Met Office

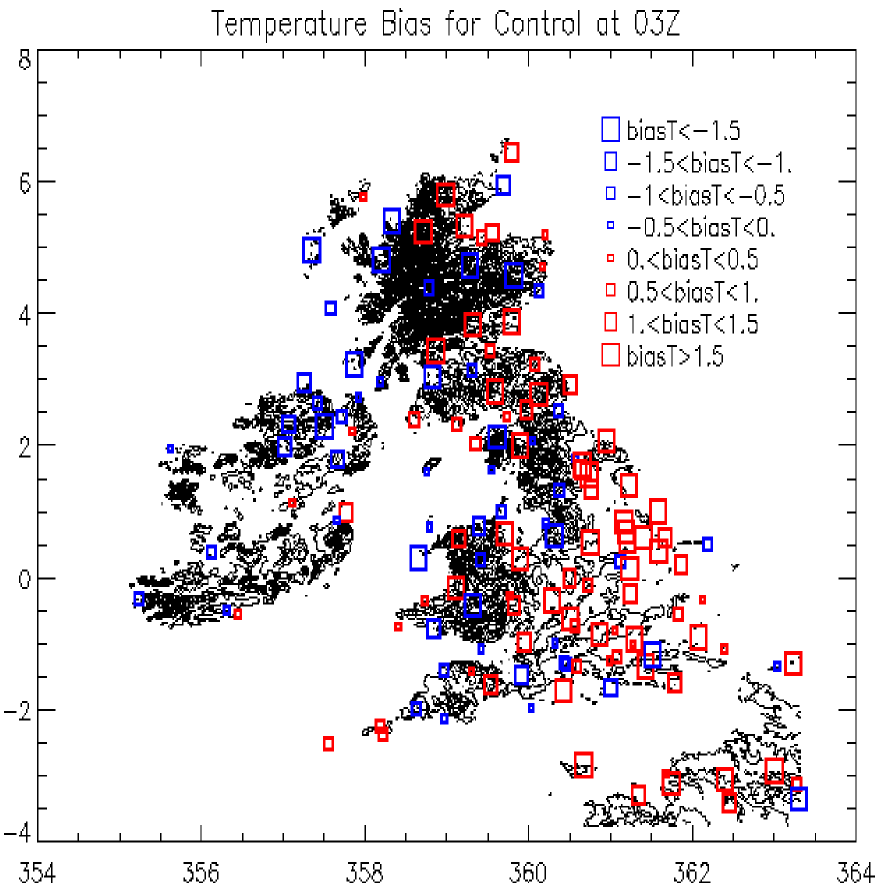
Clear sky cases over the UK with the high resolution MetUM

Aurore Porson, Workshop FMI Helsinki, 3rd December 2012

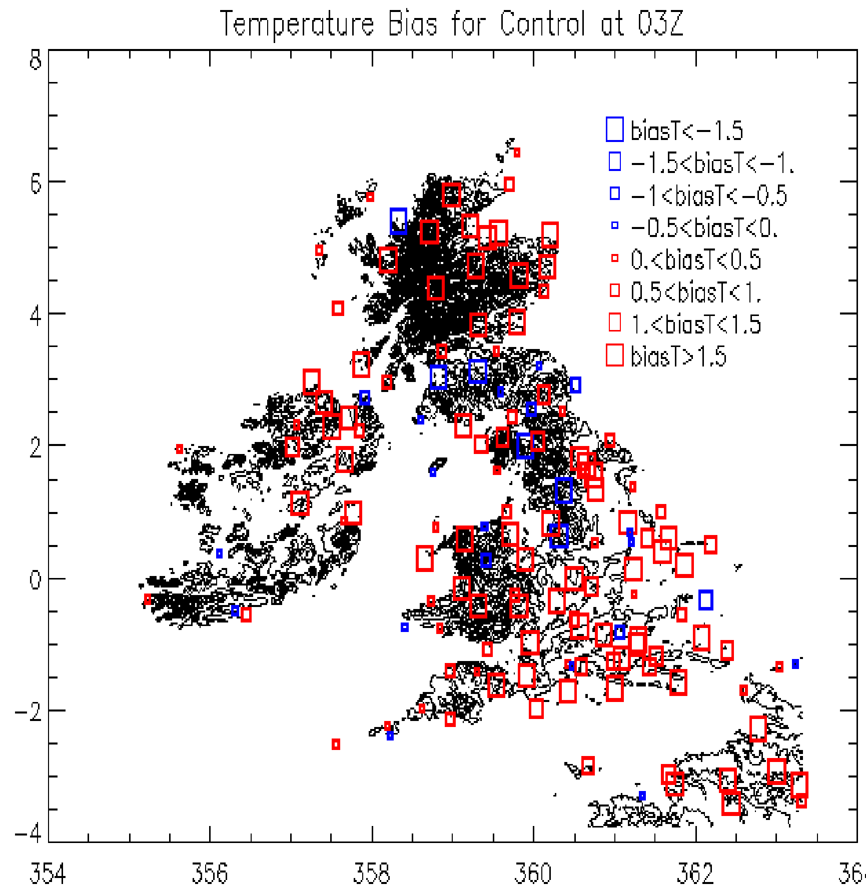
Acknowledgments: Adrian Lock, Nigel Roberts, Bernie Claxton, Gabriel Rooney, John Edwards, Jorge Bornemann, Jessica Standen, Martin Best, Jeremy Price

- Clear-sky cases
  - Diurnal cycle bias: examples
  - Improvements to the operational high resolution model (UKV model - 1.5 km)
  - Surface energy budget at Cardington

Clear-sky case examples with the UKV (night)

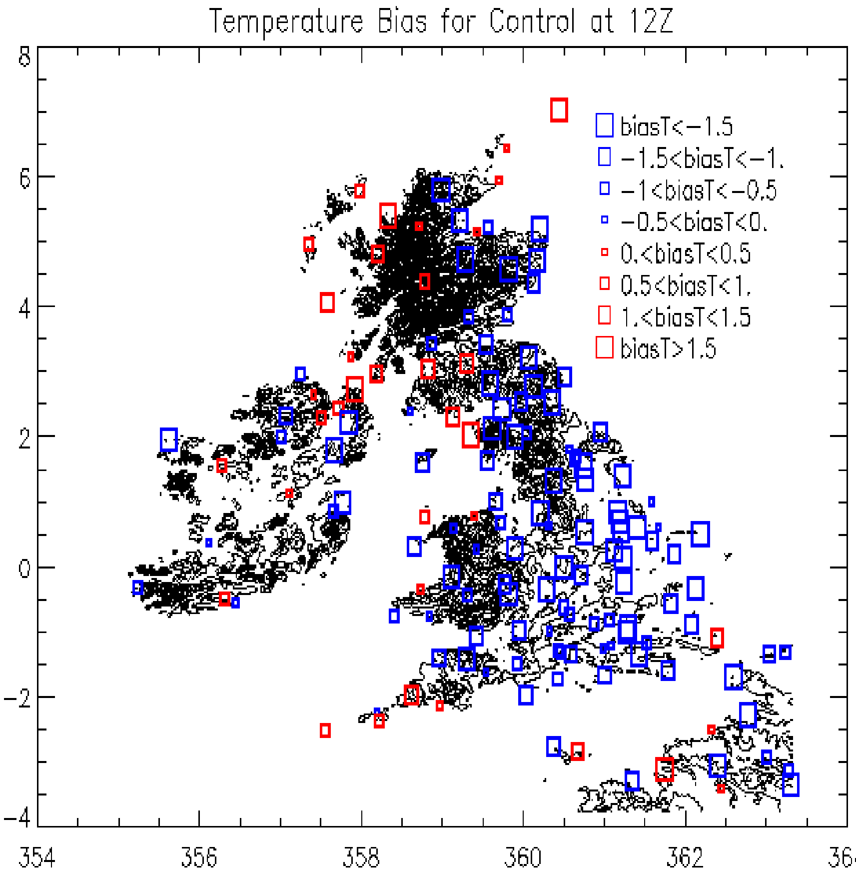


summer

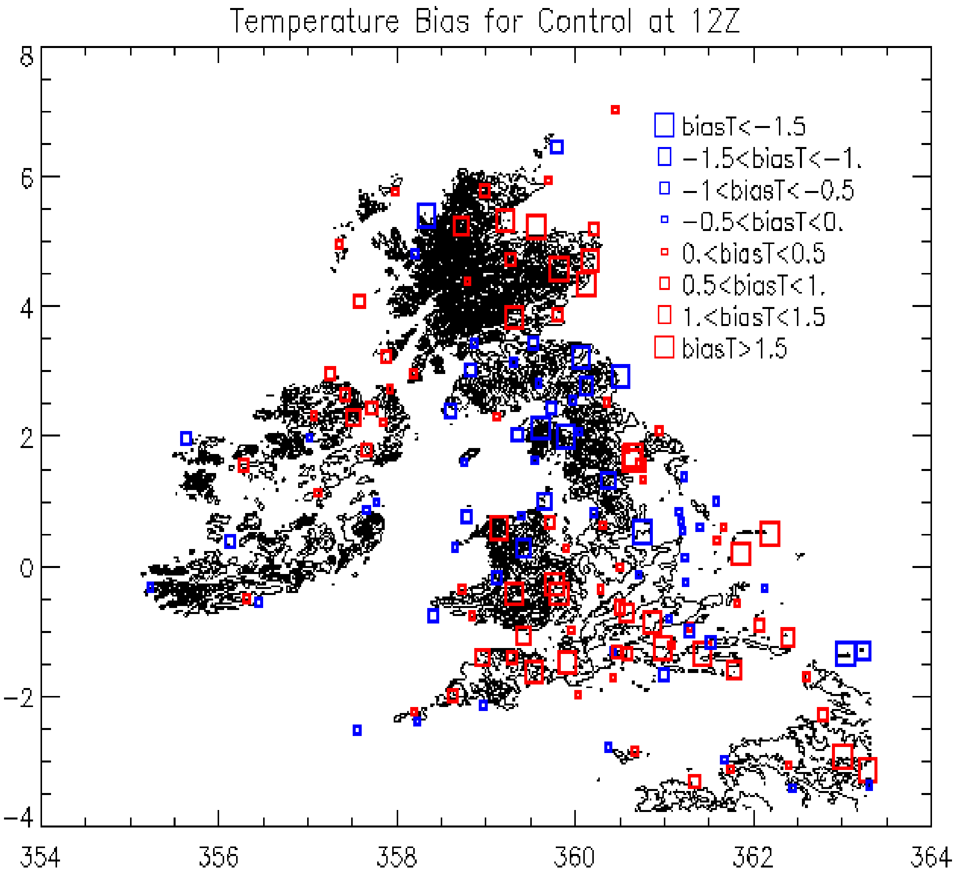


winter

Clear-sky case examples with the UKV (day)

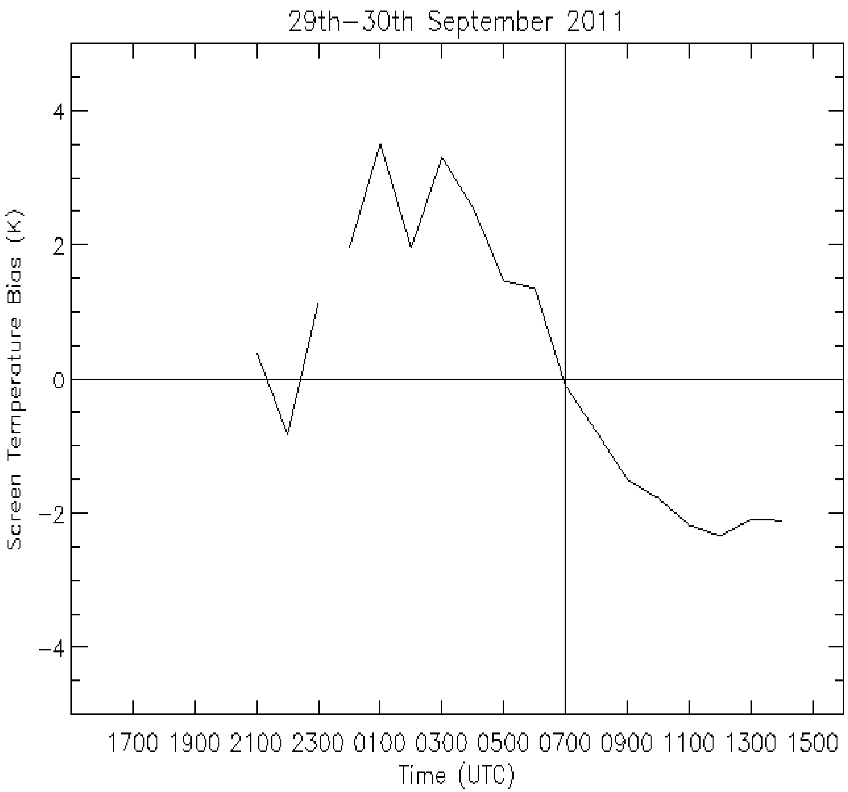


summer

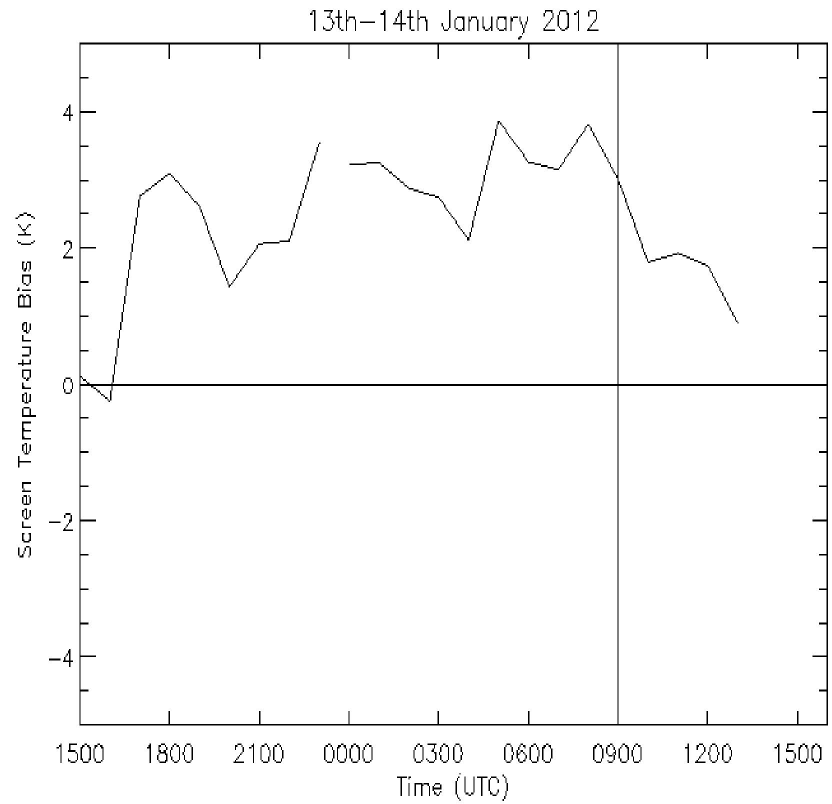


winter

Clear-sky case examples with the UKV

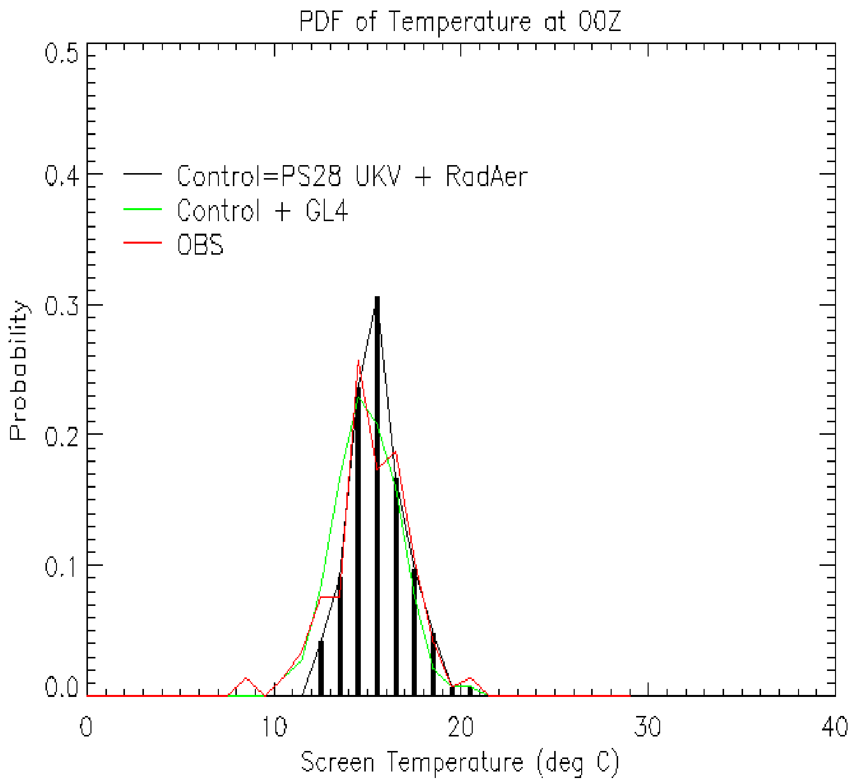


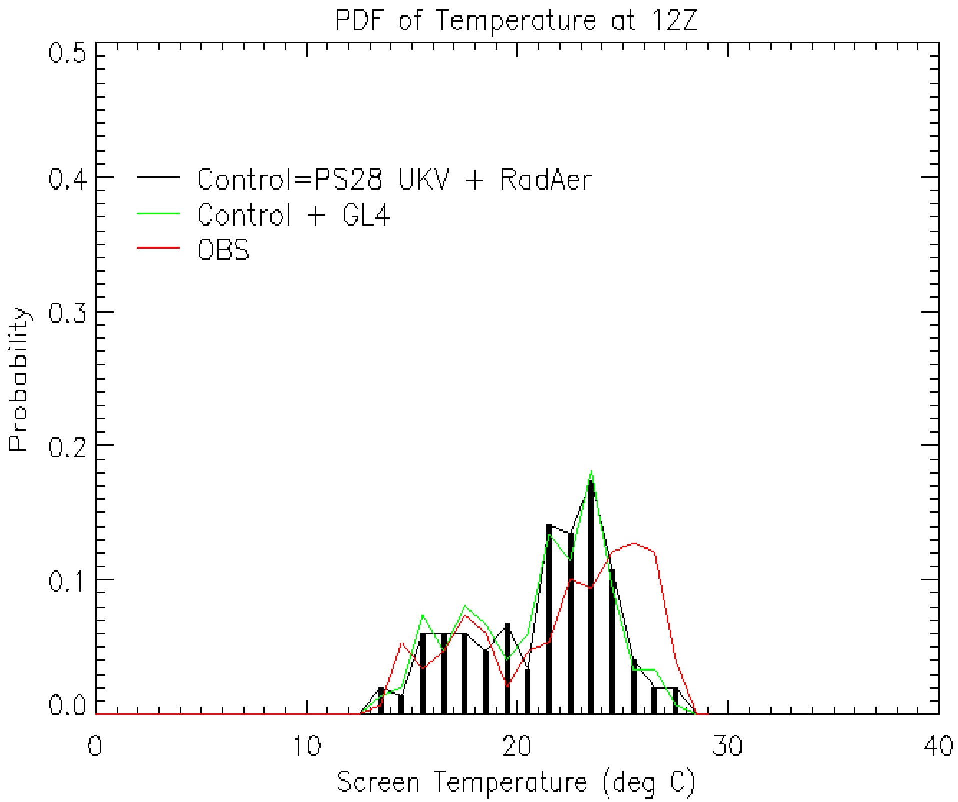
summer



winter

29th-30th September 2011





Summary and impact on relative humidity

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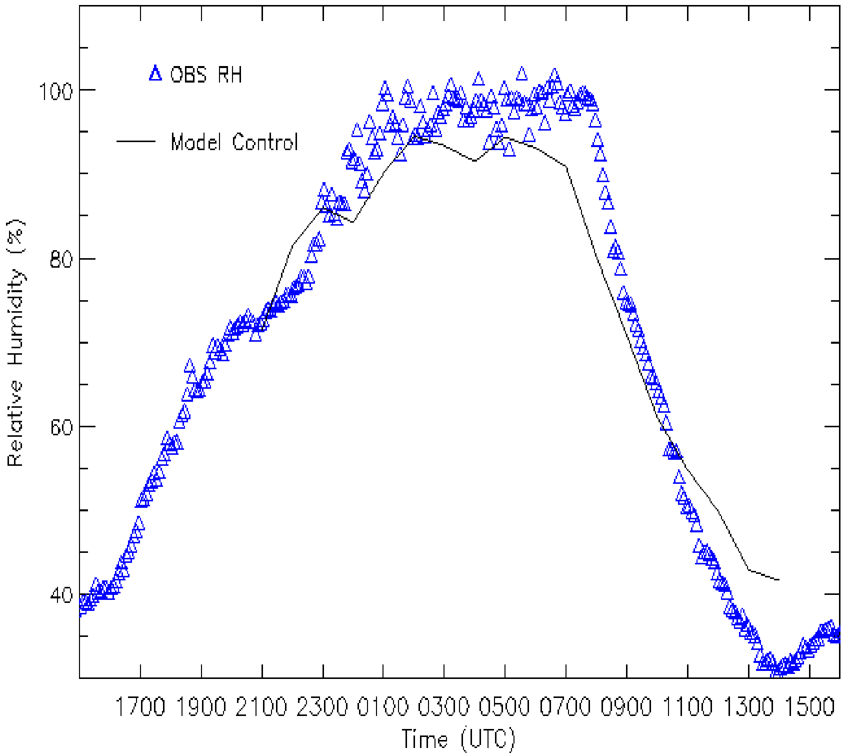
- The modelled diurnal cycle in temperature is too small.
- The winter forecasts seem to suffer mostly from a warm bias.
- The summer forecasts seem to suffer from a warm bias at night and a cold bias at day. This could have an impact on the poor performance of the model to capture the fog in the summer (Unfortunately, the correction for the warm bias during the winter would not help the overestimation of the fog, still ongoing issue).

Bias in relative humidity. The model fails to capture the high RH values during the night



Summer case (29th Sept 2011)

What could cause this bias? - the strong candidates

- Too much heat exchange with the soil during the day and night (method used: verification of soil moisture and temperature against observations from Cardington)?
- Too much evaporation at daytime and dew deposition at nighttime (method used: verification of latent heat fluxes against the mast data at Cardington)?
- Land-surface heterogeneity (method used: use of the grass tile diagnostics against observations from Cardington)?
- Turbulent mixing. At night, having too warm temperatures near the surface suggests that the volume of air over which the cooling is taking place is too large -> PBL too deep. The GABLS intercomparison shows well that the forecast models use turbulence diffusion schemes that are not sharp enough. So, we will test the sensitivity to the dependence of stability of the turbulence diffusion scheme. This will mostly have an impact during the night
- Entrainment at the top of the PBL, particularly during the morning transition (there is evidence that a sharper turbulence diffusion scheme in the boundary-layer, with smaller PBLS and stronger inversions, creates a stronger cold bias). It would be good to compare boundary-layer profiles to observations.

Improvements to the UKV model: GL4 package now live in parallel suite (PS31)

- Sharper tails in the turbulence diffusion scheme in stable conditions and convective conditions
- Prandtl number varying with stability
- Variable surface emissivity
- Improved z0h for trees
- Lower z0h/z0m and higher z0m for bare soil
- Improved numerical accuracy of soil hydrology
- Correction on aerosol climatology

Testing the GL4 package in clear-sky conditions

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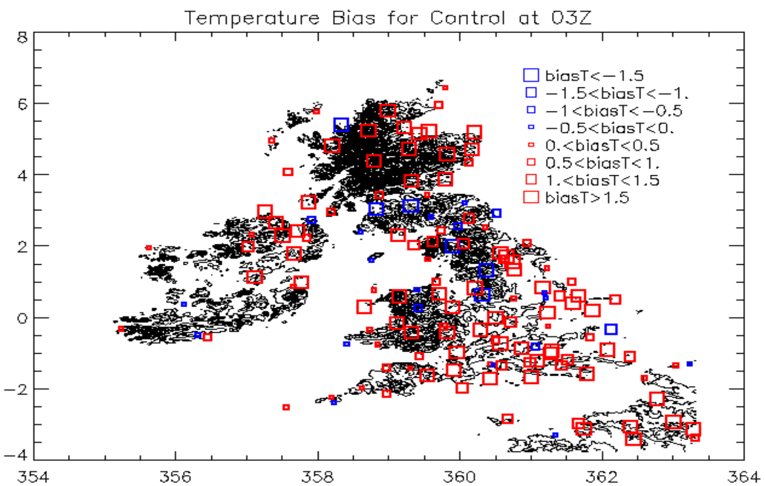
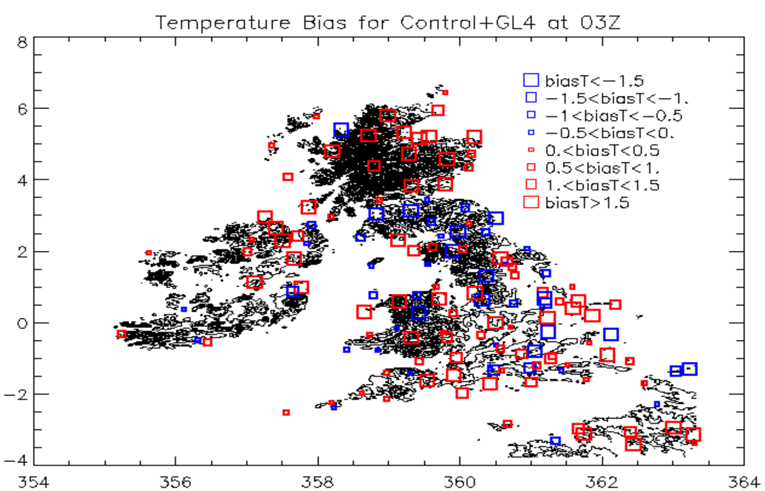
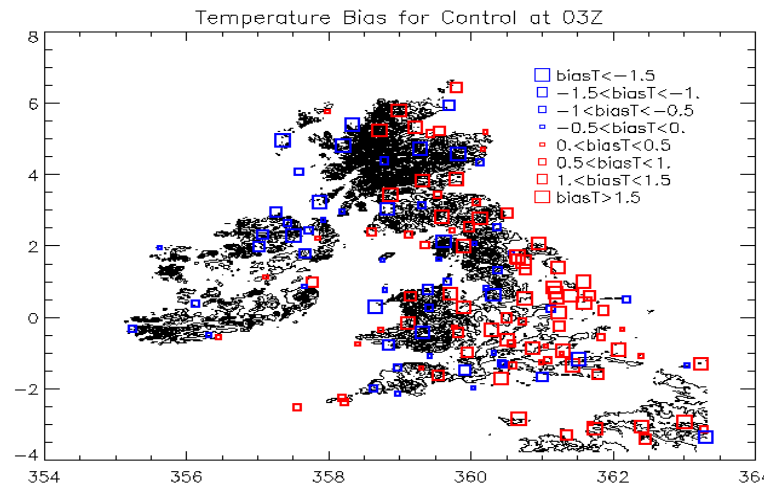
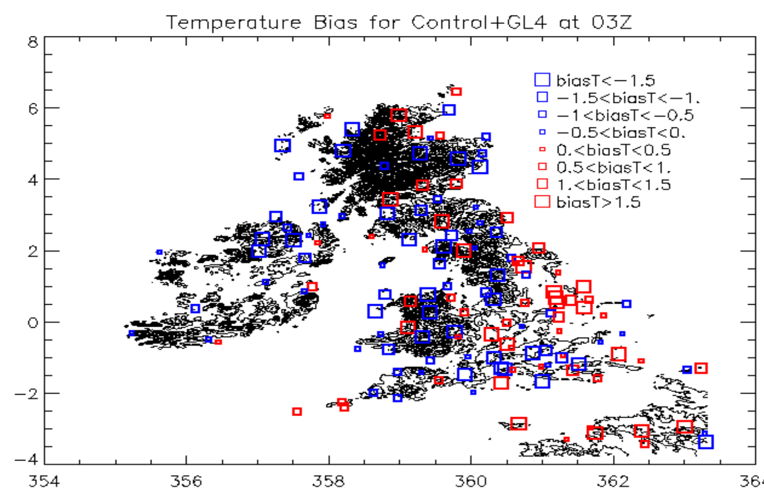
January case



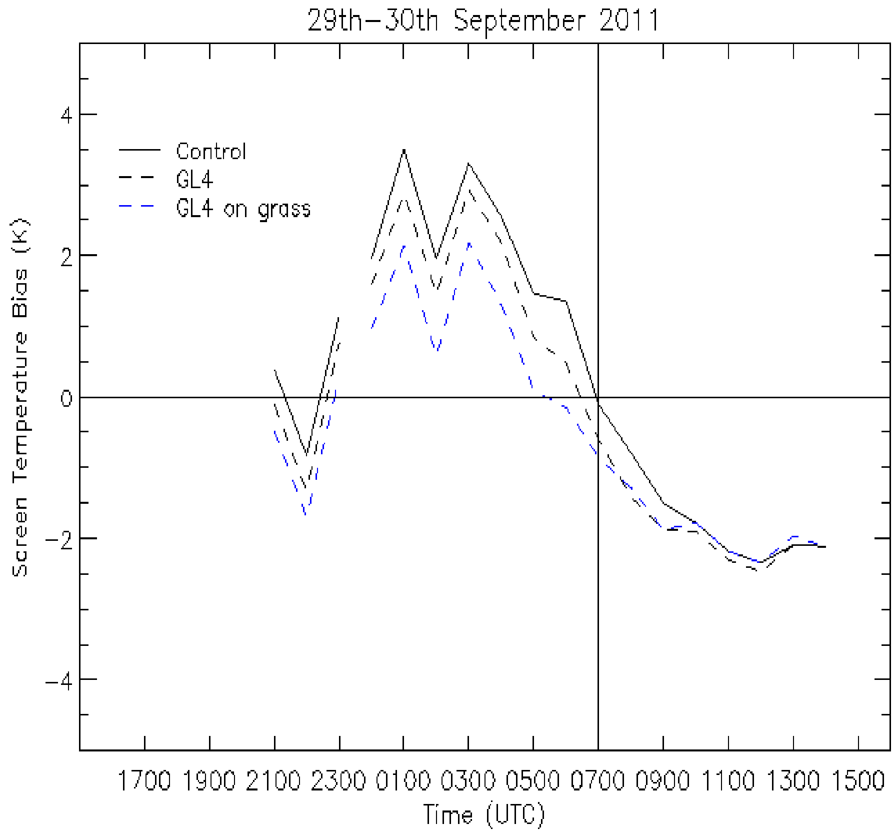


September case

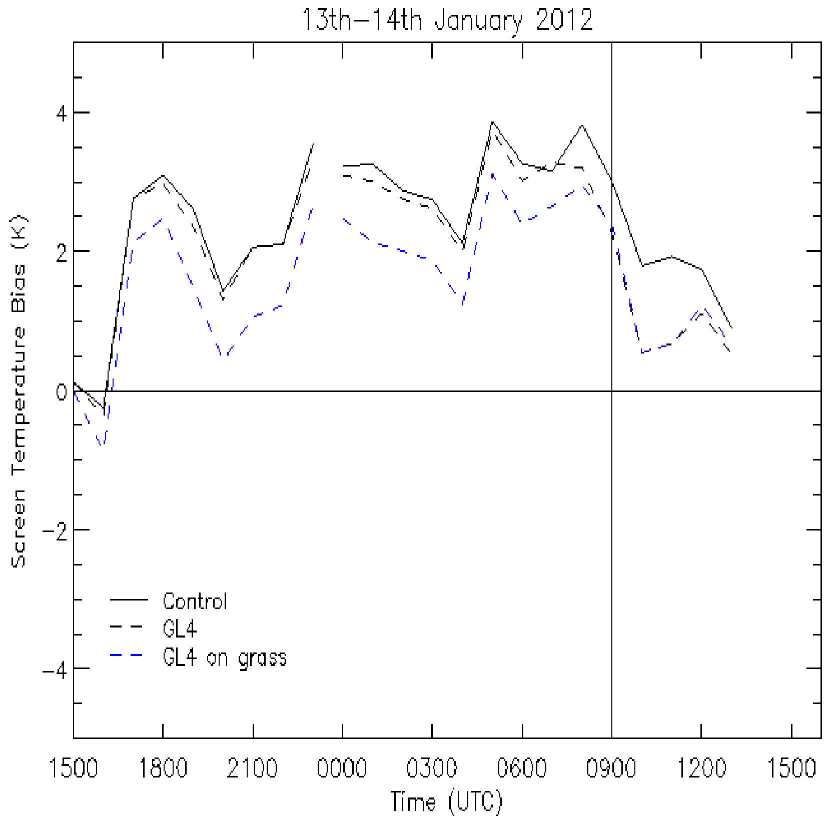




Better with GL4, but the biases are still there. So, more research is needed



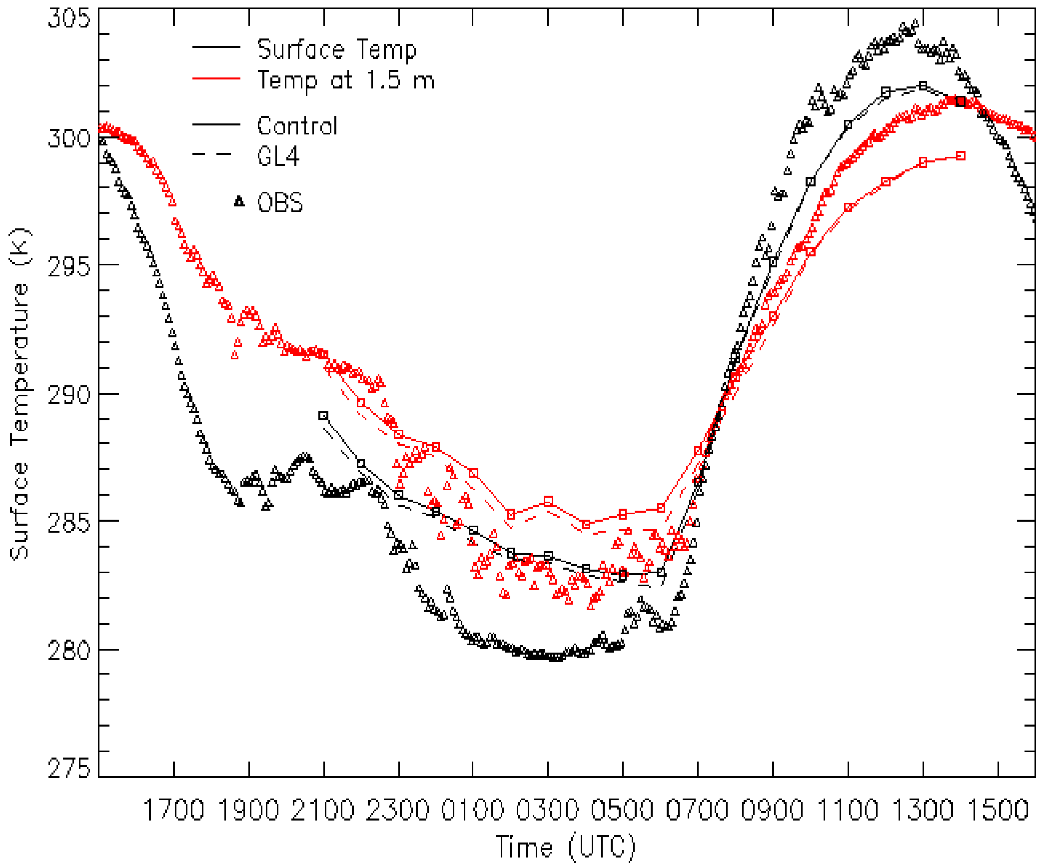
summer



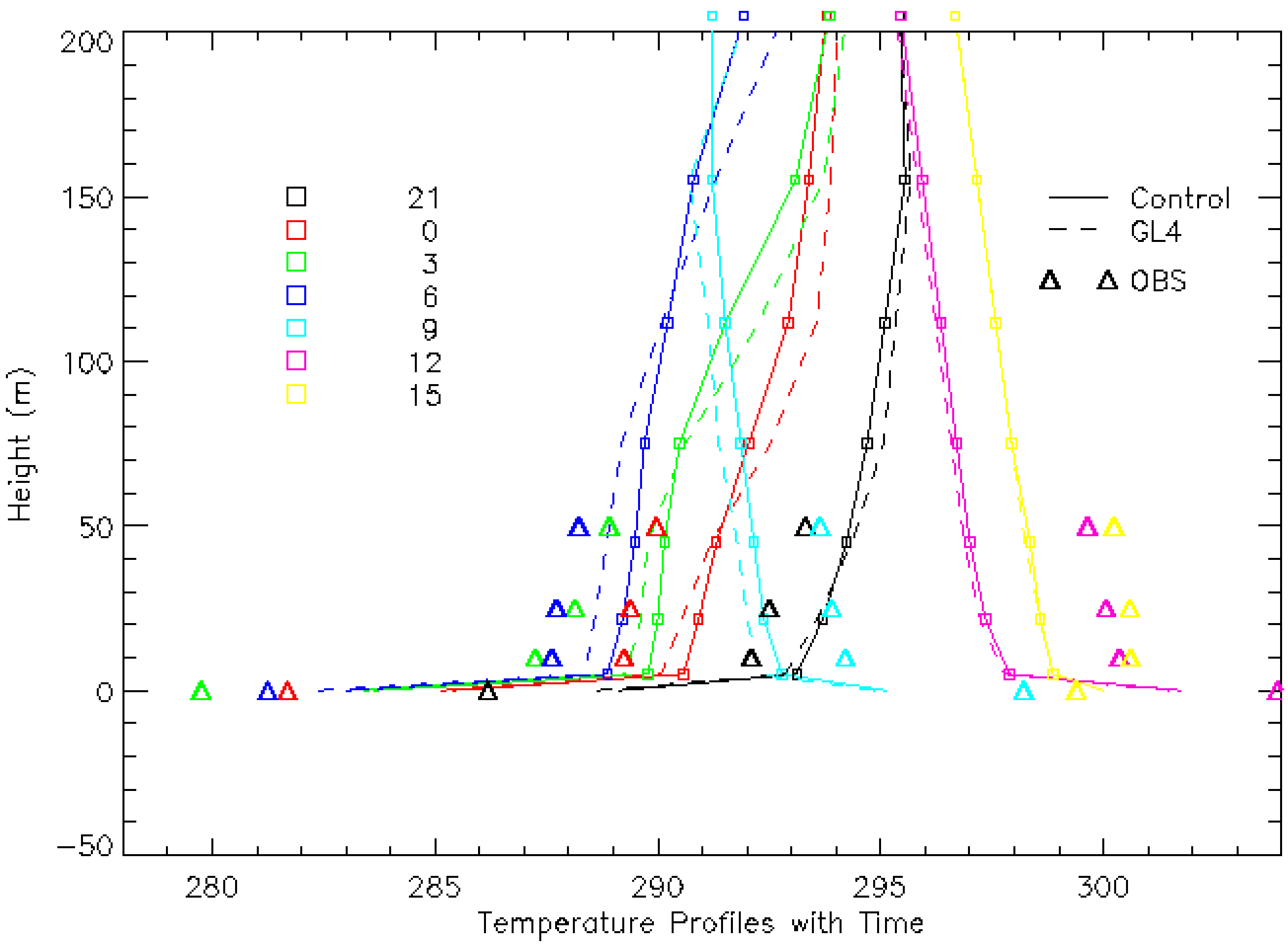
winter

UKV performance at Cardington- focus on 2 clear-sky cases (7th April 2011, 29th September 2011)

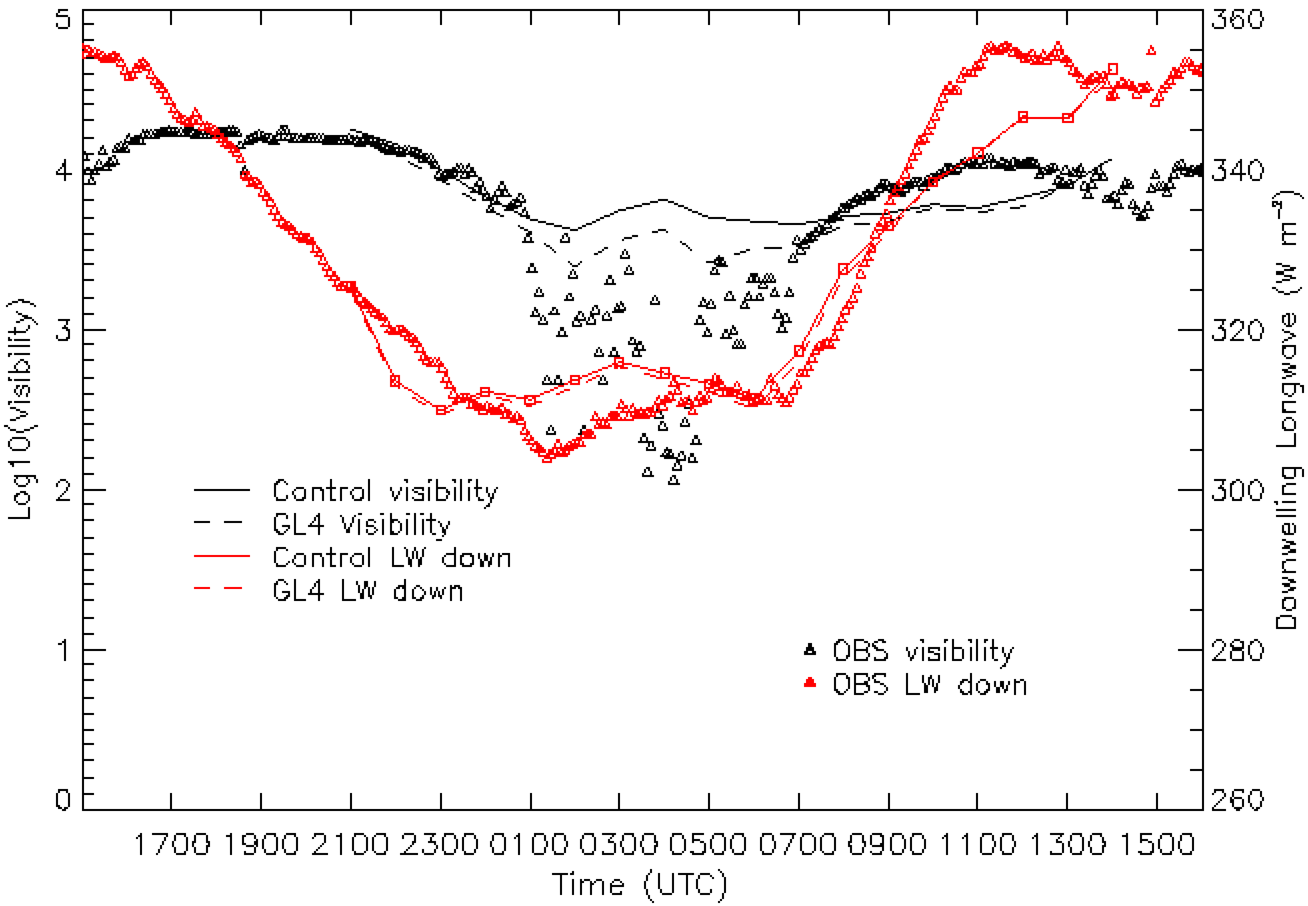
Apart from the screen-level, where else is this bias found?



Summer case (29th Sept 2011)



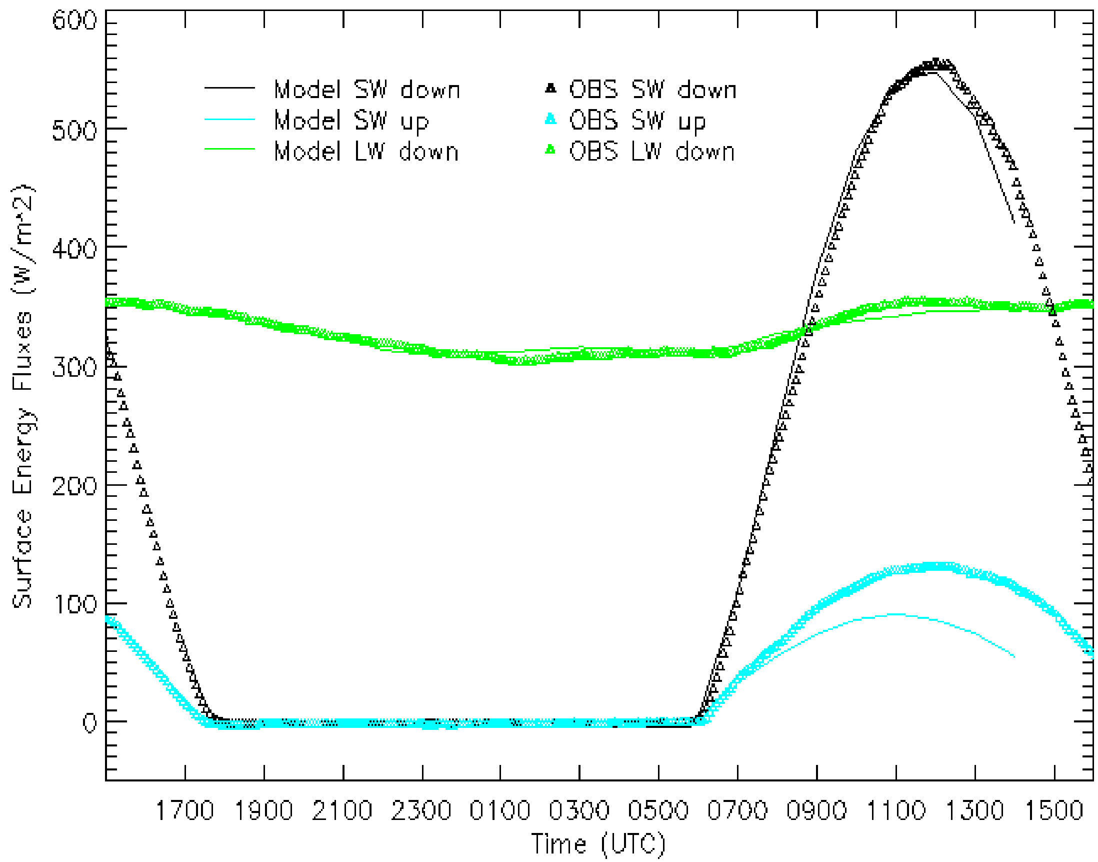
Summer case (29th Sept 2011)



Summer case (29th Sept 2011)

Surface Energy Budget: SW

- Too little SW up in model (albedo too small?)
- Max of SW down too small (aerosols not right?)
- Overall, the model should have a warm bias.



Surface Energy Budget: Turbulent fluxes

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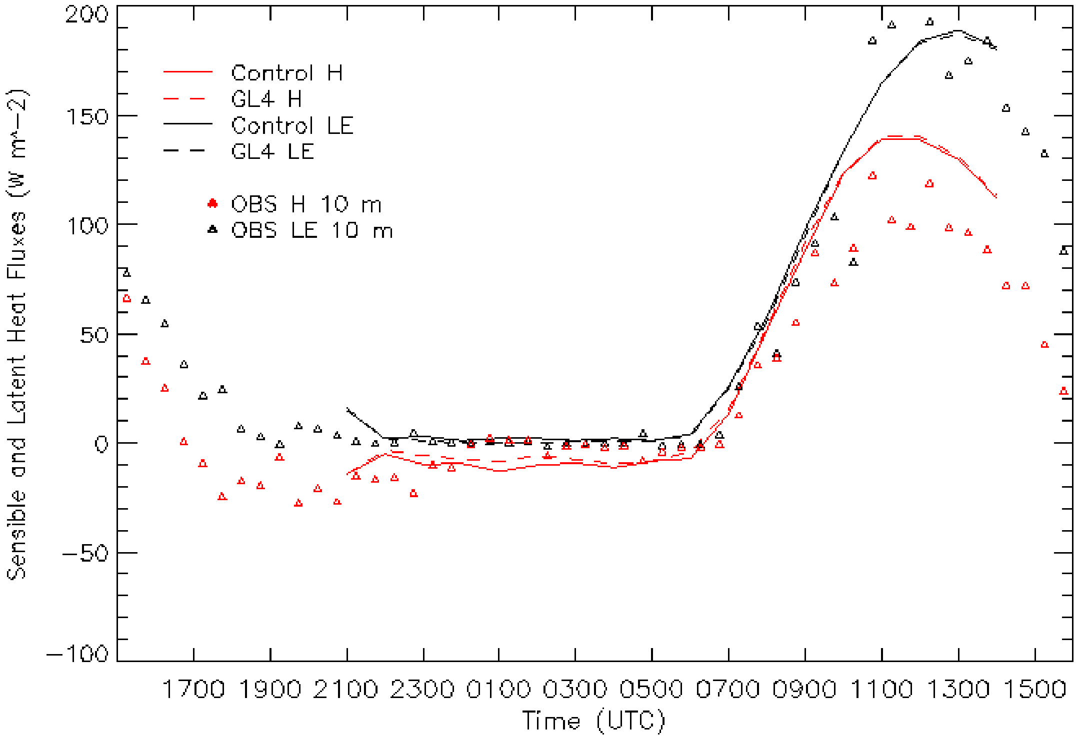
April case



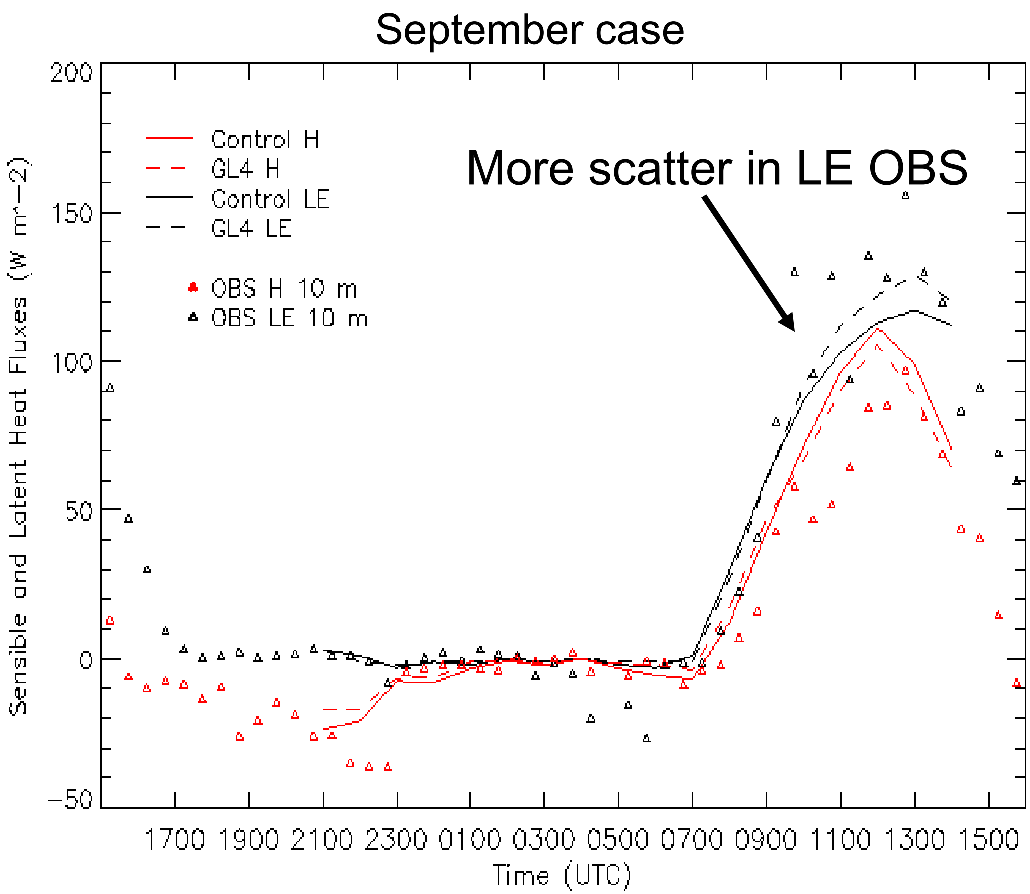
Integration of fluxes with time (based on control run):

- Day. The model looses too much energy at the surface (about 1.4 MJ/m² more heat than the obs). Only a third of this is from evaporation.
- Night. The model gains too much energy at the surface, but smaller differences (about 0.2 MJ/m²). Most of this is due to downwards sensible heat. There is no dew deposition (integration of LE fluxes +).

$Cp\ \Delta z\ \Delta T = 1.4\ MJ/m^2$, $Cp \sim 1\ MJ/Km^3$

$\rightarrow \Delta T\ \Delta z \sim 1.5$

Analysis of Surface Energy Budget: Turbulent fluxes

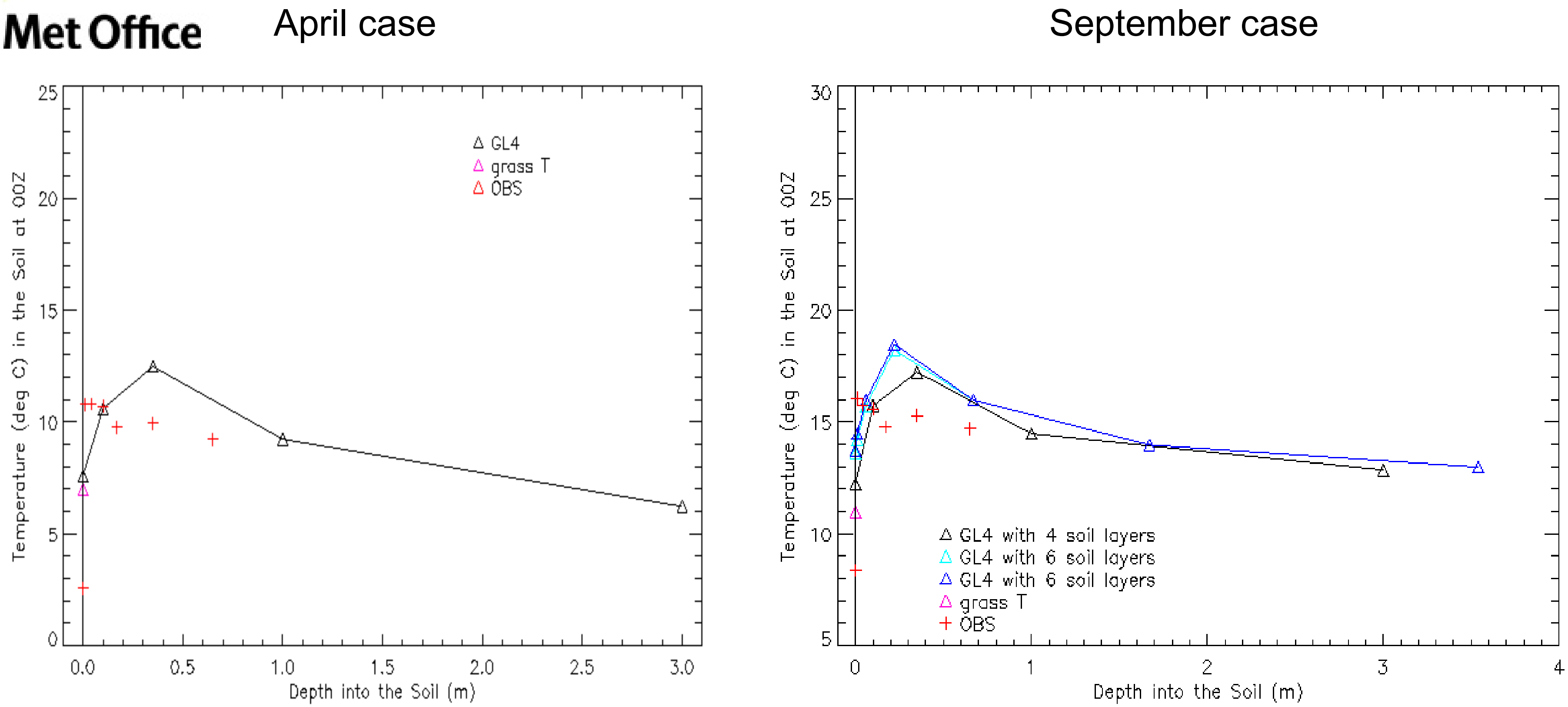


Integration of flux with time (based on control run):

- Day. The model loses too much energy at the surface (only about 0.5 MJ/m² more heat than the obs). All of this is through sensible heat as it does not evaporate enough.
- Night. Very small (about 0.05 MJ/m²) differences between model and obs (the model has a bit more dew deposition, and a bit less downwards sensible heat flux).

->At daytime, the fluxes are not right (mostly H is not right, rather than LE). This could be related to the low albedo in the model.

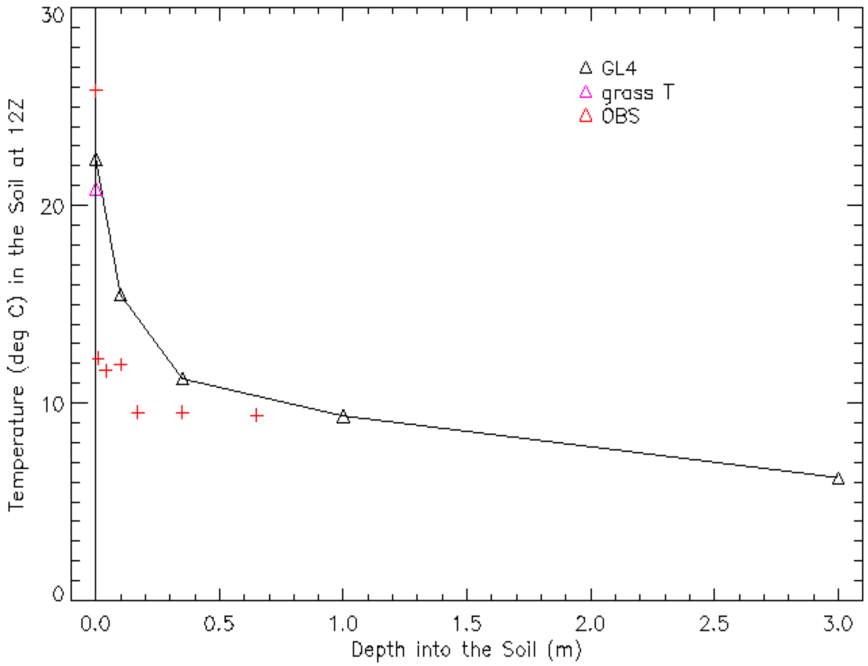
Analysis of soil data: soil temperatures at night



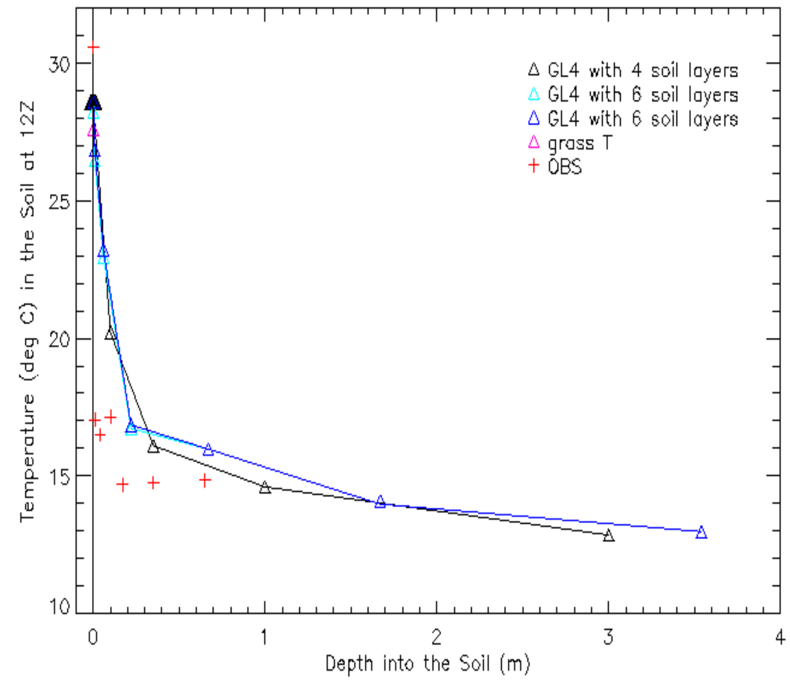
- Large thermal resistance in the canopy from the observations. Can the model capture this large gradient between the 1st soil layer and the skin?
- Increasing number of soil levels does not help (it makes surf T worse). In the 6-layer configuration, the top layer temperature is too cold, or too close to surf T.
- The soil temperature of the 2nd layer (in the standard 4-layer configuration) is too high.

Analysis of soil data: soil temperatures at day

April case



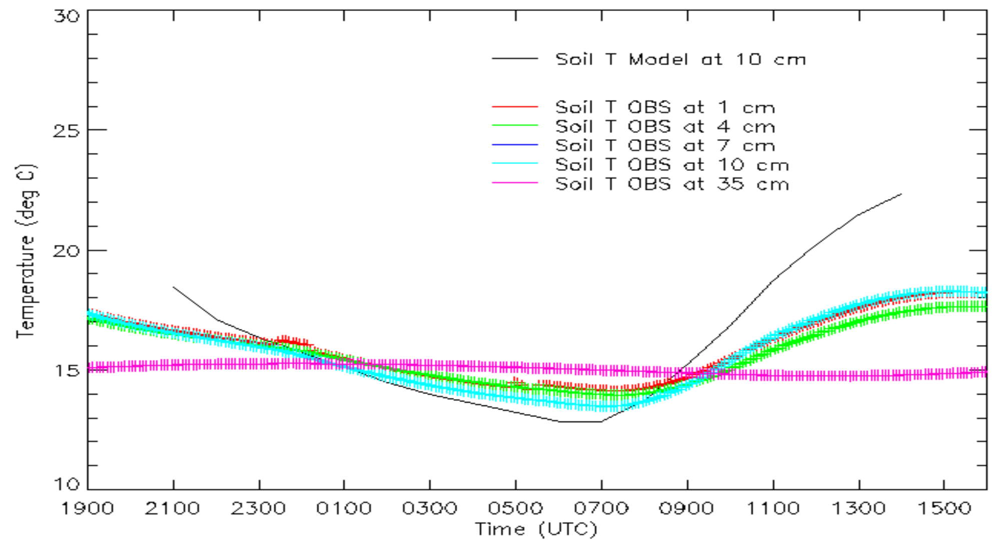
September case



- The soil temperature of the 1st soil layer is too close to surf T. Again, evidence of too much coupling?
- Increasing the number of soil layers does not help (it makes surf T worse).
- Note as well that the grass surf T is not better than the gridbox T (worse at day/ better at night)

Problem with the diurnal cycle of soil temperature at level 1

Met Office



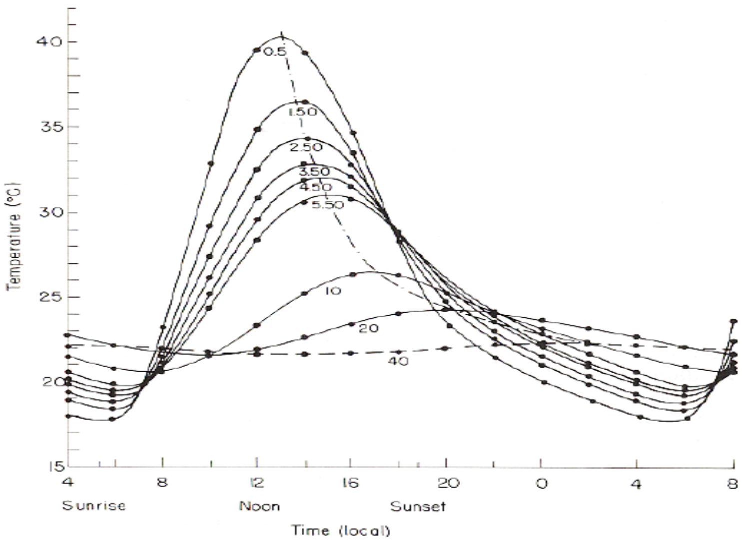


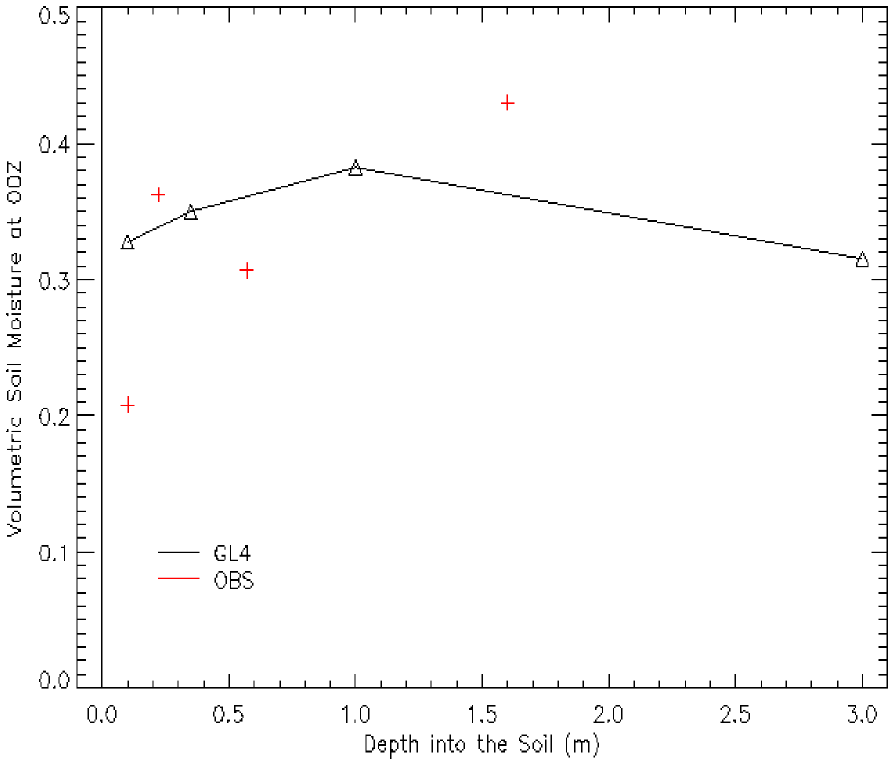
Fig. 11-18. Average diurnal temperature variations at various depths (in centimeters) in the ground, based on the University of Texas observations from 0.5 to 5.5 cm and the Johns Hopkins University observations below 10 cm taken at O'Neill, Nebraska in the summer of 1953. The dash–dot curve represents the locus of the temperature maxima (from Kuo, 1968).

The large oscillation of the soil T in the 1st layer is either related to:

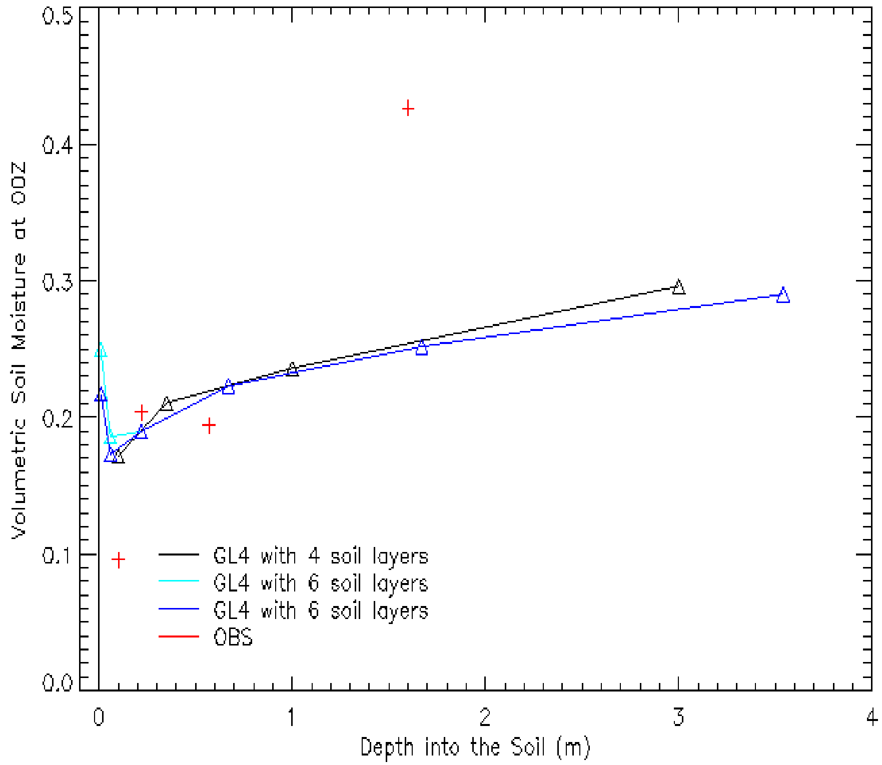
- too much coupling with the canopy (too much bare soil)
- not enough coupling with the bottom soil. However, on a diurnal cycle, the heat should not be transferred to the bottom layers ->New comparison with soil data

Analysis of soil data: soil moisture

April case



September case

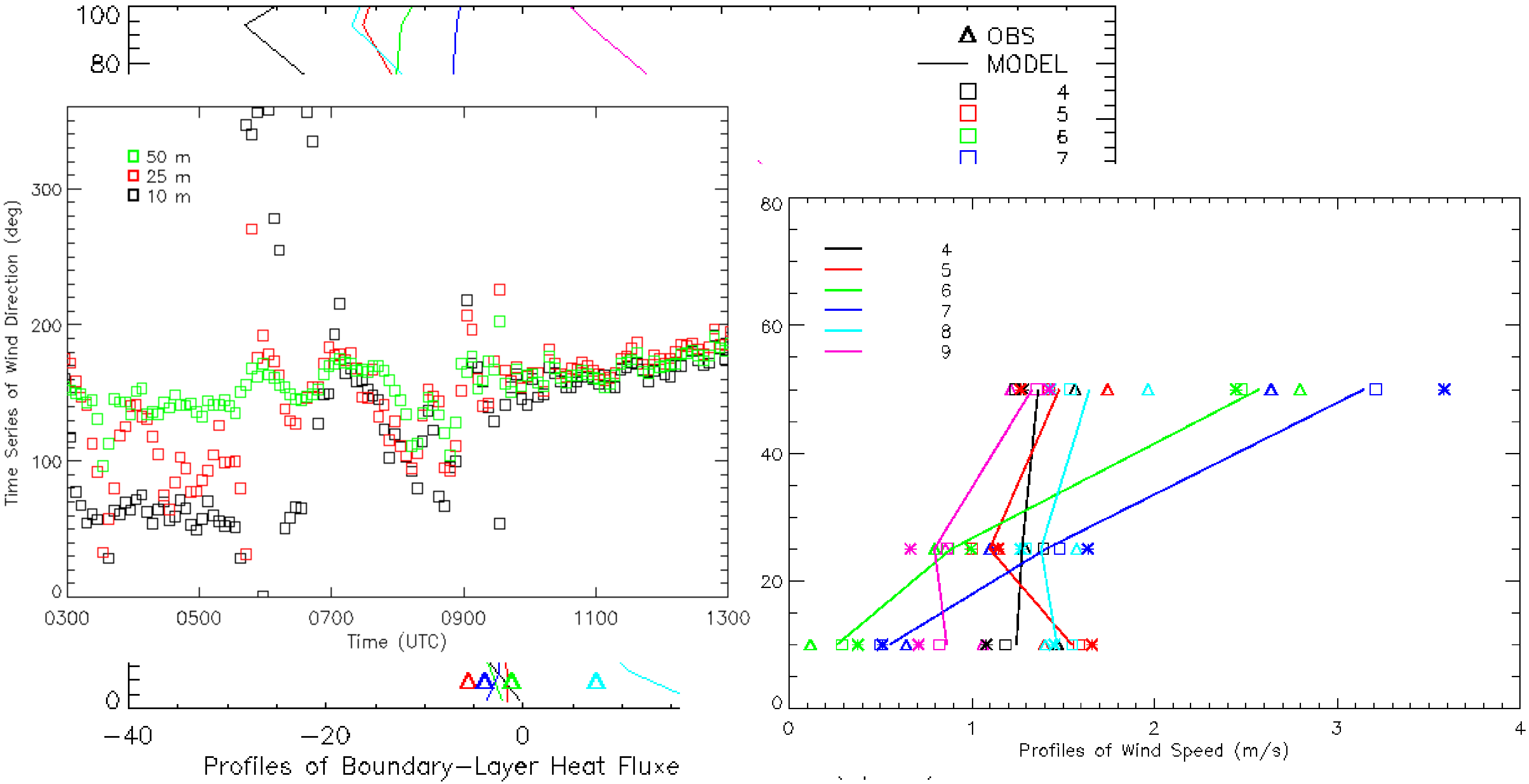


- 1st soil layer too moist. We know that the heat conductivity increases with soil moisture

 -> Could this lead to too much coupling?

- Increasing the number of soil levels does not help (NB: spurious increase in moisture at the top level in the 6-layer configurations).

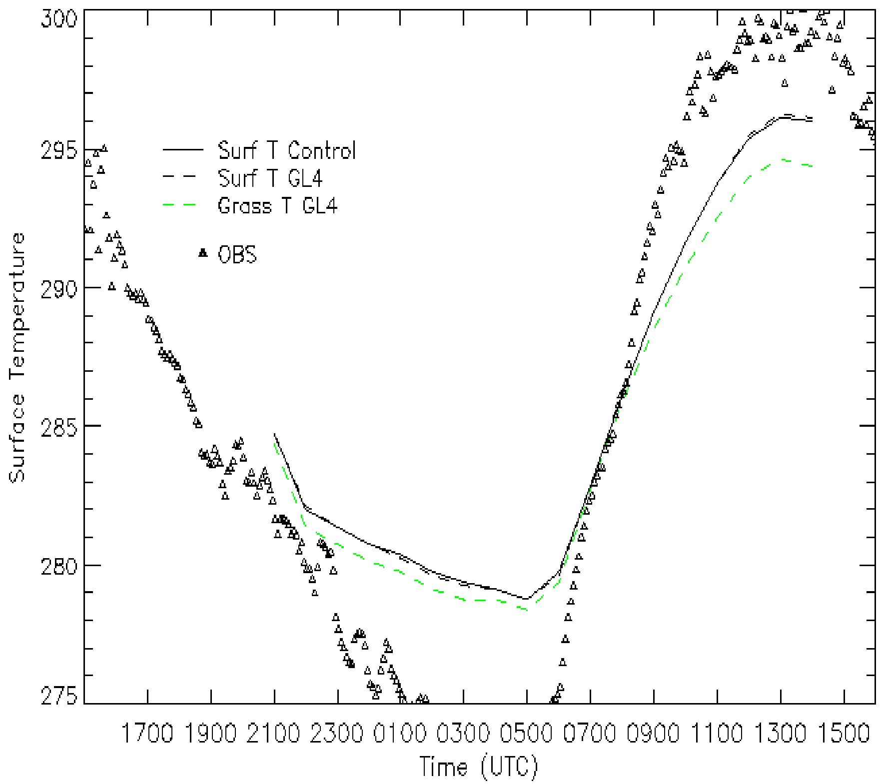
Boundary-Layer Turbulent Fluxes in the Morning Transition (29th Sept 2011)



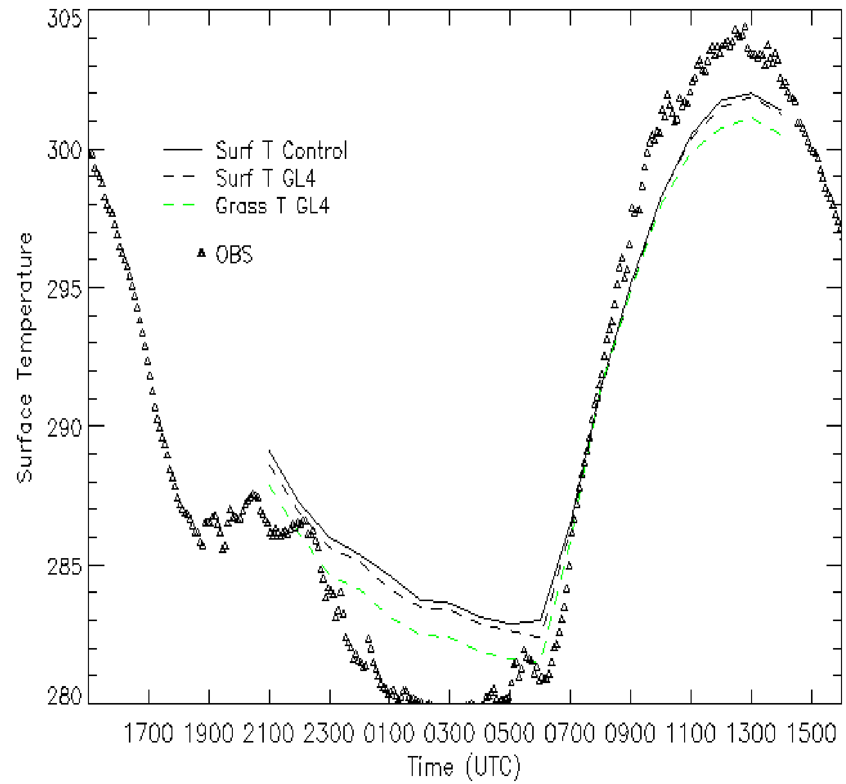
More turbulent warming in the obs during the morning transition (at 50 m). This may be associated to a strong backing of the wind near the surface. This behaviour was not observed for the other case study.

Impact of Land-Use Heterogeneity: Is the Grass Tile Any Better?

April case



September case



Not much better. At night, slight improvement, but perhaps still too much coupling with the soil (canopy resistance not efficient)? At day, too much evaporation (see next plots)?

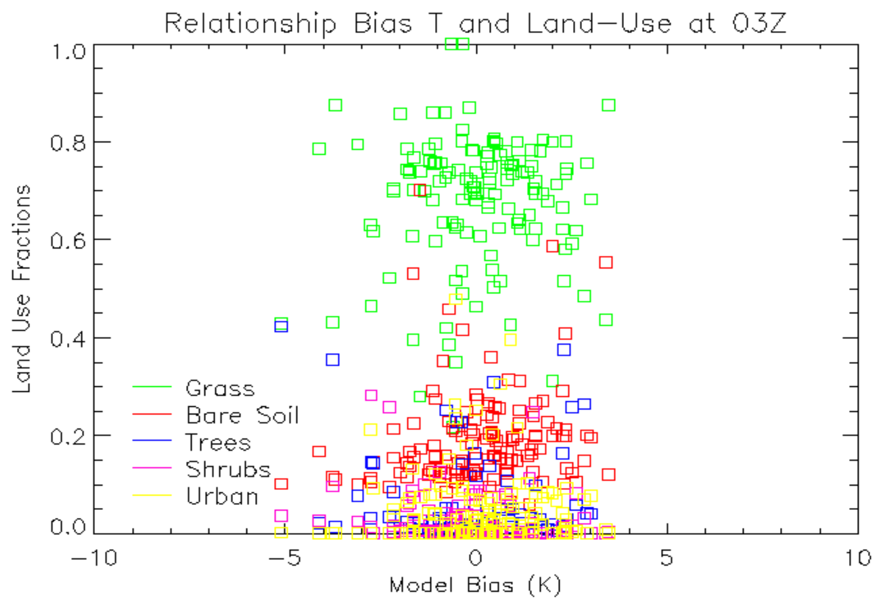
Impact of Land-Use Heterogeneity (night)

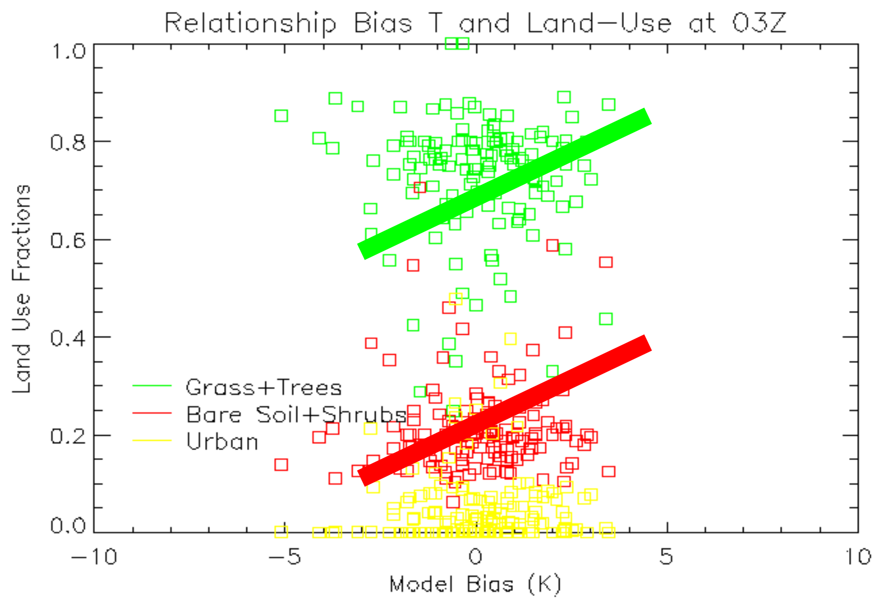
September case

Control run

No relationship found.

The scatter does not improve for the other case studies, even the winter one.





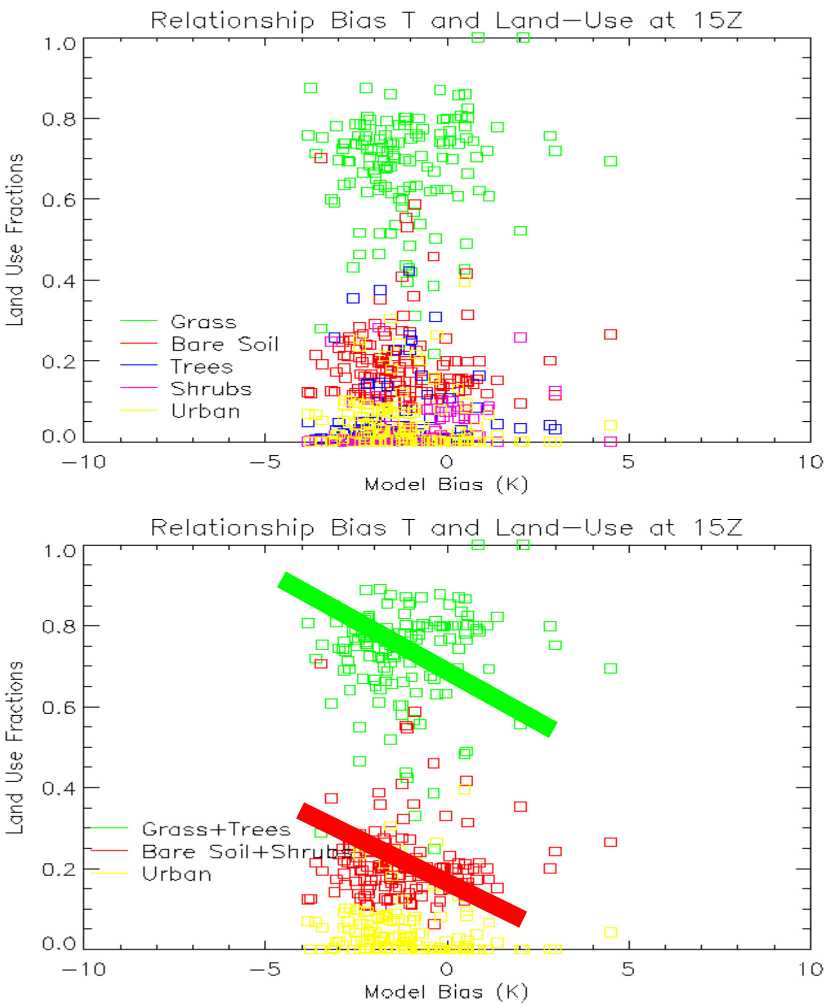
Impact of Land-Use Heterogeneity (day)

September case

Control run

Any better?

The correlation is still very poor



Impact of vertical resolution (L70/L140 tests)

Thanks to Jessica Standen

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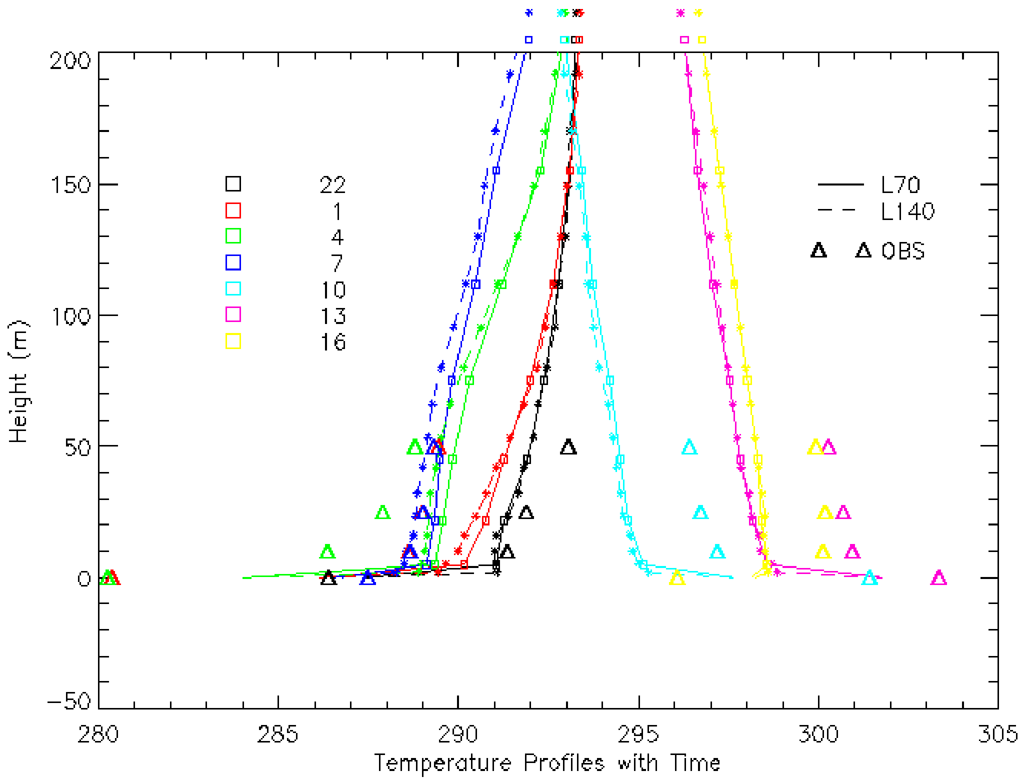
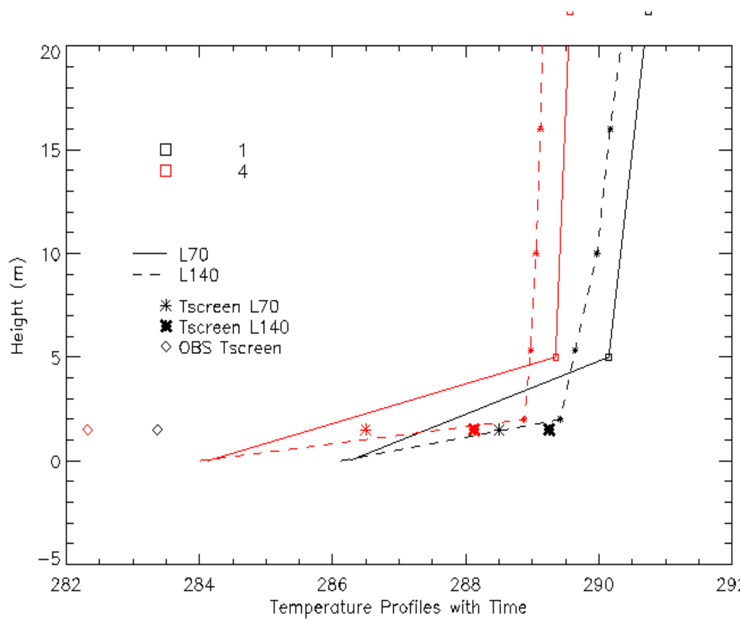


Zoom near the surface



More tests have been carried with a modified Ri, with the aim to decrease the mixing between levels 1 and 2 BL temperatures (pers. comm A. Lock), but this did not help, and perhaps requires further investigation.

General Conclusions

The UKV model shows an underestimation of the diurnal cycle in temperature. This was also found in other high-resolution models.

The bias occurs at the surface, as well as throughout the boundary-layer. Since it occurs both at the surface and within the boundary-layer, it is likely that both the coupling from below and above the surface need to be improved.

We've worked on improving this bias by modifying the physics in the boundary-layer, and we are now working on improving the bias in the soil.

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Thank you for your attention!