50 Shades of Clay- JULES gets Soil Tiled

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- Sub-grid heterogeneity (generally)
- Introducing soil tiling
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Resolution dilemma

- Higher resolution models [generally] give better results…
- …but driving data is expensive...
  - Disk space: 0.5deg WFDEI = 8.5 GB/year
  - Computationally: GCM and weather forecast resolutions (UKV = 1.5 km)
- …but ancillary data is available at very high (<100 m) resolutions
- What do we do?!

Surface Tiles in JULES

- Same driving data applied to several surface types
  - Use tiled values directly for analysis
  - Pass back a grid-box mean to the atmosphere
- Compromise between driving data expense and ancillary resolution
- “Vanilla” JULES currently (vn 3.4.1) uses 9 surface tiles:
  - 5 vegetated tiles + 4 non-vegetated
  - Others waiting in the wings

Soil in JULES

- Each grid box is a single soil column
- All surface types share the same soil
- Average soil properties cannot be used
  - Linear combinations are not necessarily physically meaningful
- Dominant soil type is usually chosen
  - Pragmatic but not ideal... 51%/49% case?!

Introducing soil tiles…

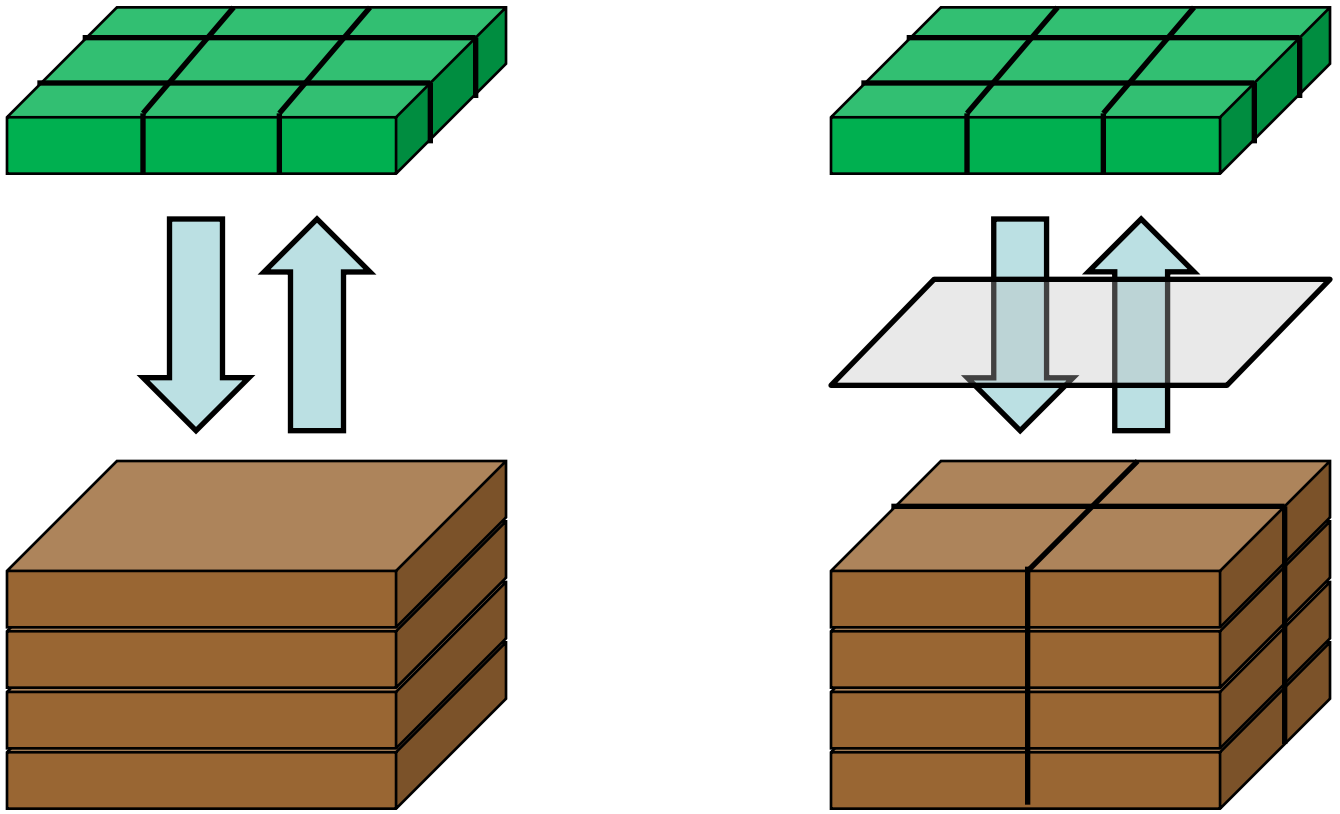
Vanilla JULES

Soil-tiled JULES

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

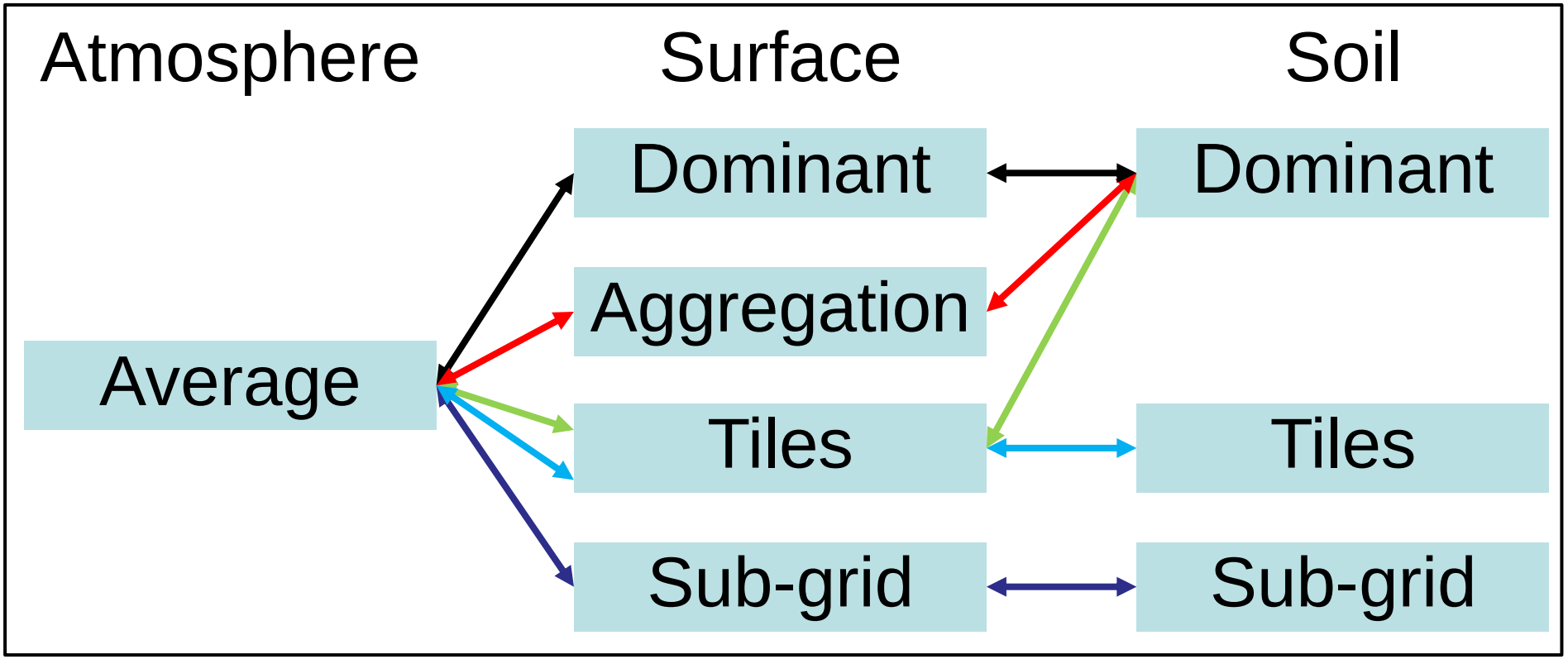
Surface-soil processes (infiltration, extraction, evaporation...)

Soil types (clay, loam...)



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

Recursive paradigms of sub-grid heterogeneity



Ave-Sub-Sub is *Ave-Dom-Dom* with a higher resolution atmosphere

Fraction Matrix

- 2 dimensional
- Summation along rows or columns give surface and soil tile fractions
- All elements total unity
- Flexible and extendable

	Tree	**Grass**	**Soil**	
Clay	0.2	0.4	0.15	**0.75**
Loam	0.1	0.0	0.15	**0.25**
	0.3	**0.4**	**0.3**	**1.0**

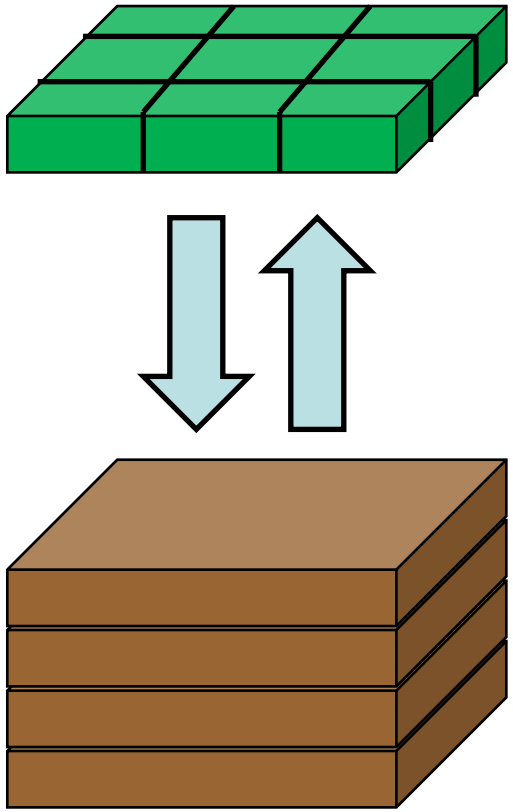
- Case for soil functional types?
  - Parameters could be defined in a new soil_param.nml
  - No soil ancil needed

Examples...

Example 1: Vanilla JULES

- Equivalent to normal JULES (*ave-tile-dom*)
- *Ave-tile-tile* with n_soiltile = 1

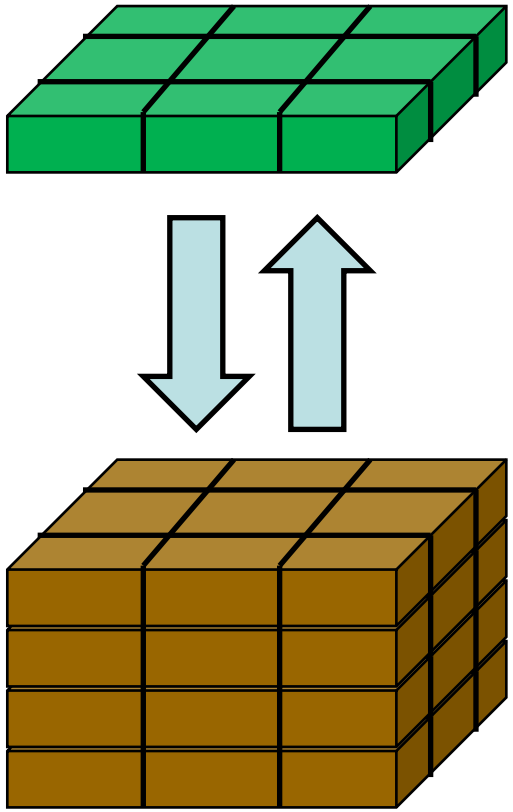
	Tree	Grass	Soil	
Clay	0.4	0.4	0.2	**1.0**
	0.4	**0.4**	**0.2**	**1.0**



Example 2: Divide & Conquer

- Each surface tile has its own soil column
- *Ave-tile-tile* with n_surftile = n_soiltile

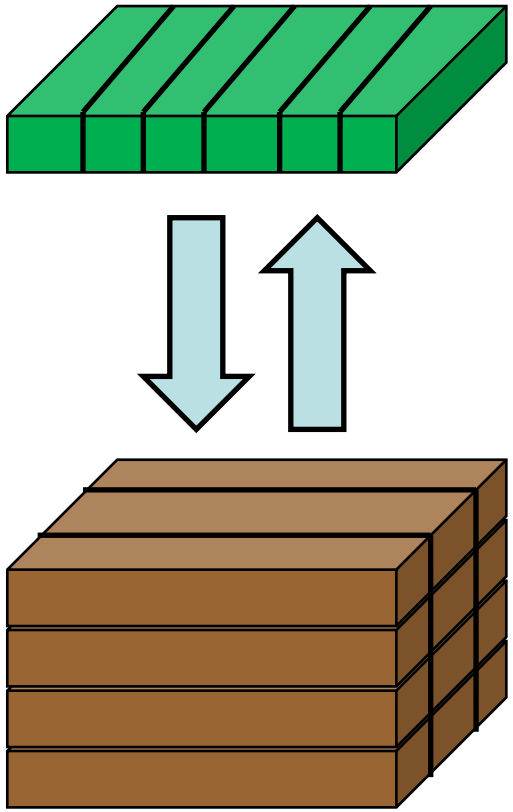
	Tree	Grass	Soil	
Clay	0.2	0.0	0.0	**0.2**
Clay	0.0	0.4	0.0	**0.4**
Loam	0.0	0.0	0.4	**0.4**
	0.2	**0.4**	**0.4**	**1.0**



Example 3: Caring & Sharing

- Every surface tile sits over both soil tiles
- *Ave-tile-tile* with n_surftile ≠ n_soiltile

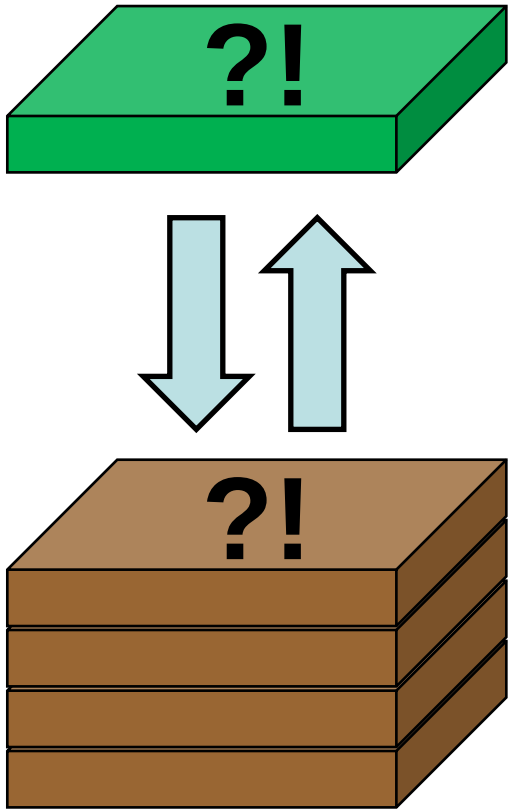
	Tree	Grass	Soil	
Clay	0.1	0.2	0.2	**0.5**
Loam	0.1	0.2	0.2	**0.5**
	0.2	**0.4**	**0.4**	**1.0**



Example 4: Arrrrrgh!

- Complex mapping of pfts to soils
- *Ave-tile-tile* with n_surftile ≠ n_soiltile

	Tree	Grass	Soil	
Clay	0.2	0.0	0.05	**0.25**
Sand	0.0	0.15	0.1	**0.25**
Loam	0.1	0.1	0.3	**0.5**
	0.3	**0.25**	**0.45**	**1.0**



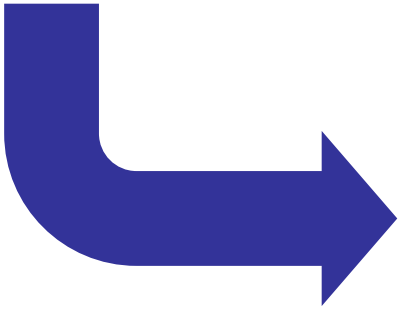
Compressed form of a very large diagonal matrix with many instances of each surface and soil types...

Compression of fraction matrix

	Tree	Grass	Soil	
Clay	0.2	0.0	0.0	**0.2**
Clay	0.0	0.4	0.0	**0.4**
Loam	0.0	0.0	0.4	**0.4**
	0.2	**0.4**	**0.4**	**1.0**

Computational saving vs. model performance

Diagonal



Compressed

	Tree	Grass	Soil	
Clay	0.2	0.4	0.0	**0.6**
Loam	0.0	0.0	0.4	**0.4**
	0.2	**0.4**	**0.4**	**1.0**

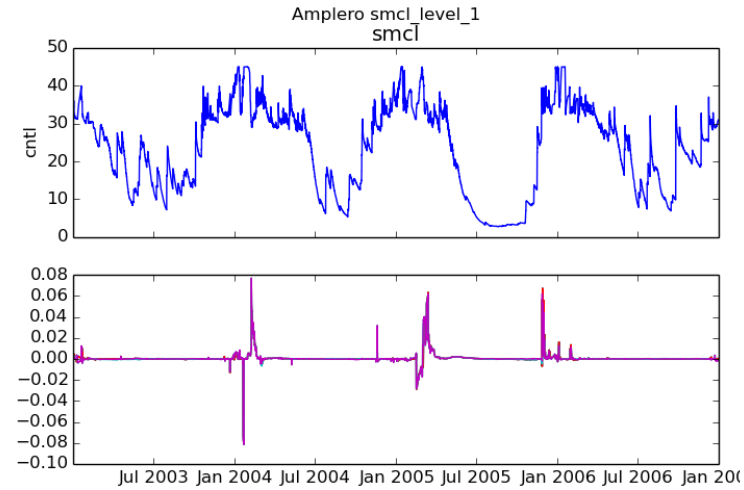
Preliminary Results...

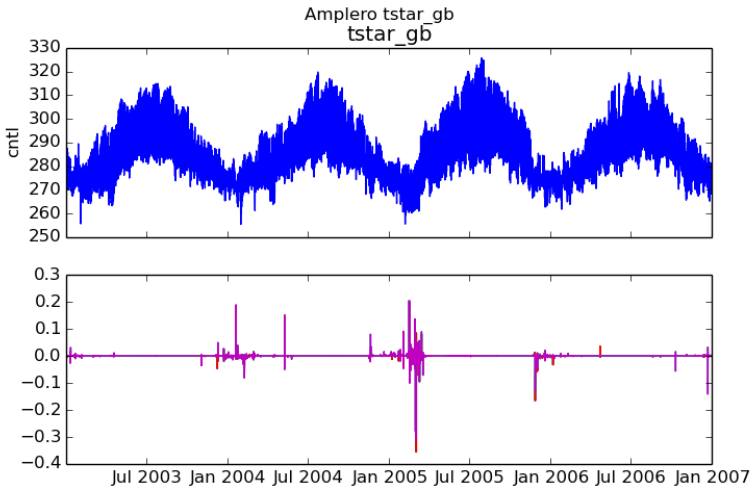
Amplero

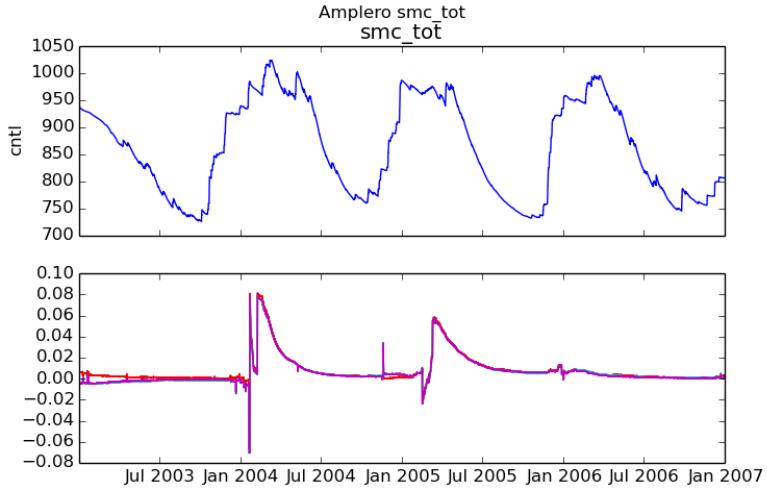
Site: Amplero	NT	BT	C3	C4	Shrub	Bare soil	
Soil 1 Clay Loam	0.067	0.028	0.272	0.029	0.016	0.087	50%
Soil 2 Sandy Loam	0.067	0.028	0.272	0.029	0.016	0.087	50%
	13.5%	5.6%	54.3%	5.8%	3.3%	17.5%	100%

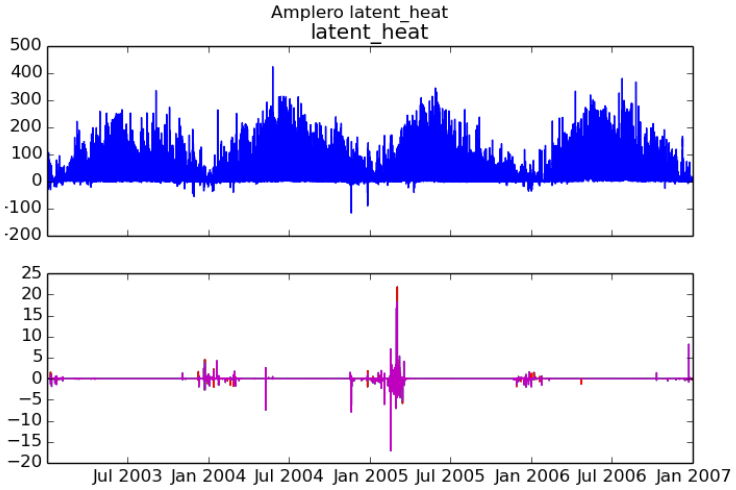
- "Caring & Sharing", *Ave-Tile-Tile*
- Also run with varying proportions and similar-soil null test (soil 1 = soil 2)
- Variations from linear combination?

Amplero- Null test

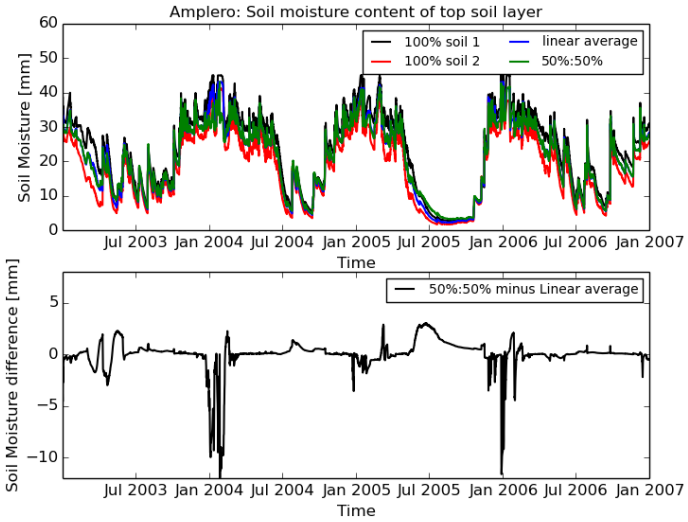


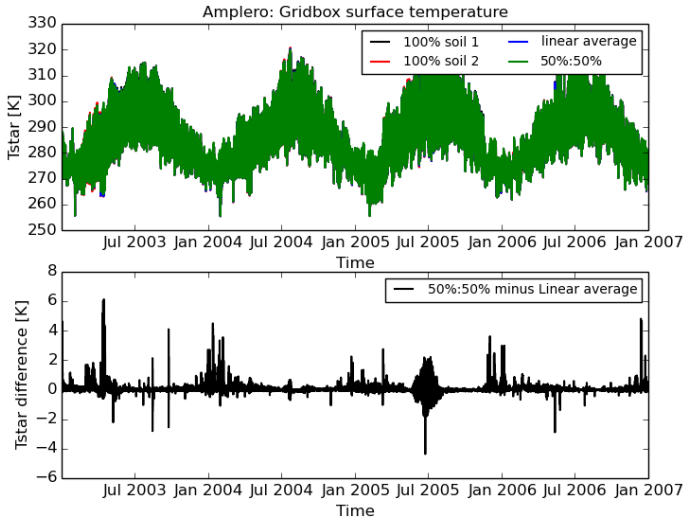


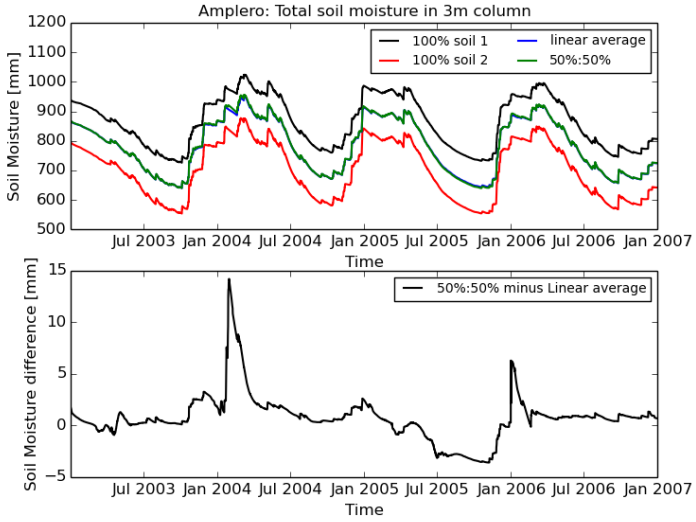


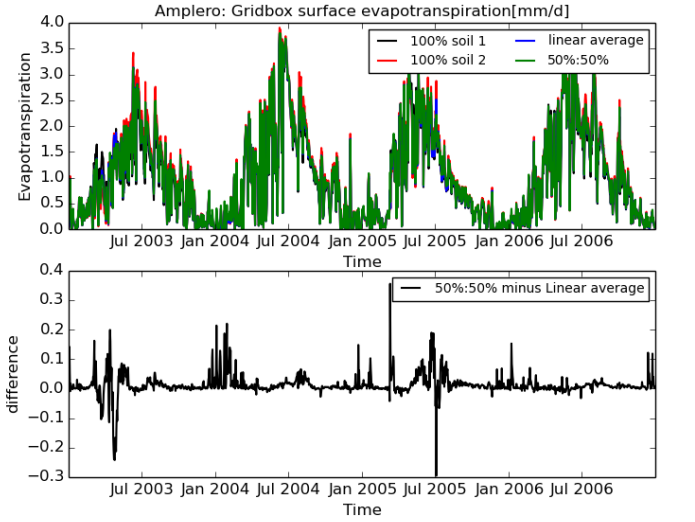


Amplero- different soils

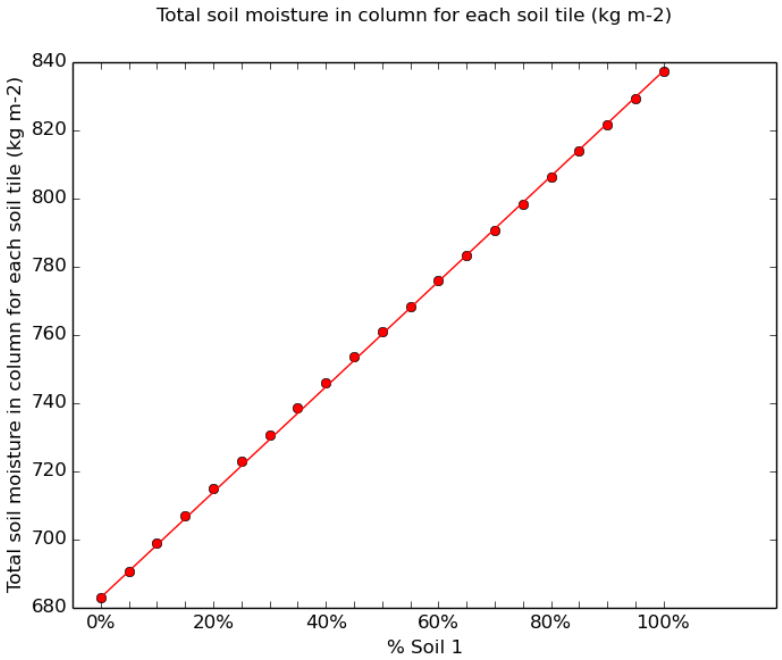


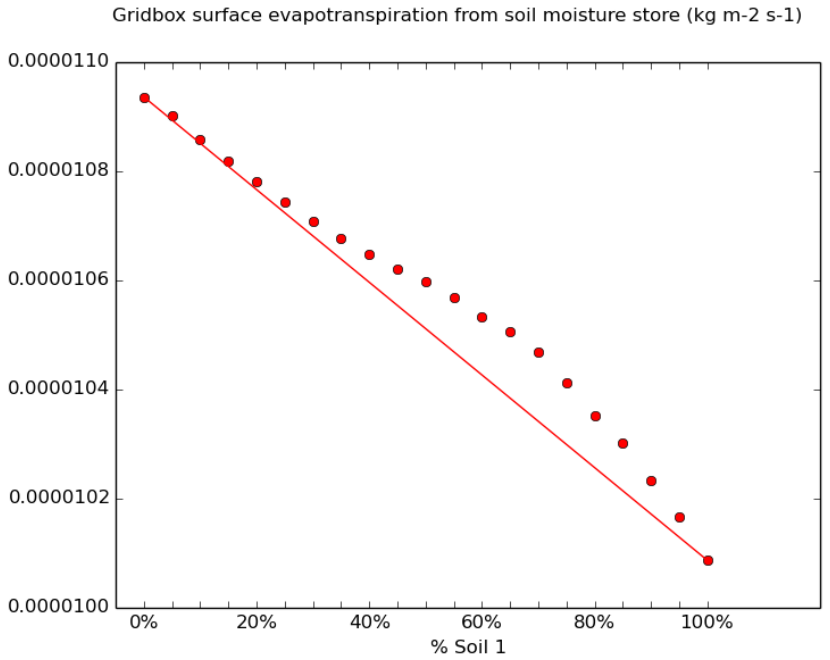






Amplero- Varying soil fractions





Excuses...

Challenges

It's not 'just' a case of adding a new dimension and a couple of DO loops

- Disentangling 'surface' things from 'soil' things
  - Massive effort to correctly identify dimensionality and INTENT of variables.
  - Move code to establish transmogrification points
- New variable naming convention
  - Helps identify dimensionality. 'Tile' is now ambiguous!
- Adding a new dimensions and required functionality
- >130 subroutines added/altered

Current limitations

- Only 1 instance of each surface tile per grid box
  - No ancil with tile properties for every grid box needed
  - Hack probably possible
- Multiple instances of a soil type per grid box allowed
  - Ancil required with every soil type listed
  - Pseudo-subgrid possible
- Ancillary vs functional type approach to tiling

Nasties (but fixable ones)

- Model output does change a little, eg during snow melt:
  - Snowdepth underflows to zero on a different timestep
  - Triggers an IF deep in the surface scheme
  - Step change in latent heat flux. Chaos ensues.
  - Tentative plan to replace with sigmoidal-like transition
- TRIFFID incompatible (for now)
  - Competition sometimes returns [slightly] negative surface tile fractions
  - Error check when updating the fraction matrix rejects the new fractions

Conclusions

- New element of sub-grid heterogeneity in JULES
- Helps mitigate the gap in resolution between driving and ancillary data
- Highly flexible configuration options
- Very large technical but scientifically small impact on codebase
- Not ready for release yet

Questions and answers