Evaluation of clouds in GCMs using ARM-data: A time-step approach

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ASR-Science Team Meeting

03-18-2014

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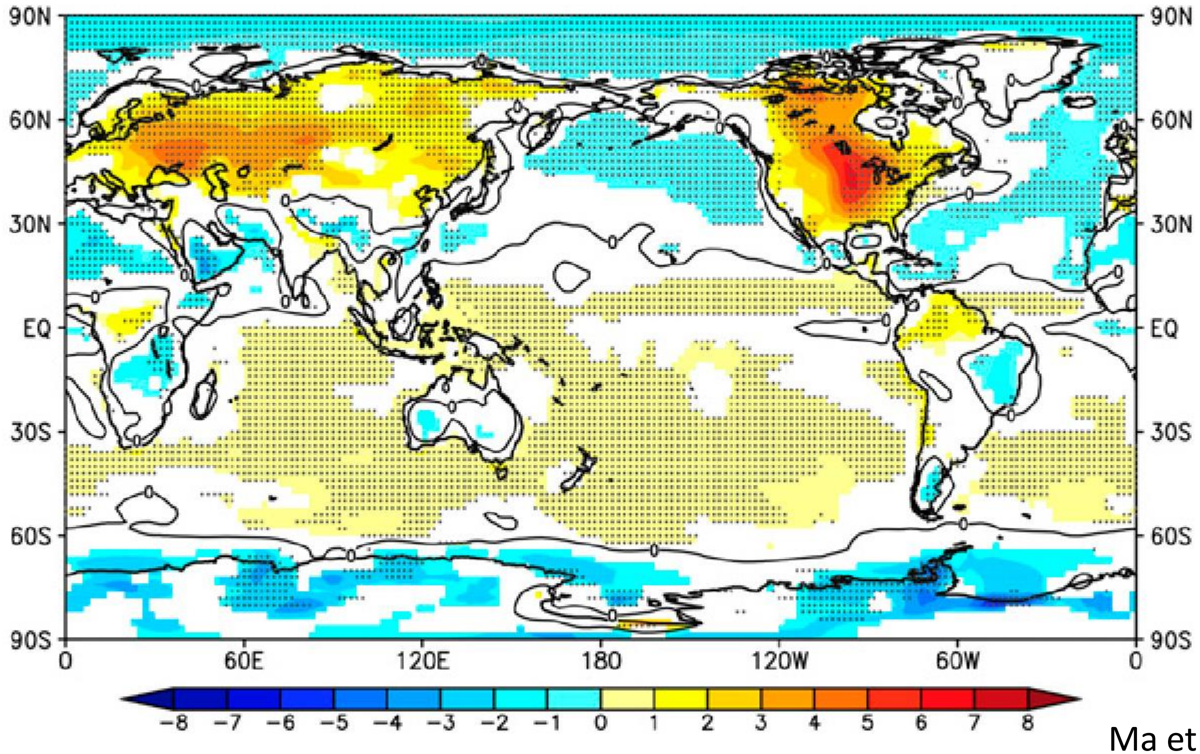
Midlatitude Continental Warm Bias



Ma et al. JC 2014

2m-Temperature Bias (K)

<u>Colours:</u> CMIP5 ensemble for 20 years
<u>Dots:</u> Day 5 forecast using same GCMs

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

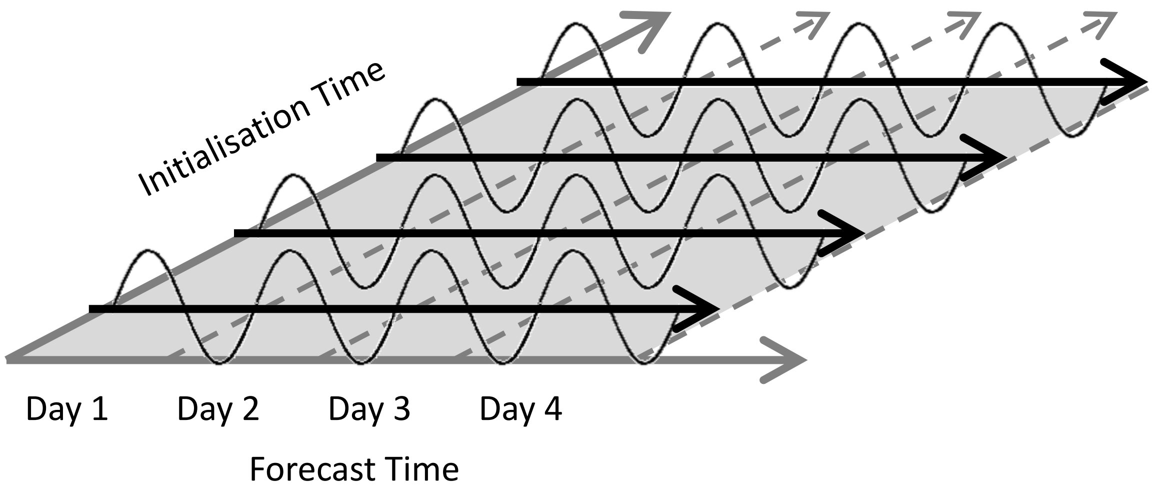
Use ARM data to understand the <u>role of clouds</u> in the creation of the US warm bias

2 GCM simulations: 4 day global hindcasts for MC^3E-period (6 weeks) in 2011

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

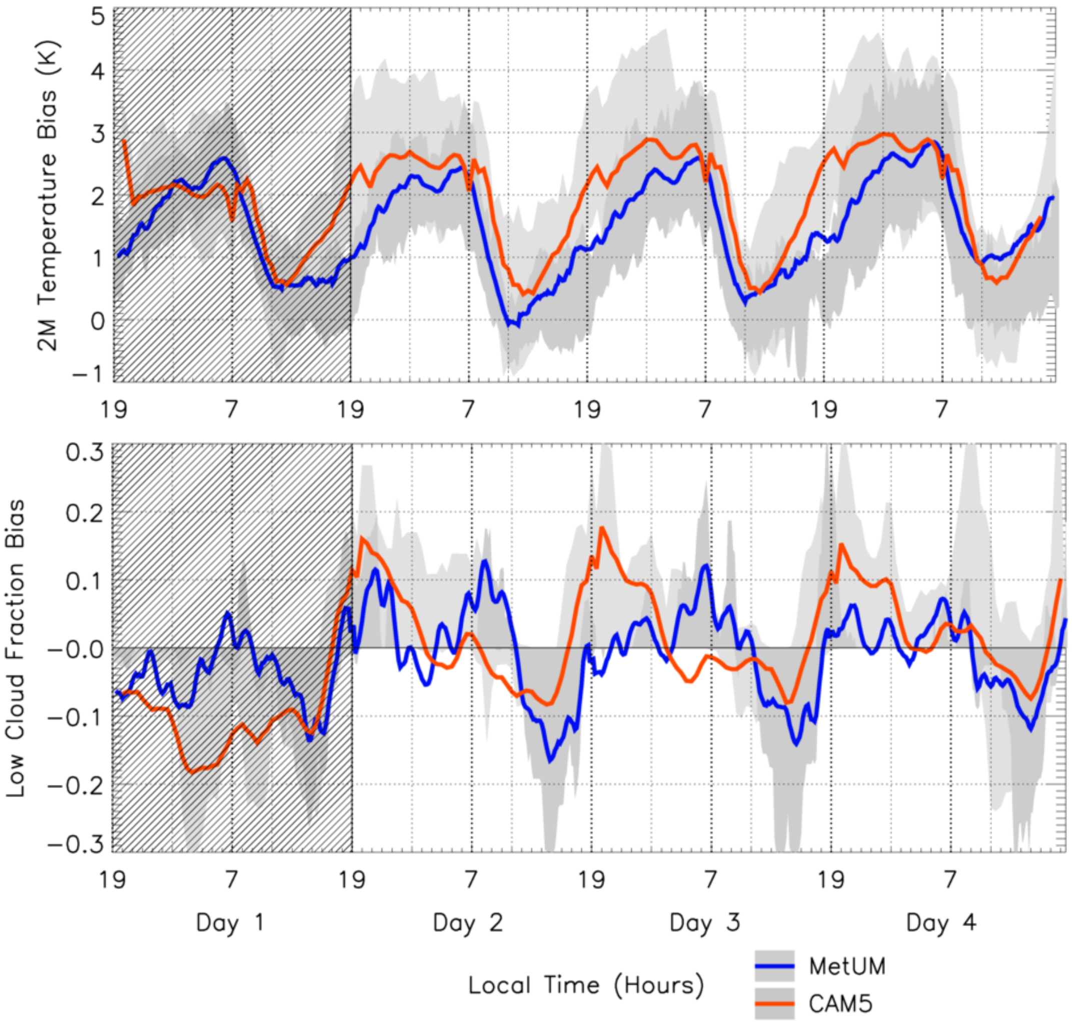
<u>CAM5:</u>
- Initialised from ERA-Interim
- 100 km grid spacing

Compare observed and simulated time series at the SGP site



Correlation of temperature and cloud errors

Use ARM data to understand the role of clouds in the creation of the US warm bias



Average evolution of the bias over the 4 forecast days

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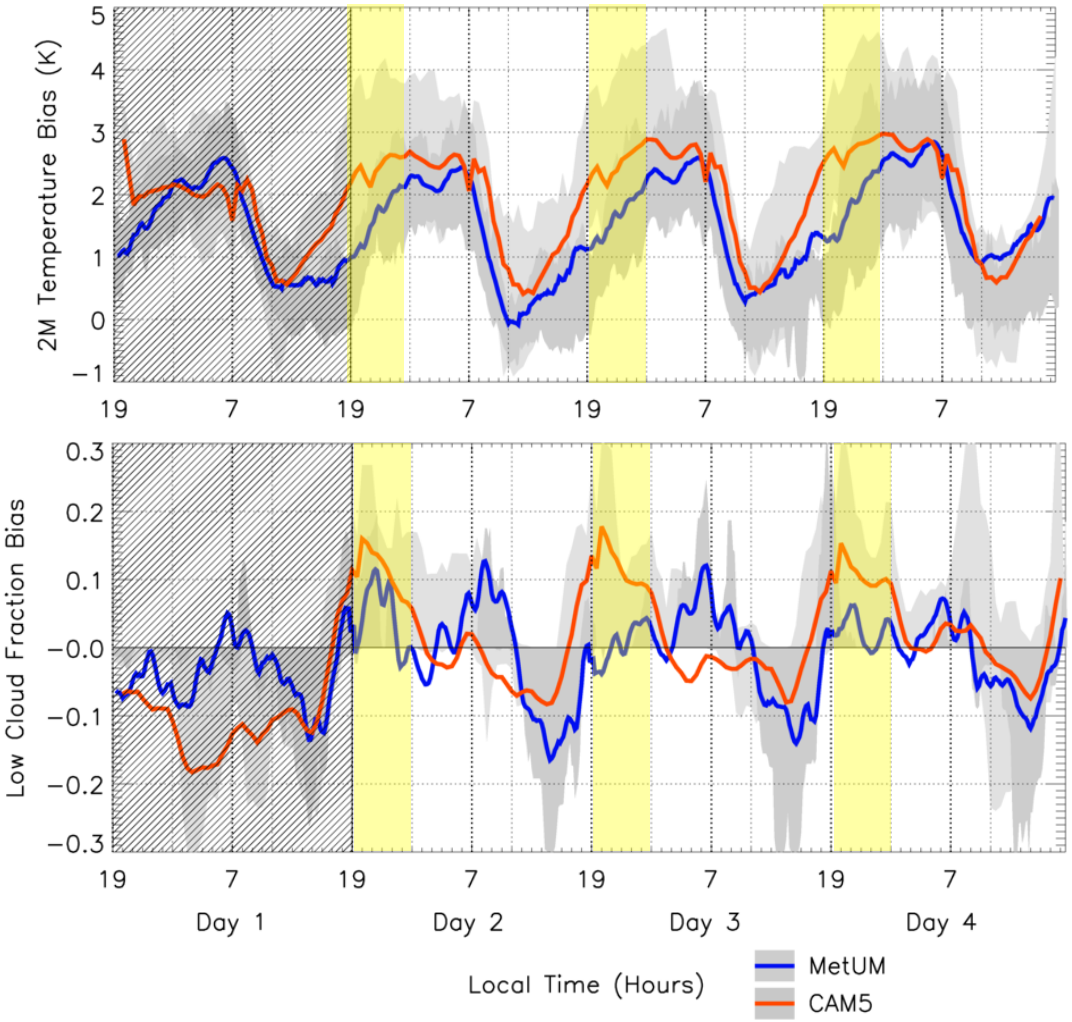

4 periods of distinct bias behaviour

<u>Evening:</u>

T_{bias} **increases**

ΔT_{bias} correlates with CF_{bias}

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

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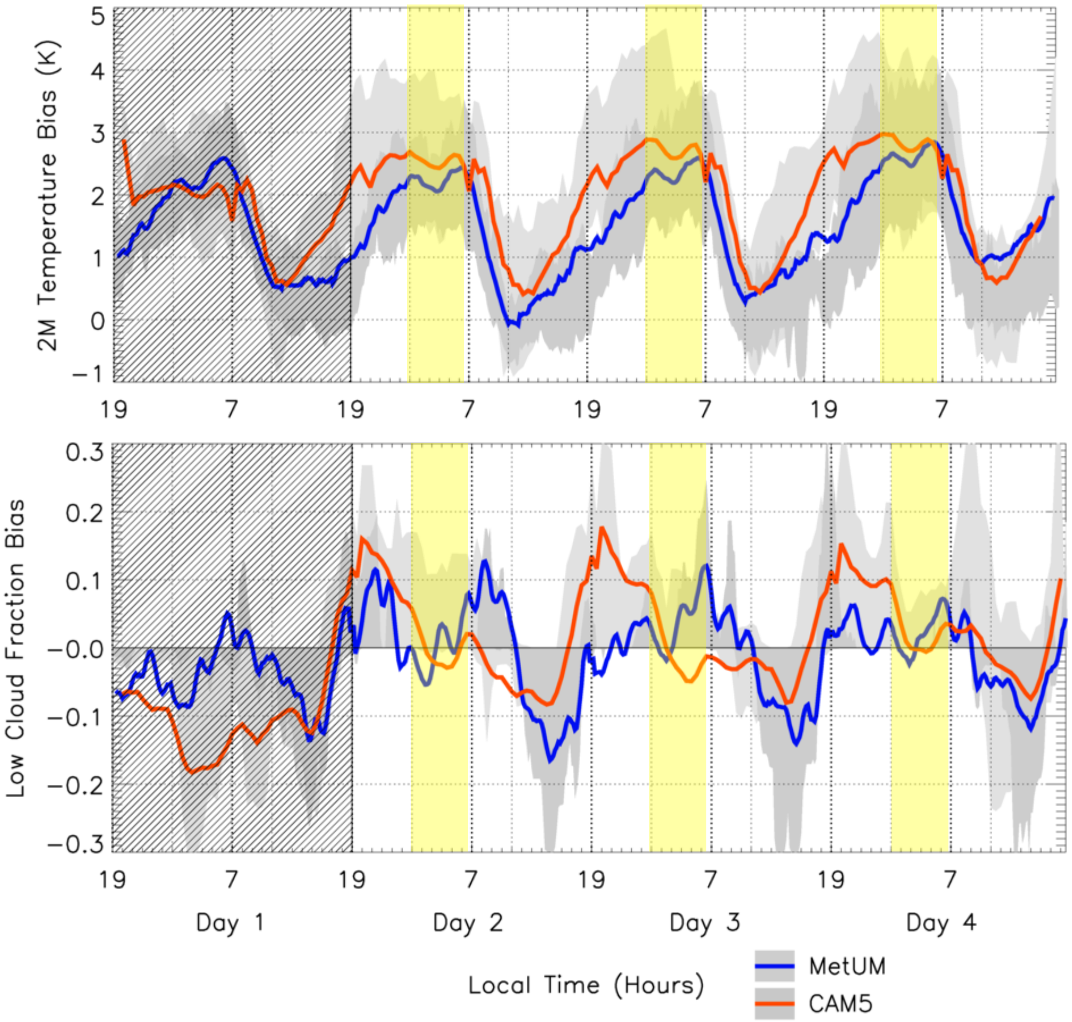

4 periods of distinct bias behaviour

<u>Night:</u>

T_{bias} fairly **constant**

Correlation of temperature and cloud errors

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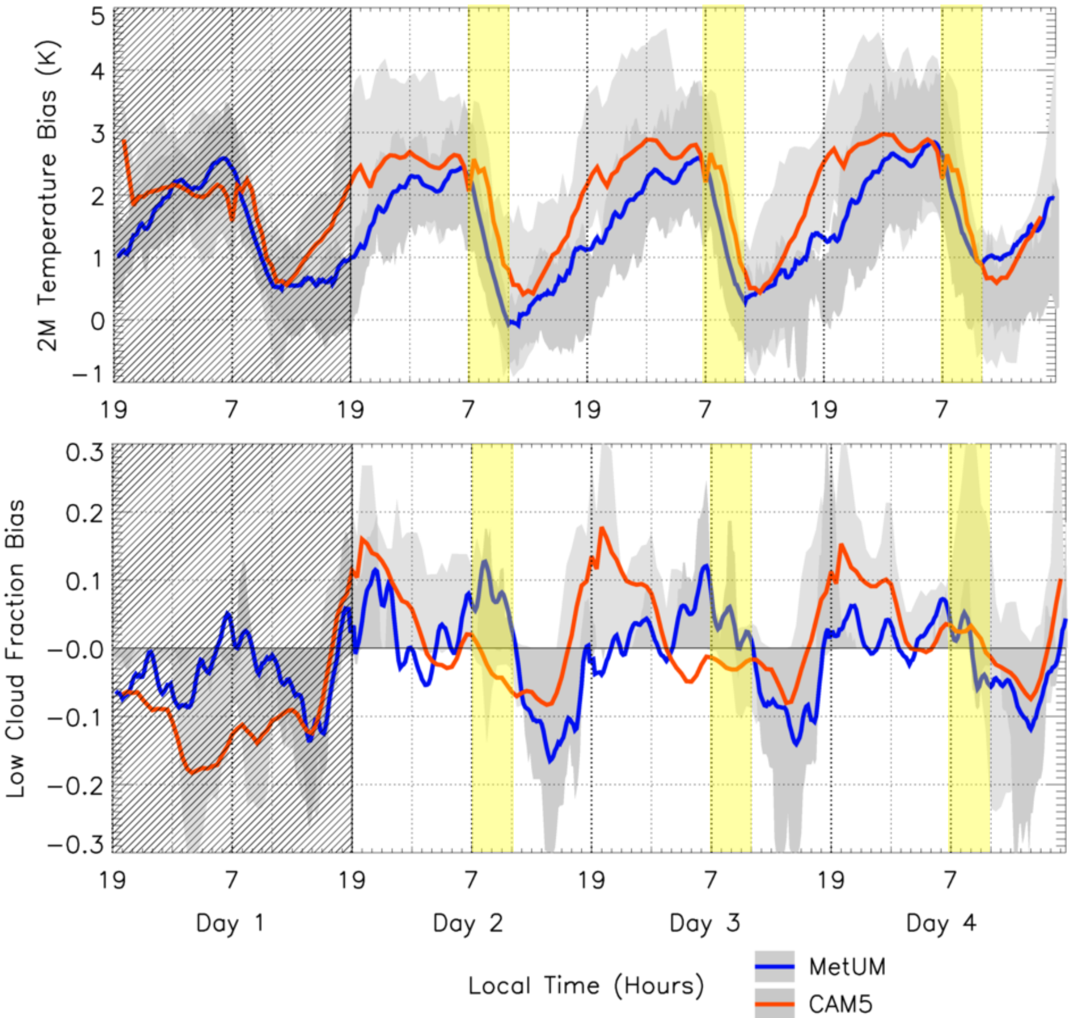

4 periods of distinct bias behaviour

<u>Morning:</u>

T_{bias} **decreases**

ΔT_{bias} correlates with CF_{bias} in MetUM, but not in CAM5

Correlation of temperature and cloud errors

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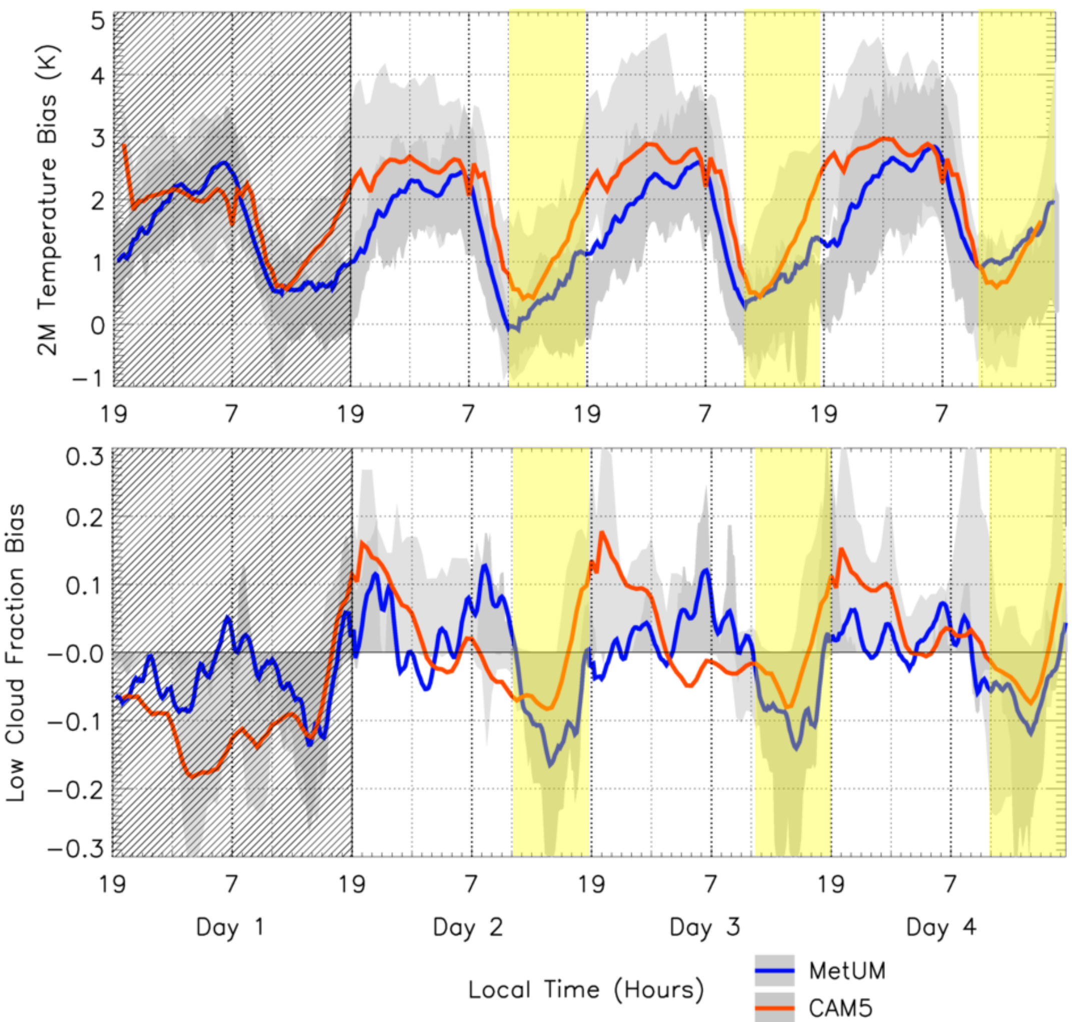

4 periods of distinct bias behaviour

<u>Afternoon:</u>

T_{bias} **increases**

ΔT_{bias} correlates with CF_{bias}

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

Time-step approach for model evaluation

Common practice model evaluation: establish relations between averaged mean-state biases

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→ **Ambiguous** since you average over many different regimes that can exhibit opposite effects
→ **Many processes** could be working together (clouds, land surface, boundary layer)

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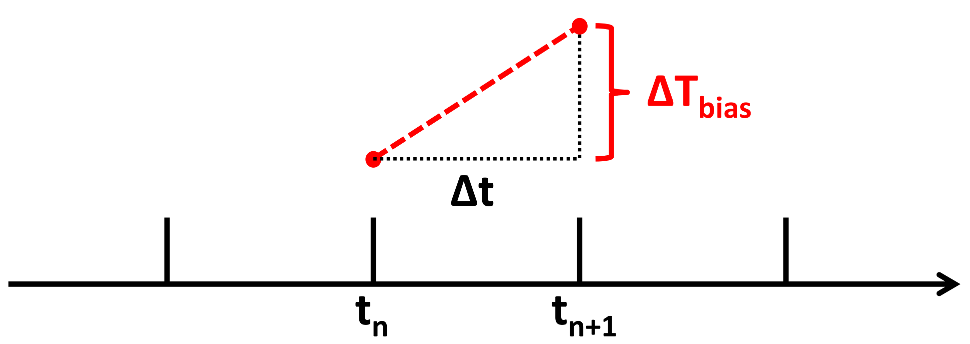
So, we need to look at time-step-level change in the bias (error growth) instead:

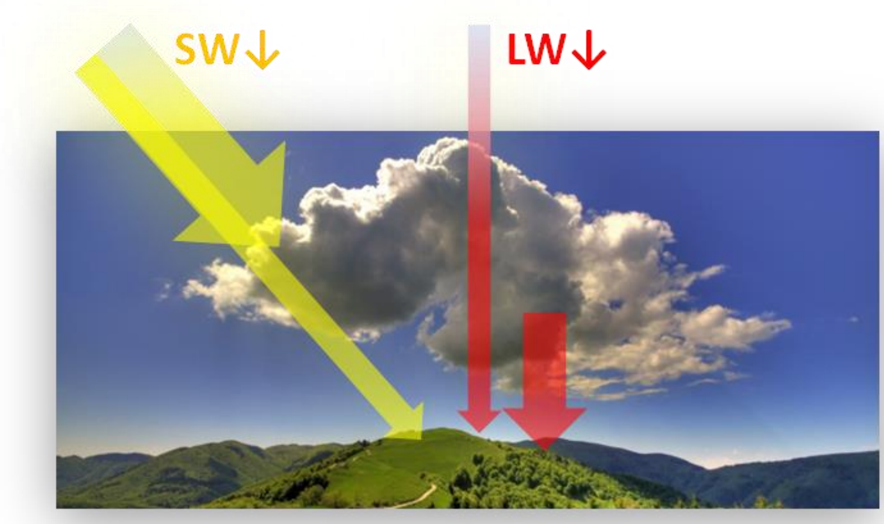
→ Error-growth T_{bias} during one time-step **unambiguously** caused by coincident biases
→ We have **observations** of sufficient temporal resolution to do so



Time-step approach for model evaluation

Compositing of ΔT_{bias} (error growth) by downwelling (SW↓ + LW↓) RAD_{bias} at Time-step level

Clouds influence surface temperature through radiation:



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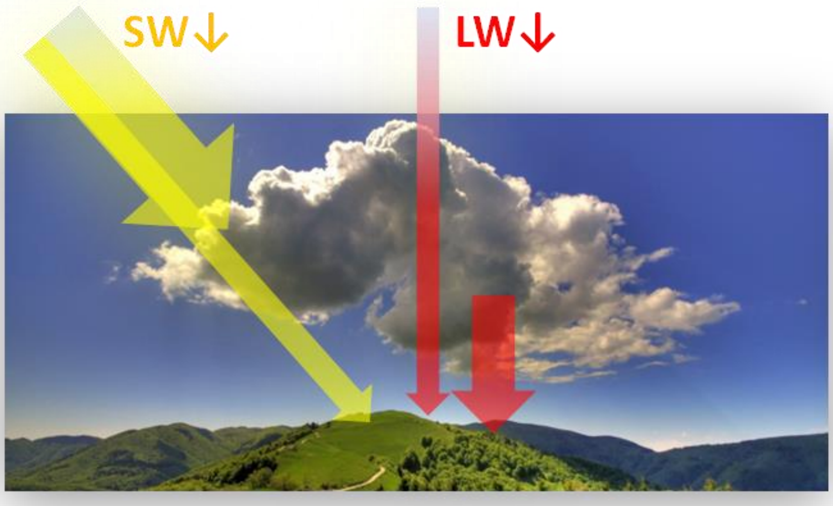

- **GOODRAD**: Cloud properties are **unbiased** and are **not** responsible for the ΔT_{bias} at Δt
- **BIASRAD**: Cloud properties are **biased** and could be responsible for the ΔT_{bias} at Δt

Downwelling radiation compositing

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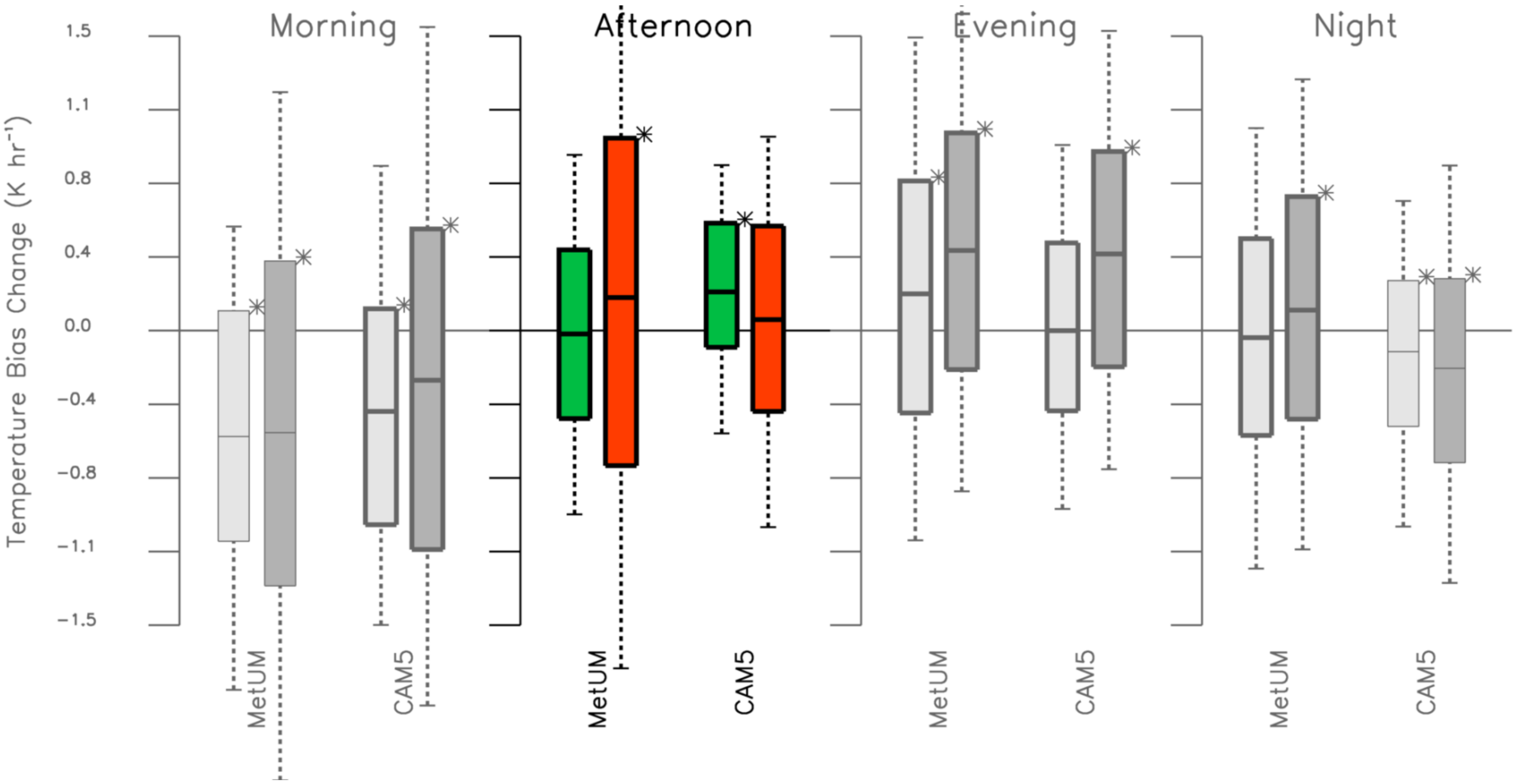

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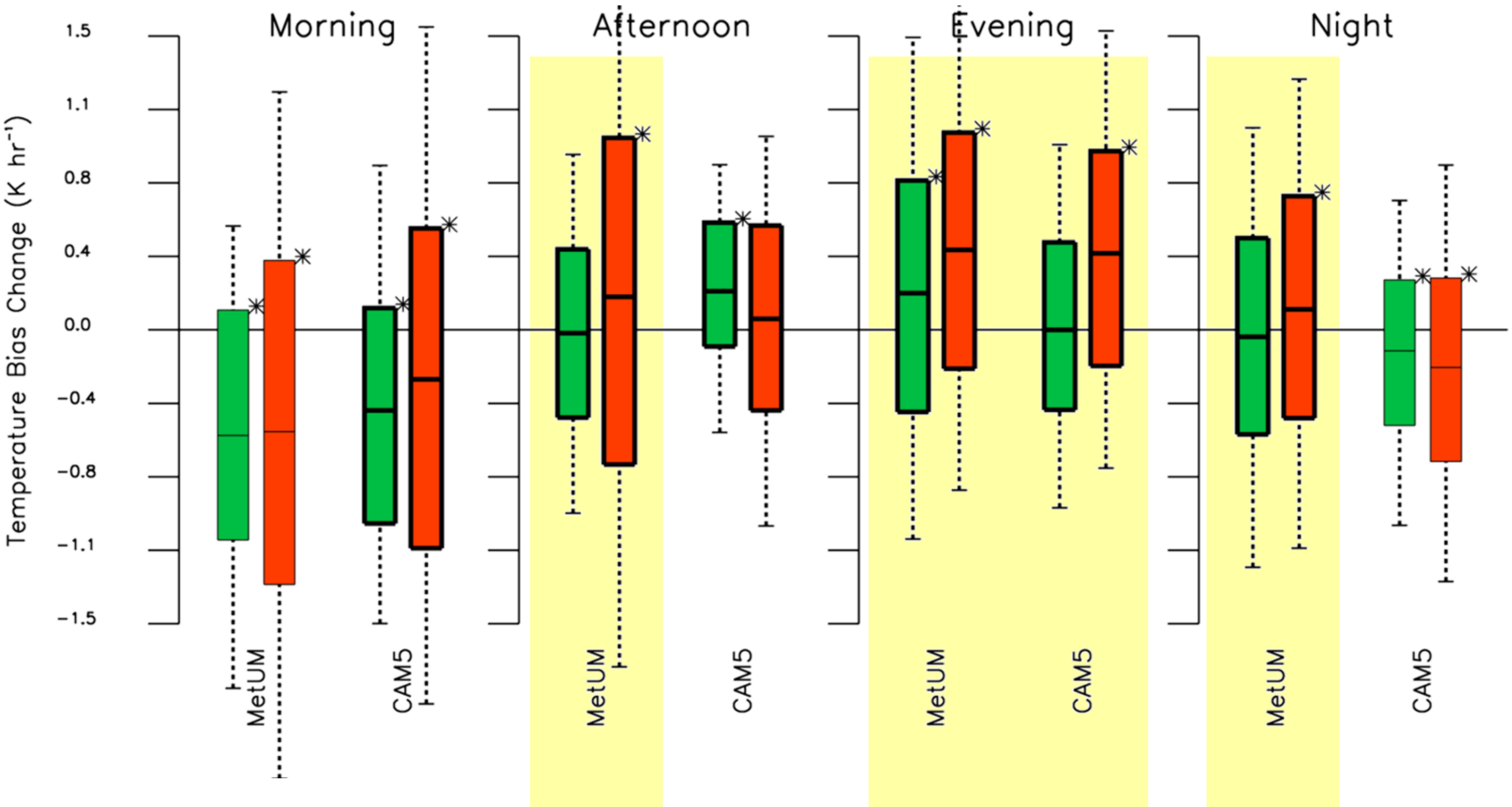


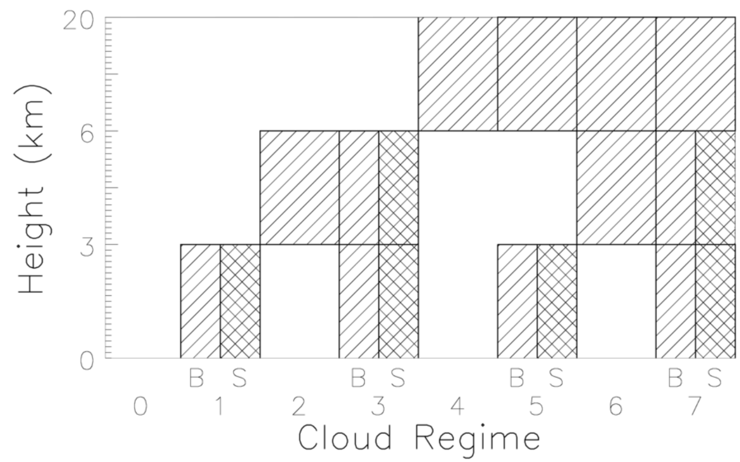
= **Dominant impact on ΔT_{bias} likely by clouds**

Cloud regime compositing

Compositing of ΔT_{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 observed/simulated **regime pair**
- → The coincident time step can be assigned to $\mathbf{\Delta T_{bias}}$
- → **Contribution** of observed/simulated regime pair ij:



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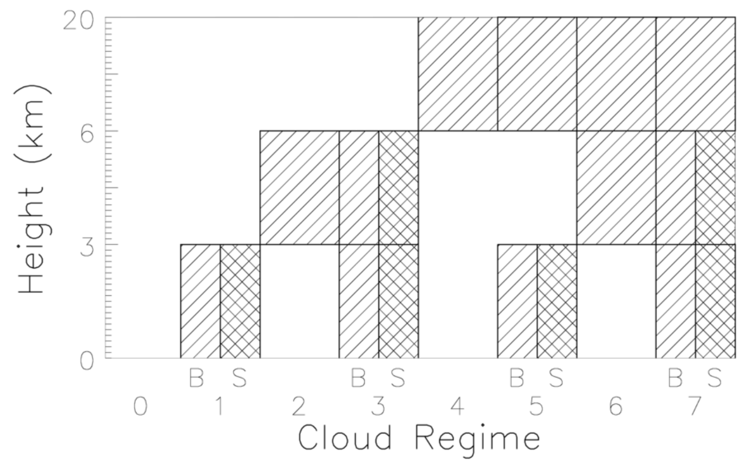

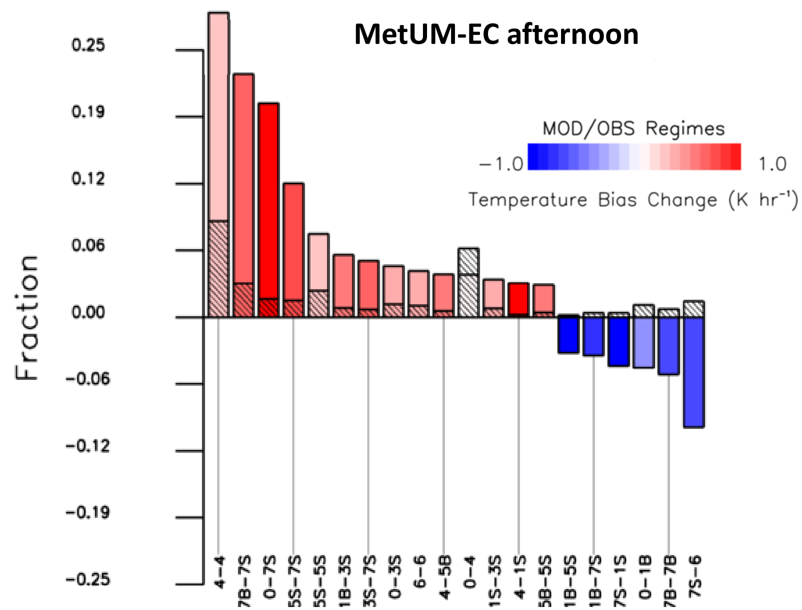

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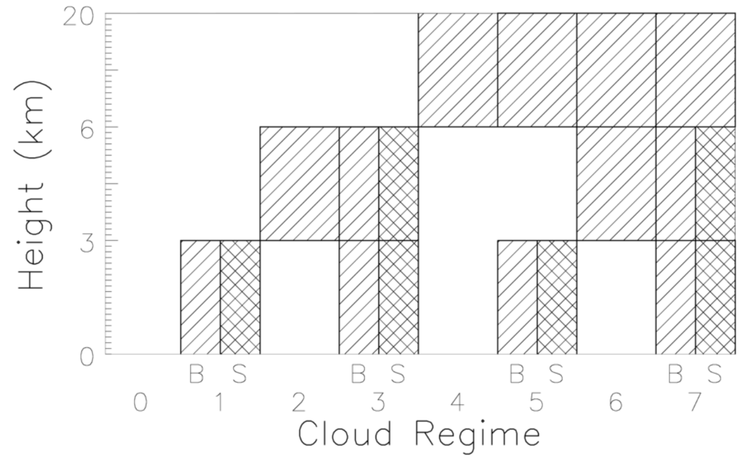

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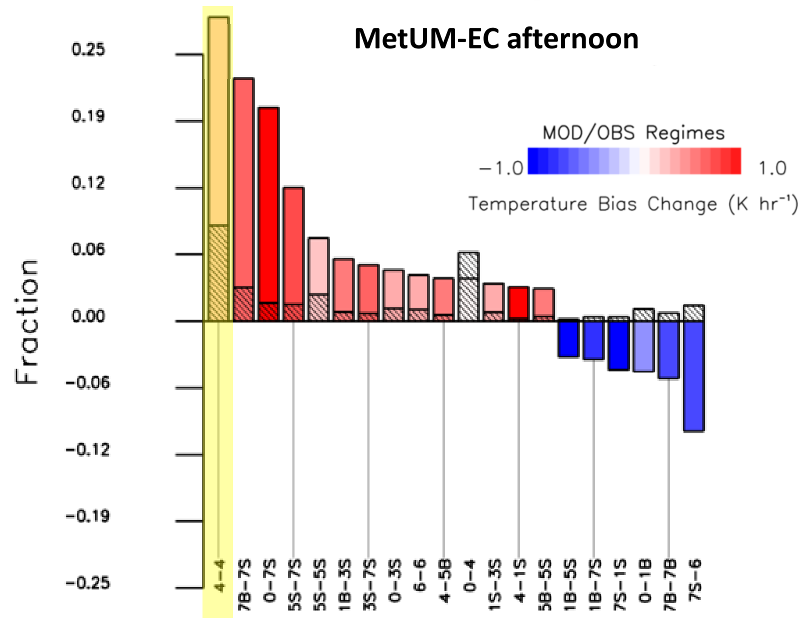
Main contribution from correctly represented high cloud cover (4-4)



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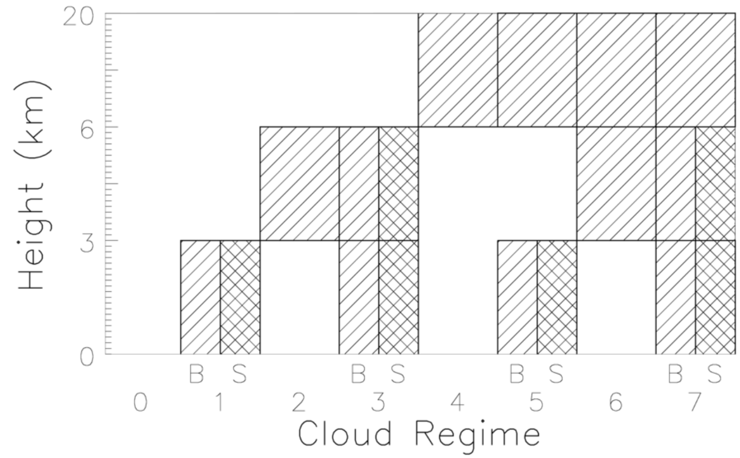

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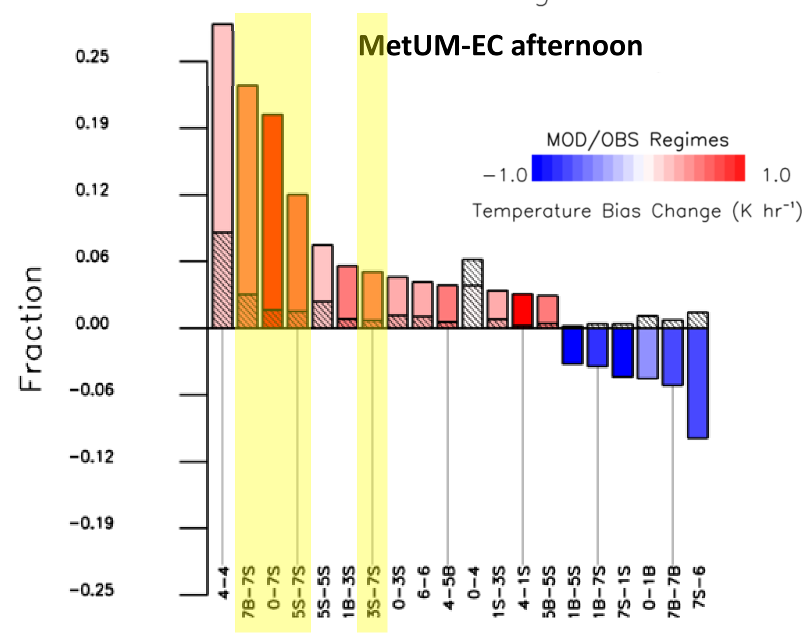
Followed by missing or under-representing deep convection (7S)



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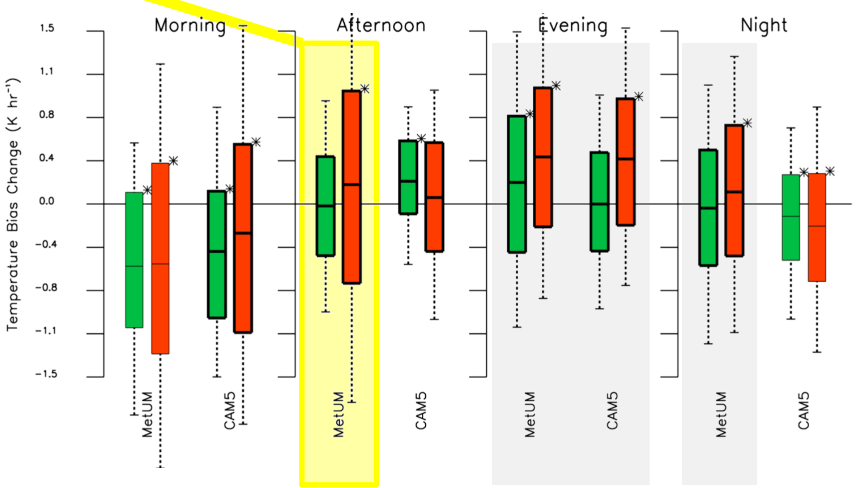

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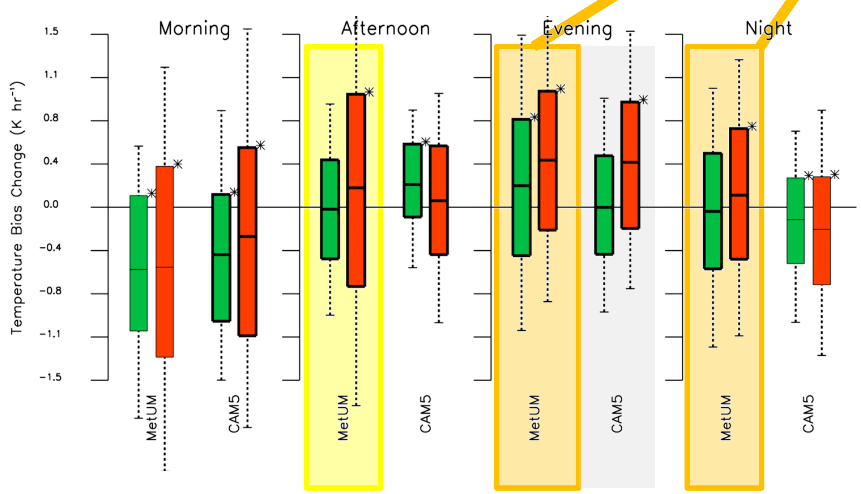

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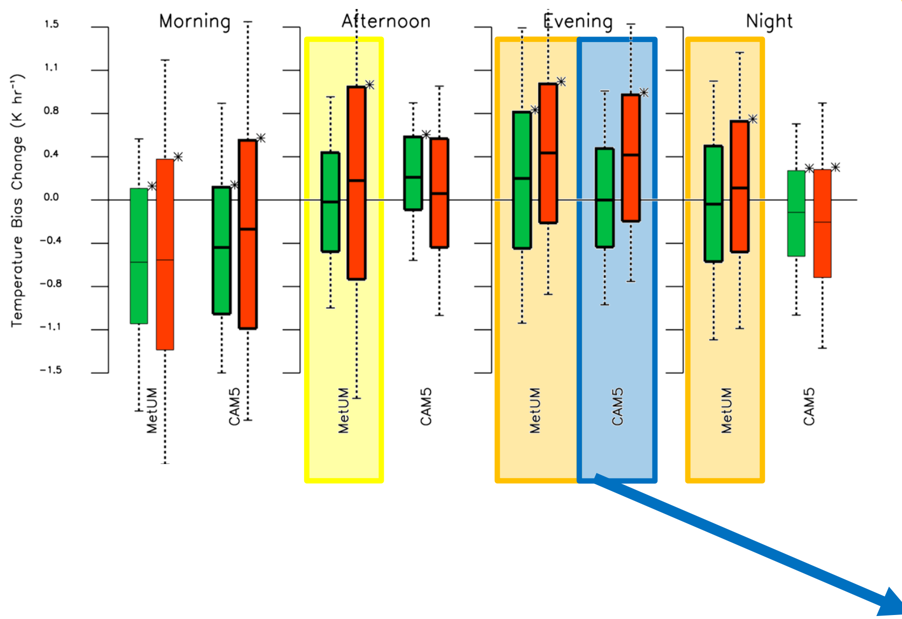

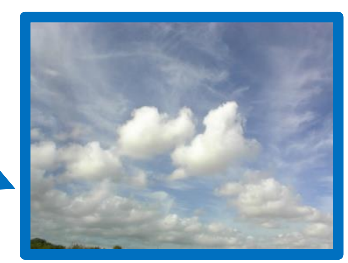

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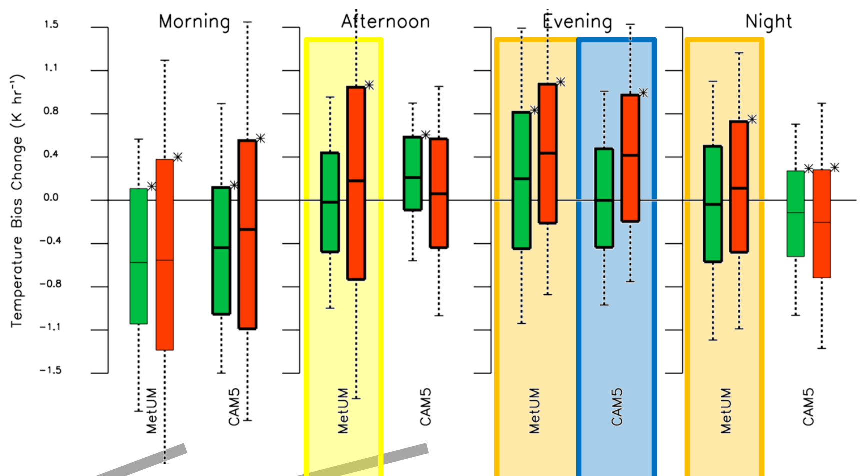

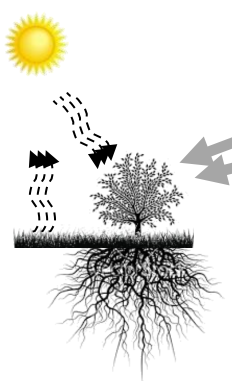

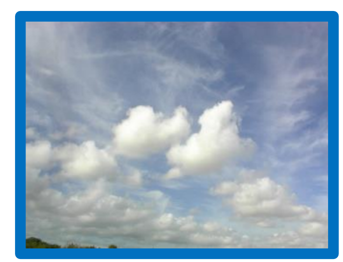

Conclusions

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 ΔT_{bias} by coincident downwelling radiation bias
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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
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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

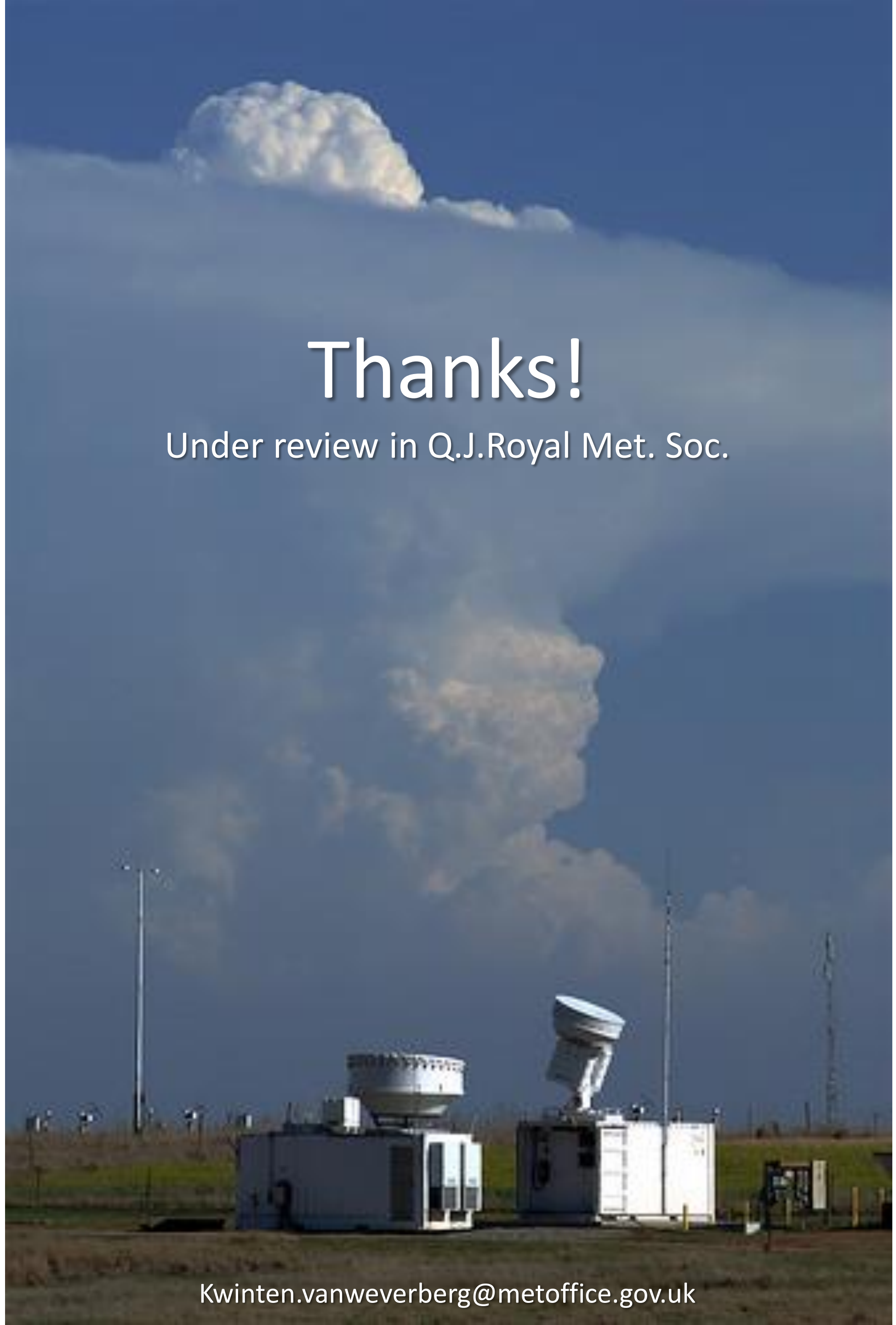
Approach will be part of analysis carried out on multiple GCMs within CAUSES

→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!

Under review in Q.J.Royal Met. Soc.

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