Rivers, inundation and validation against observations

Toby Marthews
Oxford, Sep 2022

Flooding in the UK

1. Background
2. Current work
3. Next steps / future projects

1. Background

Inundation

We are all aware that flooding and related extreme events are happening with increasing frequency around the world.

Pakistan is very much in the news right now, but this does seems to be part of a global phenomenon (which may or may not be related to La Niña).


NDTV LIVE TV LATEST INDIA COVID OPINION VIDEO CITIES WORLD OFFBEAT TRENDS

Pakistan Floods: UN Appeals For $160 Million Aid For Worst Affected

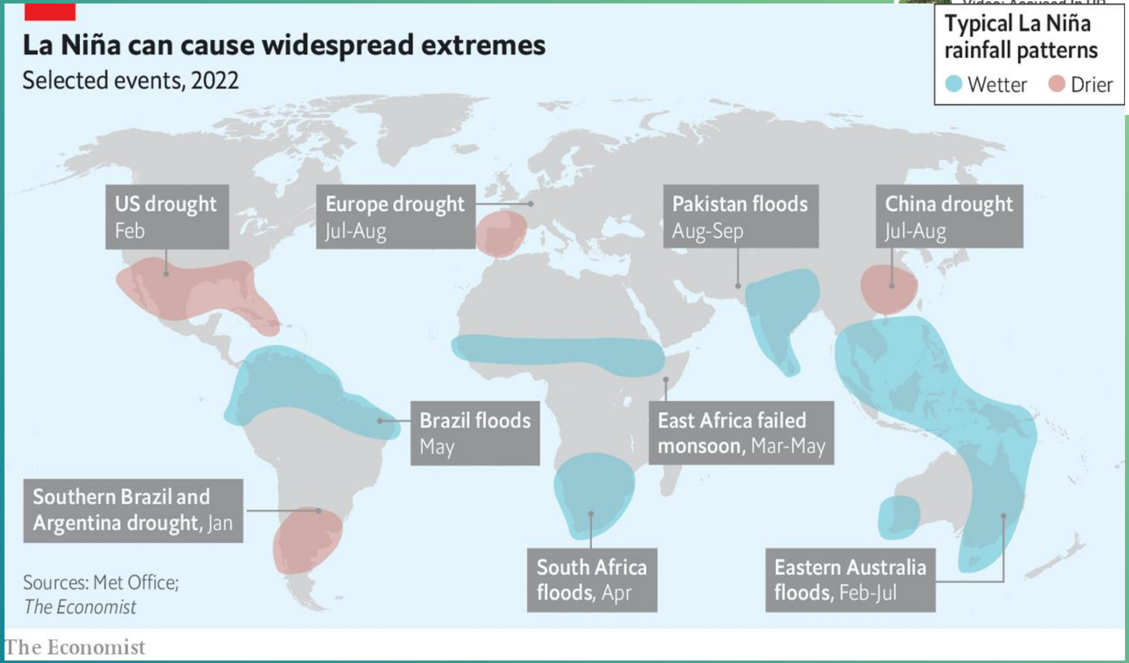
The funds will provide 5.2 million of the worst-affected and most vulnerable people with food, clean water, sanitation, emergency education, protection and health support.

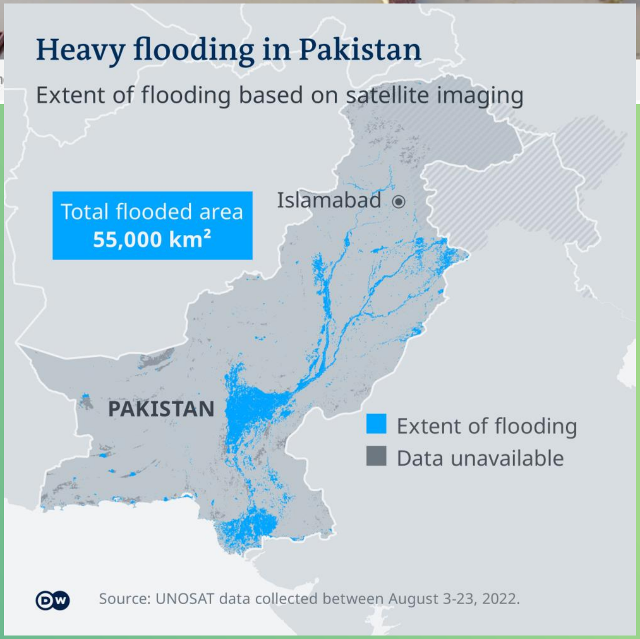
World | Agence France-Presse | Updated: August 30, 2022 11:04 pm IST

TRENDING

Russian President Vladimir Putin Survives Assassination Attempt: Report

Opinion: Team Thackeray Gains Big Point Ahead Of Key Mumbai Election





Inundation

What can we say about inundation and flooding with a model like JULES?

- JULES was not originally conceived as a hydrological / flood prediction model, but over the last ~10 years it has been moving in that direction. Routines have been inserted to improve runoff prediction (PDM/TOPMODEL), represent river routing (TRIP/RFM) and land surface inundation.

- Arguably, JULES is not yet a 'good' hydrological model: it is still missing fundamental hydrological processes and we are therefore currently restricted in the kinds of wetlands and inundated areas that we can simulate.

- However, I believe JULES is not too far away from this.

Flooding in Chennai, India

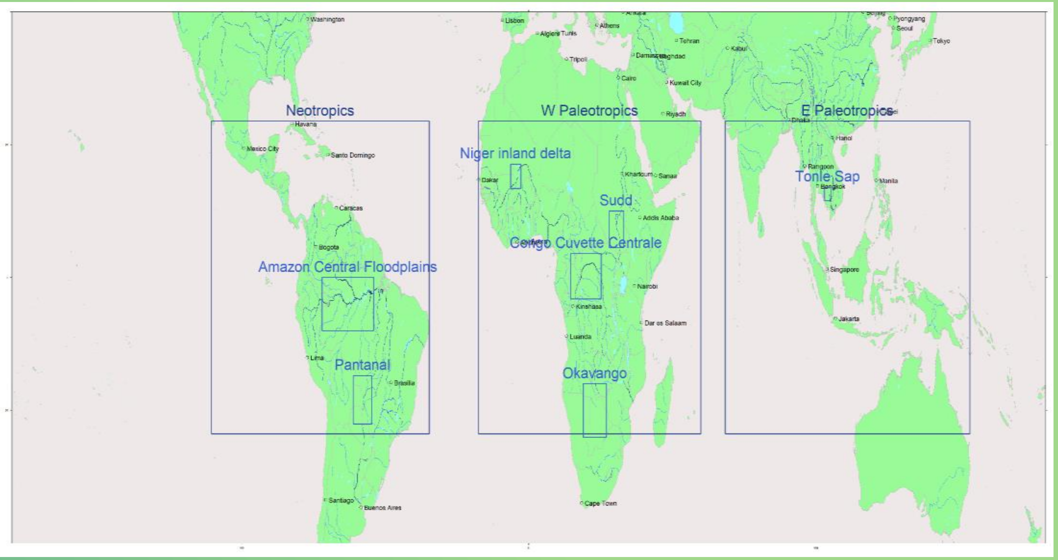
Inundation

As part of the *Hydro-JULES* project, I have been comparing wetland model predictions with observational products from remote sensing at a global level (see Marthews *et al.* 2022).

Hydro-JULES also has a lot of activity at 1km UK scale too.

We get a lot of the hydrology really quite right (perhaps more than people might expect).

Very briefly, a quick recap of the three main forms of inundation ...



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Inundation prediction in tropical wetlands from JULES-CaMa-Flood global land surface simulations

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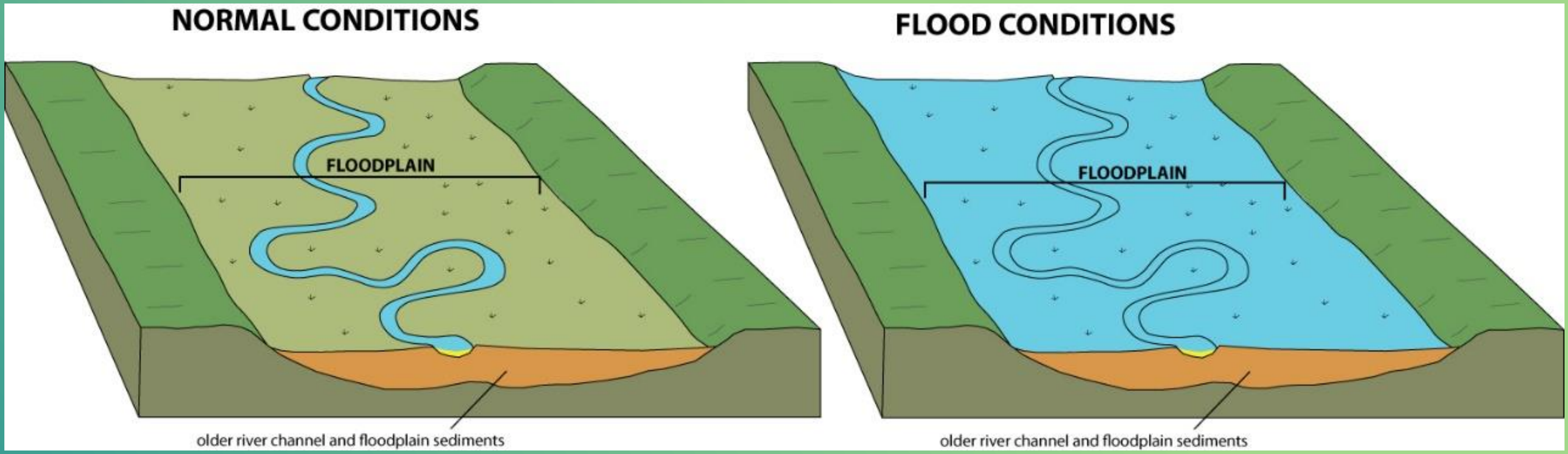
River overbank inundation



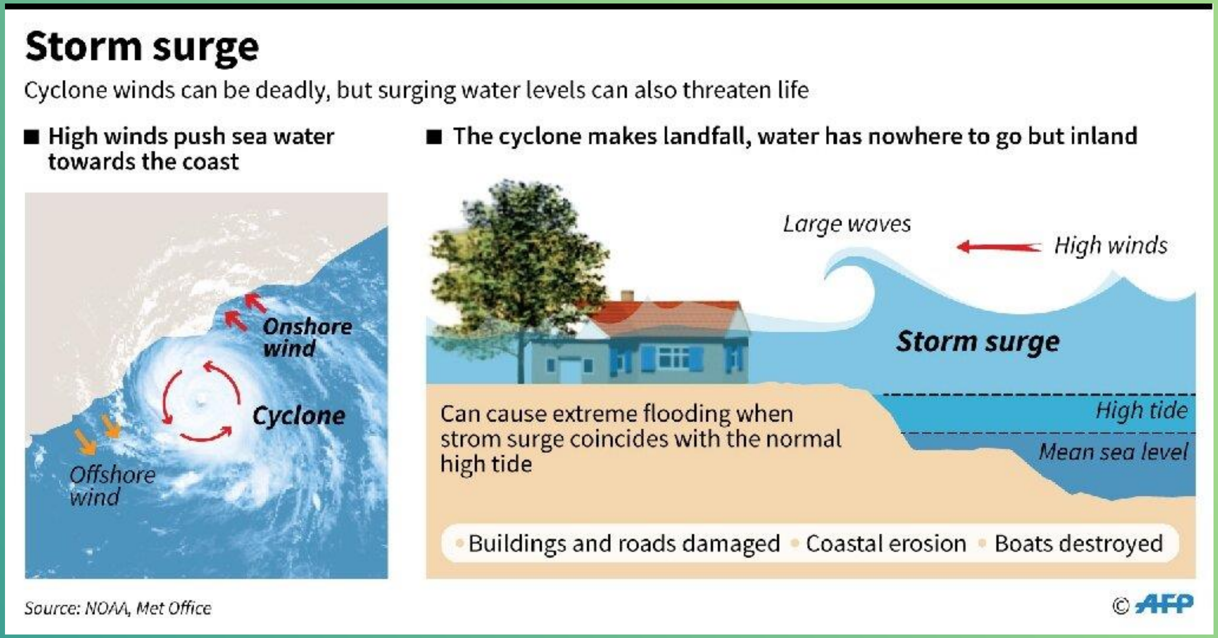
- ***Overbank inundation*** is generally the most familiar form of flooding. It is the process by which rivers burst their banks and expand temporarily to inundate part of their floodplain.

Guadalupe River (Tx, USA) during Hurricane Harvey, 2017, from https://www.today.com/video/guadalupe-river-could-reach-32-feet-above-flood-stage-in-harvey-s-wake-1033626179738

Groundwater inundation

- ***Groundwater inundation*** occurs when a natural underground drainage system is incapable of sufficiently draining itself, resulting in the emergence of groundwater at the surface. For example, in Republic of Ireland, the most extensive form of groundwater flooding is related to prolonged rainfall causing water table rise in limestone lowland areas (e.g. above, from https://www.gsi.ie/en-ie/programmes-and-projects/groundwater/activities/groundwater-flooding/Pages/default.aspx)

Coastal inundation



Source: https://phys.org/news/2019-05-storm-surge-dangerous.html

- ***Coastal inundation*** is partly a result of river flow and groundwater (e.g. permanent coastal wetlands), but can have large components of tidal surge and storm surge from the ocean. This can only be simulated if we couple a land surface model to an ocean model.

- A key process we need to be able to simulate slow-moving wetlands (i.e. groundwater and coastal flooding) is *backwater effects*.

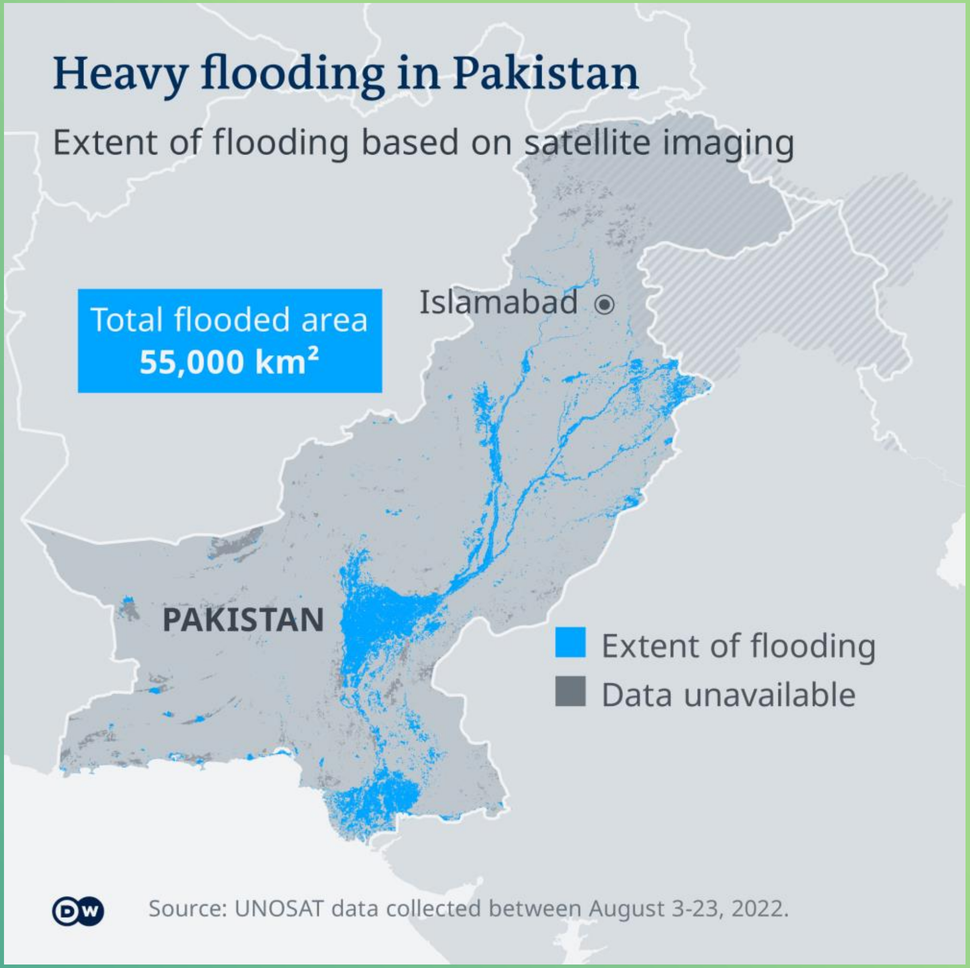
Modelling inundation

Take the example of the Pakistan floods this summer. How much of the dynamics of this situation can we simulate using JULES?

The Pakistan floods this year were an example of a ‘combination extreme event’ with more than one driver:

- Prolonged heatwaves in April and May led to (i) glacial melt in the mountains and (ii) much heavier monsoon rains beginning mid-June.
- The topography of the country led to particular ‘pinch points’ where the rivers ran faster and overflowed their banks.
- Relatively minor coastal flooding (the Indus delta flooded mostly because of excess rainfall, not ocean intrusion).

(Information summarised from Flooding in Pakistan shows the need for climate resilience - News @ Northeastern)



Modelling inundation

YES

- River routing and flow regime. We do get river flows approx. correct in comparison to gauge data (*UKEP* and *REP* projects).
- Groundwater inundation is also well-validated, i.e. topography ('pinch points').
- Overbank inundation has been in the code since 2015. It could do with some more validation (see Marthews *et al.* 2022) and there are caveats (e.g. receding of floodwater), but we have this too.

PARTIALLY

- The necessary *backwater effects* have been put into a temporary branch of *JULES* by developing some code from a more sophisticated model *CaMa-Flood*, Japan, in collaboration with JAMSTEC. It is not yet in the code base of JULES.

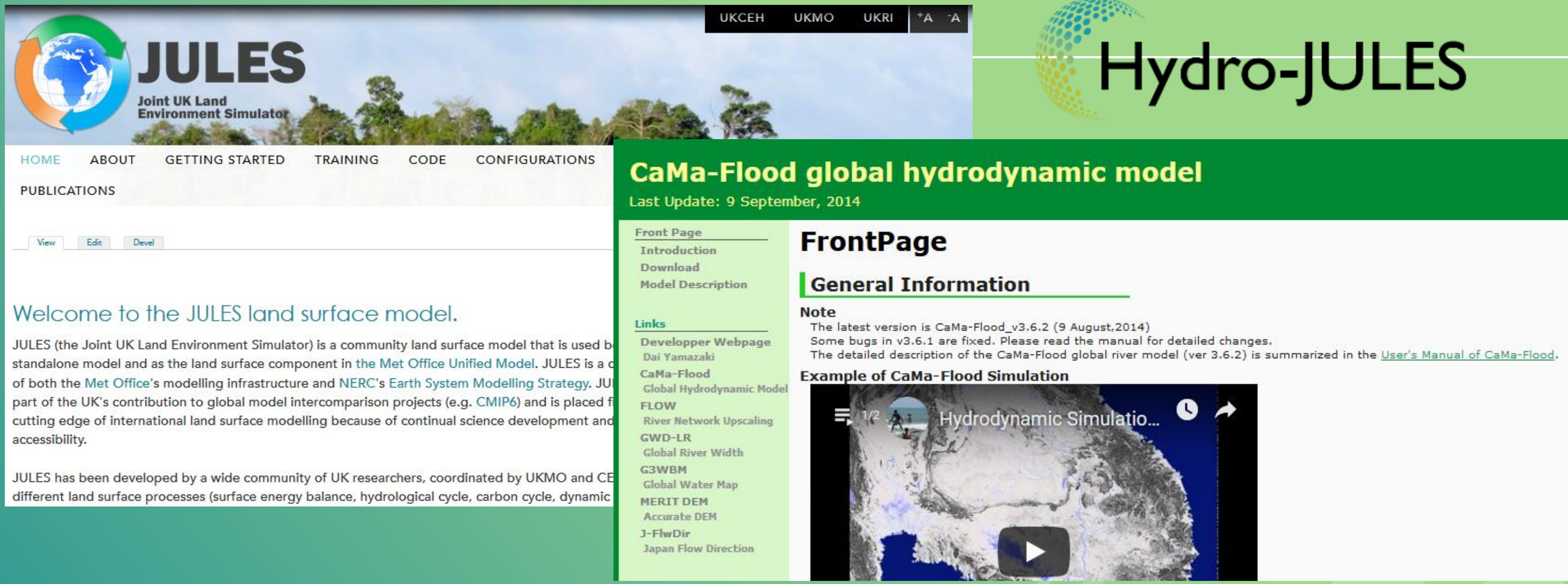
CaMa-Flood: Global River Hydrodynamics Model

JAMSTEC 国立研究開発法人 海洋研究開発機構 Japan Agency for Marine-Earth Science and Technology 海洋・地球・生命の総合的理解への挑戦

NOT YET

- Where rivers meet the ocean, we need to look at model coupling (https://code.metoffice.gov.uk/trac/jules/wiki/OceanRiverInterface):
  - Water transfer river -> ocean (i.e. river outflow)
  - Water transfer ocean -> river (storm and tidal surges)
  - This has been partly implemented by Met Office colleagues.
- Glacial melt
- Fluxes from the flooded area (e.g. evaporation, methane flux from semi-permanent inundated areas such as wetlands).

2. Current work

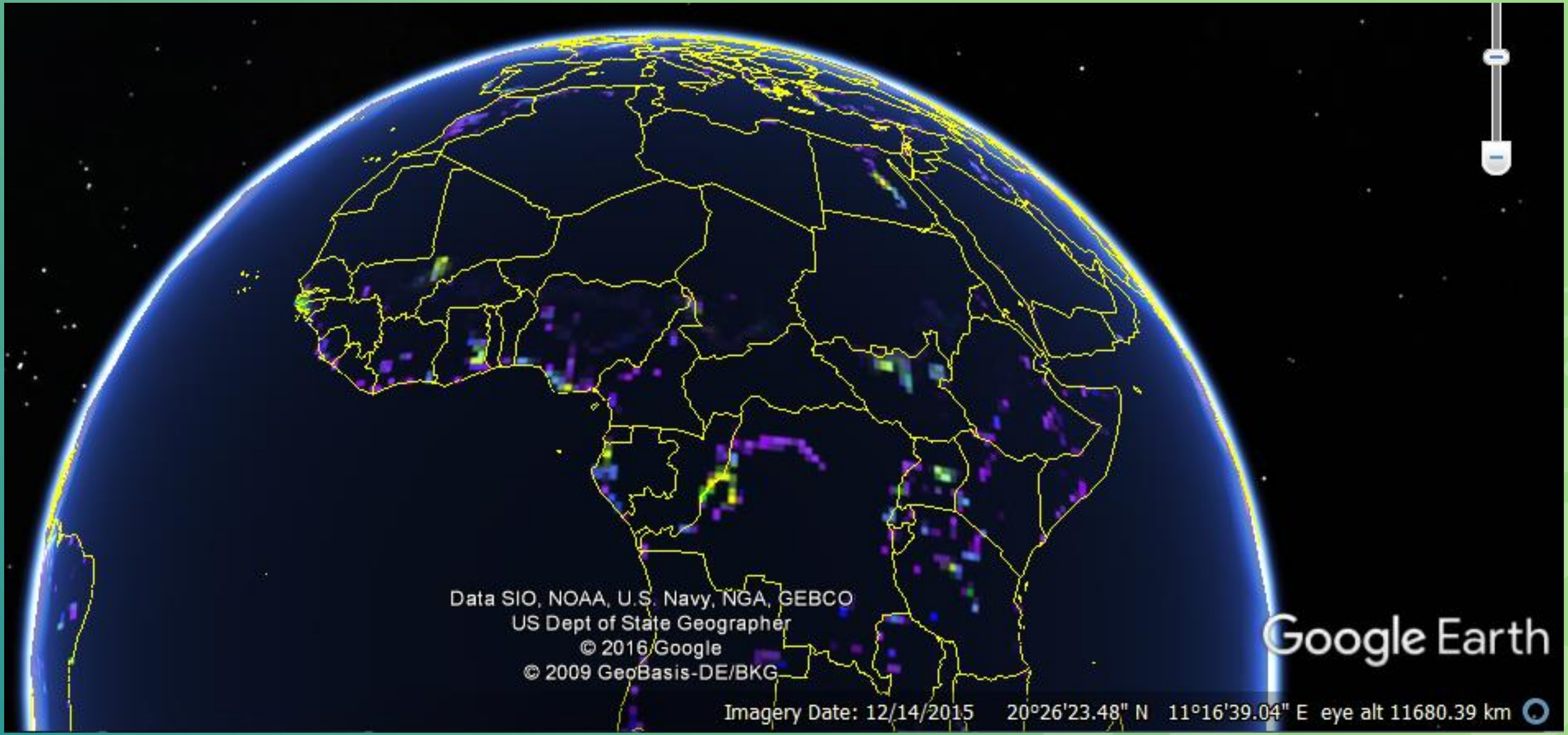


Hydro-JULES

- I work for the *Hydro-JULES* project with the aim to achieve an improved representation of hydrological processes (inc. river flow), including the process of overbank inundation.

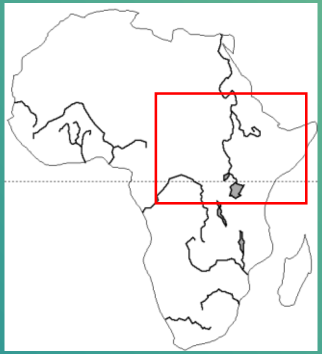
- We are testing the ***JULES* River Flow Model (RFM)** and also an implementation of the global hydrodynamic model ***CaMa-Flood***.

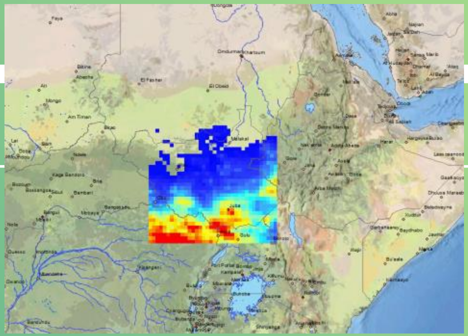
- *CaMa-Flood* is the only open-source global river routing model based on the local inertial approximation of the Saint Venant equations



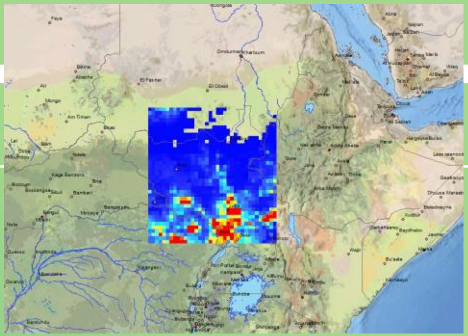
- For benchmark observations, we use ***GIEMS-2*** (Global Inundation Extent from Multi-Satellites vn2.0), a global inundation extent product available monthly over 1993-2015 (Prigent *et al*. 2020).
- Resolution is 0.25°x0.25°, i.e. approx. 25 km x 25 km at the Equator

Simulated water cycle elements of the Sudd wetland, South Sudan, during 2009-2015.



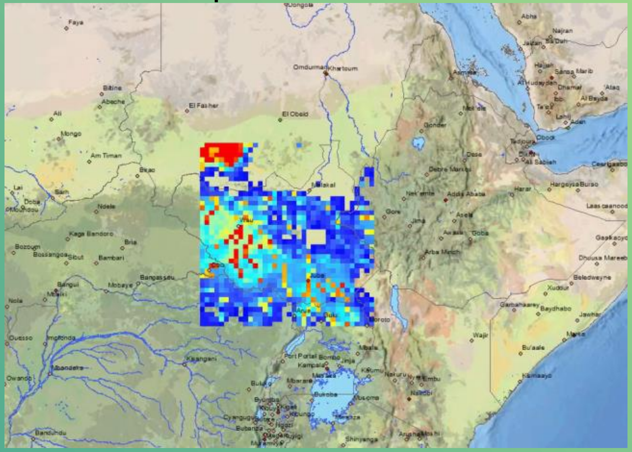


Precipitation

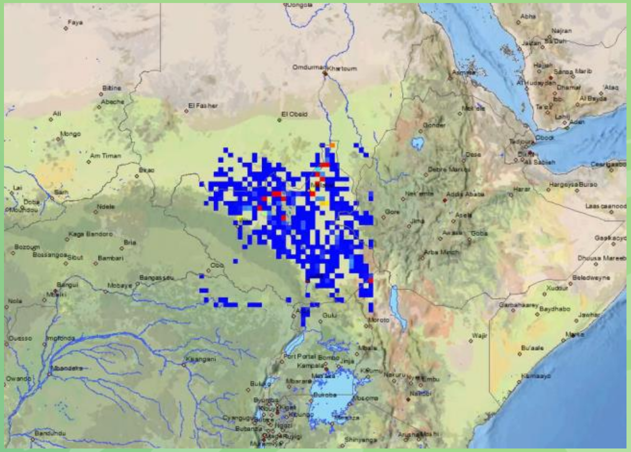


Runoff

River flow



Area of shallow inundation (*fwetl*)

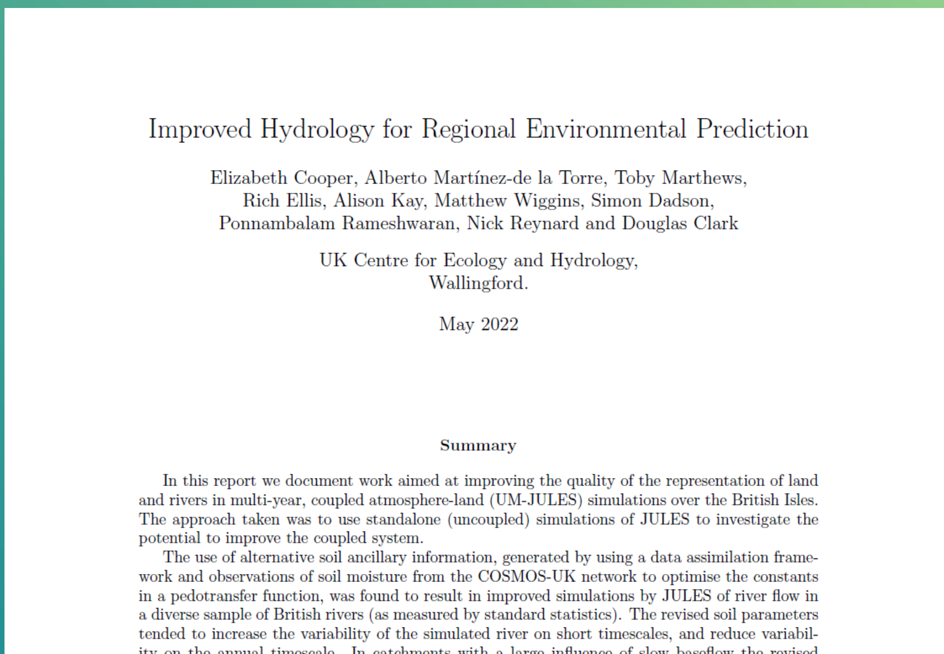


Overbank inundation (*frac_fplain*)

- You can see the ‘path of the water’ moving from precipitation to land surface runoff to river flow, and eventually to inundation.
- Movies are from a gridded JULES run using TOPMODEL for runoff and RFM for rivers + overbank inundation.
- Apologies: equivalent movies for CaMaFlood not shown: runs only finished last night (!).

Regional Environmental Prediction (REP):

Project led by Ségolène Berthou at the UK Met Office (see UKEP webpage https://www.metoffice.gov.uk/research/collaboration/ukenvironmentalprediction). Through REP I have been applying JULES-CaMaFlood in a selection of UK catchments.



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

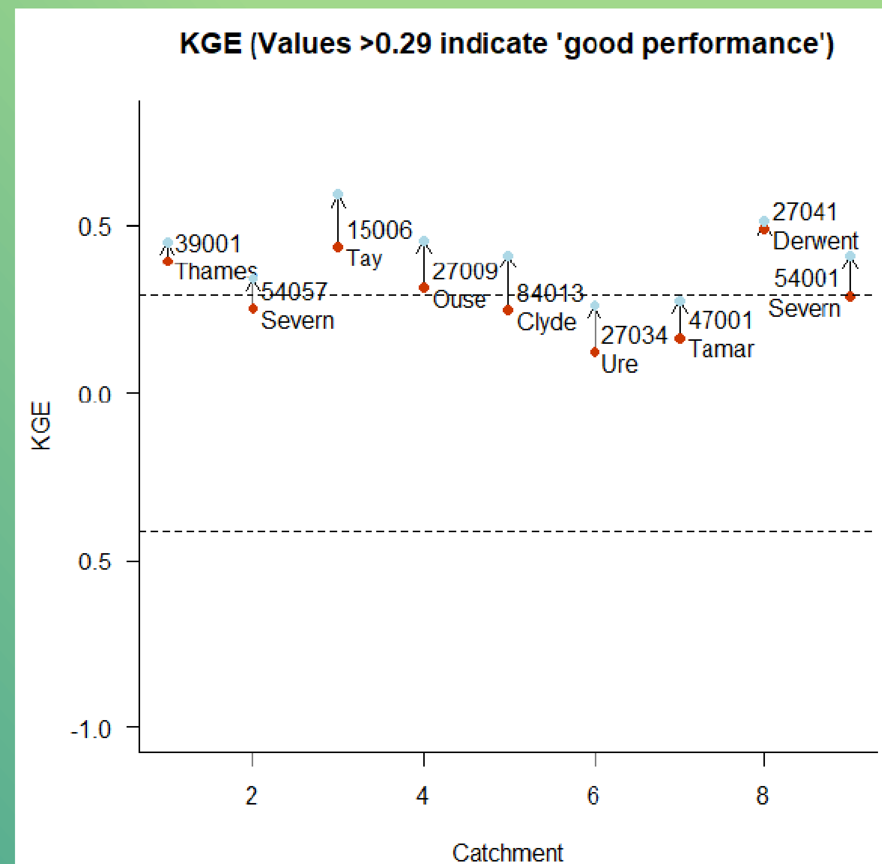
UK Centre for Ecology and Hydrology, Wallingford.

May 2022

Summary

In this report we document work aimed at improving the quality of the representation of land and rivers in multi-year, coupled atmosphere-land (UM-JULES) simulations over the British Isles. The approach taken was to use standalone (uncoupled) simulations of JULES to investigate the potential to improve the coupled system.

The use of alternative soil ancillary information, generated by using a data assimilation framework and observations of soil moisture from the COSMOS-UK network to optimise the constants in a pedotransfer function, was found to result in improved simulations by JULES of river flow in a diverse sample of British rivers (as measured by standard statistics). The revised soil parameters tended to increase the variability of the simulated river on short timescales, and reduce variability on the annual timescale. In catchments with a large influence of slow baseflow the revised



Combining

There have been a lot of issues with this (JASMIN, Grrr...! and CaMa-Flood even more Grrr....!), but we have just about finished all the runs.

Analysis is next!

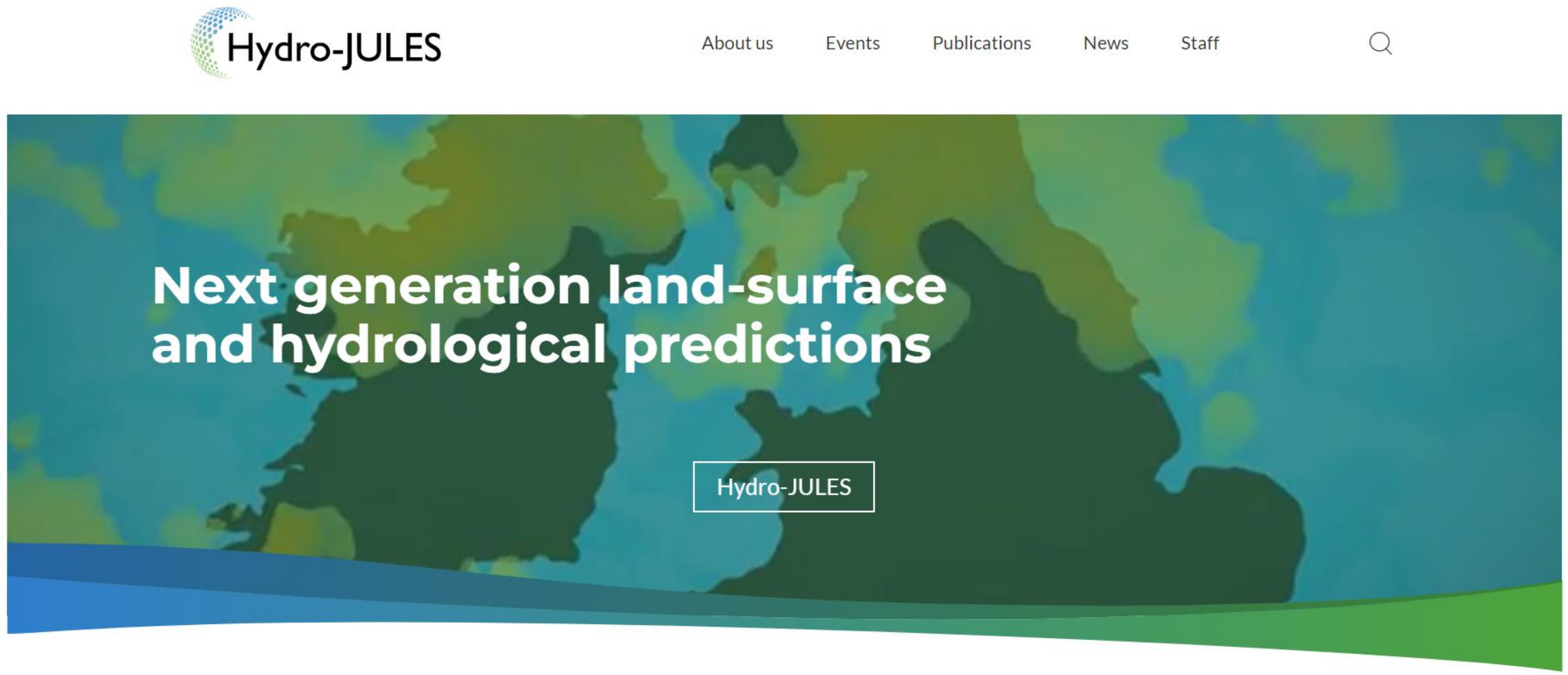
	Scale=UK	Scale=Global
Using JULES-RFM	Yes (in REP)	Yes (e.g. Sudd example)
Using JULES-CaMaFlood	Yes (in REP)	Yes just about (i.e. last night ....)

3. Next steps / future projects

Future projects

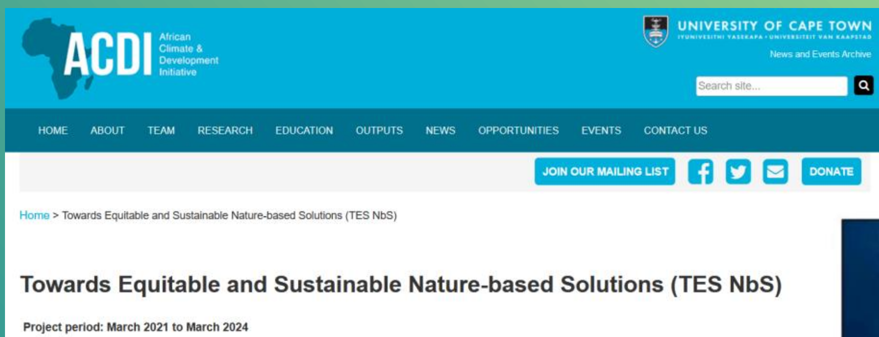
I’m involved in a lot of projects peripherally: here I’ll just mention a few:

Hydro-JULES is my main job and I am producing a comprehensive validation of the RFM river routing scheme in a global context.



TES-NbS:

Project at Univ Cape Town, SA, with Prof. Mark New, Petra Holden and Assumpta Onyeagoziri http://www.acdi.uct.ac.za/towards-equitable-and-sustainable-nature-based-solutions-tes-nbs . This project is looking at nature-based solutions across the Southern African region



TES NbS
Towards Equitable & Sustainable Nature-based Solutions in Southern Africa's Water Towers

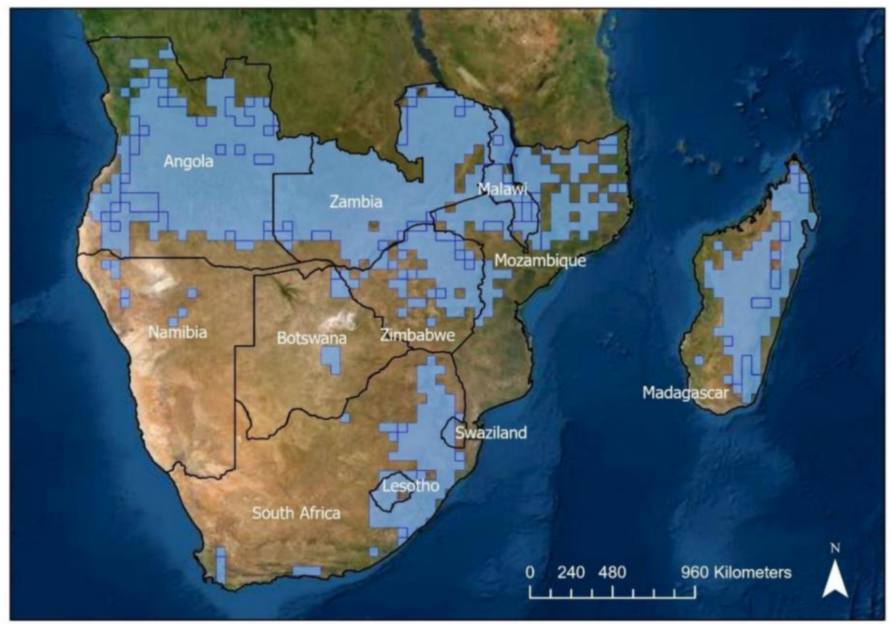
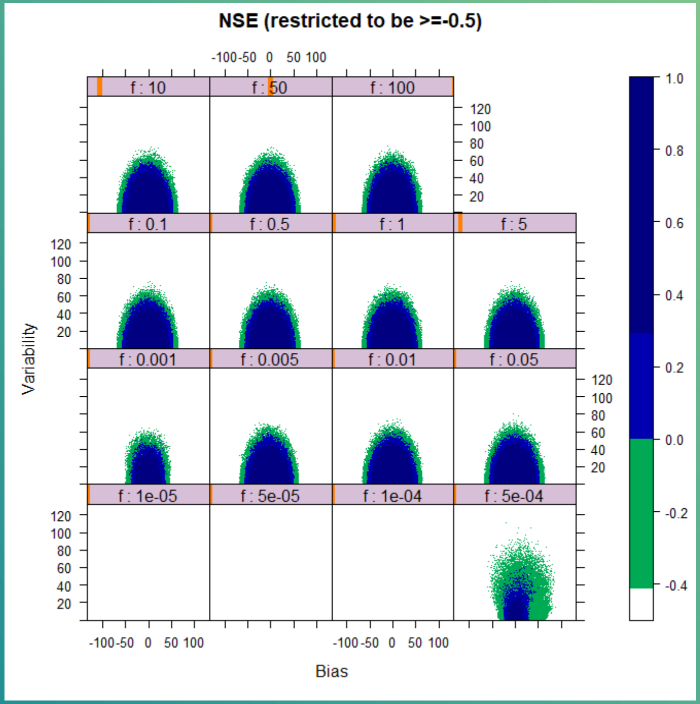


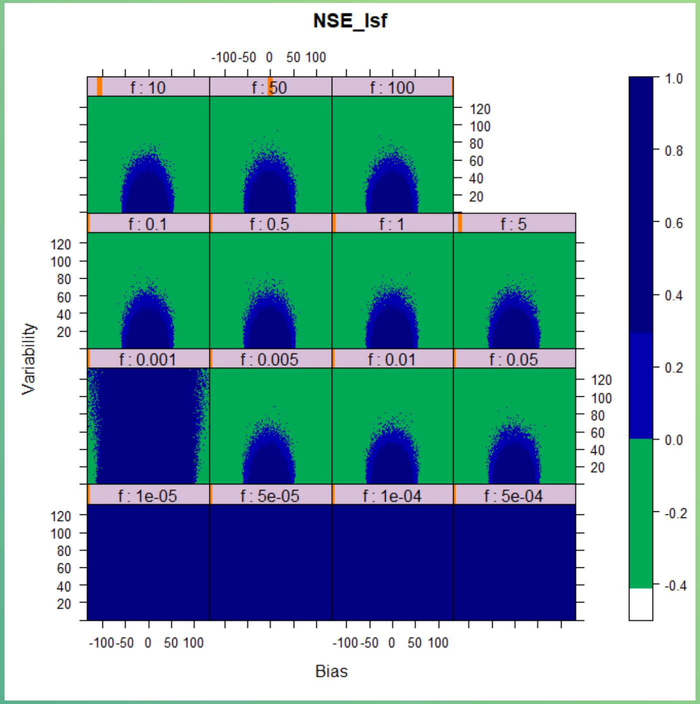
Figure 1 Rough boundaries for Water Towers in Southern Africa (Sources: Viviroli et al 2007; Esri, Maxar, GeoEye, Earthstart Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN and the GIS User Community)

BoM:

I am working on improving the Nash-Sutcliffe Efficiency (NSE) and Kling-Gupta Efficiency (KGE) indices for ephemeral rivers.

When we evaluate outputs of river flow and/or inundation extent, it is standard to use the two metrics NSE and KGE, but I have found they don't work too well when flows are low and/or very stable. I've proposed two modified indices NSE_lsf and KGE_lsf and I am working with BoM colleagues Huqiang Zhang, Christoph Rudiger and Zaved Khan to see how well these new indices perform in Australian rivers.





CHAMFER:

Project led by Laurent Amoudry at NOC Liverpool https://noc.ac.uk/projects/chamfer .

I’m now task leader for ***Task 1.3:*** *River modelling: the river meets the ocean*. I am planning to use this time to address some issues of river outflow/coastal inflow.

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Oxford, Sep 2022

Flooding in the UK