An Evaluation of Cloud Cover, Cloud Effect, and Surface Radiation Budgets at the Tropical Western Pacific Darwin Site

C.N. Long and K. Gaustad
Pacific Northwest National Laboratory
Richland, Washington

Shortwave Flux Analysis Value Added Product

The Shortwave Flux Analysis (SWFA) Value-Added Product (VAP) was developed originally for daily fitting of coefficients (Long and Ackerman 2000). However, daily fitting calls for at least 110 one-minute clear data/day as minimum requirement. As shown in Figure 1 (top left), the ARM Climate Research Facility's (ACRF's) Southern Great Plains (SGP) and North Slope of Alaska (not shown) site climates easily meet the minimum daily fitting requirements. For the ARM equatorial tropical sites, persistent cloudiness precludes daily fitting (top right), and a composite fitting approach was developed (Long and Gaustad 2004). For Manus and Nauru, an 8-month running composite fit is used for the clear-sky total downwelling shortwave (SW), with fit coefficients for the clear-sky ratio of diffuse over total SW adjusted in a final pass through the data. The monsoon climate of Darwin (bottom), however, requires daily fitting for the dry season, but composite fitting for the wet. The switch between the two fitting methodologies as appropriate requires a knowledgeable decision. It is proposed that Darwin ARM data be manually processed for the SWFA VAP submission to ARM Archive.

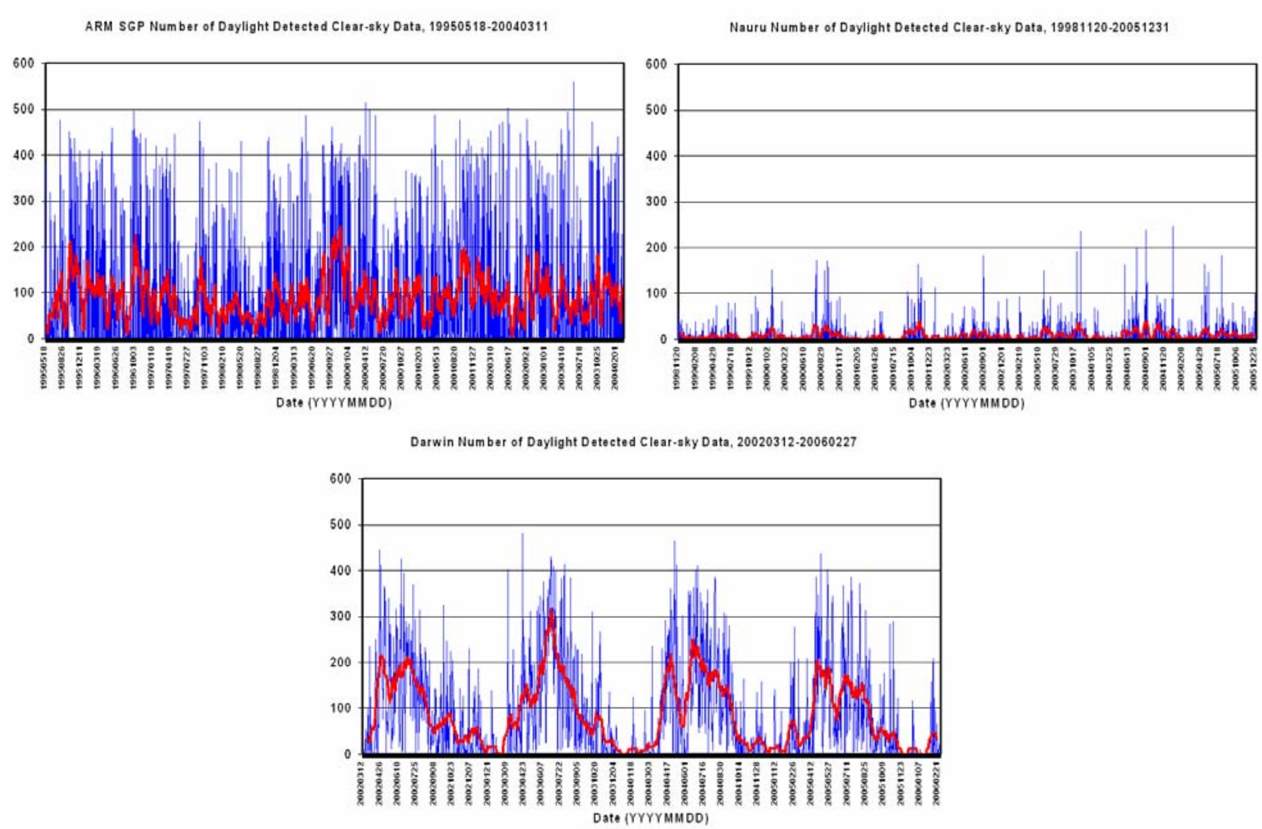


Figure 1. Daily number of 1-minute periods detected as clear-sky (blue) and corresponding 21-day running mean (red) for Southern Great Plains (top), Nauru (middle), and Darwin (bottom).

Surface Radiative Energy Budget

Monthly averages of downwelling clear- and all-sky SW (Figure 2, top left) show greater seasonal variation in the clear-sky than the all-sky, with the peak clear-sky SW occurring in the wet months. Monthly averages of daylight fractional sky cover (Figure 2, top right) show that the wet season exhibits much greater cloudiness than the dry. These two “opposing” conditions act to reduce the wet/dry seasonal variation in all-sky downwelling SW. However, the monthly average all-sky downwelling longwave (LW) (top left) peaks during the wet months due to the contribution of clouds. This is not the case for the downwelling SW cloud effect (lower left), which shows that the frequent cloudiness during wet season decreases the downwelling SW by up to 160 Wm^{-2} on a monthly basis, compared to a modest 20 Wm^{-2} decrease during the dry months. The clear-sky downwelling direct and diffuse SW mimic the clear-sky downwelling SW in seasonal cycle (lower right), though with some variation in partitioning between the two. For the all-sky, diffuse SW is greater corresponding to times of greater cloudiness, where the direct SW is strongly negatively correlated with cloudiness. The surface albedo (top right) exhibits only small variation on a monthly basis, with slightly greater values associated with greater downwelling direct SW. The upwelling SW and LW (top left) both exhibit relatively small variability across the months.

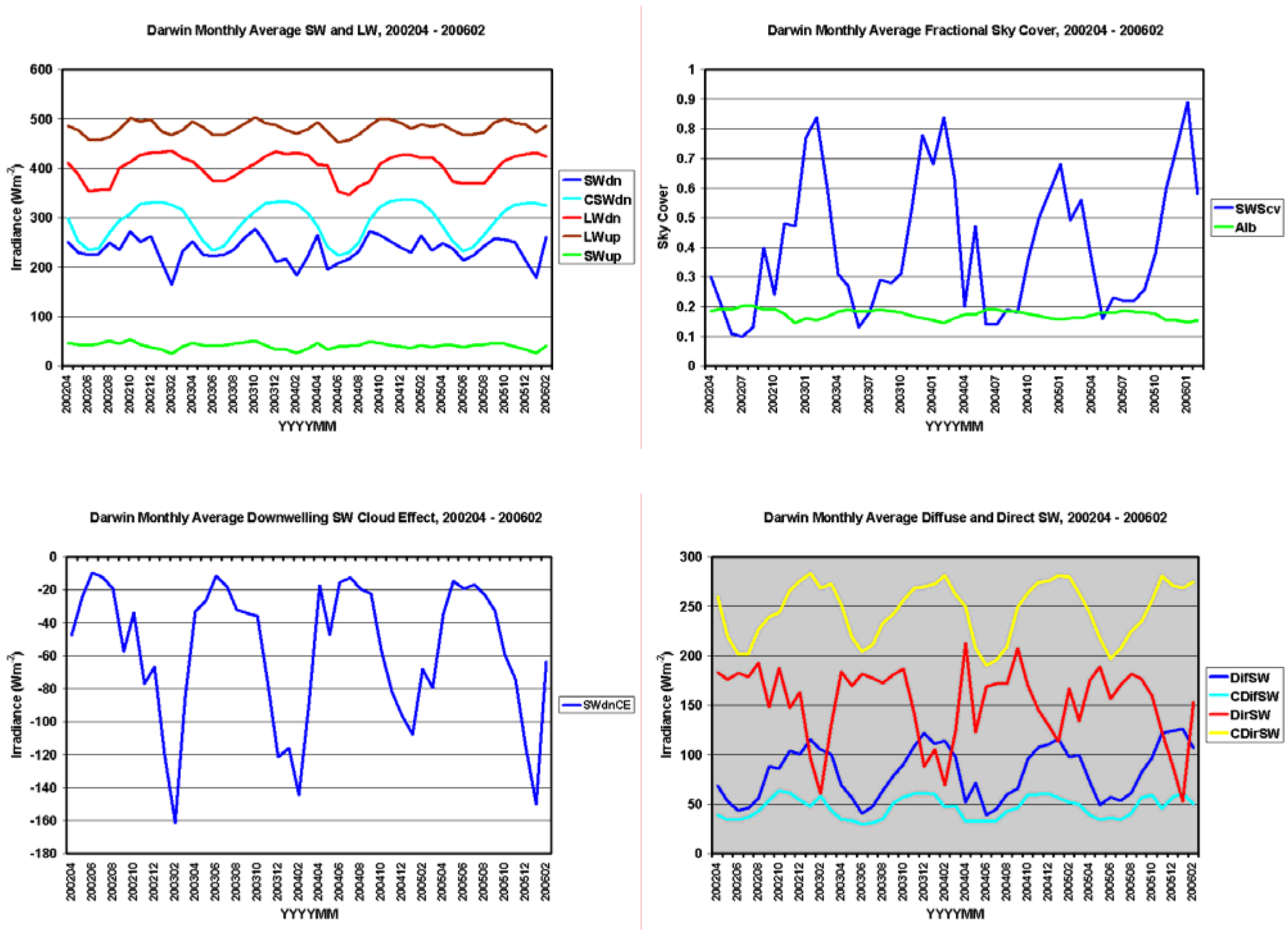


Figure 2. Top left: Monthly average downwelling clear-sky (light blue) and all-sky SW (blue), downwelling LW (red), upwelling SW (green), and upwelling LW (brown) for the Darwin ACRF site. Top right: Monthly average daylight sky cover (blue) and surface albedo (green). Lower left: Monthly average downwelling SW cloud effect. Lower right: Monthly average clear-sky (light blue) and all-sky (blue) diffuse SW, and clear-sky (yellow) and all-sky (red) direct SW.

Including the all-sky upwelling and downwelling SW and LW components, the net SW, net LW, and Total Net surface radiative energy budgets are calculated (Figure 3). The net SW exhibits reduced variability across the seasons, highly correlated with the downwelling SW due to the relatively invariant albedo. Thus, the Total Net radiation is strongly driven by the net LW, which in turn is mostly driven by the downwelling LW, resulting in greater total net radiative input into the surface during the wet months.

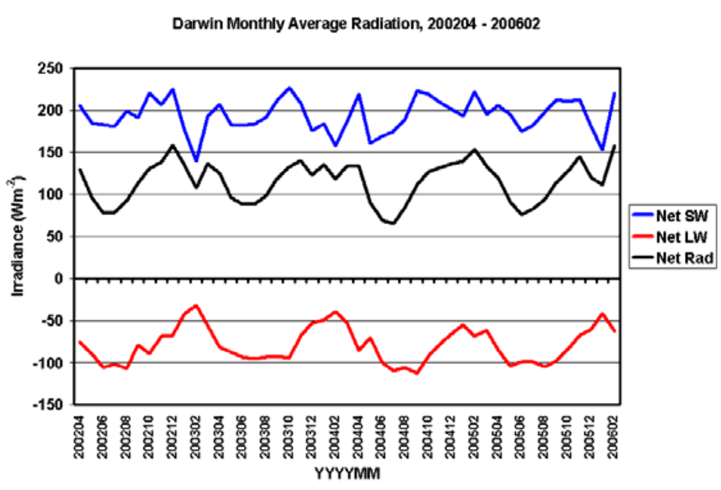


Figure 3. Monthly average all-sky net SW (blue), net LW (red), and Total Net surface radiation budget (black) for the Darwin ACRF site.

Wet/Dry Diurnal Analyses

We use composite diurnal cycles from the 4 available January (wet) and June (dry) months to contrast the wet/dry seasons. The clear-sky downwelling SW diurnal cycle peaks much higher in June than in January (Figure 4, left), with far less difference between the wet/dry seasons for the all-sky downwelling SW. The average January vapor pressure (right) is greater than that in June, and remains fairly constant as opposed to the June cycle where the vapor pressure tends to increase in the early night time.

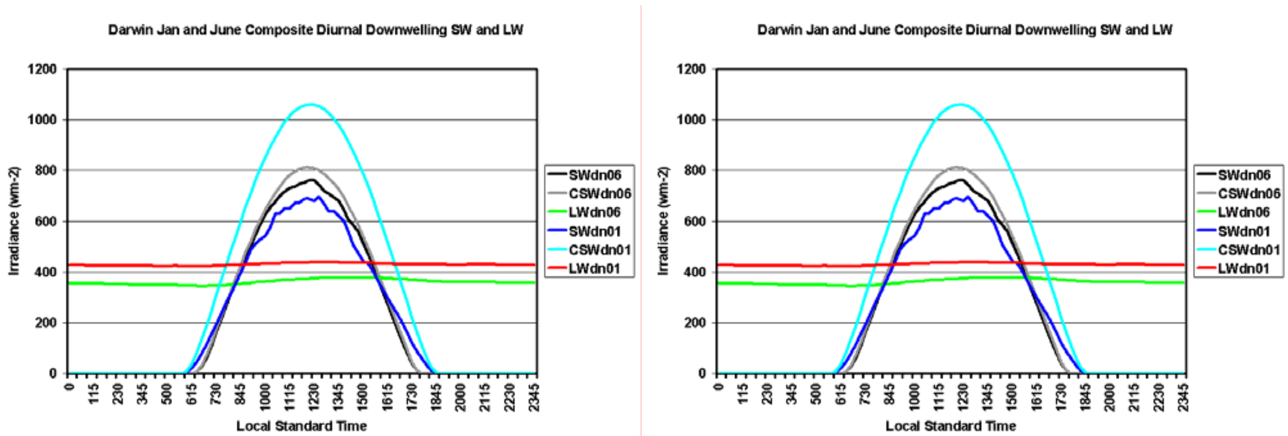
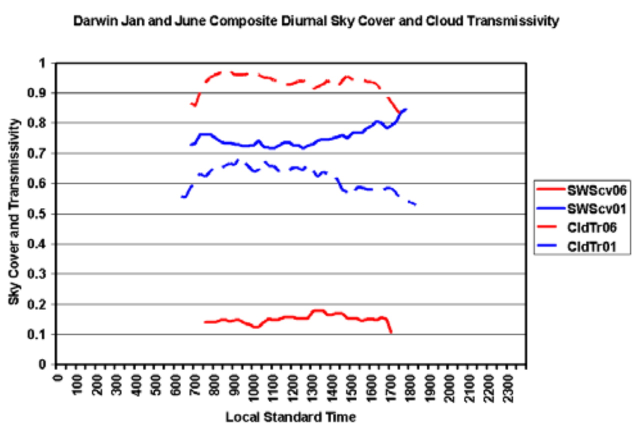


Figure 4. Left: Composite average monthly diurnal clear-sky downwelling SW for January (light blue) and June (gray), all-sky SW for January (blue) and June (black), and all-sky downwelling LW for January (red) and June (green). Right: Same as left but for vapor pressure (blue) and air temperature (red) for January (solid) and June (dashed).



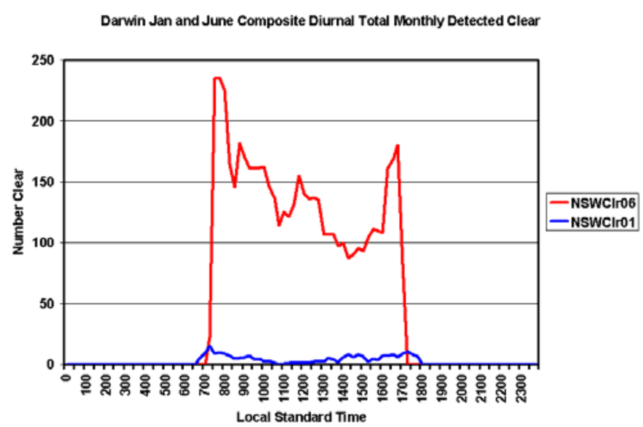


Figure 5. Left: Composite average monthly diurnal daylight fractional sky cover (solid) and cloud field effective transmissivity (dashed) for January (blue) and June (red). Right: Same as left but for the number of daylight 1-minute data detected as clear-sky for Jan. (blue) and June (red).

The monthly composite daylight fractional sky cover (Figure 5, left) in June is far less (~15%) than in January (~75%), and remains fairly constant where the January sky cover tends to increase across the daylight period. The cloud transmissivity is negatively correlated with sky cover. While there is infrequent occurrence of clear skies (right) in January, in June clear skies are more frequent overall, and occur more often in the morning than the afternoon.

References

Long, CN, and TP Ackerman. 2000. "Identification of clear skies from broadband pyranometer measurements and calculation of downwelling shortwave cloud effects." *Journal of Geophysical Research* 105(D12)15609-15626.

Long, CN, and KL Gaustad. 2004. The Shortwave (SW) Clear-Sky Detection and Fitting Algorithm: Algorithm Operational Details and Explanations, Atmospheric Radiation Measurement Program Technical Report, ARM TR-004, Available via http://www.arm.gov/publications/techreports.stm.