Antarctic Snowfall and its relationship to Synoptic Conditions

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Hawcroft et al. (2012) identified that up to 90% of precipitation in Northern hemisphere winter was connected to extra-tropical cyclones. Catto and Pfahl (2013) also quantified the relationship between extra-tropical cyclones and their associated frontal systems and precipitation. They identified 51% of precipitation between 60°N and 60°S could be connected to these systems, with this number rising to 90% in the mid-latitude storm tracks.

More recently, Turner et al. (2019) identified that extreme precipitation events consisting of the largest 10% of daily totals are shown to contribute more than 40% of the total annual snowfall across much of the continent, with some areas receiving in excess of 60% of their total snowfall from these events.

This study aims to quantify the relationship between extra-tropical cyclones and extreme snowfall over the Southern Ocean and Antarctica to determine the importance of these systems for snowfall in this region.
This study uses the Lagrangian cyclone tracking scheme developed at NSIDC (Crawford and Serreze, 2016) to derive cyclone positions for the period 1980-2019 from the ERA5 reanalysis at 3 hourly intervals around the Southern hemisphere. The track density for ERA5 is shown to the left.
ERA5 snowfall

The mean occurrence of snowfall events (left) and the mean annual accumulation (right) derived from ERA5 model output between 1980 and 2019.
The annual snow accumulation over Antarctica for 2019 (right) and the cumulative distribution of snowfall events (left) for the regions over the Antarctic coastline. Note the logarithmic scale on the x-axis.
Snow Accumulation and extreme events

The annual snow accumulation over Antarctica for 2019 (left) and the proportion of the annual accumulation connected to extreme precipitation events (events above 90\textsuperscript{th} percentile) in ERA5 data.
Connecting extreme events to extra-tropical cyclones

The figure to the left shows the principle used to connect precipitation events and cyclone tracks. Initially, we examined a 1000km radius circle centred on each low pressure centre and then counted all the precipitation above the 90\textsuperscript{th} percentile for that location which occurs within that mask. The movie shows that MOST, but not ALL precipitation events are linked to cyclone tracks.
One question you might be asking is why did we pick 1000km?

The main reason is that the statistics from the cyclone tracking algorithm show that the mean radii of most cyclones throughout their lifetime is 500km (top), but to cover the maximum size of each extra-tropical cyclone during its lifetime we need to consider 1000km on average (bottom).
Extreme events and synoptic conditions

The proportion of snow accumulation related to extreme precipitation events (left) and the proportion of those events connected to extra-tropical cyclones (right) for a 1000km radius.
The mean extreme snowfall connected to extra-tropical cyclones, using this admittedly simple methodology, for the period 1980 through 2019 is shown to the left.

Extra-tropical cyclones clearly play a significant role in extreme snowfall events over Antarctica and the Southern Ocean.
We also used the Laplacian to identify the radius of each cyclone and used this information in a mask.

This reduces the importance of the cyclones on extreme events overall and also reduces the relative importance around the Amundsen-Bellinghausen sea region. Though, the importance in the Weddell sea of extra-tropical cyclones is largely unaffected.
Using ERA5 snowfall data and cyclone tracks, derived ERA5 mean sea level pressure output, we have quantified the relationship between low pressure centres and extreme snowfall events.

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This preliminary work would be significantly improved by analysing the ability of ERA5 output to represent extreme snowfall events. We plan to use CloudSat snowfall data for case study based evaluation.

A thorough analysis of the uncertainties and errors in this quantification technique are ongoing.

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