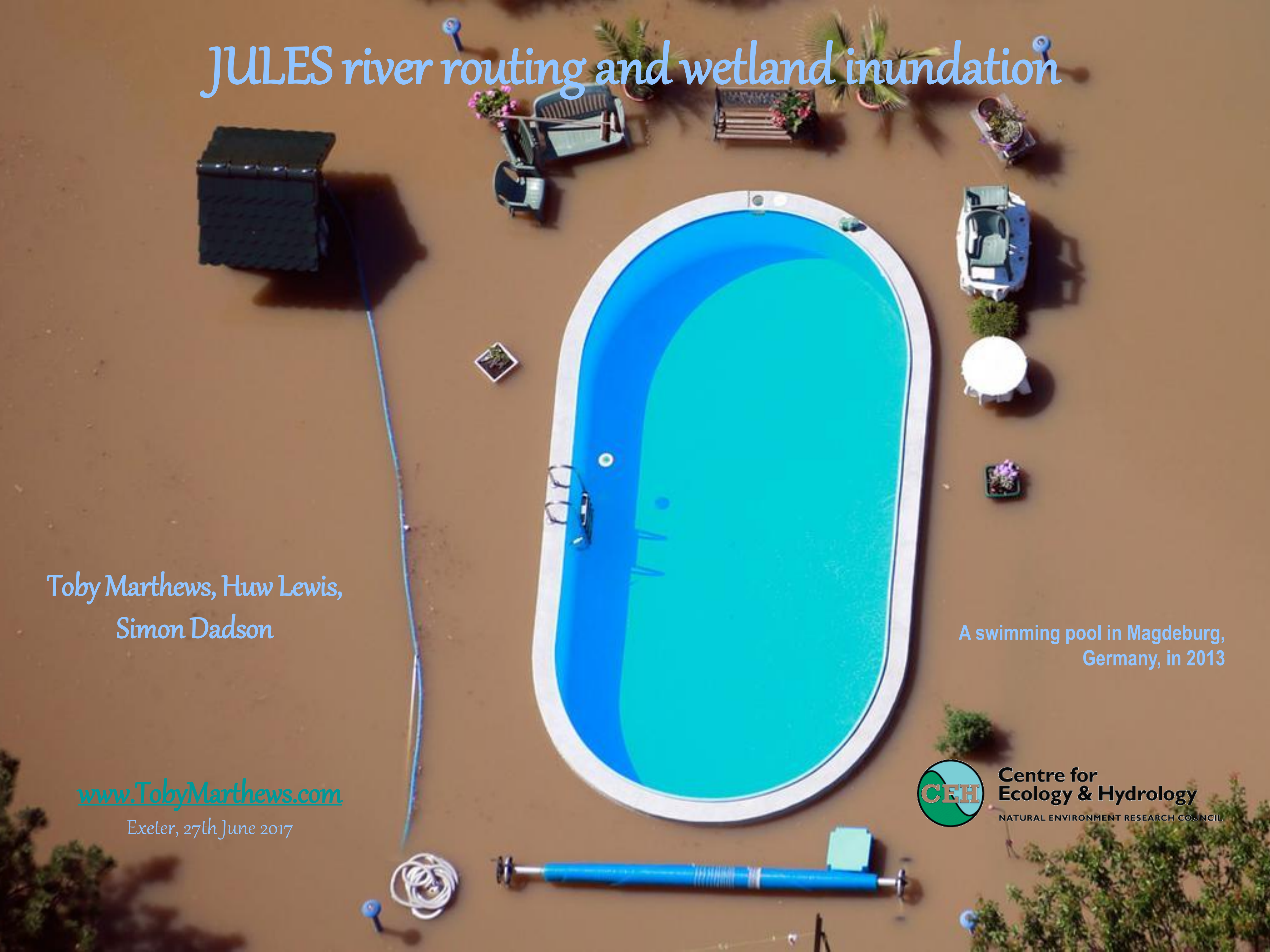
JULES river routing and wetland inundation

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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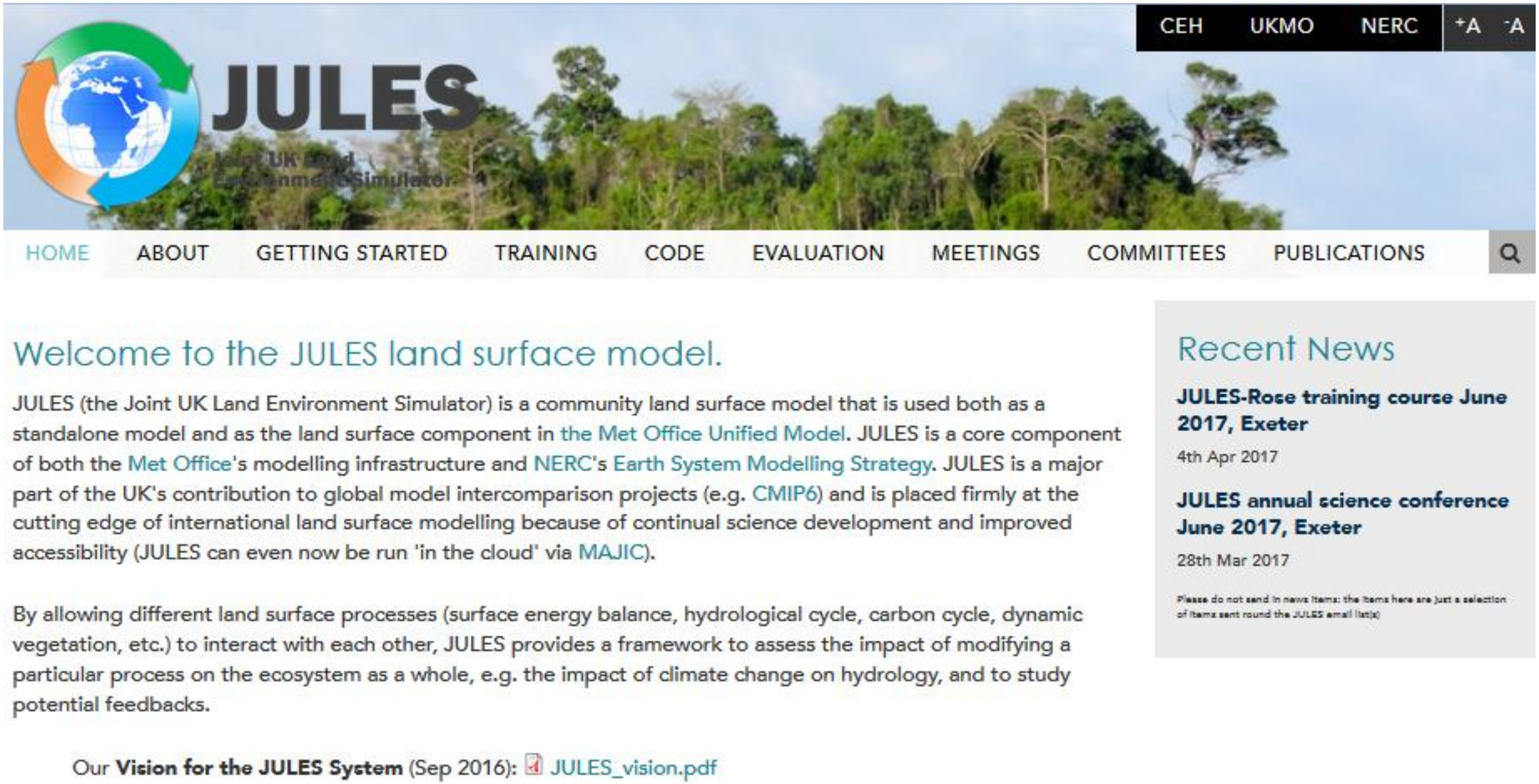
NATURAL ENVIRONMENT RESEARCH COUNCIL

New JULES website

https://jules.jchmr.org

has become

http://jules.jchmr.org



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 ABOUT GETTING STARTED TRAINING CODE EVALUATION MEETINGS PUBLICATIONS

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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- Results using my o/inun (overbank inundation) code
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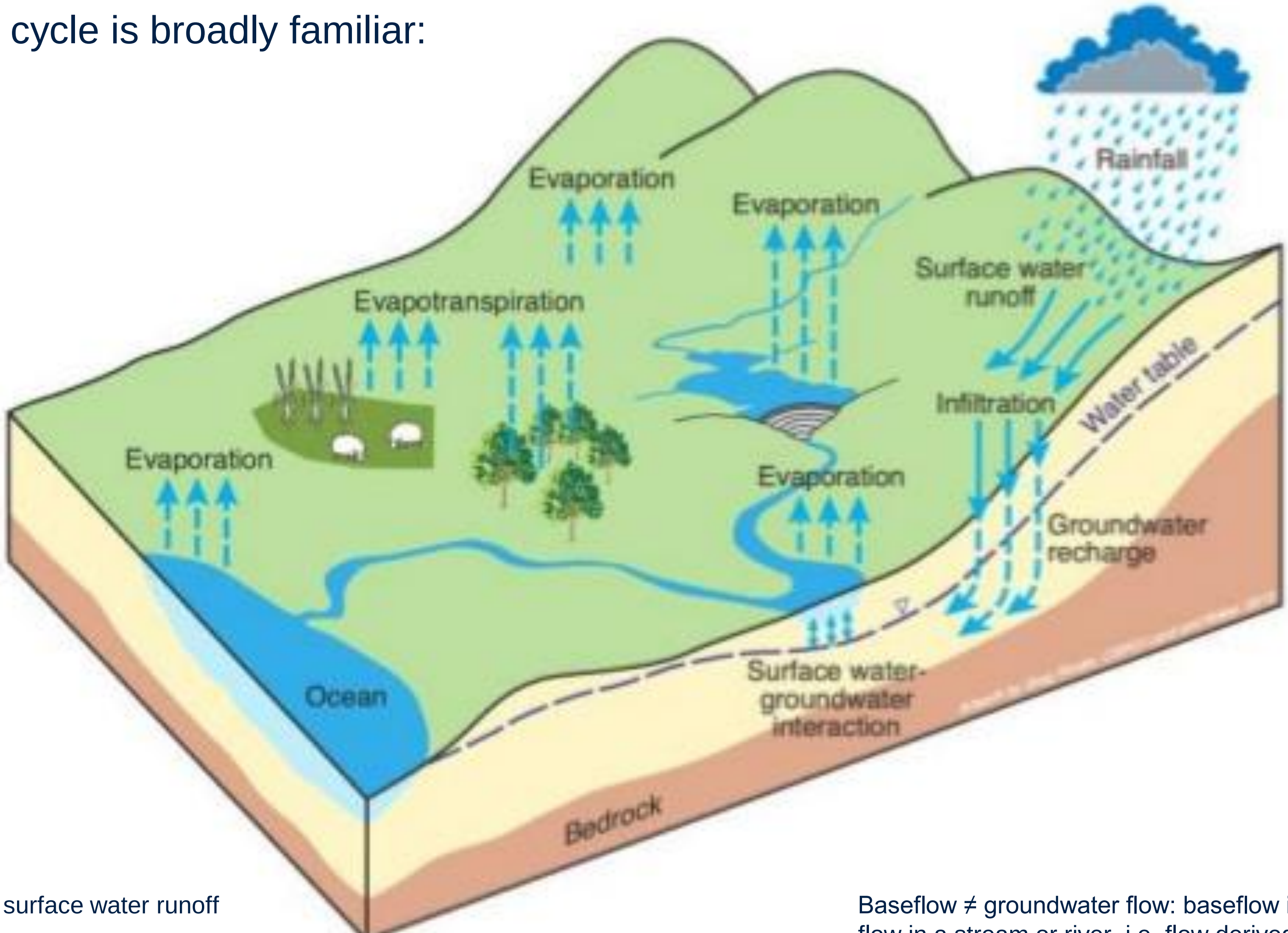
Hydrological modelling

The water cycle is broadly familiar:



Overland flow = surface water runoff

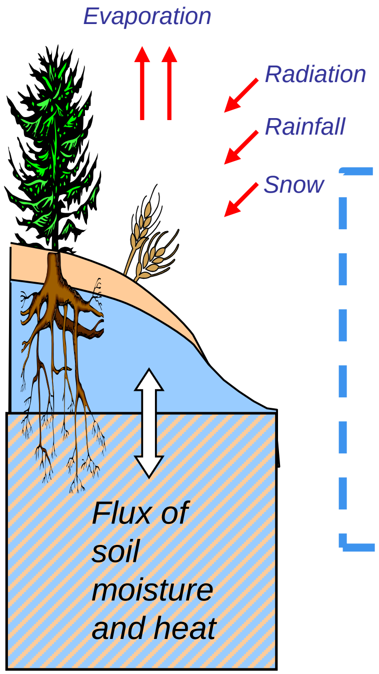
Surface and subsurface flow do both occur. Subsurface flow is sometimes split into unsaturated subsurface flow (‘throughflow’, above the water table) and saturated subsurface flow (groundwater flow).

Baseflow ≠ 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*)

Within-gridcell processes

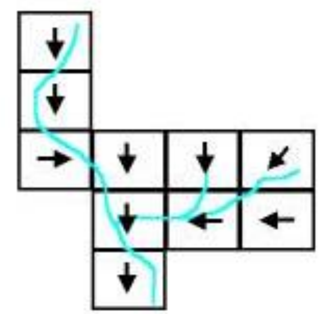
The **soil water characteristic** controls vertical fluxes (options are Brooks & Corey or van Genuchten in *JULES*; Marthews *et al.* 2014, *GMD*)

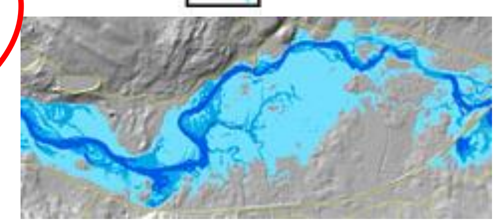
Rainfall-runoff production in *JULES* is either handled by *TOPMODEL* (=*LSH*) or *PDM* (Marthews *et al.* 2015, *HESS*)

River routing

Runoff routing follows a 1D kinematic wave equation either using *TRIP* or *RFM* (see Lewis *et al*. 2017, *GMD*)

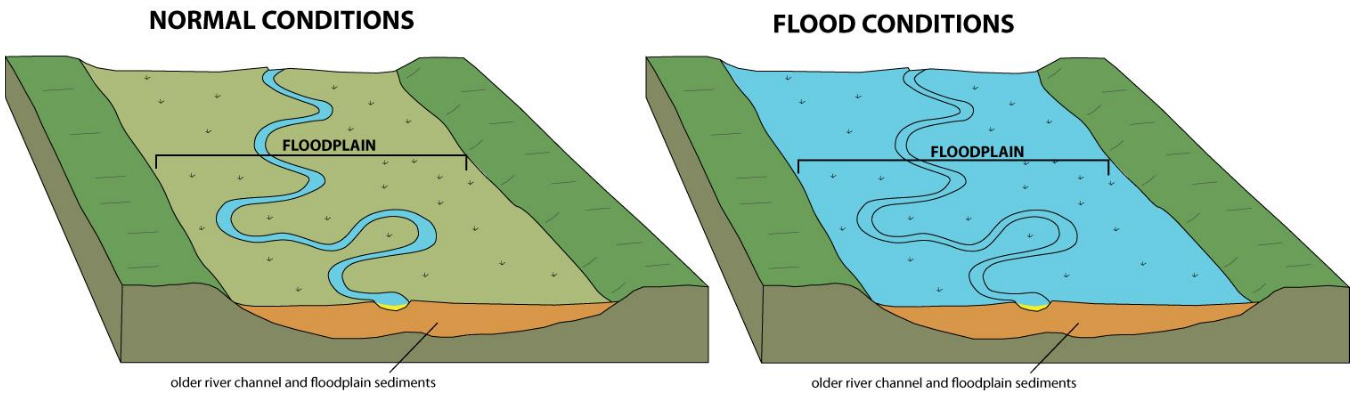
Overbank inundation is a necessary process whereby rivers can expand into their floodplains (see my ticket #467 on the *JULES TRAC*)





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).



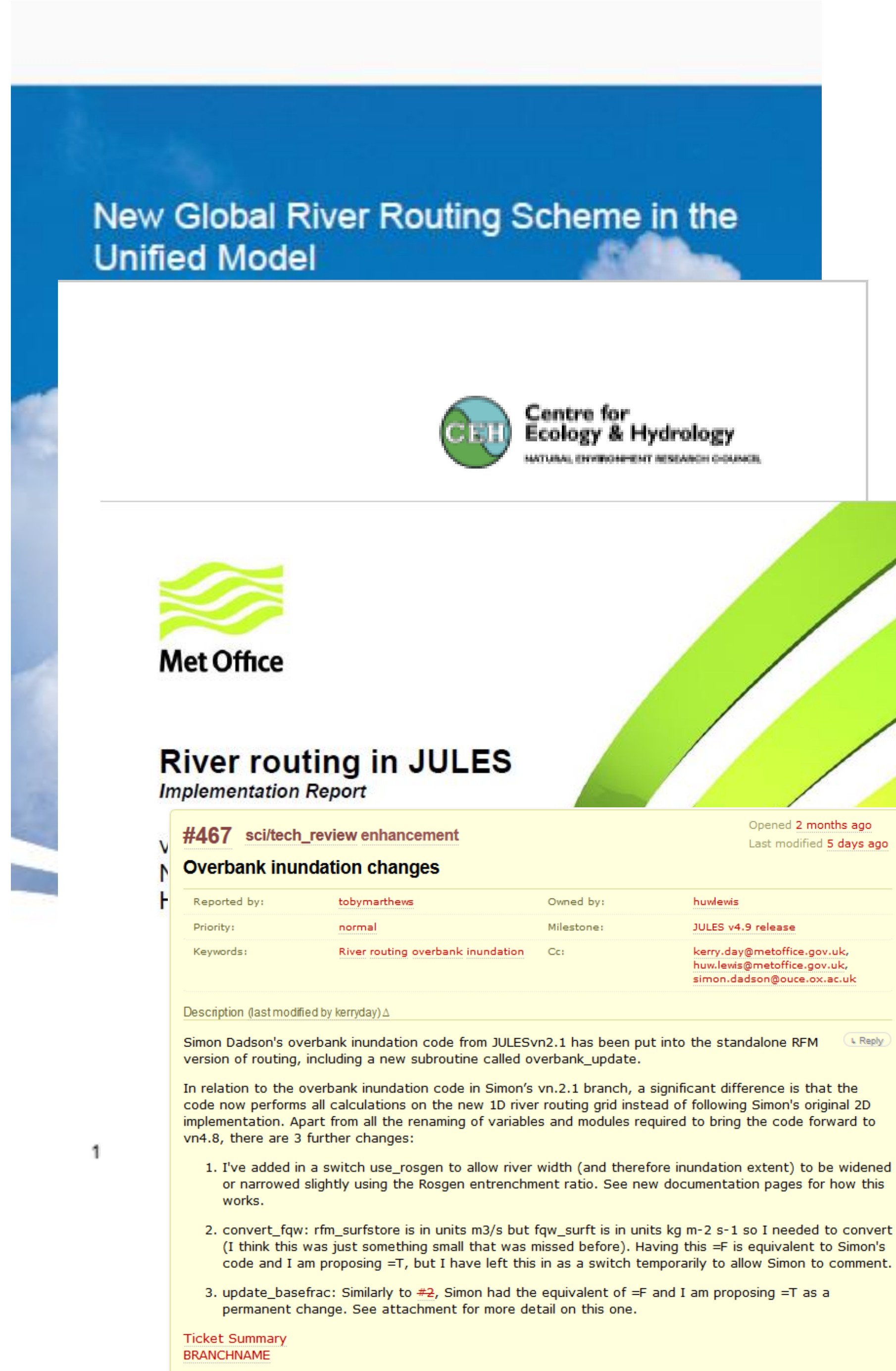
River routing in JULES

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).



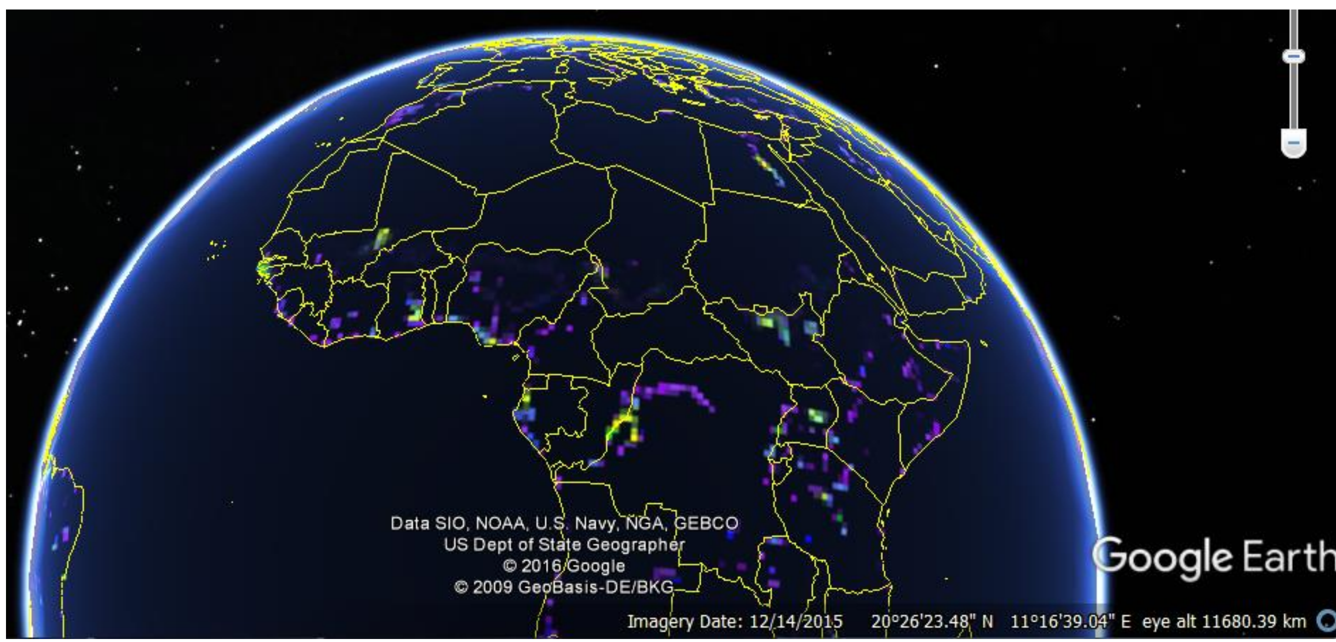
River routing in JULES

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).

l'Observatoire de Paris | LERMA

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°x0.25° at the equator, i.e., roughly 28kmx28km), at a monthly time-scale.



SCIAMACHY

Greenhouse gases Observing SATellite GOSAT PROJECT

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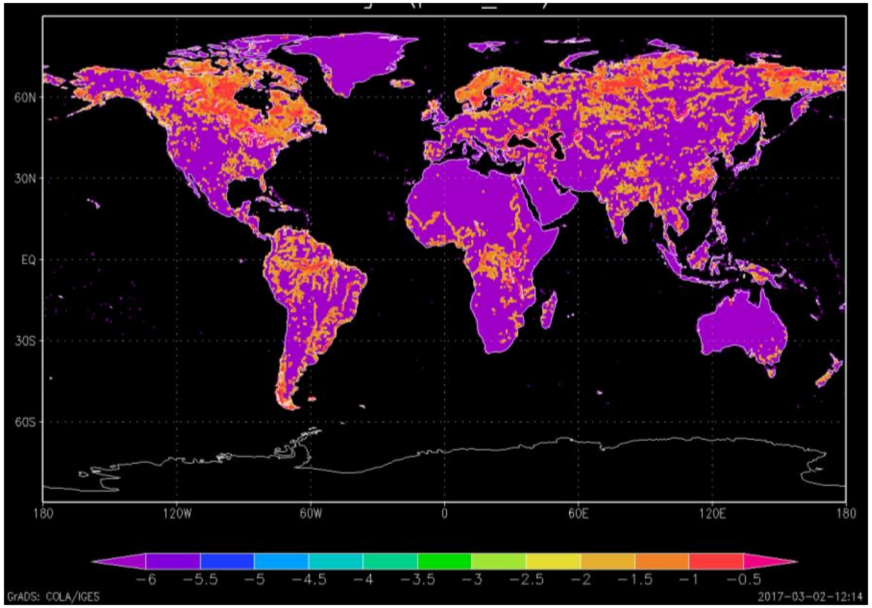
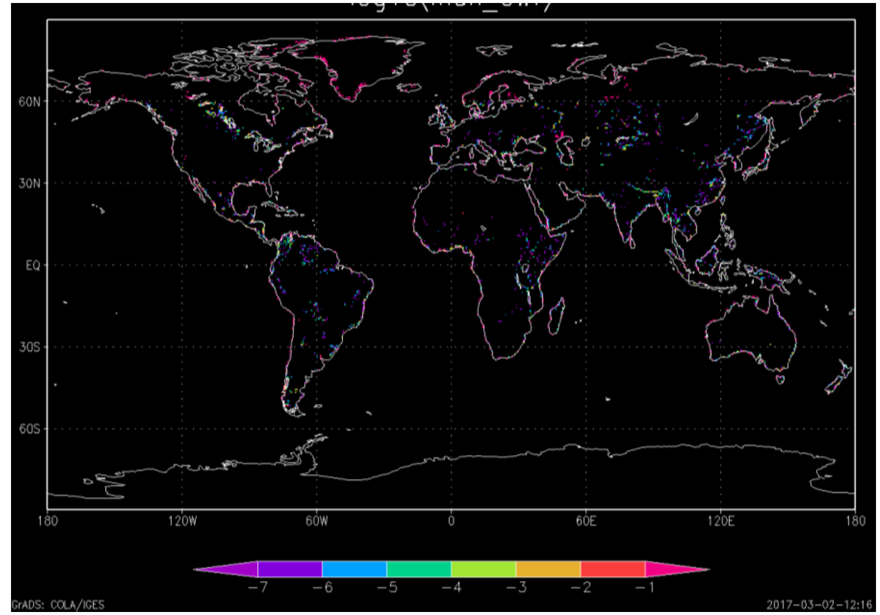
Results using my o/inun code

log10(*frac_opwat_lp*)



log10(*frac_fplain_lp*)



River routing with overbank inundation will not be in JULESvn4.9, 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).

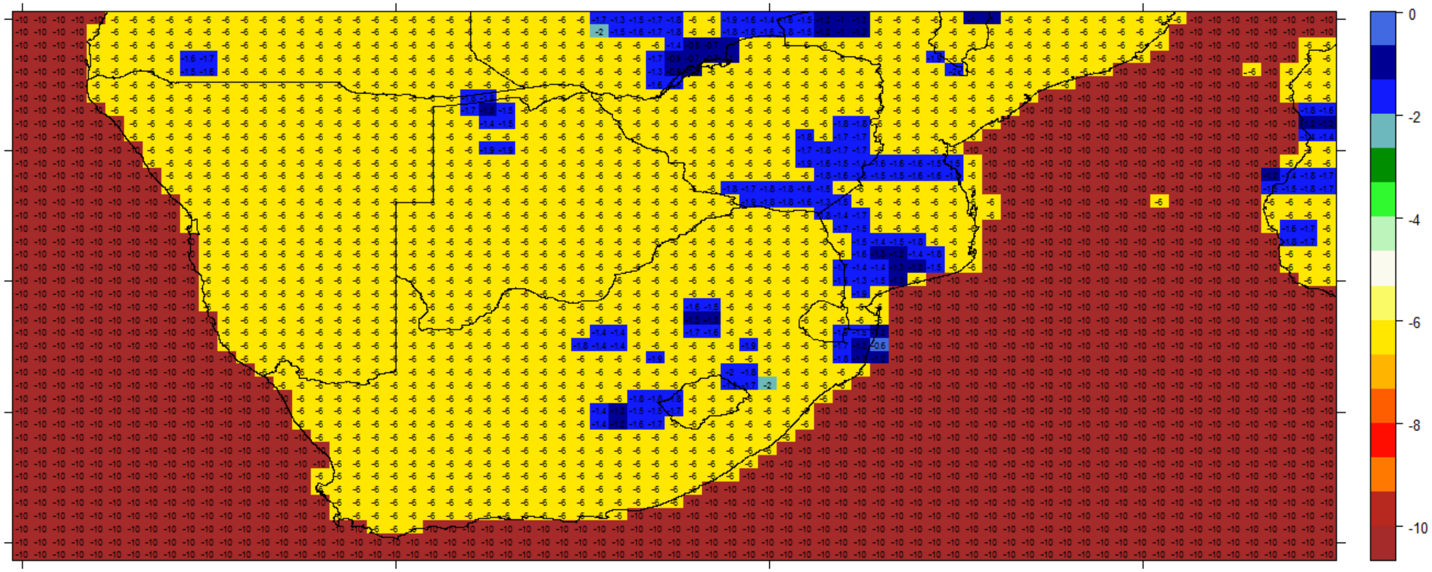
Above are plots of gridcell permanent and inundation open-water fractions. Note log scale from which you can see that inundation fraction *frac_fplain_lp* is usually only a small addition to open water fraction *frac_opwat_lp* overall (which is right). Both plots are for 7th June 2003 @ 5am.

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)



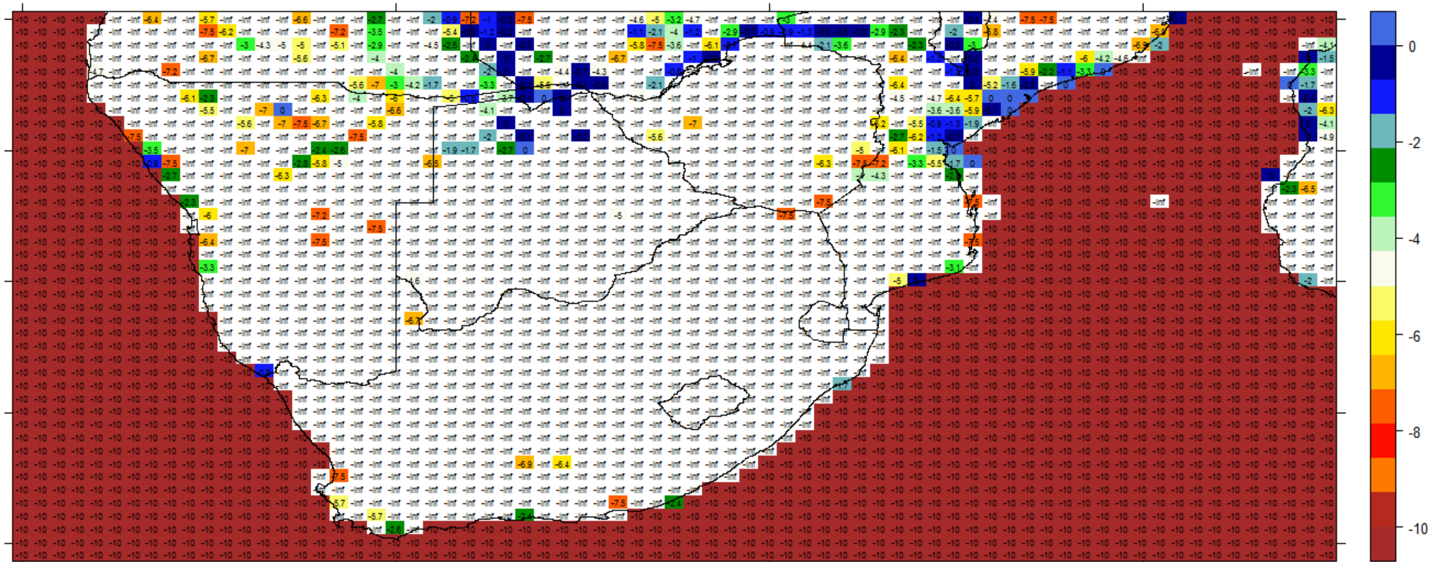
frac_fplain_lp:

with *l_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

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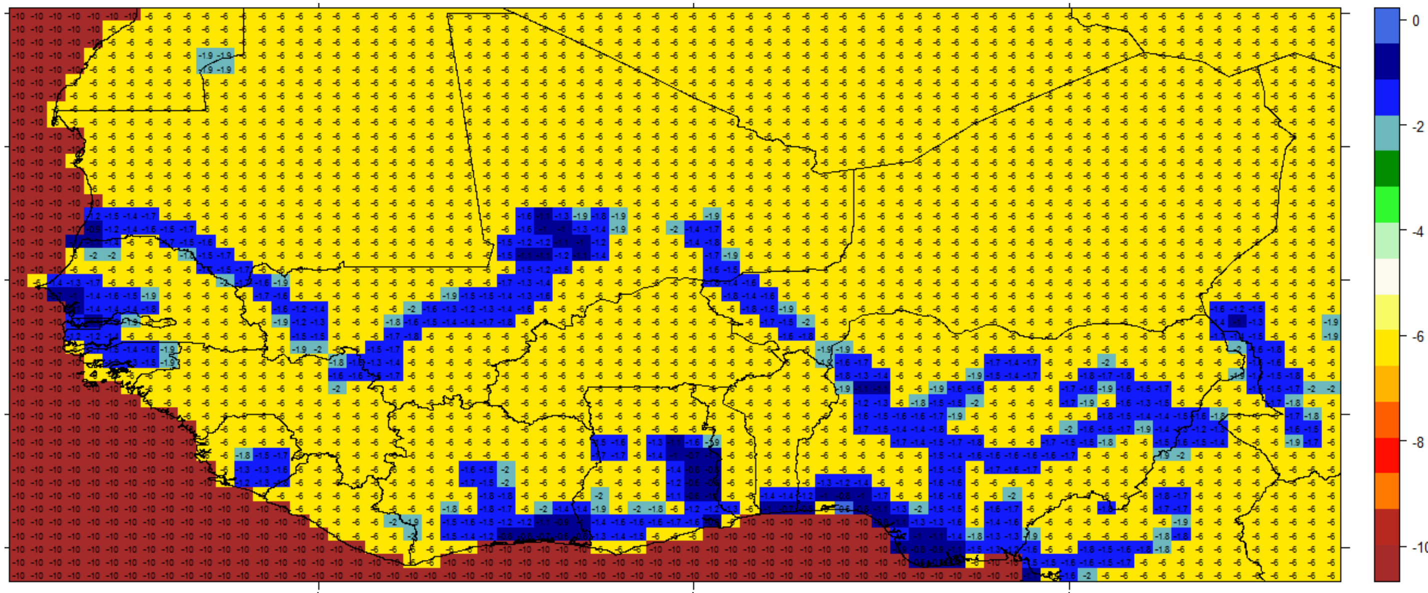
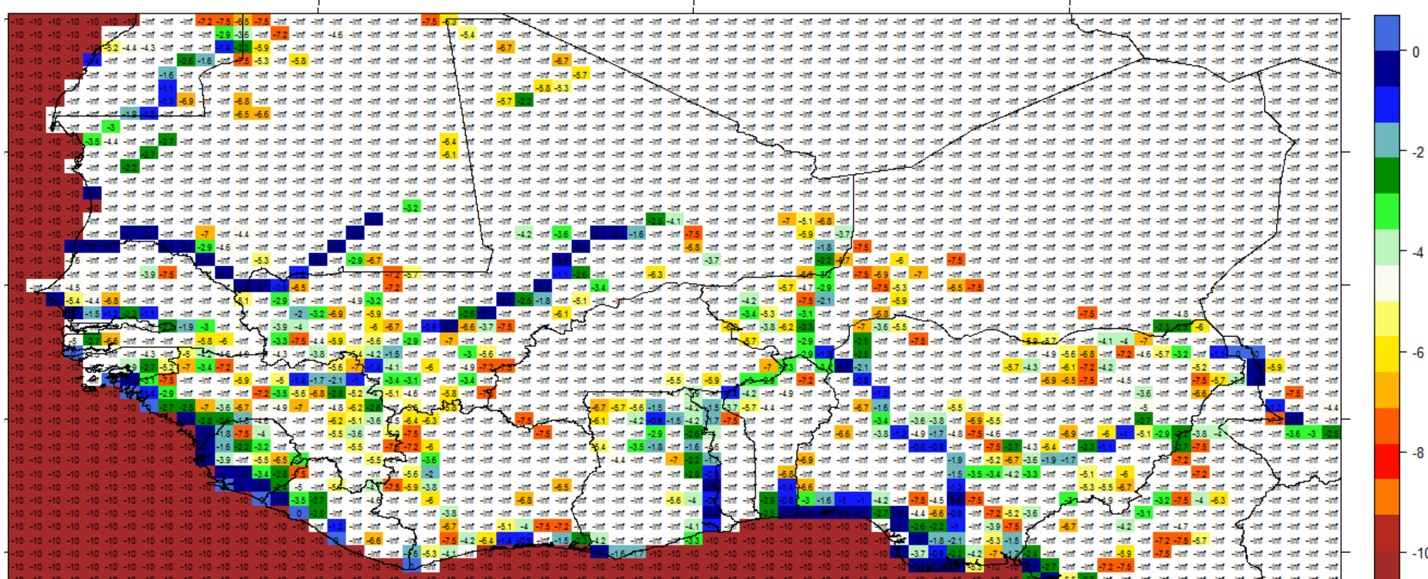


frac_fplain_lp:

with *l_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 -Inf, at sea 1e-10)



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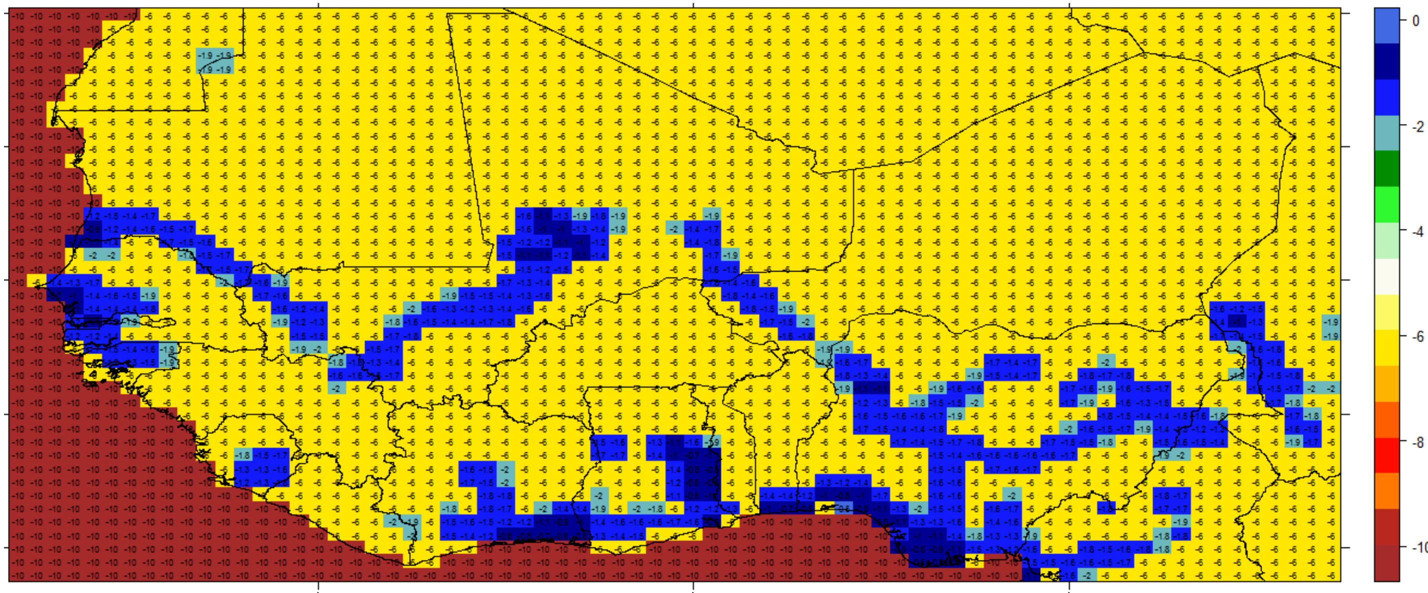
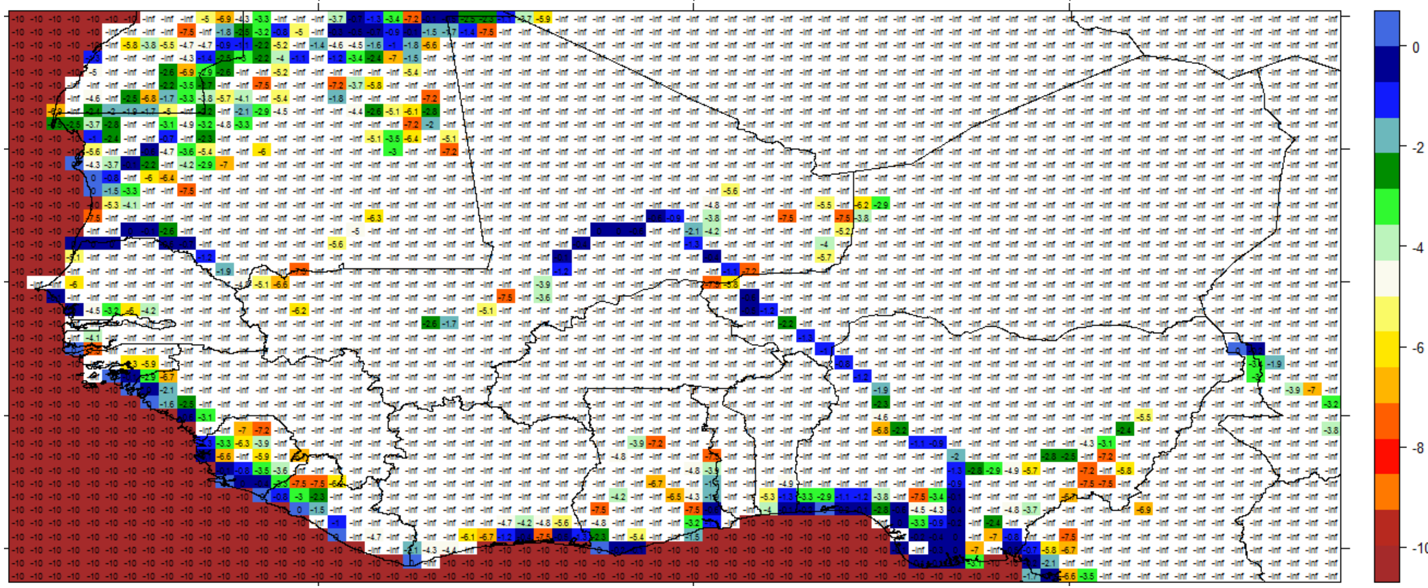


frac_fplain_lp:

with *l_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 -Inf, at sea 1e-10)

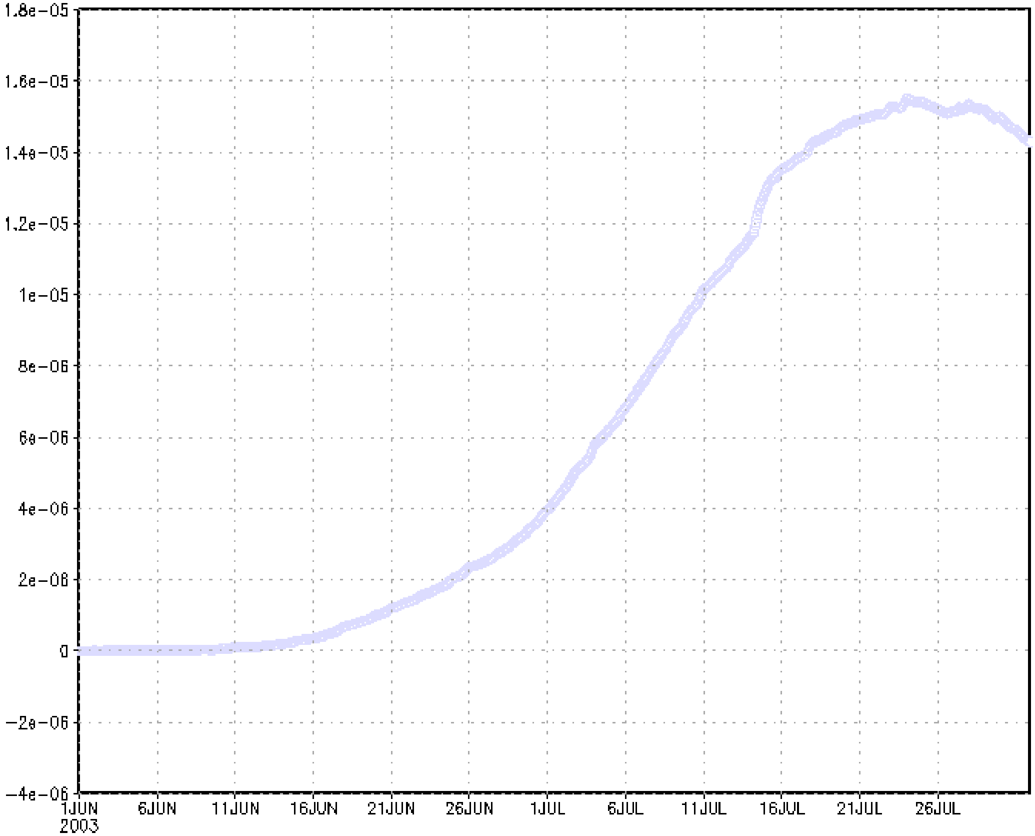


Results using my o/inun code

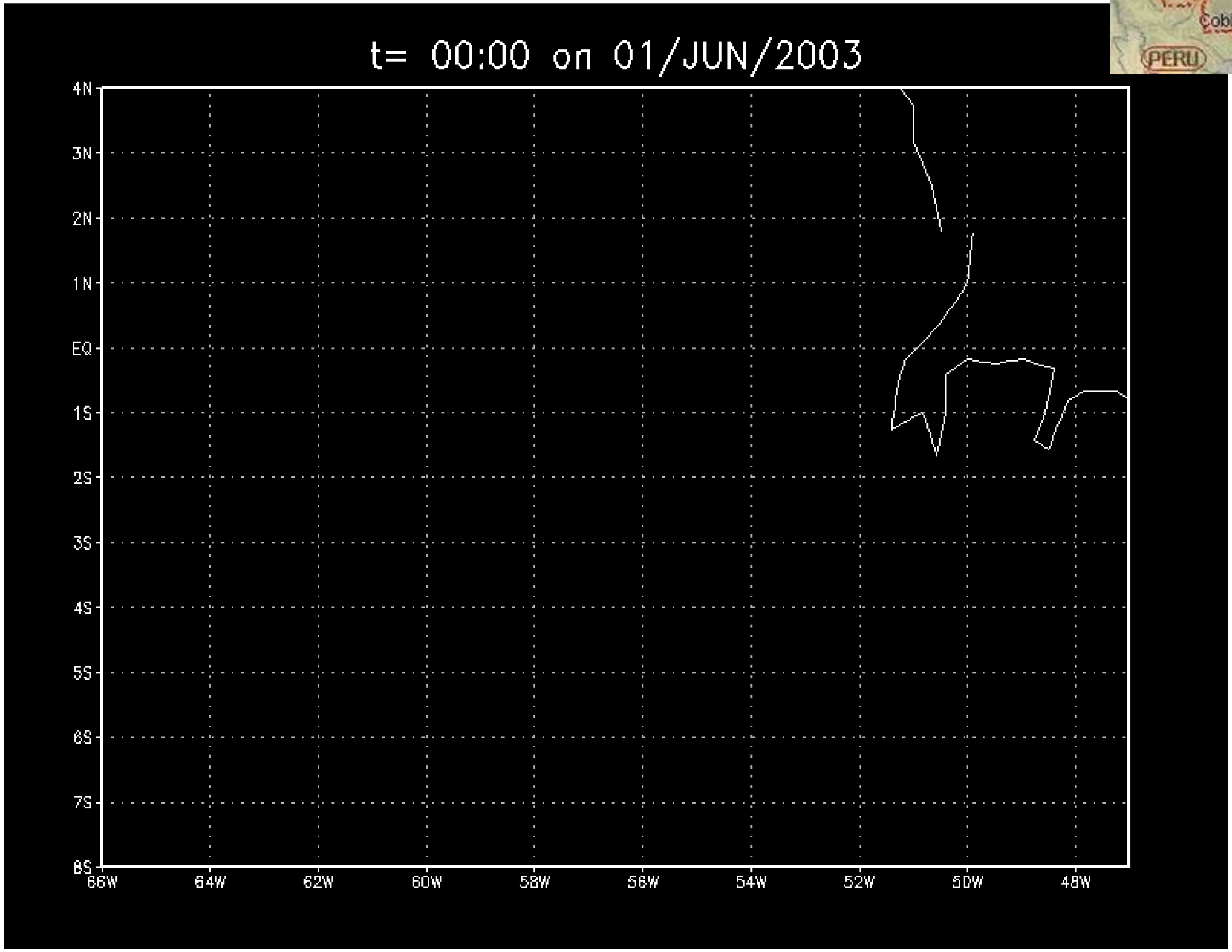
frac_fplain_lp:

with *l_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 1.6e^{-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 m^2, 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



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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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