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Characterization of Sea Breeze Circulation Related Precipitation on the DelMarVa Peninsula

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Abstract

Sea breeze circulation (SBC) is a local meteorological phenomenon that occurs when coastal regions experience a significant daytime temperature gradient between the land and sea surfaces, leading to a surface pressure gradient, and causing moist, cool air to move over land, heat, and rise. The DelMarVa peninsula, located between the Chesapeake and Delaware Bays, experiences SBC regularly in the summer, with occasional convergence of multiple sea breeze fronts from the two Bays and adjoining Atlantic coastline. In some cases, there is enough uplift and convection related to the SBC that precipitation will form. We explore the environmental factors that lead to convective precipitation associated with the SBC on the DelMarVa. Using a variety of data sources, including meteorological stations, radiosondes, and RADAR, we have developed objective criteria to identify precipitation occurrences related to sea breeze circulations. Characteristics of the associated precipitation events, such as precipitation intensity, onset, and inland penetration are presented. This characterization is part of a larger study to determine the impact of land use and land cover change on the local summertime climate, in which SBC plays a central role.

Sea Breeze Circulation

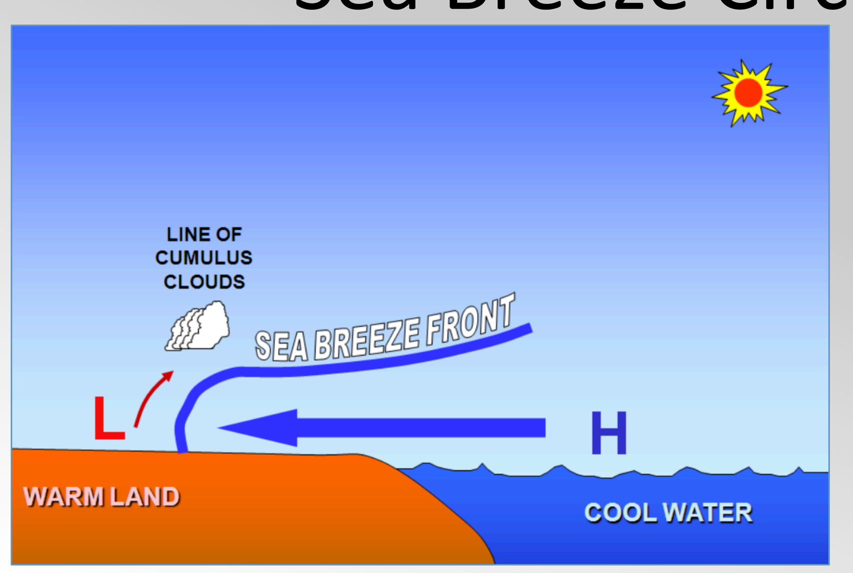

Fig. 1: Diagram of sea breeze circulation (adopted from U.S. FAA AC 00-6A, Chapter 9, Figure 9.3)

Sea Breeze Circulations (SBCs) over the DelMarVa peninsula result from a temperature difference creating a pressure gradient. This causes cool, moist air to move from the Atlantic Ocean and Delaware Bay onto the DelMarVa Peninsula. As seen in Figure 1, convection can be strong enough for cloud formation and, ultimately, convective precipitation.

Meteorological Station Data

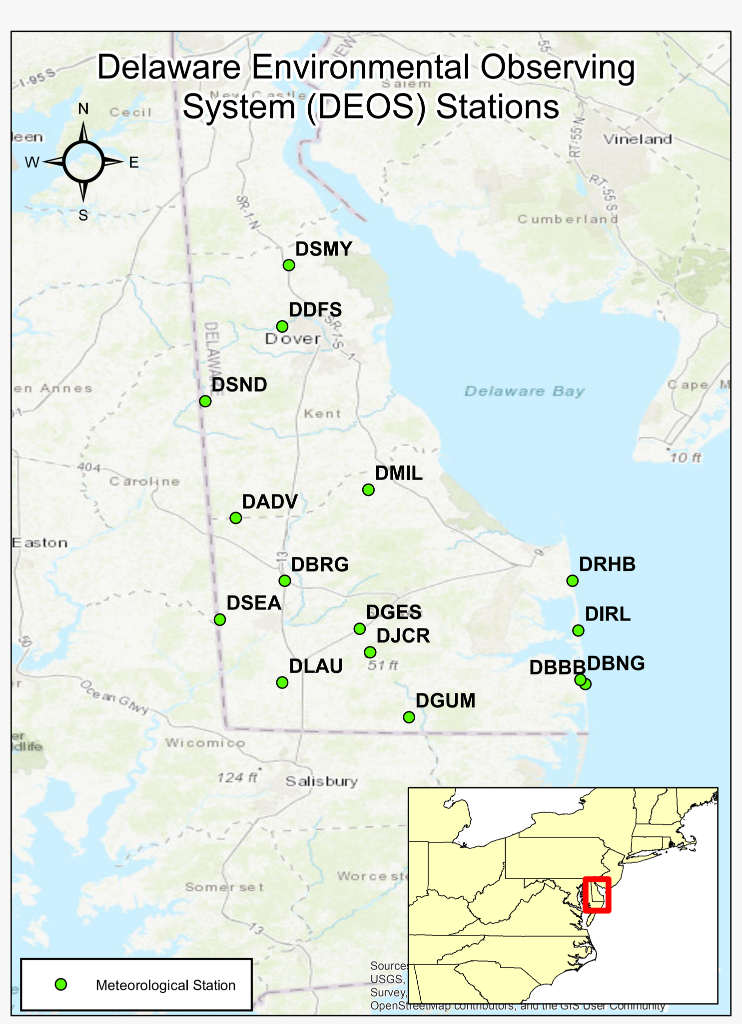

Fig. 2: Map of DEOS stations utilized in this study

The Delaware Environmental Observing System (DEOS) mesonet is believed to be the densest statewide meteorological mesonet in the country.

Fifteen stations in Sussex and Delaware counties, Delaware were used in this study to detect and analyze sea breeze related precipitation events on the DelMarVa peninsula.

The five-minute meteorological data was obtained for May to September, inclusive for the time period of 2013 to 2017, and an objective detection algorithm was developed to detect target events based on several criteria found in Figure 5.

A total of 1826 days were considered and Sea Breeze Related Precipitation Events (SBRPEs) were detected on 55 days. Note that multiple stations successfully detected an event on 19 of the 55 days. In this study, each detection was treated as an individual event, resulting in **79 cases** of sea breeze related precipitation.

Case Study: August 1, 2016

Radar data are employed to verify the presence of a Sea Breeze Front (SBF) crossing the DelMarVa peninsula from the Delaware Bay and Atlantic Ocean coastlines of Delaware westward toward the Chesapeake Bay, resulting in precipitation. The evolution of the front on August 1, 2016 is shown below.

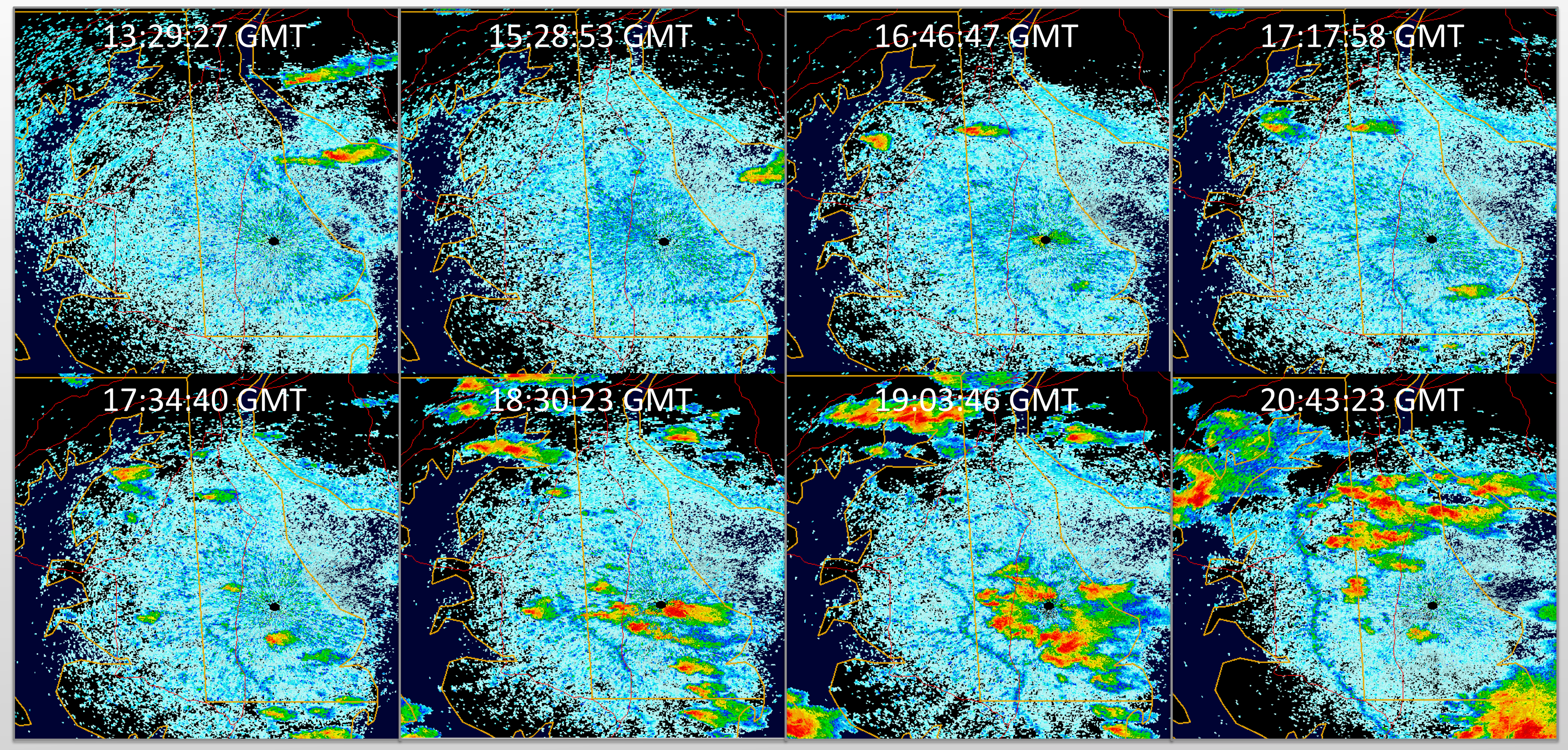

Fig. 3: Radar imagery from August 1, 2016 showing the development of a bay/sea breeze propagating inland from the Delaware Bay and the Atlantic Ocean westward toward the Chesapeake Bay. The front is seen as the (roughly) north-south oriented blue stripe.

The Impact of Sea Breeze Passage

There is a distinct variation between environmental conditions one hour before and one hour after the onset of a sea breeze with associated precipitation. A case study of temperature, precipitation onset and wind is presented in Figure 6. A complete set of statistics is found in Figure 7.

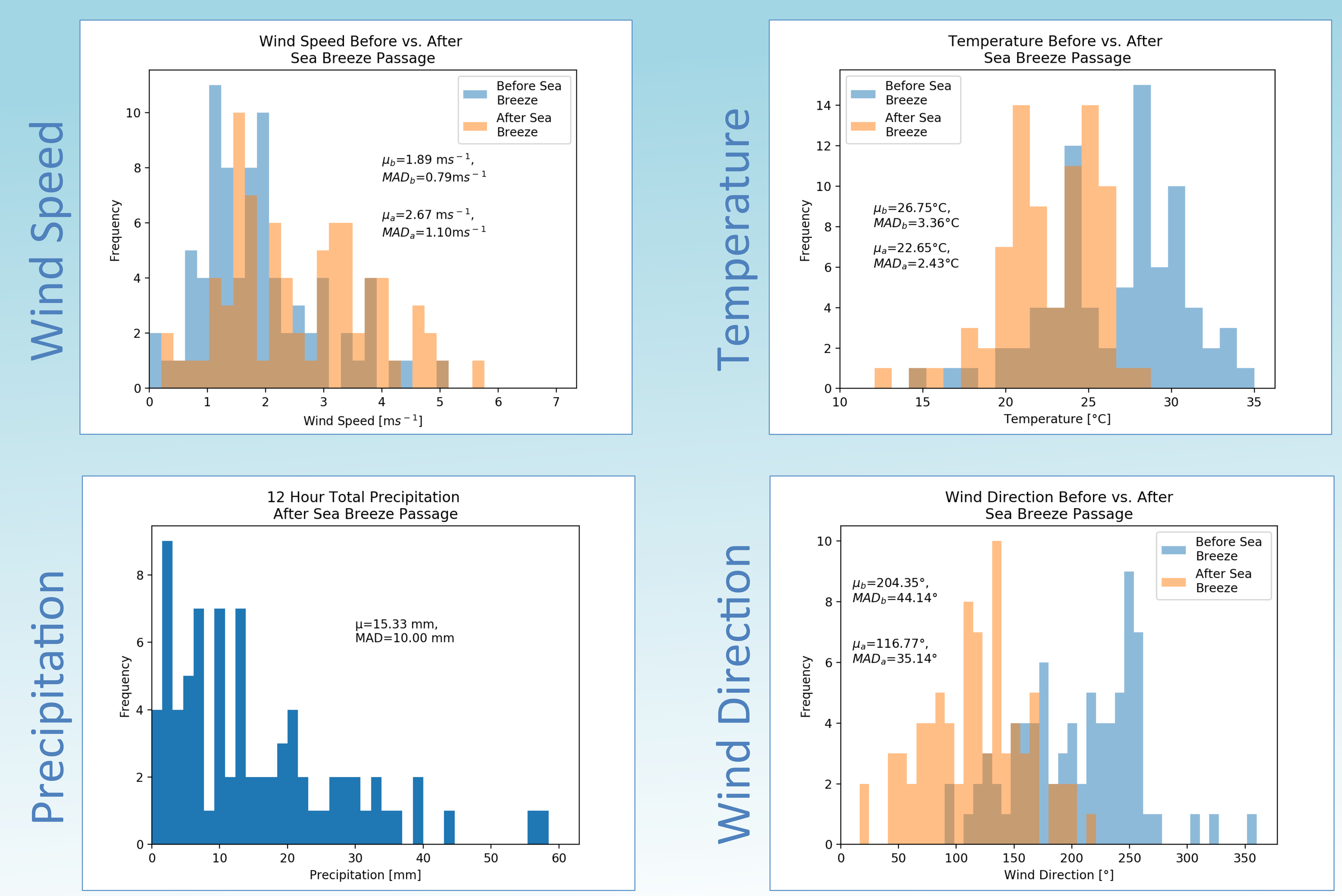

Fig. 4: Histograms of environmental factors of sea breeze related precipitation development.

Case Detection

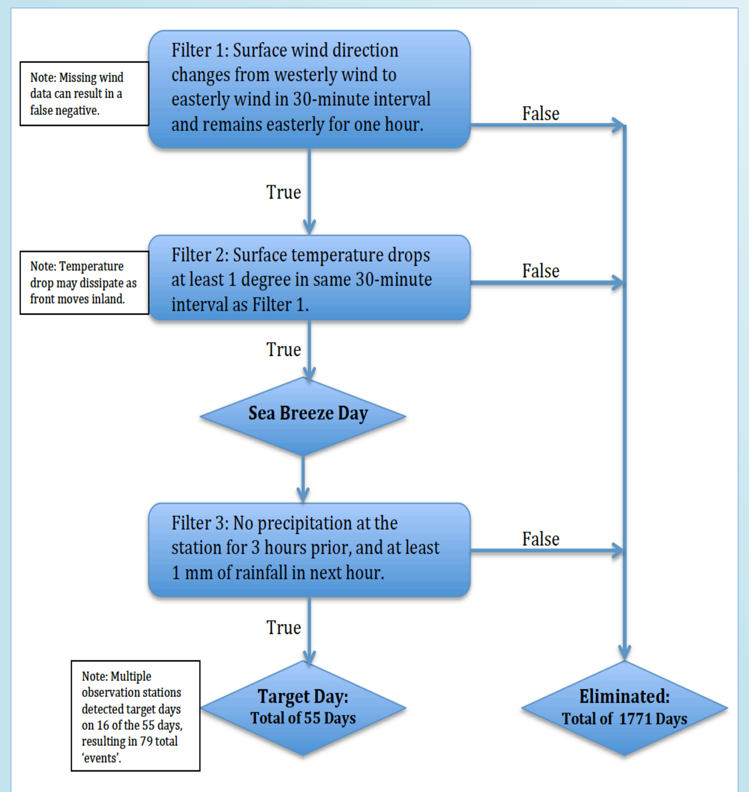

Fig. 5: Schematic showing the filters used to detect Sea Breeze Related Precipitation Events for May-September for years 2013-2017.

Three filters were used to identify sea breeze related precipitation events (SBRPEs).

The first two establish the presence of a sea breeze based on temperature and wind direction following Gilchrist (2013).

The third filter requires no rainfall in the preceding 3 hours and at least 1 mm of rainfall in the hour following the detection of a SBF.

If any criteria was not met, that time step (5-minute intervals) was eliminated. If all the criteria were met, the time-step was flagged as a target event.

Case Study: July 14, 2017

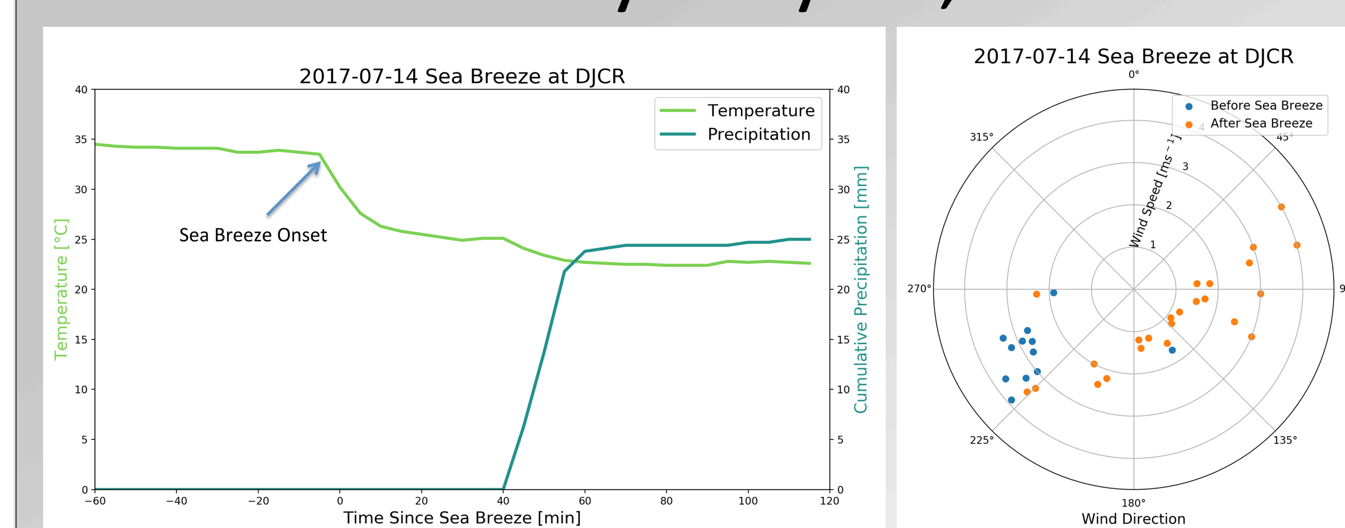

Fig. 6: (left)Time series of the developing sea breeze and associated precipitation at Georgetown, DE. (right) Wind direction for one hour prior to the sea breeze onset were used for the 'before' values, and two hours following the sea breeze onset were used for 'after' values.

Descriptive Statistics

Factor	Mean	MAD	Unit
12-Hour Cumulative Precipitation	15.33	10.00	mm
Time of Precipitation After Sea Breeze Detection	25.06	12.60	min
Relative Humidity After Sea Breeze Detection	87.01	5.17	%
Relative Humidity Before Sea Breeze Detection	72.03	10.92	%
Temperature After Sea Breeze Detection	22.65	2.43	°C
Temperature Before Sea Breeze Detection	26.75	3.36	°C
Wind Direction Before Sea Breeze Detection	116.77	35.14	°
Wind Direction After Sea Breeze Detection	204.35	44.14	°
Wind Speed After Sea Breeze Detection	2.67	1.10	$m\ s^{-1}$
Wind Speed Before Sea Breeze Detection	1.89	0.79	$m\ s^{-1}$

Future Work

This work is a part of a larger study, which will explore the dynamics of precipitation events that are created and/or altered by the onset of a sea or bay breeze circulation through additional observational analysis and modeling studies. Further investigation into how land use and land cover (LULC) change may alter the hydrological cycle on the peninsula will be pursued. This may include studying future changes in agricultural practice, such as an increase in irrigation or a decrease in tillage, and/or future increases in urbanization along the Atlantic

Observational Meteorological Data obtained from Delaware Environmental Observation System (DEOS).

RADAR Data obtained from the National Weather Service (NWS), an agency of the National Oceanic and Atmospheric Administration (NOAA)