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ASSESSING THE REPRESENTATIVENESS OF BARROW SOUNDINGS USING AEROSONDES

J. O. Pinto[1], J. A. Maslanik[1], J. Inoue[2], J. A. Curry[2], and G. J. Holland[3]
[1]University of Colorado, Boulder, CO
[2]Georgia Institute of Technology, Atlanta, GA
[3]Aerosonde, Inc, Melbourne, AU

Introduction

Performance of radiosonde humidity sensors is known to degrade with decreasing temperature (e.g., Wang et al. 2002). Biases arise from a temperature-dependent lag in the sensor response (Miloshevich et al. 2001) and temperature dependence errors in the calibration coefficients (Wang et al. 2002). These biases are magnified in the polar regions where the entire profile is often well below 0 C and thin layers of moisture often exist.

The representativeness of soundings obtained at Barrow is not well known. This question is of importance as Barrow serves as the location for several climate observing systems including the DOE Atmospheric Radiation Measurement (ARM) North Slope of Alaska (NSA) site. This site is supposed to represent a typical GCM grid cell in the Arctic for process studies and climate monitoring. A key tool used by ARM researchers to understand 1D thermodynamic processes is the Single Column Model (SCM) which is assumed to represent processes occurring at horizontal scales of 30-50 km (Randall et al. 1996). Mesoscale processes (such as sea breezes, lead-induced internal boundary layers), which are neglected in SCM studies, could result in substantial horizontal variability in thermodynamic profiles that would limit the usefulness of SCM studies.

In this paper we discuss Aerosonde operations in Barrow and their application to determining the accuracy and representativeness of operational radiosondes launched by the NWS and ARM. The comparison is made in both spring and fall, representing entirely different surface and atmospheric conditions.

Description of the Aerosonde and its Operations in Barrow

The Aerosonde is a small long-endurance robotic aircraft that can obtain measurements in remote data sparse regions of the globe at an economy of cost. The Aerosonde flies with a mean speed of about 25 m s-1 and is highly maneuverable. The small size of the Aerosonde allows it to be extremely fuel efficient so that flight durations can easily exceed 20 hrs. The Aeorsonde communicates to the base station via UHF at ranges of 150 km or less. The use of satellite comms extends the Aerosonde's range to nearly 1000 km. It has an altitude range of between 100 and 4000 m. The Aerosonde carries two RS901 met sensors which are located on the wings. The Aerosonde is also equipped carry a downward-looking KT-11 radiometer and/or a digital camera.

The capability of Aerosonde operations in the Arctic has been developed through the NSF sponsored Arctic Long-Term Observing Program. To make operations in the Arctic feasible, engineering research and development was necessary in areas ranging from icing detection and mitigation systems to satellite comms, to engine and airframe modifications (Holland et al. 2001). Modifications to the Aerosonde resulting from these studies lead to major improvement in the capacity of the Aerosonde to operate in the Arctic (Curry et al. 2003).

Two month-long field missions were undertaken during 2002. A total of approximately 250 flight hours were flown during these two field missions with sounding profiles being obtained during most of the flights. Data from these flights are used to evaluate the accuracy and representativeness of operational sounding made by the National Weather Service (NWS) and at the DOE ARM site.

Sounding accuracies

Soundings are launched operationally by the NWS and the DOE ARM facility manager. The NWS launches VIZ-B2 radiosondes at 00 and 12 UTC each day. High resolution (6 sec or 30 m) data from these sondes have been made available by the JOSS. The ARM NSA recently switched from RS80-15H sondes prior to 25 April to RS90-A sondes. Sondes are launched from the ARM NSA site at 00 UTC just 5 days a week. These data are available in raw form at 2 sec time resolution

Corresponding author address: James O. Pinto, University of Colorado, Dept. of Aerospace Engineering, CB 429, Boulder, CO 80309; Email pinto@ucar.edu

or as 10 sec averages. The two fixed sounding sites are separated by less than 8 km (Fig.1).

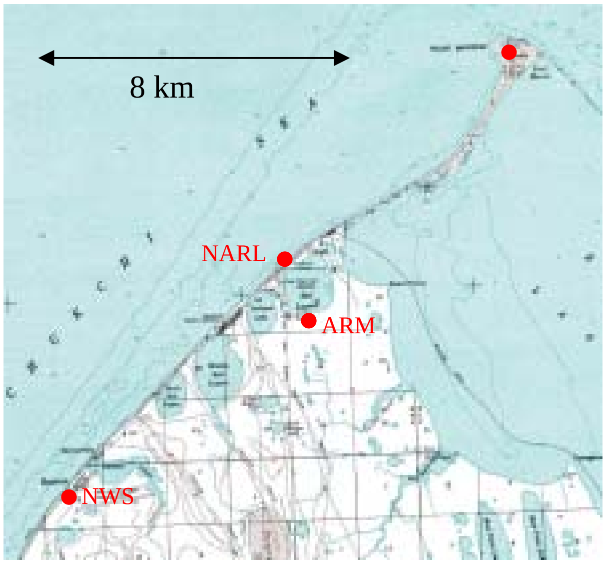

Figure 2. Relief map of Barrow and vicinity denoting locations of the NWS and ARM soundings sites and Aerosonde profiling locations at the NARL and Point Barrow.

An additional set of RS90 sondes were launched from the ARM NSA site as part of the Atmospheric Infrared Sounder (AIRS) validation project which is supported by NASA. In a few instances, these RS90 sondes launches were collocated with Aerosonde profiling at Point Barrow.

The Vaisala RS901 sensors used by the Aerosonde are carefully calibrated before each flight using a controlled environmental chamber. The RS901 humidity sensor has a faster response time than the RS80 and VIZ sensors. At -40 C, the RS90 sensor has a response time of 10 sec while the RS80-H sensors have a response time of 30 sec. This lag in the sensor's response to sharp variations in humidity is crucial when trying to sample the thin moisture layers commonly observed in the Arctic.

A total of 10 profiling missions were flown at Point Barrow for comparison with NWS and ARM sonde launches. Profiles were obtained with Aerosondes between 2300 UTC and 0100 UTC coincident with the operational sonde launches. An example is shown in Figure 2. Subtle differences in the profiles obtained between the three observation sites (just 16 km apart) can be attributed to both variations in sensor accuracies and horizontal variability.

The profile depicted in Fig. 2 is characterized by a moist layer surmounted by an extremely dry layer aloft. Winds from the west indicate that the flow is off the Arctic ice pack. The VIZ sonde tends to be too moist

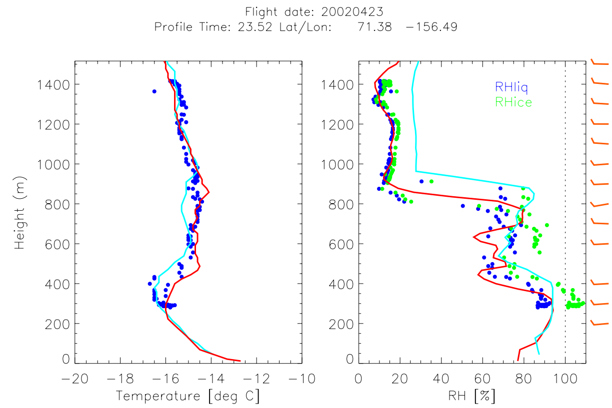

Figure 2. Sounding data obtained around 0000 UT on 24 April 2002 for the locations depicted in Figure 1 using the NWS VIZ-B2 sonde (cyan) and the ARM RS-80H sonde (red). Aerosonde data (blue or green dots) are from an up-down profile obtained at Point Barrow between 2330 and 0007 UTC. Wind barbs in the right margin are also from the Aerosonde.

throughout, particularly in the extremely dry layer above 900 m. This bias is similar to that reported by Wang et al. (2003) for sensors passing from a moist layer to an extremely dry one at cold temperatures or possibly due to temperature-dependent calibration issues or sensor freezing. The ARM and Aerosonde RHs agree fairly well. Variations between all three soundings between 300 and 900 m can be attributed to horizontal variability. The BL is rather moist and varies in depth (denoted by inversion) between 300 and 400 m based on NWS and ARM launches. The two profiles obtained by the Aerosonde seem to bracket this variability. Above the BL, air remains moist up to 900 m with RHs varying between 60 and 90% perhaps indicating entrainment of the extremely dry air aloft.

Comparison of Aerosonde profiles with that from collocated AIRS IOP sounding at Point Barrow on 9 May 2002 revealed surprising discrepancies. This particular RS90 sonde from the AIRS IOP had a dry bias of 5-10% throughout the lowest 1500 m of the atmosphere (not shown).

A more rigorous intercomparison using all the available profile data is presented in the talk.

Sounding Representativeness

As discussed above, the RH can vary by up to 30% over distances less than 20 km along the coast. This point is further demonstrated using data collected during a profiling mission flown on 6-7 September. The track was flown due north from the NARL runway with profiles being performed every 10 km. Variations of up to 20% are seen to occur over short distances, particularly at low levels (Fig. 3). In general, the RH in the BL increases with distance from shore. This might have been expected as winds were blowing off-shore for most of the day.

The temperature profiles obtained at the NARL by the Aerosonde and at the NWS at 0000 UTC differ dramatically below 200 m (Fig. 4). The strong surface-based inversion seen in the Aerosonde data is not evident at the NWS office. The surface air temperature at the NARL site is 2 C cooler than the NWS site located in town. The southerly wind component suggests that perhaps the air temperature at the NARL is modified somewhat by the surrounding lagoons!

The representativeness of the operational sondes is discussed in more detail in the talk.

Discussion

Sounding data collected at two fixed sites and with the Aerosonde indicate the presence of significant horizontal variability in T and q profiles in September, particularly below 1 km. These variations are caused by the presence of different surface types in September ranging from open tundra to developed land areas to open water. Variations in surface conditions in April and September are likely to have resulted in the minimal amount of horizontal variability compared with that which may be present at other times of the year including near-shore leads in winter, snow cover land vs open water in mid fall, and sea ice vs bare land in summer. Nonetheless, this study indicates that horizontal variations in T,q are likely significant throughout the year which may hamper SCM studies at Barrow in the future.

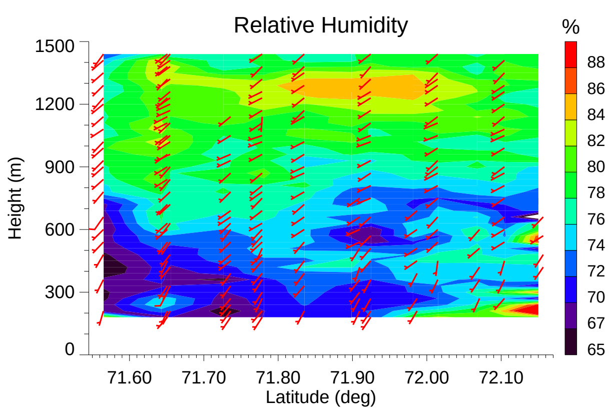

Figure 3. RH variability observed during N-S transect of profiles obtained by Aerosonde between 71.5 and 72.2 N along 156.7 W. This profiling transect was begun at 0030 UTC on 7 Sept 2002 and took 4.5 hours to complete.

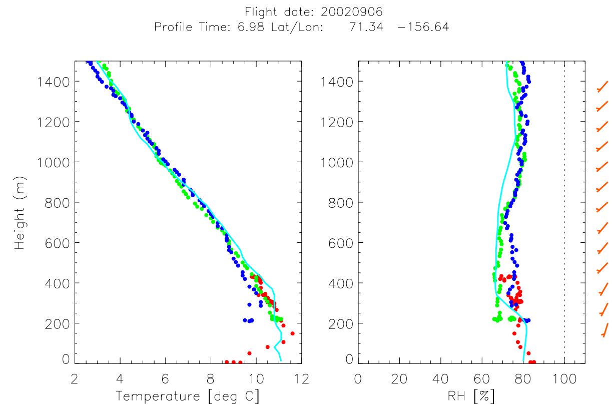

Figure 4. Temperature and humidity profiles obtained on 06-07 September 2002 by NWS radiosonde launched at 0000 UTC and 3 profiles by Aerosonde obtained at 2345 (#1 - red), 0045 (#2 - green) and 0400 UTC (#3 - blue). Wind barbs are from Aerosonde profile #2. Profile #1 was obtained during initial ascent from NARL runway. Profile #2 was flown 25 km north of #1 and profile #3 was flown 60 km north of #2.

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