



Paving new roads for the rubber to meet

*Incorporating climate information into seasonal
streamflow and drought forecasting*

Flavio Lehner^{1,2}, Andy Wood², Dagmar Llewellyn³, Douglas Blatchford⁴

¹Research Applications Lab, NCAR, Boulder, USA

²Climate & Global Dynamics Lab, NCAR, Boulder, USA

³Bureau of Reclamation, Albuquerque, USA

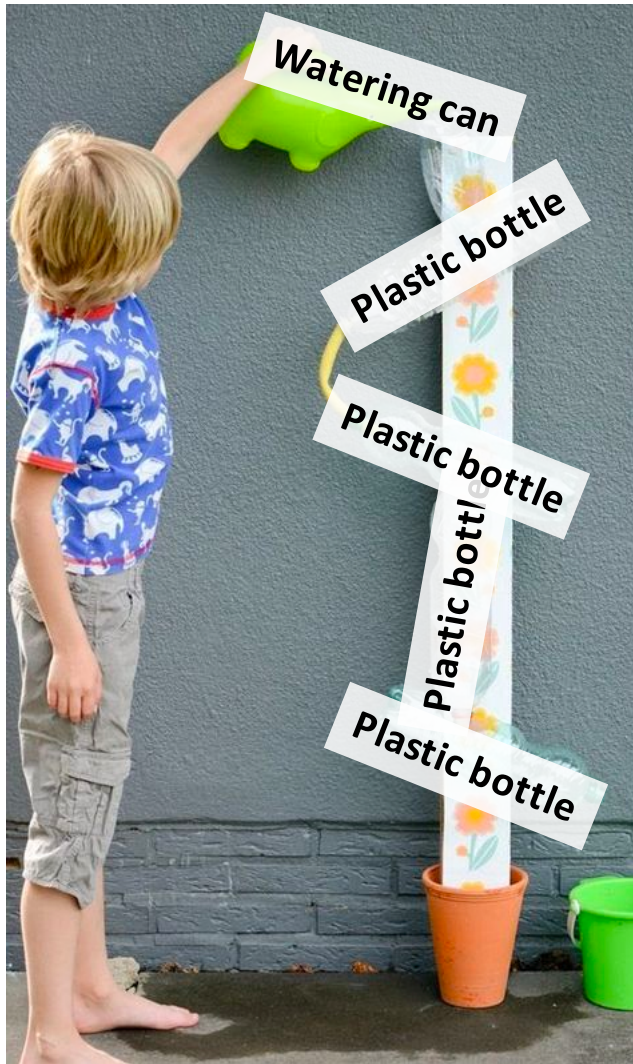
⁴Bureau of Reclamation, Boulder City, USA



1. Temperature influence on streamflow
2. Incorporating temperature into streamflow forecasting



Runoff efficiency
= water out/water in
= streamflow/precipitation

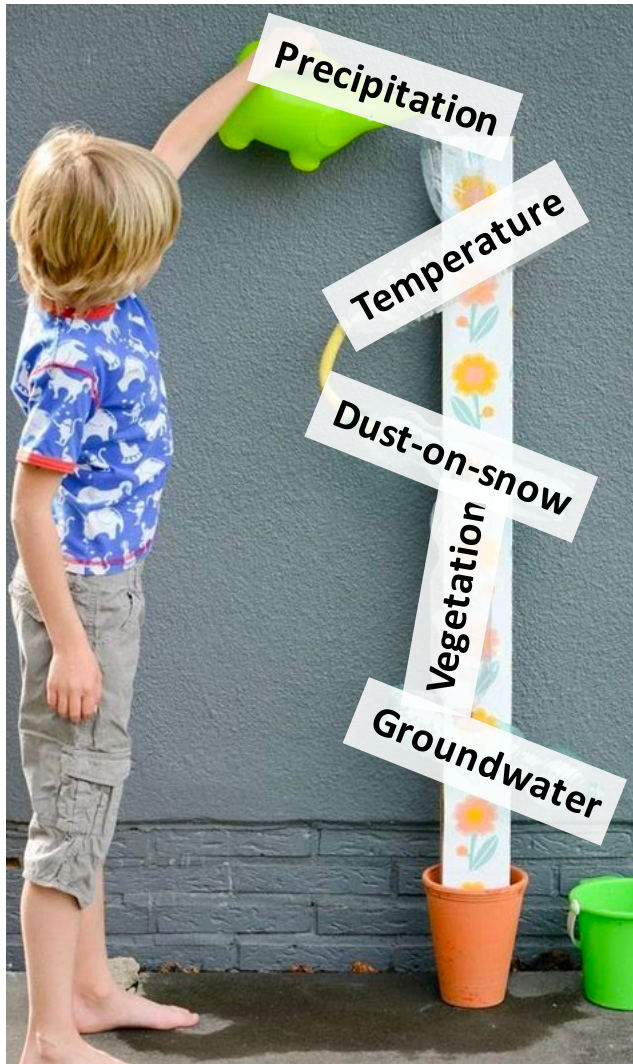


Runoff efficiency

= water out/water in

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$$RE = f(\text{watering can, plastic bottle})$$

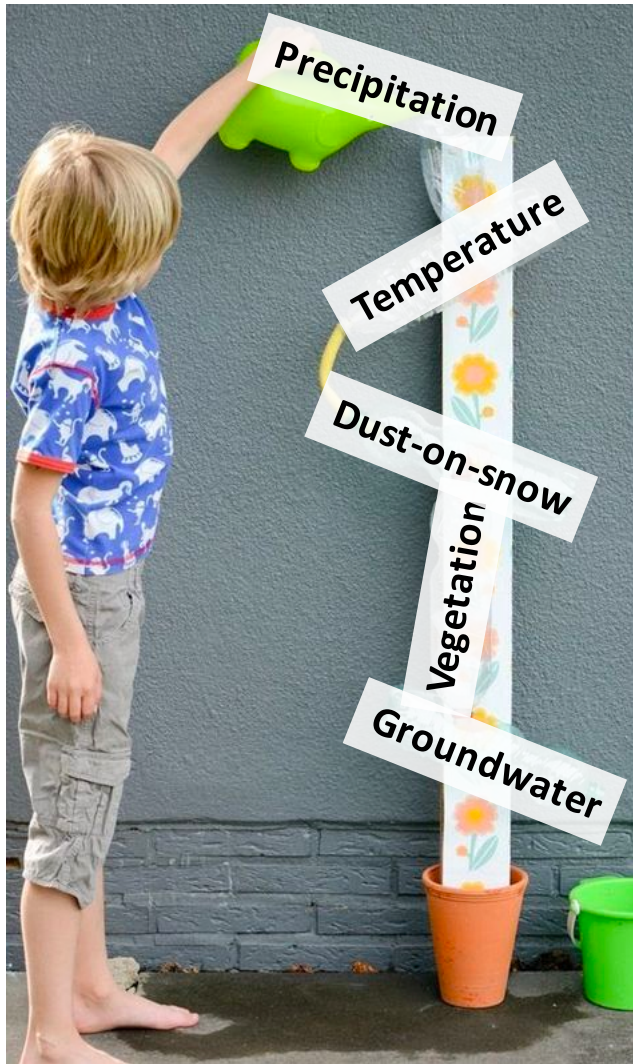


Runoff efficiency

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Runoff efficiency

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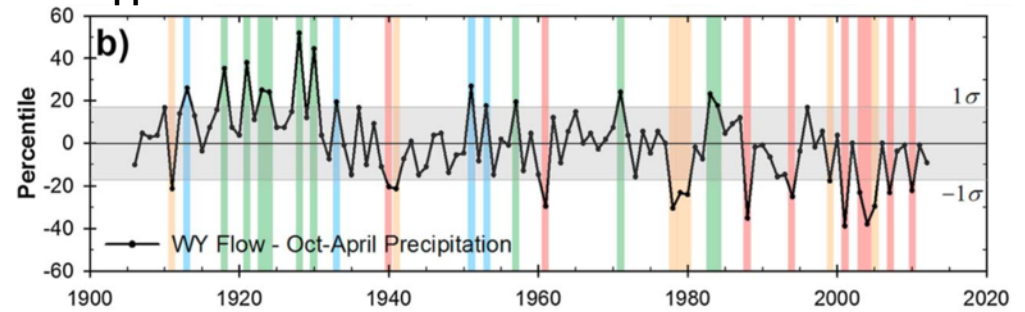
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The concept of runoff efficiency



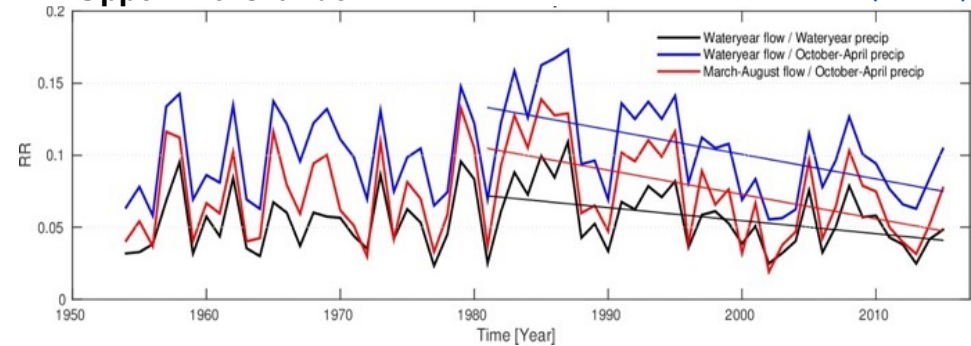
Upper Colorado River

Woodhouse et al. (2016)



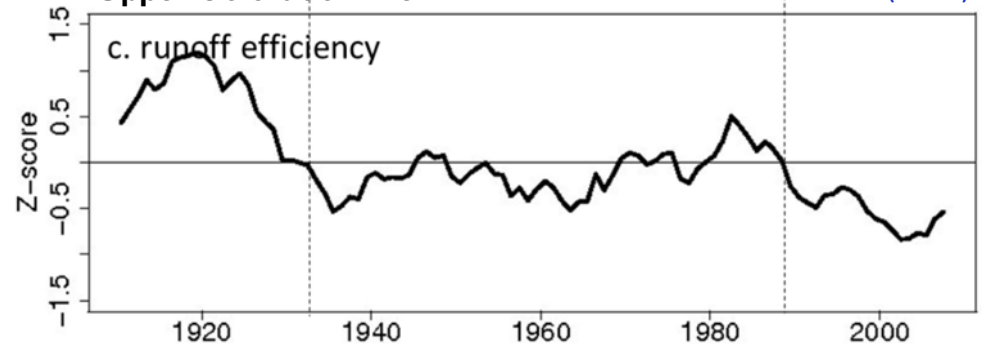
Upper Rio Grande

Lehner et al. (2017a)



Upper Colorado River

McCabe et al. (2017)



Growing evidence for temperature influence on streamflow

Geophysical Research Letters

RESEARCH LETTER

10.1002/2017GL073253

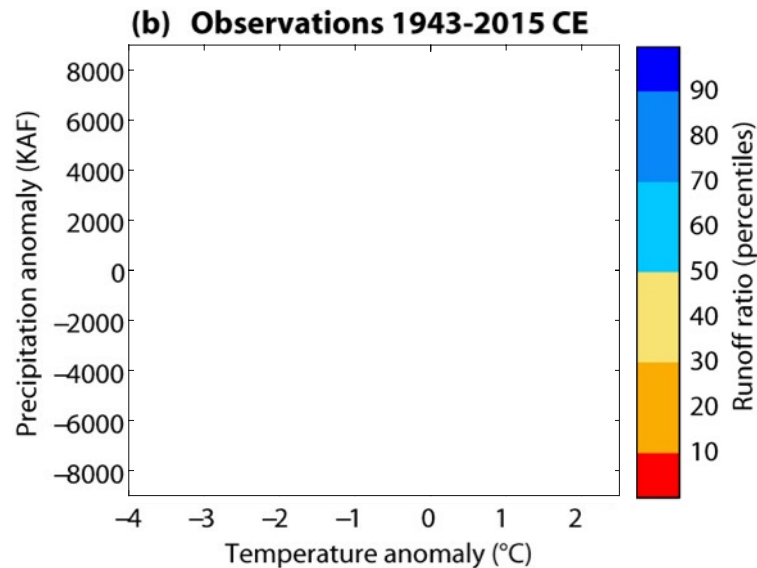
Key Points:

- The decreasing runoff efficiency trend from 1986 to 2015 in the Upper Rio Grande basin is unprecedented in the last 445 years
- Very low runoff ratios are 2.5–3 times more likely when temperatures are above-normal than when they are below-normal
- The trend arises primarily from natural

Assessing recent declines in Upper Rio Grande runoff efficiency from a paleoclimate perspective

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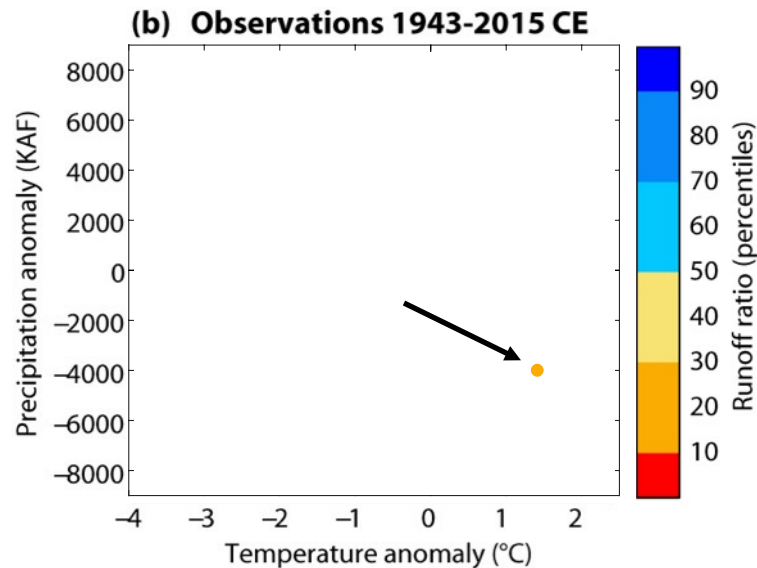
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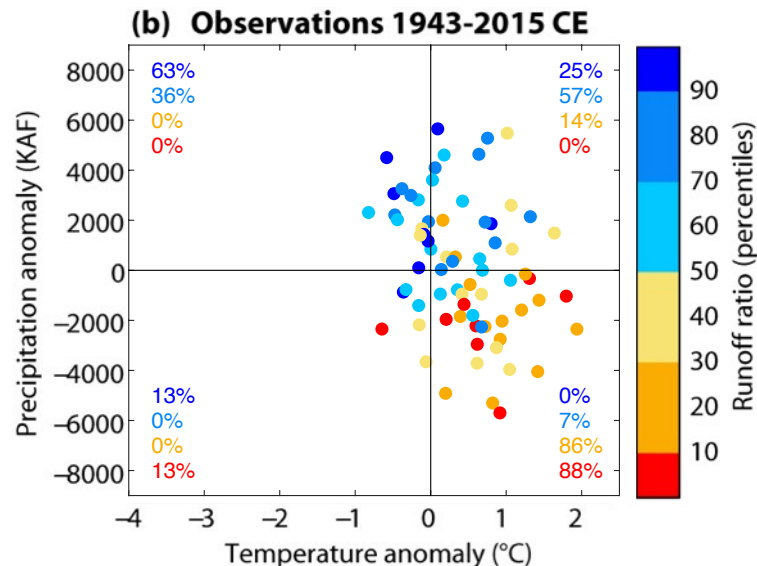
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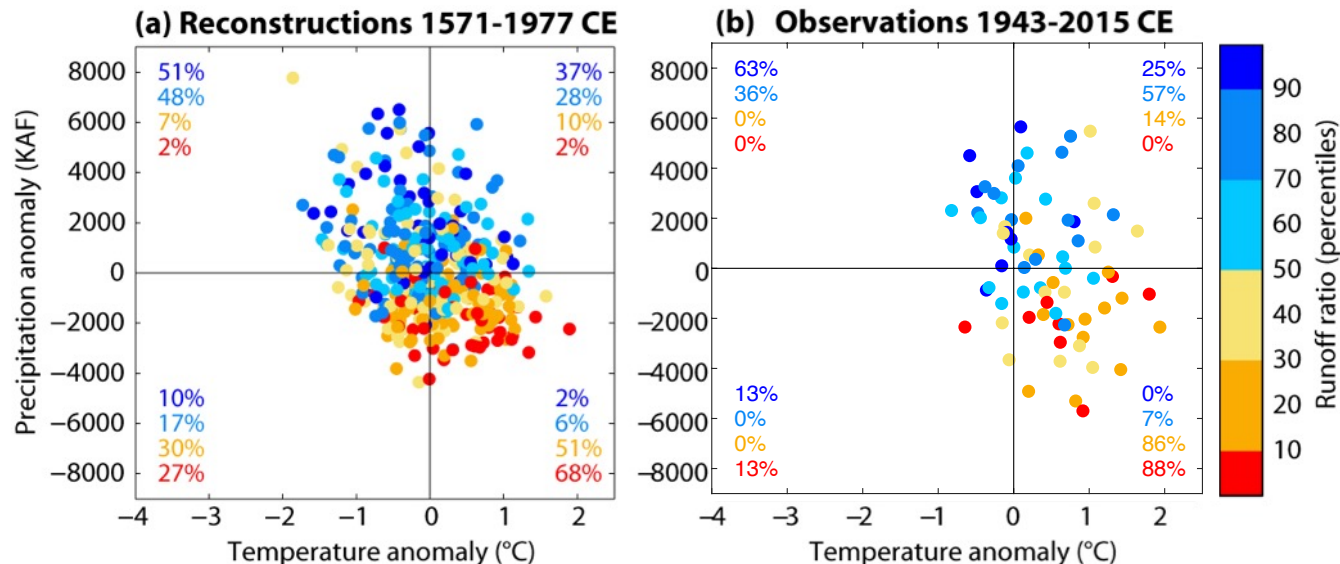
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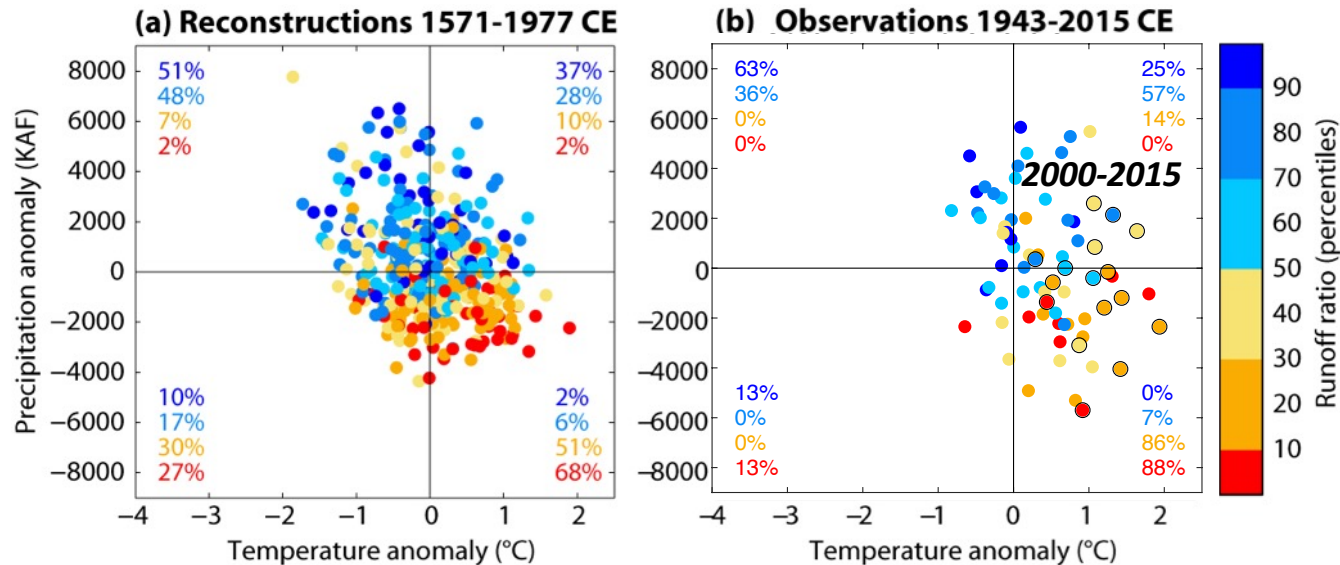
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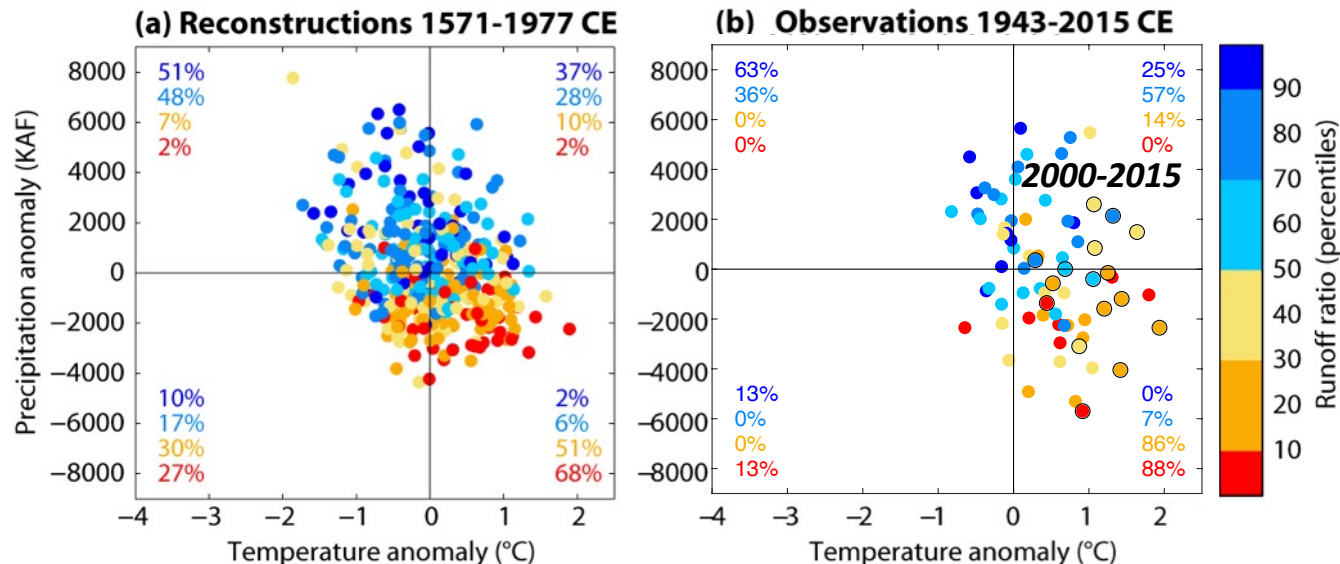
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- First paleo-reconstruction of runoff efficiency
- When P is low and T is high → low runoff efficiency



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- First paleo-reconstruction of runoff efficiency
- When P is low and T is high → low runoff efficiency
- Other studies with similar conclusions:

[Woodhouse et al. \(2016\)](#)

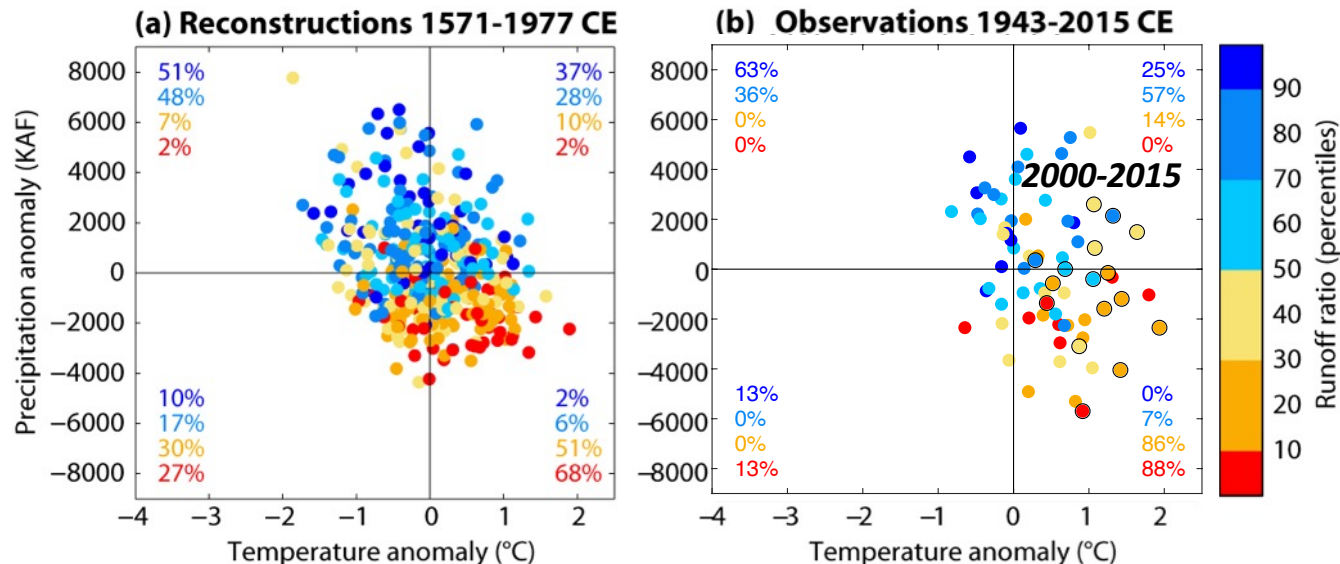
[Udall & Overpeck \(2017\)](#)

[McCabe et al. \(2017\)](#)

[Woodhouse et al. \(2018\)](#)

[Chavarria & Gutzler \(2018\)](#)

etc





Geophysical Research Letters

RESEARCH LETTER

10.1002/2017GL076043

Key Points:

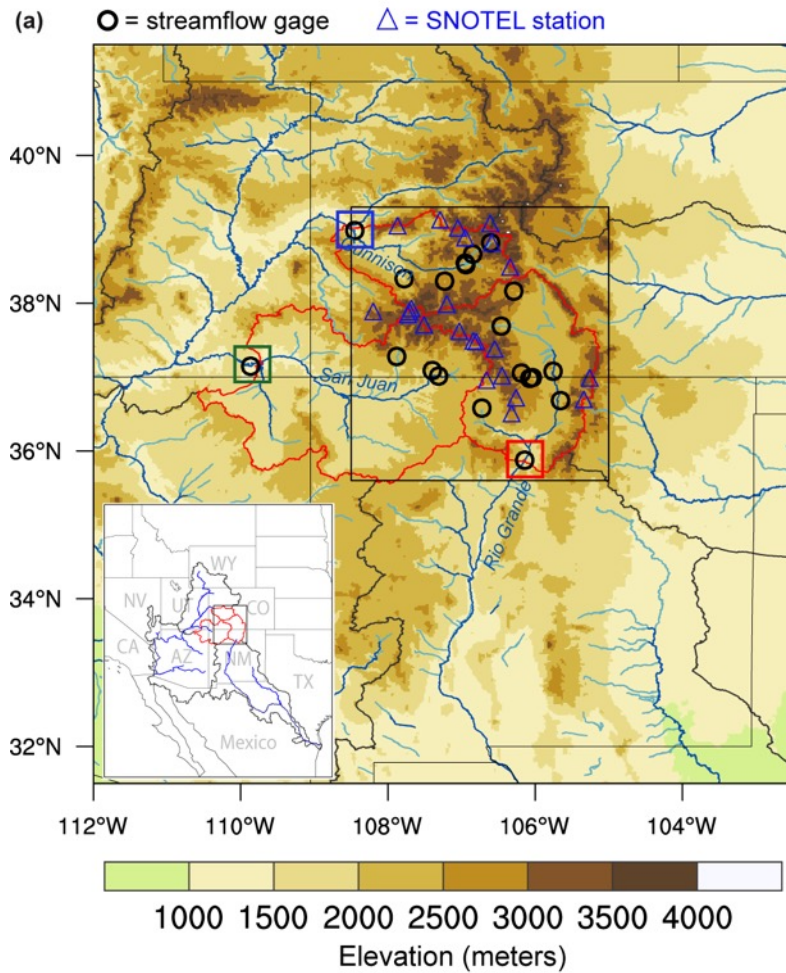
- Seasonal temperature forecasts from climate prediction models are skillful over the headwaters of the Colorado and Rio Grande river basins
- Adding temperature information to current operational seasonal streamflow forecasts in snowmelt-driven basins improves forecast skill
- Temperature forecasts help mitigate impacts of nonstationarity on U.S.

Mitigating the Impacts of Climate Nonstationarity on Seasonal Streamflow Predictability in the U.S. Southwest

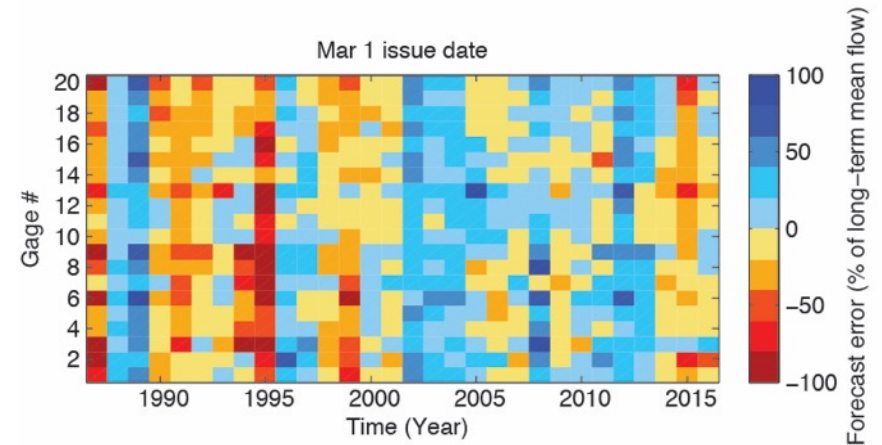
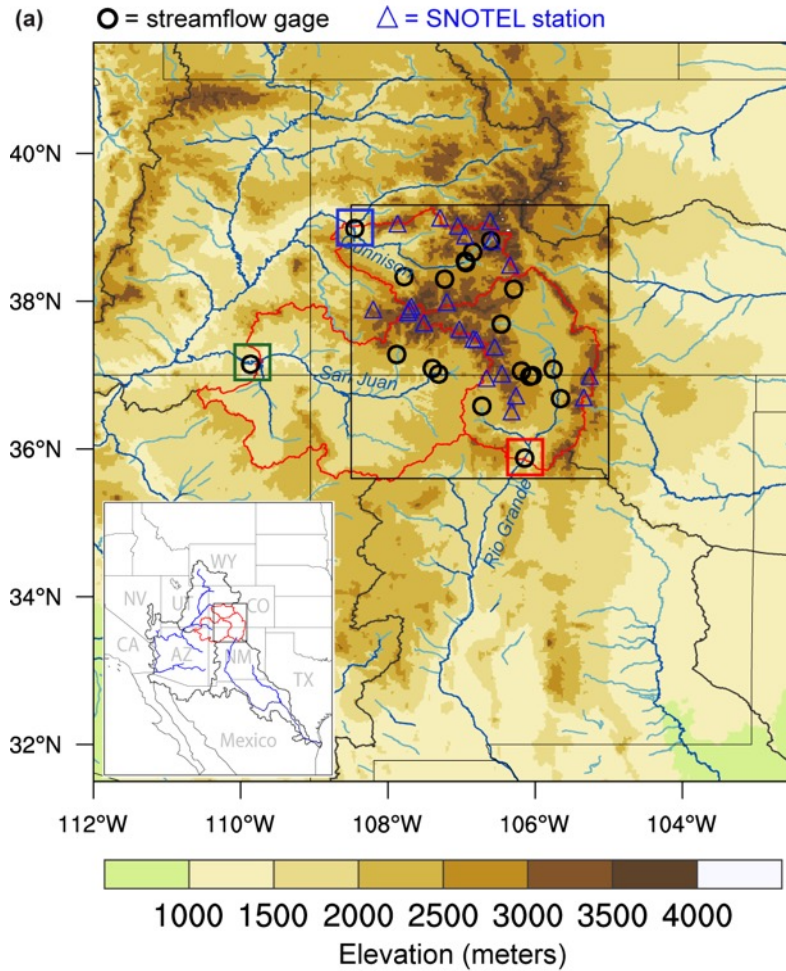
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Including temperature into streamflow forecasting

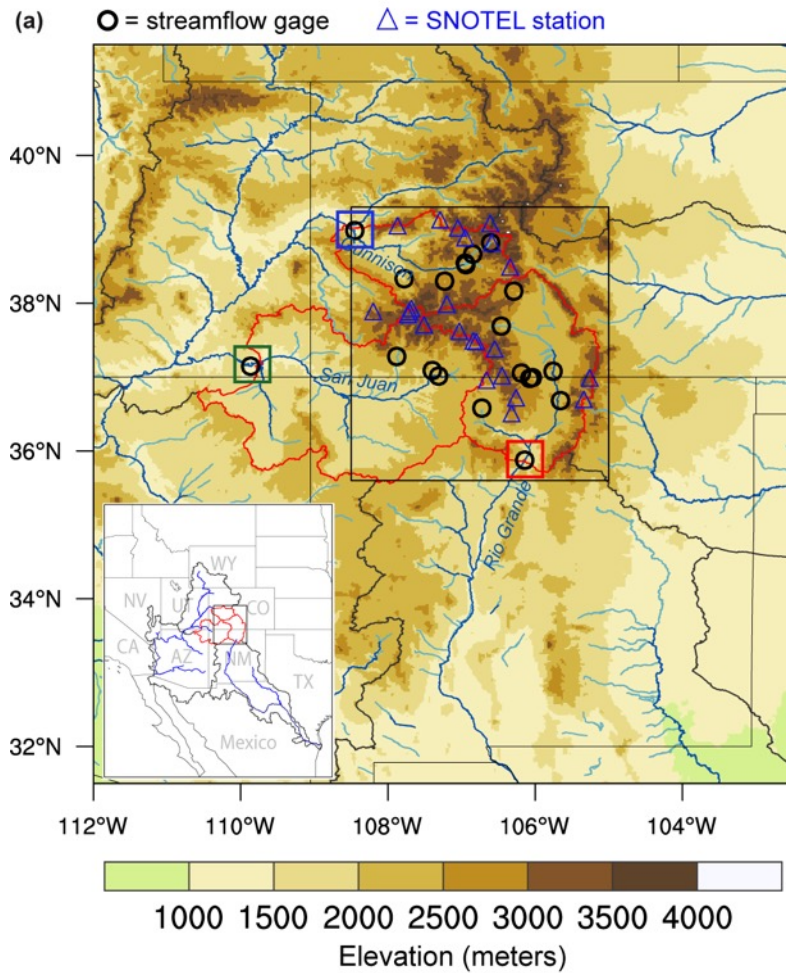


Including temperature into streamflow forecasting

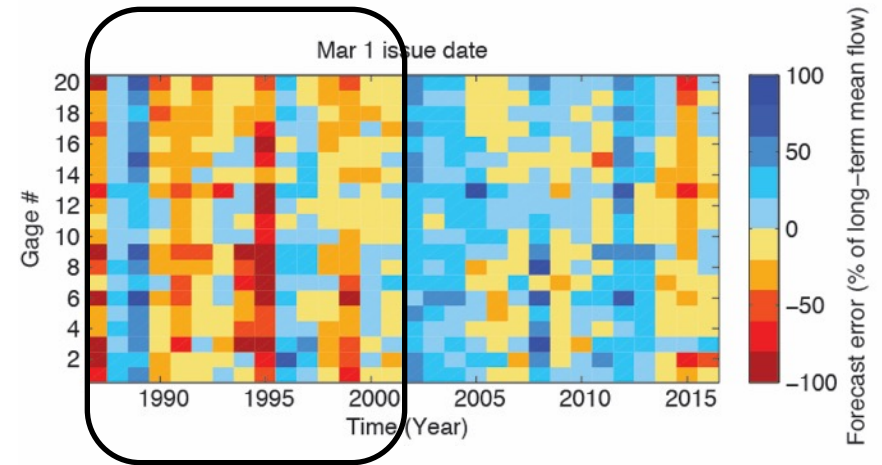


‘Baseline forecast’ (mimicked NRCS forecast)

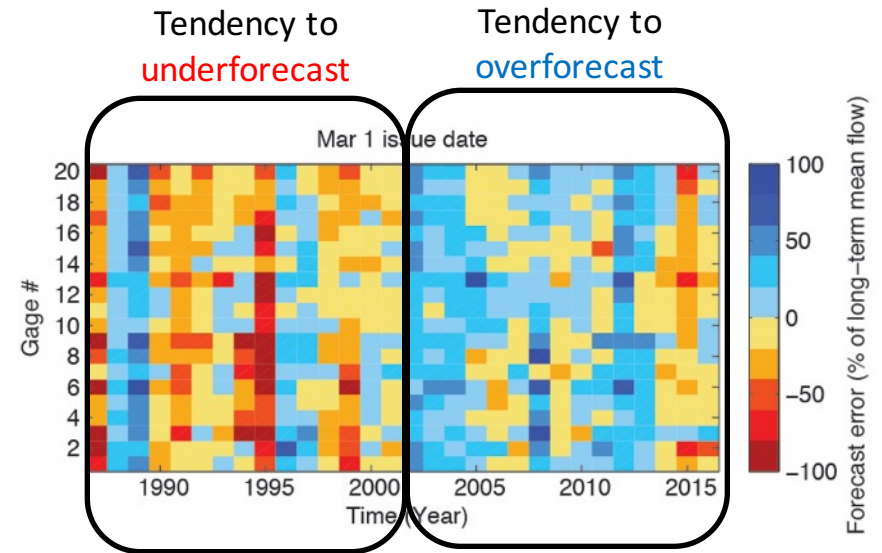
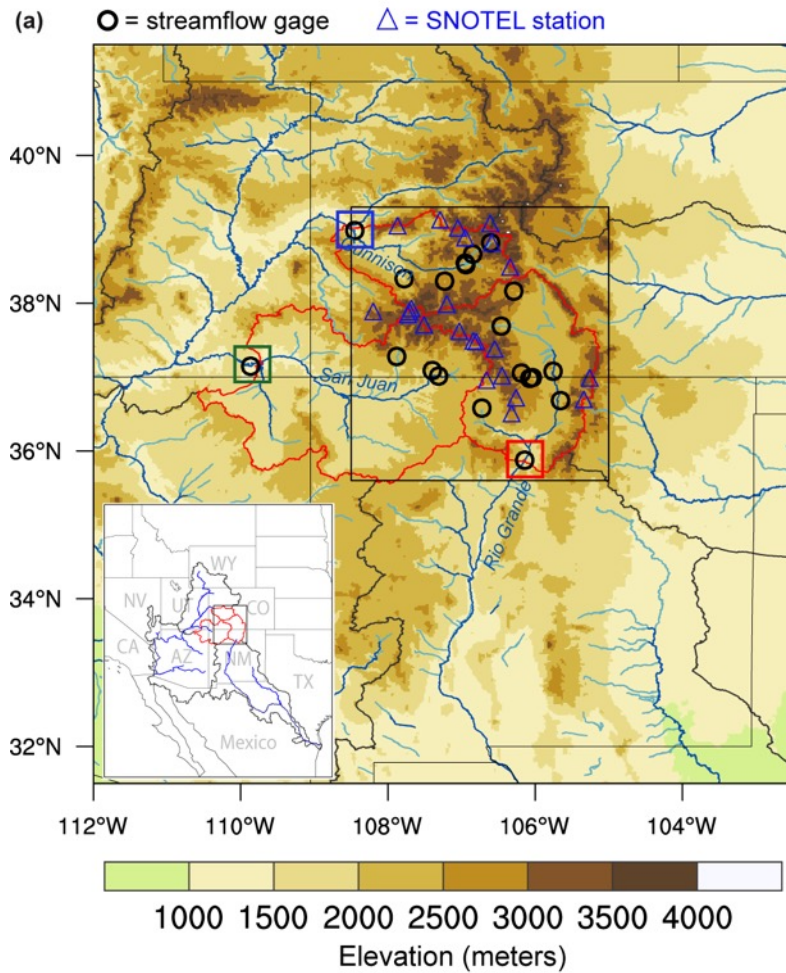
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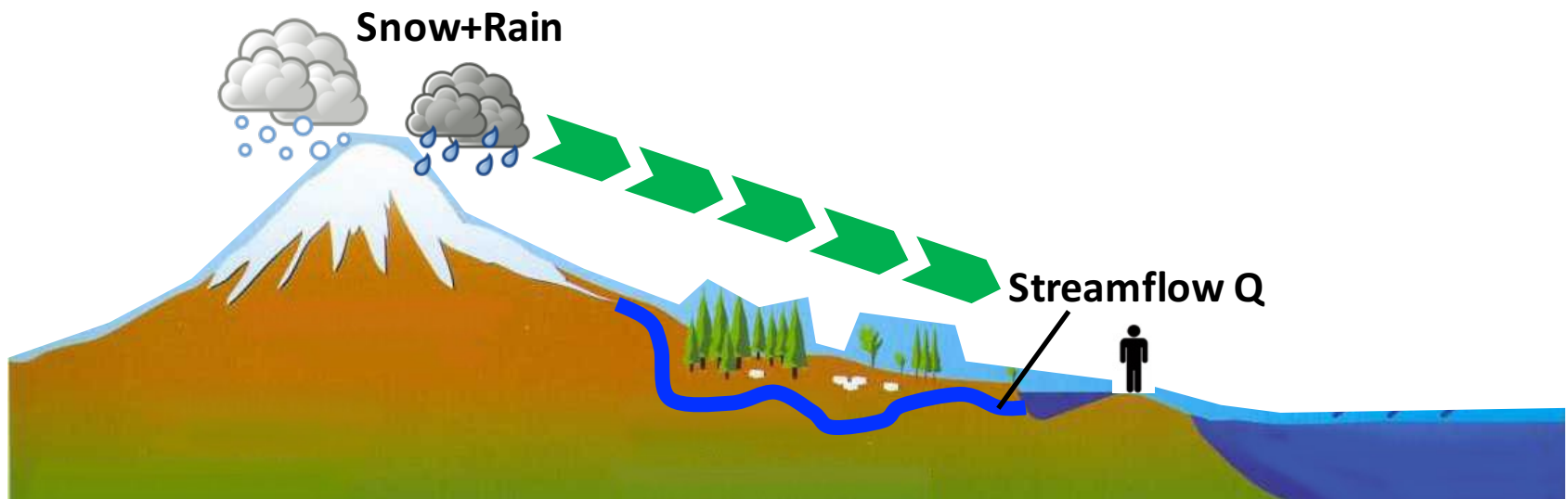
Tendency to
underforecast



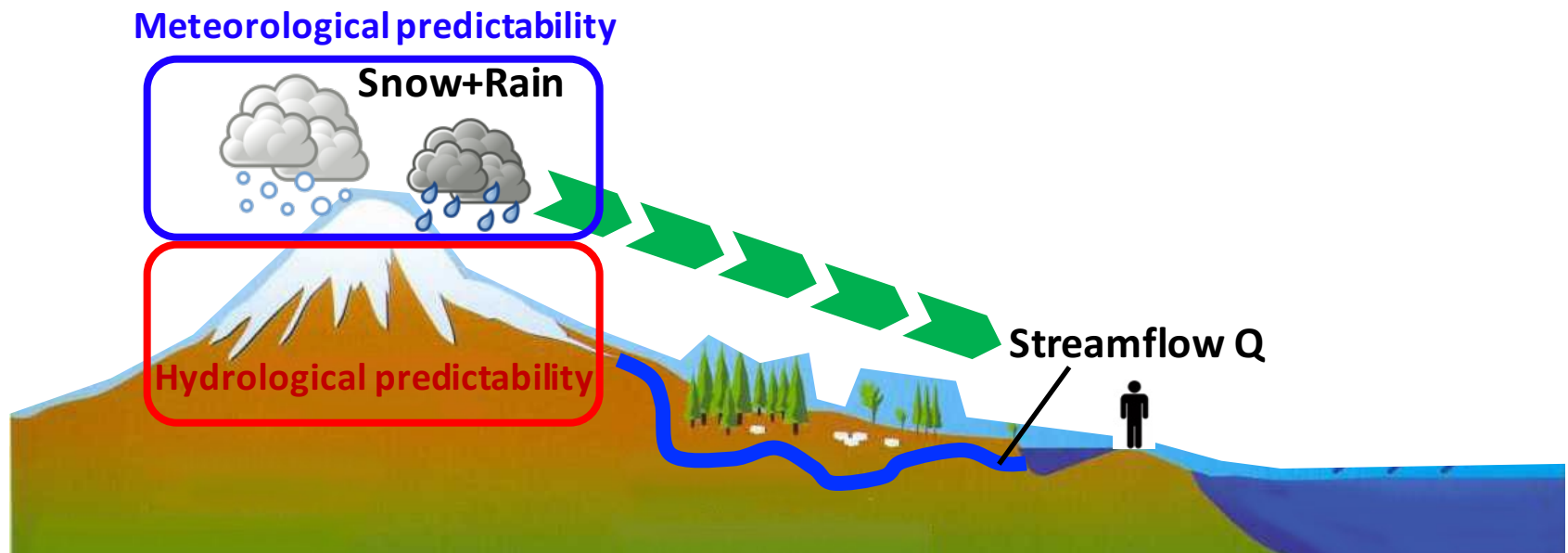
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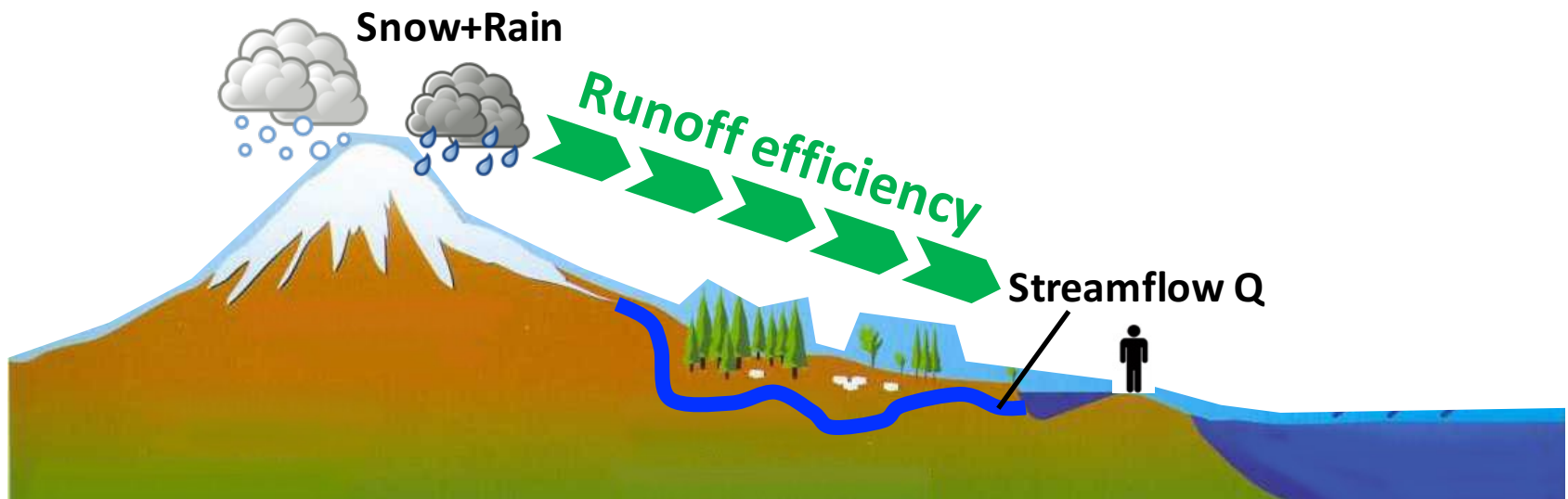
Statistical seasonal streamflow forecasting “Water Supply Forecasts”



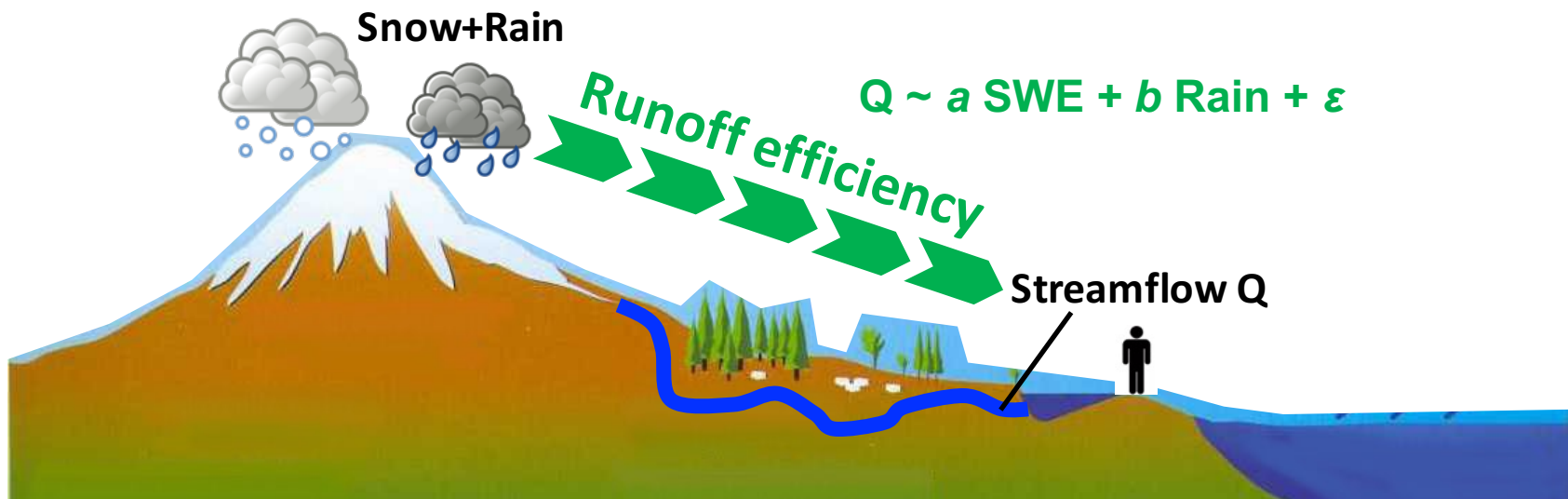
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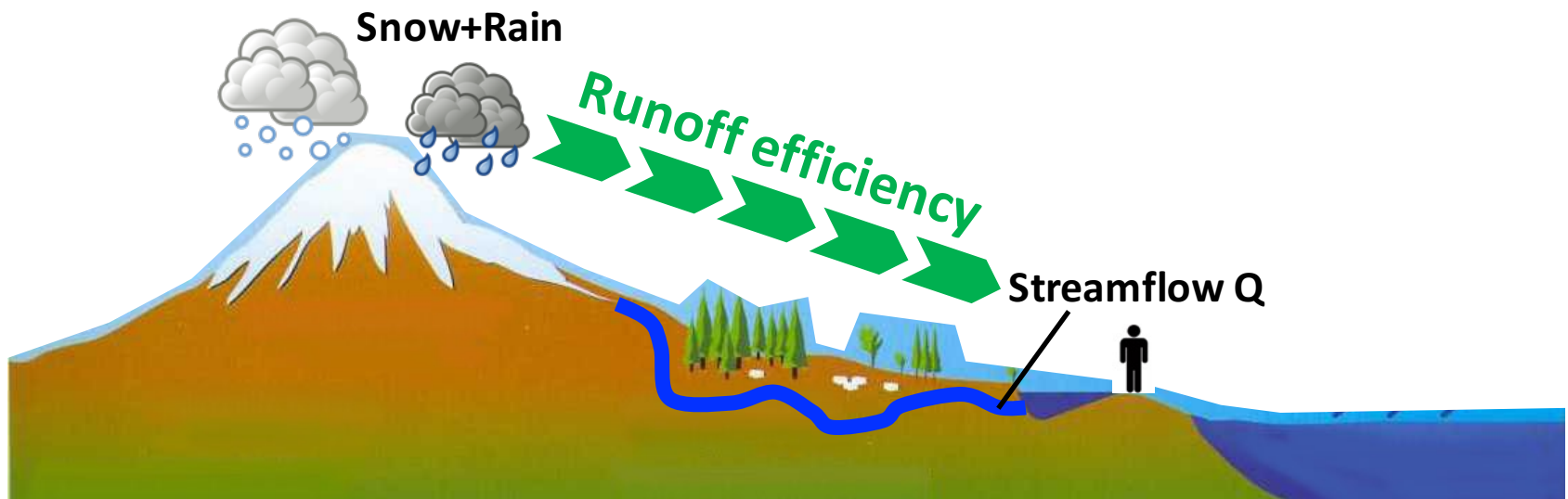
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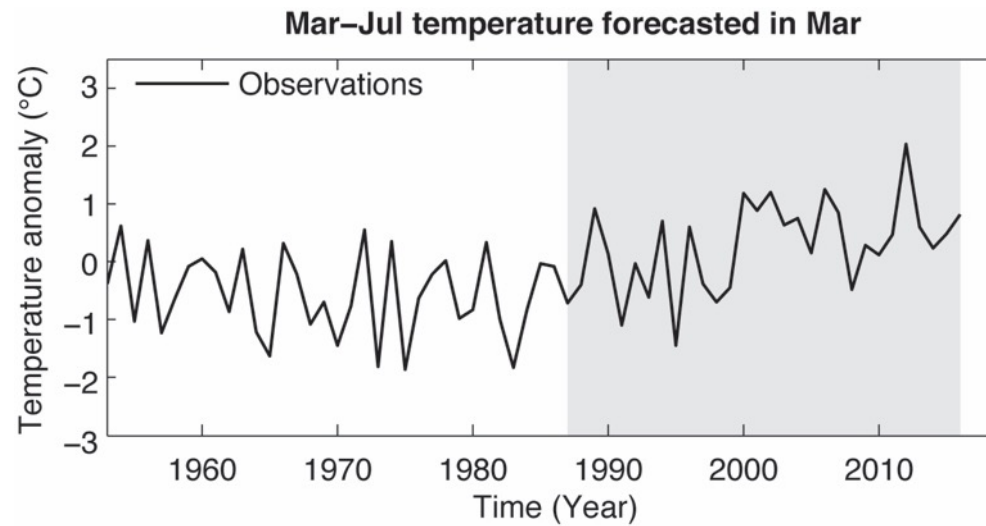
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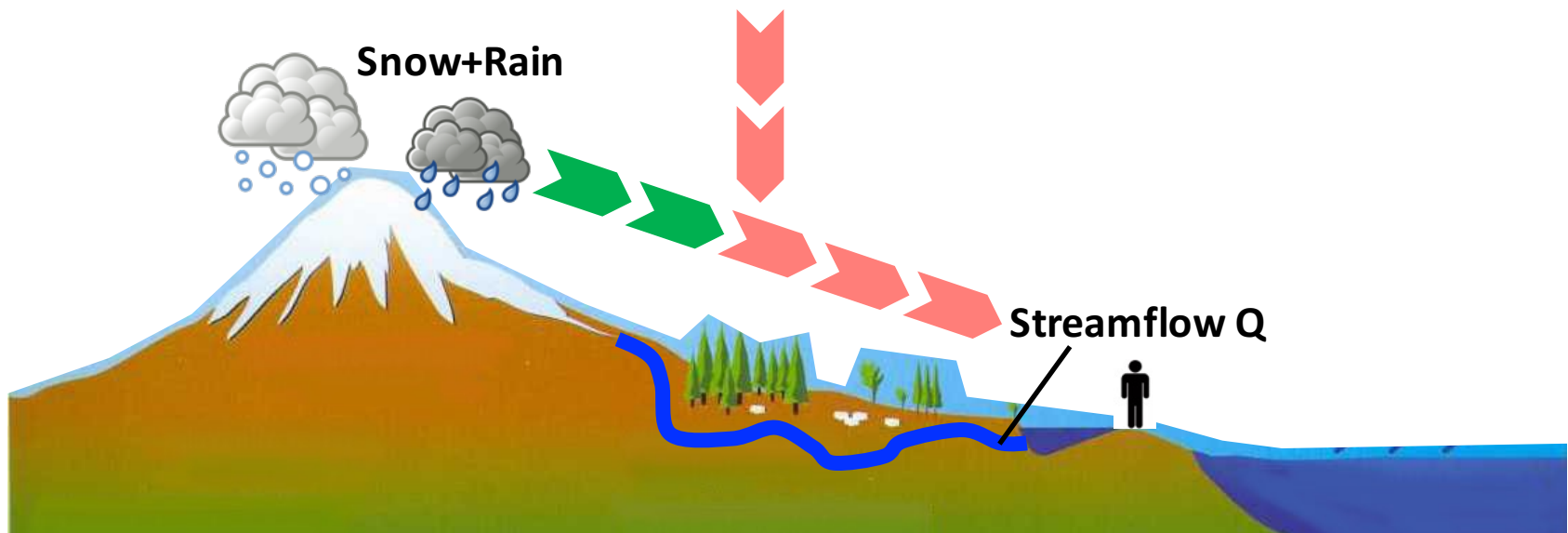
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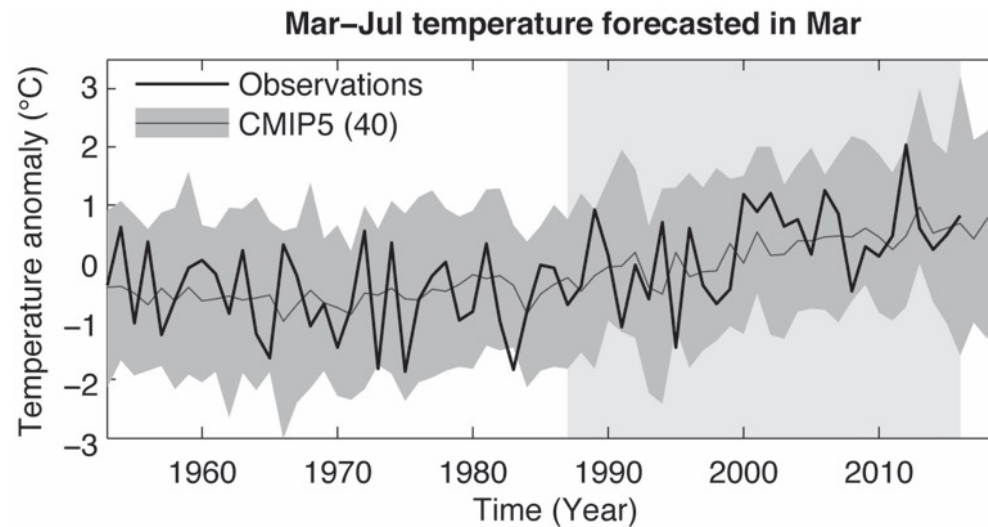
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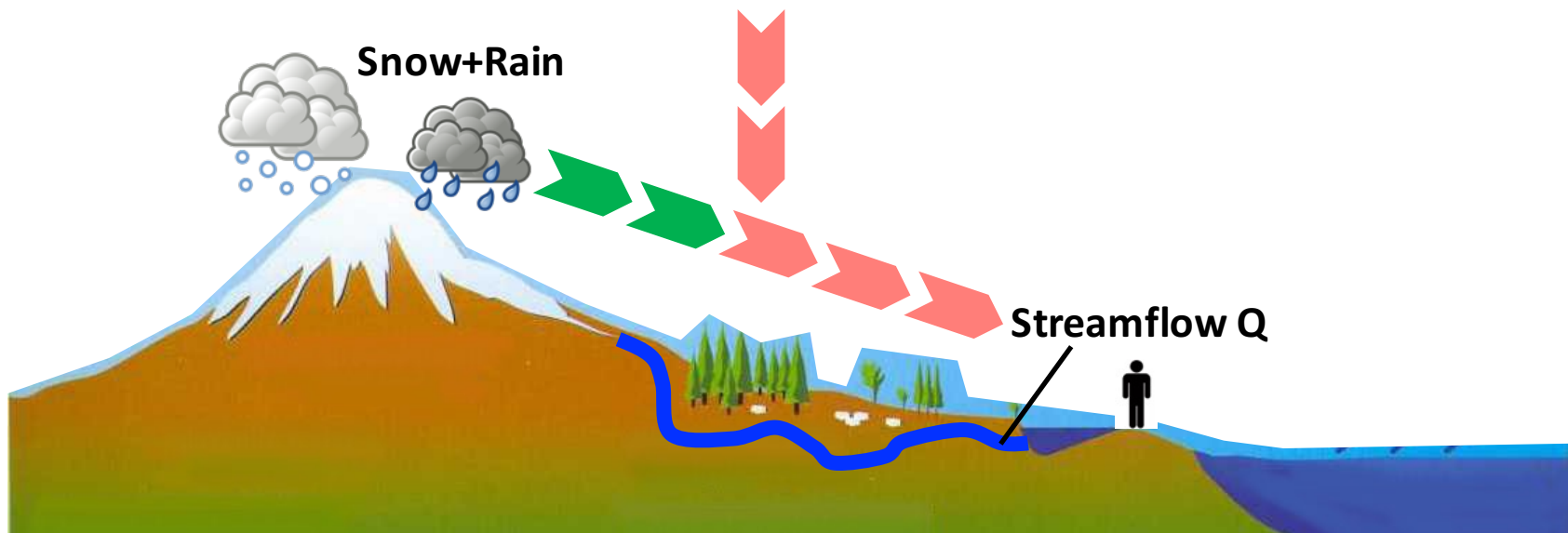
Colorado/Rio Grande headwaters



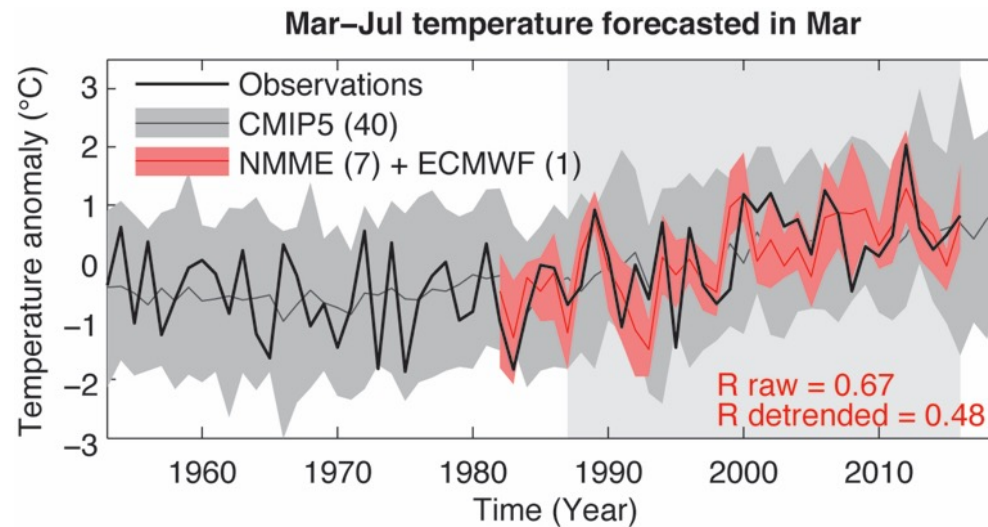
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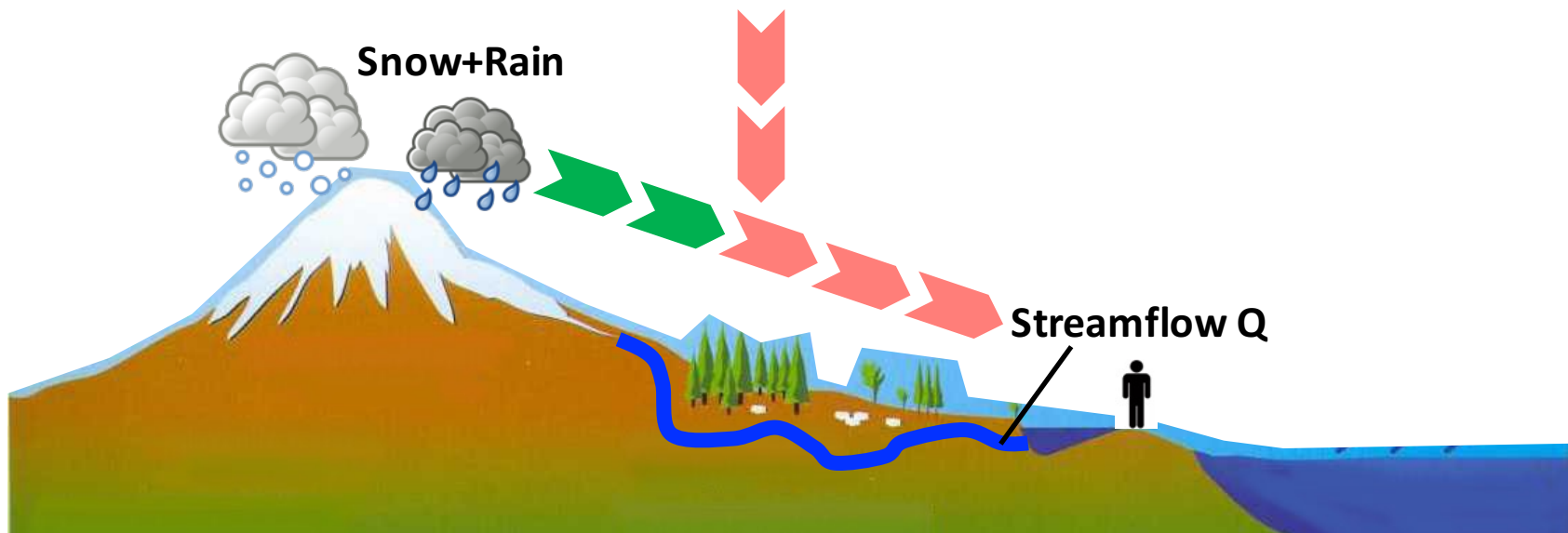
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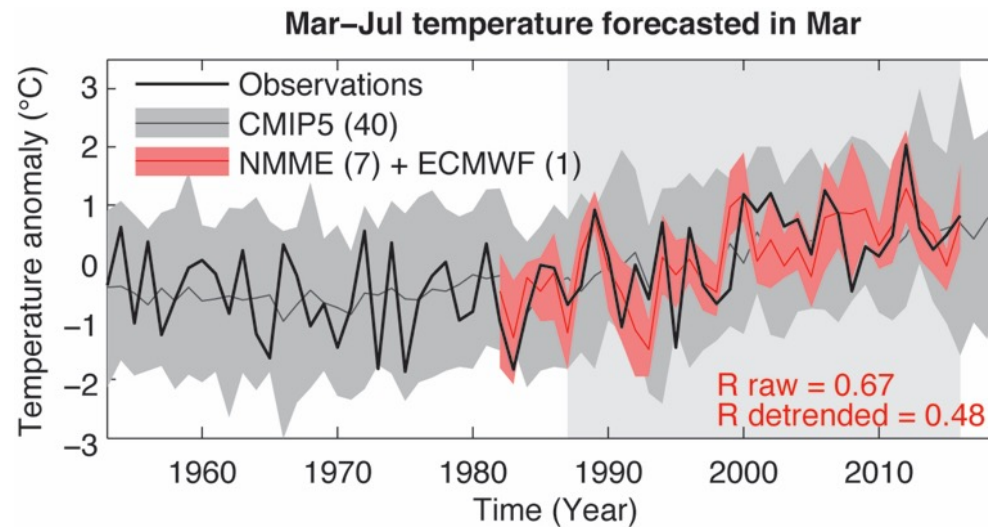
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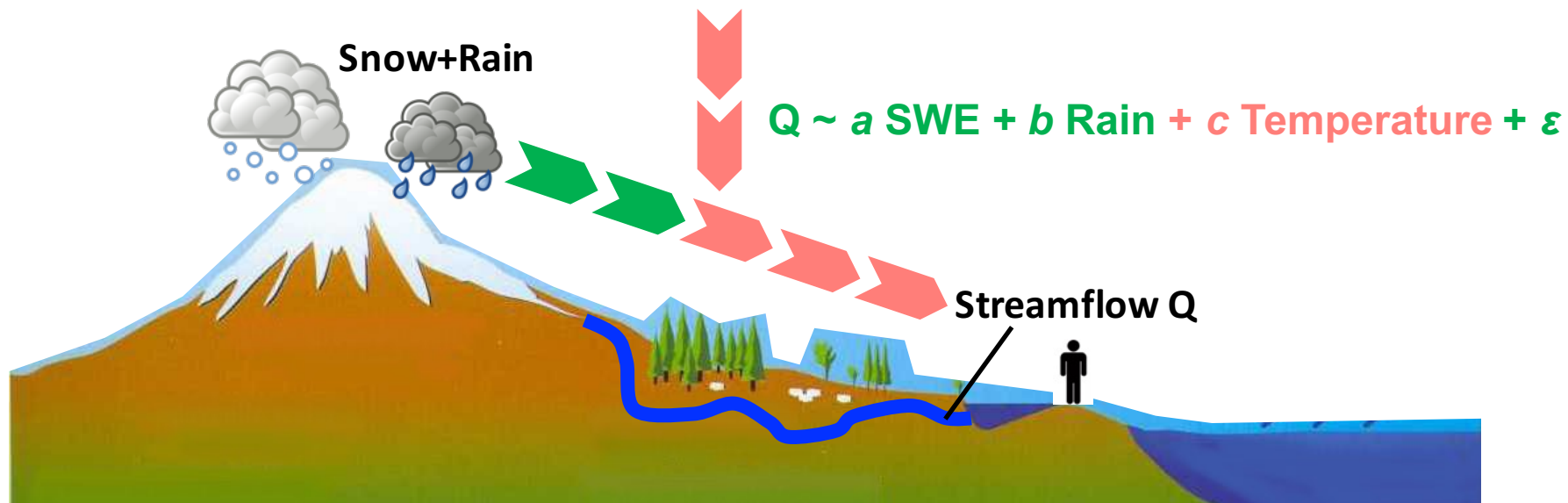
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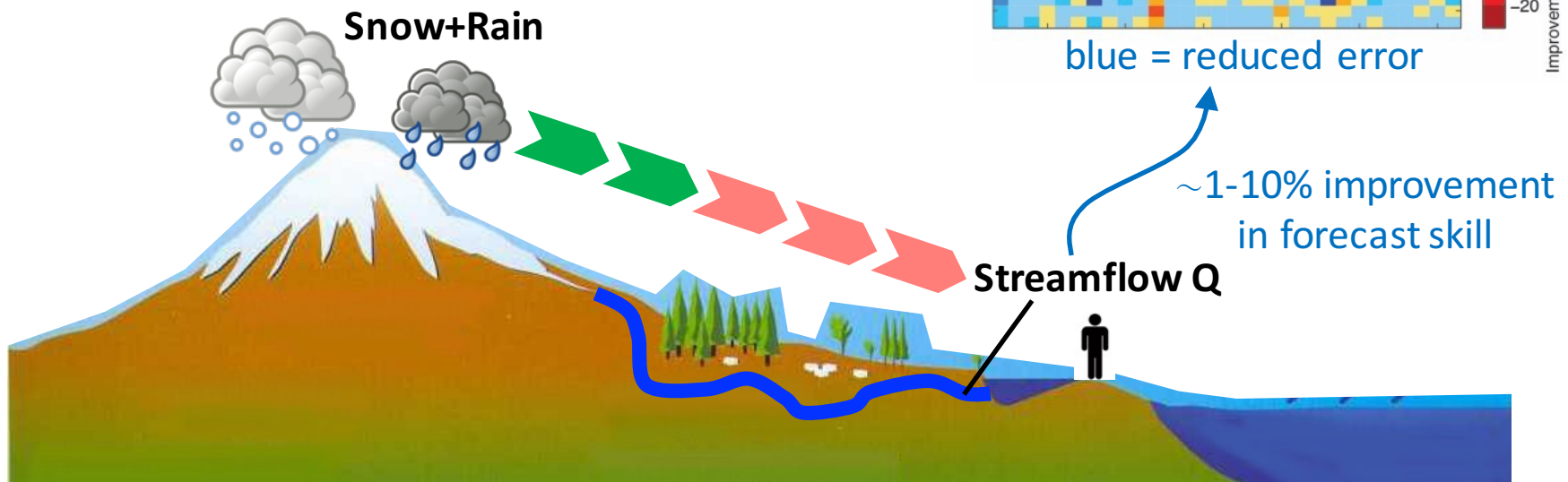
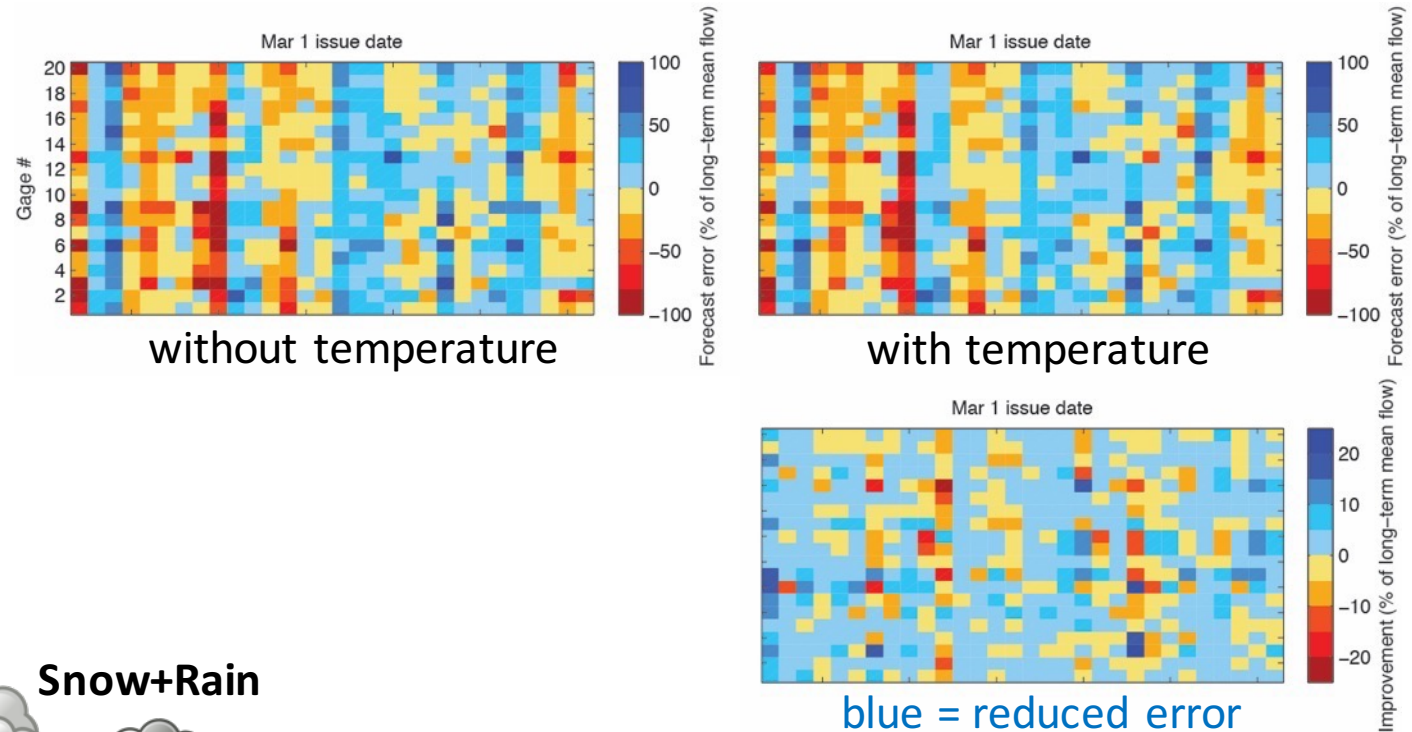
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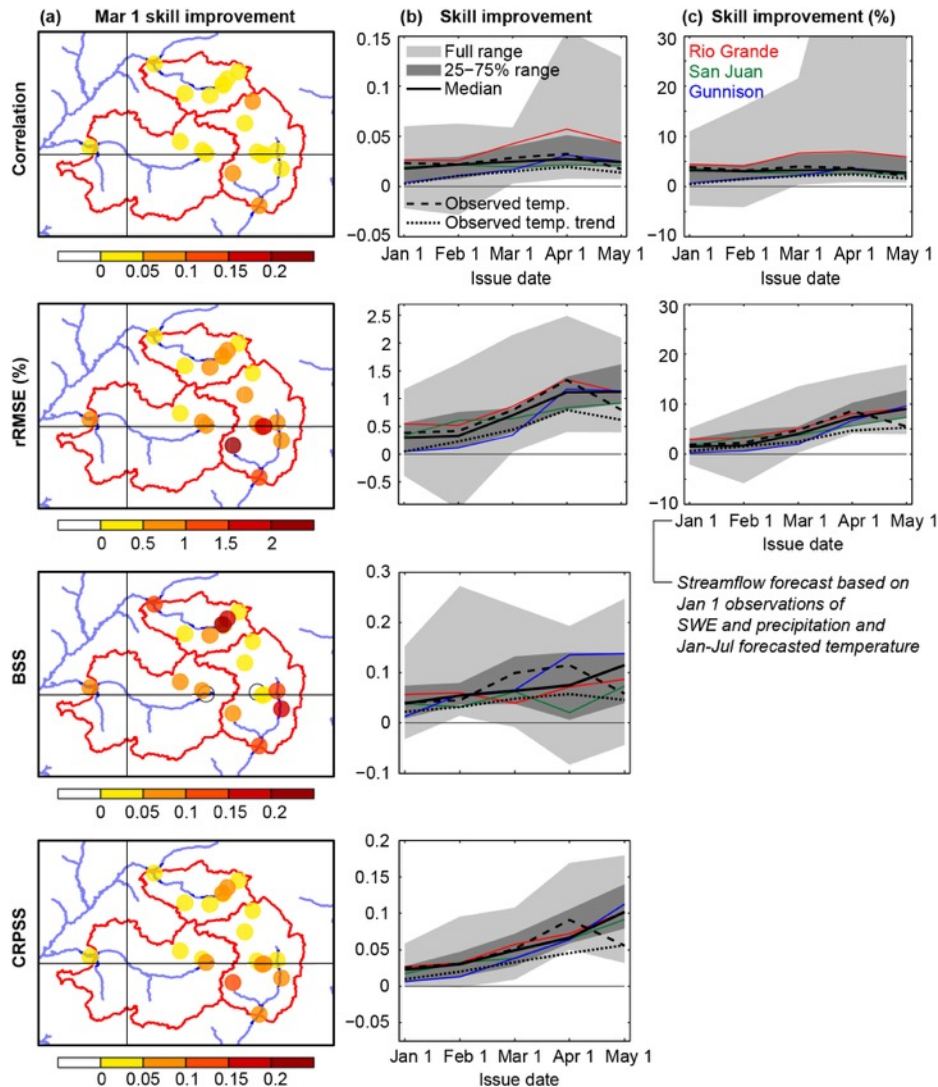
Colorado/Rio Grande
headwaters



Including temperature into streamflow forecasting



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Correlation



rRMSE



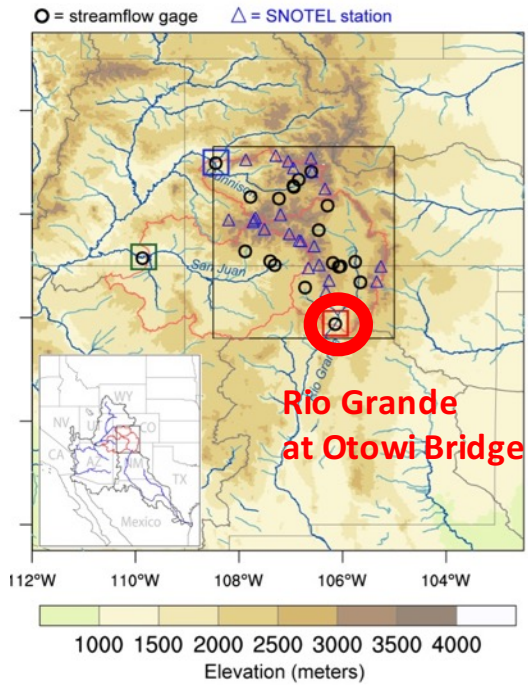
BSS < 33rd percentile



CRPSS

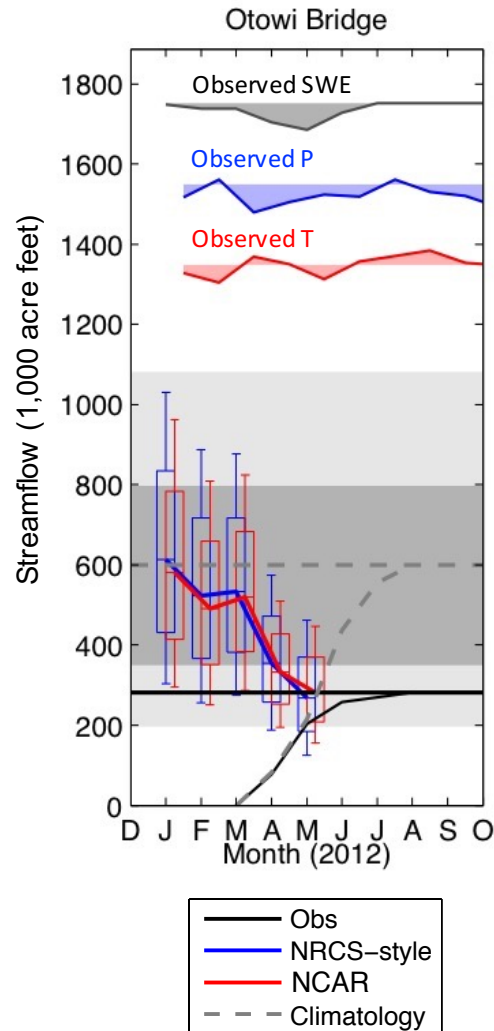
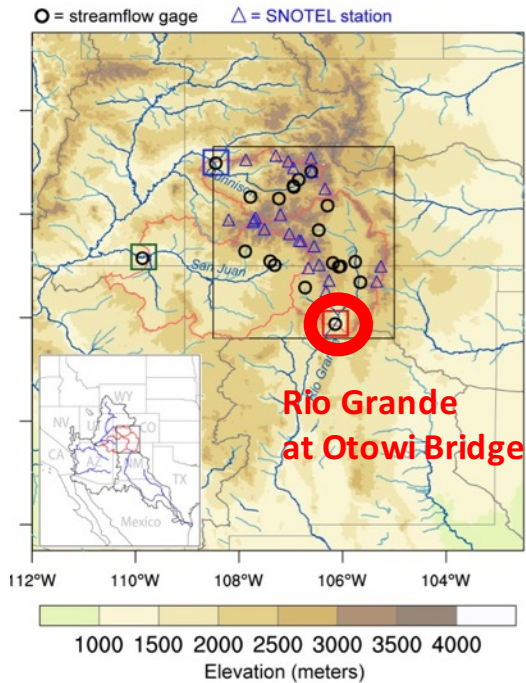


Streamflow hindcasts

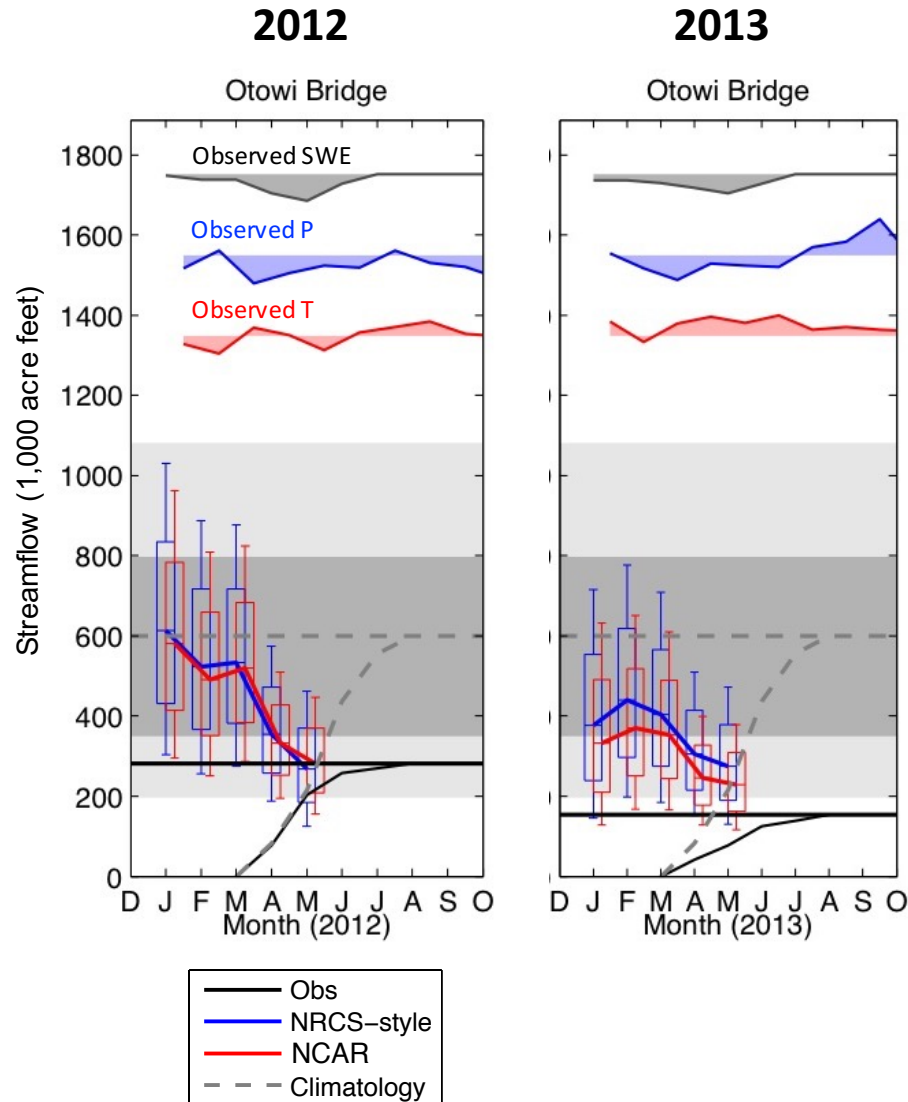
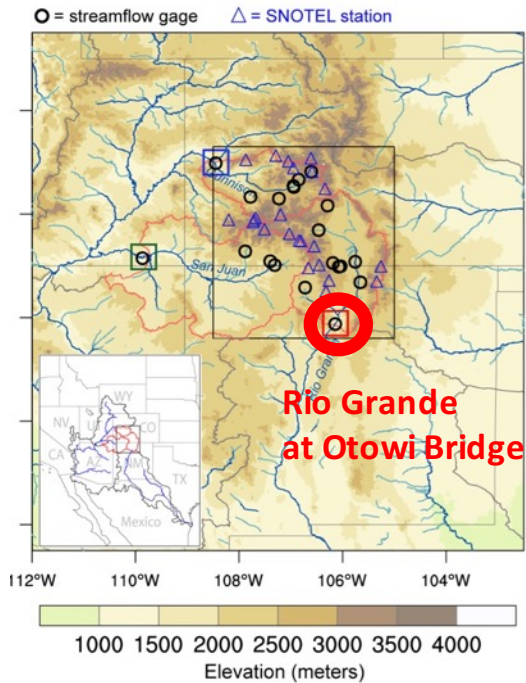


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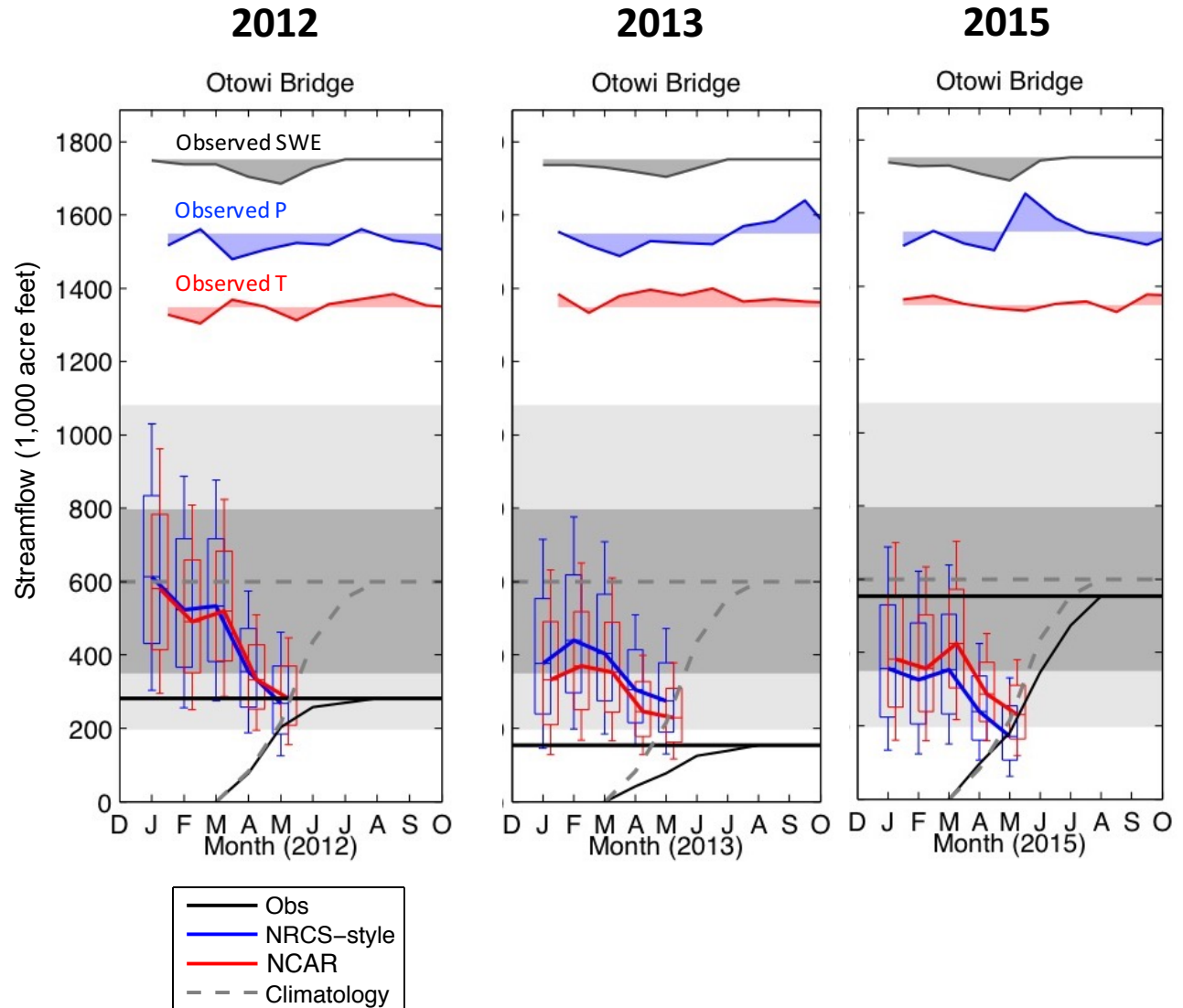
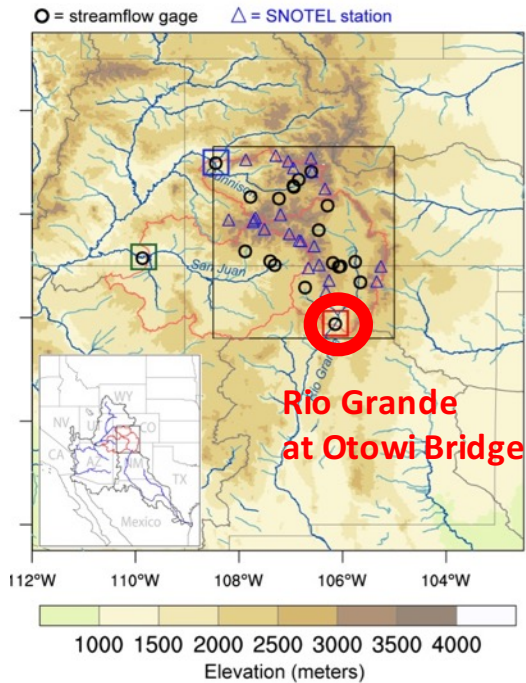
2012



Streamflow hindcasts



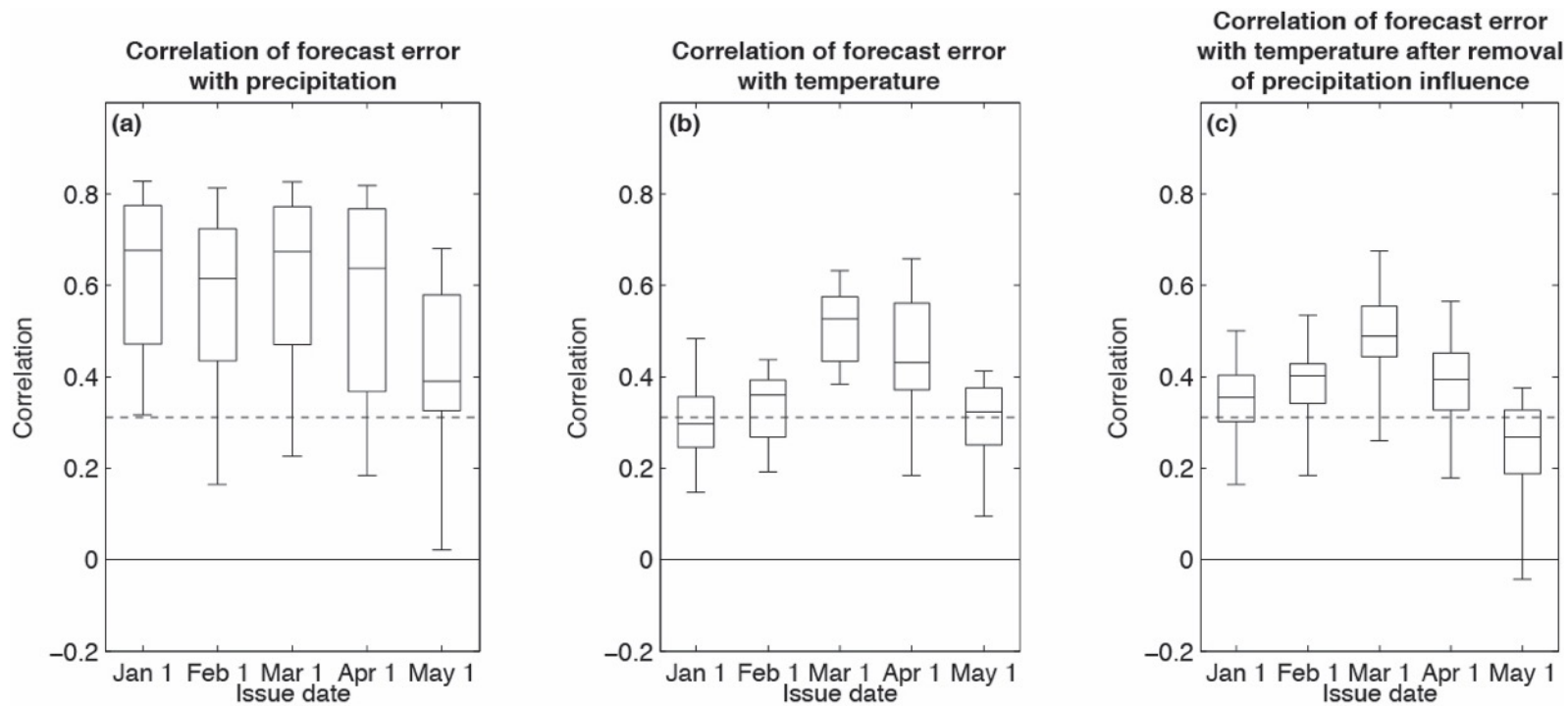
Streamflow hindcasts

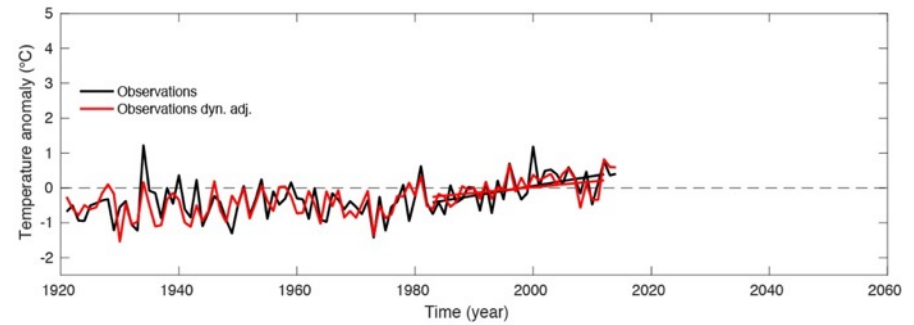
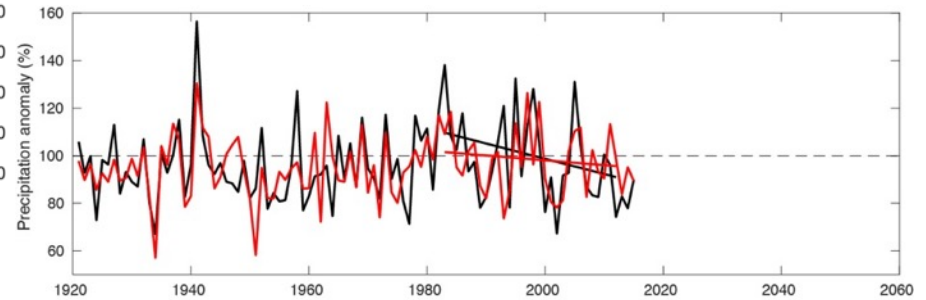
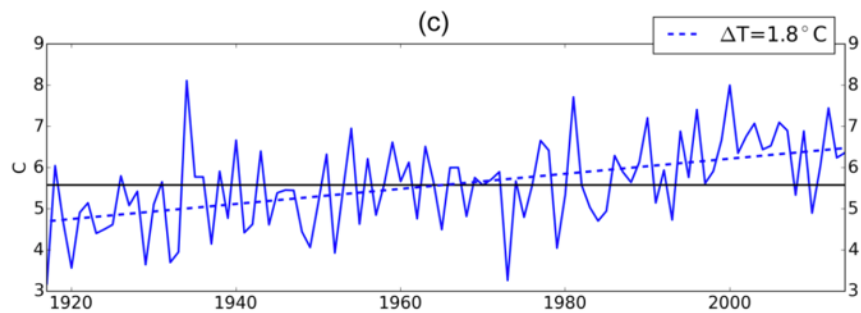
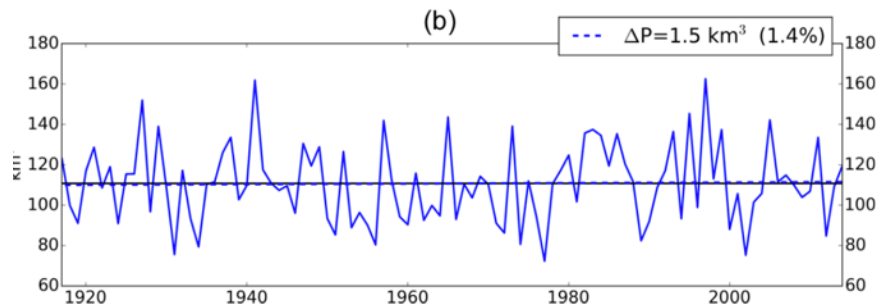
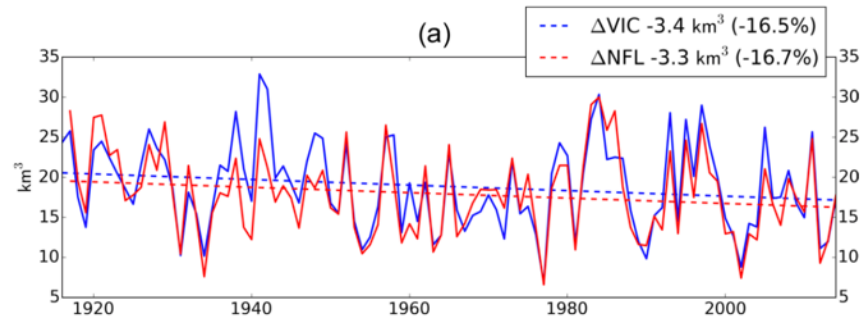


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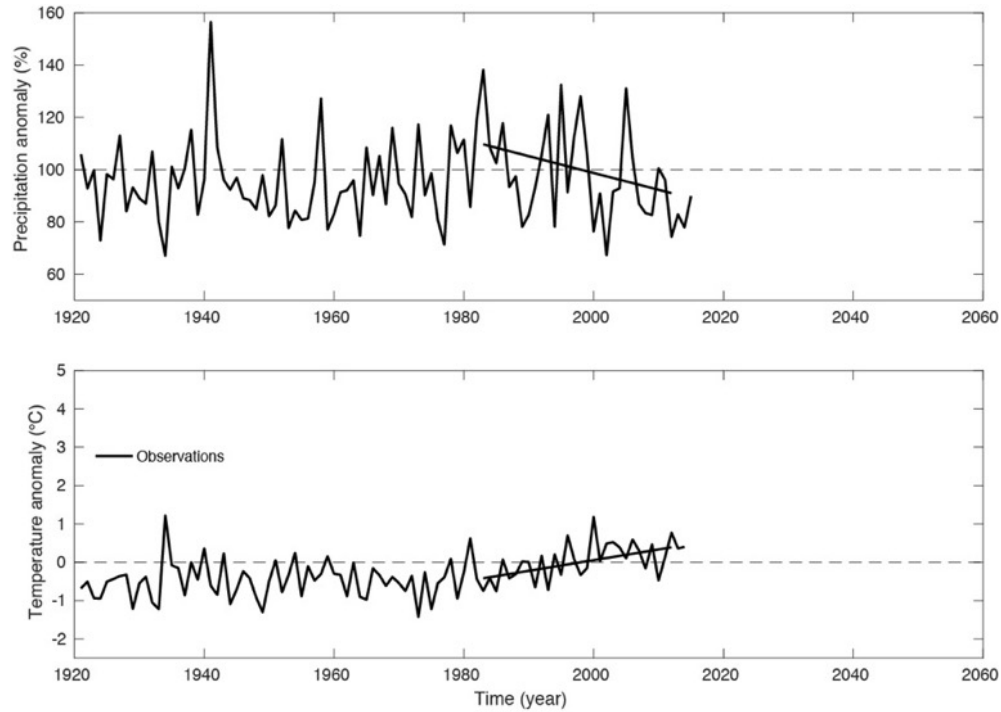
Next steps:

- Research to operations
- Domain expansion
- S2S
- Ensemble Streamflow Prediction

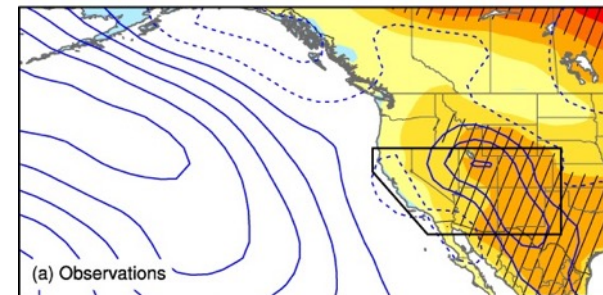
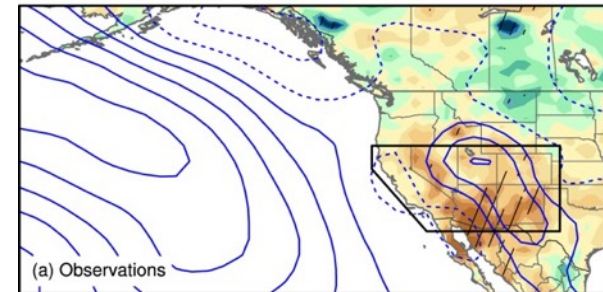




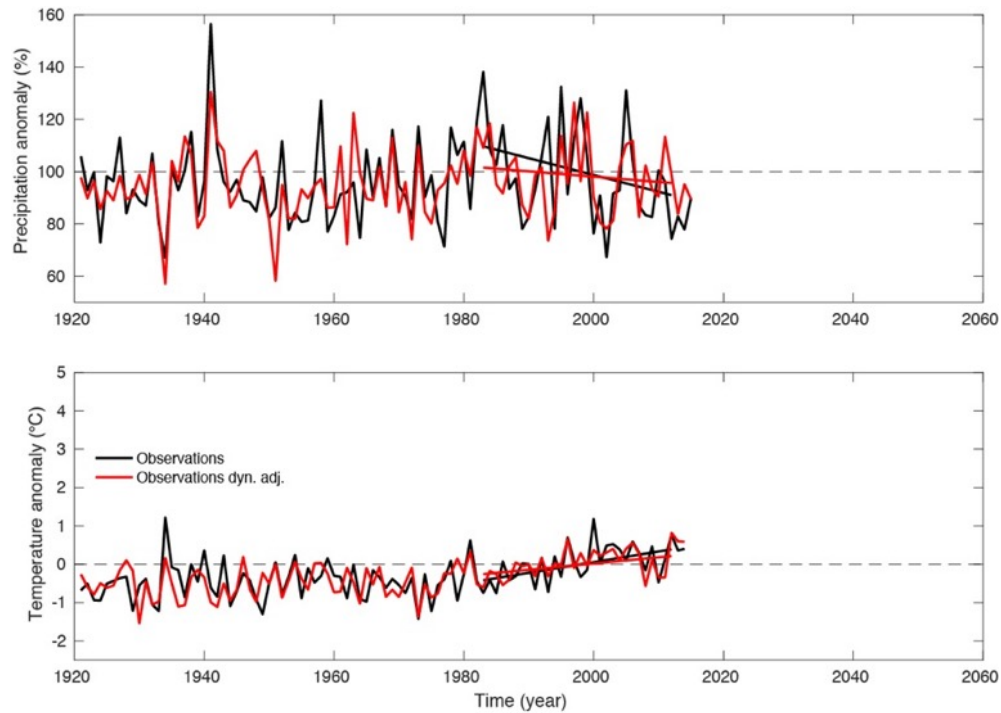
Southwest drying and warming



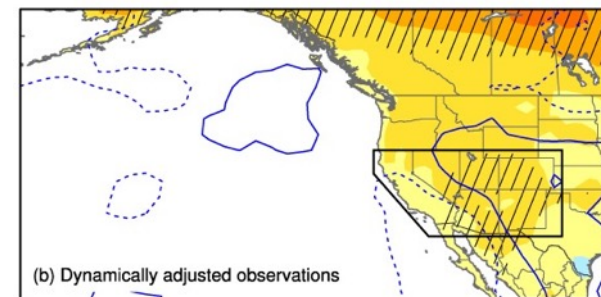
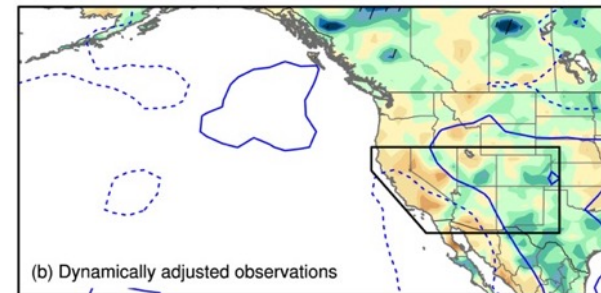
1983-2012 water year trend

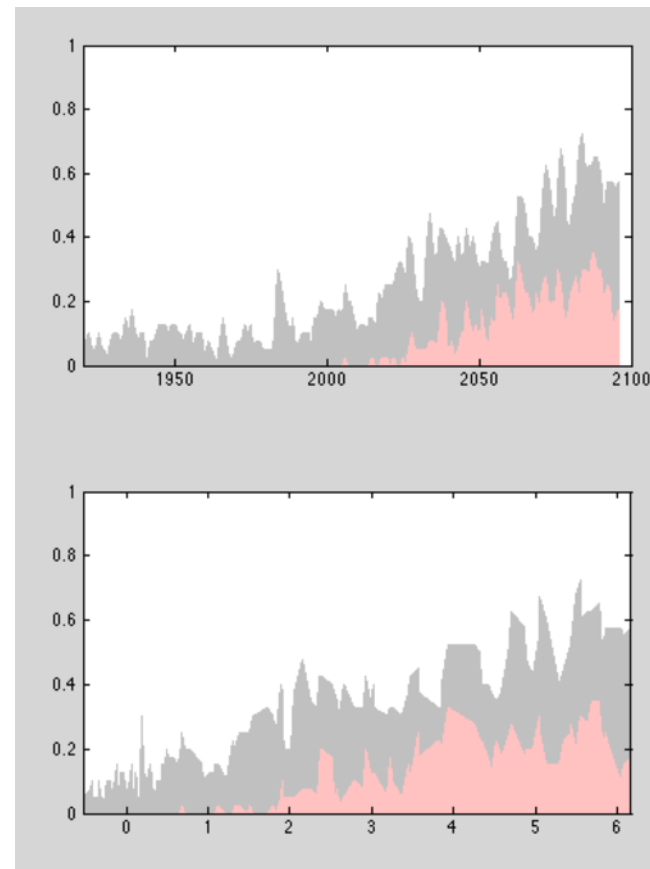
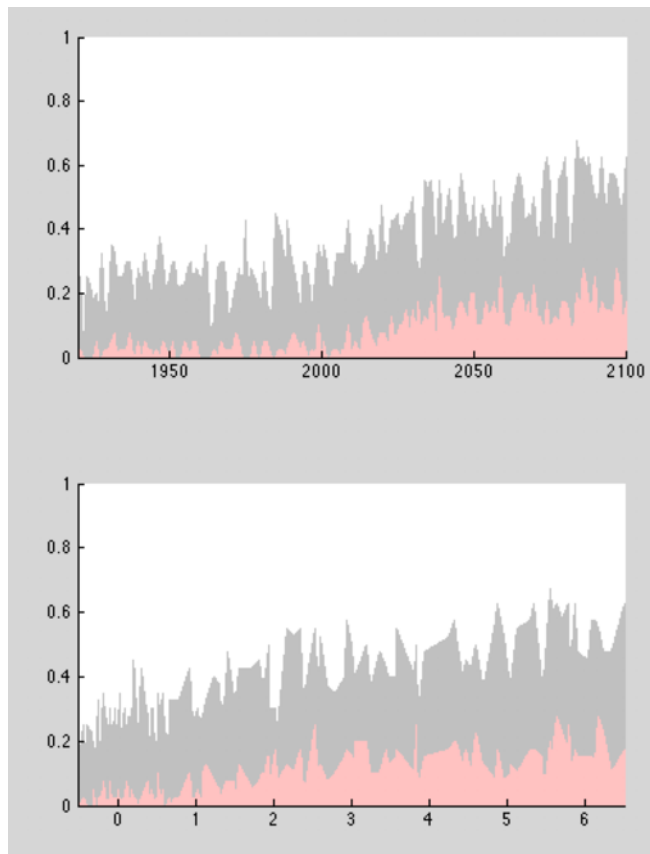


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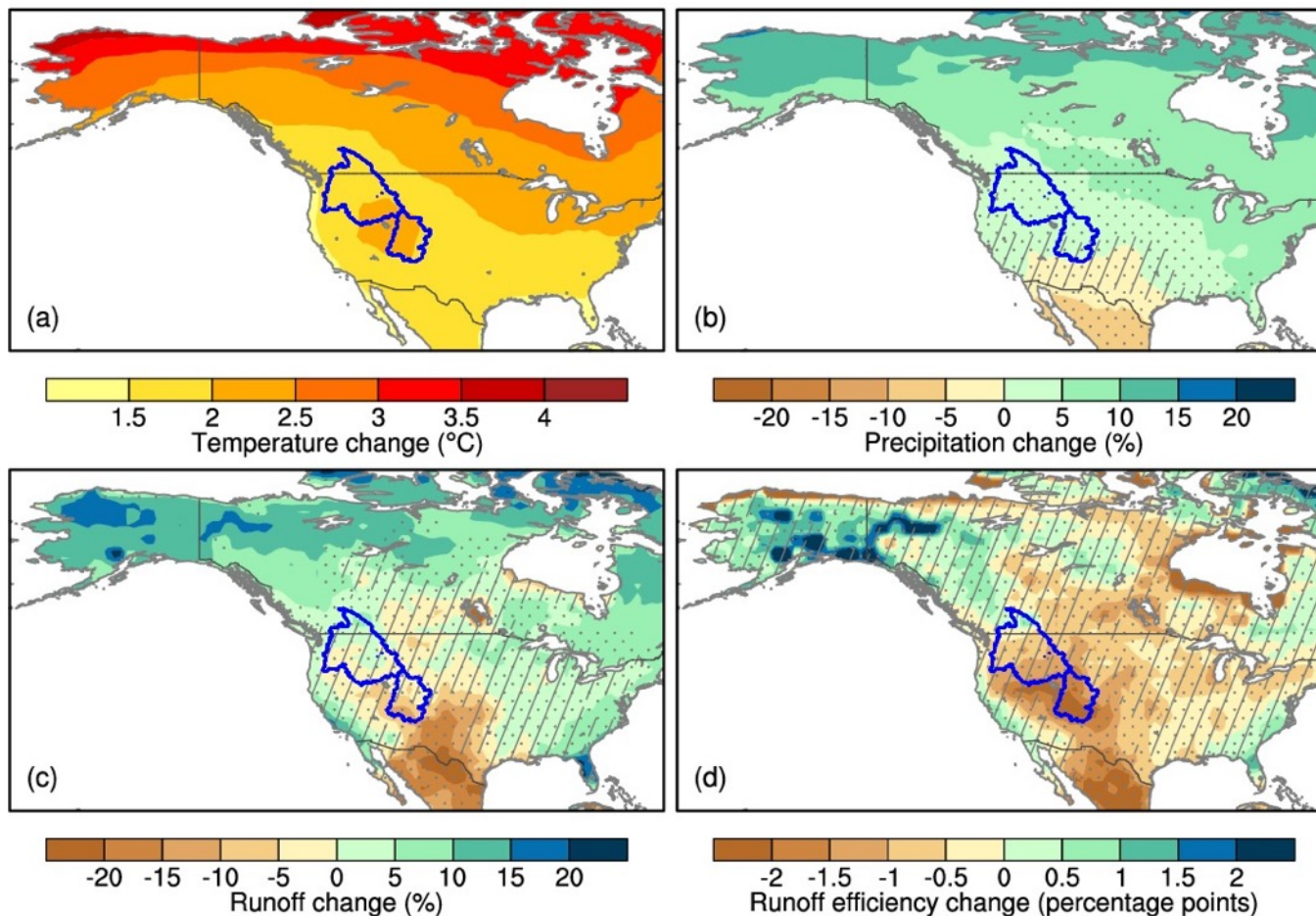
1983-2012 water year trend





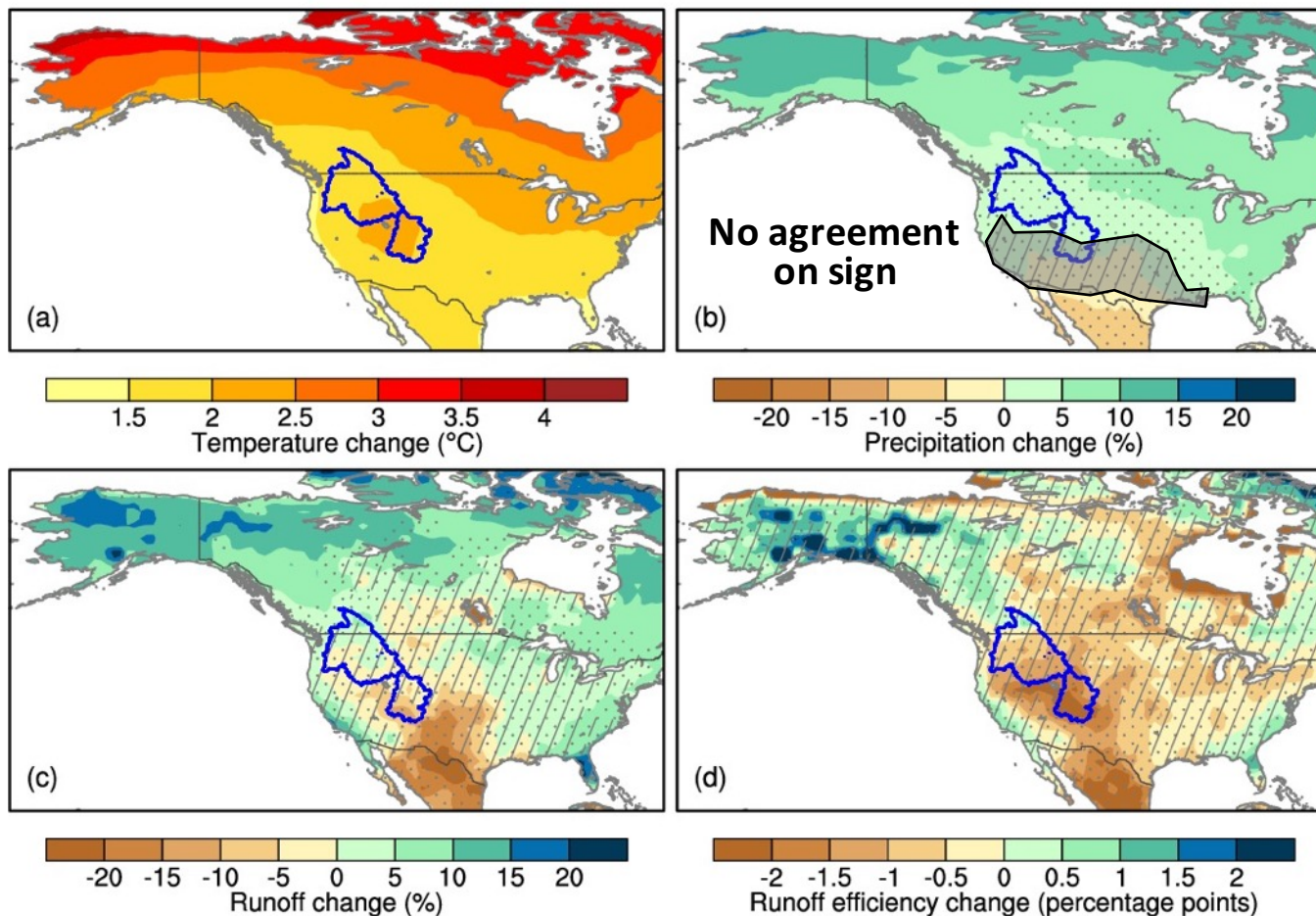
3. Runoff sensitivities in Earth System Models

CMIP5 multi-model mean change (2021-2050)-(1929-2008)



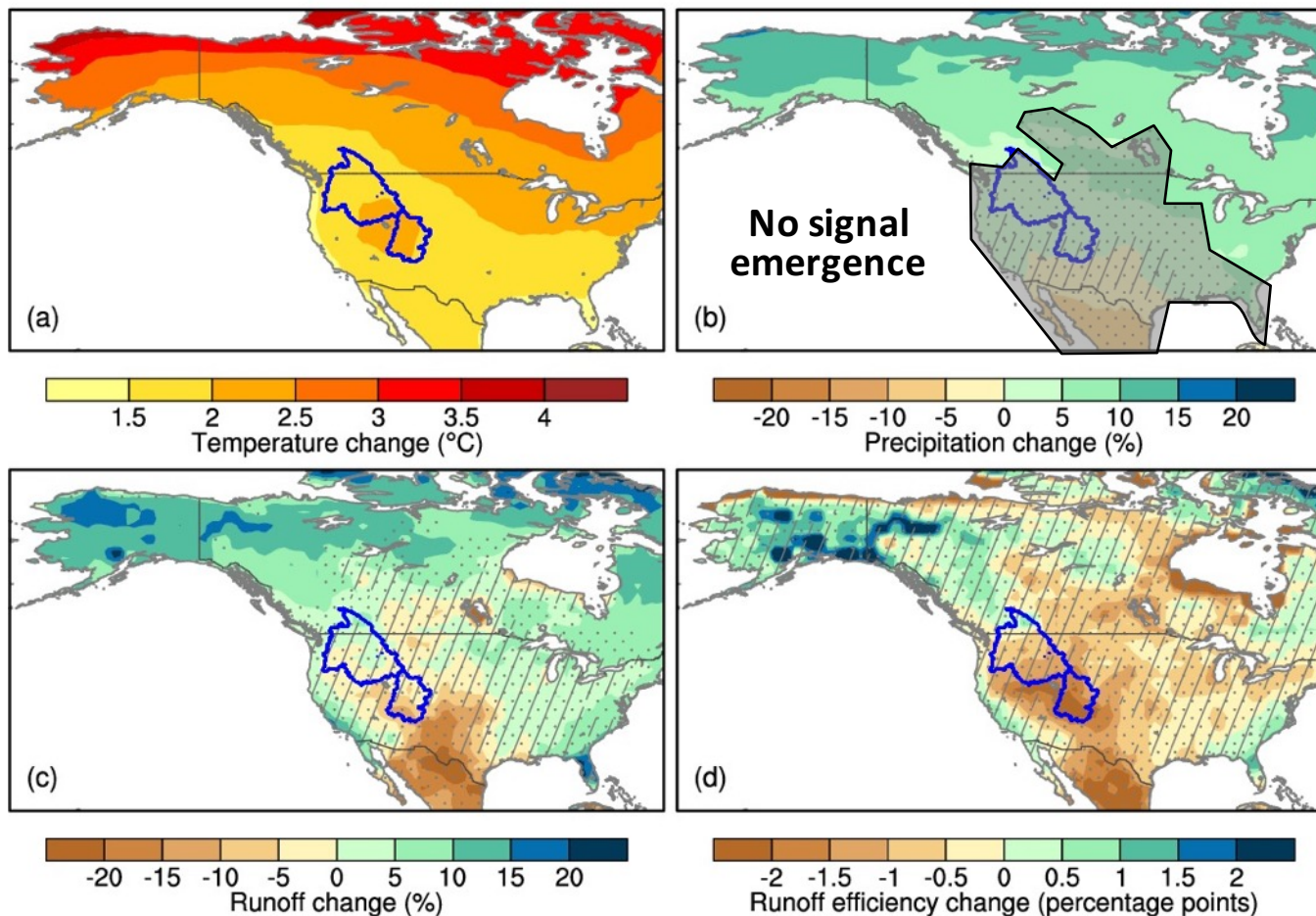
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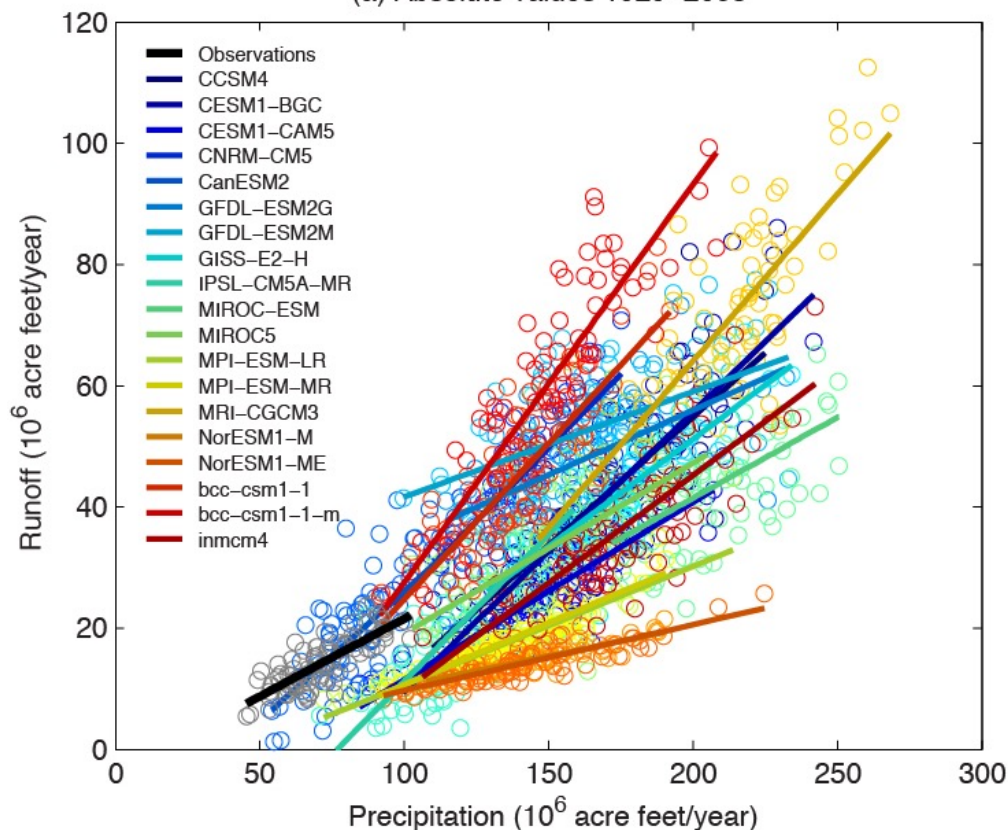
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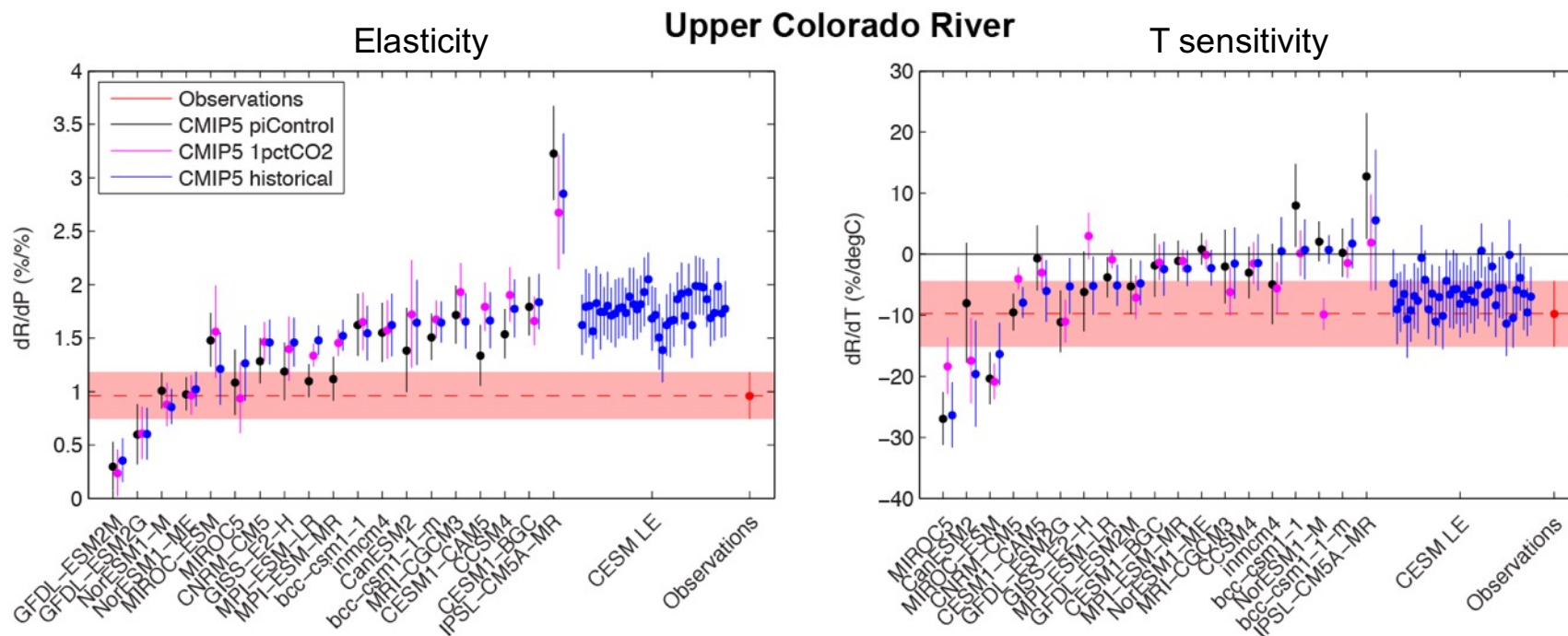
Upper Colorado River

(a) Absolute values 1929–2008

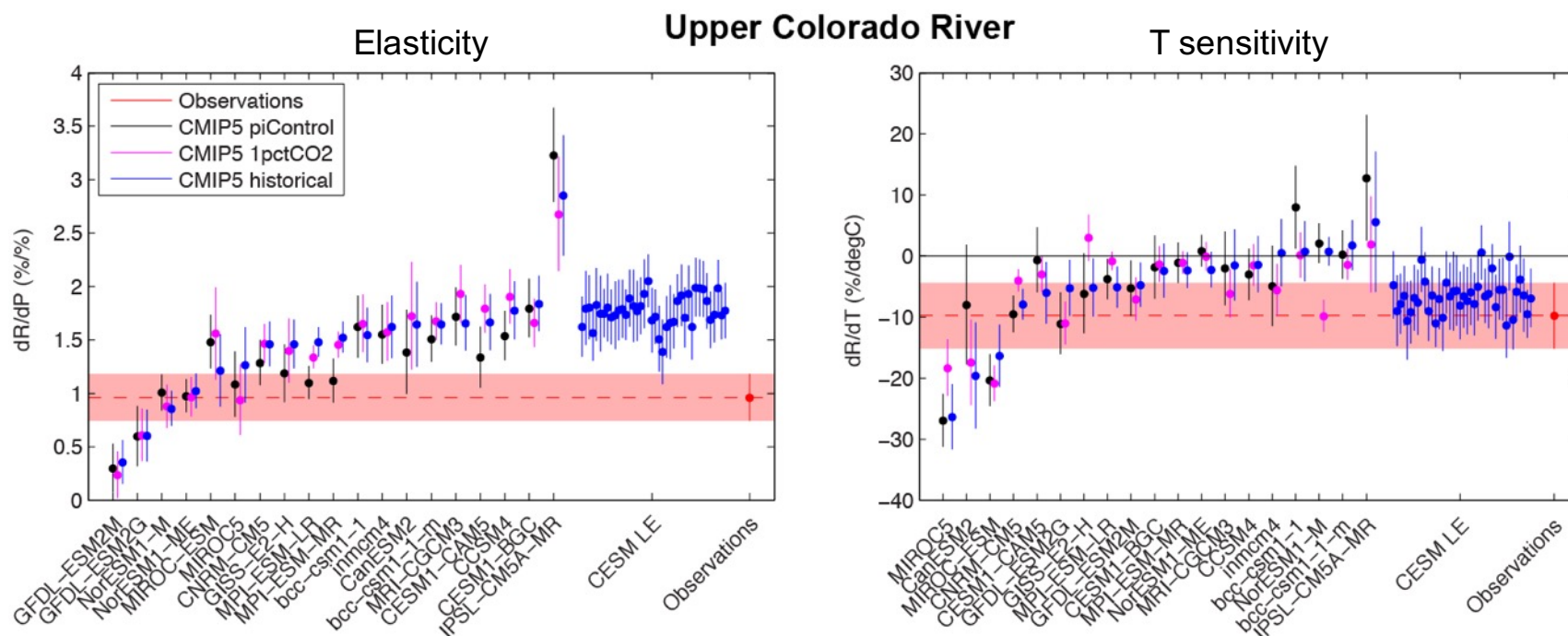


Runoff or P-E
projections with
GCMs or ESMs

3. Runoff sensitivities in Earth System Models



3. Runoff sensitivities in Earth System Models



- Implications for runoff and P-E projections?
- Reasons for model spread?
- Observational constraint possible?

Lehner, Wood, et al. (in prep.): *Hydrologic sensitivities in Earth System Models and their importance for regional hydrologic change projections*

Thanks! Questions?