Update on mizuRoute coupled with Community Terrestrial System Model

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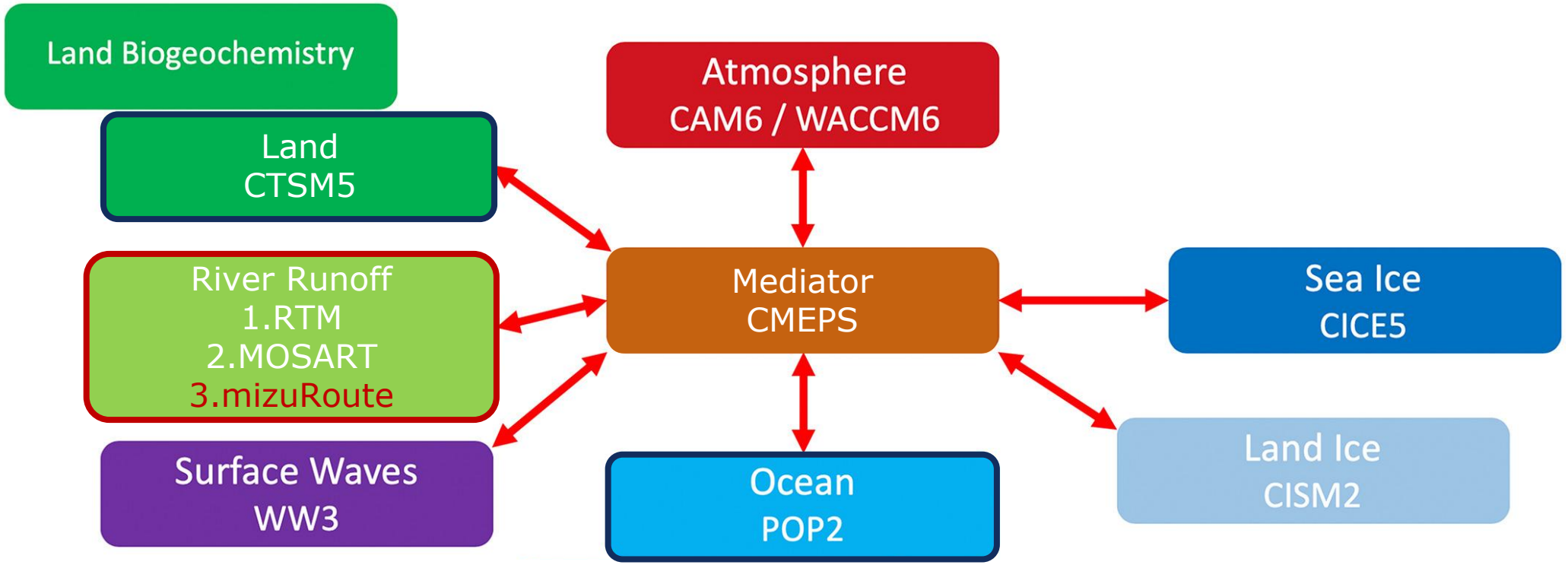
Topics

- ❑ One-way or two-way CTSM and mizuRoute coupling
- ❑ Lake model in mizuRoute

mizuRoute in CESM



Adapted from Danabasoglu et al, 2020 JAMS, 12, 2, DOI: (10.1029/2019MS001916)

	Spatial discretization
RTM	Regular grid
MOSART	Regular grid
mizuRoute	Unstructured grid (catchment polygon) or regular grid

mizuRoute catchment data

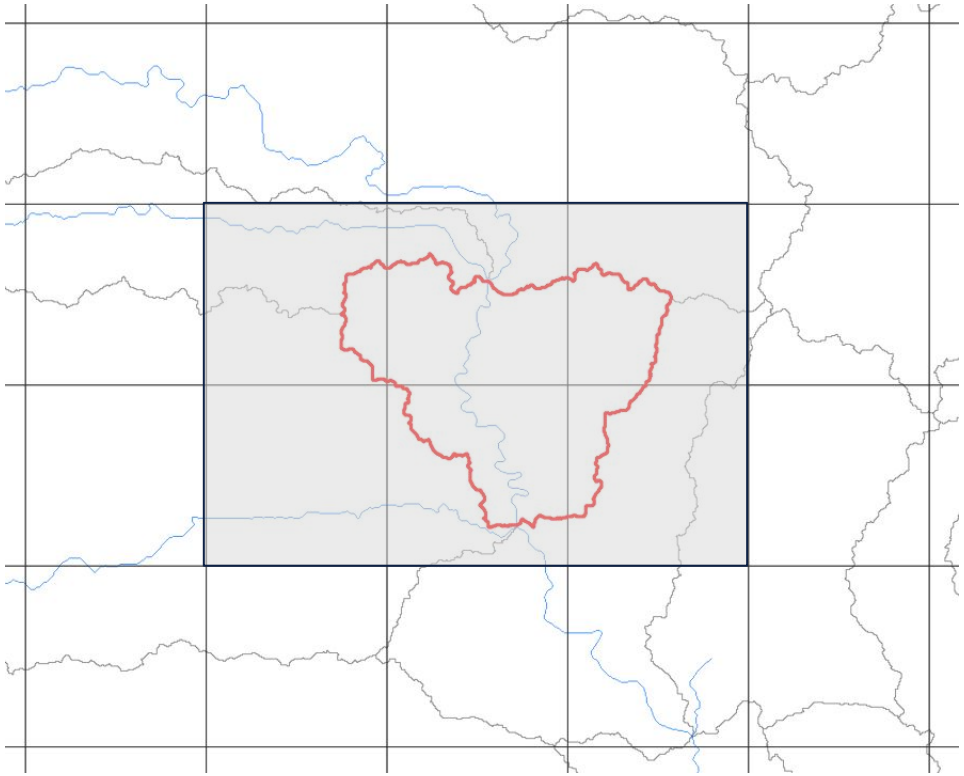
Grid name	Domain	# of elements
rHDMA	Global	295,335 catchments
	CONUS	20,924 catchments
rMERIT	Global	2,996,635 catchments
	CONUS	227,247 catchments
rHDMAlk	Global	298,277 catchments and 4236 lakes
f05	Global	99,427 grid boxes

Precomputed re-grid mapping file (land grid and mizuRoute catchment).

- rHDMA : nldas2(conus 1/8°), f19 (2.0°), f09 (1.0°), hcru (0.5°)
- rHDMAlk : f19 (2.0°), f09 (1.0°), hcru (0.5°)
- rMERIT: nldas2 (conus 1/8°), f19 (2.0°), f09 (1.0°), hcru (0.5°)

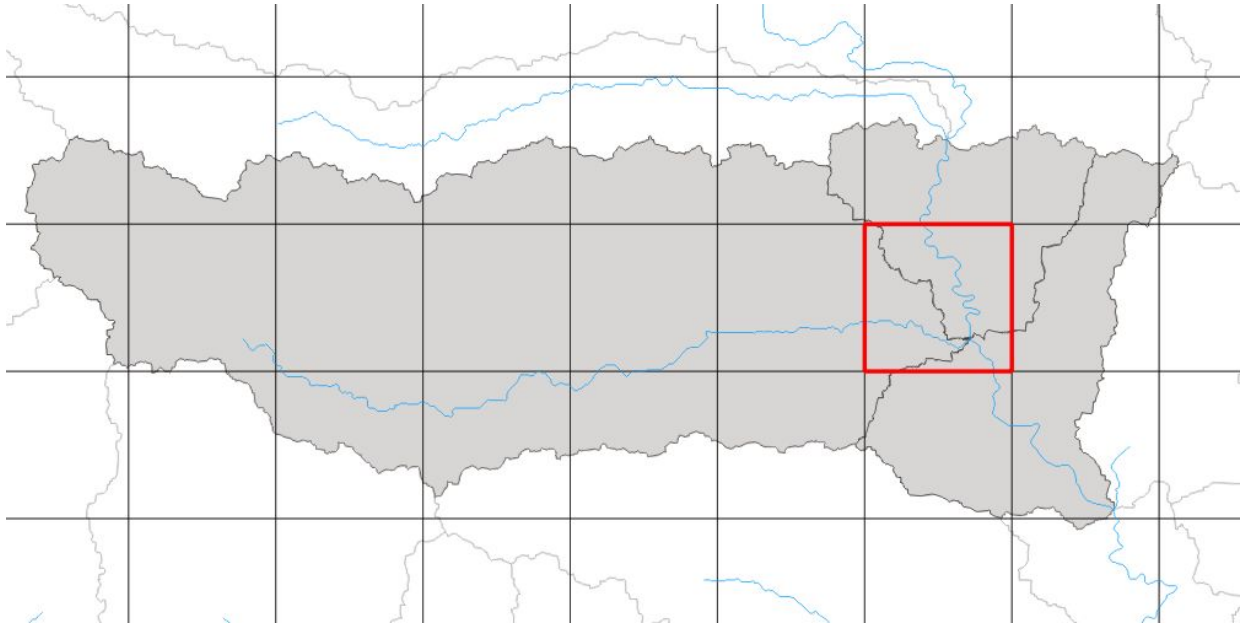
Regridding between CTSM grid and mizuRoute catchment

e.g., mapping CTSM grid (gray) to mizuRoute catchment (red)



- Runoff: surface, subsurface, and qgwl (glacier, wetland, lake)
- Irrigation demand from surface

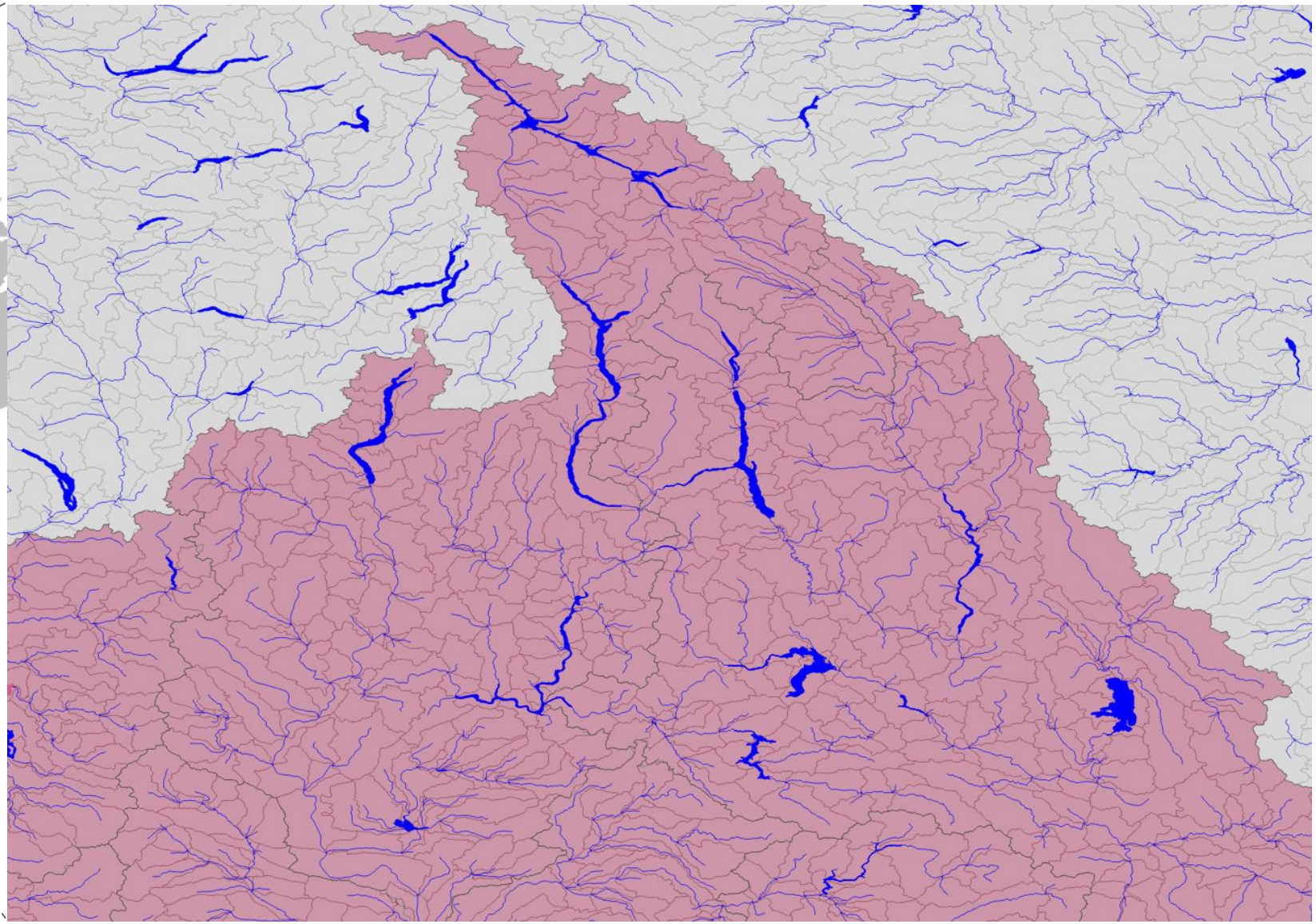
e.g. Mapping mizuRoute catchment (gray) to CTSM grid (red)



- River volume
- Discharge
- Flood (not active)

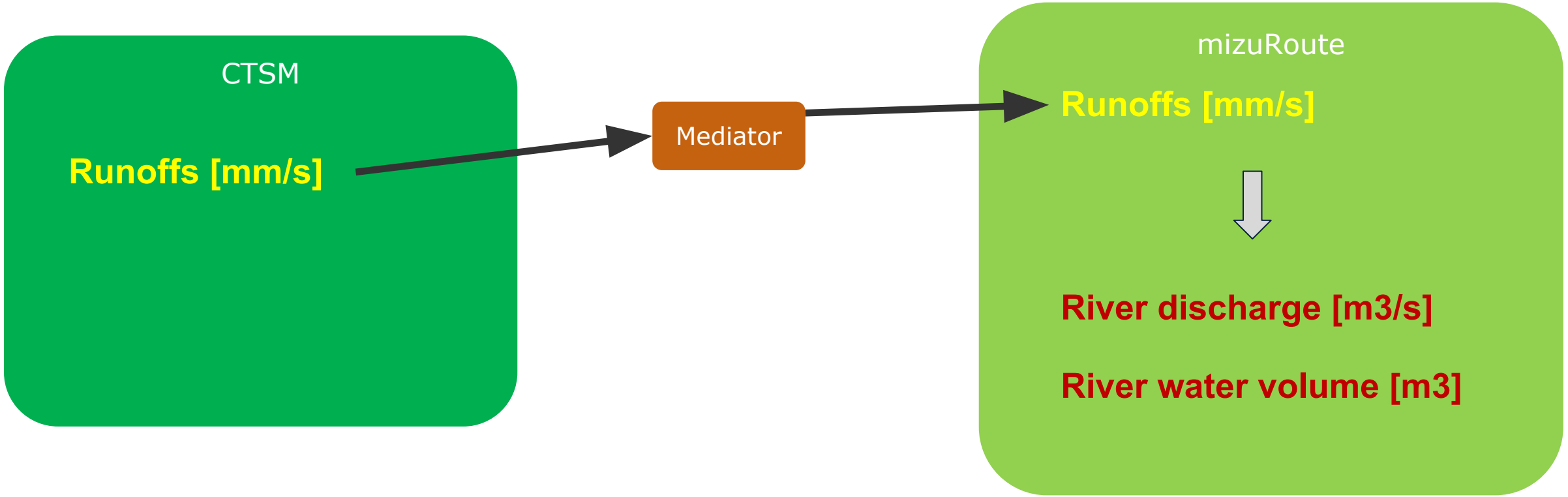
HDMAlk (HDMA+HydroLake) grid

Greenland, Antarctica missing



CTSM-mizuRoute coupling

One-way CTSM coupling (CTSM → mizuRoute)

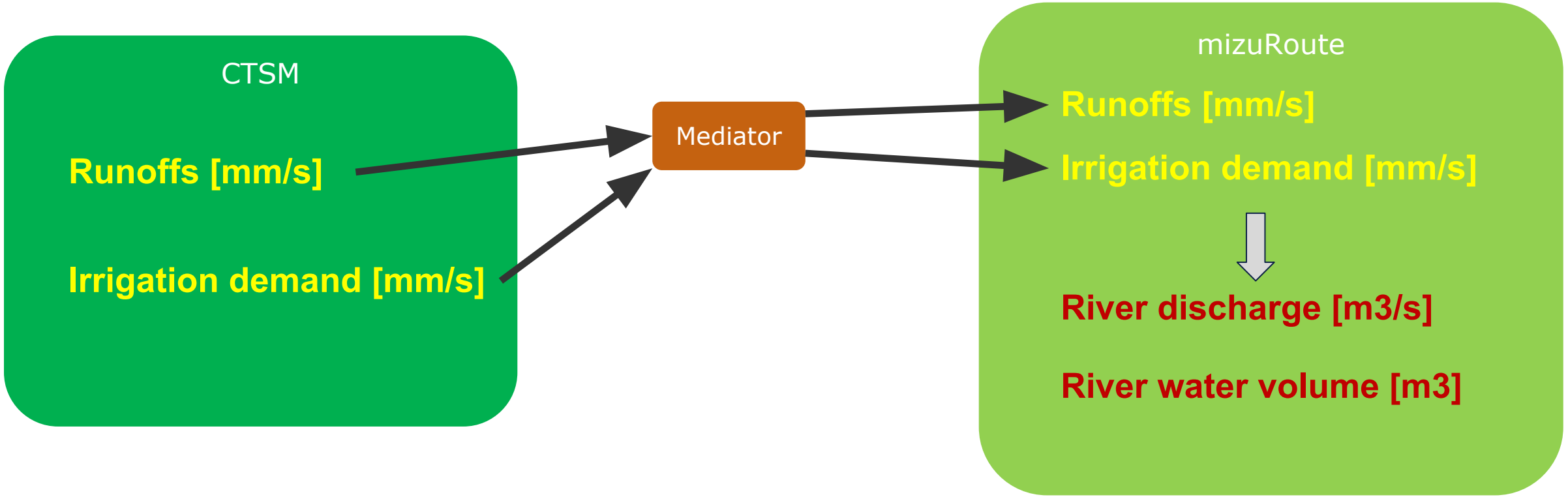


CLM namelist option

- *irrigate* = false

CTSM-mizuRoute coupling

One-way CTSM coupling (CTSM → mizuRoute)

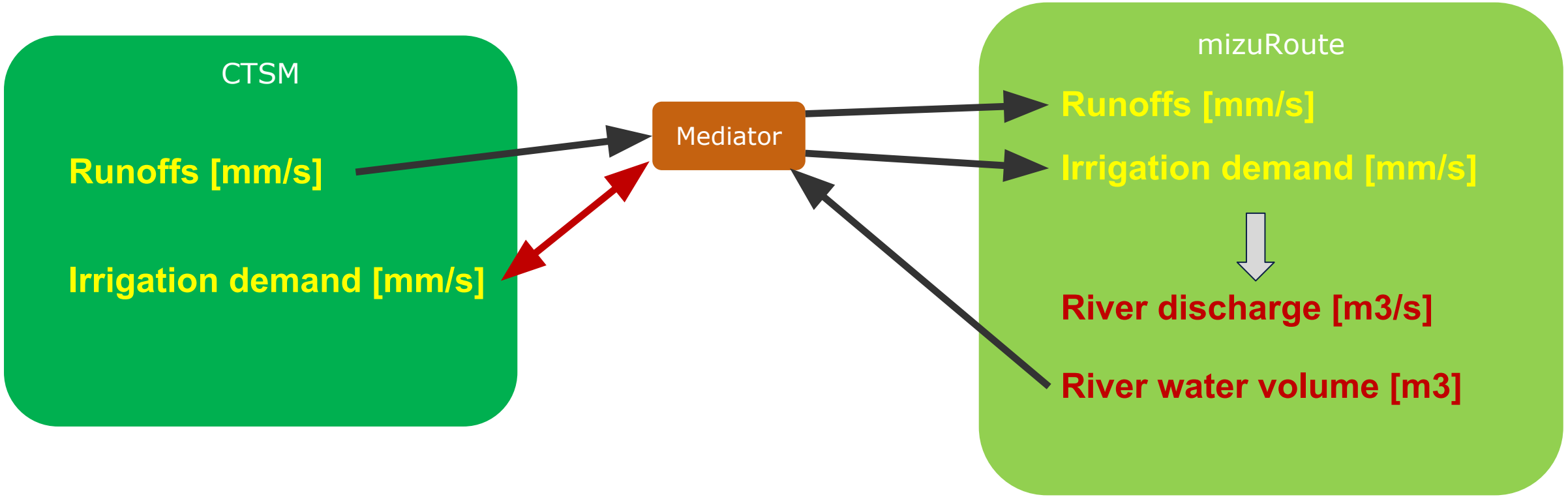


CLM namelist option

- *irrigate = true*
- *limit_irrigation_if_rof_enabled = false:* Shut off irrigation depending on river volume

CTSM-mizuRoute coupling

Two-way CTSM coupling (CTSM ↔ mizuRoute)



CLM namelist option

- *irrigate = true*
- *limit_irrigation_if_rof_enabled = true:* Shut off irrigation depending on river volume
- *irrig_river_volume_threshold :* fraction of river volume below which irrigation is shut off

Simulation comparisons – CTSM irrigation options

- ❑ 3yr runs
- ❑ GSWP3, CLM: f09 (1 degree)
- ❑ ROF:
  - mizuRoute: r05 (0.5 degree)
  - MOSART : r05 (0.5 degree)

1) CLM-mizuRoute and 2) CLM-MOSART

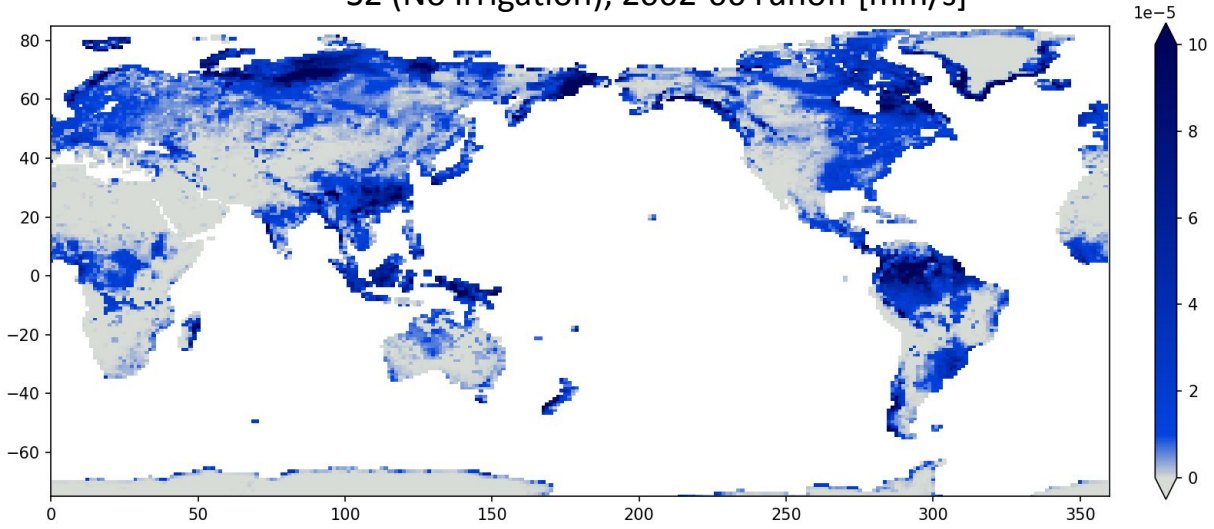
Simulations	Irrigation	Threshold	Routing bypass	qgwl_runoff_option
S1			direct_to_outlet	negative
S2	✓		direct_to_outlet	negative
S3	✓	✓	direct_to_outlet	negative

Threshold: limiting irrigation demand or not by setting *limit_irrigation_if_rof_enabled* and *irrig_river_volume_threshold = 0.1*

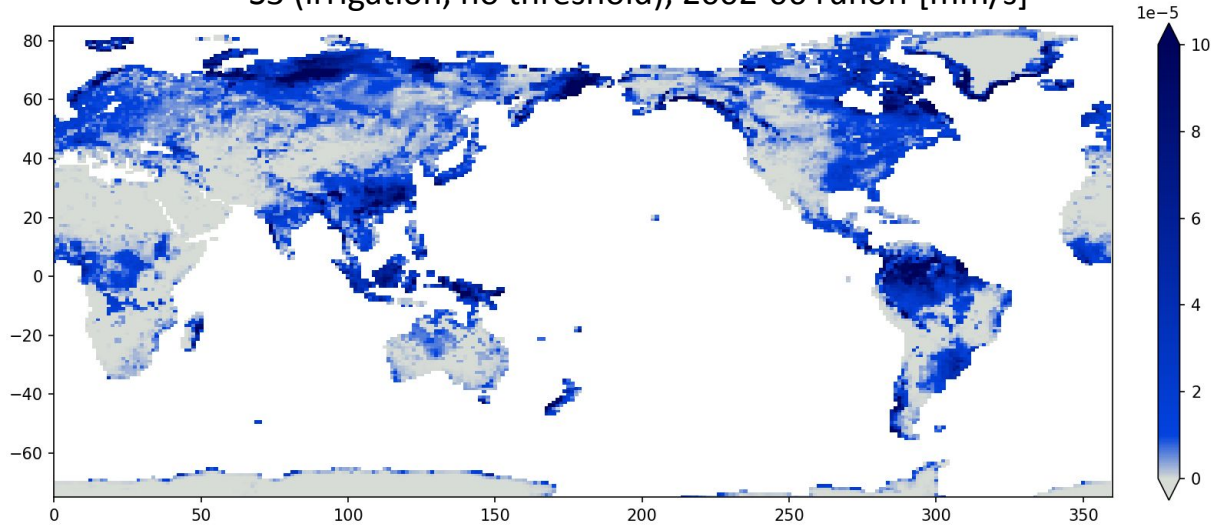
Comparisons	Sim1	sim2	
c1	S1	S2	Effect of Irrigation
c2	S2	S3	Effect of limiting irrigation

C1 (effect of irrigation) MOSART – total runoff from CLM

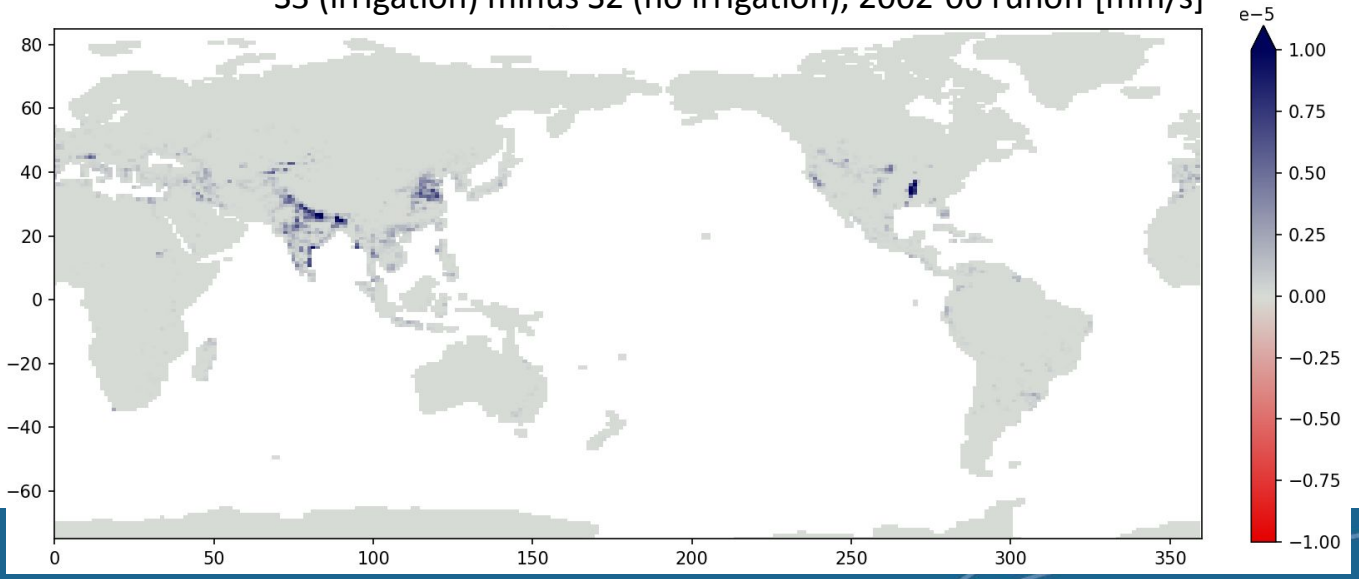
S2 (No irrigation), 2002-06 runoff [mm/s]



S3 (irrigation, no threshold), 2002-06 runoff [mm/s]

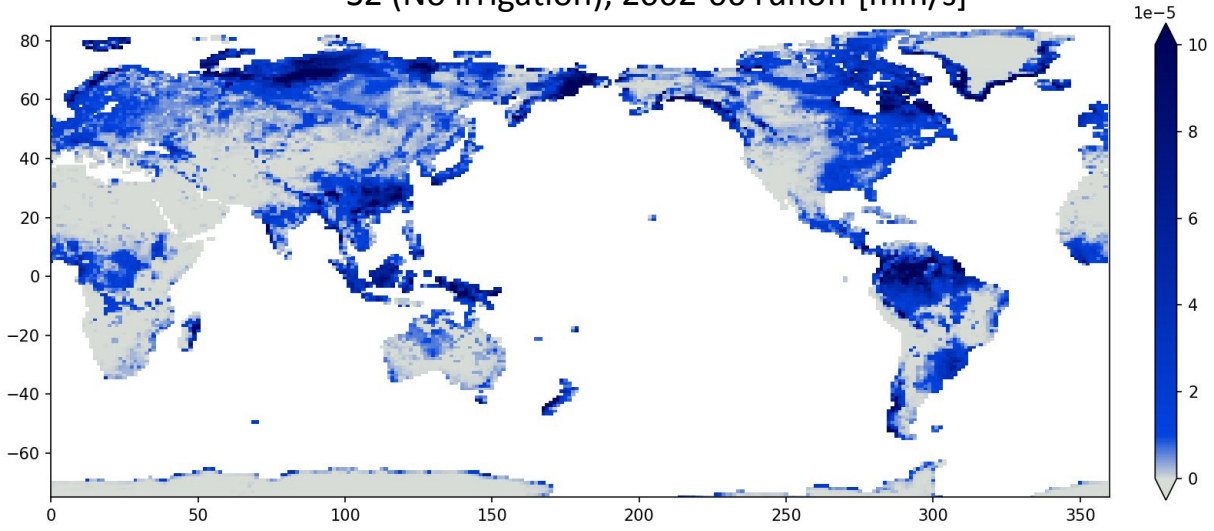


S3 (irrigation) minus S2 (no irrigation), 2002-06 runoff [mm/s]

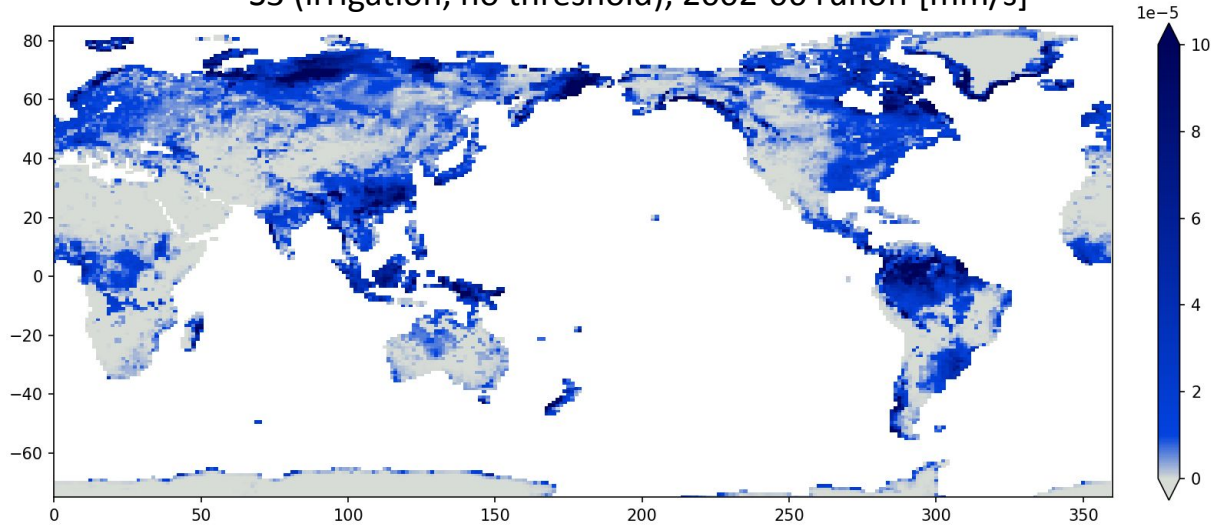


C1 (effect of irrigation) mizuRoute - total runoff from CLM

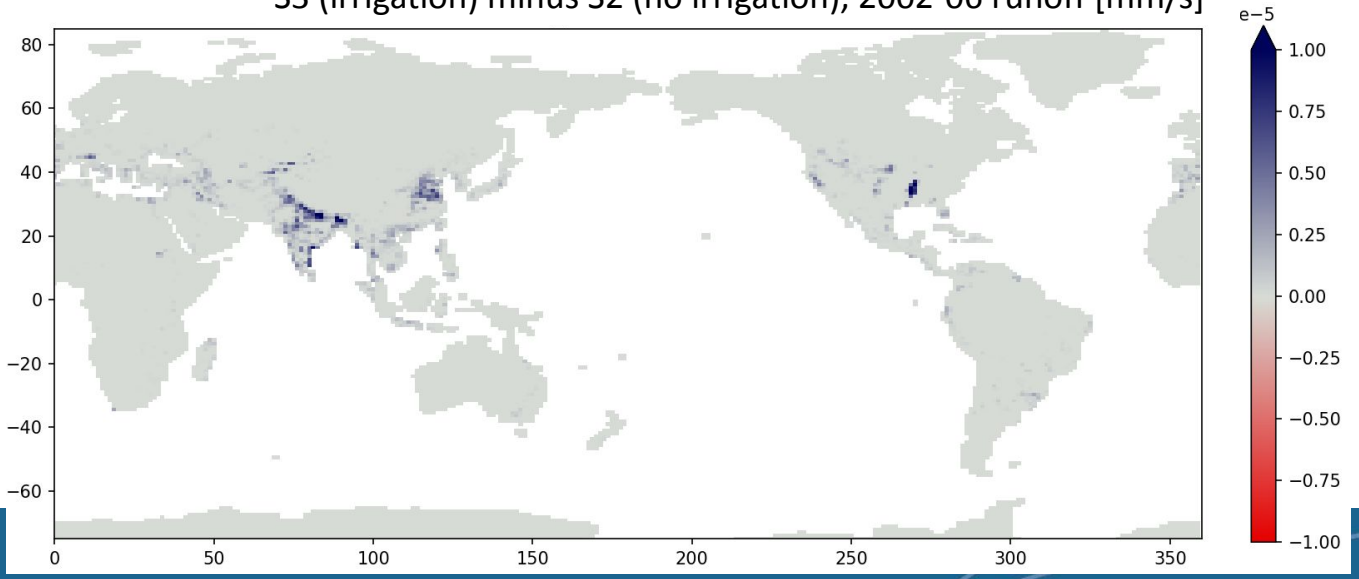
S2 (No irrigation), 2002-06 runoff [mm/s]



S3 (irrigation, no threshold), 2002-06 runoff [mm/s]

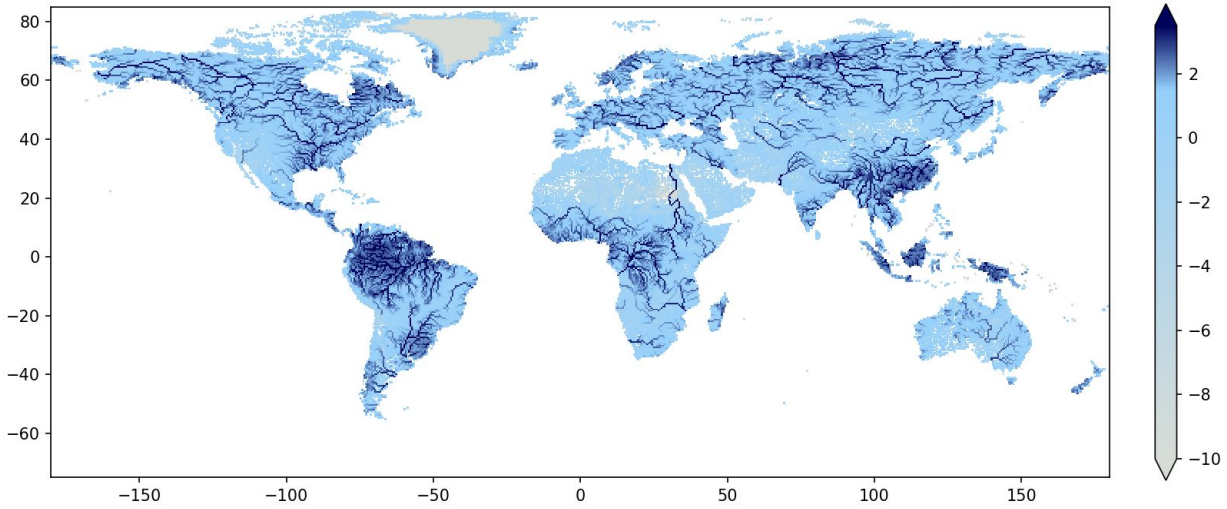


S3 (irrigation) minus S2 (no irrigation), 2002-06 runoff [mm/s]

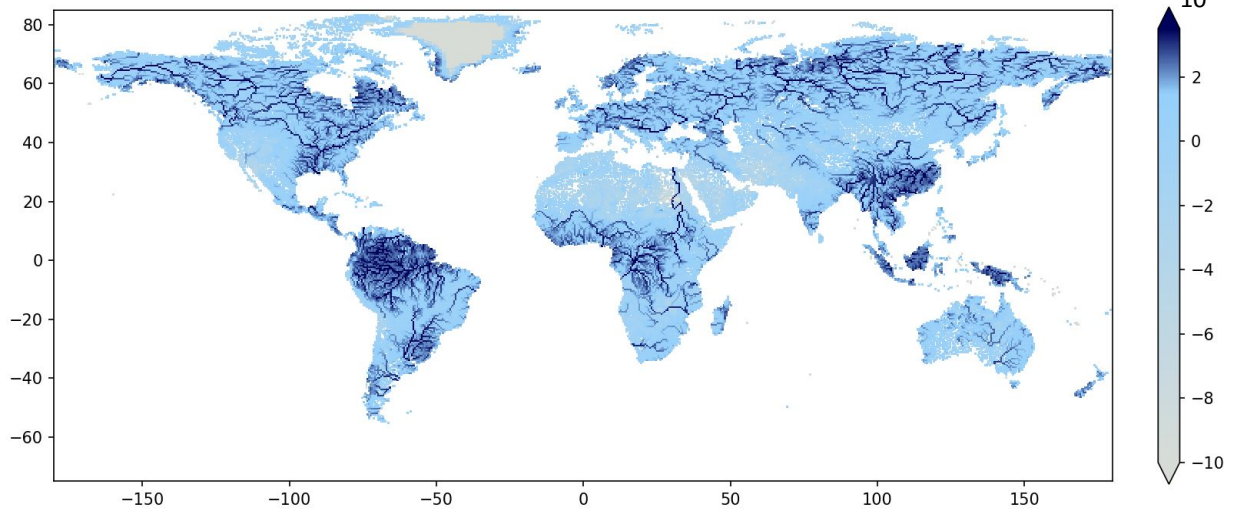


C1 (effect of irrigation) MOSART – river discharge

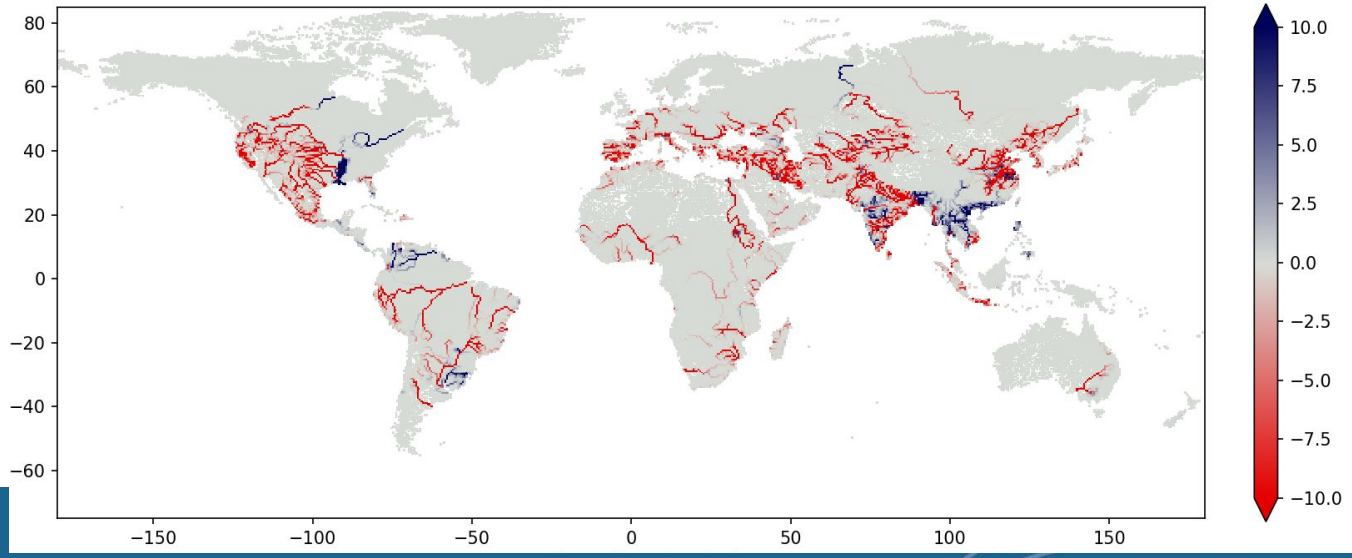
S2 (no irrigation), 2002-06 flow [m3/s]



S3 (irrigation, no threshold), 2002-06 flow [m3/s]

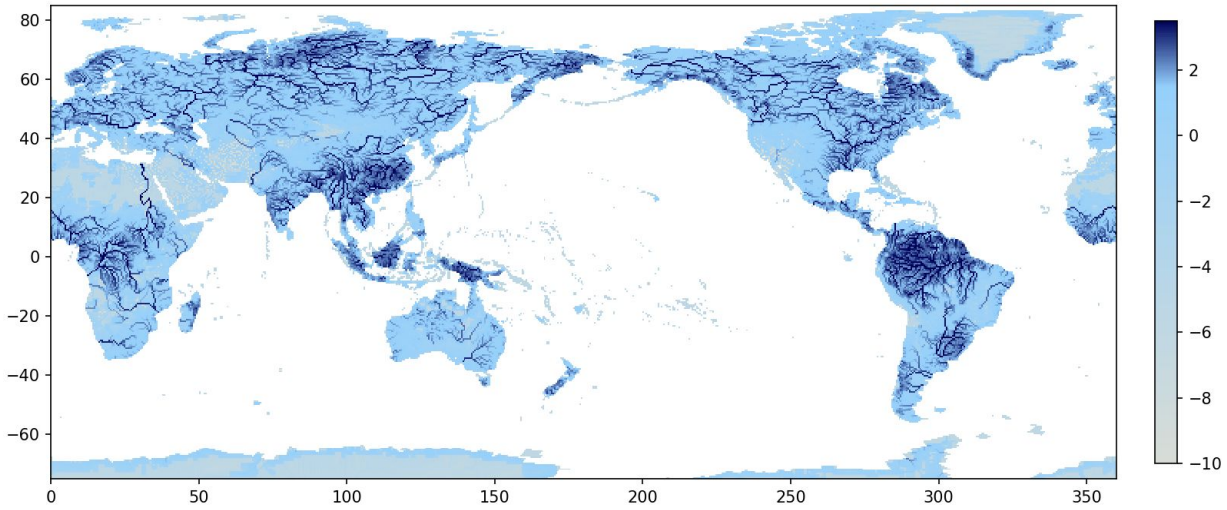


S3 (irrigation) – S2 (no irrigation), 2002-06 flow [m3/s]

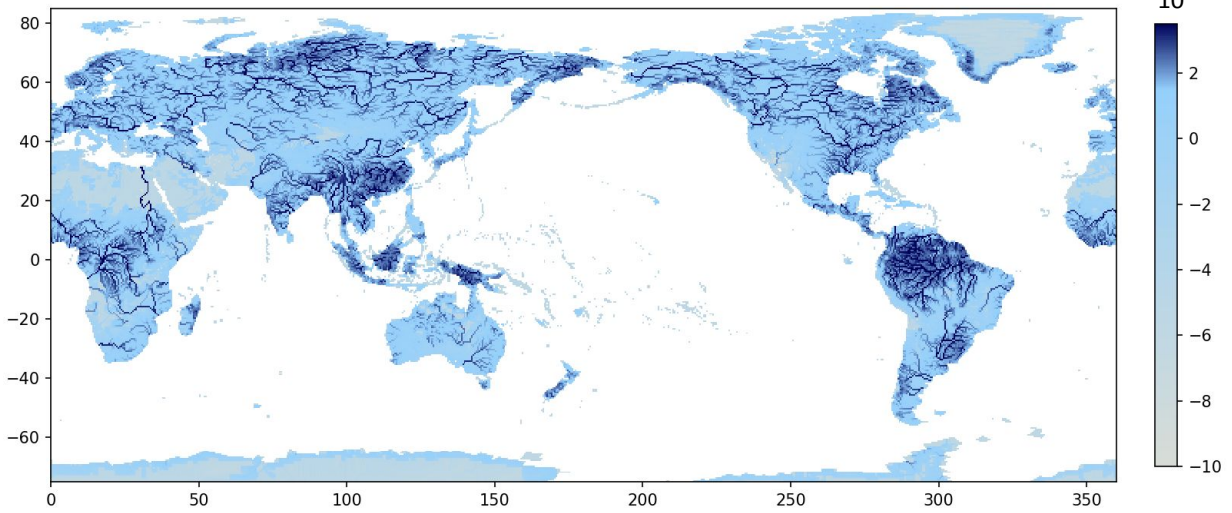


C1 (effect of irrigation) mizuRoute – river discharge

S2 (no irrigation), 2002-06 flow [m3/s]



S3 (irrigation, no threshold), 2002-06 flow [m3/s]



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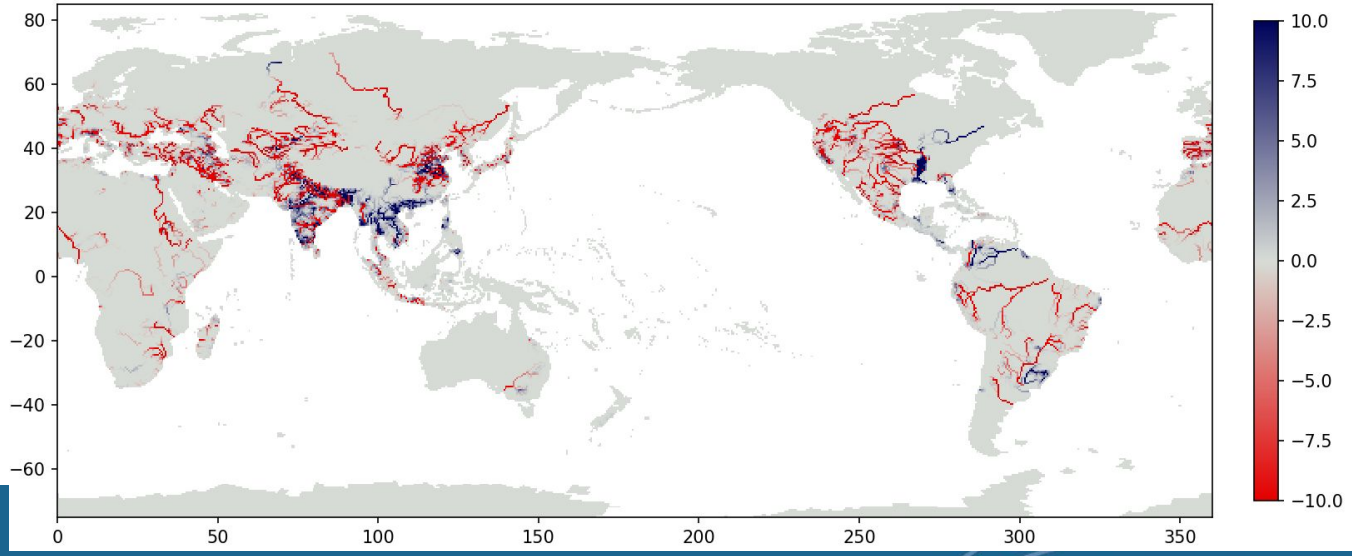
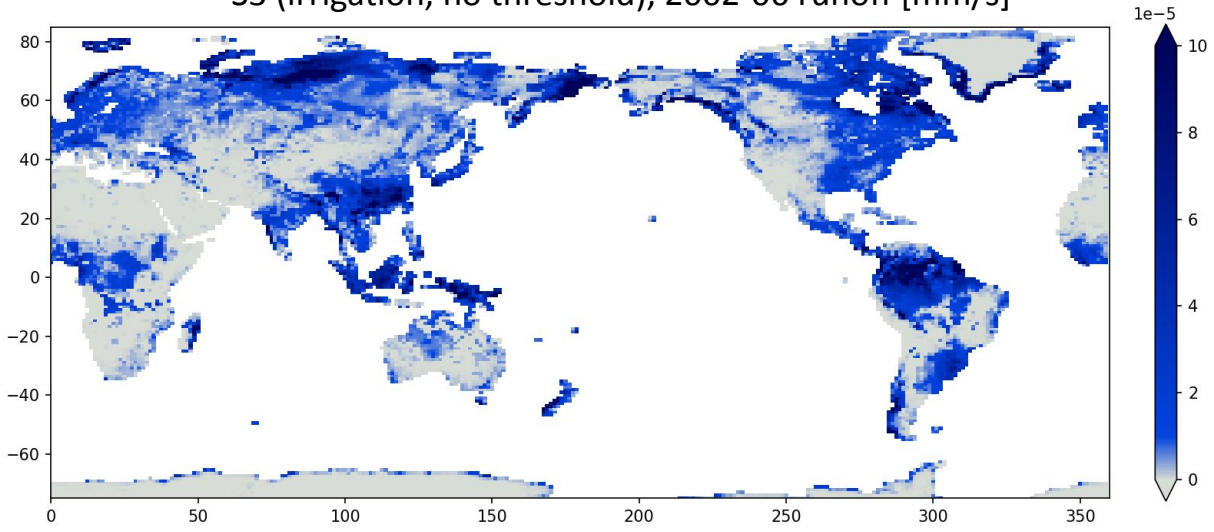
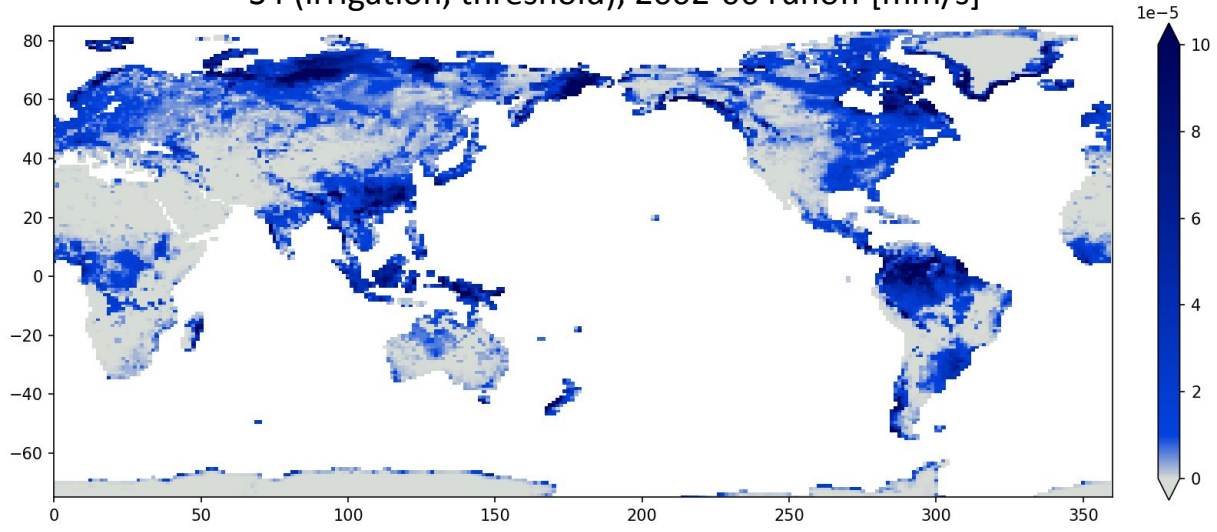


C2 (effect of limiting irrigation) MOSART - total runoff from CLM

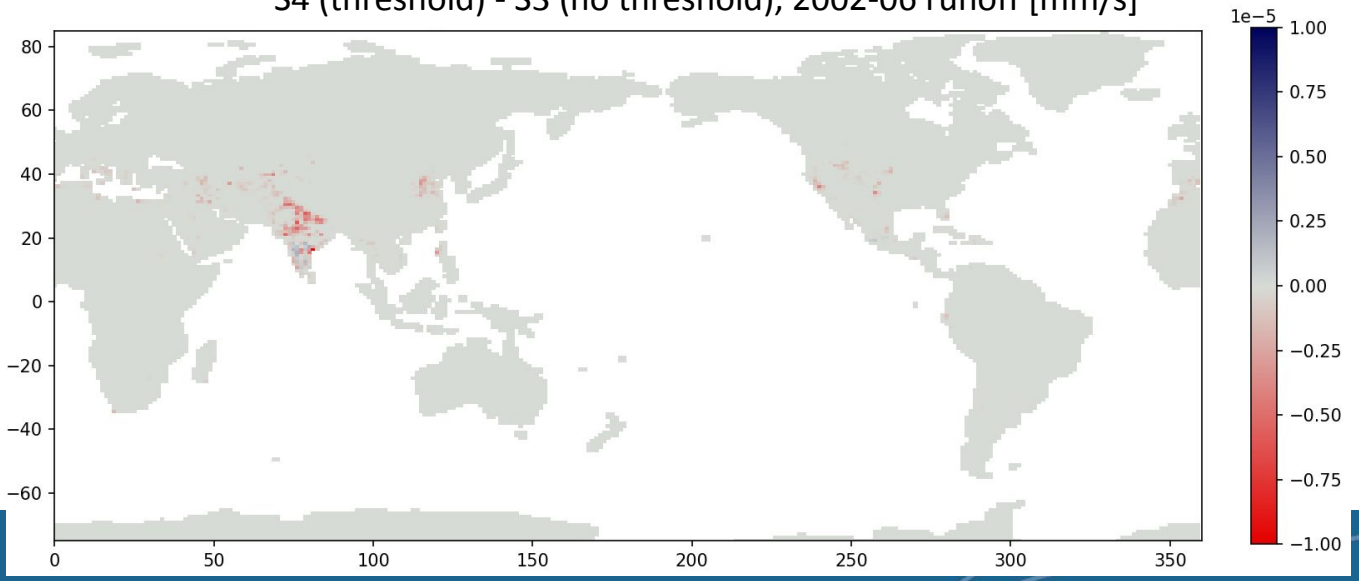
S3 (irrigation, no threshold), 2002-06 runoff [mm/s]



S4 (irrigation, threshold), 2002-06 runoff [mm/s]

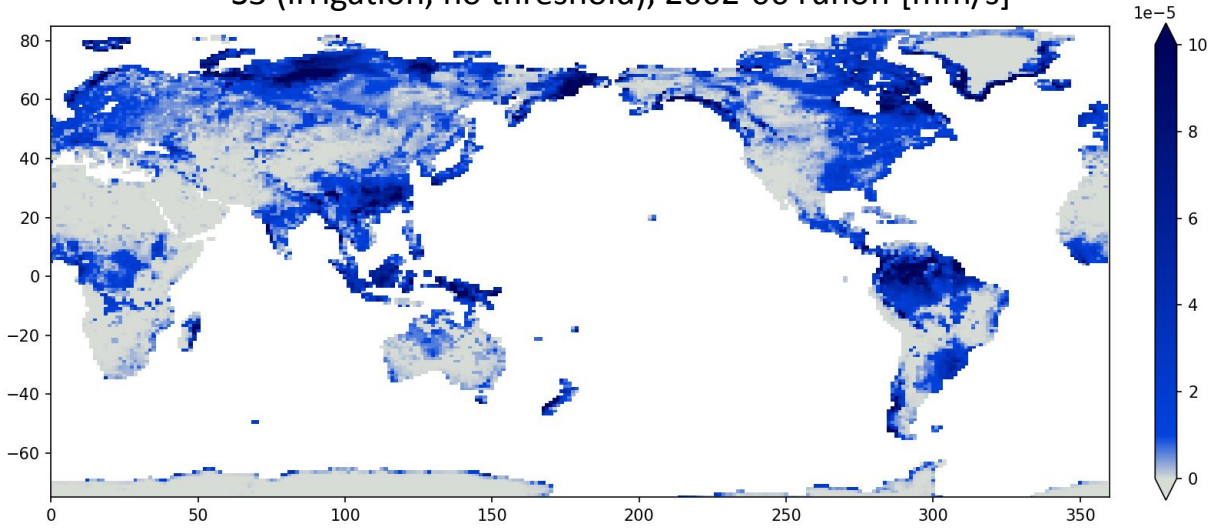


S4 (threshold) - S3 (no threshold), 2002-06 runoff [mm/s]

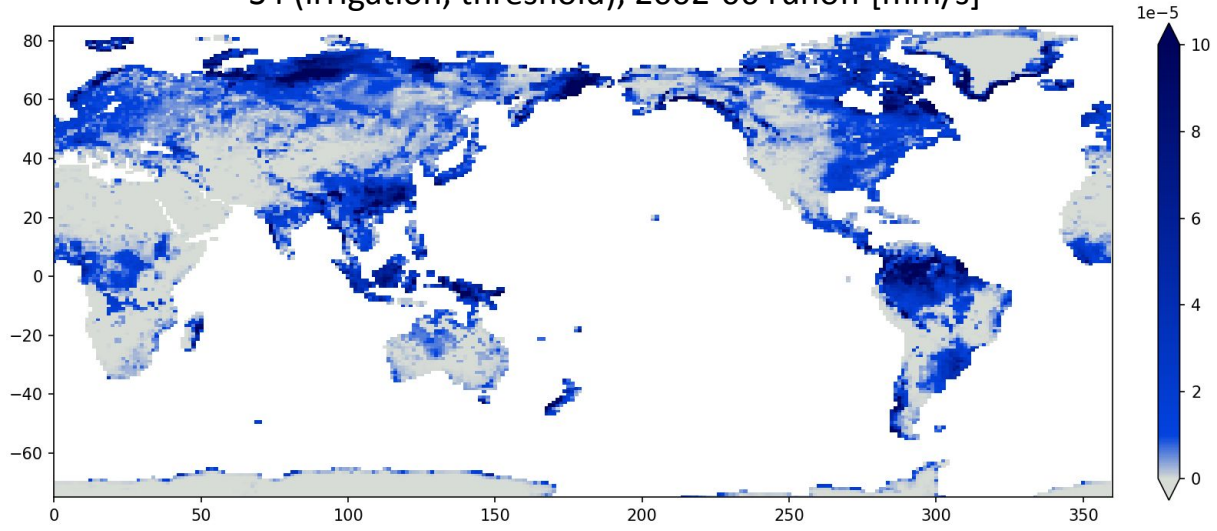


C2 (effect of limiting irrigation) mizuRoute - total runoff from CLM

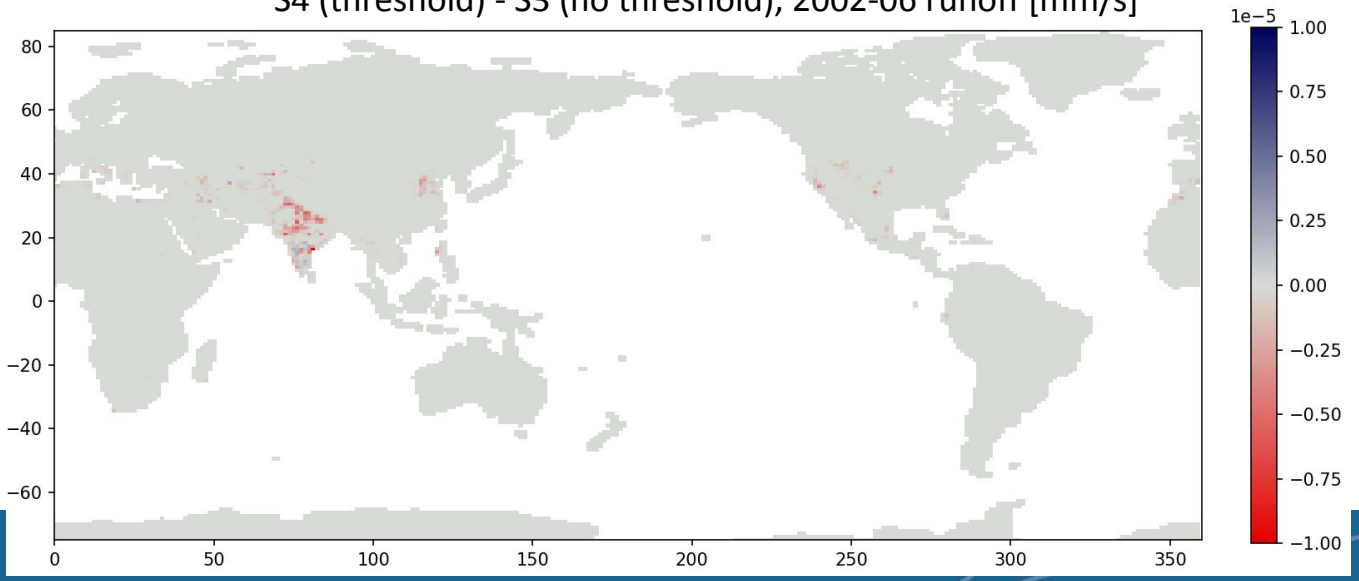
S3 (irrigation, no threshold), 2002-06 runoff [mm/s]



S4 (irrigation, threshold), 2002-06 runoff [mm/s]

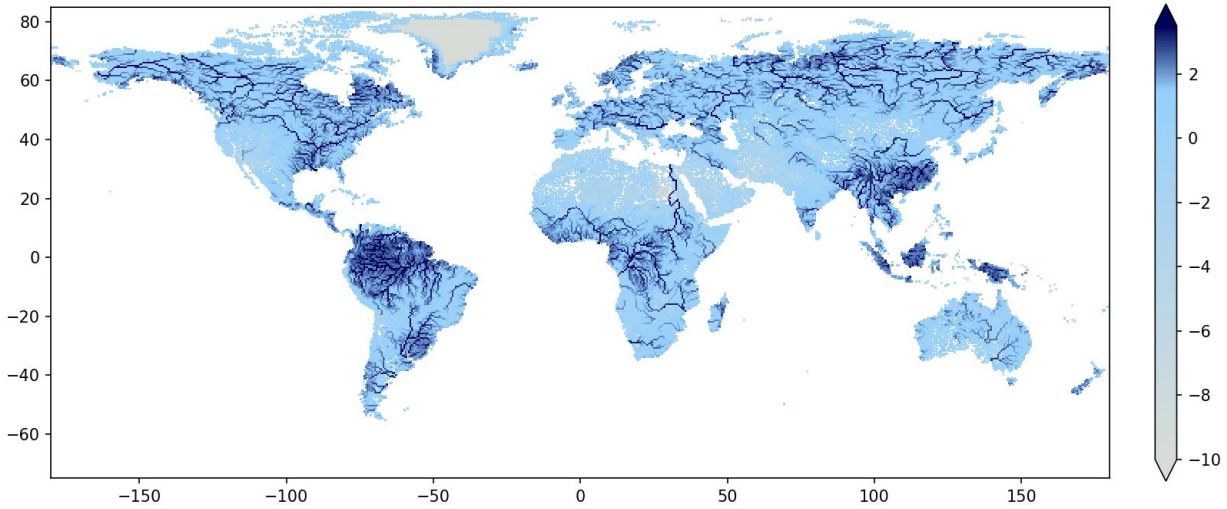


S4 (threshold) - S3 (no threshold), 2002-06 runoff [mm/s]

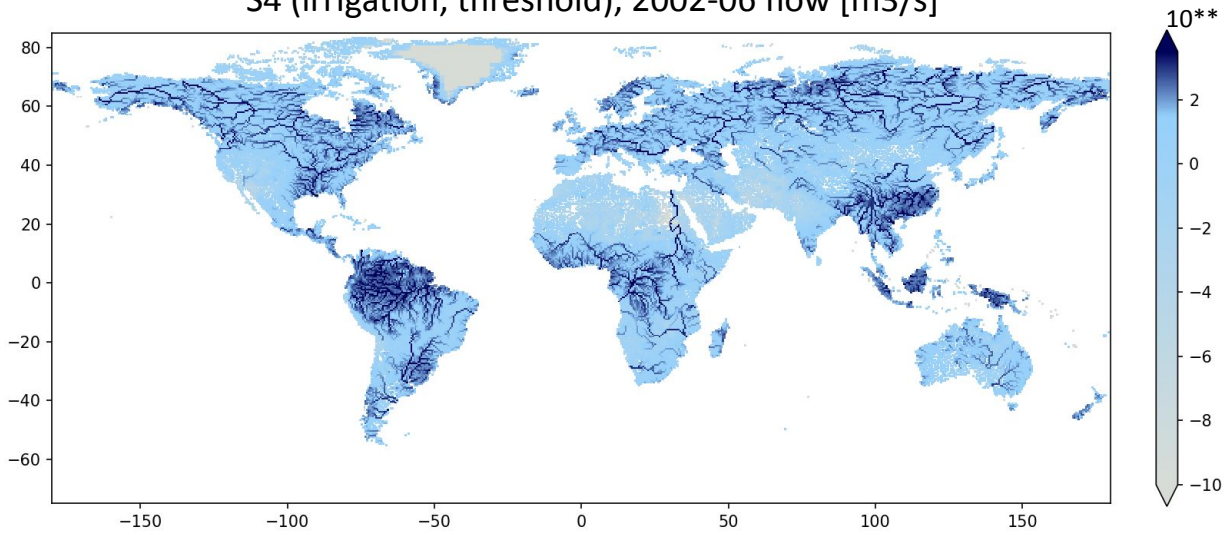


C2 (effect of limiting irrigation) MOSART – river discharge

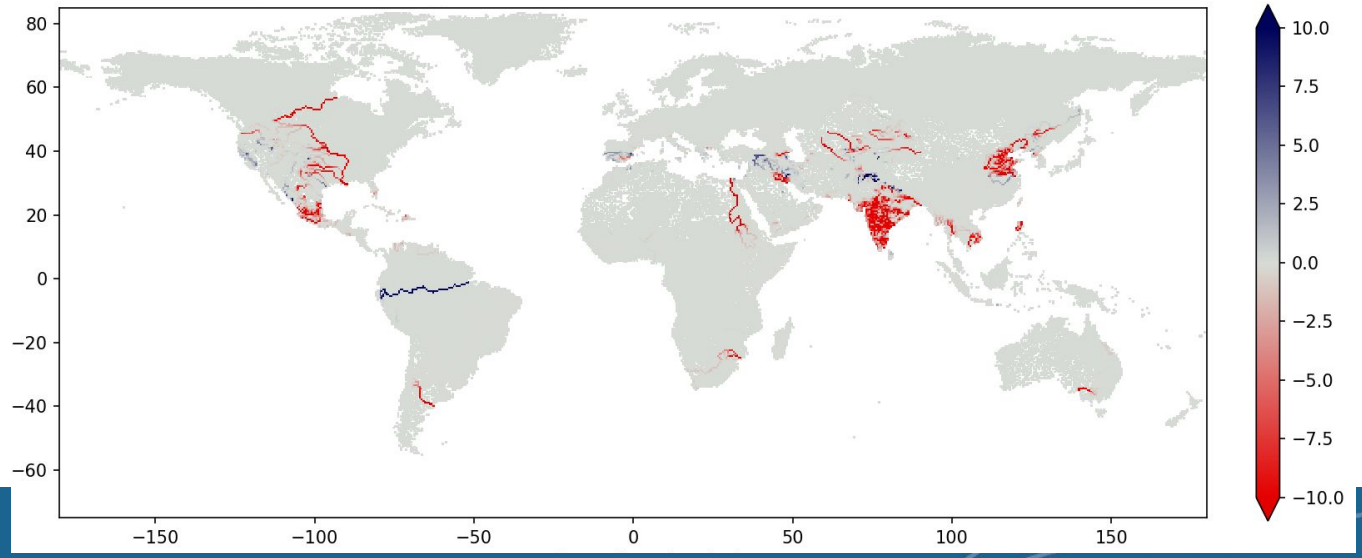
S3 (irrigation, no threshold), 2002-06 flow [m3/s]



S4 (irrigation, threshold), 2002-06 flow [m3/s]

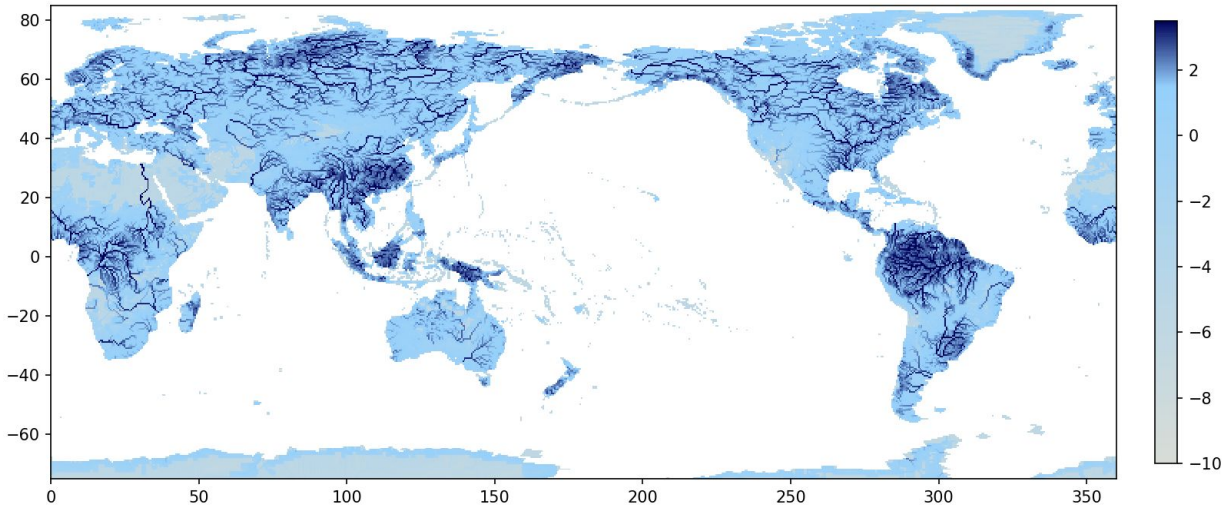


S4 (threshold) - S3 (no threshold), 2002-06 flow [m3/s]

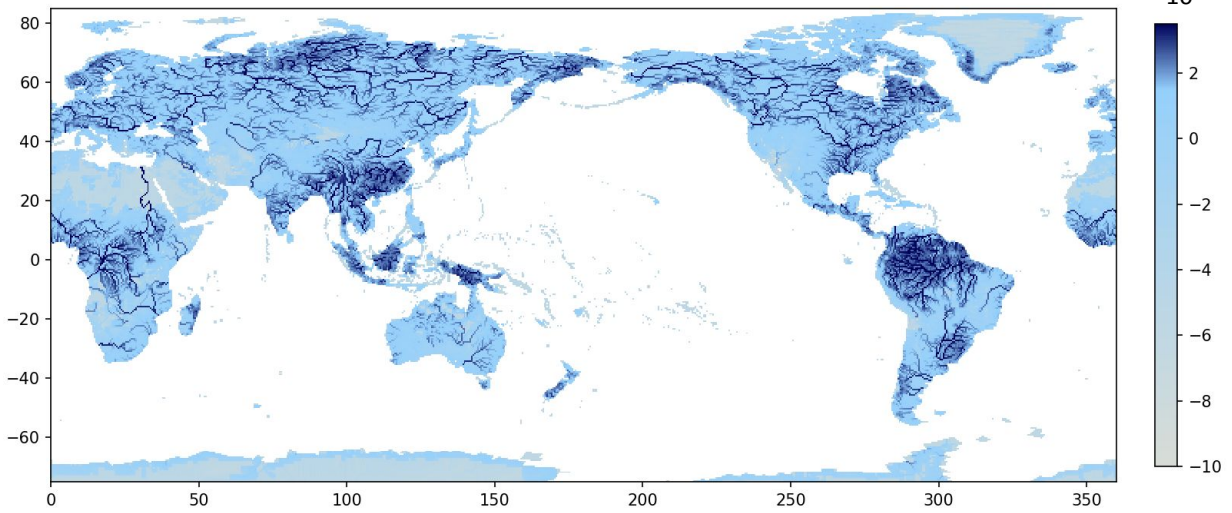


C2 (effect of limiting irrigation) mizuRoute – river discharge

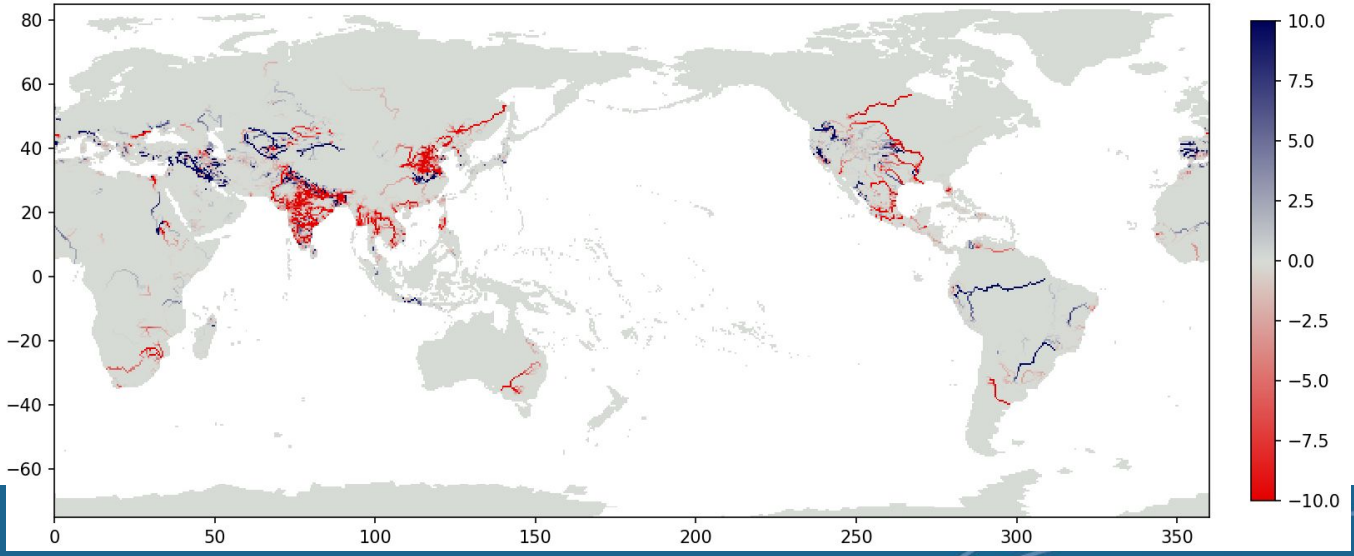
S3 (irrigation, no threshold), 2002-06 flow [m3/s]



S4 (irrigation, threshold), 2002-06 flow [m3/s]



S4 (threshold) - S3 (no threshold), 2002-06 flow [m3/s]

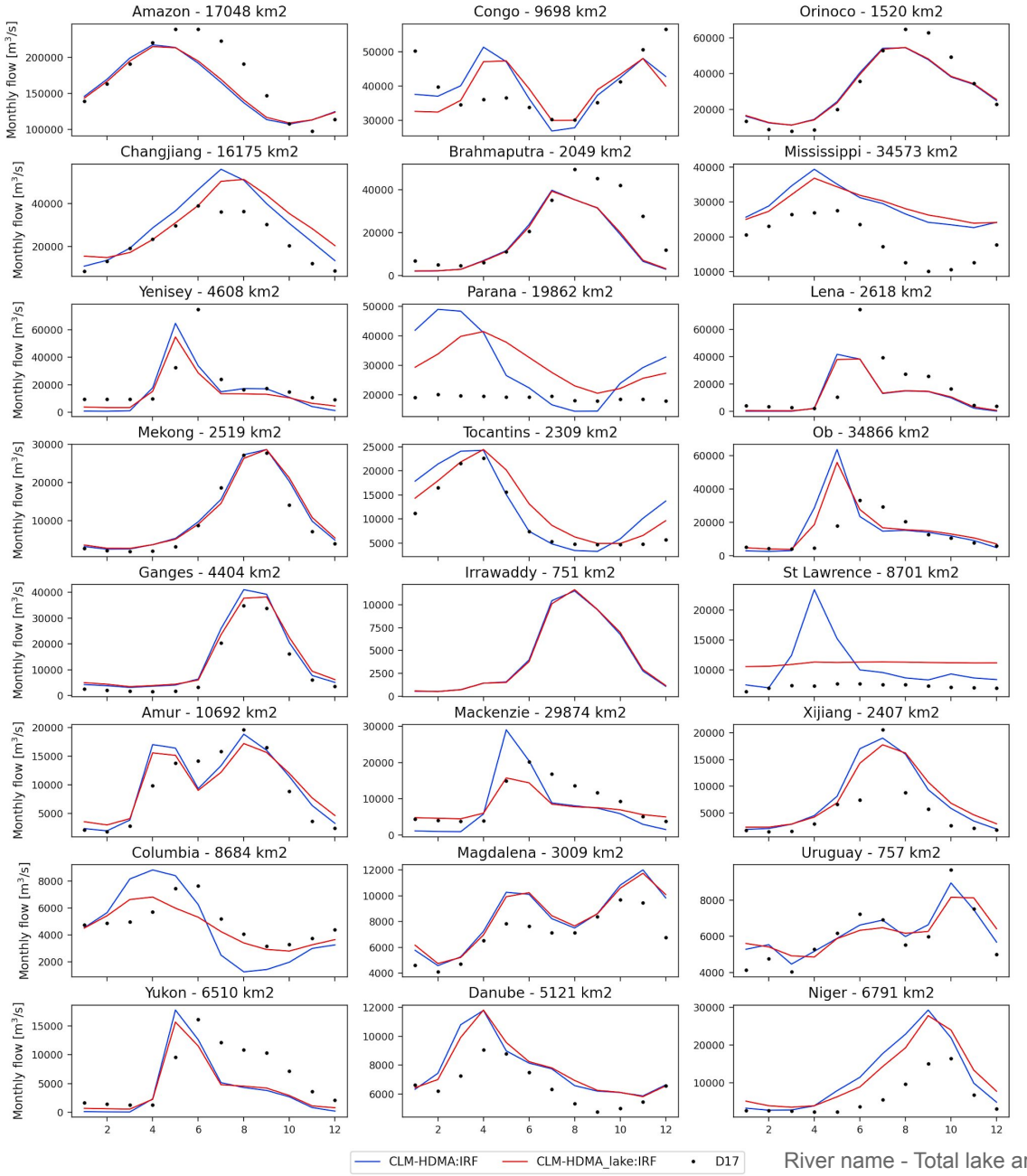


Summary - irrigation effects on river model

- This is preliminary work. Need more testing and analysis on water balance.
- mizuRoute overall reproduces MOSART for irrigation effects on river flow if irrigation is unlimited.
- Differences appears when river volume limits irrigation demand.

Impacts of lake on river discharge simulations

- ❑ CTSM-mizuRoute-lake: re-gridding issues 😢
- ❑ Use standalone mizuRoute-lake
  - Forcing: Runoff/Precip./Lake evaporation from CLM5.0, 0.5deg, GSWP3v1
  - Simulation period: 1989-2014



River name - Total lake areas

1990-2010 annual cycle at major river outlets

Natural lake discharge equation (Doll 2003)

$$Q = a(S/S_{max})^b$$

a, b: parameters

Q: Discharge from lake [m^3/s]

S: water volume in lake [m^3]

S_{max}: maximum lake storage [m^3]

To-Do: mizuRoute-lake for CTSM coupling

- ❑ Fix regridding issue for mizuRoute-lake grid (rHDMAlk) 🤔
- ❑ Ensure water balance closure in river-lake-irrigation system
- ❑ Need to understand lake model behavior (sensitivity to parameters and lake states
- ❑ Implement reservoir models

Thanks!

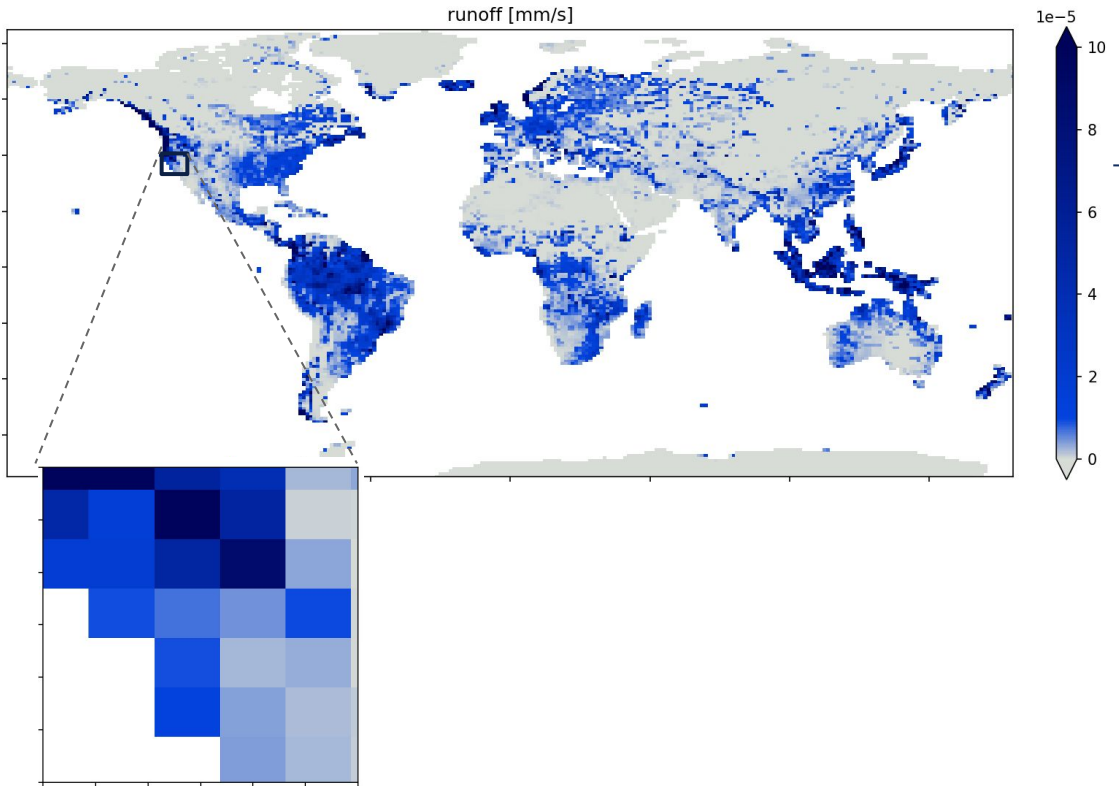
Acknowledgements:

- David Lawrence (NCAR/CGD: overall direction, funding)
- Erik Kluzek (NCAR/CGD: software engineering)
- Sean Swenson (NCAR/CGD: CLM discussion)
- Shervan Gharari (U. of Saskatchewan: lake modeling)
- Inne Vanderkelen (Vrije Universiteit Brussel, now U. of Bern : lake modeling)

Extra slides

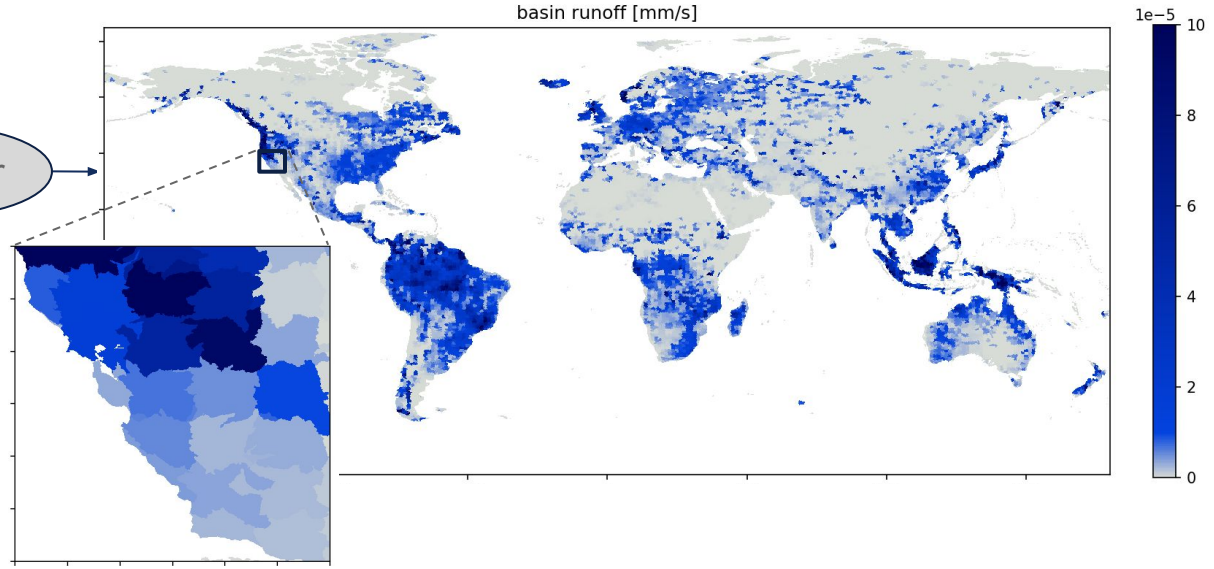
CTSM-mizuRoute coupled run

CTSM total runoff

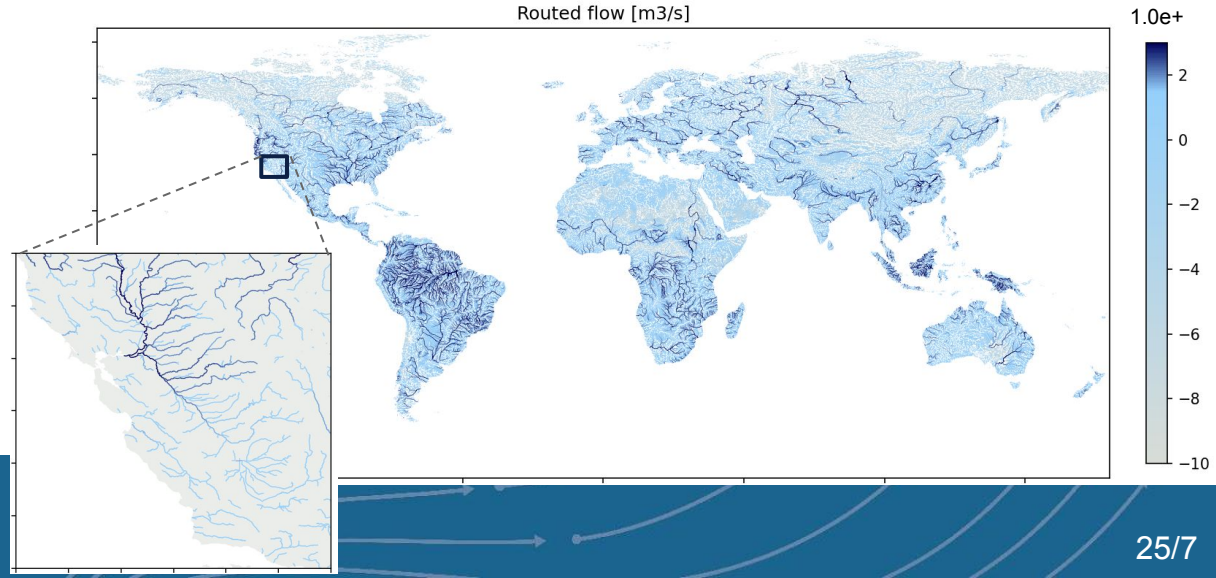


Mediator

Runoff remapped to catchment



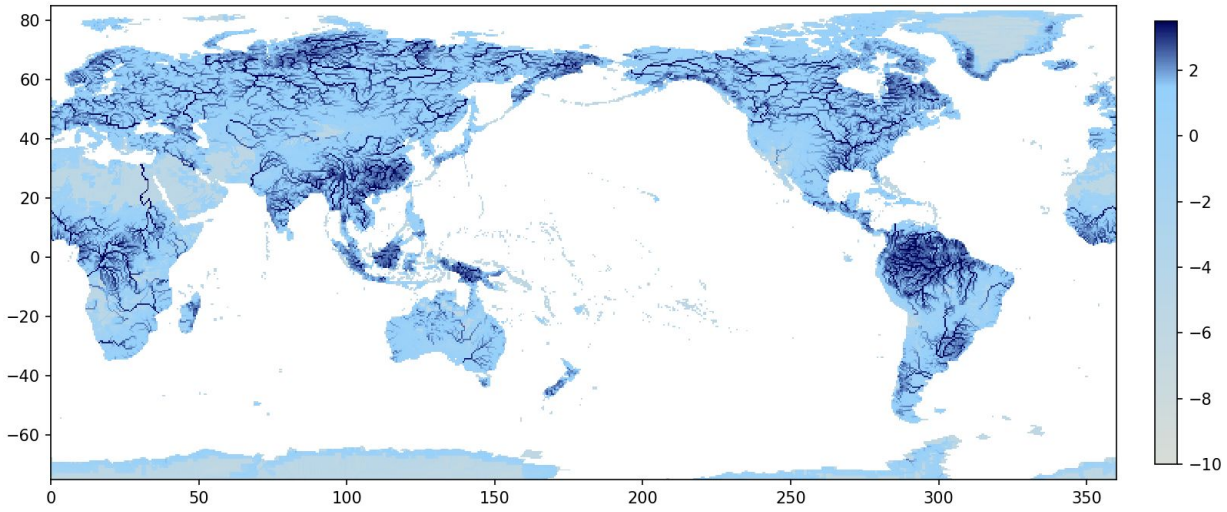
Routed runoff in river reach



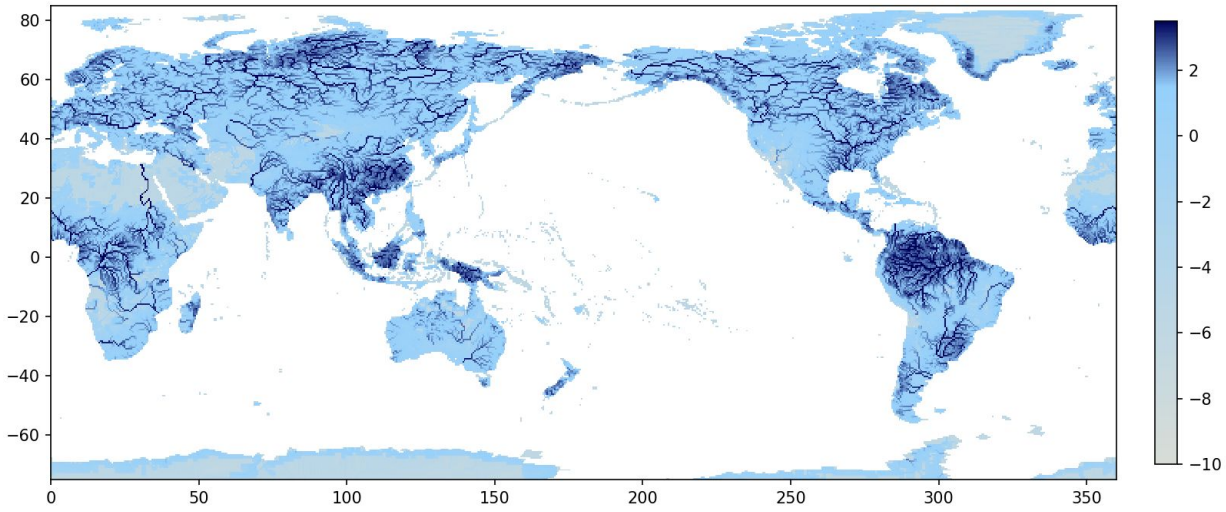
CTSM Grids: f09
mizuRoute grids: rHDMA

Effect of routing bypass: mizuRoute – River discharge

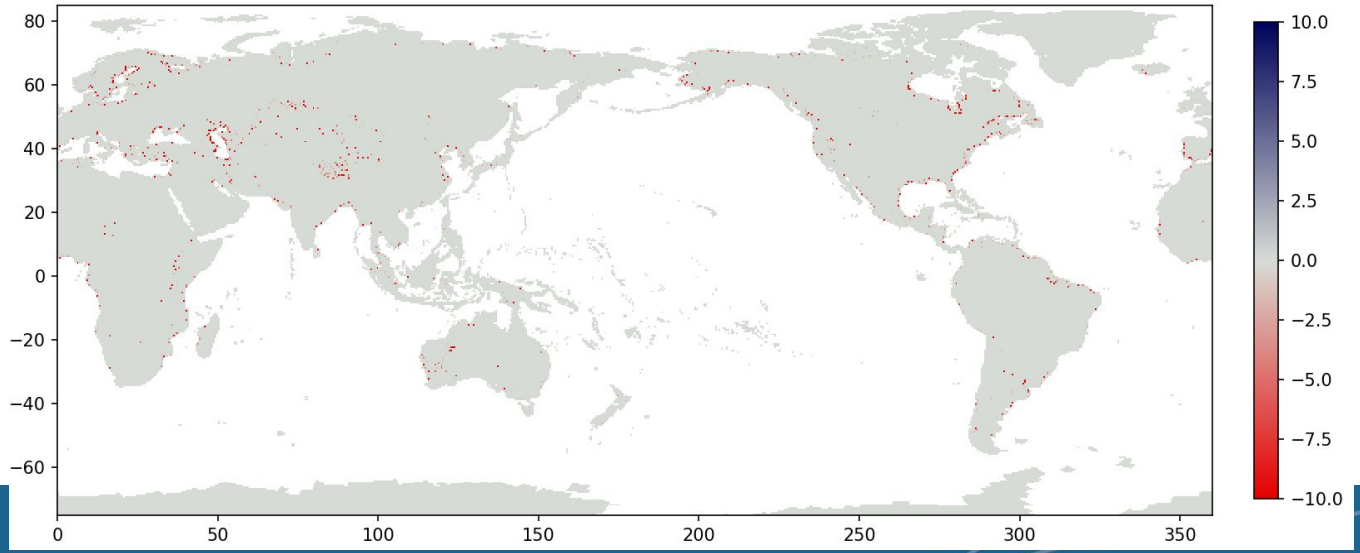
S1 (direct_in_place), 2002-06 flow [m3/s]



S2 (direct_to_outlet), 2002-06 flow [m3/s]



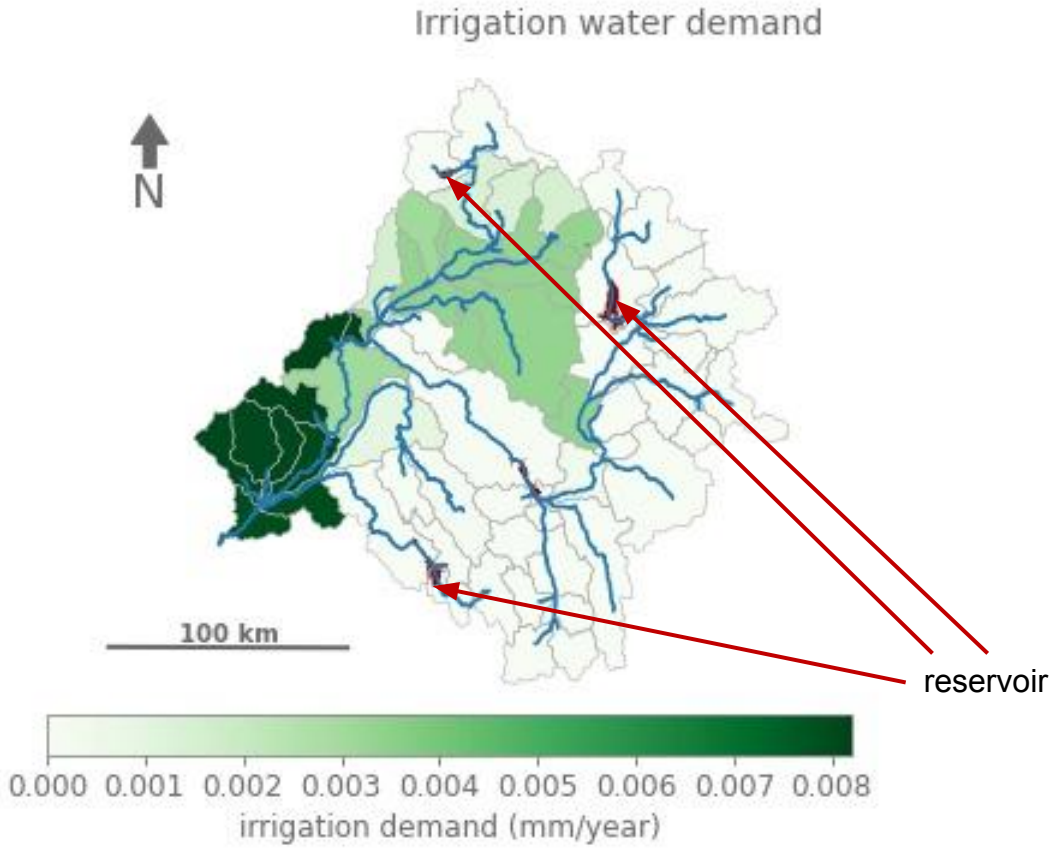
S2 (direct_to_outlet) – S1 (direct_in_place), 2002-06 flow [m3/s]



No irrigation

Irrigation water abstraction

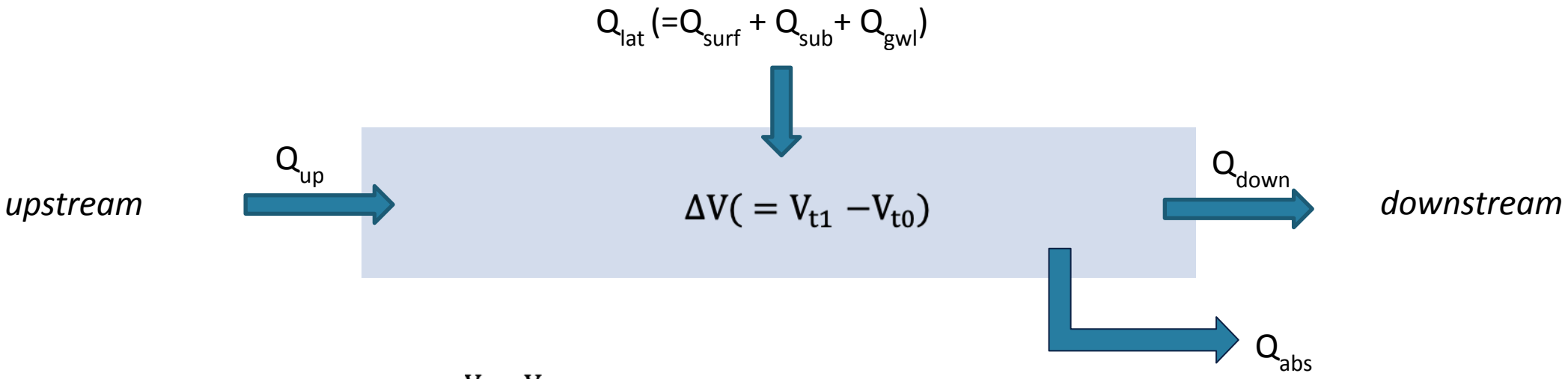
- Connecting irrigated areas to lakes/river reaches



From Inne Vanderkelen

River reach water balance

Time period: Δt = t1 – t0 [sec]



$$\frac{V_{t1}-V_{t0}}{\Delta t} = Q_{up} + Q_{lat} - Q_{down}$$

$$\max(Q_{abs}) = \frac{V_{t_1}}{\Delta t} + Q_{down} \quad \Longrightarrow \quad Q_{down} = 0 \quad V_{t1} = 0$$