already downloaded COSP

EarthCARE: Aim should be to develop modules corresponding to the individual EarthCARE instruments for inclusion within COSP

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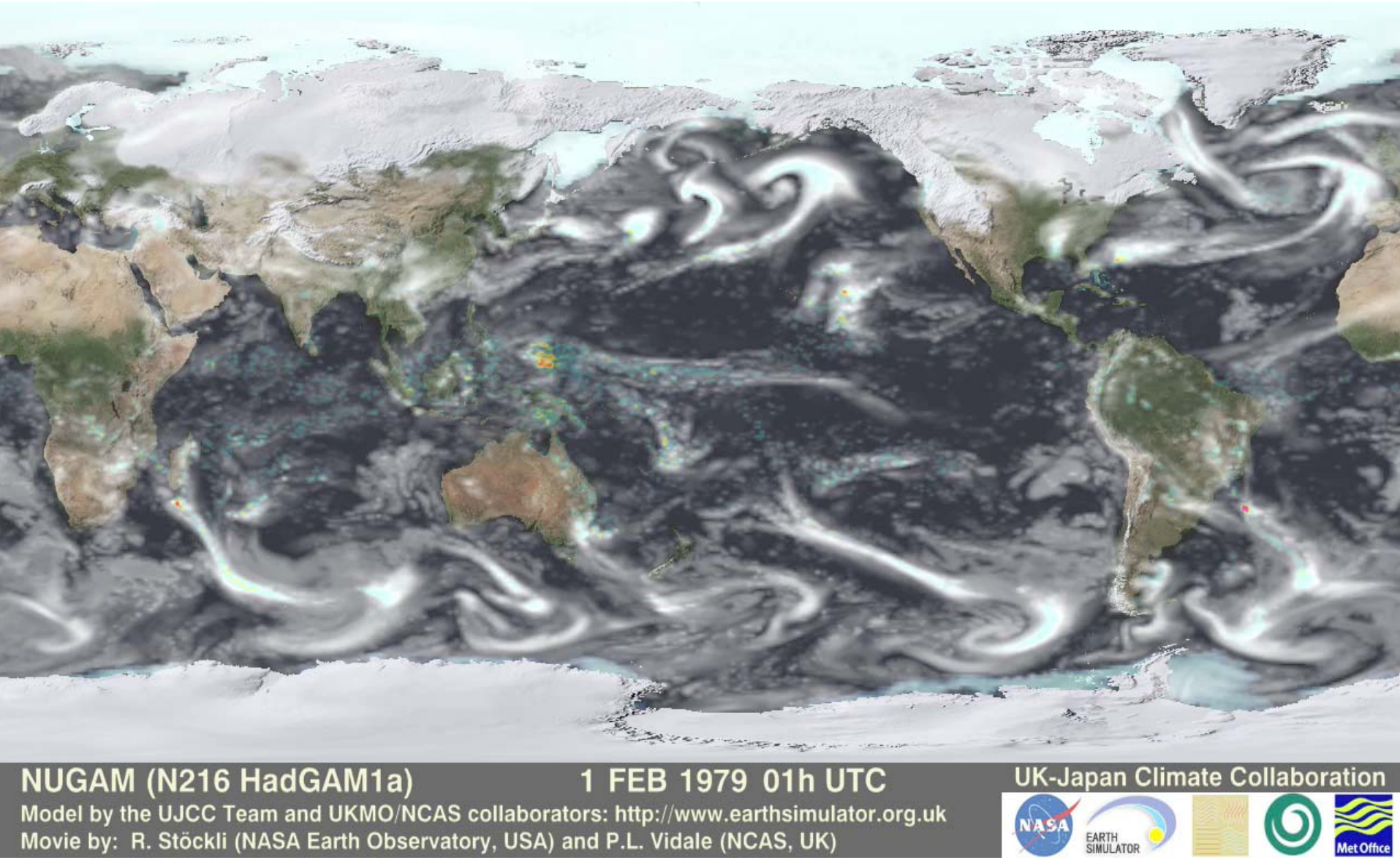

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What do modellers require?

- Better error/uncertainty estimates on satellite products
- Parameters required
  - LWP;
  - Diurnal cycle;
  - Cloud top/inversion height;
  - Drizzle rates;
  - 3D fields of cloud fraction, LWC/IWC, drop sizes
  - T, q profiles & meteorology associated with cloud systems;
- As important as this information are climatological statistical summaries appropriate for use by modellers, cf ISCCP TAU-CTP histograms; CloudSat reflectivity-height histograms (CFADS)
  - A large part of COSP development has been devoted to this

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