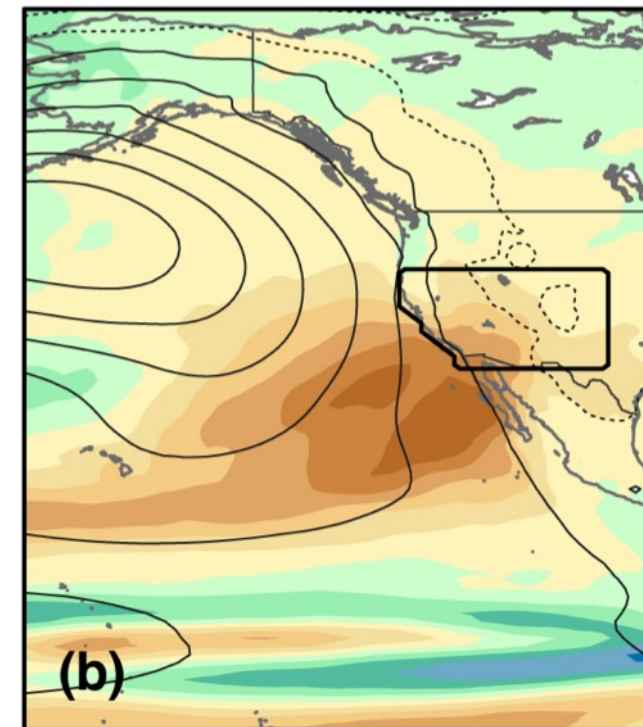


Challenges in understanding climate non-stationarity and its influence on water resources in the US Southwest



Flavio Lehner¹, Clara Deser¹, Ruixia Guo^{1,2}, Laurent Terray³, Pedro DiNezio⁴, Andrew W. Wood¹

¹National Center for Atmospheric Research, Boulder, USA

²Key Laboratory for Semi-Arid Climate Change, Lanzhou University, Lanzhou, China

³CECI, Université de Toulouse, CERFACS/CNRS, Toulouse, France

⁴Institute for Geophysics, University of Texas at Austin, Austin, USA

COMPUTATIONAL HYDROLOGY
ral.ucar.edu/hap/computational-hydrology



The water for the Southwest



The water for the Southwest



Growing evidence for temperature influence on streamflow

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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 Lehner¹ , Eugene R. Wahl² , Andrew W. Wood¹ , Douglas B. Blatchford³ , and Dagmar Llewellyn⁴

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Runoff efficiency = streamflow / precipitation



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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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- 1980s to 2010s exceptionally steep trend

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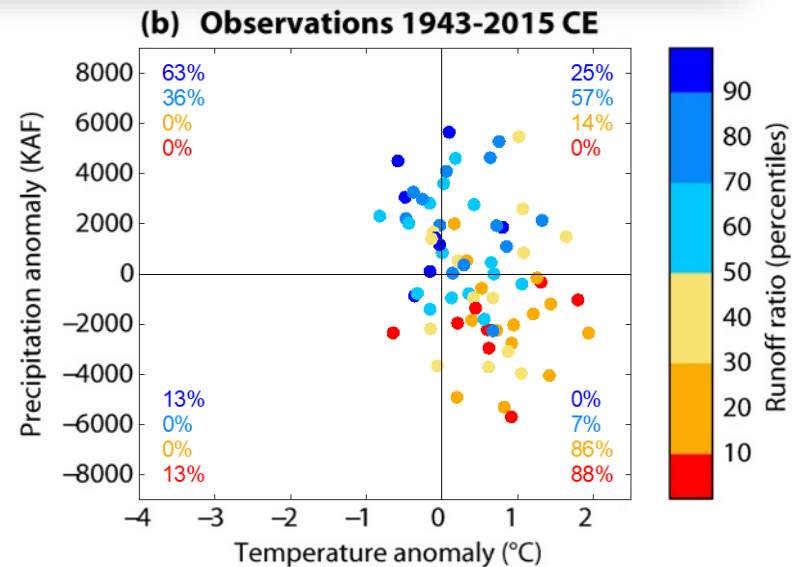
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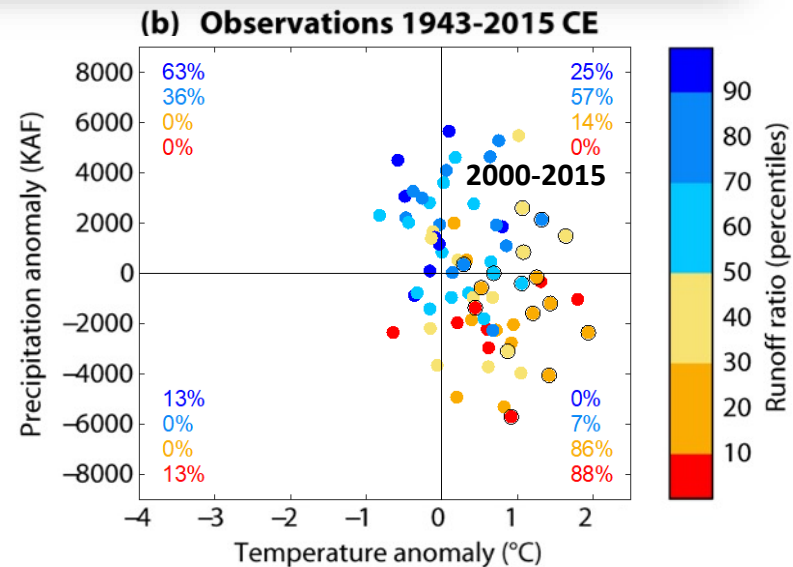
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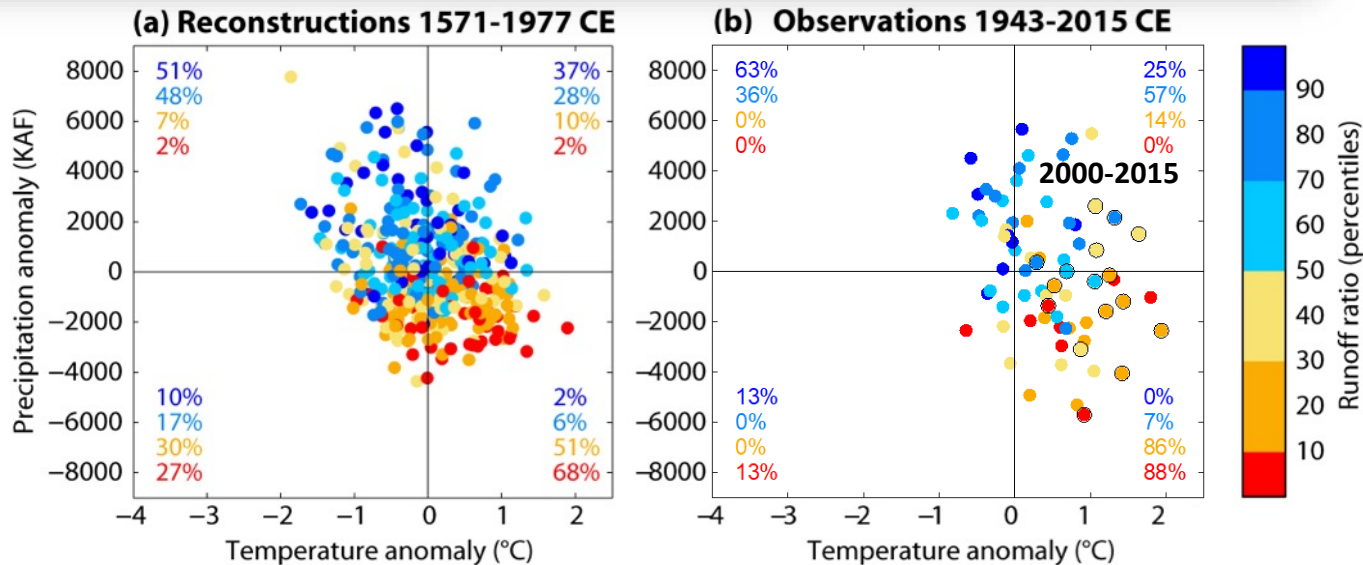
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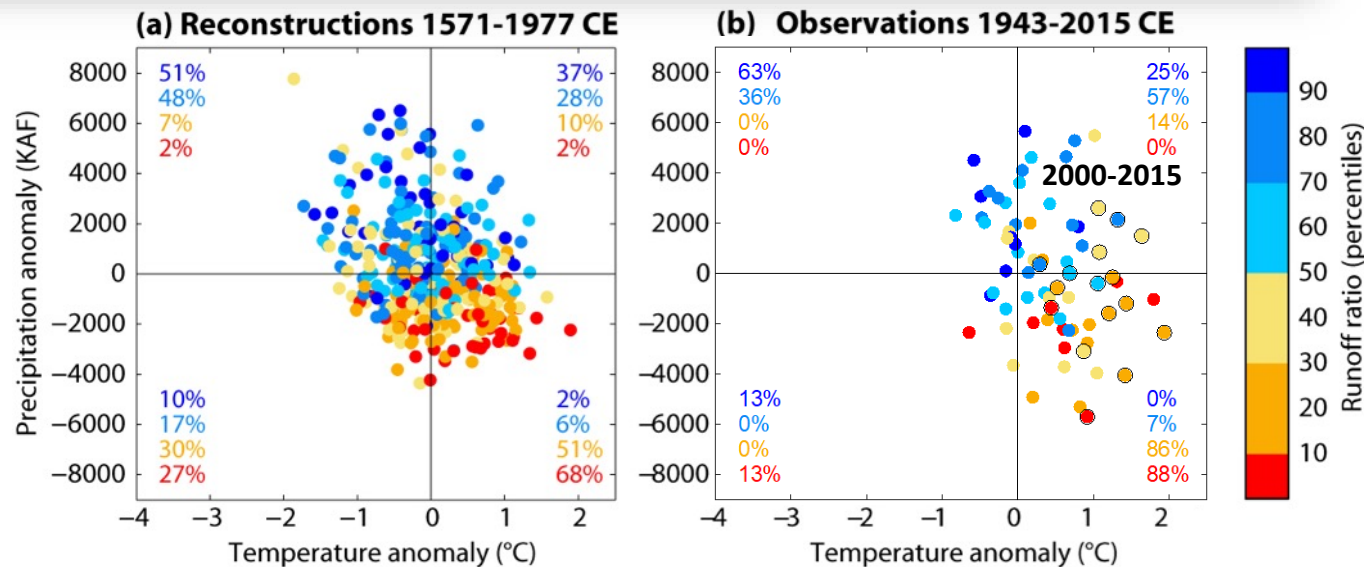
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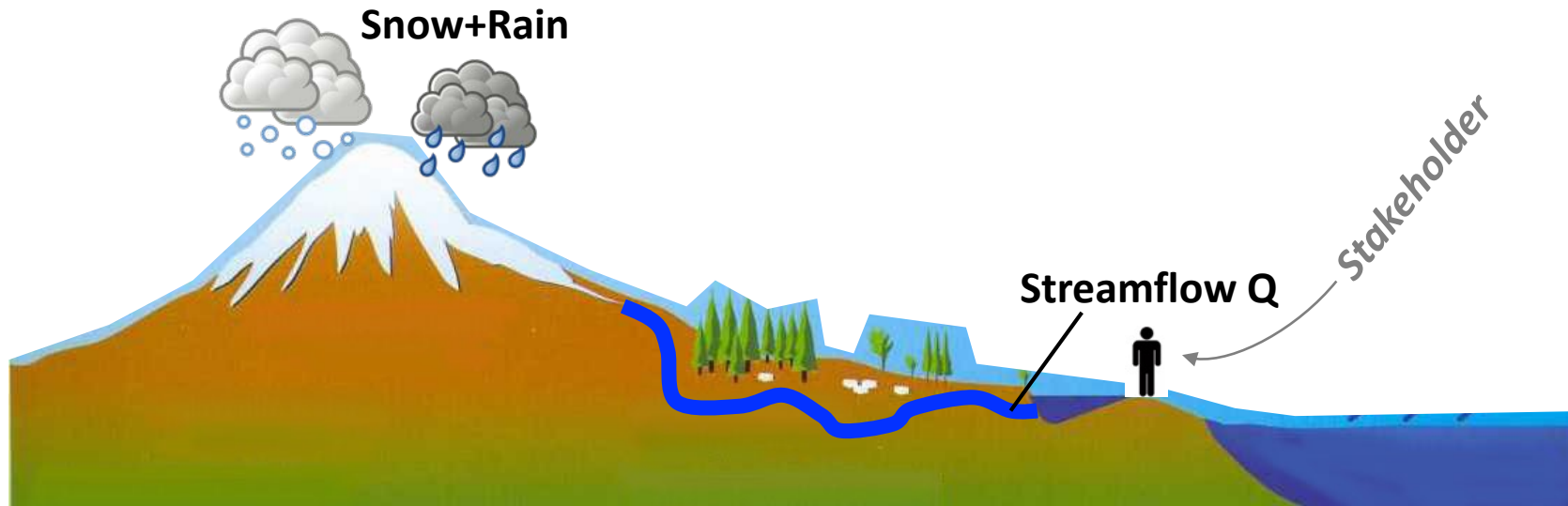
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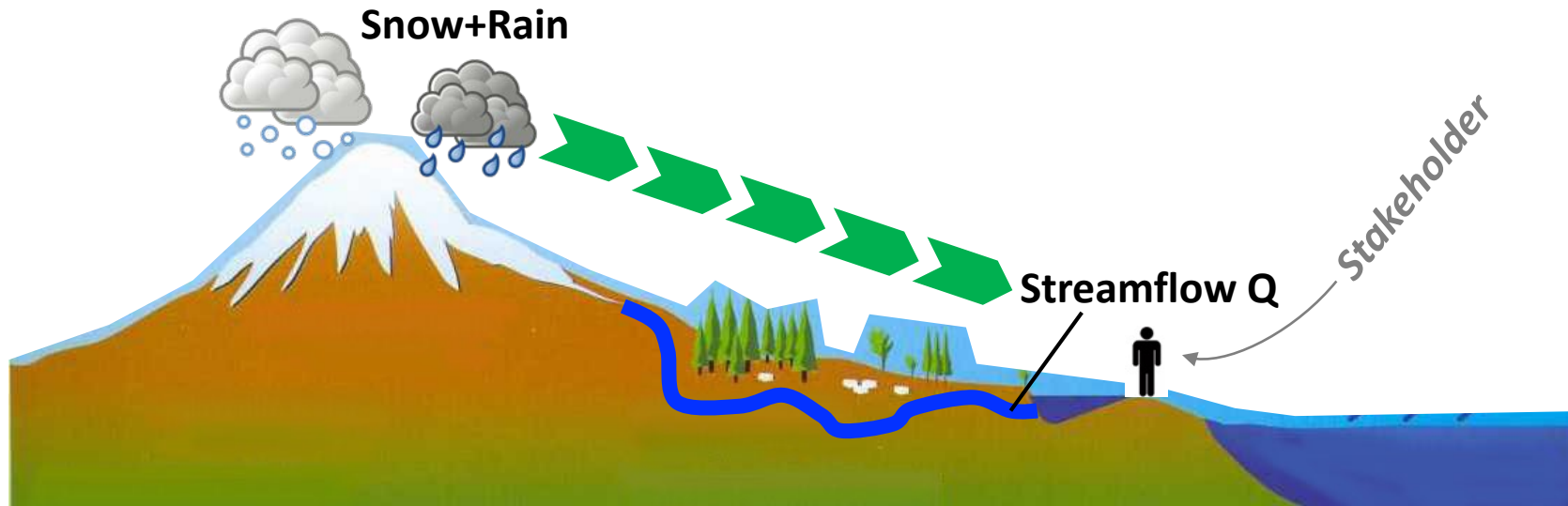
Other studies with similar conclusions:

- Woodhouse et al. (2016)
- Udall and Overpeck (2017)
- McCabe et al. (2017)
- Woodhouse & Pedersen (in press)
- Chavarria & Gutzler (submitted)

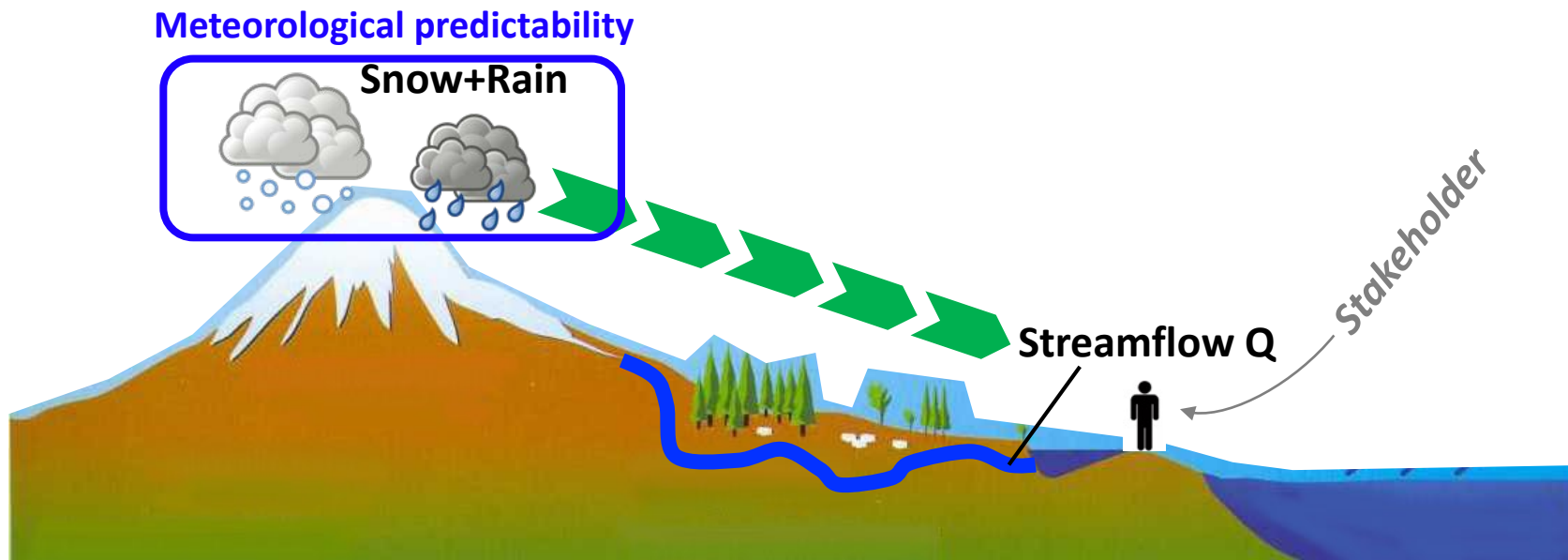
Is temperature also affecting streamflow predictability?



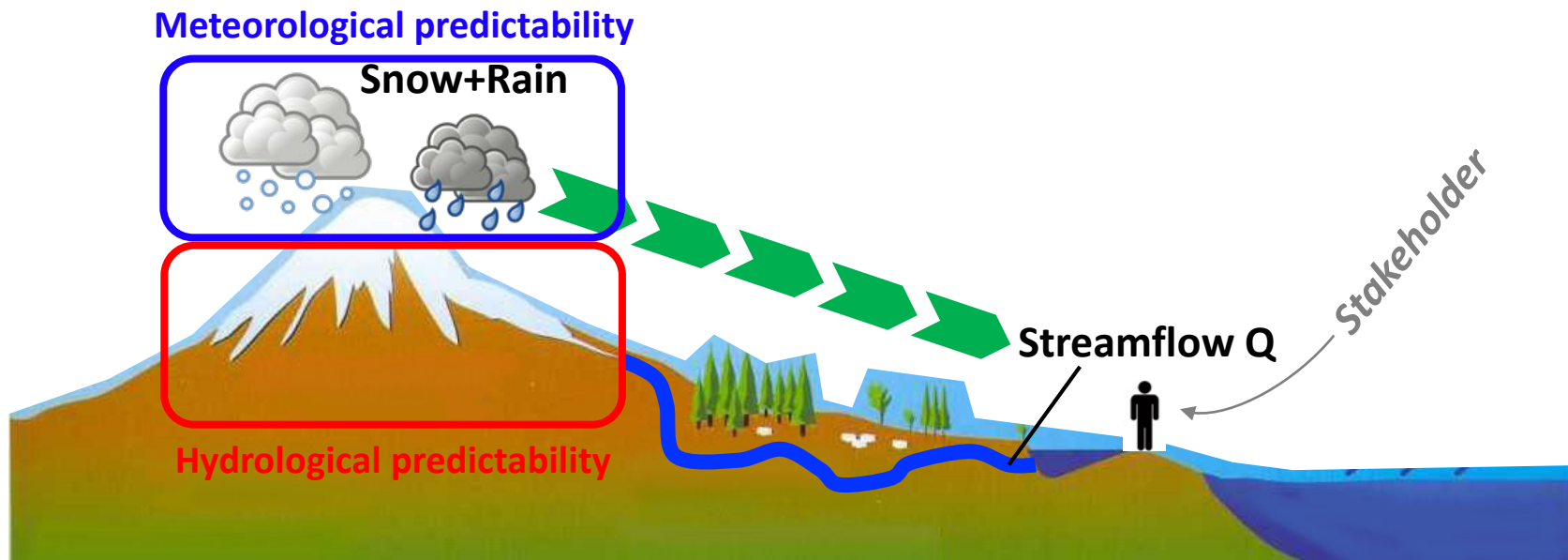
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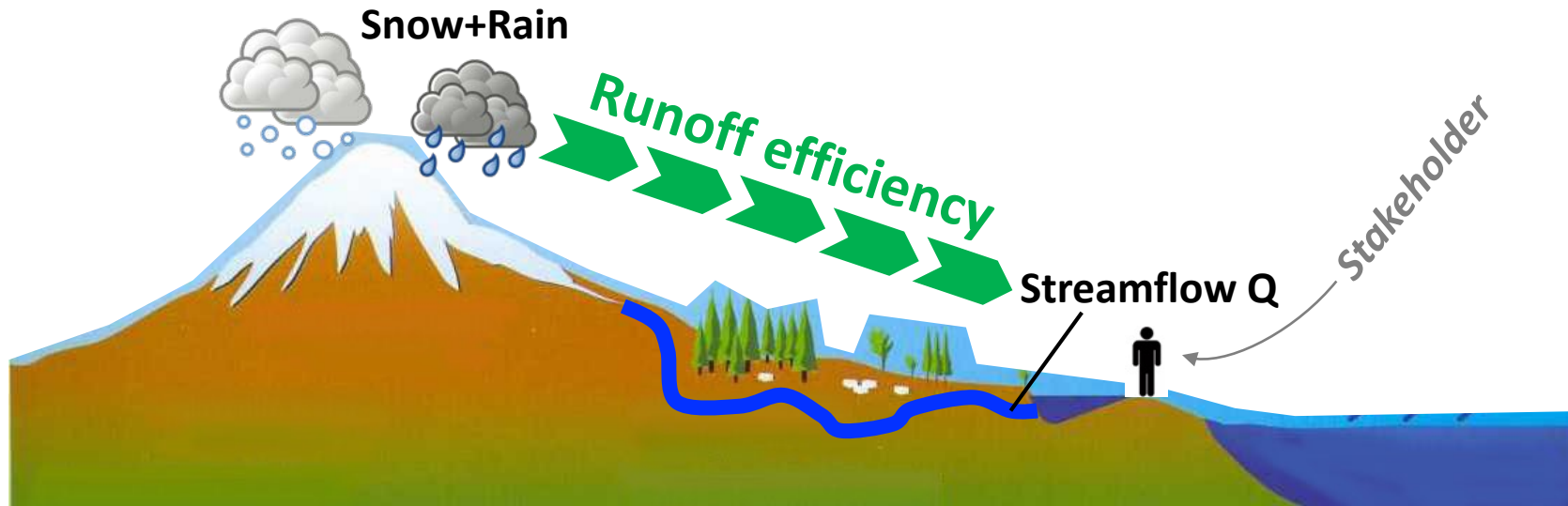
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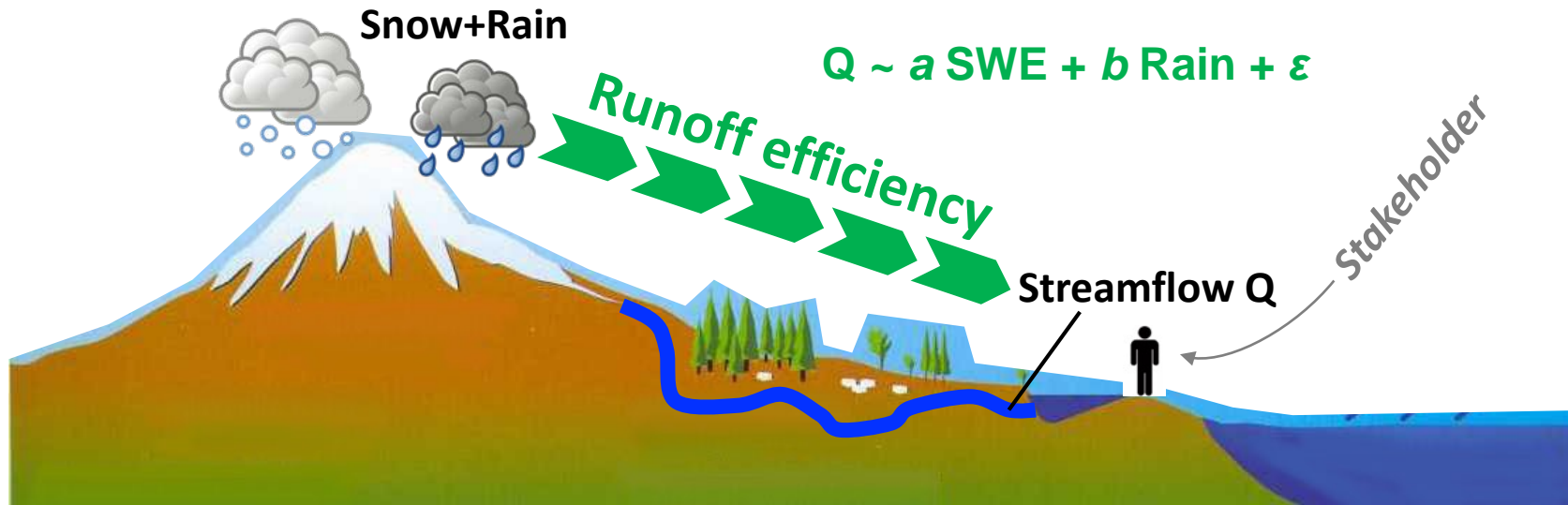
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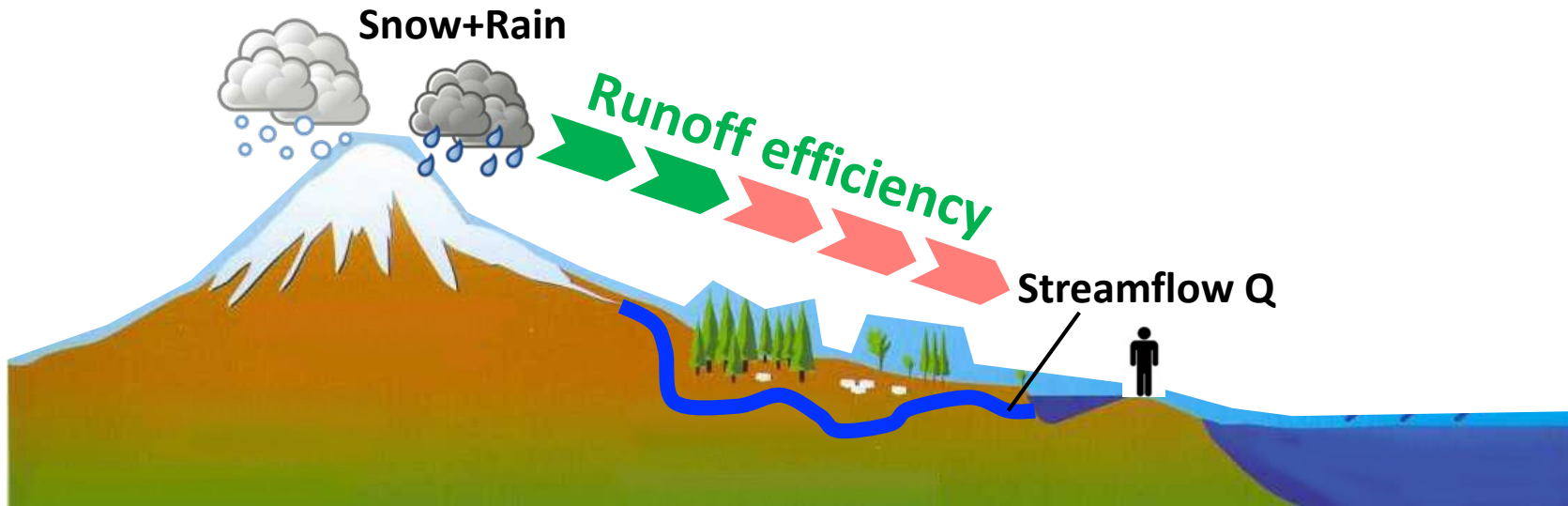


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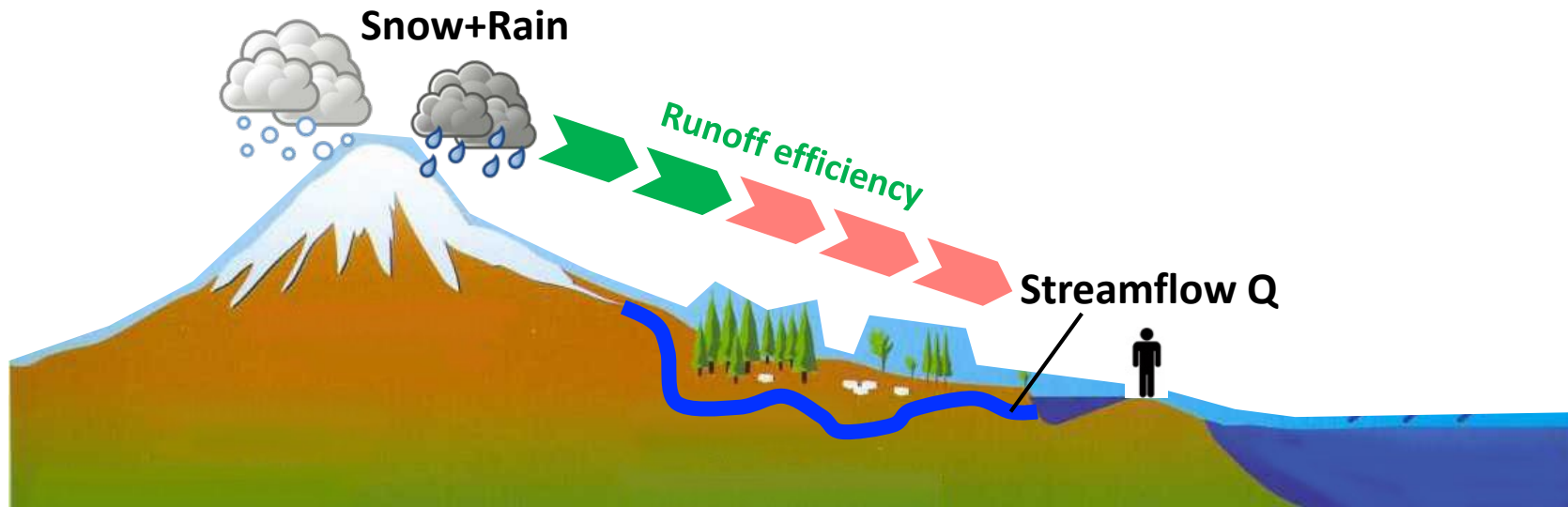
Current NRCS practice for seasonal streamflow forecasts

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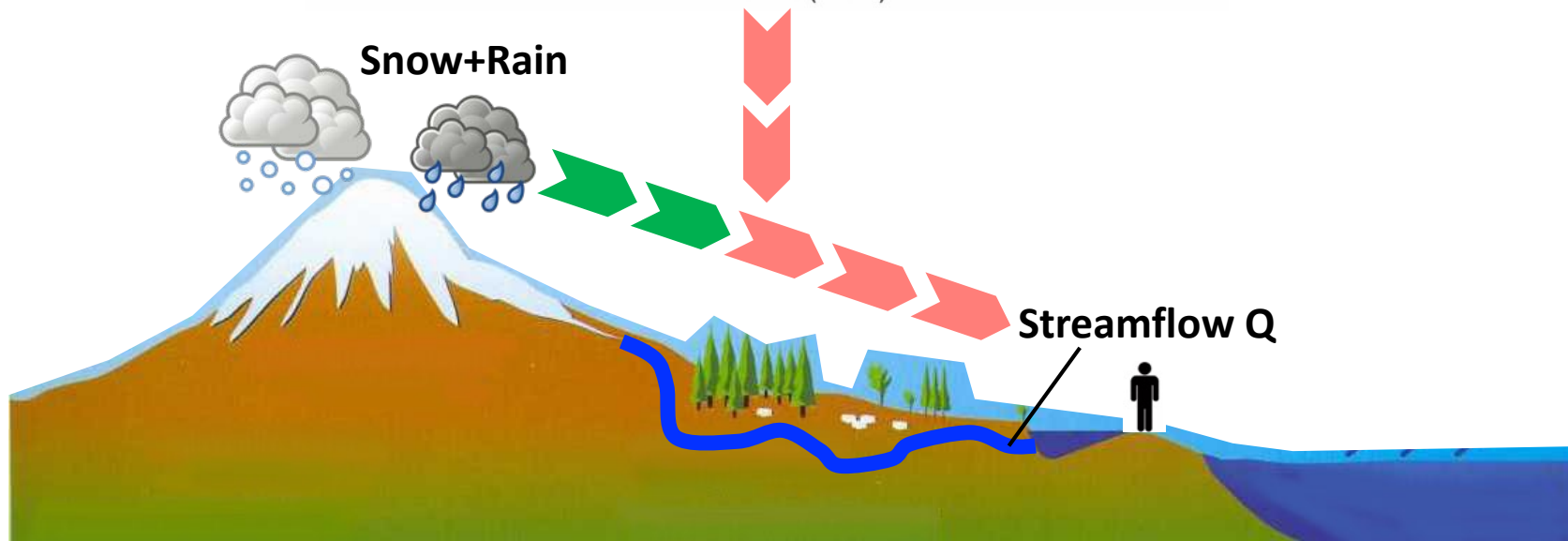
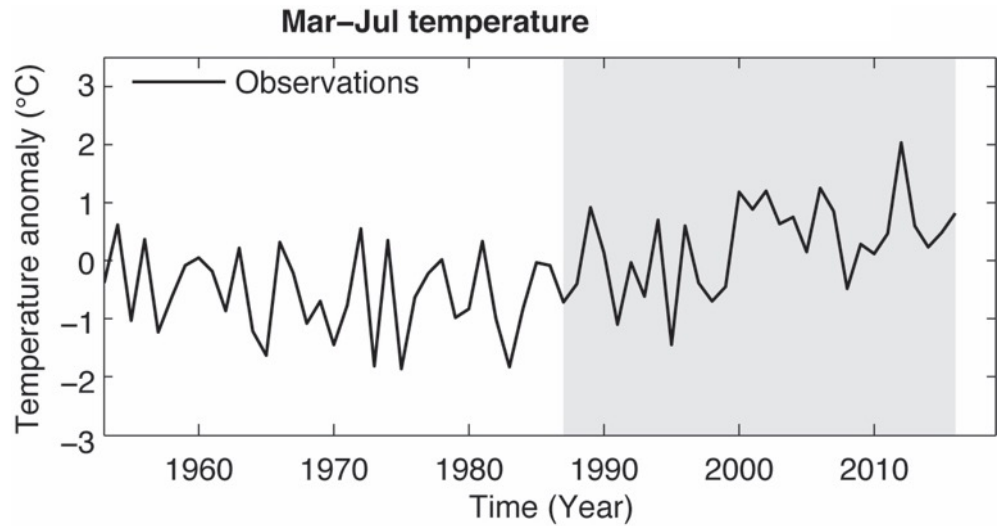
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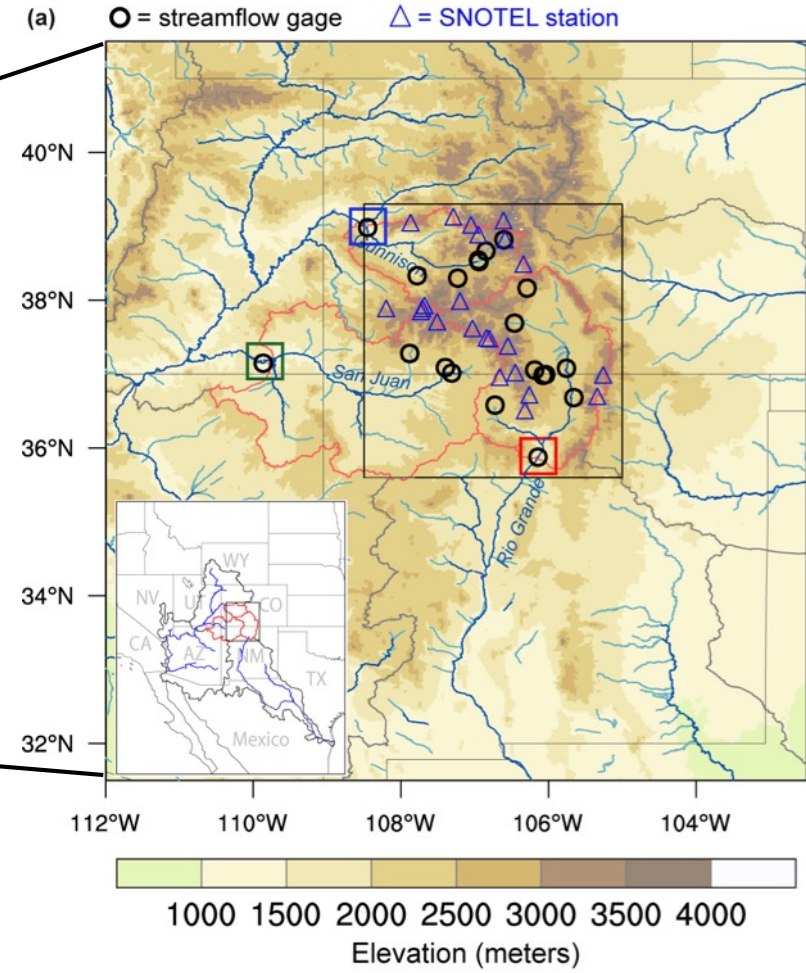
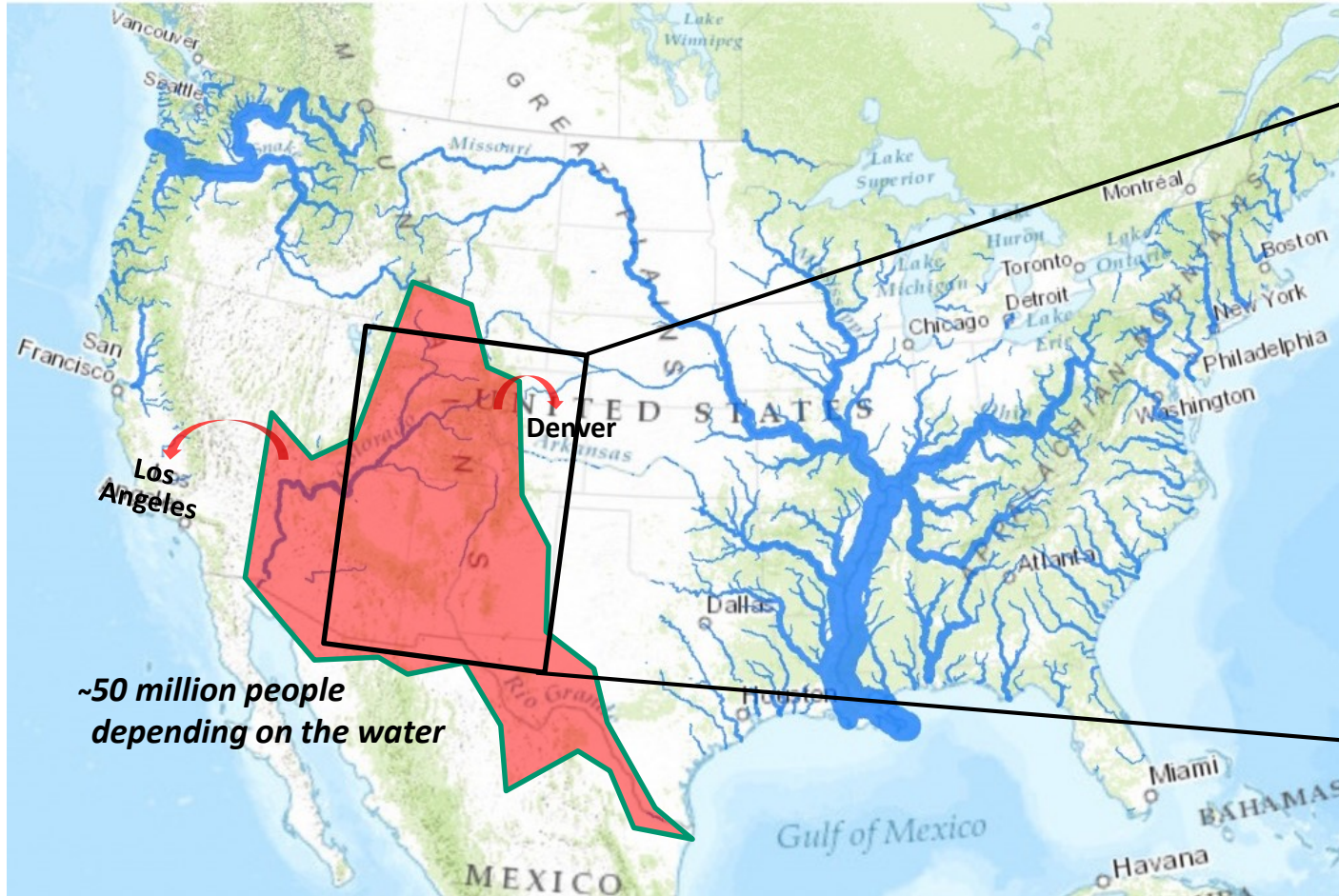
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Incorporating temperature into streamflow forecasts

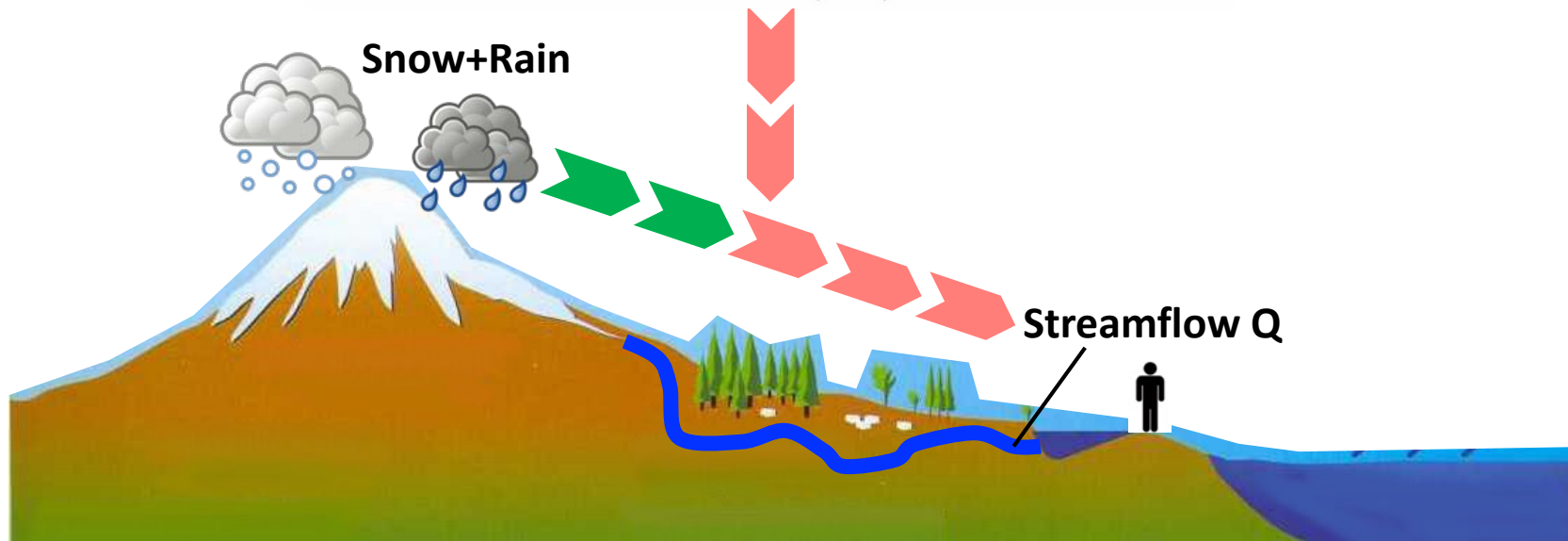
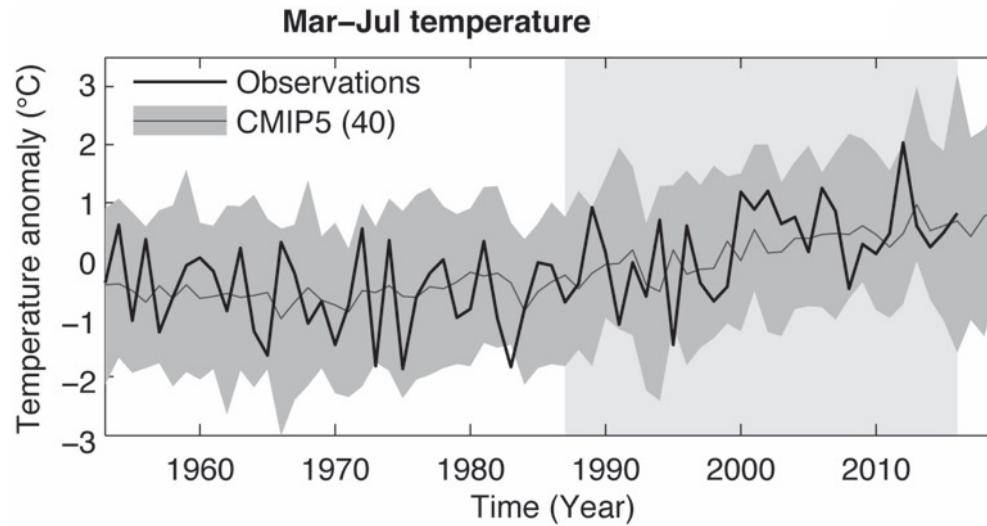


Proposed new practice for seasonal streamflow forecasts

Headwater region of Colorado River and Rio Grande

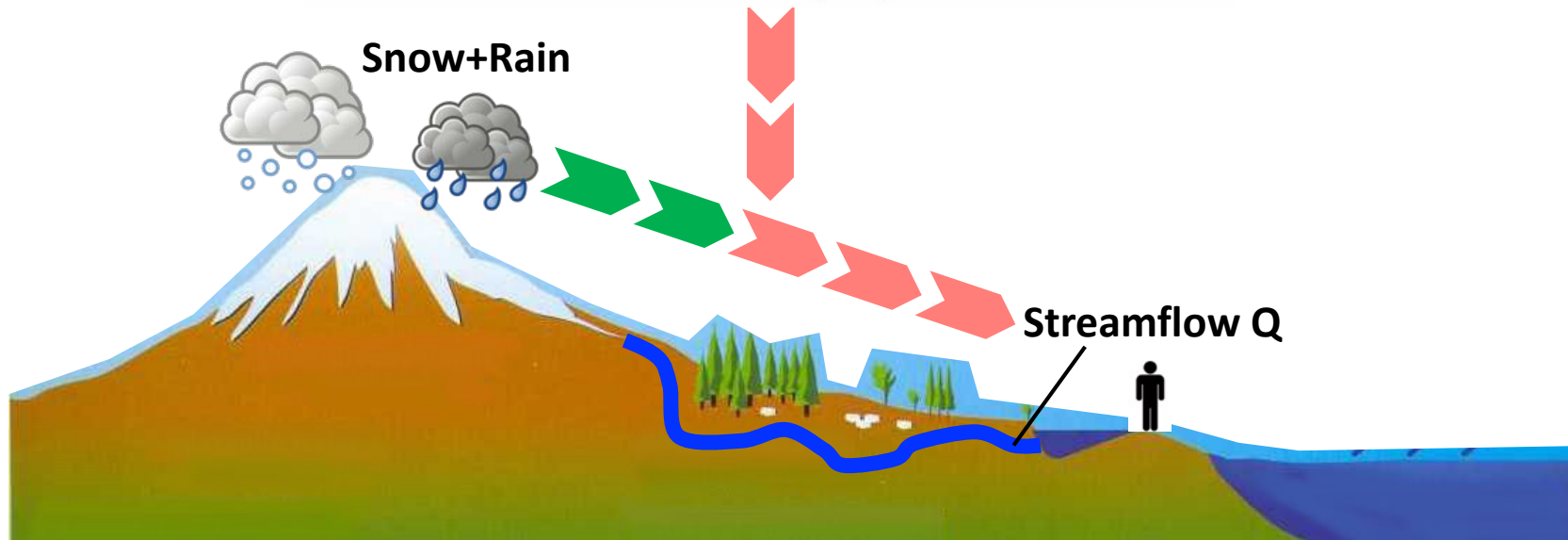
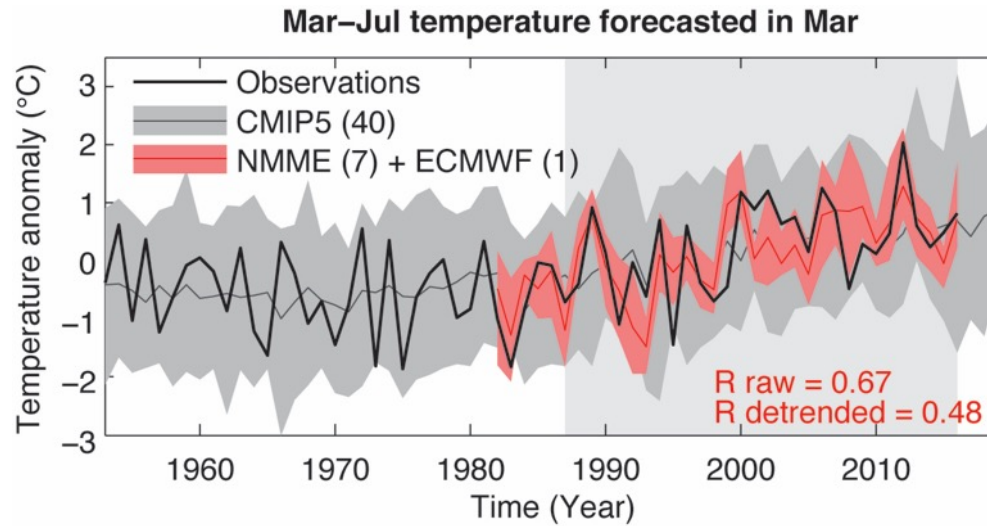


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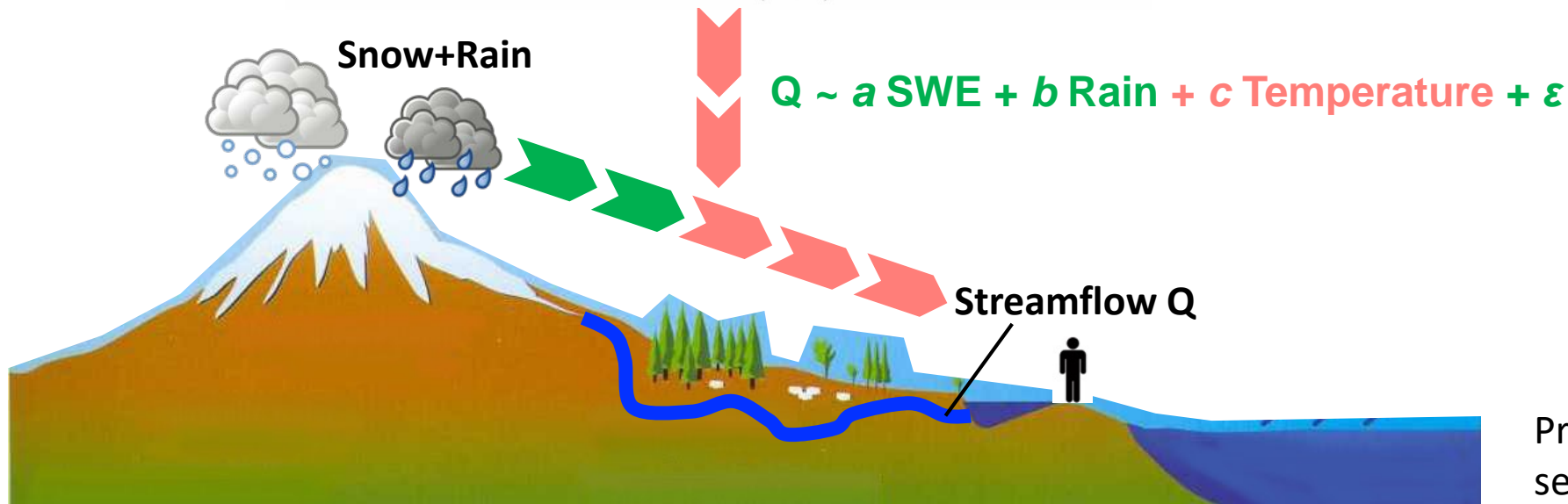
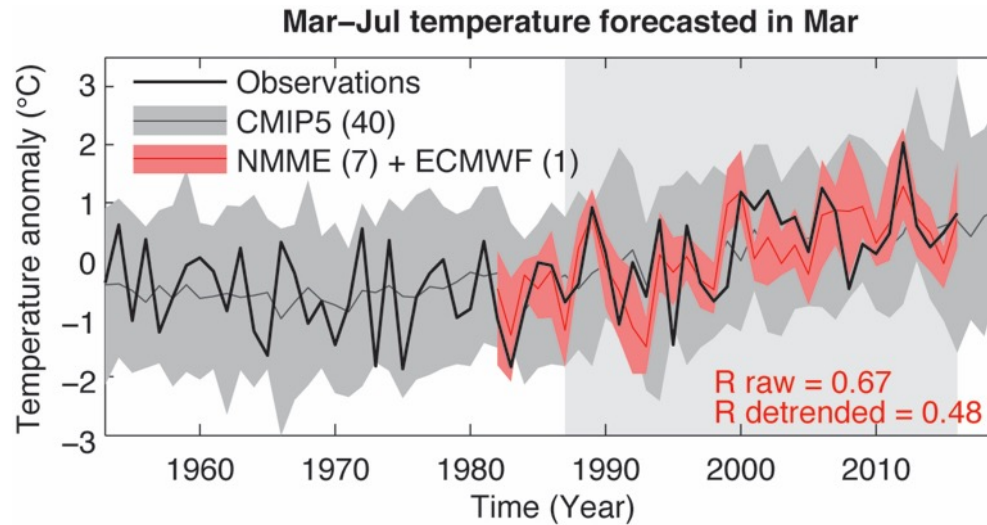
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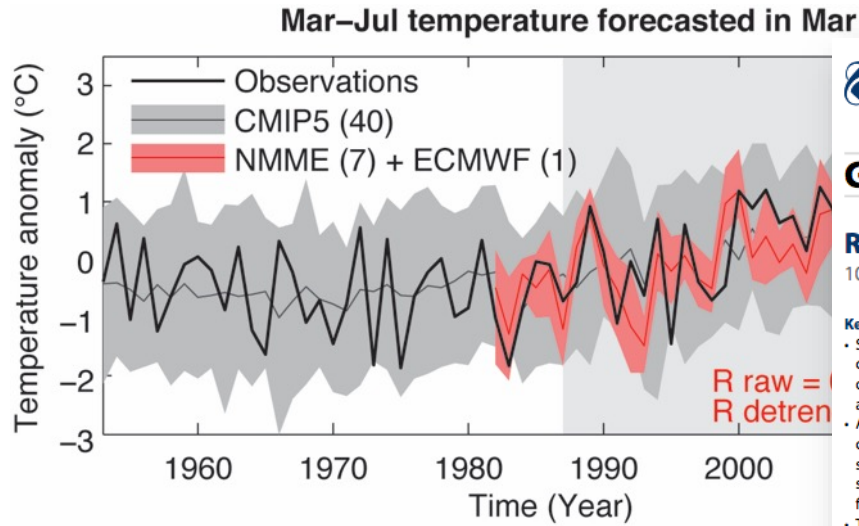
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10.1002/2017GL076043

Key Points:

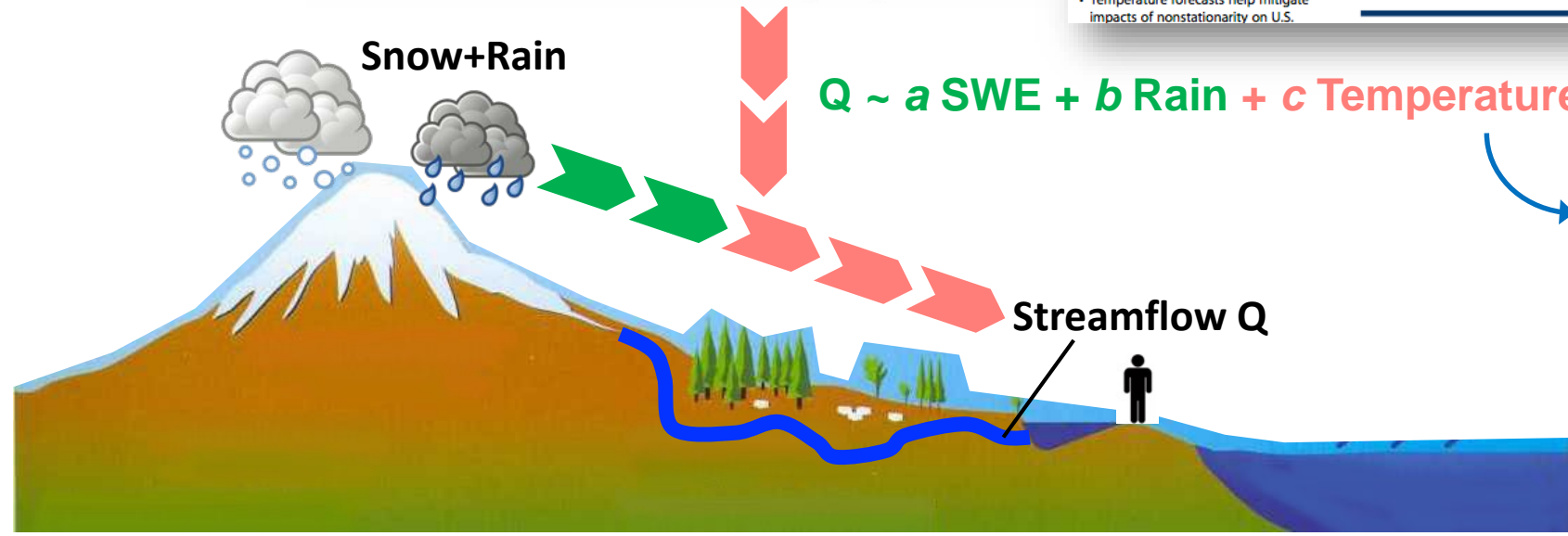
- Seasonal temperature forecasts from climate prediction models are skillful over the headwaters of the Colorado and Rio Grande river basins
- Adding temperature information to current operational seasonal streamflow forecasts in snowmelt-driven basins improves forecast skill
- Temperature forecasts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

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

Flavio Lehner¹, Andrew W. Wood¹, Dagmar Llewellyn², Douglas B. Blatchford³, Angus G. Goodbody⁴, and Florian Pappenberger⁵

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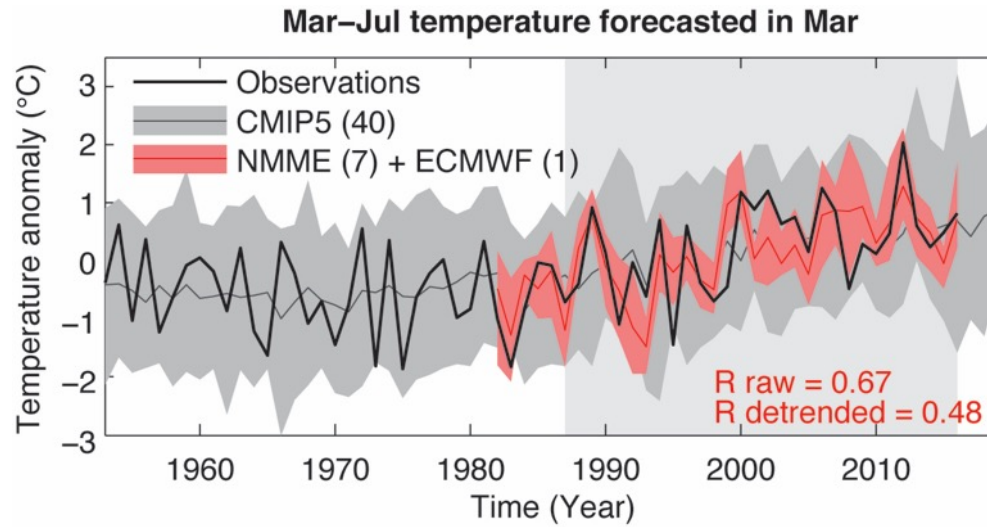
$$Q \sim a \text{ SWE} + b \text{ Rain} + c \text{ Temperature} + \epsilon$$



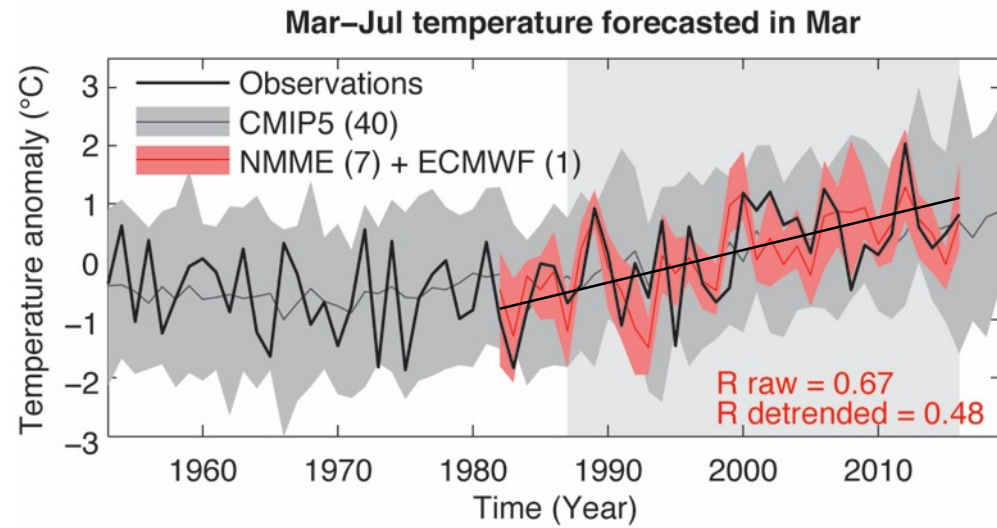
~10% improvement in forecast skill

Proposed new practice for seasonal streamflow forecasts

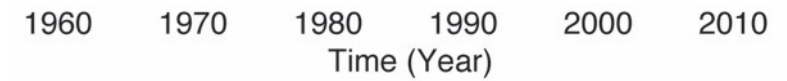
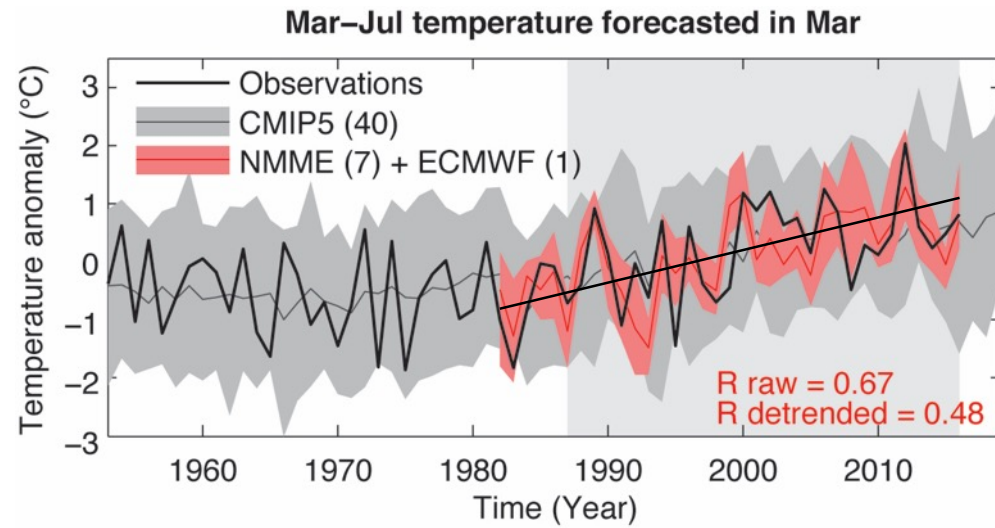
Southwest warming ...



Southwest warming ...

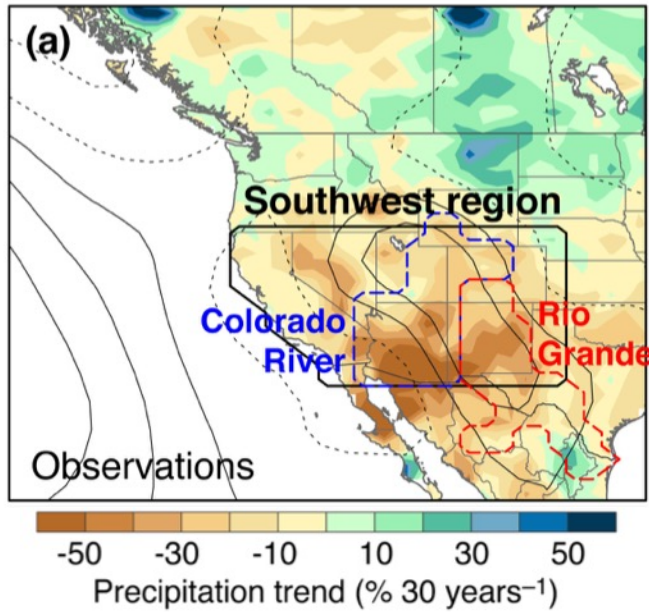


Southwest warming ... and drying



Southwest drying

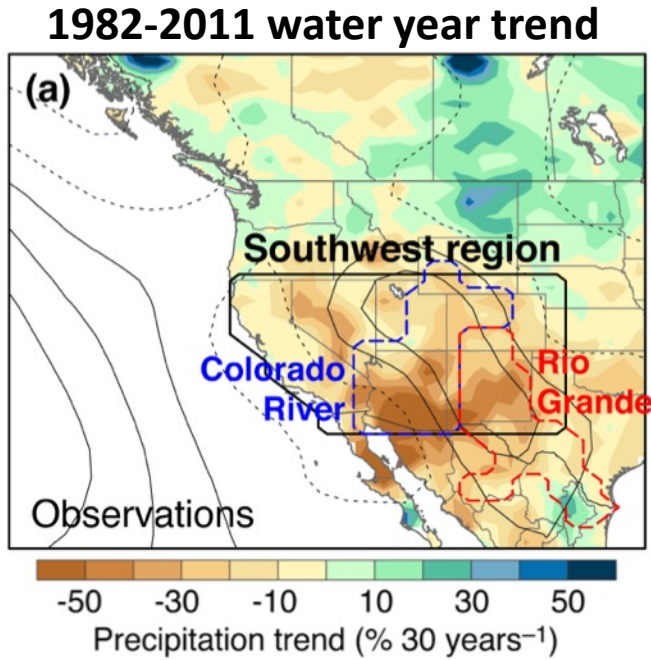
1982-2011 water year trend



Observations:

- GPCC
- 20CR

Southwest drying



Observations:
- GPCC
- 20CR

Possible reasons for US Southwest drying:

- Forced:

- Changes in North American monsoon (Pascale et al. 2017)
- ENSO changes (Seager et al. 2012)
- Expansion of subtropics (Davis and Rosenlof 2012)
- Weather patterns change (Prein et al. 2016)

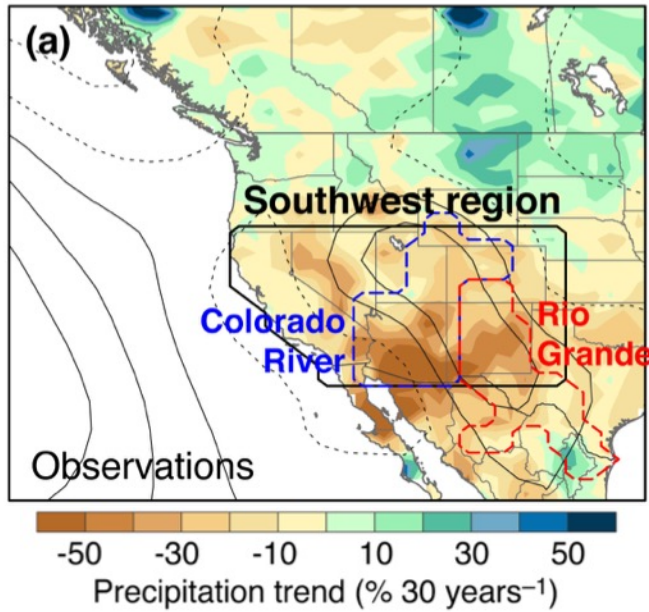
- Internal:

- Chaotic atmospheric circulation variability
- Teleconnections from tropical SSTs variability

(Seager et al. 2005, Schubert et al. 2006, Hoerling et al. 2010, Seager and Hoerling 2014, Delworth et al. 2015, Hoerling et al. 2016, Seager and Ting 2017)

Southwest drying

1982-2011 water year trend



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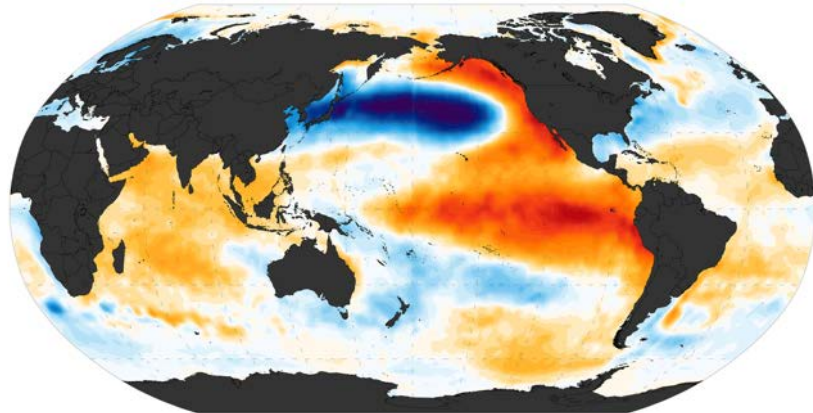
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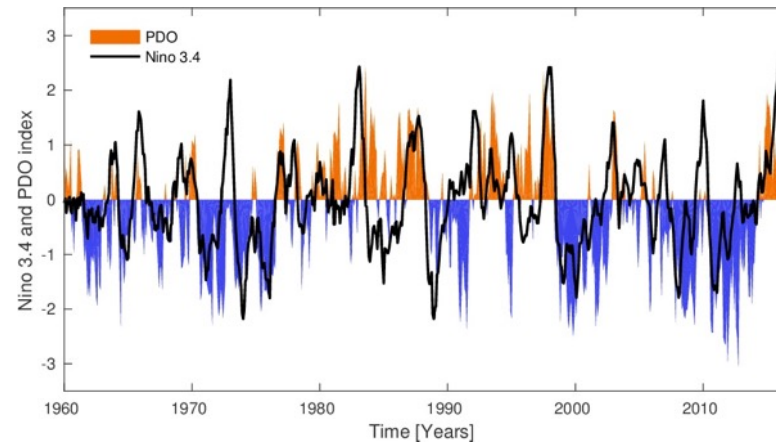
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Pacific Decadal Oscillation

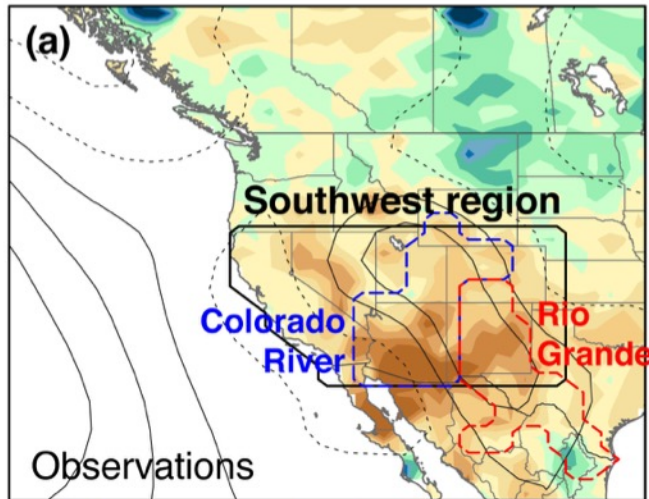


Temperature (°C sd⁻¹)



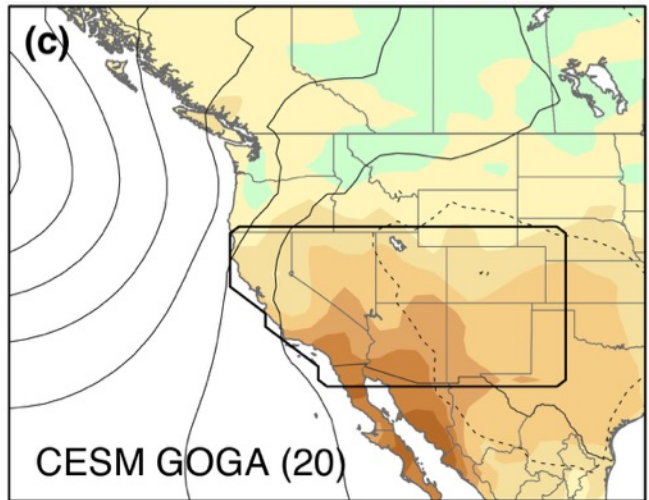
Southwest drying

1982-2011 water year trend



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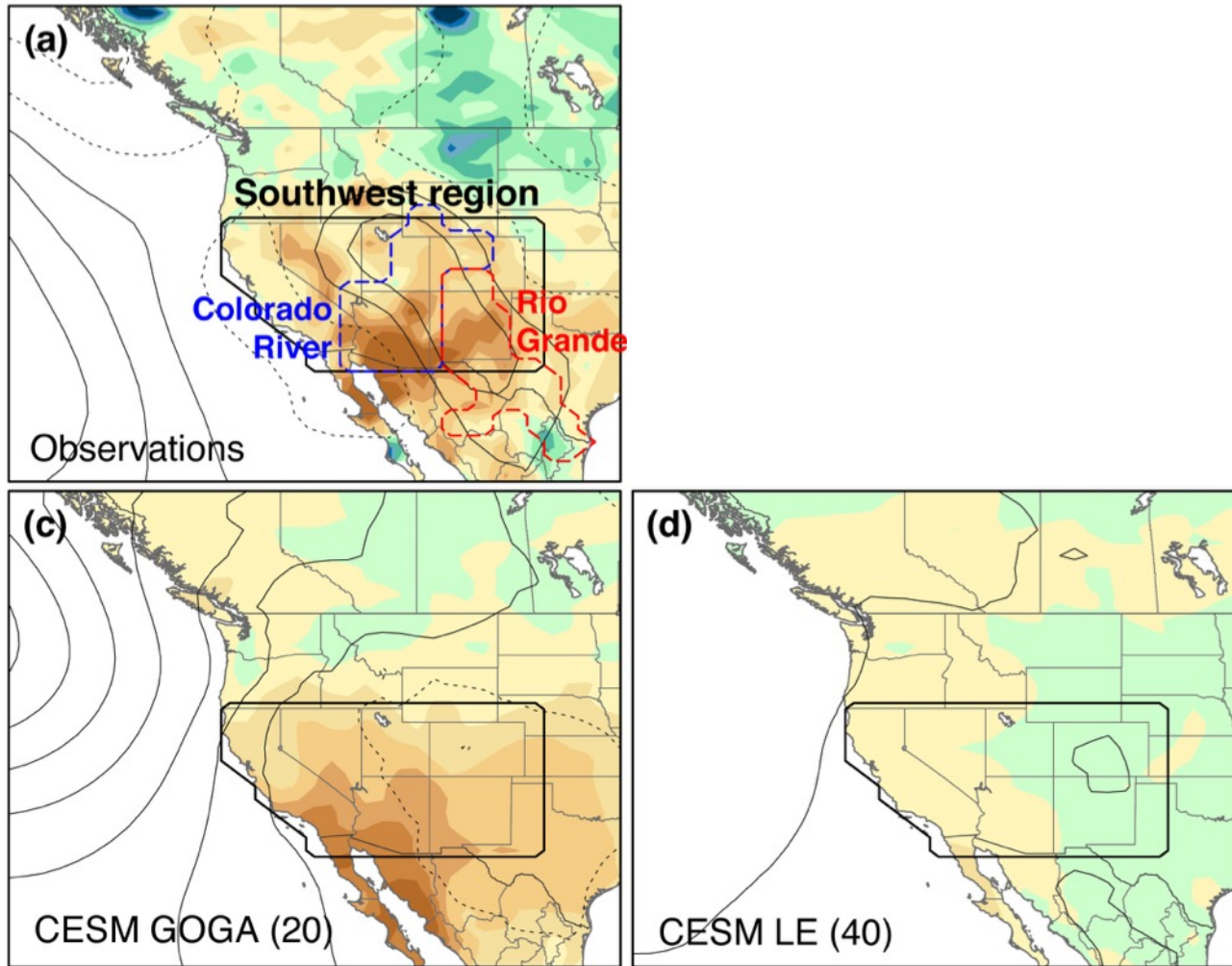
Model:

- Atmosphere-only (CAM5)
- Prescribed observed SSTs
- Historical GHG forcing



Southwest drying

1982-2011 water year trend

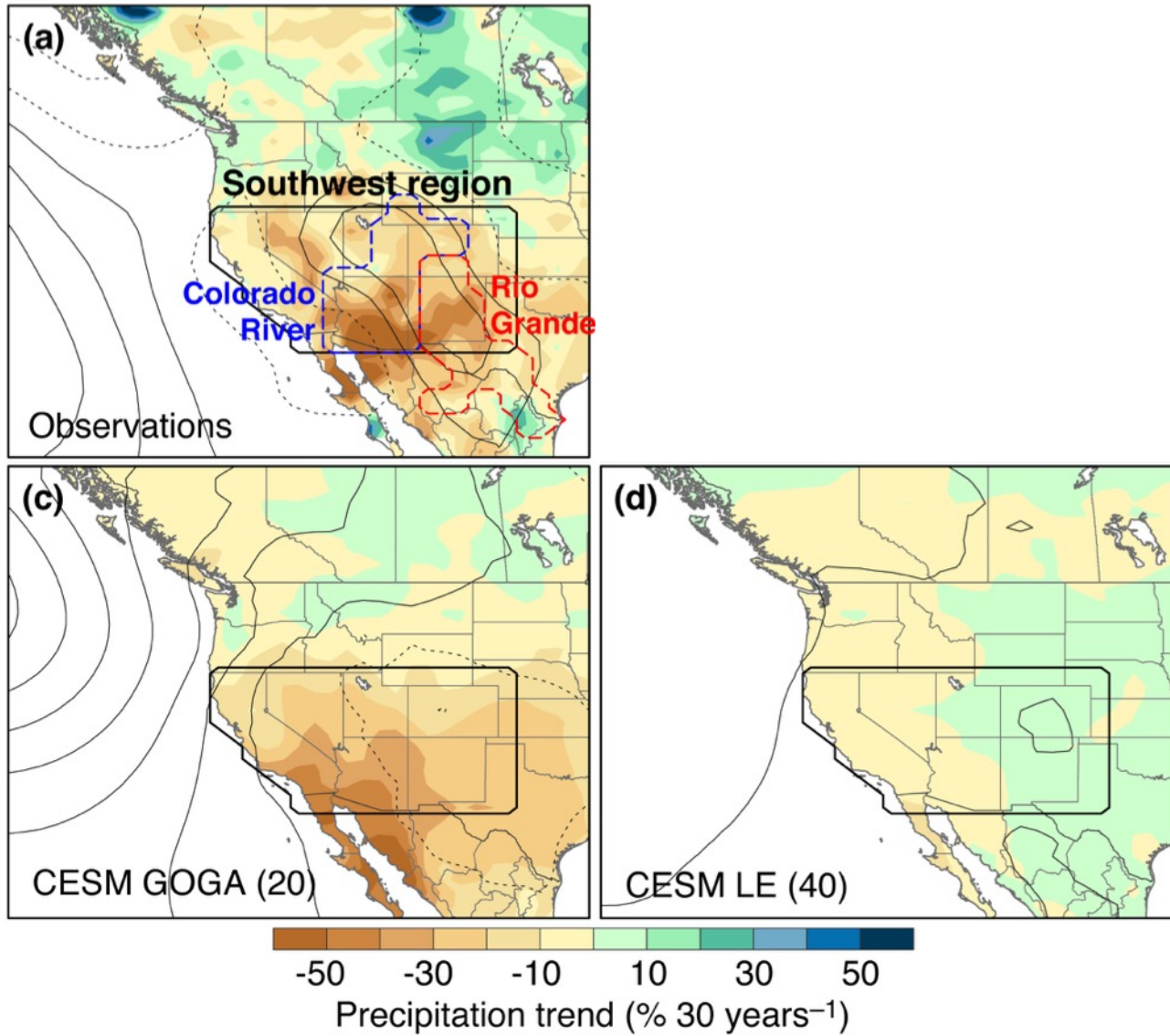


Model:
- Coupled GCM (CESM)
- Historical GHG forcing

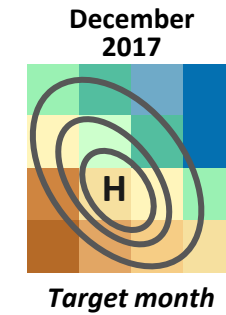


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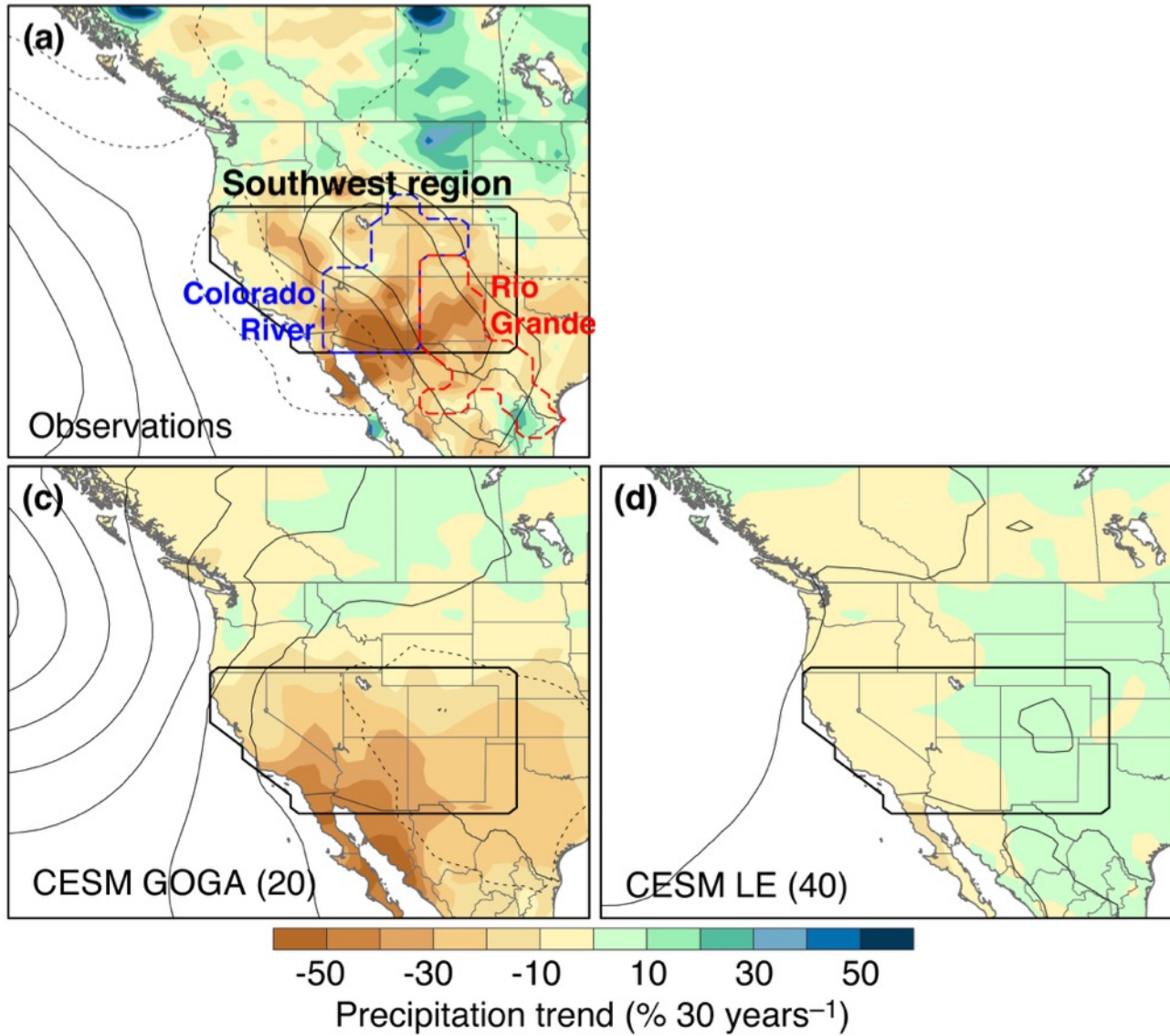


Dynamical adjustment:

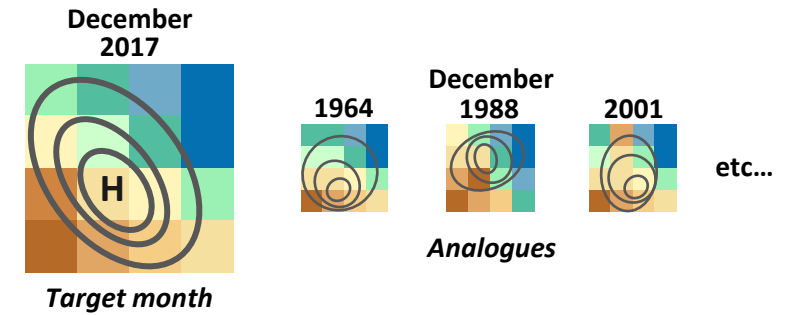


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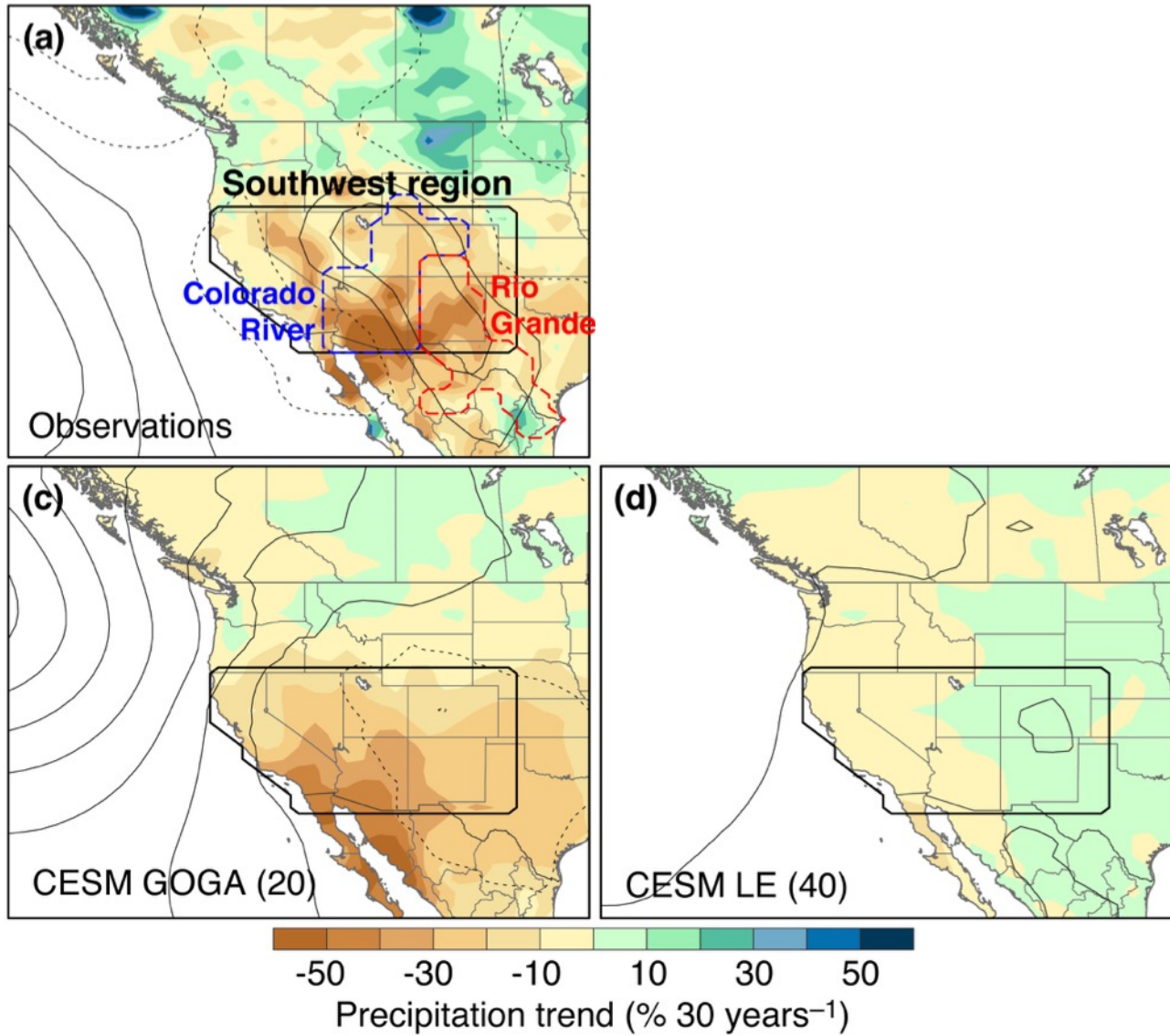


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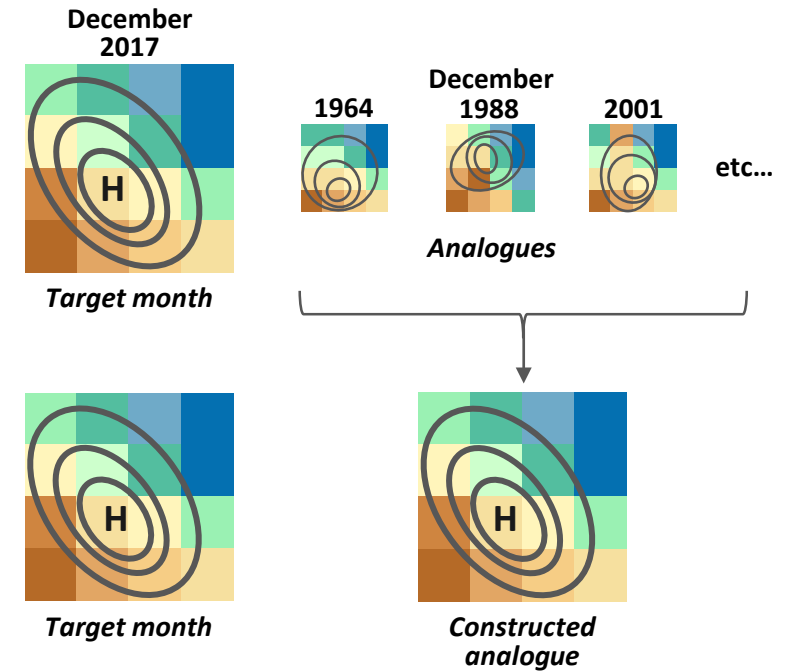


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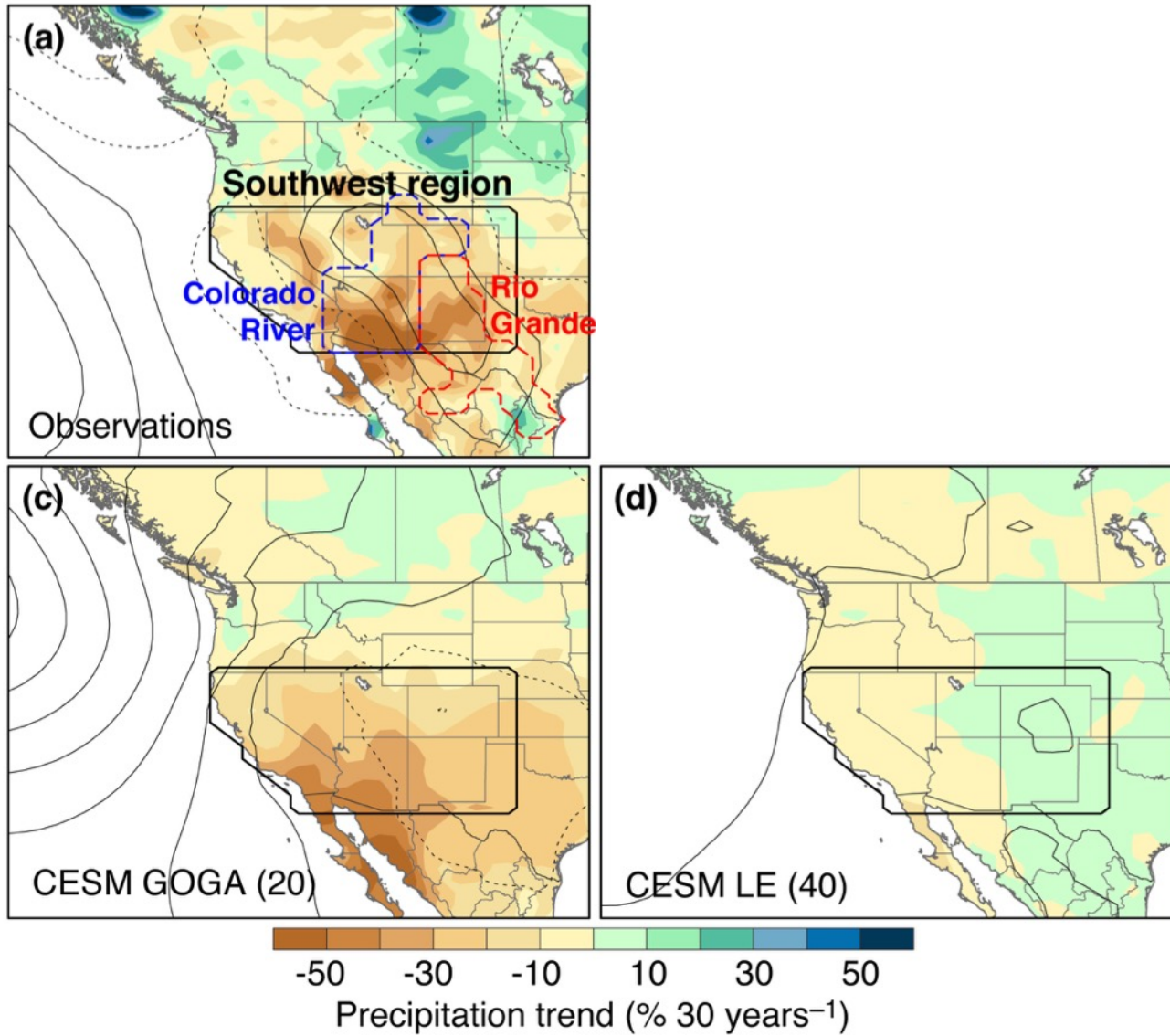


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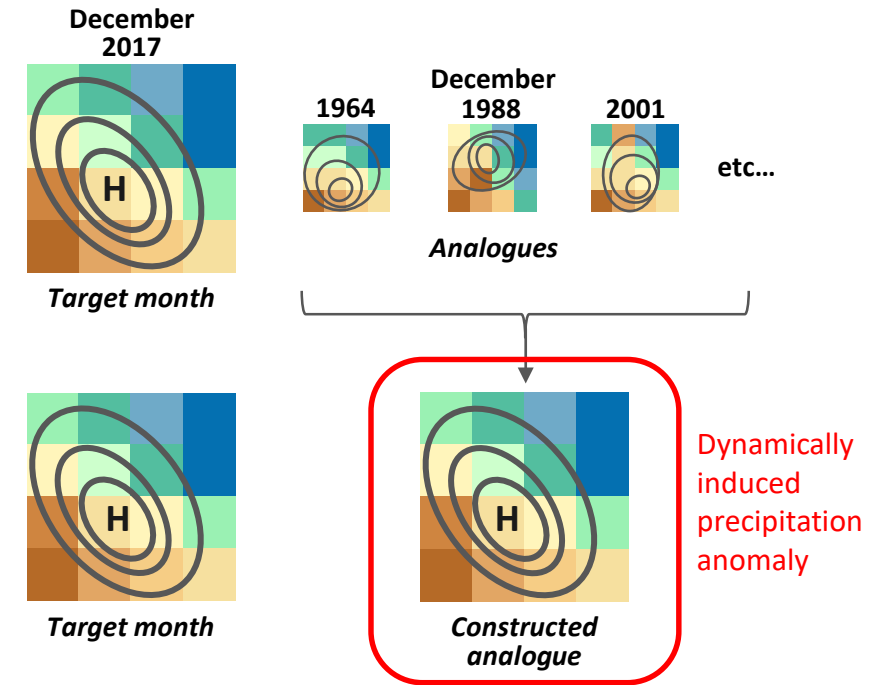


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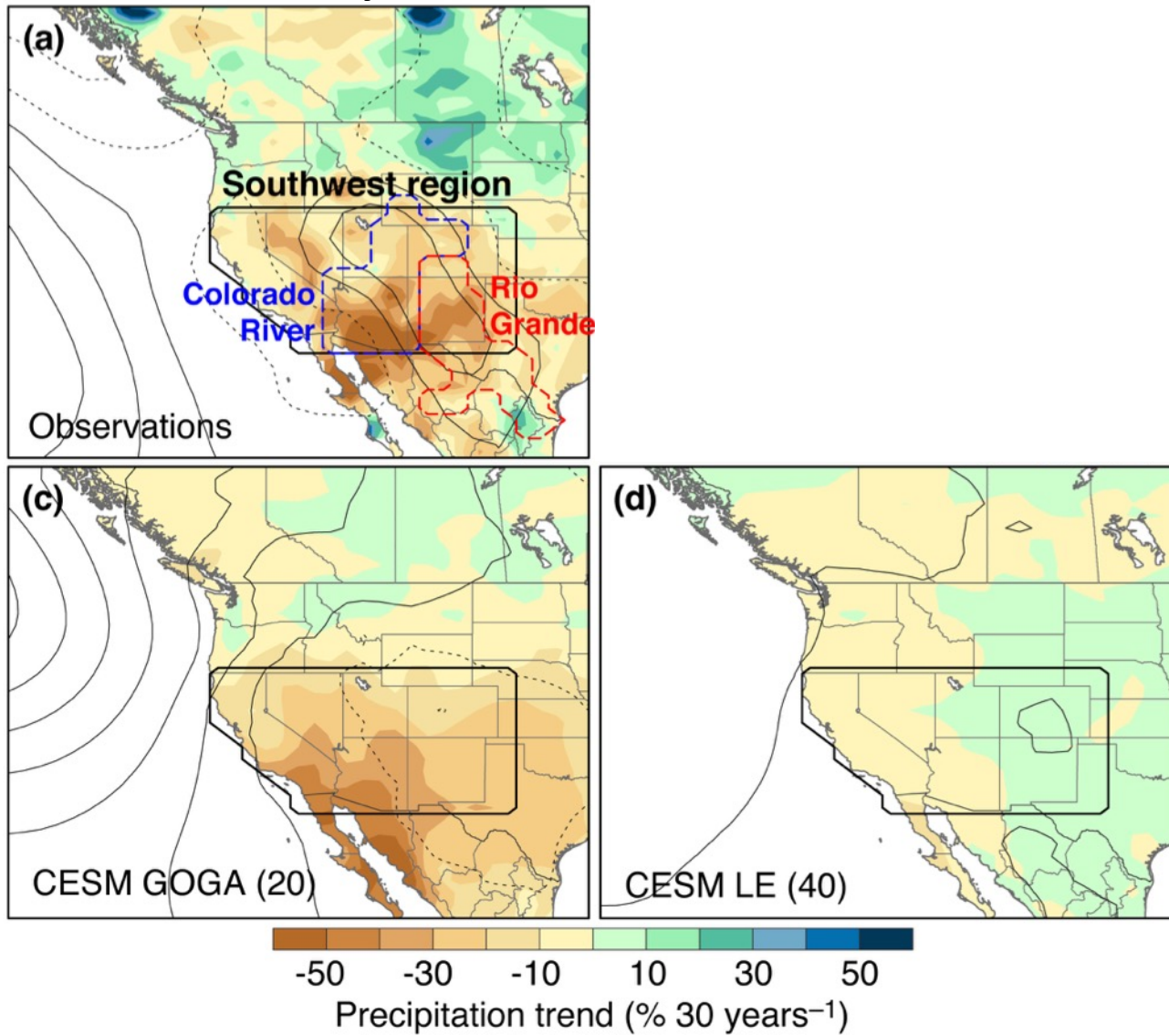


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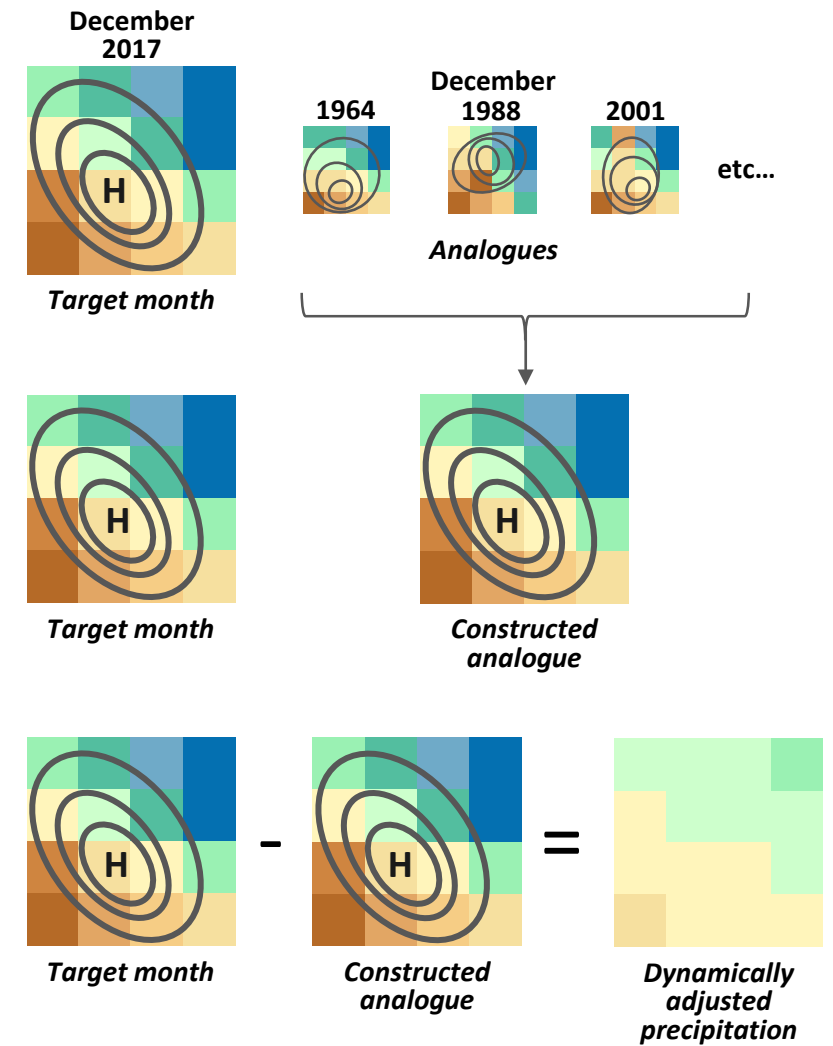


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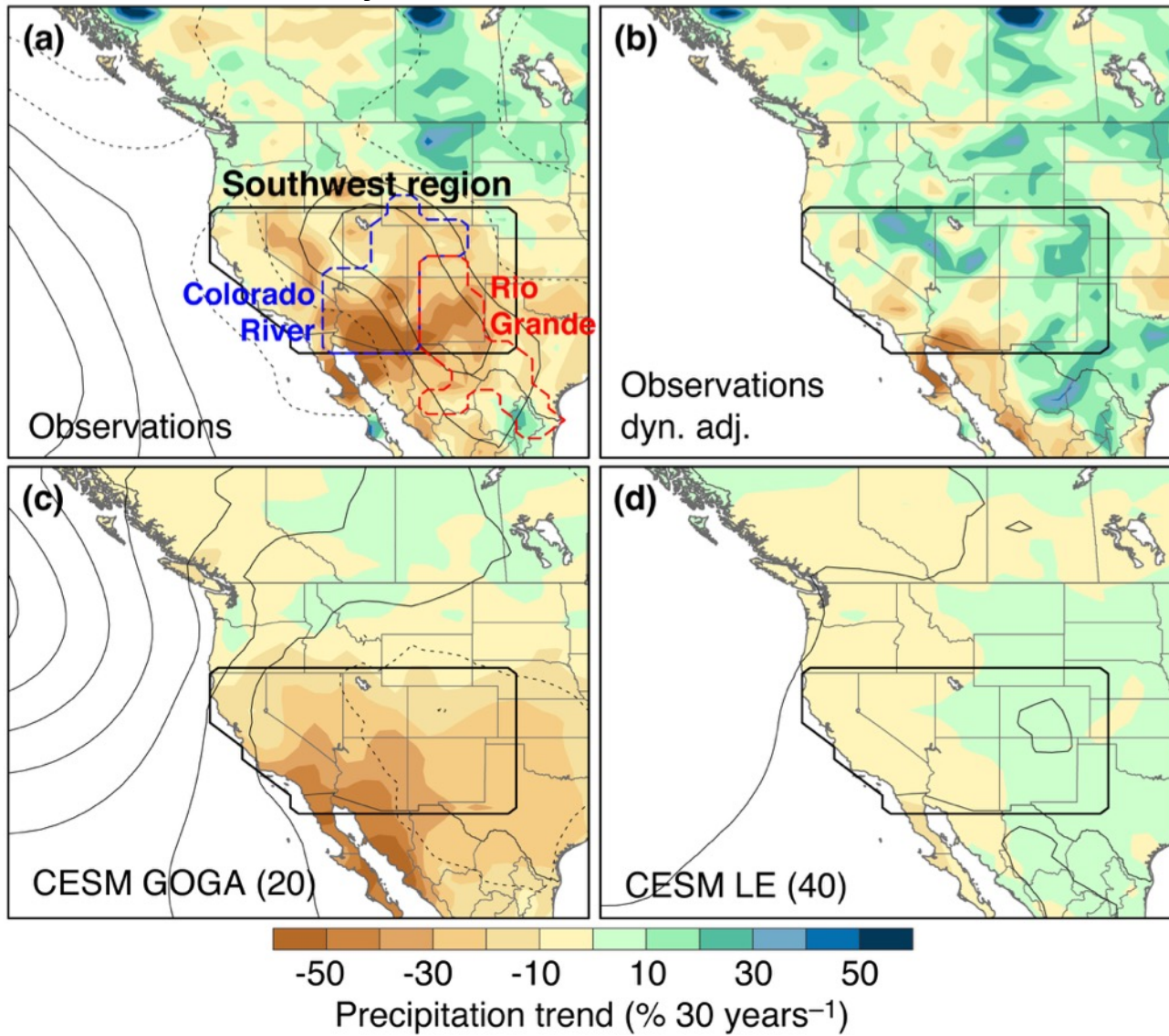


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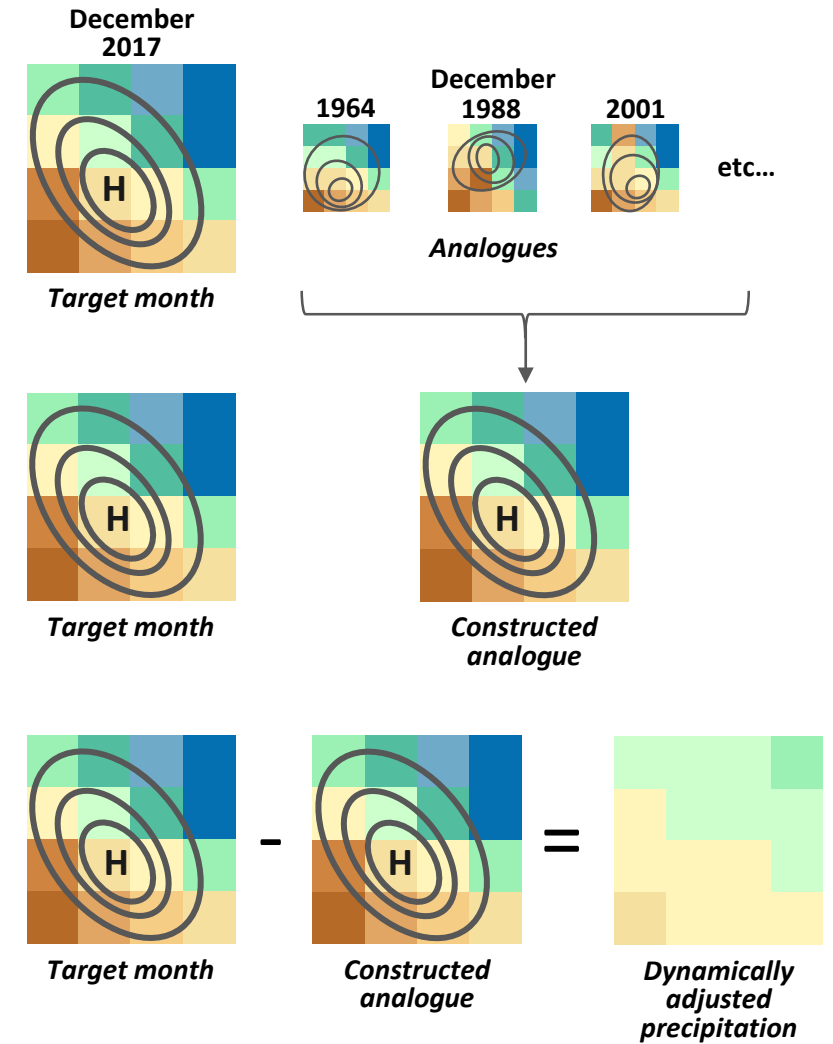


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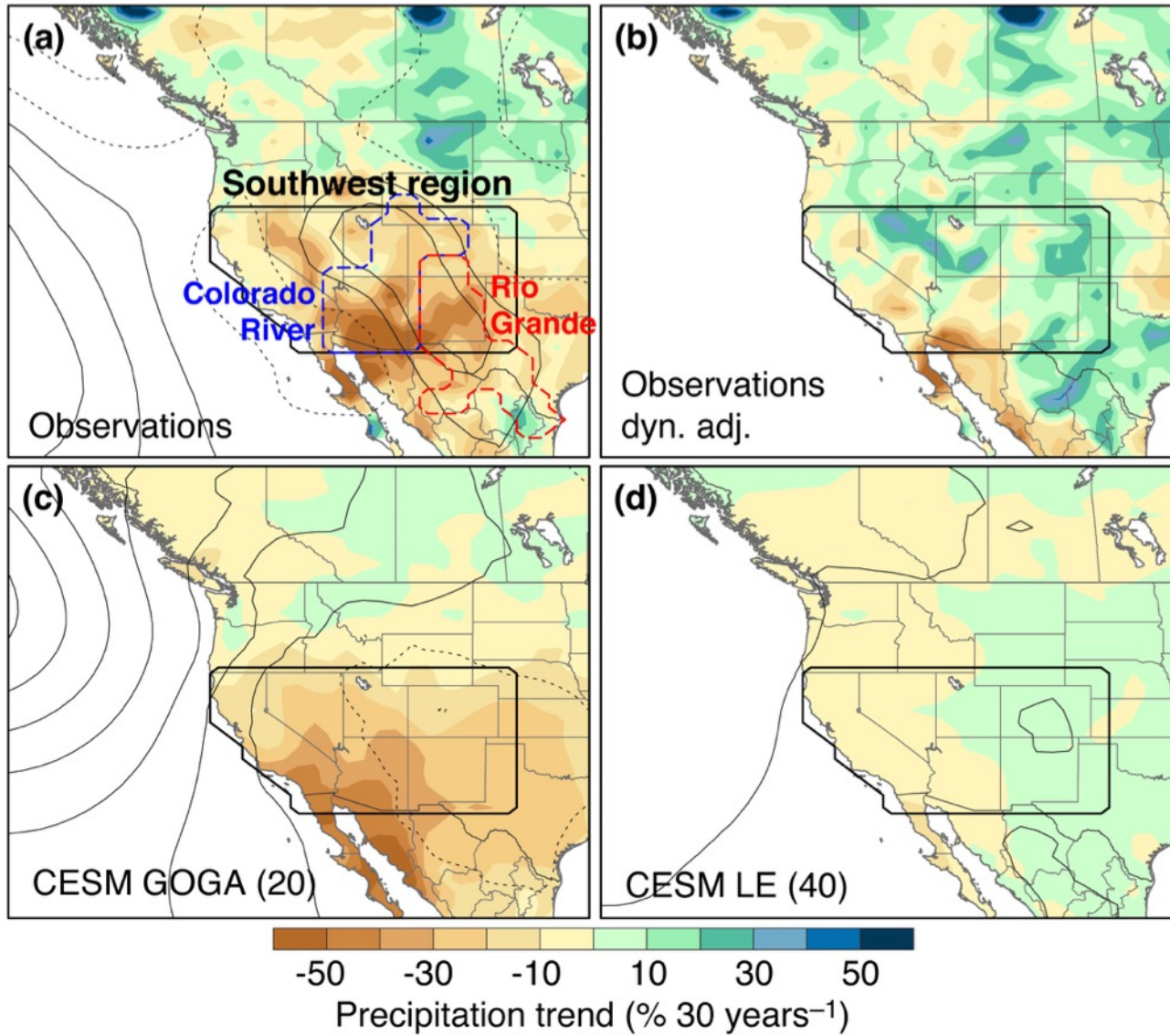


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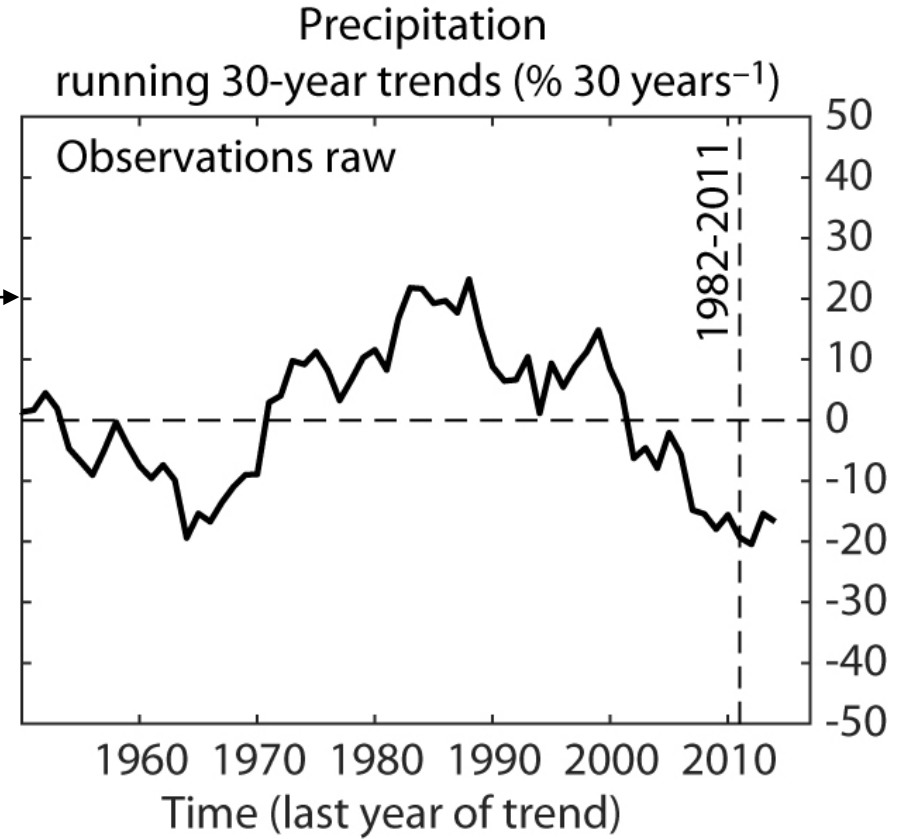
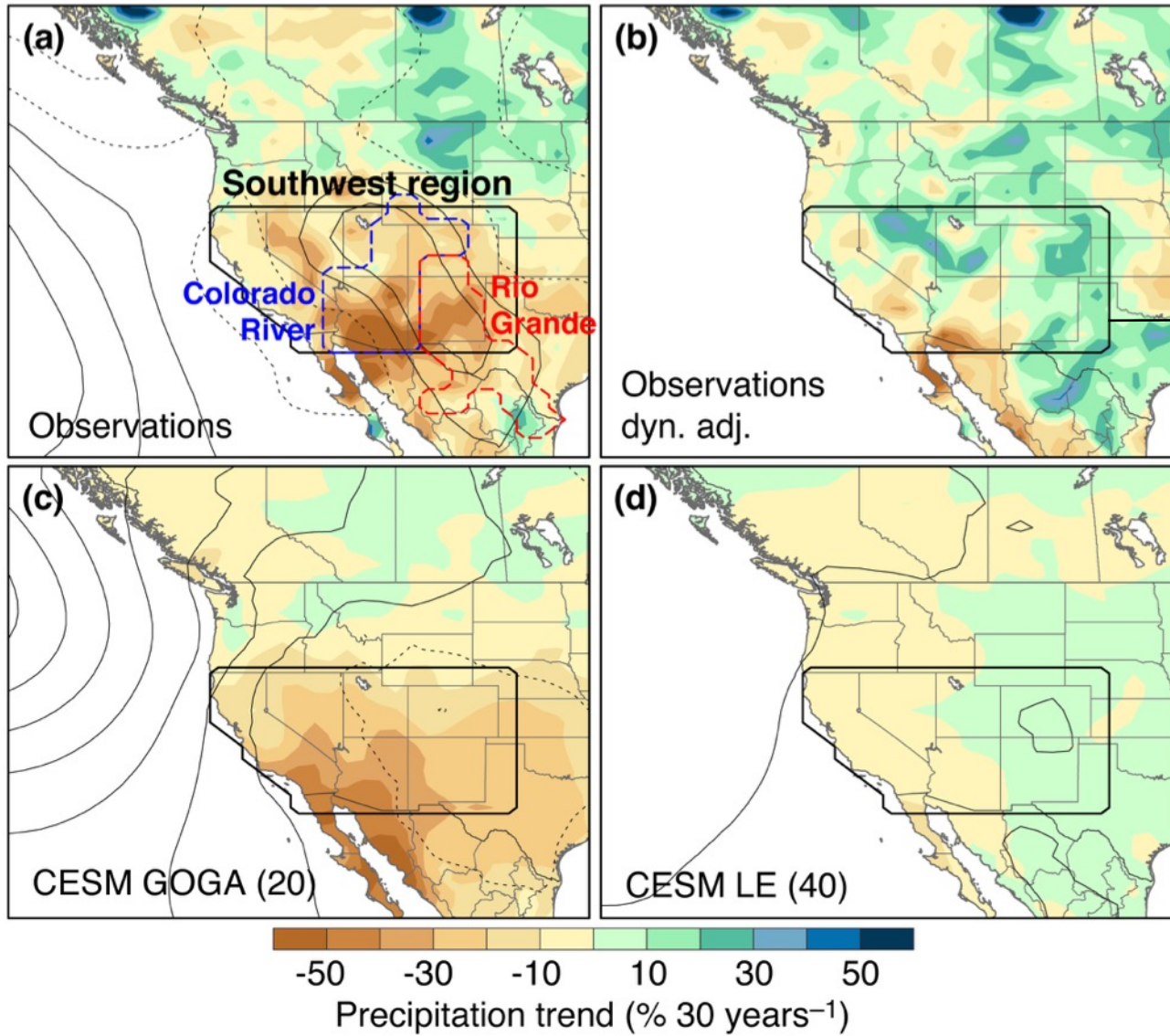
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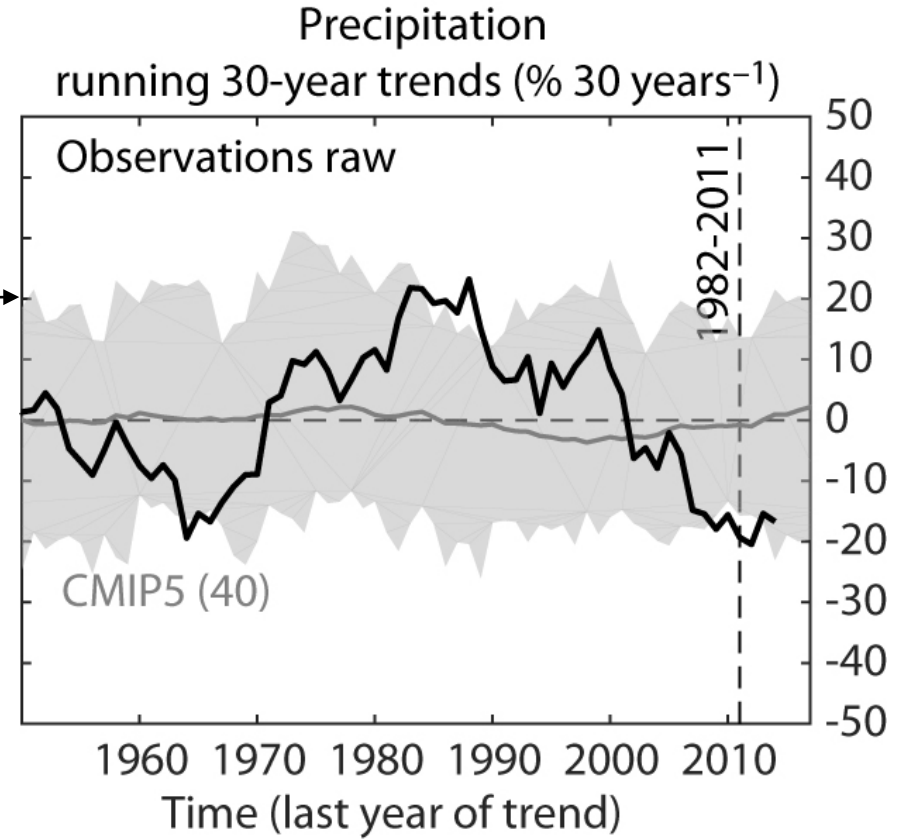
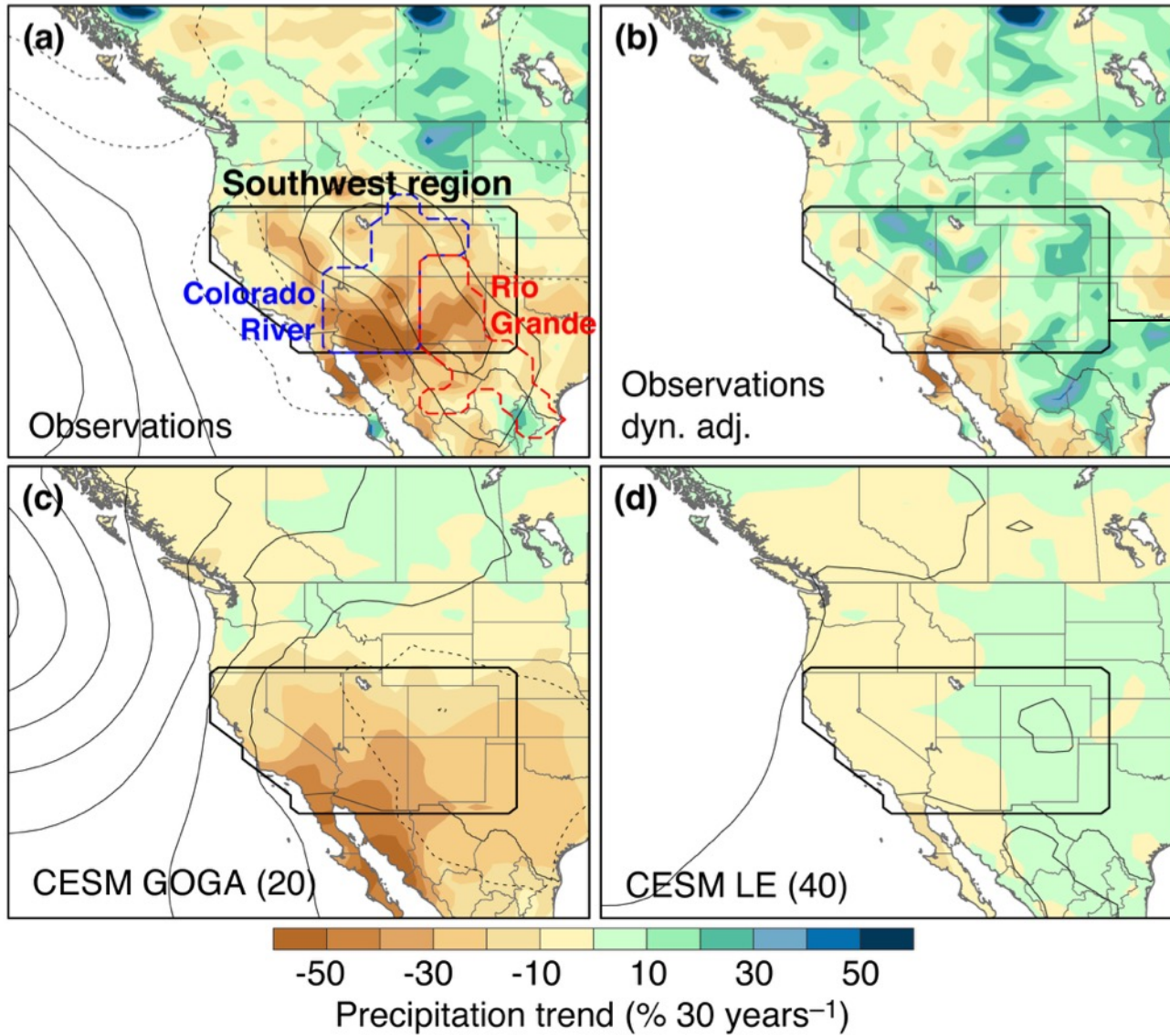
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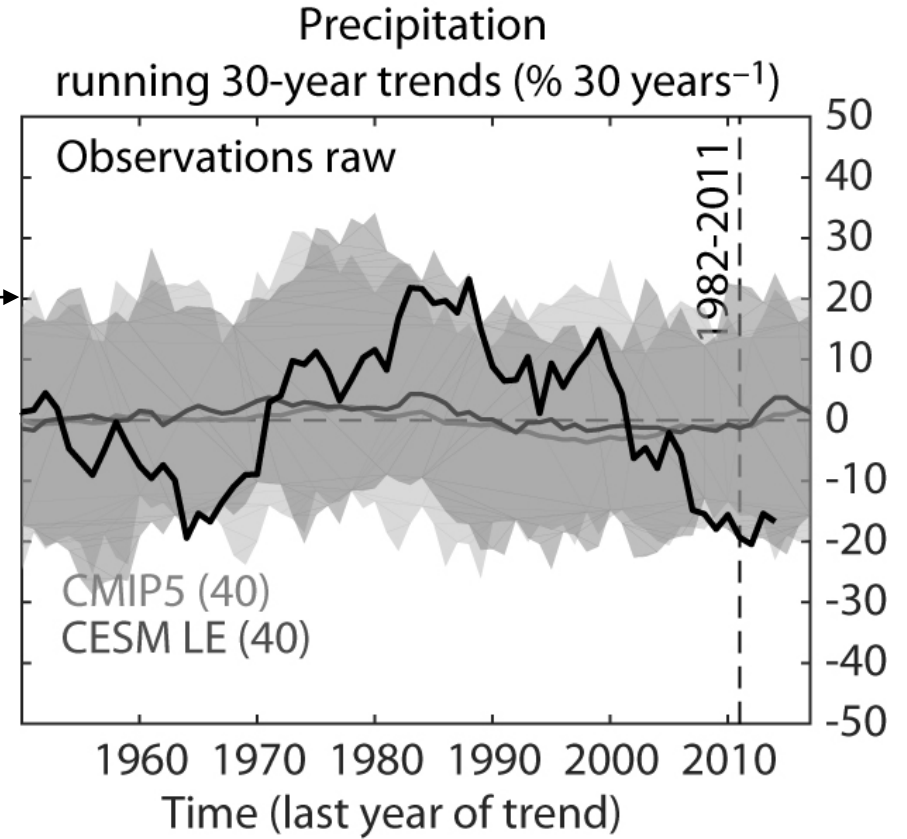
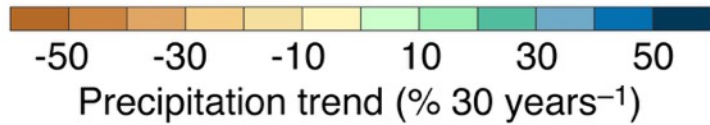
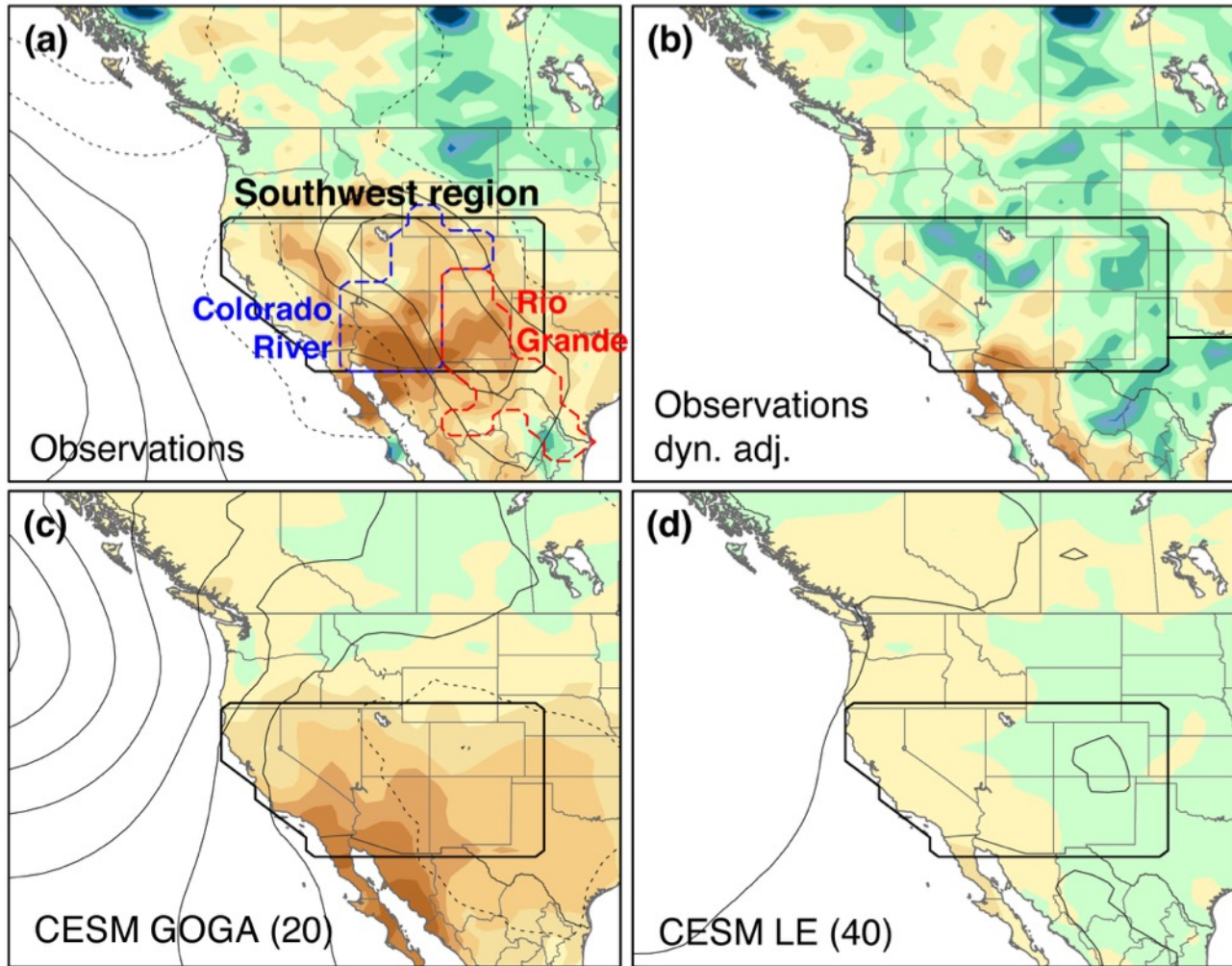
Southwest drying

1982-2011 water year trend



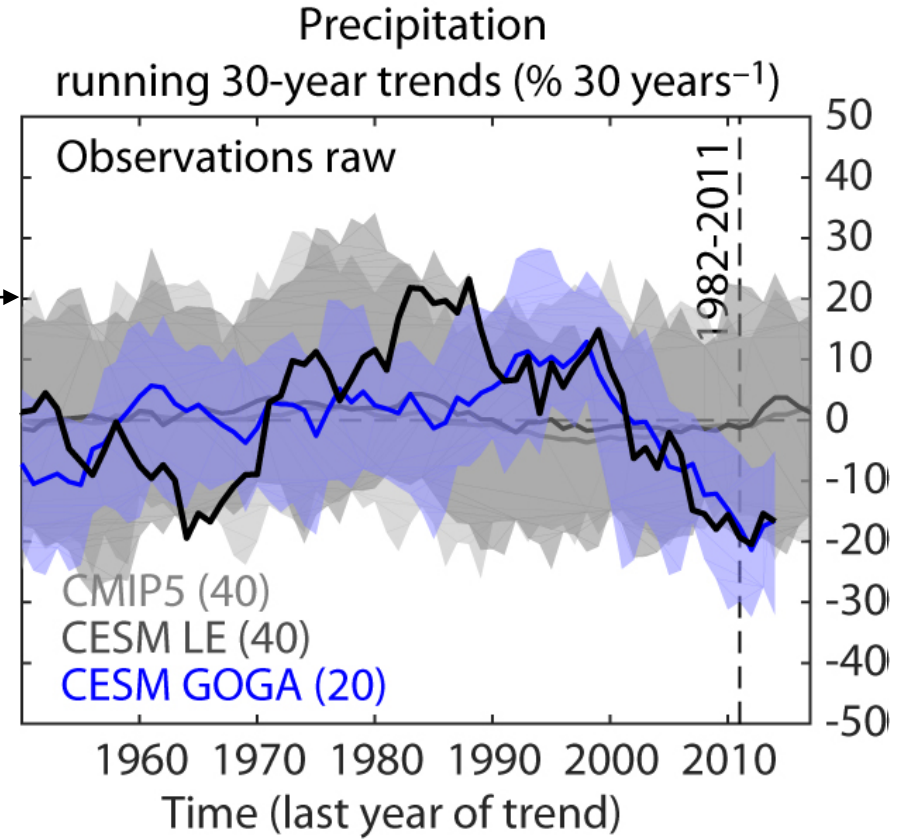
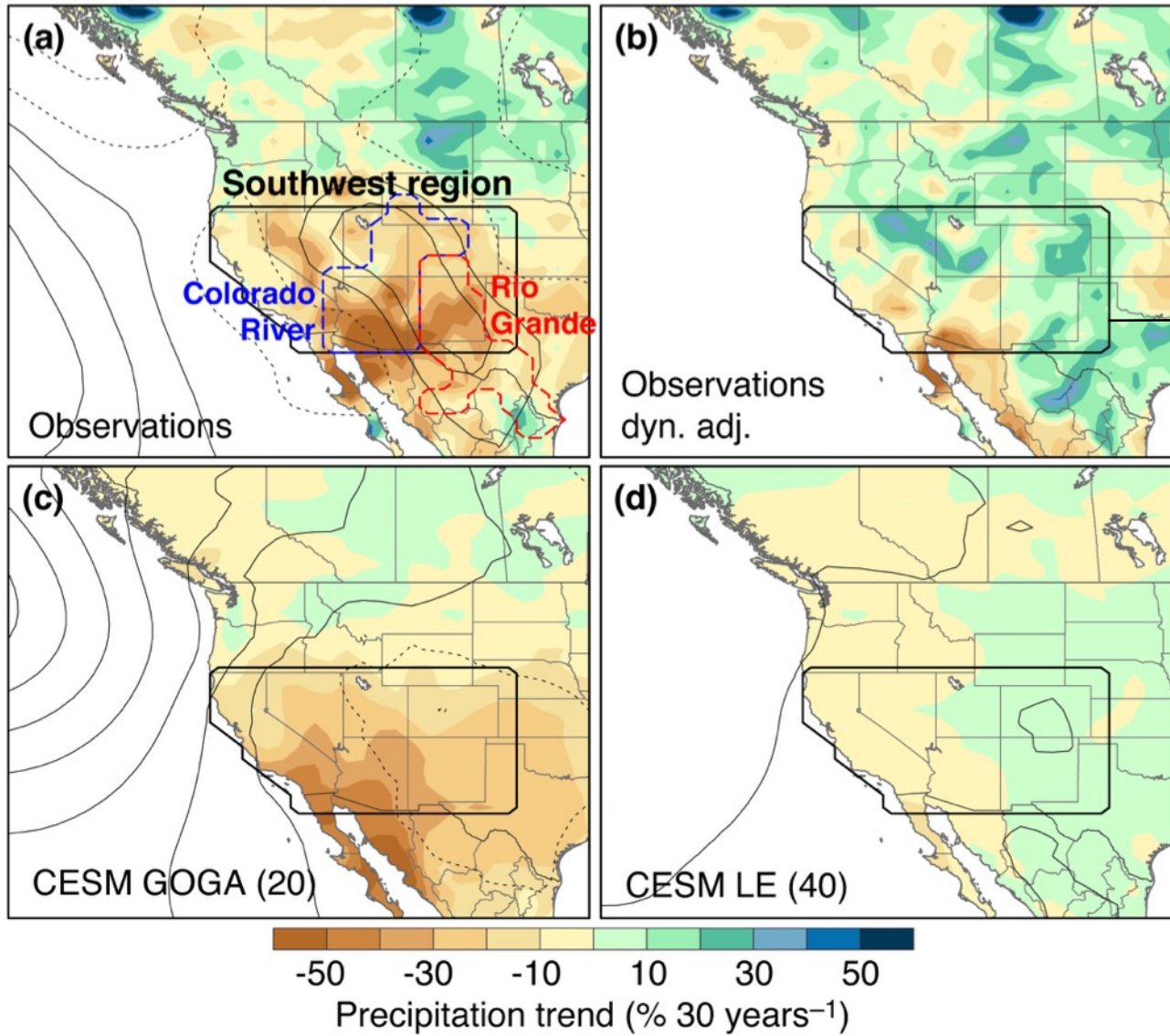
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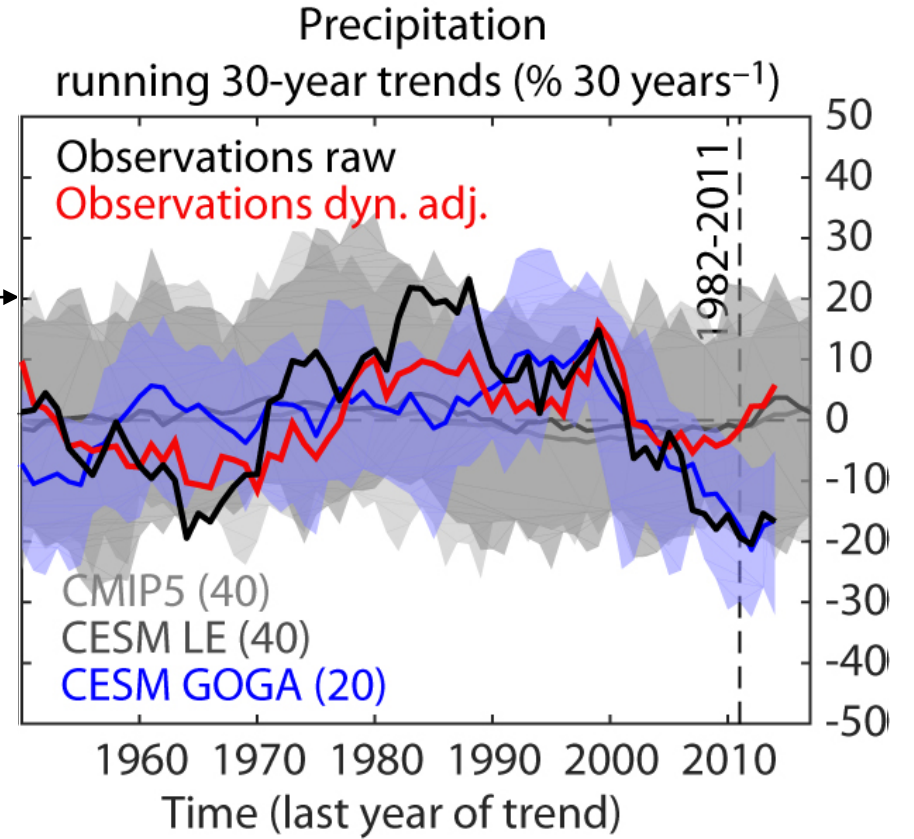
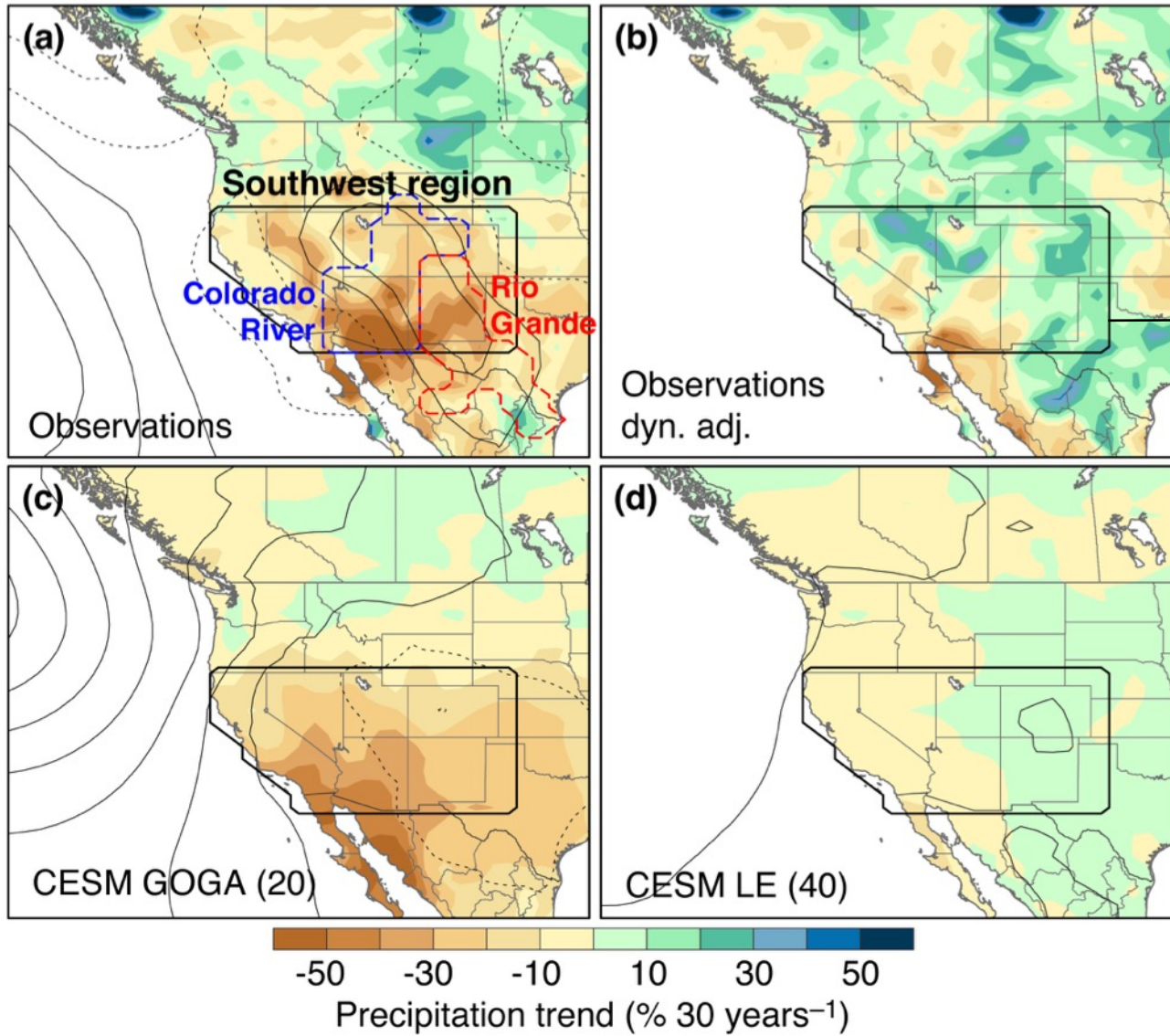
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Summary and outlook

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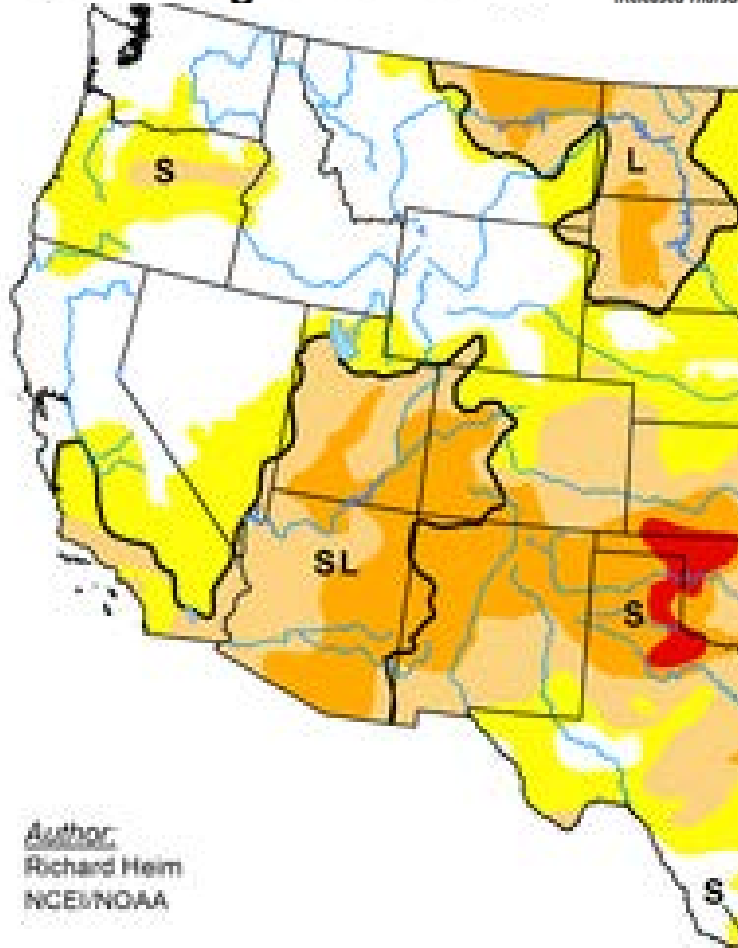
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Thanks!

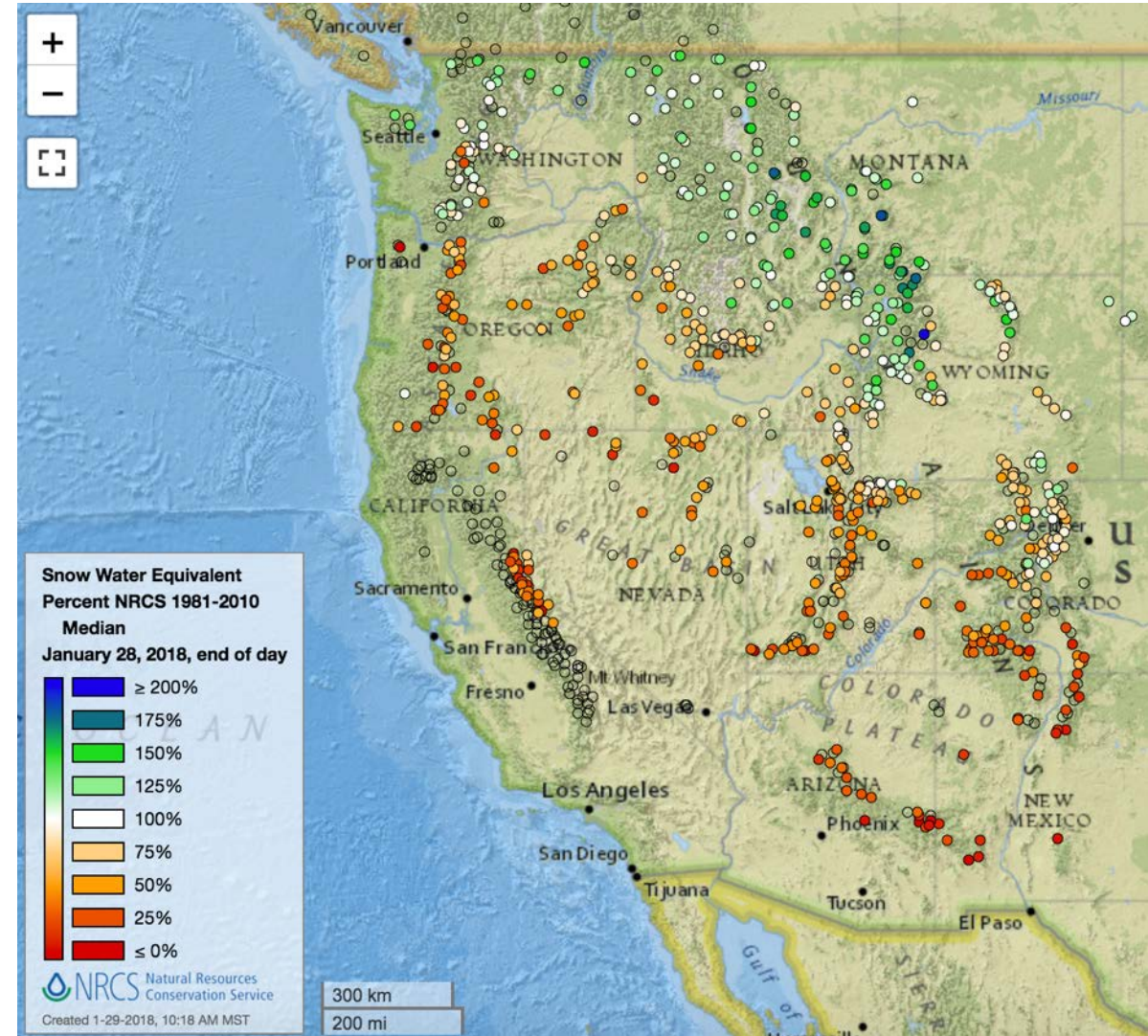
Snow Water Equivalent as of yesterday (% of average)

U.S. Drought Monitor

January 23, 2018
(Released Thursday, Jan. 25, 2018)

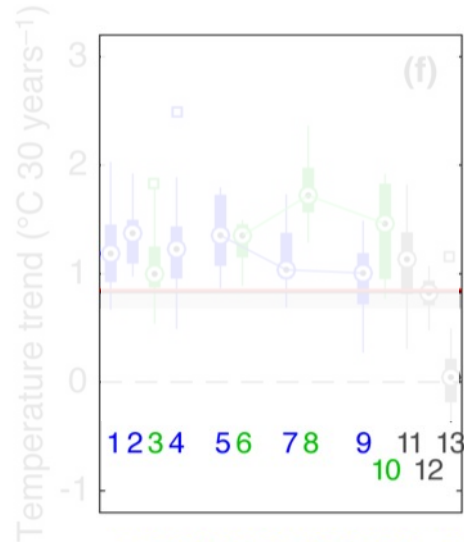
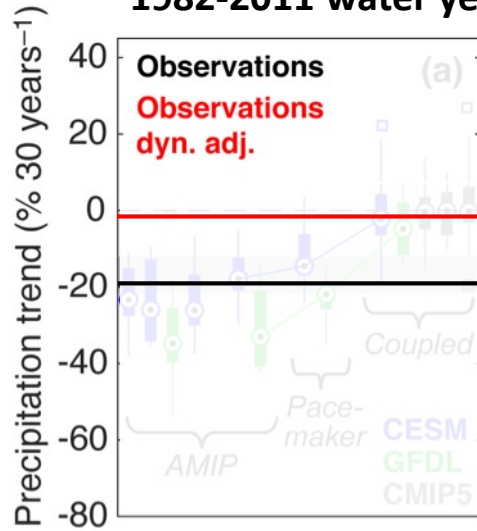


Author:
Richard Heim
NCEI/NOAA



Supplementary Material

1982-2011 water year trend



- 1 CESM TOGA ERSSTv4 (10)
- 2 CESM TOGA ERSSTv3b (10)
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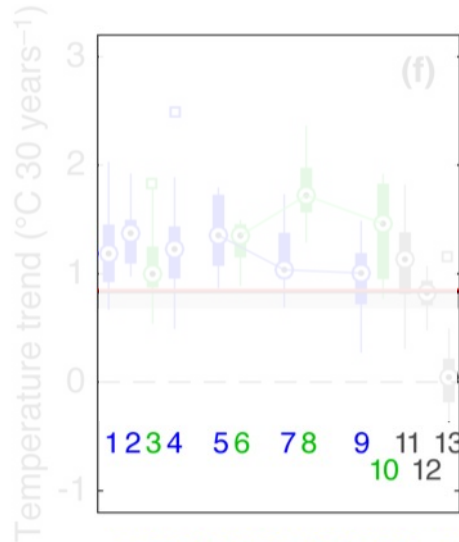
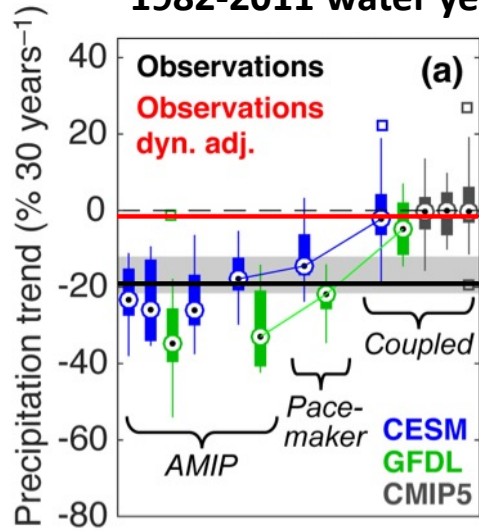
- 5 CESM GOGA (20)
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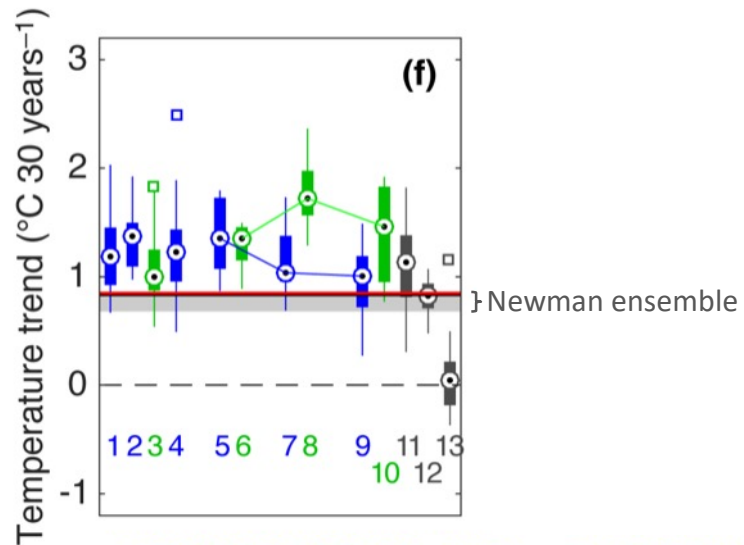
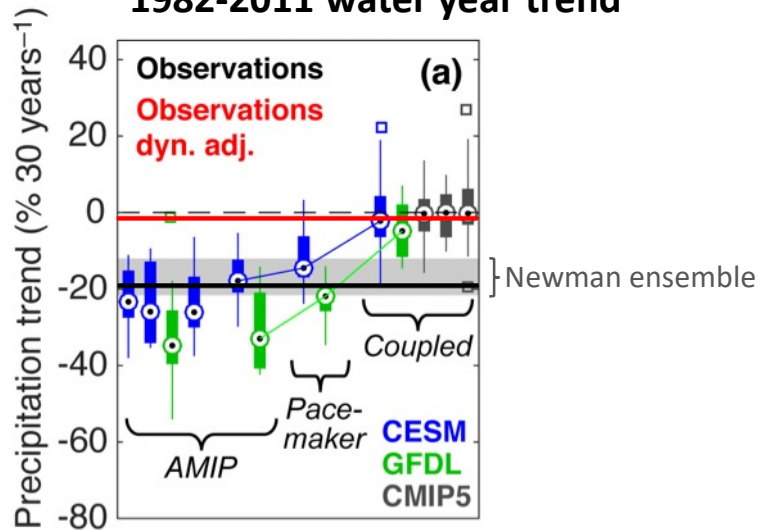
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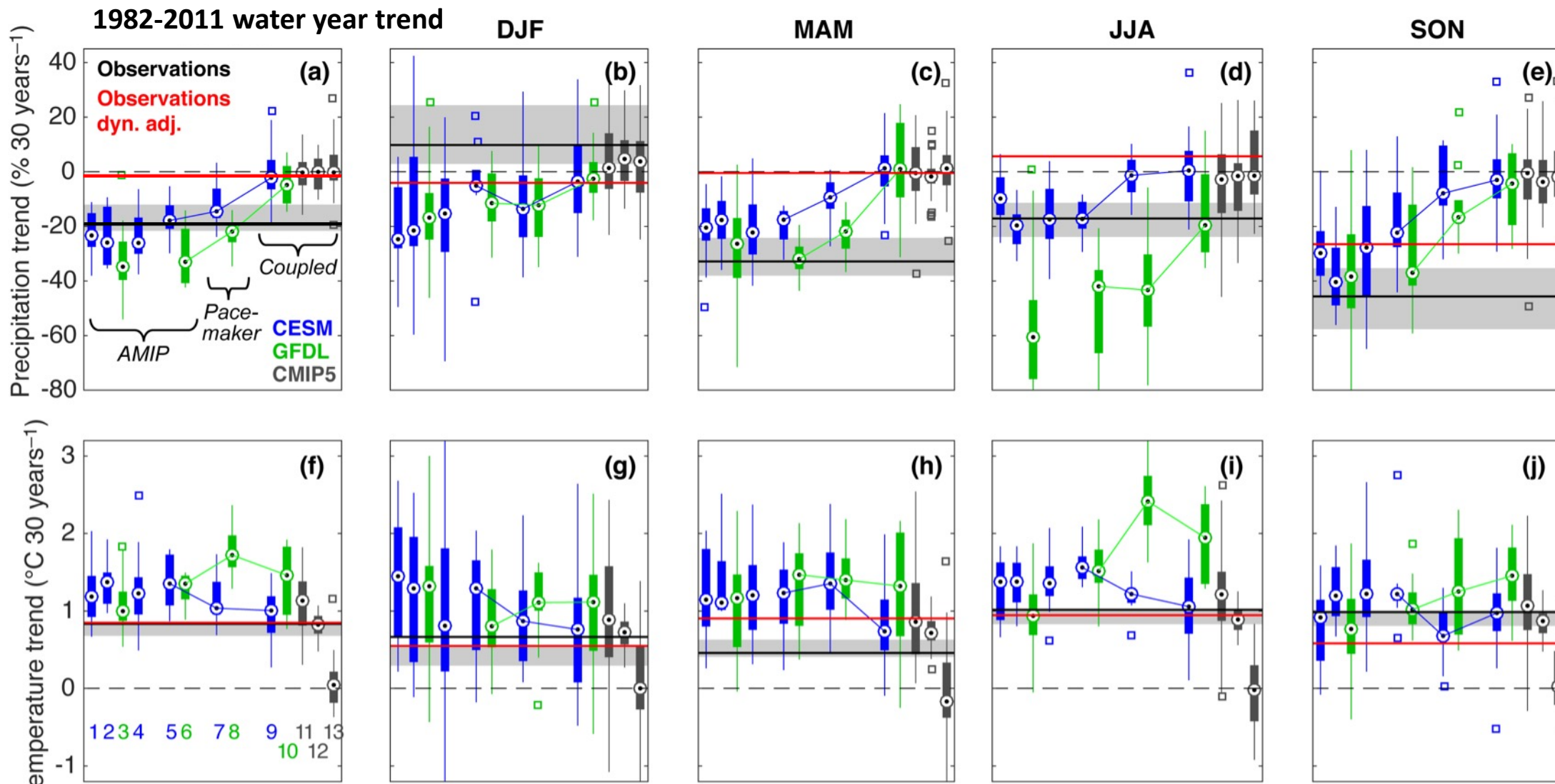
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