The impact of Arctic sea ice cover on seasonal modulation of the M2 tide

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1. Background

Observed seasonal variation in M2 amplitude across the globe (Fig. 1).

To what extent can this be related to Arctic ice cover?

Knowing this will give us insight in consequences of long term ice decline…

Very few tide gauges in Arctic

→ SAR altimetry provides possibilities

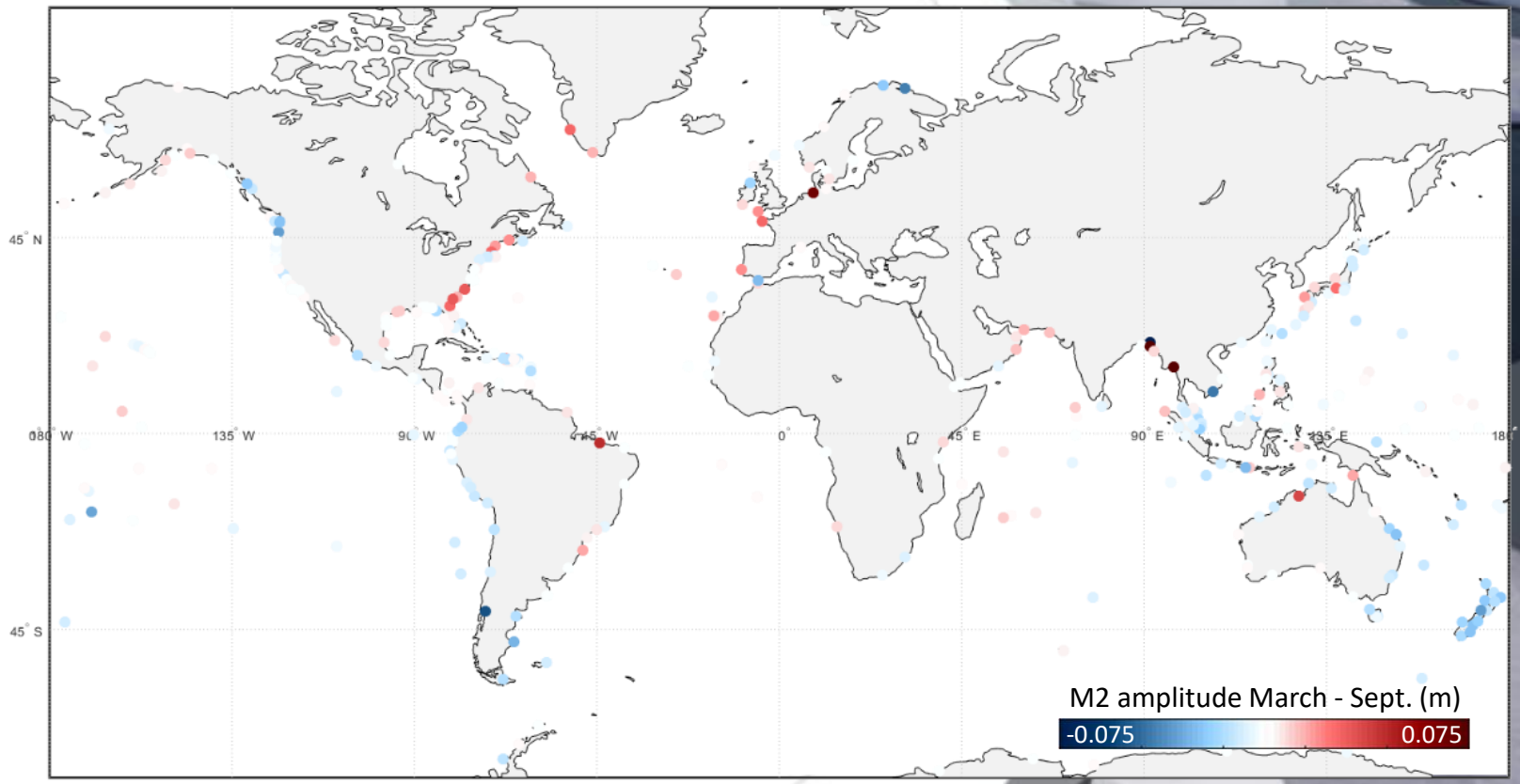

Fig 1: Mean difference in March and September amplitude of M2, derived from tide gauge records (since 2000)

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2. Seasonal modulation M2 from SAR altimetry

Data from SAR altimeters CryoSat-2 (2011-2019) & Sentinel-3 (2016-2019).

- Solve low temporal resolution by stacking data on grid cell-basis (Fig 3).
- Tidal analysis with utide, using satellite constituents of M2 > reconstruct yearly signal > compute March and Sept amplitude and phases (Fig. 4, 5).

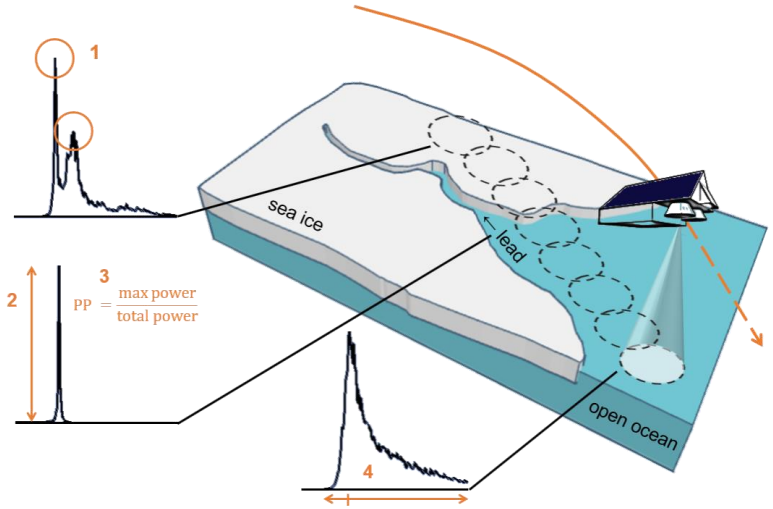

Fig 2: Obtaining water levels from ice covered regions, for more information click here.

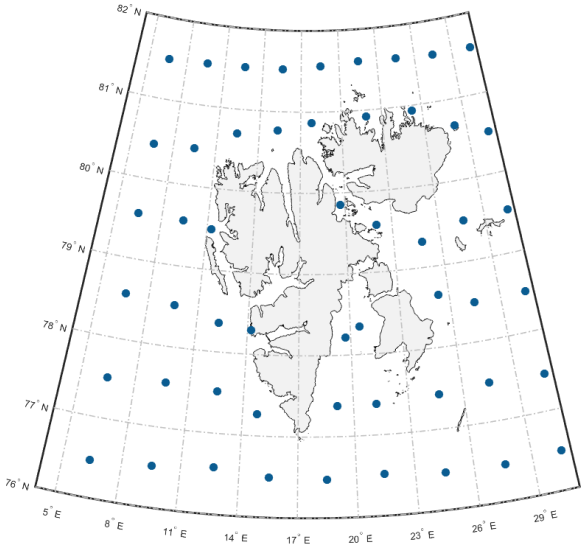

Fig 3: All data within grid cell are combined into one record with location of blue dots (inspired by Cancet et al., 2017)

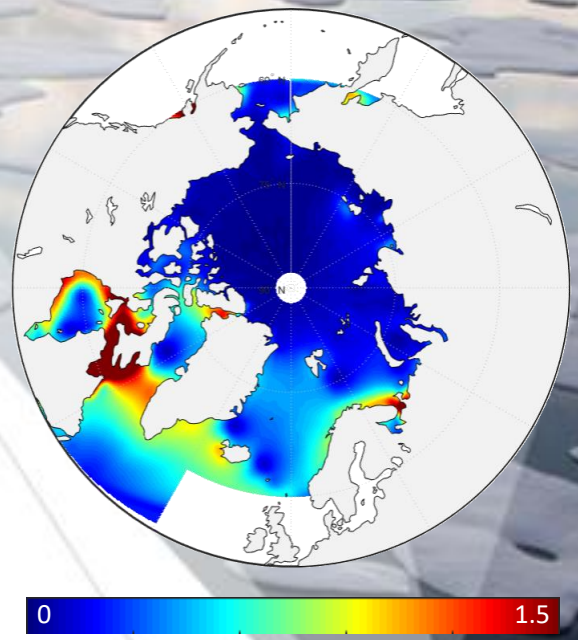

Fig 4: Mean M2 amplitude (m)

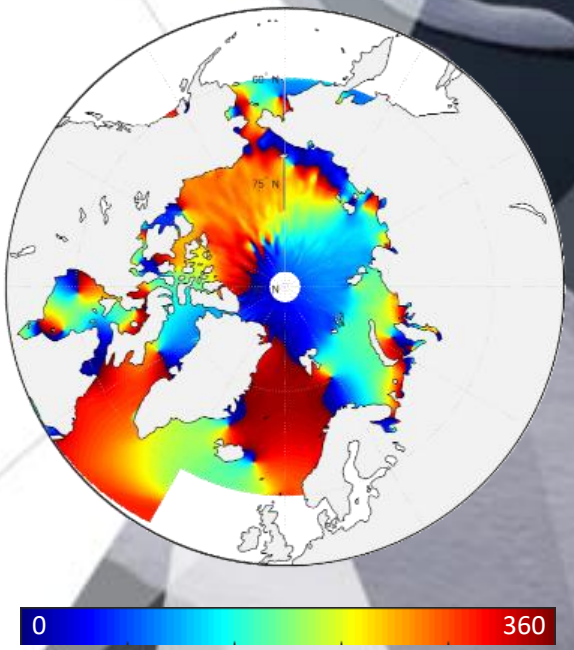

Fig 5: Mean M2 phase (◦)

2. Seasonal modulation M2 from SAR altimetry

Results:

- Seasonal variation in amplitude up to 25 cm (Fig. 6).
- Dominant negative difference, positive in northern Hudson bay, Hudson strait, southern Labrador Sea and north of Bulunsky (Russia).
- Phase difference < 20◦, except for central Arctic ocean, where amplitude approximates 0 (Fig. 7).

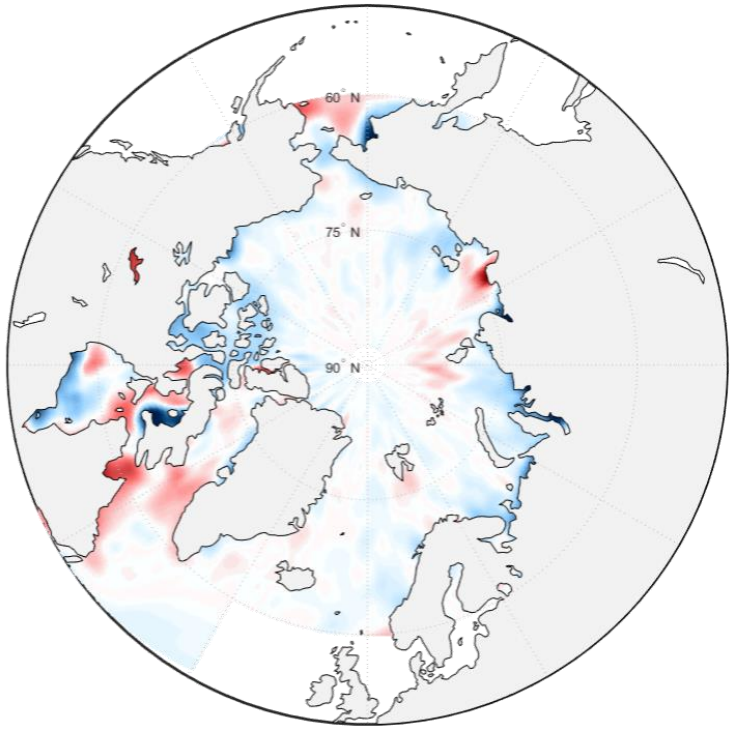

Fig 6: M2 amplitude March - Sept. (m)

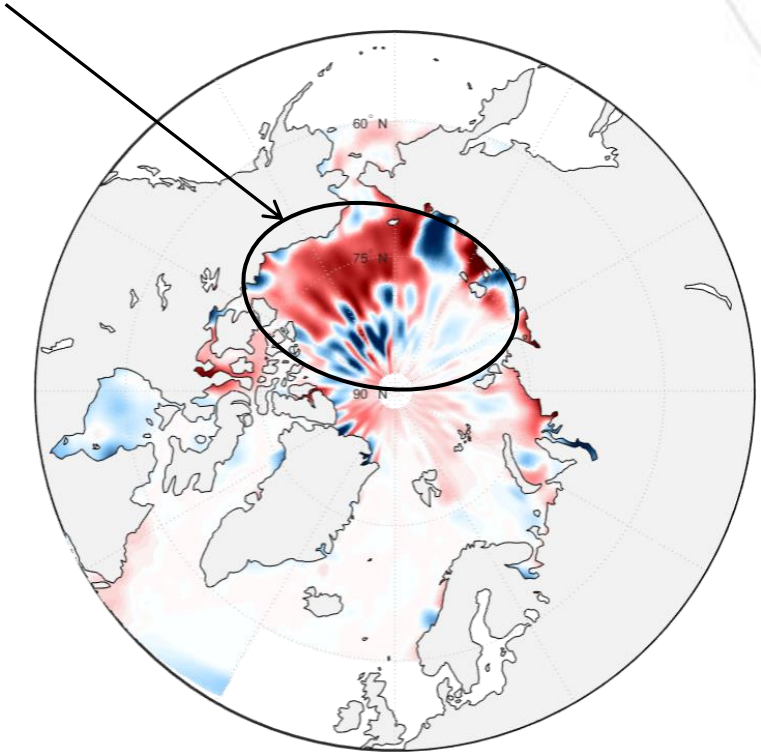

Fig 7: M2 phase March - Sept. (◦)

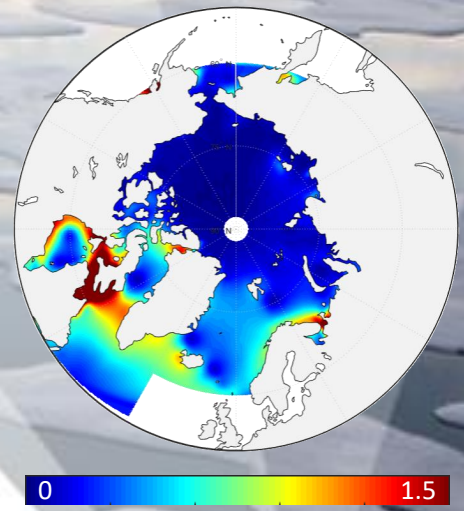

Fig 8: M2 amplitude (m)

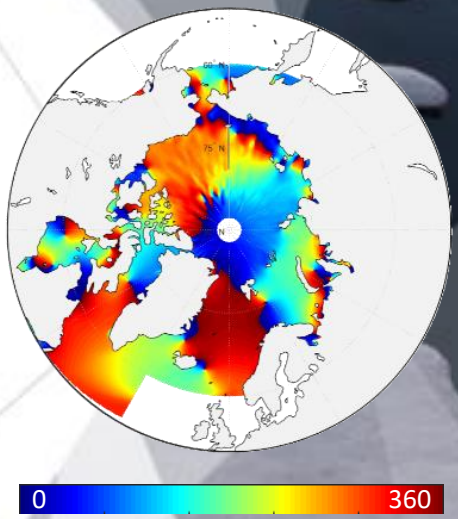

Fig 9: M2 phase (◦)

3. Impact of land fast sea ice cover on M2 tide (model)

Global Tide and Surge Model

2D model in Delft3D flexible mesh (Deltares; Verlaan et al., 2015).

Resolution varies: 50 – 5 km.

Method: Effect of fast ice on tides modelled in **GTSM** by additional friction term

more information

- Simulated for 2013 (shown) and 2014, respectively the max. and min. fast ice extent within data range (Fig. 10).
- Simulated for March (with ice) and Sept (no ice). Monthly M2 amplitude computed with utide.

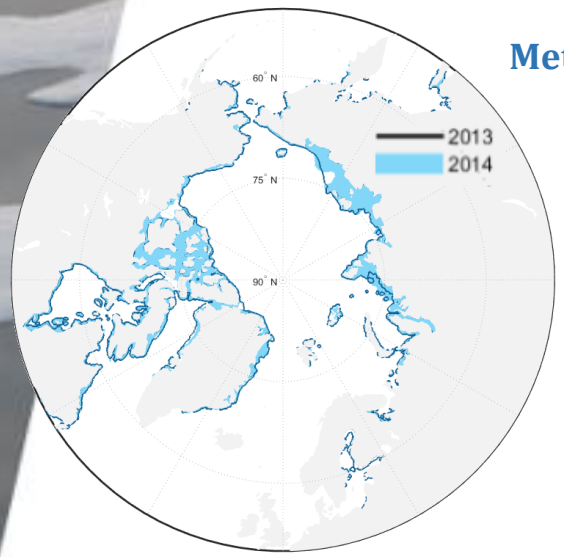

Fig. 10: fast ice extent (source: NSIDC)

Results:

- Overall, similar magnitude of amplitude difference (Fig. 11).
- Disagreement: Hudson bay, Hudson strait and Foxe basin
- Similar magnitude of phase difference, except for the central Arctic ocean (Fig. 12).

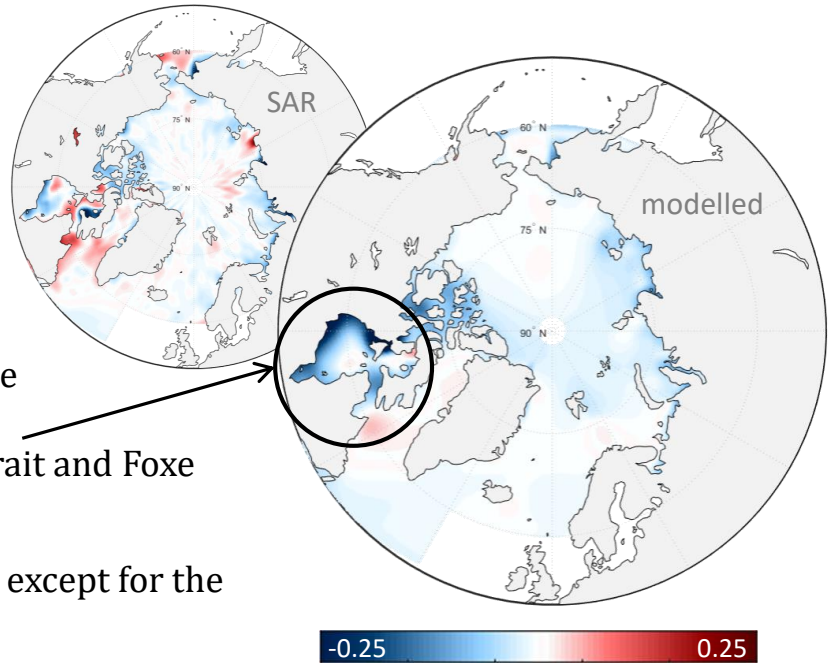

Fig 11: M2 amplitude March - Sept. (m)

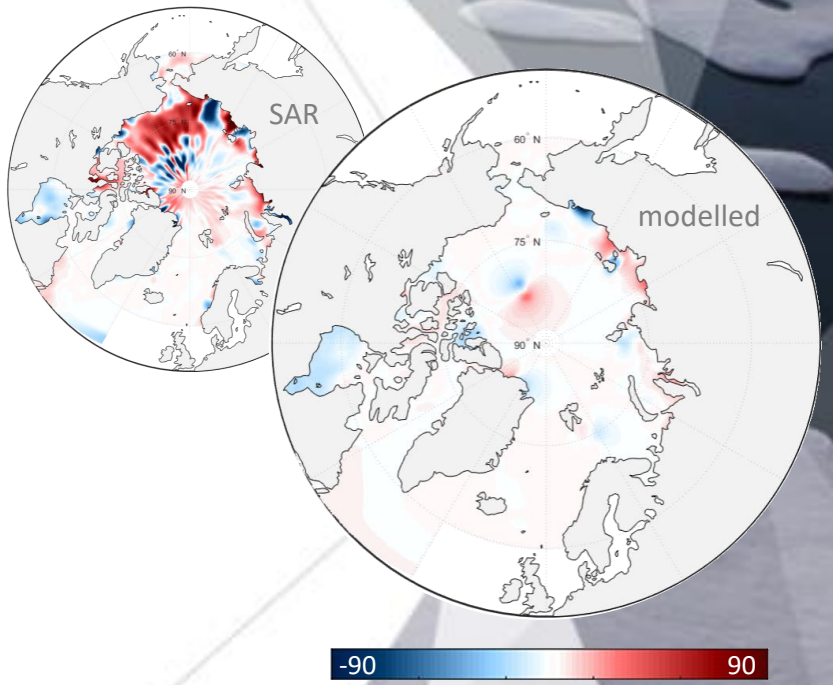

Fig 12: M2 phase March - Sept. (◦)

3. Impact of land fast sea ice cover on M2 tide (model)

Comparison between globally observed (tide gauges) and modelled differences in M2 amplitude (Fig. 13), indicates the extent to which Arctic fast ice causes seasonal modulation of the M2 tide across the globe.

Conclusions & outlook

- Presence of fast ice affects M2 amplitude on local (< 0.25 m) and global (< 0.075 m) scale.
- In some area this accounts for the full observed seasonal modulation.
- In other areas, disagreement between modelled and observed seasonal modulation suggests other processes play along
- Next, relate seasonal modulation to interannual trends amplitude

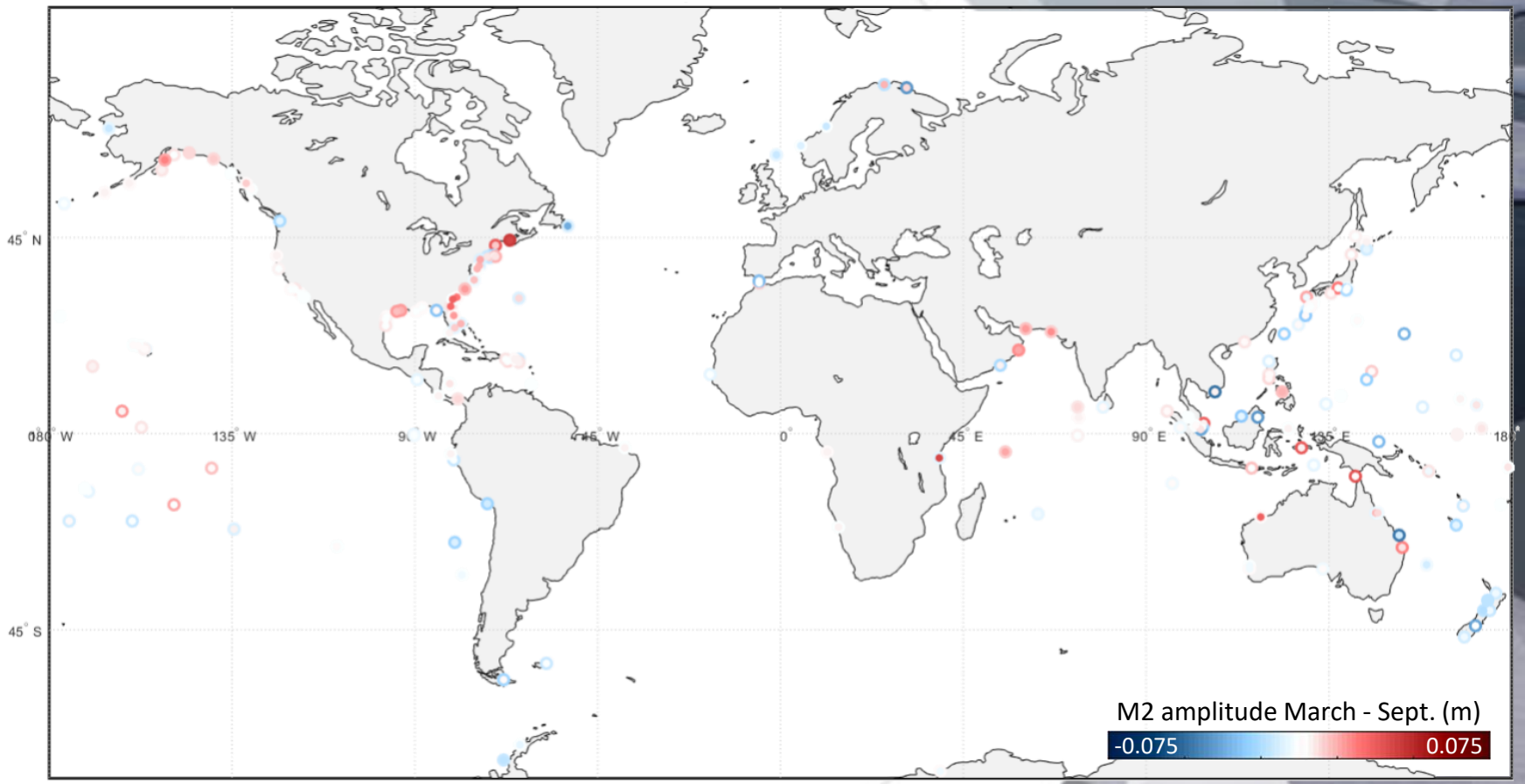

Fig 13: Observed difference in M2 amplitude (outer ring) vs. modelled values (center dot) for 2013.