The impact of global reservoir expansion on the present-day climate

Inne Vanderkelen

Nicole P. M. van Lipzig, William J. Sacks, David M. Lawrence, Martyn Clark, Naoki Mizukami, Yadu Pokhrel, Wim Thiery

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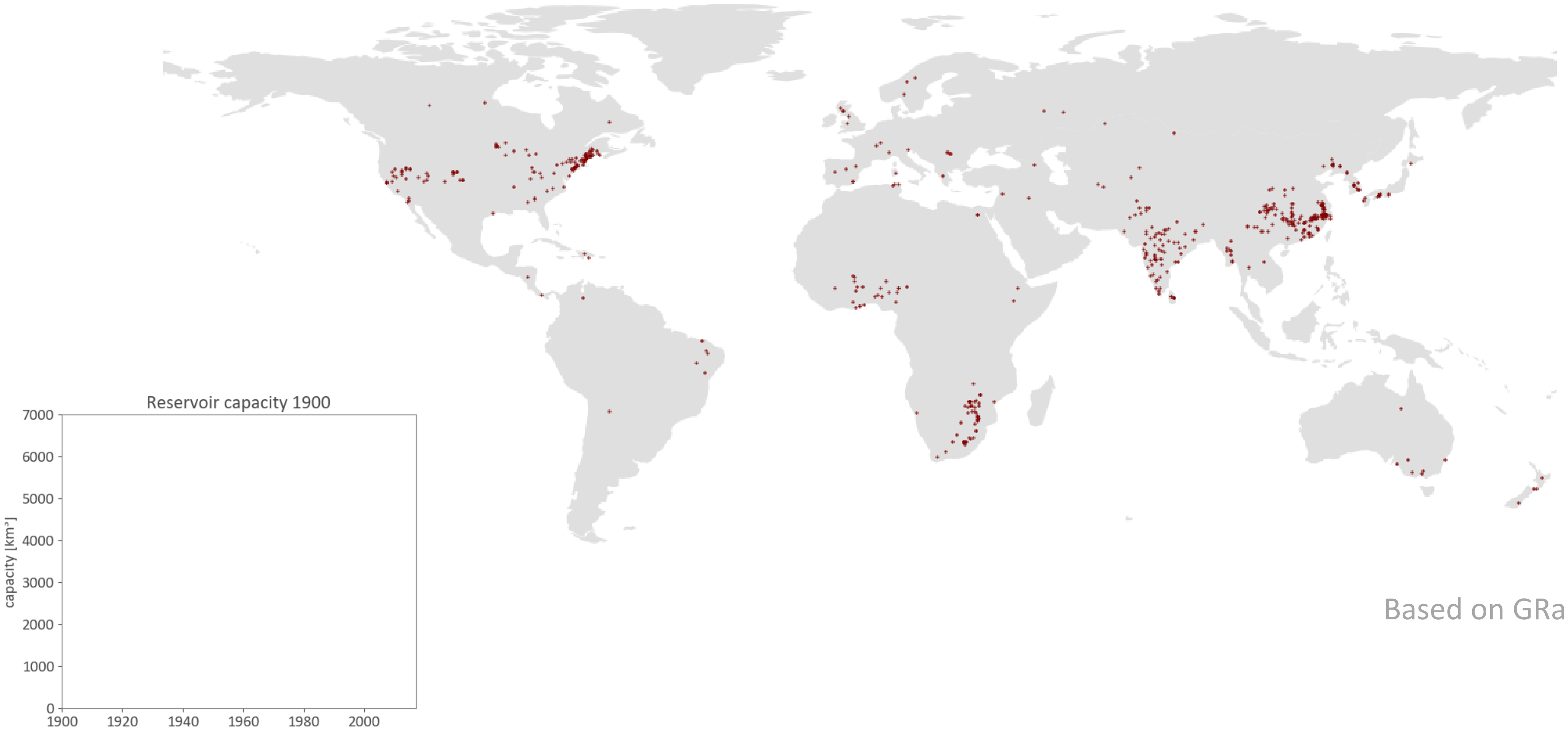
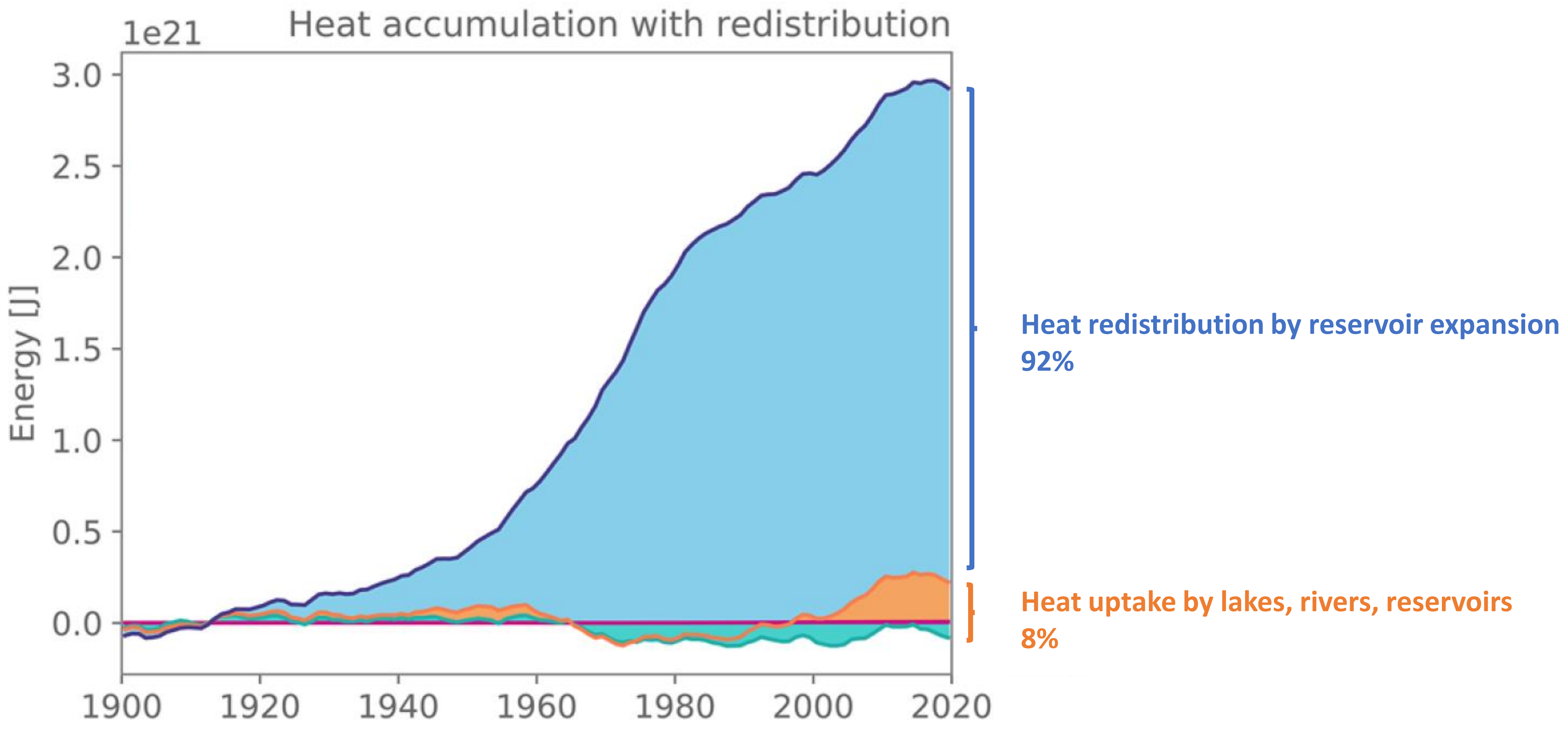
Dams build from 1900 onwards



Based on GRanD data

Reservoir expansion redistributes water and heat from ocean to land



Vanderkelen et al., 2020, GRL

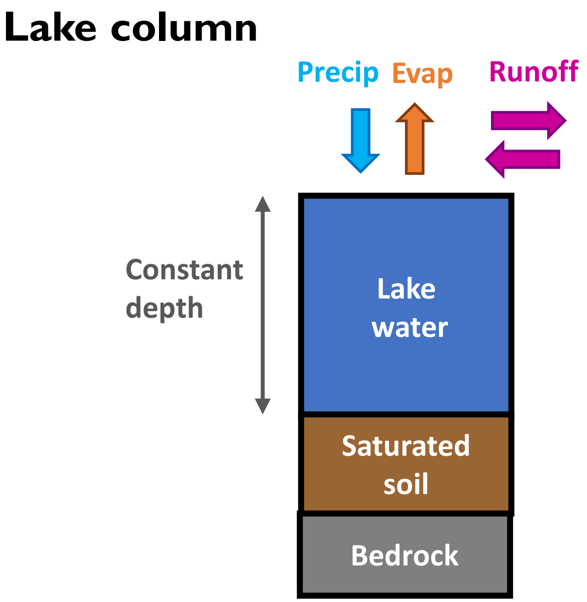
What is the impact of reservoir expansion on the global climate?

1. Represent reservoir expansion in the Community Land Model

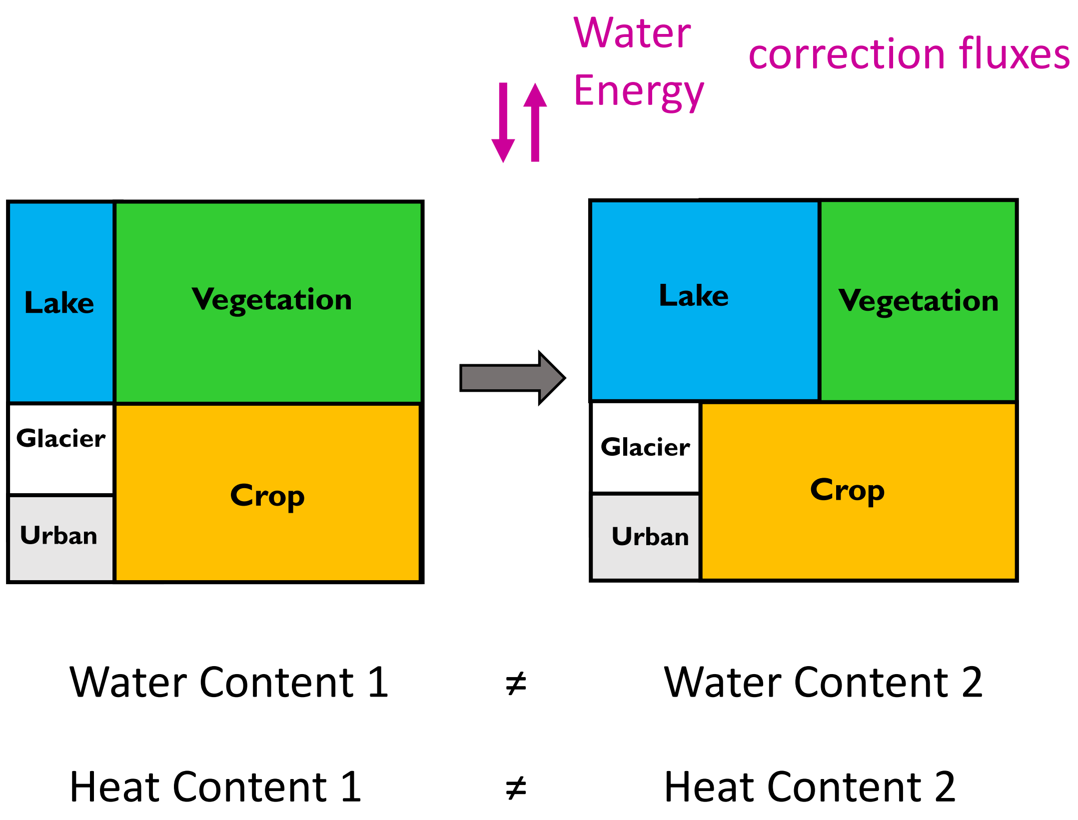
2. Transient impacts of reservoir expansion
   Land-only experiment with CLM

3. Impacts on temperature and the surface energy balance
   Coupled experiment with the Community Earth System Model (CESM)

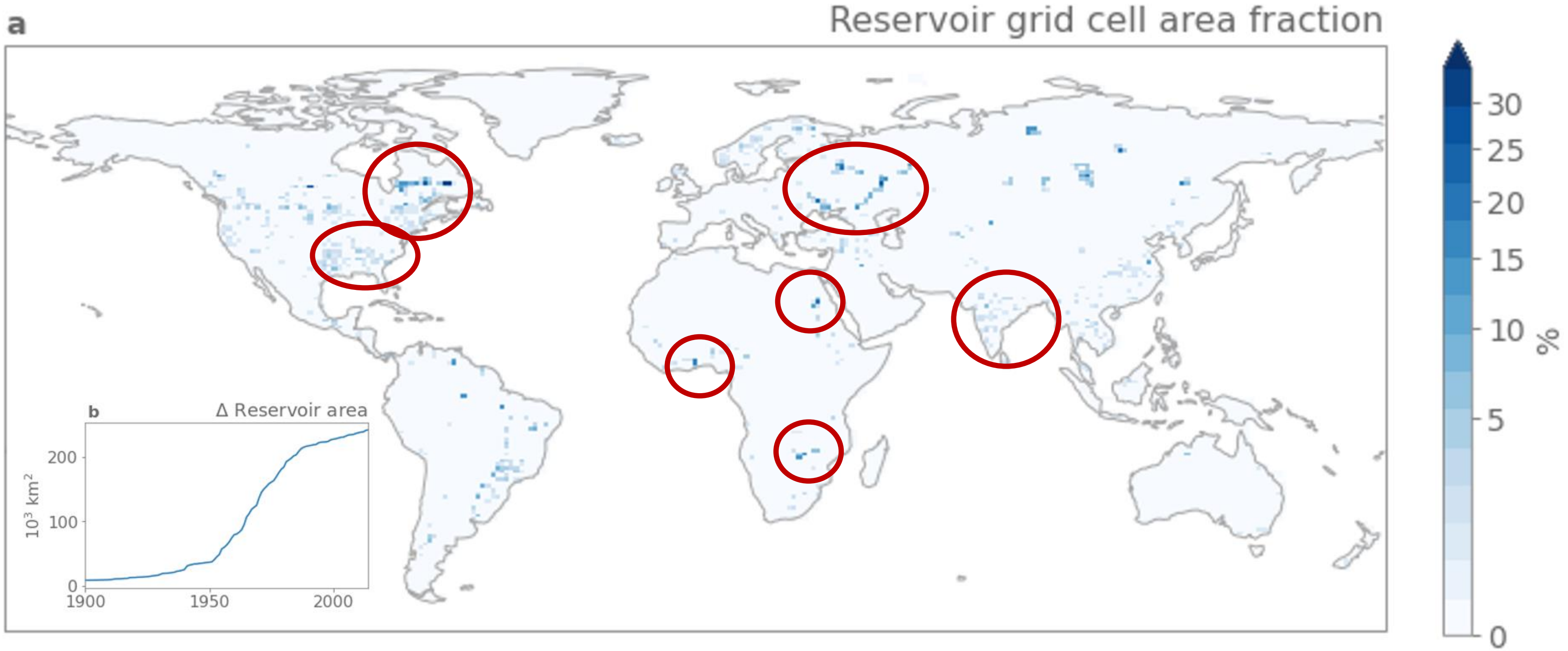
In CLM, reservoirs are simulated as lakes (with a constant depth)



Reservoir expansion is simulated as growing lake fraction in the grid cell

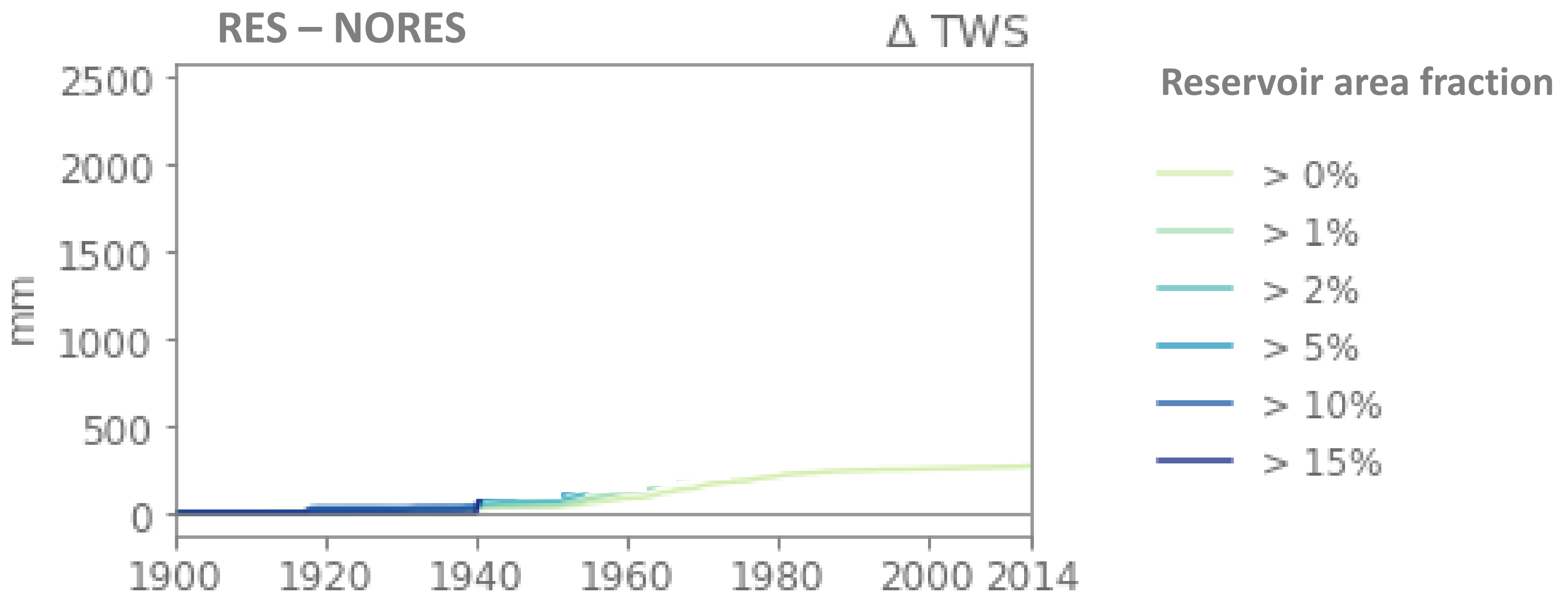


A reservoir appears in its construction year, based on the GRanD dataset

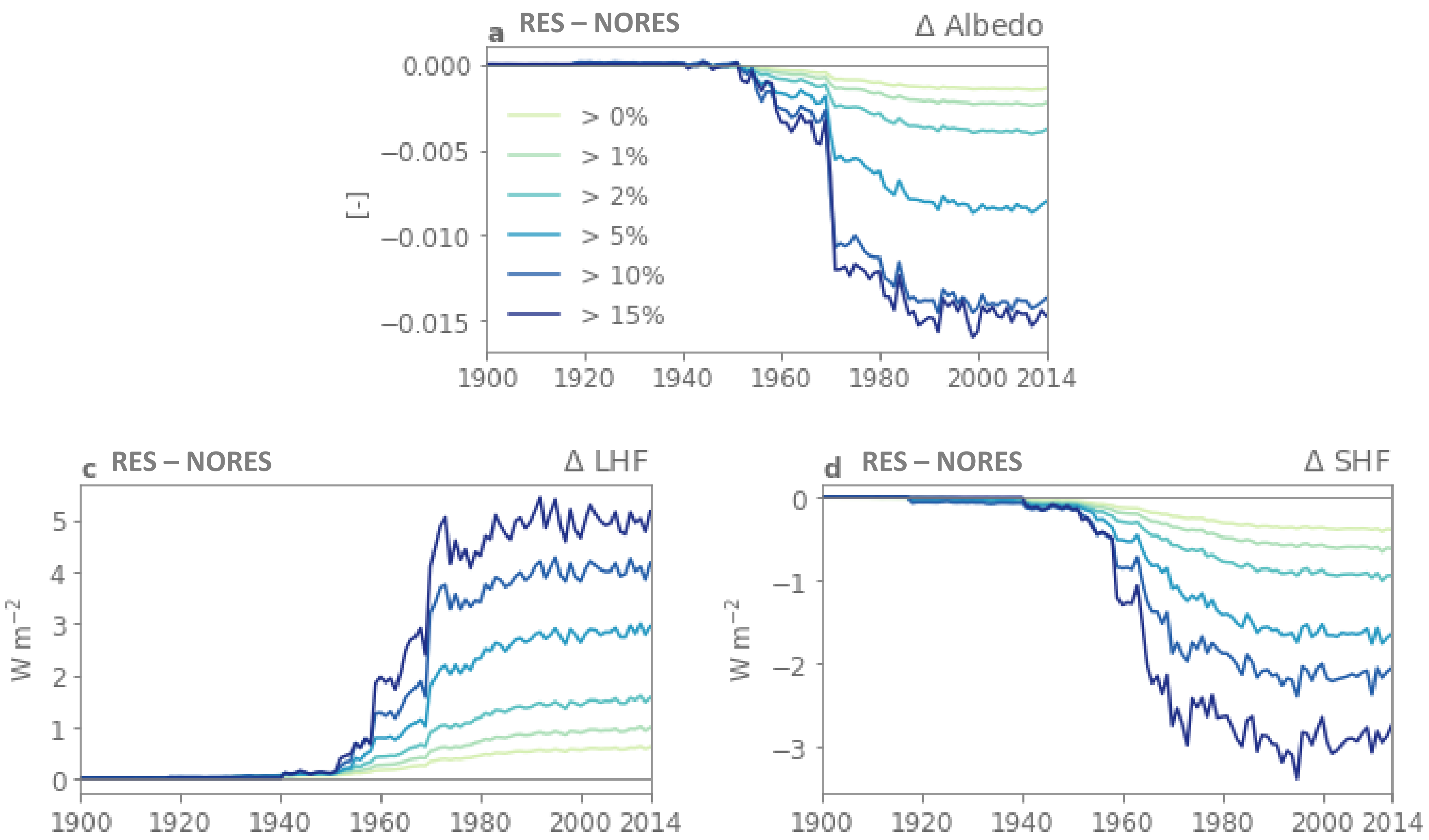


Transient reservoir expansion increases the total water storage

Land only simulations
1900-2014 (115 years)
0.9° by 1.25°
CLM5 with data atmosphere
Transient land use
- RES: transient reservoirs
- NORES: no reservoirs



Transient reservoir expansion decreases albedo, increases latent heat flux and decreases sensible heat flux



Coupled experiments with Community Earth System Model (CESM)

Coupled simulations (AMIP-style)
1980-2014 (35 years)
0.9° by 1.25°
CLM5 coupled to CAM6 atmosphere model
Prescribed ocean & sea ice
Constant land use
- RES: 5 ens members with reservoirs
- NORES: 5 ens members without reservoirs

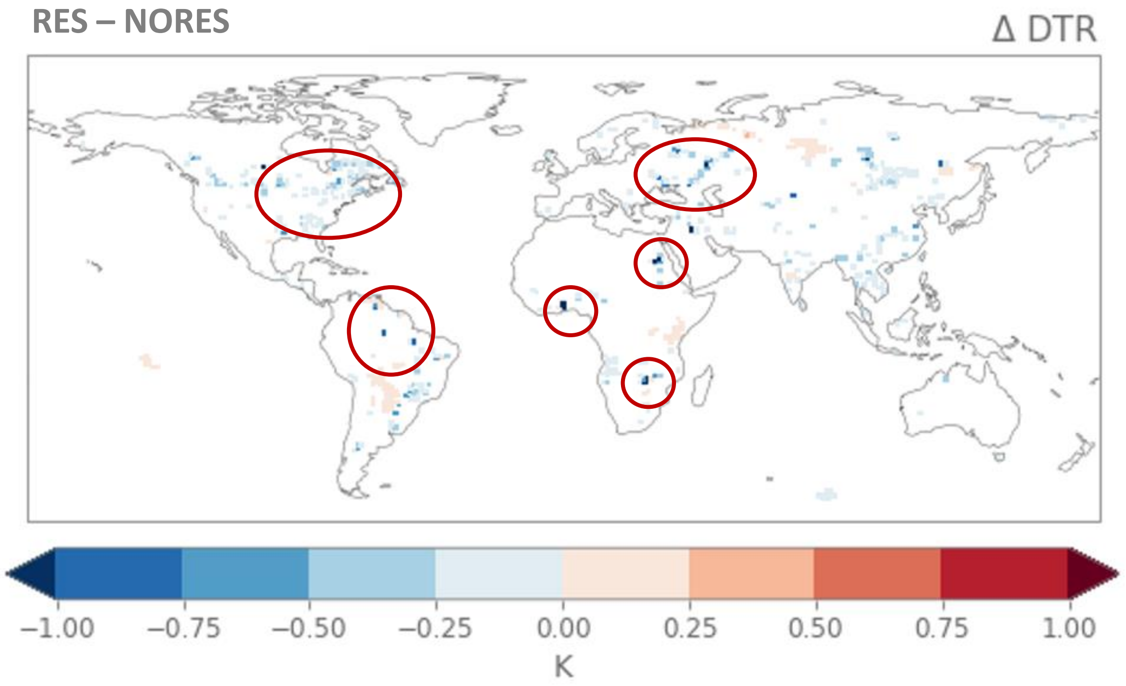
RES – NORES

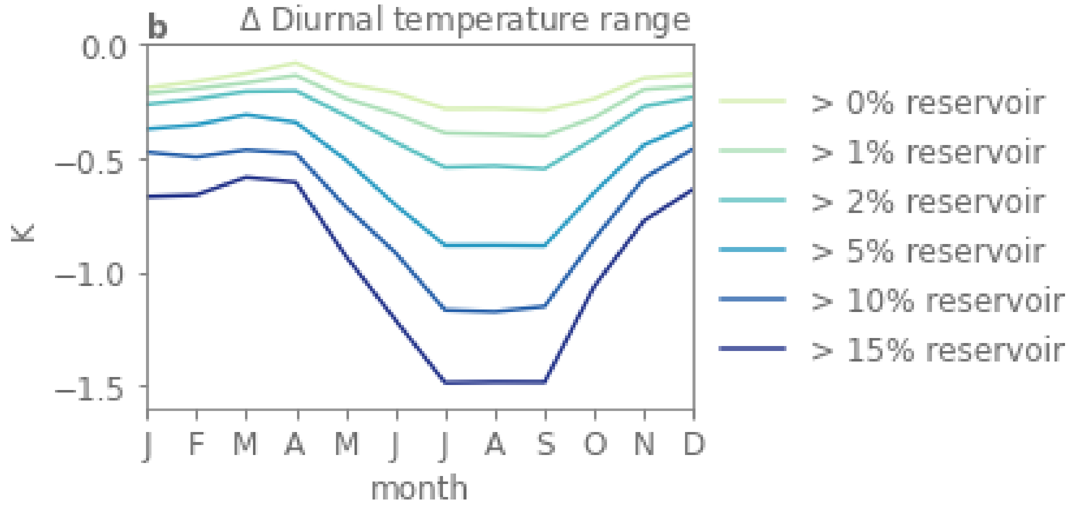
Overall increase in LHF, localized to reservoir grid cells

Responses in energy balance related variables: DTR, temperature, energy balance

Responses in precipitation, moisture related variables not detectable from natural variability

Reservoirs dampen the diurnal temperature cycle
by decreasing the Diurnal Temperature Range (DTR)

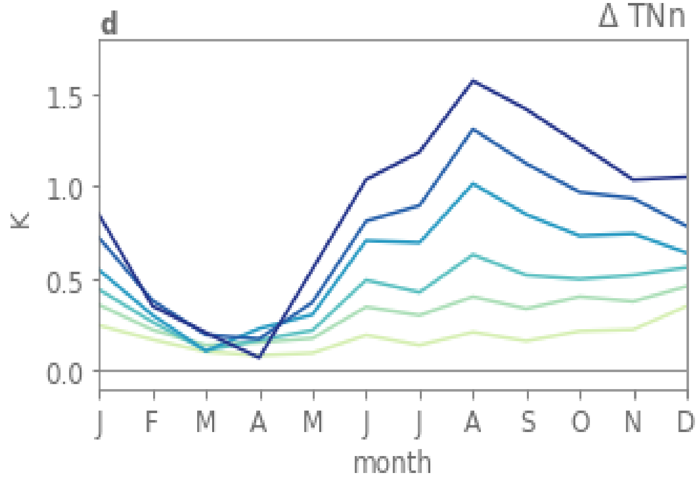




Localized to reservoir grid cells, largest decrease during summer

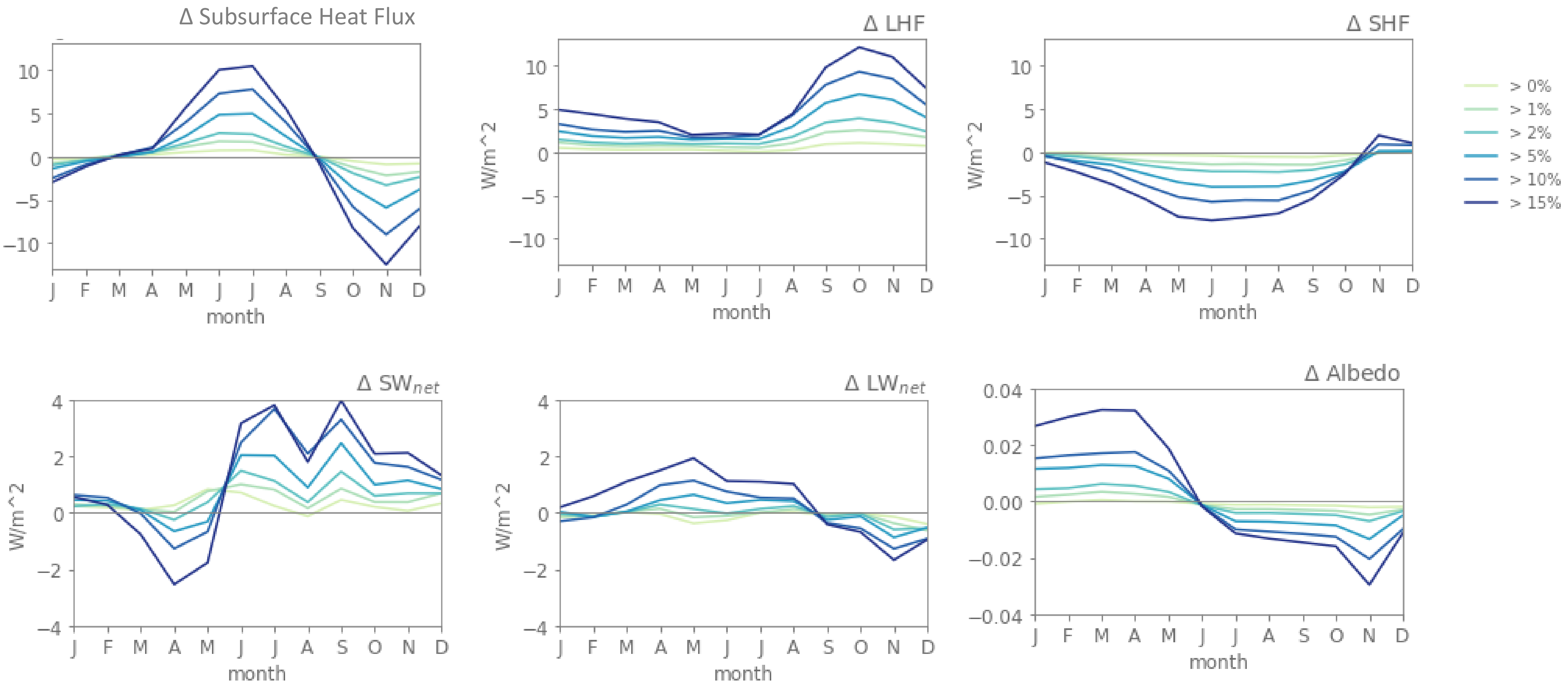
Reservoirs dampen temperature extremes

by increasing monthly minimum nighttime temperature (TNn)



Localized to reservoir grid cells, warming from spring until fall

Response on seasonal cycle of energy balance components



Conclusions

Represent reservoir expansion in Community Land Model using dynamical lakes

Reservoirs dampen the daily and seasonal temperature cycle and temperature extremes, especially in summer and fall

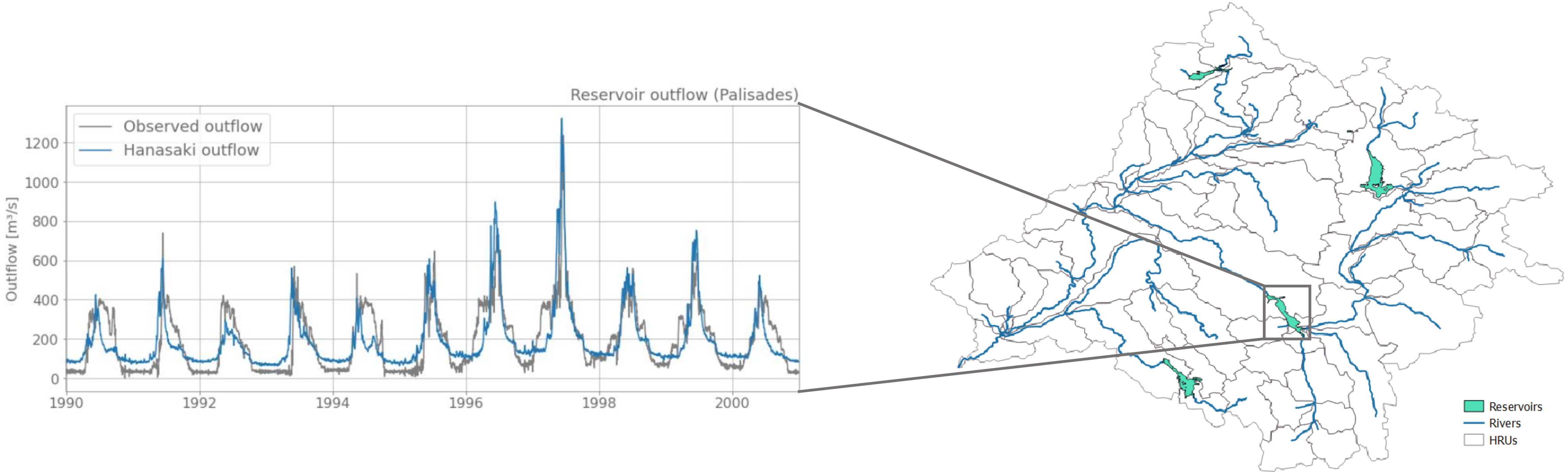
Substantial where reservoirs make up a large fraction

Globally, reservoirs climate impacts are small and localized to reservoir grid cells, but responses scale to reservoir extent

Towards a coupled representation of reservoirs in CLM

Integration of flow regulation in MizuRoute

Implementation reservoir parametrization of Hanasaki, 2006



One way coupling of MizuRoute and CLM

Communicate outflow and irrigation demands

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THANK YOU

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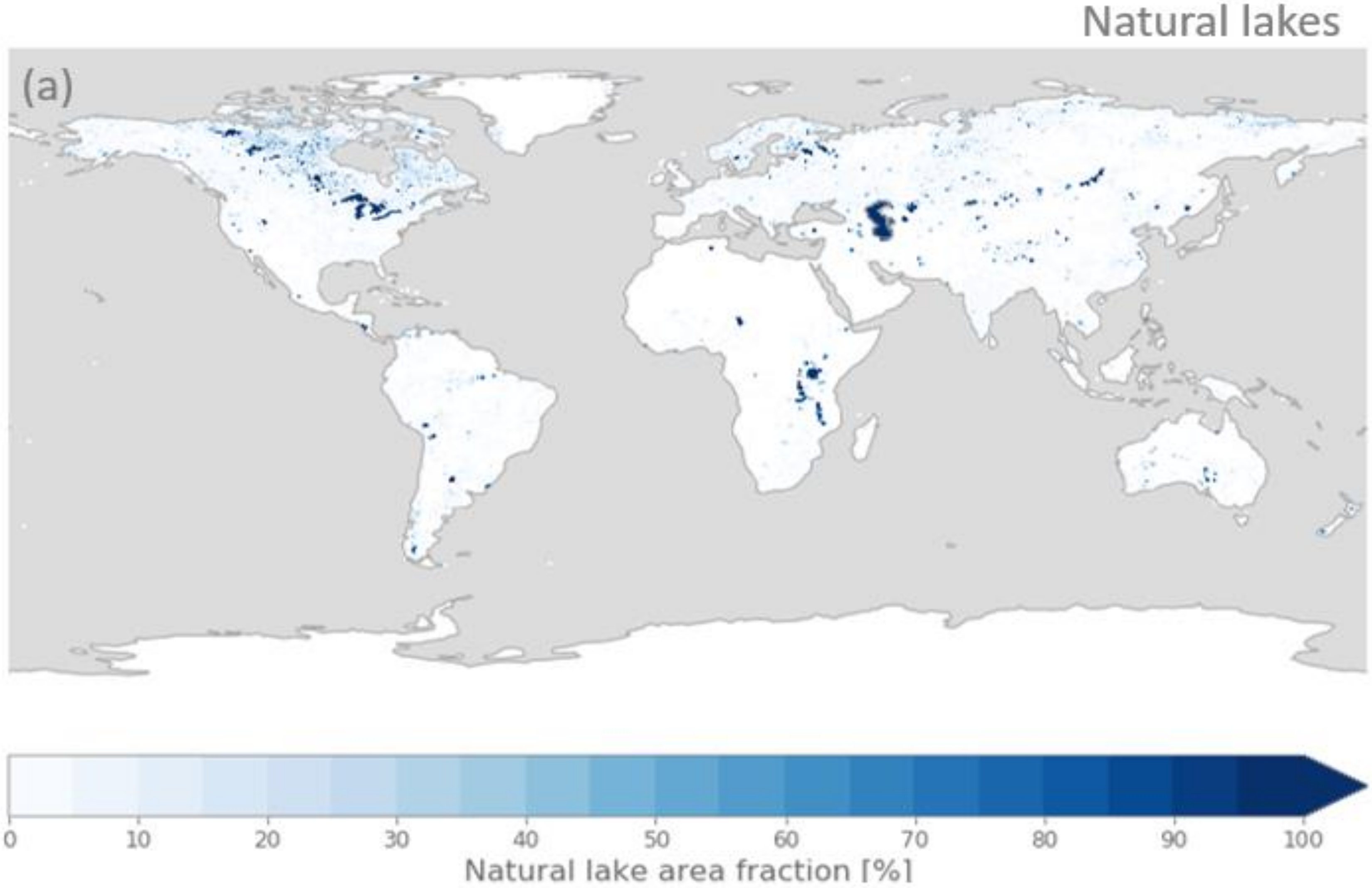
Picture: Glen Canyon Dam Adaptive Management Program

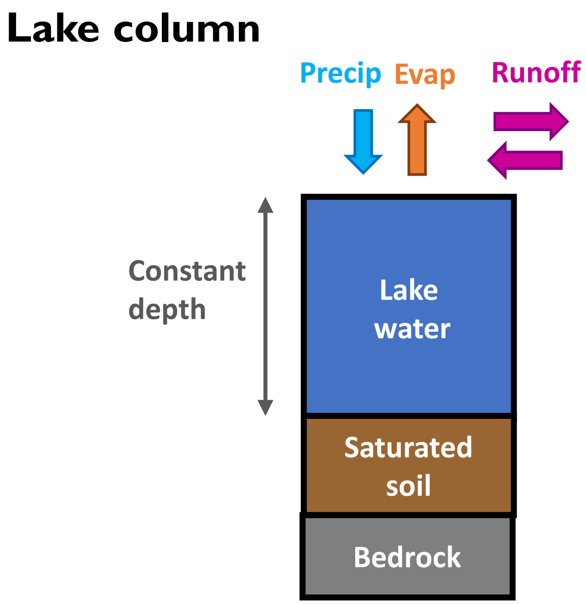
A new lake mask for CLM, based on HydroLAKES



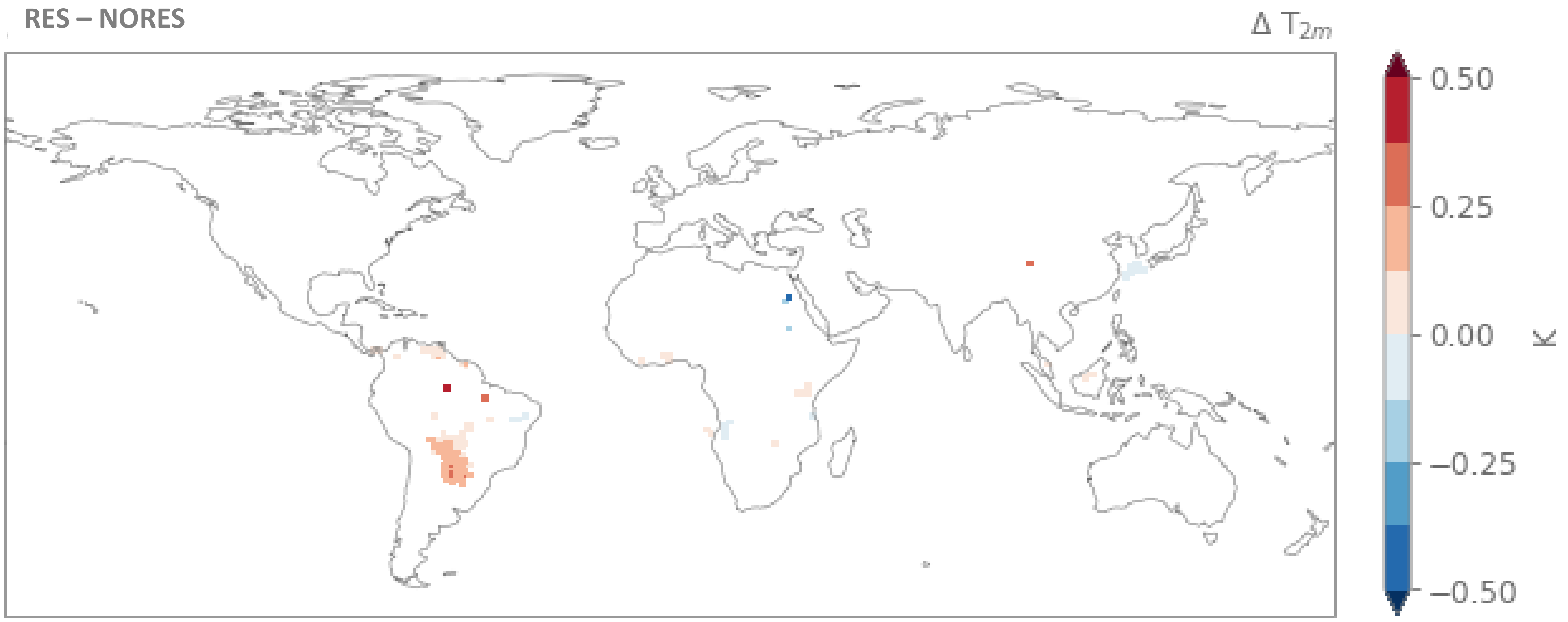
Present day reservoir distribution on CLM grid (0.9° x 1.25°)

Reservoir %	# grid cells	% of land grid cells
> 0%	1175	6.10 %
> 1%	450	2.34%
> 2%	249	1.29 %
> 5%	91	0.47 %
> 10%	42	0.22 %
> 15 %	15	0.08 %

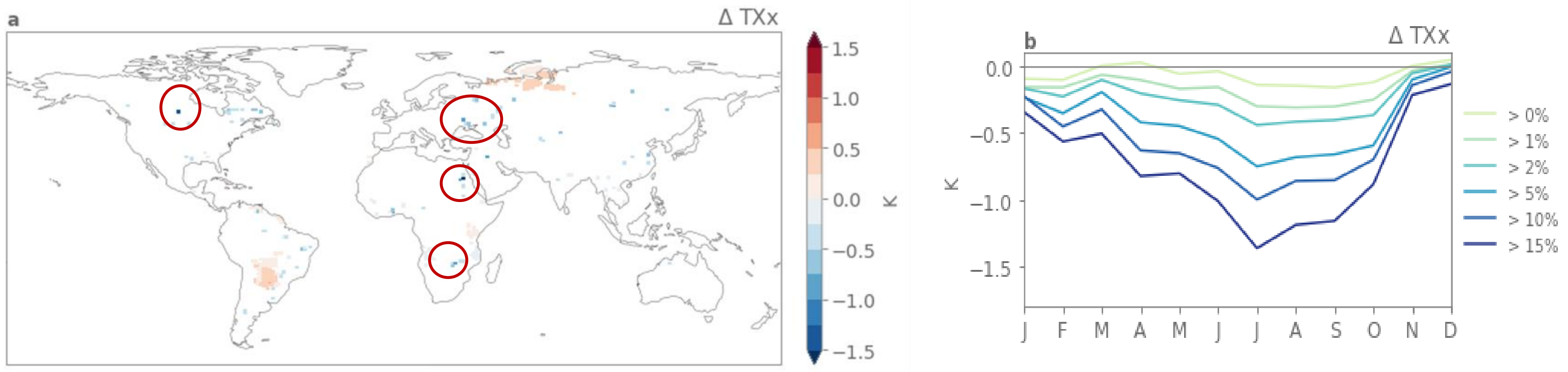
CLM lake model



Impact of reservoirs on 2 meter air temperature (T_{2m})

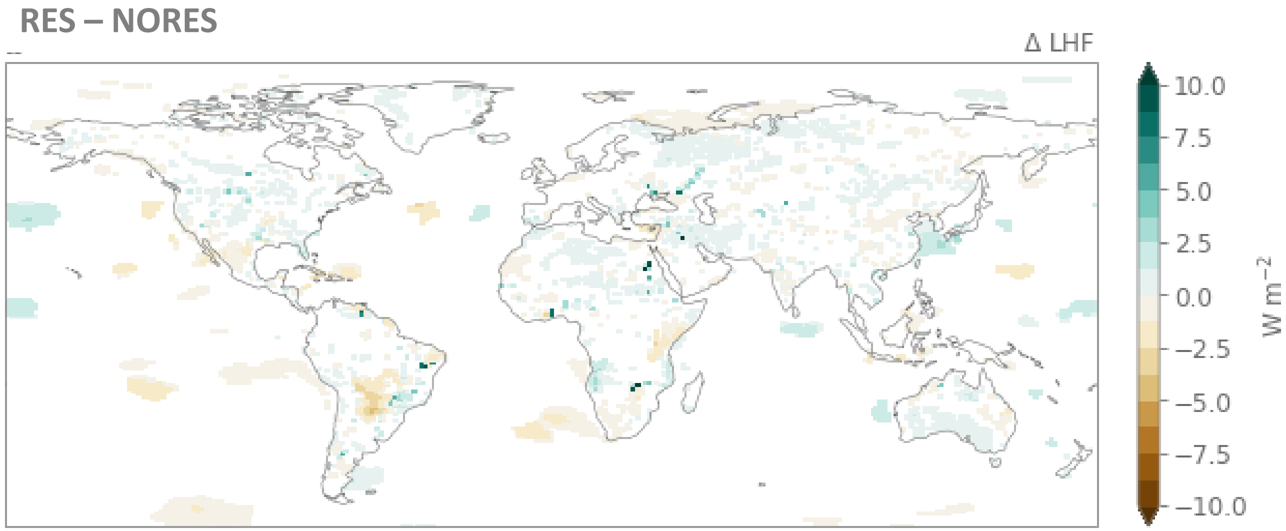


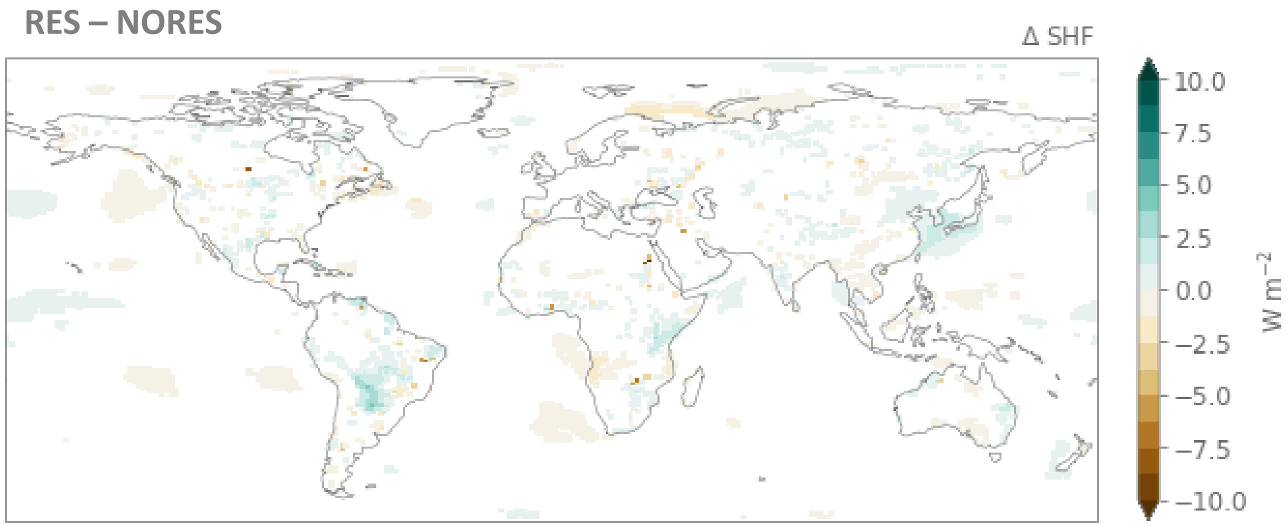
Reservoirs dampen temperature extremes
by decreasing monthly maximum daytime temperature (TXx)



Localized to reservoir grid cells, largest cooling during summer

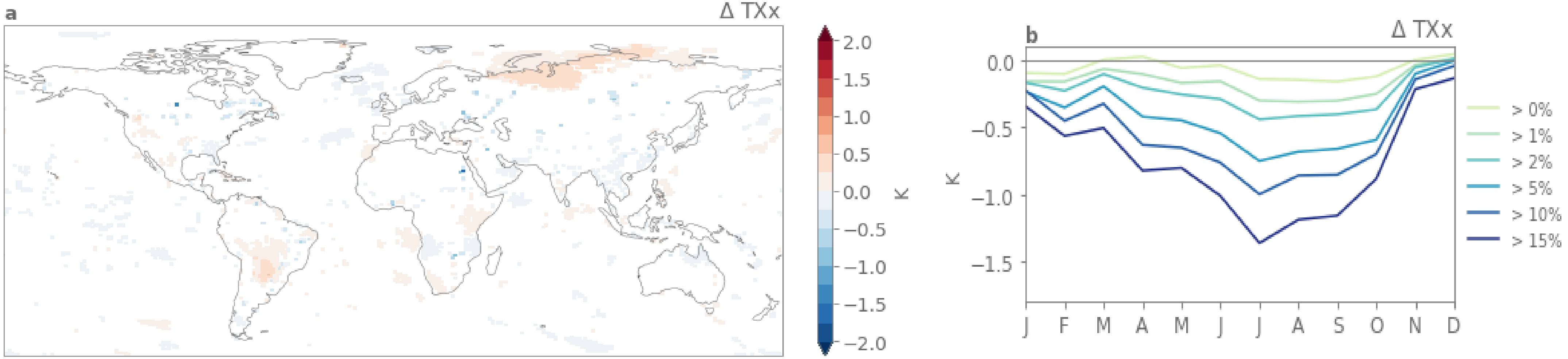
Impact of reservoirs on Latent Heat Flux and Sensible Heat Flux



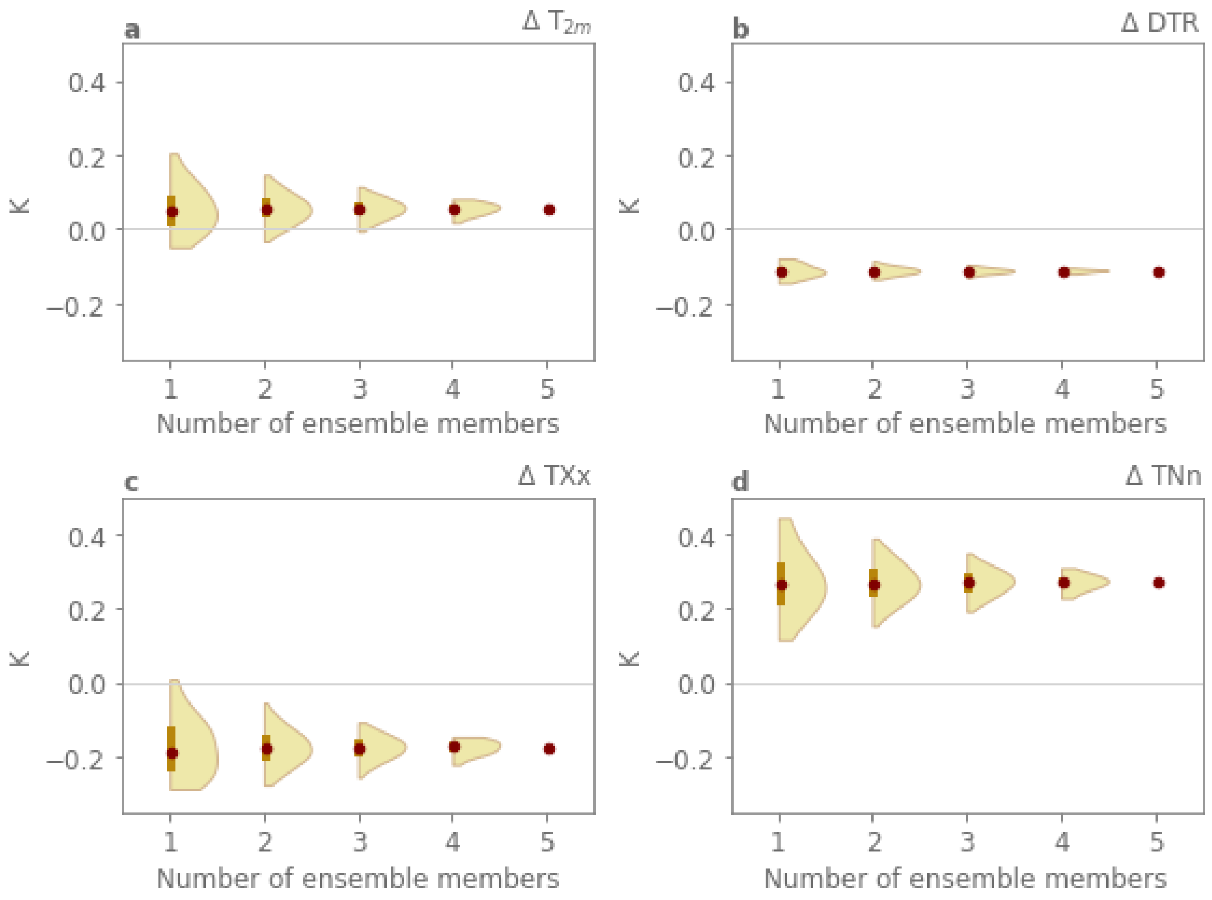


Impact of reservoirs on temperature extremes

Monthly maximum daytime temperature (TXx) and monthly minimum nighttime temperature (TNn)



Signal spread is decreased with increasing number of ensemble members



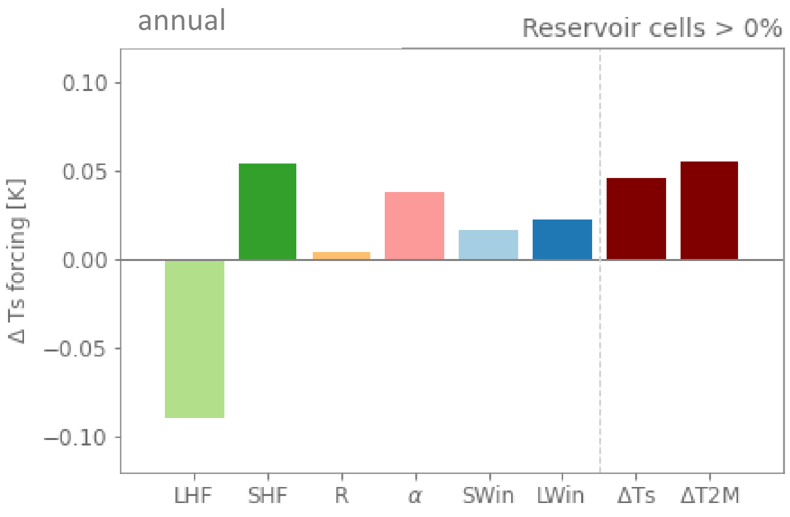
Impact of reservoirs on temperatures: surface energy balance decomposition

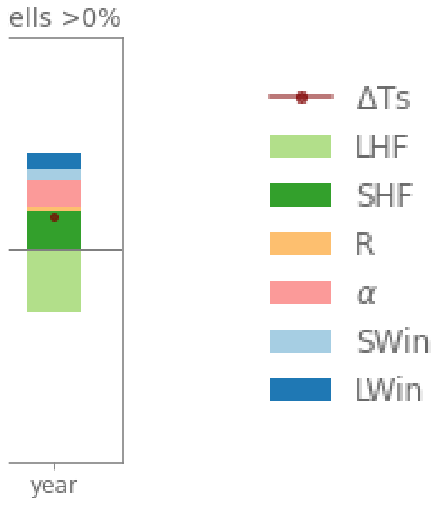
Energy balance at the surface

$$\epsilon\sigma T_s^4 = (1-\alpha)\mathrm{SW_{in}} + \mathrm{LW_{in}} - \mathrm{LHF} - \mathrm{SHF} - R$$

Take total derivative and solve for Ts

$$\Delta T_s = \frac{1}{4\sigma T_s^3}\left(-\mathrm{SW_{in}}\Delta\alpha + (1-\alpha)\Delta\mathrm{SW_{in}} + \Delta\mathrm{LW_{in}} - \Delta\mathrm{LHF} - \Delta\mathrm{SHF} - \Delta R\right)$$

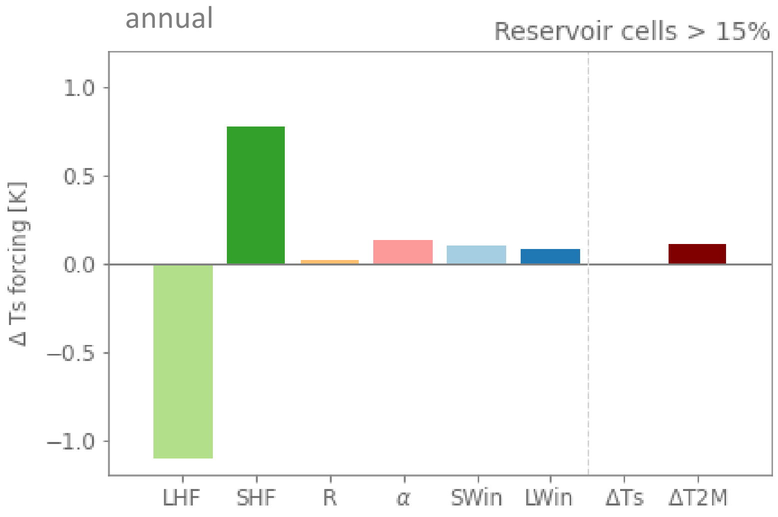


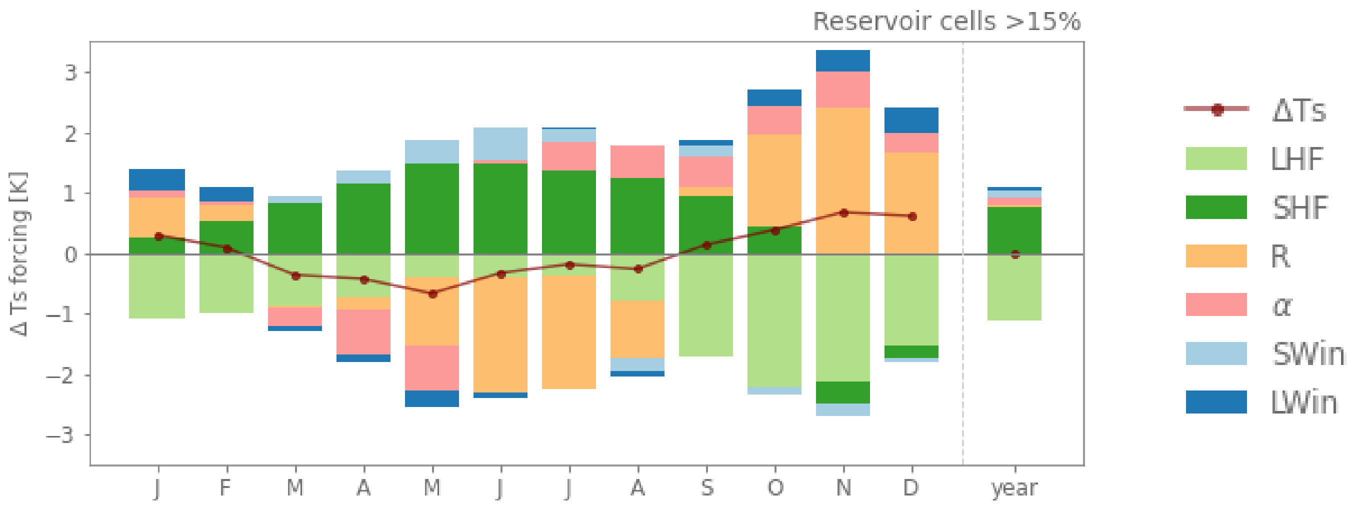


Luyssaert et al., 2014; Akkermans et al., 2014; Thiery et al., 2015

Impact of reservoirs on temperatures: surface energy balance decomposition

Contributions larger for grid cells with large reservoirs





Reservoirs dampen the seasonal temperature cycle