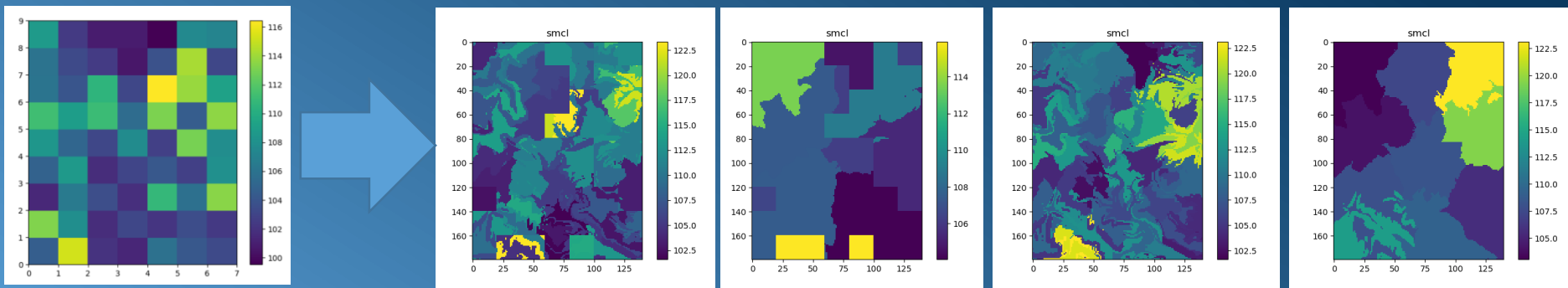


# Clustering approaches for JULES

Elizabeth Cooper, Rich Ellis, Eleanor Blyth, Simon Dadson UKCEH



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Usually we run JULES on a gridded system.

Each grid cell has

- a column of soil with derived soil physics parameters (and e.g. Carbon content.....)
- a/several land cover type(s) (PFTs)
- met drivers (usually up or downscaled from a modelled product)
- no communication between neighbouring cells

We can then route our surface and subsurface flows to give streamflows (usually no further interaction with the land)


HRU or hillslope approach is different because

We cluster 'SIMILAR' grid cells together

*These clusters may then exchange water between them (communication)*

# Some existing clustering approaches:

Geosci. Model Dev., 12, 2285–2306, 2019  
<https://doi.org/10.5194/gmd-12-2285-2019>  
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**Geoscientific Model Development** 

## DECIPHeR v1: Dynamic fluxEs and Connectivity for Predictions of HydRology

Gemma Coxon<sup>1,2</sup>, Jim Freer<sup>1,2</sup>, Rosanna Lane<sup>1</sup>, Toby Dunne<sup>1</sup>, Wouter J. M. Knoben<sup>3</sup>, Nicholas J. K. Howden<sup>2,3</sup>, Niall Quinn<sup>4</sup>, Thorsten Wagener<sup>2,3</sup>, and Ross Woods<sup>2,3</sup>

<sup>1</sup>School of Geographical Sciences, University of Bristol, Bristol, BS8 1SS, UK  
<sup>2</sup>Cabot Institute, University of Bristol, Bristol, BS8 1UJ, UK  
<sup>3</sup>Department of Civil Engineering, University of Bristol, Bristol, BS8 1TR, UK  
<sup>4</sup>Fathom Global, The Engine Shed, Station Approach, Bristol, BS1 6QH, UK

Correspondence: Gemma Coxon (gemma.coxon@bristol.ac.uk)

Received: 16 August 2018 – Discussion started: 24 September 2018  
 Revised: 18 April 2019 – Accepted: 30 April 2019 – Published: 14 June 2019

**Abstract.** This paper presents DECIPHeR (Dynamic fluxEs and Connectivity for Predictions of HydRology), a new model framework that simulates and predicts hydrologic flows from spatial scales of small headwater catchments to entire continents. DECIPHeR can be adapted to specific hydrologic settings and to different levels of data availability.

**1 Introduction**

Water resources require careful management to ensure adequate potable and industrial supply, to support the economic and recreational value of water, and to minimize the impacts of hydrological extremes such as droughts and floods on the

**JAMES** Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE  
 10.1029/2019MS001833

## Representing Intrahillslope Lateral Subsurface Flow in the Community Land Model

Sean C. Swenson<sup>1</sup>, Martyn Clark<sup>2</sup>, Ying Fan<sup>3</sup>, David M. Lawrence<sup>4</sup>, and Justin Perket<sup>5</sup>

**Key Points:**

- Representative hillslopes are implemented in the Community Land Model
- Topographically driven lateral moisture fluxes are explicitly modeled across each hillslope
- Soil moisture convergence in lowlands is shown to support higher evapotranspiration rates relative to uplands

Climate and Global Dynamics Laboratory<sup>1</sup>, National Center for Atmospheric Research, Boulder, Colorado, USA, <sup>2</sup>Centre for Hydrology and Catchment Soilwater Lab, University of Saskatchewan, Camrose, Alberta, Canada, <sup>3</sup>Department of Earth and Planetary Sciences, Rutgers University, New Brunswick, NJ, USA, <sup>4</sup>Goddard Space Flight Center, National Aeronautics and Space Administration, Greenbelt, MD, USA

Correspondence to: S. C. Swenson, swenson@ucar.edu

**Citation:** Swenson, S. C., Clark, M., Fan, Y., Lawrence, D. M., & Perket, J. (2019). Representing intra-hillslope lateral subsurface flow in the community land model. *Journal of Advances in Modeling Earth Systems*, 11, e2018ms001833. <https://doi.org/10.1029/2019MS001833>

AGU 100 ADVANCING EARTH AND SPACE SCIENCE

HYDROLOGICAL PROCESSES  
*J. Hydrol. Process.* 38, 3543–3559 (2016)  
 Published online 19 August 2016 in Wiley Online Library  
 (wileyonlinelibrary.com) DOI: 10.1002/hyp.10801

## HydroBlocks: a field-scale resolving land surface model for application over continental extents

Nathaniel W. Chaney<sup>1,2,3</sup>, Peter Metcalfe<sup>2</sup>, and Eric F. Wood<sup>1</sup>

<sup>1</sup>Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ, USA

Land surface spatial heterogeneity is a key driver of hydrologic response. Until now, the most simplistic schemes because of complex land surface model that represents response units (HRUs). HydroBlock hydrologic model. The HRUs are 2D data. The clustering mechanism allows validation. The Little Washita watershed validation. A 0.5 that using 1000 HRUs is sufficient performance using available in situ observed spatial and temporal dry parameter uncertainty. HydroBlock

Geosci. Model Dev., 14, 6813–6832, 2021  
<https://doi.org/10.5194/gmd-14-6813-2021>  
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## HydroBlocks v0.2: enabling a field-scale two-way coupling between the land surface and river networks in Earth system models

Nathaniel W. Chaney<sup>1</sup>, Laura Torres-Rojas<sup>1</sup>, Noemi Vergopolan<sup>2</sup>, and Colby K. Fisher<sup>3</sup>

<sup>1</sup>Department of Civil and Environmental Engineering, Duke University, Durham, NC, USA  
<sup>2</sup>Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ, USA  
<sup>3</sup>Princeton Climate Analytics, Princeton University, Princeton, NJ, USA

Correspondence: Nathaniel W. Chaney (nathaniel.chaney@duke.edu)

Received: 27 August 2020 – Discussion started: 28 October 2020  
 Revised: 14 September 2021 – Accepted: 23 September 2021 – Published: 9 November 2021

**Abstract.** Over the past decade, there has been appreciable progress towards modeling the water, energy, and carbon cycles at field scales (10–100 m) over continental to global extents in Earth system models (ESMs). One such approach, named HydroBlocks, accomplishes this task while maintaining computational efficiency via Hydrologic Response Units (HRUs), more commonly known as “tiles” in ESMs. In HydroBlocks, these HRUs are learned via a hierarchical clustering

between the land surface and the river network leads to appreciable differences in the simulated spatial heterogeneity of the surface energy balance. (2) a limited number of HRUs (~300 per 0.25° cell) are required to approximate the fully distributed simulation adequately, and (3) the surface energy balance partitioning is sensitive to the river routing model parameters. The resulting routing scheme provides an effective and efficient path forward to enable a two-way coupling be-

All of these involve hydrology (as well as land)

Here we take the HYDROBLOCKS approach but apply only to the LAND parts of JULES

# Land response units (LRUs) in JULES/hydroJULES

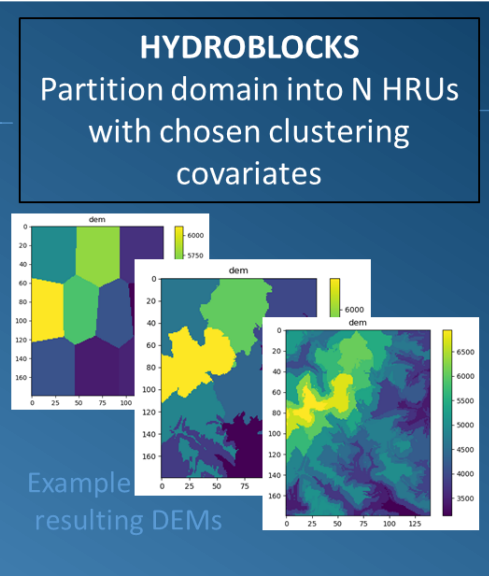
Digital terrain

Land cover

Meteorology

Soil properties

Topmodel pars



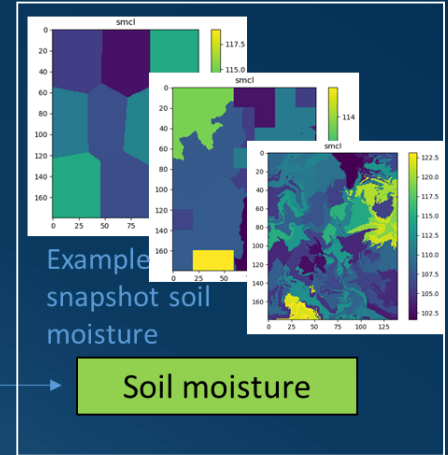
JULES runs for N columns

**HYDROBLOCKS**  
Map back into physical space

Runoffs

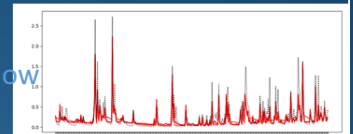
Flow dirs

Flow acc



**UNIFYH**  
streamflows

Example streamflow w/obs



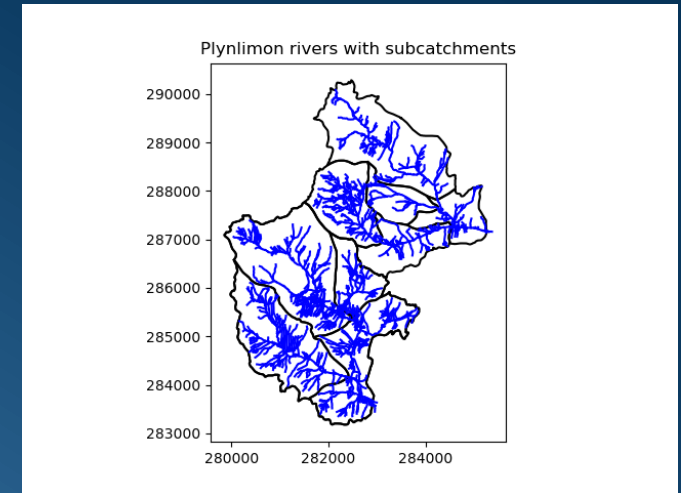
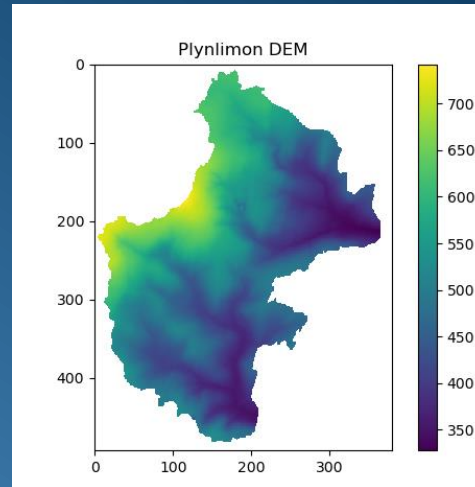
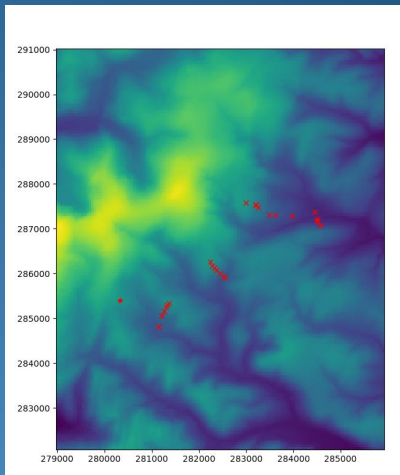
IHDTM 50m resolution

CHESS 1km resolution

OUTPUTS 50m resolution

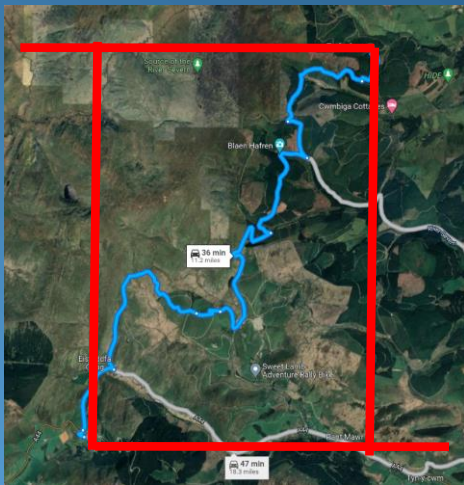
For basis of clustering code see:  
<https://github.com/chaneyn/HydroBlocks>  
For unifyh see: <https://github.com/unifyh-org>

# Initial POC: Plynlimon, Wales

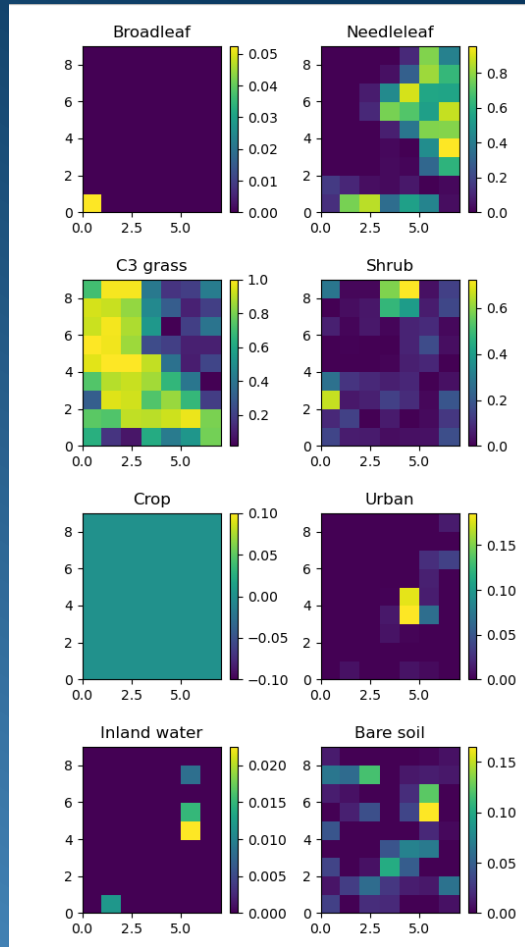


50m resolution, total area =  
(140\*180\*50m\*50m) = 63km<sup>2</sup>

# Land cover

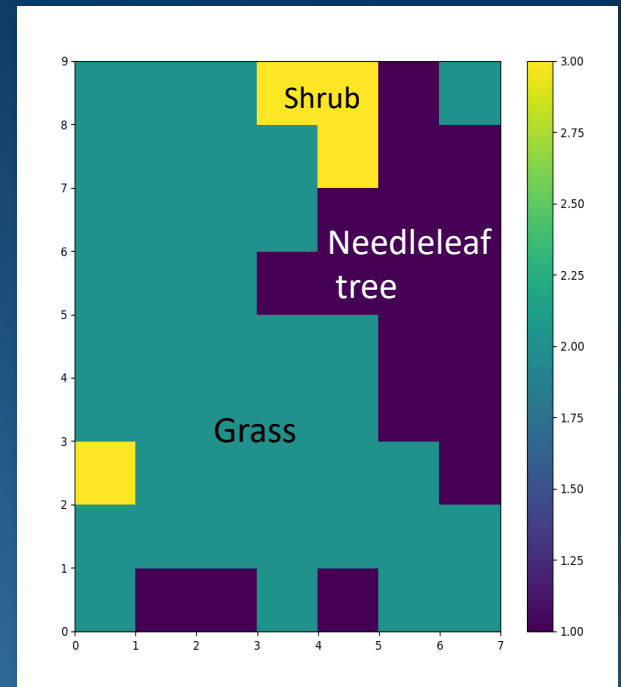


Credit: Google maps



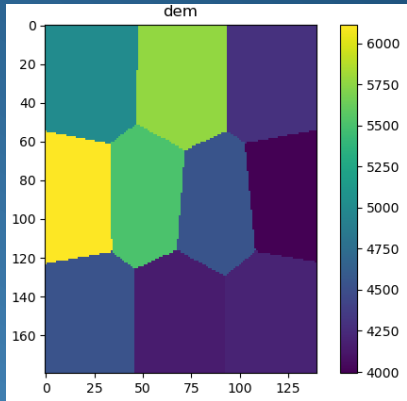
JULES CHES fractions

NB soil ancils all the same!

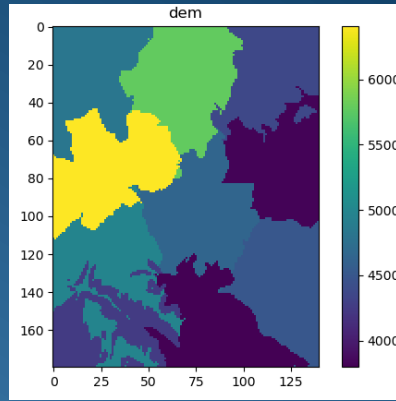


Dominant land type for use in clustering

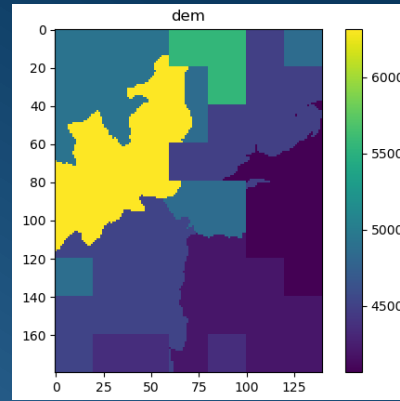
# Some clustering results: DEM



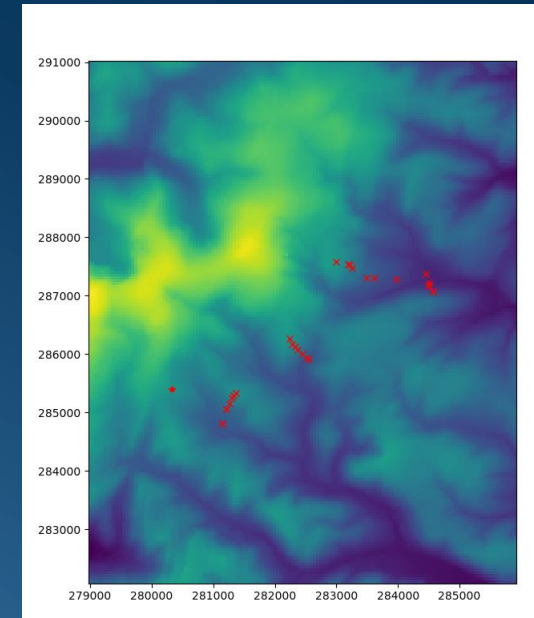
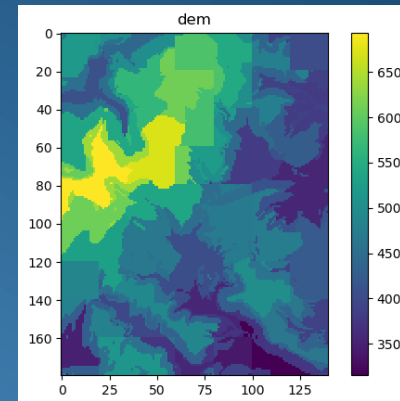
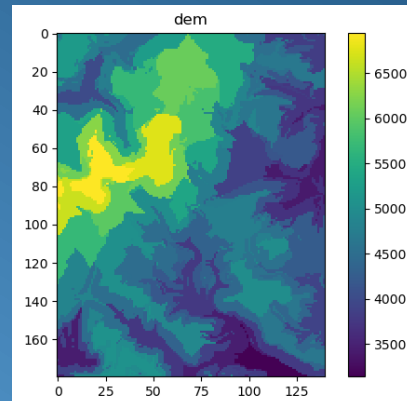
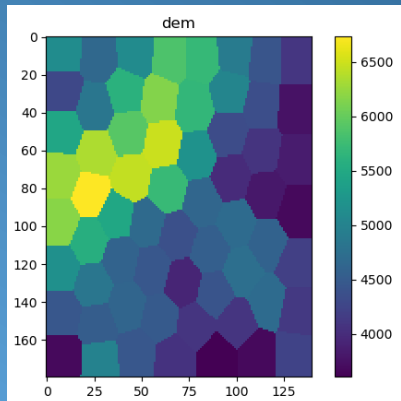
Lat and lon



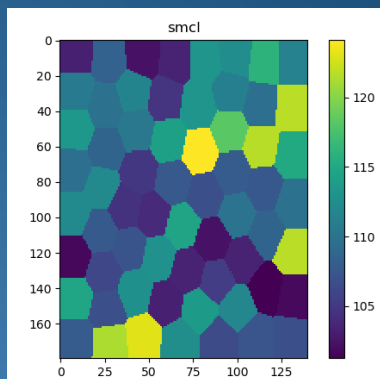
+ elevation and slope



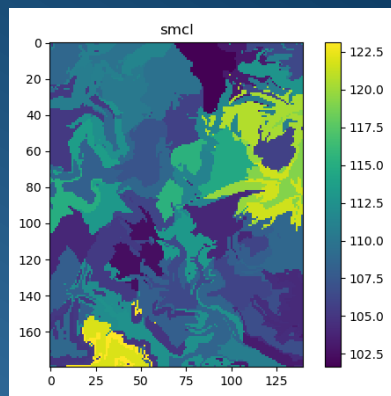
+ land cover



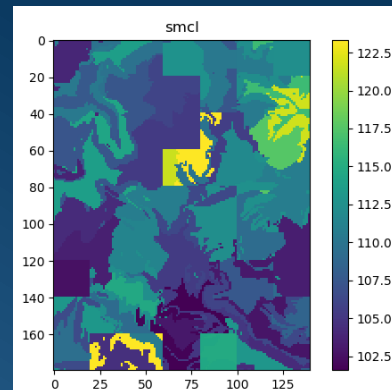
# Some output results: snapshot soil moisture



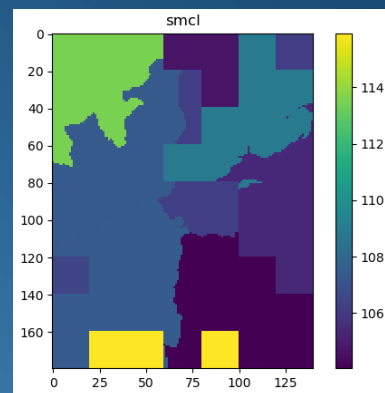
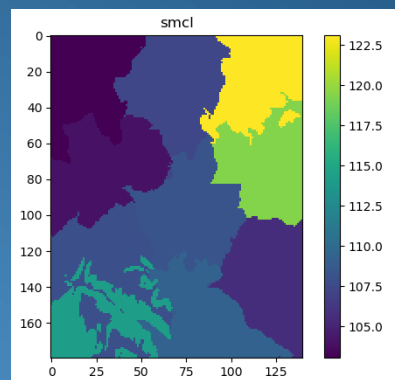
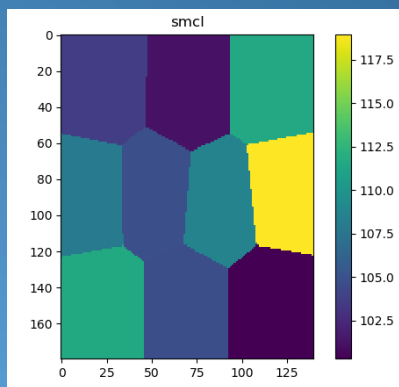
Lat and lon



+ elevation and slope



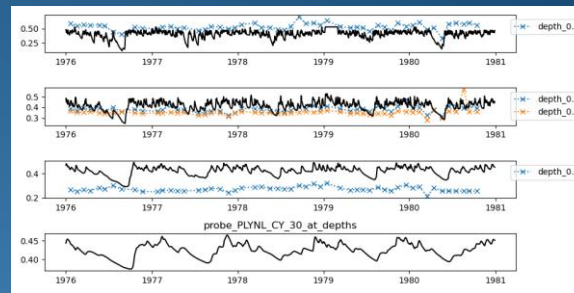
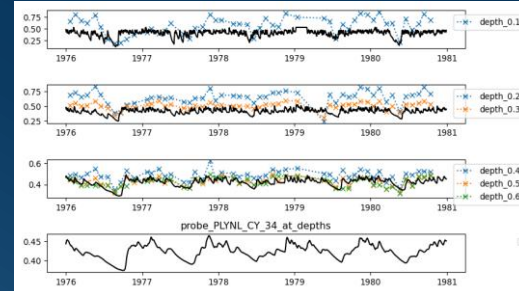
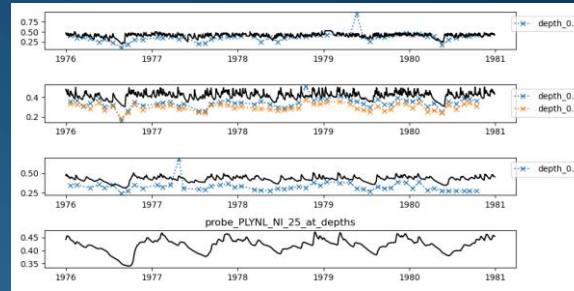
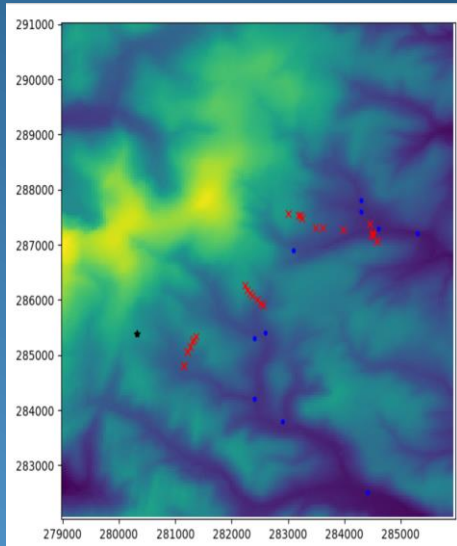
+ land cover



Increasing complexity, but now we have no 'truth'



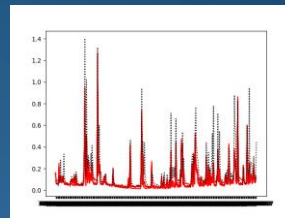
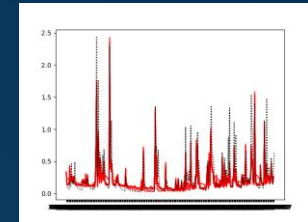
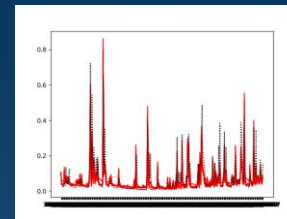
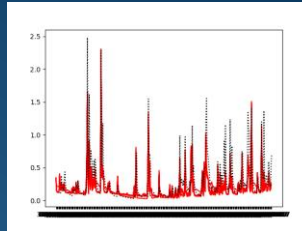
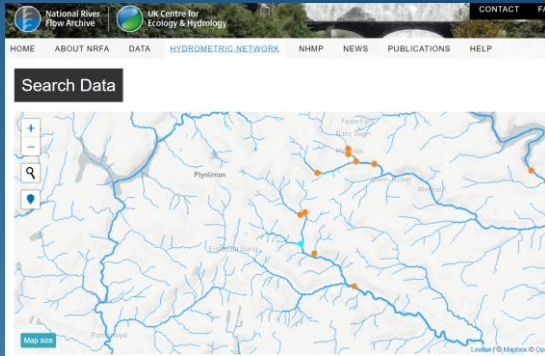
# Some output results: soil moisture



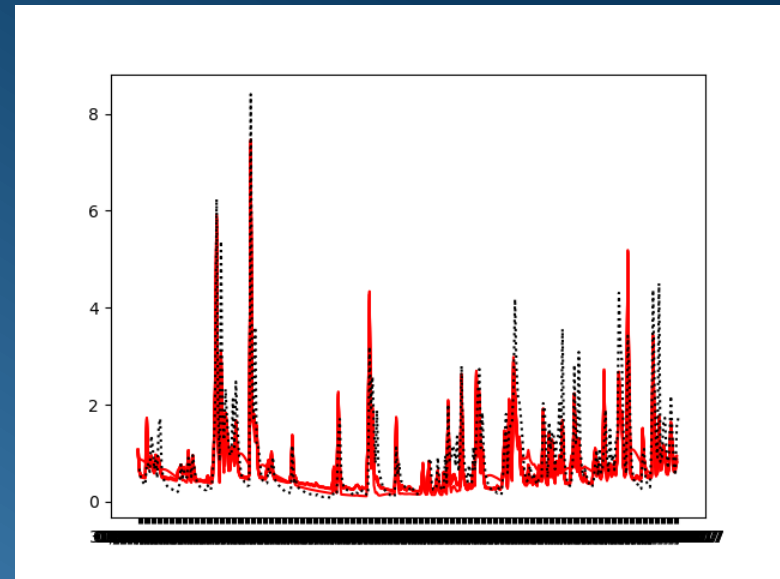
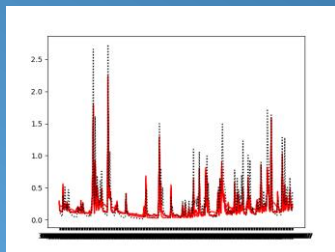
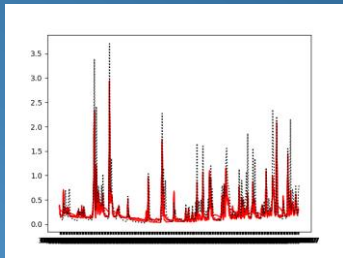
Mix of results!  
Remember: point probes  
are not representative of  
LRU average (or km grid  
cell!)

(Bell, V.A.; Davies, H.N.; Fry, M.; Zhang, T.; Murphy, H.; Hitt, O.; Hewitt, E.J.; Chapman, R.; Black, K.B. (2022). Collated neutron probe measurements and derived soil moisture data, UK, 1966-2013. NERC EDS Environmental Information Data Centre. <https://doi.org/10.5285/450bb14b-c711-47af-8792-f9bd88482cd4>)

# Some output results: river flow

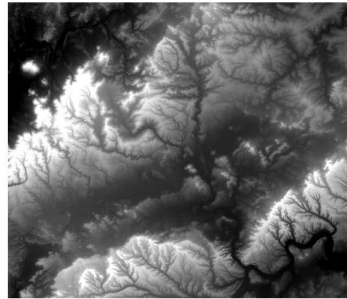


Hydrographs (daily m<sup>3</sup>/m<sup>3</sup>) for 2017 show NRFA obs in black and model output in red. **Hardly any difference for 10 or 63 LRU configurations**



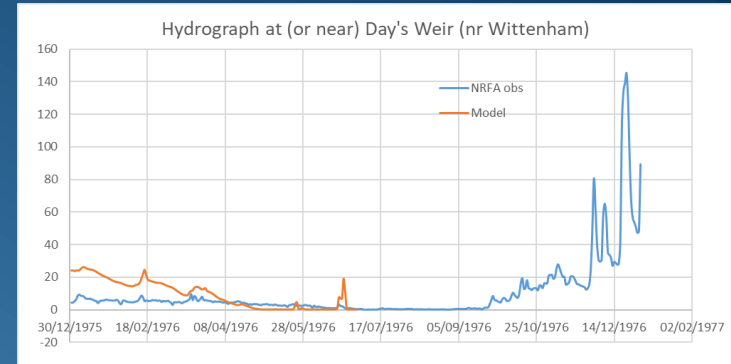
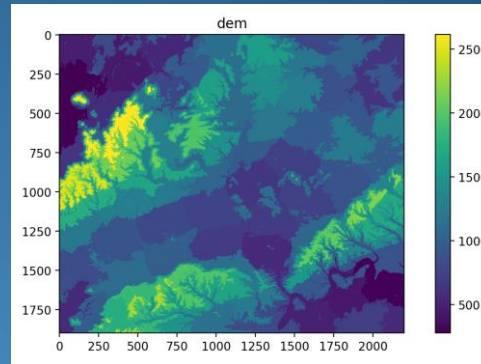
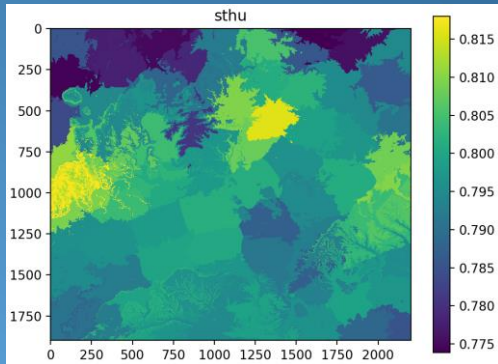
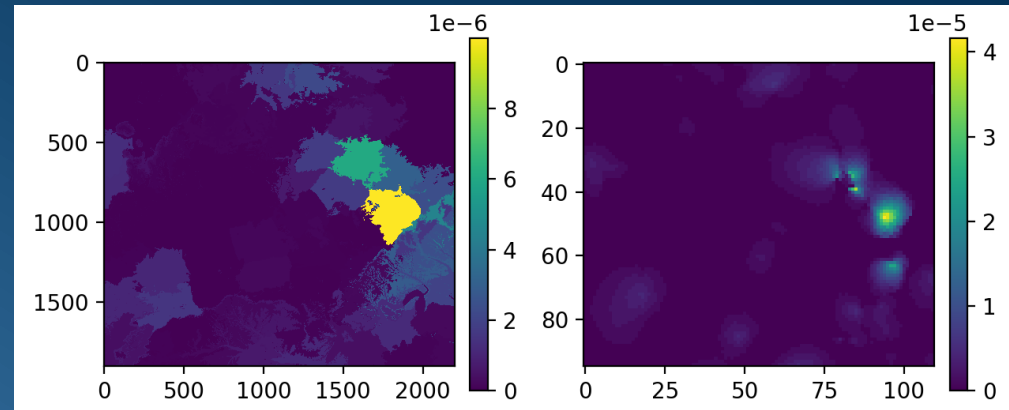
# Next stop: the Thames! (to Reading)

 Plynlimon 63km<sup>2</sup>



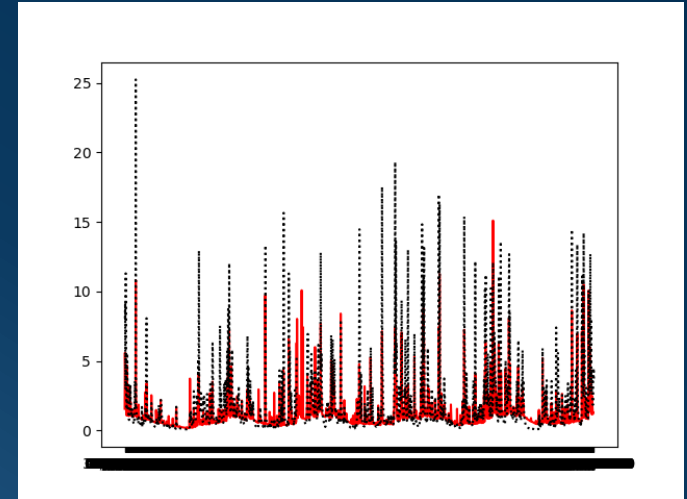
Thames to Reading  
10,450km<sup>2</sup>

Precip

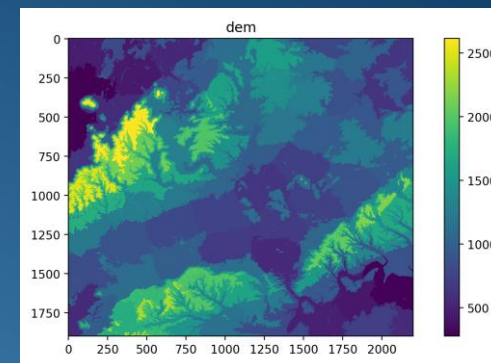


# Conclusions and future

- Plynlimon river results promising – indicate 10 HRUs can be as good as 63 grid cells(?)
- Streamflow VERY sensitive to river routing resolution
- Thames results likely to be more interesting – larger, more heterogenous etc
- Hope to answer:
  - Is this a useful approach in JULES?
  - WHICH characteristics are most important for LRUs?



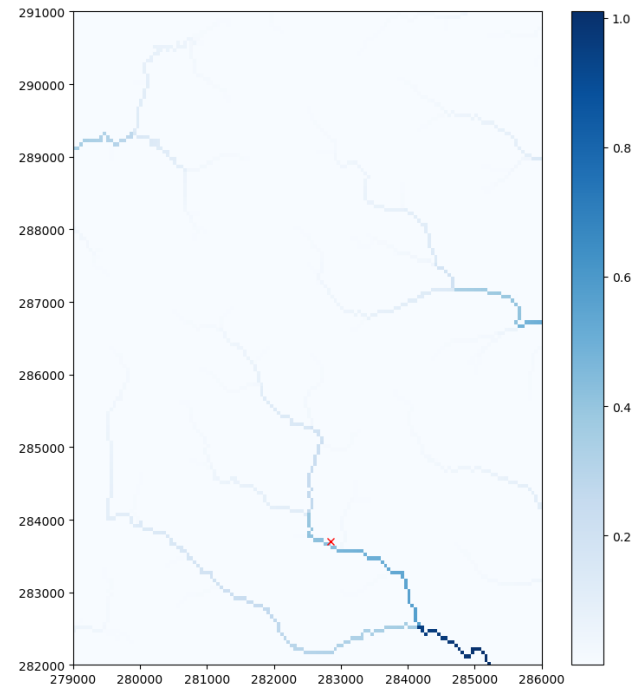
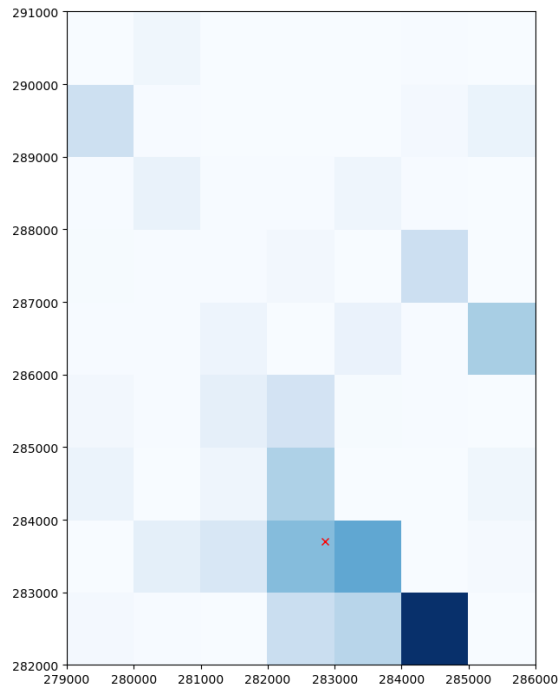
Hydrographs for 1976 – 1980 (inc)  
Black NRFA obs, red JULES\_10LRU



Thames  
dem  
100LRU

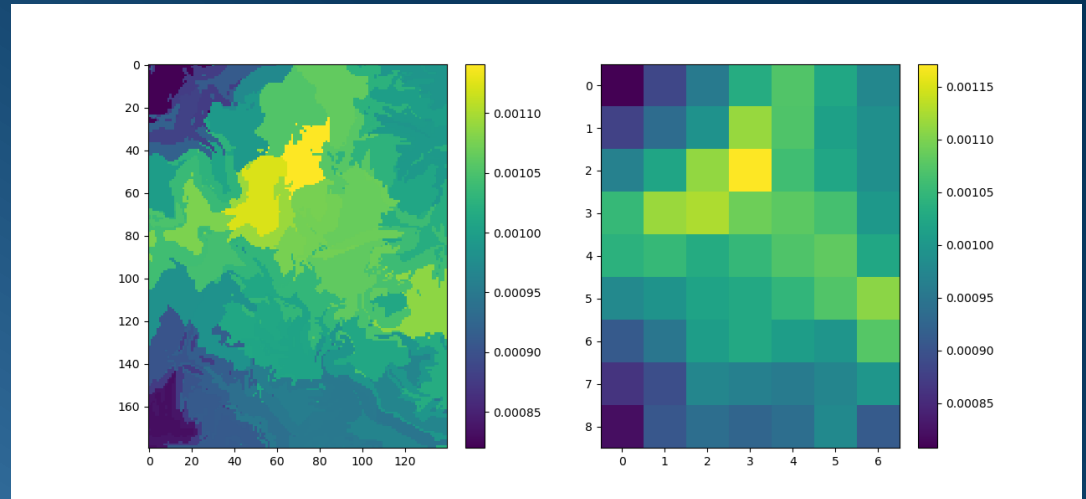
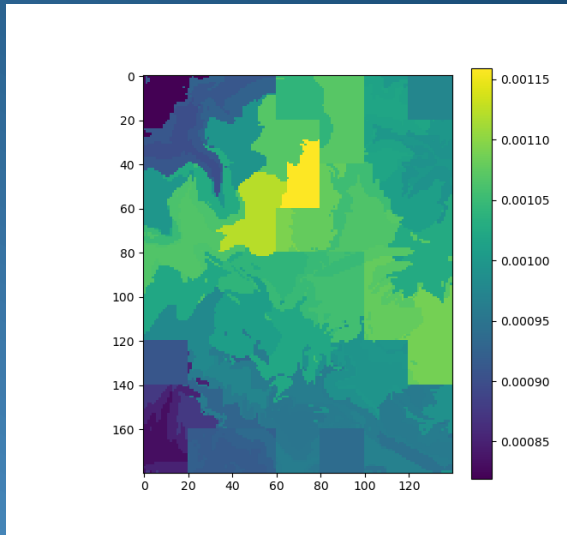


## Comparison with JULES GRIDDED



... is a bit tricky.....

# Some clustering results: snapshot precip



# BUT WHAT about the precip for 10HRUs?

smcl (layer 2 day 75) for 10 hrus ll, llds, llds+lc covariates

