Automated Detection of Sea Breeze Circulations: A Climatology of Sea Breeze-Initiated Precipitation

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Abstract

The Delmarva Peninsula, located on the East Coast of the United States between the Chesapeake and Delaware Bays, experiences sea breeze circulations (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. Under certain conditions, the sea breeze front (SBF), which tends to be greater in vertical extent near the advancing edge of the SBC, is visible using radar reflectivity data. We introduce a state of the art detection method for objectively identifying and tracking the formation and movement of the Delmarva SBC. Reflectivity data from the KDOX NEXRAD station in Dover, Delaware are pre-processed to eliminate both ground clutter and precipitation by limiting acceptable values between 8-25 dBZ. A series of longitudinal transects are traversed step-wise from east to west to identify the SBF by detecting clusters of acceptable reflectivity values. We then develop a climatology of summer precipitation attributed to the SBC by associating the timing of precipitation events with the detection of a SBF. Characteristics of the SBC and associated precipitation events, such as precipitation intensity, spatial coverage, and inland penetration are presented. Results from this project will be used to inform a sensitivity study that will explore the impact of coastal urbanization and other land use and land cover (LULC) changes on the local summertime climate, in which SBC plays a central role.

Background

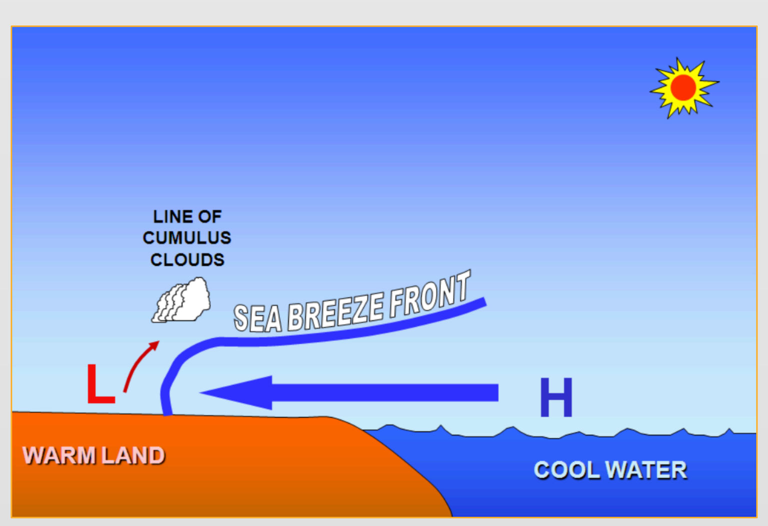

Figure 1 – Diagram of sea breeze circulation (adopted from U.S. FAA AC 00-6A, Chapter 9, Figure 9.3)

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. The Sea Breeze Front (SBF) can entrain particles and biota. This phenomena is sometimes detectable via radar reflectivity data. Further, associated convection can be strong enough for cloud formation and, ultimately, convective precipitation (Figure 1).

Delaware is believed to have the densest statewide meteorological mesonets in the country. 15 Delaware Environmental Observing System (DEOS) Stations have been used in previous studies (e.g. Gilchrist, 2013; Hughes & Veron, 2018) to analyze the Delaware SBC.

Few studies have utilized radar reflectivity data, to date. The KDOX Next-Generation Radar (NEXRAD) station located in Dover, Delaware will be used to detect and track SBC formation and propagation.

It has been shown that the sea breeze on the DelMarVa can be detected via station data on ~70% of summer days, although most are weak and, thus undetectable via radar reflectivity data (Hughes & Veron, 2018).

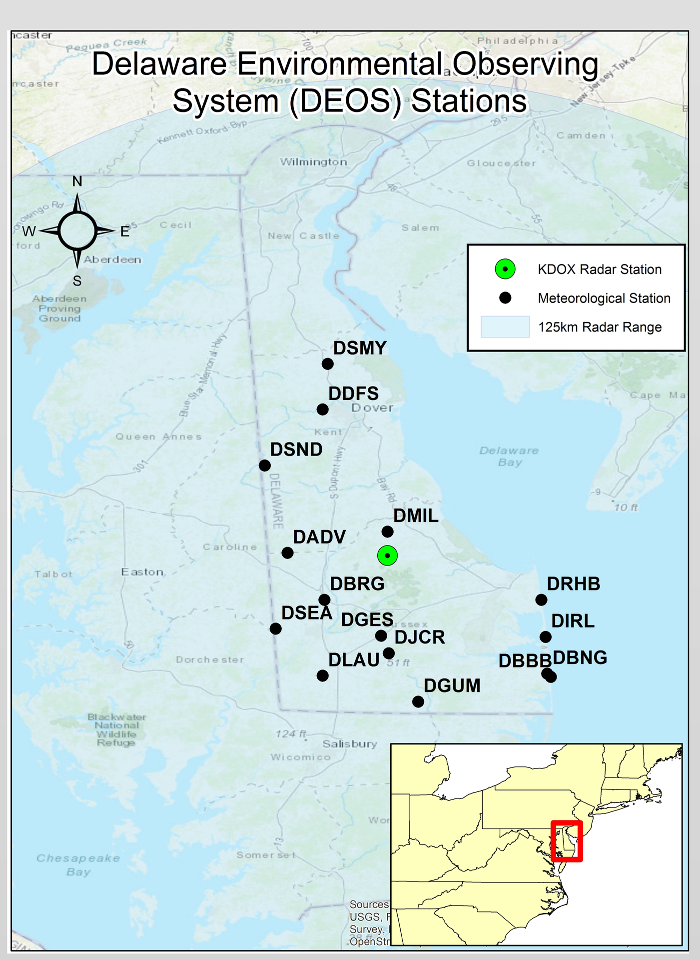

Figure 2 – Locations of meteorological weather stations and KDOX radar station used in this study.

Sea Breeze Radar Detection

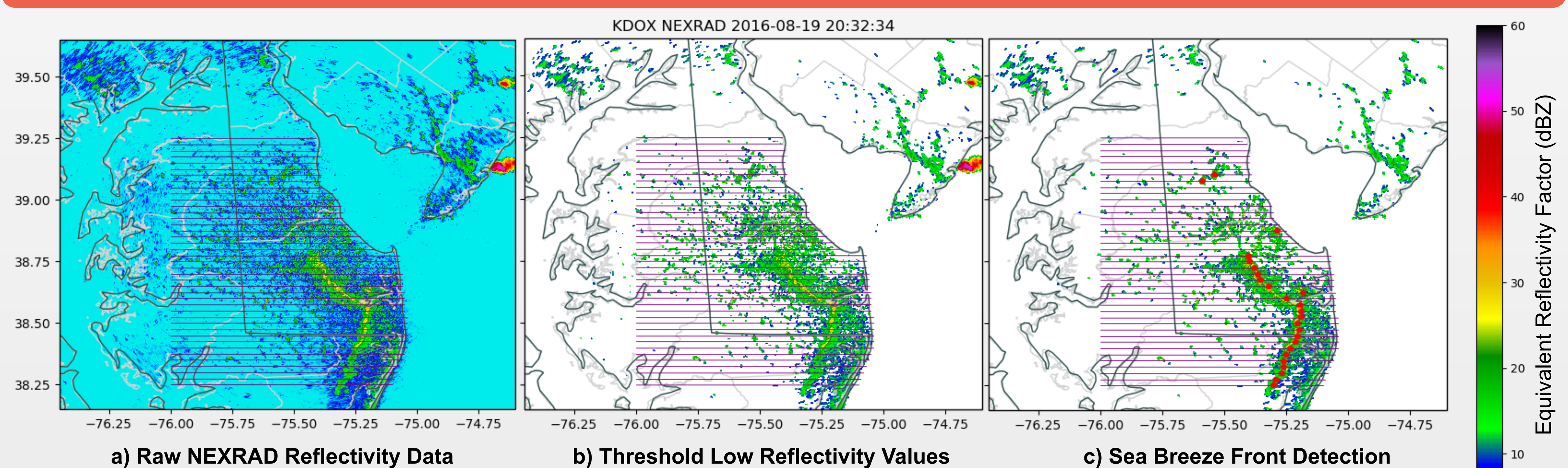

Figure 3 – Raw radar reflectivity data from August 8, 2016 (a) is processed by an algorithm to detect the presence and location of the SBF (red circles – c). The purple horizontal lines are used to track the location of the SBF as it propagates inland. The cluster analysis between b and c eliminate small clusters of <10 pixels, in addition to detecting, tracking, and eliminating precipitation regions (mean reflectivity >25 dBZ), as can be seen at approximately 39.2N, 74.7W in b and c.

Beginning with the raw reflectivity data (a), ground clutter and other insignificant values are eliminated by masking reflectivities above 8 dBZ and eliminating low values.

The algorithm uses spatial statistics to analyze contiguous regions of pixels, ensuring that erroneous reflectivities are not used for final detection of the SBF (c). The location, extent, and intensity of precipitation regions are recorded and will be used for further analysis.

The following criteria are used in the cluster analysis (b):

- Small (<10 pixels) clusters are eliminated
- Clusters representing precipitation (mean reflectivities >25 dBZ) are eliminated from final SBF detection

The SBF is detected by traversing transect lines from east to west, finding a pixel that fits the following conditions:

- 80/100 surrounding pixels are nonzero
- Region mean reflectivity > background reflectivity

Radar & Station SBF Detection – Case Study – July 4, 2017

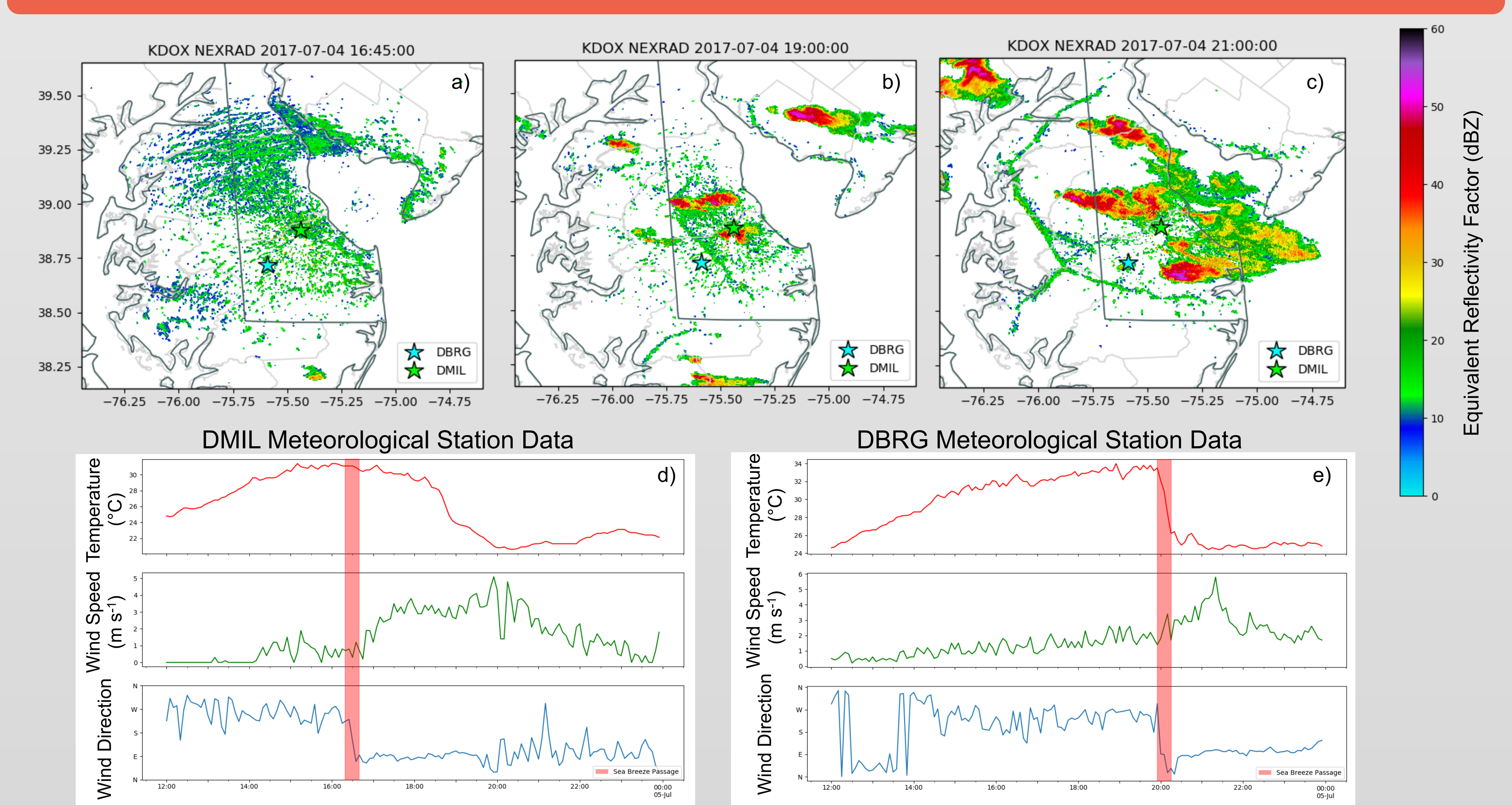

Figure 4 – Radar reflectivity data (a-c) from KDOX NEXRAD station in Dover, Delaware depicts a visible sea breeze with associated precipitation on July 4, 2017. Imagery from 16:45 UTC (a), 19:00 UTC (b), and 21:00 UTC (c) show the formation and propagation of the SBF as well as the formation of isolated convective cells (b & c). The location of two DEOS stations are depicted on the maps (a-c) and a time series of meteorological data from DMIL (d) and DBRG (e) are shown.

Station detection of sea breeze (see results section) is not flawless. DMIL station data fails to detect sea breeze due to the lack of temperature drop at the time of SBF passage (d), although it is visible via radar imagery (a).

As the SBF propagates inland, convective activity results from possible convergence behind the SBF (b).

Although DBRG is more inland, this station detects a large temperature drop of nearly 10°C (e). This is possibly associated with thunderstorm outflow (b & c).

It is beneficial to use both station and radar detection to analyze the characteristics and properties of summertime SBC.

Results

Data from meteorological stations and the KDOX radar station are used to detect the presence of the SBC on the DelMarVa Peninsula for the period May-September of 2016-2017.

Following Gilchrist (2013), meteorological station data are used to detect the passage of a SBF at the 15 locations depicted in Figure 1. SB days are defined by the following criteria:

- Decrease in air temperature by at least 1°C over a 30-minute period, and
- Shift in wind direction from a westerly to an easterly direction over the same 30-minute period.

Associated precipitation days are defined by the following:

- No precipitation in 3 hours preceding SBF passage
- At least 1mm of rainfall in the hour following SBF passage

The radar detection method described was used to analyze the same time period. The results are shown in the table below.

	Station Detection	Radar Detection
SB Days (2016-2017)	128	16
SB Days w/ Precipitation (2016-2017)	18	8

Only 12.5% of station detected SB days were captured by radar imagery.

A higher proportion of precipitation days to SB days are found via radar. Hence, an SBF identified by the radar detection algorithm is associated with a higher potential for producing precipitation.

Conclusion

The preliminary results shown here indicate the potential effectiveness of an automated radar detection algorithm for studying the formation and evolution of a SBF, especially those associated with precipitation events. **11 of the 16** SBF detected via radar were also detected via station data. As a result, further analysis must be done to decrease false detections. The algorithm described will be used to study the SBC on the DelMarVa Peninsula from 2013-2017, expanding upon preliminary results. Work from this study will be used to determine environmental factors that contribute to SBC related precipitation events on the DelMarVa Peninsula.

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References

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