Surface attached vortices as a proxy for mass transfer in free-surface turbulent flow

O. Babiker[*], I. Bjerkebæk[†], A. Xuan[‡], L. Shen[‡] and S. A. Å. Ellingsen[*]

Mass transfer between ocean and atmosphere is primarily governed by the turbulence in the topmost centimetres beneath the free surface. It has been frequently observed that areas of strong positive divergence of the surface-tangential velocity field correspond to efficient surface renewal and consequently increased transfer of mass across the interface. Patches of strong positive surface divergence occur in the form of intermittent upwelling events visible as "boils" on the surface. It has been qualitatively observed that surface-attached "bathtub" vortices tend to appear at the edges of upwelling boils, hence a correlation between the density of these long-lived vortices and average surface divergence might be expected. Surface-attached vortices leave imprints on the surface which are particularly simple to detect: they live for a long time compared to turbulence turn-over, and their imprints are in the form of nearly circular dimples.

From direct numerical simulations, we use a newly developed method whereby the surface-attached vortices are identified and tracked from their surface imprint only. We show that a correlation of around 0.9 (Fig.1) exists between the time-dependent number of surface-attached vortices and the mean square of the surface divergence. Peaks in the number of vortices occur a little time after the peak in surface divergence, approximately half of the integral timescale of the bulk turbulence. Thus, observation of surface dimples can act as a proxy for surface divergence, with the prospect of remote sensing of mass transfer rates.

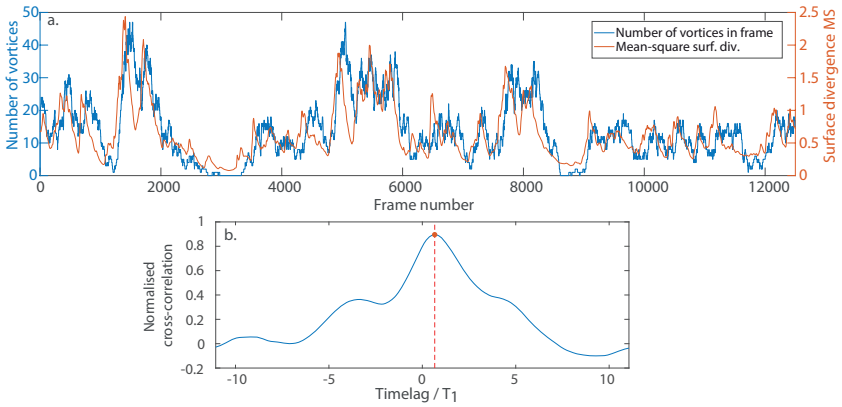

Figure 1: a. Time series of the number of detected vortices and the mean square surface divergence, b. Normalized cross-correlation between the two time series.

[*]Dep. Energy and Process Engineering, Norwegian University of Science and Technology, 7491 Trondheim, Norway

[†]SINTEF Energy Research, 7465 Trondheim, Norway

[‡]Dep. of Mechanical Engineering and Saint Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN 55455, USA