

JULES river routing and wetland inundation

Toby Marthews, Huw Lewis,
Simon Dadson

A swimming pool in Magdeburg,
Germany, in 2013

www.TobyMarthews.com

Exeter, 27th June 2017

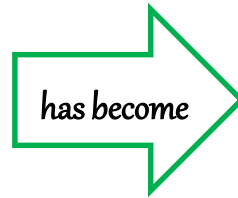


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New JULES website

<https://jules.jchmr.org>



<http://jules.jchmr.org>



Welcome to the JULES land surface model.

JULES (the Joint UK Land Environment Simulator) is a community land surface model that is used both as a standalone model and as the land surface component in the [Met Office Unified Model](#). JULES is a core component of both the [Met Office's](#) modelling infrastructure and [NERC's Earth System Modelling Strategy](#). JULES is a major part of the UK's contribution to global model intercomparison projects (e.g. [CMIP6](#)) and is placed firmly at the cutting edge of international land surface modelling because of continual science development and improved accessibility (JULES can even now be run 'in the cloud' via [MAJIC](#)).

By allowing different land surface processes (surface energy balance, hydrological cycle, carbon cycle, dynamic vegetation, etc.) to interact with each other, JULES provides a framework to assess the impact of modifying a particular process on the ecosystem as a whole, e.g. the impact of climate change on hydrology, and to study potential feedbacks.

Recent News

JULES-Rose training course June 2017, Exeter

4th Apr 2017

JULES annual science conference June 2017, Exeter

28th Mar 2017

Please do not send in news items: the items here are just a selection of items sent round the JULES email list(s)

Our **Vision for the JULES System** (Sep 2016):  [JULES_vision.pdf](#)

New JULES website

Not intended to be a competitor to the JULES Manual pages or the JULES TRAC: as I said yesterday, it's complementary (and I've put many cross-links in too):



Home

Training

JULES users training

- Please see the [JULES manual pages](#), which contain links to (a) the manual for your version of JULES (the first few sections of which give you an overview of the model and steps for *Building and running JULES*) and (b) all Kerry Smout-Day's JULES-Rose tutorials. For me, Kerry's tutorials are generally better to follow than (a) because they are more up to date.
- The [JULES TRAC](#) contains a large number of information pages and self-teach tutorials (e.g. the *Unofficial How-to Guide to using JULES on Jasmin*) as well as links to useful pages like the [JULES Tip of the Day](#), [JULESWithRose](#), [JULESRosePractical](#) and [UsingGriddedDatasets](#).
- You might also want to try Toby's [JULES from scratch](#) tutorial.

Also, be aware of [MAJIC](#), a web application designed for easy use that allows users to run JULES 'in the cloud'.

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- Hydrological modelling (a quick overview) and river routing in JULES
- Results using my o/inun (overbank inundation) code
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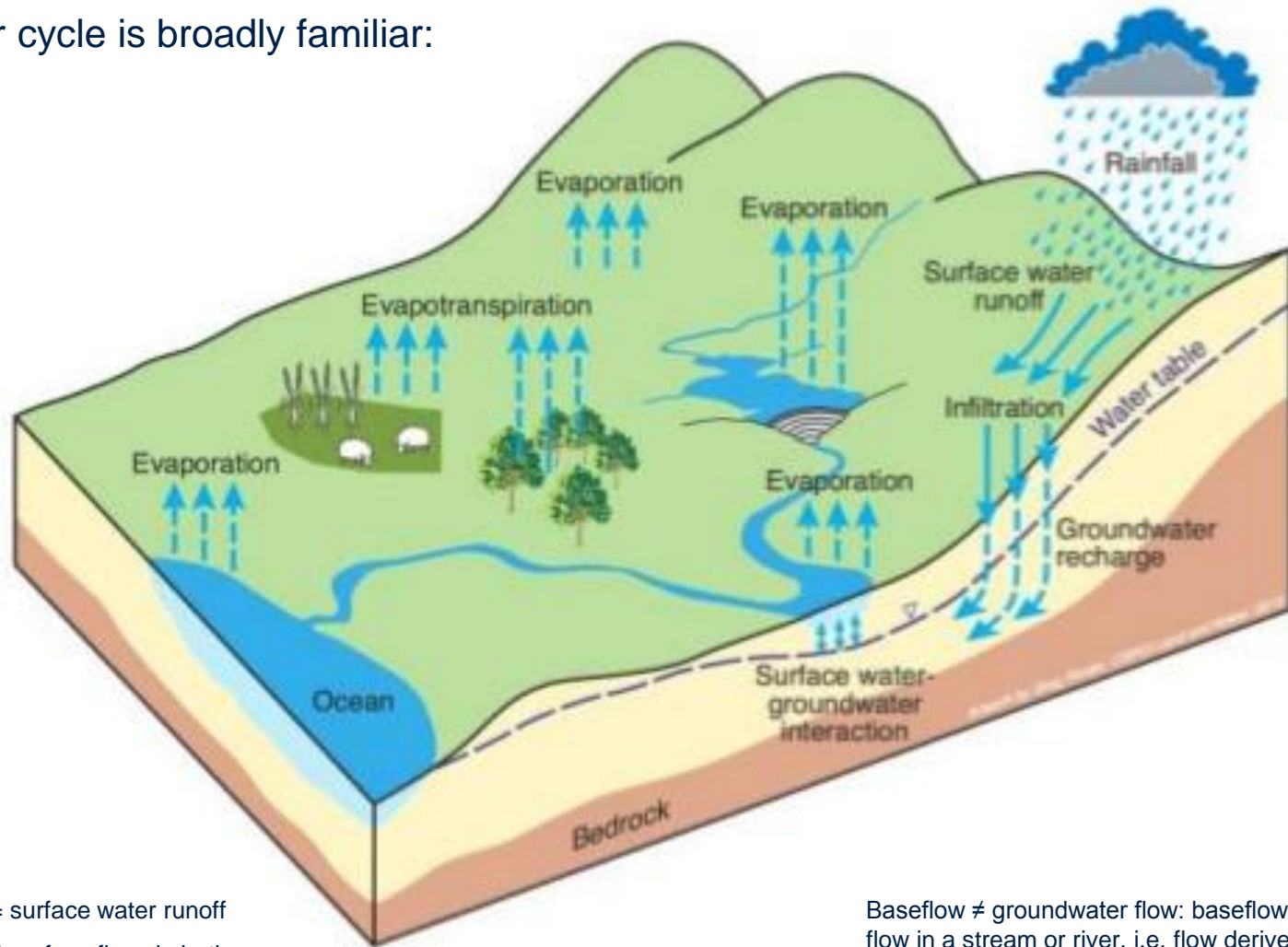


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Hydrological modelling

The water cycle is broadly familiar:



Overland flow = surface water runoff

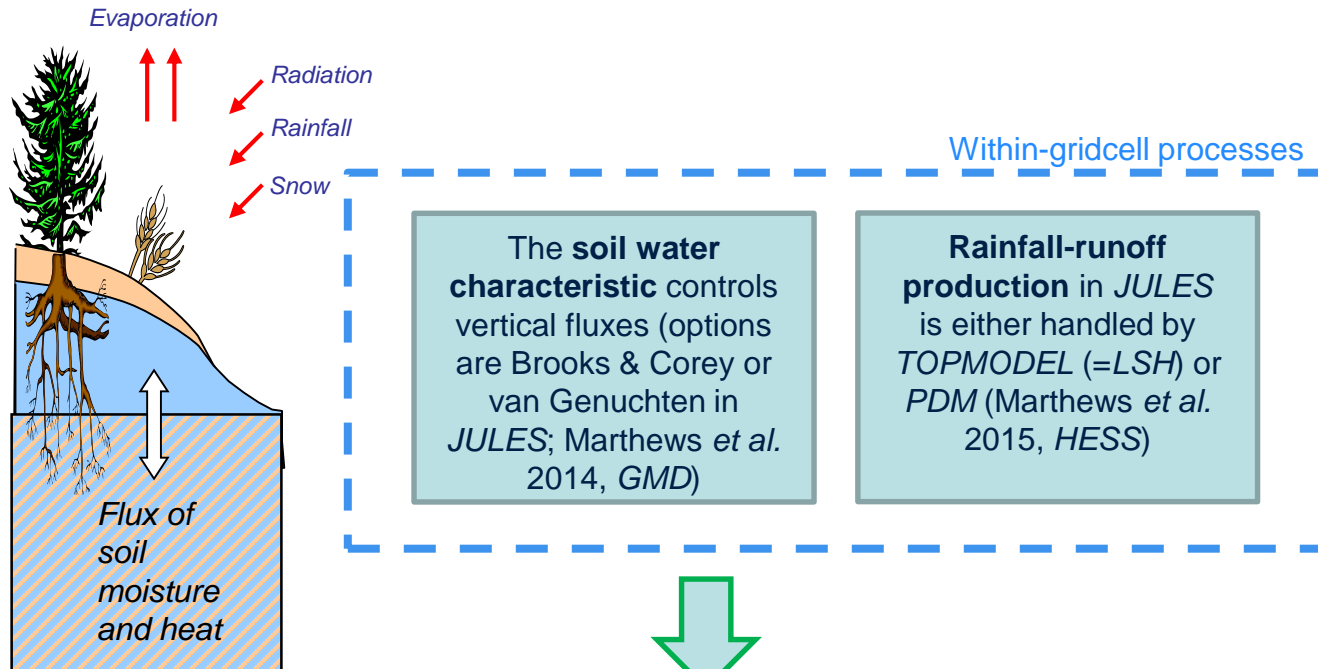
Surface and subsurface flow do both occur. Subsurface flow is sometimes split into unsaturated subsurface flow ('throughflow', above the water table) and saturated subsurface flow (groundwater flow).

Baseflow \neq groundwater flow: baseflow is dry-weather flow in a stream or river, i.e. flow derived from the seepage of groundwater flow and/or throughflow that still occurs in very dry weather

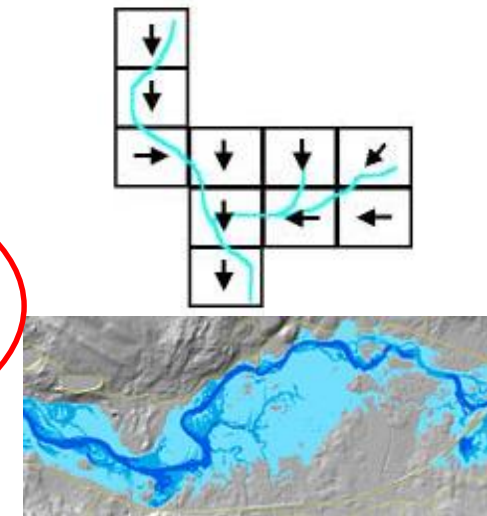
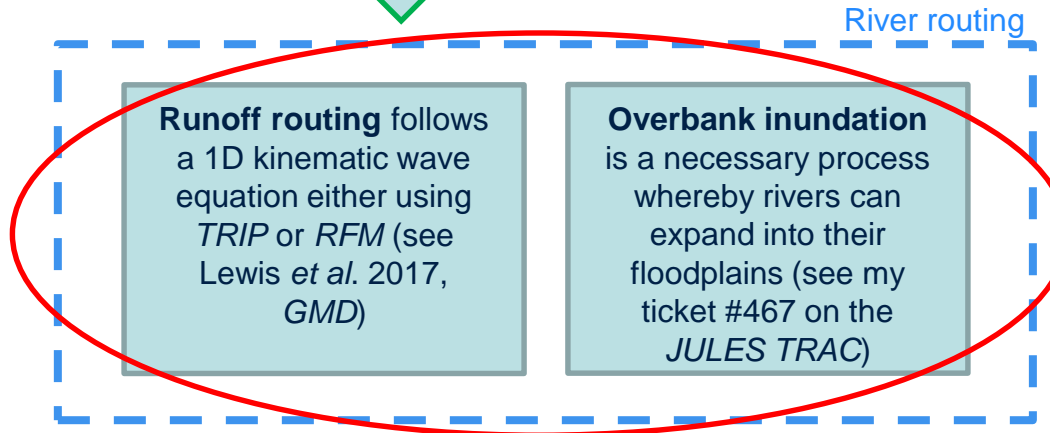
Confined aquifers can also occur (water above the bedrock but underneath an impermeable layer).

Hydrological modelling

The water cycle is implemented in LSMs like *JULES* in steps:

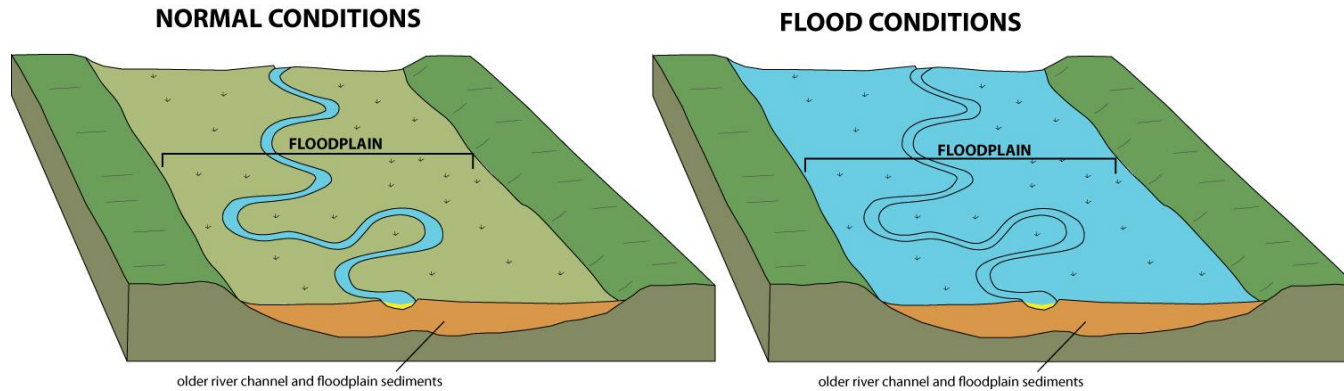


Dadson *et al.*
(2010, *JGR*)



Hydrological modelling

Overbank inundation is the process by which rivers can overflow their banks and widen temporarily into their floodplain. Without this process, JULES can't simulate riverine flooding (e.g. London) or fluvial wetland formation (e.g. Niger inland delta).



London's flood risk area



River routing in JULES

2007: River routing using the TRIP model was implemented in the UM and JULES.

2008ish: River routing using the Grid-to-Grid model (a precursor to RFM) was implemented in the UM and partially in JULES (vn2.1) by Simon Dadson, but not in the JULES trunk.

2014/15: Huw Lewis resolved the code conflicts with the UM and implements RFM in JULES (at vn4.2), however overbank inundation is missing

2016/17: I'm in the process of putting in the missing overbank inundation process (see my ticket #467).

The image shows a screenshot of a ticket page for 'River routing in JULES Implementation Report'. The ticket is titled '#467 sci/tech_review enhancement' and is categorized as 'Overbank inundation changes'. It was reported by 'tobymarthews' and owned by 'huwlewis'. The priority is 'normal' and the milestone is 'JULES v4.9 release'. The keywords are 'River routing overbank inundation'. The description states that Simon Dadson's overbank inundation code from JULESvn2.1 has been put into a standalone RFM version, including a new subroutine called 'overbank_update'. It also mentions that in relation to the overbank inundation code in Simon's vn.2.1 branch, a significant difference is that the code now performs all calculations on the new 1D river routing grid instead of following Simon's original 2D implementation. Three further changes are listed: 1. A switch 'use_rosgen' is added to allow river width (and therefore inundation extent) to be widened or narrowed slightly using the Rosgen entrenchment ratio. 2. 'convert_fqw' is added, converting 'rfm_surfstore' (m3/s) to 'fqw_surfst' (kg m-2 s-1). 3. 'update_basefrac' is added, similar to '#2', with a permanent change from '=F' to '=T'.

New Global River Routing Scheme in the Unified Model

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Met Office

River routing in JULES
Implementation Report

#467 sci/tech_review enhancement
Opened 2 months ago
Last modified 5 days ago

Overbank inundation changes

Reported by: tobymarthews
Owned by: huwlewis
Priority: normal
Milestone: JULES v4.9 release
Keywords: River routing overbank inundation
Cc: kerry.day@metoffice.gov.uk, huw.lewis@metoffice.gov.uk, simon.dadson@ouce.ox.ac.uk

Description (last modified by kerryday) [Δ](#)

Simon Dadson's overbank inundation code from JULESvn2.1 has been put into the standalone RFM version of routing, including a new subroutine called overbank_update. [Reply](#)

In relation to the overbank inundation code in Simon's vn.2.1 branch, a significant difference is that the code now performs all calculations on the new 1D river routing grid instead of following Simon's original 2D implementation. Apart from all the renaming of variables and modules required to bring the code forward to vn4.8, there are 3 further changes:

1. I've added in a switch use_rosgen to allow river width (and therefore inundation extent) to be widened or narrowed slightly using the Rosgen entrenchment ratio. See new documentation pages for how this works.
2. convert_fqw: rfm_surfstore is in units m3/s but fqw_surfst is in units kg m-2 s-1 so I needed to convert (I think this was just something small that was missed before). Having this =F is equivalent to Simon's code and I am proposing =T, but I have left this in as a switch temporarily to allow Simon to comment.
3. update_basefrac: Similarly to #2, Simon had the equivalent of =F and I am proposing =T as a permanent change. See attachment for more detail on this one.

[Ticket Summary](#)
BRANCHNAME

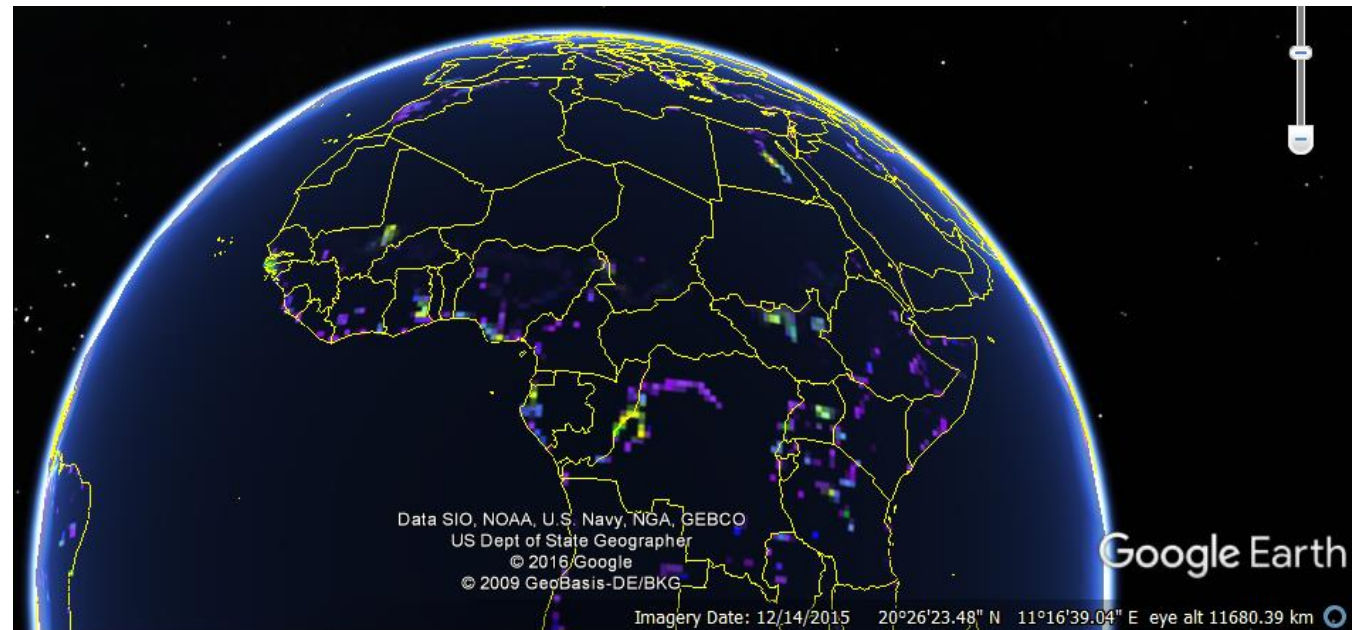
River routing in JULES

The new code needs to be validated, e.g. against standard inundation datasets such as GIEMS and methane emission data from SCIAMACHY & GOSAT (in collaboration with Garry Hayman at CEH).



GIEMS (Global Inundation Extent from Multi-Satellites)

The Global Inundation Extent from Multi-Satellites (GIEMS) is a unique dataset that provides the surface water extent and dynamics over the globe and over a long time record (1993-2007), based on a collection of satellite observations. The percentage of inundation is estimated over an equal-area grid (pixels of $0.25^\circ \times 0.25^\circ$ at the equator, i.e., roughly $28\text{km} \times 28\text{km}$), at a monthly time-scale.



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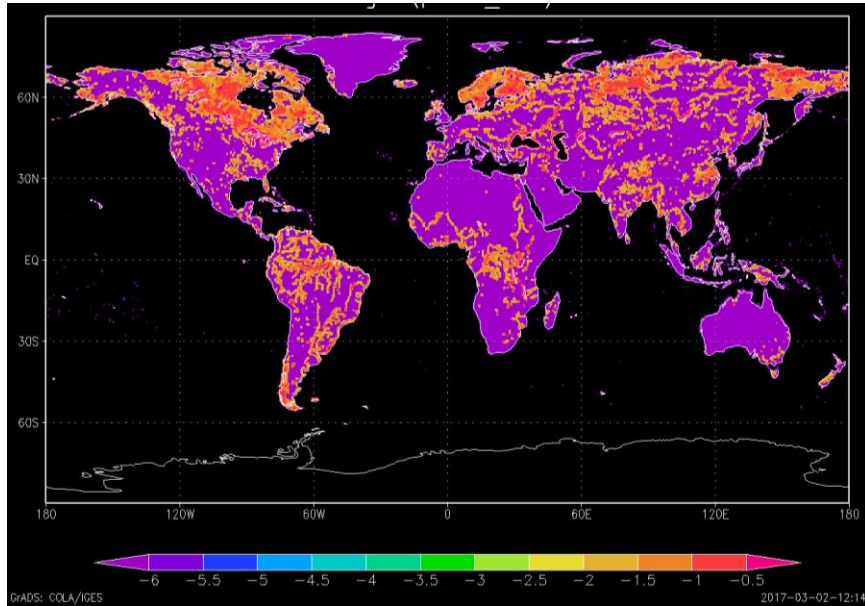


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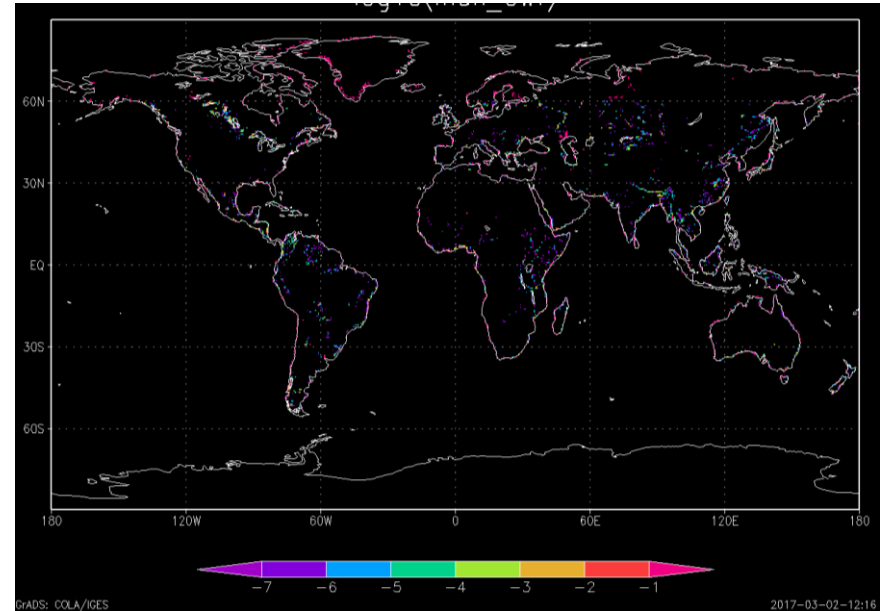
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Results using my o/inun code

$\log_{10}(\text{frac_opwat_lp})$



$\log_{10}(\text{frac_fplain_lp})$



River routing with overbank inundation will not be in JULESv4.9, but is functional in a development branch of JULES ([main/branches/dev/tobymarthews/r8311_ovinun](#); n.b. you need my modified Rose suite to make it work, available as u-am539 on Rosie Go).

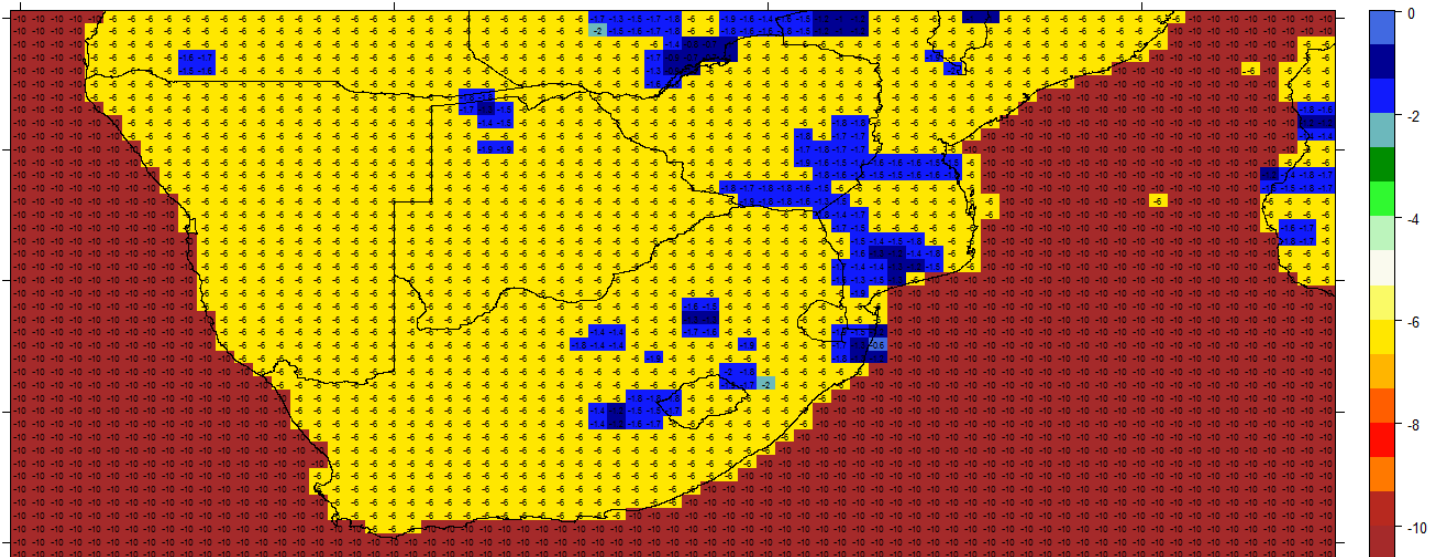
Above are plots of gridcell permanent and inundation open-water fractions. Note log scale from which you can see that inundation fraction frac_fplain_lp is usually only a small addition to open water fraction frac_opwat_lp overall (which is right). Both plots are for 7th June 2003 @ 5am.

Results using my o/inun code



frac_opwat_lp:

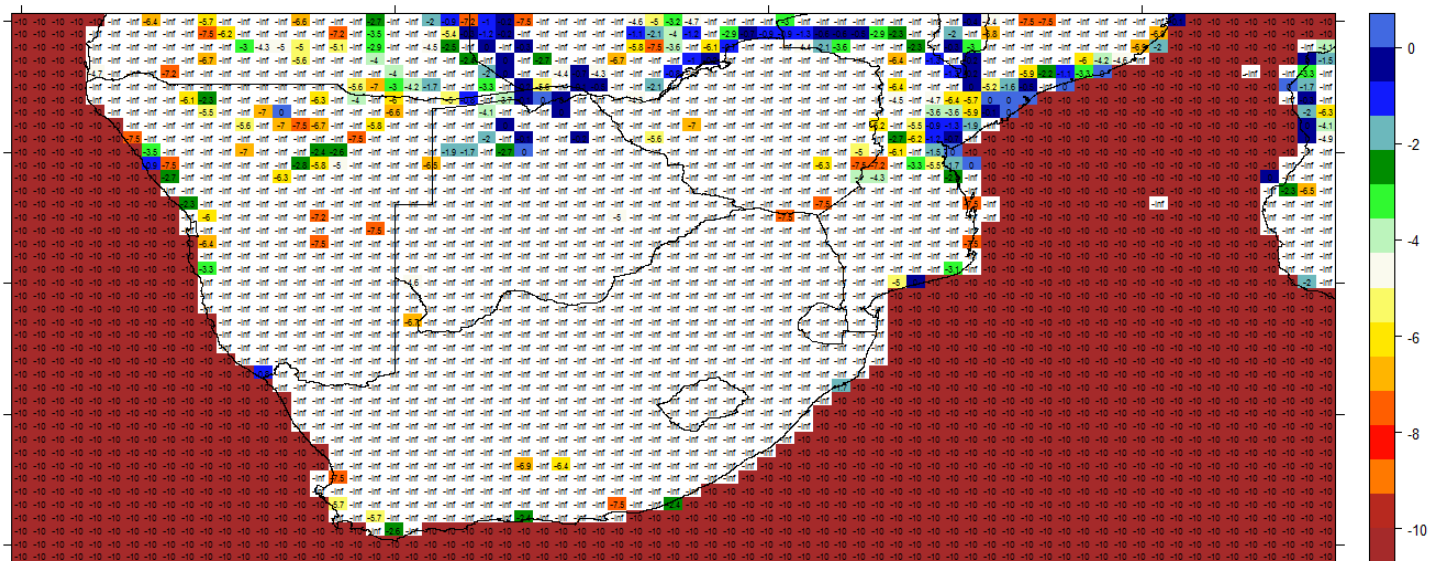
the fraction of each gridcell covered by permanent open water.
(values are logged fractions, i.e. -4.7 means $10^{(-4.7)} = 0.00002 = 0.002\%$ of the cell (for this plot, zero value on land is $1e-6$, at sea $1e-10$))



frac_fplain_lp:

with
I_riv_hypsometry=T
(end Feb 1979)

the fraction of each gridcell covered by river surface and overbank inundation.
(for this plot, zero value on land is -Inf, at sea $1e-10$)

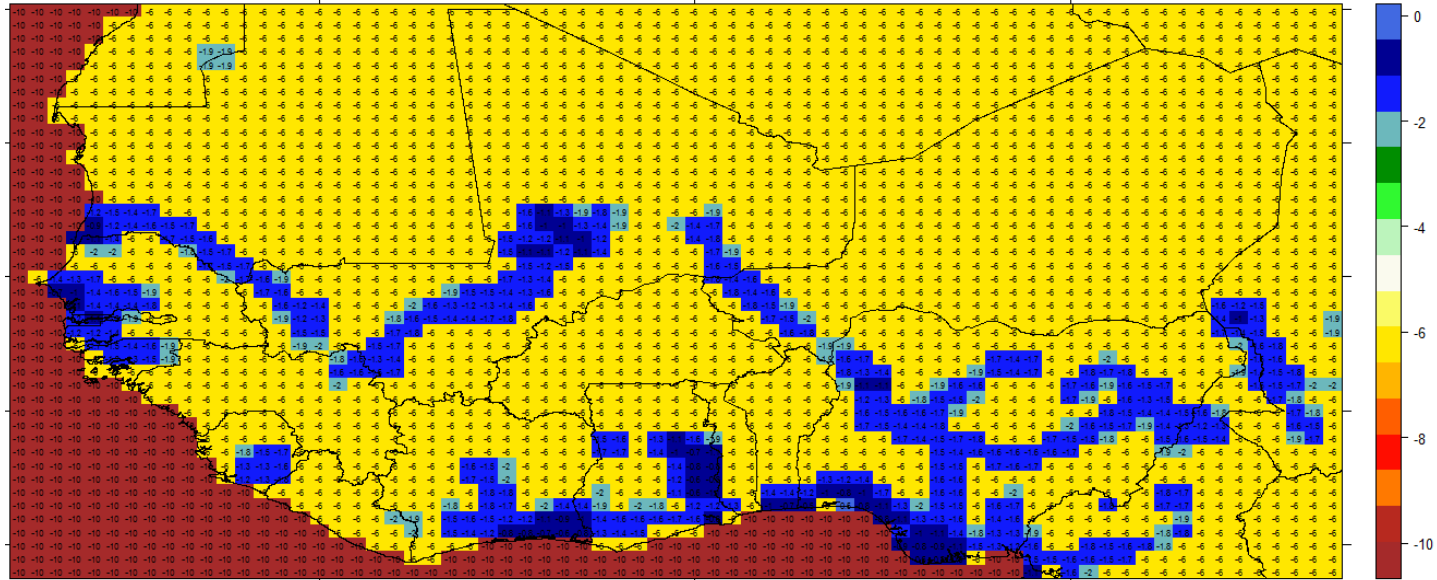


Dadson *et al.* (2010)'s results for Mali



frac_opwat_lp:

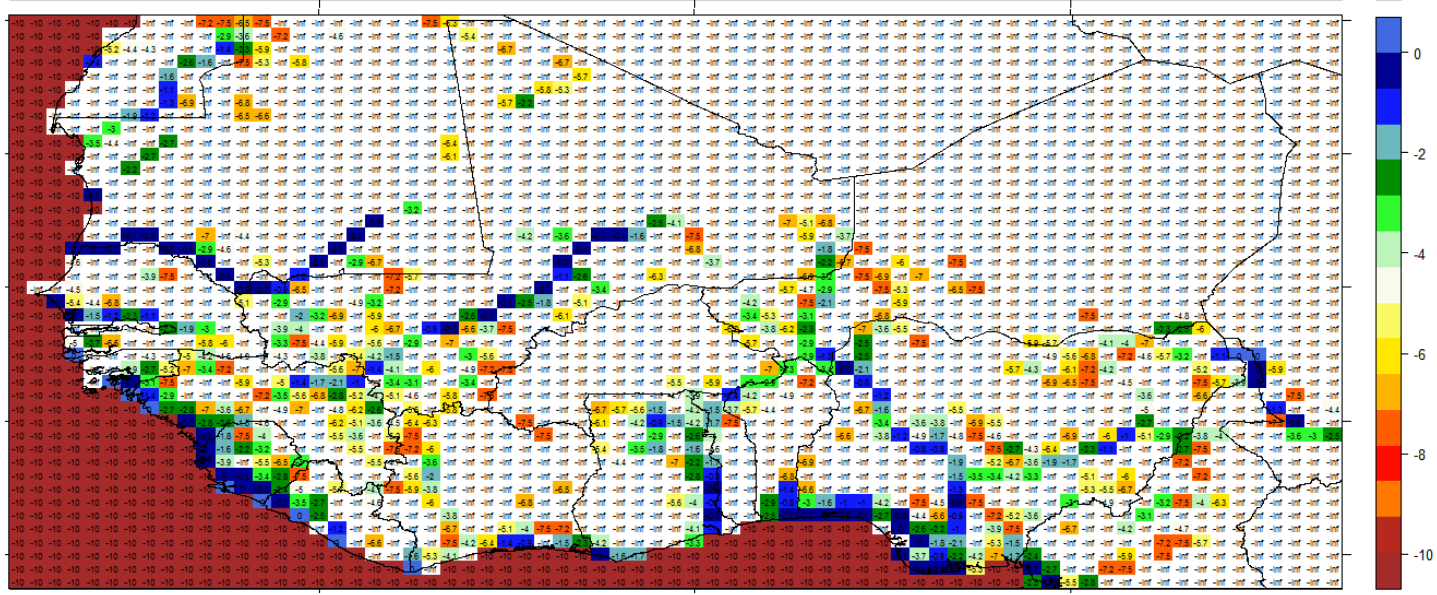
the fraction of each gridcell covered by permanent open water.
(values are logged fractions, i.e. -4.7 means $10^{(-4.7)} = 0.00002 = 0.002\%$ of the cell (for this plot, zero value on land is $1e-6$, at sea $1e-10$))



frac_fplain_lp:

with
 $I_{riv_hypsometry} = T$
(20th Sep 2003)

the fraction of each gridcell covered by river surface and overbank inundation.
(for this plot, zero value on land is $-\text{Inf}$, at sea $1e-10$)

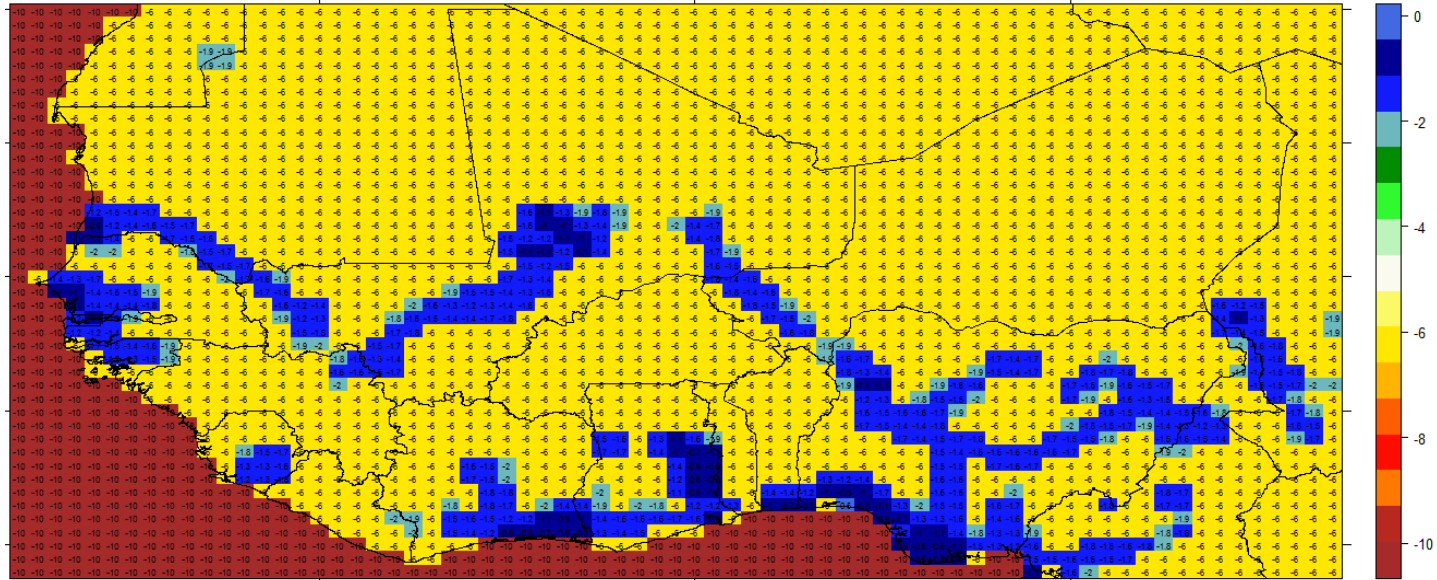


Dadson *et al.* (2010)'s results for Mali



frac_opwat_lp:

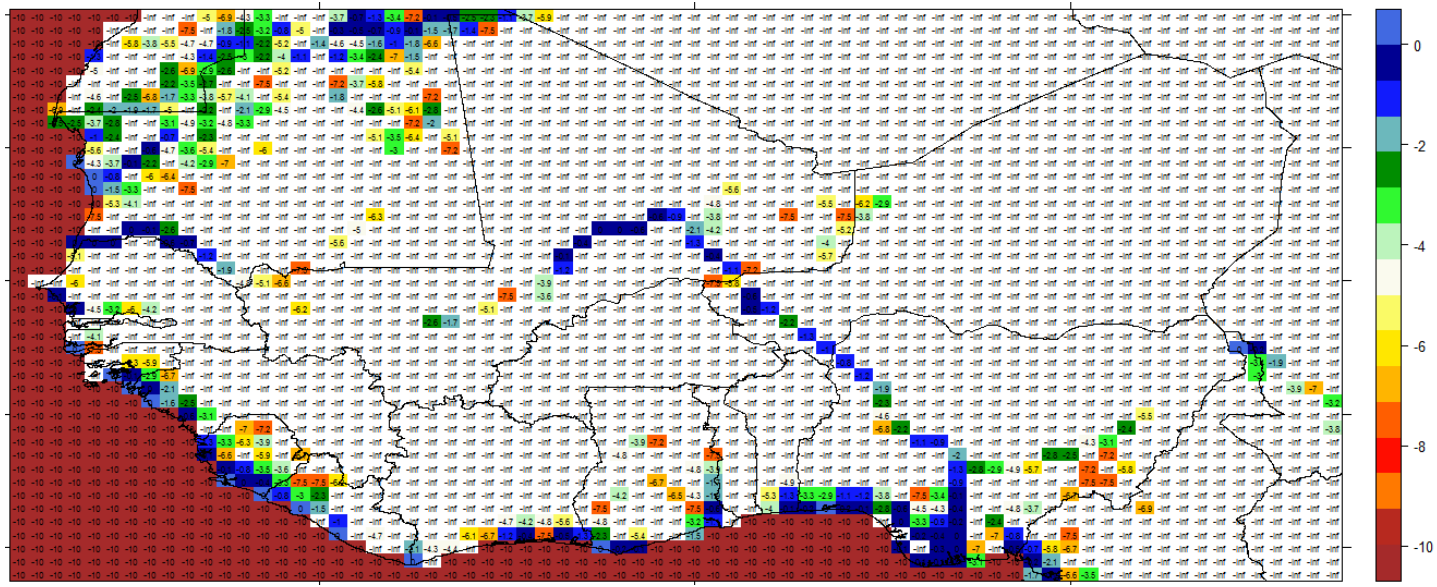
the fraction of each gridcell covered by permanent open water. (values are logged fractions, i.e. -4.7 means $10^{(-4.7)} = 0.00002 = 0.002\%$ of the cell (for this plot, zero value on land is $1e-6$, at sea $1e-10$))



frac_fplain_lp:

with $I_{riv_hypsometry} = T$ (20th Oct 2003)

the fraction of each gridcell covered by river surface and overbank inundation. (for this plot, zero value on land is $-\text{Inf}$, at sea $1e-10$)

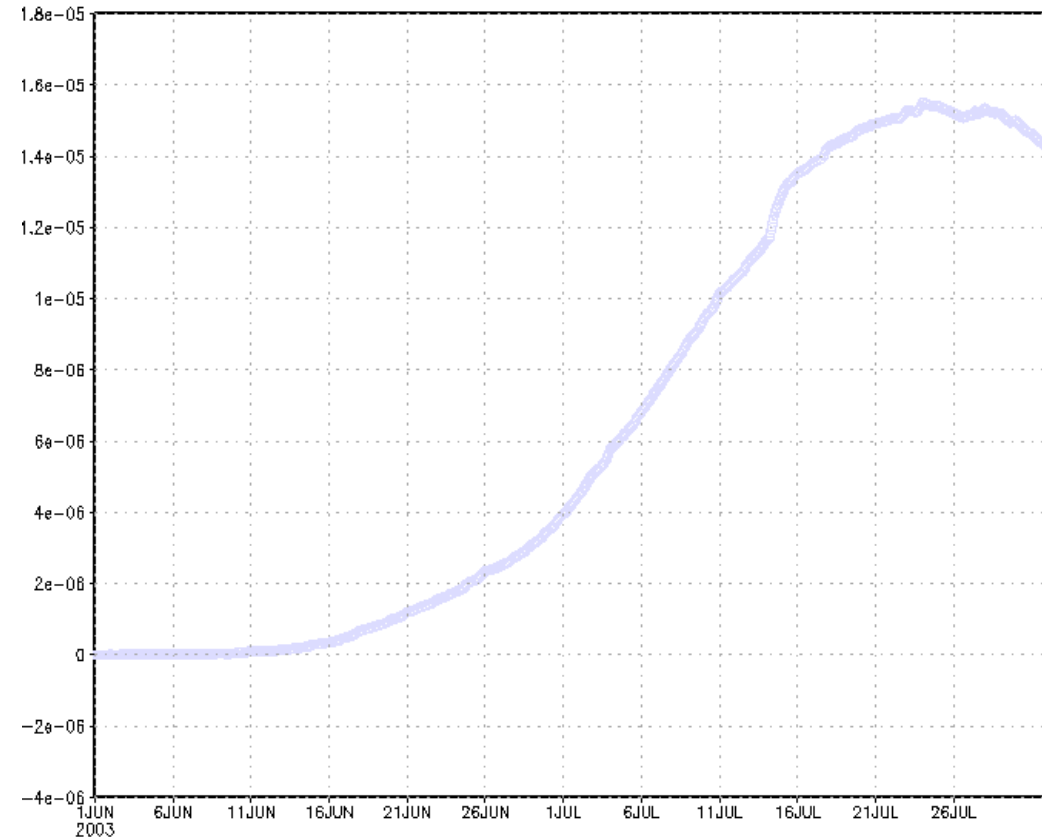


Results using my o/inun code

frac_fplain_lp:

with *I_riv_hypsometry=T*

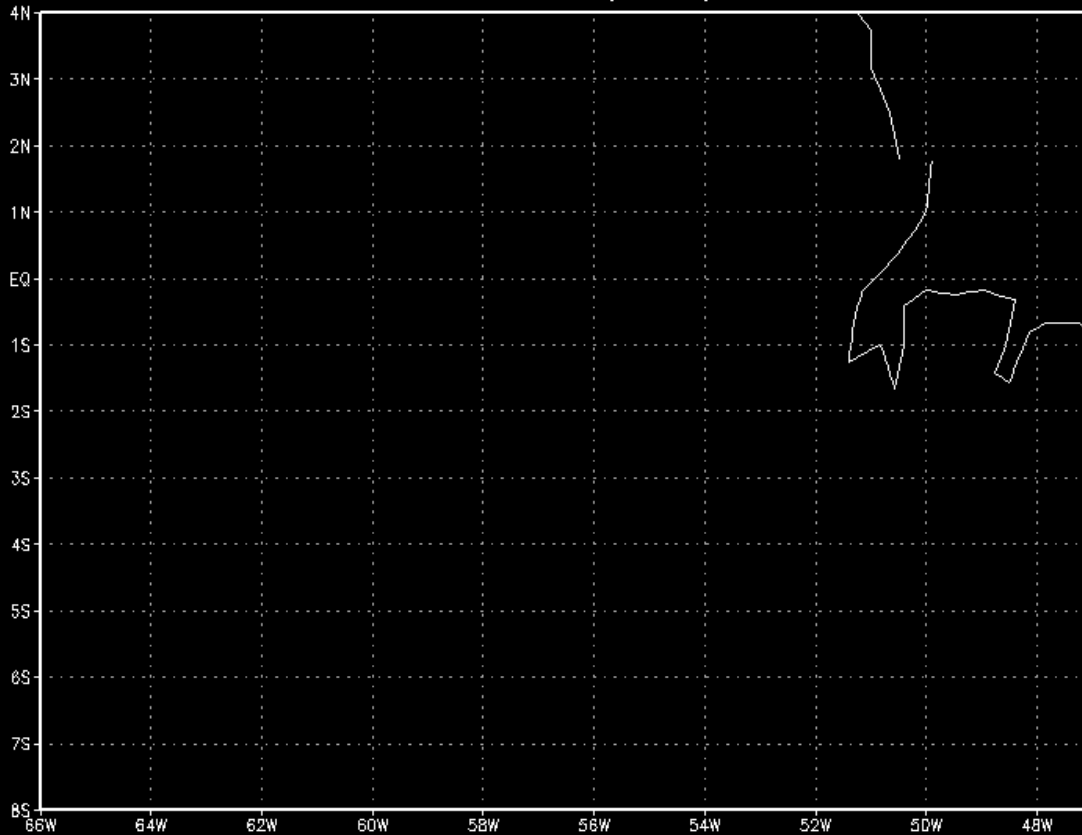
Overbank inundation for the Amazon at Santarém, Brazil (4 pixels lat -2.5 -1.5, lon -55.5 -54.5), which steadily increases from 0 to 1.6×10^{-5} (i.e. 0.000016 fraction or 0.0016% of the gridcell). That's not a lot of inundation, it seems, but these gridcells are 50 km x 50 km, which makes this 40000 m², or equivalent to a 1 km stretch of river within the gridcell flooding a distance of 40 m. Note that from another plot (not shown) I know that the open water fraction in these cells is a constant 33% of these gridcells (we are right on the Amazon river) so the gridcell is a third river anyway and this inundation represents only a slight widening of the river. March is the wettest month in Santarém so we're at the end of the rainy season in June and this is a reasonable amount of inundation going into the dry season



Results using my o/inun code



t= 00:00 on 01/JUN/2003



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Why didn't I make it into JULESvn4.9?

- In short, not enough time and I admit I underestimated the requirements of the science & code review process:
 - ❑ **Sep-Dec 2016:** Updated Simon Dadson's JULESvn2.1 overbank inundation code for JULESvn4.6
 - ❑ **Jan 2017:** Release of vn4.7 and within a week I had a code branch working with my proposed changes (all correctly switched so can turn it all off).
 - ❑ **Jan-Feb:** River routing modules were all changed over from 2D calculations to 1D, necessitating a complete rewrite and reorganisation of my code (lots of help from Huw Lewis inc. a meeting in Bristol).
 - ❑ **1st March:** Release of vn4.8
 - ❑ **24th March:** Resolved all issues with vn4.8 and code worked again. Science review starts.
 - ❑ **Mid-May:** Passed science review with HL, but Nic Gedney makes very good points about possible conflicts from use of open water fraction $frac(:,7)$ in SD's code. Recommends inserting option to have inundation purely as a diagnostic (now implemented using switch *fplain_opt*).
 - ❑ **26th May:** *fplain_opt* switch implemented, but I miss code submission deadline for vn4.9.
 - ❑ **2nd June:** Kerry VERY kindly allows my code to move forward to code review. Next two weeks involve several changes to code inc. splitting module into 3 modules and other edits and reorganisations.
 - ❑ **19th June:** Kerry requests second science review because so many changes. HL completes same day.
 - ❑ **21st June:** Despite last minute help from Doug Clark, code rejected. Reasons given are (i) outstanding coding standard contraventions, (ii) request that my code should be implemented for both RFM and TRIP and (iii) insufficient demonstration on my part of how water recedes after inundation.
- Quite a lot of lessons for me here (this is my first attempt to put changes into the JULES trunk). I've benefited a lot from goodwill from many people (esp. allowing me to move to code review), but I just wasn't quick enough to get it all in.

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Outstanding issues and next steps

- I need to decide whether it is feasible to apply these changes to TRIP as well as RFM. Early on in this project it was decided to leave TRIP well alone because that would involve potentially serious conflicts with the UM, but perhaps something can be switched in.
- I need to have more test run results and I need to make a much better case proving that Simon Dadson's code (or rather my version of it) is the best way to model o/inun in the JULES context.
- I have suggested several corrections to RFM (discussed with Simon on 13th Jan in Oxford and with Huw on 2nd Feb in Bristol). These are all still valid, but now postponed to later tickets to deal with after #467 (i.e. after overbank inundation has gone into the trunk in some form). Details are in tickets #466, #469 and #484.
- The code needs to be validated more robustly (although gridded data is sparse).
- I'm now aiming to get this into JULESvn5.1, hopefully in early 2018 (project commitments allowing).
- Some/all of this needs to be published (!).

Thank you for your attention

Toby Marthews, Huw Lewis,
Simon Dadson

A swimming pool in Magdeburg,
Germany, in 2013

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Exeter, 27th June 2017



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