Potsdam Institute for
Climate Impact Research

PIK

How to integrate wetland processes in river basin modeling?

A West African case study

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Leibniz
Gemeinschaft

Outline

Why is an inundation module required?

- Case study: Inner Niger Delta

How does the inundation module work?

- Data requirements
- Preprocessing
- Processes
- Model parameters
- Limitations

Inner Niger Delta (Mali)

Upper Niger Basin
~350,000 km^2

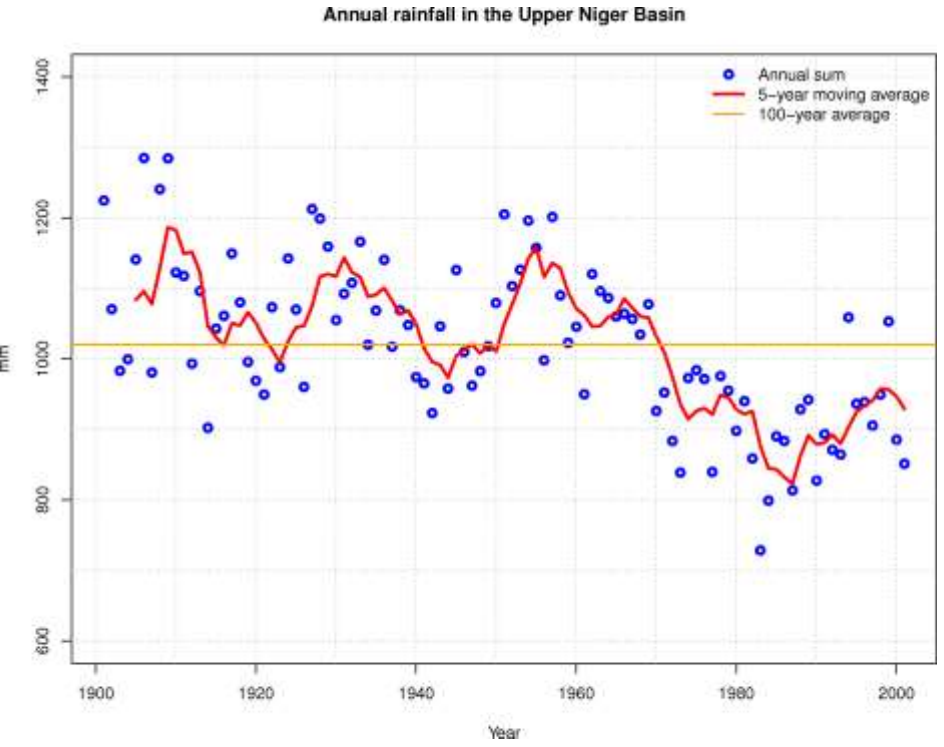
Inundated area
5,000 – 45,000 km^2

Peak discharge
2000 – 10,000 m^3/s

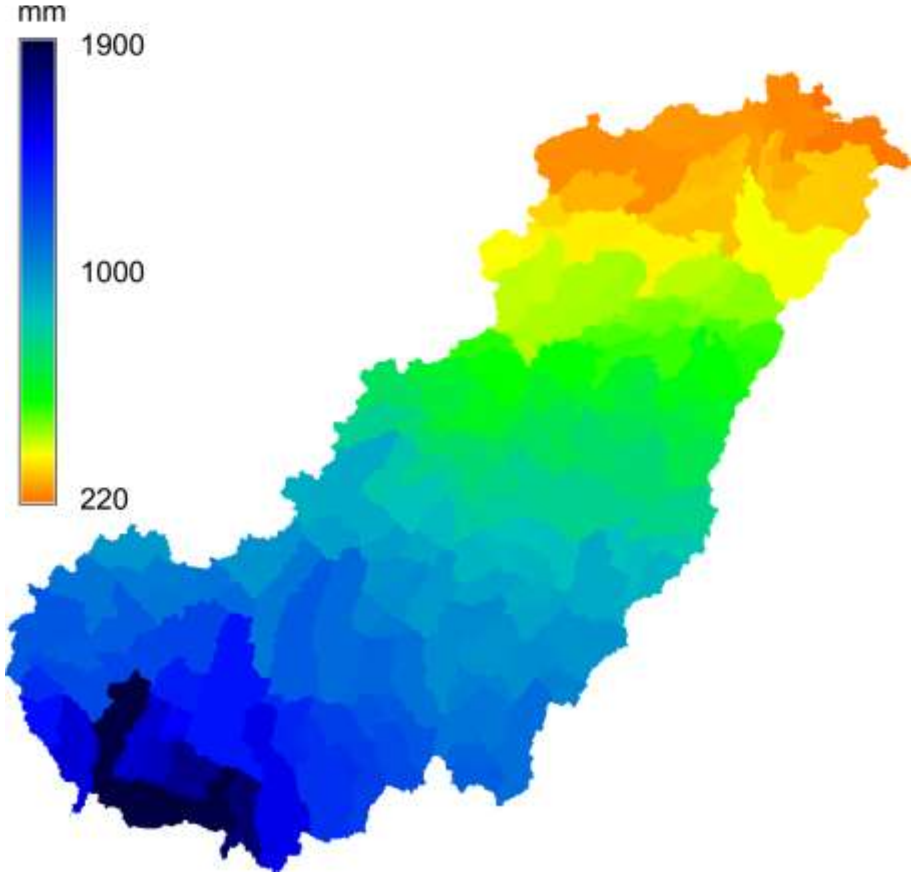
Monsoon-type of rainfall
Annual rainfall
~830 mm
(200 – 2000mm)

Rainfall in the Upper Niger Catchment

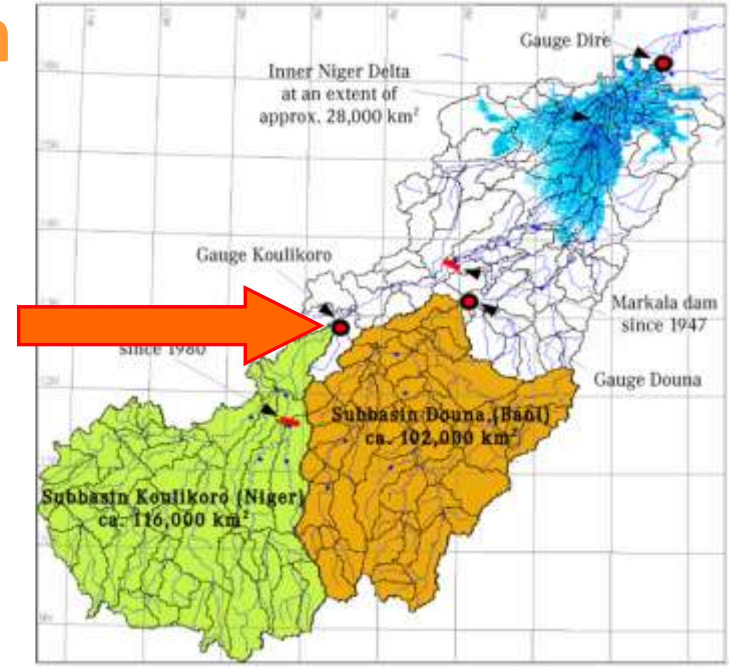
20th century



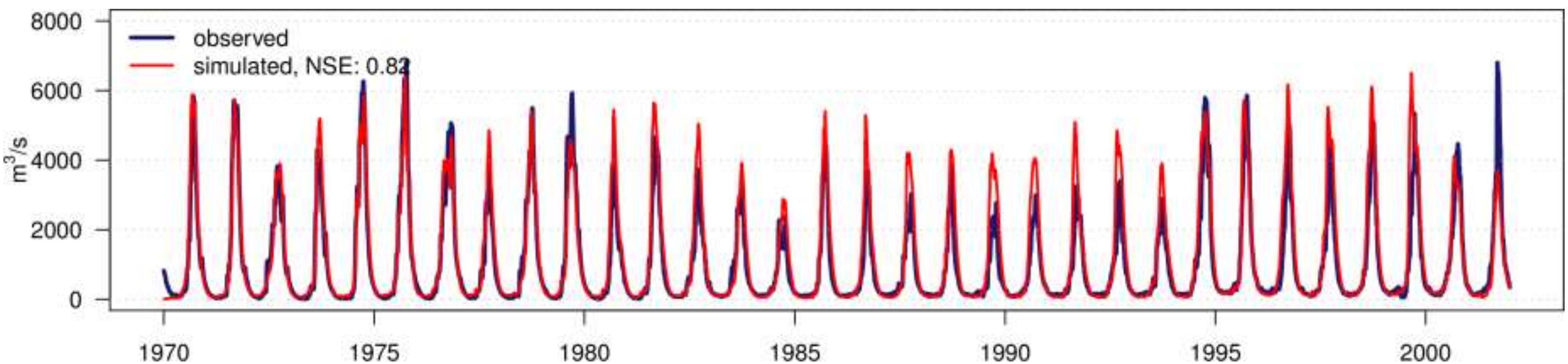
1981-2000

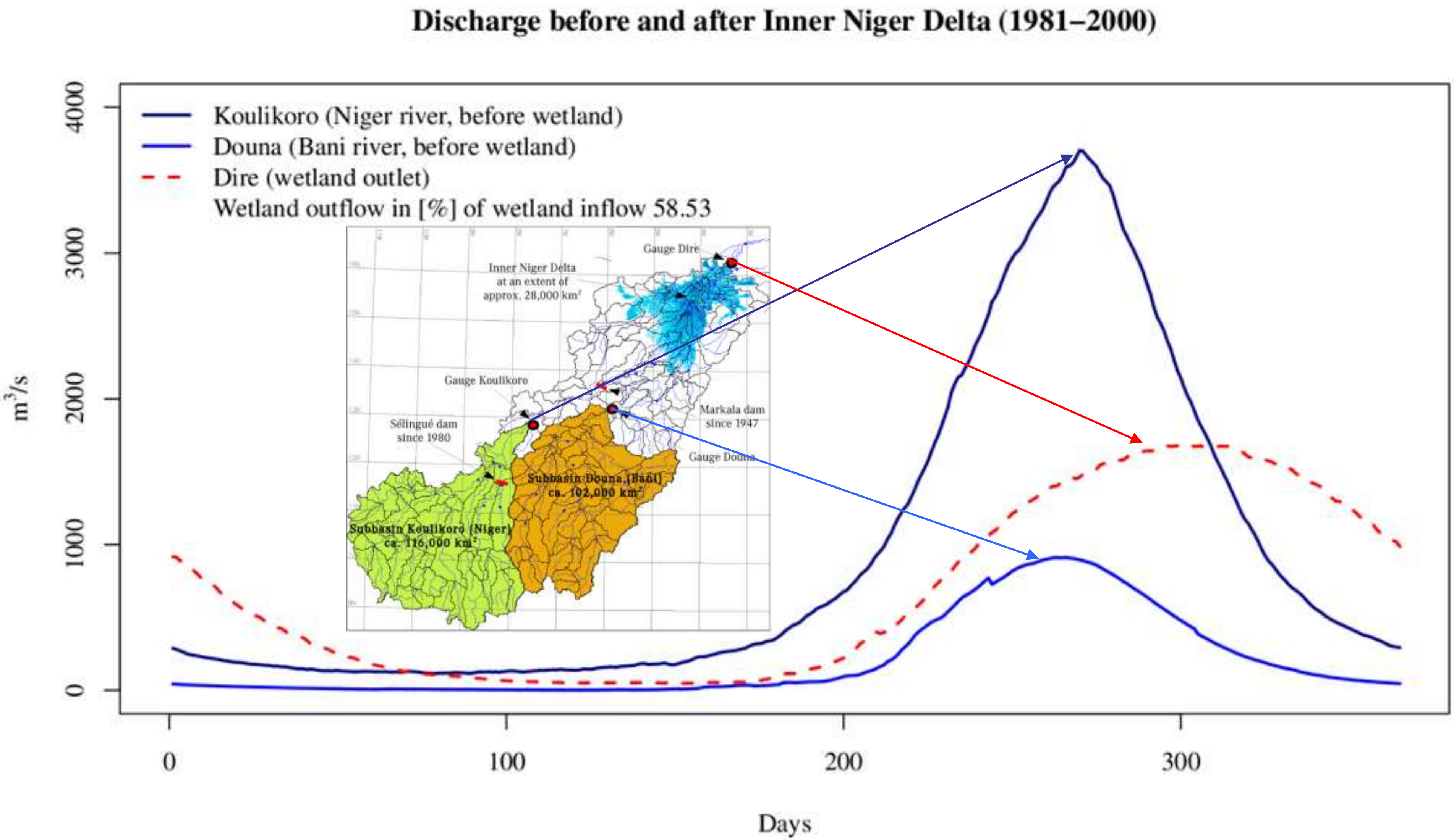


SWIM Streamflow Simulation



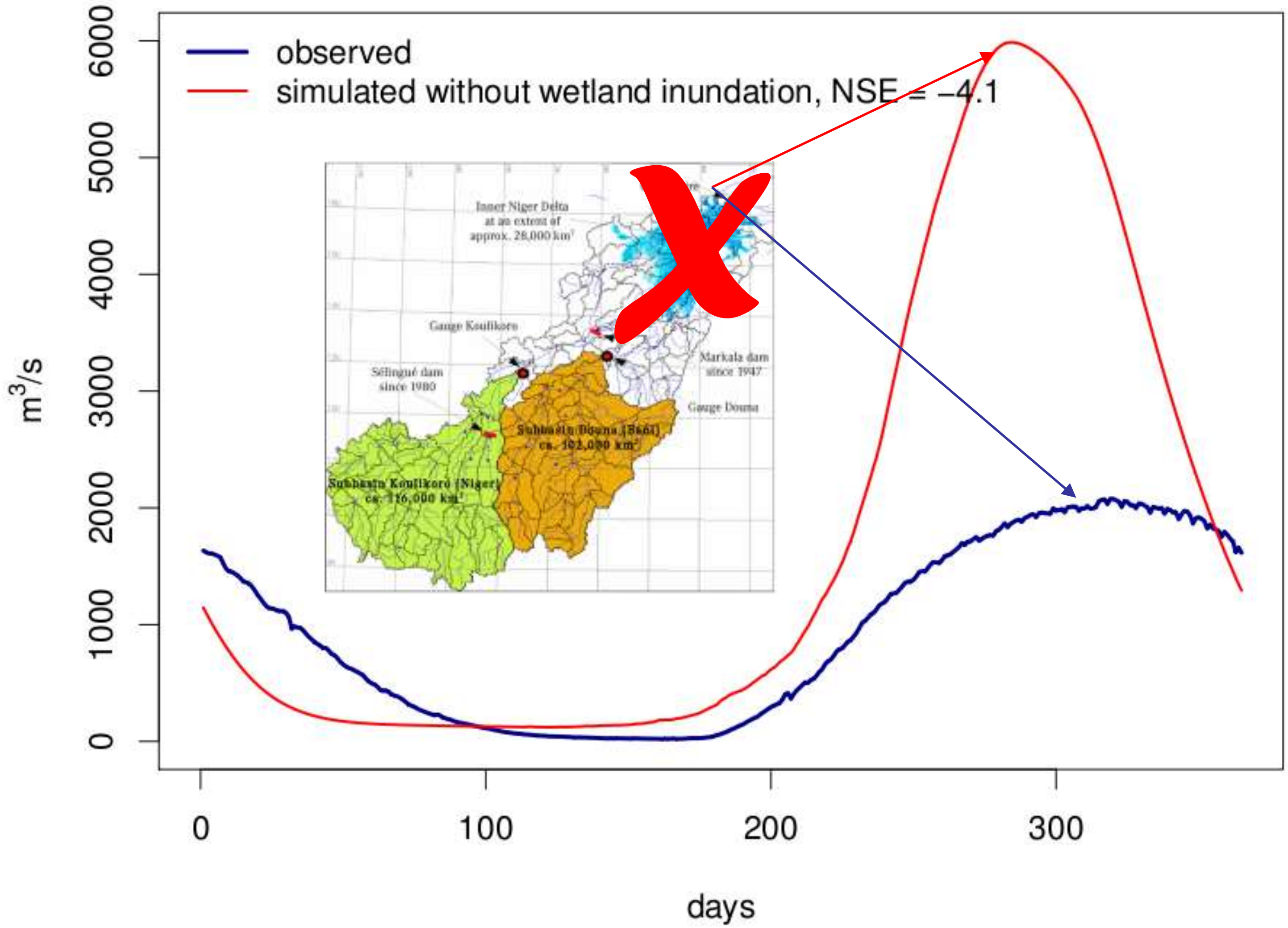
Koulikoro 1970-2001



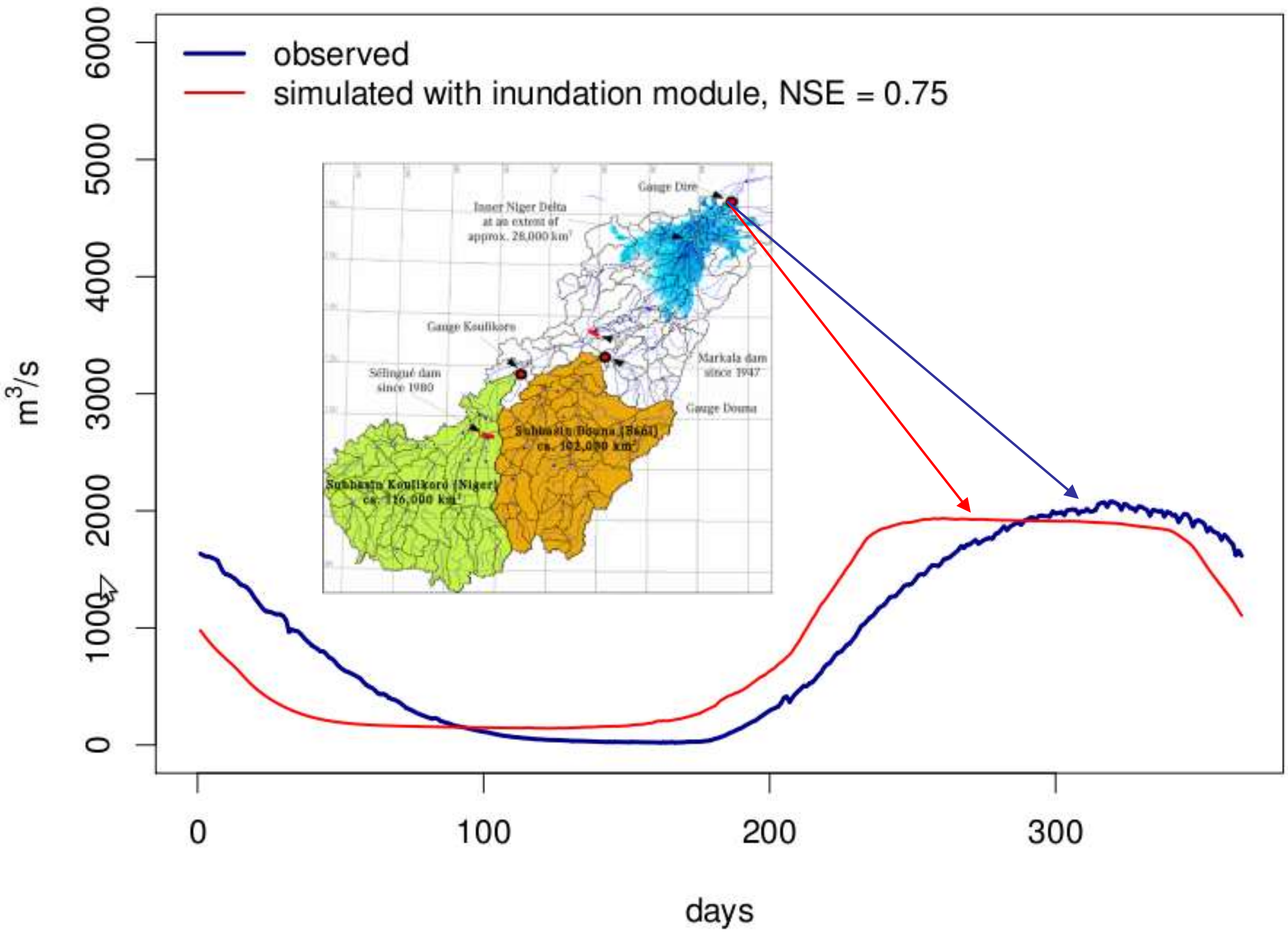


Discharge before and after Inner Niger Delta (1981–2000)
Koulikoro (Niger river, before wetland)
Douna (Bani river, before wetland)
Dire (wetland outlet)
Wetland outflow in [%] of wetland inflow 58.53
Gauge Dire
Inner Niger Delta at an extent of approx. 28,000 km²
Gauge Koulikoro
Markala dam since 1947
Sélingué dam since 1980
Gauge Douna
Subbasin Douna (Bani) ca. 102,000 km²
Subbasin Koulikoro (Niger) ca. 116,000 km²
m³/s
0
1000
2000
3000
4000
0
100
200
300
Days

Streamflow gauge Dire (wetland outlet) 1970–1979



Streamflow gauge Dire (wetland outlet) 1970–1979



Some Reasons to Integrate Wetland Processes

- **To adequately simulate discharge downstream of the wetland**
- **To account for evapotranspiration "losses" within the wetland**
    - Important information for regional climate models

- **Relevant for the Inner Niger Delta**
    - **To assess usable area for floating rice production**
    - **To assess climate change & variability impacts on agriculture, fishery, and cattle**

Data Requirements

Spatial Data

- DEM
- Flow accumulation map

Calibration

- Spatial and temporal information about inundation

Preprocessing

Identify **wetland outlet** (in GIS)

Assume that **wetland is a lake**

- **Flood** the lake (e.g. module *r.lake* in GRASS GIS)
- Identify **inundation zones**
  - Water levels [m^2]
  - Inundation storage volumes [m^3]

GRASS module *r.param.scale* to **identify ponds** (**water traps**)

- Map with grid cells that are identified as sinks (no surface runoff)

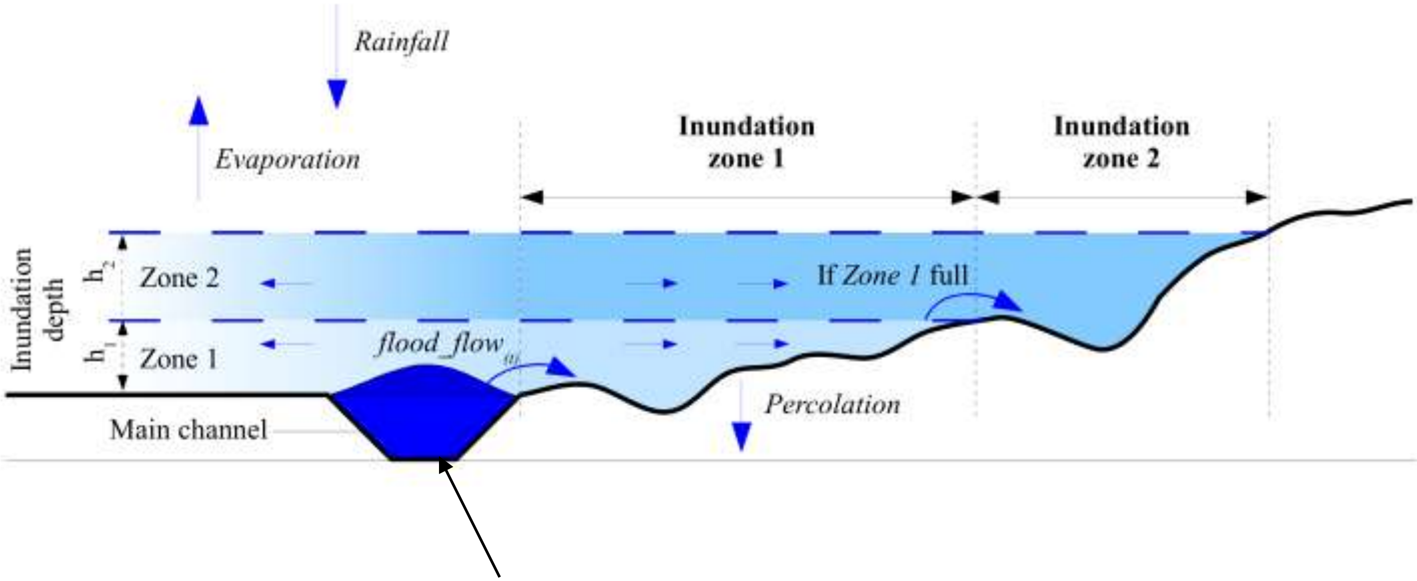
► **2 new HRU attributes**

- **inundation zone**
- **water trap (ponds)**

Processes: Overview

- **Flooding**
- **Routing, backwater**
- **Evaporation (water surface)**
- **Percolation**
- **Release**
- **HRUs**
  - Switch from land to water phase
- **Parameters**
  - Flow-threshold for flooding (cross-sectional area)
  - Parameter for release (linear storage)
  - *Backwater subbasins* input file

Processes: Flooding



Cross-sectional area A [m^2]

Flow velocity (bankfull) v [$m*s^{-1}$]

▶ **A*v = inflow threshold [m^3*s^{-1}]**

Calibration parameter: correction of inflow threshold

Processes: Routing, Backwater

`If inflow(sub) > flowThresh(sub) then`

- Remove *inflow volume* > *flowThresh* from routing
- Route only *inflow volume* <= *flowThresh*
- Put *excess volume* into inundation storage(s)
- Perform *leveling* due to backwater effects

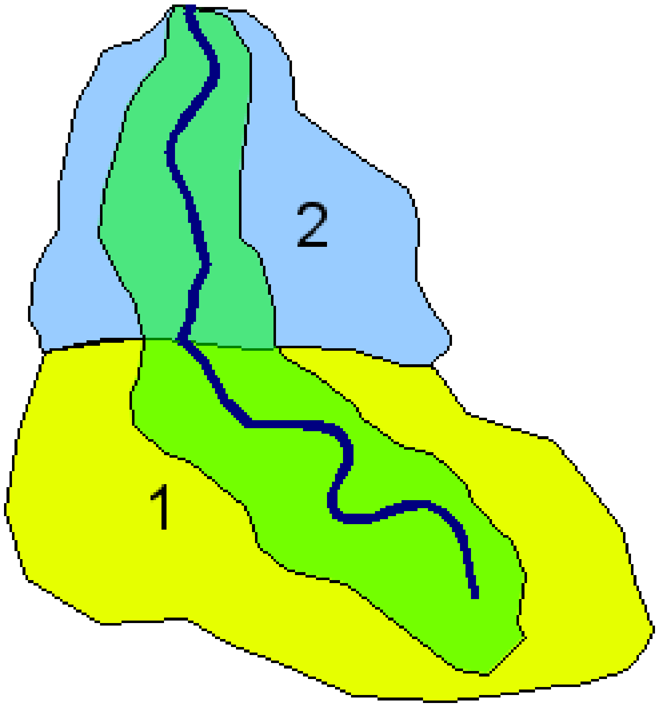
`else`

- Route normally

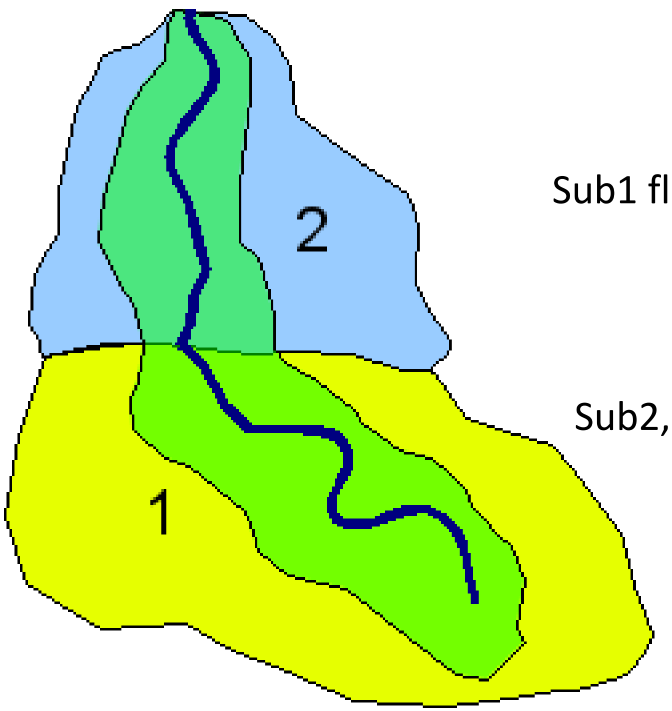
`If upstream subbasin has a share on wetland then`

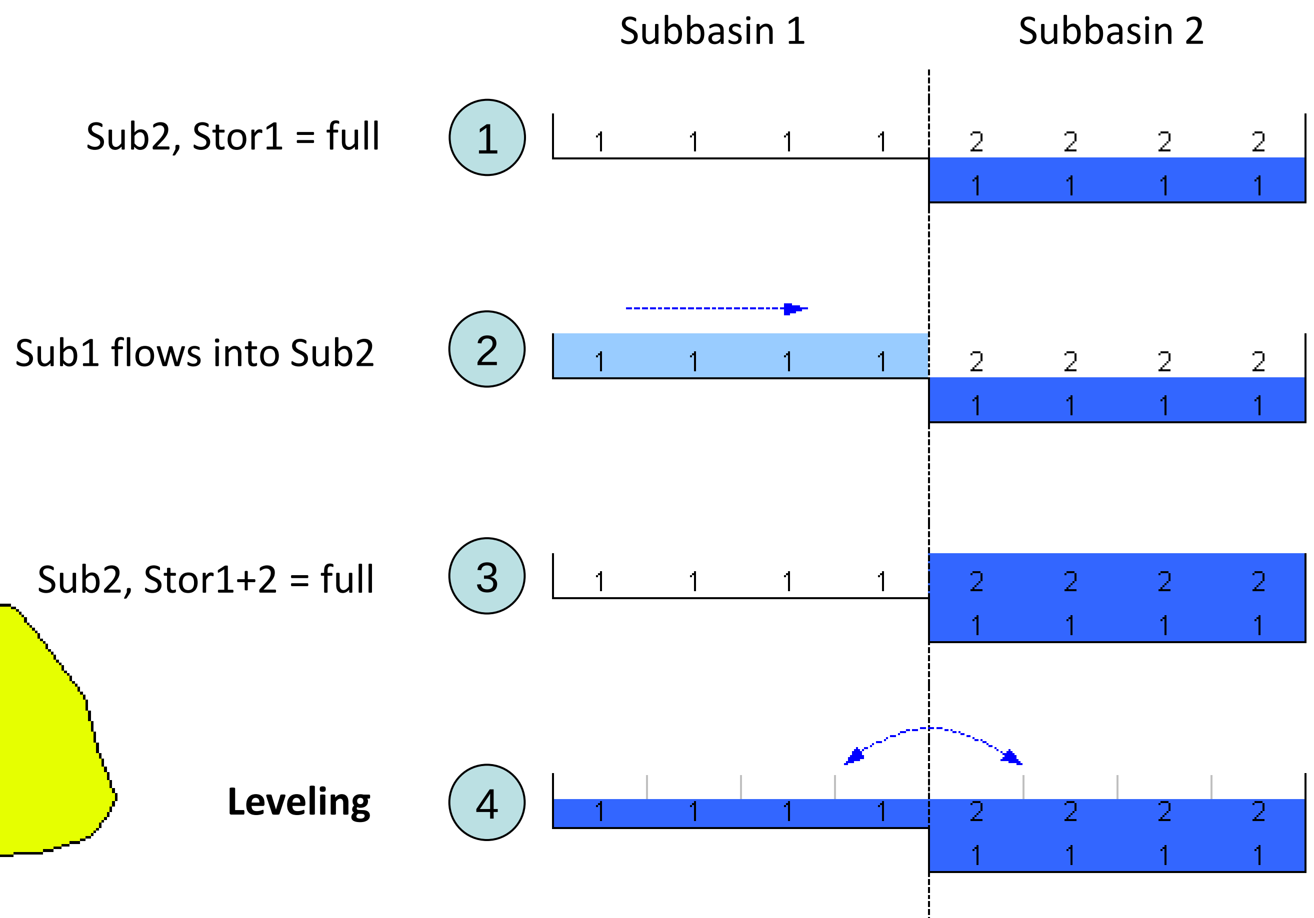
- Perform leveling of inundation storages of corresponding subbasins

Processes: Backwater, Leveling



Processes: Backwater, Leveling





Processes: Evaporation, Percolation

If HRU inundated (threshold) then

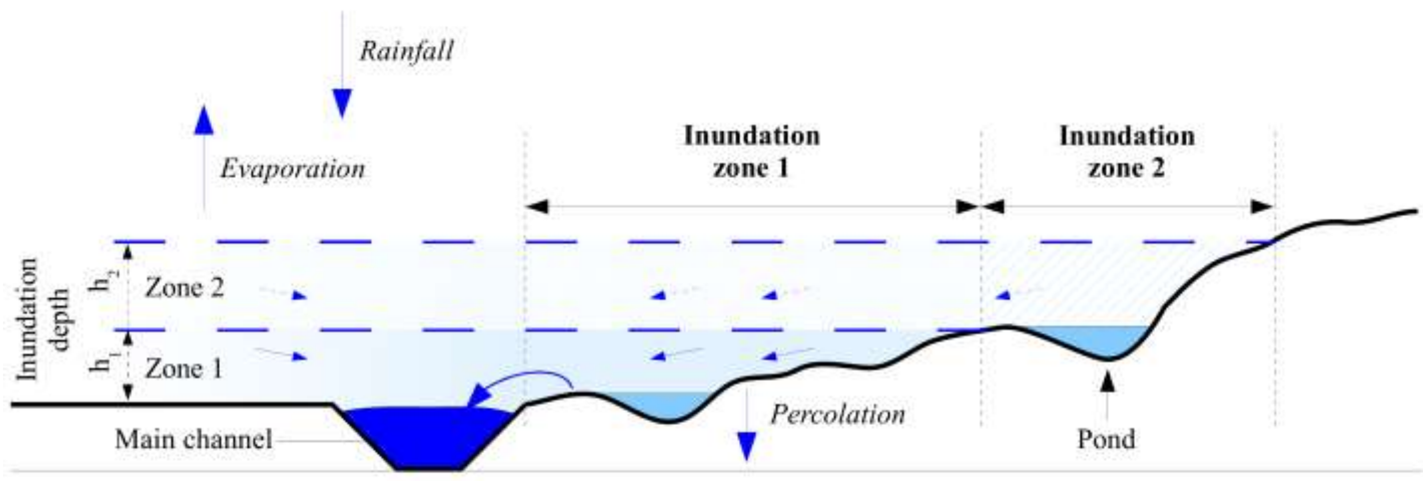
▶ Switch from land to water phase

- $ET_{act} = ET_{pot}$ (water surface)
- No surface runoff
- Percolation (percolation volume = unsaturated water capacity of upper soil layer)
  - Ground water recharge
  - Subsurface runoff

else

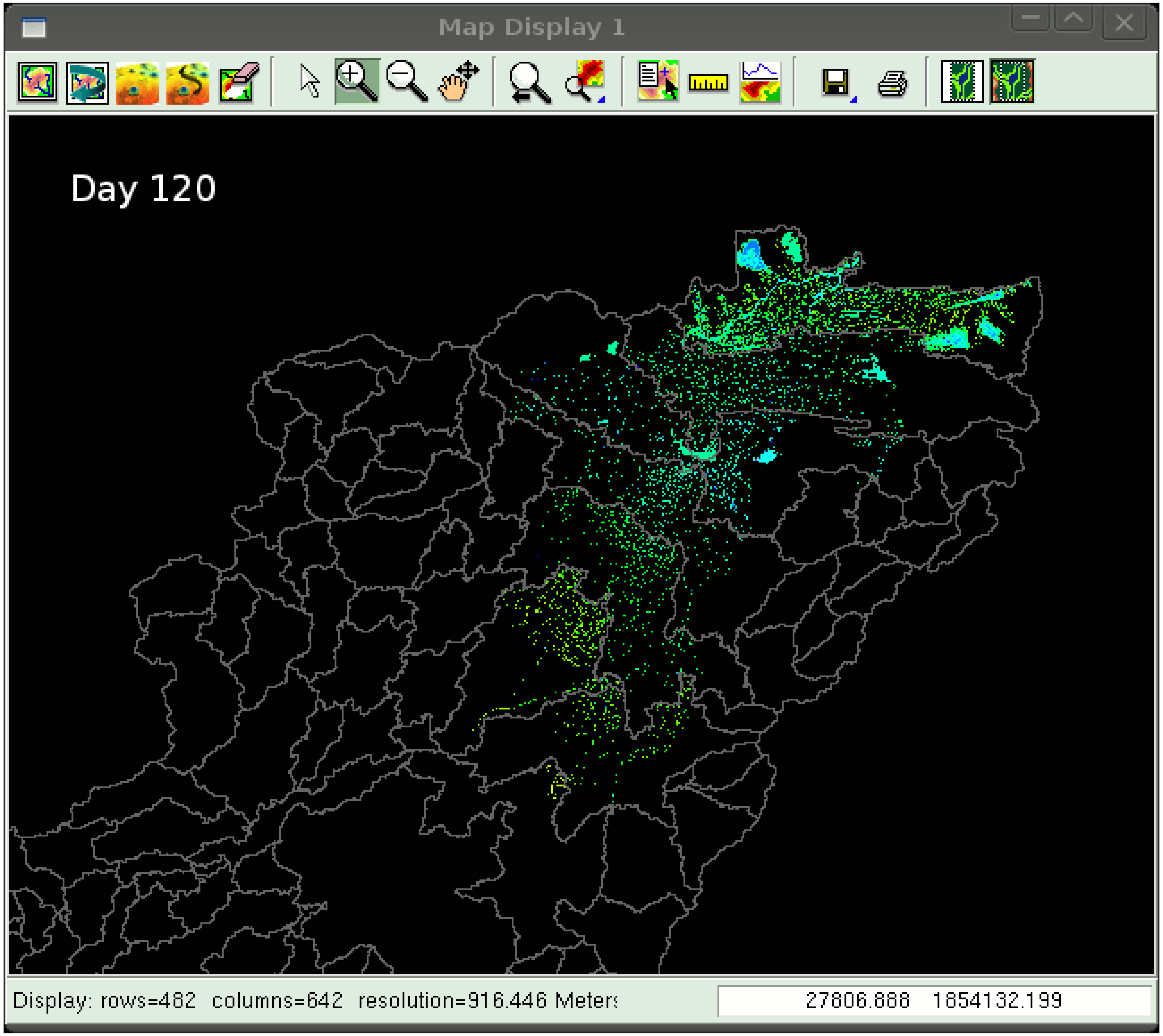
- Proceed normally

Processes: Release



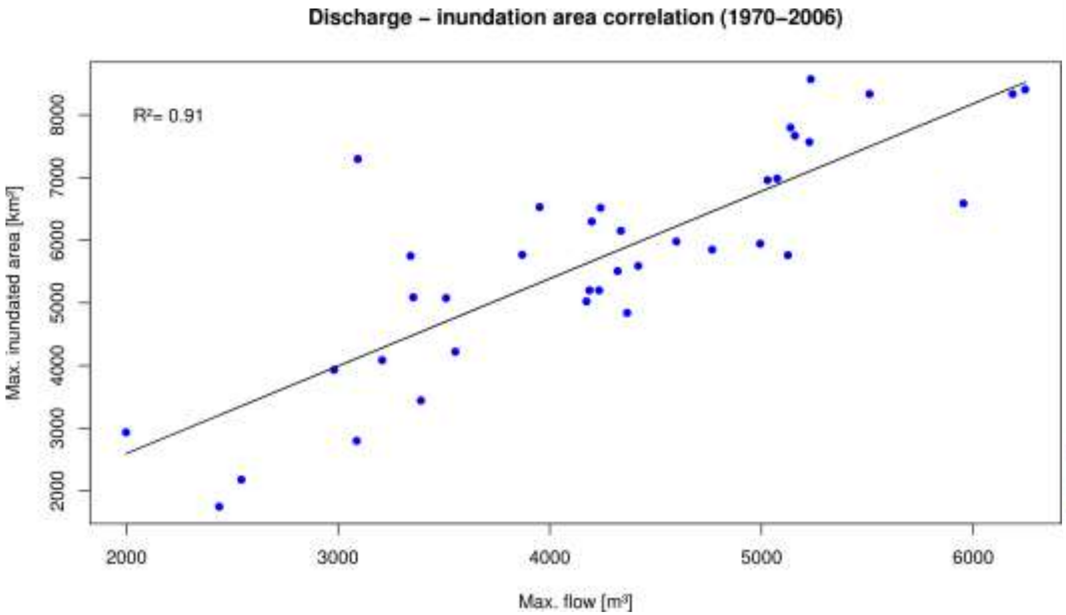
- **Calculate** **release volume** **per time step**
- **Add release to volume to be routed into downstream subbasin (next time step)**

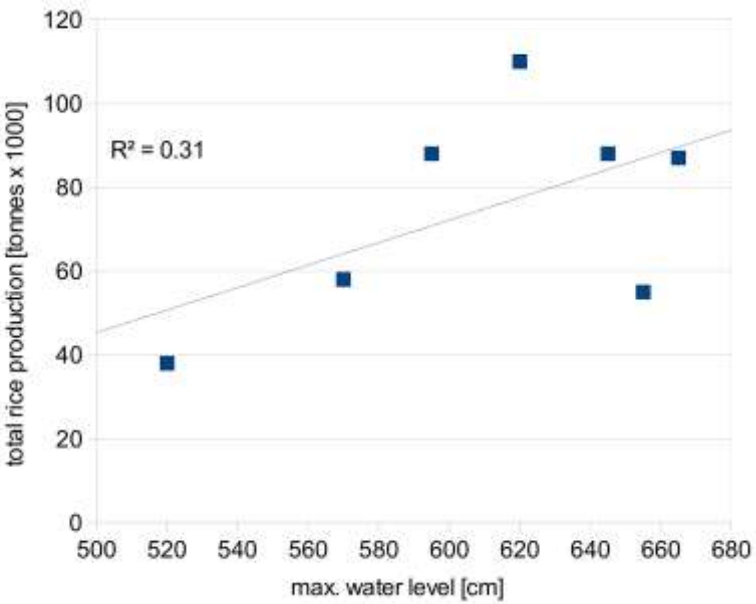
Calibration parameter: release coefficient [%] of storage volume



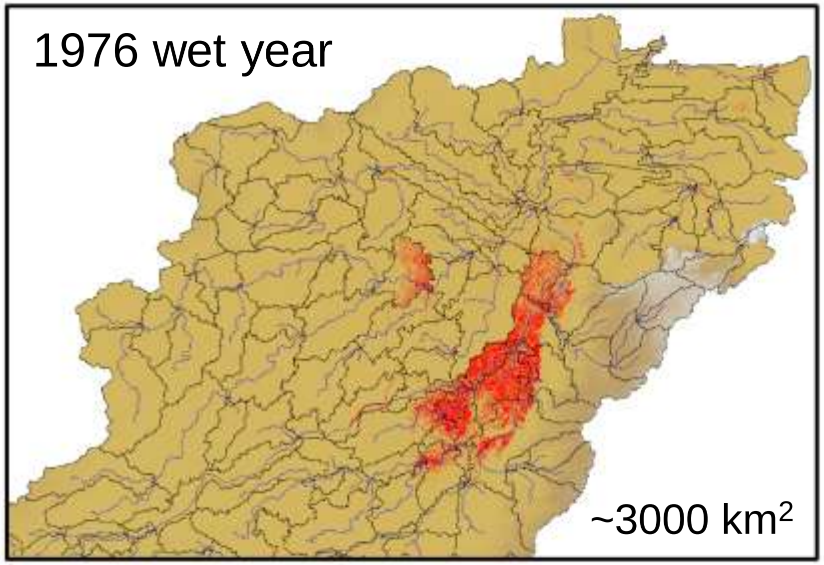
Map Display 1
Day 120
Display: rows=482 columns=642 resolution=916.446 Meter:
27806.888 1854132.199

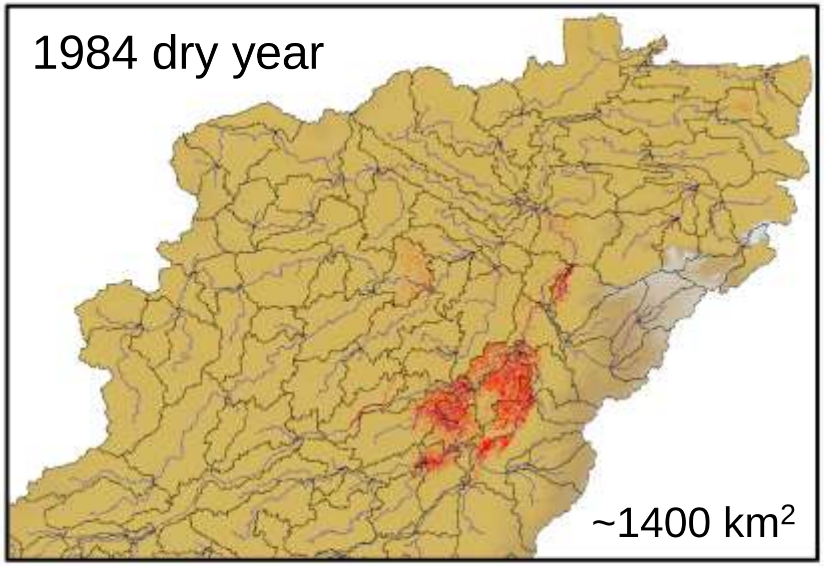
Inundation





Usable area for floating rice





Limitations of the Current Version

- **Scale issue**, the Inner Niger Delta is a huge (meso-scale) wetland, like the Sudd in Sudan (White Nile)
  - Can the inundation module be applied to small wetlands?
- Not a hydrodynamic model but process-based
- Not fully spatially explicit but “semi-explicit”
- Vegetation processes
- Ground water processes

Problems

- Accuracy of DEM, a **few centimeters** of elevation can have **large impacts** on inundation area
- Niger splits into **two rivers**
- Climate data
    - How reliable are GPCC and CRU rainfall data in West Africa?

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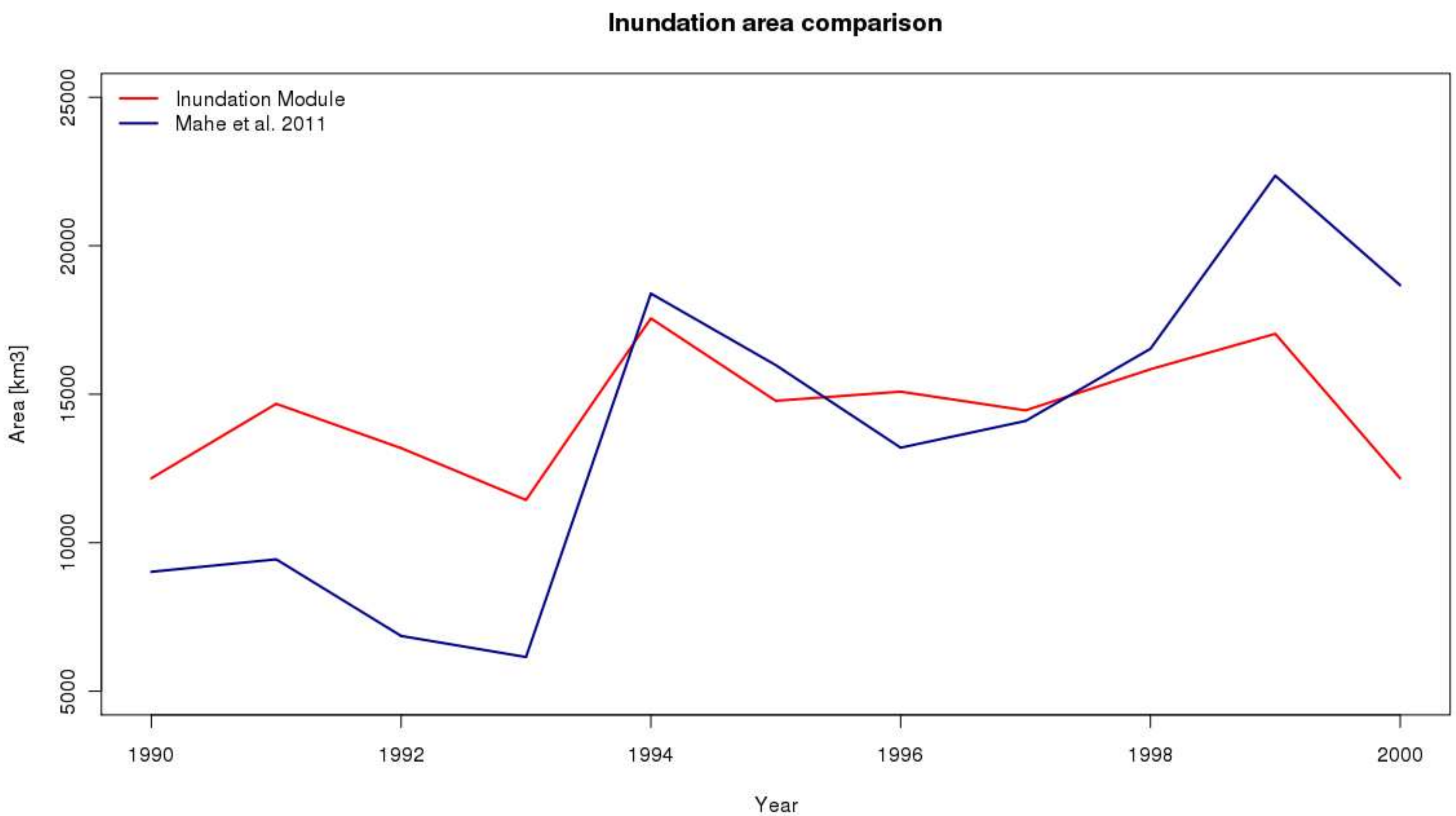
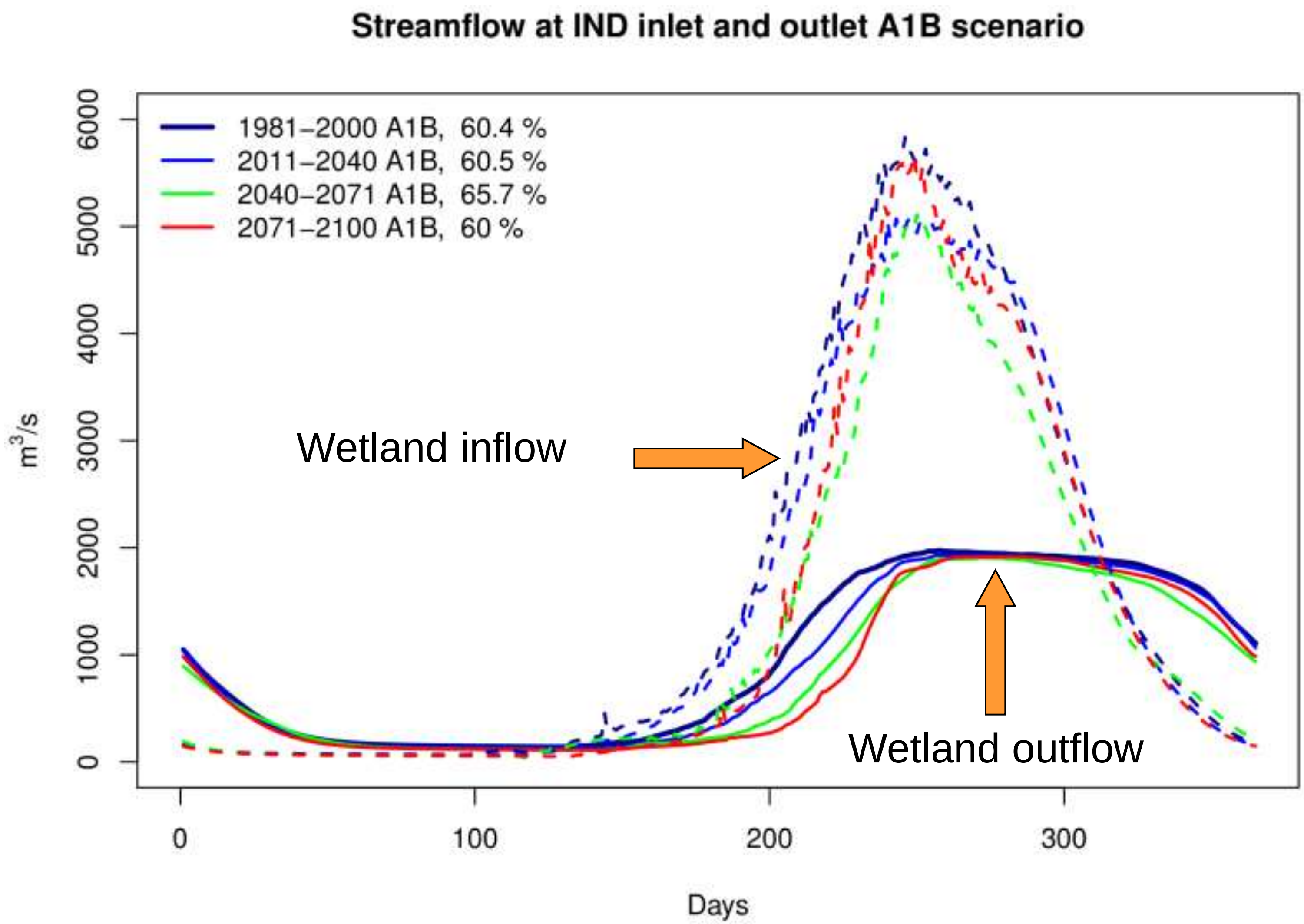
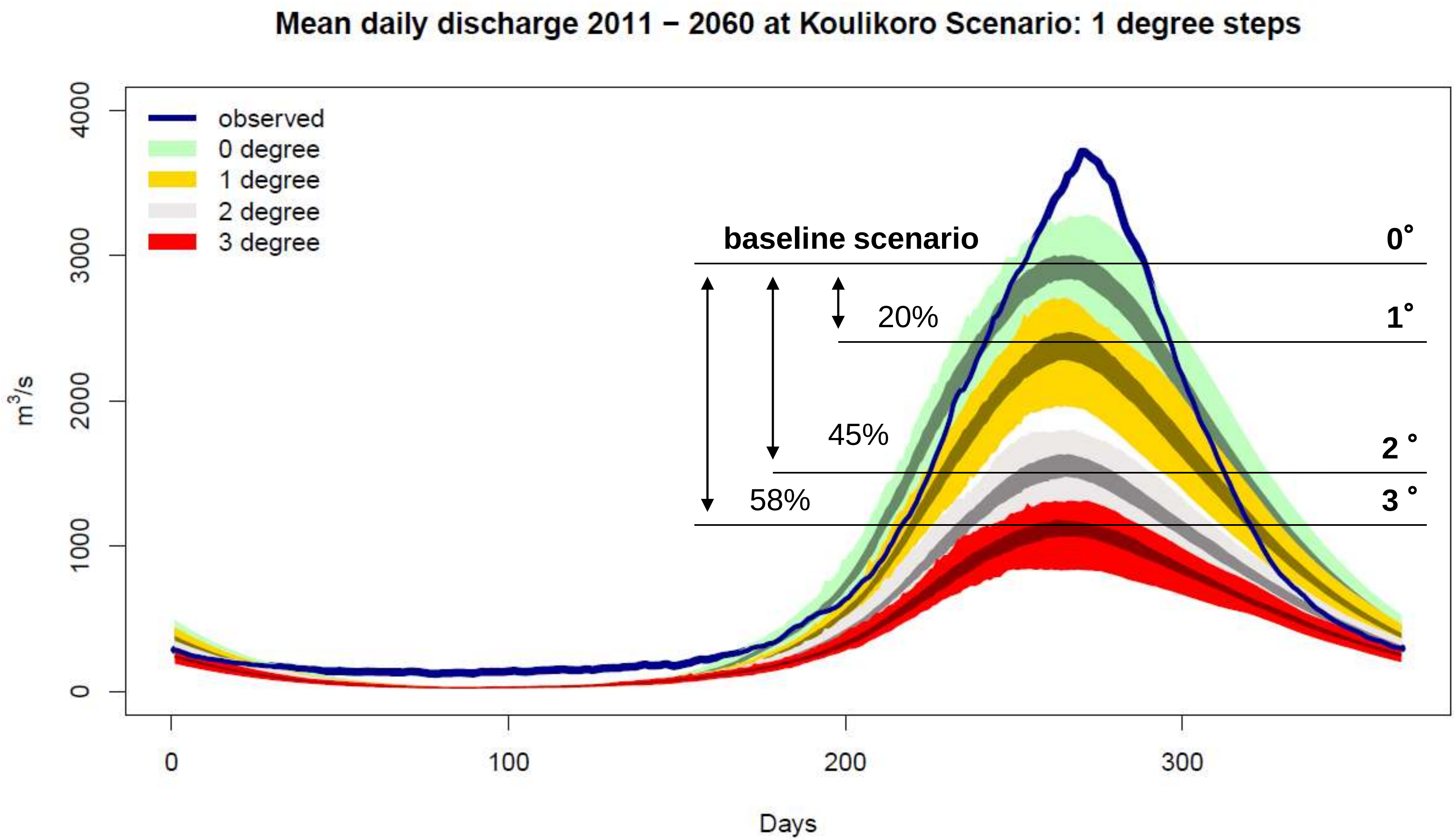
Thank you for your attention!


Inundation area comparison
Inundation Module
Mahe et al. 2011
Area [km3]
25000
20000
15000
10000
5000
1990
1992
1994
1996
1998
2000
Year


Streamflow at IND inlet and outlet A1B scenario
1981–2000 A1B, 60.4 %
2011–2040 A1B, 60.5 %
2040–2071 A1B, 65.7 %
2071–2100 A1B, 60 %
Wetland inflow
Wetland outflow
m3/s
0
1000
2000
3000
4000
5000
6000
0
100
200
300
Days

SWIM Streamflow + STAR Climate Scenarios



Preprocessing: Inundation Zones

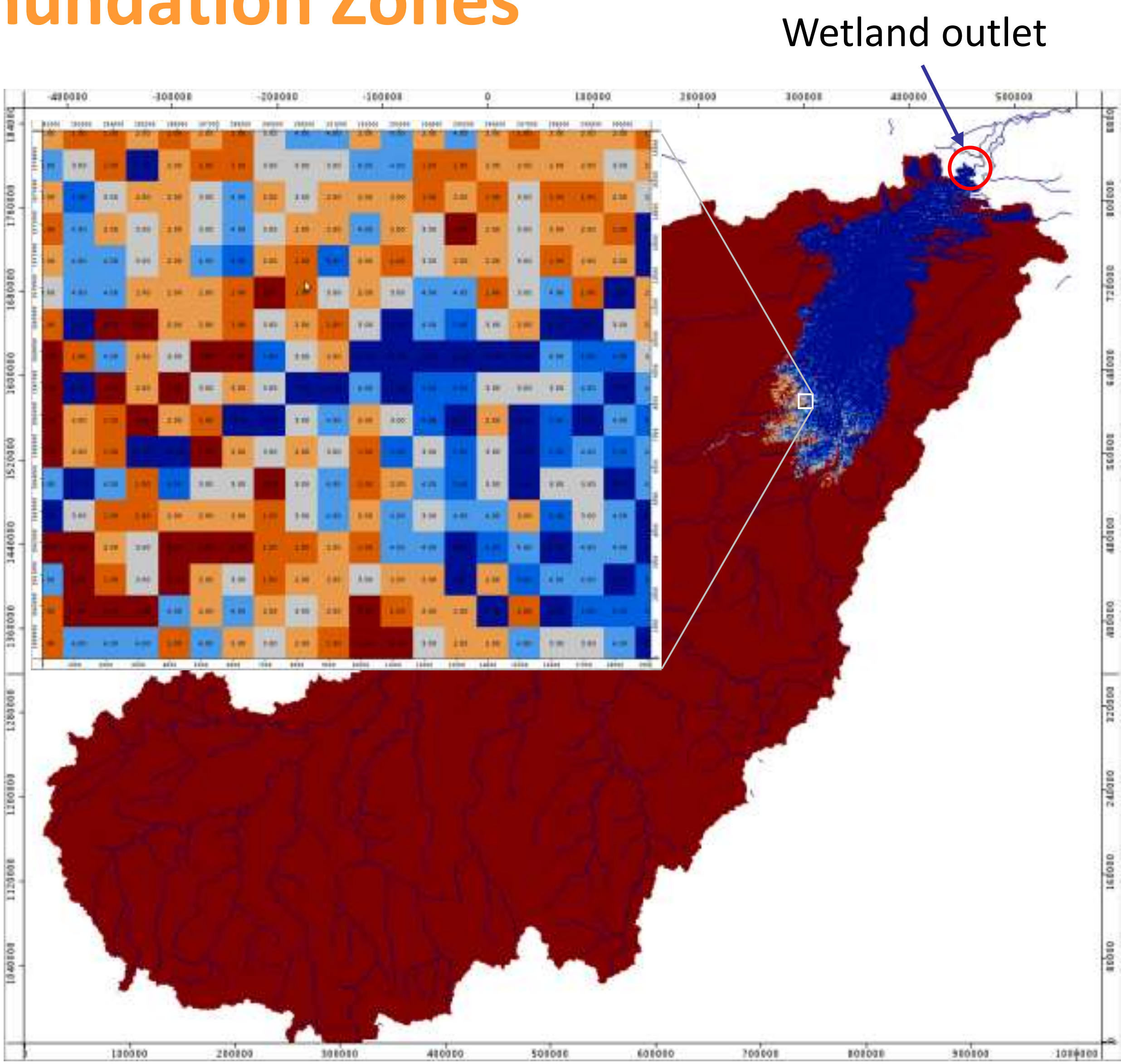
GRASS module: *r.lake*

Input

- DEM
- Flow accumulation
- xy-location
- water level
  (max. inundation depth)

Output

- Lake area [m^2]
- Inundation Zones [m^2]
- Volume per zone [m^3]



- How much water is evaporated in the delta?
- In average ~10 km^3/a (5-20 km^3)
  - New York City or Berlin inundated 10m

- Modification / control of routing during preprocessing
  - SWIM MapWindow Interface