Rijkswaterstaat
Ministry of Infrastructure and the Environment

TU Delft

Deltares

The sensitivity of hydrological model predictions to ecosystem adaptation in response to climate change

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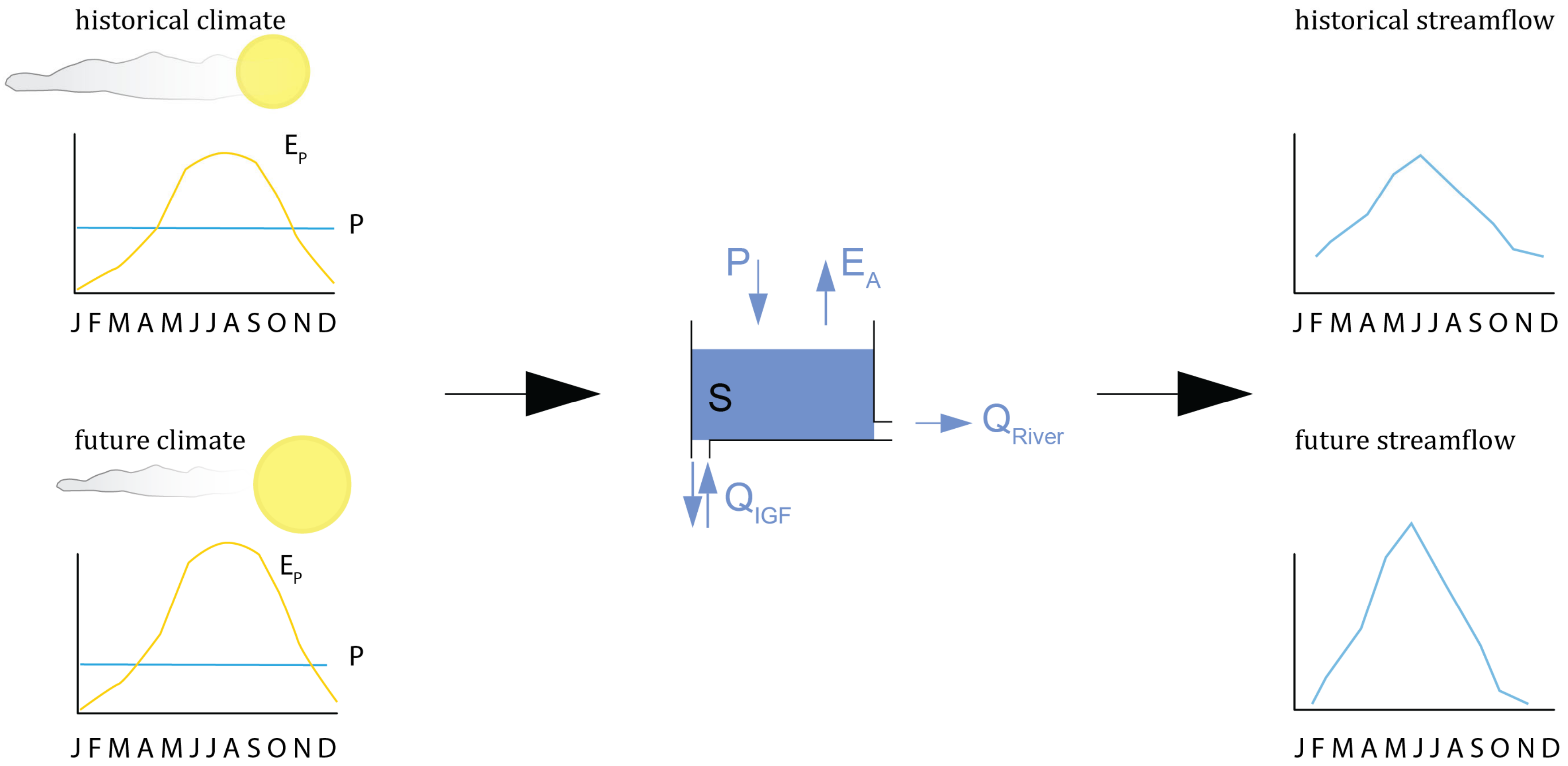
If climate changes, how should we change our models?

Source: NOS


historical climate
E_P
P
J F M A M J J A S O N D
future climate
E_P
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J F M A M J J A S O N D
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E_A
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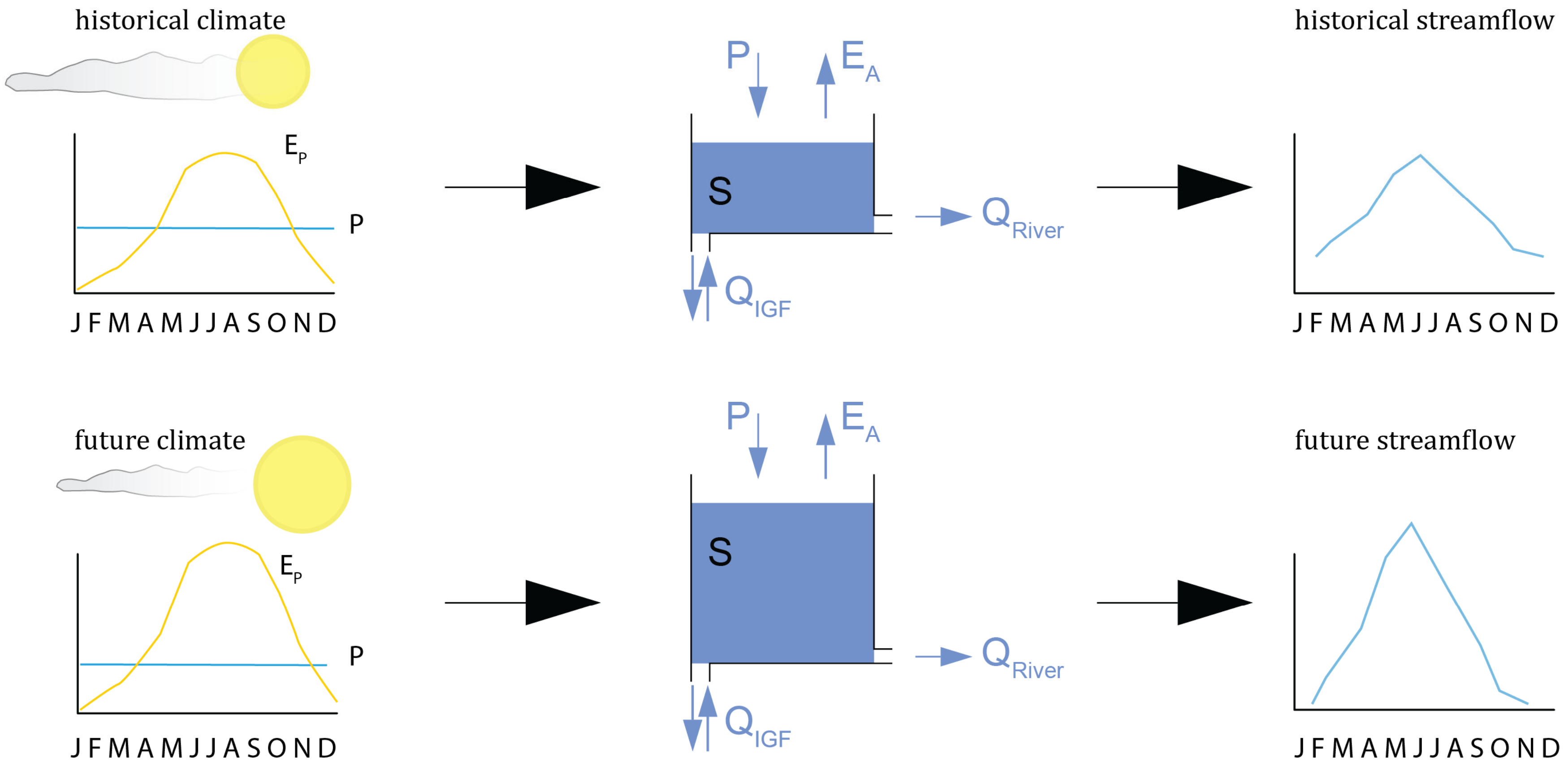
historical streamflow
J F M A M J J A S O N D
future streamflow
J F M A M J J A S O N D


historical climate
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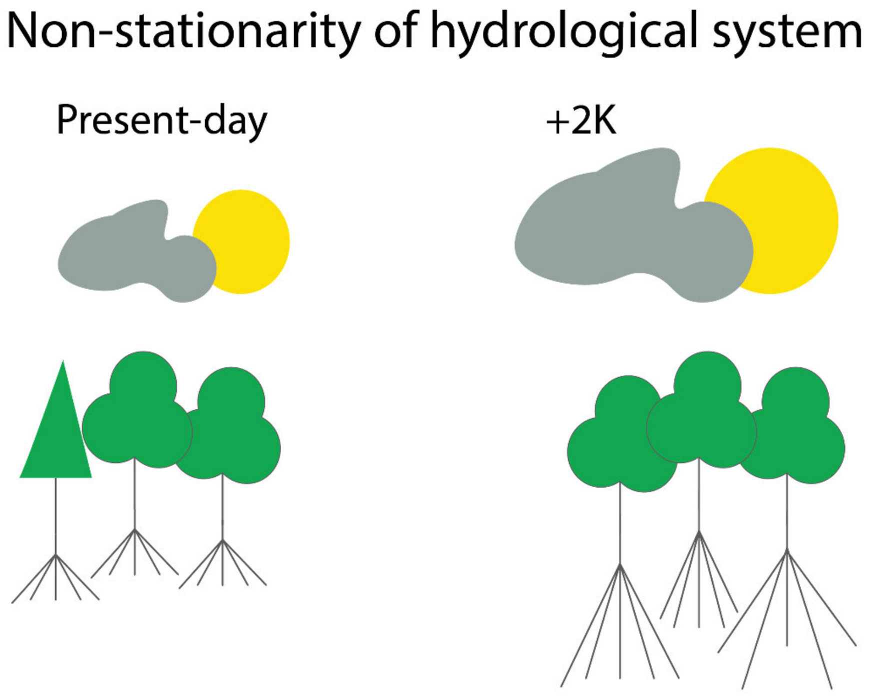
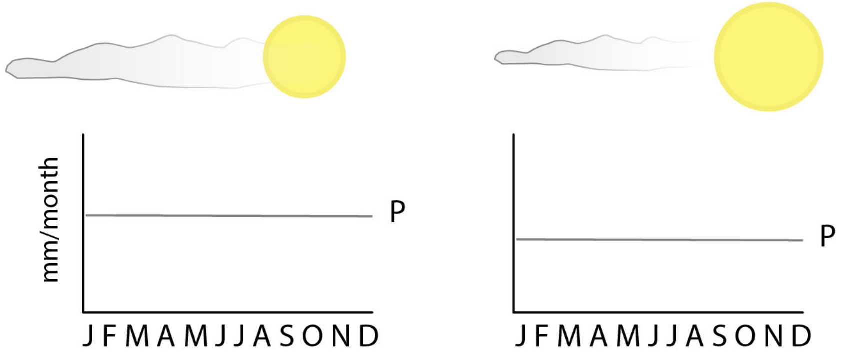


Shift in dominant species

Ecosystem likely adapt their root-zone storage capacity

"How can hydrological models be adapted to be able to extrapolate to changing conditions, including changing vegetation dynamics" Blöschl et al., 2019, Hydrol. Sci. J.


mm/month
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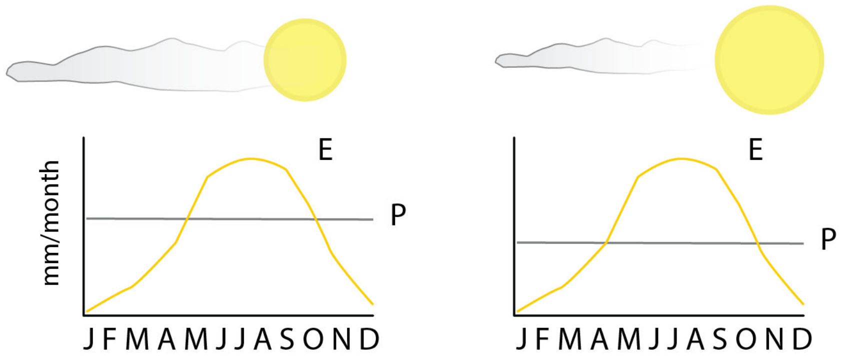
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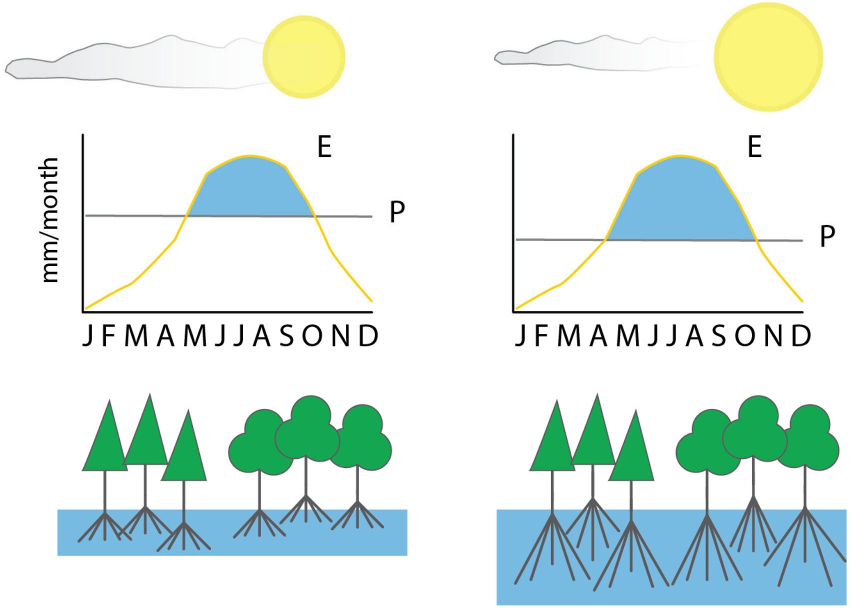
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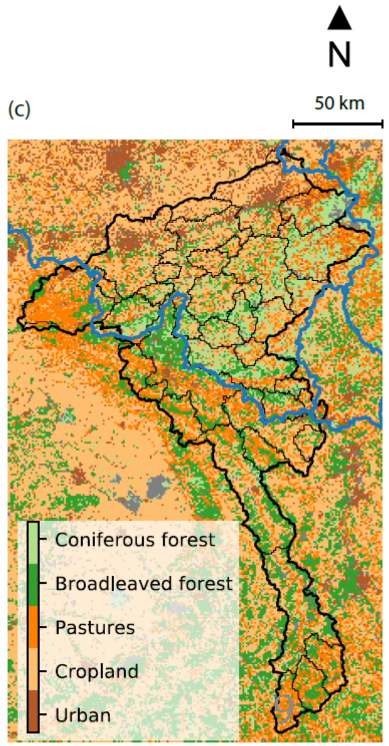
hypothesis

Changes in the **predicted hydrological response** as a result of **+2K global warming** in comparison to current day conditions are more pronounced when explicitly considering an **adapted root-zone storage capacity** to reflect changes in seasonality and magnitude of hydro-climatic variables as well as potential land-use changes.



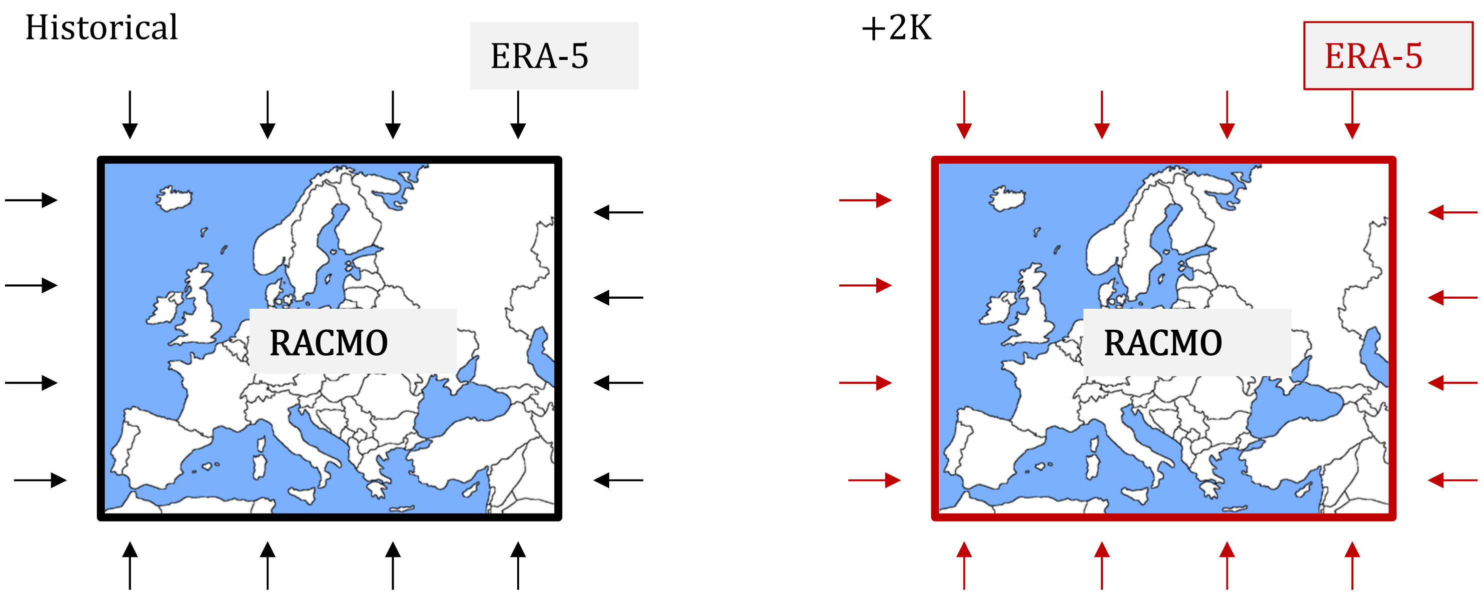
Land use variability

Climate data

Simulated observed and +2K climate data

Pseudo-global warming simulation

(KNMI, Aalbers et al. 2021)

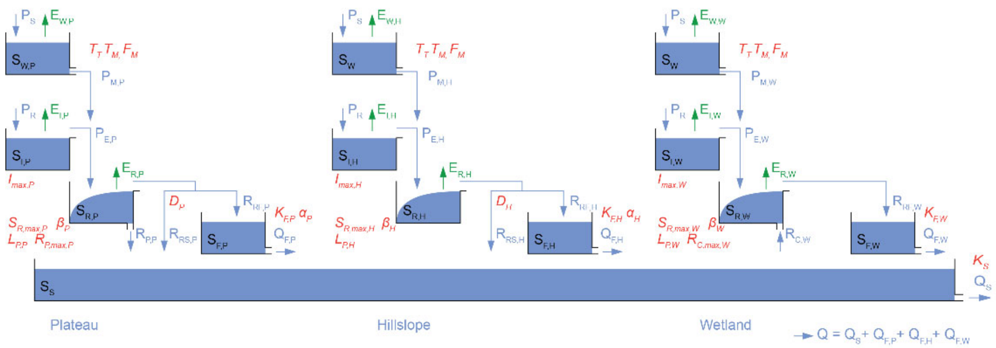


Hydrological model – wflow_FLEX-Topo

Distributed process-based wflow_FLEX-Topo model with three hydrological response units:

- Plateau
- Hillslope
- Wetland

Connected through their groundwater reservoir



Model scenarios

- Scenario $2K_A$

  Stationary system: no changes in root-zone storage capacity and historical land use

- Scenario $2K_B$

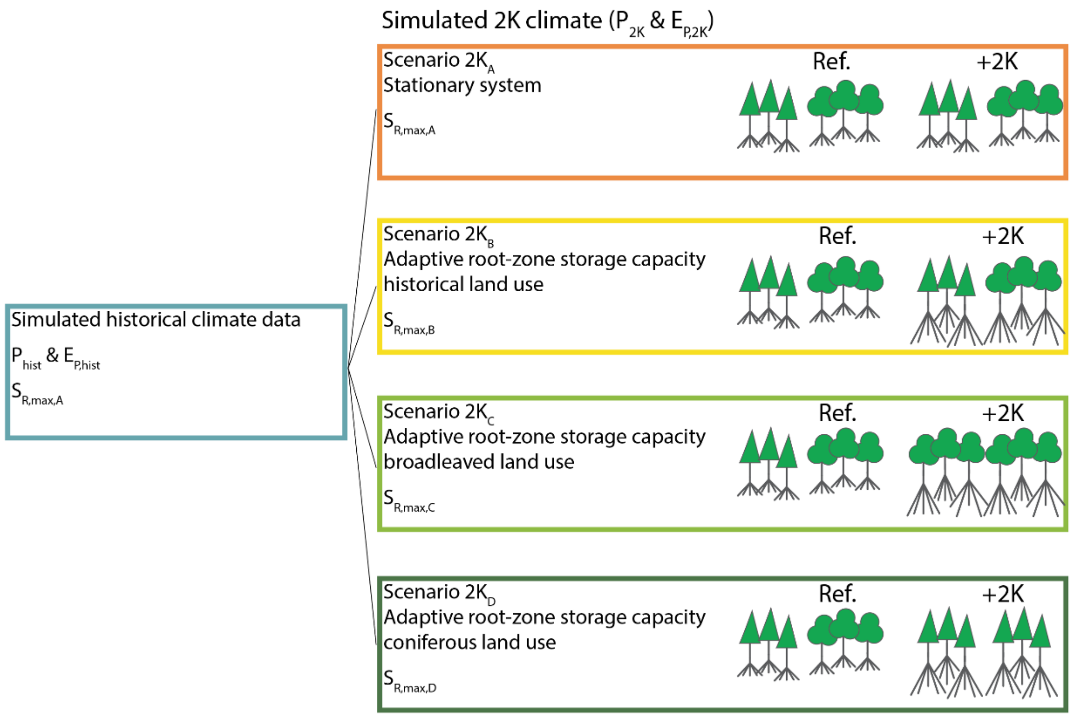
  Adapted root-zone storage capacity in response to climate change and historical land use

- Scenario $2K_C$

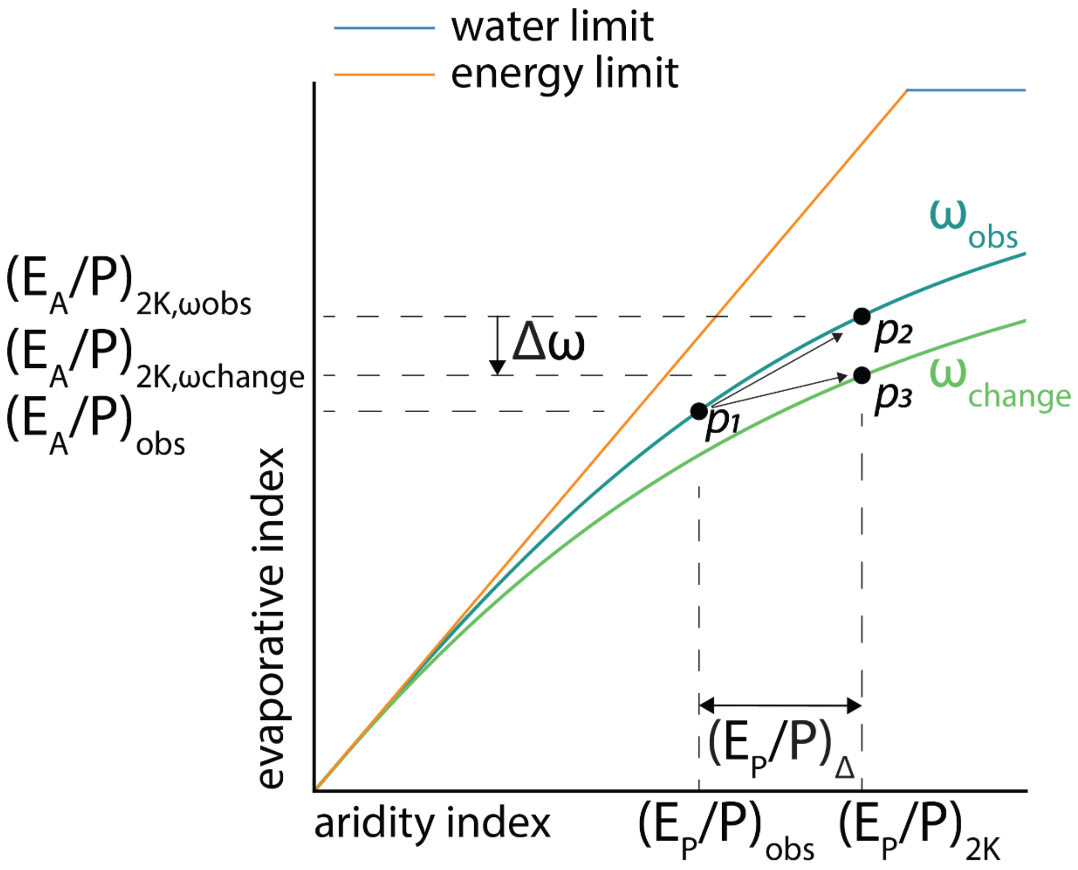
  Adapted root-zone storage capacity in response to climate change and land-use conversion from coniferous plantations to broadleaved forest

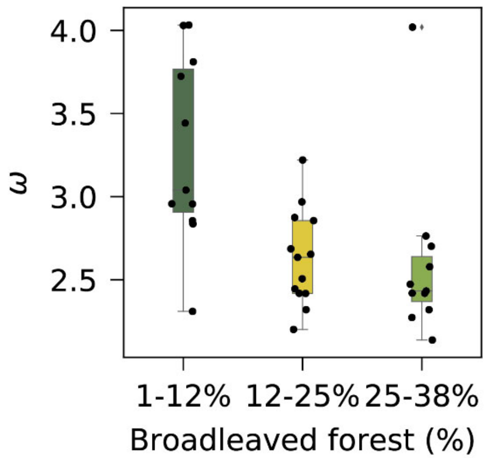
- Scenario $2K_D$

  Adapted root-zone storage capacity in response to climate change and land-use conversion from broadleaved forest to coniferous plantation



Budyko framework

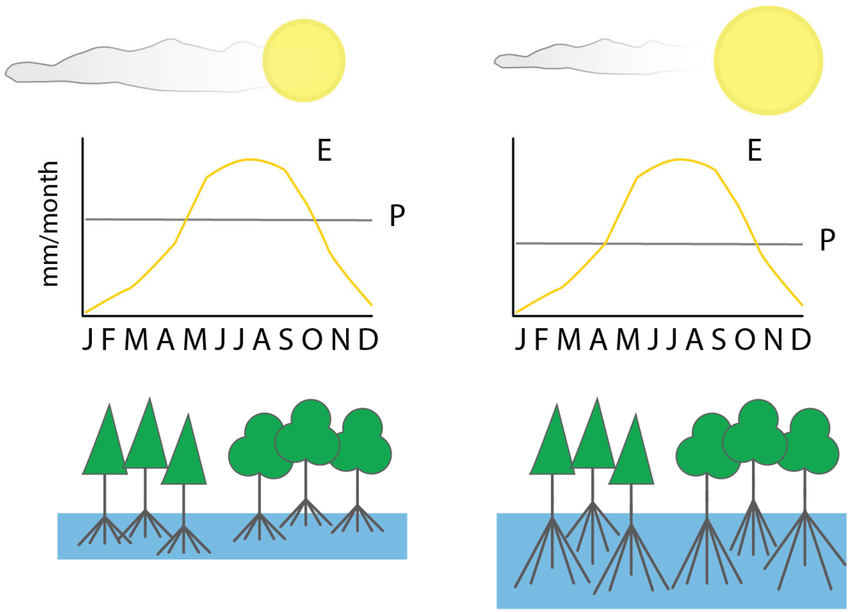


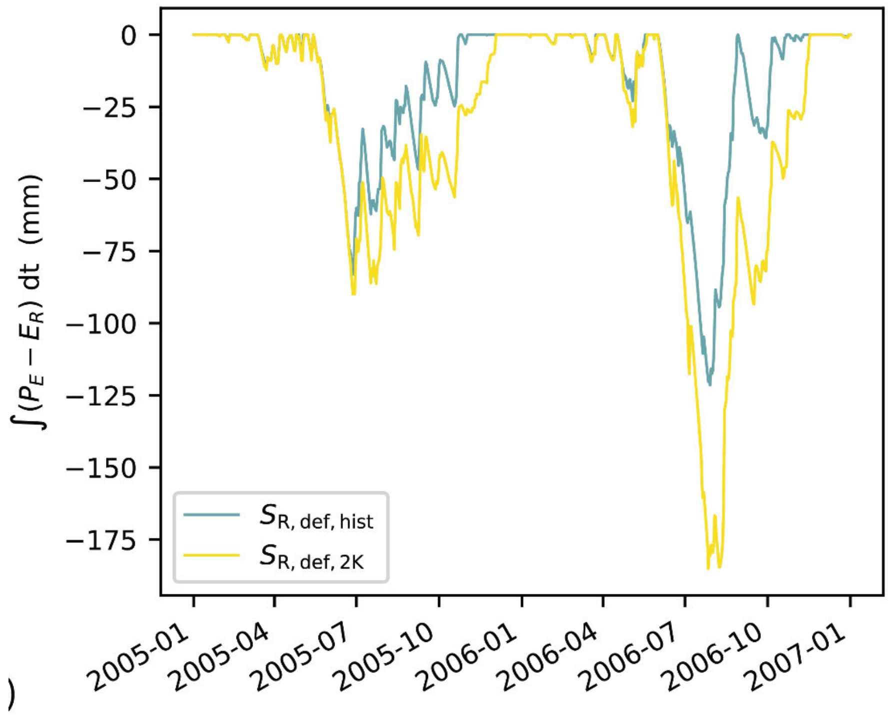


$$\frac{E_A}{P} = 1 - \frac{\boldsymbol{Q}}{\boldsymbol{P}} = 1 + \frac{E_P}{P} - \left(1 + \left(\frac{E_P}{P}\right)^{\omega}\right)^{1/\omega}$$

Zhang et al., 2004 (WRR)

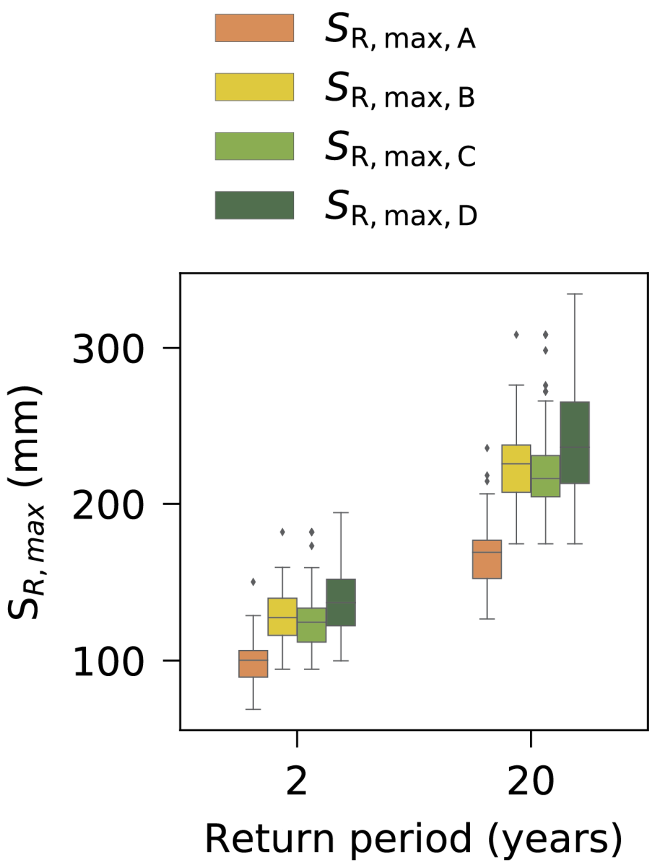
Root-zone storage capacity from estimated future long-term runoff coefficients and storage deficits





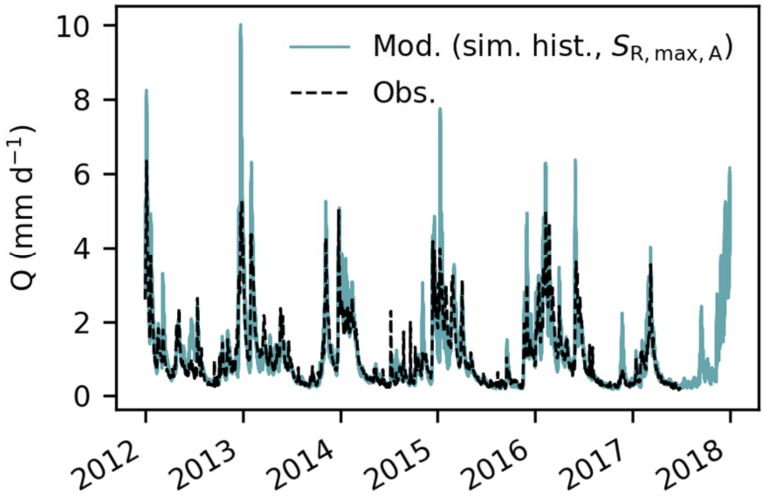
Hydrological change evaluation – Root-zone storage capacity parameter

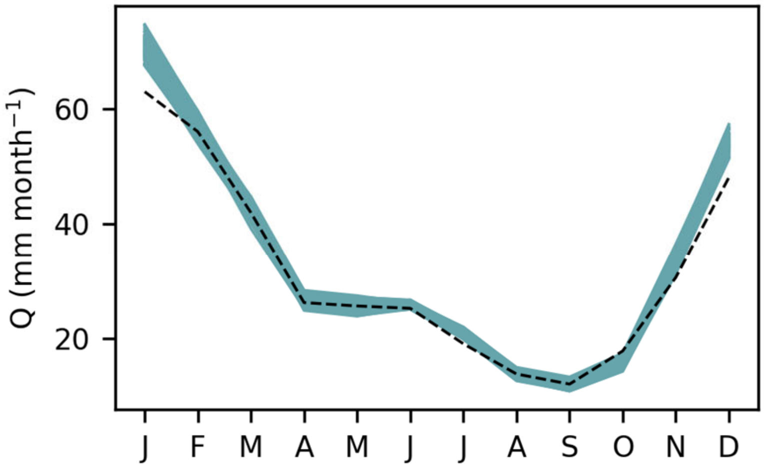
Increase of root-zone storage capacity parameter ($S_{R,max}$) with approx. 34% due to more pronounced seasonality with drier summers under 2K global warming.



Model evaluation – historical climate data

Model reproduces daily and seasonal streamflow observations relatively well.

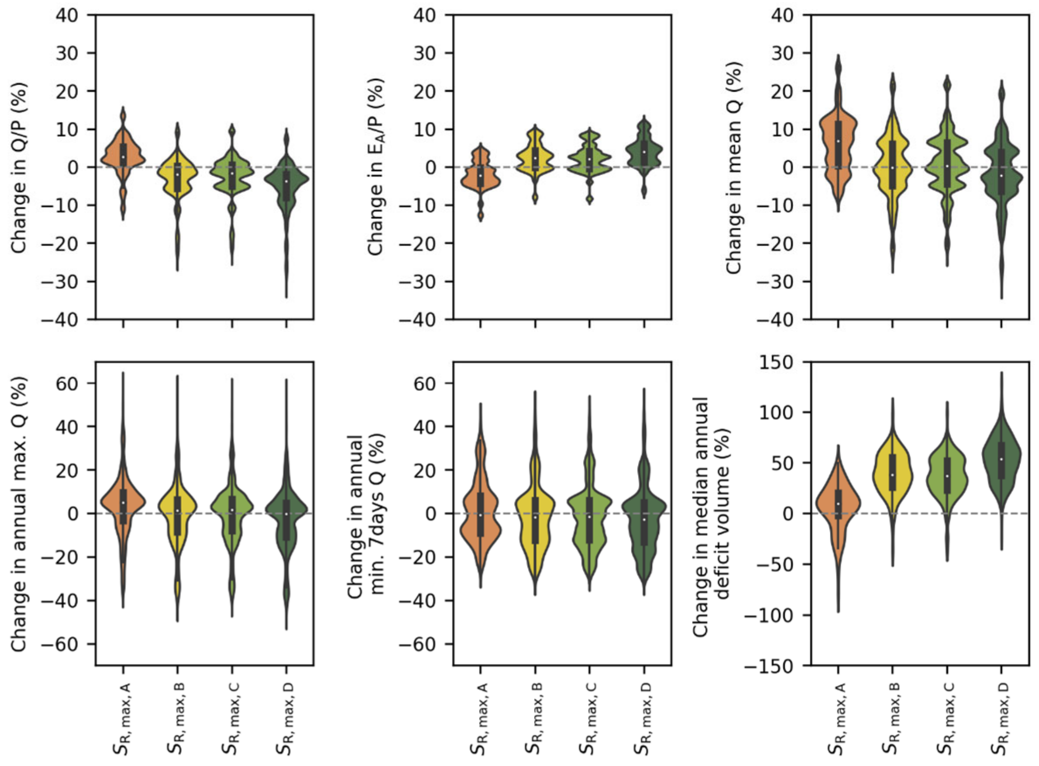




Hydrological change evaluation under +2K global warming and potential land-use change (4 scenarios)

Percentage change in annual hydrological response indicators between the +2K and historical model runs for the four scenarios

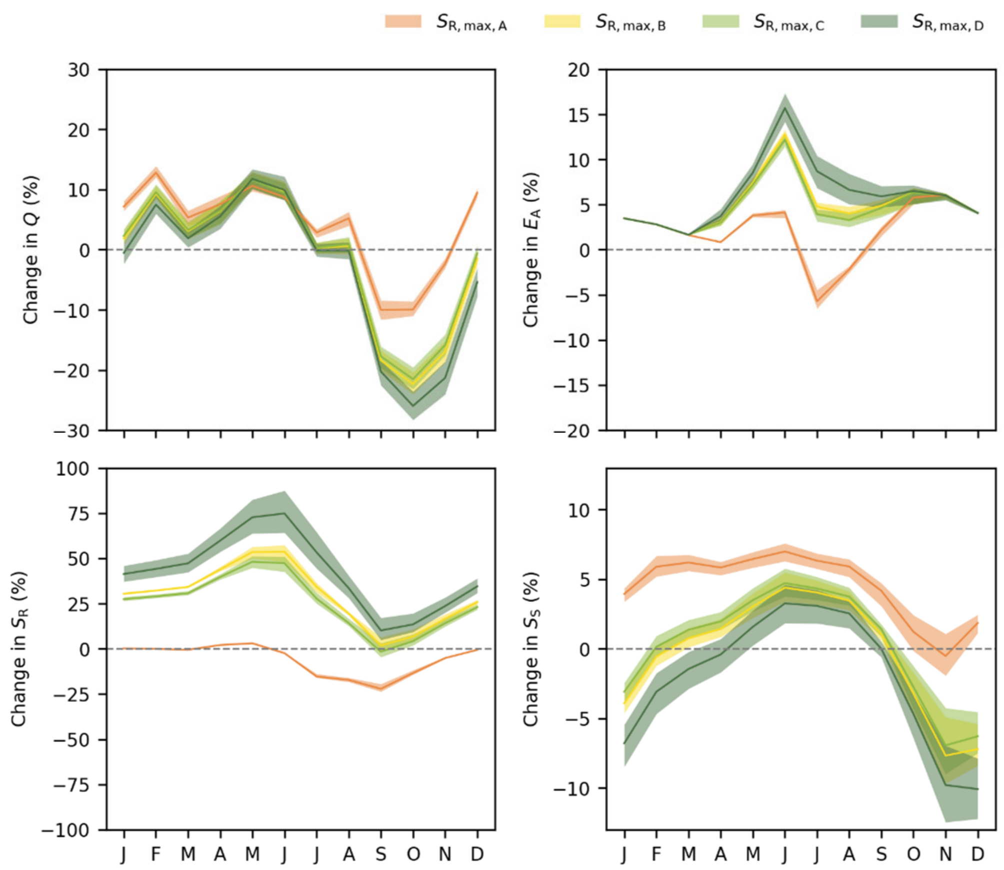
- Runoff coefficients increase (+3%) for the stationary system, while they are projected to decrease (-3%) for the non-stationary systems
- Stronger increase in median annual volume deficit for the non-stationary systems in comparison to the stationary systems



Hydrological change evaluation under +2K global warming and potential land-use change (4 scenarios)

Mean monthly percentage change between the +2K and historical model runs for the four scenarios

- More pronounced decrease in streamflow (-20%) between Sept and Nov for the non-stationary systems in comparison to the stationary system
- Actual evaporation is no longer reduced as a result of moisture stress in the non-stationary systems
- Groundwater recharge reduces (-5%) from Oct to Feb in the non-stationary systems, while it increases in the stationary system



Take home messages

- Ecosystems adapt to changing climate conditions (how fast?)
- Future climate projections to estimate how vegetation may adapt its root system
- Adapt vegetation parameters in response to climate change
- Altered hydrological response: decreased streamflow and groundwater recharge, increased evaporation

Thank you

More details in discussion paper: https://doi.org/10.5194/hess-2021-204