A Climatology of Precipitating Open-Cell Convection over the Northeast Gulf of Alaska

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ABSTRACT

This brief paper addresses the frequency of precipitating open-cell convection over the northeastern Gulf of Alaska during a 5-yr period (2002–06). The research employs 154 previously documented satellite synthetic aperture radar–derived wind speed (SDWS) images that contain open-cell convection signatures. Each SDWS image is paired with a near-in-time, National Weather Service Weather Surveillance Radar-1988 Doppler Level-III 0.5°-elevation-angle short-range base reflectivity image from coastal Alaska for which coverage spatially overlaps open-cell convection signatures. The time difference between any two images of a single pair is typically a few minutes or less. For 65% of the image pairs, at least one SDWS open-cell convection signature in the overlap region is associated with precipitation. That percentage may be conservative given the method used in this research. Thus, the results of this research support a suggestion that has been posed in previous studies that the organization of open-cell convection can be controlled by the interaction of the environmental vertical wind shear and precipitation-driven cold pools.

1. Introduction

Sikora et al. (2011) present a climatography of open-cell convection for the northeastern Pacific Ocean. That climatography was constructed using satellite synthetic aperture radar–derived wind speed (SDWS) images and reanalysis data from the National Centers for Environmental Prediction–National Center for Atmospheric Research reanalysis project. Background information on SDWS can be gleaned from Monaldo et al. (2014), and that for the reanalysis data was available online at the time of writing (http://www.cdc.noaa.gov/cdc/reanalysis/reanalysis.shtml). Detailed reviews covering, among other topics, open-cell convection include Atkinson and Zhang (1996) and Wood (2012).

Of interest to the research that is presented here is the finding by Sikora et al. (2011) that the vertical distribution of environmental vertical wind shear found in their climatography is conducive to the organization of convection via the shear's interaction with precipitation-driven cold pools (e.g., Johnson et al. 2005). That interaction is referred to herein as cold-pool dynamics. The resulting organization reported by Sikora et al. (2011) manifests as an arc of deeper convective clouds that correspond to a squall and trailing shallower convective clouds ringing a nearly cloud-free lull, with the open-cell convection typically occurring in fields. See Figs. 1 and 2 in Sikora et al. (2011) for examples of the SDWS and the Moderate Resolution Imaging Spectroradiometer (MODIS) true-color signature of open-cell convection, respectively.

Sikora et al. (2011) were motivated by an earlier case study, focused on the Gulf of Alaska (Young et al. 2007), in which the connection between cold-pool dynamics and the organization of open-cell convection is hypothesized. That said, neither study employed precipitation data. Thus, Young et al. (2007) and Sikora et al. (2011) do not document precipitation, which is a necessary ingredient for precipitation-driven cold pools.

Other researchers have investigated the role of precipitation-driven cold pools in the organization of open-cell convection [see section 5 of Sikora et al. (2011) and section 7 of Wood (2012) for a review]. As Sikora et al. (2011) and Wood (2012) state, however, there is a

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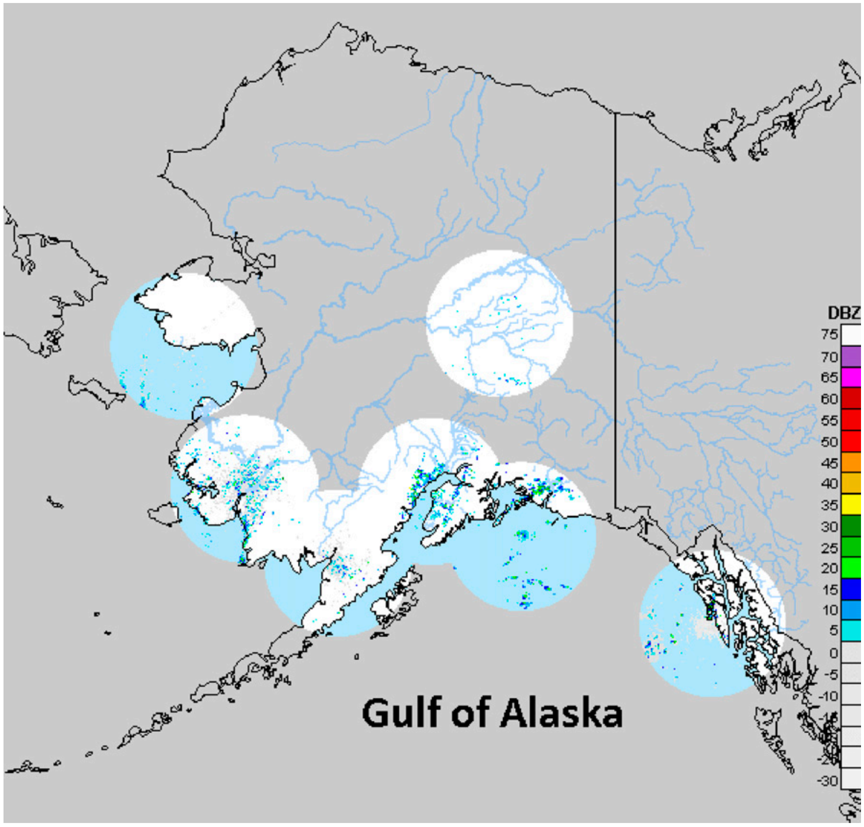

FIG. 1. Sample National Weather Service Alaska weather radar mosaic. The four WSR-88Ds that border the Gulf of Alaska were considered in this study. From right to left, they are Sitka/Biorka Island (PACG), Middleton Island (PAIH), Kenai (PAHG), and King Salmon (PAKC).

need for additional research on the relationship between precipitation and open-cell convection morphology. Also, that need exists at mid- and high latitudes.

To that end, this research extends the work of Sikora et al. (2011) by comparing a subset of their documented events of open-cell convection with National Weather Service Weather Surveillance Radar-1988 Doppler (WSR-88D) base reflectivity data from coastal Alaska. Thus, it addresses whether open-cell convection from the Sikora et al. (2011) climatography is associated with precipitation.

2. Methods

The climatological period of Sikora et al. (2011) is from 1999 to 2006. For that period, Sikora et al. (2011) document 616 fields of open-cell convection signatures within their SDWS images. Their SDWS images were acquired from the Johns Hopkins University Applied Physics Laboratory's online archive (http://fermi.jhuapl.edu/sar/stormwatch/web_wind/). Refer to section 3 of Sikora et al. (2011) for additional information about the SDWS images that were examined.

The WSR-88Ds considered in the research that is presented here are the four that border the Gulf of Alaska: Sitka/Biorka Island (PACG), Middleton Island (PAIH), Kenai (PAHG), and King Salmon (PAKC) (see Fig. 1). The source of WSR-88D data for this research is the National Climatic Data Center's Next Generation Weather Radar (NEXRAD) online data archive (http://www.ncdc.noaa.gov/nexradinv/). Level-II data for the years of interest were not available for download at the time that this research was conducted. Full year Level-III data were available for years from 2002 onward. Therefore, the period of study for this research is from 2002 to 2006. The Level-III product used in this research is 0.5°-elevation-angle short-range base reflectivity. Latitude and longitude lines were added to the WSR-88D images by using the Integrated Data Viewer software package. Upon inspection of the WSR-88D images, it became clear that the data from PAHG and PAKC would be of little value to this research because of both terrain

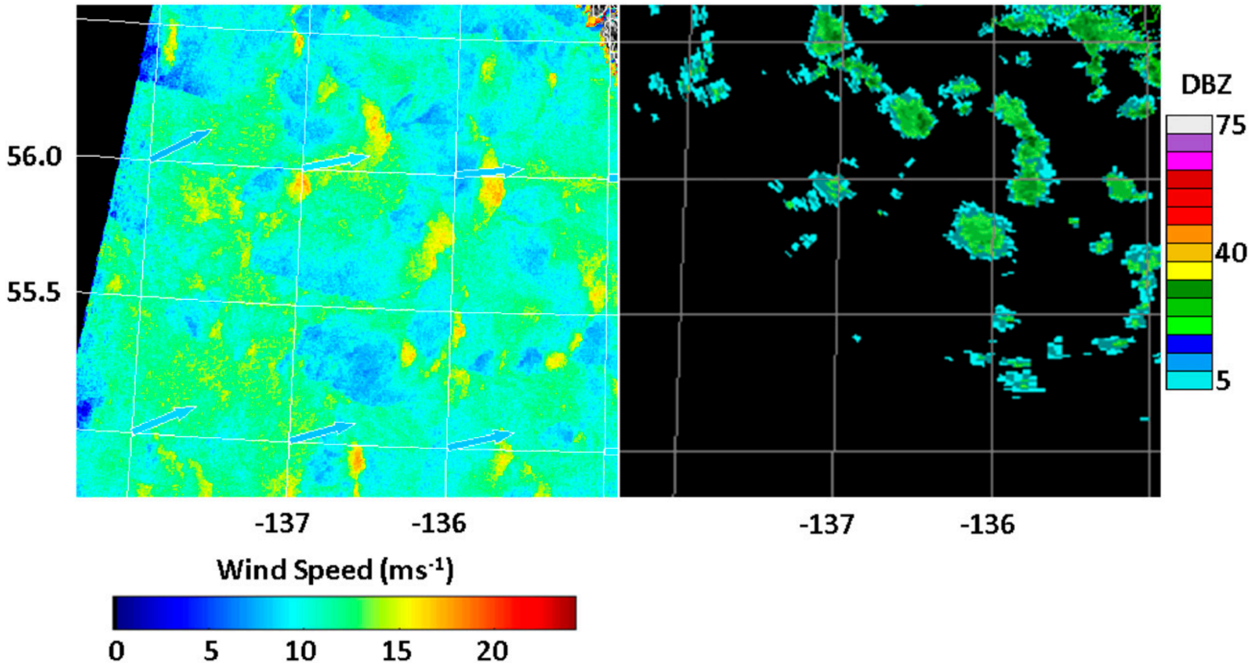

FIG. 2. (left) Portion of an SDWS image from 1516 UTC 9 Mar 2004. For image properties, see online (http://fermi.jhuapl.edu/sar/stormwatch/web_wind/04mar//sar200403091516221344w565n.txt). (right) Portion of a PACG 0.5°-elevation-angle short-range base reflectivity image from 1516 UTC 9 Mar 2004.

blockage and, in the absence of that, limited extent over the Gulf of Alaska. Data from those two locations were therefore eliminated.

A total of 154 SDWS images from the Sikora et al. (2011) climatography contain open-cell convection signatures that overlap in space with coverage in contemporary WSR-88D images from either PACG or PAIH. Corresponding image pairs were formed. The time difference between any two images of a single pair is typically a few minutes or less, with the average and standard-deviation time difference being 1.5 and 1.3 min, respectively. This method allowed for direct comparison of individual cells in the overlap region.

Although it is relatively straightforward to identify visually a field of open-cell convection signatures within an SDWS image, the act of visually assessing the number of individual signatures that compose a single field can introduce subjectivity because of the varying shape, size, and wind speed gradient that are associated with the corresponding signatures [e.g., see Fig. 1 in Sikora et al. (2011)]. Thus, an attempt to deduce the total number of SDWS open-cell convection signatures that correspond to precipitation from the 154 image pairs was not undertaken.

Instead, each of the 154 image pairs was visually inspected to assess whether at least one of the SDWS open-cell convection signatures in the overlap region was associated with precipitation. If at least one SDWS open-cell convection signature in the overlap region was associated with precipitation, the corresponding image pair was dubbed a "hit." If no SDWS open-cell convection signatures in the overlap region were associated with precipitation, the corresponding image pair was dubbed a "nonhit." Figure 2 presents a portion of an image pair (the parent SDWS image and WSR-88D image are both larger than is shown in the figure). Similarities between the northeastern portions of the two images in Fig. 2 abound. Thus, the image pair corresponding to Fig. 2 is a hit.

3. Results and discussion

Figure 3 shows image-pair hits, nonhits, and combined hits and nonhits by month. As expected, given the results of Sikora et al. (2011), the open-cell convection sampled in this research is a seasonal phenomenon, occurring more frequently during the cold season than during the warm season. Of the 154 image pairs, 100 are hits and 54 are nonhits. Therefore, nearly 65% of the image pairs are hits.

The number of hits reported herein could be conservative. The wind speed within SDWS images is that at 10 m above sea level (Monaldo et al. 2014) while the WSR-88D beam height varies with range. As reported by Young et al. (2007), there is a spectrum of cloud-top height associated with open-cell convection. The tallest

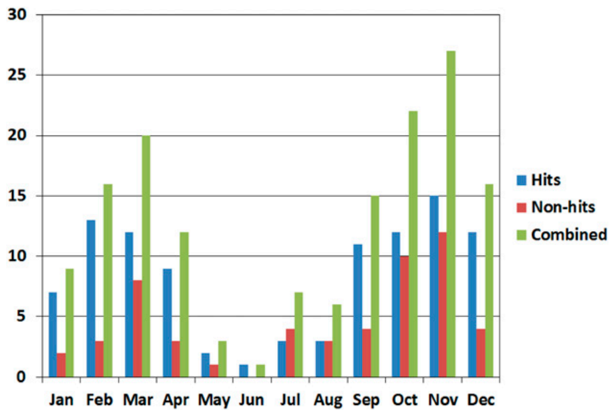

FIG. 3. Number of image-pair hits, nonhits, and combined hits and nonhits by month.

open-cell clouds of their study reach approximately 500 hPa, which corresponds to about 5490 gpm (see their Fig. 8). Short-range base reflectivity data range to near 230 km. At that range, the 0.5° beam center height is close to 5400 m above the elevation of the WSR-88D for standard refractive conditions. Therefore, it is possible that the PACG (radar elevation of 78 m above sea level) beam and the PAIH (radar elevation of 35 m above sea level) beam (elevation data were obtained online at http://www.roc.noaa.gov/WSR88D/Program/SiteID.aspx) overshot certain open-cell convection precipitation, with the chance of overshooting increasing with distance from the WSR-88Ds.

As a modest first step toward quantifying this issue, for each image-pair hit, robust SDWS open-cell convection signatures that were associated with precipitation were identified. In a similar way, for each image-pair nonhit, robust SDWS open-cell convection signatures in the overlap region were identified. Then, for each image pair, the robust signature chosen for further analysis was that closest to the WSR-88D of interest. Those signatures are referred to herein as hit signatures and nonhit signatures. Next, the distance between each hit/nonhit signature and the corresponding WSR-88D was calculated. The result is two distance distributions, one for hit signatures and the other for nonhit signatures. First-quartile, second-quartile (median), and third-quartile values for each distribution, along with the distributions' skewness and kurtosis, are found in Table 1. The nonhit-signature distribution possesses larger quartile distances than does the hit-signature distribution, and both distributions exhibit slight negative skewness and negative excess kurtosis. Proceeding, then, with the assumption that the two distributions' shapes are similar, a Mood's median test (Mood 1954) was conducted. The resulting P value is 0.04, indicating that the medians of the two distance distributions are different at the 95% confidence level.

TABLE 1. First quartile, median, third quartile, skewness, and kurtosis for hit-signatures and nonhit-signatures distance distributions.

	Hit signatures	Nonhit signatures
First quartile (km)	97	99
Median (km)	141	163
Third quartile (km)	173	195
Skewness	−0.3	−0.7
Kurtosis	−0.8	−0.7

Therefore, this analysis supports the overshoot suggestion that was discussed above. Further quantification of this issue is left for future work.

4. Summary

Both Young et al. (2007) and Sikora et al. (2011) suggest that the organization of open-cell convection observed over the Gulf of Alaska/northeastern Pacific Ocean is controlled by cold-pool dynamics, but neither study confirms the existence or nonexistence of precipitation corresponding to the open-cell convection. The research that is presented here fills that data gap by employing a subset of the SDWS images of open-cell convection signatures reported by Sikora et al. (2011). Each SDWS image is paired with a near-in-time WSR-88D Level-III 0.5°-elevation-angle short-range base reflectivity image from either PACG or PAIH whose coverage spatially overlaps open-cell convection signatures. The time difference between any two images of a single pair is typically a few minutes or less. For nearly 65% of those image pairs, at least one SDWS open-cell convection signature in the overlap region is associated with precipitation. Given the expected maximum depth of Gulf of Alaska open-cell convection (~500 hPa), it is possible that the 0.5°-elevation-angle WSR-88D beams overshot certain open-cell convection precipitation. Thus, the percentage of image pair hits reported herein could be conservative.

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