I've moved.

Development of a set of metrics for clouds & cloud feedback: Can estimates of climate variations during the satellite observation period be used to constrain cloud feedbacks under global warming?

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Hadley Centre The Met Office

CFMIP/GCSS/EUCLIPSE meeting, Met Office, UK

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Development of a set of metrics for clouds & cloud feedback Why?

- Cloud feedback is the biggest uncertainty for climate sensitivity in global warming simulations.
- Commonly used metrics for clouds are bulk quantities of cloud radiative effects.
- We need an algorithm for finding out of source of the problem.
- We need metrics which are more physically based, help our understanding of cloud and cloud feedback.

Cloud regime metrics

(Williams and Webb, 2009)

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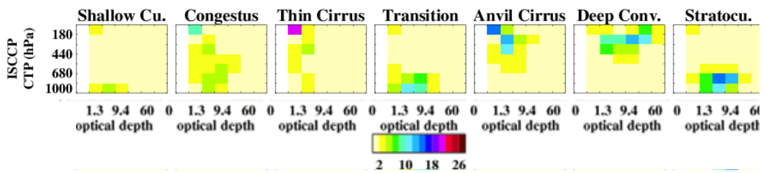
Cloud regimes from clustered daily ISCCP data



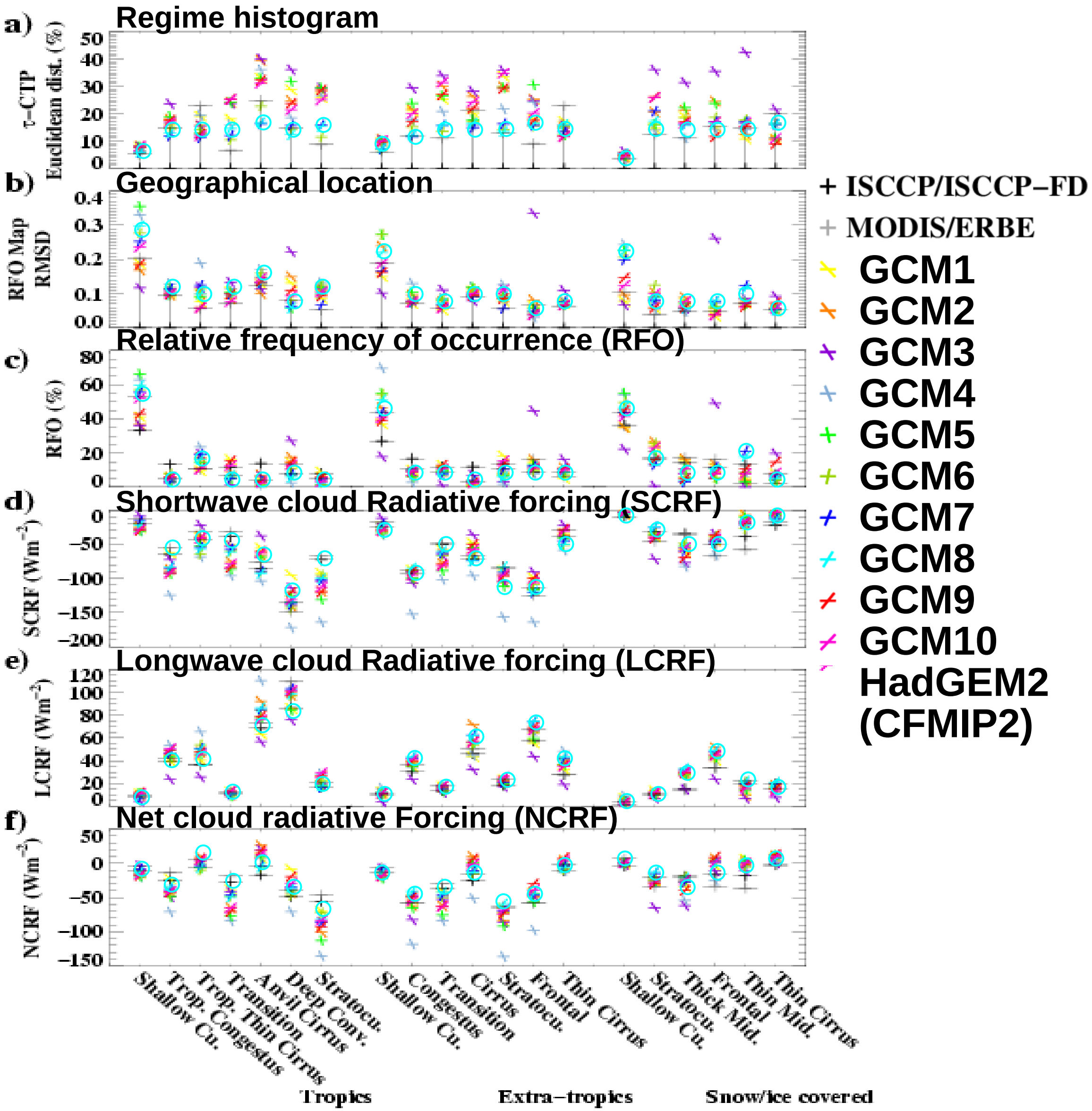
Albedo, cloud top pressure and cloud top temperature

Assign model ISCCP simlator in COSP to the observed regimes

NCRF’:NCRF bias within the cluster
RFO’ :RFO bias of the cluster
aw :area weighting term

$$\mathrm{CREMpd} = \sqrt{\frac{\sum_{r=1}^{\mathrm{nregimes}} \mathrm{CREMpd}_r^2}{\mathrm{nregimes}}}$$

$$\mathrm{CREMpd}_r = \mathrm{aw}\sqrt{(\mathrm{NCRF}'_r \mathrm{RFO}_{\mathrm{obs}r})^2 + (\mathrm{RFO}'_r \mathrm{NCRF}_{\mathrm{ol}}}$$



Extend cloud regime metrics for state of climate to annual/interannual variation

- Data:
  - ISCCP D1 total cloud fraction, Cloud albedo, Cloud top pressure
  - ISCCP FD daily radiative flux
  - ERBE radiative flux for a reference
- Method
  - Reference cloud regimes: Those by Williams and Webb (2009), constructed from daily observational data of all months and years.
  - Pick up data of specific period in a annual/interannual variation, and project it onto the reference.
  - Analyze each regime's deviation from the climatological reference.
- Period: Mar1985-Feb1990
- Area:
  - Tropics[20S,20N]
  - Ice-free extra-tropics
  - Snow/ice covered

NCRF':NCRF deviation within the cluster
RFO' :RFO deviation of the cluster
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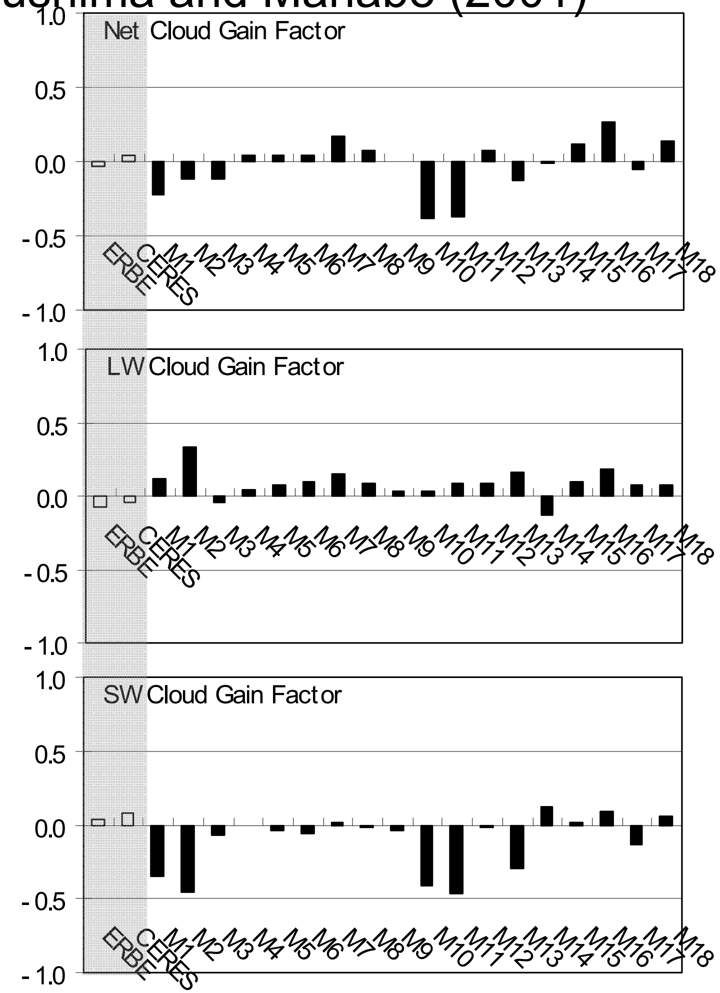
Cloud feedback in natural climate changes – observation & models

Annual Variation

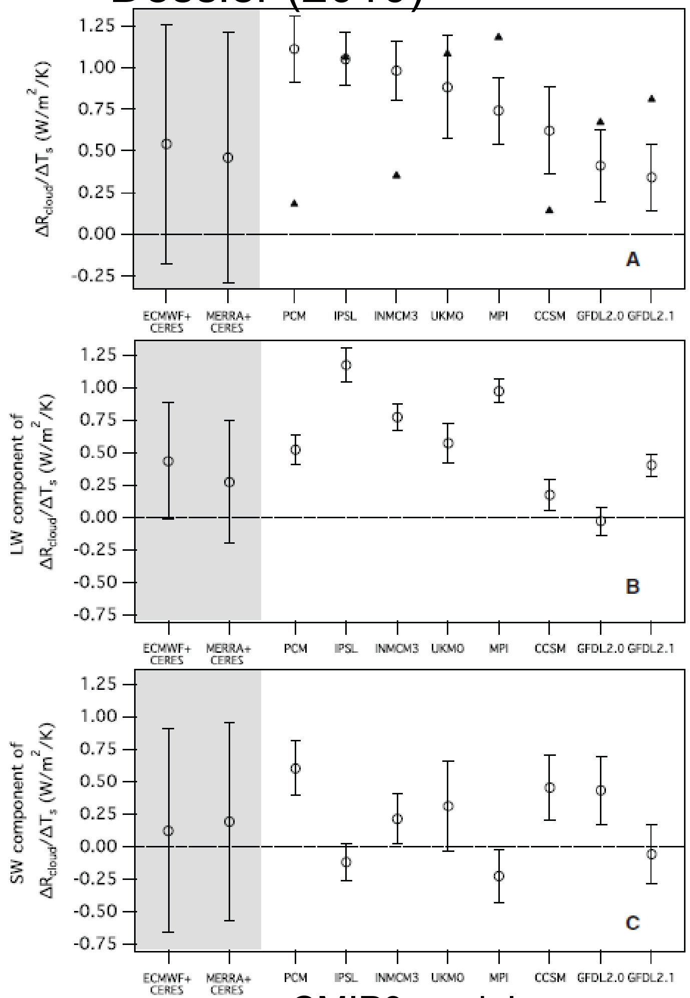
Tsushima and Manabe (2001)



CMIP3 models

Interannual variation

Dessler (2010)



CMIP3 models

Spread of Model's results
is not any more special in SW than in LW.

Cloud feedback in natural climate changes - What do they tell us???

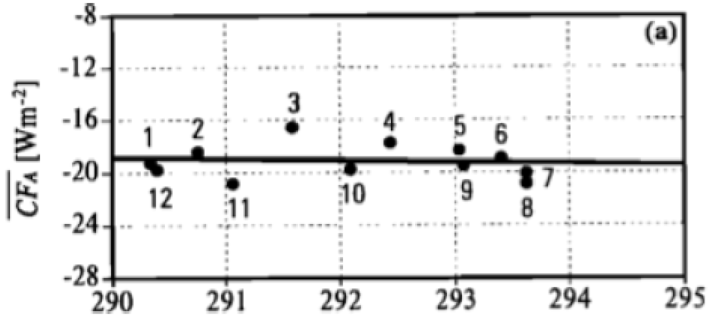
Cloud feedback parameter

$$\lambda = \frac{dR}{dT_s},$$

Slop regression of global mean surface temperature and global mean cloud radiative effect

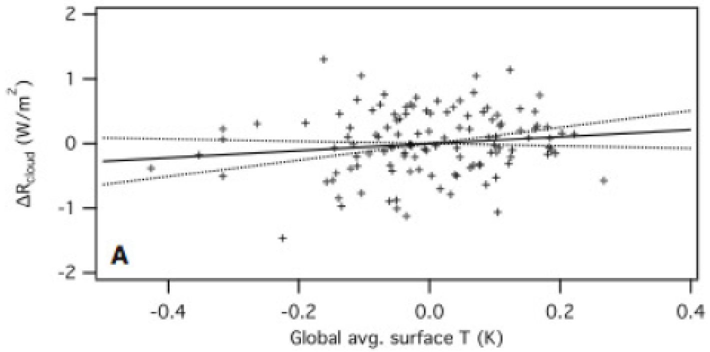
Annual variation

Tsushima and Manabe (2001)

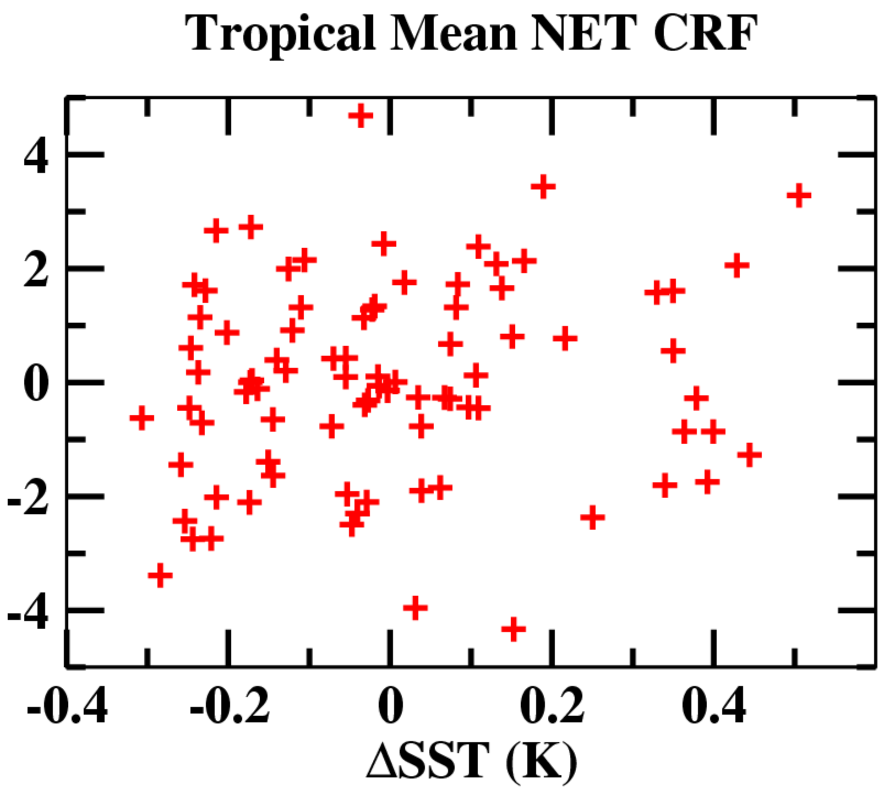


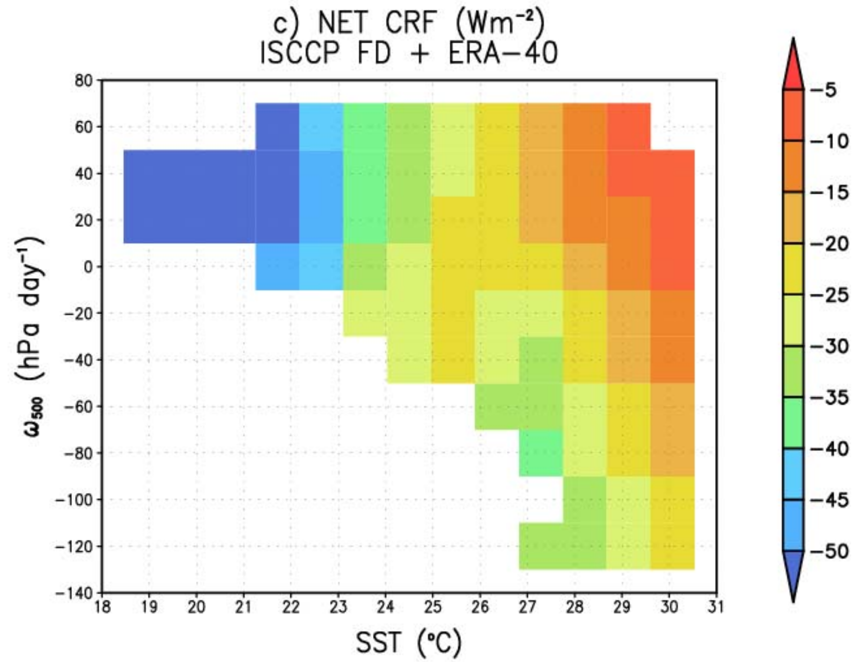
Interannual variation

Dessler (2010)



- Can estimates of climate variations during the satellite observation period be used to constrain cloud feedbacks under global warming?
- Global cloud feedback (Change in global mean net cloud radiative effect) is a result of balance of response in SW/LW, of various region and various regime.



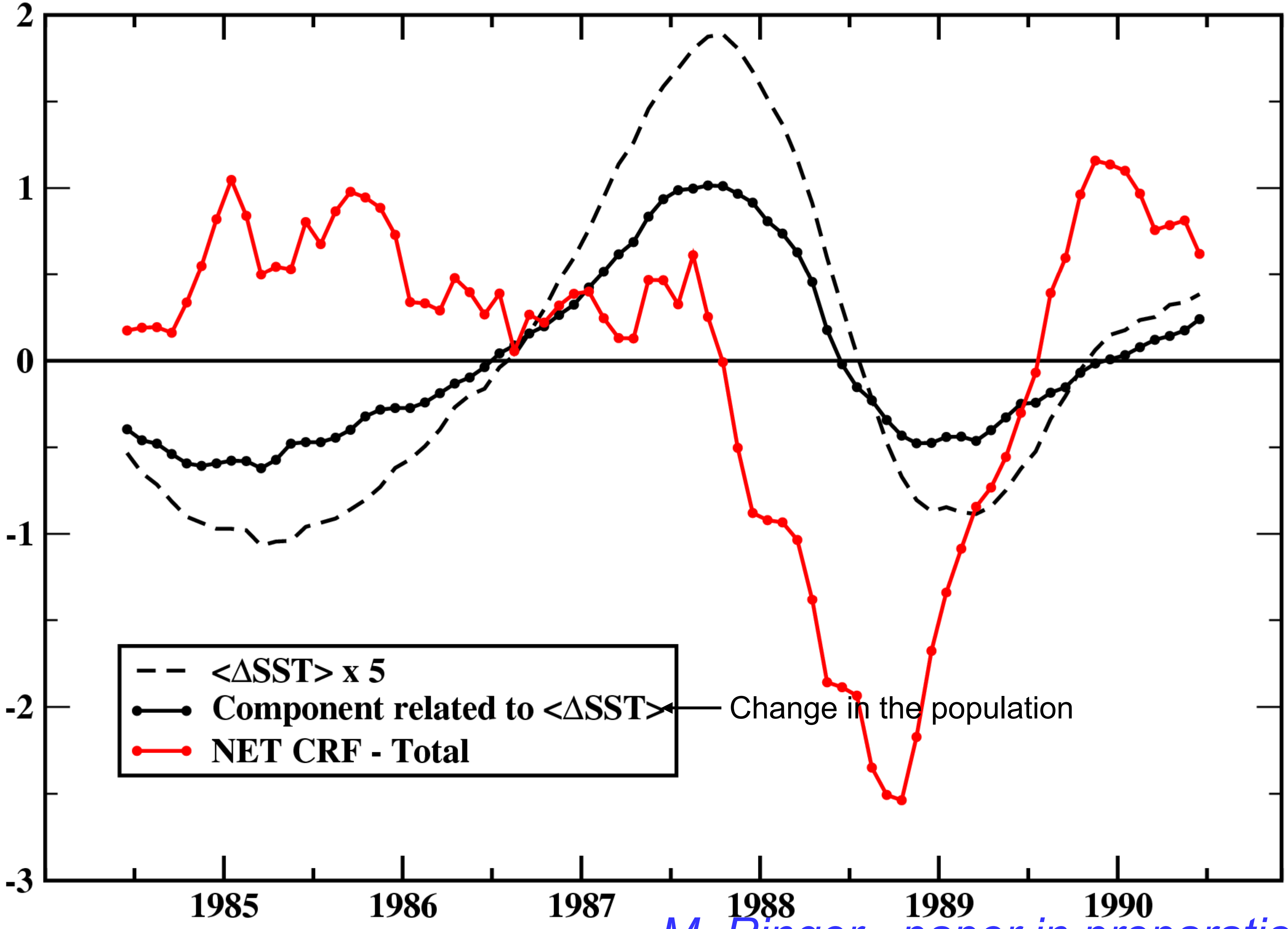


- Analogous to Bony et al (2004), Yuan et al (2008) construct time series of ω-SST CRF distributions

- Component of tropical mean CRF anomaly due to
  - *changes in CRF within the ω-SST bin*
  - *changes in the populations of the ω-SST bins*

M. Ringer , paper in preparation

Tropical Mean Net Cloud Forcing - ISCCP-FD



M. Ringer , paper in preparation

Understanding cloud feedback by breaking into contribution of cloud regimes

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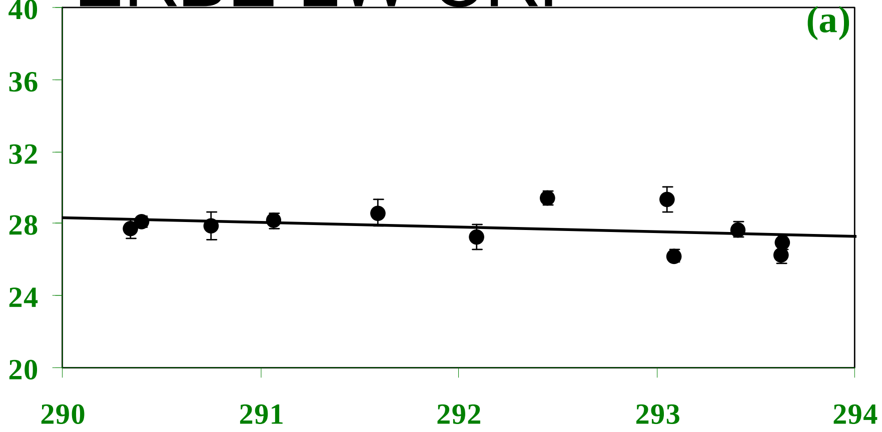
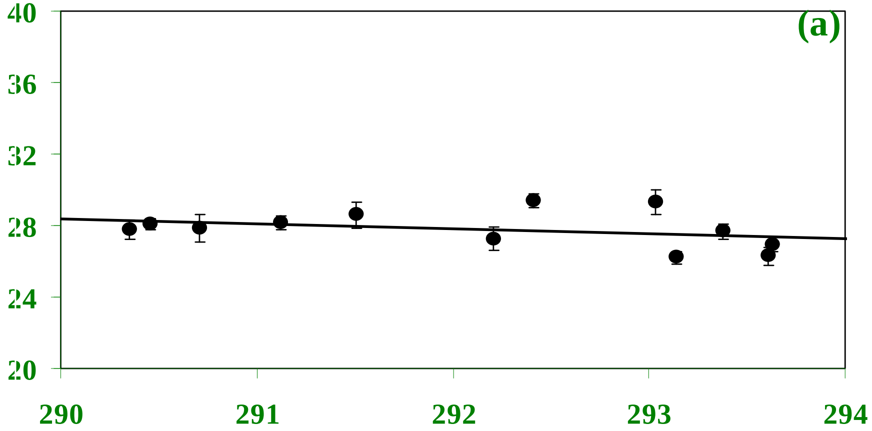
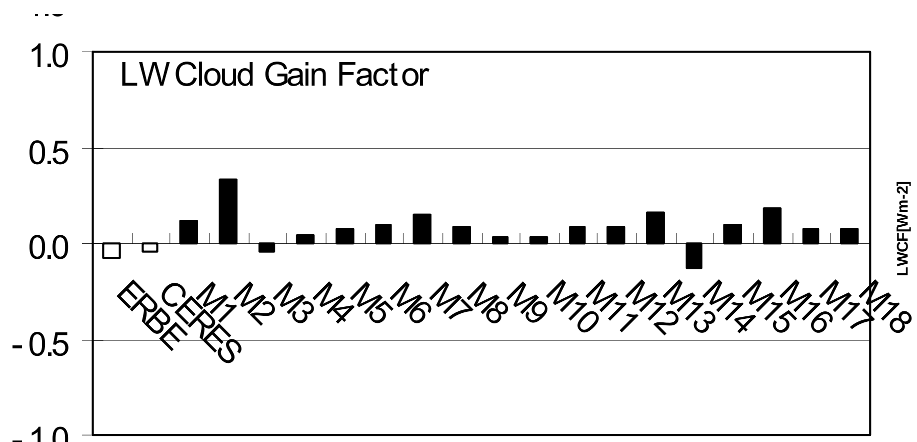
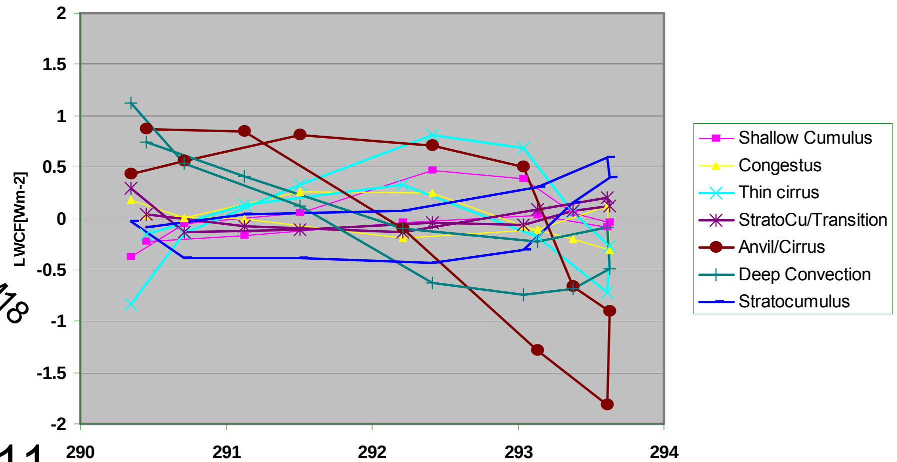
ERBE LW CRF



LW CRF Sum of all regimes

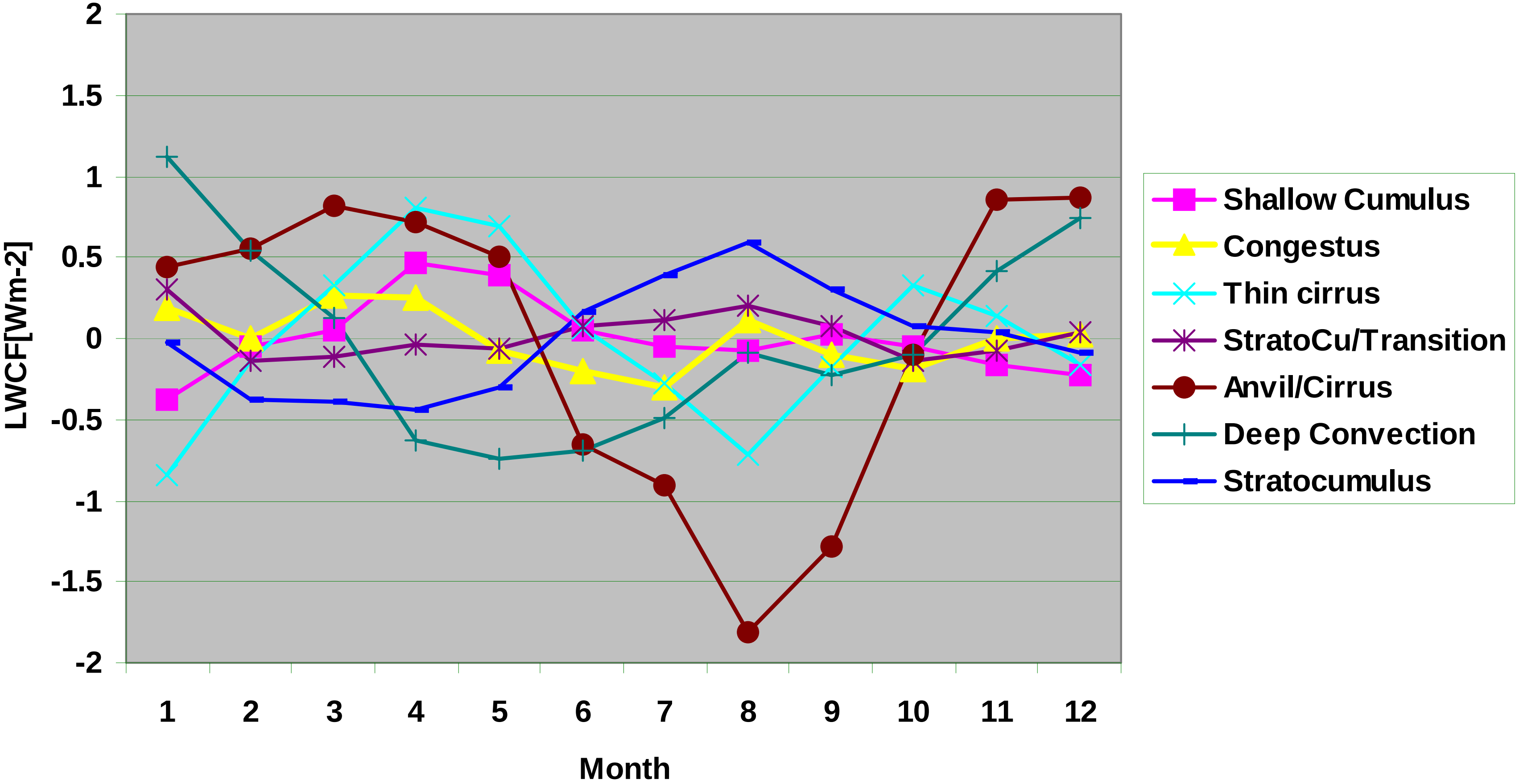






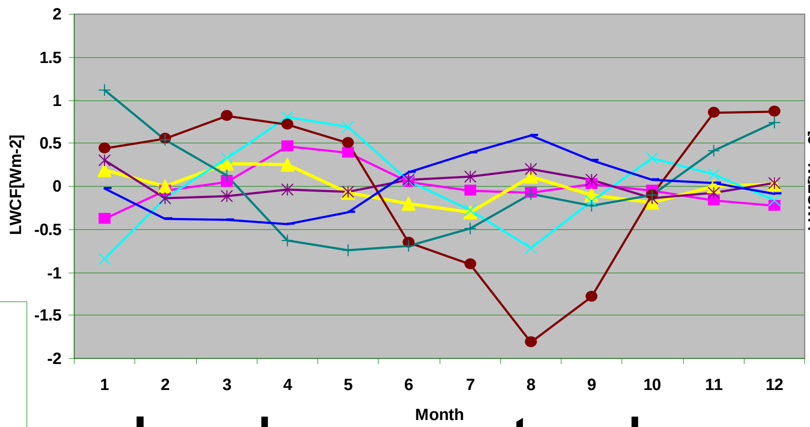
Tsushima and Manabe, 2011

Cloud Regime in the Annual Variation
Tropics

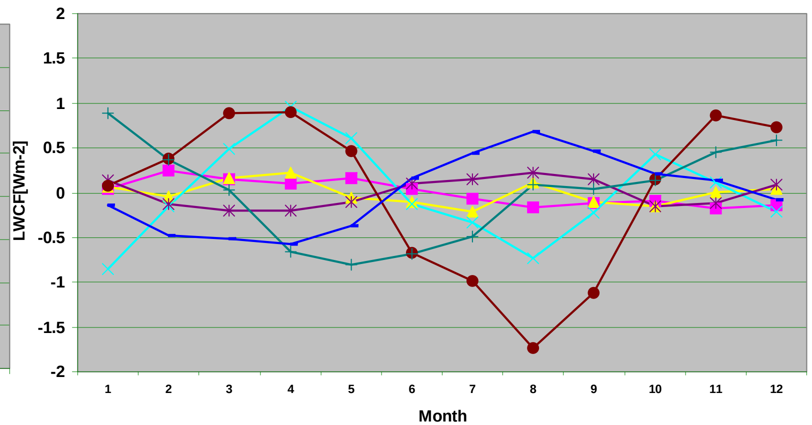


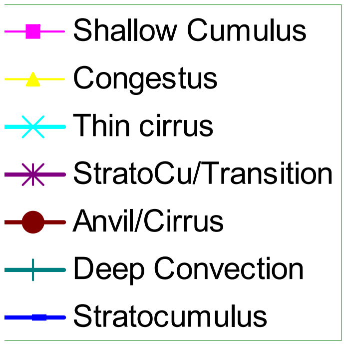
Cloud fraction change? Cloud property change?

total

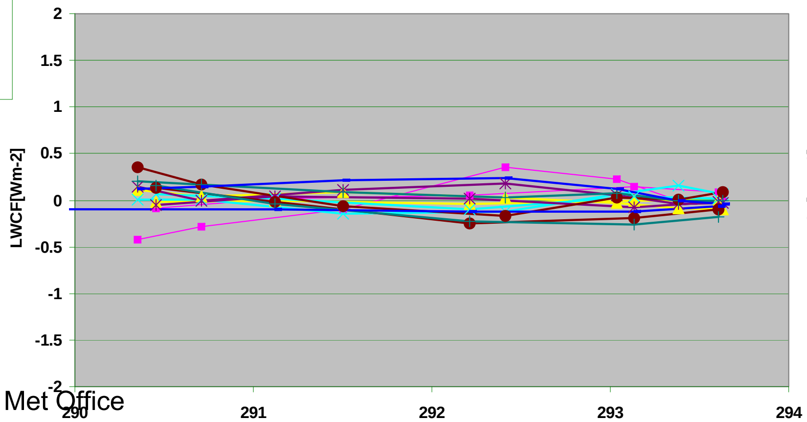


fraction change

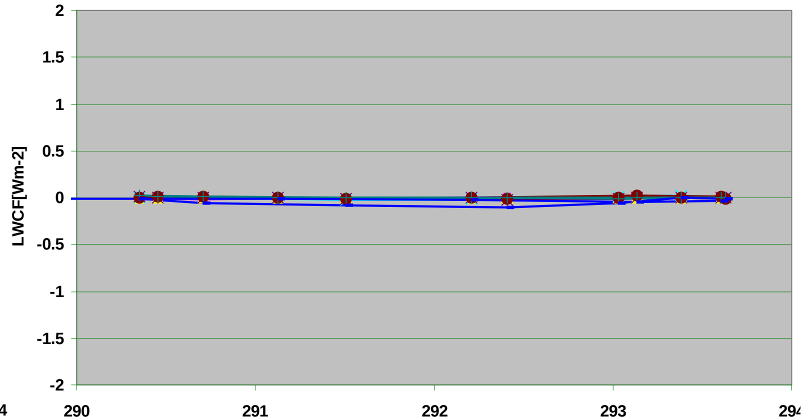




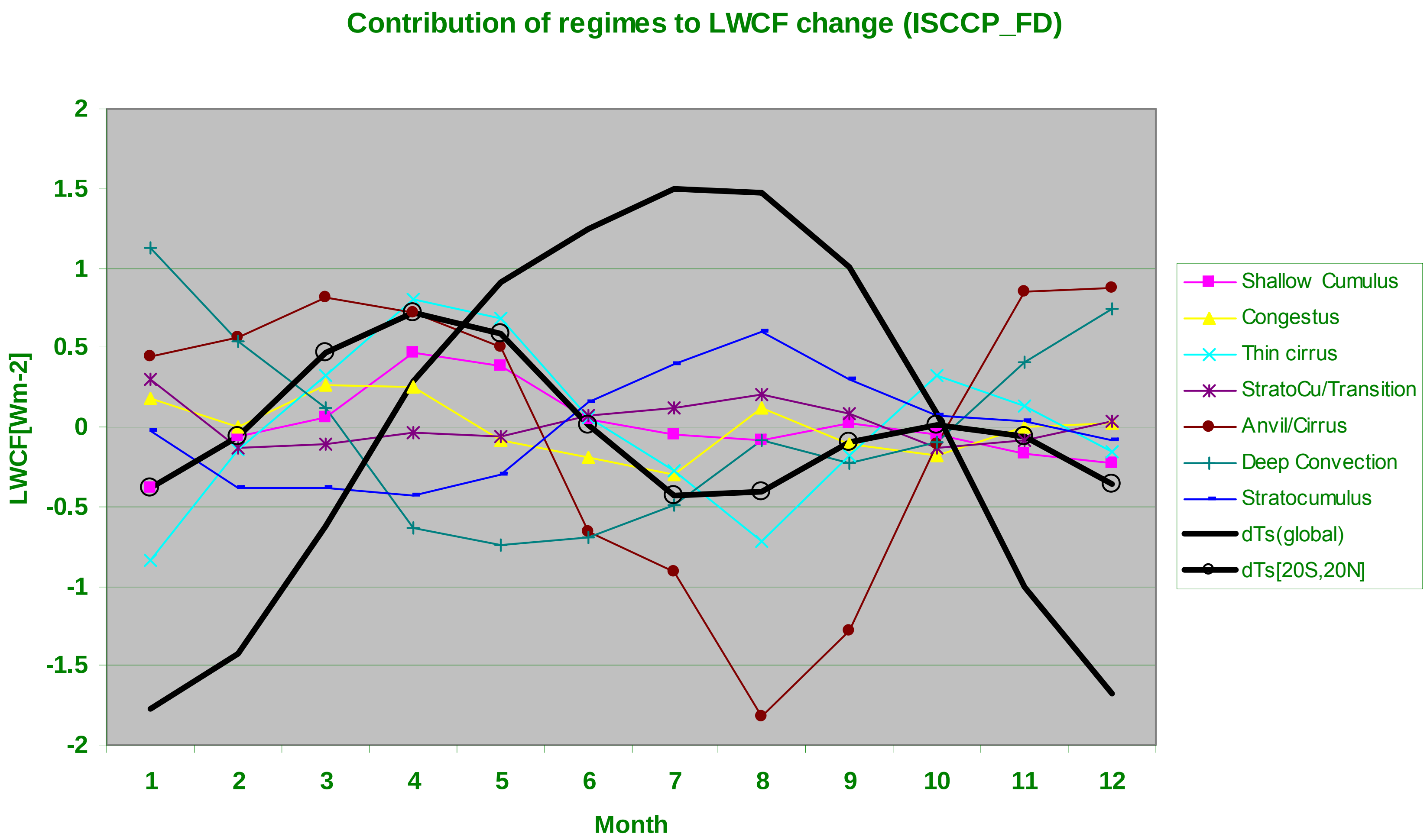
cloud property change



non-linear term



Any relevance to surface temperature variation?



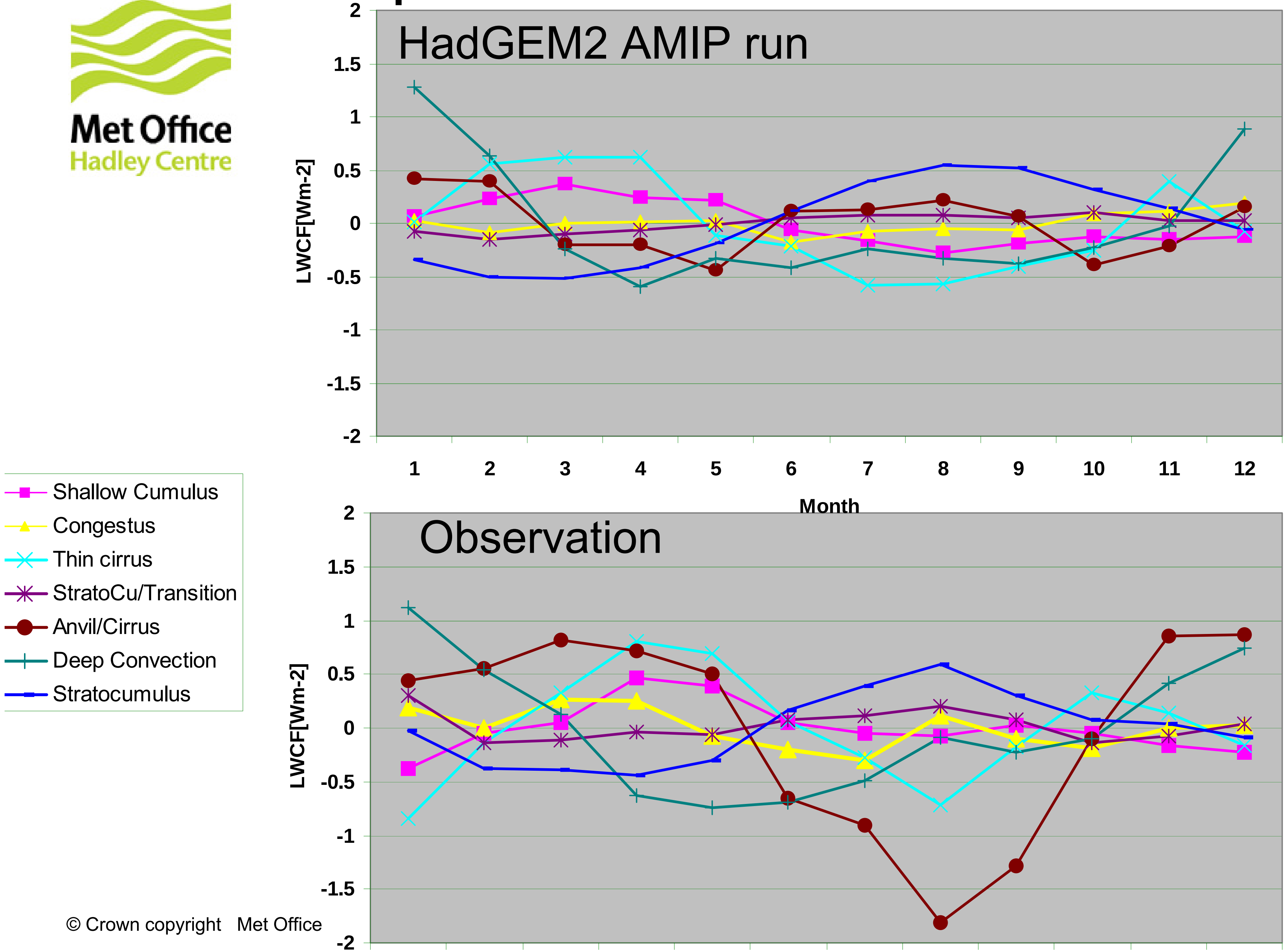
Correlations
cloud regime's Longwave cloud radiative effect
vs
global mean surface temperature,
tropical mean surface temperature

Tsg: global mean surface temperature
Tst: tropical mean surface temperature
C: cloud fraction
LCF: Longwave Cloud radiative effect

Correlation_Tsg	Shallow Cu.	Congestus	Thin cirrus	Transition	Anvil/Cirrus	Deep Convection	StratoCu.
Total	0.50	-0.47	0.13	0.17	-0.77	-0.88	0.55
C change	-0.18	-0.35	0.07	0.32	-0.69	-0.78	0.53
LCF per C change	0.68	-0.64	0.27	-0.32	-0.54	-0.64	-0.31
dCdLCF	0.35	0.17	0.22	0.18	0.08	-0.69	-0.05

Correlation_Tst	Shallow Cu.	Congestus	Thin cirrus	Transition	Anvil/Cirrus	Deep Convection	StratoCu.
Total	0.42	-0.14	-0.27	-0.73	-0.47	-0.49	-0.78
Ccover change	0.59	0.39	0.91	-0.78	0.56	-0.58	-0.70
LCF per C change	0.54	0.16	-0.49	0.57	-0.43	0.08	0.61
dCdLCF	0.42	-0.14	-0.27	-0.73	-0.47	-0.49	-0.78

Comparison with a CFMIP2 GCM



Future Plan

- Application to interannual variation
- Application to CMIP5 models and see relevance of each cloud regime's response in global warming and natural climate variation.
- Introduction of the metrics to GCM metrics community.

Summary

- Extension of cloud regime metrics from state of climate to natural climate variation is presented.

  It is demonstrated that they are useful for our understanding and evaluation of clouds.

- Natural climate variation does not show significant cloud feedback.

  Cloud regime analysis helps our understanding. Some regimes show significant relationship.

  Interannual variation: RFO change responds well to global mean surface temperature.

  Annual variation: Deep convective clouds and Anvil cirrus anti-correlates to global mean surface temperature, which contribute to make longwave cloud feedback negative in the observation.

- Preliminary analysis of CFMIP2 AMIP data is conducted for HadGEM2.

  For most cloud regimes, annual variation is well reproduced, but not for anvil cirrus.