Evaporation Duct Heights derived from Rawinsonde Kite Profiles and the Bulk Method

LT Dave Kuehn
18 Sep 2002
OC 3570

Introduction

Meteorology plays an integral role in Electro magnetic (EM) propagation paths and greatly influences radar and communication performance. EM propagation is directly related to the meteorological properties: pressure, temperature and partial pressure of water vapor. These parameters are readily measured and mathematically manipulated into the modified index of refraction, M. Once M profiles are created, EM propagation ducts and paths become evident. In particular, strong gradients of temperature and partial pressure of water vapor at the surface of the ocean can lead to evaporation ducting. Evaporation ducting leads to significant increases in propagation distances compared to the standard atmosphere. Precise near surface measurements are difficult to gather and normally the evaporation duct in the M profile is approximated by bulk methods. This study is designed to take near surface measurements, develop an M profile and compare them to the M profiles derived from the bulk method.

Method

Three independent systems measured the atmospheric parameters needed to calculate M in-situ and to derive M profiles using bulk methods. R/V Point Sur’s Serial ASCII Interface Loop (SAIL) system was used to obtain air temperature, wind speed, relative humidity, pressure and sea surface temperature. The data was received after being averaged over approximately one minute intervals. All of the instruments (except the sea surface boom probe) were mounted 17 meters from the sea surface. Additionally, a hand-held infrared sensor was used hourly to measure sea surface temperature as part of routine meteorological observations. A rawinsonde attached to a kite measured air temperature, relative humidity, pressure, dew point temperature and pressure relative height. Near surface data is gathered by raising and lowering the kite (between about 1-50 meters) and recording approximately when and how low the rawinsonde gets during the lowering phase (referred to from now on as “low kite data”). While flying, the rawindsonde is sampling every two seconds. There were 5 recorded kite launches, only two were of significant length with recorded low kite data. The two most useful launches were 17Jul2002 at 2100 UTC and 20Jul2002 at 0100 UTC (Rawinsonde Log Sheet #8 and #17).

Collected data was loaded in a Matlab program (workingkite_mat.m). Over the course of the kite flying, the surface pressure changes, thus altering the surface height relative to pressure. The program allows the user to define surface heights based on initial pressure and recorded low kite data (shown in figure 1). Bad data areas, such as time on the deck of the ship prior to kite launch or heavily ship influence sonde data is removed from the data set.

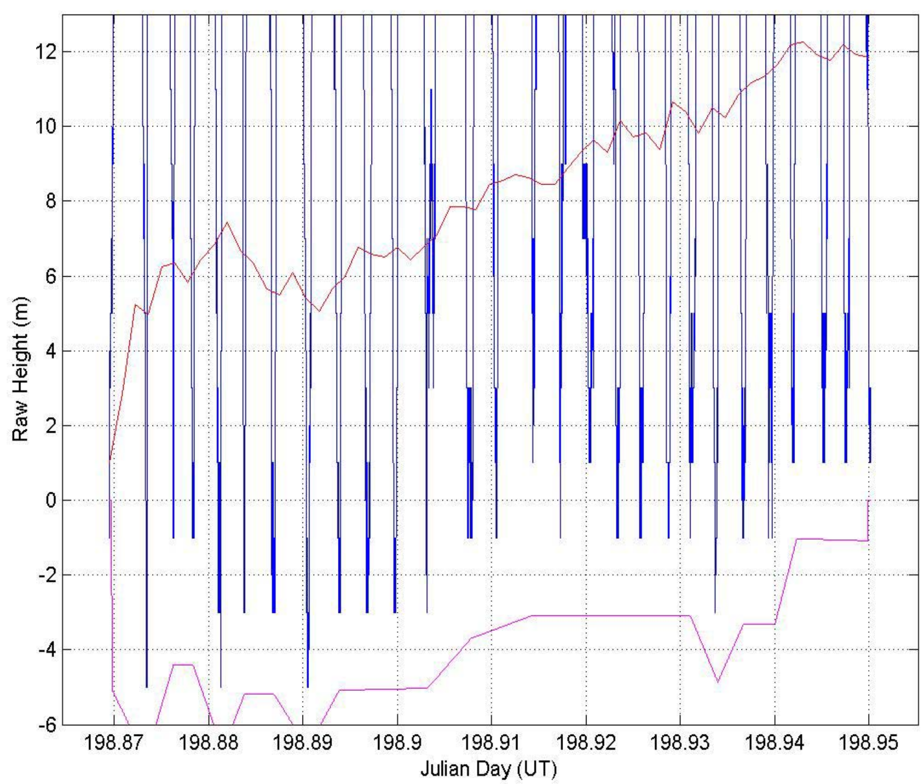


Figure 1

Then the kite data is divided into averaging intervals based on atmospheric characteristics of temperature and relative humidity (shown in figures 2 and 3). Air temperature, sea temperature and relative humidity are input based on average kite data or observations.

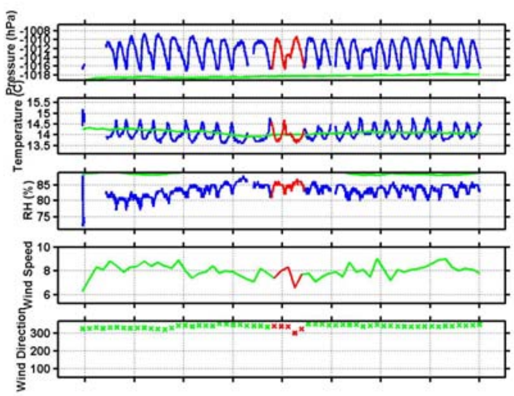


Figure 2

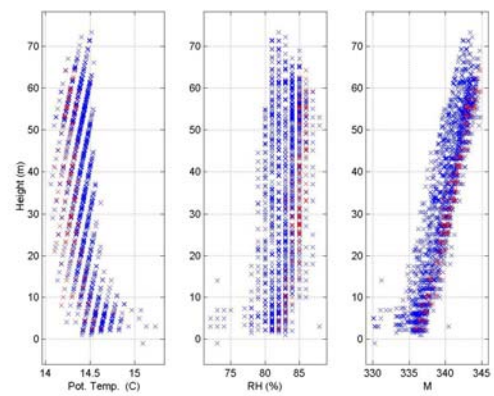


Figure 3

Then in-situ M profiles are derived from the kite data with Fairlee’s bulk method (Journal of Geophysical Science 1996) M profiles overlayed for each averaging interval (shown in figure 4).

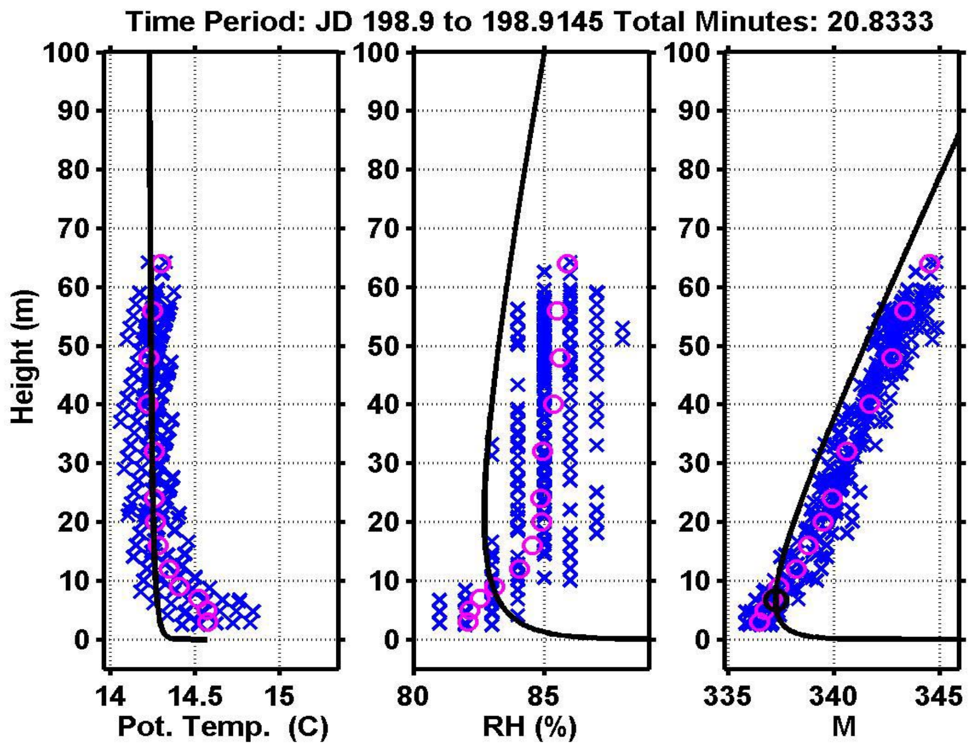


Figure 4

Limitations/Error

It is important to understand the limitations of these methods. Most error associated with this study is subjective error. The low kite data is an estimate on the height of the rawinsonde from the sea surface and is observed from a distance of up to 75 meters. Also air and sea temperatures and relative humidity data for bulk method is pulled from an average of the kite data or the ship observation data. Again, subjective data goes into the Matlab program.

Certain data recording devices could also be in error. The response time of the rawinsonde could cause bogus data and contaminate averages throughout the column especially at the surface. Calibration in sensors could be a source of error also. In fact, the ships data and sonde data have a margin of separation in most atmospheric parameters.

Results

Results varied throughout the experiment. In-situ profiles starting at about 1910 on 19 July show an obvious evaporation duct, however, the duct height does not coincide with the bulk method duct height. Figure 5 is a

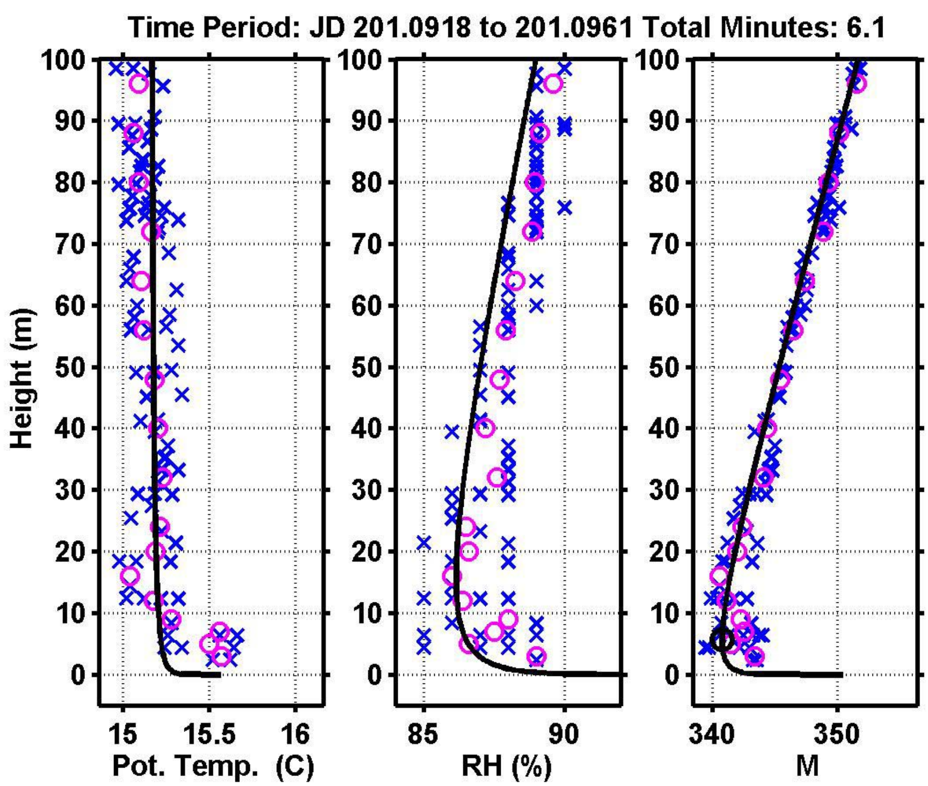
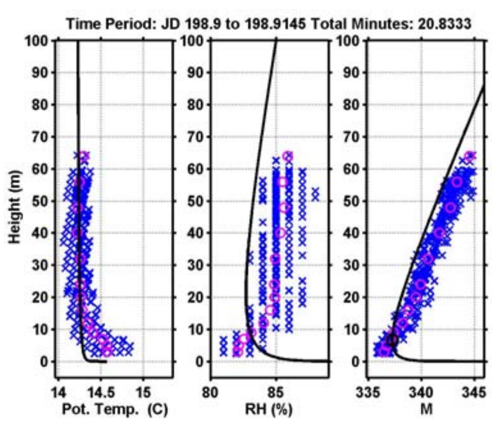
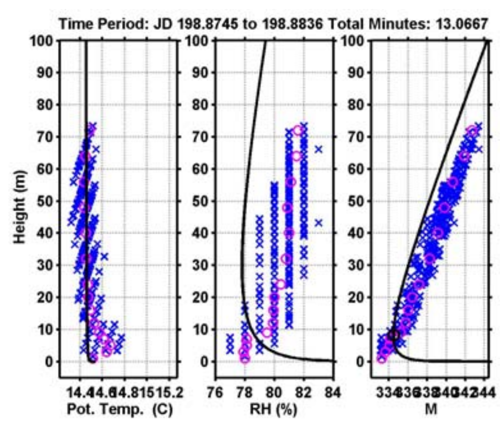


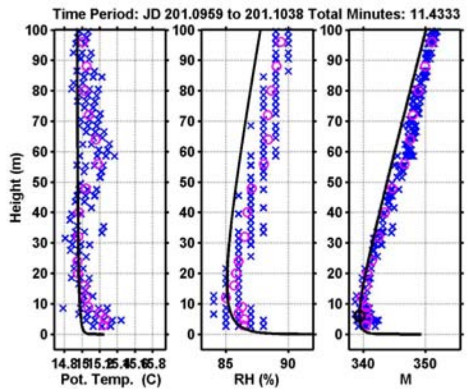
Figure 5

profile from the evening of 19 July at about 1910. Figure shows a negative temperature gradient from the surface up to 16 meters with a strong negative relative humidity gradient up to 5 meters and again from 8 meters to 16 meters. The result is an evaporation duct up to the low relative humidity mark at 16 meters with perhaps a “secondary duct” up to 5 meters. Bulk Method shows an evaporation duct of about 6 meters given the sonde averaged temperature and relative humidity criteria. In this case, actual profile evaporation duct is much higher than bulk method duct, but the “secondary duct” is very similar. Also important to note about figure 5 is the wide range of relative humidity (85-89%) in lower levels during the 6 minute interval. Conclusions relating to this humidity trend will be drawn from this figure later in this paper

Figures 6, 7 and 8 are other examples of in-situ profiles versus bulk method profiles. As illustrated, most







Figures 6, 7, 8

bulk method profiles are not concurrent with the actual sonde measured profiles. All figures have a bulk method profile showing evaporative ducts between 7 and 9 meters. Figures 6 and 7 are both from the afternoon of 17 July. Profiles from this day show no ducting whatsoever in the sonde measured M profile. Thus the bulk method fails in its approximation of the atmosphere on 17 July. Figure 8 illustrates the presence of an evaporative duct up to 12 meters. Again the "secondary duct" exists at approximately the 6 meter mark, coincident with bulk method findings, but the actual evaporative duct is 6 meters higher than the bulk method output.

Conclusions

No evaporation duct was derived from the 17 July kite data. Keeping in mind that the boundary layer is theoretically 100% relative humidity, an evaporation duct must exist. Since the low kite data was generally down to a height of 1 to 2 meters, one can conclude that the kite was not low enough to detect the duct, and that the duct was less than 1-2 meters in height.

Starting at about 1910 on 19 July, an evaporative duct becomes evident in the kite data. Figure 5 shows a wide range of relative humidity measurements, from 85-89% over an interval of 6 minutes at a height of 5-12 meters. It appears that during that 6 minute interval, the relative humidity dropped enough to create a sufficient negative relative humidity gradient and form an evaporative duct. This evaporative duct is evident throughout the rest of the 19 July data as represented in figure 8. Also evident in both figures 5 and 8 is a secondary duct at 5-6 meters in height, again due to a drying trend at this level. Explanations for this drying trend are a case for study itself and not obviously apparent, but a theory would be cooling and less moisture mixing into air at 5-12 meter level perhaps due to decreased solar heating at this time. Another theory is an increase in air-sea interaction just below these levels to increase gradient.

When comparing the Frailee bulk method to the actual atmospheric sampling, the bulk method failed to accurately represent the near surface environment. Bulk method, based on a standard atmosphere assumption, determined evaporative duct heights between 6 and 10 meters for all profiles. Actual data from this experiment does not concur, showing no evaporative ducts on 17 July or before 1910 on 19 July. After 1910 on 19 July, the measured evaporative duct is between 12-16 meters, significantly higher than bulk method heights. Thus it can be concluded that the area of the experiment, central coast of California, is not a standard atmosphere. The sea temperature is slightly warmer than air temp and the lower levels are well-mixed, thus no significant temperature or humidity gradient.

Operational Significance

Tactically speaking, the evaporative duct is very important in today’s Navy. Refractive conditions and ducting can have significant impact on radar ranges, both for detection and counter-detection, which influence almost all aspects of military planning. Figure 9 shows a generic and unclassified illustration of radar propagation within an evaporation duct.

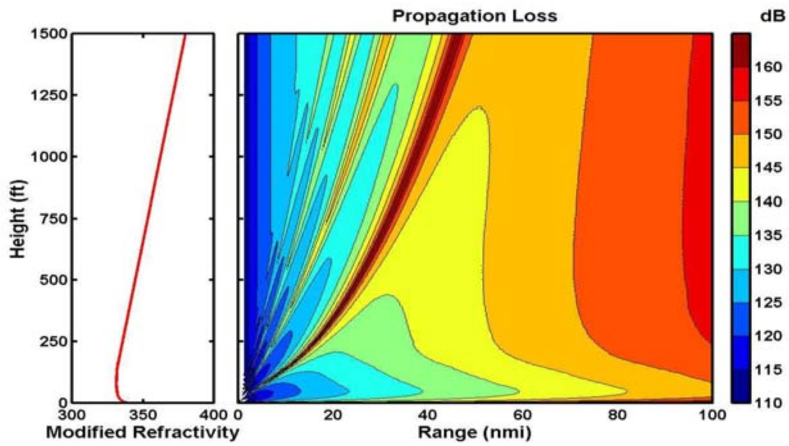


Figure 9 AREPS derived generic radar propagation loss plot within evaporative duct.

Acknowledgements:

- Professor Peter Guest for his help with directing this study, his Matlab program and as a source of knowledge
- Professor Ken Davidson for a few graphics and slides and sharing his knowledge as well