The CHAMFER and NC-International projects: JULES-related tasks

Toby Marthews, UKCEH Wallingford

with huge thanks to colleagues at

- UKCEH (all 4 sites),
- UK Met Office,
- Univ. Oxford,
- BGS and
- NOC Liverpool,
- Univ. Liverpool,
- Univ. Exeter,
- Aus. Bureau of Meteorology

5th September 2024

UK Centre for Ecology & Hydrology

Map credit: Robert Szucs

1. CHAMFER project

2. NC-International

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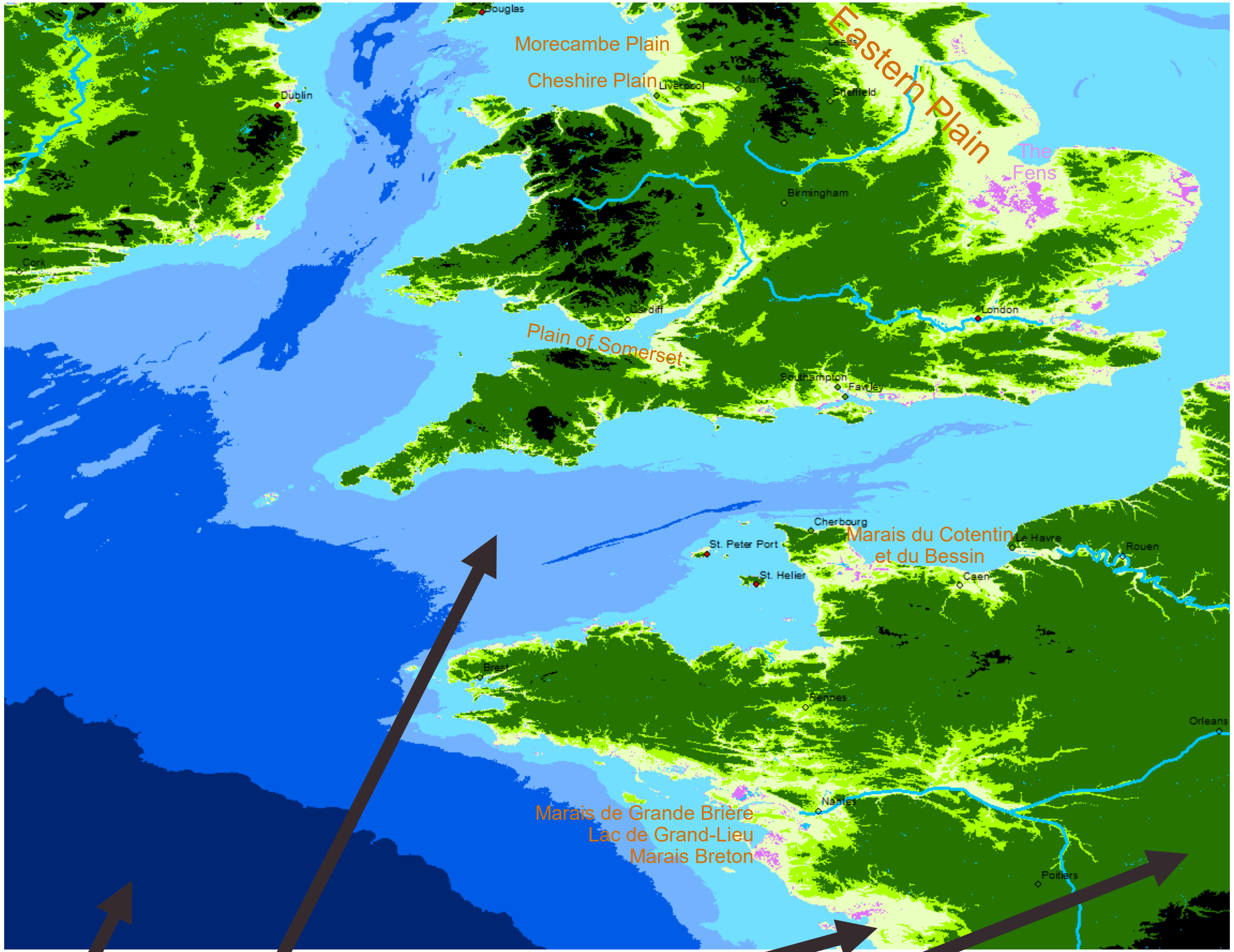
Focus on COASTS

Approximately one third of the UK population lives within 10 km of the coast (Hadley 2009)

Additionally, 200 million people worldwide live along coastlines less than 5 m above sea level, and it is estimated that this figure could increase to 400 to 500 million by the end of the 21st century.

In the UK, responsibility for coastal zone research is divided between UKCEH and NOC. However, I've been learning through my interactions with UKCEH Bangor and NOC that there is a great need for a more 'joined-up' approach to the coastal zone (q.v. #3 of Eleanor's six functions serviced by JULES).



UKCEH →

National Oceanography Centre →

UPLANDS / PIEDMONT (>60 m asl)

COASTAL PLAIN (yellow <30 m asl; light green <60 m asl)

COASTAL OCEAN / SHELF SEAS (light blue <60 m depth; middle <100 m; dark <200 m

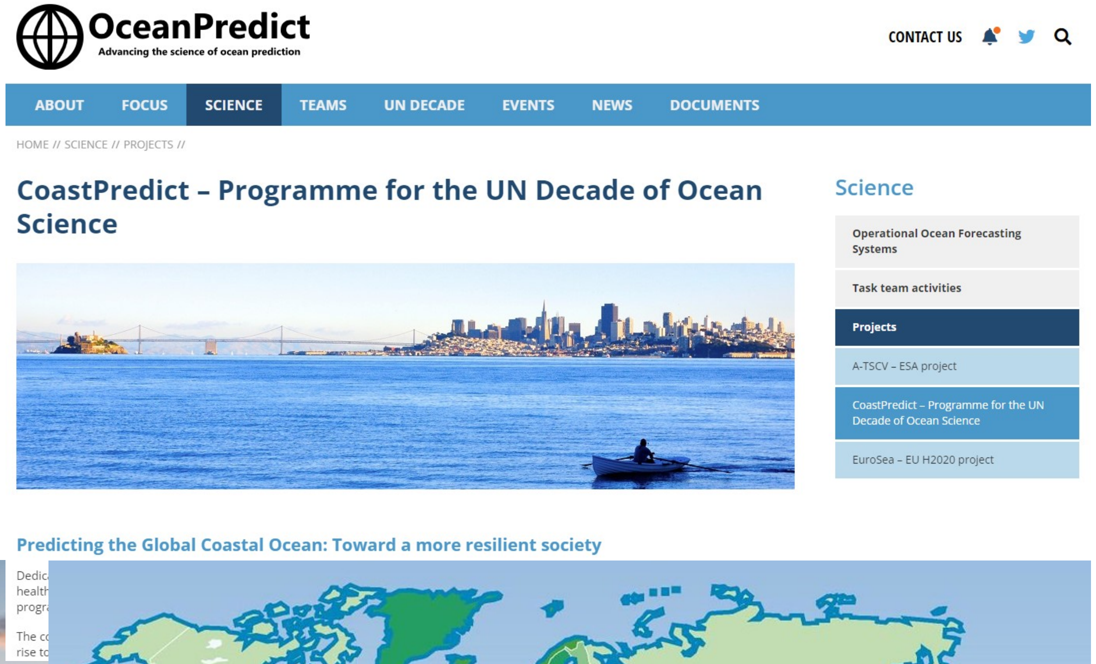
OCEANIC ZONE (>200 m depth)

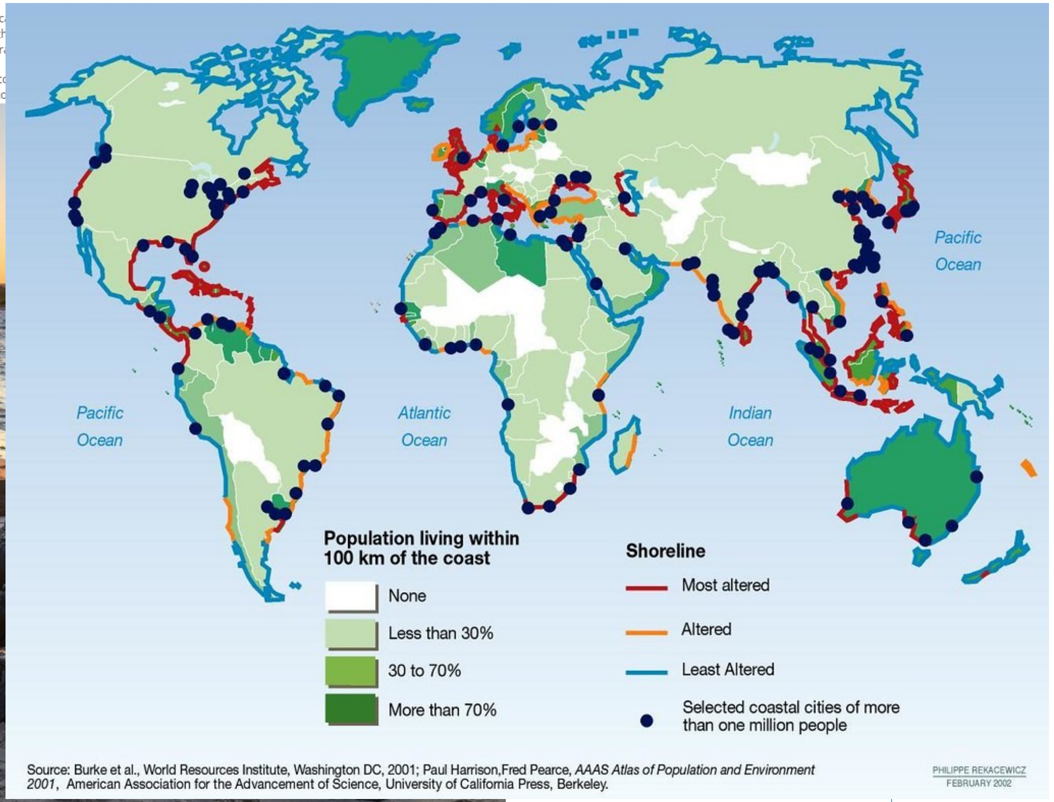
Focus on COASTS

New regional, national and international programmes highlight the importance of the coastal zone (both the coastal plain and the coastal ocean).

FLOOD 2023 & COAST
floodandcoast.com

Flood & Coast 24

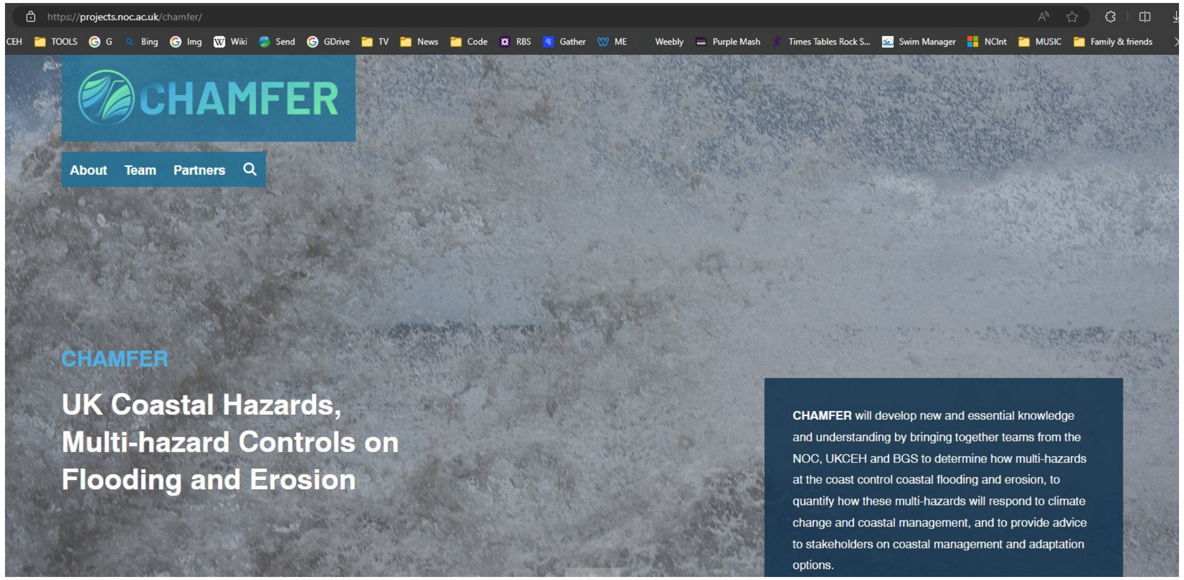


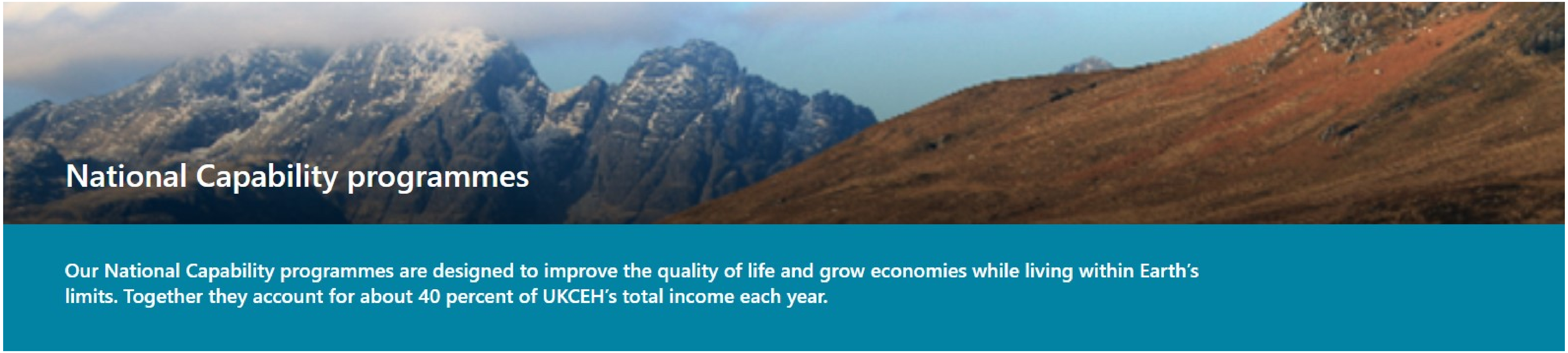


Modelling the Coastal Zone in CHAMFER

CHAMFER is a UK National Capability project.

https://projects.noc.ac.uk/chamfer/





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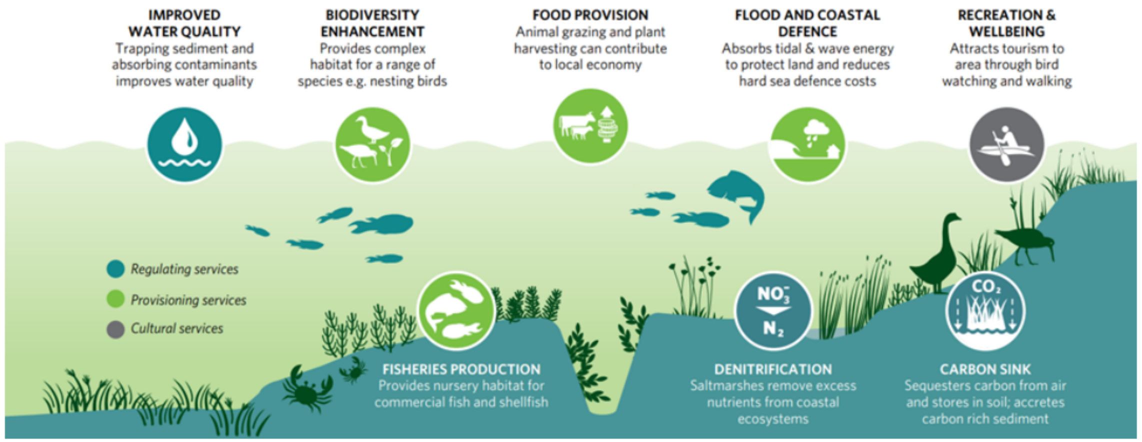
UK Coastal Ecosystems

CHAMFER is concerned with quantifying coastal impacts, including flooding, coastal erosion and ecosystem degradation.

In order to do this, we need to improve our understanding of UK coastal ecosystems and exchanges across this 'border zone' between the ocean and the land.

This is part of current attempts to quantify 'blue carbon'.



Saltmarshes provide a range of ecosystem services such as coastal defense improving water quality, enhancing biodiversity, supporting fisheries and grazing, recreation and wellbeing and storage and removal of carbon and excess nutrients. Graphic from: Hudson, R, Kenworthy, J and Best, M (eds) (2021). *Saltmarsh Restoration Handbook: UK and Ireland*. Environment Agency, Bristol, UK.

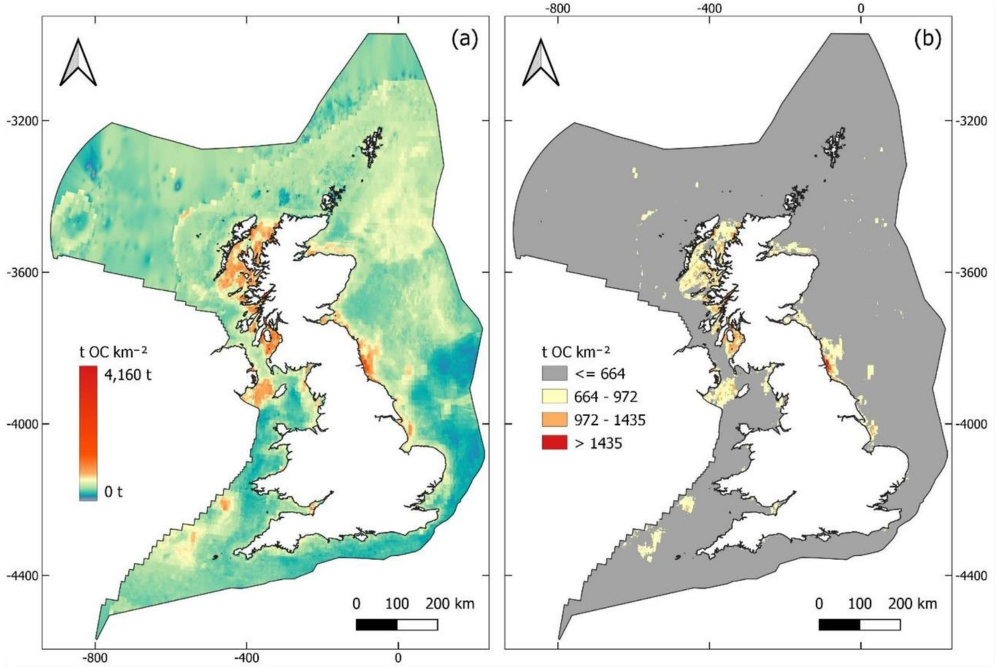
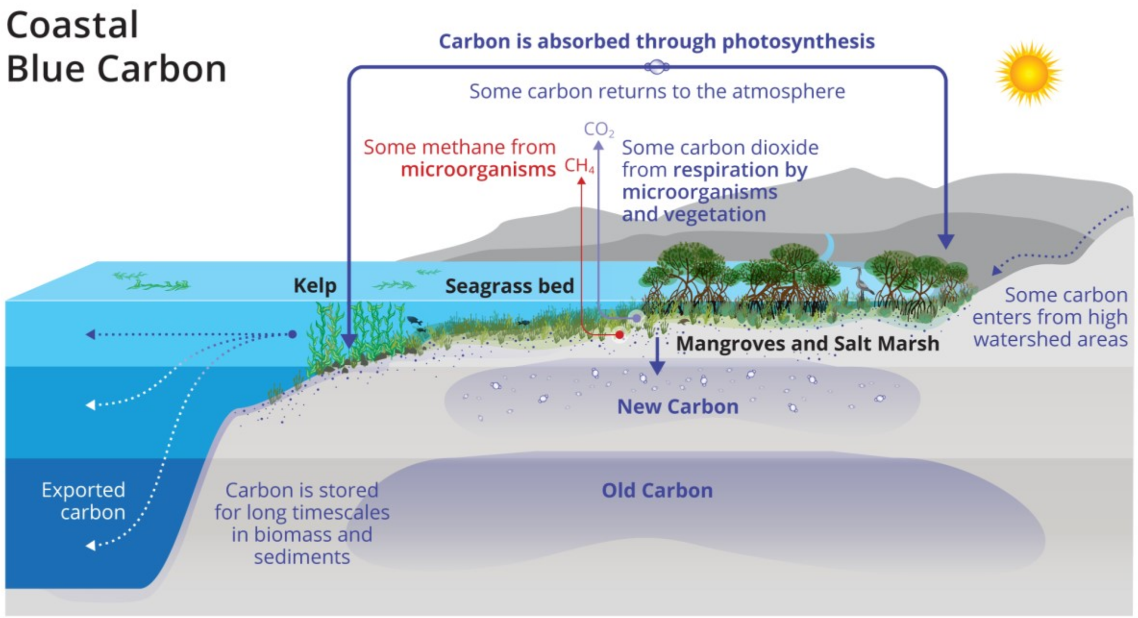


Fig. 1.Seabed organic carbon (OC) stocks in the top 10 cm of sediment across the UK EEZ.(A) Concentration of OC across the study area. Colours follow an exponential scale from low concentrations in blue to high concentrations in red. **(B)** Areas of the study region which contain the highest concentrations of OC. Colours are equivalent to highest 0.1% of values - red, 1% - orange, and 5% - yellow. From Epstein & Roberts (2022) https://doi.org/10.1101/2022.02.10.479679

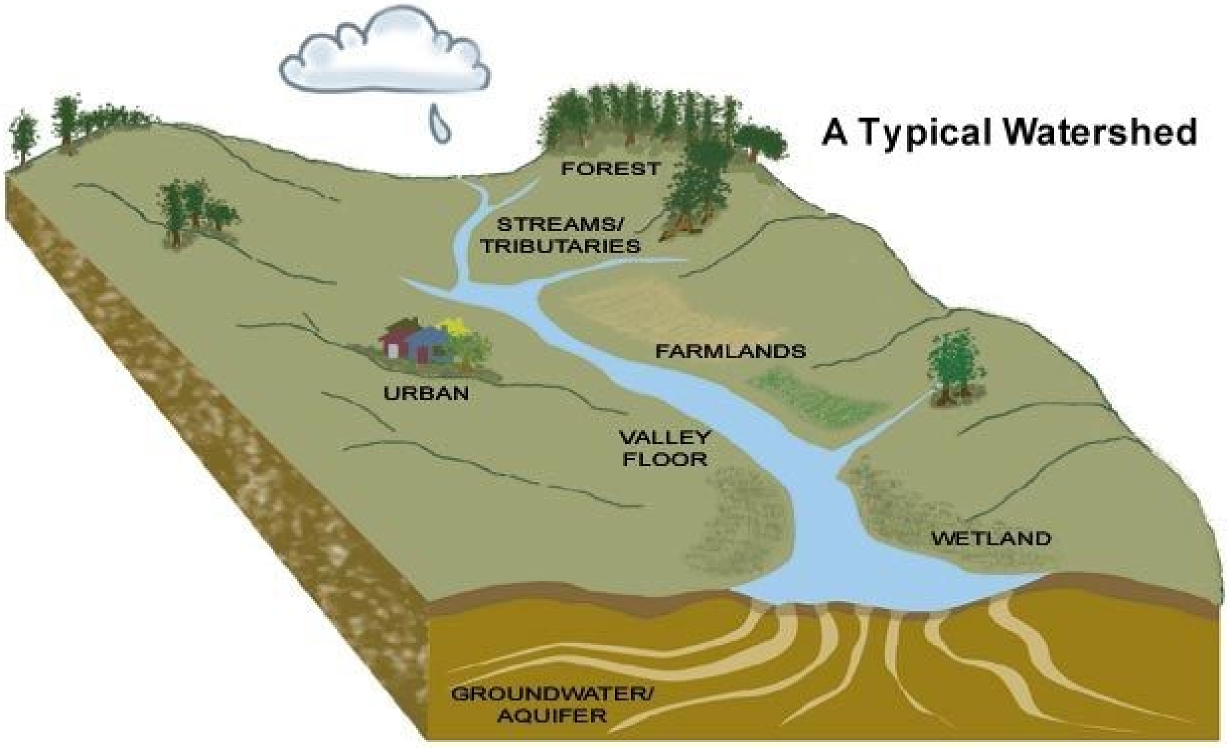


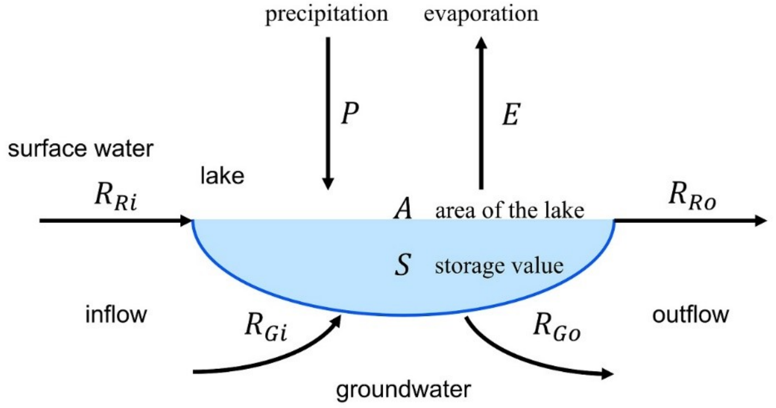
Inundation

On the land surface, the main stores of water are (of course) rivers and lakes, so we need to look at these very closely.

As with all land surface models, JULES calculates a water balance at each of its gridcells, which includes all the main movements of water into and out of that location.

However, water it doesn't always stay inside well-defined rivers and lakes: we need to be able to model inundation processes too.





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Inundation

At the moment, we cannot model all forms of inundation in JULES.

A good example comes from the CHaRIM project in Belize (2016): Three types of flooding: PLUVIAL (left), FLUVIAL (middle) and COASTAL (right).

In the *JULES* model, we have fluvial and pluvial flooding (to reasonable accuracy). Part of the CHAMFER project is to put in place the capability to include also coastal inundation.

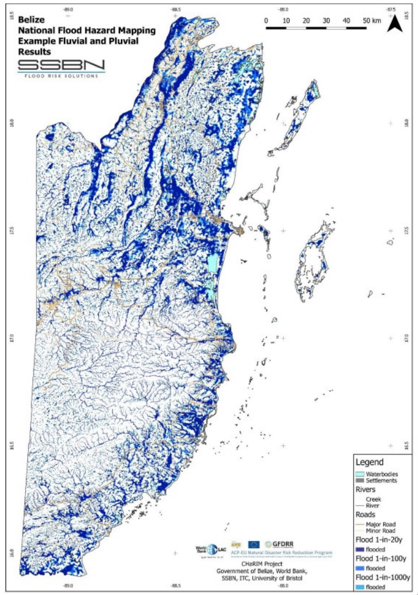


Figure 9 – Final fluvial and pluvial results for Belize NFHM. Note, only 3 return periods out of 10 shown for clarity.

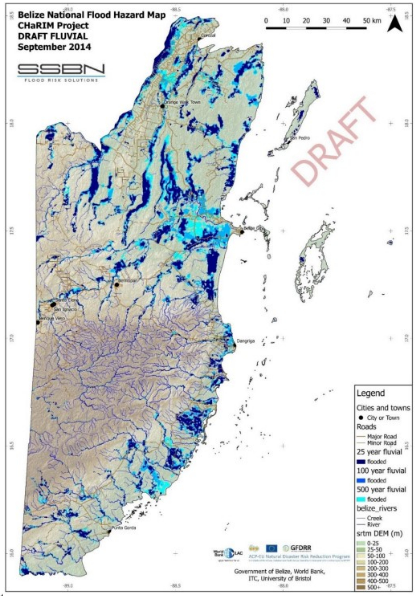


Figure 8 – Draft Fluvial (no pluvial or coastal) National Flood Hazard results for Belize.

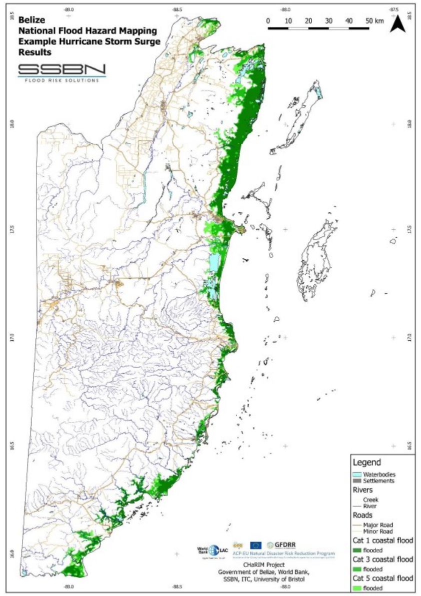


Figure 10 – Final coastal flood results for Belize NFHM. Note, only 3 out of 5 categories shown for clarity.

CHaRIM Project (www.charim.net)
Belize National Flood Hazard Mapping
Methodology and Validation Report
(FINAL VERSION)

SSBN Ltd & University of Bristol, as part of ITC Consortium

Date:

17 May 2016

Authors:

Mark Trigg, Senior Engineering Hydrologist and Flood Risk Expert, Willis Research Fellow, University of Bristol

Andrew Smith and Christopher Sampson, National Flood Hazard Modelling Experts, SSBN Ltd

Inundation

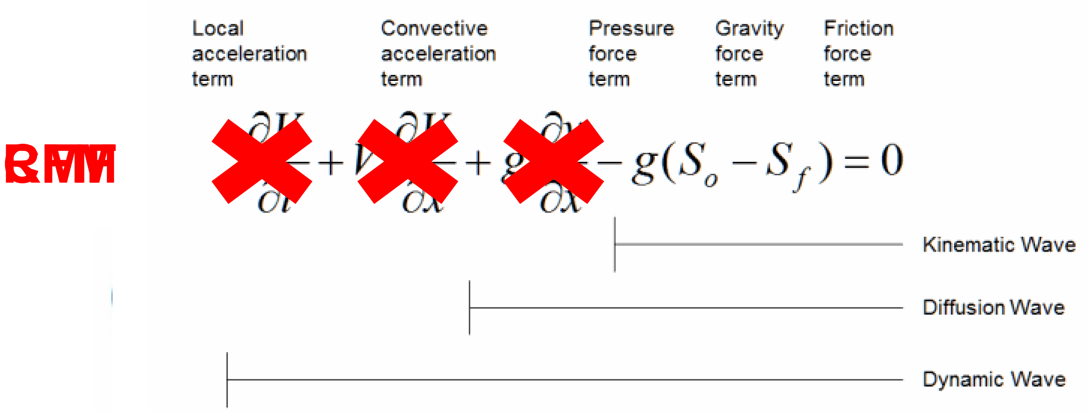
Our approach is to use the well-tested global hydrodynamic model *CaMa-Flood*. This is a necessary 'upgrade' from the current river models in *JULES* (called *TRIP* and *RFM (=River Flow Model)*).

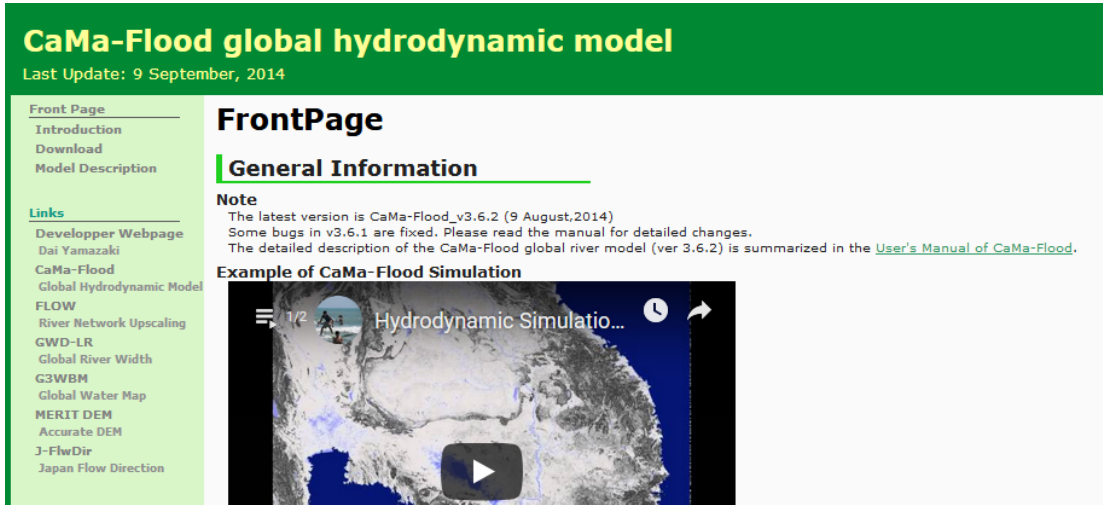
A key part of this upgrade is moving from a kinematic wave model (used by *RFM*) to a local inertial approximation where only the convective acceleration term is neglected (de Almeida & Bates 2013).

de Almeida GAM & Bates P (2013). Applicability of the local inertial approximation of the shallow water equations to flood modelling. *Water Resources Research* 49:4833-4844.

Various Forms of the Momentum Equation

$$\frac{1}{A}\frac{\partial Q}{\partial t}+\frac{1}{A}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+g\frac{\partial y}{\partial x}-g(S_o-S_f)=0$$





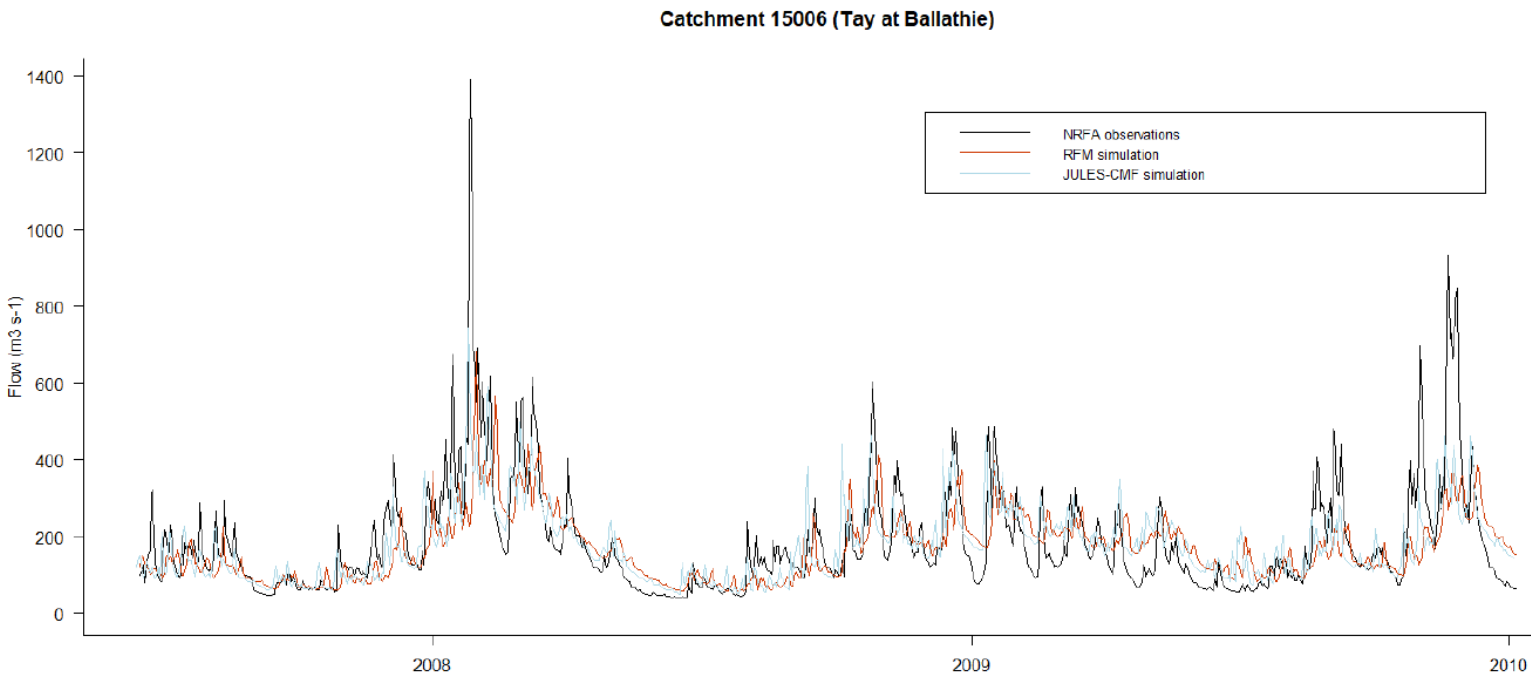
CaMa-Flood is a Global Hydrodynamic model developed by Dai Yamazaki at Univ. Tokyo. It is the only open-source global river routing model based on the local inertial approximation of the Saint Venant equations.

Crucially, this version of the Saint Venant equations includes *backwater effects*, i.e. temporary reversals of flow in river branches.

This is something we need to be able to model coastal inundation: NEMO communicates the height of the sea wall to JULES (via Oasis), but then the river routing scheme in JULES must be able to allow that water to travel upstream to produce inundation. This is not possible with RFM because it follows the kinematic wave equation that assumes no flow reversals.

Inundation

We are currently assembling all the UK data we need to use *CaMa-Flood* and make these sorts of predictions.

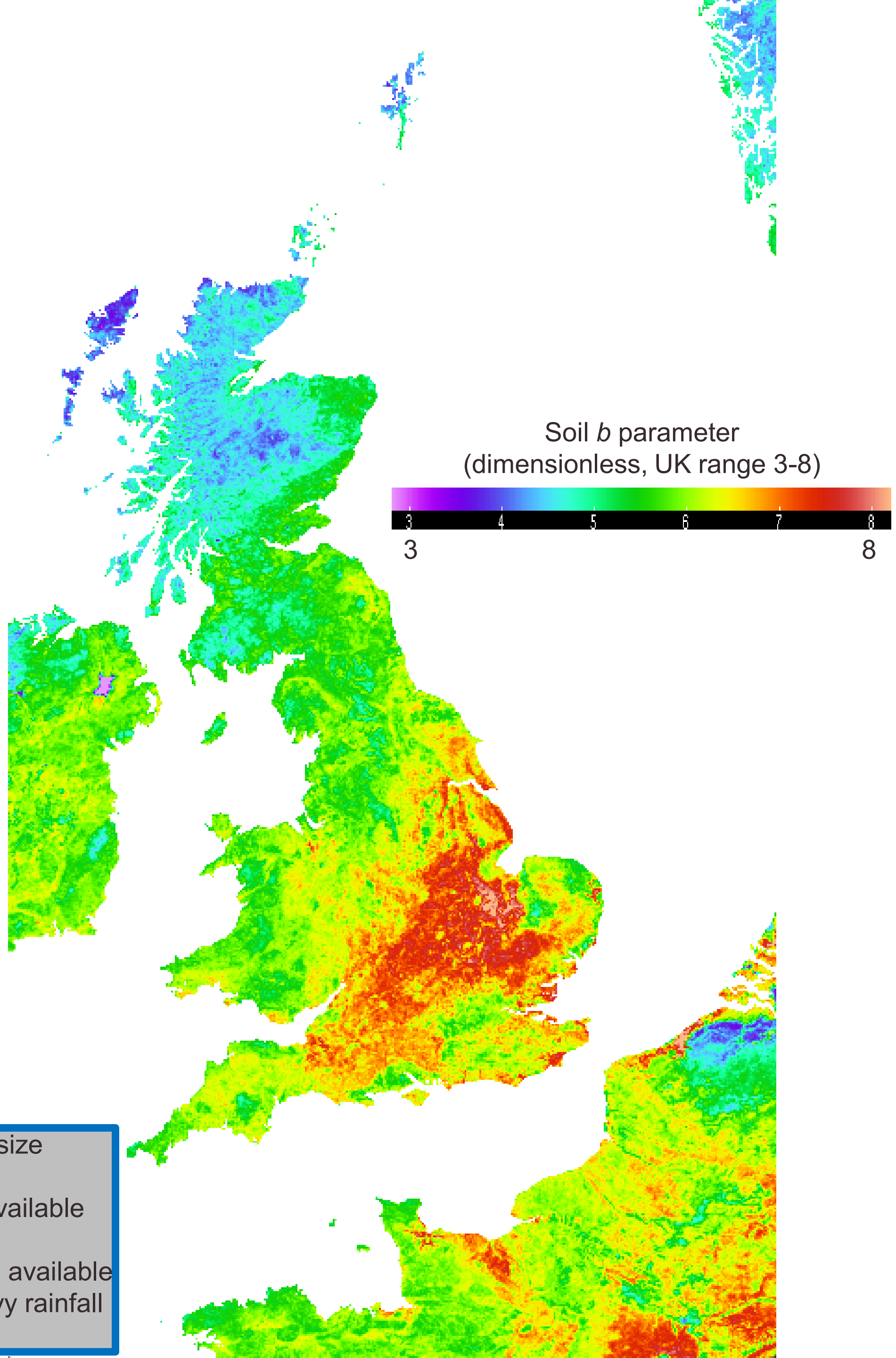


Improved Hydrology for Regional Environmental Prediction

Elizabeth Cooper, Alberto Martínez-de la Torre, Toby Marthews, Rich Ellis, Alison Kay, Matthew Wiggins, Simon Dadson, Ponnambalam Rameshwaran, Nick Reynard and Douglas Clark

UK Centre for Ecology and Hydrology,

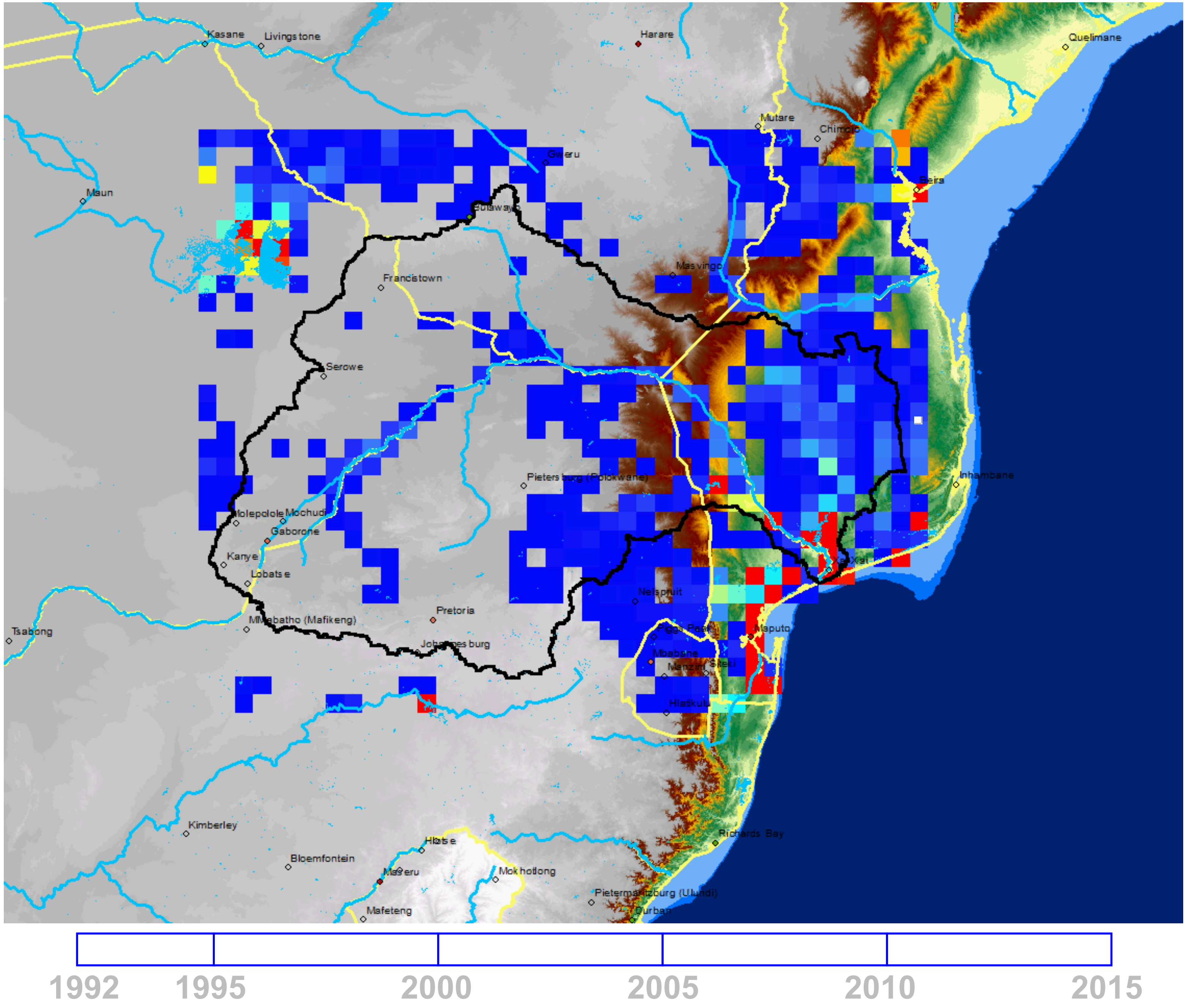
What is the Soil *b* parameter? It's a 'pore size distribution parameter':
LOW VALUES = the SWC is steep, so available water decreases rapidly as soil dries
HIGH VALUES = the SWC is gradual, so available water remains higher for longer after heavy rainfall (= generally better for agriculture).

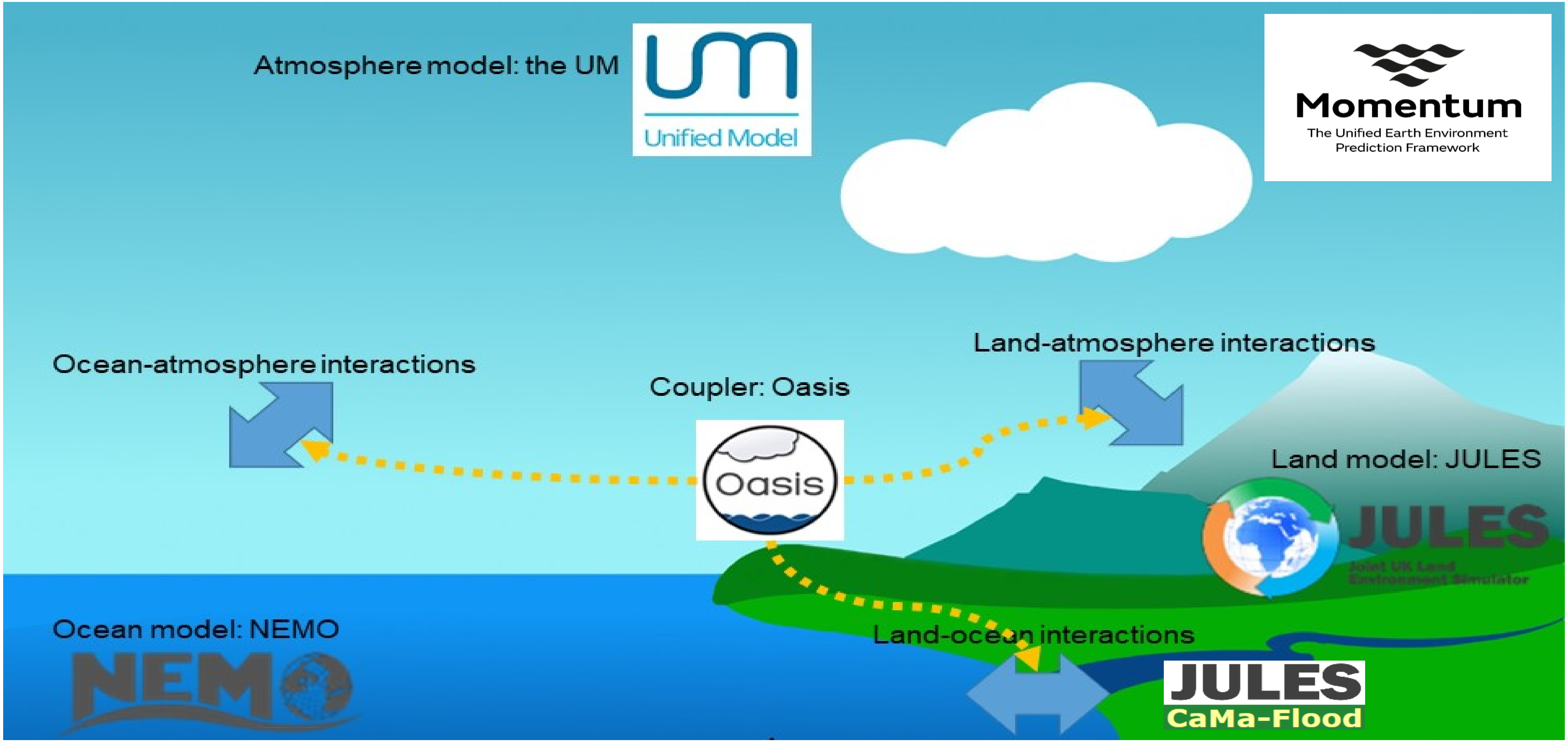


Limpopo river basin Southern Africa

As an example of how this can be used, I generated surface inundation data for the Limpopo river basin in Southern Africa.

- 22 years of data showing seasonal ebb and flow.
- Generated using the CaMa-Flood hydrodynamics module, driven by JULES runoffs.
- Animation done in ArcGIS





Coupling arrangements of the UK Met Office's *Momentum* framework, of which *JULES* is a part.

Marthews TR, Wiggins M & Garbutt A (2023). The land-ocean interface in land surface models. *UKCEH Report*.

A new UK scale ocean-wave-river modelling system for predicting extreme sea levels at the coast

Michela De Dominicis[1] , Lucy Bricheno[1] , Ryan Patmore[1] , Toby Marthews[2] , Segolene Berthou[3] , and Laurent Amoudry[1]

[1]National Oceanography Centre, Liverpool, United Kingdom (micdom@noc.ac.uk)
[2]Centre for Ecology and Hydrology, Wallingford, United Kingdom
[3]Met Office, Exeter, United Kingdom

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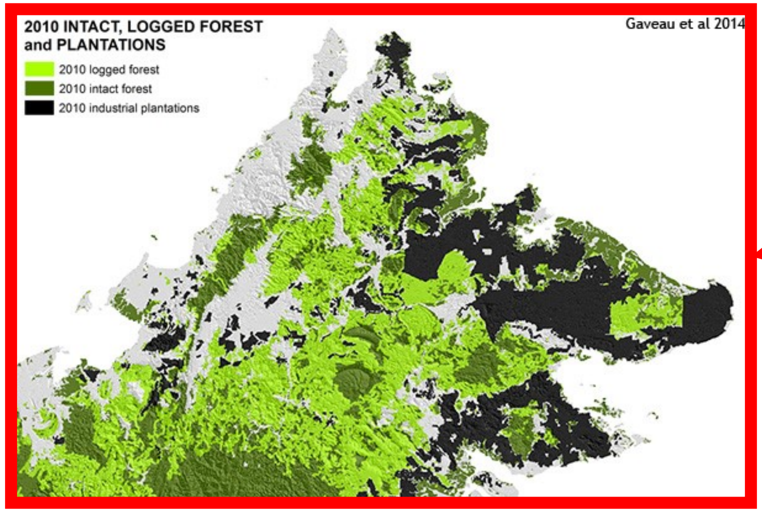
JULES & Oil Palm

WP1B: Informing land management options for Net Zero+ in **Southeast Asia**

- My task focuses on **oil palm**



- Test run area is Sabah, Malaysia, where there are substantial oil palm plantations

- Can we use JULES at 1km resolution with an added oil palm plantation 'plant functional type' (PFT) to make future predictions?

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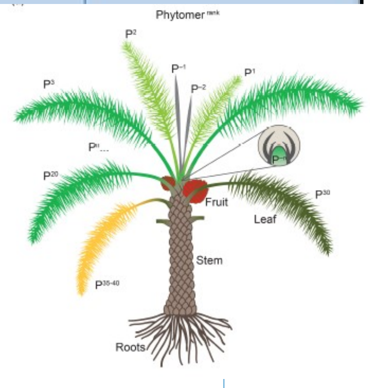

JULES & Oil Palm

- JULESvn7.3 used with 15PFTs (a standard-ish 13 PFT setup + 2 PFTs for oil palm plantations, developed with help from Emma Littleton at Univ. Exeter).

- I have two oil palm PFTs to account for differences between smallholder and commercial plantations in SE Asia.

- For oil palm, assumed (for now) a universal LAI 2 m^2/m^2 and canopy height 10 m.

- Driving data comes from ISIMIP (Mathison *et al.* 2023), regridded to 1km resolution for period 2000-2050 (historical data to 2014, scenario SSP585 from UKESM1-0-LL thereafter) and cropped to the domain. No downscaling (for now).

- Ancillaries generated from many sources, including *SoilGrids* for soils, *CropGrids* for oil palm distribution (Tang *et al.* 2024).

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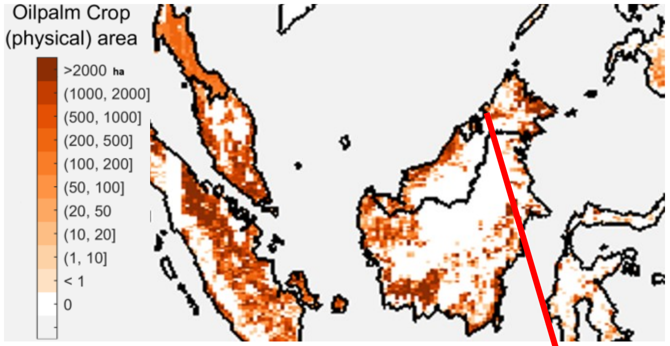
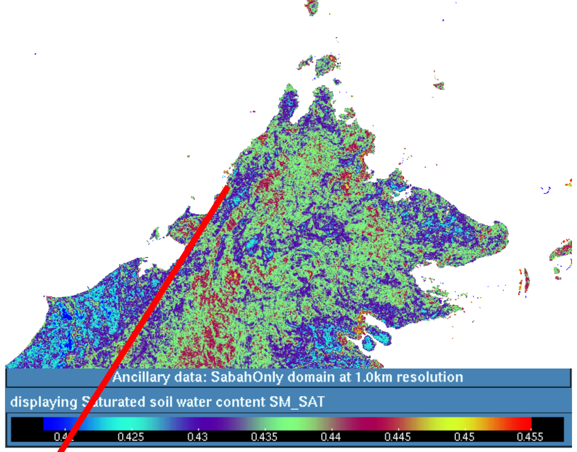
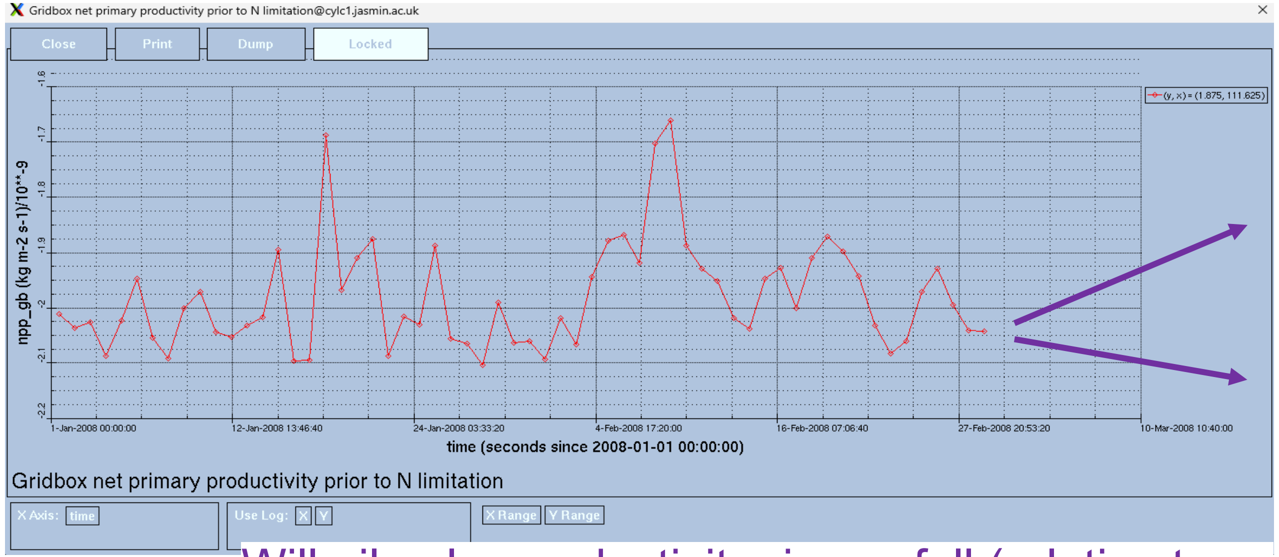


Global distribution of oil palm plantations from CropGrids at 0.05° resolution



Ancillary data generated at 1 km resolution

At an oil palm gridcell near Kota Kinabalu, productivity (NPP) varies over time.



Will oil palm productivity rise or fall (relative to other PFTs) under climate change?

JULES should be able to tell us this.

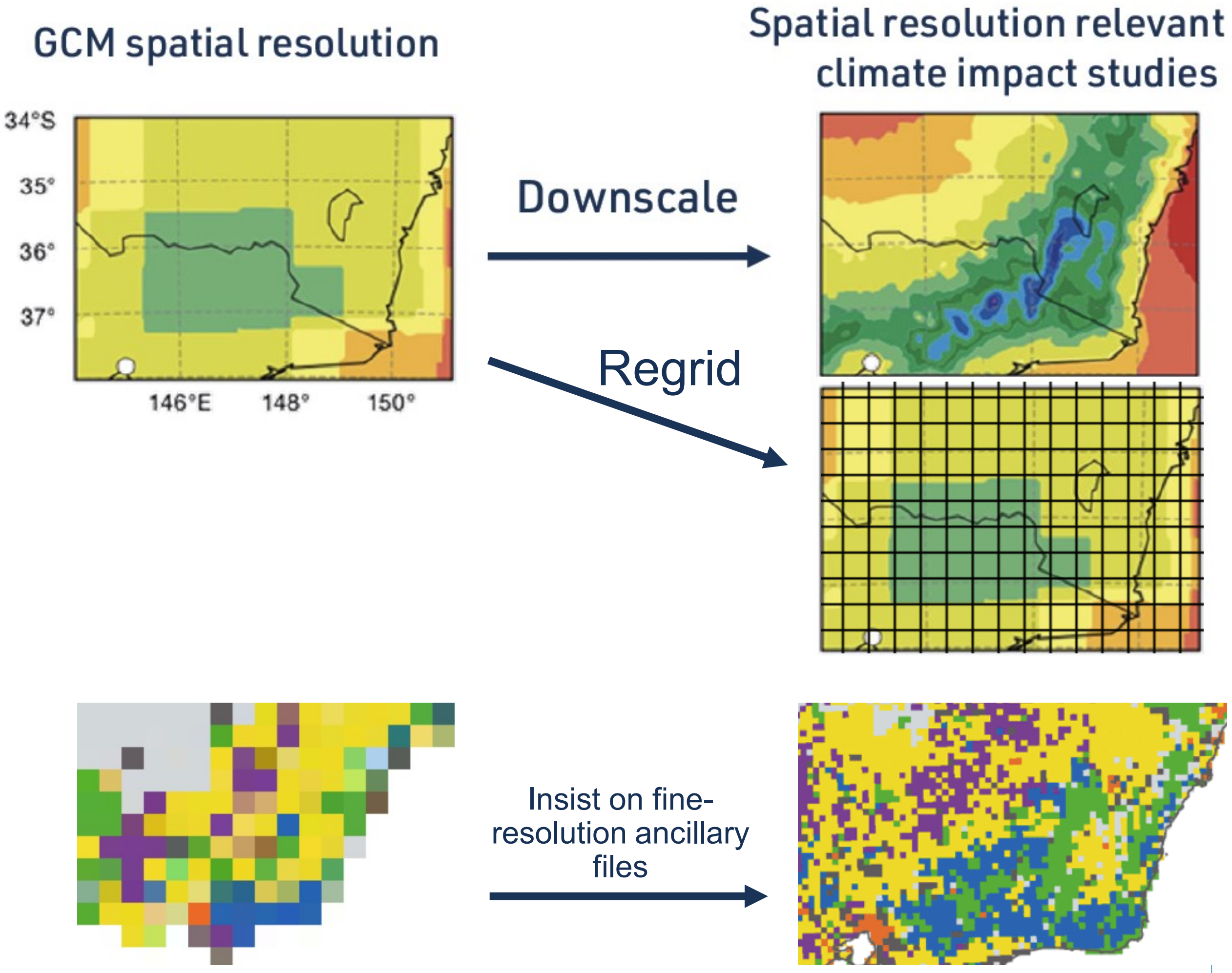
WP1B. Informing land management options for Net Zero+ in Southeast Asia

In WP1B, while waiting for downscaled met data (to be generated in WP1A), I am using an alternative source to make **provisional runs** (provisional because I am using regridded climate data rather than the downscaled data we eventually intend to use in NC-International).

Regrid means (here) to take GCM climate data and simply copy the numbers to a finer resolution grid, producing approximate values for a fine-scale run.

Downscale means additionally to apply an algorithm that uses ancillary information (e.g. topography) and locally-optimised rule sets to deduce a most likely fine-resolution version of the GCM data.

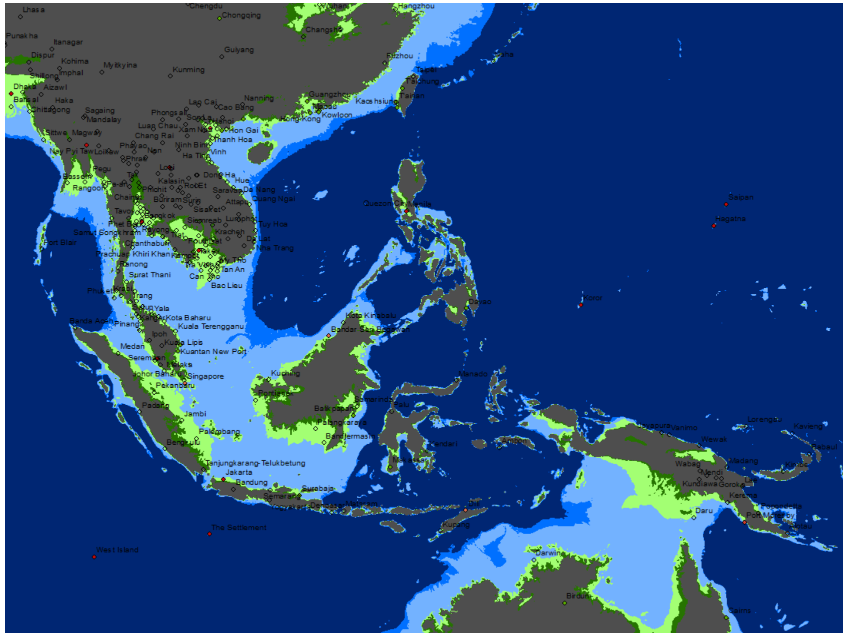
- Downscaling is better than regridding, of course, but deducing those rule sets can involve a large investment of time.
- If we know that our simulation results will most likely be more sensitive to ancillary data than to driving data (e.g. in the aseasonal tropics), then we can opt for regridding the climate data and devote more effort to improving the ancillary data (e.g. land use maps). This approach can provide good, provisional results.



WP1B. Informing land management options for Net Zero+ in Southeast Asia

My first step was to implement JULES with crops over SE Asia without oil palm at 2 deg resolution. Results are below.

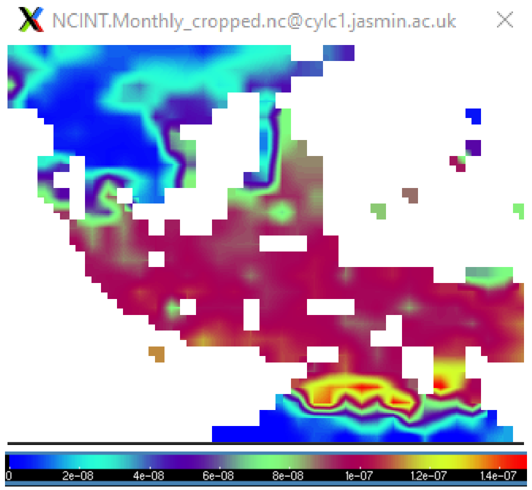
(I am using *TRIFFID-Crop*: n.b. for the 4 different options for modelling crops in JULES, see https://jules.jchmr.org/research-community-configurations).

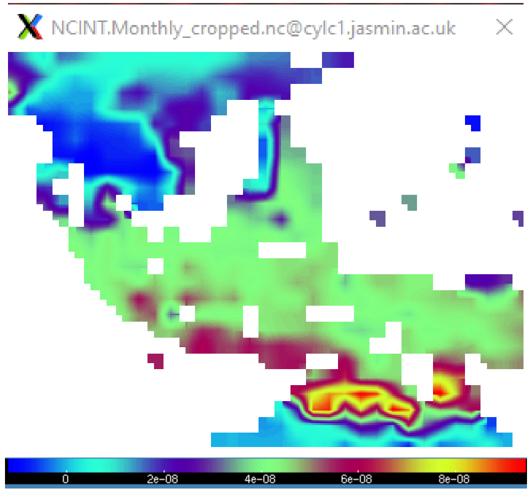


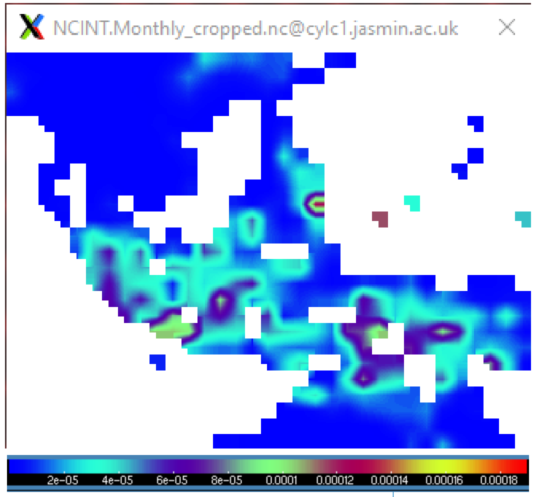
Next, I upped the resolution to 1km and focused on Sabah.

Examples are:

- **Gross Primary Productivity** (GPP, gridbox) in kg/m2/s (left)
- **Net Primary Productivity** (NPP, gridbox) in kg/m2/s (middle)
- **Surface runoff** (gridbox) in kg/m2/s (right)



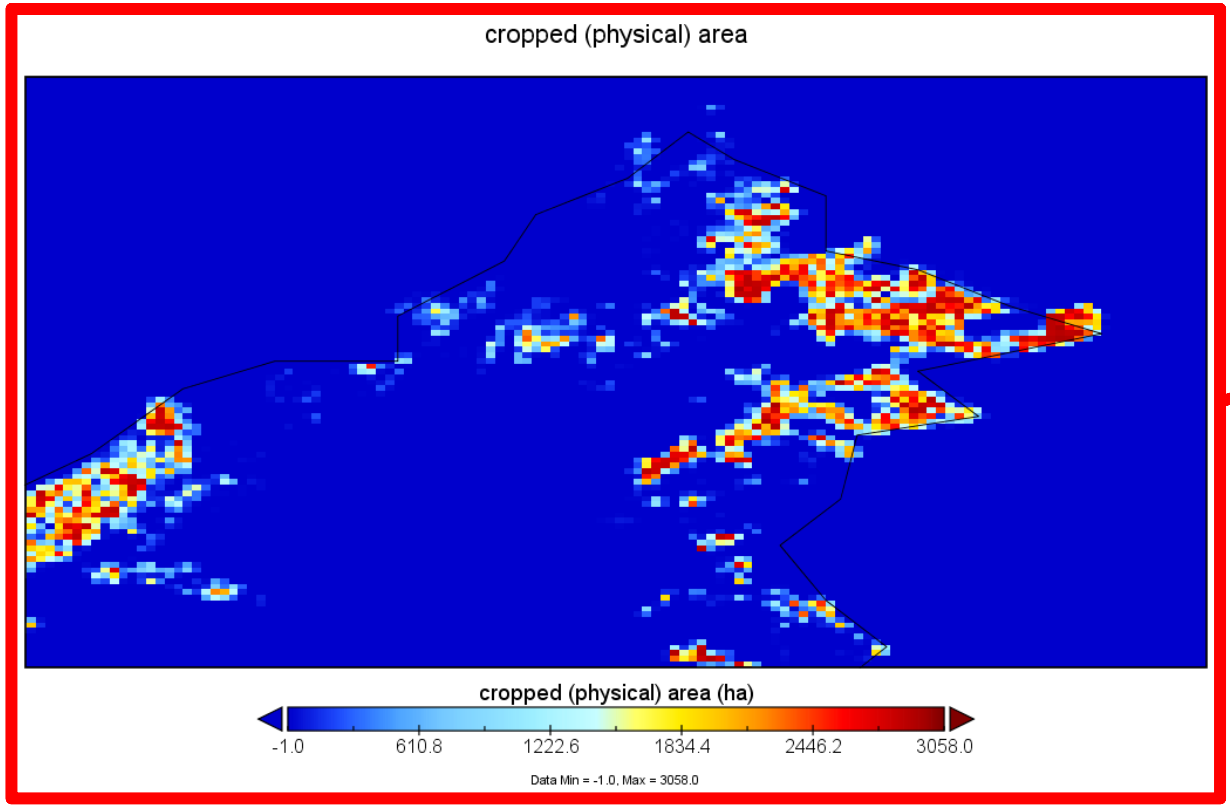


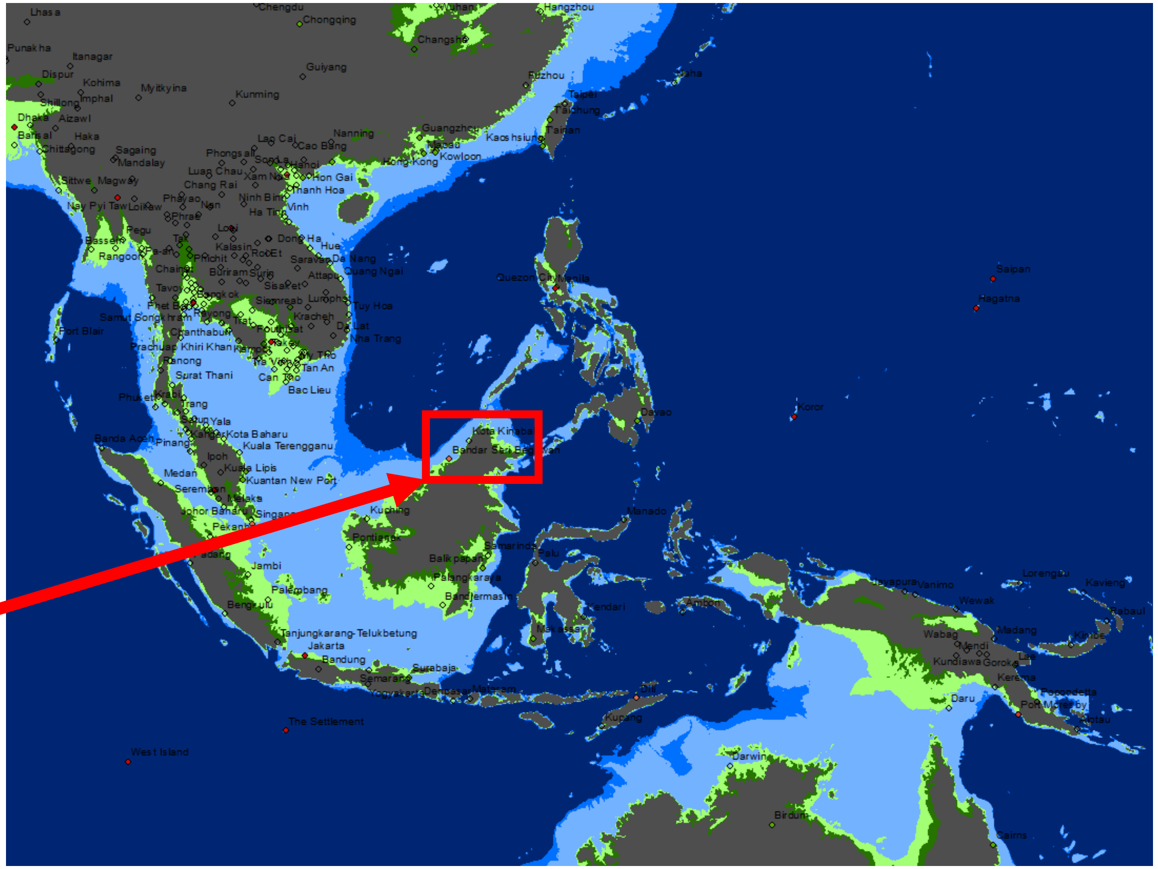


WP1B. Informing land management options for Net Zero+ in Southeast Asia

Next, 1km runs over Sabah, Malaysia.

I'm using Tang *et al.* (2024)'s *CropGrids* distribution of oil palm (data from 2020) as a first guess at oil palm distribution.





WP1B. Informing land management options for Net Zero+ in Southeast Asia

I will be working with Dr Albanito at UKCEH Bangor doing a comparison simulation.

Fabrizio will be running APSIM and I will be running JULES and we will both be trying to characterise oil palm dynamics as closely as possible across 40 oil palm farms in Malaysia, with validation data provided by Prof. McNamara at UKCEH Lancaster.

Prof. Niall P McNamara

Group Leader, Plant-Soil Interactions

Dr. Fabrizio Albanito

Senior Soil Health and Carbon Specialist

APSIM

AGRICULTURAL PRODUCTION SYSTEMS SIMULATOR

The CHAMFER and NC-International projects: JULES-related tasks

Toby Marthews, UKCEH Wallingford
https://www.tobymarthews.com/

For more information, please get in touch!

@UK_CEH
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Map credit: Robert Szucs

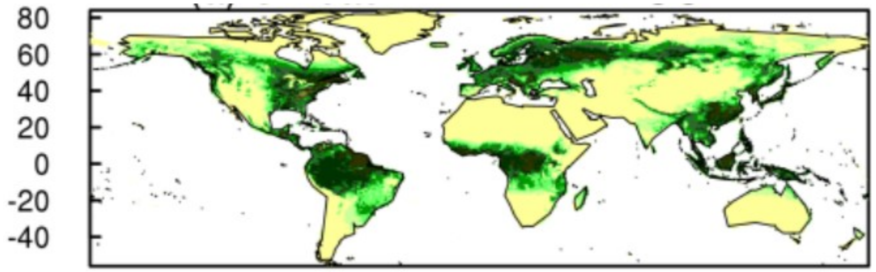
1A Global modelling for Net Zero [slide from Emma Robinson]

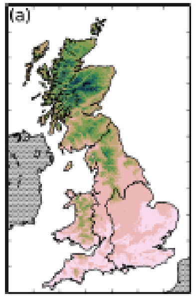
This project will:

- Quantify C uptake and storage (and associated water stores) at the global scale for future scenarios, including adaptation of plant physiology
- Provide meteorological data and JULES model outputs, globally at 0.5°and regionally at ~1km – to be used by other studies
- Create workflows that can generate data for any region at ~1km and a prototype for Near Real Time provision
- Improve coordination of the global-scale terrestrial modelling community

Current land surface models do not represent plant adaptation, and input data at a suitable scale for regional applications are not readily available.

Recent activities (e.g. in Hydro-JULES and UK-Scape) have provided building blocks, and are developing an international community and activities (e.g. the International Land Modelling Forum).





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