8.4 COASTAL OCEAN METEOROLOGICAL PROCESSES INFLUENCING THE MARINE ATMOSPHERIC SURFACE LAYER NEAR THE VIRGINIA EASTERN SHORE

Robert E. Marshall* and Edward H. Burgess, III, Naval Surface Warfare Center, Dahlgren Division, Dahlgren, VA, J. Ross Rottier, The Johns Hopkins University Applied Physics Laboratory, Laurel, MD

1. INTRODUCTION

During the multi-agency Wallops 2000 Microwave Propagation Measurement Experiment (MPME) organized by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), a wealth of sea surface and upper air meteorological observations were collected by helicopter, rocketsonde, buoy and boat in order to document the spatial and temporal structure of the coastal atmospheric boundary layer near the Virginia Eastern Shore, Stapleton (2001). The goal of the experiment was to quantify the radio frequency propagation environment induced by the structure of the marine atmospheric surface layer. Figure 1 represents the experiment configuration.

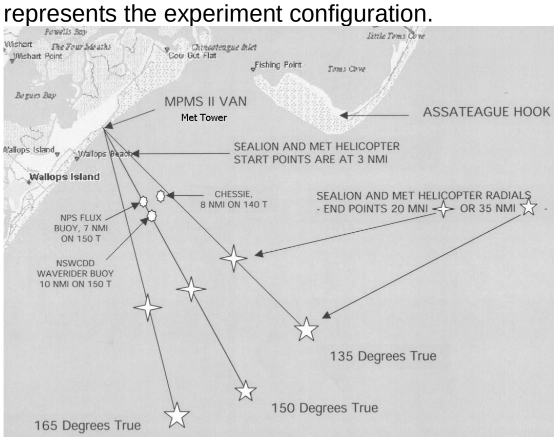

Figure 1: Wallops 2000 MPME configuration

Wallops Island is a NASA test facility located on the Atlantic coast of the Virginia Eastern shore at approximately 37.85 E latitude and 77.47 W longitude. The MPME gathered range dependent propagation data using the NSWCDD Microwave Propagation Measurement System II (MPMS II). This three-band communication system consisted of receivers at the MPMS II van located on the beach and transmitters located in the stern of the NSWCDD project boat, Sealion. The Sealion was also equipped with meteorological measurement equipment that recorded air temperature, sea surface temperature, relative humidity, pressure, wind speed, wind direction, and solar radiation. The Sealion moved along one of the three radials indicated collecting S, C, and X band propagation and meteorological data from 5 to 65 kilometers offshore.

* *Corresponding author address :* Robert E. Marshall, T44 , Dahlgren Division, Naval Surface Warfare Center, 17320 Dahlgren Rd, Dahlgren, VA 22448-5100, MarshallRE@nswc.navy.mil

As often as practical, the Johns Hopkins University Applied Physics Laboratory (JHU/APL) helicopter measured spaced vertical profiles of temperature, relative humidity, and pressure along the same bearing as followed by the Sealion. The JHU/APL project boat, Chessie was also instrumented for collecting meteorological data and it would drift close to 11 kilometers offshore close to a 140 degree true north bearing from the MPMS II van. A meteorological tower collecting temperature, relative humidity, pressure, wind speed and wind direction was located on the beach adjacent to the MPMS II van.

The Naval Postgraduate School Flux Buoy (NPSFB) was located 13 kilometers offshore and collected bulk meteorological data as well as high frequency turbulence and platform motion data.

2. SYNOPTIC CONDITIONS

This study focuses on meteorological processes influencing the surface layer from April 28, 2000 through May 5, 2000. The period began with a weak extra-tropical cyclone in the Carolinas nudging a weak high-pressure ridge over the MPME area. The combination of these two synoptic features resulted in air that had experienced a long Atlantic Ocean fetch from the south being accelerated onshore over the MPME area. By the next day, April 29, 2000, the cyclone had moved off the Virginia coast such that the MPME area was in NNE or down shore flow associated with the north right quadrant. On April 30, a large dome of high pressure building in from the Great Lakes placed the MPME area in NW or off shore flow. By May 1, this area of high pressure had built across the entire Atlantic coast and the MPME area was in SSE or up shore flow. By the following morning on May 2, this area of high pressure had slipped of the Atlantic coast followed by the trailing edge of a cold front anchored in an extra-tropical cyclone over New England. Winds over the MPME area veered from W to NW during the day. A strong ridge of high pressure built down the Atlantic coast on May 3 and E winds at 1200UTC veered to SE by 1500UTC. The high-pressure ridge persisted into May 4 and slowly moved away from the Atlantic coast as winds over the MPME area veered SSE to S from 1200UTC through 1600 UTC. On May 5, a dome of high pressure centered over the northern South Carolina coast pumped WNW winds over the MPME area.

3. April 30, 2000

The data set for April 30 is the most complete and will be presented in this manuscript. Results for the entire study period will be summarized at the conference.

Strong surface layer stability was measured in NNW flow on April 30, 2000. Figure 2. depicts the eta Data Assimilation System (EDAS) surface analysis provided by the Air Resources Laboratory archive for 1200 UTC on April 30. An extra-tropical cyclone is NE of the MPME area while high pressure builds in from the NW.

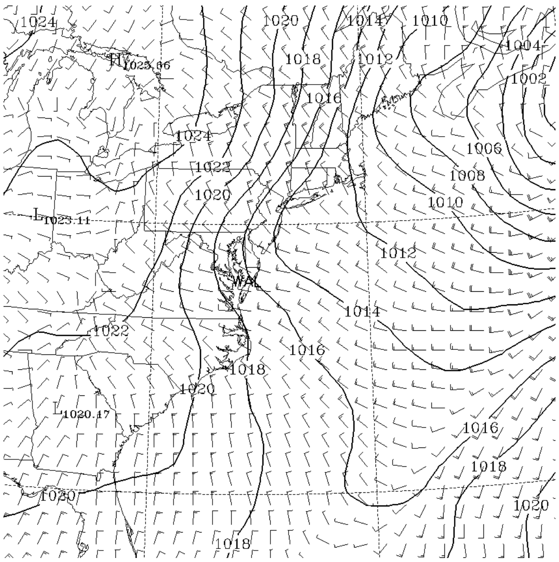

Figure 2: EDAS analysis, 1200 UTC, April 30

Figure 3 displays the surface wind direction as measured by the MPMS tower located on the beach and the NPS buoy located 13 km offshore. Winds 13 km offshore are more westerly and winds at both sites gradually veer during the day as high pressure builds towards the MPME area. Winds throughout the period are gusty and average approximately 6 m sec^{-1}.

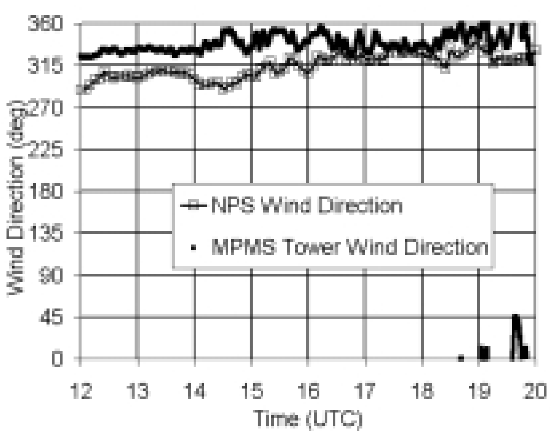

Figure 3: NPS buoy and MPMS tower wind direction on April 30

Figure 4 is a time series plot of air temperature recorded at the MPMS tower and the NPS buoy. Temperatures at the beach contain a diurnal land-heating signature. At 13 km offshore, the temperatures have been modified and the diurnal signature is less pronounced.

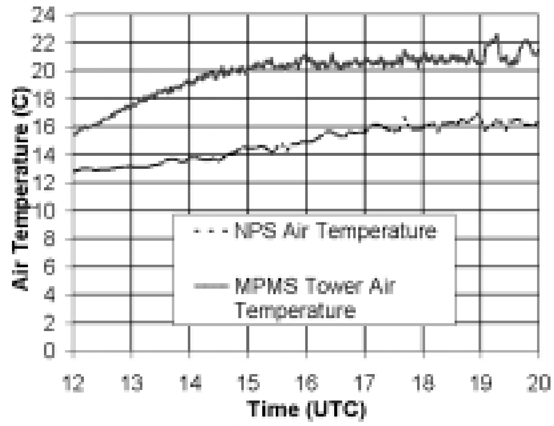

Figure 4: Near surface air temperature at the shore and 13 km offshore.

Figure 5 compares the time series of sea surface temperature and air temperature measured 13 km offshore by the NPS buoy. The diurnal signature in the offshore flow is responsible for an increased air/sea temperature difference with time.

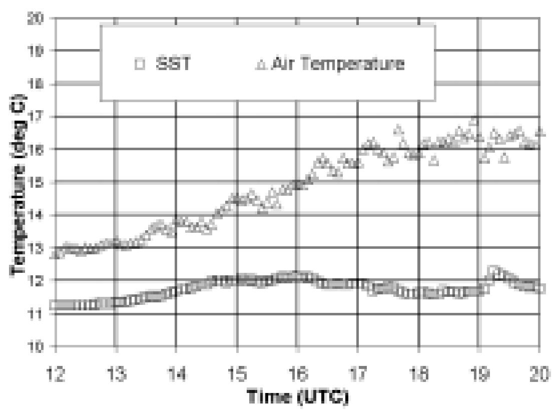

Figure 5: Air temperature and sea surface temperature measured 13 km offshore.

The offshore extent of the stability indicated in Figure 5 is observed in the Sealion data plotted in Figure 6. The air remains significantly warmer than the sea surface out to the extent of the measurement 65 km offshore. The data plotted in Figure 6 are approximately 2 km averages. Similar air-sea temperature differences were recorded by the JHU/APL project boat 11 kilometers offshore.

As is typical in the early spring along the middle Atlantic, drier Canadian air flows offshore as high pressure builds in from the NW behind a surface cold front. This is observed at both the MPMS tower on the beach and the NPS buoy 13 km offshore. Water vapor pressure generally decreases from 11 mb to 6 mb during the period as indicated in Figure 7. The JHU/APL project boat, Chessie recorded similar characteristics in the airflow 11 kilometers offshore throughout the day.

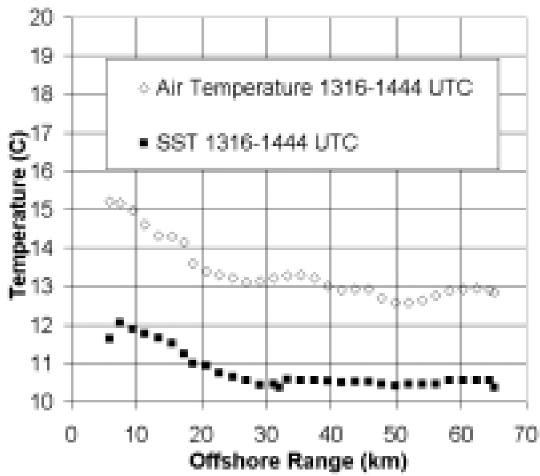

Figure 6: NSWCDD project boat Sealion measurement of air temperature and SST on April 30.

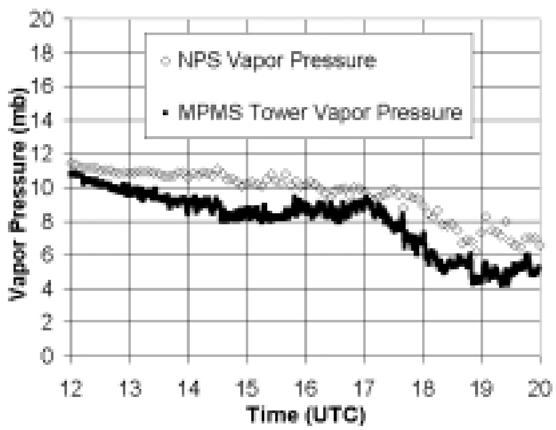

Figure 7: Water vapor pressure measured on the beach and 13 km offshore on April 30.

Clouds from the extra-tropical cyclone to the NE were clear of the MPME area as indicated in the GOES-8 1 kilometer resolution visible image in Figure 8. The locations of the MPMS tower, Sealion track, and NPS buoy are also delineated in Figure 8. The location of the NASA wind tower is also shown. This tower provided wind speed and wind direction data at 15, 30, 45, 60, 75, and 90 m ASL. These one-minute averages of five-second data are displayed in Figure 9 and indicate consistent wind speeds at all levels. Wind direction data from the NASA wind tower reported NNW winds at all levels throughout the day.

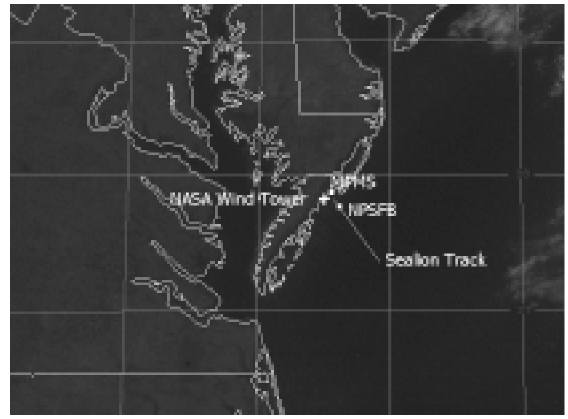

Figure 8: GOES-8 1 km visible image. 1400 UTC, April 30, 2000

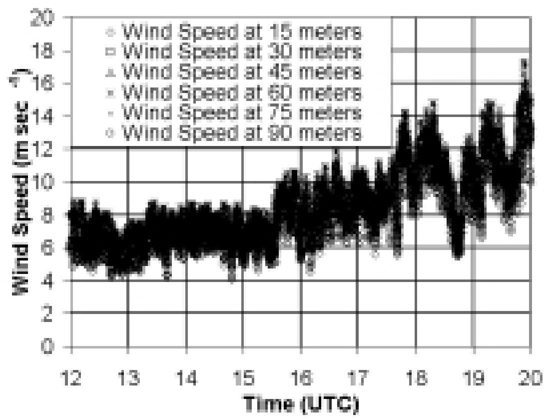

Figure 9: Wind speed at multiple heights on shoreline, April 30, 2000

The characteristics of the resulting clear air marine atmospheric boundary layer (MABL) are influenced by an offshore flow that becomes increasingly stronger, warmer and drier throughout the day on April 30, 2000.

3. MABL STRUCTURE

The JHU/APL helicopter performed high vertical resolution profiles along the bearing taken by the Sealion between 1309 and 1853 UTC on April 30, 2000. Temperature, pressure, relative humidity, altitude, latitude and longitude were recorded approximately every 5 meters above the ocean. Figure 10 represents profiles of virtual potential temperature near 6 km offshore at 1453 UTC, 1757 UTC and 1850 UTC. All three profiles indicate a stable surface layer up to 20 meters ASL and are generally well mixed above. Vapor pressure at 20 meters ASL drops from 8.5 to 6.5 mb during the period while temperature only increases by 0.2 degrees K.

Three profiles taken at 1412 UTC, 1804 UTC and 1842 UTC are available near 10 km offshore and are shown in Figure 11. All three profiles indicate a stable layer up to 30 meters ASL. By 1804 UTC, the increased temperatures due to heating on land are evident in the strong inversion at 60 meters ASL. A 2 mb reduction in vapor pressure is also evident in the well-mixed layer. The increase in virtual potential temperature in the surface layer is due entirely to temperature modification as the water vapor profile is identical to that at 1412 UTC. But by 1842 UTC,

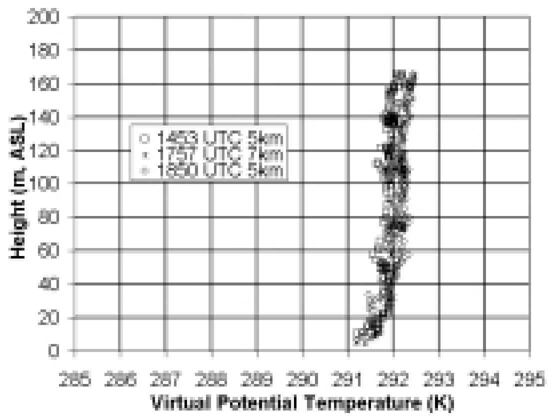

Figure 10: Profiles of Virtual Potential Temperature near 6 km offshore at 1453 UTC, 1757 UTC and 1850 UTC.

the lower values of vapor pressure in the adiabatic layer have mixed down into the surface layer and reduced vapor pressure by 2 mb.

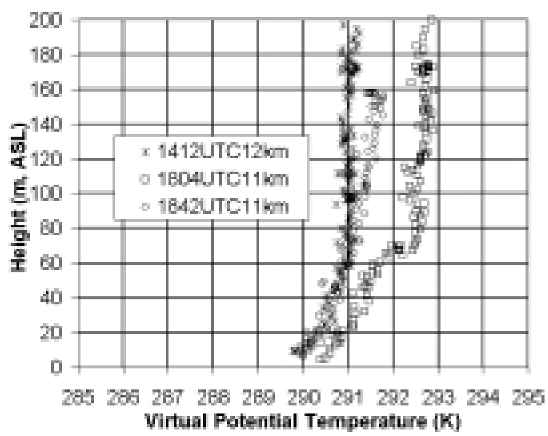

Figure 11: Profiles of Virtual Potential Temperature near 11 km offshore at 1412 UTC, 1804 UTC and 1842 UTC.

A similar plot was created for profiles near 19 km offshore. In Figure 12 it can be observed that the profiles from 1309 UTC through 1705 UTC contain a 30-meter deep stable surface layer. At 1309 UTC, stability remains above 30 meters as the diurnal heating begins to accelerate. By 1444 UTC, a warmer mixed layer forms above this surface layer near 50 meters ASL. At 1705 UTC, this mixed layer is warmer and extends down to 30 meters, ASL. By 1749 UTC the surface layer is stable up to 20 meters ASL, is well mixed from 30 to 50 meters ASL, and returns to stable up to 90 meters ASL above which the layer is well mixed. By 1839 UTC the surface layer is only slightly stable.

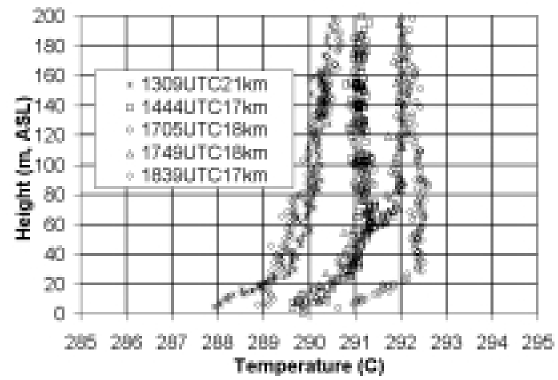

Figure 12: Profiles of Virtual Potential Temperature near 19 km offshore at 1309 UTC, 1444 UTC, 1705 UTC, 1749 UTC, and 1839 UTC

Figure 13 displays vertical profiles of virtual potential temperature further offshore near 28 km.

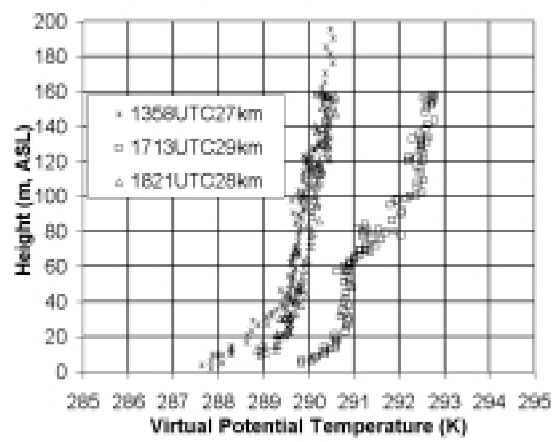

Figure 13: Profiles of Virtual Potential Temperature near 28 km offshore at 1358 UTC, 1713 UTC, and 1821 UTC.

At 1358 UTC the stable surface layer extends up to 40 meters ASL. By 1713 UTC, the stable surface layer height is reduced to 20 meters ASL with mixing occurring between 20 and 60 meters ASL. This can be seen in both the temperature and water vapor profile. The decrease in virtual potential temperature at 1821 UTC is due almost entirely to reductions in temperature from the surface up to 160 meters ASL.

4. CONCLUSIONS

A ridge of high-pressure building towards the Atlantic coast after the passage of an extra-tropical cyclone produced a NW offshore flow over the MPME area. The flow was warmed by diurnal heating and became drier during the day. There were no clouds over the land upwind or the observed MABL. The air-sea temperature difference was 2 to 4 degrees K positive out to 65 kilometers offshore.

The MABL structure initially contained a stable surface layer that grew from a depth of 20 meters near shore to 40 meters 30 kilometers offshore. The mixed layer above the surface layer gained the characteristics of the diurnally heated boundary layer over the land. In time, an intervening third layer developed that tended to blend the thermal and humidity characteristics of the surface and mixed layers.

5. REFERENCES

Stapleton, Janet, et al, Radar Propagation Modeling Assessment Using Measured Refractivity and Directly Sensed Propagation Ground Truth-Wallops Island, VA 2000, NSWCDD/TR-01/132, September, 2001