# Mesh density distribution for tidal energy resource assessment

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## Introduction & location

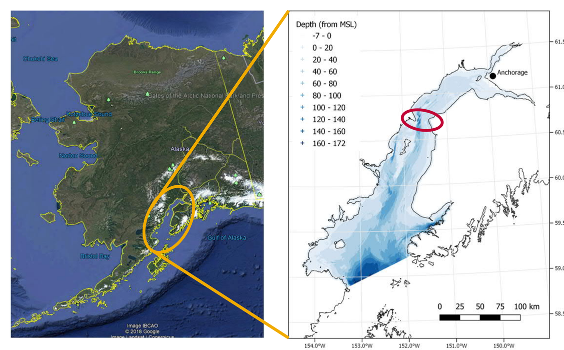


Fig. 1: Location of, and bathymetric map of, the Cook Inlet. The area of interest for tidal energy extraction is marked in red.

The Cook Inlet is a large estuary on the south coast of Alaska, with the city of Anchorage near its head (Fig 1). It has the largest tidal range in the USA, with an annual maximum of over nine meters (Fig 2). With large tides and a nearby center of population, it is a strong candidate for tidal energy extraction. The area of primary interest is marked on Fig 1.

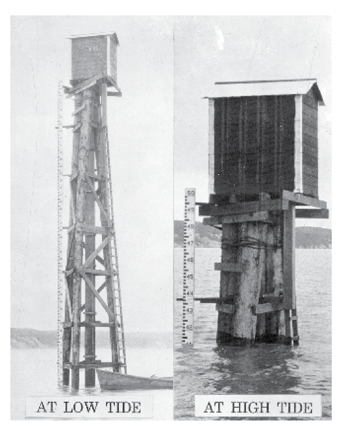



Fig. 2: Historical photographs illustrating the tidal range in the Cook Inlet. Source: NOAA

In order to study this potential, a regional-scale hydrodynamic model is required. In this case, the Finite Volume Community Ocean Model (FVCOM) code[1] was selected. Initially a moderately coarse mesh was produced (Fig 4a), and then two different methods were explored for refining it (Fig 4b).

## Initial model

An initial model was built using triangle sizes as shown in Fig. 4a: the upper inlet, including the area of interest, was uniformly meshed at approx. 350 m resolution, while in the lower inlet this smoothly expanded to 1200 m at the open boundary. Ten equally-spaced sigma layers were used.

This model performed well in the lower part of the inlet, but showed modest amplitude errors around the area of interest in the middle, as well as larger areas in the upper inlet (Fig. 5). Known eddies in the middle area were not resolved, so it was decided to explore mesh refinements in this area.

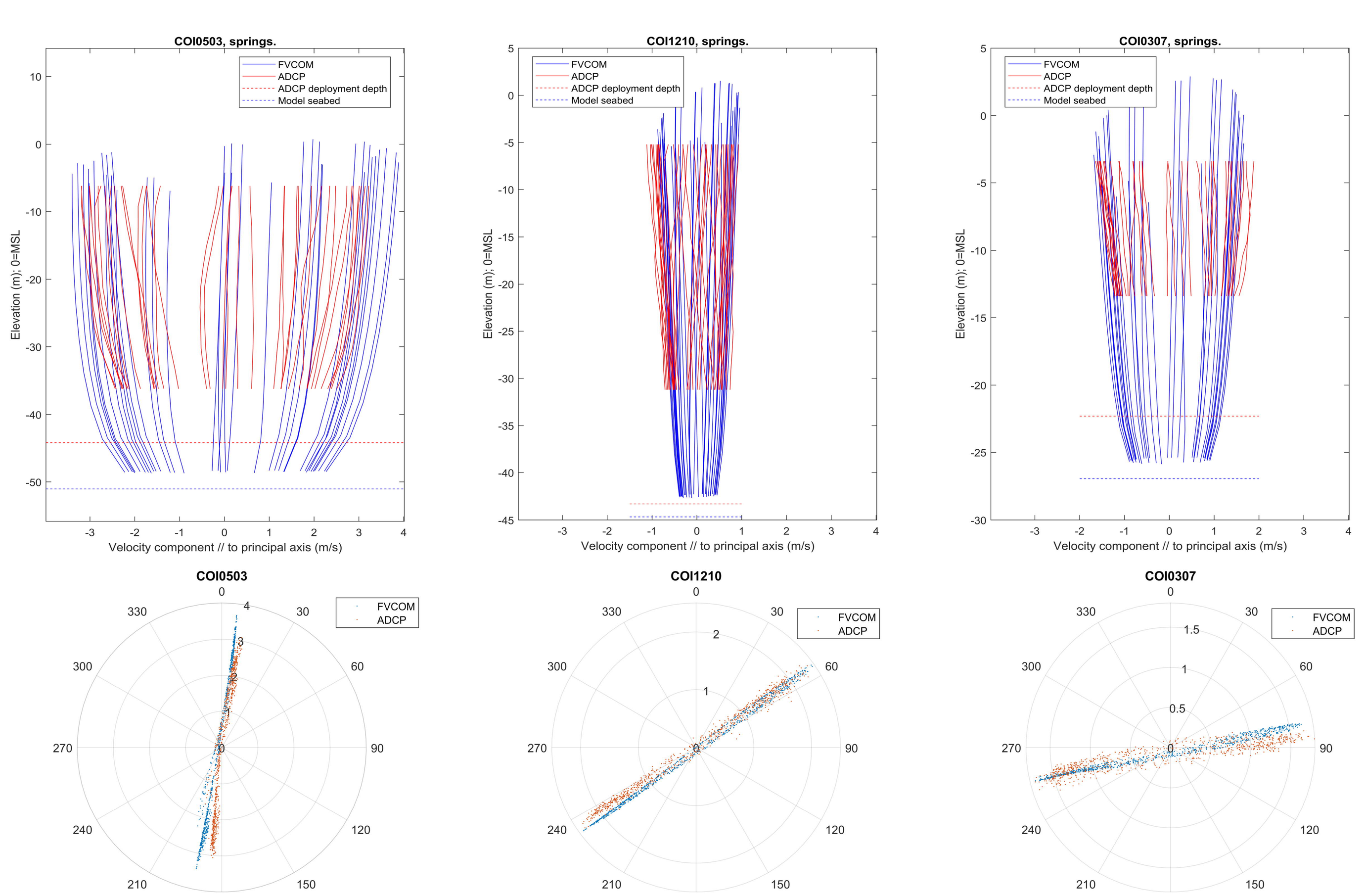
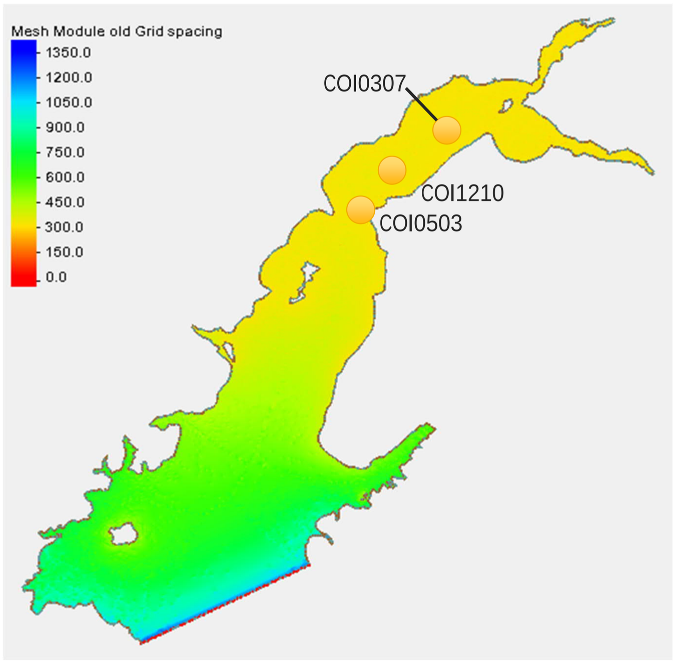



Fig. 3: Sample plots showing validation of current speeds in the initial model against ADCP measurements. Upper plots show hourly profiles over 36 h at Springs. Lower plots show hourly depth-averaged velocities over approx. 1 month. Locations are shown on Fig 4a.

## Mesh refinement approaches

Two approaches to mesh refinement were tested: a conventional one based on the gradient of the bathymetry, and a novel method based on the peak turbulent kinetic energy (TKE) reached in each mesh element of the initial model, during a 24-hour period at springs.

In each case the maximum resolution was constrained to 80 m in the middle and upper inlet, and slightly coarser values in the lower inlet. The minimum resolution was limited to that of the initial model. Additionally, a zone of minimum 200 m resolution was specified around the area of interest, and in the bathymetry-based version a similar zone was placed in the upper inlet. Error scores for the two new mesh versions may be seen in Fig 5.




| Mesh version | # of elements |
|---|---|
| Initial | 239,475 |
| Bathy gradient | 392,002 |
| TKE | 364,659 |

Table 1 : Number of horizontal mesh elements in each mesh version.

Fig. 4a (left): Map showing mesh density in the initial model. Units are meters, referring to typical triangle face length. Yellow marks show locations of measurement sites shown in Fig 3.

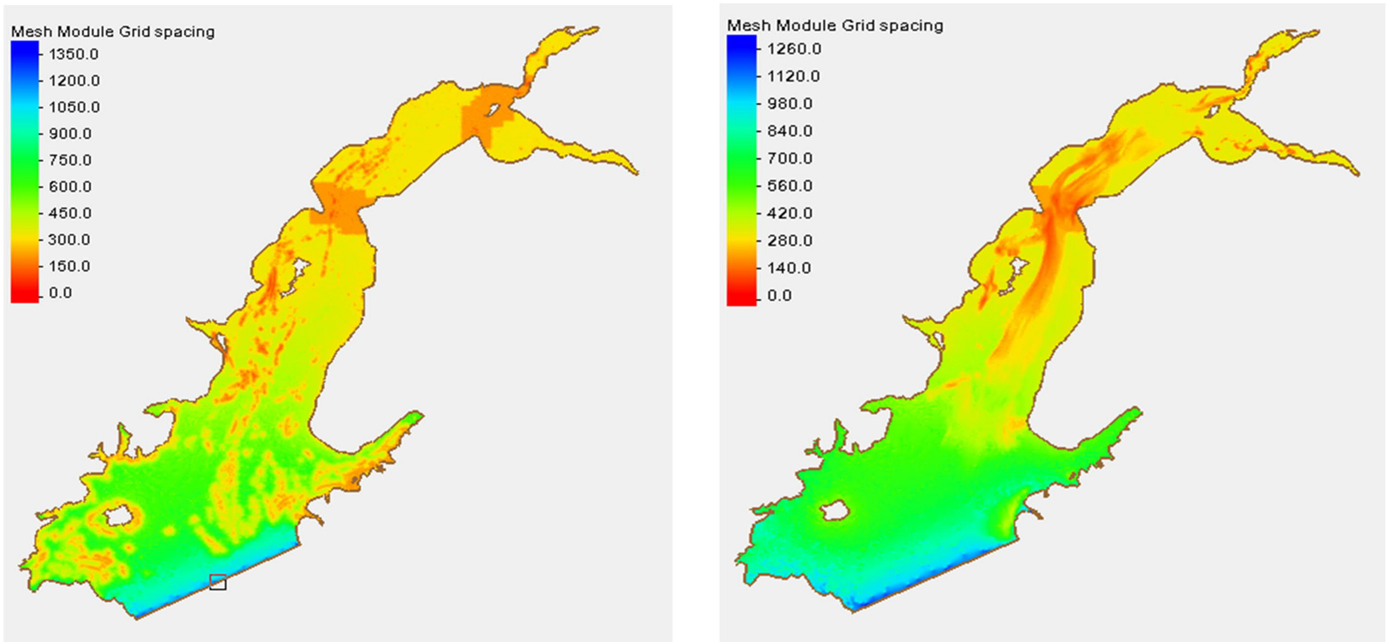



Fig. 4b: Maps showing mesh density in refined meshes. Left: mesh refinement based on bathymetry gradient; Right: Mesh refinement based on TKE in prior model. Units are meters, referring to typical triangle face length.

## References

[1] C. Chen, H. Liu, and R. C. Beardsley, "An Unstructured Grid, Finite-Volume, Three-Dimensional, Primitive Equations Ocean Model: Application to Coastal Ocean and Estuaries," *J. Atmos. Oceanic Technol.*, vol. 20, no. 1, pp. 159–186, Jan. 2003.

## Acknowledgements & Contacts

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## Results

The maps below show error scores (smaller is better) for the semi-major axis and phase at each available ADCP location, generated as follows: At each site, harmonic analysis is performed and tidal ellipse parameters generated from observations and predictions. The absolute (positive) errors in semi-major axis amplitude and phase for the four most energetic constituents are combined using a weighted mean, where the weighting is determined by the proportion of the total energy that is in that constituent.

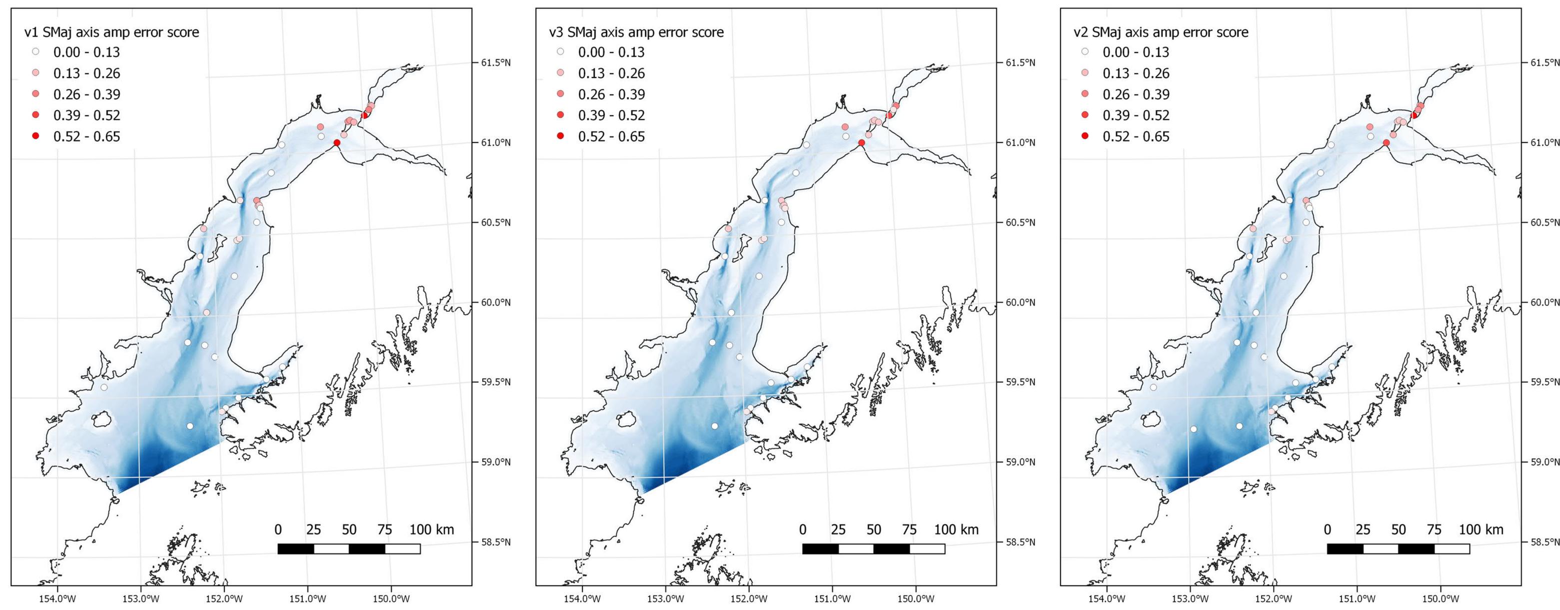

Fig. 5a: Semi-major axis amplitude error scores. Left: Initial; Mid: bathymetry gradient based; Right: TKE based

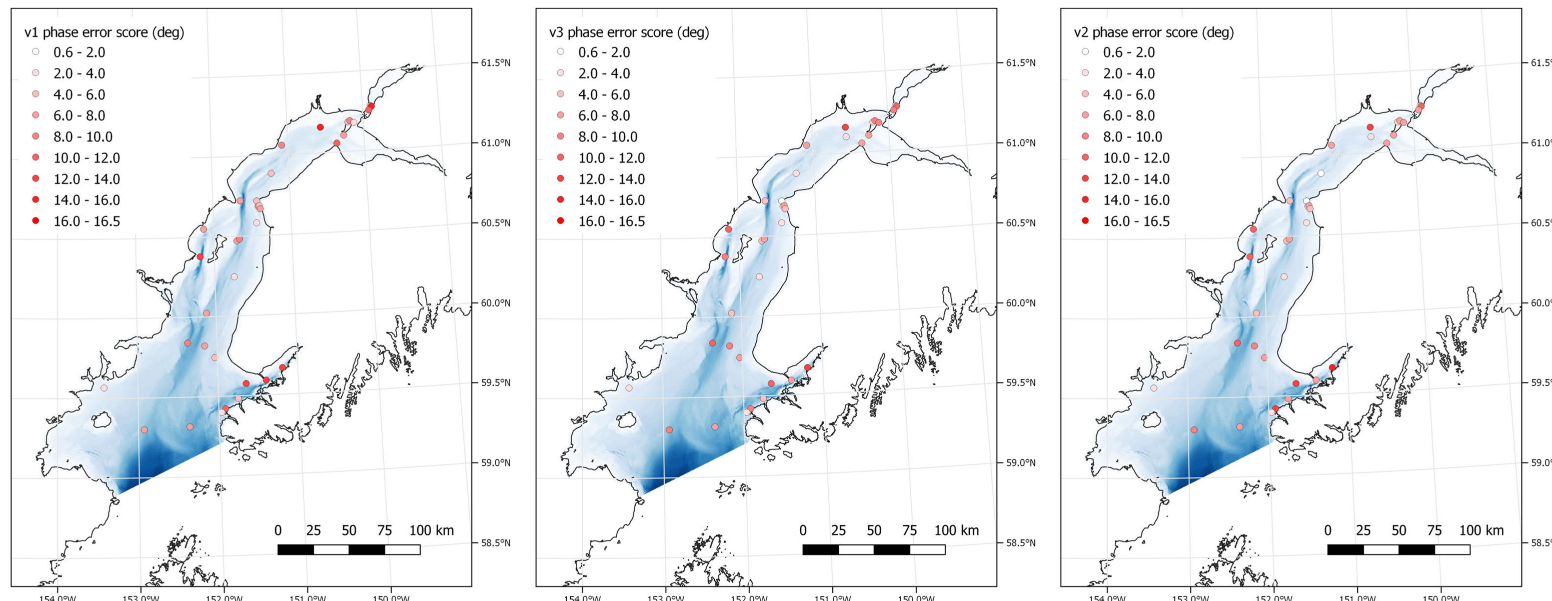

Fig. 5b: Phase error scores. Left: Initial; Mid: bathymetry gradient based; Right: TKE based
The point marked with a * has a large phase error score (approx. 160°) that cannot be shown on the same color scale as the others. The reason for this large error is under investigation.

## Discussion

The TKE-based approach is intuitively attractive, because high TKE is a direct indication that there is unresolved detail in the flow at a smaller scale than the mesh. It carries the disadvantage that it requires a prior model to provide the TKE data.

This study is a work in progress. Both refined meshes provide better model skill than the original, especially in the area of interest, but neither of the refined meshes is clearly better than the others. In the future we hope to reduce the number of elements in both meshes, and study which approach gives better "value" in terms of the ratio of model skill : computational expense.