WRF Historical and PGW Simulations over Alaska

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GEWEX CPCM Workshop II

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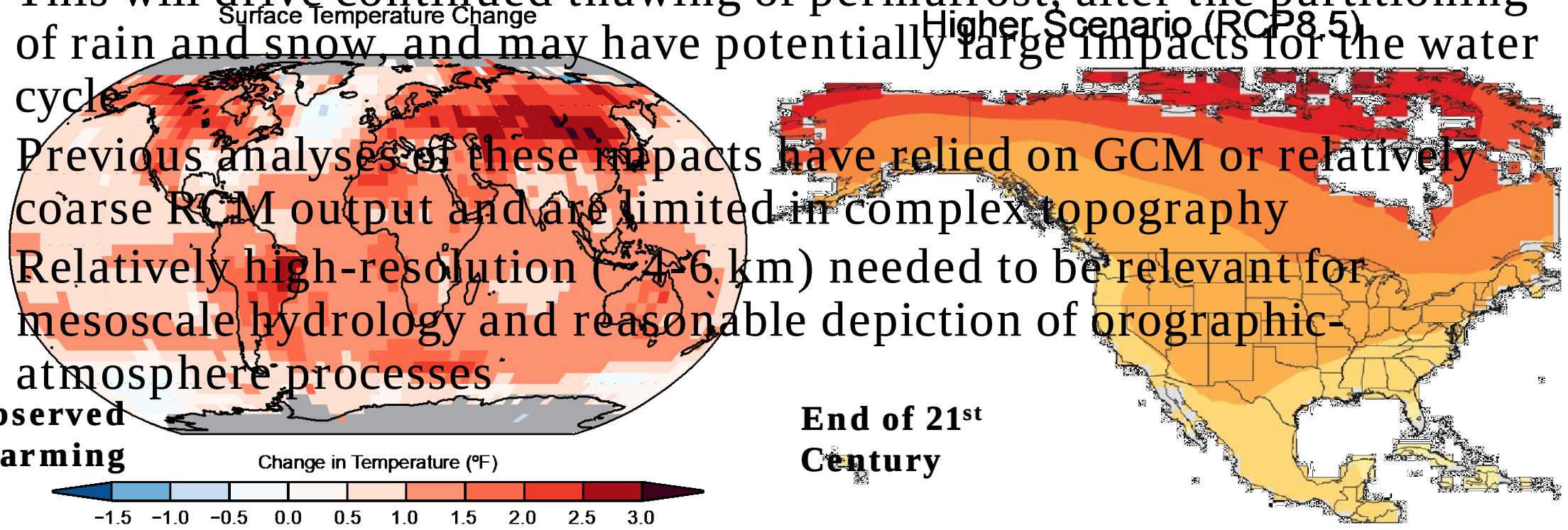
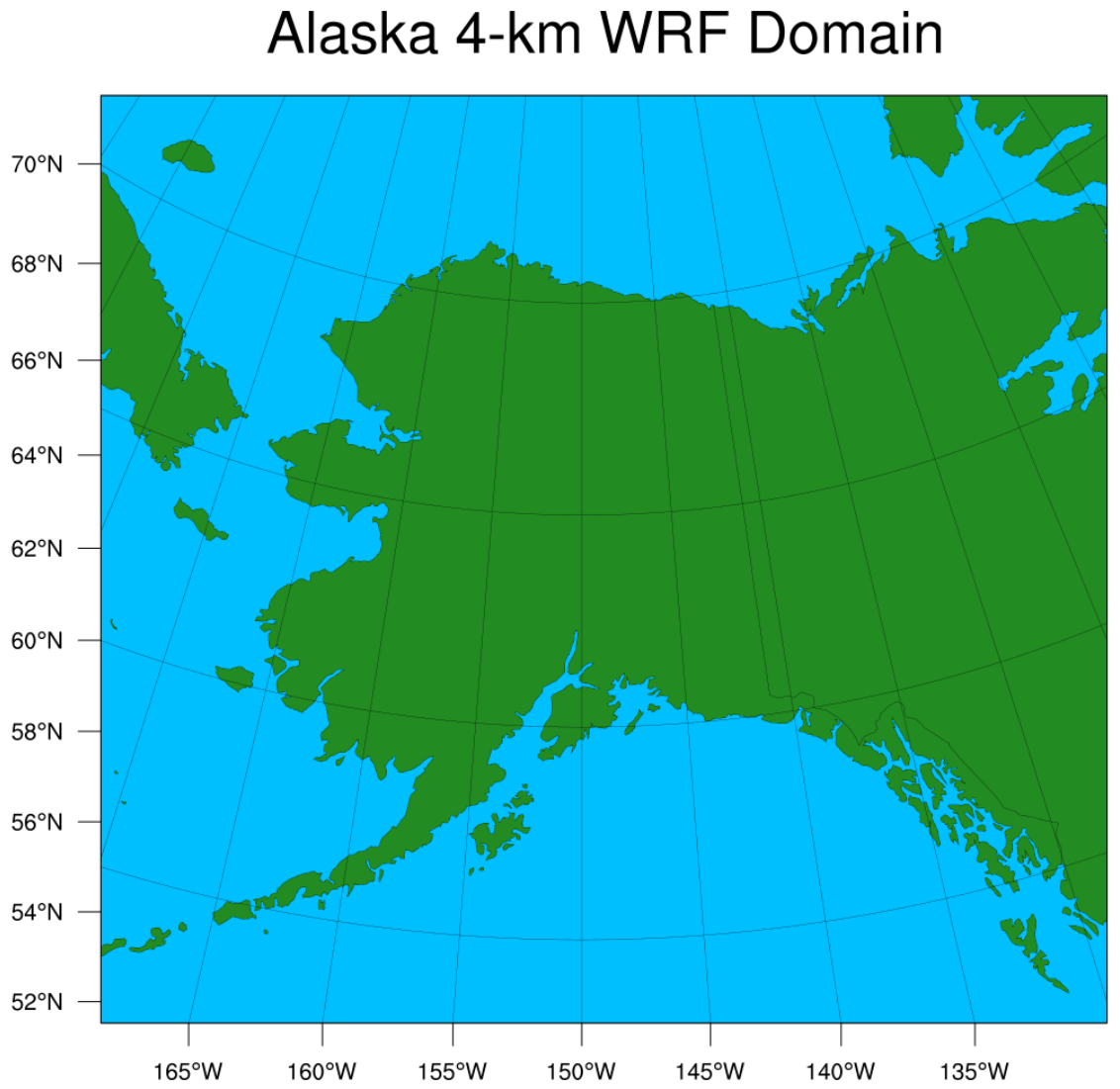
Motivation

- Alaska has warmed during the recent observational record and is projected to keep warming through the end of the 21st century
  - Extensive observed and projected warming under RCP8.5
- This will drive continued thawing of permafrost, alter the partitioning of rain and snow, and may have potentially large impacts for the water cycle
- Previous analyses of these impacts have relied on GCM or relatively coarse RCM output and are limited in complex topography
- Relatively high-resolution (~4-6 km) needed to be relevant for mesoscale hydrology and reasonable depiction of orographic-atmosphere processes



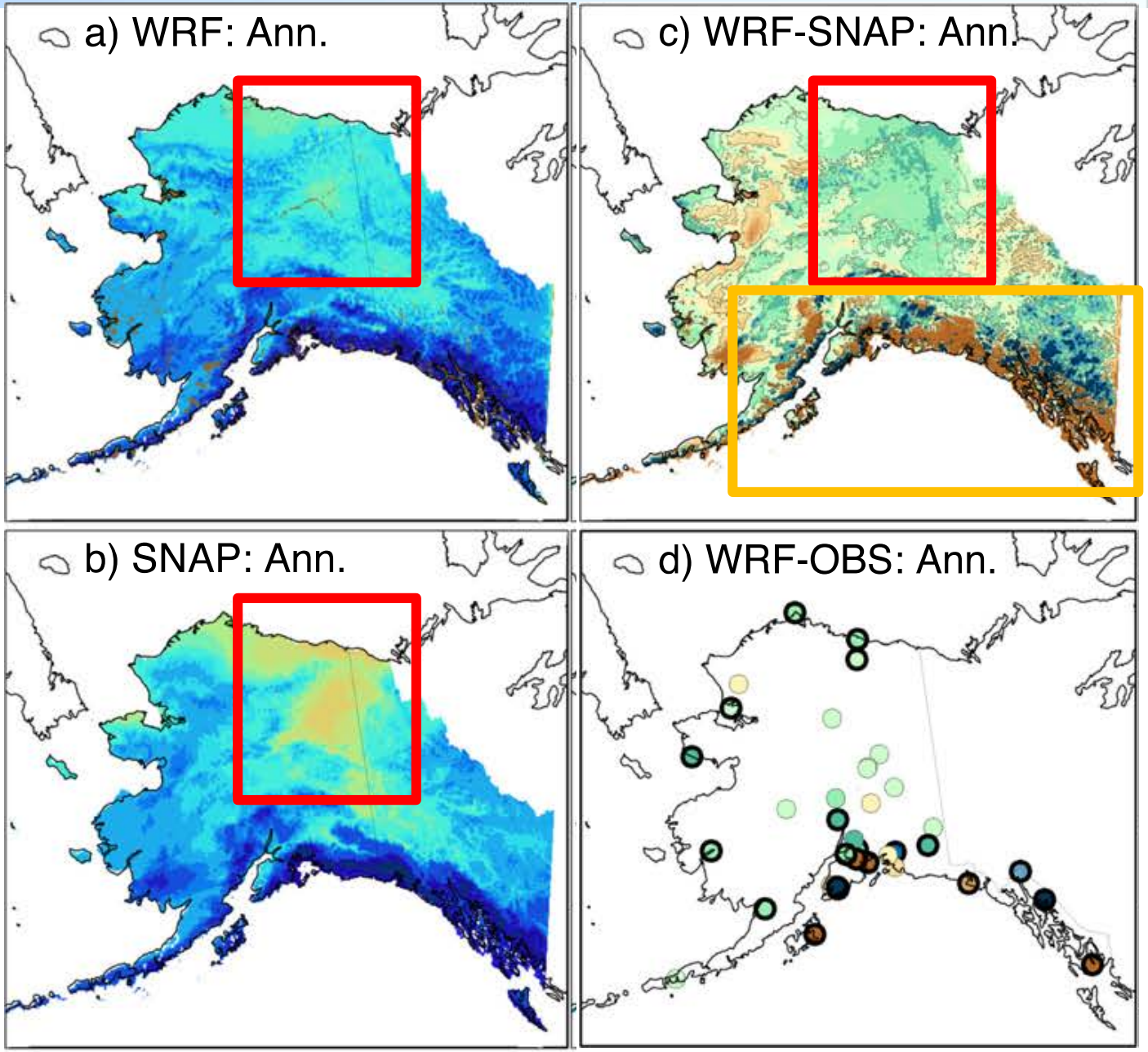
WRF Configuration

- 1 Sept 2002 – 31 August 2016
  - **4 km grid spacing**
  - ERA-I ICs and BCs
  - No spectral nudging
  - NASA hi-res sea surface temps (SSTs)
- WRF 3.7.1
  - Thompson microphysics
  - Noah-MP with modifications for improved snow simulations
- Pseudo Global Warming (PGW) approach
  - End of century CMIP5 ensemble mean
- Analysis for 10 Water Years (WY) 2003-2012
  - PGW simulation through early 2014



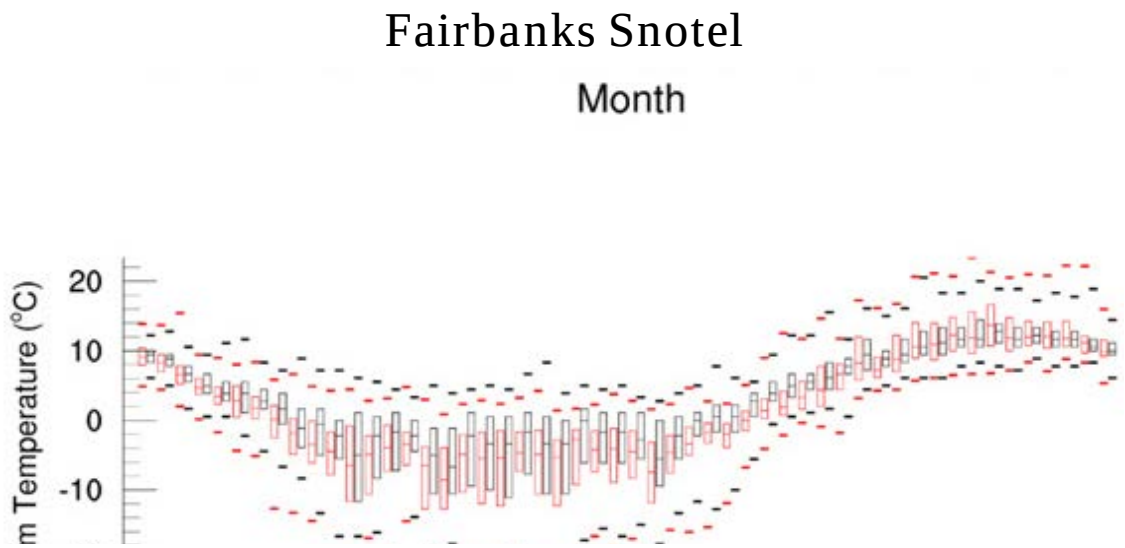
Historical Validation - Precipitation

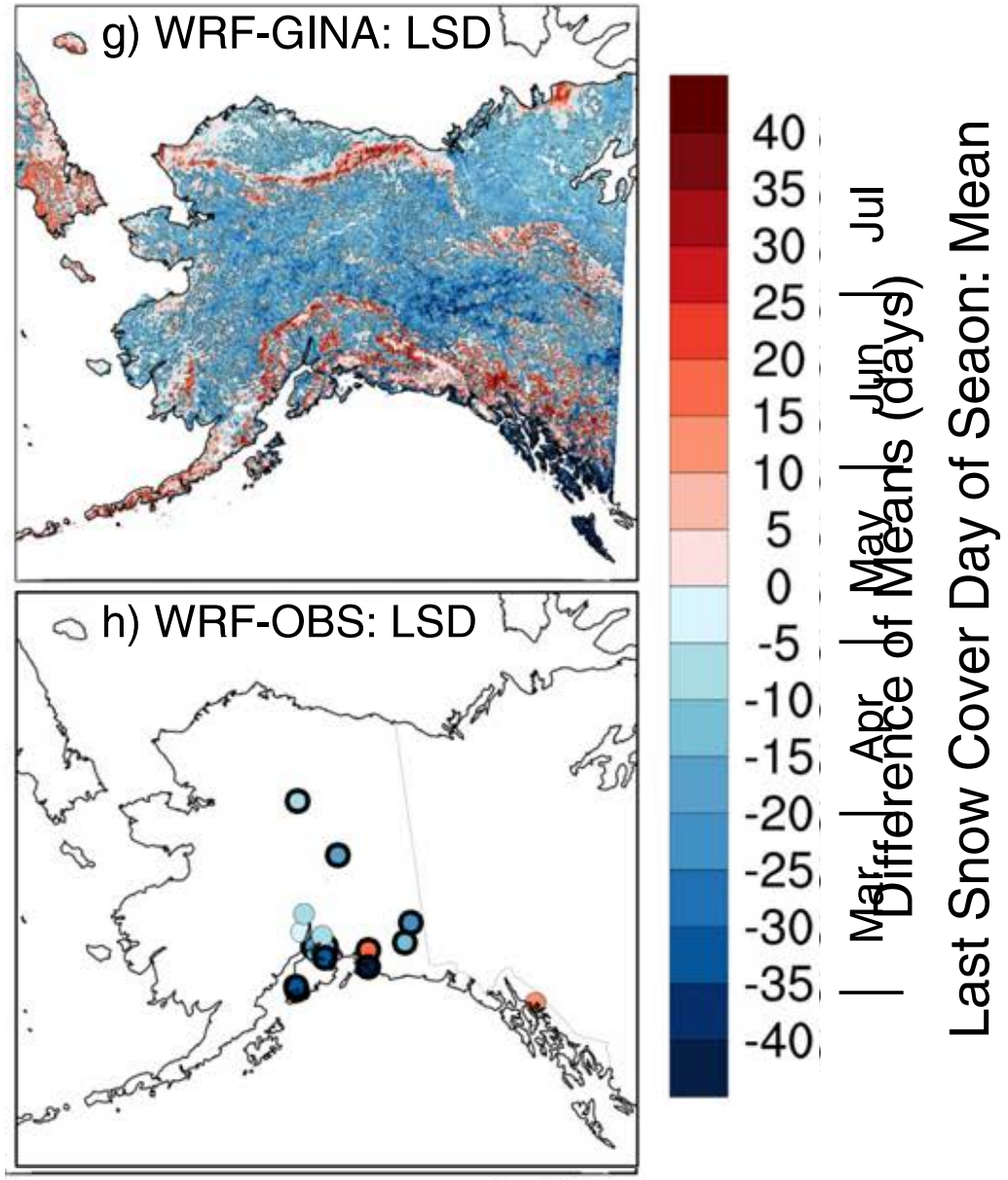
- WRF overestimates in Central and Northern Alaska
  - Observations may be flawed
    - Extremely sparse and undercatch likely
- Possible underestimation along SE mountains
  - Scale mismatch between observational grid and WRF
  - Observations are based on very coarse CRU gridded anomalies



Historical Validation - Snow

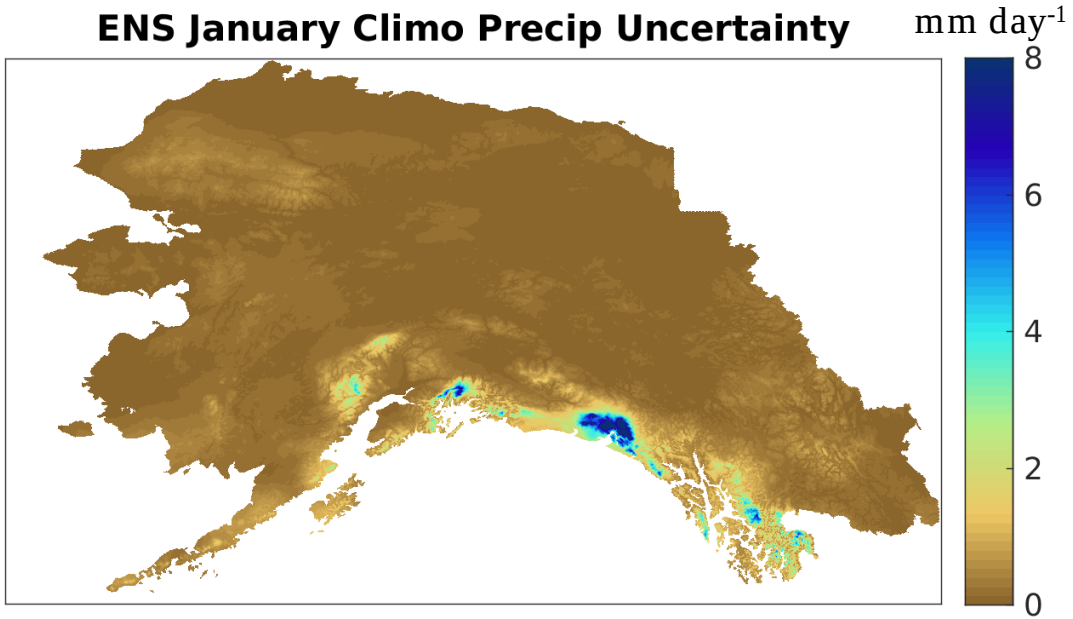
- Noah—MP LSM reproduces seasonal snow except for melt period
  - Melt is too fast in Noah-MP

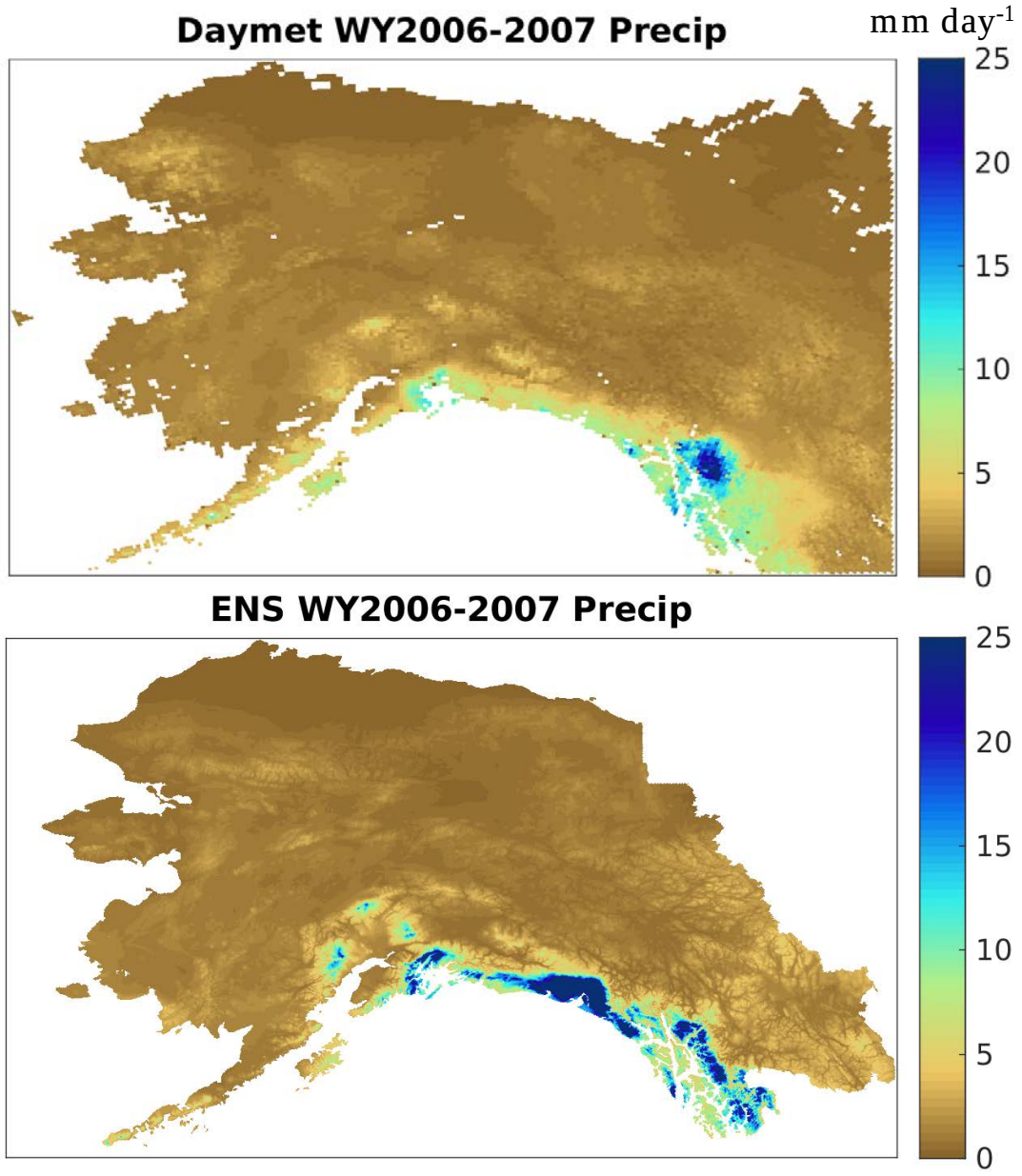




Historical Validation – An Aside for a Path Forward

- Understand and improve obs product generation



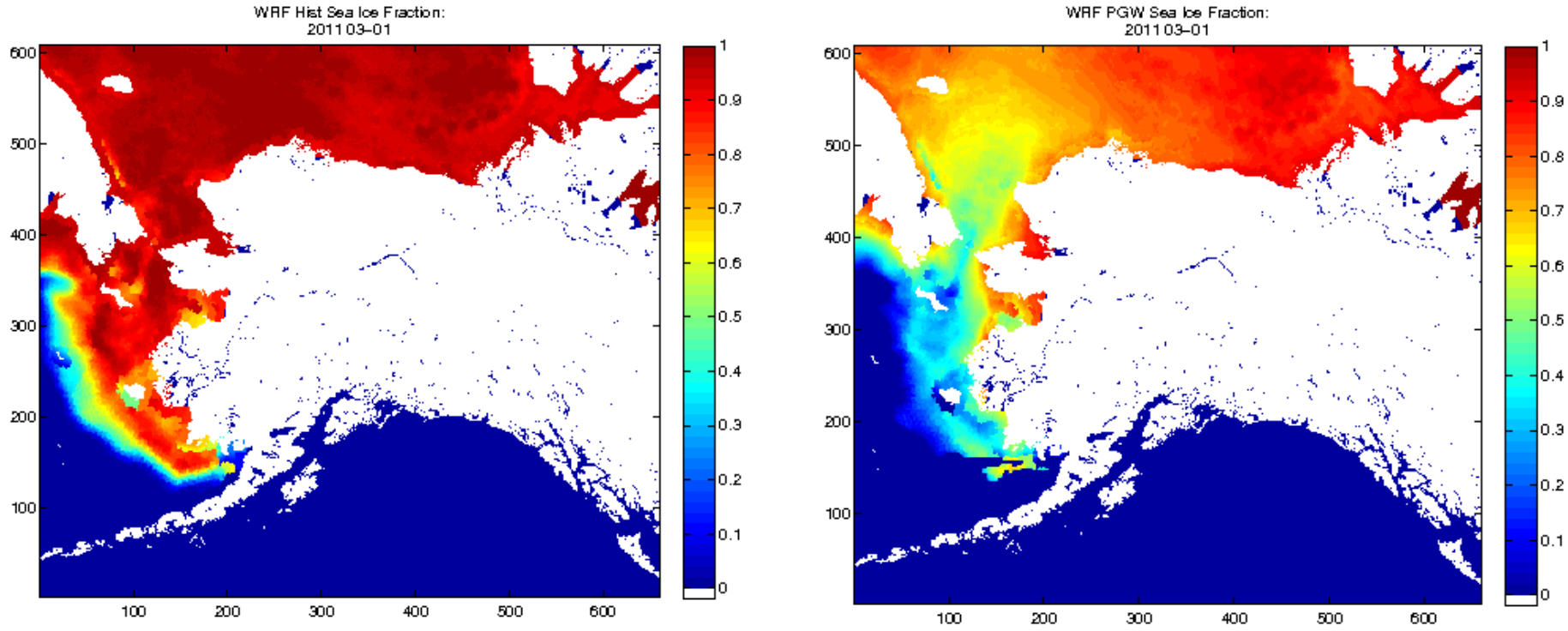


- Acknowledge uncertainty

Newman et al. 2018, in prep

PGW Modifications

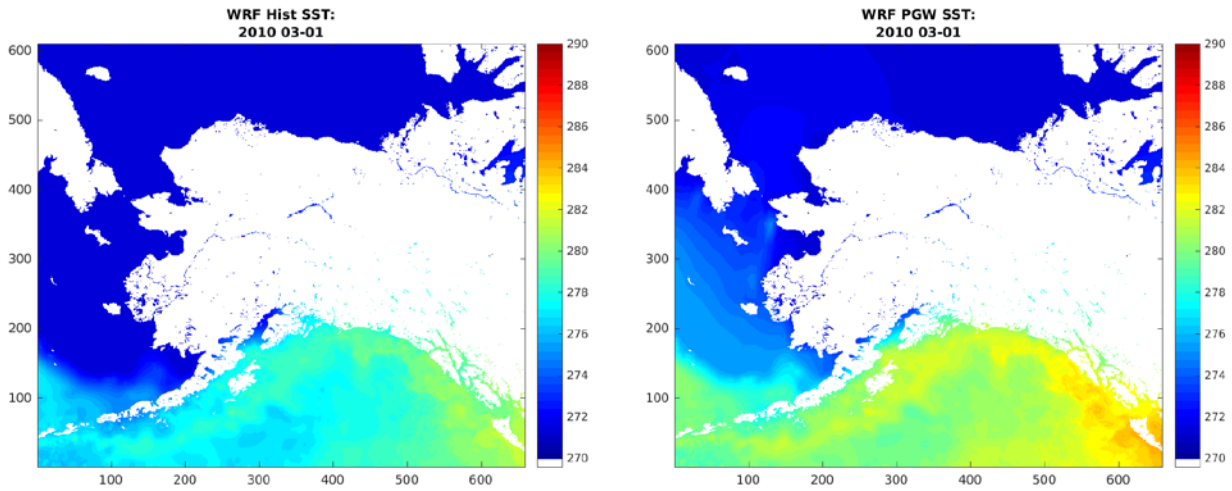
- Sea ice concentration (SIC) and SST need care in PGW simulation specification
  - Classic PGW perturbation leads to unrealistic SIC



  - Also unrealistic SST (skin temperature) perturbation in grid points that are ice free in the future

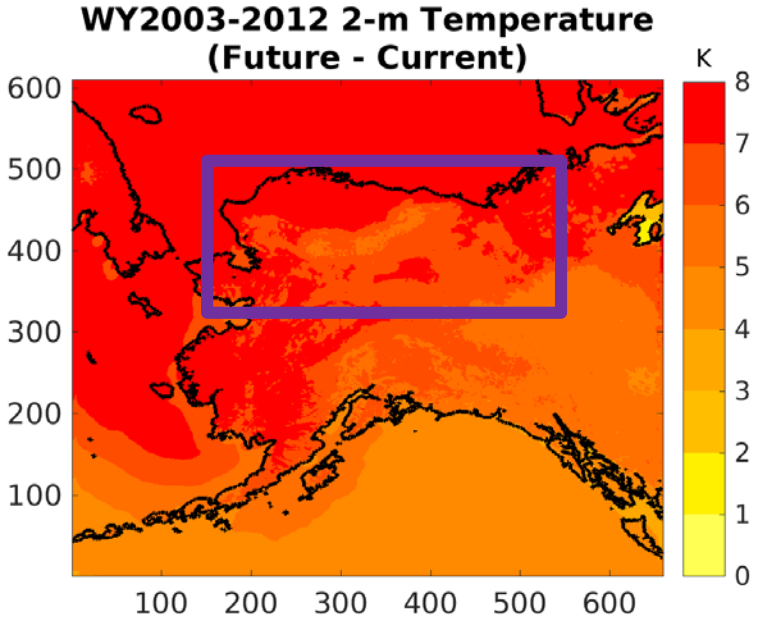
PGW Modifications

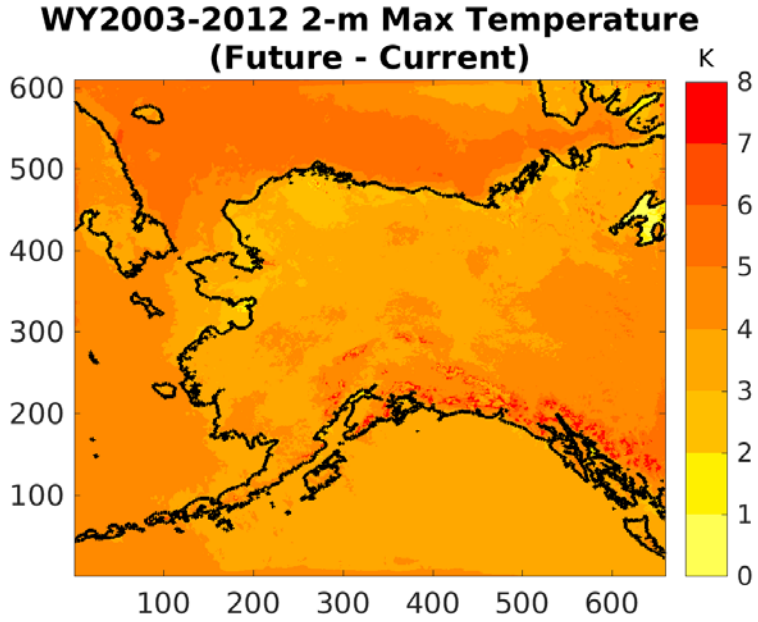
- Near surface ocean temperature for SST perturbation
- CMIP5 ensemble median SIC
  - SIC years with same rank (e.g. greatest current climate SIC corresponds to greatest future SIC year in PGW simulation)
  - Maintains current climate annual variability with realistic future SIC
  - Generally consistent with PGW methodology

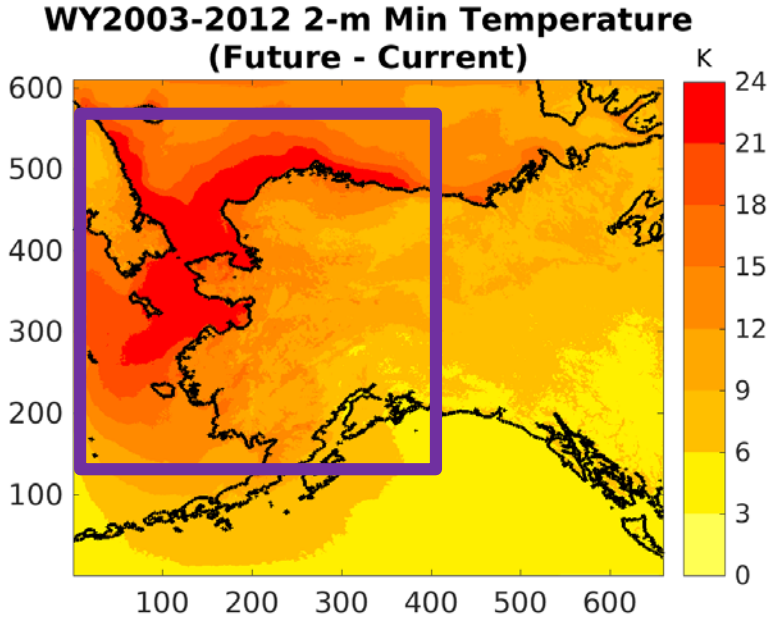


PGW – Current Climate

- Temperature
  - Mean 2-m temperature increase similar to initial CMIP5 perturbation
    - Brooks Range more resistant to warming due to persistent snow
  - Yearly (one day) T_{max} increases less than input perturbations in many regions
    - Snowpack, smaller SST increases
  - Yearly T_{min} increases by extreme amounts
    - Largest increases coincident in and around areas of sea ice loss

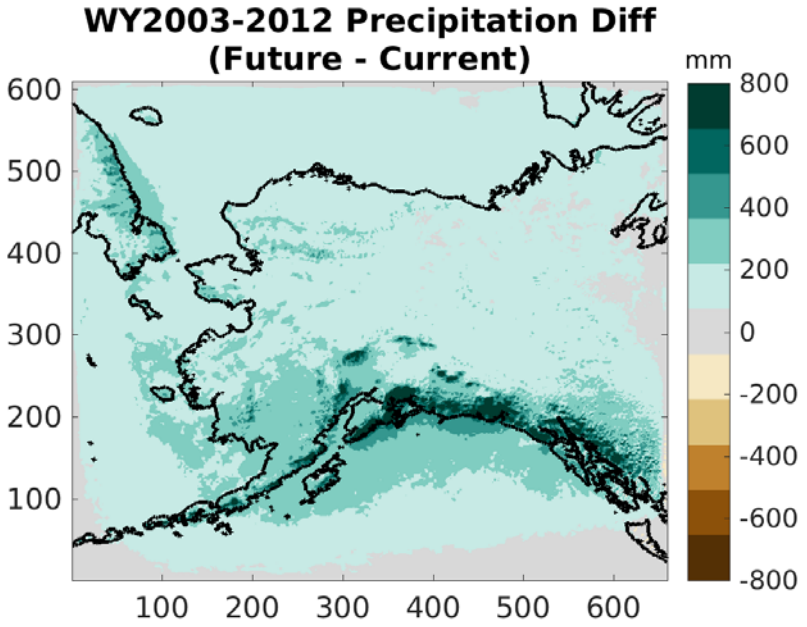


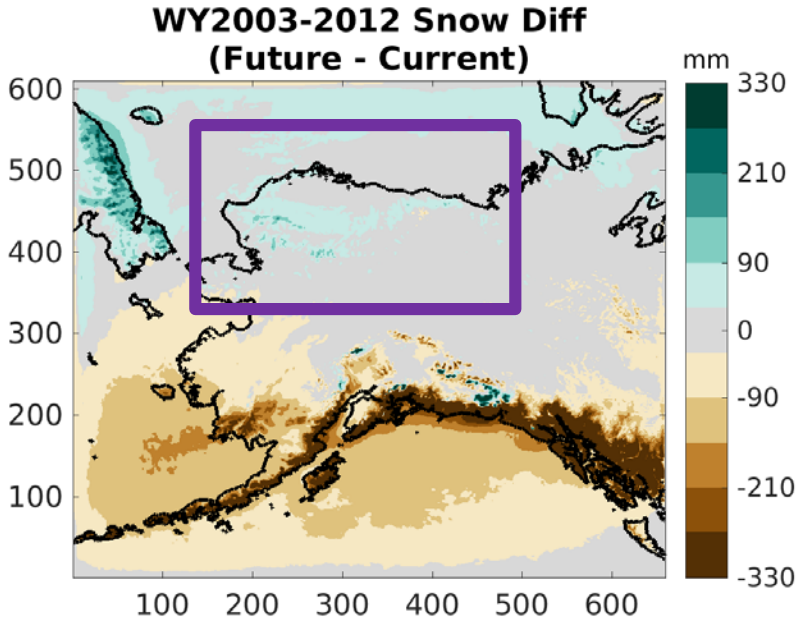


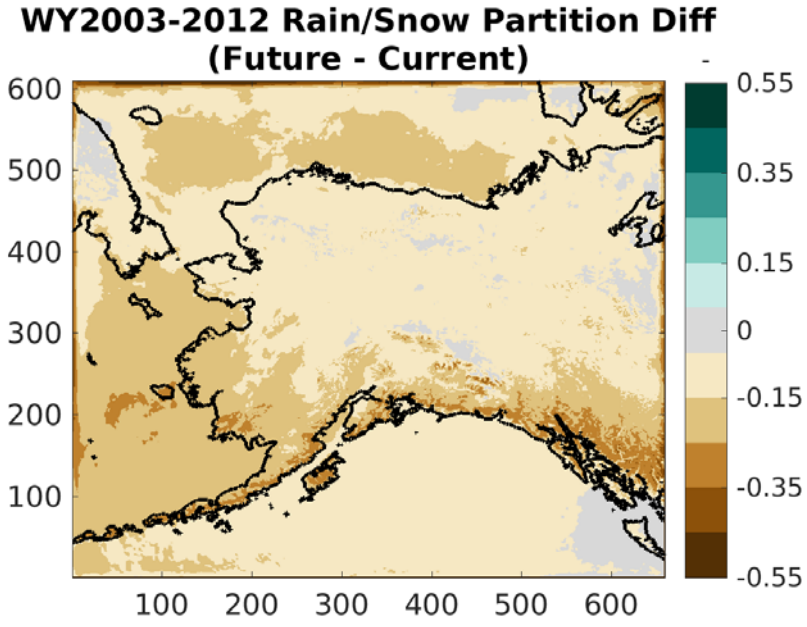


PGW – Current Climate

- Total precipitation increases across domain
  - Expected result
- Total snowfall similar or slight decreases in most areas
  - Increases in coldest regions
- Decreases in snowfall fractional contribution

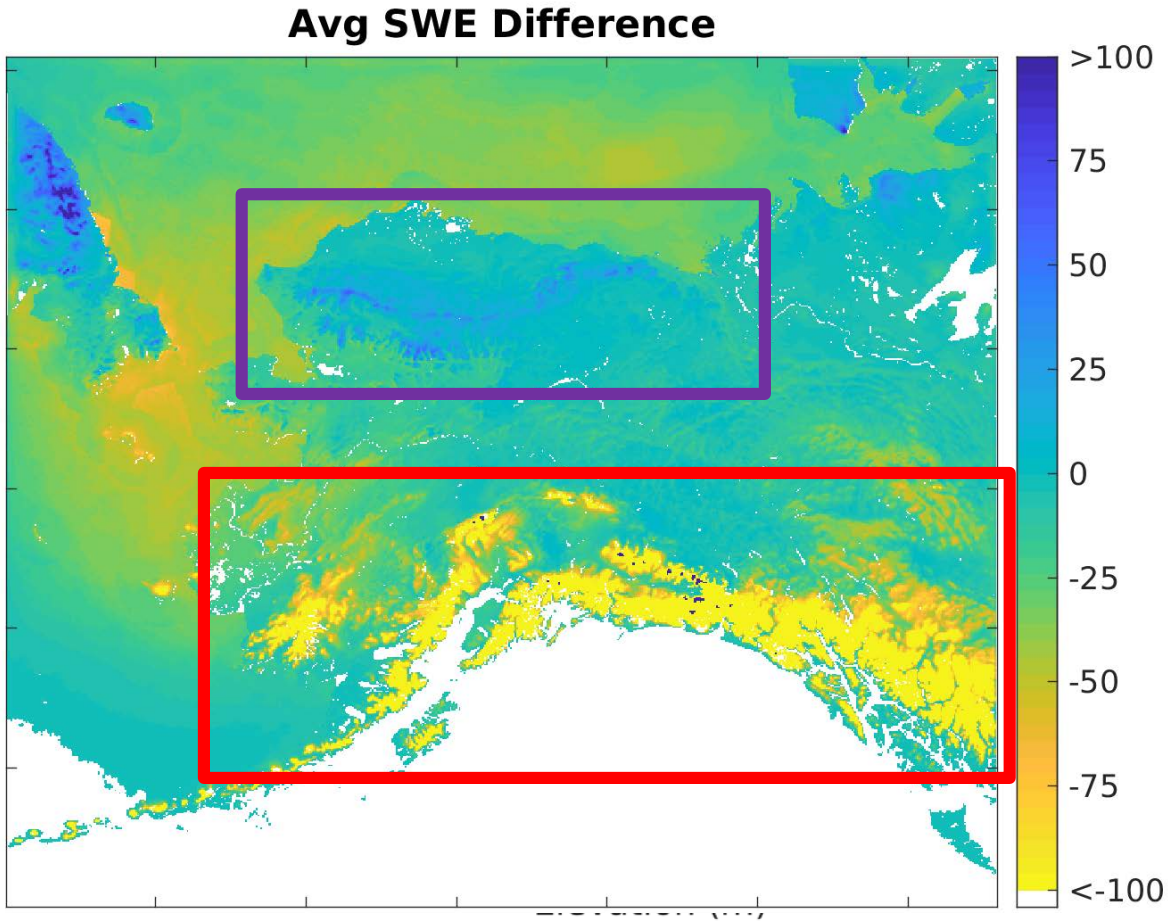






PGW – Current Climate

- Snow water equivalent (SWE)
  - Broad areas of decline and gain
  - Elevation (or climate) dependent changes
    - Normalized by historical mean SWE
  - Northern vs Southern Alaska
    - Increases in Northern Alaska across nearly all elevations
    - Increases only in highest terrain in Southern Alaska
  - Similar to other domains



Summary

- Historical and PGW simulation set for Alaska is nearly complete
  - Historical is complete and published – Monaghan et al. (2018) in JAMC
  - WRF is able to recreate historical climate and most features of snowpack
    - Early melt is most significant departure
- PGW simulation highlights
  - Increases in precipitation domain wide
  - Yearly minimum temperatures increase sharply
  - Decreases in snowfall fractional contribution
  - SWE decreases where PGW perturbation shifts climate state to more melt than additional accumulation and vice versa