CAUSES

(Clouds Above the United States and Errors at the Surface)

"Cloud-regime analysis to find the causes of surface temperature errors in weather and climate models"

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Met Office, United Kingdom

RGCM

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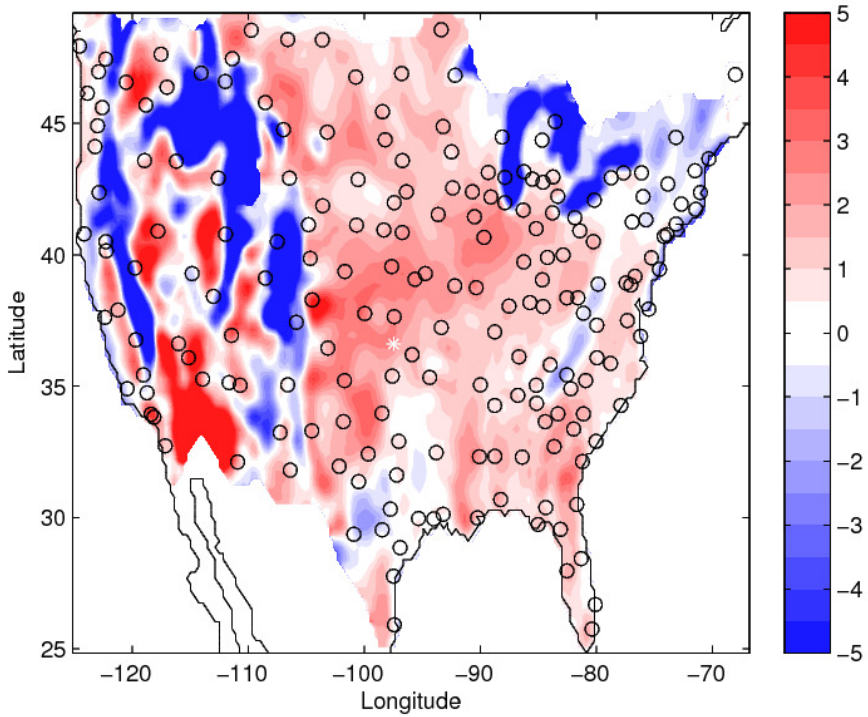
Region and Period of Analysis

- Here we evaluate **Met Office GA6.0**, running at N512 (~ **30km** grid-length)
- Focus on period of ARM field campaign: the Midlatitude Continental Convective Cloud Experiment (**MC3E, 22 April to 6 June 2011**).
- Using observational data from, and around, **SGP**.
- Model simulations: 45, 96-hours runs, starting from **analysis at 00Z** each day.
- Today we will focus on the T+72 to T+95 hour forecasts ("**day 4**")

Average screen-level temperature for MetUM GA6 (day4) over entire MC3E period.



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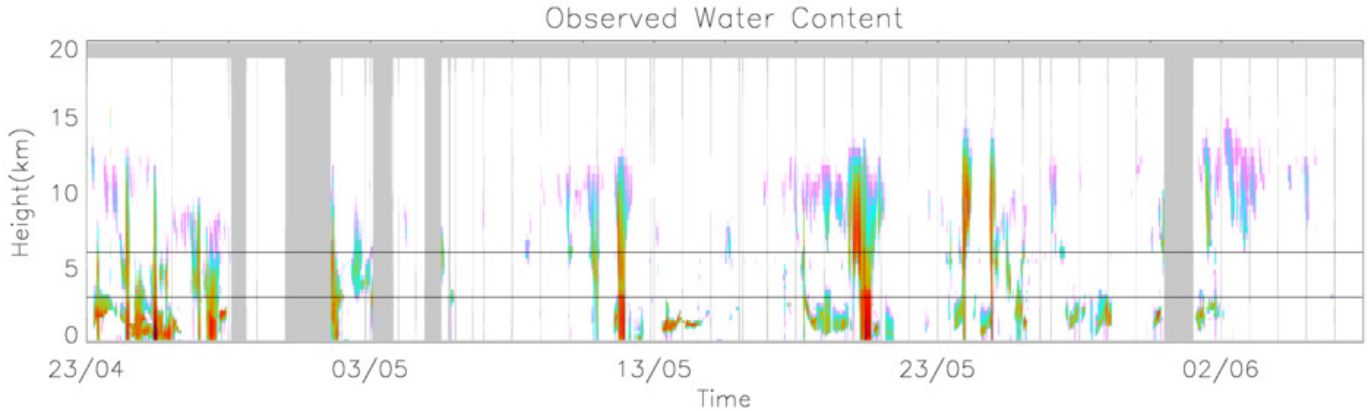
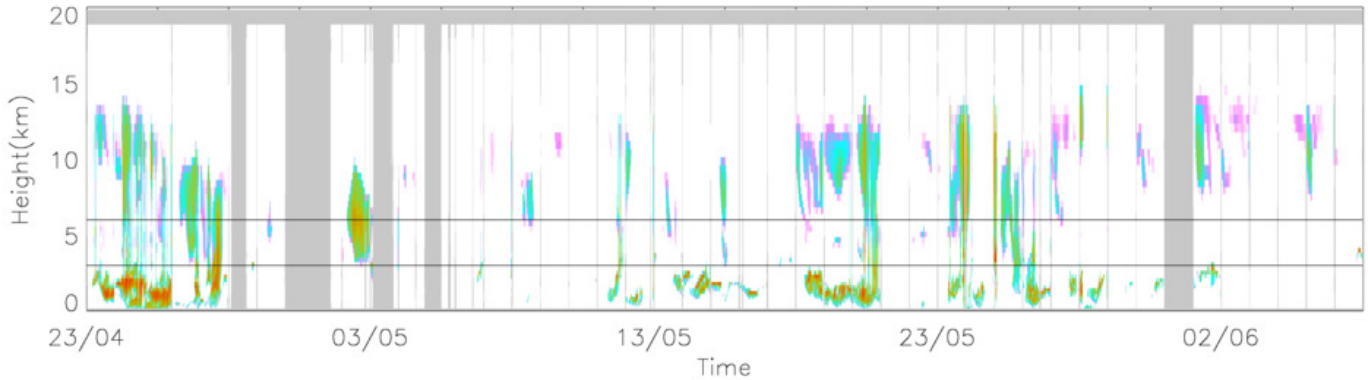
Period of Interest: 23 April-6 June 2011, Southern Great Planes (SGP), Oklahoma, US

ASR/ARM's MC3E campaign

- Atmospheric System Research
- Atmospheric Radiation Measurement
- Mid-latitude Continental Convective Cloud Experiment
- Funded by US Department of Energy



Model Water Content (T+72 to T+95)



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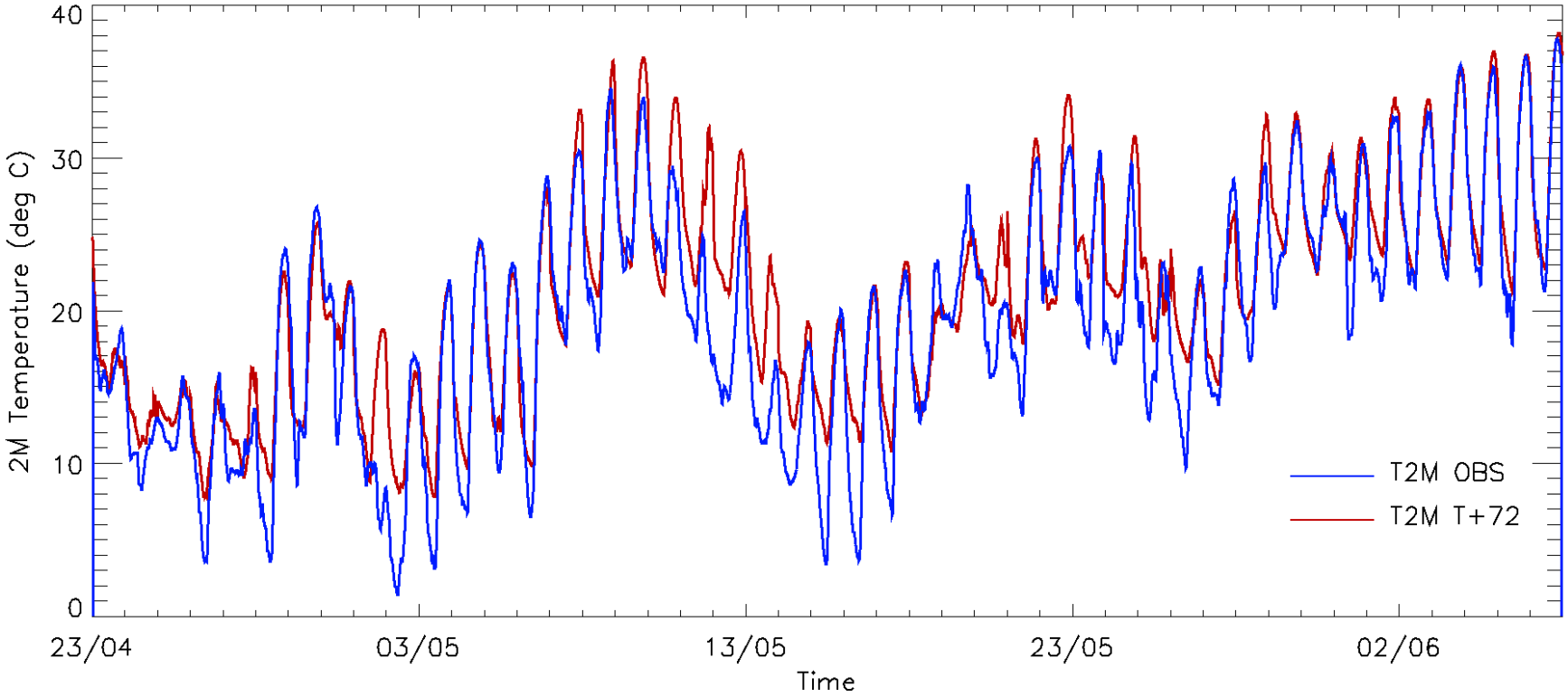
Screen-level temperature at SGP in the Spring of 2011



So how do cloud contribute to the temperature error?

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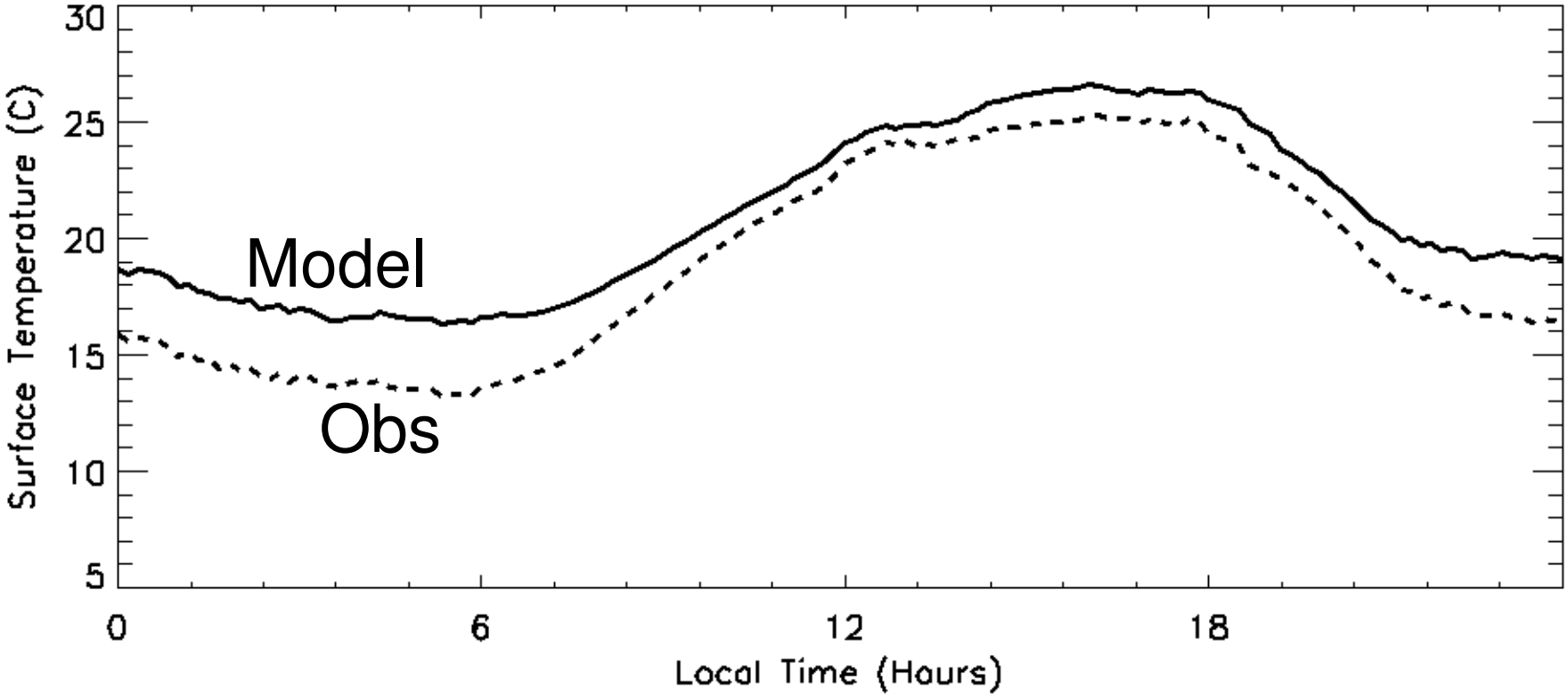
Screen-level temperature at SGP in the Spring of 2011:
Average diurnal cycle



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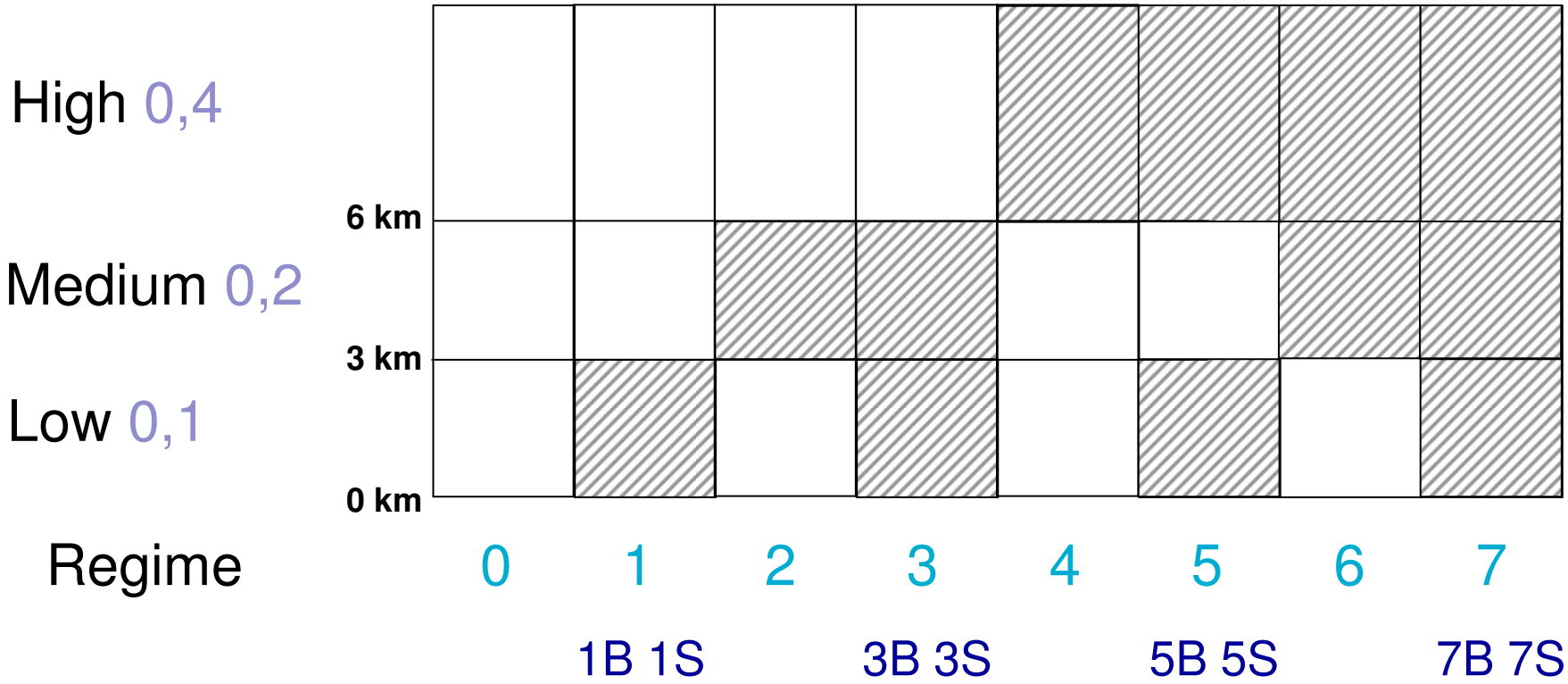
Definition of Cloud Regimes

If cloud fraction > 0



B (broken) for cloud fraction < 50%

S (stratiform) for cloud fraction > 50%

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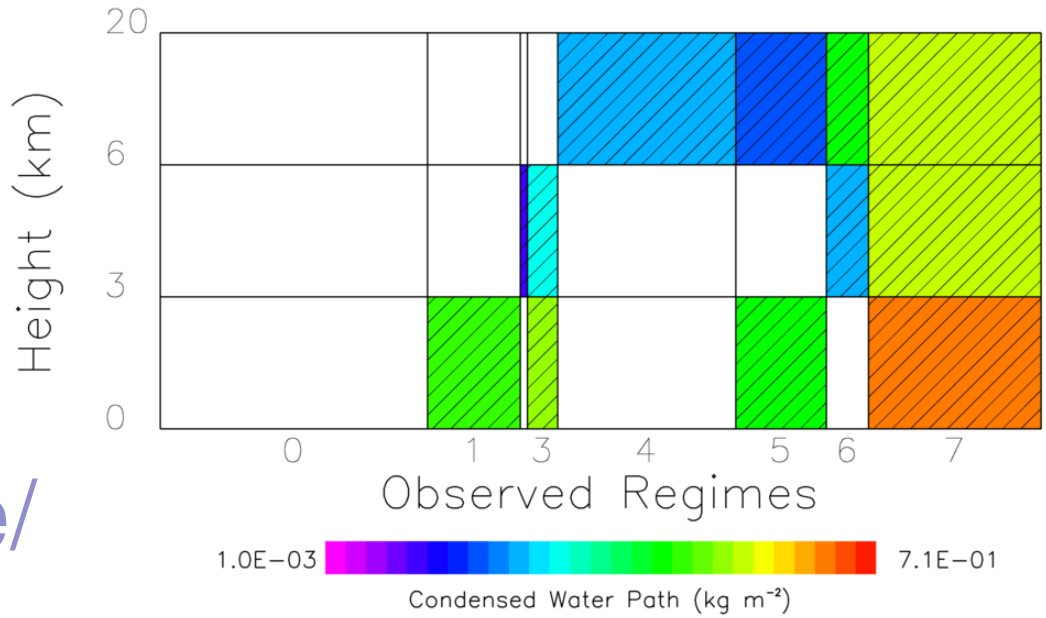
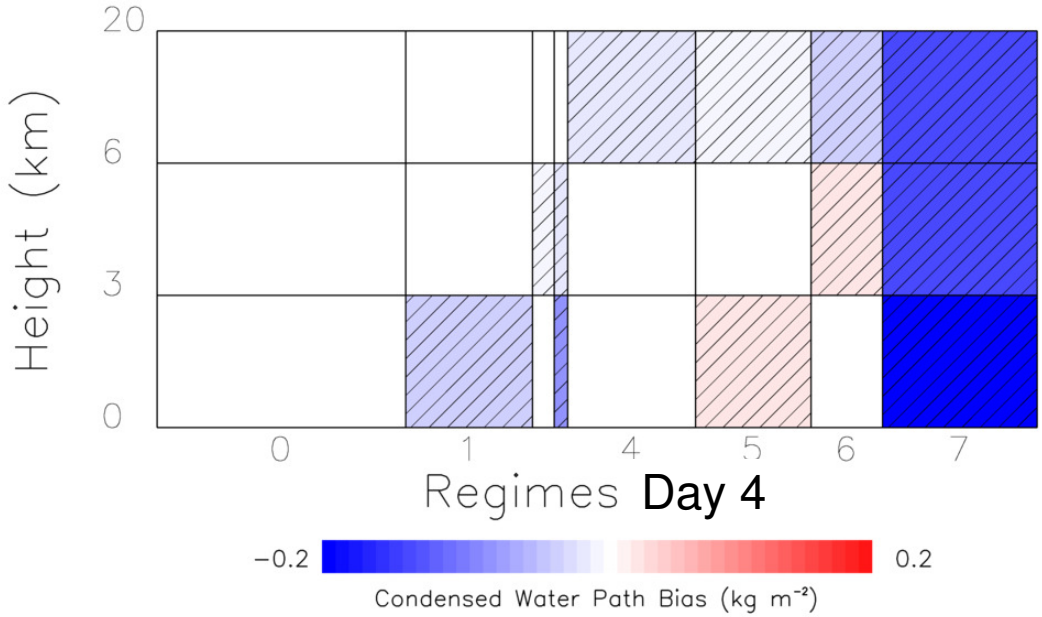
Cloud-Regime/ Frequency/ Condensate Plots





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Colour shading

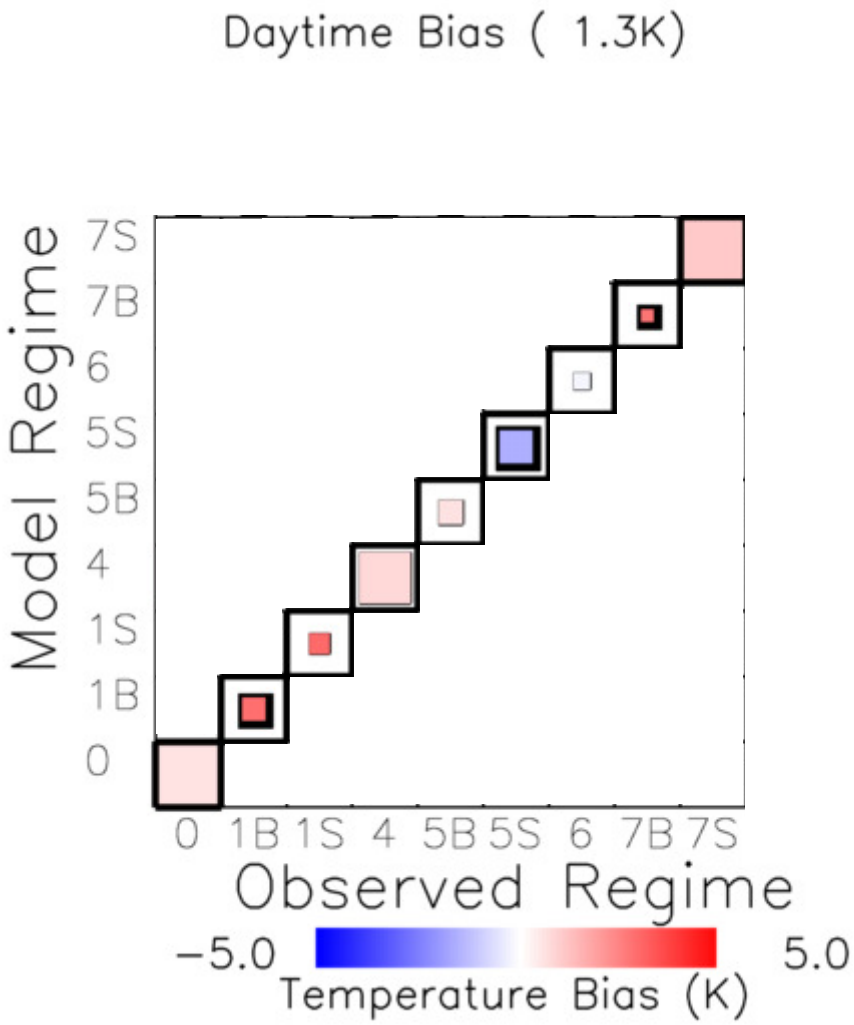
Indicates magnitude of bias in that regime

Size of square

Indicates frequency of occurrence of that regime combination.

Shadow

Indicates that bias is statistically significant.



Bar charts

Indicates frequency of occurrence of that regime in obs and model.

Summary:

When model does not predict the right clouds, there is often a T error (not surprising).

Obs: more 1S than 1B

Model: too much 1B, not enough 1S.

What are the key contributions to the error?

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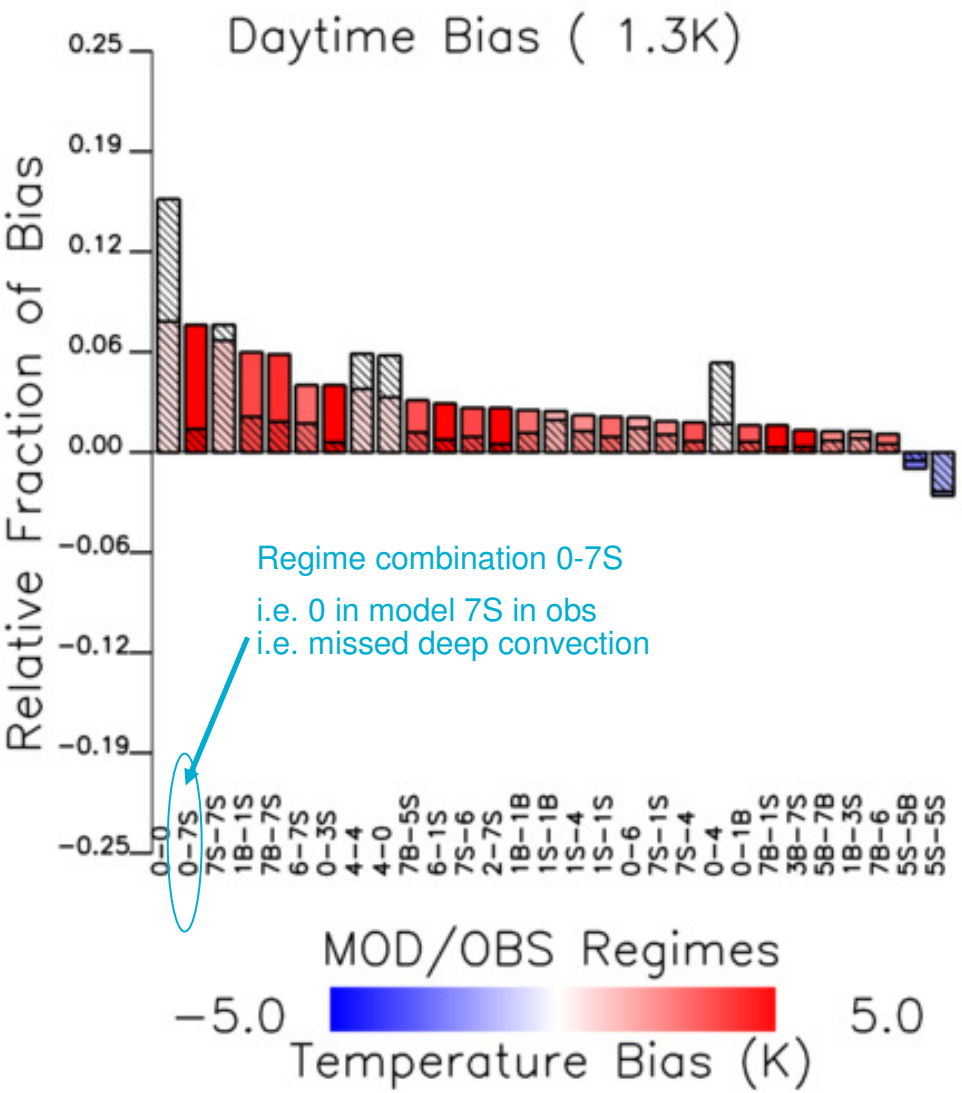
Rank the regimes in order of contribution to overall bias



Non-significant regimes are not plotted.

These bar charts contain 3 pieces of information:

a) **Height of coloured bar**: Relative contribution of that regime combination to overall T bias.

b) **Shading of coloured bar**: Average error in a variable (in this plot Temperature) for that regime combination.

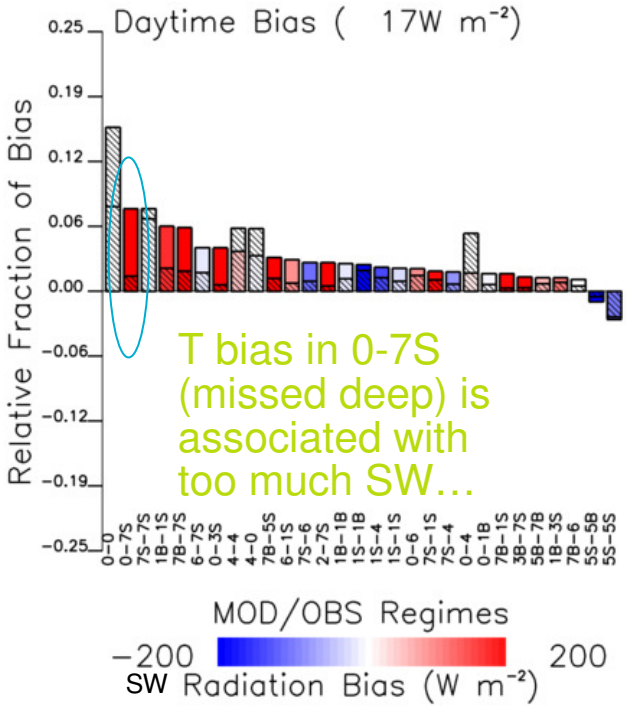
c) **Height of hatched bar**: Frequency of occurrence of that regime combination.

So a = b x c

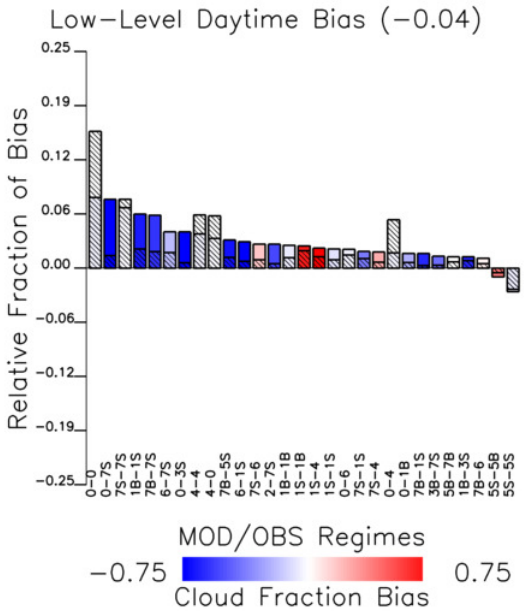
#1 is clear-sky/clear-sky, but average error is relatively small and contribution to overall bias is smaller than would be expected from its frequency.
#2 missed deep convection. This contributes 7% of the error, but occurs ~2% of the time. **Disproportionate contribution to overall error.**

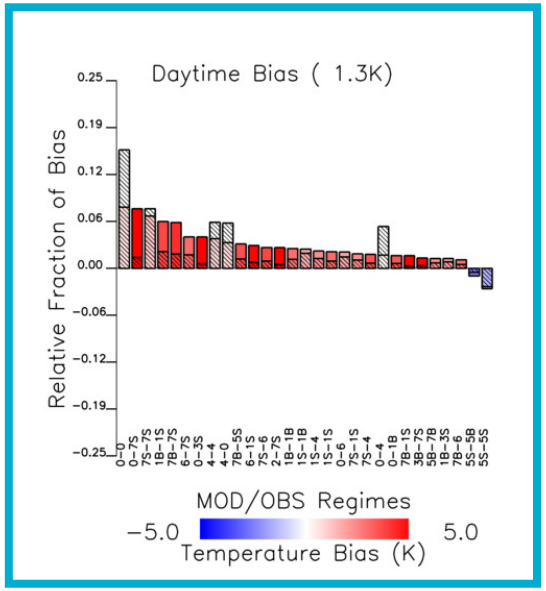
What is cause of T bias?

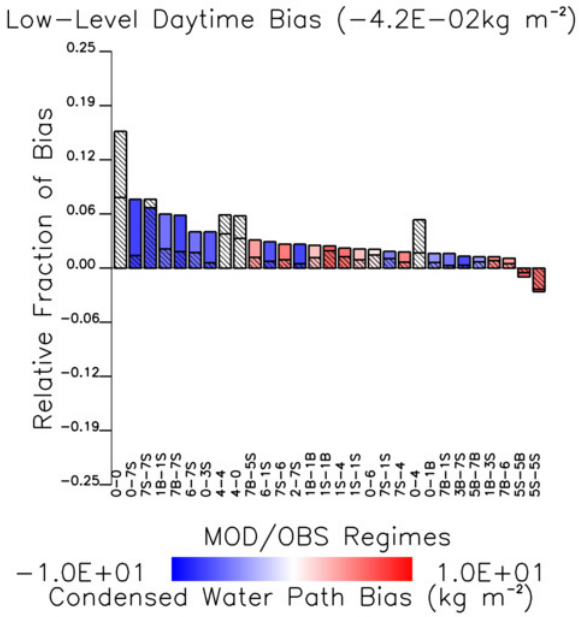
Consider a (relatively) simple example



T bias in 0-7S (missed deep) is associated with too much SW…







…and that is associated with not enough cloud fraction, or condensed water, in the low, middle and high cloud categories.

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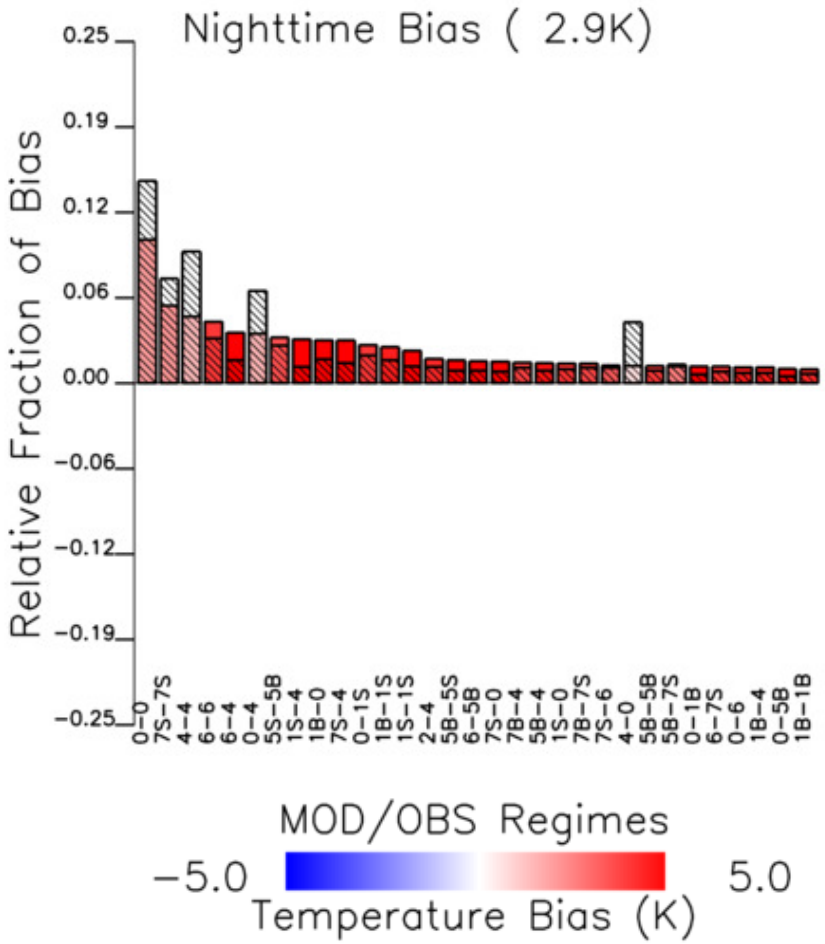
Night-time bias



Magnitude of relative contribution of each is much closer to frequency of occurrence of that regime.

i.e. magnitude of contribution does not depend (as much) on details of what the regime is, but rather on how often if occurs

So not really dependent on the clouds.

There is something else going on.

Next Steps

Look at surface energy balance.

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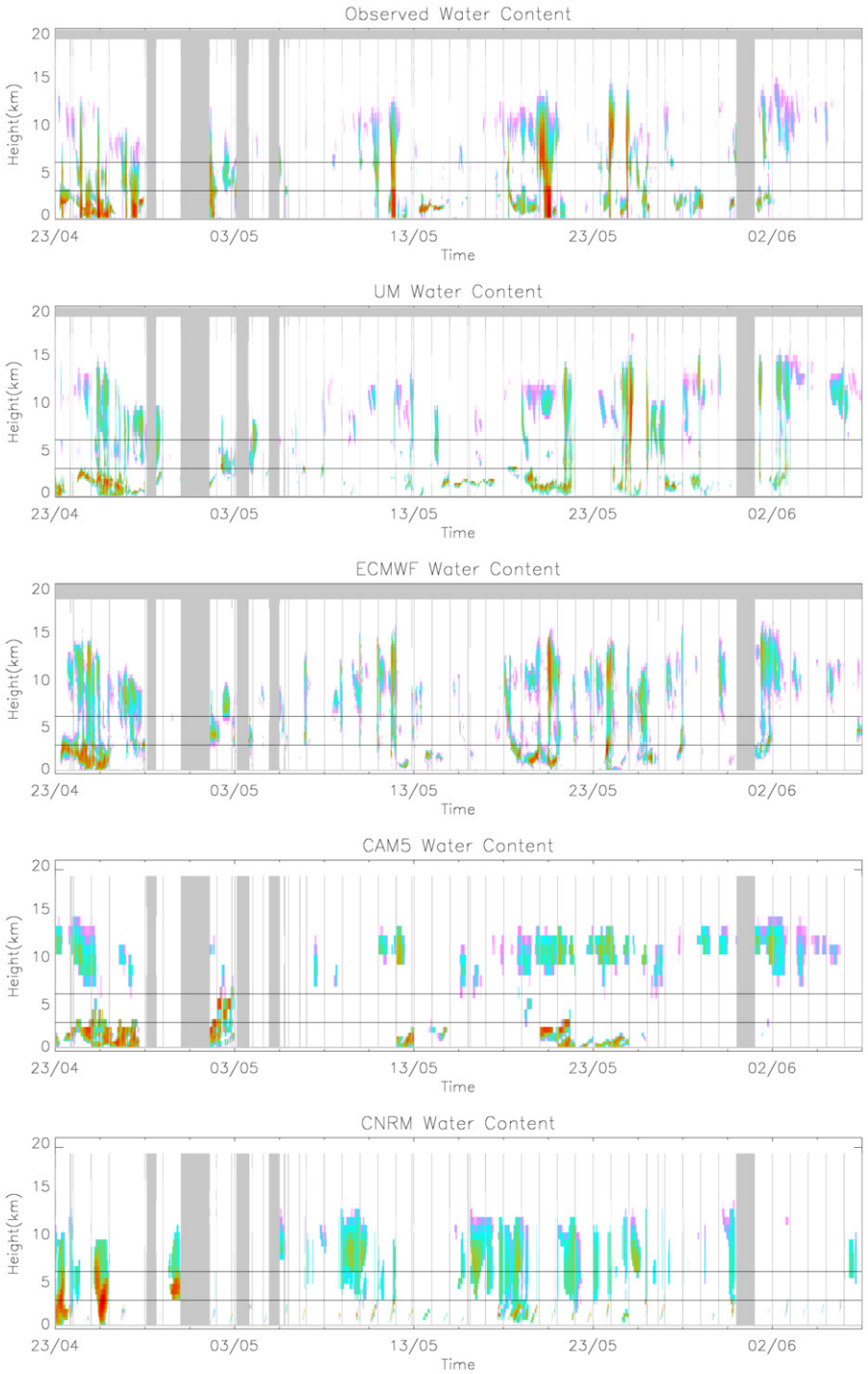


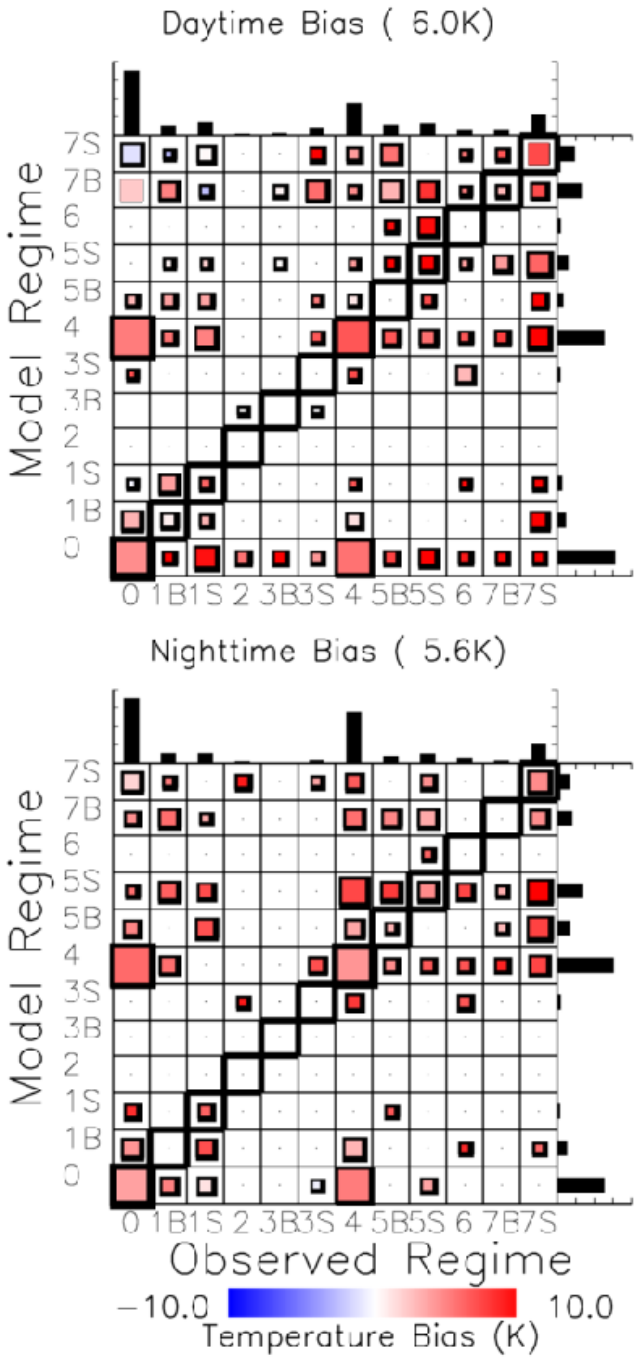
Use method just described to **analyse output from 3 other models** which have already provided data.

IFS, Maike Ahlgrimm (ECMWF)

CAM5, Hsi-Yen Ma (LLNL)

CNRM-CM5, Romain Roehrig (MeteoFrance)

Day 3 model output.



(a) CAM T2M Bias

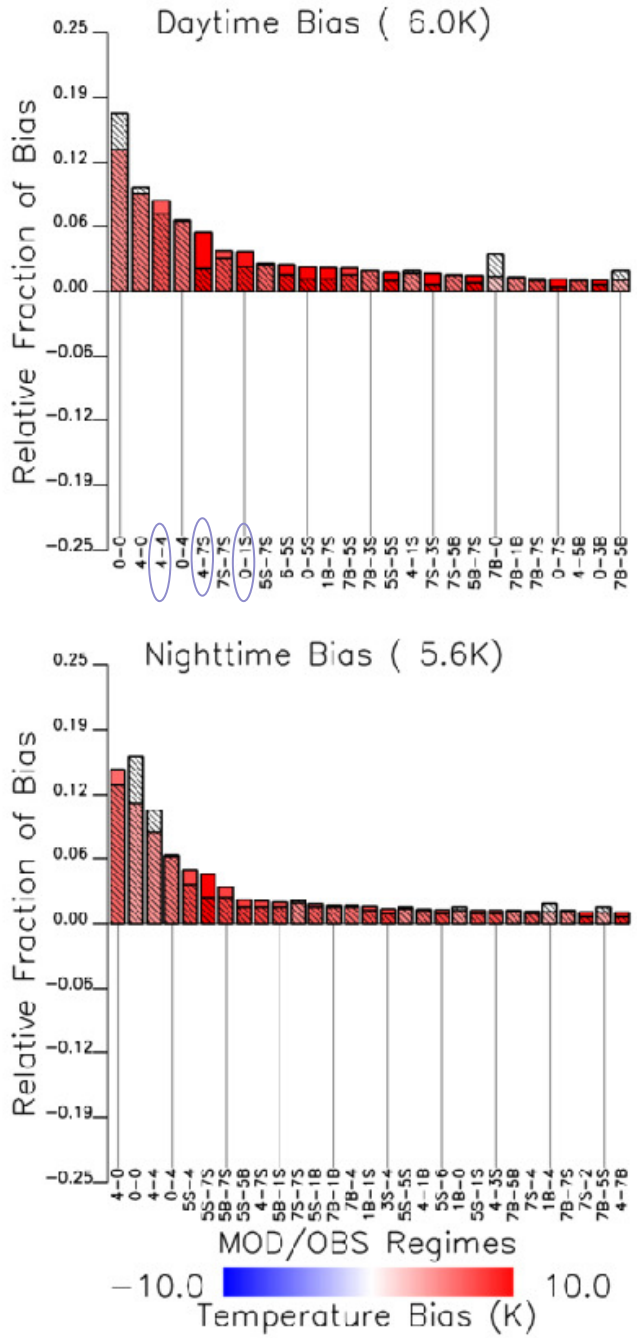
CAM5

(model data from Hsi-Yen Ma)

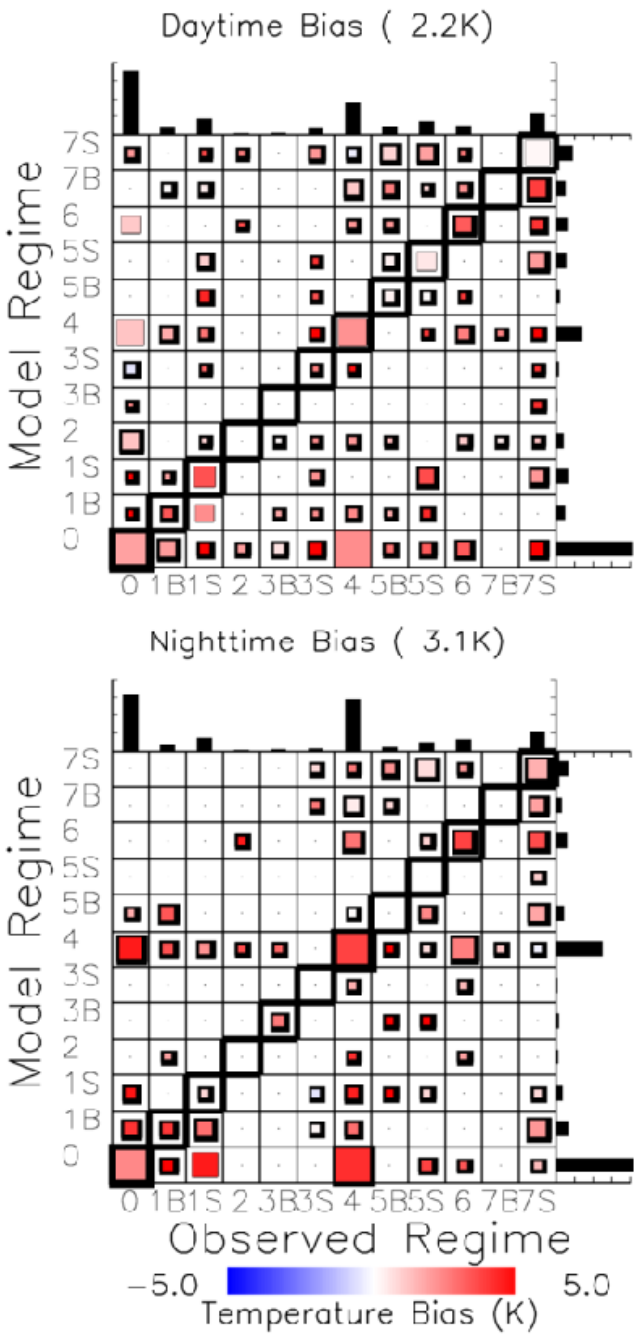
T bias about the same day and night.

Leading day-time cloud issue is high-cloud (4-4) and “anvils without stalks” (4-7S).

Missing stratiform low cloud (0-1S) and missing cirrus (0-4) are also issues.



(a) CAM T2M Bias



(a) ECMWF T2M Bias

ECMWF

(model data from
Maike Ahlgrimm)

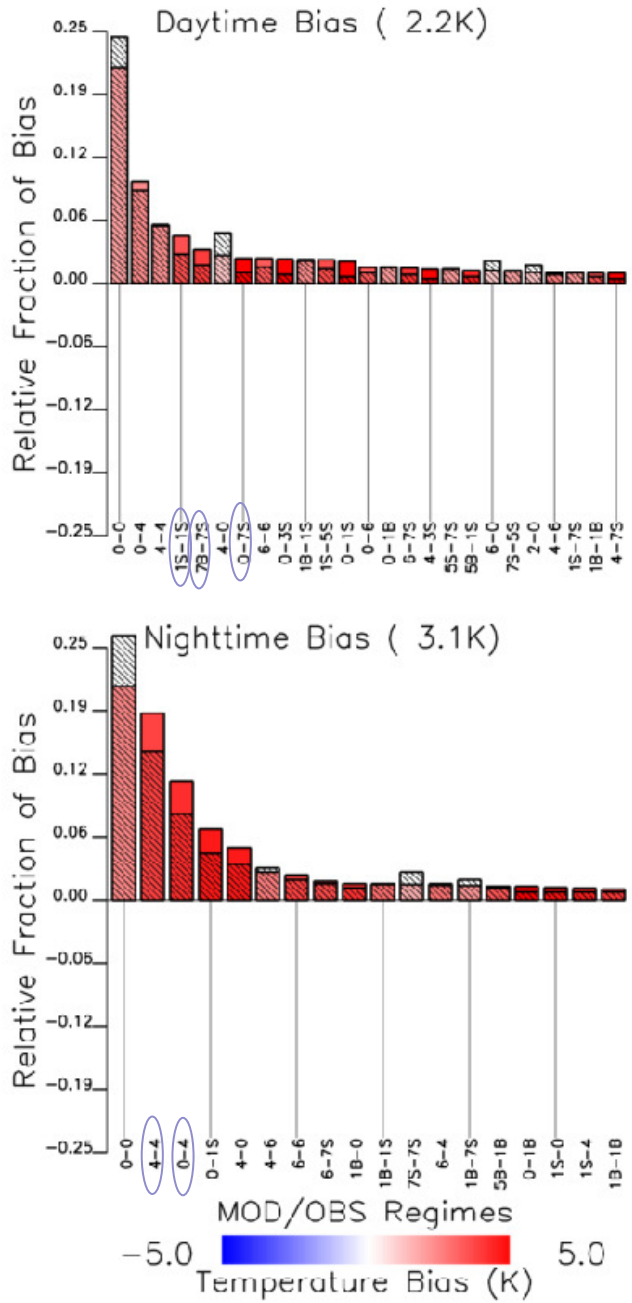
T bias bigger at night.

Day-time:

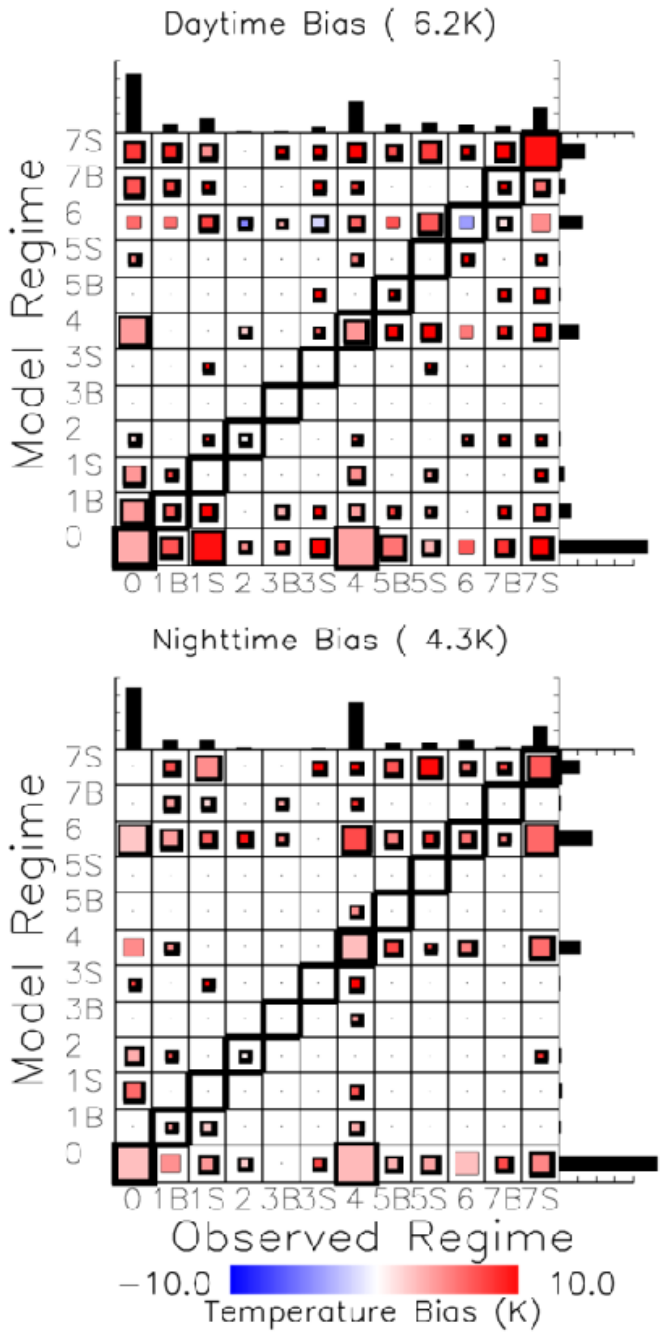
Issues with low stratiform cloud (1S-1S) and deep cloud between broken rather than stratiform (7B-7S).

Missed deep cloud also an issue (0-7S).

Night-time:
Significant bias even when model correctly gets high cloud regime (4-4).



(a) ECMWF T2M Bias



(a) CNRM T2M Bias

CNRM

(model data from Romain Roehrig)

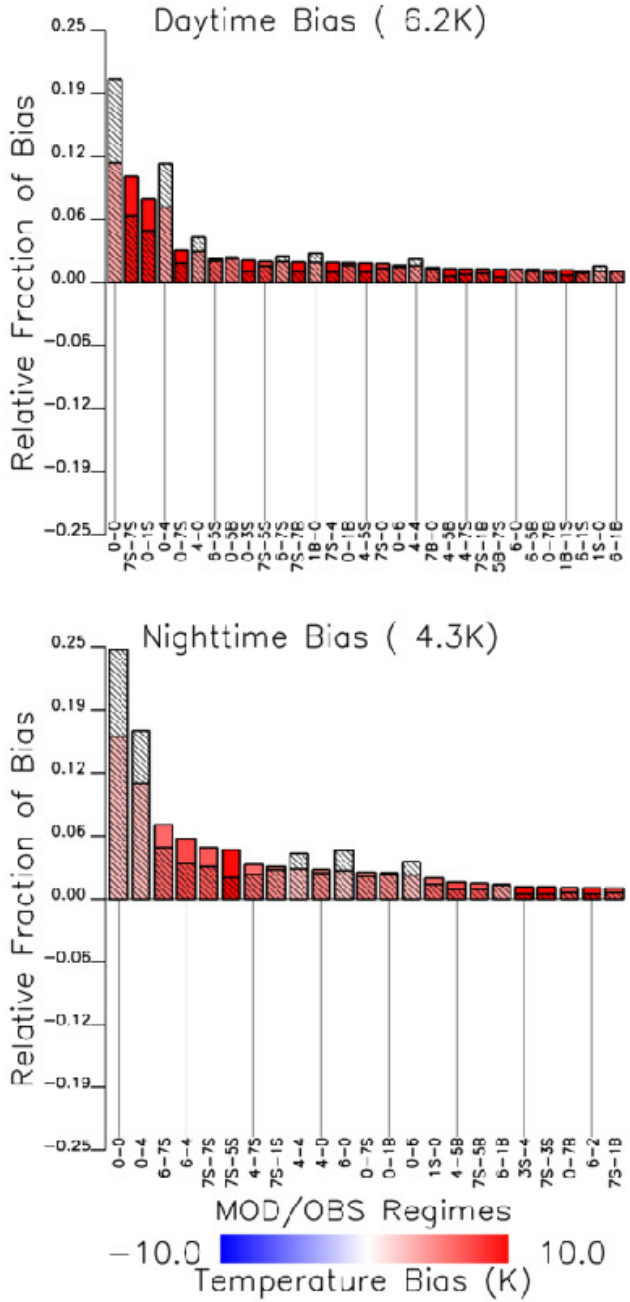
Bias bigger during the day.

Day: biggest issues are during correctly identified deep regim (7S-7S) and missed low stratiform cloud (0-1S).

Night: a number of issues involving clouds at different heights: e.g.

(6-7S) missing low cloud in deep conditions.

(6-4) mid-level cloud present when should just be high.



(a) CNRM T2M Bias

Next steps

- Look at SW, LW, LWP, IWP and CF biases for all models and all regime combinations to track down the source of each error.

- Perform off-line land-surface sensitivity tests.

- Perform some convection-permitting simulations.

- Make some parametrization changes and repeat analysis.

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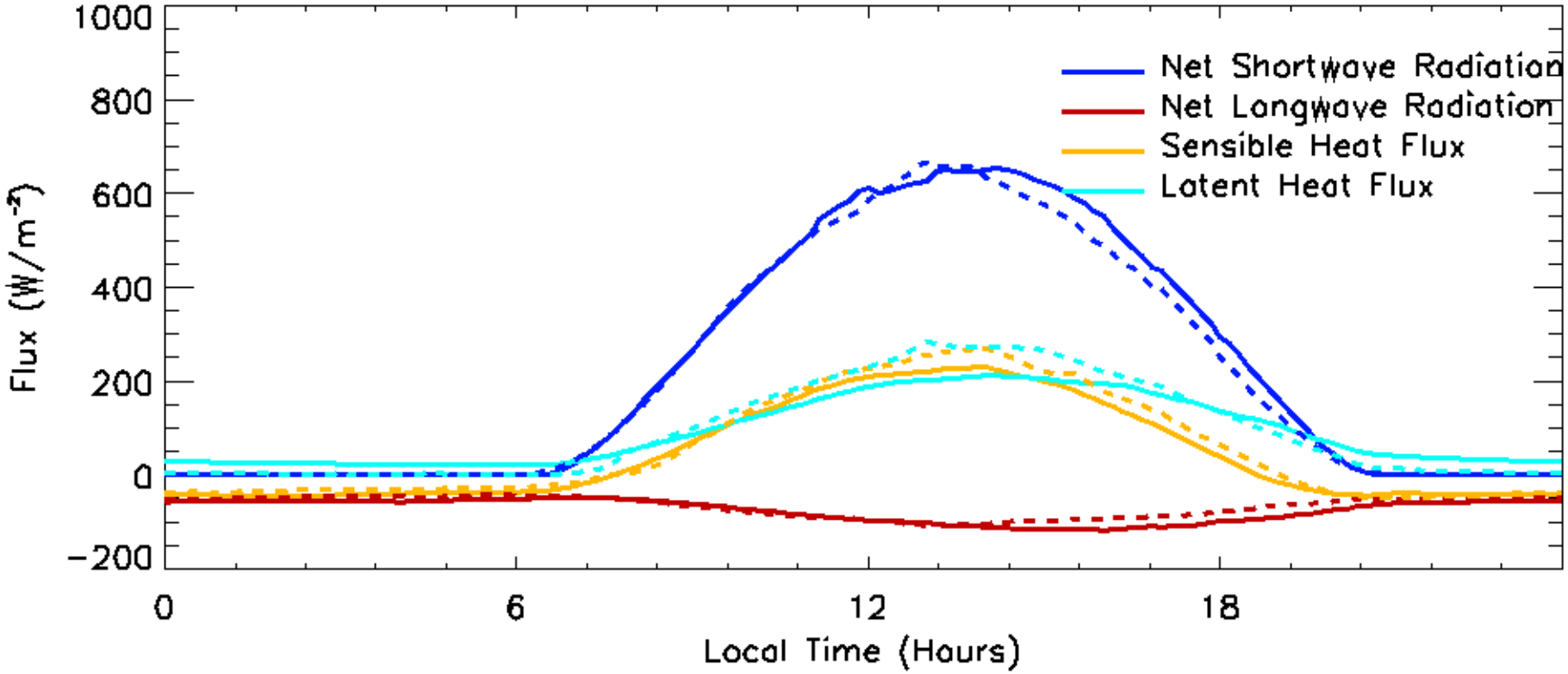
Extra slides



Model
Obs

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