JP1.5 STABILITY ASSESSMENT FROM SURFACE-BASED TEMPERATURE MEASUREMENTS

Gail M. Roth, Michael Rossetto, and Peter L. Jackson*
University of Northern British Columbia, Prince George, British Columbia, Canada

1. INTRODUCTION

Stability within the Planetary Boundary Layer (PBL) significantly influences turbulent diffusion of pollutants and hence, air quality (Kawashima et. al, 1999, Hayden et. al, 1997).

PBL stability is commonly evaluated by assessing vertical temperature and humidity profiles of the free-atmosphere. Remote sensing instruments such as satellites and radio acoustic sounding systems as well as in situ methods (e.g. radiosondes and tethersondes) can be employed to obtain these data.

Transecting a valley with surface-based temperature/RH monitors provides an alternative approach to measuring vertical profiles of the free-atmosphere within mountain-valley terrains. This method is cost-effective and provides greater temporal frequency of temperature and RH measurements relative to the conventional methods mentioned previously. However, utilizing surface-based measurements to characterise the free-atmosphere may provide unrepresentative results.

Surface temperatures are strongly characterised by vegetative cover, topographic characteristics and thermal properties of the ground (Kawashima et. al, 2000 and Blennow, 1998). Within mountain-valley terrain, surface temperatures are also influenced by anabatic and katabatic winds (i.e. up-slope and down-slope winds). These winds form as a result of temperature and pressure gradients created from surface heating and cooling, during the day and night respectively (Anquetin, S. et. al, 1998). Depending on physical and meteorological conditions, the cumulative effect of these processes may cause the surface climate to be unrepresentative of the PBL.

The primary objective of this study is to evaluate whether surface-based measurements will provide an accurate description of free-atmosphere vertical temperature profiles within the Prince George valley of central British Columbia, Canada.

A secondary objective is to create an inversion index from the surface-based temperature and wind profiles and relate them to ambient levels of SO_2, NO_x, TRS, PM_{10}, and $PM_{2.5}$ (obtained from a central monitoring location). This objective will be addressed once the majority of the field data has been collected.

2. MATERIALS AND METHODS

2.1 Site Description

The area of interest is located within the Prince George valley in central British Columbia, Canada which is at the intersection of the Fraser and Nechako Rivers. The valley is generally oriented in a north to south direction. The surface is forested, consisting of various deciduous and coniferous tree species. Shading is often greater during summer months relative to winter months at most surface based sites.

2.2 Surface-based Measurements

In August 2003, a total of 18 HOBO temperature/RH data loggers were set up in an east-west transect across the Prince George valley. The temperature/RH loggers span a distance of approximately 26 km from Cranbrook Hill (western boundary: 53° 53' 32" N, 122° 53' 04'' W) to Tabor Mountain (eastern boundary: 53° 54' 48" N, 122° 27' 14" W). Fifteen of the 18

*Corresponding author address:
Peter L. Jackson, Environmental Science and Engineering Programs, University of Northern British Columbia, 3333 University Way, Prince George BC, Canada V2N 4Z9
Email: peterj@unbc.ca

temperature/RH loggers are located on the eastern slope of Cranbrook Hill (613m to 880m ASL) and the remaining 3 are located on the western slope of Tabor Mountain (881m to 1235m ASL). The elevation interval between consecutive temperature/RH loggers is approximately 20m. The temperature/RH loggers are located approximately 1.5m above ground level (AGL), and are similarly situated within tree stands.

The loggers have been programmed to record instantaneous temperature, RH and dew point measurements in 20 minute intervals.

2.3 Radiosonde Measurements

Vaisala RS80 Radiosondes are released twice-daily at 03:20 and 15:20 Pacific Standard Time (PST) (i.e. 0 and 12 UTC) by Environment Canada. The release site is approximately 1 km from the base of Cranbrook Hill (53° 53' 59" N, 122° 47' 27" W, 601 m ASL).

The RS80 takes instantaneous measurements every 2 seconds but reports in 10 second averages. This typically results in a measurement every 45 vertical metres. The radiosonde collects meteorological data up to approximately 50km elevation, however only the data for the first 1235m ASL corresponding to the elevations of the surface-based measurements are utilized in this study.

Meteorological data obtained from the radiosondes for this study includes: temperature, RH, dew point, wind direction, and wind speed.

To allow for direct comparison of radiosonde and surface-based temperatures the radiosonde temperatures are linearly interpolated onto the elevations of the surface-based data.

3. PRELIMINARY OBSERVATIONS

3.1 Study Period

Data collection began in August 2003 and will continue until August 2004. Preliminary comparison analysis between the surface and radiosonde data is shown here for temperature and derived lapse rate from August 2003 through April 2004. If the surface-based data provides an adequate representation of the free-atmosphere vertical profile, an inversion index will be created and compared to ambient pollutant measurements from a central monitoring location to identify and elucidate stability conditions which result in high pollutant levels.

3.2 Temperature

Surface-based and radiosonde temperatures are highly correlated. The R^2 value for the correlation between surface and radiosonde temperatures for the period of August 2003 to April 2004 is 0.9766 (Figure 1).

The 3 temperature/RH loggers located on Tabor Mountain at the highest elevations and the greatest distance from the radiosonde release site, were most different from the radiosonde data. The significant spatial separation between the Tabor Mountain sites and the radiosonde station provides a probable explanation for the observed difference between the temperature profiles of the radiosonde and these sites.

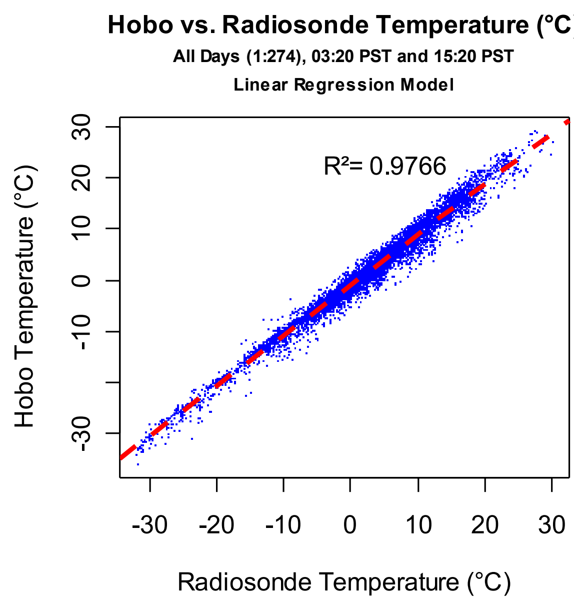

Figure 1: Relation between surface and radiosonde temperatures (°C) for all elevations, all temperature measurements (03:20 and 15:20 PST) from Aug 2003 to Apr 2004.

3.2.1 Diurnal Trends

From August 2003 to April 2004, the 03:20 PST R^2 value is 0.9725 and the 15:20 PST R^2 value is 0.9839. Cold air drainage and pooling overnight is a plausible explanation for the slightly reduced R^2 values associated with 03:20 PST measurements.

3.2.2 Seasonal Trends

A seasonal fluctuation in correlation of the surface and radiosonde measurements has been observed. Warmer months have lower R^2 values (e.g. August 2003, $R^2 = 0.8981$) relative to the colder months (e.g. January 2004, $R^2 = 0.9902$).

A reduced amount of surface radiation, cold temperatures and increased albedo (from snow cover) during winter months all contribute to reduced convective heat fluxes at the surface. This results in greater similarity between the surface-based and free-atmosphere temperatures in winter.

3.3 Lapse Rate

The lapse rate here is defined as $\Delta T/\Delta Z$ (the change in temperature with increasing height) with negative values indicating a decrease in temperature with height.

The two elevations with the lowest average absolute temperature difference between the surface-based and radiosonde temperature measurements were selected for lapse rate calculations. These elevations are 658m and 880m ASL.

As anticipated, the lapse rate R^2 values are lower compared with those for temperature. The overall R^2 value for the period of August 2003 to April 2004 is 0.8143. Significantly fewer data points were used in the lapse rate calculation (one lapse rate per sounding, rather than 18 temperature measurements) which decreases R^2. In addition, the lapse rate includes the sum of errors from two temperature measurements which also contributes to a lower correlation.

3.3.3 Diurnal Trends

Morning lapse rate estimates from the surface-based measurements are more highly correlated with the free-atmosphere lapse rate compared with those in the afternoon. The correlation coefficient for all 03:20 PST lapse rates (August 2003 to April 2004) is 0.8571 and 15:20 PST is 0.4079 (Figure 2). This is due in part to the fact that inversions rarely never occur during the afternoon and if they do, they are much weaker, so that the range of lapse rates is much greater in the early morning than in the afternoon contributing to the higher R^2 value in the 3:20 PST comparison.

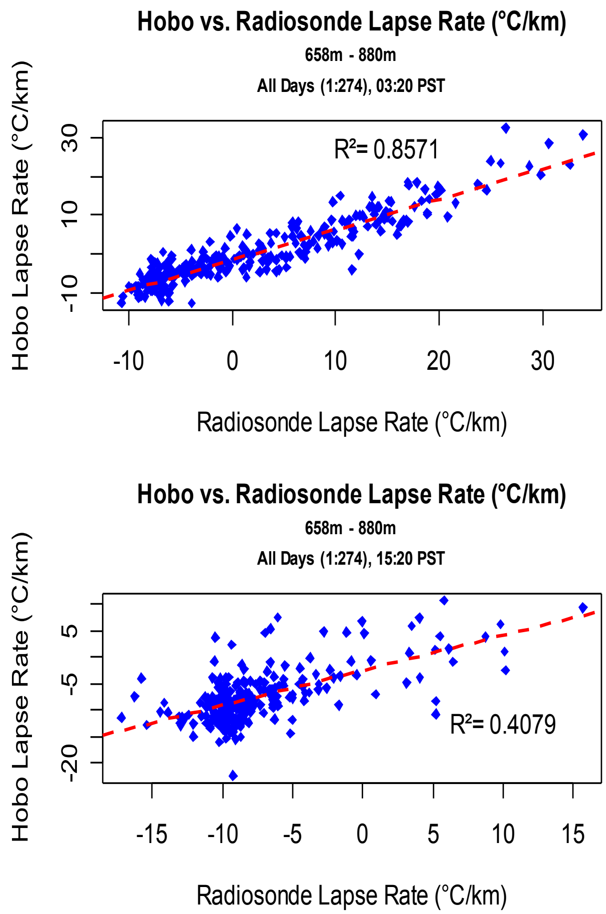

Figure 2: The relation between derived surface-based and radiosonde lapse rates (°C km^{-1}) for 03:20 and 15:20 PST, August 2003 to April 2004.

When the data were segregated into monthly intervals it became more apparent that the 03:20 PST lapse rates provide a better representation of the radiosonde lapse rates than the 15:20 PST measurements. The 3:20 PST correlation coefficients ranged from 0.7379 (March 2004) to 0.9149 (April 2004) compared with -0.03888 (August 2003) to 0.7342 (January 2004) for 15:20 PST.

Convective heat flux generated from the surface during the afternoon is likely affecting the afternoon surface-based measurements, also contributing to the decreased R^2 values.

3.3.4 Seasonal Trends

Seasonal fluctuation of lapse rate correlation coefficients is much less apparent than the seasonal fluctuation of temperature correlation coefficients. The average April lapse rate had the highest correlation ($R^2 = 0.9381$), the minimum R^2 was in September ($R^2 = 0.7141$). Further investigation is required to account for the variation.

4. CONCLUSIONS AND FUTURE WORK

From preliminary analysis, surface-based temperature and lapse rate correlations predominantly appear to provide an adequate representation of the free-atmosphere vertical temperature profile, especially in the early morning. Given that the largest deviations are associated with the 15:20 PST measurements, a detailed examination of this temperature data is required (i.e. individual days) to determine which meteorological conditions are associated with both high and low correlation coefficients. Once the relationship between the surface-based and radiosonde temperatures is more fully understood, an inversion index will be created. It will be used to see whether there is a relationship between inversion strength and ambient pollutant concentrations. Ambient levels of SO_2, NO_x, TRS, PM_{10}, and $PM_{2.5}$ will be obtained from a central monitoring location.

Upon complete analysis and formulation of the surface-based inversion index, the proficiency of surface-based measurements to detect inversion strength, and thereby indicate potential meteorological conditions for pollutant episodes in the Prince George valley will be determined.

5. ACKNOWLEDGEMENT

Funding for this work was provided by the BC Ministry of Water, Land and Air Protection and the Natural Science and Engineering Research Council of Canada via a Discovery Grant to P.L. Jackson and an Undergraduate Student Research Award to G.M Roth.

6. REFERENCES

Anquetin, S., Guilbaud, C., Chollet, J., 1998: The Formation and Destruction of Inversion Layers within a Deep Valley. *Journal of Applied Meteorology*, **37**, 1547-1560.

Blennow, K., 1998: Modelling minimum air temperature in partially and clear felled forests. *Agricultural and Forest Meteorology*, **91**, 223-235.

Hayden, K.L., Anlauf, K.G., Hoff, R.M., Strapp, J.W., Bottenheim, J.W., Weibe,H.A., Froude, F.A., Martin, J.B., Steyn, D.G., McKendry, I.G., 1997: The Vertical Chemical and Meteorological Structure of the Boundary Layer in the Lower Fraser Valley During Pacific ’93. *Atmospheric Environment*, **17**, 2089-2105.

Kawashima, S., Tomoyuki, I., Minomura, M., and Miwa, T, 1999: Relations between Surface Temperature and Air Temperature on a Local Scale during Winter Nights. *Journal of Applied Meteorology*, **39**, 1570-1579.