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Properties of small-scale interfacial turbulence from a novel thermography based approach

Jana Schnieders and Christoph Garbe
Interdisciplinary Center for Scientific Computing (IWR), University of Heidelberg, Germany

Oceans cover nearly two thirds of the earth's surface and exchange processes between the Atmosphere and the Ocean are of fundamental environmental importance. At the air-sea interface, complex interaction processes take place on a multitude of scales. Turbulence plays a key role in the coupling of momentum, heat and mass transfer [2].

Here we use high resolution infrared imagery to visualize near surface aqueous turbulence. Thermographic data is analized from a range of laboratory facilities and experimental conditions with wind speeds ranging from $1\mathrm{ms}^{-1}$ to $7\mathrm{ms}^{-1}$ and various surface conditions.

The surface heat pattern is formed by distinct structures on two scales - small-scale short lived structures termed fish scales and larger scale cold streaks that are consistent with the footprints of Langmuir Circulations. There are two key characteristics of the observed surface heat patterns: (1) The surface heat patterns show characteristic features of scales. (2) The structure of these patterns change with increasing wind stress and surface conditions.

We present a new image processing based approach to the analysis of the spacing of cold streaks based on a machine learning approach [4, 1] to classify the thermal footprints of near surface turbulence. Our random forest classifier is based on classical features in image processing such as gray value gradients and edge detecting features. The result is a pixel-wise classification of the surface heat pattern with a subsequent analysis of the streak spacing. This approach has been presented in [3] and can be applied to a wide range of experimental data.

In spite of entirely different boundary conditions, the spacing of turbulent cells near the air-water interface seems to match the expected turbulent cell size for flow near a no-slip wall. The analysis of the spacing of cold streaks shows consistent behavior in a range of laboratory facilities when expressed as a function of water sided friction velocity, u*. The scales systematically decrease until a point of saturation at u* = 0.7 cm/s. Results suggest a saturation in the tangential stress, anticipating that similar behavior will be observed in the open ocean. A comparison with studies of small-scale Langmuir circulations and Langmuir numbers shows that thermal footprints in infrared images are consistent with Langmuir circulations and depend strongly on wind wave conditions.

Our approach is not limited to laboratory measurments. In the near future, we will deploy it on in-situ measurements and verify our findings in these more challenging conditions.

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