Applying Relaxed Eddy Accumulation to Measure CH_4 Gas Exchange Rate Between the Sea Surface and the Atmosphere

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BACKGROUND

Exchanges of methane (CH_4) between sea and the atmosphere may be an important constituent in the global greenhouse gas balance. The exchange rates are previously evaluated using the bulk method using a gas concentration gradient between the atmosphere and seawater multiplied by a gas transfer coefficient as a function of wind speed. Few direct measurements of CH_4 exchange have been reported. Kondo and Tsukamoto (2007) reported that CO_2 flux measured with the eddy covariance method at the sea surface was sometimes 20 times as large as that estimated with the bulk method. More studies are needed to understand CH_4 exchanges at the sea-atmosphere interface. Our objectives were to directly measure CH_4 flux at the sea surface on a boat.

MATERIALS AND METHODS

Relaxed eddy accumulation (REA) method (McInnes and Heilman, 2005):

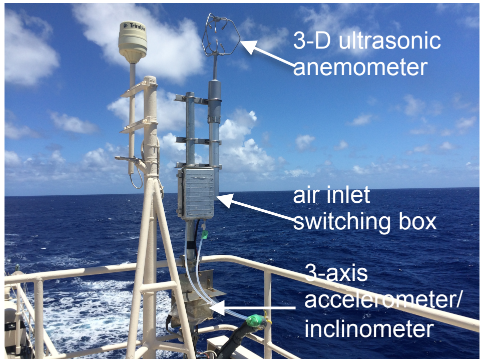
$$J = B\sigma_w\left(\overline{C_u} - \overline{C_d}\right) \times 3600$$

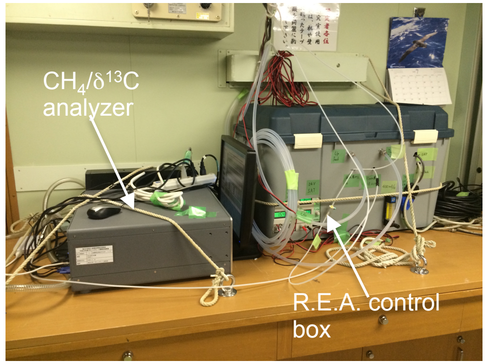
where J is the flux of CH_4 gas (mg/m^2/h), B is an empirical constant (=0.4645, Fig. 1), σ_w is the standard deviation of vertical wind speed (m/s), C_u-C_d is the difference between 30 min average CH_4 concentration of air carried by upward and downward winds (mg/m^3). CH_4 concentration and $\delta^{13}C$ were measured every 3 min using a $CO_2/CH_4/\delta^{13}C$ gas analyzer (G2201-i, Picarro Inc., Santa Clara, CA).
Wind speed measured on the ship was corrected on real time using CR5000 as (Kondo and Tsukamoto, 2007):

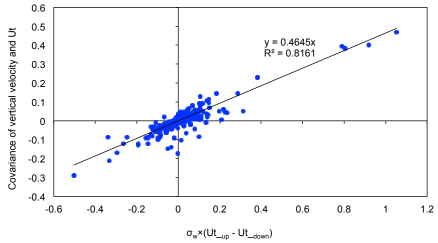
$$U_{true} = T(\phi, \theta, \Psi) U_{observed} + U_{anemo}$$

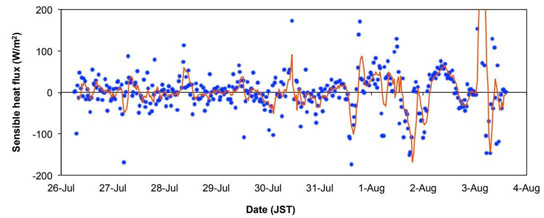
$$T(\phi,\theta,\Psi) = \begin{bmatrix} \cos\Psi\cos\theta & \sin\Psi\cos\phi + \cos\Psi\sin\theta\sin\phi & -\sin\Psi\sin\phi + \cos\Psi\sin\theta\cos\phi \\ -\sin\Psi\cos\theta & \cos\Psi\cos\phi - \sin\Psi\sin\theta\sin\phi & -\sin\Psi\cos\phi\sin\Psi - \sin\phi\cos\Psi \\ -\sin\theta & \cos\theta\sin\phi & \cos\theta\cos\phi \end{bmatrix}$$

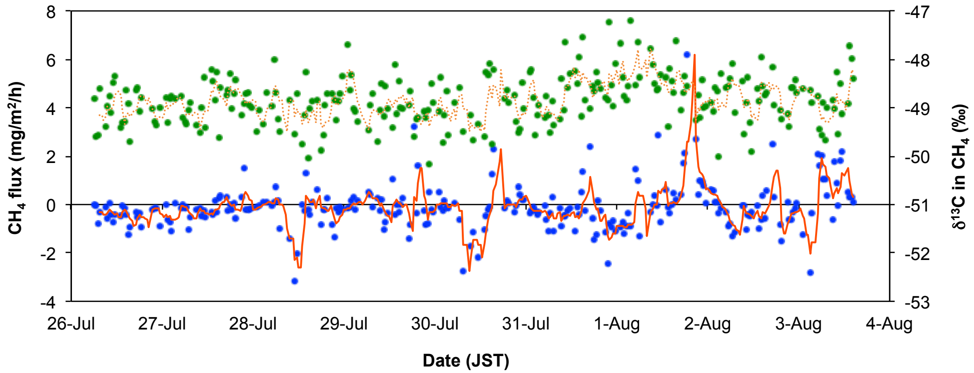
where U_{true} is the corrected wind speed (m/s), $T(\phi, \theta, \Psi)$ is the coordinate transformation matrix, $U_{observed}$ is the measured wind speed with the sonic anemometer (m/s), and U_{anemo} is the time integration of the three axis accelerometer (m/s). ϕ, θ, and Ψ were roll, pitch, and yaw angles of the ship, respectively, detected by the 3-axis inclinometer.











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