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Scaling properties of the velocity turbulent field from micro-structure profiles in the ocean

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The statistical properties of the velocity field in the ocean, measured with an airfoil mounted on a free falling micro-structure profiler, are characterized by studying the scaling of the transverse structure functions in the inertial range, which are determined by the intermittent nature of the turbulence. This is the first time, to our knowledge, that the structure functions come from space series. Previous results in air and in water were obtained from a static sensor in the atmosphere, the ocean or in a laboratory setup. Furthermore, previous works are mainly focused on the longitudinal structure functions, and the results we present here have to do with the transverse structure functions. The p-order structure function $S^{(p)}(r)$, where r is the two-point relative distance, exhibits in the inertial range for very high Reynolds number homogeneous and isotropic turbulence a r-scaling $S^{(p)}(r) \propto r^{\zeta(p)}$, or equivalently a self-scaling $S^{(p)} \propto \left[S^{(3)}\right]^{\beta(p)}$ where $\beta(p) = \zeta(p)/\zeta(3)$. For the longitudinal structure functions, the Kolmogorov exact relation $\zeta_L(3) = 1$ gives $\zeta_L(p) = \beta_L(p)$, but there isn't any theoretical relation for the transverse scaling $\zeta_T(3)$, where we refer to longitudinal and transverse functions with the subscripts L and T. The $\beta(p)$ self-scaling receives the name of extended self-similarity (ESS), because it presents an extended scaling range in relation to the r-scaling. The ESS scaling has been even measured in cases where the r-scaling doesn't exist (low Reynolds number, for instance). Furthermore, as has been reported by different experimental works, the r-scaling is generally non universal, and depends on the degree of homogeneity, isotropy or on the conditions of turbulence creation (Bolgiano scaling for thermal convection, for instance). But the ESS scaling $\beta(p)$ seems to follow a universal behavior in a broad range of Reynolds numbers, degree of isotropy and conditions of turbulence creation. First theoretical predictions on $\zeta(p)$ for 3D homogenous and isotropic turbulence with very high Reynolds number were developed by Kolmogorov (K41a), with the scaling $\zeta(p) = p/3$, but posterior theoretical and experimental refinements found a deviation or anomalous scaling from this linear trend with origin in the intermittent nature of turbulence. The first open question we want to study is if the longitudinal and transverse structure functions follow the same kind of scaling, that is if $\zeta_T(p) = \zeta_L(p)$, as is required by some theoretical results for isotropic turbulence. To do this we compare our measured oceanic transverse structure functions with previous works with longitudinal and transverse measures in different mediums (water, air) and from different experimental approaches (ADV and anemometers time series, ...). The second question we study is if the ESS scaling presents a universal behavior independent of the Reynolds number or the degree of isotropy.

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