Variation of Solar Attenuation with Height in CAPLTER

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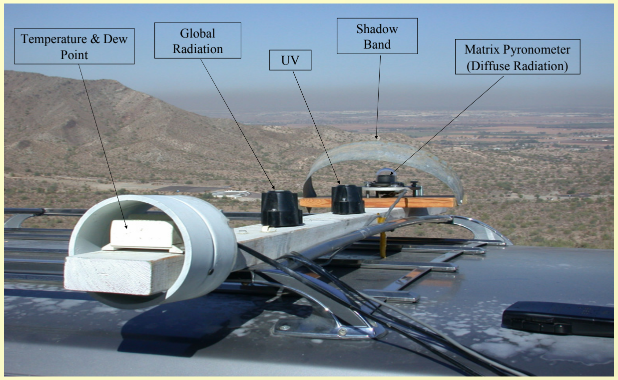
Abstract

The atmosphere over rural and urbanized areas differs in many ways in relation to terrain influences and human-induced variations (e.g., heat, humidity, wind, and pollution). The sun's energy penetrates through the atmosphere to reach the variable surface of the region. From the top of the atmosphere to the surface, there are controls on amounts of solar energy that are accumulated at any given time. These controls range from extraterrestrial, to regional, to local in scale. In the urbanized/rural landscape of CAPLTER, a question arises as to the local variability of the amount of the sun's energy across the region. Previous information on Phoenix indicates that particulates and other pollutants may induce over a 15% urban/rural contrast. The implications for this amount of variability cascade into plant productivity, solar energy technology, and urban climate processes, in general. This poster illustrates the impact of local factors (e.g., elevation, land use, pollution) on solar reception utilizing a mobile transect method. The mobile sampling method is designed to sample the horizontal and vertical domain (e.g., across the city and up and down South Mountain). Results confirm large spatial and vertical gradients to solar reception in fall and winter.

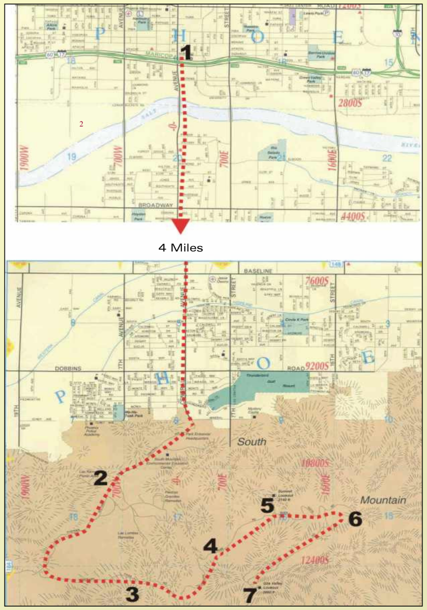
Purpose

This research examines the vertical structure of the urban atmosphere, the variation of solar attenuation with height over Phoenix Arizona during the autumn of 2001.
Previous CAPLTER studies focused on spatial variation in solar radiation receipt in the horizontal dimension (Tomalty and Brazel '01) and some implications of urban induced solar radiation reductions for solar collector efficiency (Tomalty and Brazel '00). Similar to other studies (e.g., Bach '71), this research combines direct measurements with modeling to determine the vertical structure and aerosol content of the urban atmosphere.



Oct. 24, 01: Uphill Transect, Mobile Transect Instrument Setup

View from South Mountain, at 10:42, toward Phoenix at 1600' elevation (site #3). Bulk of "Brown Cloud" appears to be at or below 1600' elevation.



Theory and Methodology

Solar radiation passing through the atmosphere is attenuated by three major factors. (Brooks '59, Bach '71)

1. Scattering by air molecules or Rayleigh scattering.
2. Selective absorption by gases e.g. water vapor, ozone and CO_2.
3. Scattering and absorption by solid and liquid particles e.g. aerosols and dust.

If solar intensity (i.e., direct beam radiation), air temperature and the water status of the atmosphere are measured at a known elevation, turbidity values may be calculated for that location.

We took a broadband approach measuring radiation in the visible and near I.R. portion of the solar spectrum between 0.1 and 1.1 microns. Global radiation was measured with a Licor pyranometer while diffuse radiation was measured with a Matrix pyranometer fitted with a miniature shadow band thus allowing us to calculate the direct beam component necessary to model turbidity values. Both pyranometers were calibrated against the laboratory standard at the Laboratory of Climatology at Arizona State University. These instruments are inexpensive and readily available compared to the more expensive monochromatic Volz sun photometer used in other studies. Also broadband readings which include the PAR radiation band relate to solar collector applications and biological applications such as primary plant productivity. The broadband approach also allowed us to evaluate the relative importance of water vapor and Rayleigh scattering in the atmospheric attenuation process.

Solar radiation (global, diffuse and UV) along with air temperature, dew point and pressure readings were observed along a "vertical" mobile transect at 6 locations up the north side (urban side) of South Mountain. A 7th site, Durango, part of the ALERT flood warning network was monitored as a central Phoenix control site. The transects averaged approximately 60mins in duration in both the up and downhill segments. Both studies covered a vertical elevation difference of about 1100ft and covered a horizontal distance of over 5 miles.

Results

Fig 1. Shows the variation of global radiation receipt (global/ETR) with height on Oct. 24 and Nov 28, '01 on both the uphill and downhill transects and the average of the two runs.

Fig 2. Shows the turbidity variation with elevation expressed as aerosol dust factor (d) for Phoenix South Mountain for Oct. 24 and Nov. 28, '01.

Fig 1 OCT. 24, 01 NOV. 28, 01

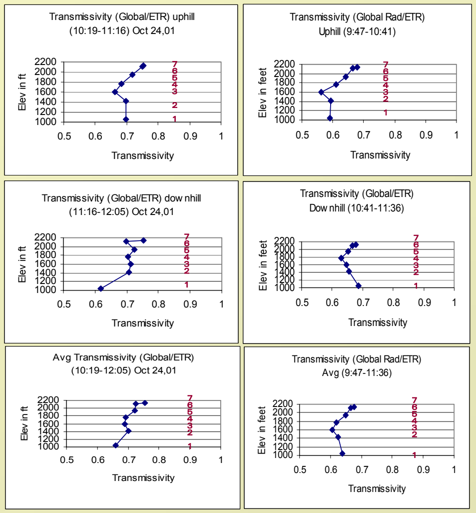
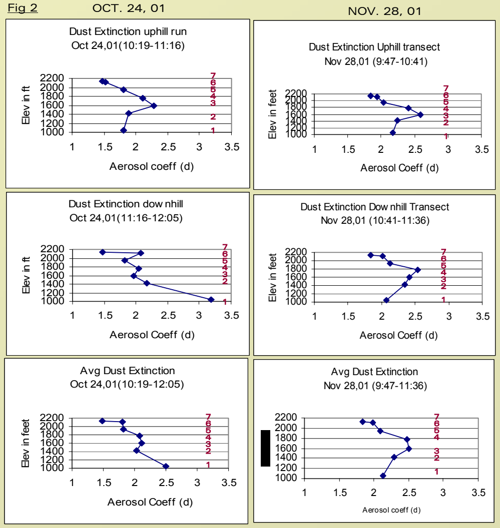


Fig 2 OCT. 24, 01 NOV. 28, 01



Direct beam radiation, temperature, Dp and pressure values were then used to calculate Turbidity values (d) using a 3 factor attenuation model after Brooks (brooks '59).

m=1/(cos Z + 0.15*(90-Z + 3.885^1.253)

Turbidity factor (d) for dust, haze and aerosol

Pressure

$$Q = ETR * \exp\left[-0.089\left(\frac{pm}{1013}\right)^{0.75} - 0.174\left(\frac{wm}{20}\right)^{0.6} - 0.083\,(dm)^{0.9}\right]$$

Direct beam Radiation 2m above the surface

Water vapor in mm after Won'77 (w)=0.1*EXP(2.2572 + (0.054*Dp))

Conclusion and Further Work

- Mobile transects are ongoing on seasonal and synoptic solar variations
- Days sampled show definite vertical pattern related to aerosol effects. (Effects are not linearly decreasing with height, but are complex)
- Top of South Mountain appears above the bulk of pollution for Oct and Nov as transmissivity increased by more than 10%.
- One problem with mobile method relates to sampling in the horizontal direction with elevation change rather than in situ vertical sampling.
- Variations exceed 10% and relevance potentially relates to ecosystem effects and human use of energy

References

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