Evaluating the Unified Model and JULES simulated LST using MODIS retrievals and ground-based eddy-covariance measurements.

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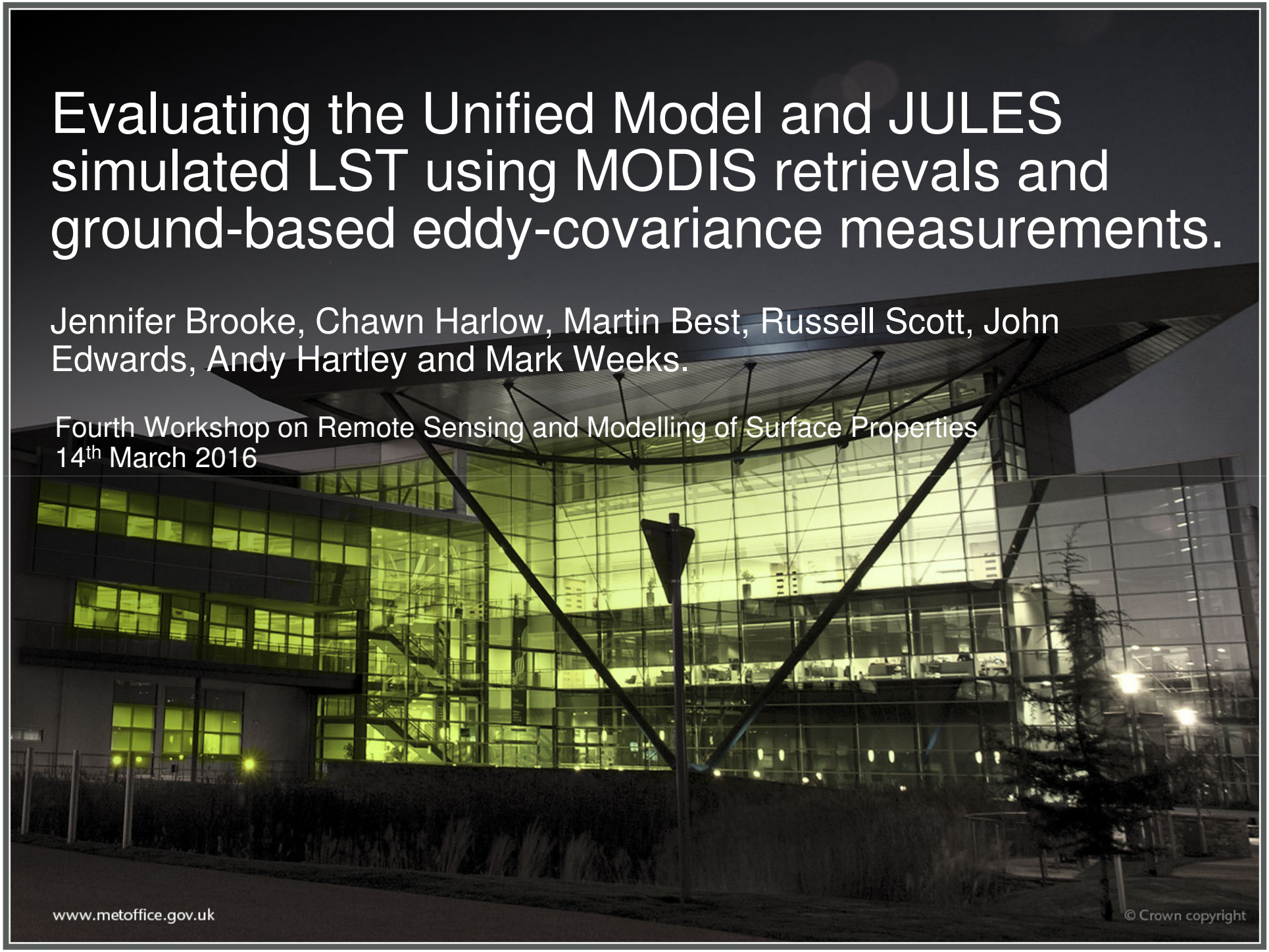
Fourth Workshop on Remote Sensing and Modelling of Surface Properties
14th March 2016



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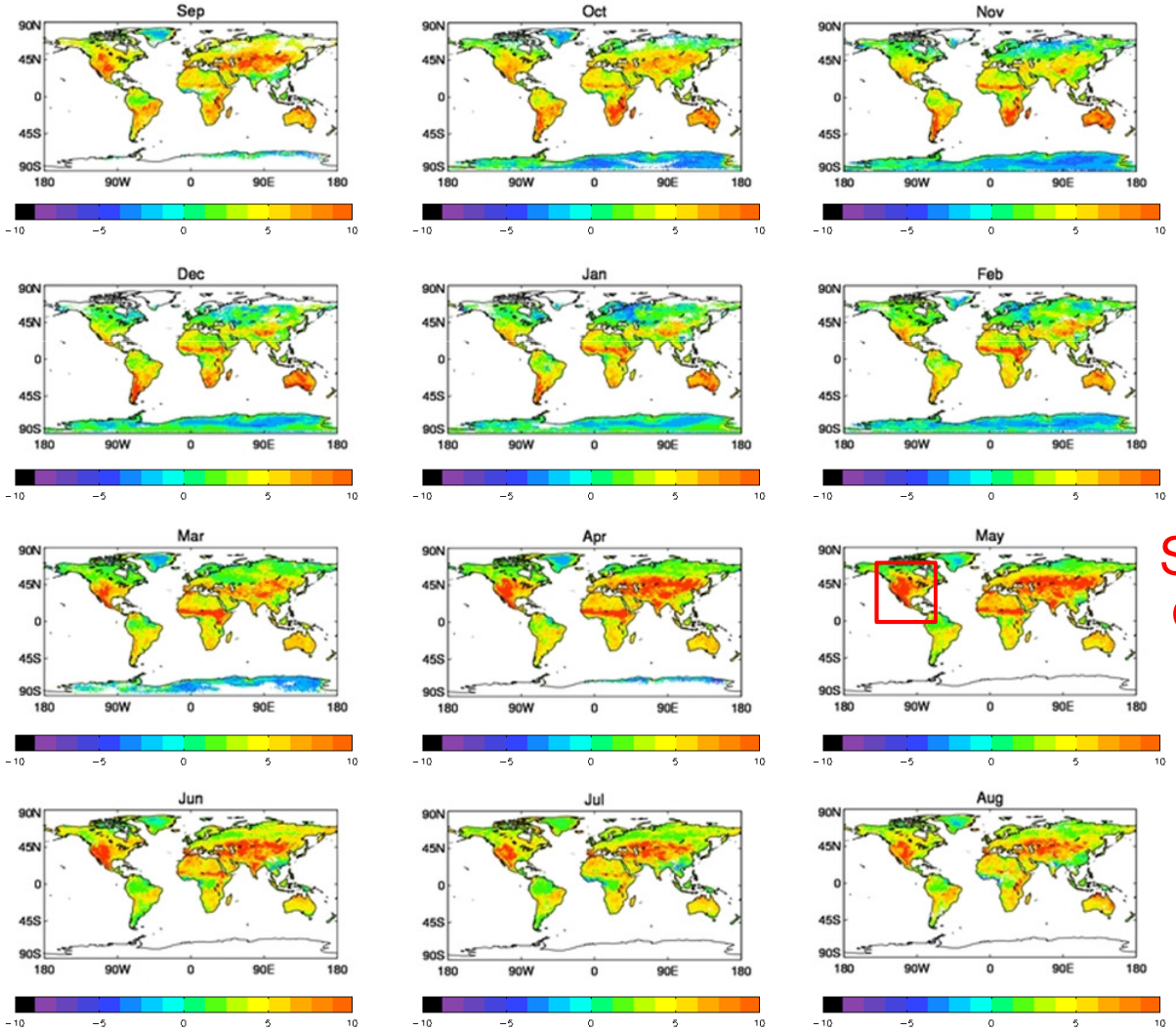
Global LST Biases

• Global UM surface temperature biases compared to IASI 1DVAR retrievals for 2011/2012 at 0900L.

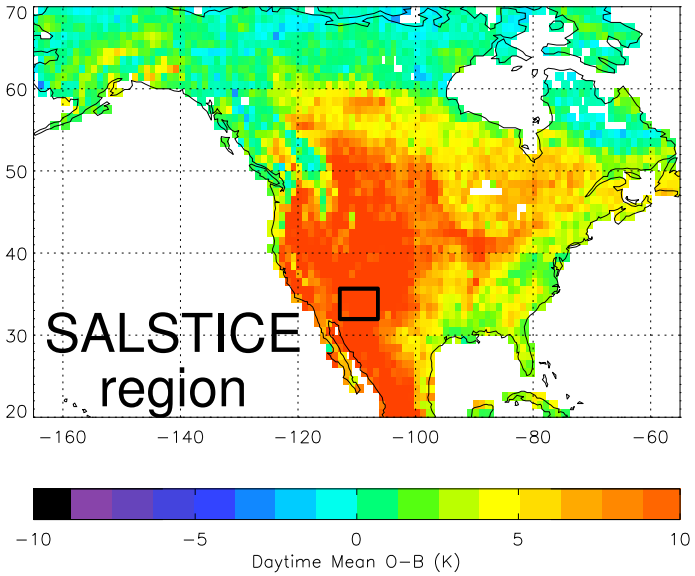


SALSTICE campaign

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

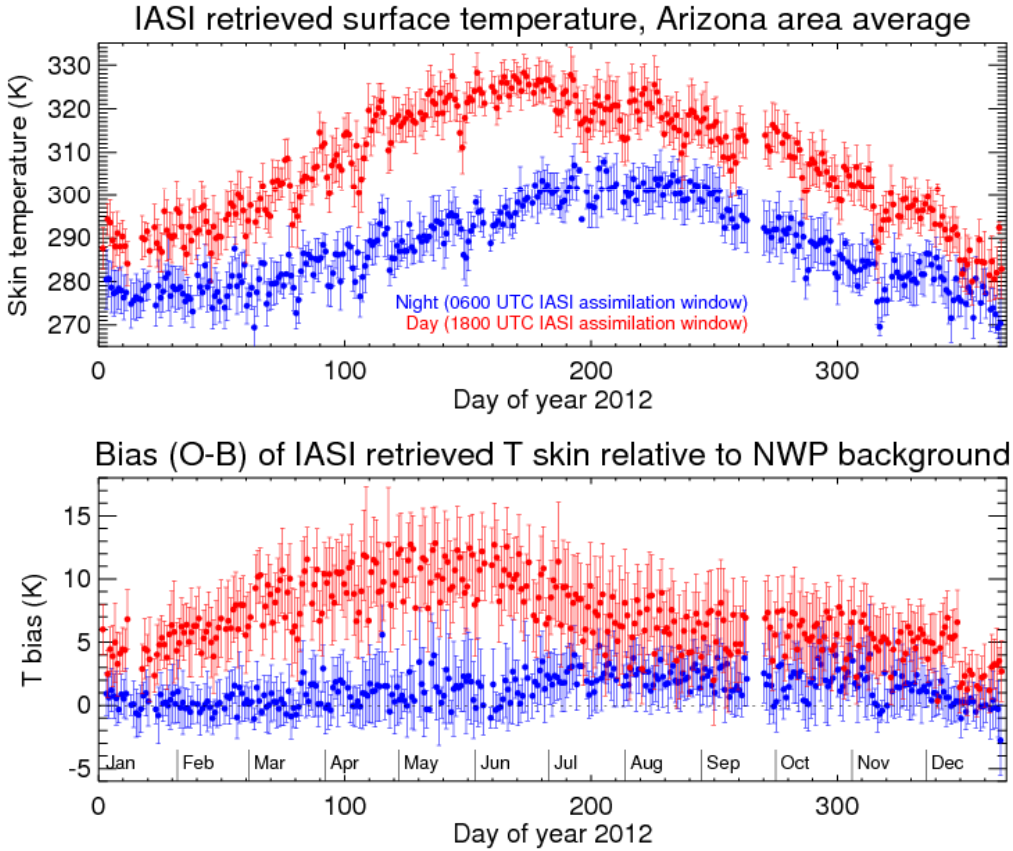


Image courtesy of Stuart Newman, Ed Pavelin and Brett Candy

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

- SALSTICE was a FAAM aircraft (BAe-146) field campaign during May 2013 based in one of these semi-arid regions, Arizona.

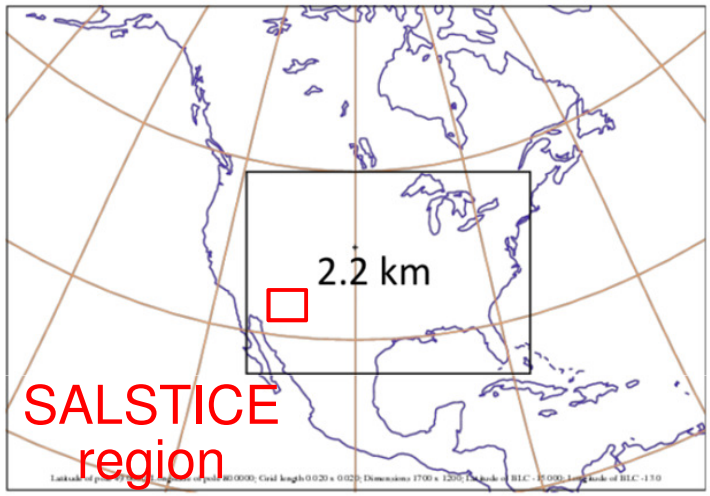
  I. Aircraft sorties using the Met Office Airborne Research Interferometer Evaluation System (ARIES)

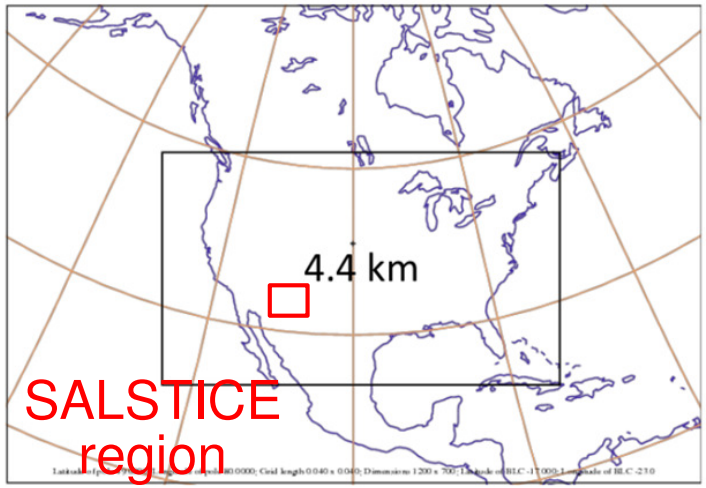
     - Unified Model (UM) LST evaluation

  II. Ground campaign

     - 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 Configuration Evaluation





Courtesy of Mike Bush, Met Office

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)

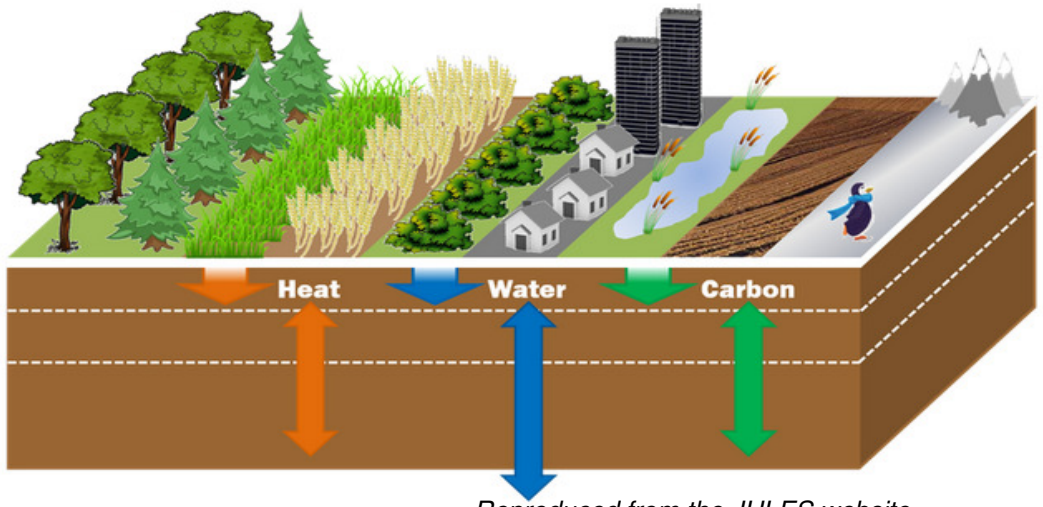
JULES simulations for AmeriFlux sites (2013)

- Evaluating model parameters including:
  - Surface fractional cover
  - Bare soil parameters (emissivity, z_{OM})
  - Vegetation parameters (LAI, canht, K_{ext})

Investigating biases in JULES

- Land surface scheme used in the UM
- Evaluation performed for flux tower sites in the Walnut Gulch Experimental Watershed in south-eastern Arizona

Radiation
Precipitation
Air temperature
Pressure
Wind Speed
Humidity



Heat
Evaporation
Momentum

Reproduced from the JULES website

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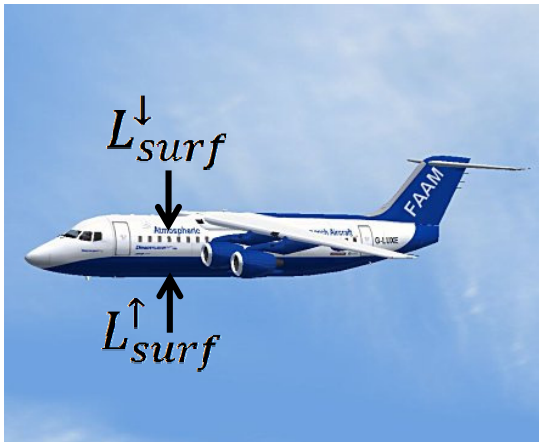
Aircraft LST Retrievals



•ARIES - hyperspectral infrared upward- and downward-pointing interferometer developed at the Met Office.

•Measures upwelling and downwelling infrared radiances: when flying at low altitude this combination is used to infer **surface temperature and emissivity**.

$$L^{\uparrow}_{surf}(\theta) = \varepsilon(\theta)B\left(T_{surf}\right) + \left(1 - \varepsilon(\theta)L^{\downarrow}_{surf}(\theta)\right)$$

1. ARIES upwelling and down welling radiances within a small enough time window to be representative of the atmospheric column.
2. These measurements are made at a relatively low altitude to minimise uncertainties due to the atmospheric path.
3. The zenith sky radiance to be reasonably uniform – the retrieval works best under clear skies (or under uniform high cirrus as an alternative).

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.

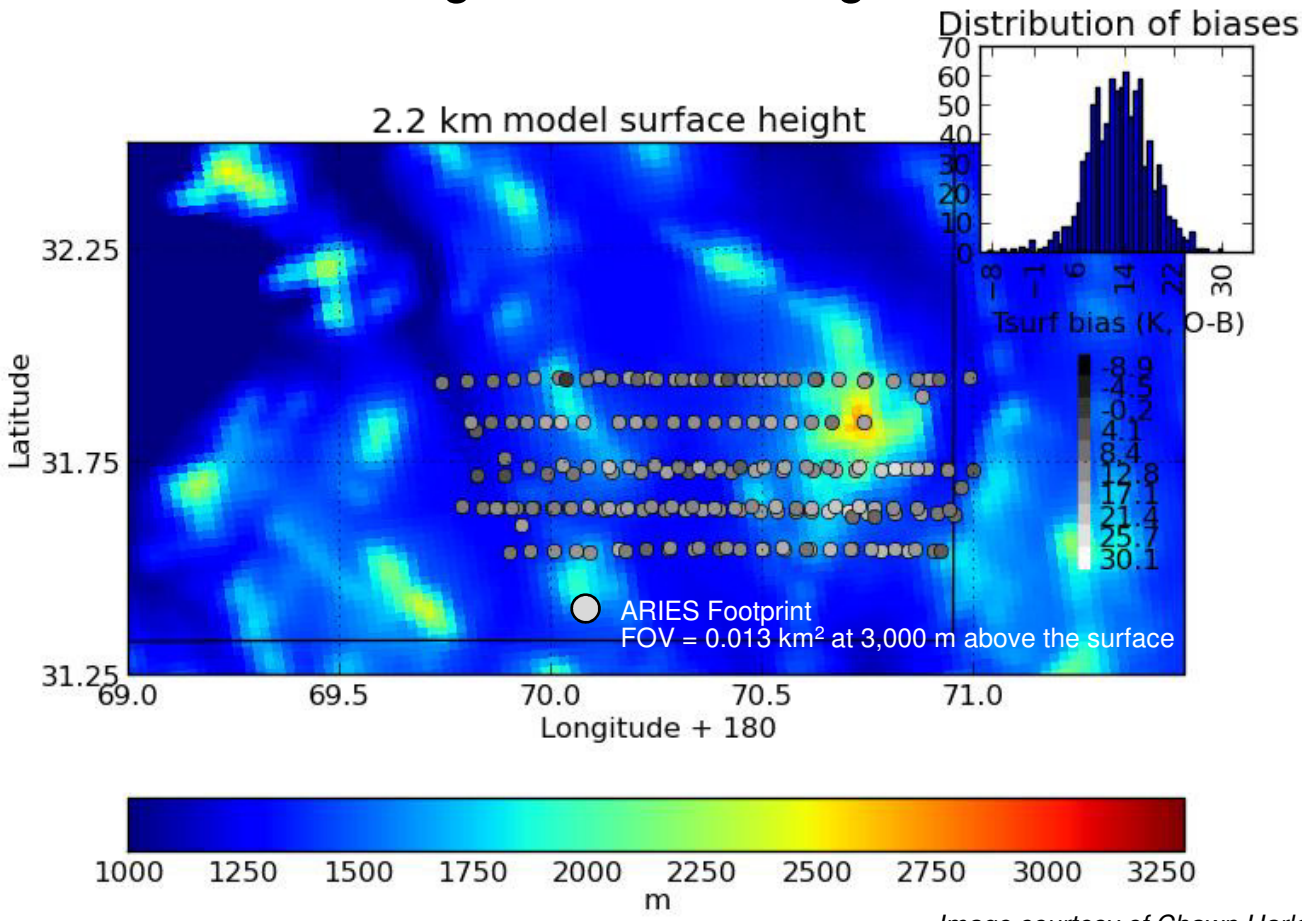


Image courtesy of Chawn Harlow

ARIES LST Evaluation

- Low level runs aligned with the San Pedro basin
- LST errors are still significant, although reduced, 4 - 6 K over basins

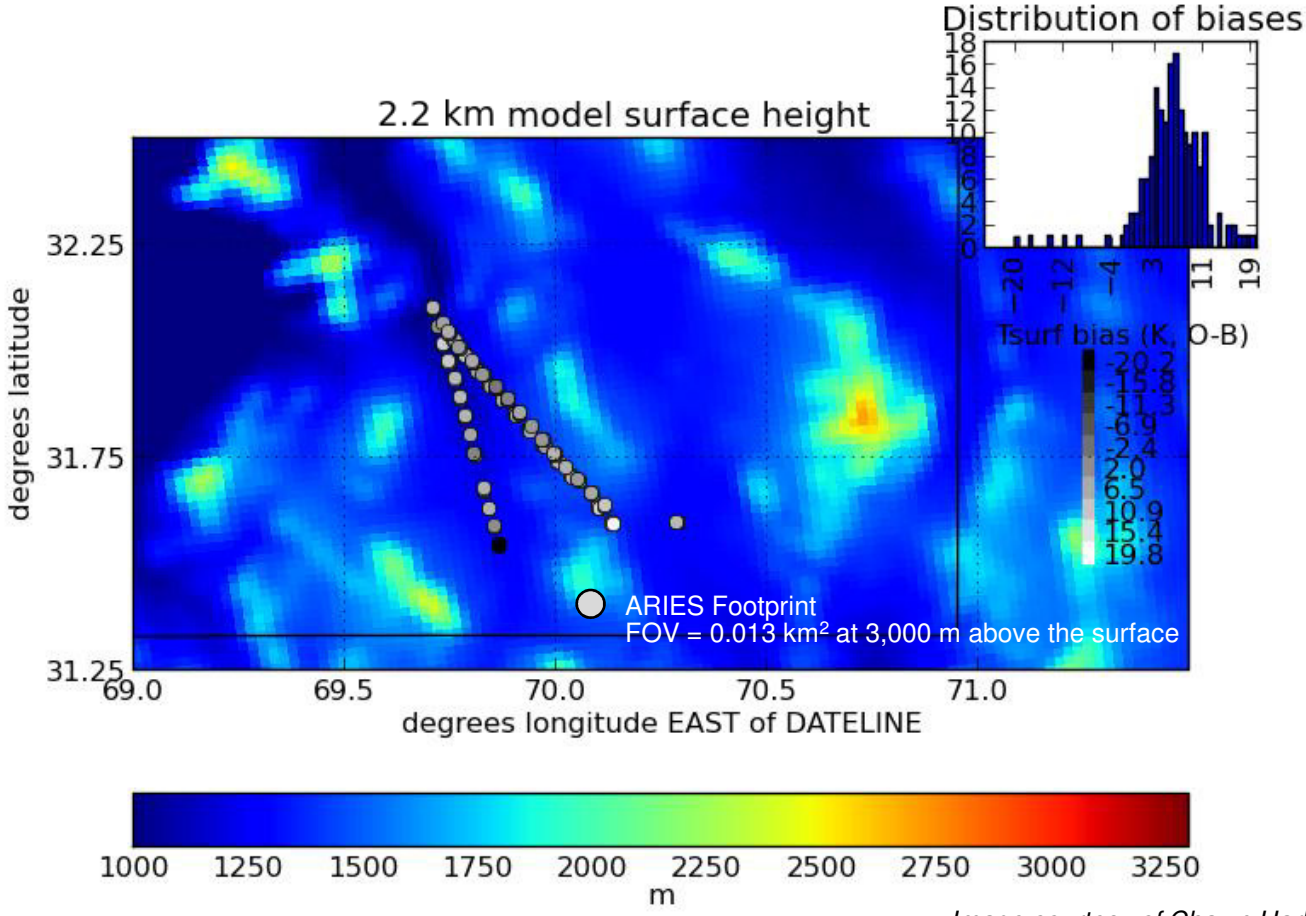


Image courtesy of Chawn Harlow

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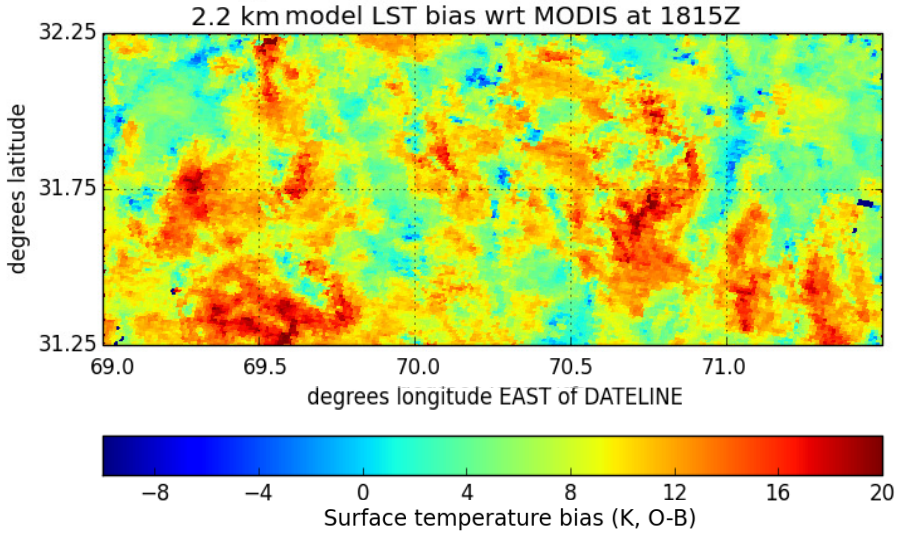
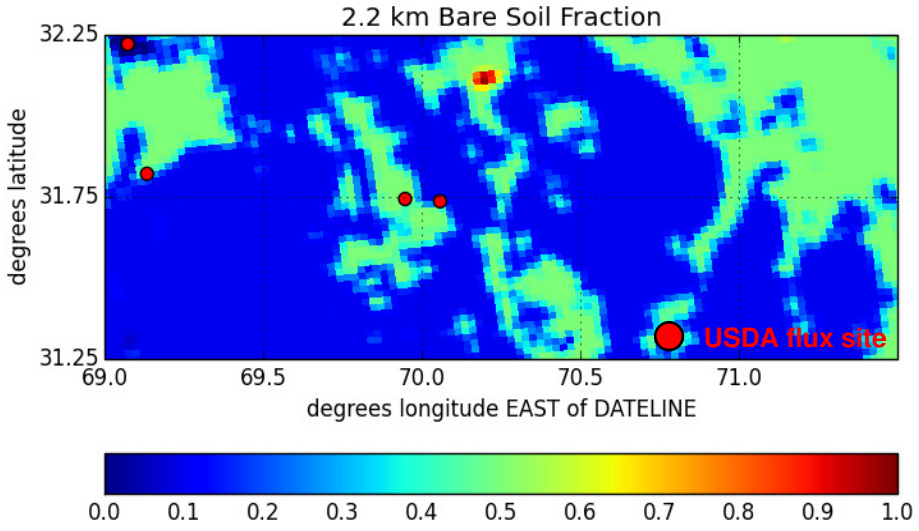
MODIS Comparisons





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)

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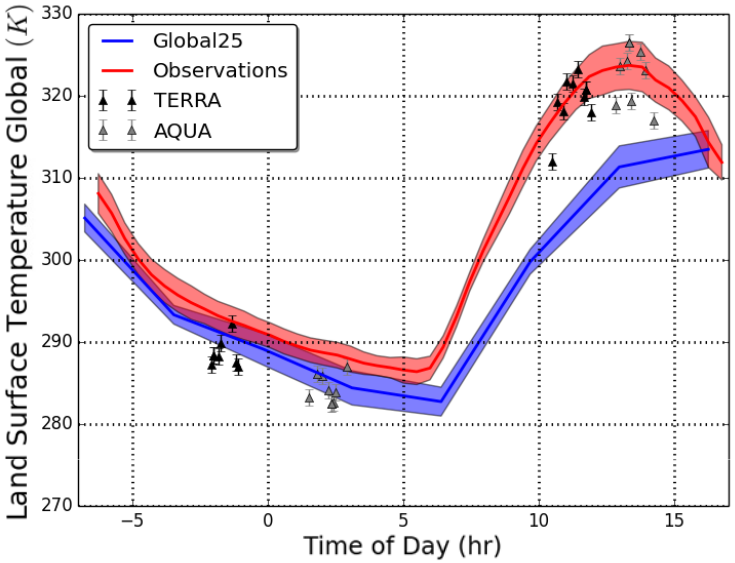
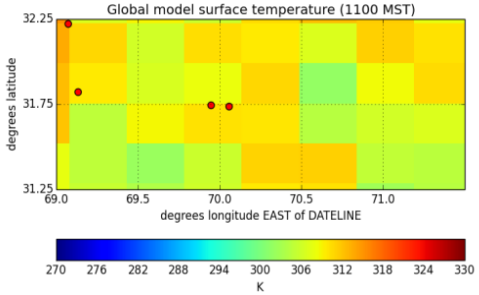
Global vs. LAM LST

Global Configuration (*blue*) Observations *(red)*

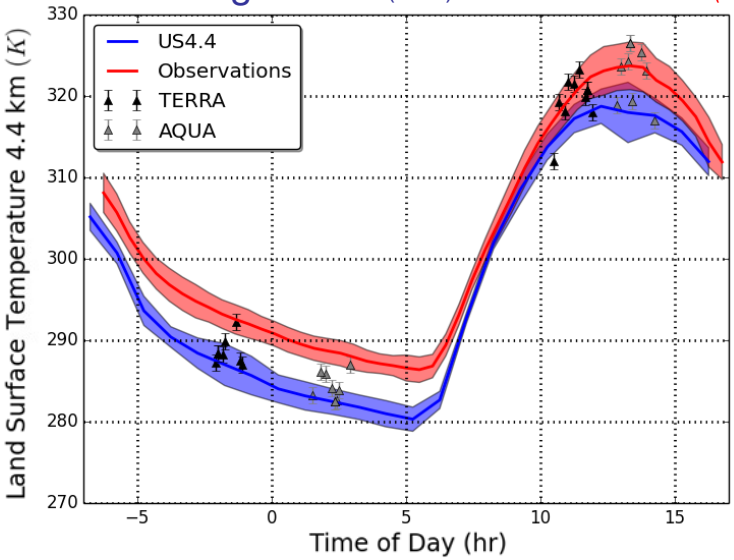


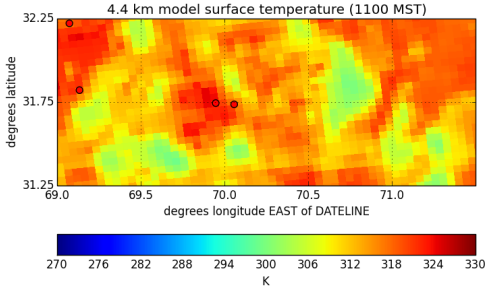


Global: Daytime LST poorly simulated both in phase and amplitude.

Daytime bias: 8.2 K / 12.0 K (Aqua / Terra)
Night-time bias: -1.1 K / 0.3 K (Aqua / Terra)

4.4 km Configuration (*blue*) Observations *(red)*





LAMs: improve representation in the daytime LST maxima with larger night time biases.

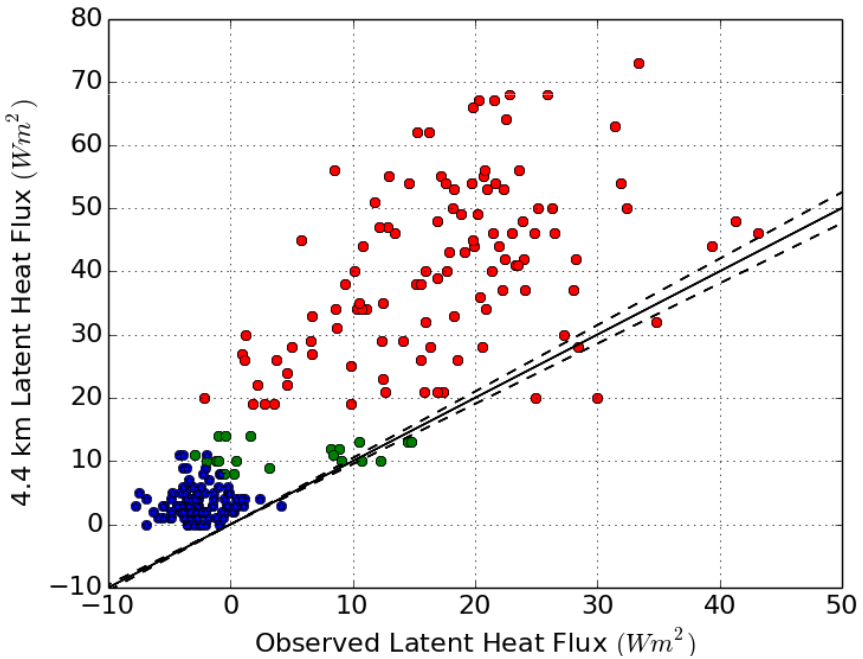
Daytime bias: 4.6 K / 2.7 K (Aqua / Terra)
Night-time bias: 1.5 K / 4.5 K (Aqua / Terra)

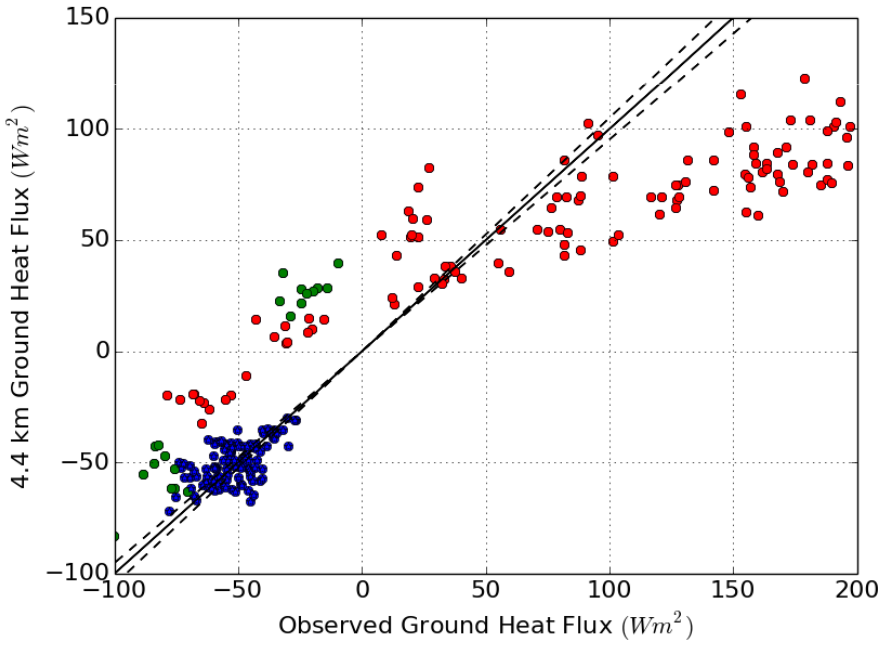
Modelled Heat Fluxes

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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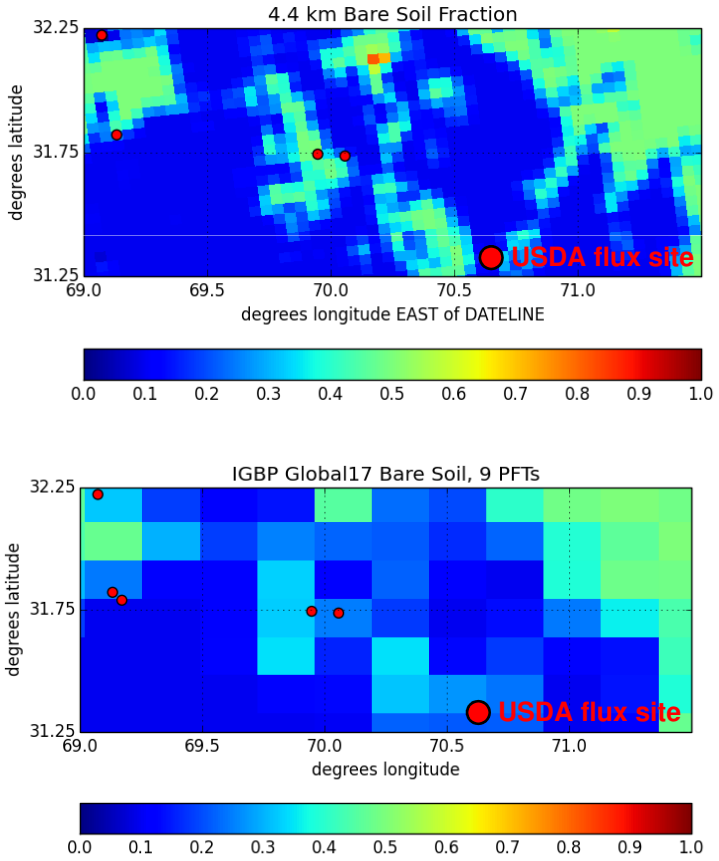
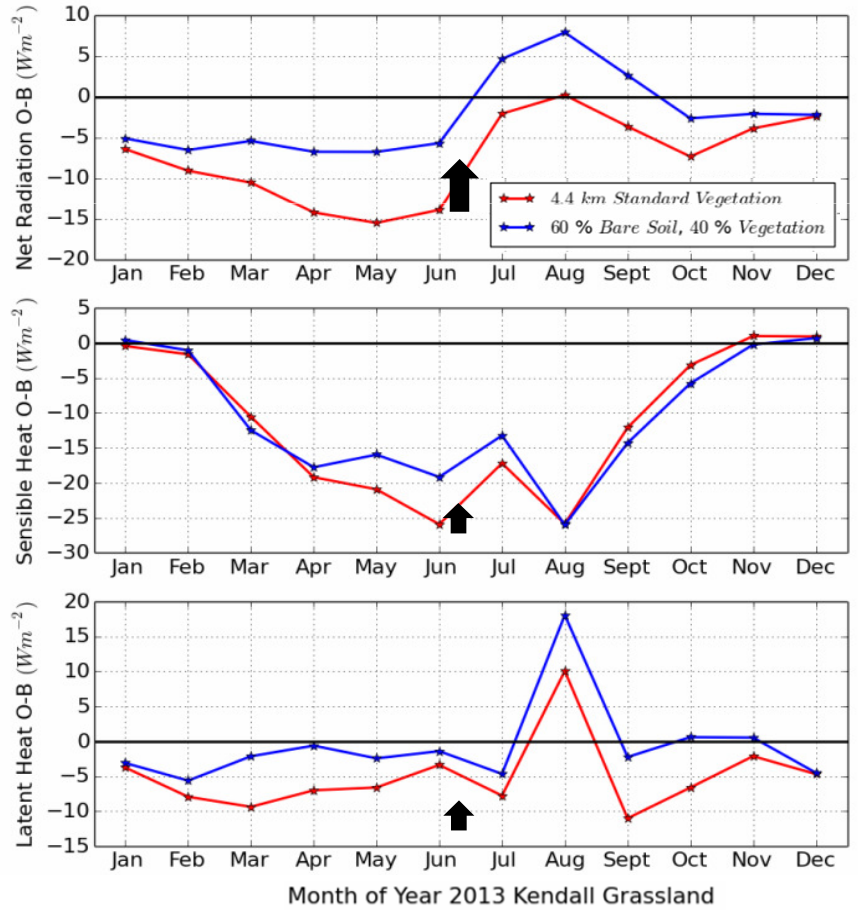
Bare Soil Sensitivity

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



JULES Sensitivity Test:

- Increase bare soil cover to 60 %
- GA3.1 bare soil parameters
- Net radiation + turbulent heat fluxes biases reduced
- Little sensitivity to the ground heat flux

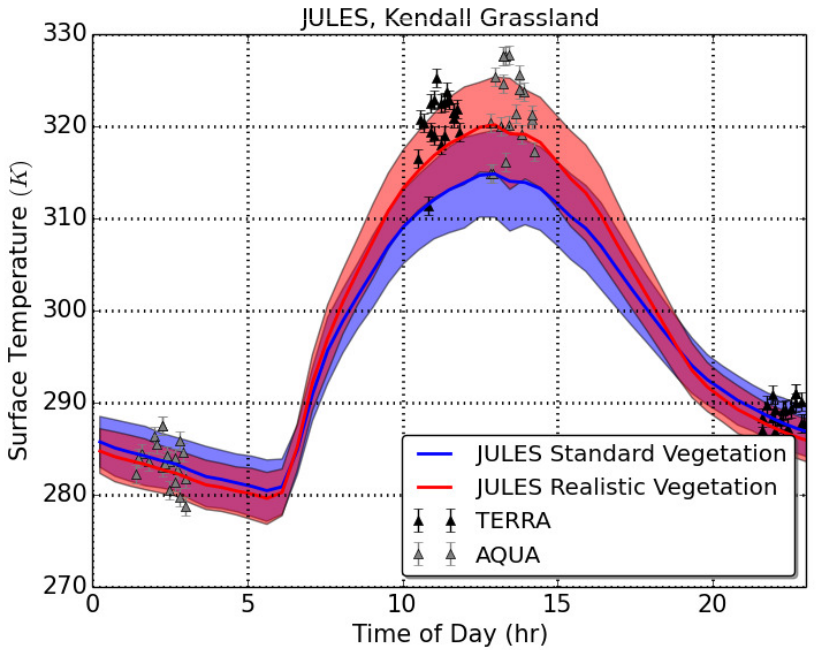


4.4 km Standard vs. Realistic Vegetation

1) Observed – 4.4 km Vegetation (O-B)
   - •GA3.1 bare soil parameters

2) Observed – Realistic Vegetation (O-B)
   - •Surface Albedo (30 min observations)
   - •Emissivity (nveg=0.9, PFT=0.9)
   - •Realistic bare soil fraction (nveg=0.60)
   - •Realistic vegetation canopy height
   - •Realistic LAI

	Surface Temperature	
	Terra (K)	Aqua (K)
US4.4 Standard	4.9	7.4
Realistic Vegetation	-1.9	1.4



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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 reduce biases in net radiation and turbulent heat fluxes. The realistic vegetation and soils representation in JULES has been shown to reduce daytime LST biases.

Questions and answers