The Atmospheric Response to the North Atlantic Gulf Stream Observed by a Ship-board Wind Profiler

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Figure 1: *The R/V Knorr (upper photo), the wind profiler (lower left), and a radiosonde sounding (lower right).*

1. INTRODUCTION

The National Center for Atmospheric Research (NCAR) operated an Integrated Sounding System (ISS) on the R/V Knorr (figure 1) in the North Atlantic in early 2007 in support of the CLIMODE project. The CLIMODE (CLIvar Mode Water Dynamic Experiment) project [1], lead by PIs from the Woods Hole Oceanographic Institute (WHOI), MIT, the University of Connecticut, and other groups, is a large multi-year oceanographic study of warm waters in the North Atlantic Gulf Stream. WHOI's R/V Knorr made multiple traverses of the northwestern boundary of the Gulf Stream off the northeast coast of the U.S. The ISS consisted of radiosonde sounding system and a UHF wind profiler radar [2]. The radiosondes and wind profiler were deployed to examine the response of the atmospheric boundary layer in this region of very strong air-sea exchange. The radiosondes were typically launched at three to six hourly intervals, whereas the wind profiler operated continuously.

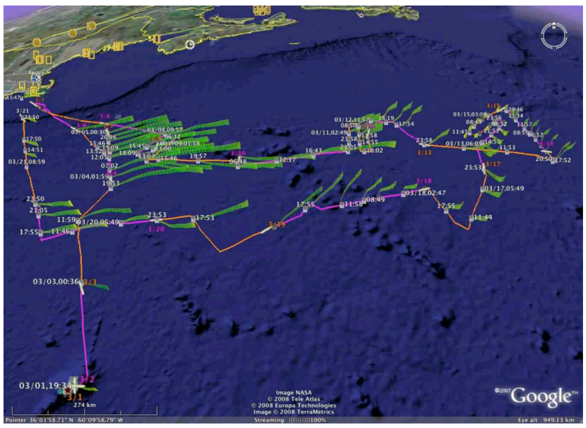

Figure 2*: The cruise track and sounding trajectories (indicated in green) for the second CLIMODE cruise of the 2007 season. The cruise began in Bermuda (lower left) on 1 March and ended 3 weeks later in Woods Hole, Massachusetts (upper left).*

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2. RADIOSONDES

NCAR operated its GAUS (GPS Advanced Upper-air Sounding) system launching 150 balloon-borne Vaisala RS-92 radiosondes during the course of the two cruises. The ship track and the course of the balloons during the second cruise are indicated in figure 2.

Figure 3 shows an example of a sounding taken during the second cruise. The multiple features in the temperature and humidity profile result from advection of the atmospheric over regions of varying surface temperature and energy exchange upwind (here to the east) of the launch site. Boundary depth was derived from subjective analysis of the potential temperature profiles of the soundings. In the case of the sounding in figure 3, the depth was determined to be about 800 meters.

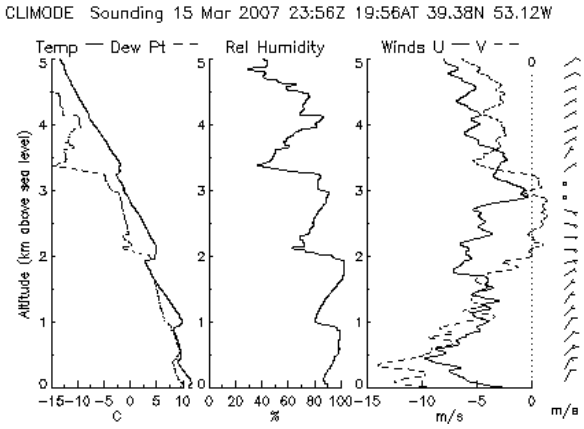

Figure 3: *Profiles of temperature (and dew point temperature), relative humidity, and wind (eastward U, and northward V, also shown as wind bards on the far right) as functions of altitude for a radiosonde sounding launched at 2356 UTC on March 15.*

3. WIND PROFILER

The wind profiler was a 915 MHz boundary-layer Doppler Beam Swinging (DBS) profiler mounted on a gyroscopically stabilized platform. Wind measurements from the profiler were compared with radiosondes wind measurements and agreed to within about 2 m/s (standard deviation), which is a reasonable agreement given active weather conditions and that the radiosondes and ship drift some distance apart during the observations.

Figure 4 shows a 48-hour example of observations made by the wind profiler. Reflectivity is shown in the upper panel and wind measurements are shown in the lower panel. The top panel shows radar reflectivity. The red asterisks mark boundary layer top derived from the radiosonde soundings and as can be seen, the radiosondes boundary layer depth generally correspond well with increased reflectivity as seen by the wind profiler. Other reflective layers originate from inversions generated as the atmosphere interacted with the varying sea surface in the region. The lower panel shows wind measurements corrected for ship motion.

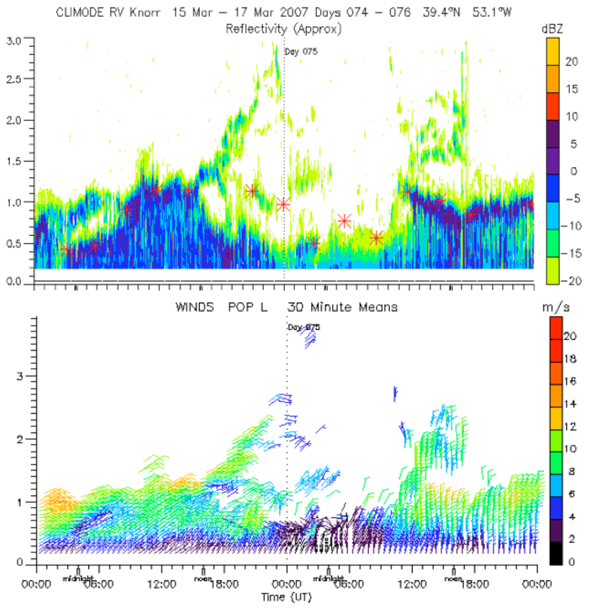

Figure 4: Time-height (km) plot of *wind profiler observations from 0Z on March 15 to 0Z March 17. The upper panel shows SNR (Signal to Noise Ratio) and the lower panel shows wind barbs (30 minute averages, color coded by speed) as functions of altitude. The sounding of figure 3 was taken about the time of the dashed vertical line.*

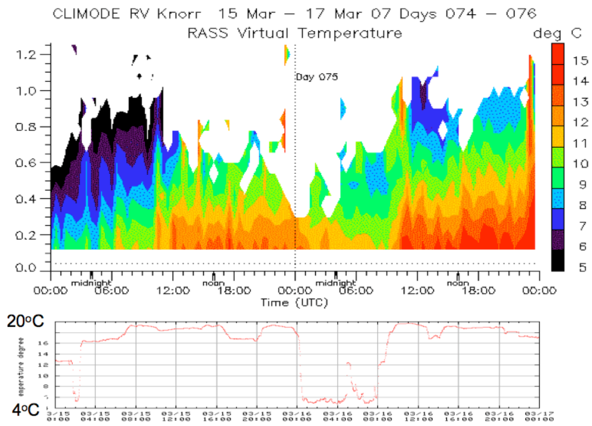

Figure 5: *RASS Virtual temperature (upper panel) and sea surface temperature (lower panel) for the same 48-hour period as figure 4.*

In addition to measuring the wind and atmospheric reflectivity, the profiler included a Radio Acoustic Sounding System (RASS) to measure virtual temperature aloft. RASS virtual temperatures for the same period as figure 4, along with corresponding sea surface temperatures as measured by an in-situ probe are given in figure 5. Notice that when the sea surface temperature drops (0 UTC on March 16) as the R/V Knorr moved out of the Gulf Stream, the temperature measured by RASS also drops. The radar reflectivity (figure 4) also is reduced and the boundary depth is shallower. Approximately 8 hours later, the Knorr moved back into warm waters, and RASS temperatures and radar reflectivity recovers and the boundary layer depth grows.

Boundary layer depth derived from the radiosondes and wind profiler reflectivity for the entire three-week cruise is shown in figure 6. Also plotted is the sea surface temperature. There are many factors that affect marine boundary layer depth including advection, surface flux, precipitation, the synoptic situation and others (e.g. [3]), however it can be seen that the boundary layer was generally deepened over, or near, the warm seas of the Gulf Stream.

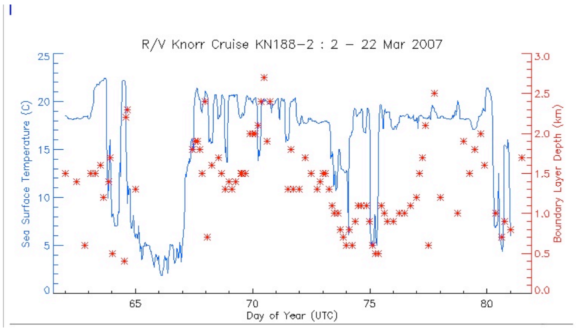

Figure 6: *Time-series plots of sea surface temperature (blue) and atmospheric boundary layer depth (derived from the radiosonde soundings and wind profiler reflectivity).*

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