## Dataset Title

Projected Snow Cover Reductions and Mid-latitude Cyclone Responses in the North American Great Plains

## Short name or nickname you use to refer to this dataset:

The Snow-Cyclone Set

## Abstract

Extratropical cyclones are responsible for major weather events and trends in the mid-latitudes and preferentially develop in regions of enhanced cyclogenesis and proceed along climatological storm tracks. It has been shown that terrestrial snow cover exerts considerable influence on atmospheric baroclinicity which is largely responsible for the aforementioned cyclogeneses and storm tracks. Research about the effect which terrestrial snow cover exerts on cyclones’ intensities, trajectories, and precipitation characteristics is limited but indicates a robust relationship with these factors. Many examinations of climate model projections have generally shown a poleward shift in storm tracks by the late 21st century though none have determined the degree to which the coincident poleward shift in snow extent is responsible.

A method of imposing 10th, 50th, and 90th percentile values of snow retreat between the late 20th and 21st centuries as projected by 14 models of the Coupled Model Intercomparison Project Phase Five (CMIP5) is used to alter 20 historical cold season cyclones which tracked over or adjacent to the North American Great Plains. Simulations by the Advanced Research version of the Weather Research and Forecast Model (WRF-ARW) are initialized at 0 to 4 days prior to cyclogenesis. Including control and sensitivity testing wherein snow is unaltered or removed entirely, each cyclone case is simulated 25 times for a total of 500 simulations.

## Investigators

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## License

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## Keywords

WRF, WRF-ARW, Snow cover, Extratropical cyclone, Midlatitude cyclone, Baroclinicity, Surface forcing, Integrated kinetic energy, Winter storm, Climate change

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|  |  |  |  |  |  |  |
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| PI First Name | PI Middle Initial | PI Last Name | PI ORCID ID (optional) | Title of Grant | Funding Agency | Funding Identification Number |
| Ankur | R | Desai | 0000-0002-5226-6041 | Does Northern Hemisphere Snow Cover Influence  Mid­latitude Cyclone Trajectories? Weather  System Implications for a Changing Climate | NSF | 1640452 |

## Timeframe

* Begin date: 1986-01-17 0600Z (All time in GMT)
* End date: 2005-11-11 2100Z
* Data collection completed
* Data not temporally continuous

## Geographic location

* Verbal description: Continental United States and surrounding regions, lambert conformal projection centered at 43.5 N 98 W with resolution of 30 km.
* More specific information about the lambert projection can be found in the *WRF\_output\_variables.txt* document attached and mentioned below.
* North bounding latitude (decimals): 63.041 N
* South bounding latitude (decimals): 19.306 N
* East bounding longitude (decimals): 46.001 W
* West bounding longitude (decimals): 149.991 W

## Methods

1. Experimental design and data

In order to test the effect of snow line position on extratropical cyclones, 20 North American cold season cyclones between 1986-2005 were simulated using the Advanced Research core of the National Center for Atmospheric Reasearch Weather Research and Forecasting model (WRF-ARW) version 4.0.3 with perturbed snow cover extent (SCE). Four cyclone cases were subjectively selected from each of the months from November through March based on manual observational evaluation of all mid-latitude cyclones identified by low-pressure centers through this period in daily surface and upper-level weather charts. The criteria of selected cases required storm trajectories over or adjacent to the Great Plains study area which resemble either the Alberta Clipper track or that of the Colorado Low with lifetimes of at least 2 days, based on presence of well-defined central minimum pressure. Cases were chosen until a sufficient variety of differences in the lifetime minimum sea-level pressure and magnitude of upper level forcings in the form of 500 hPa height curvature and vorticity advection by the thermal wind were found. Cases were simulated with observed initial conditions and validated against observations using the 32-km spatial resolution North American Regional Reanalysis (NARR) to ensure that WRF could accurately simulate each case.

Alterations to the SCE of each case were made by applying average poleward snow line retreat from the 20-year periods of 1986-2005 (historical) to 2080-2099 (projected) for each of the five months examined in this study. Projected PSLR was determined by examination of the grid cell snow mass change in 14 models of the 5th phase of the Coupled Model Intercomparison Project (CMIP5) wherein daily snow mass data were available and experiments were conducted with two Representative Concentration Pathway forcings: RCP4.5 and RCP8.5. Grid cells were identified as snow-covered if their simulated snow mass was at least 5 kg m-2, which corresponds to typically 5 cm of snow depth (assuming a 10:1 snow to water ratio), sufficient to cover the surface. We did test other thresholds and did not find a strong sensitivity to this choice in the projected snow cover maps. The southernmost such grid cells were considered to comprise the snow line if the 5 degree span to the north of a cell had an average snow mass exceeding that threshold. This search radius was employed in order to exclude outlying isolated southern patches of snow. To limit artifacts that arise from small-scale variability in snow cover, a 600 km moving window average was then applied to all derived southern extent of snow cover, hereafter referred to as the “snow line”. For each month, the 20-year average snow line of the historical and projected periods was calculated, and the amount of projected snow line retreat was determined from west to east in 30 km-wide bins across North America. Different iterations, realizations, and physics options belonging to experiments of the same model were combined in a “one model, one vote” scheme. With snow line retreat calculated for both RCP forcings for each of the 14 models, each month contained 28 snow line retreat values from which the 10th, 50th, and 90th percentiles were determined.

The modeling effort involved simulating each of the 20 mid-latitude cyclone cases with five degrees of snow line perturbation, each at five different initialization times, from zero to four days prior to cyclogenesis, yielding a total of 500 distinct simulations. One hundred simulations were generated without changes made to snow cover (control). The remaining 400 runs imposed projected snow line changes of varying magnitude (10th, 50th, and 90th percentiles) or complete snow removal across the domain in order to determine the degree to which the position of the snow line influences storms as opposed to that attributable solely to snow removal. Snow lines for perturbed simulations were determined by applying values of snow line retreat to corresponding 30 km bins of the snow lines, as determined based on the method above, for each case and removing all snow south of the new snow line except at altitudes greater than 2,000 m, where snowpack may persist even in warmer climates. It should be noted that the removal of all snow south of the assigned snow line creates a discontinuous step function in snow depth, a hard margin which is not necessarily characteristic of real snow extent boundaries.

1. WRF model configuration

All WRF-ARW simulations were executed in the same domain comprised of the continental United States, central and southern Canada, northern Mexico, and the surrounding oceans. 30 km horizontal resolution was used to best capture synoptic scale transport with a 150 km buffer zone on each side and 45 vertical levels. Initial and lateral boundary conditions were acquired from 3-hour NARR data provided in grib format by NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, at https://www.esrl.noaa.gov/psd/. Version 4.0 of WRF offers a “CONUS” suite of physics options which was used in this experiment. The NOAH Land Surface Model was altered to reduce surface snow accumulation to zero during simulation in order to avoid snow deposition prior to the arrival of the cyclone of interest into the area without removing precipitation in the atmosphere. NOAH uses a single layer snow model which calculates the albedo of the snow-covered portion of a grid cell as

where *αmax* is the maximum albedo for fresh snow in the given grid cell, *t* is the age of the snow in days, and *A* and *B* are coefficients which are, respectively, 0.94 and 0.58 (0.82 and 0.46) during periods of accumulation (ablation). Coefficients A and B were set to accumulation phase for simulations in every month except for March, when the snow was considered to be ablating.

## Data Information

Data files are each stored in directories according to their case number (C00, C01, C02, …).

Desciptions of variables within each netCDF file are available in the attached file, *WRF\_output\_variables.txt*. The file may also be found at http://co2.aos.wisc.edu/data/snowcover/outputs/WRF\_output\_variables.txt. Alternatively, if users have netCDF installed, data for each file can be viewed in a Linux terminal with the command:

$ ncdump –h <*filename*>

## Filename Convention

<case number>\_T-<days initialized prior>\_<perturbation degree>\_<datetime string>

e.g. C00/Case00\_T-1\_fif\_1993-01-30\_03:00:00

## Data provenance

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| --- | --- | --- | --- |
| Dataset title | Dataset DOI or URL | Creator (name & email) | Contact (name & email) |
| North American Regional Reanalysis (NARR) | 10.1175/BAMS-87-3-343 | Mesinger, Fedor  fedor.mesinger@sanu.ac.rs | Shafran, Perry  perry.shafran@noaa.org |
| Community Model Intercomparison Project, Phase 5 (CMIP5) | 10.1175/BAMS-D-11-00094.1 | Taylor, Karl E.  taylor13@llnl.gov |  |