
# Global Modelling of Water Availability and Water Use under Current Conditions and Future Scenarios

Water Resource Modelling

wholeSEM Annual Conference
6-7 July 2015

Helen Houghton-Carr
Egon Dumont, Simon Parry, Nathan Rickards, Jose Moyano-Capilla
Terry Marsh & James Miller
NERC Centre for Ecology & Hydrology

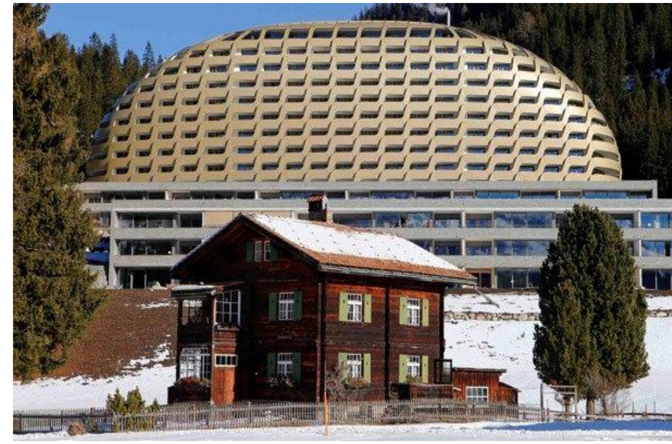
# Content

- Why do we want to model water resources?
- How do we do it?
- GWAVA model and example applications
- Water-food-energy nexus

# World Economic Forum – Davos 2015

## Top 5 Global Risks in Terms of Impact:

- 1 **Water crises (societal risk)**
- 2 Rapid and massive spread of infectious diseases (societal risk)
- 3 Weapons of mass destruction (geopolitical risk)
- 4 Interstate conflict with regional consequences (geopolitical risk)
- 5 **Failure of climate-change adaptation (environmental risk)**



# The Nile basin

- Politically volatile region
- Countries rely heavily on the Nile for water and power
- Ancient hydrometric monitoring
- Allocation of share of the Nile's water problematic
- Depletion of the Nubian Sandstone aquifer a growing concern
- Inadequate contemporary hydrometric monitoring in many areas
- Major water quality challenges
- 'East Africa Climate paradox' - modelled rainfall increasing but observed rainfall decreasing)


Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Photos: The Expeditioner

# Why do we want to model water?

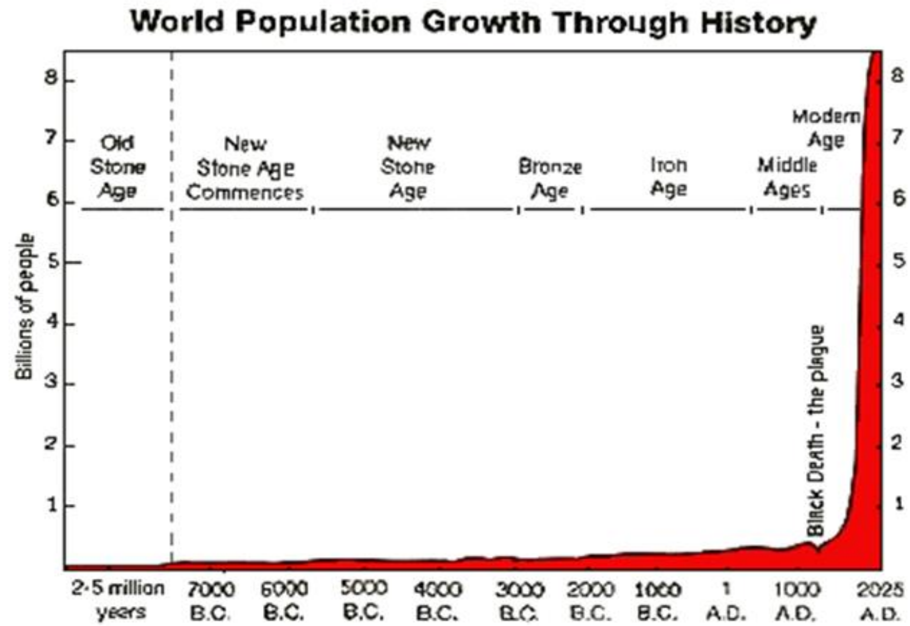
- Understand behaviour of hydrological systems
- Understand impacts of pressures on hydrological systems
- Assess water resources and estimate flows for design of water-related schemes
- Generate evidence to inform management and policy decisions
- Mediate between competing demands to achieve equitable and sustainable water use for all
- Enable adaptation to reduce vulnerability to future change
- Contribute to economic development and poverty alleviation

- Population (land use, economic activity)
- Climate

# Water is life, but…

- People need water, food, shelter, land, materials, energy – and a nice environment

- World population grew by 30% (1.6B people) between 1990-2010 (and by >250% since 1950)




- Substantial uncertainty in forward projections of global and regional populations – combined with uncertainties of impacts of climate change

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

*Source: UN Population Fund*

# Population pressure: nexus examples

Tanzania

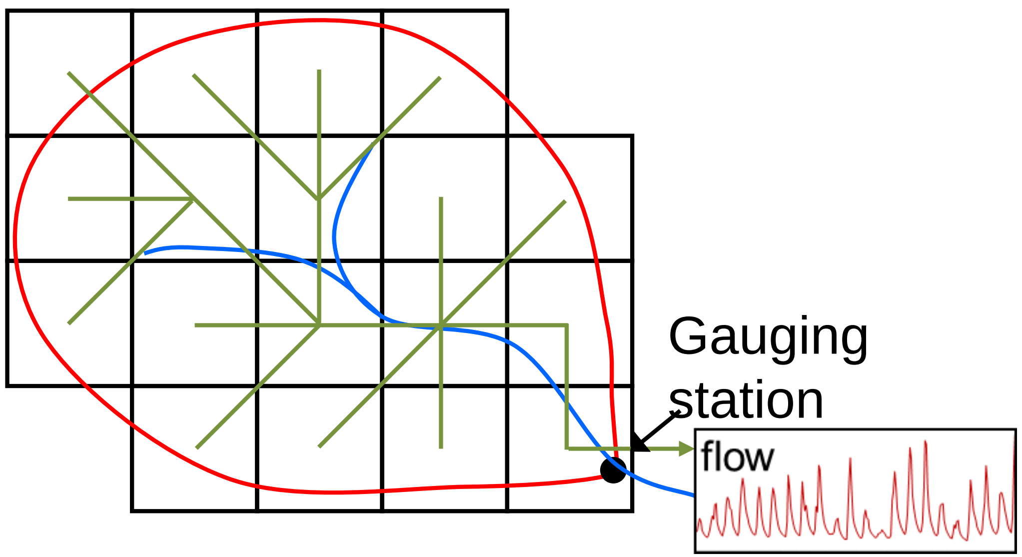
- Plan to designate water supplies of 153 HEP stations as ‘protected sites’
- Ban other economic activity that uses protected water sources, including irrigation-fed farming, fishing, livestock raising
- Caused by increasing water demand and/or climate change?

India

- Cheap diesel and electricity has lead to unsustainable groundwater use – to irrigate crops
- As water tables drop, more energy is needed to pump water out
- Concern that when efficient solar-powered pumps are developed, groundwater abstraction will spin out of control

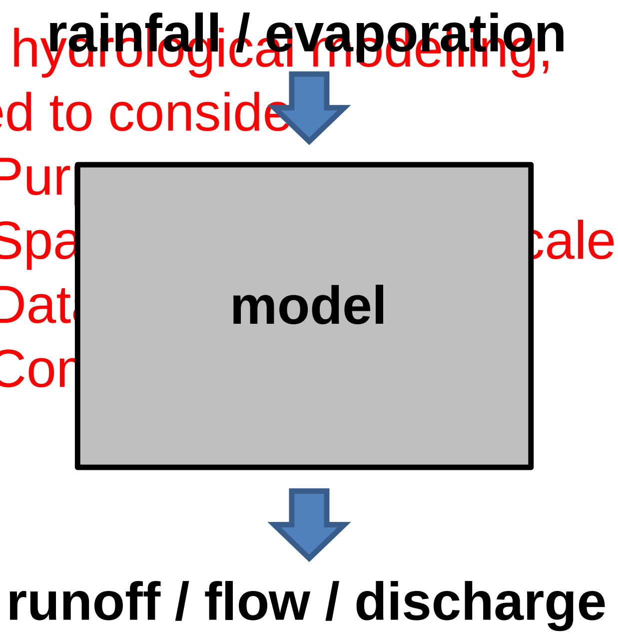
# Hydrological modelling

## Distributed model




For hydrological modelling, need to conside

- Pur
- Spa cale
- Dat
- Con




Basin model can be tailored to local conditions – can potentially be more accurate

Distributed model can provide flow estimates ‘everywhere’ but less easy to tailor to local conditions

# Types of model

## Land surface hydrology models (LSHMs)

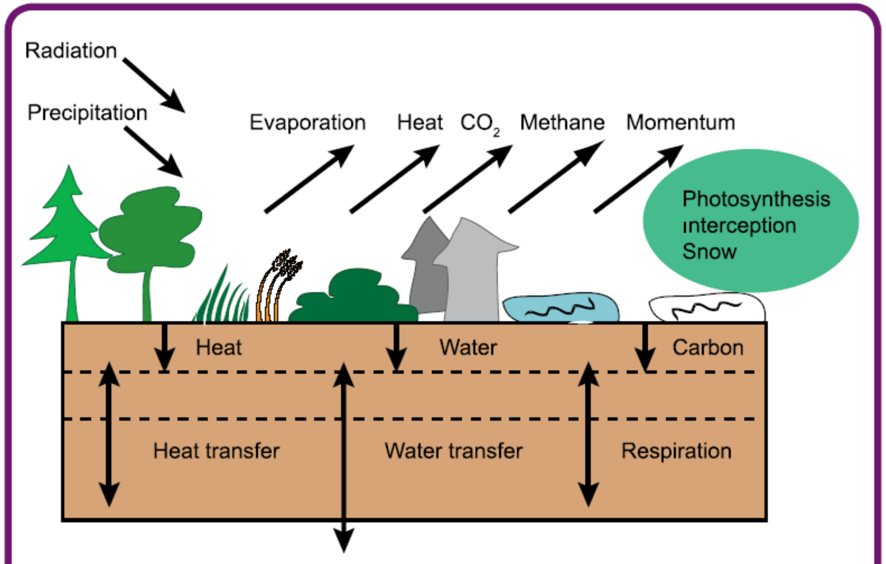
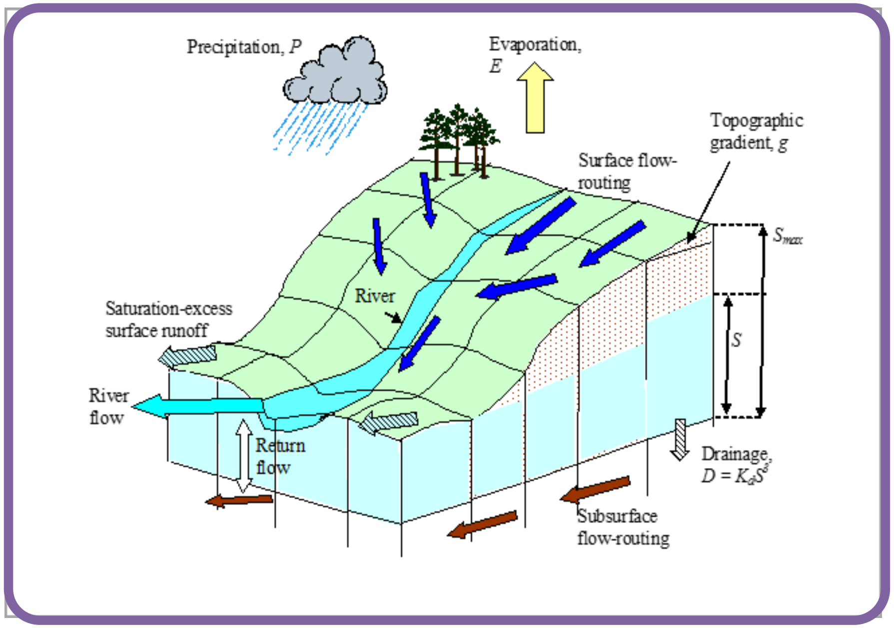



Figure 1. Schematic diagram of the new Land Surface Model, JULES.

Focus on processes and vertical exchanges between atmosphere and land surface e.g. JULES

## Global hydrological models (GHMs)




Simulate: river flow, runoff (surface and sub-surface), recharge, soil moisture e.g. G2G, GWAVA

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

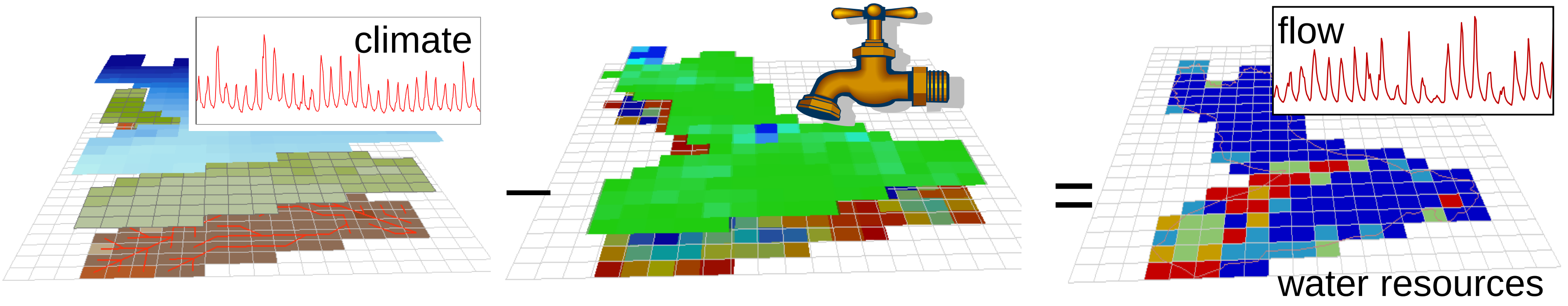
*Source: Blyth et al, 2006; Bell et al, 2009*

# Global Water AVailability Assessment model

GWAVA is a gridded hydrological (rainfall-runoff) model that:

- Reads gridded driving data (precipitation, climate)
- Calculates gridded runoff and routes along network of flow paths to estimate river flows
- User can extract flows for any grid square

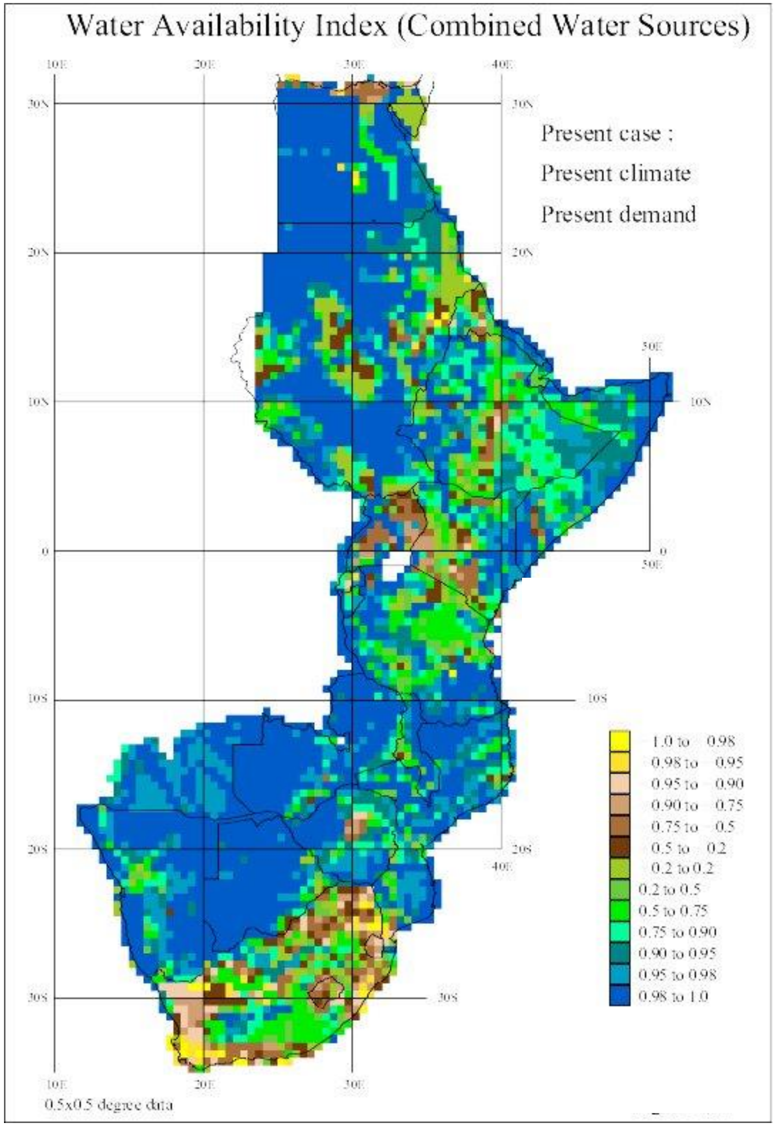
But GWAVA also incorporates water demand and water infrastructure components that modify water quantity and flow regime - to give assessment of overall water resources

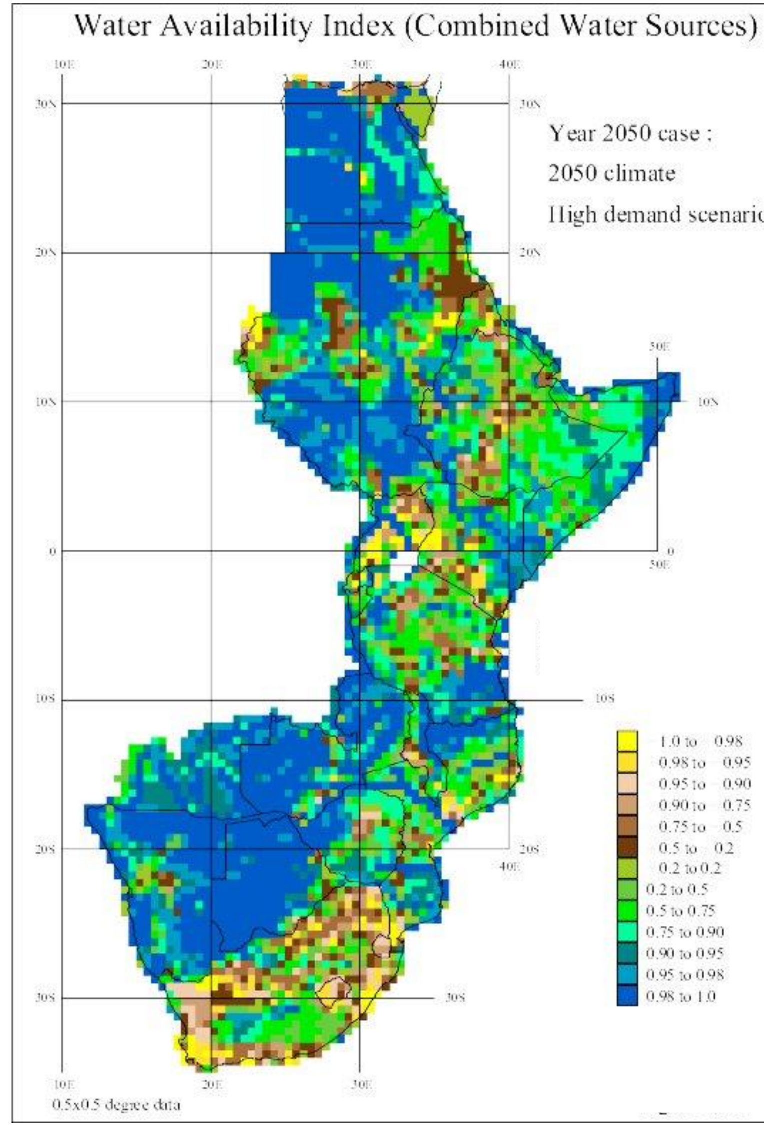



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Source: Meigh et al, 1999

# Eastern & Southern Africa: 1994-1997



# GWAVA data

GWAVA uses spatial datasets to generate routing flow paths and sectoral water demands for all grid squares at the required resolution (typically 0.1°, 0.5°):

**Rainfall-runoff model**

- Elevation, drainage network
- Lakes, reservoirs, wetlands
- Soil type, land cover
- Climate (P, PE, T)

**Demand estimation**

- Human population
- Livestock
- Cropping, irrigation
- Industry, energy
- Dams, water transfers
- Abstractions, returns, losses

Publically available data sources include:

- USGS land cover map and DEMs
- FAO Soil Map
- FAOSTAT and AQUASTAT
- ESRI digital maps
- Climate Research Unit (CRU)

Supplemented where possible by local datasets

Routing of generated runoff less demand from each grid square to the next one downstream via network of flow paths

GWAVA is calibrated on flow data measured at river gauging stations

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# GWAVA approach

- Representation of spatial variability in water availability/ supply and water demand → water resources/stress
- Ability to model future scenarios of climate, water demand and land use
- Consistent methodology across large areas and applied at a range of scales → scale is a compromise between data, detail and run-time
- Tackling problems of international basins
- Modules for water quality and environmental flows

The challenge is to ensure that our models provide the kind of information that is needed by and useful to stakeholders to inform policy and to lead to actions promoting adaptation

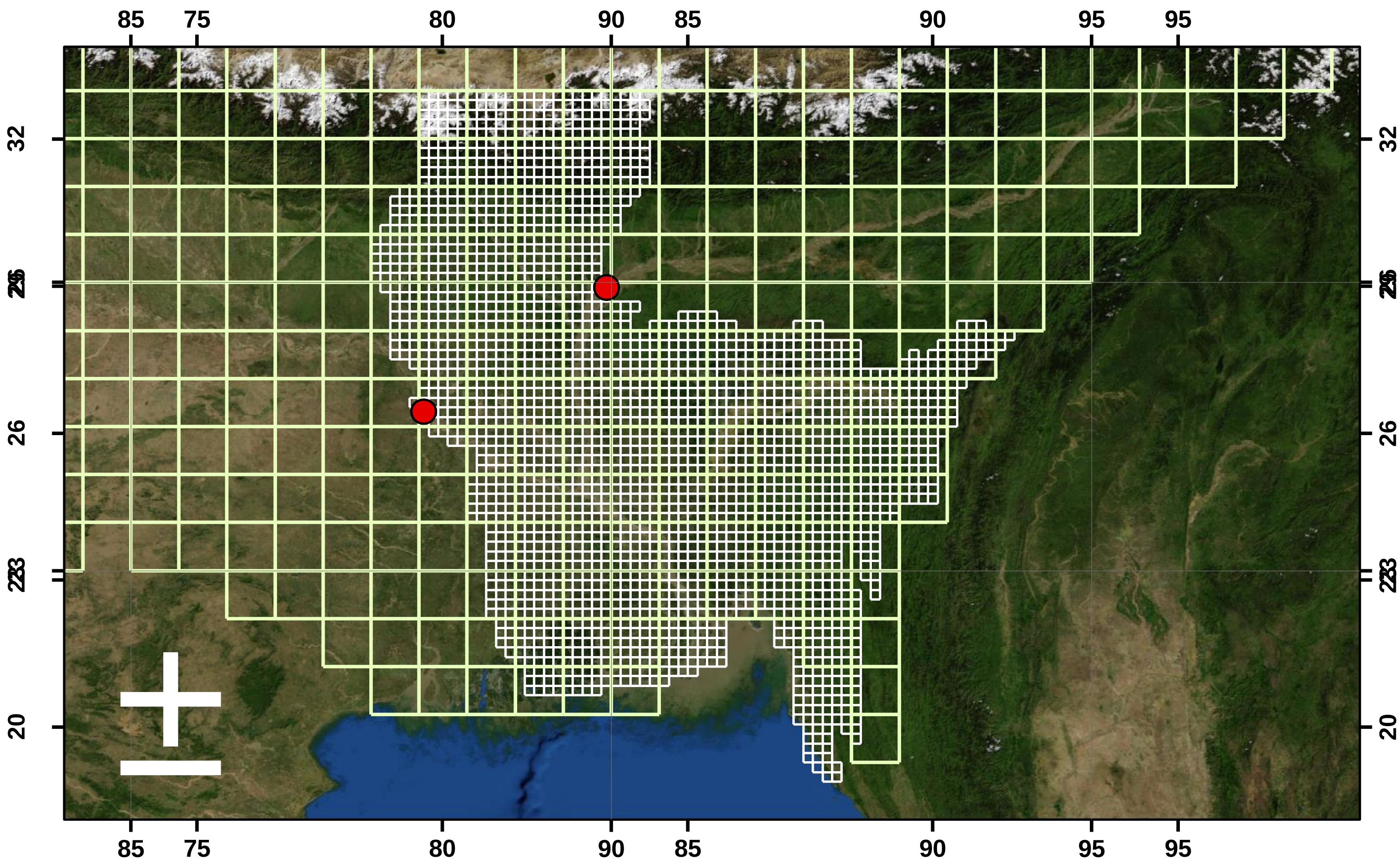
# Ganges-Brahmaputra-Meghna basin: 2003-2008

EU-funded project to examine the implications of changes in climate and sea level on water resources and coastal flooding in part of the Indian subcontinent with particular reference to Bangladesh

- First use of Regional Climate Change Model (PRECIS) by Met Office Hadley Centre, combined with:
- GWAVA applied by CEH and Bangladesh partners, feeding
- Fluvial flooding model applied by Bangladesh partners and
- Sea Level and Storm Surge Model applied by Proundman Oceanographic Lab

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

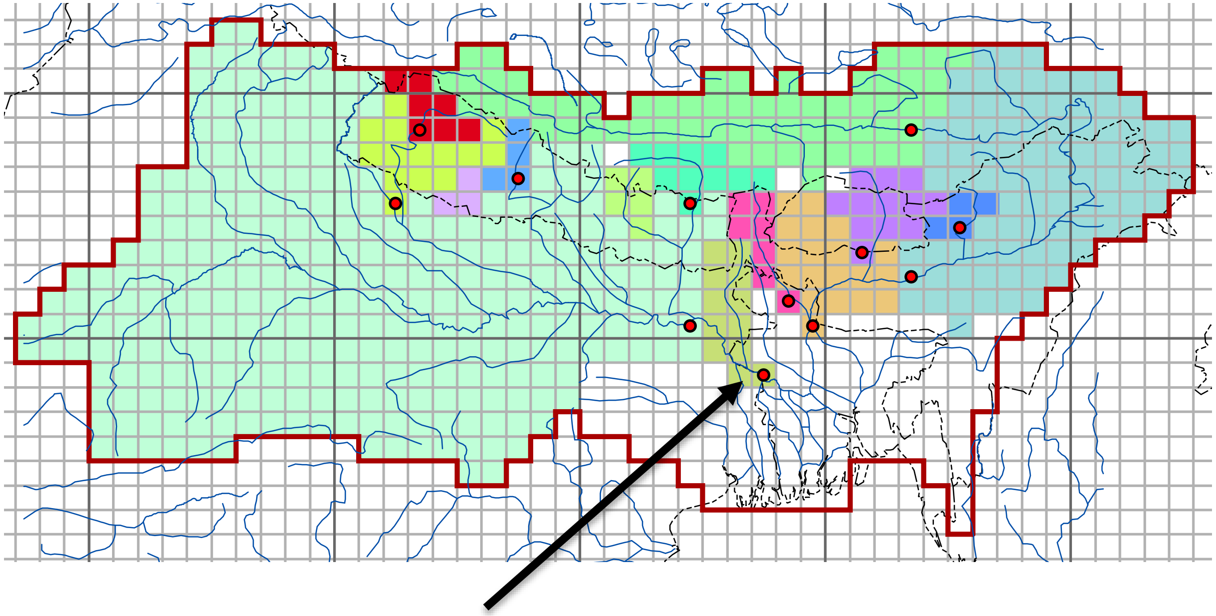
# GBM basin: grid refinement

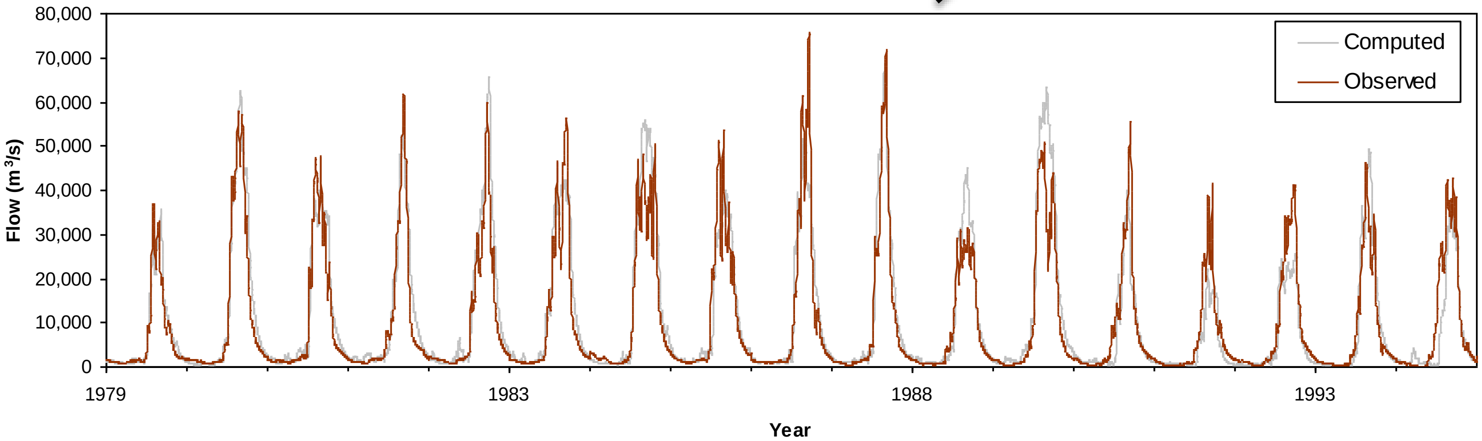



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# GBM basin: model calibration

Model calibrated against observed flows for a number of sub-basins for coarse and fine scale grid

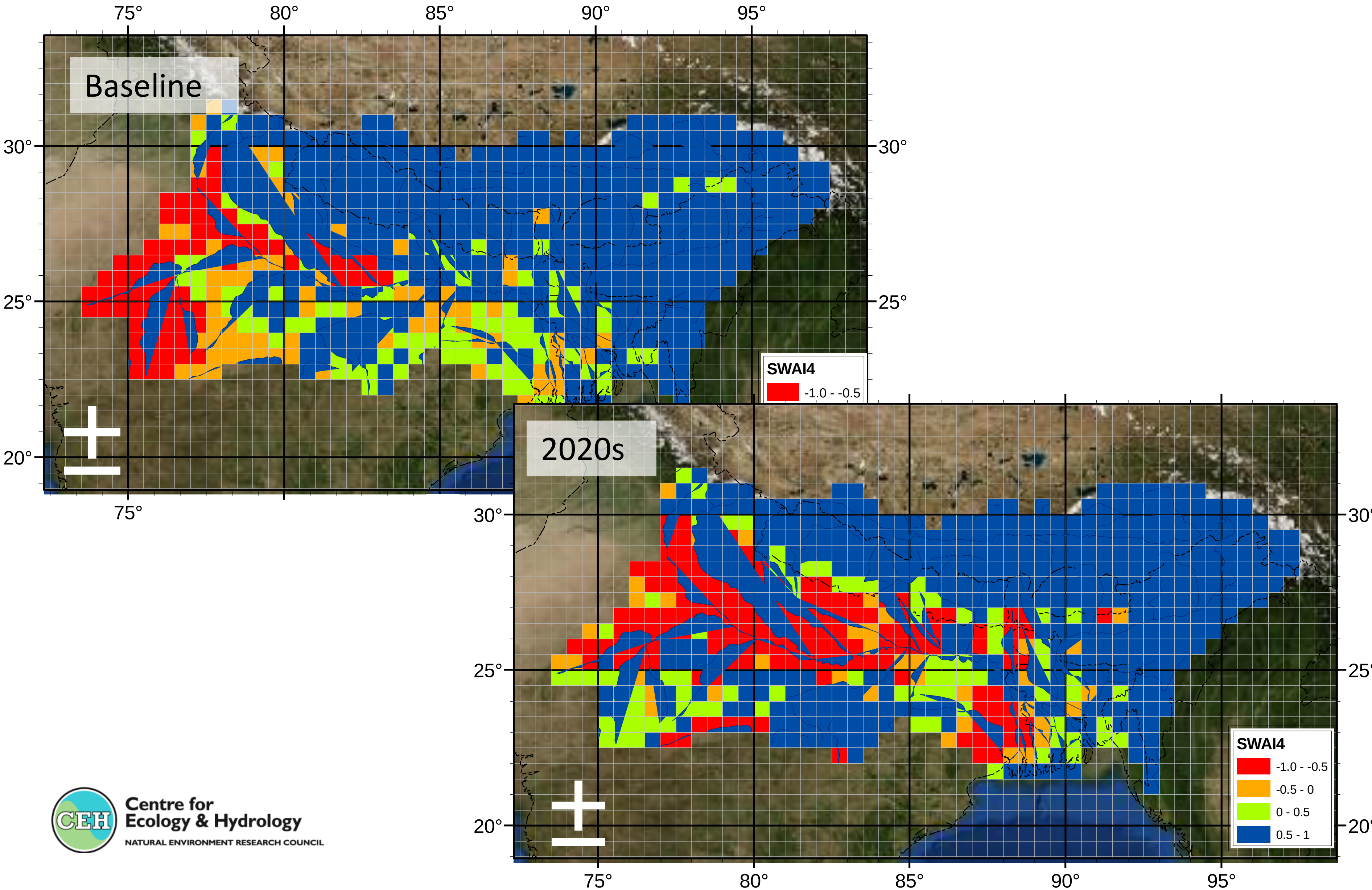





Flow at Hardinge Bridge, Ganges, 1979-1995

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# GBM basin: water resources 2020



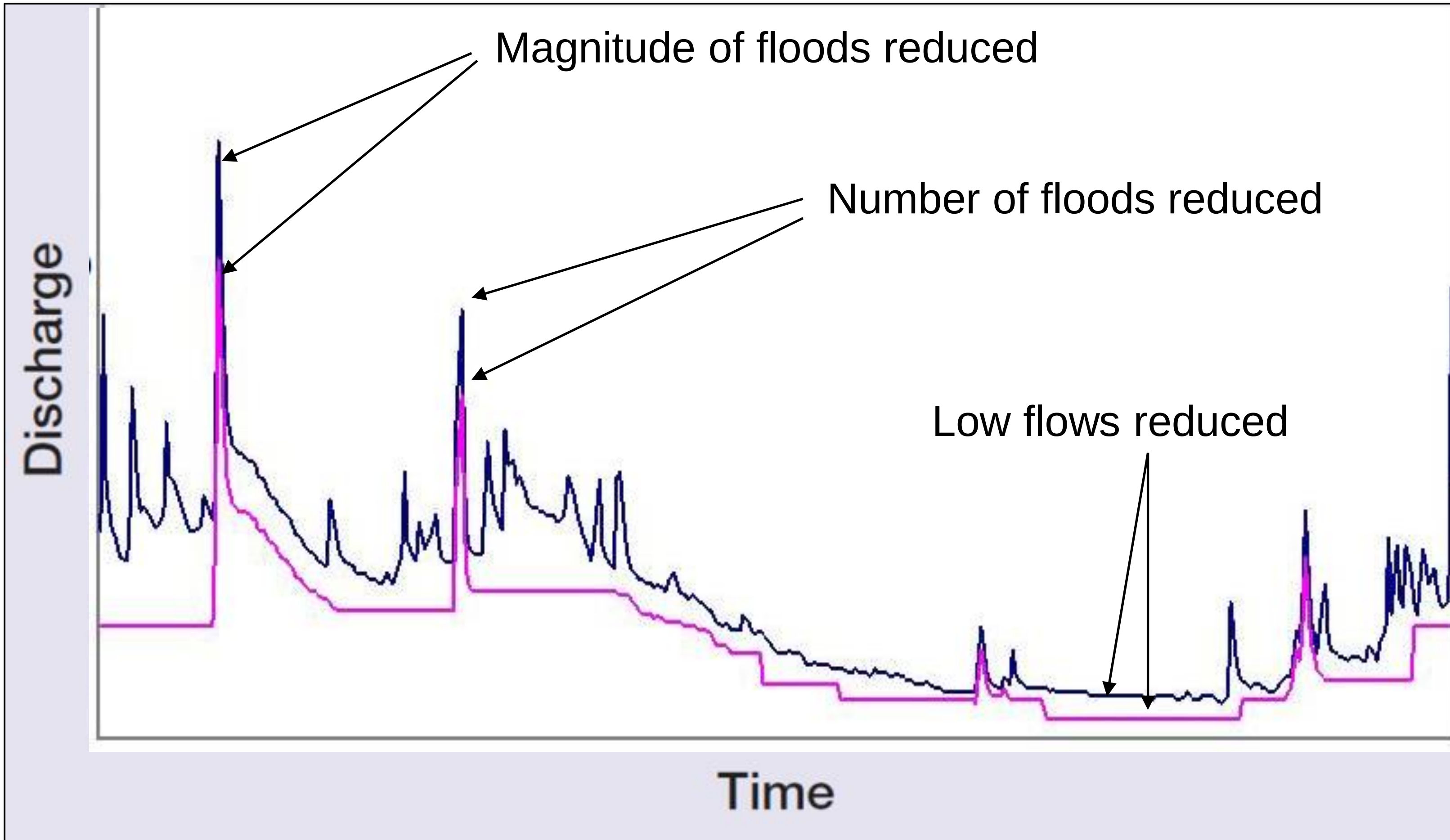

CEH Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

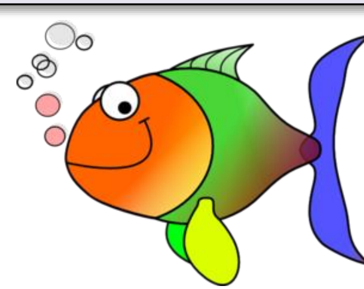
# Europe: 2006-current

European $0.1^{o}$ GWAVA model used to support several EU-funded projects and for testing new developments:

- **Water quality model** – TN, TP, BOD from diffuse and point sources, and pharmaceuticals, nano-particles (Ag, Zn) from point sources
- **Environmental flows** – Assessing the (ecological) implications of projected future changes in flow regimes using an approach based on indices of hydrological alteration (primarily magnitude and timing)

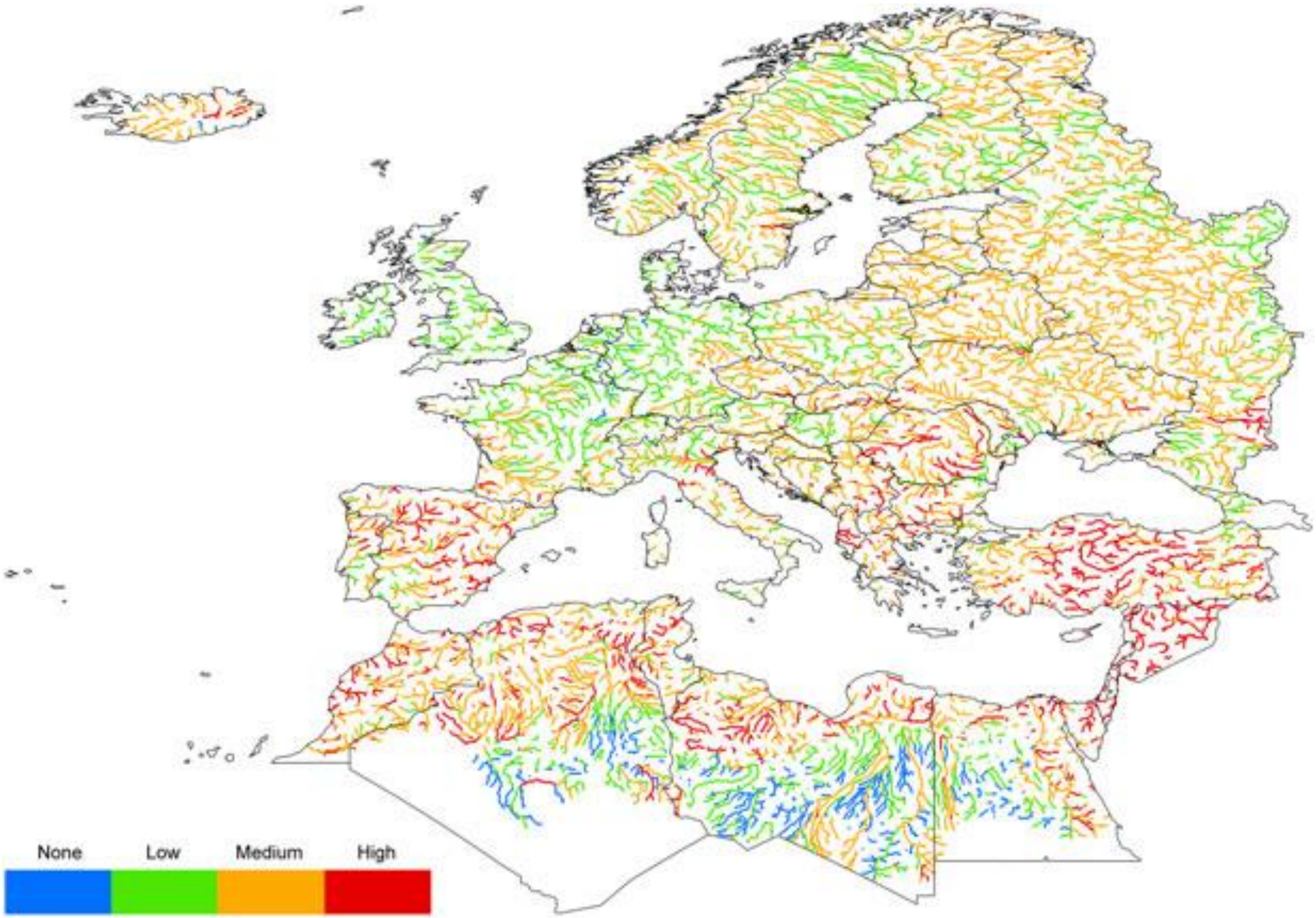
# Environmental flows (e-flows)



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Europe: e-flows 2050s climate

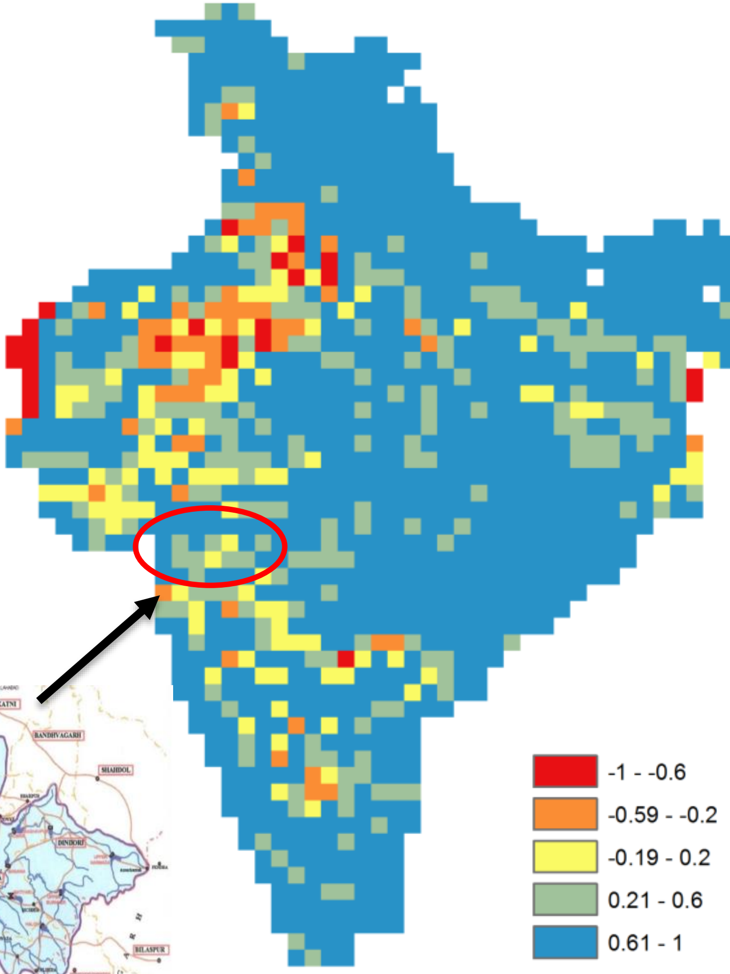


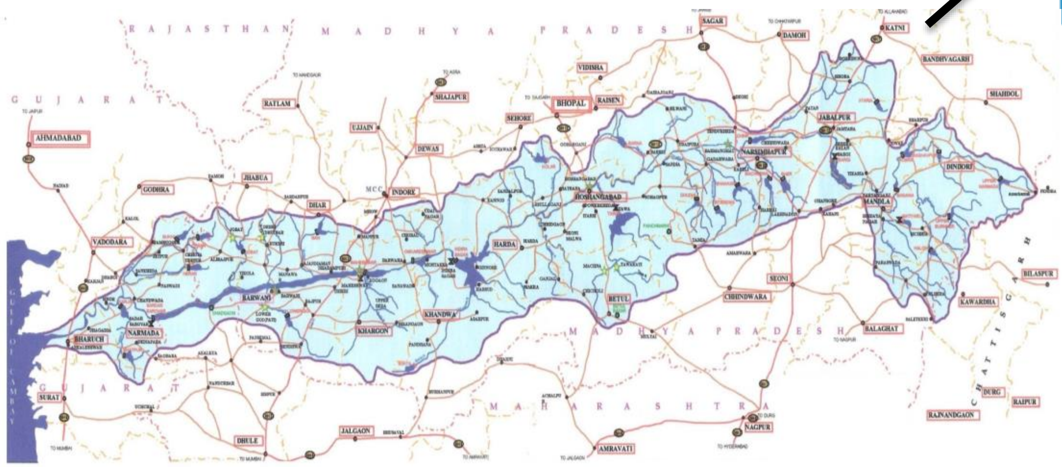

Change from baseline

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# India: 2014-16

- Collaboration with National Institute of Hydrology, Roorkee
- Multi-scalar approach (national 0.5º, basin 0.125º) with locally-derived datasets
- Future scenarios to include dam construction, climate change, population increase



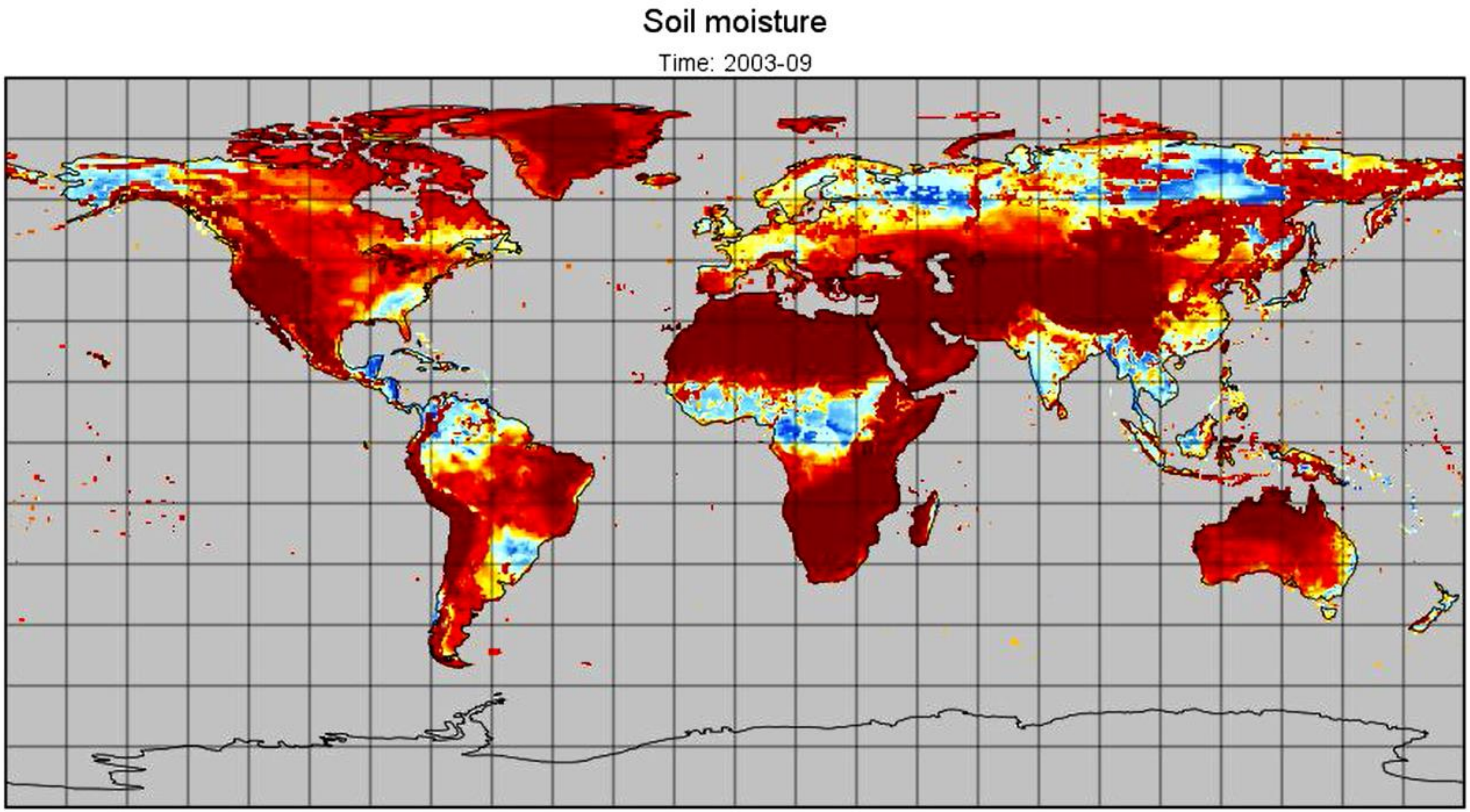



# Global: 2006-2012

- Global 0.5° GWAVA model in ensemble of LSHMs and GHMs in EU-funded WATCH (WATer and global CHange) project
- GWAVA performed well in model inter-comparison exercises
- Results used to develop tool for visualising GWAVA outputs

# Global: soil moisture 2000-10

Global Soil Moisture 1991-2000




Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

# Concluding remarks

- Recognition of complex linkages and interactions between water, food and energy is not new – relationships will vary within countries and regions depending on resources, pressures, priorities and infrastructure

- GWAVA models some of these linkages and interactions, thereby providing a useful tool for exploring these relationships further and assessing the impacts of competing demands for water from different sectors

# Thank You

Centre for
Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL