

The logo for Vrije Universiteit Brussel (VUB), consisting of the letters 'VUB' in white on a blue square background.

VRIJE  
UNIVERSITEIT  
BRUSSEL

The logo for the Research Foundation Flanders (fwo), featuring the lowercase letters 'fwo' in a stylized white font.

Research Foundation  
Flanders  
Opening new horizons

## THE IMPACTS OF RESERVOIRS ON THE CLIMATE: TOWARDS REPRESENTING RESERVOIRS IN CLM5

Inne Vanderkelen

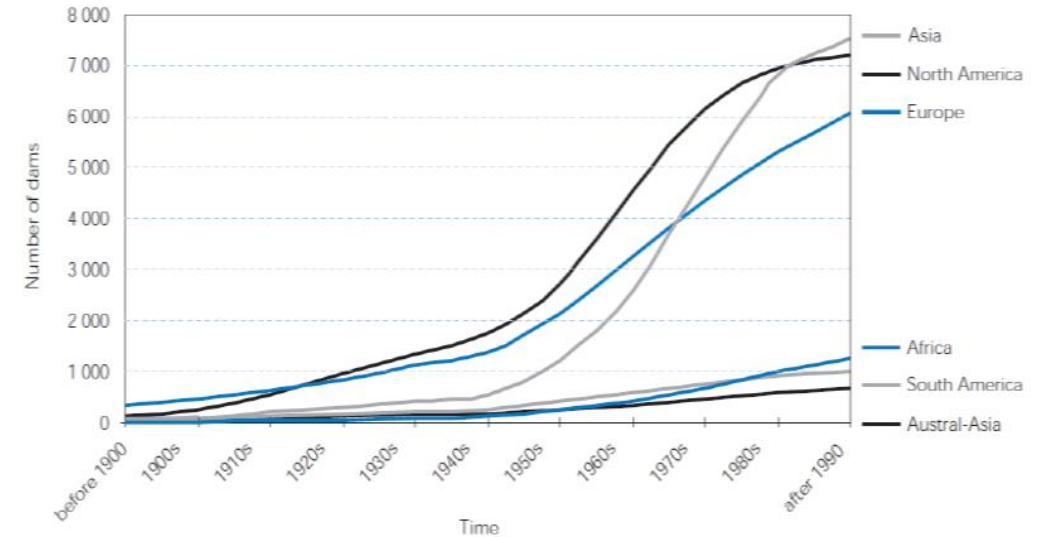
Wim Thiery, Dave Lawrence, Bill Sacks,  
Martyn Clark, Naoki Mizukami, Sean Swenson

*Glen Canyon dam on Colorado River, Arizona, USA.*



# Dams and reservoirs

- 45 000 large dams globally
- Impound 1/6<sup>th</sup> of annual continental discharge
- Cover 10% of global lake area



WCD, 2000



Irrigation



Hydropower



Flood control

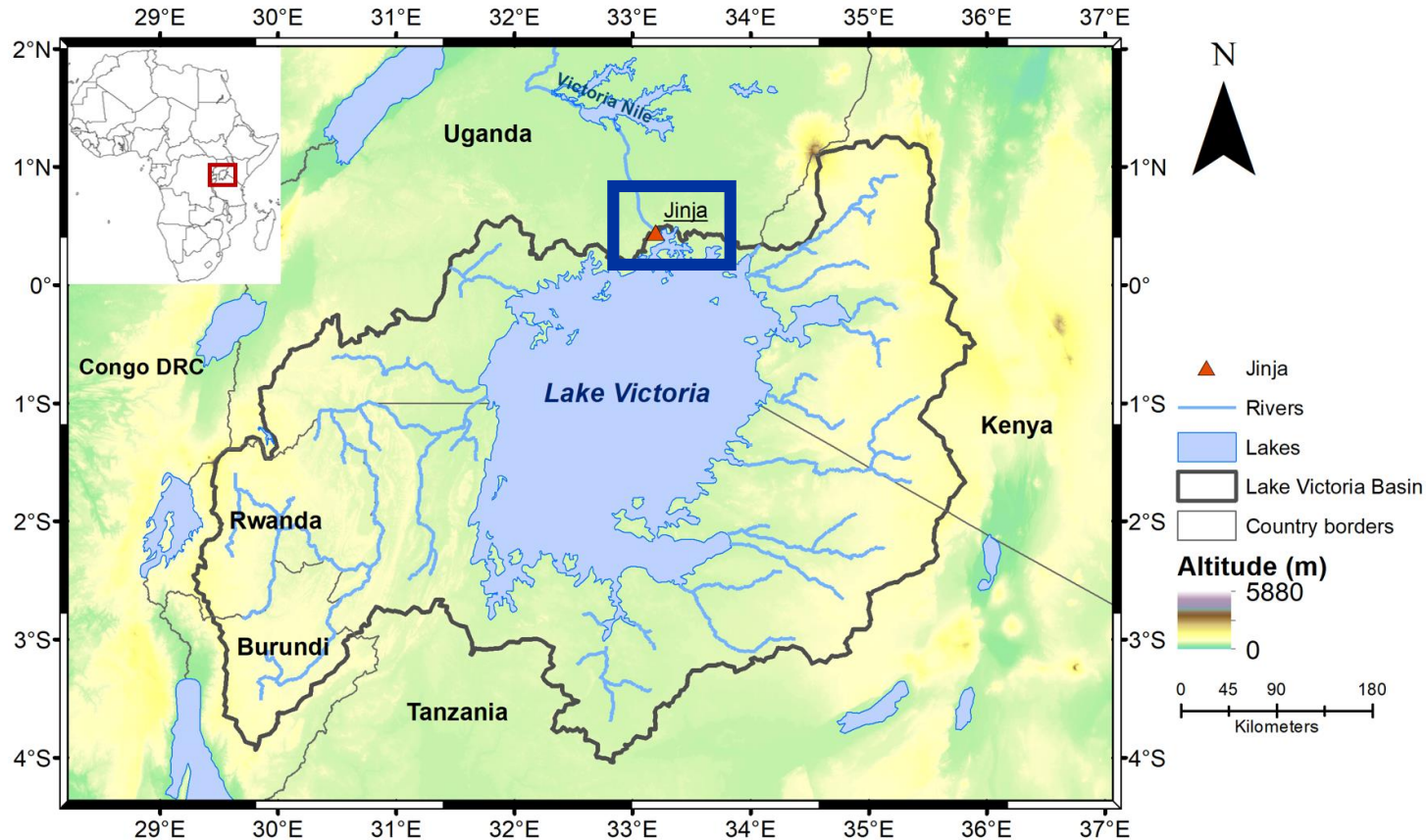


Navigation and recreation



Water supply

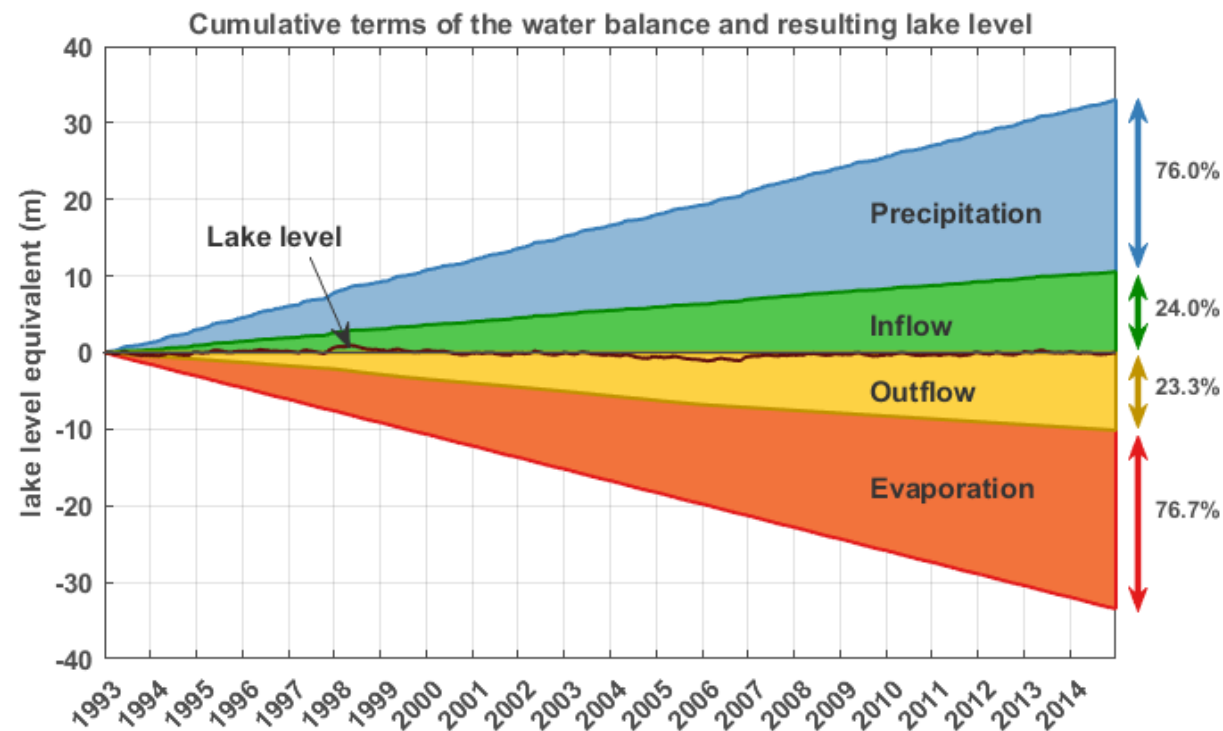
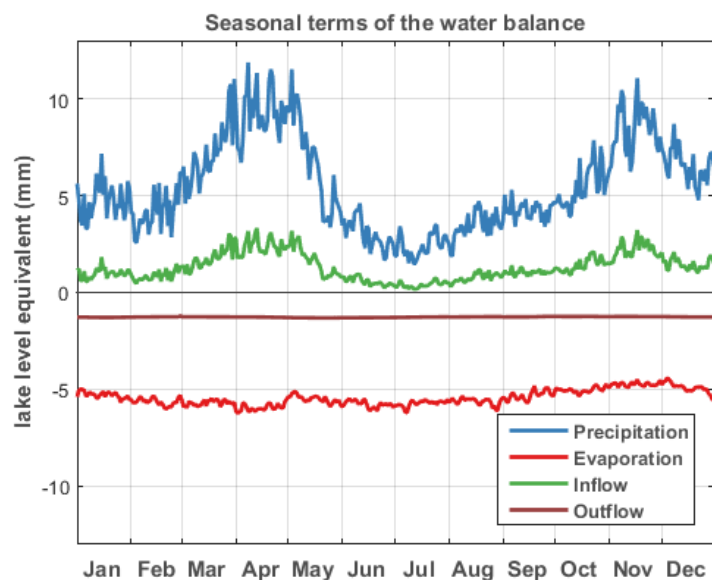
# The importance of dams: Lake Victoria (East Africa)



*Vanderkelen et al., 2018a, b*

# Lake Victoria's water balance

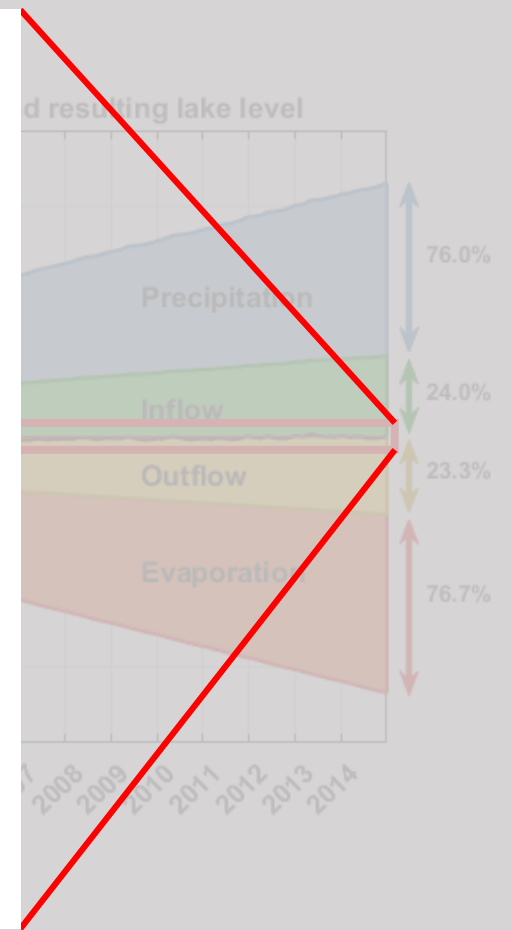
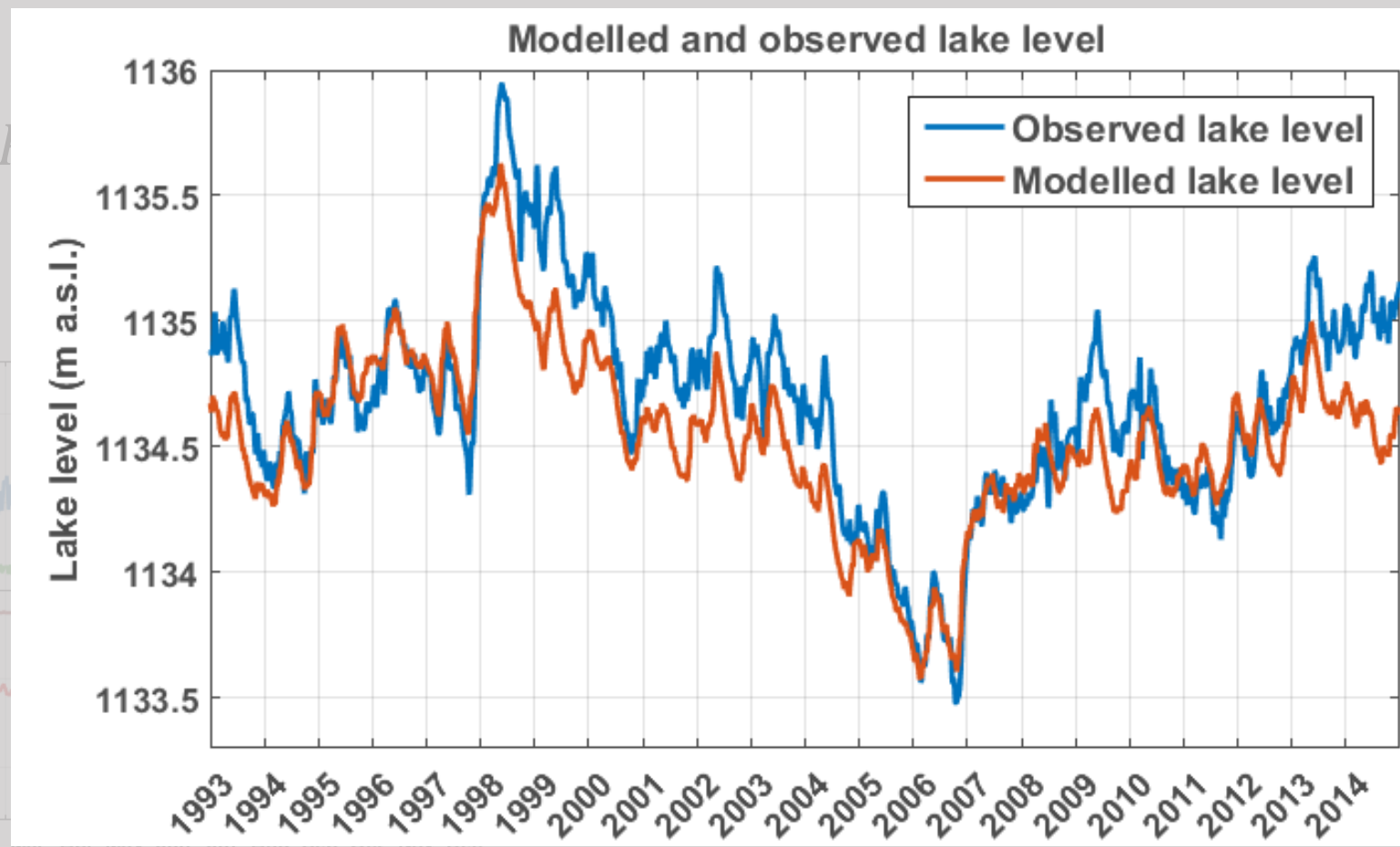
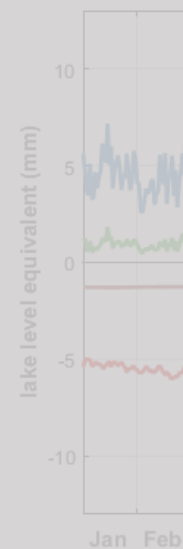
$$\frac{dL}{dt} = P - E + \frac{Q_{in} - Q_{out}}{A_{lake}}$$



*Vanderkelen et al., 2018a*

# Lake Victoria's water balance

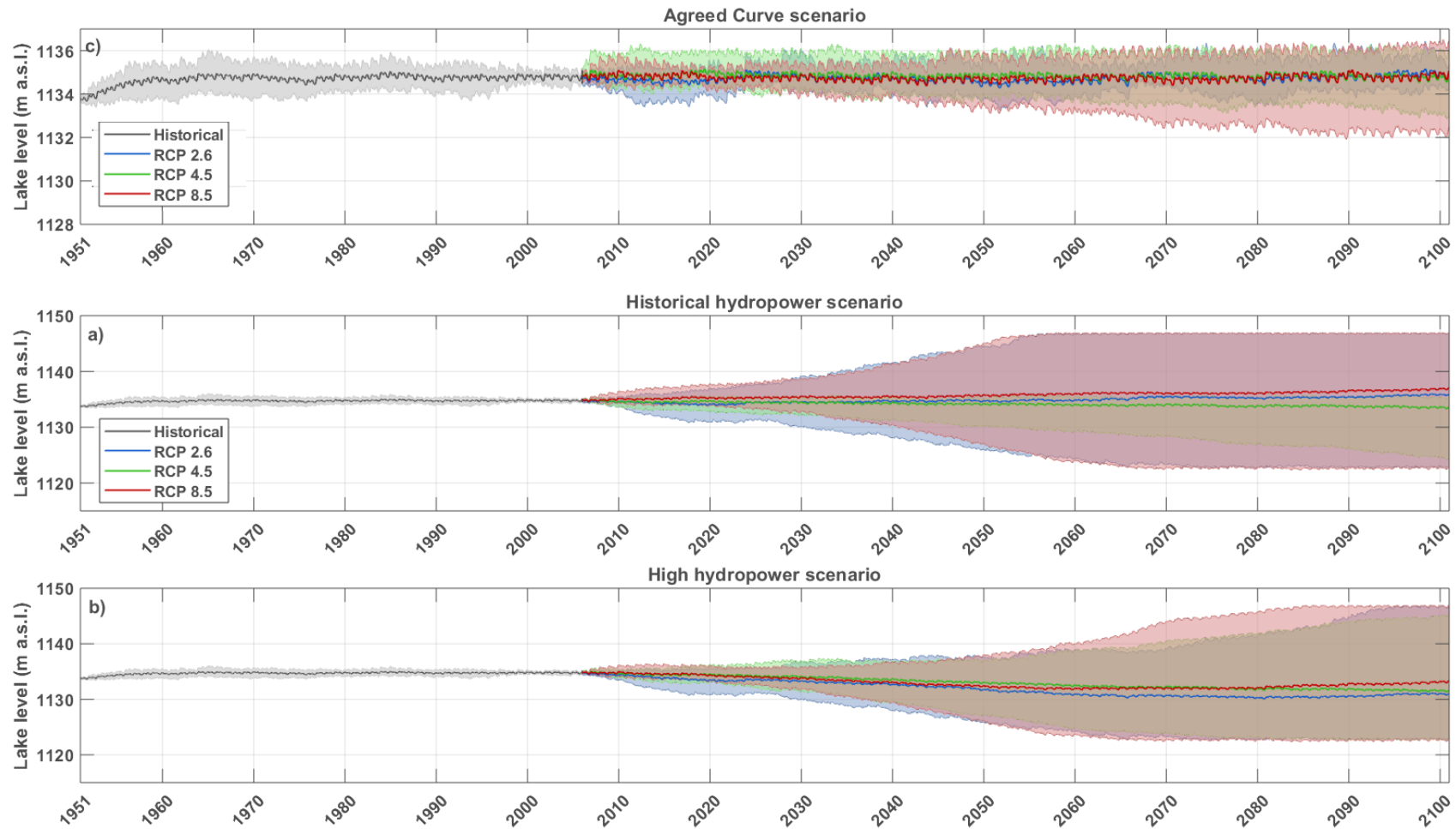
$$\frac{dL}{dt} = I - O - E + P$$



*Vanderkelen et al., 2018a*

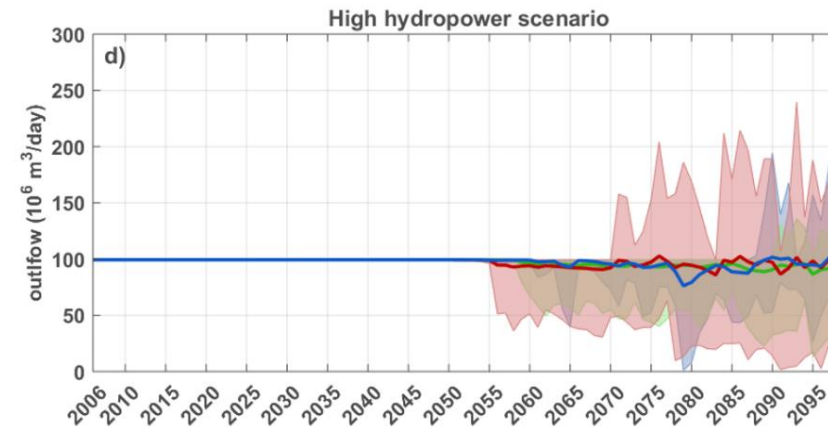
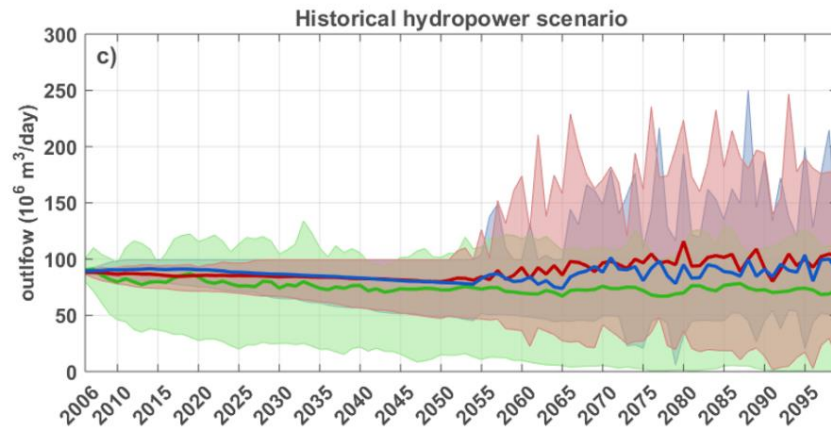
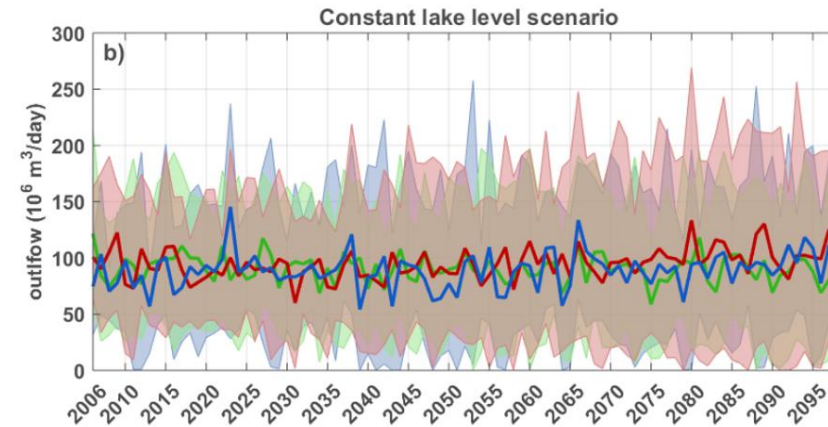
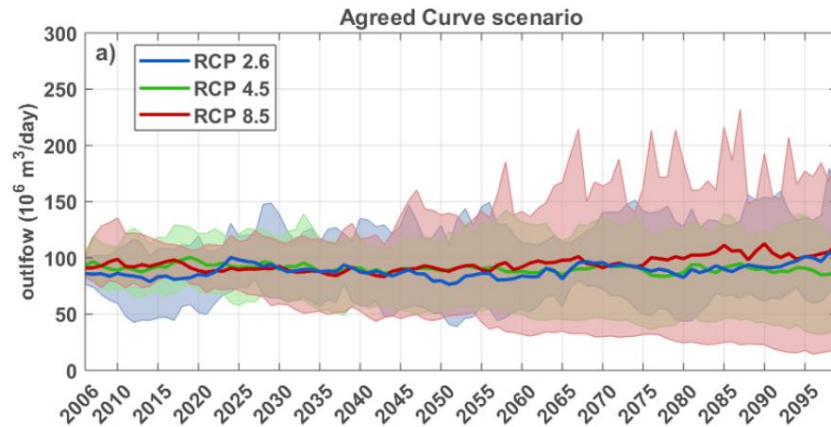


# Future lake level projections



*Vanderkelen et al., 2018b*

# Future outflow projections



Vanderkelen et al., 2018b

# Reservoirs in Global Hydrological Models

GHM	Reservoir parametrisation
VIC	Haddeland 2006
PCR-GLOBWB	Haddeland, 2006
WaterGAP	Hanasaki, 2006
H08	Hanasaki, 2006
LPJmL	Hanasaki, 2009
MATSIRO	Hanasaki, 2006
LISFLOOD	Zajac, 2017
MESH	Yassin et al 2019
SWAT	Arnold, 2018
WBM	Wisser, 2010

**So far, no reservoirs included in ESMs, no coupled simulations**



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## Parametrisation Families

1. Haddeland, 2006  
**Optimization based**

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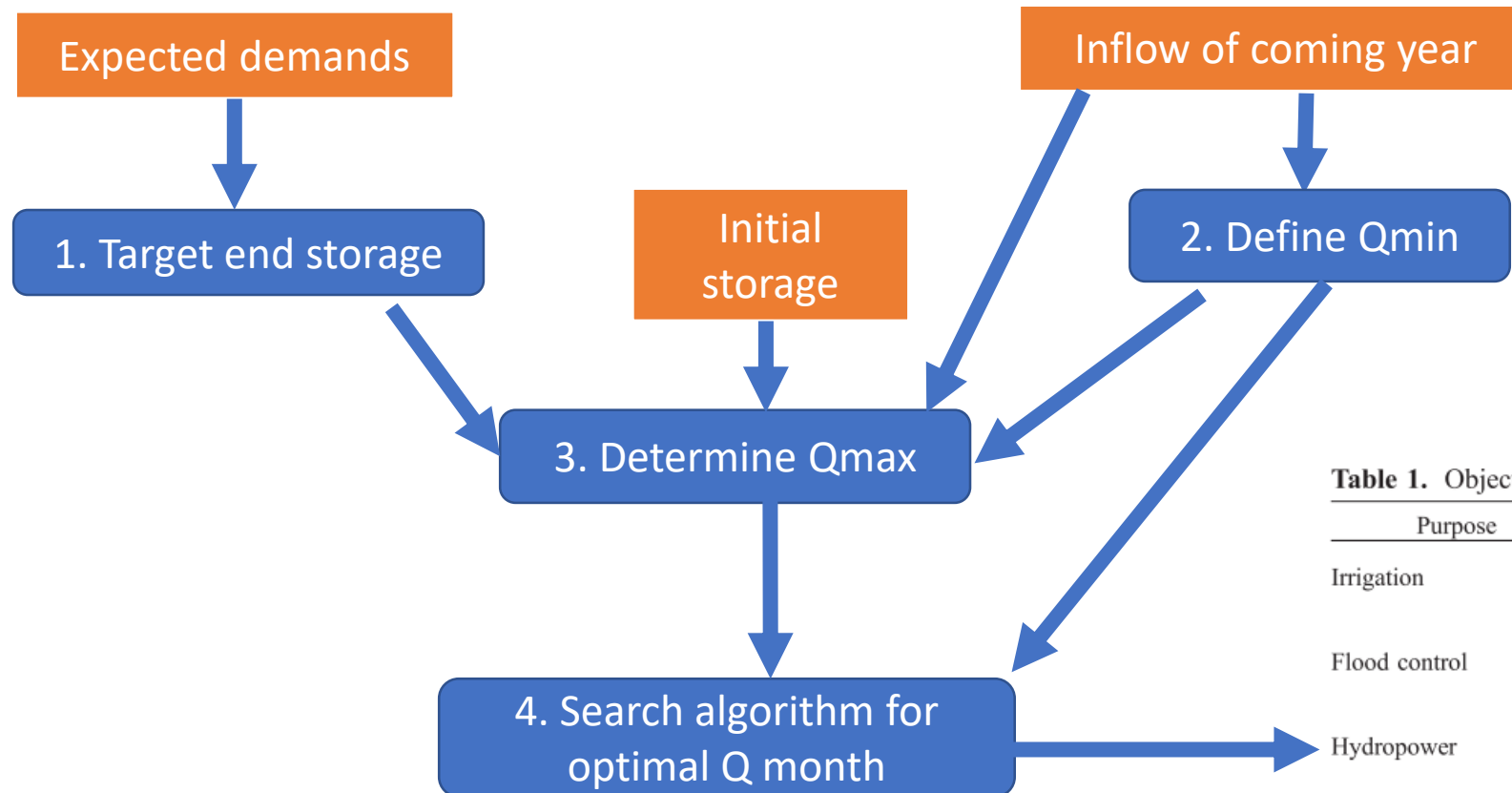
## Parametrisation Families

1. Haddeland, 2006  
**Optimization based**
2. Hanasaki, 2006  
**Simulation based**
3. Storage targeted  
**Simulation based**

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# 1. Haddeland, 2006 (Optimization based)



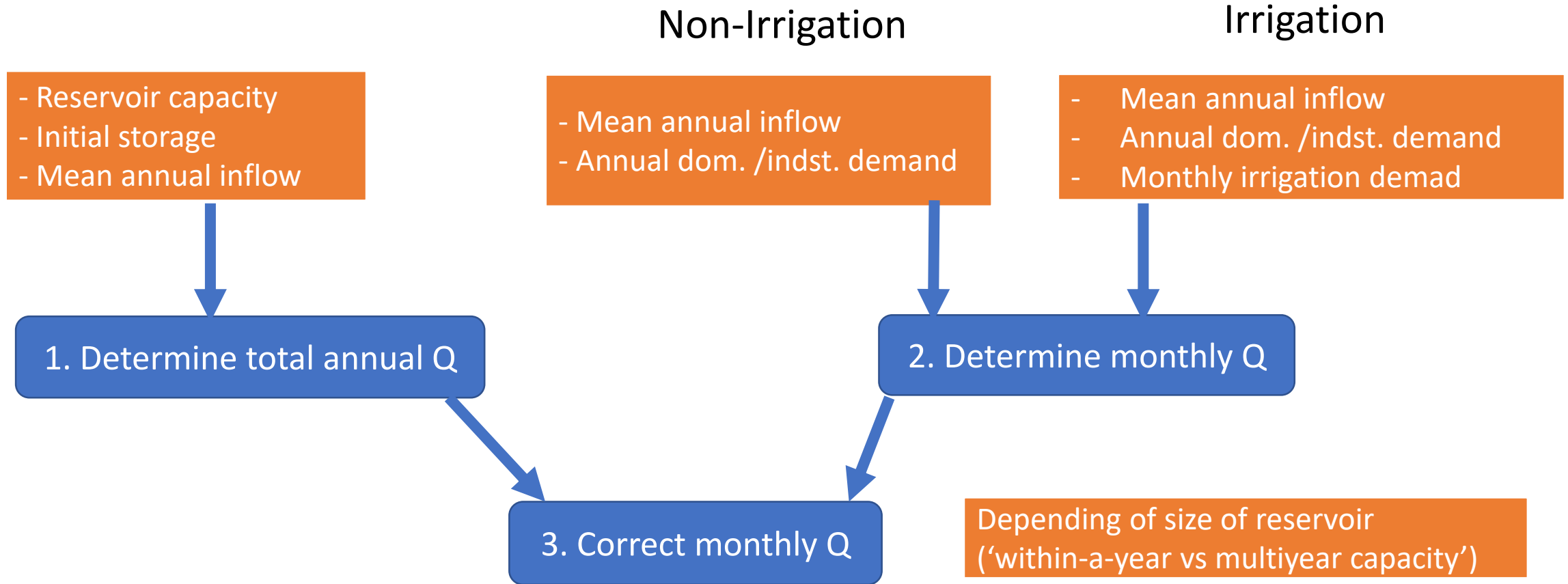
**Table 1.** Objective Functions Used in the Reservoir Model<sup>a</sup>

Purpose	Objective Function
Irrigation	$\min \sum_{i=1}^{365} (Q_{d_i} - Q_{r_i}), Q_d > Q_r$
Flood control	$\min \sum_{i=1}^{365} (Q_{r_i} - Q_{flood})^2, Q_r > Q_{flood}$
Hydropower	$\min \sum_{i=1}^{365} \frac{1}{Q_{r_i} \rho \eta h g}$
Water supply, navigation	$\min \sum_{i=1}^{365}  (Q_{r_i} - Q_{mean}) $

Operational year: starts in dry season (per reservoir)

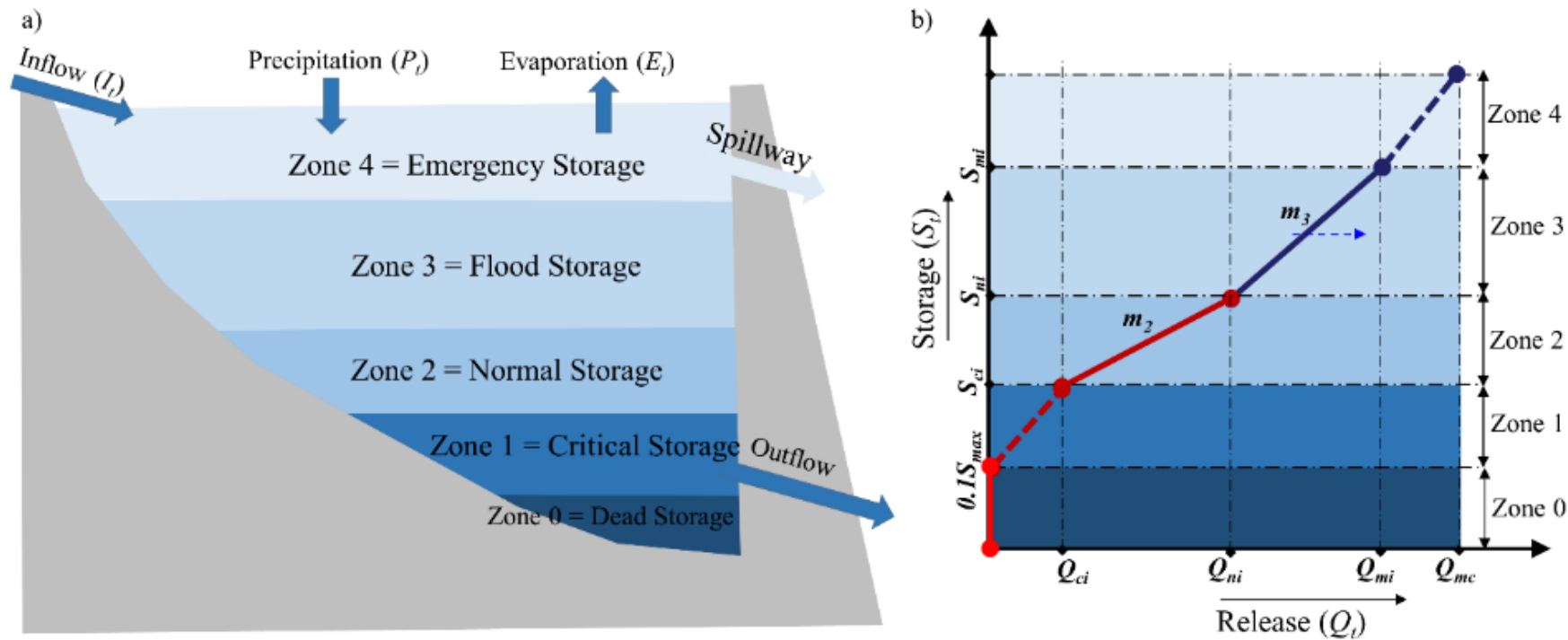
## 2. Hanasaki, 2006

Operational year: starts in dry season (per reservoir)



# Parametrization of Yassin, 2019

## Dynamically Zoned Target Release (DZTR model)



Yassin et al, 2019



# Parametrizations Overview

+

-

**Haddeland, 2006**

Accounts for reservoir purpose

Prior knowledge of future daily inflow required

**Hanasaki, 2006**

Simulation based

Different storage levels ignored

**Yassin, 2019**

Generalized storage and release target parametrizations

Irrigation demand ignored

# Lakes in CLM5

## Static lakes:

- Occurrence of major water surfaces based on **GLWD**
- Variable **lake depth** per gridcell, but static in time

$$\Delta W_{sno} + \sum_{i=1}^{n_{levsoi}} (\Delta w_{liq,i} + \Delta w_{ice,i}) = (q_{rain} + q_{sno} - E_g - \boxed{q_{rgwl}} - q_{snwcp,ice}) \Delta t$$

*snow*                                  *soil*

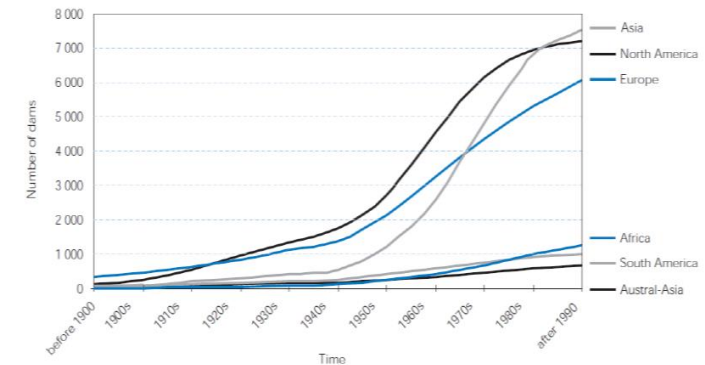
# Towards implementing reservoirs in CLM

## Current developments:

- Lakes in **MizuRoute**, coupled to CLM5
- Lake water balance will be calculated in MizuRoute, energy balance in CLM5.

1. Implement and test **reservoir parametrizations** in MizuRoute

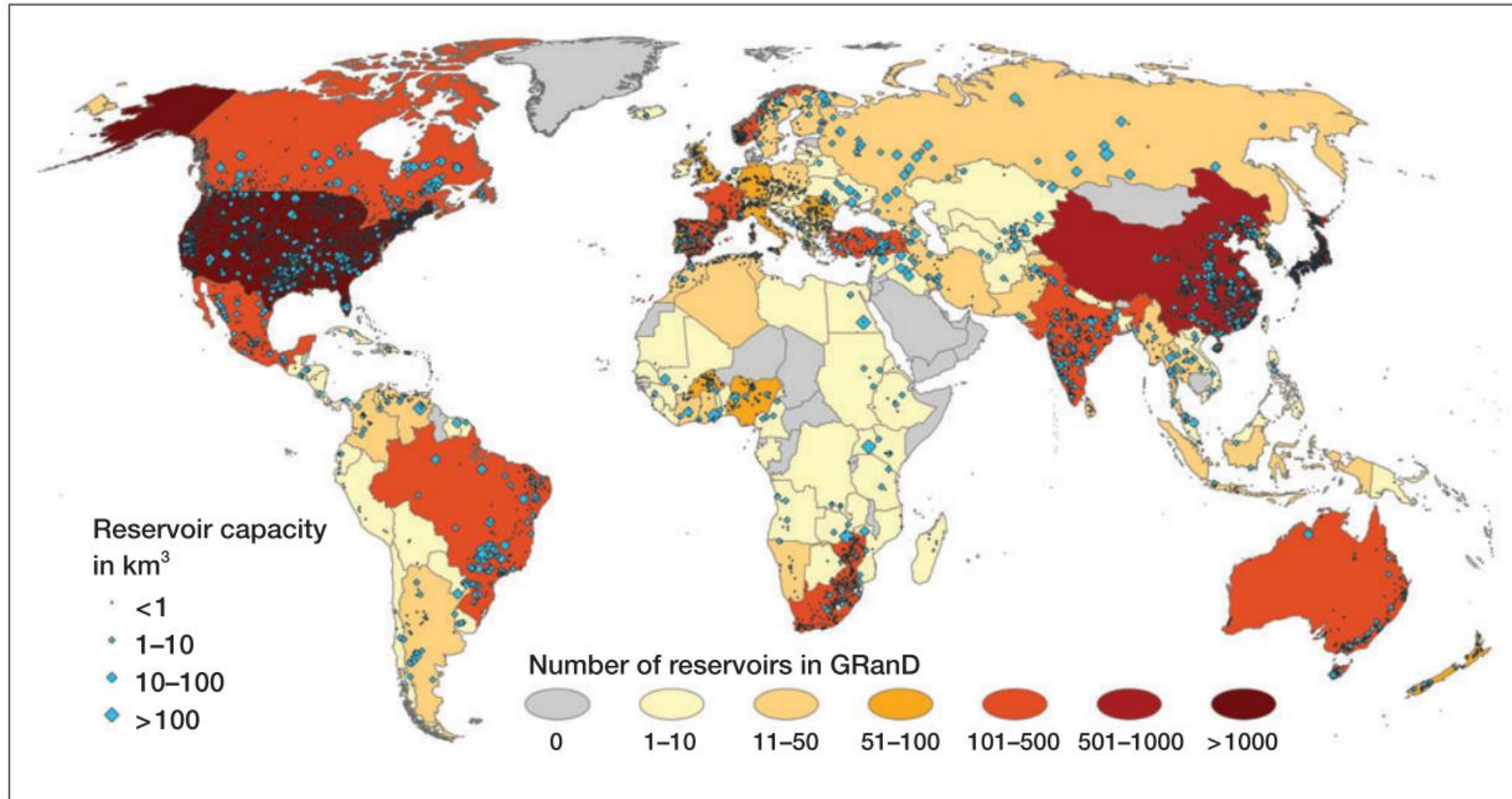
2. **Lakes as a dynamical land unit** in CLM



WCD, 2000



# Global Reservoir and Dam (GRanD) database



Lehner et al, 2011

# Outlook

1. Implementing reservoirs in CLM5 and MizuRoute
2. Evaluating the added value of reservoir representation for CLM5 and coupled to CESM2
3. Assessing the impacts of reservoirs on the 20<sup>th</sup> century climate (fully coupled CESM2 simulations: DAM – CTL)
4. Separating local and non-local effects of reservoirs
  - Local effects: direct evaporation and irrigation within grid cell
  - Downstream effects: downstream water availability for irrigation



**THANK YOU**

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