

Figure 1 (below) shows time series plots of data from the UNR weather station (Valley Road) for September, 2010.

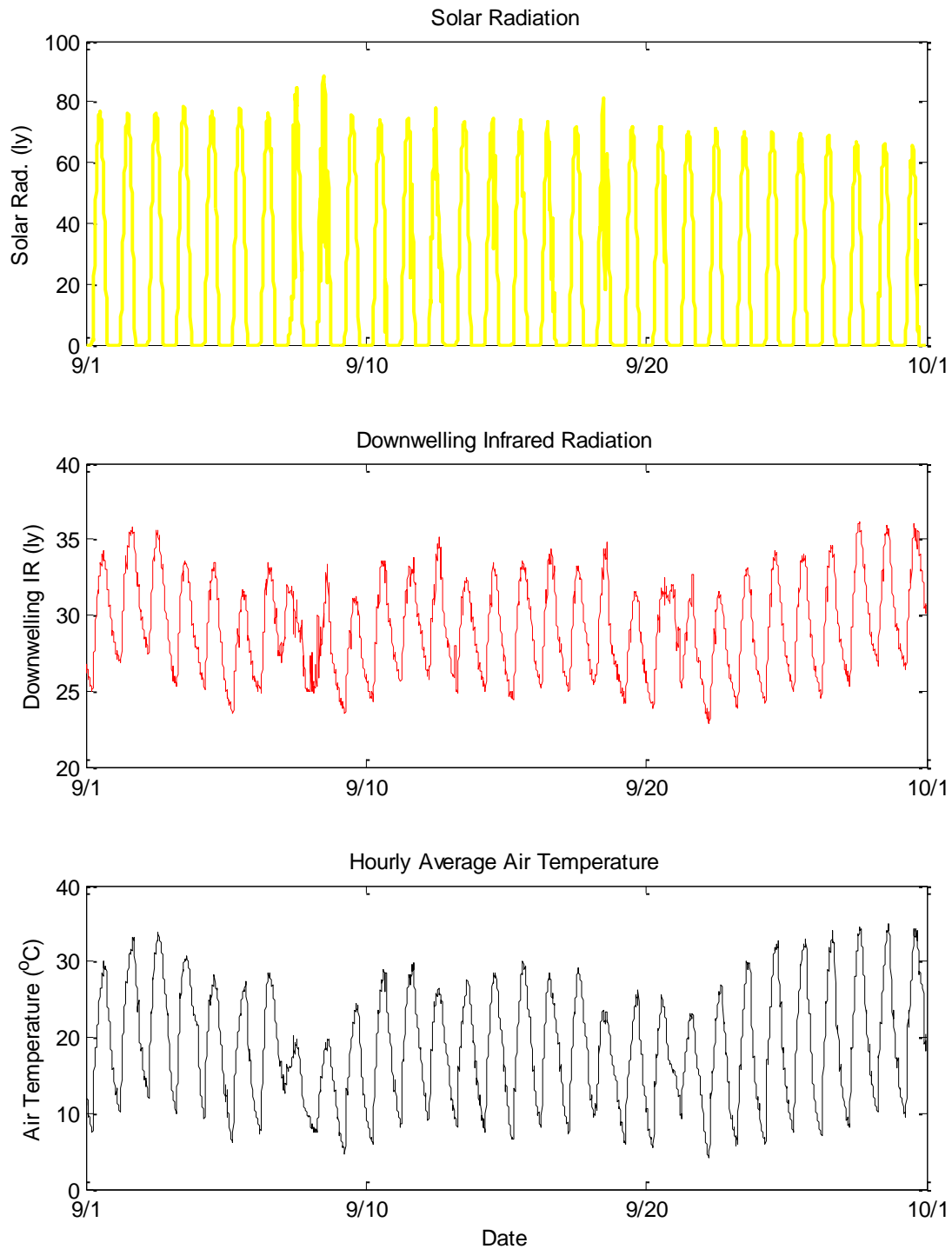


Figure 1: Time series of data observed at UNR's Valley Road weather station.

This homework focuses on the downwelling infrared (IR) radiation measured at the UNR Valley Road weather station during September, 2010. Scatter plots showing the relationship between downwelling IR radiation and UNR air temperature, DRI air temperature, and UNR mixing ratio are presented below. The coefficients of correlation for these three relationships are 0.95, 0.90, and -0.32, respectively.

Figure 2 (below) shows good agreement ($R = 0.95$; $R^2 = 0.90$) between the air temperature and the downwelling IR radiation measured at the Valley Road weather station. The relationship is not surprising, since the radiation emitted by the atmosphere is dependent on its temperature. What is a little surprising to me is the strength of the relationship. The downwelling IR should be controlled by the temperature of the upper atmosphere, not the near-surface temperature recorded by the weather station. The strength of the relationship implies that the near-surface temperature responds to the same factors that control the upper atmosphere temperature.

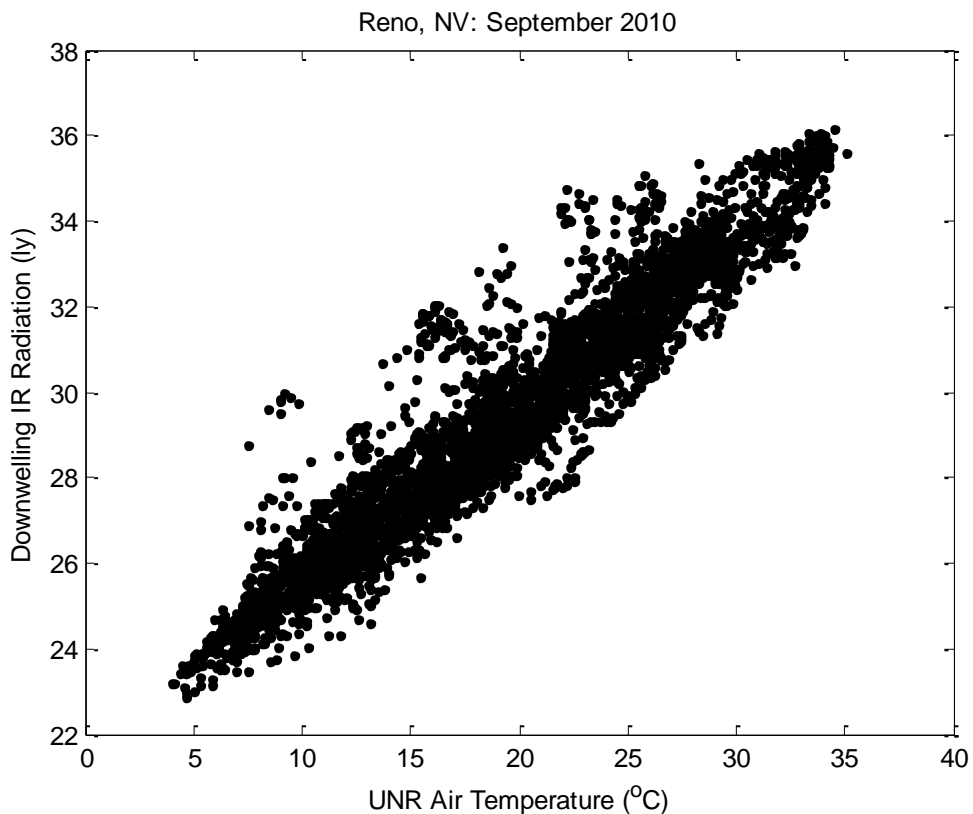


Figure 2: Air temperature and downwelling infrared radiation observed at Valley Road.

The second scatterplot (Figure 3, below) shows the relationship between the air temperature at the DRI weather station and the downwelling IR measured at the Valley Road station. While the relationship is again fairly strong ($R=0.90$, $R^2 = 0.80$), it is not as strong as the relationship shown above. This was initially surprising to me, since the DRI station is measuring air temperature approximately 140 m higher in the atmosphere, closer to the source of the atmospheric radiation. However, the DRI weather station is still measuring the near-surface air

temperature, and is consequently influenced by a number of factors that play little or no role in controlling the temperature of the upper atmosphere.

I suspect that the correlation between the DRI air temperature and the downwelling IR at UNR is primarily caused by the fact that the air temperatures at UNR and DRI weather stations are correlated and respond to similar stimuli. The DRI weather station does not seem to me to be high enough to measure the atmospheric temperature at the source of the downwelling radiation.

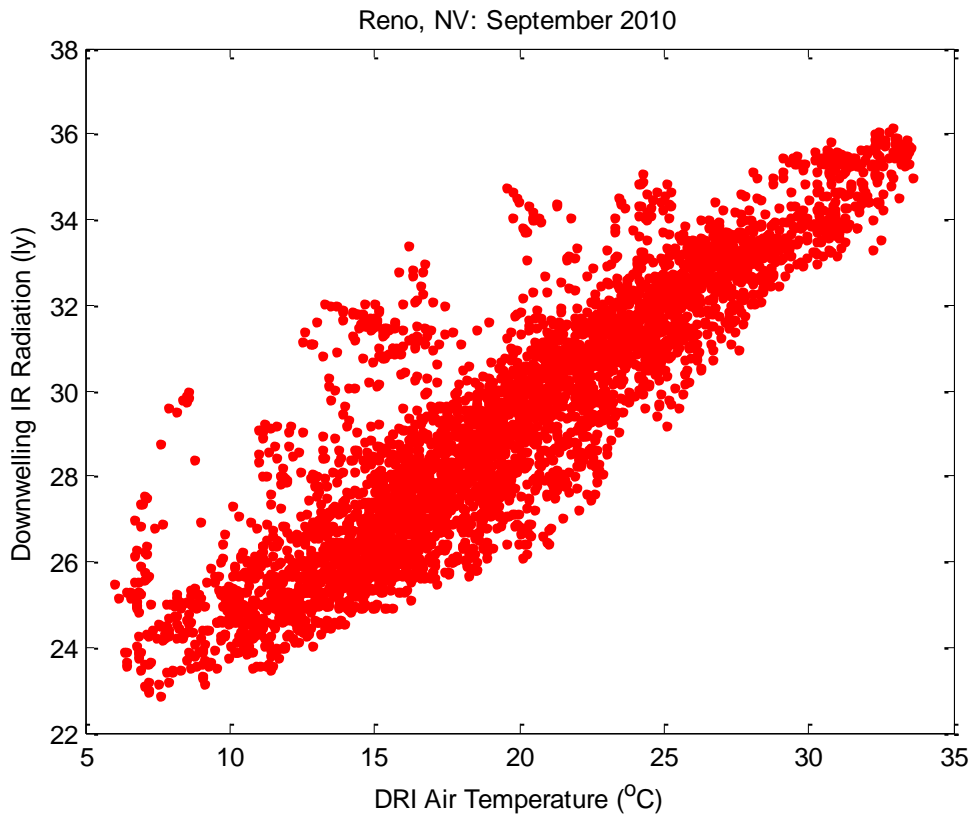


Figure 3: Air temperature measured at DRI weather station (143 m higher than UNR) and downwelling IR radiation observed at UNR.

Figure 4 (the final scatter plot shown below) shows the relationship between the mixing ratio w (calculated according to equation 1) at the UNR weather station and the downwelling IR radiation measured there. While there appears to be a modest negative correlation ($R = -0.32$, $R^2 = 0.10$), variations in mixing ratio explain only about 10% of the variation in downwelling IR. While mixing ratio may have an effect on downwelling IR radiation, it is clear that the IR is controlled primarily by the temperatures.

Calculation of Mixing Ratio:

$$w = 621.97 \frac{e}{P - e} \quad (1)$$

The mixing ratio is calculated according to equation 1, where w is the mixing ratio in g H₂O / kg air, e is the vapor pressure (mb) of water in the air, and P is the air pressure (mb) measured by the weather station. The vapor pressure e is calculated by multiplying the saturation vapor pressure $e_{sat}(T)$ by the relative humidity. The saturation vapor pressure is a function of temperature, as shown below (Allen *et al.*, 1998).

$$e_{sat}(T) = 0.6108 \exp\left(\frac{17.27T}{T + 237.3}\right) \quad (2)$$

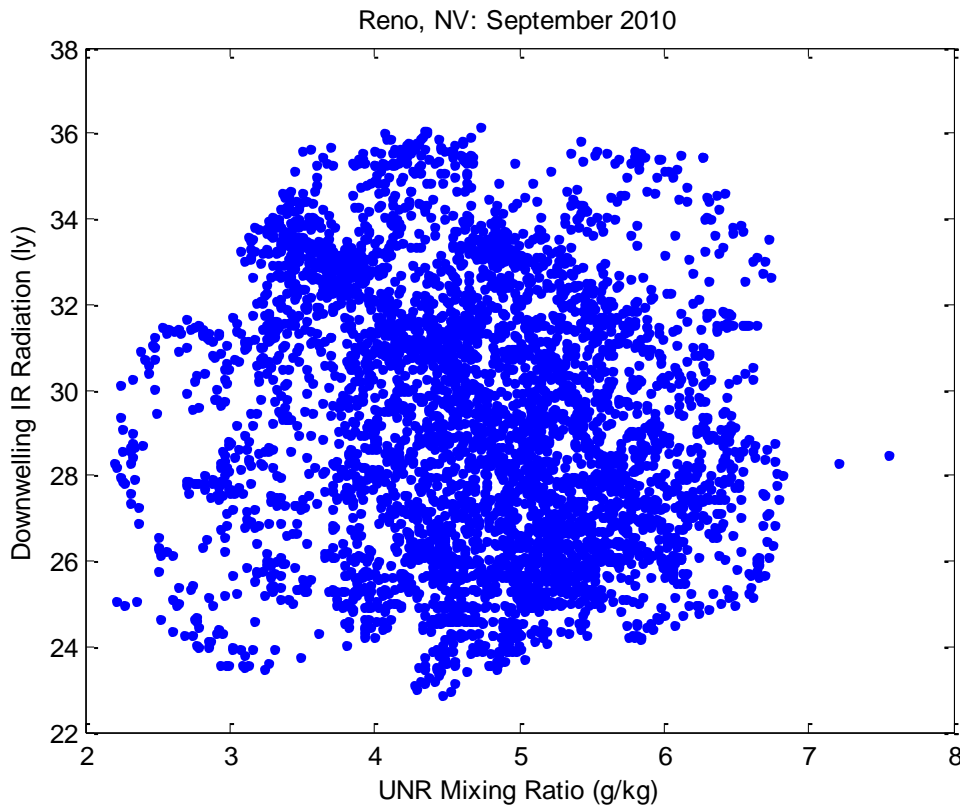


Figure 4: Water vapor mixing ratio vs. downwelling IR radiation measured at UNR weather Station, Valley Road.

Figure 5 (below) shows the relationship between the empirical estimate of the Boltzmann constant proposed by Staley and Jurica (1972) and the downwelling IR radiation measured at the Valley Road weather station. This relationship, shown below in equation 3, relates the downwelling IR radiation at a point on the surface to the air temperature and vapor pressure at that point.

$$\frac{F \downarrow}{\sigma T_0^4} = C e^m \quad (3)$$

In conjunction with equation 3, the data collected from the UNR weather station allow us to estimate the Stefan-Boltzmann constant. After integrating the radiation data recorded during each time step and then converting from langleys s^{-1} to $W m^{-2}$, the value of the Stefan-Boltzmann constant σ was estimated to be $8.88 \times 10^{-8} W m^{-2} K^{-4}$, approximately 30% greater than the actual value of $5.67 \times 10^{-8} W m^{-2} K^{-4}$. This error is very reasonable, considering the empirical nature of the relationship and limited data available for the estimation.

For the data recorded at the UNR weather station during September, a separate relationship was developed to better match the observed downwelling IR to the other observed parameters. Initially, the downwelling IR was compared solely to the fourth power of temperature, and the results were roughly proportional ($R = 0.95$, $R^2 = 0.90$). The constant of proportionality had a mean of 6.69×10^{-8} , with a standard deviation of 2.20×10^{-9} .

Attempts were then made to refine this relationship by including the mixing ratio or the vapor pressure of the air. Linear and power relationships were examined, and natural logarithm and exponential transformations were also explored. The equation that was finally derived to represent the data from September 2010 is shown below in Equation 4, and a scatterplot of the data is shown in Figure 5.

$$F \downarrow = 5.98 \cdot 10^{-8} T_0^4 e^{0.0745} \quad (4)$$

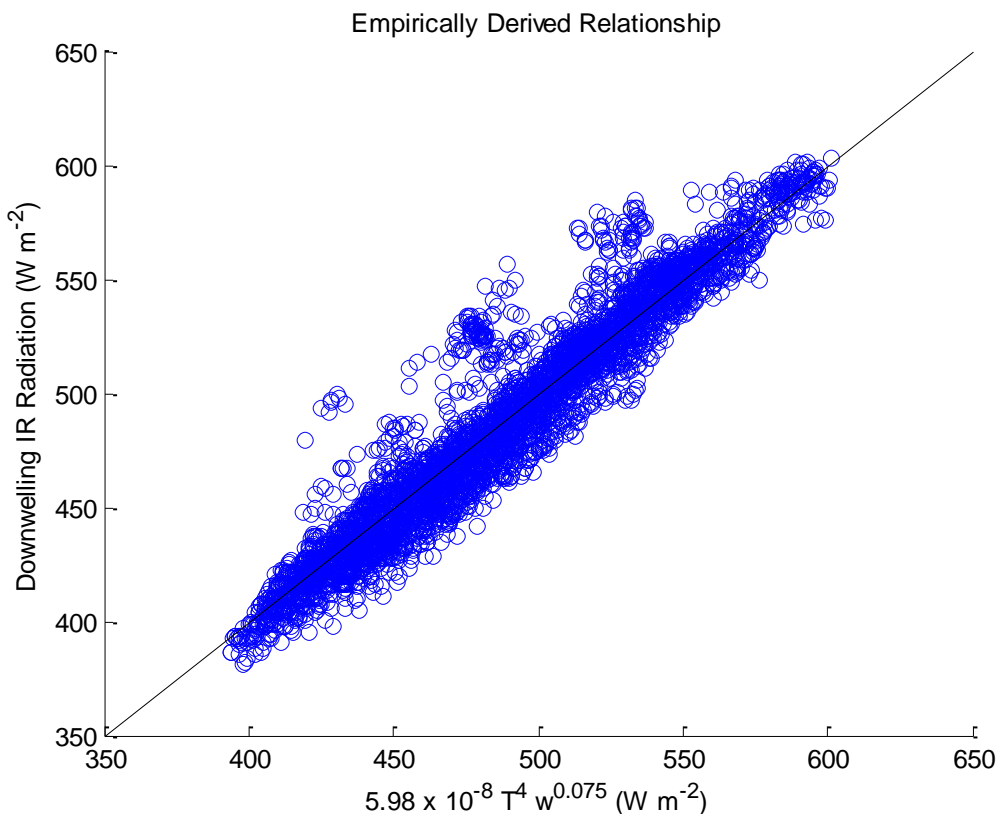


Figure 5: Empirically derived predictor of downwelling IR radiation at the UNR weather station

Ultimately, the influence of temperature (specifically, the influence of T^4) almost always overwhelmed the contributions of humidity to the downwelling IR radiation. In addition to the

fact that the fourth power of temperature controls radiation, the variance of the temperature was much greater than the variance of the humidity parameters. That equation, however, yielded a correlation between IR radiation and weather data ($R = 0.961$, $R^2 = 0.923$) that was only slightly greater than the correlation between IR radiation and temperature alone. The addition of the moisture parameter to the equation explains just over 2% of the variation in IR radiation that was left unexplained by the temperature variation. A more full data set, especially one in which humidity varied more significantly, would likely result in an equation that better captures the influence of water vapor on the downwelling IR radiation at the study site.

Works Cited

Allen, R.G., Pereira, L.S., Raes, D., and Smith, M. 1998. Crop evapotranspiration – Guidelines for computing crop water requirements. *Irrigation and Drainage Paper 56*. Food and Agriculture Organization of the United Nations, Rome, Italy.

National Oceanographic and Atmospheric Administration. 2010. Mixing Ratio. Accessed 11/18/2010, from <http://www.srh.noaa.gov/images/epz/wxcalc/mixingRatio.pdf>. 1 page.

Staley, D.O. and Jurica, G.M. Effective emissivity under clear skies. *Journal of Applied Meteorology*, 11: 349-356.