Harnessing NMME predictions to support seasonal hydrologic prediction

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The water for the Southwest
The water for the Southwest

-50 million people depending on the water
Southwest warming and drying

Lehner et al. (2018): “Attributing the U.S. Southwest’s Recent Shift Into Drier Conditions”
Southwest warming and drying

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
Statistical seasonal streamflow forecasting

Forecast error

‘Baseline forecast’ (mimicked NRCS forecast)
Statistical seasonal streamflow forecasting

Tendency to underforecast

Lehner et al. (2017a)
Statistical seasonal streamflow forecasting

Tendency to underforecast

Tendency to overforecast

Lehner et al. (2017a)
Statistical seasonal streamflow forecasting

Tendency to underforecast

Tendency to overforecast

Wet and cold period

Dry and warm period

Lehner et al. (2017a)
Statistical seasonal streamflow forecasting

Lehner et al. (2017a)
The concept of runoff efficiency

Runoff efficiency

= water out/water in

= streamflow/precipitation
Runoff efficiency

= water out/water in

= streamflow/precipitation

RE = f(precipitation, temperature, dust-on-snow, vegetation, groundwater, ...)
Runoff efficiency

= water out/water in
= streamflow/precipitation

\[ RE = f(\text{precipitation, temperature, dust-on-snow, vegetation, groundwater, } \ldots) \]

“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

Runoff efficiency

= water out/water in

= streamflow/precipitation

$\text{RE} = f(\text{precipitation, temperature, dust-on-snow, vegetation, groundwater, } ...)$

McCabe et al. (2017)
Including temperature into streamflow forecasting

Statistical seasonal streamflow forecasting

“Water Supply Forecasts”

Lehner et al. (2017a)
Including temperature into streamflow forecasting

Lehner et al. (2017a)
Including temperature into streamflow forecasting

Lehner et al. (2017a)
Including temperature into streamflow forecasting

Lehner et al. (2017a)
Including temperature into streamflow forecasting

Hydrological predictability

Runoff efficiency

Q ~ a SWE + b Rain + ε

Lehner et al. (2017a)
Including temperature into streamflow forecasting

\[ Q \sim a \text{ SWE} + b \text{ Rain} + \epsilon \]

\text{Hydrological predictability}

\text{Runoff efficiency}

\text{Streamflow Q}
Including temperature into streamflow forecasting

\[ Q \sim a \text{ SWE} + b \text{ Rain} + \epsilon \]

Lehner et al. (2017a)
Including temperature into streamflow forecasting

Lehner et al. (2017a)
Including temperature into streamflow forecasting

Lehner et al. (2017a)
Including temperature into streamflow forecasting

Mar–Jul temperature over Colorado River / Rio Grande headwaters

Q ~ a SWE + b Rain + ε

Hydrological predictability

Lehner et al. (2017a)
Including temperature into streamflow forecasting

**Equation:**

\[ Q \sim a \text{ SWE} + b \text{ Rain} + c \text{ Temperature} + \varepsilon \]

**Legend:**
- **Observations**
- **CMIP5 (40)**
- **CESM DP LE (1)**
- **NMME (7) + ECMWF (1)**

**Graph:**
- Mar–Jul temperature over Colorado River / Rio Grande headwaters
- Temperature anomaly (°C)
- Time (Year)
- R raw = 0.67 / 0.6
- R detr. = 0.48 / 0.31

**Lead Times:**
- 17-21 months
- 1-5 months

*Lehner et al. (2017a)*
Including temperature into streamflow forecasting

Lehner et al. (2017a)
Including temperature into streamflow forecasting

- Correlation
- rRMSE
- BSS < 33rd percentile
- CRPSS

Lehner et al. (2017a)
Temperature influence on streamflow, possibly via runoff efficiency


Incorporating temperature into streamflow forecasting improves skill

Temperature influence on streamflow, possibly via runoff efficiency


Incorporating temperature into streamflow forecasting improves skill


Next steps:
- Non-linear models
- Research to operations
- Domain expansion
- S2S model weighting
- Ensemble Streamflow Prediction
Thanks!
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Southwest warming and drying

Lehner et al. (2018)
Southwest warming and drying

*Constructed circulation analogues:*

⇒ Precipitation decline mostly due to internal variability
⇒ Warming mostly not due to internal variability

Lehner et al. (2018)
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

Lehner et al. (2017a)
Growing evidence for temperature influence on streamflow

**Geophysical Research Letters**

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

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(a) Reconstructions 1571-1977 CE

(b) Observations 1943-2015 CE

Lehner et al. (2017a)
Growing evidence for temperature influence on streamflow

Lehner et al. (2017a)
Growing evidence for temperature influence on streamflow

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

Lehner et al. (2017a)
Growing evidence for temperature influence on streamflow

- 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

Lehner et al. (2017a)
Streamflow hindcasts

Rio Grande at Otowi Bridge
Streamflow hindcasts

2012

Otowi Bridge

Observed SWE
Observed P
Observed T

Streamflow (1,000 acre feet)

Month (2012)

Rio Grande at Otowi Bridge
Streamflow hindcasts

![Map of Rio Grande at Otowi Bridge]

**2012**

- **Otowi Bridge**
  - Observed SWE
  - Observed P
  - Observed T

**2013**

- **Otowi Bridge**
  - Observed SWE
  - Observed P
  - Observed T

Legend:
- **Obs**
- **NRCS-style**
- **NCAR**
- **Climatology**
Streamflow hindcasts

Rio Grande at Otowi Bridge

### 2012
- **Otowi Bridge**
  - Observed SWE
  - Observed P
  - Observed T

### 2013
- **Otowi Bridge**

### 2015
- **Otowi Bridge**

**Legend:**
- Obs
- NRCS–style
- NCAR
- Climatology