Adding water management in the ORCHIDEE model

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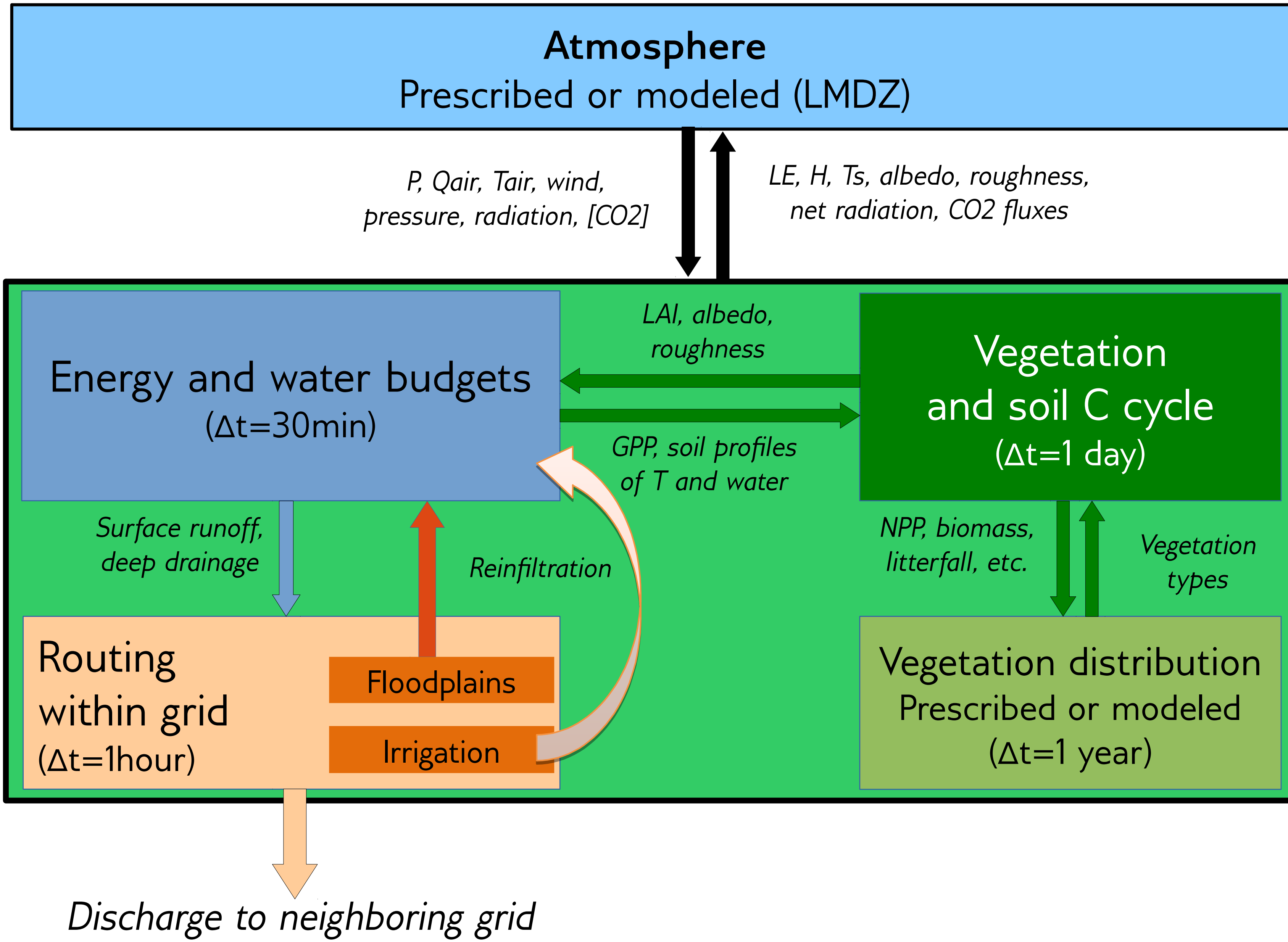
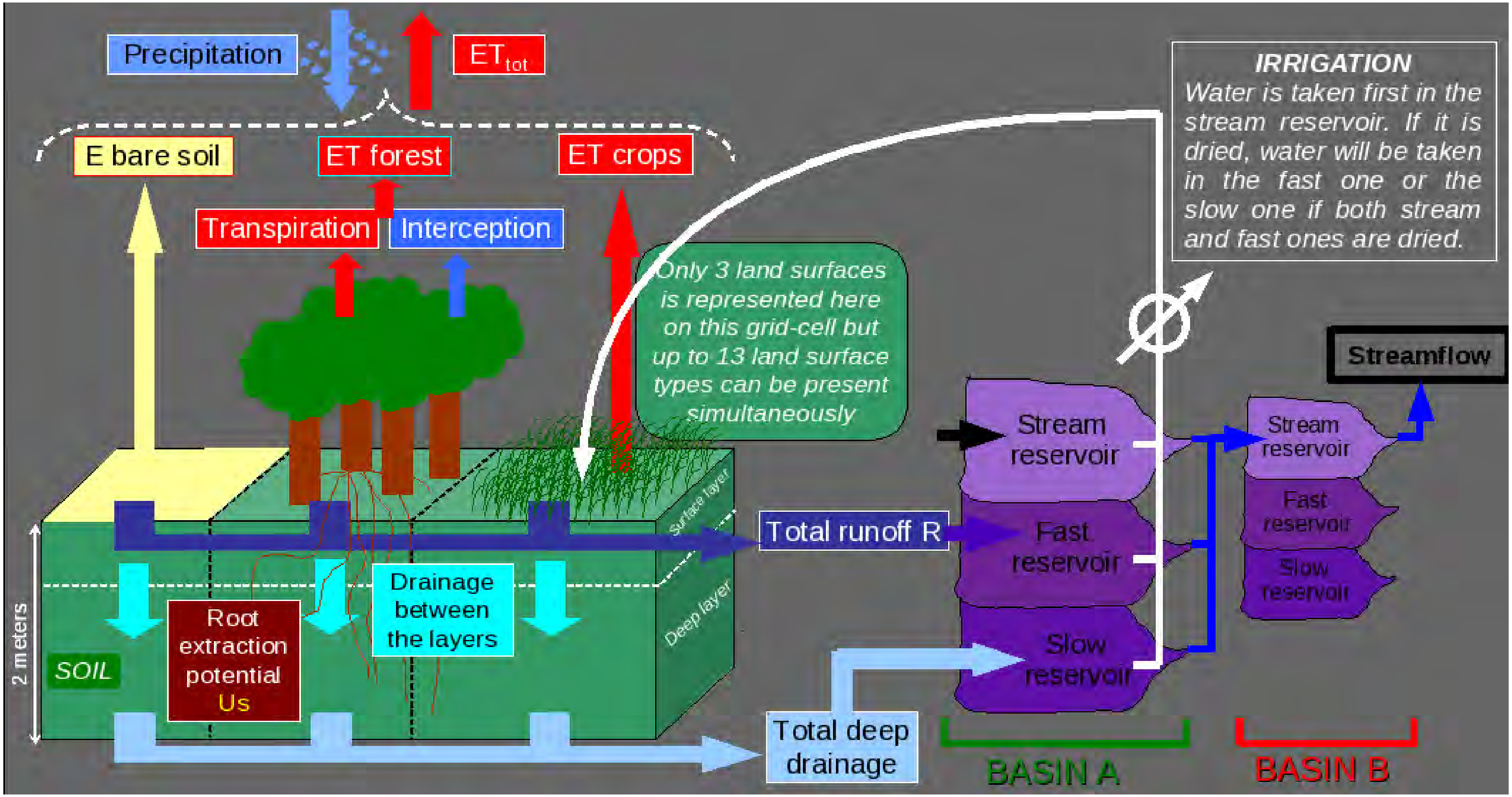
- Current irrigation scheme in ORCHIDEE
- Limitation of the current scheme
- Development of a high resolution routing scheme (1km)
- Introduction of a new reservoir module

Processes at grid level in ORCHIDEE



Sub-grid divisions in hydrology and routing

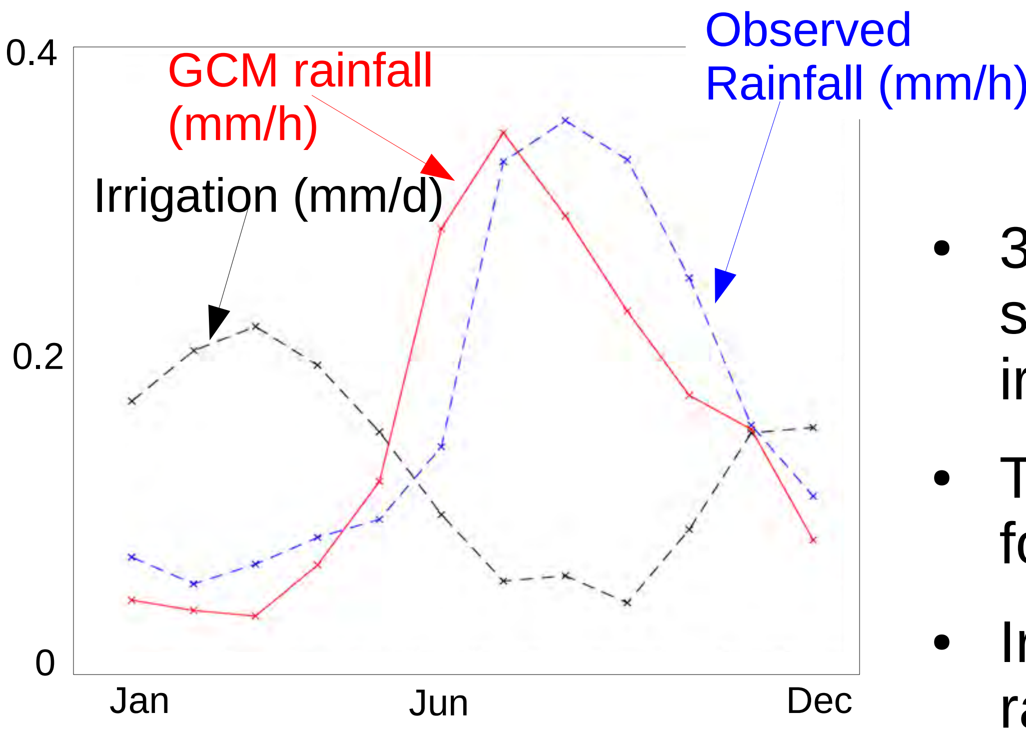


Current implementation of the irrigation scheme

- The original irrigation scheme is documented in de Rosnay et al. 2003
- The basin maps are obtained from the 50km resolution maps of Vörösmarty 2000.
- The irrigated fractions is taken from Döll and Siebert 2002
- The water need for the irrigated area is a function of the actual to potential transpiration ratio.
- Irrigation only occurs if the LAI of the crops is developed.
- The local river is used as a water source for irrigation thus preserving water conservation.

Application to the Indian Monsoon in the GCM

Guimberteau et al., 2012

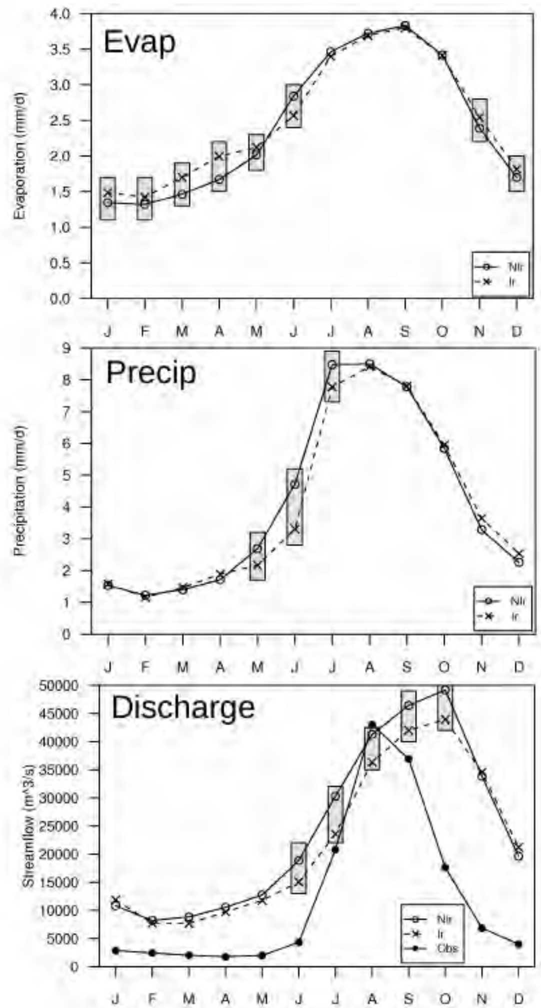


Precipitation and irrigation over India.

- 30 year GCM (LMDZ-ORC) simulations with and without irrigation.
- The annual cycle of water usage for irrigation is realistic.
- Irrigation represents 10% of rainfall from November to May.

Land irrigation delays the onset of the monsoon

2 simulations with ORCHIDEE coupled with the atmosphere:
Nir (no irrigation) and **Ir** (with irrigation) *Guimberteau et al., 2012*



On average over India and 30 years

Feedbacks irrigation-monsoon precipitation

Winter-spring irrigation (∼ 10% of precipitation)

⇓

↗ evaporation (∼ +9%)

⇓

Cooling (from February to May)

⇓

↘ thermal contrast between ocean and continent

⇓

Weakening of the monsoon onset early June

⇓

↘ precipitation after the 20th May

⇓

Warming of the continental surfaces

- delayed onset + water withdrawals by irrigation => ↘ Ganges-Brahmaputra discharge

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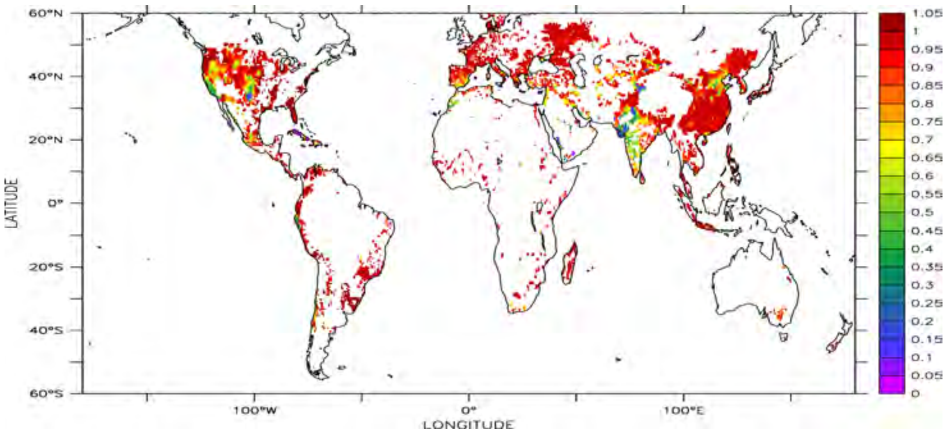
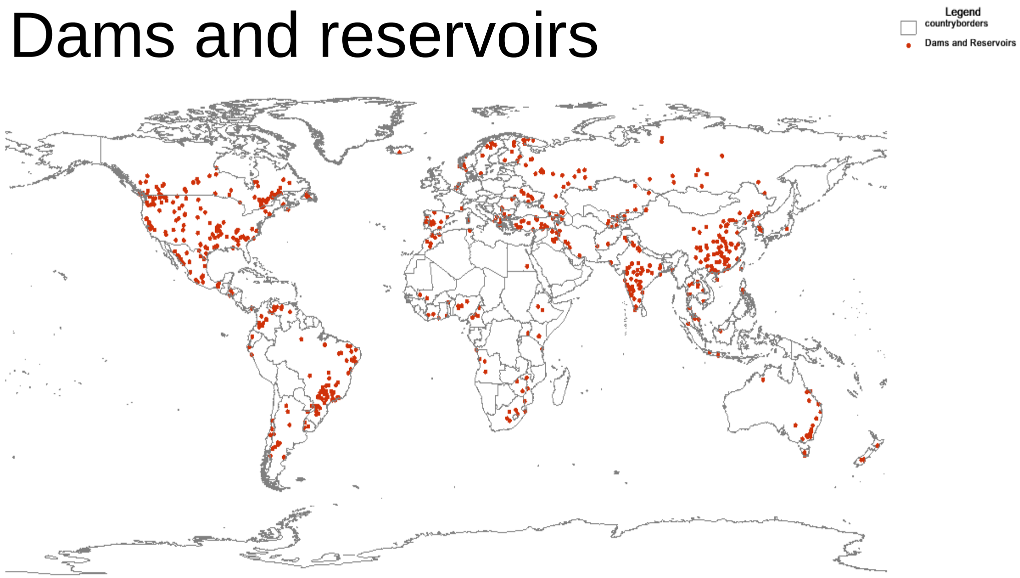
Limitation of the scheme at higher resolution

Irrigation over irrigation requirement



Dames and reservoirs

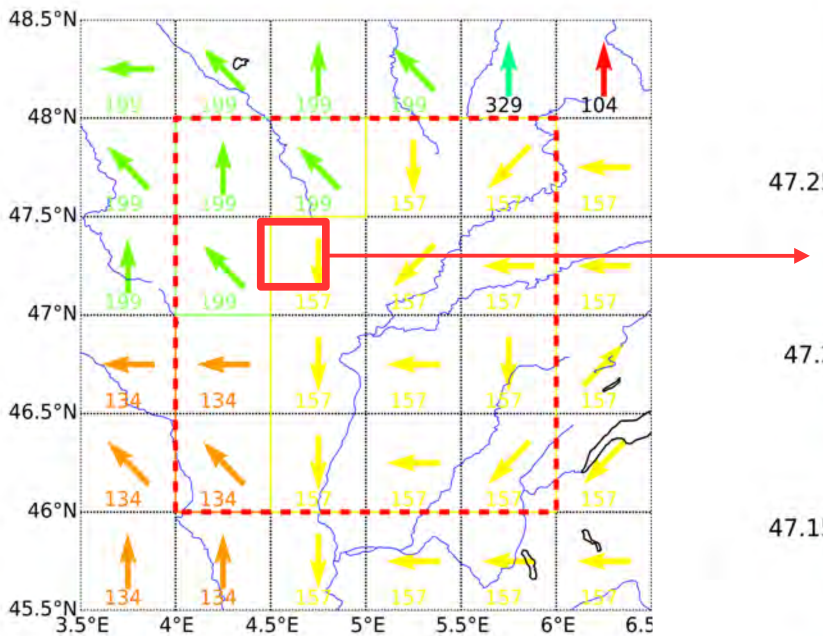


- The irrigation scheme changed behavior as the resolution moved to 0.5°.
- In many areas of the world the computed irrigation demand is not anymore satisfied by local water.
- The quick-fix was to allow the model to take water from neighboring grids.
- Irrigation infrastructures (dams, reservoirs, adduction networks) need to be explicitly represented.

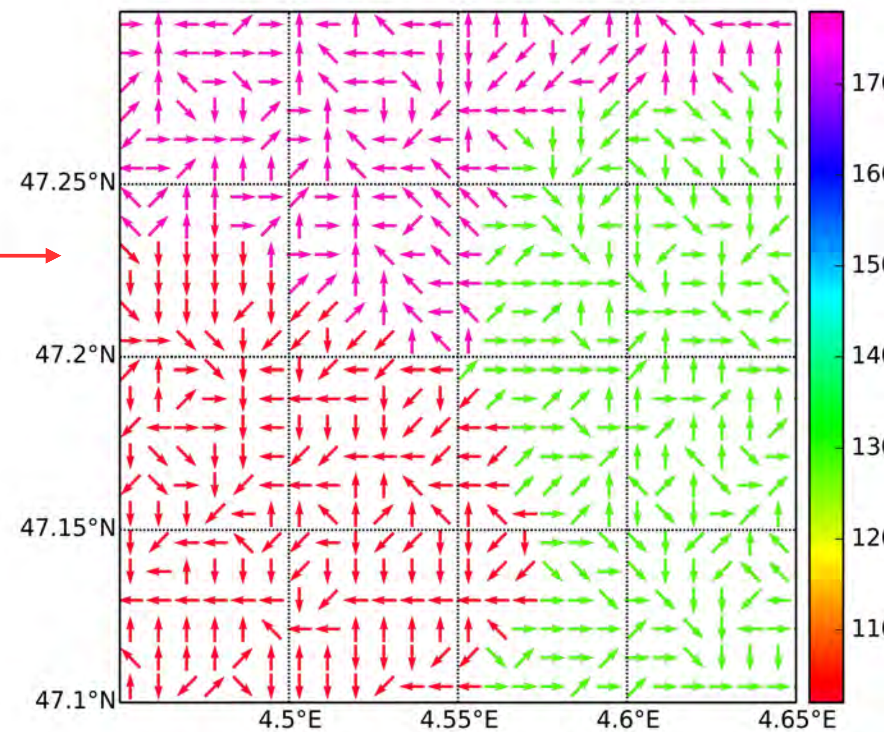
Three Gorges Dam
(S: 1084km2, L:~660km, D:~1.1km)

New routing scheme in ORCHIDEE

- **(HydroSHED) Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives(30 arc-second, ~1km at equator)



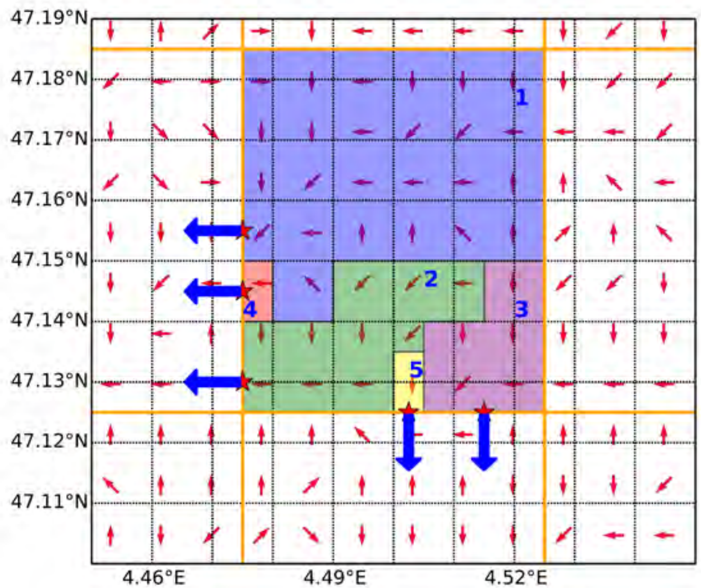
TRIP (Vörösmarty 2000)

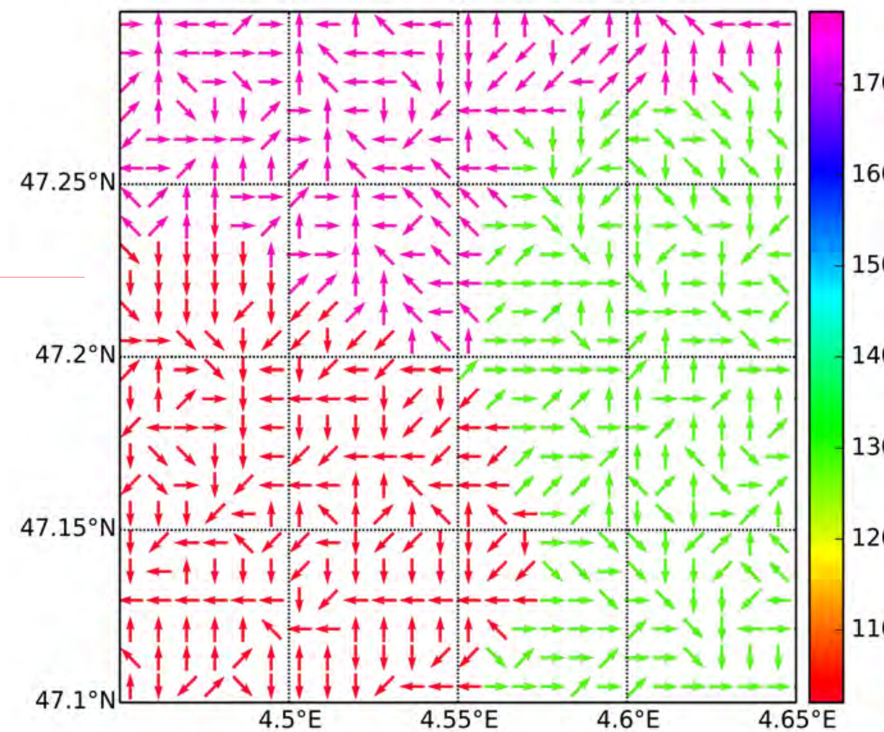


HydroSHEDS

New routing scheme in ORCHIDEE

- Sub-basins in ORCHIDEE





HydroSHEDS

Advantages of using high resolution routing scheme

- Get more details about the river structures
- Allow us to define more sub-basins per grid box
- The detailed topographic index allows the water flow movement be closer to real situation
- Short residence time in small grid allows routing in a short time span (up to 1h), and benefits to evaluate model at a daily scale
- Consider adduction infrastructures (reservoirs, man-made channels)

Consistency of information at the sub-basins of ORCHIDEE

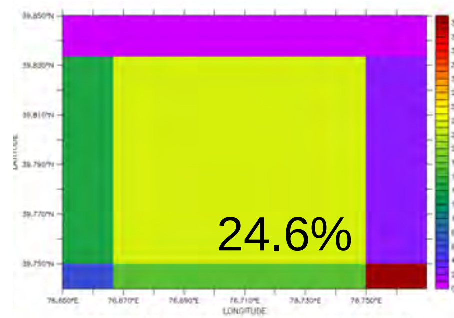
Definition of irrigated area

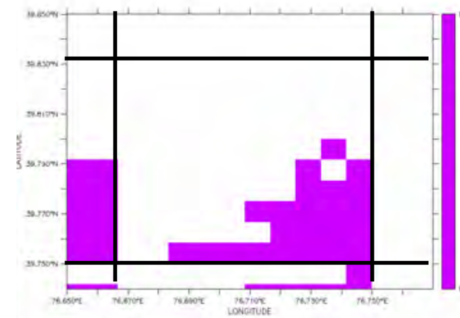
FAO(~10km) – Area equipped for irrigation as percentage of total area (%)

Irrigated from lower to higher

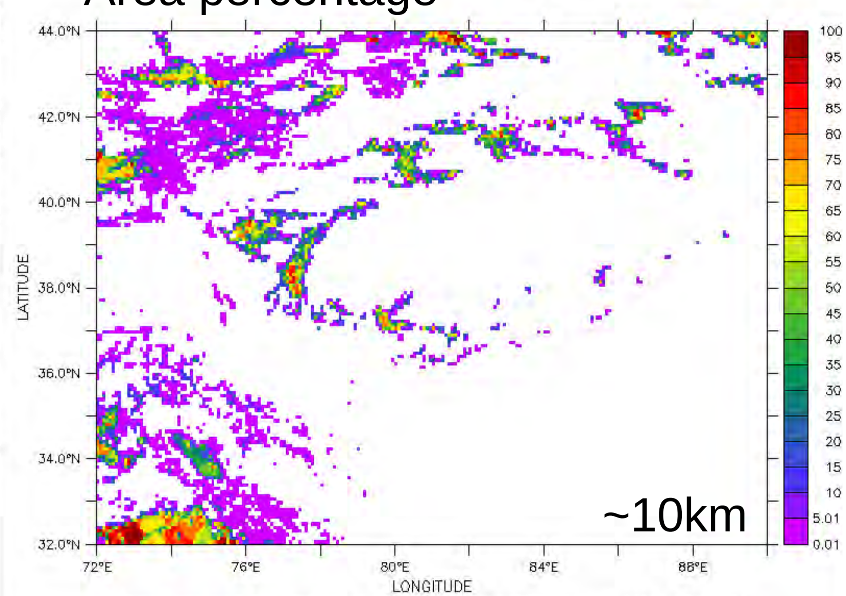
Irrig (~1km) – Irrigated Area

Siebert et al., 2012

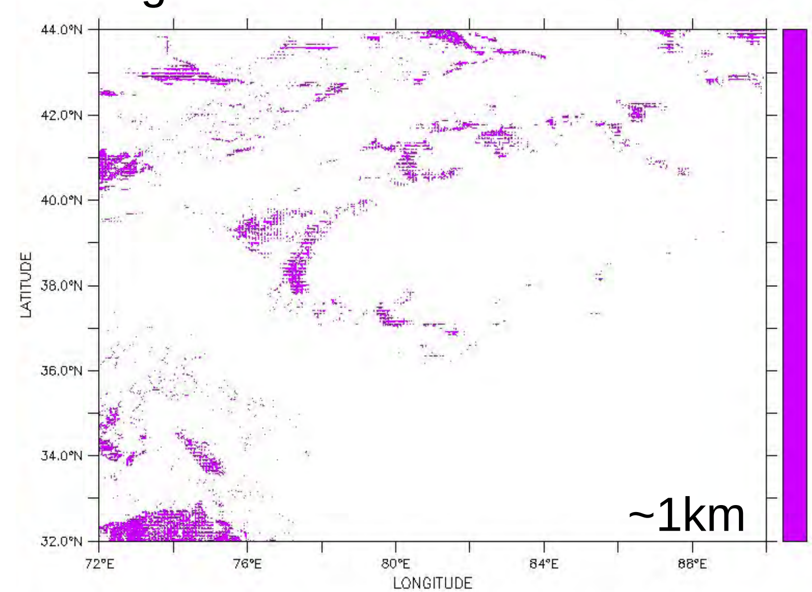




Area percentage



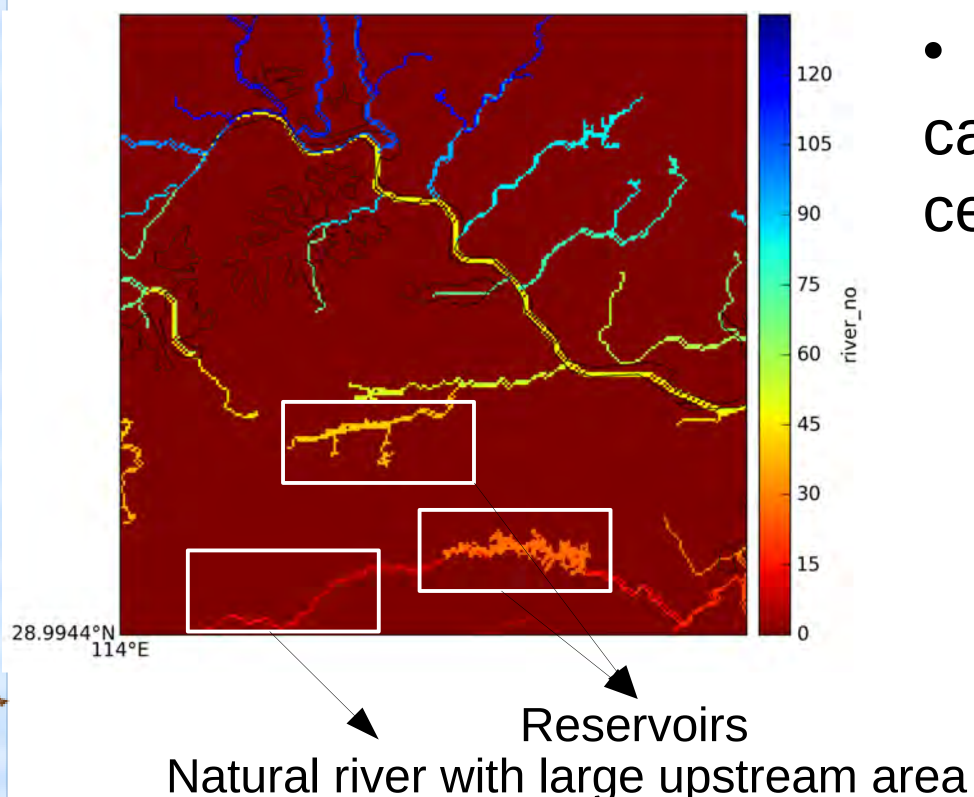
Irrigated area



Definition of abstraction points

- Managed rivers – Rivers connecting to reservoirs upstream

Water are withdrawn from river channels rather than directly from reservoirs



- Large natural rivers – Rivers with catchment area larger than a certain area
  - Large amount of reservoirs are not recorded in GRanD
  - Scattered agriculture can rely on natural rivers nearby

Dataset: Global Reservoir and Dams (Lehner and Döll, 2004)

Supply-demand path

- Cost from irrigation unit to abstraction point

ODDYCCEIA :

$$cost = min\left(d^{path} + kh \cdot H^{path}\right)$$

(Neverre et al., 2016)

New

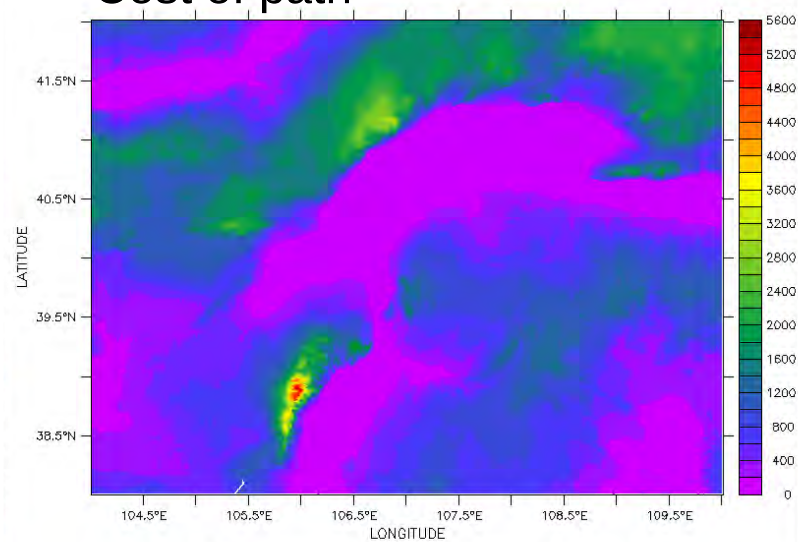
$$cost = \frac{min\left(d^{path} + kh \cdot H^{path}\right)}{log\left(U\right)}$$

U : upstream area of the abstraction point
kh : penalty coefficient of uphill movement
  – (default 10) Going up one meter is 10 times more costly than covering one kilometer horizontally
d : Distance covered along a supply-demand path
H : Altitude differential of uphill movements

Supply-demand path

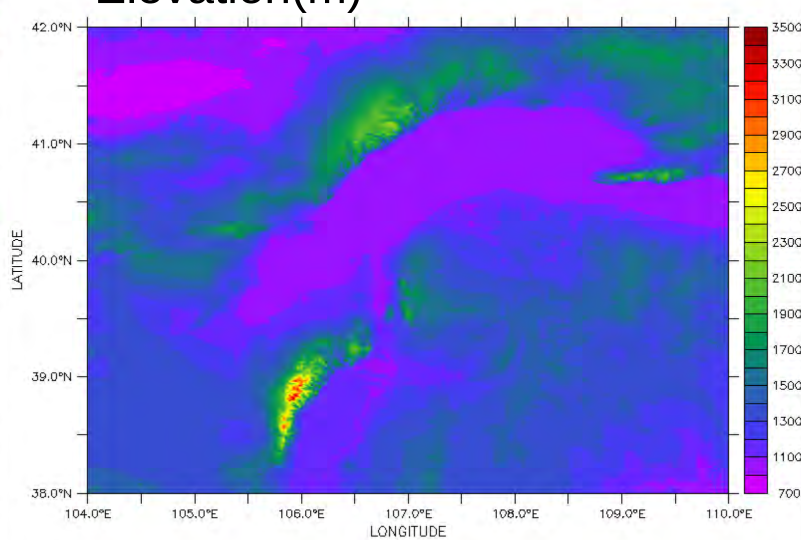
- Cost estimation is highly restricted by topography

Cost of path

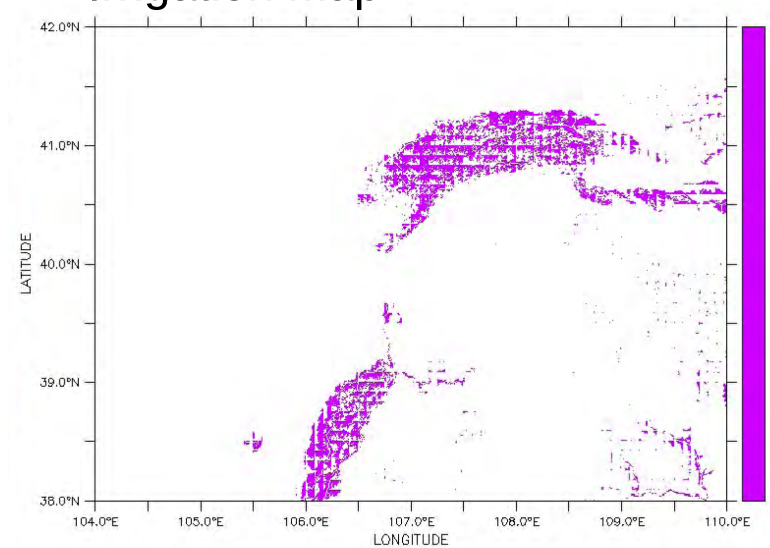


The cost of path is logical consistent to the irrigation map and also to the topography

Elevation(m)

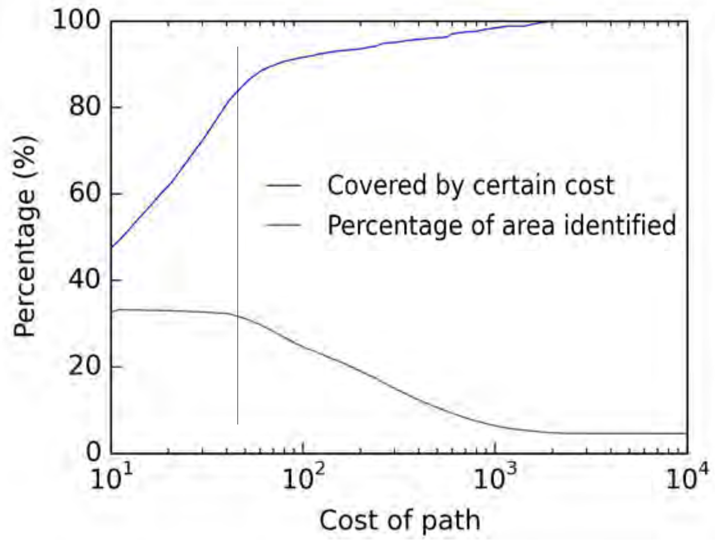


Irrigation map



Supply-demand path

- A criterion exists for the cost along supply-demand path



- The cost is no longer the key factor for irrigation after a certain criterion.

- The criterion helps us make a decision how to supply the water demands for each grid.

- A mixture of local irrigation and irrigation with water transportation are both needed in models.

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Supply-demand path

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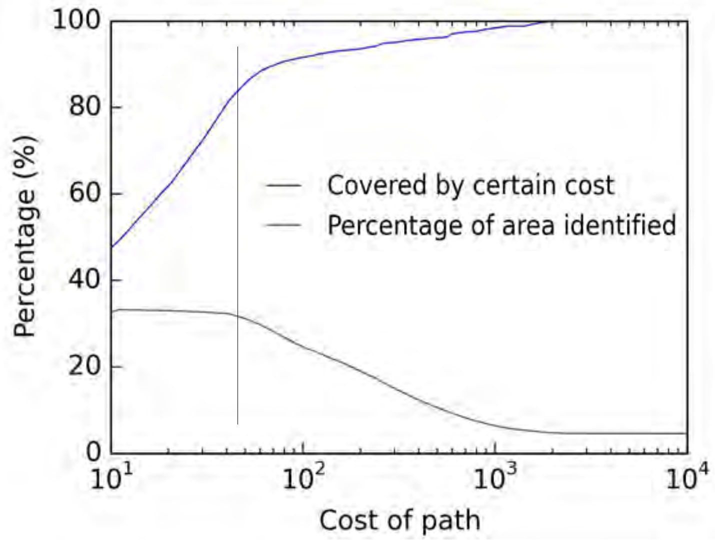

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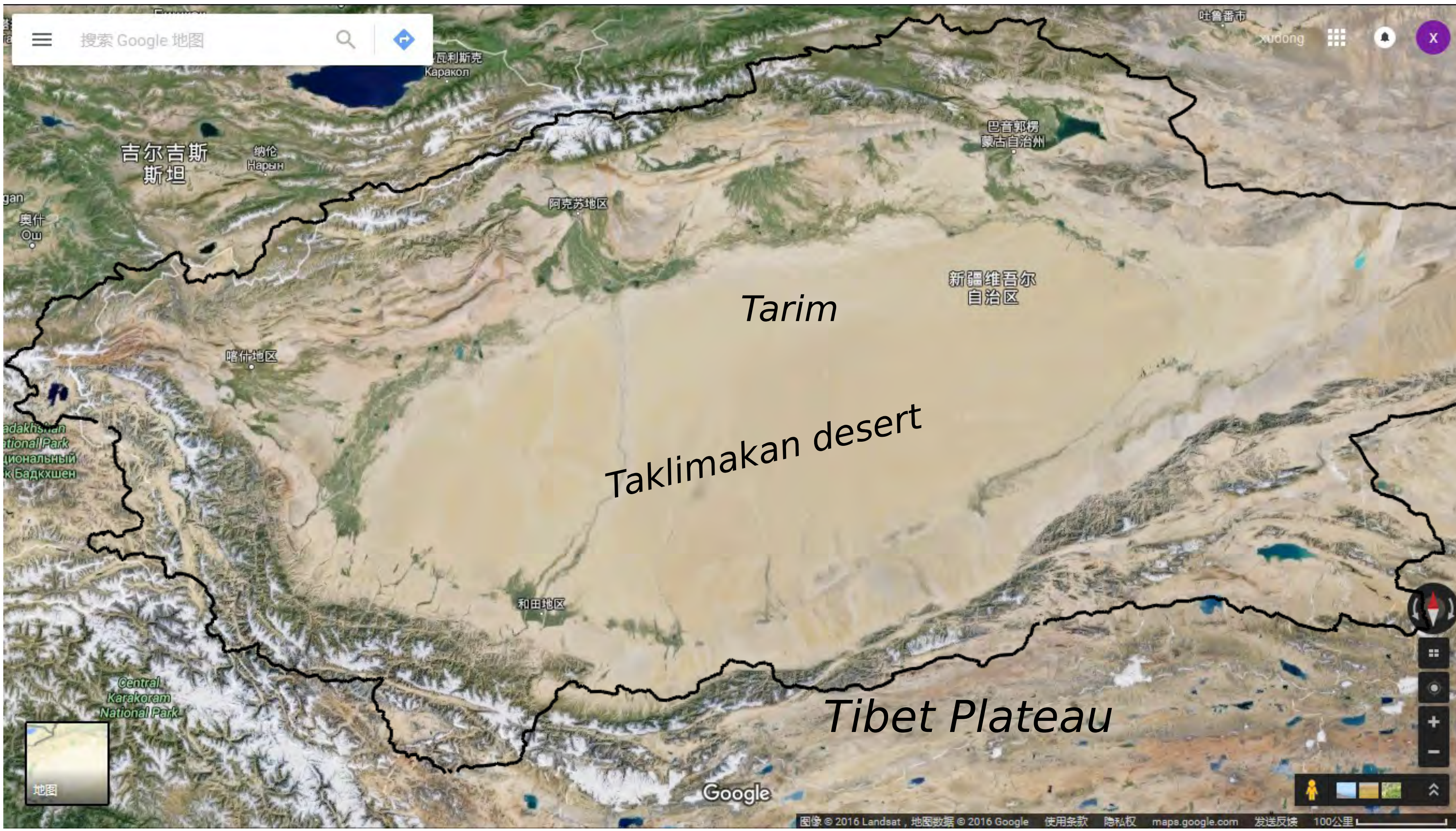
Further development are needed

- Quantification of demand for irrigation
- Reservoir management and rules development with water values

Application in Tarim basin

Application in Tarim basin



Application in Tarim basin

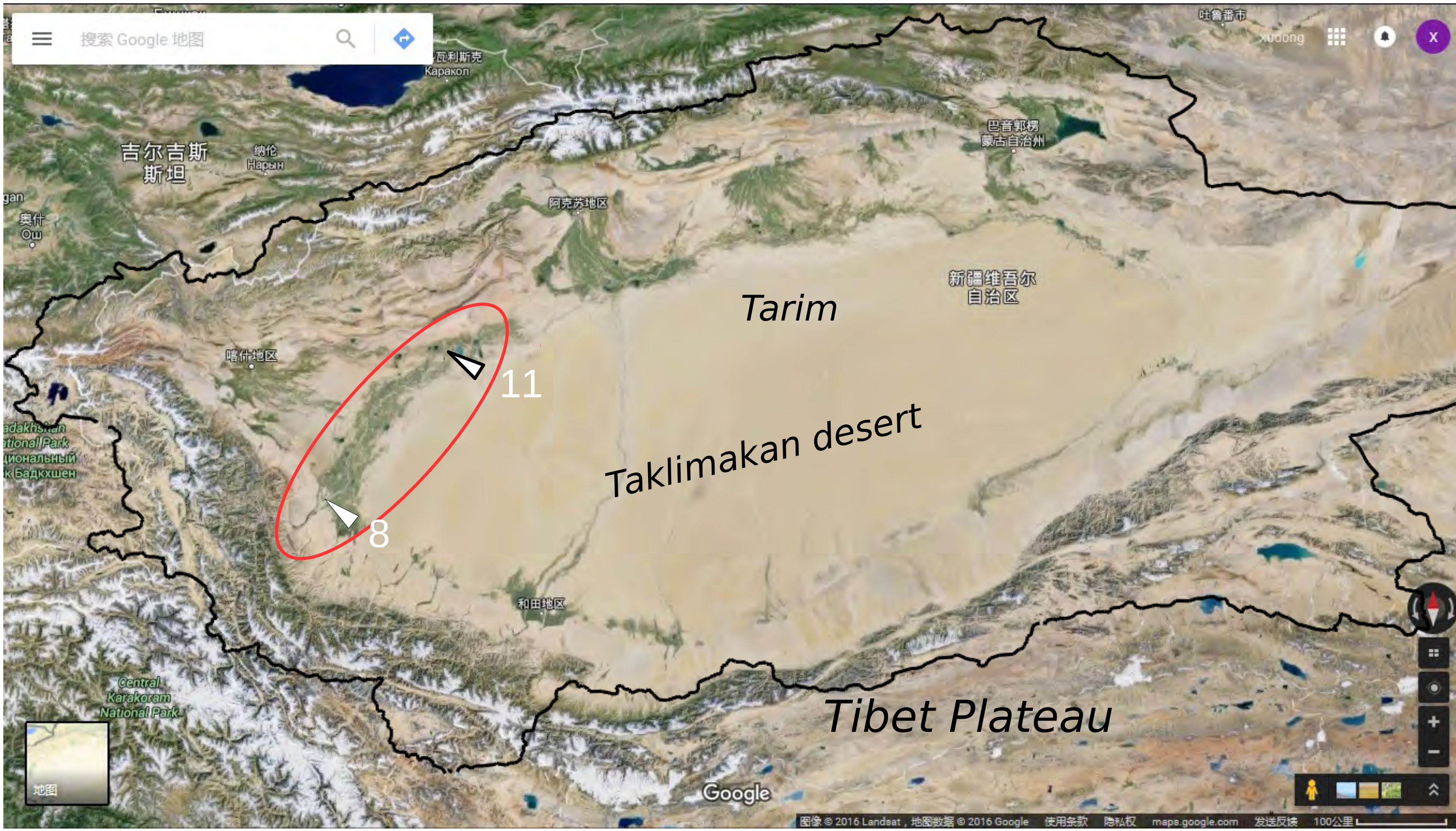
Reasons to choose:

1. Perfect endorheic basin (close water budget)
2. Full hydrological processes
3. Less complicated water usage (little industry water)
4. Easily located water usage (irrigation, domestic use)

Challenges:

1. Data availability
2. Glacier/snow scheme
3. Unclear underground water movement

Application in Tarim basin



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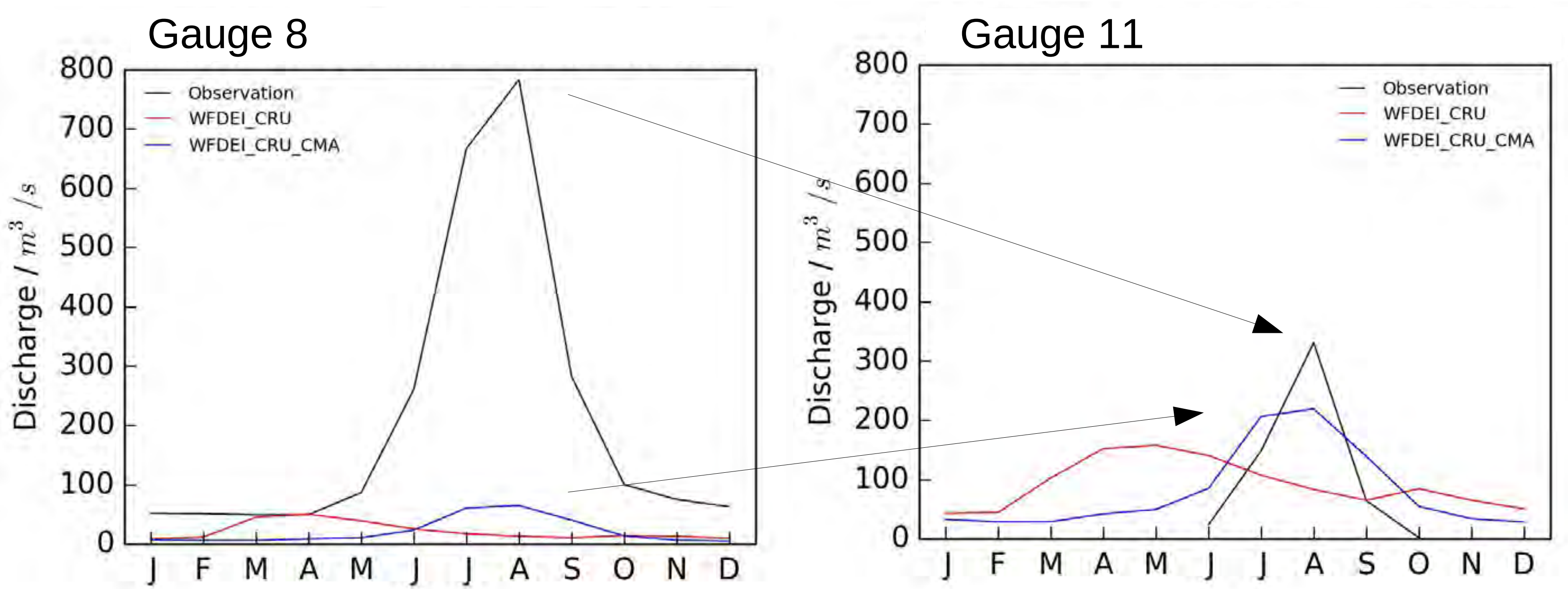
Application in Tarim basin

- Intensive irrigation usage is detected from discharge observations
- Significant contribution from glacier melting should be taken into account in the model



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Thanks for your attention!

Reference

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