Colorado Flood Magnitude and Timing: An exploration of possible climate change impacts

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Introduction

In Colorado, temperatures have increased about 2°F in the past 30 years (1). There is a potential connection between this temperature rise and decrease in snowmelt peak, earlier timing of peak flows and an increase in the variability of the peak flows.

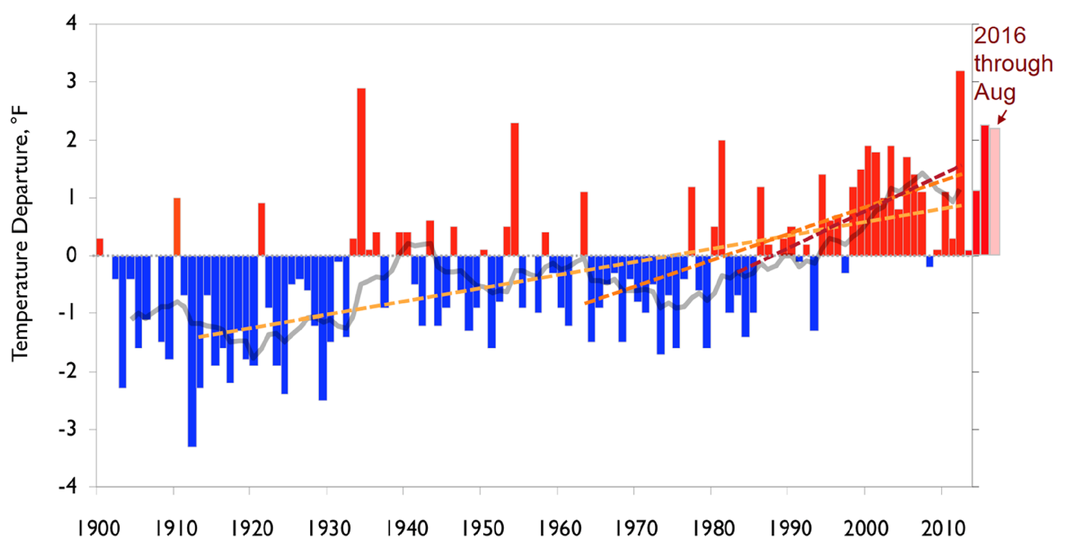

Figure 1 Colorado Statewide Annually-Averaged Temperature (°F) from *Climate Change in Colorado* (Lukas 2014), Edited by Jeff Lukas, Sept. 2016, Western Water Assessment

The objective of this project was to analyze flood magnitude and timing for select stream gages in Colorado to identify if there is a shift in the magnitude and timing associated with increased temperatures in Colorado (~1985).

The Indicators of Hydrologic Alteration (IHA), a software developed by The Nature Conservancy (2), was used in order to conduct a comparative analysis of hydrologic data over two time periods pre- and post-1985.

Through the use of the IHA software, we expect to observe a decrease in magnitude of peak flow, earlier peak flows, and an increase in variability of these events.

Methods

Data from 40 stream gages were analyzed. Gages were selected from Capesius and Stephens (2009) based on the following criteria:
- Minimum of 18 years of continuous streamflow data pre- and post- 1985
- Maximum of 5% upstream regulation, as indicated in USGS StreamStats 4.0 (4).

Daily streamflow data were downloaded from USGS's data archive (5) and imported into the IHA software for analysis. IHA non-parametric statistical analyses were run to compare two time periods:
- up to and including 1985
- 1986 and after.

The IHA results for change in peak flows (1-day, 3-day and 7-day maximum), timing of peak flows and change in variability of peak flows were analyzed. A maximum coefficient of dispersion (comparable to a p-value) was set to 0.10 and results for $p < 0.10$ were extracted from the results.

Map

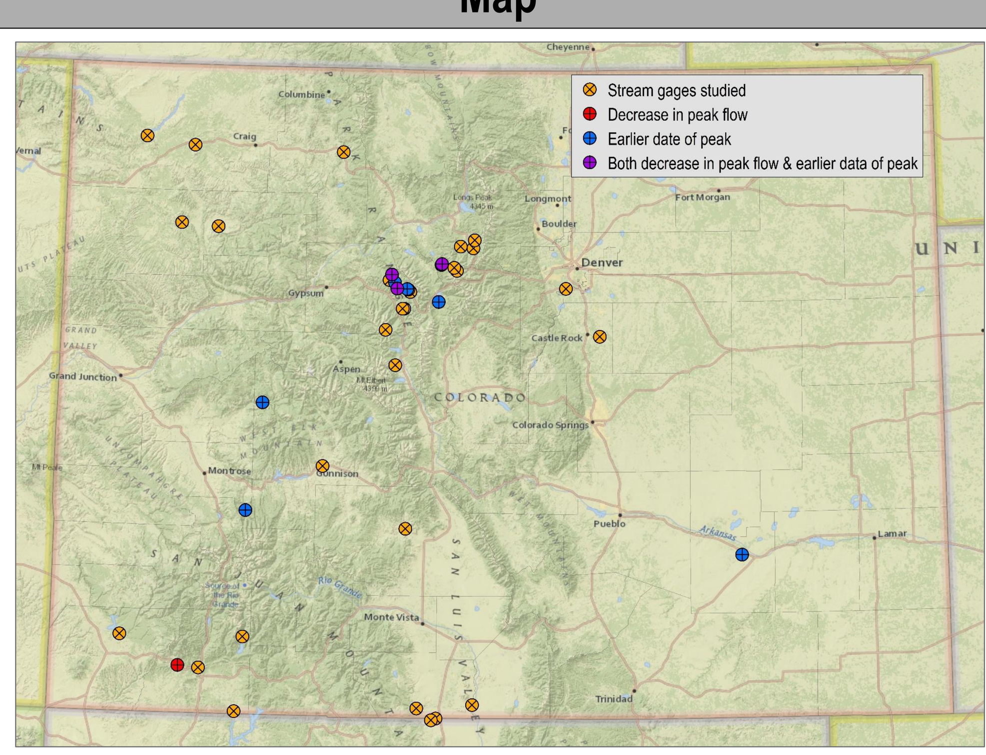

Figure 2 Locations of stream gages used in analysis

Results

Of the 40 stream gages analyzed, 29 showed a decrease in 1-day peak flows, but only two exhibited a statistically significant ($p<0.10$) reduction (Figure 3). Similarly for the 3-day, 27 exhibited a decrease with only 2 being statistically significant ($p<0.10$, Figure 3), and for the 7-day 27 decreased with three being statistically significant ($p<0.10$, Figure 3). No gages exhibited a statistically significant increase in median peak flow.

Of the 40 stream gages analyzed, 4 showed a later date of maximum flow, 2 showed no change, and 34 indicated an earlier date. Of these, 8 were statistically significant ($p<0.10$, Figure 4) with 7 gages showing an earlier date and 1 having a later date.

Of the 40 stream gages analyzed, 21 showed an increase in coefficient of dispersion for 1-day peak flow, of these 8 exhibited a statistically significant ($p<0.10$) increase (Figure 5). Similarly for the 3-day, 17 indicated an increase, 8 being statistically significant ($p<0.10$) (Figure 5). For 7-day, 22 showed an increase with 6 being statistically significant ($p<0.10$) (Figure 5). No gages exhibited a statistically significant decrease in coefficient of dispersion.

East Meadow Creek near Minturn, CO (USGS 09058800) was the only gage to show a significant change in all three measures of peak flow (Figure 6) and 1 of 4 gages to exhibit significant change in variability for all three peak-flow variables analyzed. The IHA graphs visually demonstrate the changes between time periods for both median flow (dashed line) and coefficient of dispersion, indicated by the solid lines above and below the median. The median deceased while the coefficient of dispersion increased post-1985.

Percent Change in Annual Peak Discharge

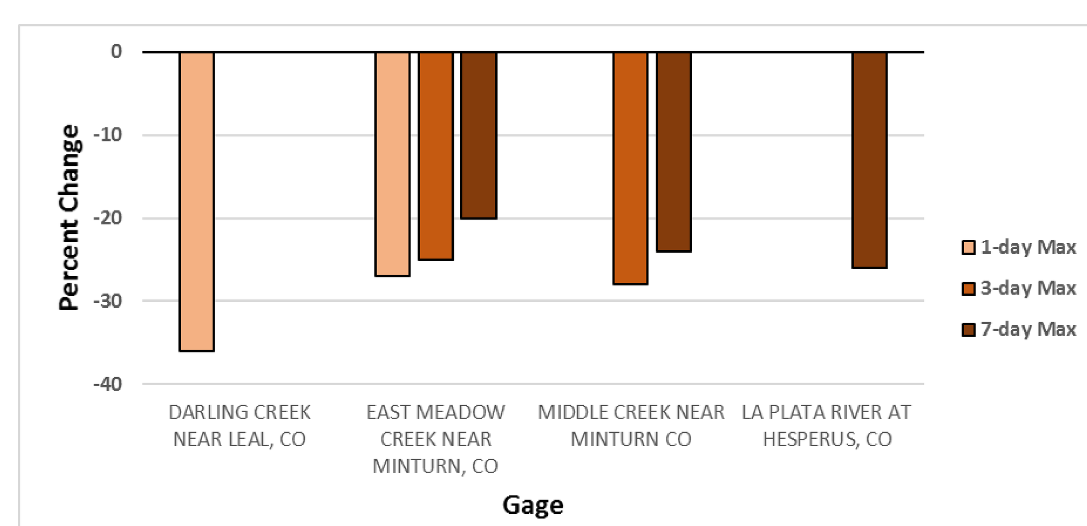

Figure 3 Percent Change in Annual Peak Discharge for 1-day, 3-day, and 7-day periods. Statistical significance ($p<0.10$).

Change in Date of Maximum Flow

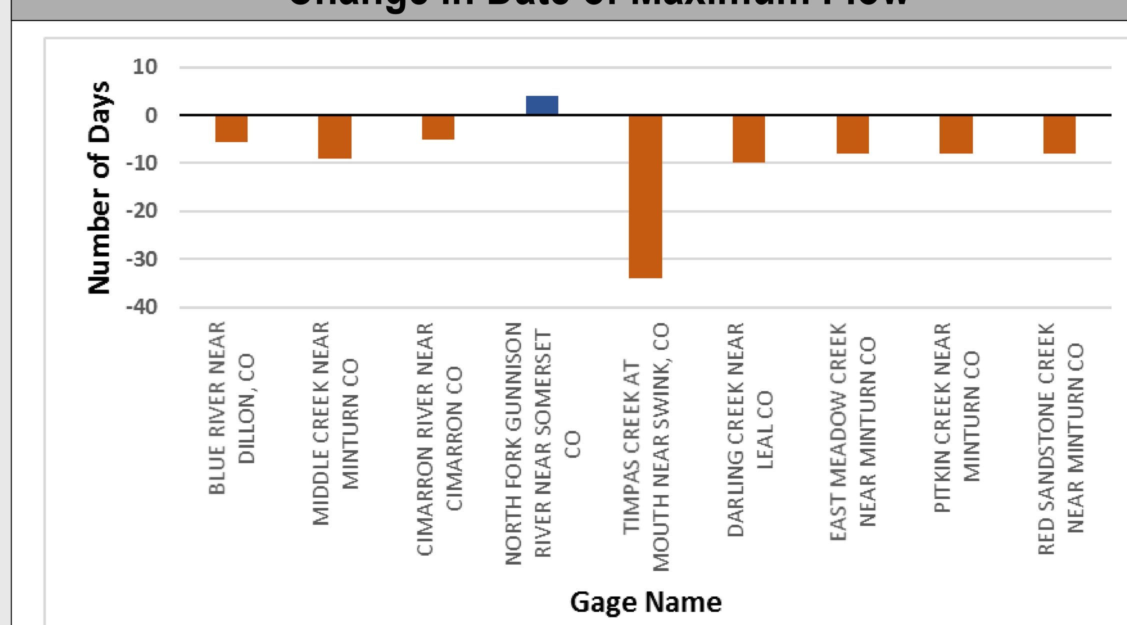

Figure 4 Change in Date of Maximum Flow. Statistical significance ($p<0.10$).

Discussion/Conclusions

Roughly 70% of the stream gages analyzed showed a decrease in median peak flow for 1-, 3-, and 7-day periods. Only 5% of these were significant for the 1- and 3-day period and only 7.5% for the 7-day period. While the decrease in median was consistent with our expectations, the low number of significant results combined with the less stringent p-value do not provide strong support and further study is recommended.

In addition, results only show correlation, not causation, so we can't know if the decreases in peak flows are a direct result of temperature increase. Population growth and increased water use may be factors as well. Furthermore, there may be diversions from these streams that are not accounted for in StreamStats that could have influenced the peak flow magnitude and timing.

Changes to the magnitude and timing of floods in Colorado impacts the availability of water to Colorado's water resource managers. Implications to changes in flood magnitude and duration may include:
- Creation of sites for plant colonization
- Structuring of aquatic ecosystems by abiotic vs. biotic factors
- Structuring of river channel morphology and physical habitat conditions

Implications to changes in flood timing may include:
- Compatibility with life cycles of organisms
- Predictability/avoidability of stress for organisms
- Access to special habitats during reproduction or to avoid predation

Future research on flood magnitude and timing could include analysis of flood frequency curves for pre and post 1985 time periods.

Furthermore, western states have seen a decline in their snowpack, however the majority of Colorado's snowpack lies above 8,200 feet where temperatures remain colder. Comparison of Colorado watersheds at different elevations to see if changes in peak flows are different between snowmelt vs. rain driven floods could be a future part of this analysis.

Percent Change in Variability

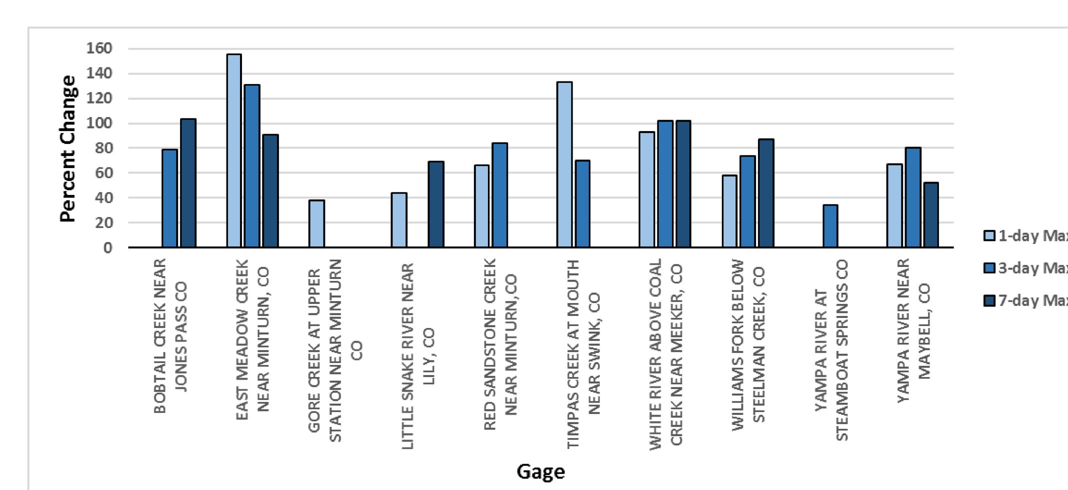

Figure 5 Percent Change in Coefficient of Dispersion for 1-day, 3-day, and 7-day periods. Statistical significance ($p<0.10$). Coefficients of Dispersion (CD) for each period is defined as = (75th percentile - 25th percentile) / 50th percentile.

09035700 WILLIAMS FORK ABOVE DARLING CREEK, NEAR LEAL, CO

East Meadow Creek IHA Results

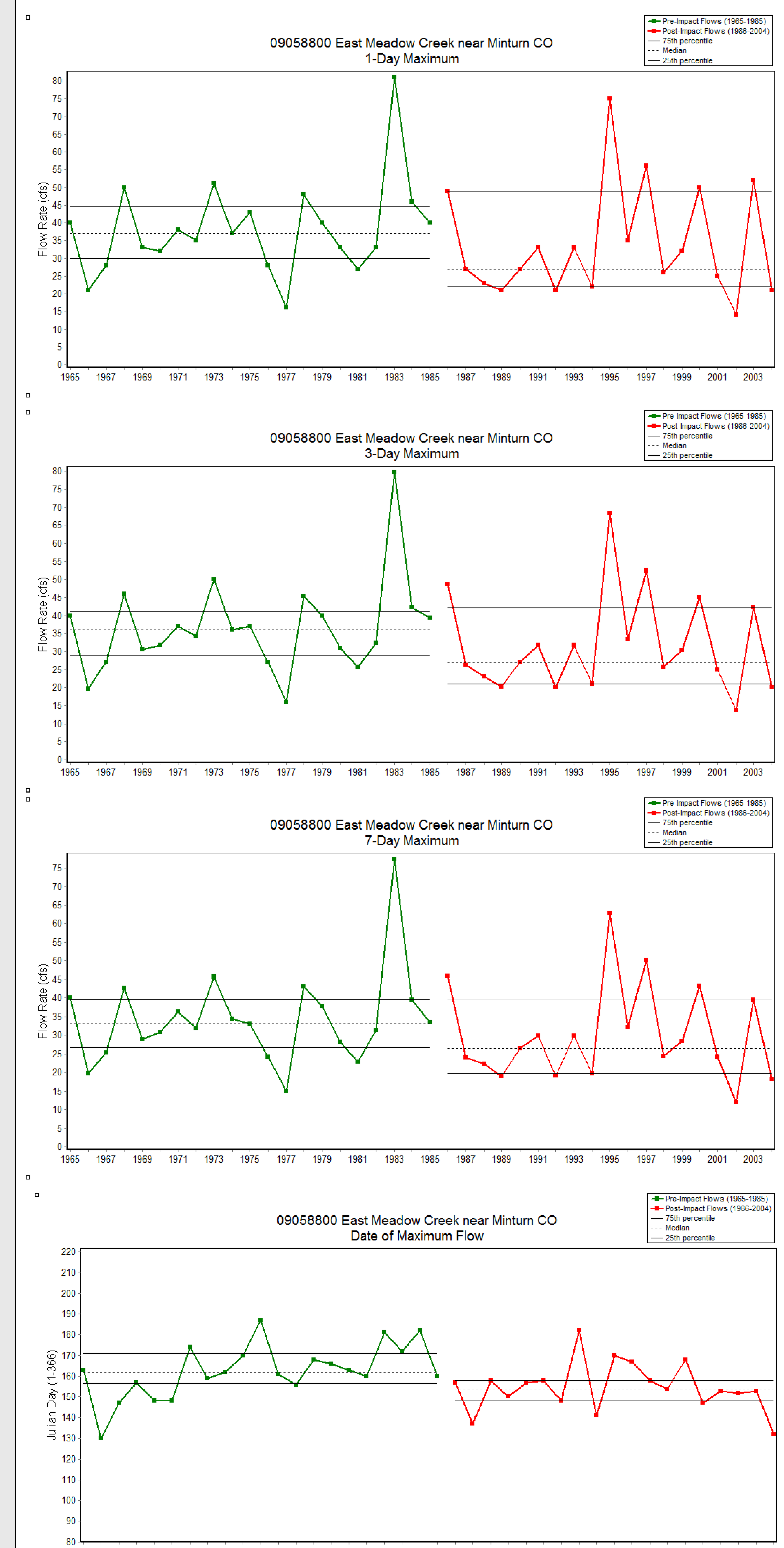

Figure 6 IHA results for East Meadow Creek near Minturn, CO.

References

1. Lukas, J., 2014, *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation*, 2nd Edition, A Report for the Colorado Water Conservation Board
2. The Nature Conservancy, 2009. *Indicators of Hydrologic Alteration Version 7.1 User's Manual*.
3. Capesius, J.P., and Stephens, V.C., 2009, *Regional regression equations for estimation of natural streamflow statistics in Colorado: U.S. Geological Survey Scientific Investigations Report* 2009–5136, 46 p.
4. https://streamstatsags.cr.usgs.gov/streamstats/
5. https://water.usgs.gov/