Regional Climate Variability in the Western U.S.: Observed vs. Anticipated

Klaus Wolter
University of Colorado at Boulder, klaus.wolter@noaa.gov

Kudos to Joe Barsugli and Jon Eischeid

- Seasonal Precipitation Cycle
- ENSO Footprint(s)
- Recent Climate Trends
- Outlook to Mid-21st Century

Range Mgmt. Symposium, Denver, 10 February 10
Average Annual Precipitation for the Western U.S.

Based on PRISM OSU/WRCC
Warm and cold phases of the ENSO (El Niño/Southern Oscillation) cycle

**ENSO is the most thoroughly modeled coupled ocean-atmosphere system, and it is still good for ‘surprises’...**
El Niño is often associated with ‘split flow’ regimes over the Western U.S., leaving Colorado relatively calm.

La Niña is often associated with a strengthened polar jet stream, and tends to give us more frequent wind storms.

NOAA Climate Prediction Center/NCEP/NWS
Correlations with U.S. precipitation (PRISM; MEI(L))

JJA Precipitation versus MEI (1956–2005)

SON Precipitation versus MEI (1956–2005)

MAM Precipitation versus MEI (1956–2005)

DJF Precipitation versus MEI (1956–2005)

Correlation Coefficient

-0.8 -0.6 -0.4 -0.2 -0.1 0.1 0.3 0.4 0.5 0.6 0.8
Correlations with U.S. temperatures (PRISM; MEI(L))
Temperature trends in Colorado, or elsewhere: Caveat emptor!

• More so than in other states, Colorado has seen a lot of station location changes, which can easily result in +/-2° F mean temperature changes in orographic regions. *Most of these location changes are well documented*...

• U.S. COOP temperature records are based on once daily full degree Fahrenheit readings of Tmin&Tmax. Many of these are taken in the morning, some in the afternoon, and fewer still at midnight. Observers have been nudged towards a morning observing time which introduces an apparent ‘cool’ bias for previous afternoon reading stations. Conversion from ‘liquid in glass’ thermometers to thermistors (MMTS) can give a cool bias of 0.2-0.5° F which may be more than compensated for by placement near electric outlets... *Surprising gaps in metadata*...

• Land-use/land-cover changes are also quite common around here, such as (sub-)urbanization and increased irrigation on eastern plains of the state. *Poorly documented impacts (but: urban heat island, cooler growing seasons in irrigated areas).*
Observations: Regional Temperature Trends

Source: CO Climate Report, 2008
Online at: http://cwcb.state.co.us/
More remarks on climate variability & trends

Climate = GHG + ‘Natural Variability’ + Surface Changes + Noise

GHG: Greenhouse-gas-related ‘Global Change’

Natural Variability: Decadal (PDO,…); Interannual (ENSO, …)

Surface Changes: Land-use/ land-cover changes (vegetation+irrigation),
Urban Heat Island, station siting, …

Noise: Instrument errors, observer errors,…

We do NOT fully understand all of the above components of the climate system, leaving room for surprises!

Lemma: Not every weather & climate ‘wiggle’ is greenhouse-gas-related, nor will it ever be & don’t underestimate the “noise” = our (in-)ability to measure correctly!
Observed Trends In Precipitation

Since 1901

Since 1979

IPCC, 2007: Fig. 3.13
- note contrast between two periods in Western U.S. and Sahel!
Even if emissions drop before 2100 -

Greenhouse gases will keep going up -

Except for Pinatubo-like volcanic eruptions, this means more energy input -

And higher global temperatures
Projected Temperature & Precipitation Changes in 2050

Source: CO Climate Report, 2008

Temperature
Widespread warming

Precipitation
Wet northern tier; dry southwest. Potential seasonal shift in Utah/Colorado region

Model Agreement for Precipitation
Colorado/Utah is in a region of weak-to-modest model agreement
• Summers warm more than winters
• Average summer temperatures similar to the hottest months in the past fifty years.
• Heat waves; fewer cold winters
• Projected precipitation trends small compared to the variability.
• Note: Range includes model differences AND model internal variability.
Projected declines in the high mountain snowpack of Colorado and Utah are not as severe as elsewhere in the West at lower elevations.

Data: Christensen and Lettenmeier, 2007
Earlier snowmelt leads to wetter conditions in April, and much drier conditions by summer.

Source: CO Climate Report, 2008
Data: Dennis Lettenmaier, UW
Take-home messages & Key unresolved issues

- Temperatures have been increasing in Western U.S., and will continue to rise, if not always at the same accelerated pace as recently
- Great uncertainty in precipitation projections
- In the absence of precipitation changes, temperature increases alone combined with related changes in evaporation and soil moisture lead to a decline in runoff for most of Western U.S. river basins by the mid-21st century in all recent hydrologic projections

An incomplete laundry list of unresolved topics:

- Need to separate recent impact of drought on snowmelt vs. higher temperatures (how much of that is GHG-related?!)
- Importance of (multi-)decadal ‘natural’ climate drivers
- Possible changes in monsoon system due to earlier snowmelt versus possibly higher incidence of forest fires
- Causes of drought: role of global oceans versus local forcing (soil moisture)