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# USING A MESOSCALE MODEL AND UAVS TO QUANTIFY THE UNDER-REPRESENTATION OF CLIMATE VARIABILITY IN THE NCEP REANALYSIS OF COASTAL REGIONS IN THE ARCTIC

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## Introduction

The NCEP reanalyses are widely used to study pan-Arctic climate including the evaluation of global climate model simulations of present day climate (e.g., Walsh et al. (2002) and the assessment of the arctic hydrological cycle (Cullather et al. 2000; Serreze and Hurst 2000; Serreze et al. 2003) and energy budget (Walsh et al. 2002). While these analyses provide a best guess of the atmospheric variability over polar regions for the past 40+ years, the horizontal resolution of this dataset and others like it (e.g., ERA-40) are inadequate for assessing the local climate in regions of complex surface characteristics such as those found in coastal regions.

Profiles from the 2.5 degree NCEP reanalyses obtained at the four grid-points surrounding Barrow are compared with data from observations and a mesoscale model. Time periods of maximum surface variability have been chosen to assess the importance of resolving surface conditions in polar coastal regions. Key variables from NCEP reanalyses and the mesoscale model analyses (e.g., temperature, cloud cover, precipitation, surface energy budget) are compared to quantify the amplification of climatic variability associated with model resolution and surface heterogeneity.

In this study we discuss potential biases in the NCEP reanalysis data in coastal regions of the western Arctic focusing on an area within about 200 km of Barrow, Alaska. Implications for arctic coastal studies requiring a long history of atmospheric data are given.

## Data and Methodology

Observations used in this study include those collected during UAV flights and those obtained at the Department of Energy's North Slope of Alaska (NSA) Atmospheric Radiation Measurement (ARM) site.

Atmospheric and surface data has been collected over the Arctic Ocean using miniature UAVs called Aerosondes over the past 3 years. 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. Because it can communicate via satellite, the Aeorsonde has a range of over 750 km. It has an altitude range of between 100 and 4000 m. The Aerosonde carries two RS901 sensors which are located on the wings. This observational platform is described in detail in Holland et al. (2001) and Curry et al. (2003).

The ARM NSA data include measurements from a variety of surface-based remote sensors for sampling cloud properties (e.g., cloud radar, micropulse lidar) and soundings. Soundings are typically launched from the ARM NSA site once per day at 2230 UTC. Additional soundings are launched during IOPs. the sensor package was recently upgraded from RS80-15H to the more accurate RS90-A. The ARM NSA soundings are more accurate and higher resolution than those obtained with the VIZ-B2 sondes used by the NWS.

The NCEP/DOE AMIP-II Reanalysis (hereafter referred to as R-2) is used in this study. This version of the reanalysis is described in detail by Kanamitsu et al. (2003). The profile data are given on a 2.5 deg x 2.5 deg grid. The profile data is given in 17 pressure levels, but with only four at or below 700 hPa (1000, 925,850,700 hPa).

We employ Version 5.3 of the NCAR/PSU mesoscale model in "polar mode" for our high resolution simulations. The polar model physics adaptations are described in Bromwich et al. (2001) with the most substantive change being the treatment of a sea ice surface category that allows for specifying an ice concentration. The model configuration is shown in Figure 1. The inner-most domain has a horizontal resolution of 20 km and a vertical grid spacing that increases with height with resolution in the boundary layer of nominally 40 m.

The model is run using Reisner microphysics, RRTM radiation, Eta PBL and forced at the lateral boundaries using NCEP Global Data Assimilation System (GDAS)

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product. These high resolution runs are compared with the NCEP reanalyses to ascertain the degree of variability lacking in the global model in coastal regions of the Arctic.

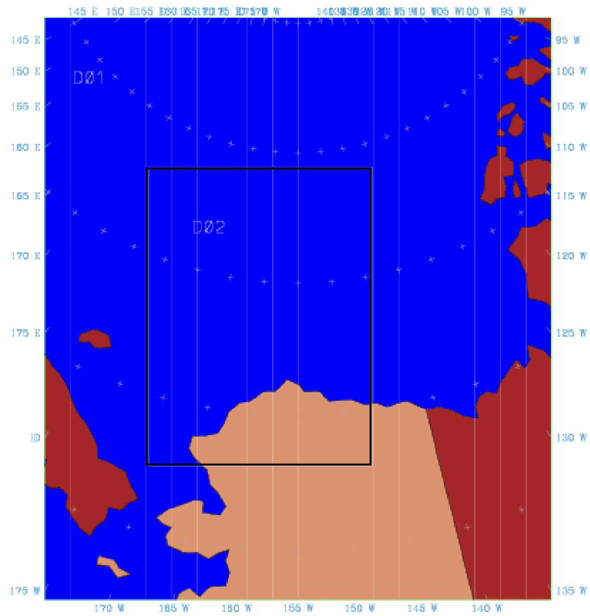


*Figure 1. Configuration of Polar MM5 for high resolution runs of the north coastal region of Alaska. Grid spacing for the inner and outer domains are 60 km and 20 km, respectively.*

### NCEP R-2 Data vs Observations

The temperature and relative humidity data from R-2 are compared with DOE/ARM and UAV sounding data obtained on 07 September 2002. This case was chosen because of the anomalous conditions that occurred on this day resulting in record warmth at Barrow, AK. The synoptic weather charts indicated that a low pressure system was tracking up through the Bering straight. The resulting south to south easterly flow ahead of the system spanned much of the western NSA and extended out over the Chukchi and Beaufort Seas. Warm advection associated with this pattern combined with an anomalously large area of open water produced an uncharacteristically warm layer of air that extended well out over the ocean in a deep layer.

The R-2 temperature and relative humidity profile data 00 and 06 UTC are compared with the observations in Figure 2. The observations indicate that there is not much temporal or latitudinal variation in temperature between 71.2 N (the ARM NSA sounding site) and 72.1 N (as observed by the UAV). So, the warm layer extended over 100 km offshore in the observations. The R-2 temperatures are much cooler than observed out over the ocean at 72.5 N, 157.5 W. Biases of up to -6 K are evident at the lowest level of the R-2 data. These biases may be attributed to poor treatment of the surface or vertical diffusion in the reanalyses. It is noted that some of the discrepancy may be attributed to the fact that the UAV data is not exactly coincident in space and time with the 06 UTC R-2 profile at 72.5 N, 157.5 W.

Biases are also evident in the relative humidity data. The R-2 relative humidities are too high below 900 mb over land and ocean with both the ARM sounding and the UAV indicating that a relative humidity inversion is present. A cross section of RHs obtained with the UAV during its northbound profiling transect over the Arctic Ocean reveals the large spatial extent of the RH inversion (Figure 4). This type of structure in the relative humidity profile is commonly observed in the Arctic (Curry 1986) and has been proposed as a possible mechanism for the maintenance of mixed-phase clouds in the Arctic. Thus, obtaining this structure may be vital for correctly representing low-level clouds in the reanalysis products.

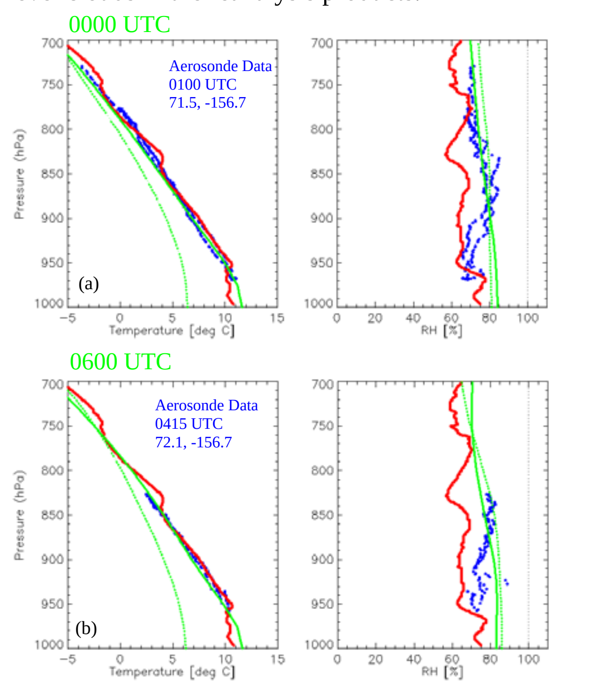


*Figure 2. Comparison of NCEP Reanalysis-2 temperature and relative humidity profiles with observations. Observations are from ARM NSA radiosonde at 2230 UTC on 6 September 2002 (red line) and up-down profiles obtained with the Aerosonde UAV (blue dots). Aerosonde profiles were obtained at (a) 0100 UTC and (b) 0415 UTC on 7 September. Profiles from NCEP Reanalysis-2 are obtained along 157.5 W at (a) 0000 UTC and (b) 0600 UTC on 7 September for 70.0 N (solid green line) and 72.5 N (dotted green line).*

The Aerosonde UAV data also captures the top of the moist shallow marine layer starting around 71.95 N

(Figure 4). So, the internal boundary layer deepens to a depth of only 200 m at a distance of roughly 70 km off-shore. Note that there is no indication of this shallow moist layer in the R2 data.

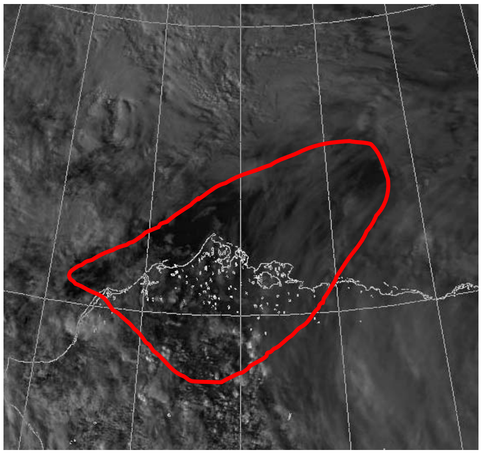

*Figure 3. AVHRR visible satellite imagery obtained at 0247 UTC on 07 September 2002. The mostly cloud free region (dark area in this image) is enclosed by a polygon.*

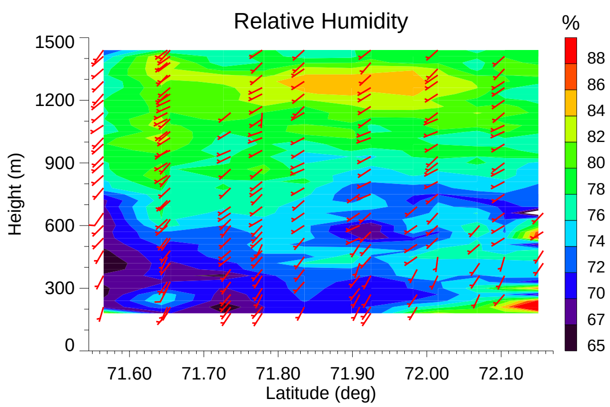


*Figure 4. RH variability observed during N-S transect of profiles obtained by Aerosonde UAV between 71.5 and 72.2 N along 156.7 W. Wind direction and speed are indicated by the wind barbs. This profiling transect was begun at 0030 UTC on 7 Sept 2002 and took 4.5 hours to complete.*

## NCEP R-2 Data vs Mesoscale Model

Owing to the lack of observations over much of the coastal Arctic, comparisons are also made between R-2 data and higher resolution simulations with MM5. An example of this comparison is shown in Figure 5 where surface pressure and 850 hPa temperature are plotted for 05 May 1998 at 1200 UTC. This case was chosen because an extensive modeling and observational data base exists for its study (e.g., Zuidema et al. 2004 Morrison and Pinto 2004). This is not a case in which you'd expect large biases owing to the lack variation in the surface conditions.

Of note in the comparison of the two datasets is the difference in the strength of the area of high pressure to the north and east of Barrow. The area of high pressure is stronger and spans a much large area than that depicted in the R-2 data. Also of note is that the R-2 850 hPa temperatures are colder than in the mesoscale simulation in the northwestern portion of the domain by about 1 C. At the same time there is a warm bias in the R-2 data compared with the mesoscale model along the coast including near Barrow of 1-2 C. A more detailed statistical comparison of this comparison will be given in the talk. In future work this analysis will be systematically carried out for different time of year using both available data from Barrow and mesoscale simulations to determine whether or not the biases revealed in these case studies are systematic.

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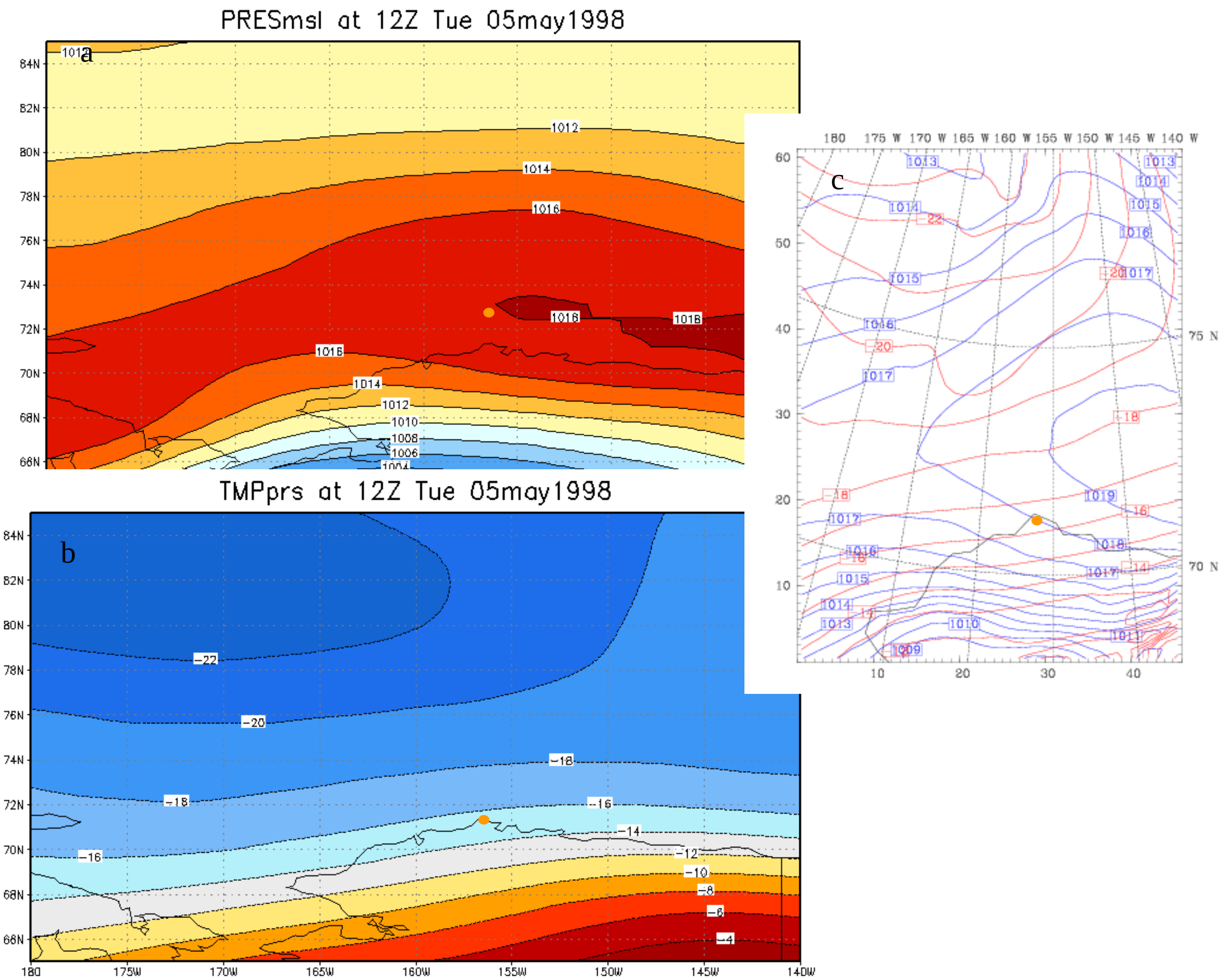


*Figure 5. Comparison of R-2 (a) mean sea level pressure and (b) 850 hPa temperature for 05 May 1998 at 1200 UTC with (c) data from the inner domain of a 36 hours simulation with Polar MM5 valid at the same time. The location of Barrow is given by the orange filled circle.*