

Globally extensive, Subgrid scale, Seafloor Roughness (z0) for Input to Circulation Models

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SUMMARY

By using spatially-varying estimates of seabed roughness (z0), the performance of ocean current and tide numerical models may be improved. To an extent, the seabed database dbSEABED is able to supply these values from data on the seabed materials and features. But then adjustments for varying dynamic (wave, flow) conditions are also required. So the data and model must work closely together. We developed methods for calculating inputs of z0 for circulation models in this way. Preliminary outputs from this new globally capable facility are demonstrated for the NW European Shelf region (NWES).

MOTIVATION

Operational ocean modeling systems with high computational power are treating increasingly complex situations - including the dynamics of shallow, tidally dominated, coastal waters. One such system at the U.K. Met Office is the Atlantic Margin Model (AMM). It provides forecasts of the 3D ocean state at 7km resolution for the North-West European Shelf.

As is common in models, it currently uses a constant bottom roughness length scale. This may be practical for coarse resolution non-tidal open ocean models, but model accuracy could be improved by utilizing spatially variable, local roughness information.

ABOUT z0

A conventional metric for bottom boundary drag is z0, a length-scale: “.. z0 is .. defined as the elevation at which the mean flow vanishes when extrapolated toward the bed. ... there is no assumption .. regarding the physical meaning of the hydraulic roughness ..” (Green & McCave 1995) . Nevertheless, empirical relations do link z0 values to physical and dynamic metrics.

The standard expression for the logarithmic velocity profile uses z0 as follows:
$$\left(- \right) . \text{ in terms of the mean flow } (\bar{U}), \text{ friction velocity } (u^*) \text{ and the von Karman constant } (\kappa, \sim 0.41). \text{ Variable } z \text{ is the height of some level in the flow higher than } z_0. \text{ Soulsby (1997) recognized three additive components in } z_0: z_0 = z_{0_{\text{grain}}} + z_{0_{\text{form}}} + z_{0_{\text{transport}}}, \text{ being for grain texture, bedforms and objects, and transport of sediment.}$$

For a flow, z0 is a function both of the bed conditions and the flow dynamics, which together create the drag. Therefore to generate z0 values suitable as input to models firstly an estimate is formed based on the bed character. Then those values are modified according to time and space for the runtime modeled flow conditions and developing wave climate.

SCALE CONSIDERATIONS

A grid resolution of ~7km is envisaged for this particular tidal modeling. Good resolution public access bathymetry (GEBCO08) exists at 1km resolution and at much finer resolutions within agencies. Thus, at least topographic roughness at 2km Nyquist could be included in the model sub grid scales. This roughness component was calculated in terms of area rugosity.

At scales finer than gridded bathymetry, mapping sonar systems and direct observations (samplers, imagers) detail the patterns of occurrence of the seabed features and materials. This very heterogeneous data collection is available from published scientific literature, hydrographic charts and pilots, maps and governmental-commercial reports. dbSEABED database and software procedures were used to integrate the data from those disparate 198 sources. The procedures involved text parsing, inter-parameter calibration, GIS data analysis, raster image analysis, and database methods including building metadata.

STATIC AND ACTIVE ROUGHNESS

The direct observational data - as valuable as it is - can only provide snapshots of the usual conditions. For static features such as ledges this is acceptable. For mobile and active features predictions of distributions and scales are needed. In the case of smaller bedforms ‘ripple predictors’ (Soulsby& Whitehouse 2005) provide a suitable framework and consensus on methods. Despite evidence for their migration on scales of 0-100m/yr (e.g., Buijsman & Ridderinkhof 2008), the mapped distributions of larger bedforms can be practically assumed to be stable over the term of the current modeling. Obviously, temporal change at the seabed is an important issue on which database and modeling will need to work together.

RESULTS

Gridded maps of the sediment textures, rock areas, and fixed physical roughness are compiled. Wavewatch wave data has been used with those to build a map of the predicted transient roughness such as ripples. The combination of both is shown (Figs 3, 4). An estimation of z0 and its uncertainty across the spatial grid is made using the pointwise z0 median and variance values in each cell and then extrapolating the values to the grid vacancies. The coupling with high flow-regime model dynamics has yet to be made.

Further work is required to see how much spatially varying z0 do improve numerical circulation models and to find the most effective procedures.

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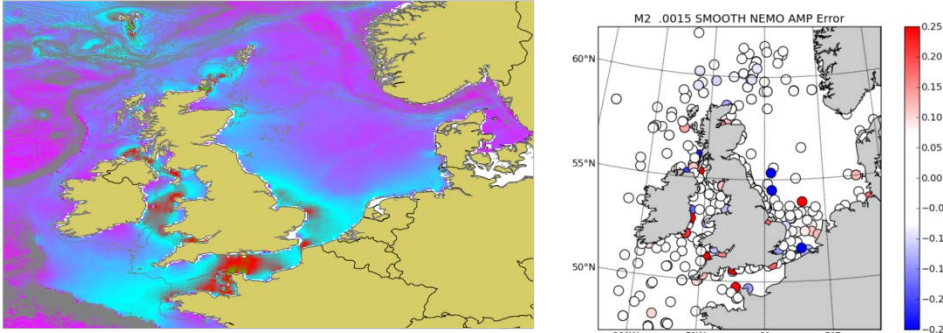


Figure 1. A. Modeled average bottom currents for 2007. Red intense, purple weak. B. Calibration of NEMO model tidal heights for the UK region against a standard set of tide measuring stations. Scale: error of M2 Amplitude (m) for uniform Z0 = 0.0015 (m) and smoothed bathymetry. The overall model RMS is <15cm.

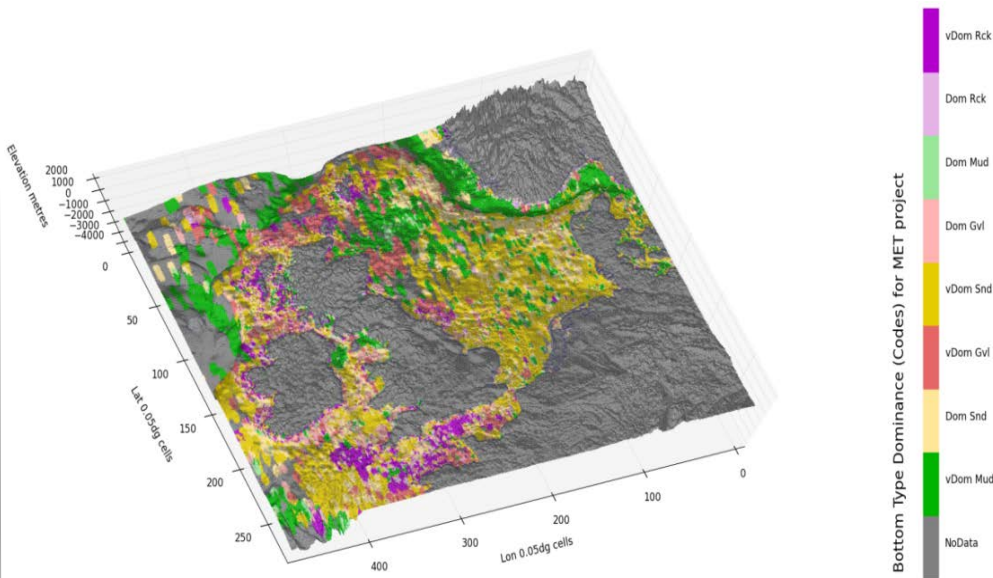


Figure 2. General form of the seabed of the region, color coded for dominant bottom type.

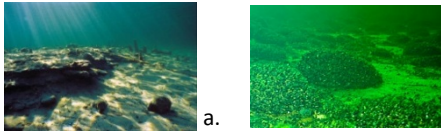


Figure 3. Some unexpected but widespread forms of rough seabed: a. rock outcrops, b. mussel microreefs (Courtesy: BFN, DEU). In the North Sea boulder fields from glacial episodes are also widespread

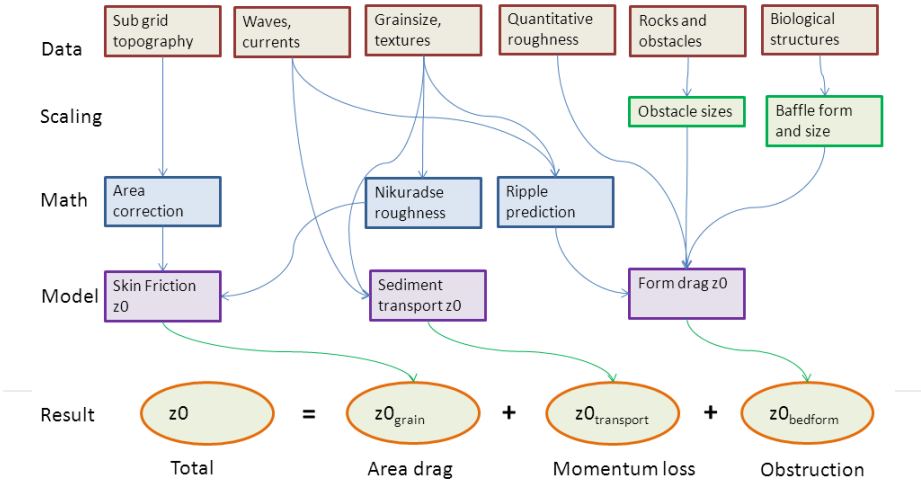


Figure 4. Schematic of the methods. A default value of 0.0015m underlies the results.

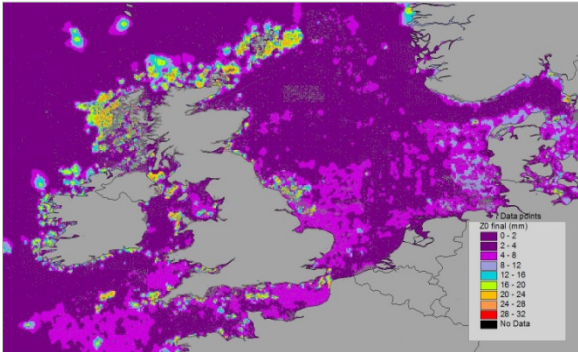


Figure 5. Gridded outputs on z0 final, taking into account physical roughness of geo- and bio-origins, grainsizes, ripple development, subgrid rugosity and flow strengths. The distribution of the supporting point data is shown as fine grey dots.

ACKNOWLEDGEMENTS

The dbSEABED project is grateful to the data providers who allowed repurposing of their seabed data by making it publically available in papers, reports and on the internet.