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**Text S1.**

The coordinate transformation matrix in equation (5) for a rotation from the ship frame to the reference frame and is given by

$$\mathbf{T} = \begin{pmatrix} \cos\varphi\cos\theta & -\sin\varphi\cos\phi + \cos\varphi\sin\theta\sin\phi & \sin\varphi\sin\phi + \cos\varphi\sin\theta\cos\phi \\ \sin\varphi\cos\theta & \cos\varphi\cos\phi + \sin\varphi\sin\theta\sin\phi & -\cos\varphi\sin\phi + \sin\varphi\sin\theta\cos\phi \\ -\sin\theta & \cos\theta\sin\varphi & \cos\theta\cos\varphi \end{pmatrix} \quad \text{(S1)}$$

where $\theta$ is the pitch angle, $\phi$ is the roll angle, and $\varphi$ is the yaw angle. In (S1) and throughout this study, right-handed reference frames are employed and the right-hand rule is used to determine the sign of angles $\theta$, $\phi$, and $\varphi$.

**Table SI.** General condition of measurements

| Date | Route | Weather condition | Average solar radiation ($W/m^2$) | Run | Time (JST) | $\bar{t}$ (℃) | $\overline{U}$ (m/s) | Significant wave height (m) |
|---|---|---|---|---|---|---|---|---|
| June 16, 2018 | Tsuchuura-Itako | Cloudy | 291 | 1-1 | 10:10-10:25 | 14.1 | 7.2 | 0.22 |
| | | | | 1-2 | 10:18-10:33 | 14.3 | 8.5 | 0.20 |
| | | | | 1-3 | 10:20-10:35 | 14.3 | 8.6 | 0.21 |
| | | | | 1-4 | 10:33-10:48 | 14.5 | 8.1 | 0.21 |
| June 16, 2018 | Itako-Tsuchiura | Cloudy | 144 | 2-1 | 15:20-15:35 | 15.3 | 8.4 | 0.28 |
| | | | | 2-2 | 15:30-15:45 | 15.3 | 7.0 | 0.29 |
| | | | | 2-3 | 15:35-15:50 | 15.3 | 7.1 | 0.29 |
| | | | | 2-4 | 15:45-16:00 | 15.3 | 6.2 | 0.29 |
| | | | | 2-5 | 15:50-16:05 | 15.3 | 5.6 | 0.28 |
| June 17, 2018 | Tsuchuura-Itako | Cloudy | 562 | 3-1 | 10:07-10:22 | 16.7 | 5.3 | 0.05 |
| | | | | 3-2 | 10:15-10:30 | 16.8 | 4.9 | 0.05 |
| | | | | 3-3 | 10:20-10:35 | 16.9 | 4.6 | 0.11 |
| | | | | 3-4 | 10:30-10:45 | 17.1 | 4.7 | 0.04 |
| | | | | 3-5 | 10:35-10:50 | 17.2 | 5.1 | 0.06 |
| June 17, 2018 | Itako-Tsuchiura | Cloudy | 237 | 4-1 | 15:30-15:45 | 18.8 | 4.3 | 0.14 |
| | | | | 4-2 | 15:40-15:55 | 18.9 | 4.3 | 0.18 |
| | | | | 4-3 | 15:45-16:00 | 19.0 | 4.0 | 0.19 |
| June 24, 2018 | Tsuchuura-Itako | Cloudy | 185 | 5-1 | 10:20-10:35 | 19.6 | 2.2 | 0.04 |
| | | | | 5-2 | 10:25-10:40 | 19.5 | 2.0 | 0.04 |
| | | | | 5-3 | 10:35-10:50 | 19.5 | 1.4 | 0.06 |
| June 24, 2018 | Tsuchuura-Itako | Cloudy/ Sunny | 287 | 6-1 | 15:27-15:42 | 22.8 | 2.7 | 0.10 |
| | | | | 6-2 | 15:35-15:50 | 22.9 | 2.9 | 0.10 |
| | | | | 6-3 | 15:42-15:57 | 23.0 | 2.4 | 0.10 |
| September 23, 2018 | Tsuchuura-Tamatsukuri | Sunny | 577 | 7-1 | 9:52-10:07 | 23.2 | 5.2 | 0.10 |

The significant wave height was measured at the Koshin Observatory of the Kasumigauyra River Office near the center of the lake. $\bar{t}$ is the average air temperature and $\overline{U}$ is the average wind speed.

**Table SII.** List of ship-based measurements

| Category | Items | Equipment | Sampling intervals | Average time | Height above the upper deck |
|---|---|---|---|---|---|
| Turbulence | 3 components wind speed and air temperature | Sonic anemometer thermometer (R3A or Windmaster, Gill Instruments Ltd.) | 0.1 s | N/A | 4.6 m |
| | $H_2O$ and $CO_2$ concentration | Open-path infrared gas analyzer (LI-7500, LI-COR, Inc.) | 0.1 s | N/A | |
| Meteorology | Water surface temperature | Infrared radiation thermometer (505, Minorta) | 5 s | 1 min | 3.8 m |
| | Air temperature and specific humidity | Temperature and humidity prove (HMP45C, Vaisala, KK) with a radiation shield | 5 s | 1 min | 3.6 m |
| | Downward short and long wave radiation | 4-component radiometer (CNR-1, Kipp & Zonen B.V.) | 5 s | 1 min | 3.7 m |
| Ship motion | Three-axis accelerations, angular rates, and angles; position | Inertial measurement system (INS) (IMU-440CA-200, MEMSIC INC.) | 0.1 s | N/A | 2.3 m |

The sensors were installed on a 4.2-m mast located next to the bridge on the starboard side. The upper deck floor is 2.9 m above water surface.