IMPORTANCE OF MODELLED PROCESSES IN THE EVOLUTION OF SNOW COVER VERSUS SNOW MASS

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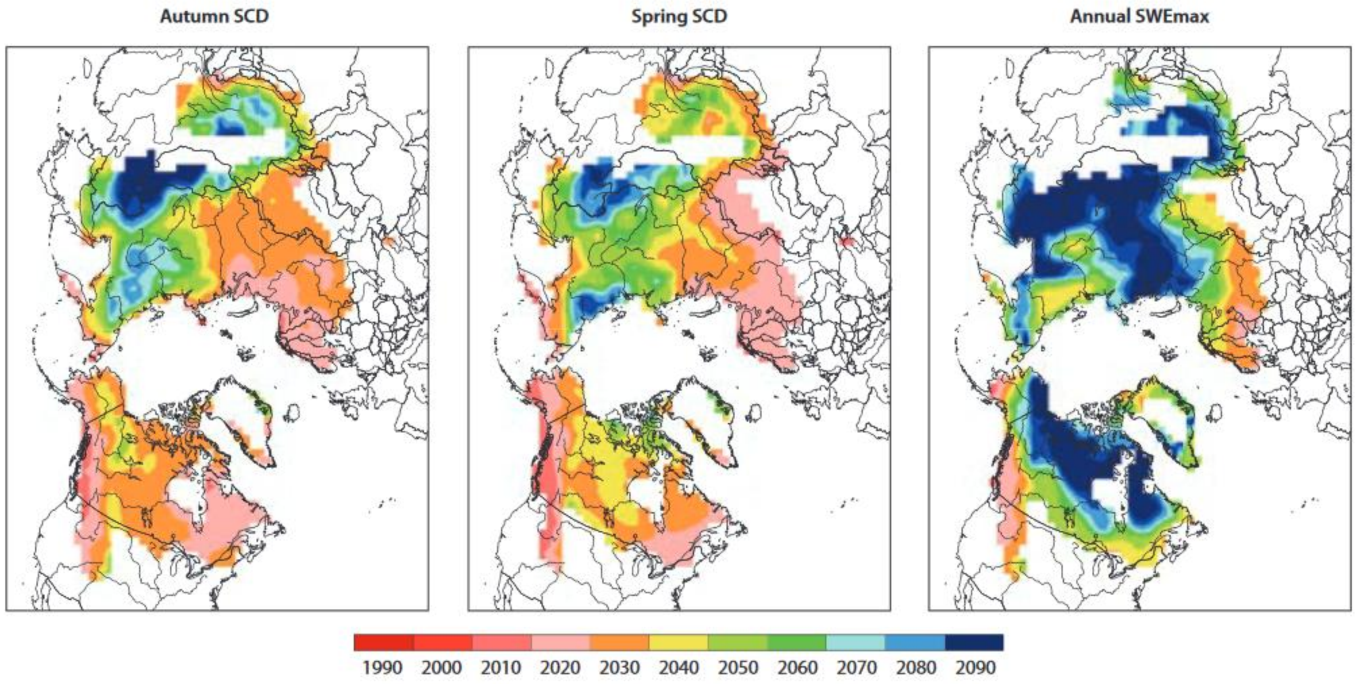
Context

In this presentation, I show results from two studies, an analysis of snow cover extent (SCE) projections from CMIP6 models (under review in The Cryosphere: Mudryk et al, 2020) and ongoing work based on output from the NASA Snow Ensemble Uncertainty Project (SEUP; work by Kim et al., submitted to WRR). The results are *suggestive* (along with previous work and physical expectations) that there could be different degrees of influence from subgrid scale processes in the long term evolution of snow water equivalent (SWE) as compared to SCE.

Please feel free to comment on the claims and conclusions regarding the analyses and on other studies which agree or disagree.

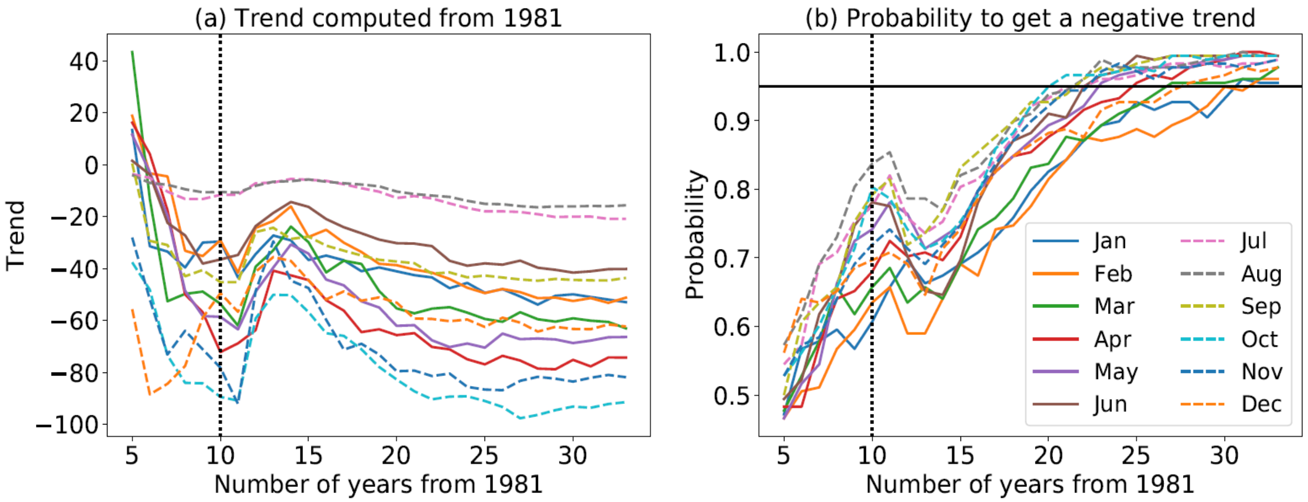
Controls on Snow Cover vs Snow Mass



Expected year of emergence of climate warming signals in northern hemisphere snow cover in each half of the snow season and for annual maximum snow water equivalent (SWEmax) following de Elía et al. (2013) from an 11-member ensemble of CMIP5 models for emission scenario RCP8.5. Figure from Brown et al., 2017 (SWIPA).

- Trends in snow extent are primarily controlled by temperature and stem primarily from changes in the marginal snow zone (Mudryk et al., 2017). Together these factors lead to earlier emergence of trends amidst background variability.
- Snow mass trends are expected to evolve due to both temperature and precipitation with different prevailing influences regionally. This leads to later emergence of climate change related trends.

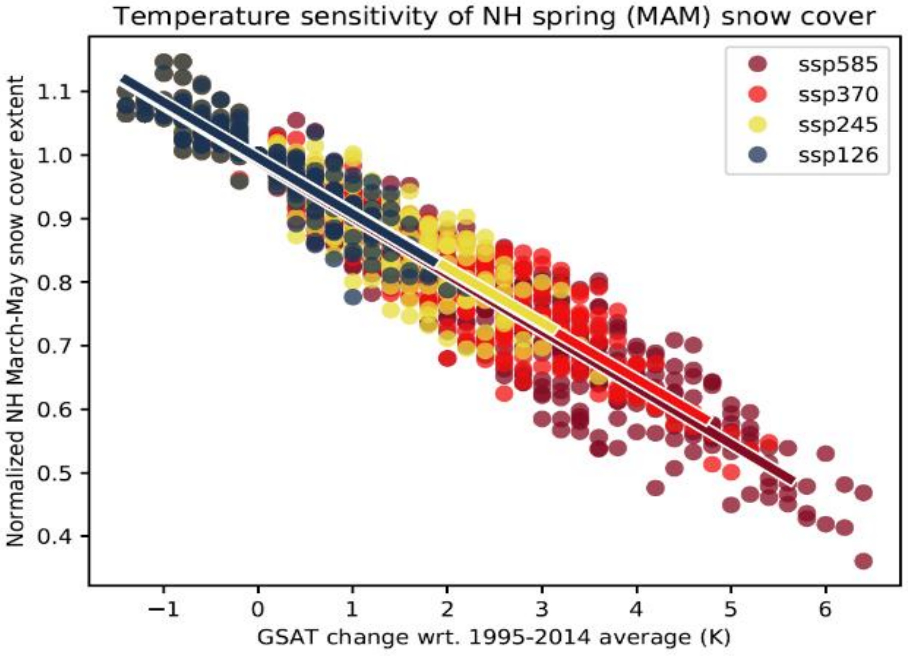
Controls on Snow Cover vs Snow Mass



a) Northern Hemisphere monthly trends of snow extent in CMIP6 models over 1981-2014 computed with 178 members from 21 CMIP6 models as a function of the number of years from 1981 and starting from a 5-year time series;
(b) Probability of negative monthly trends estimated from the full ensemble members. The horizontal bar highlights a probability of 95%, and the vertical bars correspond to the year of the Pinatubo eruption.
Figure in Mudryk et al., 2020.

- Across the NH as a whole the signal of SCE loss emerges after about 20-30 years (results from CMIP6 models shown at left).
- For SWE 30yr trends would still be expected to be dominated by internal variability (not shown).

Evolution of snow extent in CMIP6 models



Spring (March to May) NH snow cover extent against GSAT (relative to 1995-2014) for CMIP6 Tier 1 scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5), with linear regressions. Each data point represents the average snow extent from one CMIP6 simulation (first ensemble member for each available model). Figure in Mudryk et al., 2020

- Simulated snow cover extent projections from CMIP6 models follow a single linear relationship between projected spring snow extent and global surface air temperature (GSAT) changes, which is valid across all future climate scenarios.
- This finding suggests that Northern Hemisphere spring snow extent will decrease by about 8% relative to the 1995-2014 level per °C of GSAT increase.
- The sensitivity of snow cover to temperature forcing largely explains the absence of any climate change pathway dependency, similar to other fast response components of the cryosphere such as sea ice and near surface permafrost
- This result is consistent with the expectations of strong control by temperature with minimal influence due to model parametrizations

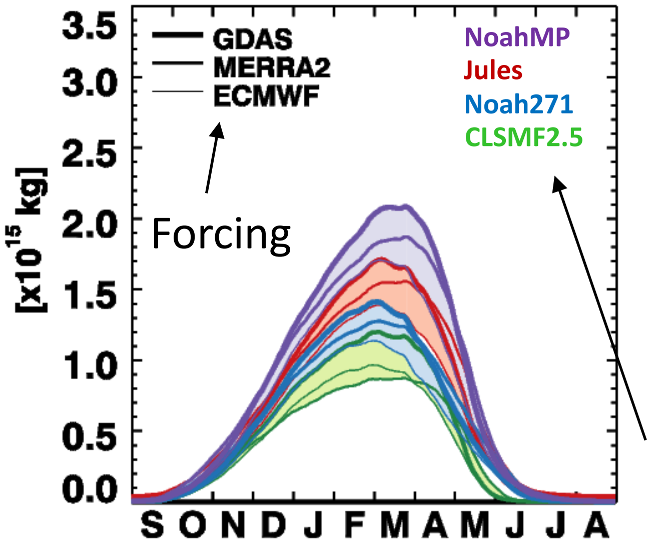
NASA Snow Ensemble Uncertainty Project

- By contrast there is large spread among simulations of climatological snow water equivalent (SWE) as seen in the NASA Snow Ensemble Uncertainty Project (Kim et al., submitted to WRR).

- The spread is due to multiple processes which influence snow accumulation: how will these processes combine to control hemispheric and regional snow mass evolution occurring due to forcing from both temperature and precipitation changes?

NASA Snow Ensemble Uncertainty Project

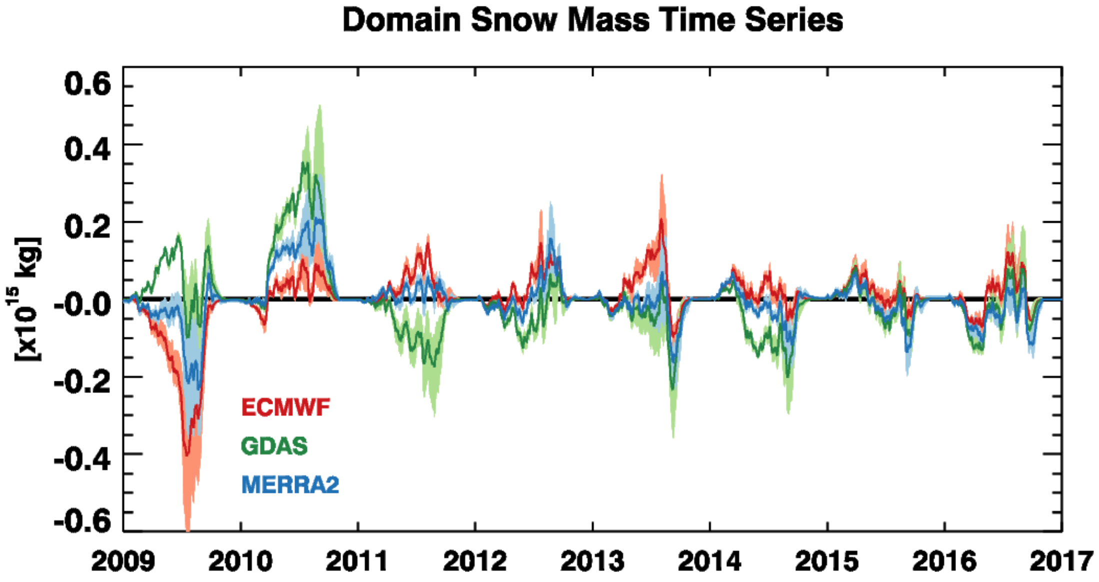
Domain Snow Mass



Land Surface Model

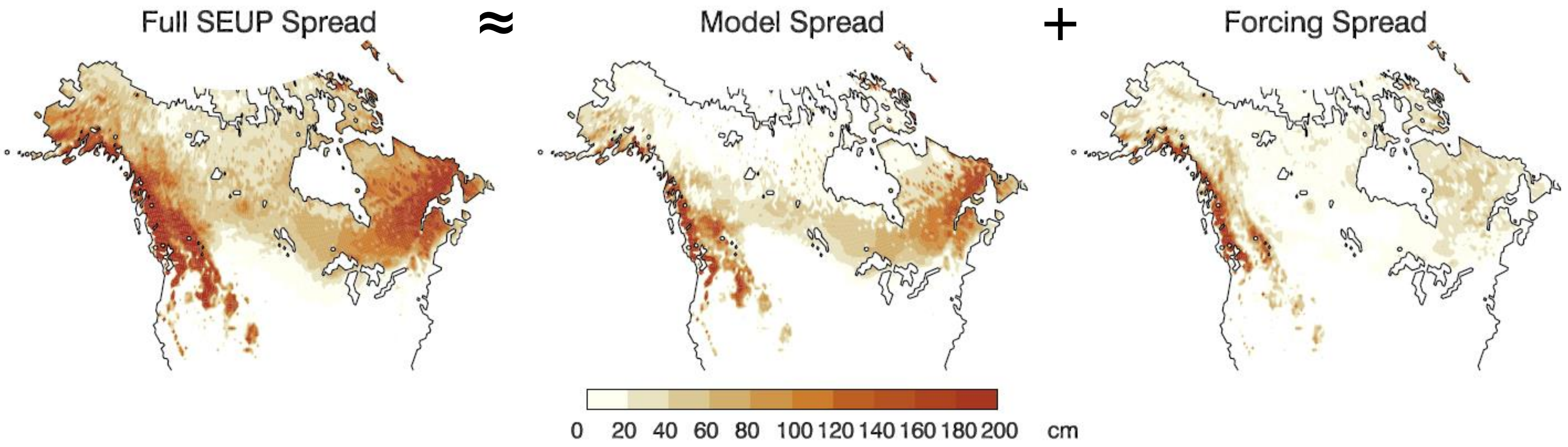
(left) Climatological North American snow mass from twelve simulations: combinations of 4 different land surface models and 3 different estimates of meteorological forcing. Shading shows spread for a given LSM for the 3 choices of forcing.

(right) Anomalous North American snow mass (computed independently for each LSM) averaged together for each choice of forcing.



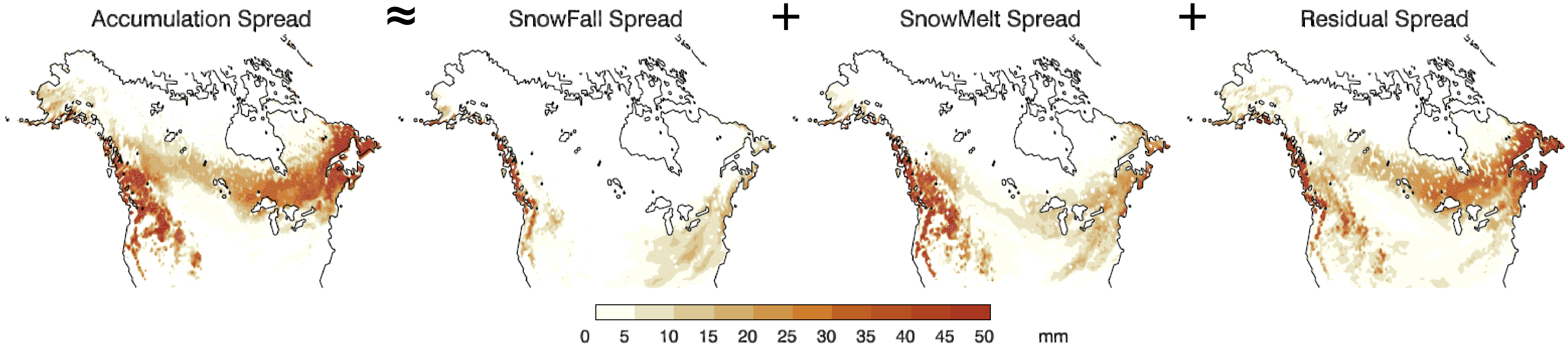
- There is a large spread in climatological SWE due to choice of land surface model
- Seasonal evolution of SWE still controlled by differences in forcing

NASA Snow Ensemble Uncertainty Project



Additional climatological spread in the SEUP ensemble is seen over mountainous regions, portions of eastern Canada and over boreal regions. In mountainous regions, this increased spread represents a combination of differences in forcing (likely precipitation) and model spread. Over boreal regions the spread is mostly related to model differences.

NASA Snow Ensemble Uncertainty Project



February spread in accumulation due to choice of LSM attributed to 3 component processes.
Differences in residual model processes are the dominant source of climatological spread among the SEUP models (rather than rain/snow partitioning or snow melt). A substantial portion of this residual spread is due to differences in sublimation parametrizations.

Questions to consider

- Are there regional differences on the extent to which model-parametrizations influence SCE evolution? Are there second-order effects such as effective snow thickness to consider?

- How could differences in model treatments of precipitation and sublimation translate to long-term differences in SWE evolution?

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