Validation of inundation prediction from JULES-CaMa-Flood global land surface simulations

Toby Marthews, Simon Dadson, Doug Clark, Eleanor Blyth, Garry Hayman, Dai Yamazaki & Olivia Becher

JULES Annual Science Meeting, 9th September 2020

Photo: lower Padma river, Bangladesh (NASA)

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Next generation land surface and hydrological prediction

This study is part of the five year NERC National Capability project *Hydro-JULES* **https://hydro-jules.org/**

I maintain the *JULES* website: **https://jules.jchmr.org/**

For more about me and my research, see **https://www.tobymarthews.com/**

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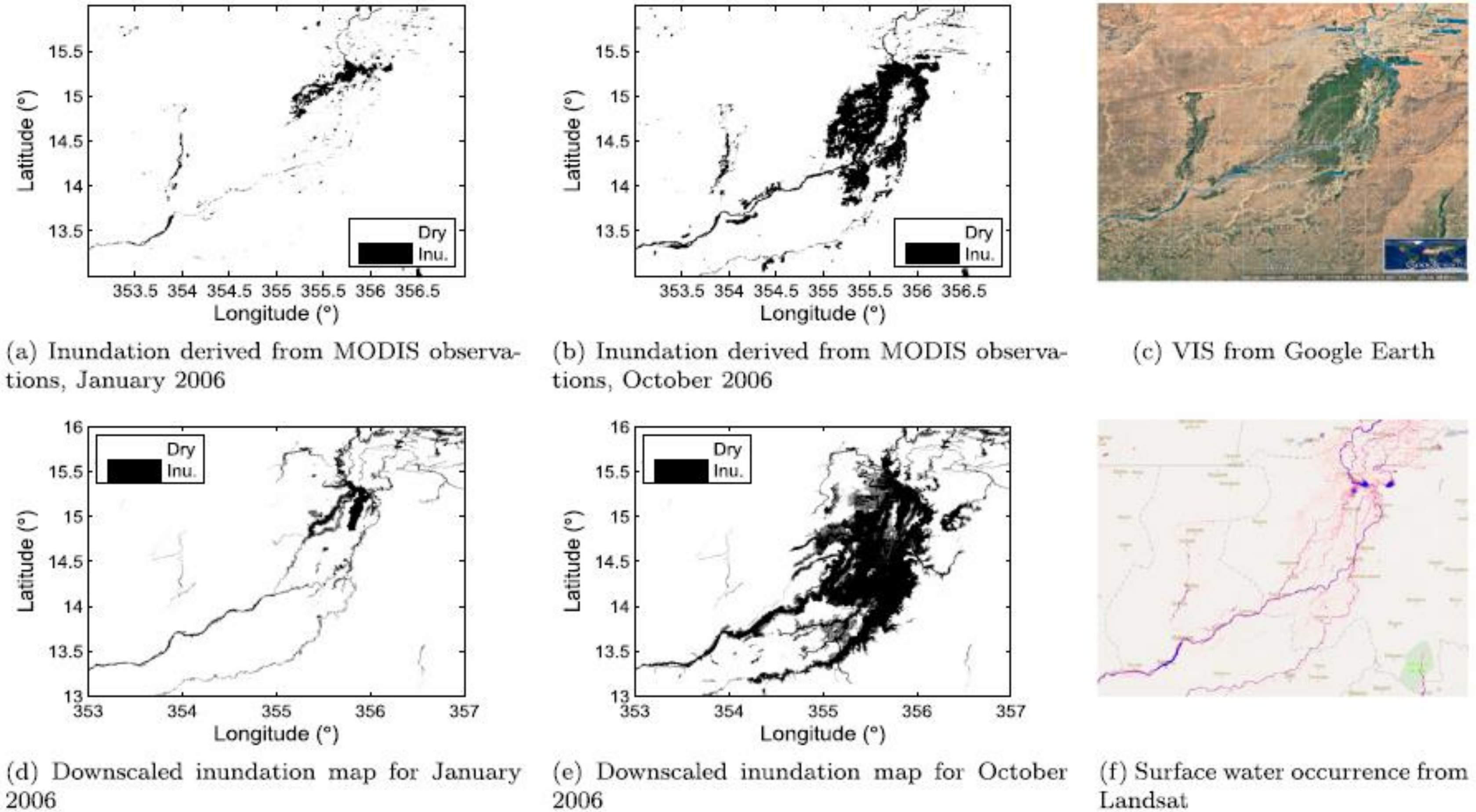
Background



(a) Inundation derived from MODIS observations, January 2006

(b) Inundation derived from MODIS observations, October 2006

(c) VIS from Google Earth

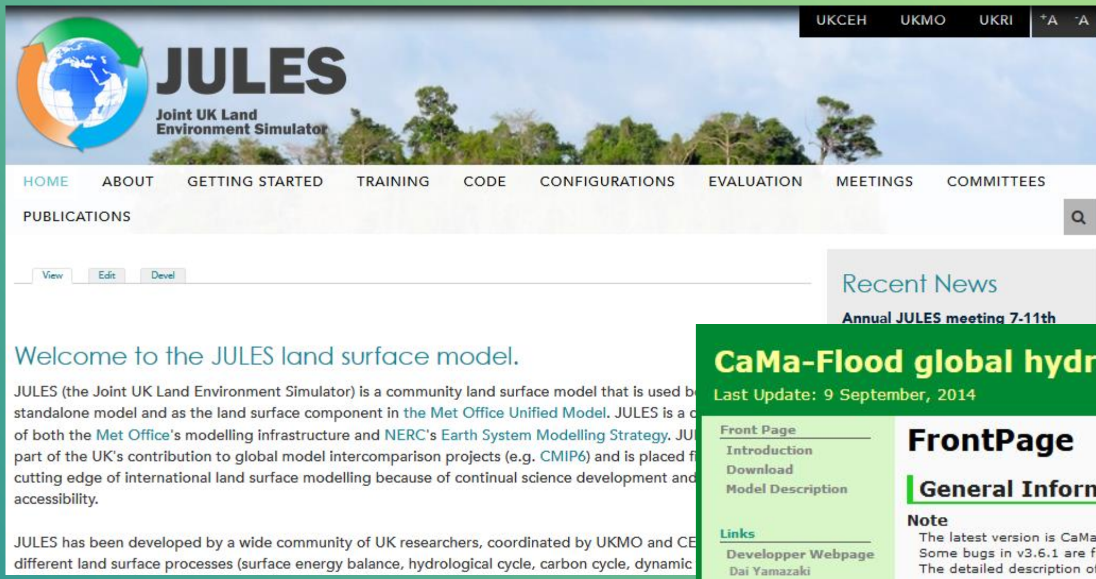
(d) Downscaled inundation map for January 2006

(e) Downscaled inundation map for October 2006

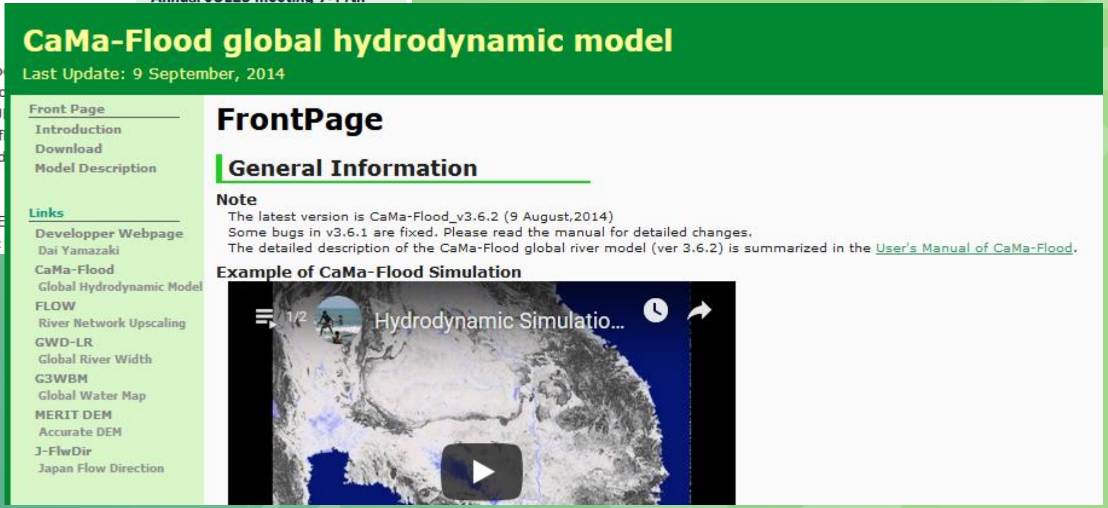
(f) Surface water occurrence from Landsat

FIG. 13. MODIS-derived and GIEMS-D3 inundation maps, for January and October 2006, over the Inner Niger Delta. A map in the visible wavelength (from Google Earth) is also provided for comparison purpose, together with the GSWO from Landsat.

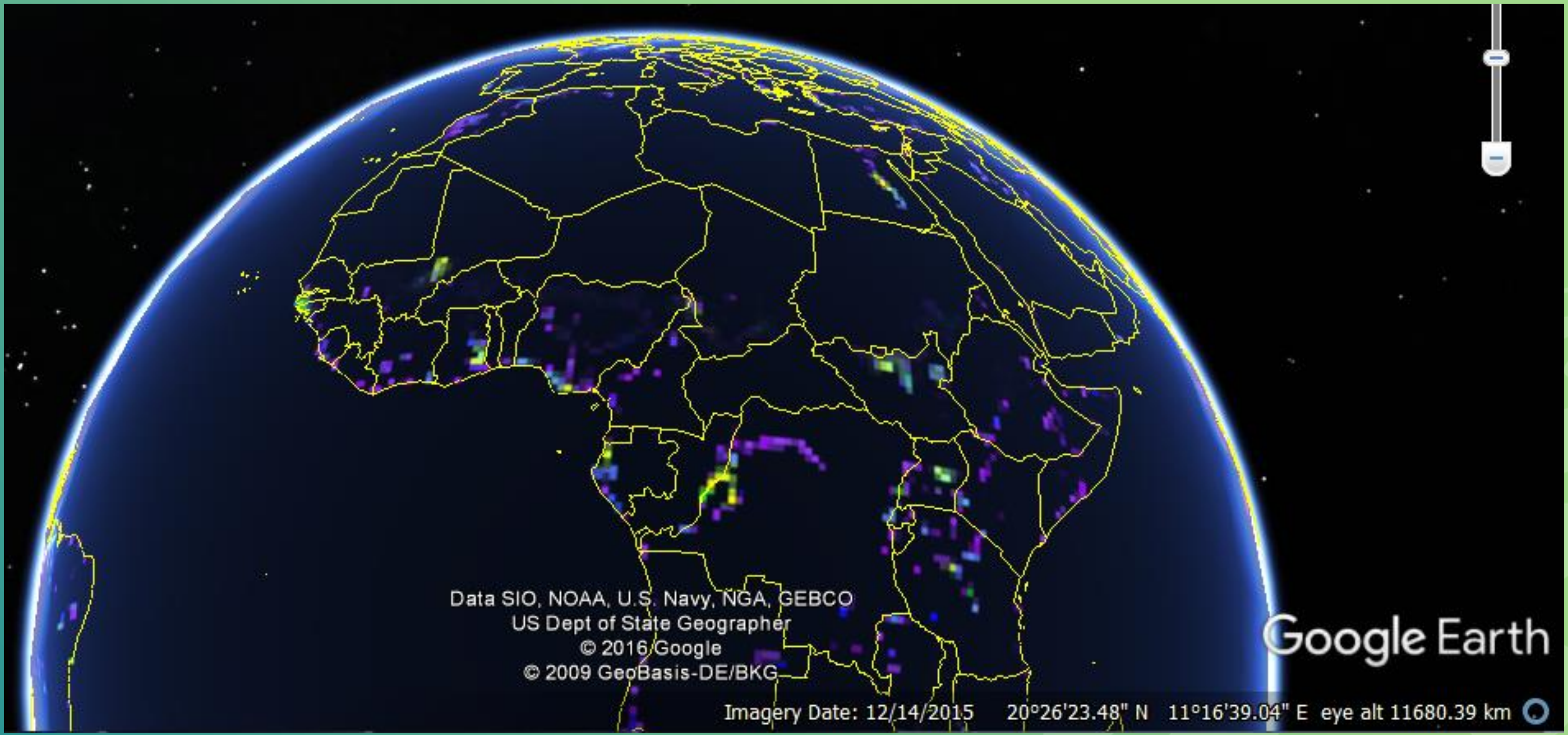
- Despite some uncertainty in global inundation products (e.g. above; Fig. 13 is the Niger Inland Delta Wetland, Mali, from Aires *et al.* 2017, *J Hydromet*), ...
- ... inundation products are now sufficiently precise to be used as benchmarks for model predictions of global inundation.



https://jules.jchmr.org/



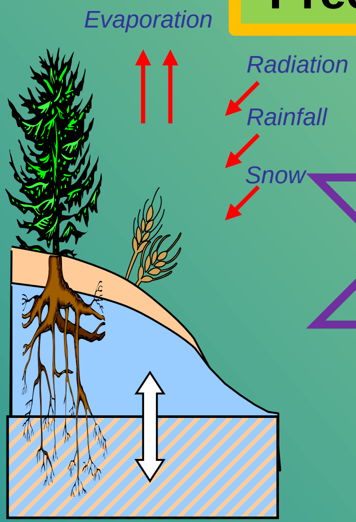
- We are using inundation predictions from the global land surface model ***JULES*** (Best *et al*. 2011, Clark *et al.* 2011) coupled sequentially to the global hydrodynamic model ***CaMa-Flood*** (Yamazaki *et al*. 2009, 2011).
- Dr Dai Yamazaki at the Institute of Industrial Science, University of Tokyo.



- For benchmark observations, we use ***GIEMS*** (Global Inundation Extent from Multi-Satellites), a global inundation extent product available monthly over 1993-2007 (Prigent *et al*. 2007).
- Resolution is 0.25°x0.25°, i.e. approx. 25 km x 25 km at the Equator

Water balance calculations in raster-based hydrological models

Precipitation



Dadson *et al.* (2010, *JGR*)

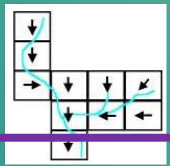
Within-gridcell processes

Basic **water balance**: Incoming precipitation is split into interception, evaporation, drainage and runoff

Runoff production: e.g. using options like *TOPMODEL* or *PDM*

Runoff

CaMa-Flood



River routing using a kinematic wave equation model (e.g. *RFM*), diffusive wave equation or inertial equation

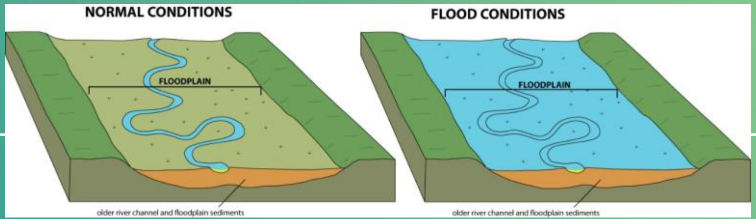
Overbank inundation e.g. using a hypsometric integral

Exchange with ocean i.e. river flow to ocean and storm surge into rivers

River flow

River inundation

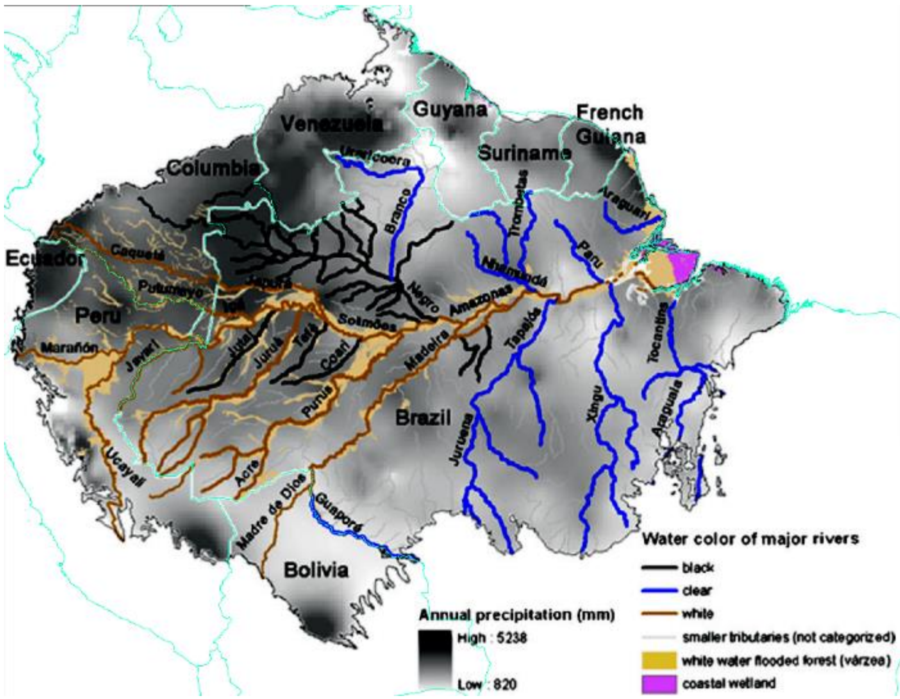
Between-gridcell processes

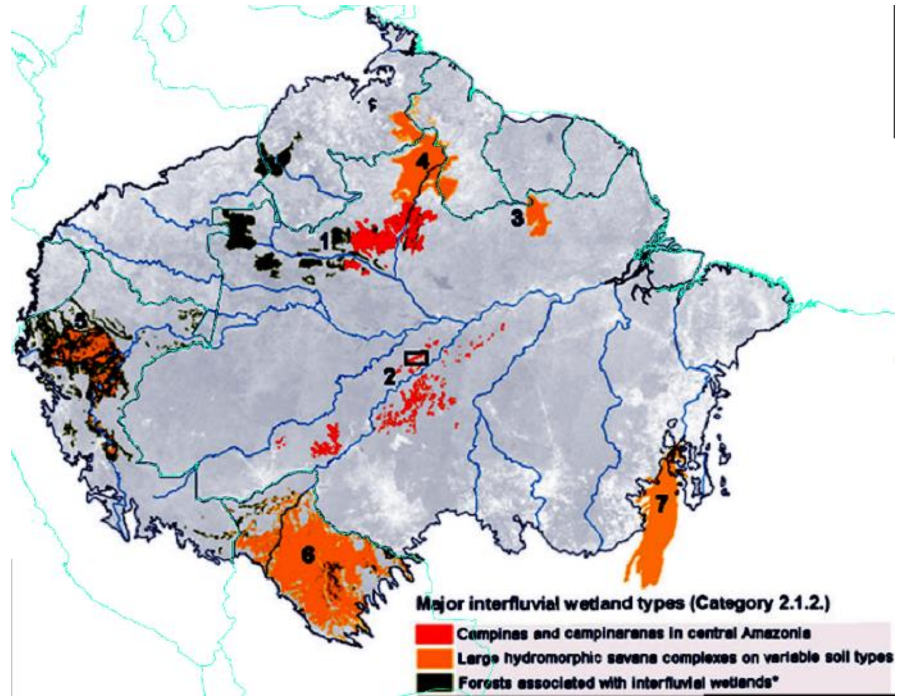


Wetlands

Junk *et al.* (2011, *Wetlands*) divided Amazonian wetlands into:

- Fluvial (maintained by inundation, left) and
- Interfluvial (groundwater-maintained, right).



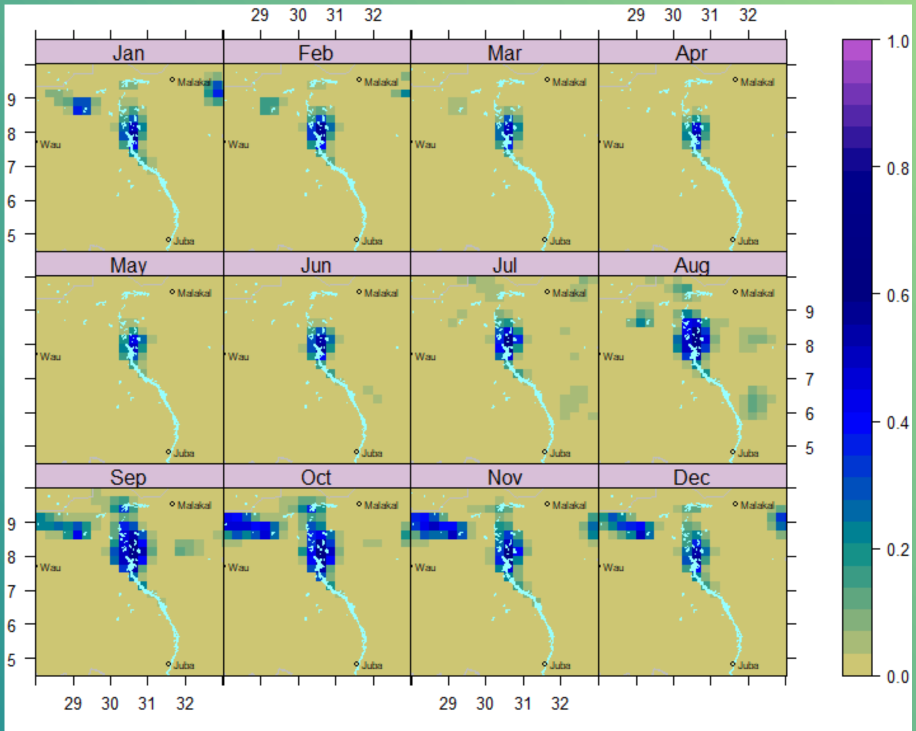


- Although most large wetlands are mixed (e.g. Pantanal), maintained by both processes.

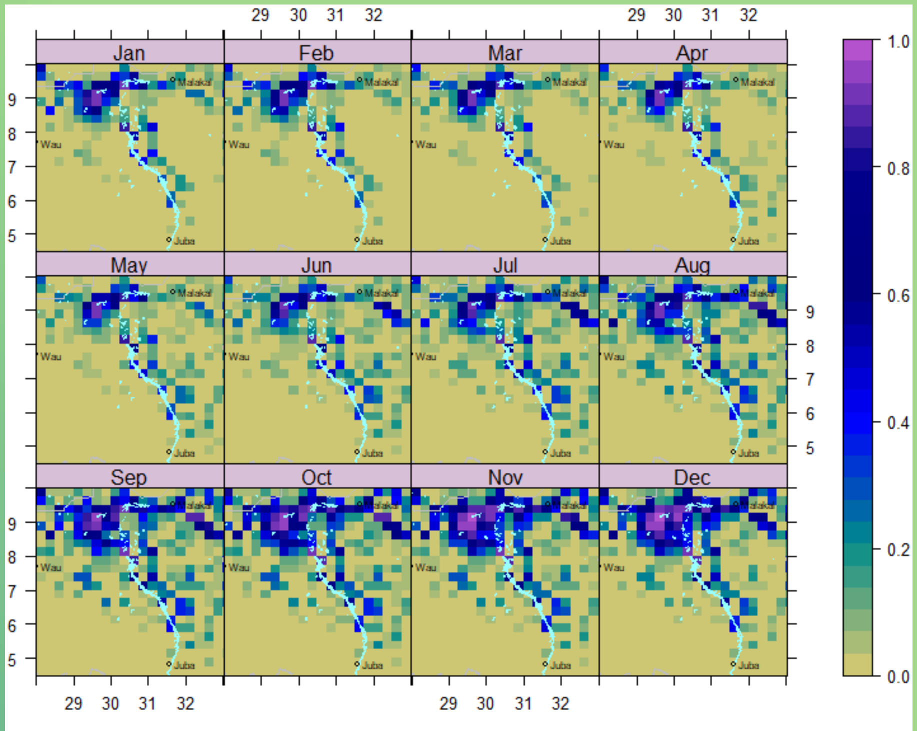
- Is it possible to ***score*** individual wetlands on how groundwater-maintained they are? That would be useful in terms of the future response of these wetlands to climate change, e.g. if precipitation halves in the future then presumably fluvial wetlands are immediately affected, but interfluvial perhaps not at all for quite some time.

Results

The Sudd in South Sudan



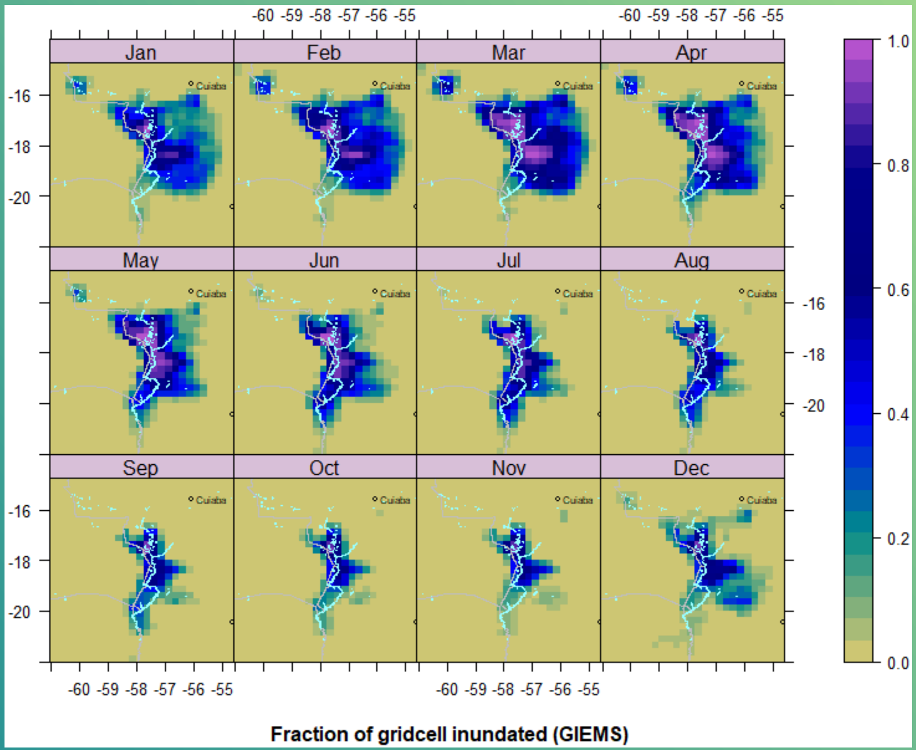
Fraction of gridcell inundated (GIEMS)

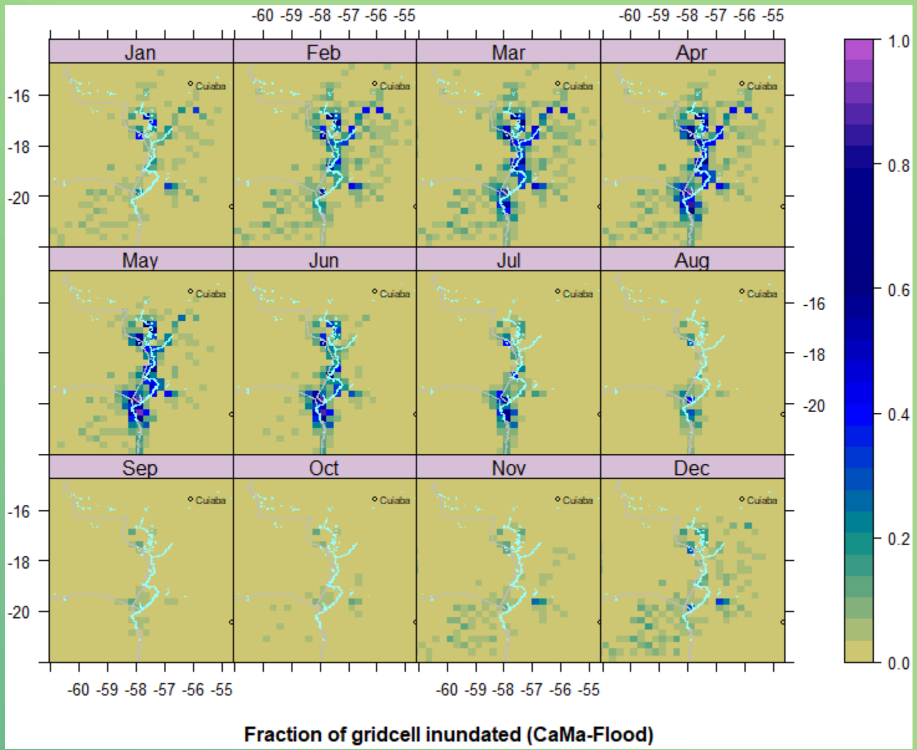


Fraction of gridcell inundated (CaMa-Flood)

- Data shown are from GIEMS observations (left) and JULES-CaMa-Flood simulations (right) (both an average over all years 1993-2007).
- Note that JULES-CaMa-Flood appears to overestimate inundation for this wetland.

The Pantanal in Brazil, Paraguay and Bolivia





- This time, JULES-CaMa-Flood appears to underestimate inundation
- However, JULES has been run with PDM runoff generation which does not include groundwater effects, so really we can think of the CaMa-Flood results as the portion of Pantanal wetland attributable to fluvial inundation only.

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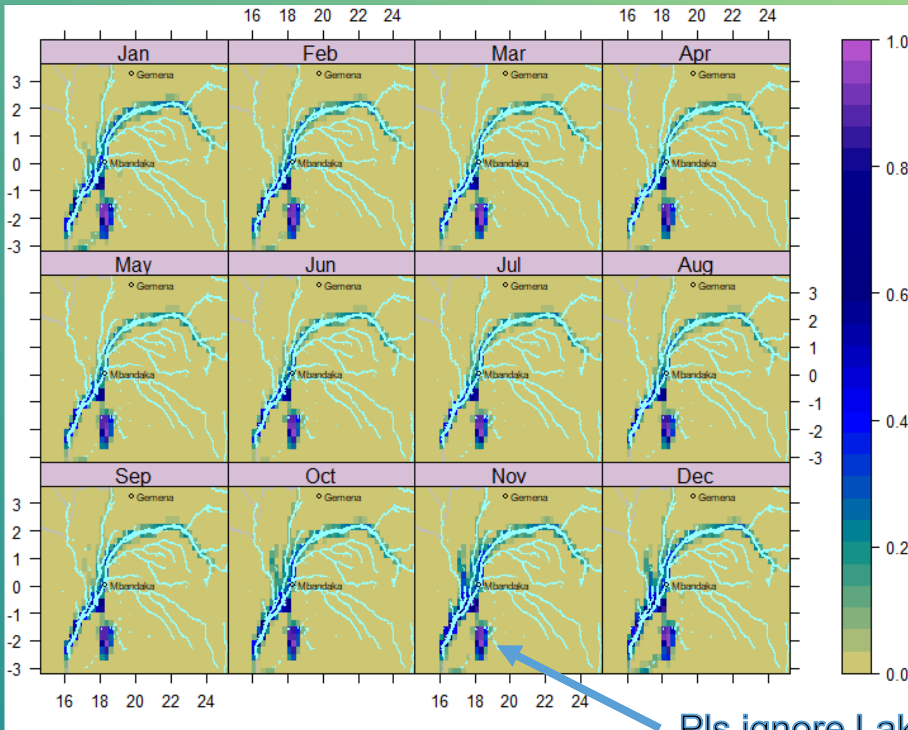
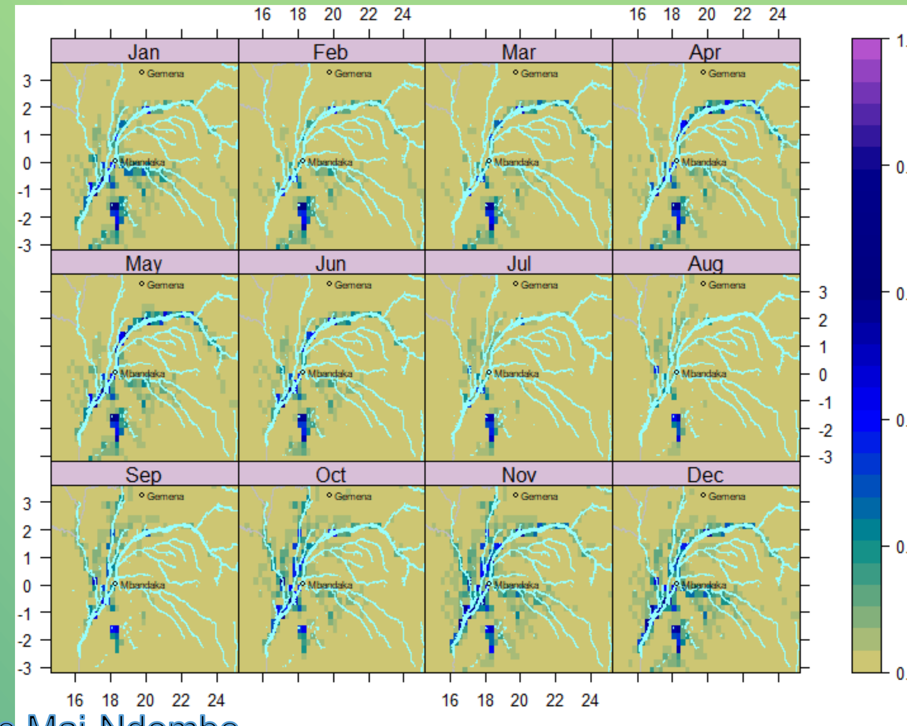
The Cuvette Centrale in DRC and Congo-Brazzaville



Fraction of gridcell inundated (GIEMS)

Pls ignore Lake Mai-Ndombe

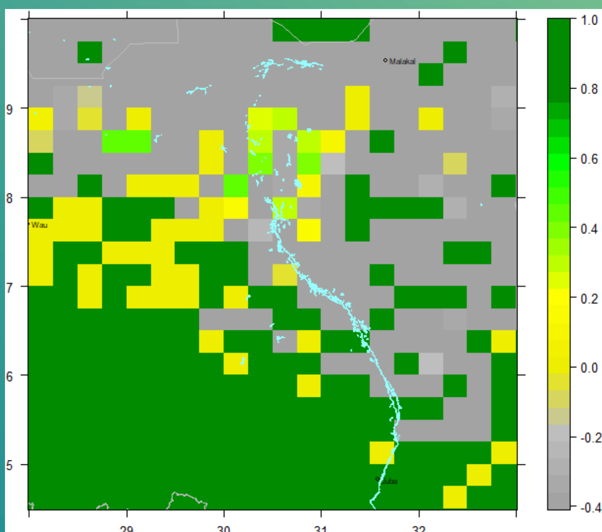


Fraction of gridcell inundated (CaMa-Flood)

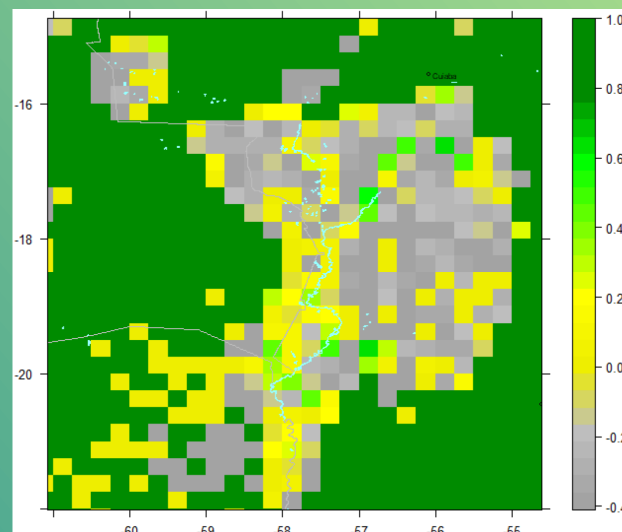
- For the Congo river, the climate is much more aseasonal and the wetland area is larger (view is ~2000 km across now rather than ~600 km).
- The fit appears to be much closer here, but much is potentially hidden by the scale.

Kling-Gupta Efficiency

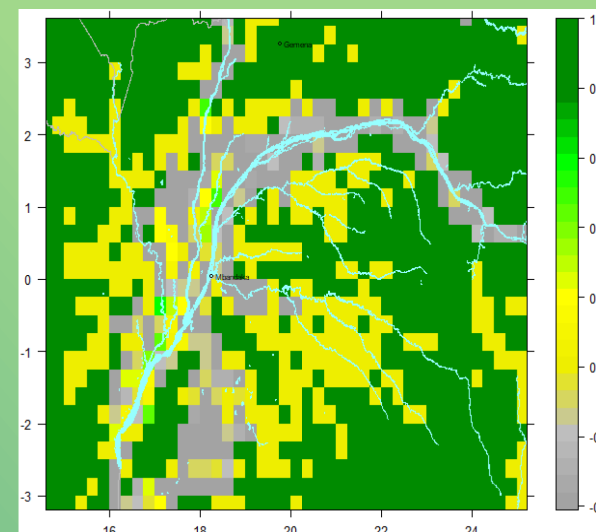
Kling-Gupta efficiency (KGE)*	$KGE = 1 - \sqrt{(r-1)^2 + \left(\frac{\sigma_{sim}}{\sigma_{obs}} - 1\right)^2 + \left(\frac{\mu_{sim}}{\mu_{obs}} - 1\right)^2}$	→ 1.00 = Ideal model performance → > $(1 - \frac{1}{\sqrt{2}} =)$ 0.29 = Good performance (Knoben *et al.*, 2019) → $(1 - \sqrt{2} =)$ -0.41 = No predictive skill (mean of observations provides as good an estimate as simulations) (Knoben *et al.*, 2019) → < -0.41 = Increasing divergence between simulations and observations



The Sudd



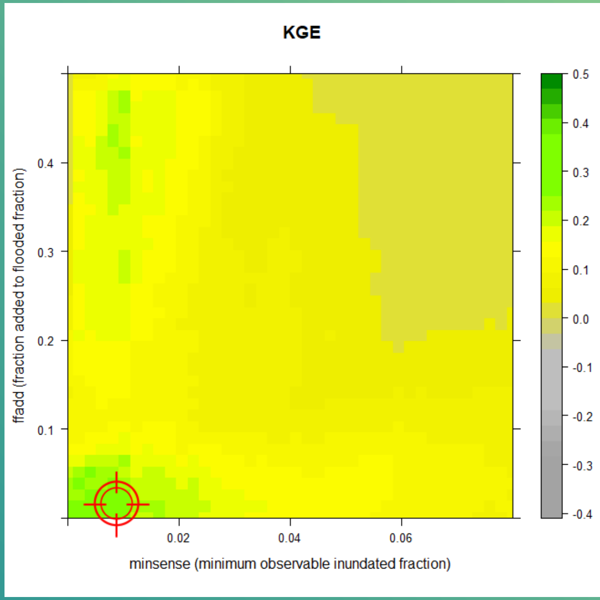
The Pantanal



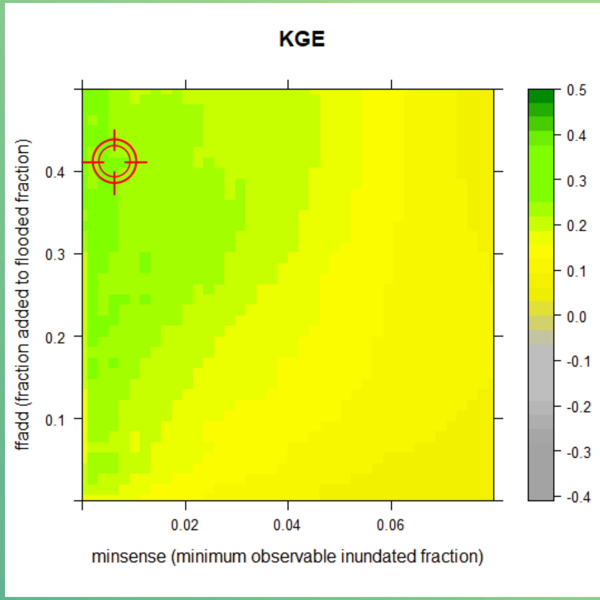
Congo Cuvette

- In all three wetlands KGE values are high on the main branches of the feeding rivers (and trivially high in the dark green areas away from the wetland. Values are fairly low in between, however.

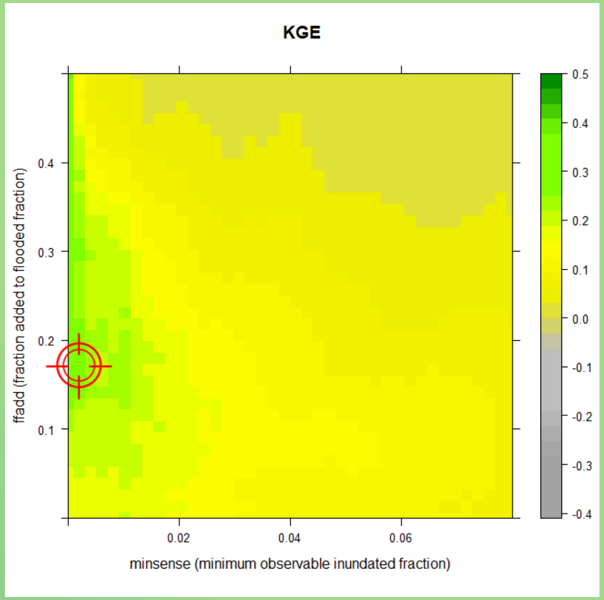
ffadd, a measure of how groundwater-maintained a wetland is



The Sudd



The Pantanal



Congo Cuvette

- If groundwater inundation is underestimated by the JULES-CaMa-Flood modelling sequence we are using, then it's logical to see whether we can simply add it in? If adding *ffadd* inundation to every inundated gridcell improves the average KGE score, then an optimal value of *ffadd* must be a measure of how groundwater-inundated the wetland in question is.
- So: looking at the *y* coordinate of the optimal green area on these plots, it looks like the Sudd scores low, the Pantanal scores high and the Congo in the middle.

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Summary (am not quite ready to call these “Conclusions”!)

1. CaMa-Flood compares well to GIEMS, but in groundwater-maintained wetlands it underestimates inundation

2. We can estimate the missing inundation, potentially providing a measure of high value for predicting the effects of climate change on particular wetlands.

3. This needs to be confirmed across a wider selection of wetland case studies.

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