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# Norwegian Young Sea Ice Experiment (N-ICE) Field Campaign Report

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ARM
CLIMATE RESEARCH FACILITY

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# Norwegian Young Sea Ice Experiment (N-ICE) Final Campaign Summary

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# Executive Summary

The Norwegian Young Sea Ice (N-ICE) experiment was conducted aboard the *R/V Lance* research vessel from January through June 2015. The primary purpose of the experiment was to better understand thin, first-year sea ice. This includes understanding of how different components of the Arctic system affect sea ice, but also how changing sea ice affects the system. A major part of this effort is to characterize the atmospheric conditions throughout the experiment. A micropulse lidar (MPL) (S/N: 108) was deployed from the U.S. Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility as part of the atmospheric suite of instruments. The MPL operated successfully throughout the entire experiment, acquiring data from 21 January 2015 through 23 June 2015. The MPL was the essential instrument for determining the phase (water, ice or mixed) of the lower-level clouds over the sea ice.

Data obtained from the MPL during the N-ICE experiment show large cloud fractions over young, thin Arctic sea ice from January through June 2015 (north of Svalbard). The winter season was characterized by frequent synoptic storms and large fluctuations in the near-surface temperature. There was much less synoptic activity in spring and summer as the near-surface temperature rose to 0 C. The cloud fraction was lower in winter (60%) than in the spring and summer (80%). Supercooled liquid clouds were observed for most of the deployment, appearing first in mid-February. Spring and summer clouds were characterized by low, thick, uniform clouds.

# Acronyms and Abbreviations

| | |
|---|---|
| ARM | Atmospheric Radiation Measurement Climate Research Facility |
| BBC | British Broadcasting Corporation |
| DOE | U.S. Department of Energy |
| ICECAPS | Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit Experiment |
| MPL | micropulse lidar |
| N-ICE | Norwegian Young Sea Ice Experiment |
| NPI | Norwegian Polar Institute |
| RHi | relative humidity with respect to ice |
| RHw | relative humidity with respect to water |

# Contents



# Figures

# 1.0 Background

The Norwegian Young Sea Ice experiment (N-ICE; pronounced "en ice") was conducted aboard the *R/V Lance* research vessel from January through June 2015. The primary purpose of the experiment was to better understand thin, first-year sea ice. This includes understanding how different components of the Arctic system affect sea ice (e.g., atmosphere, ocean), but also how changing sea ice affects the system (e.g., ecology, biology). Therefore, a major part of this effort was to characterize the atmospheric conditions throughout the experiment. As part of the atmospheric suite of instruments, a micropulse lidar (MPL) (S/N: 108) was deployed from the U.S. Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility. The MPL operated successfully throughout the entire experiment, acquiring data from 21 January 2015 to 23 June 2015. Minor data gaps occurred only 21 times during otherwise normal operations due to temporary power outages and problems with the computer data acquisition system.

Figure 1 shows the track of the *R/V Lance* during the experiment when the MPL was in operation. The experiment was not conducted at a particular ARM site, but rather north of Svalbard as shown.

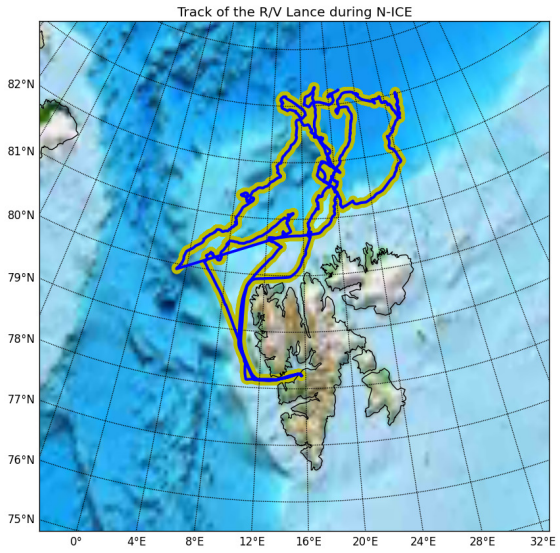


**Figure 1**. Track of the R/V Lance during the N-ICE experiment, January through June 2015.

The principal investigator of the N-ICE experiment is Dr. Harald Steen from the Norwegian Polar Institute (NPI) in Tromsø, Norway. The leader of the "Atmospheric Work Package" (atmospheric measurement group) is Dr. Stephen R. Hudson, also from NPI. The principal investigator of the DOE ARM deployment of the MPL is Dr. Von P. Walden from the Laboratory for Atmospheric Research at Washington State University. Dr. Lana Cohen is a postdoctoral researcher at NPI and was involved in the deployment and operation of the MPL aboard the *R/V Lance*.

# 2.0 Notable Events or Highlights

Figure 2 shows the meteorological measurements that were obtained near the *R/V Lance* during N-ICE. Two distinct weather regimes were experienced during this experiment. Large pressure fluctuations were observed during the first two months of the experiment from mid-January through mid-March. The rapid decreases in pressure were associated with the passage of synoptic weather systems that were also accompanied by precipitation events (see blue stars in Figure 2). These storms caused extremely large increases in the near-surface temperatures with transitions from -35 to -40 C to nearly 0 C. Large variations were also seen in the relative humidity with respect to water (RHw), but the RH with respect to ice (RHi) remained near saturation (100%) throughout the entire winter. The wind speeds were high during the synoptic storms, and the wind direction was quite variable in winter.

In contrast, spring and summer conditions (from mid-April through June) were characterized by fewer synoptic events and much less variation in the surface pressure. There were only a few small precipitation events. The near-surface temperature gradually increased from -10 to -20 C to a constant value of 0 C after 1 June. More variation was observed in the RHi with sub-saturated values dipping to 70 and 80%. The maximum wind speeds were lower than in winter, and the wind direction was more constant. Northerly winds were common with occasional winds from the south when the surface pressure was low.

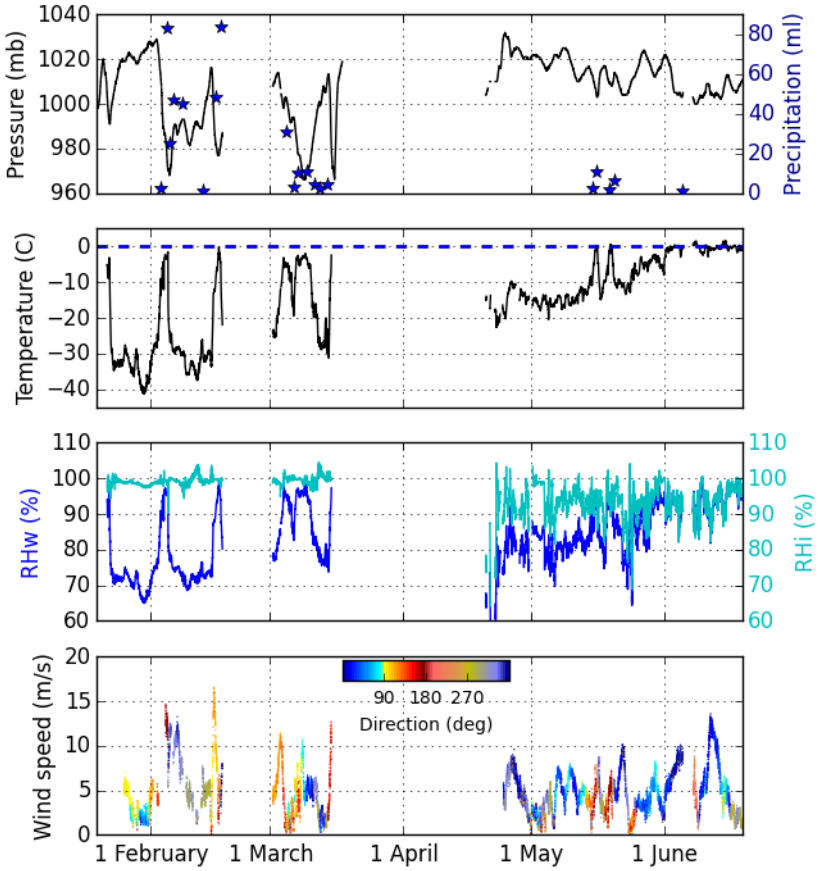


**Figure 2.** Meteorological observations obtained during the N-ICE experiment conducted from January through June 2015 aboard the *R/V Lance*.

The ARM micropulse lidar was installed above the bridge aboard the *R/V Lance* throughout the entire experiment. The cloud fraction during winter was lower (about 60%) than in spring/summer (80%). The percentage of completely overcast days was much higher in spring (39%) than in winter (13%).

Figure 3 shows some raw MPL data from 17 February 2015. (These data were obtained directly from the MPL data acquisition system and were not processed by ARM.) This day was the first time during N-ICE that a liquid-layer cloud was observed, the blue layer at approximately 1.5 to 2 km between 0600 and 1200 UTC. This cloud was the result of an influx of higher temperatures and moisture values from lower latitudes during the synoptic event in mid-February (see Figure 2). Liquid clouds are characterized by low depolarization ratios, which indicate spherical cloud particles, or droplets. After this day, liquid-cloud layers were quite common in spite of the fact that temperatures were always below 0 C.

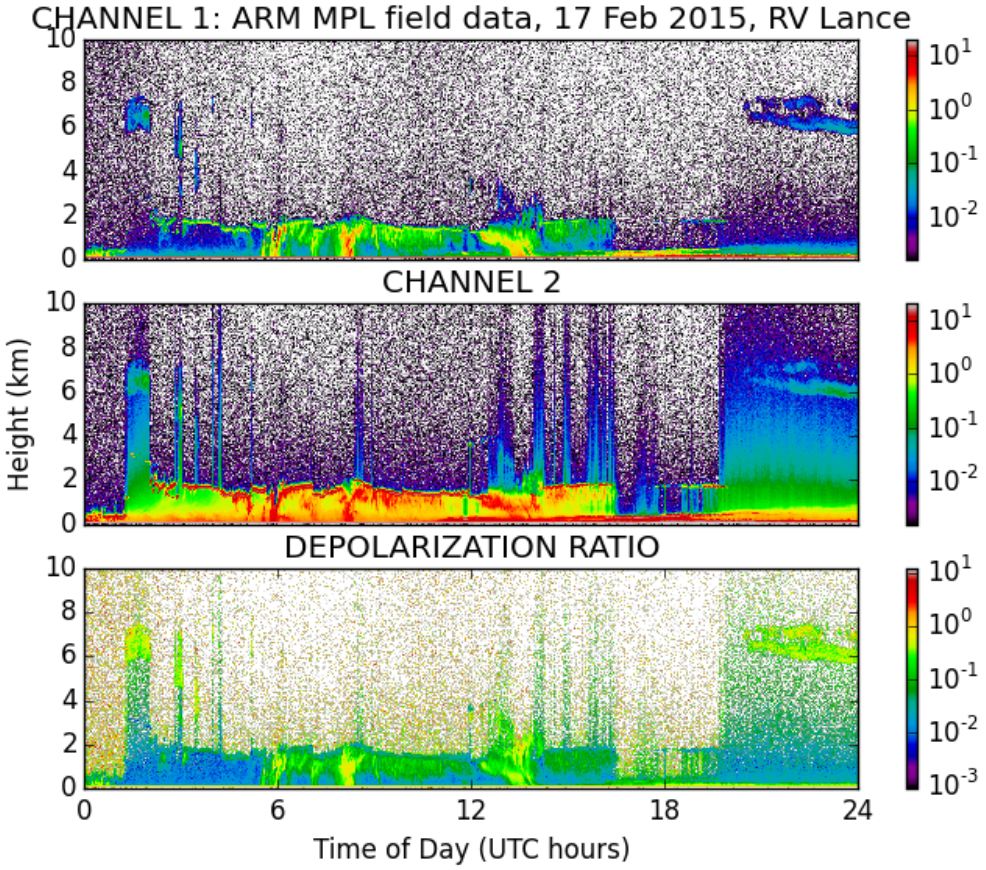


**Figure 3**. Raw data obtained during winter from the ARM MPL on 17 February 2015 from the N-ICE experiment aboard the *R/V Lance*, located on this day at 81.5 N, 19.6 E.

Figure 4 shows typical cloud conditions during the spring and summer during N-ICE. At this time of year, clouds are low (between 0.5 and 1 km) and are quite uniform. Due to the large cloud liquid water path, the MPL likely did not have enough energy to penetrate through the cloud to observe any additional upper-level clouds. However, this was not a limitation for the N-ICE experiment since we were primarily interested in how clouds affect the surface energy balance. Since these low water clouds observed in spring/summer are optically thick, they are the primary influence on the surface radiation, both through

the reduction of solar radiation and the increase (or trapping) of infrared radiation emitted by the surface. Because of this, the MPL cloud measurements will be combined with surface radiation measurements throughout N-ICE to determine the shortwave and longwave cloud radiative forcing.

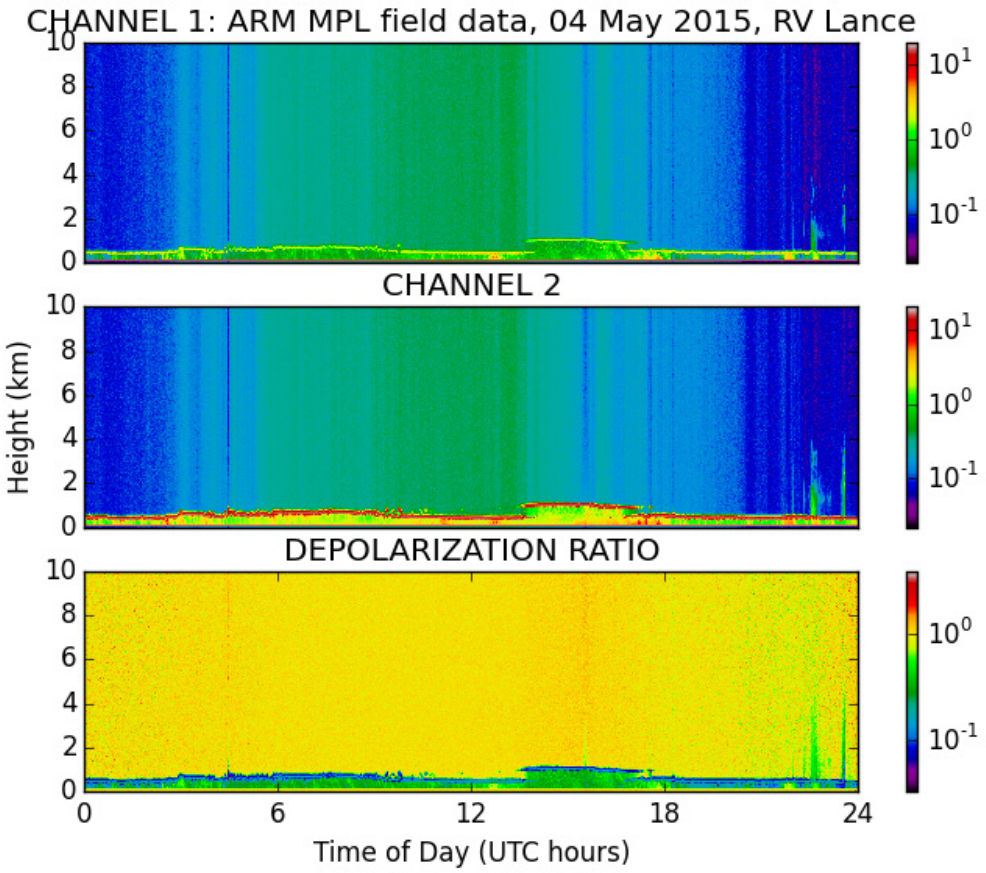


**Figure 4**. Raw data obtained during spring from the ARM MPL on 4 May 2015 from the N-ICE experiment aboard the *R/V Lance*, located on this day at 81.8 N, 13.0 E.

# 3.0 Lessons Learned

The MPL worked very well throughout the experiment; however, we had occasional issues with the computer acquisition system, which were difficult to diagnose. At least some of the events seemed to be caused by a temporary failure of the USB hub in the computer. The solution was to simply perform a "hard reboot" of the computer.

# 4.0 Results

Data obtained from the ARM micropulse lidar (S/N: 108) during the N-ICE experiment shows large cloud fractions over young, thin Arctic sea ice from January through June 2015 (north of Svalbard). The winter

season was characterized by frequent synoptic storms and large fluctuations in the near-surface temperature. There was much less synoptic activity in spring and summer as the near-surface temperature rose to 0 C. The cloud fraction was lower in winter (60%) than in the spring and summer (80%). Supercooled liquid clouds were observed for most of the deployment, appearing first in mid-February. Spring and summer were characterized by low, thick, uniform clouds.

The MPL raw data have been converted to ARM files (oscmplpolfsS6.b1.yyyymmdd.HHMMSS.cdf.v0) and have already been archived at the ARM Data Archive (http://www.archive.arm.gov/discovery/#v/results/s/fiop::osc2014nice). The PI, Von P. Walden, is currently processing these raw data files into value-added products, including lidar depolarization (cloud hydrometeor phase), cloud-base height, backscattered radiation, and cloud fraction.

Data analysis is continuing in collaboration with colleagues at the Norwegian Polar Institute over the next couple of years, with anticipated publications that will acknowledge DOE ARM Climate Research Facility support for this project. In particular, preparation is underway for the submittal of manuscripts to a special issue on N-ICE that will appear in the *Journal of Geophysical Research*; the submission deadline is 31 July 2016.

It should be noted that the MPL instrument that was used during N-ICE was shipped directly from Tromsø, Norway to Summit Station, Greenland, where the instrument is now deployed as part of the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) experiment.

# 5.0 Public Outreach

There was significant public outreach and press coverage of N-ICE, especially in Norway and Europe. Below are web links that show a sample of these activities:

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|---|---|
| Main project web site | http://www.npolar.no/en/projects/details?pid=b98886ce-590a-48a8-b113-4b96e98c65c8 |
| Project blog | http://www.npolar.no/en/expedition-field/n-ice2015/ |
| BBC coverage | http://www.bbc.com/news/science-environment-32553668 |

# 6.0 N-ICE Publications

## 6.1 Journal Articles/Manuscripts

Granskog, M, P Assmy, S Gerland, H Steen, and LH Smedsrud. 2016. “Arctic research on thin ice: Consequences of Arctic sea ice loss.” *EOS Earth and Space Science News* 97(5): 22-26, https://eos.org/project-updates/arctic-research-on-thin-ice-consequences-of-arctic-sea-ice-loss

## 6.2 Meeting Abstracts/Presentations/Posters

Hudson, SR, L Cohen, and VP Walden. 2015. "Atmospheric measurements over Arctic Sea Ice from winter to summer: Preliminary results from N-ICE 2015." Poster presentation at the 2015 American Geophysical Union annual fall meeting, 14-18 December 2015.

Graham, RM, A Rinke, L Cohen, SR Hudson, VP Walden, M Kayser, M Maturilli, W Dorn, and K Dethloff. 2016: "Two Arctic winter states observed during the N-ICE 2015 campaign." Poster presentation accepted at the 2016 European Geophysical Union annual meeting, 16-22 April 2016.

Cohen, L, SR Hudson, and VP Walden. 2016: "Seasonal variations of surface radiation and energy balance over Arctic sea ice during N-ICE2015 experiment." Oral presentation accepted at the 2016 International Radiation Symposium, 16-22 April 2016.


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