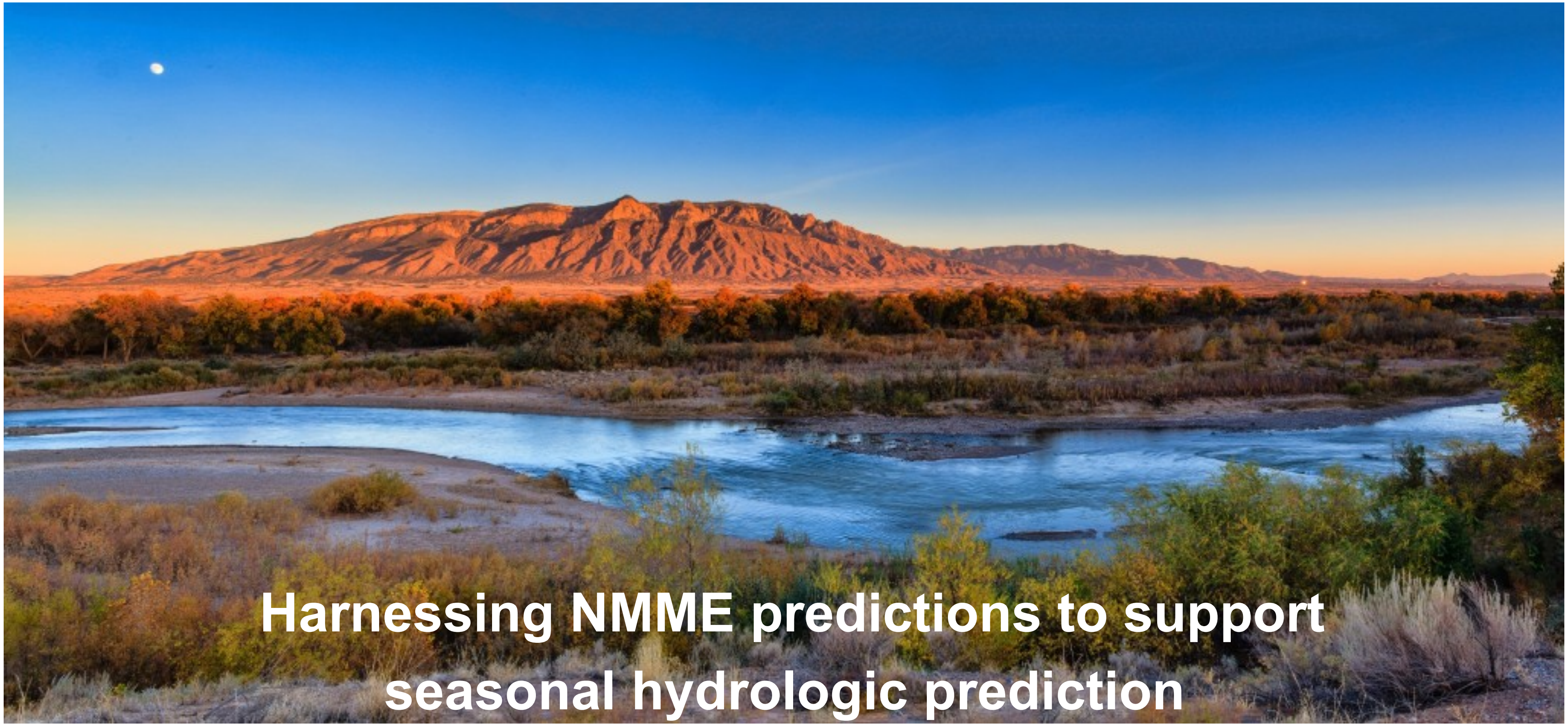


Harnessing NMME predictions to support seasonal hydrologic prediction

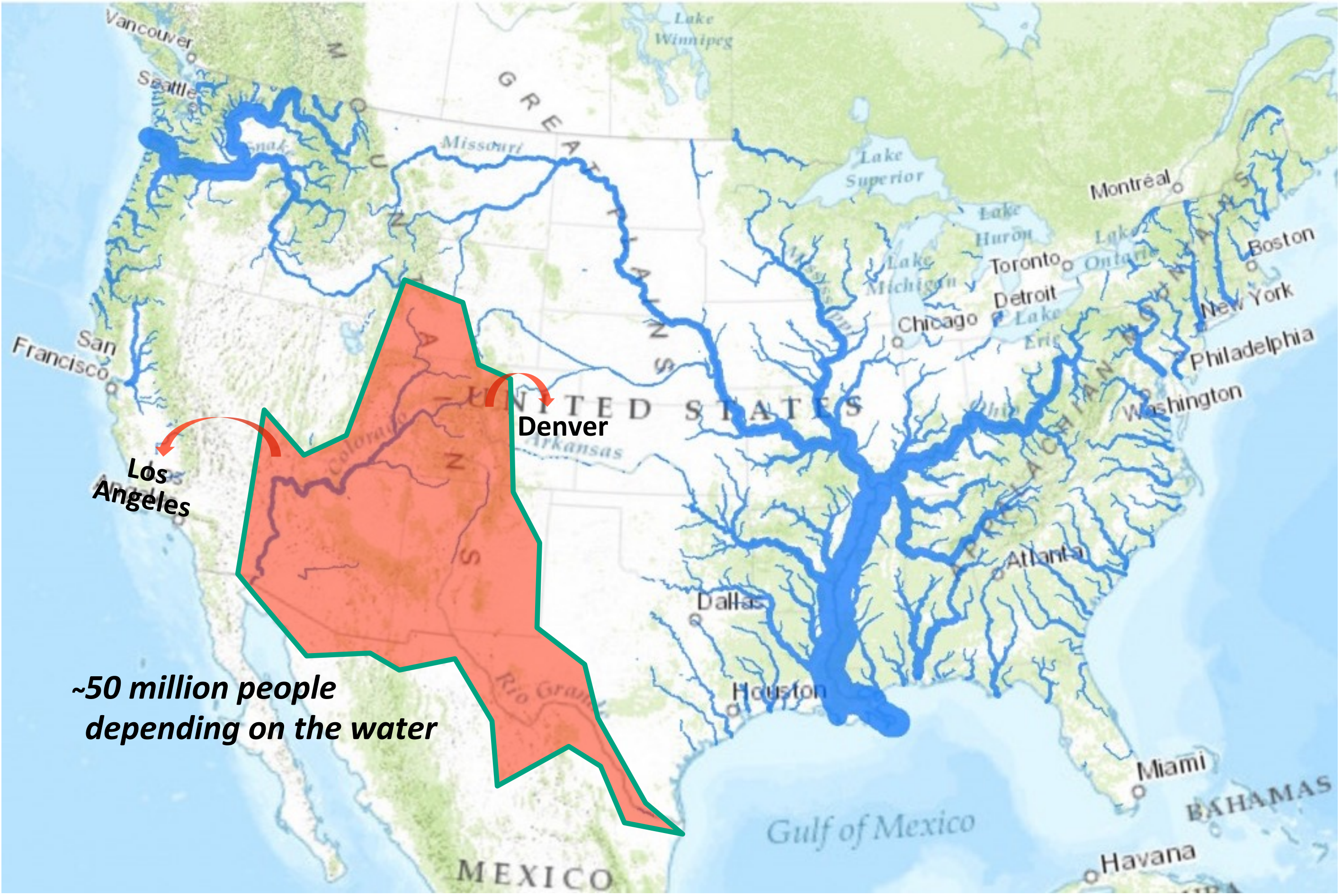
Flavio Lehner[1,2]

Andy Wood[2], Dagmar Llewellyn[3], Douglas Blatchford[4], Angus Goodbody[5], Florian Pappenberger[6]

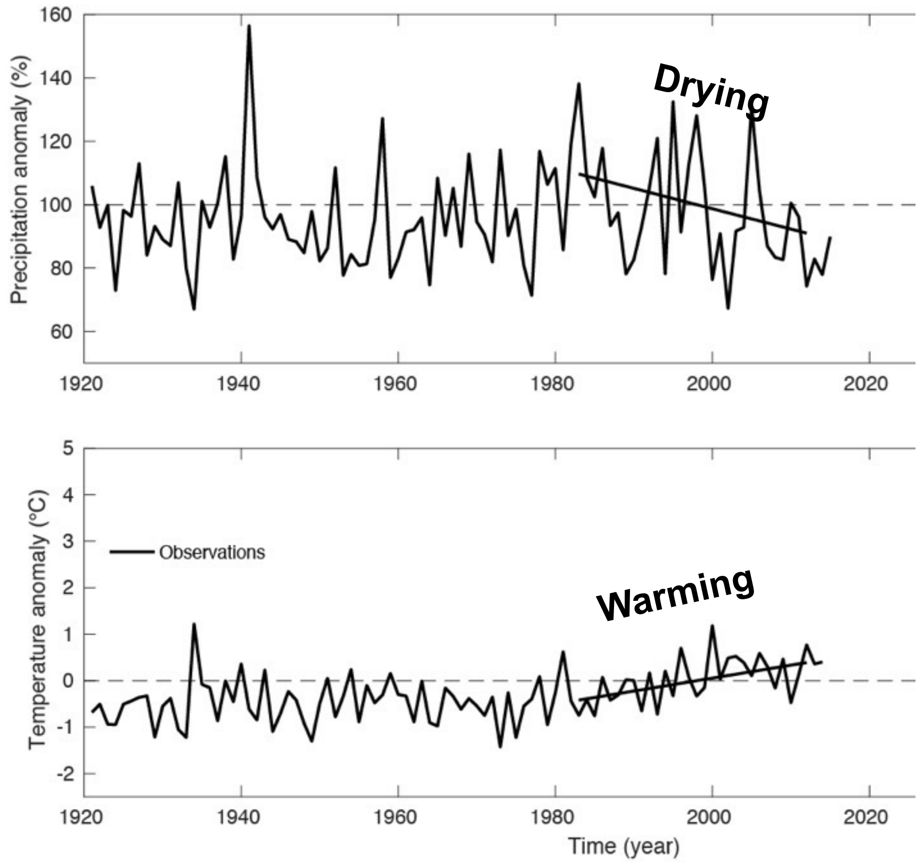
[1]*Research Applications Lab, NCAR, Boulder, USA*
[2]*Climate & Global Dynamics Lab, NCAR, Boulder, USA*
[3]*Bureau of Reclamation, Albuquerque, USA*
[4]*Bureau of Reclamation, Boulder City, USA*
[5]*National Water and Climate Center, Portland, USA*
[6]*ECMWF, Reading, UK*

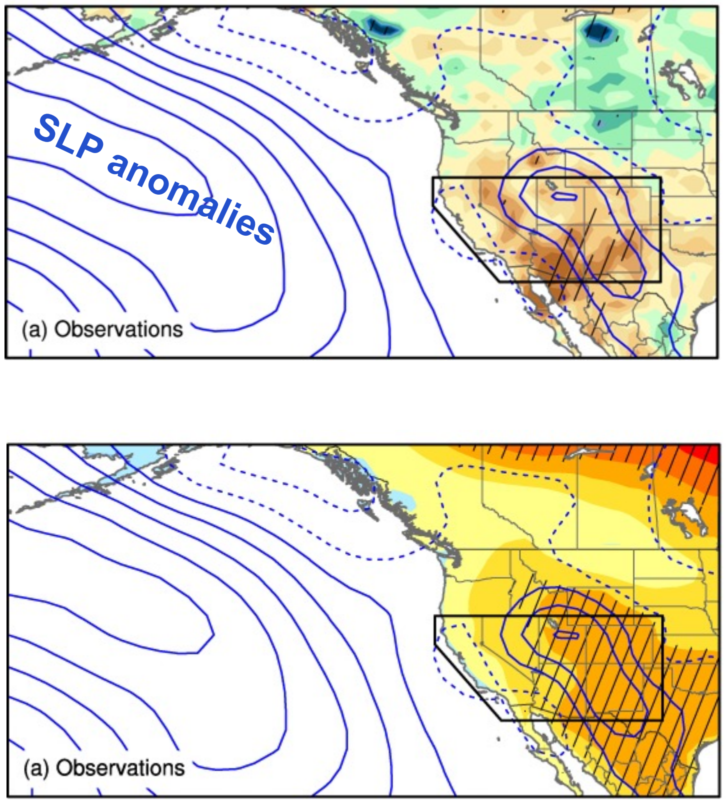
The water for the Southwest

The water for the Southwest



Southwest warming and drying





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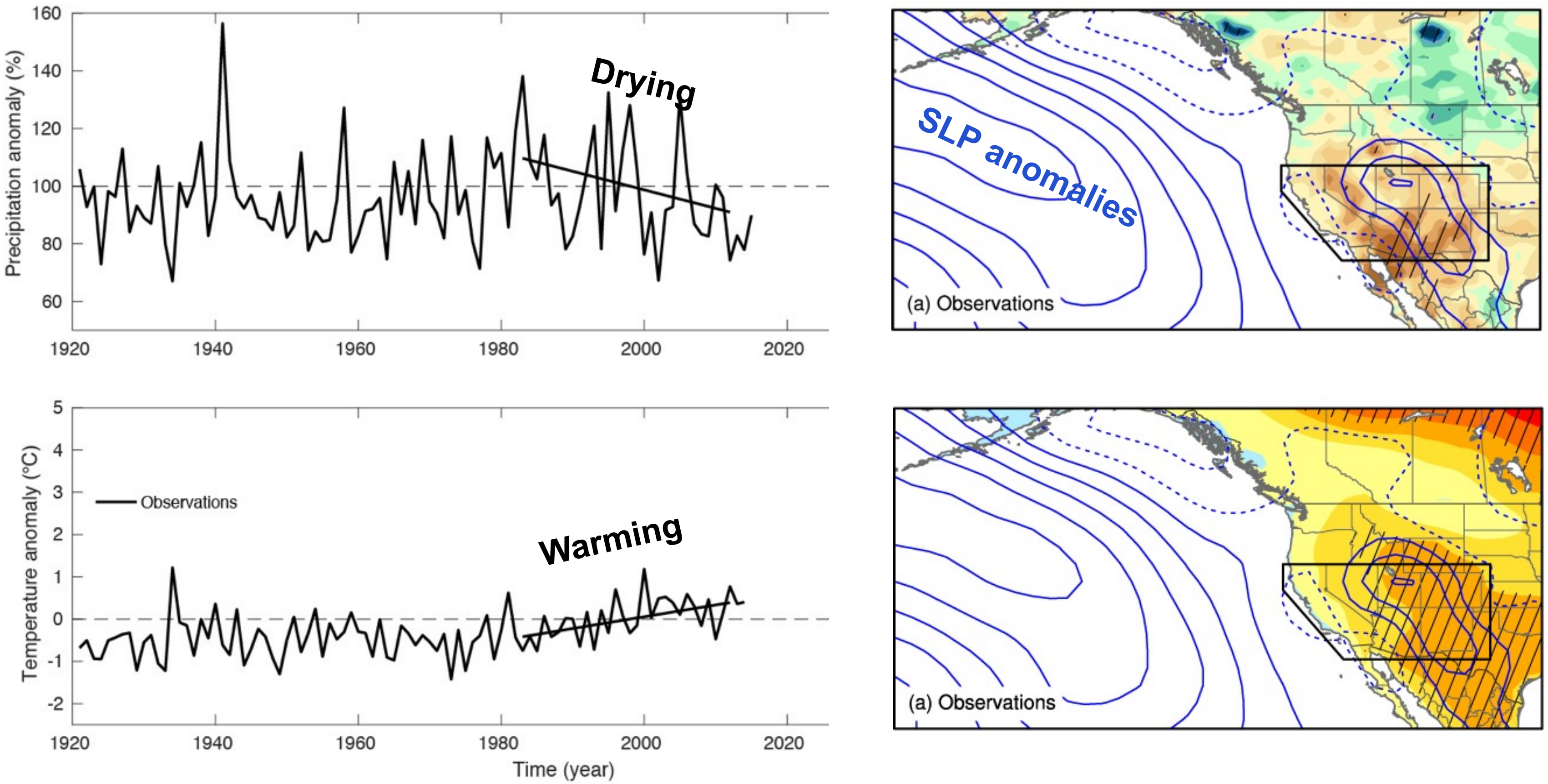
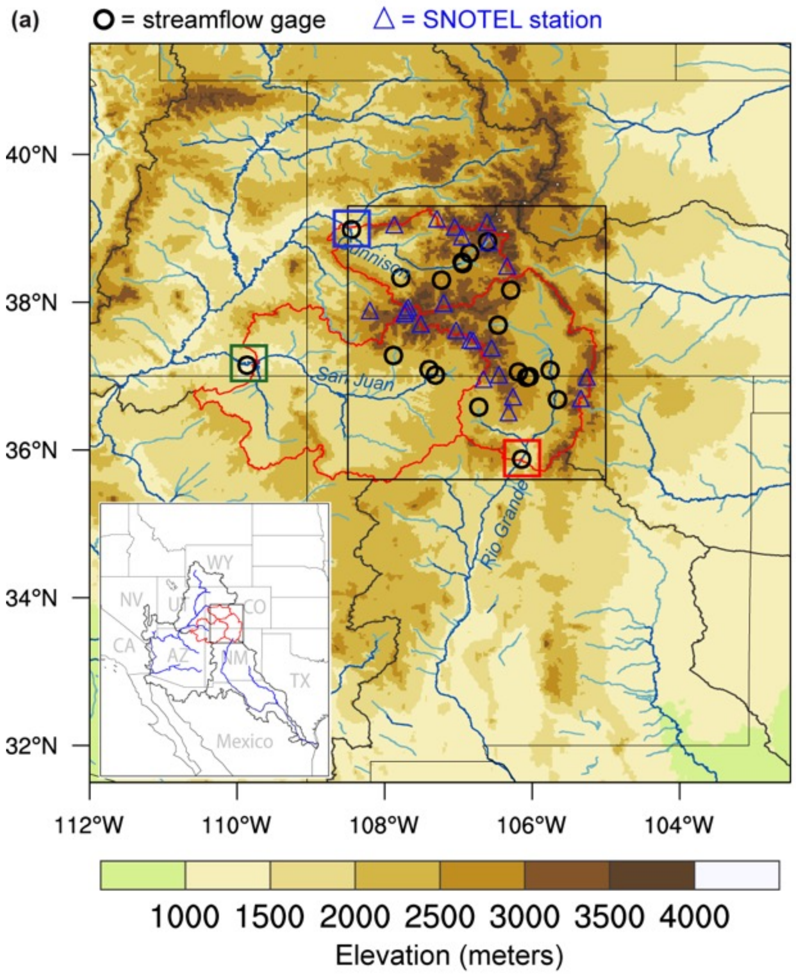


Strong hydroclimate trend → impacts on water resources (streamflow and reservoirs)

Lehner et al. (2018): "Attributing the U.S. Southwest's Recent Shift Into Drier Conditions"

Statistical seasonal streamflow forecasting



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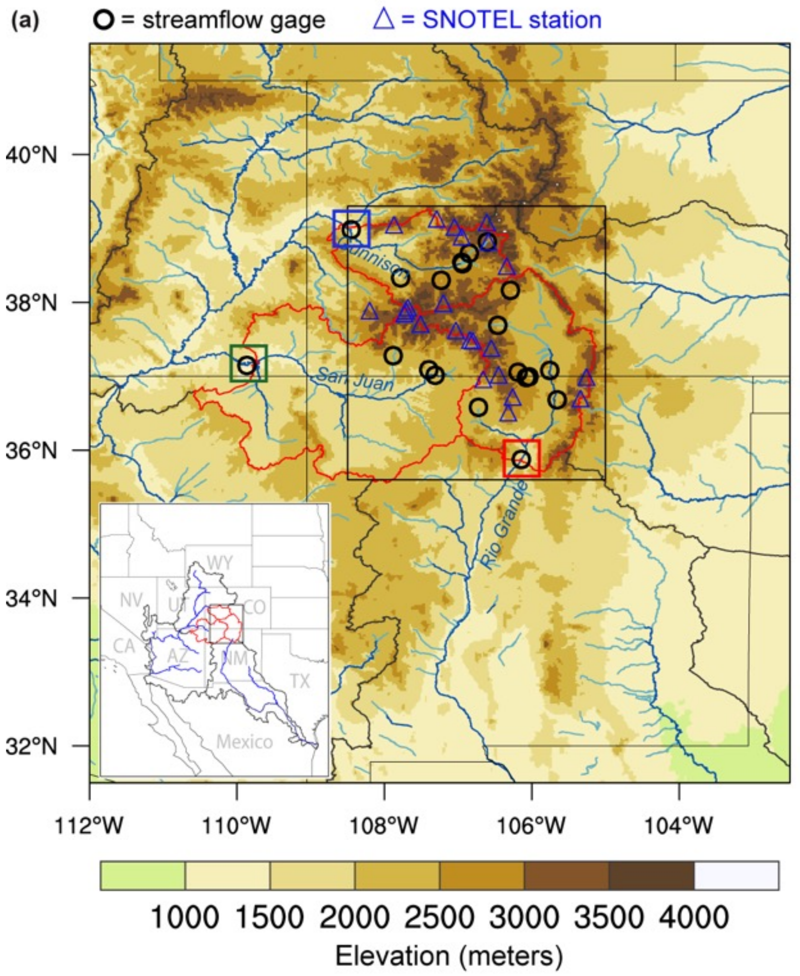
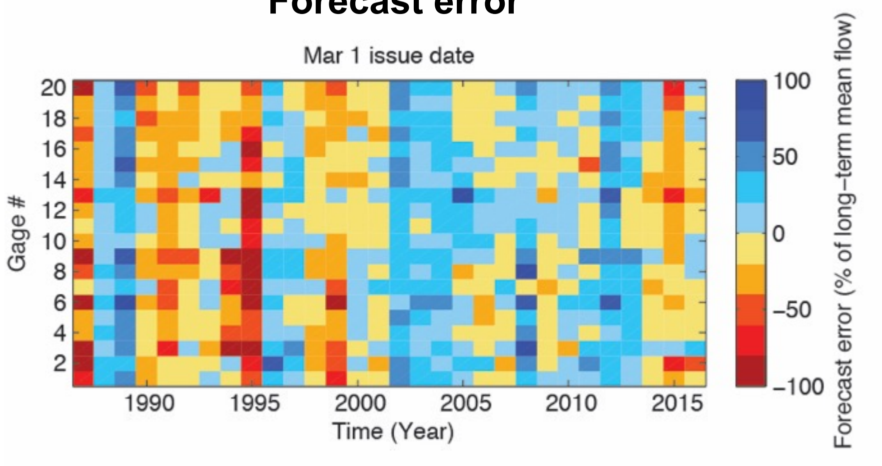


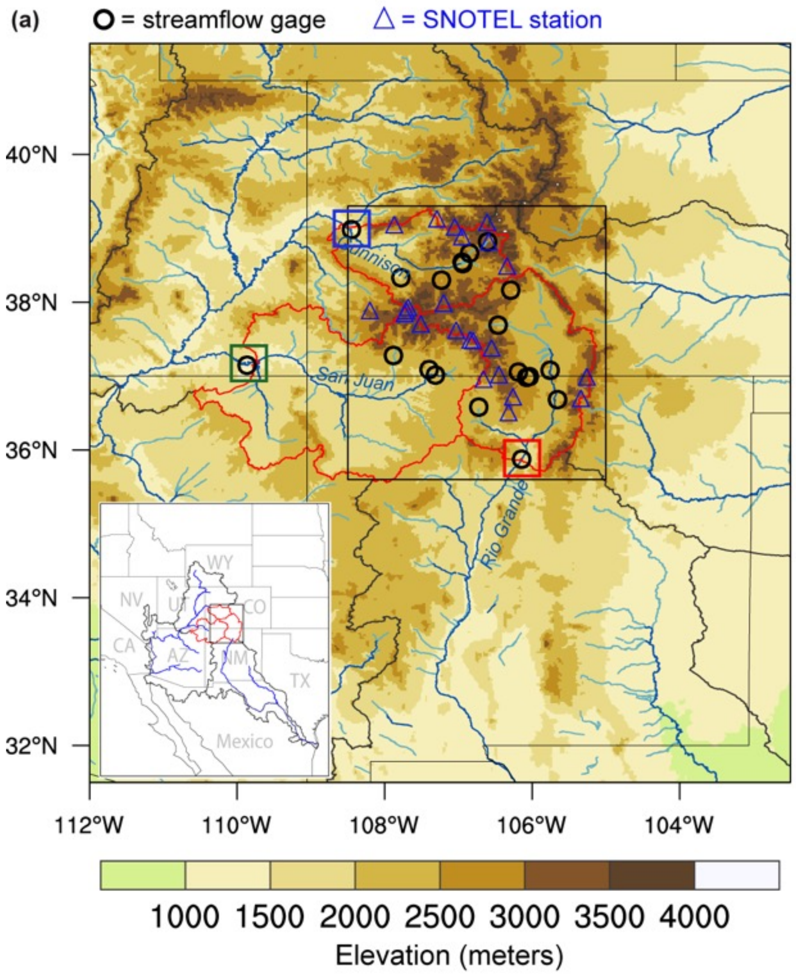
Forecast error



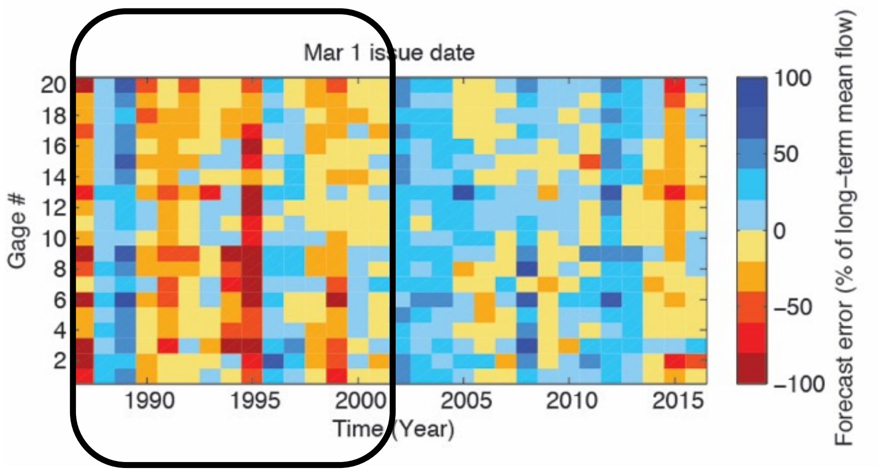
'Baseline forecast' (mimicked NRCS forecast)

Lehner et al. (2017a)

Statistical seasonal streamflow forecasting



Tendency to
underforecast



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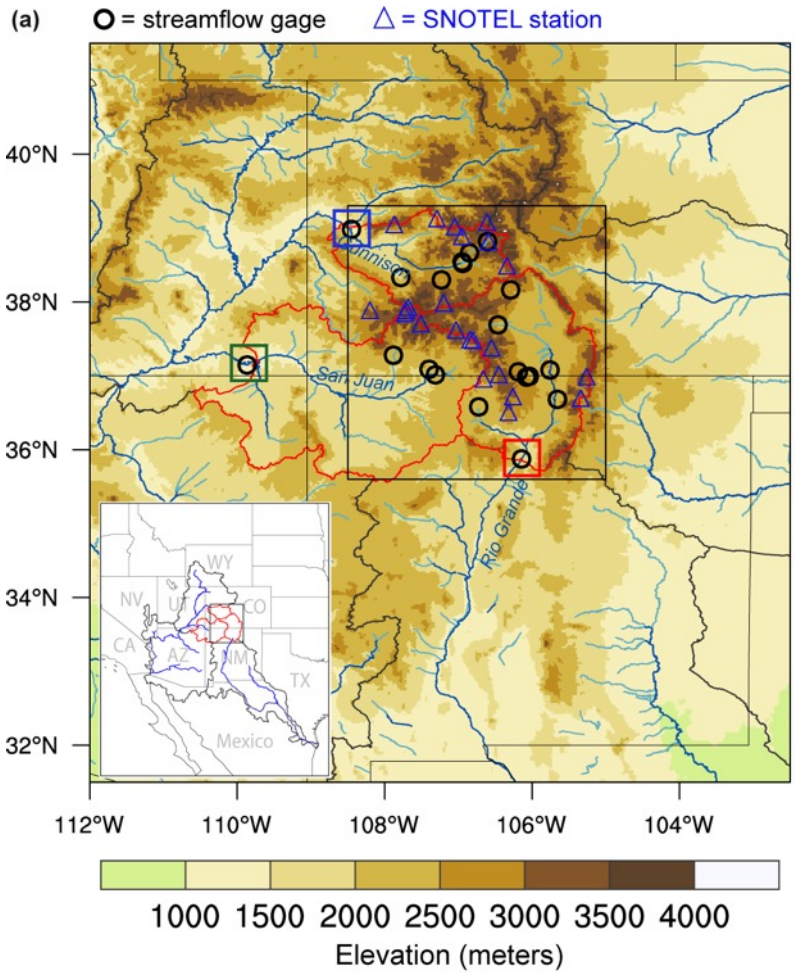

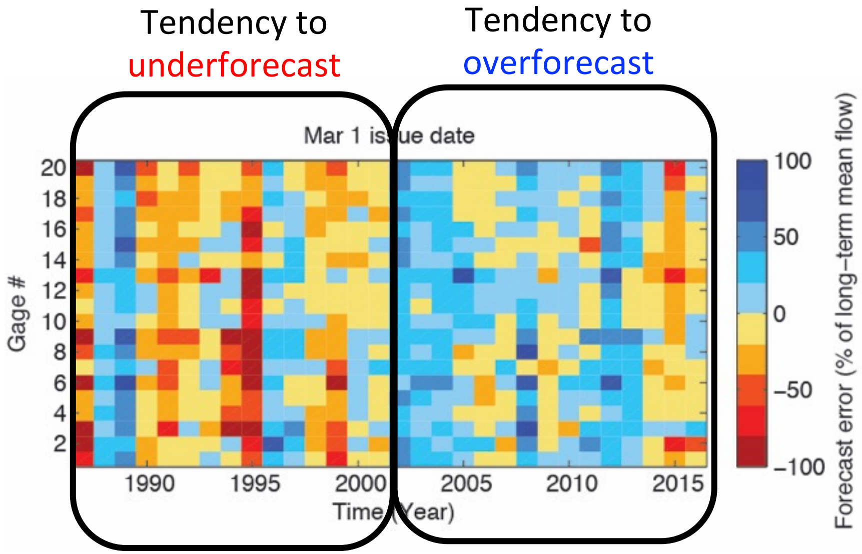

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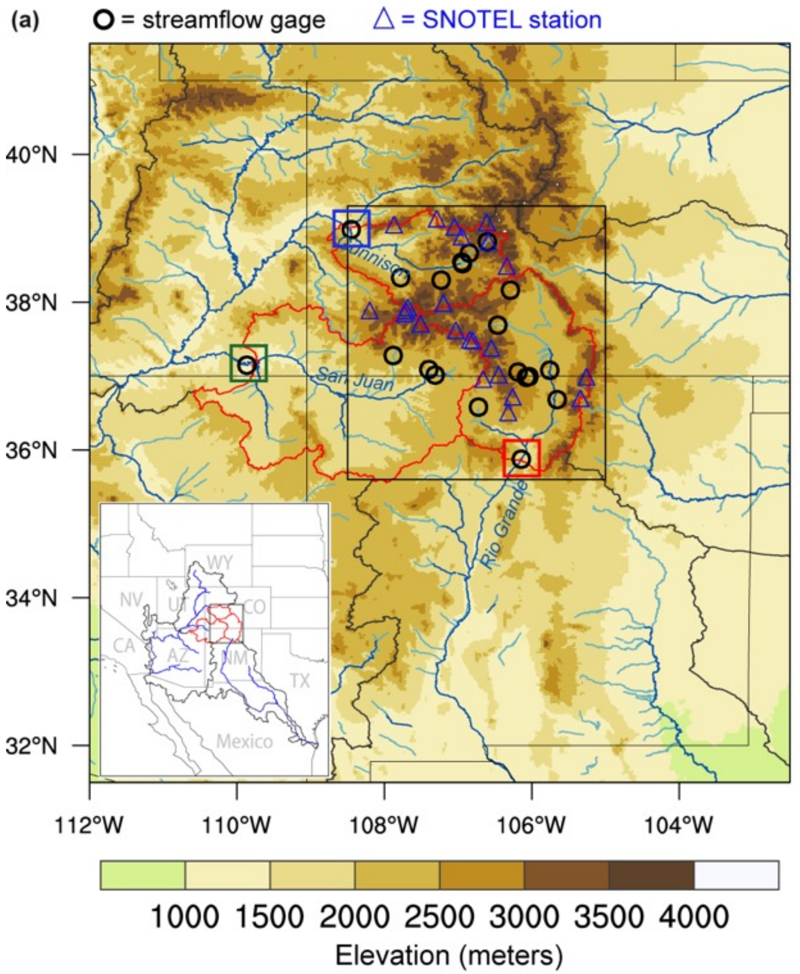

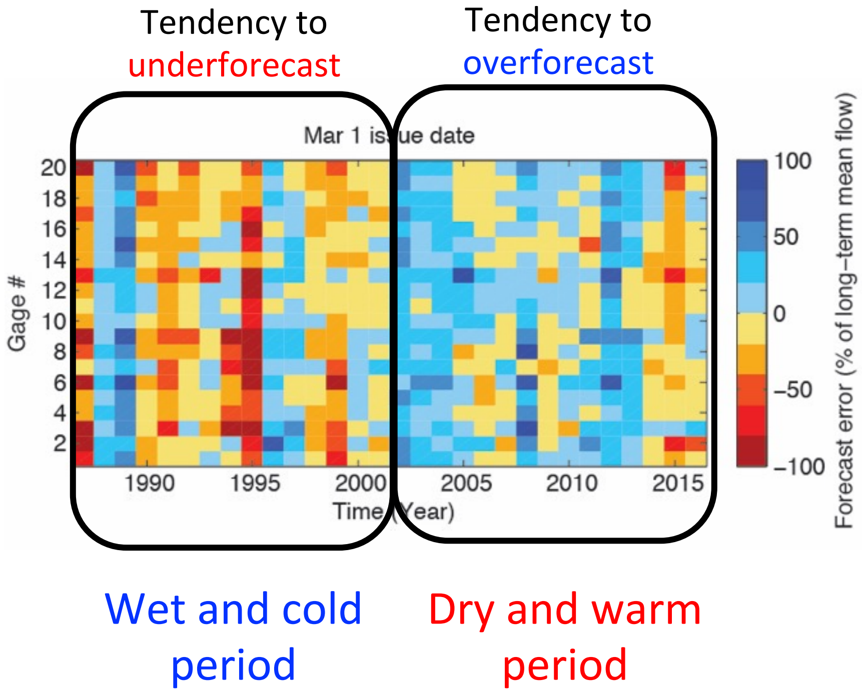

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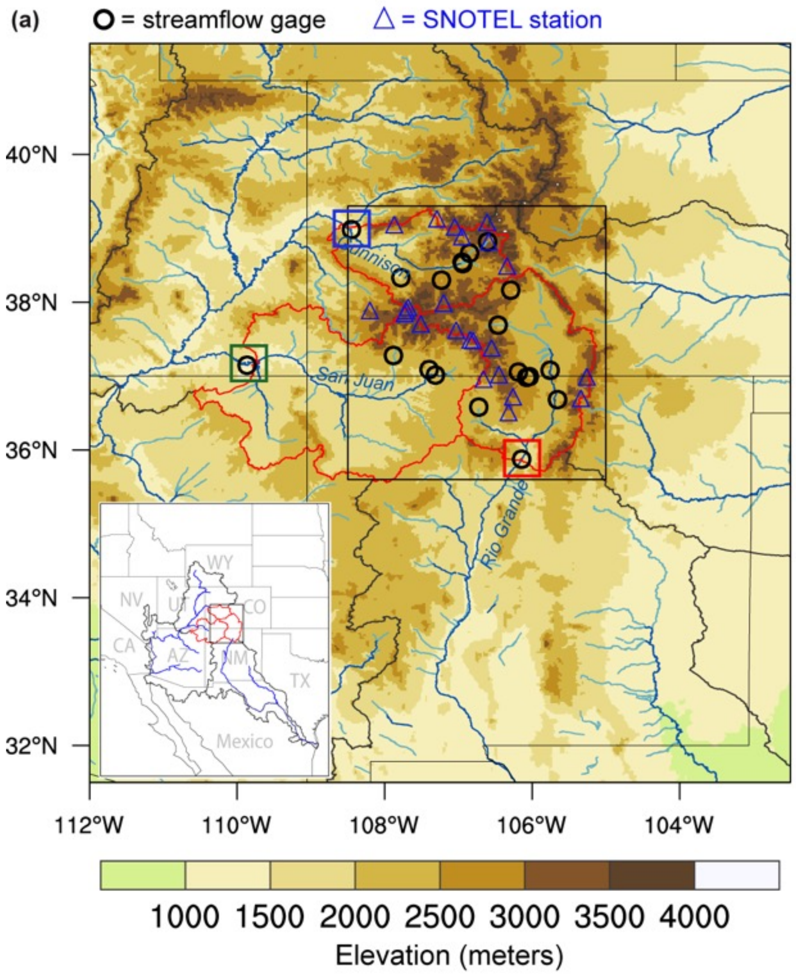
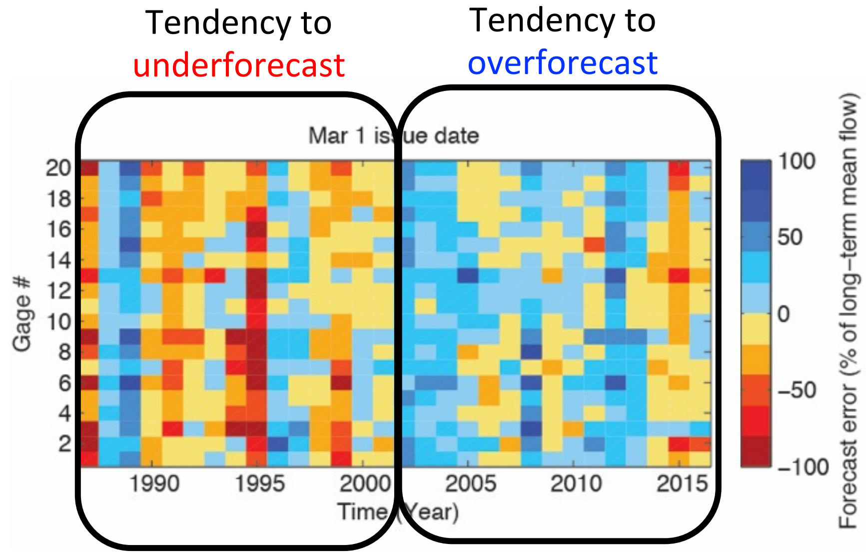




Wet and cold period

Dry and warm period

Efficient period?

Inefficient period?

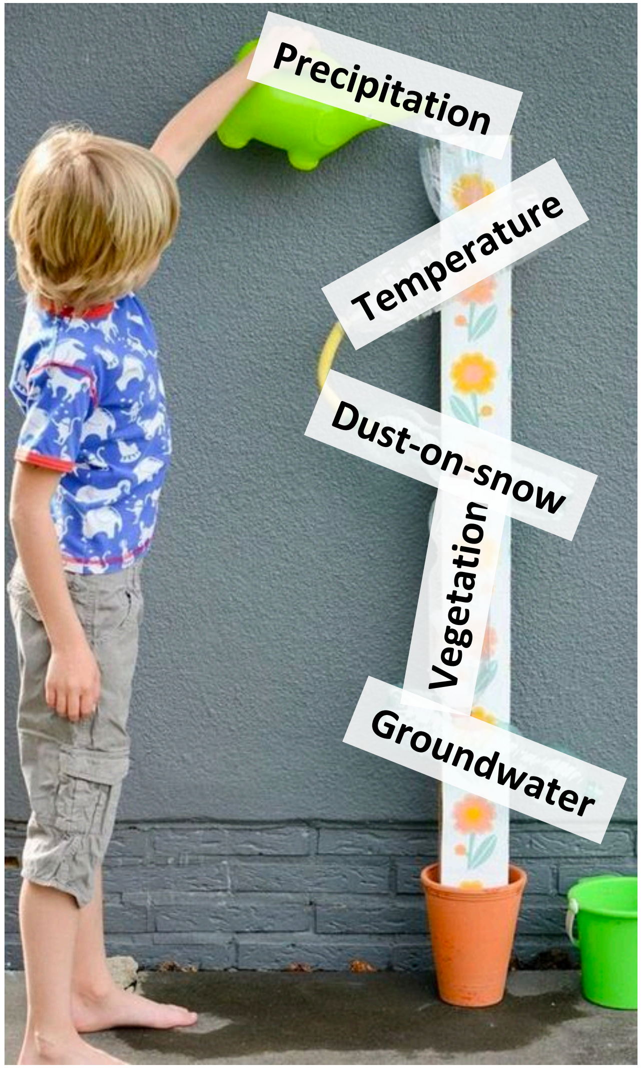
The concept of runoff efficiency

Runoff efficiency

= water out/water in

= streamflow/precipitation

The concept of runoff efficiency



Runoff efficiency

= water out/water in

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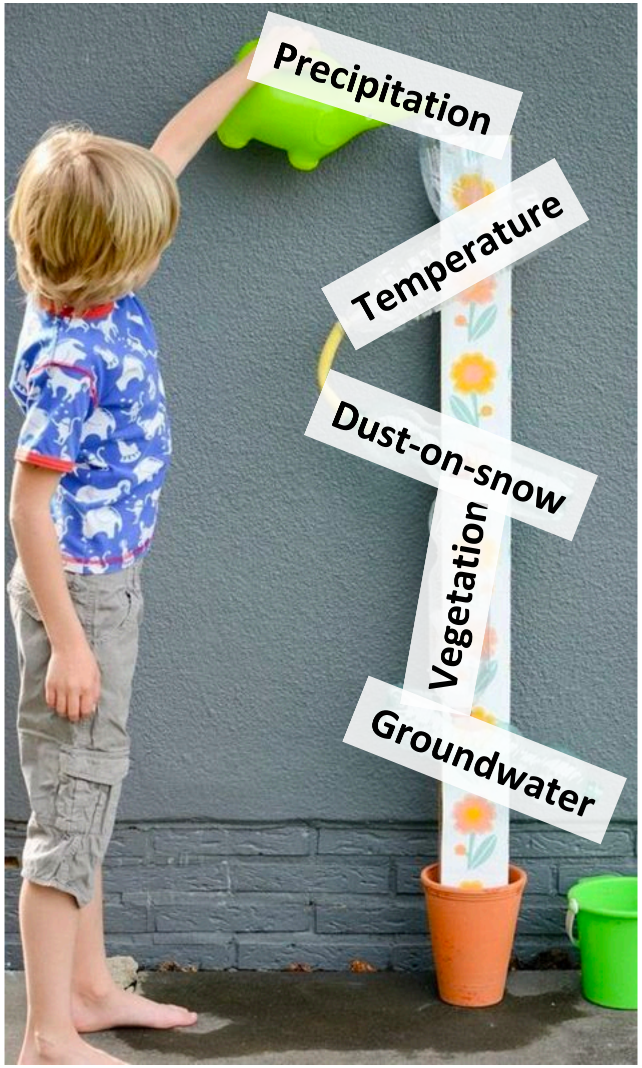
RE = f(precipitation, temperature, dust-on-snow, vegetation, groundwater, …)

The concept of runoff efficiency



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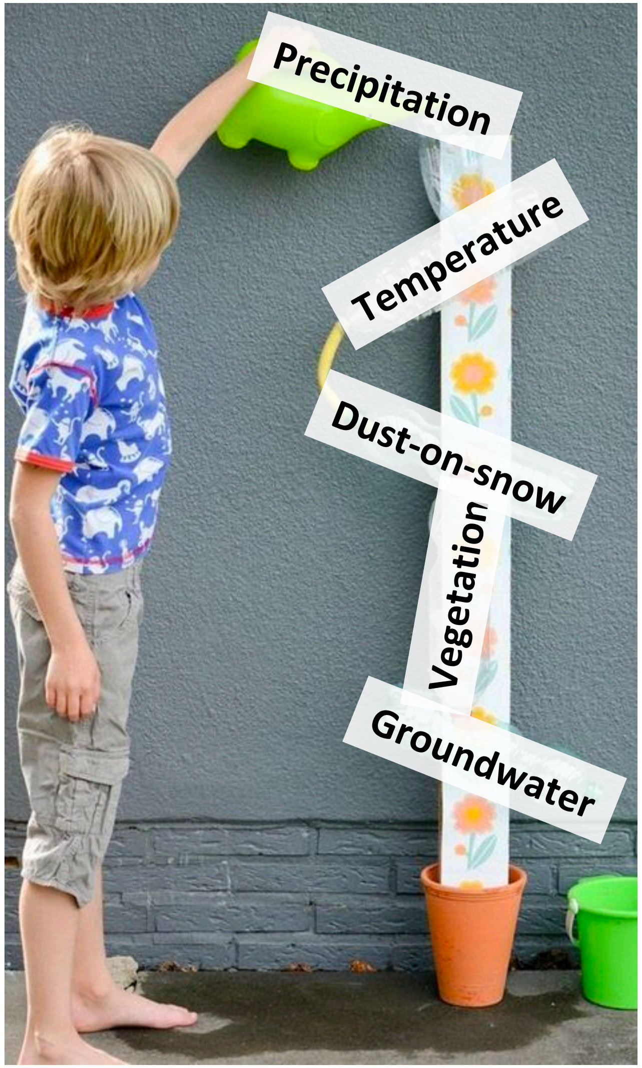
“**Runoff efficiency** is found to vary primarily in proportion to precipitation, but there exists a secondary influence of temperature.”

Lehner et al. (2017b)

The concept of runoff efficiency



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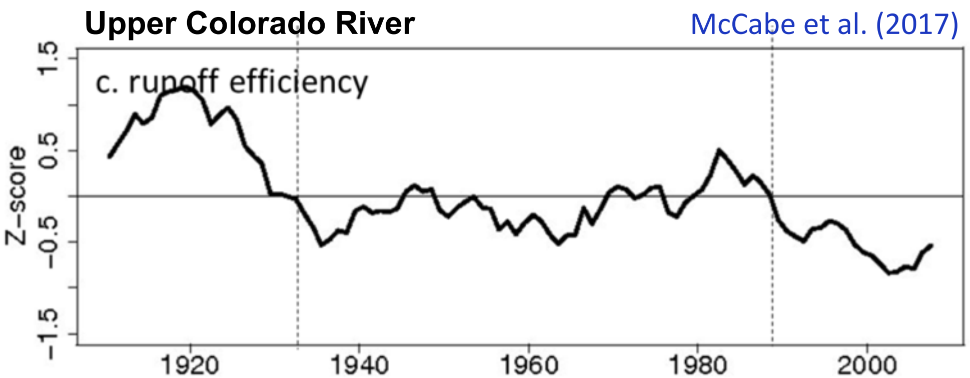
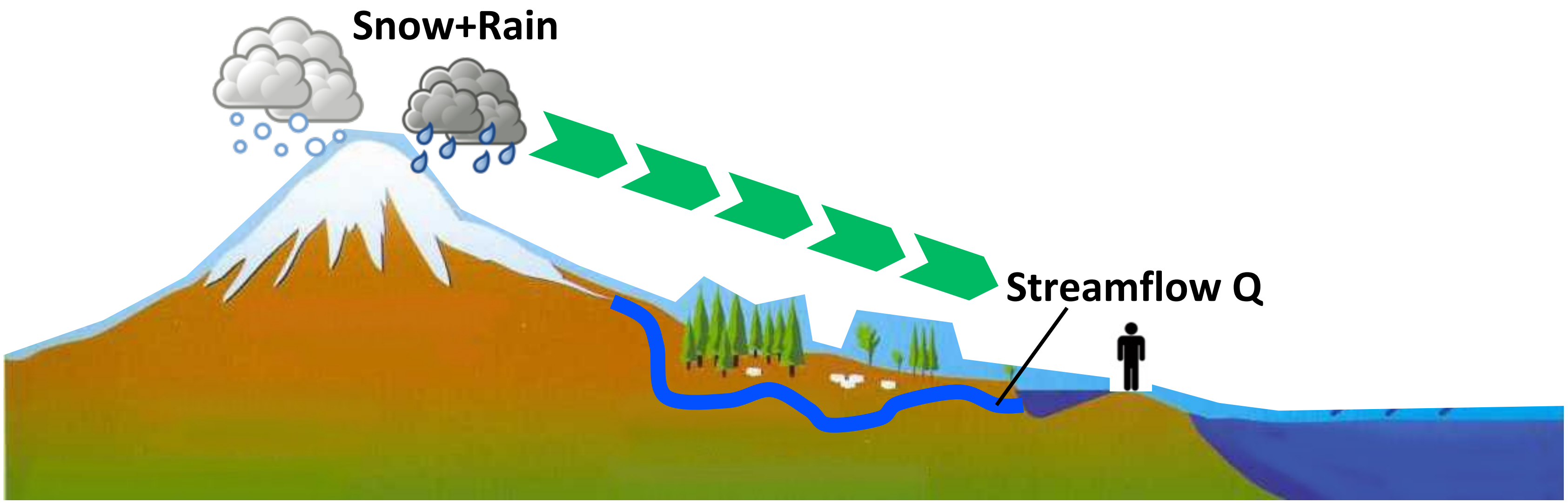


Including temperature into streamflow forecasting

Statistical seasonal streamflow forecasting

"Water Supply Forecasts"



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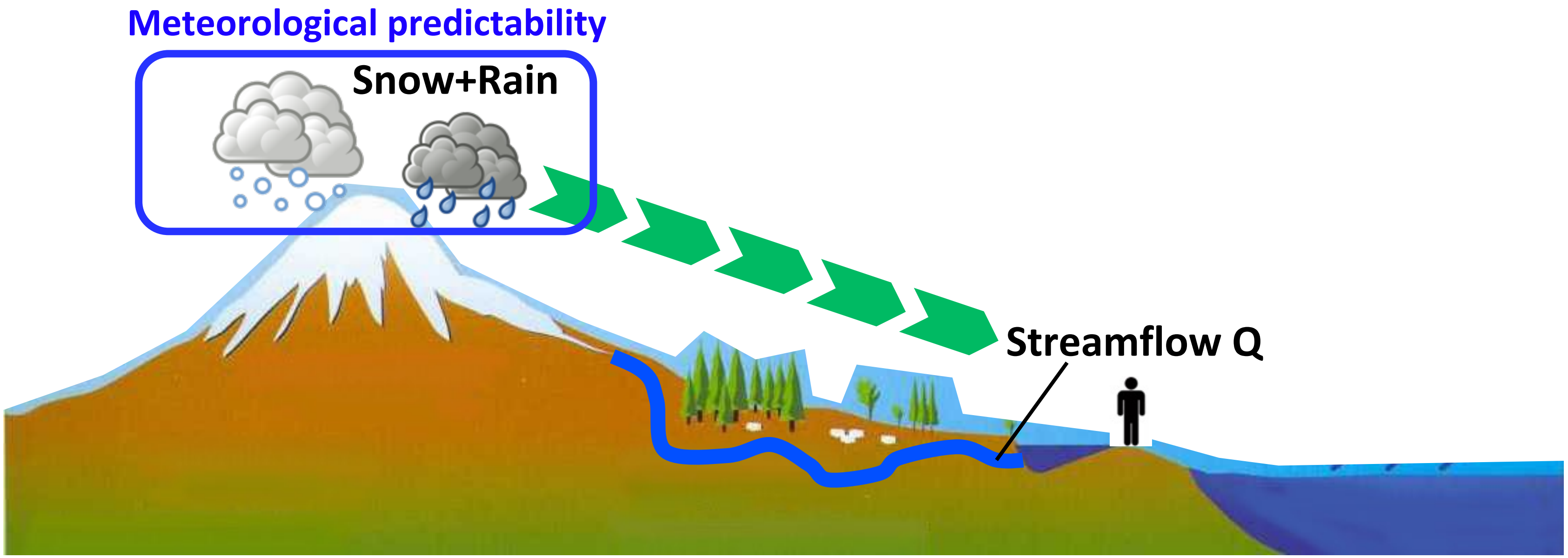

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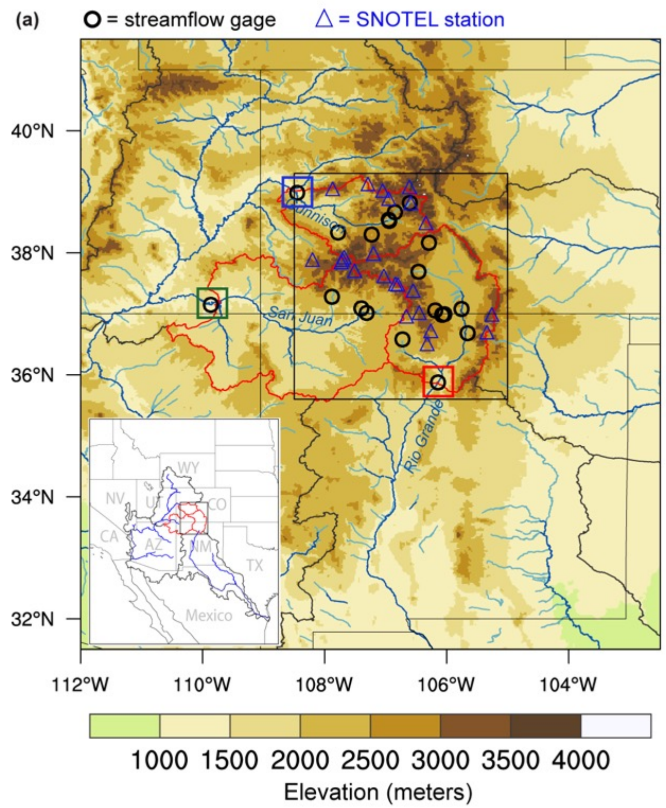

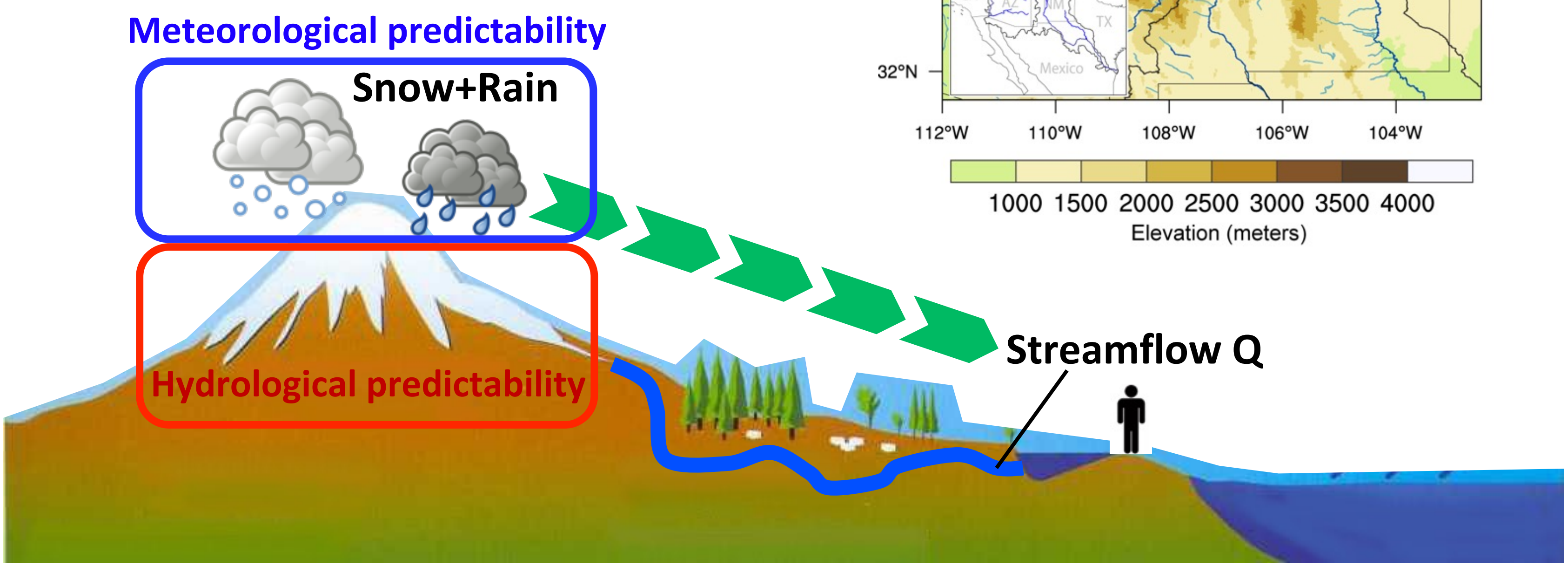

Lehner et al. (2017a)

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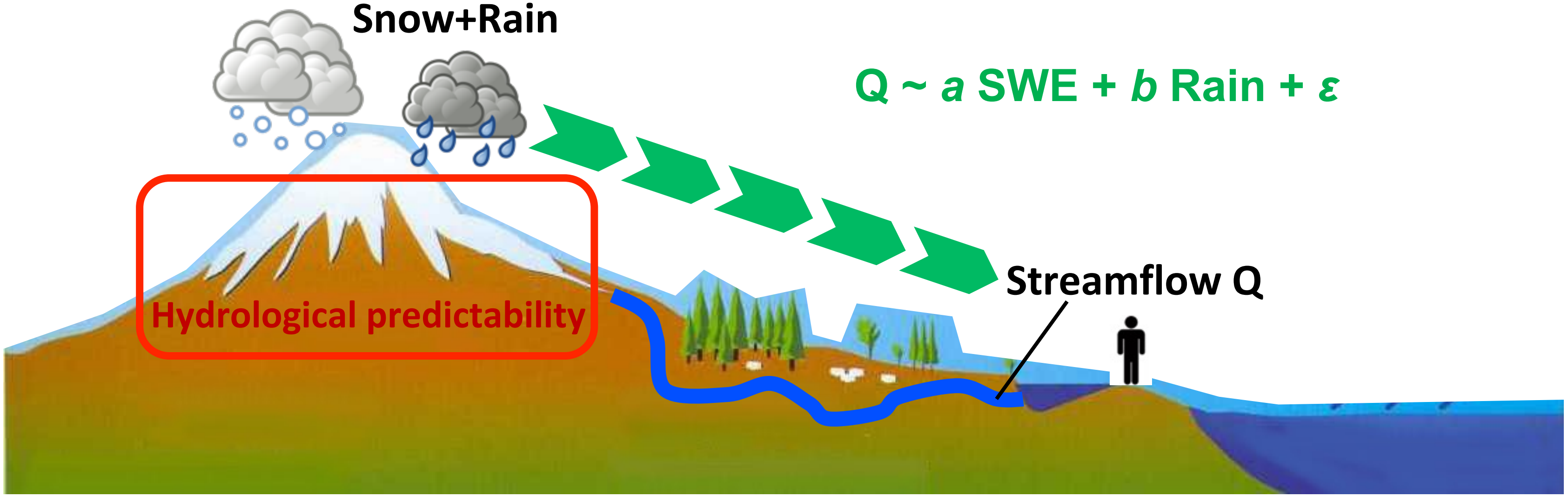

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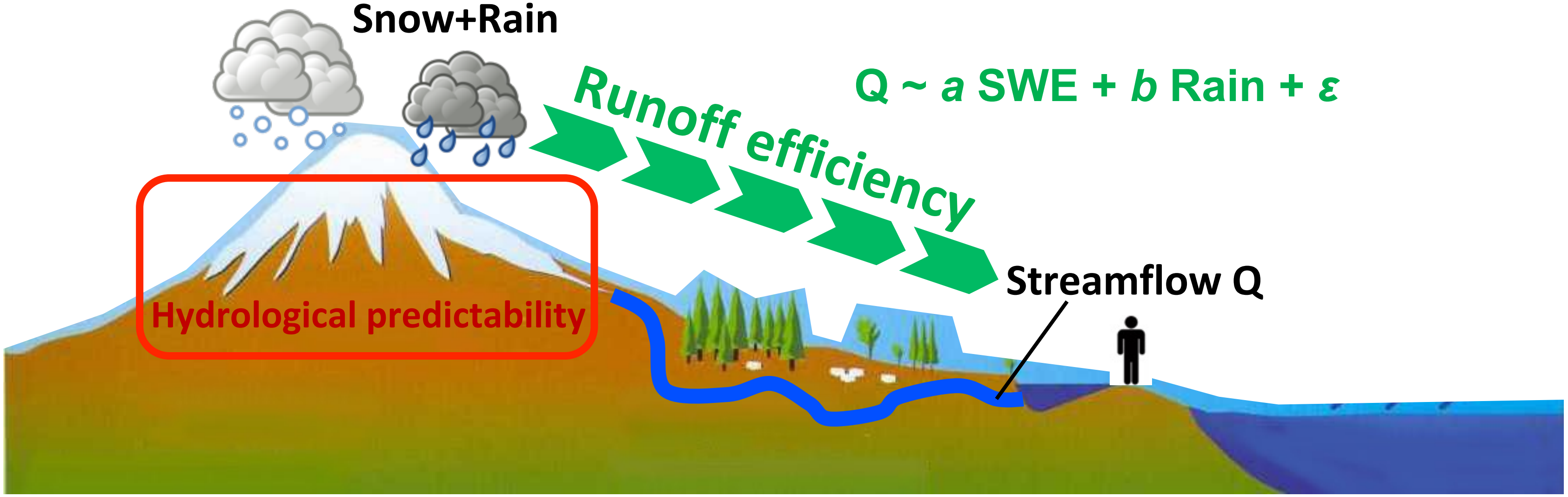

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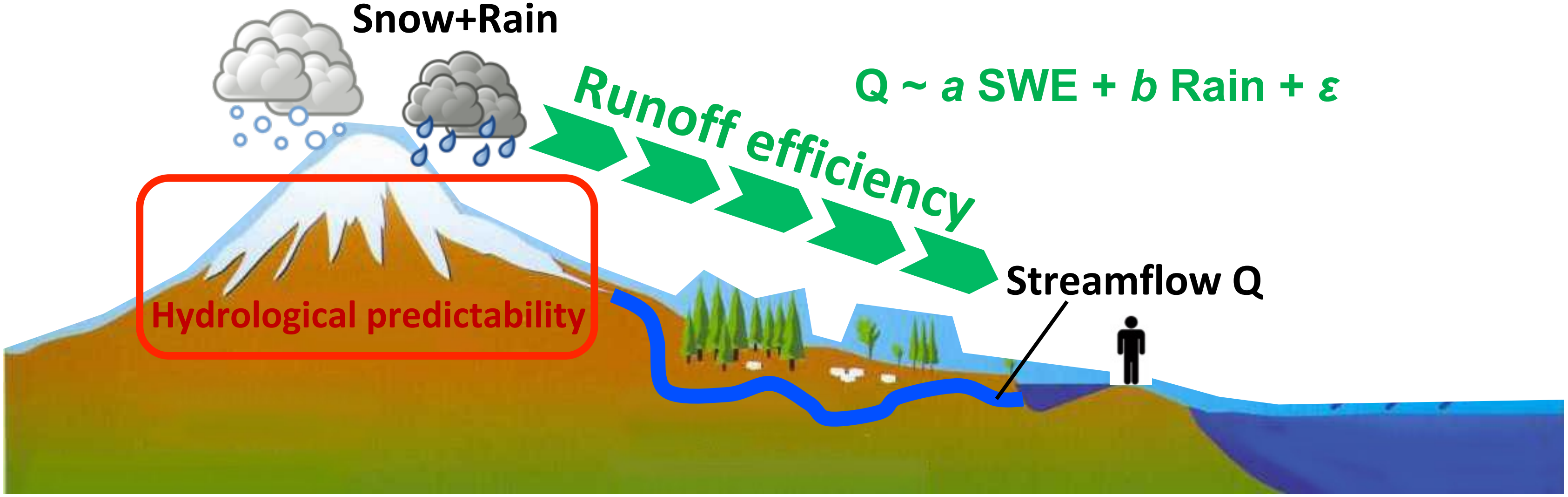

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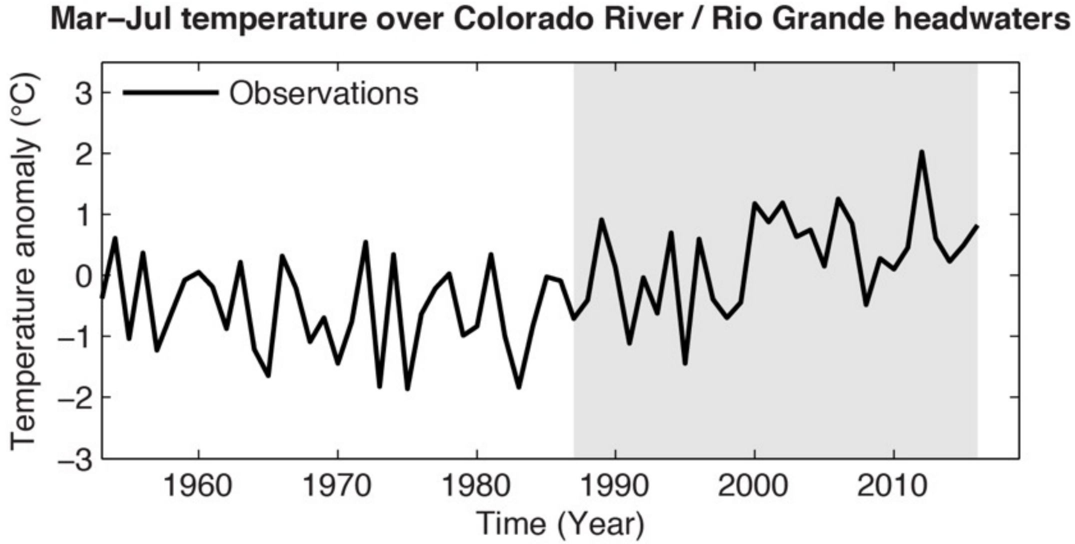

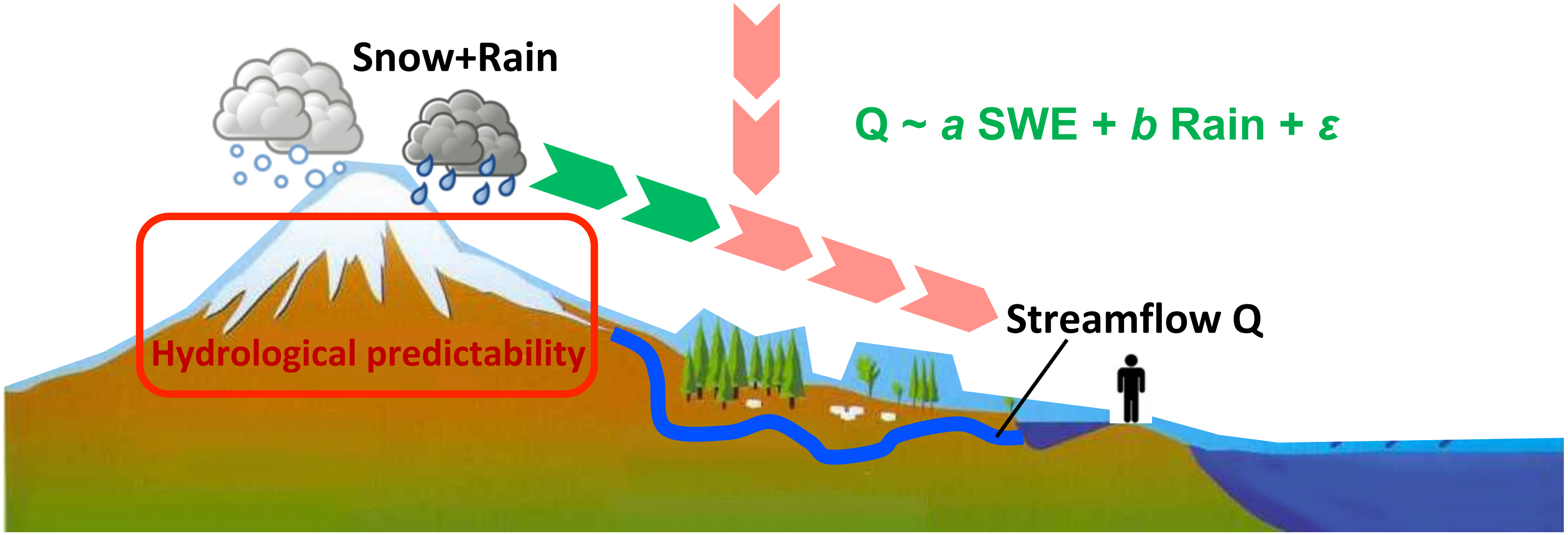

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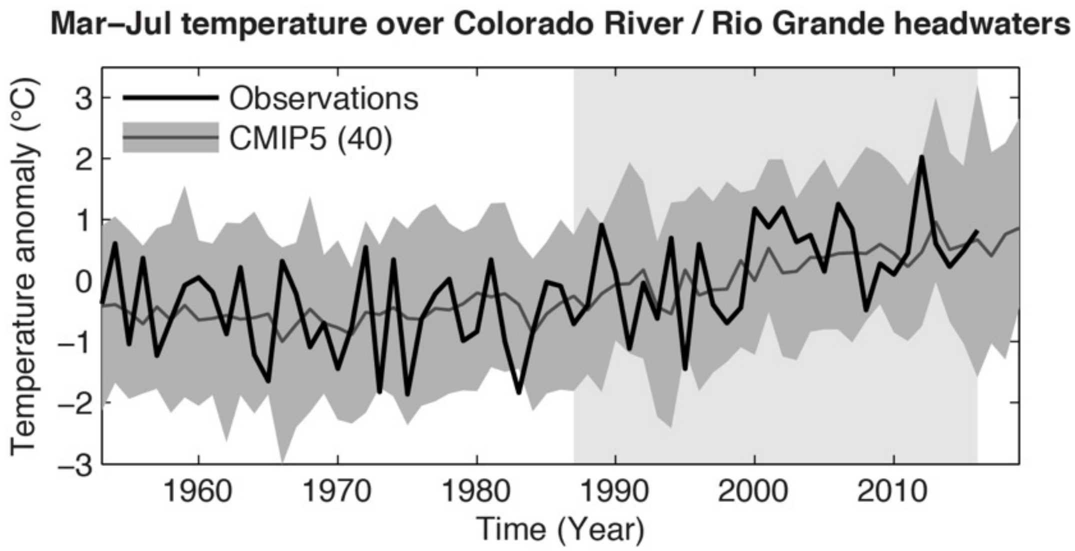

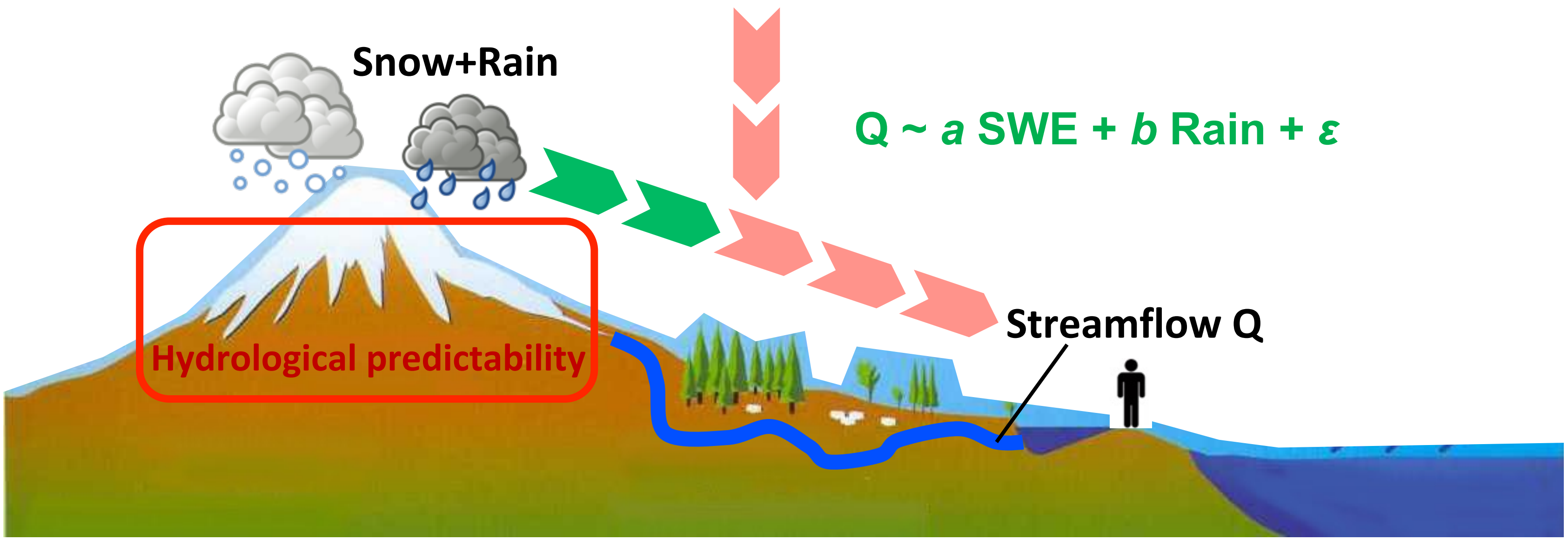

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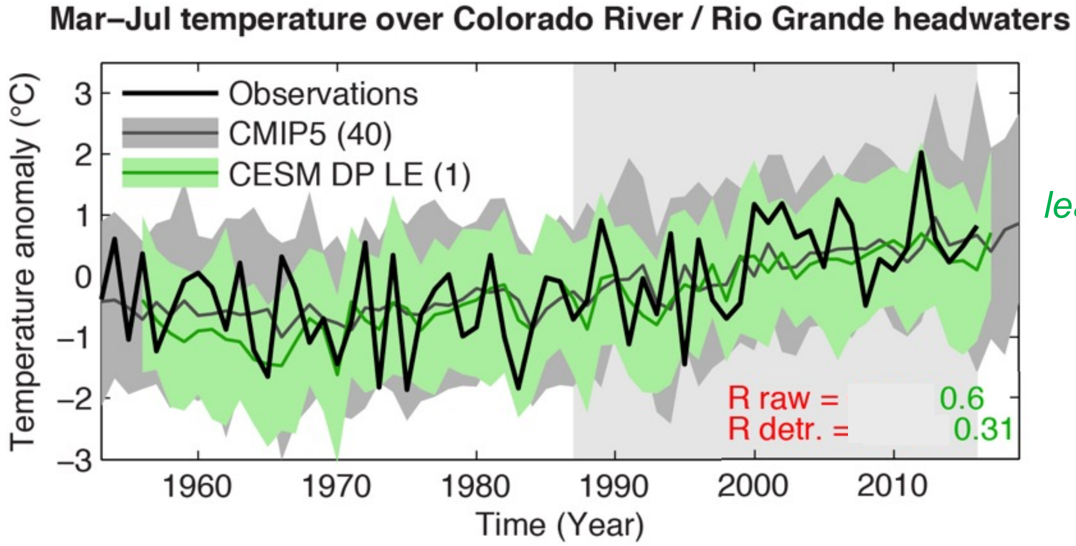
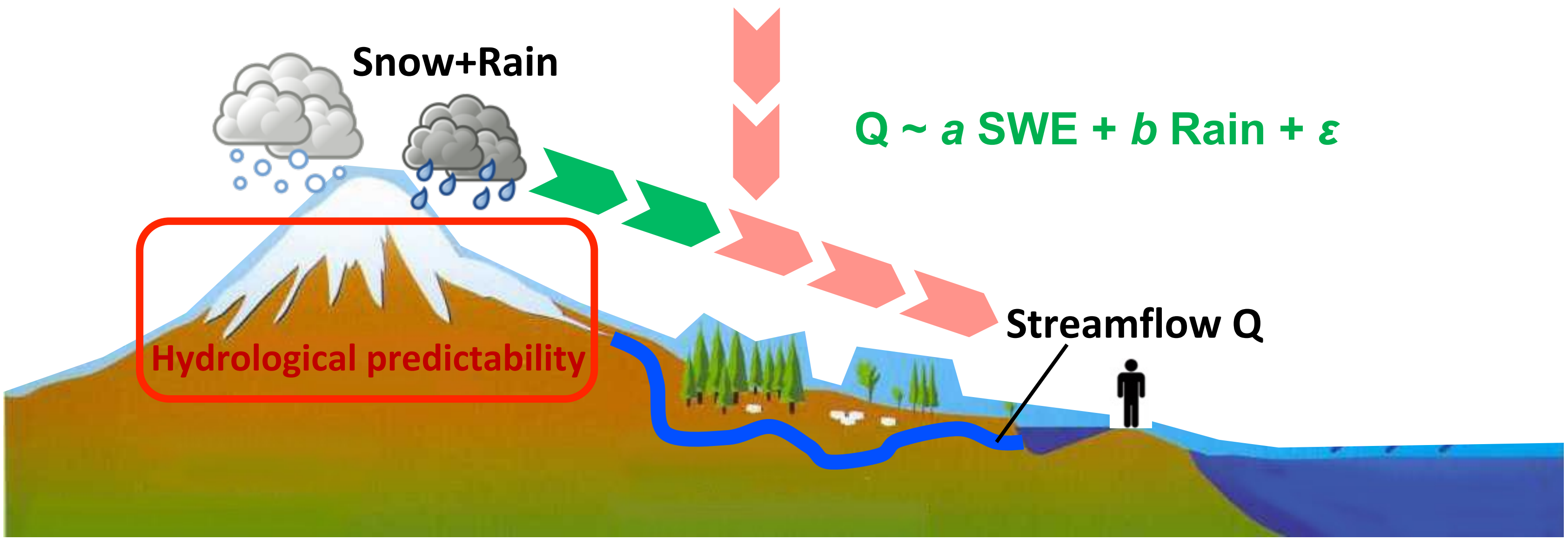
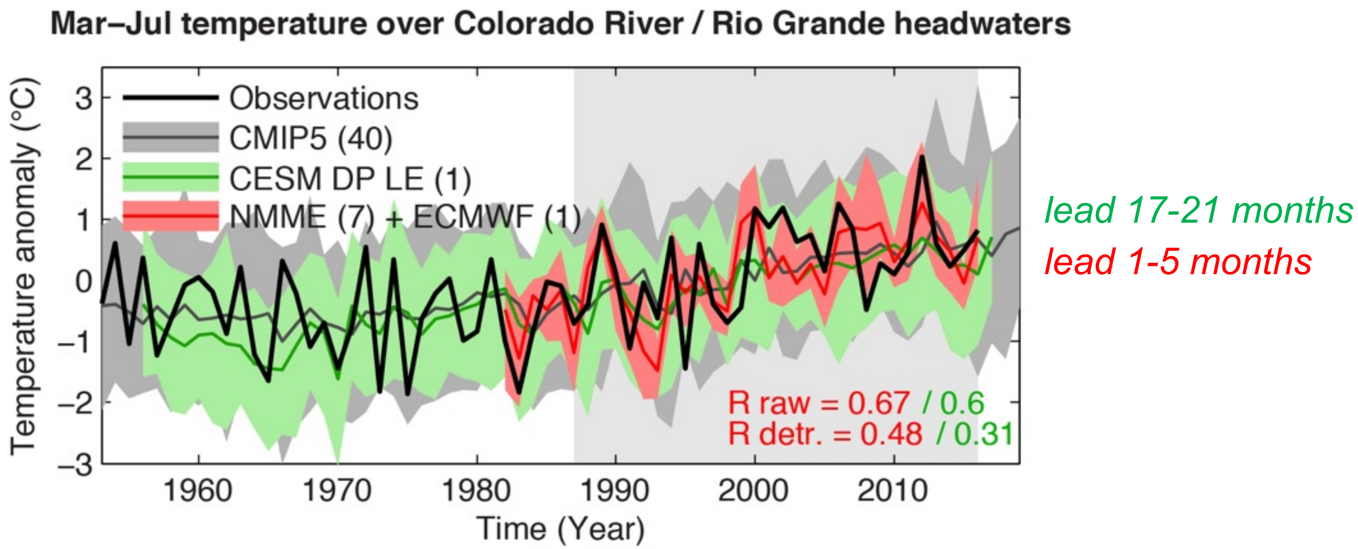


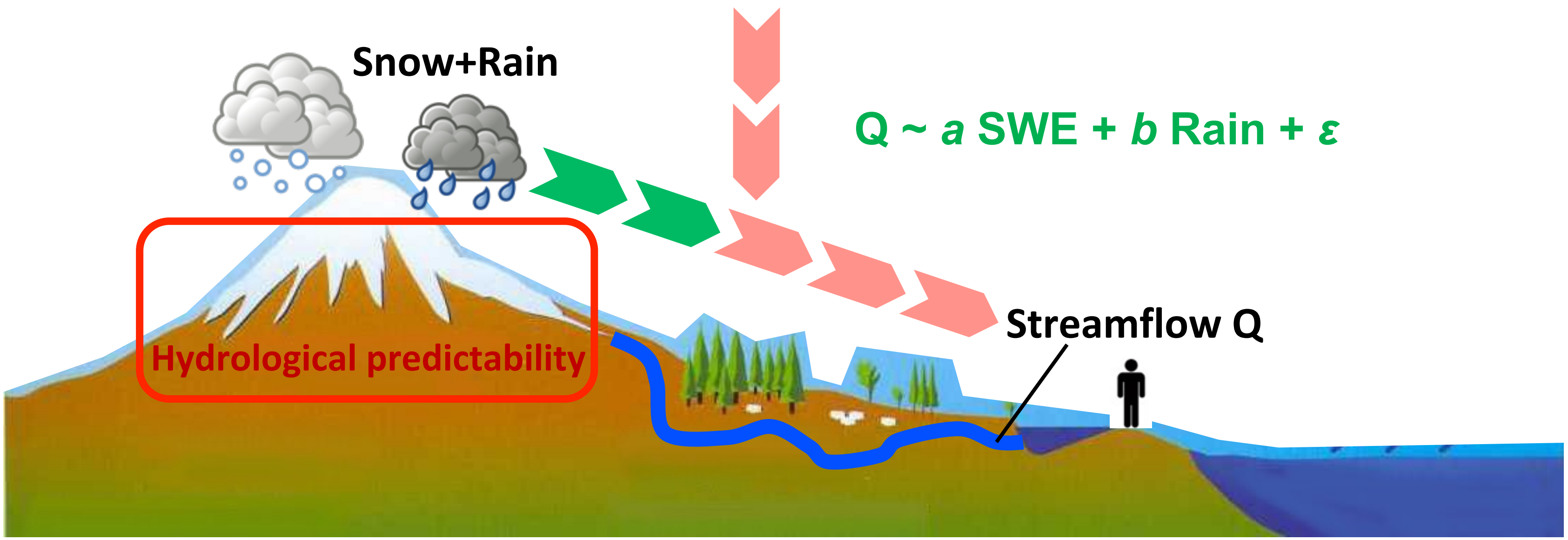
lead 17-21 months



Q ~ *a* SWE + *b* Rain + *ε*

Including temperature into streamflow forecasting





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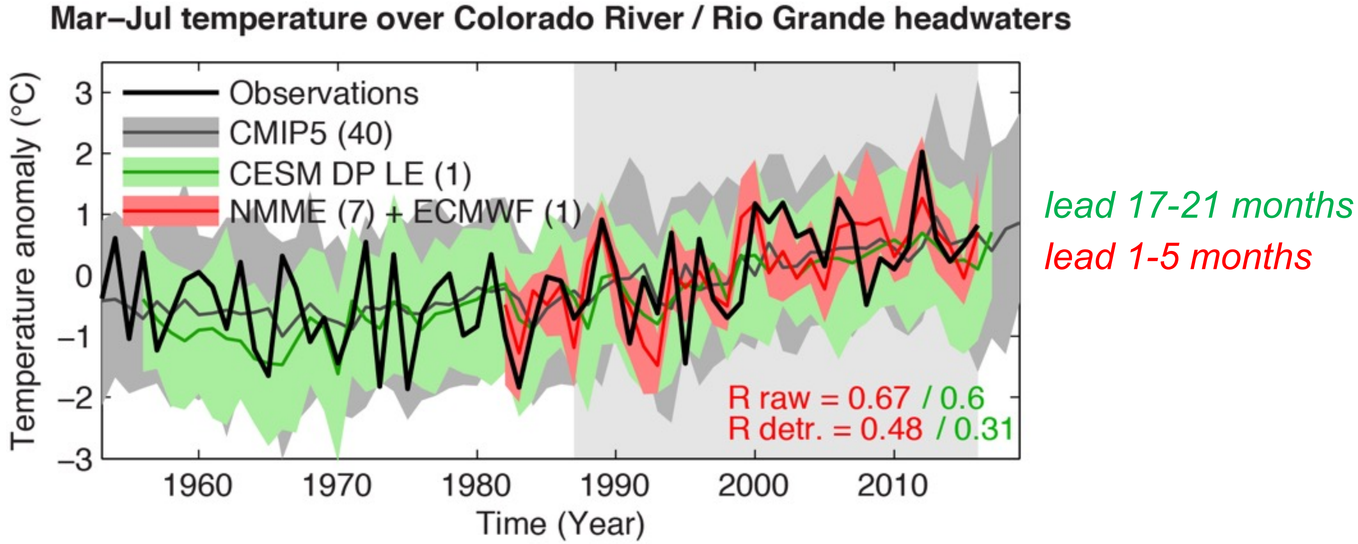

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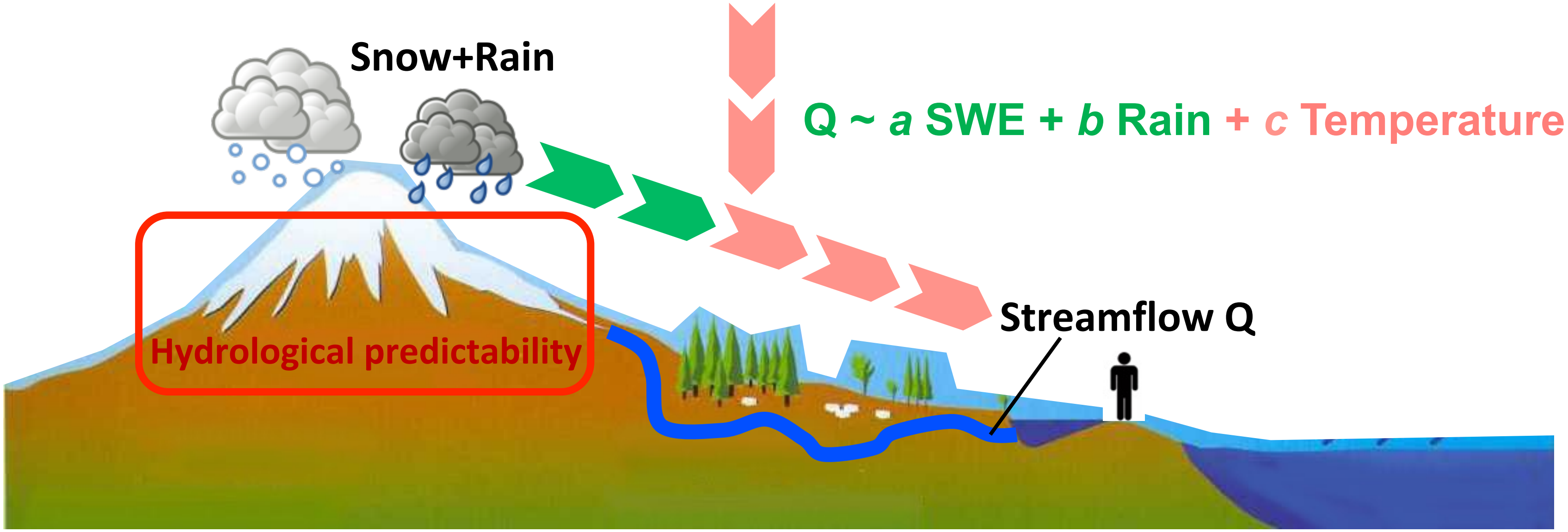

Lehner et al. (2017a)

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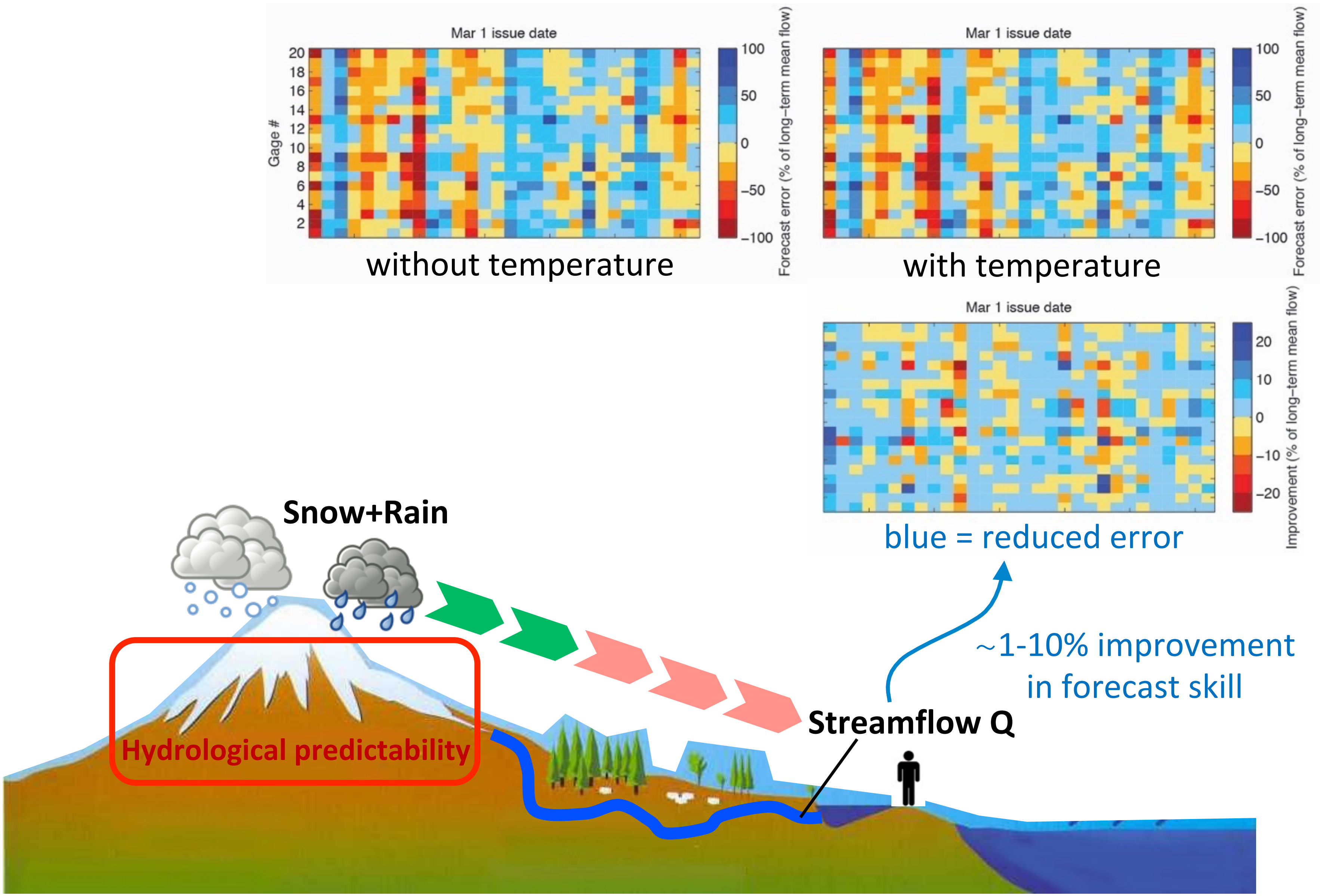

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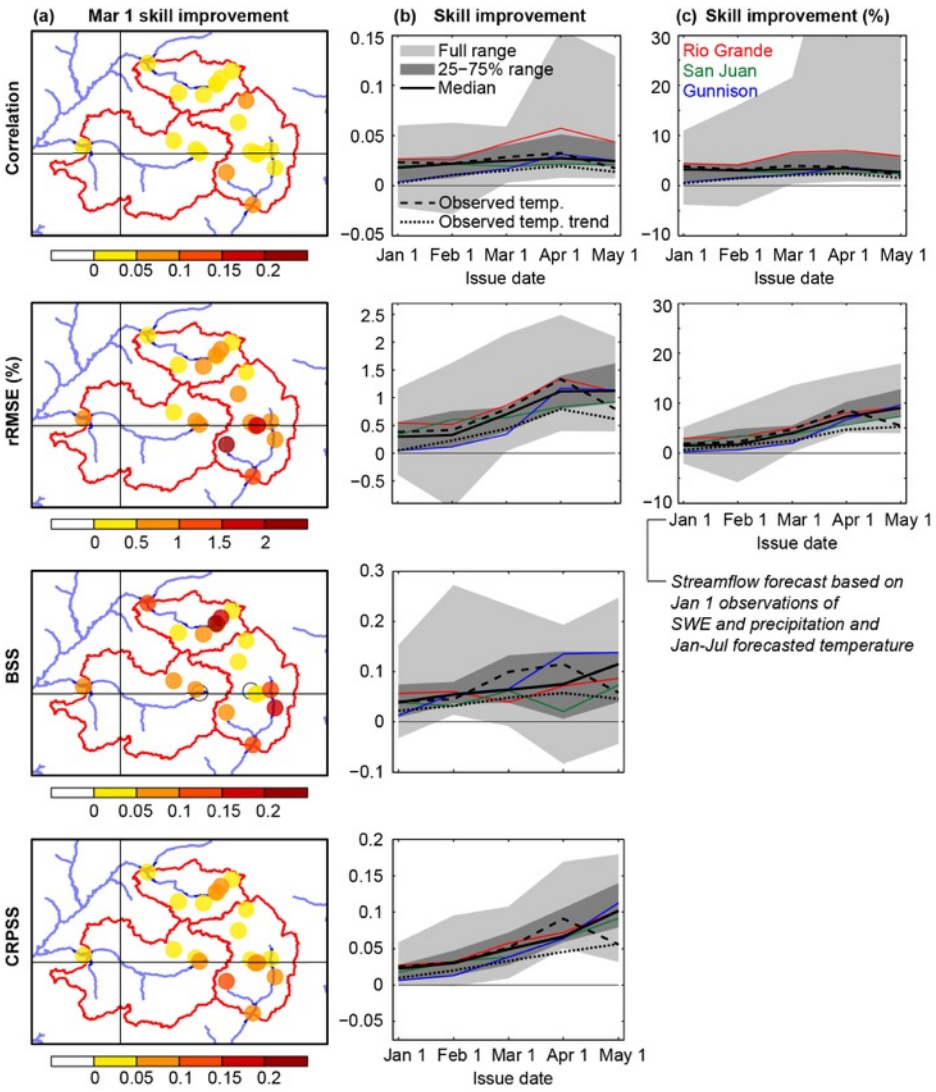

Correlation ✓

rRMSE ✓

BSS < 33rd percentile ✓

CRPSS ✓

Summary

Temperature influence on streamflow, possibly via runoff efficiency

Lehner et al. (2017b): "Assessing recent declines in Upper Rio Grande runoff efficiency from a paleoclimate perspective", Geophys. Res. Let.

Incorporating temperature into streamflow forecasting improves skill

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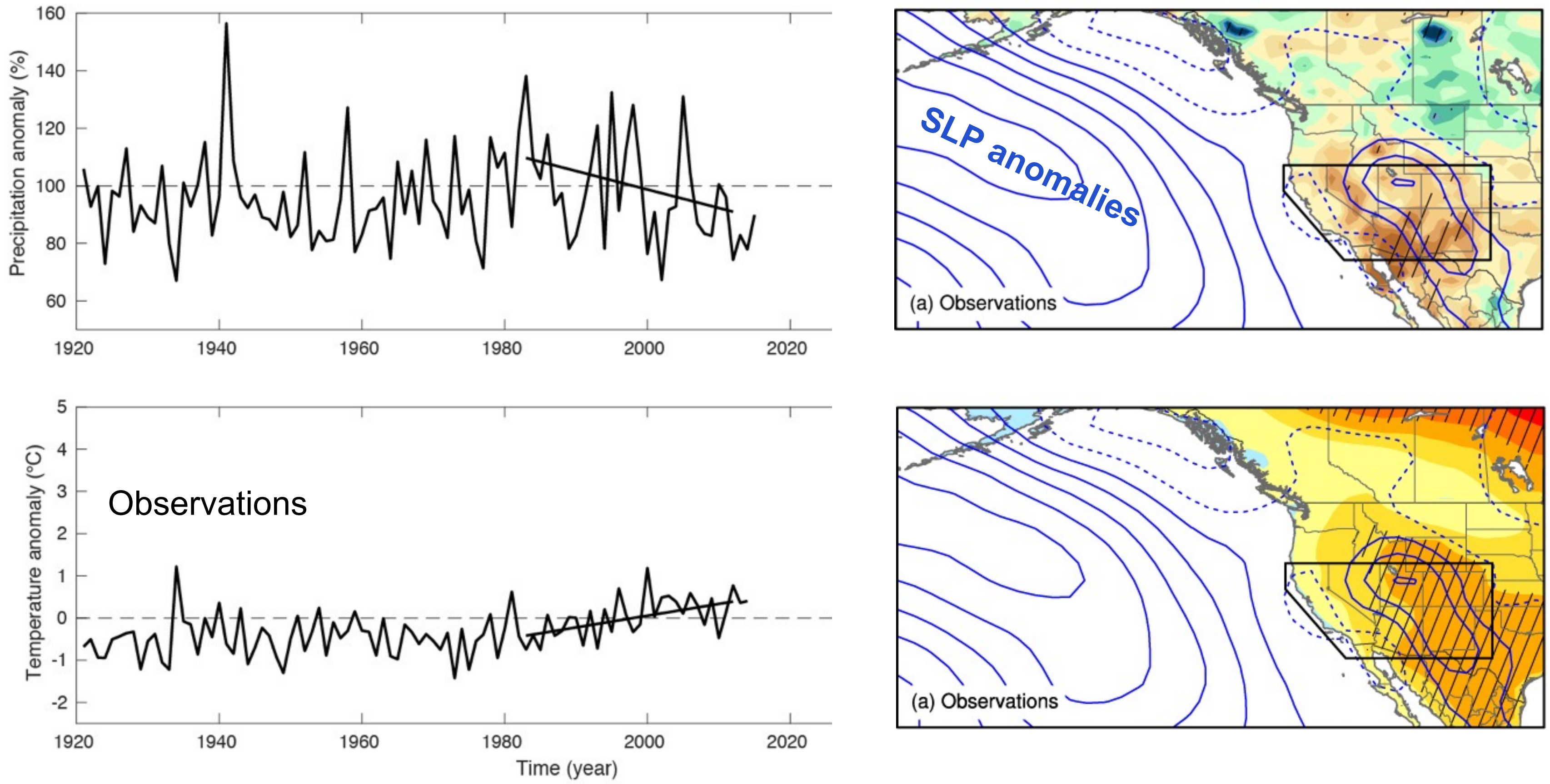
Next steps:

- Non-linear models
- Research to operations
- Domain expansion
- S2S model weighting
- Ensemble Streamflow Prediction


Thanks!
flehner@ucar.edu

Southwest warming and drying



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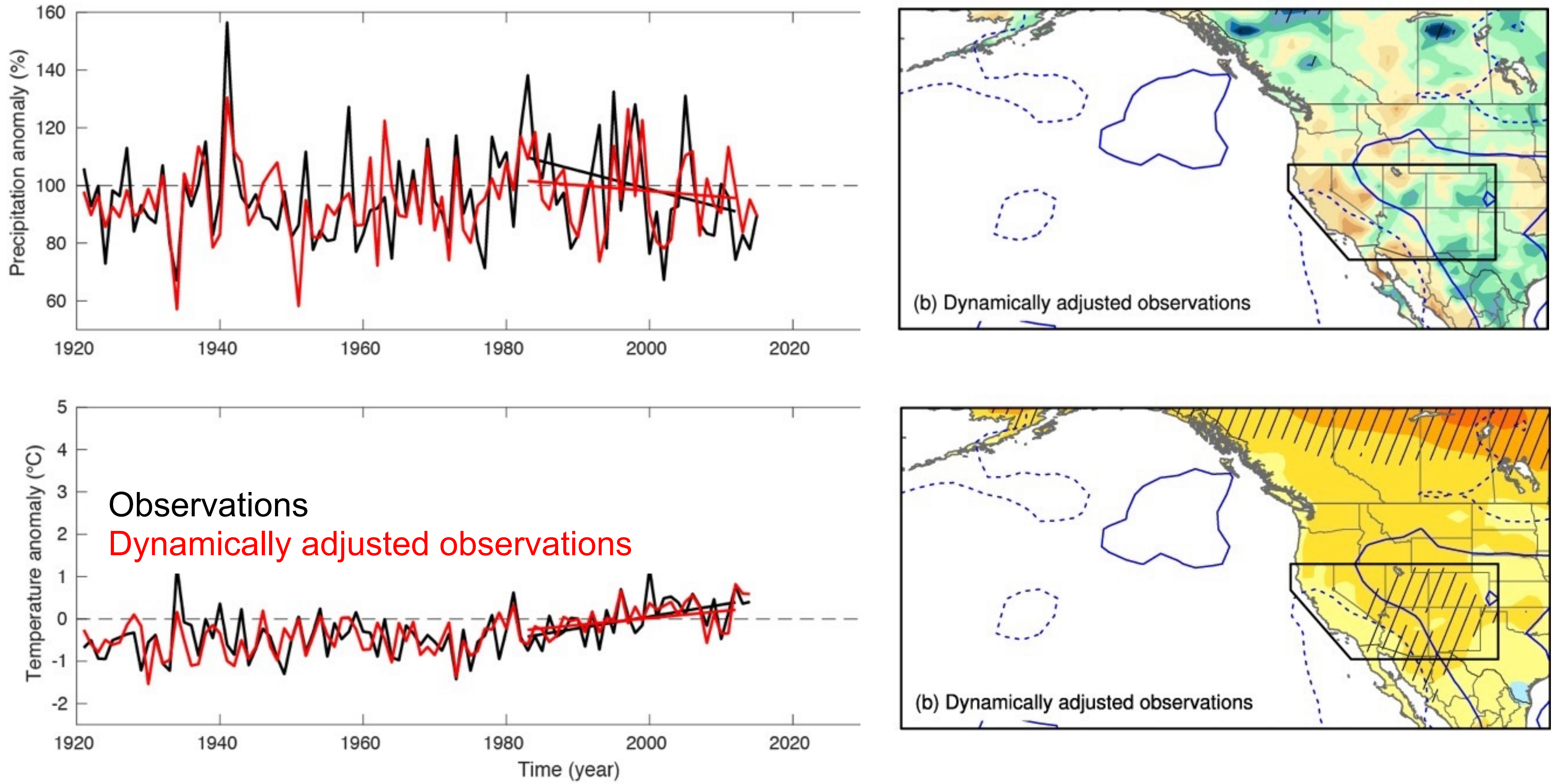
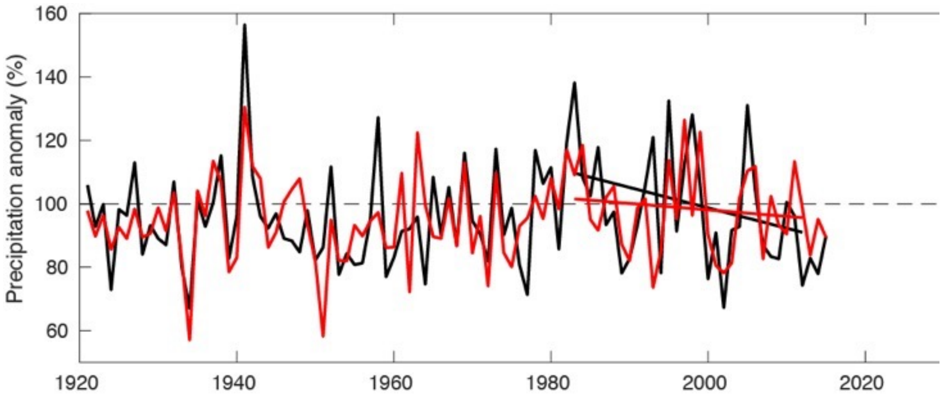


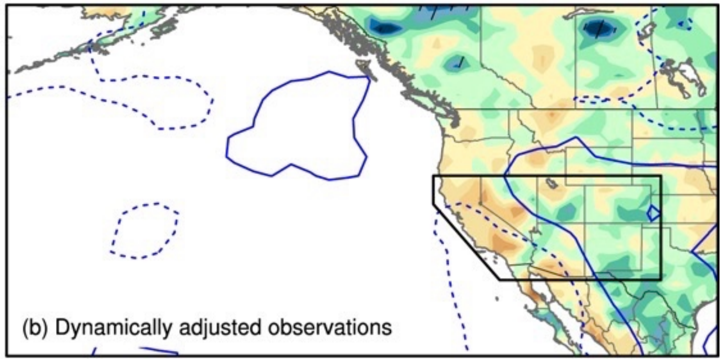
Constructed circulation analogues:

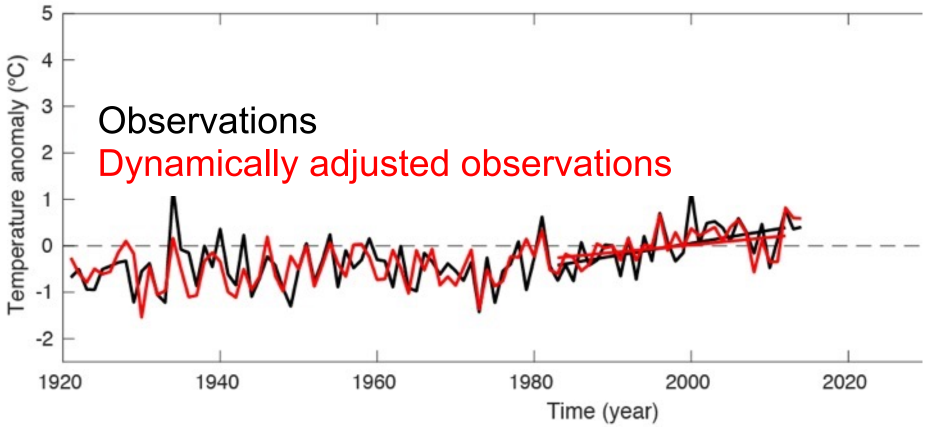
→ Precipitation decline mostly due to internal variability

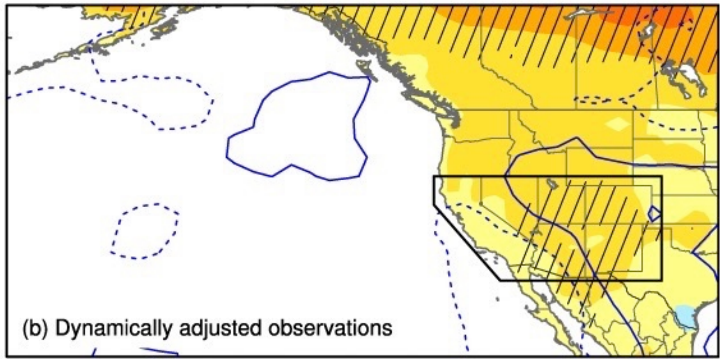
→ Warming mostly not due to internal variability

Southwest warming and drying









Constructed circulation analogues:

→ Precipitation decline mostly due to internal variability

→ Warming mostly not due to internal variability

→ Consistent w/ coupled models

Lehner et al. (2018)

Growing evidence for temperature influence on streamflow

AGU PUBLICATIONS

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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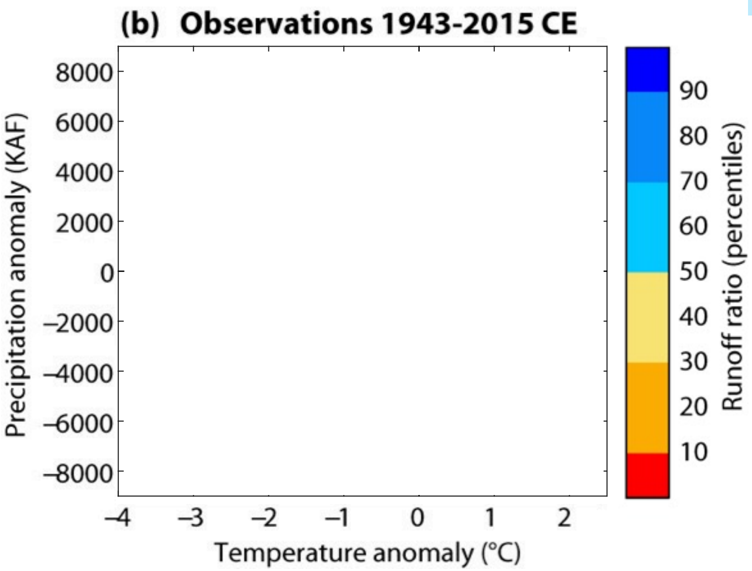
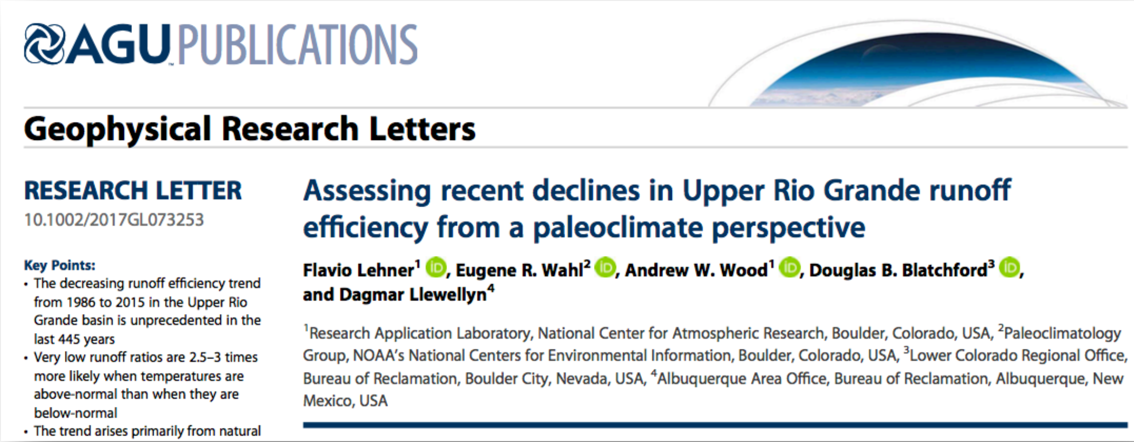


Lehner et al. (2017a)

Growing evidence for temperature influence on streamflow



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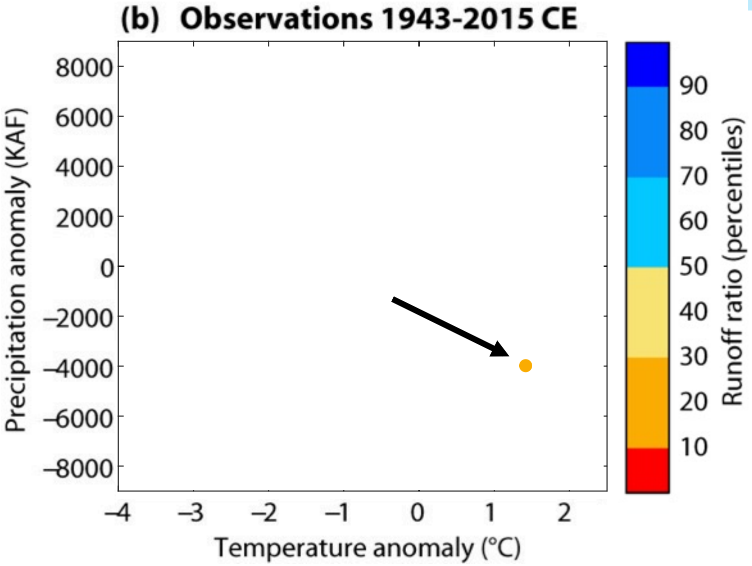

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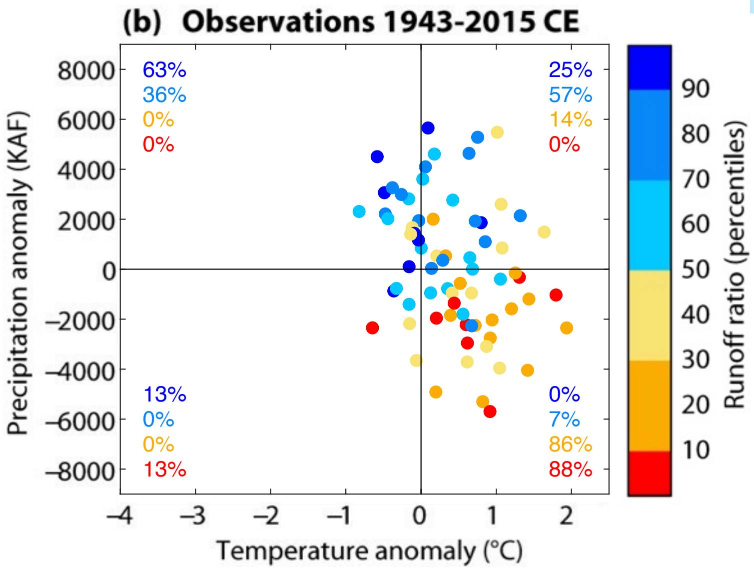

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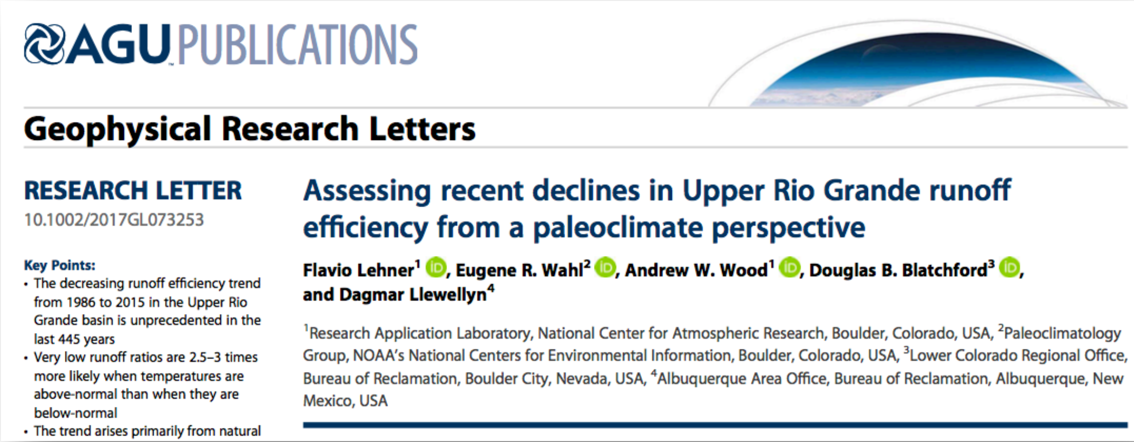
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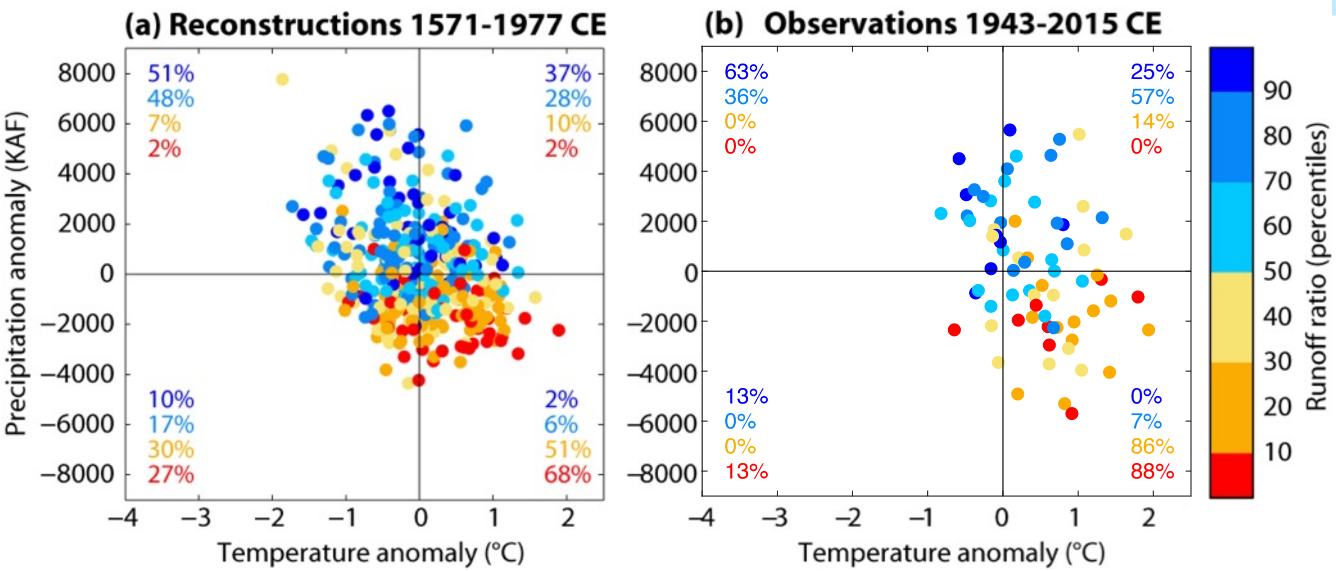

Lehner et al. (2017a)

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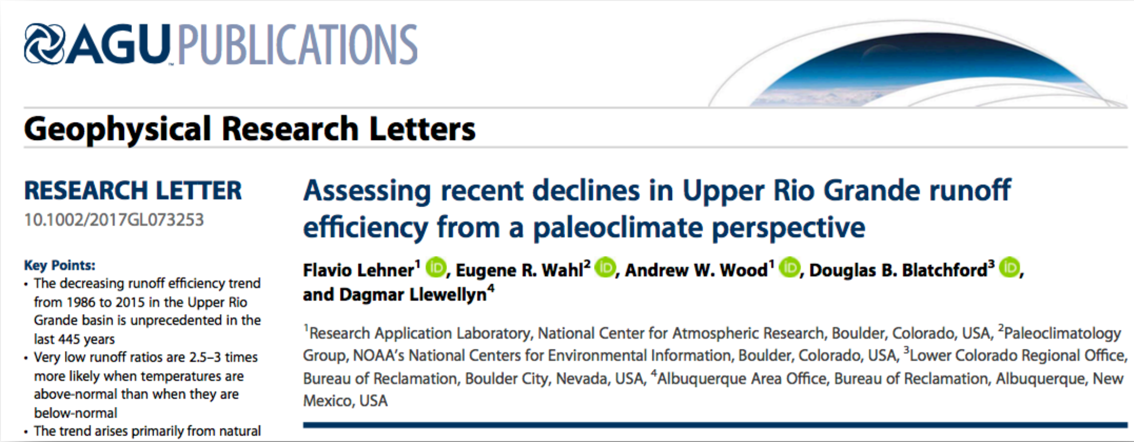

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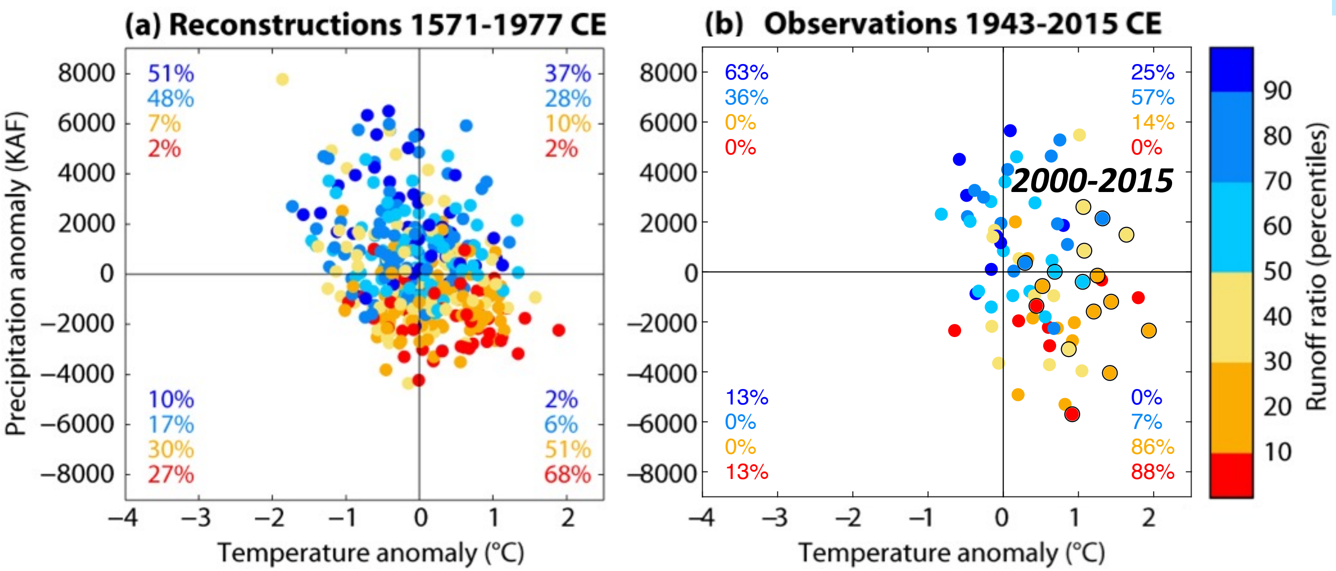

Lehner et al. (2017a)

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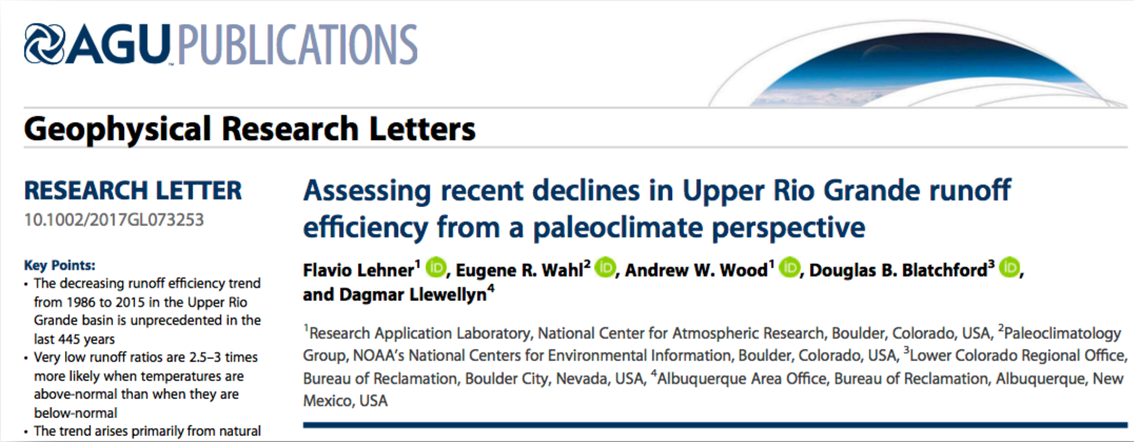

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Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL073253

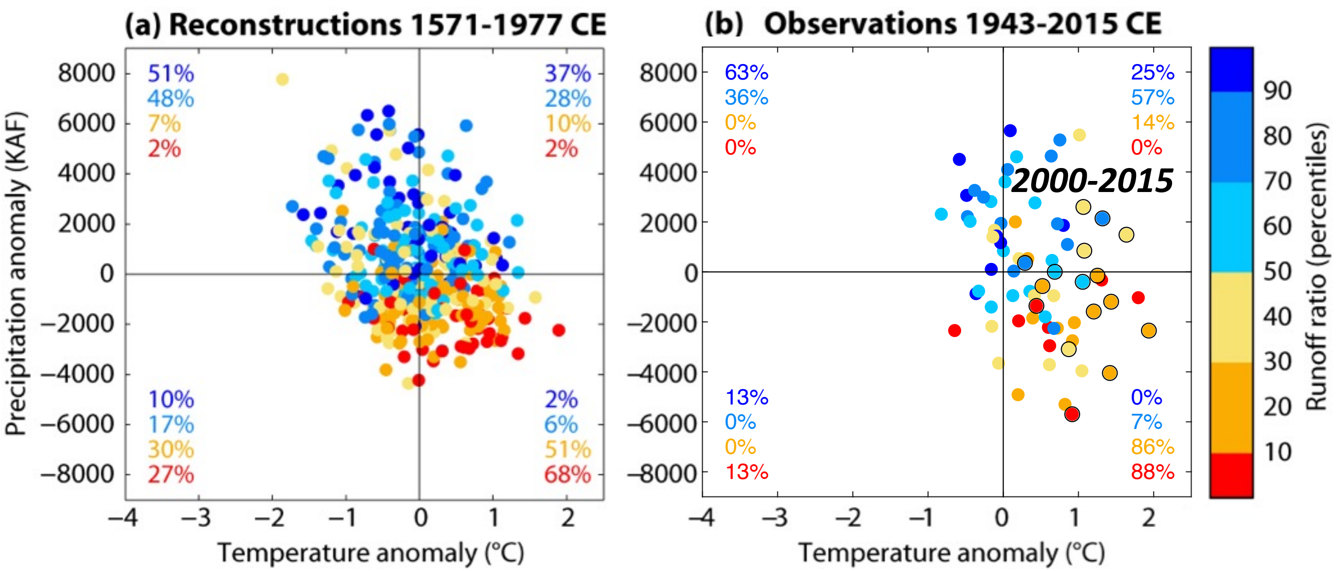
Key Points:
- The decreasing runoff efficiency trend from 1986 to 2015 in the Upper Rio Grande basin is unprecedented in the last 445 years
- Very low runoff ratios are 2.5–3 times more likely when temperatures are above-normal than when they are below-normal
- The trend arises primarily from natural

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

Flavio Lehner[1], Eugene R. Wahl[2], Andrew W. Wood[1], Douglas B. Blatchford[3], and Dagmar Llewellyn[4]

[1]Research Application Laboratory, National Center for Atmospheric Research, Boulder, Colorado, USA, [2]Paleoclimatology Group, NOAA's National Centers for Environmental Information, Boulder, Colorado, USA, [3]Lower Colorado Regional Office, Bureau of Reclamation, Boulder City, Nevada, USA, [4]Albuquerque Area Office, Bureau of Reclamation, Albuquerque, New Mexico, USA

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



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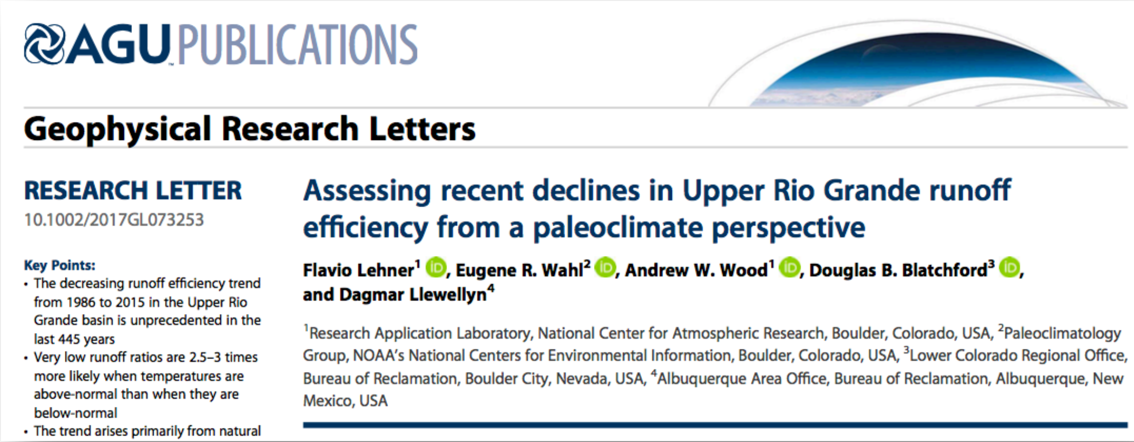

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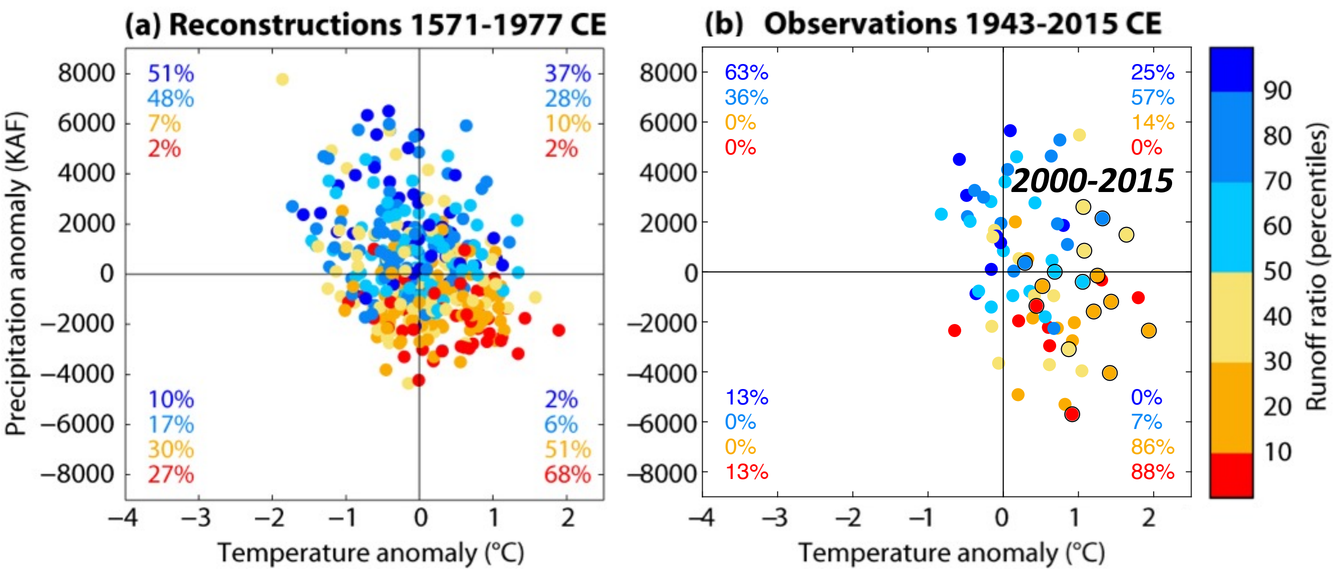
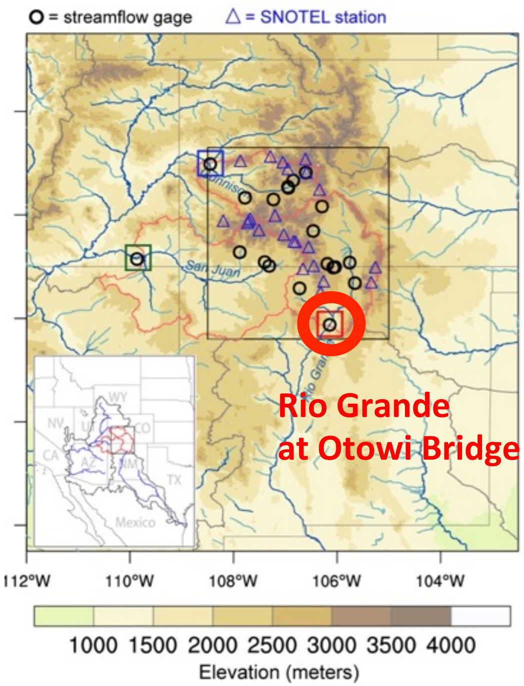
- First paleo-reconstruction of runoff efficiency
- When P is low and T is high → low runoff efficiency
- Other studies with similar conclusions:
  - Woodhouse et al. (2016)
  - Udall & Overpeck (2017)
  - McCabe et al. (2017)
  - Woodhouse et al. (2018)
  - Chavarria & Gutzler (2018)
  - etc



Streamflow hindcasts



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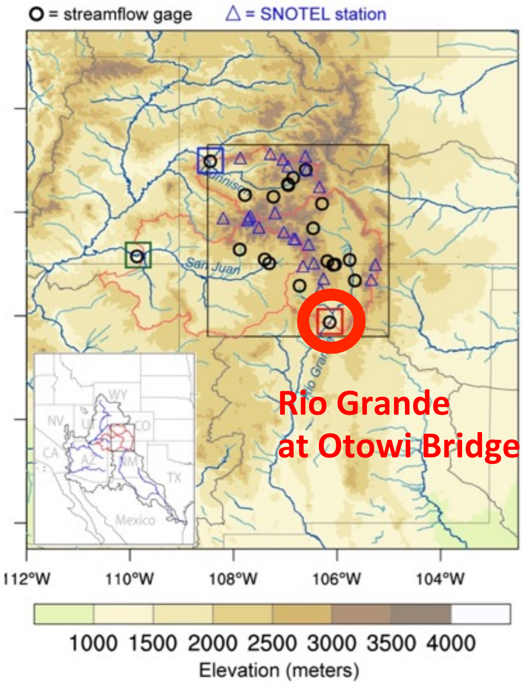
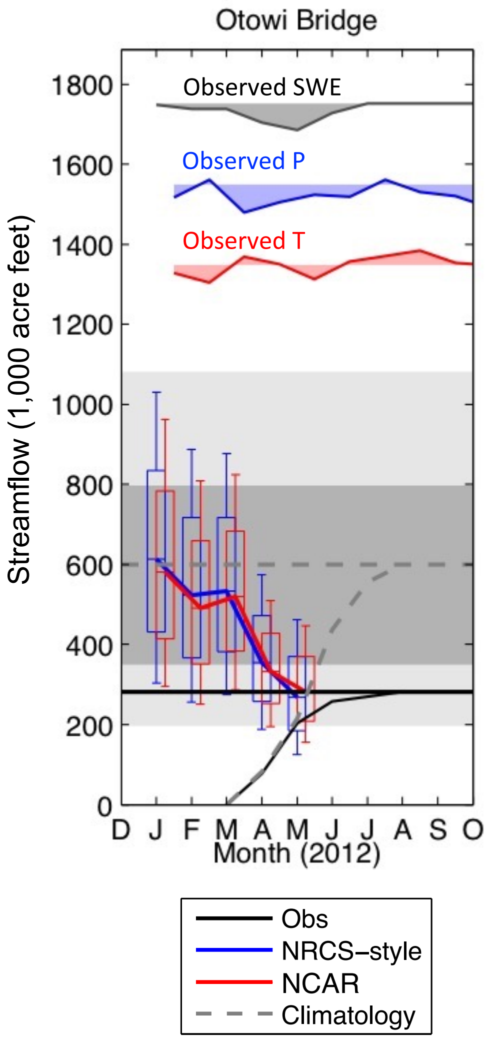


2012



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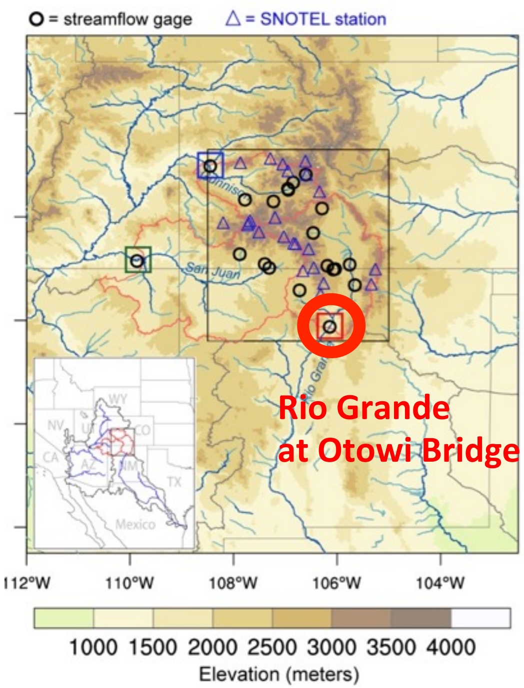

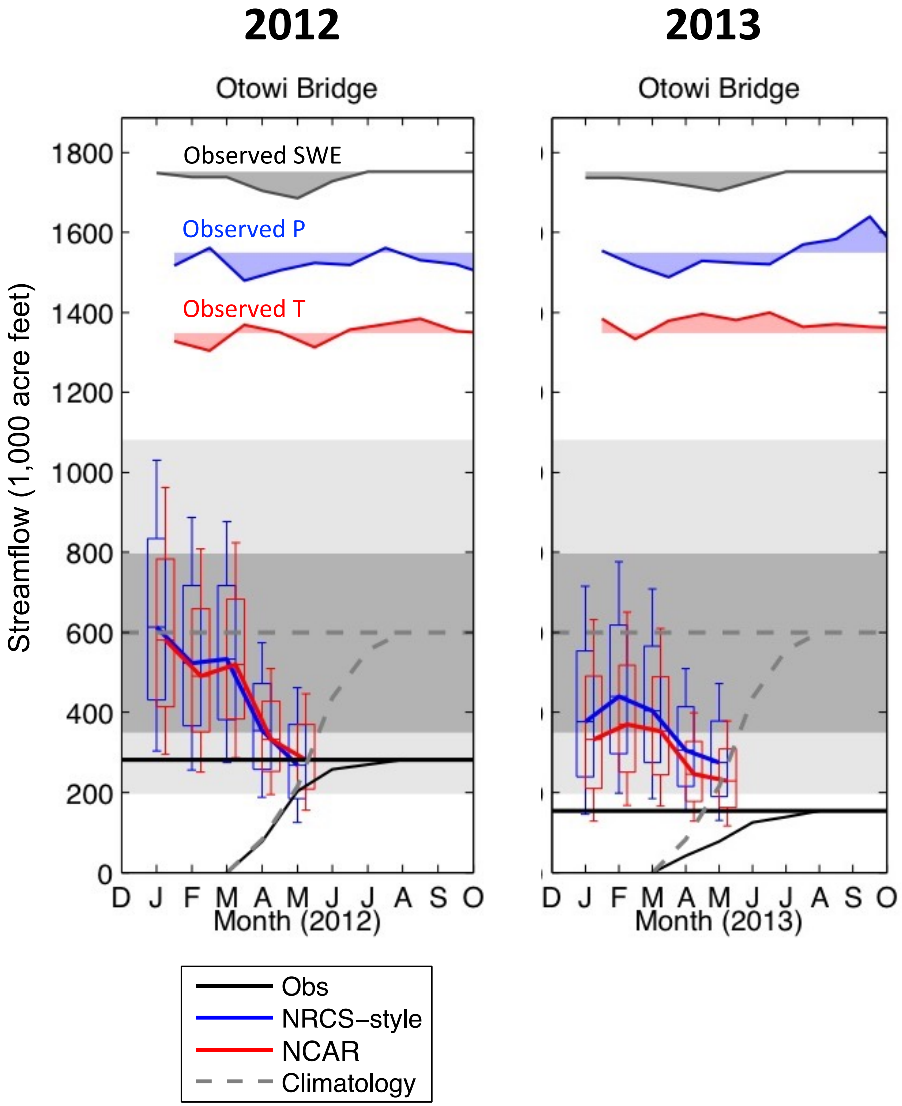

Streamflow hindcasts