Climatology of Surface Radiation, Cloud Cover, and Cloud Radiative Effects for the ARM TWP

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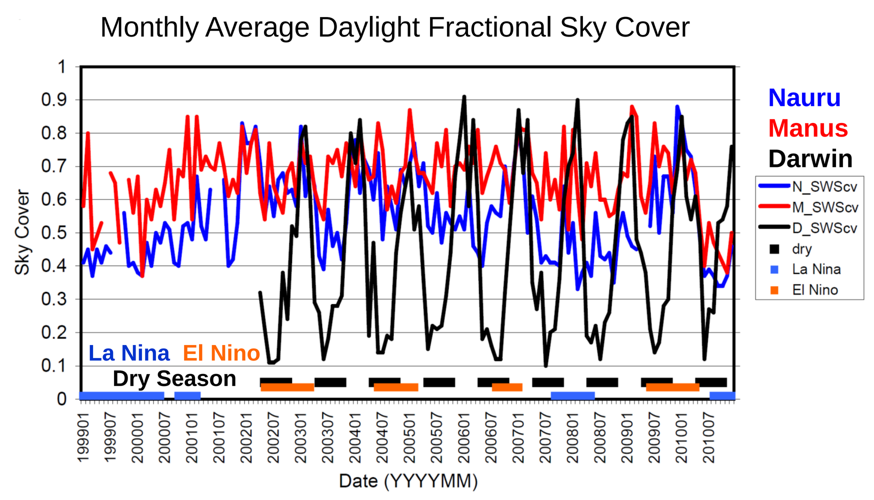
Motivation and Objectives

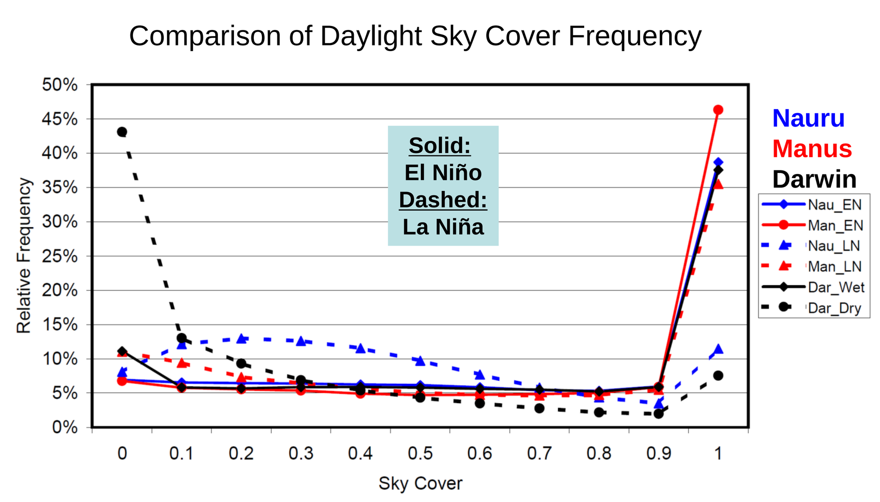
Absorbed solar energy in the tropics is redistributed through longwave radiative exchange, the hydrologic cycle, and dynamical transport. Clouds, which vary on interannual and intraseasonal timescales, significantly impact the radiative exchange.

Our goal is to determine the bulk climatological cloud effects on the surface radiation budget overall, and:

1. By ENSO phase for Manus and Nauru
2. By wet/dry season for Darwin
3. By cloud type
4. Across the diurnal cycle for all of the above

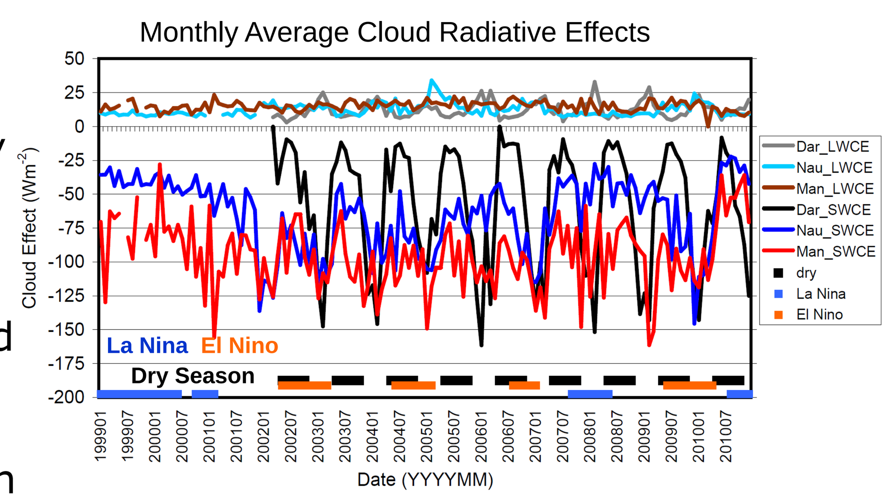
Cloudiness and Cloud Effects





Nauru has less cloudiness during La Nina periods than El Nino periods, but Manus cloudiness and frequency distributions are largely the same. Nauru frequency is about the same as Manus for El Nino, but for La Nina, 2/3 the time cloudiness is 50% or less.

Darwin (black) has far less cloudiness in the dry season than wet, with 40% overcast in wet but 45% clear in dry.



Monthly average LW cloud effects are rarely greater than 25 Wm^{-2} at all three sites, and average from 12-15 Wm^{-2} overall. SW cloud effects are more variable at all sites, with Darwin dry season exhibiting the smallest, and all three having periods where monthly SW is decreased by 125 Wm^{-2} or more. The Table gives aggregate averages for SW, LW and cloud effects.

	SW dn	CSW dn	SW CRE	LW dn	CLW dn	LW CRE
Manus	204.9	299.6	−94.7	422.6	407.5	15.1
El Niño	196.9	300.4	−103.5	422.6	406.9	15.7
Neutral	200.1	297.9	−97.8	423.1	408.5	14.6
La Niña	208.7	307.8	−99.1	421.5	407.4	14.1
Nauru	237.0	302.0	−65.0	420.5	408.2	12.3
El Niño	211.9	302.5	−90.6	429.0	413.2	15.8
Neutral	235.1	300.6	−65.5	421.9	409.6	12.3
La Niña	268.8	307.0	−38.2	410.4	400.9	9.5
Darwin	234.2	293.8	−59.6	404.0	391.6	12.4
Dry	239.1	266.1	−27.0	385.6	377.0	8.6
Wet	225.3	321.1	−95.8	426.1	409.1	17.0

SW Effects by Cloud Type

Simple cloud type classification uses cloud base, top, and thickness from radar-lidar data. Note that drizzle and rain are included as "cloud" thus stratiform with drizzle below freezing may be mis-identified as deep convection.

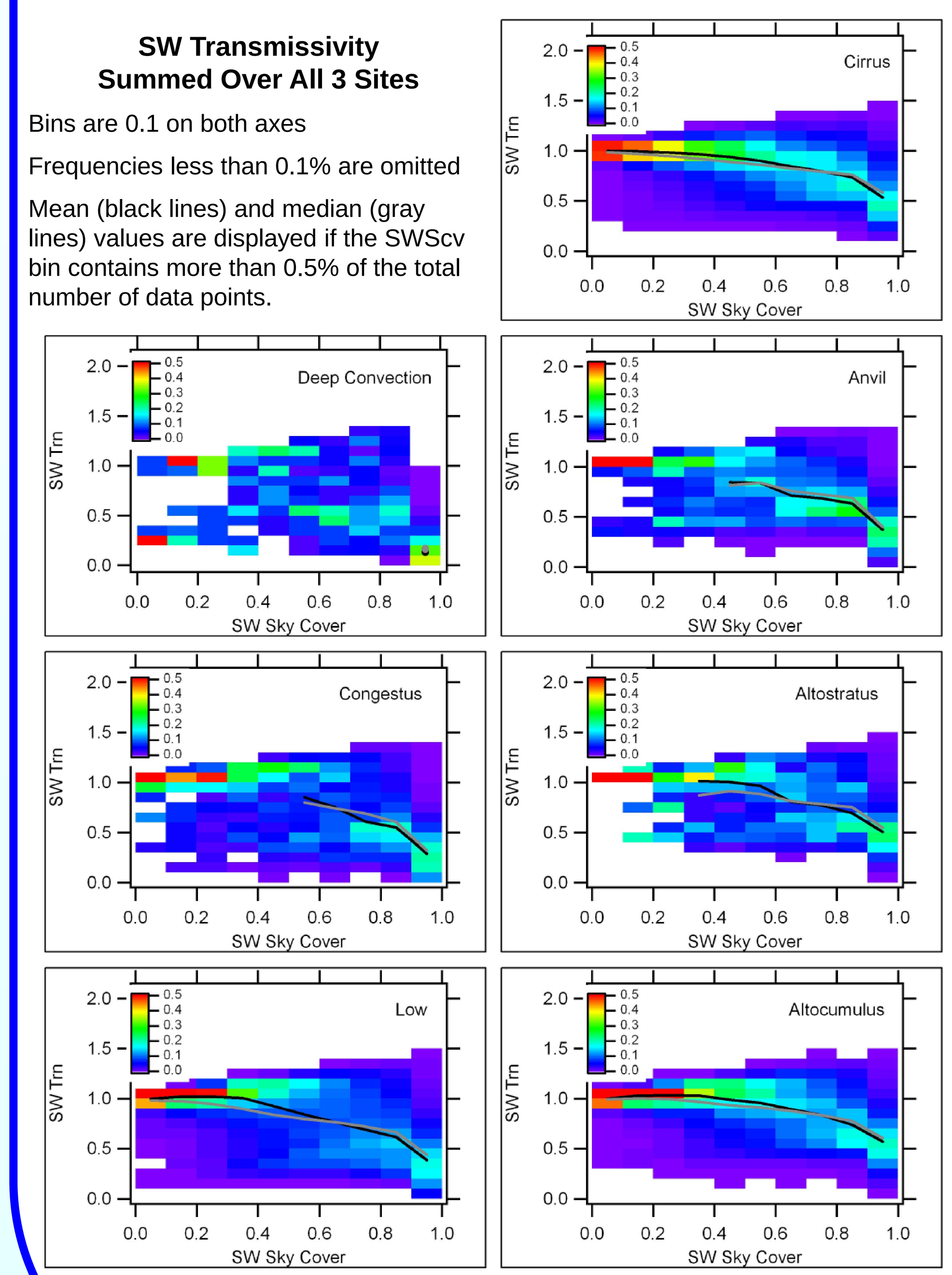
Cloud type	Cloud base	Cloud top	Cloud thickness
Low clouds	<4 km	<4 km	<4 km
Congestus	<4 km	4–8 km	≥1.5 km
Deep convection	<4 km	>8 km	≥1.5 km
Altocumulus	4–8 km	4–8 km	<1.5 km
Altostratus	4–8 km	4–8 km	≥1.5 km
Cirrostratus/anvil	4–8 km	>8 km	≥1.5 km
Cirrus	>8 km	>8 km	No restriction

SW Transmissivity Summed Over All 3 Sites

Bins are 0.1 on both axes

Frequencies less than 0.1% are omitted

Mean (black lines) and median (gray lines) values are displayed if the SWScv bin contains more than 0.5% of the total number of data points.

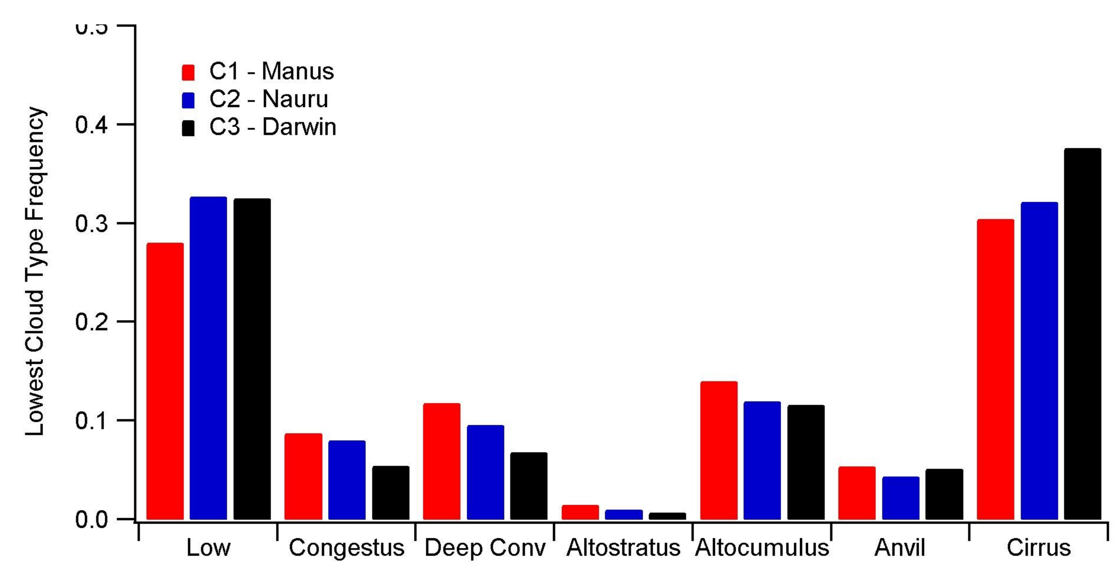


Frequency plots of SW cloudy sky effective transmissivity versus sky cover (left) show that to first order cloud amount is a larger factor than cloud type.

The frequency of occurrence of cloud amount by type then determines overall radiative impact. On average, 80% of clear-sky possible SW reaches the surface for cirrus, but only 17% for deep convection.

McFarlane, S. A., C. N. Long, J. Flaherty, 2013: A Climatology of Surface Cloud Radiative Effects at the ARM Tropical Western Pacific Sites. J. Appl. Meteor. Climatol., 52, 996-1013. doi: http://dx.doi.org/10.1175/JAMC-D-12-0189.1

Lowest Cloud Type Frequency



Of the major cloud types, low and cirrus clouds occur most often (60% of all occurrences), with altostratus occurring least often at all three sites.

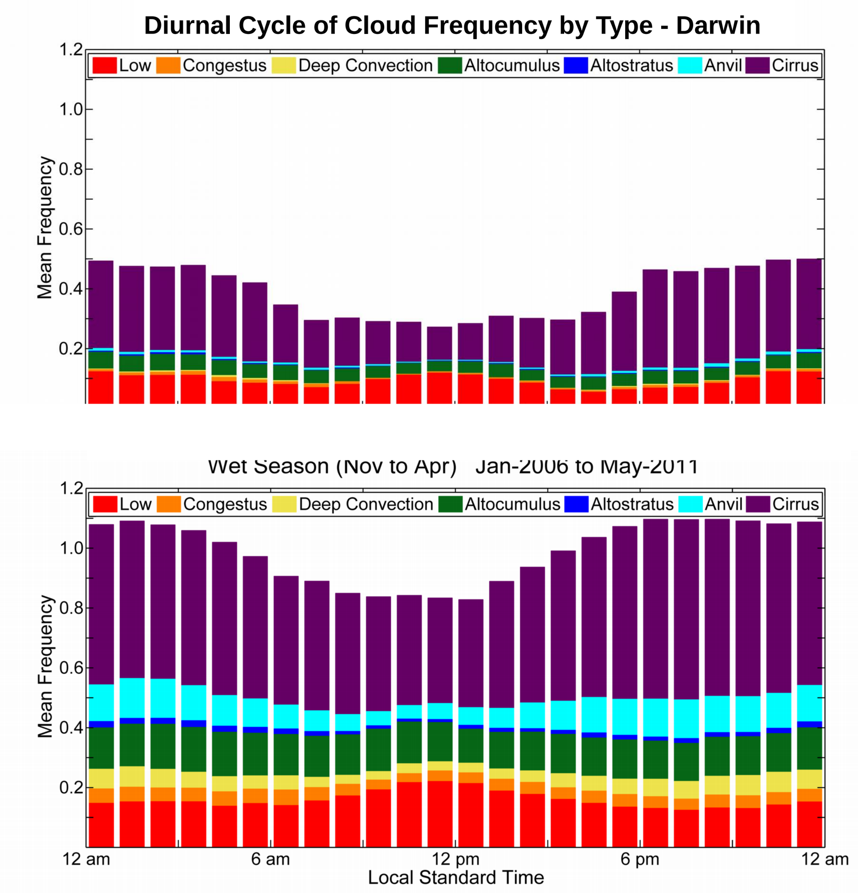
Summary

The long-term data available from the three TWP sites are analyzed to characterize the surface radiation budget, total cloudiness, occurrence of different cloud types, and cloud radiative effects. These quantities are partitioned by ENSO phase for Manus and Nauru and by wet/dry season for Darwin. Continuing efforts are aimed toward analyses of all the above in the context of the diurnal cycle to characterize the full range of variability across daily, seasonal, and interannual scales. The resultant data set and analysis results will be an invaluable tool for comparison with and testing of global climate models

Diurnal Studies

Dry Season May to Oct

Wet Season Nov to April



Data spans Jan 2006 through May 2011

Efforts are in progress toward determining the diurnal signature of cloudiness, cloud types, and radiative effects including by ENSO phase and wet/dry season. The figures above show the diurnal distribution of cloud types for Darwin during the dry (top) and wet (bottom) seasons. More frequent occurrence of all cloud types occurs during the wet season, with evidence of transition to more frequent deep convection and anvil occurrence in the late afternoon into the night. Lesser dry season cloud occurrence translates to significantly smaller cloud effects (below) across the diurnal cycle. The increased afternoon-to-evening wet season convection is evident in the asymmetry of the SW cloud effect (light blue) between morning and afternoon.