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Portfolio Paper

Thermal and Dynamic Surface Signatures of the Wake of a Submerged Sphere

Voropayev, S. I.*[1,2], Fernando, H. J. S.*[1] and Nath, C.*[1]

*1 Arizona State University, Tempe, AZ 85287-9809, USA.
E-mail: s.voropayev@asu.edu

*2 Institute of Oceanology, Russian Academy of Sciences, Moscow, 117851, Russia.

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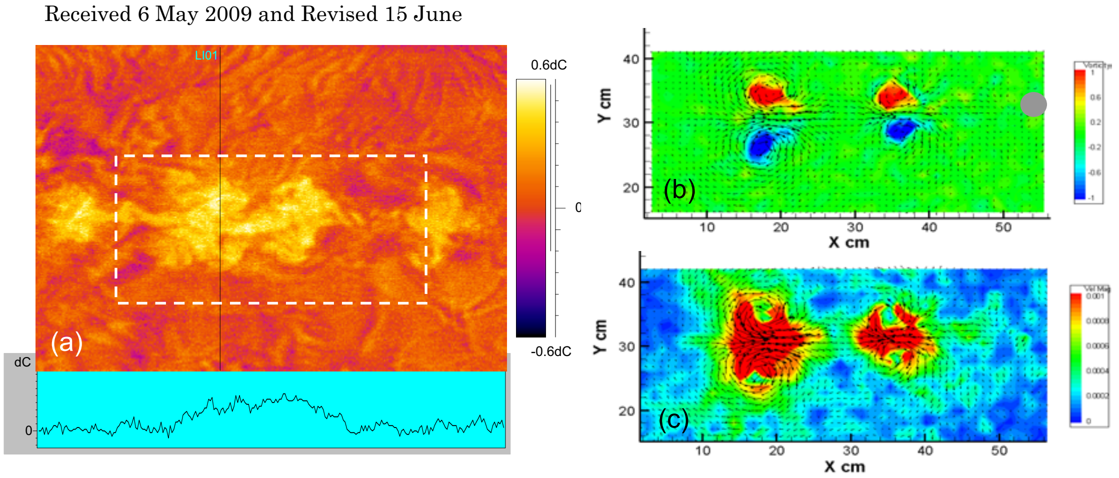

Fig. 1. Thermal (a) and dynamic (b,c) surface signatures of the wake of a submerged sphere [grey circle in (b)] dragged from left to right along the bottom at Re=8000. In (a) – IR surface temperature (top) and temperature trace along the thin vertical black transect (bottom). In (b,c) - PIV data on near surface vertical vorticity (b) and horizontal velocity (c) inside the dashed area shown in (a).

Remote sensing of surface signatures of travelling underwater objects is important for many applications[1]. Given the complexity of the problem and considering poor understanding of the coupling between free surface and underwater features, laboratory experiments have been reported using canonical underwater features such as vortex rings, pairs, single vortices and jets with the hope of delineating their surface signatures[2-5]. In our experiments, a travelling underwater obstacle was used, and penetration of turbulent wake of this obstacle to the water surface was documented using surface skin temperature as a surrogate (Fig. 1a). Thermal imagery of the surface was obtained using a researcher series cooled IR ThermoCAM SC4000 camera (FLIR Systems, sensitivity <0.02 ºC, dynamic range of 14 bits). Near surface velocity/vorticity fields were also mapped (Fig. 1b,c) using a commercial PIV system (TSI Incorporated). Both measurements were conducted simultaneously and this, perhaps, is the first attempt of this kind. To produce a well controlled submerged wake, a sphere of diameter D was dragged at the bottom of the fluid layer, at a depth H/D=1.5 and with Reynolds number Re=8000. The water was homogeneous in temperature, but a thin cool skin layer exists at the top of the water (because of evaporation)[6,7]. For example, in the ocean, although the diurnal thermocline vanishes at night, a skin layer usually exists both during the day and nighttimes and even in windy conditions. The thickness of this layer is on the order of 0.1-1 mm, and the temperature of the top of the skin layer is generally a several tenths of a degree colder than the temperature beneath. In our experiments it was found that at values Re>Re*, where Re* is the critical Reynolds number that depends on H/D, underwater disturbances penetrate to the surface and disturbs the cool skin layer, thus resulting in local increase of surface temperature (Fig. 1a). As can be seen in Fig. 1, the intensity (contrast number[4]) of surface signatures can be significant and disturbances are easily discernible in both dynamic and thermal fields.

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