OFFICE OF UNDERGRADUATE RESEARCH

IMMERSIVE RESEARCH INTERNSHIP EXPERIENCE
CLIMATE COMPUTING

SIMULATING THE IMPACTS OF ARCTIC SEA ICE EXTENT ON THE STRATOSPHERIC POLAR VORTEX

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Introduction

The **Arctic Stratospheric Polar Vortex (SPV)** is a wintertime ring of **high-altitude winds** that confines cold air to the North Pole. When the SPV weakens, it can **displace, split, or collapse**, allowing cold air to surge southward into mid-latitudes. While recent research links Barents-Kara sea-ice loss with a weakened SPV via **intensified planetary-scale waves**, the direct impact of varying sea ice extent on overall vortex behavior remains poorly understood. This study investigates how the **variations of sea ice** extent influence **SPV strength** and evolution.

Methods & Data

- Used the European Centre for Medium-Range Weather Forecasts Reanalysis version 5 (**ERA5**) dataset.
- Ran a Weather and Research Forecasting (**WRF**) simulation, investigating three cases: Control, High Ice, and Low Ice.
  - **Control:** Simulated December 14, 2015 at 00:00 UTC, simulated through January 12, 2016 at 18:00 UTC.
  - **High Ice:** Replaced sea ice data with that of the same time period in 1982-1983.
  - **Low Ice:** Replaced sea ice data with that of 2025-2026.
- **5 simulations** for each case with stochastic variation. Simulation outputs are **averaged to produce the final outputs** that we analyze.
- Measured the strength of the SPV by **the zonal-mean zonal wind, averaged between 60 and 70 degrees N at 75 hPa.**
- Plotted the **wind speeds** at 75 hPa to take note of **the shape of the vortex**. Time-averaged the **6 days before the Arctic rain-on-snow event (AROS)** (12-22 to 12-28) and the time **during the event** (12-28 to 01-01).

Physics Parameterization	
Physics Catagory	Scheme
Microphysics	Morrison 2-Moment
Longwave Radiation	RRTM
Shortwave Radiation	Dudhia
Surface Layer	Revised MM5
Land Surface Model	Unified Noah LSM
Boundary Layer (PBL)	Yonsei University
Cumulus Convection	Kain-Fritsch
Sea Ice Treatment	Fractional Sea Ice

Results

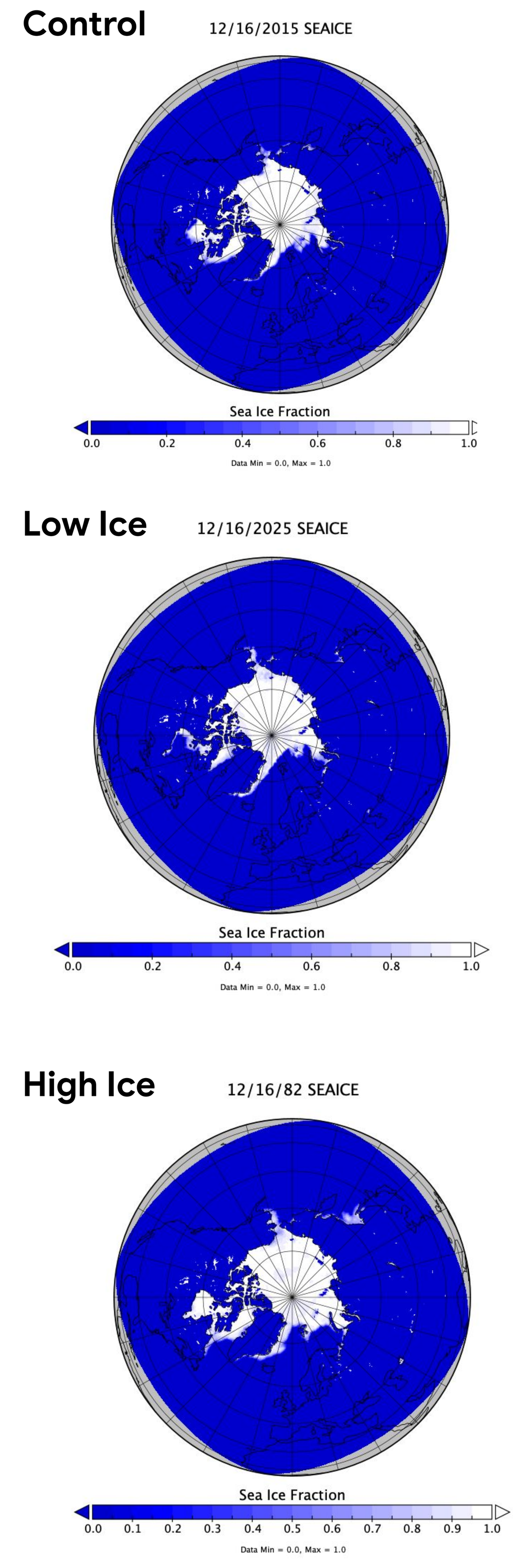

Figure 1: Sea ice extent

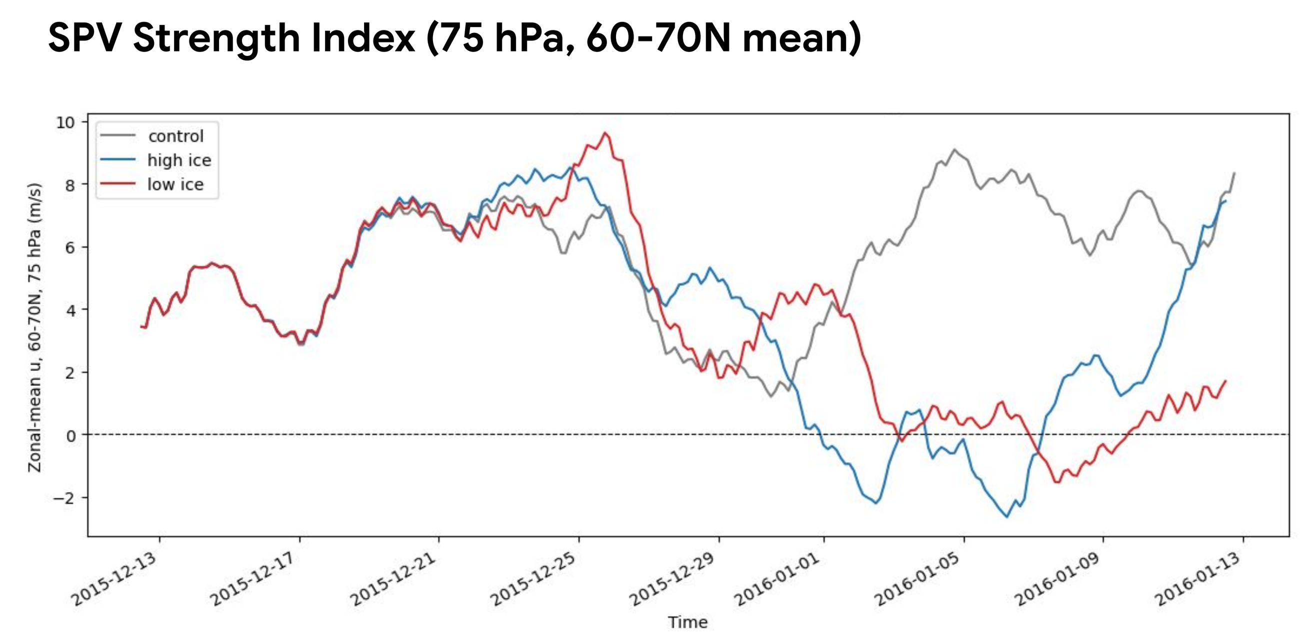

Figure 2: Strength of the SPV over time, sampled from an ensemble member from each case.

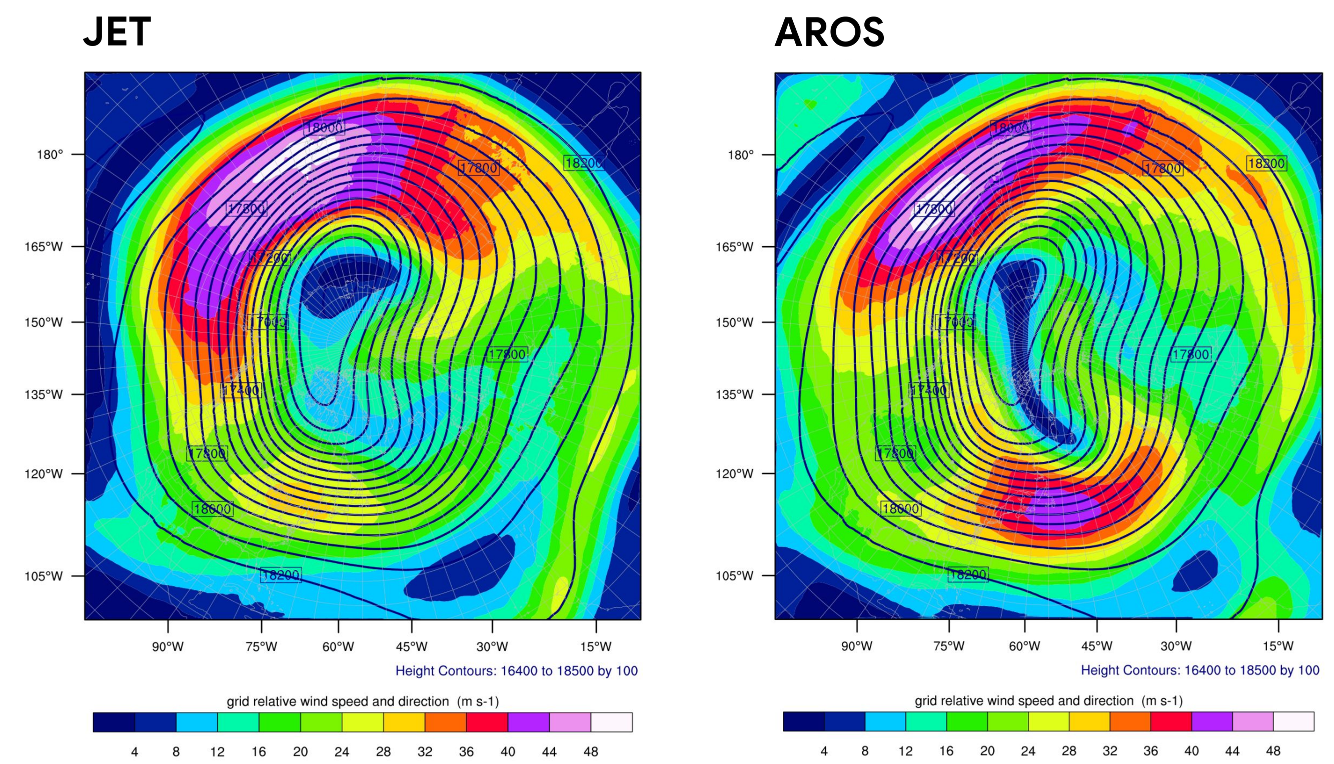

Figure 3: Grid relative wind speed at 75 hPa of the Control case, before and during the rain-on-snow event

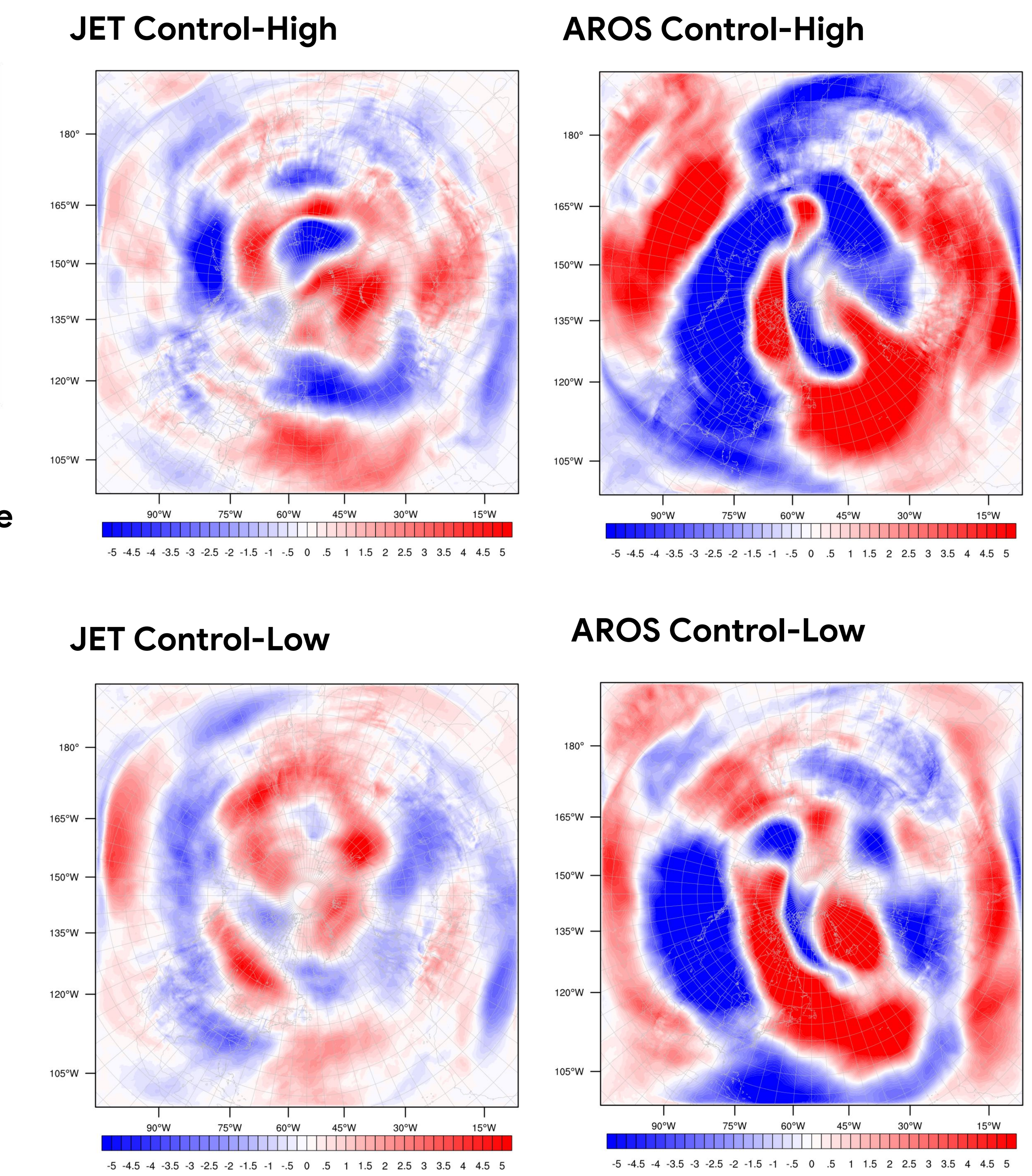

Figure 4: Grid relative wind speed difference at 75 hPa between the test cases and the control case before and during the rain-on-snow event

Discussion

- **Figure 2:** In all cases, the SPV weakens beginning around 12-26. We note that this coincides with the time of the Arctic rain-on-snow event of 2015-16, although the extent of this connection is unclear. In the control case, the vortex recovered quickly after, reaching its previous strength by January 3rd; however, both the high ice and low ice cases saw larger decreases. The high-ice case recovered by January 13, and the low ice case didn't recover within the simulated time.
- **Figure 3:** During our two observed time periods, the SPV is not centered at the North Pole, and is somewhat eccentric. This suggests a limitation of the metric used in Figure 2, that it doesn't fully capture the SPV. Further study is needed to develop a better metric for studying the SPV when it does not fit within a narrow latitude.
- **Figure 4:** These charts suggest that sea ice has a strong effect on the vortex, particularly during the AROS event. It is noticeable that in the low ice case, a more fragmented, multi-lobed pattern of change in wind speed in the polar area might suggest a more disorganised disturbance to the SPV.

Future Work

- Examine the mechanism behind how sea ice changes drive these strength differences.
- Investigate a possible connection to the 2015-16 AROS event.
- Repeat with a higher model height and more common metrics of SPV strength (particularly zonal-mean zonal winds at 60 N 10 hPa).

Acknowledgements

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References