Tidal modelling in high fidelity: the Sound of Islay

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Sound of Islay: overview

- Continuation of NERC-funded project, under eCSE programme, with support from Scottish Power

- Sound of Islay is a proposed site for a tidal array

- Peak ebb/flood ~ 3 m/s

- Highly turbulent flow, across scales from < 25 m to > 500m

- (Still) work in progress - but almost finished
Current modelling strategies

Discretisation methods

• Shallow-water models (e.g. Telemac 2D): cheap to run. Hydrostatic assumption.
• Sigma-layer models (Delft 3D, FVCOM): Quasi-3D. Layers of essentially 2D flow, with friction coefficients to effect momentum transport between layers. Again, hydrostatic.
• Fully non-hydrostatic models (?): Three-dimensional flow capture, vertical momentum transport. Expensive.

Turbulence methods

• Constant eddy viscosity
• Reynolds Averaged Navier Stokes (common engineering approach)
• Large Eddy Simulation (expensive; grid resolution dependent)
So why non-hydrostatic LES?

Reasons against
- Very expensive to run: 80-500 computational cores
- Grid dependence means large, fine grids, small time-steps: masses of data (TB/month)
- Most LES models parameterise isotropic turbulence only
- Boundary layers can be a problem
- Tidal turbulence is highly anisotropic

Reasons for
- Detailed time-series of velocity possible
- Turbulence spectra: information on eddy size, frequency
- Realistic tidal turbine interaction in fluctuating flow (cf. Creech 2015 Lillgrund paper)
- Vertical flow features can be resolved: eg. upwellings, boils.
Tidal turbulence :: Grey Dogs race
Modelling development

Necessary features:

• Anisotropic Large Eddy Simulation, two scales simultaneously

• Boundary layers: Van Driest conditions: distance to wall

• Non-dissipative, numerical stable, conservative finite-element scheme: Compact Discontinuous Galerkin

Non-trivial to develop.

• Fluidity provided Compact DG (+ nuts and bolts)
• Much optimisation work still to be done (1 month simulation -> 3 months run-time)
Sound of Islay LES model
Vorticity visualisation

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Results :: virtual ADCP

One of ADCP sites, at surface (blue), and 22m depth (red)

Velocity magnitude:

Flow direction:
To-do list

• Turbulence intensity measurements
• Second ADCP site
• Max velocity profiles (should be logarithmic), average profiles
• Comparison with tidal gauge data (Port Ellen)
• Flow rate / flux
• More optimisation + feature development
• Release back to community as open source
Conclusions

- Large Eddy Simulation coastal models are extremely challenging
- Offer prospect of greater understanding of tidal turbulence
- Much work still to be done in developing new methodologies
- With attention to performant coding, resolving down to tidal turbine scale not too far away.
Any questions?