P 0344

Effects of phytoplankton on ocean turbulence: Observations using 2D Particle Tracking Velocimetry (PTV)

Ian R. Jenkinson

Agence de Conseil et de Recherche Océanographiques

19320 La Roche Canillac, France

ian.jenkinson@wanadoo.fr

A Objectives

•To **test a model** (Jenkinson, 2004, this symposium) of hierarchical **Kolmogorov-type** turbulence as modified by lumpy, shear-thinning mucus secreted by phytoplankton (Jenkinson & Biddanda, 1995);

•To **produce turbulence** in the laboratory, closely mimicking that in the sea, improving on "grid turbulence"

•To **improve** on Particle Image Velocimetry (**PIV**) and adapt it for water movement **pertinent to plankton**, using the water parcels themselves as reference points (**Lagrangian** approach)

•The data are also compatible with Particle Tracking Velocimetry (**PTV**) allowing particles to be **identified and followed**, to give particle-pair velocities (both **elongational** and shear=-**vortical**) **v** vs. inter-particle **distance** *d* over a **range of time scales**. However, only a single time scale, 0.1 s, has been used to produce the data shown here.

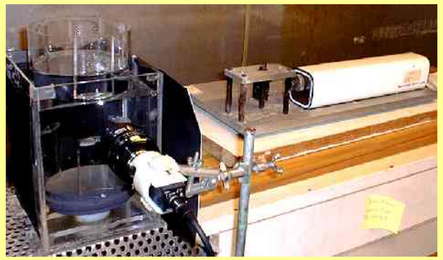
B Methods in brief

•A single CCD camera (*x*-y plane) and a roughly 1-mm thick **laser light sheet** were used.

•The turbulence vessel was a cylinder with 3 internal ridges on the wall. It was oscillated at one of two constant speeds.

•The 2D particle-pair velocities were binned in 16 bins from 0.0-0.1 cm to 1.5-1.6 cm (Fig. 2).

•**Correction** was done for the **"sheet-thickness effect"**: particle-pairs, for instance, can have apparent elongational velocity in 2D, which is really contributed by vortical movement in the unseen dimension, z (i.e. one behind the other). This was done by assuming that flow in the lowest two bins (low Reynolds no, *Re*) was laminar (slope of 1 in log-log plot), and correcting the velocities accordingly (Fig. 2)



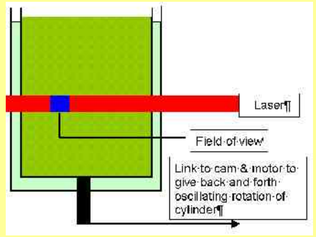


Fig. 1. Apparatus: 3-L container, CCD camera and laser producing 1-mm thick light sheet. Water movement tracked with quasi-neutrally buoyant particles.

Material	Concentration
Millipore water	
Sucrose solution	45.8 g.L^{-1}; 10 x viscosity of water
Ditylum brightwellii	353 ppm, 10,700 cells.mL^{-1}
Chaetoceros sp.	27.5 ppm, 165,000 cells.mL^{-1}
Thalassiosira weissflogii	78 ppm, 71,700 cells.mL^{-1}
Skeletonema costatum	31.9 ppm, 42,250 cells.mL^{-1}

All measurements at 20°C

C Results

•For both pure water and the sucrose solution, the distribution of mean log velocities (vortical and elongational) at *d* from 0.15 to 1.55 cm followed a relationship close to $d^{2/3}$, that characteristic of the high-*Re* regime. Both types of velocity showed this relationship and had very similar values (Fig 2).

•For pure water, sucrose solution and algal cultures, standard deviation (SD) of log velocity (both types) was also remarkably constant, mostly 0.4 to 0.5 (factor of 2.5 to 3.2).

C Results (cont.)

•For the different phytoplanktopn cultures, the relation-ships of **v** to *d* resembled those shown in Fig. 2, although light attenuation sometimes reduced the number of particles that could be discerned.

D Discussion

•The mean of both types of strain rates, for both water and sucrose solution, shown in Fig. 2, ranged from 0.065 and 0.085 s^{-1}, giving turbulent dissipation rates ε of 10^{-8} m^2.s^{-3} for water and $3x10^{-8}$ for sucrose solution, and corresponding respective Kolmogorov lengths, *L*, of 0.3 and 1.3 cm. Experiments with a higher rate of oscillation of the cylinder was also carried out, giving mean **v** 1.5 to 3 times higher (not shown), and *L* values ~24% lower.

•Although inflexions between a slope of 1 (low *Re*) and one of 2/3 (high *Re*) for log(**v**) vs. log(d) were thus predicted to occur in the different fluids in the range of *d* investigated, changes in this slope were inconsistent (see in particular Fig. 2b, right).

•Formation of long-lived resonant circulation cells (Solomon & Mezi?, 2003), with relatively large components of residual circulation, may have altered the turbulence patterns and rendered the turbulence non-stochastic and poorly hierarchical at the scales observed.

•As a result, it has been impossible to use these measurements in water and sucrose solution (Newtonian but 10 times as viscous) to calibrate the effects of phytoplankton mucus on turbulence fields in this study.

•Phytoplankton does, however, markedly change viscosity and elasticity of its medium (Jenkinson, 1993; Jenkinson & Biddanda, 1995). To investigate how it changes the turbulence around it, more fundamental studies of ocean turbulence may be required *in situ* or in very large water tanks, preferably with 3D optics.

10 pooled 5-s data series

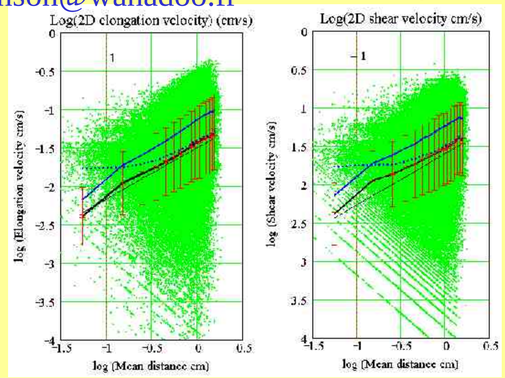


Fig. 2a) Water: n=3.8x10^5 particle-pairs (10% shown)

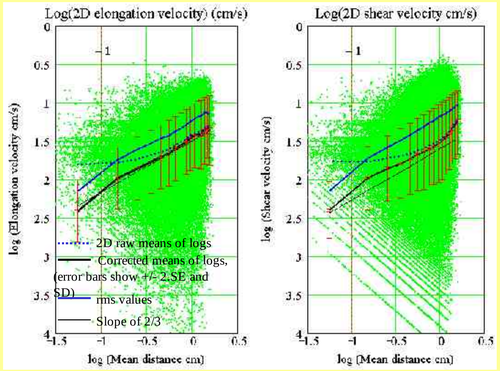


Fig. 2b) Sucrose solution, 10 times as viscous as water: n=1.2x10^6 particle-pairs (10% shown)

Thank you...

Charlottenlund, Denmark
Thomas Ki¢rboe, Josefin Titelman, Lars Pedersen
Napoli and Aversa, Italy
Maurizio Ribera d'Alcalà
Michele Di Natale
ACRO
Sophie Deschamps
Evelyne Fusilier
Danish Research Council: Started under Grant no. 9401060 to Thomas Ki¢rboe
European Commission
FP4; ESPRIT; Project 28168-ALICE

References

Jenkinson, I.R. (1993). *Oceanol. Acta*, 16: 317-334.

Jenkinson, I.R. (2004). **This Conference, Oral Presentation**, Lecture Room Uranie, Tuesday, **27 April, 11:15**.

Jenkinson, I.R. & Biddanda, B.A. (1995). *J. Plankt. Res.*, 17: 2251-2274.

Solomon,T.H. & Mezi?, I. (2003). *Nature*, 425: 376-380.