



Evaluating the Unified Model and JULES simulated land surface temperature (LST) using a multi-platform approach

Jennifer Brooke, Chawn Harlow, Martin Best, Russell Scott, John Edwards, and Mark Weeks.

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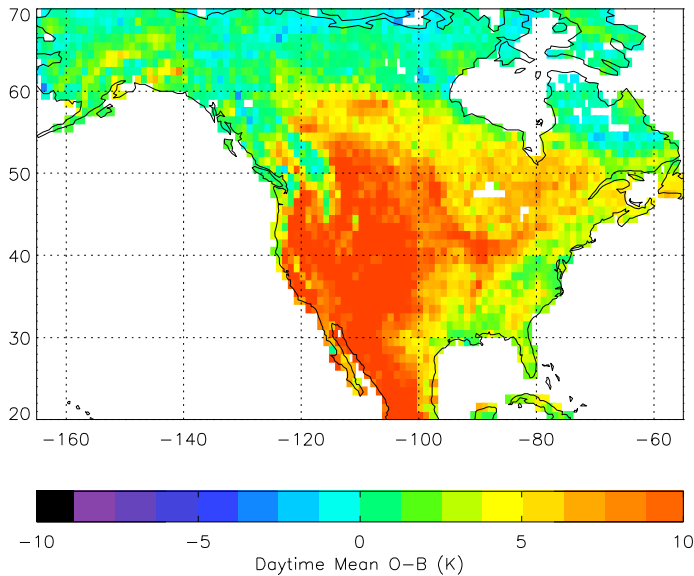
Overview

This presentation covers the following areas

- Motivation
- The SALSTICE campaign
- Aircraft surveys of LST
- MODIS Comparisons
- Diagnosing UM biases with ground data
- Diagnosing JULES biases with ground data
- Conclusions

Motivation for SALSTICE: Land surface temperatures (LST)

- Large **COLD** bias between UM representation of skin temperature and that retrieved from satellite data.
- Largest bias in the spring.



Spatial distribution of LST biases (May 2012)
Image courtesy of Ed Pavelin

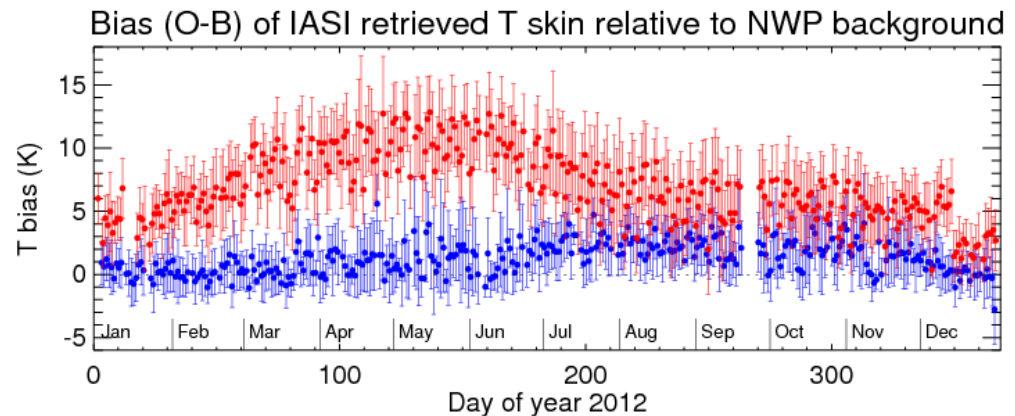
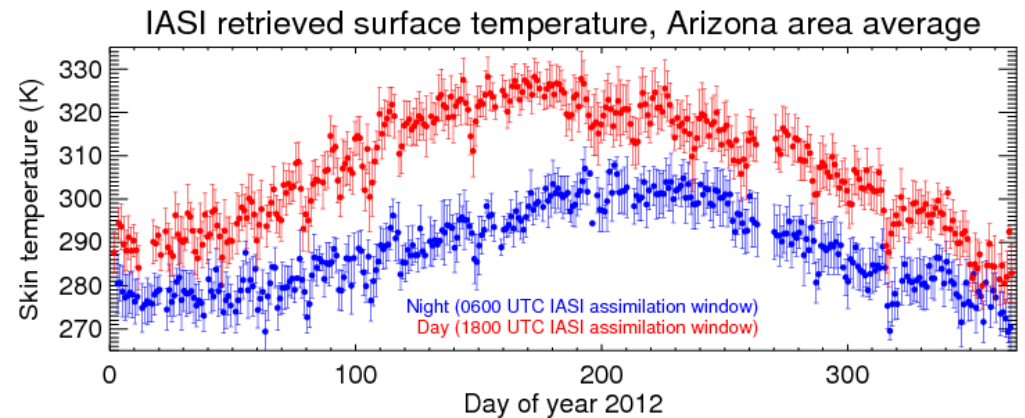


Image courtesy of Stuart Newman, Ed Pavelin and Brett Candy



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Semi-Arid Land Surface Temperature and IASI Calibration Experiment (SALSTICE)

- SALSTICE is a FAAM aircraft (BAe-146) field campaign during May 2013 based in one of these semi-arid regions, Arizona.
 - I. Aircraft sorties using the Met Office Airborne Research Interferometer Evaluation System (ARIES)
 - Unified Model (UM) LST evaluation
 - II. Ground campaign
 - Six flux tower sites in the Walnut Gulch Experimental Watershed run by USDA-Agricultural Research Service
 - Turbulent and radiant flux measurements.
 - Soil and near surface temperatures.
 - Focus on Kendall grassland and Lucky Hills sites.

Model Configurations



UM Configurations (2013, 2014 and 2015):

- Global 25 km configuration
- Global 17 km configuration
- 4.4 km Limited Area Model (LAM)
- 2.2 km Limited Area Model (LAM)

JULES single column runs (2013)





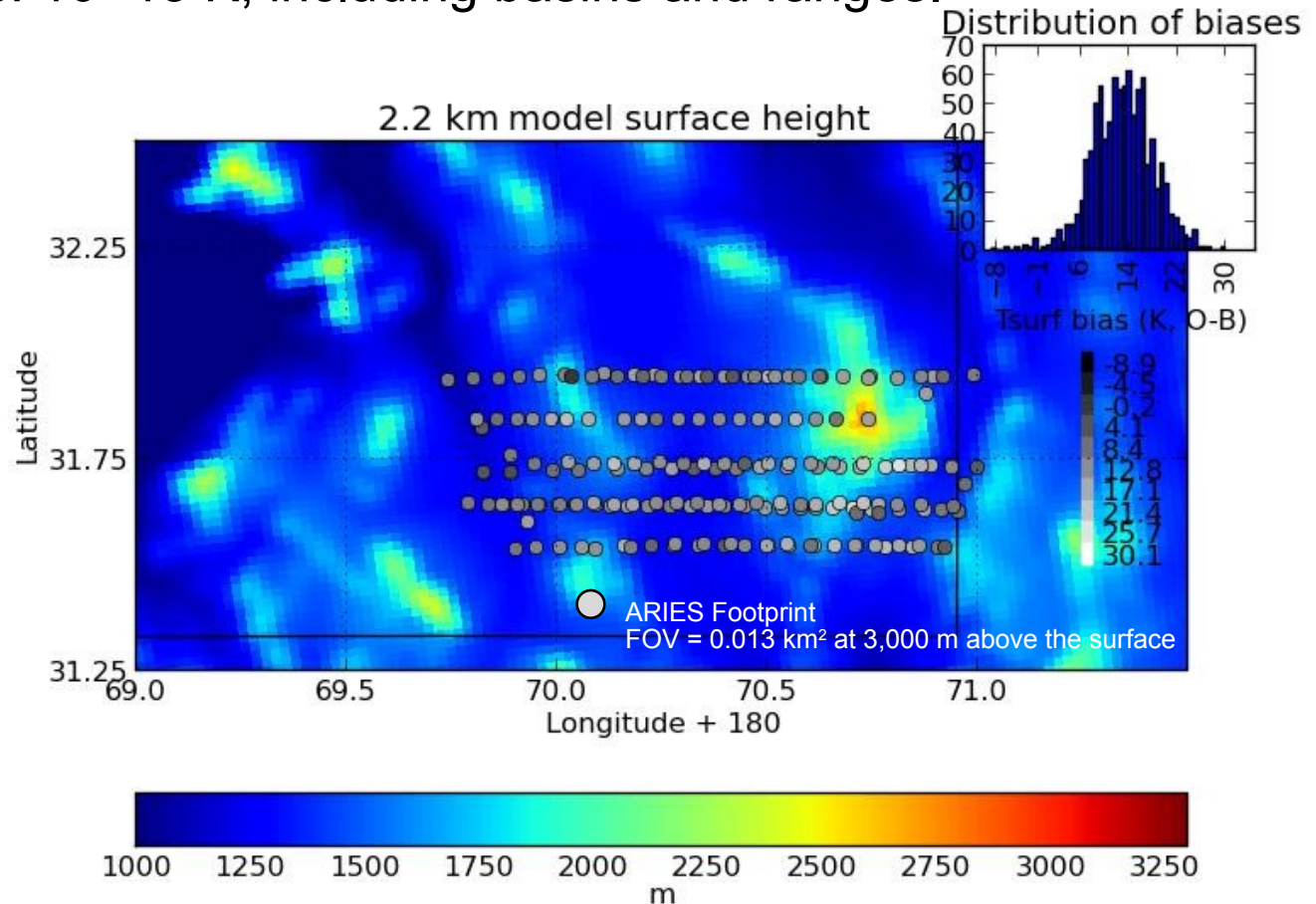
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Aircraft LST Evaluation

- Aircraft data shows LST errors are most significant over complex terrain.
- Mode of LST biases: 10 -13 K, including basins and ranges.





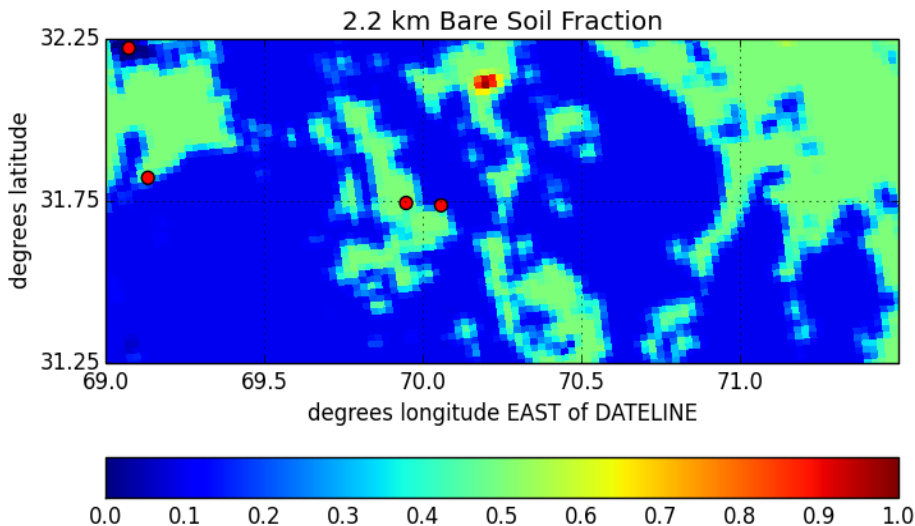
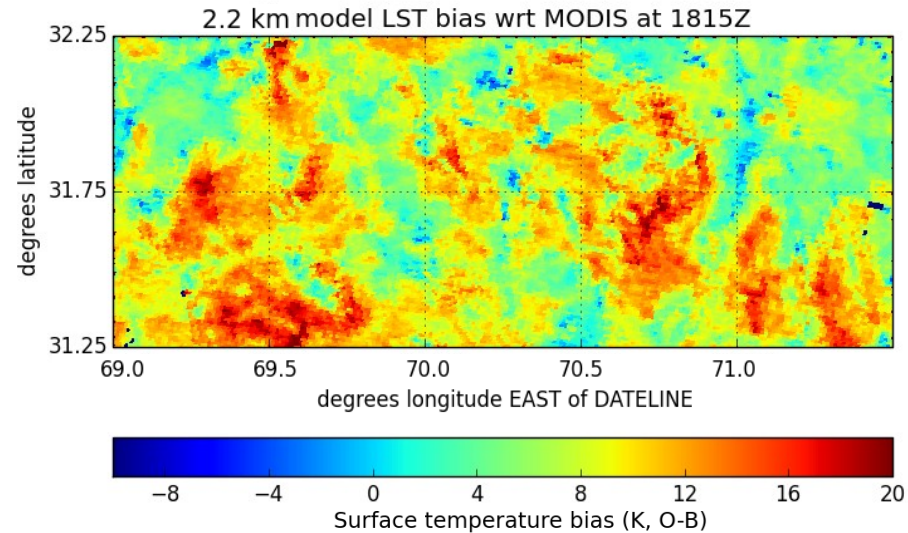
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MODIS Comparisons



MODIS Collection 5 1 km LST product.

Mean bias: 8.4 ± 3.7 K.

High degree of variability in LST biases which is related to heterogeneity in surface vegetation.

The bare soil cover fraction is too low across the whole region.

Regions of large LST bias are associated with low bare soil cover fraction during the day.

The LST bias is negatively-correlated with the bare soil cover fraction during the daytime;

Correlation coefficient of **-0.62** (2013)

Correlation coefficient of **-0.48** (2014)

At night the LST bias is weakly correlated to the bare soil cover fraction.

Correlation coefficient of **0.21** (2013)

Correlation coefficient of **0.08** (2014)



Overview

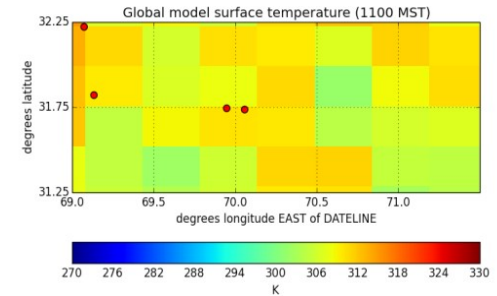
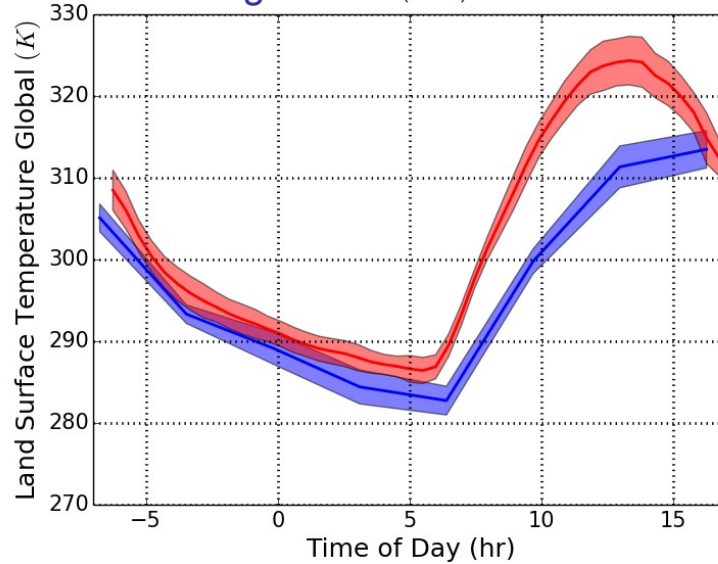
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Global vs. LAM LST

Global Configuration (blue) Observations (red)



Global: Daytime LST poorly simulated both in phase and amplitude.

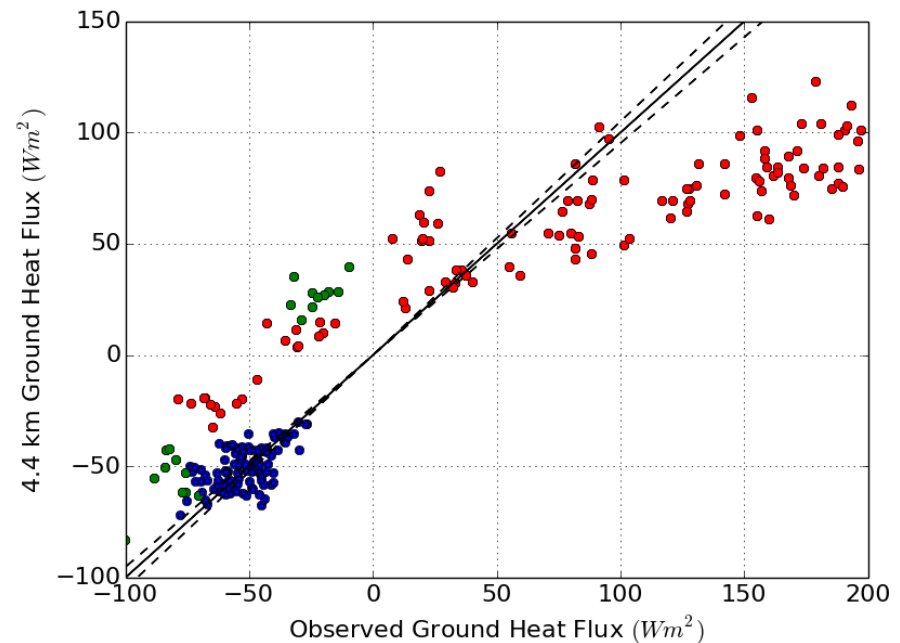
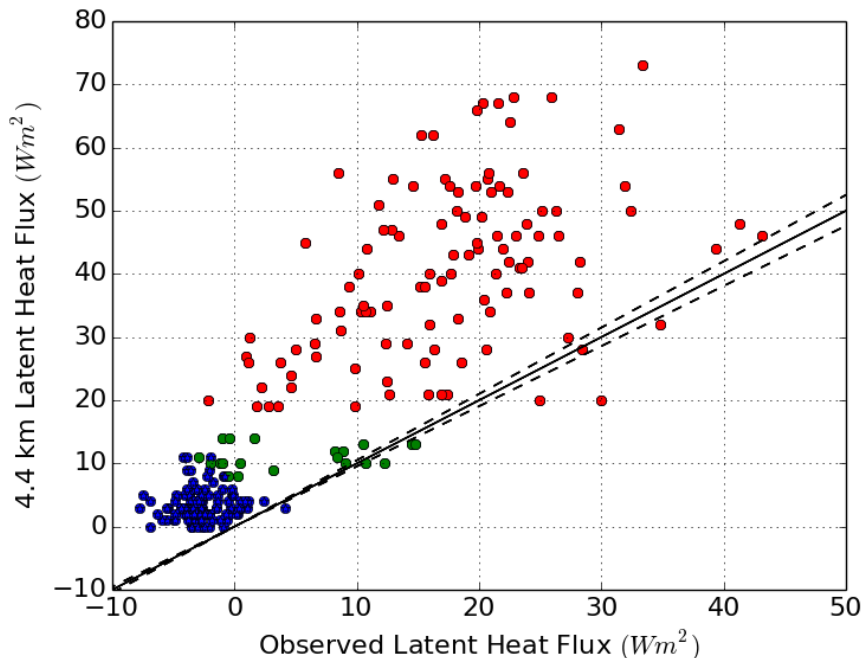
Daytime bias: 9.4 ± 3.7 K
Night-time bias: 3.0 ± 1.5 K

Modelled Heat Fluxes

Latent & Sensible Heat Flux
 -too large (21 $W m^{-2}$, monthly average)

Ground Heat Flux
 -too small (3.5 $W m^{-2}$, monthly average)

Too much heat transported into the atmosphere and not enough used to heat the soil



Blue = Night time ($SWD < 5 W m^{-2}$), Green = Transition period ($SWD > 5 W m^{-2}$ and $< 200 W m^{-2}$), Red = Day time ($SWD > 200 W m^{-2}$)



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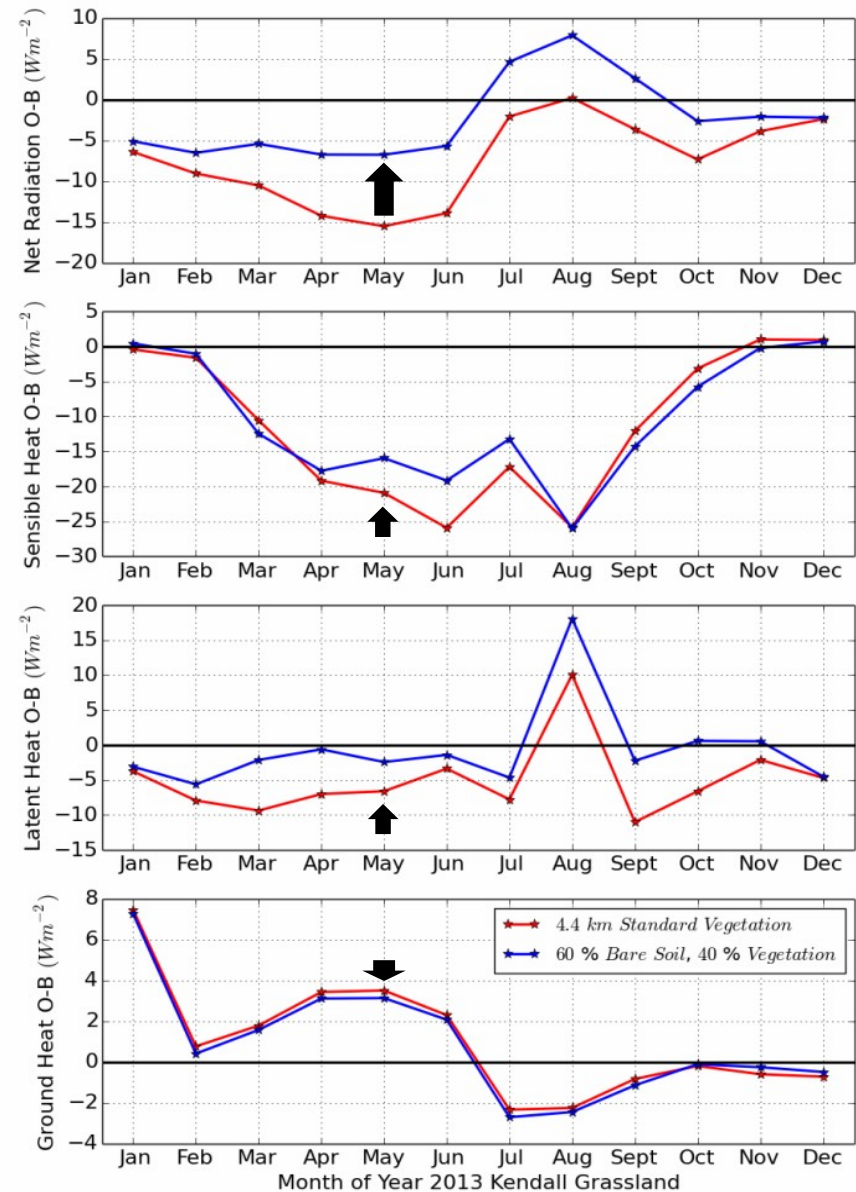
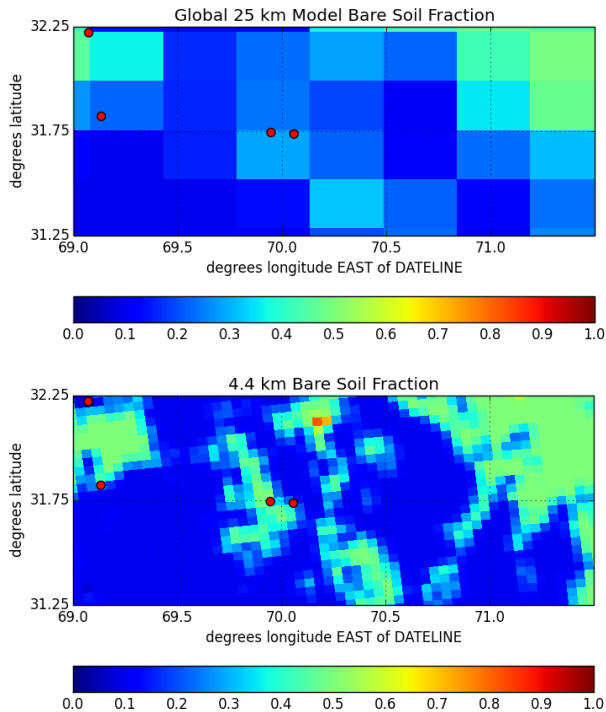


Bare Soil Sensitivity

JULES Sensitivity Test:

- Increase bare soil cover to 60 %
- Net radiation + turbulent heat fluxes biases reduced
- Little sensitivity to the ground heat flux

Bare soil fraction for south-eastern Arizona for each model configuration.





4.4 km Standard vs. Realistic Vegetation

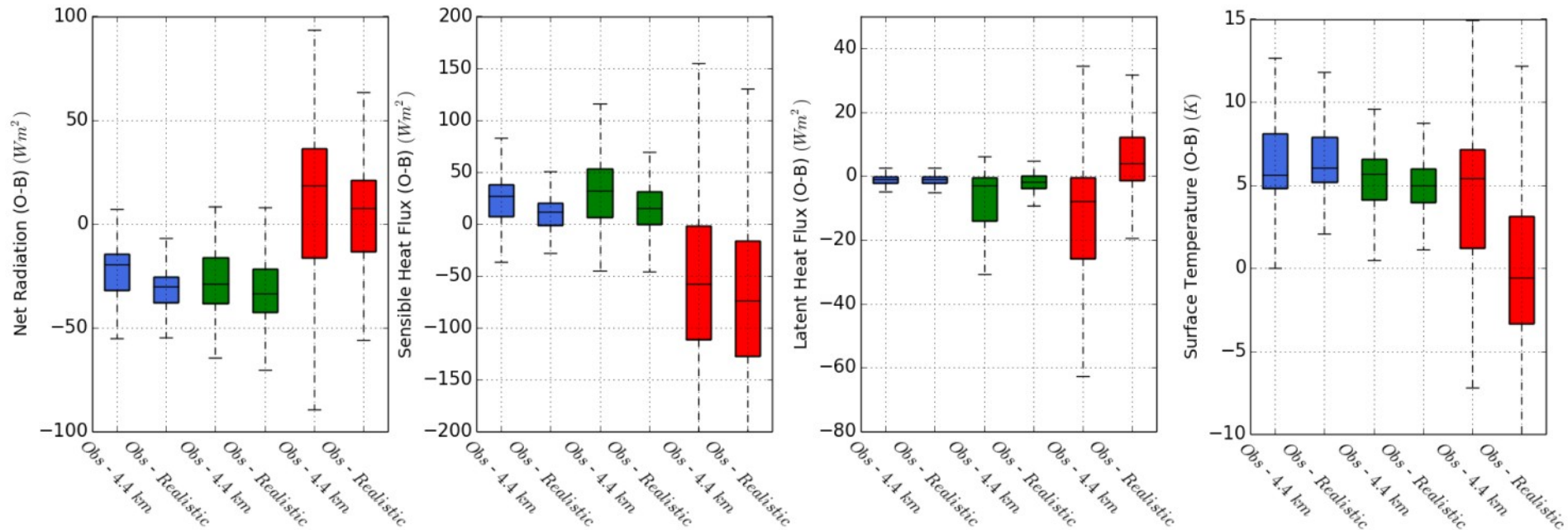
- 1) Observed – 4.4 km Vegetation (O-B)
- 2) Observed – Realistic Vegetation (O-B)

- Surface Albedo (30 minute observations)
- Emissivity (nveg=0.9, PFT=0.9)
- Realistic bare soil fraction (nveg=0.60)
- Realistic vegetation canopy height
- Realistic LAI

Night-time LST O-B biases increased by 1 K compared with the standard set-up.

This supports earlier findings of the weak to null correlation between bare soil cover and night time LST biases.

Daytime LST O-B biases reduced from 4.8 K to 0.9 K using a realistic vegetation compared with the 4.4 km standard set-up.





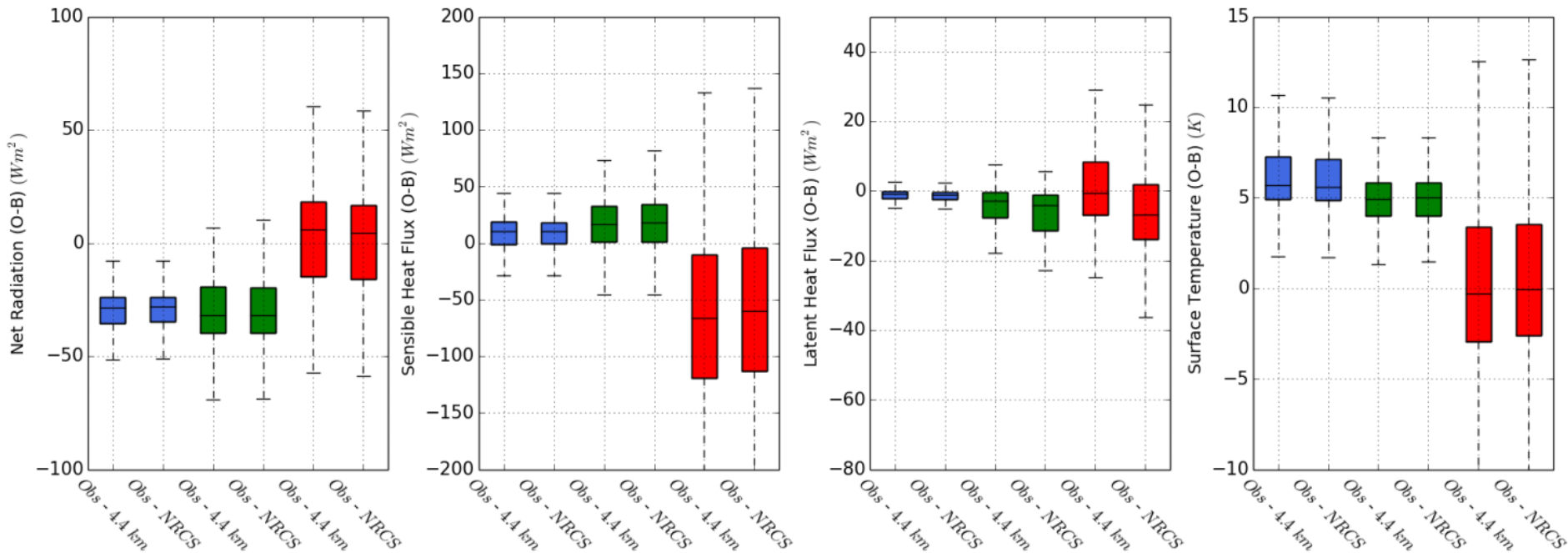
4.4 km Standard vs. Realistic Soils

- 1) Observed – 4.4 km Soil (O-B)
- 2) Observed – NRCS Soil Survey, 2003

| | Sand | Silt | Clay |
|-------------|------|------|------|
| Lucky Hills | 65 | 29 | 6 |
| Kendall | 67 | 16 | 17 |

The 4.4 km soil ancillary over the US is of higher quality compared with soil datasets from other parts of the globe.

O-B biases in net radiation and sensible heat are improved with the NRCS, 2003 soil thermal and hydraulic properties.





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Conclusions

- The UM has a significant cold bias in LST when run at Global, 4.4 km and 2.2 km resolutions. Verified in ground-based, airborne and satellite observations. The magnitude of the bias is dependent on the model resolution and on the dataset used for comparison.
- MODIS data indicates that LST biases are negatively-correlated with the bare soil fractional cover during the day and only weakly correlated with the bare soil fractional cover at night.
- UM turbulent heat fluxes too large and ground heat fluxes too small. Too much heat transported into atmosphere and not enough used to heat the soil.
- Offline tests with JULES have shown that increasing the bare soil fraction reduces biases in net radiation and turbulent heat fluxes. The realistic vegetation and soils representation in JULES has been shown to reduce daytime LST biases.



Further Work

- Further work is needed to investigate the performance of the Global 17km configuration (currently in version GA6).
- Investigate performance of high resolution LAMs (May 2015).
- Investigate the soil resolution in JULES offline simulations through sensitivity tests.
- LST has been recently recognised as an important parameter to verify the UM against. It is to be incorporated as a variable to be monitored during the benchmarking and testing phase of upcoming model versions.
- The multi-platform approach demonstrated in this talk can be applied to other regions where LST bias have been identified e.g. India as part of the multi-disciplinary Indian Monsoon field campaign.



Questions and answers