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On the annual cycle and variability of oceanic low-topped clouds and the large-scale circulation using Aqua MODIS and ECMWF reanalysis

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Observationally understanding the extent to which low-topped clouds are fundamentally connected physically to the large-scale circulation of the atmosphere is of utmost importance in both constraining and improving estimates of Earth climate sensitivity. Low-topped clouds are furthermore significant in modulating the SST annual cycle particularly in the eastern equatorial region and certain subtropical areas, which are furthermore important for determining cold tongue phasing and the Hadley and Walker circulations, still imperfect in general circulation models. The Aqua satellite was launched in 2002 and contains MODIS cloud data, and the level-three product in conjunction with collocated ECMWF reanalysis datasets of surface temperature and pressure, winds, and vertical velocity, are used to construct climatologies of low-topped clouds and their relationships to dynamics and thermodynamics at various timescales. Correlations of low-topped cloud cover with relevant atmospheric and oceanic (SST) variables are examined as a function of averaging timescale, and except in the northeast subtropical Pacific and Atlantic as well as the western Pacific and Indian Ocean warm pool regions, SST and low-topped cloud fraction are strongly connected on sufficiently long time-scales (>10 days). In the eastern North Pacific, however, low cloud cover is positively correlated with SST, and we show that vertical velocity variability, a proxy for synoptic-scale storminess, is better related to the low cloud annual cycle in this region. We also perform harmonic analysis of daily low cloud, SST, SST advection, sea-level pressure, and 500-hPa vertical velocity to quantify amplitudes of these variables and how well clouds are in phase with meteorological variables. Except in the northern Indian Ocean and equatorial western Pacific, the fraction of variance explained by the SST annual cycle is extremely high everywhere in low and mid-latitudes. The fraction of variance explained by the low cloud annual cycle is greater than 0.5 in areas where the annual cycle amplitude is high, primarily along 15-20^{o}S in the southern hemisphere, and much of the North Pacific save for some portions of the central Pacific. Low-topped clouds tend to lead SSTs by ~10-30 days in most of the southern hemisphere subtropical regions (between 15-20^{o}S), the eastern equatorial Pacific, and the western subtropical North Atlantic and Pacific, suggesting that clouds feedback onto SST. The low cloud maximum is well out of phase with SST in most of the rest of the northern hemisphere, and the eastern Pacific subtropical low cloud phasing is similar to the mid-latitudes. Dynamically, the eastern North Pacific subtropics are somewhat more similar to the mid-latitudes as well. Finally, global subtropical highs are stronger everywhere during maximum cloud cover, though in the eastern North Pacific the subtropical high is shifted eastward during minimum cloud cover, so that local SLP is actually higher, suggesting more remote forcing in the well-known Californian stratus region.