An upper tropospheric cloud-convection (UTCC) process study

Graeme Stephens and Claudia Stubenrauch

The WCRP clouds/climate Grand Challenge

Q1: How will storm tracks change in the future?
Q2: What controls the position and strength of tropical convergence zones?
Q3: Is convective aggregation important for climate?
Q4: How does convection contribute to cloud feedbacks?

GEWEX PROES - Process Evaluation Studies underdevelopment

This grew out of the obs4mip meeting where participants felt the issue of using obs more intelligently to probe process understanding was missing in obs4mip II

PROES is likely to grow into a WCRP cross cut activity

Five GEWEX-related PROES activities developing, one led by CliC

Å Upper Tropospheric Clouds & Convection (UTCC) (lead Stubenrauch, Stephens)
Å Ice mass balance (lead Larour, Nowicki), GEWEX with CLiC
Å Radiative Kernels for Climate (lead Soden)
Å Mid-lat storms (lead Tselioudis, Jakob)
Å Soil moisture climate (lead Seneviratne)

Convection

Given
convection
Clouds?

Given clouds
Convection?

Clouds & Radiation
& Precipitation

GEWEX PROES UTCC

1) Scientific Motivation: How does convection affect UTC ? And how does UTC affect convection?

2) Goal: To understand the relation between convection, UTC and the radiative heating , & provide observational based metrics of these relationships as a way of evaluating detrainment processes in models

relate convective strength to properties of high clouds
Test hypothesis that majority of UT heating is from thinner (anvil) clouds

Tools & steps:

Å **Develop/study proxies of convective strength from the A-Train (**e.g. colocate **CloudSat** *(Takahashi & Luo 2012, 2014),* **AIRS**)

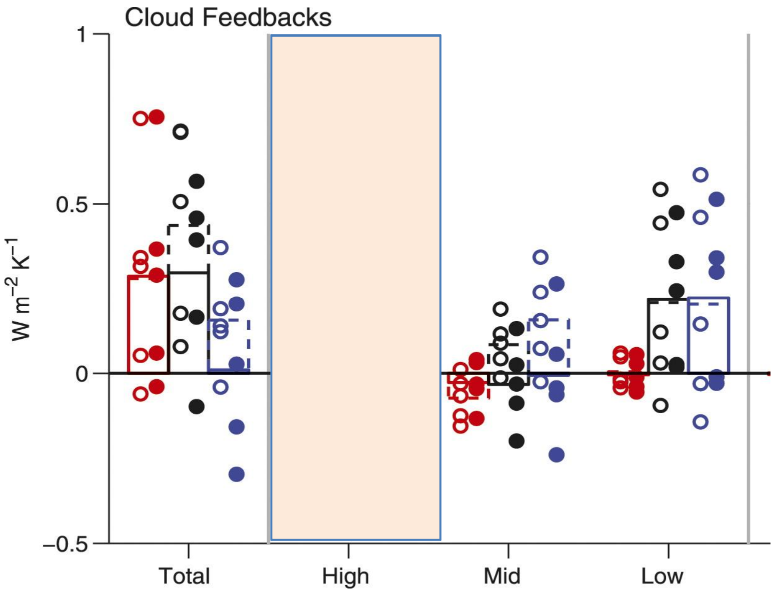
Å **determine horizontal extent & cloud types** (convect core, CiAnvil, thin Ci) **from AIRS, IASI**
& study multi-layering from CALIPSO-CloudSat per cloud type

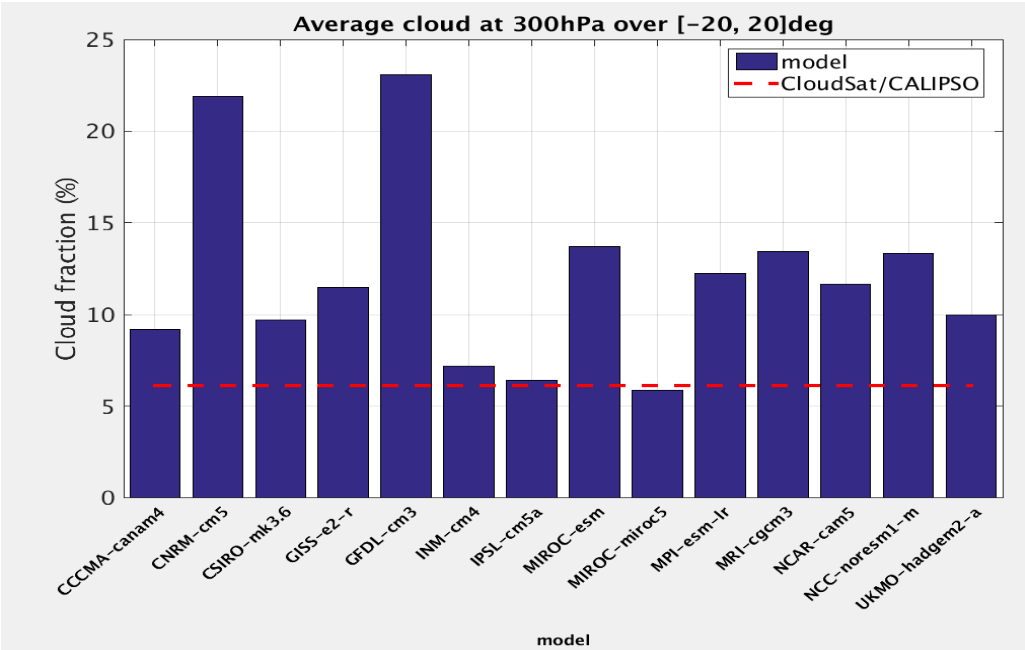
study life cycle of convective systems (MeghaTropiques, ISCCP H, geostationary finer spat. res., AIRS-IASI)

Add large scale cirrus to study

High Clouds – the climate modeler's canary

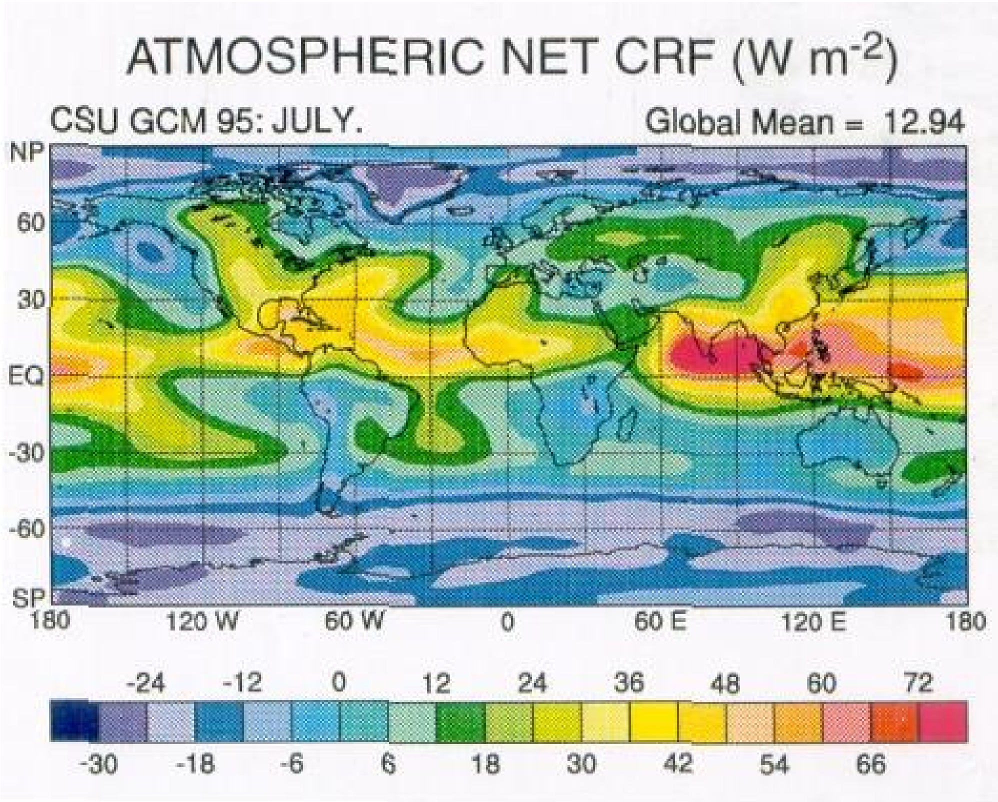
"High clouds are the modeling communities last line of defense against top-of-atmosphere observations of energy fluxes", A DelGenio, 2002, ECMWF, Reading UK.



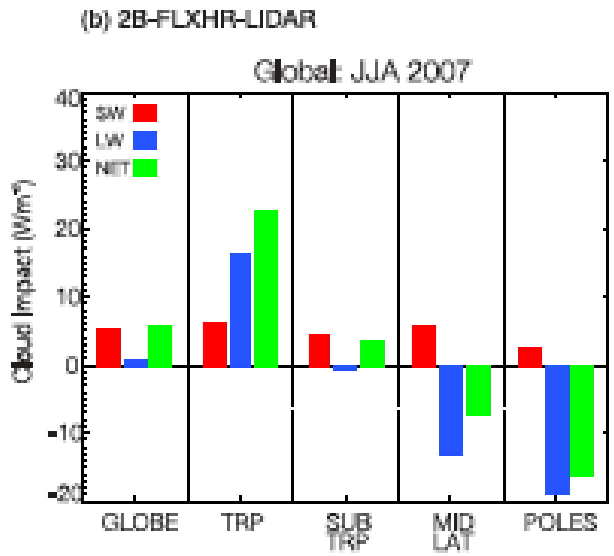


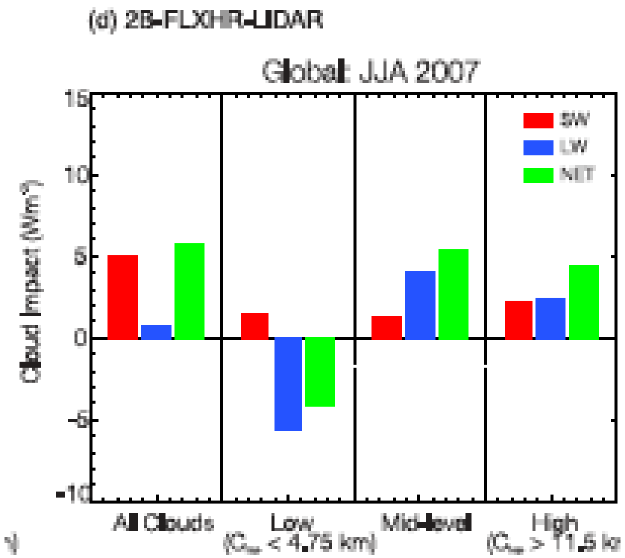
CloudSat/CALIPSO

Cloud influences on atmospheric radiative heating



A-Train observations





The radiative effects of high clouds dominate the heating at low latitudes, and low clouds largely determine the cooling at high latitudes

Two concepts Clouds -radiation ➔ convection feedbacks

Differential heating/cooling: I horizontal

Gray 1973

(i) Disturbed-undisturbed radiative heating; Gray and Jacobsen, 1977; Raymond, 2000; Mapes, 2002

Think of this as a self-sustaining of the convectively disturbed regions and reinforcing of the clear sky – a positive feedback (+). This is a key aggregation mechanism

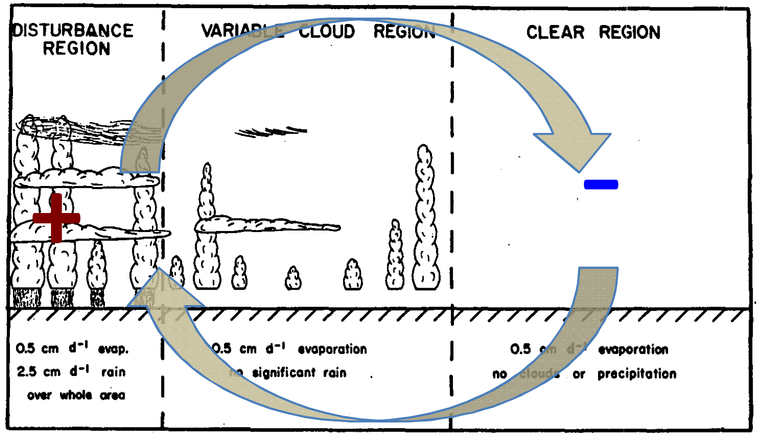


FIG. 2. Schematic of cloudiness in the cloud cluster disturbance and its environment.

Differential heating/cooling: II vertical

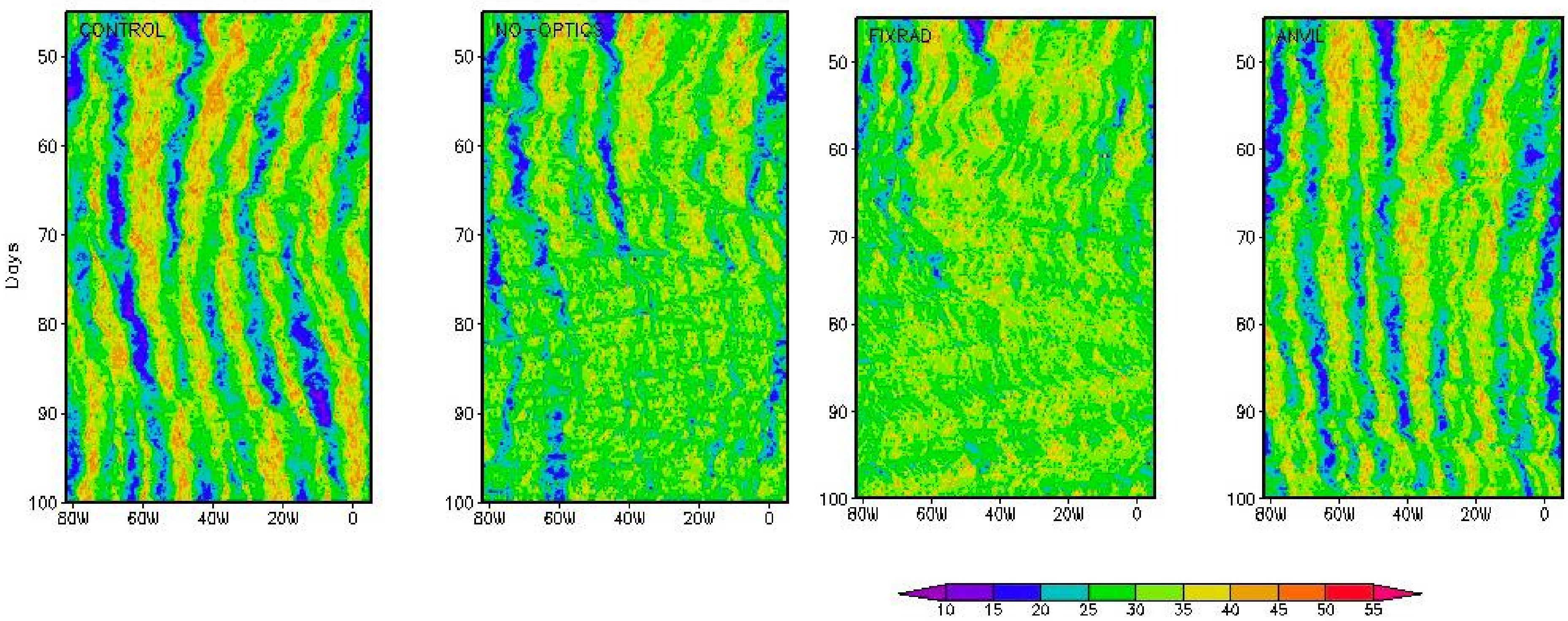
(i) Destabilization by strong cloud top radiative cooling over regions of deep convection– Webster and Stephens, 1980; Tao 1996; Xu and Randall, 1995 (positive feedback)

(ii) Stabilization by upper tropospheric heating of cirrus anvils – Fu et al., 1995; Stephens et al., 2003; Slingo and Slingo, 1988;Lebsock et al., 2010 (negative feedback)

Large domain CRM Radiative-convective equilibrium expts

Stephens et al., 2008

Column water vapor



Control

Water vapor only

Uniform radiative cooling

Water vapor plus anvils

Mauritsen and Stevens, 2015

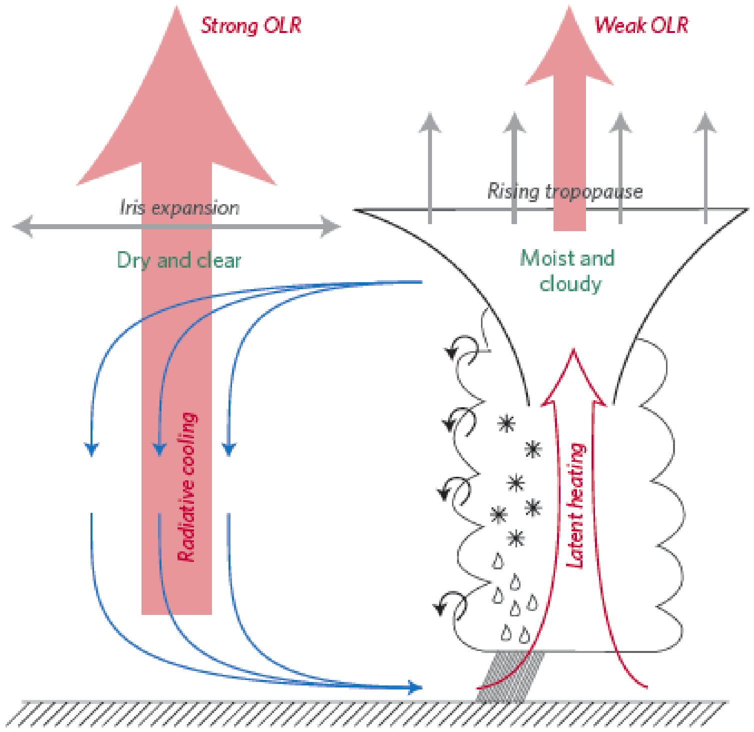
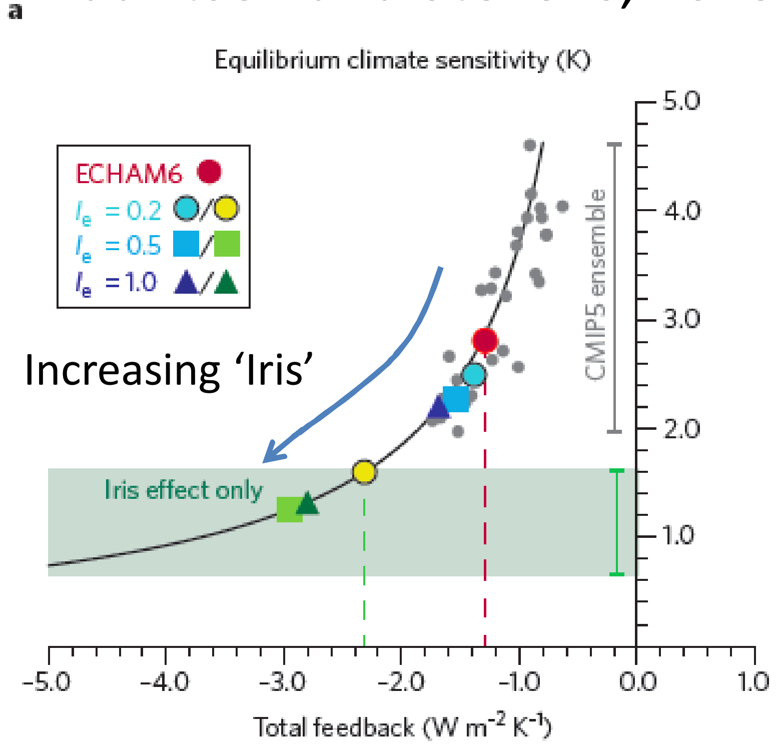


Figure 1 | Illustration of the tropical atmospheric circulation.



Clearly the convectively produced high clouds can effect both the climate and hydrological sensitivities – increasing strength of the IRIS effect lowers the ECS but enhances the hydrological sensitivitiy