High resolution soil hydrology in JULES and the Met Office Unified Model

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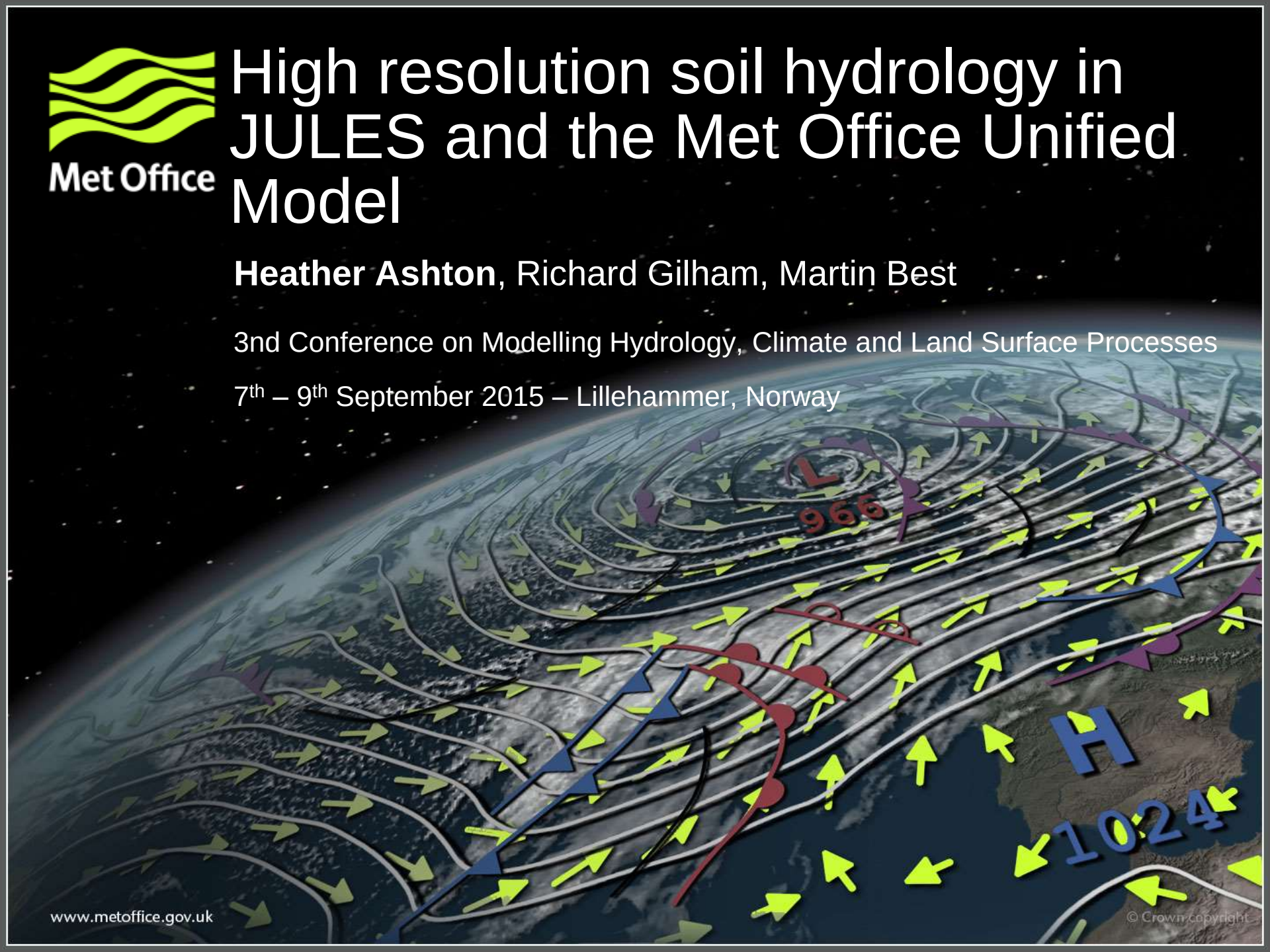
3nd Conference on Modelling Hydrology, Climate and Land Surface Processes

7th – 9th September 2015 – Lillehammer, Norway



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Outline

- Motivations
- JULES land surface model
- New JULES with flexible surface and soil tiling capability
- Experimental configurations
- Results
- Conclusions

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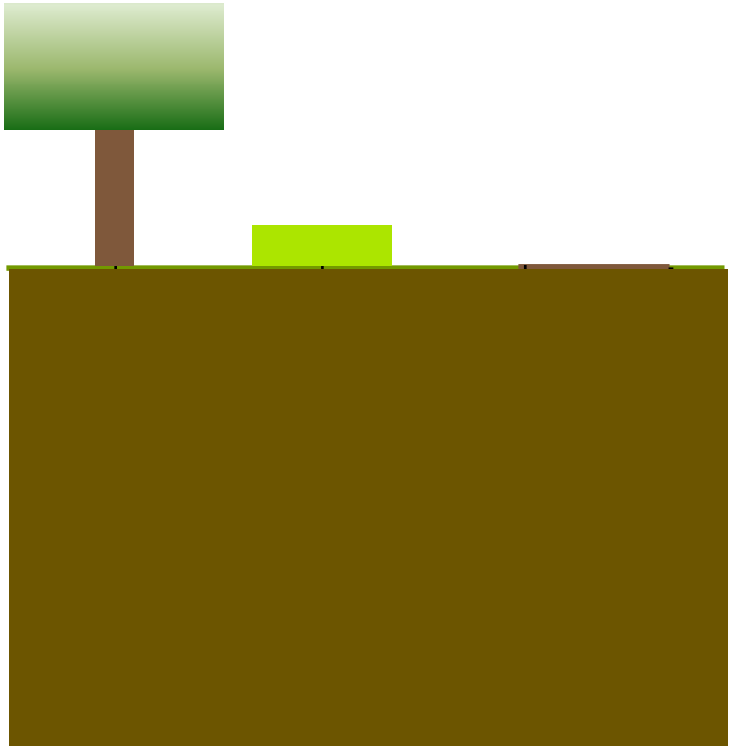
Motivation

• Evapotranspiration from a vegetated surface depends on how much water can be extracted by the plants.

• Dependant on the root zone distribution and the type of soil(s) present.

‘Real world’

‘Modelling world’



How can we model soil heterogeneity?

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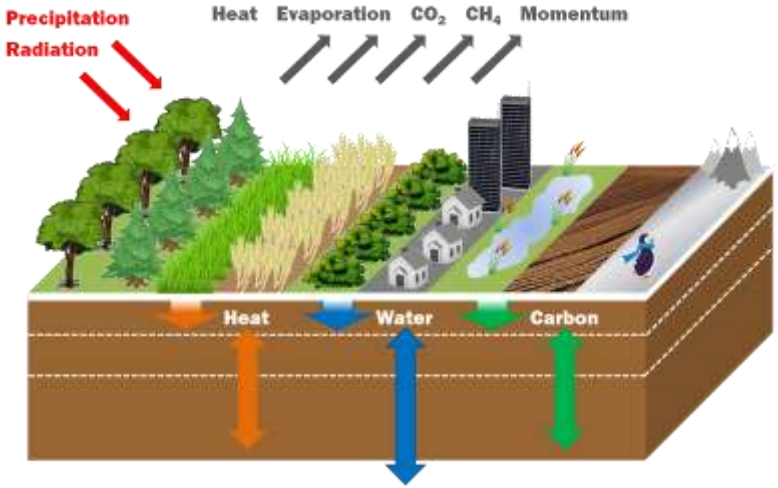
JULES: Joint UK Land Environment Simulator



- Community land surface model
- 9 surface tiles - 5 vegetated & 4 non-vegetated
- 4 soils layers, single soil column per gridbox
- All surface types share the same dominant soil type
- Surface runoff generated from PDM (Moore *et al* 1985)

Best et al. (2011) The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes. Geosci. Model Dev., 4, 677–699

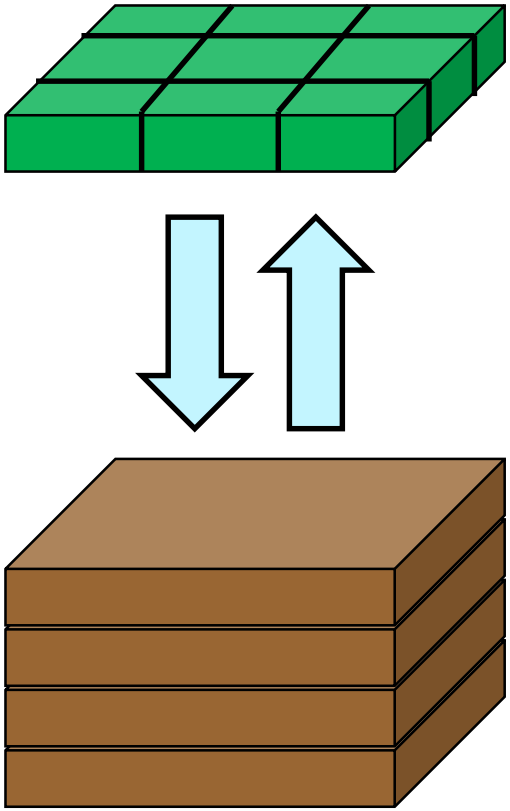
Introducing soil tiles…

Surface types (trees, grasses, bare soil...)

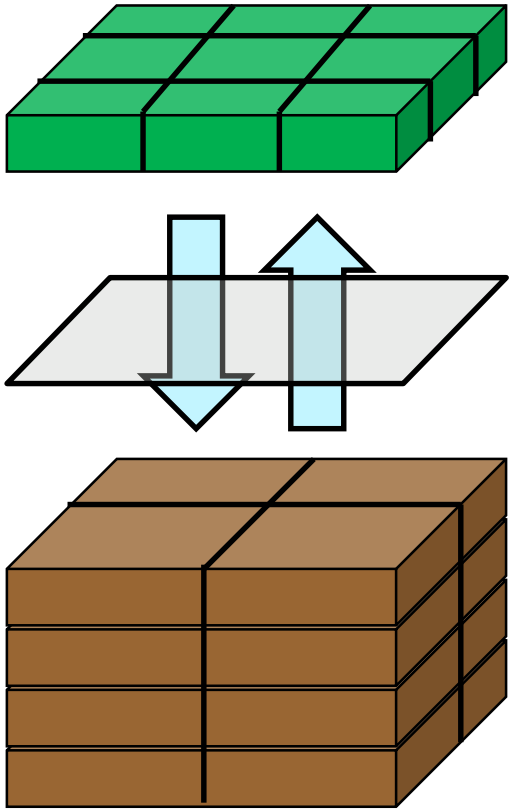
Surface-soil processes (infiltration, extraction, evaporation...)

Soil types (clay, loam...)

Standard JULES



Soil-tiled JULES



Transmogrifier
- Manages overlap of surface and soil tiles
- Proportionate distribution of fluxes
- Highly flexible configuration options

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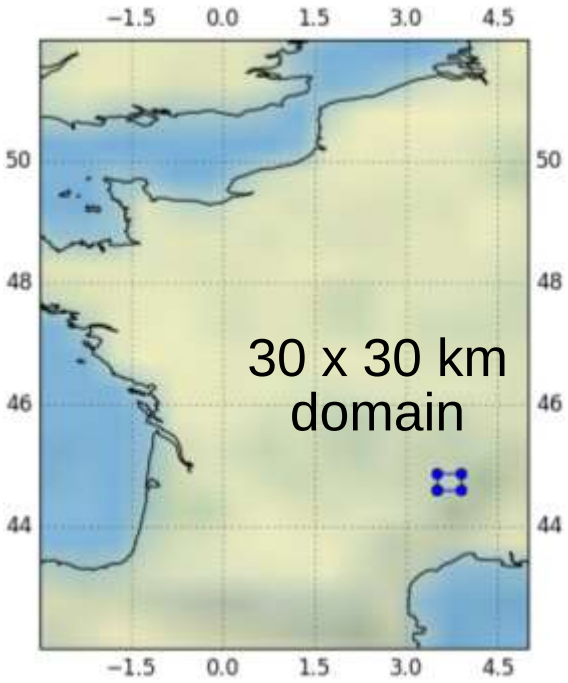
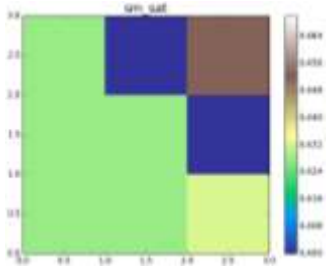
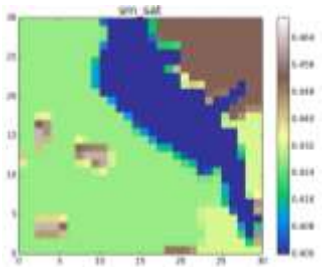
Domain and Setup

- JULES vn3.4.1 with operational UK forecast model configuration
- HWSD soils, IGBP surfaces
- 1km meteorological driving data from offline Unified Model nested suite run (1 year - 2011).



- Synthesis experiment
- Domain choice based on
  - i. Heterogeneity in soil type
  - ii. Intensity of summertime convective rainfall





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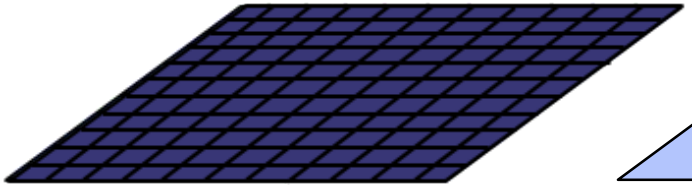
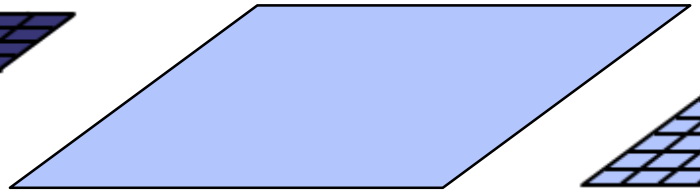
Atmosphere & Land Configurations

A1



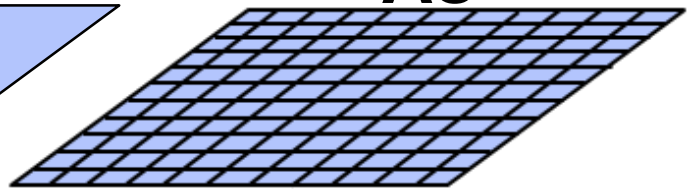
1km

A2



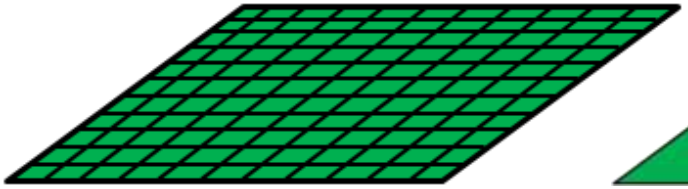
10km

A3



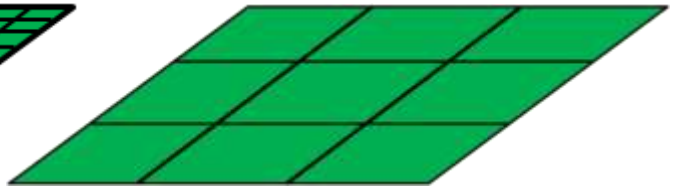
1km Average Meteorology

L1



1km – 100 predominant surface types

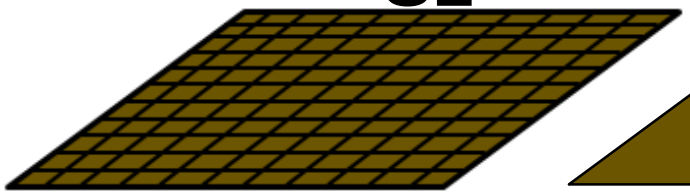
L2



10km – 9 surface types

Soil Configurations

S1

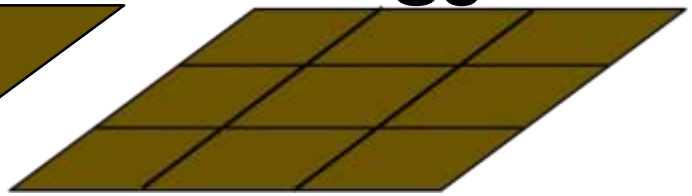


1km –
100 Soils

S2

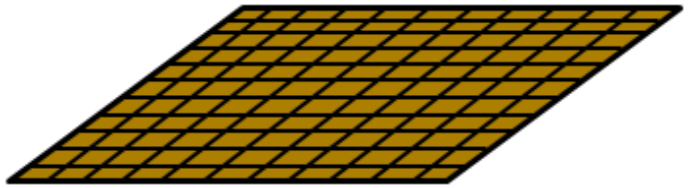
10km – 1 predominant soil

S3

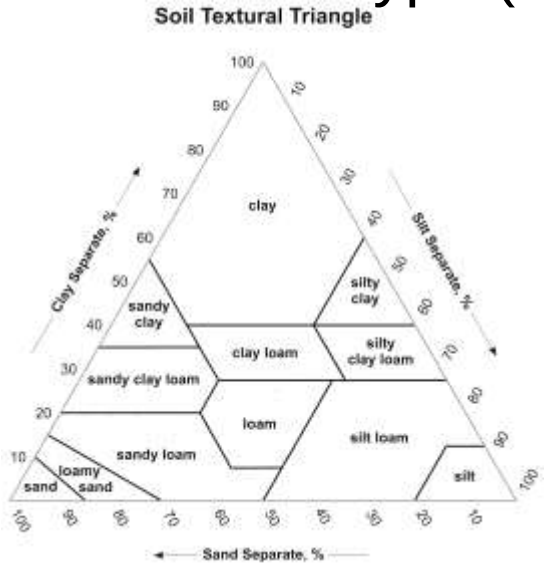


10km – predominant soil for each surface type (i.e. x9)

S4

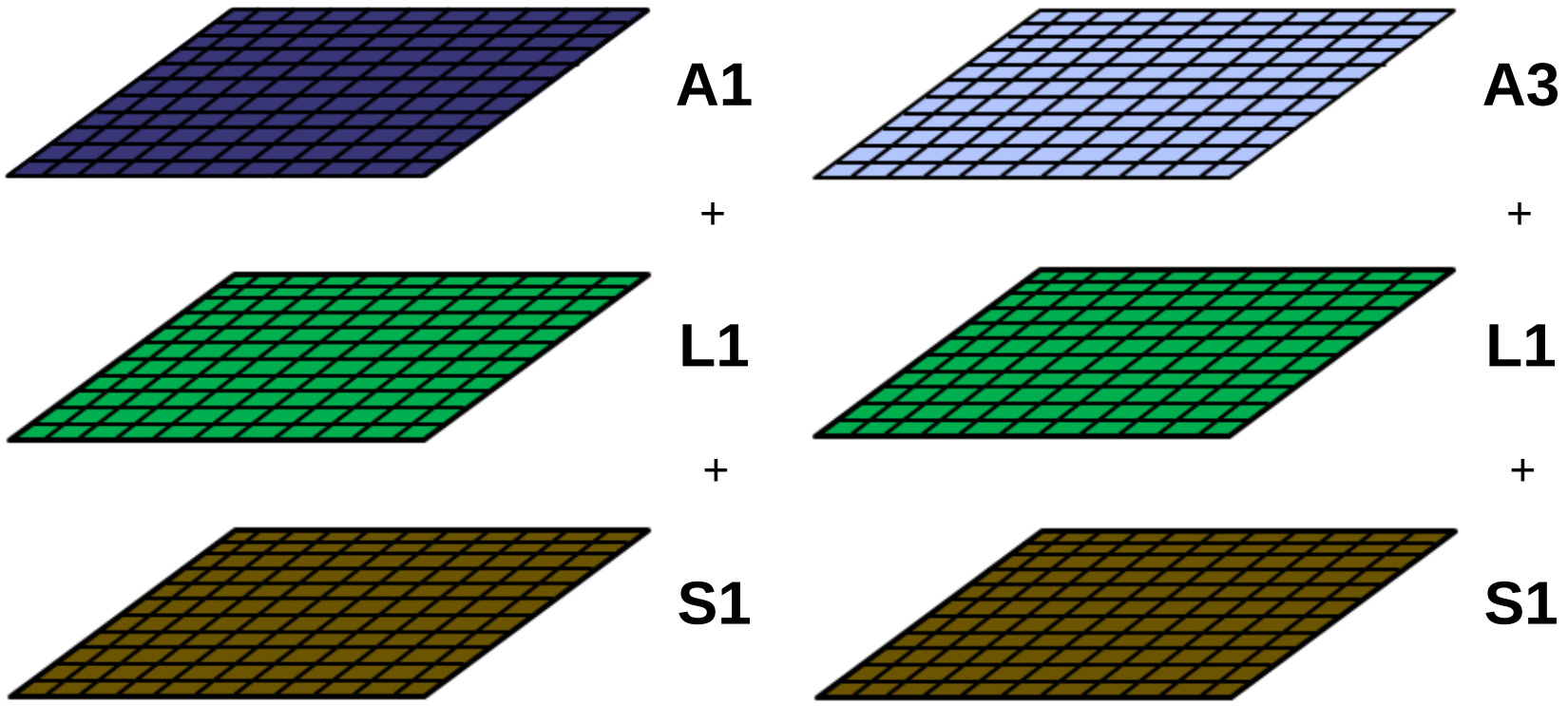


1km – 12 soil textural classes



High vs. Low Resolution Forcing

1km ‘Truth’ Control Run vs. 1km run with Low Resolution Forcing, No Soil Tiling

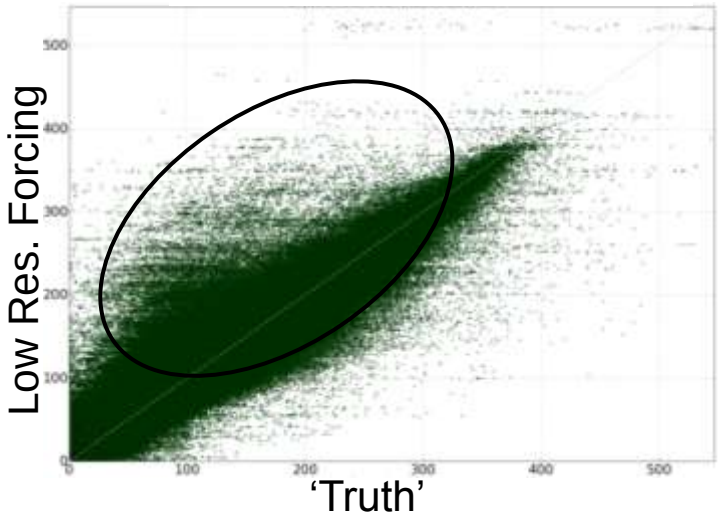


‘Truth’

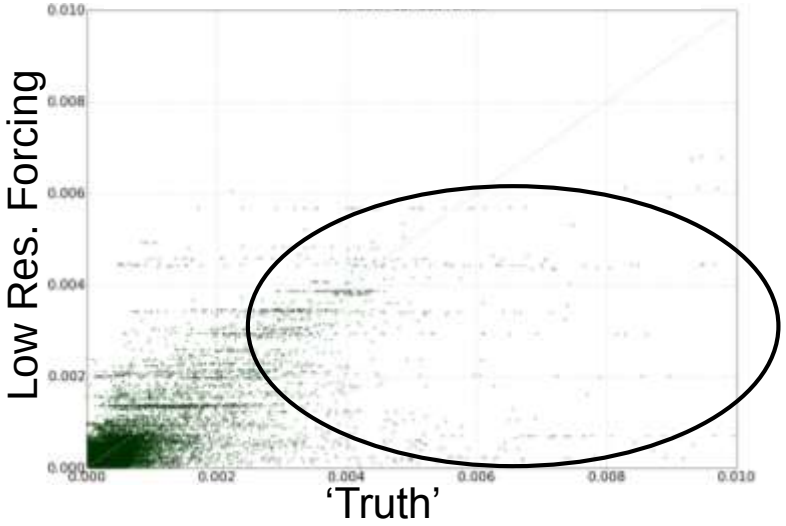
Low Res. Forcing

Resolution Impact of forcing data

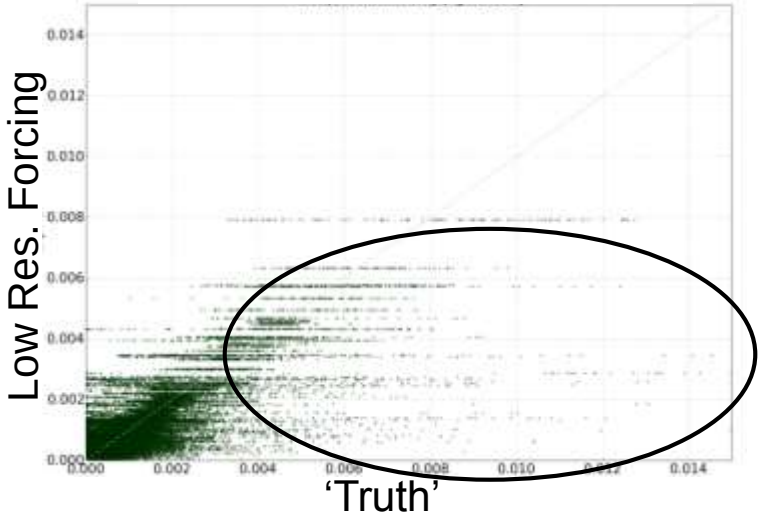
JJAS Latent Heat Flux



JJAS Surface Runoff



JJAS Precipitation Rate



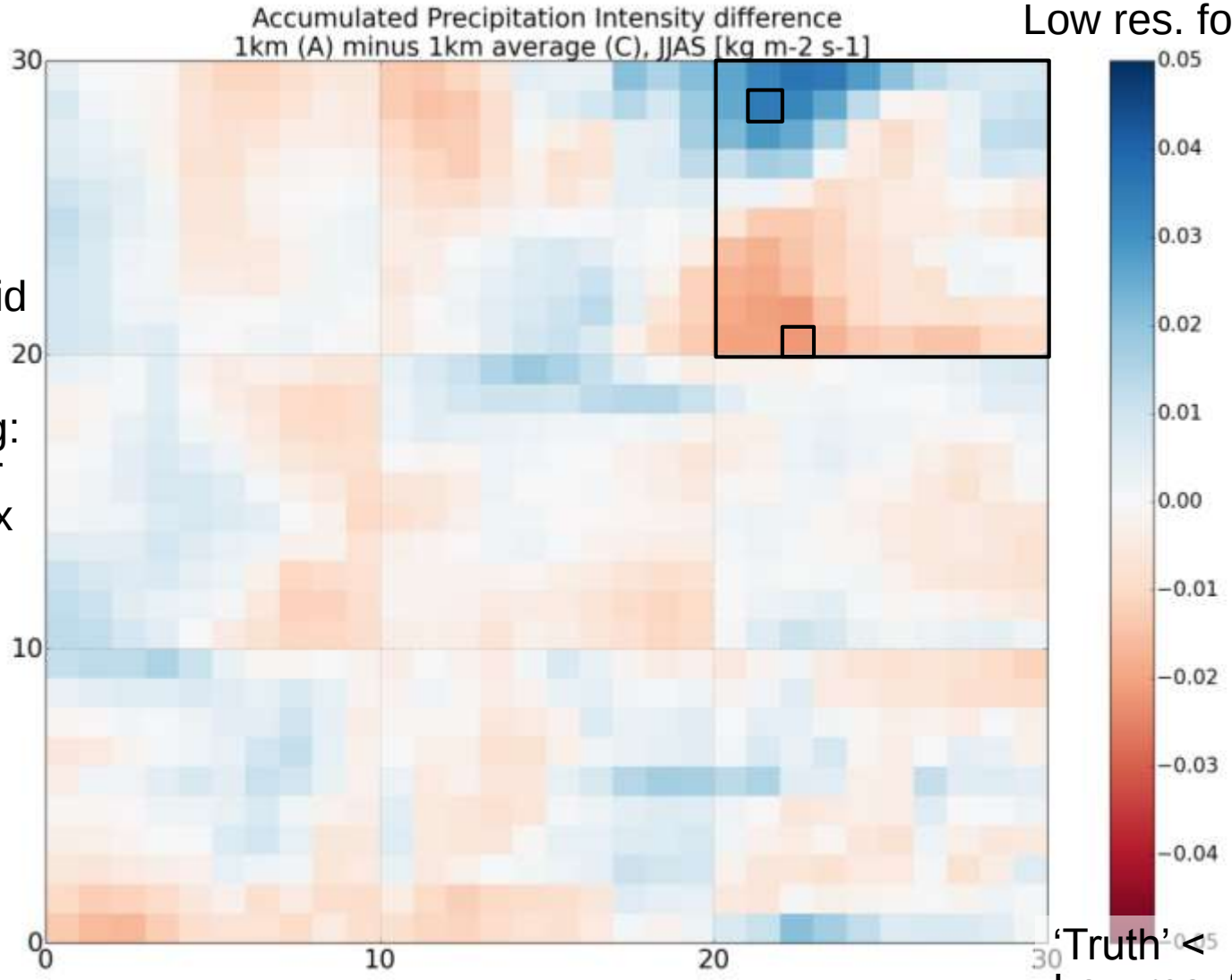
Positive latent heat bias from coarse meteorology driven run

More intense precipitation rates captured in higher resolution meteorological forcing → more surface runoff

Resolution Impact of forcing data

‘Truth’:
Spatial variability over 10x10km grid box

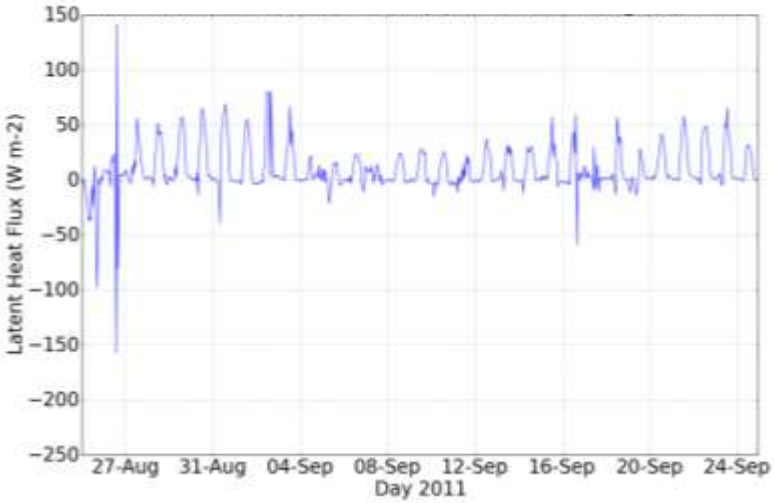
Low Res. Forcing:
Single value over 10x10km grid box



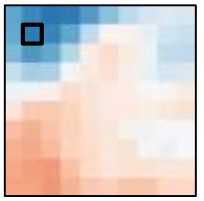
‘Truth’ >
Low res. forcing

‘Truth’ <
Low res. forcing

Latent Heat flux differences

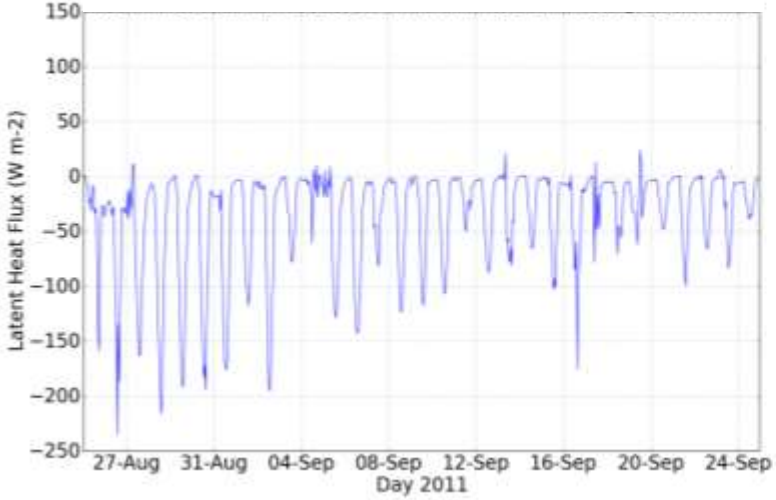


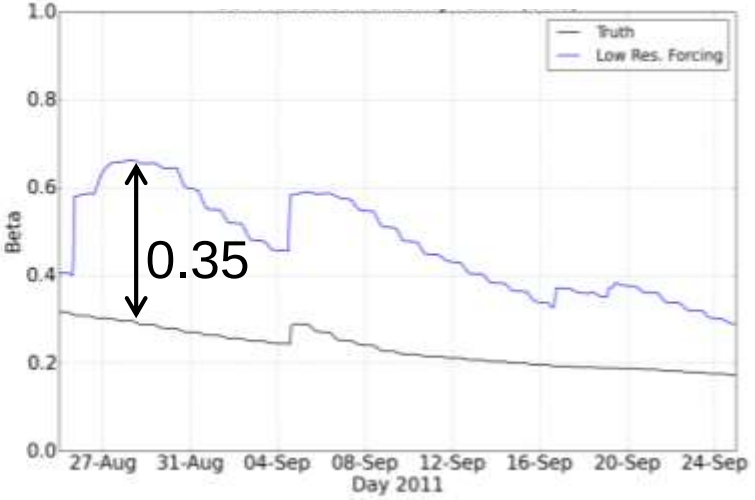
Soil Moisture Availability Factor (beta)

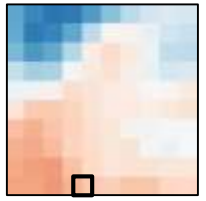


Precipitation intensity greater in 'truth' run.

('Truth' minus Low Res. Forcing)





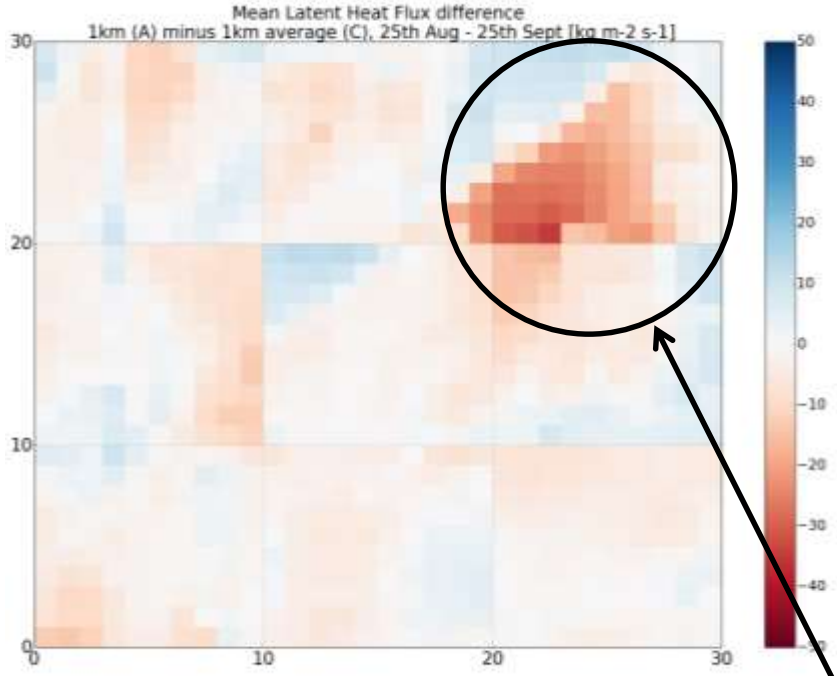


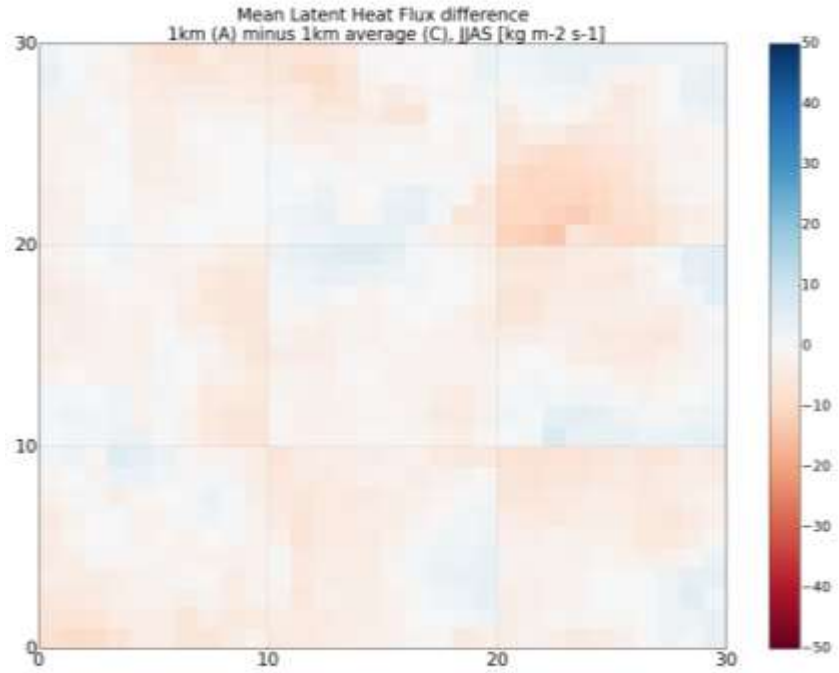
Precipitation intensity lower in 'truth' run.

Non linear response in beta for Low Res. Forcing run = Overall positive latent heat flux bias

Resolution Impact of forcing data

Mean Latent Heat Flux Difference ('Truth' minus Low Res. Forcing)





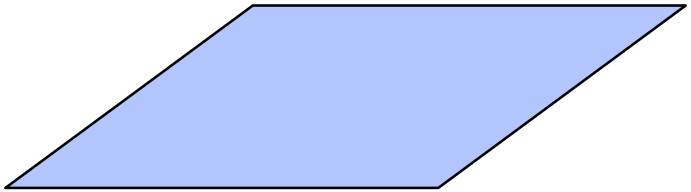
25^{th} Aug – 25^{th} Sept 2011

June – Sept 2011

Positive latent heat flux bias

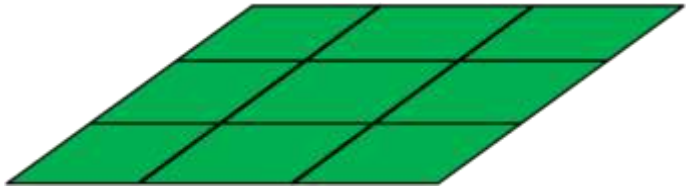
Compare all soil tiling experiments back to Low Res. Forcing Run...

Soil Tiling Experiments



A2

+



L2

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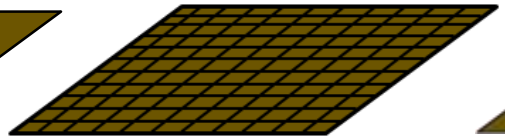
+ 

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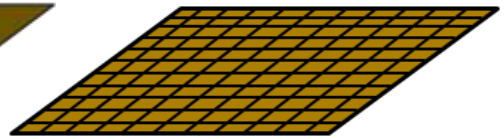
+ 

S2

Expt B:
10km, no soil tiling
Standard Run

S1

Expt D:
10km, soils tiled by 1km high res. soil

S3

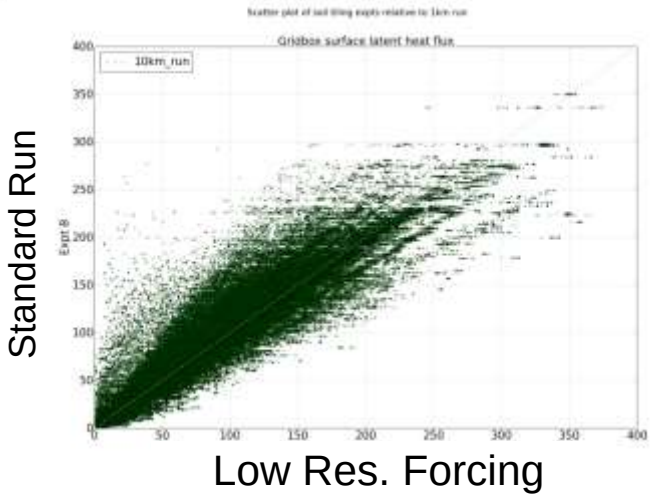
Expt E:
10km, soils tiled by surface type

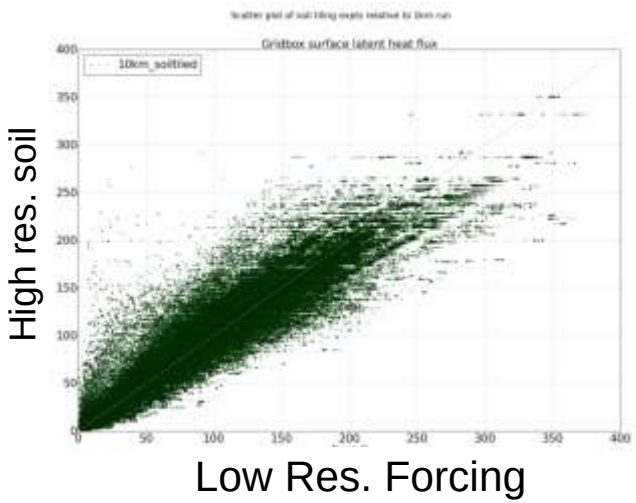
S4

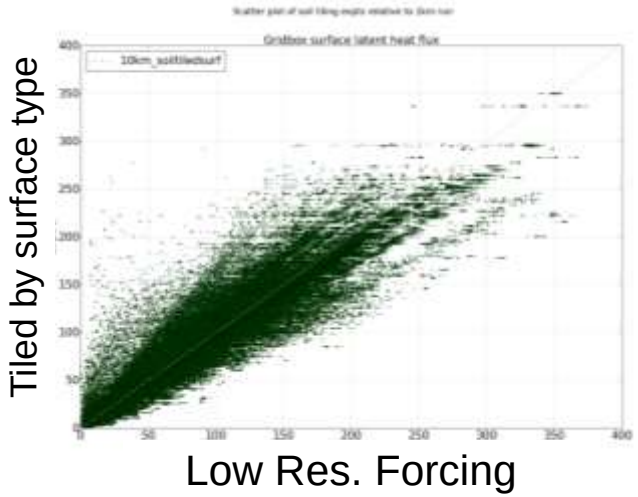
Expt F:
10km, soils tiled by soil texture class

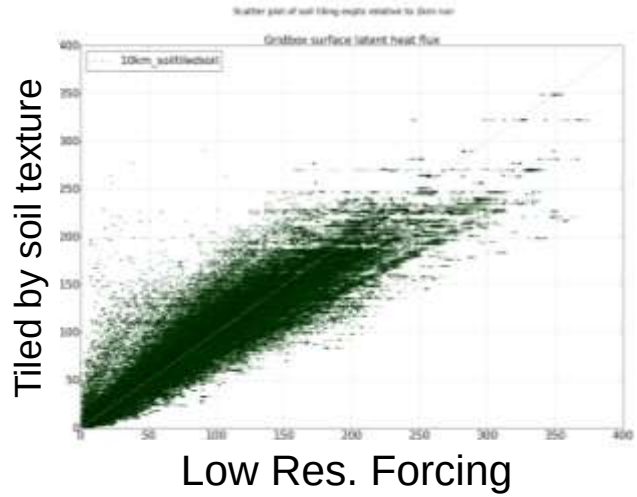
Results – Latent Heat Flux scatter

25th Aug – 25th Sept 2011







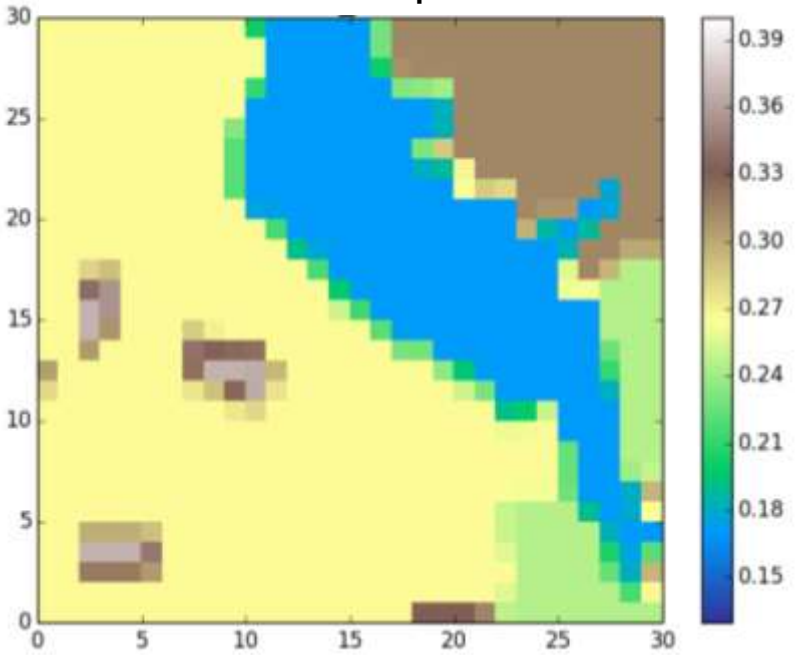


Aim: 1-2-1 between Low res. forcing run and soil tiling experiments

Normalised Mean % Differences

25th Aug – 25th Sept 2011

Volumetric moisture content at critical point

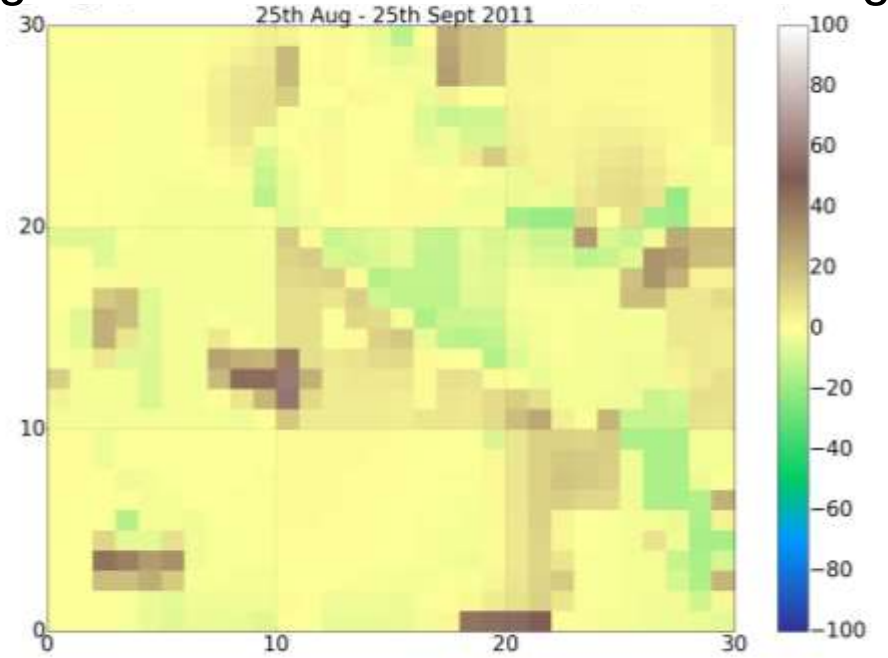


Clay

Silt

Sand

High Res. soils minus Low Res. Forcing



High res. soil shows smallest differences in latent heat compared to low res. forcing, and closest resemblance to the soil map

Sand: 0-20% LE decrease
Clay: 20-50% LE increase

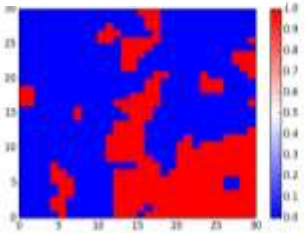
Normalised Mean % Differences

25th Aug – 25th Sept 2011

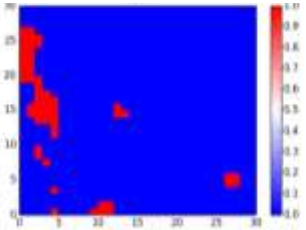
Vegetation Fractions

Red = 100%
Blue = 0%

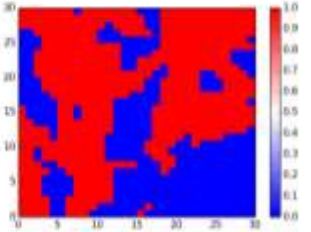
Broadleaf Tree



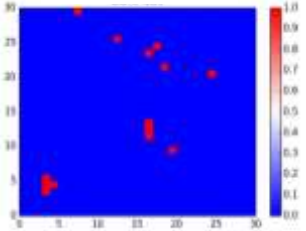
Needle leaf Tree



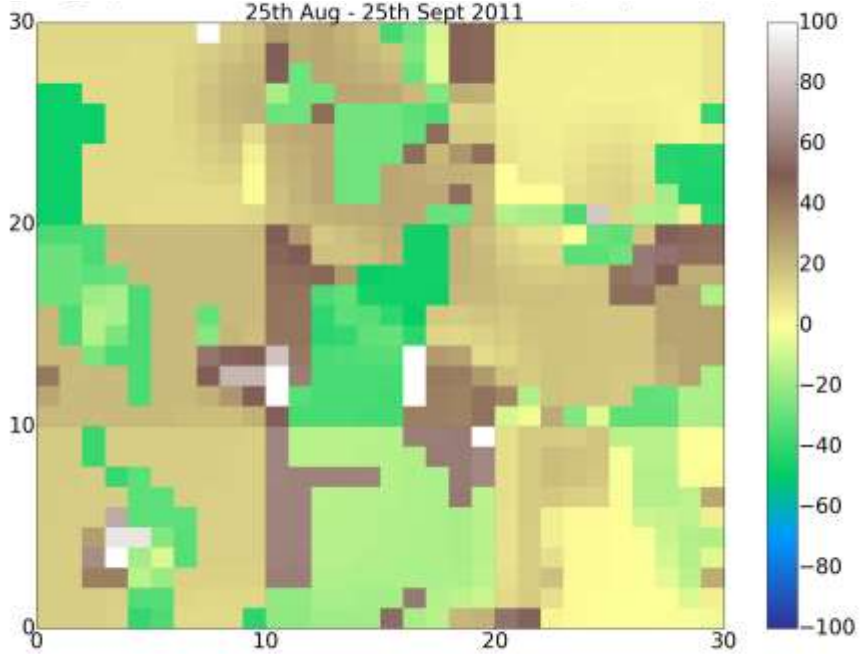
C3 Grass



Bare Soil



Standard Run minus Low Res. Forcing



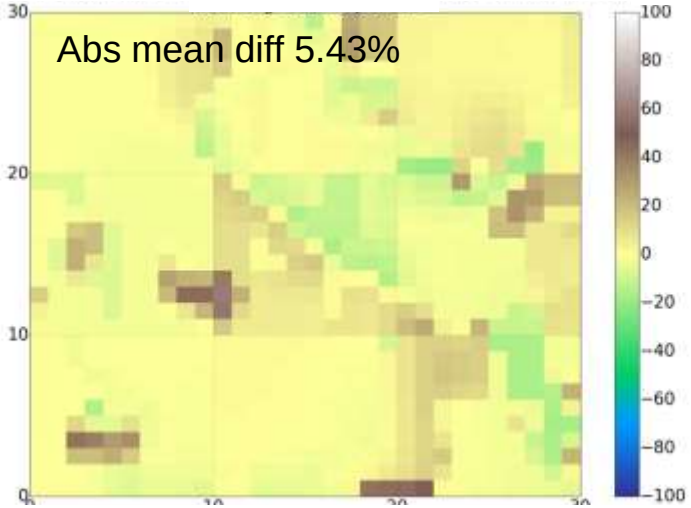
Standard run shows the largest difference in LE compared to Low res. forcing, & closer resemblance to vegetation fractions.

Trees: 20-60% LE decrease
C3 grass: 20-80% LE increase

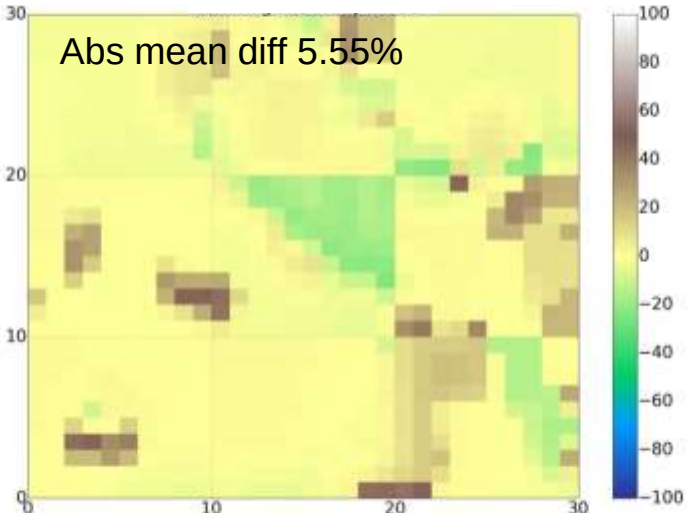
Normalised Mean % Differences

Latent Heat Flux, 25th Aug – 25th Sept 2011

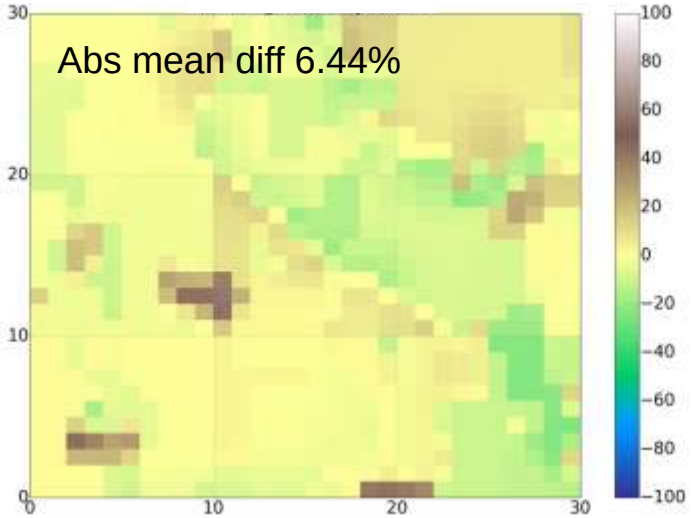
High res soil – Low res forcing



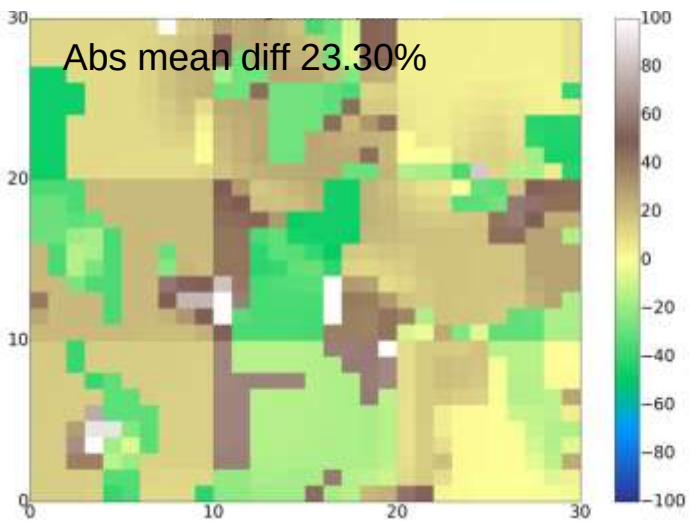
Tiled by surface type minus Low res forcing



Tiled by soil texture minus Low res forcing



Standard Run minus Low res forcing



Average Soil Moisture Availability

1 month

25th Aug – 25th Sept 2011	BL Tree	C3 Grass	Diffs
Sand	0.581	0.278	0.303
Clay	0.383	0.105	0.278
Diffs	0.198	0.173	

JJAS

June – Sept 2011	BT Tree	C3 Grass	Diffs
Sand	0.634	0.561	0.073
Clay	0.442	0.285	0.157
Diffs	0.192	0.276	

- Short term - differences between BL tree and C3 grass larger than between clay and sandy soils.
- As soil dries out, difference between sand and clay will reduce.
- Seasonally - differences between BL tree and C3 grass reduce and soil texture more important

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Conclusions

- The resolution of the forcing data has an impact on model simulation

- More intense precipitation rates are captured by the higher resolution simulation, however more of this water goes into surface runoff, reducing soil moisture and evaporation, compared to the coarser simulation.

- 'High res. soil' and 'Tiling by surface type' produce latent heat fluxes which are closest to the 'Low Res. forcing' simulation.

- Getting the distinction between short & tall vegetation and sand & clay soils is important for capturing summertime fluxes.

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Any questions?

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