

CAUSES: Identifying the contribution of clouds to surface-temperature errors in GCMs

K. Van Weverberg¹, C. J. Morcrette¹, H.-Y. Ma², S. A. Klein², J. C. Petch¹

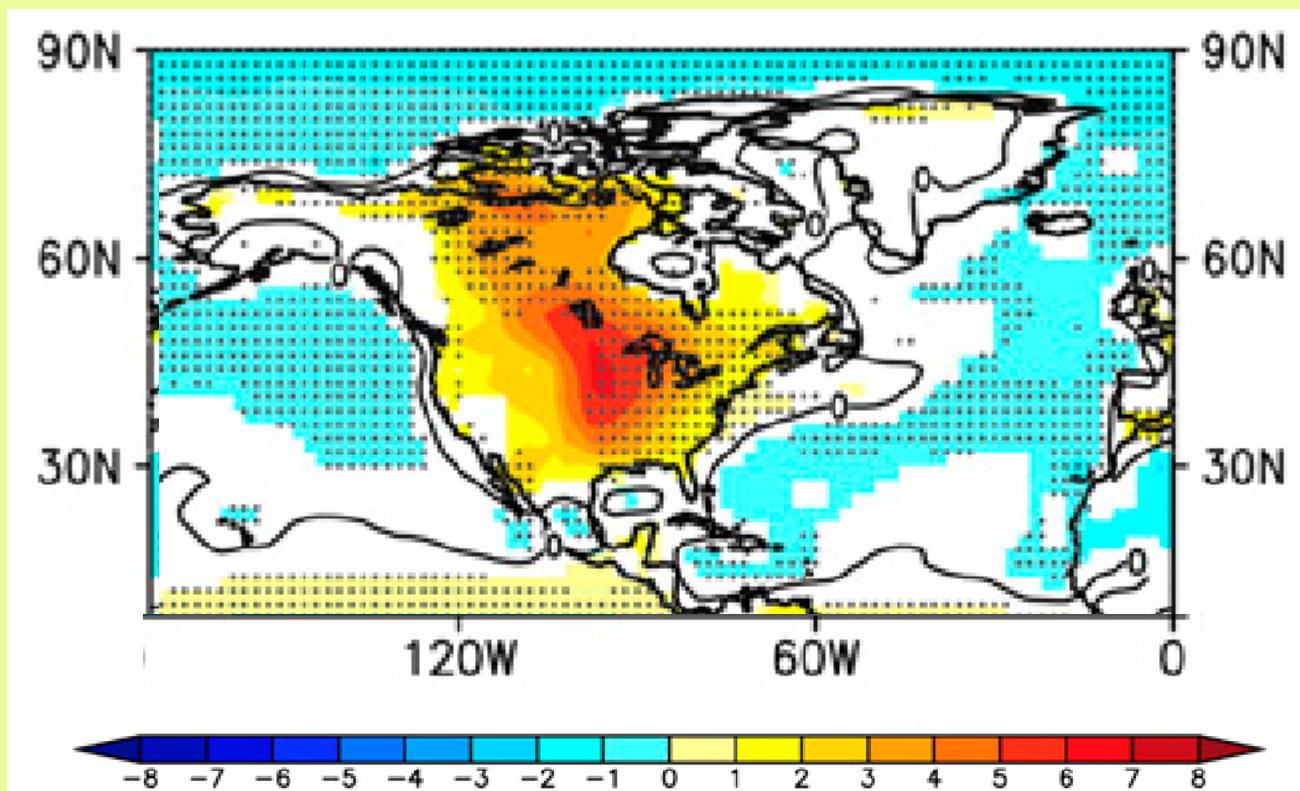
Under review in Quarterly Journal of the Royal Meteorological Society

¹Met Office, Exeter, United Kingdom

²Lawrence Livermore National Laboratory, Livermore, California

Motivation

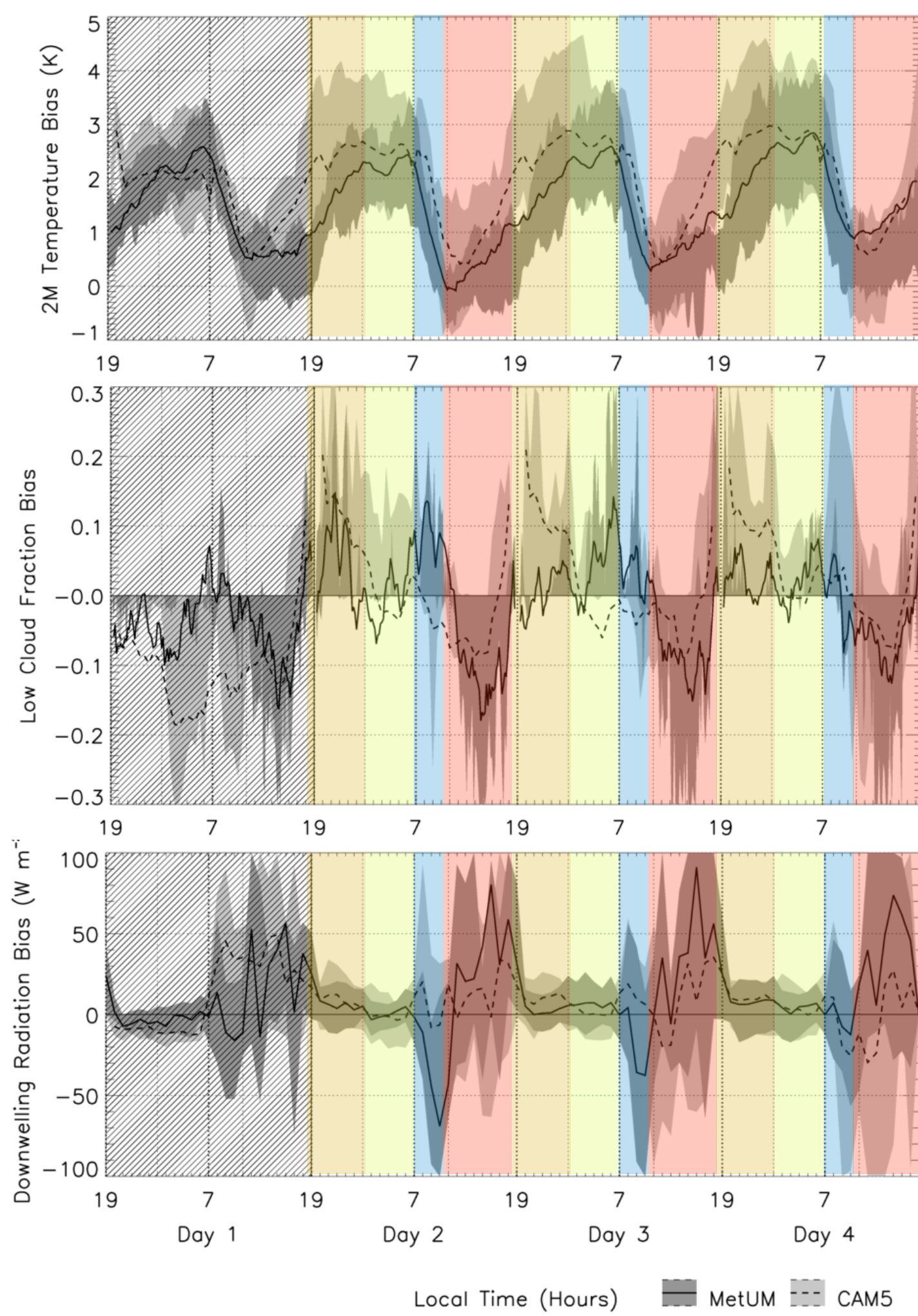
- Many GCMs exhibit surface **warm bias** over the SGP
- Role of **clouds** in the creation of the bias unclear



GCMs: MetUM and CAM5 run in NWP-mode 4-day hindcasts
Analysis period: 6-week period of the MC3E-campaign April-June 2011

Mean T-bias in 5 CMIP5 GCMs (Ma et al. 2014)

Error-growth Attribution at time-step level



Correlation of biases:

Diurnal cycle in T-bias during 4-day hindcasts

Morning (07-11LT): T-bias ~ clouds/rad in MetUM, but not in CAM5

Afternoon (11-19LT): T-bias ~ clouds/rad in MetUM and CAM5

Evening (19-01LT): T-bias ~ clouds/rad in MetUM and CAM5

Night (01-07LT): T-bias ==

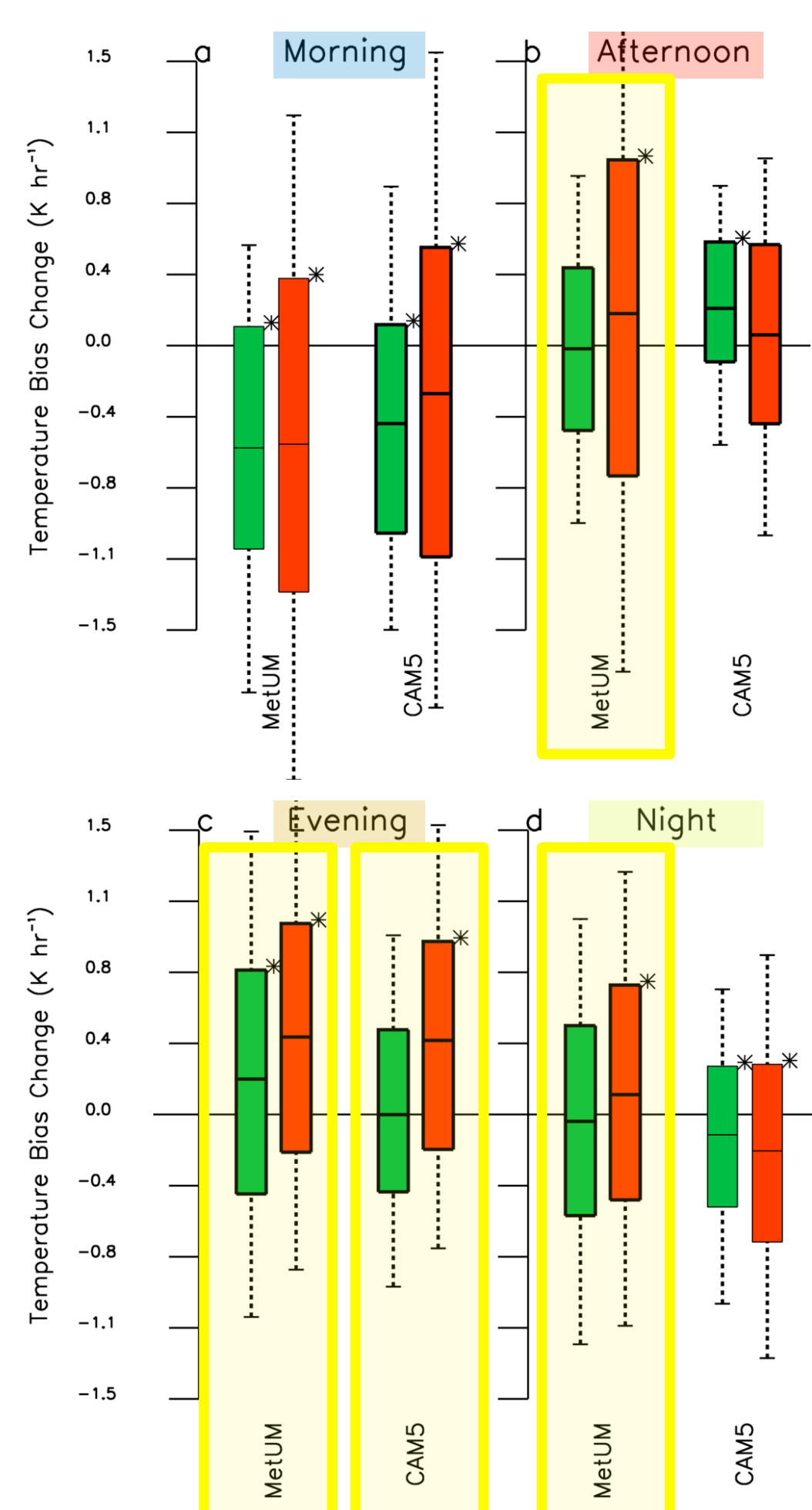
Composition of biases:

BUT:

- Ambiguous to correlate mean time series
- Multiple processes could play together

→ Composition of T-bias growth per period:

- **Green box-whisker:** Unbiased downwelling radiation (~ no cloud deficiency)
- **Red box-whisker:** Biased downwelling radiation (~ cloud deficiency)
- If red-box mean absolute ΔT -bias significantly larger than green-box mean: → **Dominant cloud effect!**

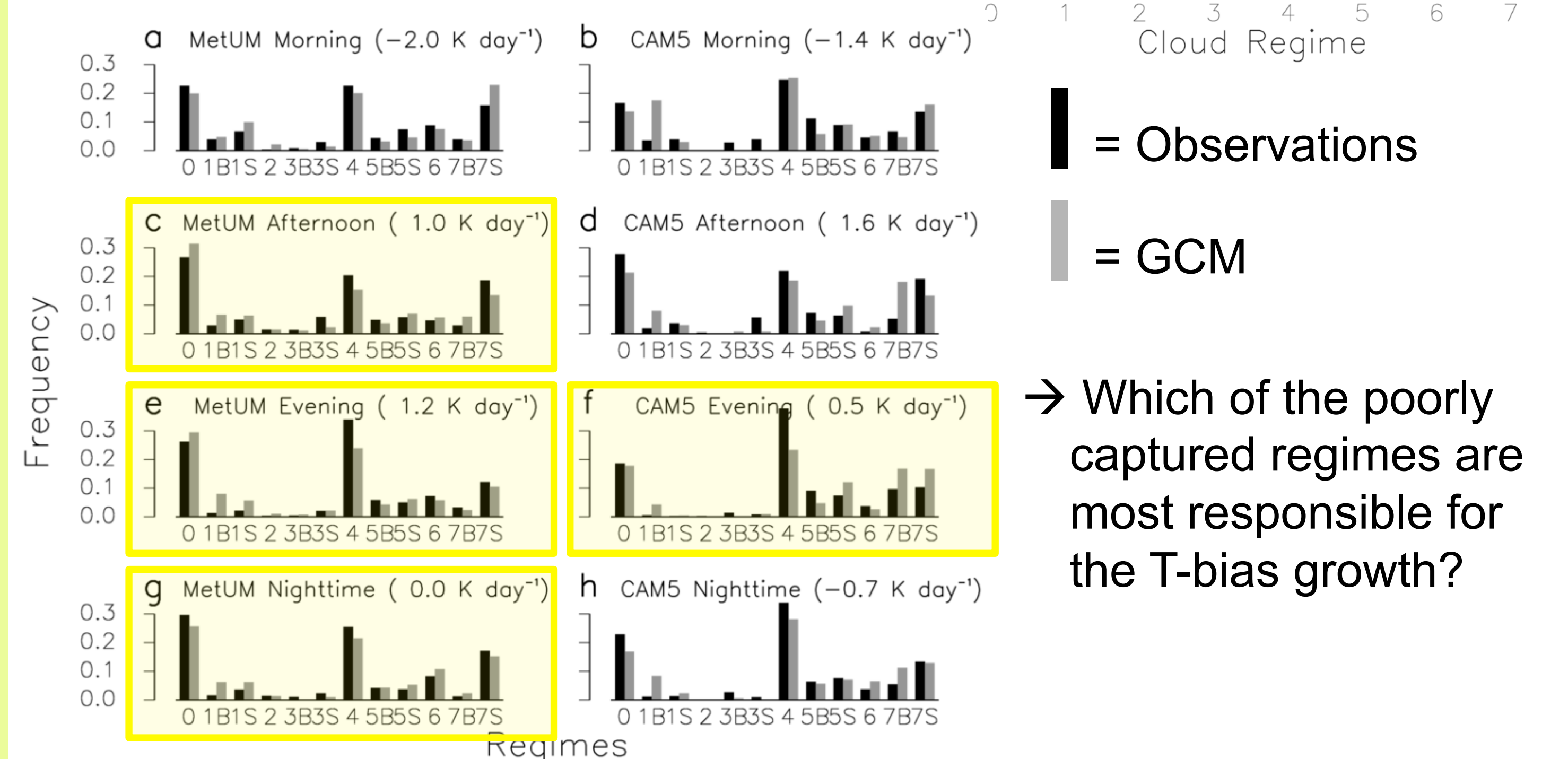
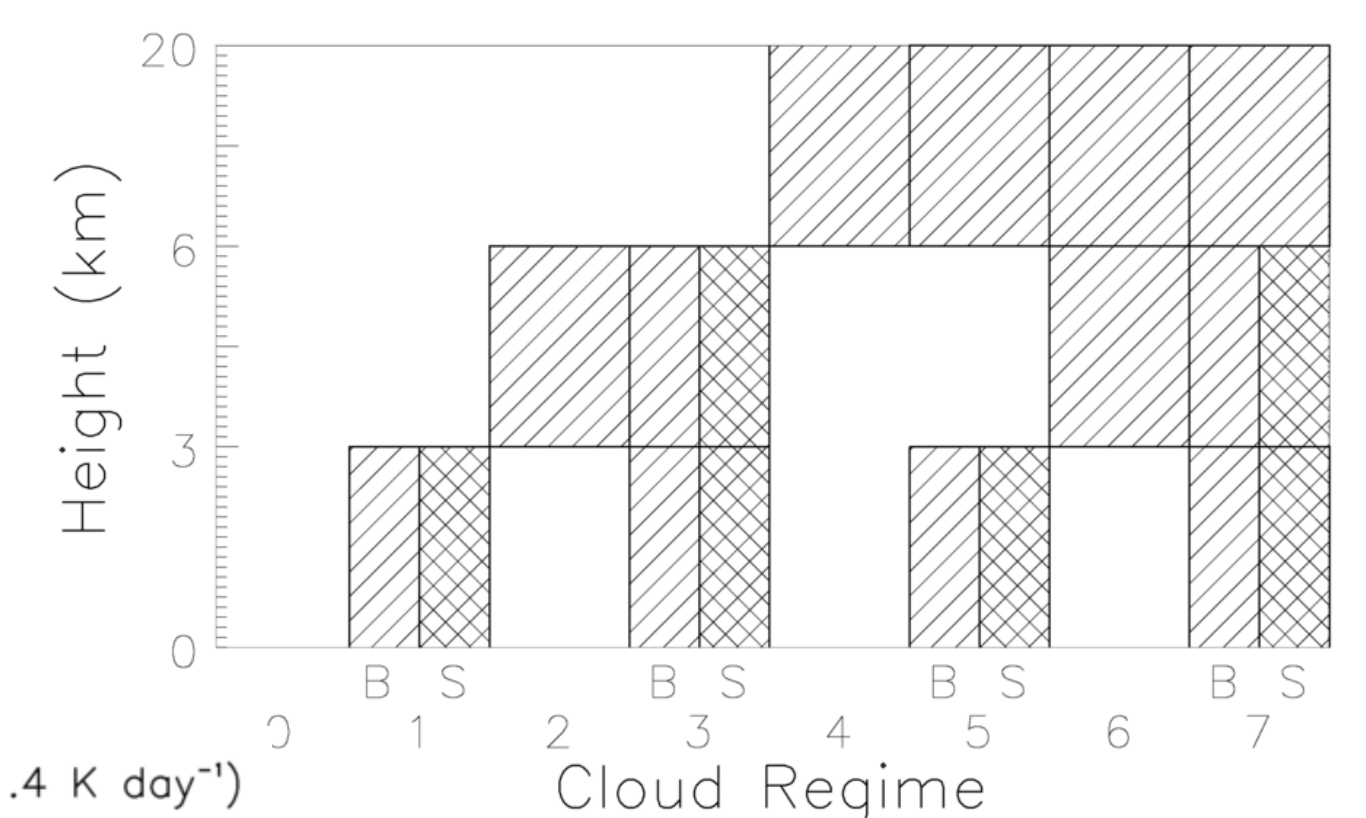


Role of Clouds

Clouds dominate the error-growth during afternoon, evening and night in MetUM and during evening in CAM5

Which regimes contribute most?

- 12 cloud regimes defined
- Based on cloud occurrence at three height-levels



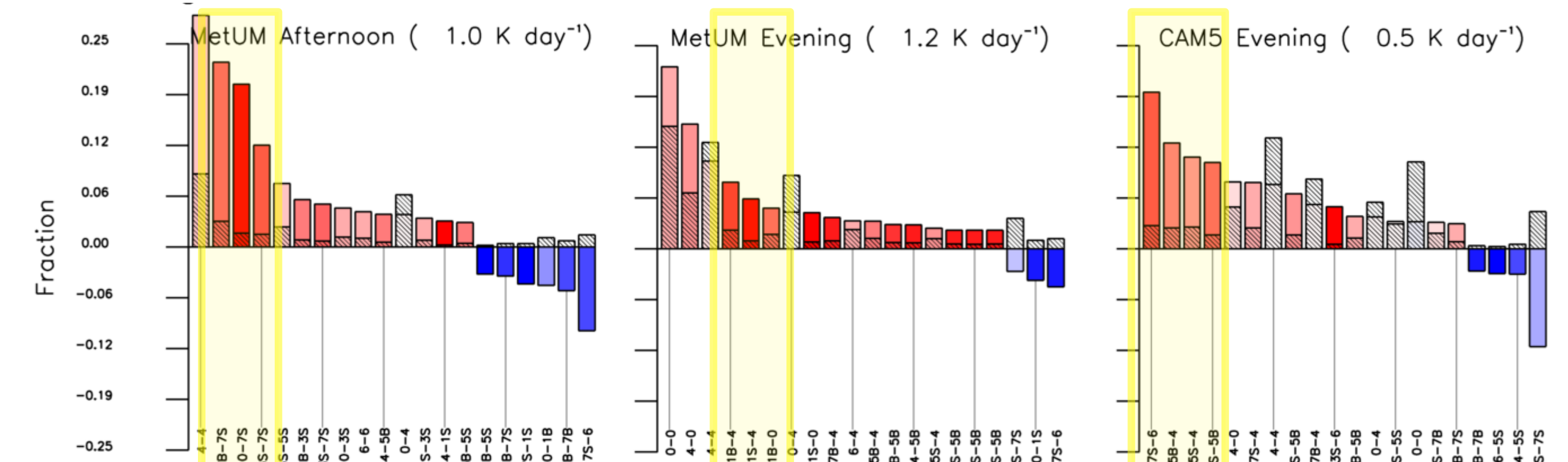
→ Which of the poorly captured regimes are most responsible for the T-bias growth?

Composition of T-bias by observed-simulated regime pair ij:

$$contribution_{ij} = \frac{Frequency_{ij} \cdot \Delta T_{bias_{ij}}}{|\Delta T_{bias}|}$$

MetUM: deep (7) and low clouds (1) in afternoon and evening respectively

CAM5: deep (7) and cirrus-over-low clouds (5) in evening

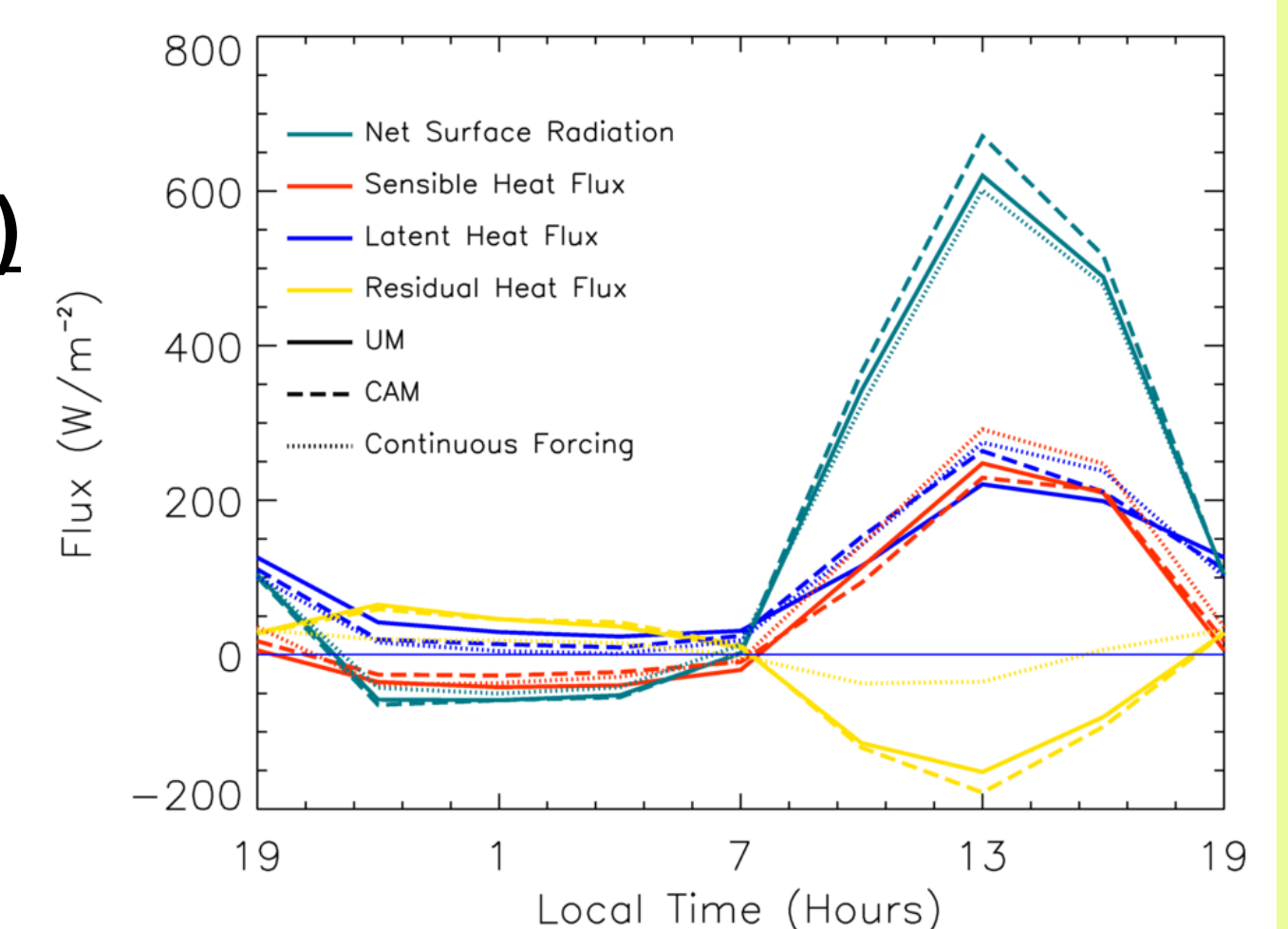


Role of Land-Surface

Clouds do not dominate the error-growth during morning in both GCMs and afternoon in CAM5

Energy balance for unbiased downwelling radiation (no cloud issues)

- CAM5: Too much net surface radiation due to too **low albedo** → T-bias growth afternoon
- CAM5, MetUM: too **low turbulent fluxes** morning → T-bias decrease morning



Conclusions

- New methodology to (1) objectively identify whether clouds dominate in the creation of T-bias and (2) find contribution of each cloud regime pair.
- Unique feature is its focus on error-growth at time-step level (more unambiguous than focus on model mean state)
- T-bias growth in the MetUM mainly from missing deep clouds in afternoon and too many low clouds in the evening
- T-bias growth in the CAM5 mainly from too low albedo and too persistent deep and cirrus-over-low clouds in the evening