Offshore GPS buoy measurements and comparison with JASON-1 radar altimeter data

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Abstract Satellite radar altimeter missions are the basic means to monitor the sea surface topography on a global scale and to provide measurements of sea level variations over the deep sea with a dense and homogeneous coverage in space and time. Due to the increasing needs in accuracy and long-term integrity, it has become mandatory to validate and calibrate the satellite systems by establishing onshore calibration sites. In Europe, onshore calibration is currently provided by the stations on the islands of Corsica, France, and Gavdos, Greece. The latter was set up in the frame of the recently terminated EU project GAVDOS, with the aim to establish a European sea-level monitoring and radar altimeter calibration site for JASON-1, ENVISAT and EURO-GLOSS. Common methods applied are tide-gauge observations and deployments of GPS buoys in harbors located under satellite tracks. With facilities like the ones on Corsica and Gavdos the accuracy of the oceanographic products is being improved. What is missing in this scenario, however, are offshore in situ sea surface height (SSH) data in the open sea.

In order to contribute to the improvement of sea level monitoring, enhanced ground-based methods for validation and calibration of satellite radar altimeters have been developed. They consist in offshore ground-truth measurements of the sea surface height adjacent to sub-satellite tracks using lightweight GPS equipped buoys (Fig. 2), designed and constructed by the GGL based on previous experiences. The GPS buoys have been deployed under JASON-1 ground-tracks in the Ionian and Northern Aegean Seas in the Eastern Mediterranean (Fig. 3, 4 and 5). These dedicated offshore GPS measurements provide precise in situ information on the instantaneous sea surface height underneath a JASON-1 track simultaneously with the overflight of the satellite. This will ultimately allow to contribute to the validation and calibration of the radar altimeter data.

Preliminary results for the sea surface height solutions obtained from offshore GPS buoy measurements are very promising in terms of accuracy and repeatability. First comparisons with JASON-1 radar altimeter data on dedicated profiles showed encouraging results but revealed geographically-correlated variations of the height difference between 0.1 and 0.2m (Fig. 7).

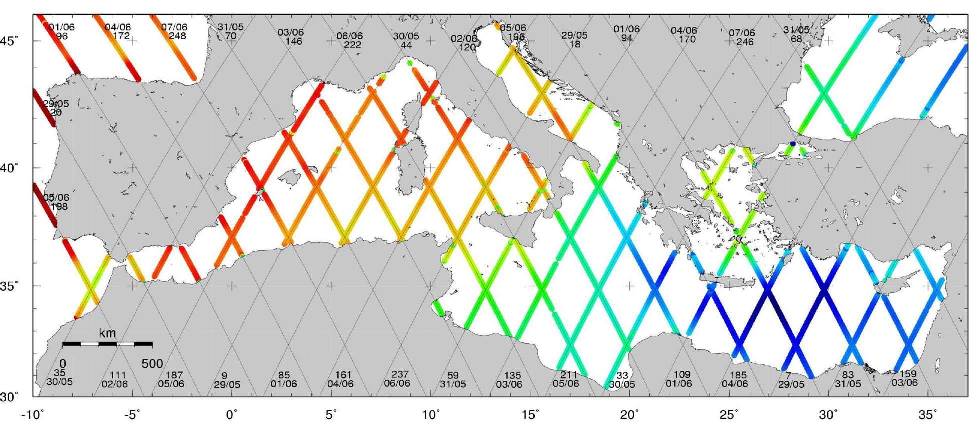

*Fig. 1: **JASON-1** ground-tracks (cycle 125, May/June 2005) in the Mediterranean Sea with color-coded **sea surface heights** from 1Hz radar altimeter data and indication of track-numbers and dates (day/month).*

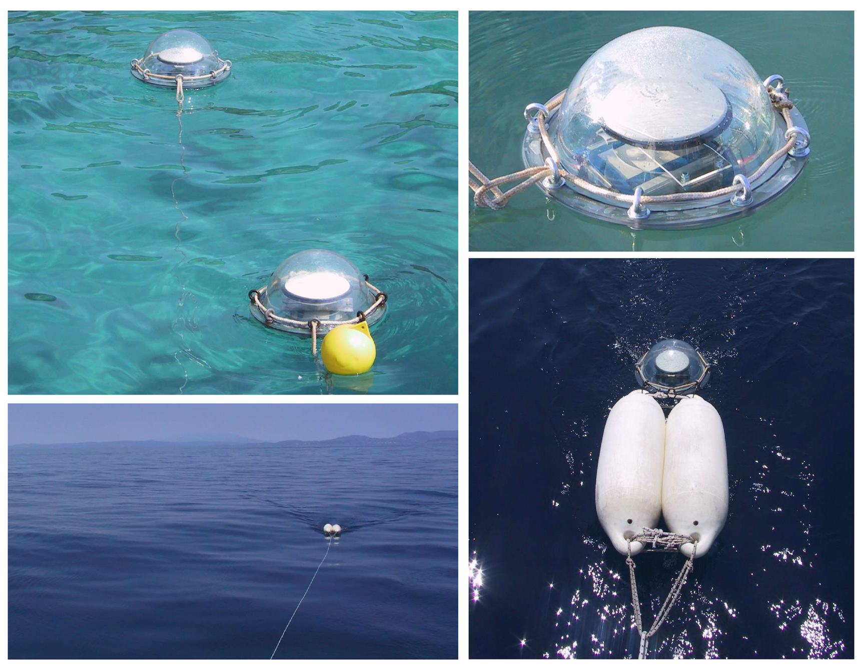

*Fig. 2: **GPS equipped buoys** deployed in coastal region (upper pictures) and offshore (lower pictures), where the pulled buoy is attached to a floating construction to maintain buoyancy. The shell of the buoys is fabricated from microwave-transparent polycarbonate, so they can be waterproofed sealed containing the receiver (NovAtel DL-4), antenna and battery.*

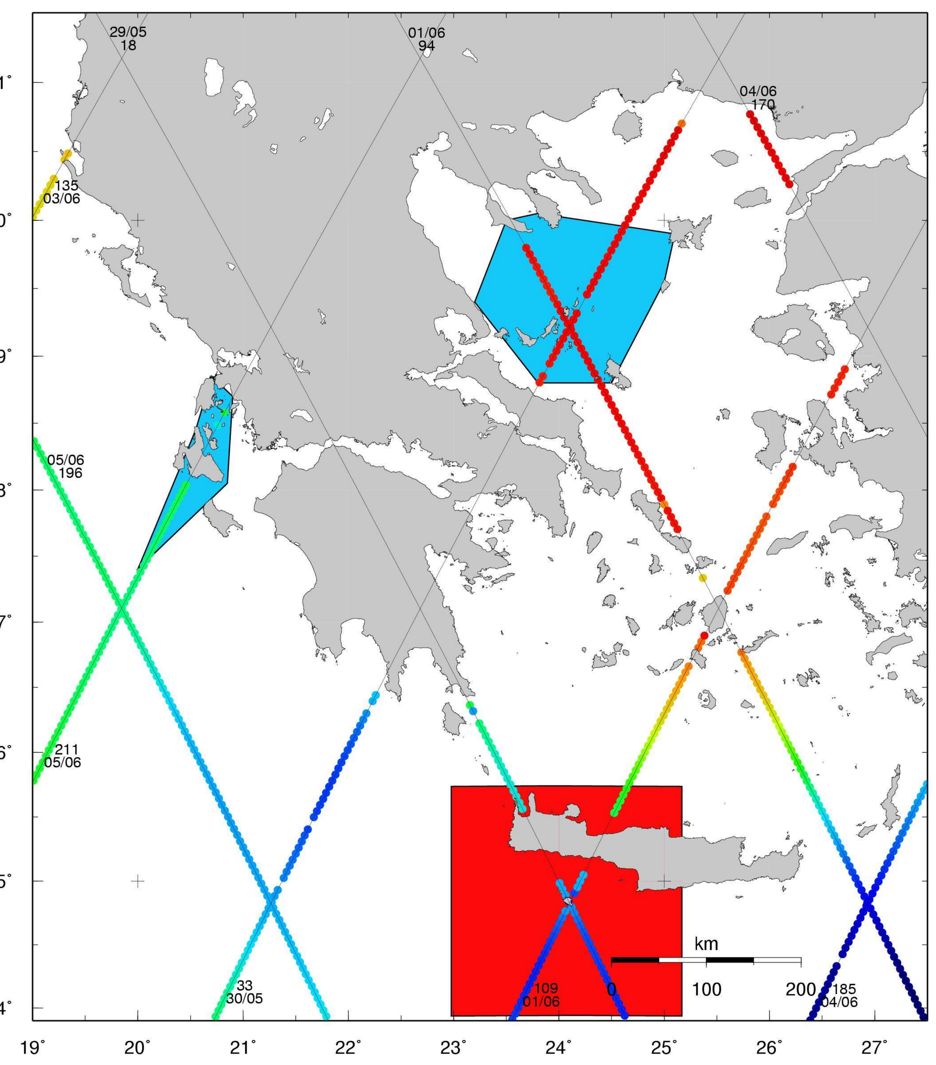

*Fig. 3: **Survey areas** of offshore GPS buoy measurements and airborne laser altimetry in the Eastern Mediterranean. The red square depicts an area where a detailed airborne laser altimetry and gravimetry campaign was carried out in the framework of the EU project GAVDOS in 2003. The blue areas show the offshore GPS buoy surveys under JASON-1 tracks conducted in the Ionian Sea in 2003 (Fig. 4) and in the Northern Aegean Sea in 2004 and 2005 (Fig. 5). JASON-1 ground-tracks are indicated by the inclined grid-lines with color-coded sea surface heights from 1Hz radar altimeter data.*

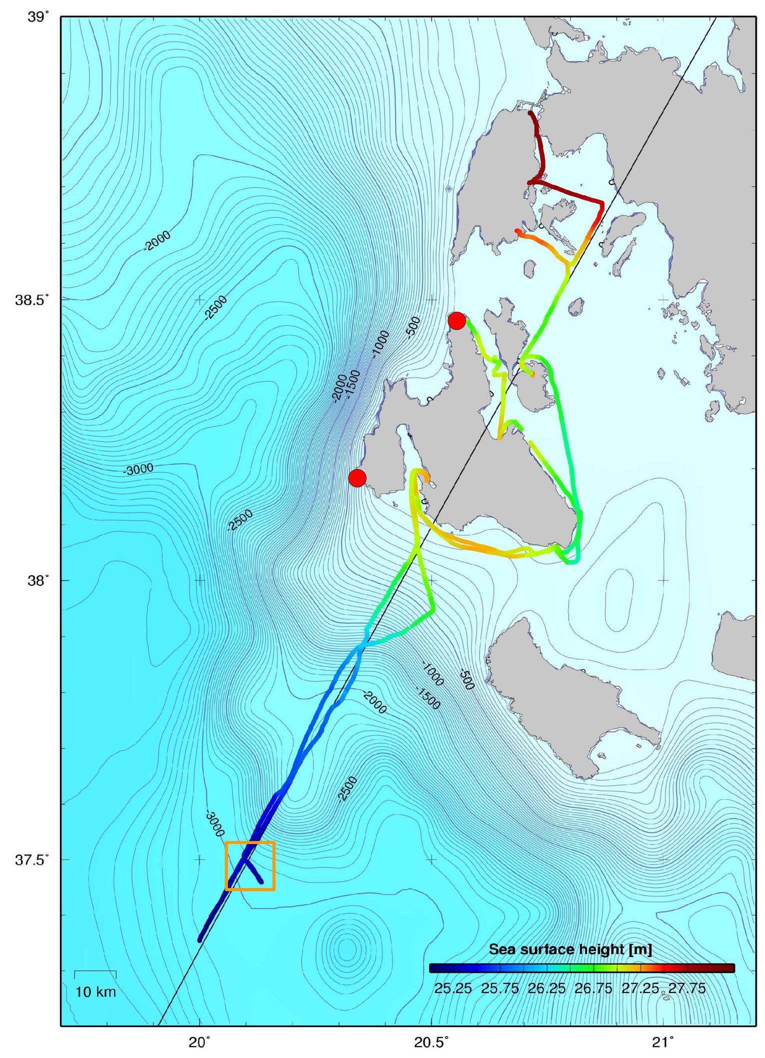

*Fig. 4: **GPS buoy survey** in the **Ionian Sea** along the JASON-1 ascending track 211 (black line) in Sept. 2003. Boat-track with color-coded sea surface heights from shipborne GPS observations totalling 330nm, with a 75nm segment along JASON-1 track. The campaign involved two GPS buoys, one GPS receiver aboard the boat and two GPS reference stations (red circles). Orange square: JASON-1 encounter on Sept. 20th, 2003. Background: bathymetry, isolines interval 50m.*

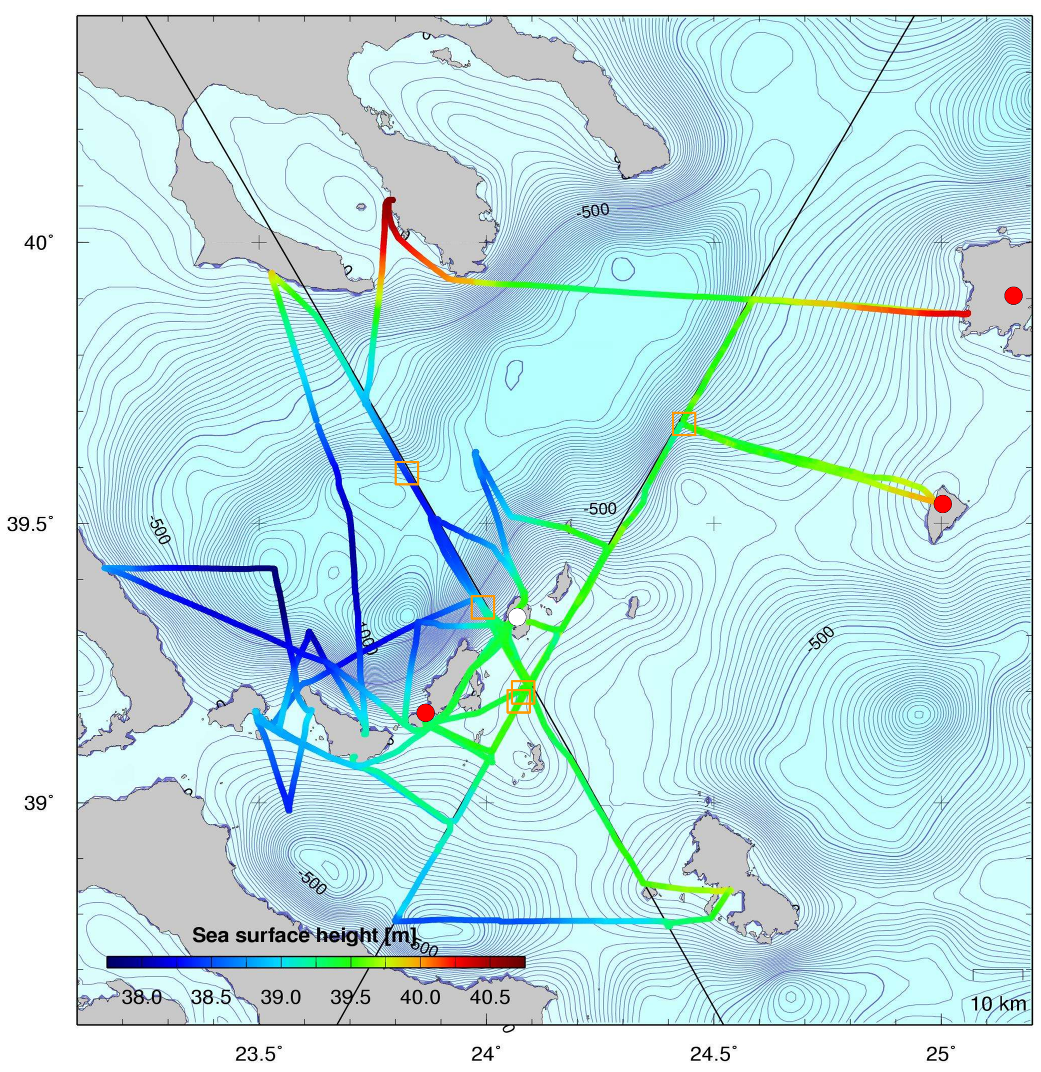

*Fig. 5: **GPS buoy survey** in the **Northern Aegean Sea** along the JASON-1 ascending track 33 and descending track 94 (black lines) in Sept. 2004 and May/June 2005. Boat-track with color-coded sea surface heights from shipborne GPS observations totalling more than 1000nm. Both campaigns involved two GPS buoys, four GPS receivers aboard the boat, two tide-gauges and three GPS reference stations (red circles). White circle: permanent tide-gauge station. Orange squares: JASON-1 encounters. Background: bathymetry, isolines interval: 20m.*

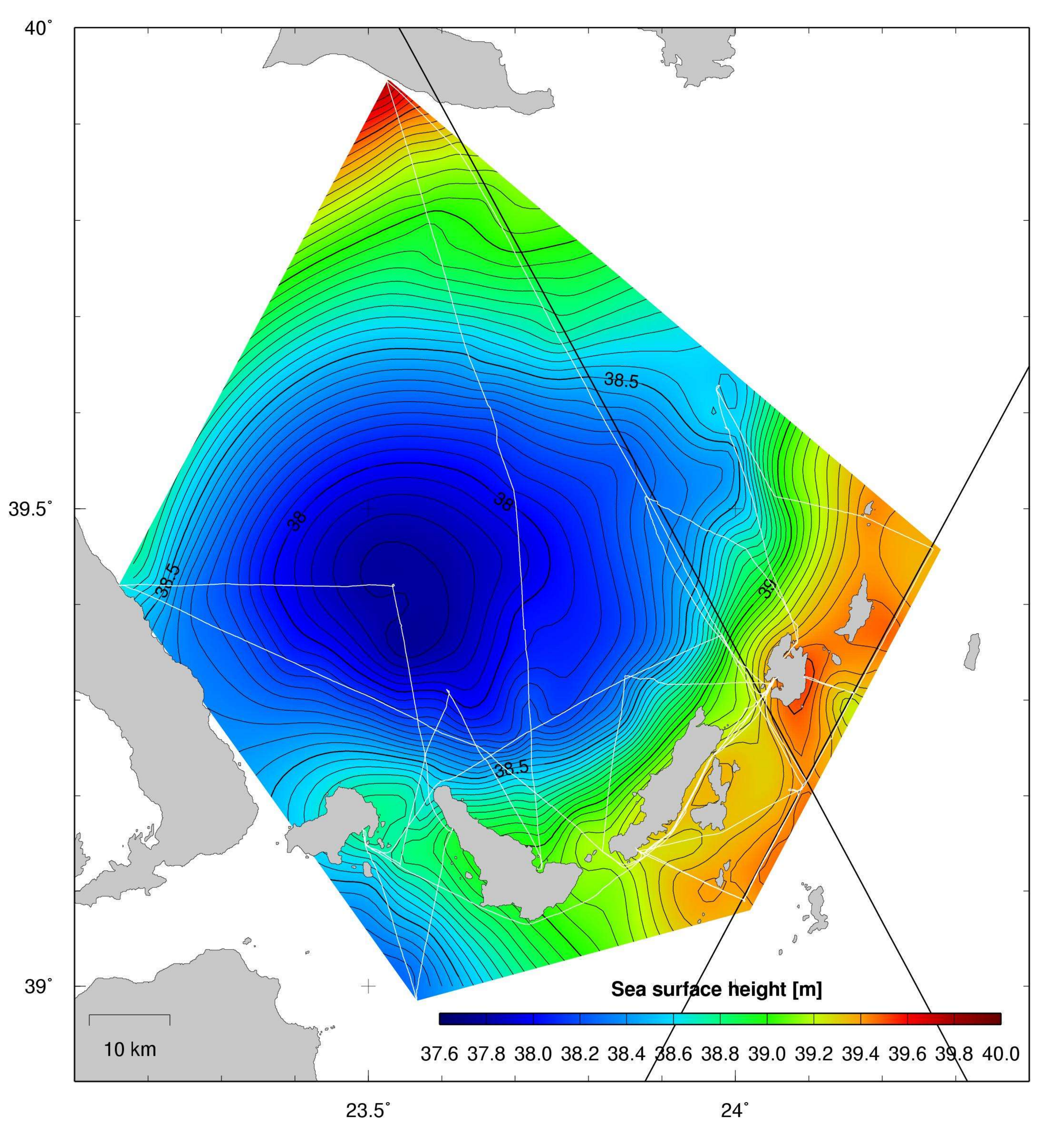

*Fig. 6: Preliminary **sea surface topography** obtained by gridding the shipborne GPS data from the 2005 Aegean Sea campaign (white lines). Isolines interval: 0.05m. Note that parts of the surface like the north-western region and most of the near-boundary regions are to be considered as highly suggestive due to extrapolation.*

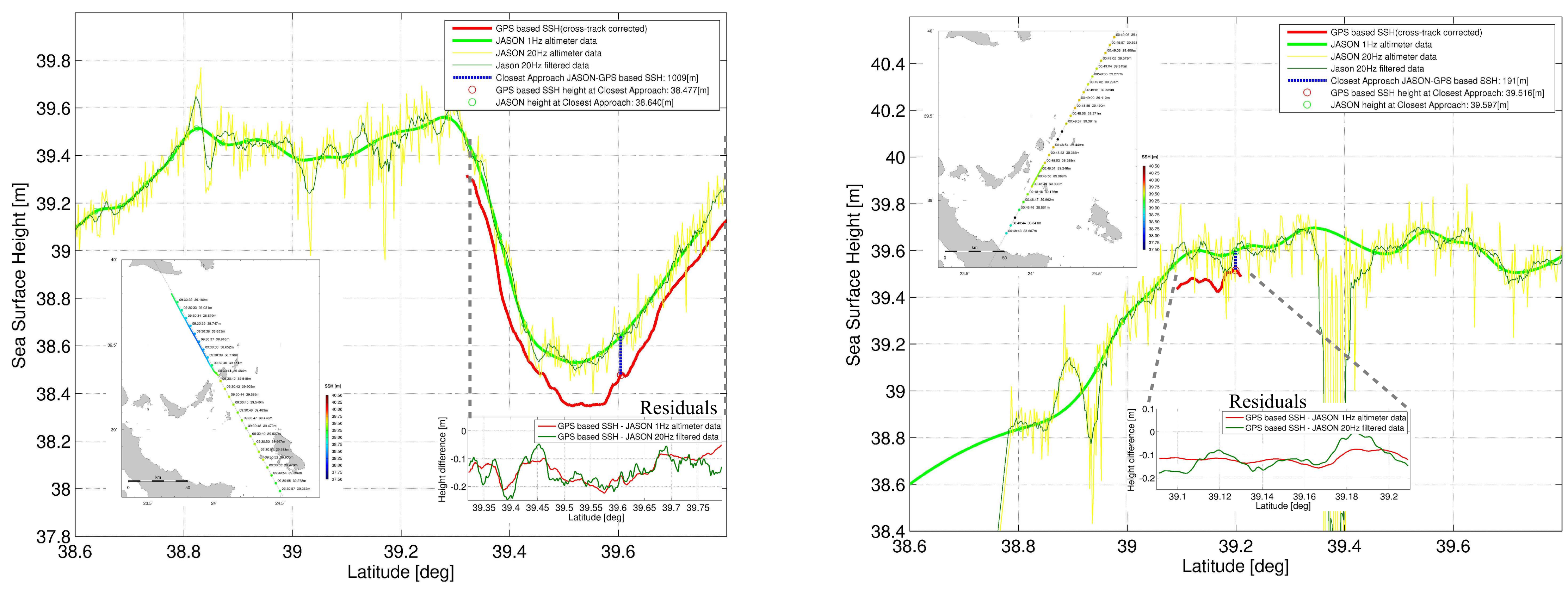

*Fig. 7: Two examples of **comparisons** between a **JASON-1** SSH profile (green line) and the preliminary results of combined in-situ shipborne and buoy **GPS data** (red line). Similar tide corrections have been previously applied to both datasets, as well as a cross-track gradient correction to account for the horizontal offset between the radar altimeter ground-points and the GPS profiles. The encounter (closest approach) is marked by the dashed blue line.*

Left figure: JASON-1 descending track 94
Mean height difference along the profile: -0.142m ± 0.042m std dev.
Maximum / minimum height difference: -0.224m / -0.045m

Right figure: JASON-1 ascending track 33
Mean height difference along the profile: -0.108m ± 0.022m std dev.
Maximum / minimum height difference: -0.157 / -0.075m.

The significant variations of the height differences along a profile seem to be mostly due to the effect of the distinct spatial resolution of the two methods amplified in regions with strong sea surface height gradients and strong gradient variations.