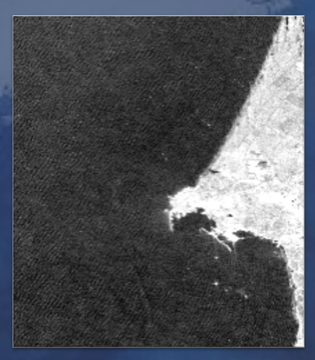
Coastal bathymetry estimation from Sentinel – 1 data

LUISA LAMAS[1] (luisa.lamas@hidrografico.pt)
J. PAULO PINTO[1], **FRANCISCO SANCHO**[2], **ALBERTO AZEVEDO**[2], **FLORENT BIRRIEN**[2], **PEDRO VILAR**[1] and **ANA MOURA**[1]

[1] Instituto Hidrográfico, Lisboa Portugal [2] Laboratório Nacional de Engenharia Civil, Lisboa, Portugal

Introduction

Depth estimation by refraction of swell waves using SAR data



Linear dispersion relationship for ocean surface waves:

$$\omega^2 = gk\ \tanh(kh)$$

$$h(k,\omega) = \frac{1}{k}\tanh^{-1}\left(\frac{\omega^2}{kg}\right)$$

k → wave number
ω → angular frequency
h → depth

Two methodologies to retrieve h from k and ω:

"Ray-Tracing Method" [1] - *Instituto Hidrográfico*

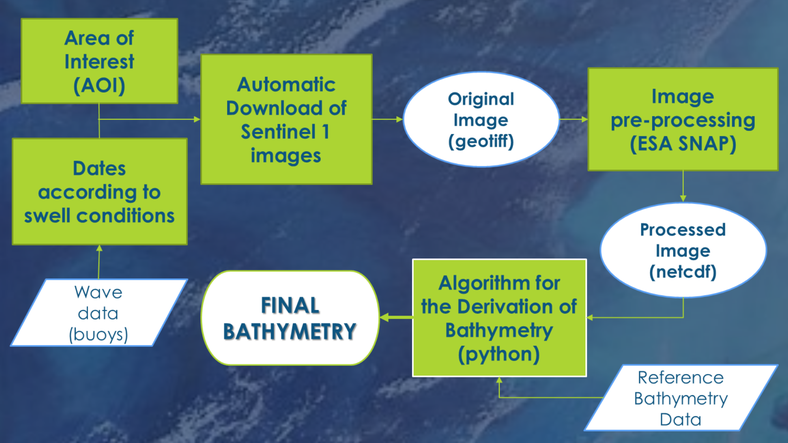
- ω constant for each wave track
- ω computed offshore using a reference bathymetric model

"Fixed Grid Method" [2] – *Laboratório Nacional de Engenharia Civil*

- ω constant for the entire grid (regular or unstructured)
- ω computed offshore from wave data (buoys or models)

✓ Both methods need optimal swell conditions (ω constant)

Ray-Tracing Method



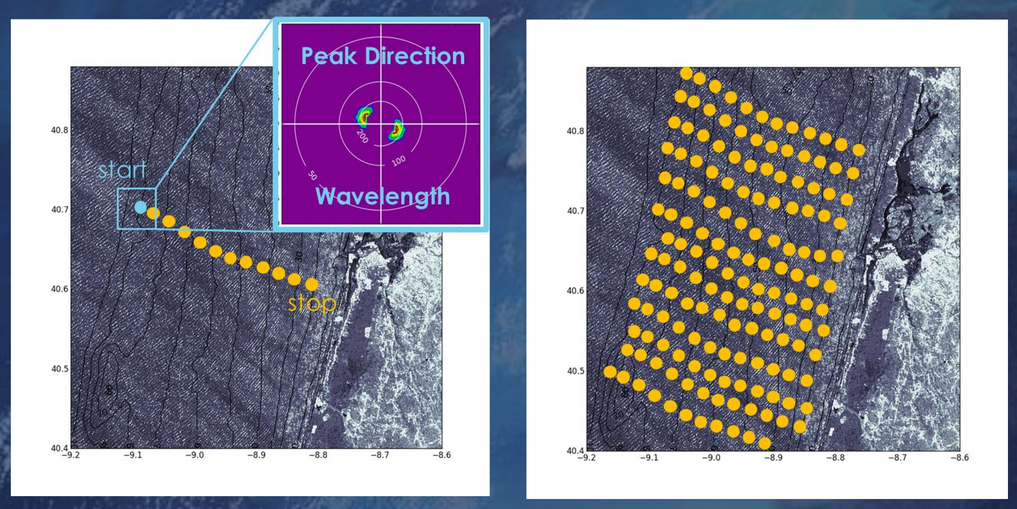


Figure 1. Left: SAR image (Sentinel-1A over Aveiro, Portugal) superimposed with isobaths from the reference bathymetric model [3] and an example of the tracking positions (yellow circles) in a single wave ray. A Fast Fourier Transformation (FFT) algorithm is applied in a square sub-image of 1km² centered at all tracking positions (for example, the blue square represents the sub-image centered at the starting position which is marked as a blue circle), and the wave's length and direction is retrieved. The next tracking position is obtained by the displacement of one wavelength in the wave direction. Right: Example of the tracking positions for some wave rays traced by the algorithm using this image.

Improving the retrieval of k from the FFT analysis

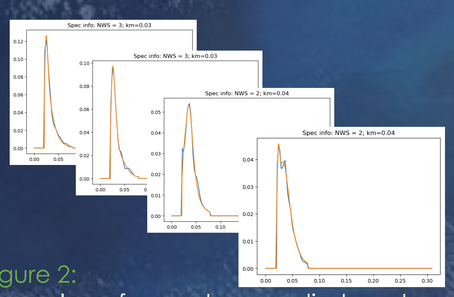


Figure 2: Example of spectrum adjustments, on different tracking points, to a Pierson-Moskowitz function, which depends on the local maxima number (NWS). This method increases the discretization of k, allowing for a better estimation of the depth.

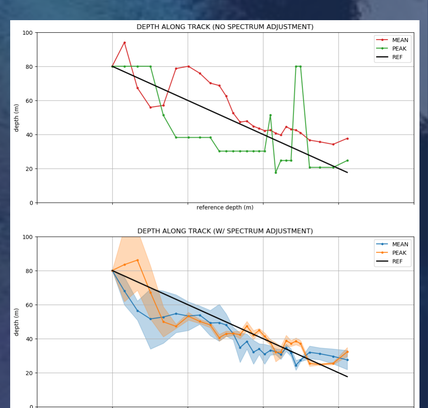


Figure 3: Example of the bathymetry estimated along one singe wave ray, with (bottom) and without (top) the spectrum adjustment. The black line represents the reference bathymetry [3] along that wave ray.

Results

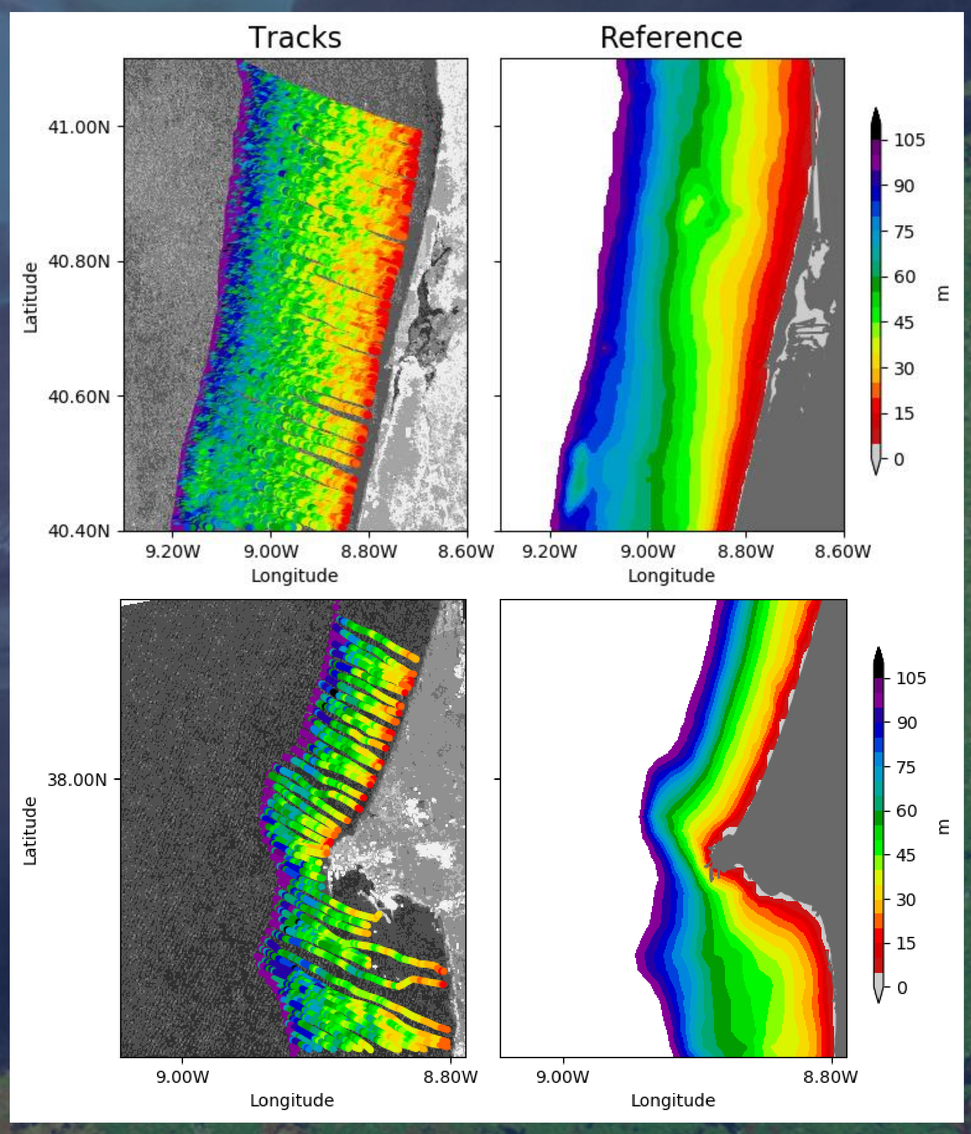


Figure 3. Top, left: Depth estimated using the linear dispersion relationship for ocean surface waves with the Ray Tracing Algorithm, for a SAR image over the coastal region near Aveiro, Portugal (image reference: S1B_IW_GRDH_1SDV_20170131T183449_20170131T183514_004096_007148_CDB9)
Top, right: the reference bathymetric model [3] near Aveiro.
Bottom, left and right: Same as top figure but for the region near Sines, Portugal (image reference: S1A_IW_GRDH_1SDV_20170206T183457_20170206T183522_015167_018D0A_F984)

Discussion and Future Work

- The resulting bathymetric models show most of the topographic structures and reproduced the correct slope, with an average of 15 to 20% errors for the absolute depth values, mainly due to the small scale variability of the SAR image.
- In the future, the final bathymetry for a given region will result from the average of multiple images, in order to reduce the high variability obtained by individual images.
- SAR derived bathymetry looks promising and can provide topographic information at higher resolution, especially in remote areas where the traditional hydrographic surveying methods are not performed regularly.
- Comparissons between Fixed Grid and Ray Tracing methods will be conducted in the future (Fig. 4)
- The fusion of SAR and Optical data to provide higher coverage and resolution over shallower waters is under development.
- Tests of this synergy will be conducted in the region around Sines, in the southwestern coast of Portugal (Fig. 5)

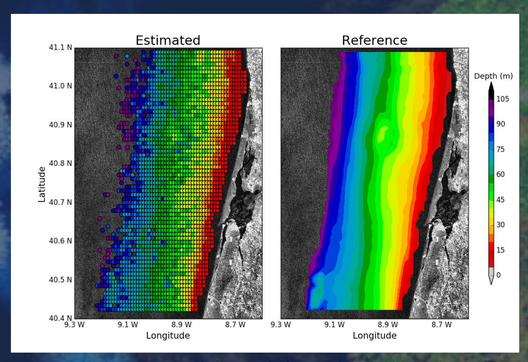


Figure 4: Same as Figure 3 top, but the depth on the left figure was estimated using the Fixed Grid Method

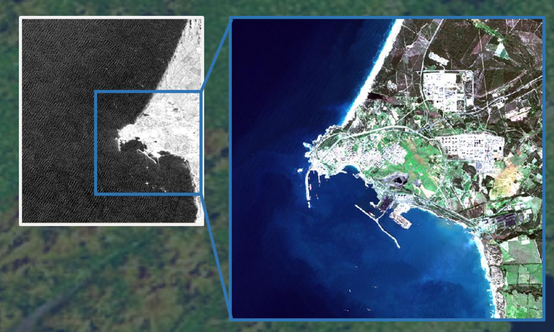


Figure 5. : SAR (Sentinel-1) and Optical (Sentinel-2) image of the region around Sines

References:

[1] Pleskachevsky, A., S. Lehner, T. Heege and C. Mott (2011). Synergy and Fusion of optical and synthetic aperture radar satellite data for underwater topography estimation in coastal areas. Ocean Dynamics, 61: 2099-2120
[2] Sancho, F., A. Azevedo, J. P. Pinto and L. Lamas (2017). Coastal Waters Research Sinergy Framework (Co-ReSyF): Project Overview and SAR-Bathymetry Estimation. *MEC 2017 | 4º Conferência sobre Morfodinâmica Estuarina e Costeira.*
[3] GEBCO_2014 Grid — global 30 arc-second interval grid (www.gebco.net)

This project has received funding from the EU's H2020 research and innovation programme under grant agreement No 687289

www.co-resyf.eu