Supplemental materials

S1. Sample of active stabilization of the ship-based lidar

At sea, active stabilization and pointing correction, implemented in the mobile lidar system, compensates for ship motions (pitch, roll, and heave) and allows measurements to be obtained of the vertical velocity without mixing in the projection of the horizontal wind speeds and their variation (Fig. S1). The pointing stabilization is achieved by real-time monitoring of platform and lidar pitch and roll, with the lidar head mounted in a motorized frame that provides pitch and roll counter to the platform. Correction of the vertical beam pointing for the pitch motions (Fig. S1a) reduced the standard deviation away from zenith from 1.17 m s^{-1} to 0.03 m s^{-1}. Similarly, correction for the roll motions (Fig. S1b) decreases standard deviation from 2.10 m s^{-1} to 0.03 m s^{-1}. The variance (0.2 m^2 s^{-2}) of the heave platform motion (Fig. S1c) was removed from the calculated wind variance profile. A sample of the uncorrected and corrected vertical velocity is shown in Fig. S1d and e. Overall, during offshore measurements, the vertical velocity profiles were obtained with the precision <0.06° root-mean-square due to pointing stabilization and with an accuracy ≈ 0.15°. The motion compensation allowed the calculation and removal of platform motions from vertical velocity profiles with 1°–2° RMS in pitch, roll, and with ±1–2 m s^{-1} vertical error due to the heave motions.

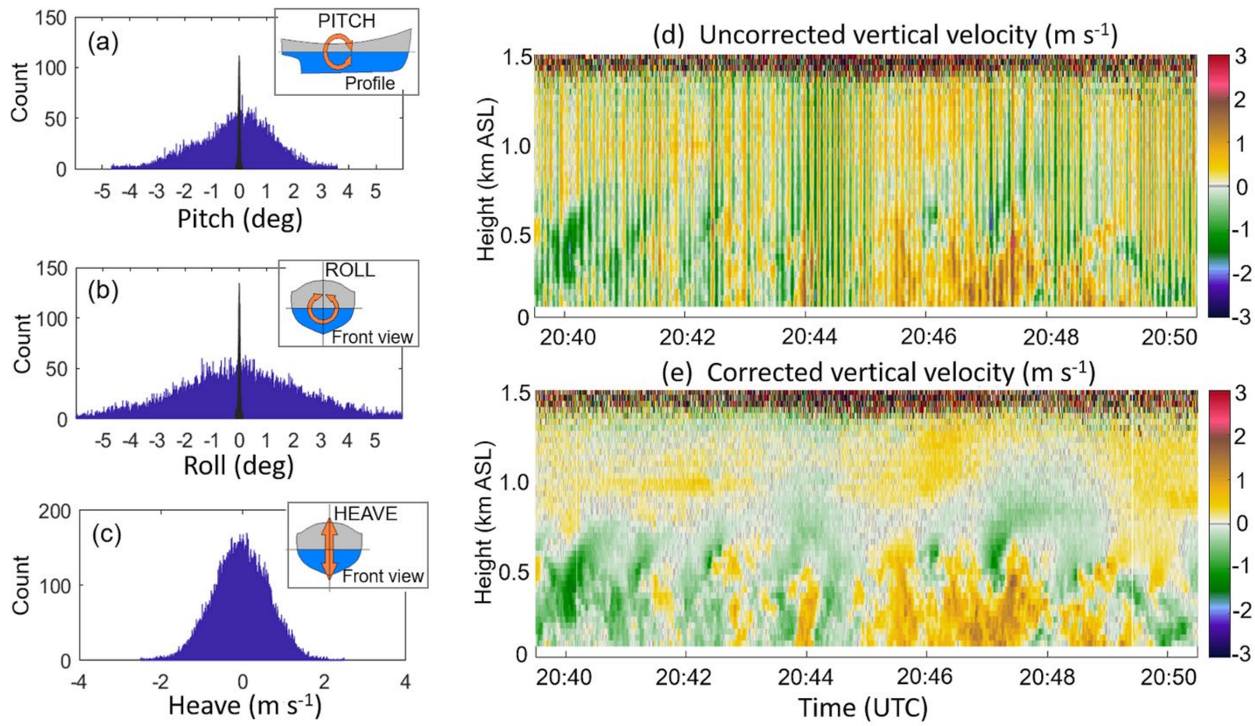

Figure S1. A sample of the ship-motion correction vertical velocity measurements from the Tradewind Ocean-Atmosphere Interaction Campaign (ATOMIC) in Western Atlantic. (a–c) Distributions of ship motions (pitch, roll, and heave) during vertical velocity measurements are shown by the blue color. The black color shows stabilized motions of the lidar (a, b). A sample of (d) uncorrected and (e) corrected vertical velocity measurements on Jan. 20., 2020.

Continuous profiling from a month-long campaign in the Western Atlantic are used us to obtain highly accurate profiles of the range-corrected intensity, wind speed, wind direction, and vertical velocity statistics, including variance, skewness, kurtosis, and compute integral length scale, turbulence kinetic energy dissipation rate, mass flux, probability density function (PDF) of vertical velocity, and plume size PDF.

This example clearly illustrates success in developing a fully capable mobile Doppler lidar that provides accurate measurements compensated for the ship's motions.

S2. Evaluation of the accuracy of PUMAS and stationary Doppler lidar measurements of the horizontal wind speed and direction.

Similar to the estimates of the accuracy of MD measurements from a large, slow-moving ship platform, the measurements from aircraft- and truck-based platforms were compared to the stationary Doppler lidar measurements during various field campaigns utilizing both types, mobile and stationary lidars. The high correlation coefficients were found for wind speed (R^2 = 0.89) and wind direction (R^2 = 0.92) from PUMAS mobile measurements and stationary ground-based lidars during the SUNVEx (Fig. S2a, b). Comparison of data from PUMAS and LEOSPHERE 200S Doppler lidar both stationed at the David Skaggs Research Center located in Boulder, Colorado, show high correlation for wind speed (R^2 = 0.90) and direction R^2 = 0.99) with very small differences between data (Fig. S2c, d).

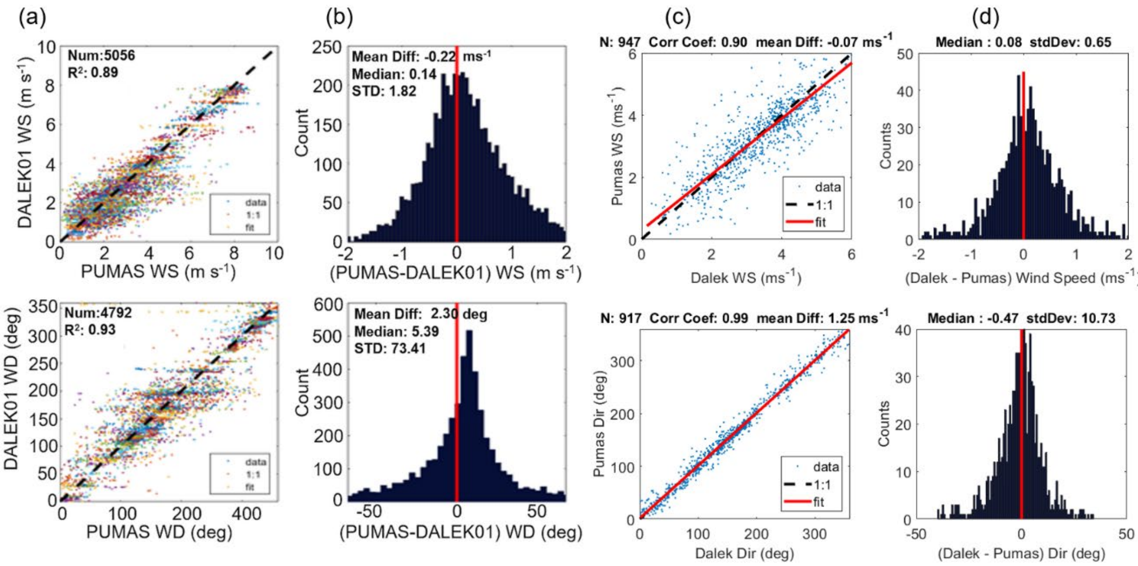

Fig. S2 Validating mobile Doppler lidar measurements: (a, b) Comparing data from mobile (PUMAS) and stationary (DALEK01) scanning Doppler lidars during SUNVEx field measurements. Data from mobile lidar are taken within 2.5 km of the stationary LEOSPHERE 200S lidar; (c, d) Static offset check. PUMAS profiles averaged over 20 minutes and compared to LEOSPHERE 200S.