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New Hampshire Space Grant Fellowship Award – Summer 2024 Report

The NHSG Fellowship has supported the chapter of my dissertation focused on the impact of ash deposition within the Polar Jet Stream and climatic-forced shifts in atmospheric transportation patterns.

Methods

To select days in which to run the hypothetical eruptions in HYSPLIT, atmospheric modes were studied with the greatest influence on the Polar Jet Stream instability. Literature reviews suggested the Arctic Oscillation Index (AO) and the El-Niño Southern Oscillation (ENSO) have the largest impact on Jet Stream instability, especially noted when the phases of the internal modes are synched or when the modes serve as connections for semi-permanent weather patterns like the Aleutian Low (Li et al., 2014). For example, when AO is in the negative phase (wobblier jet stream) and ENSO is the negative phase (La Niña), the impact of the internal mode variability is much greater. Conversely, found in the literature are positive phases of ENSO (El Niño) force instability within the Jet Stream along with the negative phase of AO (the phases are not synched). Therefore, datasets are selected fitting the following conditions: positive AO and positive ENSO, positive AO and negative ENSO, negative AO and negative ENSO, and negative AO and positive ENSO (Table 1). Target months are then selected during winter (JFMAOND) and summer (MJJAS) months to assess the strength and variability of the internal modes during different temperatures and semi-permanent weather patterns, like the Aleutian Low and the North Pacific High.

Season	Arctic Oscillation (AO) Phase	El-Niño Southern Oscillation (ENSO) Phase
Winter	+	+
Winter	+	-
Winter	-	-
Winter	-	+
Summer	+	+
Summer	+	-
Summer	-	-
Summer	-	+

Table 1. Required conditions selected within ENSO and AO indices datasets to find target months to run in HYSPLIT modeling.

Timeseries data for anomalous indices for ENSO and AO were downloaded from the National Oceanic and Atmospheric Administration (NOAA). These data were then filtered for target days with indices values greater than 1 for positive phases, or less than -1 for negative phases (Figure 1). The goal was to select three to five dates for each condition for both during the summer and winter months. Summer dates were more difficult to find, so the threshold was lowered to 0.75 for positive phases or less than -0.75 for negative phases.

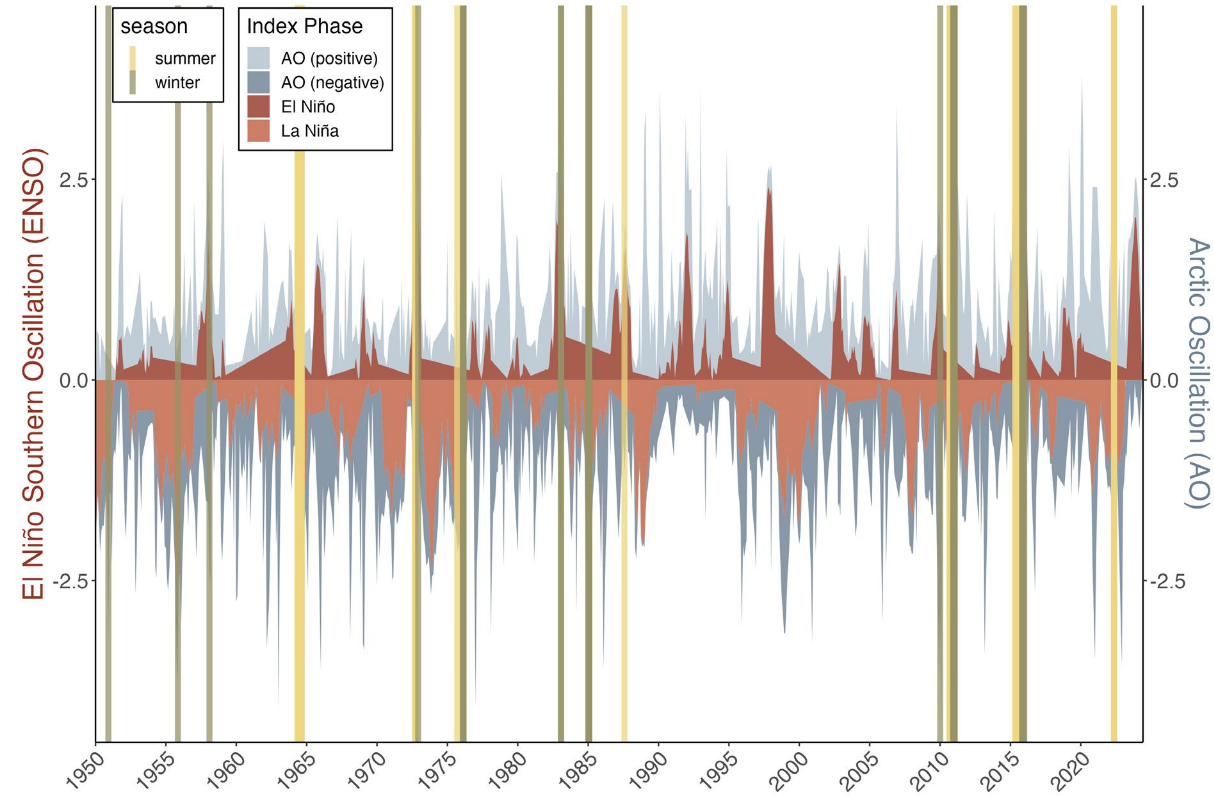

Figure 1. El-Niño Southern Oscillation (ENSO, oranges) and Arctic Oscillation (AO, blues) indices from 1950 to 2022. Data from the National Oceanic and Atmospheric Administration (NOAA). The shades of ENSO or AO reflect how the phase impacts the instability of the Jet Stream, with the darker shades representing a stronger influence. The positive phase of ENSO and the negative phase of AO lead to wobblier Jet Stream pattern. The dates on which the HYSPLIT hypothetical eruptions have been run (n=52) as of August 21, 2024 are highlighted by the vertical bars for summer months (yellow) and winter month (green).

With target months selected from the anomalous index dataset, Daily Mean Composite plots were used from NOAA's Physical Sciences Laboratory to refine the selected day in which the HYPSLIT models were to be run. Using the Vector Wind variable at 250 mb analysis level and Sea Level Pressure variable at 1000 mb analysis level plots, the Jet Stream patterns were analyzed for a continuous jet, a persistent North Pacific High and fast winds over Alaska. An unanticipated result was coming across some months in which none of these conditions were met. During these months, there was a persistent Aleutian Low, leading to slow winds, and the Jet Stream was never continuous. These months occurred during a sudden stratospheric warming event, causing temperature increases in the polar stratosphere and reversals in westerly winds (Butler et al., 2017).

HYPSLIT Modeling

The volcanic ash HYSPLIT model was run using archive dispersion with volcanic ash release type. The meteorology data used are Reanalysis meteorology data for dates before 2006 and the

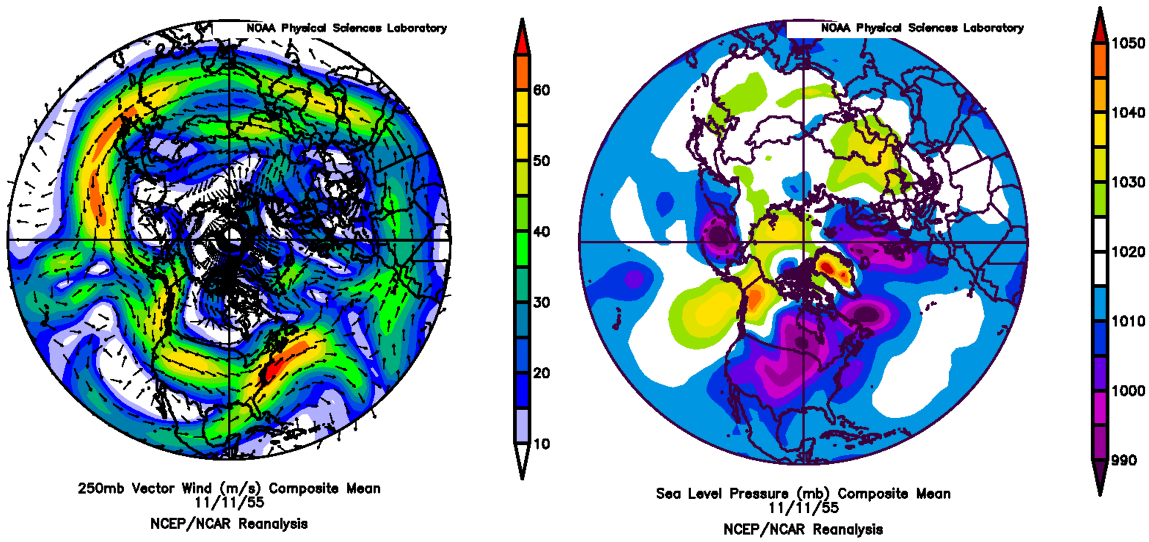

Figure 2. Example of Vector Wind (left) and Sea Level Pressure (right) Composite mean from NOAA Physical Sciences Laboratory to find ideal days for HYPSLIT inputs with a continuous jet, permanent North Pacific High, and fast winds over Alaska.

GDAS meteorology data for dates after 2006. The source location was set to Augustine volcano to run hypothetical eruptions. Two concentration layers were in the output along with deposition of ash. For setting the eruption parameters, conditions were set to those for the 1976 eruption of Augustine, which has the largest tephra deposition pattern for the modern eruptions of the volcano. The quantity was set to 1.84×10^{12} kg with a release duration of three hours from Kienle and Shaw (1979). The HYPSLIT model was run for 72 hours total with an averaging period of three hours. The ash bulk density was set to 2.6 gcm^{-3}, estimated from Mastin (2009).

Initial Results

Not all hypothetical eruption scenarios have been processed through HYSPLIT. The following results are as of August 21, 2024. Not all phase condition maps are shown, choosing to focus on the groups that have the most data. The maps below are displayed as pseudo-heatmaps of ash deposition results from HYSPLIT models. The shades represent the thickness of the deposits whereas the opacity represents overlapping deposits across the different dates (i.e. more opacity is indicative of a location more likely to receive ash deposition than others).

Comparing Figure 3 and 4, where the ENSO phase changes but not AO, positive ENSO phases (El Niño) spreads ash further from the point source and more south. Comparing Figure 5 and 6, where AO phases changes but not ENSO, ash is deposited further south but some ash plumes are transported to the north-east. Focusing on the seasonal variable will be addressed with future results when more HYPSLIT datasets are produced for a viable comparison.

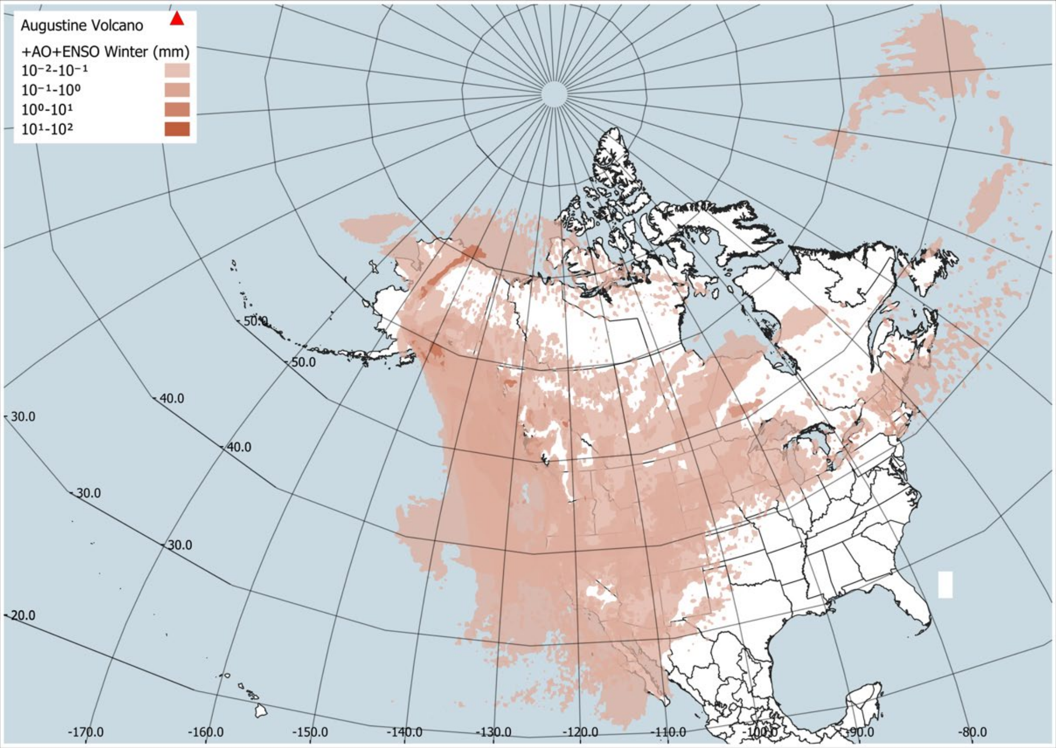

Figure 3. Cumulative HYSPLIT results for +AO and +ENSO phases during Winter for: 1972-12-03, 1983-01-22, 2015-11-02, 2015-11-03, 2015-11-08 and 2015-11-19.

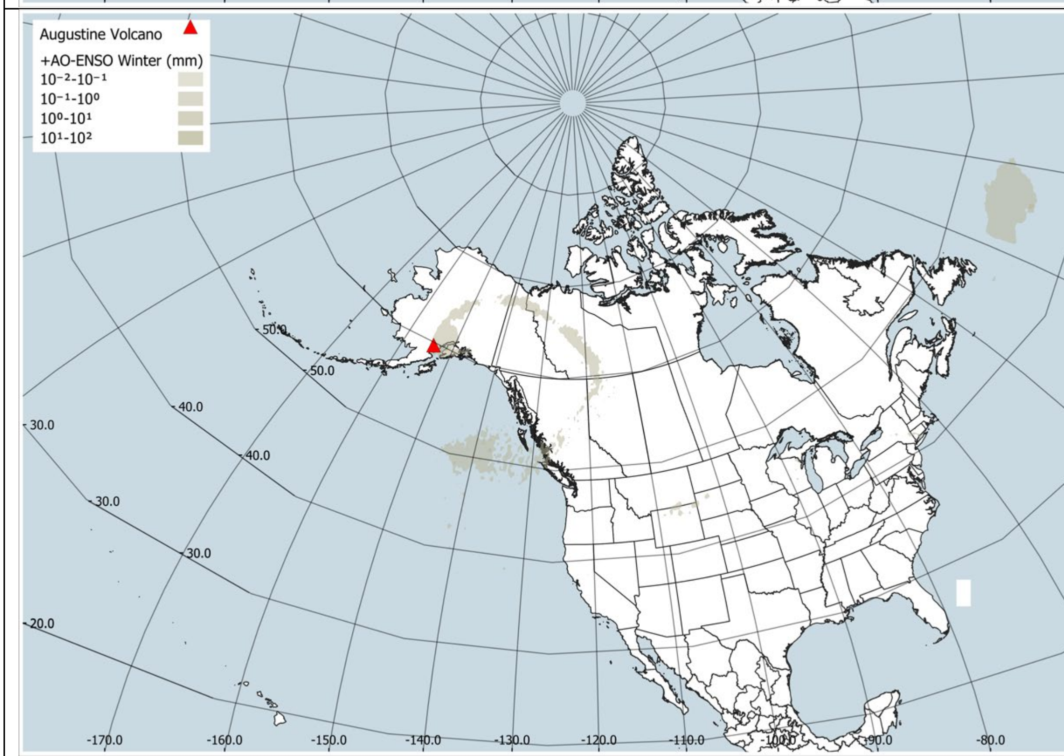

Figure 4. Cumulative HYSPLIT results for +AO and -ENSO phases during the winter for: 1976-02-01 and 1976-02-03.

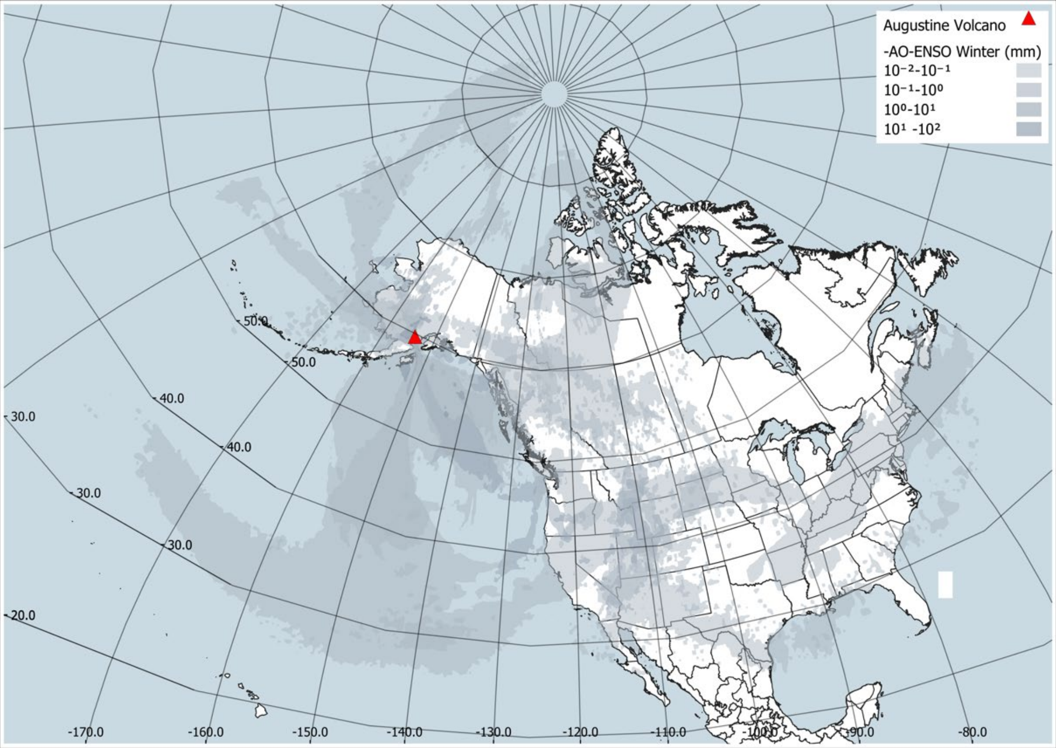

Figure 5. Cumulative HYSPLIT results for -AO and -ENSO phases during the Winter for: 1950-12-01, 1955-11-09, 2010-12-01, 2010-12-18, 2010-12-21, 2010-12-29, 2011-01-10 and 2011-01-19.

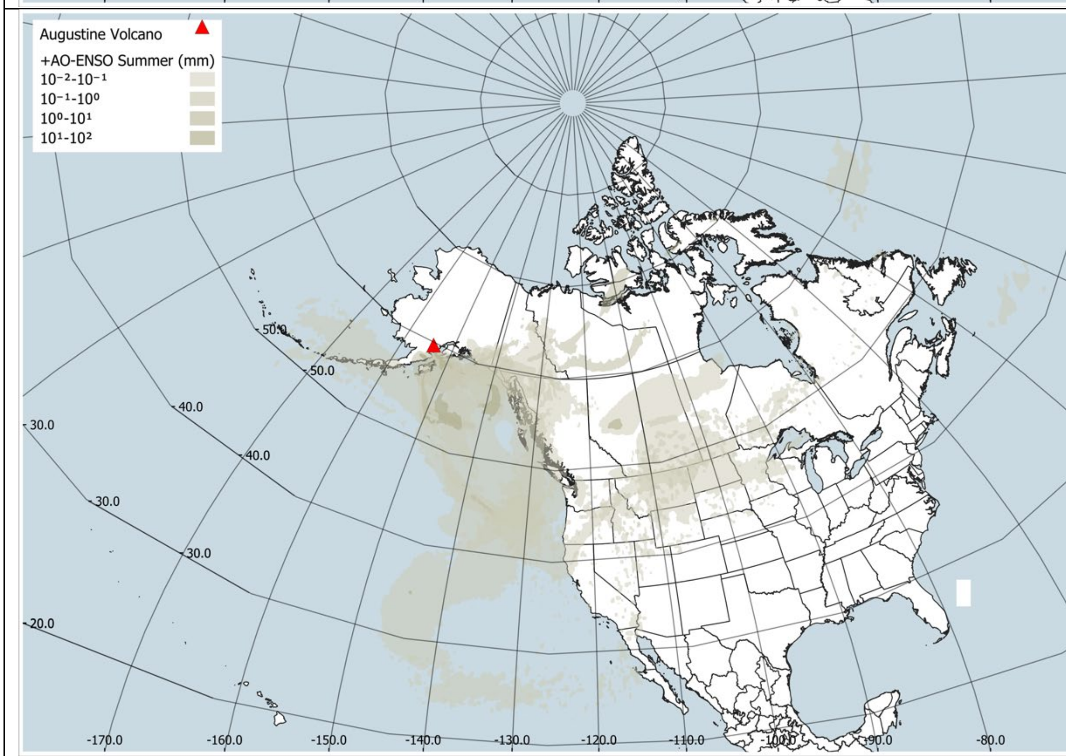

Figure 6. Cumulative HYSPLIT results for +AO and -ENSO phases during the summer for: 1964-05-07, 1964-05-12, 2022-05-09, 2022-05-10 and 2022-05-18.

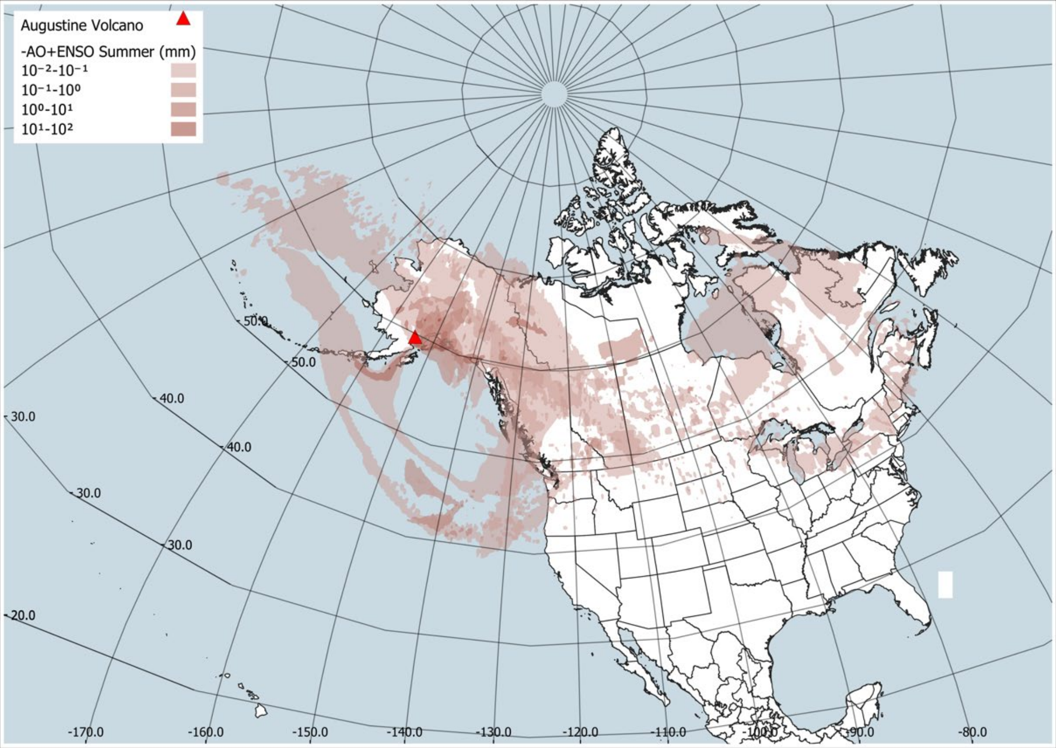

Figure 7. Cumulative HYSPLIT results for -AO and +ENSO phases during the summer for: 1972-09-09, 1972-09-20, 2015-07-04, 2015-07-18, 2015-07-18 and 2015-07-25.

Future Work

Upon completing and summarizing all models for the prescribed AO and ENSO indices, the results will be mapped in QGIS and compared with the National Landcover Database to determine which landcover types may be the most susceptible to ash hazards using spatial analyses. Volcanic hazards will be assessed for both proximal and distal impacts. Proximal hazards, such as heavy ash deposition, may result in significant vegetation loss and trigger herbivore migration. However, distal impacts of ash deposition could have beneficial effects, such as increased vegetation through enhancing soil fertility. Both conditions have the potential to impact traditional harvesting areas for Indigenous communities in Alaska, Canada, and the contiguous United States.

Conference Abstracts

I have submitted an abstract for the session V032 - What Goes Up Must (Eventually) Come Down: Dynamics of and Deposition from Volcanic Eruption Columns, Plumes, and Pyroclastic Density Currents at Fall Meeting AGU 2024 entitled: “Jet Stream Jitters: Potential Climate Change Impacts on Volcanic Ash Deposition in the Aleutians”. If accepted, I will present the above data along with the completed future work including the interpretations of ash hazard maps with increased instability within the Jet Stream for Augustine volcano.

References

Butler, A. H., Sjoberg, J. P., Seidel, D. J., & Rosenlof, K. H. (2017). A sudden stratospheric warming compendium.

Kienle, J., & Shaw, G. E. (1979). Plume dynamics, thermal energy and long-distance transport of vulcanian eruption clouds from Augustine Volcano, Alaska. *Journal of Volcanology and Geothermal Research*, *6*(1–2), 139–164. https://doi.org/10.1016/0377-0273(79)90051-9

Li, F., Wang, H., & Liu, J. (2014). The strengthening relationship between A rctic O scillation and ENSO after the mid-1990s. *International Journal of Climatology*, *34*(7), 2515–2521. https://doi.org/10.1002/joc.3828

Mastin, L. G., Guffanti, M., Servranckx, R., Webley, P., Barsotti, S., Dean, K., et al. (2009). A multidisciplinary effort to assign realistic source parameters to models of volcanic ash-cloud transport and dispersion during eruptions. *Journal of Volcanology and Geothermal Research*, *186*(1–2), 10–21. https://doi.org/10.1016/j.jvolgeores.2009.01.008