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NATURAL ENVIRONMENT RESEARCH COUNCIL

JULES
Joint UK Land Environment Simulator

JULES Science Workshop
27 June 2017

Tales from the JULES river bank

Huw Lewis
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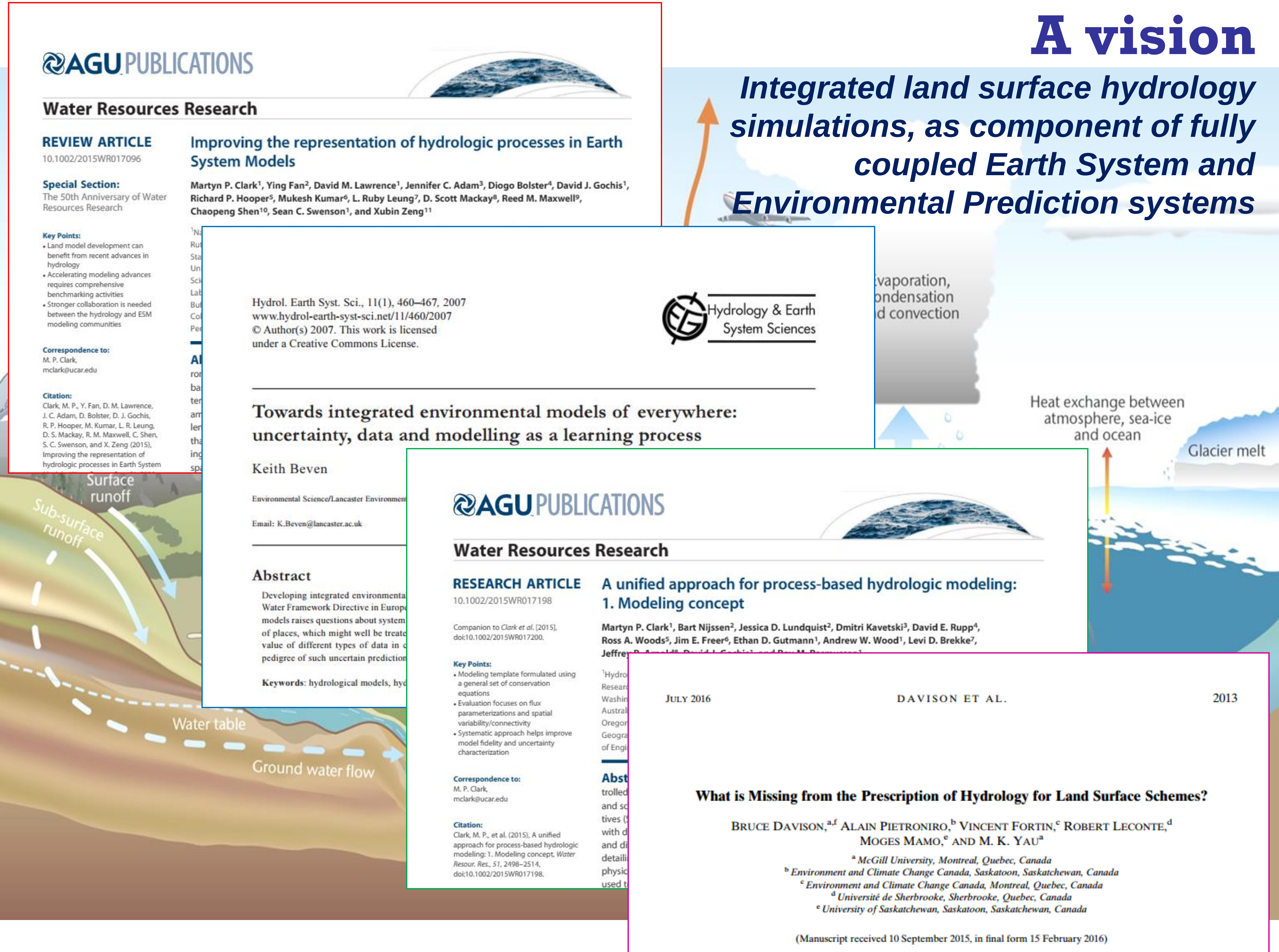
With thanks to Alberto Martinez, Simon Dadson, Helen Davies, Vicky Bell, Toby Marthews, ,…

A vision

Integrated land surface hydrology simulations, as component of fully coupled Earth System and Environmental Prediction systems



AGU PUBLICATIONS

Water Resources Research

REVIEW ARTICLE

10.1002/2015WR017096

Special Section: The 50th Anniversary of Water Resources Research

Improving the representation of hydrologic processes in Earth System Models

Martyn P. Clark[1], Ying Fan[2], David M. Lawrence[1], Jennifer C. Adam[3], Diogo Bolster[4], David J. Gochis[1], Richard P. Hooper[5], Mukesh Kumar[6], L. Ruby Leung[7], D. Scott Mackay[8], Reed M. Maxwell[9], Chaopeng Shen[10], Sean C. Swenson[1], and Xubin Zeng[11]

Key Points:
- Land model development can benefit from recent advances in hydrology
- Accelerating modeling advances requires comprehensive benchmarking activities
- Stronger collaboration is needed between the hydrology and ESM modeling communities

Correspondence to: M. P. Clark, mclark@ucar.edu

Citation: Clark, M. P., Y. Fan, D. M. Lawrence, J. C. Adam, D. Bolster, D. J. Gochis, R. P. Hooper, M. Kumar, L. R. Leung, D. S. Mackay, R. M. Maxwell, C. Shen, S. C. Swenson, and X. Zeng (2015), Improving the representation of hydrologic processes in Earth System

Hydrol. Earth Syst. Sci., 11(1), 460–467, 2007
www.hydrol-earth-syst-sci.net/11/460/2007
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Hydrology & Earth System Sciences

Towards integrated environmental models of everywhere: uncertainty, data and modelling as a learning process

Keith Beven

Environmental Science/Lancaster Environment

Email: K.Beven@lancaster.ac.uk

Abstract

Developing integrated environmenta... Water Framework Directive in Europ... models raises questions about system... of places, which might well be treate... value of different types of data in c... pedigree of such uncertain prediction...

Keywords: hydrological models, hyd...

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2015WR017198

A unified approach for process-based hydrologic modeling: 1. Modeling concept

Martyn P. Clark[1], Bart Nijssen[2], Jessica D. Lundquist[2], Dmitri Kavetski[3], David E. Rupp[4], Ross A. Woods[5], Jim E. Freer[6], Ethan D. Gutmann[1], Andrew W. Wood[1], Levi D. Brekke[7],

Companion to Clark et al. [2015], doi:10.1002/2015WR017200.

Key Points:
- Modeling template formulated using a general set of conservation equations
- Evaluation focuses on flux parameterizations and spatial variability/connectivity
- Systematic approach helps improve model fidelity and uncertainty characterization

Correspondence to: M. P. Clark, mclark@ucar.edu

Citation: Clark, M. P., et al. (2015), A unified approach for process-based hydrologic modeling: 1. Modeling concept, *Water Resour. Res., 51*, 2498–2514, doi:10.1002/2015WR017198.

July 2016 DAVISON ET AL. 2013

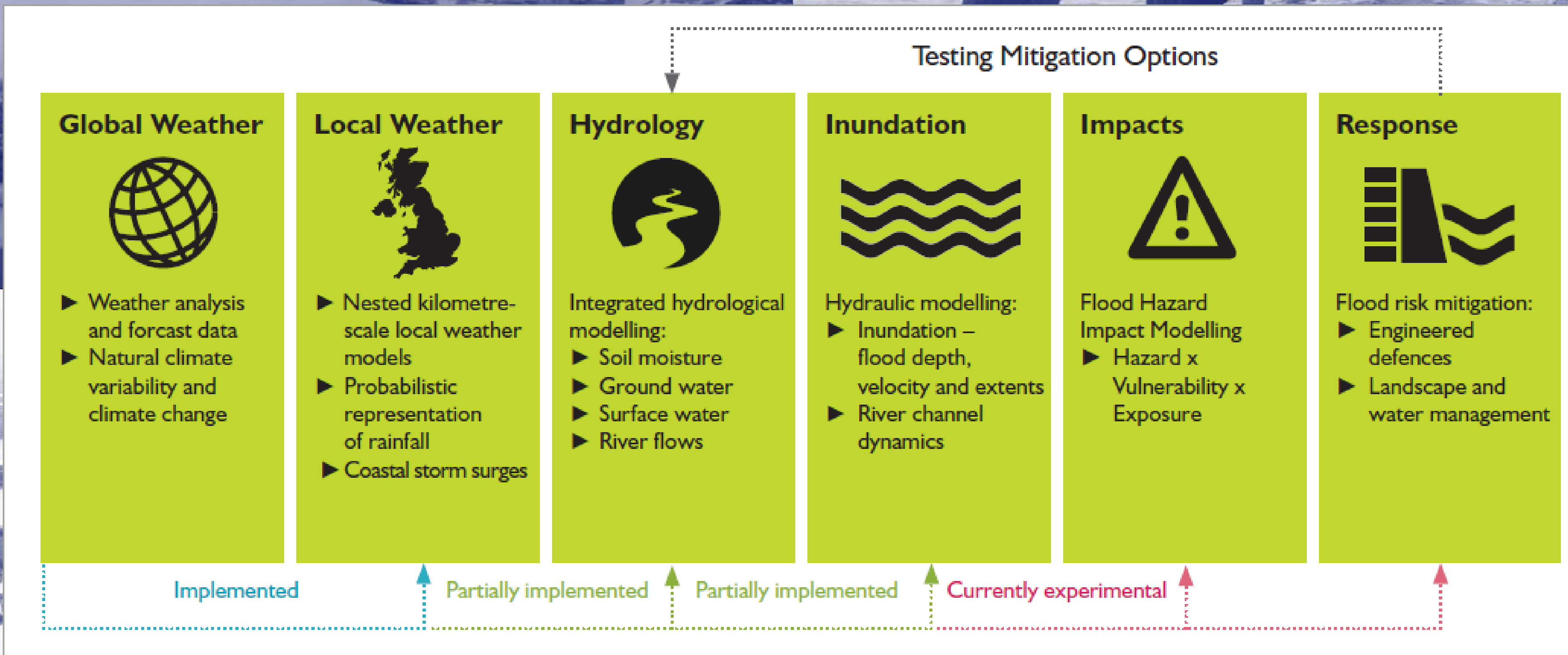
What is Missing from the Prescription of Hydrology for Land Surface Schemes?

Bruce Davison,[a,f] Alain Pietroniro,[b] Vincent Fortin,[c] Robert Leconte,[d] Moges Mamo,[e] and M. K. Yau[a]

[a] McGill University, Montreal, Quebec, Canada
[b] Environment and Climate Change Canada, Saskatoon, Saskatchewan, Canada
[c] Environment and Climate Change Canada, Montreal, Quebec, Canada
[d] Université de Sherbrooke, Sherbrooke, Quebec, Canada
[e] University of Saskatchewan, Saskatoon, Saskatchewan, Canada

(Manuscript received 10 September 2015, in final form 15 February 2016)

Towards more integrated approaches to natural hazard prediction



From the National Flood Resilience Review to future capability

HM Government

Challenges

- Skilful hydrology predictions everywhere, all the time?

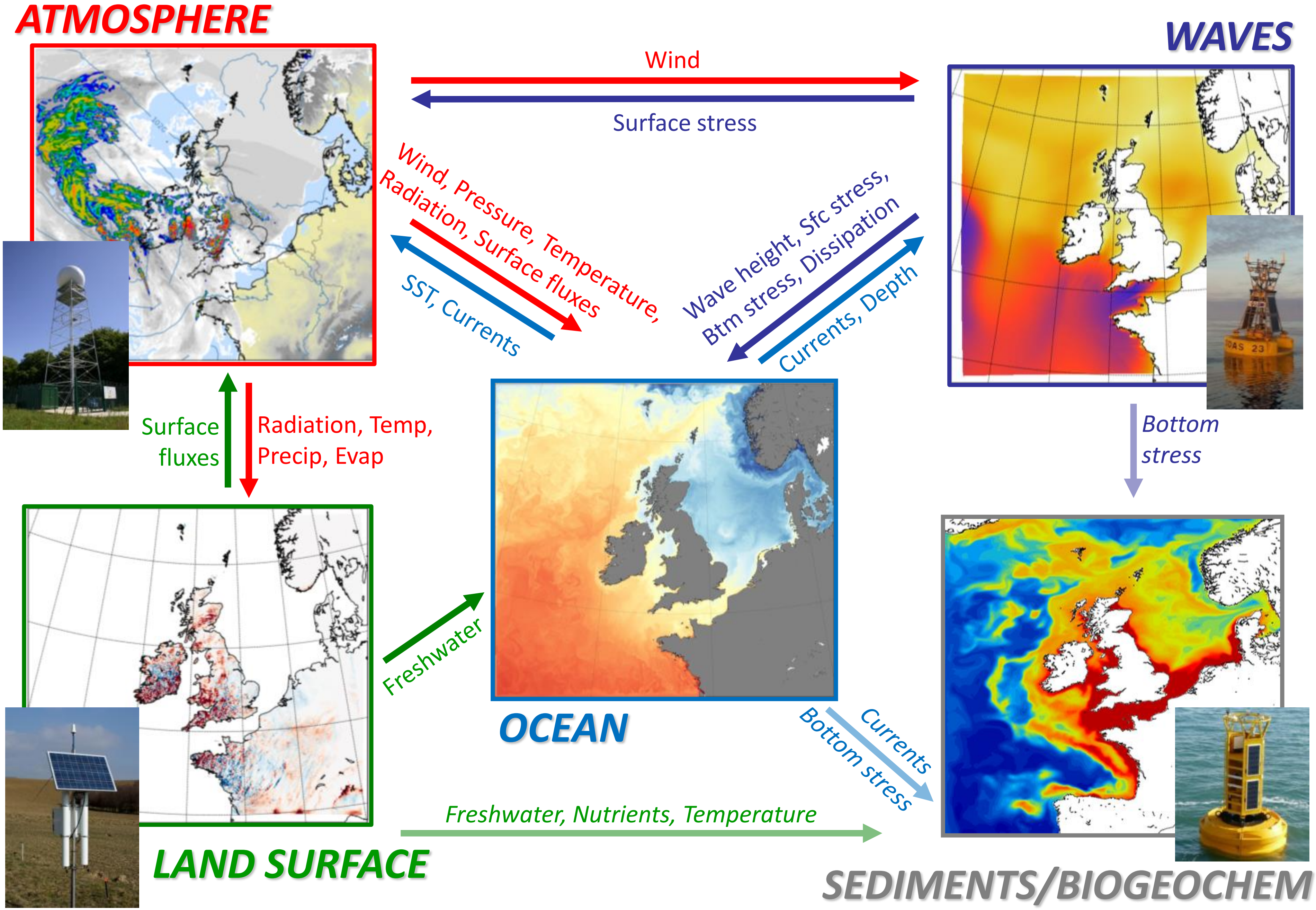
- Additional model complexity, additional constraints
- Additional model parameters (and calibration?)

- Moving from 1D vertical problem to 3D connectivity

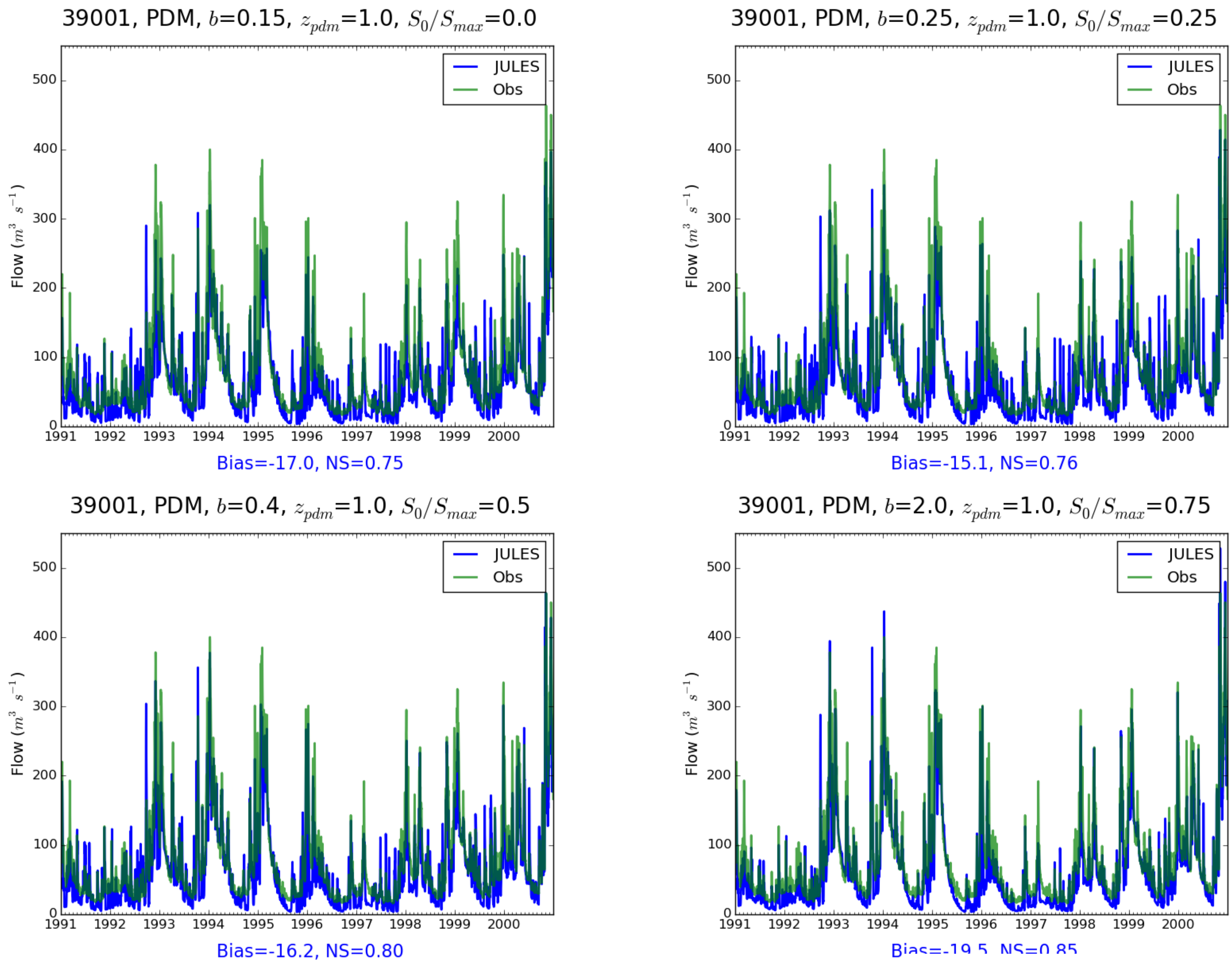
- River flow assimilation and balance with sfc exchange

- …

Towards coupled prediction?

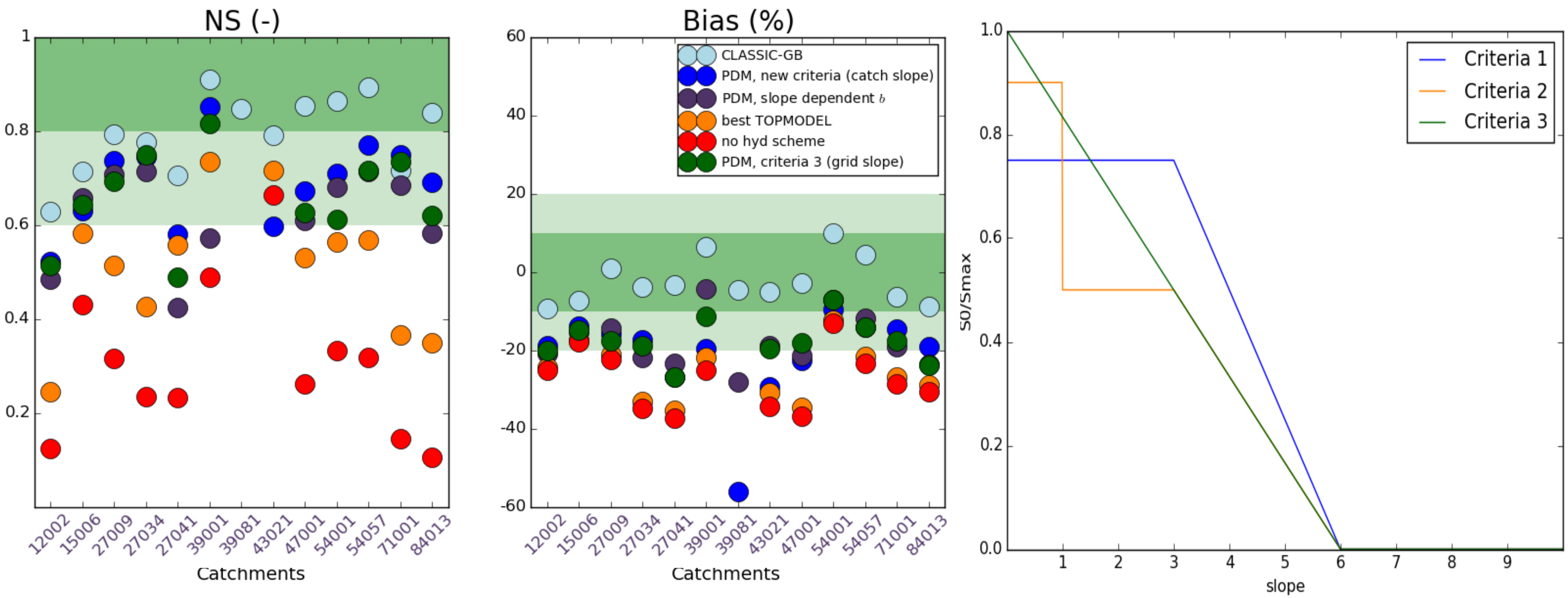


The building blocks are in place…



[Alberto Martinez de la Torre, CEH]

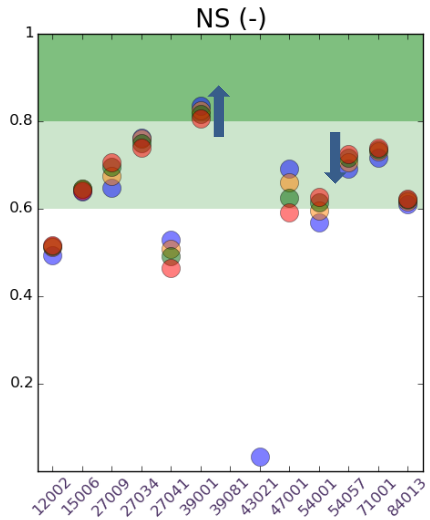
Applying slope dependent S_0

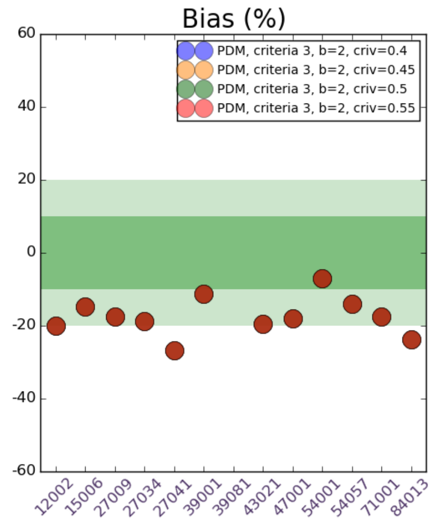


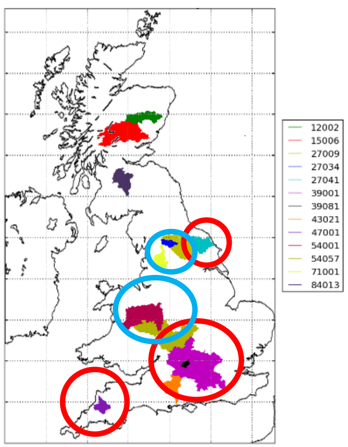
[Alberto Martinez de la Torre, CEH]

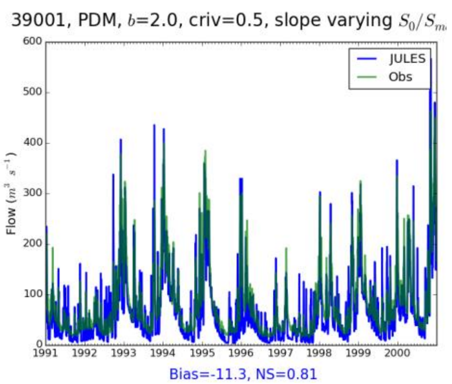
River parameters

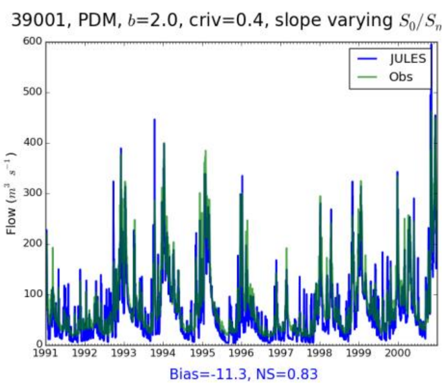
Test c_r river wave speed sensitivity

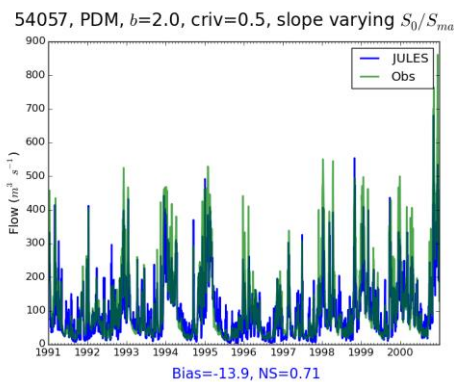


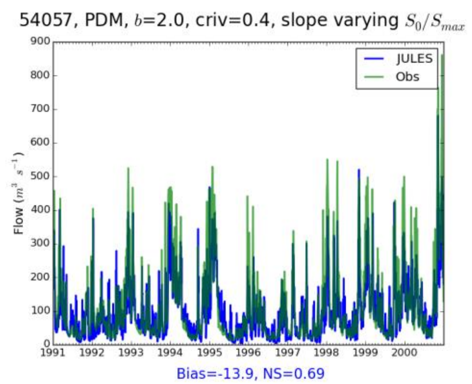












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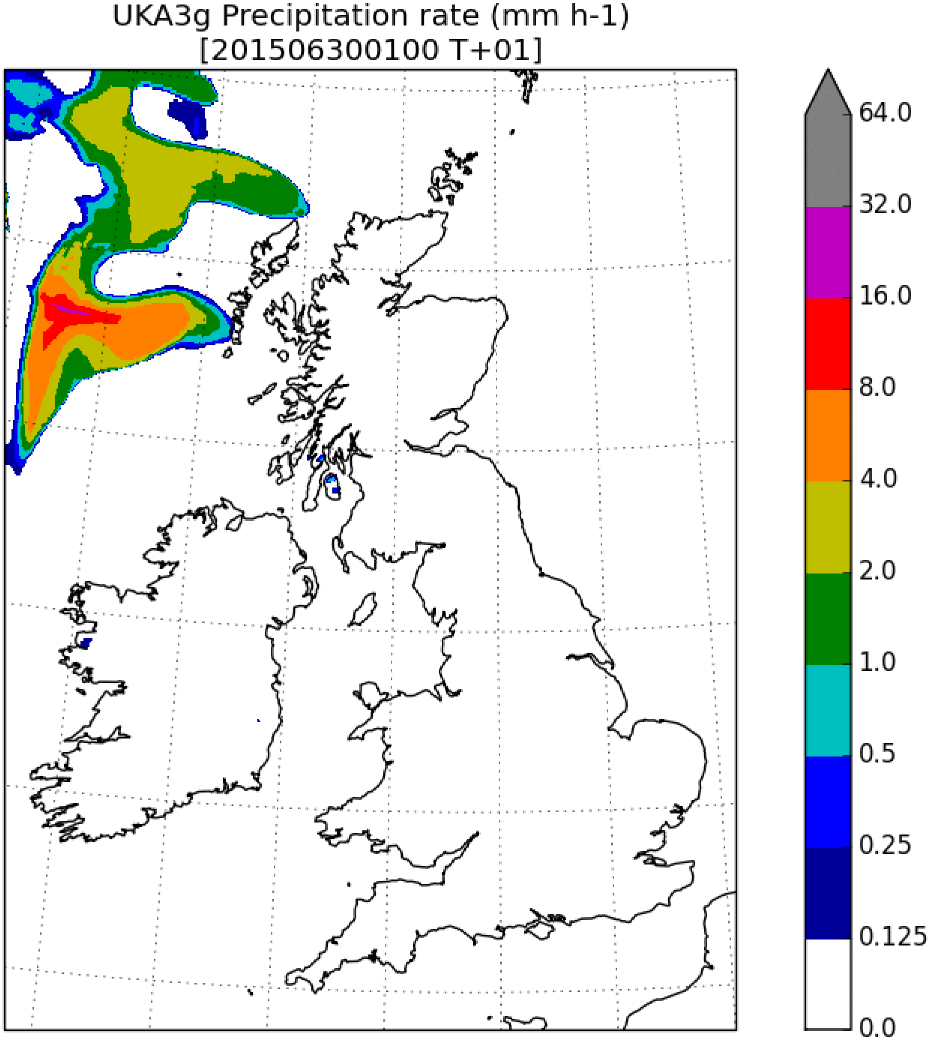
[Alberto Martinez de la Torre, CEH]

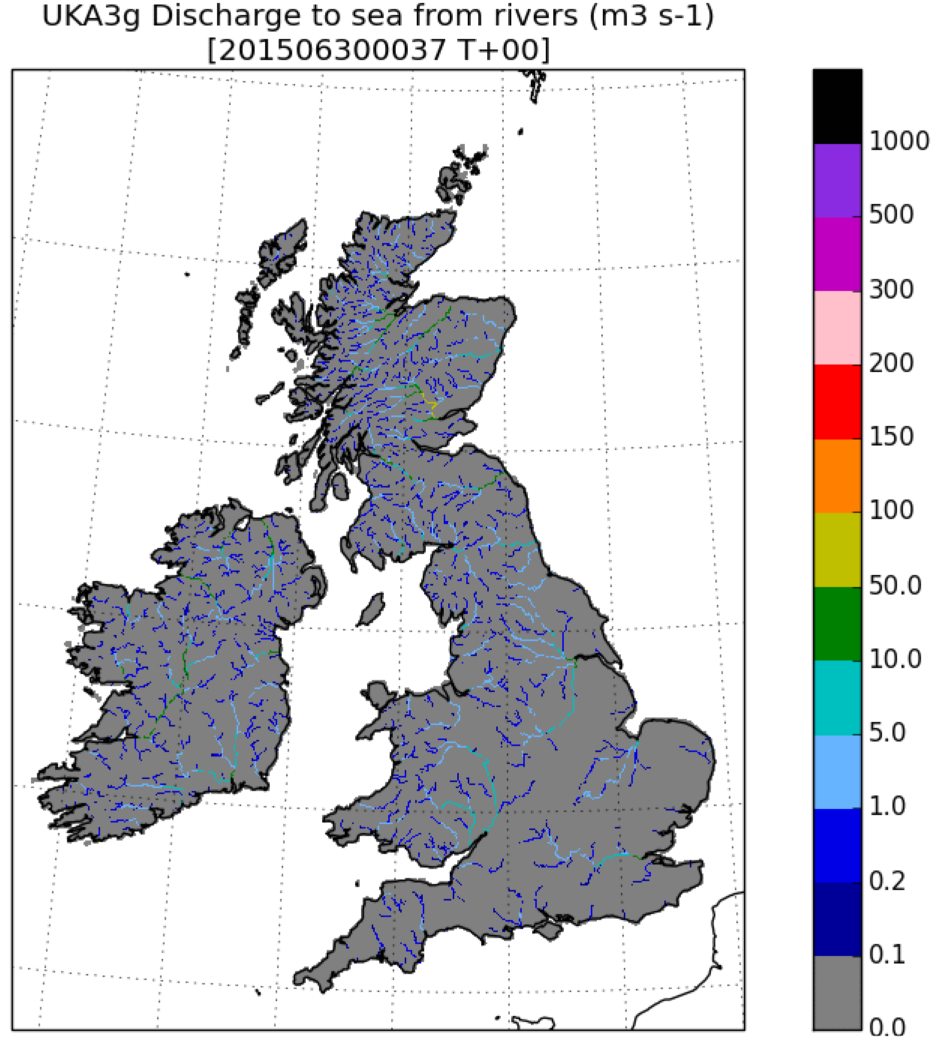
NERC SCIENCE OF THE ENVIRONMENT

Regional coupled prediction at high resolution
1.5 km river flow predictions

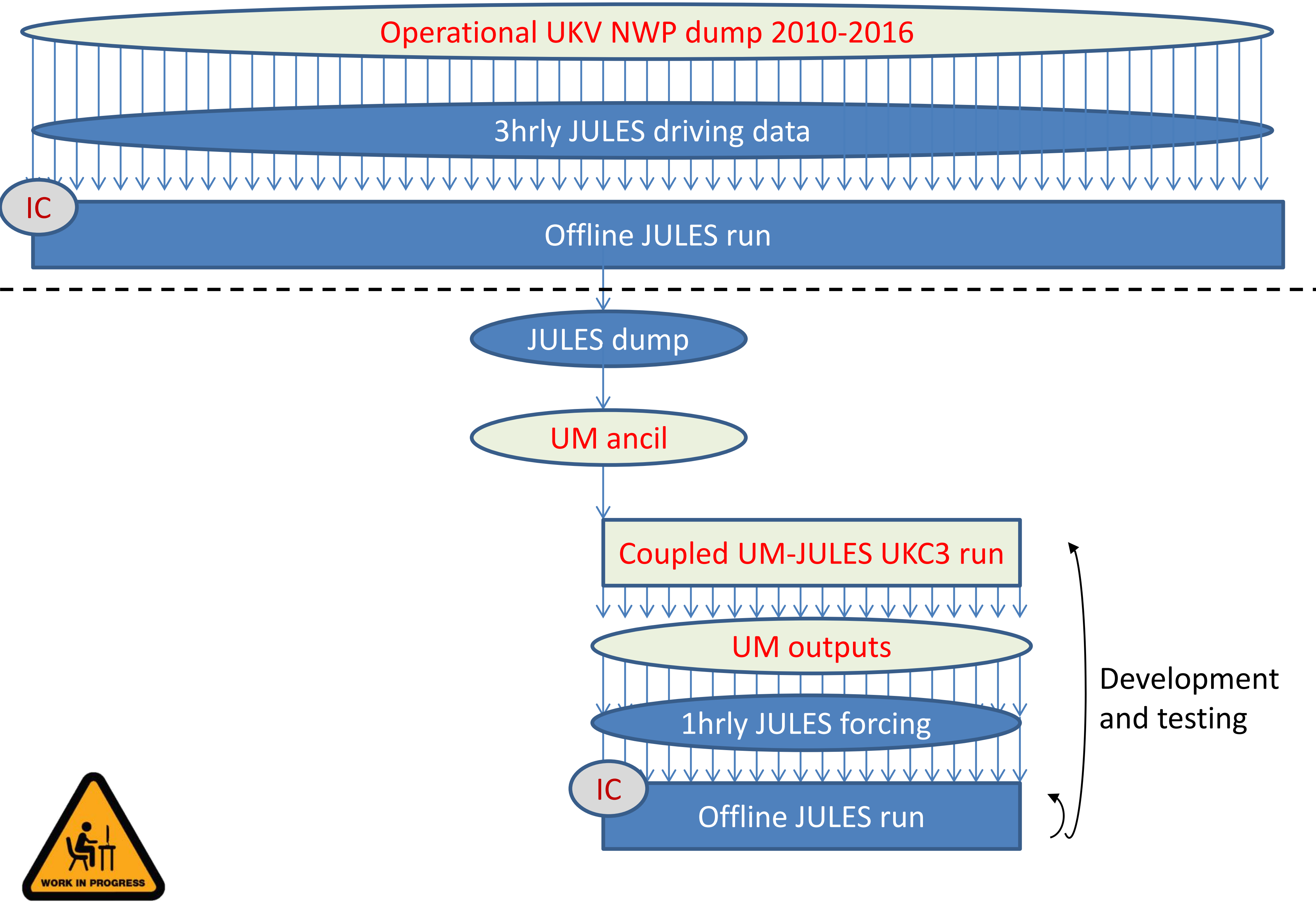
Met Office Unified Model rainfall



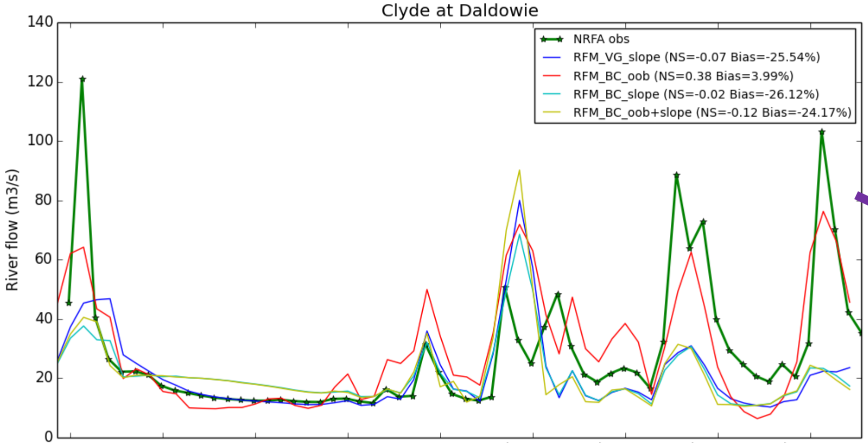
JULES kinematic wave routing river flow

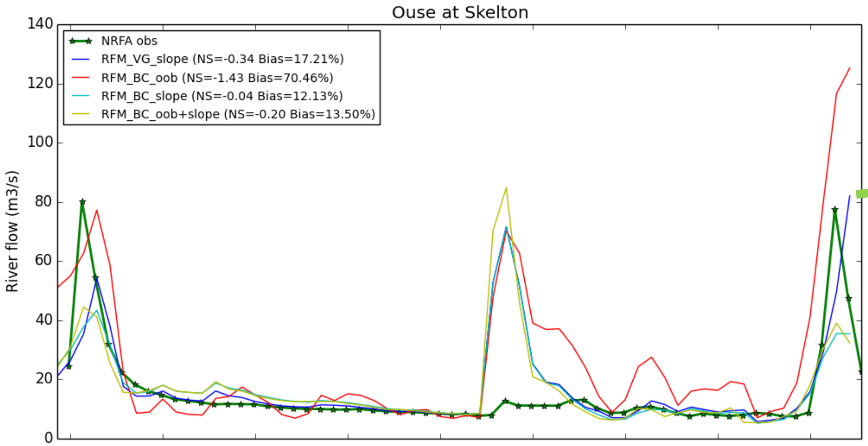


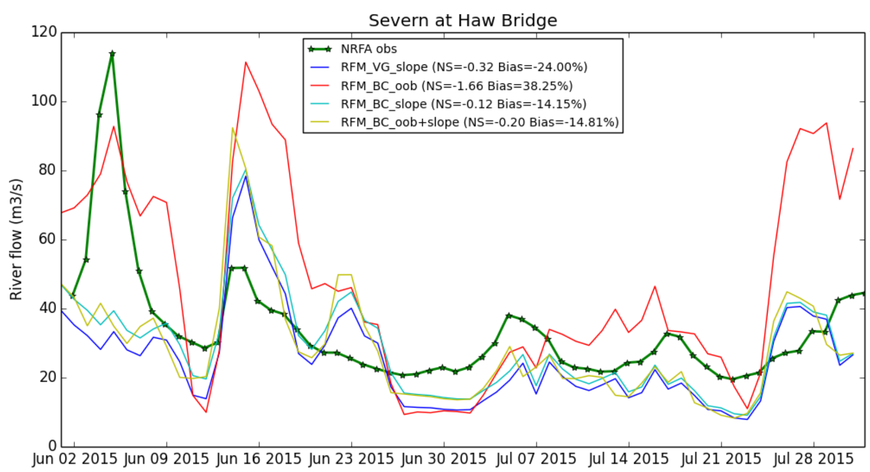
[Huw Lewis, Met Office]

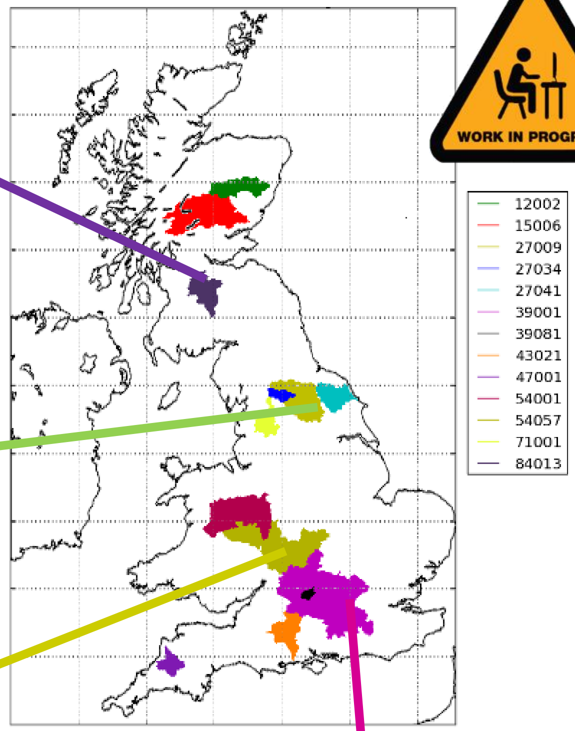

Operational UKV NWP dump 2010-2016
3hrly JULES driving data
IC
Offline JULES run
JULES dump
UM ancil
Coupled UM-JULES UKC3 run
UM outputs
1hrly JULES forcing
IC
Offline JULES run
Development and testing
WORK IN PROGRESS

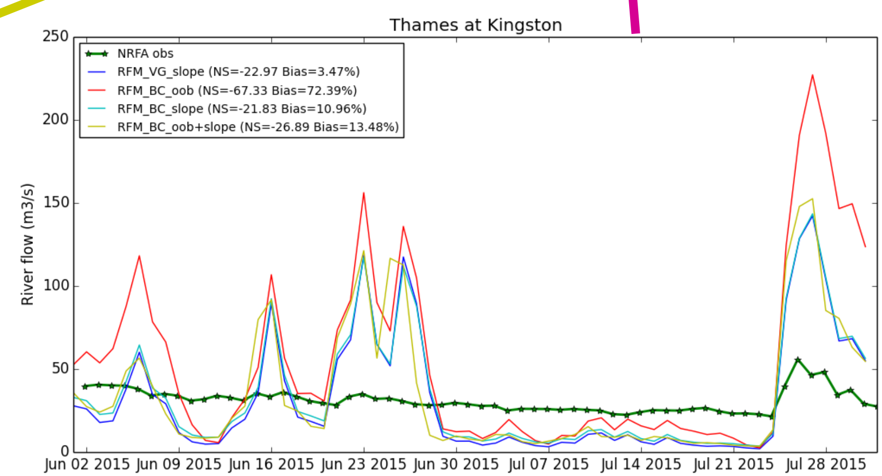
UKV-driven standalone JULES initialisation run (2010-2015)





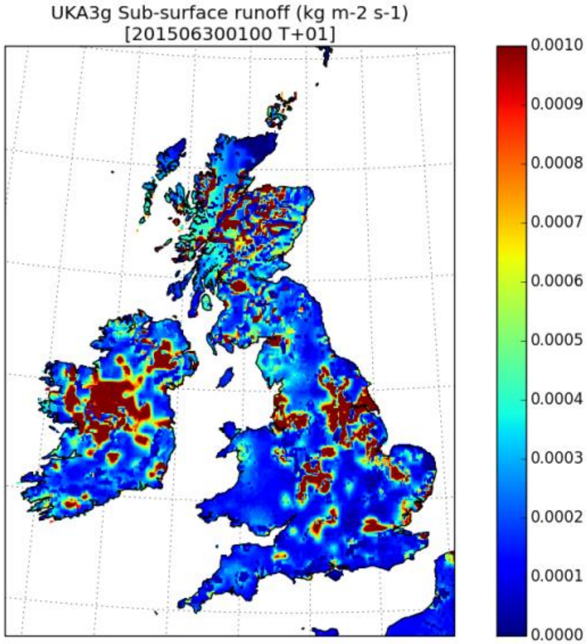


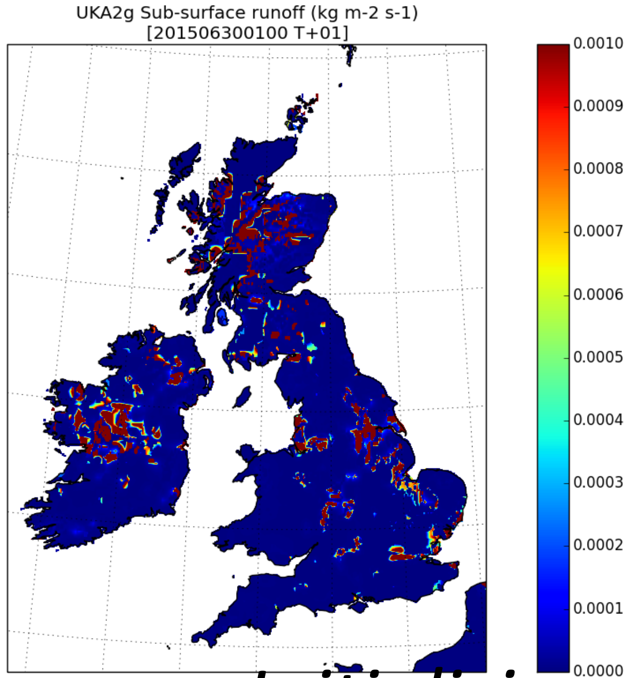




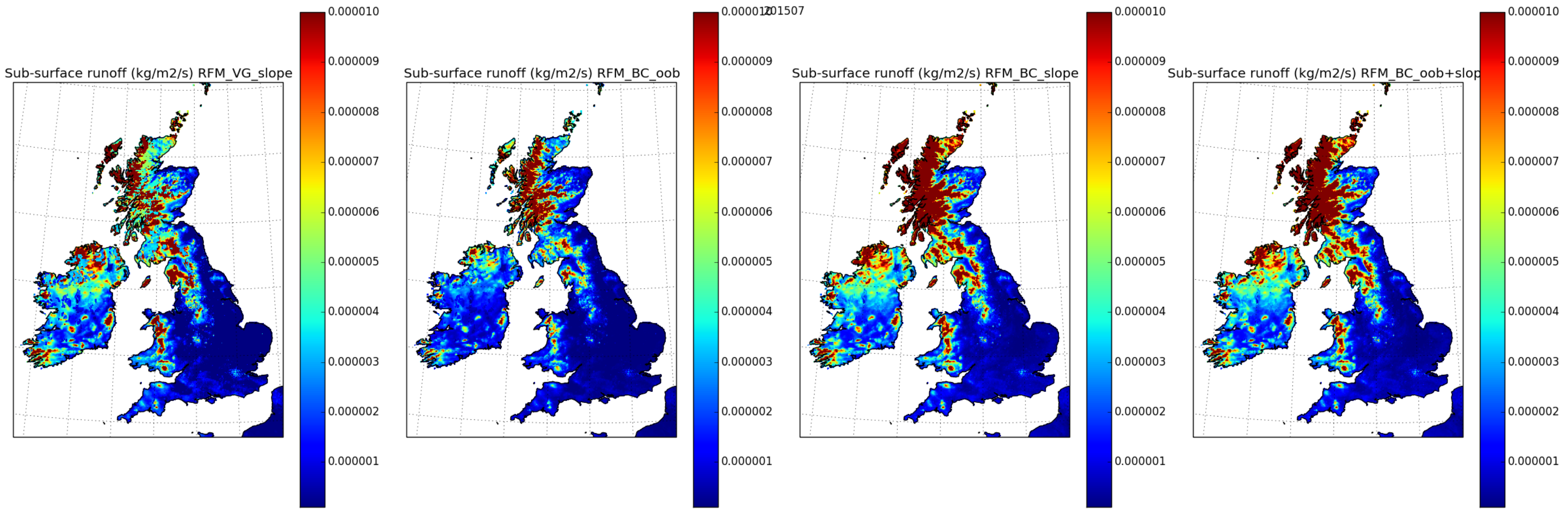
Implementation in UKC2

UM-JULES

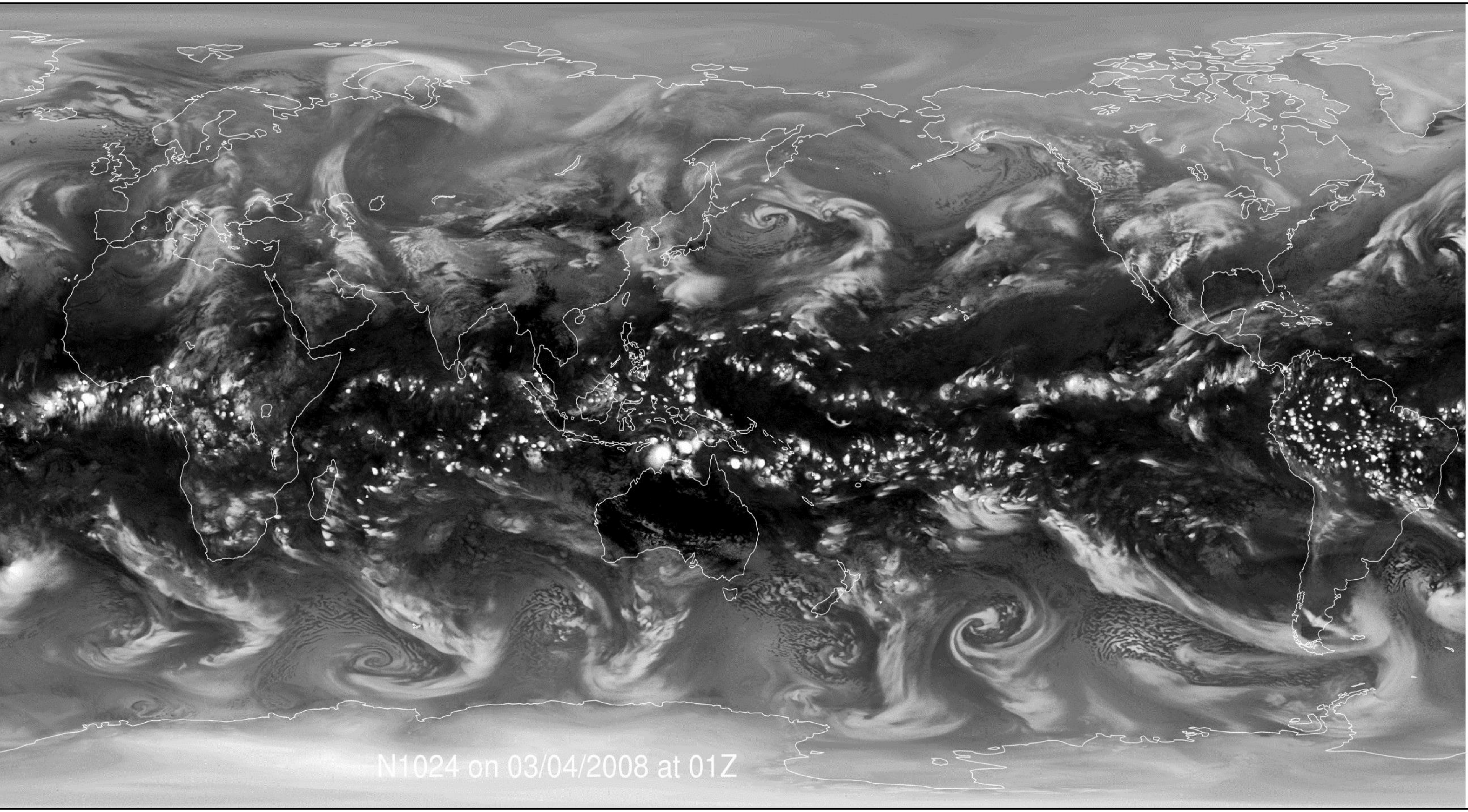




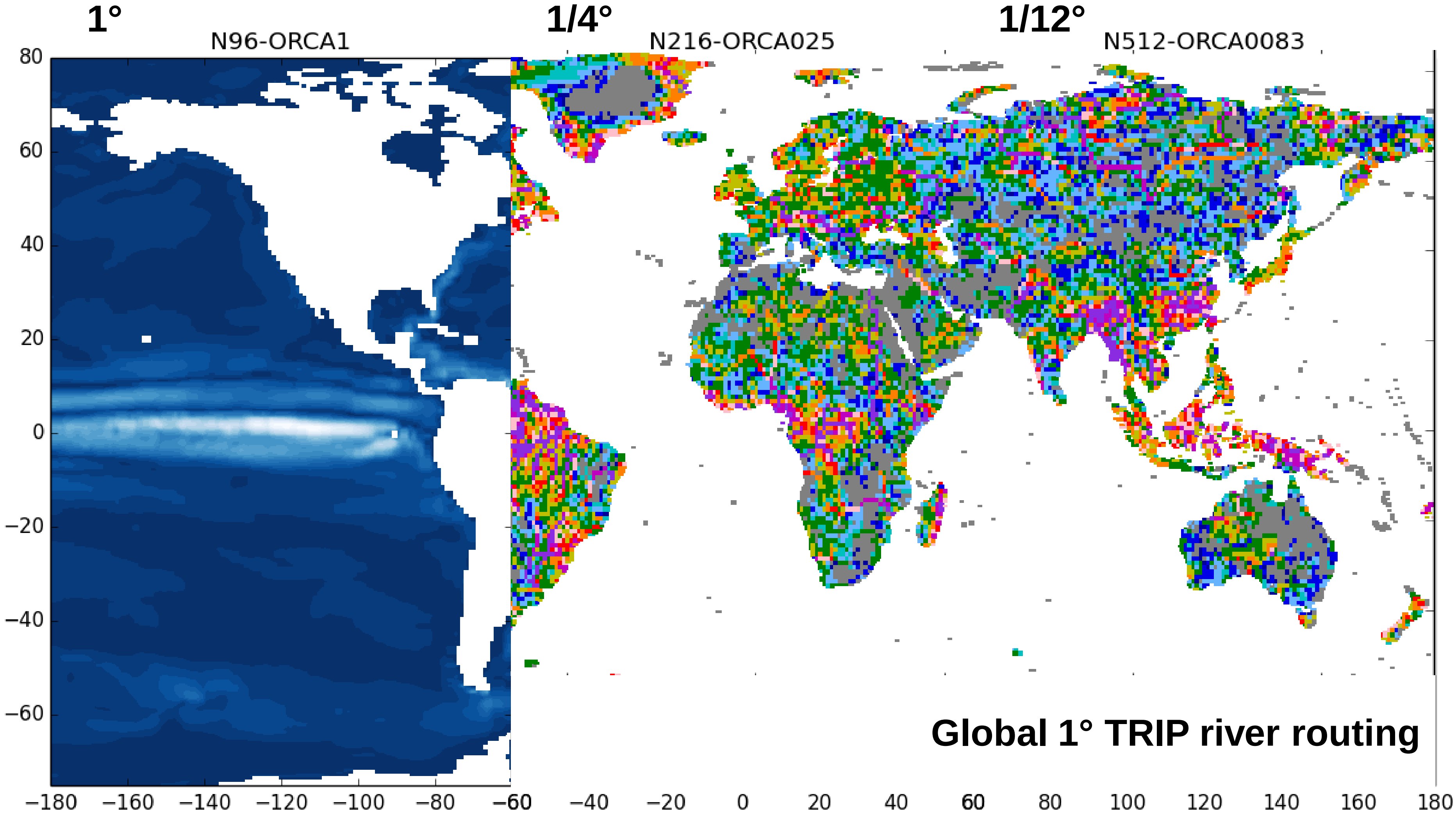
e.g. Initialising sub-surface runoff



12 km resolution global atmosphere



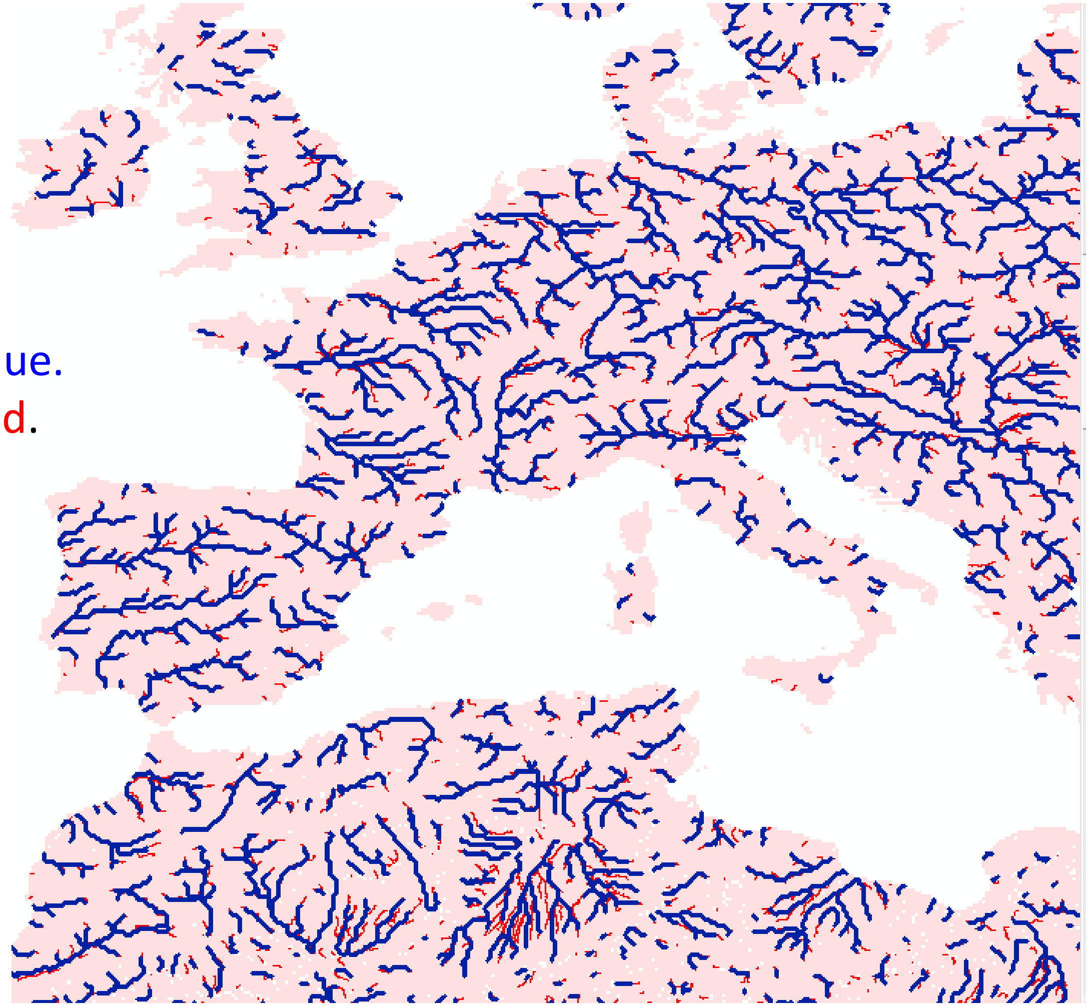
Towards 1/12° resolution global ocean



…and what about land surface science??

Global Flow Directions - prototype

Prototype 0.1 deg flow directions in blue.
Base 0.00833 deg flow directions in red.



River visible at catchment area > ~2000km^2

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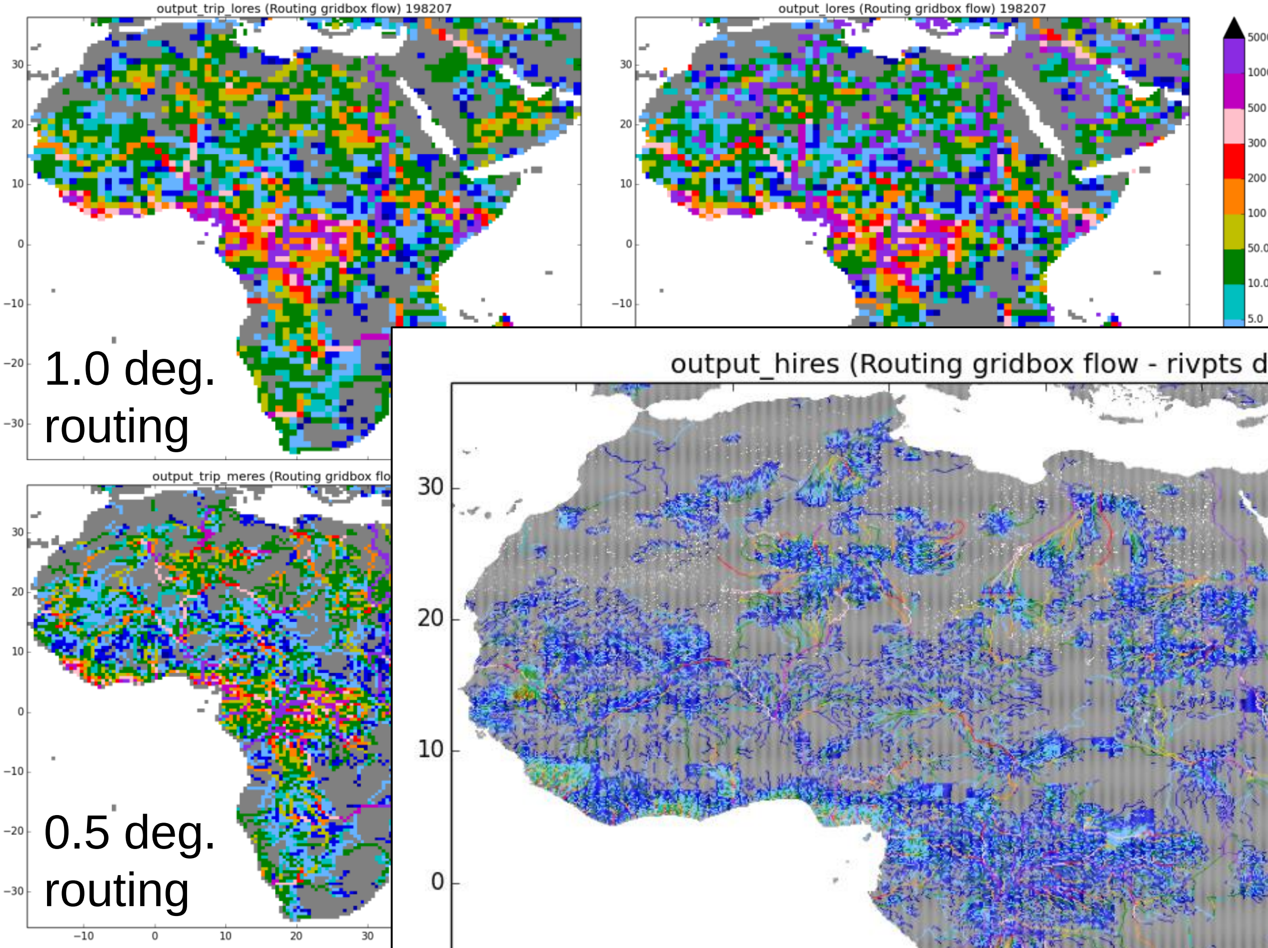
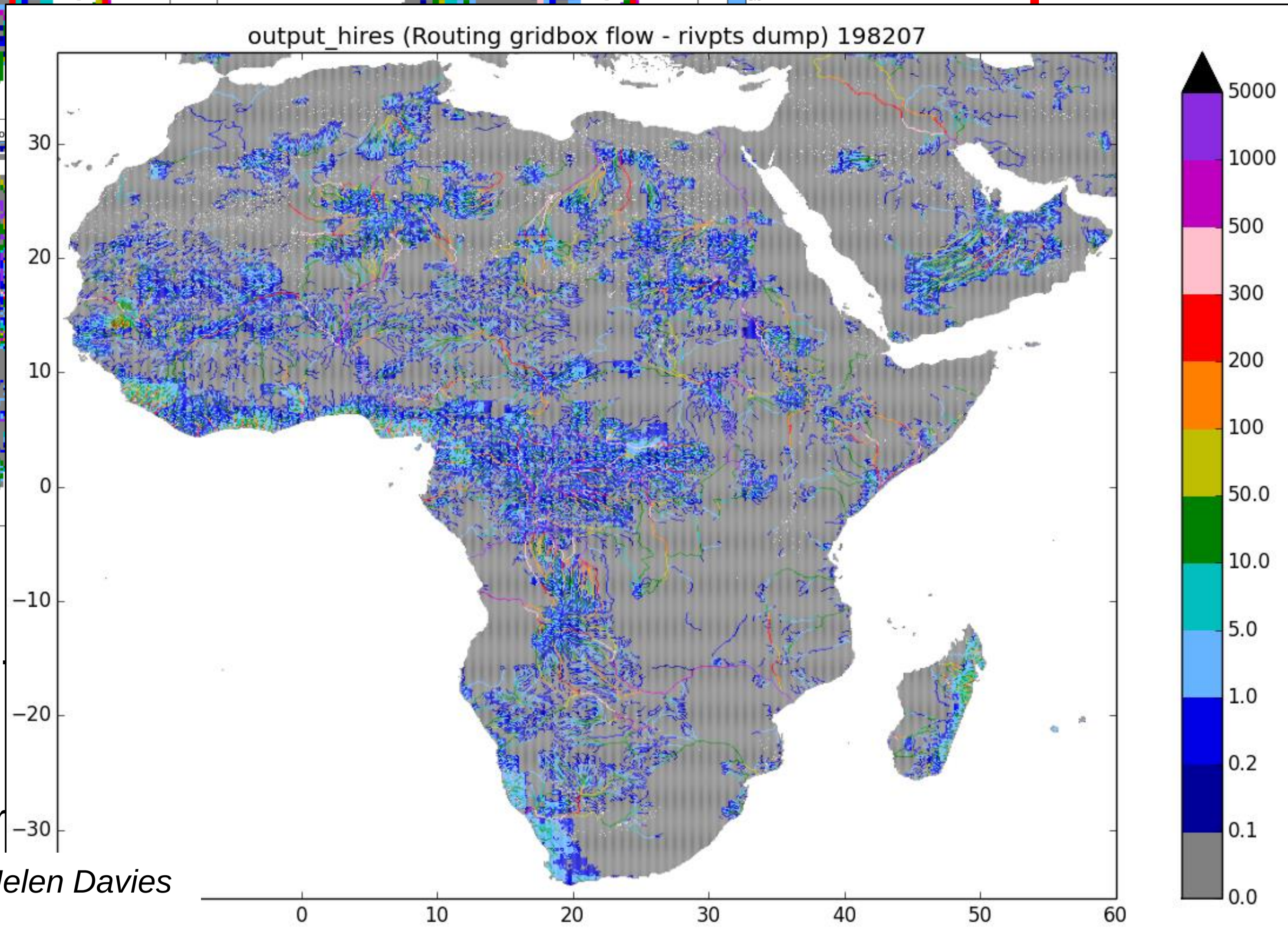
[Helen Davies, Vicky Bell, CEH]





JULES run:
0.5 deg. WFDEI
1981-2000
dt = 30min
Kinematic wave r

[In collaboration with Helen Davies and Vicky Bell, CEH]

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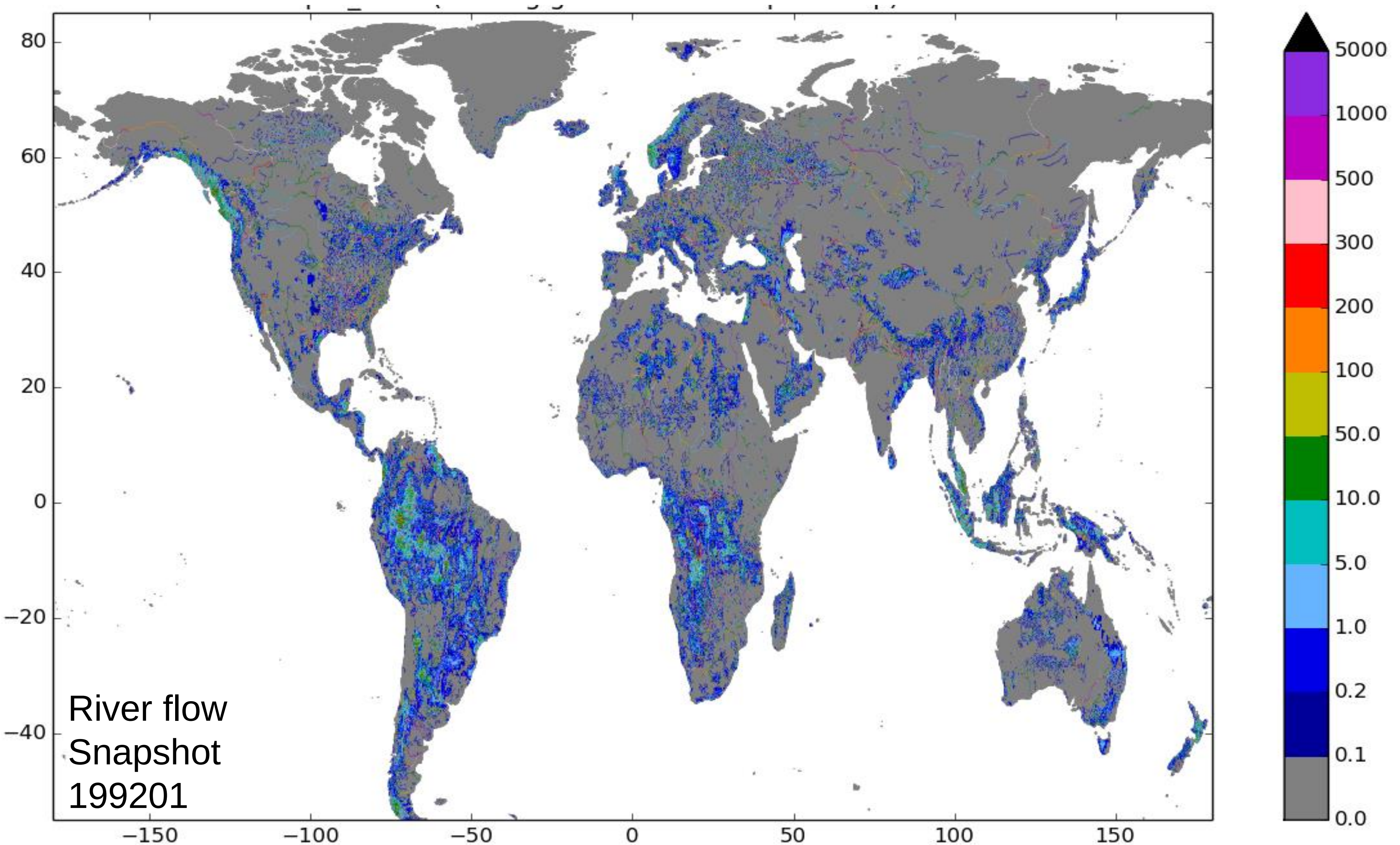
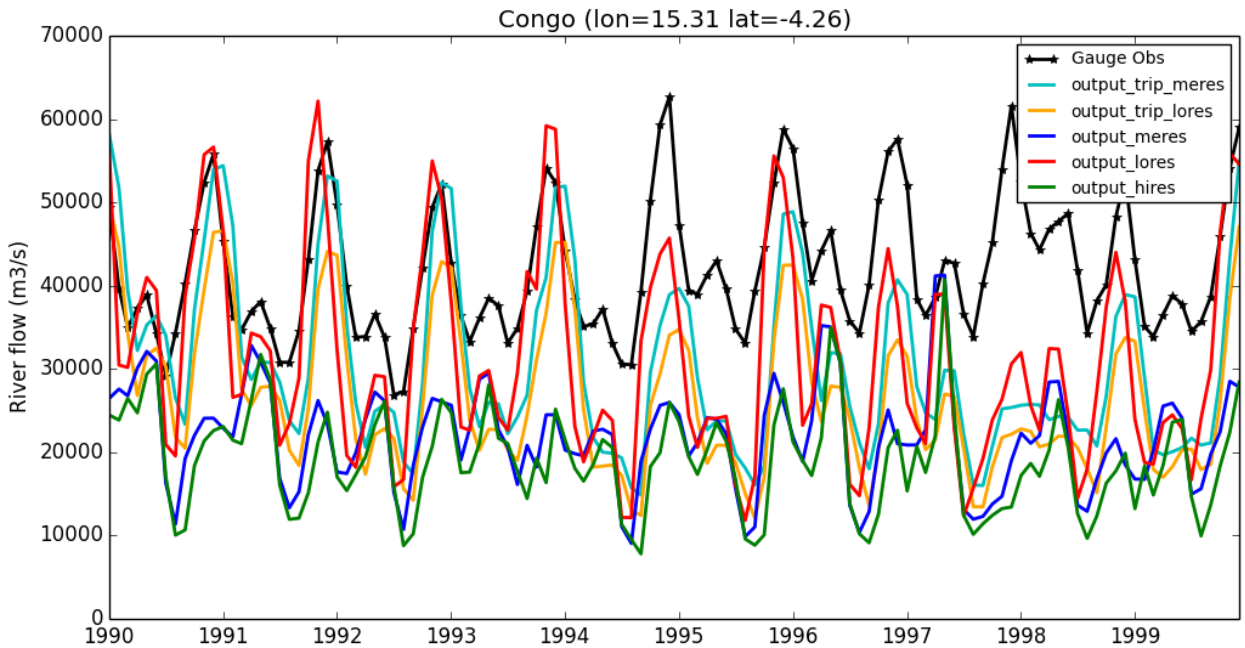
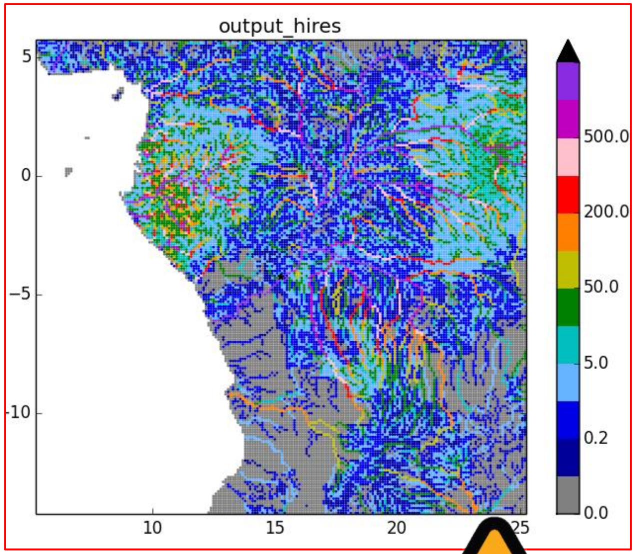
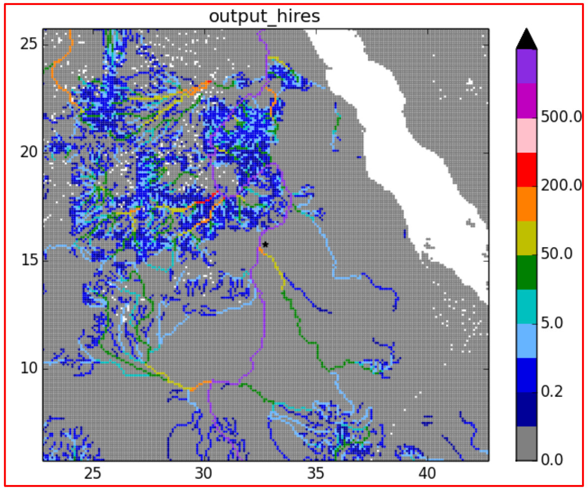


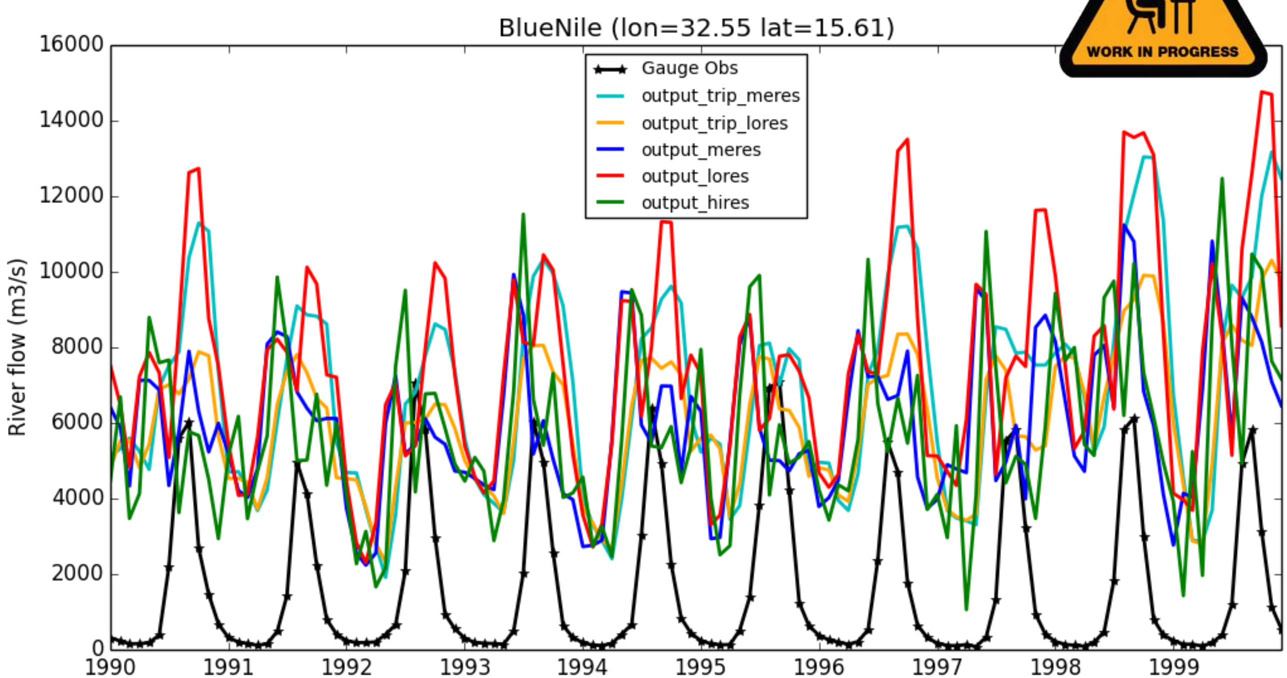
[in collaboration with Helen Davies and Vicky Bell, CEH]

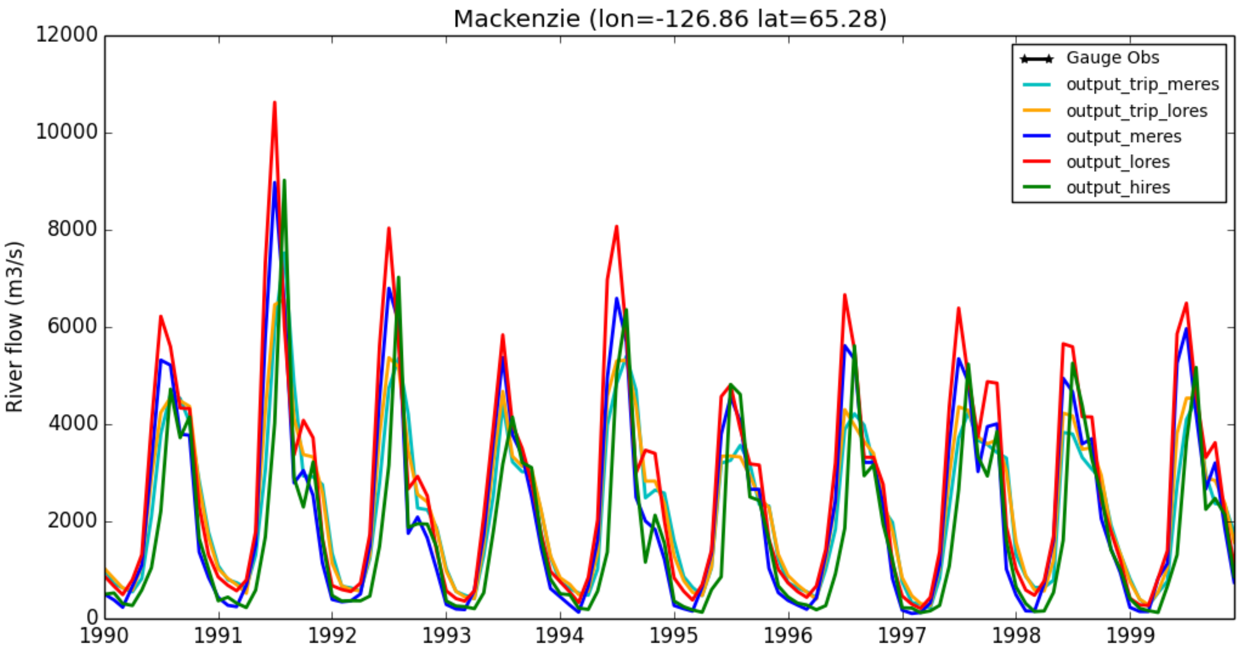

Congo (lon=15.31 lat=-4.26)
River flow (m3/s)
70000
60000
50000
40000
30000
20000
10000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Gauge Obs
output_trip_meres
output_trip_lores
output_meres
output_lores
output_hires

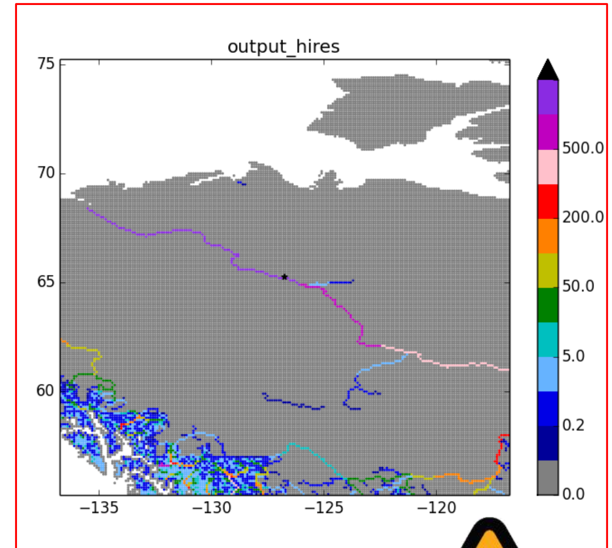

output_hires
5
0
−5
−10
10
15
20
25
500.0
200.0
50.0
5.0
0.2
0.0


WORK IN PROGRESS

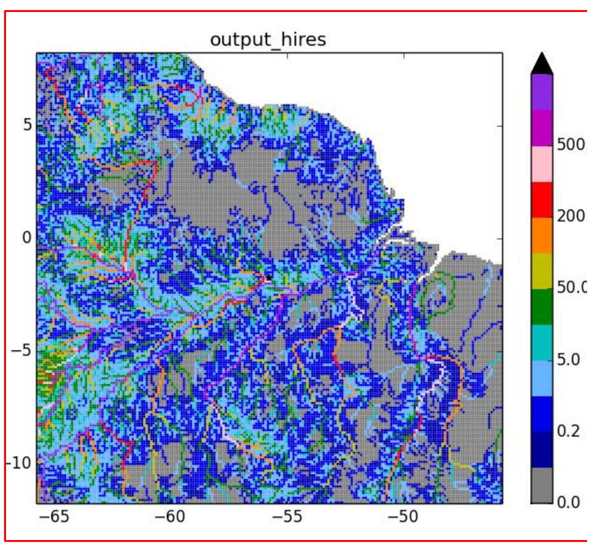

output_hires
25
20
15
10
25
30
35
40
500.0
200.0
50.0
5.0
0.2
0.0

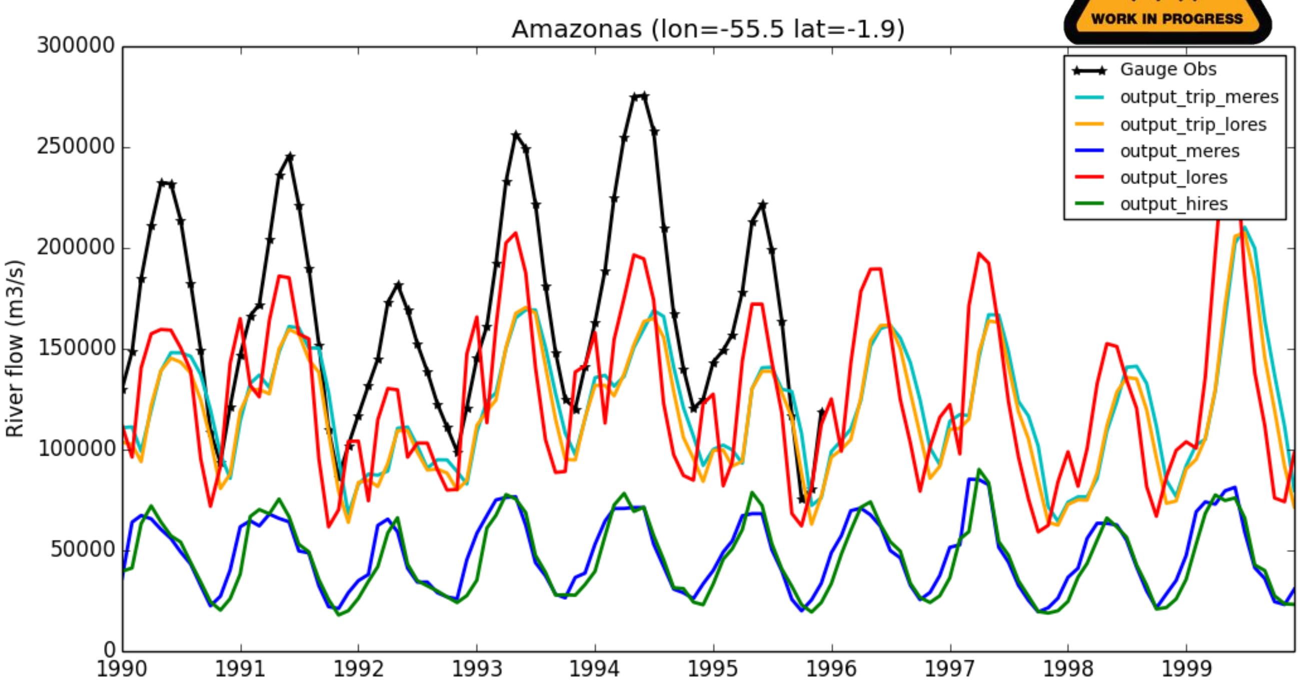

BlueNile (lon=32.55 lat=15.61)
River flow (m3/s)
16000
14000
12000
10000
8000
6000
4000
2000
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Gauge Obs
output_trip_meres
output_trip_lores
output_meres
output_lores
output_hires


Mackenzie (lon=-126.86 lat=65.28)
River flow (m3/s)
0
2000
4000
6000
8000
10000
12000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Gauge Obs
output_trip_meres
output_trip_lores
output_meres
output_lores
output_hires


output_hires
75
70
65
60
−135
−130
−125
−120
500.0
200.0
50.0
5.0
0.2
0.0

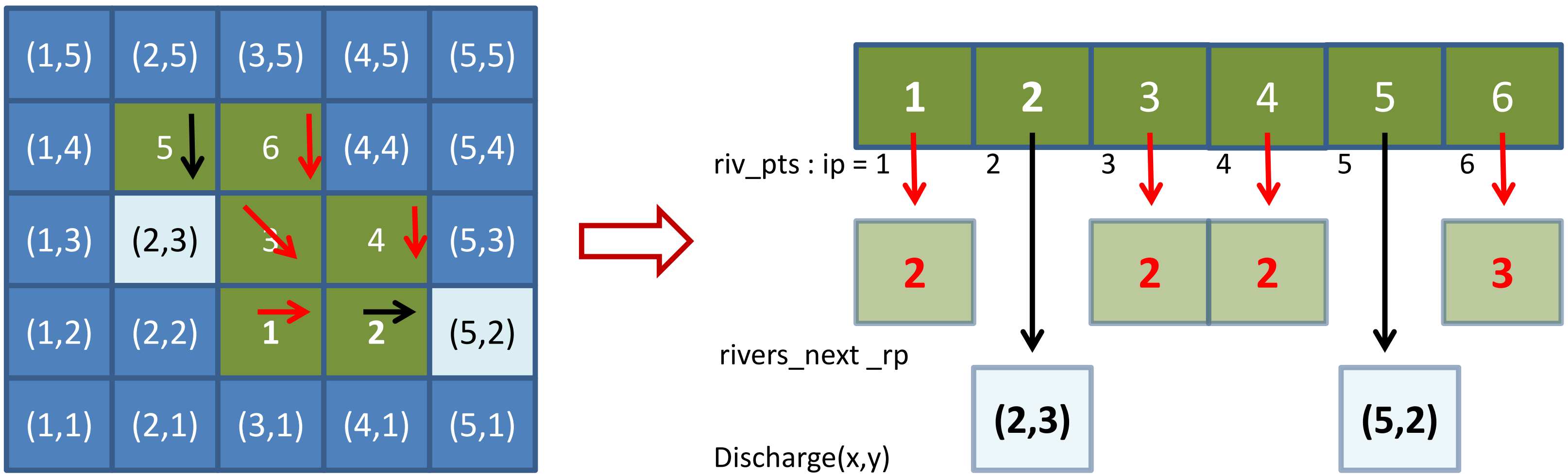

WORK IN PROGRESS


output_hires
5
0
-5
-10
-65
-60
-55
-50
500
200
50.0
5.0
0.2
0.0


Amazonas (lon=-55.5 lat=-1.9)
River flow (m3/s)
0
50000
100000
150000
200000
250000
300000
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Gauge Obs
output_trip_meres
output_trip_lores
output_meres
output_lores
output_hires

JULES routing infrastructure

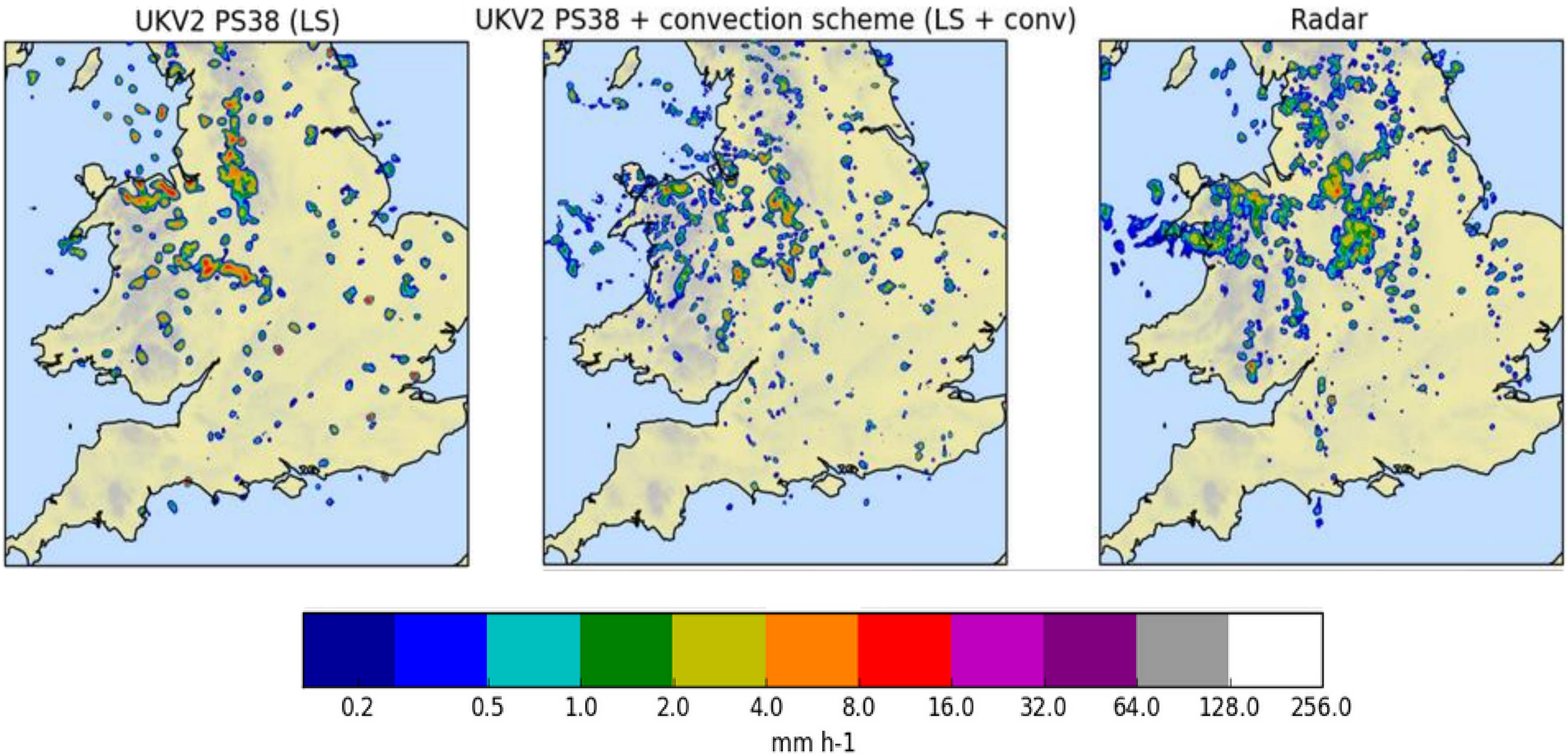
- From 2D (pre vn4.8) to 1D (vn4.8+) standalone routing



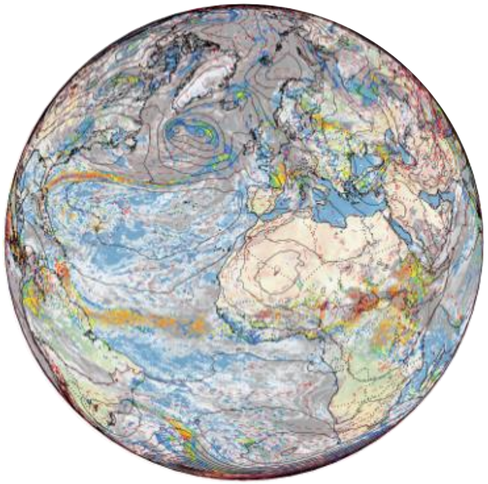
- RFM “vs” TRIP
  - -Both similar implementations of kinematic wave routing
  - -Need to support additional infrastructure (e.g. irrigation, inundation) consistently
  - -TRIP looping algorithm becomes increasingly slow at higher resolution! *Quicksort??*

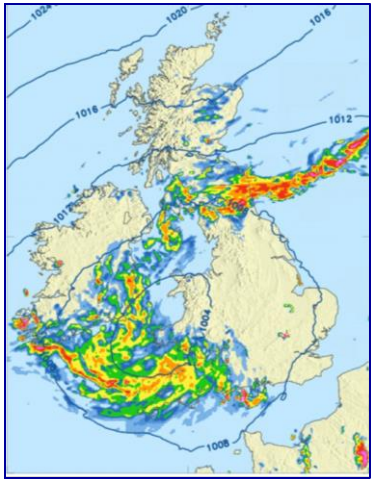
- Future development
  - -Rationalising UM vs standalone routines; consolidating TRIP ‘vs’ RFM
  - -Evolving from kinematic wave to diffusion wave representation
  - -Towards integrated land surface+hydrology and data assimilation….
  - -…

And not to forget….
…forcing characteristics continue to evolve!



End-to-End Assessment of Risk:
From Global Weather to Local Impact





N x Global simulations at ~10km :
Synoptic drivers

<N x Regional simulations at ~1km:
Local meteorology

e.g. Flooding scenarios:
Impacts

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….and for the hour, day, week, month, year, decades ahead

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JULES Science Workshop
27 June 2017

Thank you

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