Hydrological extremes: from long term planning to early warning

An inspiring collaboration across countries and disciplines

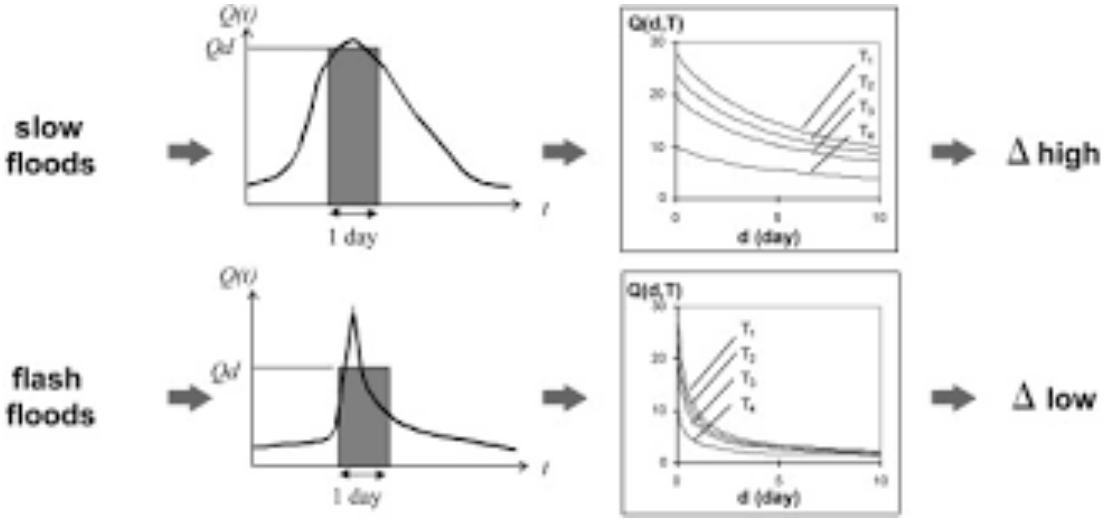
Christel Prudhomme

Christel.Prudhomme@ecmwf.int

ECMWF

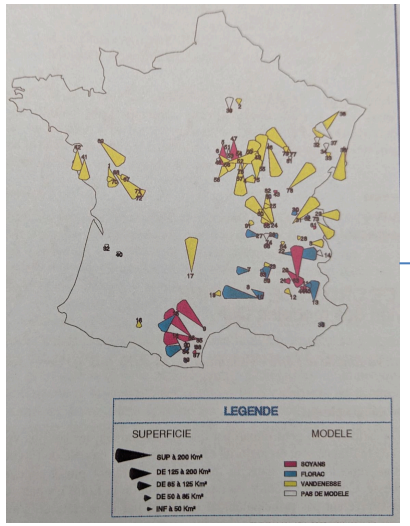
© ECMWF December 8, 2023

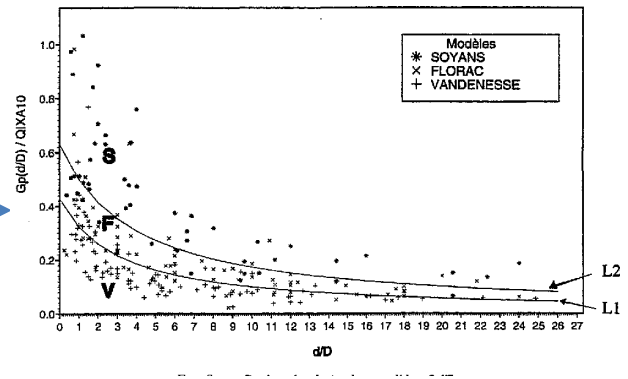
Flood design and planning – The QdF concept



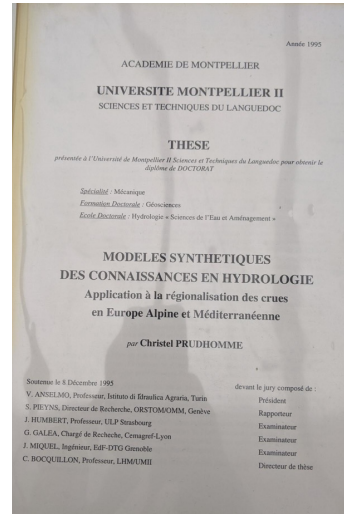
Hypothesis

- Flood ‘regime’ (Hydrological signature) is defined by its ‘Flood-Duration-Frequency’ curves
- Normalised QDFs curves can be used to describe different ‘regimes’





- PhD to explore formulation and transferability
- Characterisation of 3 hydrological signatures from ~100 catchments
- Aim for application to ungauged areas

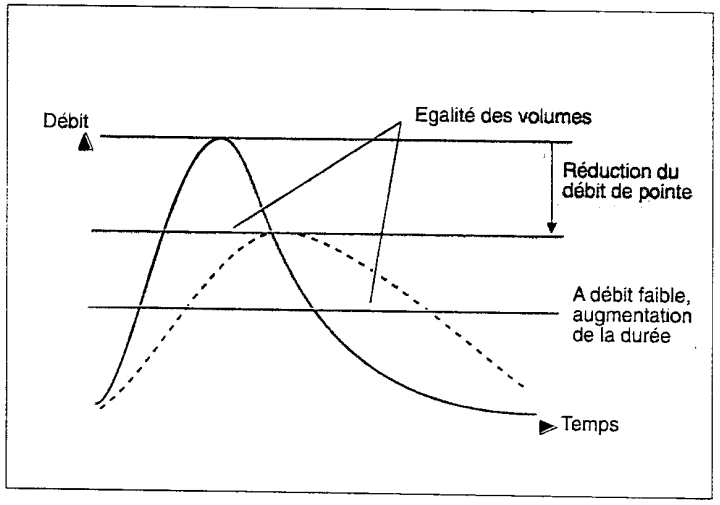

ACADEMIE DE MONTPELLIER
UNIVERSITE MONTPELLIER II
SCIENCES ET TECHNIQUES DU LANGUEDOC
THESE
MODELES SYNTHETIQUES
DES CONNAISSANCES EN HYDROLOGIE
Application à la régionalisation des crues
en Europe Alpine et Méditerranéenne
par Christel PRUDHOMME

ECMWF

Guy Oberlin
Gilles Galea

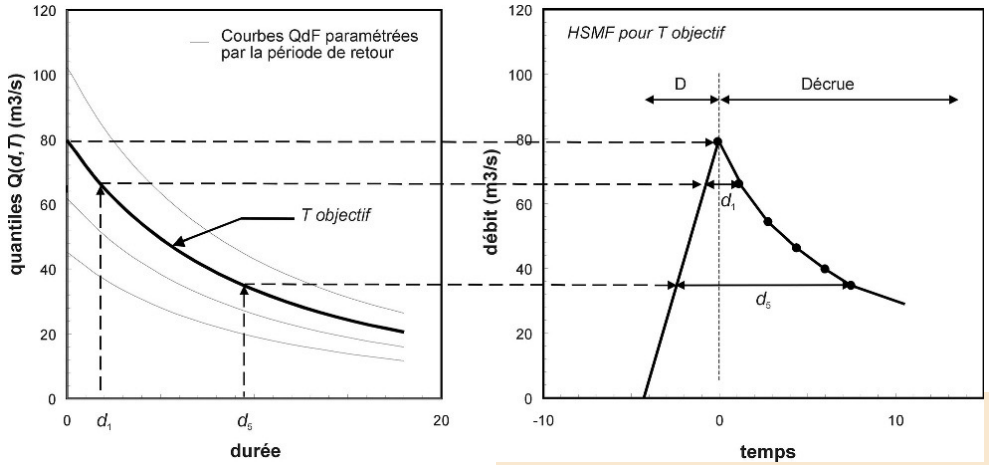
Cemagref

QDF used for nature-based solutions





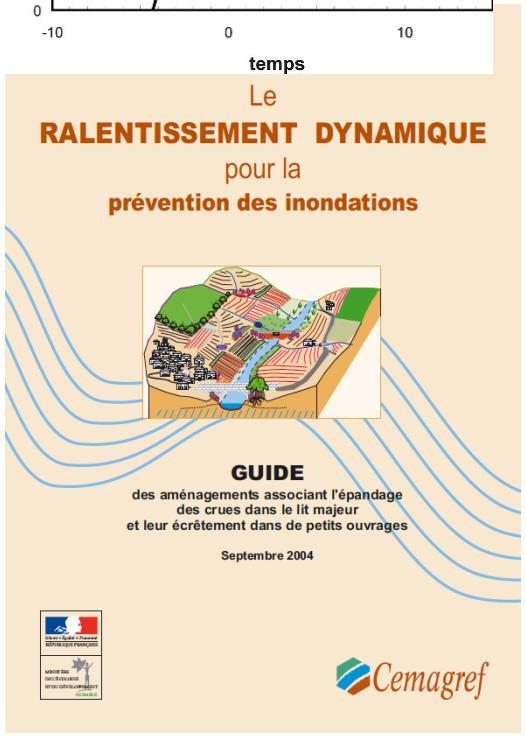
Use of QDF to identify flood design hydrographs



Wider research paradigm

- Flood volume (hazard) cannot be changed
- Where water goes can be influenced





PhD based in a hydrology-hydraulic research/ engineering lab
Mentor: Guy Oberlin, a visionary hydrologist

ECMWF

Guy Oberlin
Gilles Galea

Cemagref

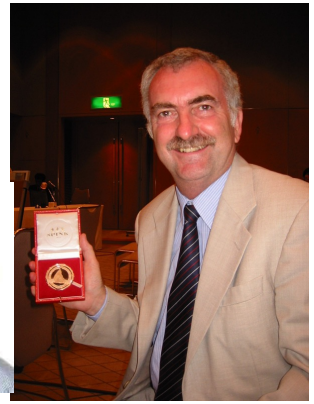
From France to UK … via ‘FRIEND’

- FRIEND International programme funded by UNESCO
- Coordinated by Alan Gustard at the Institute of Hydrology
- ‘AMHY’ region (Alpine and Mediterranean Hydrology) coordinated by Cemagref (G. Oberlin)
- PhD exposure to FRIEND Network
- Opportunity for a post-doc in the Institute of Hydrology

Principle

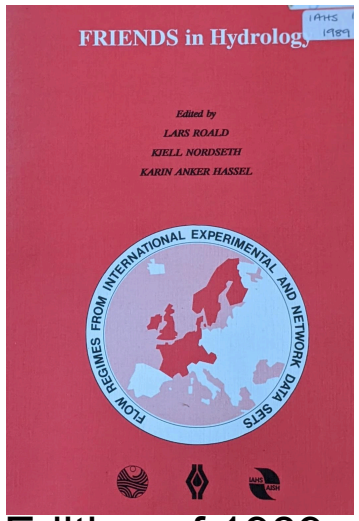
- Sharing data across countries to test local methods transferability
- Building a network of scientist to share knowledge
- FRIEND (Flow Regimes from International Experimental and Network Data

A. Gustard



G. Rees



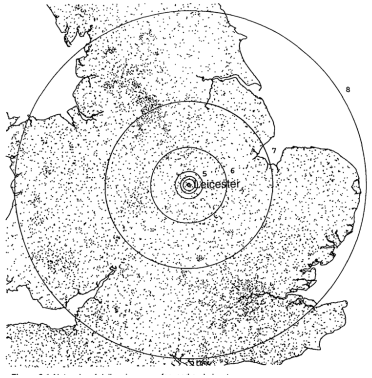


Edition of 1989



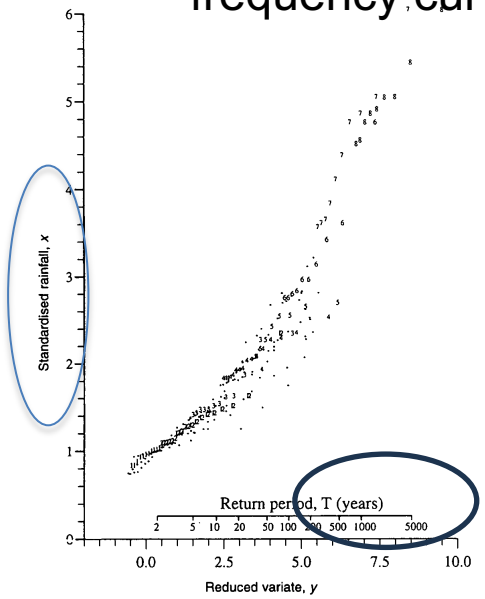
FEH: Extreme rainfall analysis

Selection of donor raingauge network



Standardization by extreme rainfall index RMED

Regional Rainfall frequency curve



- Extreme rainfall index
- Georegression used to map RMED estimates based on local estimates and geophysical features
- FEH standard for flood estimates in UK

L. Stewart D. Faulkner D. Reed

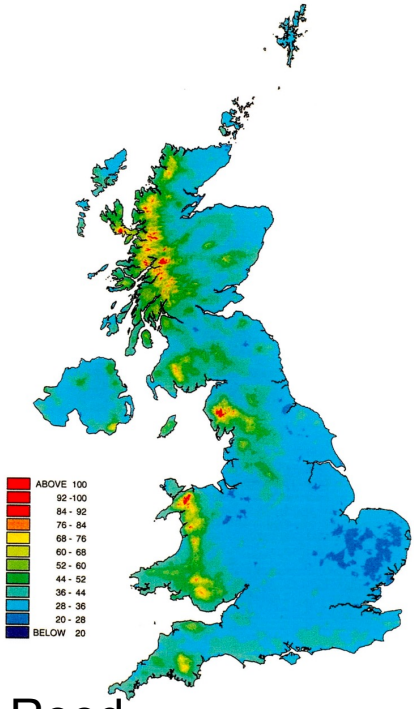


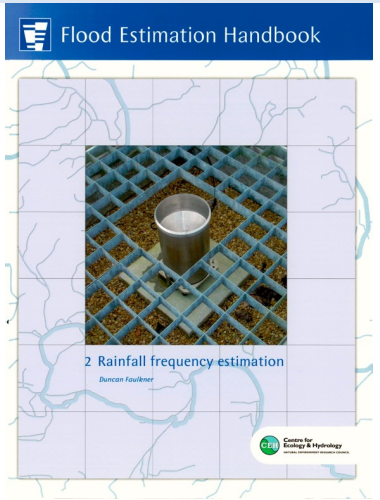


Working in the Flood Estimation Handbook team lead by Duncan Reed

Principle

- Extreme rainfall regime not locally-defined
- Record length can be increased by pooling information
- Normalise data to account for local specificity





Contribution to Flood Estimation Handbook First edition 2000 (Chap 2; Falkner)

Is Climate Change making a difference on floods? Supporting government on flood guidance

MAFF project FD0424-C

•1 GCM H
•1 Hydrol
•2 catchm
•3 monthl
•3 land us
•4 emissio

•A total of

Defra –EA project FD0424-C

•1 GCM HadRM3
•2 Hydrological models (but 1 per catchment)
•2 monthly-
•4 emission
•100 resam
•10 catchme

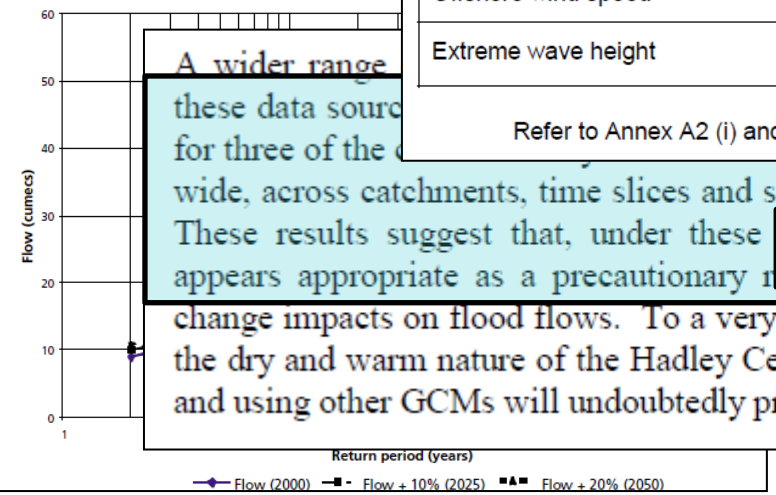
•A total of 1

Table 2: Indicative Sensitivity Ranges

Parameter	*1990-2025*	*2025-2055*	*2055-2085*	*2085-2115*
Peak rainfall intensity (preferably for small catchments)	*+5%*	**+10%**	*+20%*	*+30%*
Peak river flow (preferably for larger catchments)	+10%	**+20%**		
Offshore wind speed	*+5%*		**+10%**	*+10%*
Extreme wave height	*+5%*		**+10%**	*+10%*

Refer to Annex A2 (i) and (ii) for information on figures in bold and italic.

Figure 6.2 Flow frequency adjustment for clim



A wider range
these data sourc
for three of the
wide, across catchments, time slices and scenarios, but usually below the 20% increase.
These results suggest that, under these
appears appropriate as a precautionary
change impacts on flood flows. To a very large degree this conclusion is determined by the dry and warm nature of the Hadley Centre model used to generate all the scenarios, and using other GCMs will undoubtedly produce different results.

FCDPAG3 Defra supplementary note

Defra/Environment Agency
flood and coastal erosion risk management
R&D Programme

Impact of climate change on flood flows in river catchments – final report

R&D Technical Report W5-032/TR

n and Thames
a given return
50 years. Data
alysis for other
unlikely to be

D. Jakob

N. Reynard



Helen Davies
Sue Crooks



Context

- Flood design methods based on stationarity assumption
- Climate research suggests changes in rainfall pattern in the future
- Impact on hydrology to be assessed

Is Climate Change making a difference on floods? Supporting government on flood guidance

- Research mainly conducted to answer government questions
- Enable to explore some scientific questions regarding climate change impact assessment on hydrology
- Difference in scale between GCM outputs and hydrology (time and space)

The Flood Characteristics of Large U.K. Rivers: Potential Effects of Changing Climate and Land Use

Published: February 2001 | 48, 343–359 (2001)

N. S. Reynard, C. Prudhomme & S. M. Crooks

HYDROLOGICAL PROCESSES
Hydrol. Process. **16**, 1137–1150 (2002)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.1054

Downscaling of global climate models for flood frequency analysis: where are we now?

Christel Prudhomme,* Nick Reynard and Sue Crooks
Centre for Ecology and Hydrology, Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB, UK

Assessing uncertainties in climate change impact analyses on the river flow regimes in the UK. Part 1: baseline climate

Published: 20 August 2008 | 93, 177–195 (2009)

Christel Prudhomme & Helen Davies

Assessing uncertainties in climate change impact analyses on the river flow regimes in the UK. Part 2: future climate

Published: 17 September 2008 | 93, 197–222 (2009)

Christel Prudhomme & Helen Davies

onal Journal of Climatology RMetS

Bias correction of daily precipitation simulated by a regional climate model: a comparison of methods

Thomas Lafon, Simon Dadson, Gwen Buys, Christel Prudhomme

ELSEVIER

Journal of Hydrology
Volume 277, Issues 1–2, 1 June 2003, Pages 1-23

Uncertainty and climate change impact on the flood regime of small UK catchments

Christel Prudhomme [a b], Dörte Jakob [a], Cecilia Svensson [a]

ECMWF

D. Jakob

N. Reynard

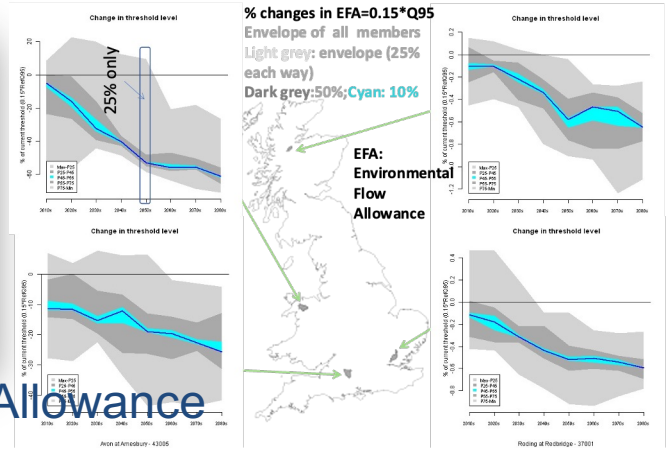
Helen Davies
Sue Crooks





Hydrological projections: the Future Flows and Groundwater levels dataset



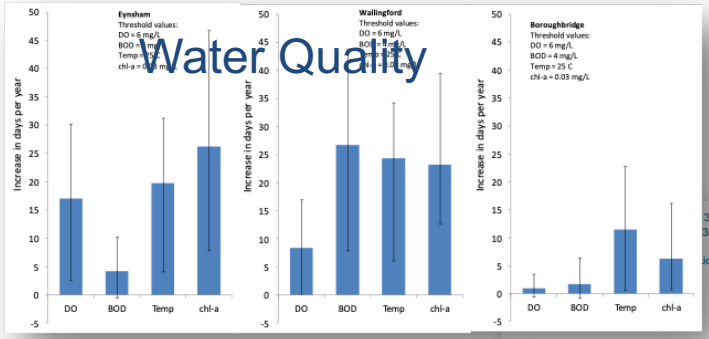


Environmental Flow Allowance

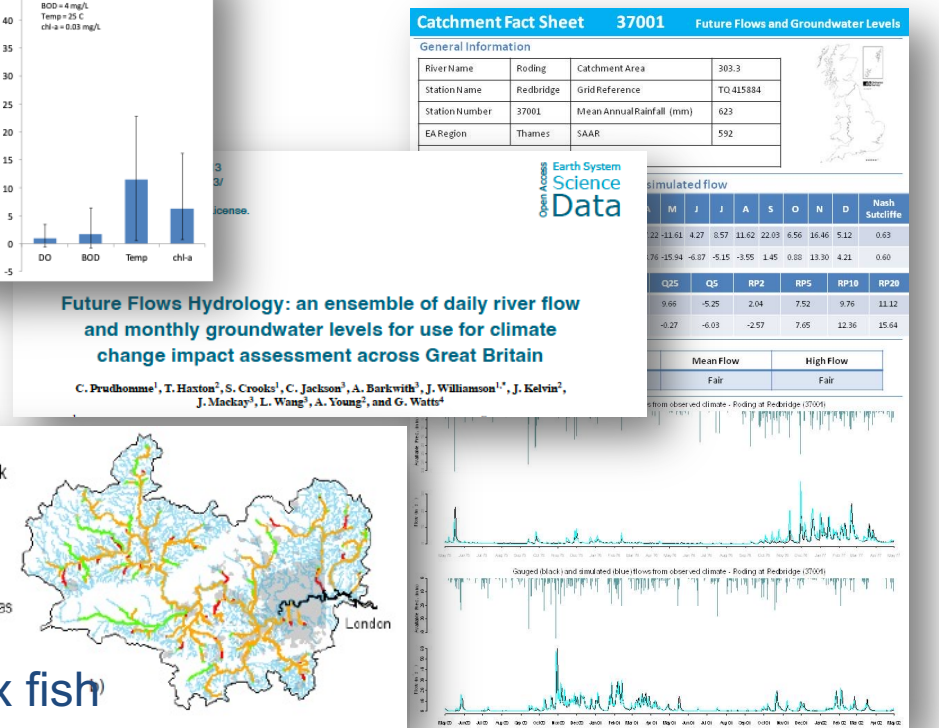
Context

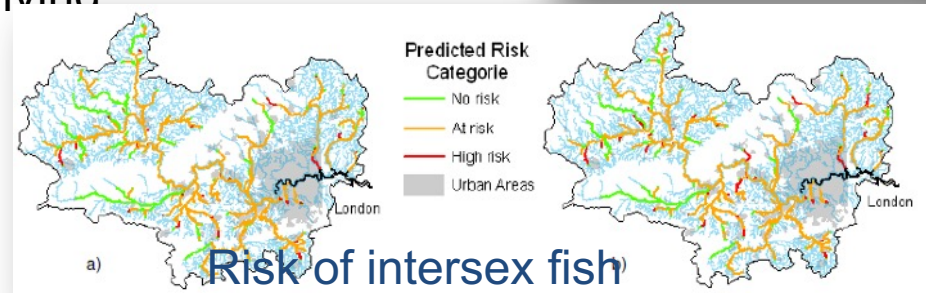
- Investment on hydrological impact research focused on single applications/ questions
- Full potential of data not exploited

- Pioneering ‘open-data’ of hydrological projections freely available to all
- Catalogue of river discharge and groundwater level multidecadal daily time series + metadata over ~ 300 catchments
- Uncertainty captured from 11 transient projections (HadRM3) + 10k samples of timeslices
- National-scale hydrological modelling for deriving key impact statistics



Water Quality





Risk of intersex fish

C. Jackson

T. Haxton

G Watts



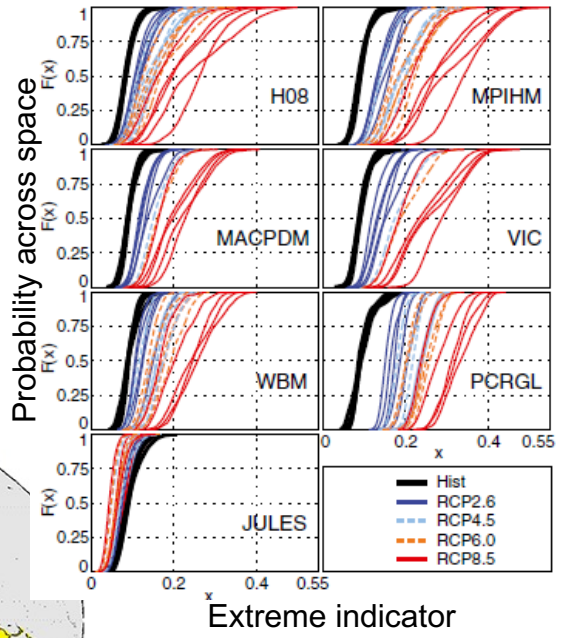
Are we accounting for all uncertainty?

- Global River discharge simulations from 5 GCMS & 7 LSM/GHM
- Exploring emission+GCM+ impact model uncertainty
- Hot spot for increased drought risk identified

Context

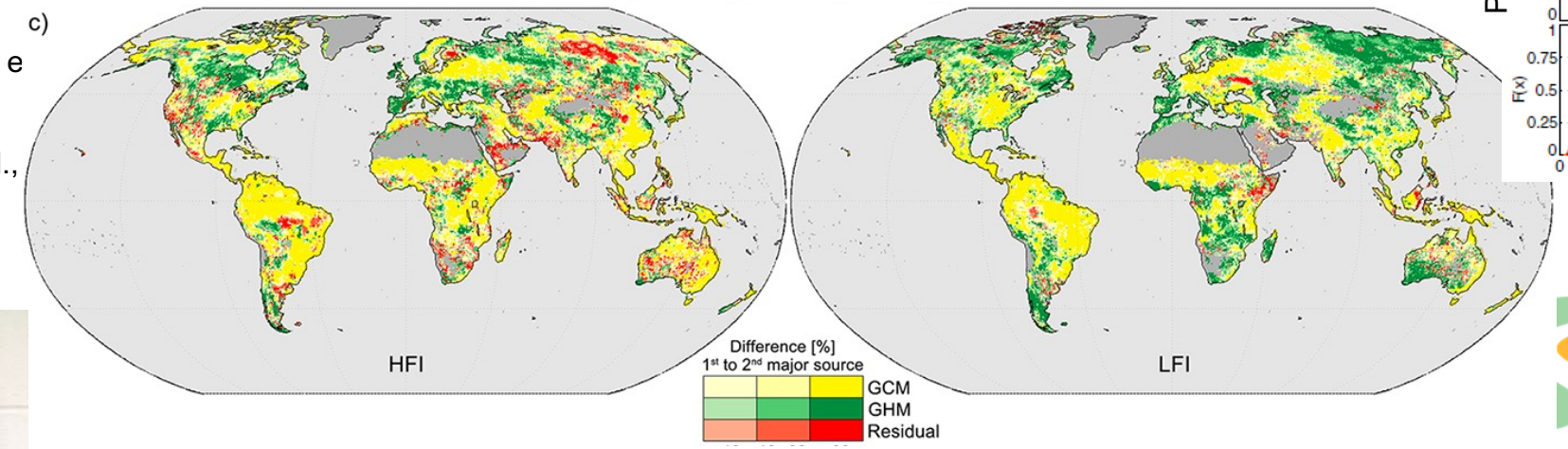
- Multiple GCMs but single downstream models
- WATCH project
- ISIMIP: Understanding uncertainty from impact models

All models except JULES show increase in drought risk
JULES only model accounting for CO2 increase in plant dynamics
Importance to consider relevant processes



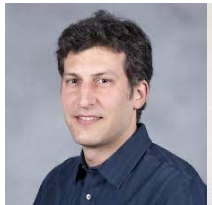
Prudhomme e 2014, PNAS

Giuntoli et al., 2015, ESD



Source of uncertainty in Hydro extreme projections

I. Giuntoli

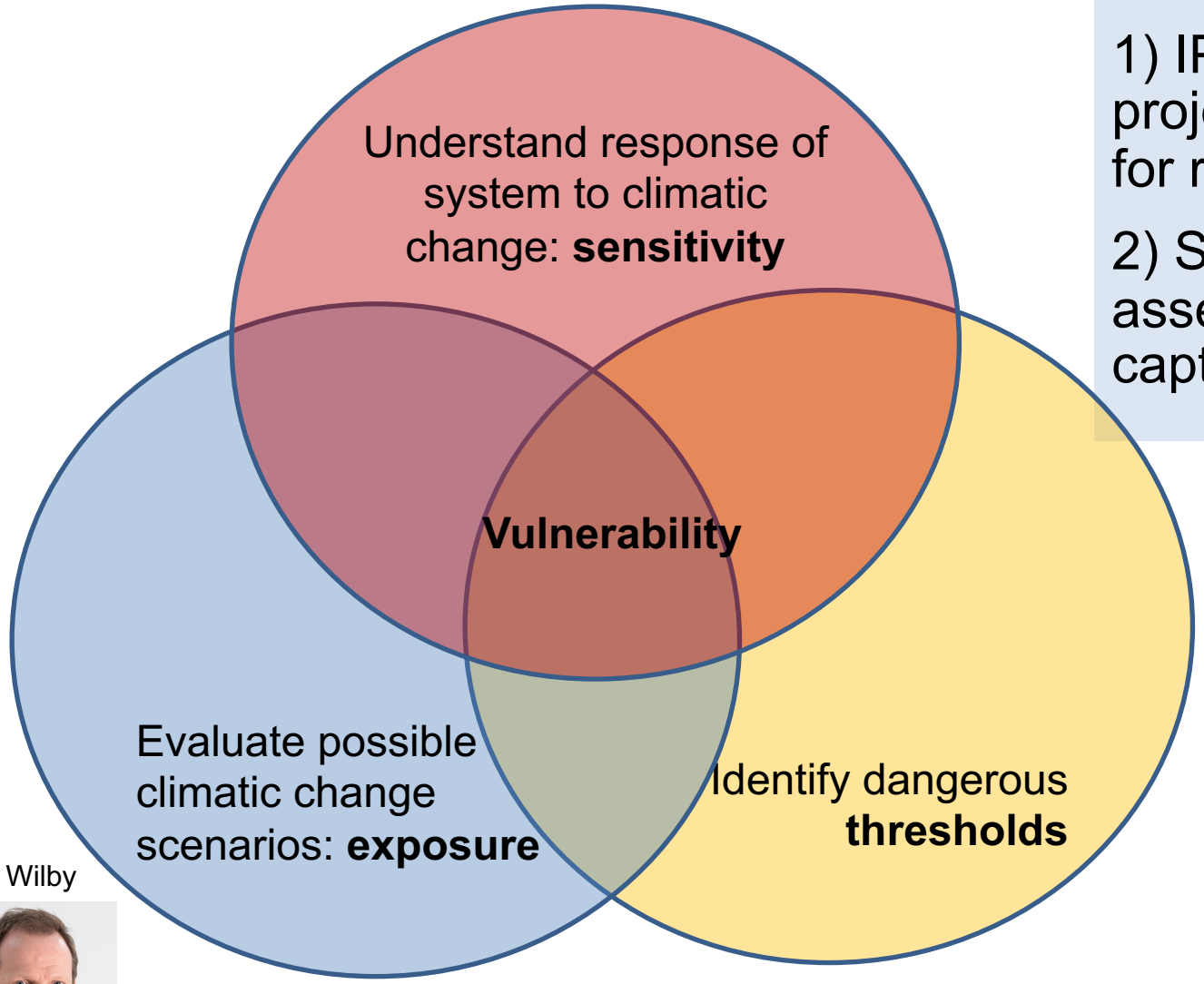


D. Clark



ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

A new paradigm for assessing impact of climate change



Context

1) IPCCs / climate projections updated asks for review of policies

2) Scenario-bound assessment does not fully capture impact behaviour

N. Reynard



A. Kay

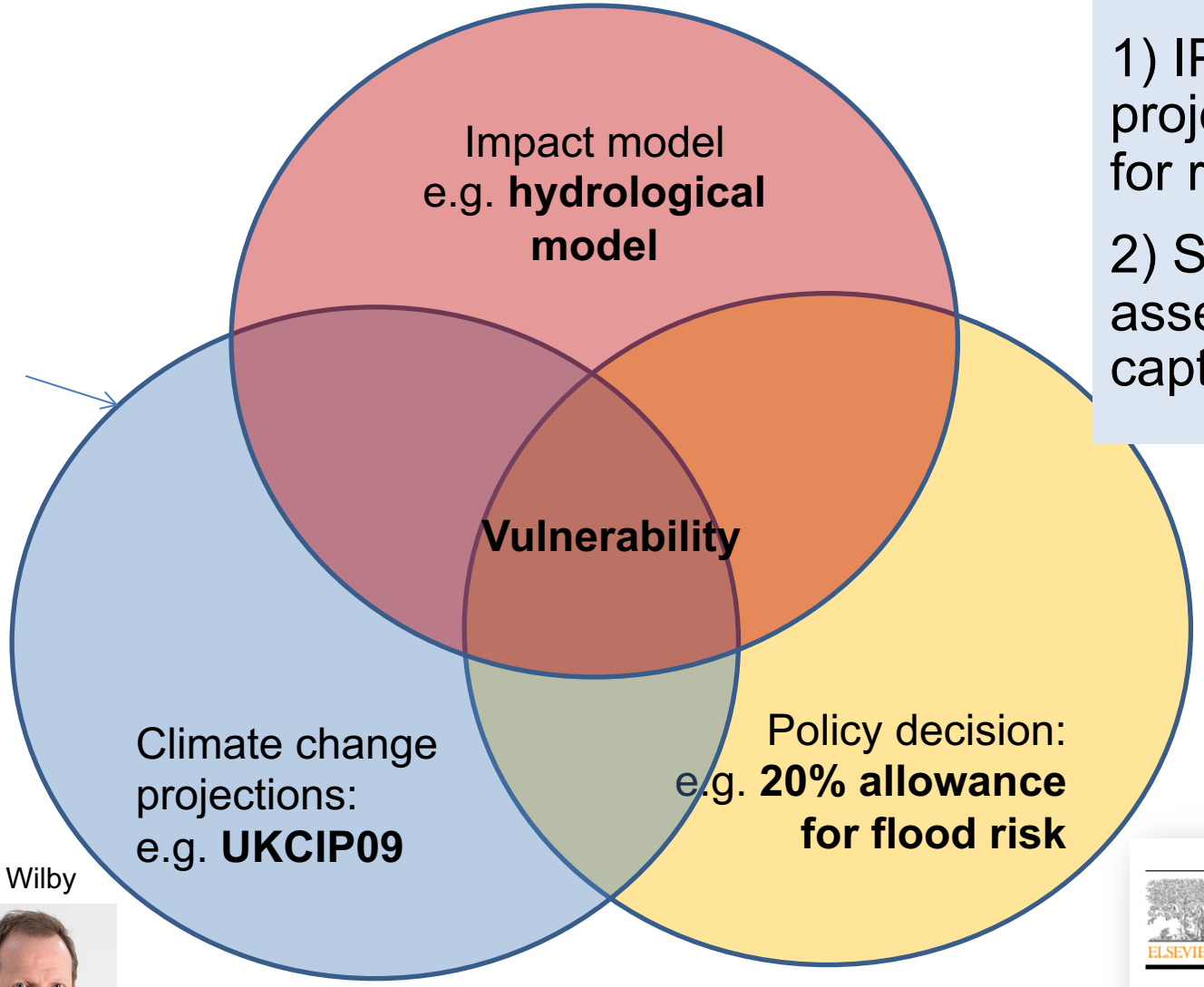


R. Wilby



A new paradigm for assessing impact of climate change

Only part to refresh with evolution of climate science



Context

1) IPCCs / climate projections updated asks for review of policies

2) Scenario-bound assessment does not fully capture impact behaviour

Implement a risk analysis framework

N. Reynard A. Kay R. Wilby





Journal of Hydrology 390 (2010) 198–209

Contents lists available at ScienceDirect

Journal of Hydrology

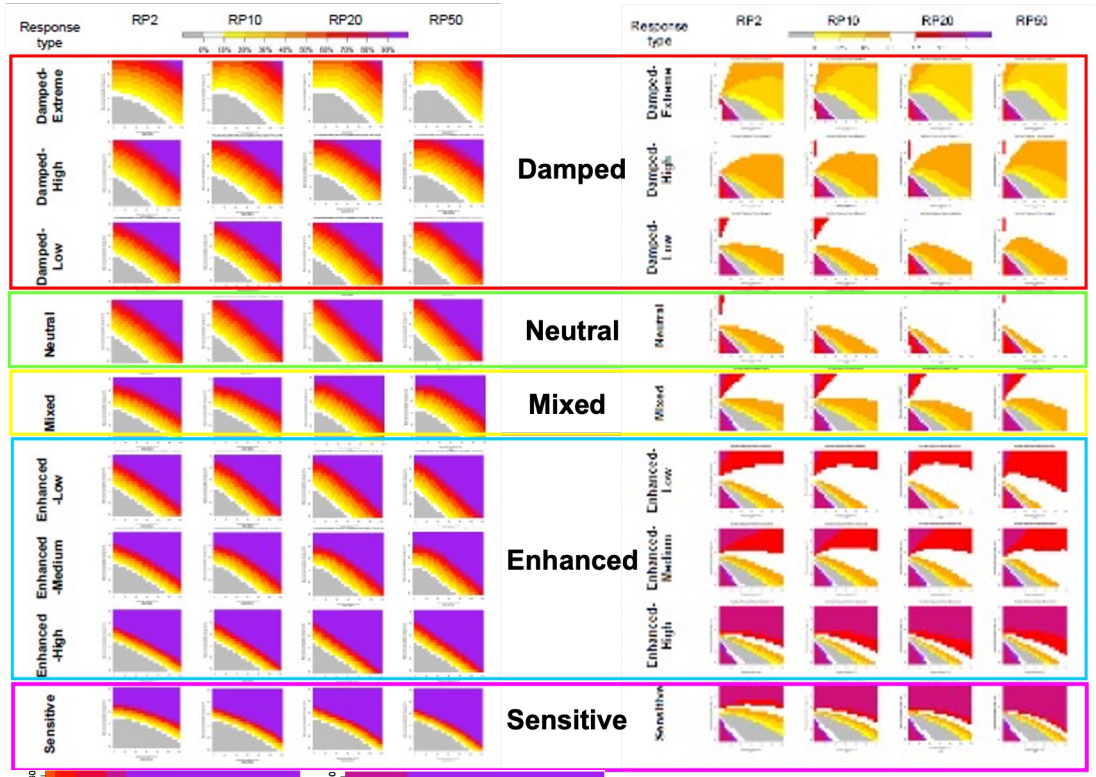
journal homepage: www.elsevier.com/locate/jhydrol

Scenario-neutral approach to climate change impact studies: Application to flood risk

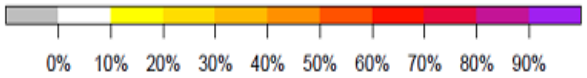
C. Prudhomme [a,*], R.L. Wilby [b], S. Crooks [a], A.L. Kay [a], N.S. Reynard [a]

A new paradigm for assessing impact of climate change

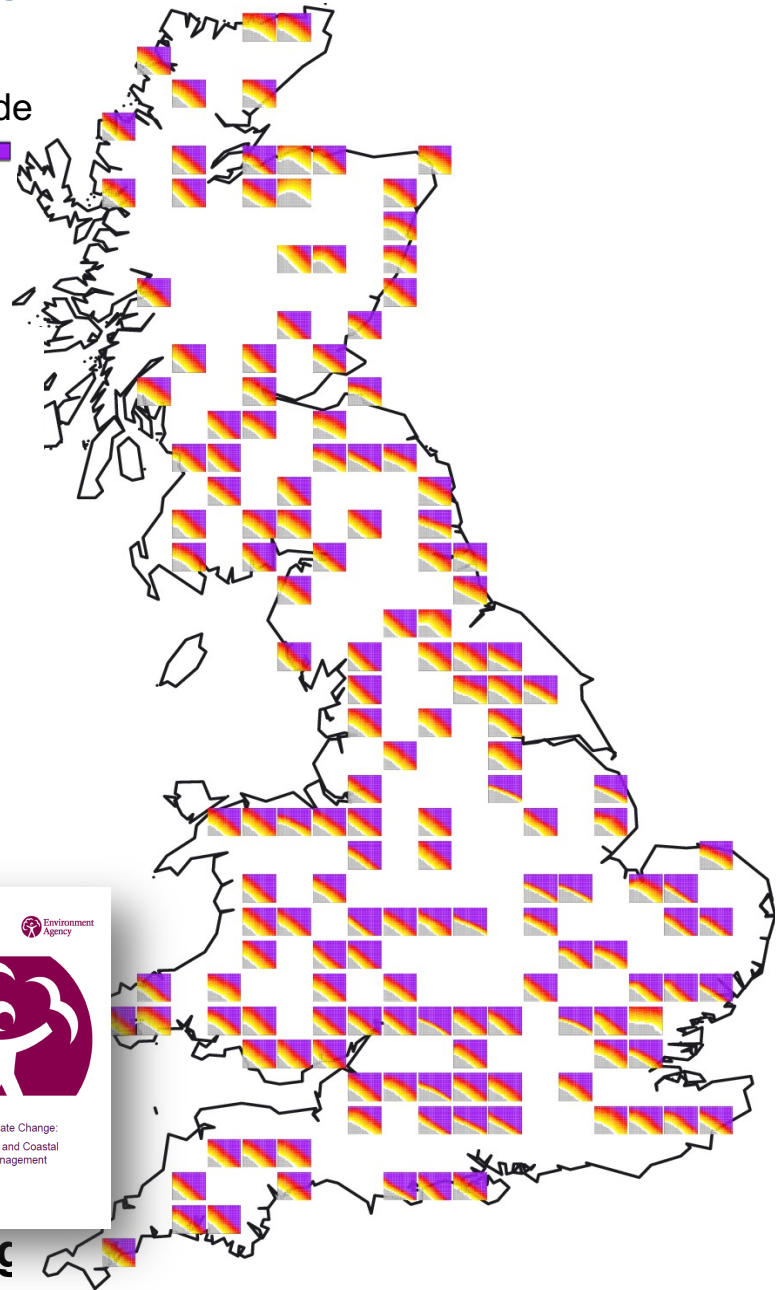
Cluster analysis: Key flood response surfaces and types

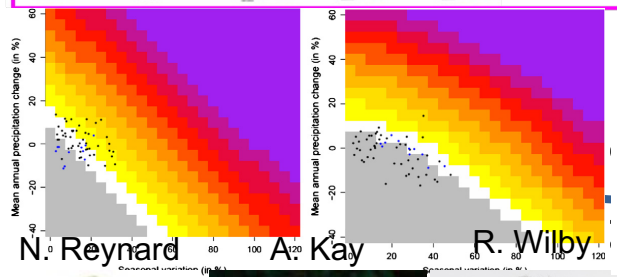


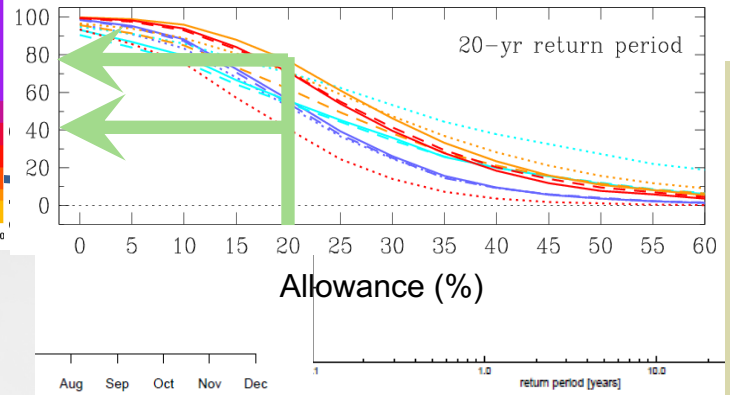
Changes in 20-year flood magnitude

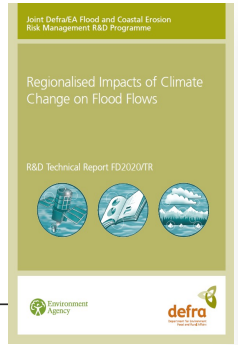


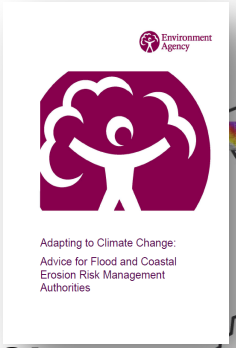
- Response to climate driver different across UK
- Changes to climate drivers easily transferable to changes in flood impact









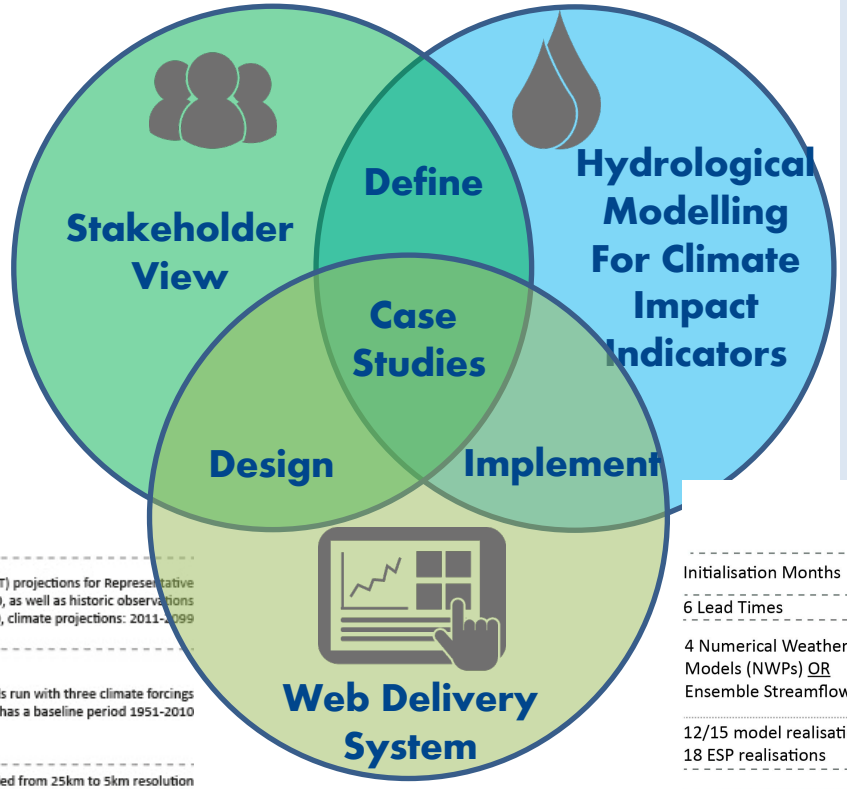


N. Reynard A. Kay R. Wilby



From science to users: climate services

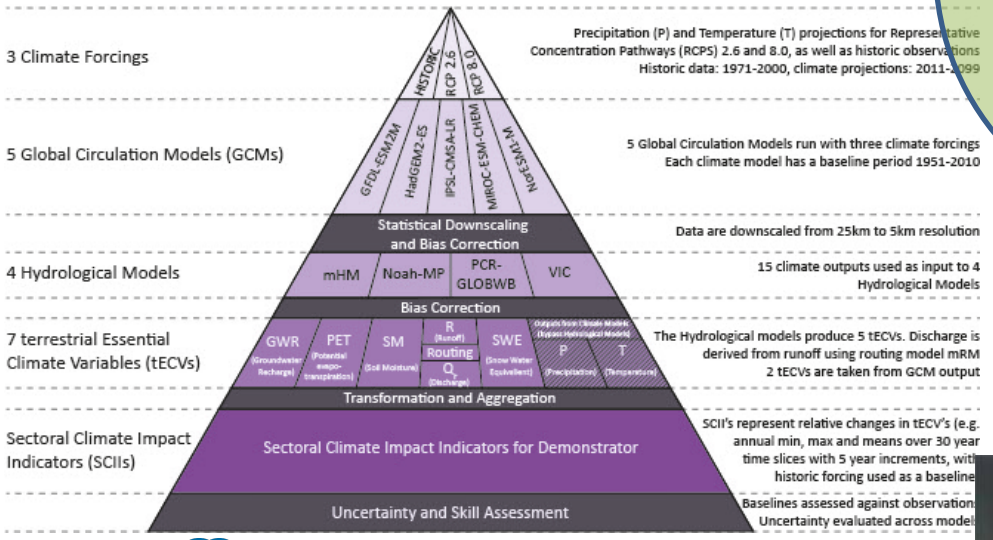
- Robust scientific assessment
- Easy-to-use web-based platform
- User-defined metrics
- Long-term projections + seasonal outlooks



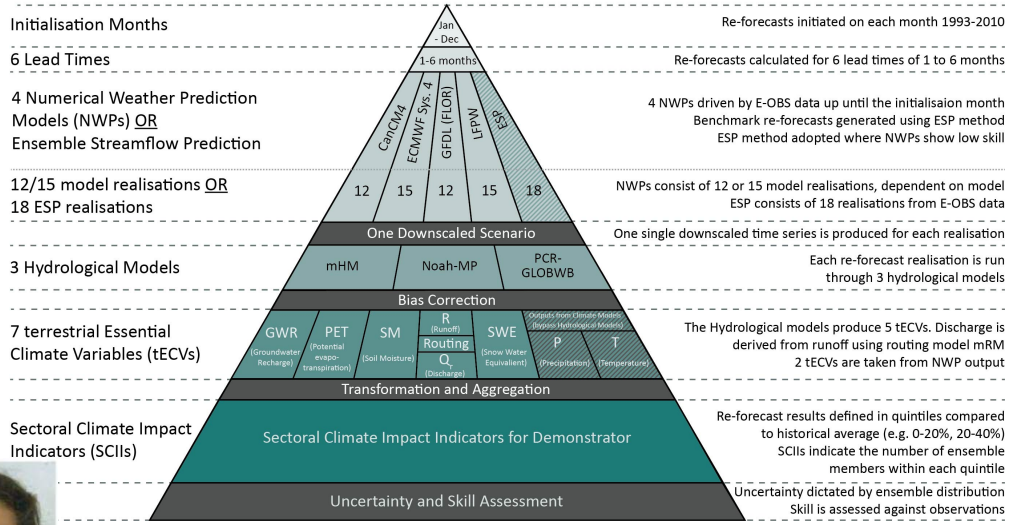
Context

- Copernicus Climate Change Service set-up to provide access to climate-related information
- Water sector identified as priority
- UKHydro Outlook precursor service for the UK

EDgE Climate



EDgE Seasonal Forecasting



M. Fry



K. Smith

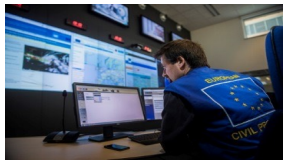




H. Houghton Carr

Hydrology in a Numerical Weather Prediction Centre

- CEMS European and Global Flood Awareness Systems (EFAS and GloFAS)
- Early probabilistic flood warnings (restricted in Europe)
- Transboundary system
- Twice daily (Europe) hydrological forecasts with flood notifications
- Forecast horizon from nowcasting (Europe), medium-range to seasonal

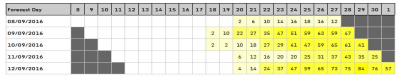


Early warning for preparation of aid assistance



European/World-wide comparable information

Complement National/regional services



EFAS
European Flood Awareness System

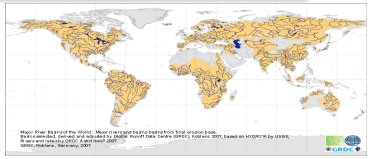
Knowledge transfer & exchange

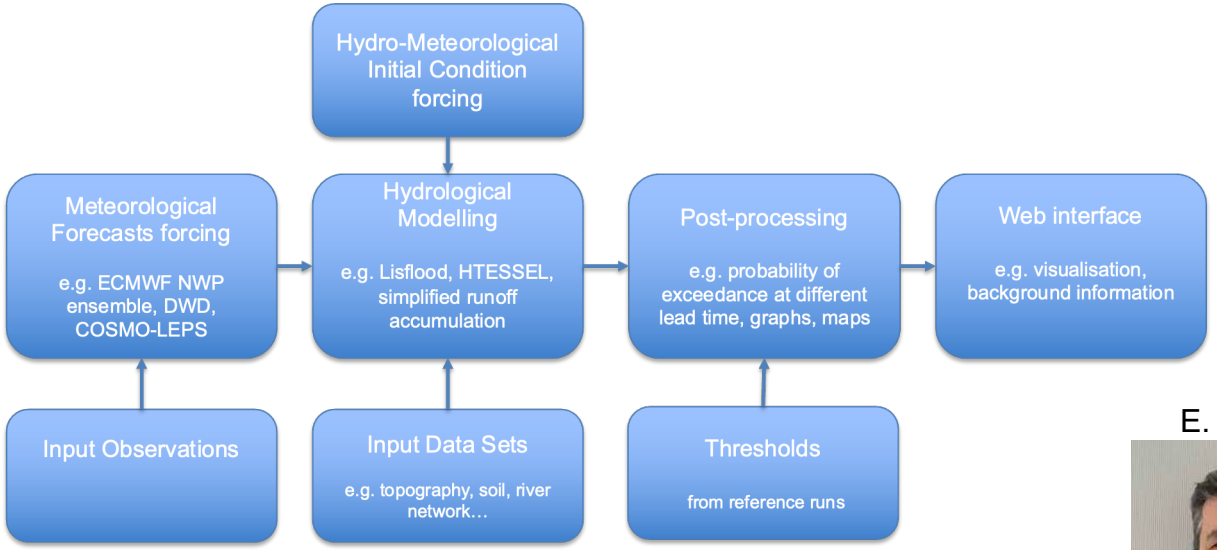
GLOFAS
Global Flood Awareness System

Support international organisations



Improved data sharing

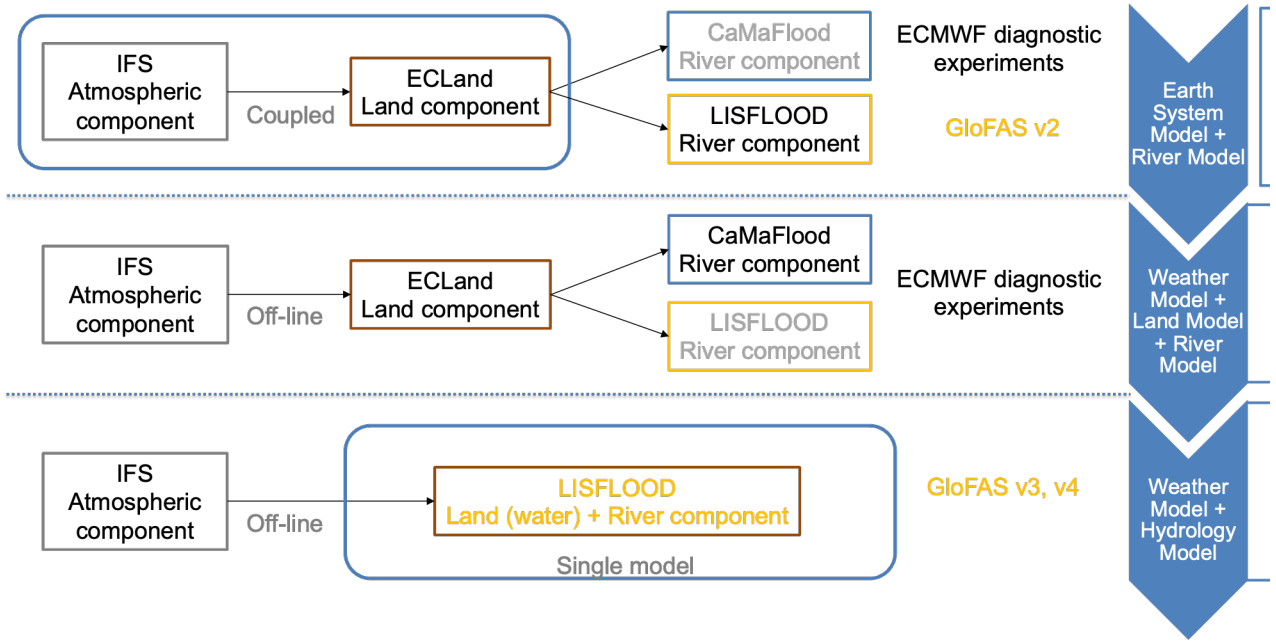




E. Zsoter G. Balsamo C. Mazzetti F. Rabier H. Cloke F. Pappenberger



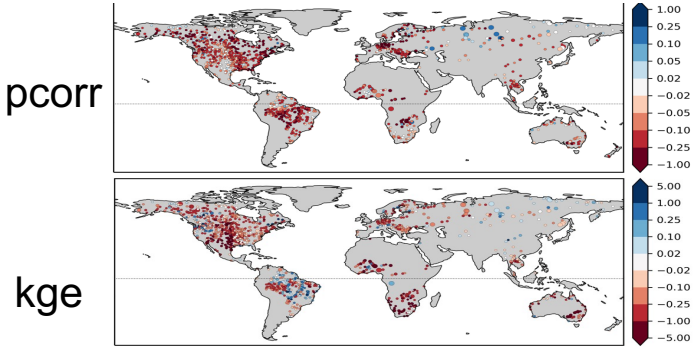
Hydrology in a Numerical Weather Prediction Centre



Context

- Different modelling systems to experiment with
- River discharge natural integrator
- Can be used as diagnostic for new land surface schemes
- Benchmarking against calibrated hydro model

Error difference in Q



Soil10 better

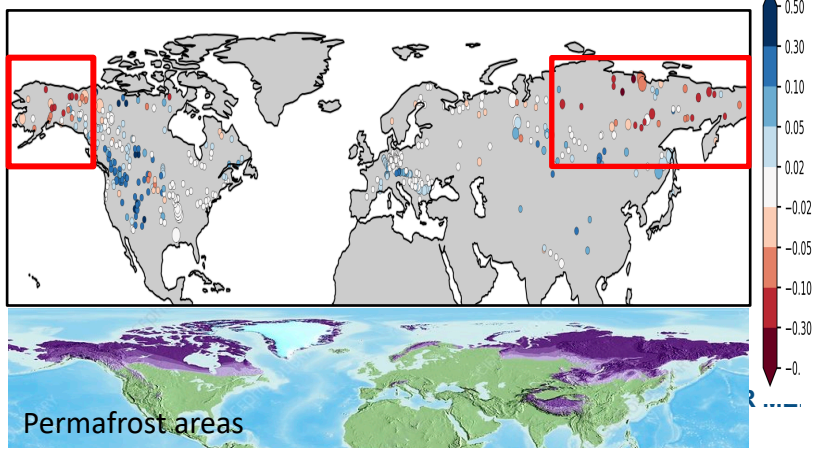
Exploration of new soil scheme

Work by Zsoter, Bousseta, Arduini

Soil10 worse

Error difference in Q

New scheme better



Snow scheme change; Zsoter, Arduini et al., 2022, https://doi.org/10.3390/atmos13050727

New scheme worse

E. Zsoter G. Balsamo C. Mazzetti F. Rabier H. Cloke F. Pappenberger



So many future path for hydrology…. Thank you all

- **Inspired** by talented, exceptional visionary scientists and people
- **Privileged** for trust given in new ideas
- Amazingly **grateful** for all incredible opportunities


































.. and so many others!!!