

Model Based Climate Predictions for Utah



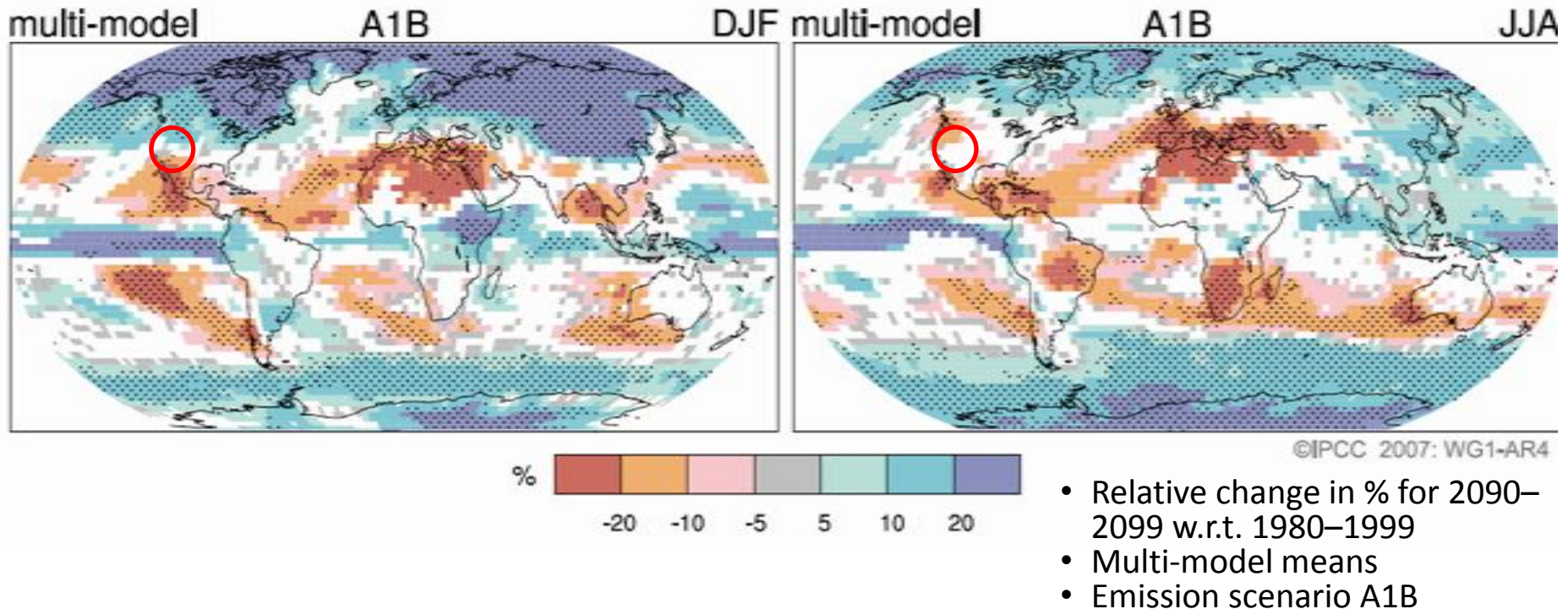
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Climate Model Prediction Results

- Northern Utah: Precipitation will increase by $\sim 10\%$ in winter and decrease by $\sim 10\%$ in summer
- Southern Utah: Similar precipitation change but smaller magnitude
- Temperatures will rise uniformly by $\sim 3^\circ\text{F}$ in winter and $\sim 4^\circ\text{F}$ in summer
- Warming and drying during summer will increase demand for water
- Effects from warming and moistening during winter oppose each other; overall impact on water supply remains to be investigated

The GCM “Resolution Problem”

IPCC-AR4: Projected Precipitation Change



- Current GCMs have grid sizes of 100-400 km
- This is too coarse for making meaningful regional predictions

Solution

A. Increase GCM resolution

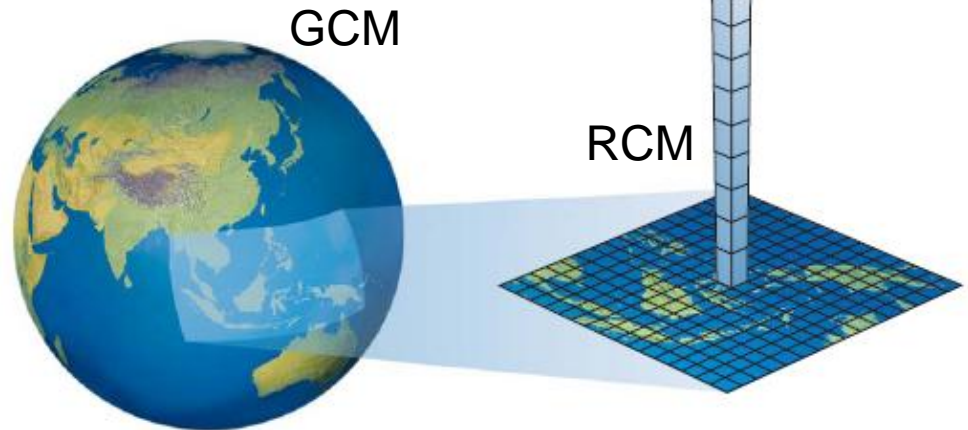
- expensive
- x2 resolution, x10 resources
- clean

B. “Downscaling” of coarse GCM output



1. Dynamical

- nest high resolution RCM into coarse resolution GCM
- expensive
- two model uncertainties
- North American Regional Climate Change Assessment Project (NARCCAP)

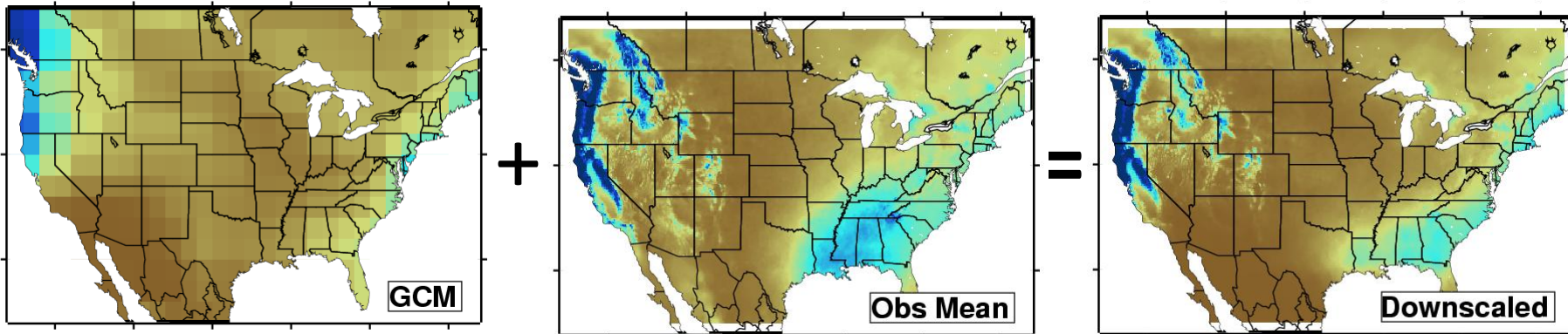


2. Statistical

- statistical correction of model prediction based on current climate
- cheap
- remainder of this talk

Statistical Downscaling

1. For present climate, establish a statistical relationship betw. coarse model data (= predictor) and fine-scale observations (= predictand)



2. Correct model deficiencies by applying the relationship, which was established for today's climate, to model data for future climate (= downscaled)

Critical assumptions

- statistical stationarity: relationship between coarse- and fine-scale data do not change
- model biases do not change

High-Resolution US Downscaling

- **Monthly mean precipitation and temperature, 1950-2099**
- Lawrence Livermore National Laboratory (LLNL), Bureau of Reclamation, and Santa Clara University (SCU)
- Methodology: Wood et al. 2004, Maurer 2007
- US only: 1/8 degree (ca. 12x12 km)
- 16 GCMs (IPCC-AR4), 3 scenarios (A2, A1B, B1)
- gdo-dcp.ucllnl.org/downscaled_cmip3_projections/



Precipitation Change

IPCC Scenario A1B (A2)

20 year averages, centered at

- 1990 (reference),
- 2050 (A1B),
- 2090 (A2)

Winter **Summer**
Nov-Apr May-Oct

Multi-model means

16 models

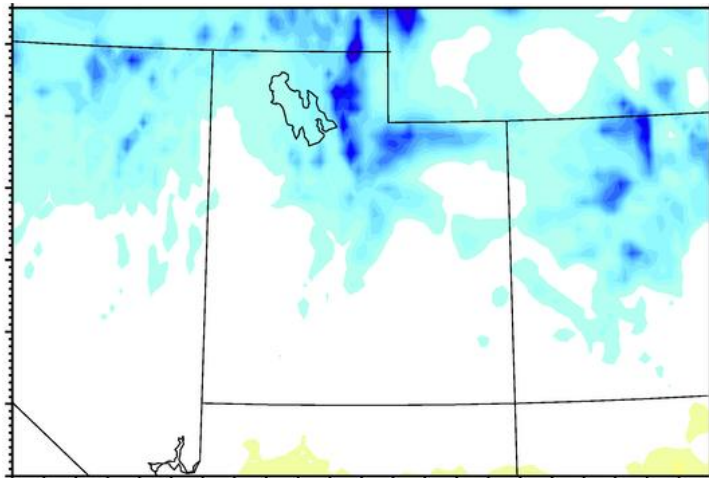
Precipitation Change

A1B, 2050 minus 1990

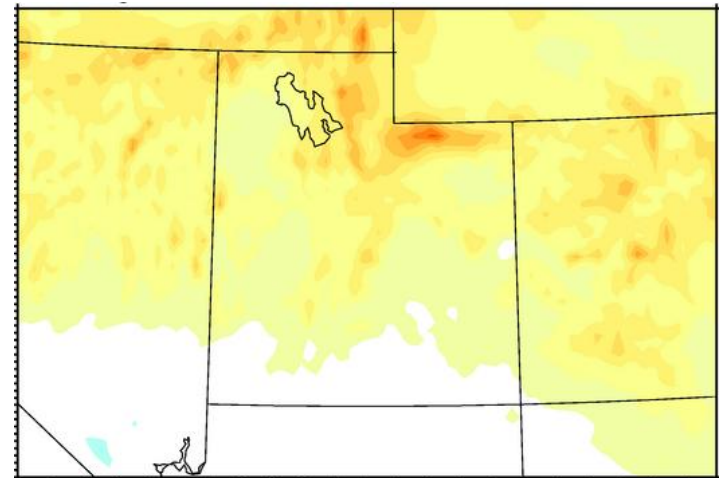
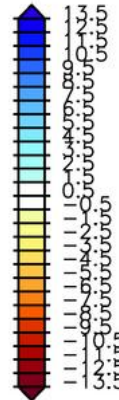
Nov-Apr

May-Oct

Absolute



mm/month



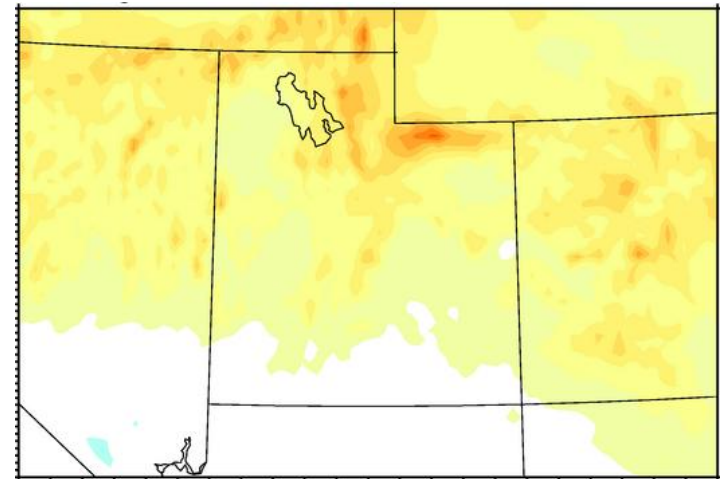
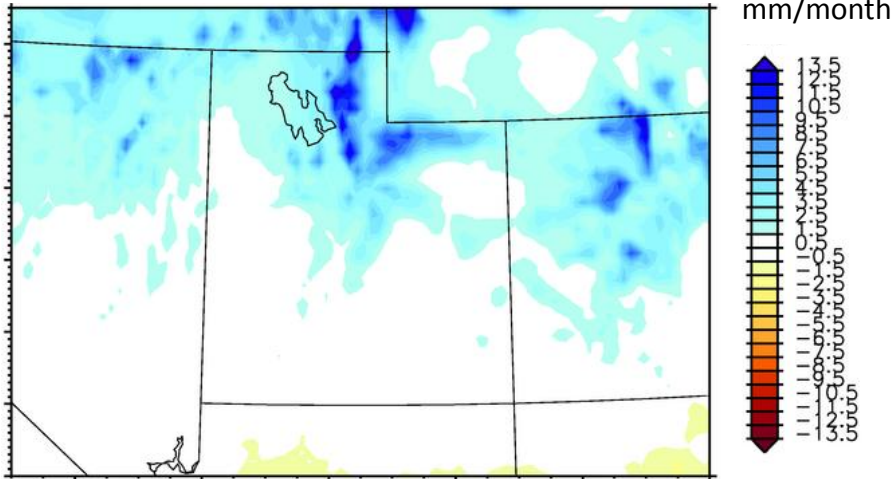
Precipitation Change

A1B, 2050 minus 1990

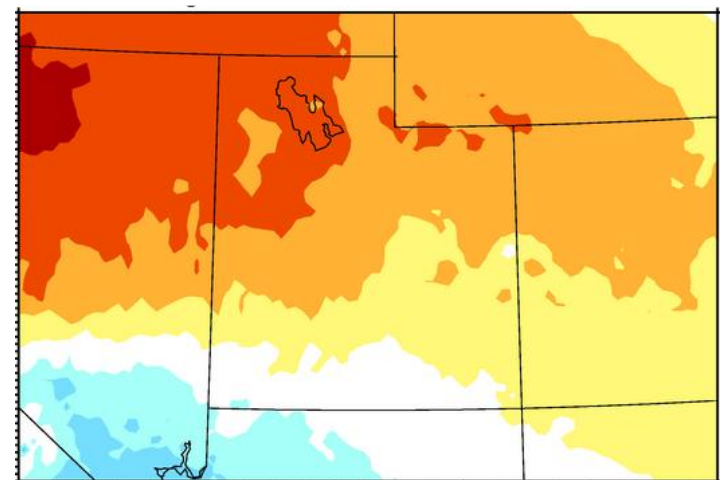
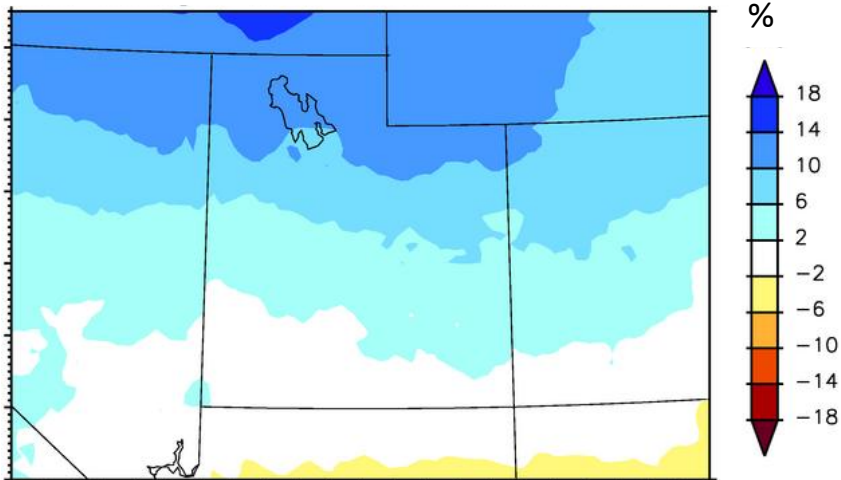
Nov-Apr

May-Oct

Absolute



Relative



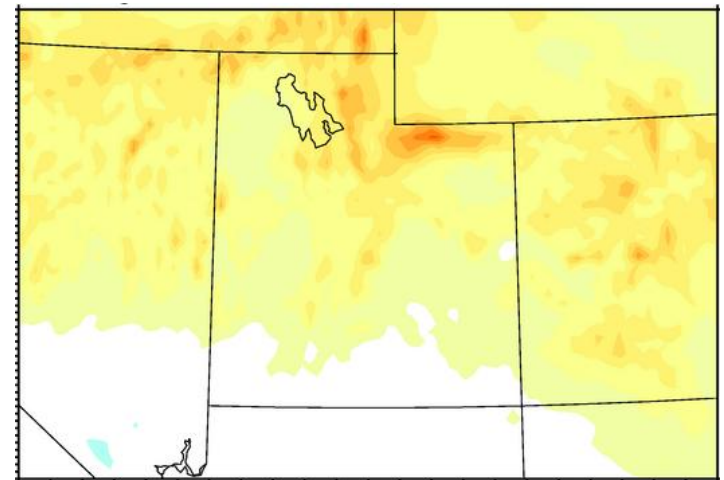
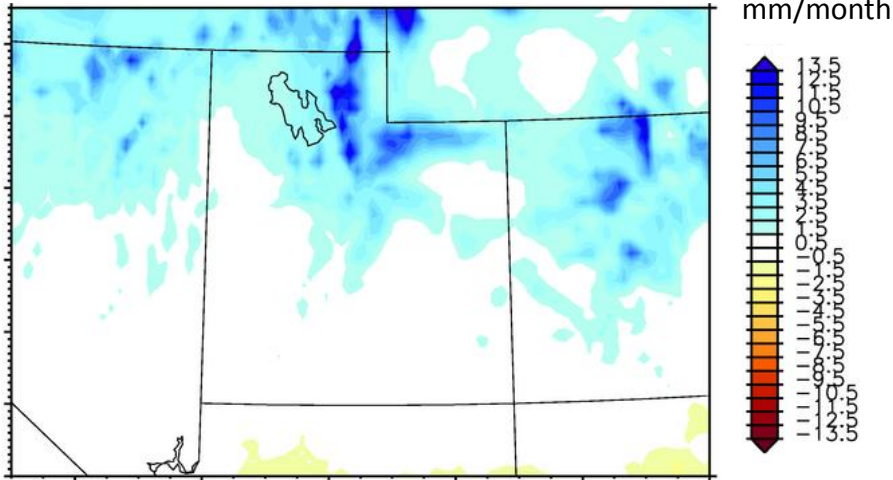
Precipitation Change

A1B, 2050 minus 1990

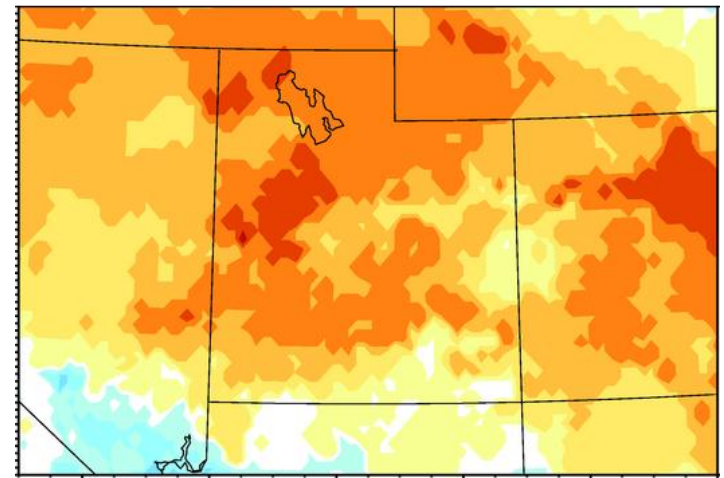
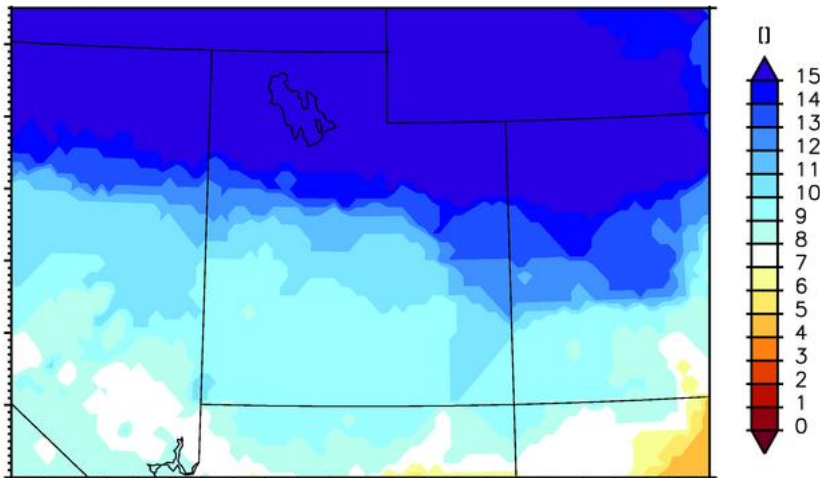
Nov-Apr

May-Oct

Absolute



of models with positive change



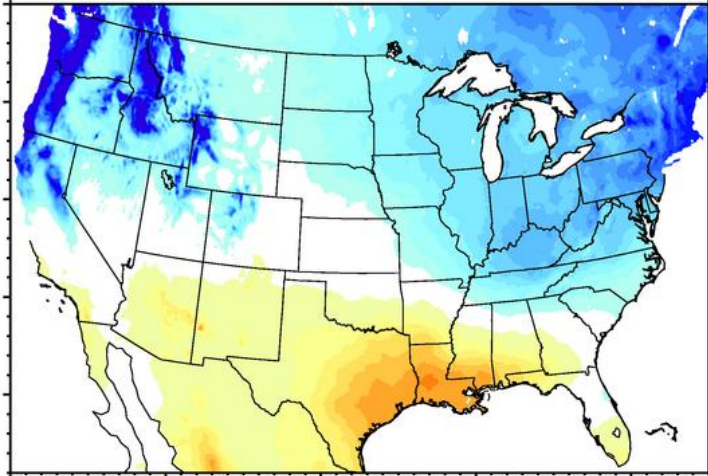
Precipitation Change

A1B, 2050 minus 1990

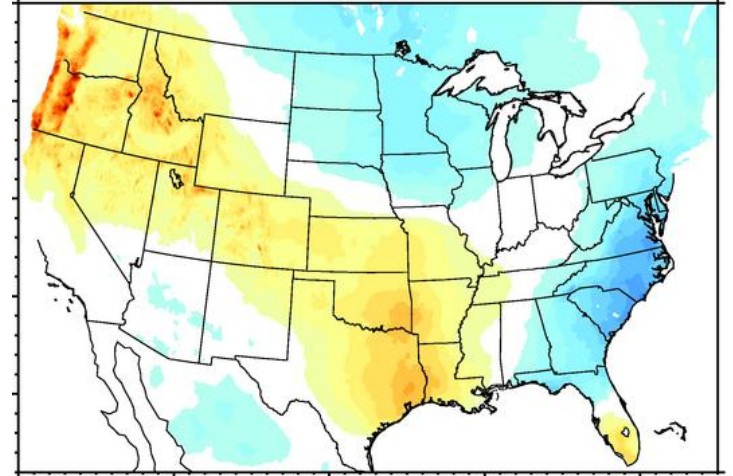
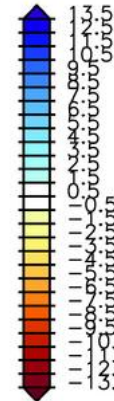
Nov-Apr

May-Oct

Absolute



mm/month



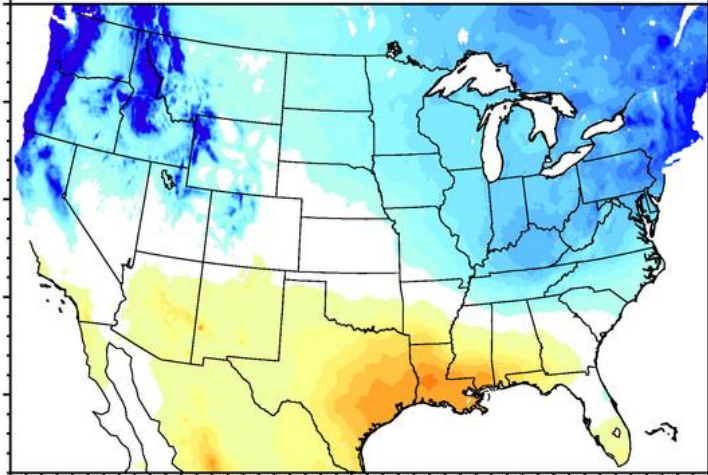
Precipitation Change

A1B, 2050 minus 1990

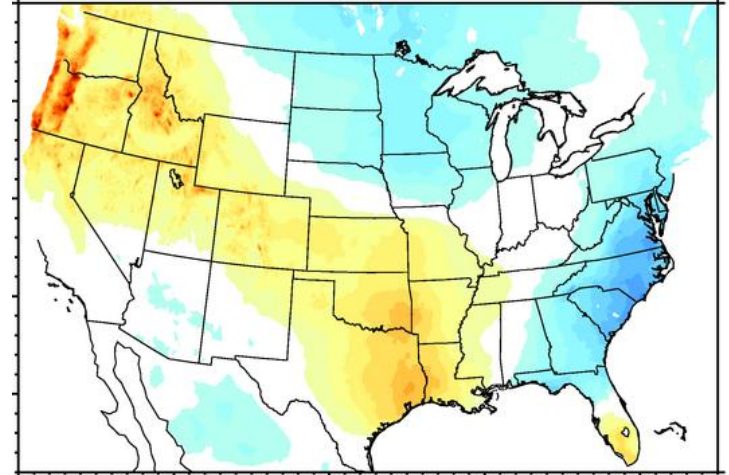
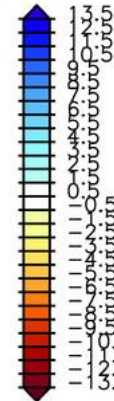
Nov-Apr

May-Oct

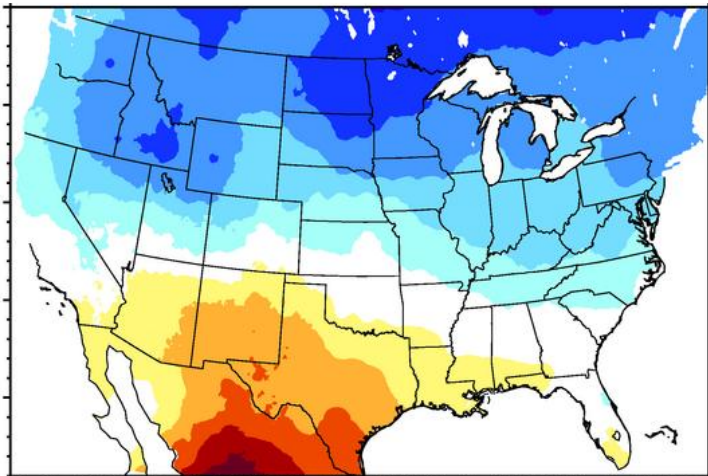
Absolute



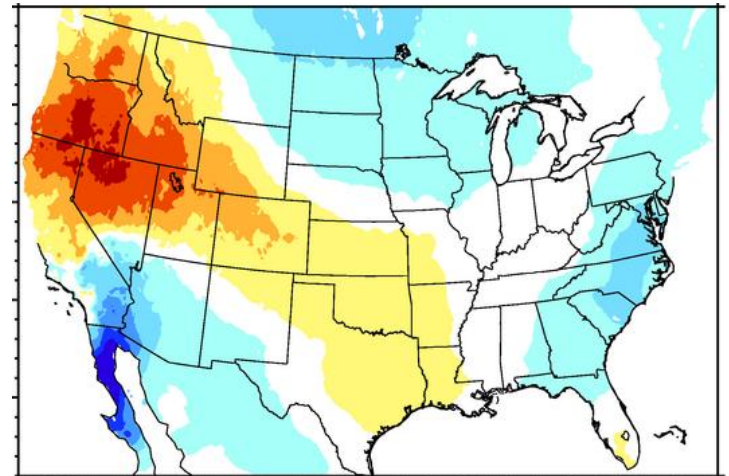
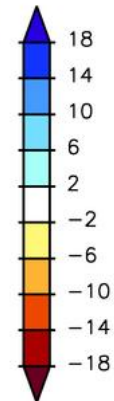
mm/month



Relative



%



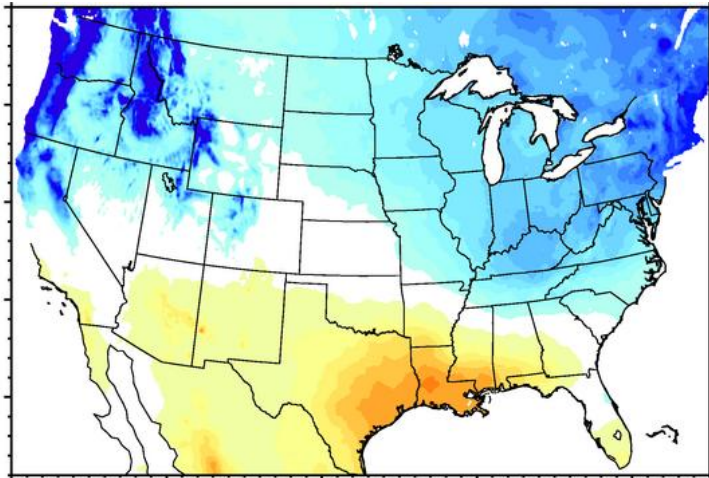
Precipitation Change

A1B, 2050 minus 1990

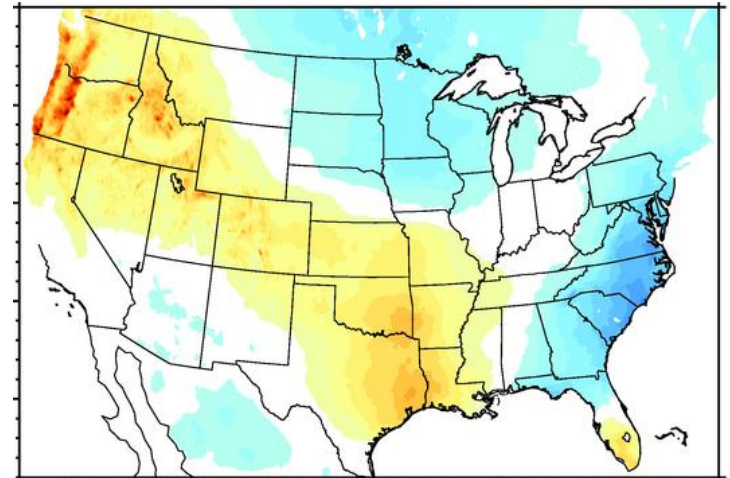
Nov-Apr

May-Oct

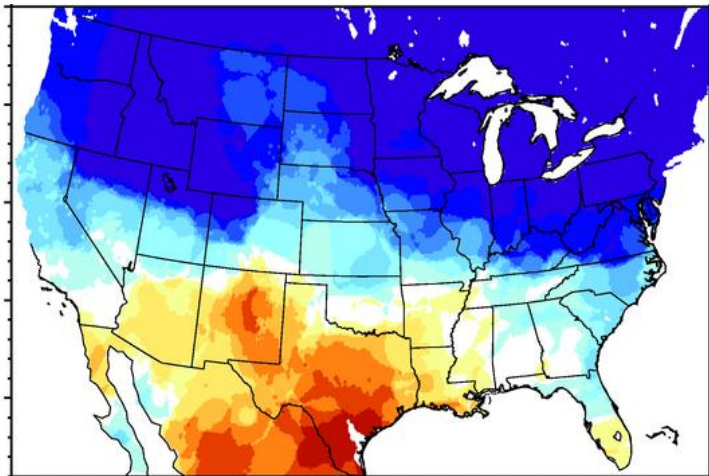
Absolute



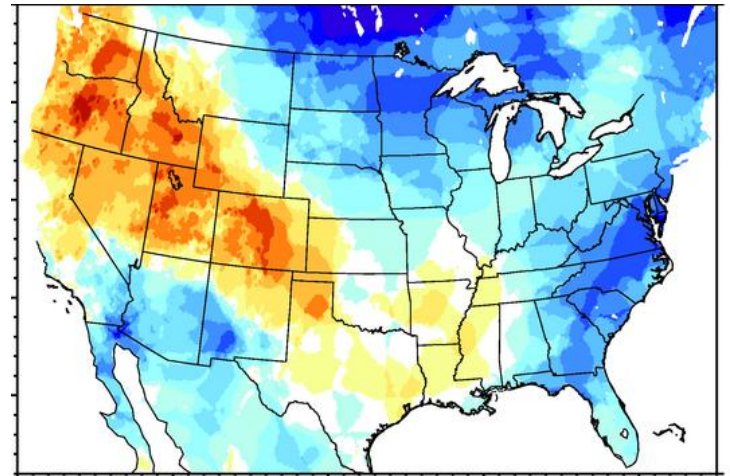
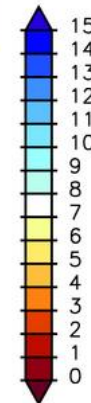
mm/month



Models with positive change

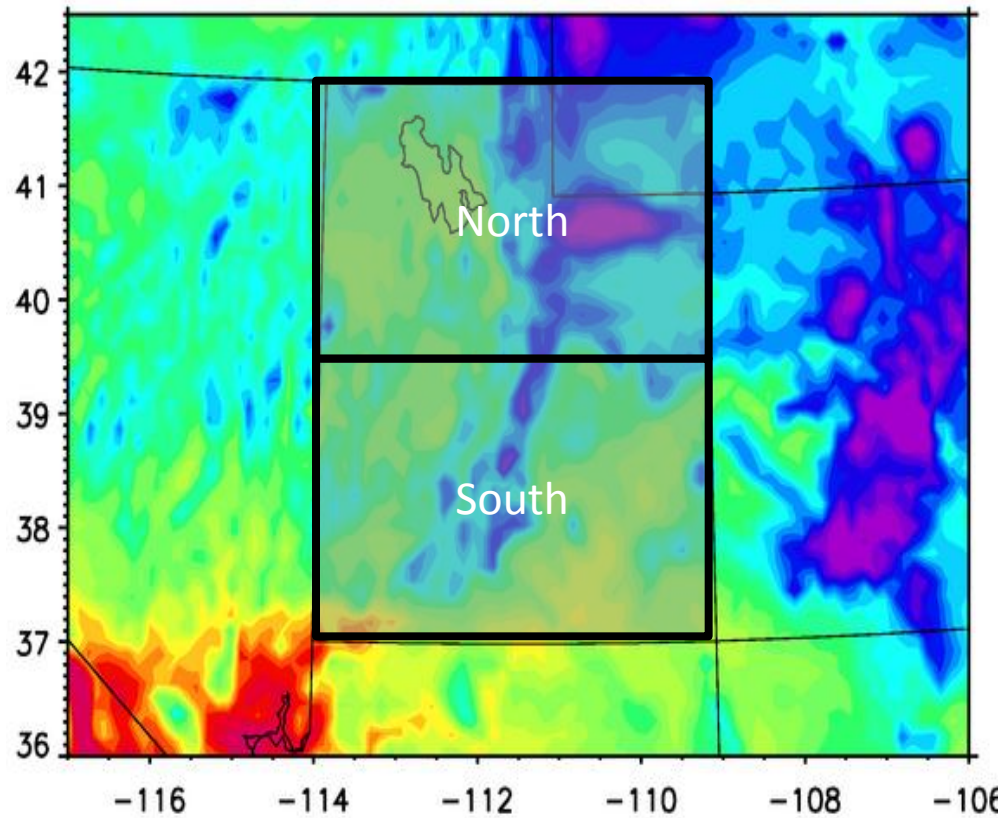


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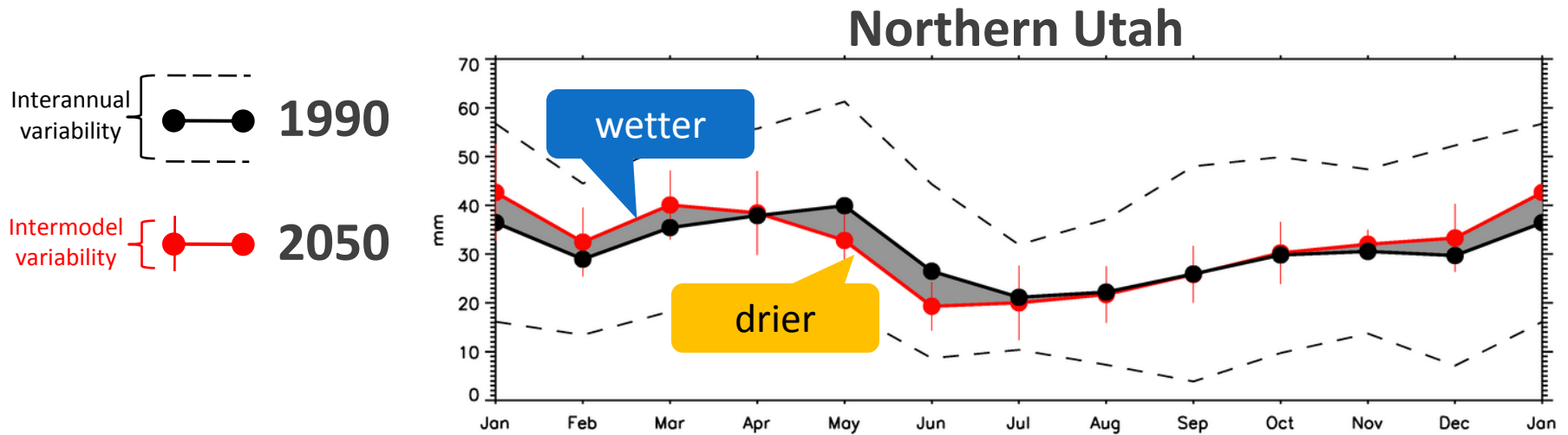


Seasonal Cycle Changes

Northern vs. Southern Utah



Precipitation Change: A1B

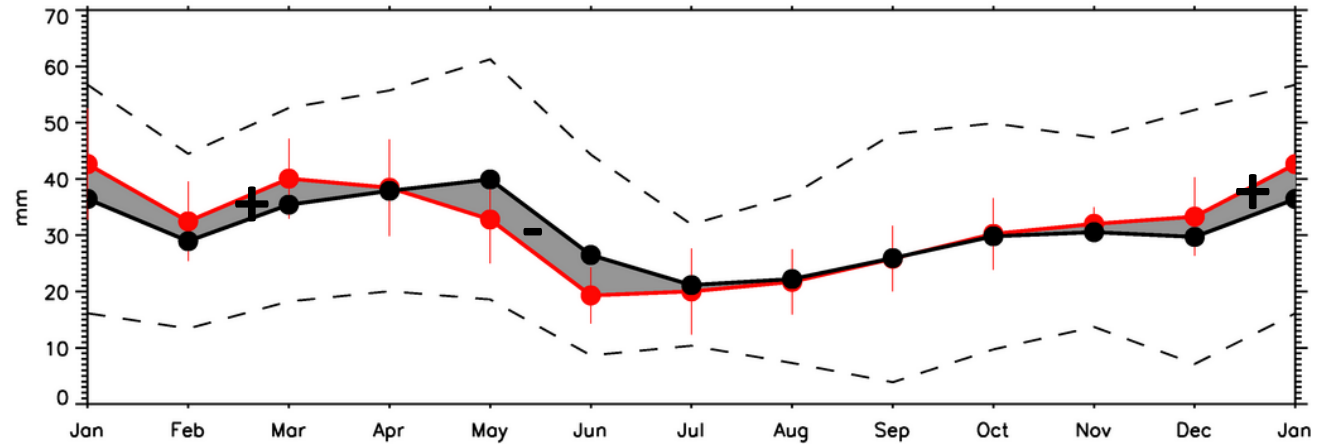


Precipitation Change: A1B

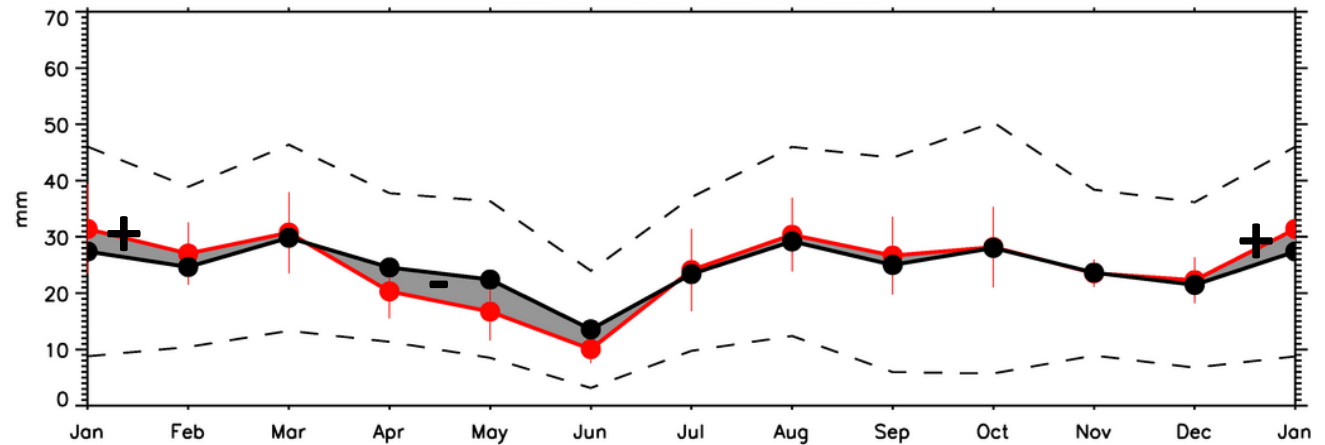
Interannual variability { ● — ● } **1990**

Intermodel variability { ● — ● } **2050**

Northern Utah



Southern Utah

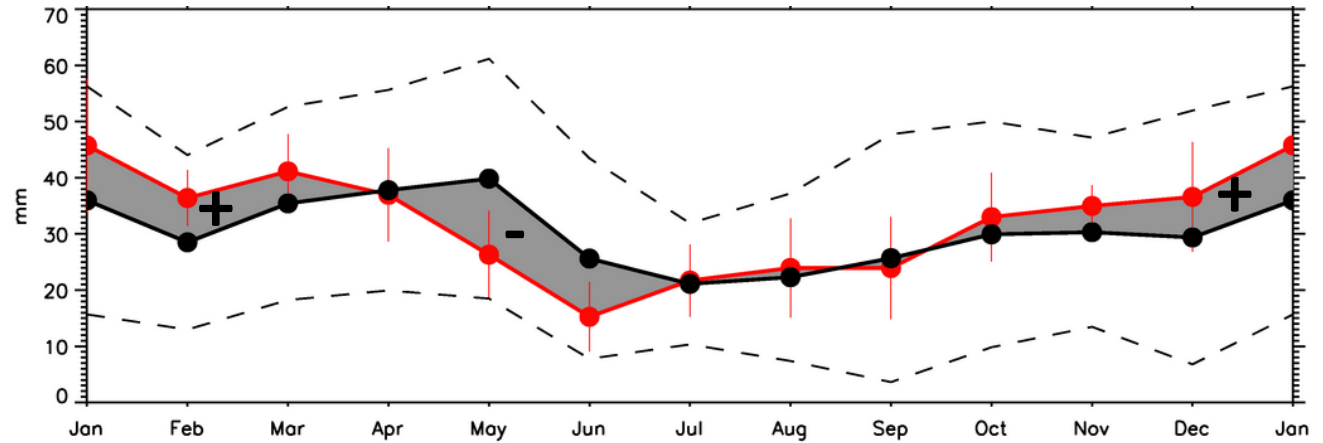


Precipitation Change: A2

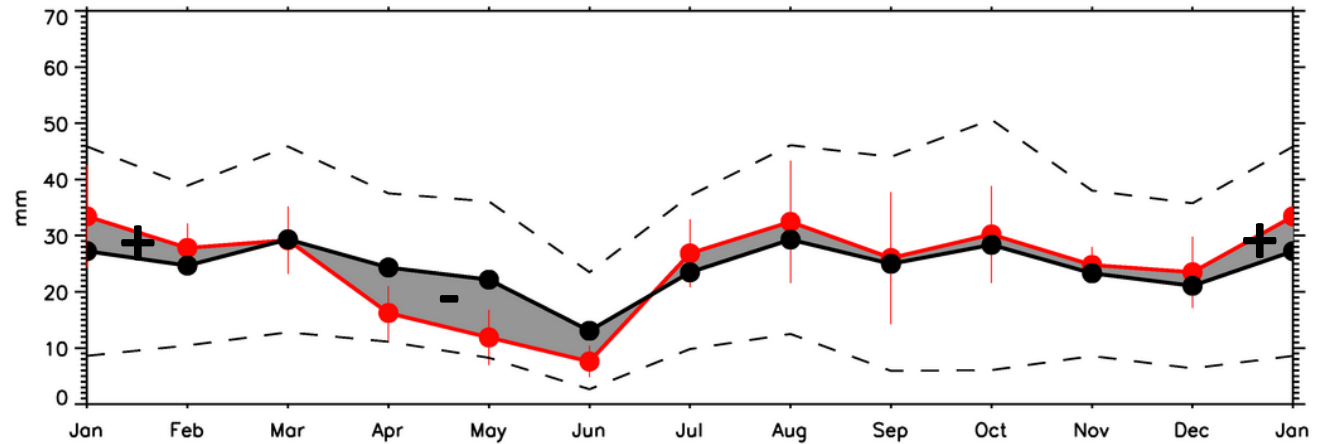
Interannual variability { ● — ● } **1990**

Intermodel variability { ● — ● } **2090**

Northern Utah



Southern Utah



Temperature Change

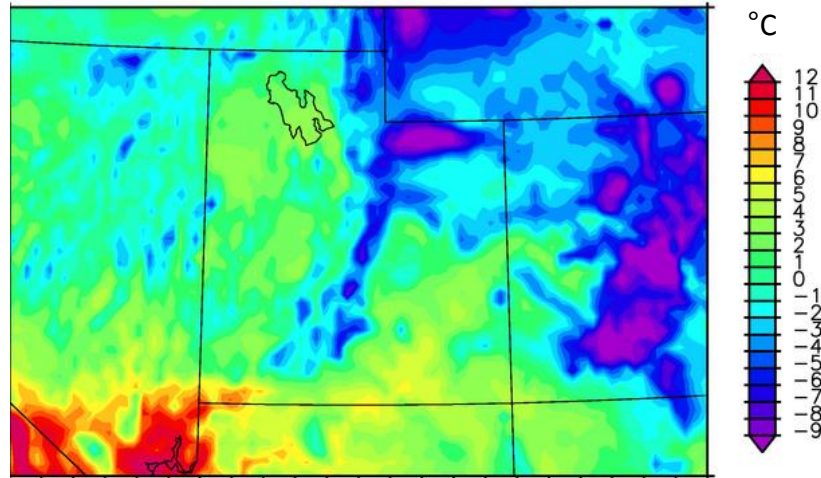
IPCC Scenario A1B (A2)

Temperature Change

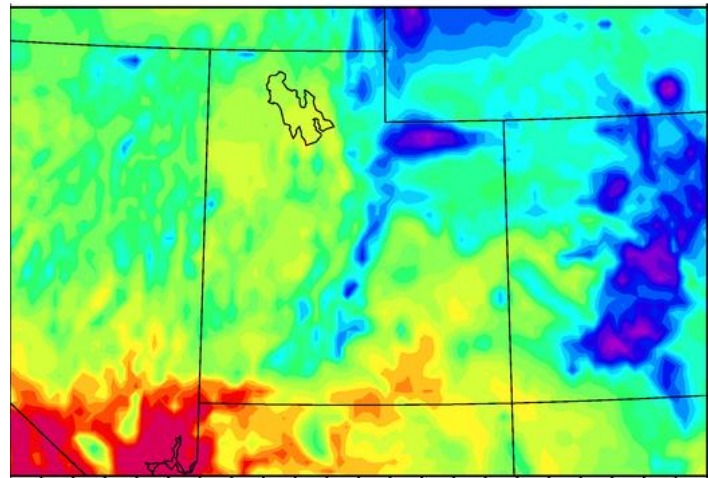
A1B, 1990 vs. 2050

Nov-Apr

1980-1999



2040-2059



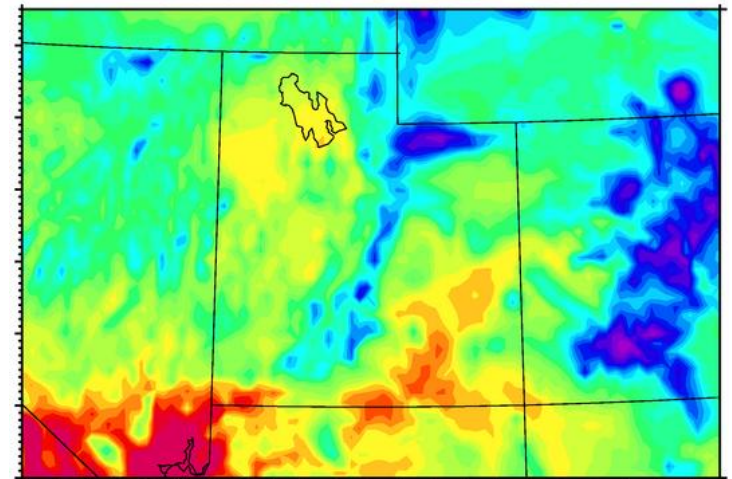
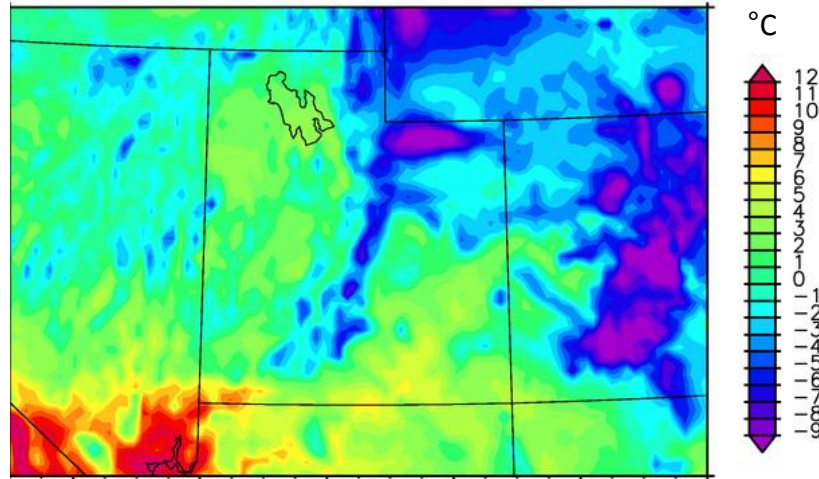
Temperature Change

A1B, 1990 vs. 2050

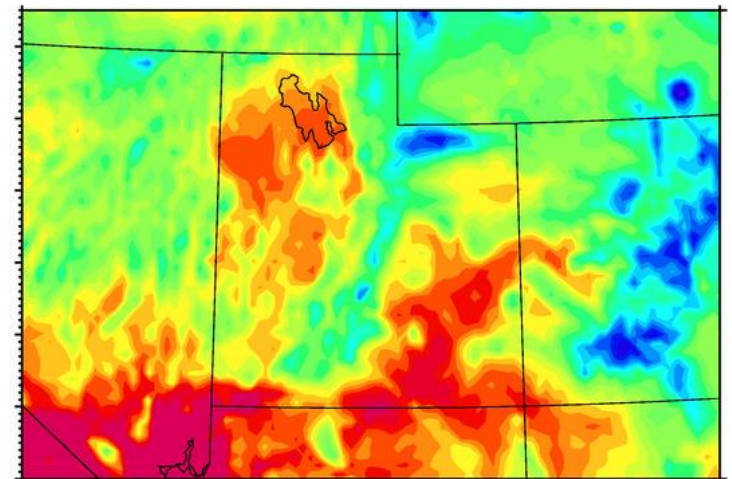
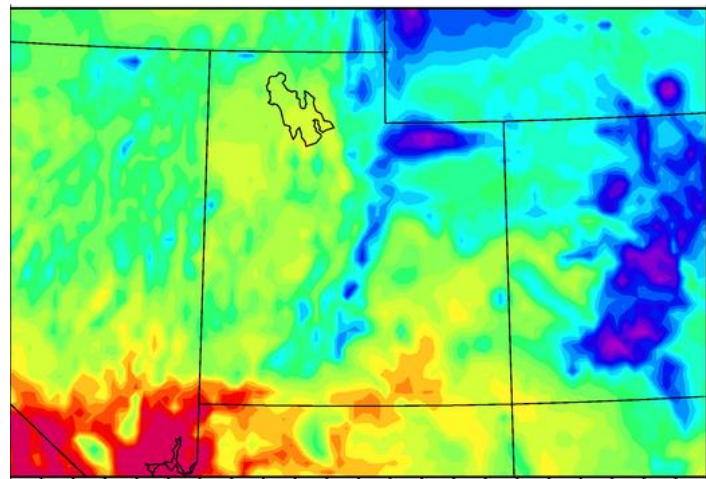
Nov-Apr

May-Oct

1980-1999



2040-2059



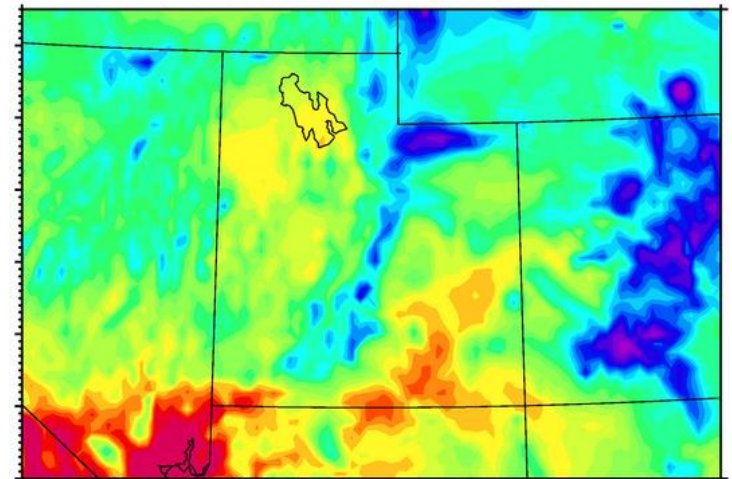
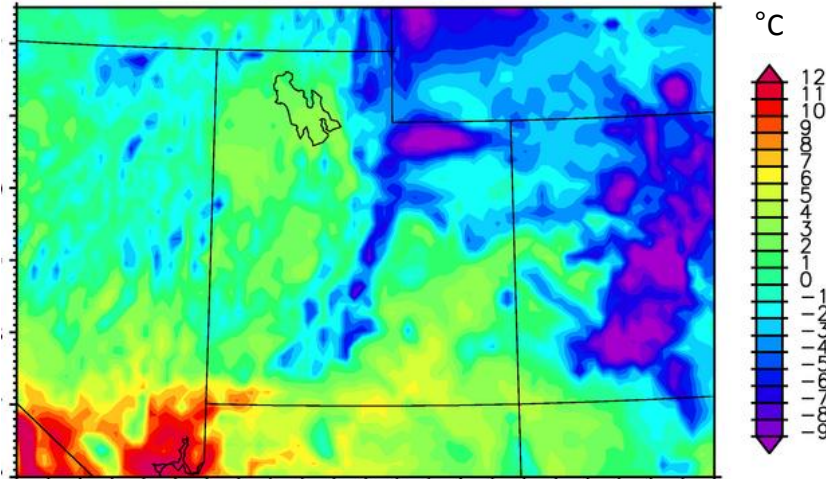
Temperature Change

A1B, 1990 vs. 2050

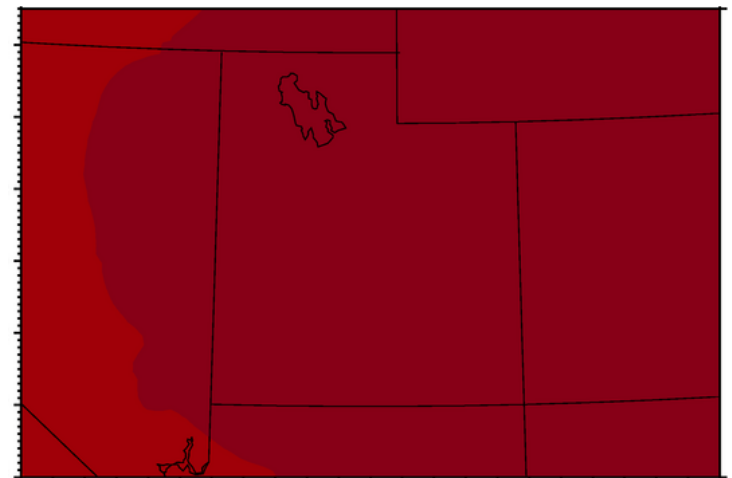
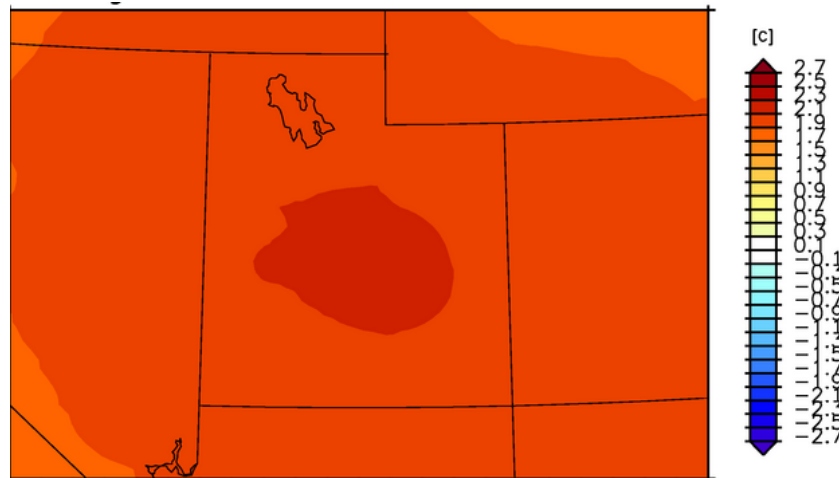
Nov-Apr

May-Oct

1980-1999



Change

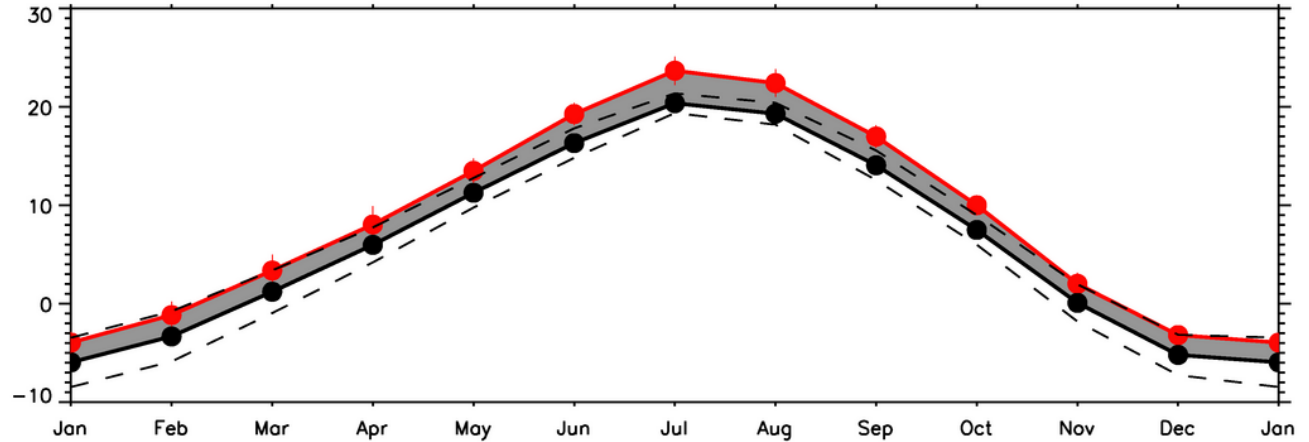


Temperature Change: A1B

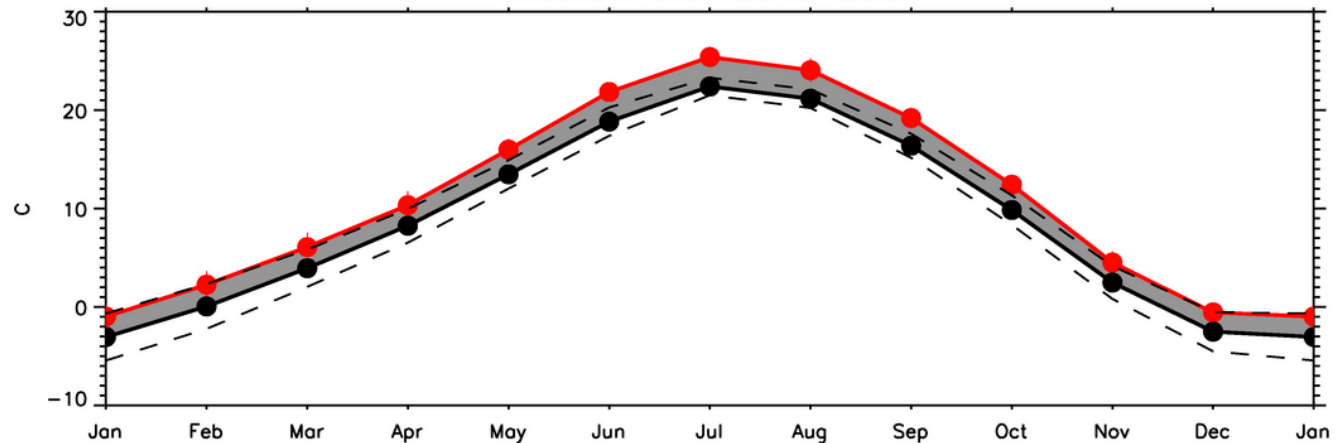
Interannual variability { ● — ● } **1990**

Intermodel variability { ● — ● } **2050**

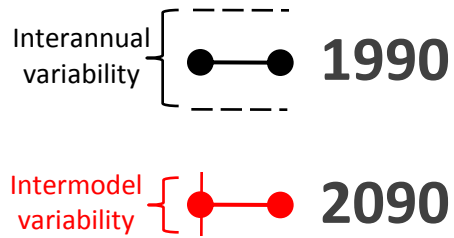
Northern Utah



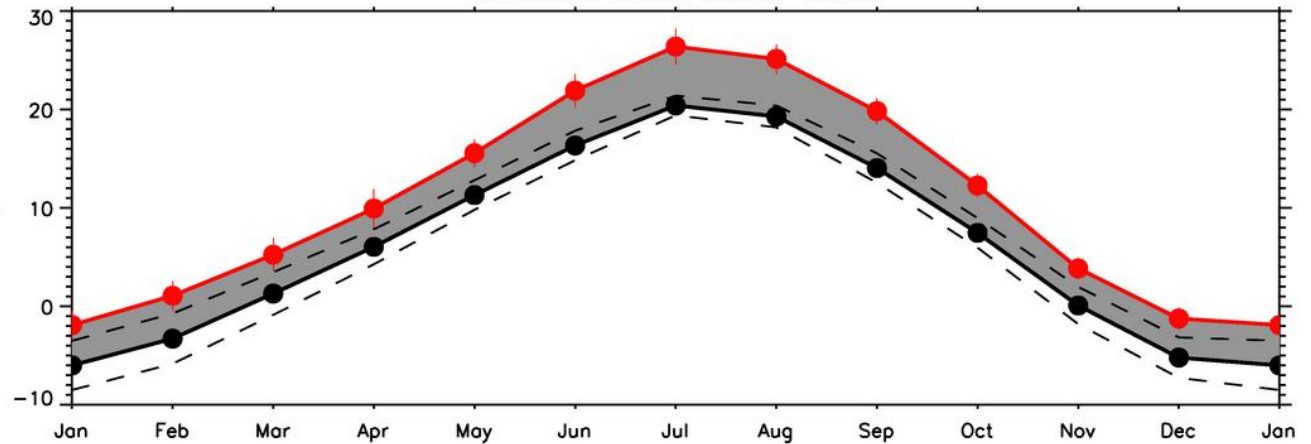
Southern Utah



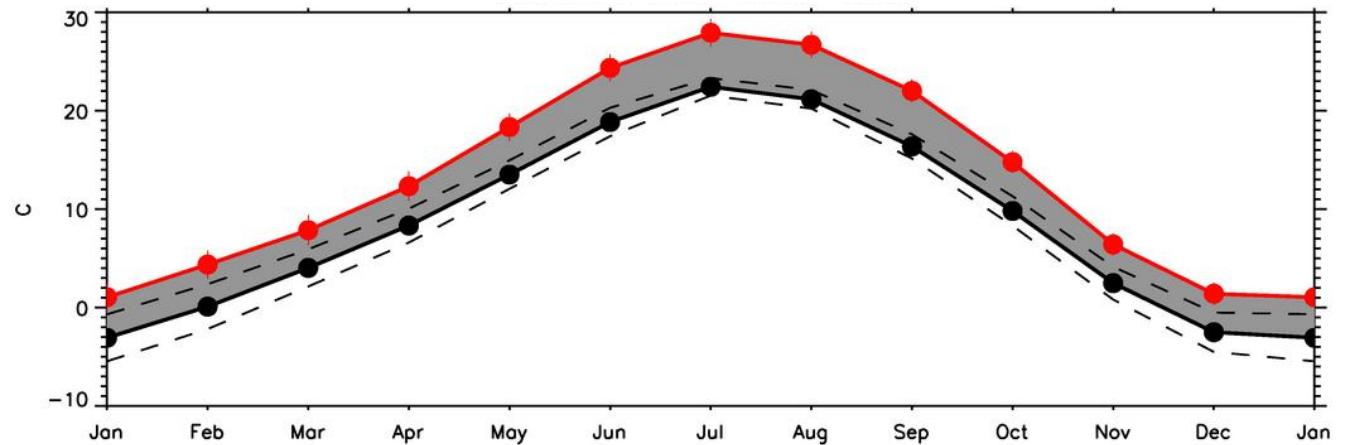
Temperature Change: A2



Northern Utah



Southern Utah



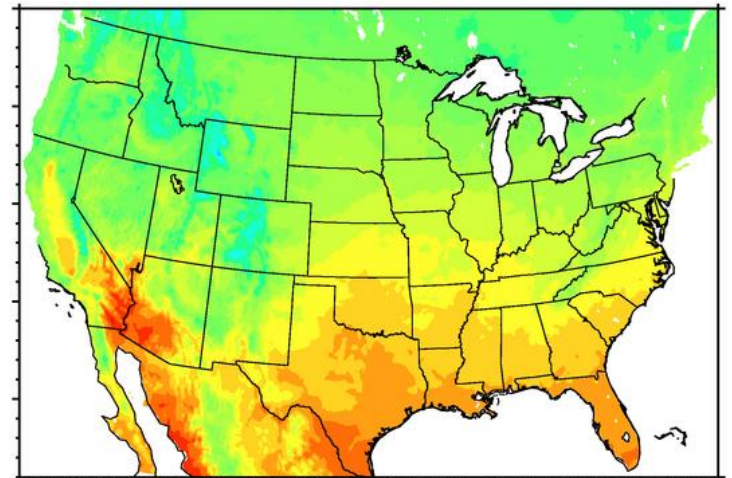
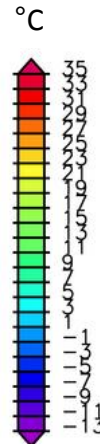
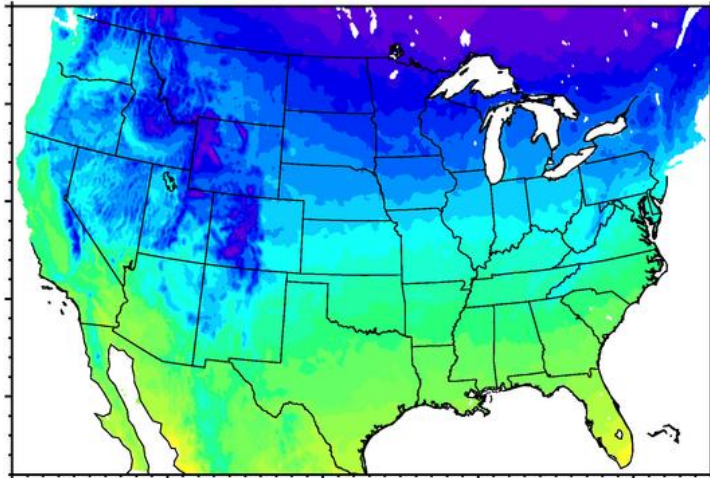
Temperature Change

A1B, 1990 vs. 2050

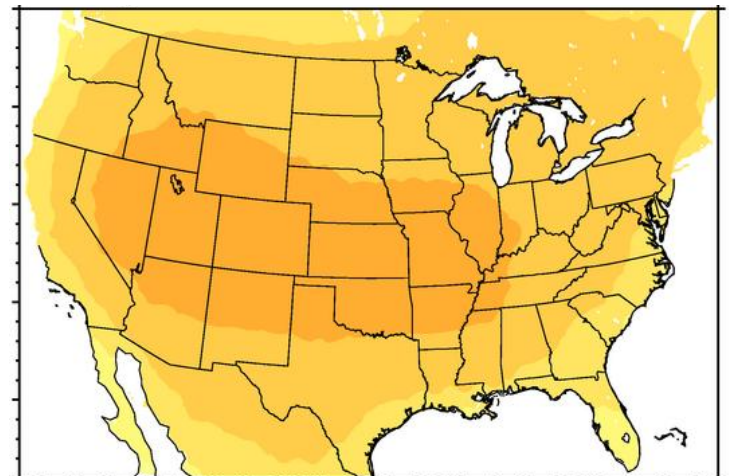
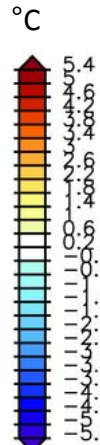
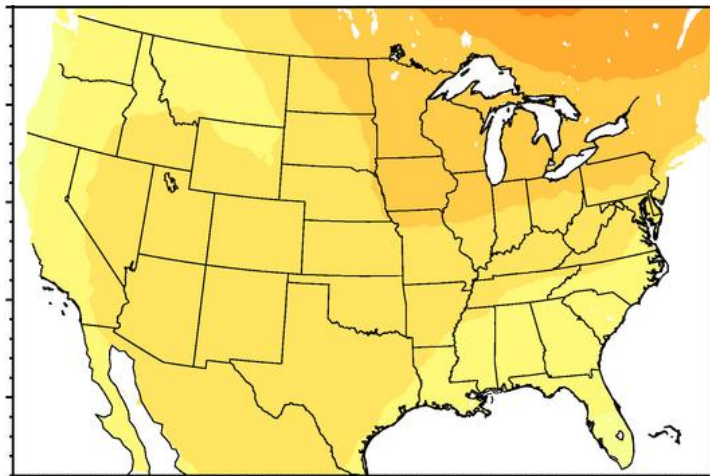
Nov-Apr

May-Oct

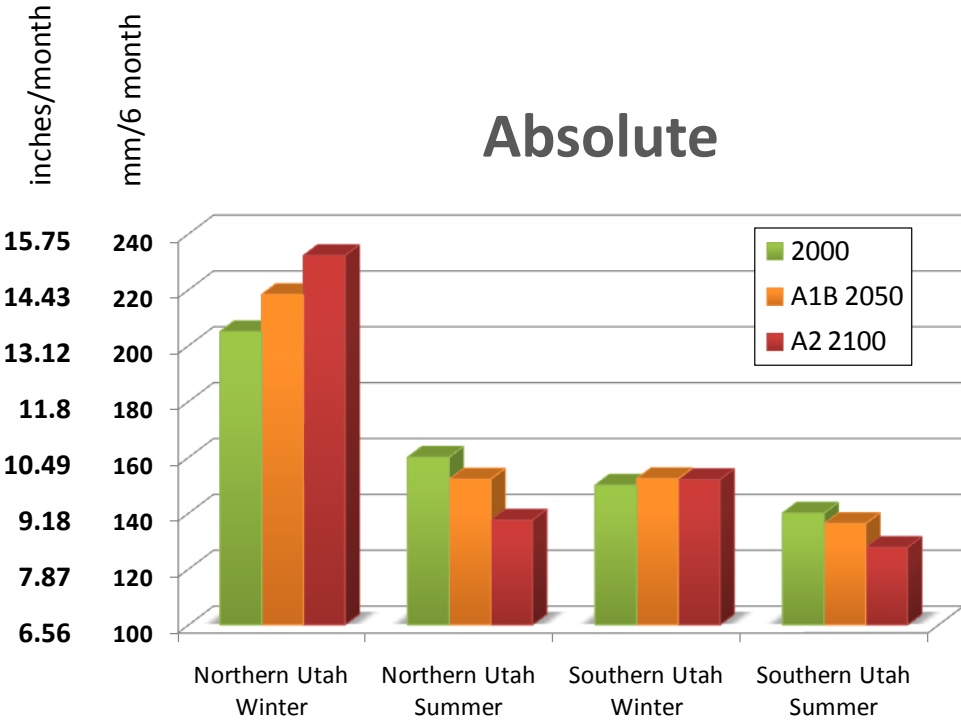
1980-1999



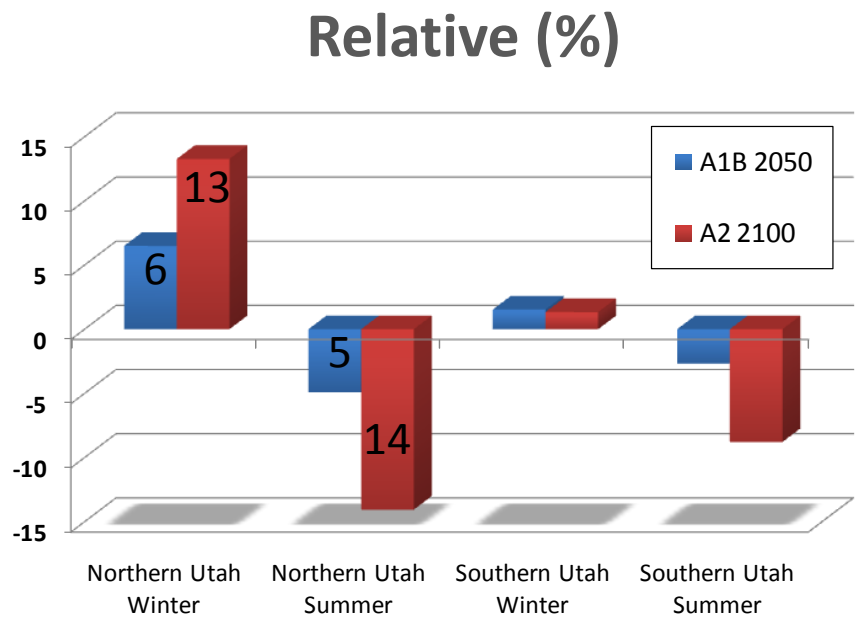
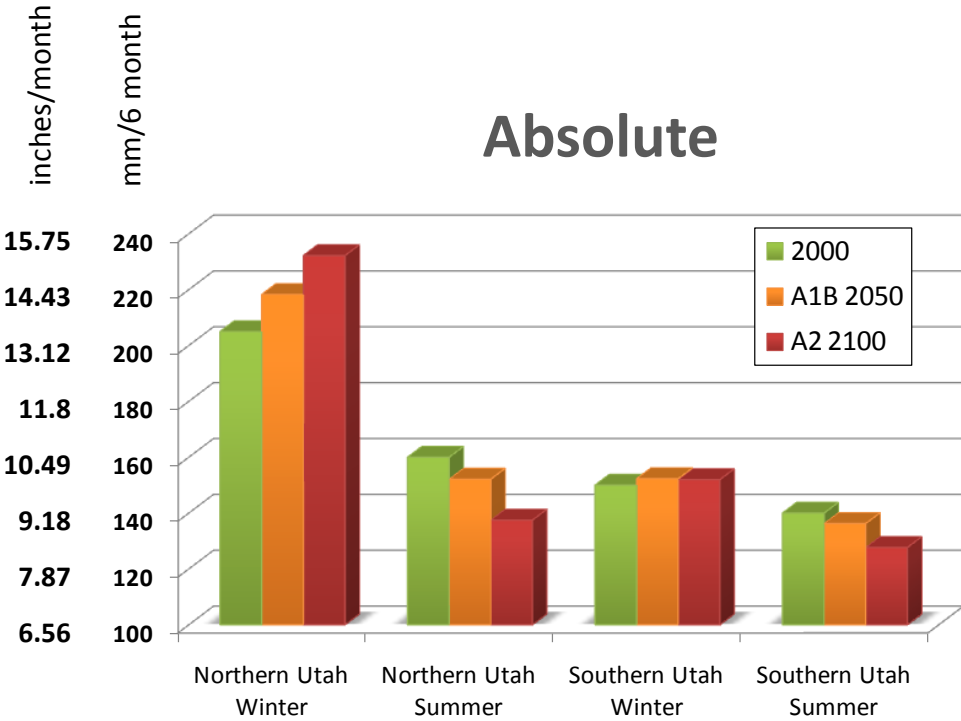
Change



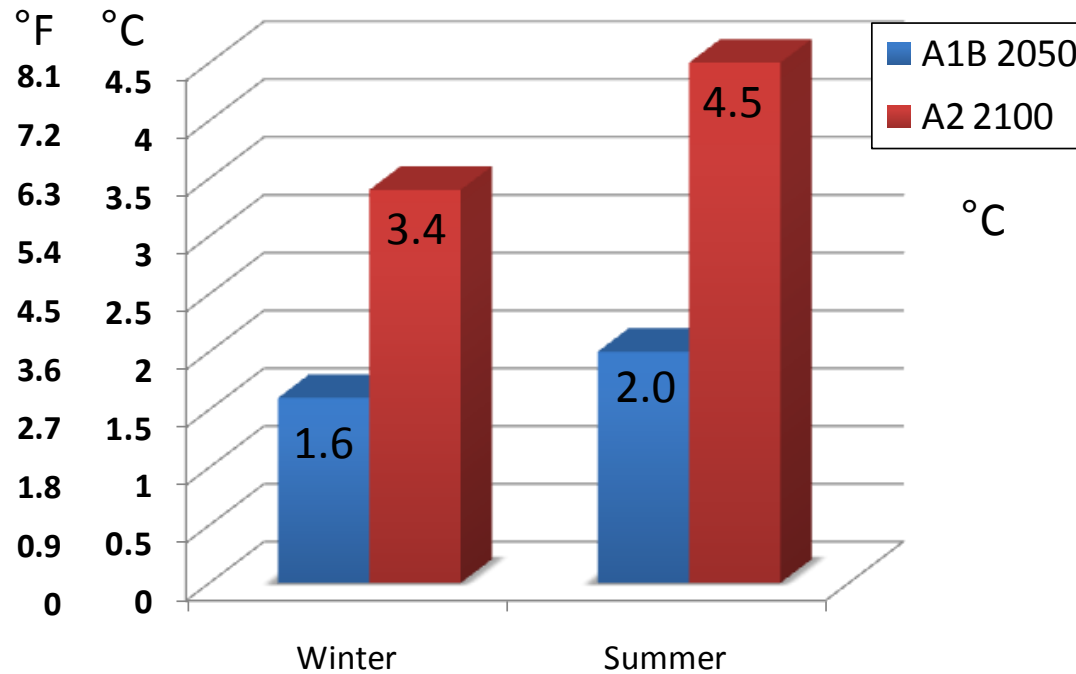
Summary: Precipitation Change



Summary: Precipitation Change



Summary: Temperature Change



Why Trust These Results?

- Models are getting better over time
 - predictions from the latest generation of models
- Multi-model means
 - are known to improve model predictions
- Degree of model agreement
 - good agreement for precipitation in winter
- Model errors are corrected by statistical downscaling
- Change is consistent with theoretical expectations
 1. General global warming
 - amplified over higher latitudes, continent interiors, mountains
 2. Intensified hydrological cycle
 - “wetter gets wetter, drier gets drier”
 3. Widening of the Tropics, poleward shift of jet and storm tracks
 - particularly a summer phenomenon; expected drying

Impact on Water Supply

- Retention of winter precipitation in the form of snow and gradual release by summer melt is an integral part of Utah's water supply
- Availability of water is thus controlled by
 - 1. precipitation**
 - 2. temperature** (snow fraction, snow melt, evaporation)
 - 3. mean, variability, and seasonal cycle**
- Temperature and precipitation increase have opposing effects, making the overall impact on supply and demand of water uncertain
- More work is required to address this issue