Observations and numerical modelling of mixed layer turbulence: Do they represent the same statistical quantities ?

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Or, with Steve Thorpe:

Does it matter that ocean turbulence is neither homogeneous nor isotropic?

Reynolds decomposition

$$U = \langle U \rangle + \tilde{U}$$

$\langle U \rangle$: **Mean part**

$\tilde{U}$: **Fluctuating part**

Averaging requirement:

$$\langle \tilde{U} \rangle = 0.$$

Averaging procedures

1. Linearity:

$$\langle U + \lambda V \rangle = \langle U \rangle + \lambda \langle V \rangle .$$

2. Exchange of Derivative and Averaging:

$$\langle \partial_x U \rangle = \partial_x \langle U \rangle$$

3. Double Averaging:

$$\langle \langle U \rangle \rangle = \langle U \rangle$$

4. Products of Averages:

$$\langle U \langle V \rangle \rangle = \langle U \rangle \langle V \rangle$$

Averaging procedures

Spatial average:

$$\langle U(\boldsymbol{x},t)\rangle = \frac{1}{|V|}\iiint\limits_V U(\boldsymbol{\xi},t)\,d\boldsymbol{\xi}$$

Temporal average:

$$\langle U(\boldsymbol{x},t)\rangle = \frac{1}{|T|}\int_{t-T/2}^{t+T/2} U(x,\tau)\,d\tau$$

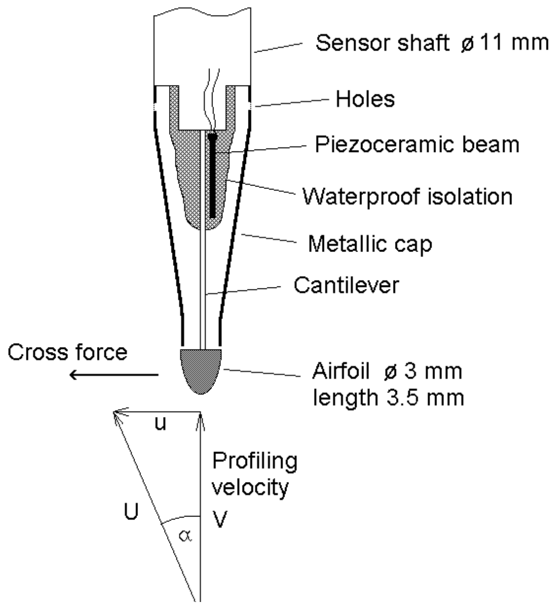
Ensemble average:

$$\langle U(\boldsymbol{x},t)\rangle = \lim_{n\to\infty}\frac{1}{n}\sum_{i=1}^{n} U_i(\boldsymbol{x},t)$$

About averaging procedures

- Only the ensemble averaging procedure is well defined in terms of theoretical considerations.
- Only for **homogeneous and stationary** turbulence, all averaging procedures are equivalent.

Microstructure observations



- Microstructure observations are usually carried out by means of one-dimensional profiling techniques
- Three-dimensional turbulence is then quantified under the assumption of **local isotropy**.

Bill Clinton:

It does matter that ocean turbulence

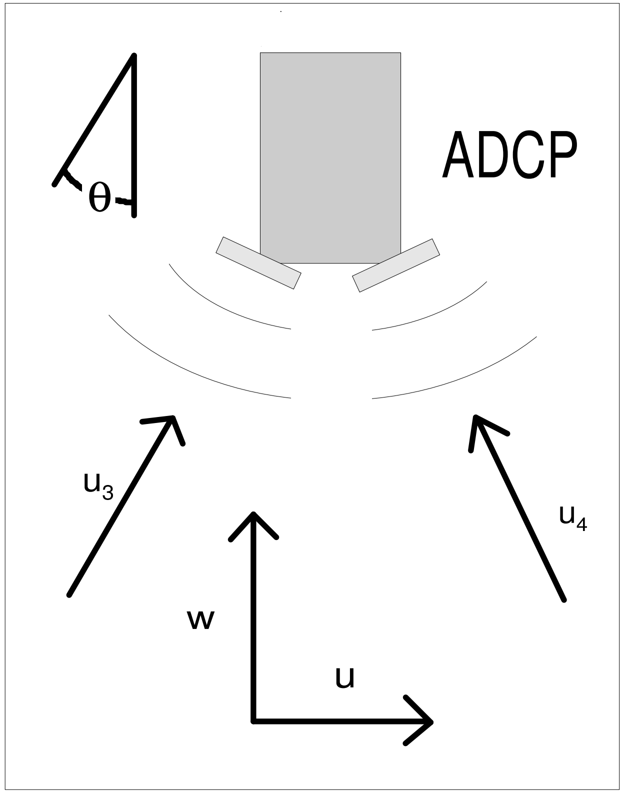
is neither homogeneous (nor stationary)

nor isotropic, stupid !

Heavy instrumentation helps

Source: http://www.me.jhu.edu/˜lefd/spiv/

High-resolution ADCP



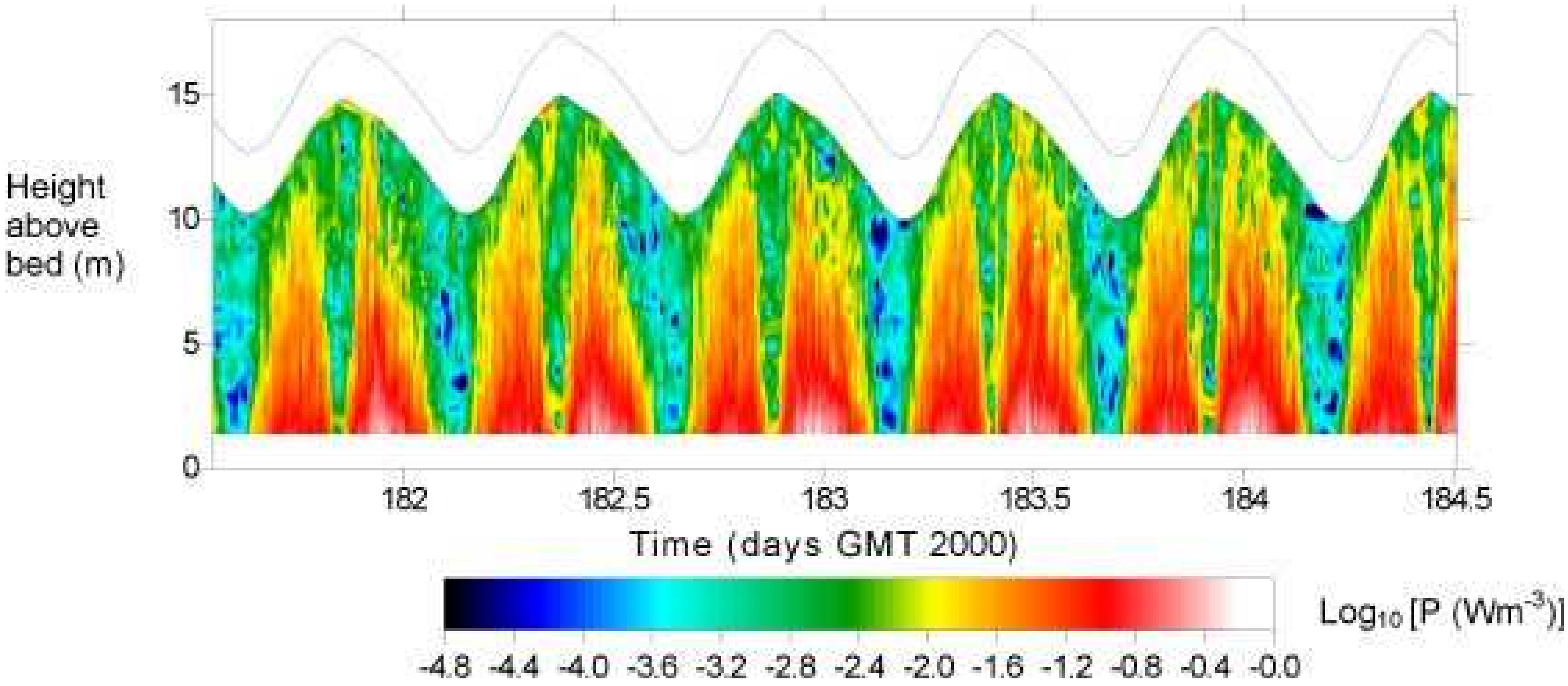
$$u_3 = u \sin\theta + w \cos\theta; \qquad u_4 = u \sin\theta + w \cos\theta; \tag{1}$$

$$\begin{aligned} \langle \tilde{u}_3^2 \rangle &= \langle \tilde{u}^2 \rangle \sin^2\theta + \langle \tilde{w}^2 \rangle \cos^2\theta + 2\langle \tilde{u}\tilde{w} \rangle \sin\theta\cos\theta \\ \langle \tilde{u}_4^2 \rangle &= \langle \tilde{u}^2 \rangle \sin^2\theta + \langle \tilde{w}^2 \rangle \cos^2\theta - 2\langle \tilde{u}\tilde{w} \rangle \sin\theta\cos\theta \end{aligned} \tag{2}$$

$$\langle \tilde{u}\tilde{w} \rangle = \frac{\langle \tilde{u}_3^2 \rangle - \langle \tilde{u}_4^2 \rangle}{4 \sin\theta \cos\theta} \tag{3}$$

Observing shear production

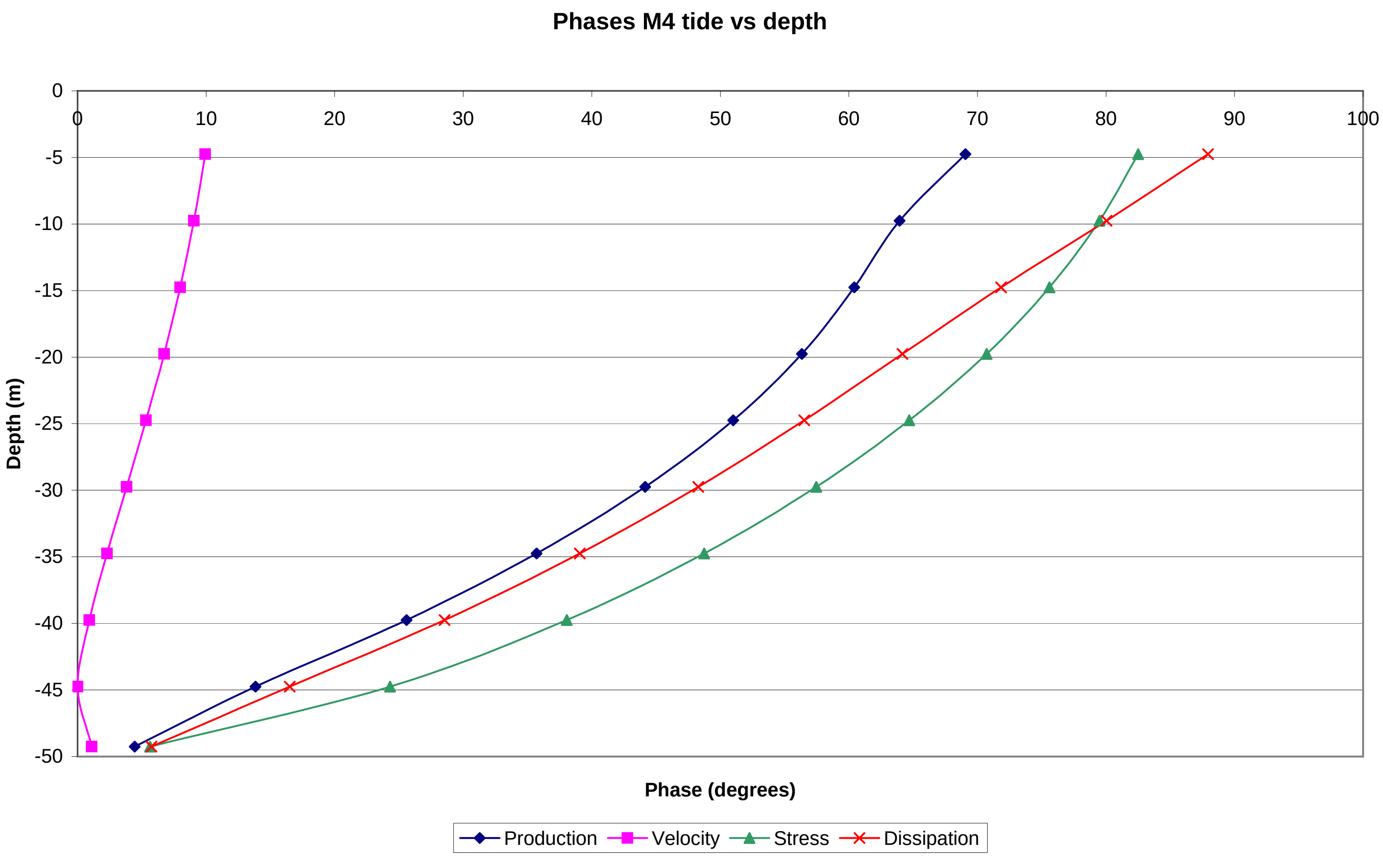
Example from Menai Strait, North Wales:



pers. comm. Tom P. Rippeth, Bangor, Wales

Modelling tidal flow

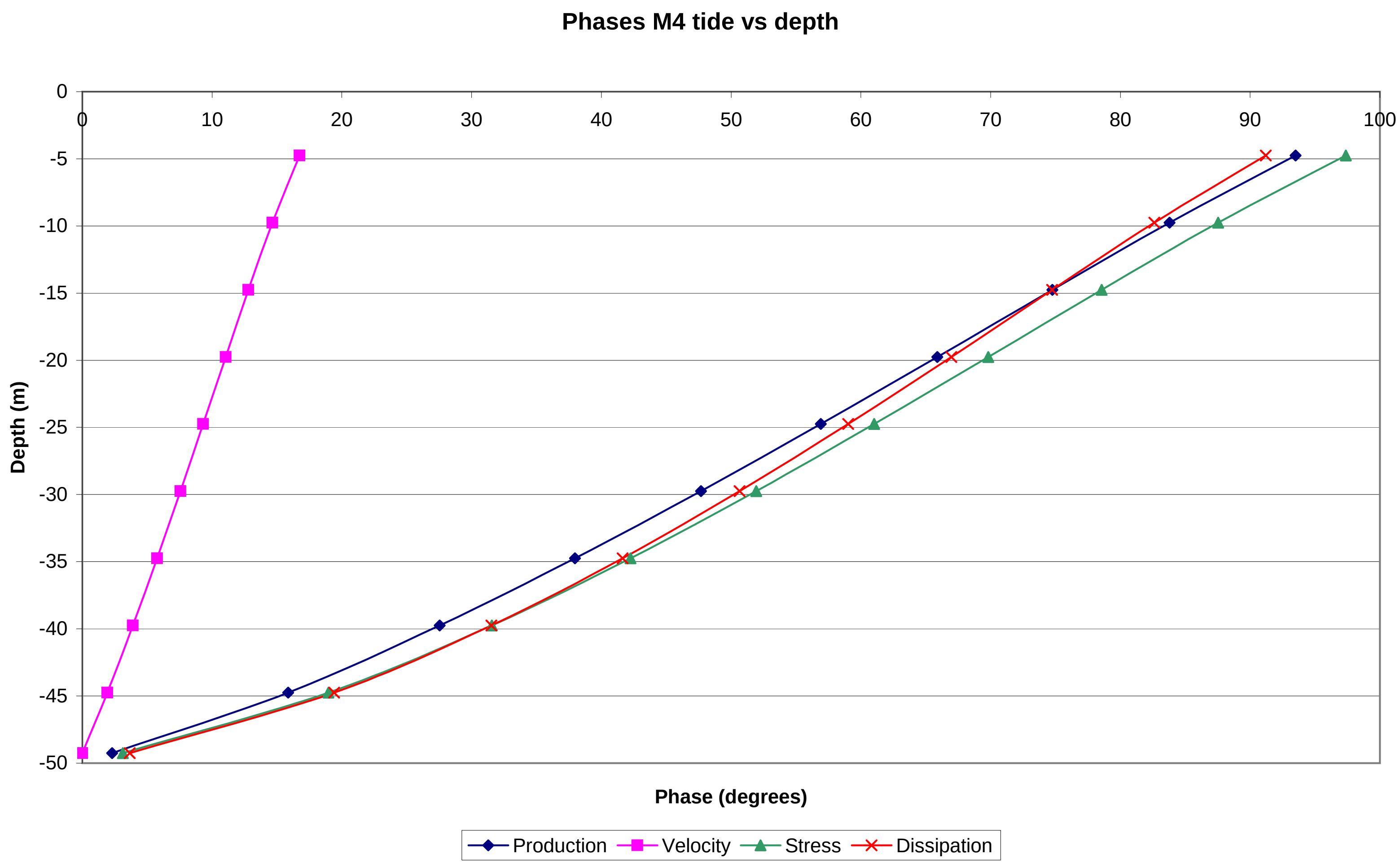
Two-equation turbulence model:



pers. comm. Calculation by Lorena Martinéz Ribés, IOW

Modelling tidal flow

One-equation turbulence model:



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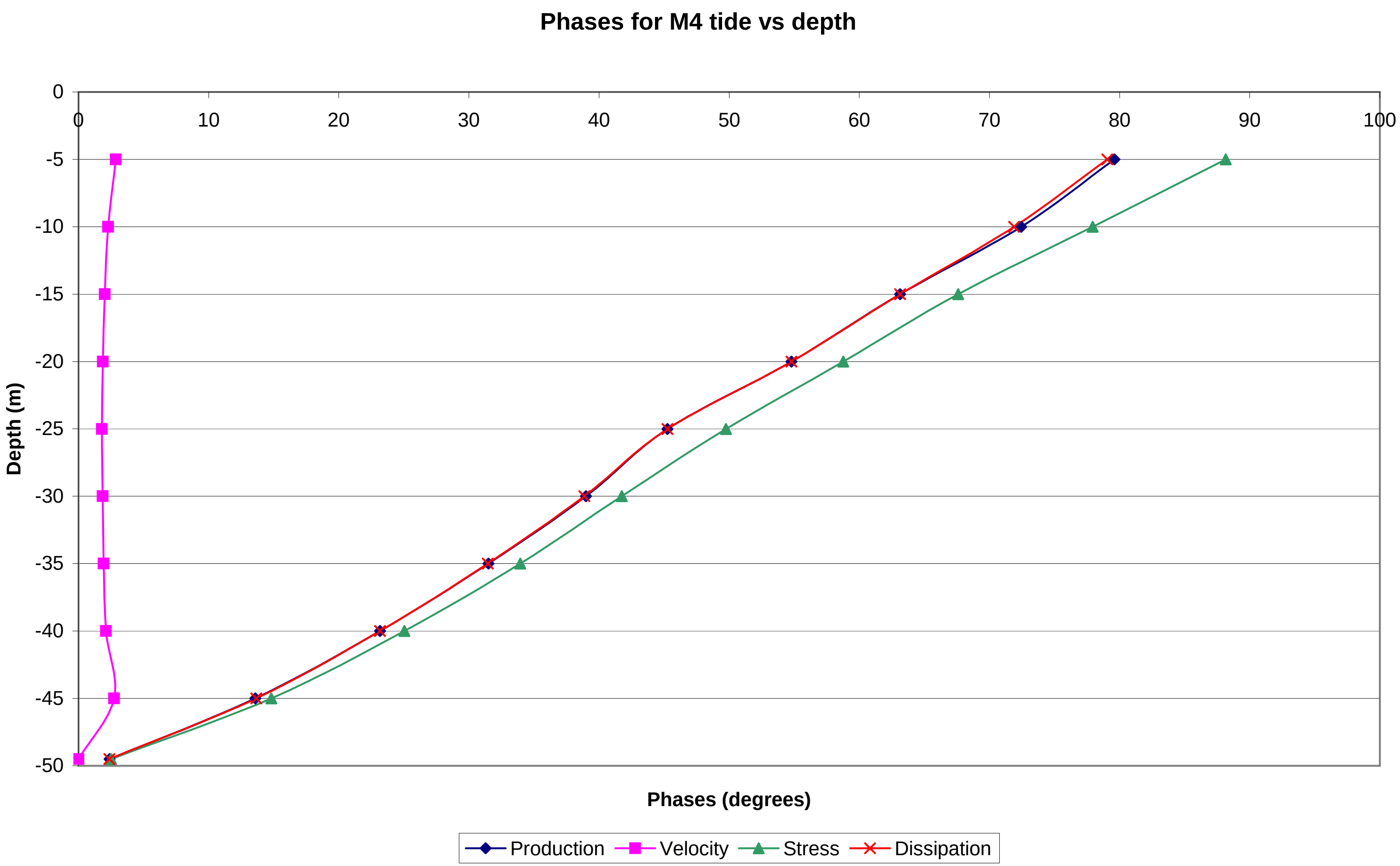
Modelling tidal flow

Zero-equation turbulence model:



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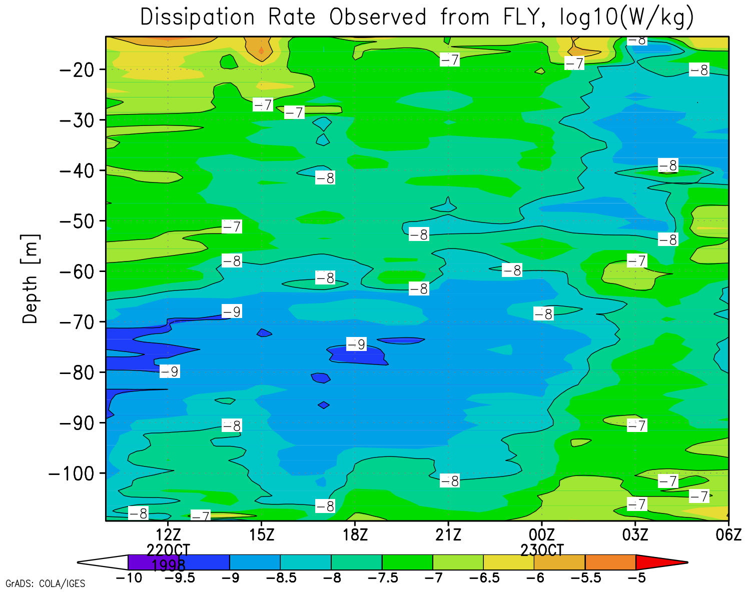
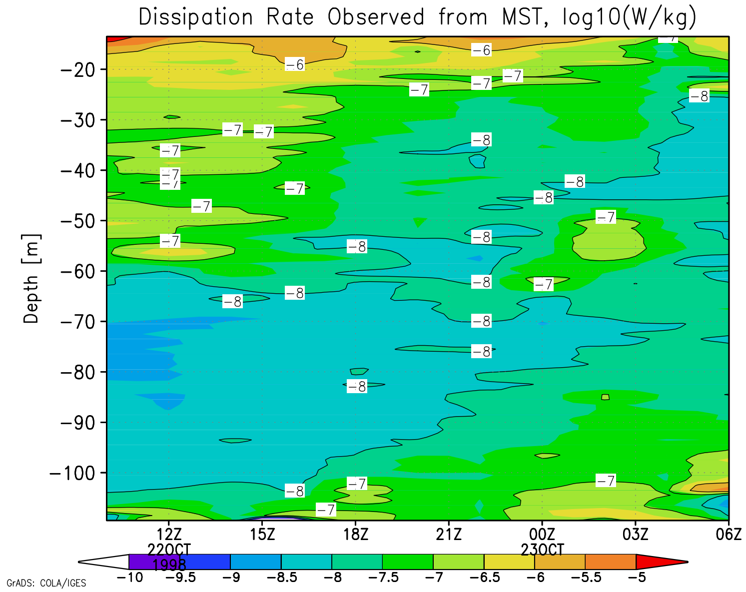
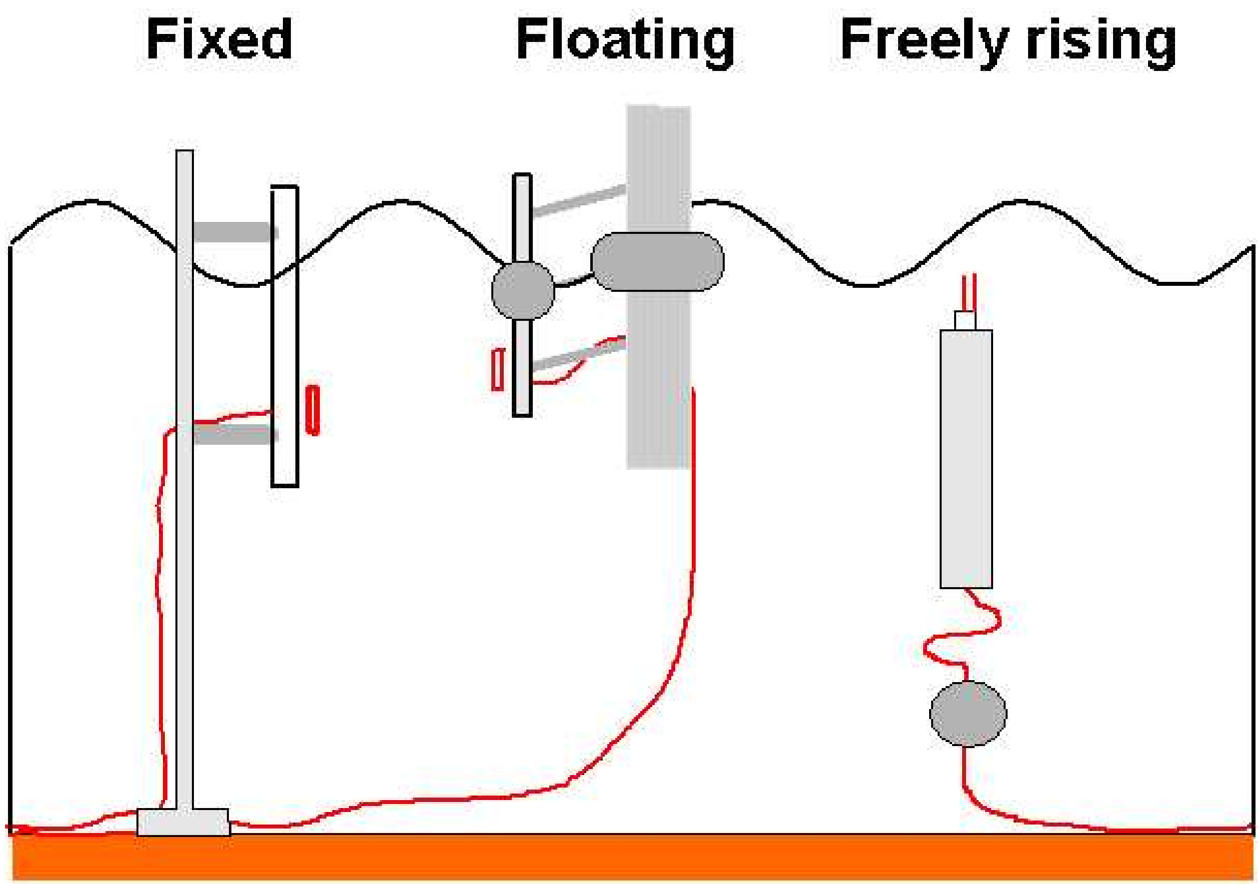
How big was ε really ?





From Burchard et al. [2002]

Turbulence under waves



What does ensemble average mean here ?

Conclusions ?

To be drawn after the first
Warnemünde Turbulence Days.

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