



Internal tides from, for, & in satellite altimeter data

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OSTST meeting – Reston

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Internal tides FROM altimetry

- Mapping internal tides empirically from multi-mission data
- Analysis of 2-D wavenumber spectra

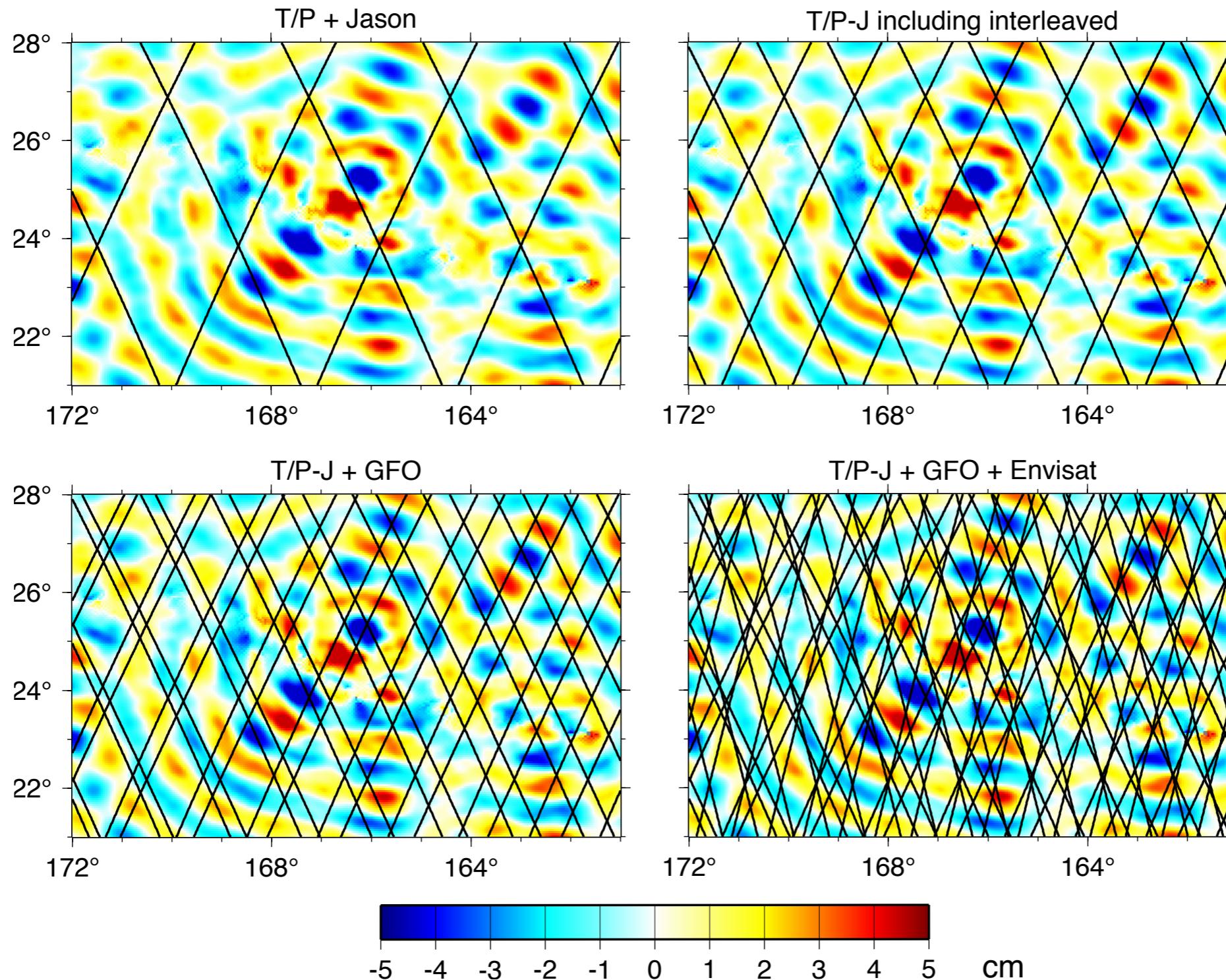
Internal tides FOR altimetry

- Use as a new tidal correction to altimetry
- Variance reduction with independent data

Internal tides IN altimetry

- Leakage of internal tides into AVISO gridded data
- Less leakage in ver.-2010 grids

M_2 internal tides near Hawaii (model from E. Zaron)



Current altimeter constellation (lower right) is marginally adequate for mapping these waves

A strictly empirical tidal analysis of satellite altimetry for internal tides

Advantage: No dynamical assumptions made about ocean waves.

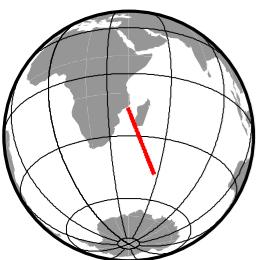
In fact, we can test dynamical theories.

Disadvantage: The present altimeter constellation is barely adequate.

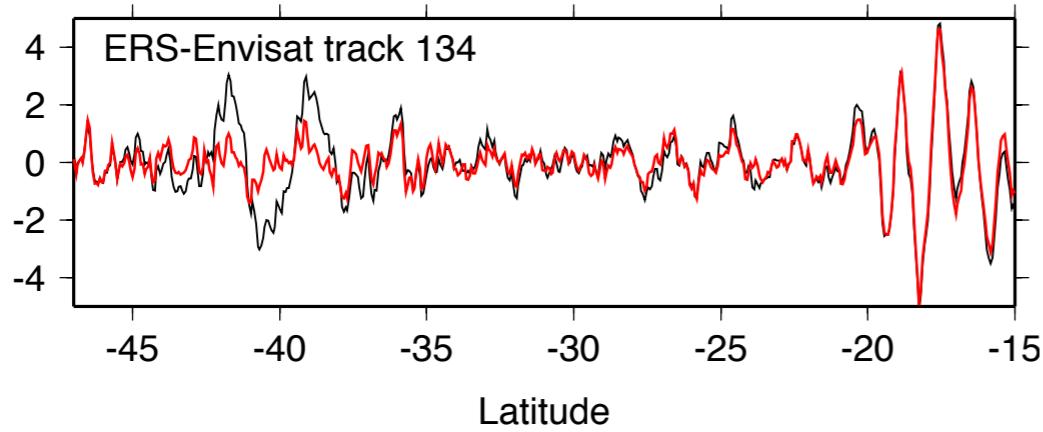
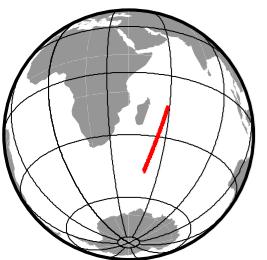
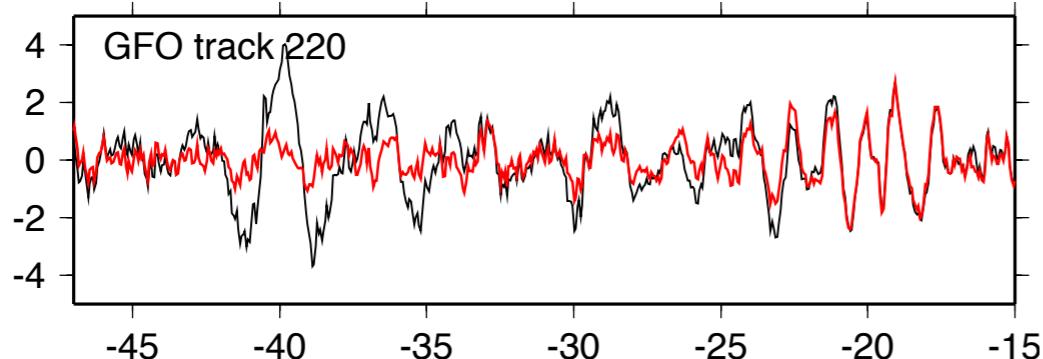
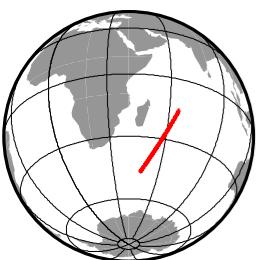
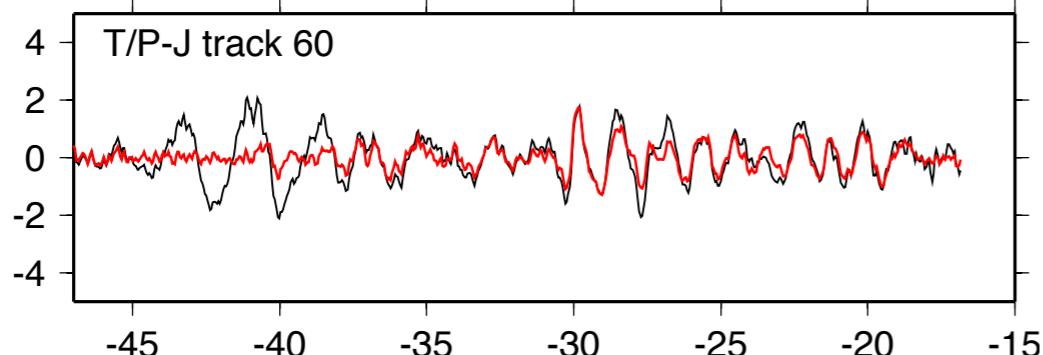
Making assumptions about wave dynamics can improve mapping results.

Advantage: Prepares for empirical analysis of SWOT data.

Using AVISO grids as a “mesoscale correction” prior to tidal analysis

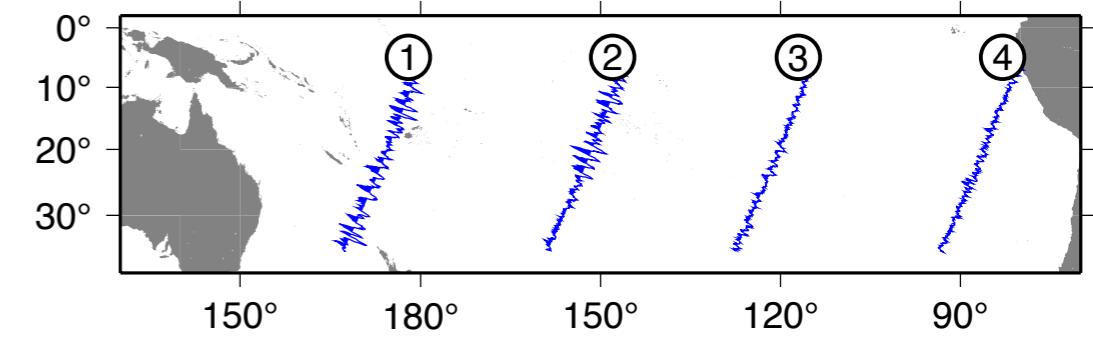


Space domain



Latitude

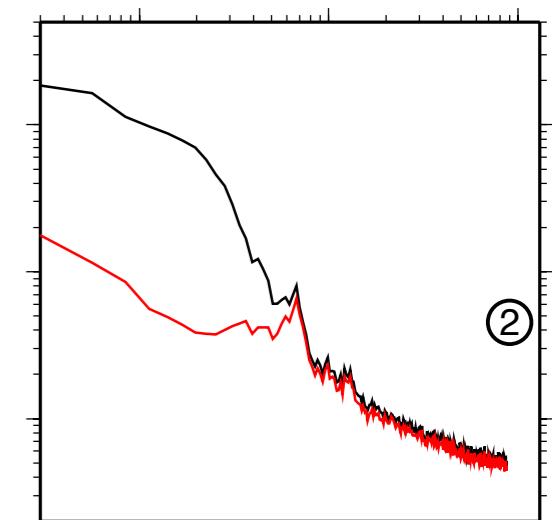
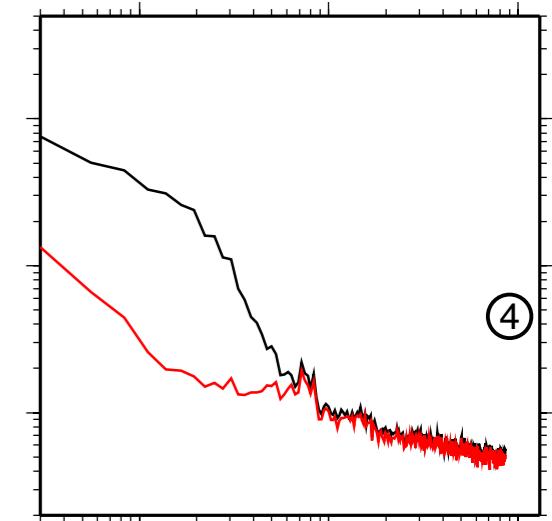
Wavenumber domain



Spectral density (cm^2/cpk)

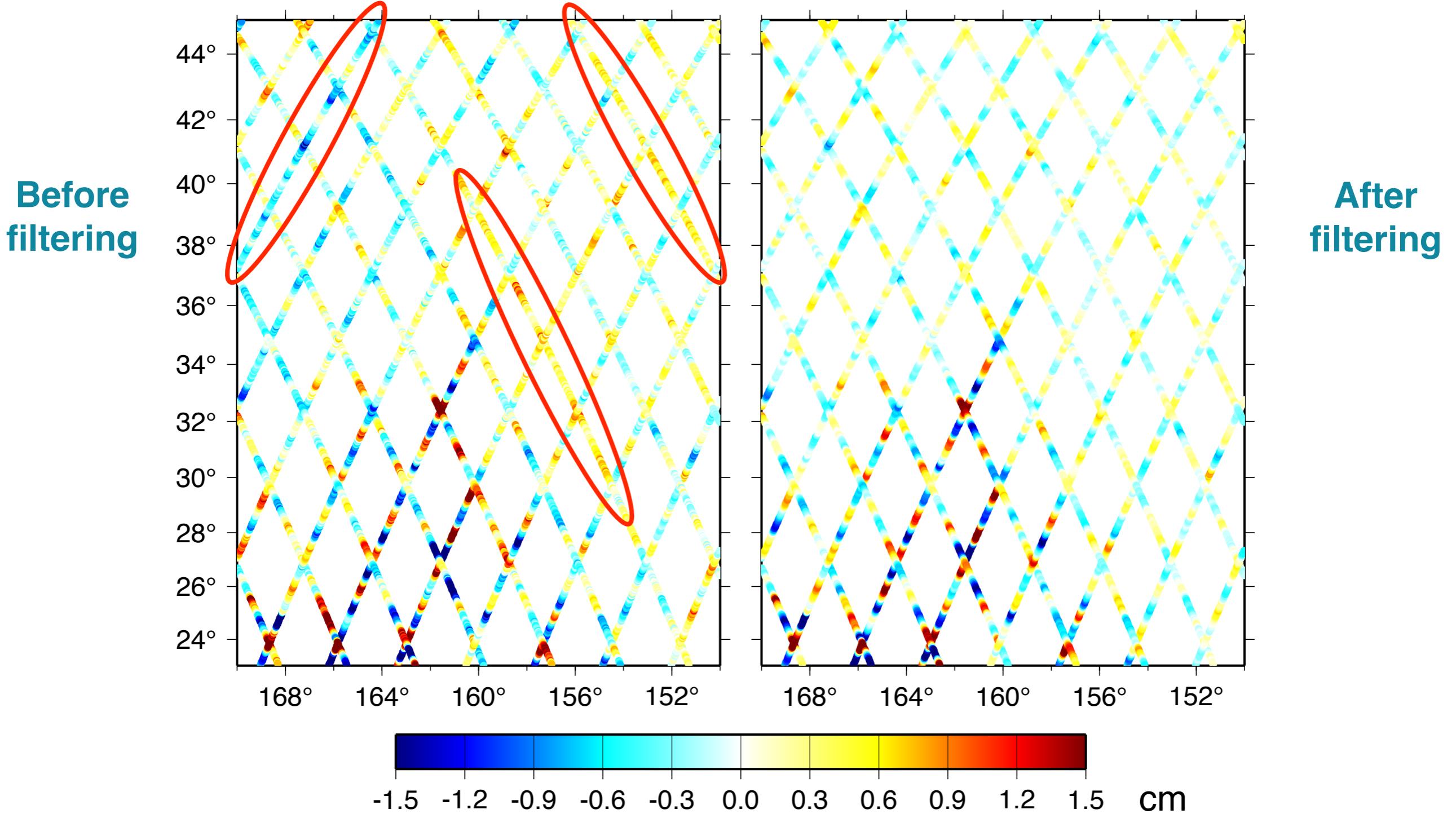
Spectral density (cm^2/cpk)

Wavenumber (cycle/km)



Wavenumber (cycle/km)

Using along-track high-pass filtering after tidal analysis



1. Advantage: internal tidal fields better defined and more consistent
2. Disadvantage: waves propagating east-west are damped.

TABLE 2. RMS differences (cm) of M_2 tidal estimates at track cross-overs^a

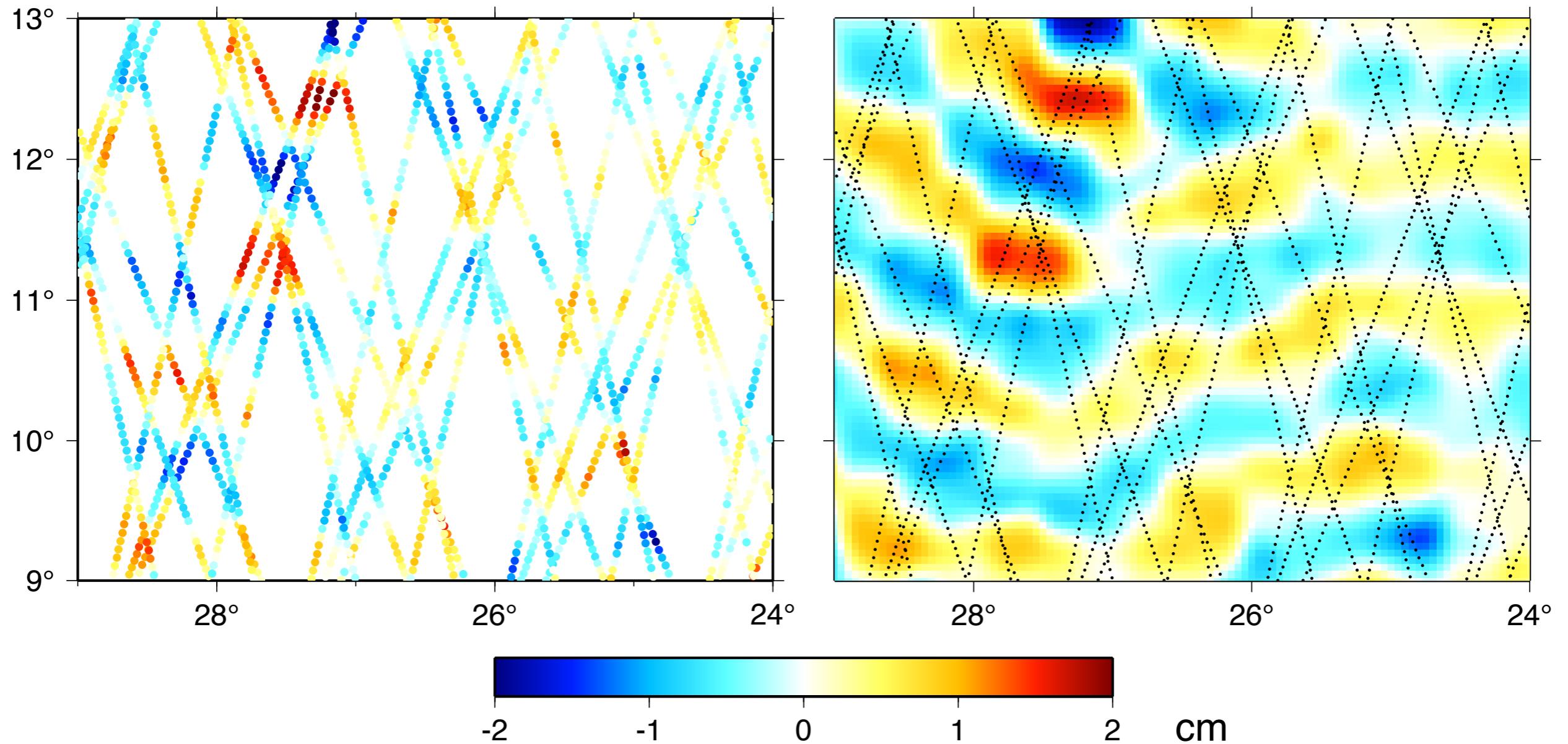
Satellite mission	Number of x-overs	$\langle \sigma \rangle$ before	$\langle \sigma \rangle$ after	RMS before	RMS after	RMS after+filter
<i>Hawaiian Ridge Region</i>						
T/P-J	73	0.50	0.24	0.56	0.40	0.38
T/P-J interlaced	74	0.80	0.40	0.86	0.59	0.51
GFO	260	1.13	0.59	2.14	0.89	0.59
ERS-Envisat	585	1.66	0.95	1.30	0.98	0.60
<i>Agulhas Region</i>						
T/P-J	60	1.19	0.41	2.70	0.55	0.36
T/P-J interlaced	60	1.87	0.68	4.21	0.83	0.64
GFO	213	2.67	1.01	6.57	2.19	0.94
ERS-Envisat	432	3.66	1.30	6.11	5.39	0.83

Note T/P-J estimates
are more accurate than
the interlaced estimates.

RMS after “mesoscale correction”

RMS after “mesoscale correction”
+ along-track filtering

Zoom view of gridding



Coherent M_2 Internal Tides

Ray & Zaron, *J Phys Oceanog*, 2016.

Mapped waves are based on:

T/P + Jason

T/P + Jason (interlaced)

GFO

ERS-2 + Envisat

We await:

Sentinel-3

SWOT

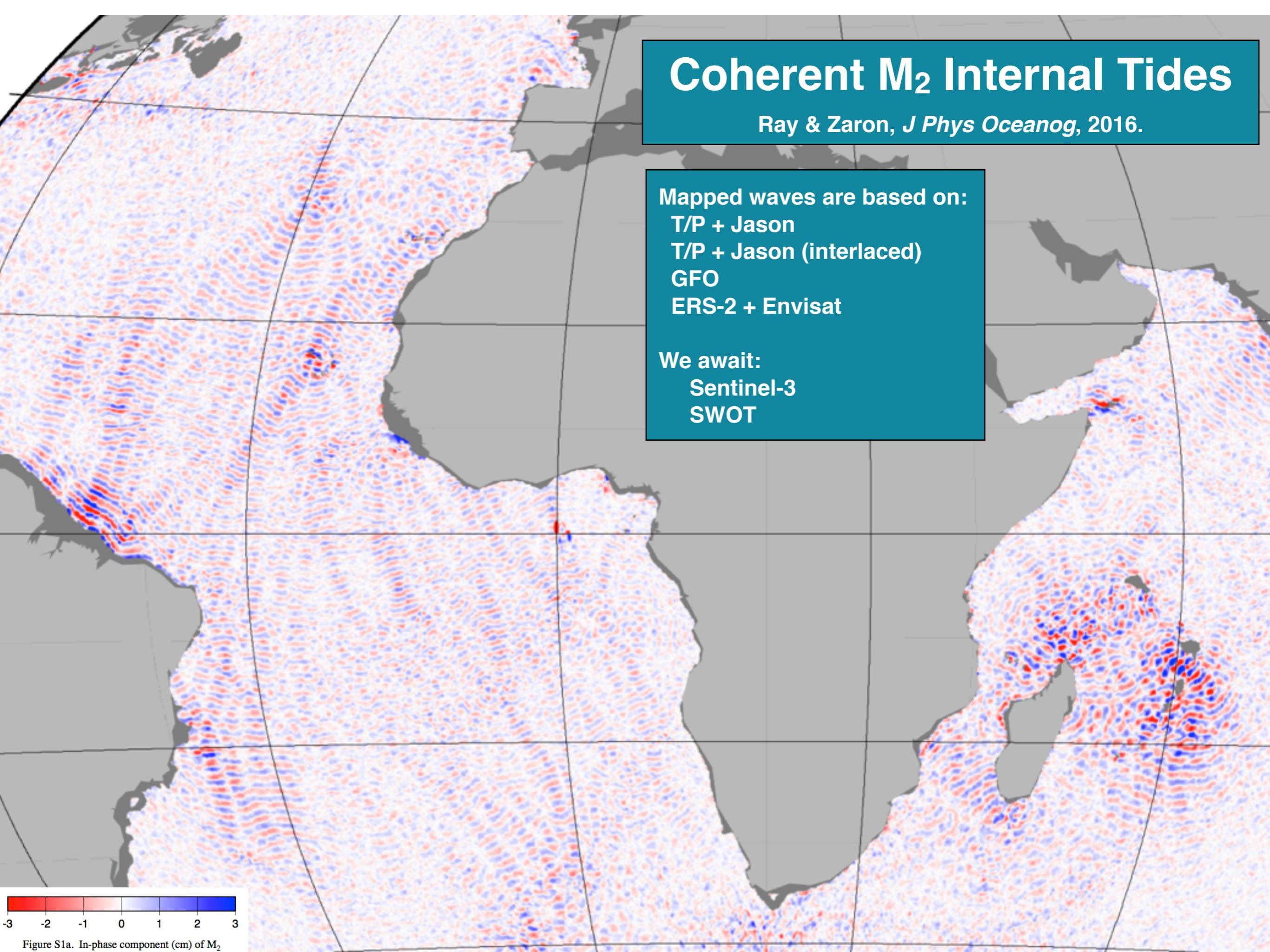
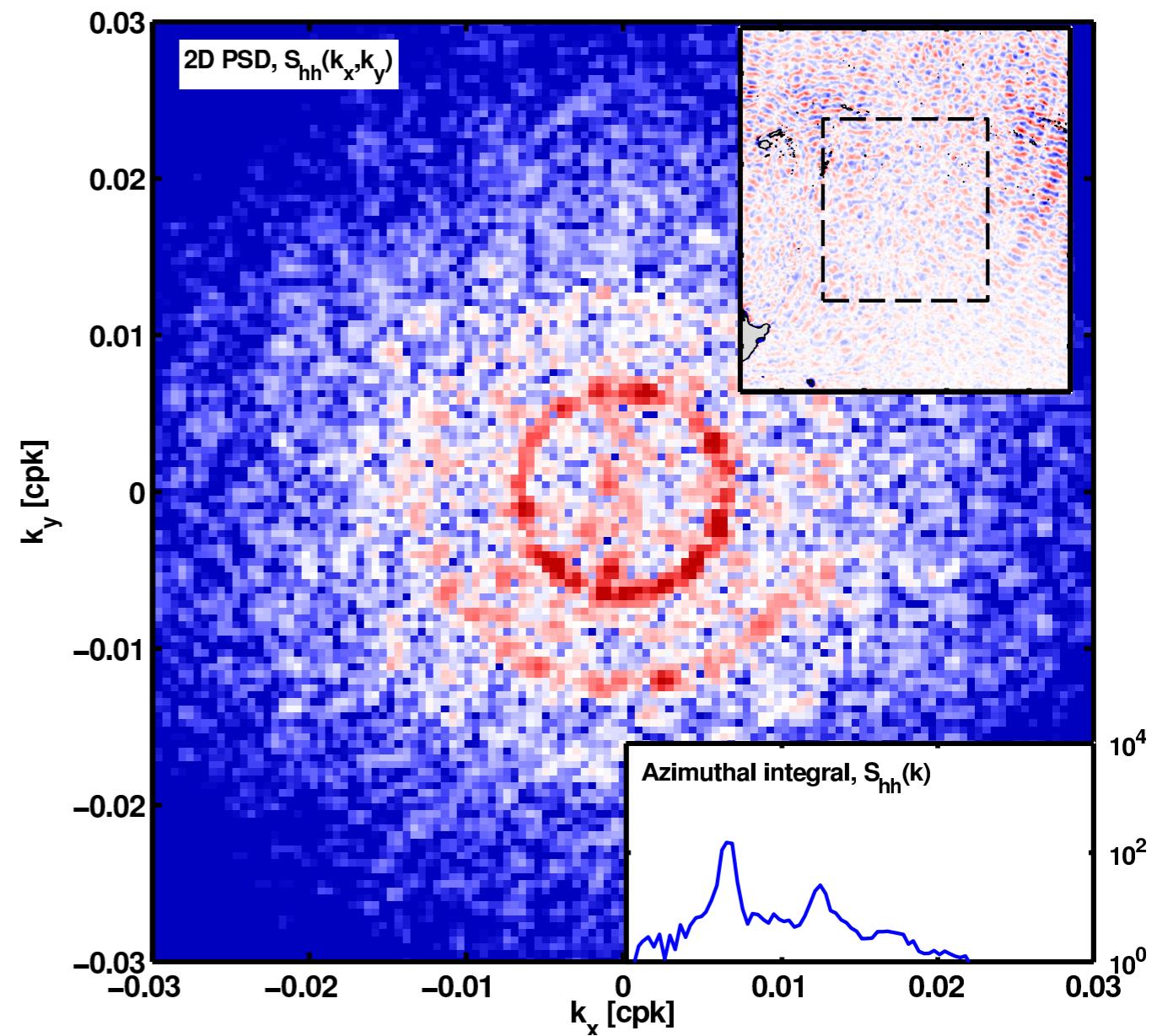
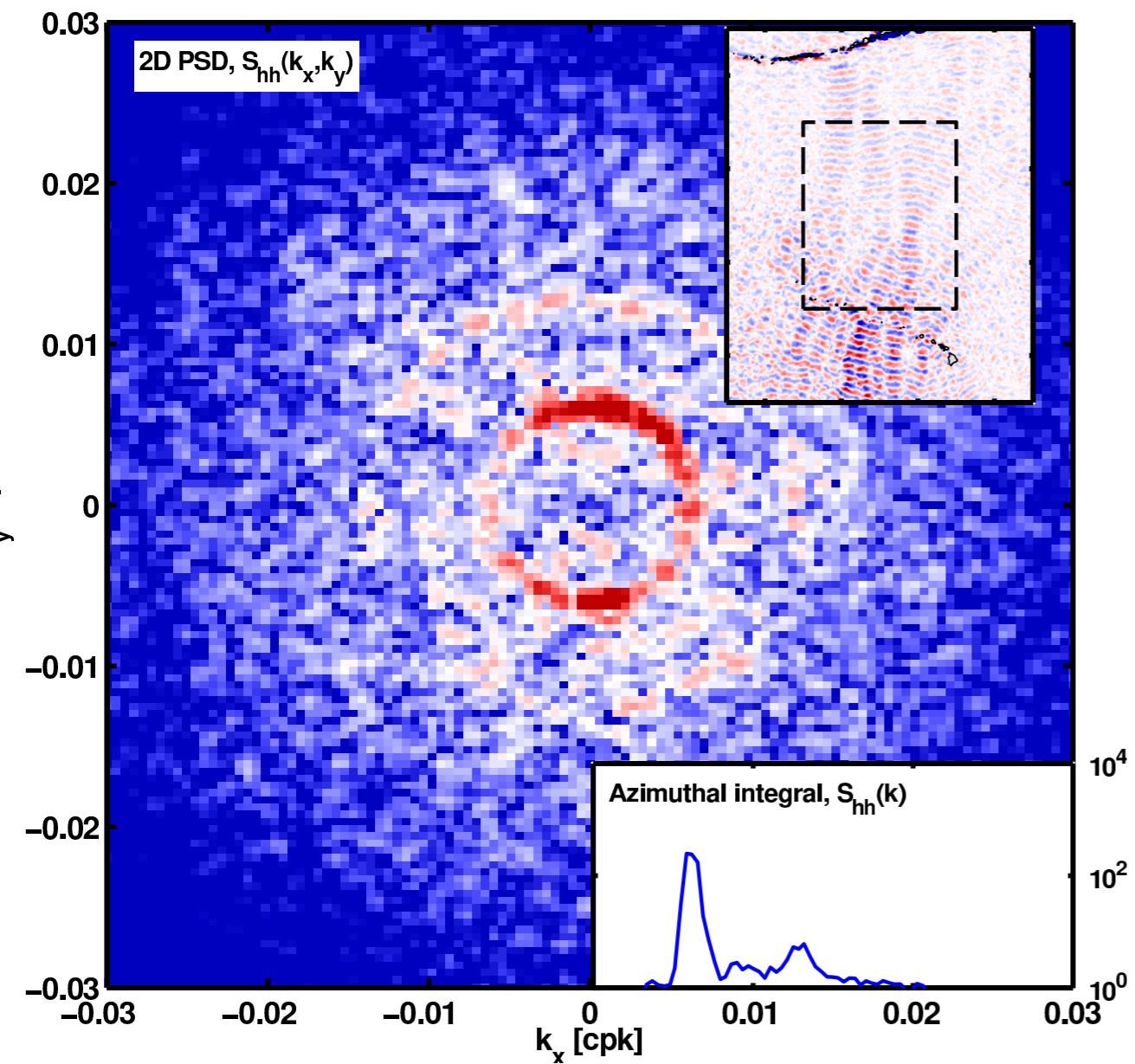
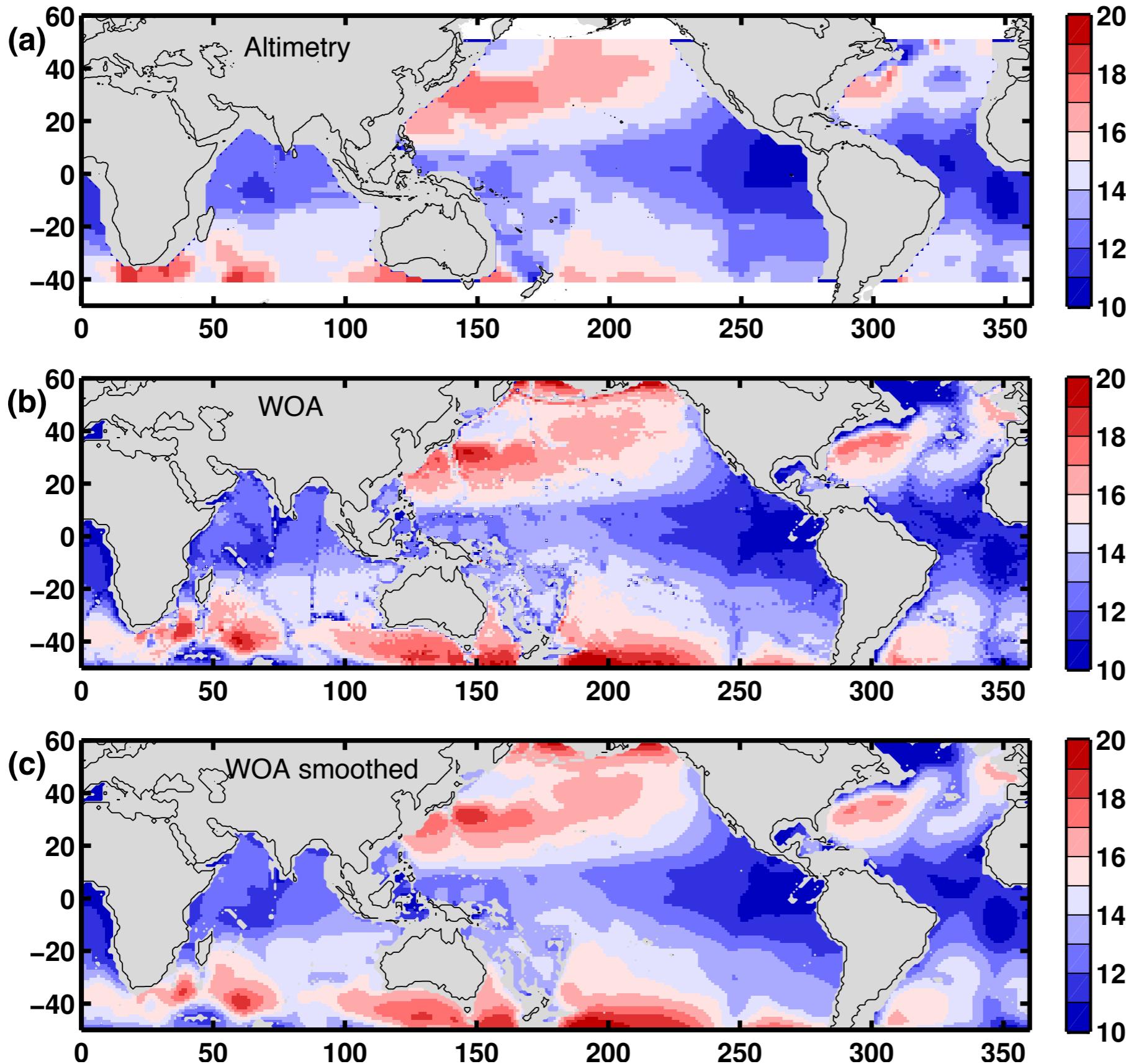


Figure S1a. In-phase component (cm) of M_2

2-D wavenumber spectra



M_2 baroclinic mode-1 wavelengths

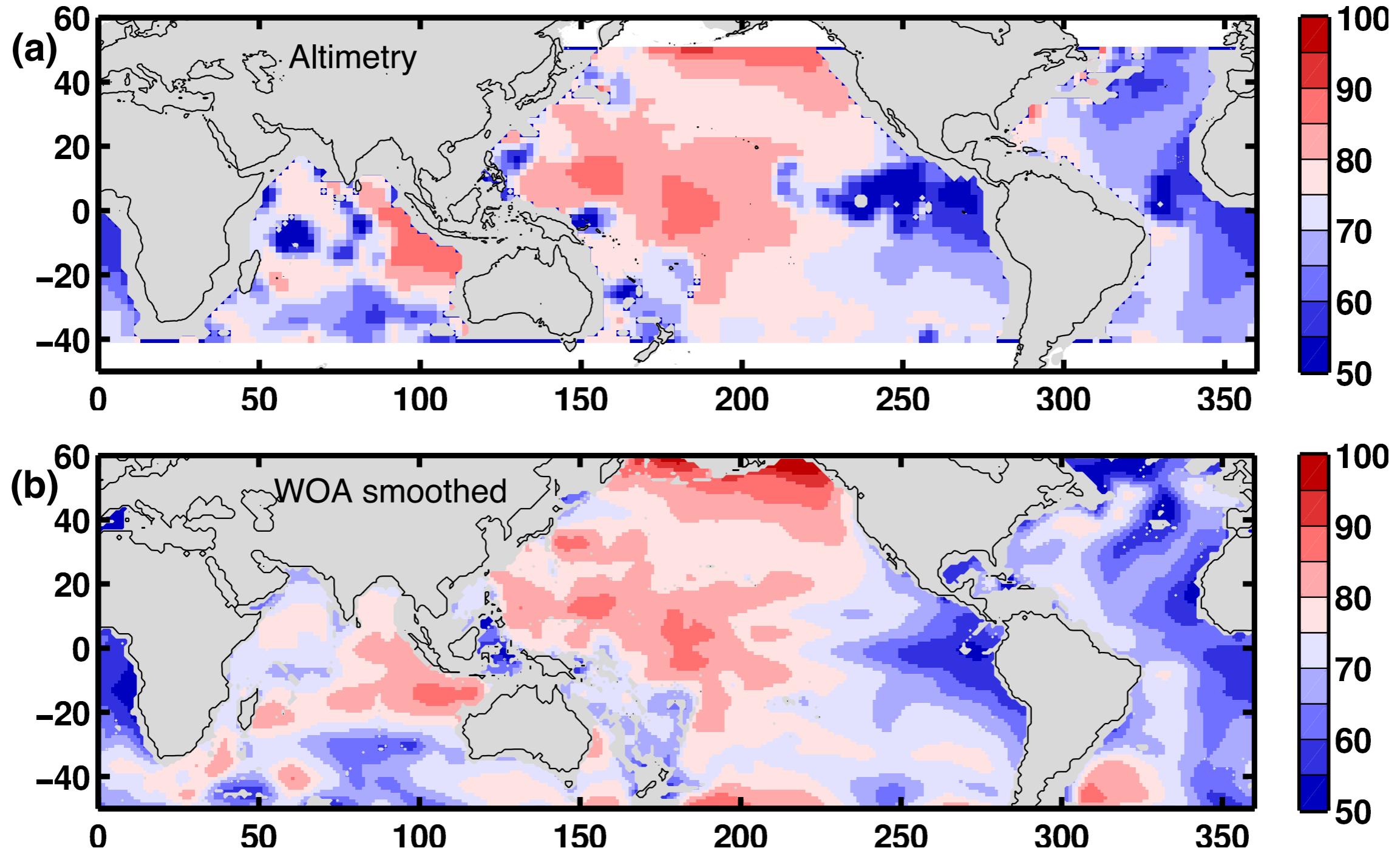


mapped by
altimetry

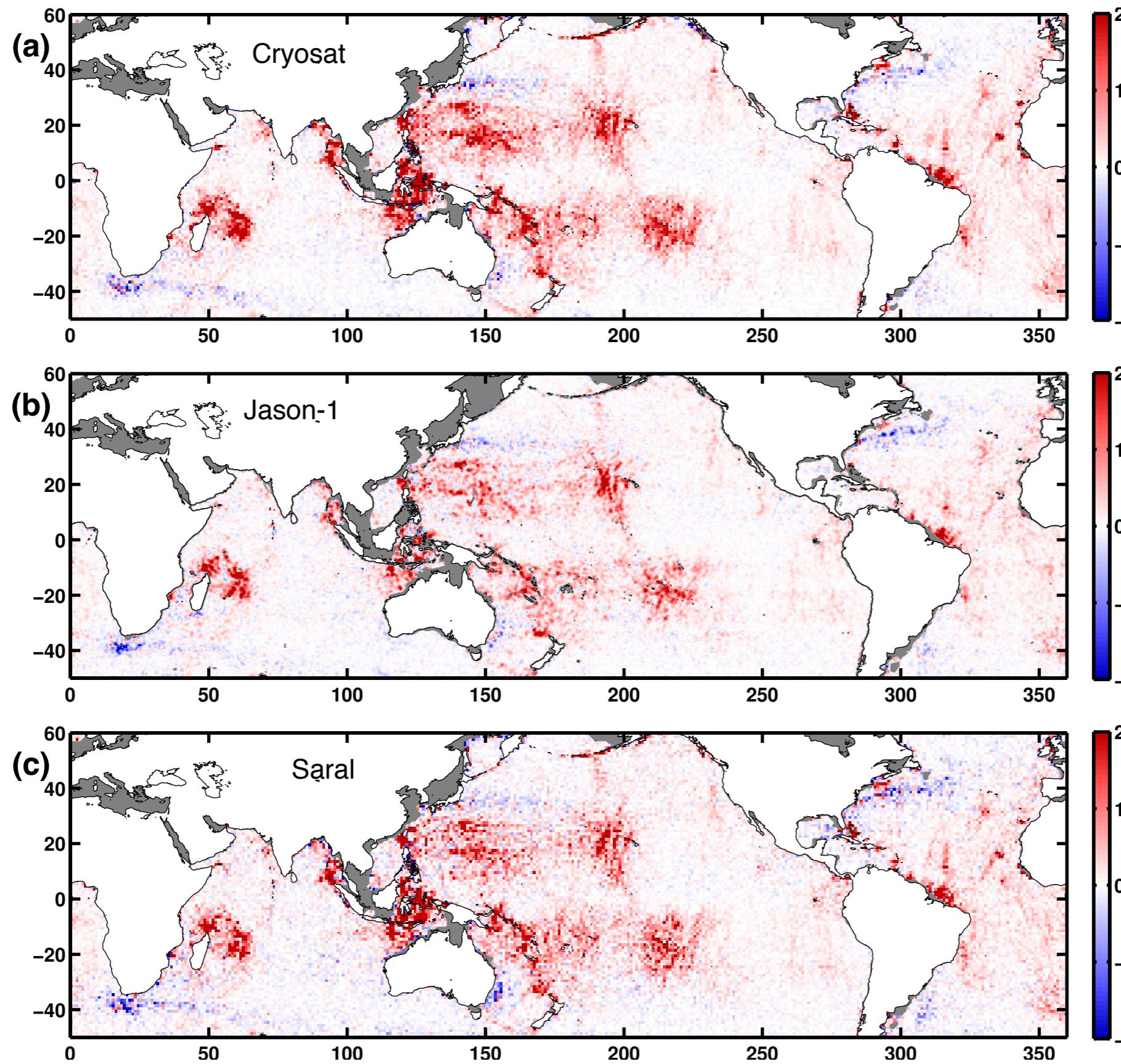
computed by
solving Sturm-
Liouville eigen-
problem for
vertical modes,
using WOA data

after smoothing
WOA map over
1000 km scales

M_2 baroclinic mode-2 wavelengths



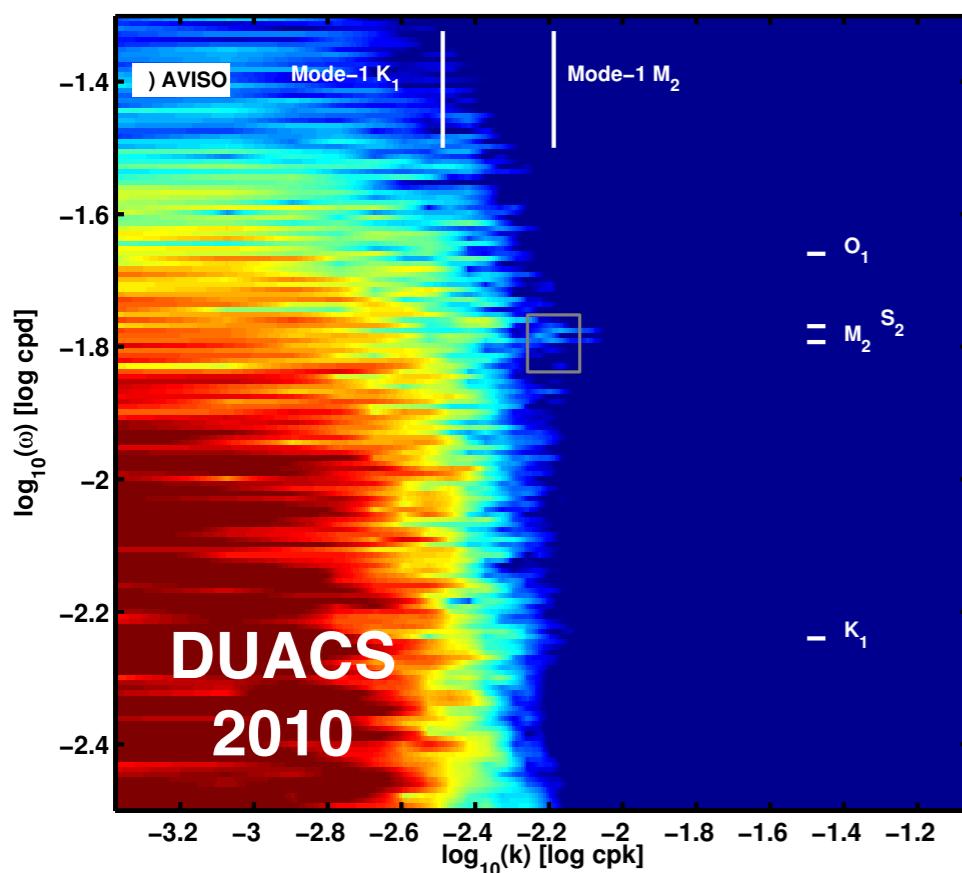
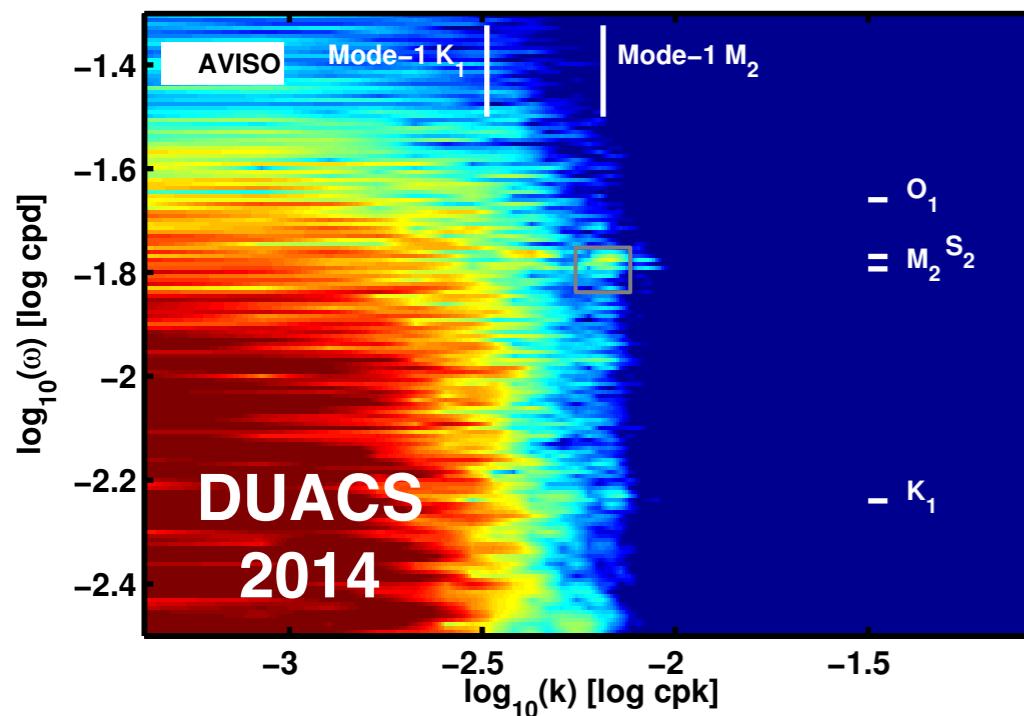
An internal-tide correction for altimetry? Variance reductions (cm^2) with independent data



Red - good
Blue - bad

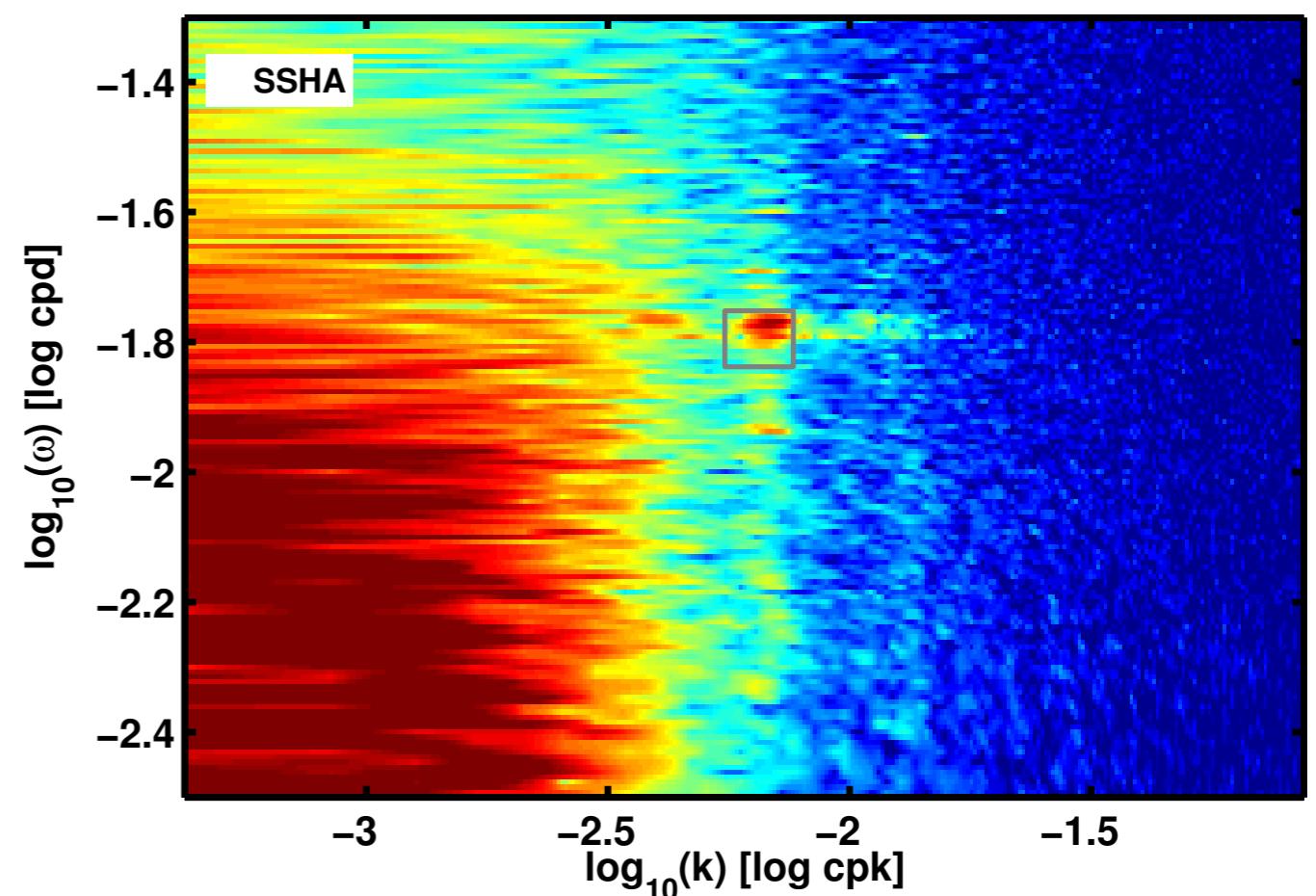
Internal tide *in* altimetry (specifically in AVISO grids)

AVISO data



frequency-wavenumber spectra

Along 1 Jason track
after removal of barotropic model



The older DUACS version is
better for our “mesoscale” correction.