Wide-swath Ocean Topography Using Formation Flying and Squinted Geometry

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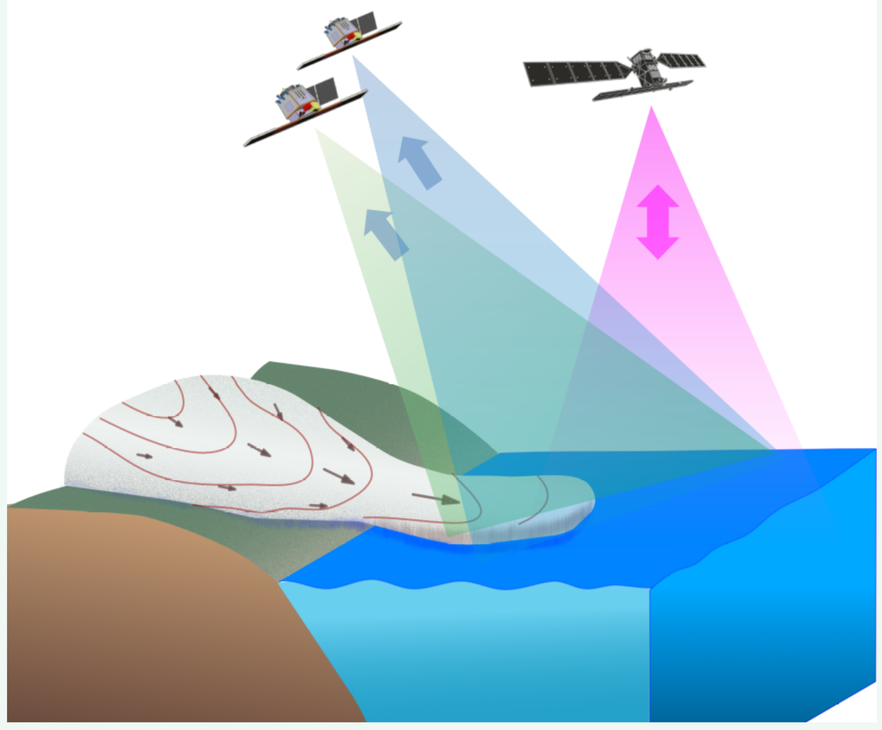
Background

The Earth System cannot be understood or modeled without adequately accounting for small scale processes. Harmony is an Earth Explorer 10 candidate mission of the European Space Agency dedicated to the observation and quantification of small-scale motion and deformation fields, primarily, at the air-sea interface (winds, waves, and surface currents), of the solid Earth (tectonic strain), and in the cryosphere (glacier flows and surface height changes).



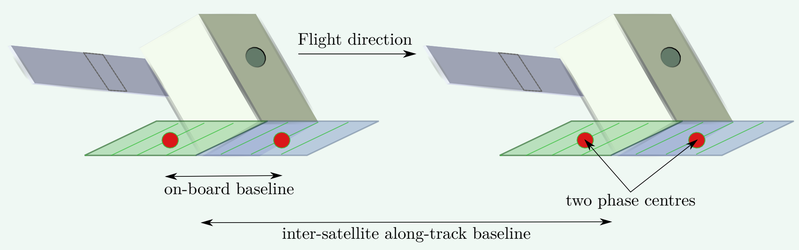
Abstract

Harmony, the 10$^{\text{th}}$ Earth Explorer, consists of two receive-only companion (SAR) satellites. Ocean topography using SAR interferometry requires coherent observations of the sea surface. Thus, minimising the along-track baseline while maintaining a cross-track baseline that allows good sensitivity to height is key for measuring the ocean height but difficult to achieve in satellite missions due to the risk involved in bringing the two satellites close together along-track.
The squinted, bistatic formation of Harmony allows the system to act as an altimeter, measuring relative sea-surface heights (SSH) over unprecedented wide swaths without compromising operational safety. The wide swath in combination with the centimetre accuracy will enable the recovery of mesoscale features in a single pass.

Highlights

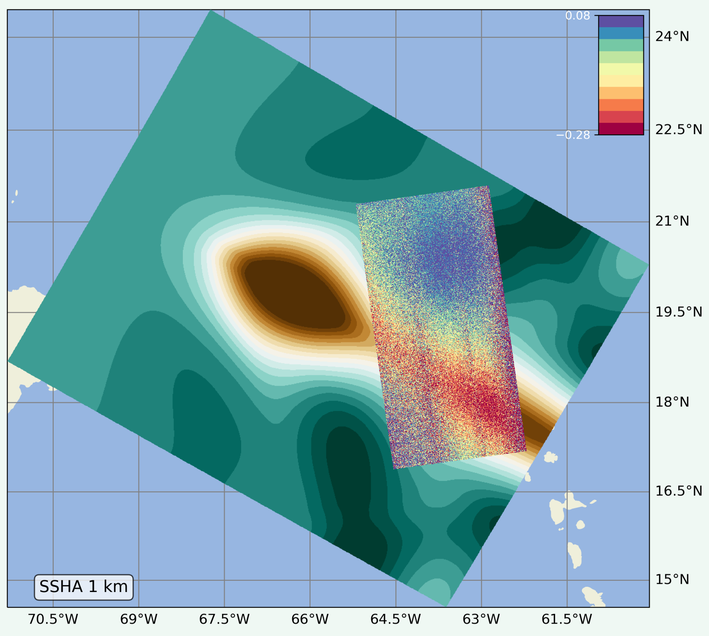
- Squinted line of sight and Helix formation allow relative height measurement of the ocean surface over unprecedented wide swaths.
- The error is approximately 10 cm over the majority of the swath at low wind speeds, throughout the orbit, with the exception of the poles.
- Two on-board phase centres allow the estimation of the ATI phase. The estimate can be used to improve the XTI phase measurement.
- The total height error is bounded by the ATI phase estimate error.
- The performance, currently presented at a product resolution of 3 km × 3 km, can be further improved by trading away resolution.

Removing the effect of the along-track phase

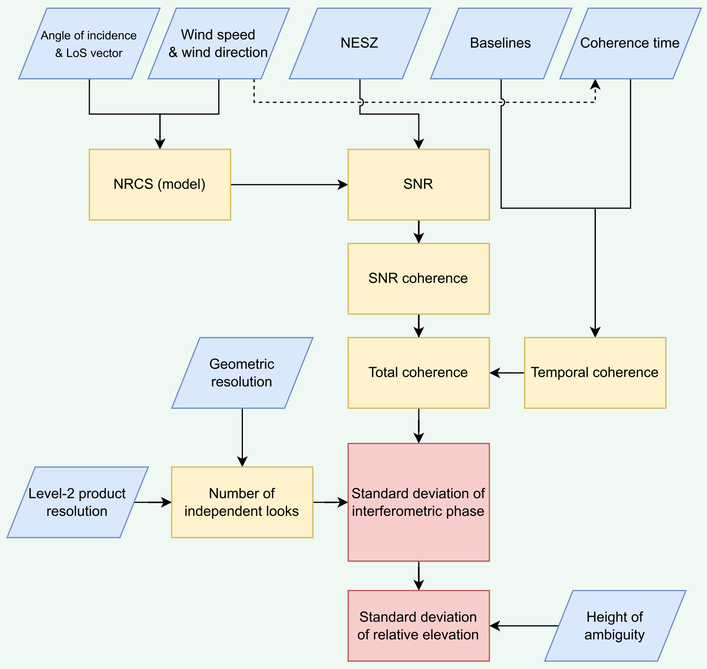


$$\hat{\phi}_{\text{topo}} = \phi_{\text{topo}} + \epsilon_{\text{ATI}} + \phi_n,$$
$$\epsilon_{\text{ATI}} = \phi_{\text{ATI}} - \frac{B_{\parallel}}{B_{\parallel s}}\hat{\phi}_{\text{ATI}}$$

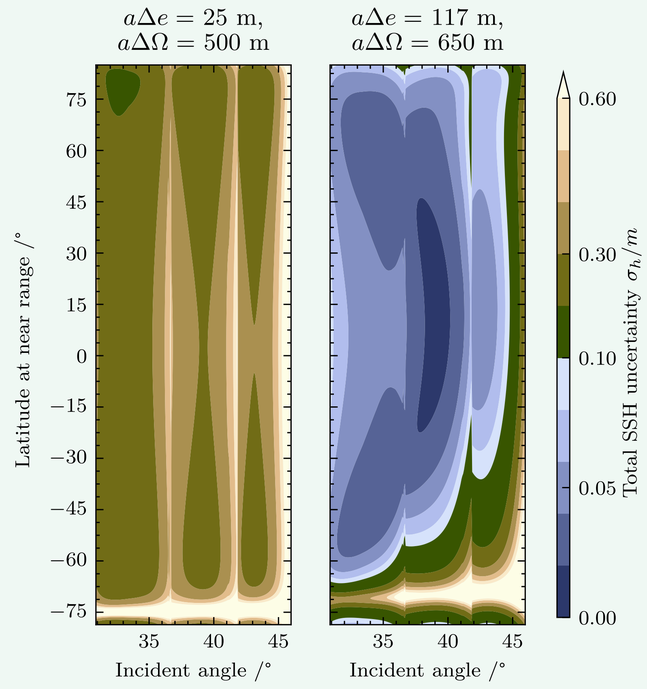
Simulation of Tropical Cyclone Wake



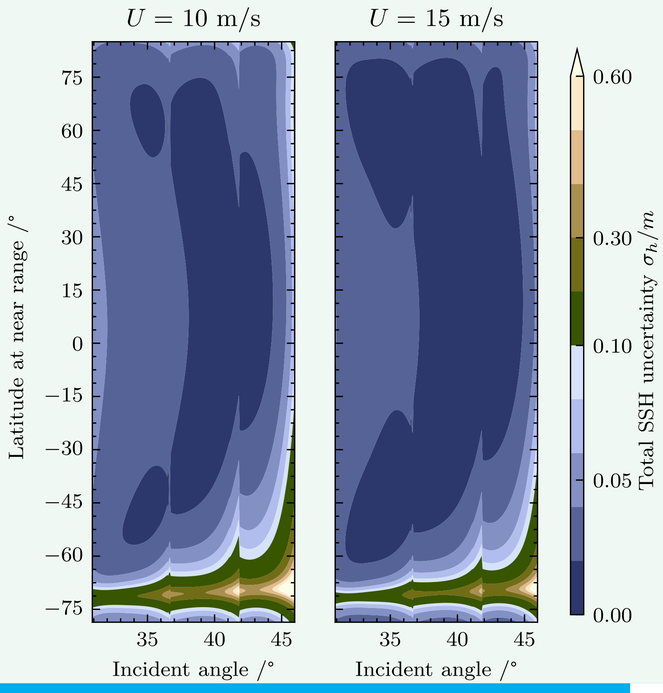
Performance Model

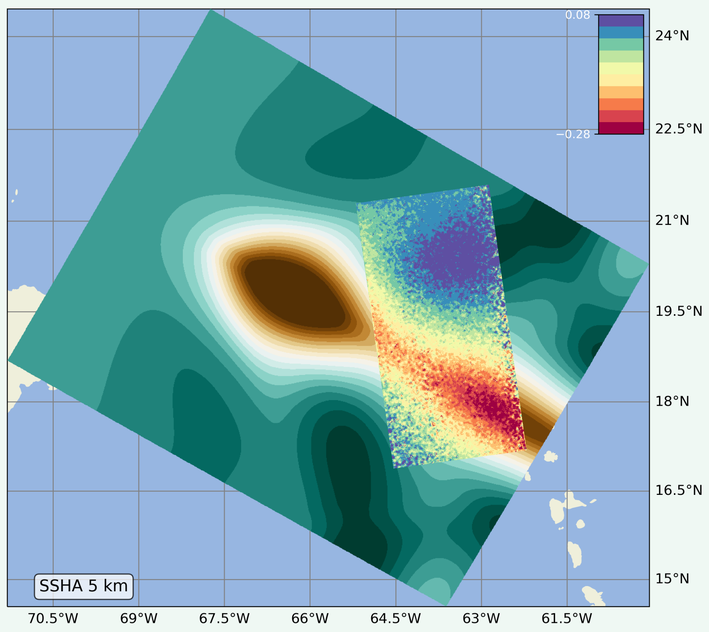


Total uncertainty in height measurement at 5 m/s wind



Total uncertainty in height measurement at higher wind speeds





Future Work

- Inclusion of the effects of systematic errors, such as clock synchronisation and baseline estimation errors.
- Compensation for the error due to clock synchronisation using a Wiener filter.
- Validation of the performance model using data.

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