JULES in Hydro-JULES

Douglas Clark and the Hydro-JULES team

JULES Science meeting, Sep 2023

Hydro-JULES
UK Centre for Ecology & Hydrology
BGS British Geological Survey
National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

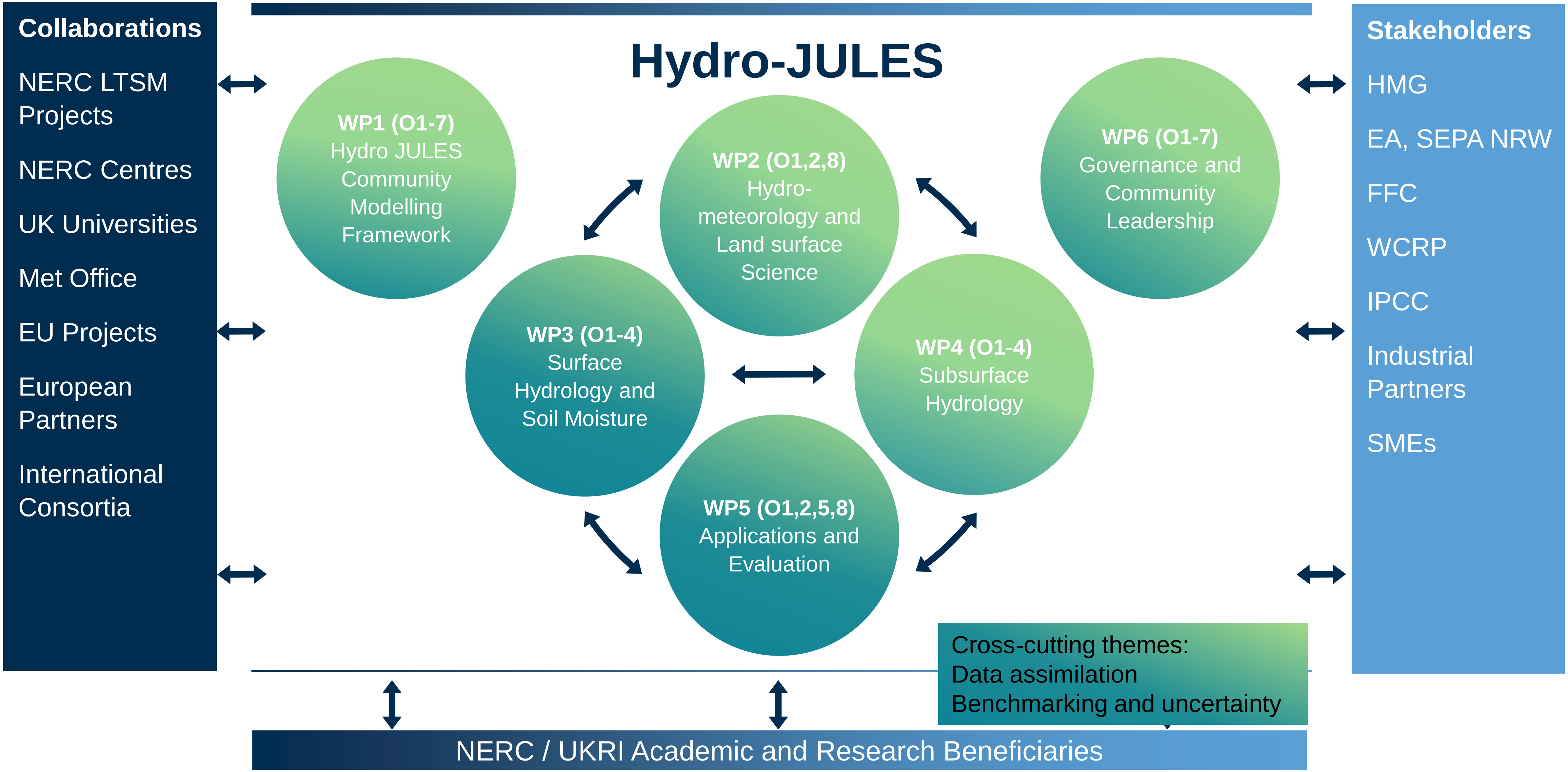
What is Hydro-JULES?

Hydro-JULES is a NERC-funded, multi-centre National Capability project

UK Centre for Ecology & Hydrology | British Geological Survey | National Centre for Atmospheric Science (Natural Environment Research Council) | National Centre for Earth Observation (Natural Environment Research Council)

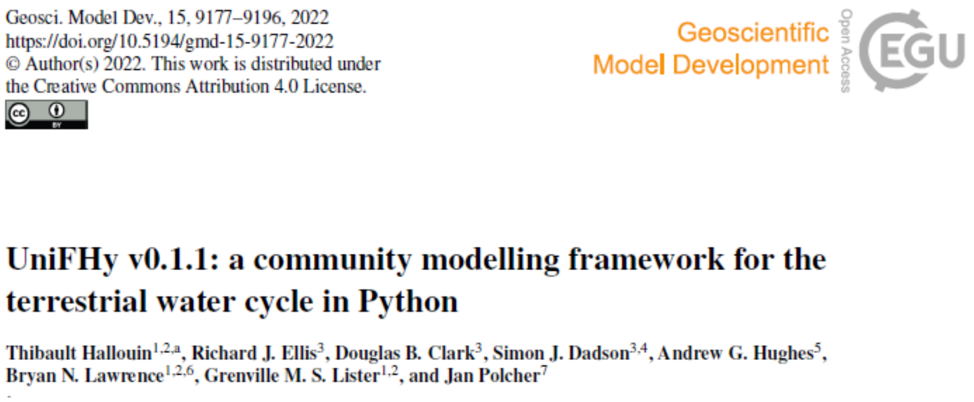
Currently funded for April 2023 – March 2027 (Phase 1 2018-23)

Many activities within Hydro-JULES involve JULES…but not all.


Collaborations
NERC LTSM Projects
NERC Centres
UK Universities
Met Office
EU Projects
European Partners
International Consortia
Hydro-JULES
WP1 (O1-7)
Hydro JULES Community Modelling Framework
WP2 (O1,2,8)
Hydro-meteorology and Land surface Science
WP6 (O1-7)
Governance and Community Leadership
WP3 (O1-4)
Surface Hydrology and Soil Moisture
WP4 (O1-4)
Subsurface Hydrology
WP5 (O1,2,5,8)
Applications and Evaluation
Cross-cutting themes:
Data assimilation
Benchmarking and uncertainty
Stakeholders
HMG
EA, SEPA NRW
FFC
WCRP
IPCC
Industrial Partners
SMEs
NERC / UKRI Academic and Research Beneficiaries

Unified Framework for Hydrology (UniFHy) – Hallouin et al. (2022)

A python framework for model components in python, Fortran,…

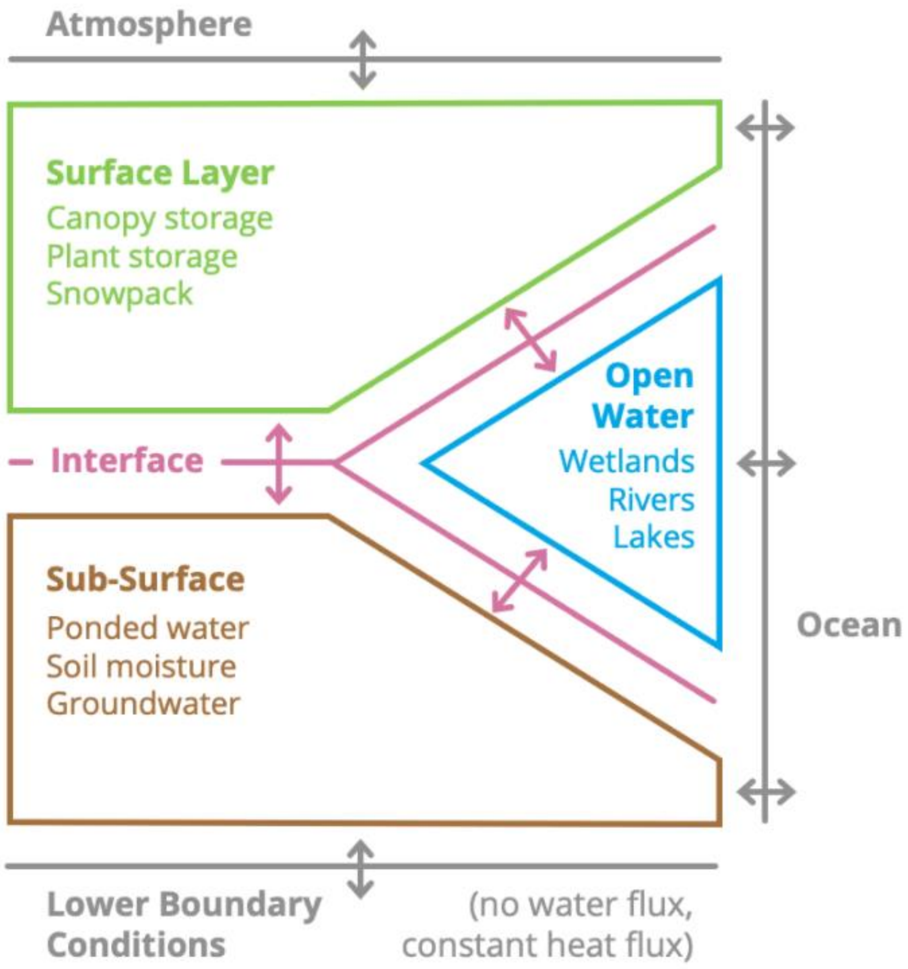

Geosci. Model Dev., 15, 9177–9196, 2022
https://doi.org/10.5194/gmd-15-9177-2022

Geoscientific Model Development

UniFHy v0.1.1: a community modelling framework for the terrestrial water cycle in Python

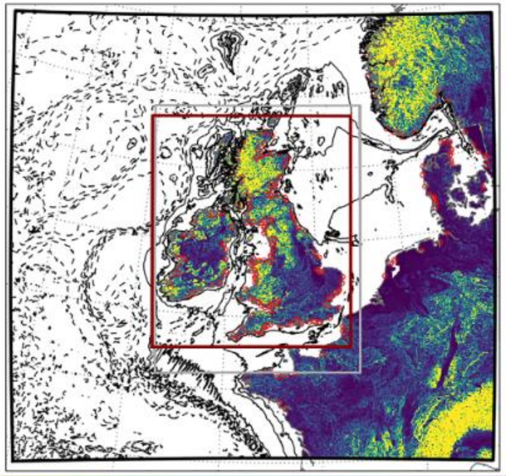
Thibault Hallouin[1,2,a], Richard J. Ellis[3], Douglas B. Clark[3], Simon J. Dadson[3,4], Andrew G. Hughes[5], Bryan N. Lawrence[1,2,6], Grenville M. S. Lister[1,2], and Jan Polcher[7]

- Existing framework will be enhanced (e.g. parallellisation)
- JULES is being split into components for UniFHy
- Implications of this approach (e.g. for coupled modelling via LFRic & UKESM) will be examined



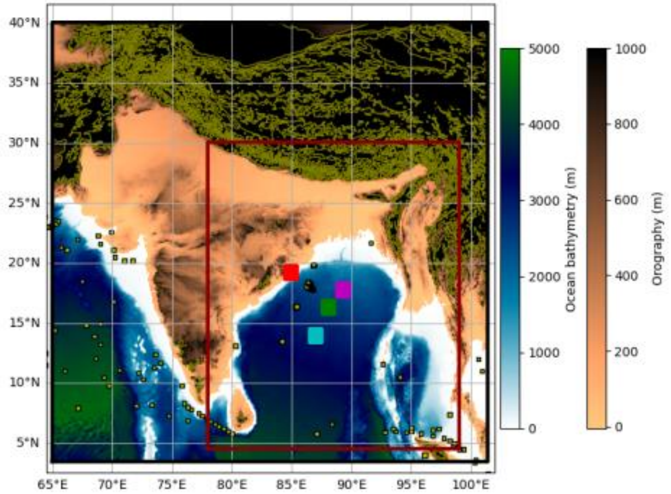
Regional coupled modelling

Coupled land-atmosphere-ocean(-wave) modelling for
- environmental prediction (days)
- climate modelling (decades)



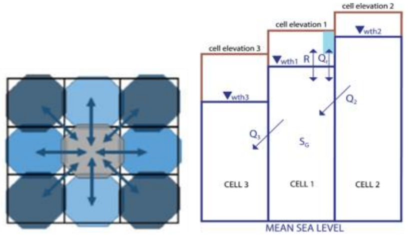
Model domain (@~1.5km)
from Lewis and Dadson, 2021

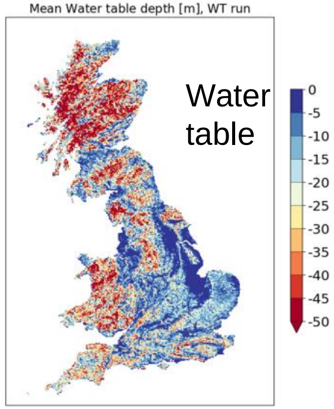
Model domain (@~4.4km)
from Castillo et al., 2022



- Working with the Met Office to evaluate and improve the representation of terrestrial hydrology
- Making new components available (groundwater, rivers) – in UM and/or offline

JULES + Dynamic Groundwater

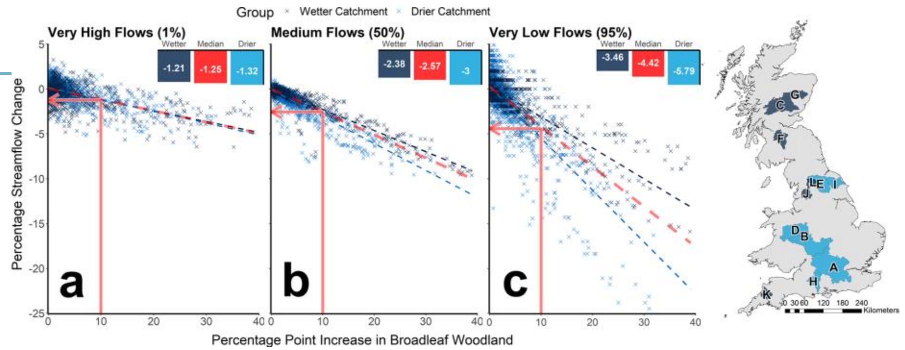




Alberto Martinez and BGS

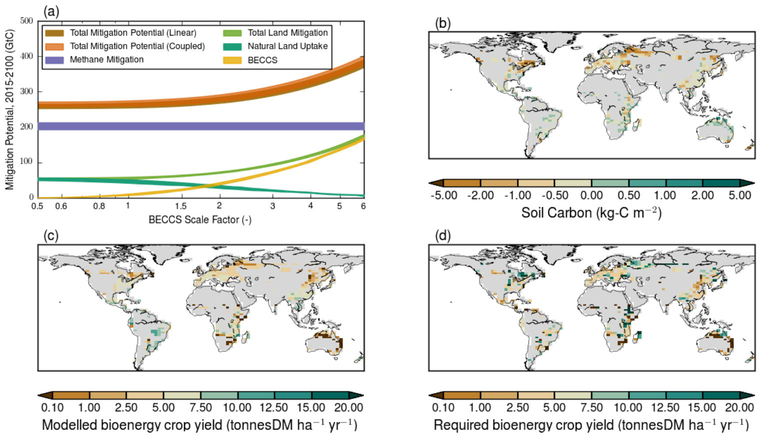
Nature-based solutions

- Some large-scale NbS can be represented by JULES as land use change



Buechel et al (2022)
https://doi.org/10.1038/s43247-021-00334-0

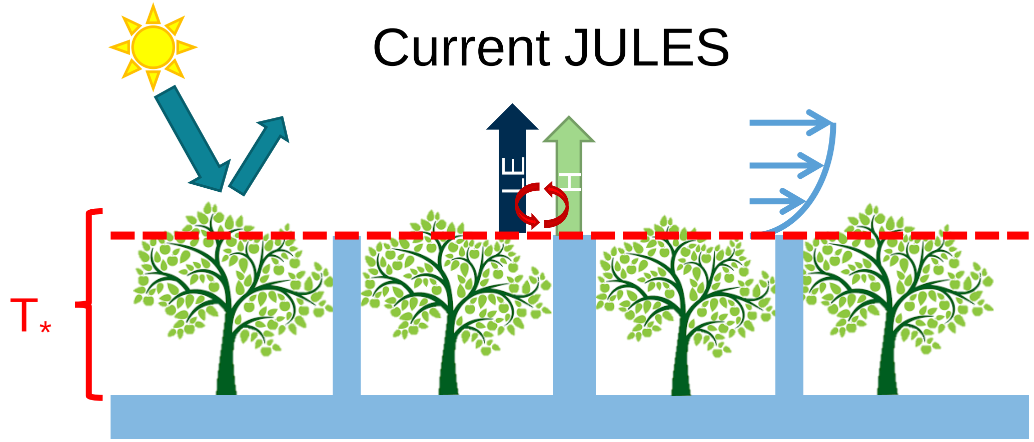
- JULES allows integrated assessment of impacts both intentional and unintended
- We will use this to explore and evaluate potential regional NbS scenarios in the UK and globally



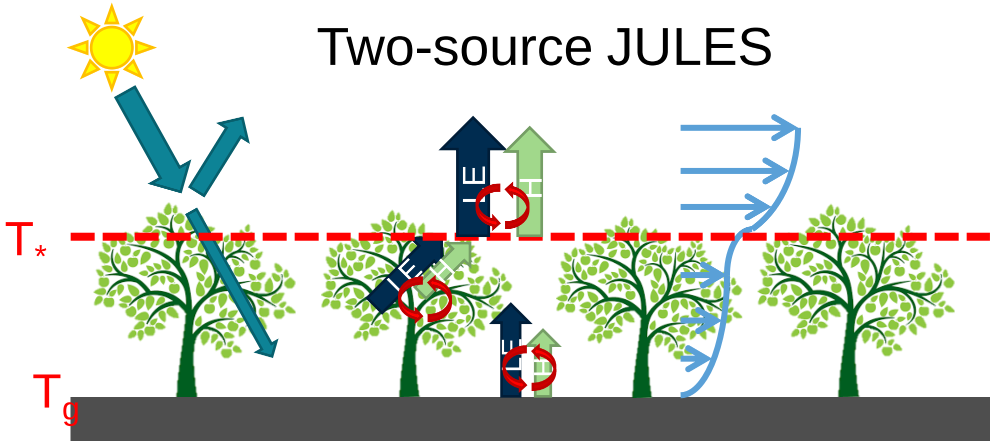
Hayman et al (2021)
https://doi.org/10.5194/esd-12-513-2021

Littleton et al (2021)
https://doi.org/10.1088/1748-9326/ac3c6c

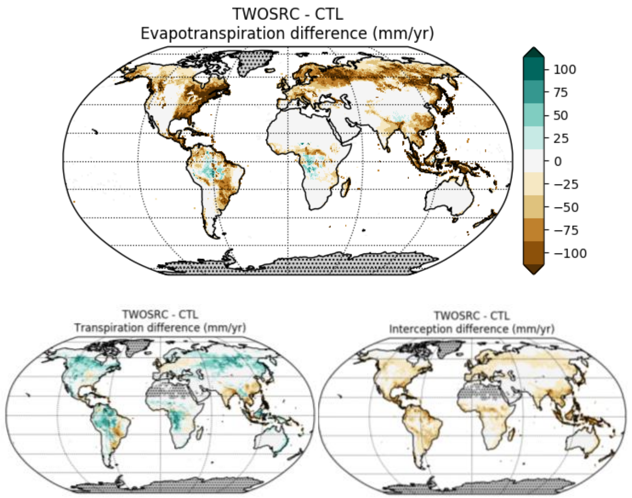
Current JULES



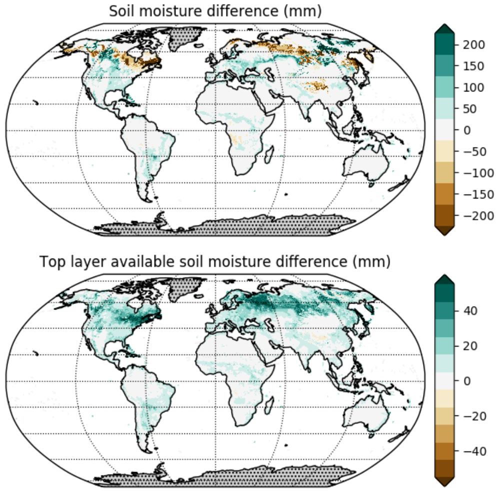
Two-source JULES



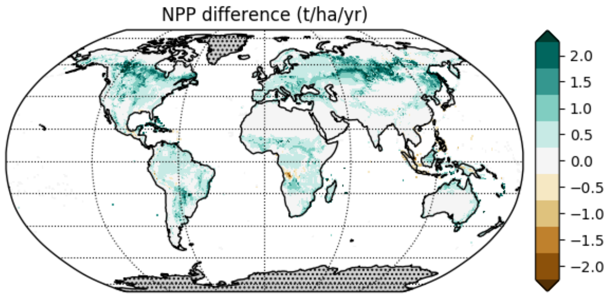
ΔET



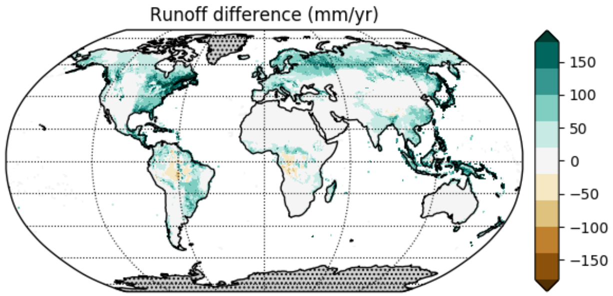
ΔSMC



ΔNPP



ΔRunoff

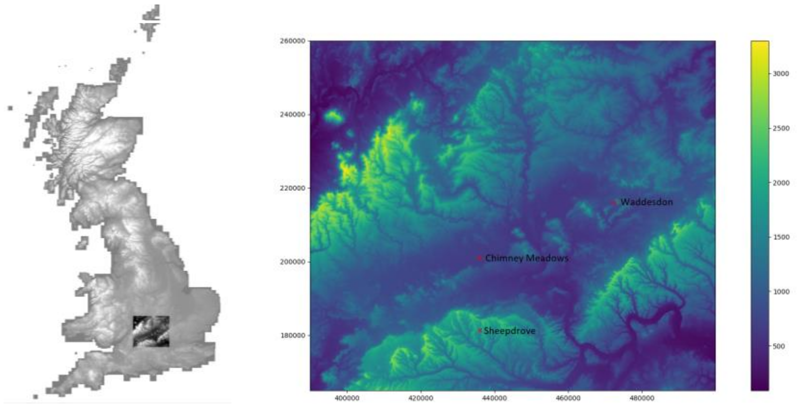


- Improved representation of energy balance will improve representation of NbS

Clustering in JULES

Liz Cooper

- Clustering ‘similar’ grid cells together can
  - reduce computational expense
  - allow for use of higher resolution underlying datasets
  - offer different approaches to sub grid heterogeneity

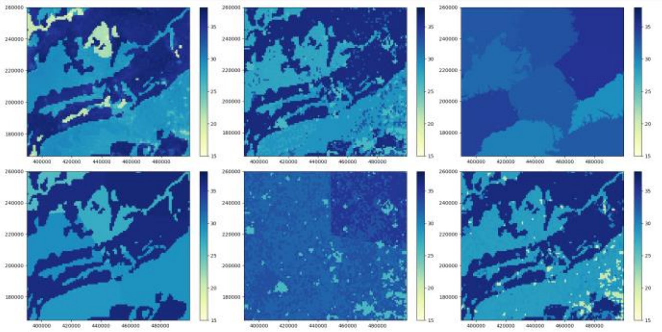


Study domain: 10,450 km^2

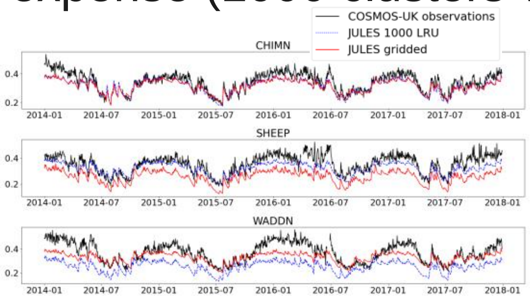
10450 grid cells for 1km gridded approach

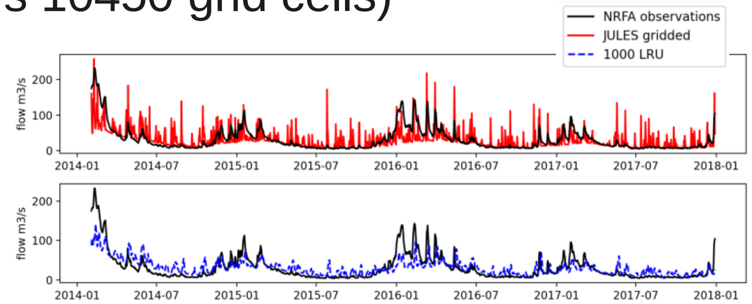
OR: 4,180,000 for 50m^2 grid cells

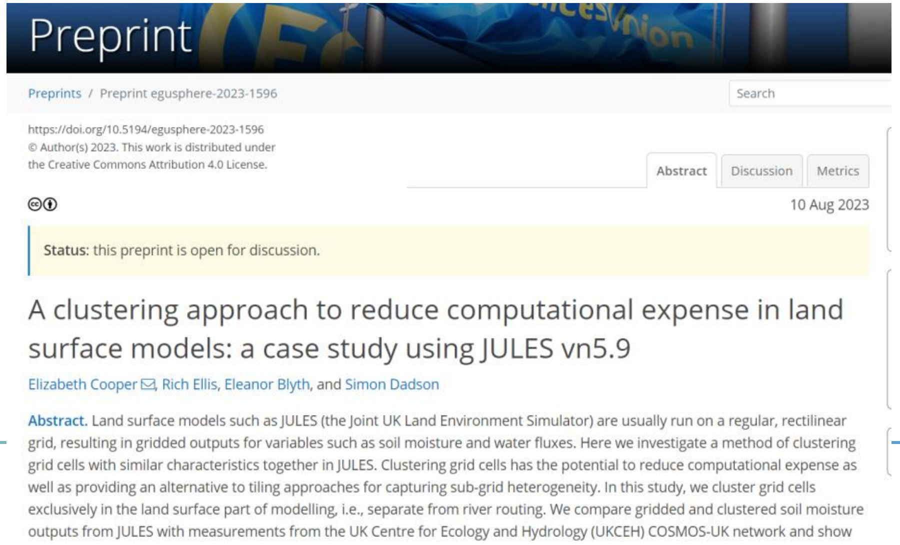
Clustering covariates are important



We can reproduce soil moisture and river flow time series pretty well for 10 times reduction in JULES computational expense (1000 clusters vs 10450 grid cells)






Preprint

Preprints / Preprint egusphere-2023-1596

https://doi.org/10.5194/egusphere-2023-1596

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Abstract | Discussion | Metrics

10 Aug 2023

Status: this preprint is open for discussion.

A clustering approach to reduce computational expense in land surface models: a case study using JULES vn5.9

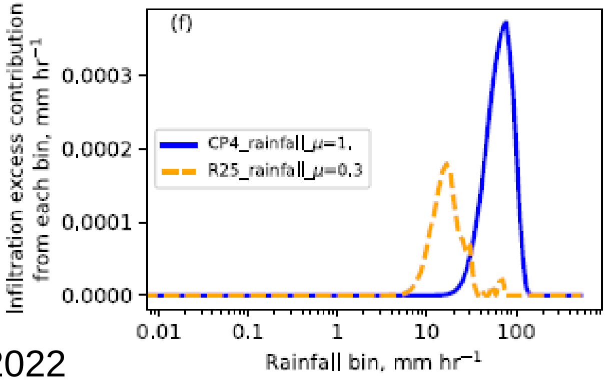
Elizabeth Cooper, Rich Ellis, Eleanor Blyth, and Simon Dadson

Abstract. Land surface models such as JULES (the Joint UK Land Environment Simulator) are usually run on a regular, rectilinear grid, resulting in gridded outputs for variables such as soil moisture and water fluxes. Here we investigate a method of clustering grid cells with similar characteristics together in JULES. Clustering grid cells has the potential to reduce computational expense as well as providing an alternative to tiling approaches for capturing sub-grid heterogeneity. In this study, we cluster grid cells exclusively in the land surface part of modelling, i.e., separate from river routing. We compare gridded and clustered soil moisture outputs from JULES with measurements from the UK Centre for Ecology and Hydrology (UKCEH) COSMOS-UK network and show

Douglas Clark, Liz Cooper, Sonja Folwell

Runoff

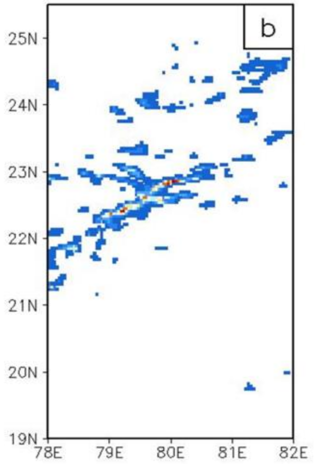
43% more surface runoff in 4km CPM v. 25km model (Africa-CP4)



Folwell et al., 2022

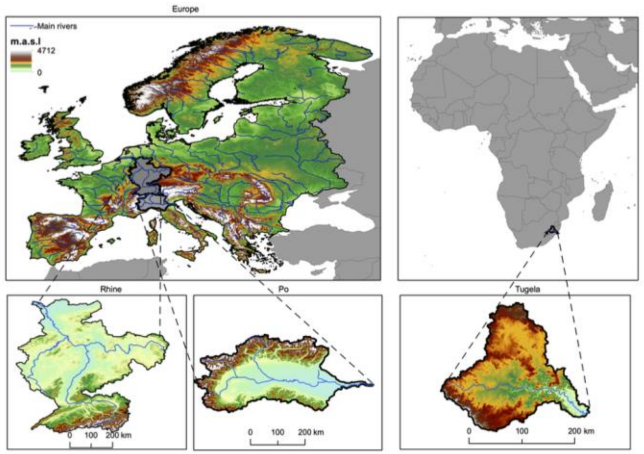
Surface ponding

4km JULES simulation of standing water in the wake of a monsoon depression (India)



Links to… ESA project 4DHydro

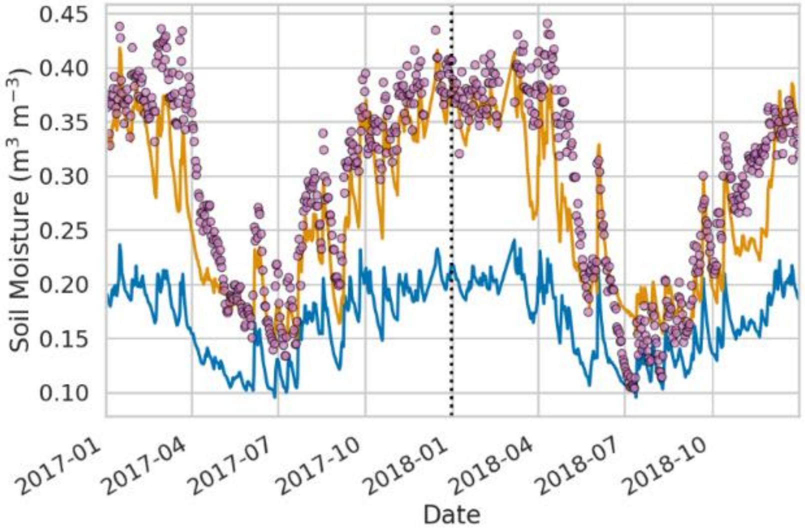
Hyper-resolution Earth observations and land-surface modelling for a better understanding of the water cycle



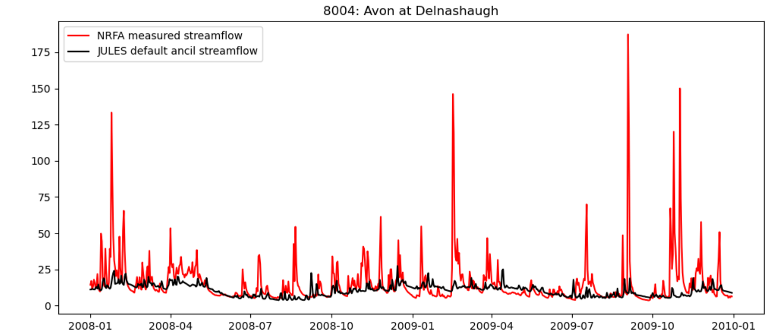
~1 km-scale simulations for:

- Continental Europe (6.5 million km^2), with a focus on Rhine and Po basins
- Tugela basin (South Africa)

Previously… we used COSMOS-UK soil moisture observations to improve soil moisture from JULES via the soil ancillary fields

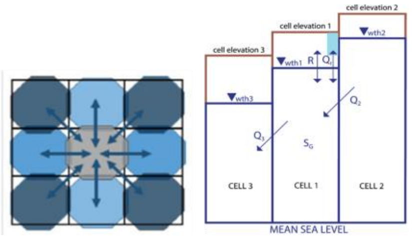


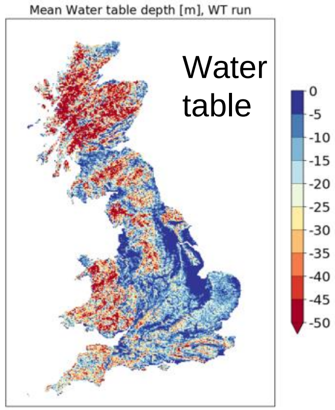
…with mixed results for river flow



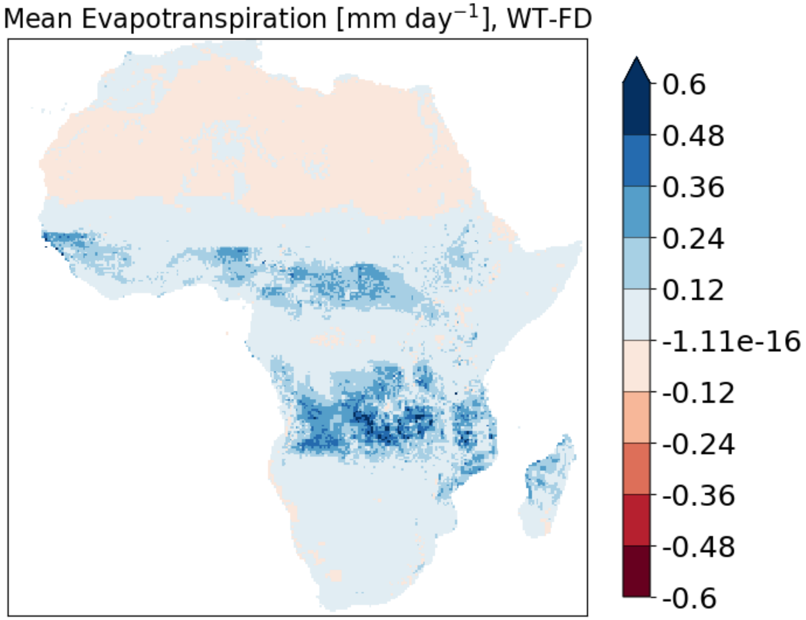
- We are building a system to optimise soil ancils based on both river flow and soil moisture observations (COSMOS-UK to start, but may also include satellite obs)
- Other activities: Using JULES-CaMaflood and SAR images for improved inundation modelling
  Investigating use of JEDI framework
  Land DA workshop early 2024

Previously we have implemented Dynamic Groundwater (DGW) in JULES and tested over GB.

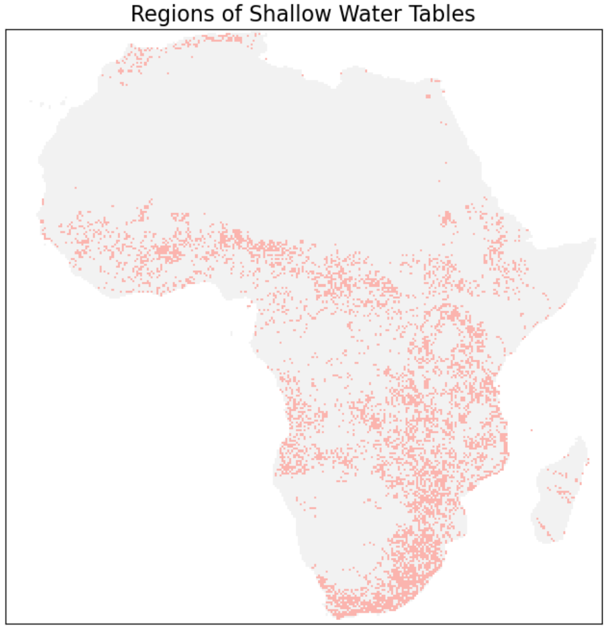




Now applying to Africa



Enhanced evaporation (freedrain – DGW runs)



Rose suite: https://code.metoffice.gov.uk/trac/roses-u/browser/c/d/4/3/9

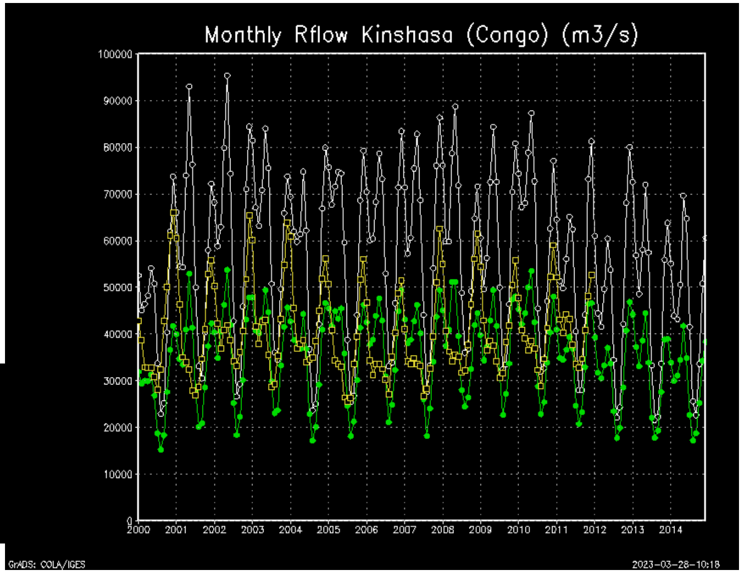
2000-2015 15-years simulations at 0.25deg resolution

Drivers from eartH2Observe (WFDI + MSWEP)

Also exploring how best to couple to UM and LFRic

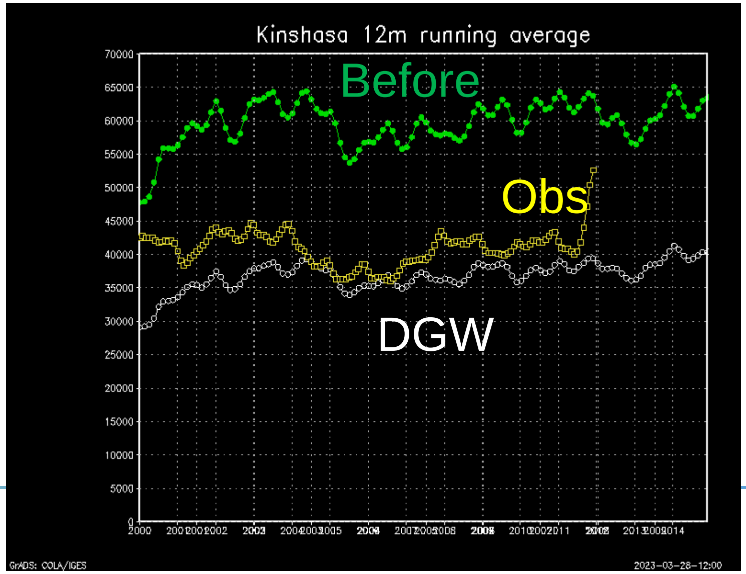
Groundwater – evaluation against GRDC river flow

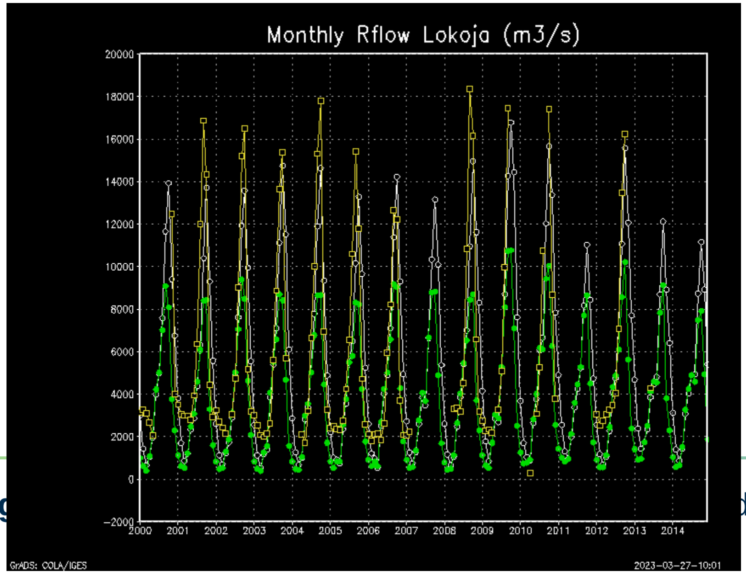
Alberto Martinez and BGS



- OBS
- WT run
- FD run

12 month running average improved using DGW





Niger: baseflow too low in both configurations

Some other activities in Hydro-JULES

Water quality modelling via UniFHy

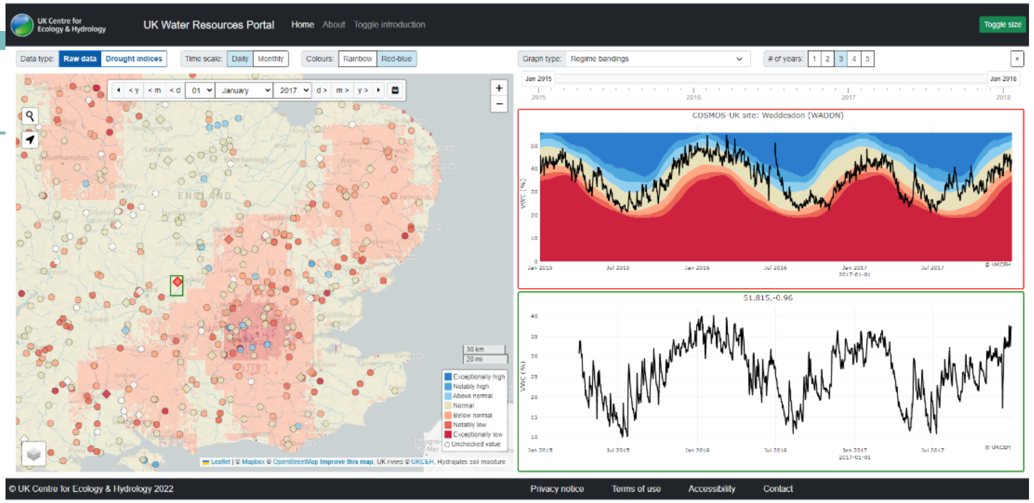
Groundwater modelling using MODFLOW6

Water resource modelling (in development)

High-resolution flood modelling

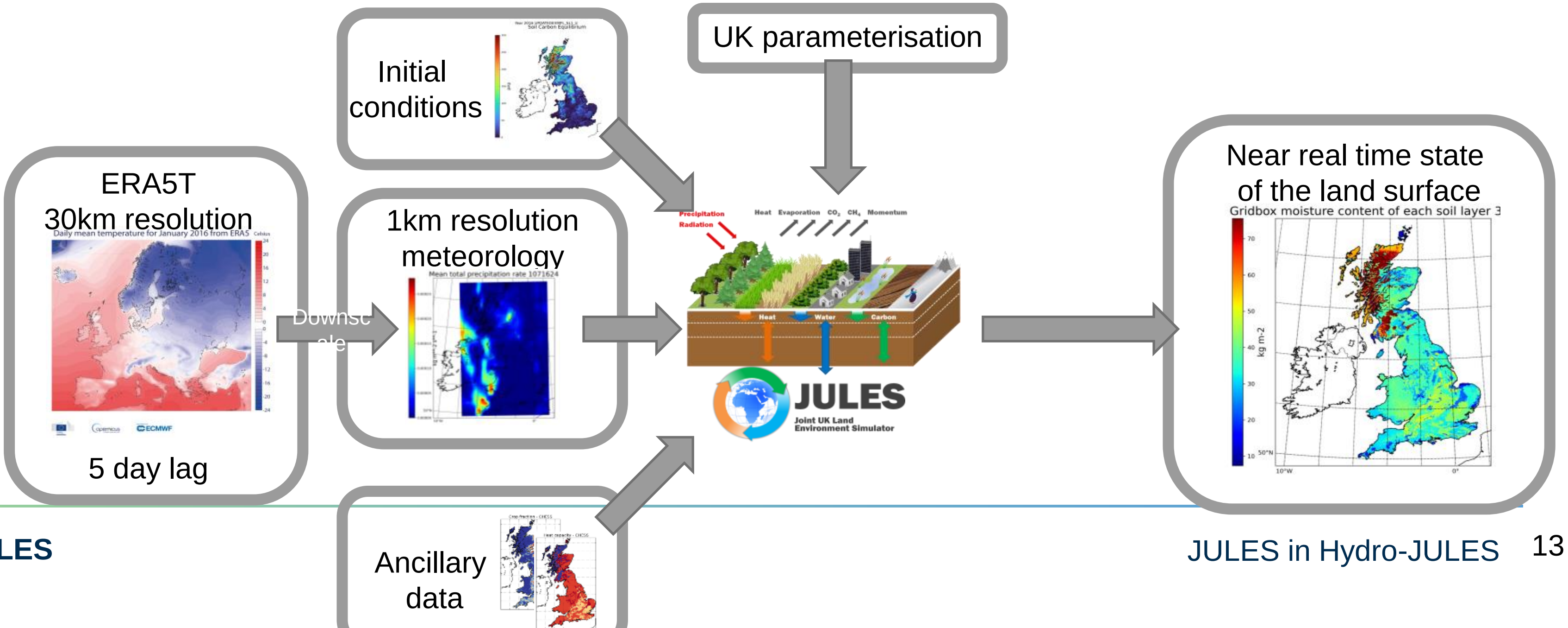
Infrastructure for Near-Real-Time modelling

Access to models and hydrological data via DataLabs



Prototype near-real-time soil moisture data served via Water Resources Portal

A prototype near-real-time digital twin



Other JULES work under National Capability

TerraFIRMA and others

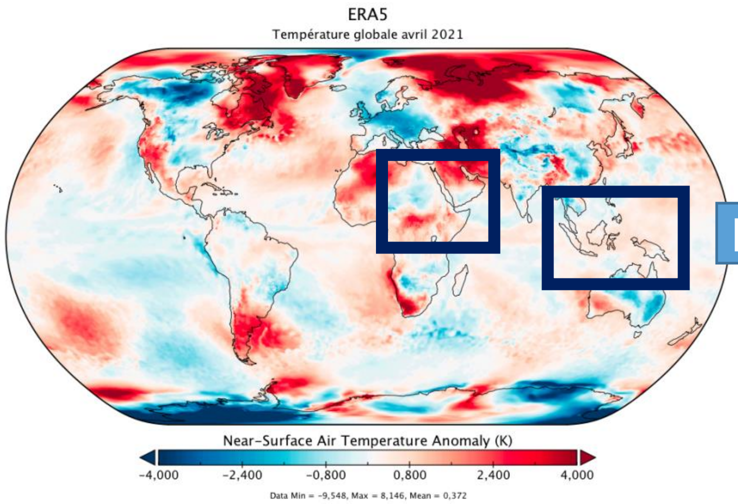
Fire modelling
Water resources and groundwater
Vegetation: thermal acclimation; dynamic allocation

CHAMFER

River modelling and land-ocean connections - see talk by Toby Marthews

NC International

ISI-MIP on JASMIN
km-scale downscaling for regional applications
Oil palm
Trade offs (C, water,…)



Downscale

Summary

Framework
Groundwater
Clustering
km-scale modelling
Nature-based solutions
Data assimilation
Towards coupled modelling