Self-Attraction and Loading in MPAS-Ocean

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MPAS-Ocean (Model for Prediction Across Scales)

• Ocean simulation model
• Unstructured mesh
• Allows for variable resolution
• Time scales from months to millennia
• Spatial scales from < 1 km to global
• Functions as ocean component in climate system models

Importance of Tides in a global ocean model

Tides themselves are not constant, they can be influenced by things like:

- Tectonics
- Water depth
- Shoreline position
- Seabed roughness
- Extent of sea ice coverage
- More!

Figure 1. Fractional trends in $M_2$ amplitude. The reference bar on the Eurasian continent shows a trend of 1% decade$^{-1}$. Red (blue) bars denote positive (negative) trends. Color contours provide the tidal amplitude in m (TPXO.7.2) [Egbert et al., 1994].


Astronomical forcing (sun and moon)

Self-Attraction and Loading

- SAL includes effects from:
  - Tides deforming the earth
  - Self-gravitation of earth
  - Self-gravitation of water
Importance of SAL

- Can be approximated by a constant or iterative methods
- Not including SAL can affect:
  - tidal amplitudes by 10%
  - tidal phases by 30deg
- Better to calculate using full spherical harmonic decomposition


Figure 2. Difference in $M_2$ amplitudes (cm) between the self-attraction and loading-online control run and an iterating simulation initialized by $\beta = 0.10$. Panels show differences after (a) three, (b) four, and (c) five iterations. As in Egbert et al. (2004), the iterative procedure employs a memory term for rapid convergence. Global-mean root mean square errors in deep (shallow) water are 5.1 cm (17.0 cm) for the control run and 5.1 cm (17.1 cm) after five iterations.
How self-attraction and loading calculation works with spherical harmonic transform

- SHTns = fast spherical harmonic transform package
- Uses OpenMP to perform transform on a single node
- Each coefficient is multiplied by a load love number

\[
\text{coeff}(i) = \text{coeff}(i) \times \text{scale}(i)
\]

Spatial data → Spherical harmonic transform → Spatial data


**Simple model: Debot**

- Twice-daily lunar tidal amplitudes in meters
- Comparison with a benchmark tidal model TPXO
- Root mean square error:
  - 3cm for >1000m depths
  - 14cm for <1000m depths
- This model does not require interpolation
- Provides basis for adding routine to MPAS


Interpolation

- Gaussian grid: position of latitudes based on zeros of Legendre polynomials
- Useful for doing fast spherical harmonic transforms

Interpolation Process

- MPAS mesh
- Gaussian grid
- Interpolation weight matrix
ESMF (Earth System Modeling Framework)

- Used for coupling models together
- Has functions for interpolation
- Massive library, so we don’t want to use the whole thing

ESMF (Earth System Modeling Framework) — Options

Regrid Options

ESMF_RegridWeightGen
- Command line tool
- Only outputs weight file
- Easy to use

ESMF_FieldRegrid
- Can perform entire interpolation
- Requires more restructuring of code
Current Progress —
Individual pieces are all working!

1. Pre-generate weight matrices
2. Interpolate with matrix multiplication
3. Do spherical harmonic transform
4. Interpolate back to original mesh
5. Perform SAL calculation
Current Challenge — Getting all the pieces working together inside MPAS-O

- Data in MPAS is spread among many nodes
- Spherical Harmonic routine must be run on single node
Current Challenge — Getting all the pieces working together inside MPAS-O

- Data in MPAS is spread among many nodes
- Spherical Harmonic routine must be run on single node
- After SAL calculation, data must be sent out to original nodes
Thank you!
References:


