REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 17/06/2013	**2. REPORT TYPE** Progress Report Technical	**3. DATES COVERED** *(From - To)* 6/15/2012 – 6/14/2013

4. TITLE AND SUBTITLE
"Sea Spray and Icing in the Emerging Open Water of the Arctic Ocean"

5a. CONTRACT NUMBER
N00014-12-C-0290

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER
ONR S068P – Progress Report 1

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution Statement A. Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

With the sea ice cover in the Arctic Ocean declining, the more extensive areas of open water will foster more frequent storms, higher winds, and bigger waves. These conditions can create copious amounts of sea spray. We anticipate that structures placed in shallow water—wind turbines or drilling rigs, for instance—will, therefore, experience more episodes of freezing spray that will create hazards for both personnel on these structures and for the structures themselves. Few observations, however, have been made of sea spray generation in high winds above, say, 15–20 m/s; and no spray observations have been made in freezing temperatures. Our objective is, thus, to observe the size distribution and rate of creation of spray droplets at air temperatures below freezing and in winds above 15 m/s—and, preferably, above 20 m/s.

Climatologically, Mt. Desert Rock, a small, well exposed island 24 miles into the Atlantic Ocean from Bar Harbor, Maine, seemed to provide just such conditions in January. Andreas and collaborator Kathy Jones thus spent most of January 2013 observing sea spray and measuring relevant meteorological and ocean conditions on Mt. Desert Rock. We are in the early stages of data analysis but did encounter frequent winds near 20 m/s and temperatures below freezing during our deployment.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	UL	6	**19b. TELEPHONE NUMBER** *(include area code)* 603-448-3555

Title: **Sea Spray and Icing in the Emerging Open Water of the Arctic Ocean**
POP: 6/15/2012–6/14/2013
CDRL A002: Progress Report Technical
Award Number: N00014-12-C-0290

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Total contract amount: $286,026
Costs incurred to date: $74,011
Estimate to complete: $212,015

ABSTRACT

With the sea ice cover in the Arctic Ocean declining, the more extensive areas of open water will foster more frequent storms, higher winds, and bigger waves. These conditions can create copious amounts of sea spray. We anticipate that structures placed in shallow water—wind turbines or drilling rigs, for instance—will, therefore, experience more episodes of freezing spray that will create hazards for both personnel on these structures and for the structures themselves. Few observations, however, have been made of sea spray generation in high winds above, say, 15–20 m/s; and no spray observations have been made in freezing temperatures. Our objective is, thus, to observe the size distribution and rate of creation of spray droplets at air temperatures below freezing and in winds above 15 m/s—and, preferably, above 20 m/s.

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LONG-TERM GOALS

The goal of this project is to develop the capability to quantify both the concentration of sea spray over the open ocean and the severity of sea spray icing on fixed offshore structures. We will use existing information on the relationship of the spray concentration distribution to wind speed (Lewis and Schwarz 2004; Jones and Andreas 2012) to estimate the sea spray climatology in ice-free northern oceans from reanalysis data and the time-varying extent of the sea ice cover. Our field campaigns in the first and second years will focus on measuring sea spray parameters and relevant meteorological conditions to characterize spray droplet distributions at high wind speeds and cold temperatures. Sea spray data at high wind speeds are sparse, and there are no measurements of the spray droplet concentration at air temperatures below freezing. This effort directly addresses two of the focus areas in the core ONR Arctic program:

- Improving understanding of the physical environment and processes in the Arctic Ocean.
- Developing integrated ocean-ice-wave-atmosphere Earth system models for improved predictions on time scales of days to months.

OBJECTIVES

Our objectives are as follows:

- Use reanalysis data to estimate spatially and temporally distributed sea spray concentrations over the northern oceans. Such estimates are currently limited by the sparse information on sea spray at high wind speeds. Adapt the Andreas et al. (2008, 2010) spray algorithms for high wind speeds and subfreezing temperatures.
- Use these estimates of sea spray concentrations to characterize the icing risk for offshore structures in northern regions by adapting the heat balance calculation for freezing rain in Jones (1996) to saline droplets and by modifying the Finstad et al. (1988) collision efficiency algorithm to take into account the larger mass of saline droplets compared to freshwater droplets.
- Determine the properties of sea spray in high wind speeds by making droplet concentration measurements on fixed offshore structures or at well exposed coastal sites at air temperatures below freezing.
- Measure the density of ice accreted from sea spray on fixed structures and develop a relationship between spray ice density and weather parameters.
- Use our sea spray measurements to revise the Jones and Andreas (2012) spray concentration distribution for high wind speeds; update our initial icing risk analysis.
- Rapidly disseminate all data and metadata.

APPROACH

This project is a collaboration between Andreas and Kathy Jones of the U.S. Army's Cold Regions Research and Engineering Laboratory, who is funded under a separate award (N0001412MP20085).

Our goal is to quantify the concentrations of wind-generated sea spray and the resulting spray icing on offshore structures, such as wind turbines and exploration, drilling, and production platforms. Our approach combines 1) the simulation of sea spray and icing from reanalysis data and data from moored buoys and coastal stations, 2) a field campaign to measure the liquid water content and median volume droplet radius of sea spray in high winds, 3) the development of a spray concentration density function for high wind speeds, 4) the estimation of the spatial distribution of sea spray in all seasons, and 5) the determination of icing risk when the air temperature is below freezing in northern oceans.

In the field, we will observe the spray size distribution with two techniques. First, we will manually expose coated glass slides briefly to the spray and then use computer software to size droplets in photographs of the slides.

Our second spray instrument will be a cloud imaging probe, which we are borrowing from Chris Fairall of NOAA's Earth System Research Laboratory. This device consists of an optical array; it photographs and then automatically sizes droplets moving through the array. It sizes droplets with

Figure 1. Mt. Desert Rock in the Alantic Ocean at 43° 58.2’ N, 68° 7.7’ W.

diameters from 25 μm up to 1.55 mm in 62 bins that are each 25 μm wide. The integral of the third moment of the droplet concentration from the cloud imaging probe is the spray liquid water content.

To characterize the meteorological conditions in which we observe the spray and, thereby, to develop parameterizations for spray concentration, spray production rate, and icing rate, we will also deploy a full suite of turbulence instruments. These instruments will provide mean wind speed, temperature, humidity, and pressure and the turbulent air-sea surface fluxes of momentum and sensible and latent heat.

WORK COMPLETED

Most of the first year’s work revolved around preparing for and participating in a one-month field experiment.

In August 2012, Andreas and Jones made a brief visit to Mt. Desert Rock (Figure 1), a small island 24 miles out to sea from Bar Harbour, Maine, to evaluate it as a potential site for our field work. At high tide, Mt. Desert Rock is roughly the size of two football fields and features the most exposed

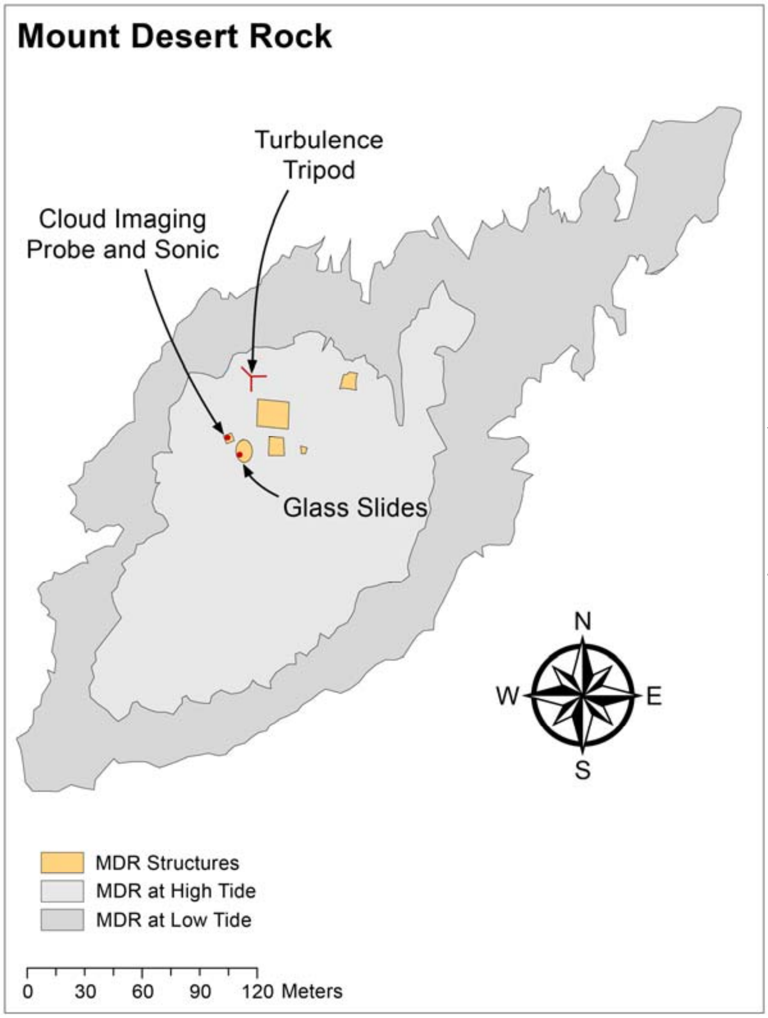

Figure 2. Map of Mt. Desert Rock showing its shoreline at low and high tide, the structures on the island, and locations of our instruments during our January 2013 experiment. The yellow oval is the lighthouse.

lighthouse on the U.S. east coast. The only other structures on the island are a rustic house that previously served as the residence for the lighhouse keeper, a boat ramp, and a foghorn. College of the Atlantic in Bar Harbor administers Mt. Desert Rock and uses it primarily for observing seals, whales, and sea birds.

Mt. Desert Rock seemed like a good location for our work because its climatology for Janaury suggested we could see winds near 20 m/s and subfreezing temperatures. Hence, we contracted with College of the Atlantic to support our month-long experiment. We were on Mt. Desert Rock from 29 December 2012 to 28 January 2013.

For our measurement on the "Rock," we had three instrument sites (Figure 2). We deployed the cloud imaging probe and its associated sonic anemometer/thermometer on the foghorn platform (Figure 3). Jones collected spray droplets on glass slides that she exposed at the top of the lighthouse or next to the cloud imaging probe and photographed the droplets on the slides for computer analysis of size and number. We also deployed a second sonic anemoeter/thermometer, a Li-Cor water vapor and carbon dioxide sensor, and an Ophir hygrometer/thermometer on a "turbulence" tripod near the northeast shore of the island (Figure 4).

Figure 3. The cloud imaging probe and its associated sonic anemometer/thermometer deployed on the foghorn platform on Mt. Desert Rock.

Figure 4. The "turbulence" tripod with its sonic anemometer/thermometer, carbon dioxide and water vapor sensor, and hygrometer/thermometer deployed near the shore of Mt. Desert Rock.

The cloud imaging probe and its associated sonic sampled almost continuously from 1 January through 27 January 2013. Instruments on the tubulence tripod ran continuously from 4 January until 26 January.

We are still in the early stages of data analysis, but conditions on Mt. Desert Rock were good for our objective of studying freezing sea spray. We had frequent episodes of winds between 15 and 20 m/s, and air temperature were well below 0°C for roughly one-third of our observations.

DELIVERABLES

This is a basic research project: We are not building things. Rather, our products are scientific knowledge that is generally disseminated in the scientific literature or at scientific conferences.

Jones will present our first such product at the Twenty-Third International Ocean and Polar Engineering Conference (ISOPE-2013) in Anchorage, Alaska, in late June and early July 2013. Our jointly authored contribution is "Risk of Sea Spray Icing to Offshore Structures"; our manuscript on this topic will also be published in the conference proceedings.

PROBLEMS

One minor problem that Andreas, in particular, faced was that ONR was unable to get a contract with NorthWest Research Associates in place by our requested start date for this project, 1 January 2012. In fact, the contract was not in effect until 15 June 2012. As a result, the January 2013 field experiment that we had planned for the second year of our project actually occurred in the first year. The upshot was that NWRA's first-year budget was insufficient to cover all of Andreas's salary and per diem for his month on Mt. Desert Rock.

Fortunately, though, ONR allocated additional funds from our second year budget before our deployment to Mt. Desert Rock. Hence, the finances turned out all right, but we have already spent about $20,00 of our second-year budget.

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