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Multiscale Covariability of Surface Wind, Humidity and Temperature in the Subtropical Marine Boundary Layer

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Trade cumulus and stratocumulus clouds in oceanic subtropical regions are sources of much uncertainty in current global climate model (GCM) simulations. Errors in low cloud fraction and rain amounts are a result of inadequate parameterizations for describing the small-scale boundary layer processes specific to the convective and cloud-formation dynamics of those regions. While most cloud parameterization techniques do consider sub-grid scale variability in specific humidity (q), the significant fluctuations in temperature (T) and wind speed (u) in the boundary layer are still often neglected. In order to better acknowledge the interactions of these fields with cloud and convection, understanding their codependence seems crucial. For example, using the negative correlations between T and q on large scales has helped to improve cloud parameterizations, and wind shear is known to modulate cloud layer decoupling and affect the liquid water path (LWP). While numerous studies document the spatial properties of T, q and u independently through power spectra and multifractal analyses, the covariation between these three variables and their spatial increments – and how these relationships change across spatial scales – has not been adequately and quantitatively characterized.

The present work focuses on the spatial covariability and multiscale coupling between fluctuations in q, T and u in the marine boundary layer and seeks to understand which pieces of information are required for better predicting LWP on a variety of scales from a few tens to a few hundred kms. We use remote-sensing measurements of thermodynamic variables from MODIS and surface wind estimates from QuikSCAT. The scale-by-scale covariability of two variables is quantified through their Fourier and wavelet cross spectra, using Haar wavelets; these spectra permit the calculation of multiscale coupling exponents when appropriate. Results from this study are threefold: (1) we quantify the contributions of wind speed and sea surface temperature (SST) spatial variability to the fluctuations in q, (2) show the importance of surface winds in modulating the value of LWP that would be expected from T and q alone, and (3) provide more information on the T-q and q-u relationships across scales, using their single-point statistics and spatial increments. This is key information for including the combined effects of temperature, humidity and wind speed sub-grid scale fluctuations into the parameterizations of low cloud liquid water path and rain rates in future GCM convection schemes.