Accounting for human impact on hydrology in the Land Surface Model ORCHIDEE

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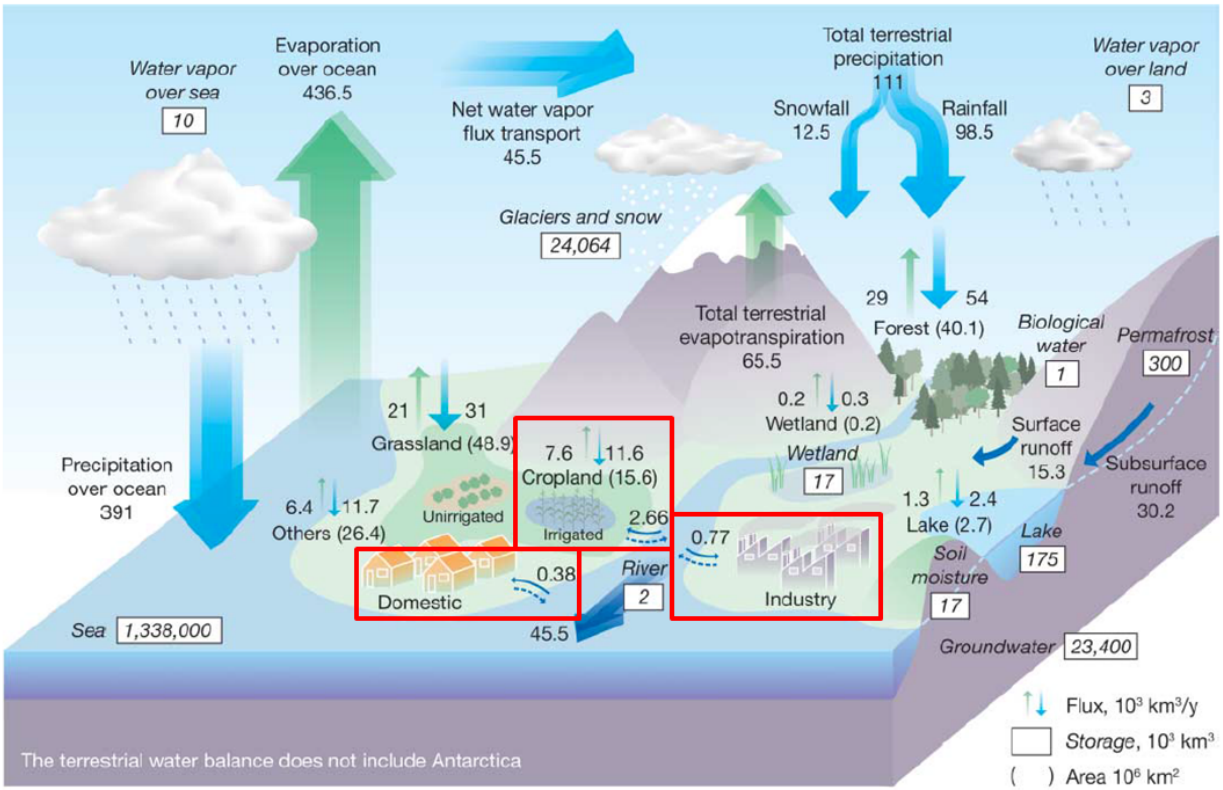
Water resources

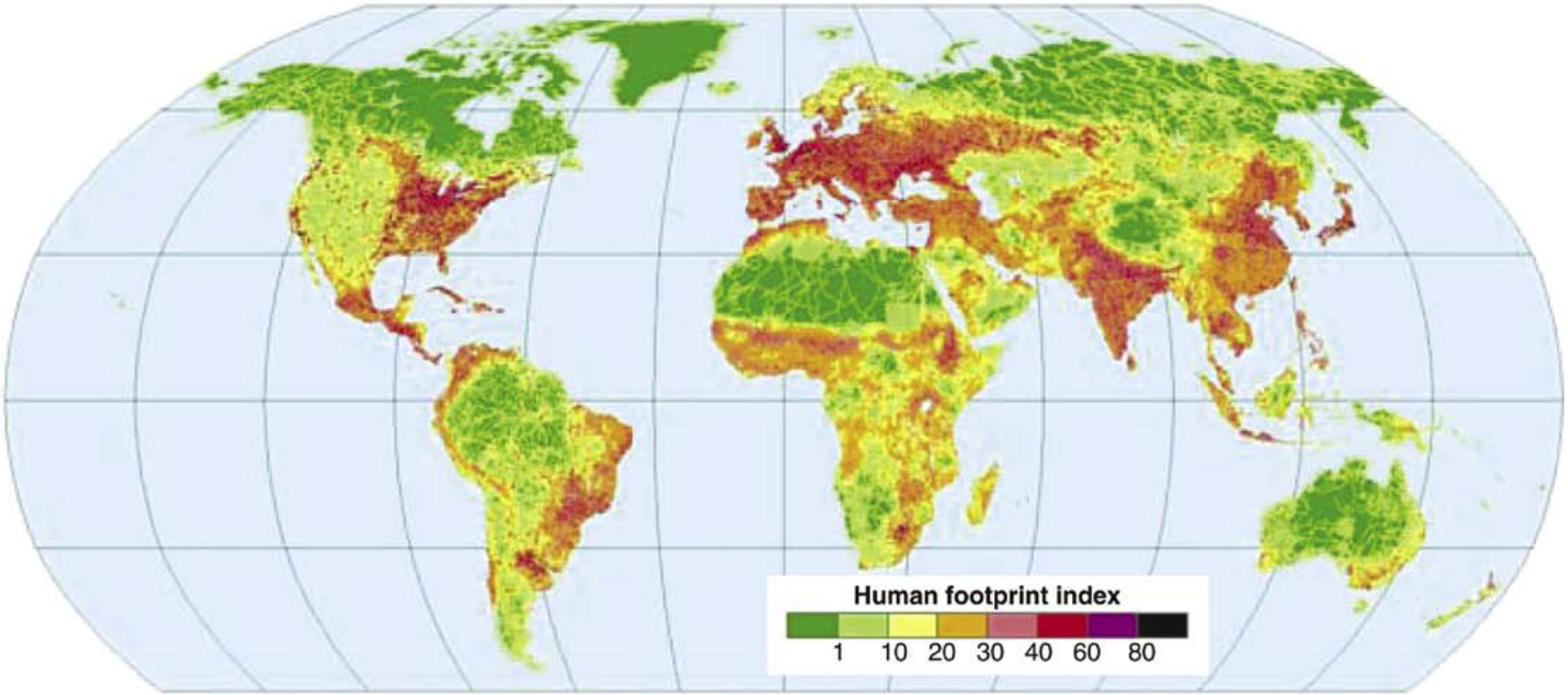
- fresh water: only **2.5%** of total water on Earth
- only **1%** of fresh water is easily accessible
- humans are able to use about **30%** of global runoff



Global hydrological fluxes and storages with natural and anthropogenic cycles (Oki and Kanae, 2006)

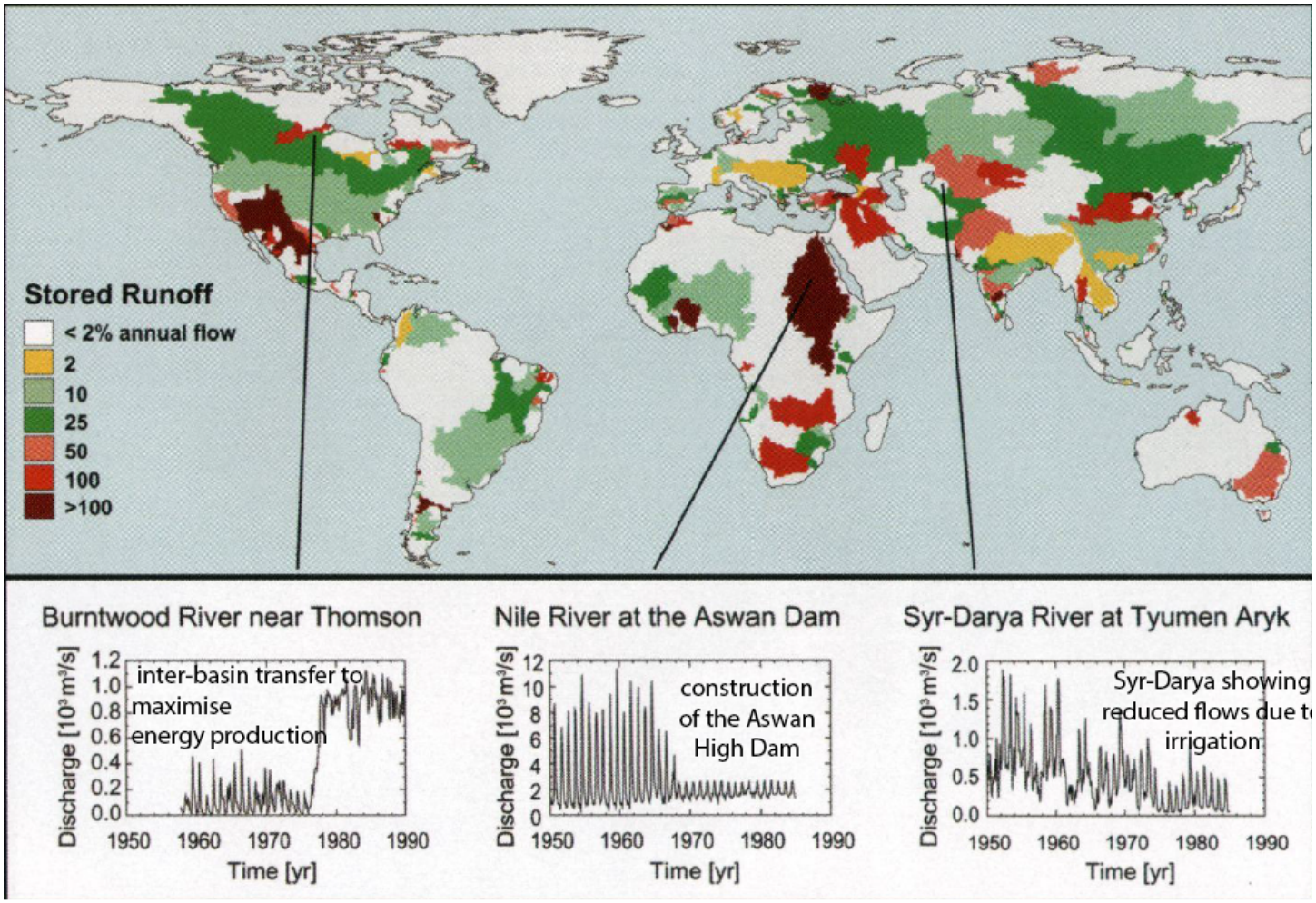
Human activities on the ecosystems

- high spatial variability in human influence



Intensity of human impact on global terrestrial ecosystems as estimated by **the Human Footprint Index**
(normalized index produced through an overlay of several global data layers on human population distribution, urban areas, roads, navigable rivers and various agricultural land uses)
(Hobbs et al., 2009)

Human activities on river discharges

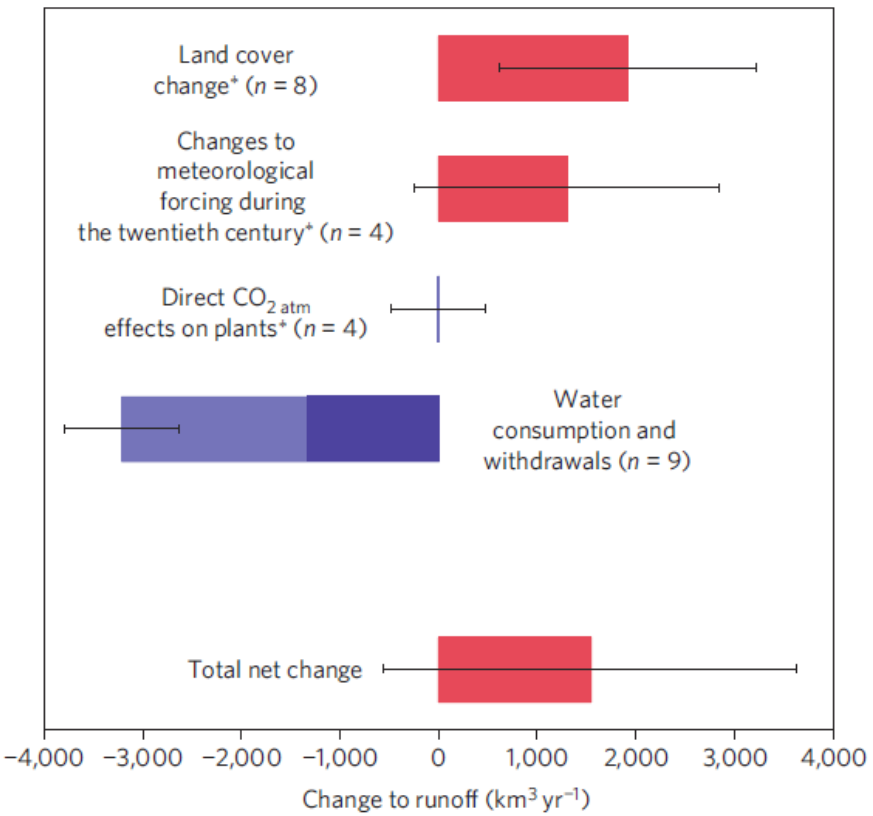


Flow distortion caused by water engineering in three heavily-regulated rivers

Vorosmarty et al., 2004

Human activities on runoff

- land cover change seems to increase runoff
  - but large uncertainties persist: what is the sign of net runoff total change?



Sterling et al. (2012)

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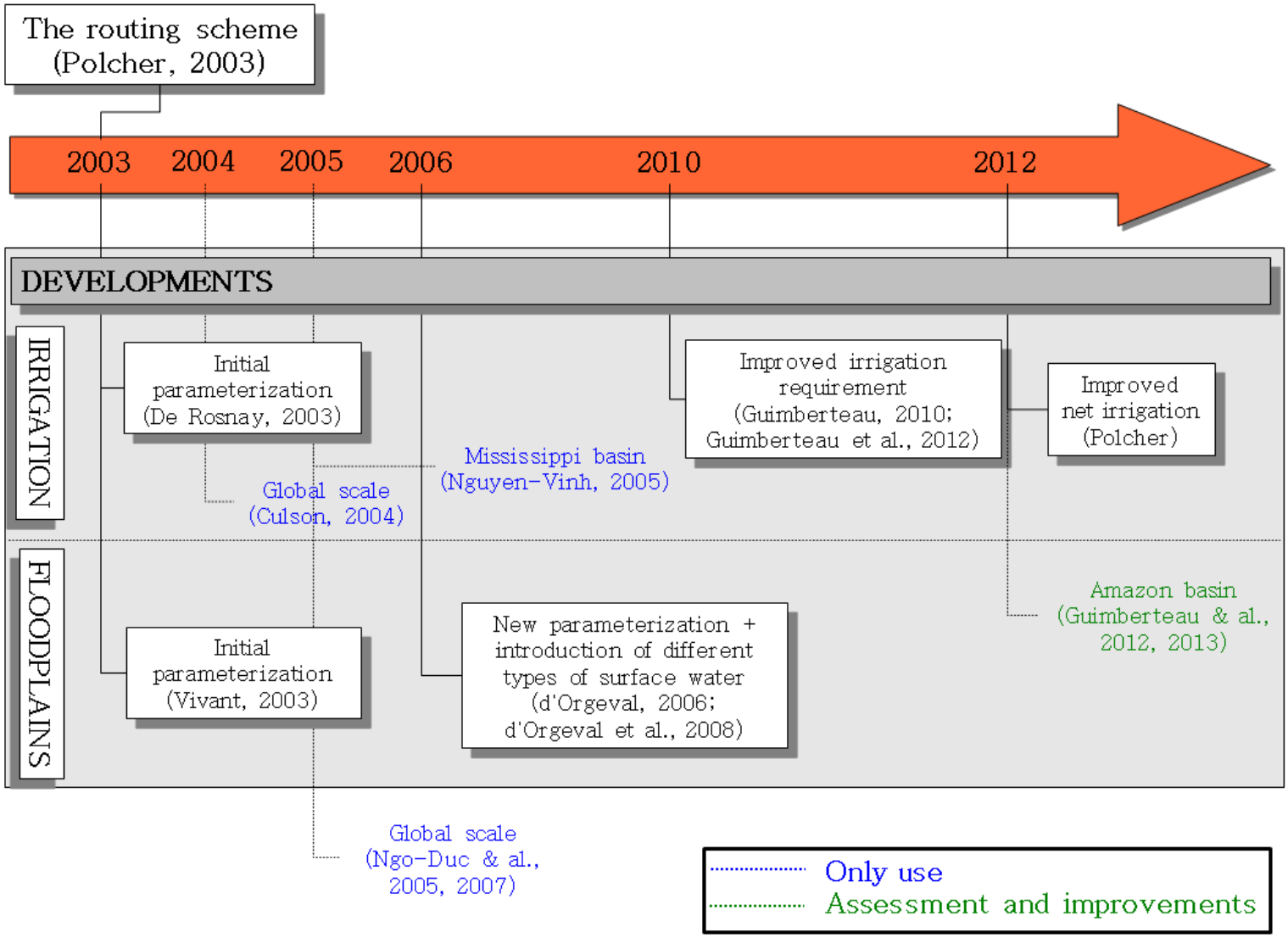
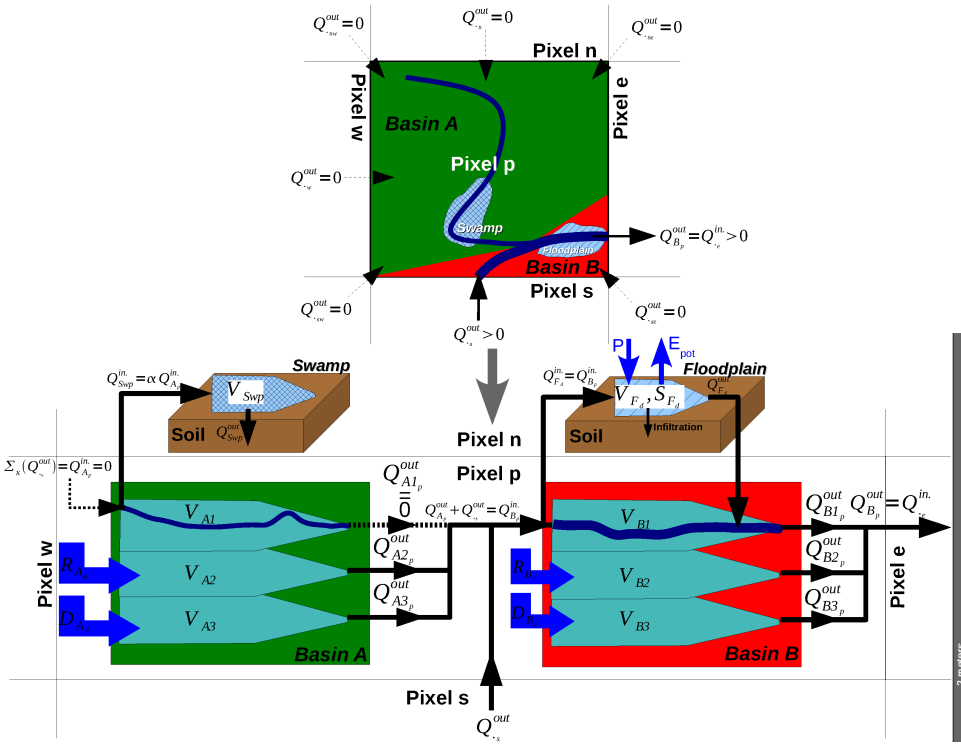
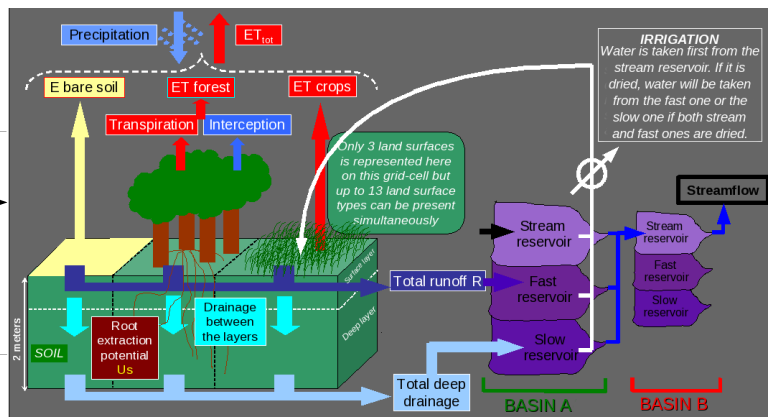
The routing scheme: historical overview



The functionning of the routing module





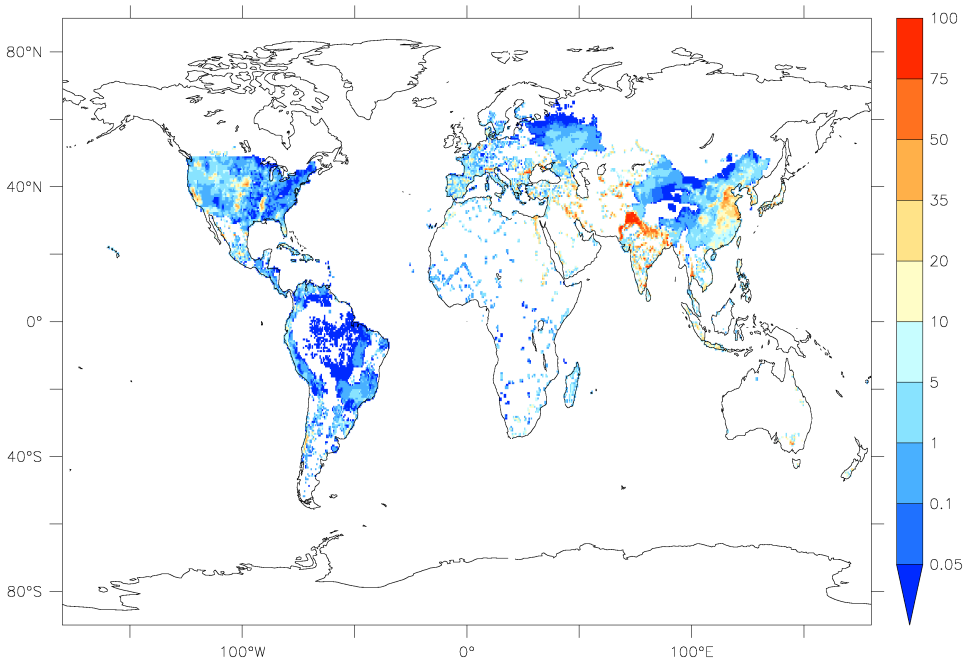
Routing scheme and floodplains

Irrigation

Guimberteau et al. (2012a)

Guimberteau et al. (2012b)

Example of human impact on hydrology: irrigation



Fractions equipped for irrigation (% of the grid box area) at 0.5°x0.5° spatial resolution from Döll and Siebert (1999, 2000, 2002) (Guimberteau et al., 2012b)

Areas equipped for irrigation: 301 million ha (Siebert et al., 2010)
Three hot spots:

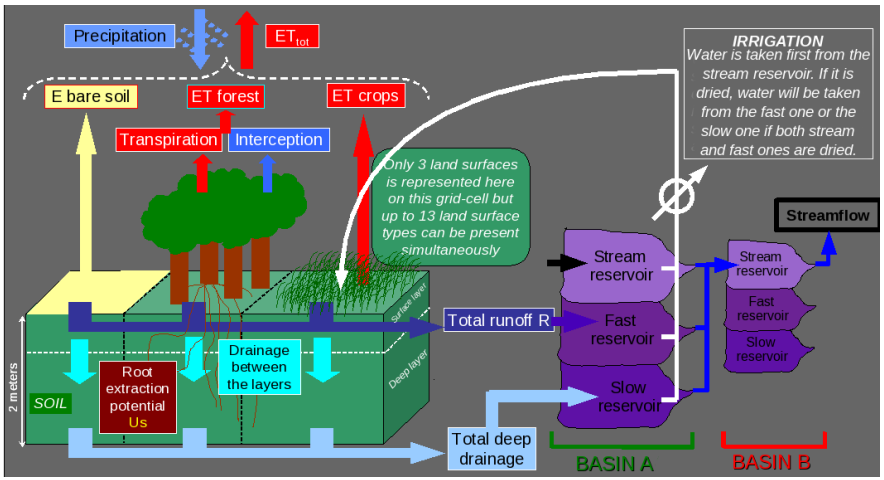
- India (60 million ha <=> 20% of total)
- China (55 million ha <=> 18% of total)
- USA (30 million ha <=> 10% of total)

Irrigation is the most important water use sector

- 70% of the global freshwater withdrawals (Shiklomanov, 2000)
- 90% of consumptive water uses

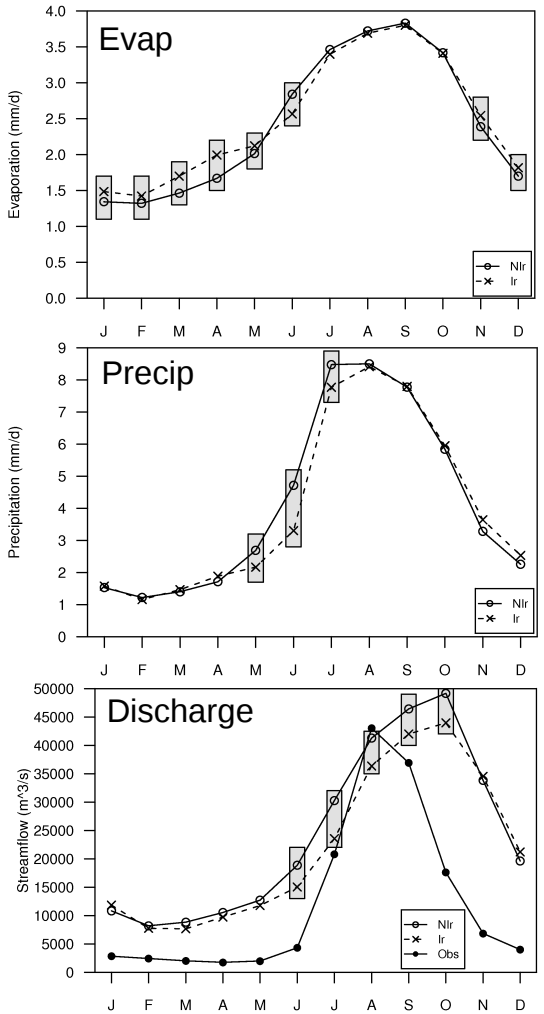
Irrigation with ORCHIDEE

- computation of water demand from the crops. Function of:
  - irrigated fraction of the mesh
  - potential transpiration
  - net water amount reaching the soil
- net irrigation computed given the demand AND the water availability in the routing reservoirs



Guimberteau et al. (2012b)

Irrigation impact on Indian monsoon



On average over India and 30 years

(Guimberteau et al., 2012b)

Feedbacks irrigation-monsoon precipitation

Winter-spring irrigation ($\sim$ 10% of precipitation)

$\Downarrow$

$\nearrow$ evaporation ($\sim$ +9%)

$\Downarrow$

Cooling (from February to May)

$\Downarrow$

$\searrow$ thermal contrast between ocean and continent

$\Downarrow$

Weakening of the monsoon onset early June

$\Downarrow$

$\searrow$ precipitation after the 20th May

$\Downarrow$

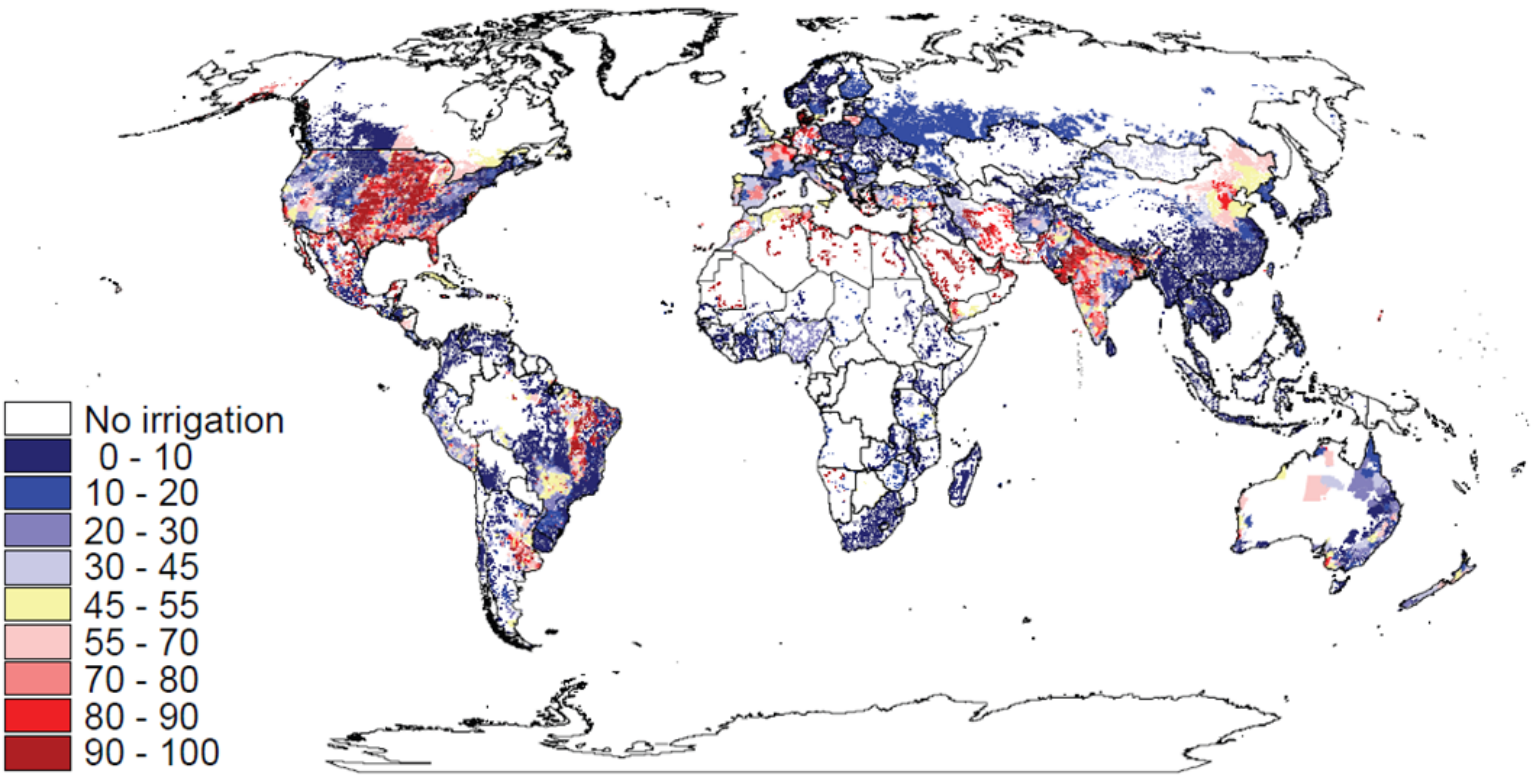
Warming of the continental surfaces

- delayed onset + water withdrawals by irrigation => $\searrow$ Ganges-Brahmaputra discharge

Next challenge for irrigation modelling: groundwater withdrawals

Siebert et al. (2010):

- 38% of areas equipped for irrigation are equipped for irrigation with groundwater
- consumptive groundwater use for irrigation: 43% of the total consumptive irrigation water use (1277 km^3/yr)



Percentage of area equipped for irrigation that is irrigated with groundwater per irrigated grid cell

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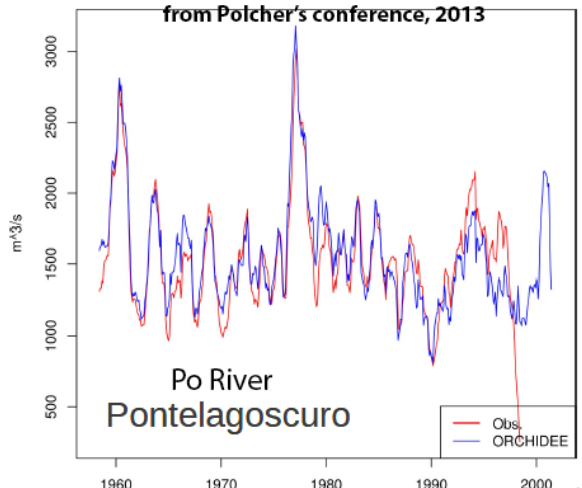
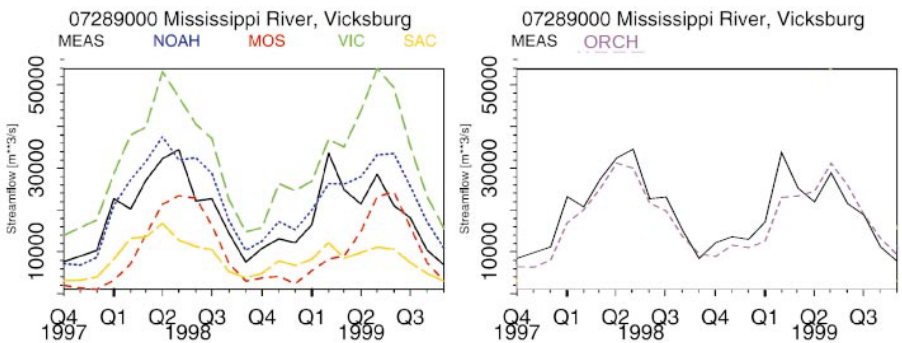
ORCHIDEE river discharges

- With ORCHIDEE, do we miss some processes?
  - sometimes it is clearly noted when results are compared with observations (ex: Ebro river)
  - but ORCHIDEE can simulate good streamflow variation (ex: Mississippi river) while river dams are not taken into account...





Guimberteau et al., 2009 (iLEAPS newsletter)

What human impacts in ORCHIDEE?

- irrigation ✔ (De Rosnay et al., 2003; Guimberteau et al., 2012b)
  - adduction of water from neighboring basins ✔ (Polcher, for WATCH project)
  - aquifer mining ✗ => linked to the project of groundwater component implementation (Ducharne, HDR 2011)
  - water diversion ✗ => ?
- river dam buildings ✗ => links with ORCHIDEE-ODDYCCEIA (Dumas, Nassopoulos)
- wetland drainage ✔ wetland functionning (Ringeval et al., 2012) => challenge: functionning with the floodplain scheme in the routing
- soil erosion (agriculture) ✗ => ?
- land-use change ✔ => (De Noblet, LUCID project)
  - desertification
  - deforestation
- urban developments ✗ => ?

Perspectives

- Start from the introduction of a groundwater component
- Going further in irrigation modelling:
  - temporally evolution of the irrigated surfaces
  - groundwater withdrawals
  - withdrawals from dams
- Towards new perspectives for the routing scheme:
  - river water temperatures
  - organic matter transport in the streams
- Urban developments
  - some examples of existent publications:
    - "Urban surface modeling and the meso-scale impact of cities" (Masson, 2006)
    - "Impact of Urban Effects on Precipitation in High Latitudes" (Mölders and Olson, 2004)
- Towards a water resources scheme?

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