



Towards GOT5
Miscellaneous Points on Polar Tides, Coastal
Tides, and Minor Tides

Richard Ray

NASA Goddard Space Flight Center

OSTST meeting

Chicago, October 2019



Towards GOT5
**Miscellaneous Points on ~~Polar Tides, Coastal~~
~~Tides, and Minor Tides~~**

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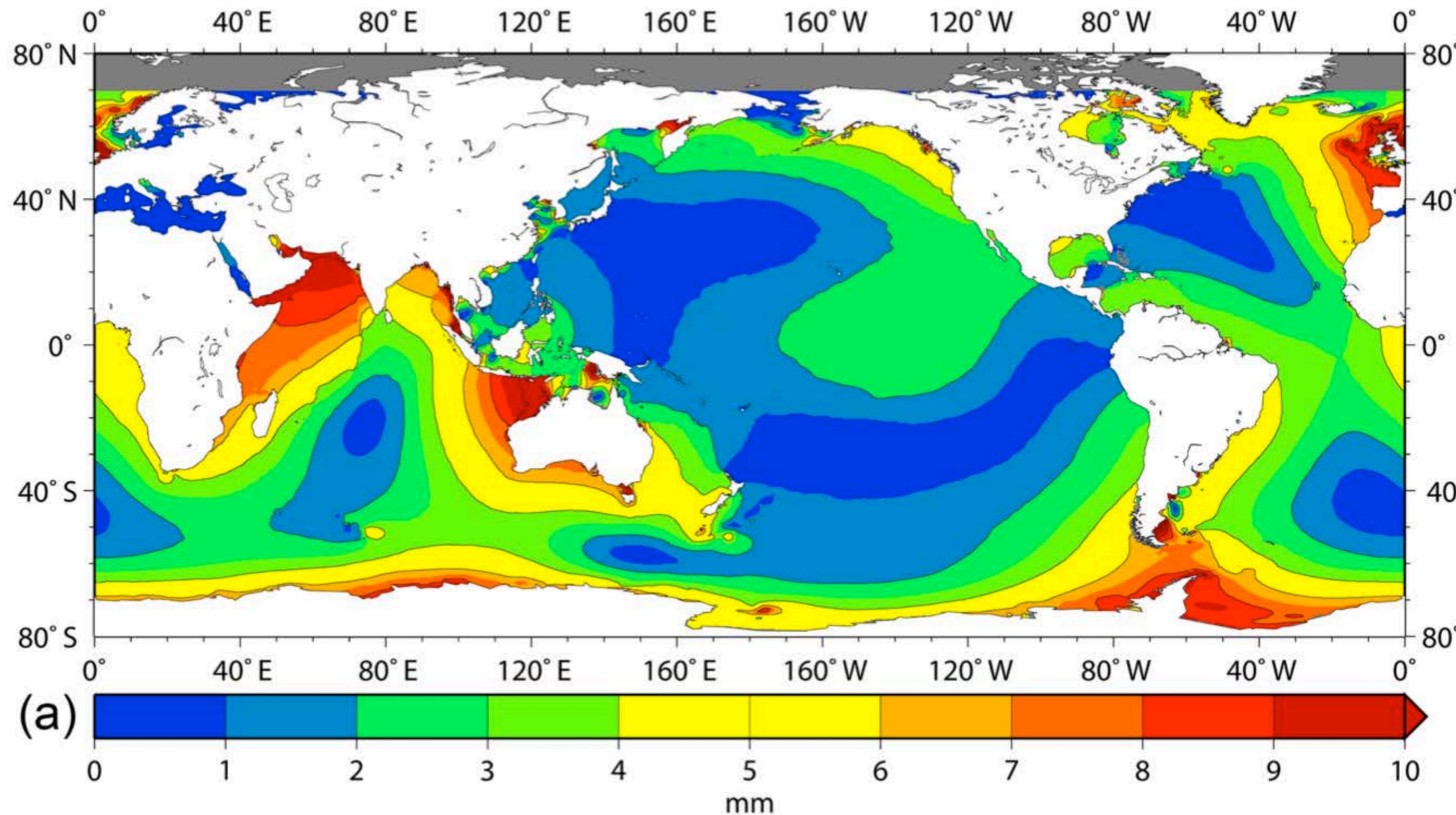
OSTST meeting

Chicago, October 2019

Degree-3 M_1 Tide

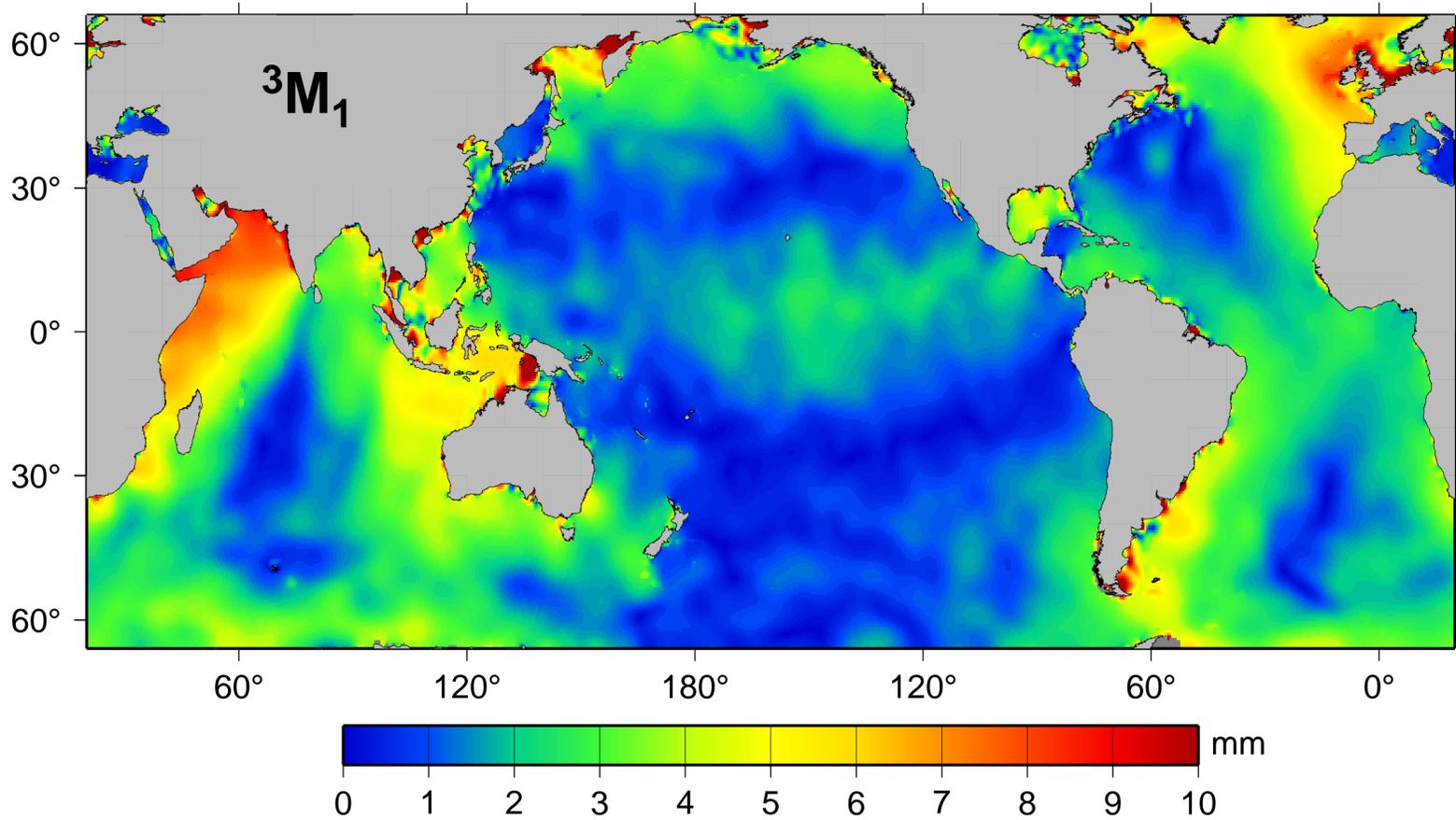
P. L. Woodworth (2019), "The global distribution of the M_1 ocean tide," *Ocean Sciences*, 15, 431-442.

Ocean response to
 $Y_{3,1}$ spherical harmonic
of astronomical potential



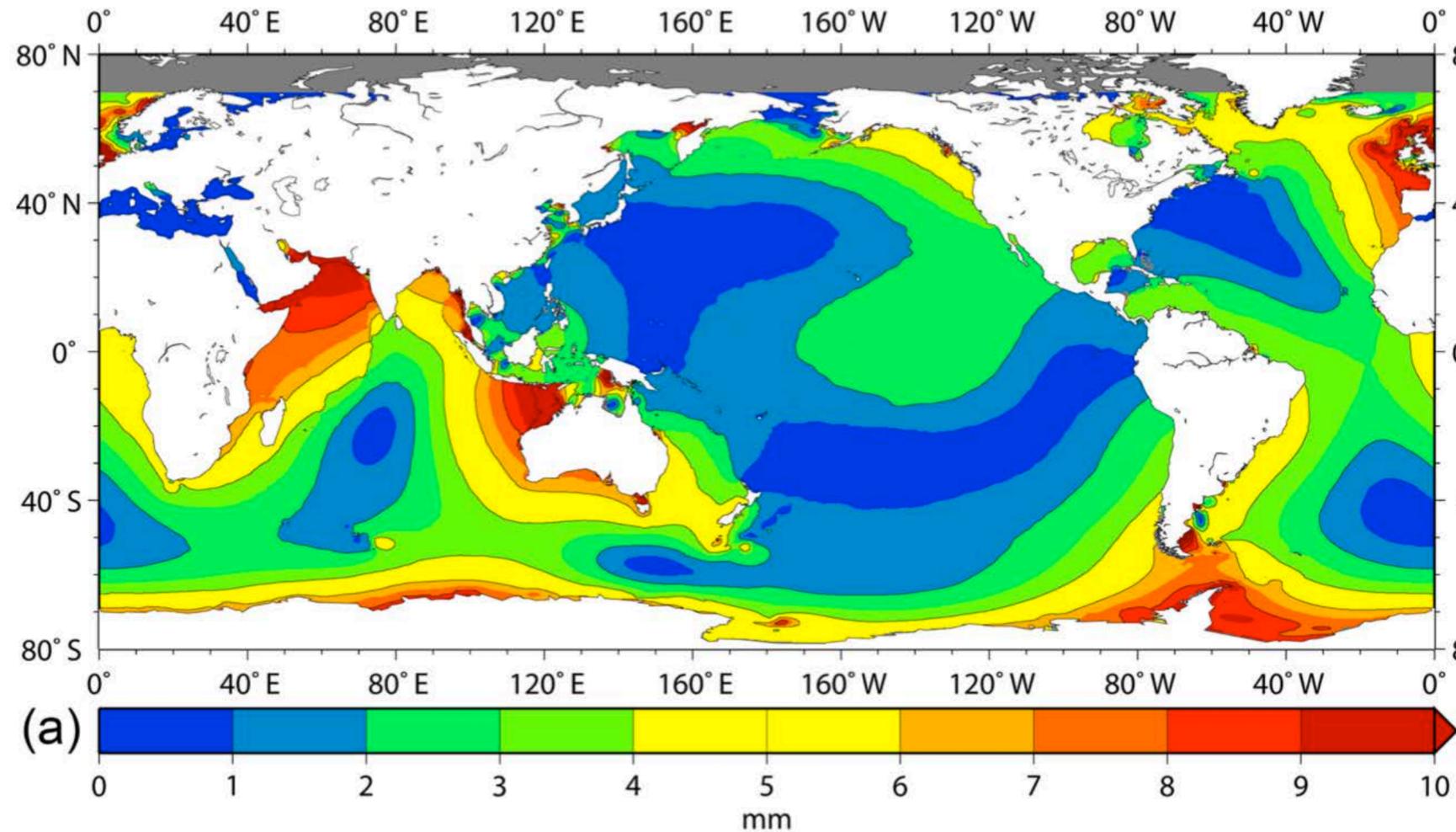
Degree-3 M_1 Tide

GOT5



Empirical (altimetry)

M1 amplitude

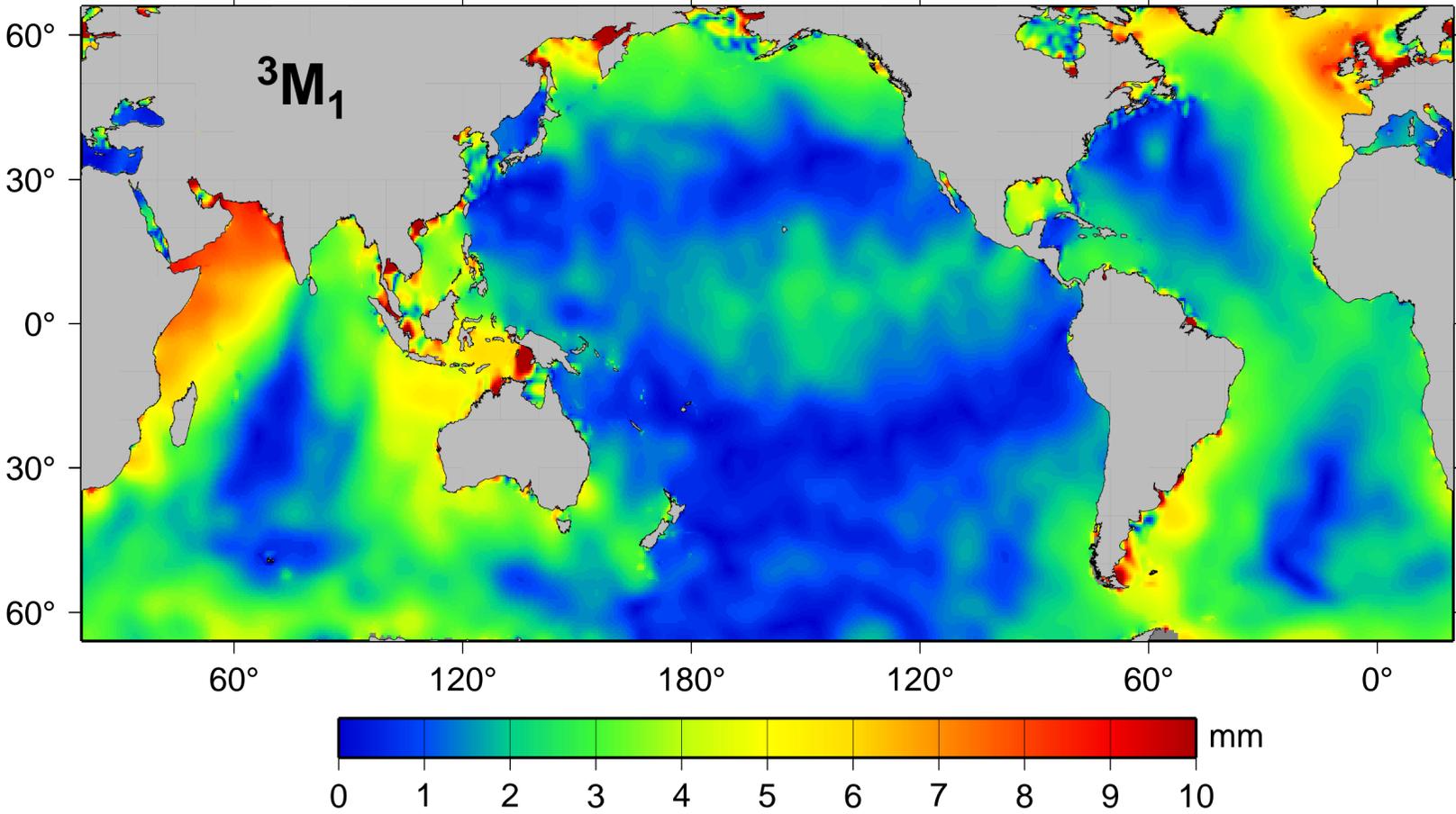


Hydrodynamic

P. L. Woodworth (2019), "The global distribution of the M_1 ocean tide," *Ocean Sciences*, 15, 431-442.

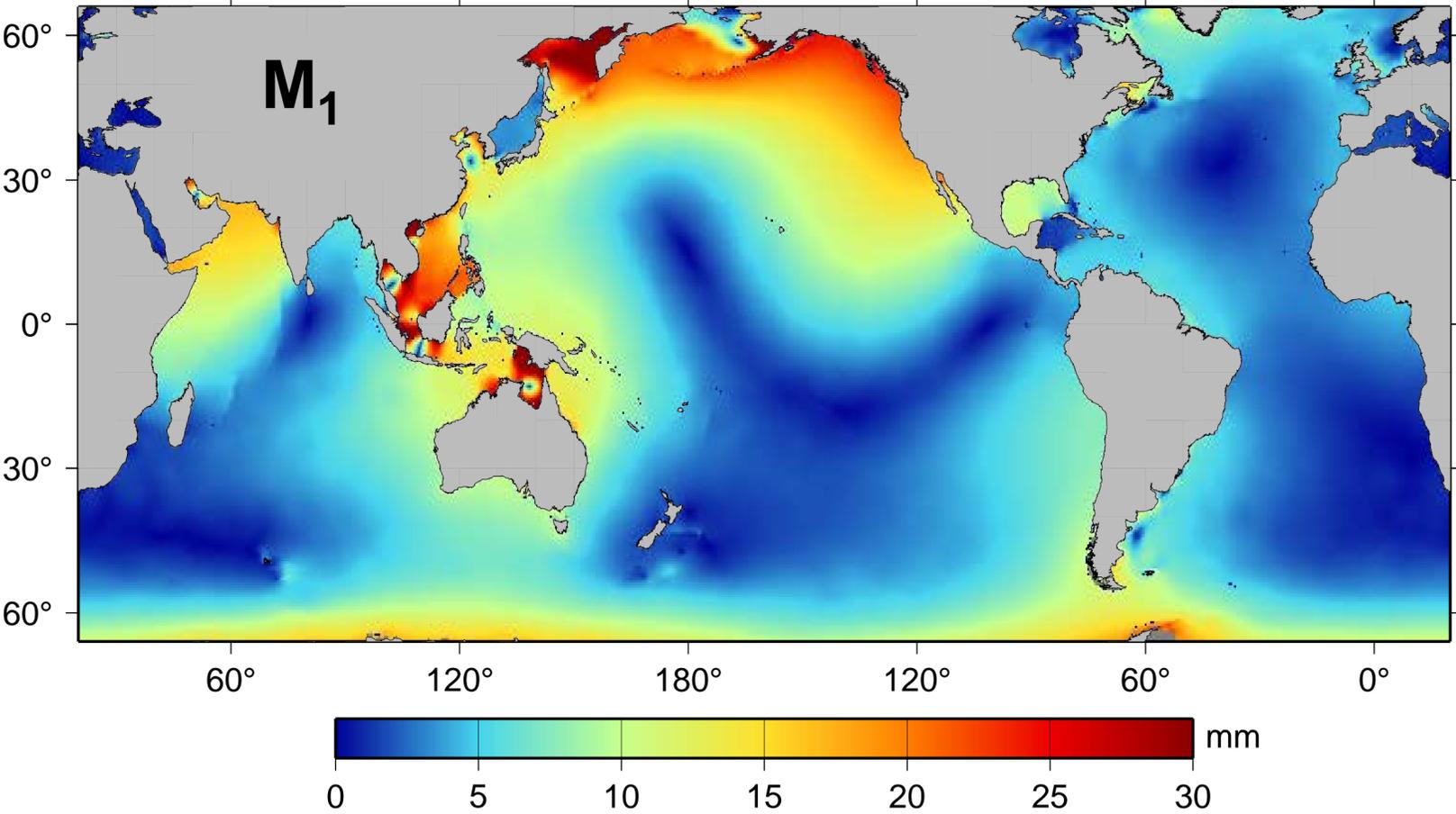
Degree-3 M_1

GOT5



Degree-2 M_1

GOT5 (via inference)



Frequency separation = 1 cycle / 8.8 years

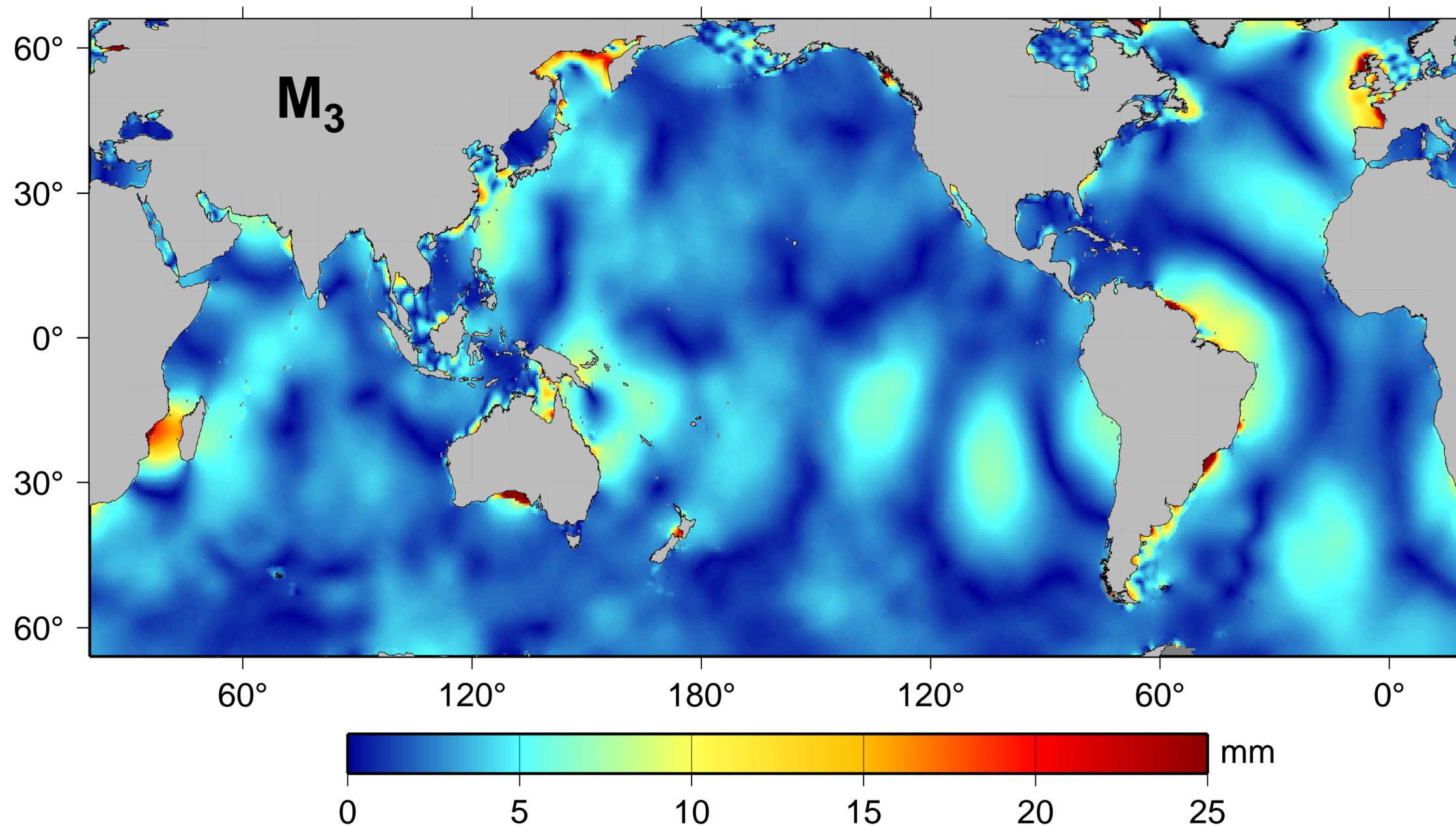
Degree-3 Terdiurnal M_3 Tide

Ocean response to
 $Y_{3,3}$ spherical harmonic
of astronomical potential

Test against deep-ocean
bottom pressure data:

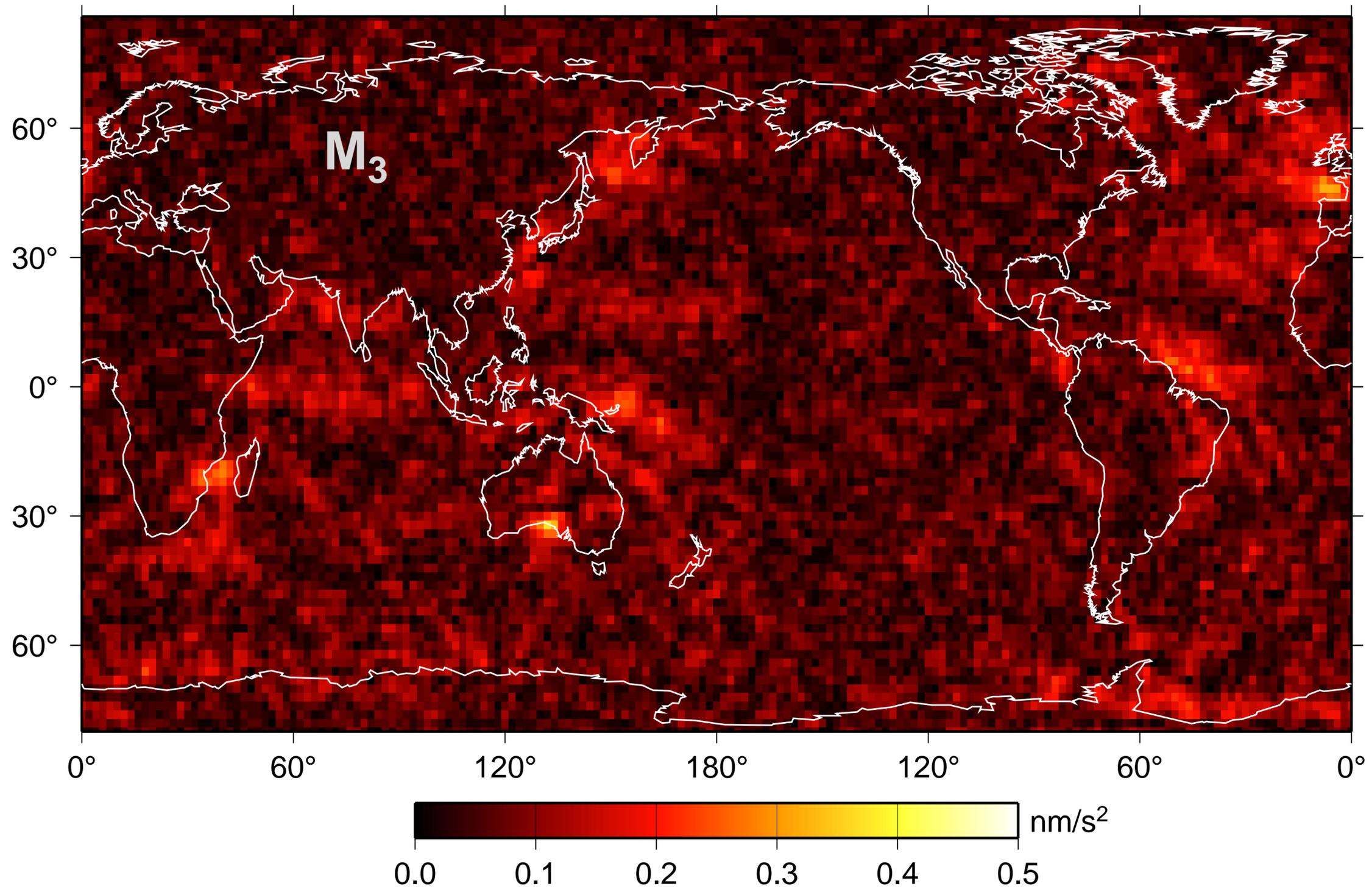
RMS signal = 2.4 mm
RMS difference = 0.9 mm

GOT5 (preliminary)



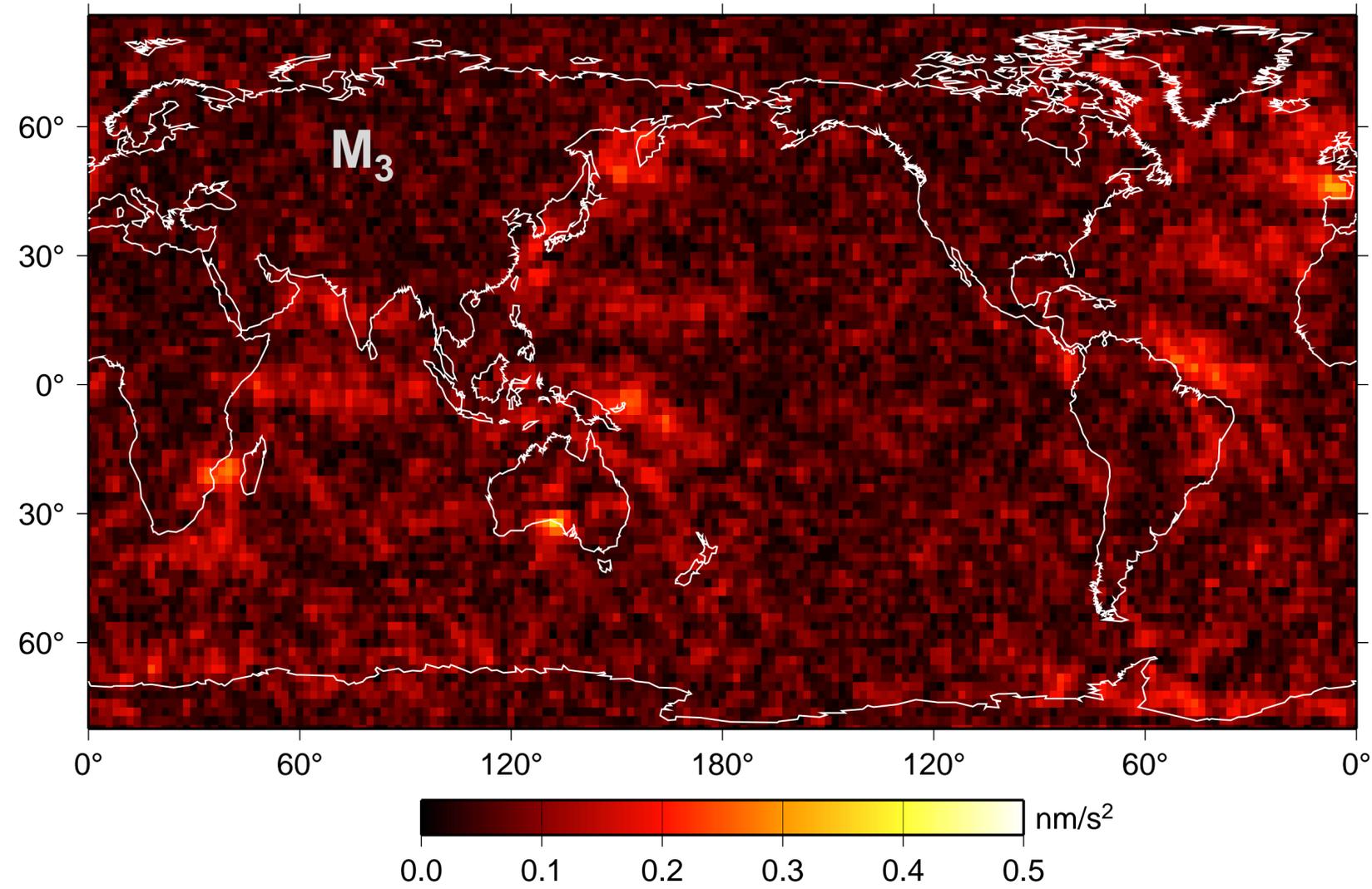
Terdiurnal M_3

Amplitude of GRACE residuals at M_3 frequency

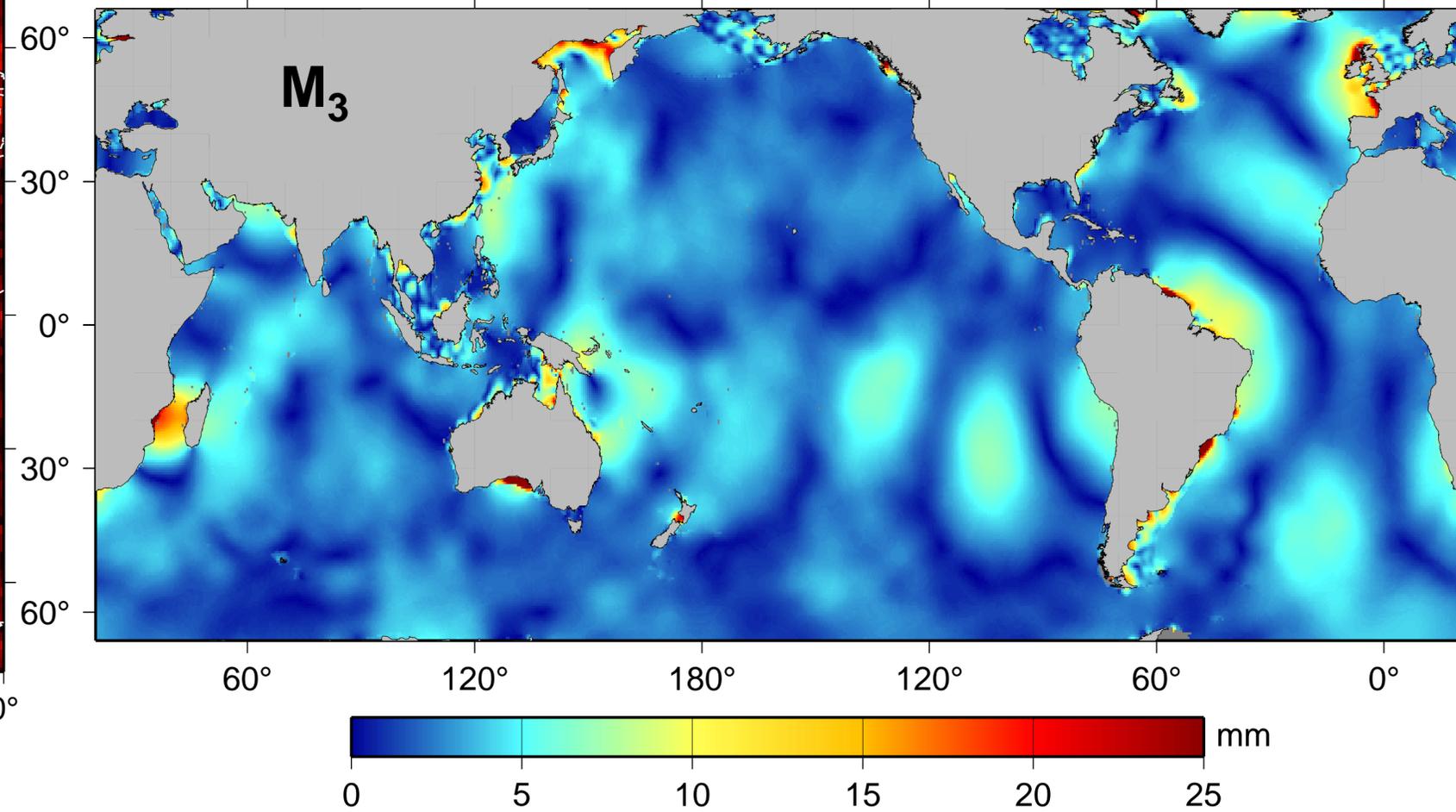


Terdiurnal M_3

Amplitude of GRACE residuals at M_3 frequency

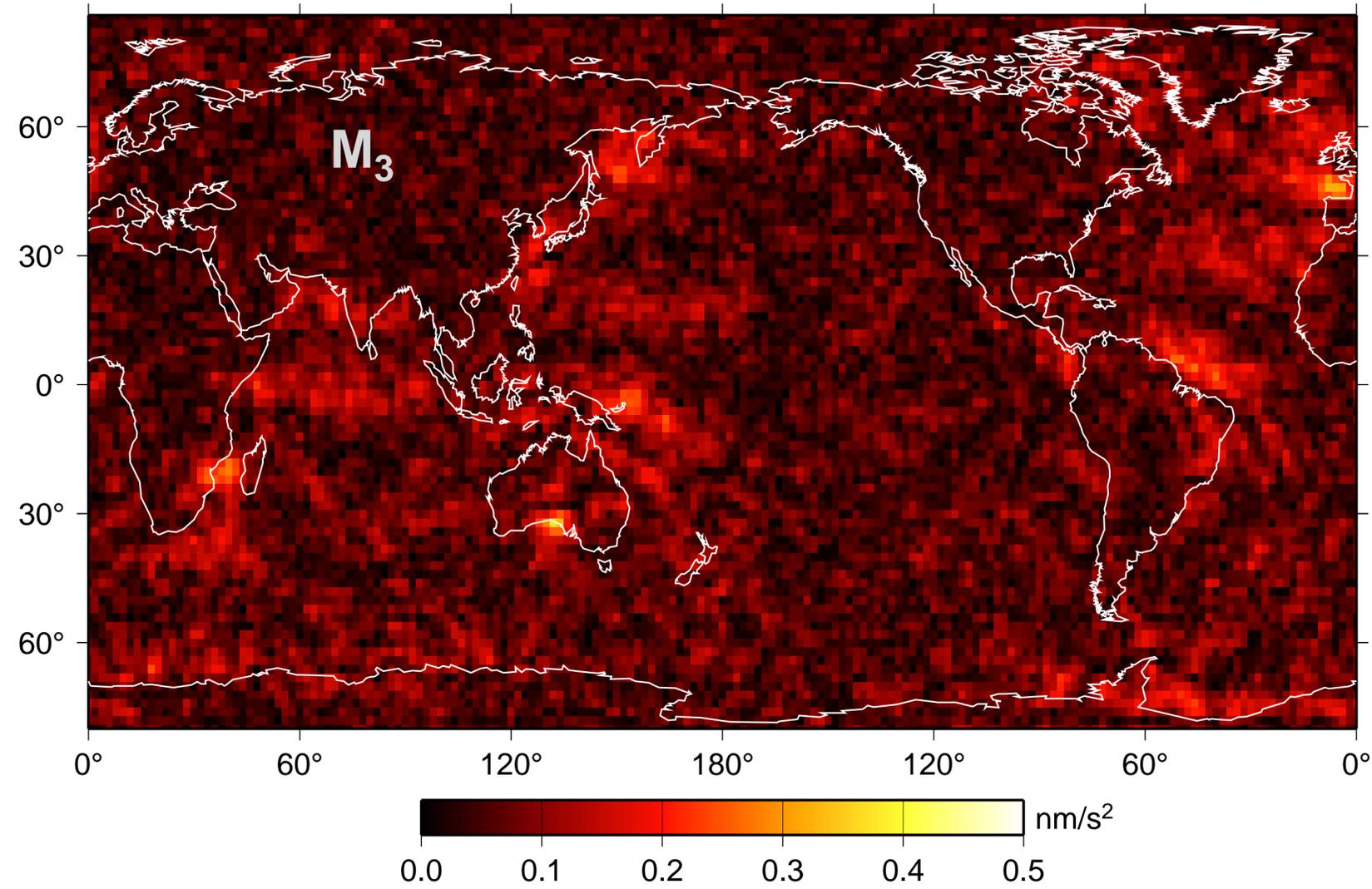


GOT5 (preliminary)

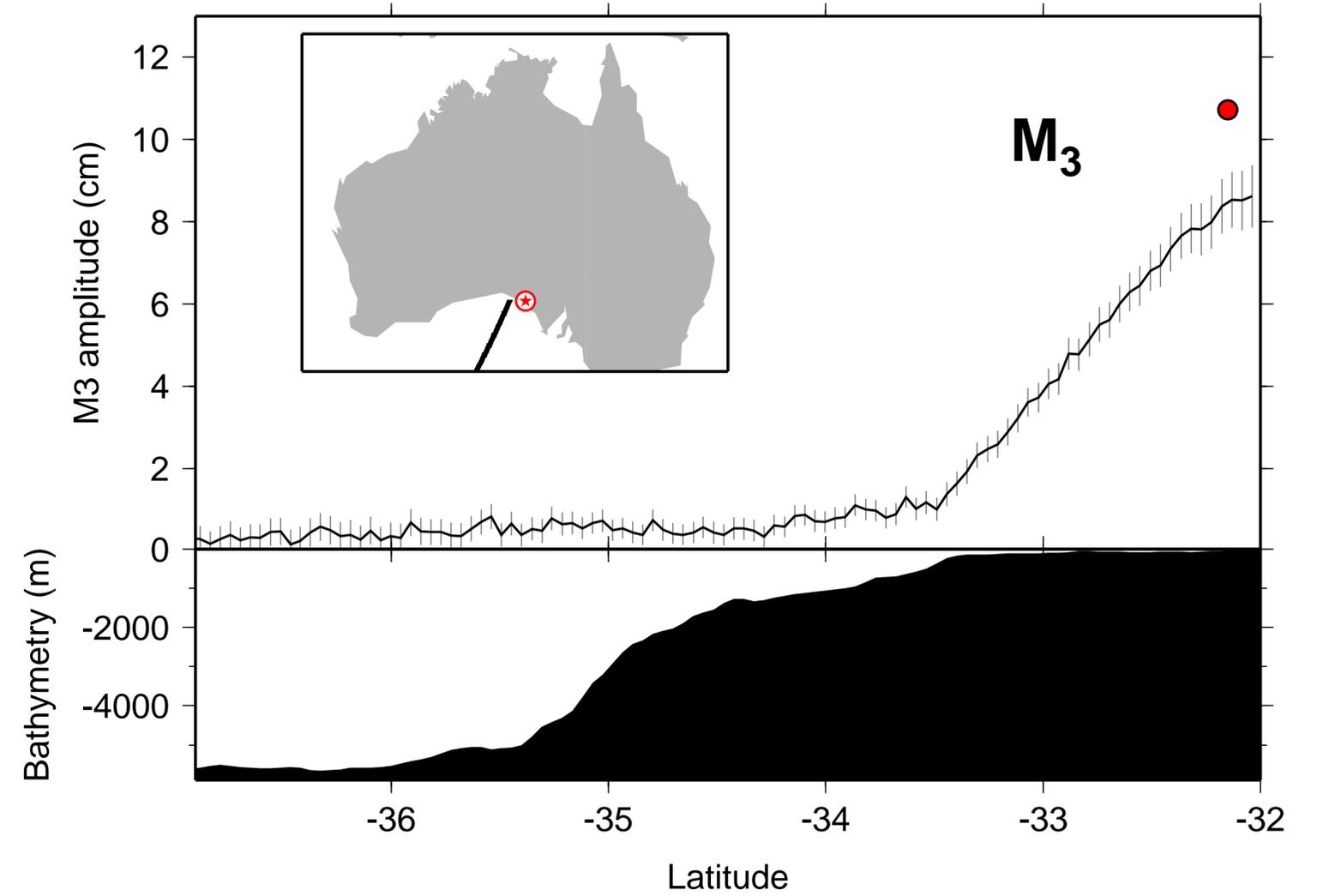


Terdiurnal M_3

Amplitude of GRACE residuals at M_3 frequency



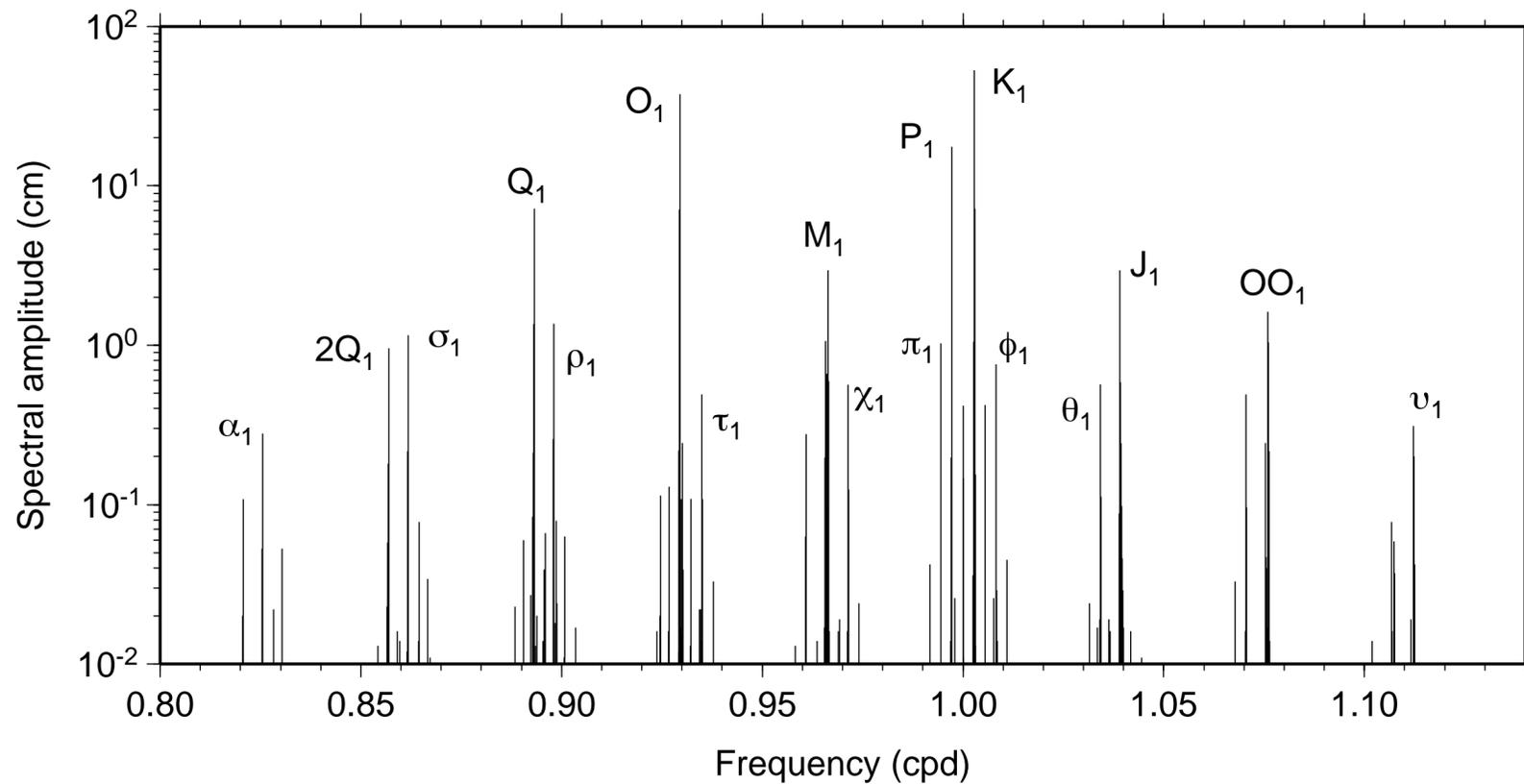
T/P-Jason track over largest GRACE M_3 residual



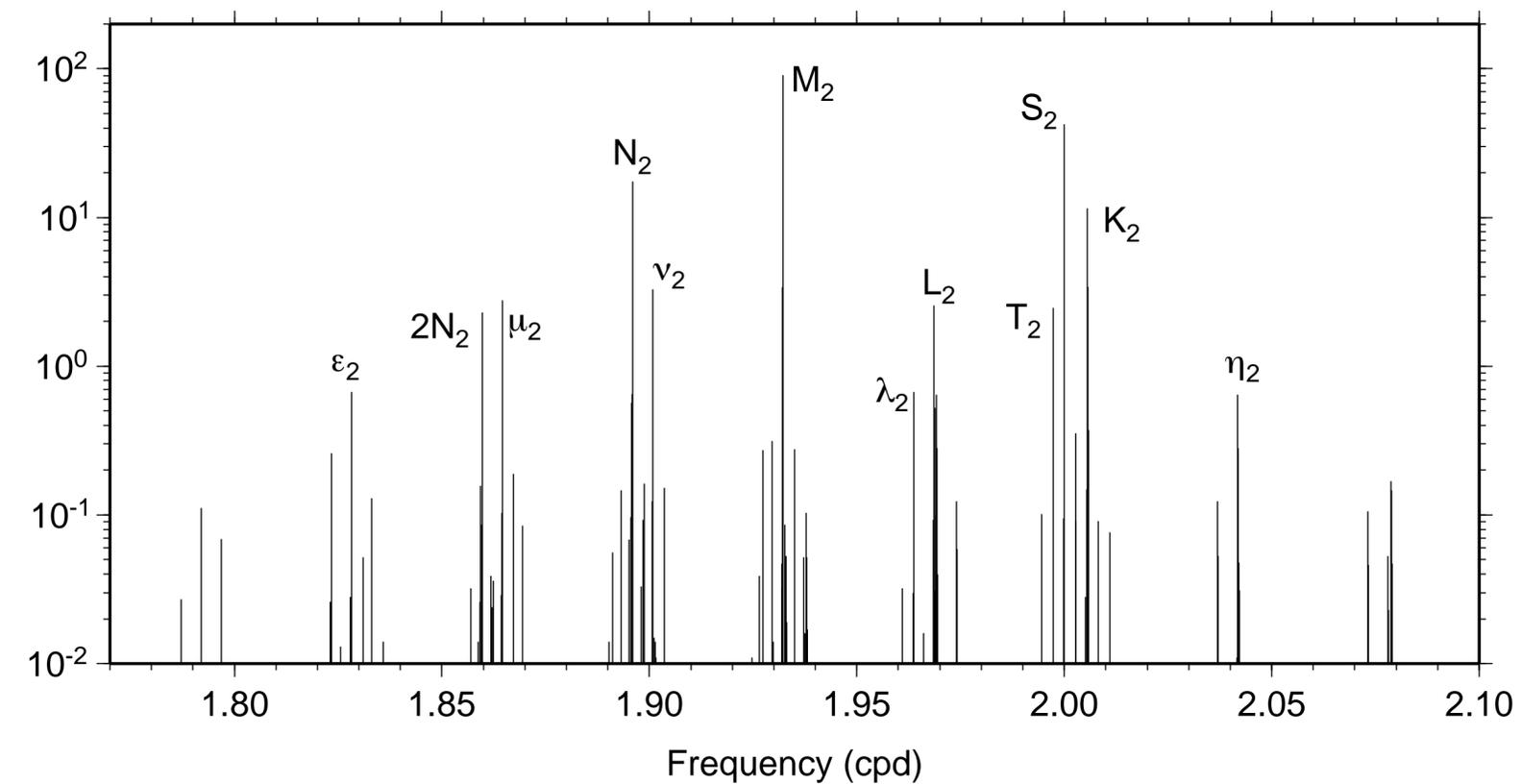
Red dot – Thevenard tide gauge

Astronomical Tidal Potential (deg 2)

Diurnal band



Semidiurnal band



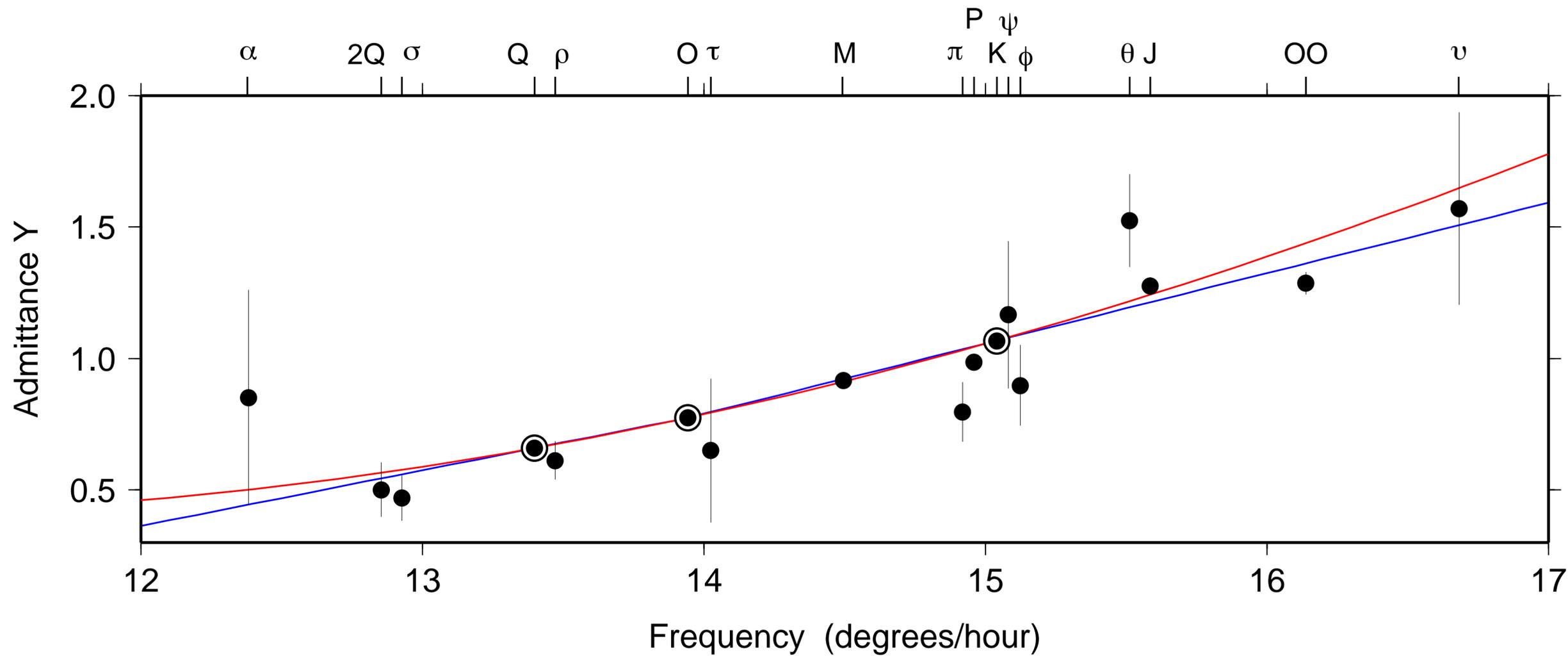
GOT4.x was distributed with 4 major diurnals, 4 major semidiurnals (plus M4)

FES2004 was distributed with same + 2N2.

FES2014 was distributed with more, but many not data-constrained

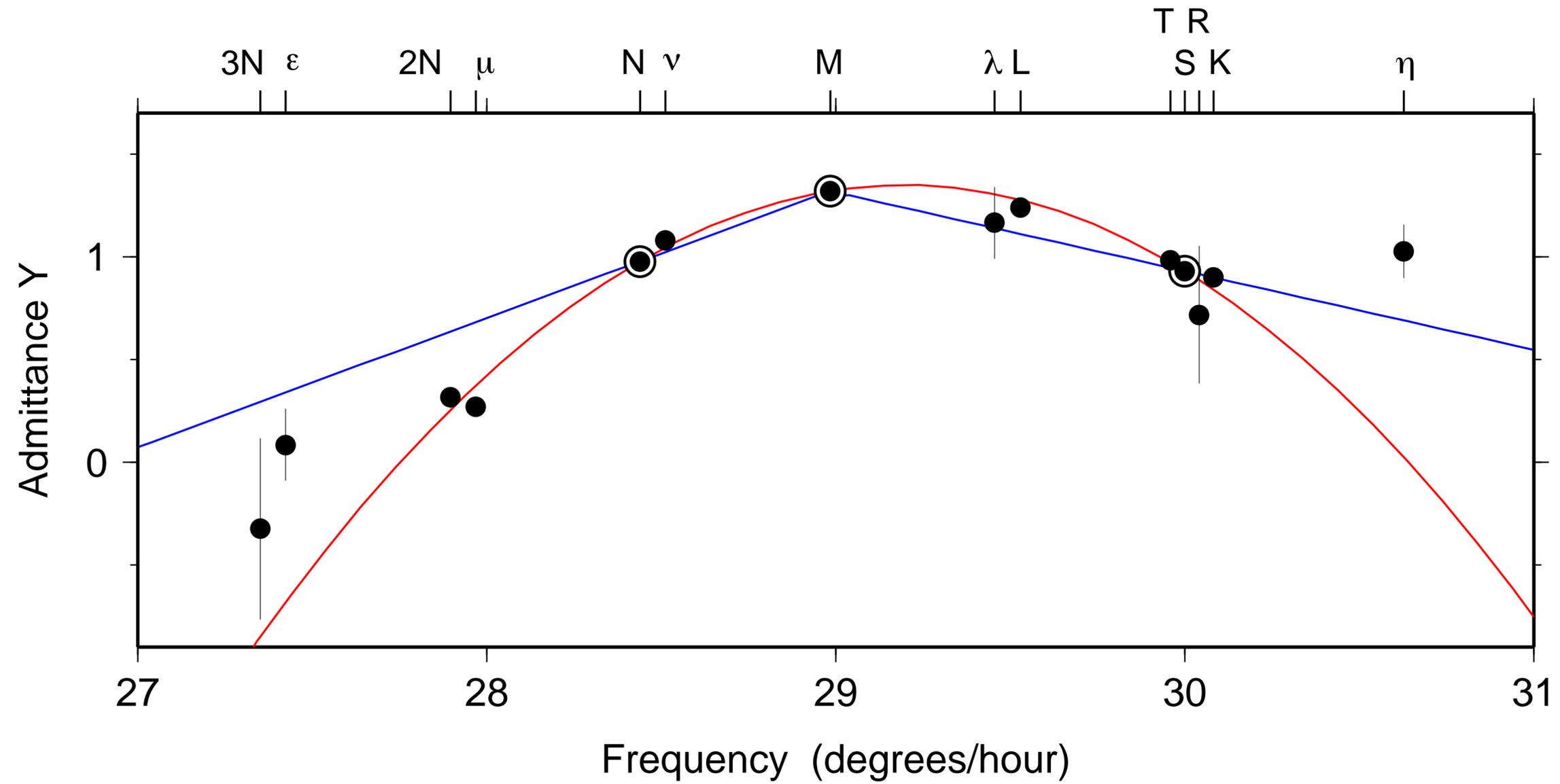
Diurnal Tidal Admittance

DART station 46419 (North Pacific)



Semidiurnal Tidal Admittance

DART station 46419 (North Pacific)

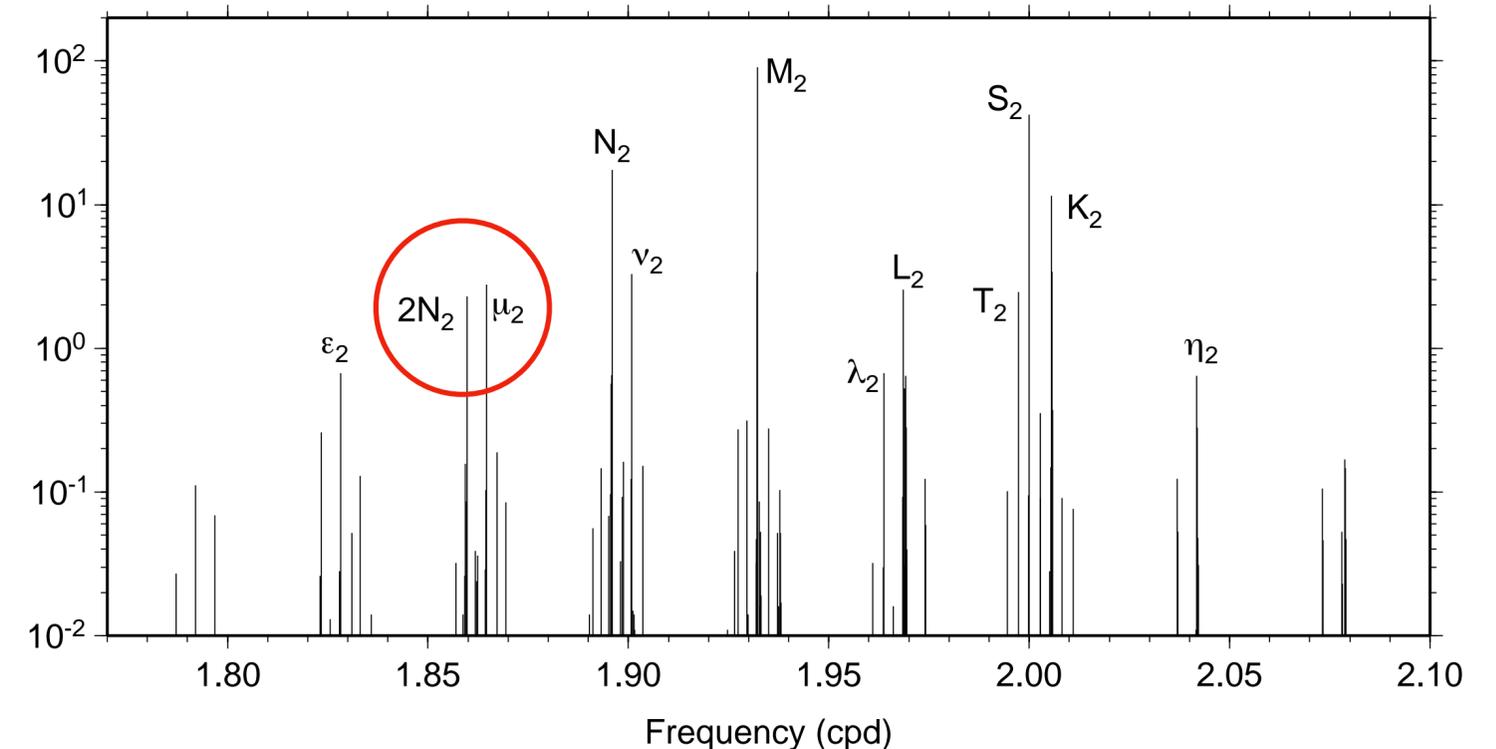
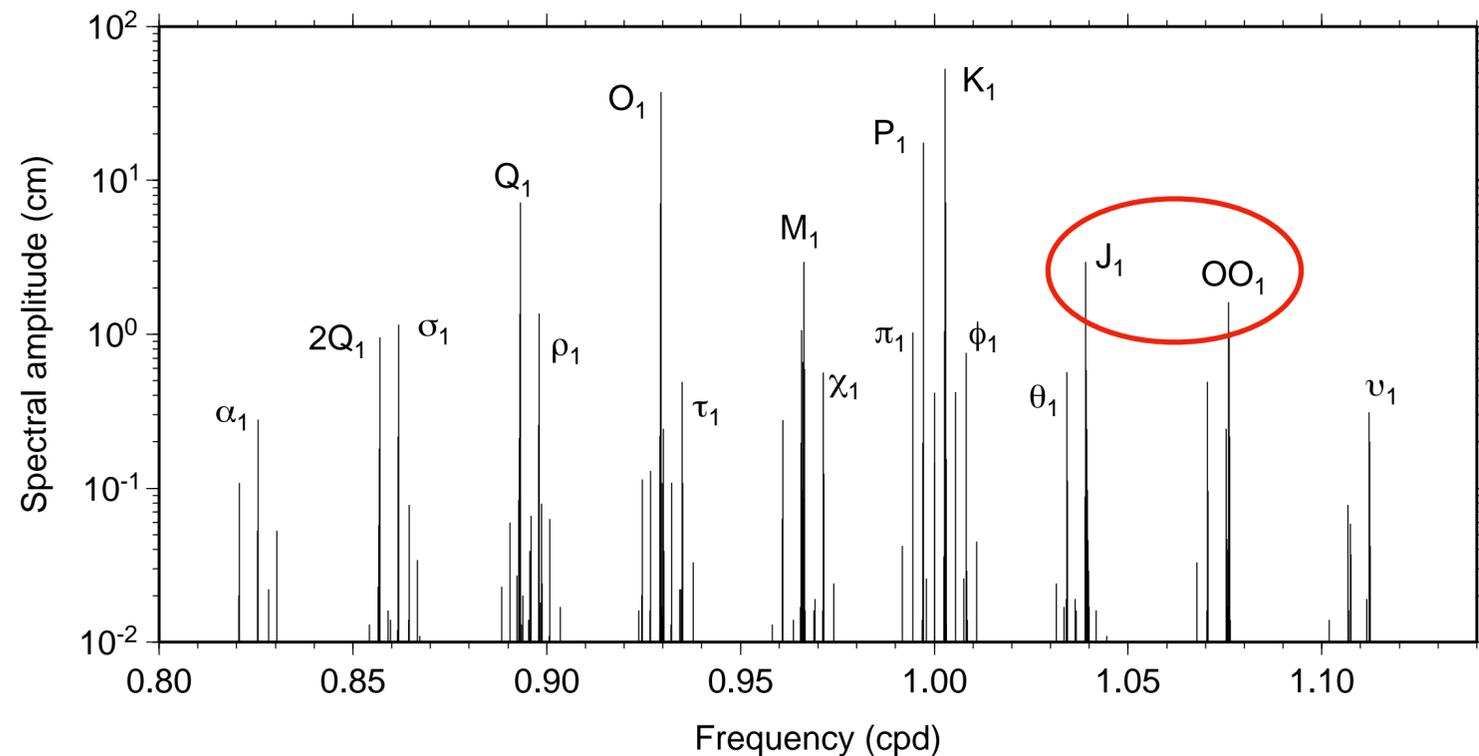


Minor Tides in Diurnal & Semidiurnal Bands

Infer them or estimate directly?

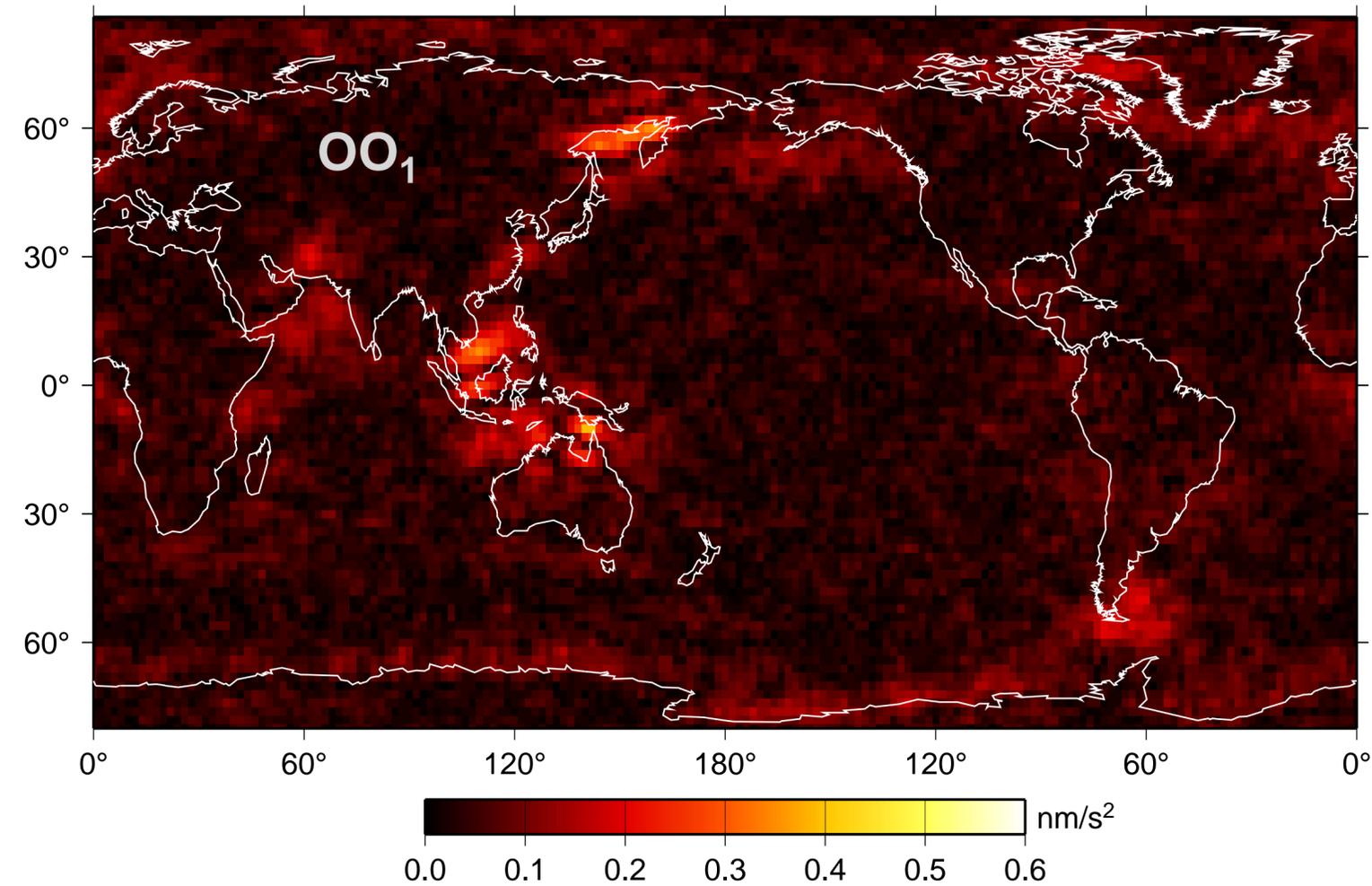
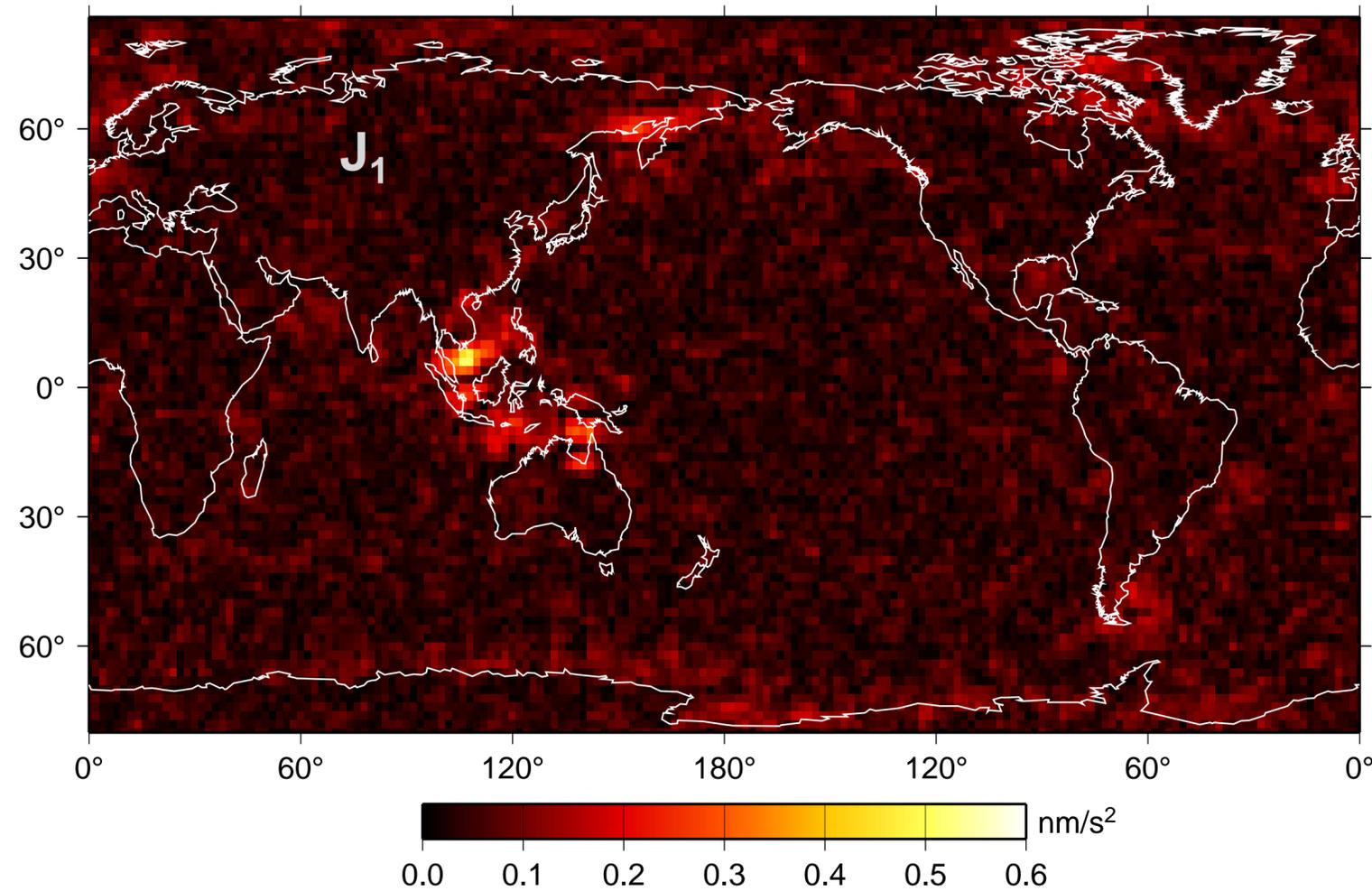
- **When altimeter time series was short, we had to infer; poor SNR.**
- **As time series lengthens, more tides can be estimated directly.**
- **Inference \rightarrow admittance interpolation vs extrapolation.**

Extrapolation is risky for $2Q_1$, J_1 , OO_1 , ε_2



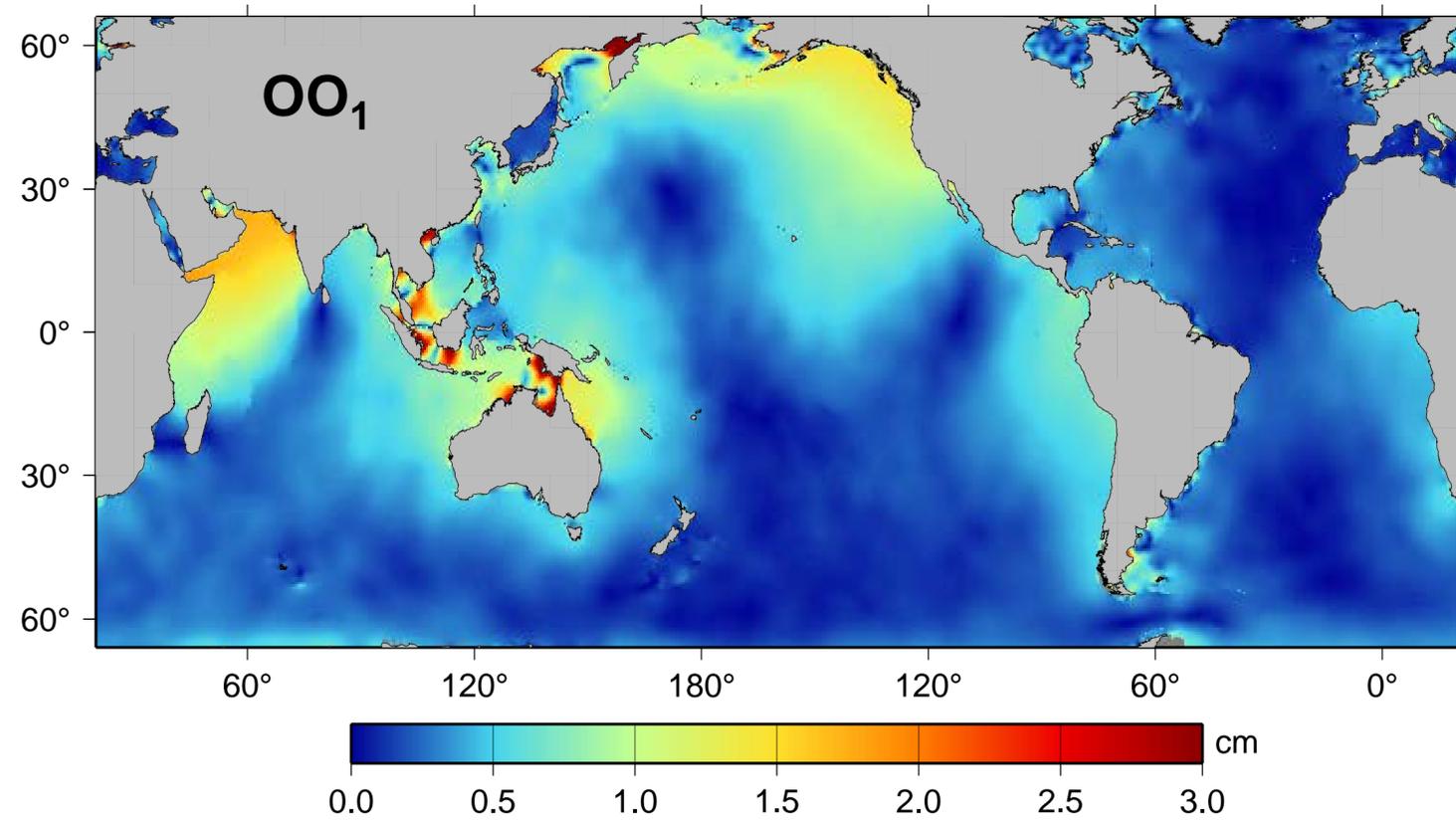
GRACE Range-Acceleration Residuals by Tidal Constituent: Diurnal Band

Prior model = GOT4.7, based on extrapolation of admittances

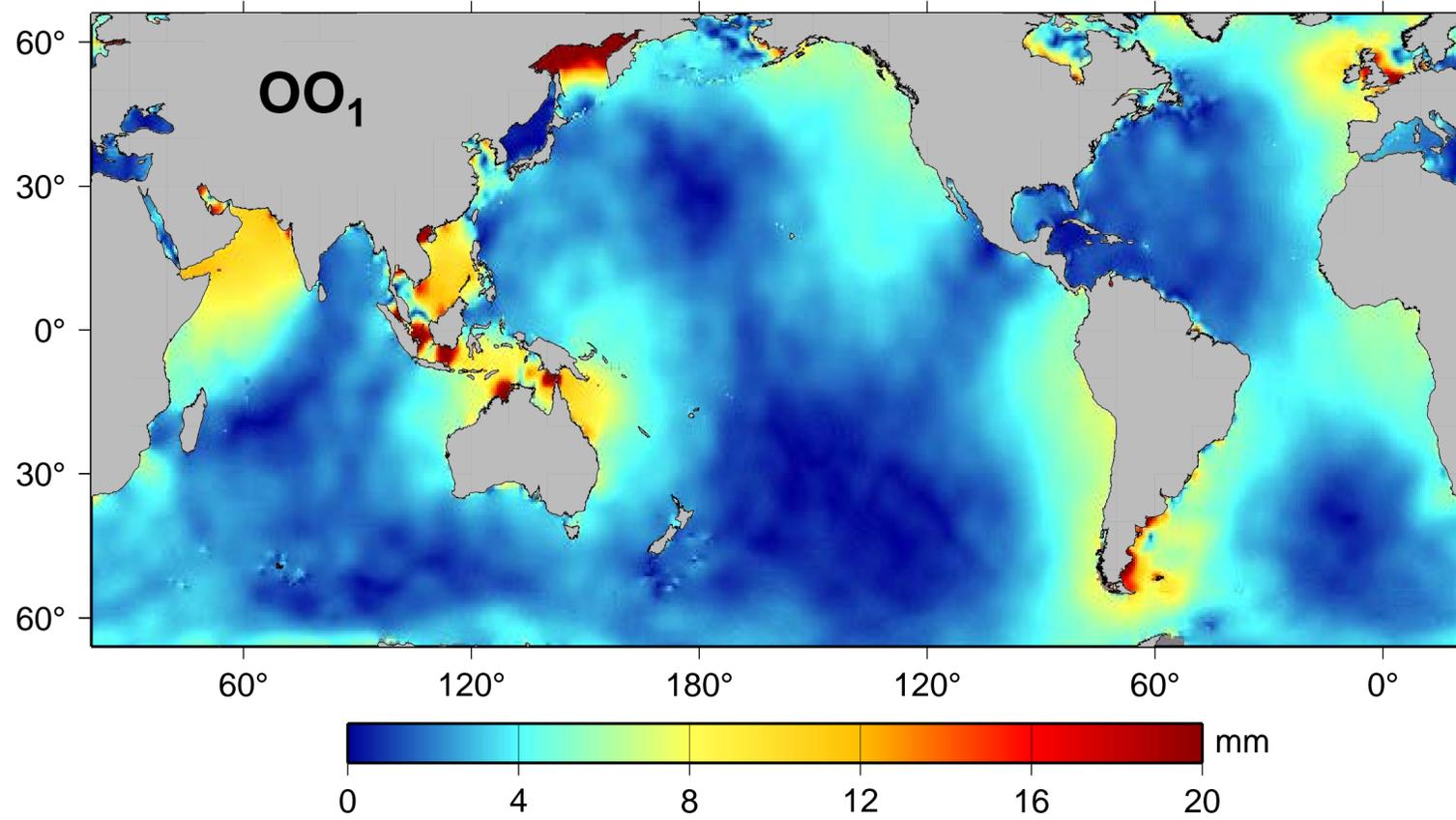


Note: OO_1 is a smaller tide than J_1 , but is higher frequency at edge of band, implying farther extrapolation of diurnal admittance, implying larger errors

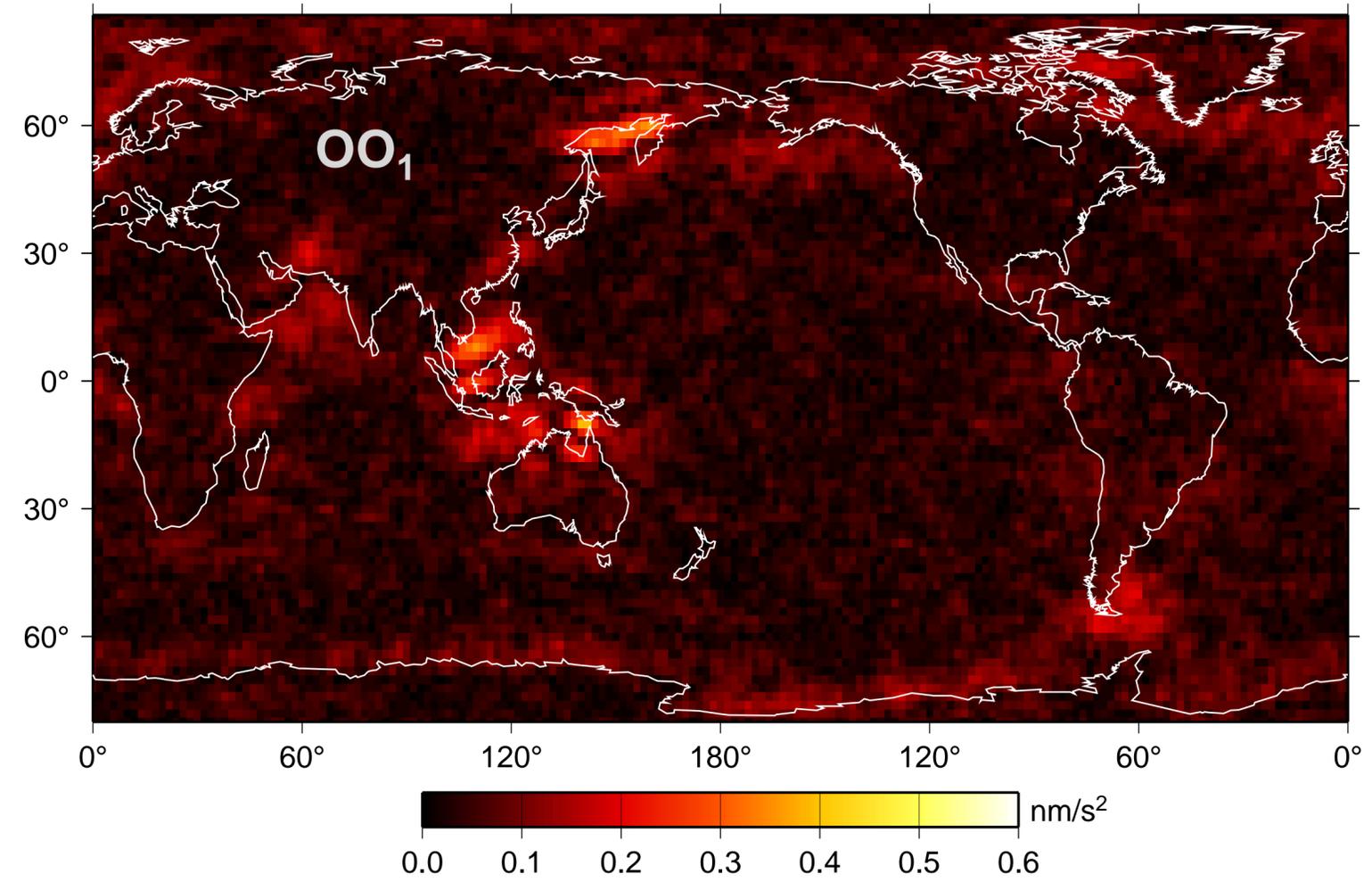
GOT5



GOT5 minus (inferred) GOT4.7

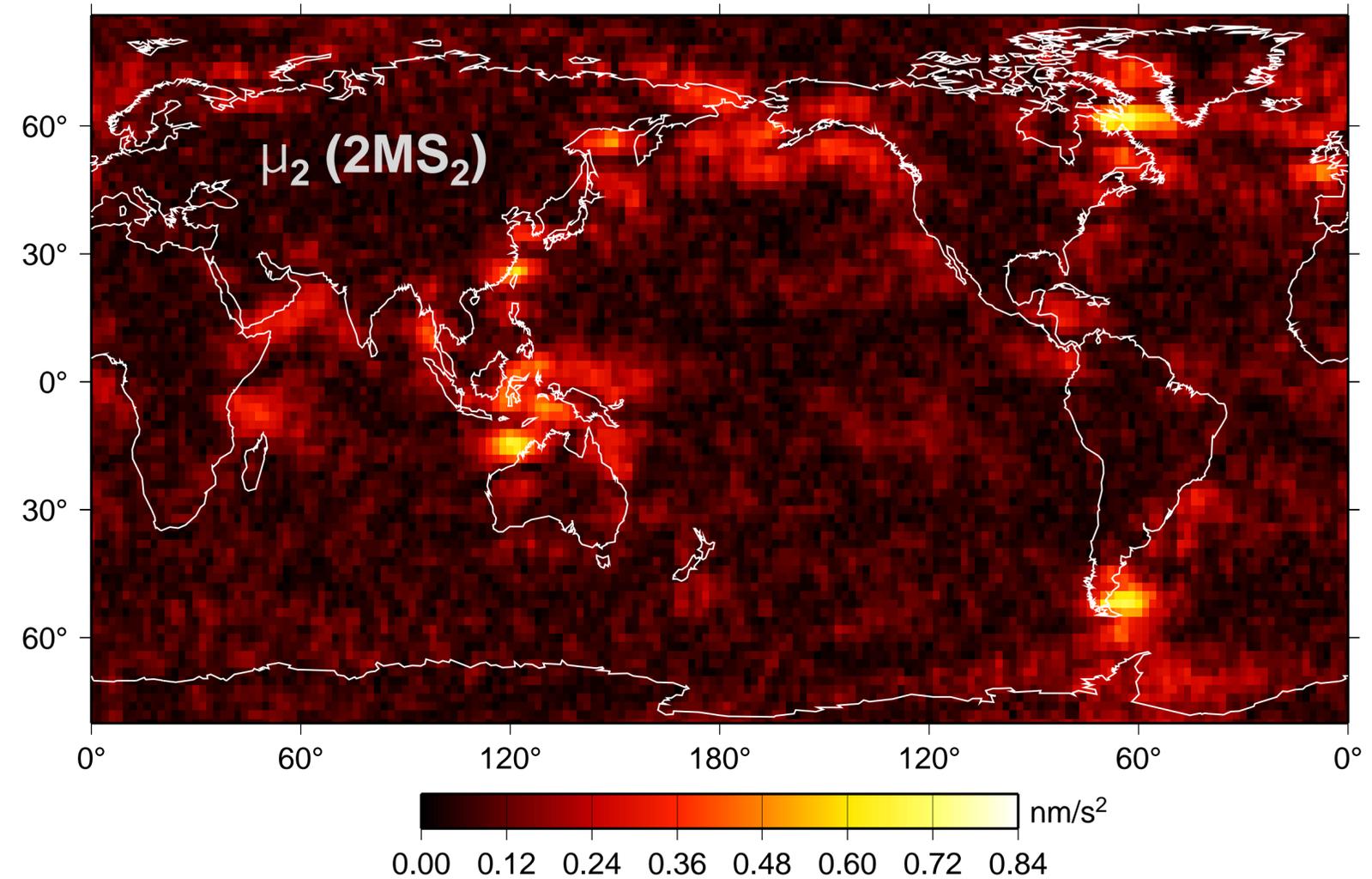
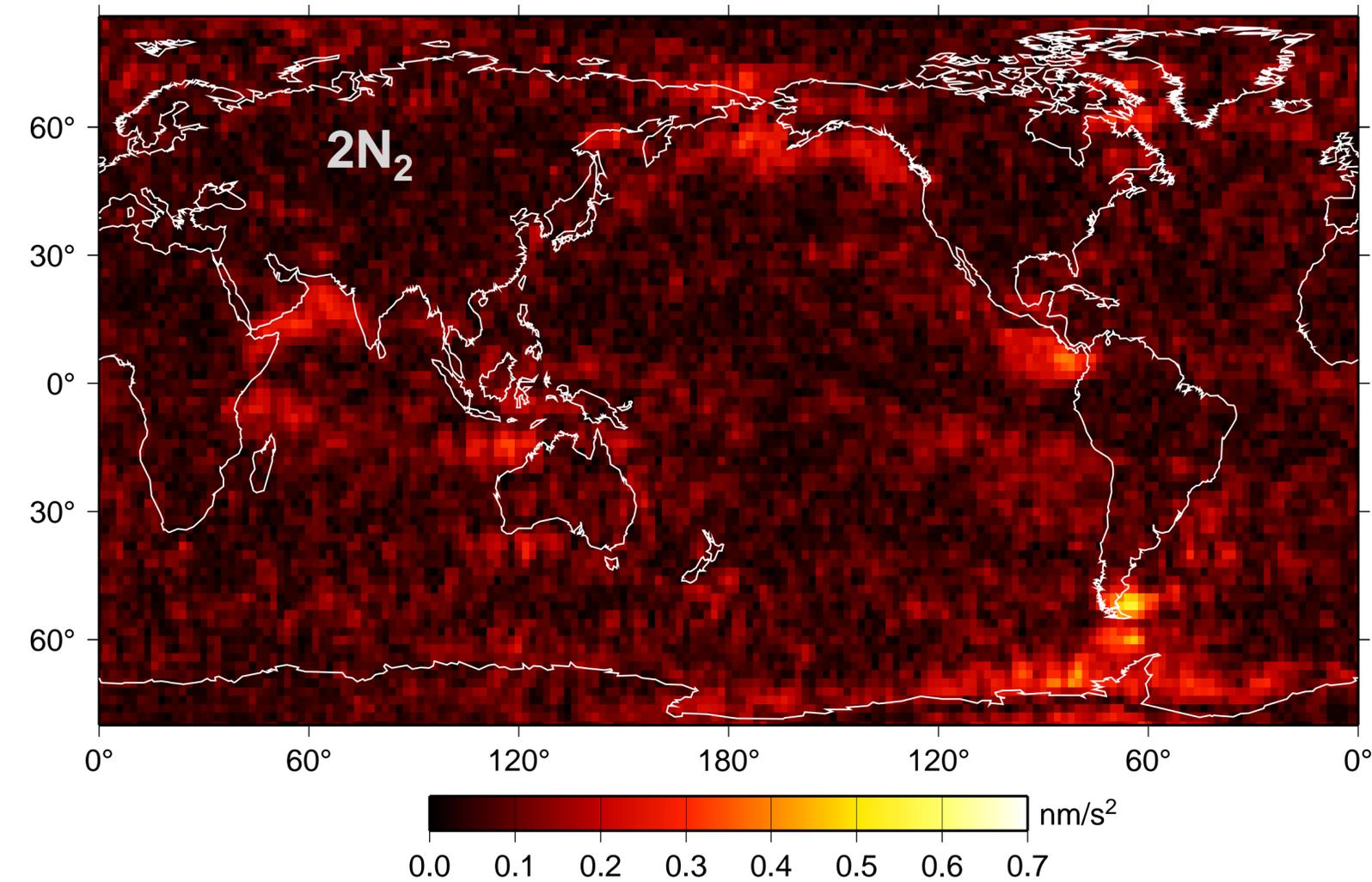


**GOT4.7 Acceleration Residuals
wrt GOT4.7 admittance extrapolation**



GRACE Range-Acceleration Residuals by Tidal Constituent: Semidiurnal Band

Prior model = GOT4.7, based on extrapolation of admittances

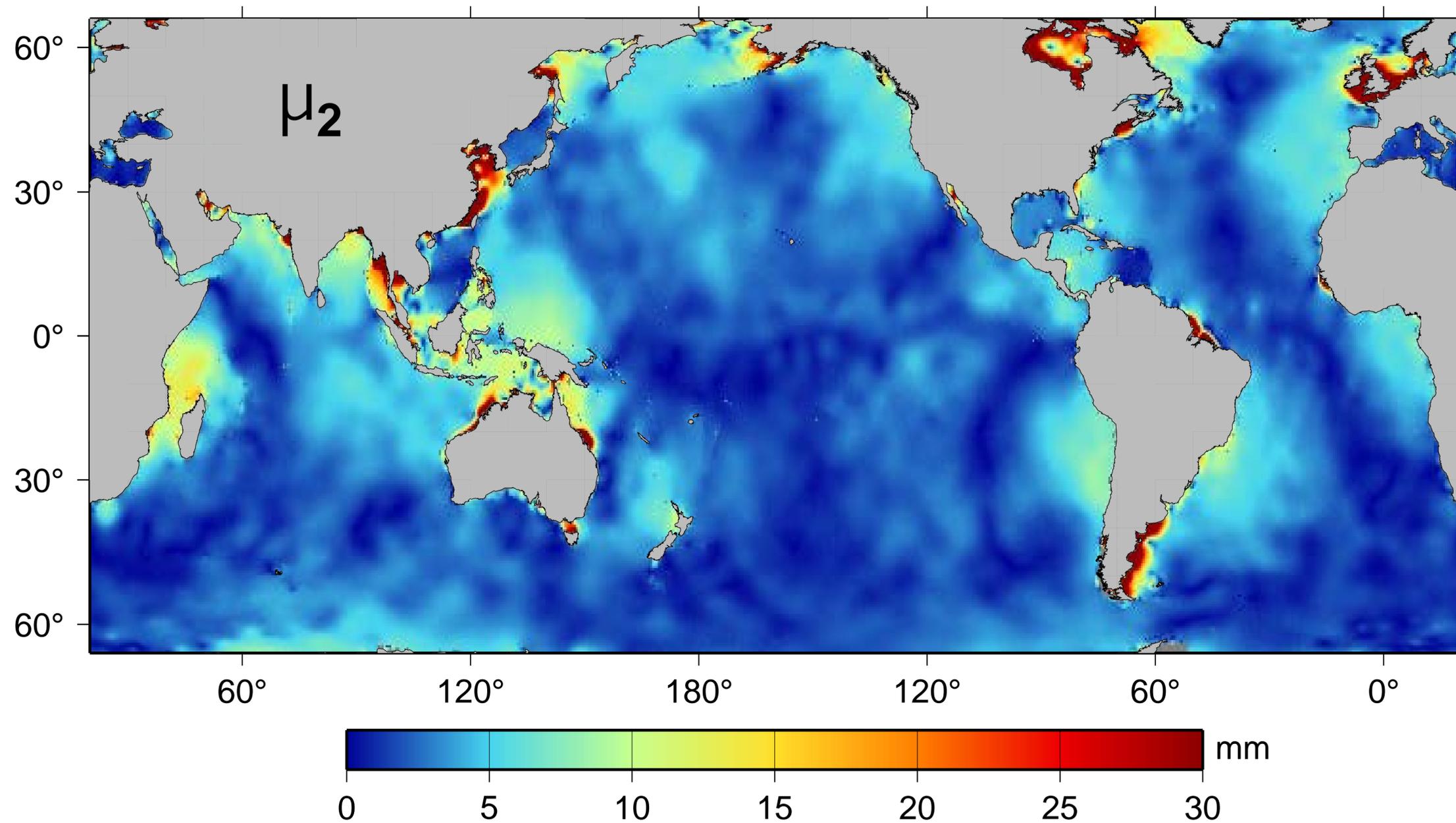


In general, μ_2 is 20% larger than $2N_2$,
so color table adjusted accordingly

Larger μ_2 residuals show presence on nonlinear $2MS_2$

Can we map the nonlinear $2MS_2$ coinciding with μ_2 ?

GOT5 minus (inferred) GOT5 = $2MS_2$?



Accuracy Assessments of Deep-Ocean Minor Tides

Direct Estimation versus Inference

RMS differences (mm) with ~150 bottom-pressure stations

	2Q1 Direct	2Q1 Infer	P1 Direct	P1 Infer	J1 Direct	J1 Infer	OO1 Direct	OO1 Infer	mu2 Direct	mu2 Infer	nu2 Direct	nu2 Infer
GOT4.7			2.34	2.02								
GOT4.10c			2.45	1.91								
GOT5 β	0.63	0.84	1.48	1.79	0.97	1.74	0.93	2.53	0.79	2.50	0.89	0.71
HAM12			1.99	1.91								
FES2014*			1.38	1.74	4.50	1.71			0.96	2.59	0.90	0.70

hydrodynamic only

*** Warning: FES2014 may have assimilated some test stations**

Recommendations for Handling Minor Tides

Tides in middle of bands can still be inferred (admittances interpolated, not extrapolated).

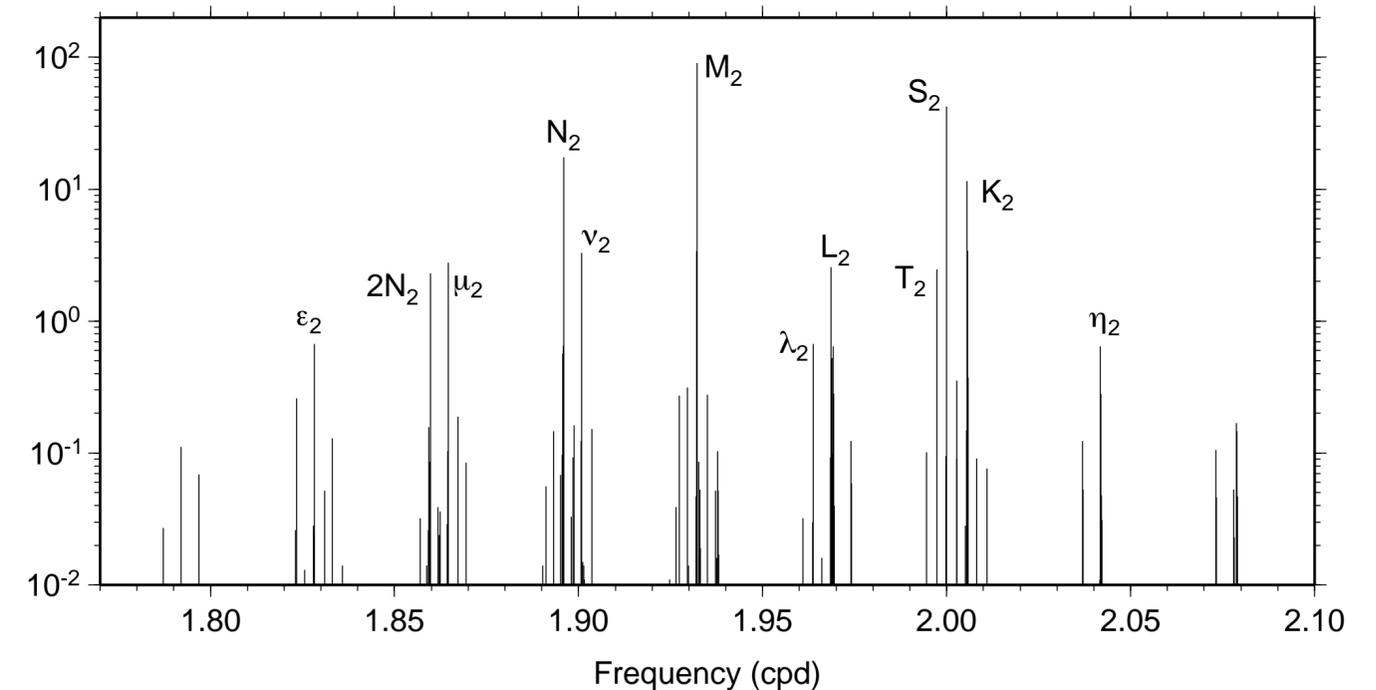
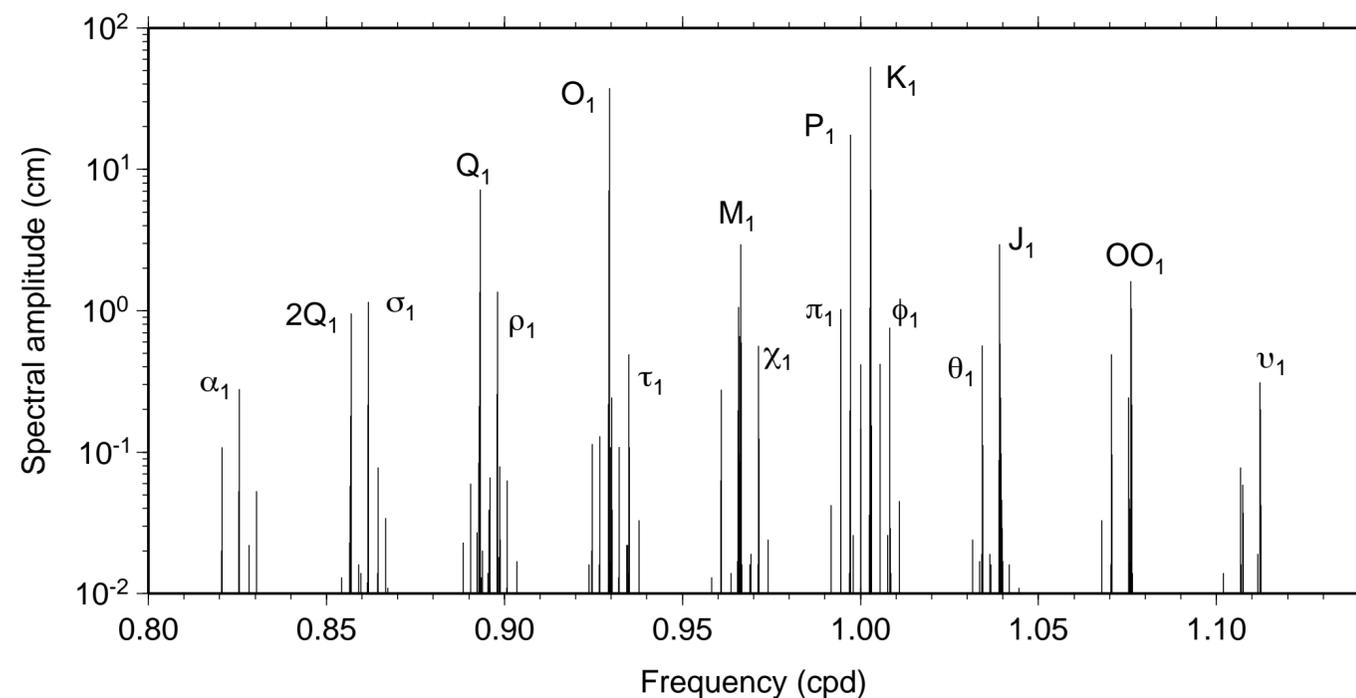
M1 nu2

Tides affected by nonlinearity must be directly estimated (but not everywhere?)

mu2 (2MS₂) L2 (2MN₂) tau1 (MP₁)

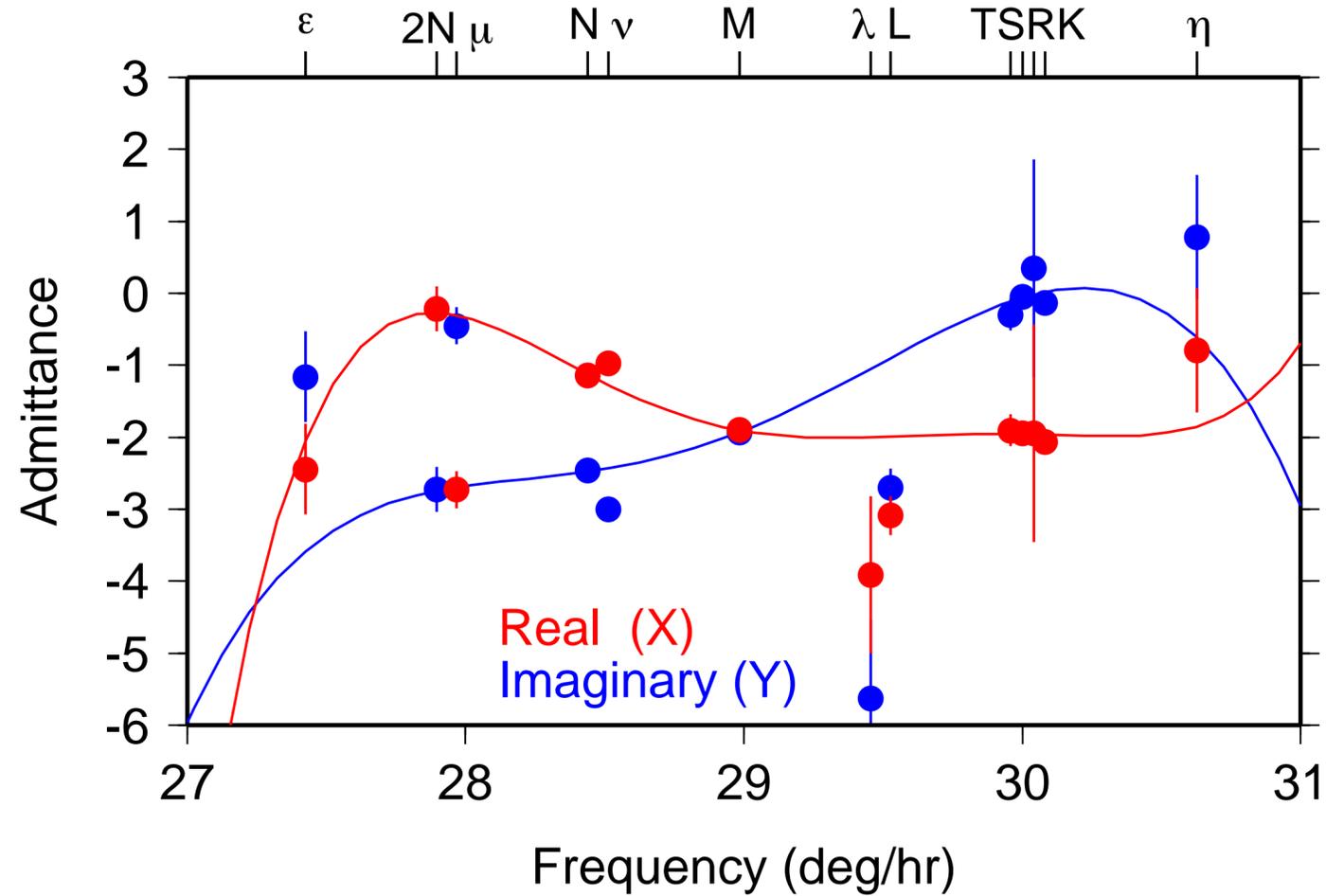
Tides at edges of bands can now be directly estimated (depending on SNR).

2Q1 sigma1 J1 OO1



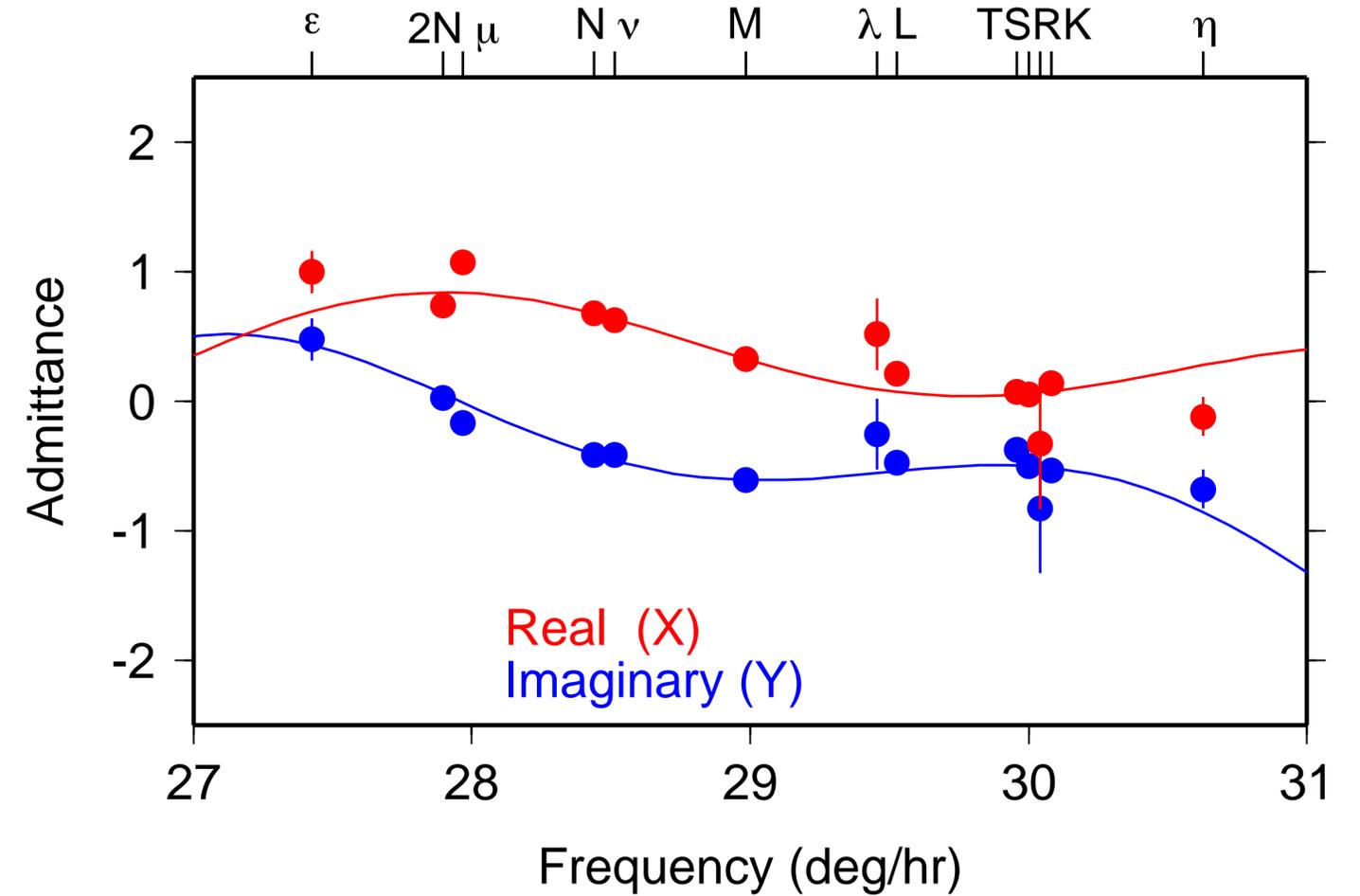
Semidiurnal Admittances

Very nonlinear at mu2



Newlyn, UK

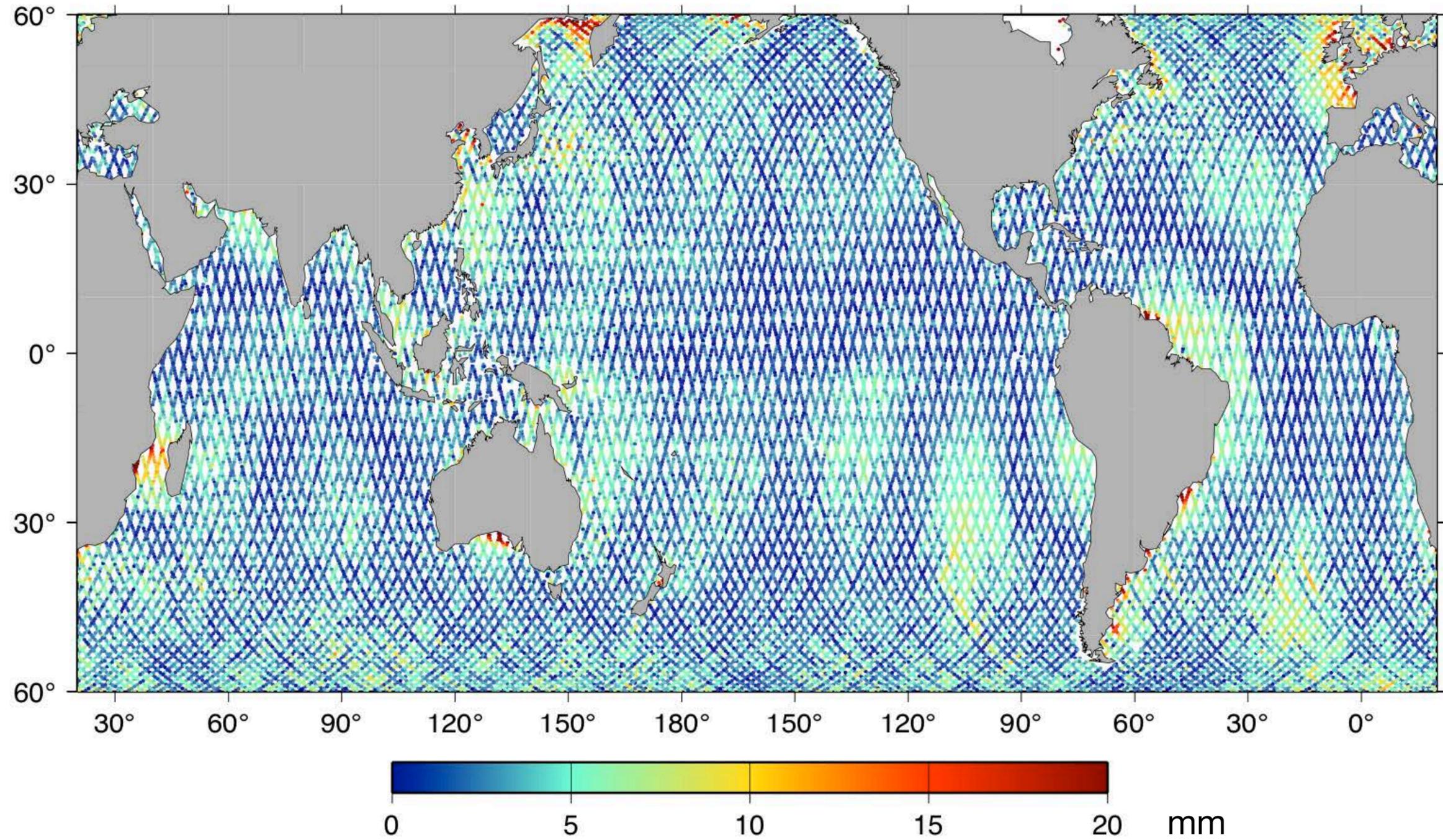
A little nonlinear at mu2



Valparaiso, Chile

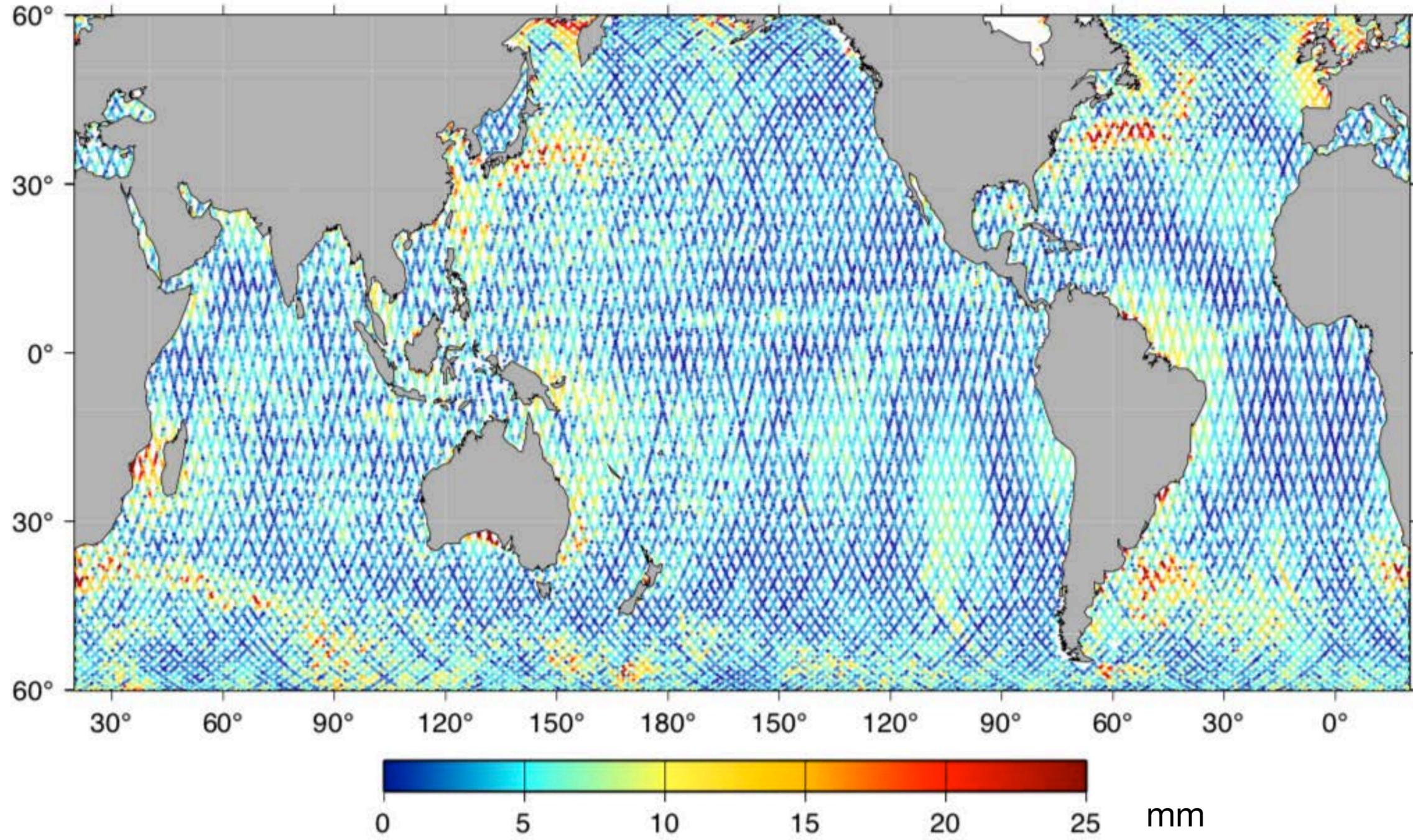
TOPEX + Jason along-track estimates of M3

27 years of altimeter measurements



TOPEX + Jason along-track estimates of M3

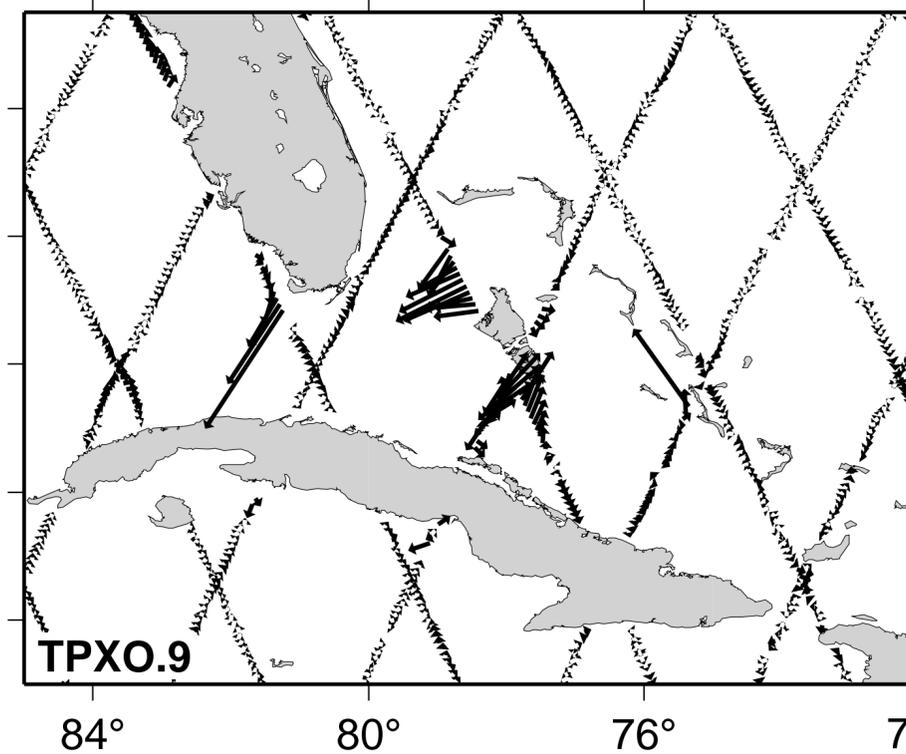
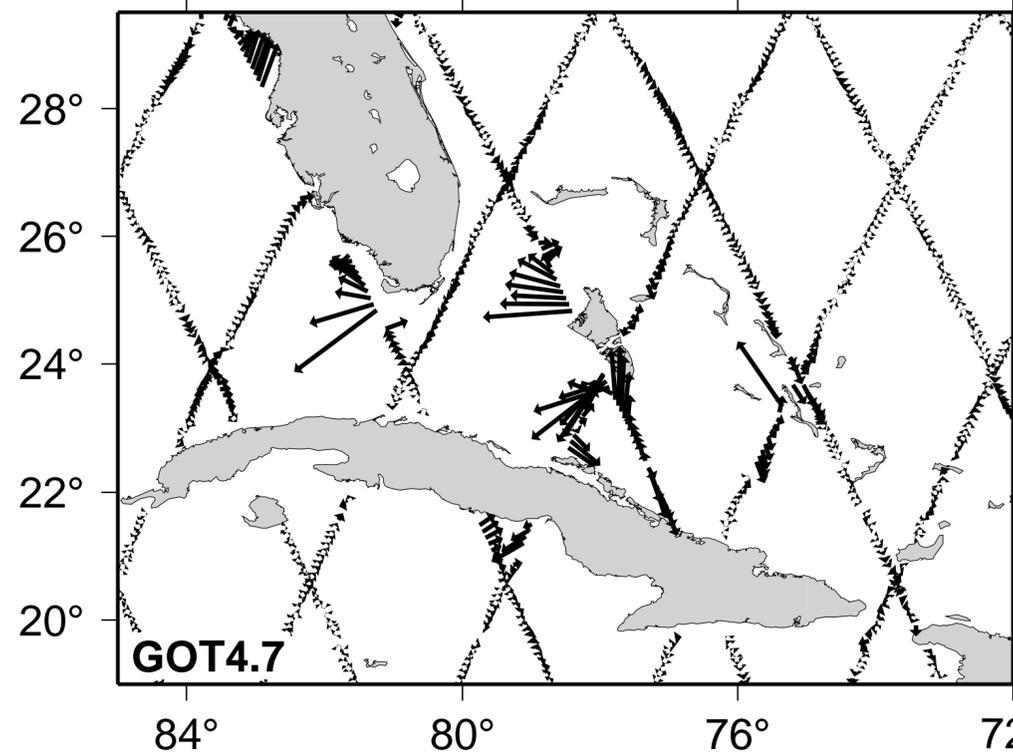
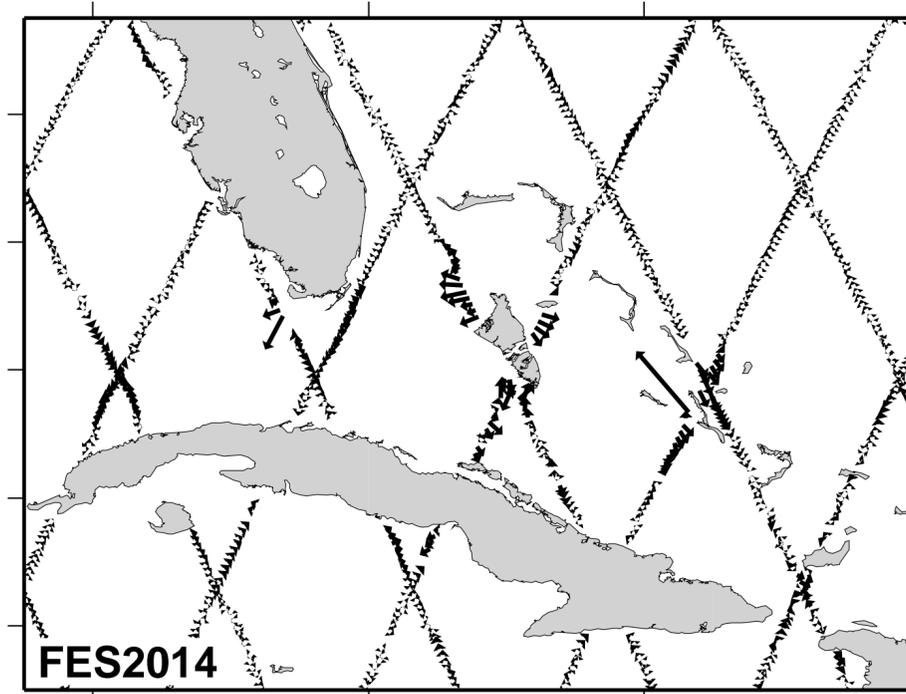
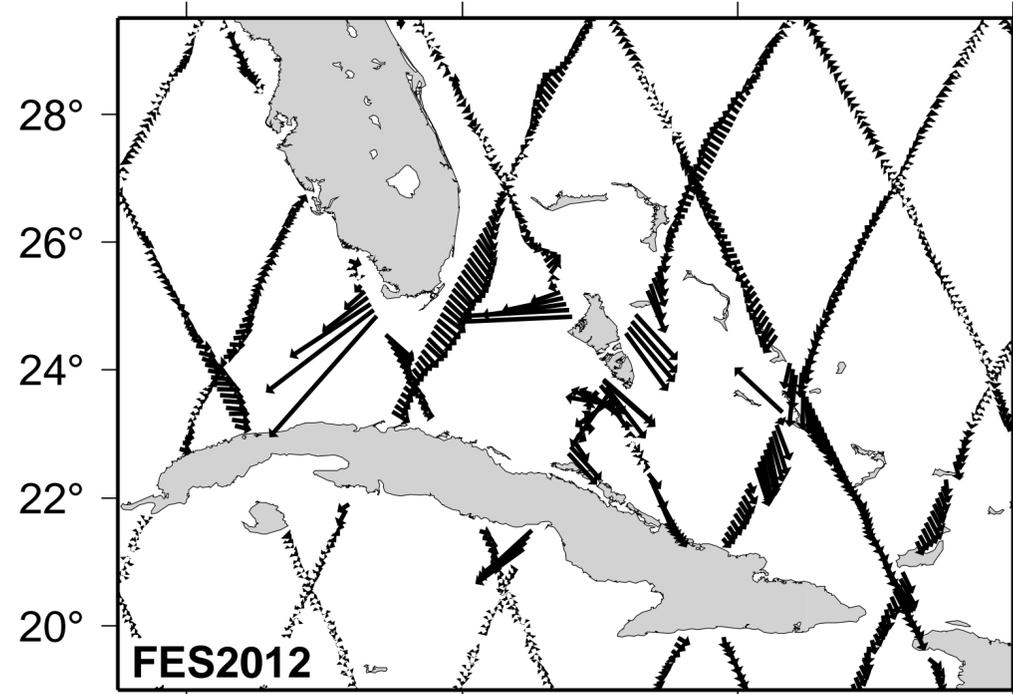
27 years of altimeter measurements



Discrepancies between Tide Models and Along-Track Altimetry

M2 Residuals

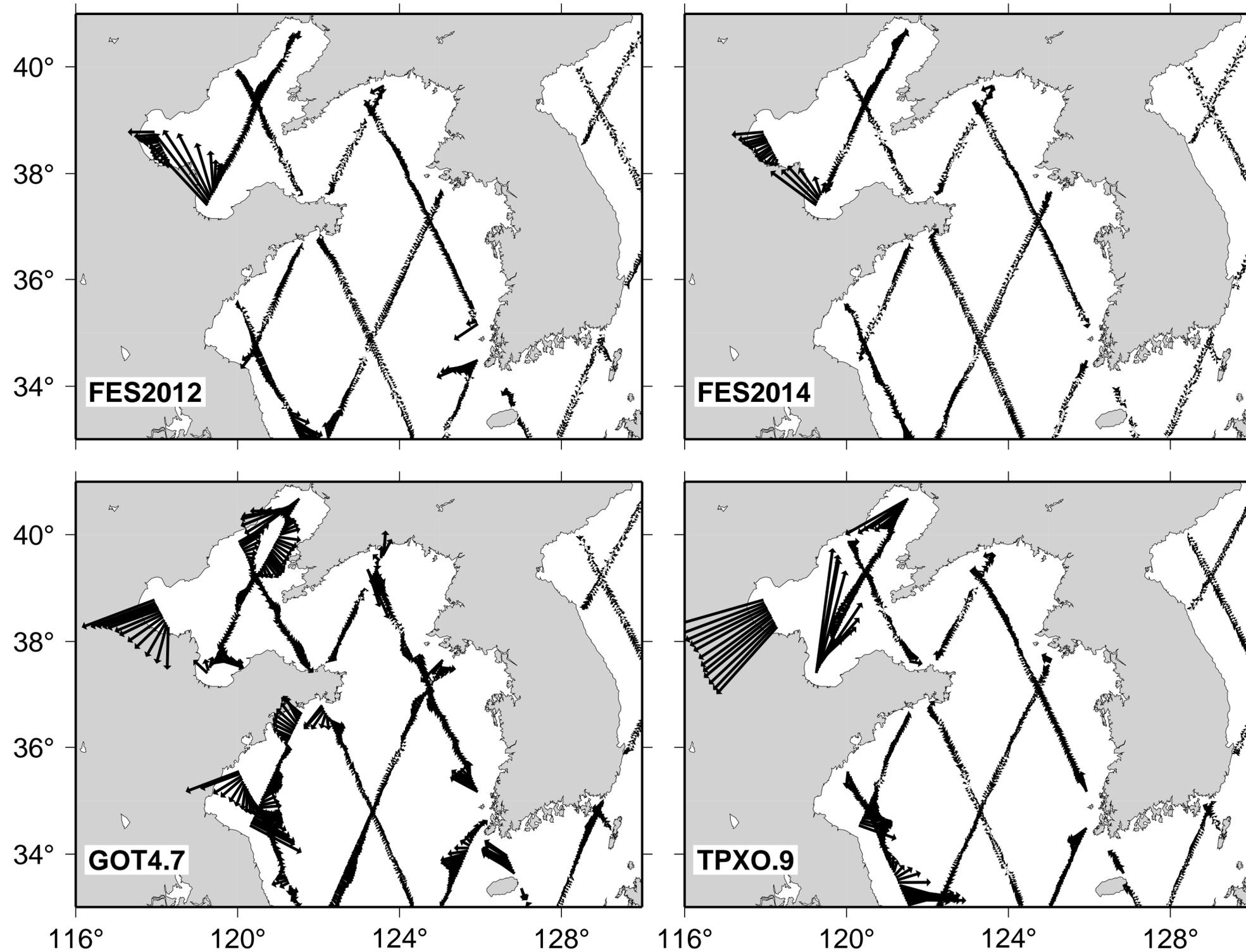
← 25 cm



Discrepancies between Tide Models and Along-Track Altimetry

M2 Residuals

← 25 cm



(Noisy) Tide Residual Amplitudes from Altimetry

Prior = FES2014

Envisat only

SARAL only

Cryosat-2 only

