

Satellite data to evaluate the cloud representation in general circulation models

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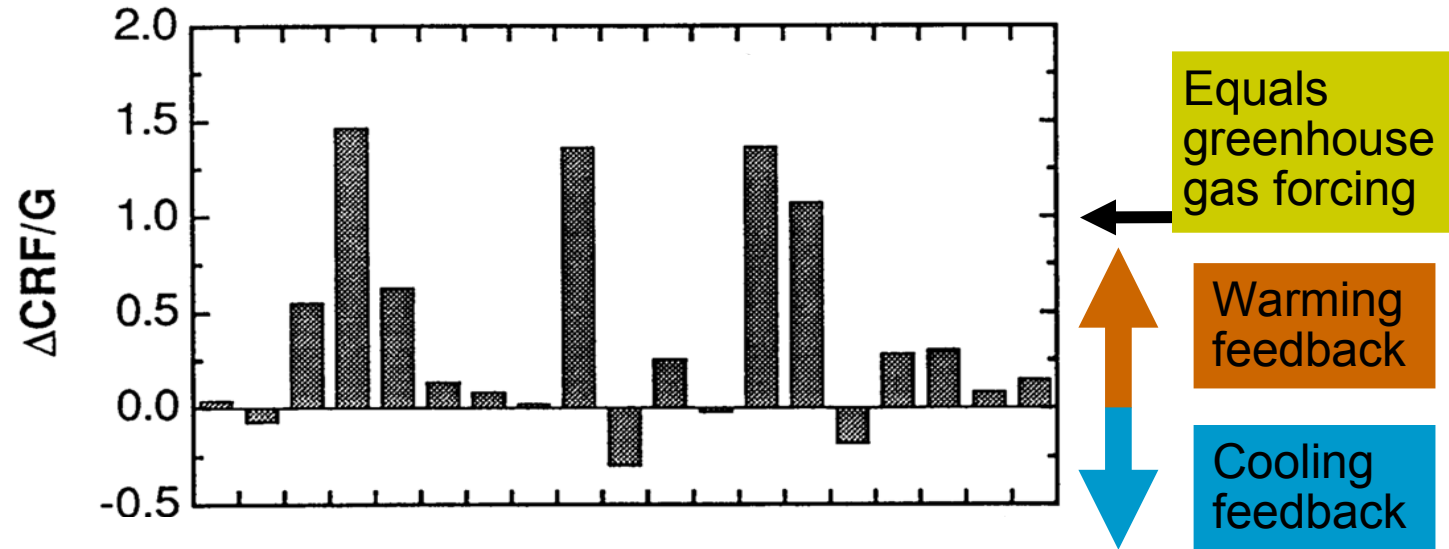


Contents

- Introduction
 - Satellite simulators and their use in GCMs
- Cloud evaluation
 - Evaluation of distributions
 - Evaluation of higher moments of subgrid-scale distribution
- Process studies
 - Cloud thermodynamic phase
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 - Needs for climate model evaluation and process studies

CFMIP

Cloud Feedback Model Intercomparison Project

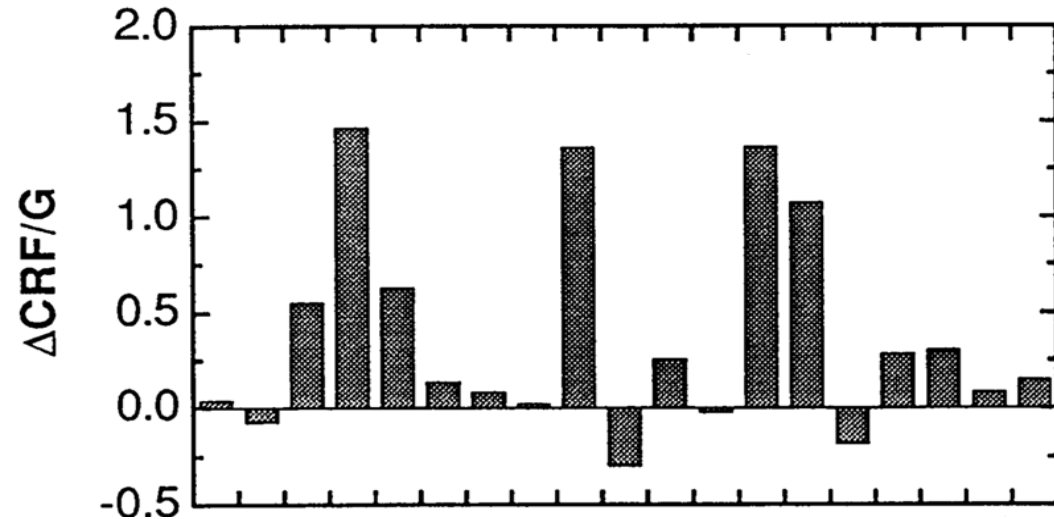


1990

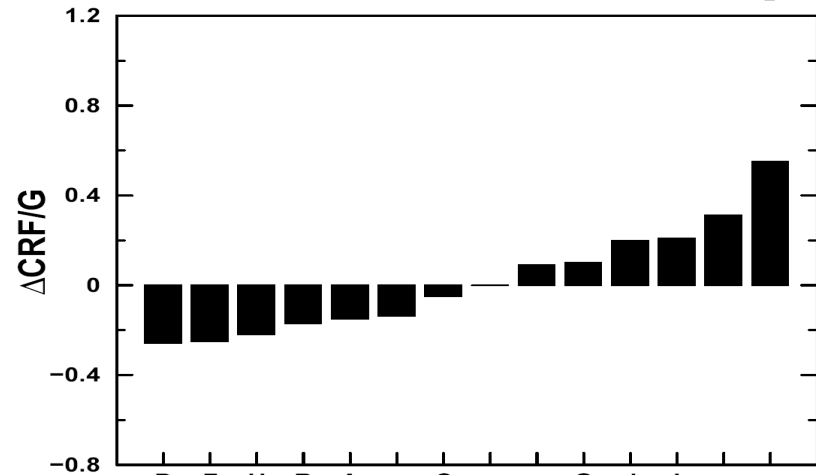
Cloud feedback (ΔCRF) normalized by anthropogenic greenhouse effect (G)
for 19 global climate models
CRF: Cloud radiative forcing

CFMIP

Cloud Feedback Model Intercomparison Project



1990



2006

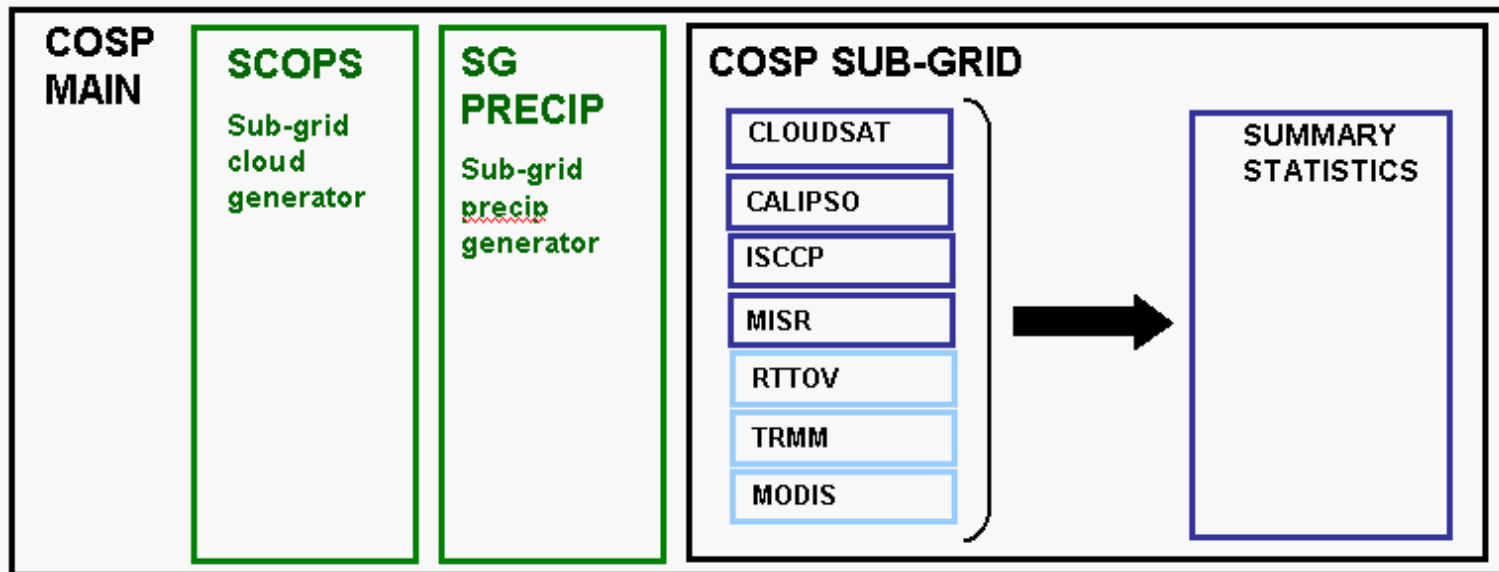
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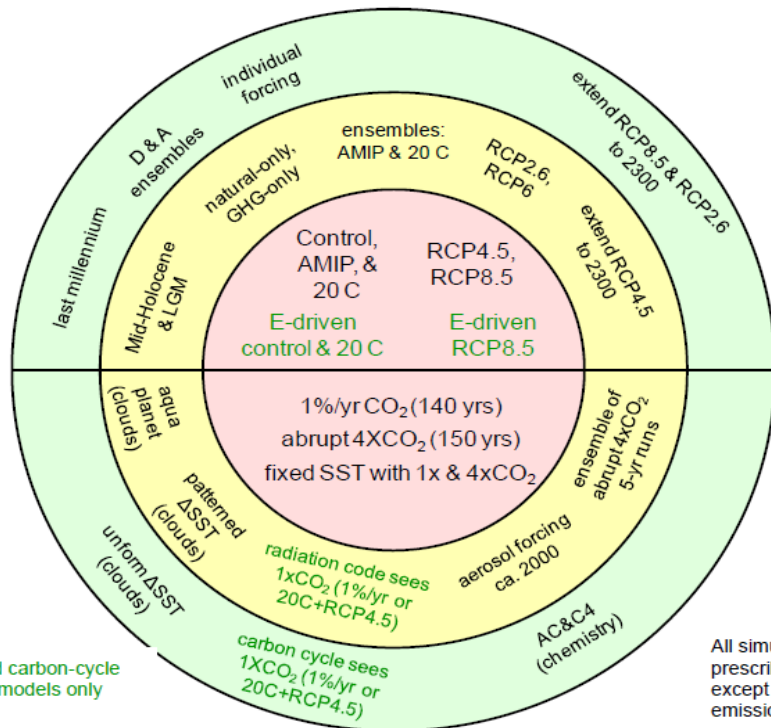
CFMIP Observational Simulator Package (COSP)

- 1) subgrid sampling
- 2) mimic retrievals
- 3) summary statistics



CFMIP

Cloud Feedback Model Intercomparison Project



Coordinated GCM simulations in preparation of IPCC AR5 (due 2013)

- specific CFMIP simulations
- COSP output from all models

All simulations are forced by prescribed concentrations except those "E-driven" (i.e., emission-driven)

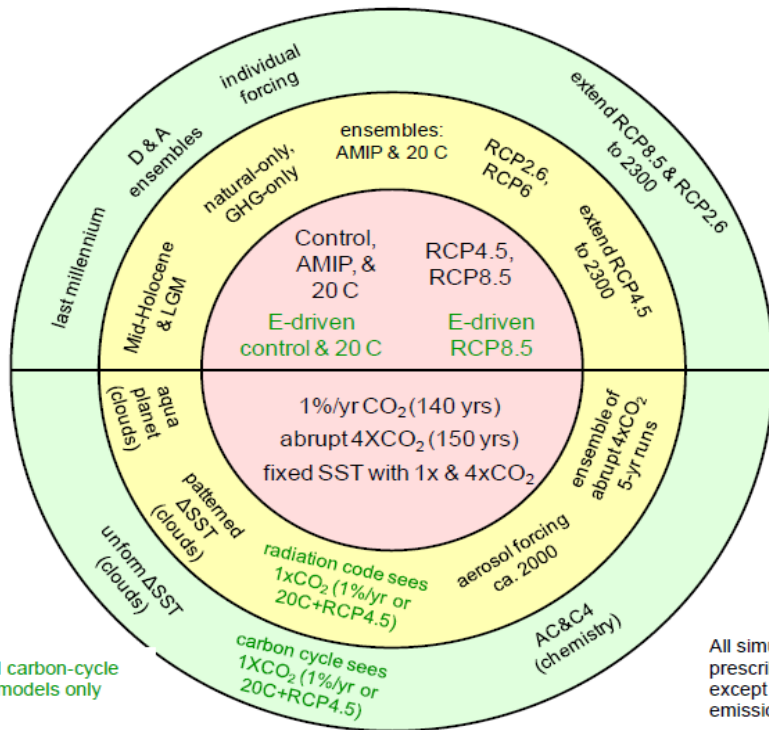
Coupled Model Intercomparison Project Phase 5 (CMIP5)

Core Tier 1 Tier 2 experiments

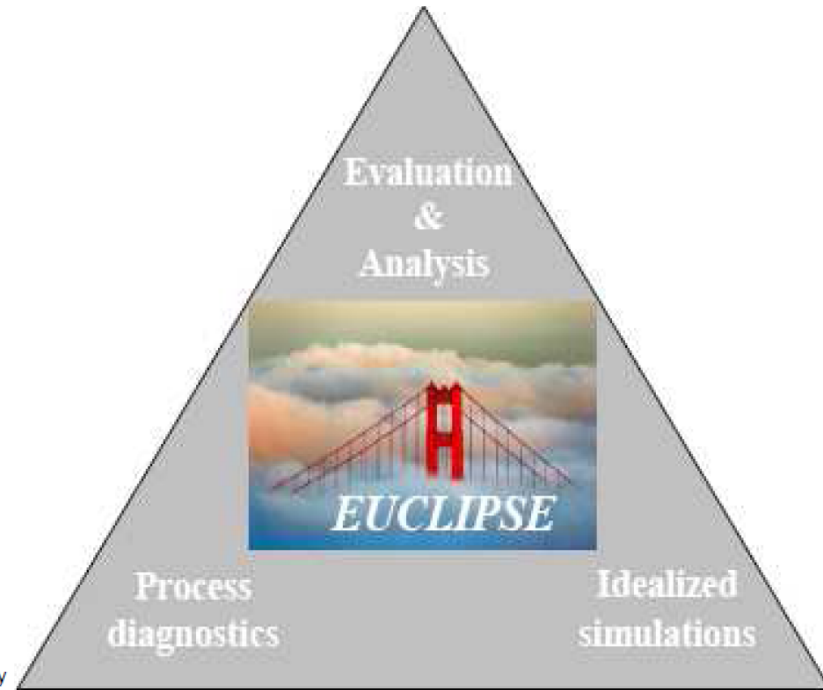


CFMIP

Cloud Feedback Model Intercomparison Project



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Coupled Model Intercomparison Project Phase 5 (CMIP5)

Core Tier 1 Tier 2 experiments

EU Cloud Intercomparison, and Process Study & Evaluation Project



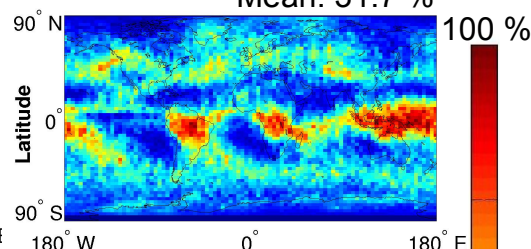
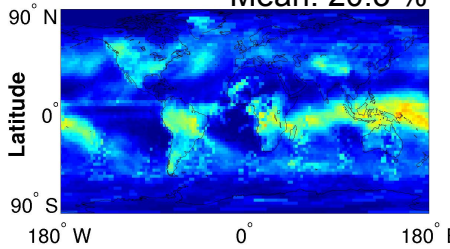
Comparison with Satellite Data - JFM 2007

ISCCP Satellite

CALIPSO Satellite

Mean: 20.3 %

Mean: 31.7 %

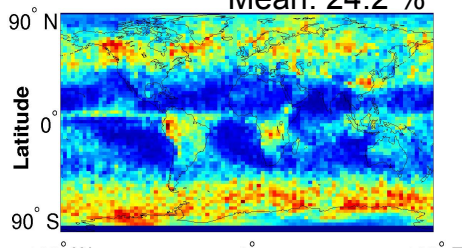
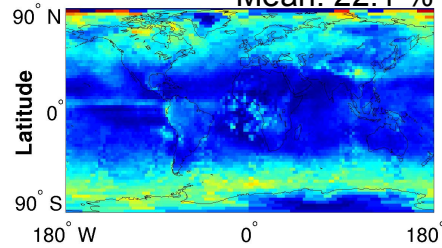


HIGH

440 hPa

Mean: 22.1 %

Mean: 24.2 %

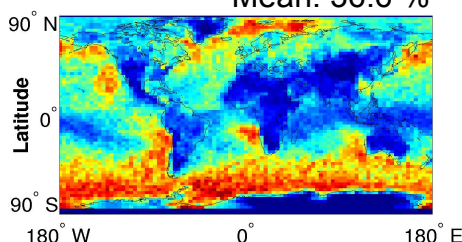
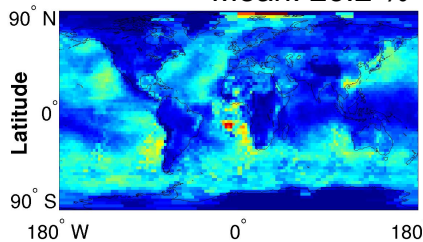


MID

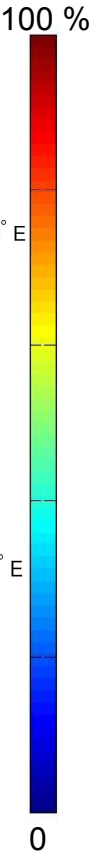
680 hPa

Mean: 23.2 %

Mean: 36.6 %



LOW



Comparison with Satellite Data - JFM 2007

ISCCP Satellite

CALIPSO Satellite

ECHAM5 GCM

ECHAM5 + ISCCP Simulator

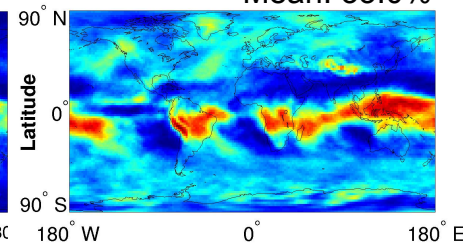
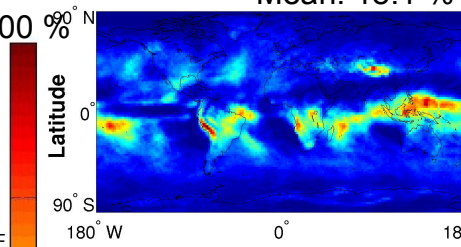
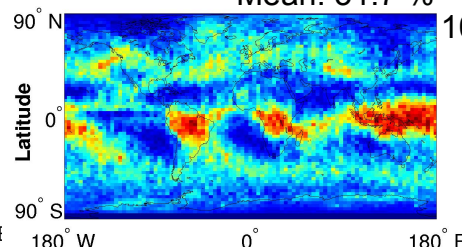
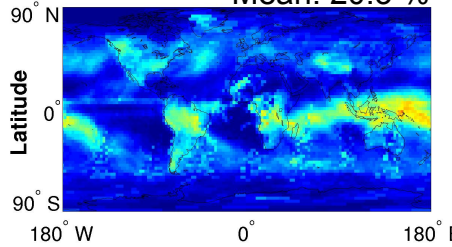
ECHAM5 + COSP Lidar Simulator

Mean: 20.3 %

Mean: 31.7 %

Mean: 18.1 %

Mean: 33.0 %

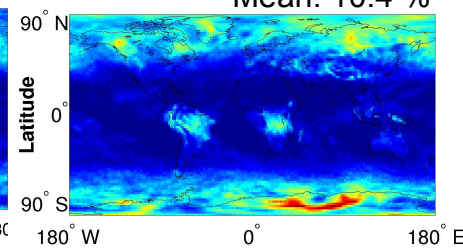
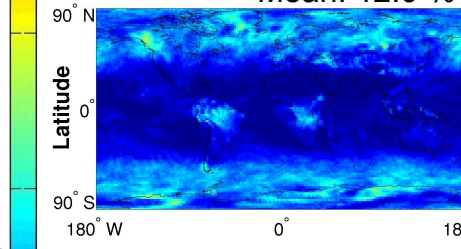
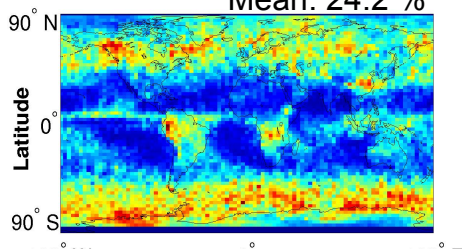
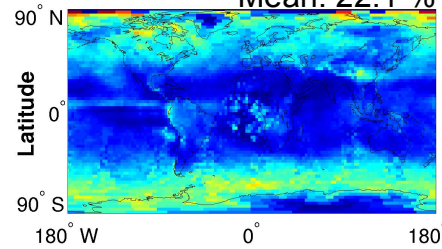


Mean: 22.1 %

Mean: 24.2 %

Mean: 12.0 %

Mean: 10.4 %

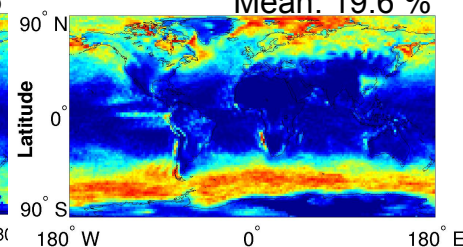
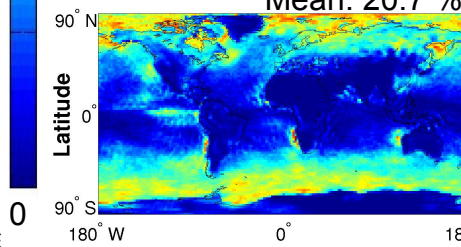
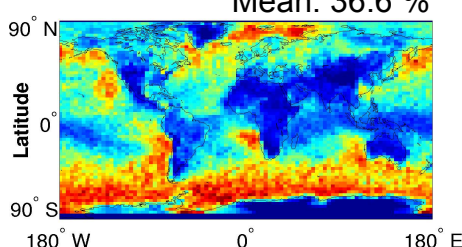
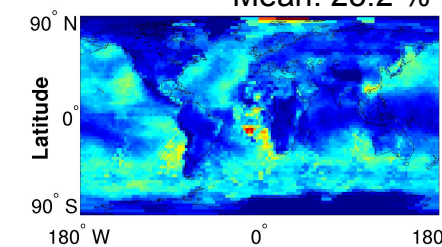


Mean: 23.2 %

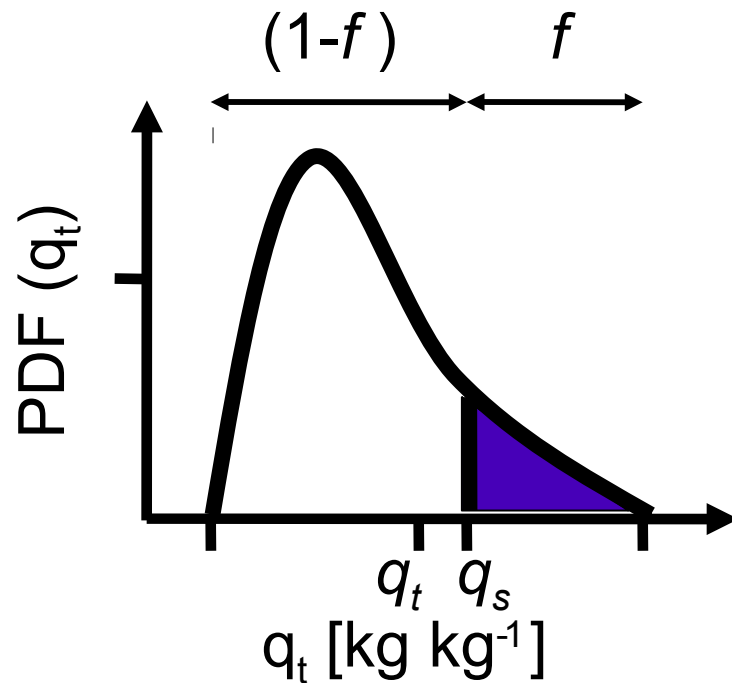
Mean: 36.6 %

Mean: 20.7 %

Mean: 19.6 %



Statistical cloud scheme: simulation of higher moments

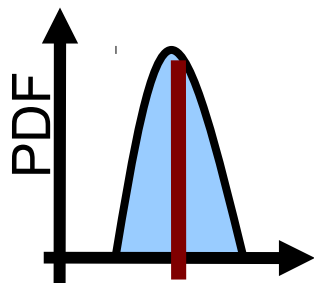


$$q_l = \int_{q_s}^{\infty} \text{PDF}(q_t) dq_t$$

Prognostic probability density function (PDF)
of total water mixing ratio

f cloud fraction [%]
 $(1-f)$ clear-sky fraction [%]
 q_t total water mixing ratio [kg kg⁻¹]
 q_s saturation mixing ratio [kg kg⁻¹]
 q_l liquid water mixing ratio [kg kg⁻¹]

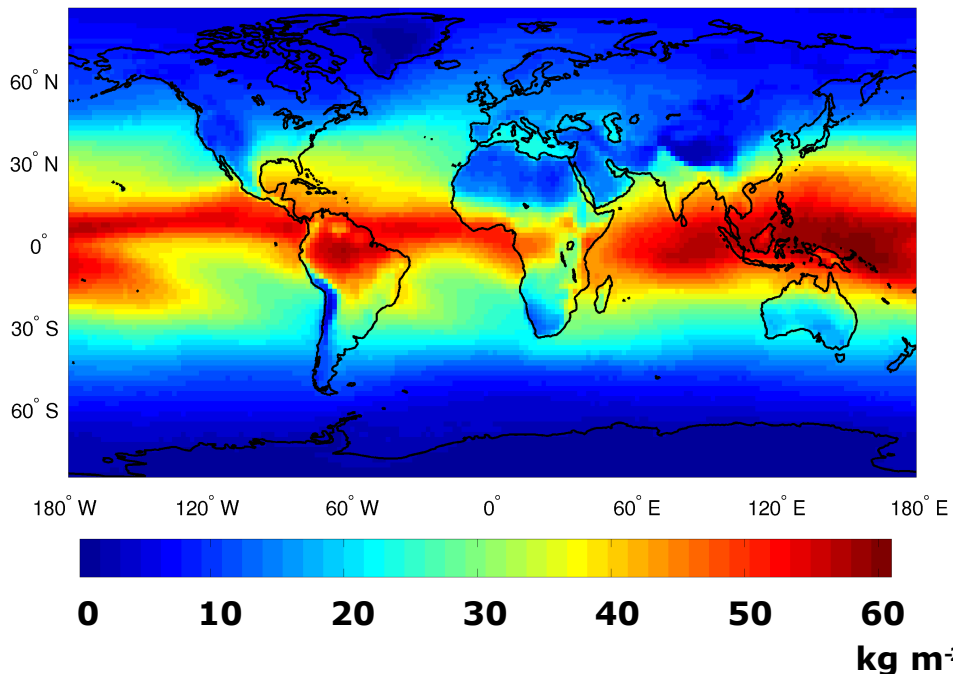
Statistical cloud scheme



MODIS satellite Data

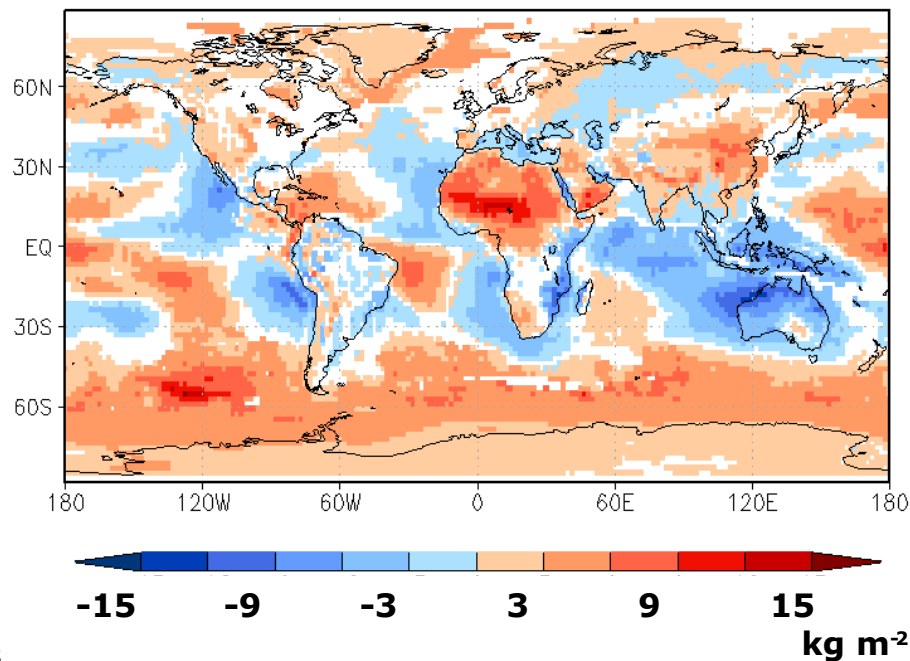
Model – Satellite Data

Mean total water path (TWP)

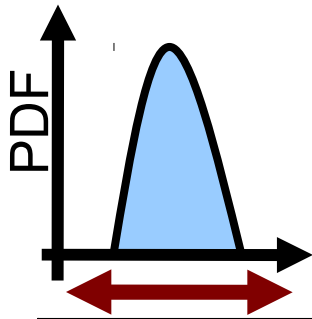


Deviation TWP

global mean bias 1.71%



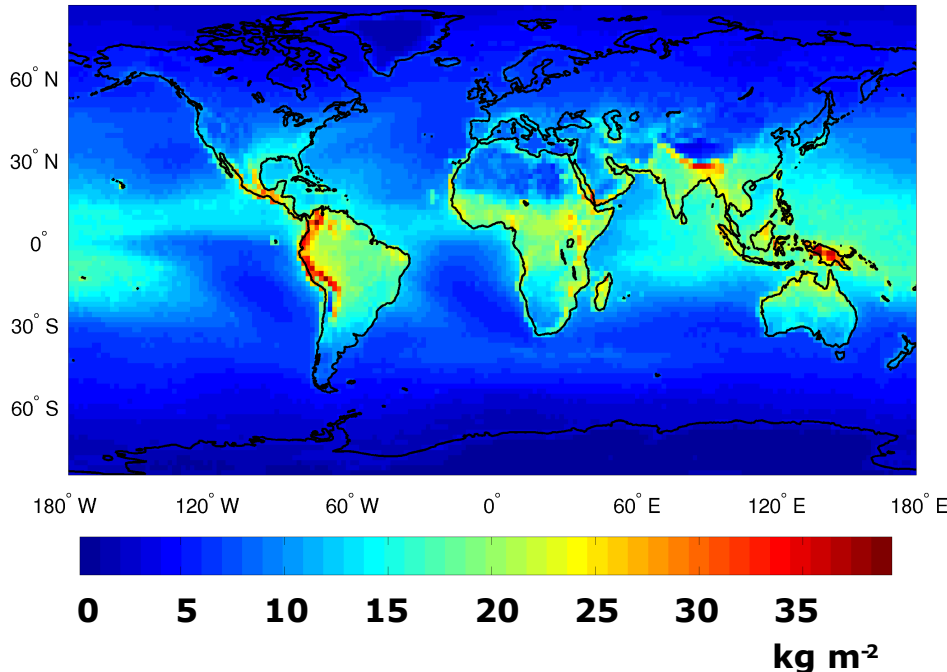
Statistical cloud scheme



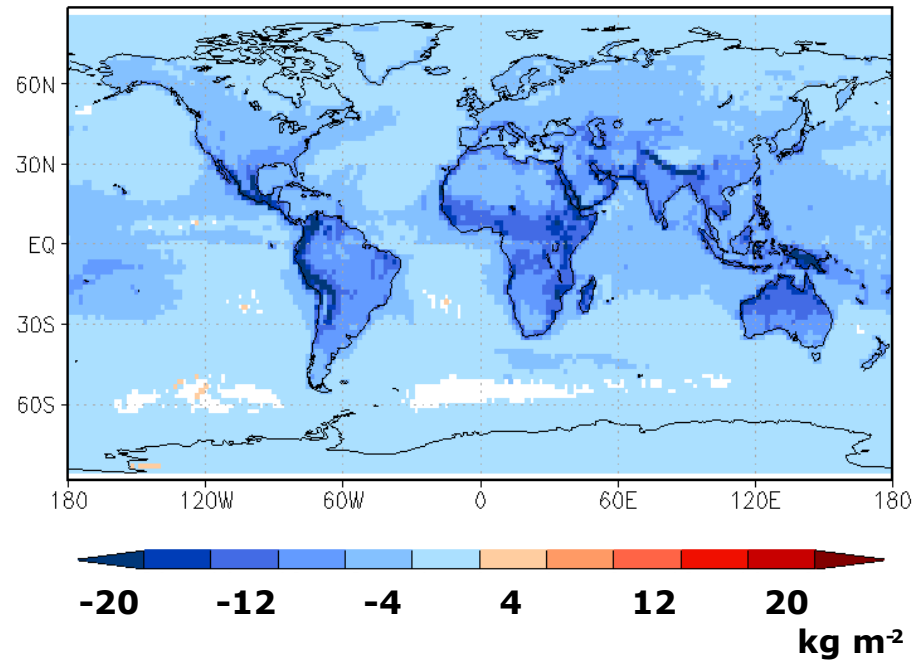
Satellite Data

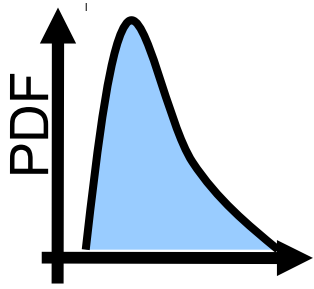
Model – Satellite Data

Distribution width



Deviation distribution width global mean bias -53.41%



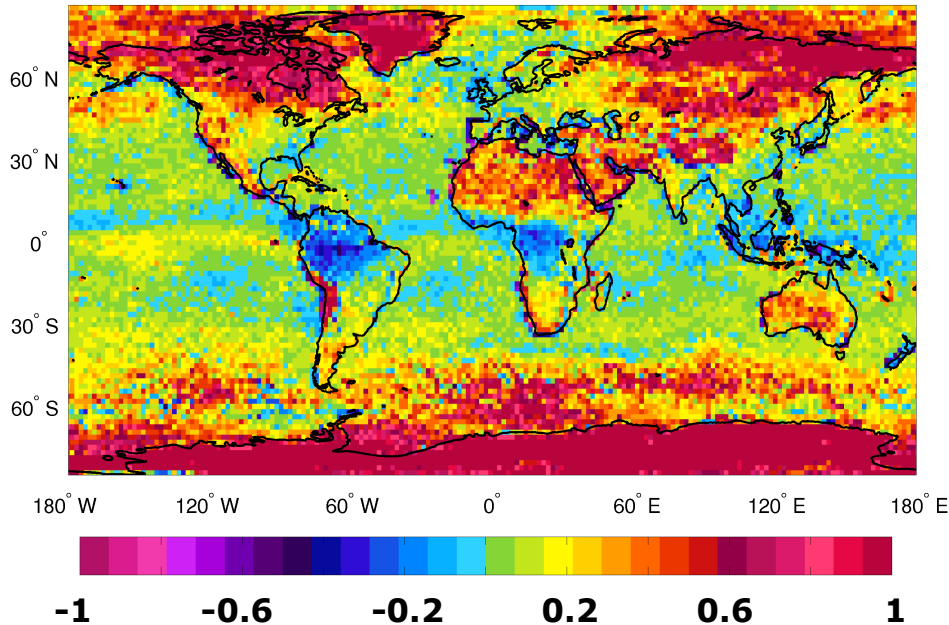


Statistical cloud scheme

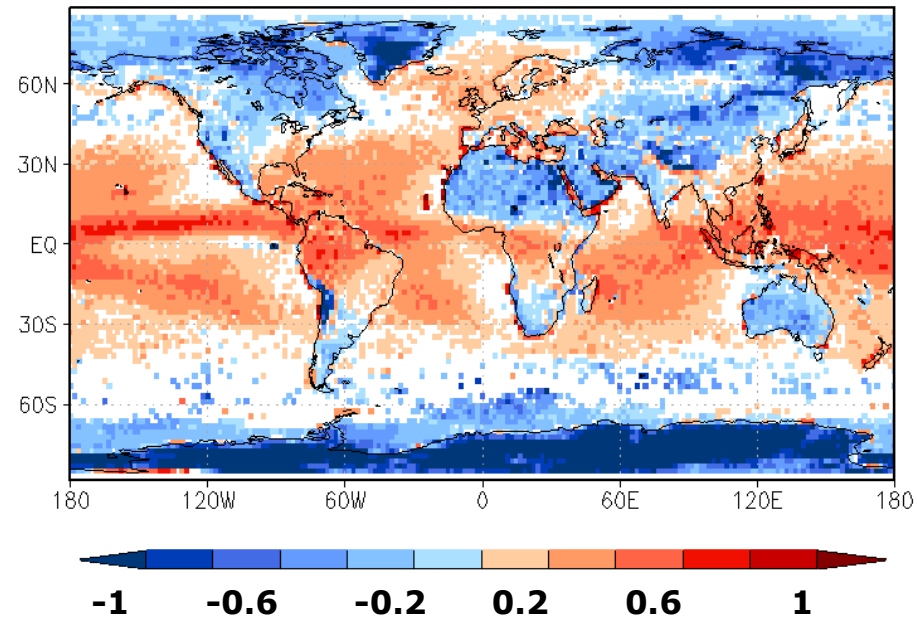
Satellite Data

Model – Satellite Data

Skewness



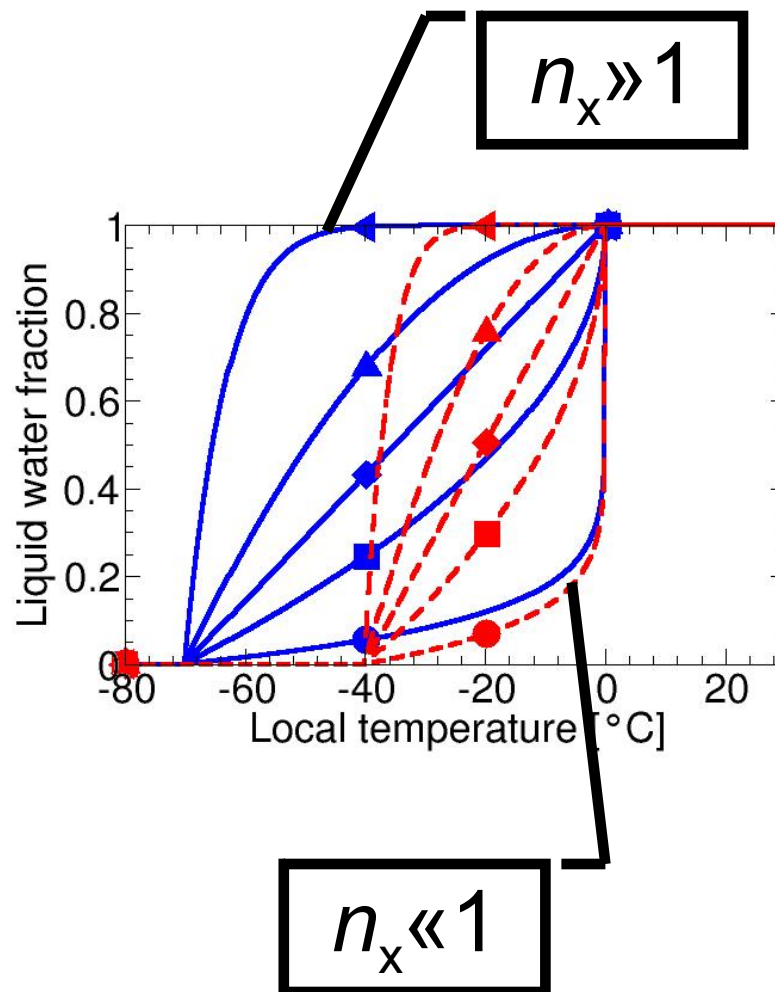
Deviation skewness global mean bias -8.46%



Parameterization of thermodynamic phase

Thermodynamic phase of condensed water:
Function of local temperature

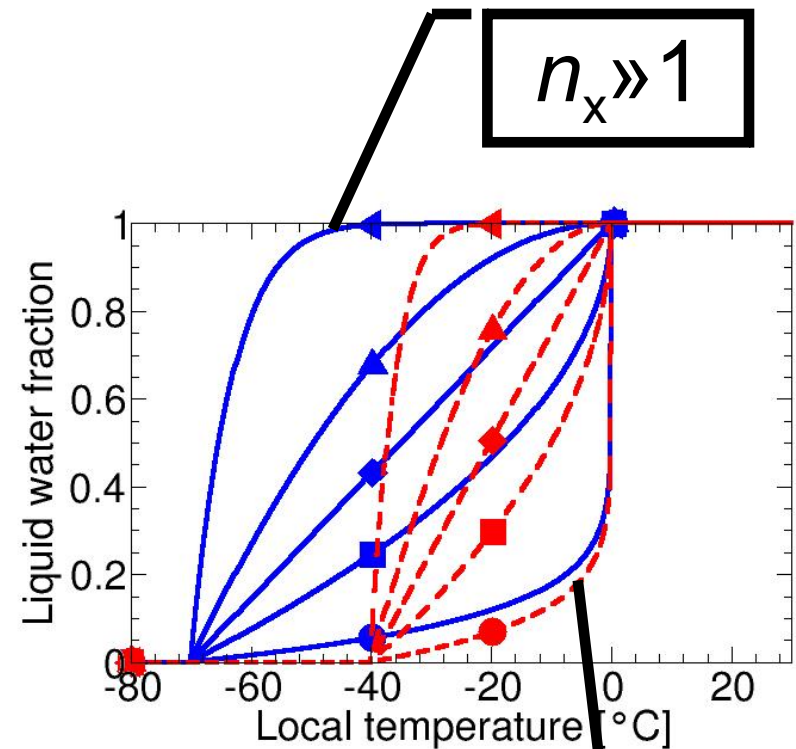
$$x_{liq} = \begin{cases} 0 & T < T_{ice} \\ \left(\frac{T - T_{ice}}{T_0 - T_{ice}} \right)^{n_x} & T_{ice} < T < T_0 \\ 1 & T_0 < T \end{cases}$$



Parameterization of thermodynamic phase

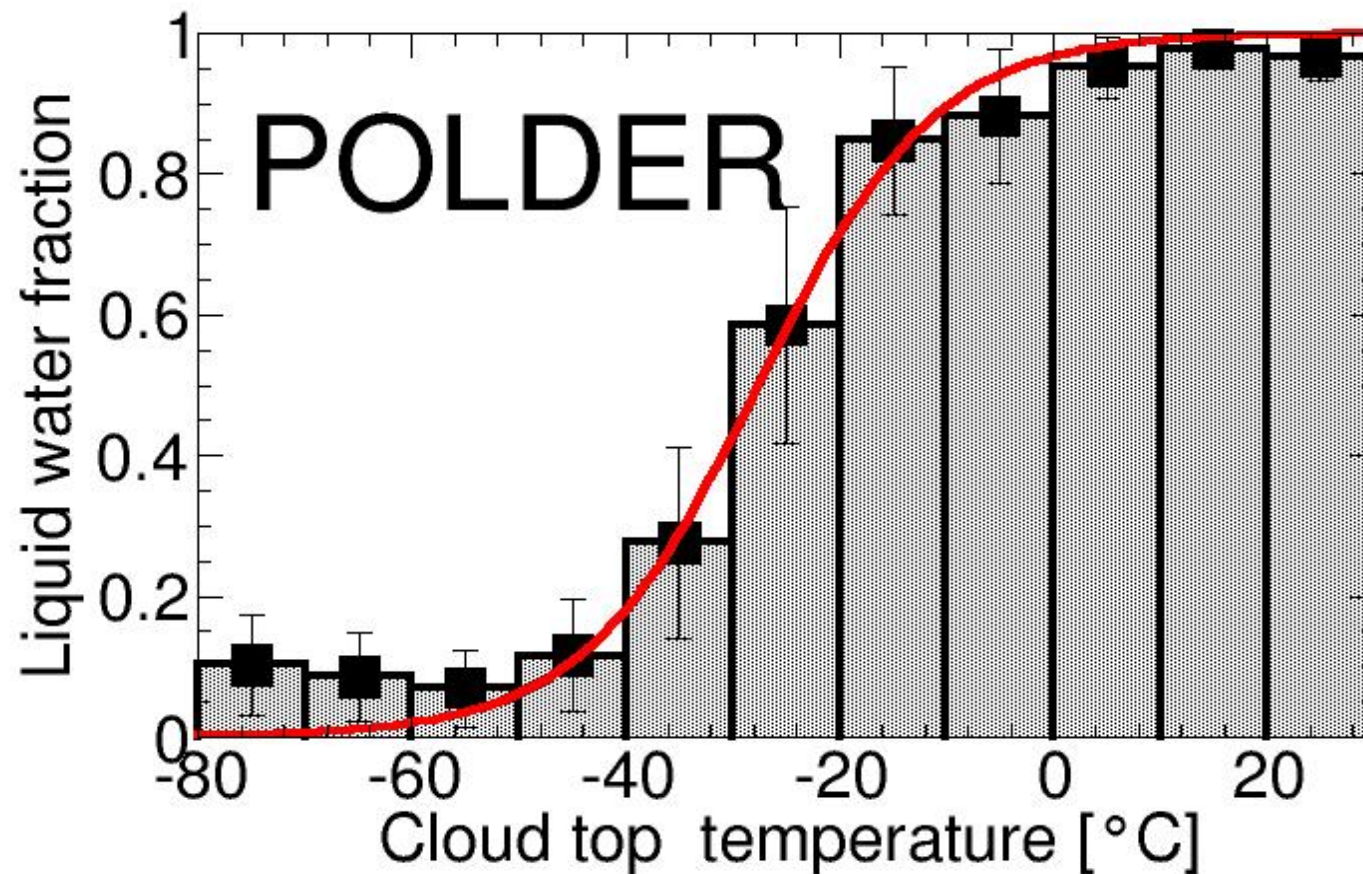
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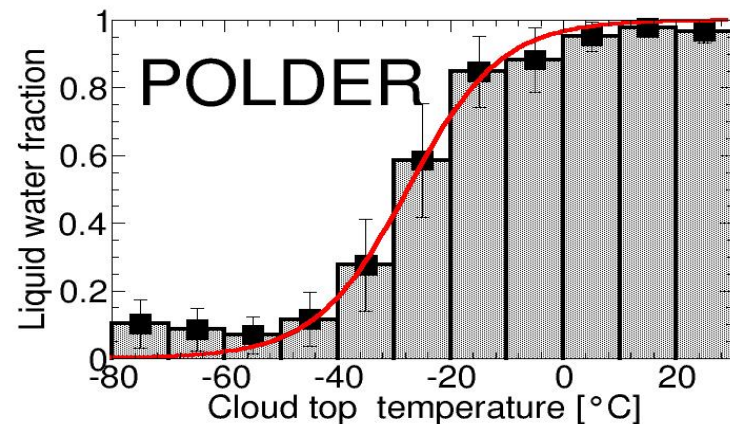
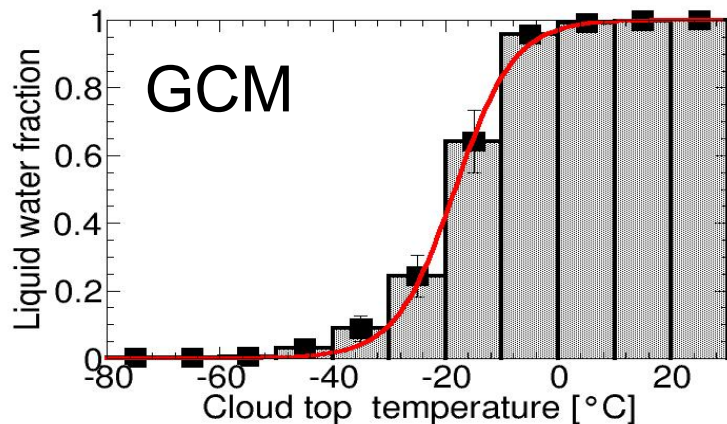


- 2 parameters:
 T_{ice} , n_x , ($T_0 \equiv 0^\circ\text{C}$)

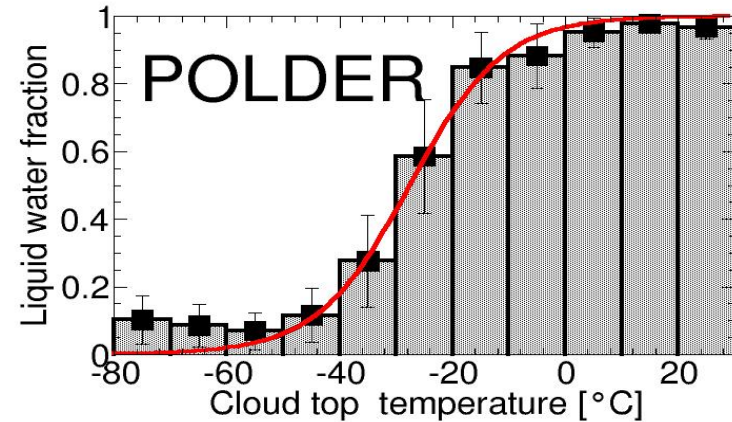
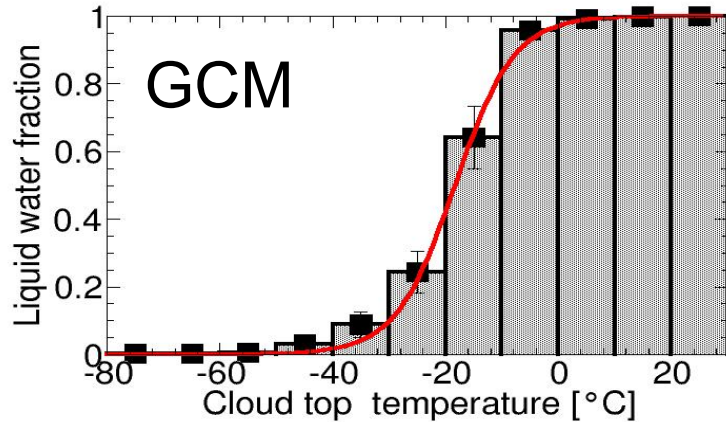
Parameterization of thermodynamic phase



Parameterization of thermodynamic phase



Parameterization of thermodynamic phase



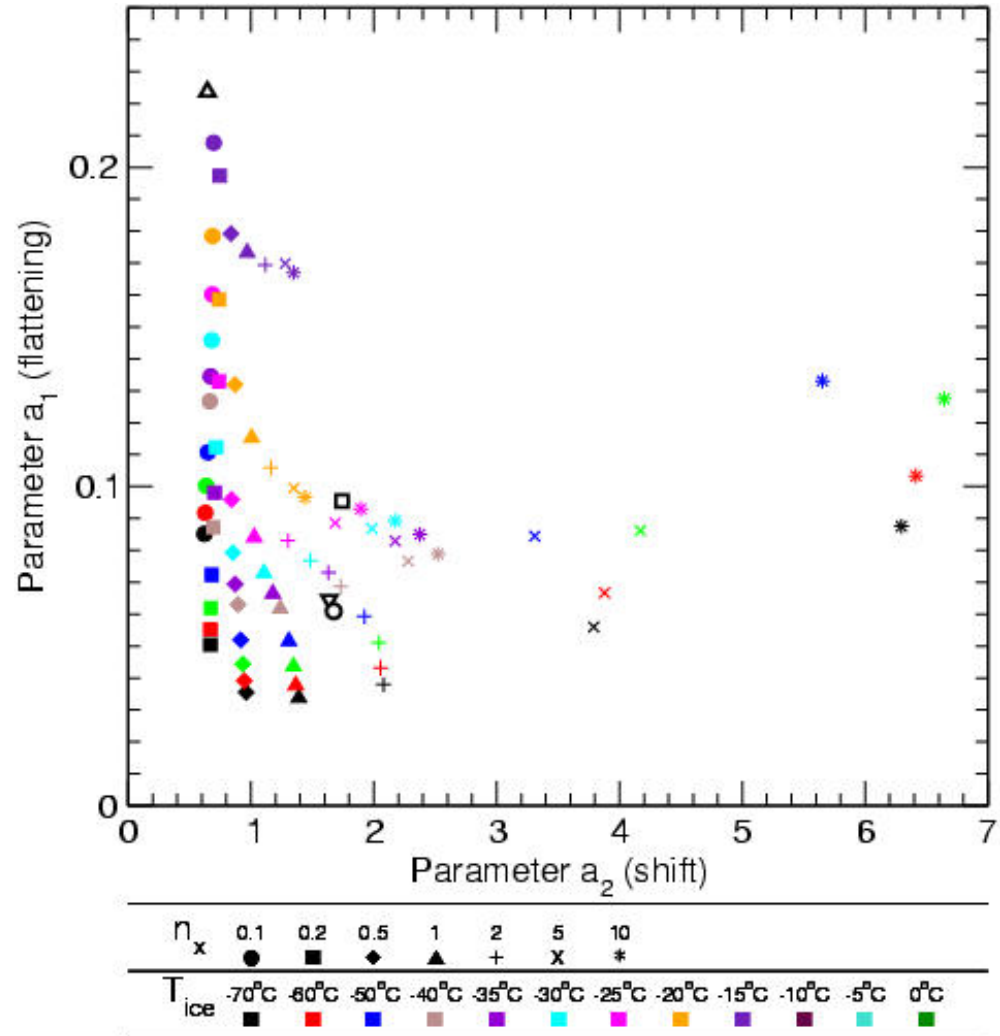
- Fit: hyperbolic tangent

$$x_{\text{liq}} = \frac{1}{2} (1 + \tanh(\mathbf{a}_1 T + \mathbf{a}_2))$$

Parameterization of thermodynamic phase

Find best fit

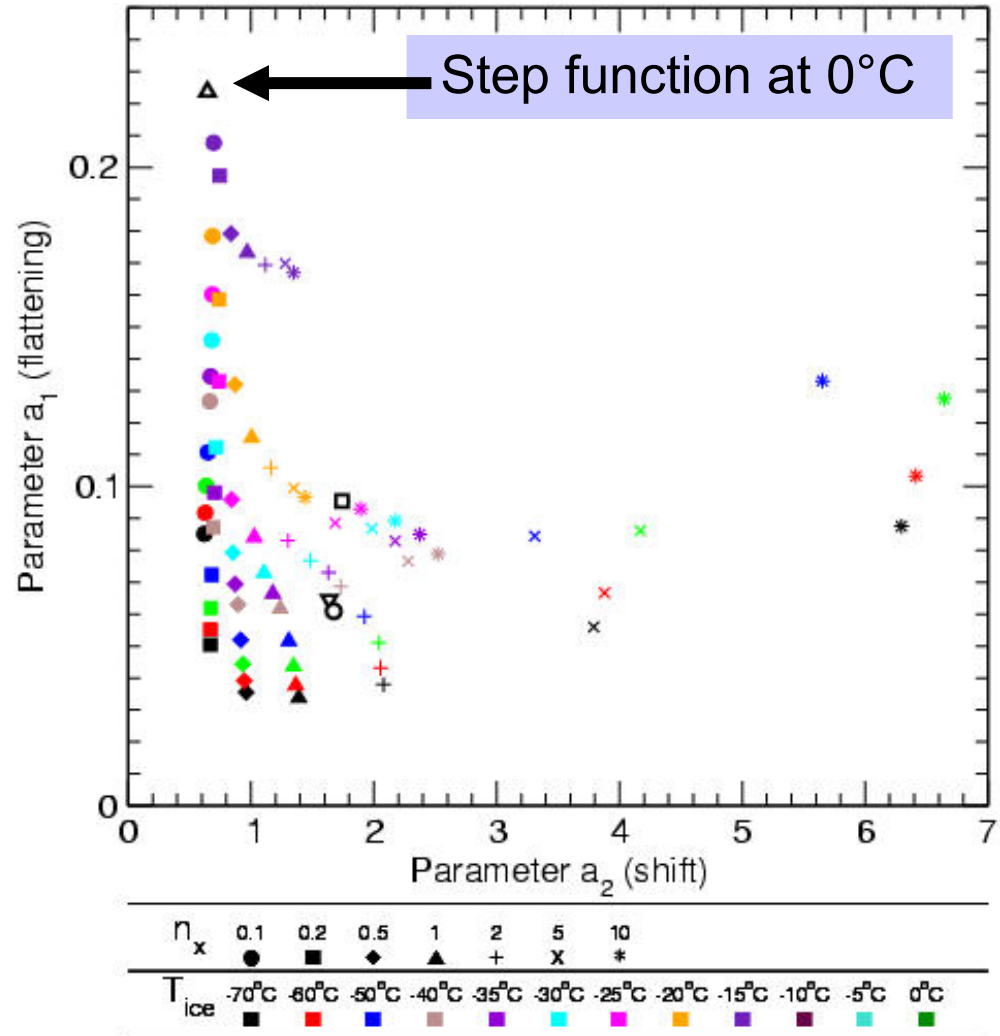
- Result 3 days \cong 8 months
- 77 short simulations



Parameterization of thermodynamic phase

Find best fit

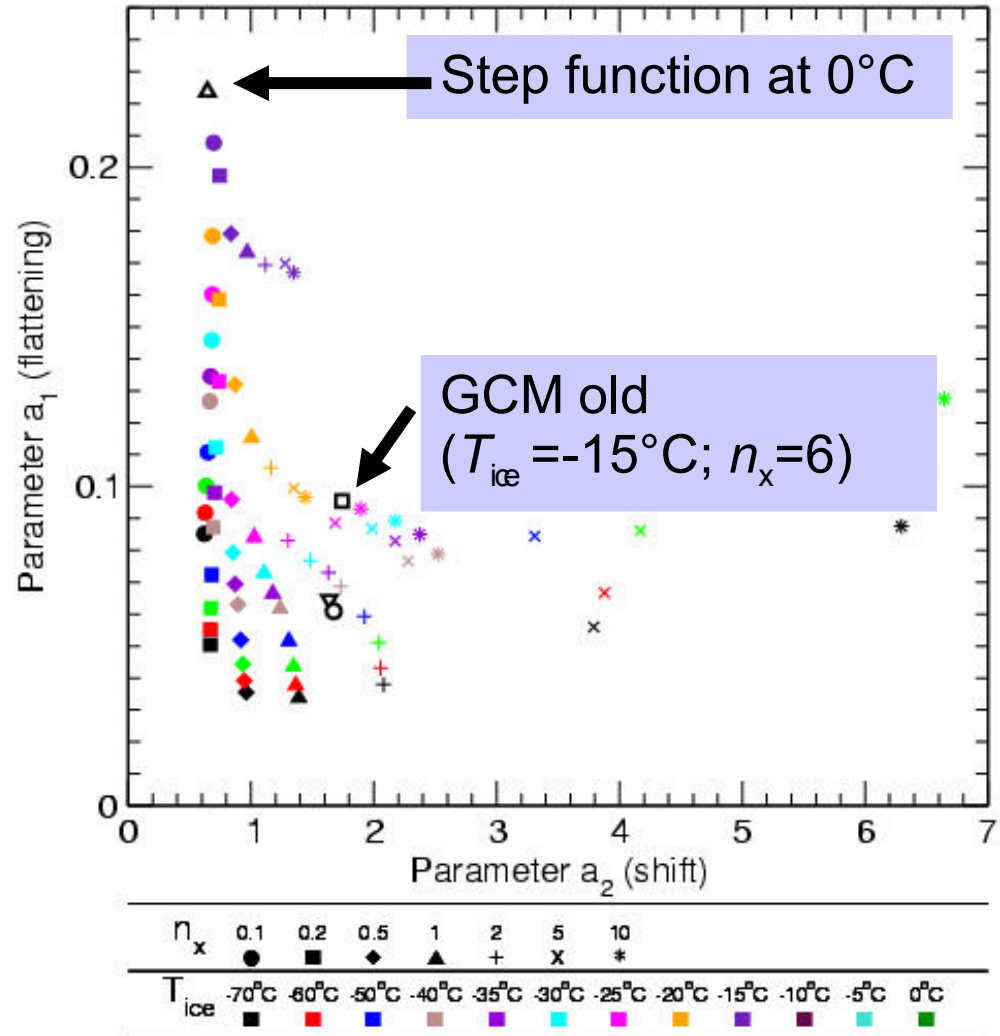
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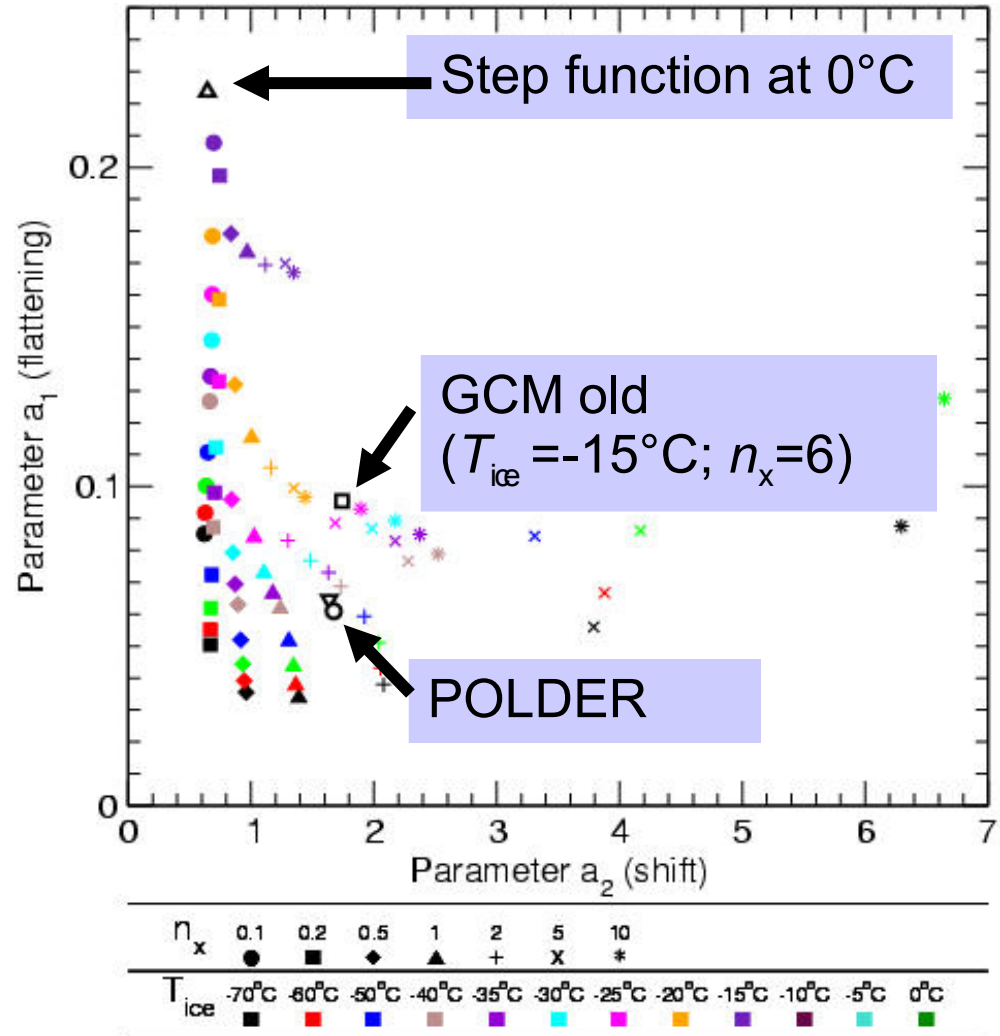
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Parameterization of thermodynamic phase

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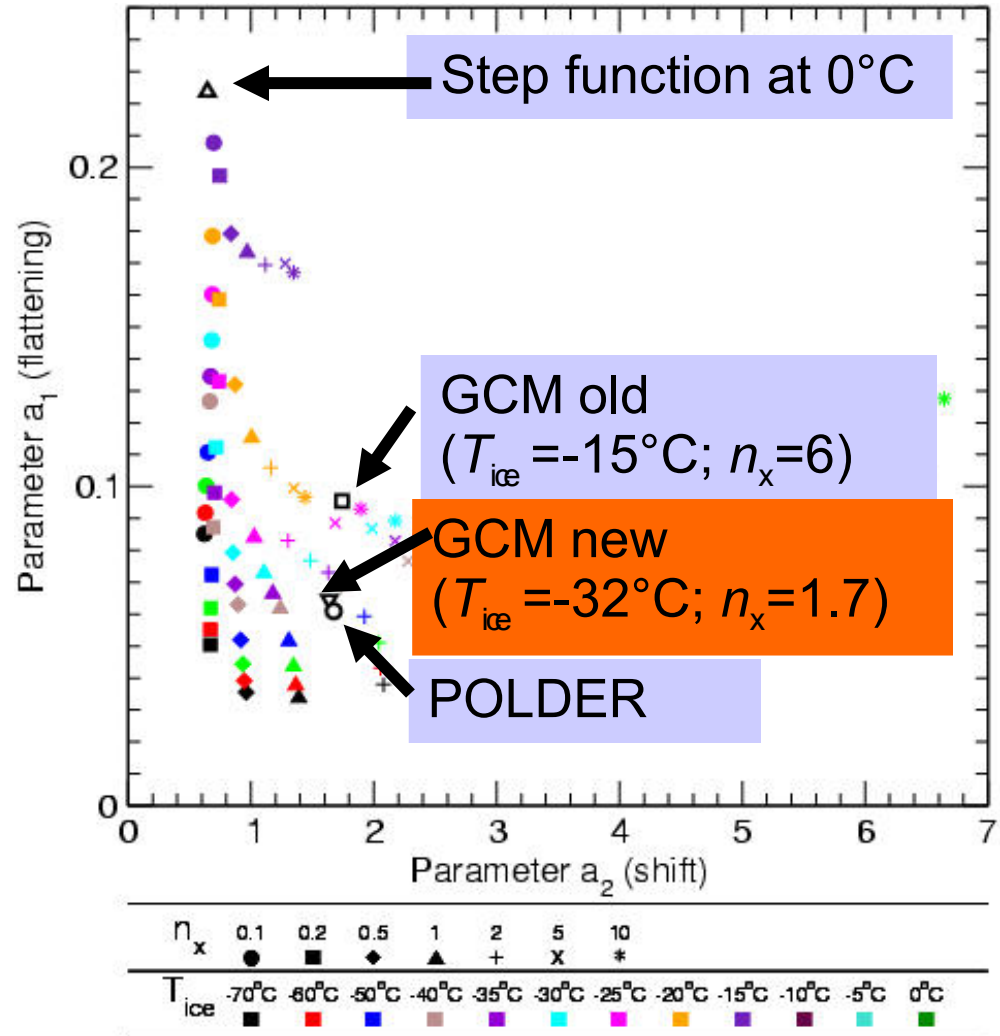
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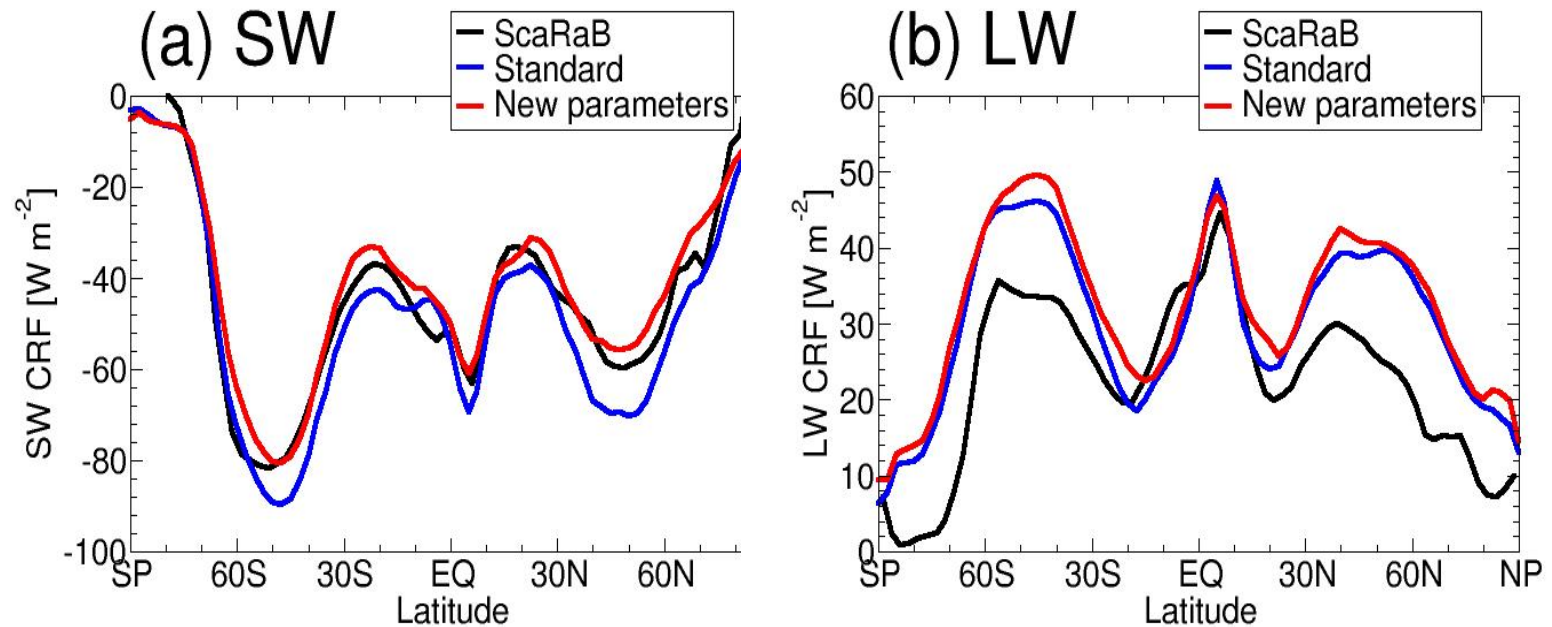
Parameterization of thermodynamic phase

Find best fit

- Result 3 days \cong 8 months
- 77 short simulations
- Parameters found:
 $T_{ice} = -32^\circ\text{C}$
 $n_x = 1.7$



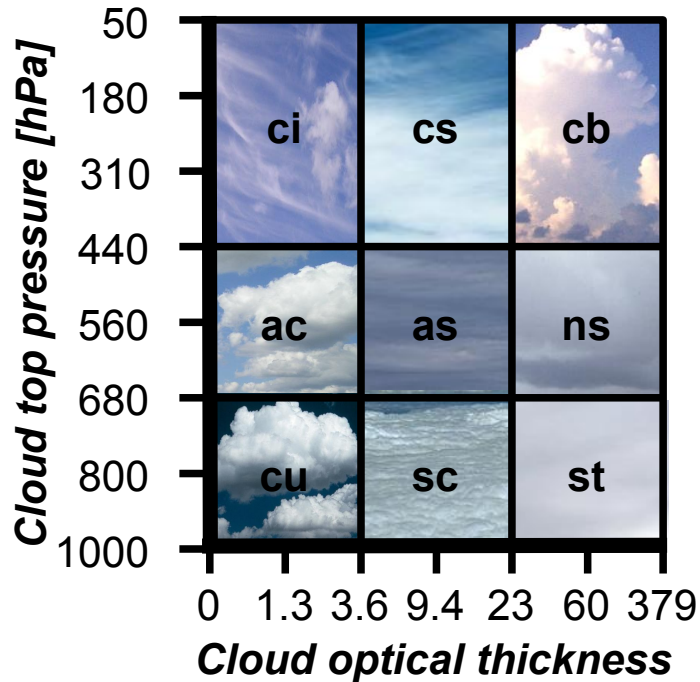
Parameterization of thermodynamic phase



Results for cloud radiative effects

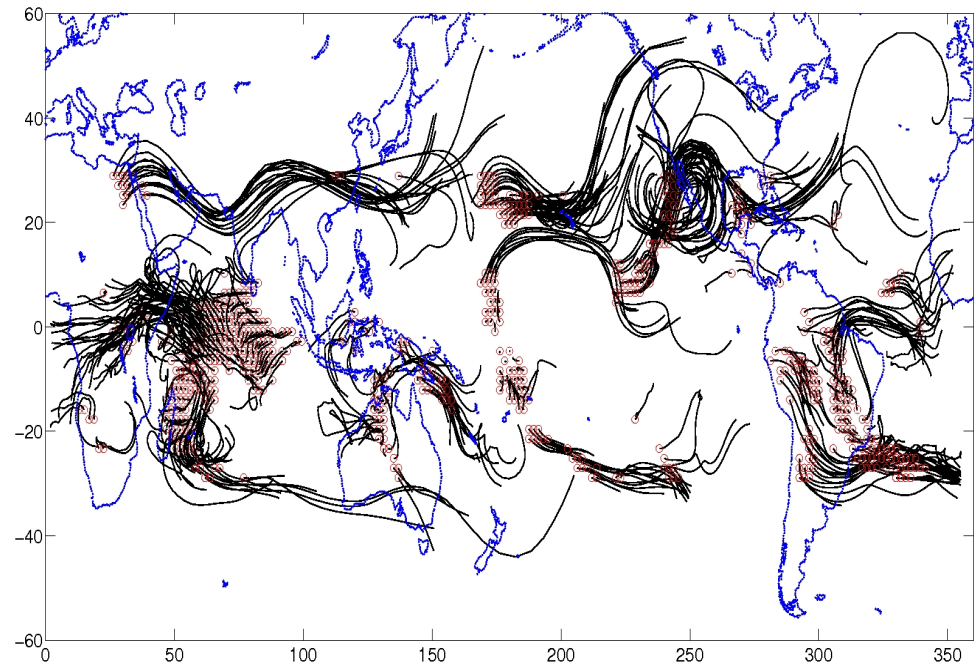
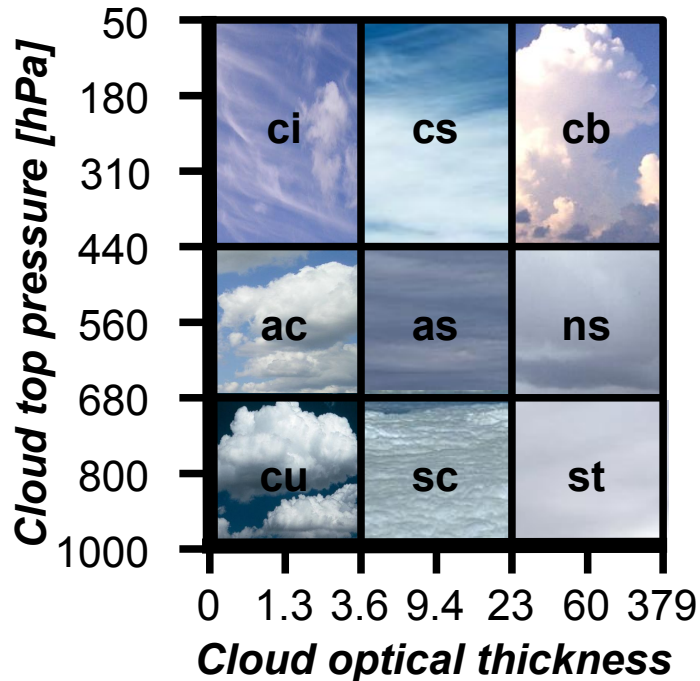
***ScaRaB**: Scanner of the earth's Radiation Budget (French broadband-radiometer)

Life cycle of convection-detained cirrus



Start Lagrangian tracking (HySPLIT) from grid-points where cb fraction > 10% and decreasing

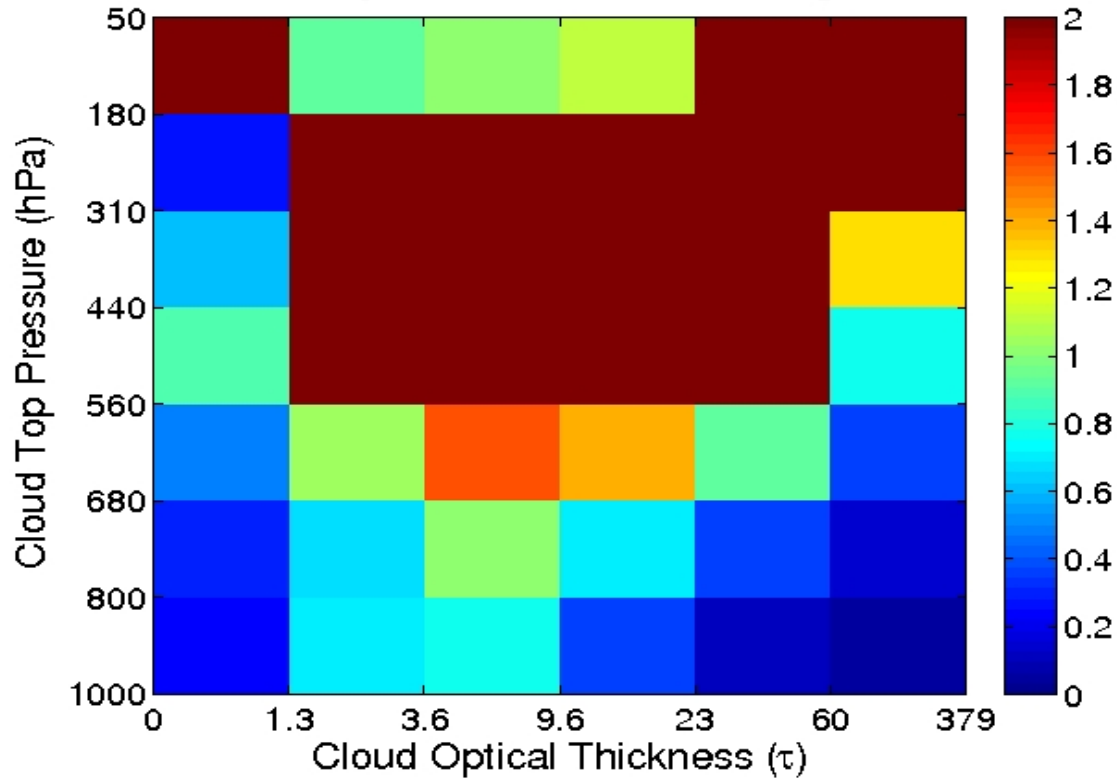
Life cycle of convection-detrained cirrus



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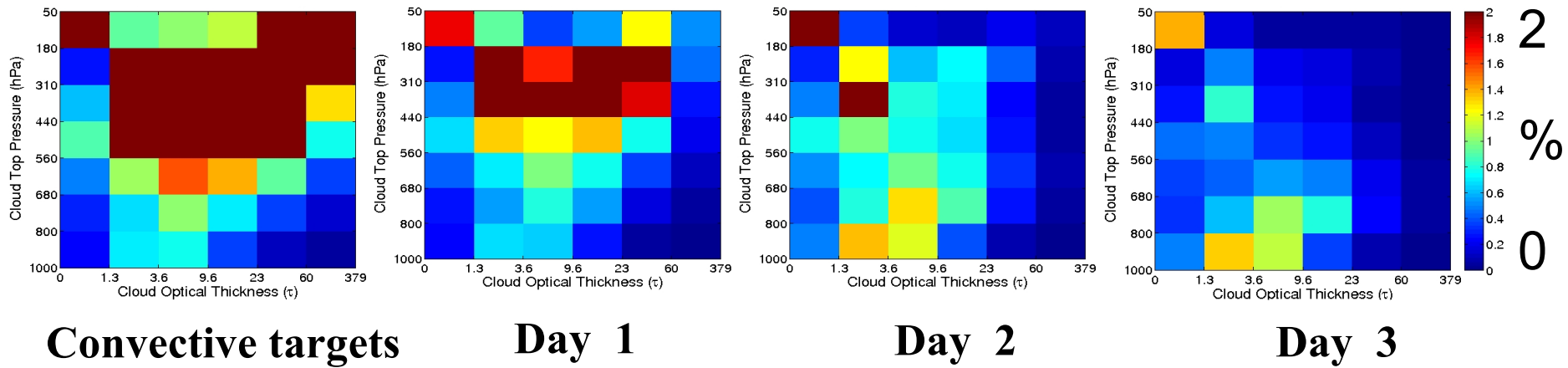
Life cycle of convection-detained cirrus

January 2002 – Convective targets



ISCCP data
ERA40 for trajectories

Life cycle of convection-detrained cirrus



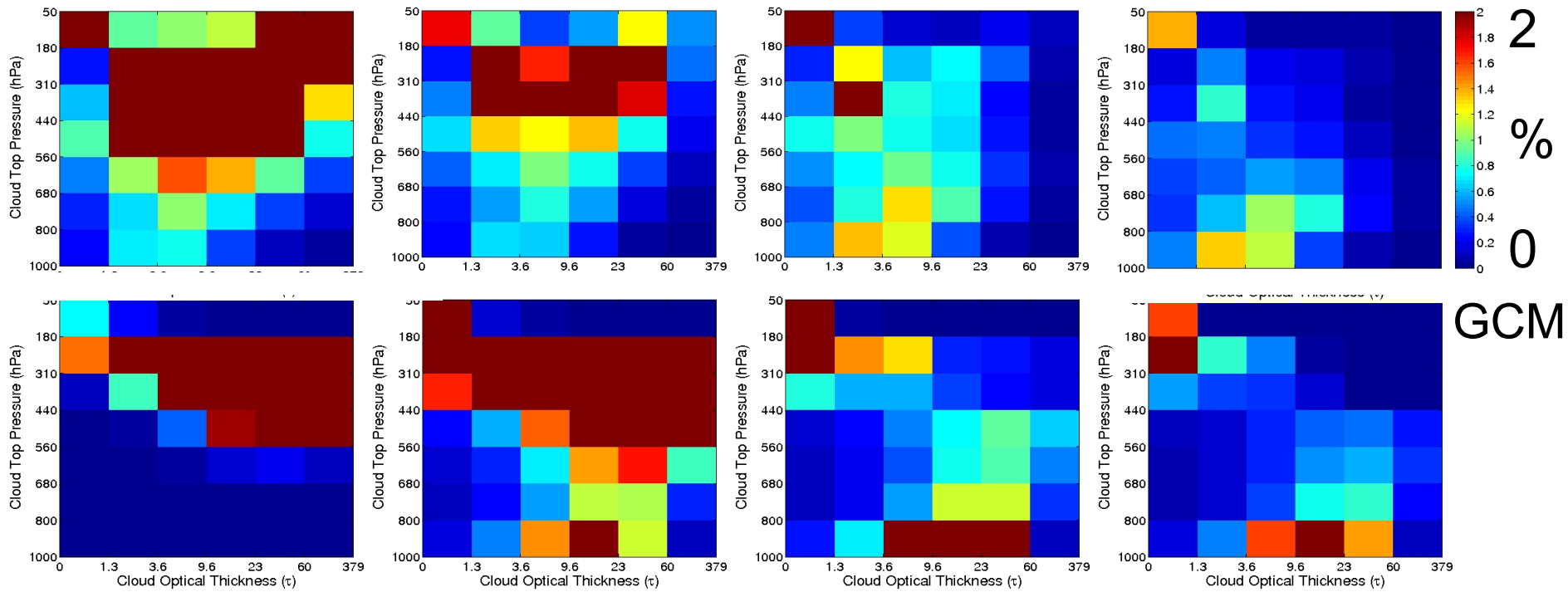
Convective targets

Day 1

Day 2

Day 3

Life cycle of convection-detrained cirrus



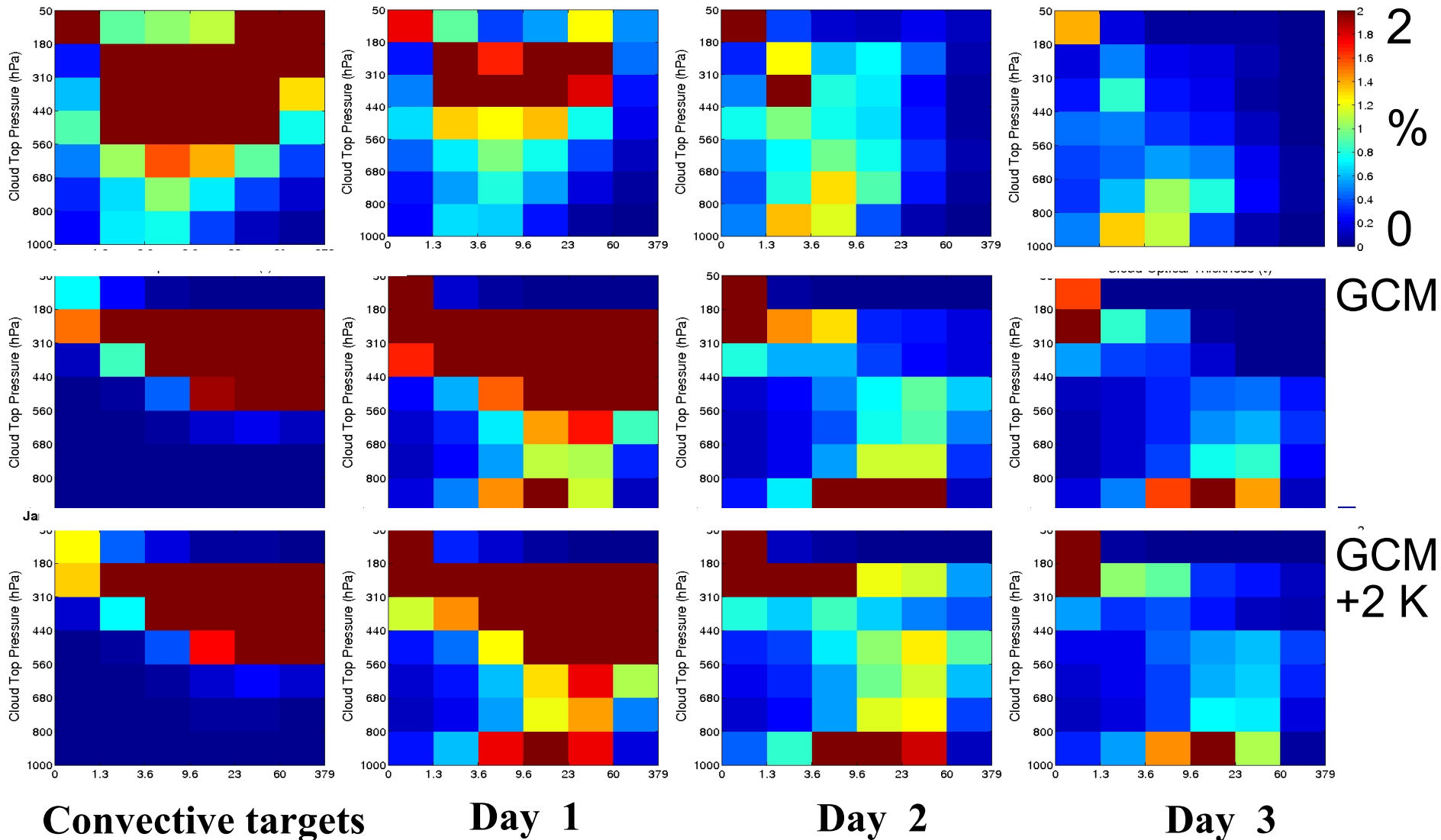
Convective targets

Day 1

Day 2

Day 3

Life cycle of convection-detained cirrus



Conclusions: Needs for GCM evaluation

- Satellite **simulators** widely used now
 - > CFMIP/COSP; CMIP5; EUCLIPSE
- Evaluation of higher moments
 - > water vapour and high resolution essential
- Process studies
 - > co-located multi-parameter datasets highly useful
 - > high spatio-temporal resolution necessary
- Retrievals remain important
 - > (but data assimilation is useful, too)

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