# New unconstrained global ocean tide solutions for satellite gravimetry including minor tides

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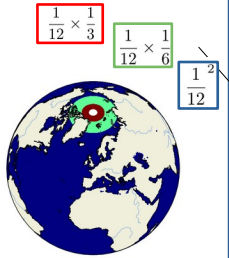
# TiME: A Barotropic Tidal Model (Weis, 2008)

**Model Physics:**
→ nonlinear shallow-water equations
→ Forcing by partial tides or ephemerides
→ Parametrized self-attraction and loading (SAL)

} **Simulation of compound- and overtides !**

**Bathymetric Data:**
→ GEBCO / ETOPO

**Numerical Scheme:**
→ finite differences, semi-implicit algorithm
→ resolution 5‘, 10‘, 20‘, 30‘, 60‘
→ Twofold resolution reduction towards north pole
Grid singularity avoided by pole cap



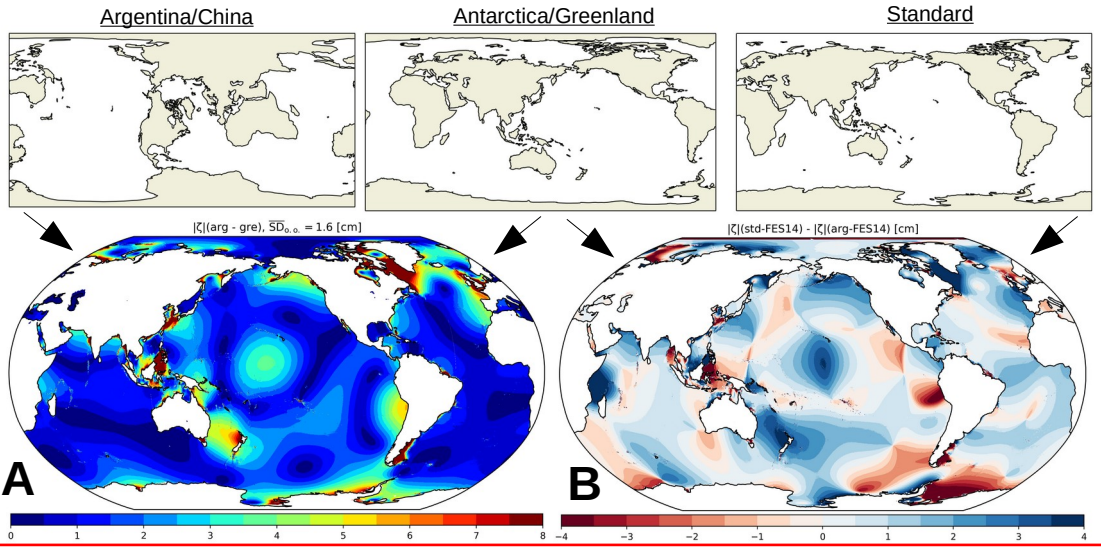

## Recent Improvements

Full **treatment of SAL** (e.g. Ray, 1998)
Computation of Load-tides

**HW95 TGP** (Hartmann & Wenzel, 1995)
3. Order Tide Generating Potential (TGP)
→ E.g. simulation of M3

Flux-conserving low-resolution interpolation of **RTOPO2** watercolumn (Schaffer, 2016)
→ inclusion of sub ice shelf cavities

## Pole rotation to dry gridcells: →Purpose: avoid numerical residuals due to pole cap




**Pole rotation procedure**
→Rotation of spherical harmonics (Gooding, 2010) to transform TGP
→Conservative Bathymetry regridding

**Inter-gridorientation comparison (A)**
→ Identical experiments: different grids
→ Reduced spread when pole cap is covered with land on both grids
→ Averaged difference: **1.6cm @10‘**

**Validation improvement (B)**
→ Comparison with FES14 data
→ rms reduced by **~0.5cm**

# Self-Attraction and Loading

**Treatment of SAL in spectral domain:** (Schindelegger, 2018)

**1.** Regridding to lat/lon-grid including poles
**2.** Decomposition into spherical harmonics (Schaeffer, 2013)
**3.** Multiplication with Load Love Numbers (LLNs)
**4.** Re-Interpolation to TiME-grid

→ Sharp tidal elevation gradients on coasts: slow decay of $\zeta_{nm}$ with (n,m)
→ Reduction of $\alpha_n$ with (n) ensures convergence of load tide fields

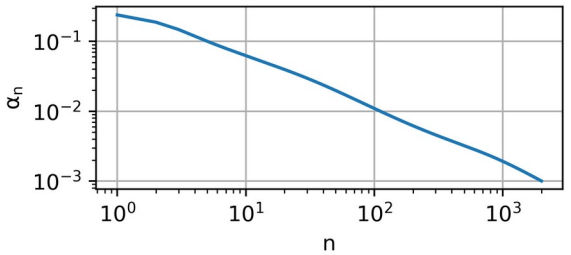
$$\zeta \rightarrow \sum_{nm} \zeta_{nm}\, Y_{nm}$$

$$\zeta_{SAL} = \sum_{nm} \alpha_l\, \zeta_{lm} Y_{lm}$$

Sea water mean density — LLNs

$$\alpha_n = \frac{3\rho_{sw}}{\rho_{se}} \frac{1 + k_n - h_n}{2n - 1}$$

Solid earth mean density




**Feedback to Tidal Dynamics:**

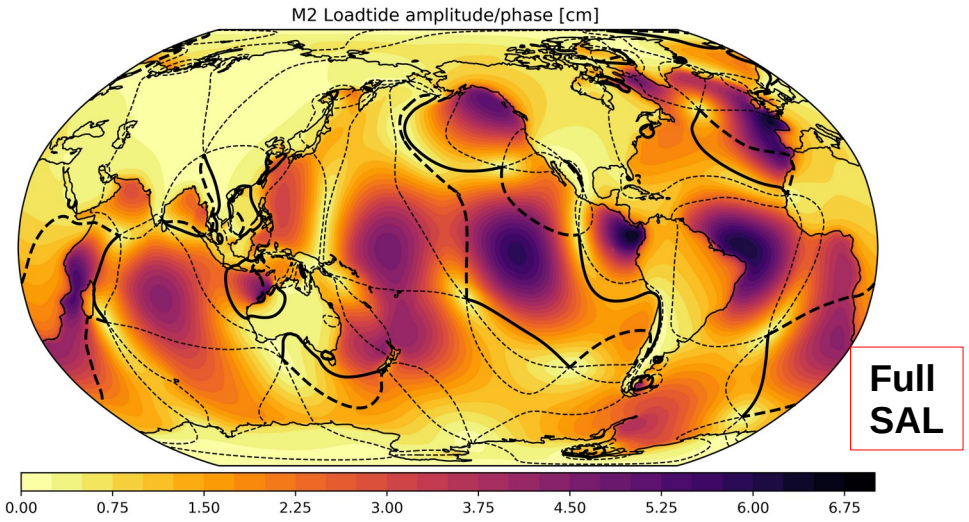
→ Forcing term additional to pressure gradient and astronomical TGP (→ equilibirum tide)
→ Feedback by modifying $\zeta \rightarrow \zeta - \zeta_{SAL}$ in solver

$$\mathbf{a} = -g\nabla\left(\zeta - \zeta_{SAL} - \zeta_{eq}\right)$$

**Experimental setup:**

Full treatment of SAL:
→ PREM-LLNs (Wang,2012)
→ Maximum degree/order=1024
→ resolution 1/12 degree
→ Forcing: M2 partial tide

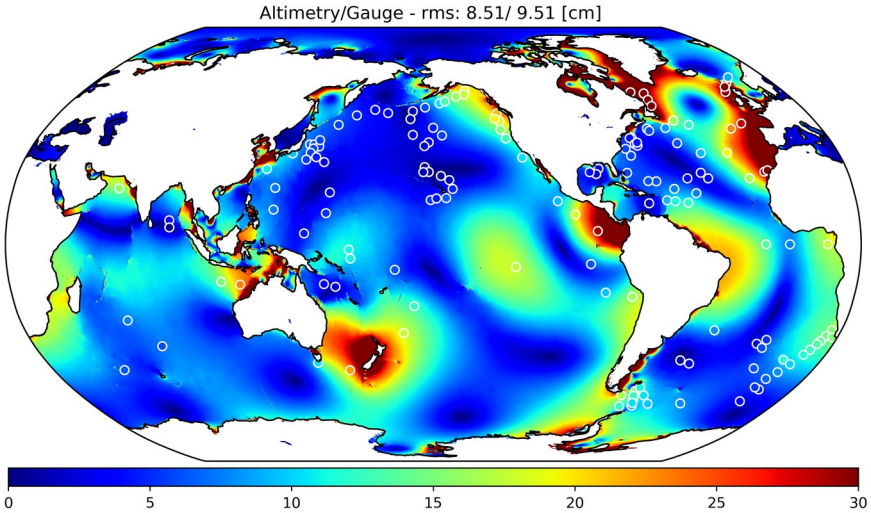
Parametrized treatment SAL:
→ SAL-parametrization by local elevation (Accad&Pekeris, 1978) $\zeta_{SAL} \rightarrow 0.1 \cdot \zeta$



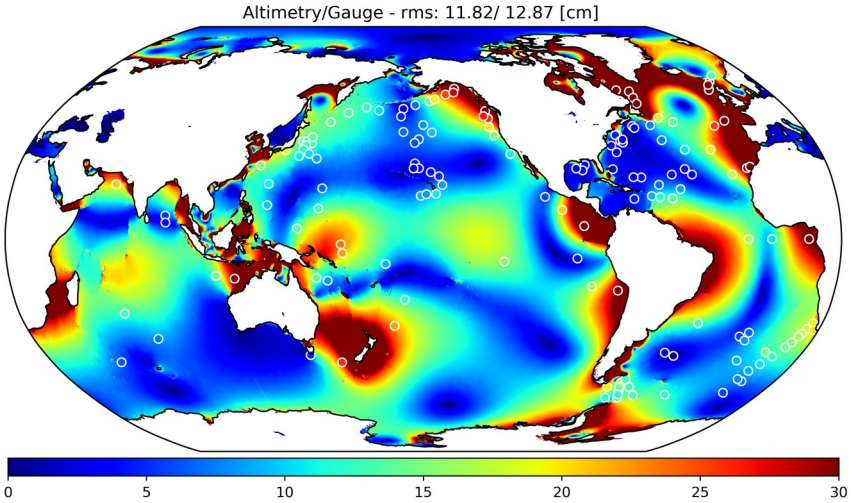

Solid line: zero degree; dashed line: 60 degree

# Self-Attraction and Loading

$\overline{|\zeta_{TiME} - \zeta_{FES}|}$ **Full SAL**




$\overline{|\zeta_{TiME} - \zeta_{FES}|}$ **Param. SAL**




**Computational overhead (full treatment):**

→ OpenMP-parallelized SHTNS-version, 9 threads

→ Overhead of ~0.45 s per time step

→ Main overhead originates from regridding

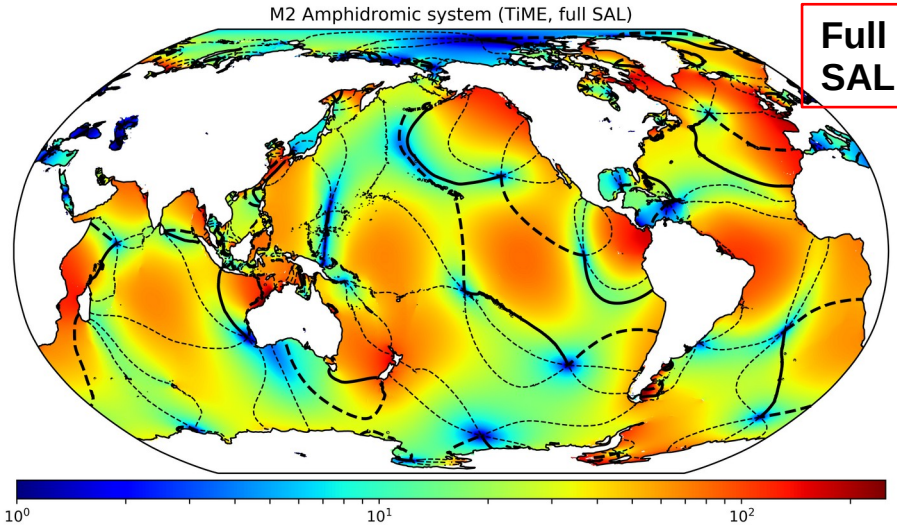
**Validation of M2 partial tide:**

→ open ocean validation against altimetry data constrained model FES14 (Carrère et al. 2012)

→ validation against 151 tide gauge stations (Ray, 2013)

rms reduction, when considering full SAL:

**3.31/3.36** cm (FES14/Gauge)



# Summary and Outlook

**Presumption:**
Accurat tidal simulations and knowledge of uncertainties of major and minor tides play a crucial role to evaulate spaceborn gravimetric data. Further increasing gravimetric precision renders accurat understanding of tidal dynamics even more important..

**Aim:**
Improve accuracy of tidal model TiME to allow precise studies of tidal dynamics.

**Results:**
Improvements of M2 partial tide accuracy
→ Implementation of Self-Attraction and Loading
→ Shifting coordinate singularity to dry gridcells
→ Inclusion of sub ice shelf watercolumn

} Open ocean rms-reduction to:

**8.51 cm**

Inclusion of third order forcing
→ Implementation of HW95 Tidal Catalogue ⟶ direct simulation of minor tides

**Outlook:**
→ Inclusion of additional effects into model physics
→ Perform experiments with ephemeridic forcing

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