P2.2 SURFACE RADIO FREQUENCY DUCTS PRODUCED BY STABLY STRATIFIED INTERNAL BOUNDARY LAYERS OFF THE VIRGINIA COAST

Robert E. Marshall
Naval Surface Warfare Center, Dahlgren, Virginia

1. INTRODUCTION

Surface radio frequency (RF) refractivity over the ocean is imposed by the mean structure of humidity and temperature in the marine atmospheric boundary layer (MABL). RF communication and sensor systems operating in the littoral MABL commonly experience anomalous propagation due to the air/sea/land interactions near the coast. One of the most influential MABL structures on littoral RF propagation is the stable internal boundary layer (SIBL) produced when diurnally heated air over land advects offshore over a cooler ocean. SIBLs produced in this manner typically demonstrate surface potential temperature (θ) and water vapor mixing ratio (w) characteristics related to the sea surface temperature (SST). θ at the top of the SIBL is more representative of the warmer potential temperature in the diurnal atmospheric boundary layer (ABL). The thermal stability in the over water SIBL dampens the turbulent mixing of water vapor from the surface to the top of the SIBL.

2. MEASURED DATA

Ducting or near surface trapping of RF energy in the SIBL occurs when the gradient of modified radio refractivity (M) is less than zero.

$$\frac{dM}{dz} \approx 0.128 + c_1\frac{dw}{dz} - c_2\frac{d\theta}{dz} \qquad m^{-1} \quad (1)$$

C_1 and C_2 are functions of temperature, pressure and humidity.

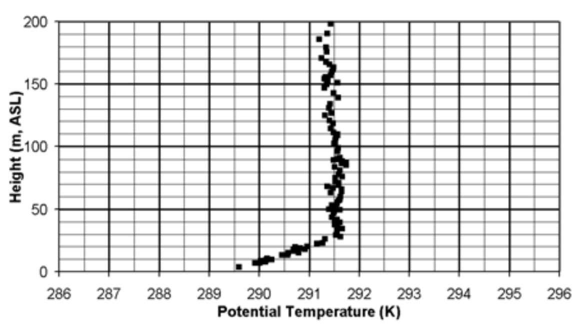

Figure 1: Potential Temperature 30 April, 2000

Figures 1-3 represent, θ, w, and M for data taken 18 km off Wallops Island, Virginia at 1705 UTC on 30 April 00.

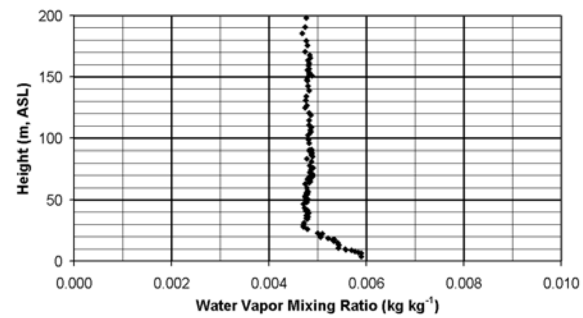

Figure 2: Water Vapor Mixing Ratio 30 April, 2000

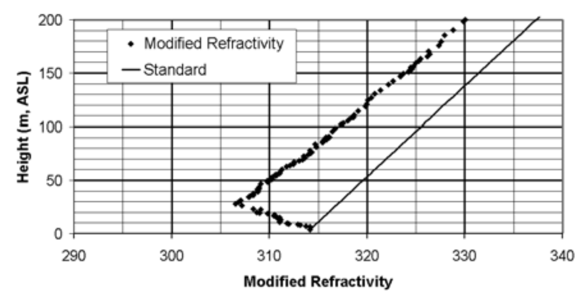

Figure 3: Modified Refractivity 30 April, 2000

It can be seen from (1) and figures 1-3 that the thermal stability and lack of mixing in the SIBL have created a 30-meter ASL RF surface duct. Notice the well-mixed diurnal layer above the SIBL where propagation is approximately 0.128 m^{-1}. Standard propagation as drawn in figure 3 is 0.118 m^{-1}.

The creation of a SIBL during offshore advection does not necessarily produce a surface duct. Figures 4-6 demonstrate a SIBL measured 31 km offshore off Wallops Island on 2 May 00 at 1520 UTC. The offshore flow is in the lee of a cold front and the diurnal ABL moisture content was approximately that of the SIBL. This created the unusual situation of a SIBL with w well mixed throughout the layer. The resulting propagation was very nearly standard.

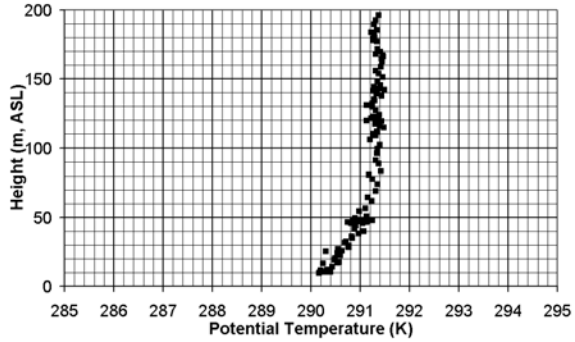

Figure 4: Potential Temperature 2 May, 2000

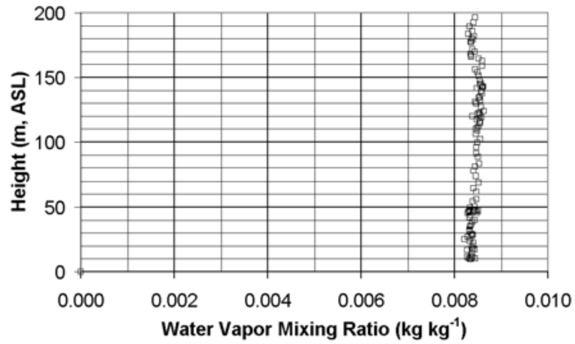

Figure 5: Water Vapor Mixing Ratio 2 May, 2000

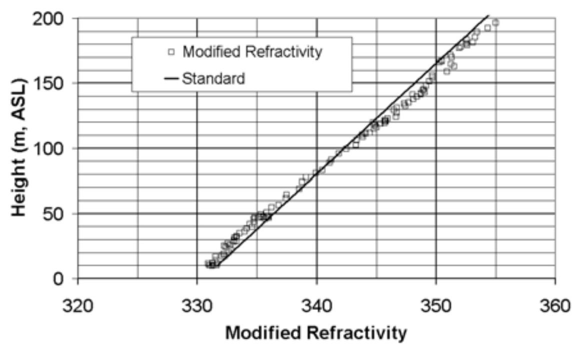

Figure 6: Modified Refractivity 2 May, 2000

It can be seen from (1) and figures 4-6 that the stability in the 50 m ASL SIBL was enough to move the RF propagation slightly above standard, however, the lack of a water vapor mixing ratio gradient prevented the formation of an RF duct. Latter in the day and the synoptic cycle, dry air from the northwest advected offshore in the overlying diurnal layer, created a strong negative gradient of w in the SIBL, and produced severe ducting.

3. RATIO OF TERMS

The relative importance of the humidity gradient to the temperature gradient in the SIBL for RF duct production is examined in figure 7. C_1 and C_2 are evaluated for a typical range of temperature and relative humidity found in the MABL.

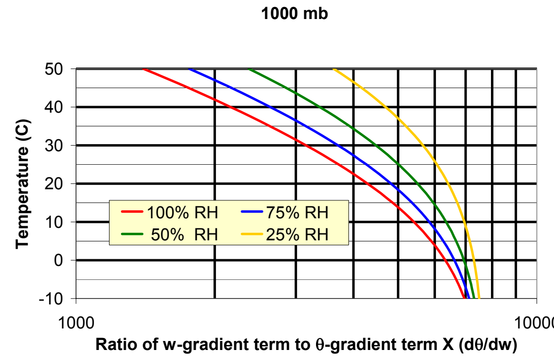

Figure 7: Ratio of the humidity gradient term to the temperature gradient term

It can be observed from figure 7 that the influence of the humidity gradient term increases as the temperature in the MABL decreases. The ratio of terms becomes much more a function of humidity at higher MABL temperatures.

For the April 30 SIBL described in figures 1-3, the temperature is approximately 15 C and the relative humidity is 60%. The ratio of dθ/dw is $2X10^3$ and using figure 7, the ratio of the humidity gradient term is 3 times that of the temperature gradient term.

4.0 CONCLUSIONS

Warm diurnal ABLs advecting offshore over cooler water create SIBLs that have the potential to create advection RF surface ducts. Stability alone is typically not enough to produce the trapping layers. A humidity gradient must accompany the stability in order for a surface duct to form. This typically happens on the east coast of the U. S. in the lee of a cold front when drier air appears in the synoptic flow.