The Circulation, Geometry, and Turbulence of Windrows: Measurements from the St. Lawrence Estuary

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In the ocean surface layer, secondary flows can often be seen by eye as bands of bubbles roughly aligned with the wind and wave direction (windrows). Bubbles are herded into surface convergence zones, and stay on the surface due to their buoyancy (rather than being advected downward with the current). These secondary flows are important for transport of buoyant materials like oil, plastics, bubbles and biota, and to the transfer of momentum, heat, and gasses between the atmosphere and ocean. Here, measurements of the geometry and circulation of windrows, as well as measurements of waves, winds, and near-surface turbulence were made in a shallow embayment in the St Lawrence Estuary over five days in March of 2018. A forward-looking pulse-coherent ADCP mounted on a small zodiac was used to map the cross-windrow structure of water velocity at 0.8 m depth. Conditionally averaged velocities showed cross-windrow convergence, downwelling under the windrows, and along-windrow enhancement, consistent with the theory that windrows are the result of counter-rotating pairs of wind-aligned vortices. The average magnitude of these circulations was comparable to the friction velocity. Windrow spacing, measured with both acoustics and sea-surface imagery, suggests that these circulations have an aspect ratio of one. Estimates of Turbulent Kinetic Energy (TKE) dissipation rate from the pulse-coherent ADCP were consistent with previous measurements of near-surface turbulence under breaking waves. TKE dissipation rates conditionally averaged to be within the windrows were seen to be 2-10 times larger than when averaged between the windrows. A rough time scale analysis suggests turbulence is dissipated before it can be advected into the convergences. The enhancement of turbulence in convergences also implies measurements made from buoyant drifters, which become trapped in convergences, may be biased relative to the surface layer cross-windrow average.