Effects of a Warming Climate on Daily Snowfall Events in the Northern Hemisphere

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1. Introduction

Snow is an important aspect of weather and climate with physical, ecological, and societal impacts (Barnett et al. 2005; Eisenberg and Warner 2005; Vavrus 2007). Global temperature has increased during the past half-century, primarily due to the emission of greenhouse gases as a result of human activities, and this trend is likely to continue and perhaps accelerate in the coming decades (IPCC 2013). However, increases in winter precipitation are also likely in middle and high latitudes due to increased water vapor content in a warming climate (Held and Soden 2006). Therefore, the total effect of global warming on snowfall is a delicate balance between increased temperature, reducing the fraction of precipitation that falls as snow, and increased precipitation, which could mean more snowfall in regions that are cold enough. This study uses models from the Coupled Model Intercomparison Project 5 (CMIP5) project in order to examine how the frequency distribution of daily snowfall events in the Northern Hemisphere (NH) will be affected by increasing temperatures, as well as how these daily snowfall projections may be affected by the temperature biases of the models.

2. Data and Methods

Observations:
- Monthly temperature observations from the Hadley Center-Climatic Research Unit (HADCRUT) dataset (1961-1990)

Models:
- 24 models consisting of 37 ensemble members from CMIP5 model suite
- Historical simulation of daily snowfall (1971-2000) and 21st-century climate simulation of daily snowfall using the RCP8.5 forcing scenario (2021-2050 and 2071-2100)
- Historical simulation of monthly temperature (1961-1990)

Methods:
- Model output and temperature observations interpolated to common 1° by 1° grid
- Discarded all grid boxes containing more than 50% water
- Snowfall determined from its water equivalent by assuming 10:1 snow-to-liquid ratio, as in Krajewski et al. (2013)

3. Spatial Patterns

- Frequency of measurable daily snowfall events projected to decrease across much of NH except for very high-latitude regions
- Much greater area expected to experience an increase in larger ≥ 10 cm events, including much of Canada, Greenland, northern Asia, and Tibet
- Jan-Feb snowfall events projected to increase in even more regions than events in all months of the year
- Trends become more pronounced by 2071-2100 compared to 2021-2050

4. Daily Snowfall Histograms

- Some regions (including southeastern US, US Mid-Atlantic, US West Coast, British Columbia, southern Alaska, and central and southern Europe) warm enough for models to project large decrease in daily snowfall for all bins in all months of the year, due to a lower fraction of precipitation falling as snow
- In other regions slightly farther north and colder (New England, Japan, Caucasus Mountains, and Baltic Sea regions), average snowfall still simulated to decrease in all months of year, but in Jan-Feb frequency of intense snowfall events stays about same or slightly increases
- Southern Quebec and New Brunswick, Labrador, eastern Hudson Bay, Tibet, and northern Scandinavia: models project overall increase or little change in daily Jan-Feb snowfall by 2021-2050 due to increase in precipitation becoming more dominant factor, with increase in large event frequency still projected for Nov-Dec and Mar-Apr
- NE Quebec, NW Siberia, and NE Siberia: frequency of daily snowfall events simulated to rise in Jan-Feb as well as Nov-Dec and Mar-Apr, with increase in large events in Sept-Oct and May-June
- Greenland: only region examined where daily snowfall projected to increase by 2021-2050 for all two-month intervals and nearly all bins, with the exception of July-August

5. Model Temperature Biases

- CMIP5 models simulate decrease in daily snowfall events across much of NH during 21st century due to warming temperatures, except at highest latitudes such as NE Canada, northern Siberia, and Greenland where increase in precipitation is expected, but temperatures are cold enough that some warming will not result in more precipitation falling as rain
- Much larger region of NH projected to have increase in daily snowfall in Jan-Feb than in warmer months of year because temperatures in warmer months more likely to be marginal for snowfall
- Frequency of large snowfall events simulated to increase in many regions/months (even while overall snowfall decreases) due to higher sea surface temperatures and more abundant atmospheric moisture in a warmer climate (Held and Soden 2006)
- Projected changes in daily snowfall exhibit some dependence on temperature biases of models, mainly in colder regions and months

6. Conclusions

- CMIP5 models simulate decrease in daily snowfall events across much of NH during 21st century due to warming temperatures, except at highest latitudes such as NE Canada, northern Siberia, and Greenland where increase in precipitation is expected, but temperatures are cold enough that some warming will not result in more precipitation falling as rain
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References


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