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# Observations for climate: Importance of submonthly variability on monthly mean latent heat flux estimates and impacts on the oceanic mixed layer

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Knowledge of the processes by which energy, moisture, and momentum are transferred across the air-sea interface is vital to understanding and predicting climate variability. Direct observations of these surface fluxes are sparse in both space and time; therefore, the applicability to climate-related studies is greatly limited. Fields of latent heat, sensible heat, and momentum are frequently estimated through the bulk flux aerodynamic formulas using meteorological data from ships, buoys, satellites, numerical weather prediction (NWP) models, or a combination thereof. Implicit in the estimated surface flux fields are errors associated with observational sampling and uncertainties, parameterizations, and the method used to construct the fields. Sustained long-term atmospheric and oceanic records are vital to better characterize climate variability; however, the representativeness and usefulness of such records are dependent on quantifying the inherent uncertainties and biases in both the observations and derived fields. Here the consequences of formulating a monthly mean latent heat flux climatology (e.g., the FSU3 in situ based flux product) using the classical time-averaging method (Esbensen and Reynolds 1981; Simmonds and Dix 1989; Gulev 1994, 1997; Josey et al. 1995; Zhang 1995; Esbensen and McPhaden 1996) are examined. The classical method (in contrast to the sampling method) applies the bulk flux formulas to the monthly averaged meteorological variables; therefore, simultaneous observations of the individual variables are not required, which is beneficial in data-sparse regions and when data from multiple platforms are being used. However, this method implicitly neglects the effects of variability on time scales shorter than the averaging period (e.g., submonthly), which can be regionally substantial and important to air-sea interaction processes on longer scales. The classical method is found to underestimate the sampling estimates by an amount which is dependent on region and season. The largest differences occur in the midlatitudes during the boreal autumn and winter, where values can exceed 90 W m-2 over the western boundary currents. In the tropics the errors are substantially smaller (typically < 10 W m-2), but not negligible, especially in regions of increased atmospheric variability (e.g., ITCZ and Indian monsoon). The effects of this error on the ocean's mixed layer temperature tendency are also examined. In general, the largest differences also occur in the midlatitudes; however, the differences are maximized (> 1$^{o}$C month-1) during the late boreal summer and autumn, when the latent heat flux errors are relatively small. The results indicate that the response of the oceanic mixed layer's temperature to the latent heat flux error is sensitive to evolving oceanic processes (e.g., depth of the mixed layer and the amount of solar radiation that penetrates beyond the base of the mixed layer). This sensitivity further illustrates the need to quantify and minimize uncertainties in both surface and subsurface measurements/fields in order to sustain long-term observational based records.