Evaluation of 20th Century Climate Model Simulations of Heavy Precipitation over North America

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OVERVIEW

A better understanding of changes in extreme precipitation events in response to anthropogenic warming requires accurate climate model simulations. It is therefore necessary to evaluate climate models against observations. Previous studies have shown that on global and regional scales, climate models tend to overestimate light precipitation and underestimate heavy precipitation (e.g., Sun et al. 2007). In the United States, climate models tend to underestimate heavy precipitation in the southeast and Pacific Northwest (e.g., Wehner et al. 2010, Iorio et al. 2004). It has been shown that climate model simulations of heavy precipitation are more realistic when the models are run at higher spatial resolution or with certain convective parameterization schemes (e.g., Wehner et al. 2010, Emori et al. 2005, Wilcox and Donner 2007). Here, we evaluate 20th century simulations of daily precipitation from numerous climate models against high quality observations over North America.

We find that model biases in the daily precipitation distribution are consistent with previous studies, but that the seasonality of heavy precipitation is simulated fairly well by the models. Additionally, the models simulate fairly realistic large scale dynamical and thermodynamical atmospheric patterns associated with extreme daily precipitation events. The latter suggests that we may reliably use the models to diagnose and understand the physical mechanisms for future changes in extreme precipitation.

DATA AND METHODOLOGY

- **Observations:** Gridded 0.5°x0.5° lon-lat daily precipitation over North America from the Climate Prediction Center (CPC). Other daily atmospheric variables from the North American Regional Reanalysis.
- **Models:** Daily variables from 17 Coupled Model Intercomparison Project Phase III (CMIP3) 20th century simulations (one ensemble member from each).
- **Time Period:** January 1, 1979 – December 31, 1999.
- **Resolution:** A common grid of 2.5°x2.5° lon-lat is used for analysis, where linear interpolation or area averaging was used in the regridding process.

ACKNOWLEDGEMENTS

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- We thank the CPC for the global gridded precipitation observations and the Climate Diagnostics Center (CDC) for hosting the North American Regional Reanalysis data.
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DAILY PRECIPITATION STATISTICS

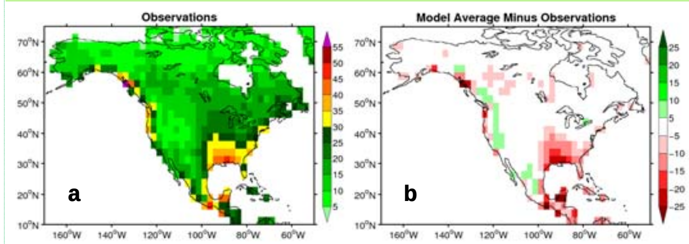

Figure 1. Total amount of annual precipitation coming from the daily 99th percentile and above (decimeters) over 1979-1999. (a) CPC observations. (b) CMIP3 model average minus observations.

- Model biases are likely caused by poor convective parameterizations in the south and inadequate terrain representation in the west.
- The model biases along the west coast are more pronounced during the winter, while model biases in the south spread north in the summer (not shown).

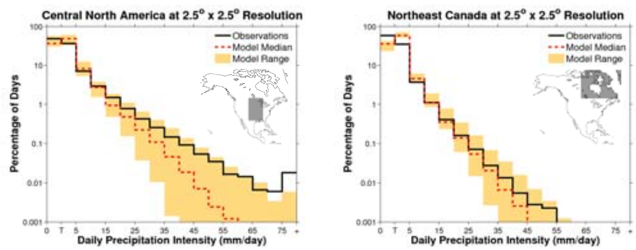

Figure 2. Annual distribution of daily precipitation for the CPC observations and CMIP3 models. The distributions are for the collection of grid cells shaded in gray on the maps. "T" is 0.254 mm/day.

- The models produce light precipitation more frequently and heavy precipitation less frequently than the observations, and the heavy biases are worse during wetter seasons (not shown).
- When analyzed on a 5.0°x5.0° lon-lat grid, model biases are qualitatively similar but smaller in magnitude (not shown).

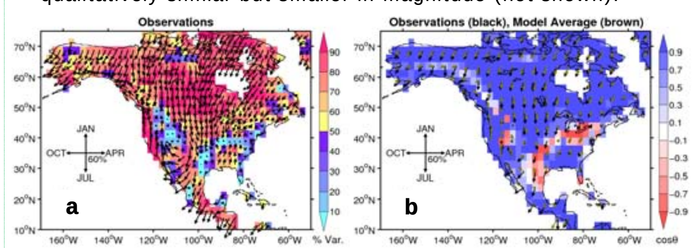

Figure 3. The seasonal timing of heavy precipitation, as determined by a harmonic fit to the 99th percentile of daily precipitation for each month. Vector amplitudes are the percentage of the maximum monthly 99th percentile. (a) CPC observations- fills show the percentage of variance explained by the harmonic fit. (b) Observed and simulated patterns- fills show the cosine of the angle between vectors.

EXTREME PRECIPITATION MECHANISMS

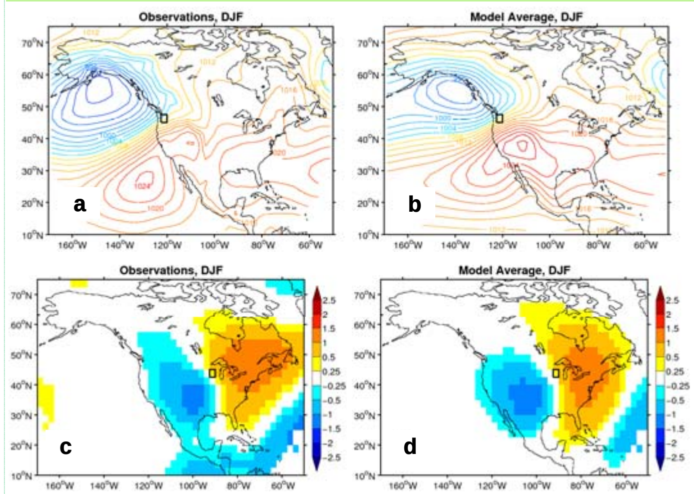

Figure 4. The average (a-b) sea level pressure (hPa) and (c-d) 500 mb geopotential height standardized anomaly for the wettest 21 winter days at the grid cells outlined in black. The standardized anomalies (anomaly over standard deviation) were computed using a seasonally varying climatology over 1980-1998.

- The model average also shows realistic composites of 300 mb winds, column integrated water vapor, lifted index, and Q-vector convergence during extreme winter events (not shown).
- Model average composites are generally realistic for extreme events that occur over all domain grid cells (not shown).
- Summertime composites are characterized by weaker anomalies and weaker spatial structure in models and observations.

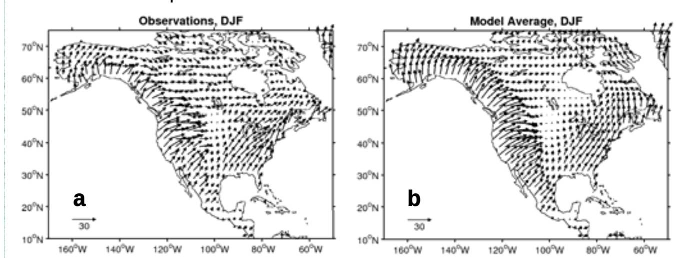

Figure 5. The low-level (surface–600-mb average) wind (m/s) averaged over the 21 wettest winter days for each grid cell on the domain. (a) Observations, (b) Model Average.

- Despite having a slight overestimation of the southerly and onshore wind component in northern parts of the domain, the models do well in capturing the average low-level winds associated with extreme winter precipitation events over most of the domain. This suggests that the large scale dynamical patterns during extreme events are realistic in the models.

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Models Used In Analysis

Model ID	Modeling Group	Country
CCCMA CGCM 3.1 T47	Canadian Centre for Climate Modeling & Analysis	Canada
CCCMA CGCM 3.1 T63	Canadian Centre for Climate Modeling & Analysis	Canada
CNRM CM 3	Centre National de Recherches Météorologiques	France
CSIRO MK 3.0	CSIRO Atmospheric Research	Australia
CSIRO MK 3.5	CSIRO Atmospheric Research	Australia
GFDL CM 2.0	NOAA Geophysical Fluid Dynamics Laboratory	USA
GFDL CM 2.1	NOAA Geophysical Fluid Dynamics Laboratory	USA
GISS AOM	NASA Goddard Institute for Space Studies	USA
GISS EH	NASA Goddard Institute for Space Studies	USA
GISS ER	NASA Goddard Institute for Space Studies	USA
IAP FGOALS 1.0 G	LASG Institute of Atmospheric Physics	China
INM CM 3.0	Institute for Numerical Mathematics	Russia
MIROC 3.2 MEDRES	Center for Climate System Research, National Institute for Environmental Studies, and Frontier Research Center for Global Change	Japan
MPI ECHAM 5	Max Planck Institute for Meteorology	Germany
MRI CGCM 2.3.2	Meteorological Research Institute	Japan
NCAR CCSM 3.0	National Center for Atmospheric Research	USA
NCAR PCM 1	National Center for Atmospheric Research	USA