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Supplementary Material for "Diurnal Variation of Surface Heat Fluxes off the West Coast of Sumatra Island as Revealed by In Situ Observation"

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Details of the implementation of the COARE3.0 algorithm

This study uses the COARE3.0 bulk flux algorithm (Fairall et al. 2003) to estimate SHF and LHF. The algorithm is available online at: ftp://ftp1.esrl.noaa.gov/BLO/Air-Sea/wcrp_wgsf/computer_programs/cor3_0/ (accessed 13 March 2020).

The COARE3.0 algorithm estimates sea surface skin temperature, which is used for estimation of the fluxes, from measured sea water temperature at a certain depth (usually from several tens of centimeters to several meters) via corrections for cool-skin and diurnal warm-layer effects (Fairall et al. 1996a, 1996b). In the present study, we use sea water temperature at 10–30 cm depth measured by sea-snake thermistors. As this depth is considered to be inside the diurnal warm layer, we decided to perform only the correction for the cool-skin effect and turn off the correction for the diurnal warm-layer effect. Furthermore, we did not take into consideration surface wave influence on roughness parameters. The depth of atmospheric convective boundary layer was set to 500 m based on ceilometer observations.

Input variables to the COARE3.0 algorithm include: T_{air}, q_{air}, surface wind, mean sea level pressure, downward shortwave and longwave radiation, surface current, and SST, as well as longitude, latitude, and time. Note that rainfall intensity is not used for the estimation of the fluxes in this study.

It is difficult to examine accuracy of the estimated heat fluxes, because we did not perform other types of flux observations (eddy covariance measurement, etc.). Instead, here we perform a surface energy budget analysis to estimate period-averaged net energy input to the ocean, Q_{net}, and compare the estimates with results in previous studies. Q_{net} can be estimated from the following equation:

$$Q_{net} = SW_{net} + LW_{net} + SHF + LHF + Q_{rain},$$

where SW_{net} and LW_{net} are net heat fluxes due to shortwave and longwave radiation, respectively, and Q_{rain} heat flux due to rainfall. SW_{net} is estimated from observed downward shortwave radiation with assumed daily-mean oceanic albedo of 0.055, and LW_{net} from observed downward longwave radiation and estimated sea surface skin temperature with assumed oceanic broadband emissivity of 0.97. Q_{rain} is estimated by the COARE3.0 algorithm from observed rainfall intensity and other surface meteorological parameters. Here all the terms, including the SHF and LHF, are defined positive when they warm the ocean (it is opposite to the definition of SHF and LHF in the main body of this paper). Period averages of these heat fluxes are summarized in Table S1. In both periods, net warming by shortwave radiation is partly compensated by cooling by longwave radiation, SHF, LHF, and the rainfall heat flux. Resultant Q_{net} is +56 W m^{-2} in YMC15 and +30 W m^{-2} in YMC17. According to DeMott et al. (2015), Q_{net} over the Indian Ocean during December–February is +35 W m^{-2} on average and +81 W m^{-2} during MJO suppressed phase. Our estimates are not different considerably from these previous estimates, suggesting that the summation of SHF and LHF estimated in the present study is reasonable.

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Table S1: Period-averaged heat fluxes to the ocean at the surface [W m^{-2}].

	YMC15	YMC17
Net shortwave radiation (SW_{net})	+197	+186
Net longwave radiation (LW_{net})	−42	−52
SHF	−12	−9
LHF	−83	−92
Rain heat flux (Q_{rain})	−4	−3
Net heat input to the ocean (Q_{net})	+56	+30