Status of Tide Modeling for SWOT

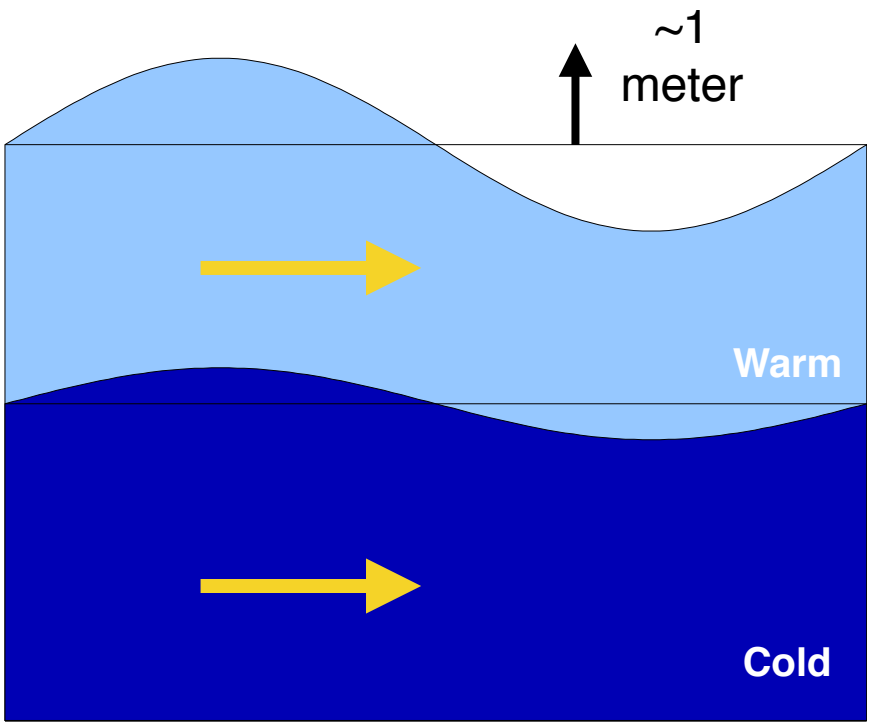
Florent Lyard
LEGOS

Richard Ray
NASA Goddard Space Flight Center

Special thanks to: Loren Carrère and Ed Zaron

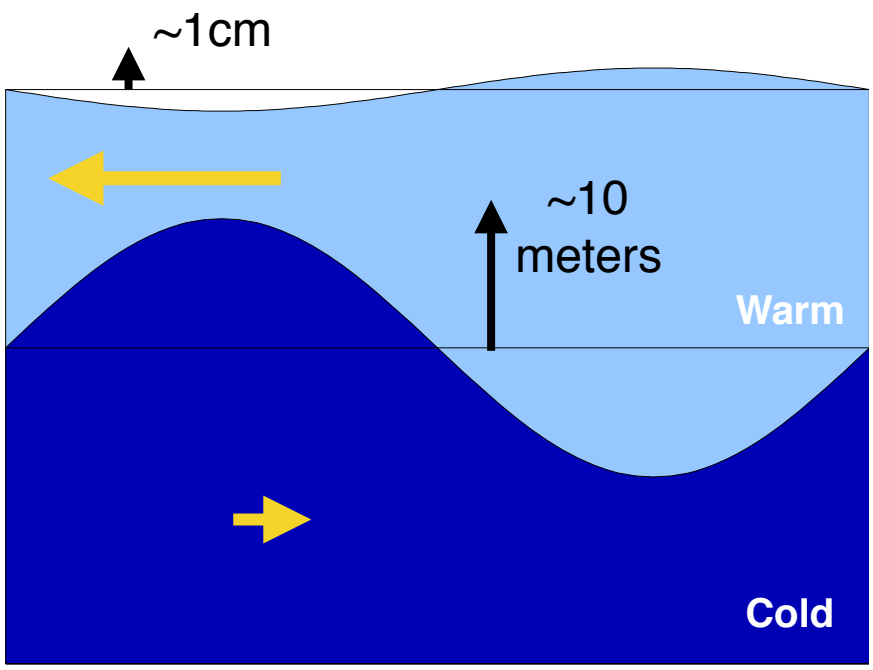
SWOT Science Team Meeting, Montreal June 2018

Surface Tide
(Barotropic)



Currents are same
top to bottom

Internal Tide
(Baroclinic)

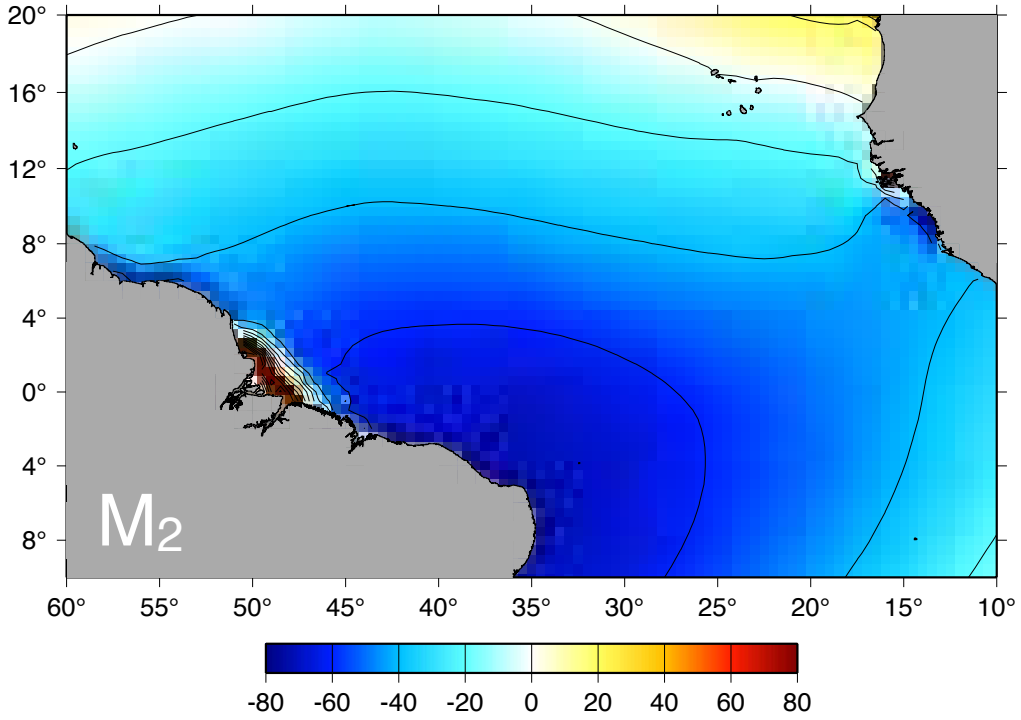


Currents undergo
vertical shear

– Sea Surface Heights –

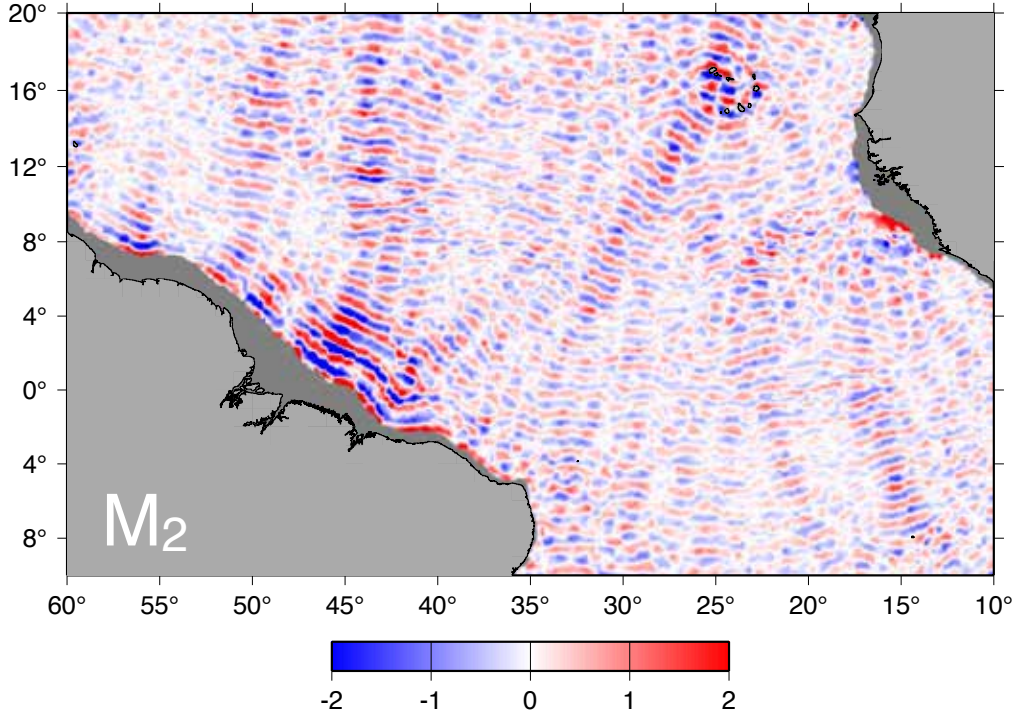
snapshot as Moon passes Greenwich

Surface Tide
(Barotropic)



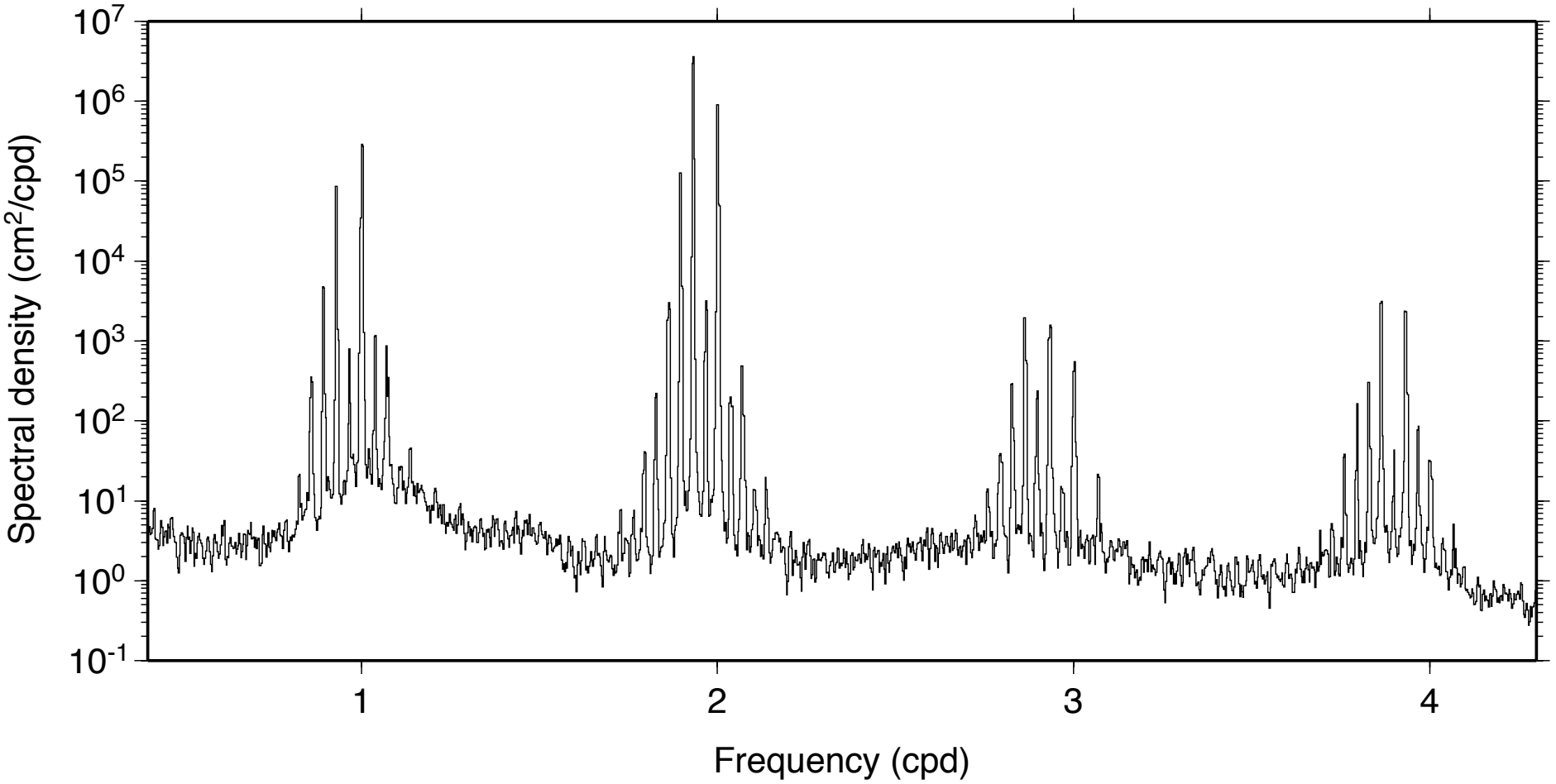
centimeters

Internal Tide
(Baroclinic)



centimeters

Sea Level Spectrum
Darwin, Australia



Frequency splitting at cycle/day, cycle/month, cycle/year, cycle/18.6y
Tidal "constituents" separated by 1 cycle/year.
Amplitude of M_2 = 185 cm; M_4 = 5.3 cm.

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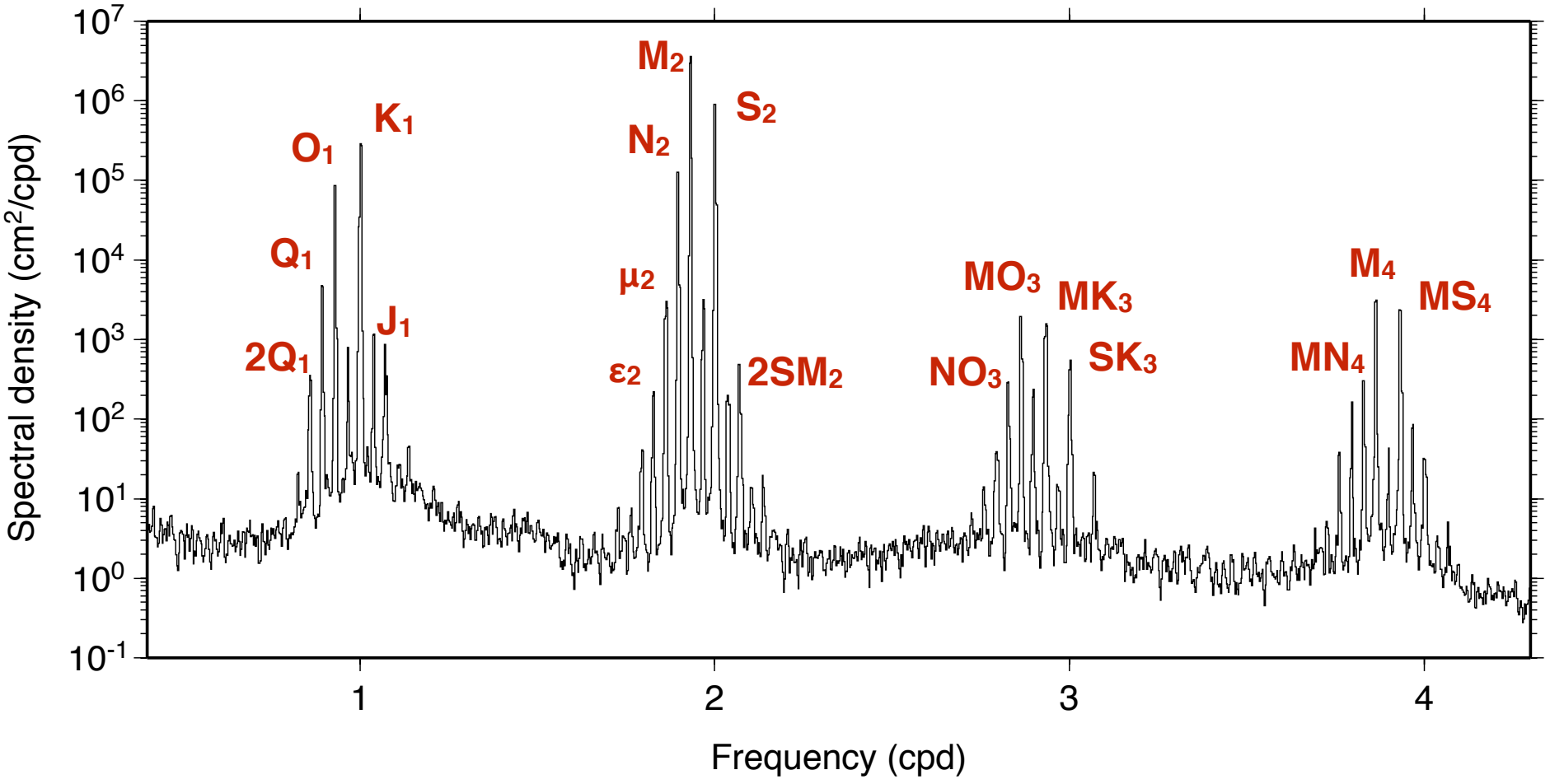
Darwin, Australia



Frequency splitting at cycle/day, cycle/month, cycle/year, cycle/18.6y
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Global internal-tide SSH models

A moving target!

Empirical / assimilation fits to satellite altimetry

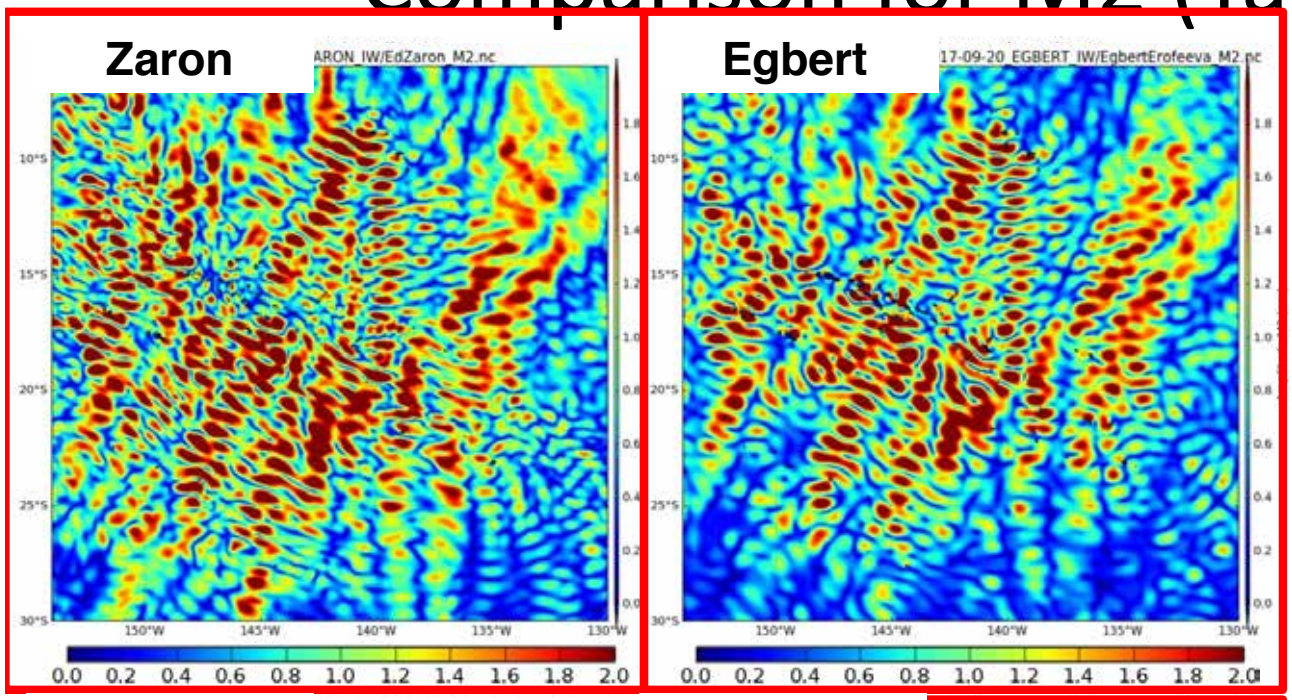
Authors	# constituents	Method
Dushaw	2	ω-k regional decomposition
Zhao	4	local plane wave fitting
Ray-Zaron	2	2-D interpolation; no physics
Zaron	4+	modified plane wave
Egbert-Erofeeva	4	reduced-gravity assimilation

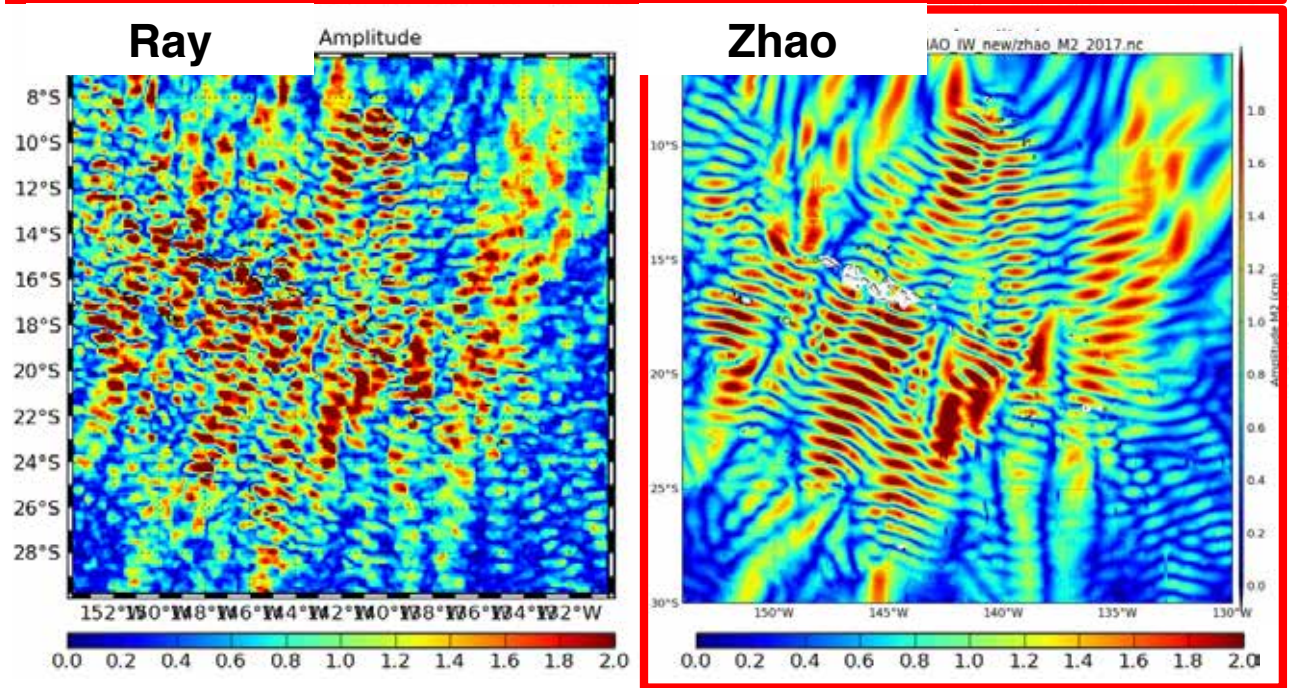
Our SWOT team

Tides in OGCMs (forward models only)

Authors	Underlying OGCM	Resolution
Arbic + NRL	HYCOM	(1/12)°, (1/25)° – 41 layers
Müller	STORMTIDE (MPI)	(1/10)° – 40 layers
Menemenlis	MITgcm	(1/12)°, (1/48)° – 90 layers
Simmons	GOLD	(1/8)° – 50 layers
Mercator group	NEMO	(1/12)° – 75 layers

Comparison for M2 (Tahiti) – V2

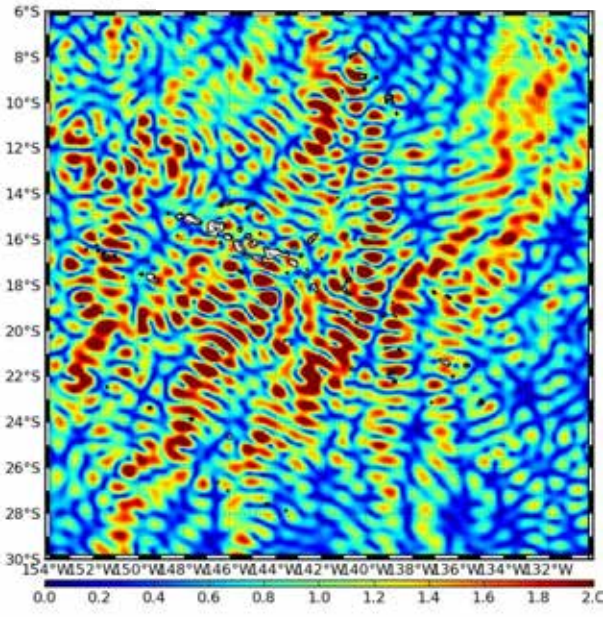




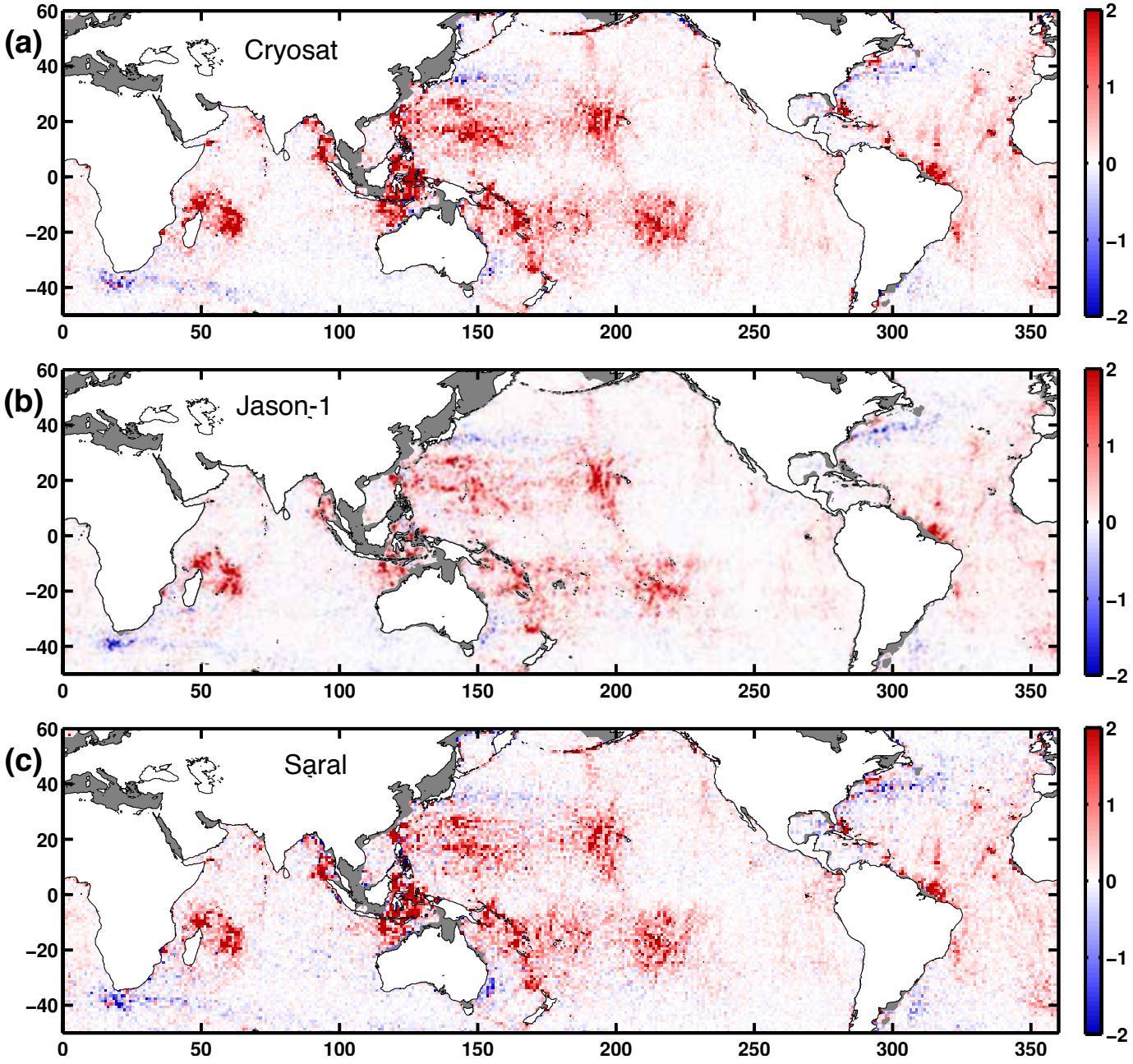
Slide courtesy of Loren Carrère

M2 amplitudes (cm)

Dushaw



Test of an internal-tide correction for altimetry: Variance reductions (cm^2) with independent data



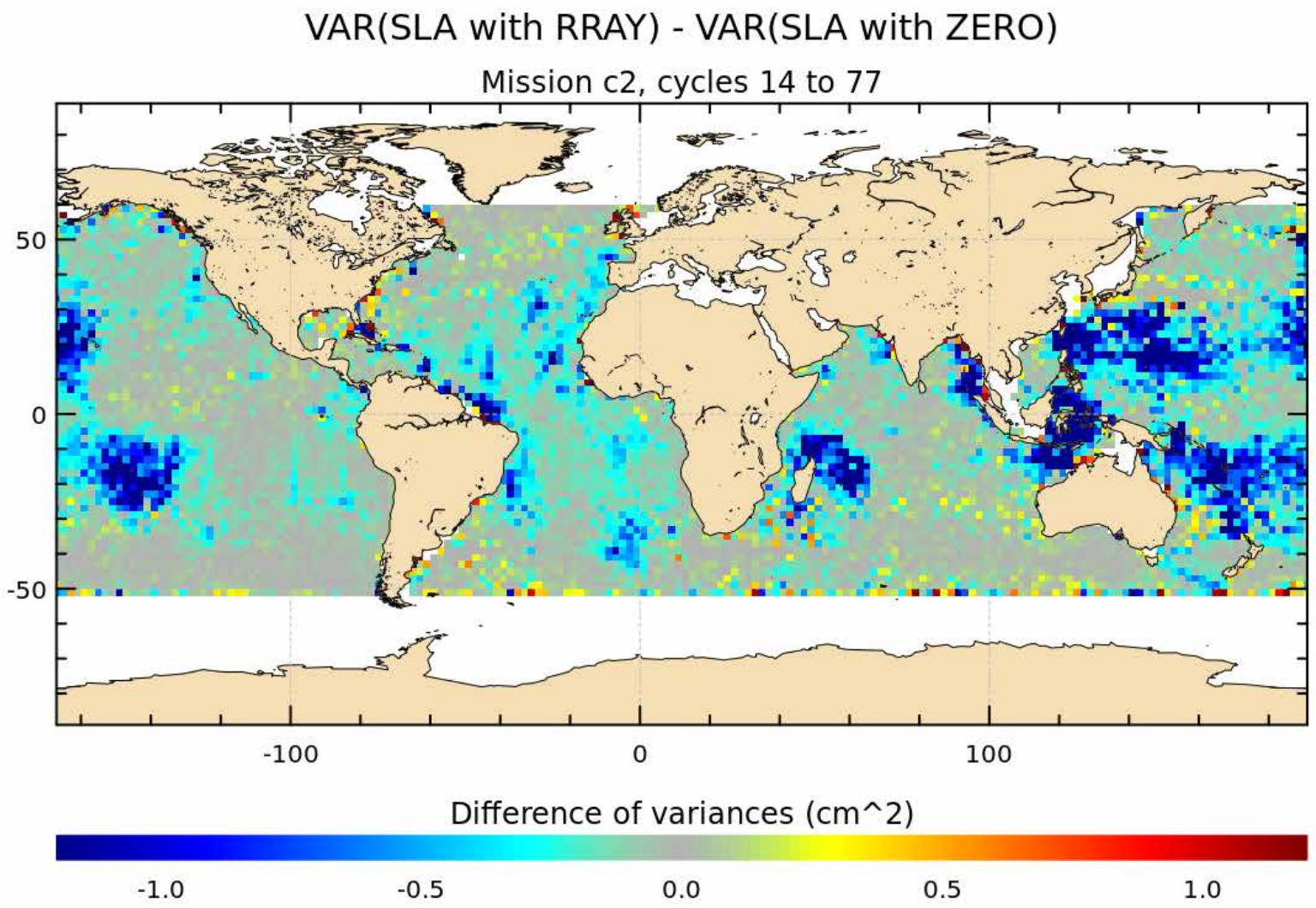
Red - good

Blue - bad

Ray & Zaron, JPO, 2016

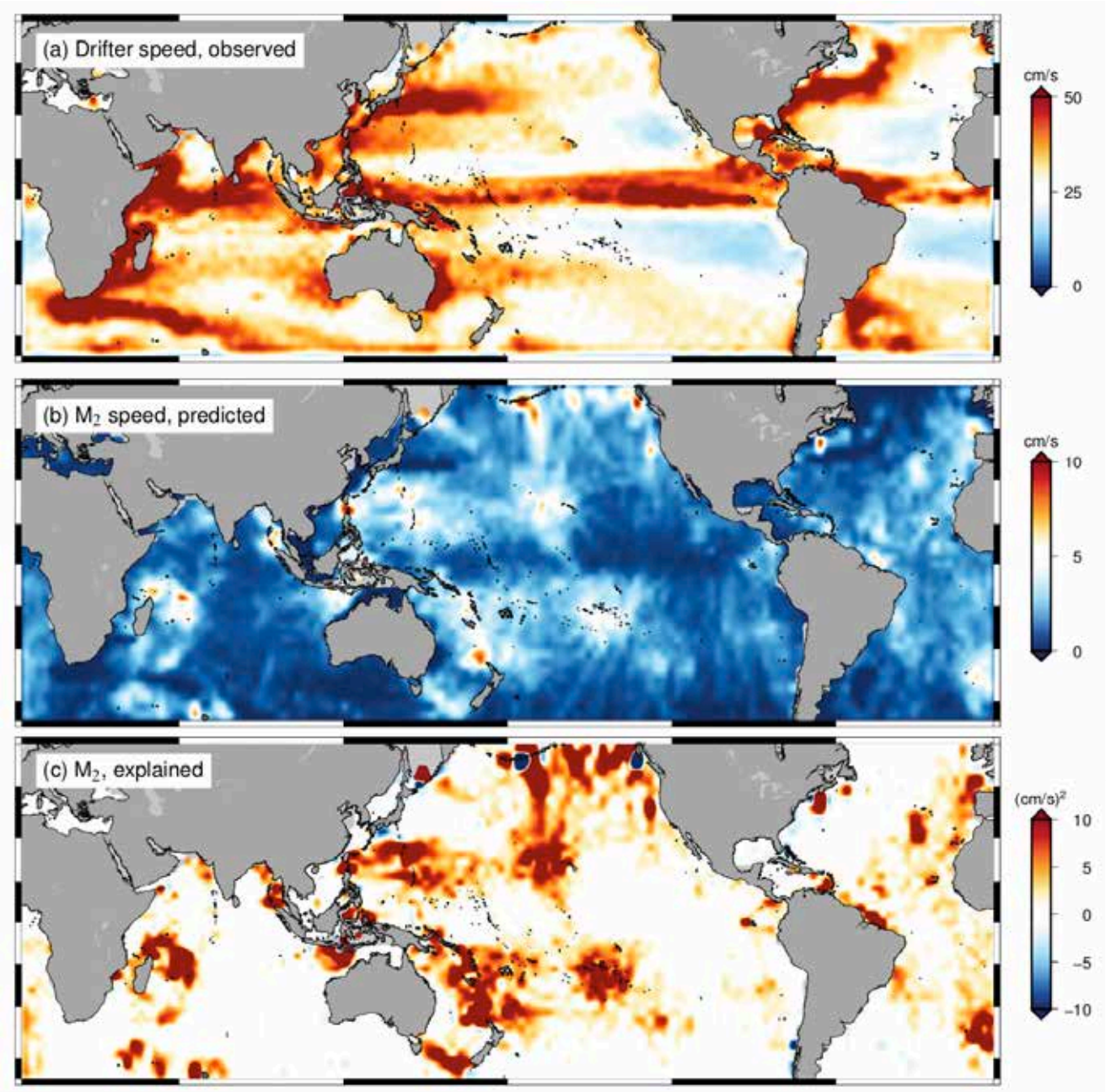
Test of an internal-tide correction for altimetry: Variance reductions (cm^2) with independent data – Cryosat-2

[slide from Loren Carrère]



blue is good; yellow/red is bad

Validation with Surface Drifter Data



The IT model reduces variance of observed surface velocity, almost everywhere

Details in Ed Zaron's splinter talk

SWOT project will have validated model(s) of stationary mode-1 internal tides for use with initial SWOT data.

Reliable for M2, O1, K1 + possibly seasonal modulations.

Less reliable: S2 (because ERS/Envisat/SARAL were sun-synch).

What to do about non-stationary internal tides?

And how bad is it?

Contents lists available at ScienceDirect

Deep-Sea Research I

journal homepage: www.elsevier.com/locate/dsri

On the predictability of mode-1 internal tides

Brian D. Dushaw [a,*], Peter F. Worcester [b], Matthew A. Dzieciuch [b]

[a] Applied Physics Laboratory. University of Washington. 1013 N.E. 40th Street. Seattle. WA 98105-6698. United States
[b] Scripps Institution of Oceanography, University of California at San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0225, United States

ARTICLE INFO

Article history:
Received 30 September 2010
Received in revised form
10 February 2011
Accepted 11 April 2011
Available online 17 April 2011

ABSTRACT

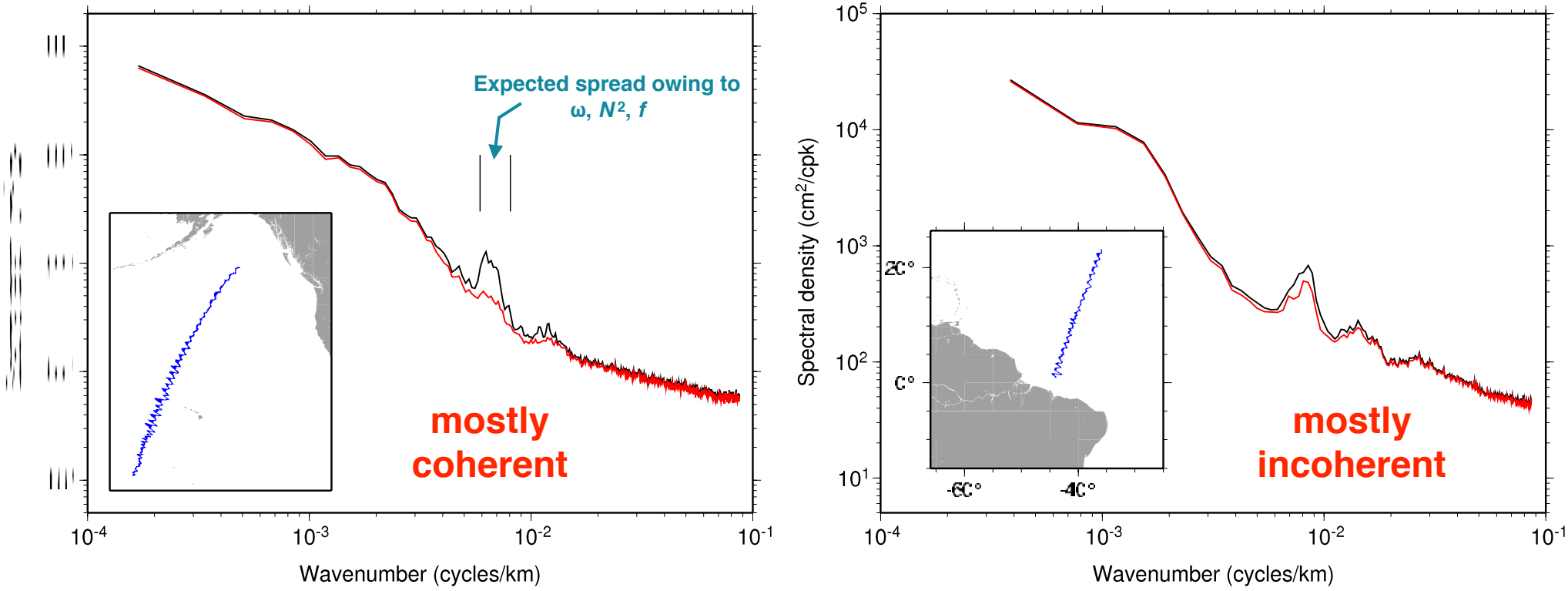
A frequency–wavenumber tidal analysis for deriving internal-tide harmonic constants from TOPEX/Poseidon (T/P) measurements of sea-surface height (SSH) has been developed, taking advantage of the evident temporal and spatial coherence and the weak dissipation of internal tides. Previous analyses consisted of simple tidal analysis at individual points, which gave inconsistent harmonic constants at altimeter track crossover points. Such analyses have difficulty in distinguishing between the effects of interference, incoherence, and dissipation. The frequency–wavenumber analysis provides an objective

"The primary conclusion of this paper is that the mode-1 internal tide is predictable… much like the barotropic tide is predictable…. Temporally incoherent contributions to mode-1 internal tides appear to be minimal."

– Dushaw et al., April 2011

Wavenumber Spectrum of Altimetric Sea-Surface Heights

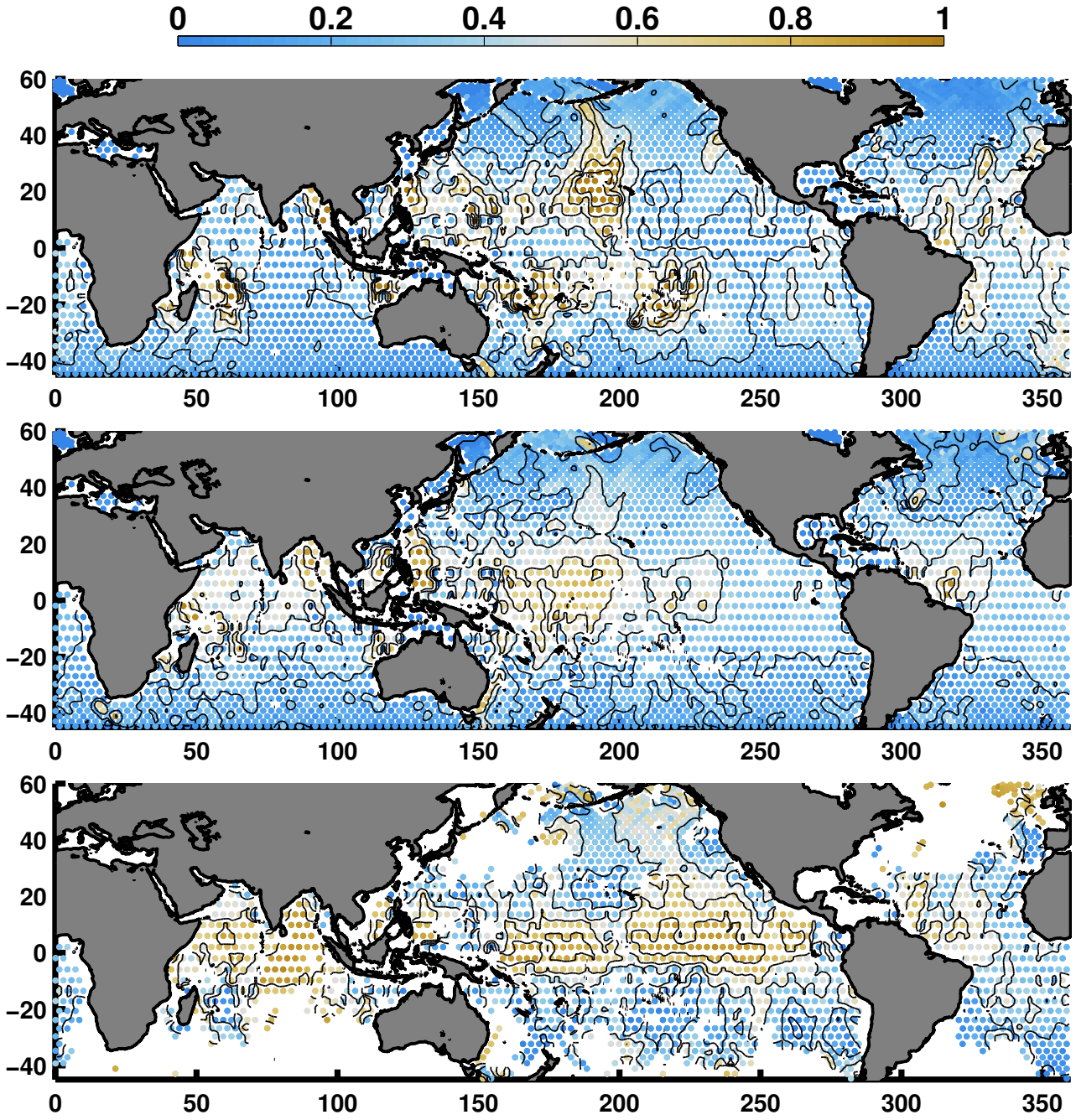
Spectral peaks in SSH from internal tides
(mostly semidiurnal mode-1)



Black curves: spectra using barotropic tide model
Red curves: spectra after removing estimated along-track tides (coherent over 17 y)

Is the ocean mostly like left panel, or right panel? Why?

Ray & Zaron, *GRL*, 2011.



RMS amplitude (cm) of stationary tide

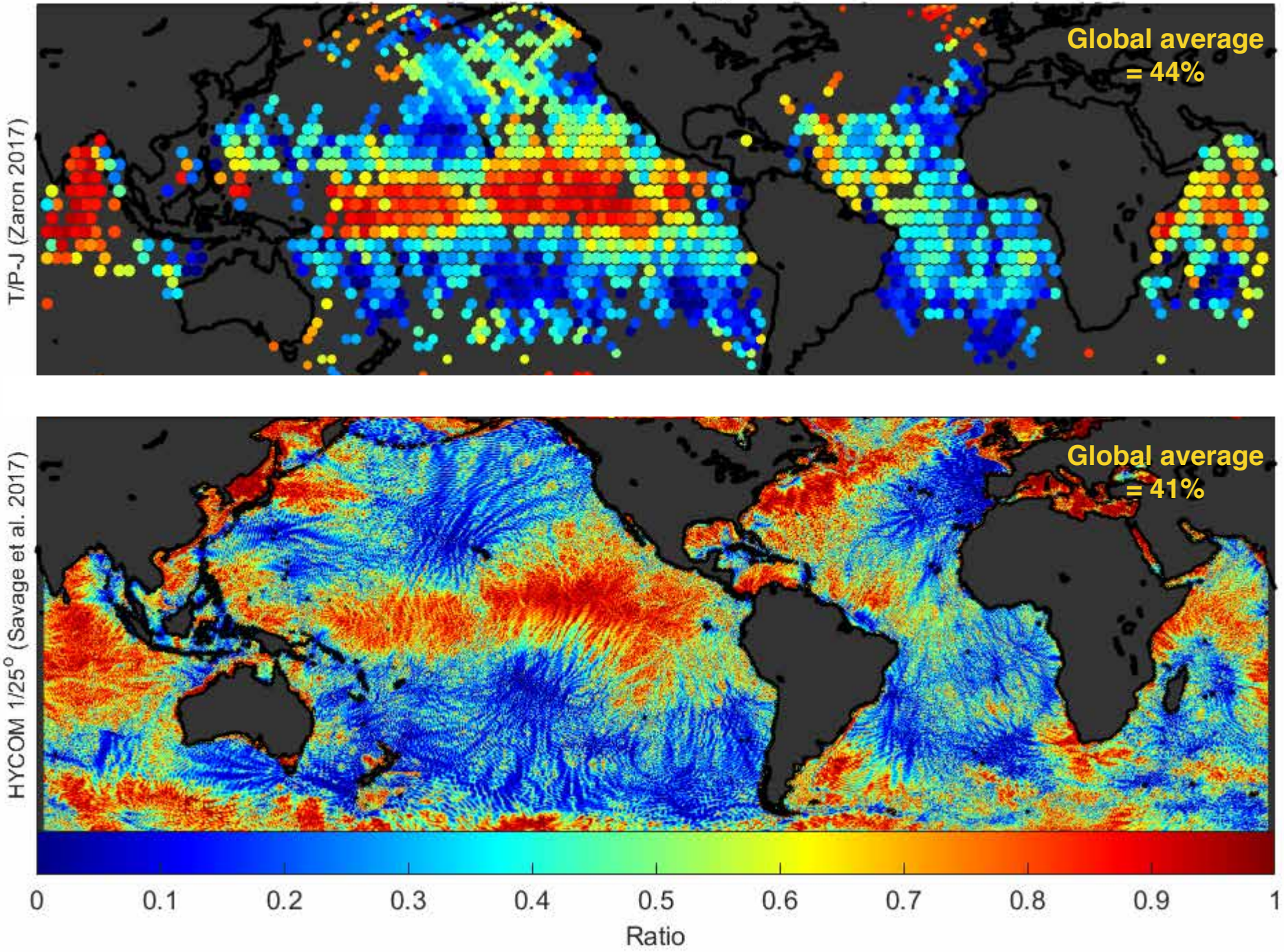
RMS amplitude (cm) of non-stationary tide

Ratio of variances non-stationary / total

Global average = 44%

Zaron, "Mapping the nonstationary internal tide with satellite altimetry," *JGR-Oceans*, 2017.

Semidiurnal Non-stationary Variance Fraction



Slide courtesy Arin Nelson

What to do about the non-stationary tide?

1. Account for seasonal variability.

   M2 → M2, MA2, MB2 (frequency splitting at 1 cpy).

2. Use OGCM to provide corrections? Not now, maybe someday.

3. Use SWOT data themselves to recognize & remove.

   Analyze non-stationarity in HYCOM, MITgcm, AMSEAS to understand signal.

   Analyze SWOT within swath with expected spatial/temporal patterns.

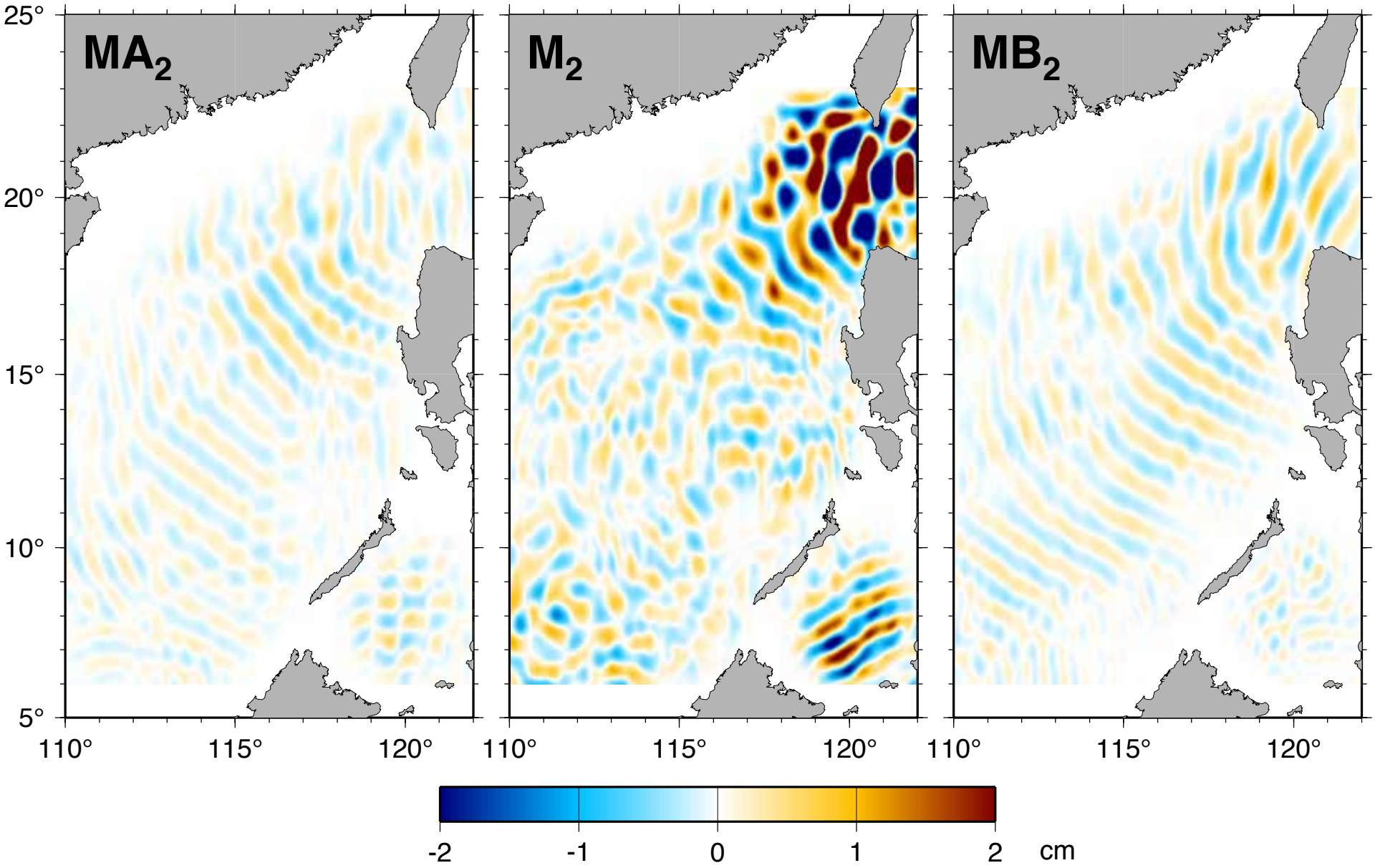
4. Live with it.

   Mildly non-stationary tides will appear (approximately) at known alias periods.

   Wildly non-stationary (e.g. intermittent) tides ?

   (But is mode-1 ever intermittent?)

Empirically mapped M2 + annual sidelines



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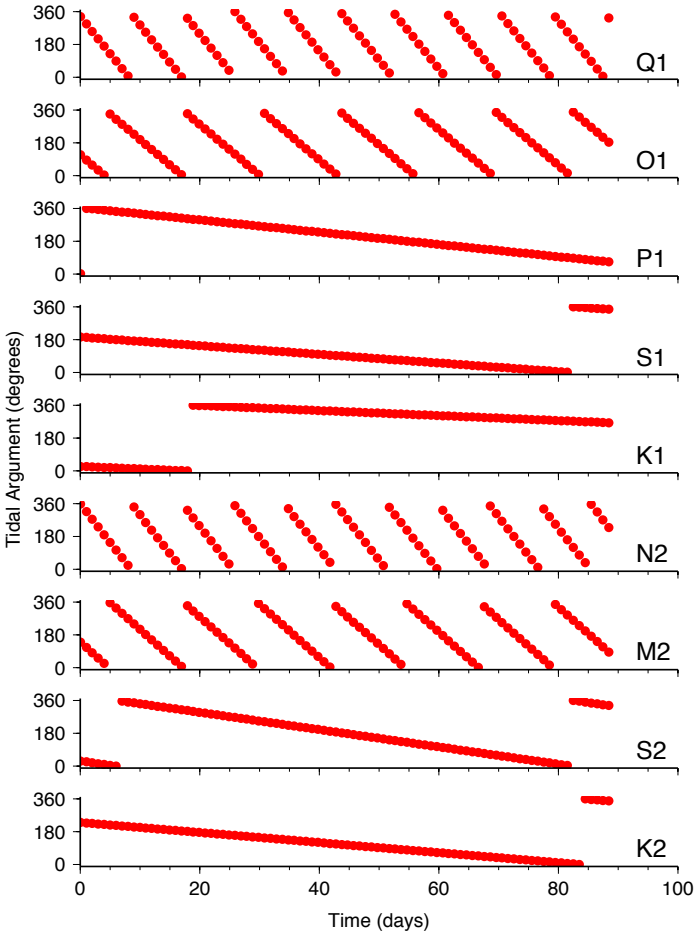
SWOT Tidal Alias Periods (days)

	1-day repeat	21-day repeat
O1	13.0	52.9
K1	262.3	266.5
N2	8.5	47.3
M2	12.4	66.0
S2	76.3	77.0

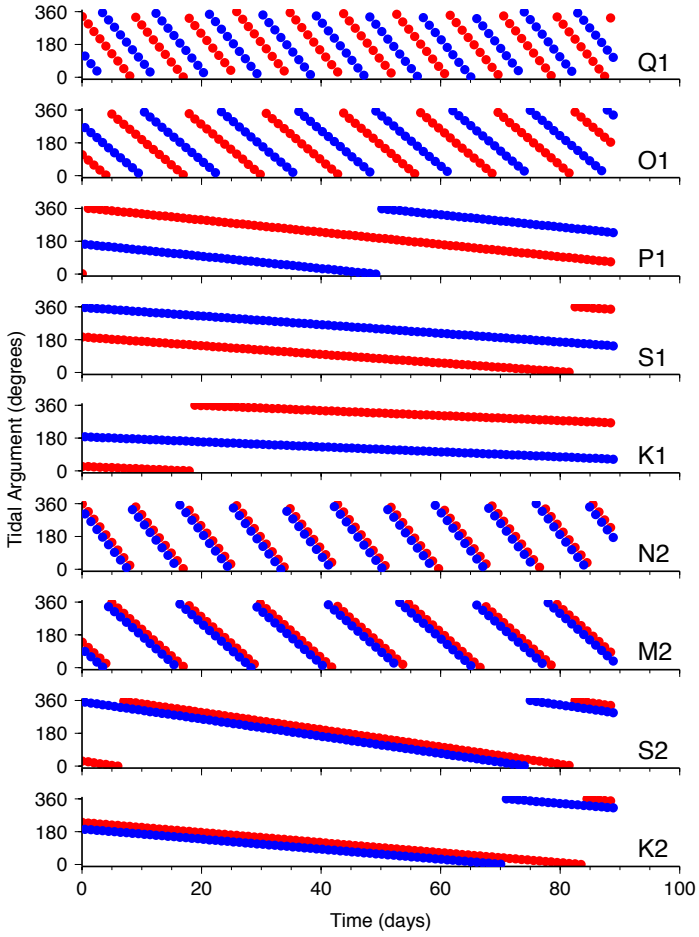
Actual repeat periods = 0.99349 days, 20.86460 days

1-day Orbit will be Fun for Tides!!

Phase sampling
over 90 days



Phase sampling
at California x-over



Red dots - ascending arcs
Blue dots - descending arcs

7 full cycles of M2 will be observed.
(M2 / O1 coupled, but not at x-overs.)