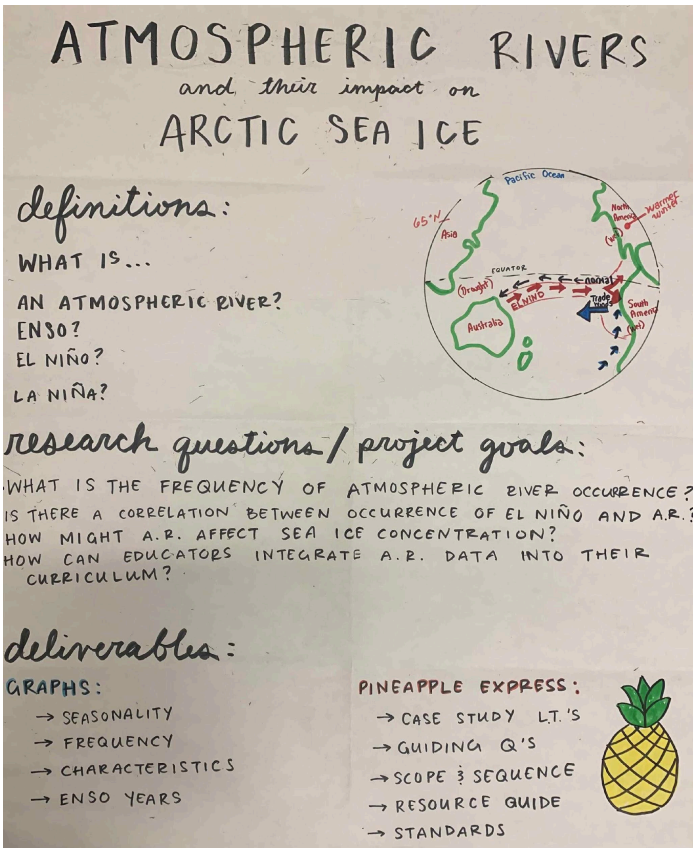

In the summer of 2022 (July 5 – August 10), the PI worked with two educators, Katie Carson, who is a high school math teacher at the Energy Tech High School, Queens, and Angela Carcione, who is a middle school science teacher at the Metropolitan Expeditionary Learning School IS 167, Queens (will start at PS207 Rockwood Park School in the coming year), on a research project on the atmospheric rivers and their impacts on Arctic sea ice. Both Katie and Angela were also part of a cohort that participated in the NSF Research Experiences for Undergraduates (REU): Beyond Basic Science – Connecting Climate to Communities, hosted by the Columbia Climate School. The project provided the educators not only an experience for working on a cutting-edge research project but also an opportunity to integrate the research experience to classroom teaching as well as to encourage middle and high school students to formulate and solve problems in real-world situations.

Atmospheric rivers (AR) are relatively long, narrow filaments of enhanced water vapor transport outside of the tropics. It's been known that the ARs play a significant role in the delivery of fresh waters and hydrological cycle in the midlatitude regions, such as California. Furthermore, recent studies have also suggested that the ARs can also travel to the Arctic region and potentially contribute to the melting of the Arctic sea ice. More background information about the project can be found here.

Four questions were formulated by Katie and Angela: (1) What is the frequency of AR occurrence over the globe, including the Arctic region? (2) Is there a correlation between the occurrence of El Nino and AR? (3) How might AR affect the Arctic sea ice concentration? (4) How can educators integrate AR data into their curriculum?

To address the questions above, Katie analyzed the 1979-2018 Global Atmospheric River Catalog which is generated following the Guan and Waliser (2015) algorithm. Plots that characterize the ARs, such as length, width, length/width ratio, equatorward tip, poleward tip, integrated vapor transport, were made. A heat map that summarizes the global wintertime (November-March) AR frequency was generated, and maxima of about 10-15% of AR frequency were found over the midlatitude oceans. ARs could also reach the Arctic region (poleward of 65^{o}N) with a frequency of about 8%. And there is a slight increase of AR frequency reaching the Arctic in the latter time period (8.2%, 1999-2018) compared to the earlier time period (7.9%, 1979-98). In addition, Katie also analyzed the AR frequency and characteristics during El Nino and La Nina years. Interesting regional differences can be seen when comparing El Nino years with all years and when comparing La Nina years with all years, for example, more ARs reach the Pacific Northwest during El Nino years, and overall more ARs reach the Arctic region, specifically both the Pacific side and Atlantic side of the Arctic, during La Nina years. All the plots that were generated by Katie can be found here.

In addition, Angela and Katie also worked out plans to integrate AR into their classroom curriculum. Angela created a case study of Pineapple Express (which describes a moisture band that flows from near Hawaii to the U.S. West Coast) for middle school science classes. The students will take part in phenomena-based learning by exploring the concept of ARs, their pathway, connection to the El Nino Southern Oscillation and potential impacts on water availability in various regions and sea ice melt. Through the lens of atmospheric rivers, the students will learn about a variety of standards-aligned topics, including energy and matter, weather and atmosphere, Earth's climate zones, water cycle, and impact of climate change, and also practice graphing skills such as reading and analyzing data in order to hone scientific literacy skills. Scope and Sequence Recommendations, Resource Guide, 10-Day Case Study – Daily Learning Targets, Ties to New York State Department of Education Standards, and plans to evaluate the case study were also provided in the document prepared by Angela.

Katie is also planning to use some of the AR data and histogram plots for her high school math classes and prepared a case study. The materials will help the students learn about standards-aligned topics, including histogram, statistics and probability, normal distribution, right skewed versus left skewed histogram, as well as drawing conclusions from the histograms.

The PI also examined a case study of AR affecting the Arctic sea ice concentration. During December 2-5, 2003, an AR event was observed over the Barents-Kara Sea region. At the same time, the Barents-Kara Sea sea ice concentration was seen to decrease, likely due to the AR event. Since ARs usually bring warm and moist air from lower latitudes, they likely cause downward energy flux (both longwave radiation and turbulent flux) from the atmosphere to the sea ice, resulting in a melting of the sea ice.

On August 8, Katie and Angela gave a final project presentation in the program and the presentation slides can be found here. The PI will continue to work with the educators on the implementation and evaluation of classroom teaching of ARs.

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funding for the two educators came from different sources but they worked together in order for both of them to be part of a cohort experience and participant in other professional development opportunities together.