Influence of grid resolution and bottom roughness on tidal resource characterization in Chacao channel, Chile

Leandro Suarez Atias, Cristian Escauriaza, and Felipe Lucero

***Abstract*—The Chacao channel is located in the south of Chile, South America, between the inland and the Chiloé island. In this narrow channel strong currents are generated, principally due to the tidal phase-lag between the pacific ocean and the Chilean inland sea, which makes this one the major potential sites for tidal energy resource in Chile. The extracted power is related to the velocity at the power three, therefore an adequate representation of the tidal currents is necessary to predict precisely the tidal resource available. Using the unstructured quasi-3D numerical model FVCOM, validated with data from tidal gauges and ADCPs, we assess the influence of grid resolution and bottom roughness on the performance of the nuemrical model to reproduce the tidal currents in this region.**

***Index Terms*—tidal resource, numerical model, grid resolution, roughness.**

I. Introduction

AMONG the ways to extract marine energy, the tidal resource has caught recent attention, as several pilot devices are installed in the ocean in various parts of the world (OES report, 2017). In Chile previous studies has shown the potential of two major sites, Chacao channel and Magallanes strait [1].

To assess the tidal energy resource, the use of numerical model is common, as the field data is scarce both in time and space. Therefore, the numerical modeling, validated with field data allows to understand the hydrodynamics of the flow and get a better understanding of the interaction of the tides from the open ocean and the complex bathymetries (REF).

In this study, we focus on Chacao channel, Chile, with a potential that has been already assessed (Guerra2017). The site is modelled with a quasi-3D numerical model with an unstructured grid, FVCOM (Finite Volume Coastal Ocean Modeling), which is validated by tidal gauges and ADCP data. We intend to understand the sensibility of the numerical model to the grid resolution and the bottom friction.

Paper submission ID: 1766, Track TRC

"This study was conducted under the support of MERIC - Marine Energy Research & Innovation Center (14CEI2-28228)"

"Powered@NLHPC: This research was partially supported by the supercomputing infrastructure of the NLHPC (ECM-02)"

L. Suarez-Atias is with MERIC - Marine Energy Research & Innovation Center, Avda. Apoquindo 2827, Santiago, Chile. (e-mail: leandro.suarez@meric.cl).

C. Escauriaza is at the Departamento de Ingeniería Hidráulica y Ambiental, Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago, 7820436, Chile. (e-mail: cescauri@ing.puc.cl).

F. Lucero is with MERIC - Marine Energy Research & Innovation Center, Avda. Apoquindo 2827, Santiago, Chile. (e-mail: felipe.lucero@meric.cl).

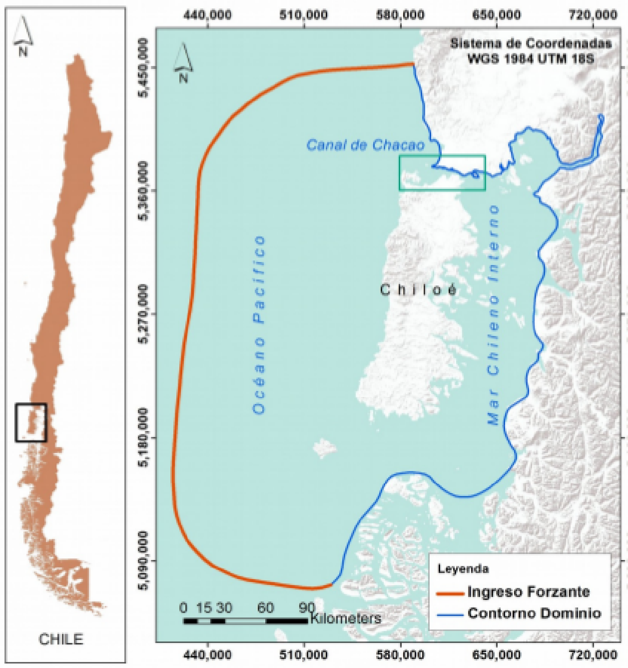

Fig. 1. Site description of the Chacao channel, between the Chiloe island and inland. The orange line is the boundary conditon for the numerical model, from [1].

II. Site description

The Chacao channel is a narrow strait, of around two km in its narrower part, and approximatively 30 km long, located in the south of Chile (41° S; 73° W), and connects the Ancud golf with the Pacific ocean (Figure 1).

The Chacao channel has a great importance in terms of environment, with a wide variety of organisms ranging from benthics to whales, but also in terms of social and economics, with around 4.000 fishermen which extract 25.000 tons of sea food per year (Castilla2012).

The tidal currents in the Chacao channel are complex, as they are dominated mainly by the phase-lag of tides at its extremities, but also to tidal resonance [2], [3]. The flow exhibit a periodic behavior, moved mainly by astronomic tides, with the M2 component of period 12.24 hours being the most important [3]. In combination with the tidal resonance from the Chileand Inland Sea, this lead to tidal amplitudes of

ISSN 2309-1983

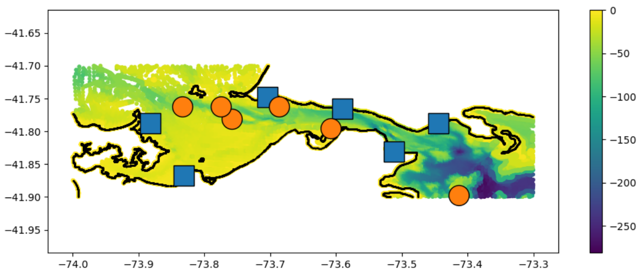

Fig. 2. Instruments deployed in the Chacao channel. The blue squares represent the tidal gauges, the orange circles the ADCPs. The color indicate the water depth.

up to 7 m in the CIS and velocities in the channel that reach 4 m/s [2], [3]. These velocities induce high level of turbulence, validated with field measurements [1]. It is therefore important to assess adequately the tidal resource, in order to observe at a later time the influence of tidal energy devices in this channel.

III. Measurements

The bathymetry of the area is obtained from a high resolution (10 m) multibeam sounding in the Chacao channel, and nautical charts in the Pacific ocean and the CIS. Furthermore, to validate the model, 6 tidal gauges and 6 ADCPs were deployed for a period 45 days (guerra2017) (Figure 2).

IV. Numerical modelling

A. FVCOM

The numerical model FVCOM (Finite-Volume Community Ocean Model, Chen2003) is a quasi 3D model with an unstructured grid which resolve the primitive ocean equations using finite volumes. This numerical model is widely used to study the physical and biological processes in coastal areas with complex bathymetries and a variety of forcing (tides, wind, river discharge, etc.) For more details on the numerical model, the reader is referred to [4].

The modeled area include the Chiloe island, the CIS and a part of the continental platform (FIGURE 2) to allow for the entrance of the tide in the south of Chile and model the tidal resonance in the CIS [2], [3].

B. grid resolution

To observe the influence of the grid resolution on numerical models, we chose two sets of grids resolution, with the same boundaries, and different refinements. The coarser grid has 22.994 nodes and 42.750 elements, and the finer grid has 40.214 nodes and 77.395 elements. The coarser elemnts in the open boundary are of 5.000 m for each grid, and the difference in refinement are located in the Chacao channel area (Figures 3, 4).

C. roughness

In this model, the bottom shear stress τ_b is modelled as:

$$(\tau_{bx}, \tau_{by}) = C_d \sqrt{u^2 + v^2}(u, v) \qquad (1)$$

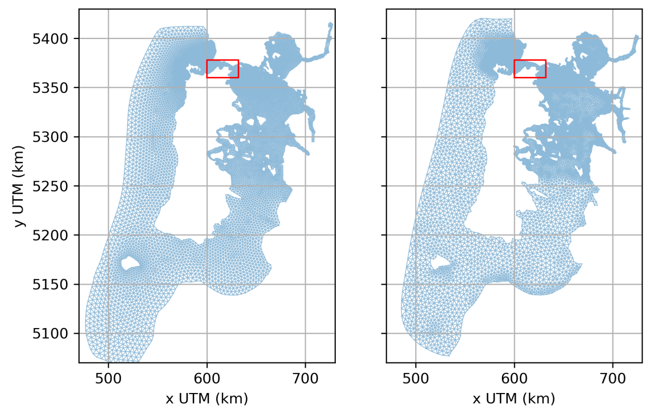

Fig. 3. Grids for the coarse (left panel) and the fine (right panel) numerical model

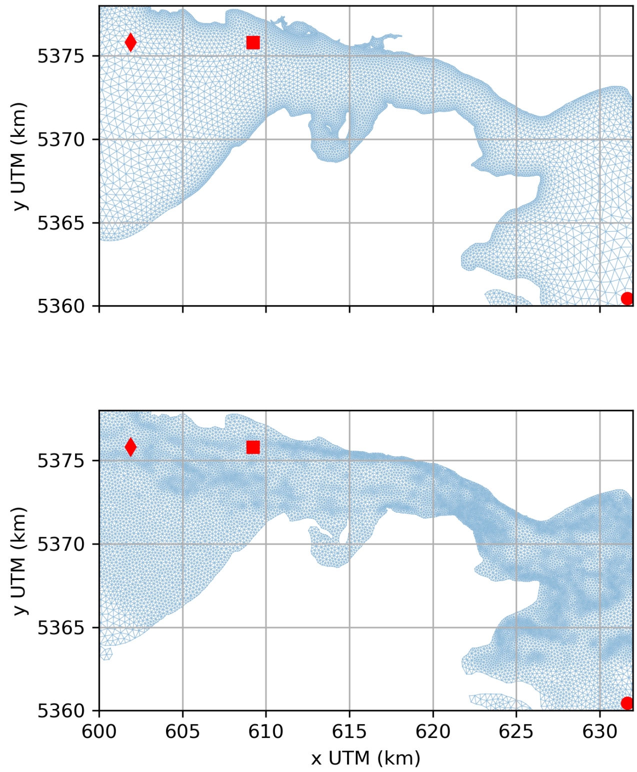

Fig. 4. Grids in the Chacao channel for the coarse (upper panel) and the fine (lower panel) numerical model. The red symbols correspond to the ADCP considered. Red cirle: Chilen site; red square: Young site; Red diamond: Corona site.

where u,v are the cratesian horizontal components and C_d the bottom friction coefficient, defined by considering a log boundary layer at the height z_{ab}:

$$C_d = \max\left(\frac{\kappa^2}{\ln\left(z_{ab}/z_0\right)}, 0.0025\right) \qquad (2)$$

where $\kappa = 0.4$ is the von Karman constant and z_0 the bottom friction component.

To observe the sensitivity to bottom friction, that is more relevant in shallower areas, we set different roughness height with two sets of grid resolution.

D. numerical setup

The numerical modeling period is of 45 days to retrieve the major harmonic components of the tides and velocities in the Chacao channel. The hydrodynamic forcing include all the astronomic tide harmonic components, obtained by the TPXO 7.1 global model [5]. Concerning other parameters of the models, the horizontal mixing coefficient is 0.4 m2.s-1 using Smagorinsky parametrization [6], the vertical mixing coefficient is 10-4 m2.s-1, and the turbulence closure scheme is of type k-ϵ

V. Analysis

E. Time-series

we first observe the time series at three sites located in the Chacao channel for the tidal gauges. For the Chilen site, located inside the CIS (Figures 5 and 6), the velocities are low, around 0.5 m/s. The velocity magnitude for the finer grid tend to over-estimate the velocities obtained from the ADCP, while the coarser grid tend to underestimate them. However, in terms of direction, the finer grid is closer to the ADCP data, in terms of direction and phase lag.

For the Young site (Figures 7 and 8), the finer grid model also tend to over-estimate the velocities, but the phase-lag is lower than the coarser grid.

For the Corona site, (Figures 9 and 10), the finer grid has much better results than the coarser grid resolution.

Considering these preliminary results, the finer grid behaves better overall in terms of velocity magnitude and directions.

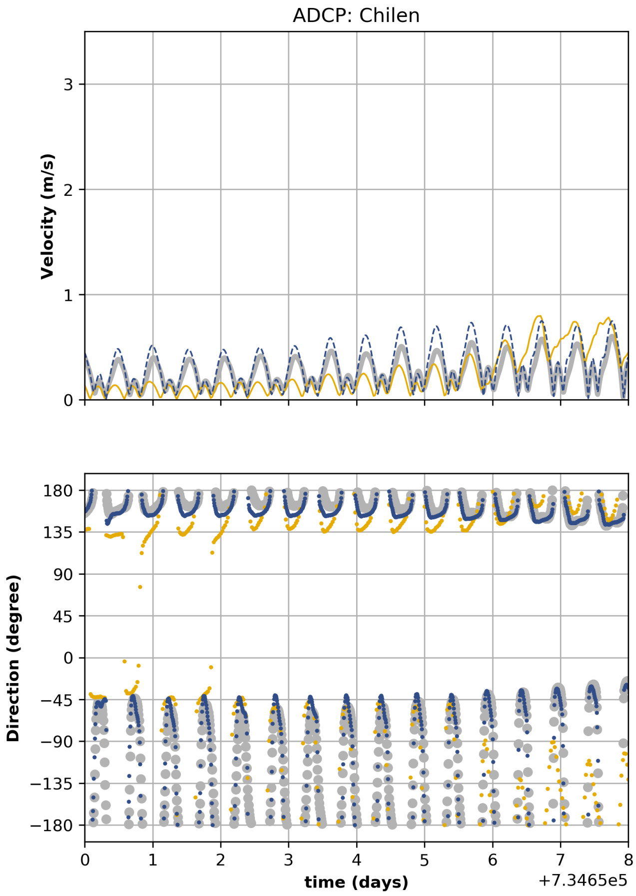

Fig. 5. Comparison between the numerical model and field data, in terms of time series of the velocity magnitude and direction for the Chilen tide gauge for a period of 8 days. Grey line and dots: ADCP results; orange line and dots: coarser resolution grid model; blue line and dots: finer resolution grid model.

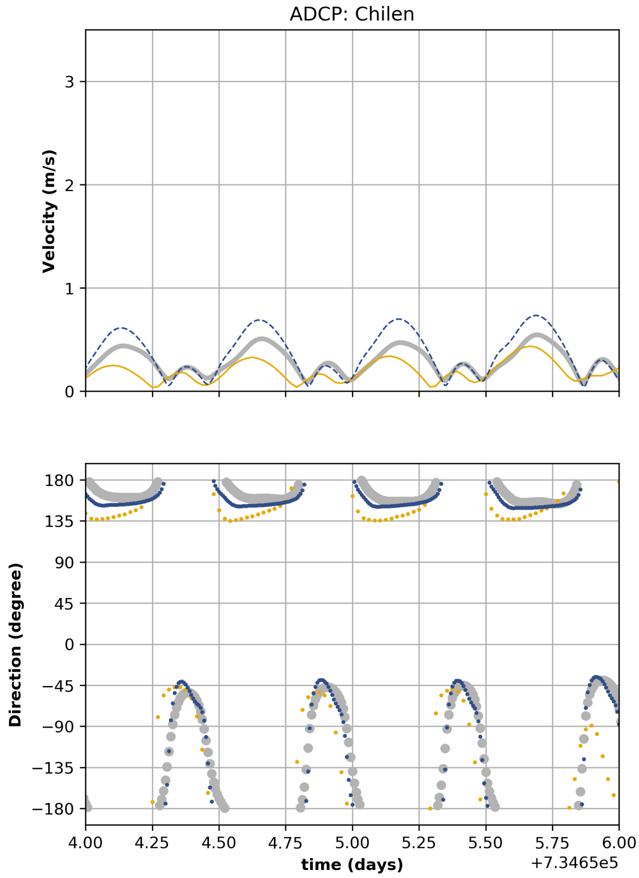

Fig. 6. Zoom in of Chilen site for two days of figure 5

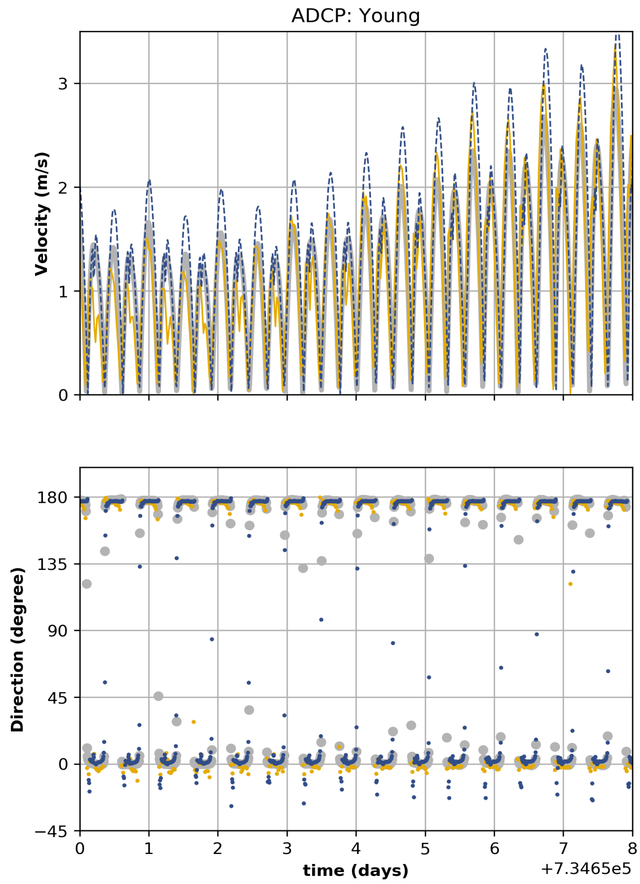

Fig. 7. Comparison between the numerical model and field data, in terms of time series of the velocity magnitude and direction for the Young tide gauge for a period of 8 days. Grey line and dots: ADCP results; orange line and dots: coarser resolution grid model; blue line and dots: finer resolution grid model.

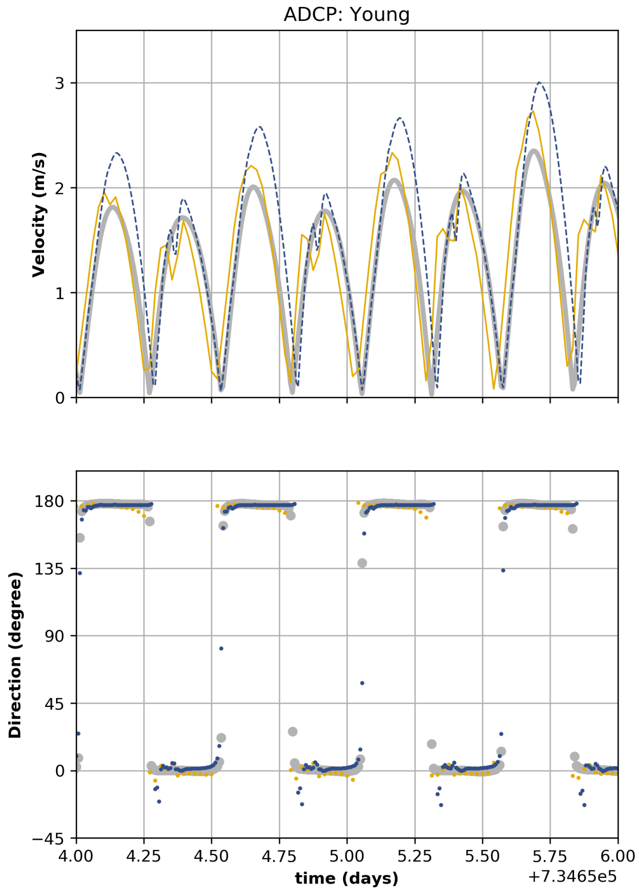

Fig. 8. Zoom in of Young site for two days of figure 7

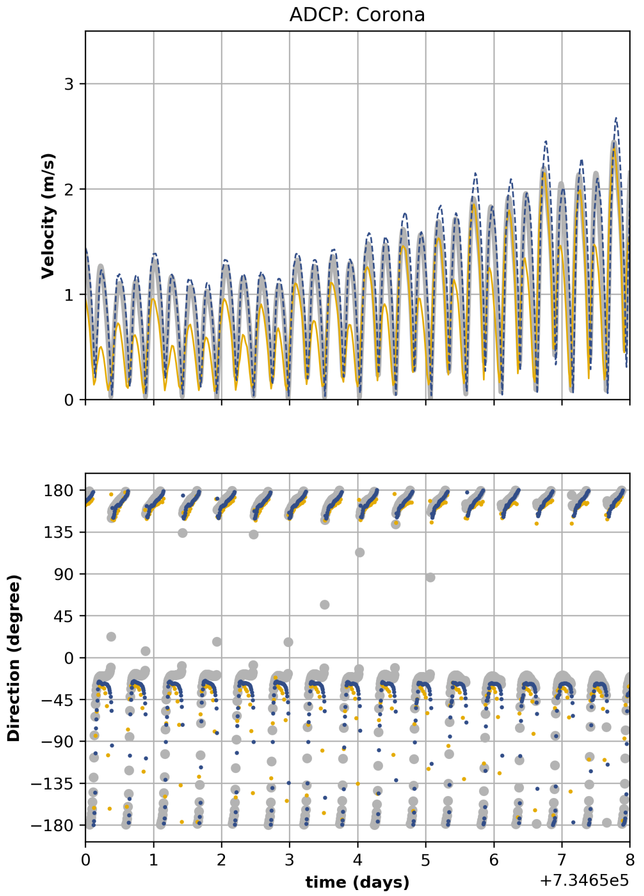

Fig. 9. Comparison between the numerical model and field data, in terms of time series of the velocity magnitude and direction for the Corona tide gauge for a period of 8 days. Grey line and dots: ADCP results; orange line and dots: coarser resolution grid model; blue line and dots: finer resolution grid model.

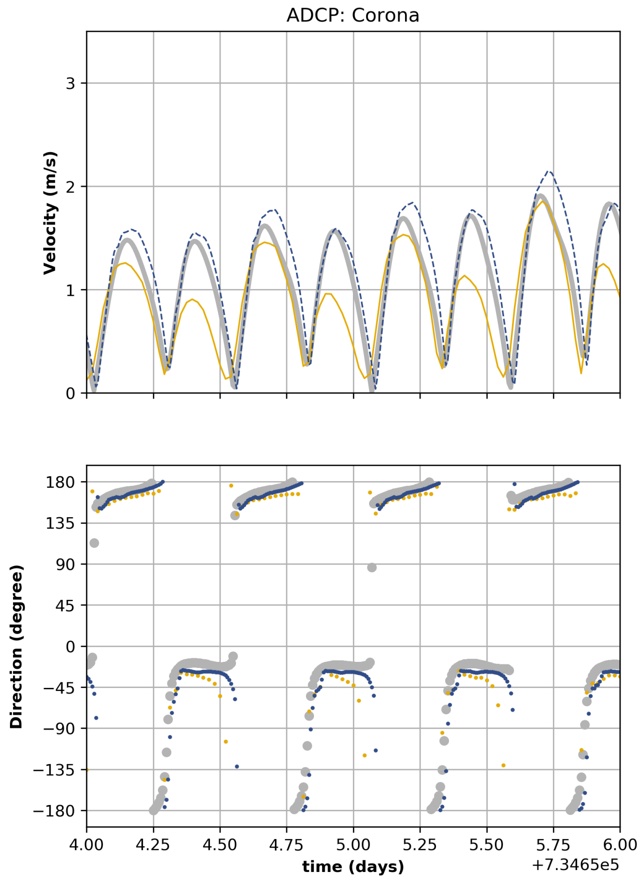

Fig. 10. Zoom in of Corona site for two days of figure 7

Acknowledgement

Work supported by Chile's Marine Energy Research & Innovation Center (MERIC) CORFO project 14CEI2-28228. Powered@NLHPC: This research was partially supported by the supercomputing infrastructure of the NLHPC (ECM-02)

References

[1] M. Guerra, R. Cienfuegos, J. Thomson, and L. Suarez, "Tidal energy resource characterization in chacao channel, chile," *International Journal of Marine Energy*, vol. 20, 11 2017.

[2] C. M. Aiken, "Barotropic tides of the chilean inland sea and their sensitivity to basin geometry," *Journal of Geophysical Research: Oceans*, vol. 113, no. C8. [Online]. Available: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2007JC004593

[3] M. Cáceres, A. Valle-Levinson, and L. Atkinson, "Observations of cross-channel structure of flow in an energetic tidal channel," *Journal of Geophysical Research: Oceans*, vol. 108, no. C4, 2003. [Online]. Available: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2001JC000968

[4] 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," *Journal of Atmospheric and Oceanic Technology*, vol. 20, no. 1, pp. 159–186, 2003. [Online]. Available: https://doi.org/10.1175/1520-0426(2003)020⟨0159:AUGFVT⟩2.0.CO;2

[5] G. D. Egbert and S. Y. Erofeeva, "Efficient inverse modeling of barotropic ocean tides," *Journal of Atmospheric and Oceanic Technology*, vol. 19, no. 2, pp. 183–204, 2002. [Online]. Available: https://doi.org/10.1175/1520-0426(2002)019⟨0183:EIMOBO⟩2.0.CO;2

[6] J. SMAGORINSKY, "General circulation experiments with the primitive equations," *Monthly Weather Review*, vol. 91, no. 3, pp. 99–164, 1963. [Online]. Available: https://doi.org/10.1175/1520-0493(1963)091⟨0099:GCEWTP⟩2.3.CO;2