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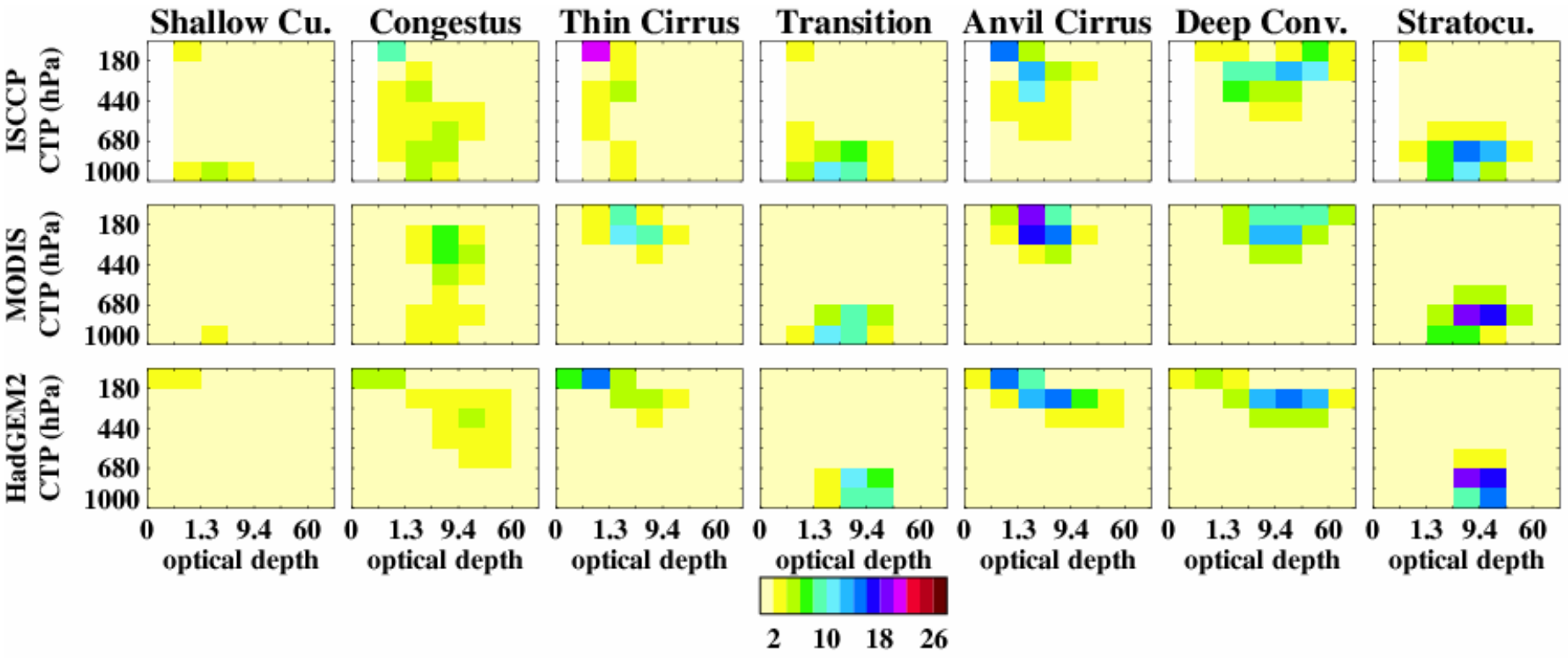
A quantitative performance assessment of cloud regimes in climate models

Keith Williams and Mark Webb (Clim. Dyn., In press)

Pan-GCSS meeting, Toulouse, 03/06/08

ISCCP tropical cloud regimes



Evaluation of regime properties

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Regime histogram

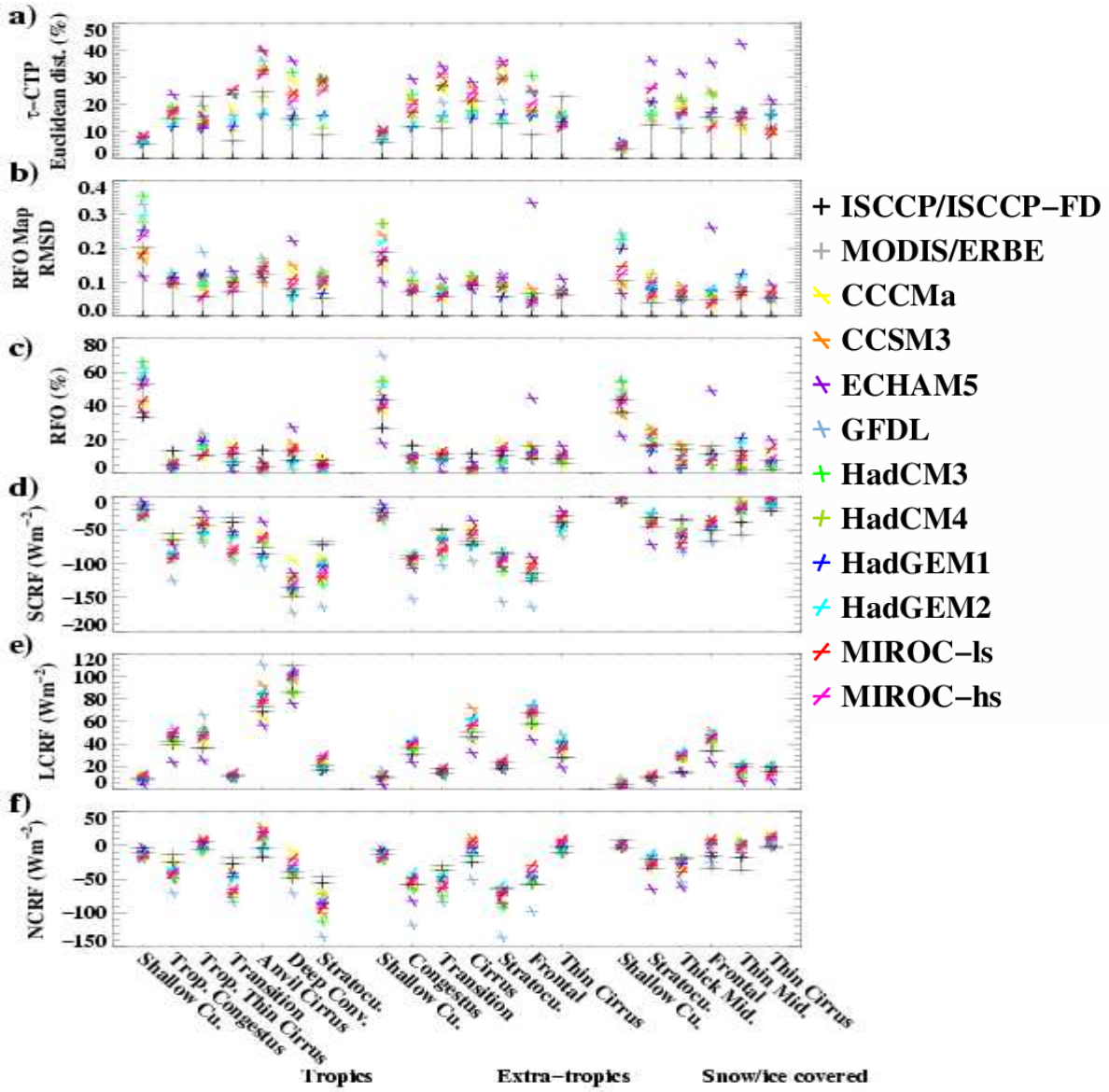
Geographical location

Relative frequency of occurrence (RFO)

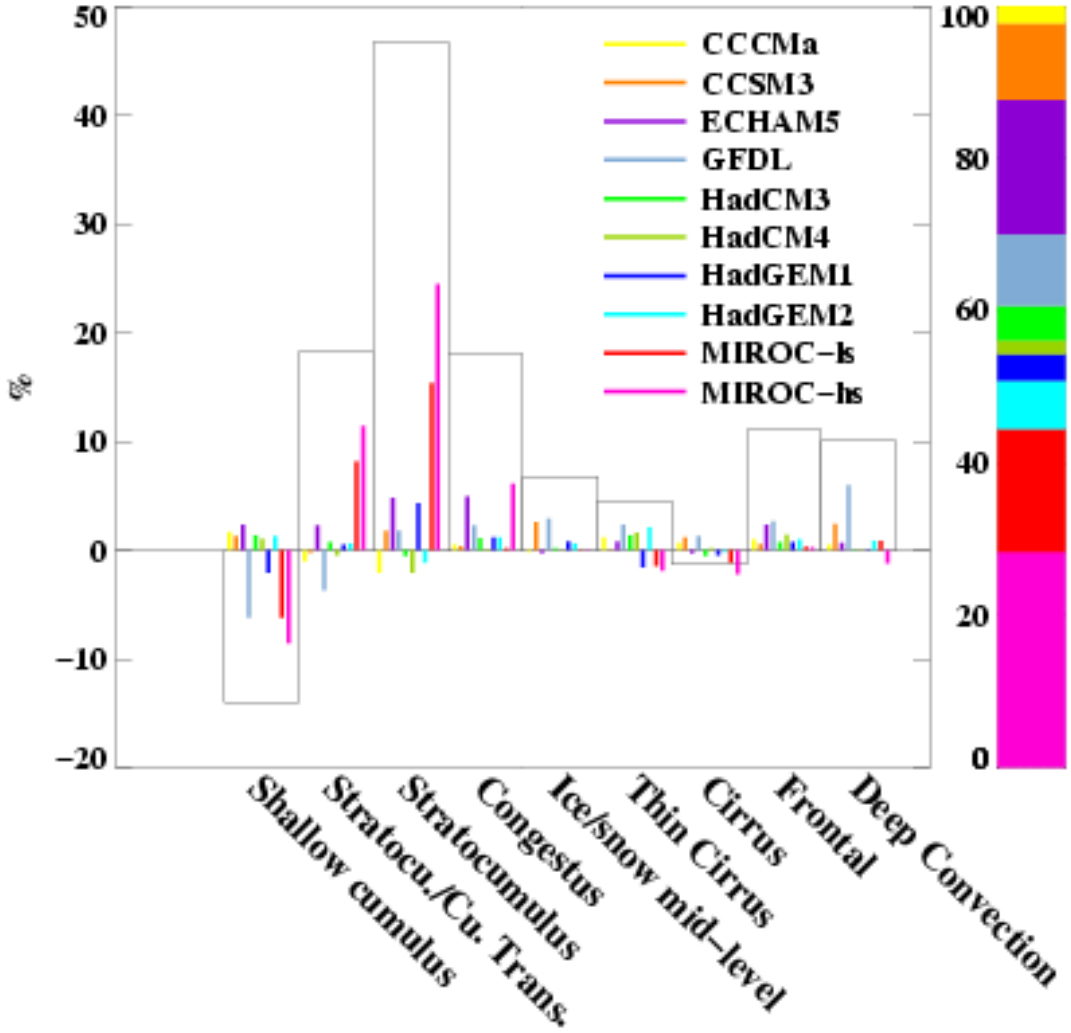
Shortwave cloud radiative forcing (SCRF)

Longwave cloud radiative forcing (LCRF)

Net cloud radiative forcing (NCRF)



Uncertainty in the radiative response under climate change



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

Climate change response

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

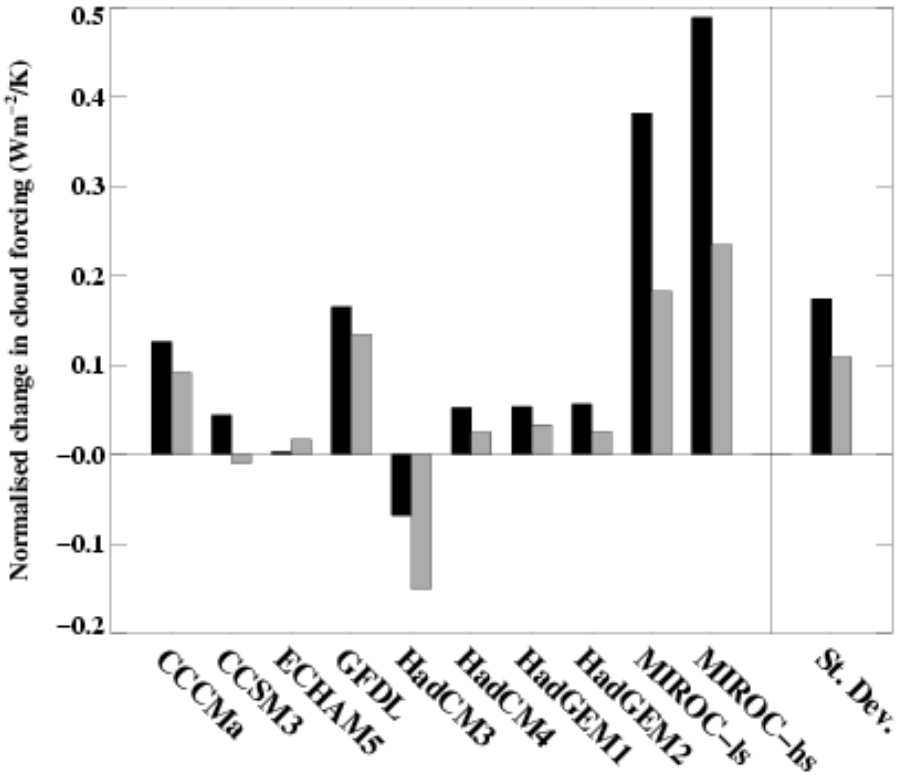
•A change in the RFO (Relative Frequency of Occurrence) of the regime

•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).

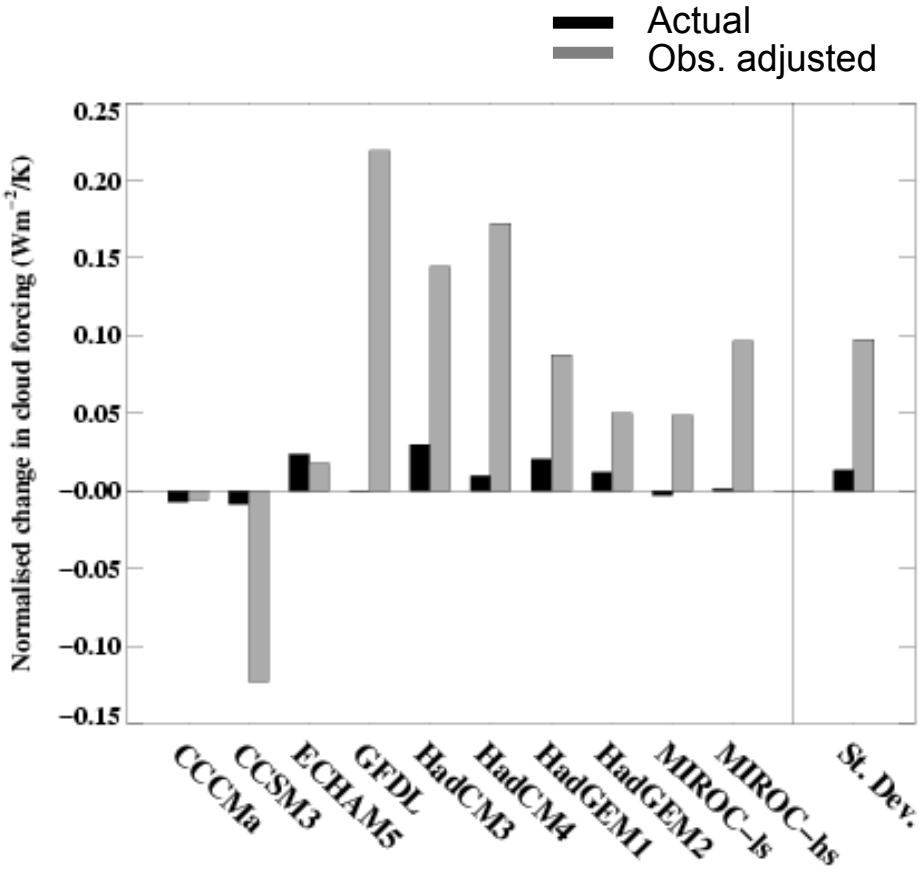
$$\overline{\Delta NCRF} = \sum_{r=1}^{nregimes} NCRF_r \, \Delta RFO_r + \sum_{r=1}^{nregimes} RFO_r \, \Delta NCRF_r + \sum_{r=1}^{nregimes} \Delta RFO_r \, \Delta NCRF_r$$

Uncertainty in the radiative response under climate change

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



2xCO2 change in CRF of tropical anvil cirrus



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)

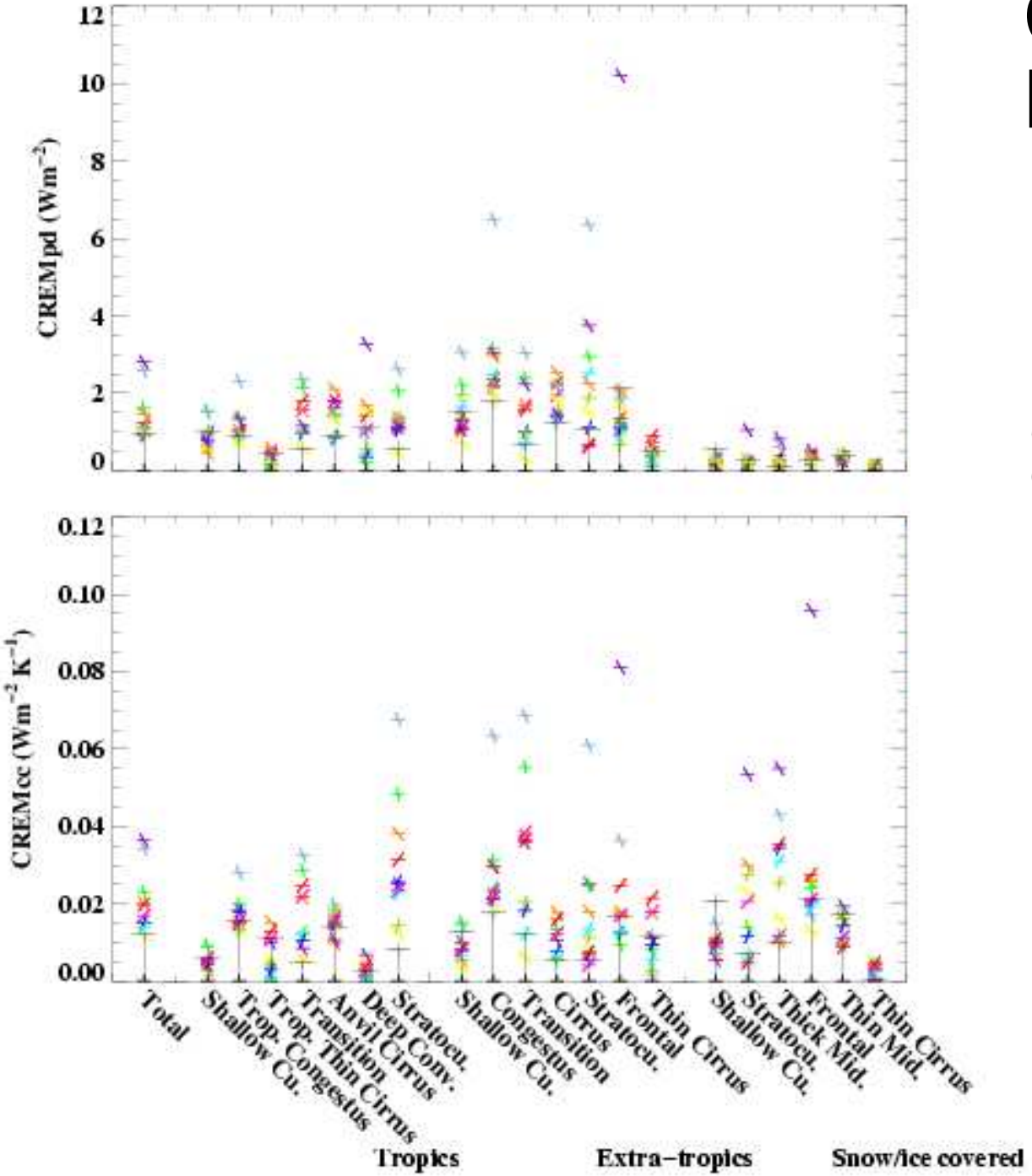
$NCRF_r$ = Net cloud radiative forcing of regime

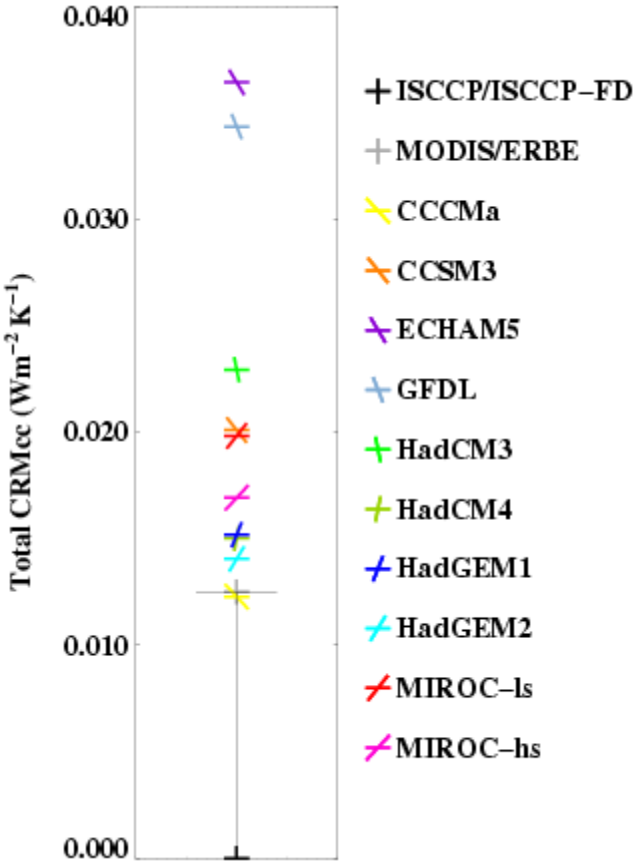
RFO_r = Relative frequency of occurrence of regime

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

' = Difference from observations

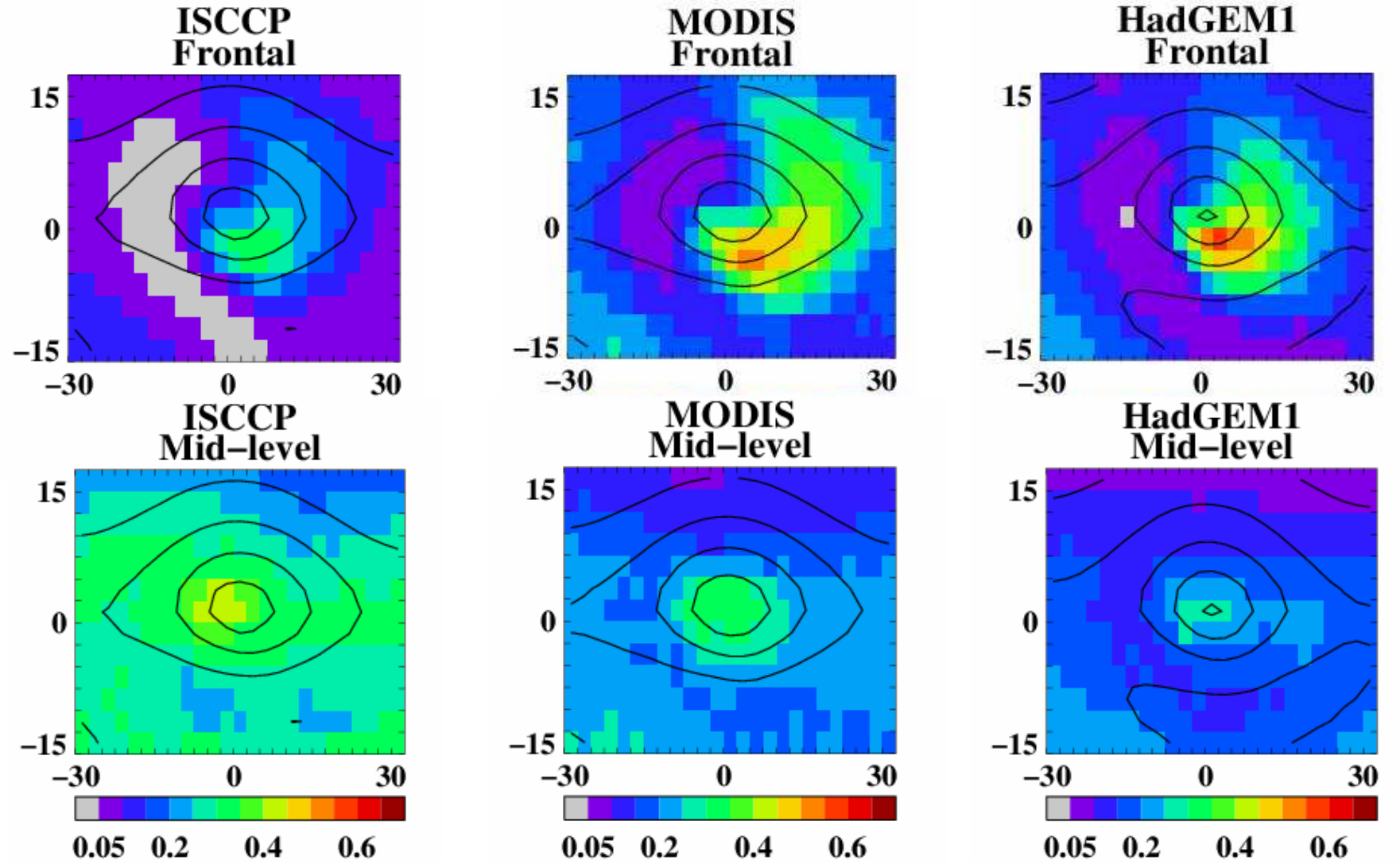
Cloud Regime Error Metrics





More detail on how robust the CREM is in the ‘Metrics’ breakout session.

Composite cyclone (based on Field and Wood, 2007) for the Southern Ocean



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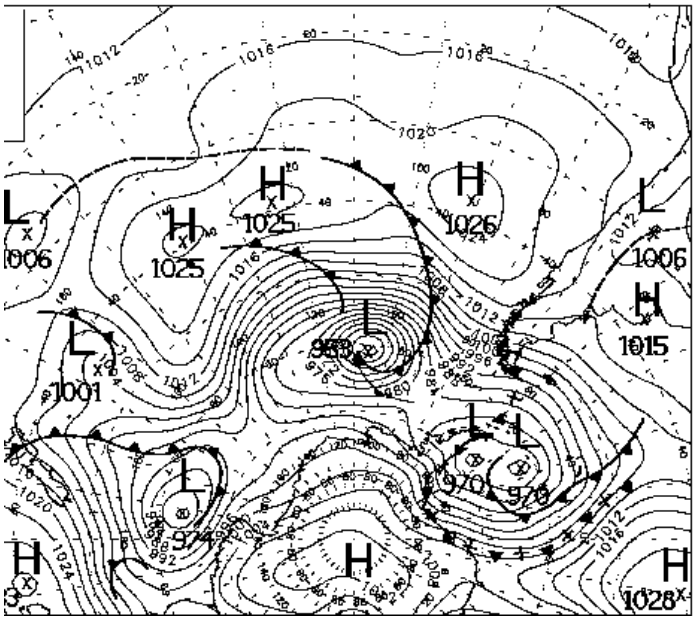
- Clear–sky
- Shallow Cu.
- Transition
- Stratocu.
- Mid–level
- Thin Cirrus
- Cirrus
- Frontal



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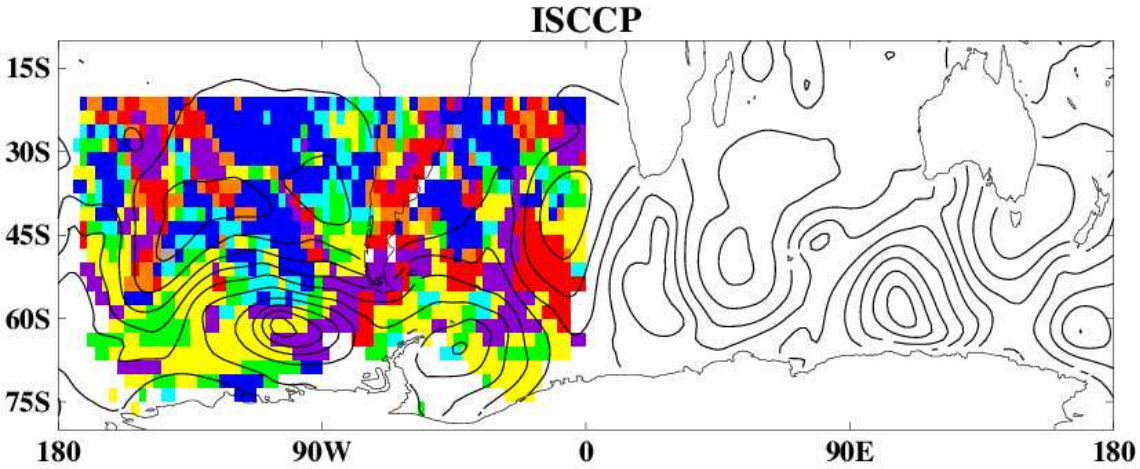

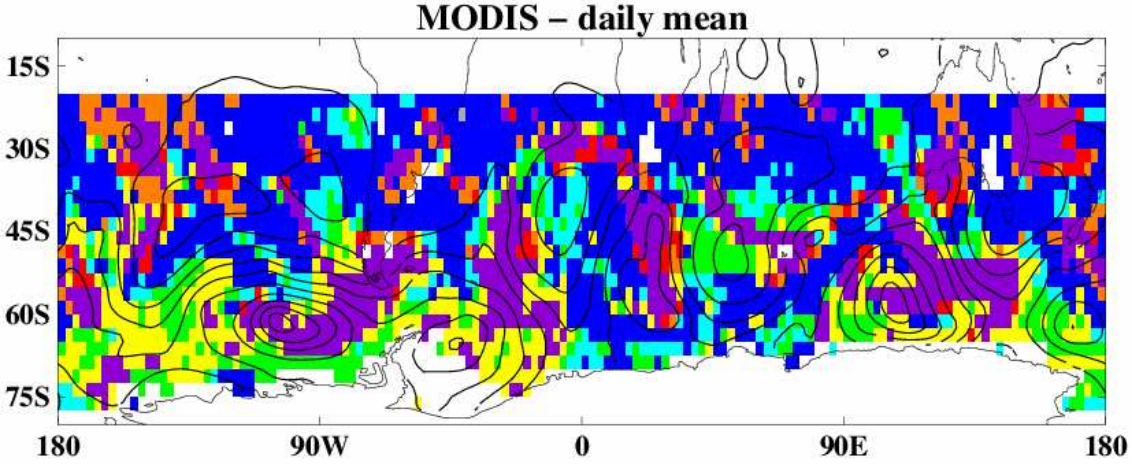

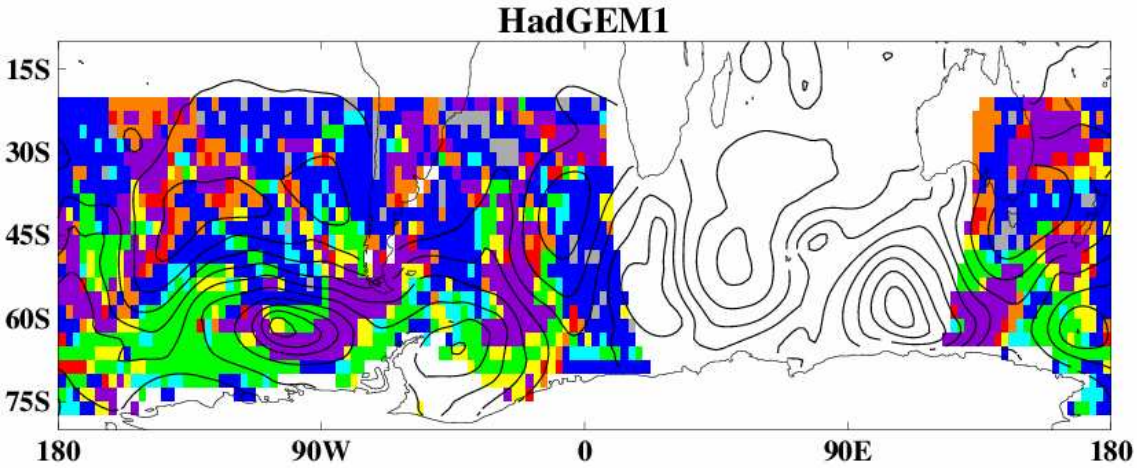

Synoptic conditions for (the lack of) mid-level cloud

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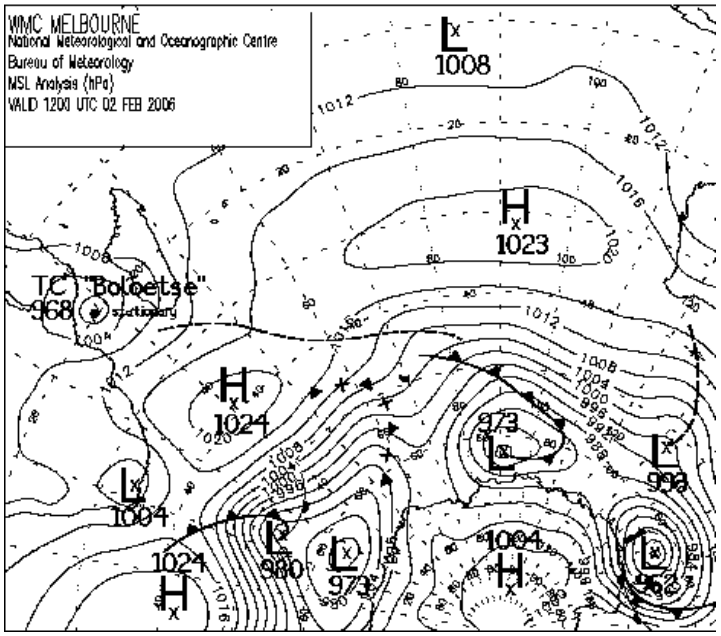
- Clear–sky
- Shallow Cu.
- Transition
- Stratocu.
- Mid–level
- Thin Cirrus
- Cirrus
- Frontal



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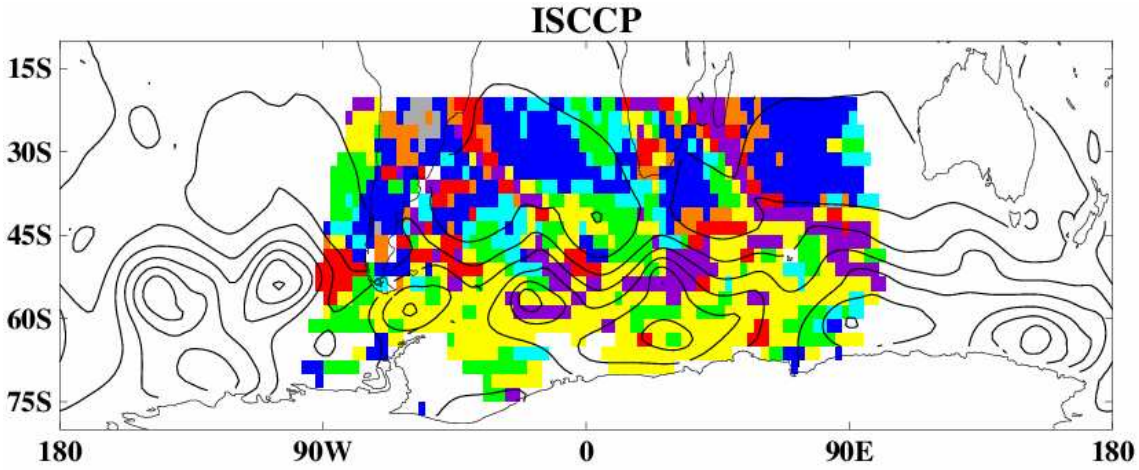

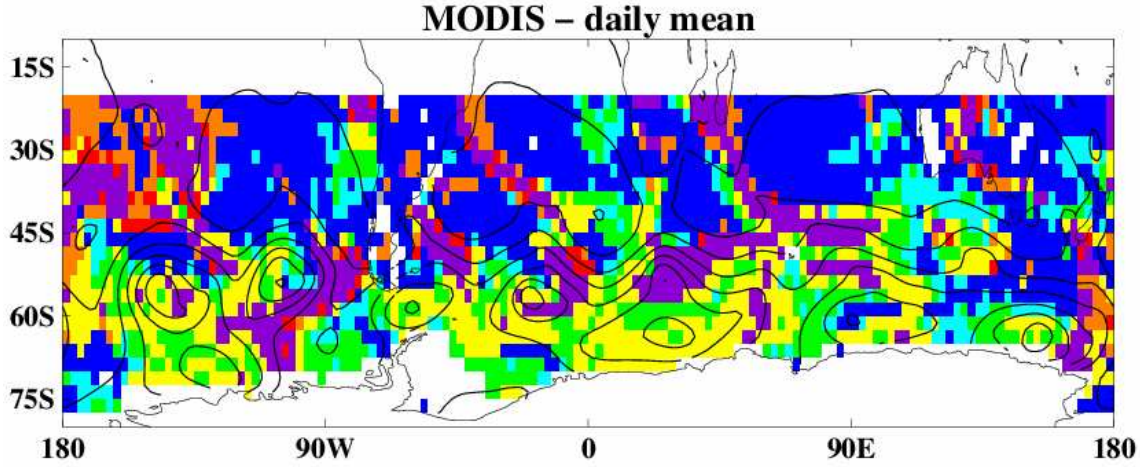

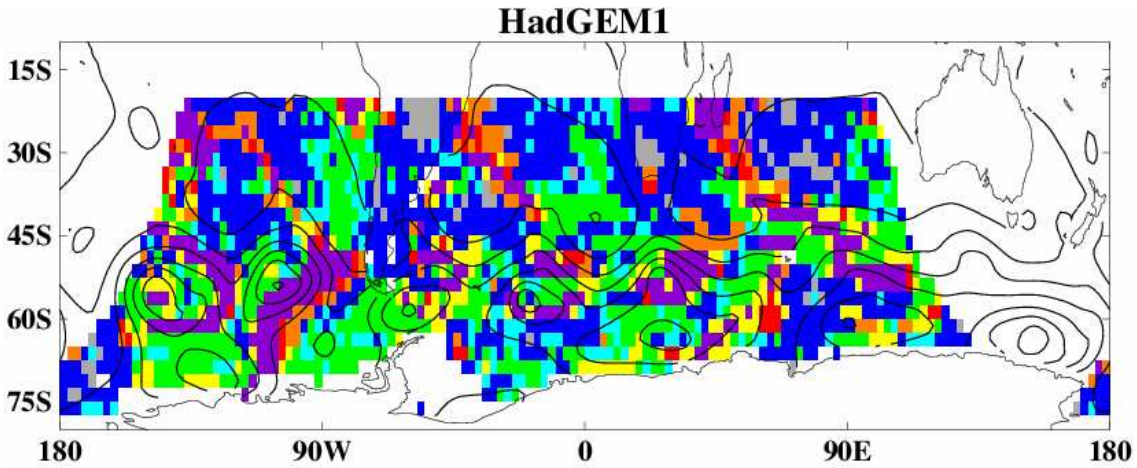

Synoptic conditions for (the lack of) mid-level cloud

Conclusions

- Most of the variance in the global cloud radiative response between GCMs is due to low cloud (47% from stratocumulus, 18% from transition).
- Shallow cumulus has a smaller response and acts to reduce the variance between GCMs.
- GCMs share a bias for stratocumulus and transition regimes to be overly reflective. If this were corrected (and all other aspects of the response remain the same), the variance in the cloud radiative response would reduce.
- Some of the high cloud-top regimes are simulated too infrequently in some GCMs. If this were corrected (and all other aspects of the response remain the same), the variance in the cloud radiative response from high-top cloud would increase.
- The ISCCP simulator diagnostics required for this study/metric will be requested within the standard output for AR5 – requires updated ISCCP simulator.

(pre-print of the paper available from www.cfmip.net)