Wonders of Water Lab

Riverine Hydrologic and Biogeochemical Interactions in Earth System Models

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September 17, 2021

Courtesy: Ruby Leung, Xiaojuan Yang & others

Why riverine biogeochemistry -- Rivers and streams as hotspots for CO2 evasion

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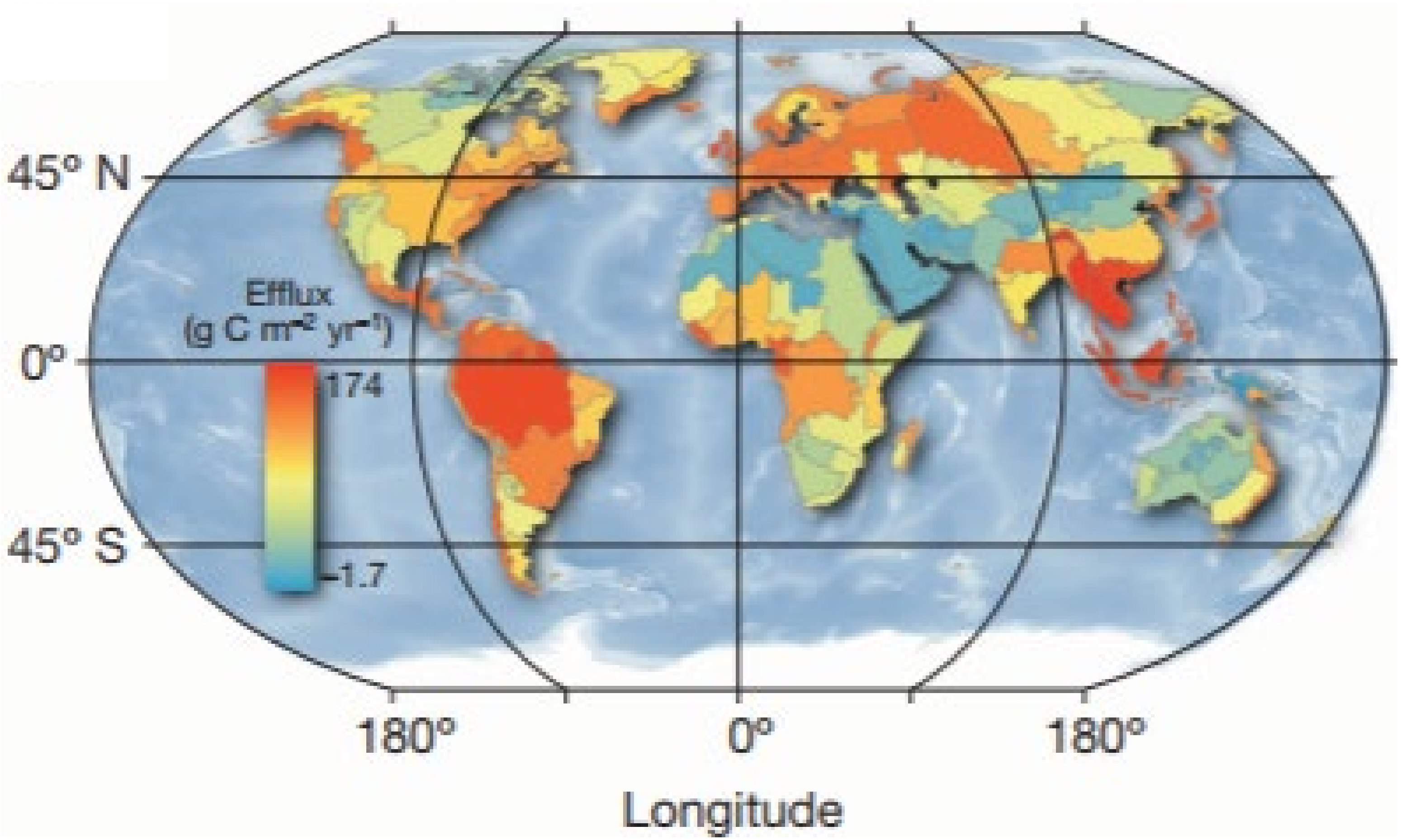
Global CO_2 evasion rates from rivers and streams are estimated to be 1.8±0.25 PgC/yr (~70% of CO_2 evasion from just 20% of land surface)



CO_2 efflux from streams and rivers

(Raymond et al., Nature, 2013)

MOSART as the riverine component of E3SM and CESM

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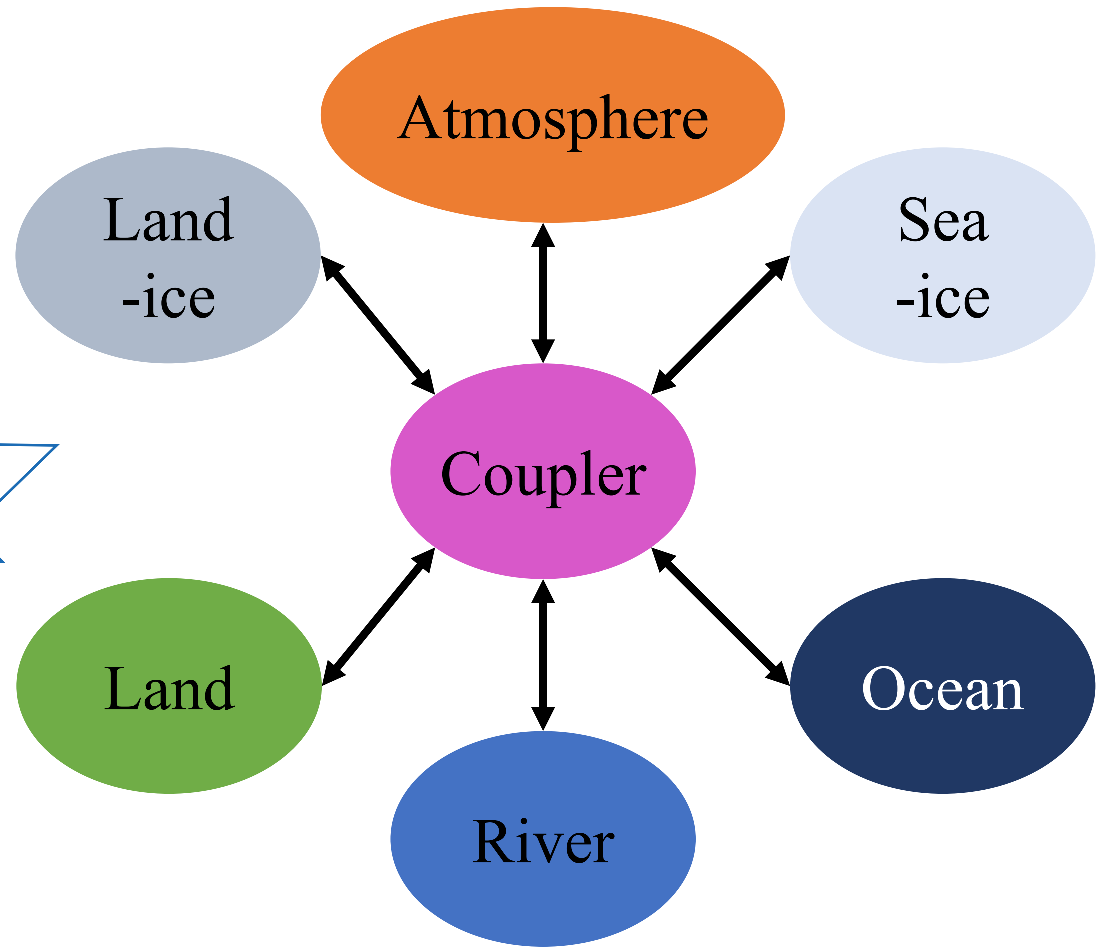
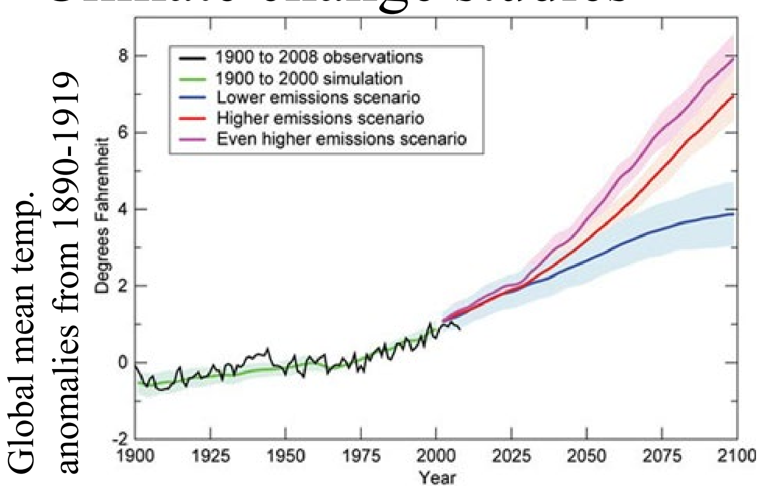
Earth System

E3SM



Climate change studies



Model for Scale Adaptive River Transport (MOSART)

MOSART accounts for impacts of both climate and human activities

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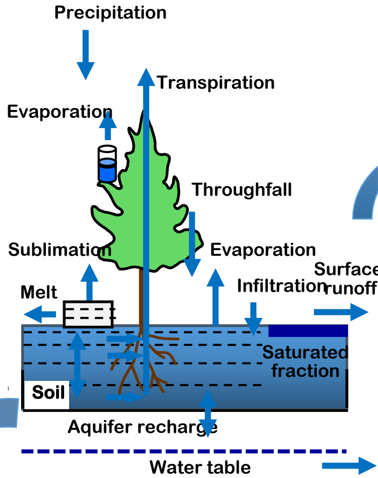
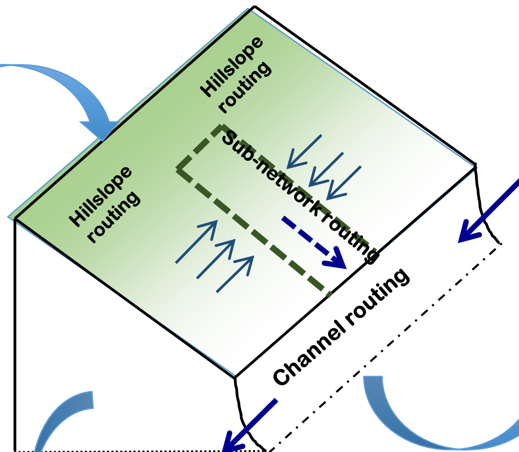
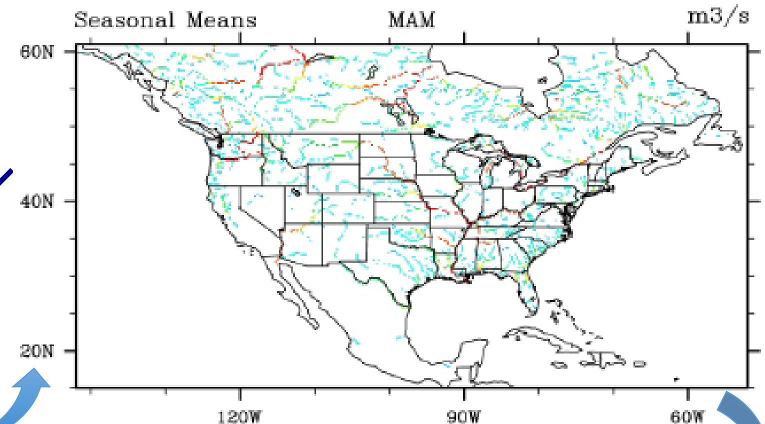
Land model (ELM)



River Model (MOSART)

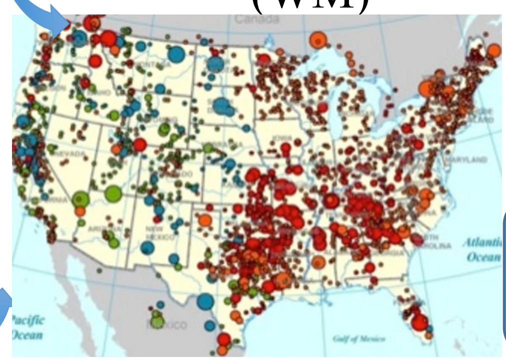


Coupled ELM-MOSART Simulation



Socioeconomic Model (GCAM)

Water Management Model (WM)

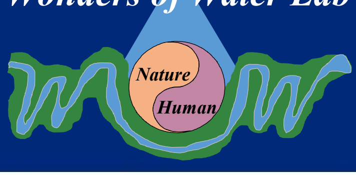


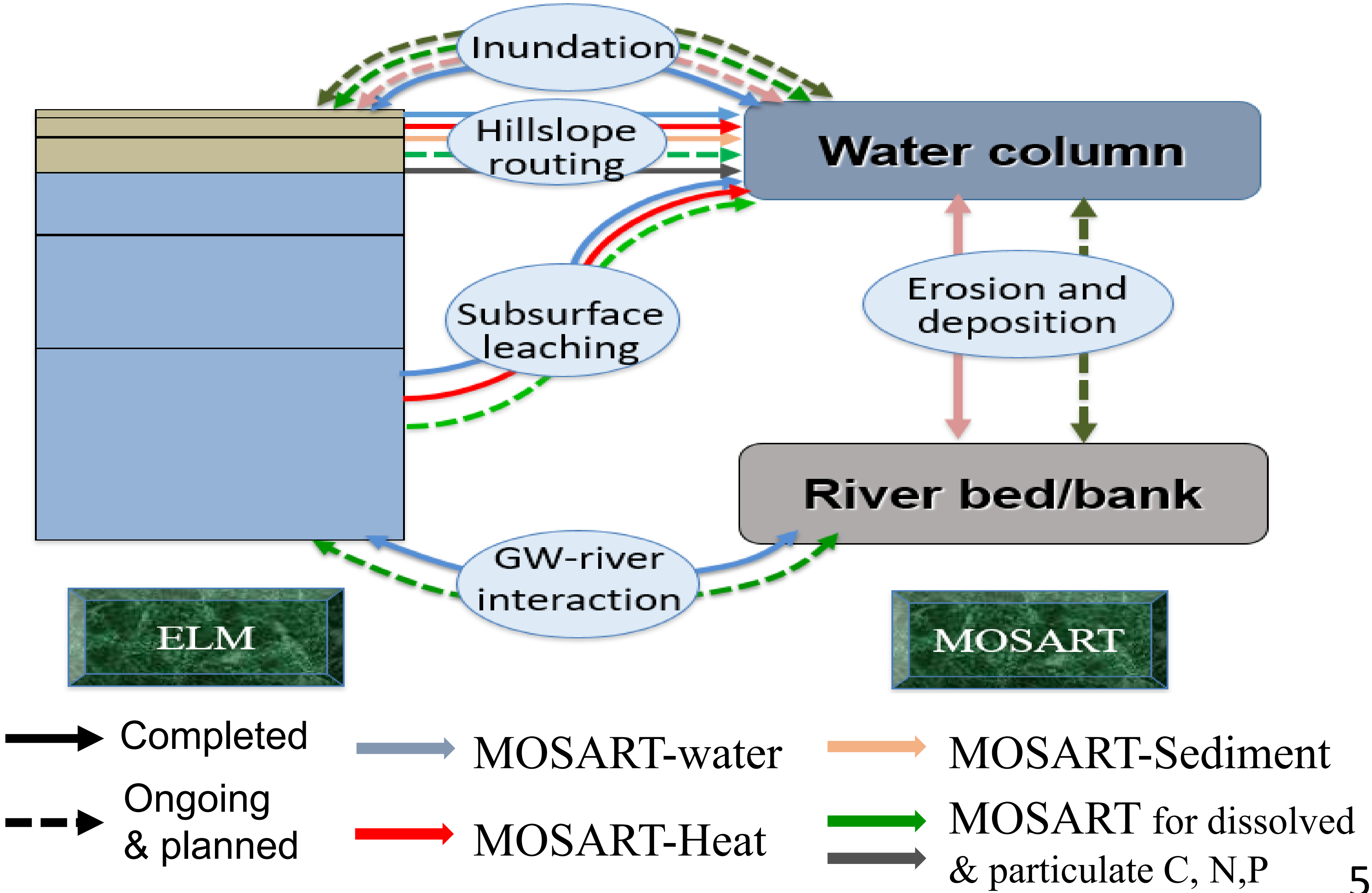
Local water extraction

Reservoir operation

(Li et al., 2013, 2015a,b; Voisin et al., 2013a, b; Yigzaw, 2019; Zhou et al., 2020)

Schematic of Riverine Processes





MOSART-heat: stream temperature evaluation against daily observations

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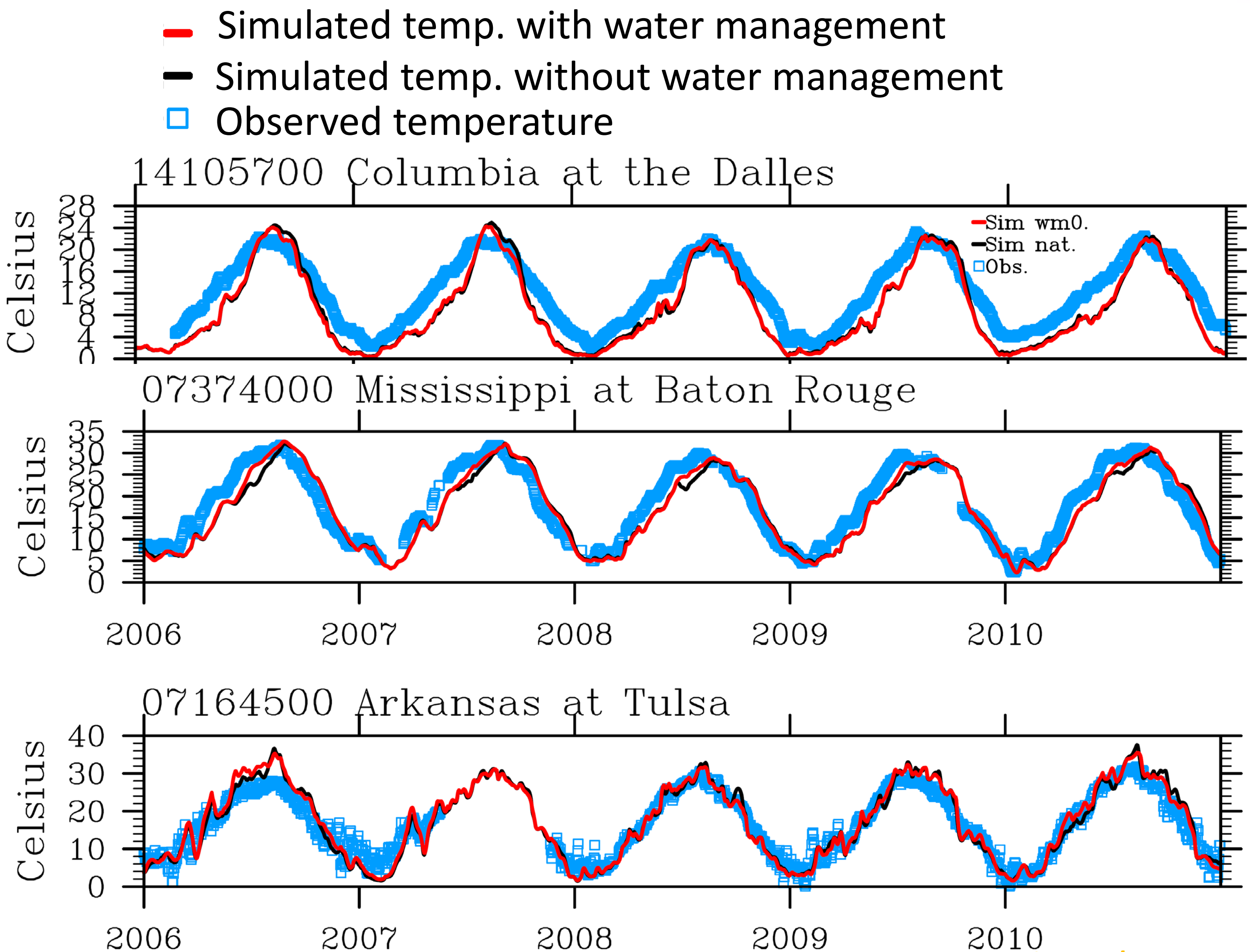

Li et al., JAMES, 2015

Reservoir impacts on summer streamflow & water temperature

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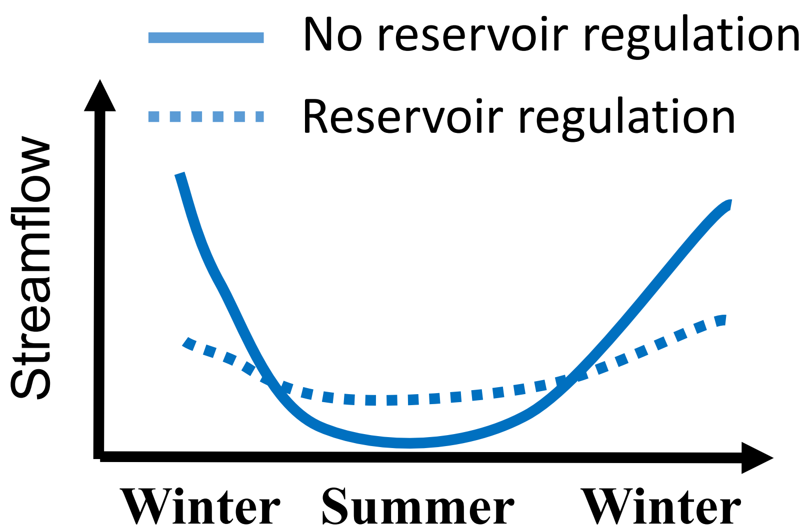
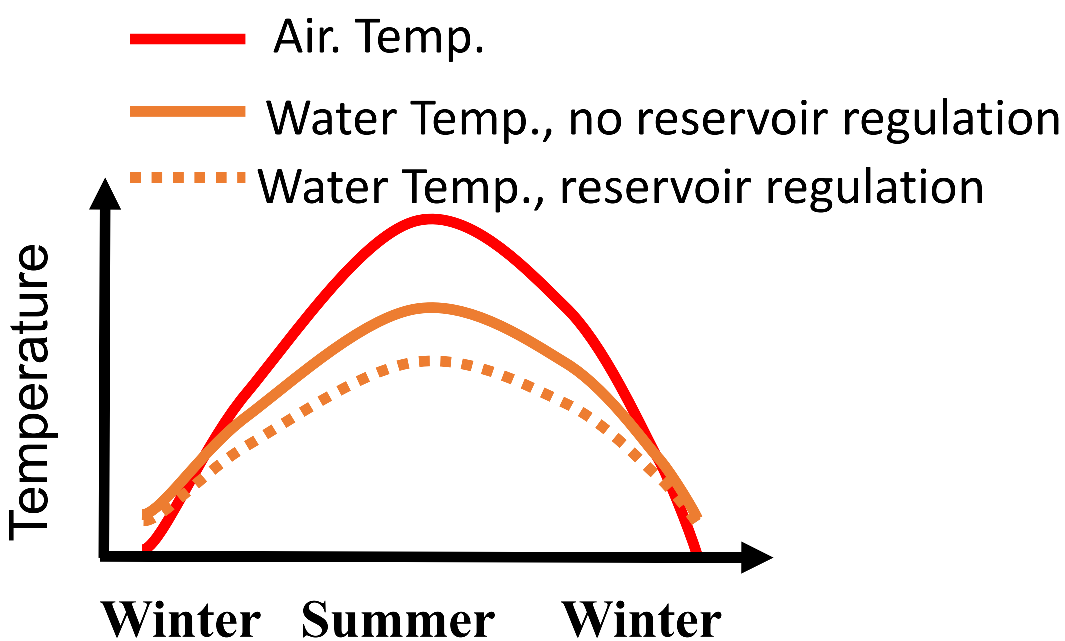


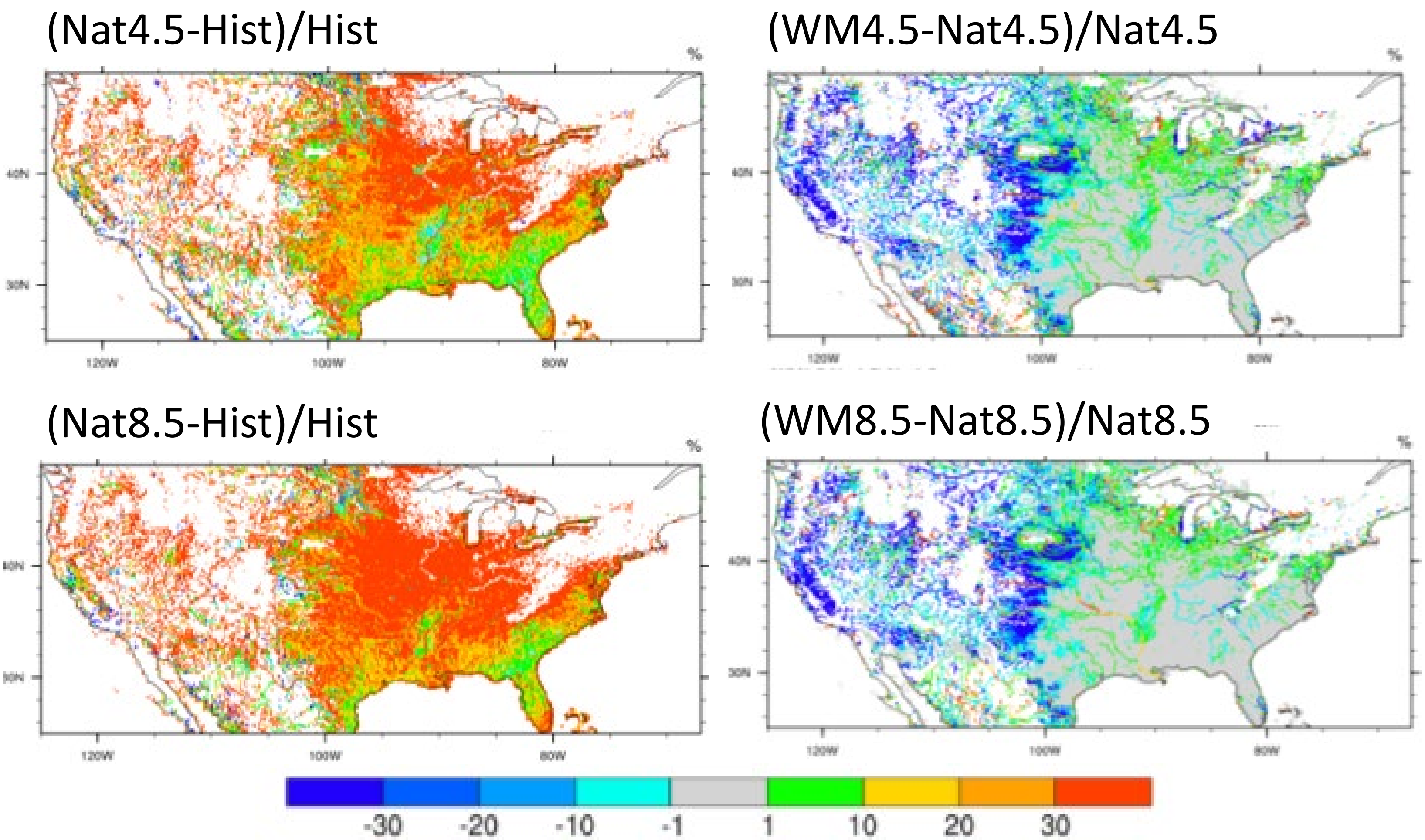


- Air temperature variation is damped in water, since heat capacity of water >> that of air
- Reservoir regulation further enhances this damping effect

Water management reduces future extreme water temperature by enhancing summer low flow

Water management reduces exceedance frequency

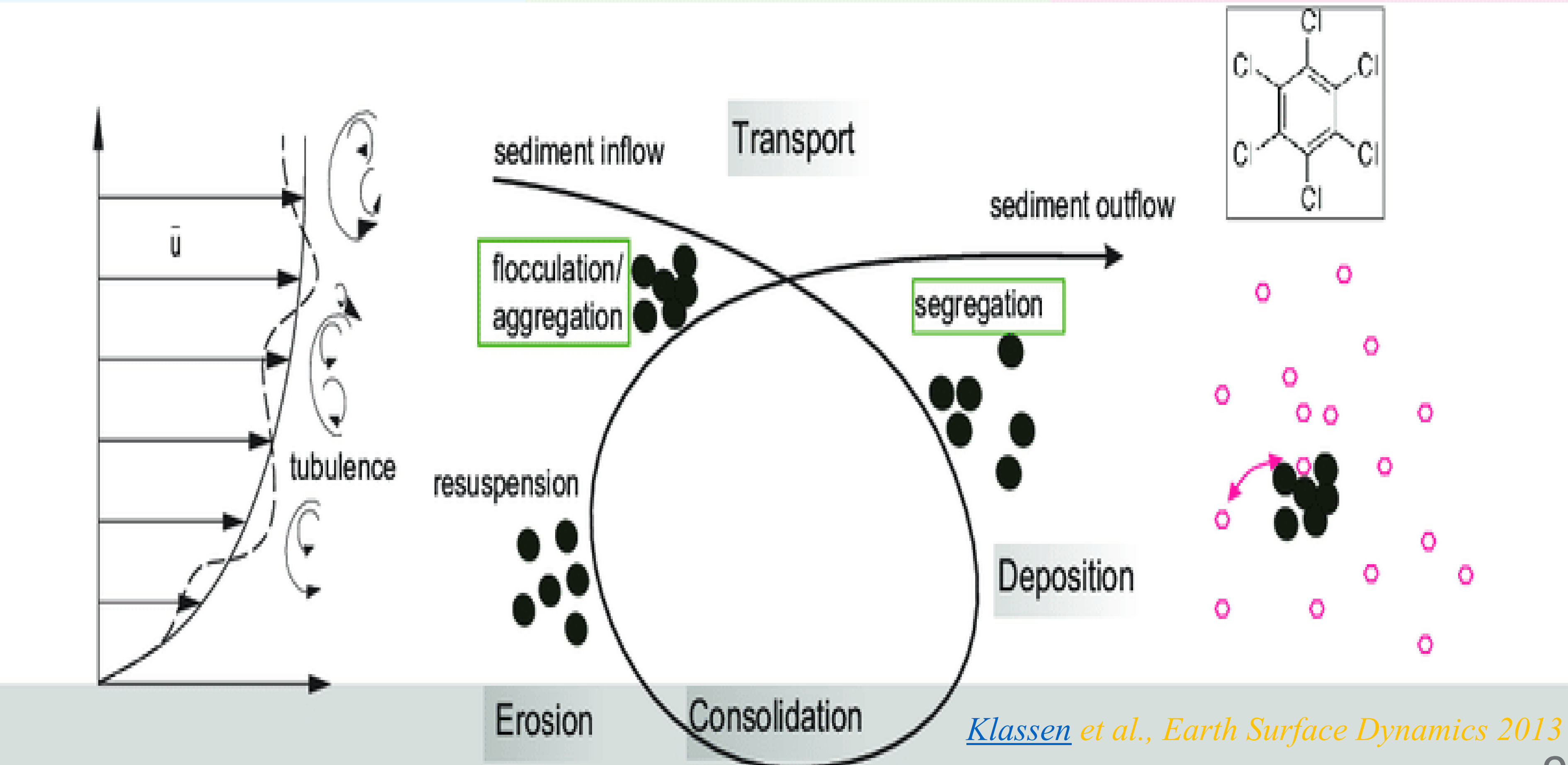
Emission mitigation reduces exceedance frequency



% change in number of hours with stream temperature > 27°C

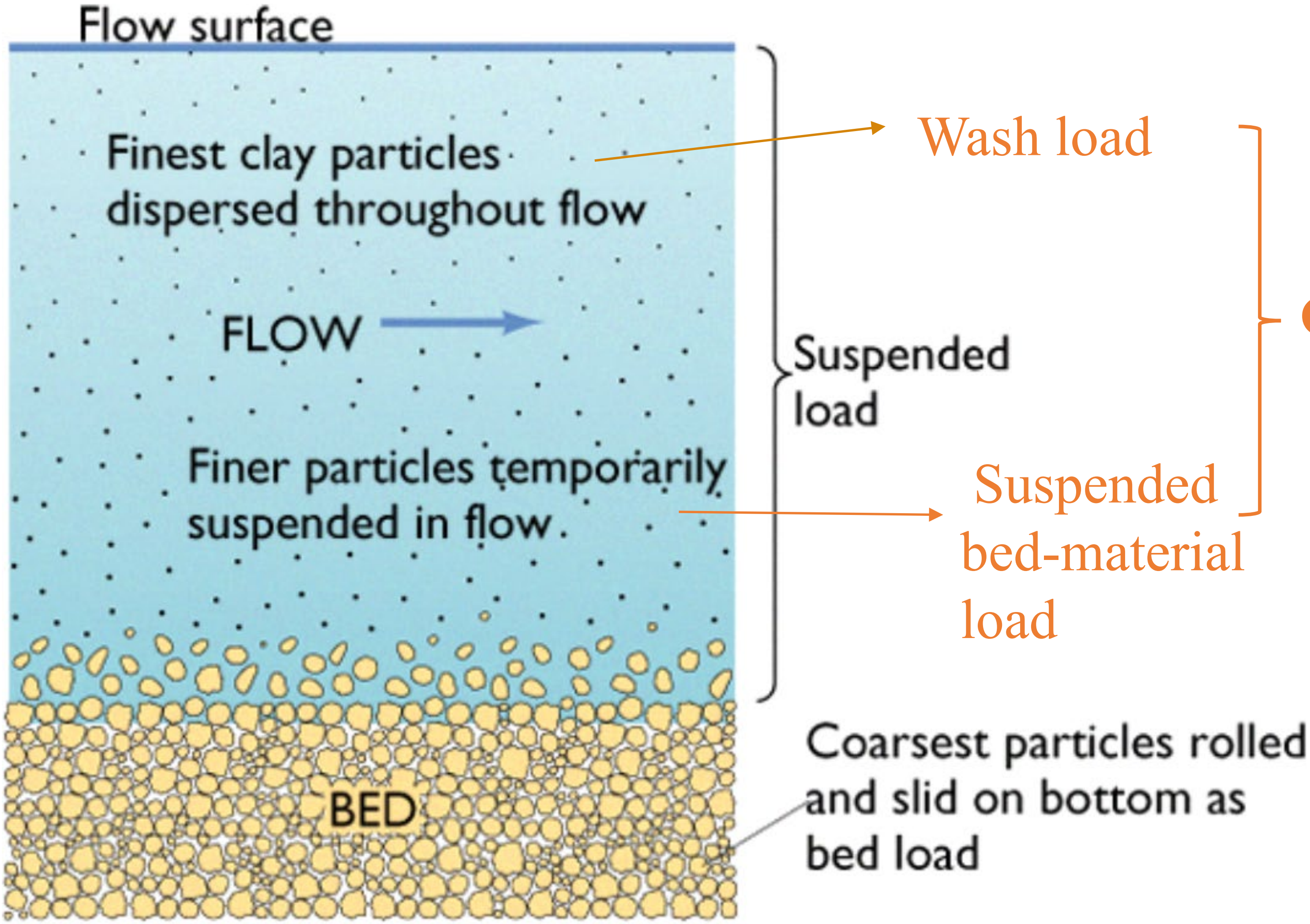
Suspended sediment carries particulate C/N/P from land to rivers and coasts

Water	Sediment	Carbon & nutrients
flow, turbulence, salt content, pH-value, temperature,...	particle properties, particle conc., organic matter	solved, particle-bound, organic, particle size distribution, water chemistry,...



Klassen et al., Earth Surface Dynamics 2013

Sediment transport in rivers



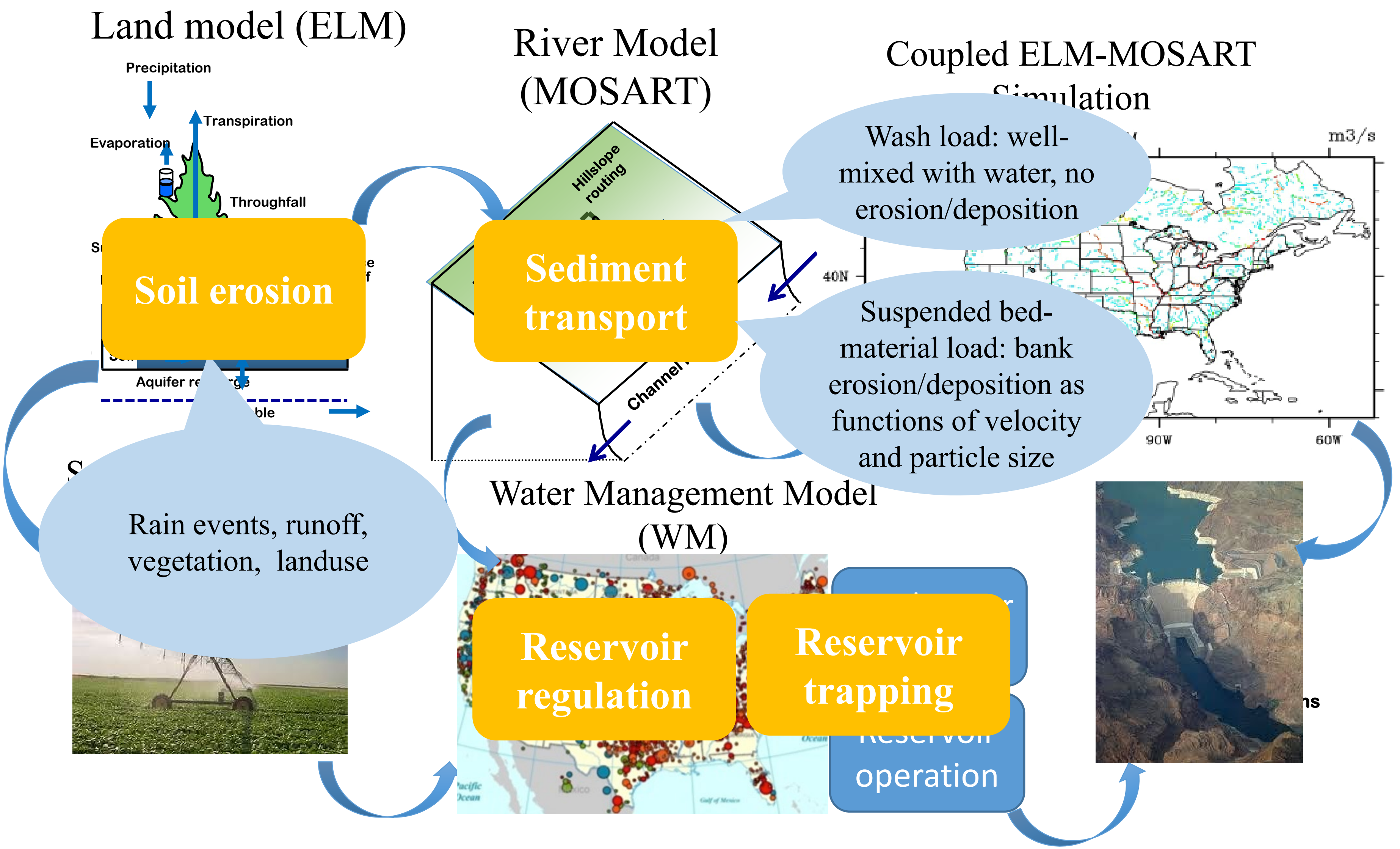
Wash load

Suspended bed-material load

Our focus

https://web.mst.edu/~rogersda/umrcourses/ge341/online_lectures/fluvial_processes/Fluvial%20Processes-pt5.ppt

MOSART-sediment: suspended sediment



Tan et al., 2017; 2018, 2020, 2021; Abeshu et al., in revision; Li et al., to be submitted

MOSART-sediment: parameterization over the U.S.

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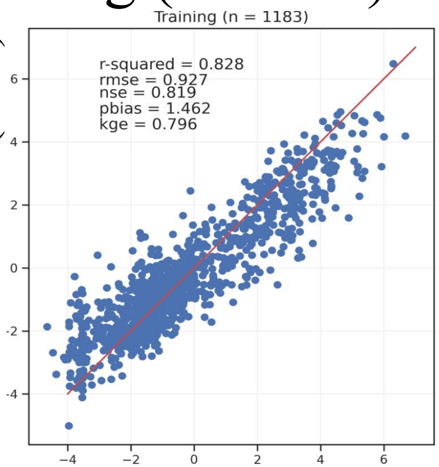
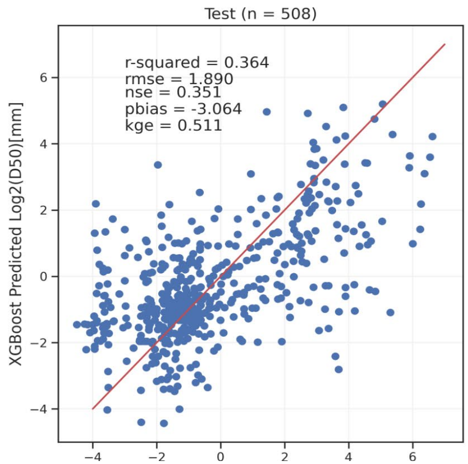
Training (n=1183) Testing (n=508)

Predicted D50 (mm)

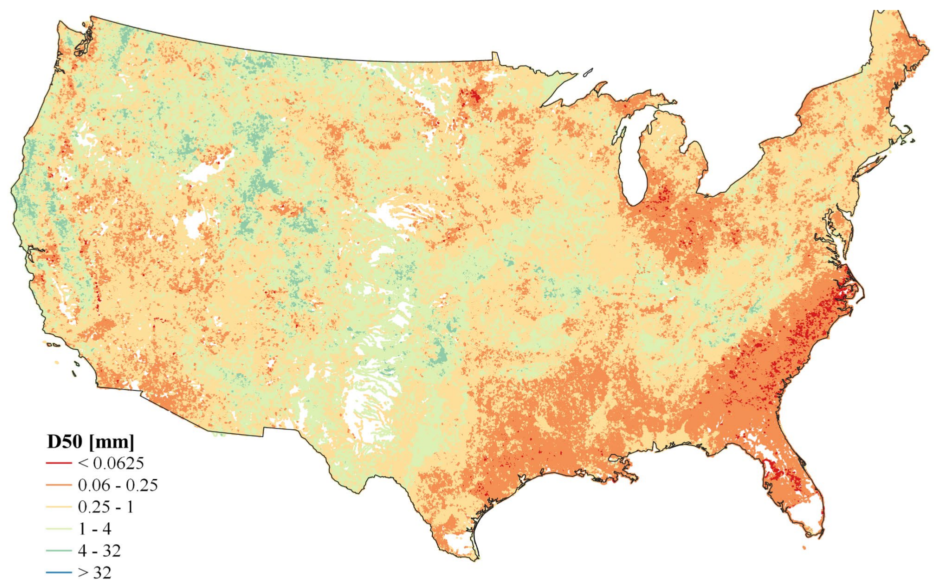




Observed D50 (mm) Observed D50 (mm)

Machine-learning method to establish a predictive model for ***median river-bed sediment particle size*** (**D50**) from existing land datasets

Predicted median river-bed sediment particle size for over 2.4 million river segments across the contiguous U.S.



Abeshu et al. (2021), Ear. Sys. Sci. Data Discussion, in revision

MOSART-sediment: Validation at 39 USGS gauges

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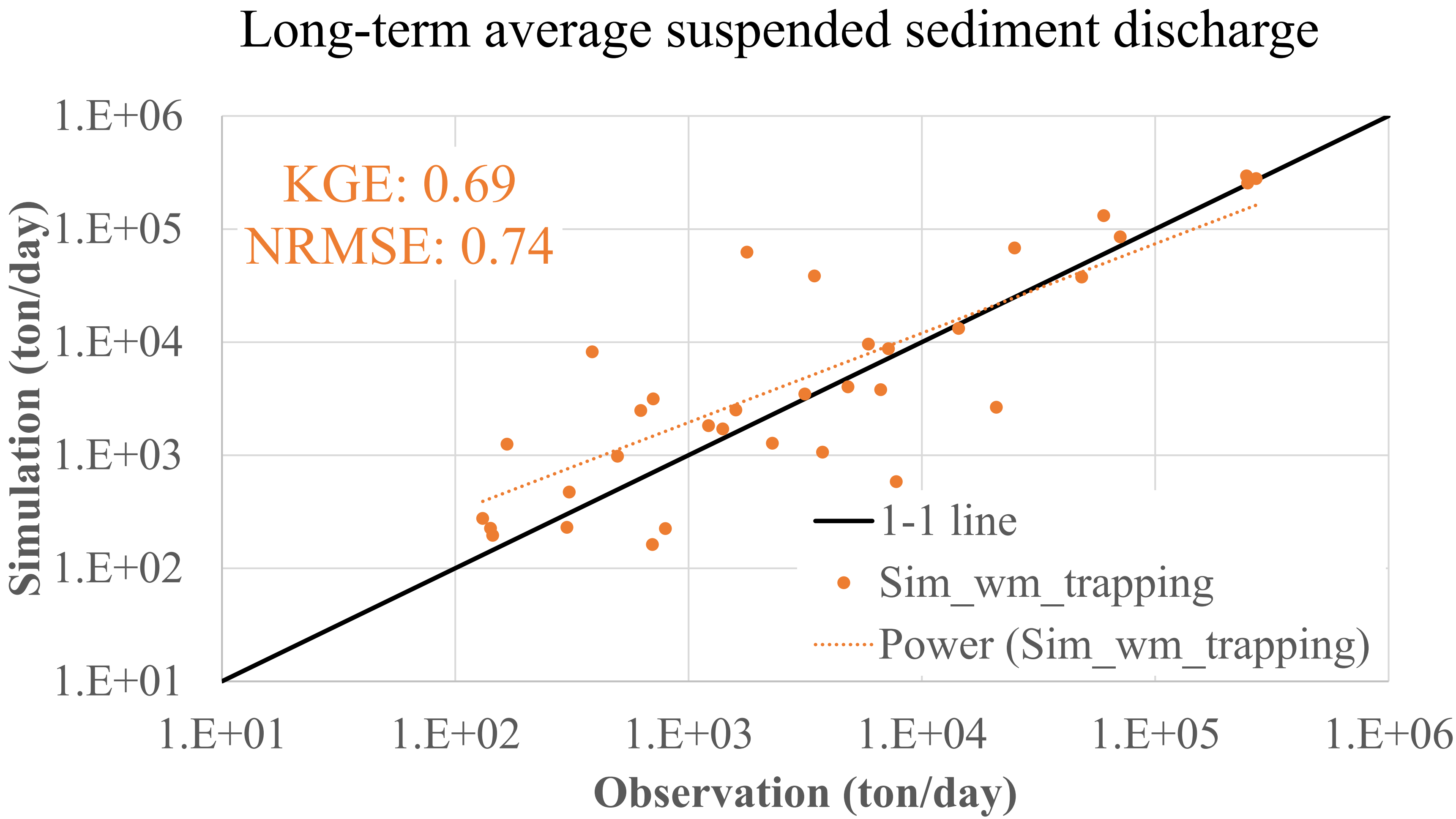


Simulation period: 1979-2012

Forcing: NLDAS2

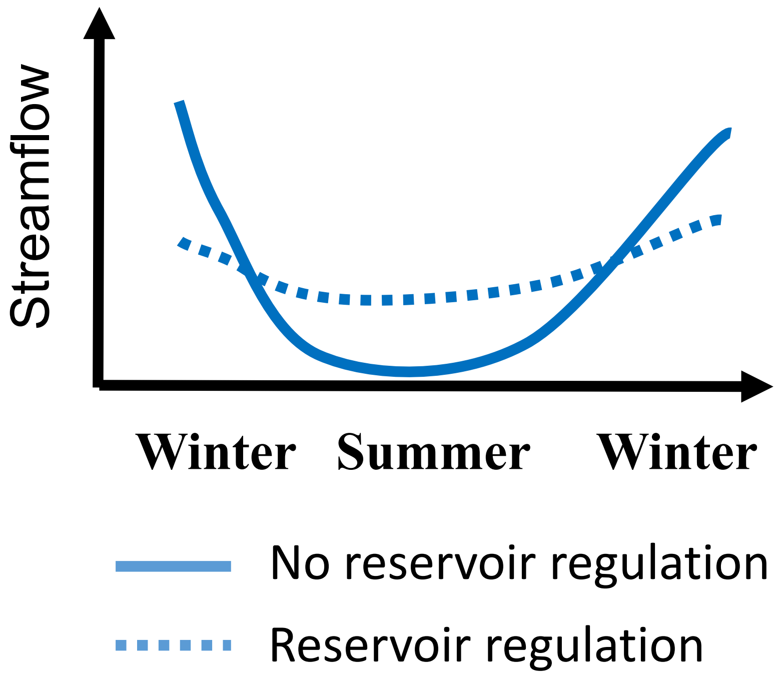
Time step: daily

Resolution: 1/8th-degree

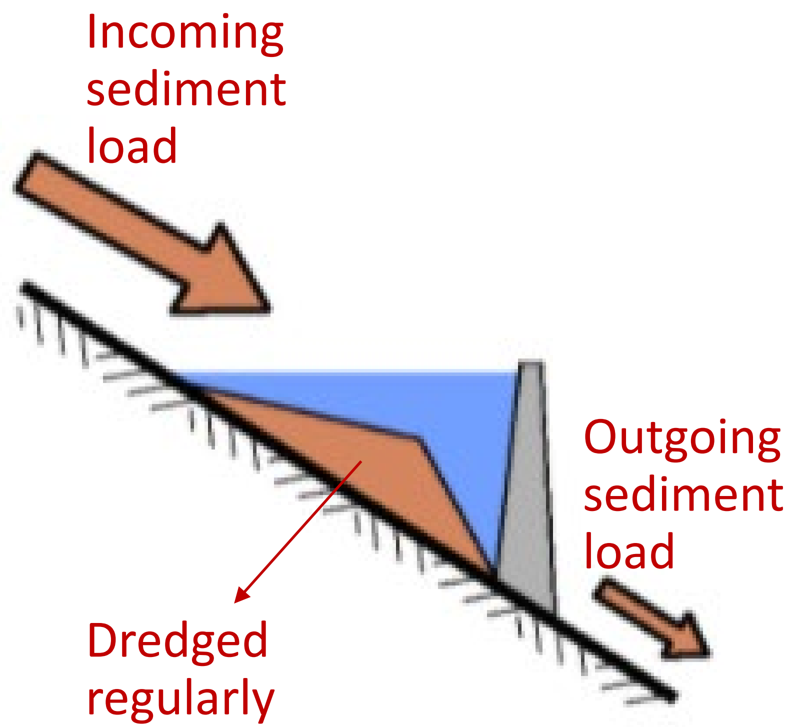
Li et al., to be submitted

Reservoir regulation & trapping effects

Regulation effect: modify natural hydraulic conditions via flow regulation



Trapping effect: directly intercept suspended sediment



Reservoir regulation & trapping effects

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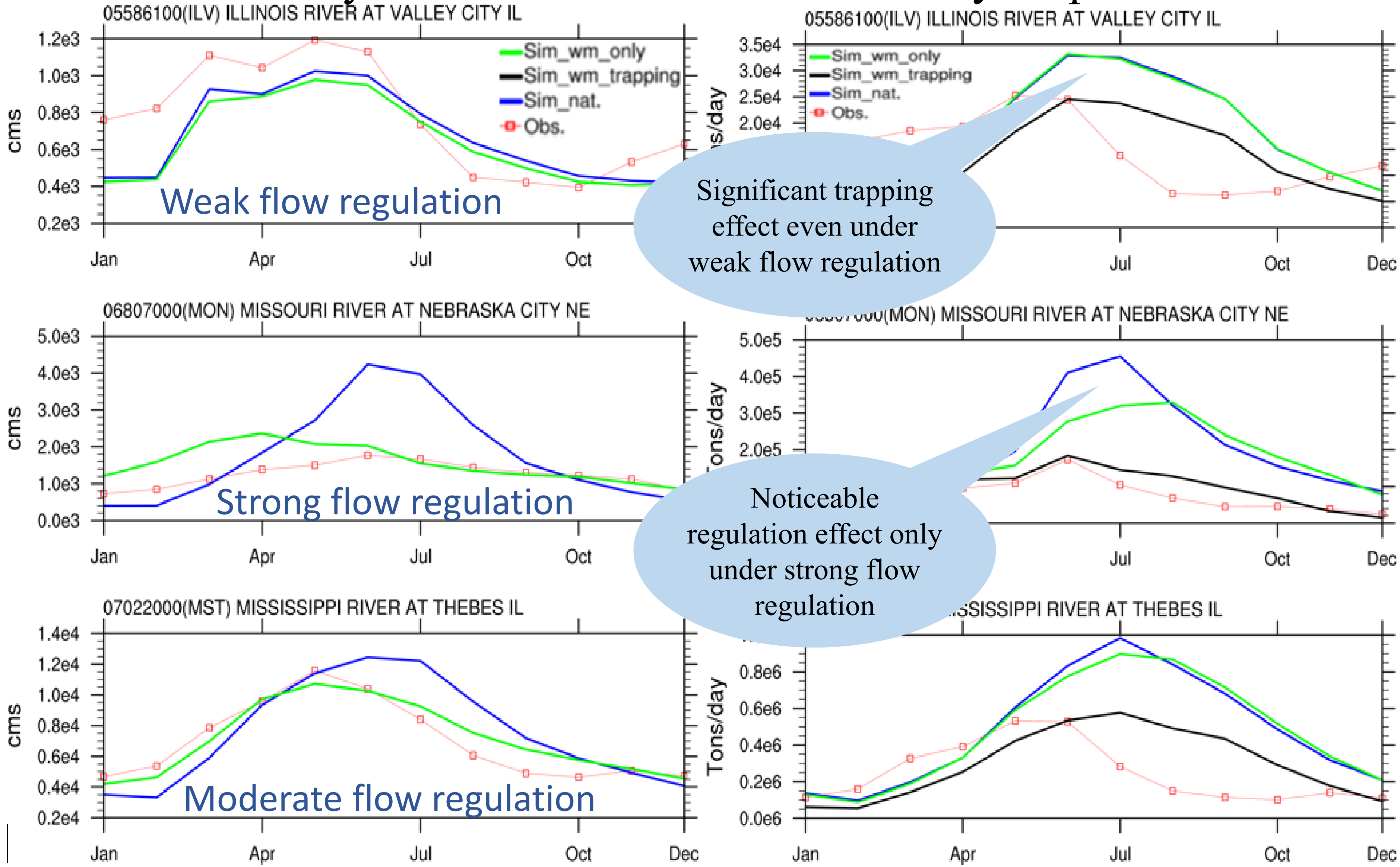
Mean monthly streamflow | Mean monthly suspended sediment



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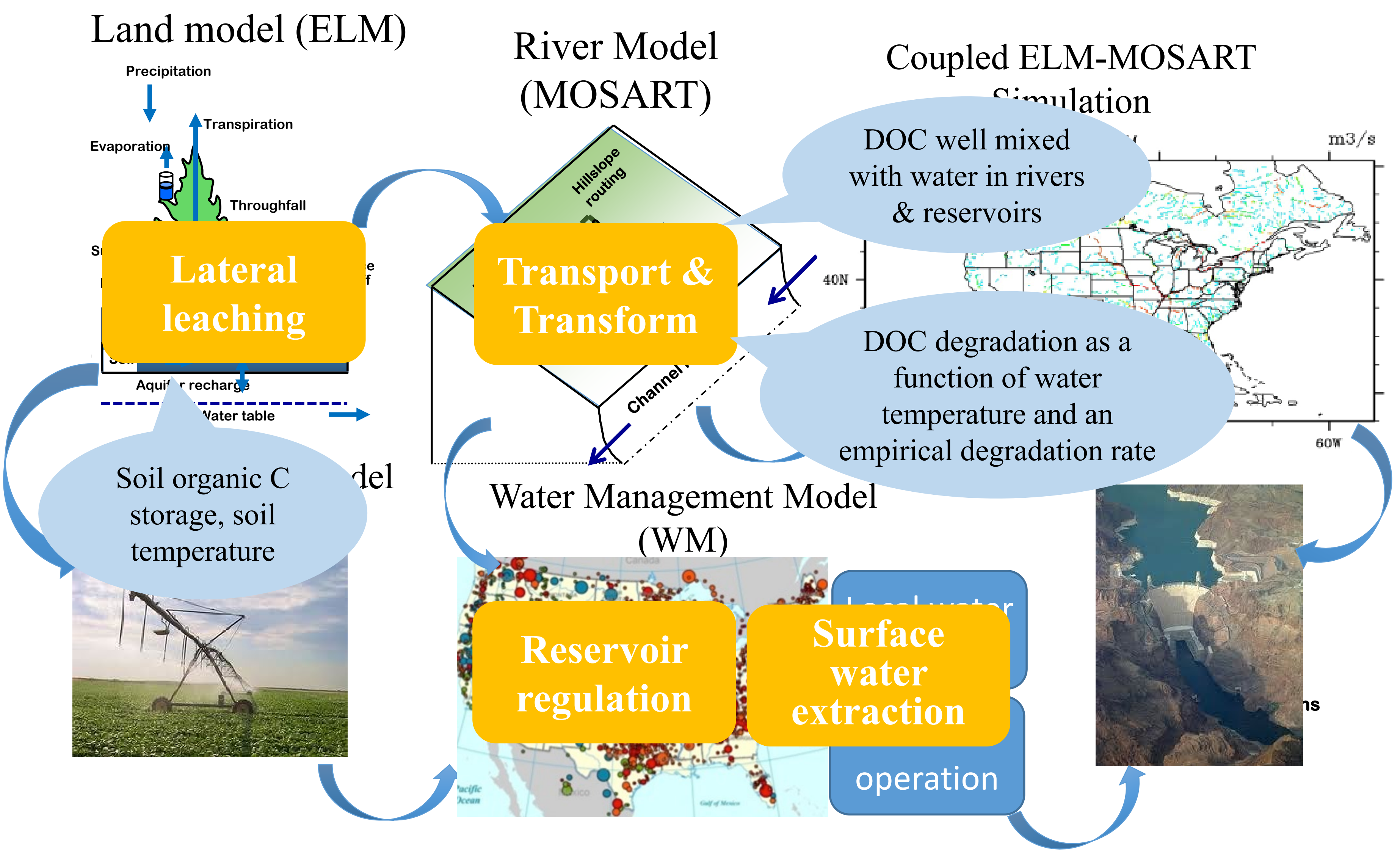
MOSART-DOC: Dissolved organic carbon



MOSART-DOC: Preliminary validation

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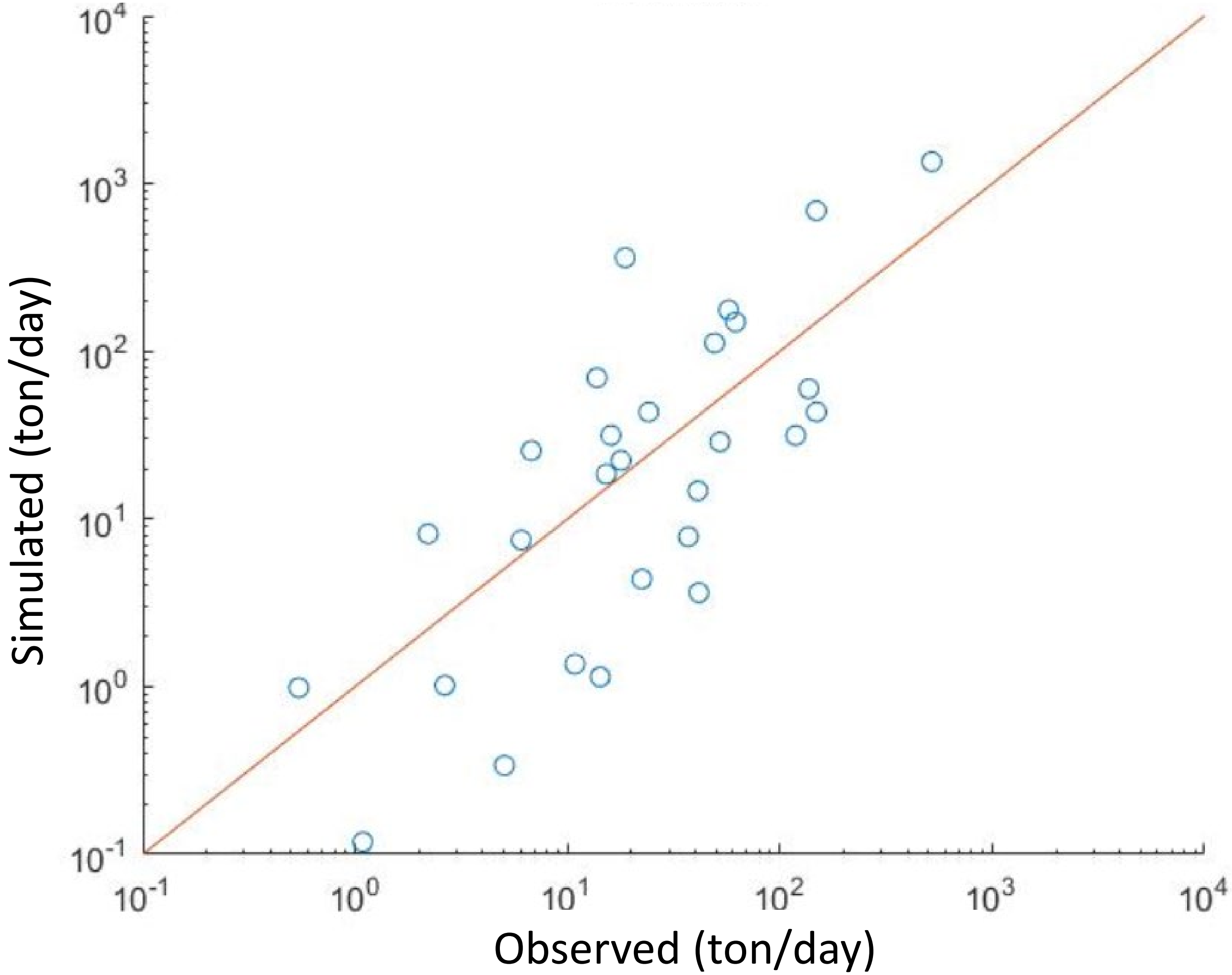
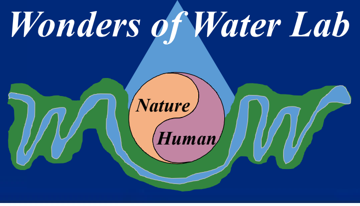
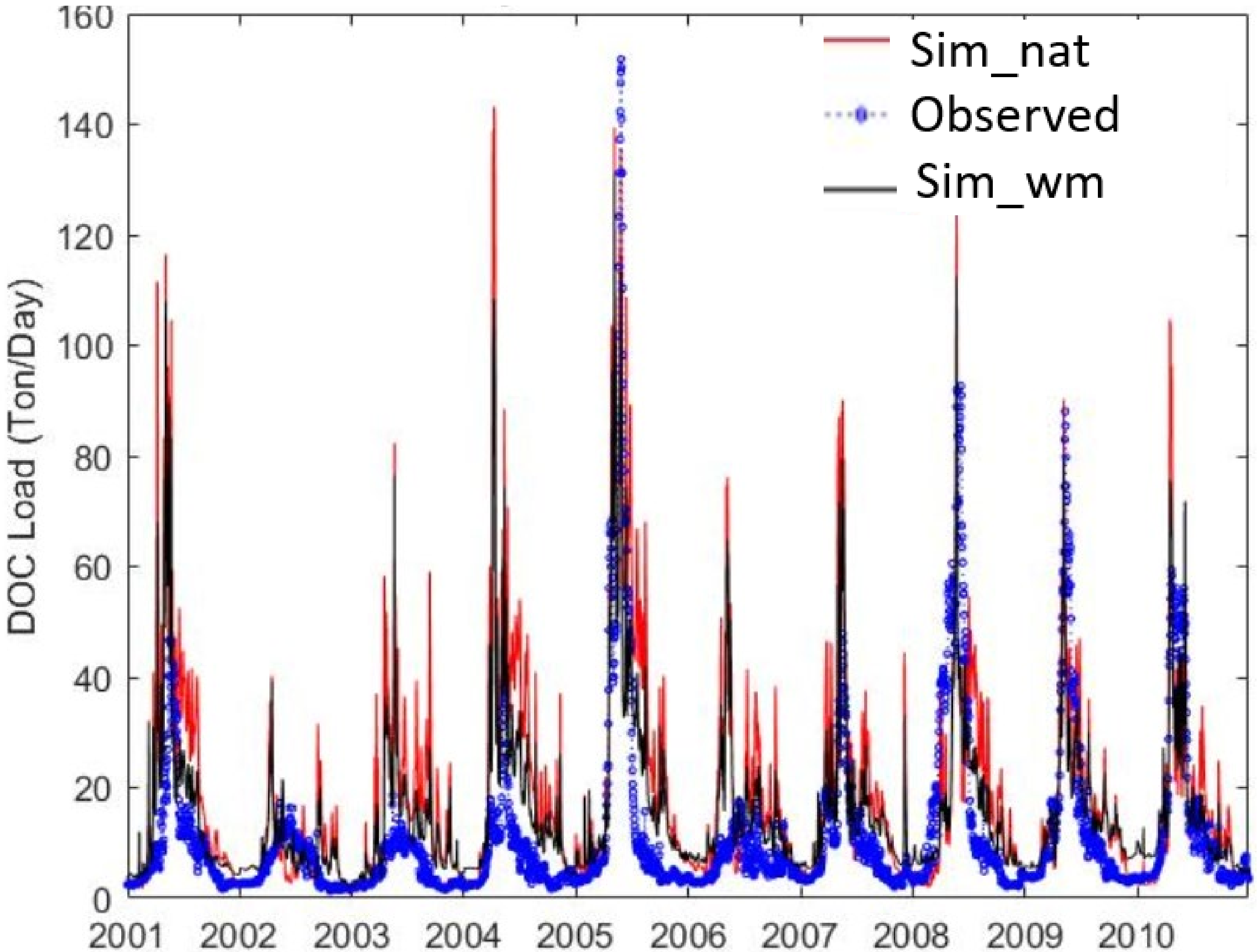
Mean DOC discharge in 2001-2010 at 28 USGS stations



MOSART-DOC: Preliminary validation



Daily DOC discharge, Rio Grande at Otowi Bridge, NM



Future work – Riverine BGC data assembling, synthesis and analysis

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- Riverine BGC (carbon and nutrients) data collection and synthesis
- New River related metrics (e.g., as part of ILAMB)
- Riverine BGC metrics to constrain land-BGC (indirectly) and river-BGC (directly) modeling

Future work -- New functional relationships to constrain model predictions

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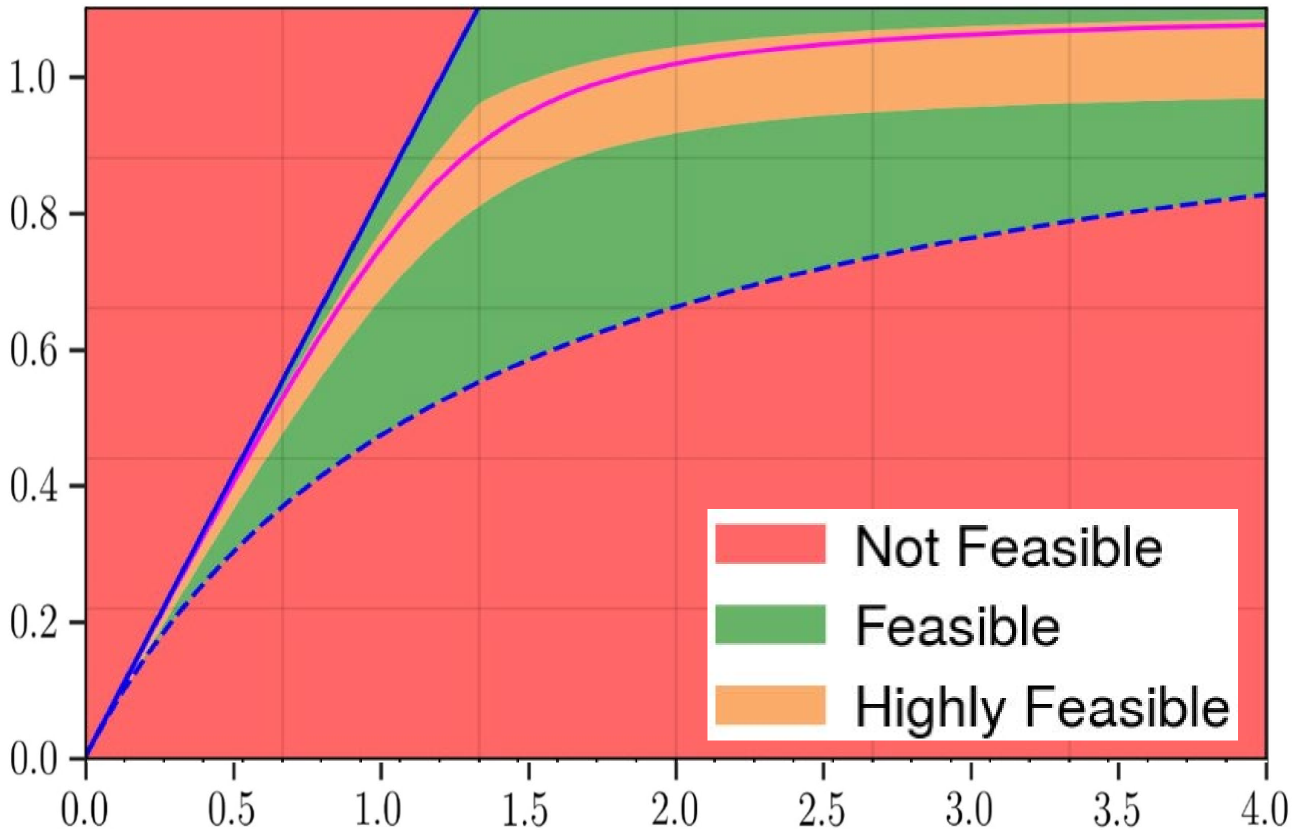
Functional relationships from analysis of observations → Constrain model prediction



Abeshu & Li (2021), Water Res. Res.

Future work – Model-driven analysis for improved understanding

- How will regional and global climate and socioeconomic drivers affect the carbon exchanges between land-river-ocean?
- How will water and land management affect CO2 emission from inland rivers?
- How will water and land management affect nutrient load from land to rivers and coast?

Appendix

Impacts of water management in August-October (low flow + high temp.)

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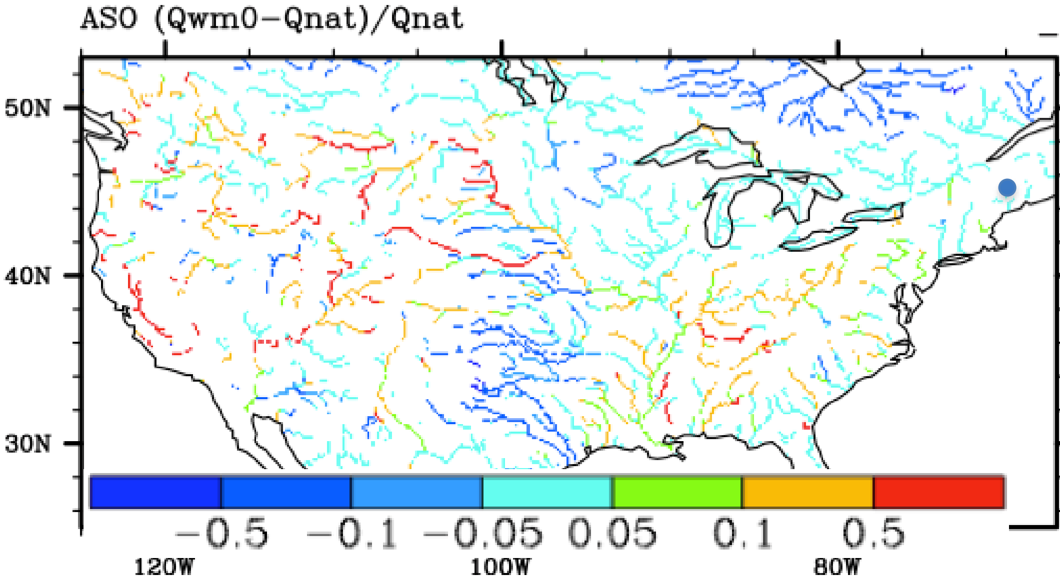
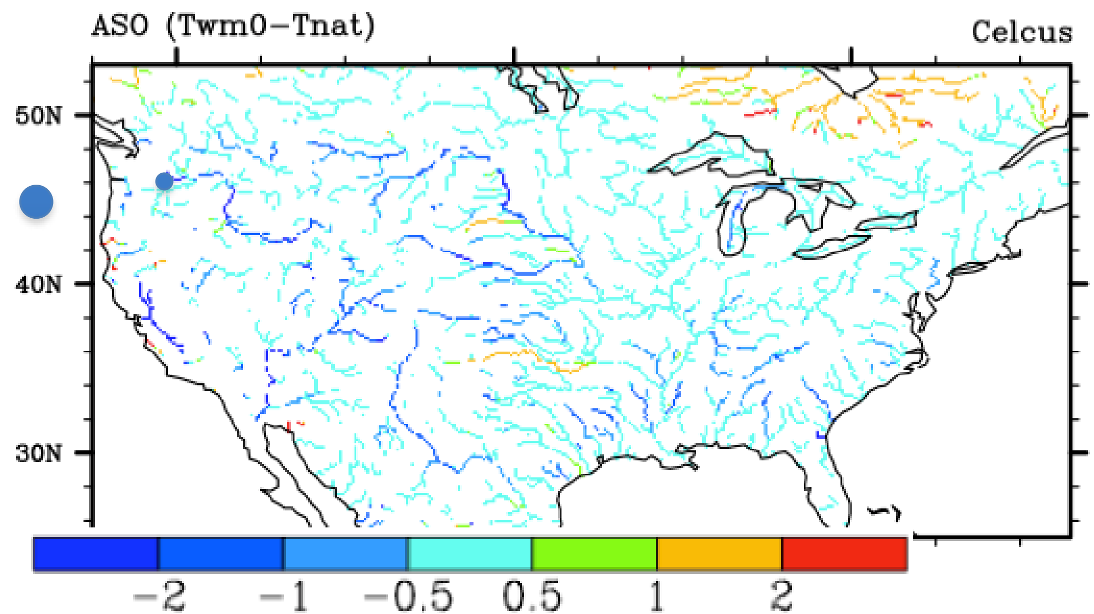


Increasing of flow

Decreasing of water temp.



MOSART-heat: reservoir thermal stratification

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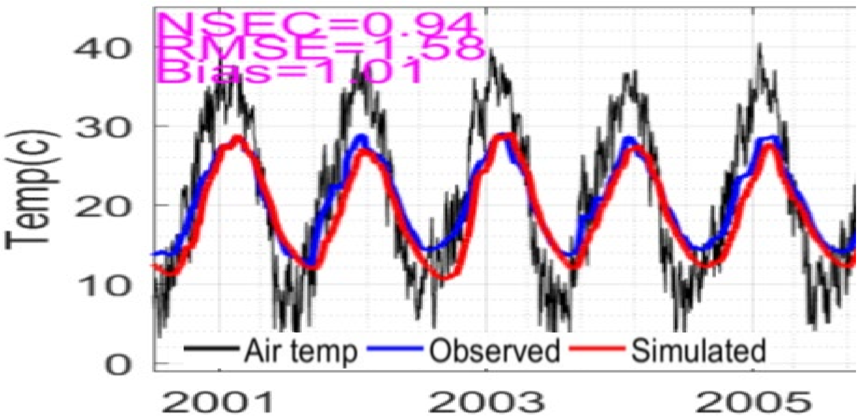
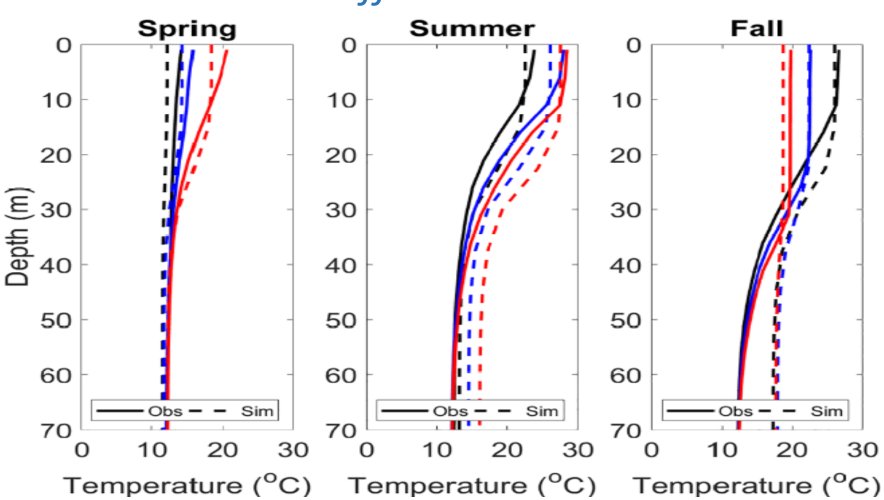
Lake-Mead surface temperature



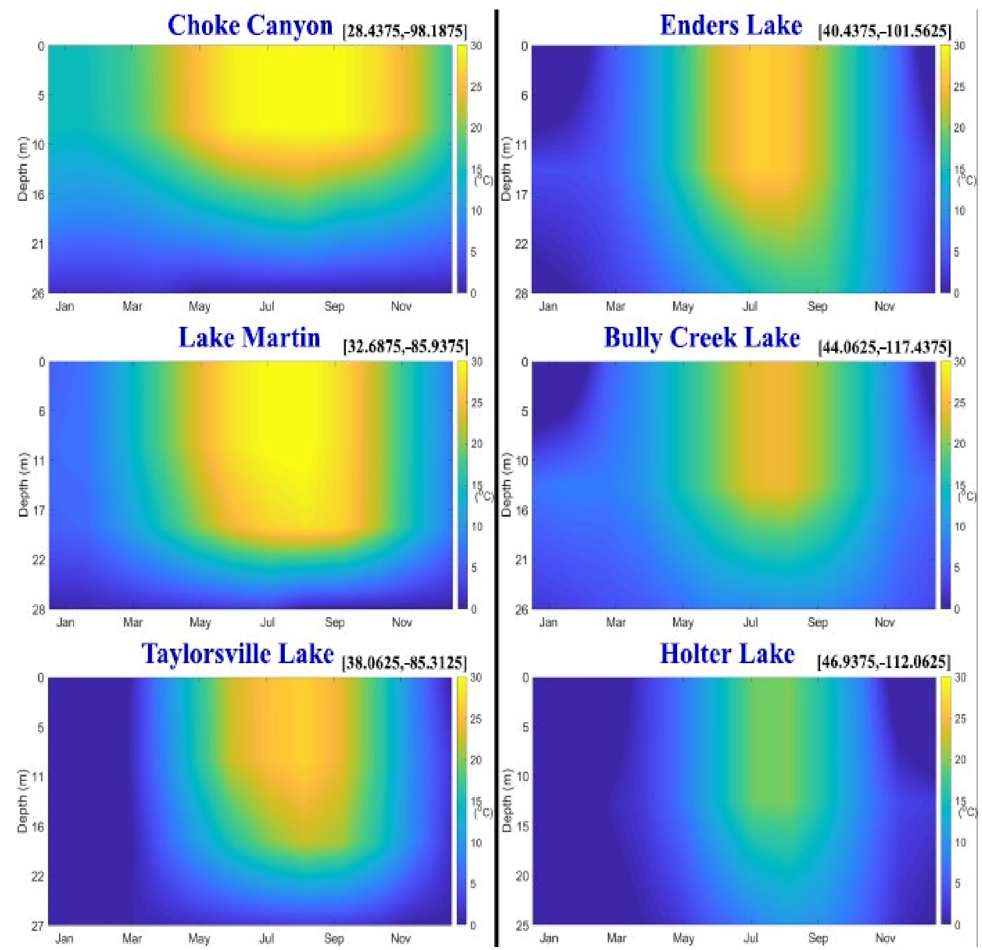
Lake-Mead vertical temp. profile

— Obs - - Sim

Different colors are for different months in a season



Stratification effects decreases from low to high latitude



Yigzaw et al., 2018, 2019

MOSART-sediment: parameterization over the U.S.