Prediction of Regional Hydrology and Snowpack

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Societal & Modeling Impacts of Snowpack

Water Supply / Flood Risk

- **50-80%** of water supply in the western US comes in the form of snowmelt; states like California only have liquid water reservoir capacity for **1/4th-1/5th** of all winter precipitation
- Water must be released to the ocean to avoid **flooding during big storms or on warm days**

Hydropower

- Hydropower follows snowmelt runoff; a shift towards an earlier spring leads to **earlier maximum power output,** and **less power** in late summer/ fall

Changes in Albedo

- Reduced snow cover can **reduce surface albedo**
- Albedo feedbacks during the melt season can intensify spring warming

Increased Fire Risk

- **Early snowmelt** increases wildfire frequency by as much as **3x** over median snowmelt timing

Source: Westerling et al. 2006 (fire); Madani and Lund 2010 (hydropower); Dettinger et al. 2009 (flood risk)

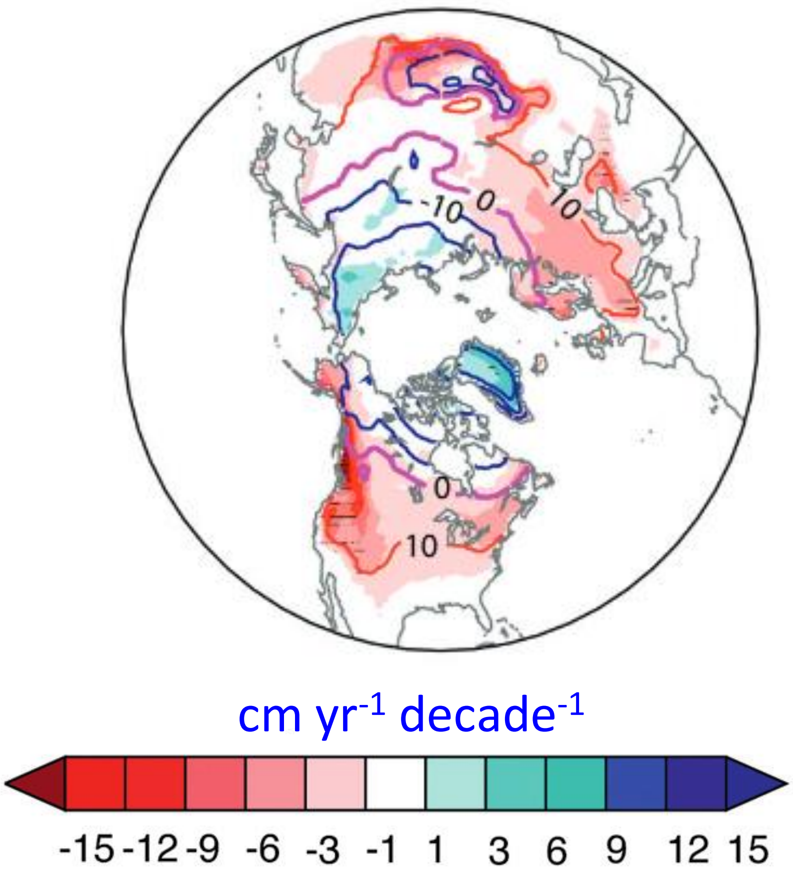
The difficulty of snow modeling

- Over a flat surface:
  - Snowfall: Snow falling from the sky requires modeling temperature and precipitation well
  - Snowpack: Snow on the ground requires modeling temperature, precipitation, *and* snowmelt
- Over complex terrain:
  - The same requirements above in addition to a high enough resolution to generate topographic variability:
    - Orographic effects
    - Freezing temperatures in the mid- and low-latitudes (e.g. the western US)

CMIP5: General Snowfall Patterns

- There is a general pattern of annual snowfall loss in the mid-latitudes and gains in the high-latitudes under RCP4.5
- Hatches represent statistical significance in the plot

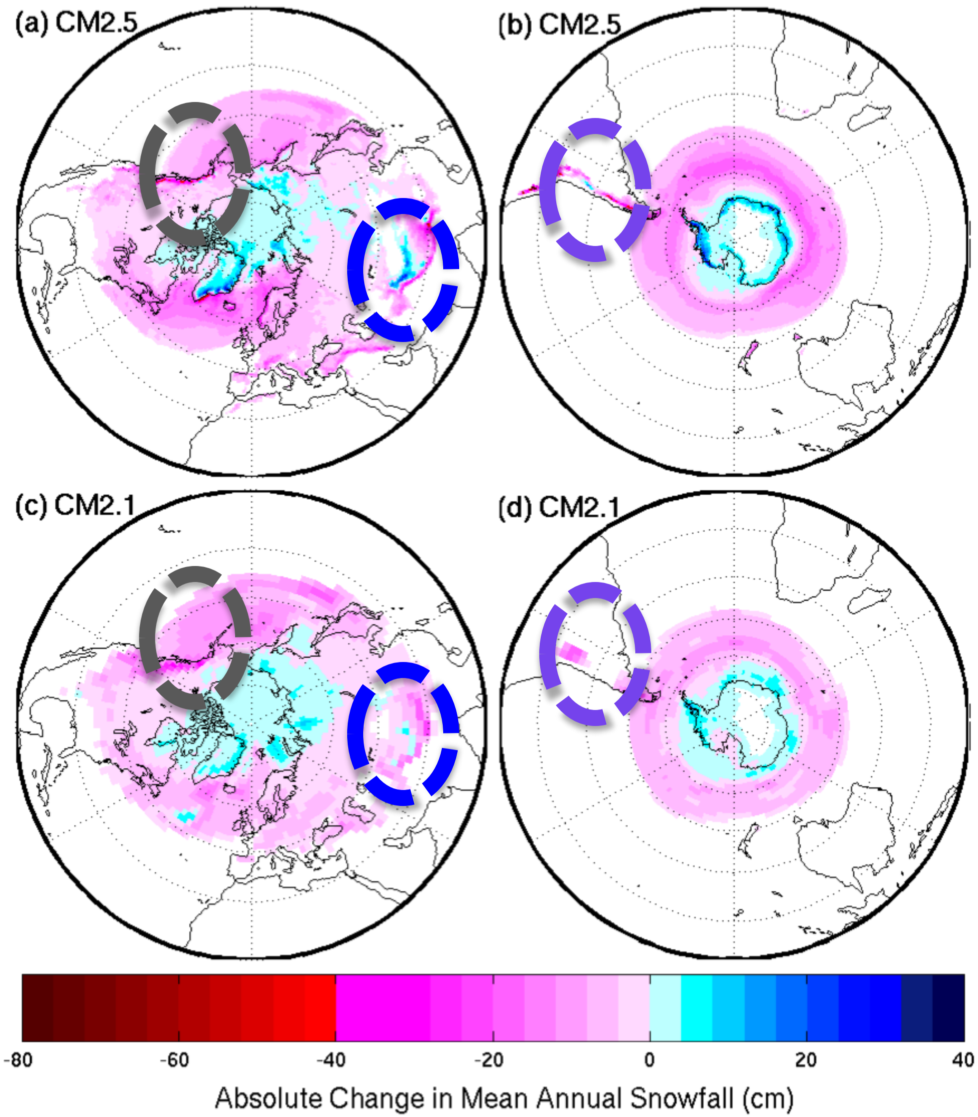
CMIP5 Snowfall Trend (2006-2100)



Source: Krasting et al. 2013 (GFDL paper)

Resolution Dependence of Snowfall

- Under double-CO_2 conditions compared to 1990, the same general patterns of changes in snowfall as Krasting et al. (2013) emerge
- Moving from **200km** (CMIP5 mean) to **50km** resolution results in signs of snowfall flipping over high-elevation regions (Yukon, Andes, Northern Pakistan)



Source: Kapnick and Delworth 2013

CM2.5 Doubled-CO2 Snowfall Change

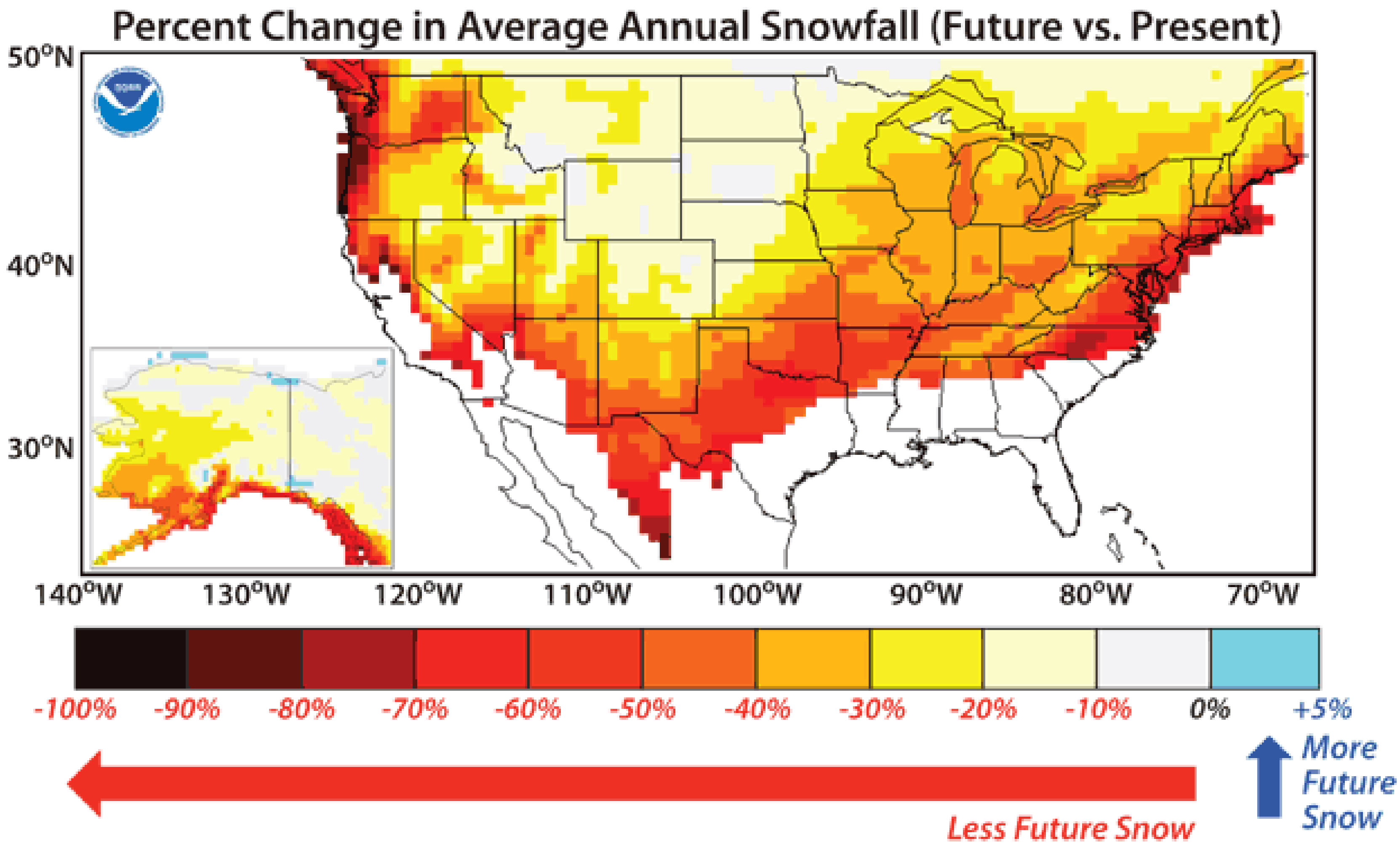
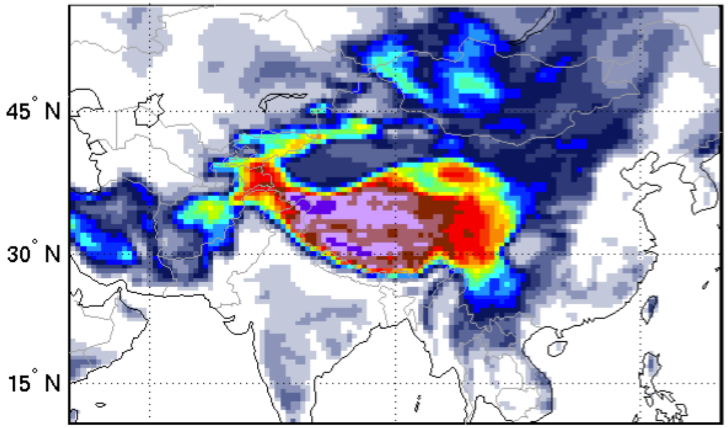


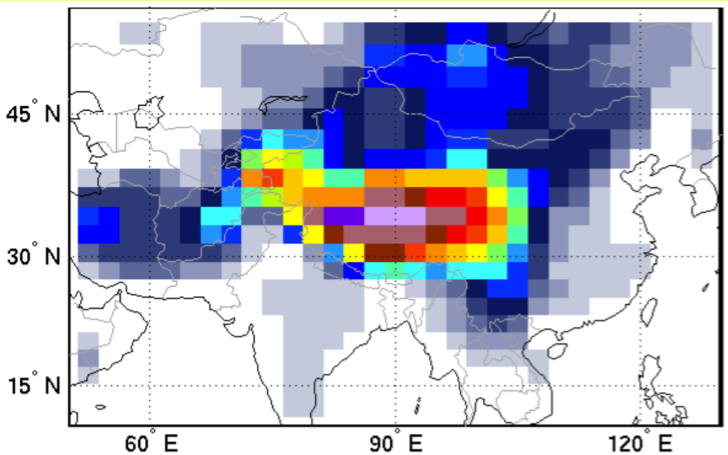
Figure used by the Associated Press for a story (e.g. Washington Post, USA Today); 150+ stories total
Source: Kapnick and Delworth 2013

Elevation Enhancement of CM2.5

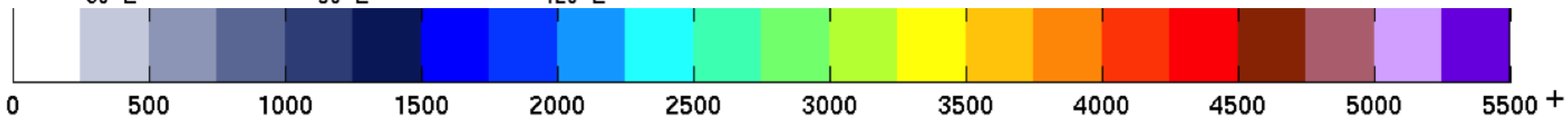
CM2.5 (50km resolution)



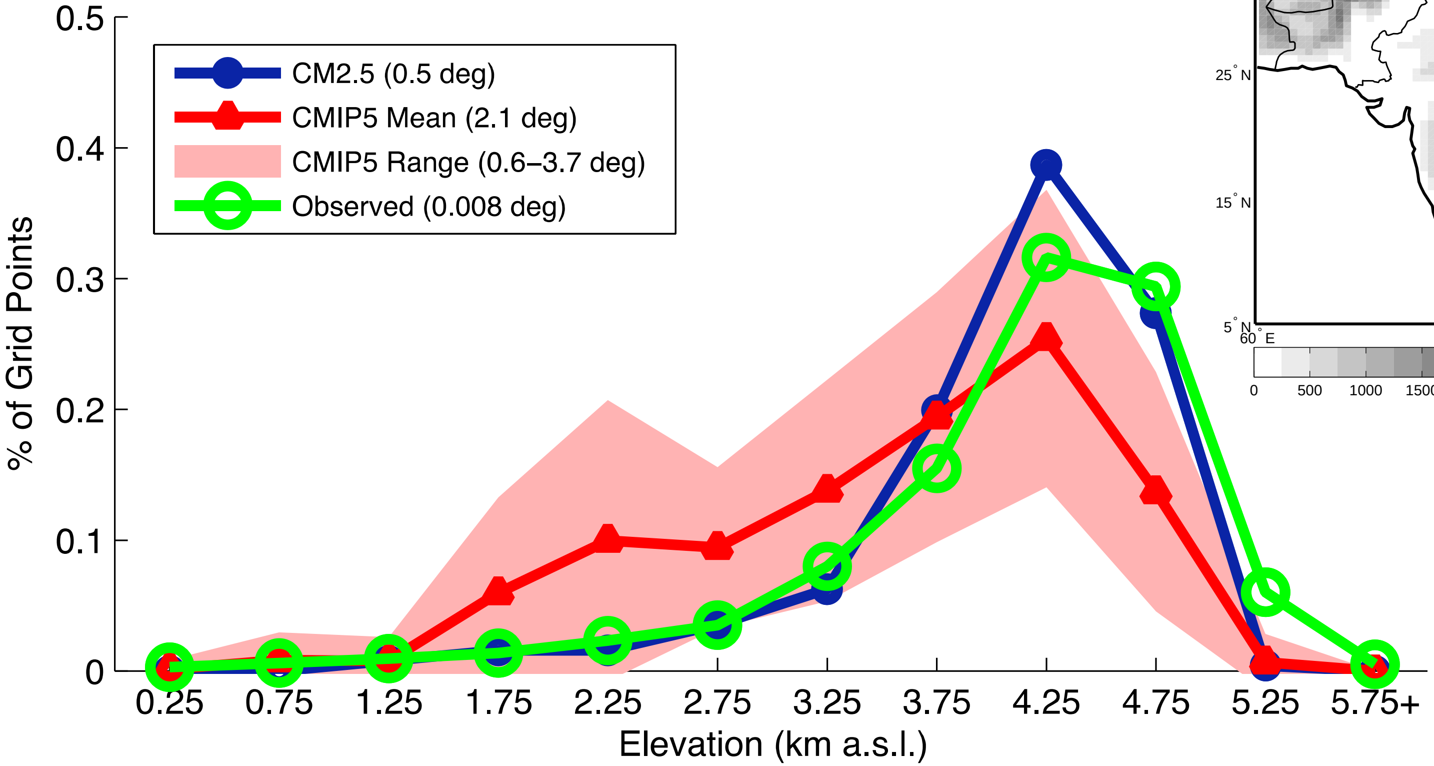
CM2.1 (200km resolution)

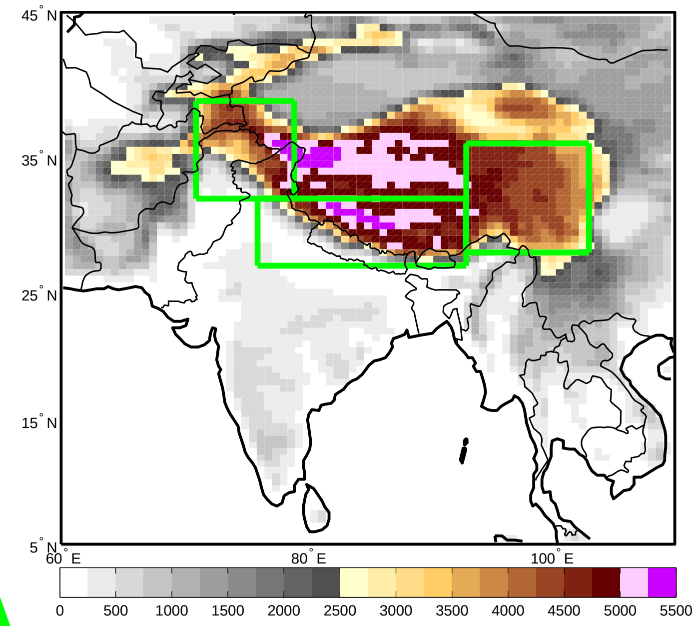


- The Himalayas provide a nice case study of improved snowfall modeling with a high-resolution model over a high-elevation region
- For simple comparison from previous work, we reproduce elevation from CM2.5 vs. CM2.1 (close to CMIP5 average resolution)



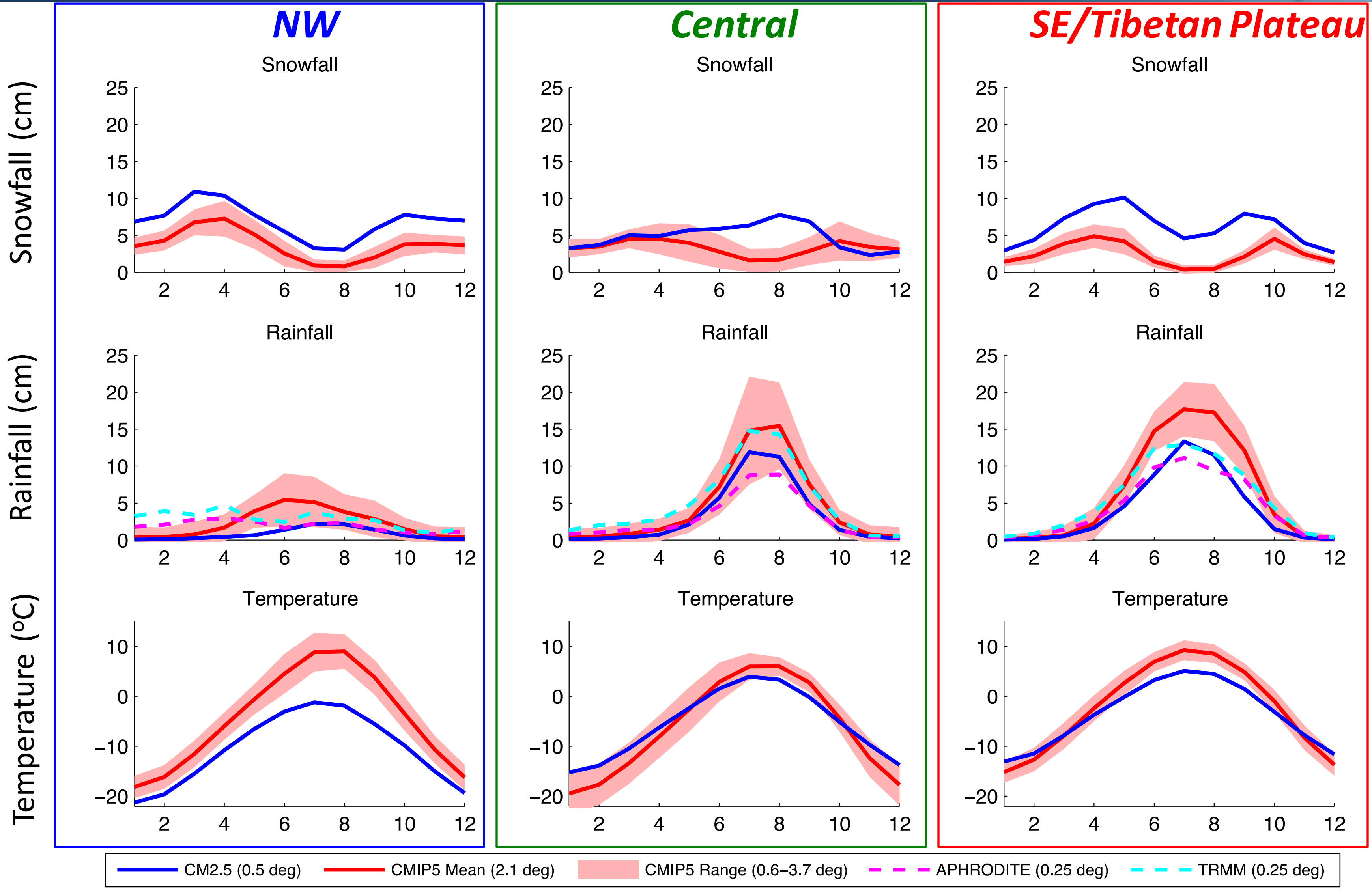
Three Main Snowy Regions





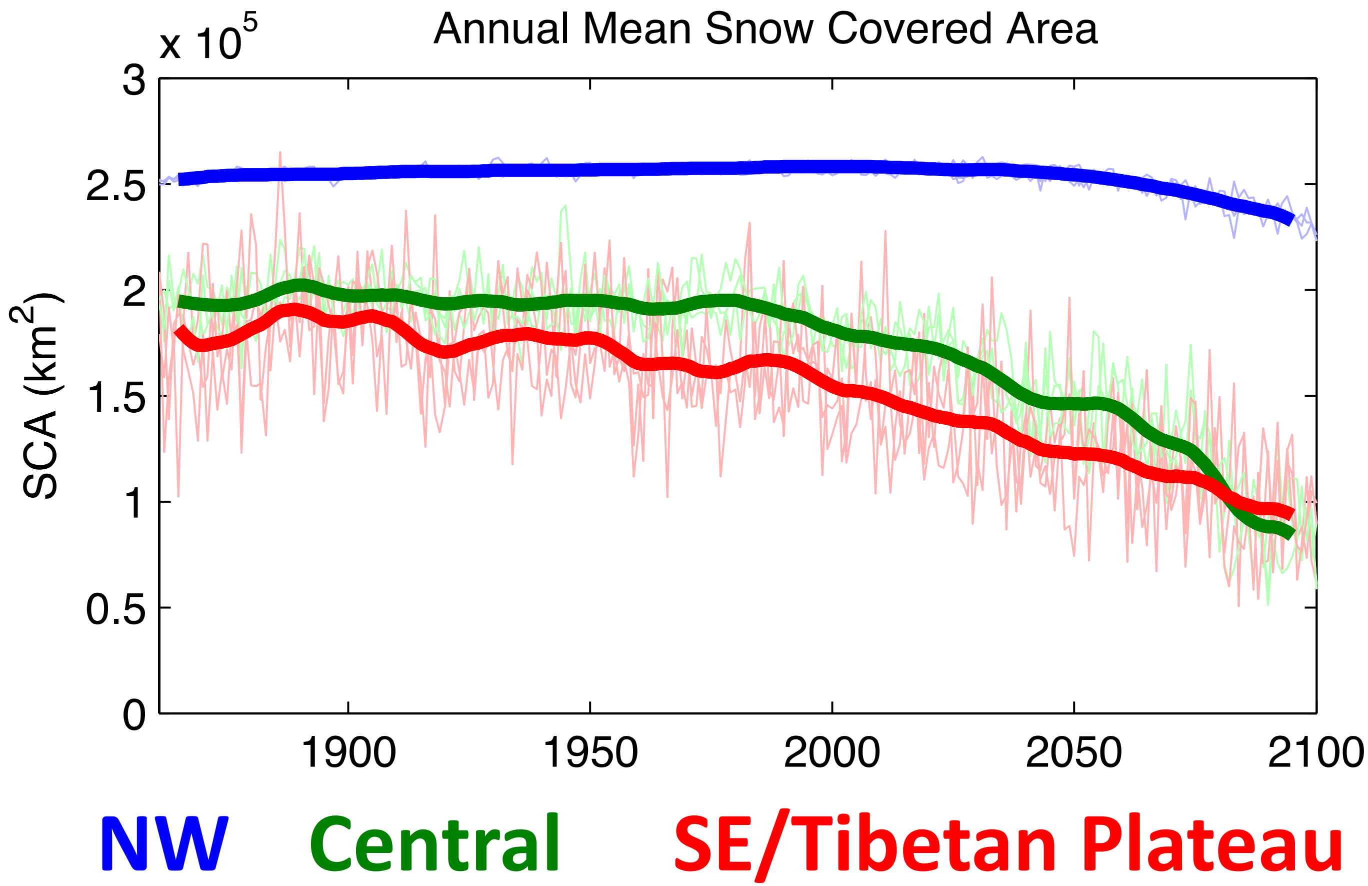
Source: Kapnick e al. 2014

Translation to Seasonal Cycle



The Third Pole Hydrologic Change

- Snow cover declines across all 3 regions, however at a significantly lower rate in the NW
- Significantly higher annual variability across the Central and Eastern regions



Summary

Factor	High Resolution Model (CM2.5)	Low Resolution Models (CM2.1 & CMIP5)
Global Snowfall	↑ High Latitudes ↓ Low Latitudes	↑ High Latitudes ↓ Low Latitudes
Select Highest-Elevation Snowfall Under Climate Change	↑ N. Pakistan, Yukon, Andes	↓ Following zonal patterns
Seasonal Cycle in Greater Himalaya Region	Colder More Snow	Warmer Less Snow

This is an important first step of validation to develop seasonal-decadal predictions and highlights the need for a high-resolution land/atmosphere for snowpack and hydrology in snowy regions

References

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