Examining Spatial and Temporal Changes in Refractive Conditions

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Introduction. The atmosphere and its properties are in a continuous state of change. Temperature, moisture content, and pressure are just a few of the many atmospheric properties that constantly fluctuate. With these fluctuations in the atmosphere comes an equally continuous fluctuation in atmospheric refractivity.

Refractivity of electromagnetic energy is an operationally significant process. By examining the vertical profile of refractivity, regions in which electromagnetic energy may be ducted or trapped can be determined. Refractivity is determined by temperature and vapor pressure in the atmosphere. More specifically, ducting is determined by the gradient of refractivity N, where

$$\mathbf{N = 77.6P/T + (3.73x10^5)}\boldsymbol{e}\mathbf{/T^2}$$

Where P is pressure in millibars, T is temperature in degrees Celsius, and *e* is vapor pressure in millibars. It is often more convenient to express the gradient of refractivity in a modified measure of N, called M units expressed as

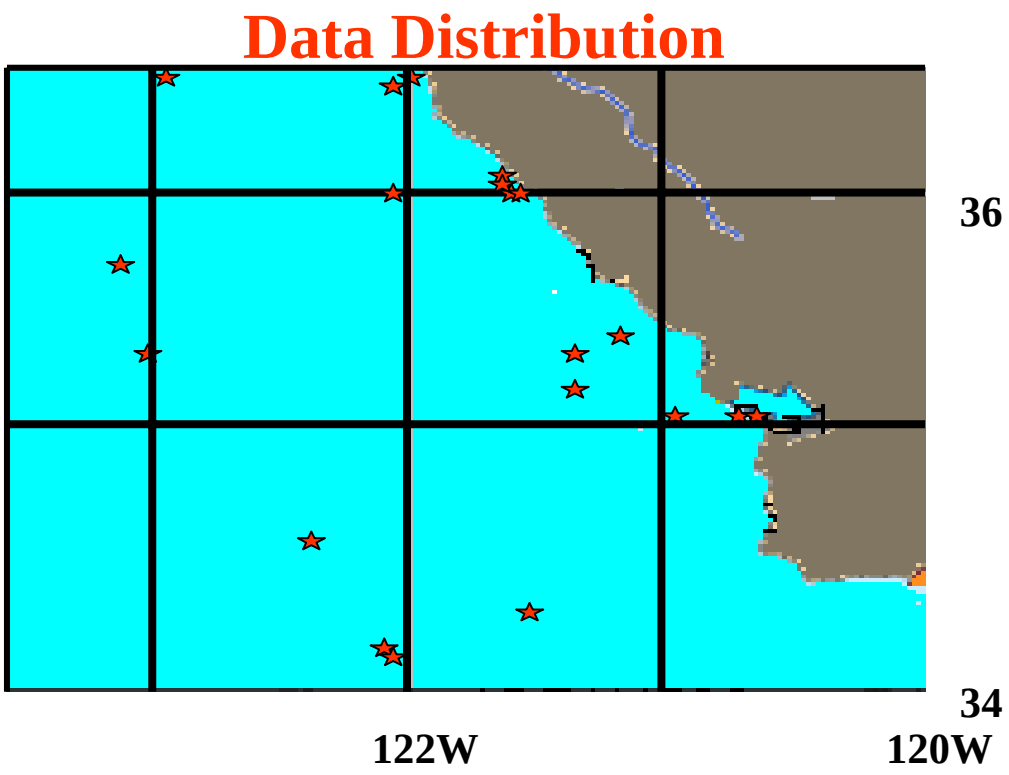
$$\mathbf{M = N + 0.157}\boldsymbol{h}$$

Where *h* is height in meters. In determining the vertical profile of M, it is possible to identify the vertical regions in the atmosphere where ducting or trapping of electromagnetic energy is most likely occurring.

Purpose. Changes in atmospheric vapor pressure and temperature occur spatially and temporally. These changes correspond directly to changes in the vertical gradient of refractivity and, therefore, atmospheric ducting. By creating M-unit profiles from data collected on the OC 3570 Summer cruise, these spatial and temporal changes in atmospheric ducting will be examined for possible trends. Specifically, the height of the lowest significant trapping layer will be identified in order to examine any correlation

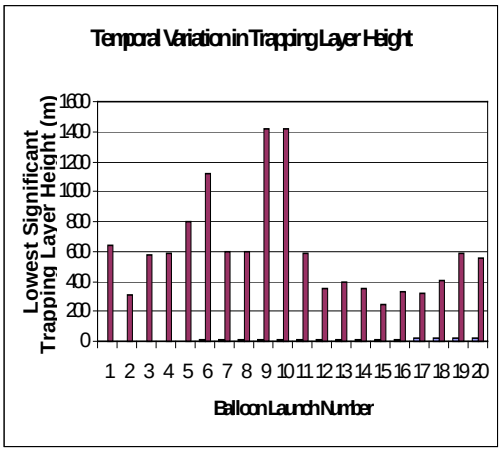
between this height and changes in time during the cruise as well as the position of the research vessel. For the purpose of this study, a trapping layer is deemed significant if it satisfies the criteria that it has a negative gradient of at least 1 M-unit per 10 meters in height overlying a positive gradient of that same magnitude, and that it is at least 100 meters thick. In addition to determining a relationship between the height of the lowest significant trapping layer and the changes in time and space for the period of the cruise, an explanation for any correlations will be offered.

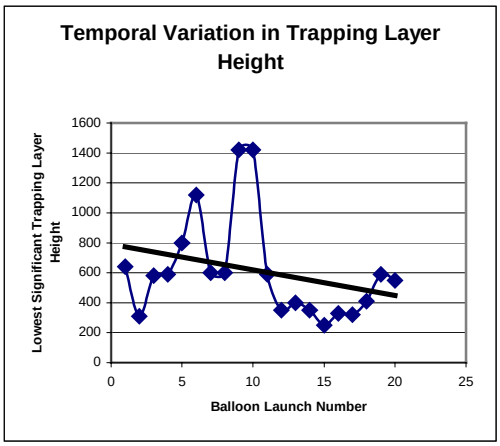
Data Collection. From the cruise dates between 02 Aug 01 – 08 Aug 01, data from twenty upper-air soundings was gathered and analyzed. During the 6 days of the cruise, the soundings collected spanned a latitudinal distance of 2.21 degrees (36.44N – 34.23N), and a longitudinal distance of 2.77 degrees (123.22W – 120.45W). This area for data collection thus represents a horizontal area of approximately 300 nm. Figure 1 depicts the location at which the 20 soundings in the data set were taken.



M-unit profiles from these 20 soundings were created in MATLAB. Only the lowest 2000 m of vertical data were examined. Each of the 20 soundings, however, contained a significant trapping layer in the lowest 2000m, so the data used for this study is comprised of a full set of 20 significant layer heights. The height of the layer was determined by the axis of the duct.

Data Analysis and Results. After generating plots of M-unit profiles and determining the height of the lowest significant trapping layer for each of the 20 soundings, the data was examined and analyzed to determine if there was any trend between the height and the changes in time and space throughout the period of the cruise. A bar graph of balloon launch number versus height (fig. 2) was created in addition to a scatter plot containing the same data (fig. 3).

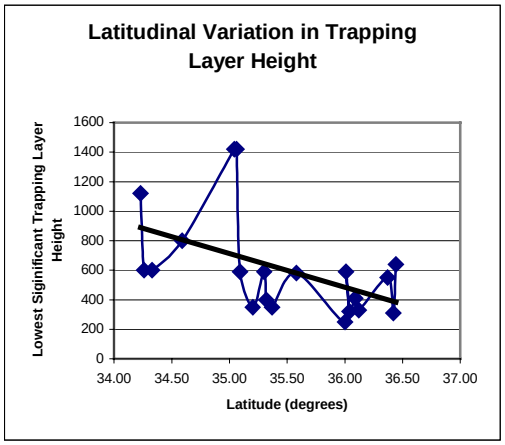


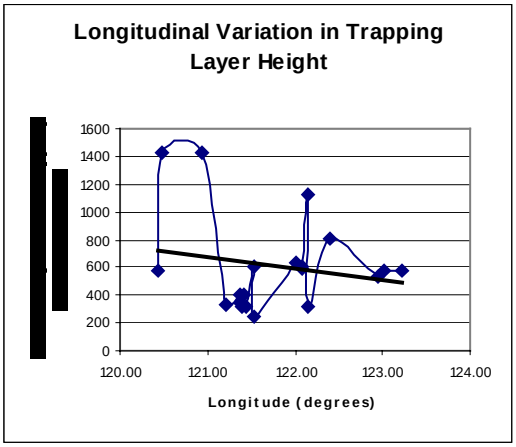


Based on the trend line plotted on fig. 3, it appears that there is a weak but noticeable correlation between layer height and time. That is, the height of the lowest significant layer becomes lower with time. The trend of a decrease in layer height with time would be more prominent if not for 2 soundings taken 5 hours apart from each other near the coast on 05 Aug 01. These two soundings were taken at 35.05N 120.49W and at

35.06N 120.94 W, the latter approximately 22 miles to the west of the first. Data from both soundings revealed a trapping layer at 1420 meters. Although this layer was relatively weak in comparison to many of the other soundings, it met the aforementioned criteria and was included. An explanation for this anomalous height will be given later.

In addition to the trend mentioned above, similar trends were also identified when comparing lowest significant layer height with latitudinal and longitudinal position (figs. 4,5).





Here, the height of the lowest significant trapping layer decreases with both an increase in latitude and longitude. Once again, the two anomalous data points near the coast skew the correlation.

Conclusions. The analyzed data reveals that, over the course of the cruise period, the height of the lowest significant layer height decreased with time. Additionally, a weak trend also existed between layer height and the change in latitude and longitude. However, after examining the synoptic pattern over the area of data collection, nothing in the overall environmental flow would explain the temporal and spatial pattern that appeared in the data. Normally, an increase in surface pressure associated with a building

high would tend to increase the subsidence and thereby lower the height of the trapping layers examined in the analysis. However, this synoptic trend did not take place over the course of the cruise, so this is not a valid explanation for the decrease in layer height with time. Likewise a gradient of higher pressure to the north or east would explain higher trapping layer heights occurring to the south or west, but the overall synoptic pattern does not support this hypothesis either, as the surface pressure obtained from observations throughout the period did not support the presence of higher surface pressure to the north or west.

The apparently anomalous soundings taken along the coast near Port San Luis, however, may be explained more clearly. When these two soundings were taken along the coast, weather conditions changed dramatically compared to the conditions at the time of the prior sounding and compared to conditions during the subsequent sounding. Specifically, near the coast the research vessel was out of the marine layer in a region characterized by clear skies and light surface winds. On the contrary, the preceding and subsequent soundings were further offshore with surface winds exceeding 15 kts and overcast skies. In this region, a rapid decrease of vapor pressure accompanied by a temperature inversion yielded a trapping layer height of 600m. On the other hand, the near shore soundings did not exhibit these same thermodynamic profiles until higher in the atmosphere, thus leading to a trapping layer height near 1400m.

Unfortunately, this data was constrained by the restriction that a significant trapping layer be characterized by a specific thickness and gradient. These parameters were selected so that most, if not all of the soundings would have a significant trapping layer in the lowest 2000m. Unfortunately, none of the trapping layers found in the 20

soundings would be considered operationally significant due to their lack of strength and vertical extent.