# Evaluation of clouds in GCMs using ARM-data:

# A time-step approach

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ASR-Science Team Meeting

03-17-2014

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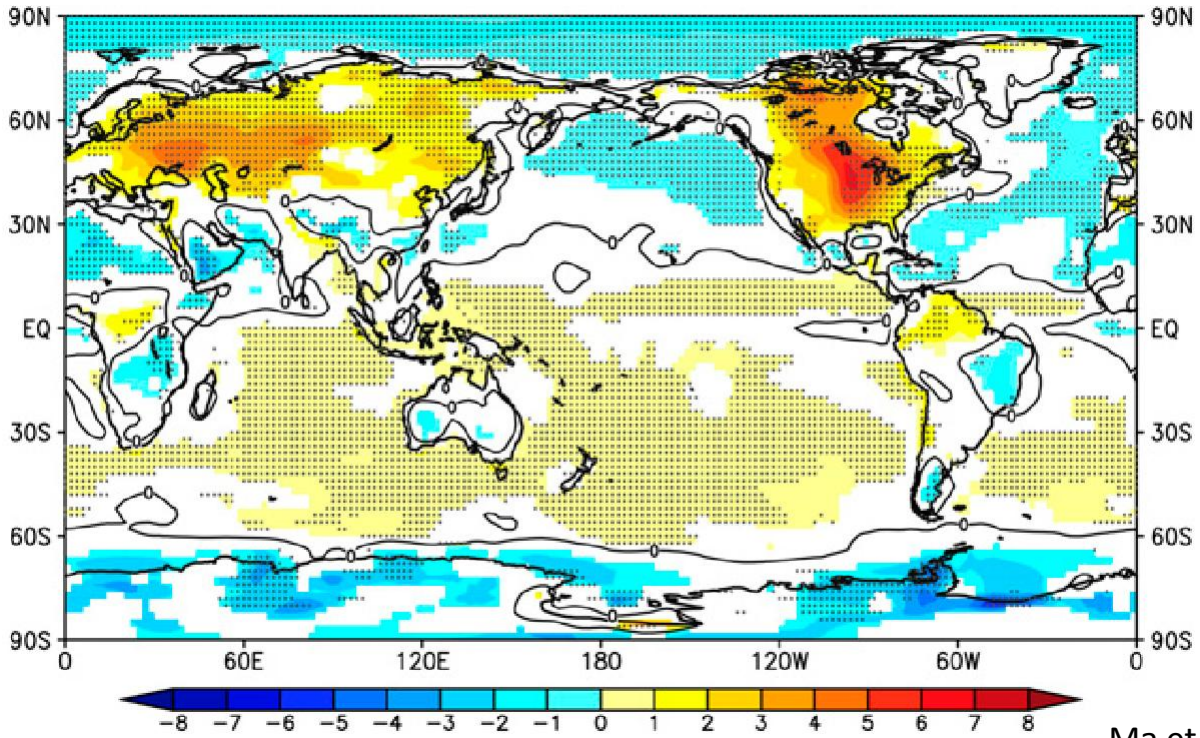
# Midlatitude Continental Warm Bias




2m-Temperature Bias (K)

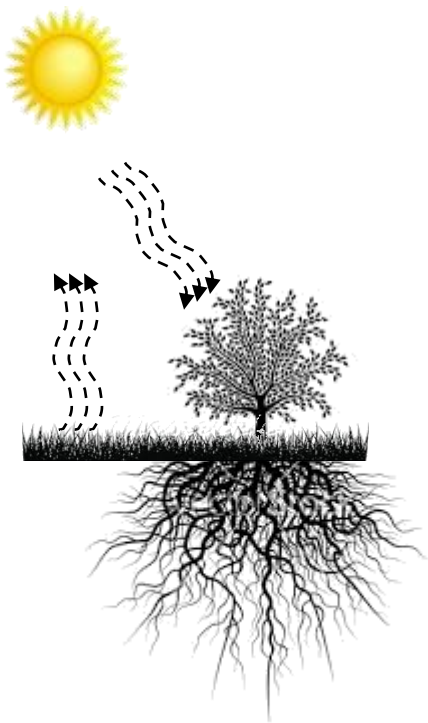
Ma et al. JC 2014

Colours: CMIP5 ensemble for 20 years
Dots: Day 5 forecast using same GCMs

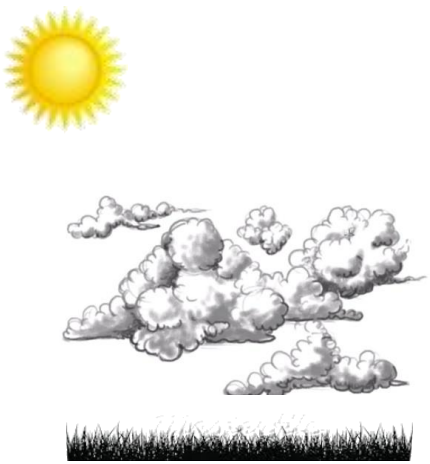
# Midlatitude Continental Warm Bias

**Hypotheses:**

Soil-vegetation-atmosphere



Boundary-layer clouds



Convective storms

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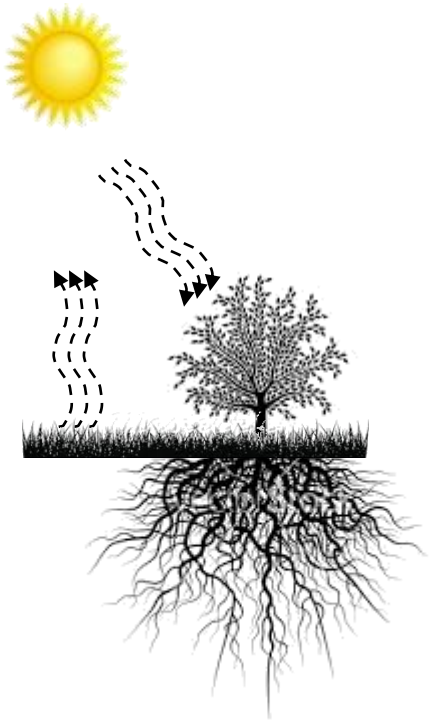

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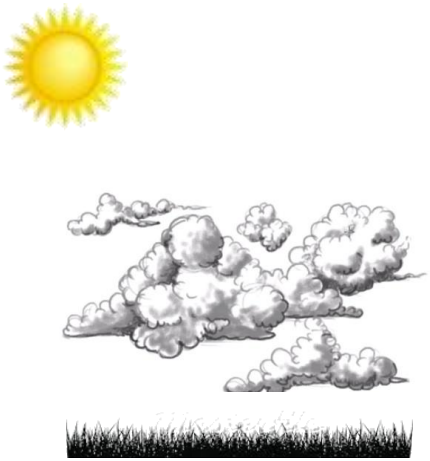


Convective storms

# Clouds Above the US and Errors at the Surface (CAUSES)

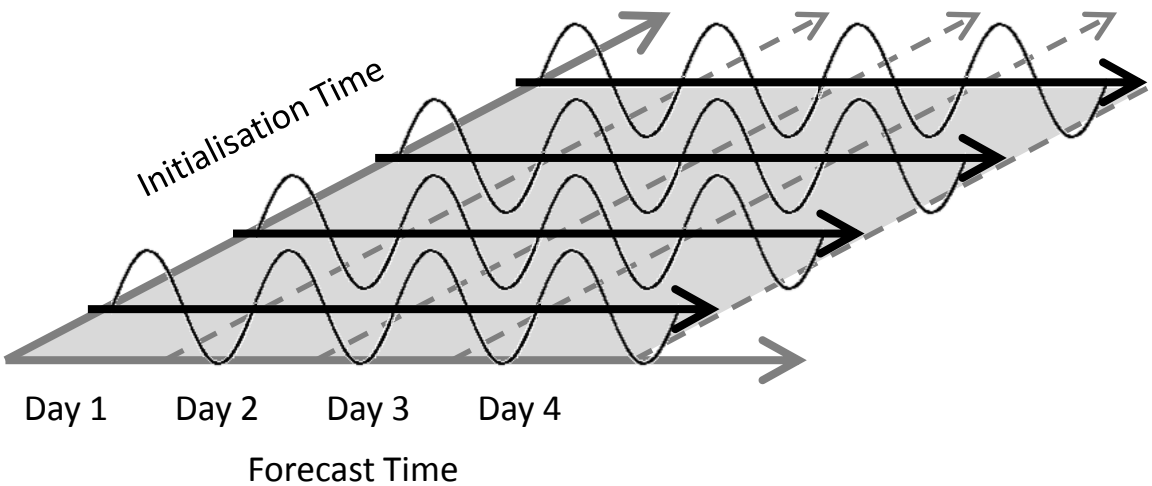
**Use ARM data to understand the <u>role of clouds</u> in the creation of the US warm bias**

**2 GCM simulations:** 4 day global hindcasts for MC3E-period (6 weeks) in 2011

**<u>MetUM:</u>**
- Initialised from ECMWF
- 30 km grid spacing

**<u>CAM5:</u>**
- Initialised from ERA-Interim
- 100 km grid spacing

**Compare observed and simulated time series at the SGP site**



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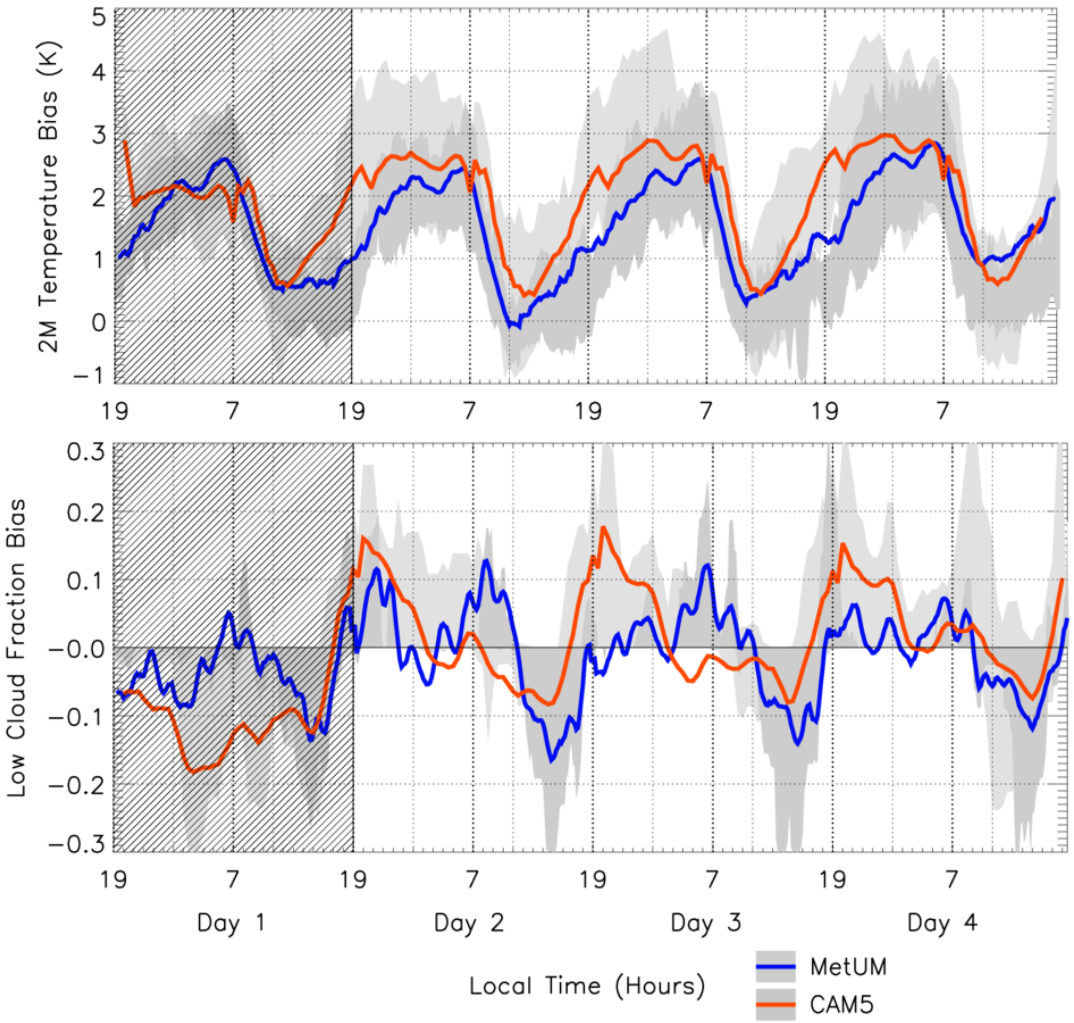


Average evolution of the bias over the 4 forecast days

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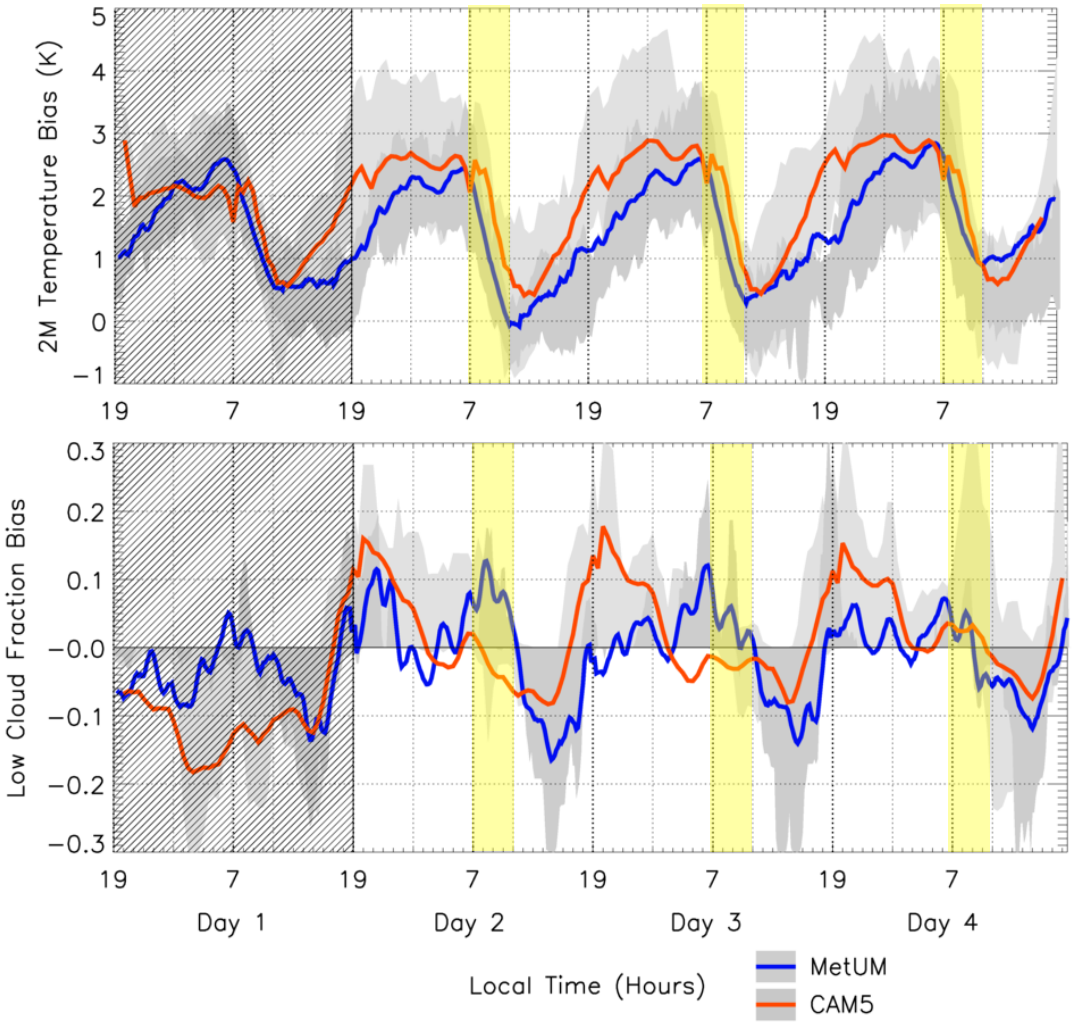


4 periods of distinct bias behaviour

**<u>Morning:</u>**

$T_{bias}$ **decreases**

$\Delta T_{bias}$ correlates with $CF_{bias}$ in MetUM, but not in CAM5

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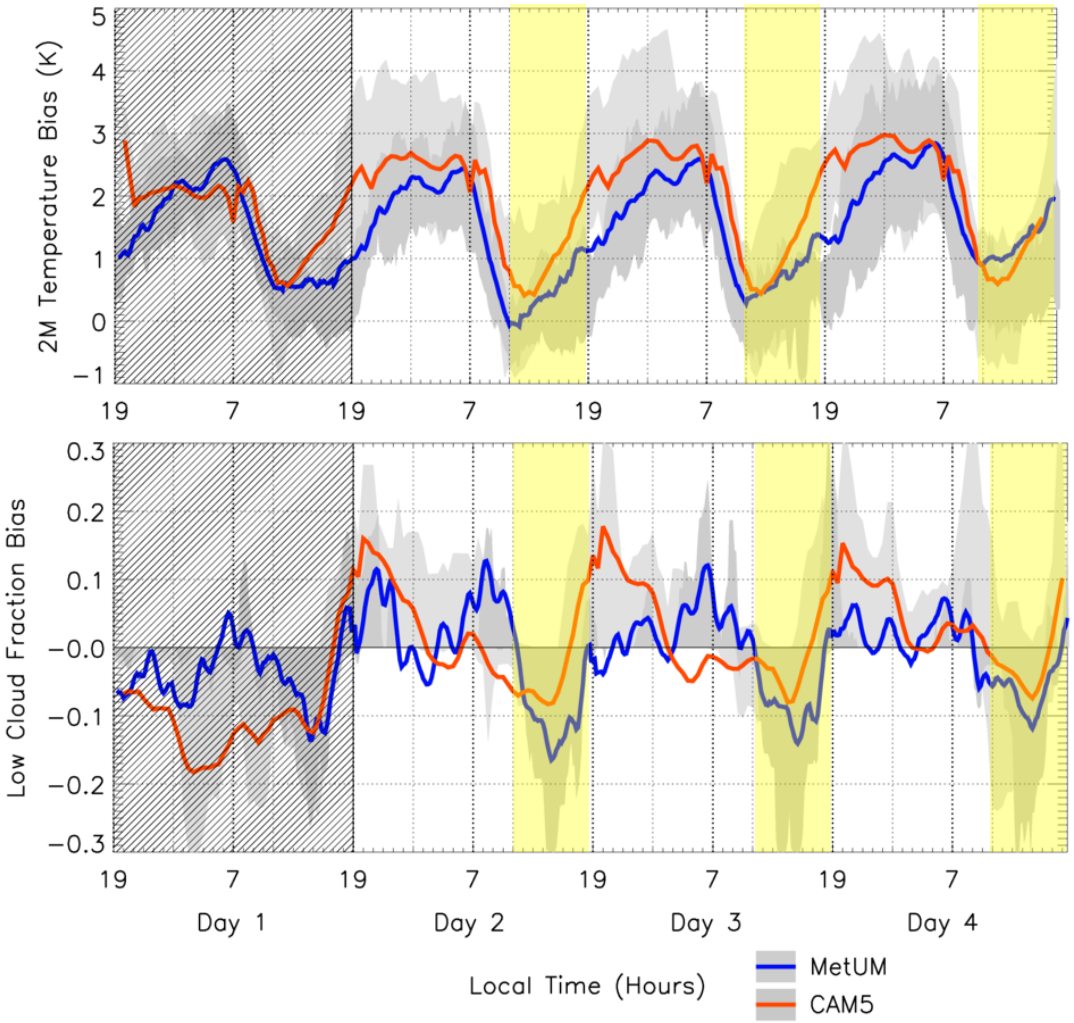


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**<u>Afternoon:</u>**

$T_{bias}$ **increases**

$\Delta T_{bias}$ correlates with $CF_{bias}$

But: Largest *increase* in $T_{bias}$ for GCM with smallest $CF_{bias}$

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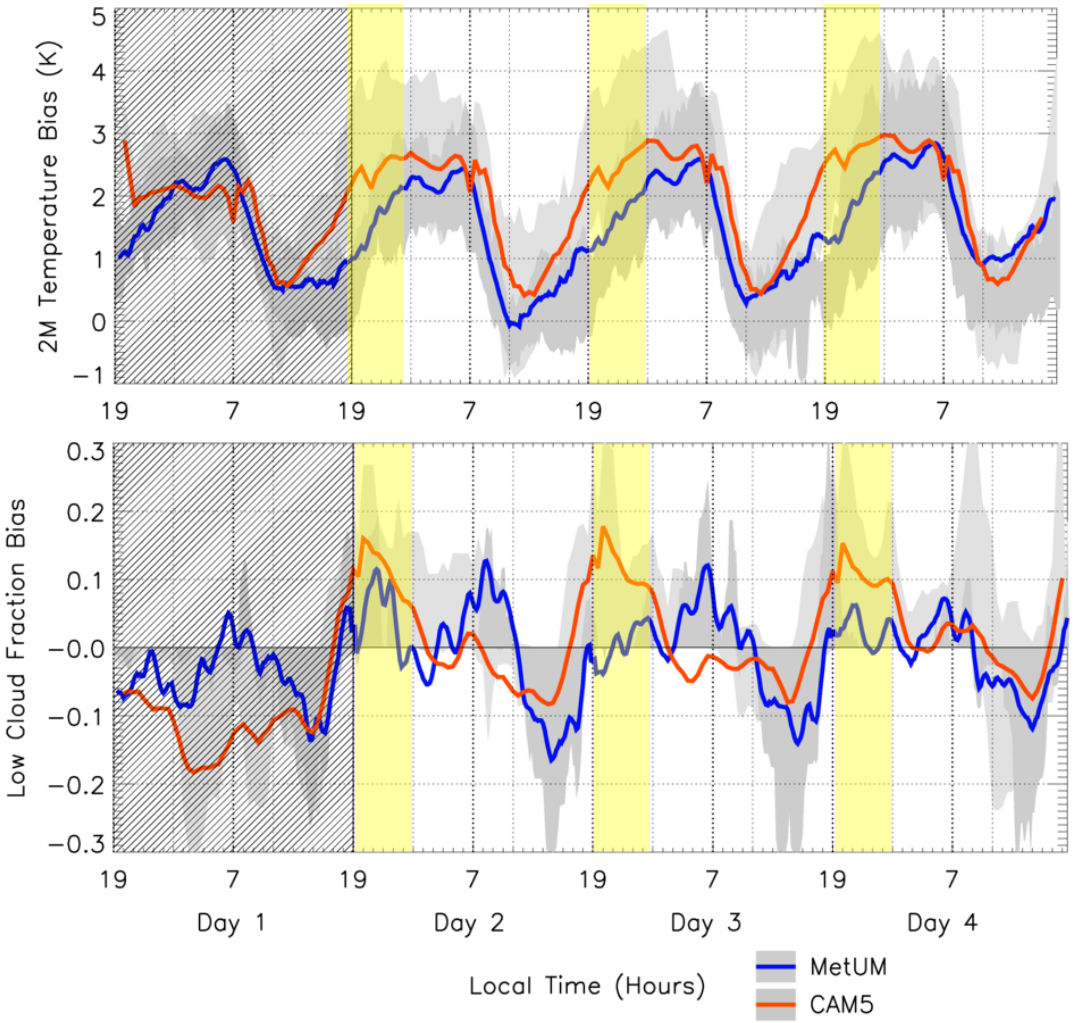


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**<u>Evening:</u>**

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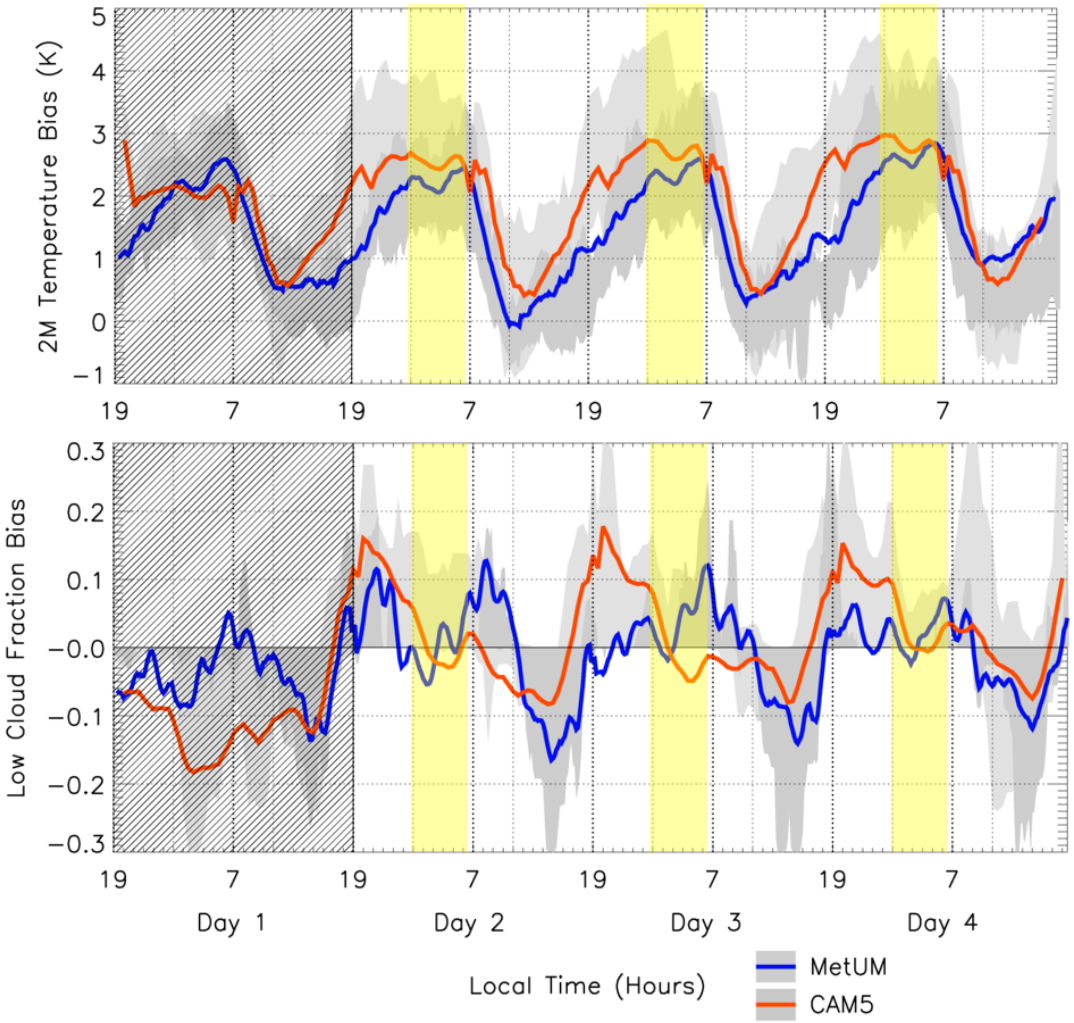


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**<u>Night:</u>**

$T_{bias}$ fairly **constant**

# Time-step approach for model evaluation

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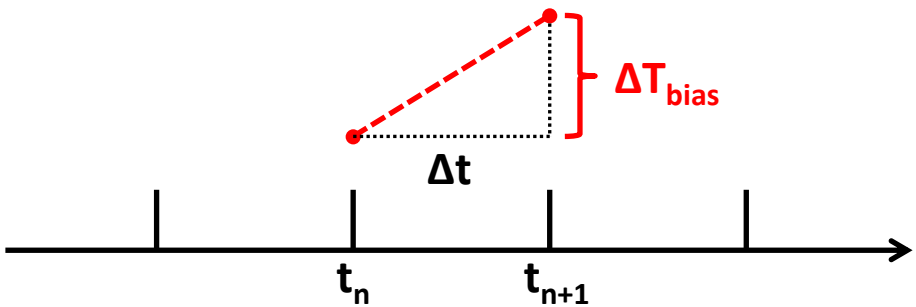

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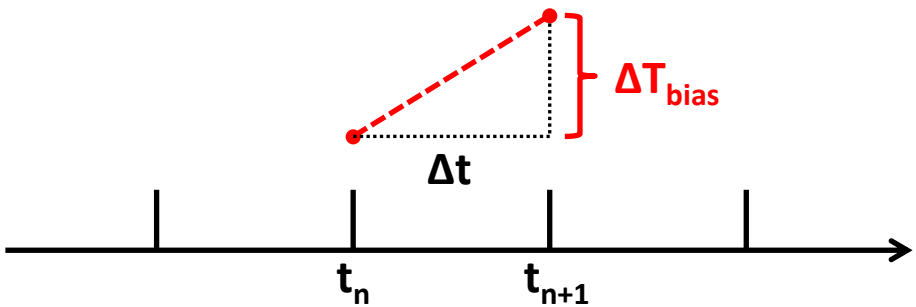

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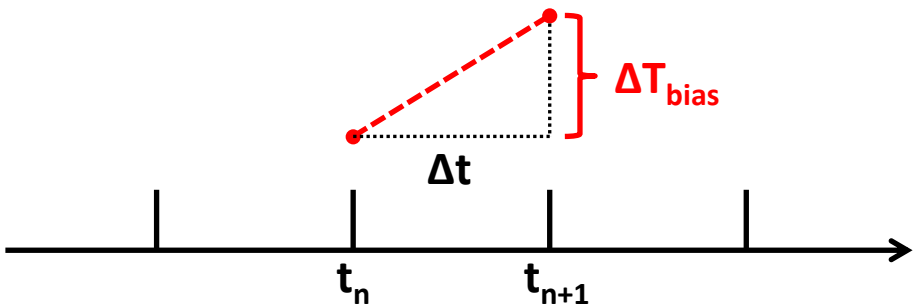

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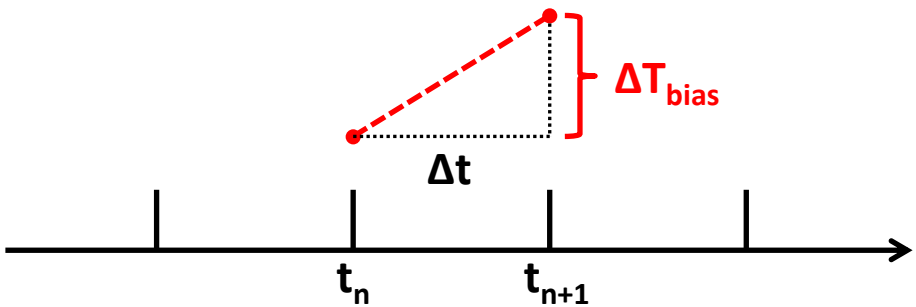
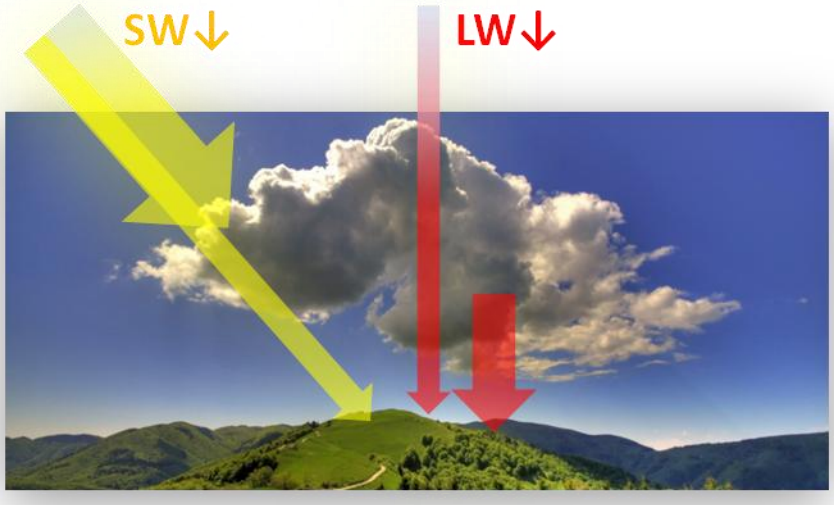
→ **Compositing** error-growth by coincident biases in other variables



# Time-step approach for model evaluation

**Compositing of $\Delta T_{bias}$ (error growth) by downwelling (SW↓ + LW↓) $RAD_{bias}$ at Time-step level**

**Clouds influence surface temperature through radiation:**



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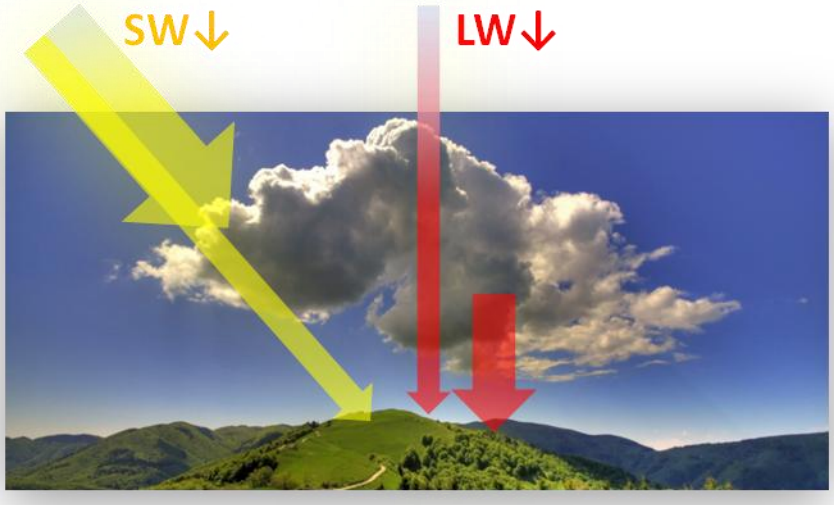


- **GOODRAD**: Cloud properties are **unbiased** and are **not** responsible for the $\Delta T_{bias}$ at $\Delta t$
- **BIASRAD**: Cloud properties are **biased** and could be responsible for the $\Delta T_{bias}$ at $\Delta t$

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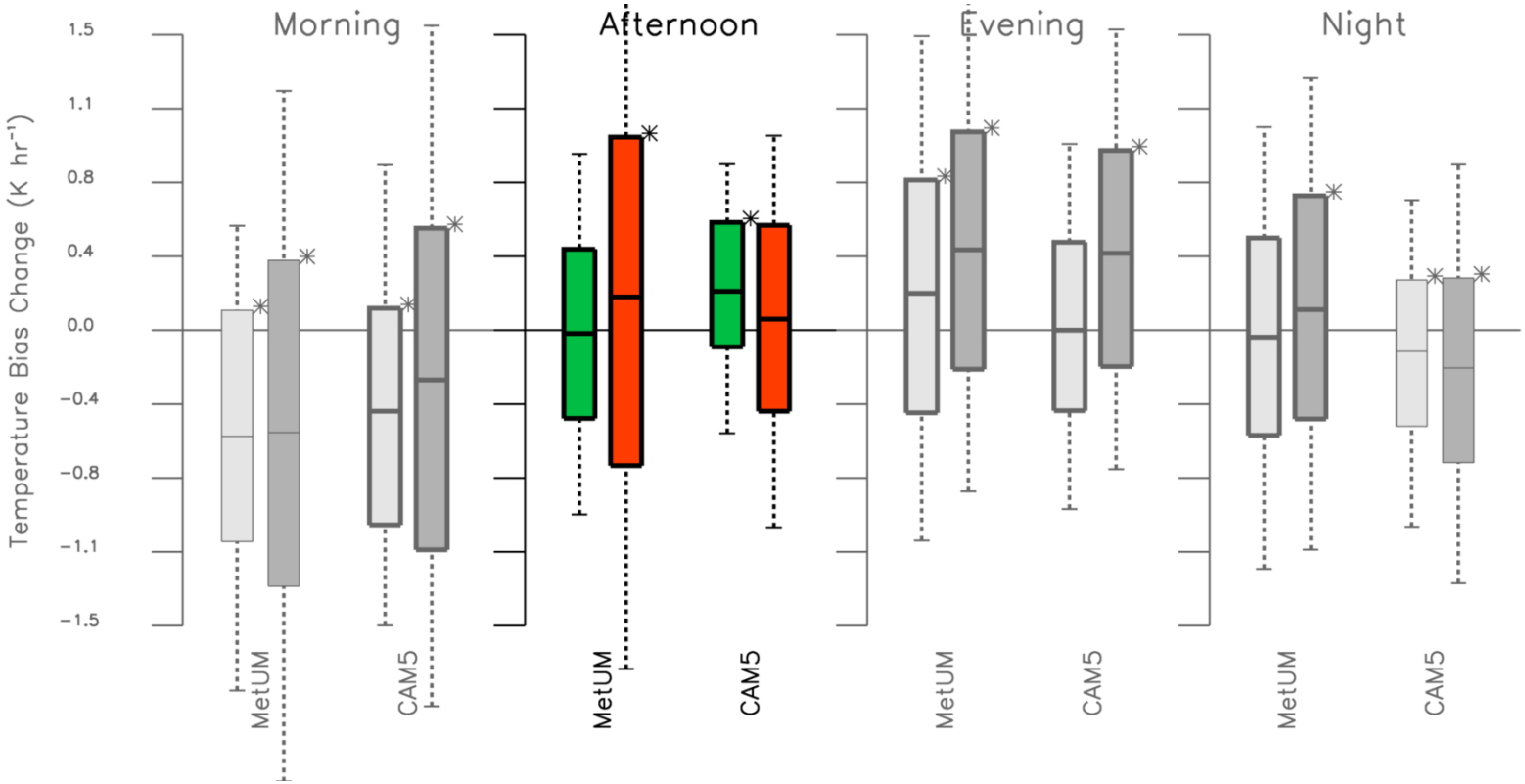

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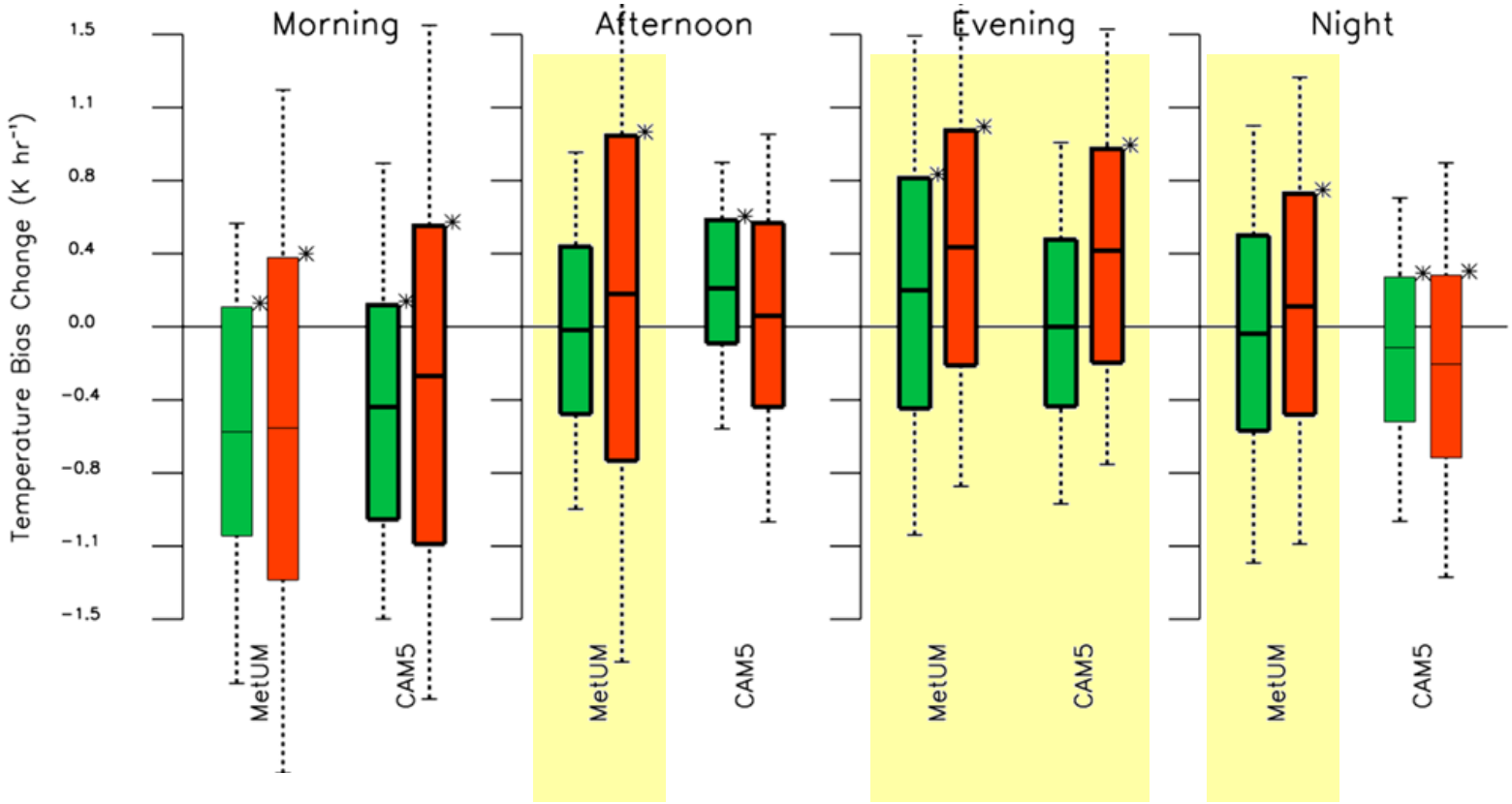

**= Dominant impact on $\Delta T_{bias}$ likely by clouds**

# Cloud regime compositing

**Compositing of $\Delta T_{bias}$ (error growth) by observed-simulated regime pair at time-step level**

12 cloud regimes defined on cloud occurrence at 3 levels

→ Each time step assigned to obs/sim **regime pair**

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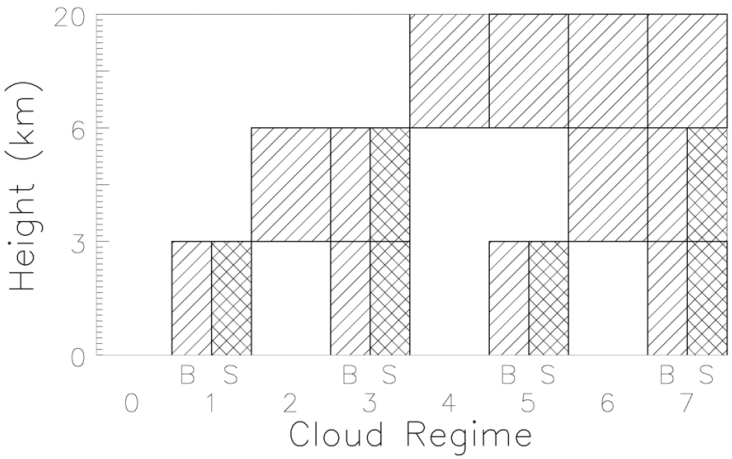
→ **Contribution** of observed/simulated regime pair ij:



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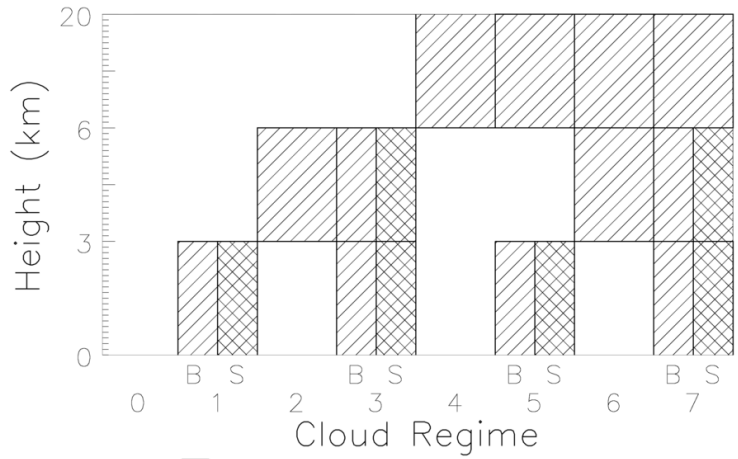


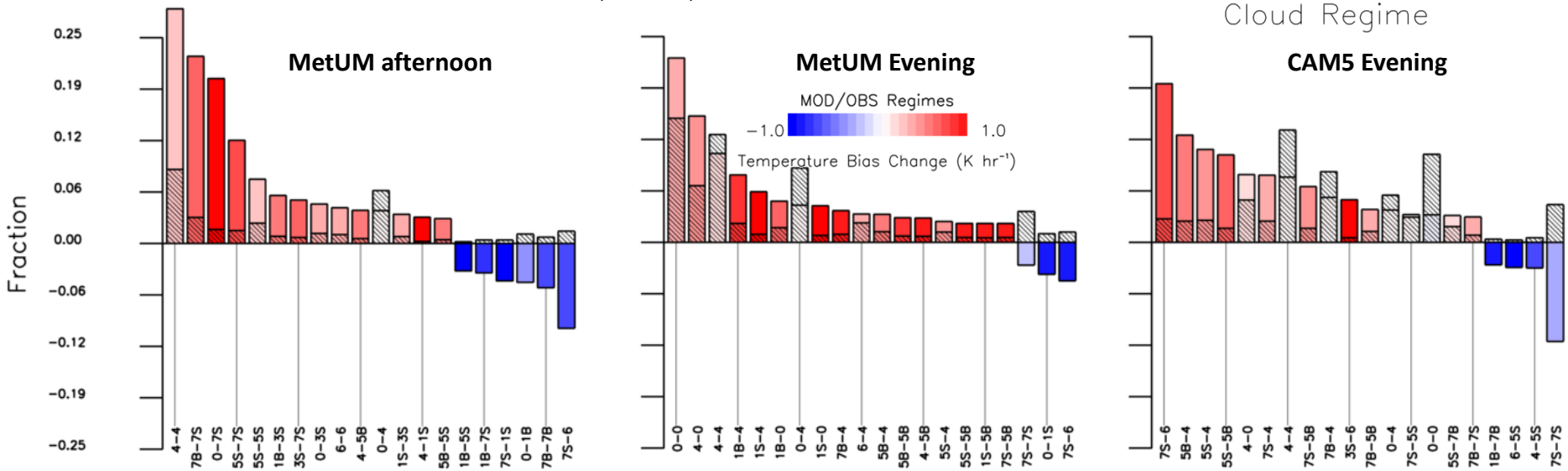

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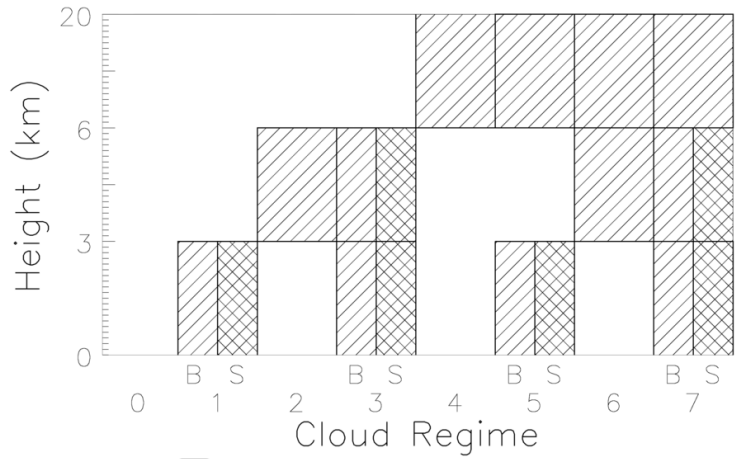


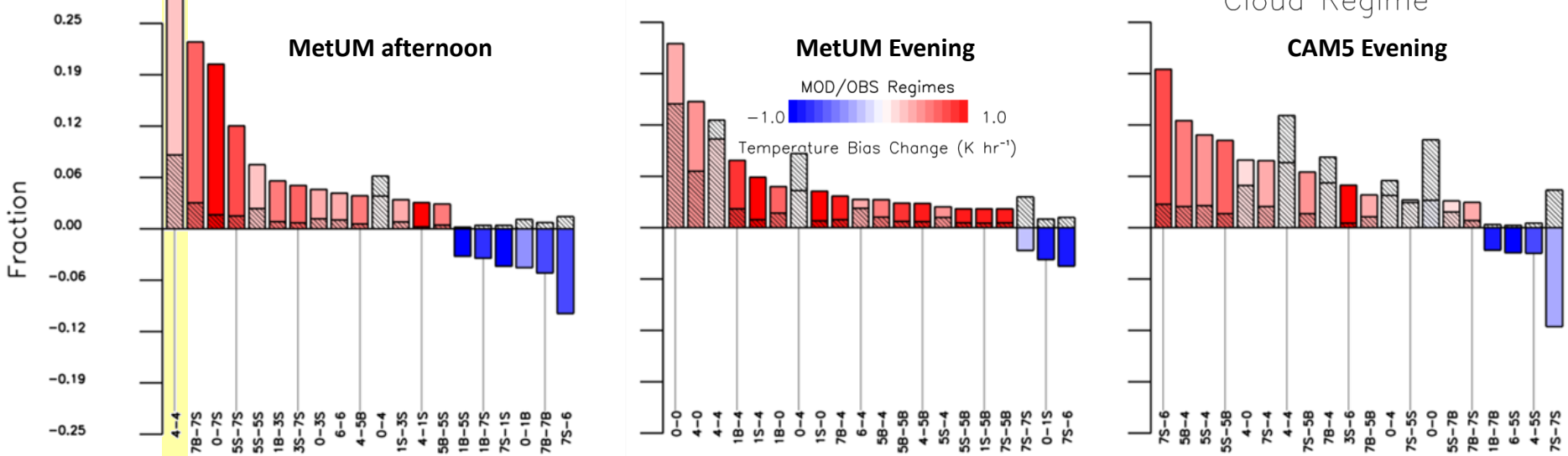


**MetUM afternoon: main contribution from correctly represented high cloud cover (4-4)**

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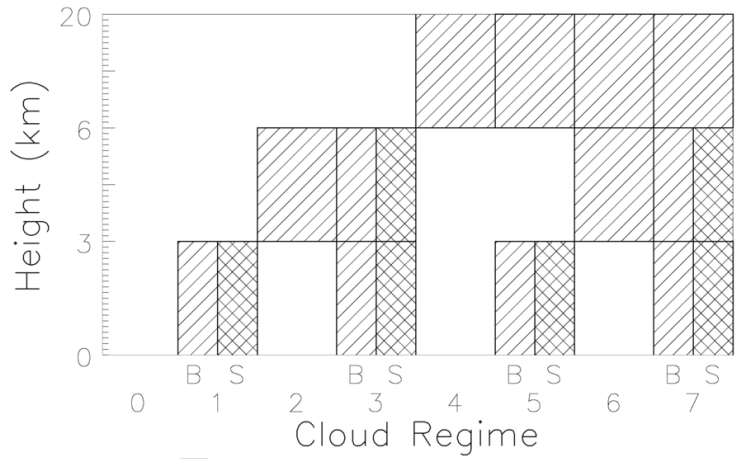


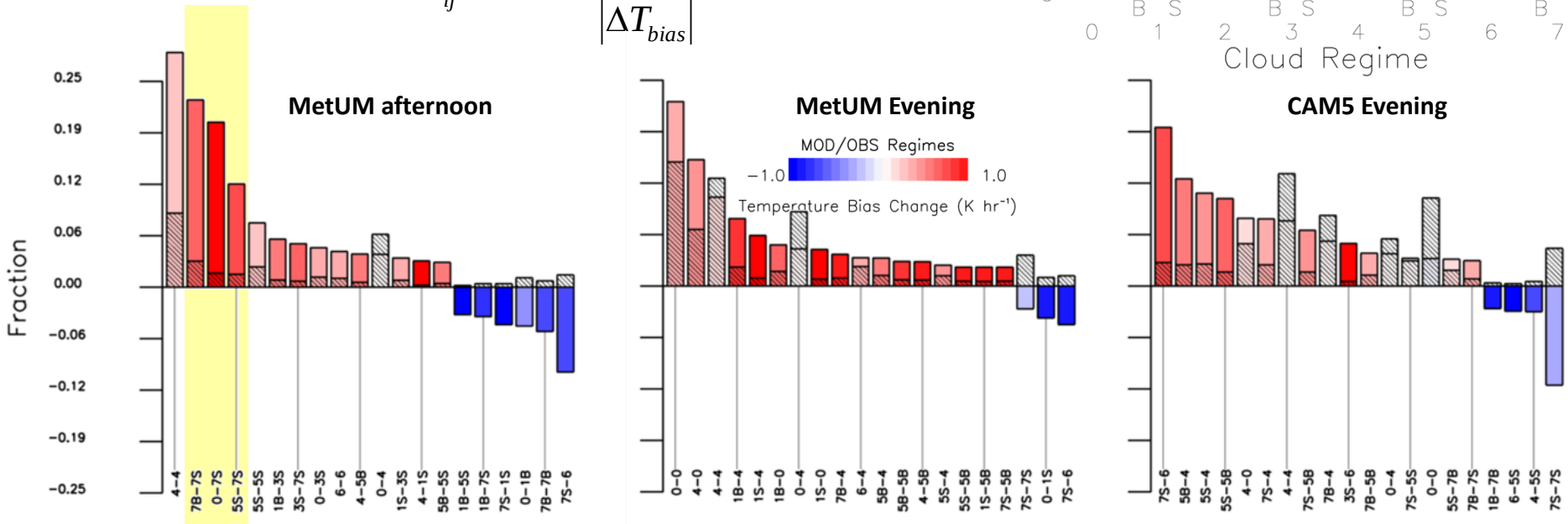


**MetUM afternoon: ... followed by missing and under-representing deep convection (7S)**

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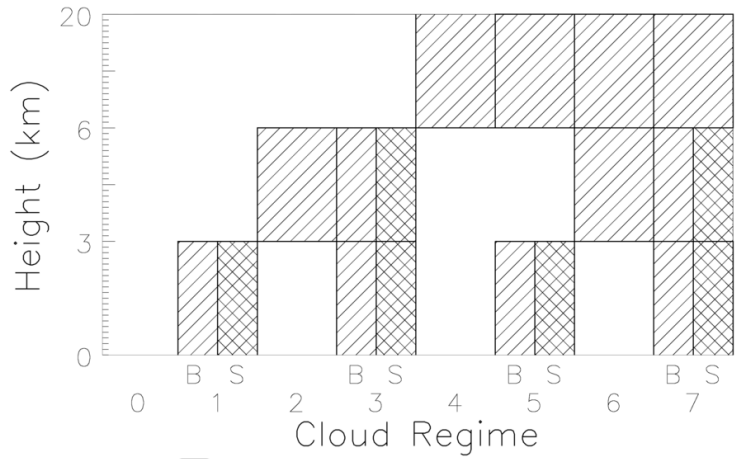


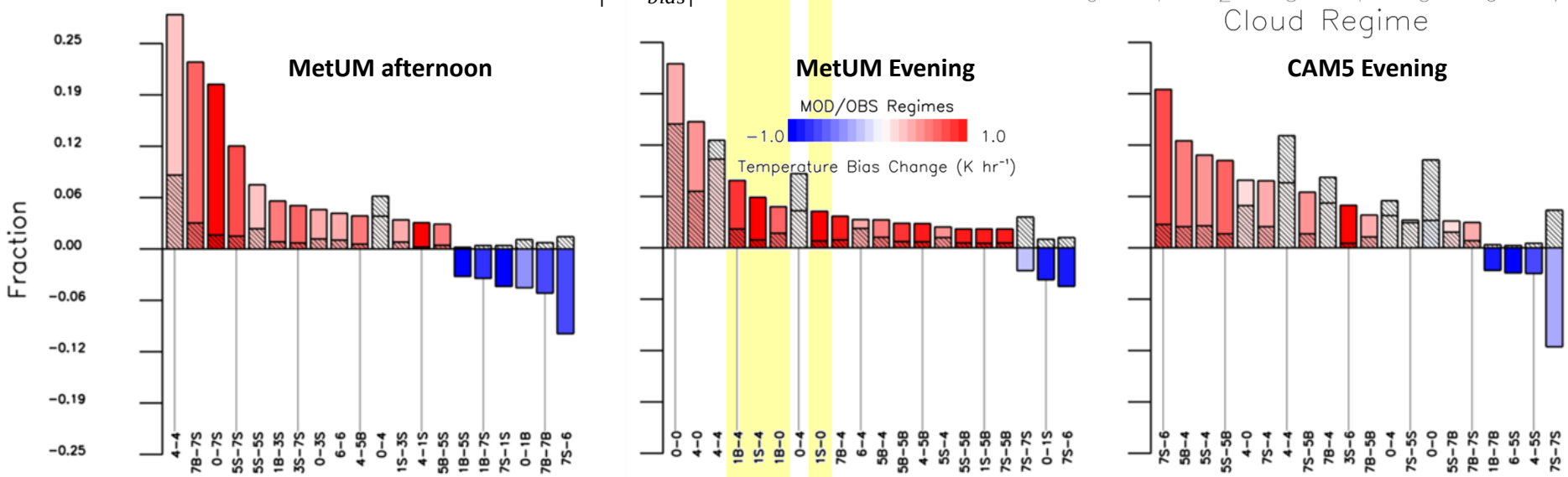


**MetUM evening: low-level clouds (and GOODRAD-regimes)**

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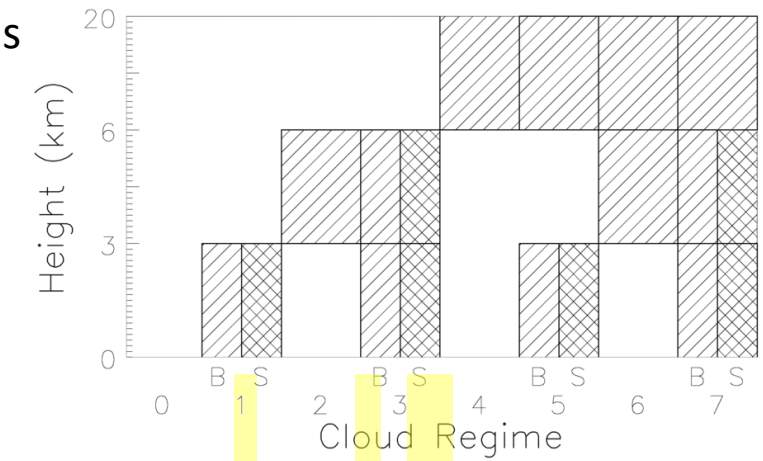


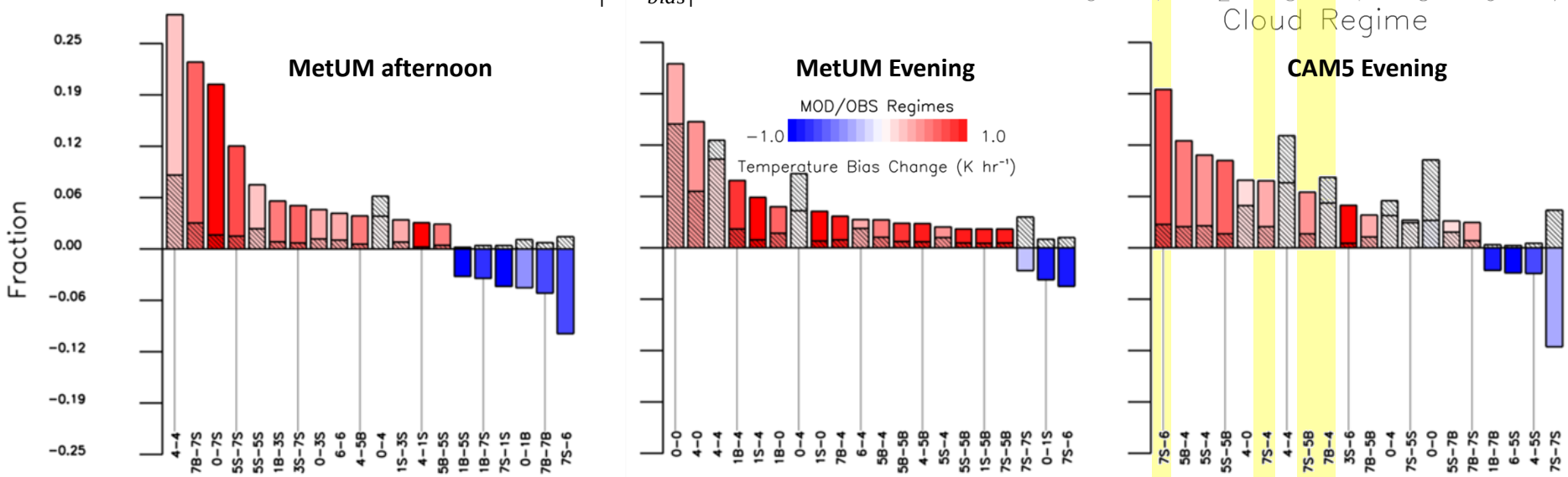


**CAM5 evening: too persistent convective clouds**

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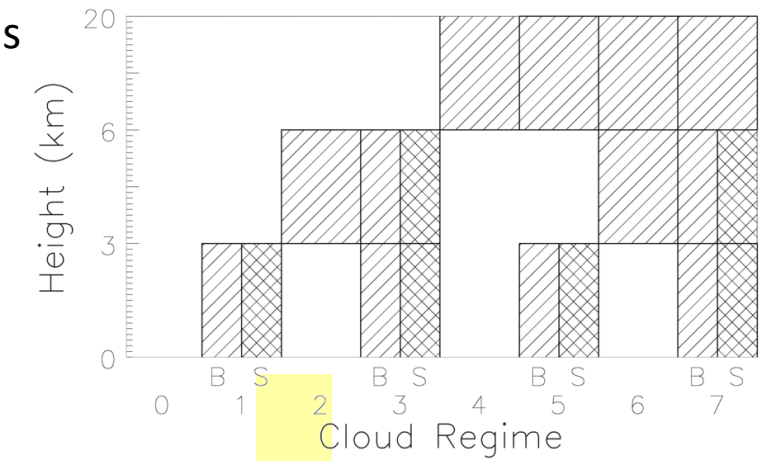


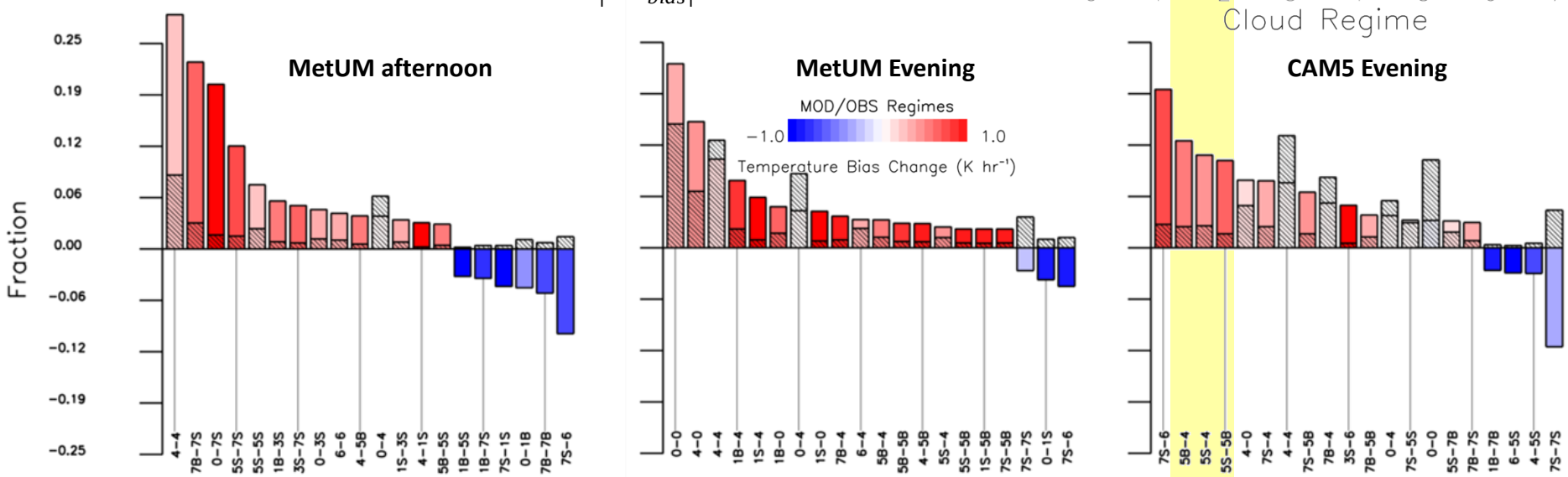


**CAM5 evening: ...and cirrus-over-low clouds**

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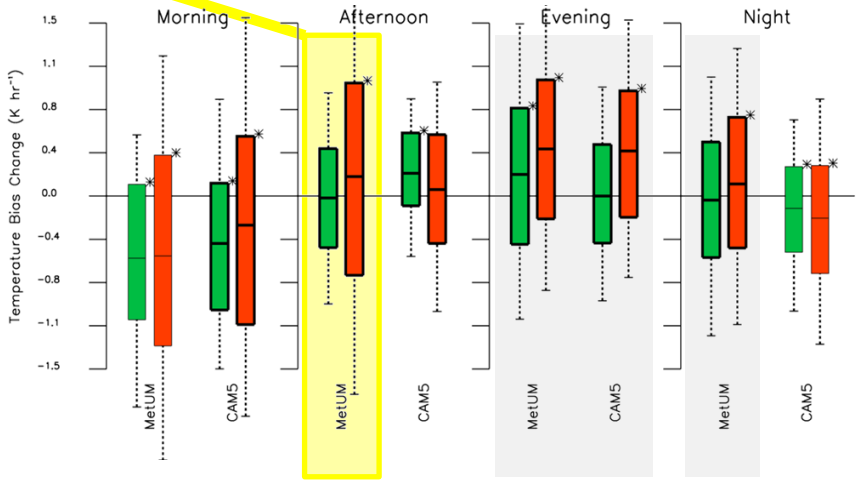

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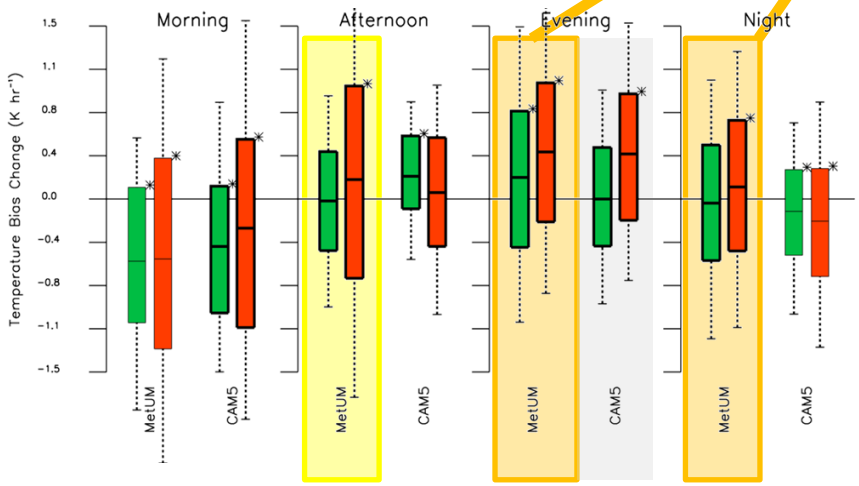

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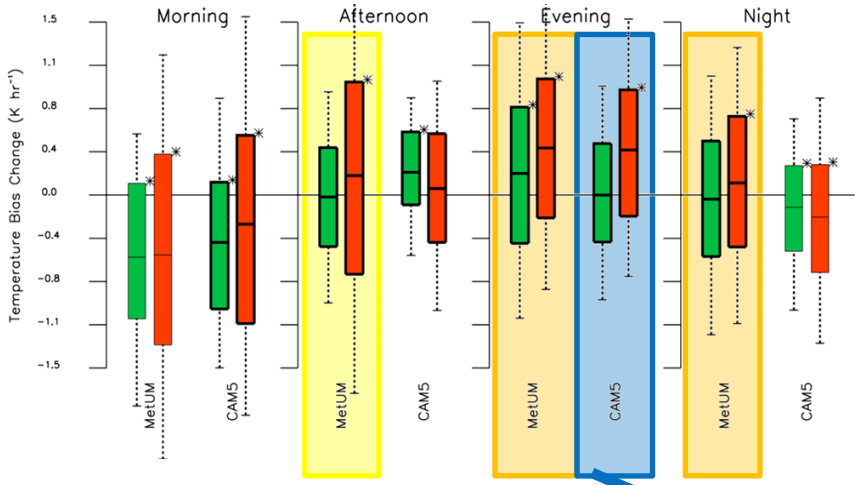

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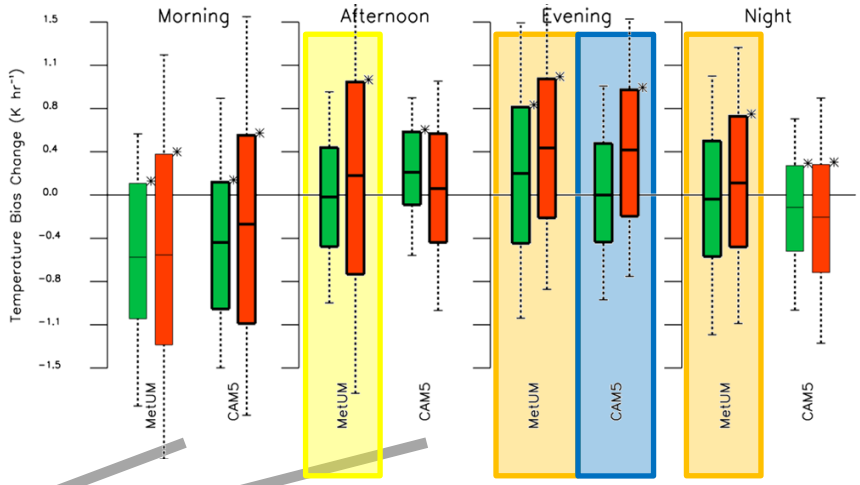
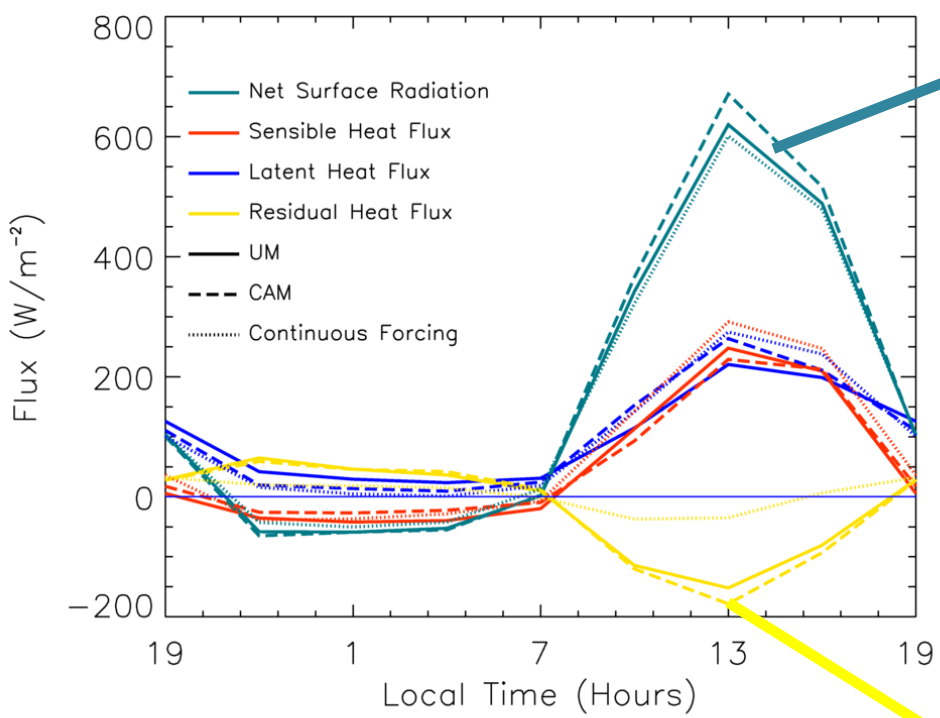


# Energy balance

**What about the land surface (preliminar)?**




**too low albedo CAM5**

**too small turbulent fluxes**

# Conclusions

**Different approach in model evaluation**

**Focus on error-growth at time-step level rather than average mean-state bias**

**Three-step methodology:**

1) Define periods in diurnal cycle with consistent temperature-bias-growth
2) Do clouds play a role? Composite the $\Delta T_{bias}$ by coincident downwelling radiation bias
3) Which clouds play a role? Apply regime-dependent analysis to find contribution

**Results for two GCMs:**

- CAM5: Evening $T_{bias}$ growth due to cirrus-over-low clouds
- MetUM: Afternoon $T_{bias}$ growth due to too transparent cirrus and lack of deep clouds; Too persistent boundary-layer clouds in evening and at night
- Morning bias reduction in both GCMs and afternoon bias growth in CAM5 due to other processes (e.g. albedo or turbulent fluxes)

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# Outlook

**Knowing where to focus efforts, approach can be starting point for model development**

→ Lack of deep convection related to missing interaction with Rockies and cold pools?

→Overestimation nocturnal boundary-layer clouds related to PBL-scheme or large-scale cloud scheme?

→These hypotheses will be tested for the MetUM

**Approach will be part of analysis carried out on multiple GCMs within CAUSES**

→Project with observationally-based focus, which evaluates the role of clouds, radiation and precipitation processes contributing to the surface temperature biases in the central US and which are seen in several weather and climate models

→About 9 modelling centres so far have agreed to provide GCM-data

→4-day hindcasts for MC3E-period as well as multi-month and multi-year AMIP-simulations

**Get in touch if you would like to participate: cyril.morcrette@metoffice.gov.uk or klein21@llnl.gov**

# Thanks!

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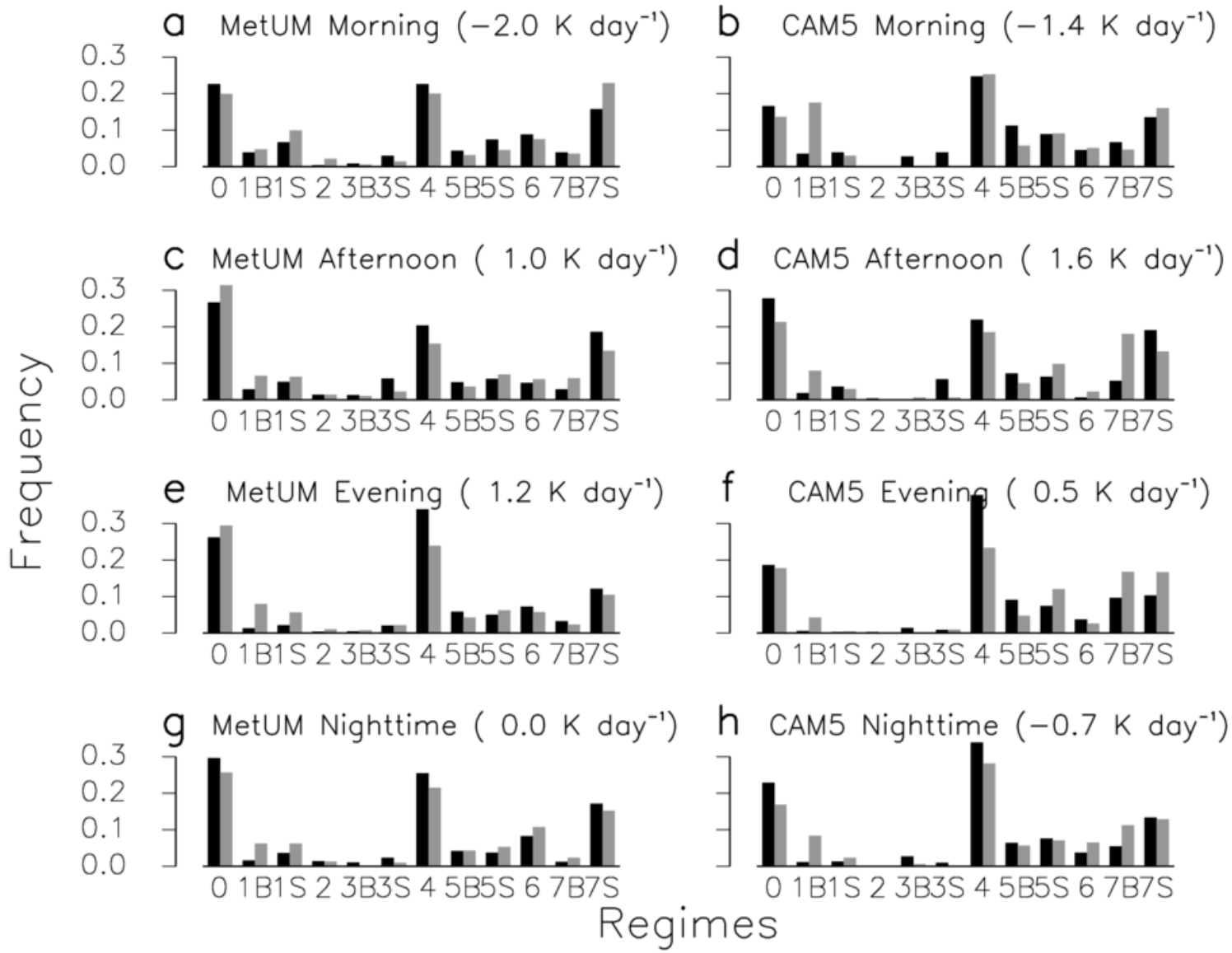
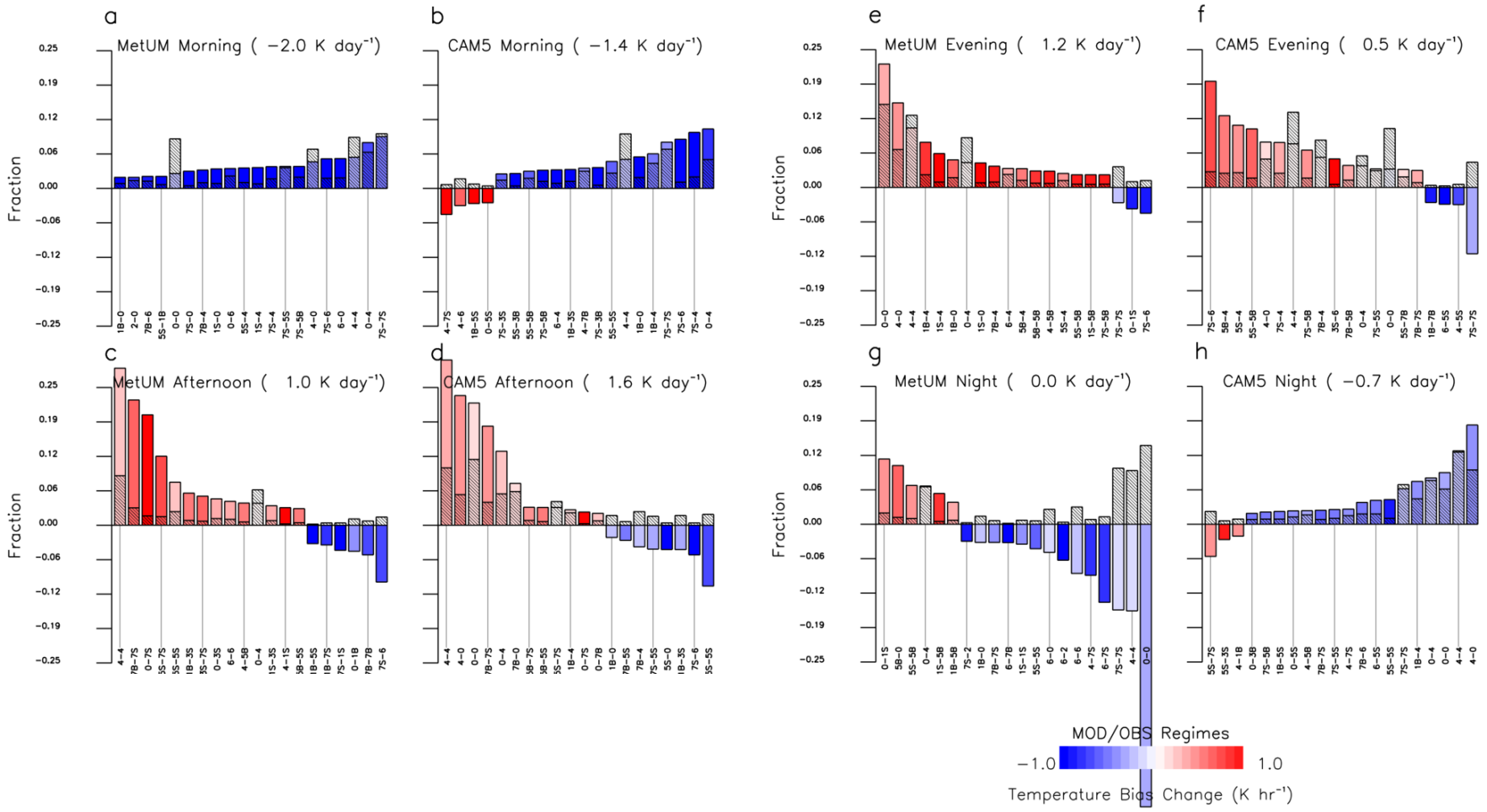
# Extra Slides



# Extra Slides