ANALYSIS OF THE INTERMITTENT NATURE OF THE TURBULENCE FROM MICRO-STRUCTURE PROFILES. CLIMSEAS European project FP7-IRSES-2009 (ref. 247512)

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MOTIVATION:

In aquatic ecosystems, turbulent oscillations of various scales influence aggregation, incubation and foraging processes of small-scale planktonic organisms. Internal intermittency can affect phyto and zooplankton species less than several millimeters in size, specifically, floating microscopic algae that are responsible for photosynthesis in coastal oceans. (Lozovatsky et al., 2010)

These localized events (patchiness, intermittency) have critical consequences at microscale (i.e. < 1 m), since planktonic mating, predator-prey contacts and chemical reactions all occur at microscale. It is thus crucial to accurately describe and model intermittency and the couplings between intermittent variables (i.e. turbulent velocity and phytoplankton abundance). (Seuront et al., 2005)

OBJECTIVES: **To analyze the properties and the relationships of small scale patchiness of velocity, temperature and chlorophyll in different conditions (stratification and turbulence intensity).**

DATA: **Oceanic measurements with a micro-structure profiler. (Lozovatsky et al., 2005).** **METHODOLOGY:** **Estimate the scaling exponents of the velocity, temperature and chlorophyll structure functions in the inertial range.**

FIRST MILESTONE: **Methodology for the velocity structure functions and comparison with previous results.**

DATA: **Free sinking MSS profiler.**

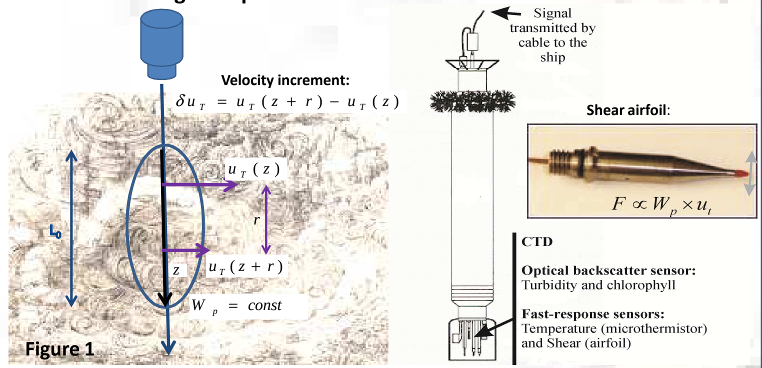

Figure 1

STRUCTURE FUNCTIONS:

Longitudinal: → $S_L^{(p)}(r) = \langle |\delta u_L|^p \rangle$ —Inertial range→ DIRECT SCALING: $S_L^{(p)}(r) \propto r^{\zeta_L(p)}$ → Theoretical result: $\zeta_L(3)=1$ → EXTENDED SELF-SIMILARITY (ESS): $S_L^{(p)}(r) \propto (S_L^{(3)})^{\beta_L(p)}$ $\zeta_L(p) = \beta_L(p)$

Transverse: → $S_T^{(p)}(r) = \langle |\delta u_T|^p \rangle$ → $S_T^{(p)}(r) \propto r^{\zeta_T(p)}$ → Does the ESS work?

Scalar (temperature, salinity, chlorophyll,…) → $S_\theta^{(p)}(r) = \langle |\delta\theta|^p \rangle$ → $S_\theta^{(p)}(r) \propto r^{\zeta_\theta(p)}$ → Does the ESS work?

Rate of dissipation of turbulent kinetic energy: ε → ε → $\langle (\varepsilon_r)^q \rangle \propto r^{-K_\varepsilon(q)}$ → $\varepsilon_r r \xleftarrow{law} (\delta u)^3$ → $\zeta(p) = -K_\varepsilon(p/3) + p/3$

Multifractal: Scale r dependence

Refined self-similarity (RSS)

Intermittency, anomalous scaling

Non patchiness, K41

Rate of dissipation of scalar variance: ε_θ → $\varepsilon_{\theta,r}$ → $\langle (\varepsilon_{\theta,r})^q \rangle \propto r^{-K_\theta(q)}$ → $\varepsilon_{\theta,r} r \xleftarrow{law} (\delta\theta)^2 \delta u$ → Statistical independence of u and θ (Seuront et al., 2005) → $\zeta(p) = K_\varepsilon(p/6) - K_\theta(p/2) + p/3$

RESULTS: **Determination of the anomalous scaling of the transverse velocity.**

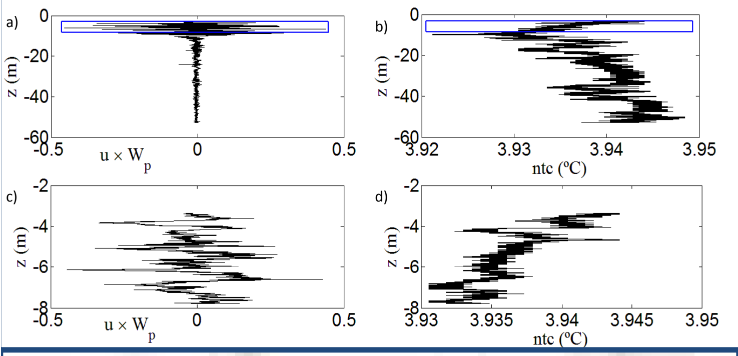

Figure 2a,b: Vertical profile of the transverse velocity (u) and temperature (ntc). c,d: Zoomed segment of 3.5m length.

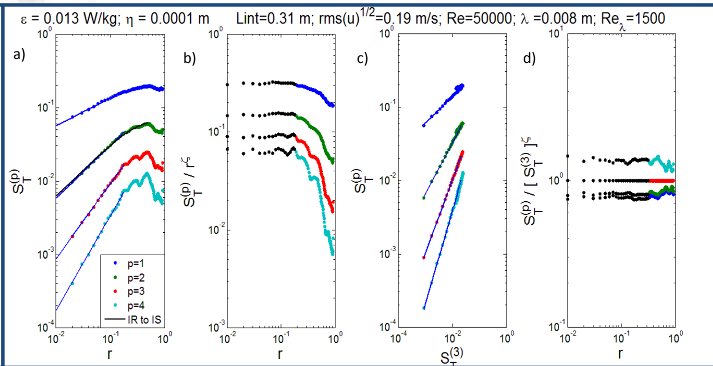

Figure 3a: Velocity structure function (p from 1 to 4). b: Compensated structure function. c) ESS scaling. d) Compensated ESS scaling.

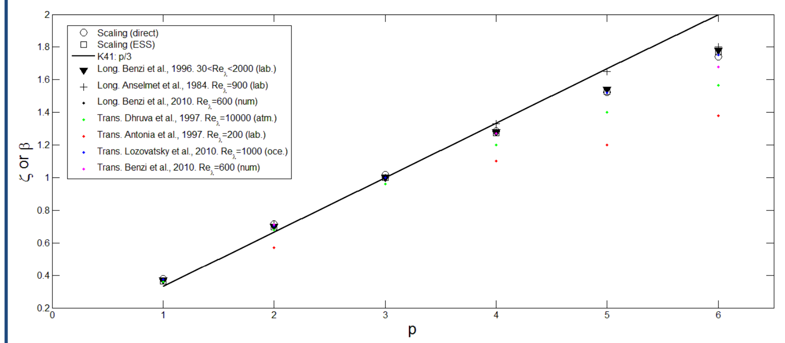

Figure 4: Direct (ζ) and ESS (β) scaling exponents of the structure functions (p from 1 to 6) and some previous results.

CONCLUSIONS AND DISCUSSION:

1) **Segments of measured data with high turbulence intensity shows a clear scaling of the structure functions of the transverse velocity in the inertial range.**
2) **The ESS and direct scaling exponents of the velocity structure functions are similar for very high Reynolds number (Figures 2,3,4), and they are in concordance with previous results of transverse and longitudinal velocity (Fig 4).**
3) **When the Reynolds number is moderate the inertial range is not well defined and the scaling exponents are typically estimated with the ESS (Figures not shown). This scaling exponents are also in concordance with previous experiments.**
4) **The first milestone is accomplished and the methodology will be used to calculate the small scale statistics or patchiness of temperature and chlorophyll and to state the role played by them (active of passive behavior).**

REFERENCES:

Benzi, R., L. Biferale, S. Ciliberto, M. V. Struglia, and R. Tripiccione, 1996: Generalized scaling in fully developed turbulence. *Physica D*, **96**, 162-181.
Lozovatsky, I., M. Figueroa, E. Roget, H. J. S. Fernando, and S. Shapovalov, 2005: Observations and scaling of the upper mixed layer in the North Atlantic. *Journal of Geophysical Research-Oceans,* **110**.
Lozovatsky, I., E. Roget, J. Planella, H. J. S. Fernando, and Z. Liu, 2010: Intermittency of near-bottom turbulence in tidal flow on a shallow shelf. *Journal of Geophysical Research-Oceans,* **115**.
Seuront, L., F. G. Schmitt, 2005: Multiscaling statistical procedures for the exploration of biophysical couplings in intermittent turbulence. Part I. Theory. *Deep-Sea Research Part Ii-Topical Studies in Oceanography,* **52**, 1308-1324.