

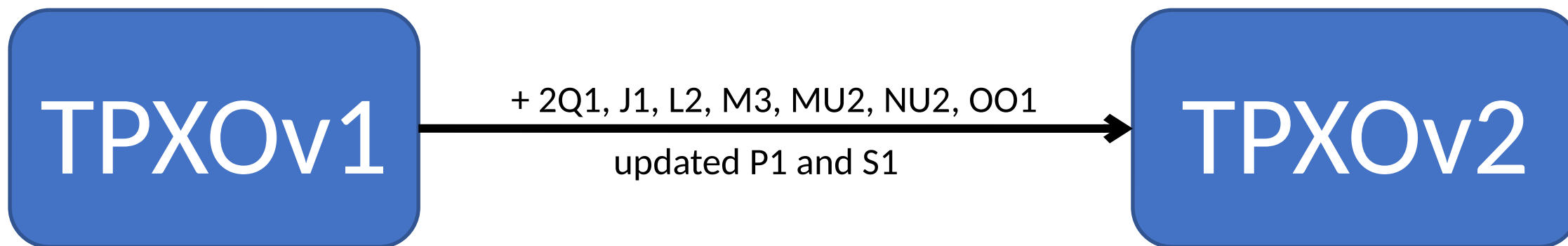
TPX09v2 and TPX09-atlas-v5

two new global barotropic tide models

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Minor tides were previously estimated using inference. However their sea surface elevations can individually exceed 5 cm in some regional domains near the coast, making them important components of altimeter sea level corrections. All minor tides we obtained with OTIS:

- on TPXO9 grid at 1/6 degree resolution;
- 890 representers calculated (760 for M3);
- Topex/Jason altimetry assimilated with MSLA correction applied (except for M3).

Fit to 150 bottom pressure stations (Stammer et al., 2014)

	2Q1	P1	J1	OO1	Mu2	Nu2	L2	M3
RMSS	2.49	3.99	7.15	4.26	9.52	11.35	7.53	2.29
GOT5β*	0.63	1.48	0.97	0.93	0.79	0.89		
FES2014*		1.38	4.50		0.96	0.70		
TPXO9v2	0.60	1.45	1.18	0.86	1.06	0.98	2.17	0.60

* Values for GOT5β and FES2014 are cited from R.Ray 2019 OSTST meeting presentation

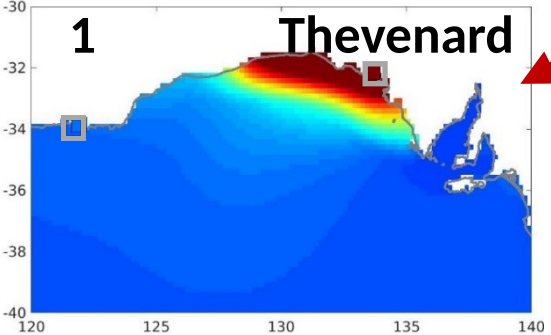
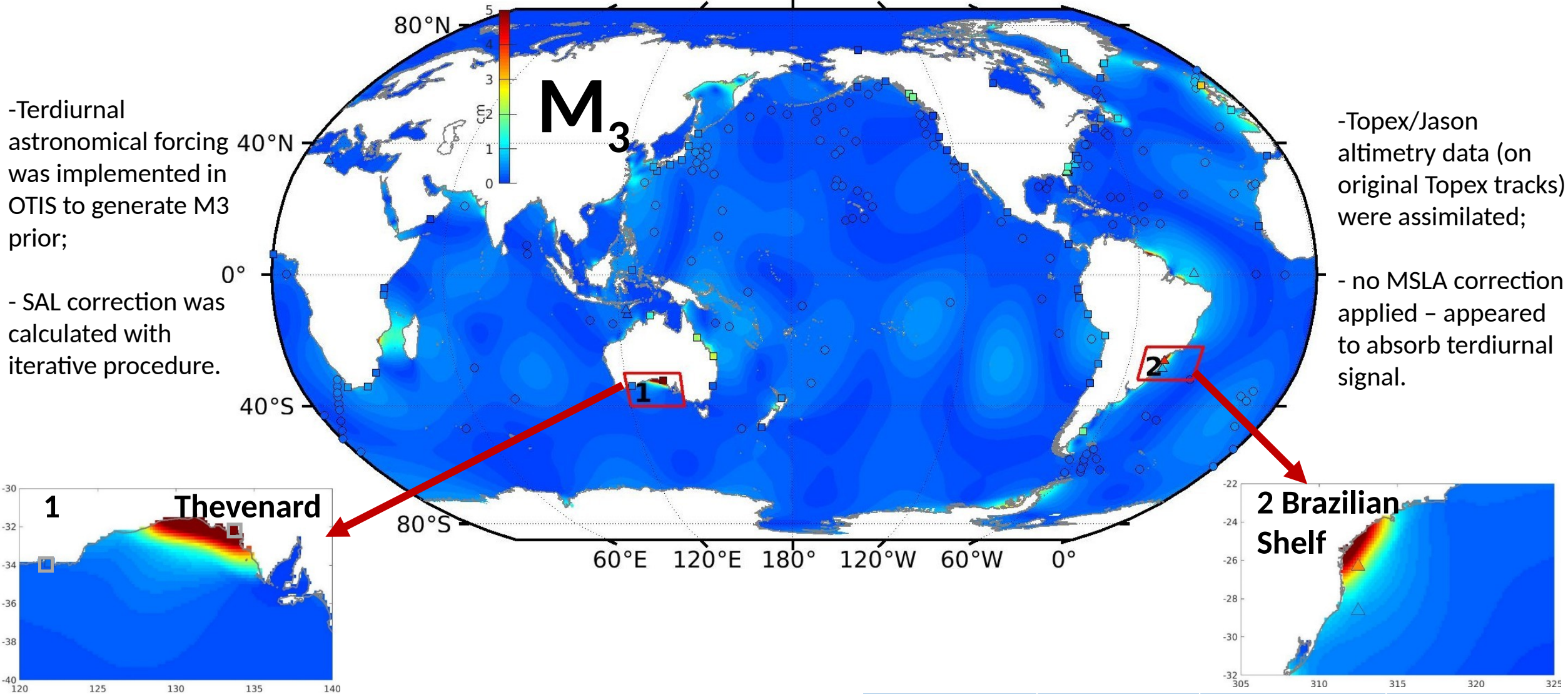
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-Terdiurnal astronomical forcing was implemented in OTIS to generate M3 prior;

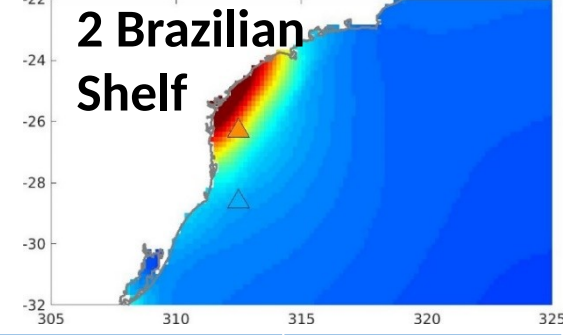
- SAL correction was calculated with iterative procedure.

-Topex/Jason altimetry data (on original Topex tracks) were assimilated;

- no MSLA correction applied – appeared to absorb terdiurnal signal.

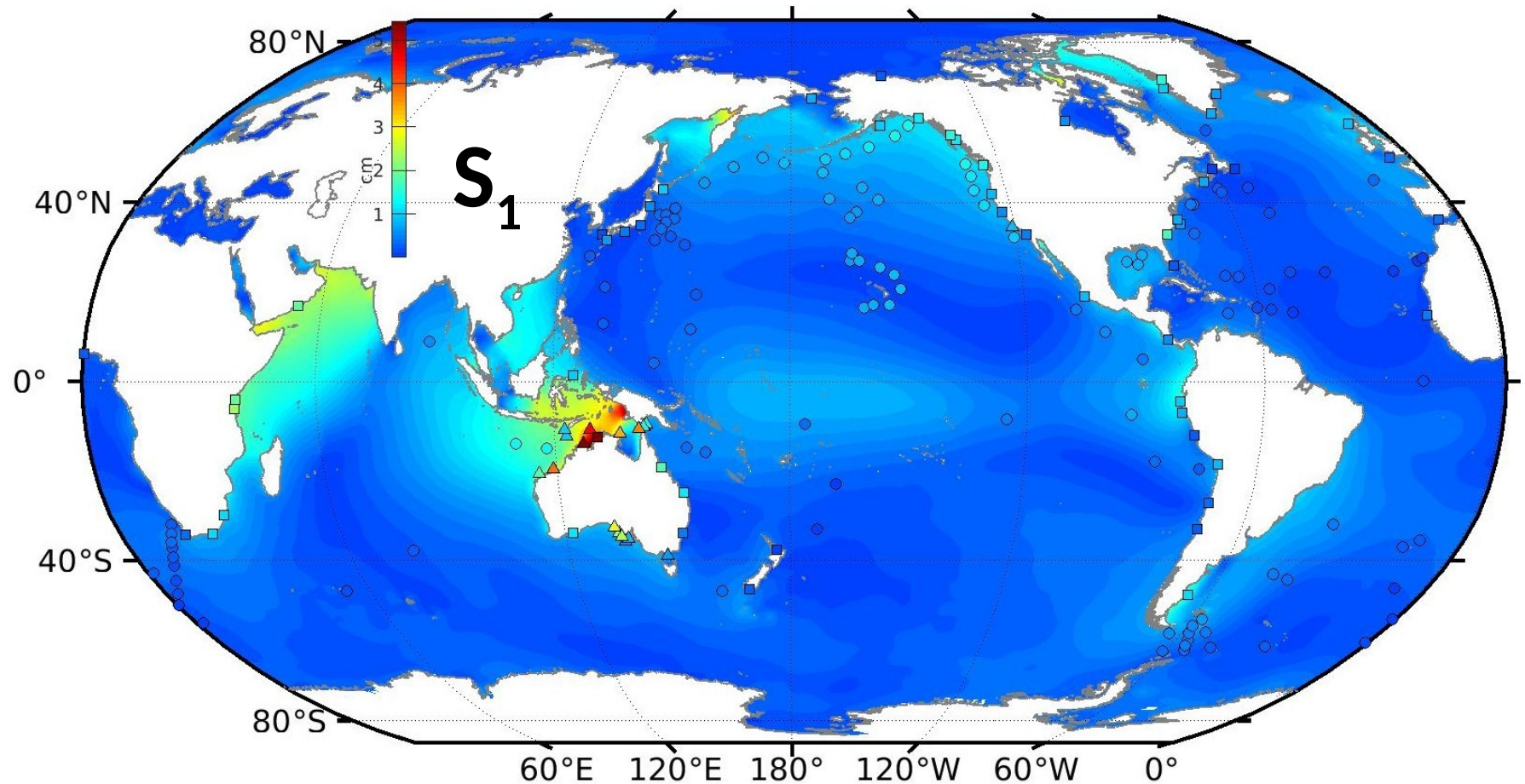


TG amp. (cm)	TG GMT phase °	TPXO amp. (cm)	TPXO GMT phase °
10.8	174.8	9.9	174.9



TG amp. (cm)	TG GMT phase °	TPXO amp. (cm)	TPXO GMT phase °
4.1	299.6	3.6	306.3

- Hydrodynamic solution only, no data assimilation (high susceptibility of S_1 to systematic measurement errors);
- S_1 forcing - predominantly ocean loading by the S_1 atmospheric pressure tide, derived from MERRA2 data set;
- iterative calculation of SAL correction, similar to Egbert&Ray 2004.

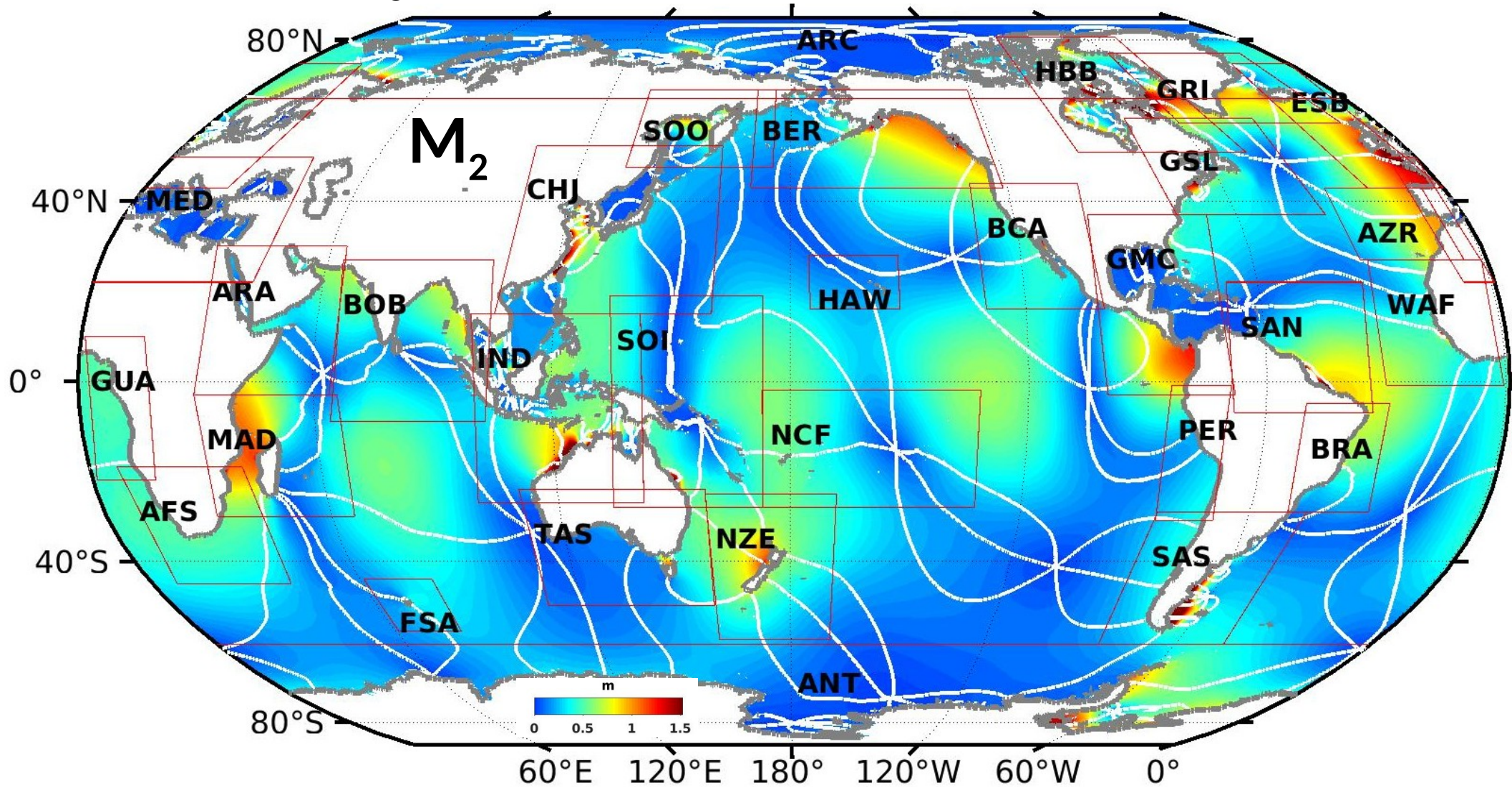


S_1 RMS misfit (cm)

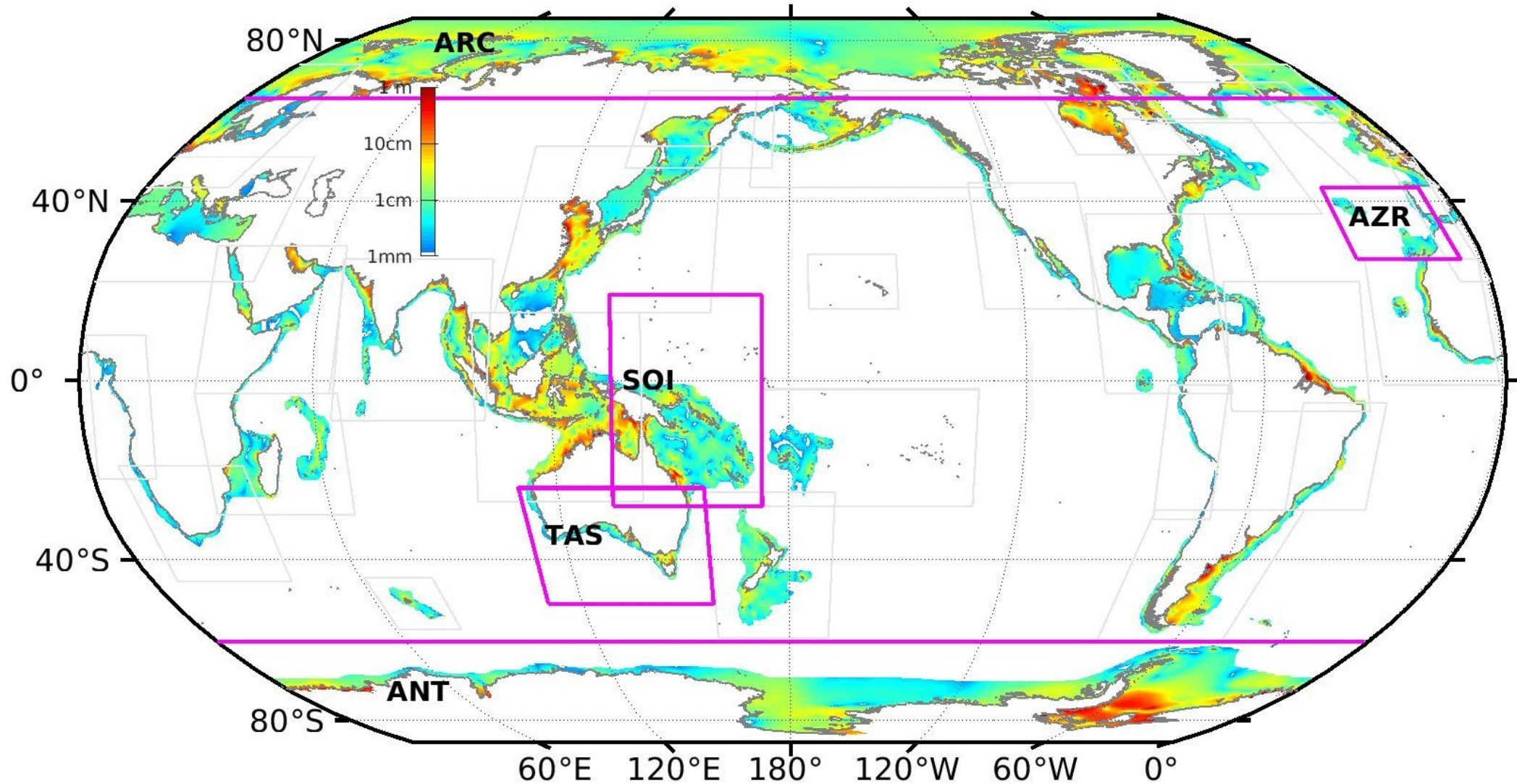
	#TG	RMS signal	E&R2004 hs1b	TPXO9v2
Stammer deep	117	4.10	2.89	2.76
Stammer Euro Shelf	11	7.78	7.22	6.29
Stammer Elsewhere	18	18.48	10.09	10.93
Stammer Coastal	54	8.72	3.86	3.70
Selected Egbert & Ray 2004	17	16.87	5.48	4.60

TPX09-atlas

is fully global updateable solution, combined of $1/6^\circ$ resolution
base global solution and 30 $1/30^\circ$ resolution coastal solutions

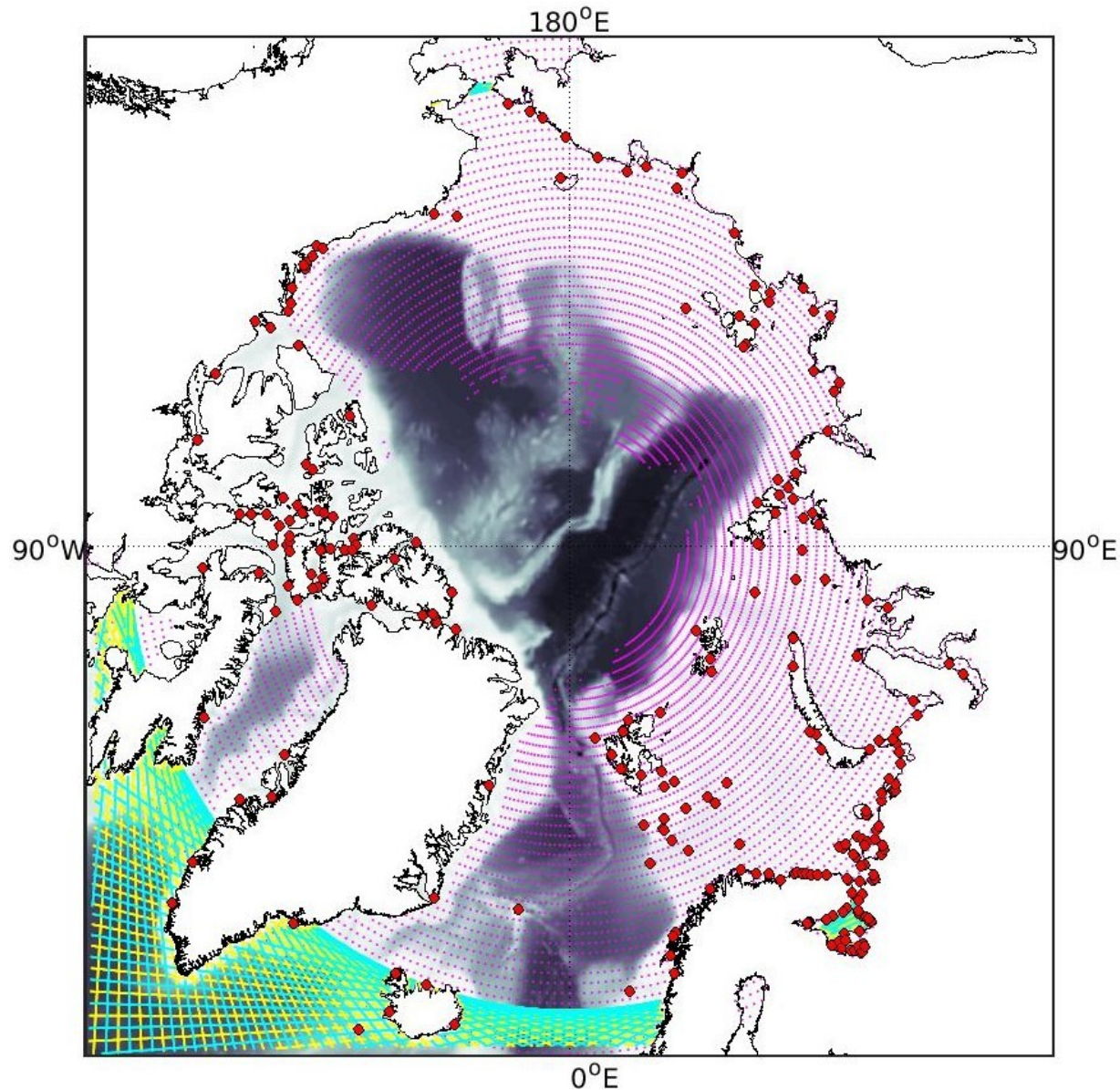


M2 elevation difference amplitude between TPXO9v2 and TPXO9-atlas-v5



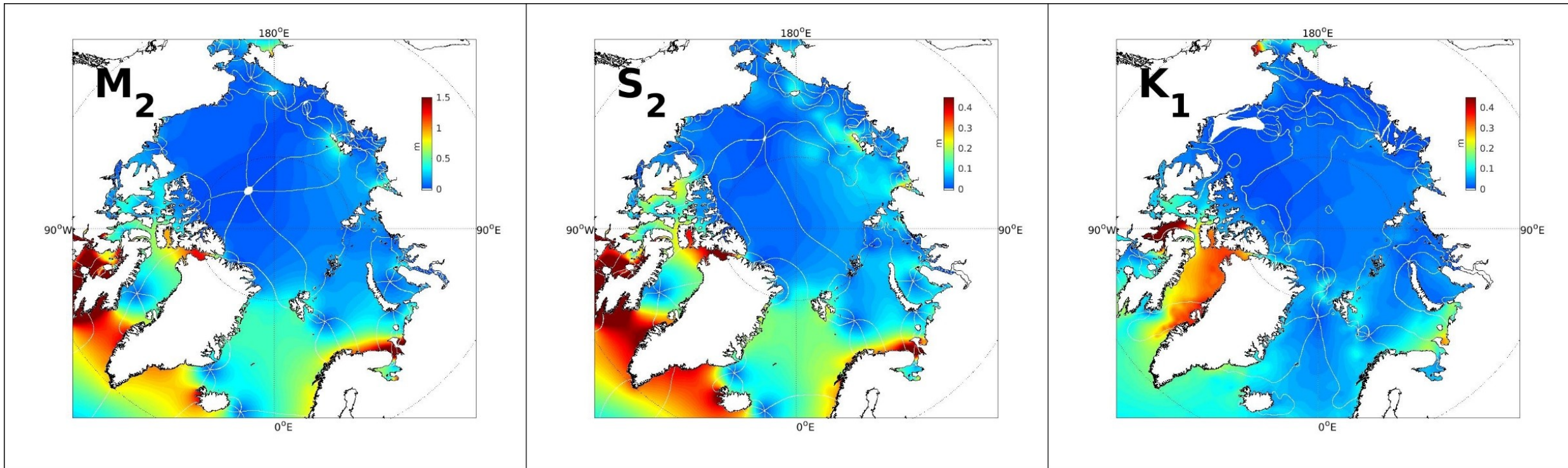
TPXO9-atlas latest version: v5, release Oct 29, 2021: TAS, AZR and SOI patches and polar areas (magenta frames) were updated using SRTM15 and IBCAO bathymetry sources and Natural Earth coastline version 4.1.0. Released Oct 29, 2021.

Arctic 4km resolution TPXO9-atlas patch



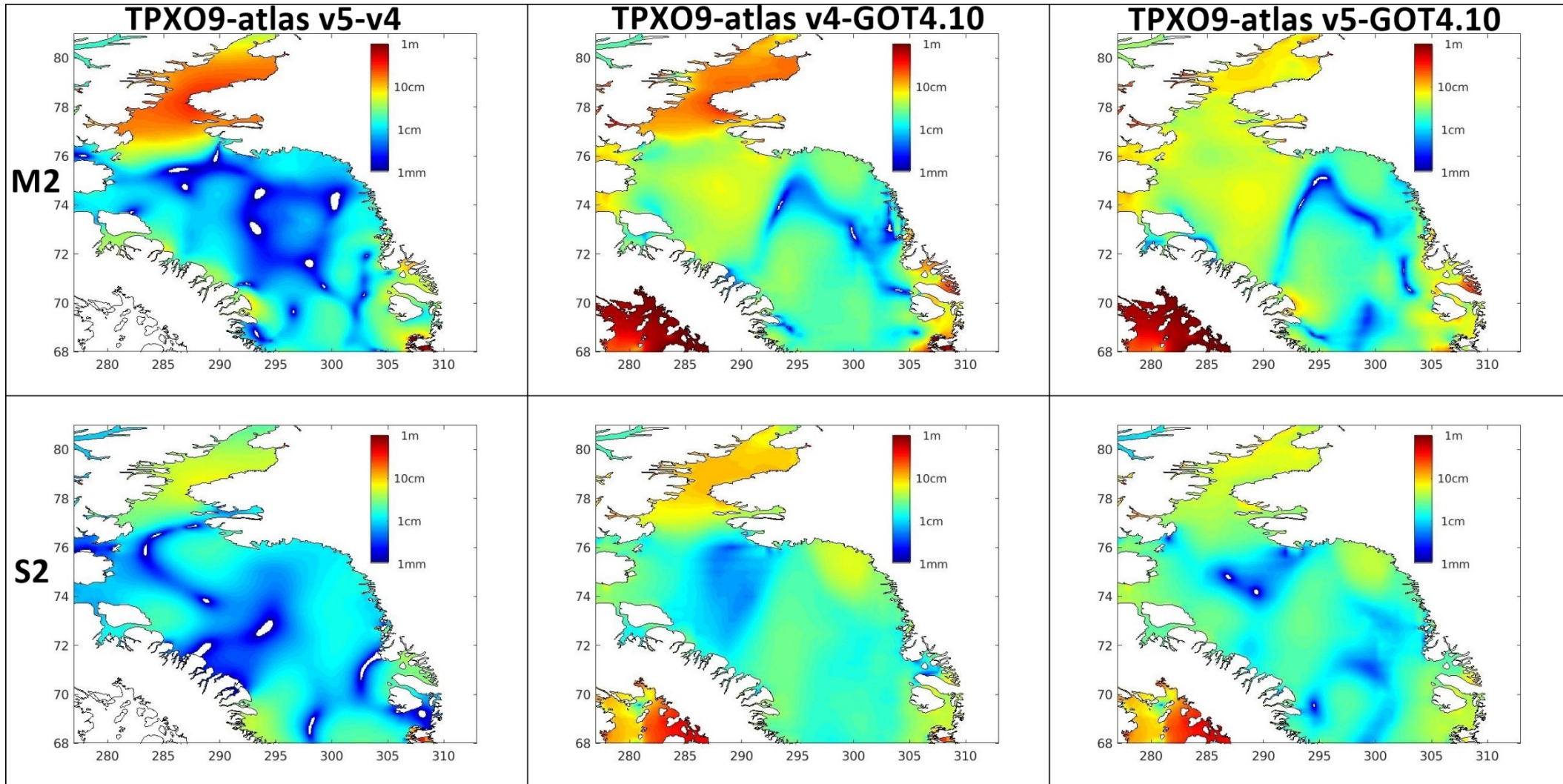
- Bathymetry source: IBCAOv4, 400m resolution averaged onto 4km stereographic grid;
- Coast lines are verified with Natural Earth coastline version 4.1.0.;
- Data assimilated: T/P+Jason (yellow); Topex2 (magenta), Croysat in $1^\circ \times 0.5^\circ$ bins (magenta) altimetry; Kowalik & Proshutinsky Arctic tide gauges data set (red dots);
- 666 representers calculated;
- Validation data sets: ERS/Envisat altimetry (not shown) and 1.04c version of the hourly GPS drifters;
- Conversion from stereographic to polar grid and back credit to Andy Bliss, 9/12/2011 – matlab script polarsterio_fwd/inv

Arctic 4km resolution TPXO9-atlas patch: elevations



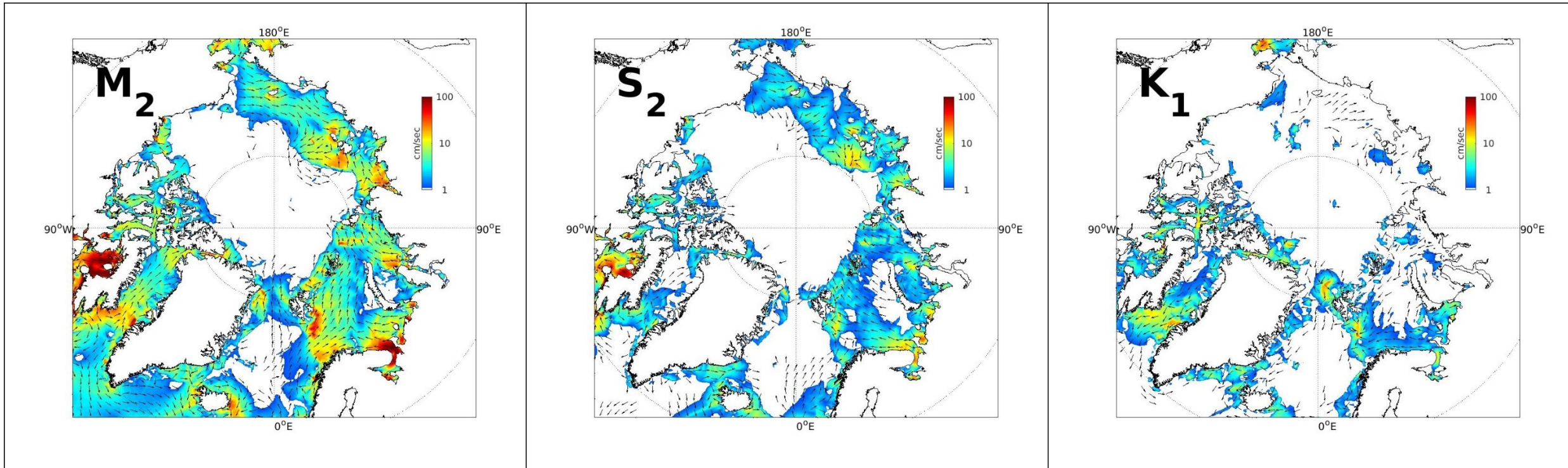
The inverse solution reduces validation set variance (ERS) 1% compared to the patch prior for 8 major constituents and fits 76% of total ERS variance (mostly on account of M_2). TPXO9-atlas-v5 fits on average 3.7% more of CryoSat variance in Arctic than v4.

Arctic 4km resolution TPXO9-atlas patch (elevations): Baffin Bay and Nares Strait zoom – compared to GOT4.10



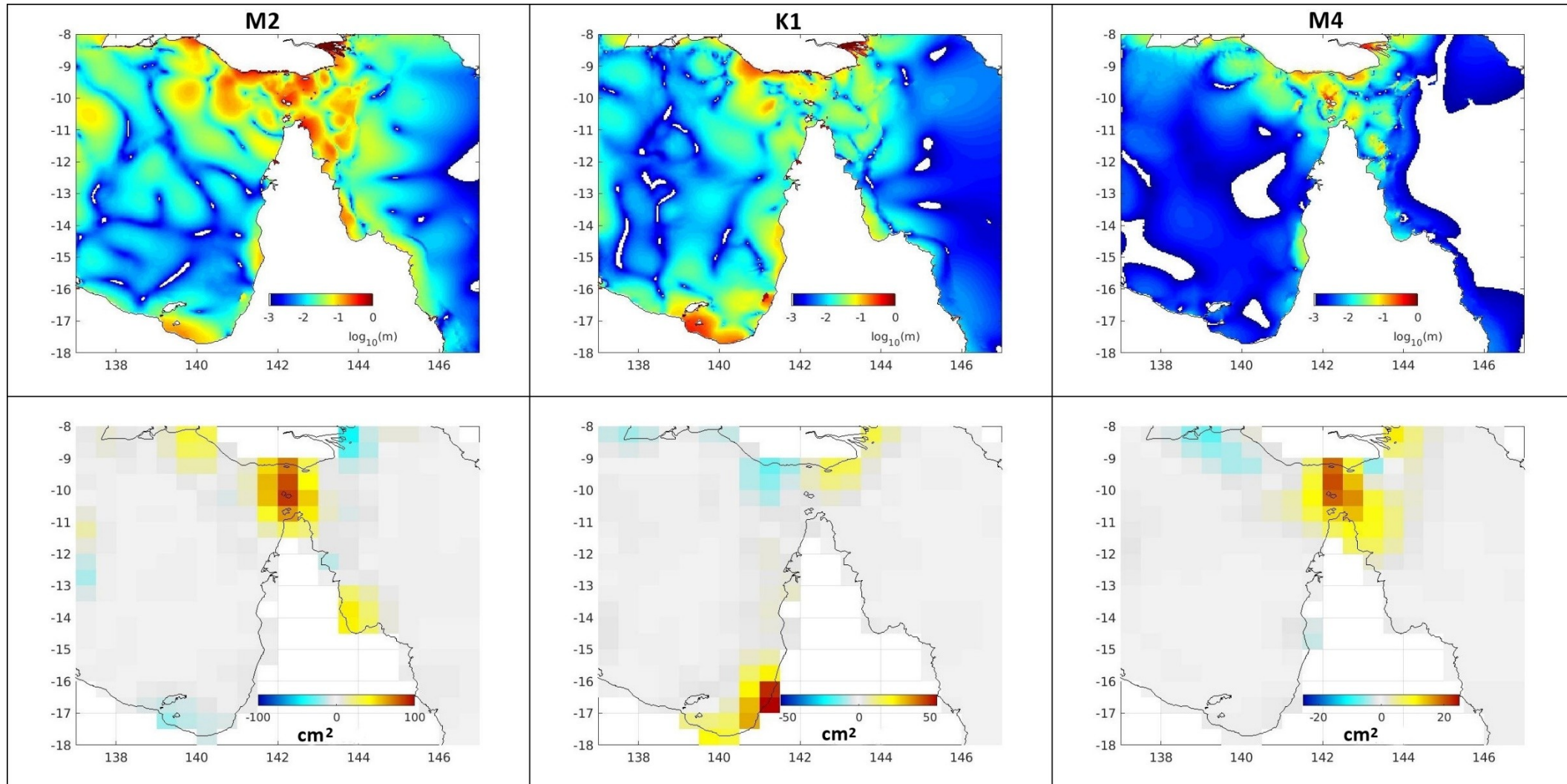
The difference between GOT4.10 and TPXO9-atlas is less for v5 than for v4.

Arctic 4km resolution TPXO9-atlas patch: currents



v5 ($M_2+S_2+K_1+O_1$) fits $9.5(\text{cm/sec})^2$ of validation set (Drifters) variance (with 0.1% of extreme values cut off), insignificant change compared to the patch prior, and $0.3(\text{cm/sec})^2$ more than v4.

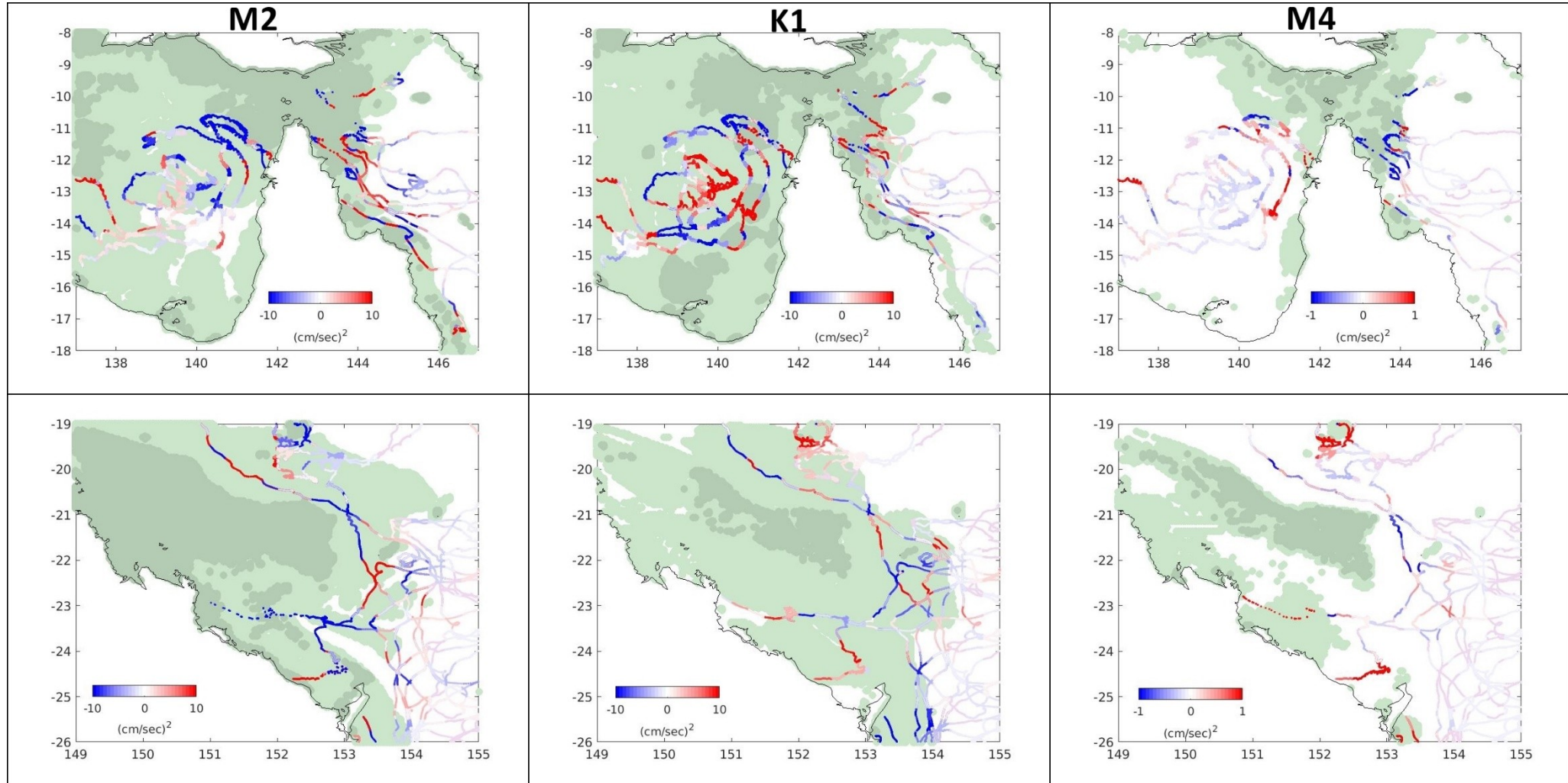
SOI patch: Gulf of Carpentaria zoom



Top: difference between v4 and v5 elevations on logarithmic scale.
Bottom: change in fitted Cryosat variance (binned $0.5^\circ \times 0.5^\circ$).

SOI currents: Gulf of Carpentaria and NE Australia zooms

Fit to drifters: binned $0.5^\circ \times 0.5^\circ$ variance



Lighter shade - magnitude of current change between TPXO9-atlas-v4 and v5 $>1\text{cm/s}$; darker shade $>10\text{cm/s}$.
Red - v5 fits more drifter variance; blue - v4 fits more drifter variance.
-> drifter data assimilation is required to improve fit overall.

Prospective:

- Improving base global prior;
- Improving coastal areas on account of updated bathymetry and increased resolution;
- Drifters data assimilation to improve currents in coastal areas;
- Adding more minor constituents; try using Cryosat for estimating annual modulates of M2 MA2 and MB2 at high latitudes;
- Applying new DT2021 MSLA product; could be less tidal/high-frequency contamination;
- Subtracting HRET baroclinic tides from the SSH before assimilating;
- Using temporal subsets of altimetry data (before and after some date) to identify and map trend in barotropic M2, if it exists.