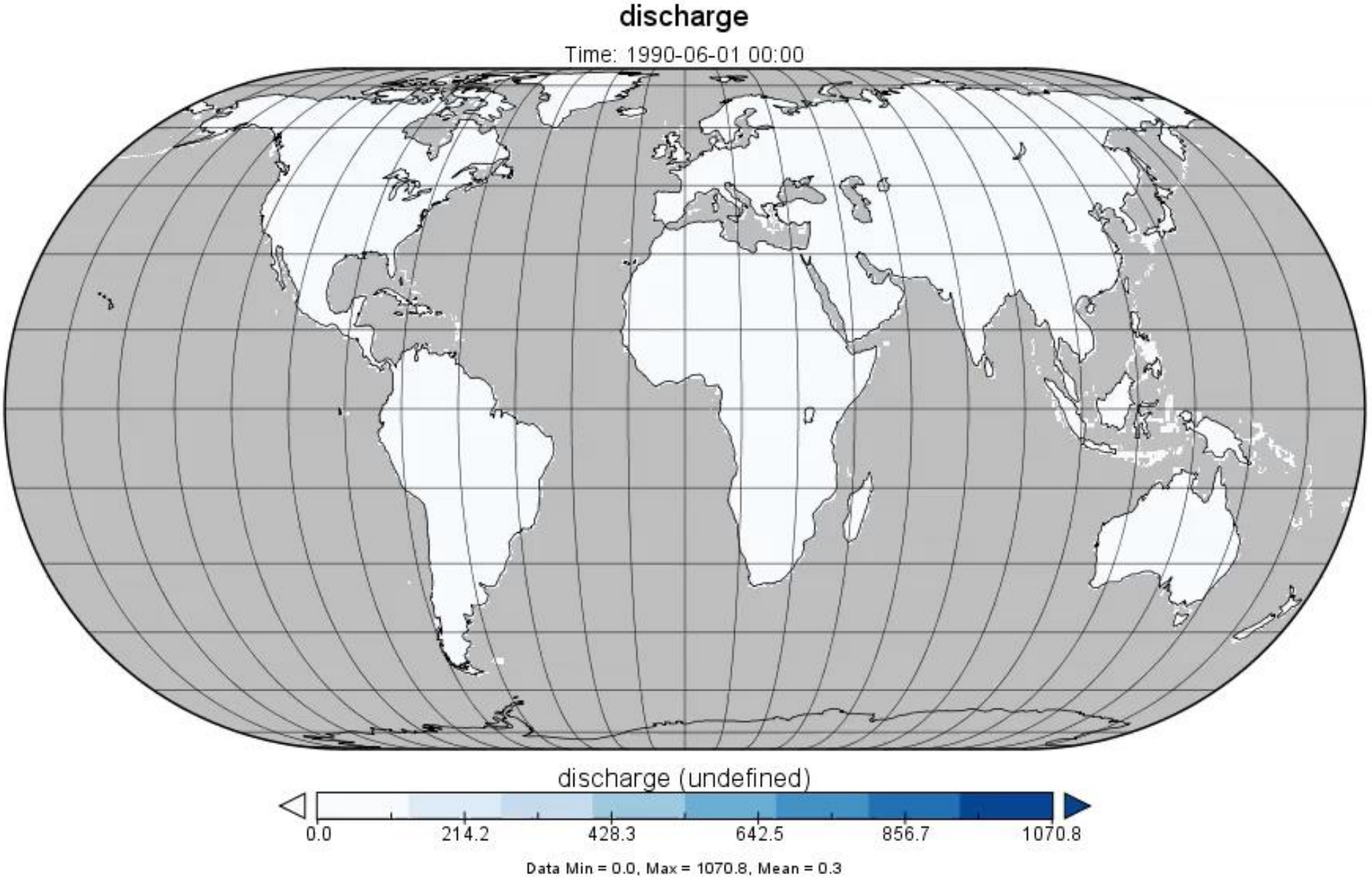
International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

Global Hydrological Model
Community **Wat**er **M**odel
(**CWATM**)

Peter Burek
&
IIASA Water Program

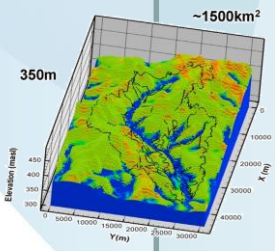
Global scale simulation with CWATM



Why global? Why large scale?

- Effects of global climate change on local water conditions
- Effects of global economy on local water use
- Inter-basin water transfers
- Teleconnections of land use – climate
- Global water use efficiency
- Water as a geopolitical resource

(see also Hoekstra 2006,2010)



fragmented

Knowledge

Consistent
Comprehensive

Local

Global

Local up

Global down

Increasing Demands, Increasing Challenges

Human needs

Ecological Health

Food

Agricultural water requirements in Asia increase (18%) due to irrigated land expansion (12%) and climate change (5%)

Domestic

Domestic water withdrawals in Asia almost triple

Energy & Industry

Industrial water withdrawals in Asia increase by a factor 2.5

Ecology

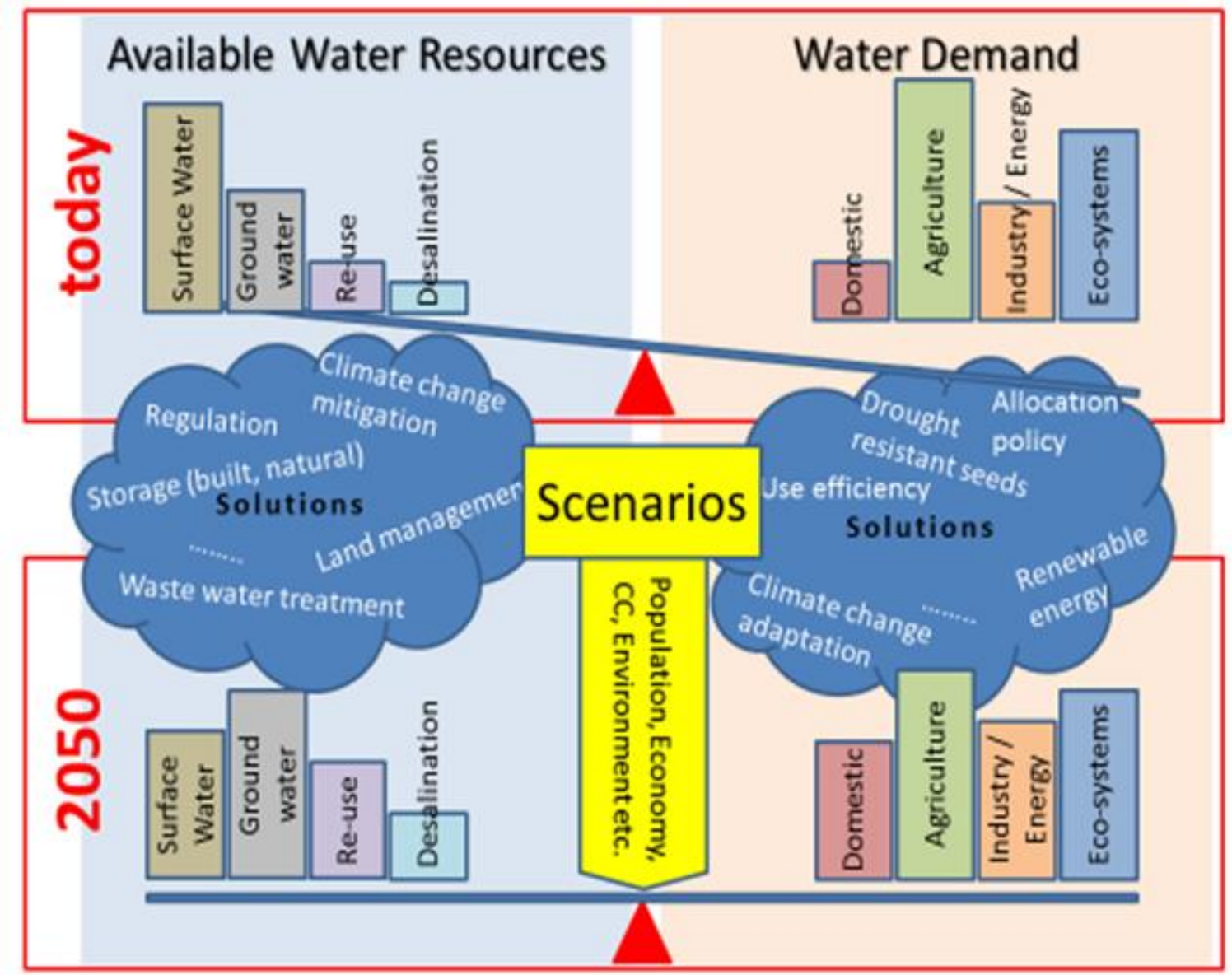
Lost of wetlands and biodiversity

River do not reach the sea

Concept of environmental flow

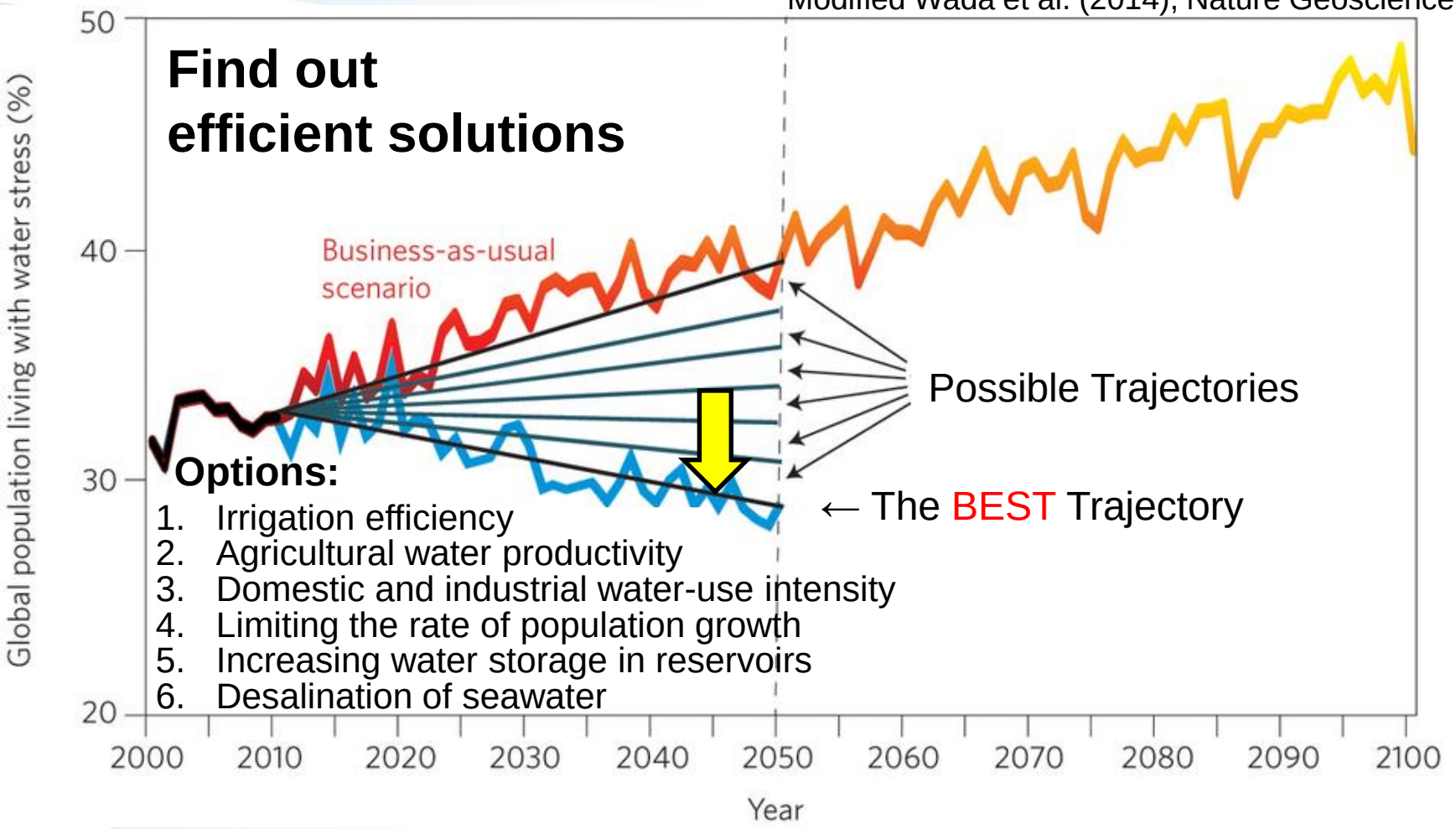
By 2050, SSP2 – Middle of the Road scenario

Models are useful “tools”



Models are useful “tools”

Modified Wada et al. (2014), Nature Geoscience



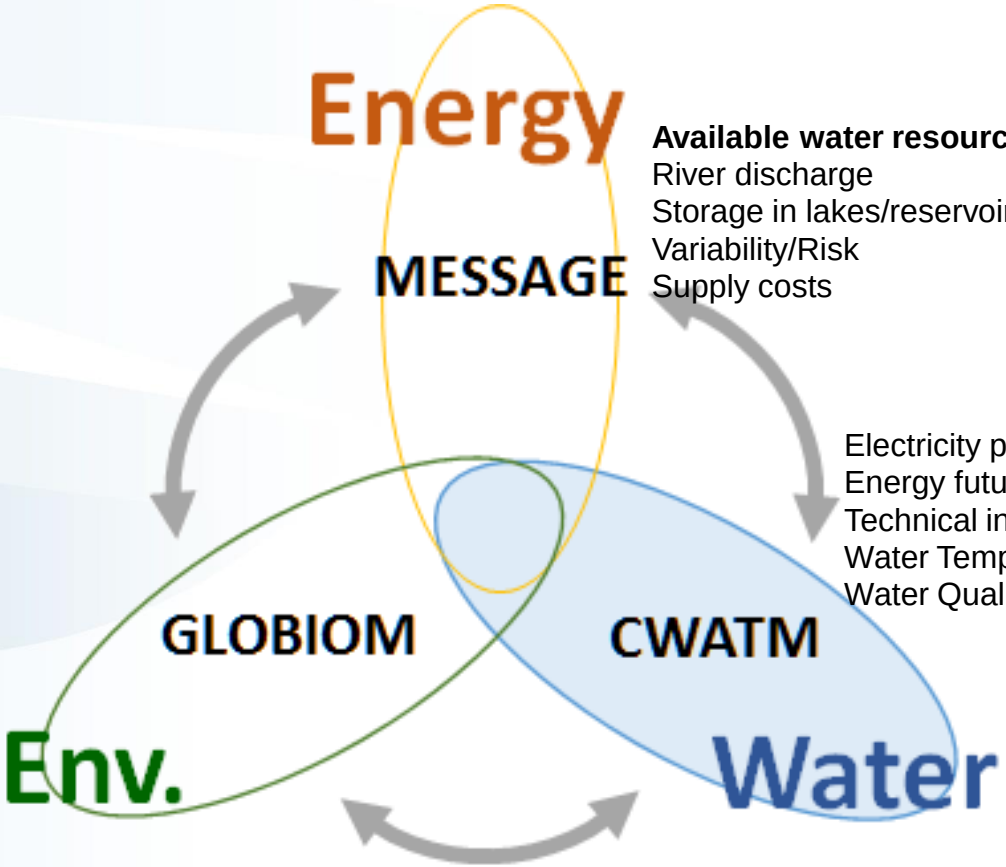
Explore possible futures

propose optimal solutions

Illustrate efficient pathways to achieve sustainable development

Development of Nexus integration modeling framework

Water-Energy-Food-Environment



Available water resource
River discharge
Storage in lakes/reservoirs
Variability/Risk
Supply costs

Electricity production
Energy futures/options
Technical innovation
Water Temperature
Water Quality

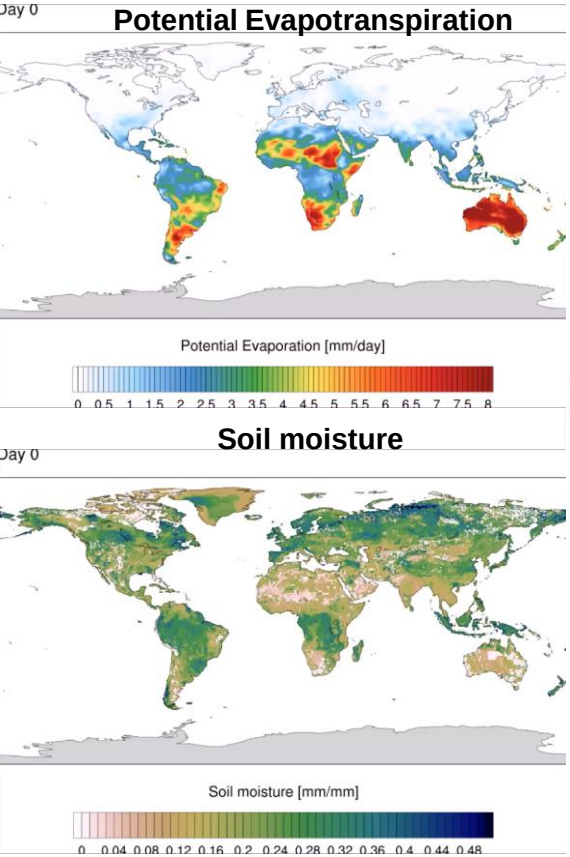
Available water resource
Soil moisture
River discharge
Groundwater
Storage in lakes/reservoirs
Variability/Risk

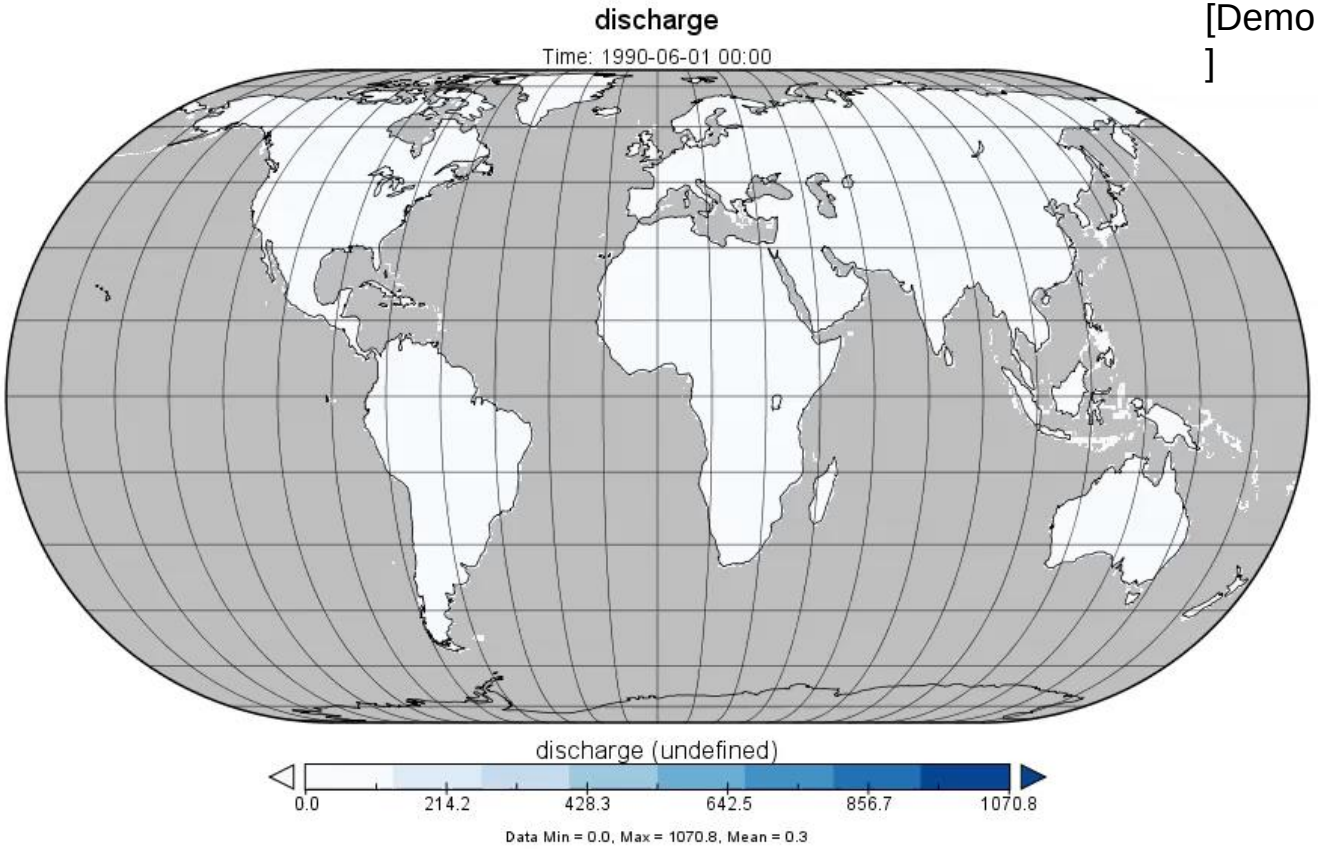
Land use/cover
Crop area/type
Irrigation area
LAI

Global Hydrological model

Community Water Model (CWATM)

Development of a community driven platform for global water studies





[Demo]

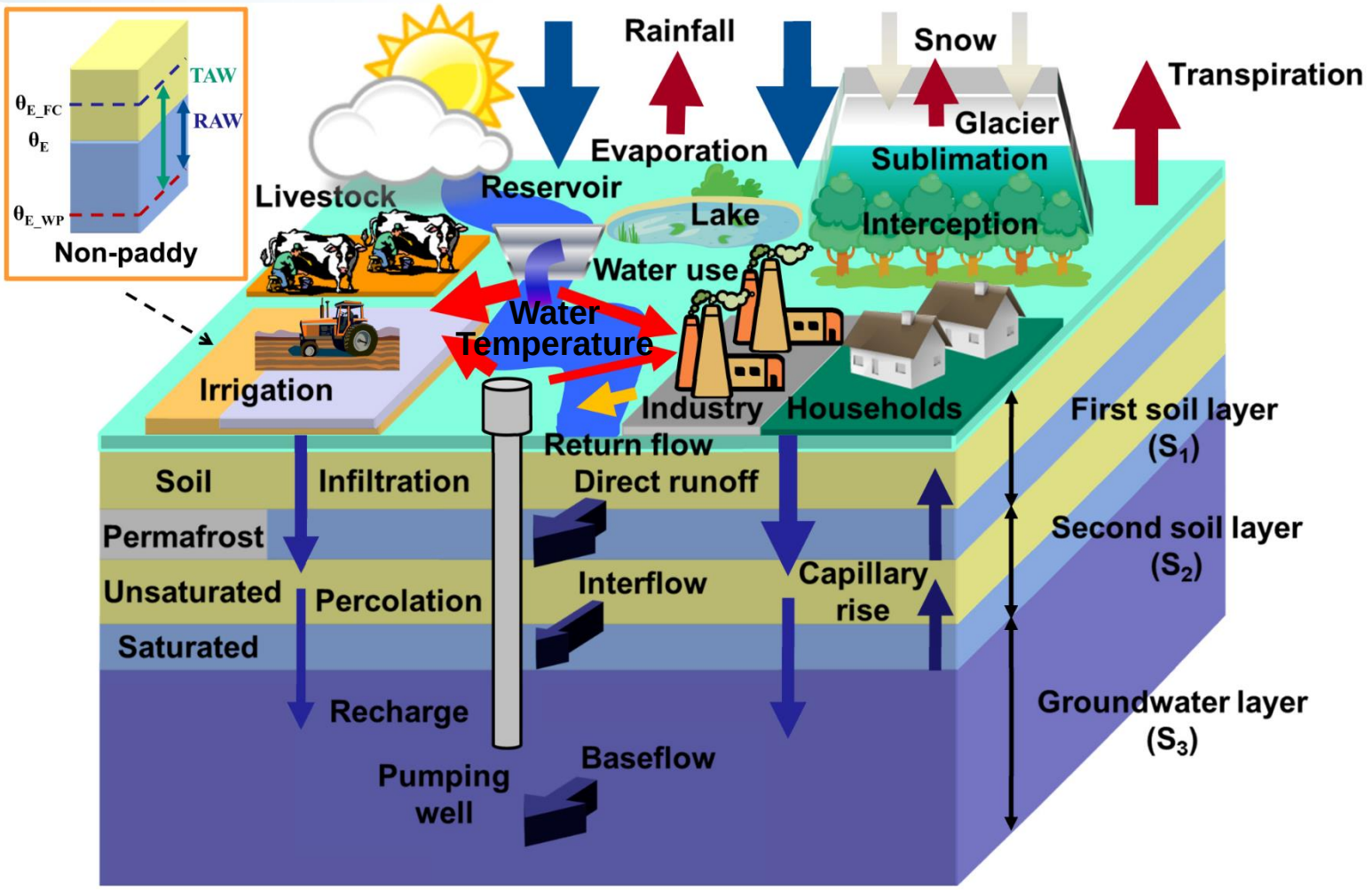
Community Water Model (CWATM)

Main purposes:

- To understand the land part of hydrological cycle at global ~ large scale
- Investigate available water resource, water hazard (flood & drought) under changing climate and socio-economic condition

Target spatial scale:	Local ~ Global
Possible temporal scale:	Past~Future
Temporal resolution:	Daily
Spatial resolution:	0.5deg x 0.5deg 5 min x 5 min
Language:	Python

Community **Wat**er **M**odel (CWatM)



CWATM

- represents one of the new key elements of IIASA's Water program to assess **water supply, water demand** and **environmental needs**
- is flexible to link in different aspects of the **water energy food nexus**

Community Water Model

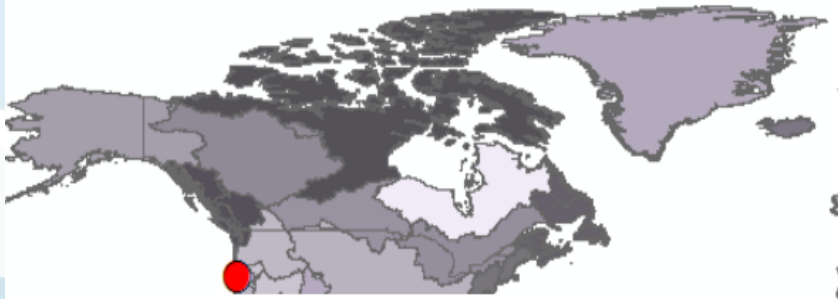
Feature	Description
Community driven	Open-source but lead by IIASA
Well documented	Documentation(Wiki), automatic source code documentation
Easy handling	Use of a setting file with all necessary information for the user
Multi-platform	Windows, Mac, Linux, Unix - to be used on different platforms (PC, clusters, super-computers)
Modular	Processes in subprograms, easy to adapt to the requirements of options/ solutions

Community Water Model

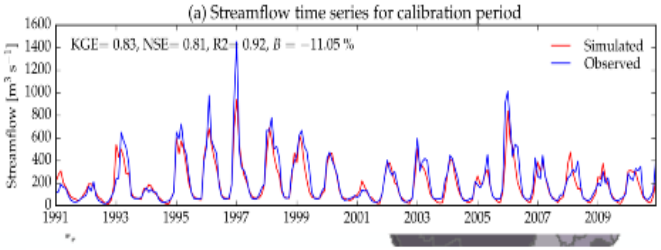
Feature	Description
Flexible	different resolution, different processes for different needs, links to other models, across sectors and across scales
Adjustable	to be tailored to the needs at IIASA i.e. collaboration with other programs/models, including solutions and option as part of the model
Multi-disciplinary	including economics, environmental needs, social science perspectives etc.
Sensitive	Sensitive to the option / solution
Fast	Global to regional modeling – a mixture between conceptional and physical modeling – as complex as necessary but not more
Comparable and exchangeable	Planned to be part of the ISI-MIP community, part of capacity development

CWATM Calibration

Calibration of discharge



River: Klamath, Station: USGS 11523000 - Orleans, CA



Calibration:

-Daily run of 12 to 20 years

-Compared to daily or monthly observed discharge

-Objective function: KGE'

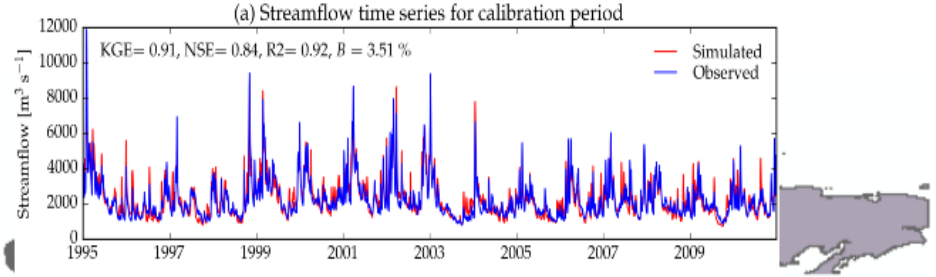
KGE': modified Kling-Gupta efficiency

NSE: Nash-Sutcliffe Efficiency

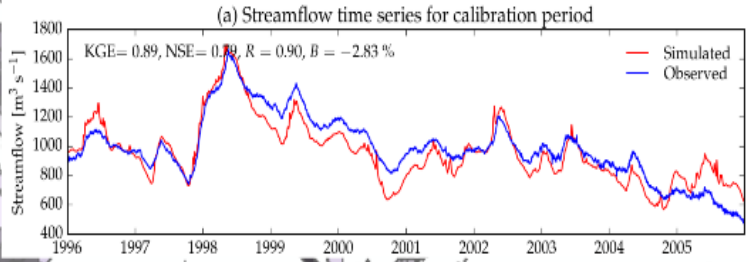
R2: Correlation coefficient

B: Bias

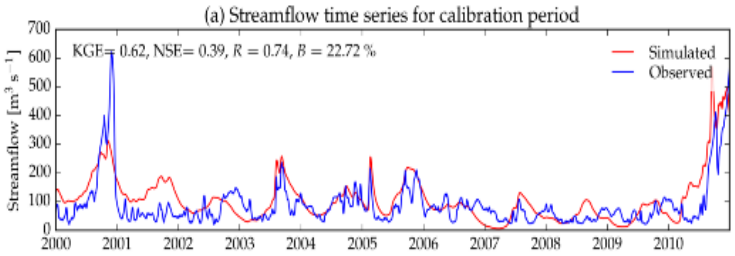
River: Rhine Station: Lobith



River: Nile, Station: Jinja Pier

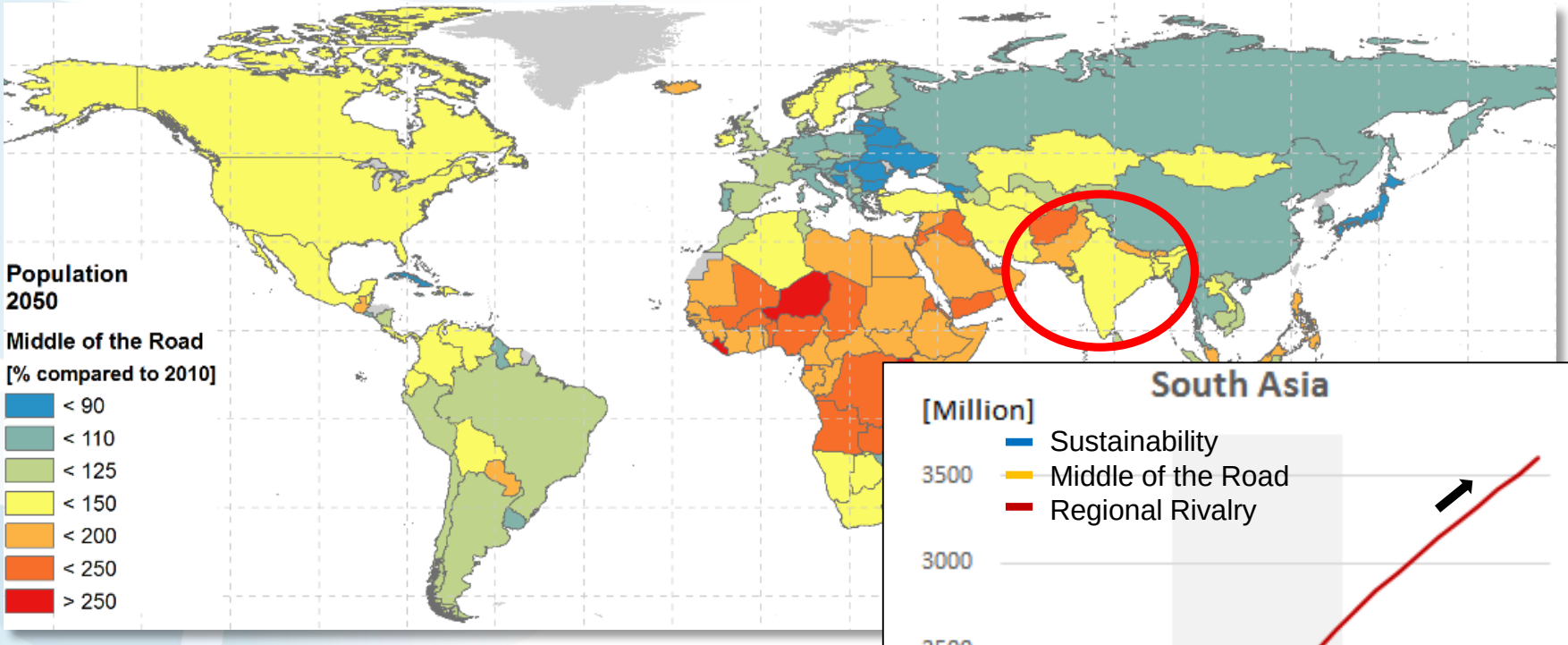


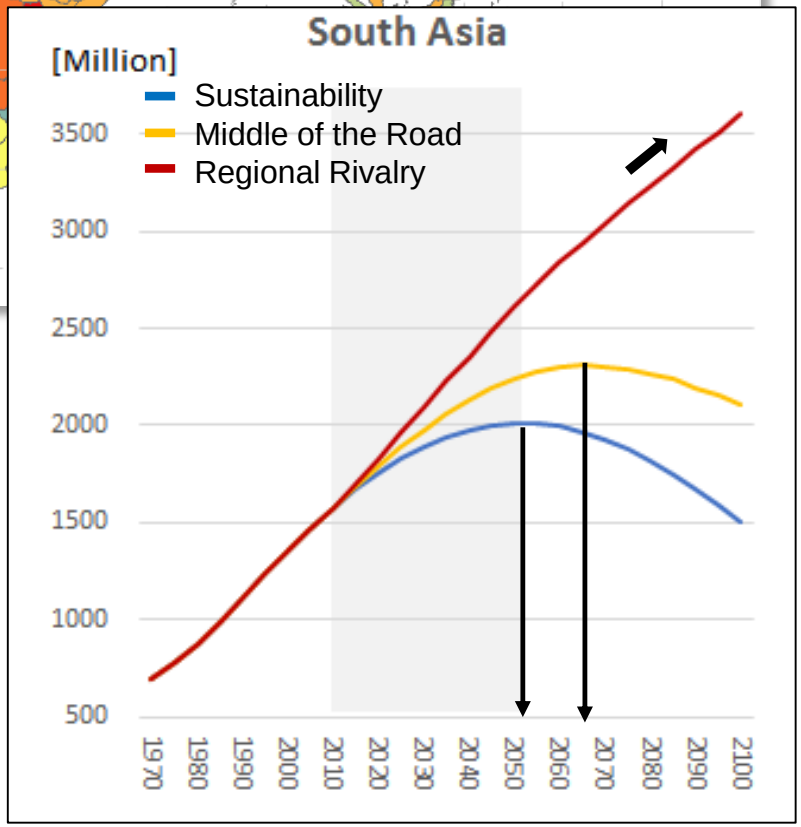
River: Murray River station: Wakool Junction



What we can do with CWatM?
What we can assess by CWatM?

Case1: Imbalance between water supply and demand



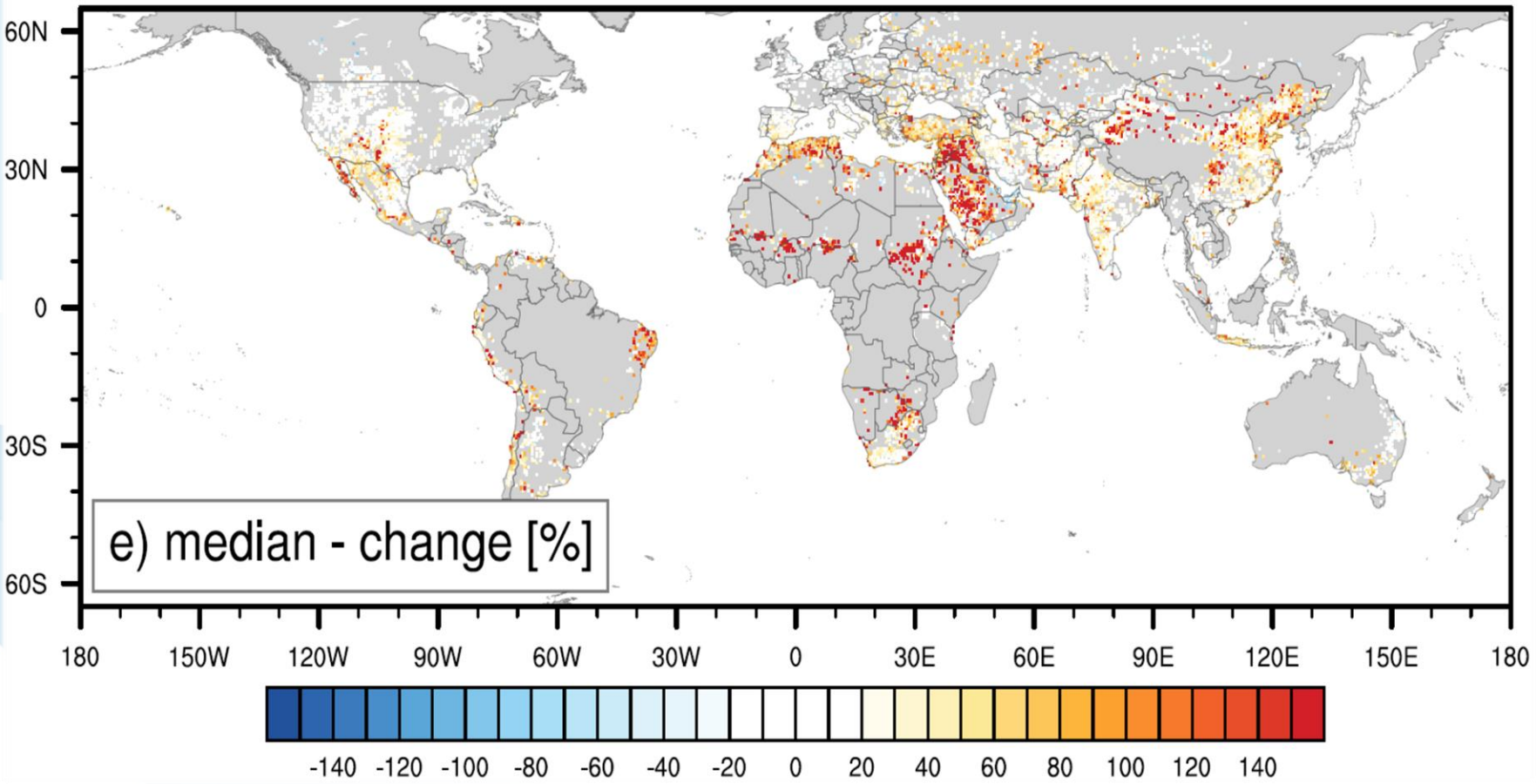


- 33% more people by 2050 compared to 2010 globally (6.8 billion to 9.1 billion)
- 24% more people by 2050 in Asia 4.1 billion to 5.1 billion

Middle of the Road scenario

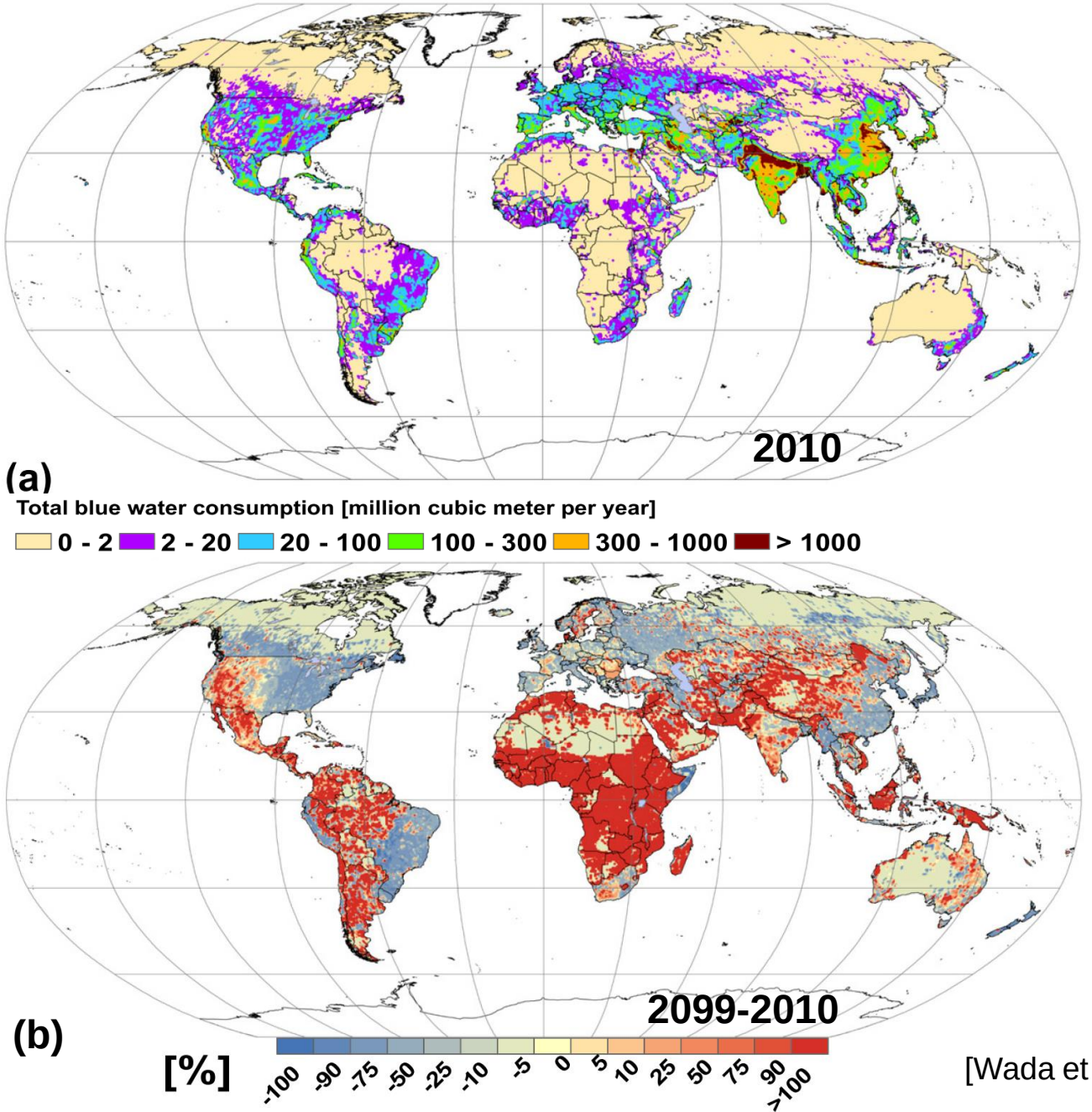
Case1: Imbalance between water supply and demand

Change in water scarcity conditions between 2010 and 2050



[Satoh et al. 2017, Burek et al. 2016, Greve et al. Forthcoming]

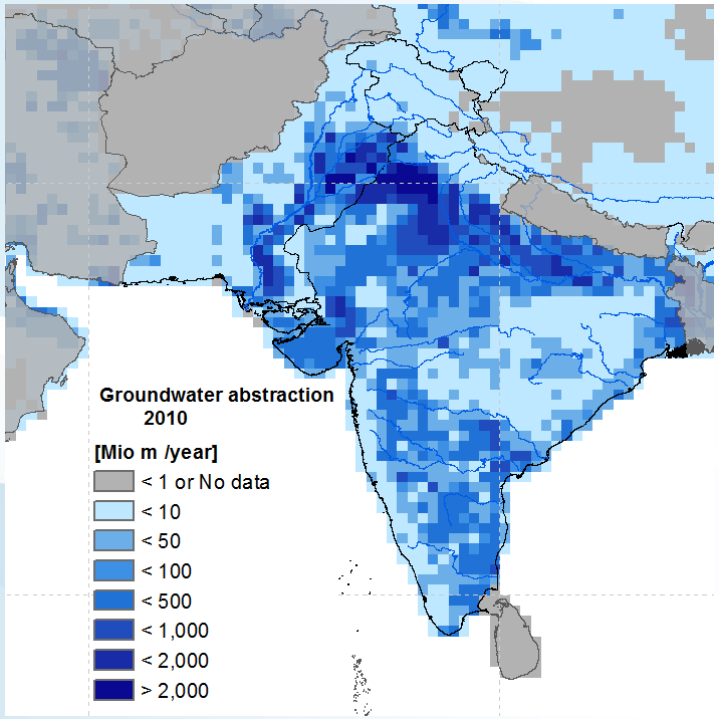
Case 2: Impacts on human activity on vulnerable WR



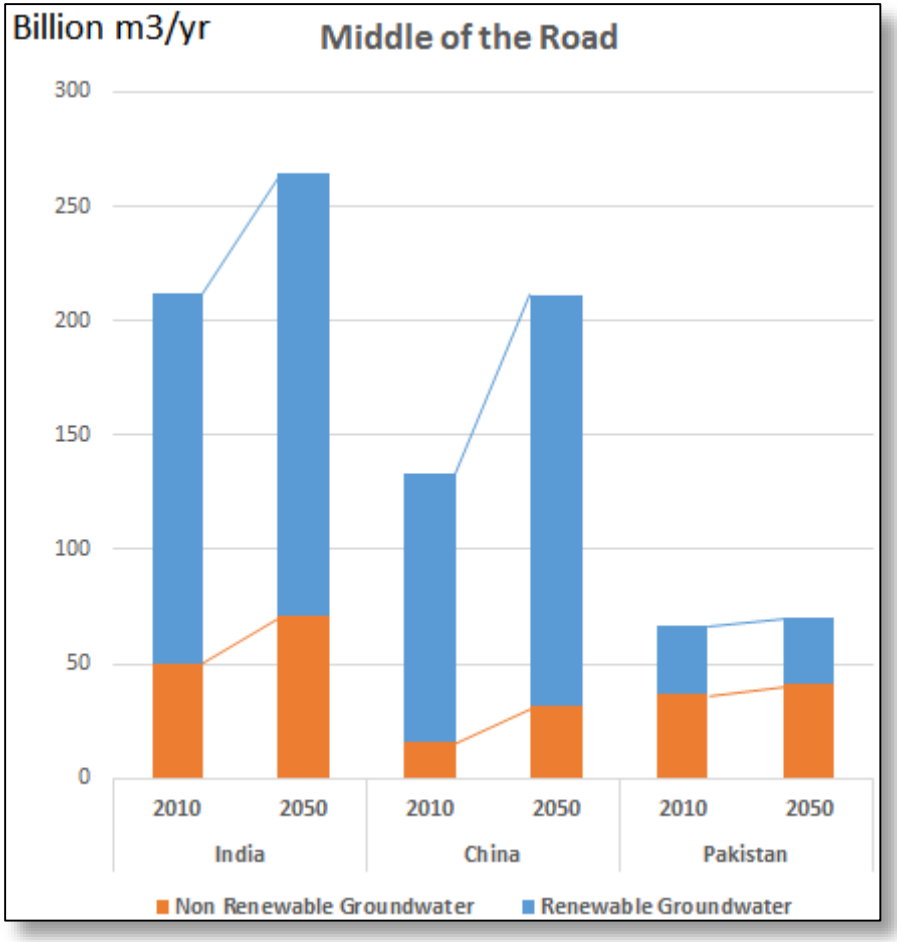
[Wada et al. 2014]

Case 2: Impacts on human activity on vulnerable WR

Groundwater use and over exploitation



Groundwater abstraction in 2010

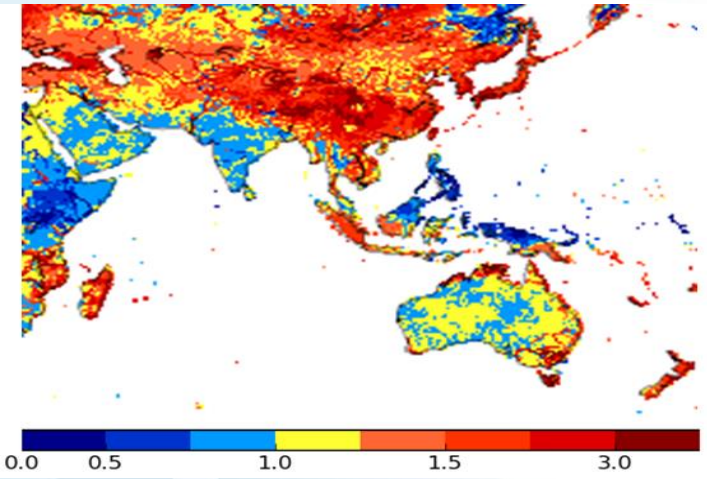


Groundwater abstraction in India, China and Pakistan

Country	2010 [km³/year]	Share [% of Global]	2050 [km³/year]	Share [% of Global]	Change rate [% of 2010]
India	201	25	278	25	139
China	102	13	152	14	150
Pakistan	60	8	70	6	116
World	800	100	1113	100	139

Case 3: Change in extreme events

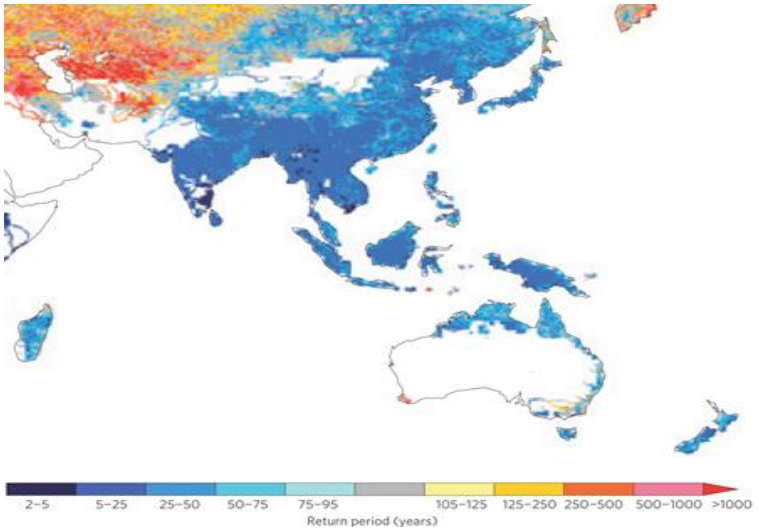
Too little – drought



Impact of climate change on drought in Asia
Ratio of number of drought days per year.
1980-1999 vs 2080-2099 (Satoh et al. 2015)

Red: increasing days of drought condition

Too much – floods



Multi-model median return period in 21th century for discharge corresponding to the 20th century 100-year flood (Hirabayashi et al. 2013)

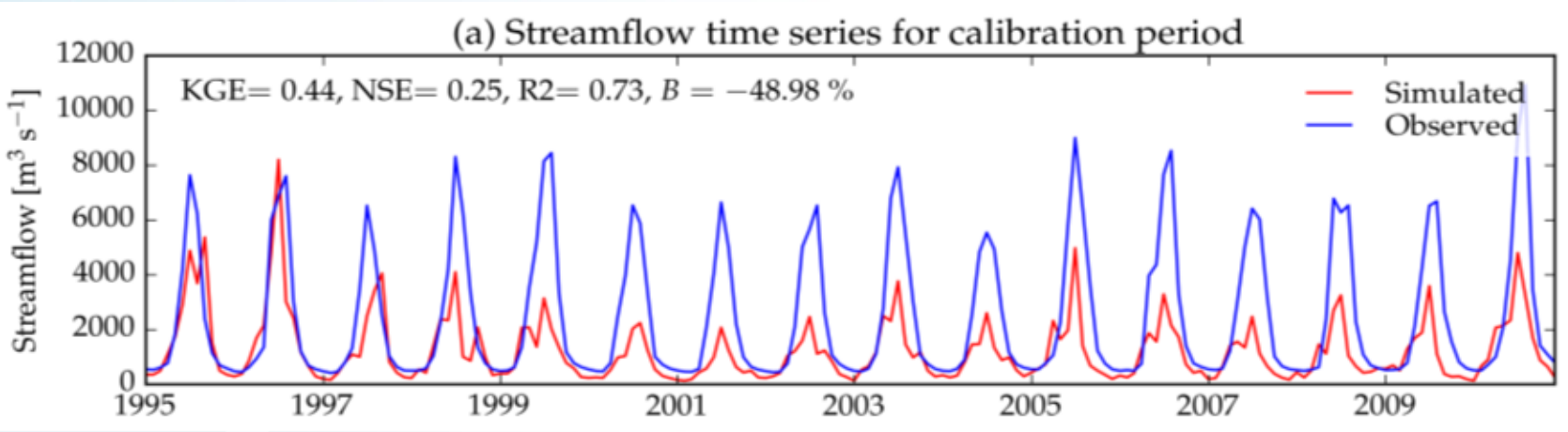
Blue: 100-year flood will occur more often

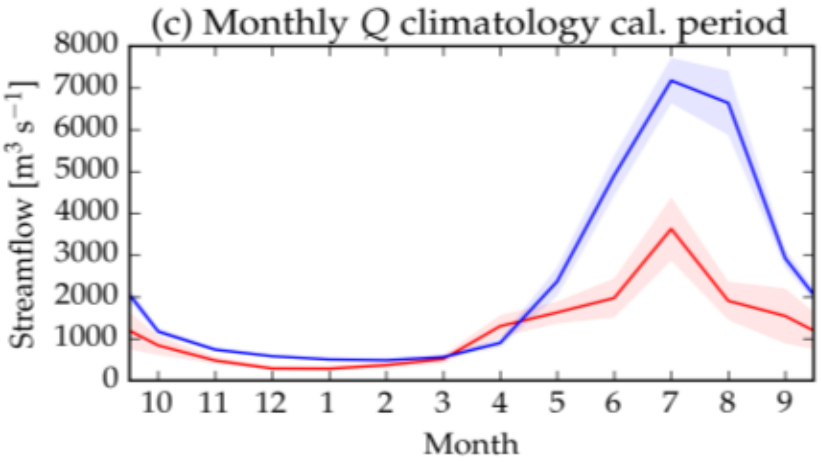
Indus


Afghanistan
China
Indus
Jhelum
Chenab
Sutlej
Pakistan
Nepal
India
0
250
500 Kilometers

CWATM Indus

First calibration with CWATM for Indus, station:
Upper Indus Basin - Besham





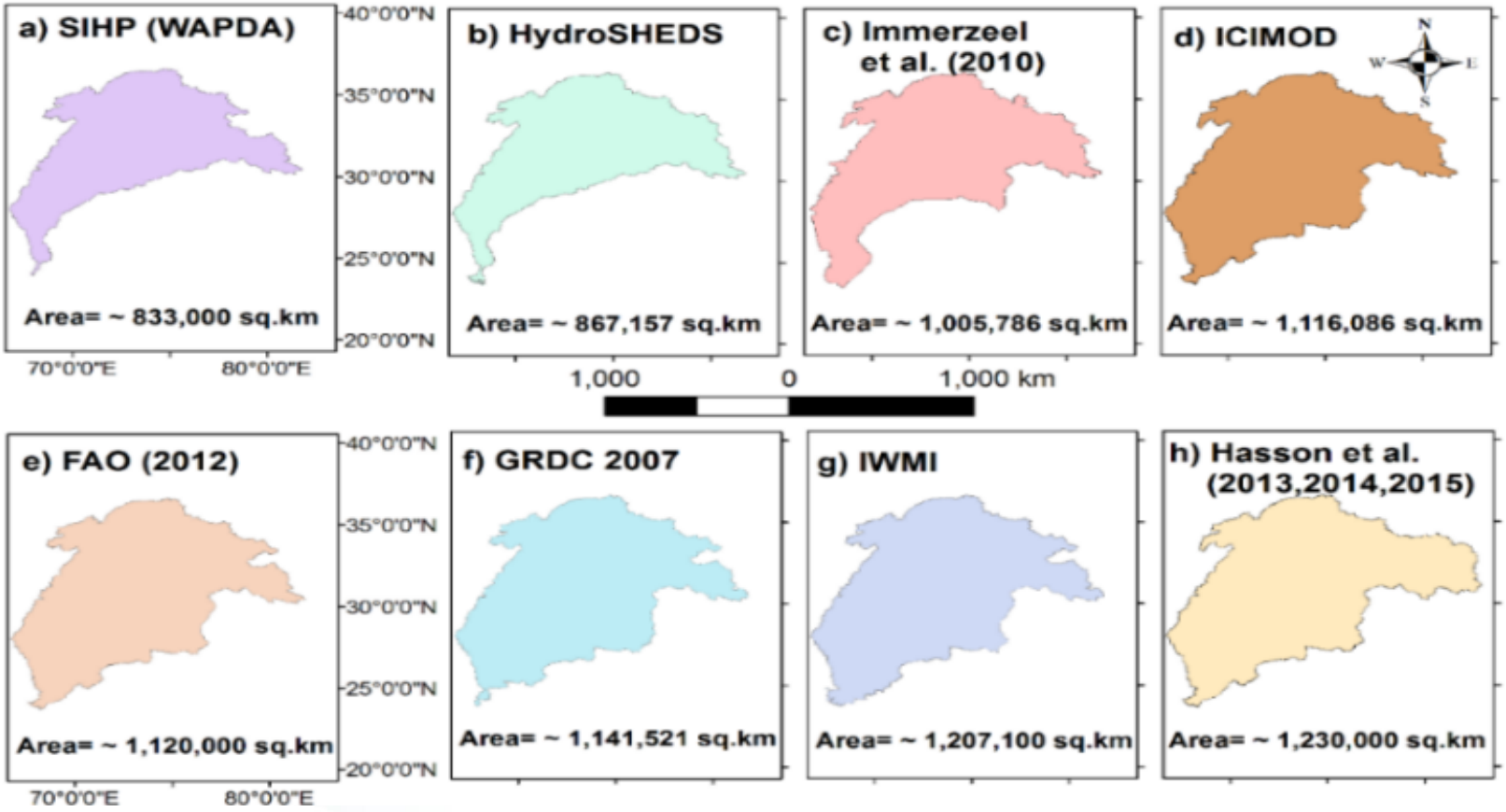
	Statistical values	
Discharge [m³/s]	Measured	Model
Min	416	127
5%	475	196
Mean	2416	1233
95%	7616	3631
Max	10933	8199

KGE: Kling Gupta efficiency
NSE: Nash-Sutcliffe efficiency
R2: Correlation R^2
B: Bias

CWATM Indus

Variability in the Indus Basin boundaries based on various studies

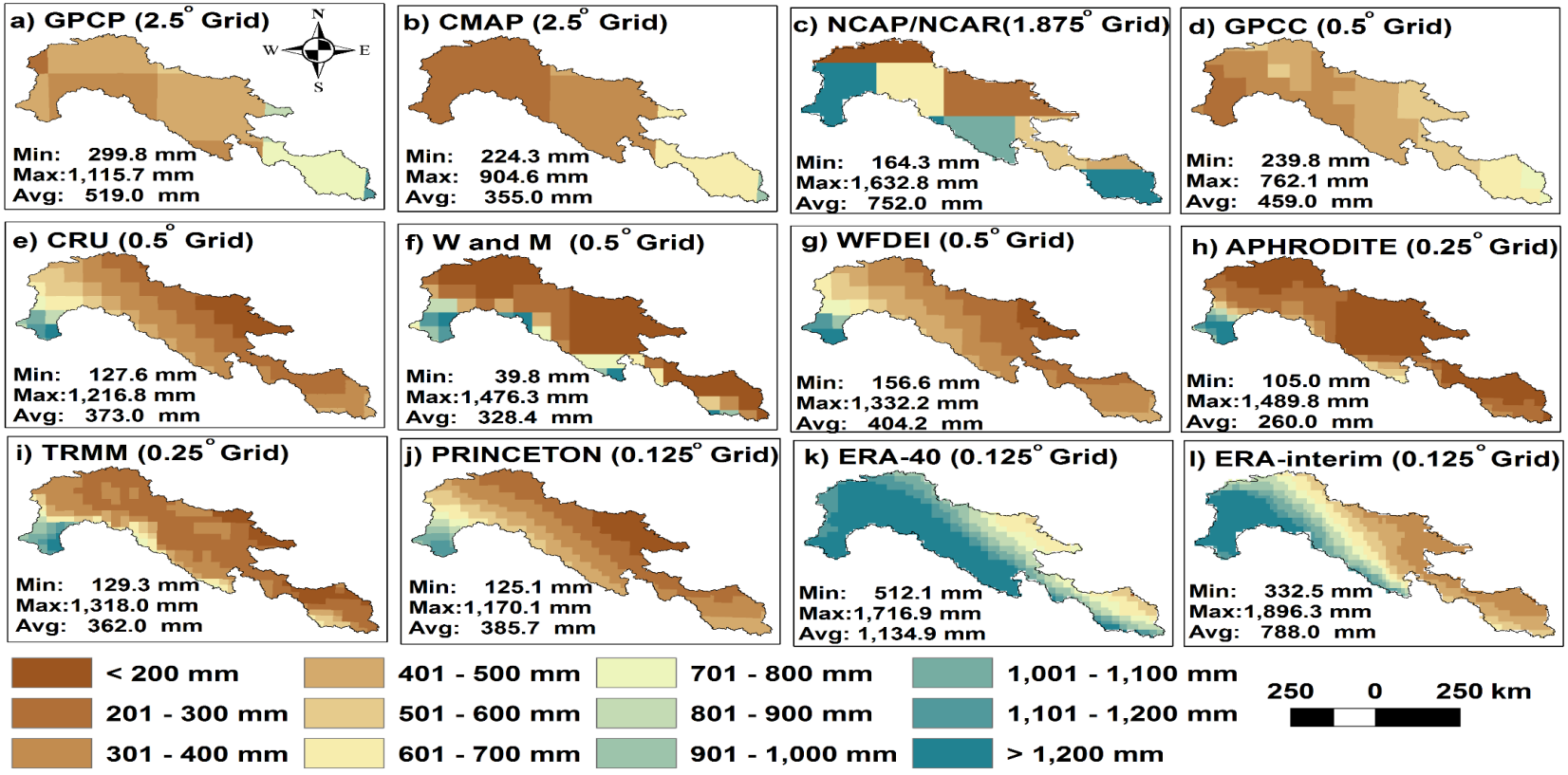
By Asif Khan



CWATM Indus

Spatial distribution of the selected gridded precipitation datasets in the Upper Indus Basin. Statistical values for the period 1999-2010

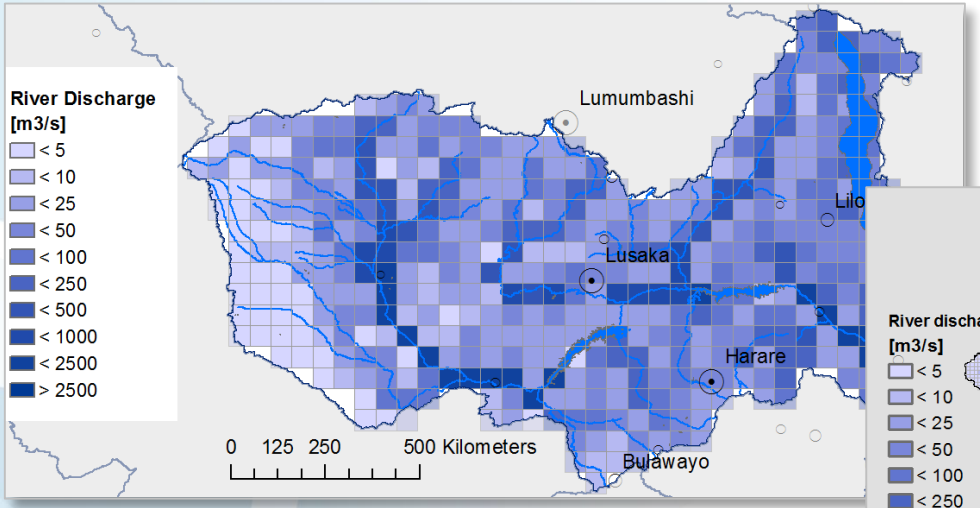
By Asif Khan



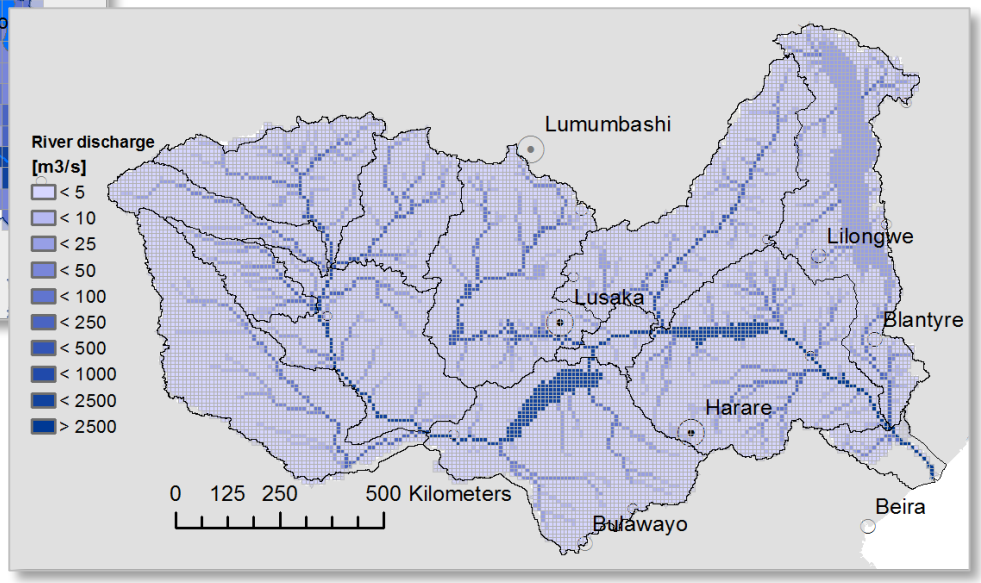
On-going efforts

Next steps: Higher resolution

Improving resolution of the water model CWatM from 0.5° to 5’



CWATM 0.5° (~50 x 50 km)

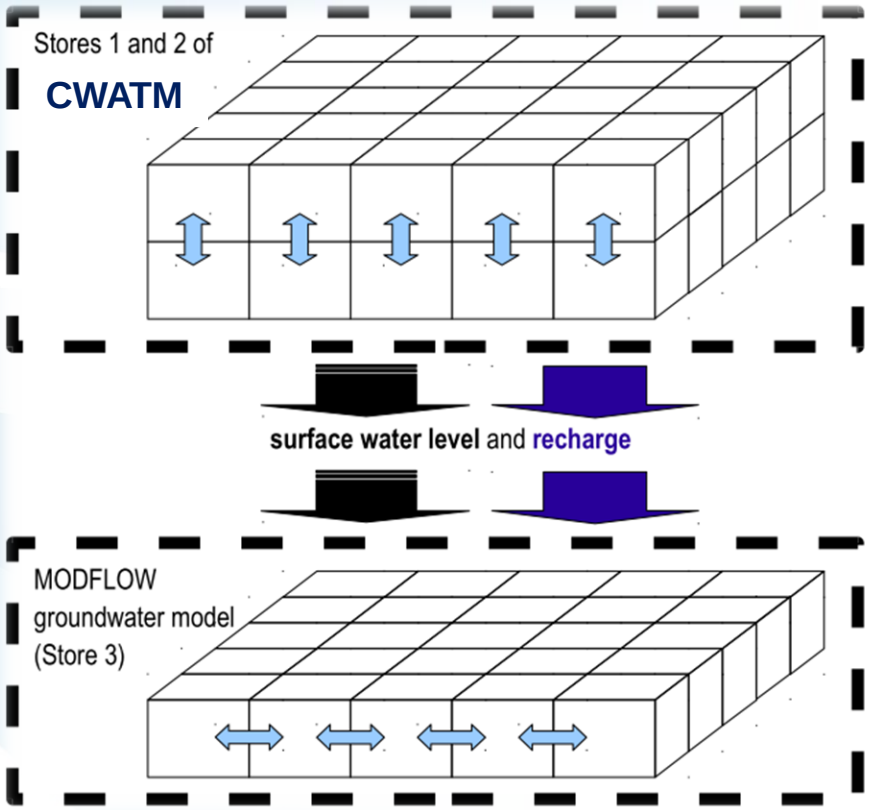


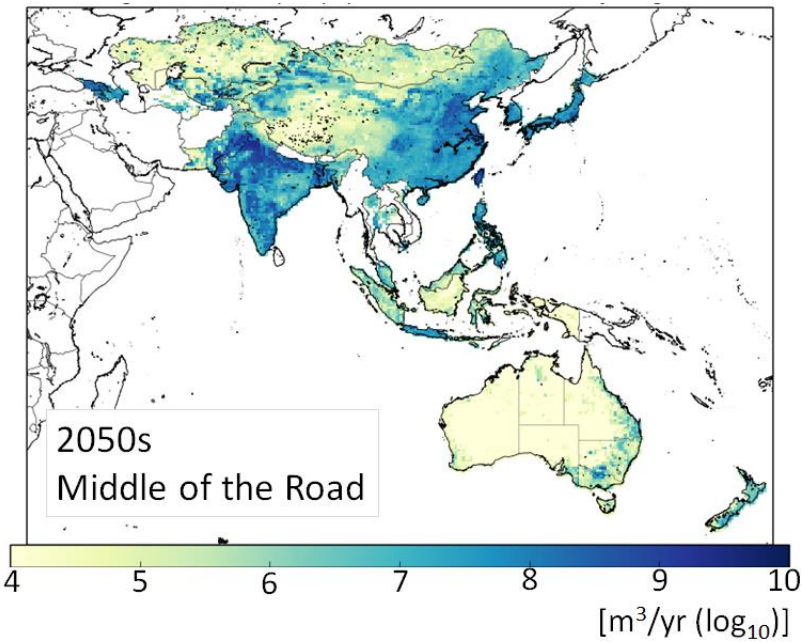
CWATM 5’ (~10 x 10 km)

Zambezi results from Community Water Model
CWATM
Historical period (1979-2010)
Average discharge [m³/s]

Next steps: Groundwater

Coupling with **MODFLOW**





Groundwater abstraction in 2050

Asia totals:
2010: 464 km^3/year
2050: 645 km^3/year

Next steps: Water Quality

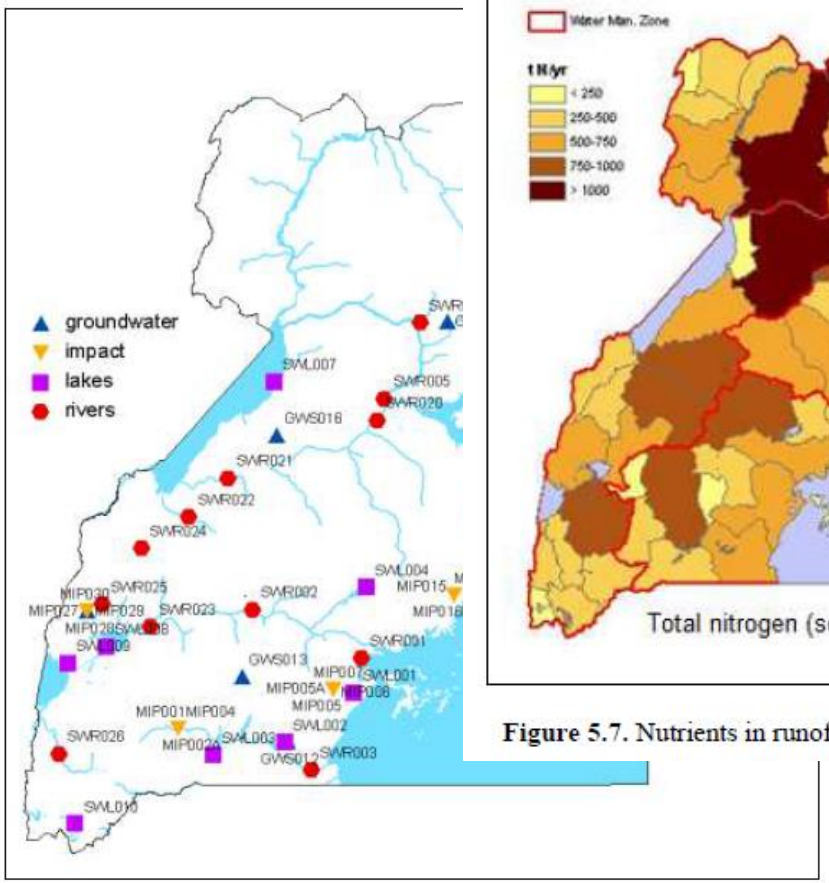


Figure 5.1. The DWRM network of operational water quality stations in Uganda.

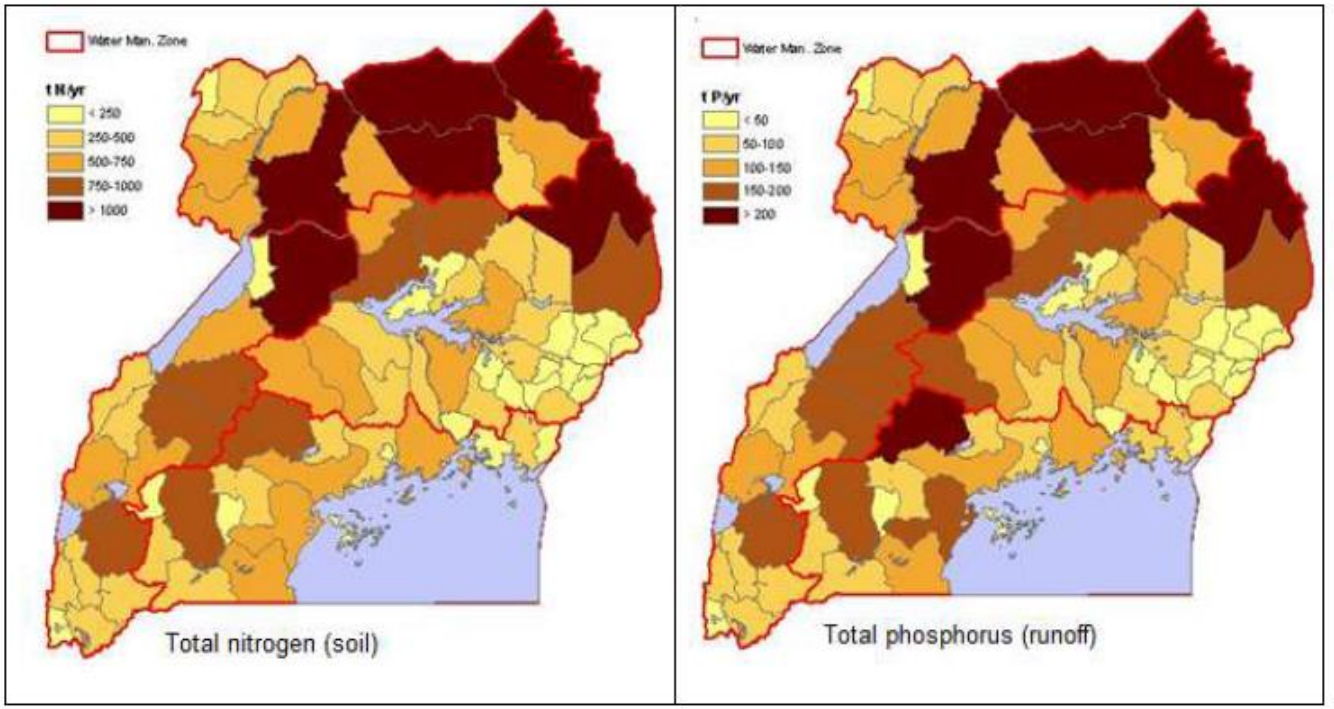


Figure 5.7. Nutrients in runoff (t/year) in from soil in each district in Uganda (data from AFRICOVER).

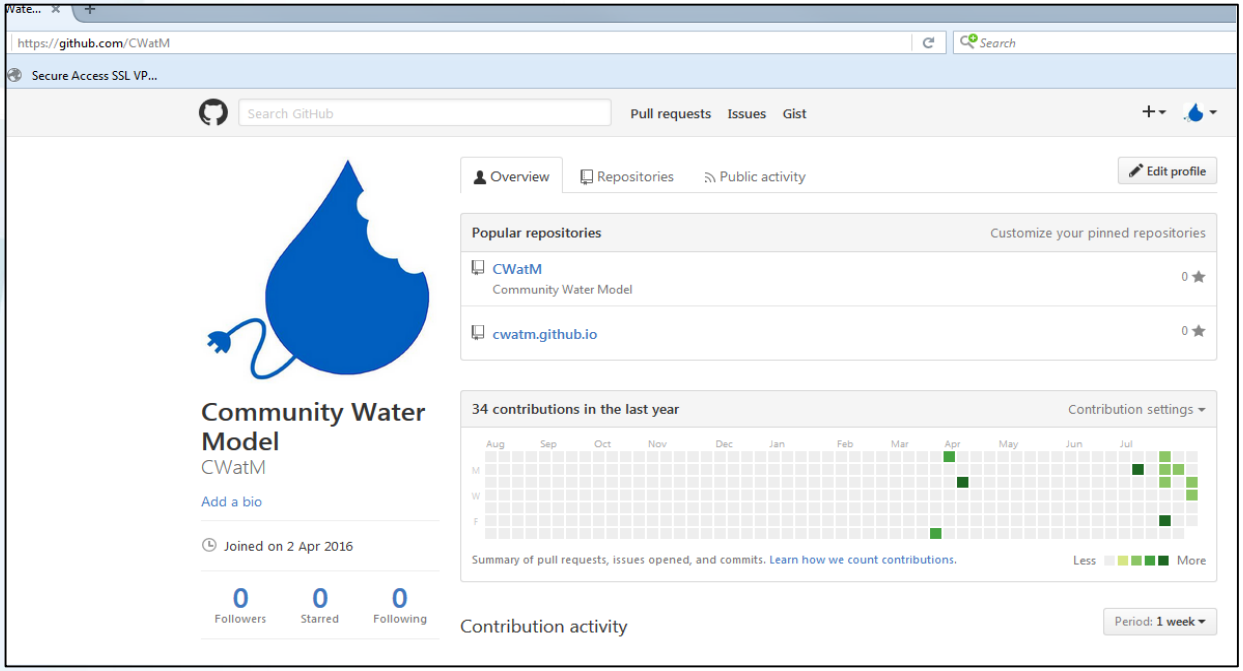
- **Water quality** becomes more and more important. This is particularly true for the Lake Victoria where deteriorating water quality already shows significant impact on fish stocks and increases treatment costs for water for domestic purpose.

The Community Water Model (CWATM)

Development of a community driven global water model

Open source on Github

https://github.com/CWatM



Contact:

http://www.iiasa.ac.at/cwatm

Thank you