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

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Upper Rio Grande Basin
Management goal:
• Early planning of allocations based on seasonal streamflow forecast

Issues:
• Only mediocre forecast skill prior to critical allocation deadline in April
• Anecdotal evidence of systematic forecast biases in recent years

End goals:
• Confirm systematic forecast bias
• Find cause
• Improve forecasts based on lessons learned
Motivation – streamflow forecasting

Apr-Jul streamflow

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  2015  Forecast issue month
Motivation – streamflow forecasting

Streamflow of interest

1st week of April: allocations

Apr-Jul streamflow

Jan Feb Mar Apr May Jun Jul Aug

Forecast issue month

2015
Motivation – streamflow forecasting

1st forecast (based on snowpack and weather climatology 1981-2010)

Streamflow of interest

1st week of April: allocations

Forecast issue month

Apr-Jul streamflow

- 90%
- 50%
- 10%

Jan   Feb   Mar   Apr   May   Jun   Jul   Aug
2015
Motivation – streamflow forecasting

1st forecast

2nd

3rd

4th

last forecast

Streamflow of interest

1st week of April: allocations

Forecast issue month

Apr-Jul streamflow

Jan Feb Mar Apr May Jun Jul Aug 2015

90%

50%

10%

1st forecast

Forecast issue month

1st week of April: allocations
Motivation – streamflow forecasting

Observed streamflow volume Apr-Jul

Streamflow of interest

1st week of April: allocations

1st forecast

2nd
3rd
4th

Forecast issue month

Jan Feb Mar Apr May Jun Jul Aug

2015

Apr-Jul streamflow

90%
50%
10%

last forecast

1st forecast
Motivation – streamflow forecasting

Streamflow forecast bounds (NRCS) and observed Apr-Jul value for Otowi Bridge, NM
Motivation – streamflow forecasting

- Recent tendency towards “overforecasting” in early phase of the calendar year
Decreasing basin efficiency?

Streamflow observed (Otowi Bridge), precipitation PRISM (HUC8 13010001-13010005 + 13020101-13020102)

Wateryear precipitation

Wateryear streamflow (x3)

Time [Year]

Decreasing basin efficiency?

Streamflow observed (Otowi Bridge), precipitation PRISM (HUC8 13010001-13010005 + 13020101-13020102)

Wateryear precipitation

Wateryear streamflow (x3)

RR = Streamflow/Precipitation

- Wateryear flow / Wateryear precip
- Wateryear flow / October-April precip
- March-August flow / October-April precip
Decreasing basin efficiency?

Similar behavior observed in Upper Colorado basin

Woodhouse et al. (2016)
Upper Rio Grande Basin

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Questions:
• How common are such trends?
• What role does temperature play?
• Is this important for forecasting?

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Reconstructions

Otowi Bridge, NM

Streamflow [KAF]

Reconstruction
Observation

r = 0.80
Reconstructions

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Streamflow [KAF]

Reconstruction
Observation

r = 0.80

Trends (30 years⁻¹)
Reconstructions

(a) Otowi Bridge, NM

Streamflow [KAF]

Reconstruction
Observation

r = 0.80

(b) Precipitation [10^4 KAF]

Reconstruction
Observation

r = 0.78

Trends (30 years⁻¹)

1986-2015

-1000 -5000 0 5000 1000

0 0.05 0.1 0.15 0.2

0 0.05 0.1 0.15 0.2

0 0.05 0.1 0.15 0.2
Reconstructions

(a) Otowi Bridge, NM

Streamflow [KAF]

Reconstruction
Observation

r = 0.80

(b) Precipitation \([10^4 \text{ KAF}]\)

Reconstruction
Observation

r = 0.78

(c) Runoff ratio

Reconstruction
Observation

r = 0.65

Trends (30 years\(^{-1}\))
Reconstructions

(a) Otowi Bridge, NM

Streamflow [KAF]

Reconstruction
Observation

r = 0.80

(b) Precipitation [10^4 KAF]

Reconstruction
Observation

r = 0.78

(c) Runoff ratio

Reconstruction
Observation

r = 0.65

Trends (30 years⁻¹)

Probability that this recent trend is the strongest in 445 years:

- 99.1%
- 97.9%
- 97.8%
Reconstructions

![Graph showing temperature anomaly over time with reconstruction and observation lines.](graphic)

- [Reconstruction](#)
- [Observation](#)
Role of temperature

(a) Reconstructions 1571-1977 CE

Median temperature

Median precipitation
Role of temperature

(a) Reconstructions 1571-1977 CE

Precipitation anomaly (KAP)

Temperature anomaly (°C)

Runoff ratio (percentiles)

-4  -3  -2  -1  0  1  2

51%  48%  7%  2%  37%  28%  10%  2%  2%  2%

10%  17%  30%  27%  2%  6%  51%  68%
Role of temperature

(a) Reconstructions 1571-1977 CE

(b) Observations 1943-2015 CE
Role of temperature
Role of temperature

Very low runoff ratio ~2.5-3 times more likely when temperatures are above-median than when they are below
Role of temperature
Role of temperature
Role of land use change
Role of temperature
Role of temperature

Graphs showing precipitation, runoff ratio, and temperature anomaly over time, with a focus on the 1980s and 2000s.
Circulation composites CESM
Circulation composites CESM

57% El Niño events
44% PDO > 1
38% La Niña events
38% PDO < -1
Upper Rio Grande Basin

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Questions:
• How common are such trends?

Answers:
⇒ Apparently not that common

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Answers:
→ Apparently not that common
→ Acts to make low runoff ratio years even lower

Questions:
• How common are such trends?
• What role does temperature play?

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Questions:
• How common are such trends?
• What role does temperature play?
• Is this important for forecasting?

Answers:
➔ Apparently not that common
➔ Acts to make low runoff ratio years even lower
➔ Adds additional skill

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Thank you

Assessing recent declines in Upper Rio Grande River runoff efficiency from a paleoclimate perspective
Supplementary slides
Role of temperature

Relationship mainly driven by low precipitation years
Internal variability or climate change or both?

Water year precipitation trend 1983-2012

Sea level pressure trend

GPCC+ERAi
Internal variability or climate change or both?

Water year precipitation trend 1983-2012

Precipitation trend [% / 30 yr]
Internal variability or climate change or both?

Water year precipitation trend 1983-2012

CESM Large Ensemble (40 members)
“free running”
main forcings: GHGs, aerosols, volcanoes

Precipitation trend [% / 30 yr]
Internal variability or climate change or both?

Water year precipitation trend 1983-2012

CESM Large Ensemble (40 members)
main forcings: GHGs, aerosols, volcanoes

Precipitation trend [% / 30 yr]
Climate change: predictable?

Change in average precipitation (1986–2005 to 2081–2100)

RCP 2.6

RCP 8.5

Number of models (CMIP5)

IPCC AR5 WG1 (2013)
Climate change: predictable?

Hatching = signal < 1 \( \sigma \)

Change in average precipitation (1986–2005 to 2081–2100)

RCP 2.6

RCP 8.5
Internal variability: predictable?

Wallace and Gutzler (1981) and others
- Atmospheric pressure indices are (anti-)correlated afar
- Modes of atmospheric circulation variability
- Emerge from a sufficiently large sample size

Hoskins and Karoly (1981), Trenberth et al. (1998) and others
- Tropical heating is balanced by divergence aloft
- Pressure anomalies alter jet stream and incite Rossby waves
- Affects weather in mid-latitudes

Barsugli and Battisti (1998) and others
- Coupling of ocean and atmosphere increases variance in both

Deser et al. (2012) and others
- The “butterfly effect” works on decadal time scales, and not only on synoptic

Barnes and Screen (2015), Shaw et al. (2016) and others
- “Tug of war” between opposing effects of climate change on mid-latitude jet position
Pacific Decadal Oscillation (PDO) and ENSO
Pacific Decadal Oscillation (PDO) and ENSO
PDO and ENSO teleconnections

Observations

M. Newman et al. (2016)
PDO and ENSO teleconnections

Newman et al. (2016)
PDO – CESM Large Ensemble
PDO – “Pacemaker” simulations
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(Forced) internal variability

Water year precipitation trend 1983-2012
(Forced) internal variability
Contributions from (forced) internal variability

Pacemaker simulations

Free-running simulations

Rio Grande basin

Water year

Observations

Precipitation trend (%/30 years)

-60 -40 -20 0 20 40

-50 -40 -30 -20 -10 0 10 20 30 40 50
Contributions from (forced) internal variability

Pacemaker simulations

Free-running simulations

Rio Grande basin

Water year

Confirms earlier results based solely on observations

Hamlet et al. (2005)
Contributions from (forced) internal variability

Rio Grande basin

Temperature trend (degC/30 years)

Pasemaker

Free-running

Observations
Rio Grande seasons

![Box plots showing precipitation and temperature trends for different seasons (DJF, MAM, JJA, SON).](Image)
Tug of war