Assessing high-wavenumber spectral slopes (and effective resolution) in new altimeter products

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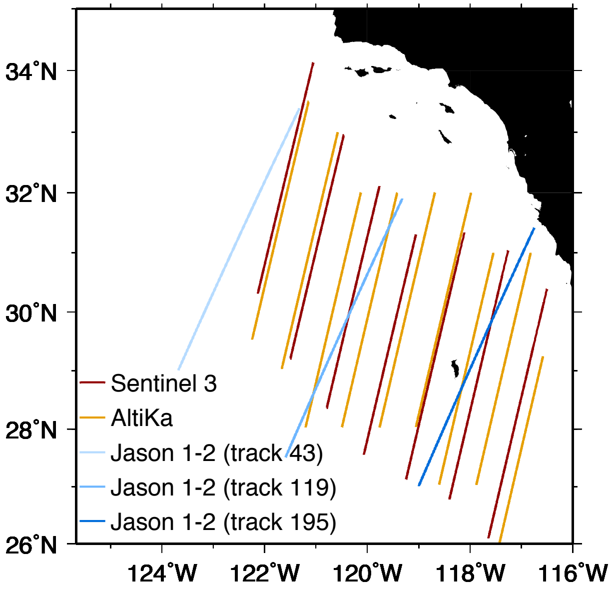
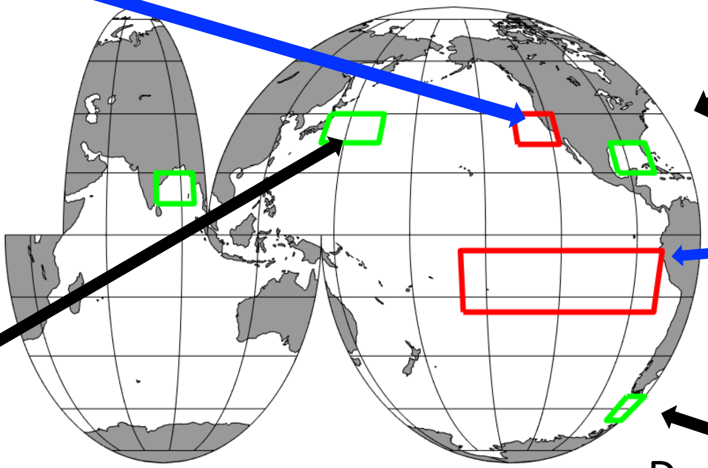


Acoustic Doppler Current Profiler data: High-wavenumber currents

California Current (Chereskin et al, submitted)

Gulf Stream *Oleander* (Callies and Ferrari, 2013)

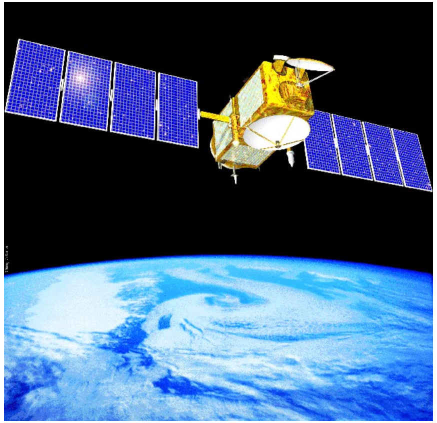


Eastern Tropical Pacific (Soares et al, in prep)

Drake Passage (Rocha et al, 2016)

Kuroshio Extension and western tropical Pacific (Qiu et al, 2017)

What can we learn from new altimetry?



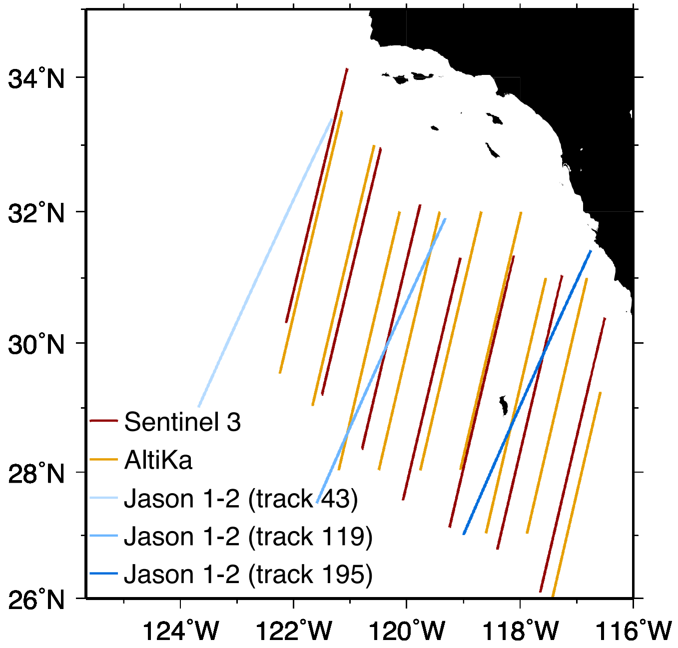
Jason-1/2 ALES processing for coastal applications

AltiKa 40-Hz data release

Sentinel-3 SAR mode

Altimeter products

- Sentinel 3: SAR mode altimeter, Jan 2017 to May 2018, 20 cycles, 7 ground tracks
- AltiKa: October 2013 to May 2016, 25 cycles 9 ground tracks
- Jason-1/2 ALES: January 2002-August 2016, 557 cycles, 3 ground tracks



Altimeter processing at high wavenumber

To minimize geoid contamination:

- Remove mean sea surface height from each satellite pass: $\eta'(x)$
- Interpolate each pass to common latitude grid: $\eta'(x_m)$
- Average over all passes to obtain mean: $\langle\eta(x_m)\rangle$ (but don't use $\eta'(x_m)$ for calculations, because interpolation is a smoothing operation)
- Interpolate mean back onto original data points: $\langle\eta(x)\rangle$
- Subtract mean: $\eta'(x)-\langle\eta(x)\rangle$

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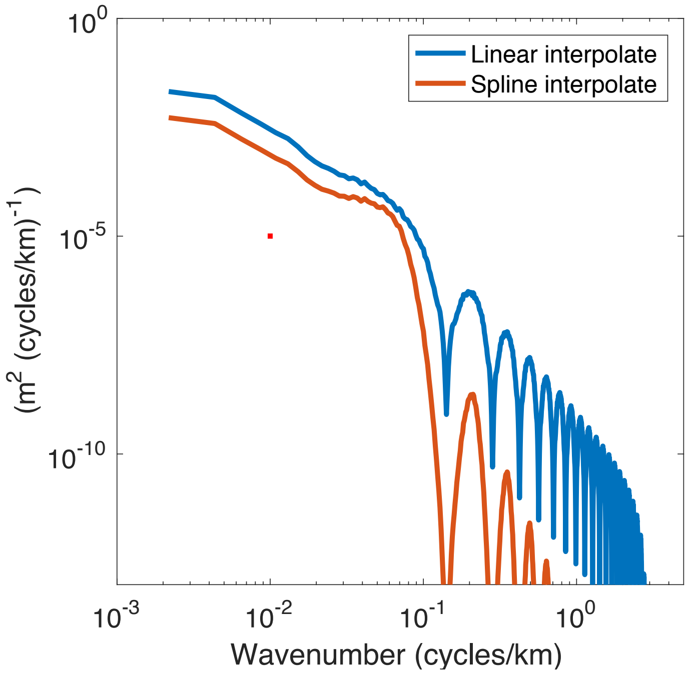
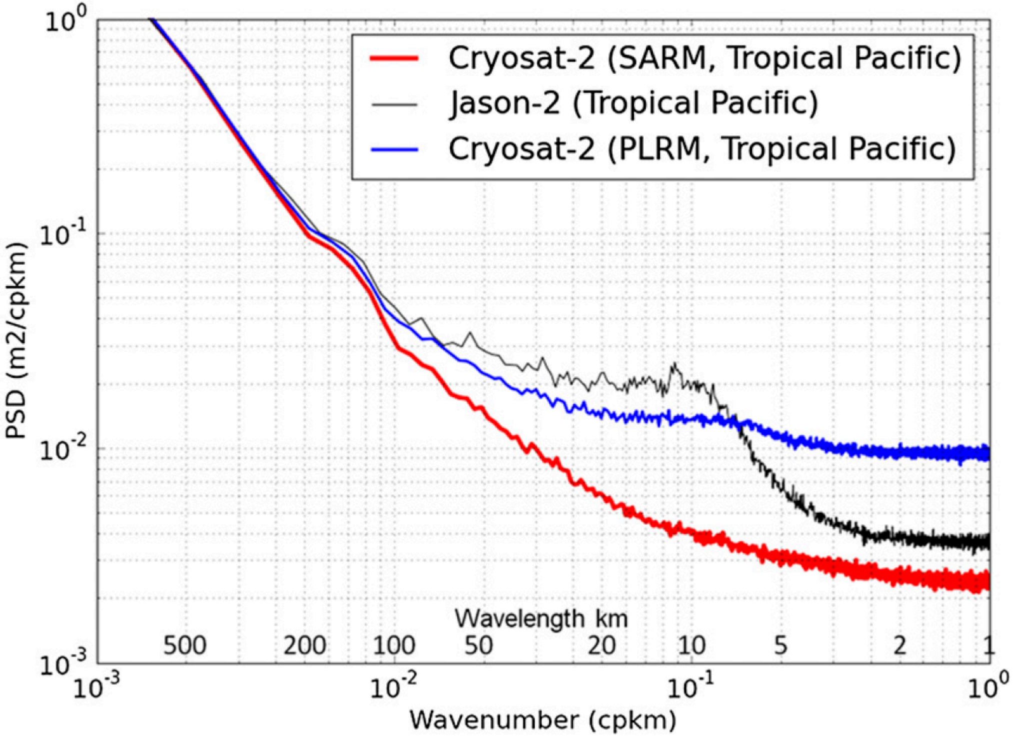
Altimeter processing at high wavenumber

Environmental corrections available at 1 Hz

- Interpolate to 20 or 40 Hz
- Caution: if energetic relative to signal, then expect spectral ringing



Anatomy of a wavenumber spectra

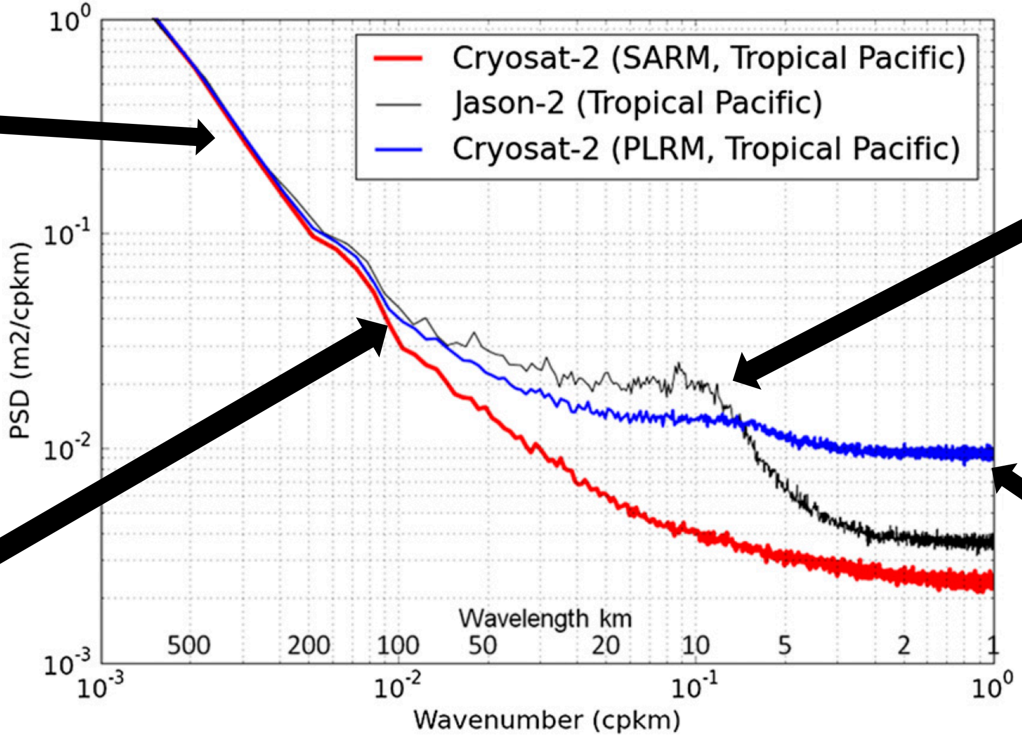


Dibarboure et al, 2014

Anatomy of a wavenumber spectra

Low wavenumbers: Geostrophic flow implies k^{-5} spectrum. Should be well resolved by most altimeters

Transition from geostrophic (balanced) to ageostrophic. Spectral slope prediction unclear



Spectral "bump" attributed to large satellite footprints

High wavenumbers: Noise floor determined by instrument

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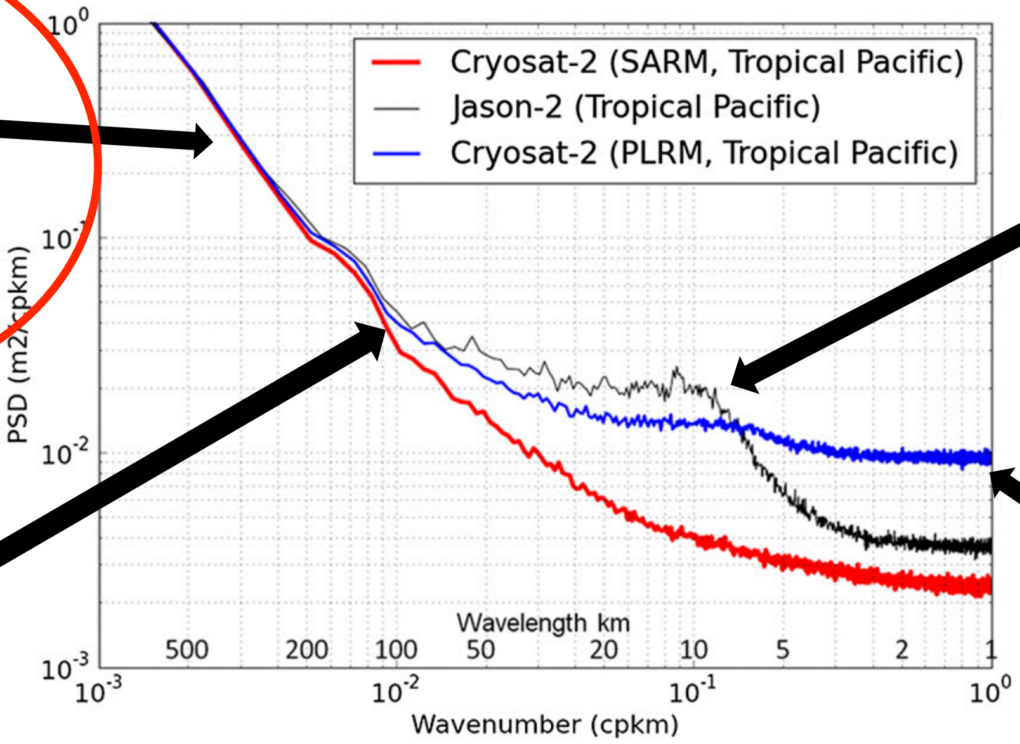

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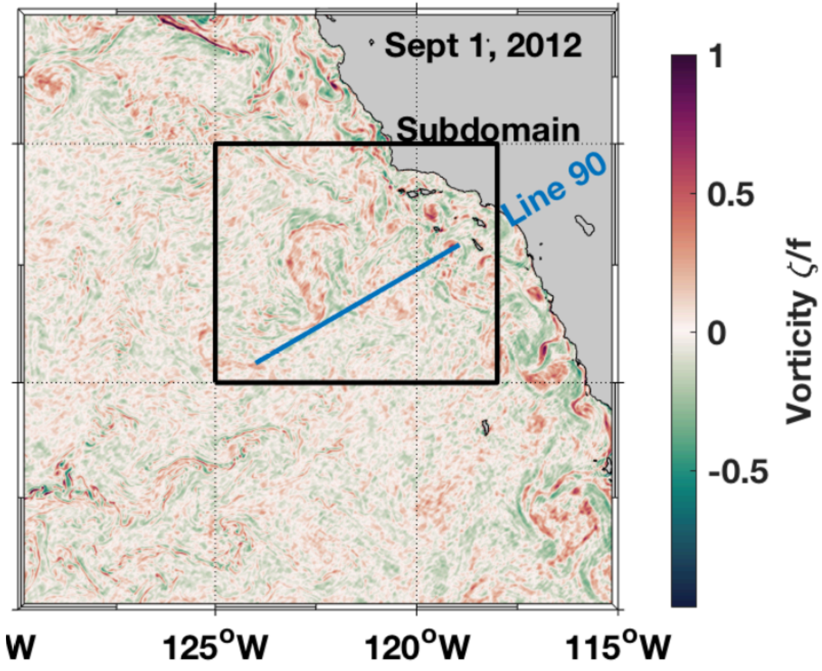
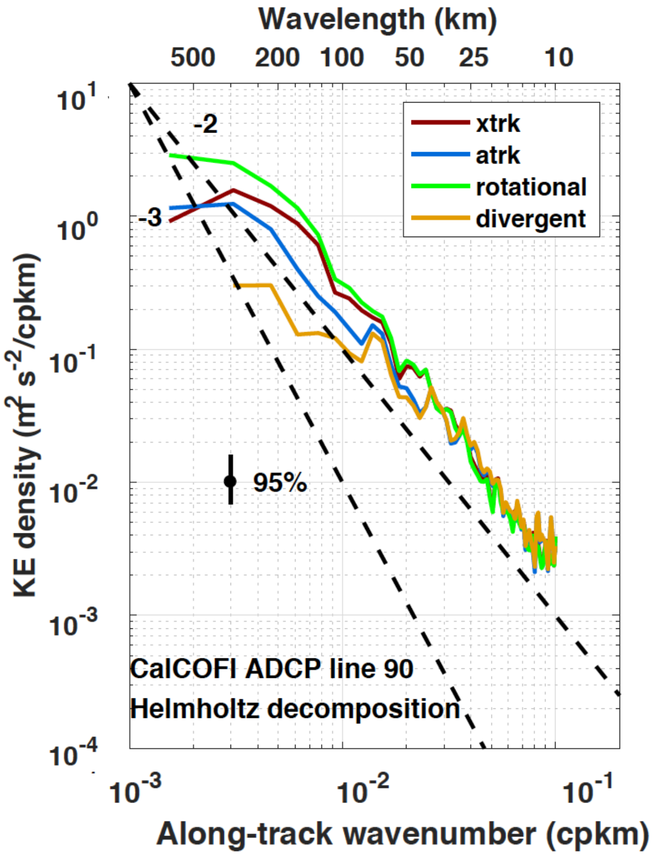
Low wavenumbers: geostrophic balance



- Hanning window
- Fourier transform both components
- Helmholtz decomposition to separate rotational and divergent components

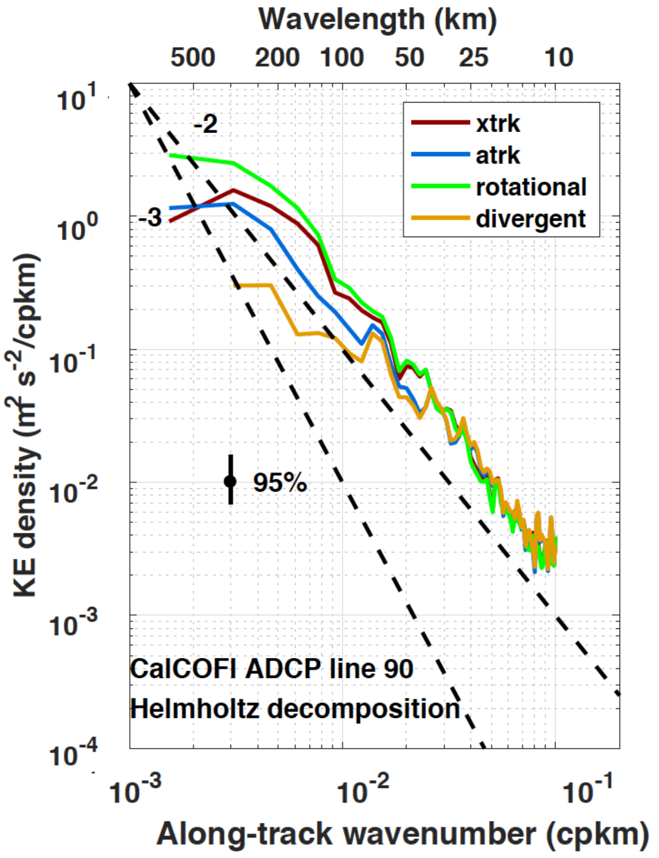


Acoustic Doppler Current Profiler data: 1993-2004, 39 cruises

Chereskin et al, submitted, 2018

Low wavenumbers: geostrophic balance

- Rotational (balanced, geostrophic) and divergent (ageostrophic) converge at 70 km.
- Scales larger than 70 expected to be in geostrophic balance.
- Slope k^{-2} for scales larger than 70 km.
- Geostrophy ($u = -g/f\, d\eta/dy$) implies k^{-2} slope difference between velocity and ssh spectra



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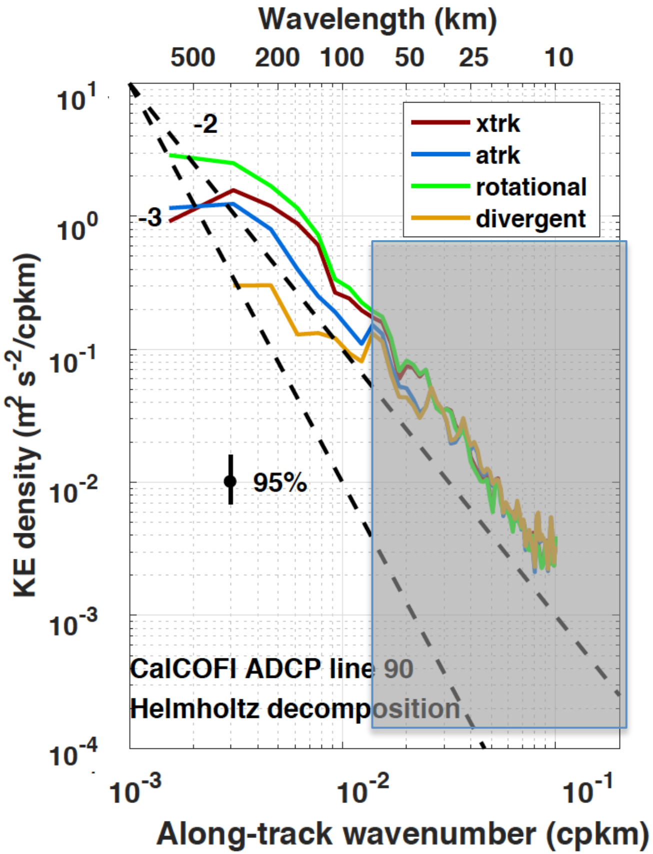

Chereskin et al, submitted, 2018

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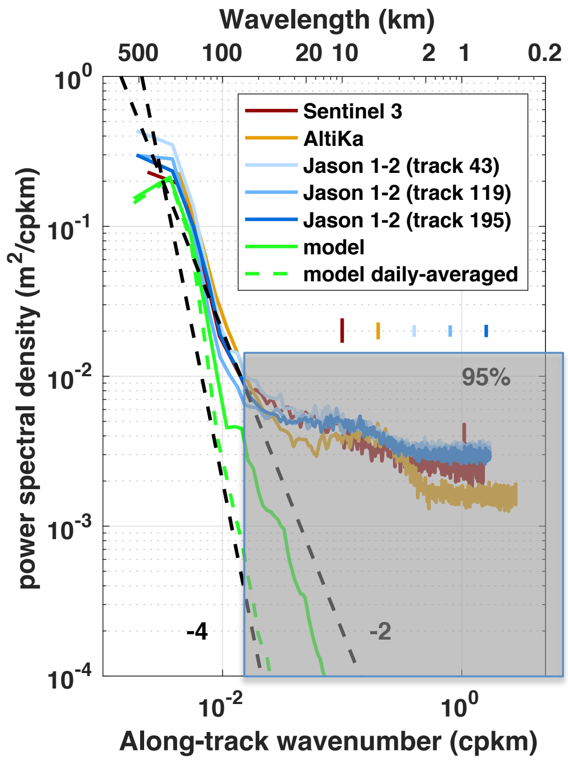
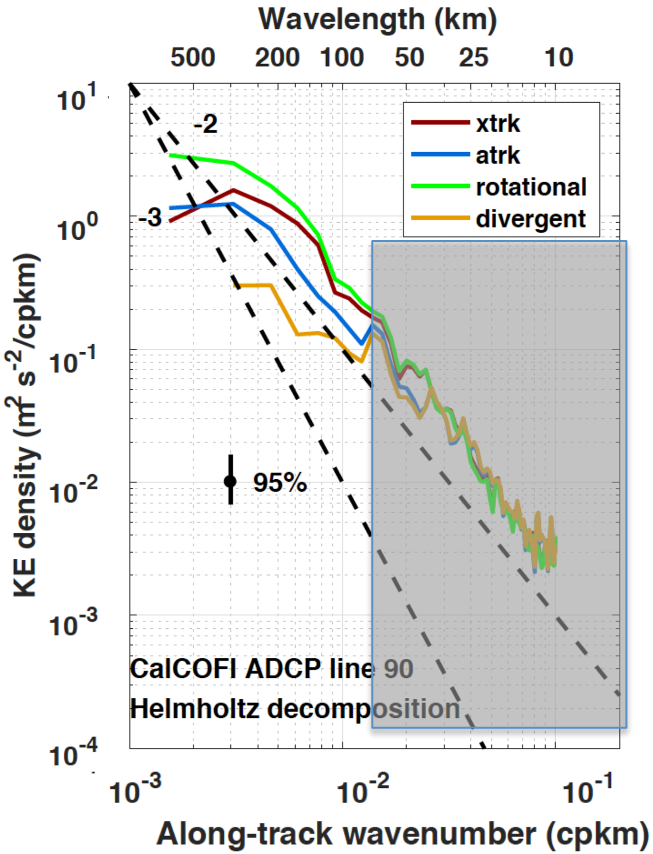


Geostrophic regime (scales > 70 km):

Velocity spectra: k^{-2}

Sea surface height: k^{-4}



Chereskin et al, submitted, 2018

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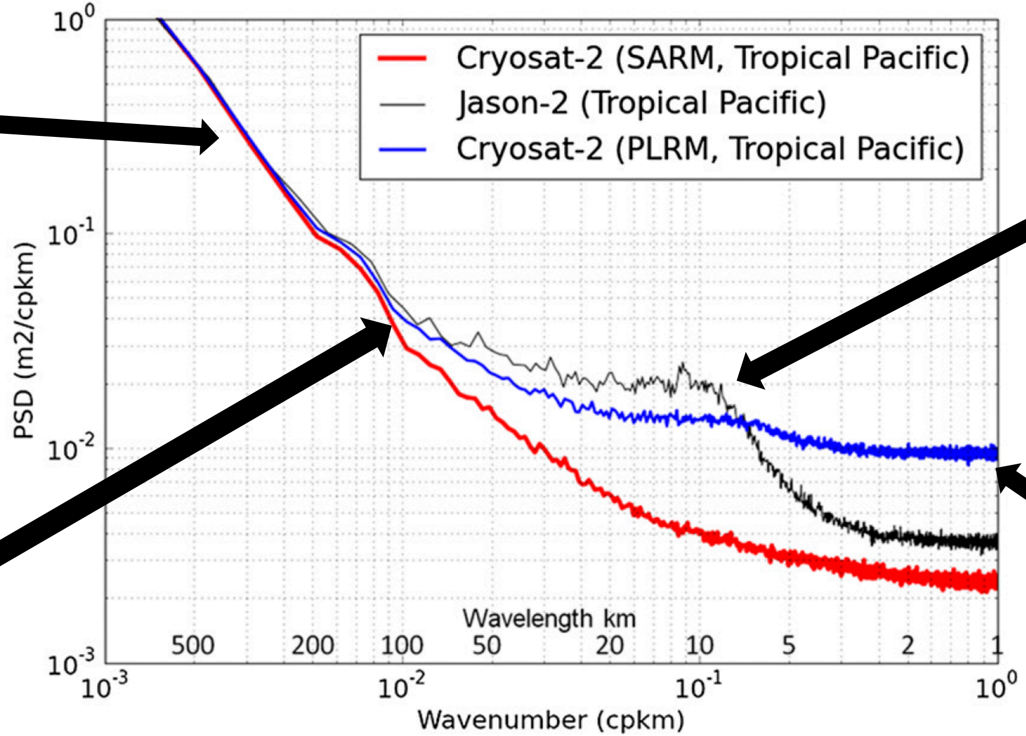

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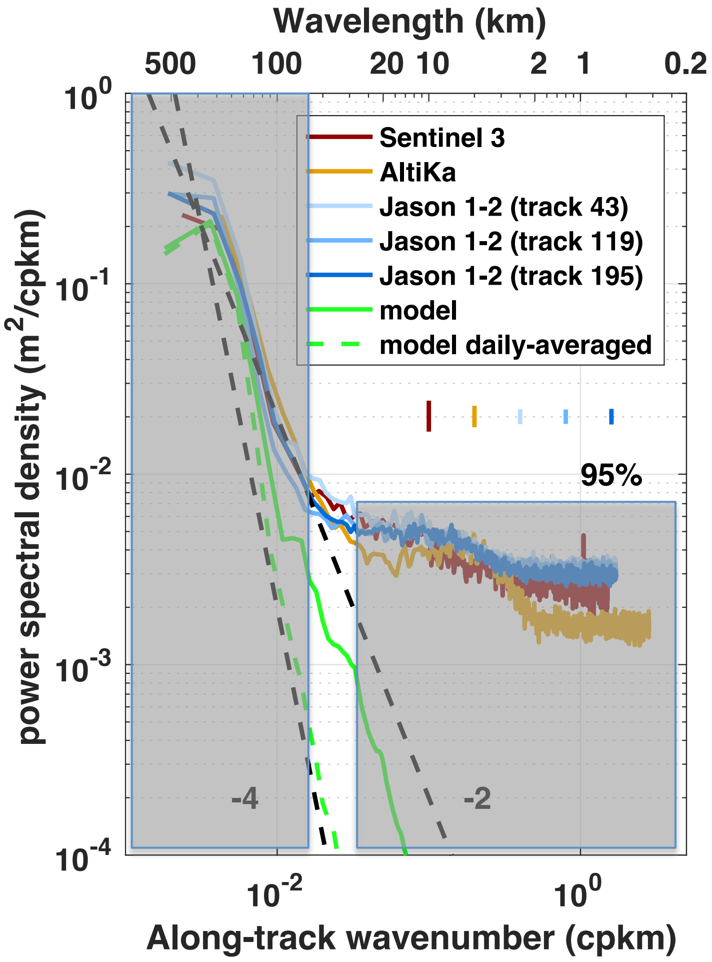

Unbalanced motion: 70 to 30 km

Sea surface height spectra: k^{-2}

Sentinel-3, Jason, and AltiKa agree within error bars

Does agreement tell us something about true sea surface height spectrum, or is it an artifact of noise floor?

Chereskin et al, submitted, 2018

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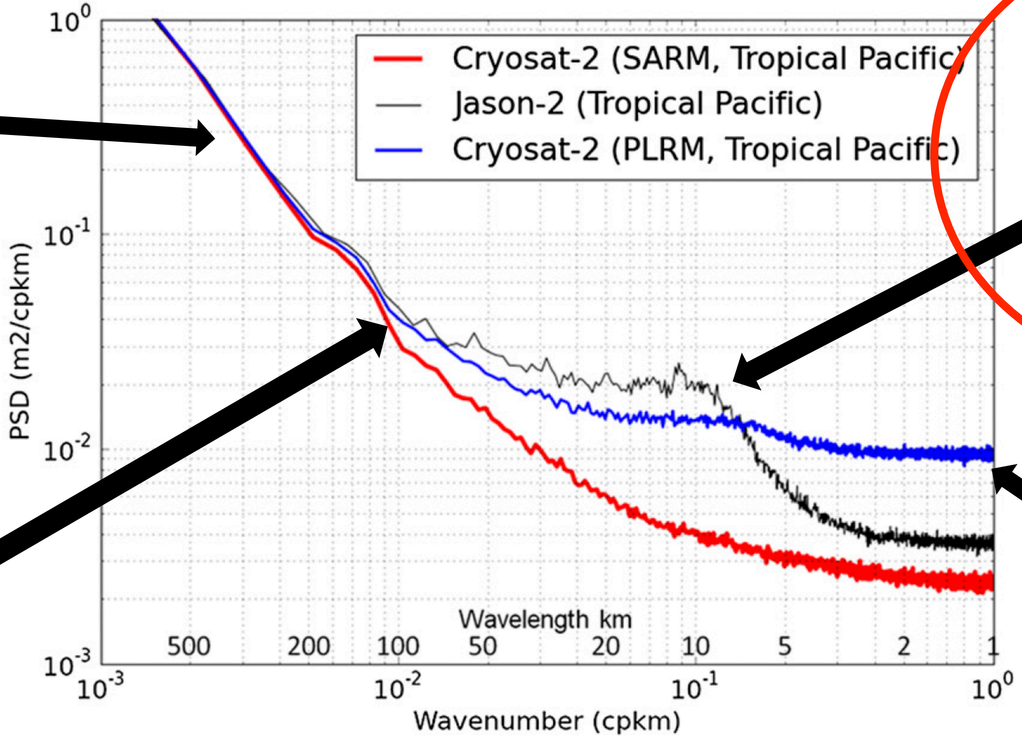

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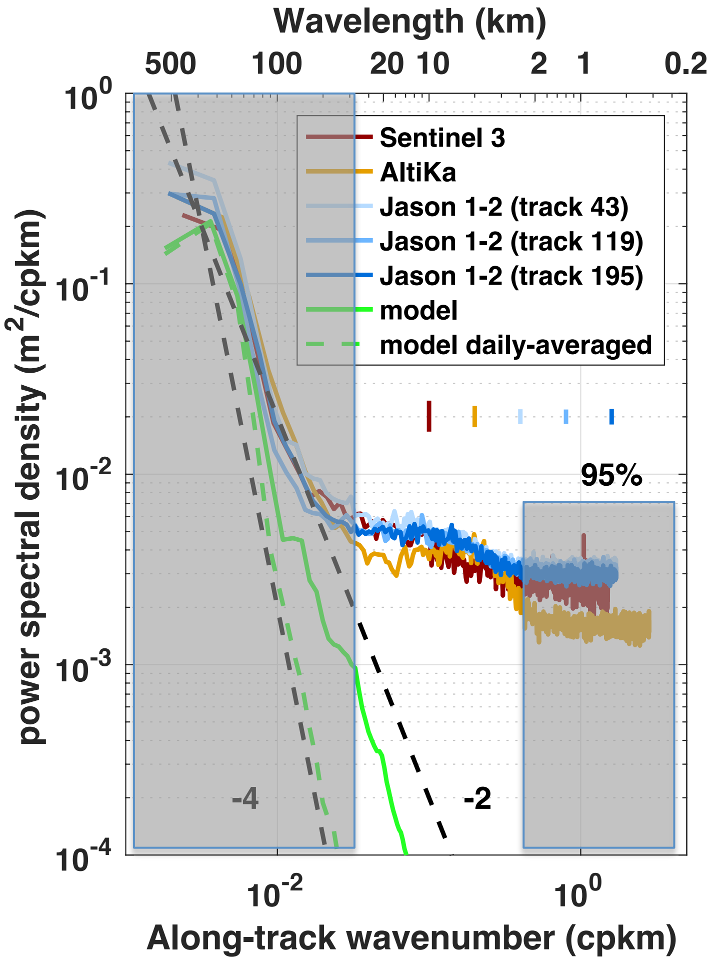

Chereskin et al, submitted, 2018

Spectral bump regime: 30 to 3 km

Altimeters diverge

AltiKa: Classic spectral bump, consistent with preferential response to bright spots on ocean surface.

Jason 1-2: ALES processing reduces bump; step change in noise level.

Sentinel-3: SAR altimeter falls off gently. Short record implies noisy data that is not statistically different from Jason 1-2.

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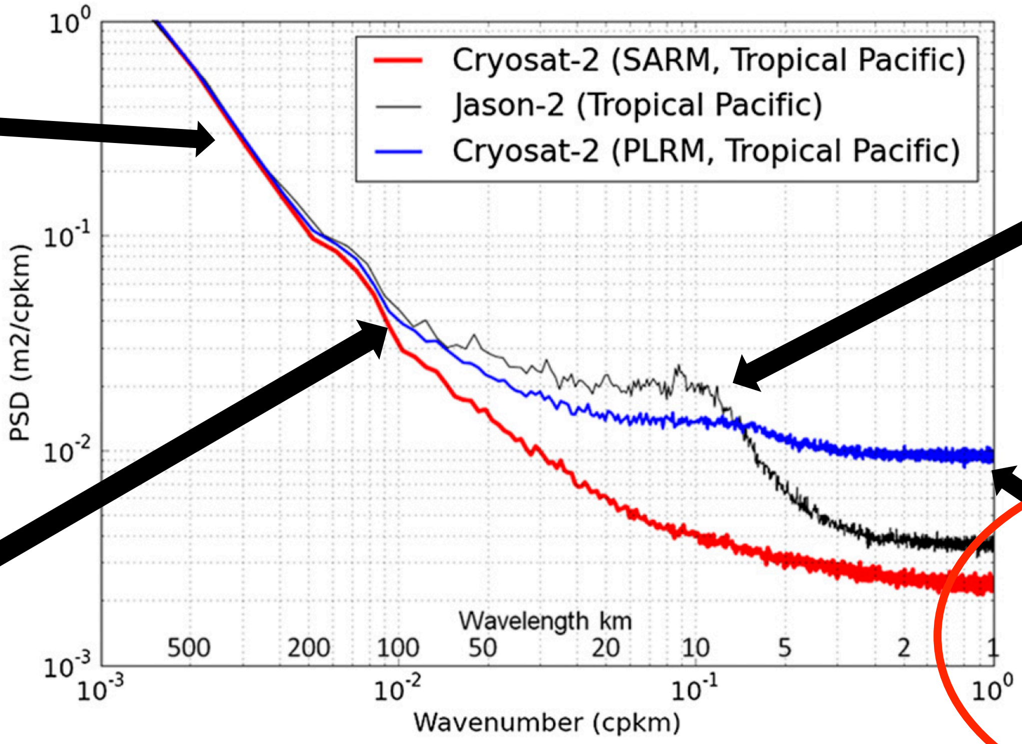

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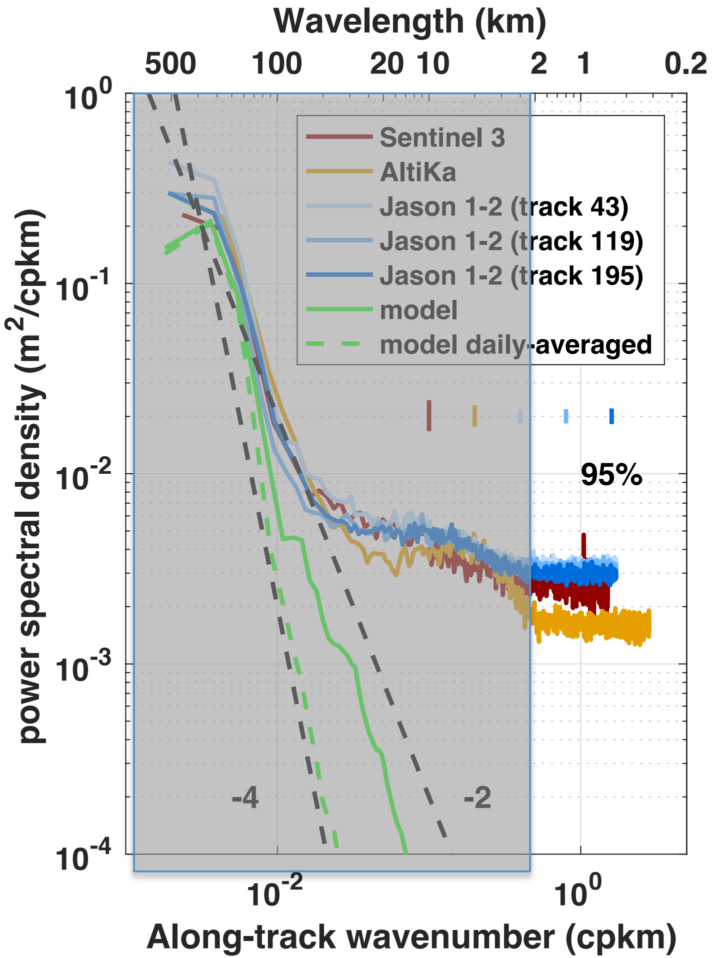


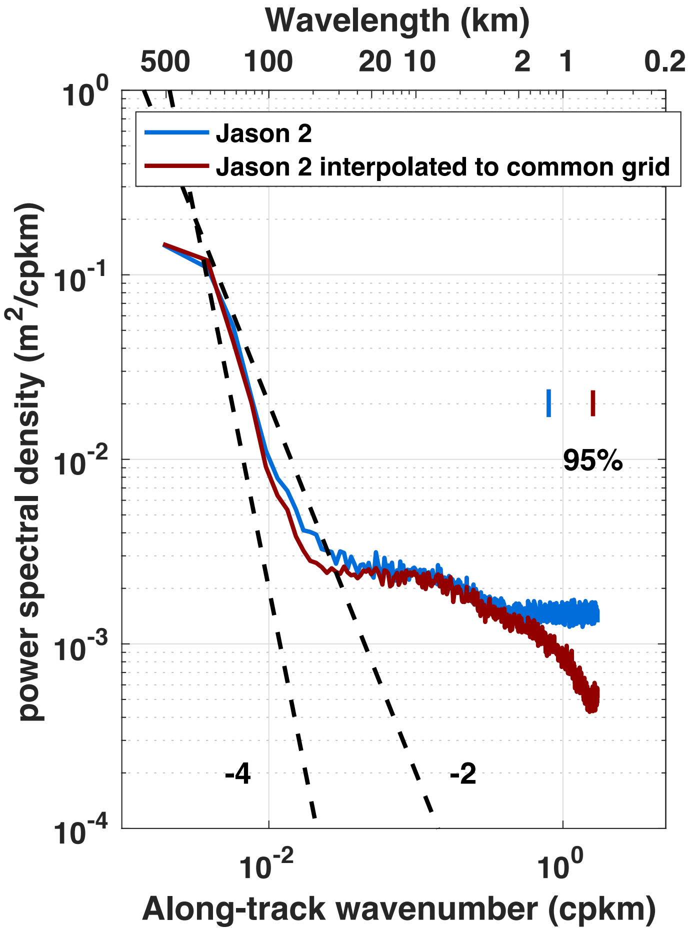
White noise floor: Scales smaller than 2-3 km

AltiKa: Lowest noise levels

Jason 1-2: Highest noise

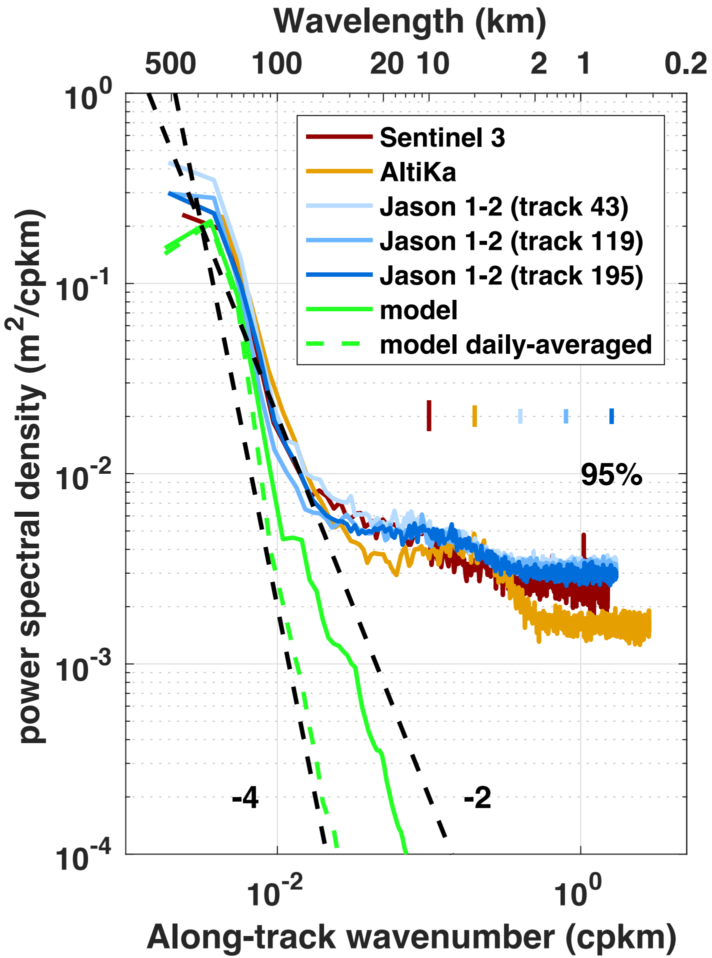
Sentinel-3: White noise, consistent with low significant wave height of region. Elsewhere Sentinel-3 has shown red spectra at high wavenumbers.

Chereskin et al, submitted, 2018



White noise floor not a foregone conclusion

- Recall: Interpolation acts as a low-pass filter
- Computing spectra from interpolated data $\eta'(x_m)-\langle\eta(x_m)\rangle$ leads to red spectrum at high wavenumbers



Conclusions

- Sentinel 3, Jason-1/2 (ALES), AltiKa consistent for geostrophic regime and imbalanced (in 70-30 km)
- Sentinel 3 has no spectral bump but otherwise similar to Jason-1/2
- High-frequency noise floors: white in all cases for California Current.