Schwarz-Christoffel Conformal Mapping based Grids for High-Resolution Ocean Models

Shiming Xu[1*], Jialiang Ma[1], Xiaonan Liu[1], Bin Wang[1,2] and Jiping Liu[2]

[1]Center for Earth System Sciences, Tsinghua University, [2]Institute of Atmospheric Physics, Chinese Academy of Sciences

1. Background

Orthogonal curvilinear grids are commonly used in current OGCMs. The only land-sea distribution information utilized during the grid generation is the relocation position of the North Pole. There are several deficiencies:

① The simulation quality of key processes, such as coastal trapped waves, is sacrificed due to the misalignment of grid lines to coastlines (Fig.1).

② Little support for multi-scale modeling, esp. compared with finite-element models with irregular meshes (Fig.2).

③ Computational load-imbalance. A non-trivial mapping between parallel processes and computational domain is indispensable for high-resolution modeling.

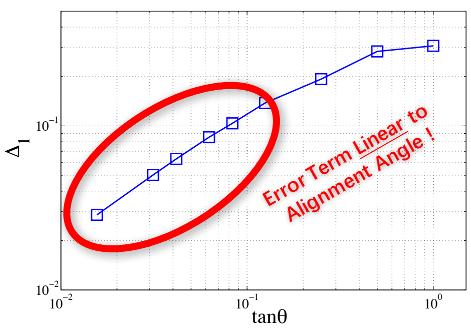


Figure 1. Numerical dispersion of coastal Kelvin waves. Relationship of the 1st order error term coef. (Δ_1) and mis-alignment angle (θ).

$$\omega = k\left(1 - \Delta_1 h + O\left(h^2\right)\right), \quad \text{as } h \to 0$$

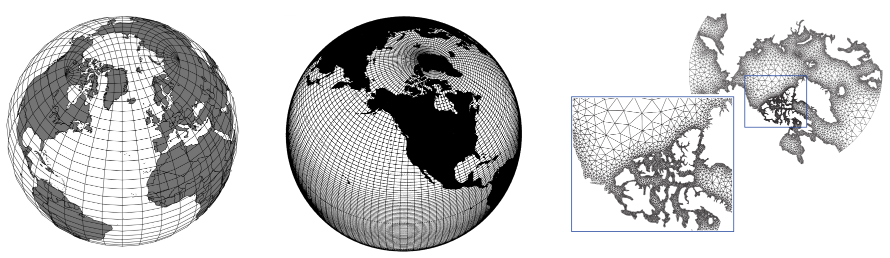


Figure 2. Tripolar & dipolar grids v.s. triangular meshes.

2. Objectives & Methodology

The objective is to design a new OGCM grid:

① To align grid lines to large-scale coastlines, with enhanced spatial resolution in coastal regions.

② To be orthogonal curvilinear, and fully compatible with existing OGCMs.

③ To remove land for easier computational load balancing.

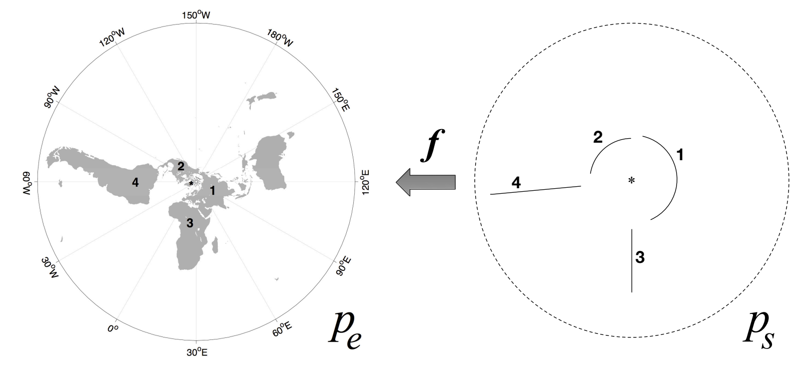


Figure 3. Conformal mapping between p_e and p_s.

Under stereographic projection (plane p_e), the inland continental areas are treated as a multiply-connected region. A Schwarz-Christoffer conformal mapping is constructed to map it to a plane (p_s) on which the continental areas are mapped to a series of radial/circular slits (i.e., the canonical forms in conformal mapping). A polar coordinate is constructed on Ps and mapped back on to earth to form an orthogonal grid for OGCMs.

User-input include the inland areas to be mapped and the type of slit each area is mapped to. Recently developed algorithms in the construction theories in conformal mapping is utilized.

3. Applications in Ocean Modeling

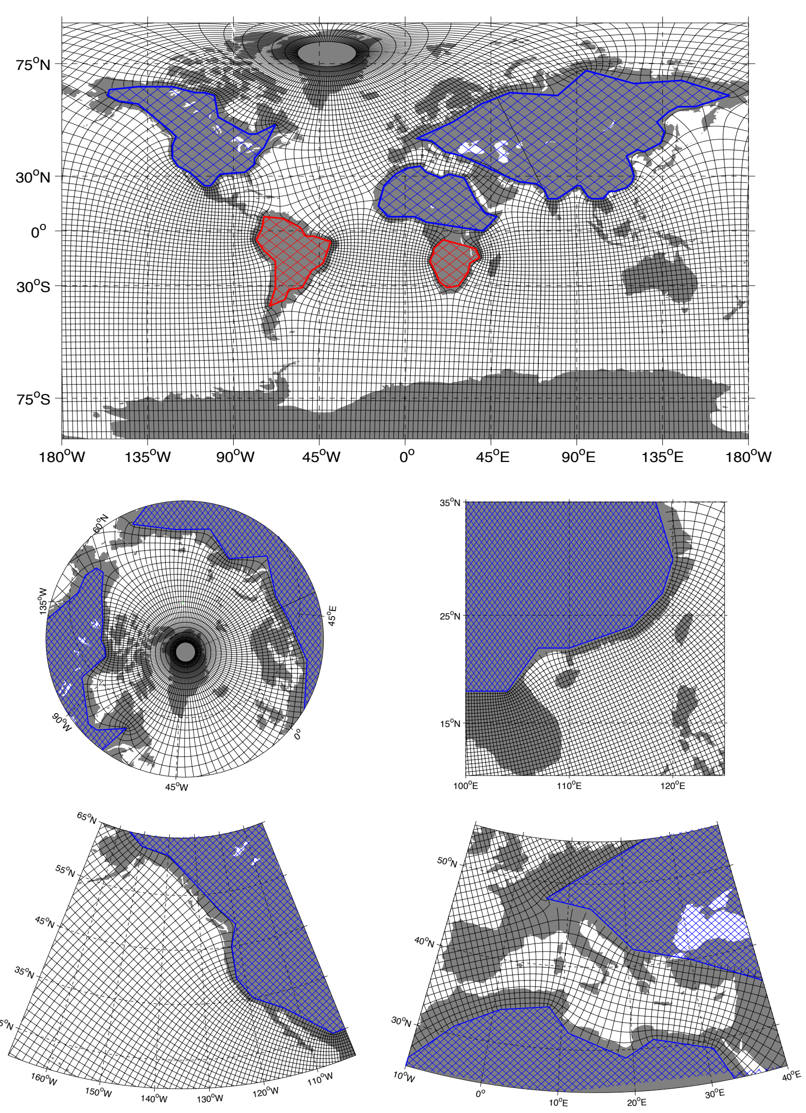


Figure 4. Sample global grid (0.25 deg.).

Generated grid (0.25 deg.) is applied in POP ocean model with spin-up run under idealized forcings (Fig. 5). Monthly mean SST and SSH fields are shown in Fig. 6 after 50 years of simulation. The integration of the new grid is straightforward by replacing several grid files, as is similar for any OGCM such as NEMO, etc. The grid generation methods can also be applied to regional ocean modeling when complex land-sea distribution is present.

Long-term Ocean-Ice coupled simulations (CESM) with the new grids under CORE-II forcings are currently underway. We also target at key regions with strong topographic effects (e.g., EBC, WBC, eddy dissipation) by spatial refinement with the new grids.

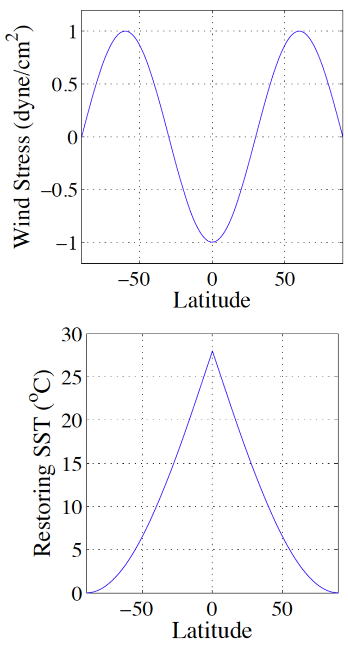
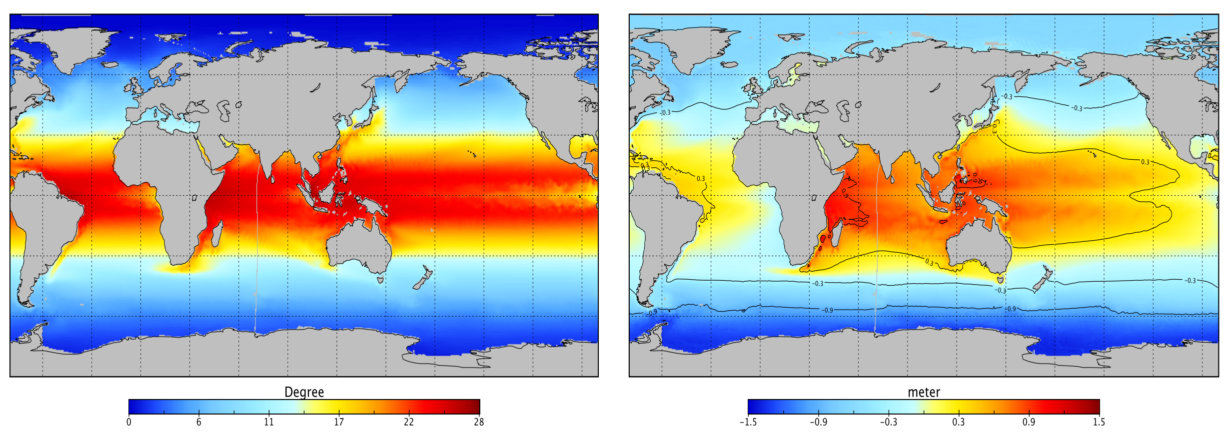


Figure 5. Idealized forcing.



(a) SST (b) SSH

Figure 6. Spin-up run with POP model (50 yrs).

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• S. Xu, B. Wang and J. Liu, *On the use of Schwarz-Christoffel conformal mappings to the grid generation for global ocean models*, Geosci. Model Dev., 8, 3471-3485, doi:10.5194/gmd-8-3471-2015, 2015.

*contact: xusm@tsinghua.edu.cn