Scenarios for Climate Change Adaptation Workshop for Natural Resource Managers in the Gunnison Basin (L. O. Mearns with contributions from J. Barsugli)*

Time frame: 2040-2060 compared to 1980-1999
Region: Western Colorado
IPCC SRES Emissions Scenario: A2 ("medium-high emissions")

Scenario #1: Moderate change
Increased annual temperatures (2+°C), no substantial change in annual precipitation, but increased cool season precipitation and decreased warm season precipitation

Season	Precip %	Temp °C	Temp °F
Annual	~0.0	+2.0-3.0	+3.6-5.4
Winter	+15.0	+2.0	+3.6
Spring	-12.0	+2.5	+4.5
Summer	-15.0	+3.0	+5.4
Fall	+4.0	+2.5	+4.5

Scenario #2: Extreme change
Increased annual temperatures (3+°C), ~10% decrease in annual precipitation, with greater decreases in warm season precipitation

Season	Precip %	Temp °C	Temp °F
Annual	-10.0	+3.0	+5.4
Winter	~0.0	+3.0	+5.4
Spring	-15.0	+3.0	+5.4
Summer	-20.0	+4.0	+7.0
Fall	-10.0	+3.0	+5.4

Qualitative statement regarding expected temperature change signal and elevation:
Most research for mid-latitude locations indicates increasing temperature change signal with increasing elevation, such that the signal should be largest at higher elevations. However, this statement must be moderated by consideration of the overall degree of warming. With very low levels of warming, this signal may not be seen. For example, in Colorado so far, in trends in observed temperature, more warming is seen at middle and lower elevations. At higher elevations, temperatures are still low enough such that snow persists and a strong feedback between snowmelt and resulting lower reflectivity and increased absorption of energy at the surface (known as the snow-albedo feedback) does not develop.

Other general features of climate change:
Due to increased temperatures, more precipitation will fall as rain as opposed to snow. Snow melt will start earlier in the spring, and snow will begin to accumulate later in the winter. This will have distinct implications for the timing of runoff, for example.

Scenario Framework

The framework for the two scenarios chosen are quantiles of the probability distributions for temperature change and precipitation change (%) for annual and seasonal values for an area covering most of western Colorado, but with input from the other reports cited above.

Quantiles: 25th to 75th++

Season	Precip %	Temp °C	Temp °F
Annual	-9.0 to +7.0	+2.0 to +2.7	+3.6 to +4.8
Winter	-5.0 to +18.0	+1.5 to +2.5	+2.7 to +4.5
Spring	-12.0 to -0.1	+1.7 to +2.5	+3.0 to +4.5
Summer	-20.0 to +6.0	+2.0 to +3.0	+3.6 to +5.4
Fall	-7.0 to +16.0	+2.0 to +2.5	+3.6 to +4.5

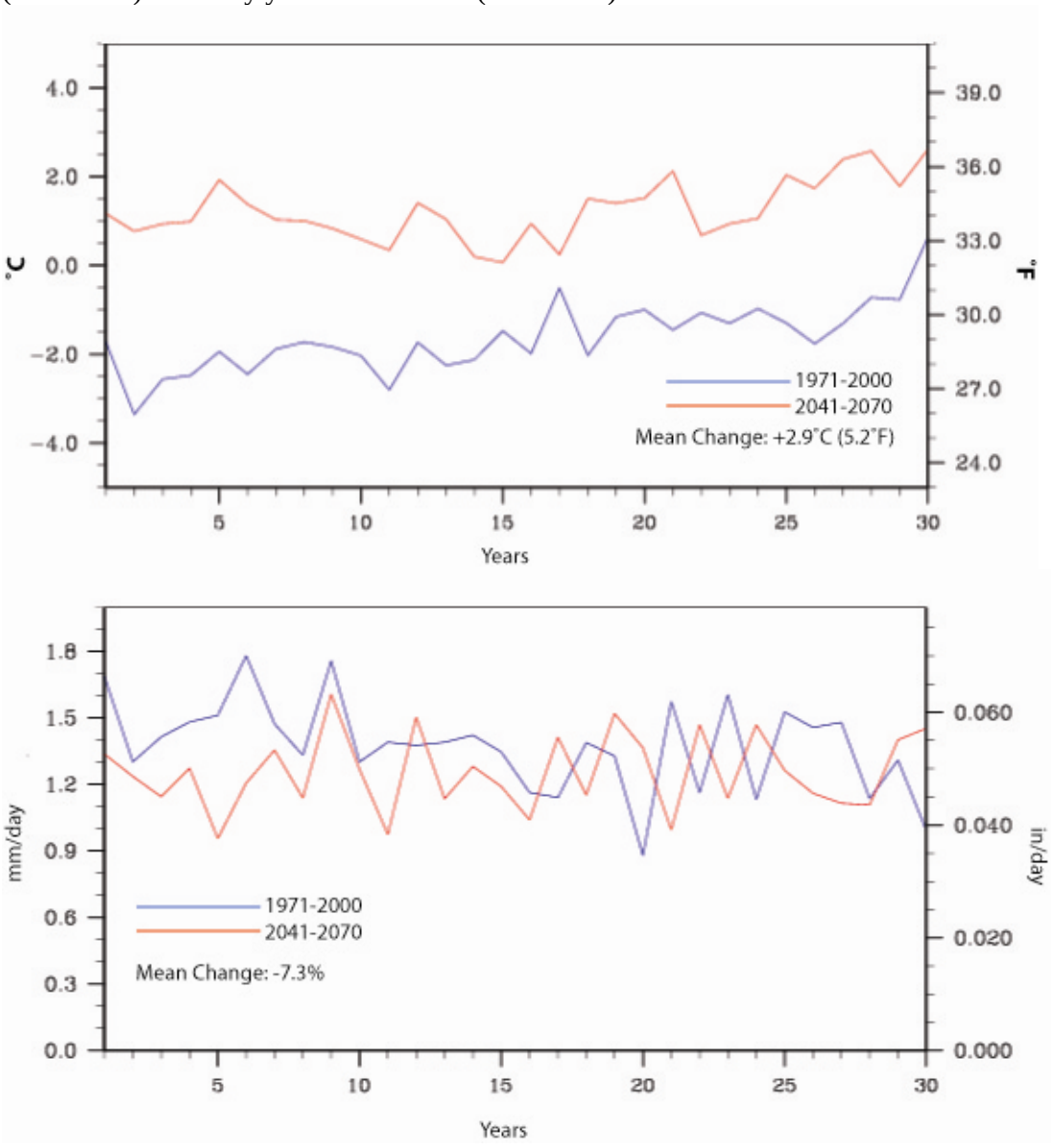
++This refers to the values associated with the lowest and highest 25% of the statistical data distribution of model runs.

Scenario Information Sources

- Ray, A. et al., 2008. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation.* Boulder, CO: Western Water Assessment. http://cwcb.state.co.us/Home/ClimateChange/ClimateChangeInColoradoReport/).
- *Climate Change and Aspen: an Assessment of Impacts and Potential Responses* (http://www.agci.org/dB/PDFs/Publications/2006_CCA.pdf).
- Probabilistic information generated using the CMIP3 suite of model results, based on methods used by Tebaldi, C. et al. 2004, 2005.
    - Tebaldi, C., L. O. Mearns, R. Smith, D. Nychka, 2004. Regional probabilities of precipitation change: A Bayesian approach. *Geophys. Res. Lett*. 31:L24213, doi:10.1029/2004GL021276.
    - Tebaldi, C., R. Smith, D. Nychka, and L. O. Mearns, 2005. Quantifying uncertainty in projections of regional climate change: A Bayesian approach to the analysis of multi-model ensembles. *J. Climate* 18:1524-1540.
- Results from *Regional Climate Projections* (Christensen, J.H., et al., 2007, in: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., et al. (eds.)] http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter11.pdf).
- Preliminary results from the North American Regional Climate Change Assessment Project (NARCCAP http://www.narccap.ucar.edu/) Regional Climate Model Simulations. The main emissions scenario considered is the **A2**, a medium high scenario. Mearns, L. O., et al., 2009. A regional climate change assessment program for North America. *EOS*, September 2009.

Sample results of a regional climate model scenario

The four plots presented here show sample results from one regional climate model (the Canadian RCM, CRCM), run at 50 km resolution, nested in one global climate model (the Canadian global model, CGCM3). The emissions scenario used is the A2. By a sample scenario we mean that the change in climate roughly falls within the range of changes seen in the two scenarios presented above, but the details of the scenario do not exactly match the scenarios presented above. Thirty years of the present (1971-2000) and thirty years in the future (2041-2070) were simulated.



The top figure shows the annual time series of temperature for both time periods. A clear upward trend is exhibited in the current and future time periods, and the mean temperature increase in the future is about 3°C (5.4°F). The bottom figure shows the same results for simulated annual precipitation for the current

and future periods. Neither time series exhibits a distinct trend, but a mean decrease in precipitation in the future of 7% is found.