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E3SM Energy Exascale Earth System Model

Improving the representation of river processes in E3SM

Tian Zhou

L. Ruby Leung

Guoyong Leng

Nathalie Voisin

Hong-Yi Li

Anthony Craig

Teklu Tesfa

Yuna Mao

U.S. DEPARTMENT OF ENERGY BATTELLE

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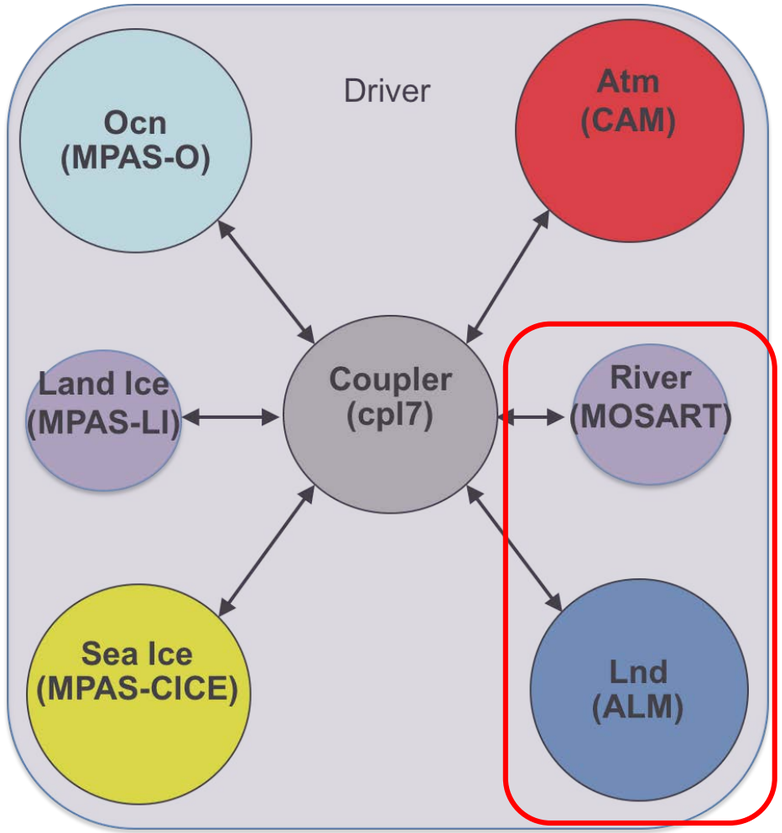
Outline

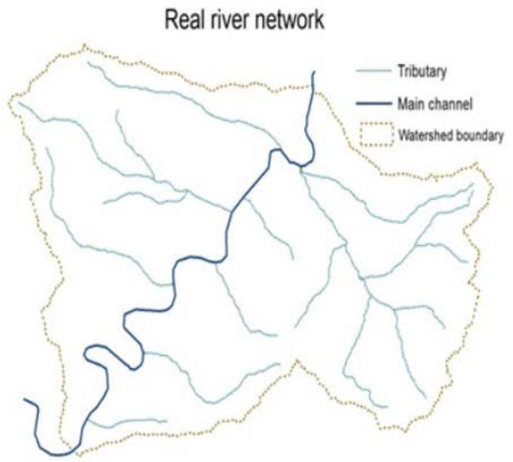
- Brief review of the river model (MOSART) in E3SM and developments in phase 1
- Study 1: two-way coupled irrigation scheme to connect ELM and MOSART
- Study 2: global floodplain inundation analysis
- Ongoing developments and future opportunities

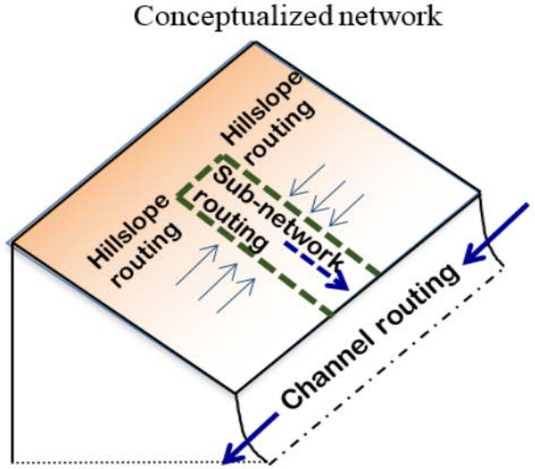
Brief review of the river model in E3SM



In E3SM phase 1, the original river model RTM (River Transport Model) has been replaced by MOSART (Model for Scale Adaptive River Transport)

Hong-Yi Li et al. (2013, 2015)



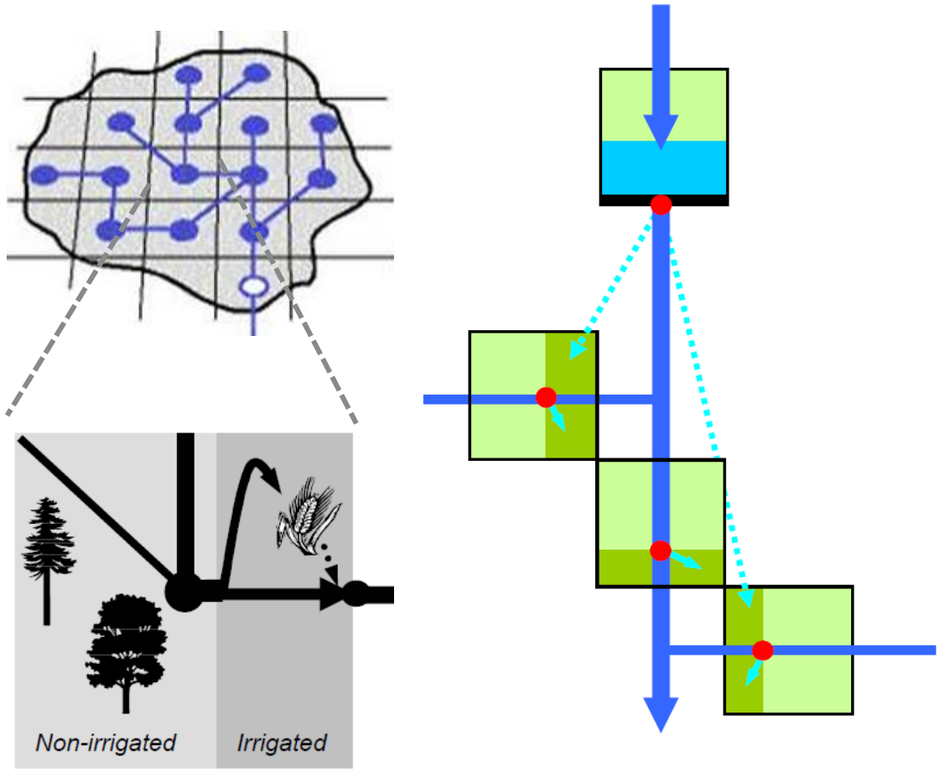


- Hillslope, subnetwork, and main channel
- More physically based algorithm

Two model developments built upon MOSART

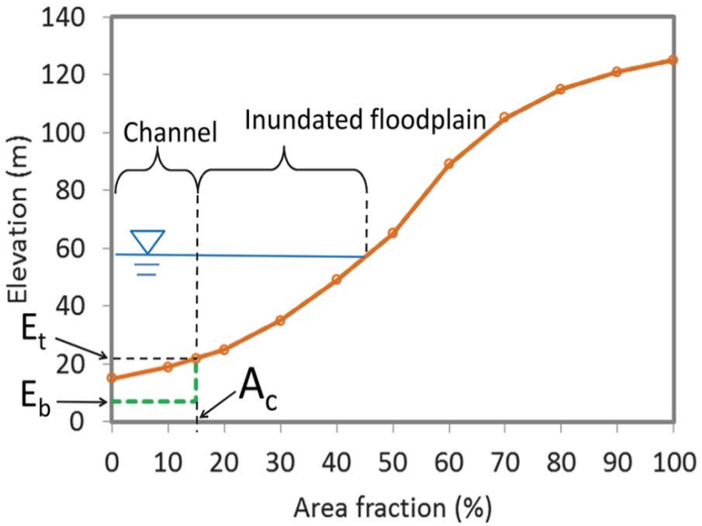
A Water Management (WM) model was developed to represent the irrigation water withdrawal and dam regulations.

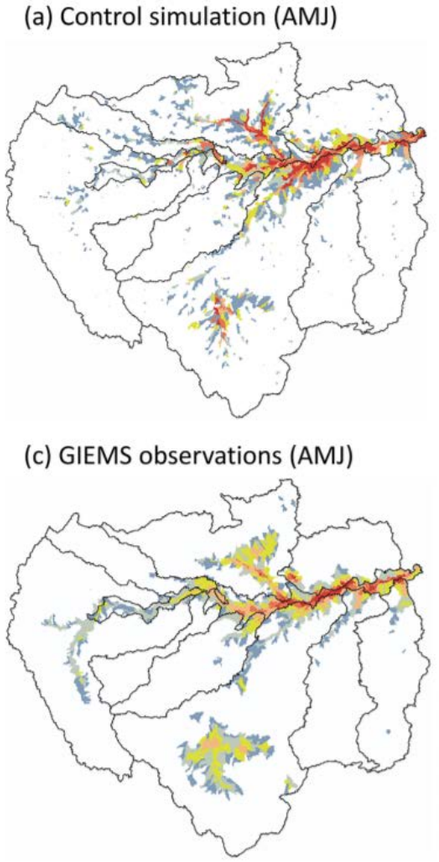
Voisin et al. (2013)



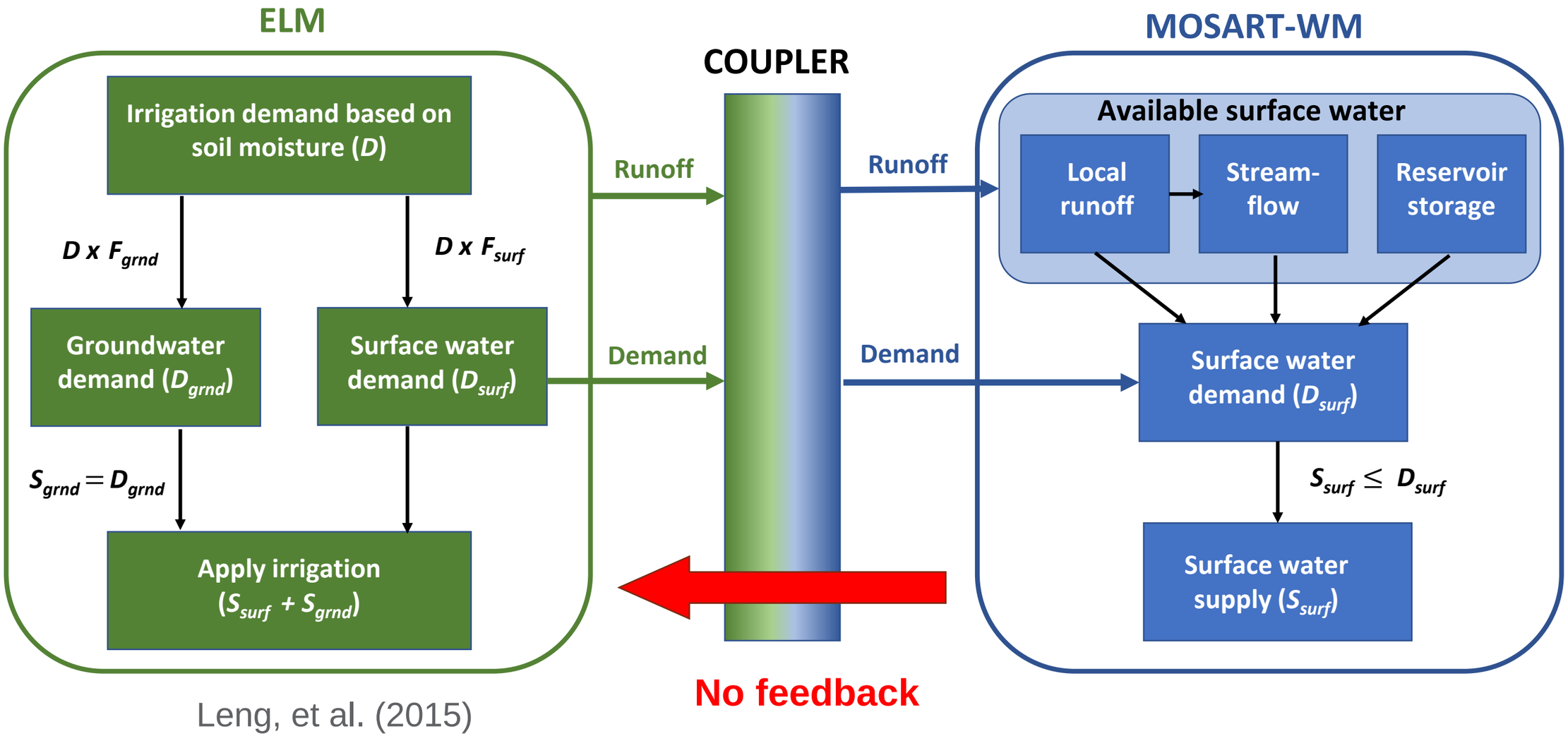
A floodplain inundation model was developed to represent flood extent based on river discharge and geomorphological features in Amazon basin.

Luo et al. (2017)



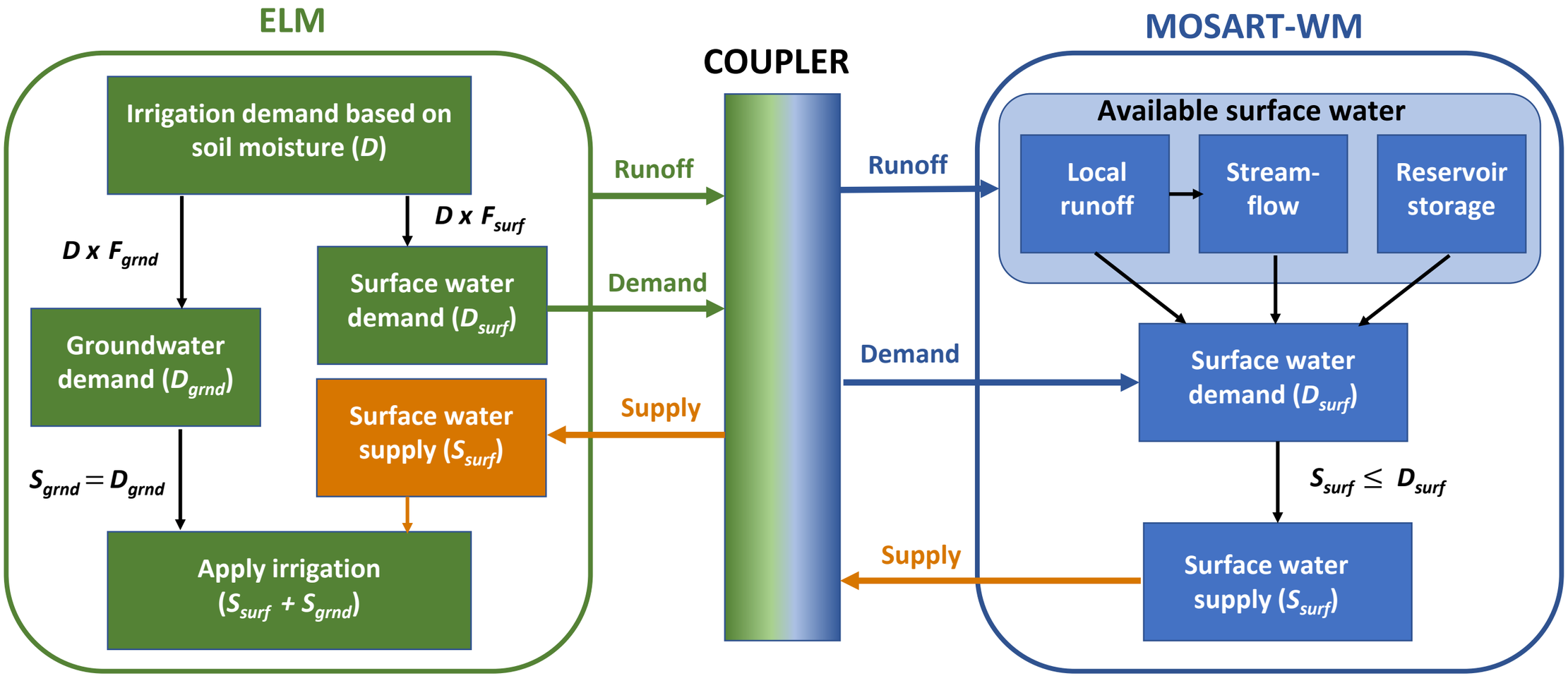


One-way coupled irrigation scheme



Leng, et al. (2015)

Two-way coupled irrigation scheme



Objectives of the study

- Implement a two-way coupled irrigation scheme and evaluate simulations for a historical 30-year period;
- Investigate the impacts of the two-way coupling scheme on representing hydrological processes and irrigation processes in contrast with the original commonly used one-way coupling scheme.

To be submitted to *JAMES*

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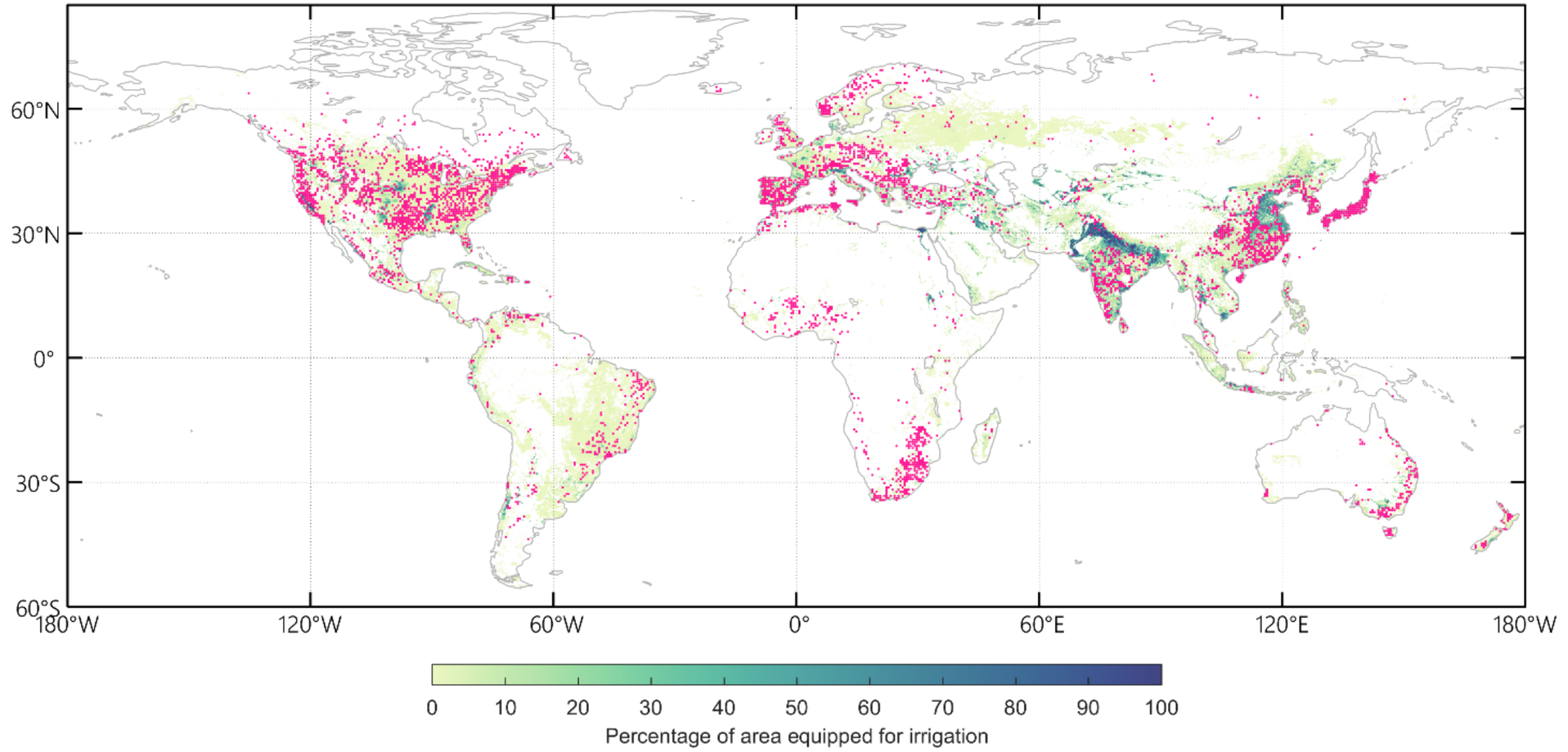
baseline →

one-way coupled →

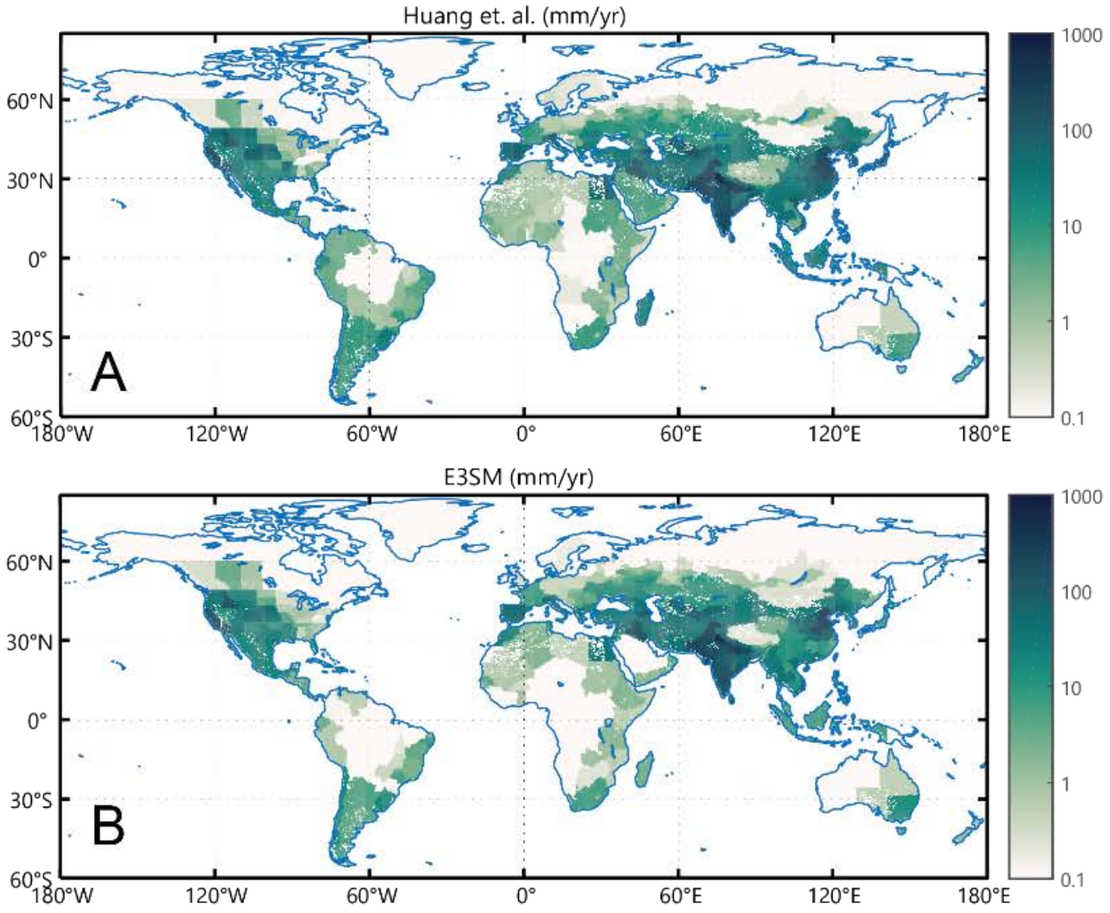
two-way coupled →

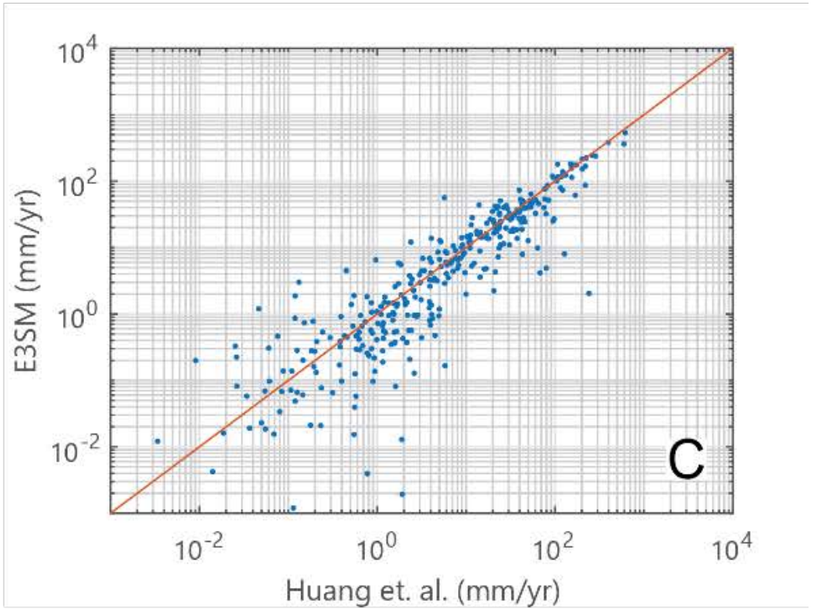
ID	Configuration	Water management	Fully coupled	Irrigation demand	Irrigation source
NAT	no-management	No	N/A	N/A	N/A
1SO	1-way-surf-only	Yes	No	always met	surface water
1SG	1-way-surf-grnd	Yes	No	always met	surface water and groundwater
2SO	2-way-surf-only	Yes	Yes	partially met	surface water
2SG	2-way-surf-grnd	Yes	Yes	partially met	surface water and groundwater
2SGM	2-way-surf-grnd-met	Yes	Yes	always met	surface water and groundwater

Experimental configurations



Pink dots are reservoirs represented in the simulation

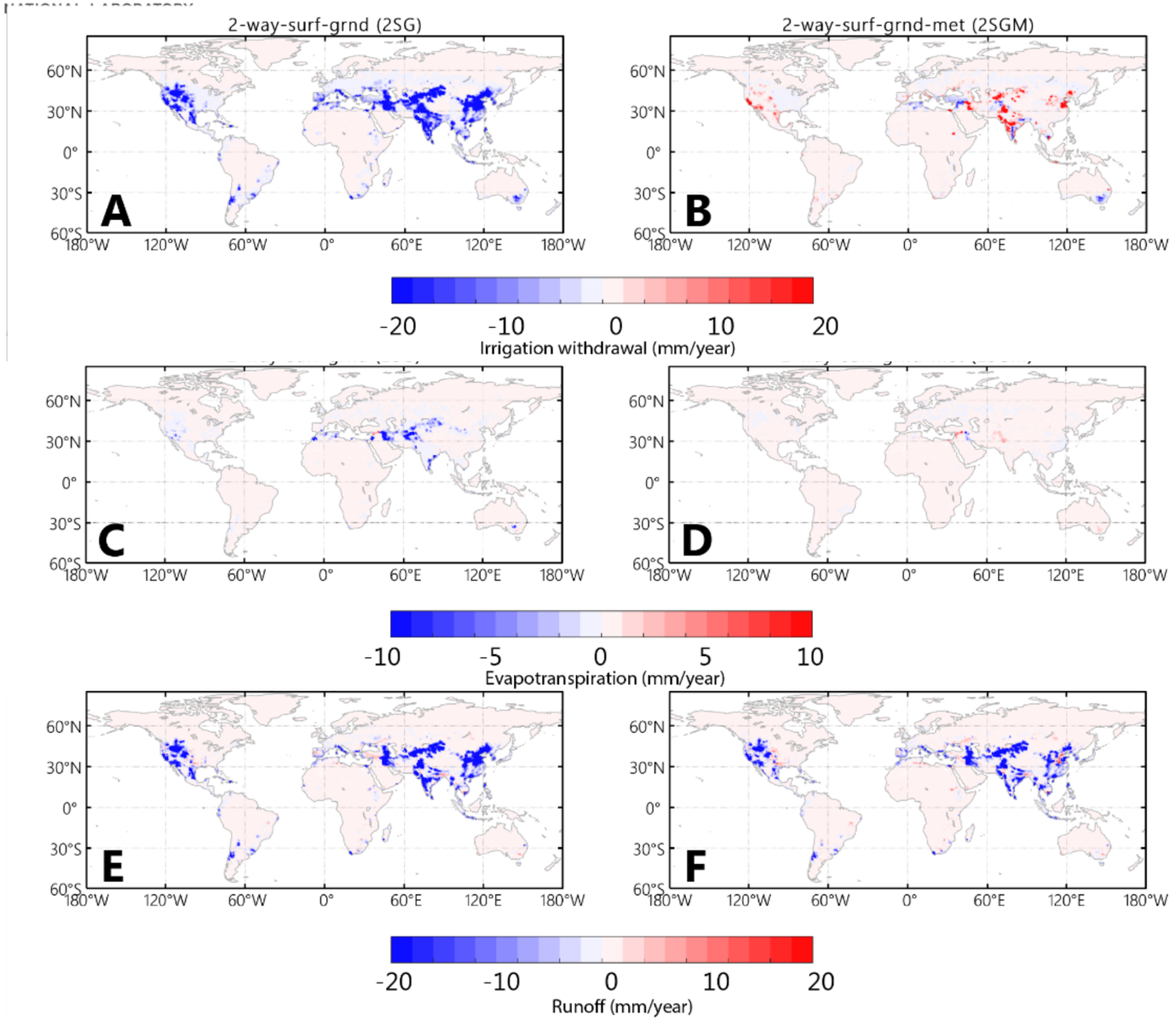




E3SM simulated annual irrigation withdrawal compared with Huang et al. (2010) across global administration units from 1981 to 1985.

Simulated gridded water budget terms

2SG - 1SG **2SGM - 1SG**

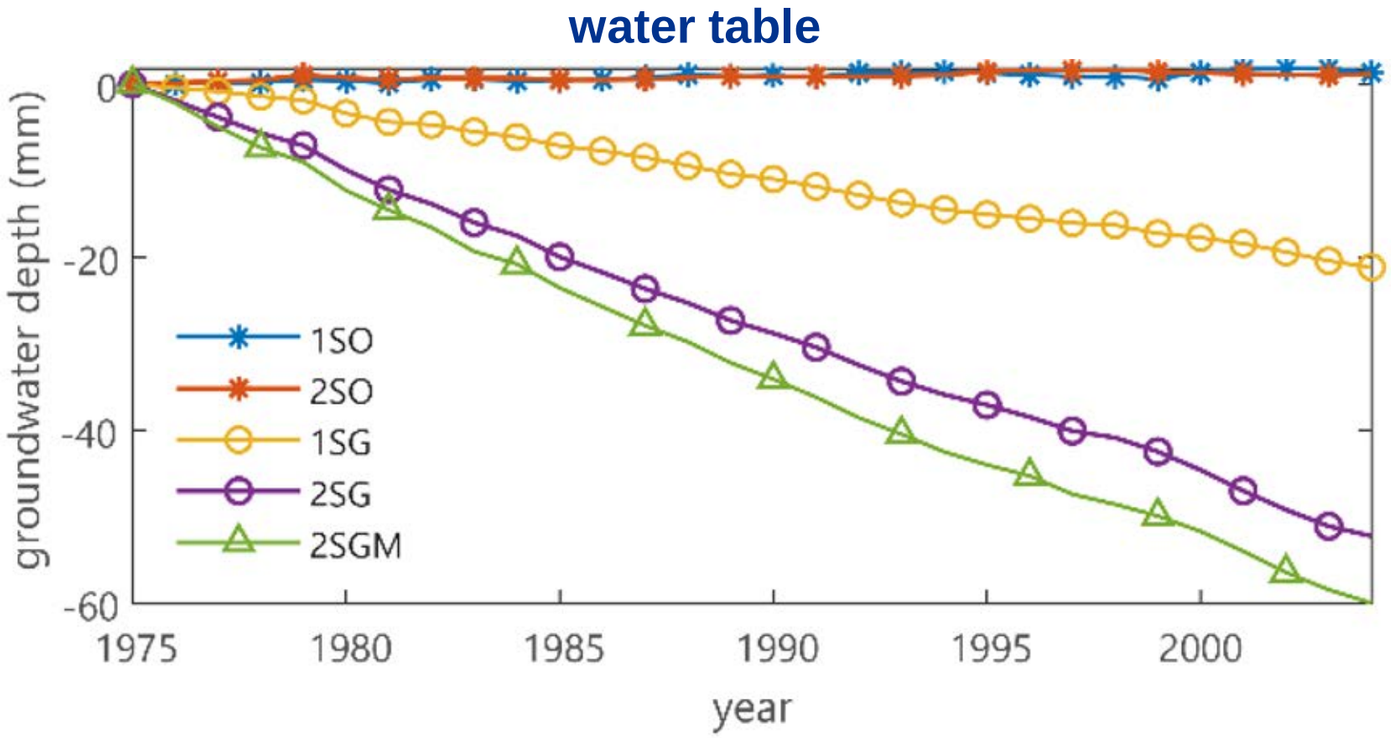


withdrawal is less in 2SG (constrained surface water and fixed groundwater pumping) but more in 2SGM (unlimited pumping), compared to 1SG

evapotranspiration is less in 2SG compared to 1SG

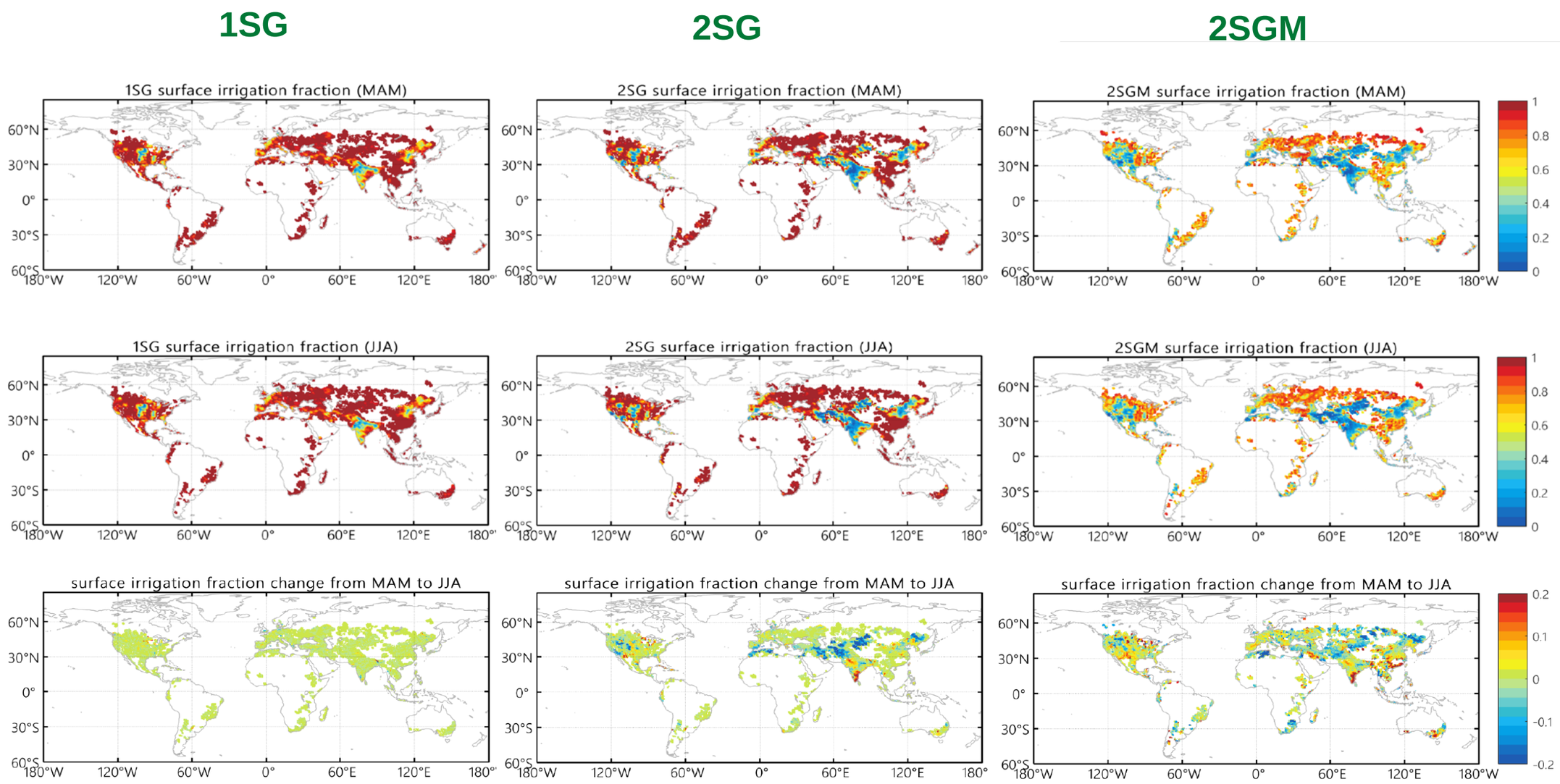
return flow is less in 2SG and 2SGM compared to 1SG

Simulated global averaged water budget terms

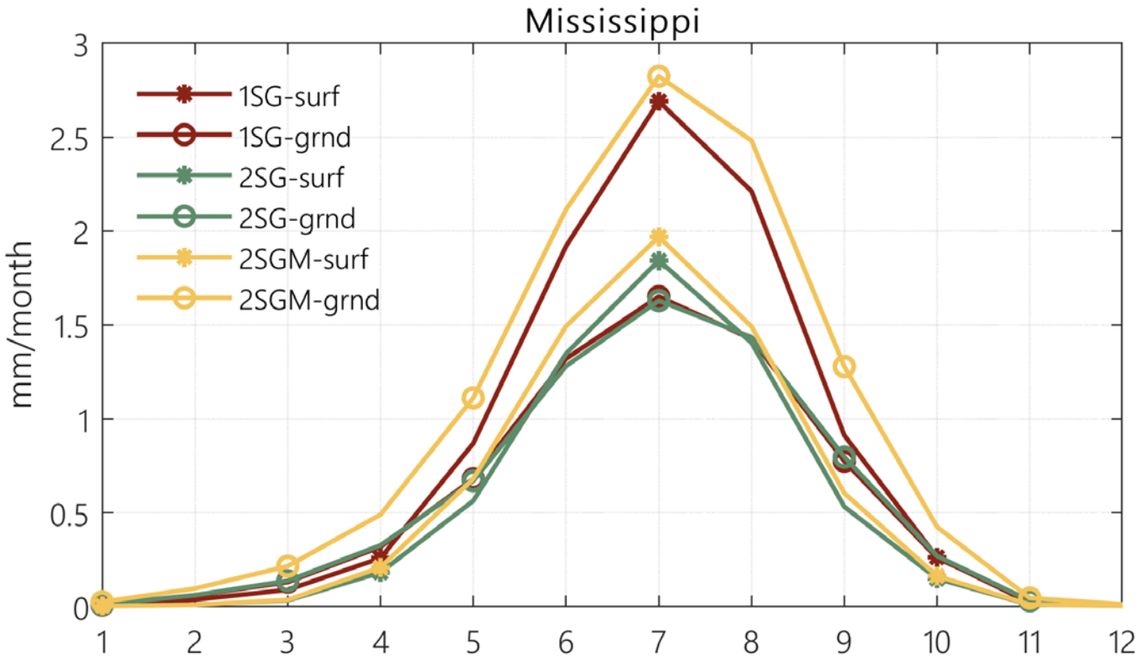


- Water table depletion rate is about 2mm/yr in 2SG and 2SGM, closer to GRACE estimate 2.6mm/yr

Global irrigation allocations (red is surface water, blue is groundwater) in MAM (top) and JJA (middle) and the changes between the two JJA and MAM (bottom)



The two-way coupled scheme is able to capture the seasonal dynamics of irrigation water allocations.



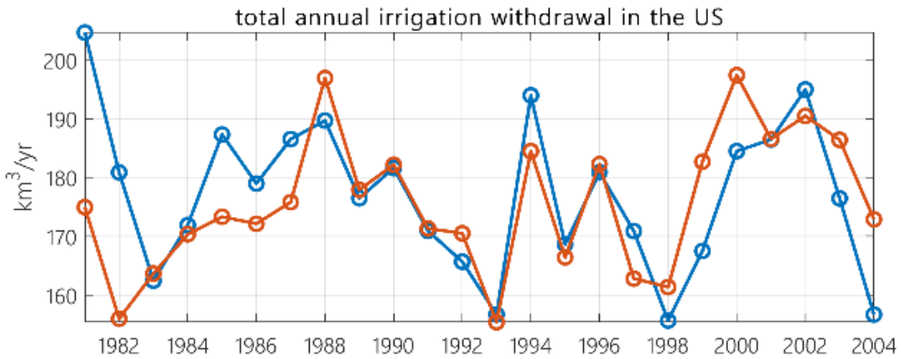
Take Mississippi as an example, the USGS reported statistics show 44% from surface water, 56% from groundwater, close to 2SG estimate (47% and 53%)

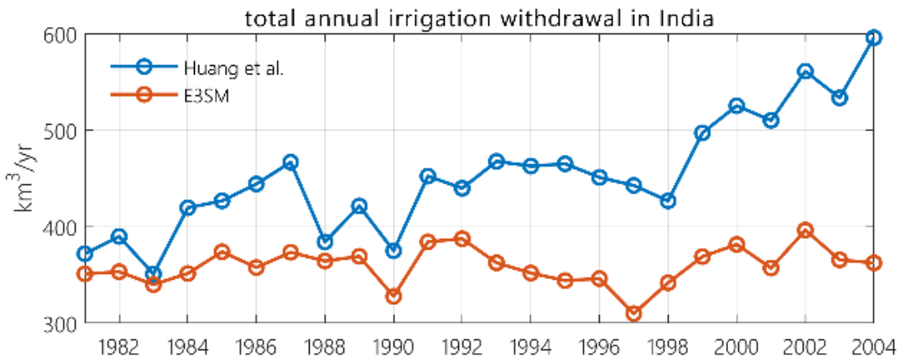
Findings

- Compared to the one-way scheme, the two-way coupling scheme with surface water constraints results in less surface water withdrawal and less return flow.
- The two-way coupled scheme better captured the groundwater depletion rate.
- The two-way coupled scheme is able to capture the seasonal dynamics of irrigation water allocations.

Uncertainties and limitations

- Representation of the irrigation application
- Water demand estimation
- Input climate data
- Fixed land use land cover data

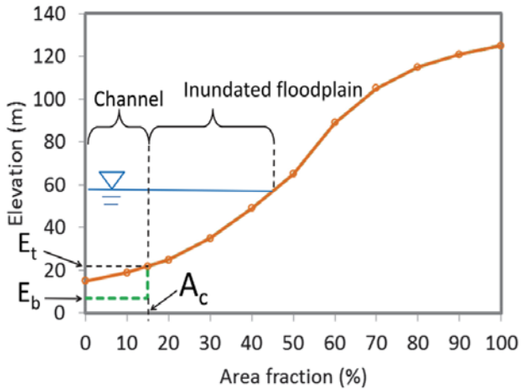




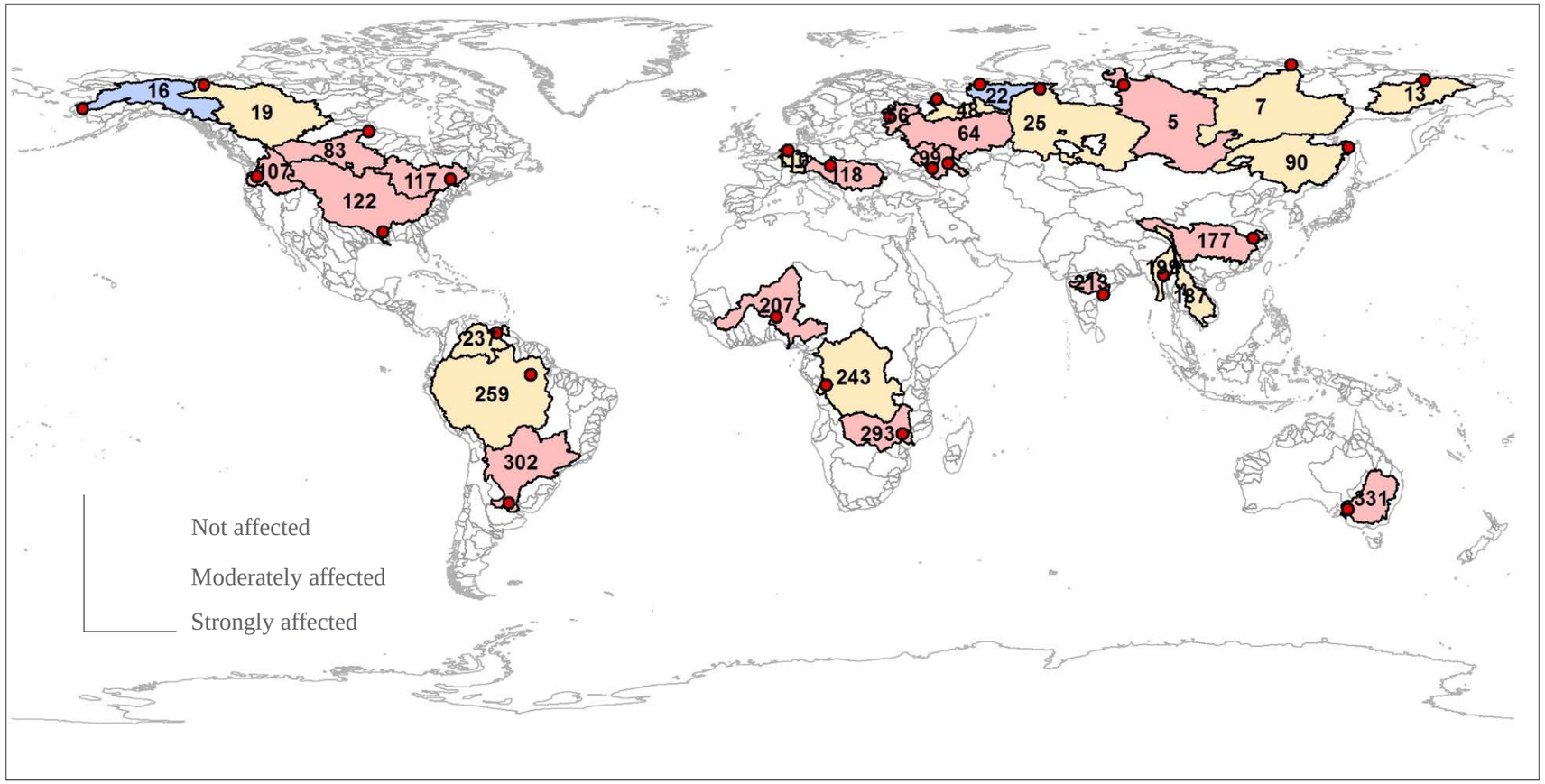
On-going study: global flood inundation analysis

Study goals:

- Evaluate the inundation scheme in global river basins
- Understand flood generating mechanisms



elevation profile in a single gridcell



simulated basins classified by the level of human impacts

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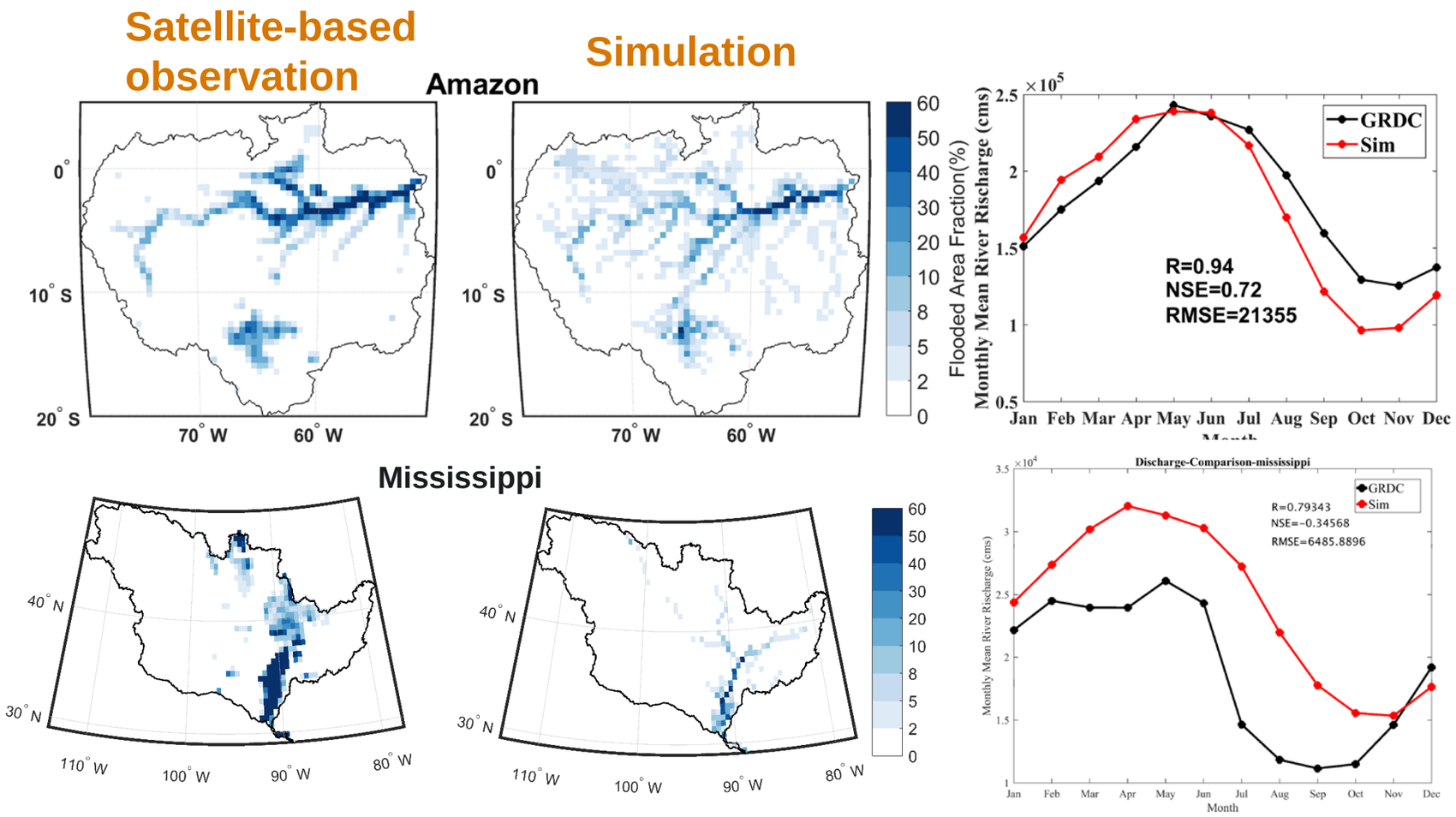
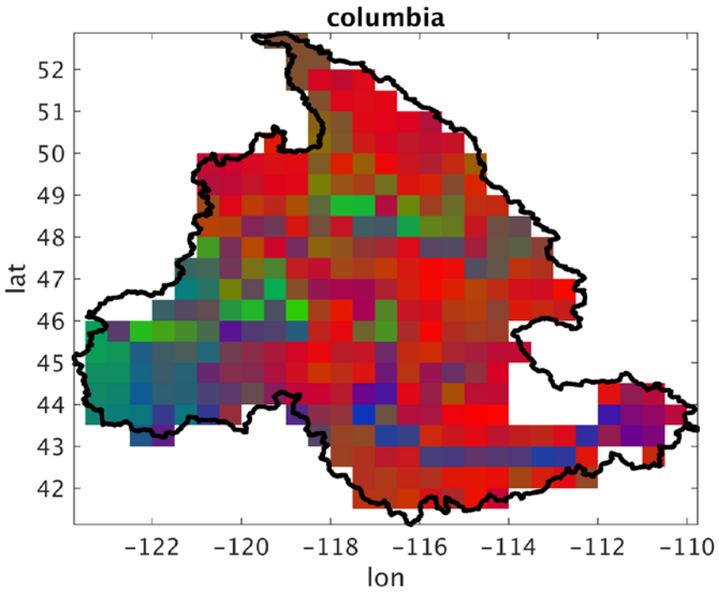


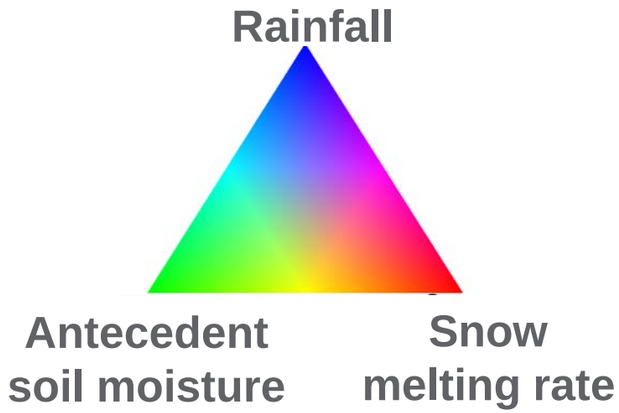
- The flood inundation scheme is able to capture the spatial extent and the dynamics of flood inundation in global river basins.

- Human impacts such as dam regulations would alter the flood inundation. Our next step is to develop a modeling scheme that couples ELM, MOSART-WM, and the inundation components.

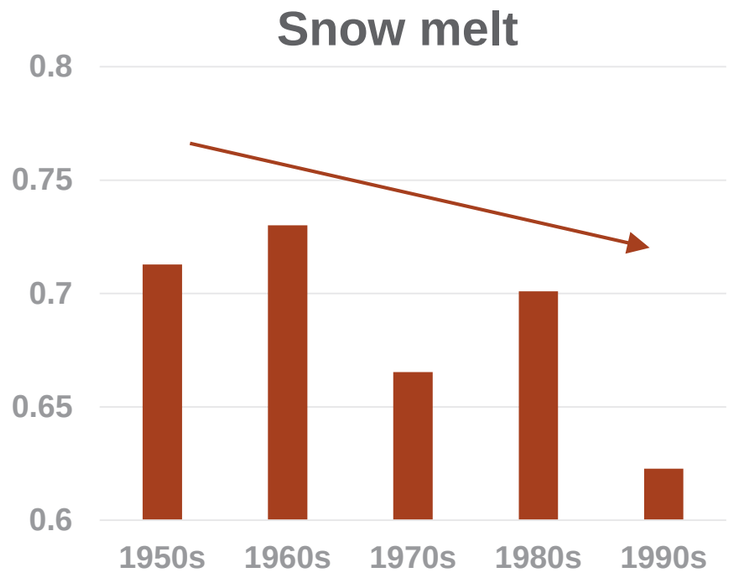
Preliminary findings



Snow melt is the leading generating mechanisms compared to the other two



Generating mechanisms of the flood inundation are represented by RGB coded colors



Decadal correlation coefficient change between flood area and dominant generating factor

Ongoing development and testing

- Represent heat transport in MOSART and reservoir stratification to support BGC simulation (carbon, phosphorus)

  Li et al. (2015)

  Yigzaw et al. submitted to *JAMES*

- Represent the sediment transport in MOSART

  Tan et al. (2018)

  Li et al. to be submitted to *JAMES*

- Coupling WM and inundation components to represent dam regulations in terms of flood control

  Zhou et al. (*ongoing development*)

Future opportunities

- Study irrigation impacts on land-atmosphere interactions using the coupled E3SM
- Using Variably Saturated Flow Model (VSFM) to better represent soil water process in irrigation
- Coupling with GCAM to represent water demand from other sectors
- Using the same grid in ELM and MOSART (proposed topic in All-hands meeting)
- Sensitivity of the floodplain inundation to model parameters such as elevation profile, grid resolution, vegetation

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Thank you