Harmony: multistatic mapping of ocean-wave spectra

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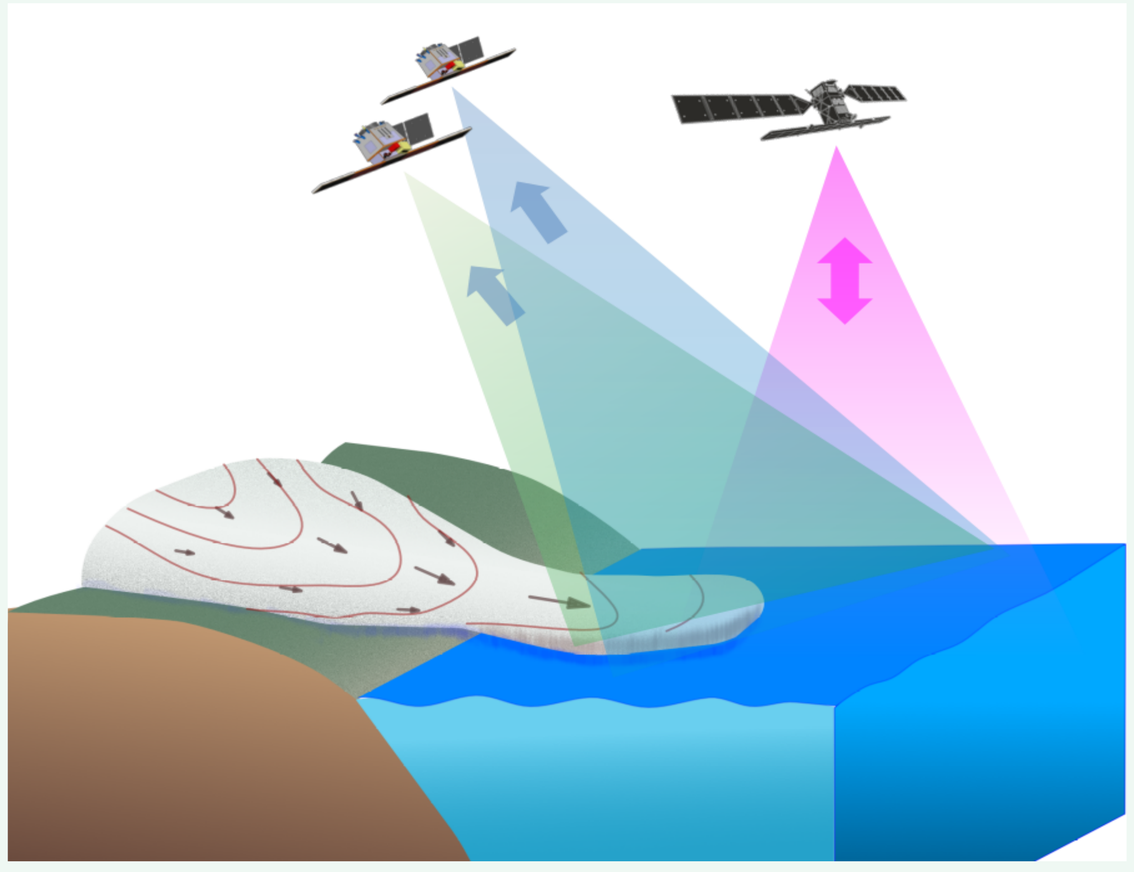
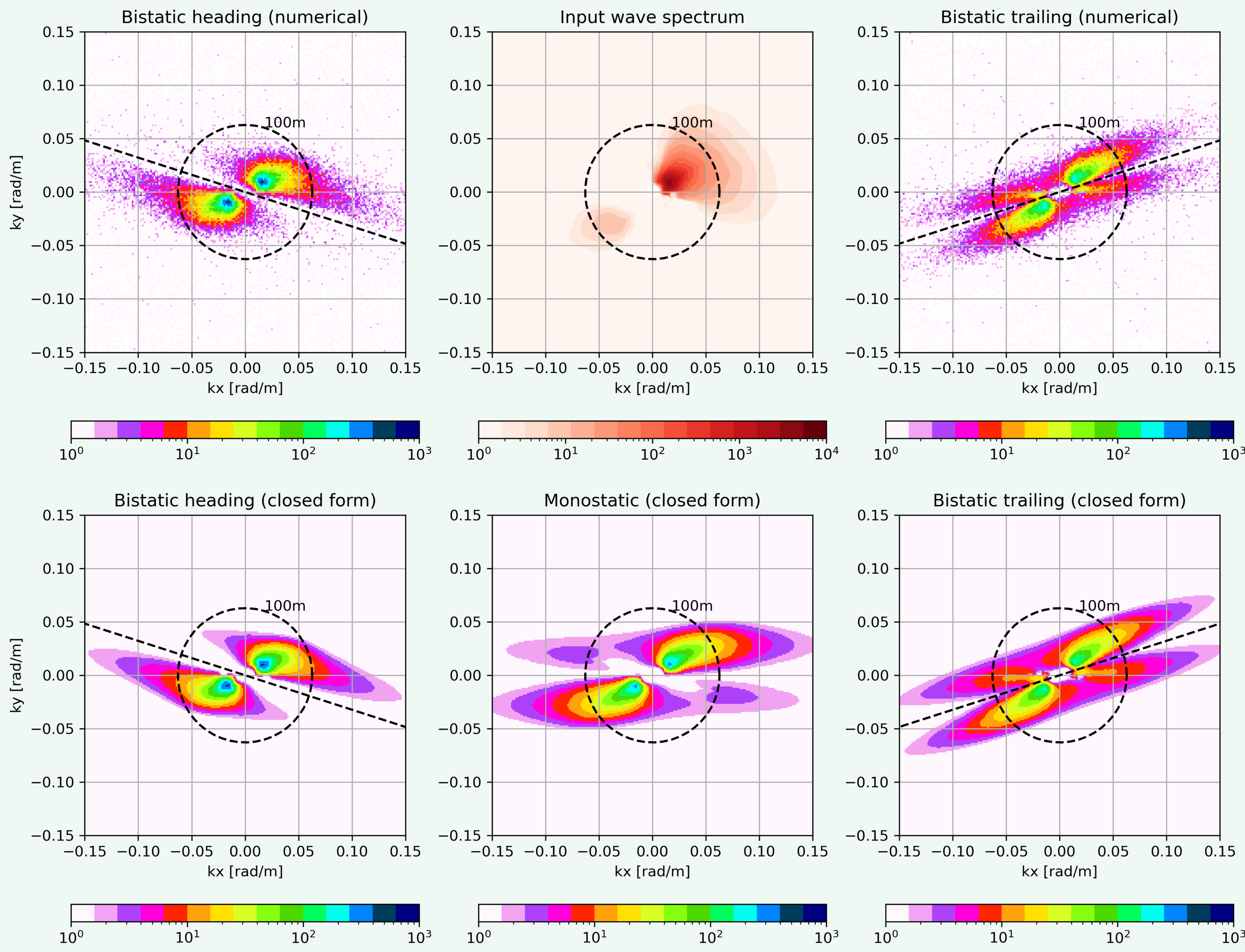
Introduction

Earth Explorer 10 Harmony consists of two satellites that fly in formation with Sentinel-1D (figure on the right). The multistatic synthetic aperture radar (SAR) system uses Sentinel-1 as an illuminator and adds two receivers to obtain three lines-of-sight. Over the ocean this enables to estimate stress-equivalent wind vectors, total surface current vectors and ocean-wave spectra. Traditionally, closed-form solutions have been used to retrieve ocean-wave spectra from SAR data. We have extended the closed-form mapping to a more general form including the squinted and bistatic cases. This allows to investigate properties of Harmony's SAR spectra, compare them to currently flying, approved and proposed ocean observation missions.



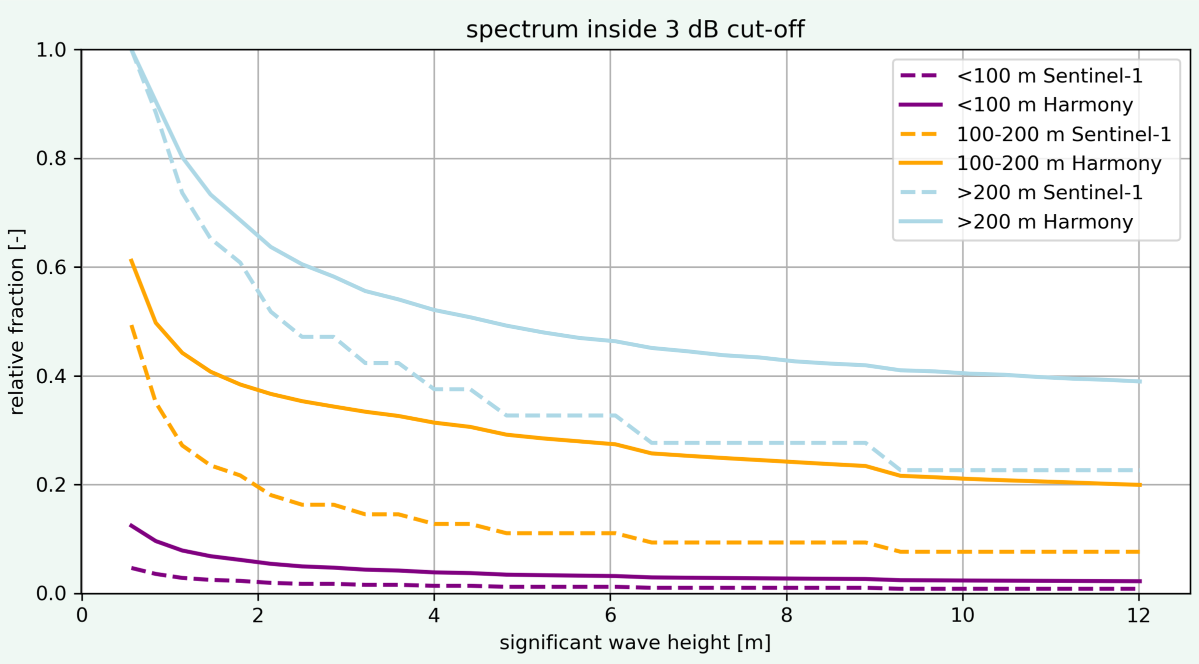


Multistatic SAR mapping

To verify our closed-corm solution, an numerical simulation has been used to compute bistatic SAR spectra (top corners) from a WaveWatch3 ocean-wave spectrum (top center). The numerical bistatic spectra show comparable spectral behavior and magnitude as the closed form (bottom corners) computed from the same ocean-wave spectrum.

The closed-form for this particular example reveals a few properties of Harmony's multistatic SAR spectra. We conclude:

1. The sensitivy changes with direction.
2. The response at the ground-range direction is weak.
3. There is a cutoff at a certain distance from the ground range.
4. The cutoff is stronger for the bistatic spectra.
5. Harmony has a larger spectral coverage with three lines-of-sight.

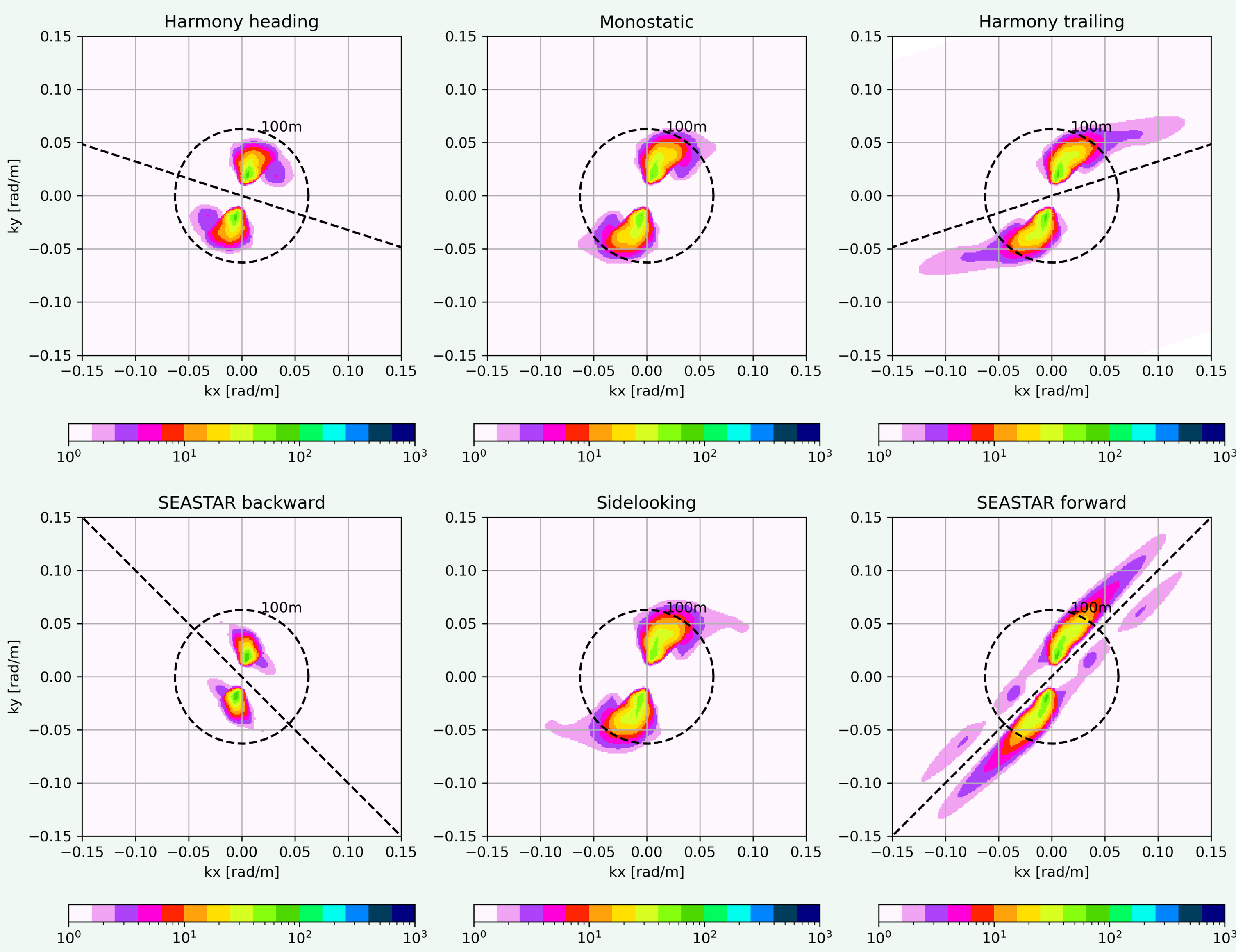


Spectral coverage

The cut-off depends on the velocity variance of the surface, which is closely linked to the SWH. The figures shows that Harmony's three lines-of-sight help to nearly double the spectral coverage for most sea states.

Harmony vs Seastar

Seastar has a larger line-of-sight diversity than Harmony. While this geometry has benefits for wind-speed and surface-current retrieval, it does not per se enhance the wave retrieval. Due to Seastars larger squint, the cutoff increases (bottom) and the relative spectral coverage for the squinted lines-of-sight reduces.



Harmony vs other missions

Harmony profits from three lines-of-sight to partially overcome the along-track cut-off of other SAR missions. Suppression of noise is required for accurate ocean-wave-spectra retrieval, which limits the resolution to ~10 km for operational SAR systems. Harmony's sampling is on par with other single-satellite radar missions: with its ground-track spacing of ~230 km at the Equator and a 12-day repeat cycle, it takes snapshots of the ocean alternating between WM1 and WM2. Harmony's IW mode data allow for a quasi-continuous wave-field charactarization. Wave-field gradients help to retrieve ocean-current vectors and ocean-floor topography.

	Spectral coverage			Sampling		
	Along-track	Cross-track	Resolution	Time	Space	Grid
CFOSat	10 m	10 m	80 km	13 days	200 km (2x)	No
Sentinel-1	150 m	10 m	10 km	6 days	120 km	250 km (IW)
Harmony	150 m (3L)	10 m	10 km	12 days	230 km	250 km (IW)
Seastar	150 m (3L)	40 m	10 km	2-30 days	100+ km	100 km
Sentinel-6	200 m	200 m	5 km	10 days	320 km	Along-track
S3-NGT	150 m	30 m	10 km	27 days	100 km (3x)	Along-track

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