Sediment dynamics in the wake of a tidal current turbine

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March 29, 2012

Research outline

What will happen to the ocean floor after deployment of tidal turbines ?

And in ten years time ?

Will it have an impact on the habitat of marine plants and animals that dwell there ?

The interaction between the wake that is produced downstream of tidal current turbines and the sediment on the seabed is the subject of present research.

PhD project of Lada Vybulkova

Wake Vorticity Field

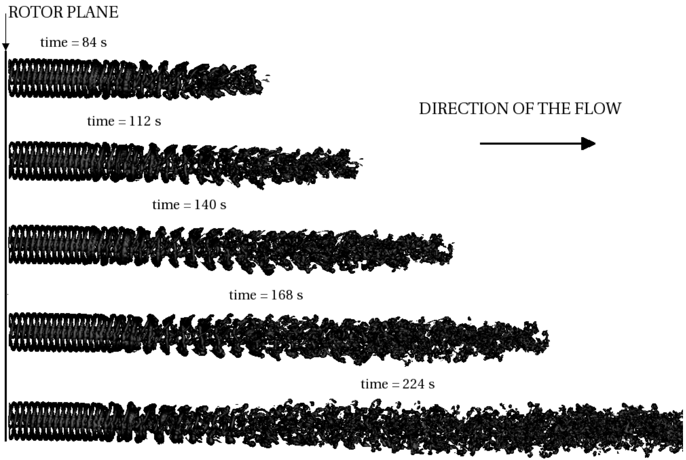


Figure: Evolution of a wake vorticity field

Vorticity Transport Equation

Vorticity field $\omega = \nabla \times \mathbf{v}$ is a solution of

$$\frac{\partial \omega}{\partial t} + (\mathbf{v} \cdot \nabla)\omega - (\omega \cdot \nabla)\mathbf{v} = S_\omega + \nu \nabla^2 \omega \tag{1}$$

which is the curl of unsteady, incompressible *Navier-Stokes equations*[1]

$$\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} = -\frac{\nabla p}{\rho} + \nu \nabla^2 \mathbf{v} \tag{2}$$

$$\nabla \cdot \mathbf{v} = 0, \tag{3}$$

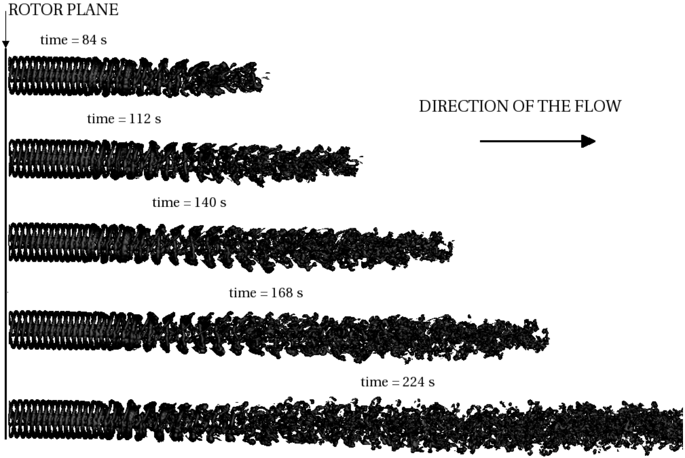
the velocity field is a solution of

$$\nabla^2 \mathbf{v} = -\nabla \times \omega \tag{4}$$

and S_ω is a source of vorticity.

[1] ν... kinetic viscosity, p... 'pressure', ρ... density of the sea water

Vorticity Transport Model



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Sediment uplift

Threshold condition for initiation of motion - Bed Shear Stress $\theta > \theta_{cm}$.

$$\theta_{cm} = 0.14(d^*)^{0.64}, \tag{5}$$

$$d^* = d\left(\left(\frac{\rho_s}{\rho} - 1\right)\frac{g}{\nu^2}\right)^{1/3} \tag{6}$$

is the dimensionless sediment size.[2]

Amount of sediment coming into suspension $\sim$ *erosion flux* $(kgs^{-1}m^{-2})$

$$E = E_0\left(\frac{\theta}{\theta_{cm}} - 1\right) \tag{7}$$

where erodibility E_0 is determined experimentally for the particular flow situation. The ambiguity was avoided by definition of a relative quantity expressing the impact of a TCT on the seabed

[2] ρ_s… sediment density, g… gravity and sediment size d

Relative Excess Erosion Flux (REEF)

$$S_r = \sum_{i \in grid} \left(\frac{E_i}{E_{fs}} - 1 \right), \tag{8}$$

represents a relative increase in erosion flux caused by presence of a tidal turbine with respect to E_{fs}, the erosion flux caused by the inflow only.

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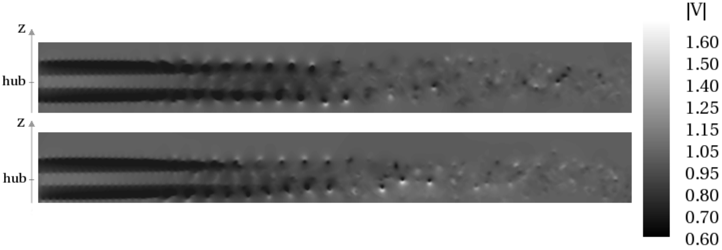
- proximity to the seabed
- flow conditions - inflow velocity, Tip Speed Ratio
- parameters of the device - number of blades, rotor diameter, blade twist distribution, etc.

Ground Effect



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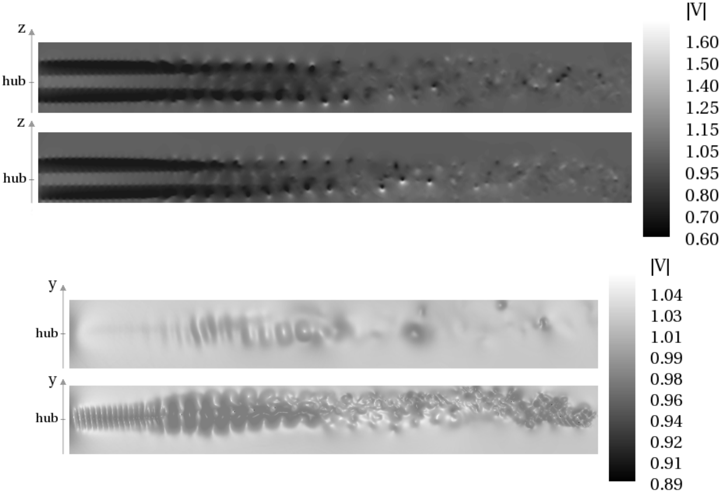

Figure: Slices through the wake velocity field, $|V|$ $[ms^{-1}]$

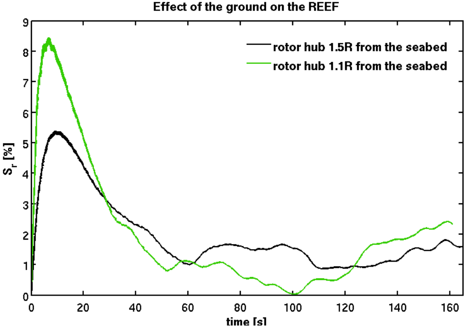

Figure: REEF change with the proximity to the seabed

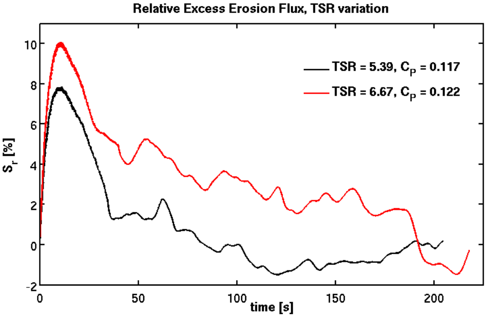

Figure: REEF change with the Tip Speed Ratio

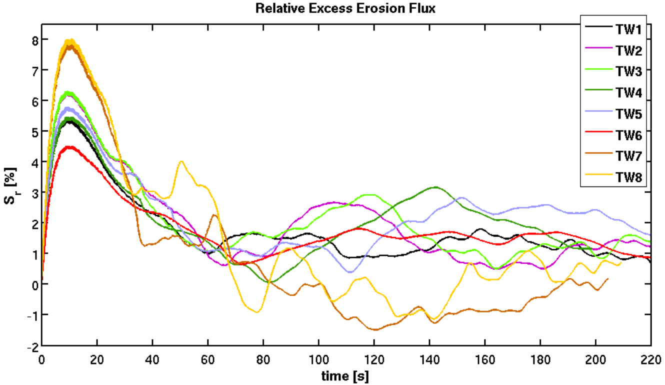

Figure: REEF for various blade twist distributions

Twist	TW1	TW2	TW3	TW4	TW5	TW6	TW7	TW8
C_P	0.101	0.111	0.110	0.102	0.108	0.091	0.117	0.113

Table: Power coefficient of used twist distributions

Conclusions and ongoing research

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The nature and scale of the change of sediment dynamics in relation to various factors is the subject of ongoing research at the University of Glasgow.

Present results indicate long-term cumulative effects on the ocean floor, caused by presence of a TCT over a period of decades.


Thank you.