Program of the day

09:30 - 10:15	**Introduction to the routing scheme**	**by Matthieu Guimberteau**
10:15 - 10:45	Implicit coupling to the atmosphere	by Frederique Cheruy
11:00 - 11:30	Why and when is a spin-up needed?	by Fabienne Maignan
11:45 - 13:00	Lunch in the IDRIS "cantine" employers restaurant	
13:00 - 14:30	Hands on session 2	
14:30 - 15:30	Introduction of the two soil hydrology schemes in ORCHIDEE : processes, parameters, options ...	by Agnès Ducharne
15:30 - 17:00	Hands on session 2 continues	

Introduction to the routing scheme in the land-surface model ORCHIDEE

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ORCHIDEE training course
Orsay, 11/07/2014

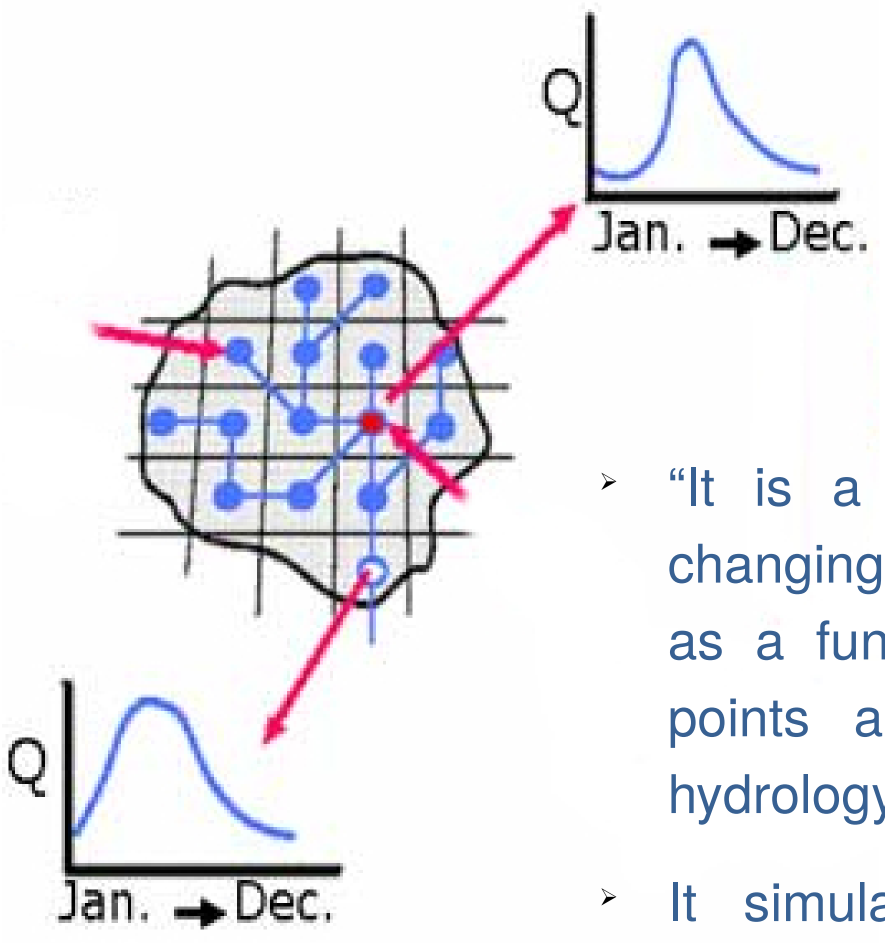
Outlines

- Generalities
- Routing scheme in ORCHIDEE
    - Inland and man-made wetlands
        - Irrigated lands
        - Floodplains
        - Swamps
        - Ponds
        - Endorheic lakes
- Applications
- Perspectives
- References

1

Generalities

What is a flow routing?

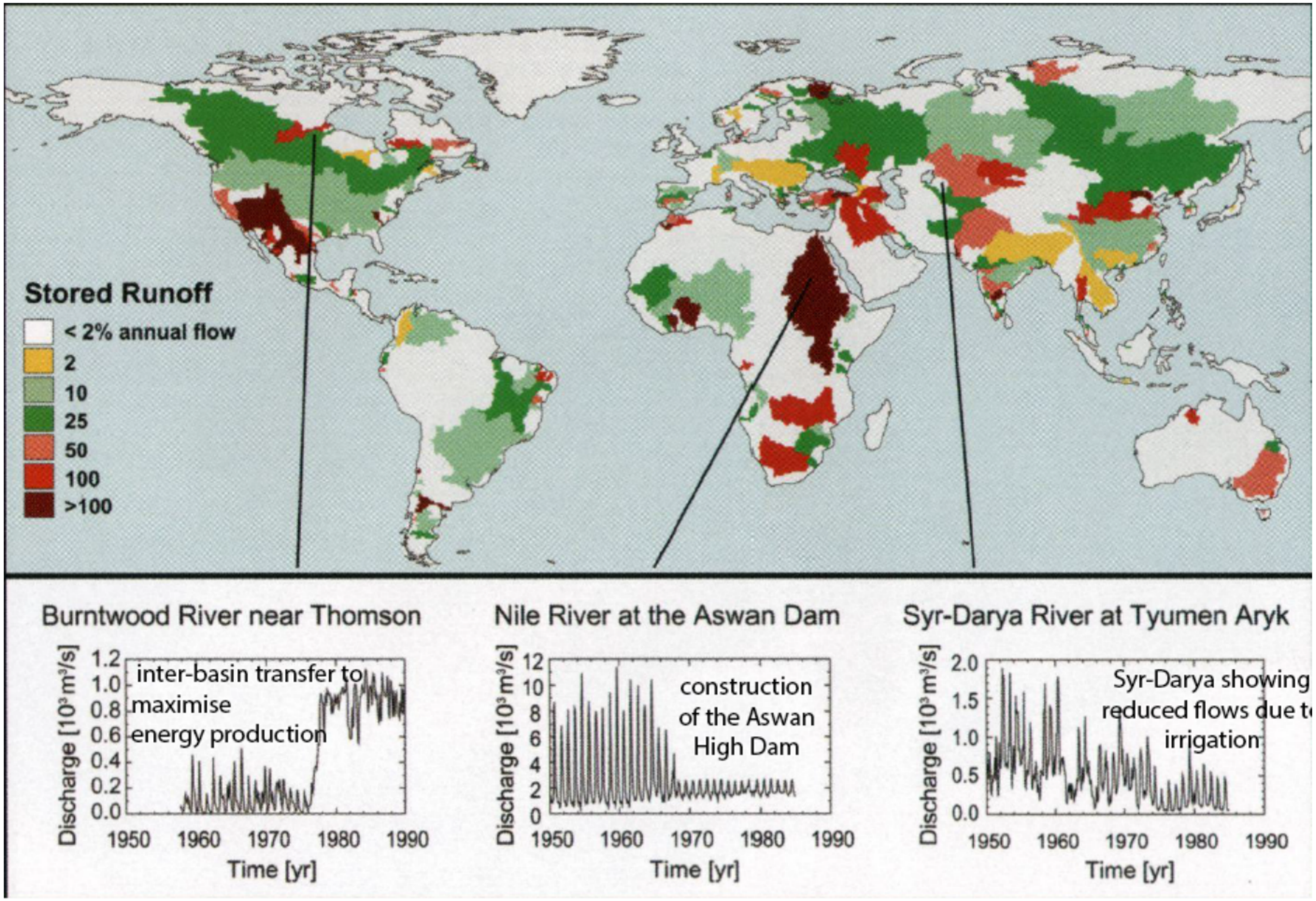


- "It is a computational procedure for predicting the changing magnitude, speed, and shape of a flood wave as a function of time (hydrographs) at one or more points along a watercourse" (Fread, Handbook of hydrology, 1992)
- It simulates the transport of runoff through river networks across continents (streamflow, river discharge) into the oceans

Why do we need it in GCMs ?

- Crucial for hydrological cycle closure (when coupled to the ocean model)
- It provides freshwater to the ocean (affects ocean salinity and thermohaline circulation)
- It gives independent measure of the performance of the hydrological cycle of the GCM: comparison of simulated streamflow with river gauge data
    - if both streamflow and precipitation given with reasonable accuracy => check of evaporation accuracy
- It enables studies of climate change impacts on water resources and the hydrology of the basins
- ...

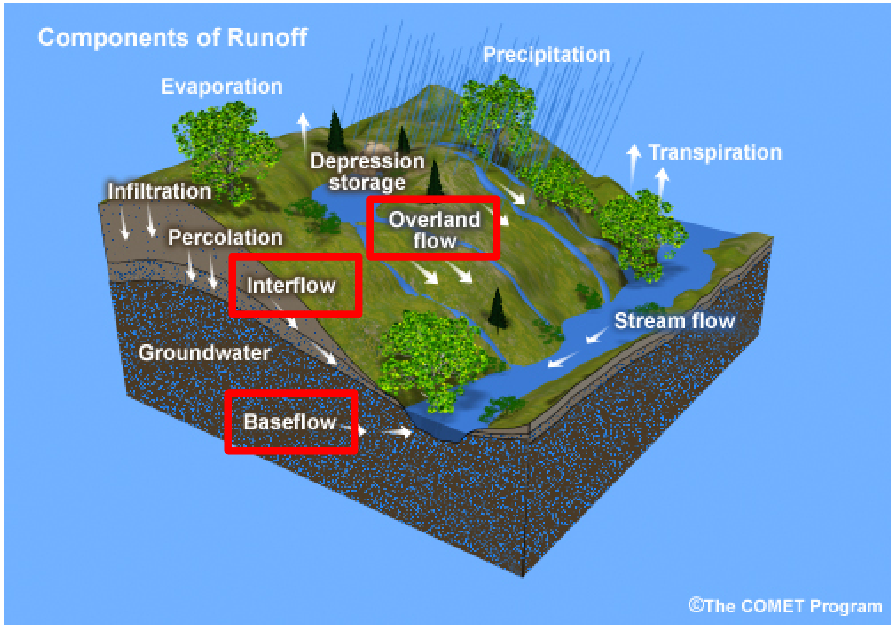
Human activities on river discharge



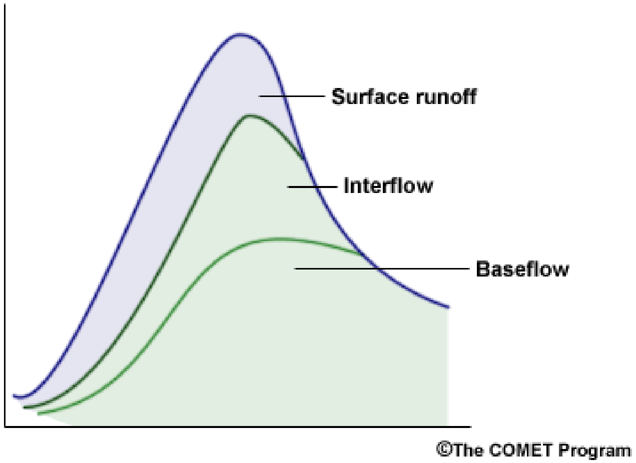
Flow distortion caused by water engineering in three heavily-regulated rivers

Vorosmarty et al., 2004

Lateral waterflow components

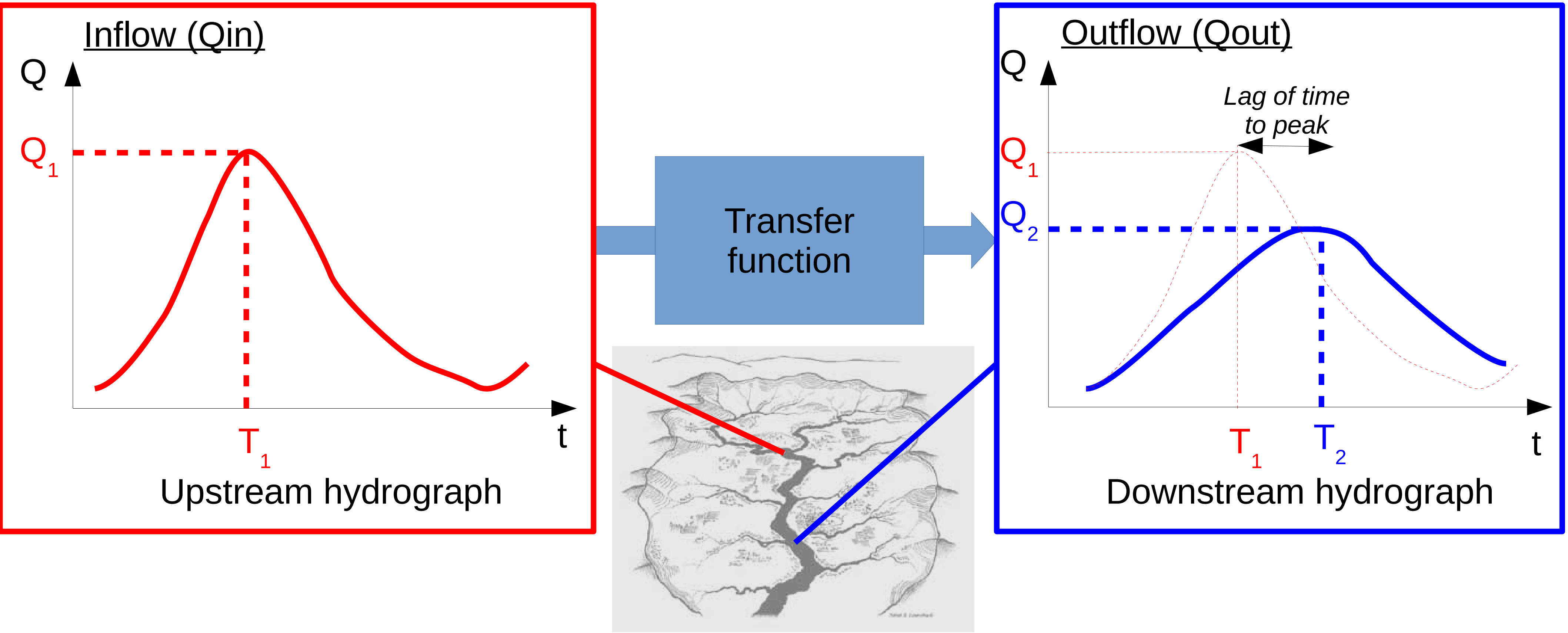


Surface Flow from Runoff Hydrograph



Lateral waterflow components

- **Overland flow (surface runoff)**: flow of water that does not infiltrate and travels relatively quickly towards the stream channel
- **Interflow (subsurface runoff)**: portion of infiltrated throughfall that moves laterally through the upper soil layers until it reaches the stream channel
- **Baseflow (groundwater runoff)**: portion of infiltrated throughfall that reaches watertables by deep drainage and then discharges into streams



- As flood wave travels downstream, it undergoes:
  - outflow peak attenuation ($Q_2 < Q_1$)
  - outflow timing delay ($T_2 > T_1$)

2

The routing scheme in ORCHIDEE

- Overview
- River network
- Transfer between reservoirs

2.1

The routing scheme in ORCHIDEE

- Overview

- River network
- Transfer between reservoirs

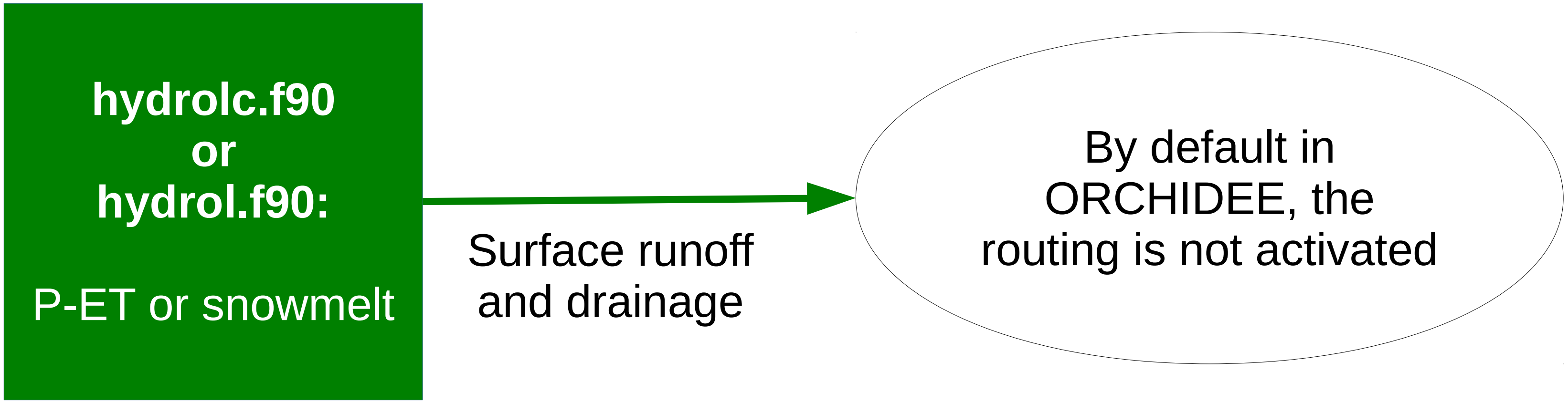
Basic functioning

- Based on existing routing schemes:
  - Ledoux (Phd Thesis, 1980)
  - Miller et al. (J. Climate, 1994)
  - Hagemann and Dümenil (Clim. Dyn., 1998)
  - Ducharne et al. (J. Hydrol., 2003)
- routing .f90 introduced by Jan Polcher (HDR, 2003) in SECHIBA

Basic functioning

- “Cell-to-cell” or “cell-based” methodology
  - simulation of the transport of runoff generated within the modeling units (e.g. grid cells), through river networks across continents into the oceans
  - a watershed can be represented as a single grid cell, a cascade of n equal grid cells, or a network of n equal grid cells (based on Singh (Hydrologic systems, 1989))
    - division of a watershed into a set of interconnected grid cells
    - each of the grid cell is approximated as a cascade of n linear reservoirs
- Computation of hydrographs at any grid cell and not only at the outlet

From precipitation to river discharge in ORCHIDEE



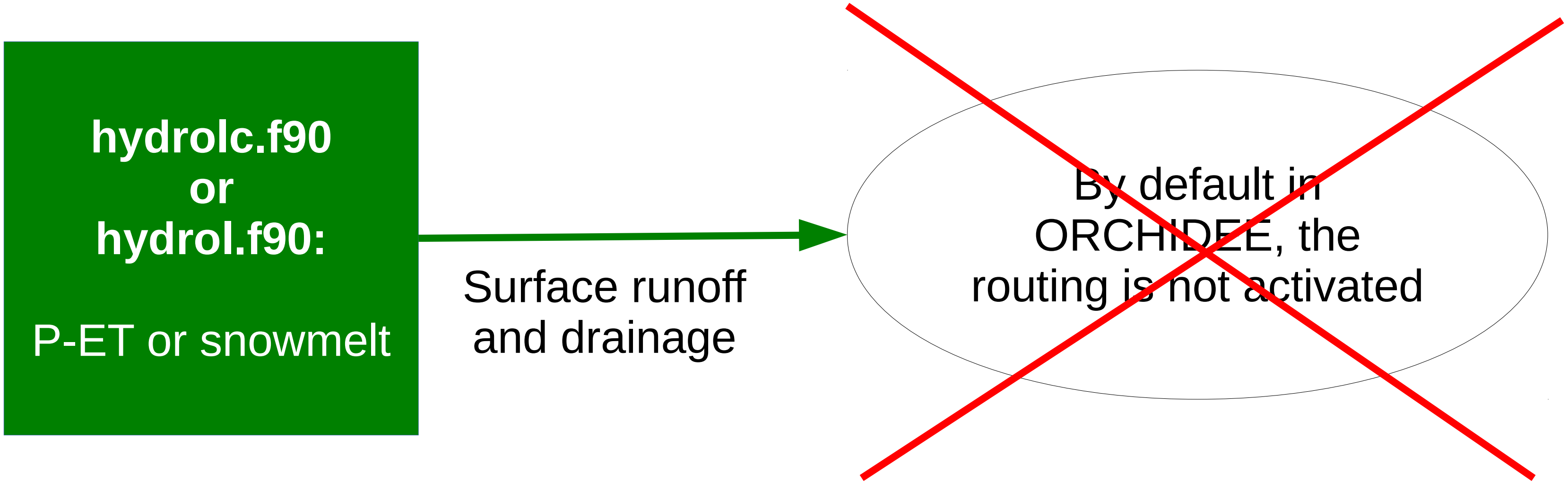
hydrolc.f90
or
hydrol.f90:

P-ET or snowmelt

Surface runoff
and drainage

By default in
ORCHIDEE, the
routing is not activated

From precipitation to river discharge in ORCHIDEE



hydrolc.f90
or
hydrol.f90:

P-ET or snowmelt

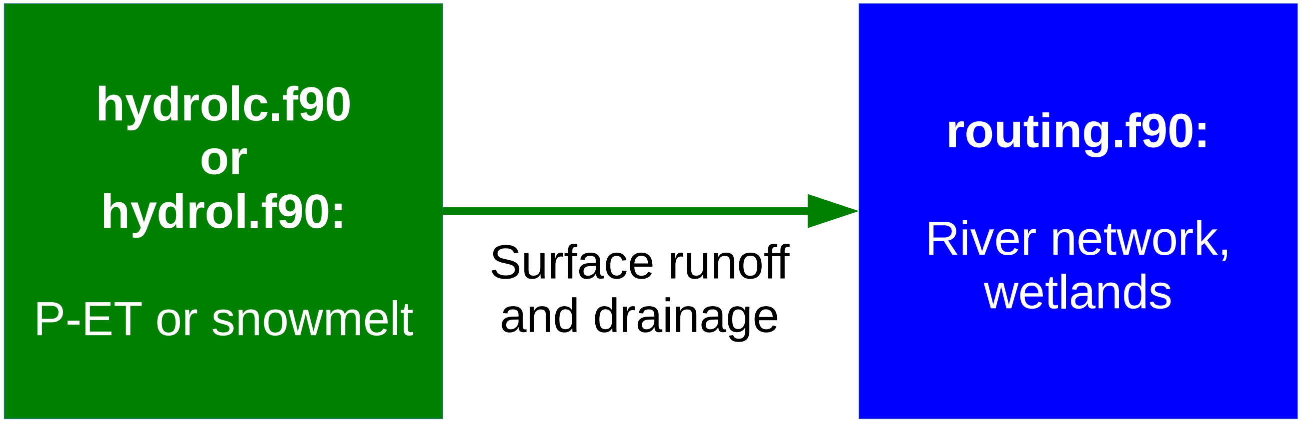
Surface runoff
and drainage

By default in
ORCHIDEE, the
routing is not activated

To activate it:

- put **RIVER_ROUTING = y** in the run.def
  or
- put **ROUTING=y** in sechiba.card

From precipitation to river discharge in ORCHIDEE



hydrolc.f90
or
hydrol.f90:

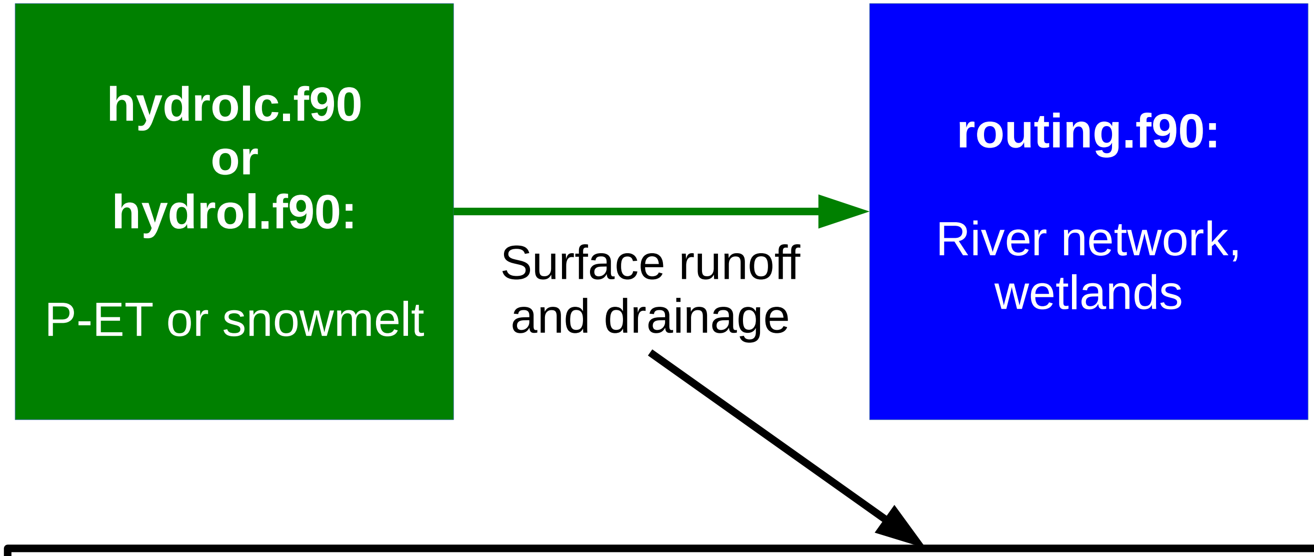
P-ET or snowmelt

Surface runoff
and drainage

routing.f90:

River network,
wetlands

From precipitation to river discharge in ORCHIDEE



hydrolc.f90
or
hydrol.f90:

P-ET or snowmelt

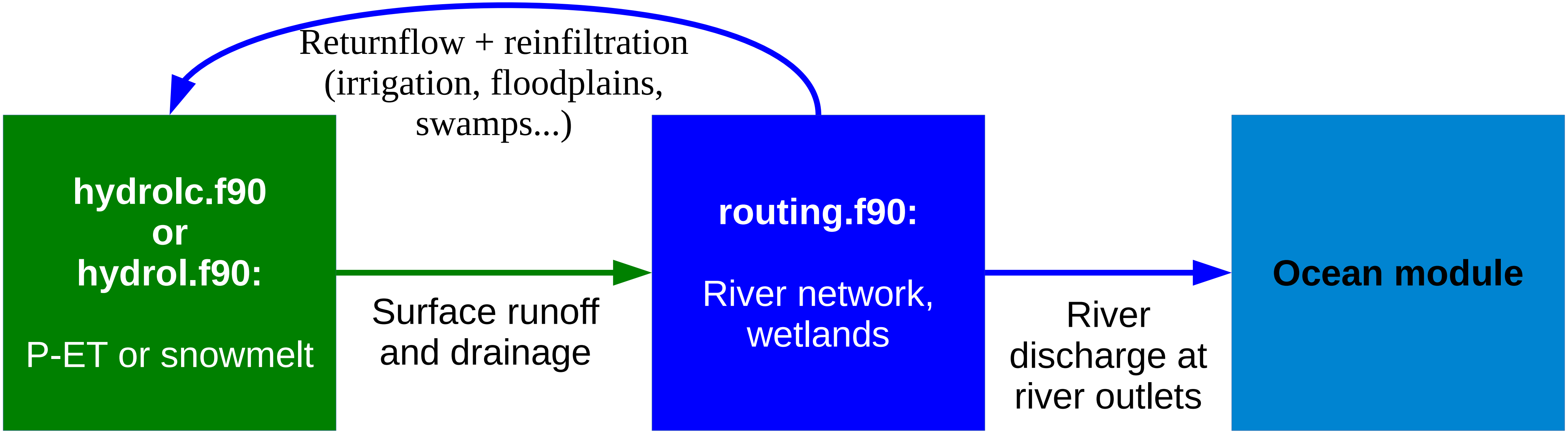
Surface runoff and drainage

routing.f90:

River network, wetlands

- 2-layer soil hydrology scheme (hydrolc.f90) => R (runoff)
    - 0.05*R = Rs (surface runoff)
    - 0.95*R = D (drainage)
- 11-layer soil hydrology scheme => Rs and D

From precipitation to river discharge in ORCHIDEE



Returnflow + reinfiltration (irrigation, floodplains, swamps...)

hydrolc.f90 or hydrol.f90:

P-ET or snowmelt

Surface runoff and drainage

routing.f90:

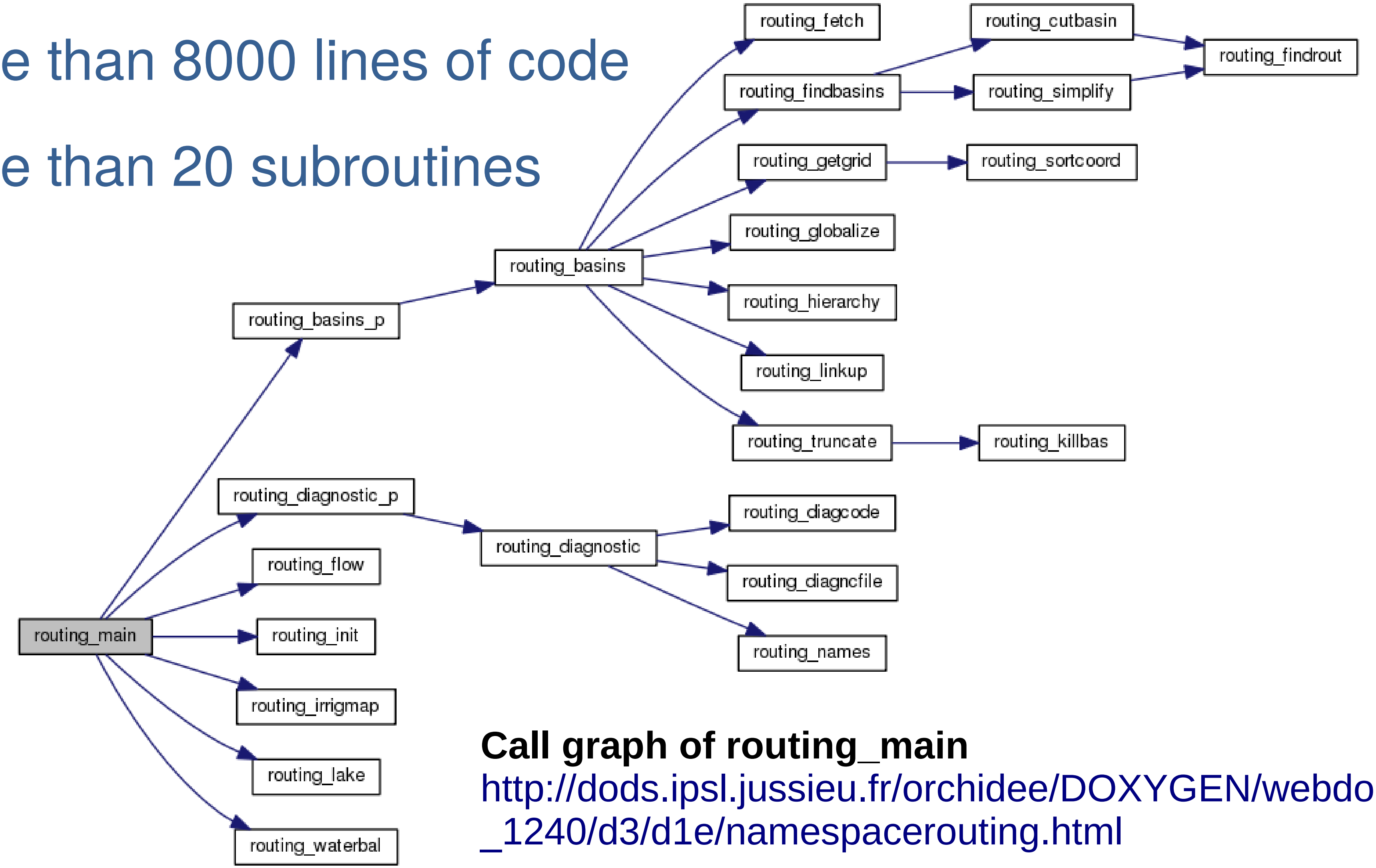
River network, wetlands

River discharge at river outlets

Ocean module

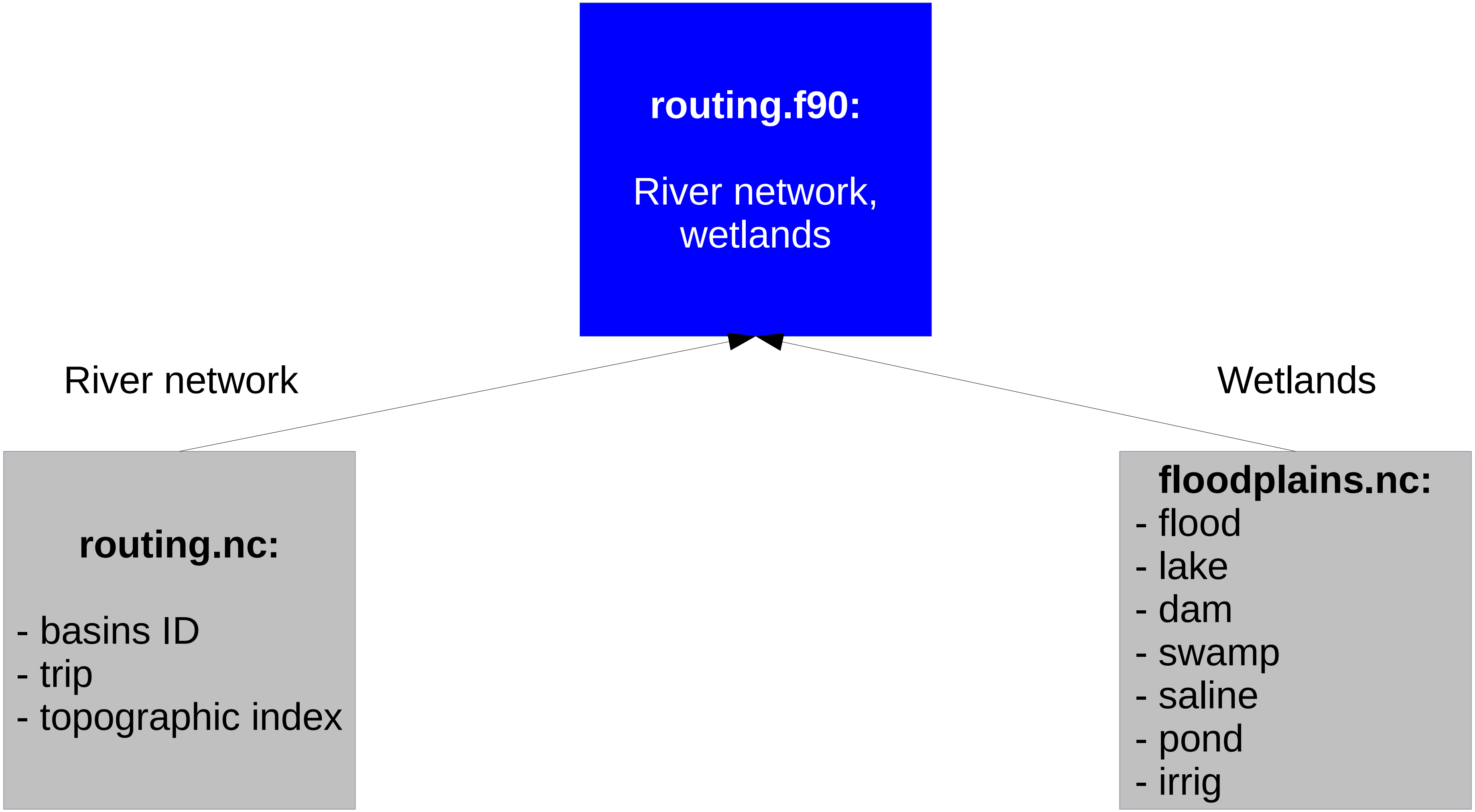
routing.f90

- More than 8000 lines of code
- More than 20 subroutines



Call graph of routing_main
http://dods.ipsl.jussieu.fr/orchidee/DOXYGEN/webdoc_1240/d3/d1e/namespacerouting.html

Maps read by routing.f90



routing.f90:

River network,
wetlands

River network

Wetlands

routing.nc:

- basins ID
- trip
- topographic index

floodplains.nc:

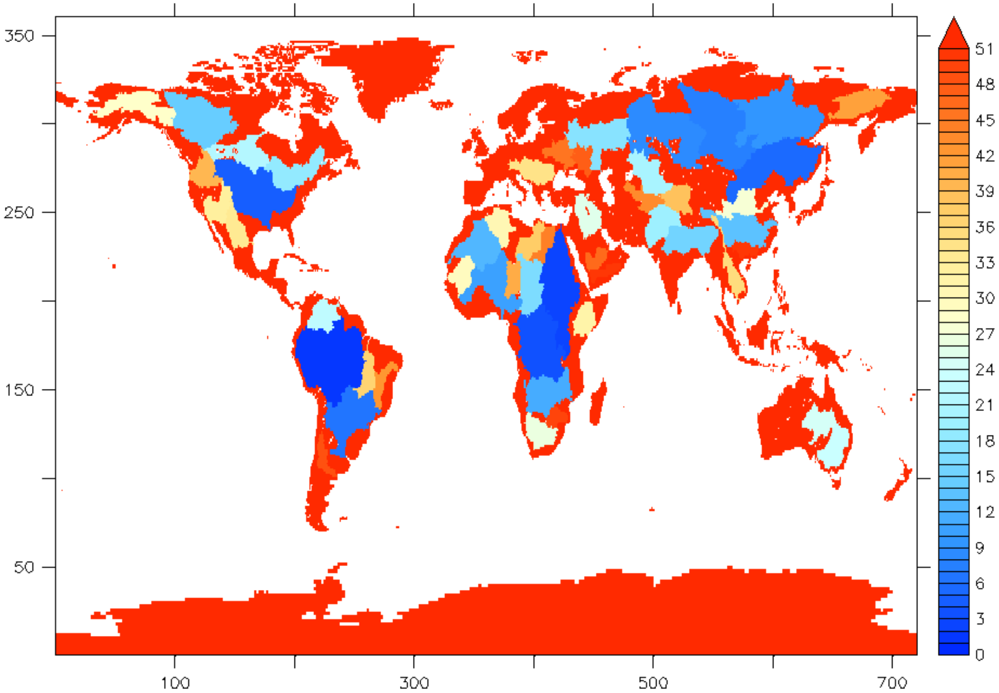
- flood
- lake
- dam
- swamp
- saline
- pond
- irrig

2.2

The routing scheme in ORCHIDEE

- Overview
- **River network**
- Transfer between reservoirs

Basin map

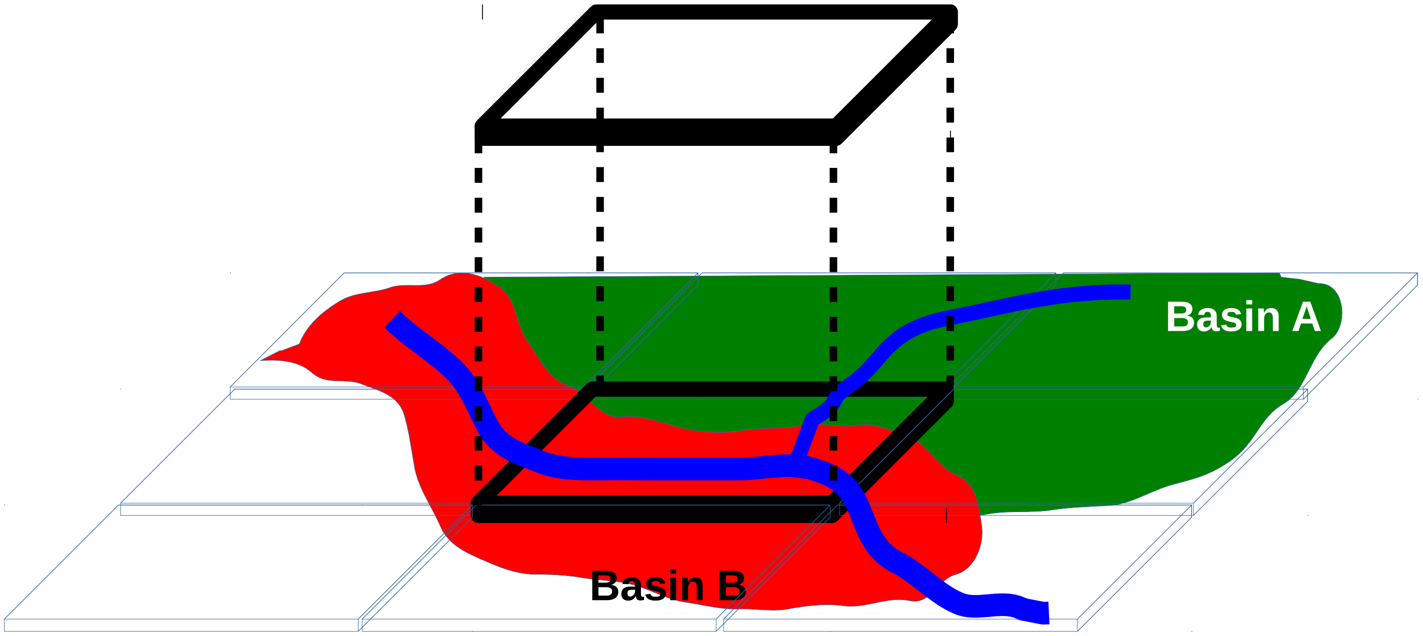


IDs of the 50 largest basins

- Basin map: 6930 basins available at 0.5°x0.5° spatial resolution
  - 6152: continental non-glacierized land area (Vörösmarty et al., 2000) available at 0.5°x0.5° spatial resolution
    - sizes ranges from ~ 390 km² to ~ 5.8.10^6 km² (Amazon basin)
  - 778: continental glacierized land area (Greenland and the poles) from TRIP (Total Runoff Integrating Pathways) (Oki et al., 1999; Oki and Sud, 1998) available at 1.0°x1.0° spatial resolution
- By default in the code, the 50 largest basins of the running area are selected in the code (num_largest parameter)
- Attribution of a unique ID by the map

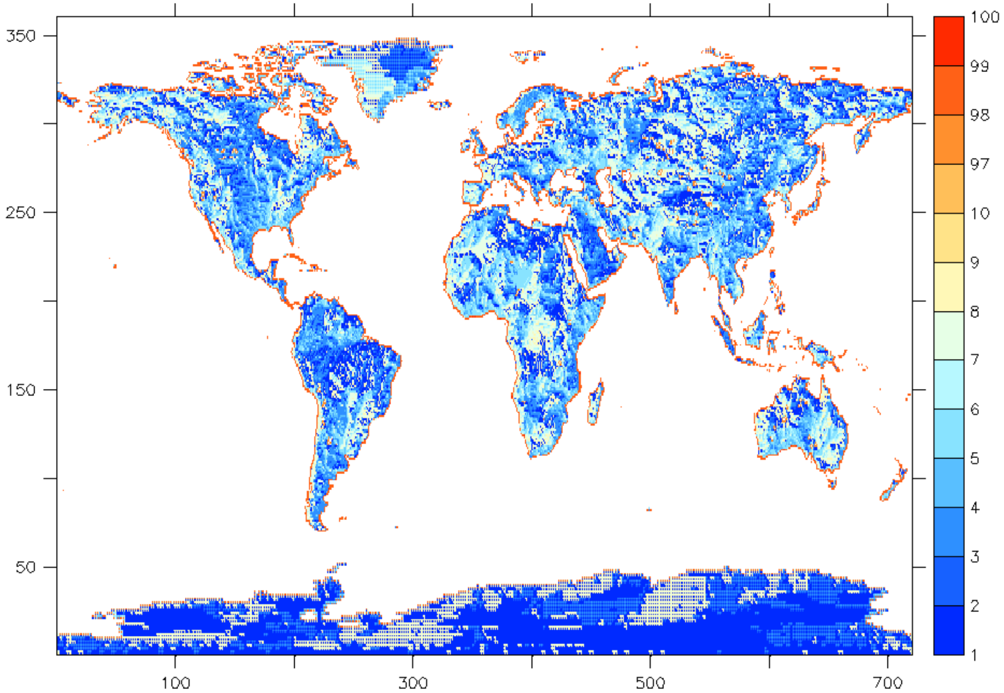
Basin map

- The spatial resolution of the atmospheric grid cell is coarser (>0.5°) than that of the routing → more than one basins can be included in the grid-cell
- Truncation: by default in the code, no more than 7 basins can be included in a grid cell (nbasmax parameter)



Trip map

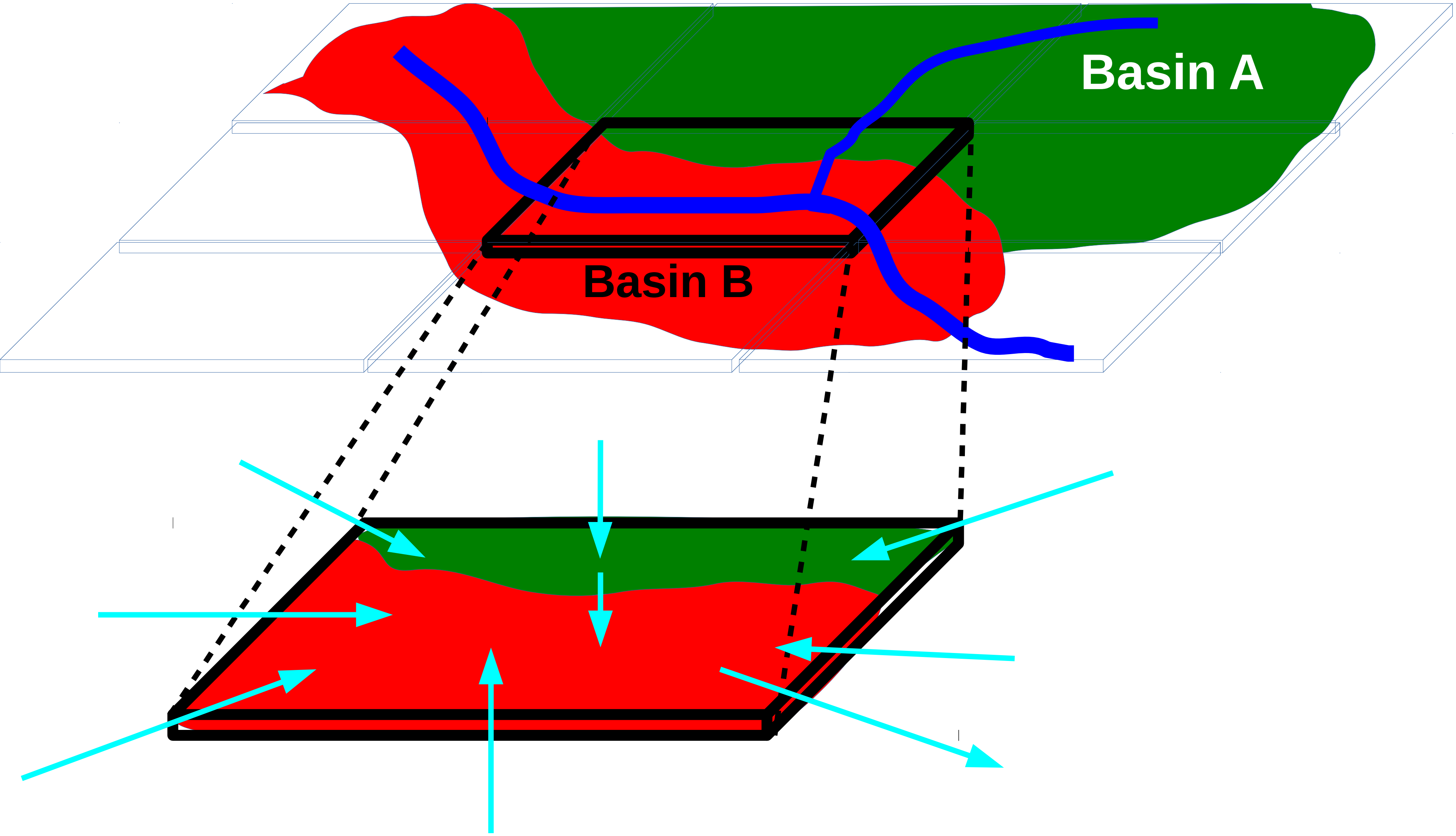
- Map at 0.5°x0.5° spatial resolution from the data of Vörösmarty et al. (2000) and Oki et al. (1999)
- For each grid cell, the map provides single flow direction among the 11 possibilities attributed by numbers in the code:
  - 8 directions (1→8) towards another grid cell
  - 3 other directions:
    - 97 → lake inflow
    - 98 → coastalflow (diffusive into the oceans)
    - 99 → riverflow (river discharge into the oceans)



Numbers giving the flow directions between grid cells

8	1	2
7		3
6	5	4

The basins (and grid cells) are now connected

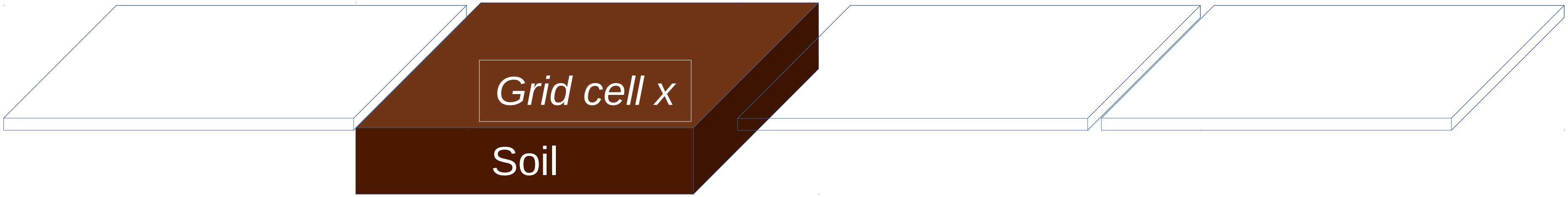


2.3

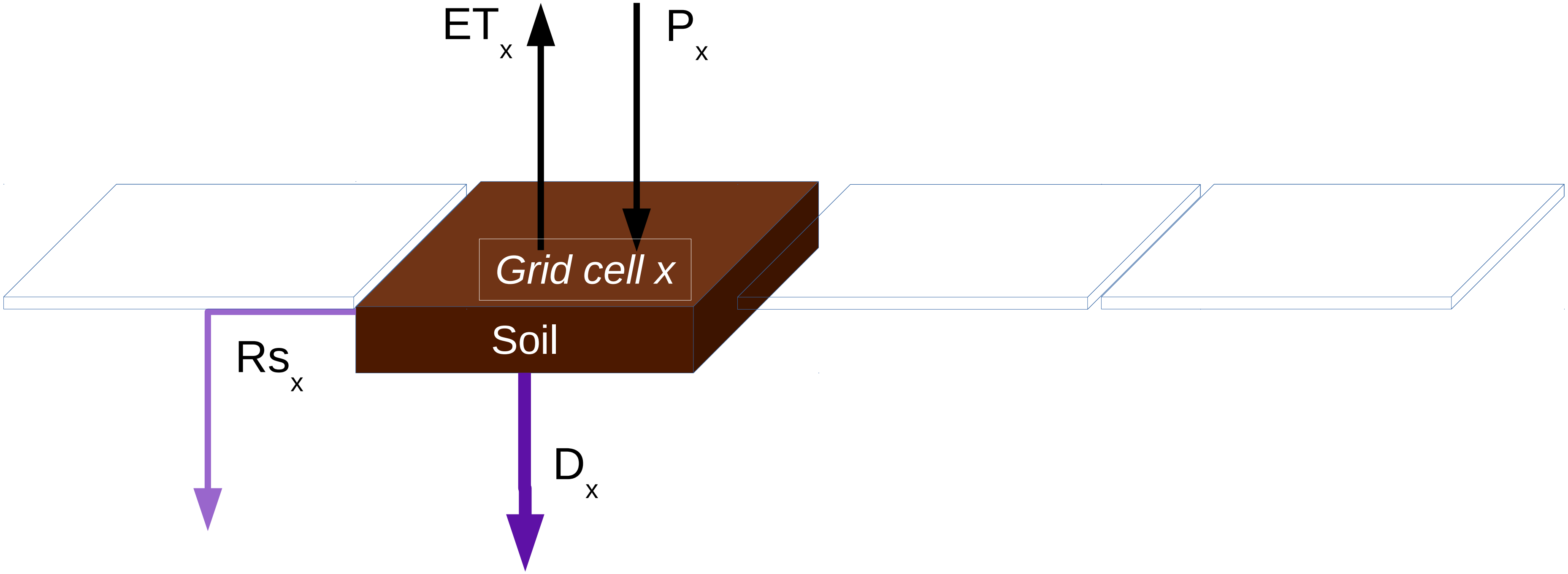
The routing scheme in ORCHIDEE

- Overview
- River network
- **Transfer between reservoirs**

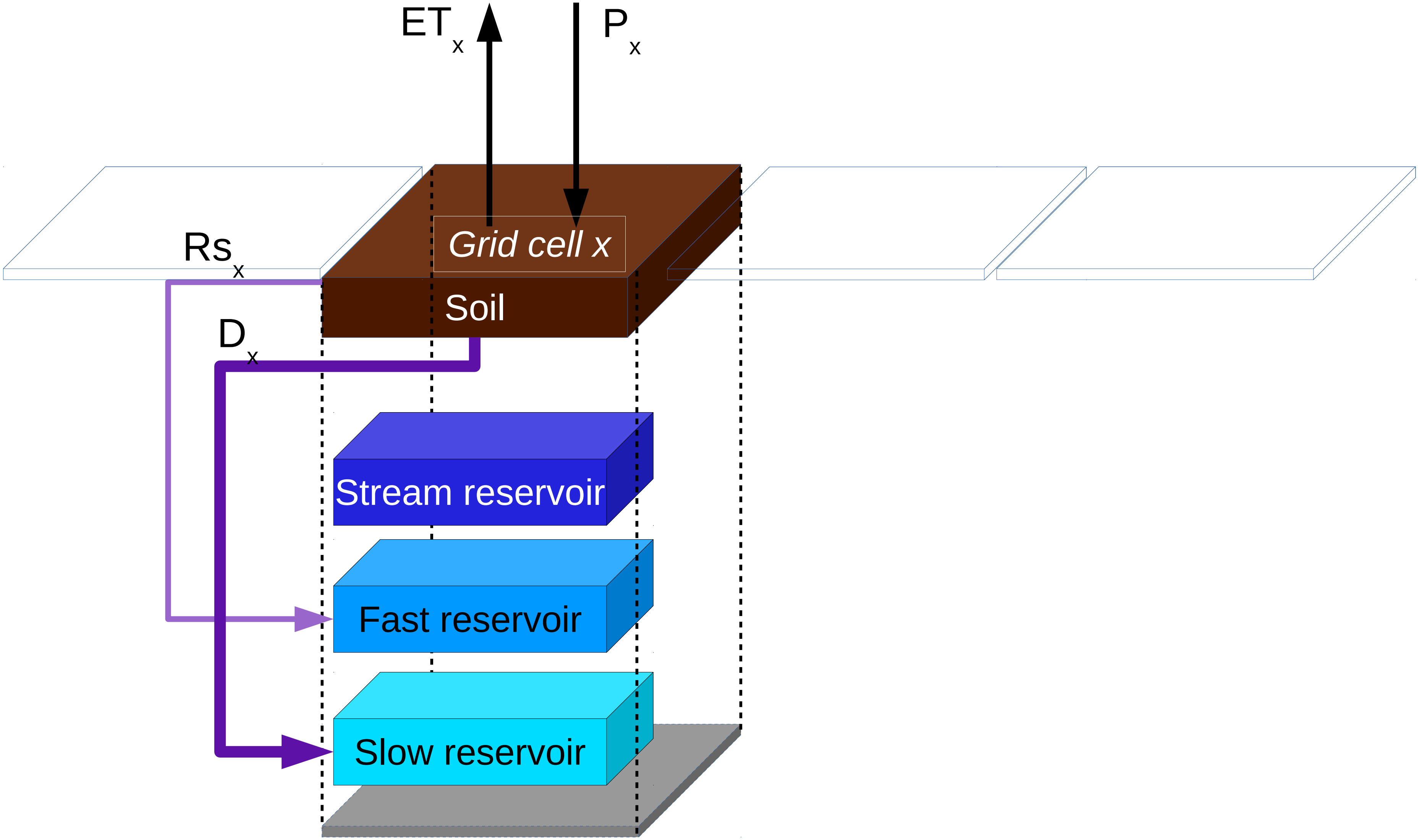
Transfer of runoff into the reservoirs



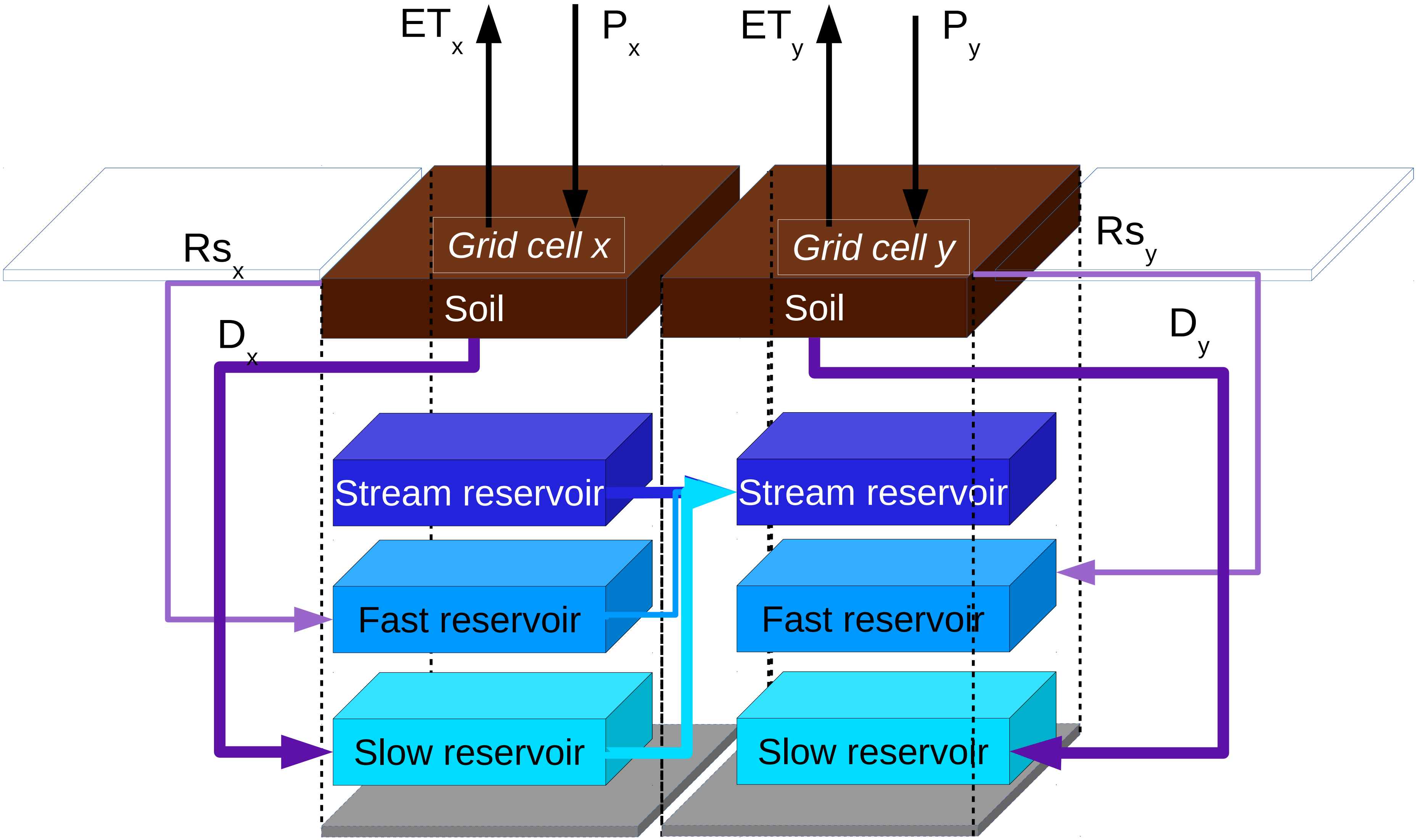
Transfer of runoff into the reservoirs



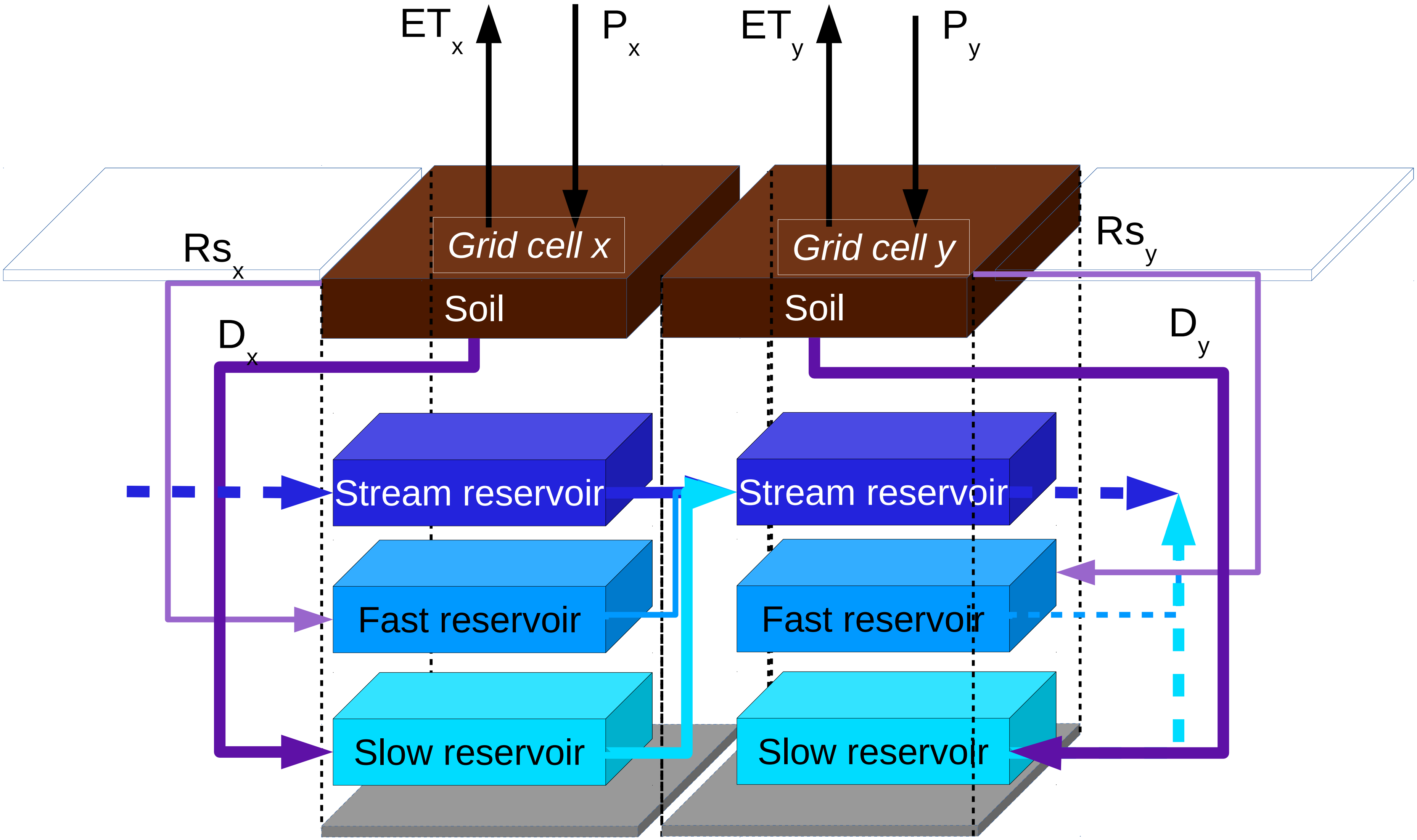
Transfer of runoff into the reservoirs



Transfer of runoff into the reservoirs



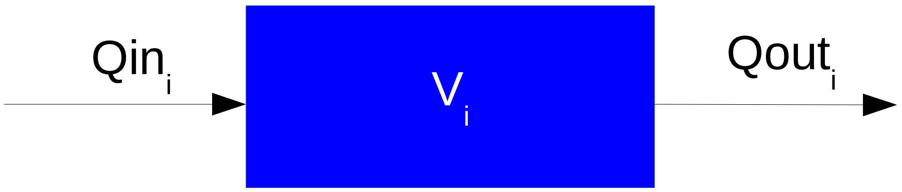
Transfer of runoff into the reservoirs

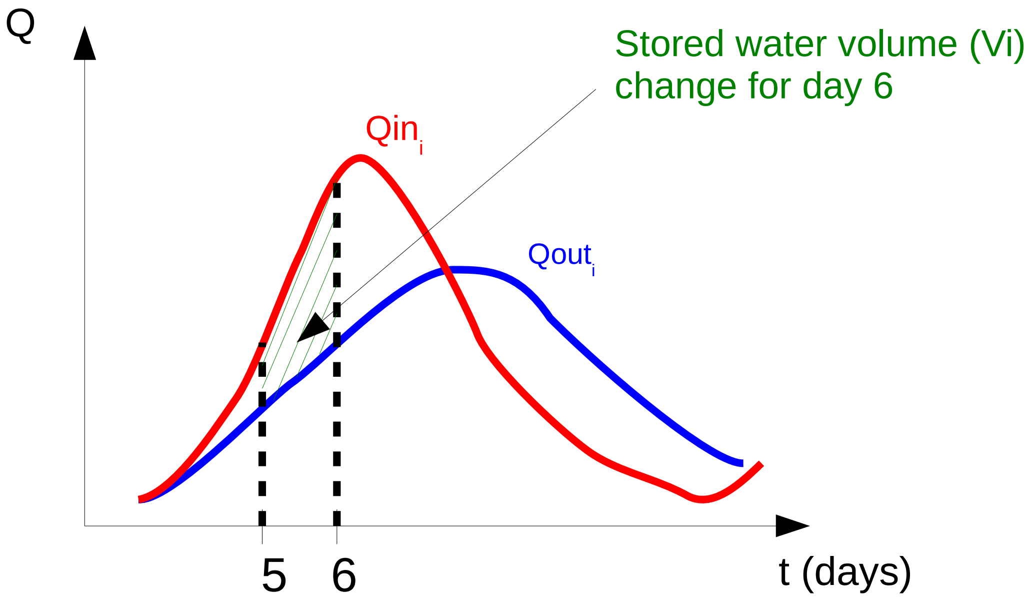


General equation of mass conservation (continuity equation)

$$\boxed{\frac{dV_i(t)}{dt} = Qin_i(t) - Qout_i(t)}$$

- $V_i(t)$ [L^3], volume of water stored in the reservoir i
- Qin_i [$L^3.T^{-1}$], rate of inflow of the reservoir i
- $Qout_i$ [$L^3.T^{-1}$], rate of outflow of the reservoir i





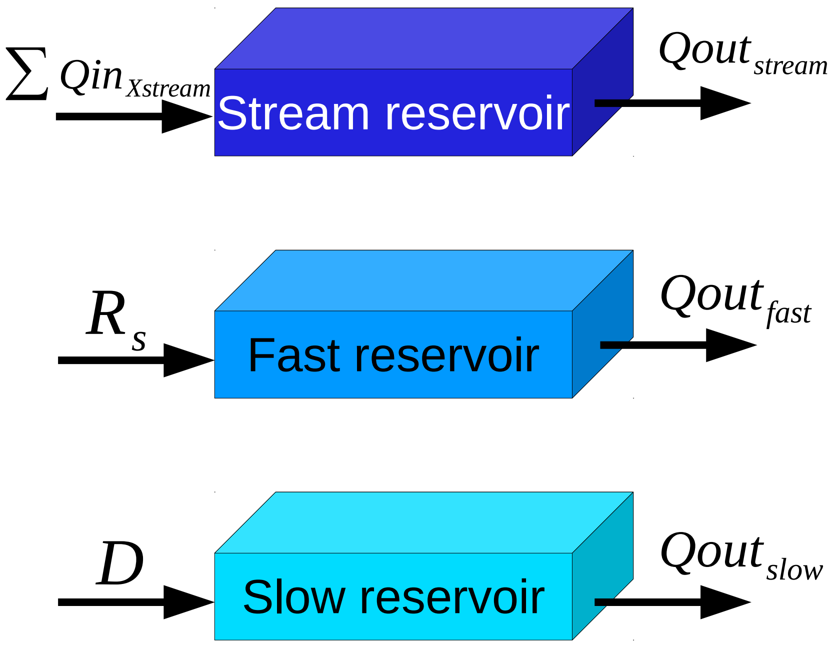
$$\frac{V_{i_{t+1}} - V_{i_t}}{\Delta t} = Qin_{i_t} - Qout_{i_t}$$

- **Δt = 1 day, time step** for the routing procedure in ORCHIDEE

General equation of mass conservation (continuity equation)

Equation of mass conservation applied for each reservoir of the grid cell:

$$\begin{cases} \dfrac{dV_{stream}(t)}{dt} = \sum Qin_{Xstream}(t) - Qout_{stream}(t) \\[2ex] \dfrac{dV_{fast}(t)}{dt} = Rs(t) - Qout_{fast}(t) \\[2ex] \dfrac{dV_{slow}(t)}{dt} = D(t) - Qout_{slow}(t) \end{cases}$$



- Qin_{stream} [kg/day], sum of all inflow from the stream reservoirs of neighbor cells ($Qin_{Xstream}$) that flow into that cell direction
- V_i [kg], Qin_i [kg/day], $Qout_i$ [kg/day]
- Rs [kg/day], surface runoff
- D [kg/day], drainage

Outflow-storage relation

$$\boxed{Qout_i(t)=\frac{1}{T_i}.V_i(t)}$$

T_i [day], the time of a water waves to travel through a reach (also called “time constant”, “residence time”)

with: $T_i=g_i.k$

The residence time in the reservoir i depends on 2 parameters:

g_i [10^{-3} day/km],	the property of the reservoir i
k [km],	the topographic index of the corresponding grid cell

Outflow-storage relation: property of the reservoir (g_i)

- g_i is constant for all grid cells and is unique for each reservoir:
  - g_{stream} = 0.24 10^{-3} day/km
  - g_{fast} = 3.00 10^{-3} days/km
  - g_{slow} = 25.0 10^{-3} days/km
- The values were obtained during a calibration of river discharge over the Senegal basin and then generalized to all the worldwide basins (Ngo-Duc et al., 2007)

Outflow-storage relation: topographic index (k)

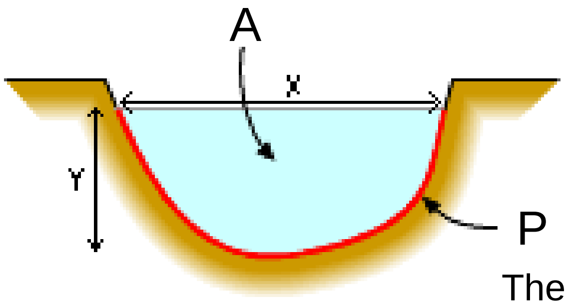
- k varies spatially and does not depend on the reservoir
- Its formulation is a simplification of Manning's formula (from Ducharne et al., J. Hydrol, 2003)

Manning equation: computes the velocity of open-channel flows

$$U = \left(\frac{u_m}{n}\right) . R_h^{2/3} . \sqrt{\tan\beta}$$

U [m/s],	open-channel flow velocity
u_m [$m^{1/3}$/s],	unit-conversion factor
n,	Manning coefficient which characterizes channel resistance
R_h [m],	hydraulic radius
tanβ,	water-surface slope

Hydraulic radius: measures the channel flow efficiency



$$R_h \equiv \frac{A}{P}$$

A [m²],	cross-sectional area of the flow
P [m],	length of the wetted portion of the flow boundary ("wetted perimeter")

The greater R_h, the greater the efficiency of the channel and the more volume it can carry.
For channels of a given width (x), R_h is greater for the deeper channels (y is high).

Outflow-storage relation:
topographic index (k)

$$\boxed{U=\left(\frac{u_m}{n}\right).R_h^{2/3}.\sqrt{\tan\beta}}$$

Manning equation

$$\downarrow$$

$$\frac{1}{U}=\left(\frac{n}{u_m.R_h^{2/3}}\right)\cdot\left(\frac{1}{\sqrt{\tan\beta}}\right)$$

$$\downarrow$$

$$\frac{d}{U}=\left(\frac{n}{u_m.R_h^{2/3}}\right)\cdot\left(\frac{d}{\sqrt{\tan\beta}}\right)$$

$$\downarrow$$

$$t_{adj}=\alpha.\left(\frac{d}{\sqrt{\tan\beta}}\right)$$

- $t_{adj}=d/U$ [s], transfer time between two adjacent grid cells. Equivalent to T_i.
- d [m], distance between two adjacent grid cells.
- α [s/m], a scaling parameter, including the influence of roughness of the river bed (influence of the water stage being neglected). Equivalent to g_i.

$$\downarrow$$

$$k=\frac{d}{\sqrt{\tan\beta}}$$

- $k=t_{adj}/\alpha$ [m], topographic index

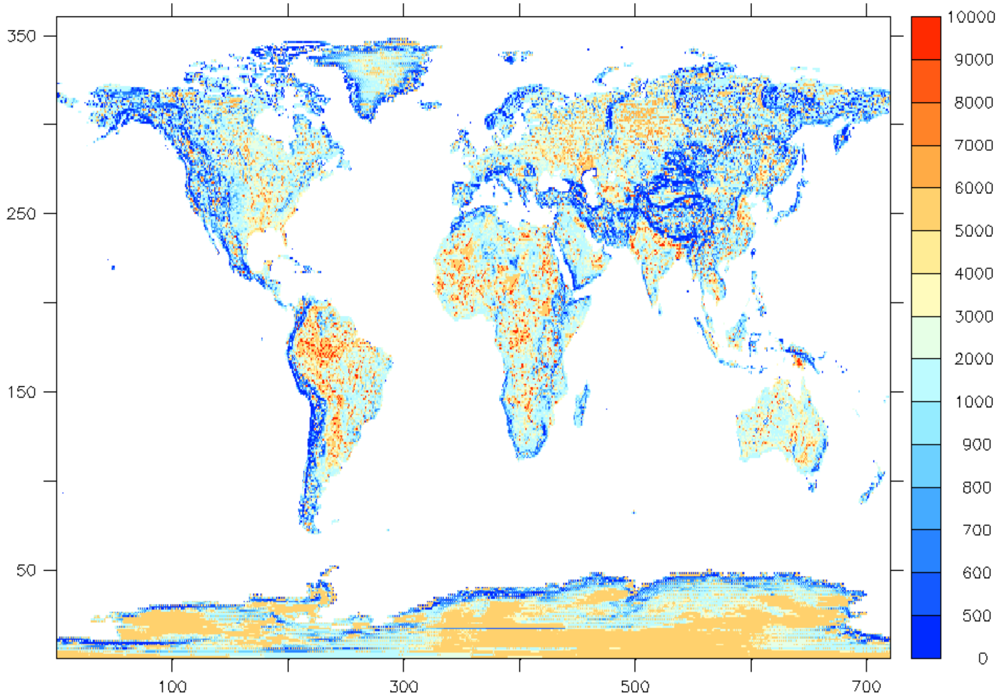
$$\downarrow$$

Topographic index in ORCHIDEE

$$k=\sqrt{\frac{d^2}{\tan\beta}}\longrightarrow k=\sqrt{\frac{d^2}{\frac{\Delta z}{d}}}\longrightarrow k=\sqrt{\frac{d^3}{\Delta z}}$$

then: $\boxed{k=\sqrt{\frac{d^3}{\Delta z.10^6}}}$ to put k in km

Outflow-storage relation: topographic index (k)



Topographic index [km]

- 0.5°x0.5° spatial resolution

$$T_i = g_i . k$$

$12.5\,days < T_{slow} < 250\,days$

Groundwater residence time estimated in the literature: 10-300 days

Inland and man-made wetlands

3

- Irrigated lands
- Floodplains
- Swamps
- Ponds
- Endorheic lakes

3.1

Inland and man-made wetlands

- **Irrigated lands**
- Floodplains
- Swamps
- Ponds
- Endorheic lakes

Man-made wetlands: irrigated lands

Marocco

Plain of Punjab, Pakistan

Irrigation:

Human intervention to modify the spatial or temporal distribution of water occurring in natural channels, depressions, drainage ways or aquifers and to manipulate all or part of this water for the production of agricultural crops.

(Small and Svendsen, Irrigation & drainage systems, 1990)

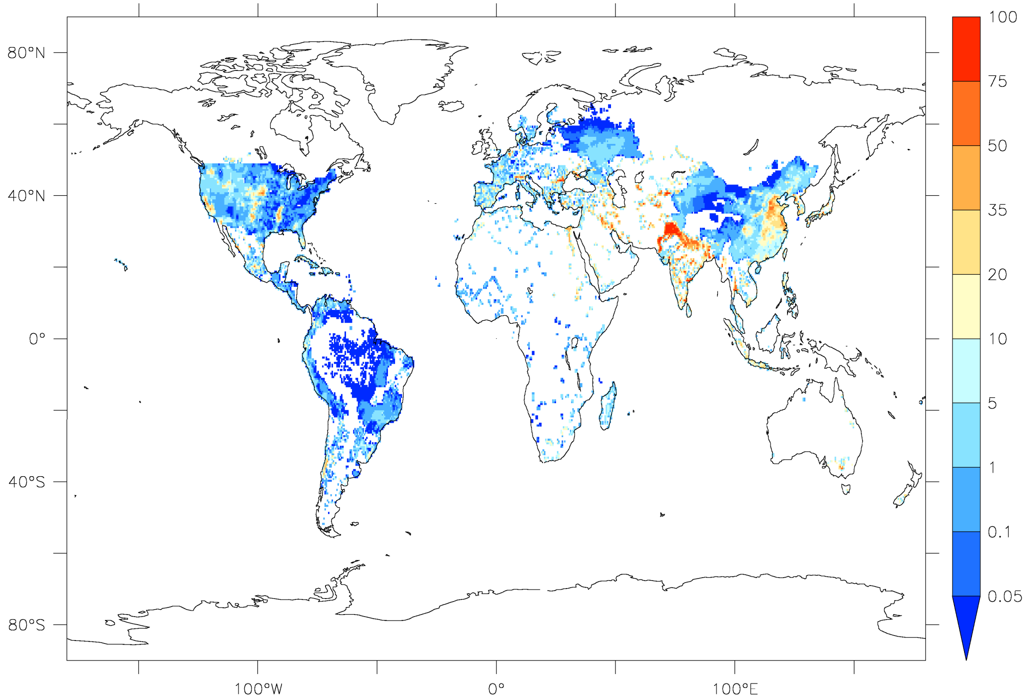
Irrigation requirement (Ir_{req})

- Computation of the water requirements by the crops for their optimal growth over each irrigated fraction => “irrigation requirement”
- Water demand from the plants => computation of potential irrigation

$$Ir_{req} = f_{ir} . \left[T_v^{pot} - \left(P + reinf \right) \right]$$

• Ir_{req},	irrigation requirement
• f_{ir},	fraction of irrigation
• T_v^{pot},	potential transpiration of PFT v
• P,	precipitation
• reinf,	reinfiltration

Fractions equipped for irrigation (f_{ir})



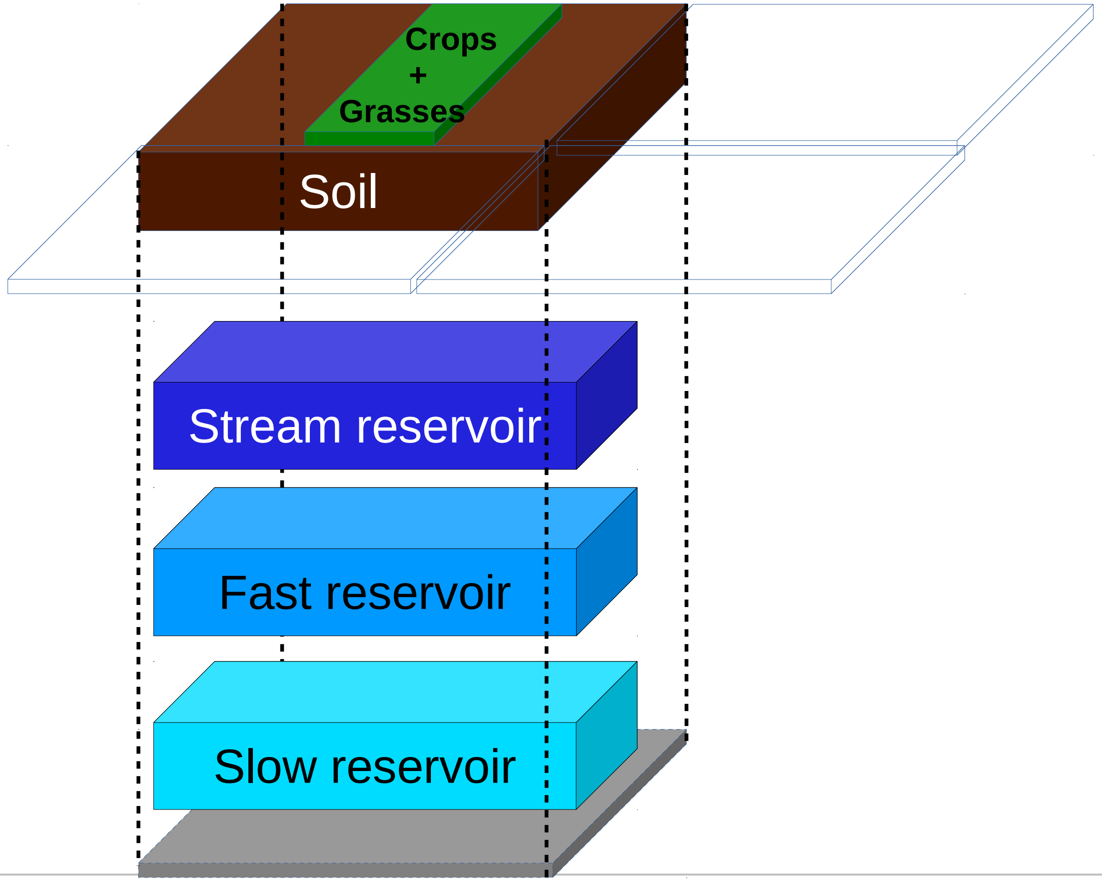
% of grid cell area equipped for irrigation

Guimberteau et al. (Clim. Dyn., 2012)

- From Döll and Siebert (1999, 2000, 2002) updated by Siebert and Döll (2001)
- Estimation of area of each grid box equipped for irrigation around 1995 (up to 1999 for Europe and Latin America)
- 0.5°x0.5° spatial resolution
- % of the grid cell area

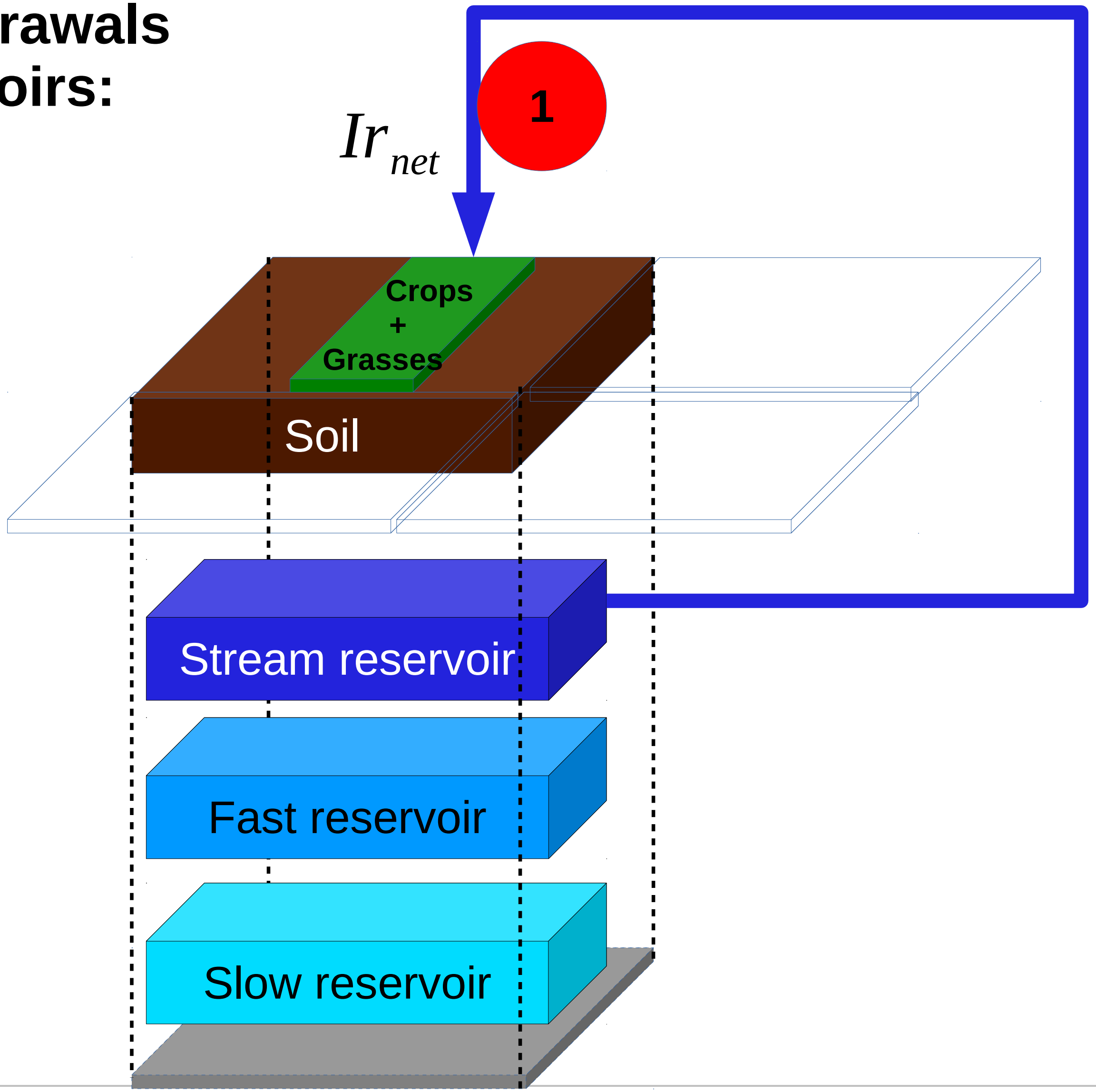
Net irrigation (Ir_{net})

Rules of water withdrawals in the routing reservoirs:



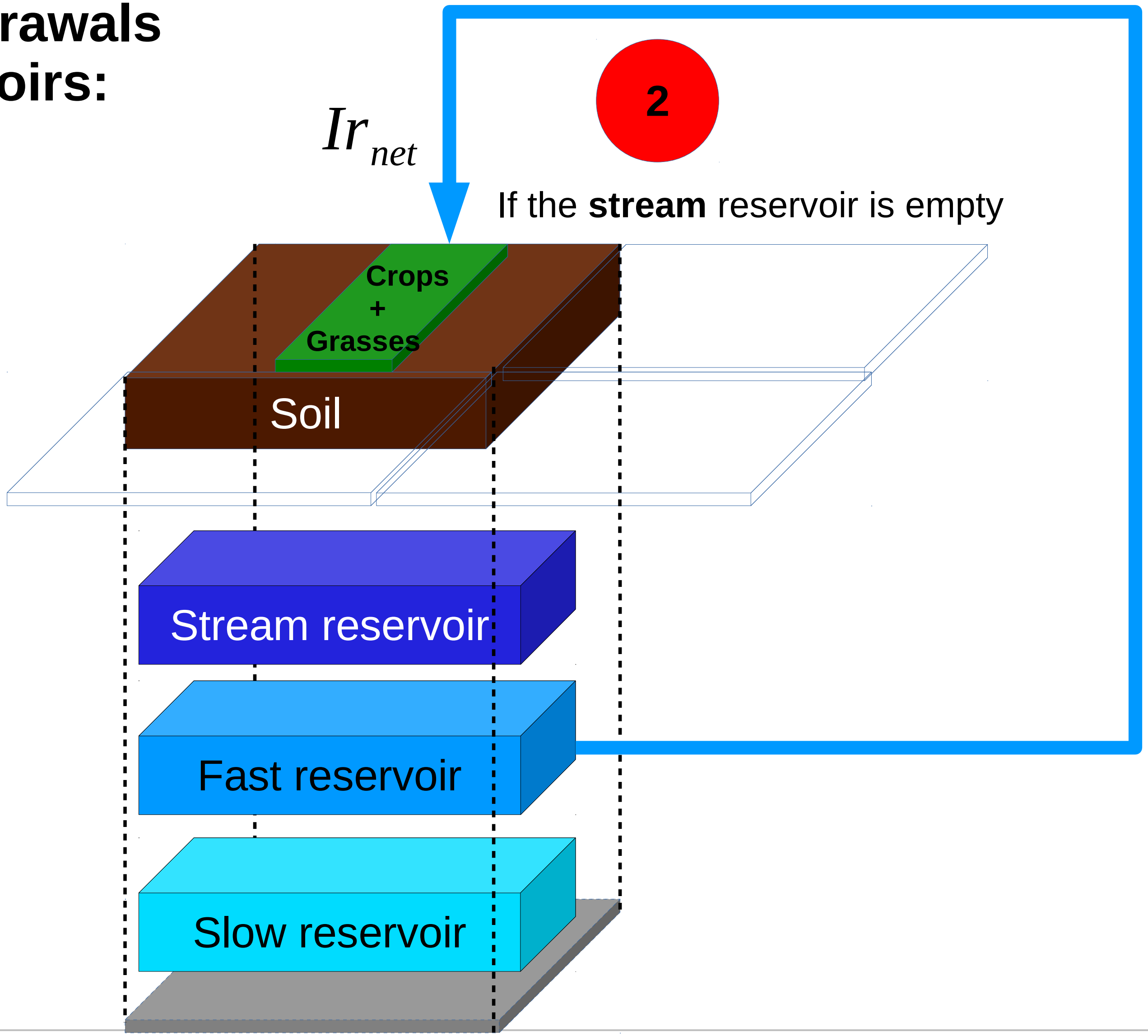
Net irrigation (Ir_{net})

Rules of water withdrawals in the routing reservoirs:



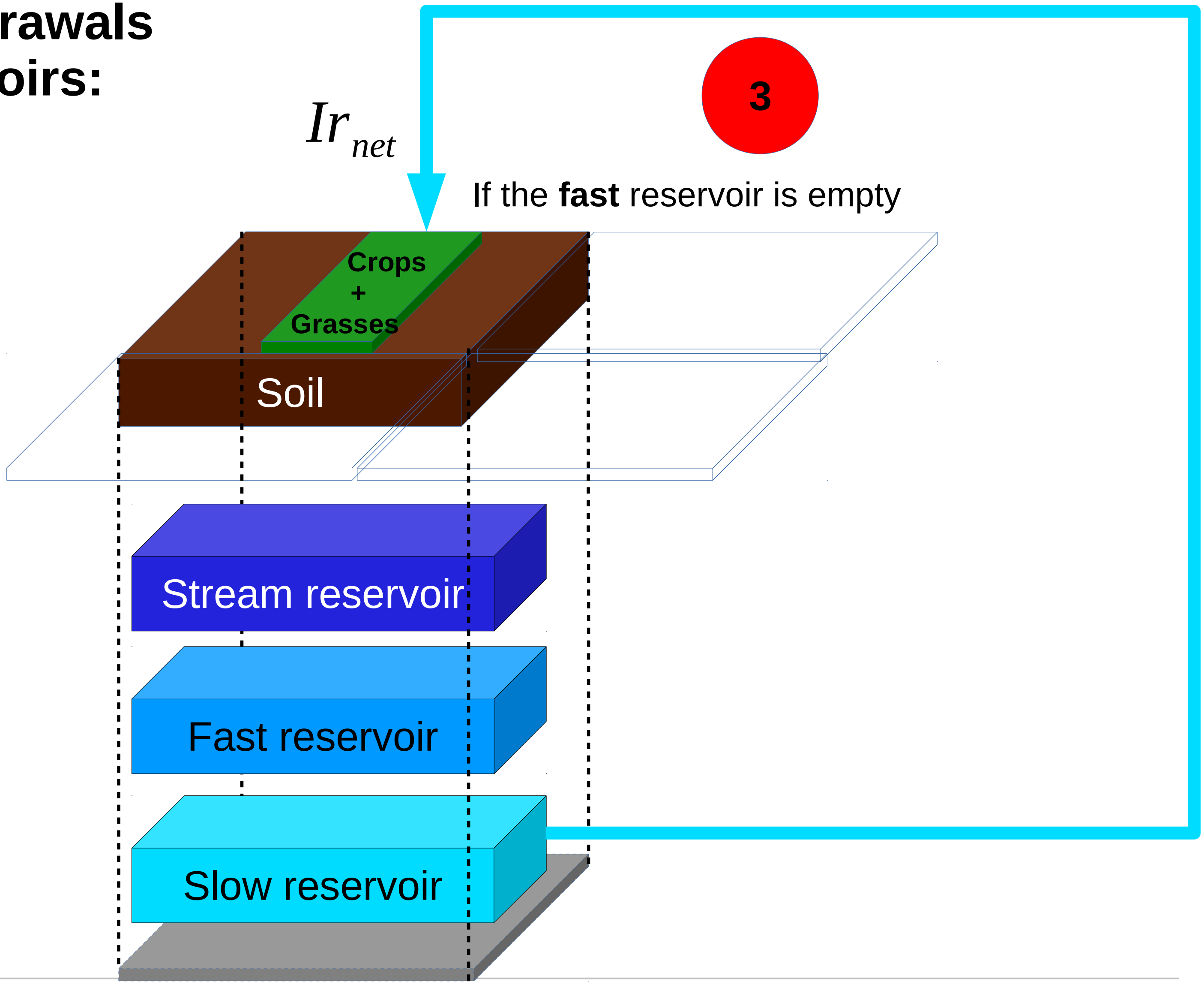
Net irrigation (Ir_{net})

Rules of water withdrawals in the routing reservoirs:



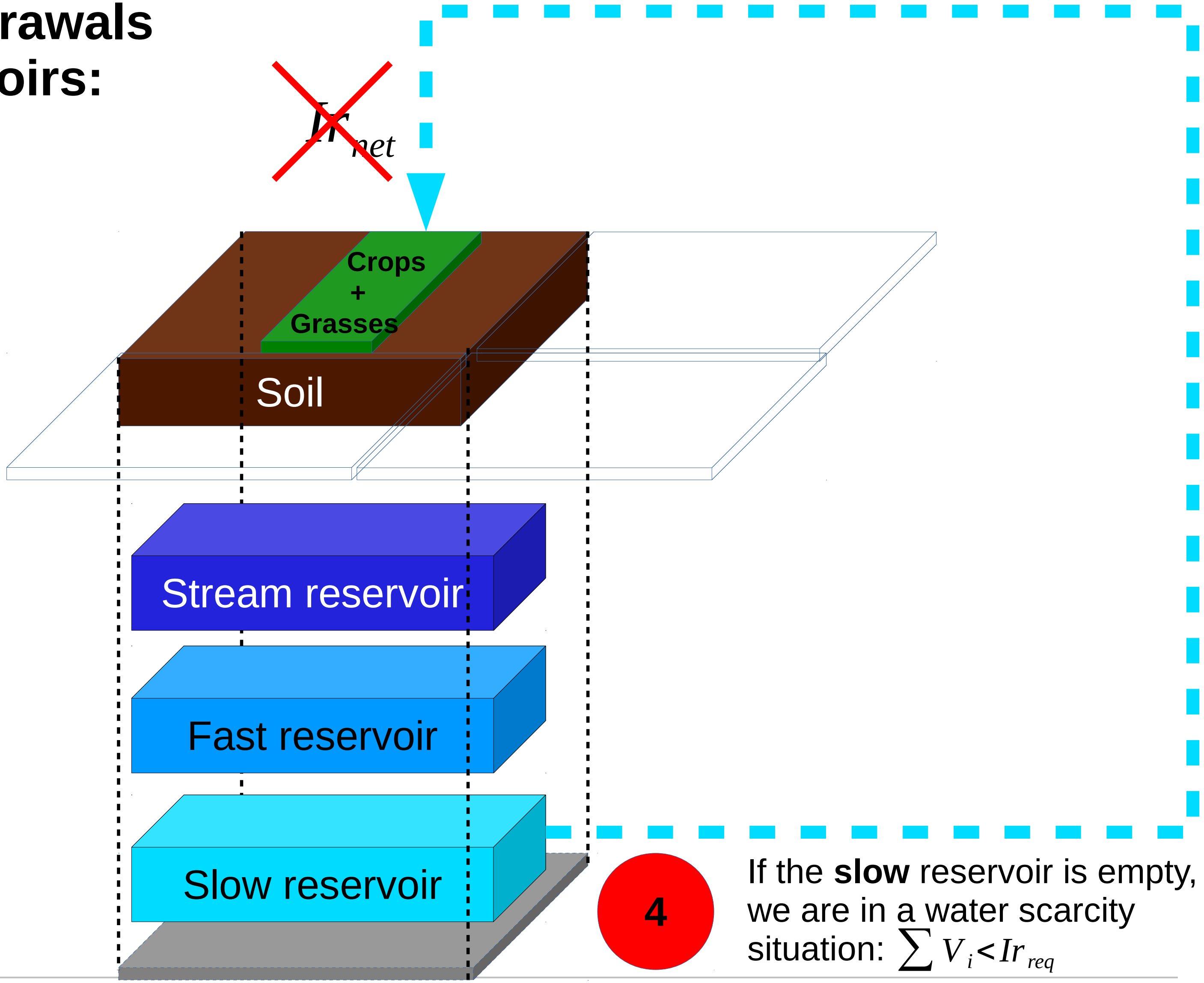
Net irrigation (Ir_{net})

Rules of water withdrawals in the routing reservoirs:



Net irrigation (Ir_{net})

Rules of water withdrawals in the routing reservoirs:



If the **slow** reservoir is empty, we are in a water scarcity situation: $\sum V_i < Ir_{req}$

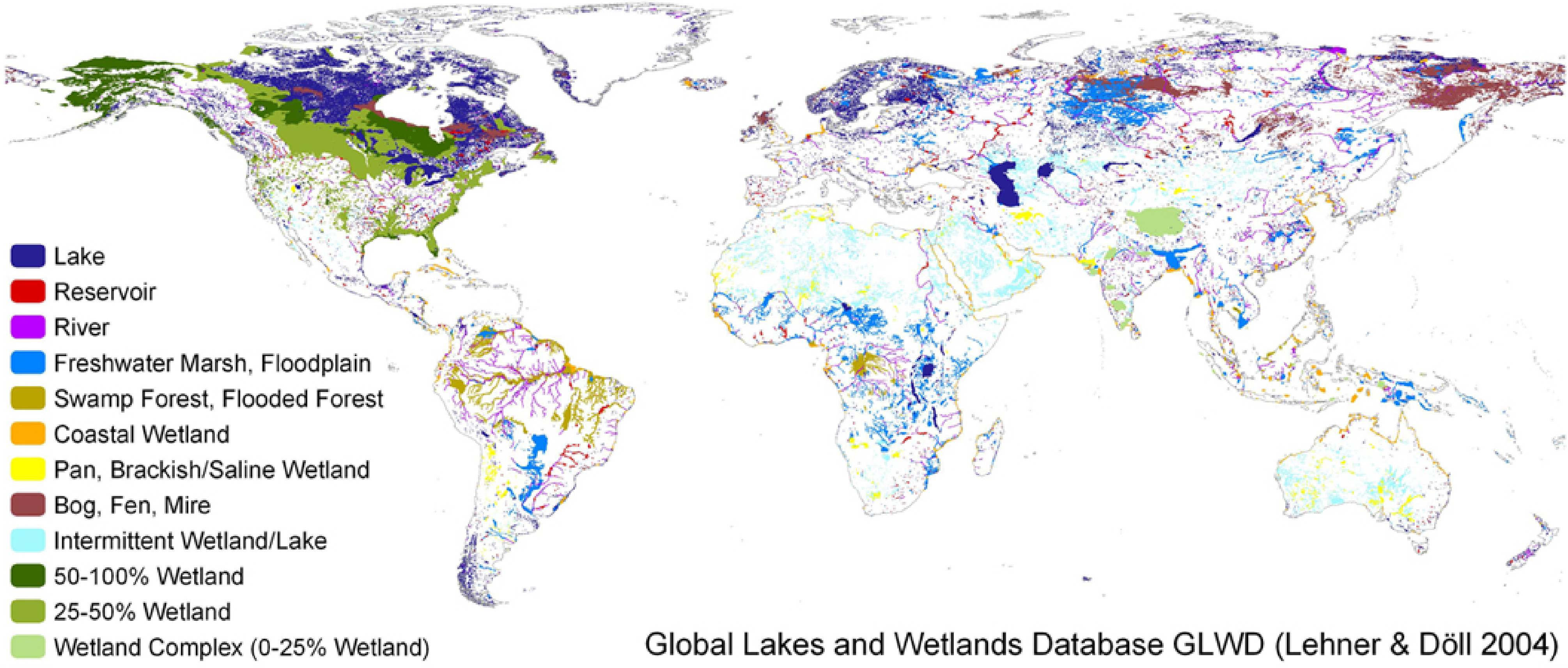
Water scarcity situation (irrigation deficit)

If $\sum V_i < Ir_{req}$:

- Adduction of water from neighboring basins is enabled: find the missing water in another basin of the same grid cell (but stream reservoir only)
- Only at a grid-cell resolution smaller than 100kmx100km, we can import water from neighboring grid cells
    - at a grid-cell resolution greater than 100kmx100km, the “pipelines” would be too long to be reasonable

Inland wetlands

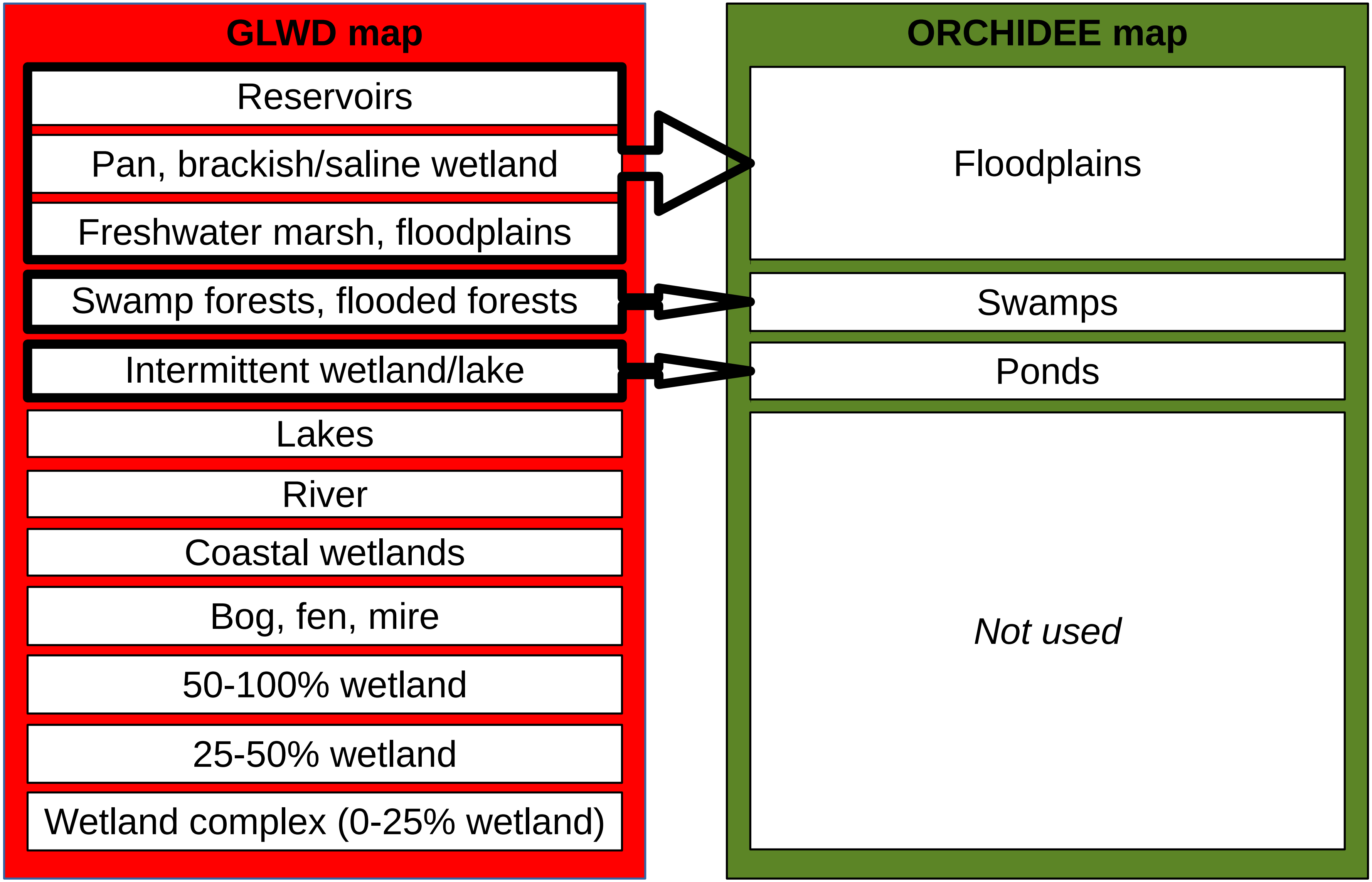
GLWD original map



Global Lakes and Wetlands Database GLWD (Lehner & Döll 2004)

- From 30'' arc resolution (~1km at the equator) => 0.5° resolution maps for ORCHIDEE

From GLWD maps to ORCHIDEE maps



GLWD map

- Reservoirs
- Pan, brackish/saline wetland
- Freshwater marsh, floodplains
- Swamp forests, flooded forests
- Intermittent wetland/lake
- Lakes
- River
- Coastal wetlands
- Bog, fen, mire
- 50-100% wetland
- 25-50% wetland
- Wetland complex (0-25% wetland)

ORCHIDEE map

- Floodplains
- Swamps
- Ponds
- *Not used*

3.2

Inland and man-made wetlands

- Irrigated lands
- **Floodplains**
- Swamps
- Ponds
- Endorheic lakes

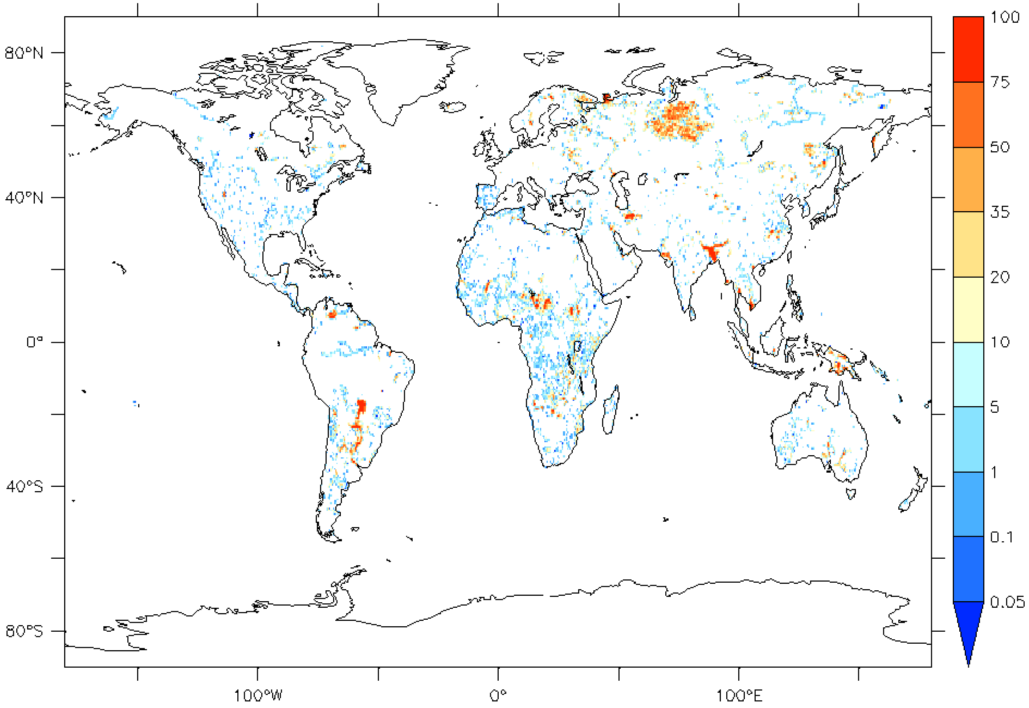
Floodplains

Amazon river during low-flow season, Brazil, Para

Areas of low lying land that are subject to inundation by lateral overflow water from rivers or lakes with which they are associated

(Junk & Welcomme, Wetlands and Shallow Continental Water Bodies, 1990)

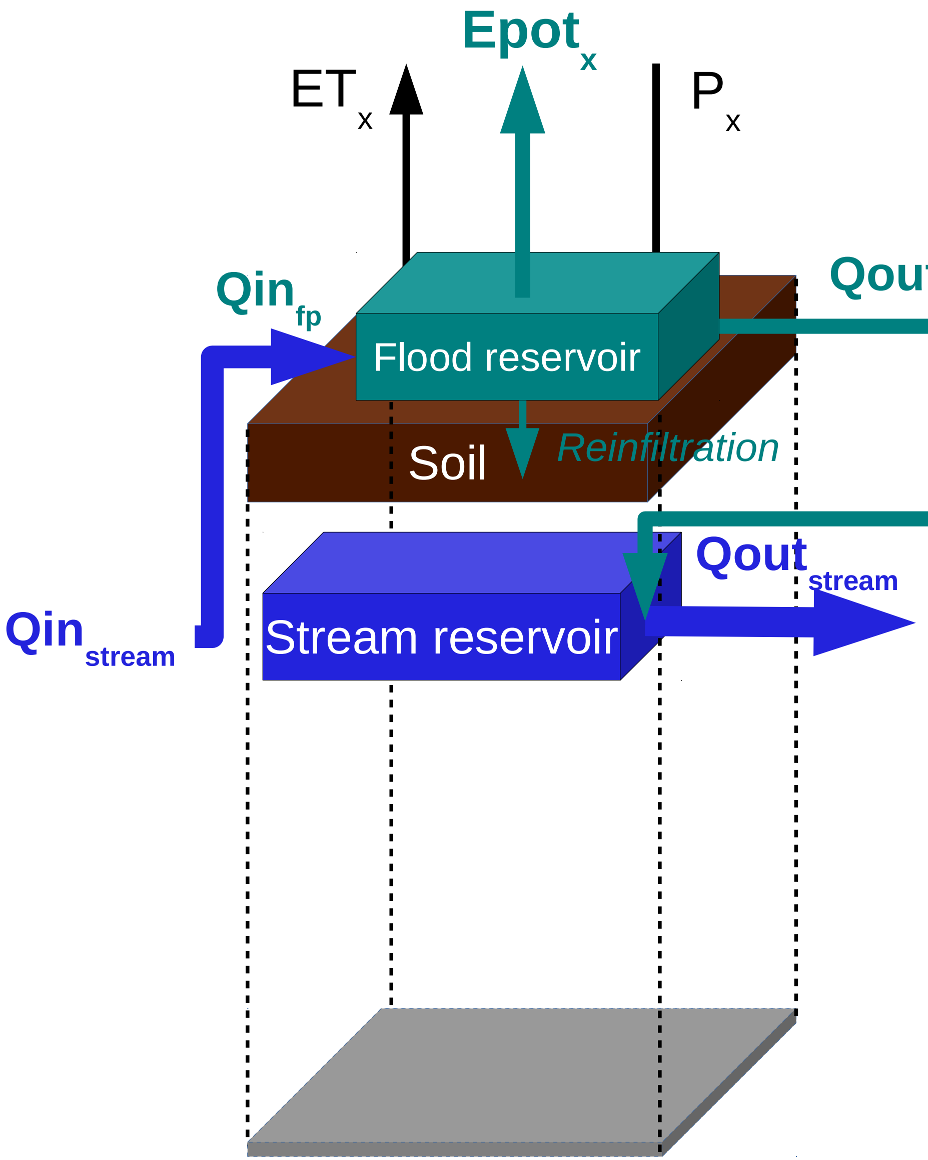
Maximal fractions of floodplains (f_{fp}^{max})



% of maximal grid cell area that can be occupied by floodplains

- 0.5°x0.5° spatial resolution

Floodplain parametrization



- If $f_{fp}^{max} > 0$:

$$Qin_{fp} = Qin_{stream}$$

$$\boxed{Qout_{fp} = \frac{1}{f_{fp} \cdot T_{fp}} \cdot V_{fp}}$$

• $Qout_{fp}$ [kg/day],	outflow of the floodplain reservoir
• f_{fp},	fraction of floodplains
• T_{fp} [day],	residence time in the floodplain reservoir
• V_{fp} [kg],	volume of water stored in the floodplain reservoir

- g_{fp} = 4.0 10^{-3} days/km

Outflow of the stream reservoir is thus modified:

$$\boxed{Qout_{stream} = \frac{1}{\left(1 - \sqrt{f_{fp}}\right)} \cdot \frac{1}{T_{stream}} \cdot V_{stream}}$$

Simulation of the variation of the floodplain fraction (f_{fp})

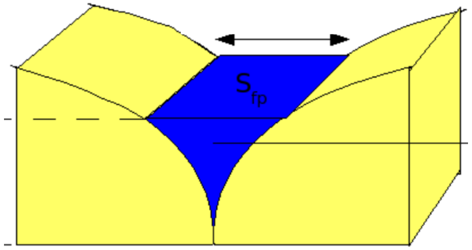
$$f_{fp} = \frac{S_{fp}}{S_B}$$

- S_{fp} (m²), floodplain surface
- S_B (m²), basin surface

$$\boxed{S_{fp} = min\left[\left(\frac{h_{fp}}{h_0}\right)^{\beta} . S_B , S_{max}\right]}$$

- h_{fp} (m), height of the floodplain
- h_0 =2m, potential height for which the basin is entirely flooded
- S_{max} (m²), maximal surface of the floodplain (given by the map)

- Shape of the bottom of the floodplains taken into account through the parameter β:
  - if β > 1 → convex cross-section (in low-gradient floodplains of most large rivers (e.g. Nile, Tigris, Euphrates, Mississippi, Amazon, Mekong, Huang He, Yangtzé, Ganges and Indus)
    - The land slopes away from the riverbank to the valley sides
  - if β < 1 → Flat or gently concave cross-section (large majority of riverplains)
- By default in ORCHIDEE => convex cross-section (β=2)



3.3

Inland and man-made wetlands

- Irrigated lands
- Floodplains
- **Swamps**
- Ponds
- Endorheic lakes

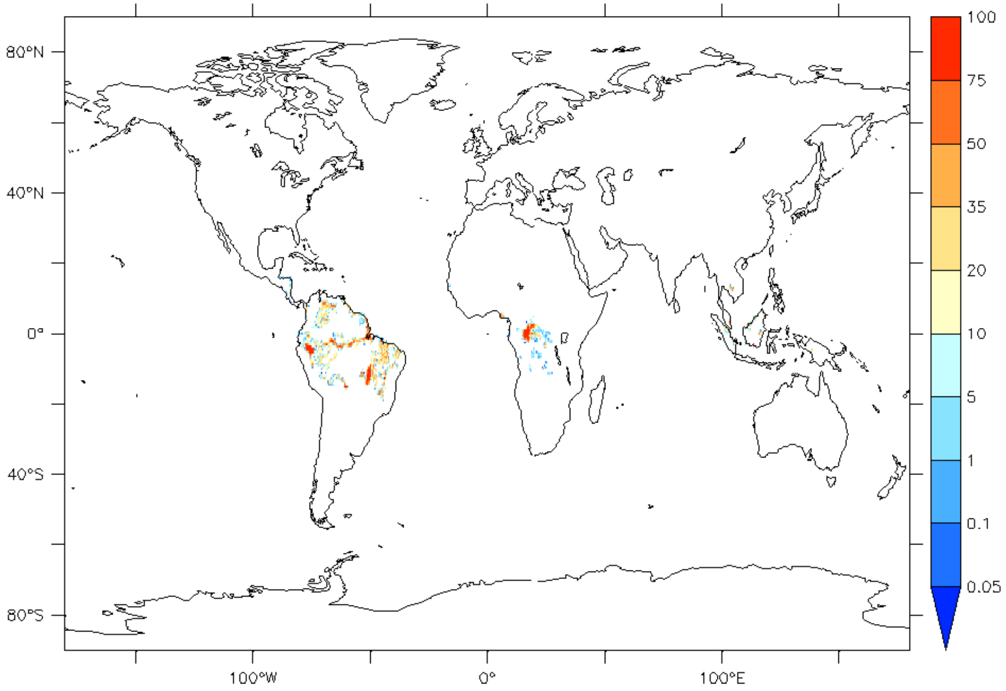
Swamps (forests)

Mamiraua, Amazonas, Brazil

Forests subject to long-lasting flooding or water-logging of the soil with freshwater

(Junk, Amazonian Floodplain Forests, 2010)

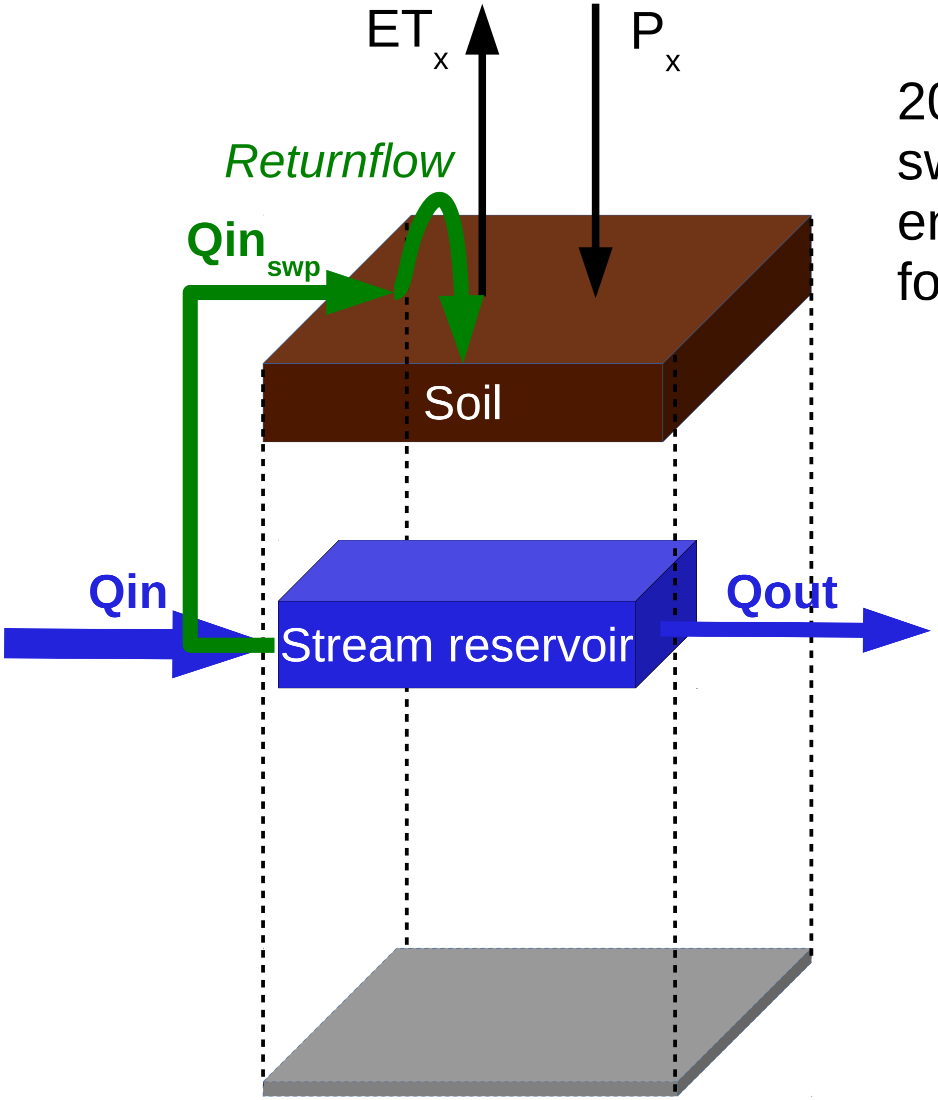
Fractions of swamps (f_{swp})



% of grid cell area that is occupied by swamps

- 0.5°x0.5° spatial resolution

Swamp parametrization



20% of the inflow in the grid-cell occupied by swamps does not return directly to the river but enters in the soil through returnflow → sustain forest transpiration in these regions

$$Qin_{swp} = f_{swp} . \alpha . Qin$$

- Qin_{swp} [kg/day], inflow of the swamp
- f_{swp}, fraction of swamps
- $\alpha = 0.20$, fraction of Qin that enters in the swamp

Inland and man-made wetlands

3.4

- Irrigated lands
- Floodplains
- Swamps
- **Ponds**
- Endorheic lakes

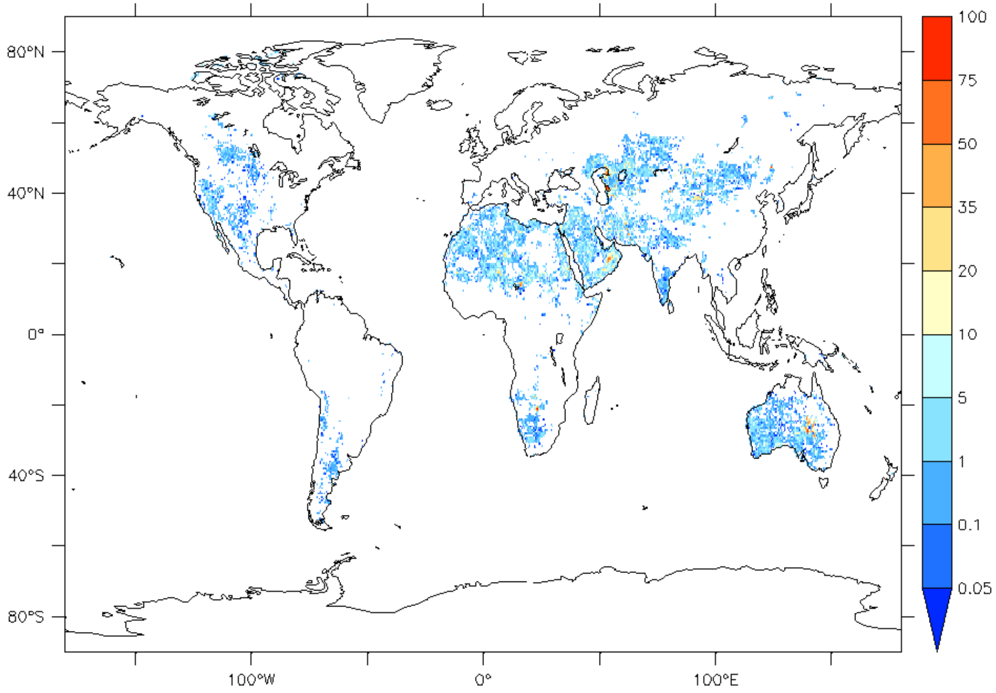
Ponds

Northern Namibia

<u>Small shallow</u> lakes, typically less than 1ha in area

(Likens, Lake Ecosystem Ecology, 2010)

Fractions of ponds (f_{pond}^{max})



- 0.5°x0.5° spatial resolution

Pond parametrization

- If $f_{pond}^{max} > 0$ → the reinfiltrated fraction goes into a pond reservoir and not directly to the soil
- The relationship between pond area and height is the same as for floodplains, but for $\beta=0.5$ (concave bottom)
- Ponds reinfiltrate into the soil at an infiltration rate that equals hydraulic conductivity of the first 2 cm of the soil (as for the floodplains)

3.5

Inland and man-made wetlands

- Irrigated lands
- Floodplains
- Swamps
- Ponds
- **Endorheic lakes**

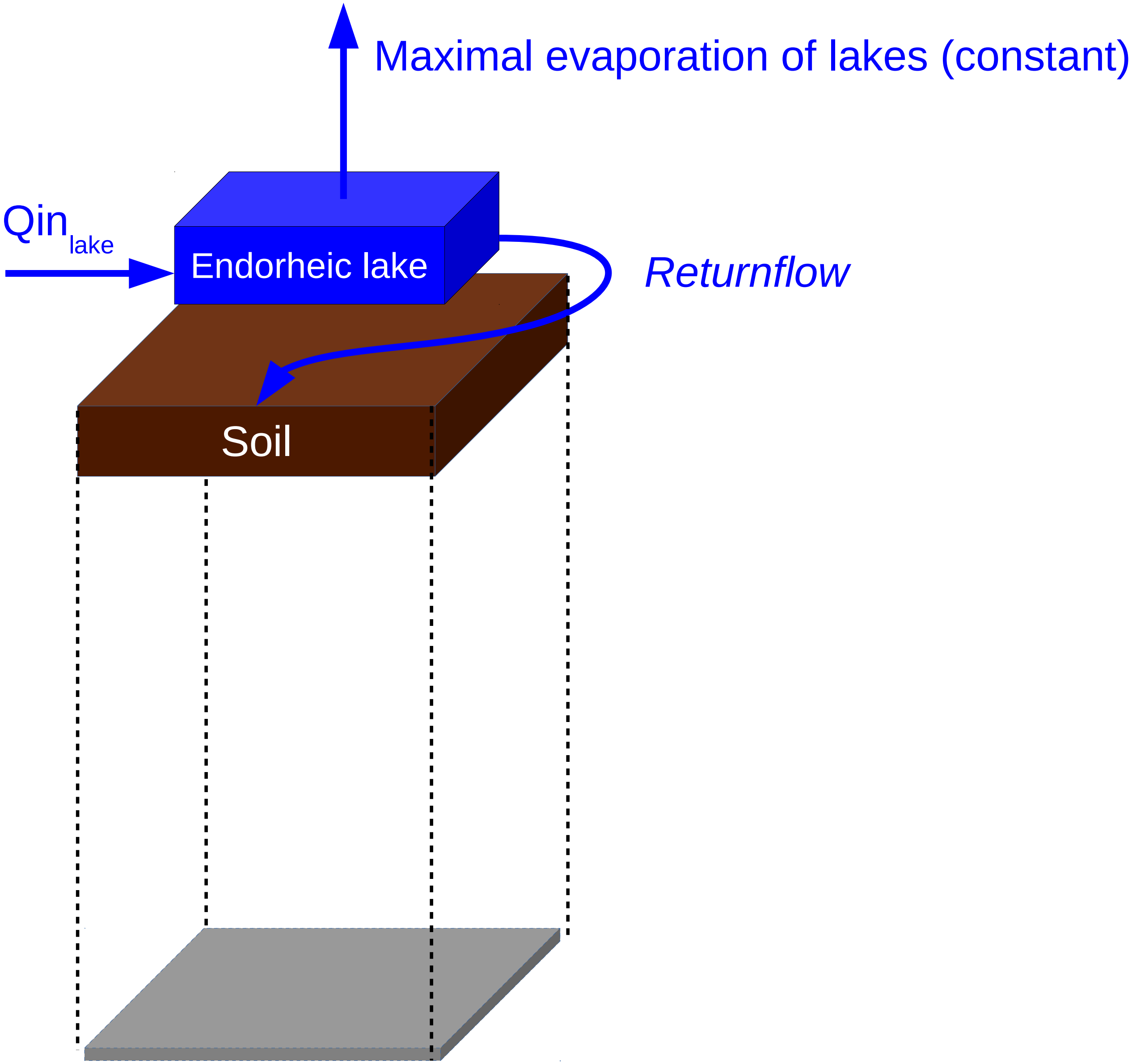
Endorheic lakes

Lake Chad

Large bodies of water that are enclosed by land, without drainage outlet ("terminal lakes" or "sink lakes")

(Likens, Lake Ecosystem Ecology, 2010)

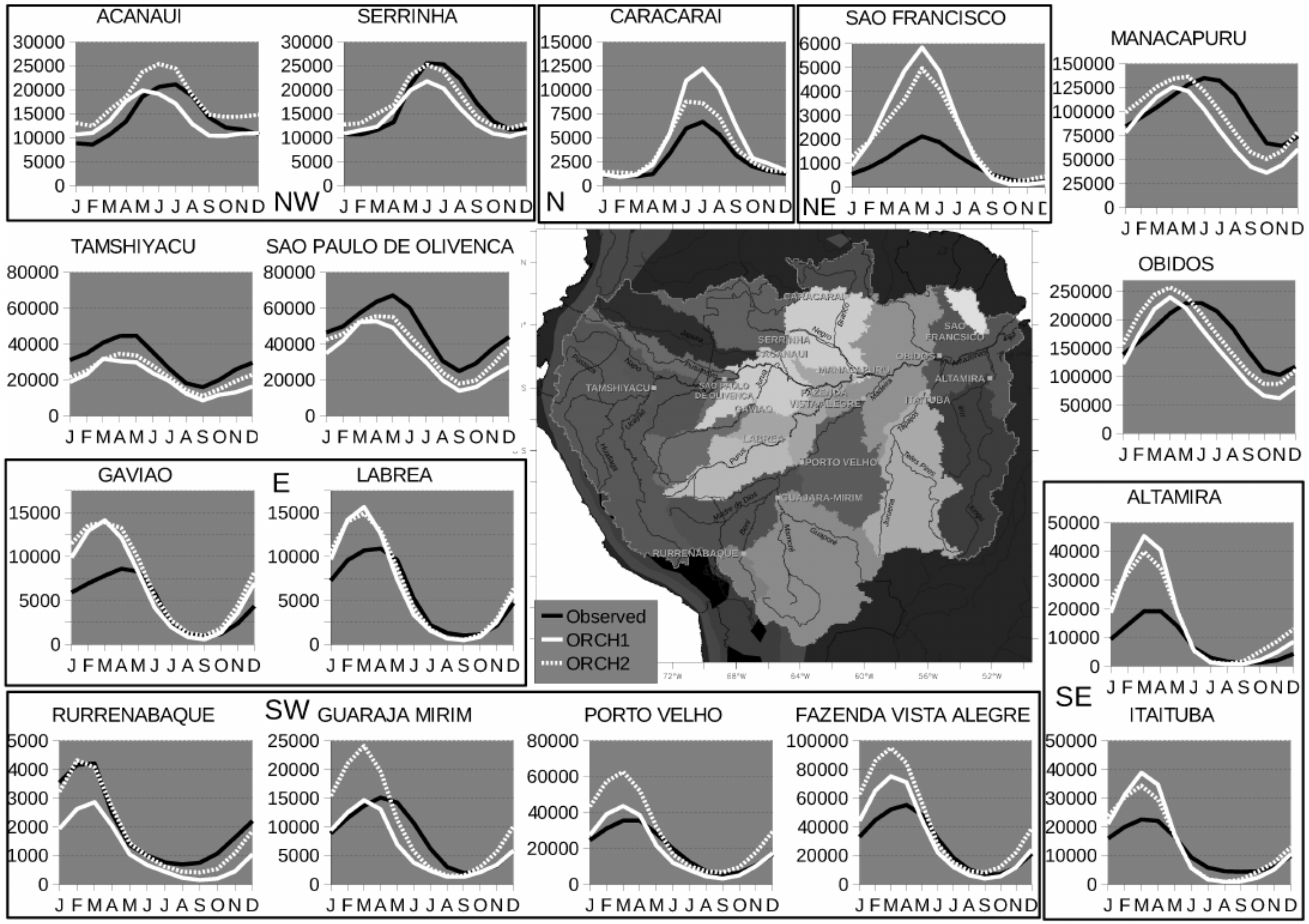
Endorheic lakes



4

Applications

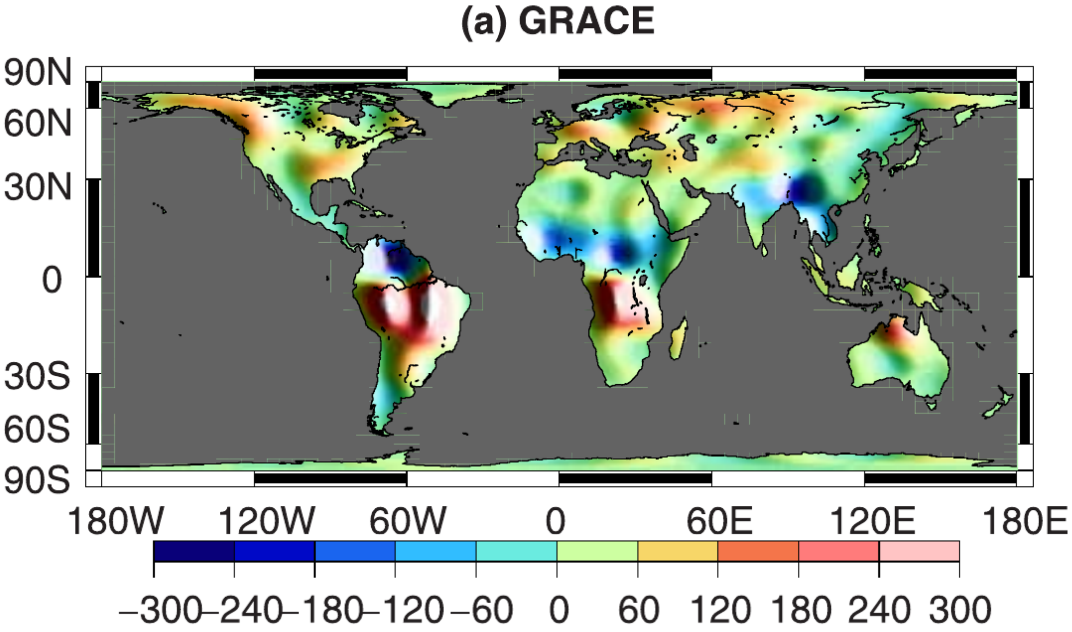
River discharge (Q)



Mean seasonal discharges (m^3/s) over the sub-basins of the Amazon basin (white: ORCHIDEE simulations; black: observations from the ORE-HYBAM database) *Guimberteau et al. (HESS, 2012)*

Simulated river discharge can be compared with data from gauging stations

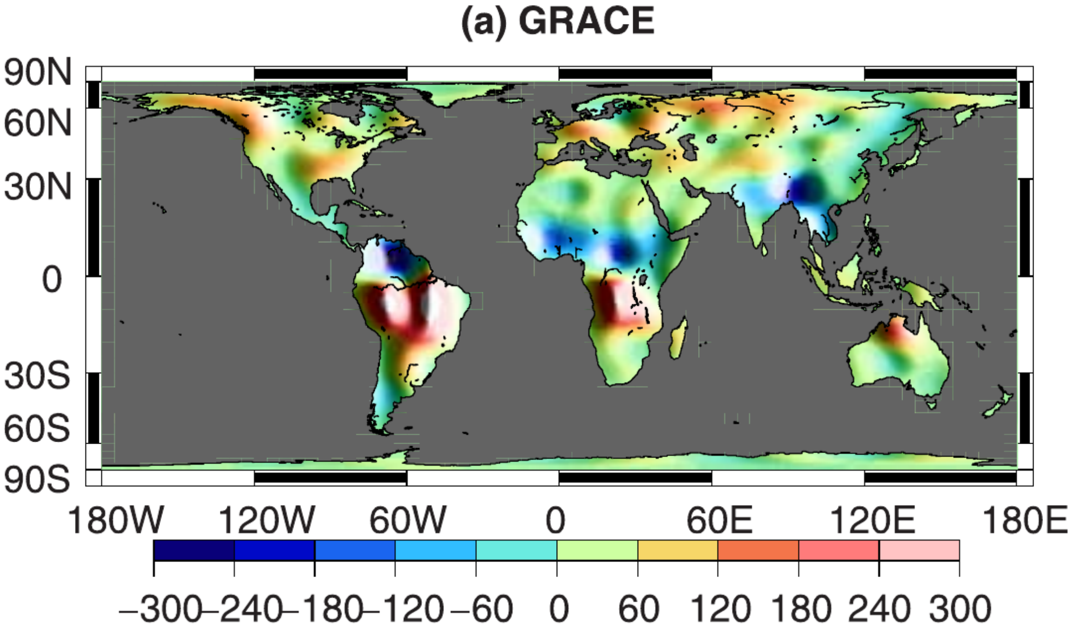
Total water storage variation (TWS): comparison with GRACE



TWS (in mm) for the time period FMA minus ASO 2003

Ngo-Duc et al. (2007, WRR)

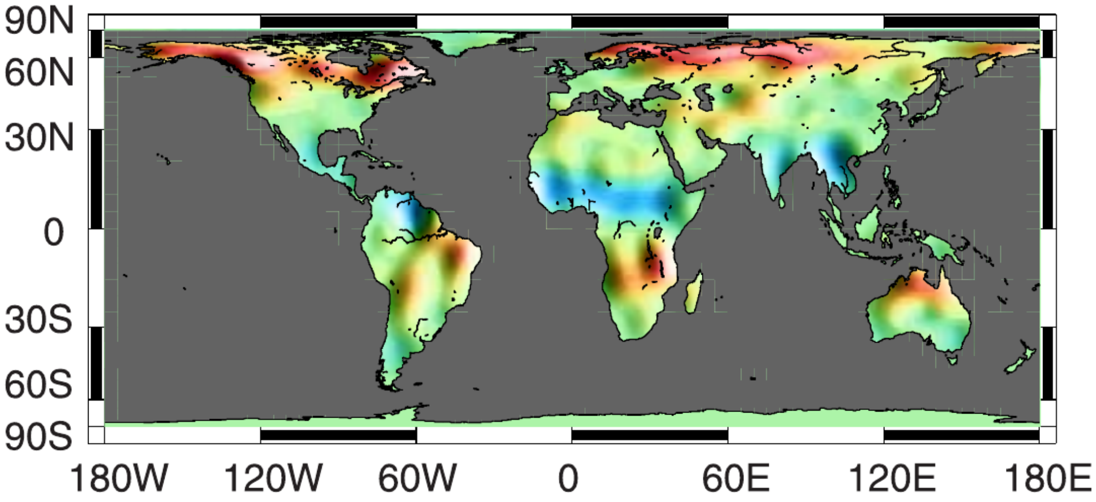
Total water storage variation (TWS): comparison with GRACE



TWS (in mm) for the time period FMA minus ASO 2003

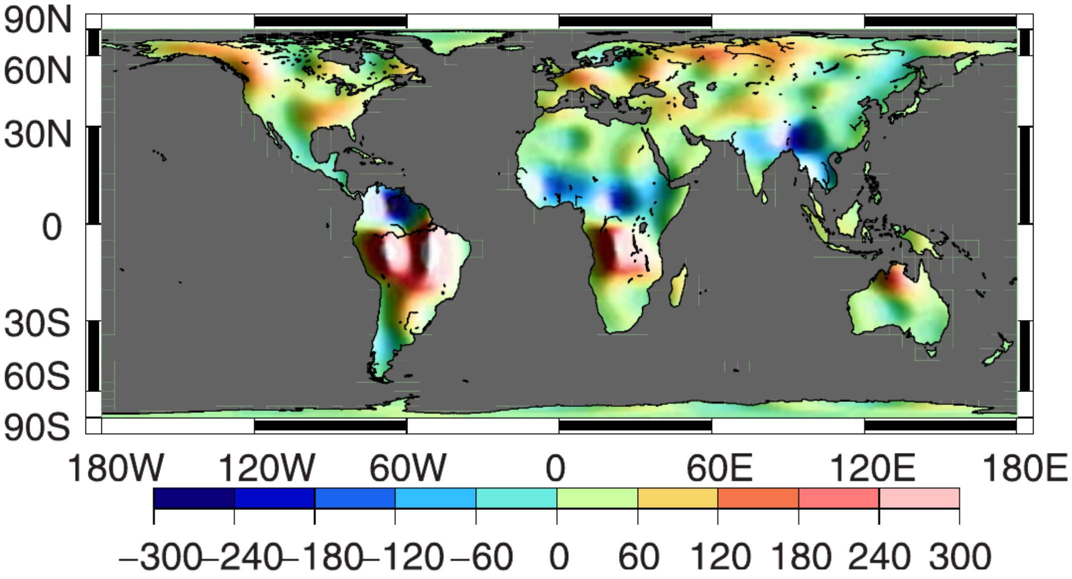
Ngo-Duc et al. (2007, WRR)

ORCHIDEE (without routing module)



Total water storage variation (TWS): comparison with GRACE

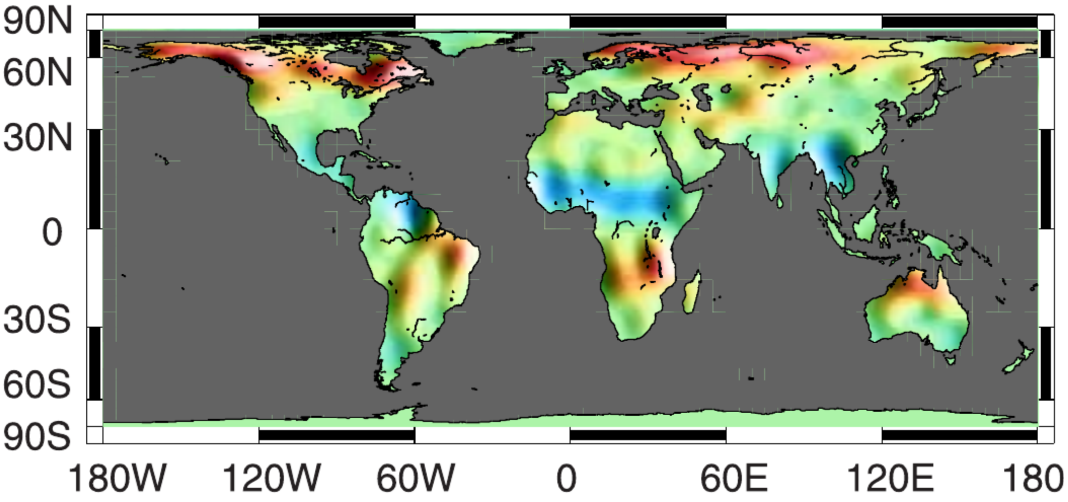
(a) GRACE



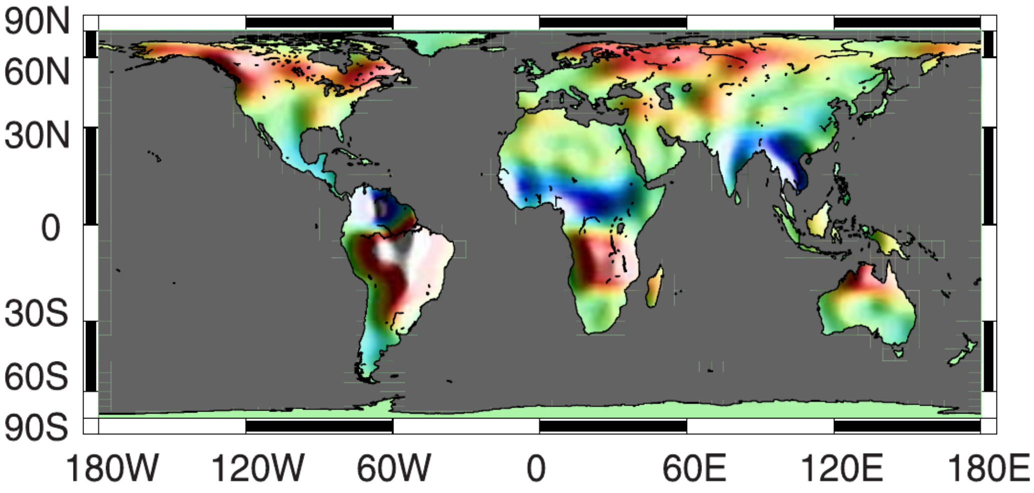
TWS (in mm) for the time period FMA minus ASO 2003

Ngo-Duc et al. (2007, WRR)

ORCHIDEE (without routing module)

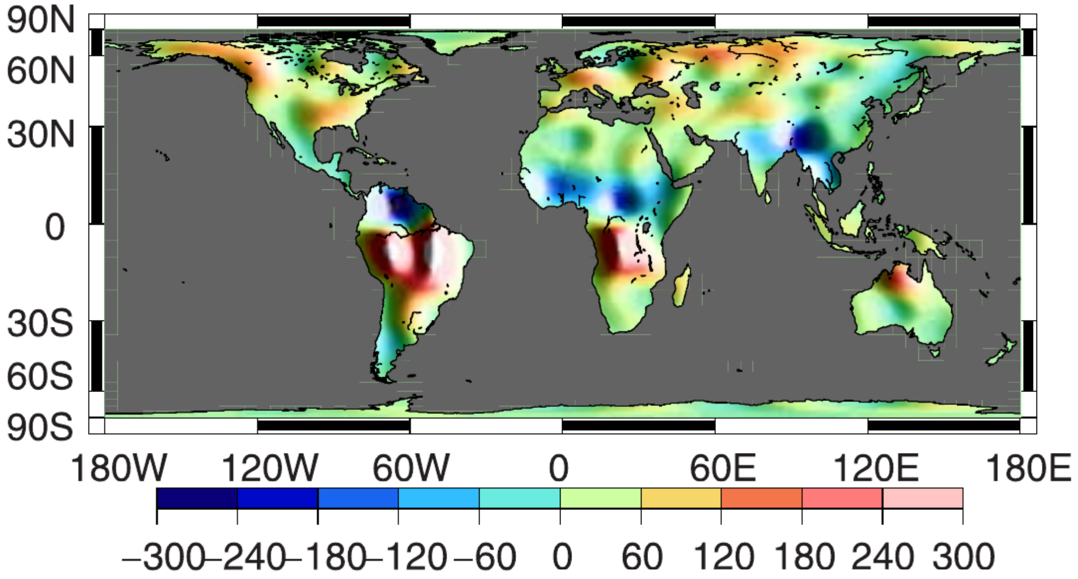


ORCHIDEE (with routing module)



Total water storage variation (TWS): comparison with GRACE

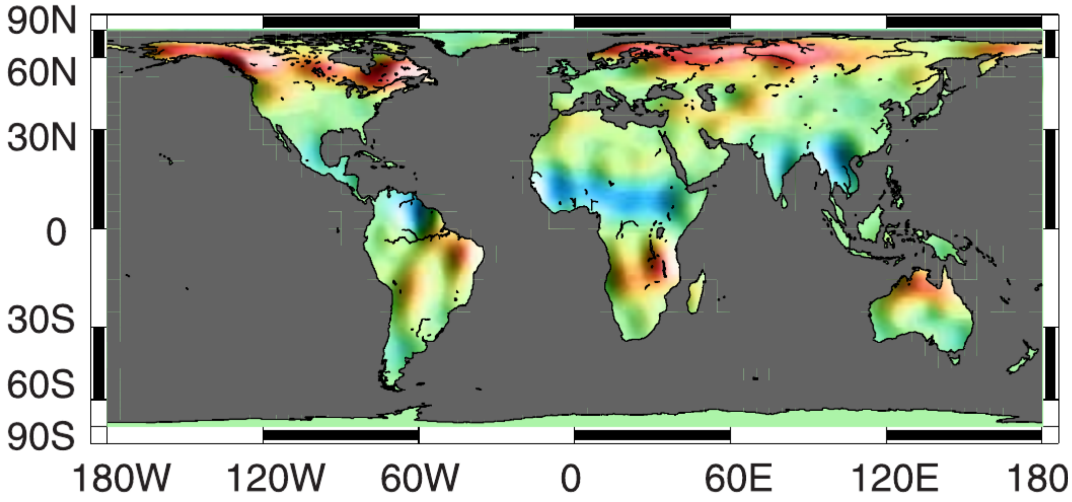
(a) GRACE



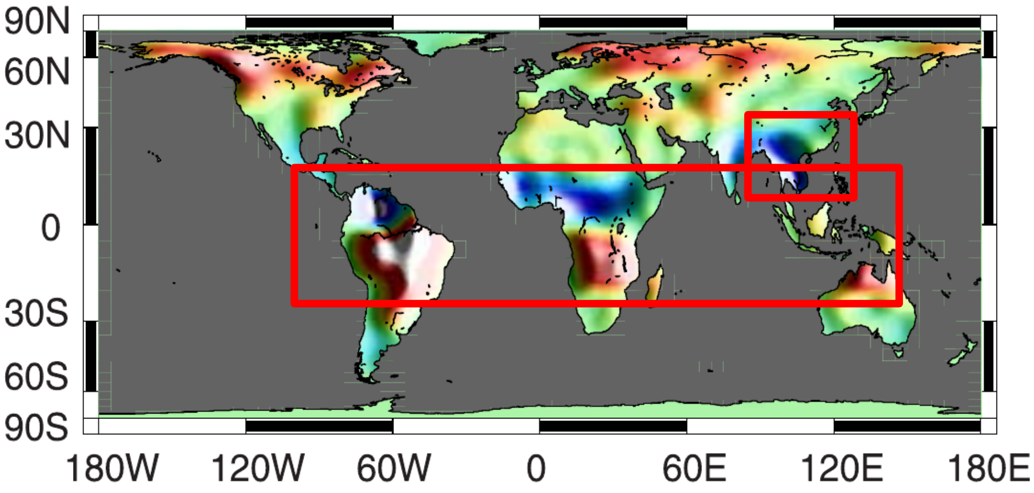
TWS (in mm) for the time period FMA minus ASO 2003

Ngo-Duc et al. (2007, WRR)

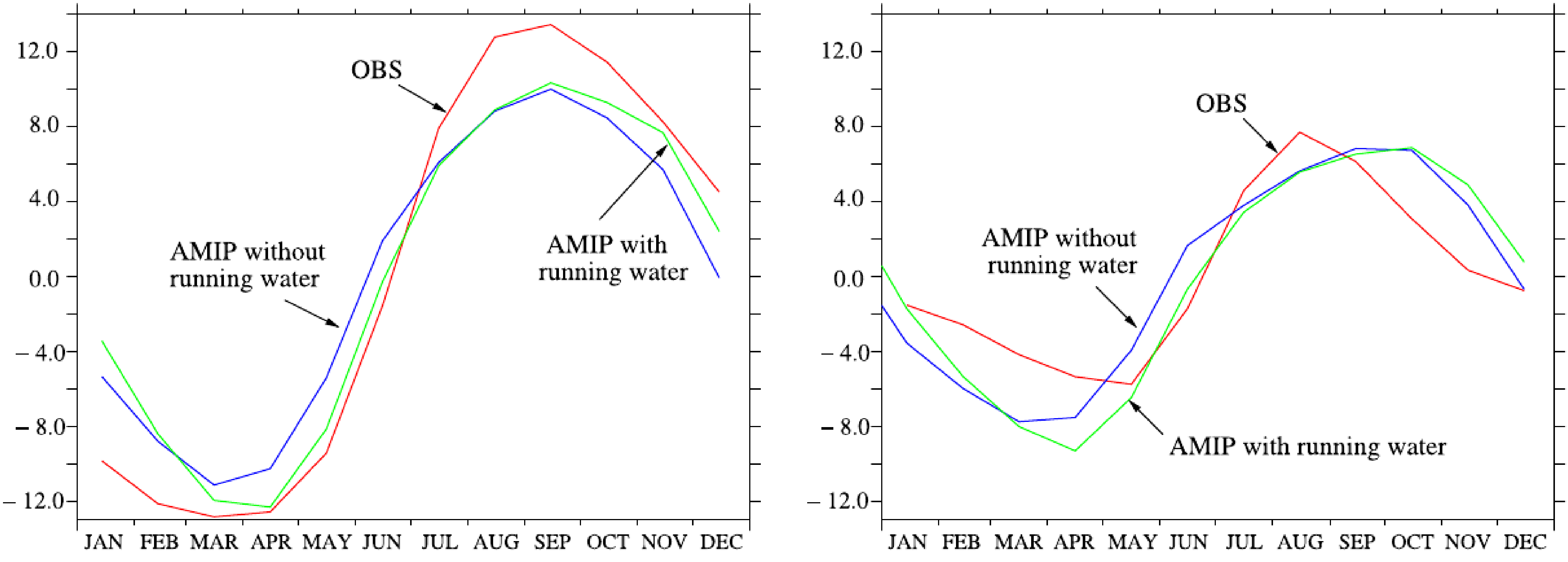
ORCHIDEE (without routing module)



ORCHIDEE (with routing module)



Contribution of continental water to sea level variations: comparison with TOPEX/POSEIDON



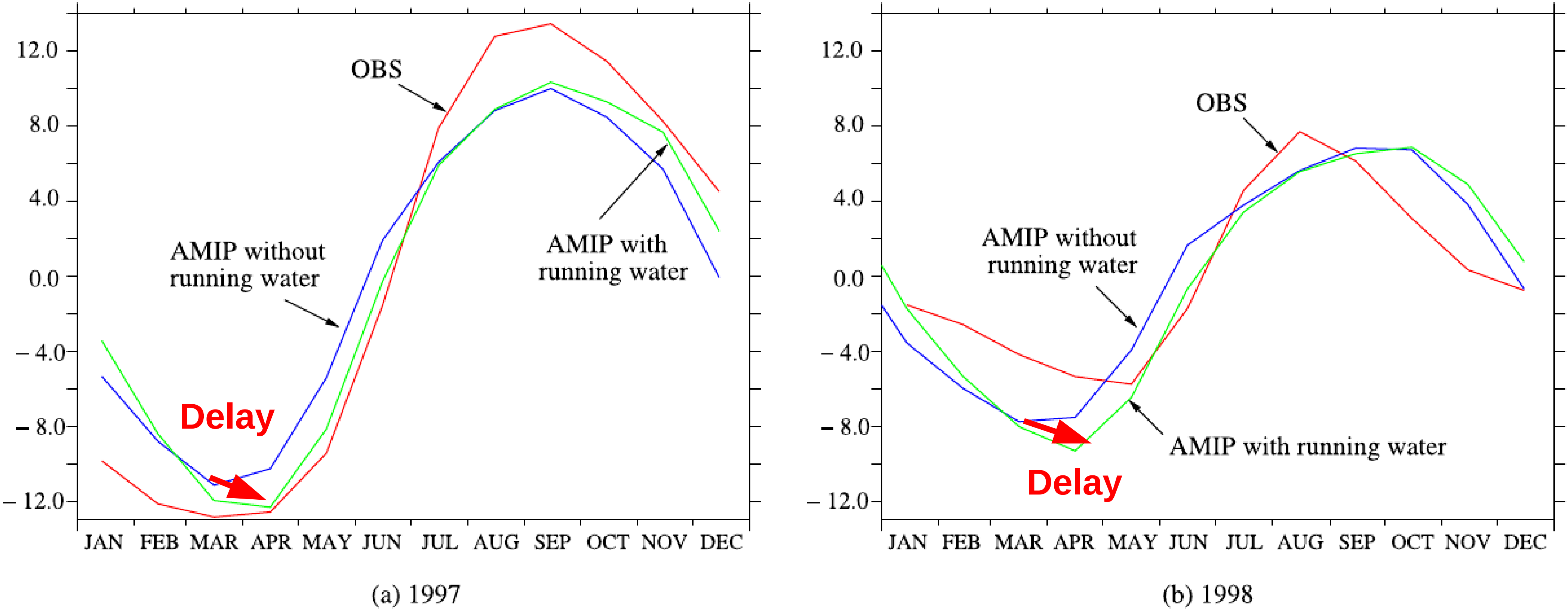
(a) 1997

(b) 1998

Contribution of continental water to sea level variations (mm)
Obs = T/P sea level - steric effect - vapor contribution (from NCEP/NCAR reanalysis)

Ngo-Duc et al. (2005, JGR)

Contribution of continental water to sea level variations: comparison with TOPEX/POSEIDON



(a) 1997

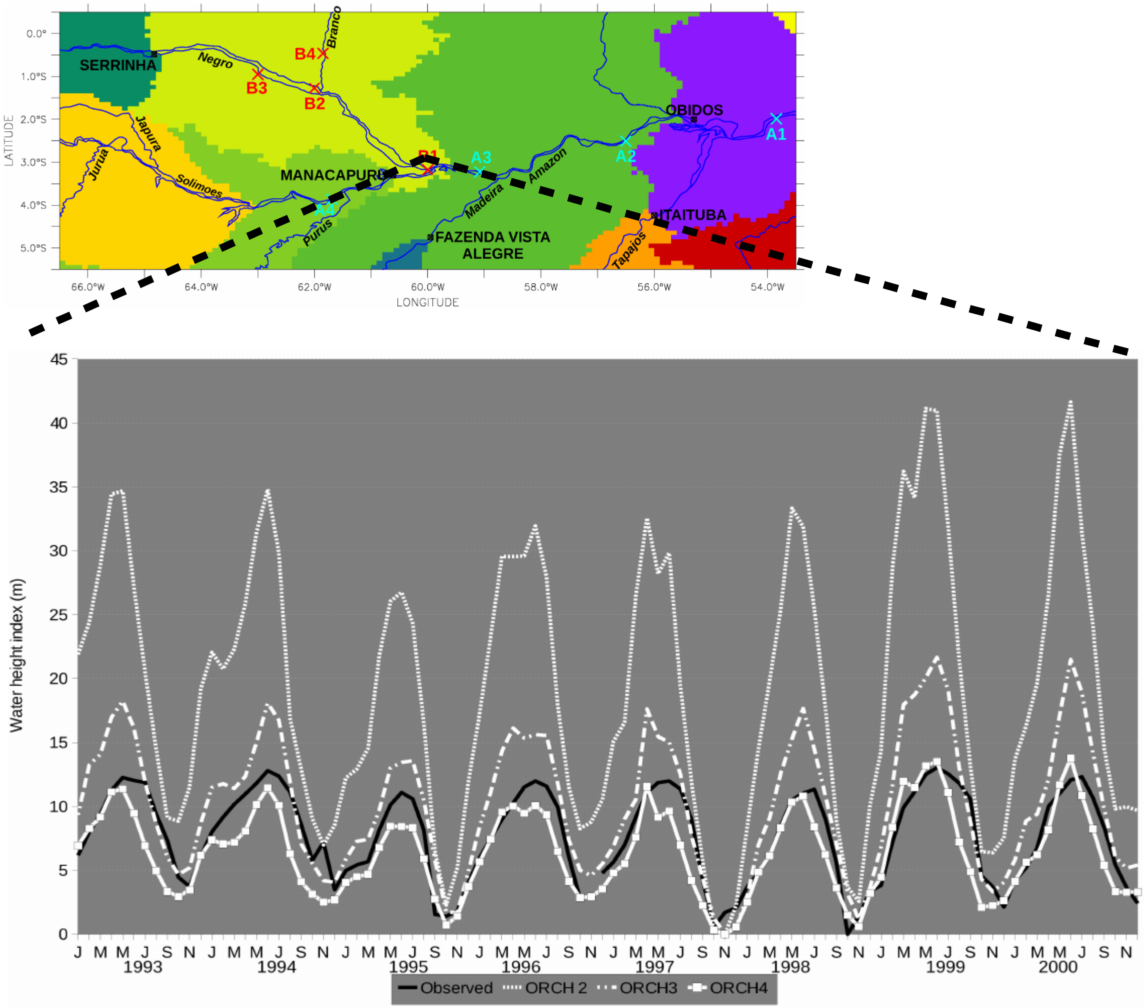
(b) 1998

Contribution of continental water to sea level variations (mm)

Obs = T/P sea level - steric effect - vapor contribution (from NCEP/NCAR reanalysis)

Ngo-Duc et al. (2005, JGR)

Floodplain water height

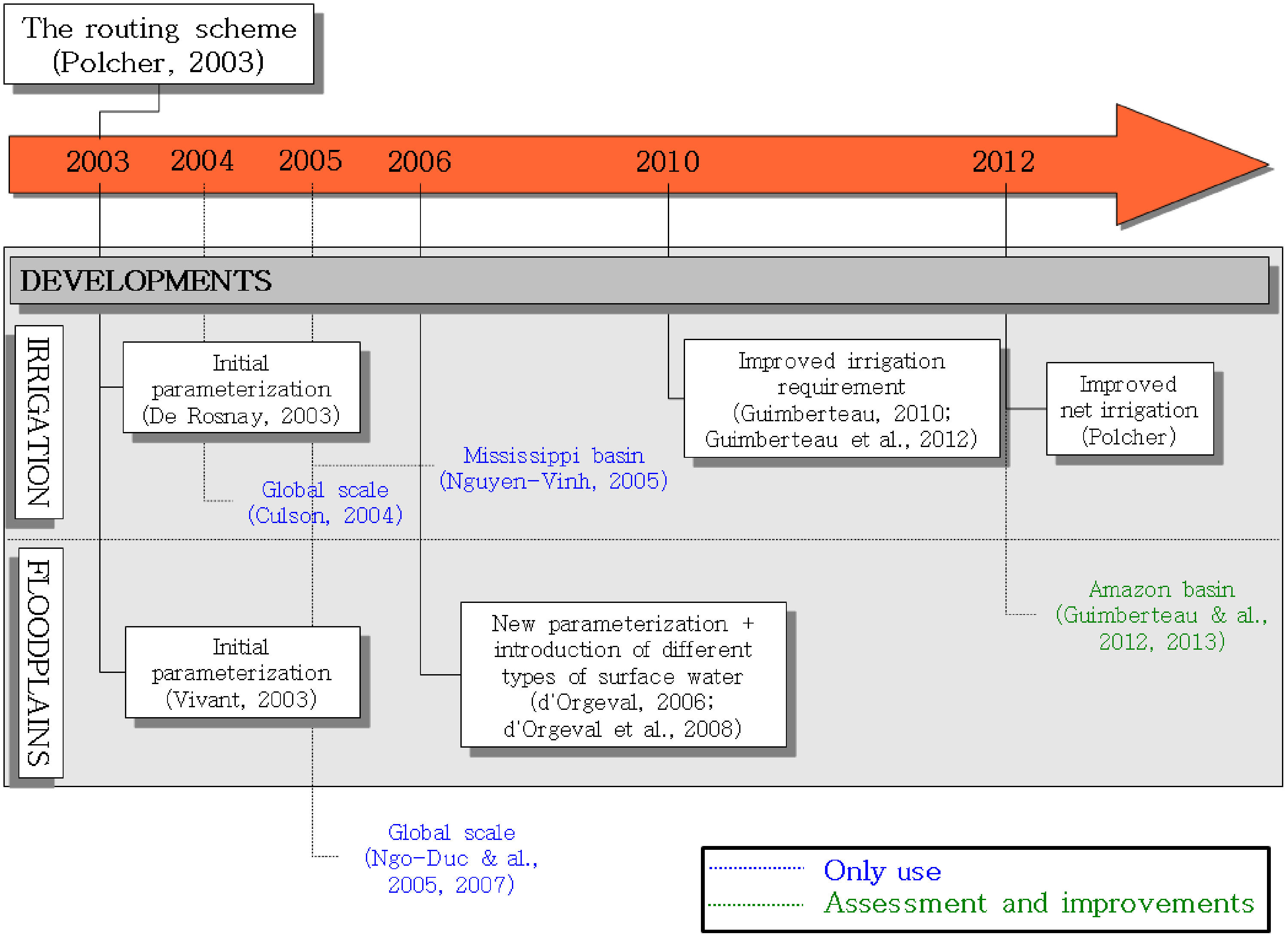


Interannual variation of monthly water height index (m) simulated with ORCHIDEE on the Rio Negro. Comparison with Topex/Poseidon observations. *Guimberteau et al. (HESS, 2012)*

5

Perspectives

Historical overview



The routing scheme (Polcher, 2003)

2003 2004 2005 2006 2010 2012

DEVELOPMENTS

IRRIGATION

Initial parameterization (De Rosnay, 2003)

Global scale (Culson, 2004)

Mississippi basin (Nguyen-Vinh, 2005)

Improved irrigation requirement (Guimberteau, 2010; Guimberteau et al., 2012)

Improved net irrigation (Polcher)

FLOODPLAINS

Initial parameterization (Vivant, 2003)

New parameterization + introduction of different types of surface water (d'Orgeval, 2006; d'Orgeval et al., 2008)

Amazon basin (Guimberteau & al., 2012, 2013)

Global scale (Ngo-Duc & al., 2005, 2007)

Only use

Assessment and improvements

Possible developments

- near-term objective (in progress with Jan Polcher and a Phd student):
    - high-resolution of maps in routing.nc and adaptation of the code in routing.f90
    - river dam buildings
- Aquifer mining: the withdrawal of groundwater from an aquifer (linked to the project of A. Ducharne who is implementing groundwater in ORCHIDEE)
- Water diversion: inter-basin transfer
- Urban areas
- ...

6

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Thank you

ORCHIDEE
LAND SURFACE MODEL

Parameters used in routing.f90

Name	Value	Unit	Description
General			
diagunit	87	*unitless*	Diagnostic file unit
dt_routing	one_day	s	Routing time step
nbasmax	7	*unitless*	Maximum number of basins per grid cell
nbvmax	440	*unitless*	
num_largest	50	*unitless*	Number of largest basins
fast_tcst	3	day/m	Fast reservoir property
slow_tcst	25	day/m	Slow reservoir property
stream_tcst	0.24	*day/m*	Stream reservoir property
Swamp subroutine			
swamp_cst	0.2		Swamp constant
Floodplain subroutine			
beta	2	*unitless*	Fix the shape of the floodplain
floodcri	2000	mm	Potential height for which all the basin is flooded
flood_tcst	4	day/m	Flood reservoir property
Pond subroutine			
betap	0.5	*unitless (0-1)*	Ratio of the basin surface intercepted by ponds and the maximum surface of ponds
pondcri	2000	mm	Potential height for which all the basin is a pond
Endoheric lake subroutine			
maxevap_lake	7.5/86400	mm/s	Maximum evaporation rate from lakes

Classification of flow routing

- By spatial and temporal variation
  - Distributed flow routing (hydraulic routing)
    - flow → f(space, time)
    - the flow is computed as a function of time simultaneously at several cross sections along the watercourse
    - governing equations used: continuity and momentum
  - Lumped flow routing (hydrologic routing)
    - flow → f(time)
    - the flow is computed as a function of time at one location along the watercourse => simplified description of the flow
    - governing equations used: continuity and flow/storage relationship
- By watercourse type
  - river flow routing
  - reservoir routing
  - overland flow routing

Routing techniques

- **Cell-to-cell or cell based streamflow routing (e.g. ORCHIDEE)**
  - **simulate the transport of runoff generated within the modeling units (e.g. grid cells), through river networks across continents into the oceans**
- Source-to-sink streamflow routing
  - defines specific sources or areas, where excess runoff enters the hydrologic system, and sinks or areas, where excess runoff leaves the hydrologic system. A hydrograph is calculated at the sinks as a summation of the contribution of all the sources
- The element-to-element streamflow routing
  - the watershed is represented as a collection of elements like basins, reaches, reservoirs, sources and sinks. Flow is routed to the outlet element-to-element. Hydrographs are calculated at each element as well as at the outlet.