A quantitative assessment of cloud regimes in climate models

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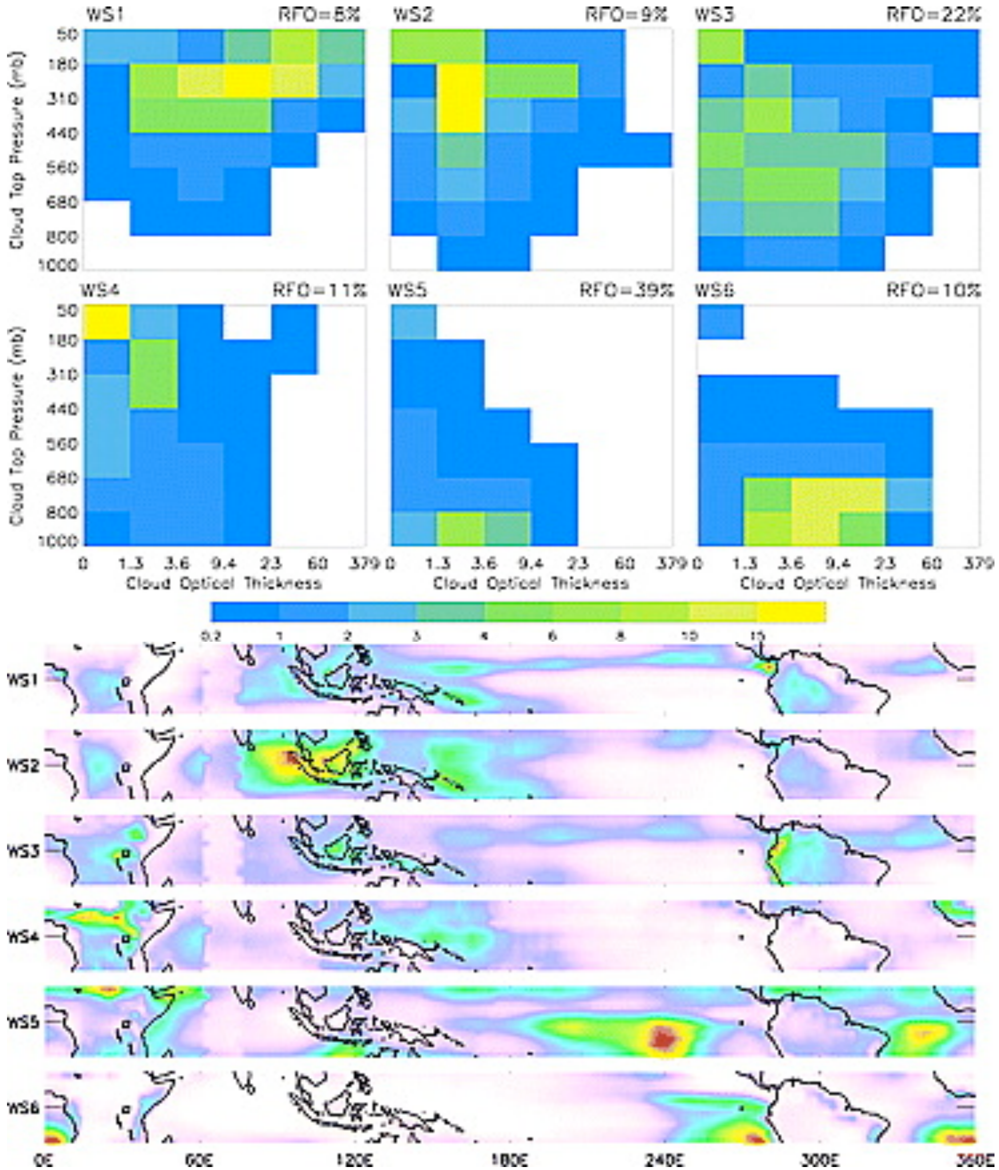
WCRP OSC, Denver, 26/10/11

Why look at cloud regimes?

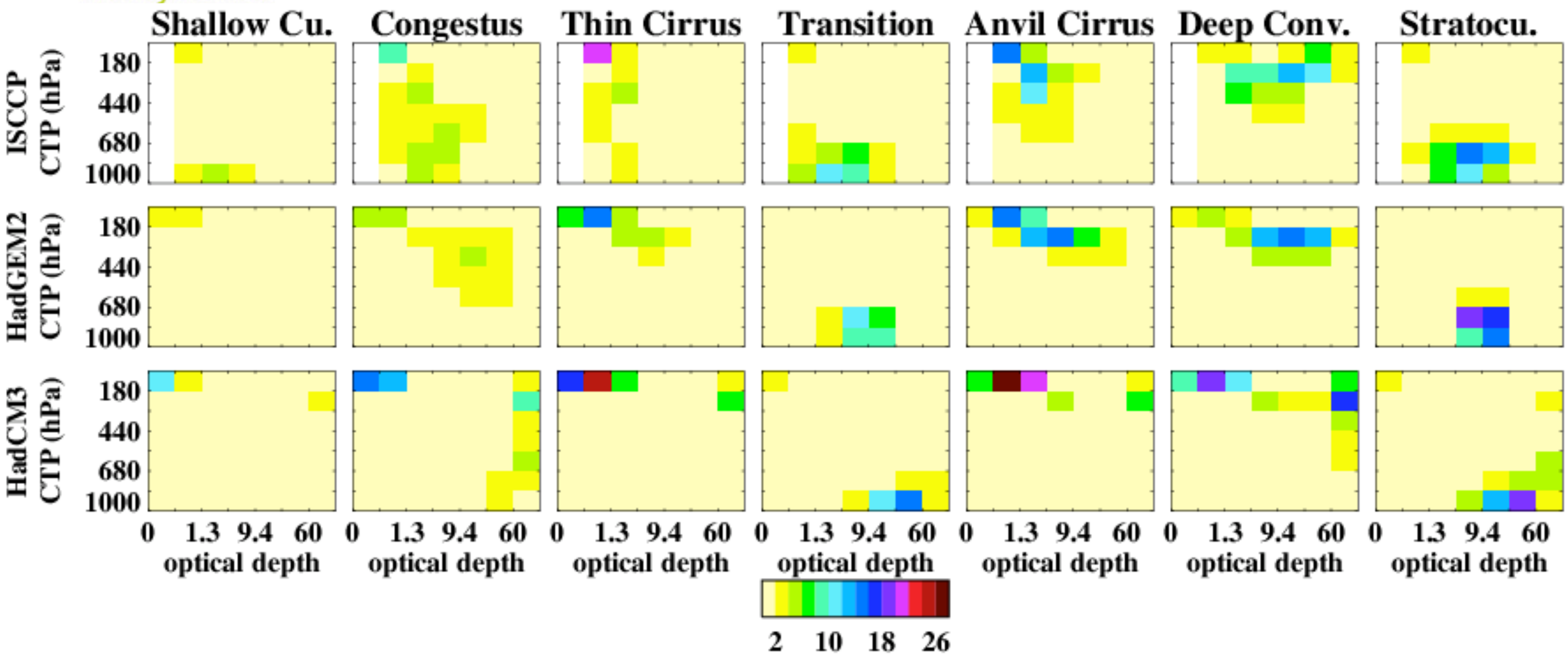
- Differences in the radiative feedback from clouds between GCMs accounts for much of the uncertainty in climate sensitivity.
- Assessment of the ability of GCMs to accurately represent the radiative properties of clouds are therefore required.
- Clouds come in lots of shapes and sizes and very different processes are associated with, say, frontal cloud, deep convection and stratocumulus.
- Traditional assessment metrics which treat cloud as one entity can overlook compensating errors,
- It is useful to split the world into a manageable number of 'cloud regimes' in order to group together grid points where similar processes are operating.

ISCCP tropical cloud regimes



Rossow et al. (2005, GRL)

Observed and simulated tropical cloud regimes



Objective methodology to assign model data to the observed regimes is described by Williams and Webb (2009, Clim. Dyn.)

Required diagnostics in the 'cfday' table for CMIP5

Climate change response

In the cloud regime framework, the mean change in cloud radiative forcing can be thought of as having contributions from:

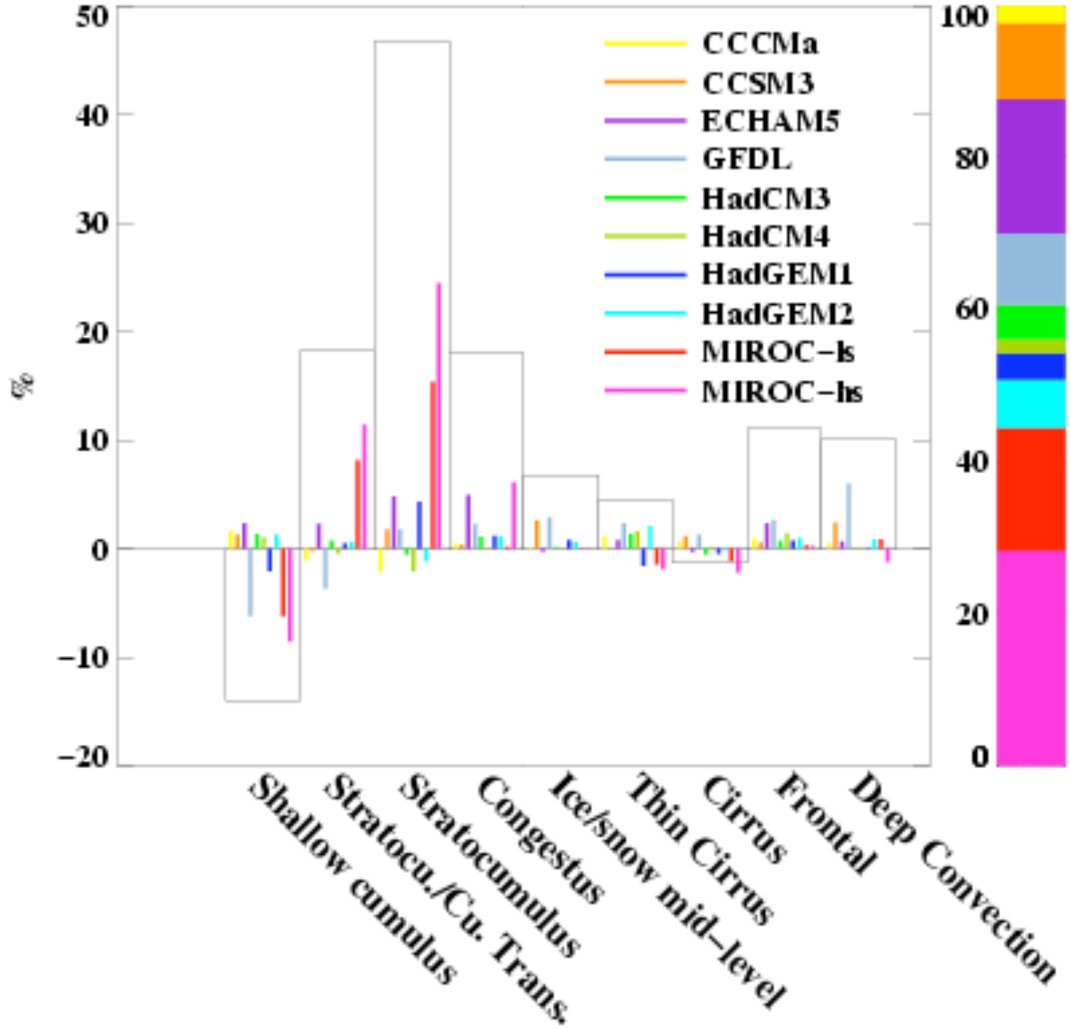
•A change in the RFO (Relative Frequency of Occurrence) of the regime

•A change in the NCRF (Net Cloud Radiative Forcing) within the regime (i.e. a change in the tau-CTP space occupied by the regime/development of different clusters).

$$\overline{\Delta NCRF} = \sum_{r=1}^{nregimes} NCRF_r \, \Delta RFO_r + \sum_{r=1}^{nregimes} RFO_r \, \Delta NCRF_r + \sum_{r=1}^{nregimes} \Delta RFO_r \, \Delta NCRF_r$$

Williams and Webb (2009)

Uncertainty in the radiative response under climate change (CMIP3)

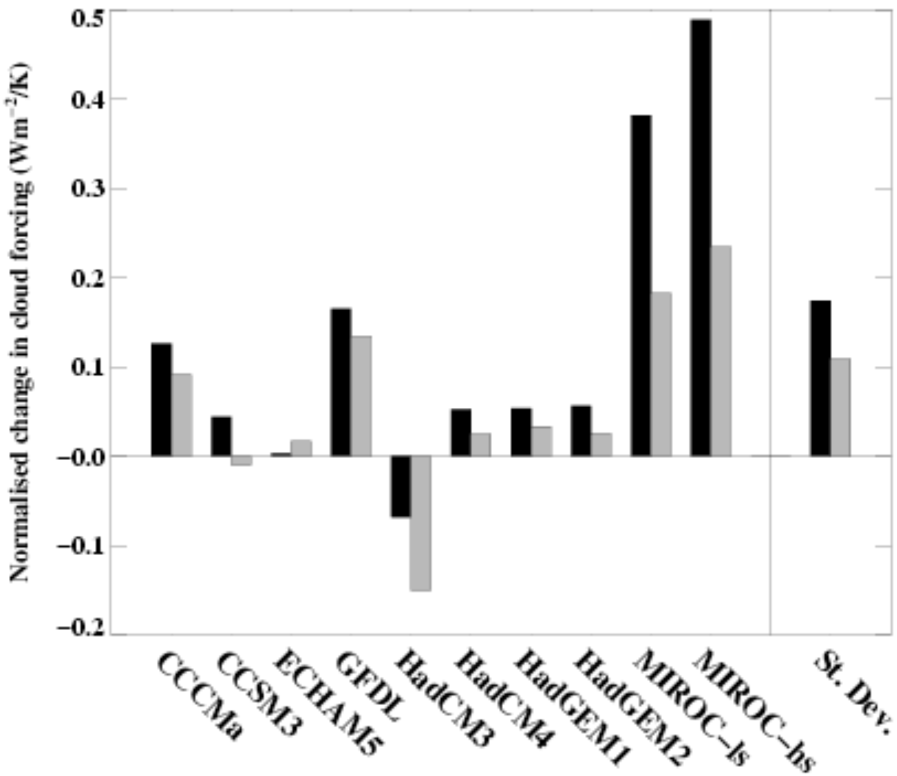


Contribution of each regime to the inter-model variance in the change in net cloud forcing.

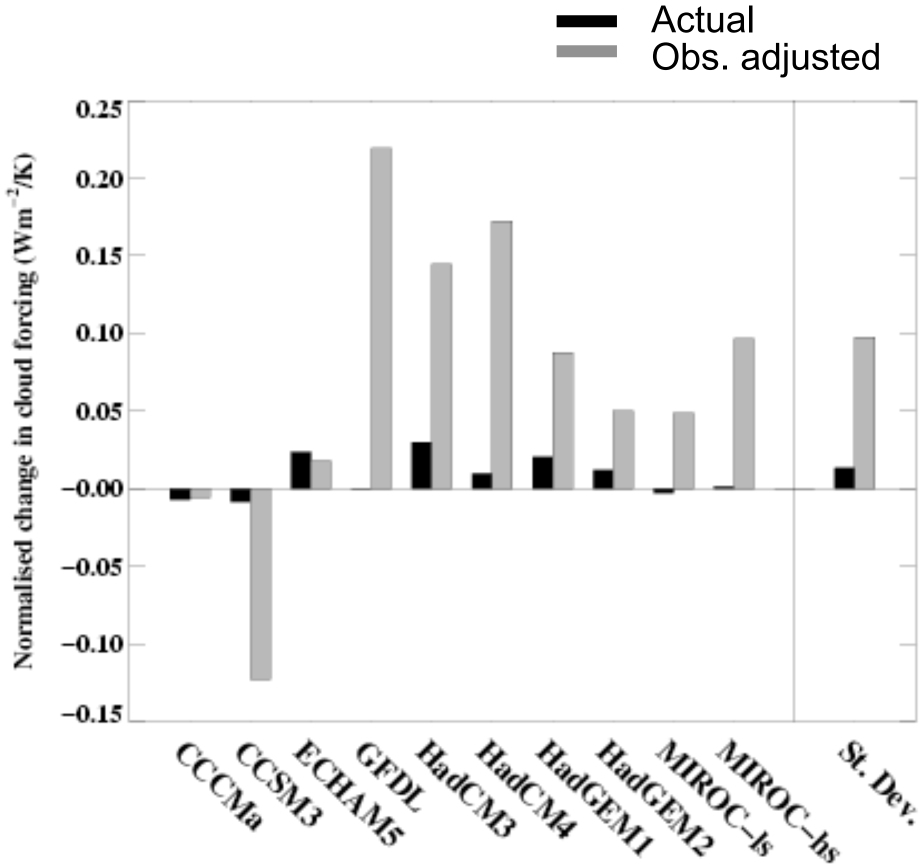
Williams and Webb (2009)

Uncertainty in the radiative response under climate change (CMIP3)

2xCO2 change in CRF of tropical transition (stratocu->cu) cloud

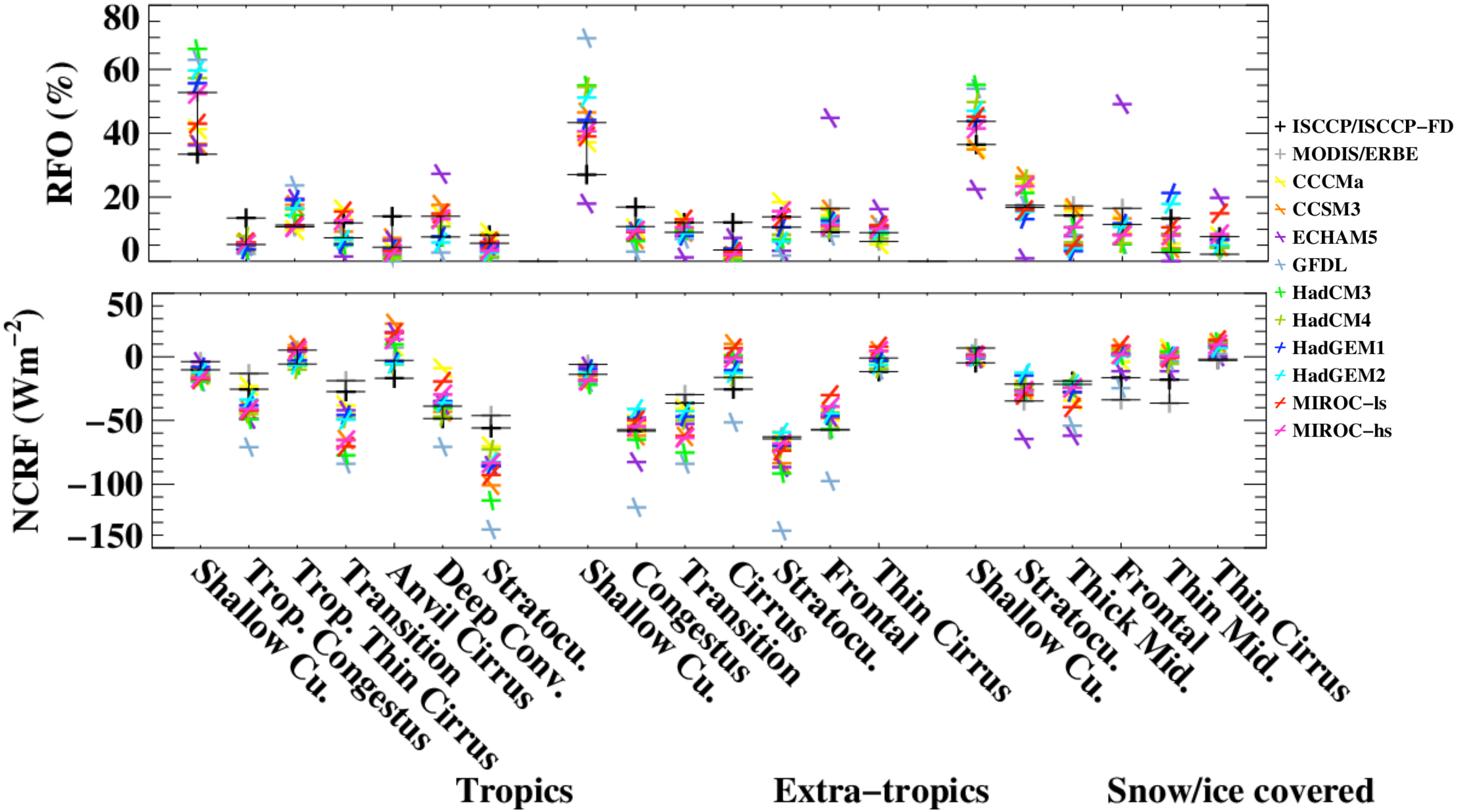


2xCO2 change in CRF of tropical anvil cirrus



Williams and Webb (2009)

Evaluation of regime properties (CMIP3)



Cloud Regime Error Metric

$$CREM_r = aw\sqrt{(NCRF'_r W_{RFOr})^2 + (RFO'_r W_{NCRFr})^2}$$

$CREM_r$ = Cloud regime error metric for regime r

aw = area weight of region (tropics, extra-tropics, polar)

$NCRF_r$ = Net cloud radiative forcing of regime

RFO_r = Relative frequency of occurrence of regime

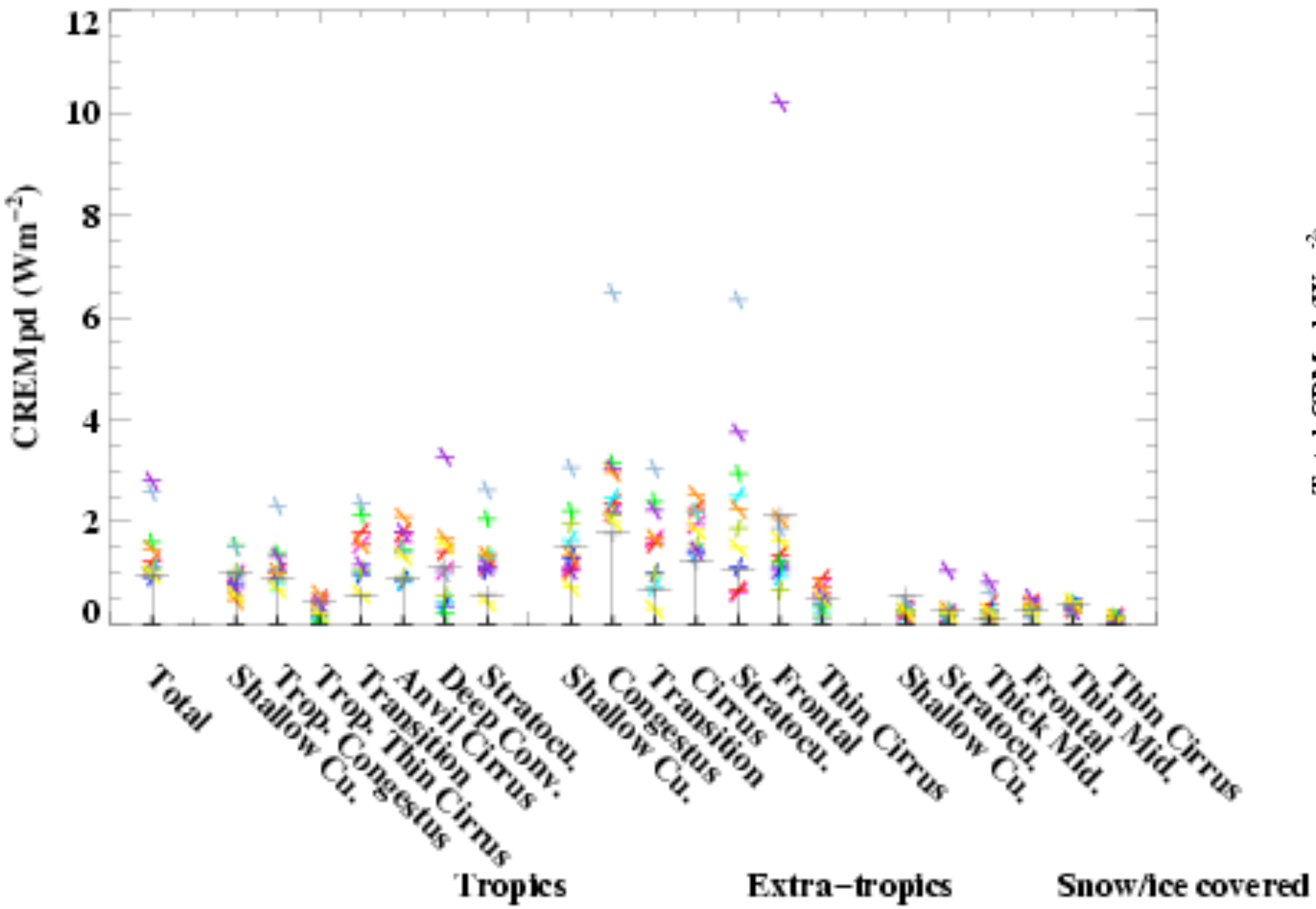
W_{RFOr} and W_{NCRFr} = Regime weights

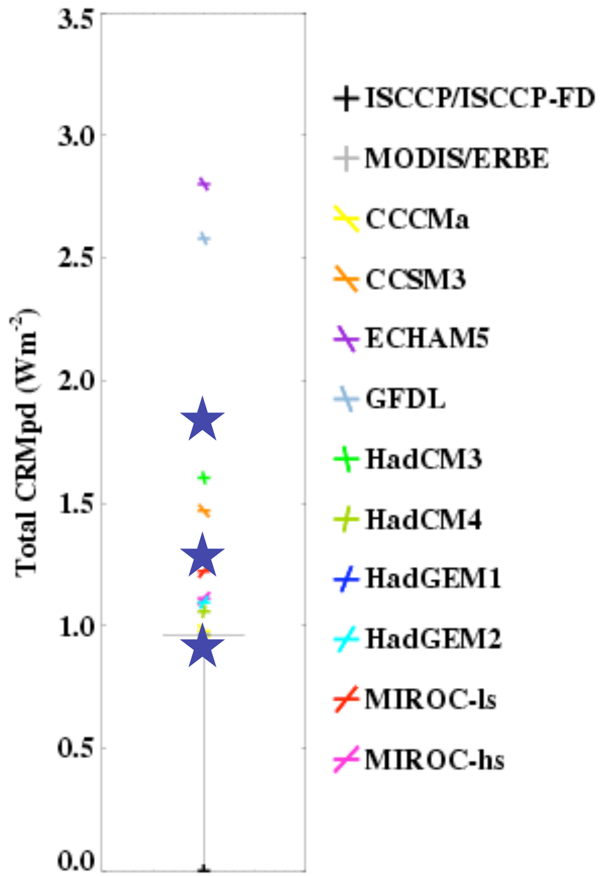
' = Difference from observations

Williams and Webb (2009)

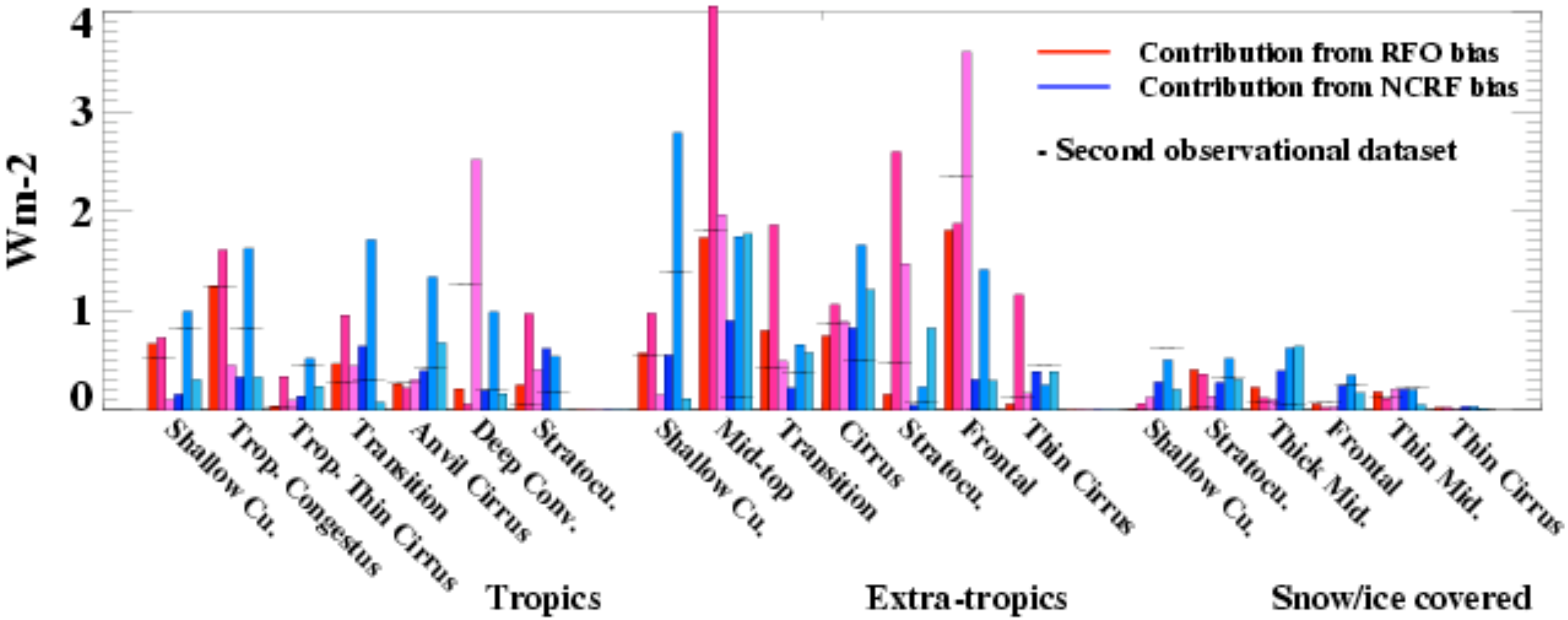
Cloud Regime Error Metric

CMIP3 & CMIP5

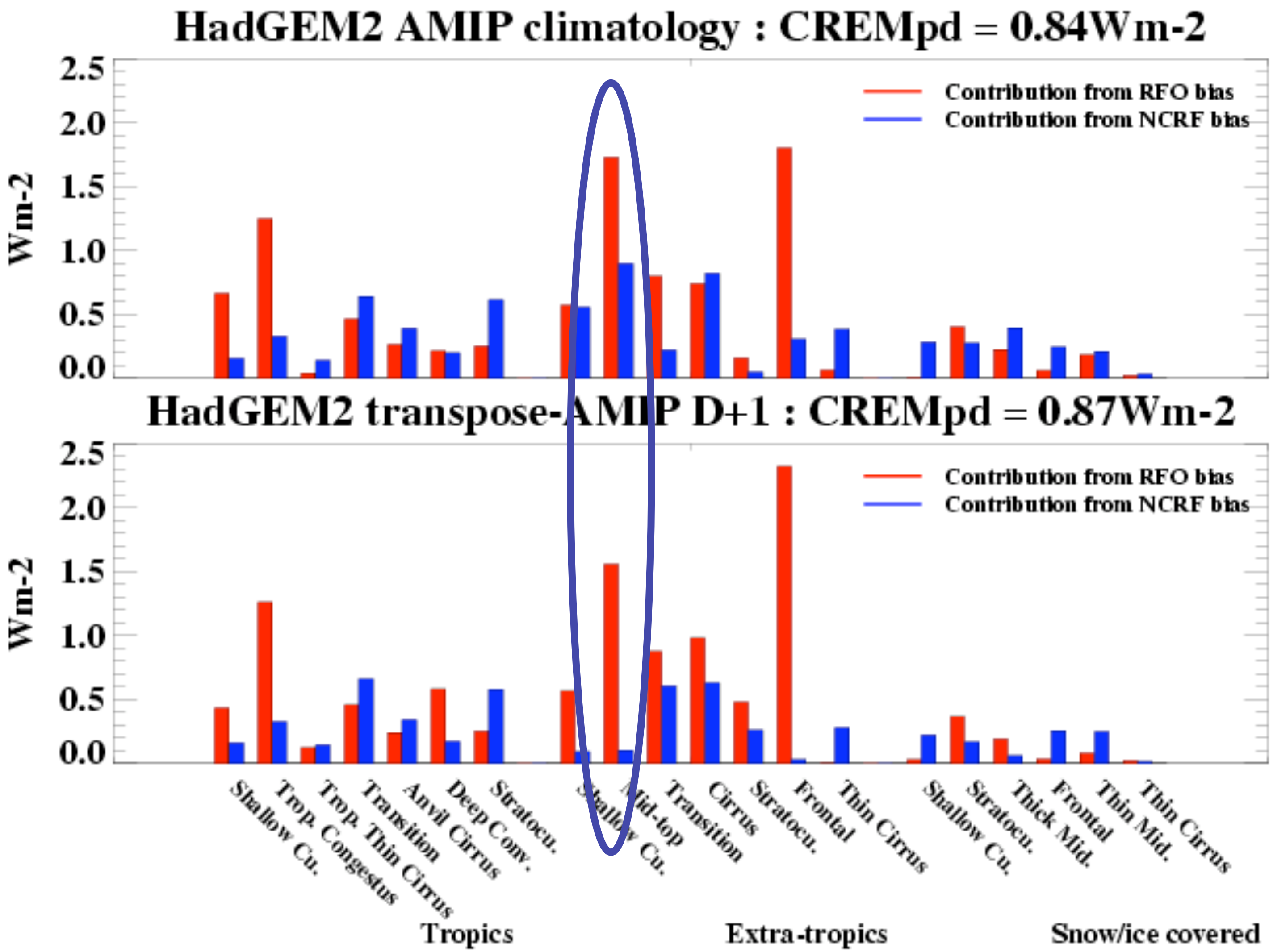




Breakdown of contribution to CREM – CMIP5 AMIP simulation

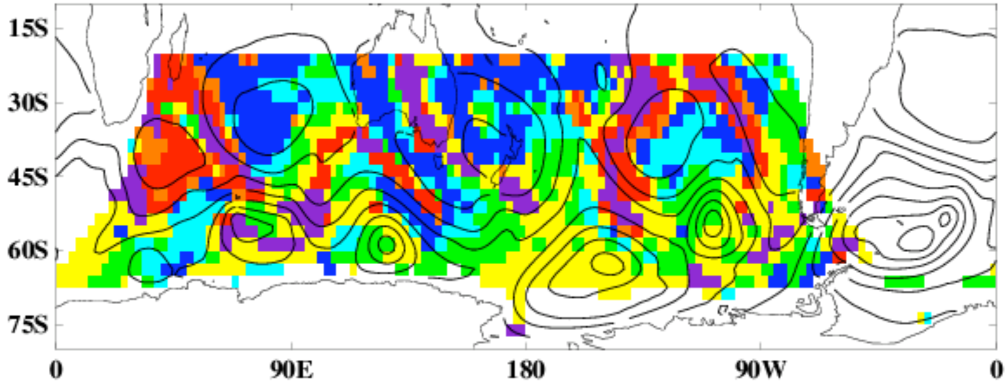


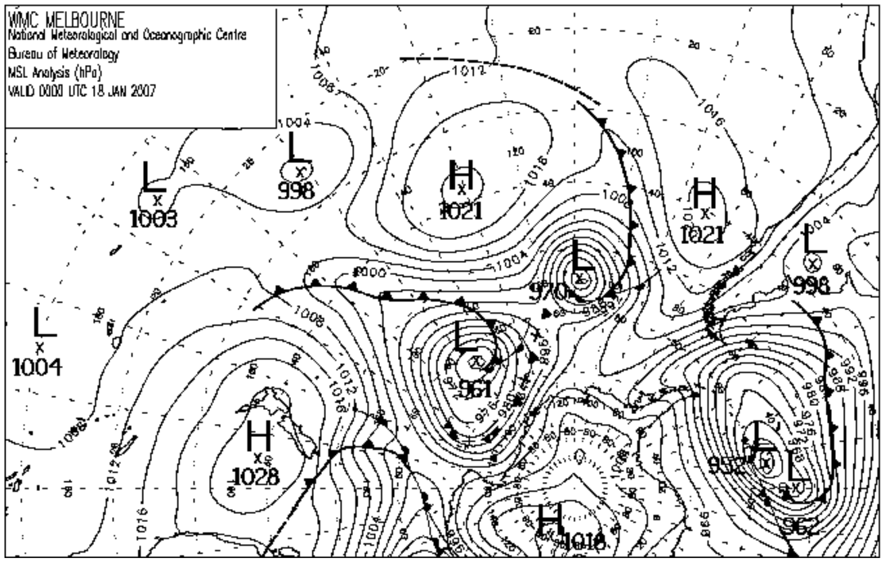
Breakdown of contribution to CREM – Transpose-AMIP



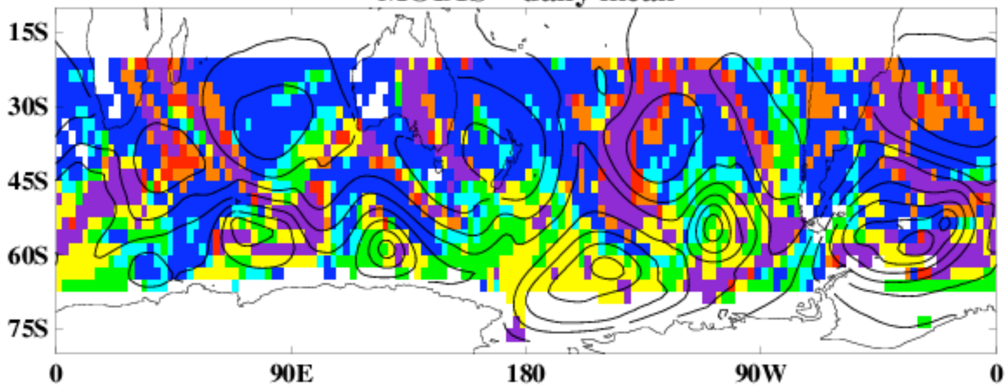
- Clear–sky
- Shallow Cu.
- Transition
- Stratocu.
- Mid–level
- Thin Cirrus
- Cirrus
- Frontal

ISCCP

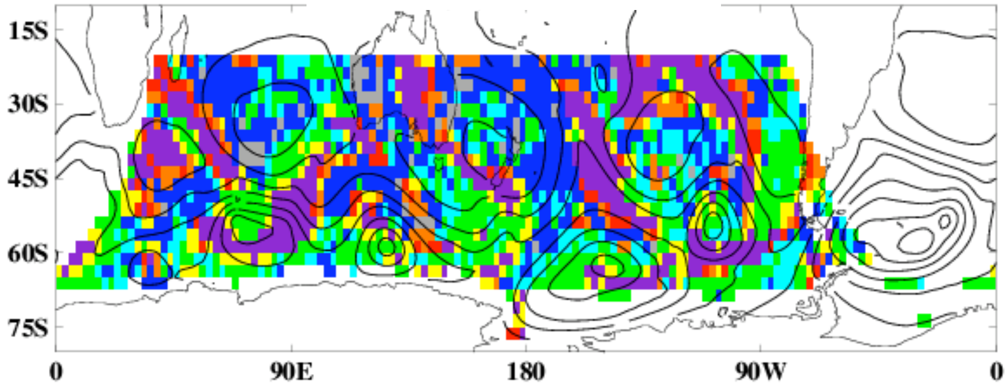




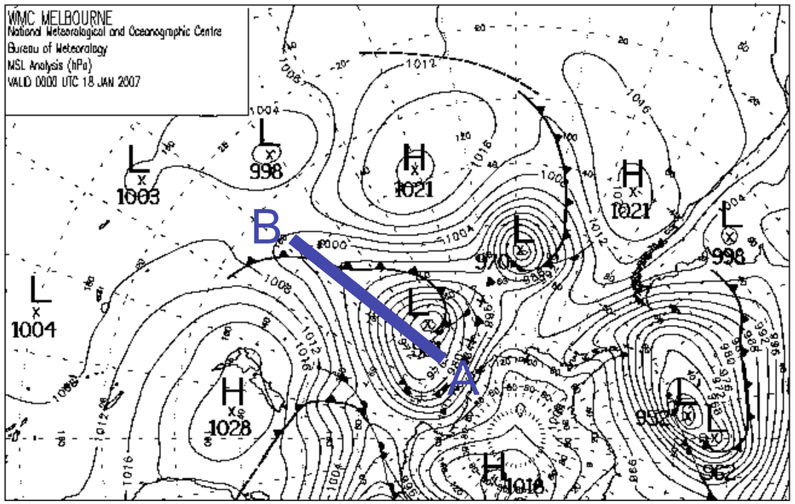
MODIS – daily mean

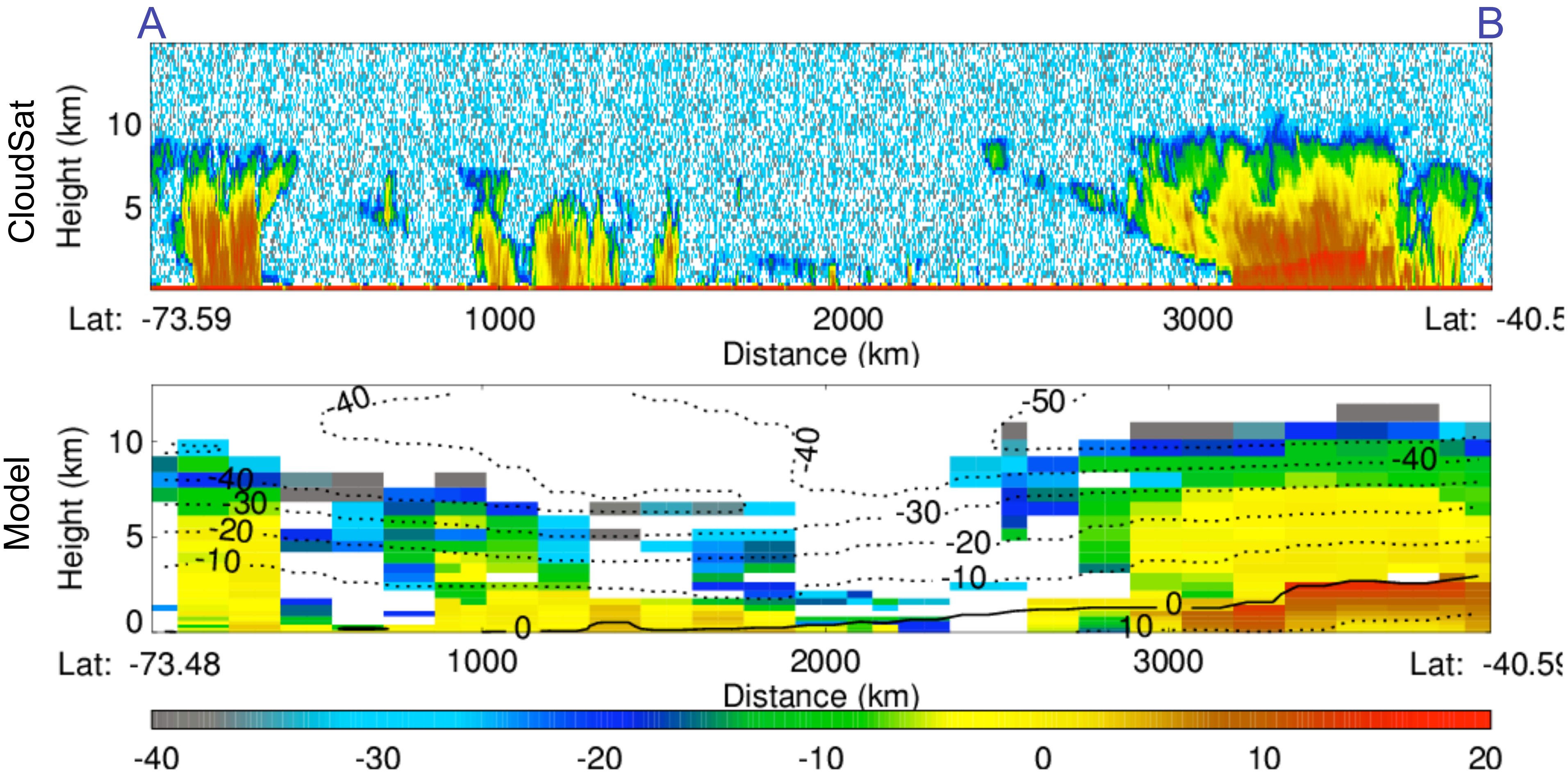


Model



Comparison with CloudSat using COSP





Summary

- Accurate simulation of cloud regime properties has been shown to be important for the climate change response.
- The Cloud Regime Error Metric is a simple scalar metric which can be used within a basket of metrics to assess models.
- The metric decomposed into it's component parts can provide a useful set of diagnostics for model development, particularly when combined with the transpose-AMIP methodology.
- Python code to calculate the CREM is available from www.cfmip.net.
- More information on transpose-AMIP from www.transpose-amip.info.

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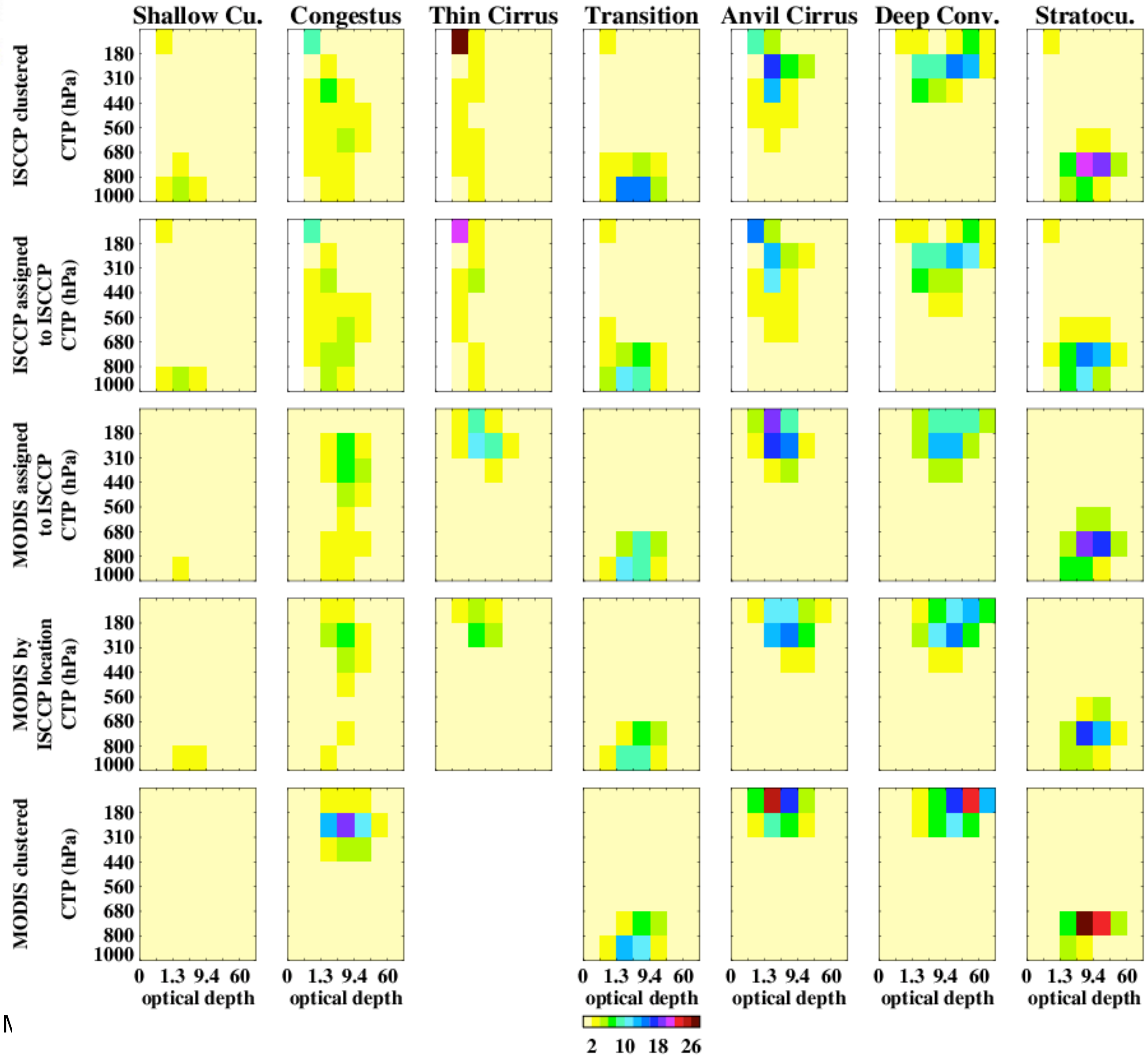
How robust are the observed cloud regimes?



Williams and Webb (2008, Clim. Dyn.)