Validation of SRTM-Derived Surface Currents off the Dutch Coast by Numerical Circulation Model Results

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Abstract – **The feasibility of exploiting the along-track separation of 7 m between the two X band antennas of SRTM for ocean current measurements was already demonstrated by us at IGARSS 2002: We presented an SRTM image of the Dutch Waddenzee with clear phase variations in water-covered areas, which could be converted into line-of-sight current variations by about 1.3 m/s. A comparison with a current map from a tidal atlas showed good qualitative agreement, but digital reference data for a quantitative validation of the SRTM results were not available. In this work we present a detailed comparison of the SRTM data with simulated current fields from the numerical circulation model KUSTWAD. We obtain an overall correlation of 0.558, a regression coefficient of 1.011, and an rms difference between SRTM and KUSTWAD currents of 0.24 m/s. Furthermore, we analyze the correlation of spatial variations in the measured and simulated current fields on different length scales. We find that SRTM can resolve the current variations which are relevant to KUSTWAD down to scales on the order of 1 km.**

I. INTRODUCTION

As already shown on previous occasions, the X band interferometric SAR data acquired during the Shuttle Radar Topography Mission (SRTM) in early 2000 [1] include some interesting phase images of ocean scenes which exhibit clear signatures of spatially varying surface currents. These signatures result from the small along-track separation of the SRTM antennas of 7 m, which permits the detection of line-of-sight target velocities with a phase sensitivity of 38.5 m/s / 2π for horizontal motions. At IGARSS 2002, we presented an SRTM-derived line-of-sight current field in the Dutch Waddenzee, which appeared to be in good agreement with a current field for the corresponding tidal phase from a current atlas, but a fully quantitative validation of the SRTM results had not been performed by that time [2].

In the meantime, simulated current fields in the test area from the circulation model KUSTWAD have become available to us in digital format. In the following we present some key results of a detailed quantitative intercomparison of the SRTM-derived current field with KUSTWAD results.

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II. THE KUSTWAD MODEL

KUSTWAD is one of the so-called WAQUA / TRIWAQ based hydraulic models [3] that are being developed and maintained at the National Institute for Coastal and Marine Management ("RIKZ" in Dutch) of Rijkswaterstaat in The Hague. Various versions of these models are available for simulations on different spatial scales, ranging from the Dutch Continental Shelf Model DCSM to more detailed local models such as KUSTWAD. They are employed in operational, management, and research activities. To calibrate the models and to improve the quality of the operational results, they have been extended with data assimilation modules [4, 5].

Both the 2d hydraulic program WAQUA and the 3d program TRIWAQ are based on advanced numerical methods. They include important physical processes such as salinity variations and turbulence, and they contain special features to model sluices, barriers, tidal flats, etc. These qualities are particularly important in areas such as the Waddenzee.

KUSTWAD is specially developed to describe and predict the consequences of management measures in the Waddenzee area. The model contains the main part of the Dutch Waddenzee, the Ijsselmeer, a part of the North Sea, and a part of the river Ijssel. It has a curvilinear schematisation with a resolution varying from 50 m up to 2.5 km. The representation of the bottom is based on the latest available depth data.

The KUSTWAD results available for this study cover one tidal cycle on 23 March 1995, 1:00 through 14:00 UTC, with a time step of one hour. That is, the model was not applied to the specific scenario at the time of the SRTM overpass (15 February 2000, 12:34 UTC), but to another scenario about five years earlier. However, the agreement between measured and simulated current fields should usually be good at the same tidal phase. The shortest time lag between the tidal phase at the time of the SRTM overpass (3:16 hours before high water in West-Terschelling) and an available KUSTWAD current field is 20 minutes.

Figure 1 shows the KUSTWAD model grid and bottom topography in the test area. For the comparison, the current fields from SRTM and KUSTWAD were interpolated onto the same 100 m $\times$ 100 m grid.

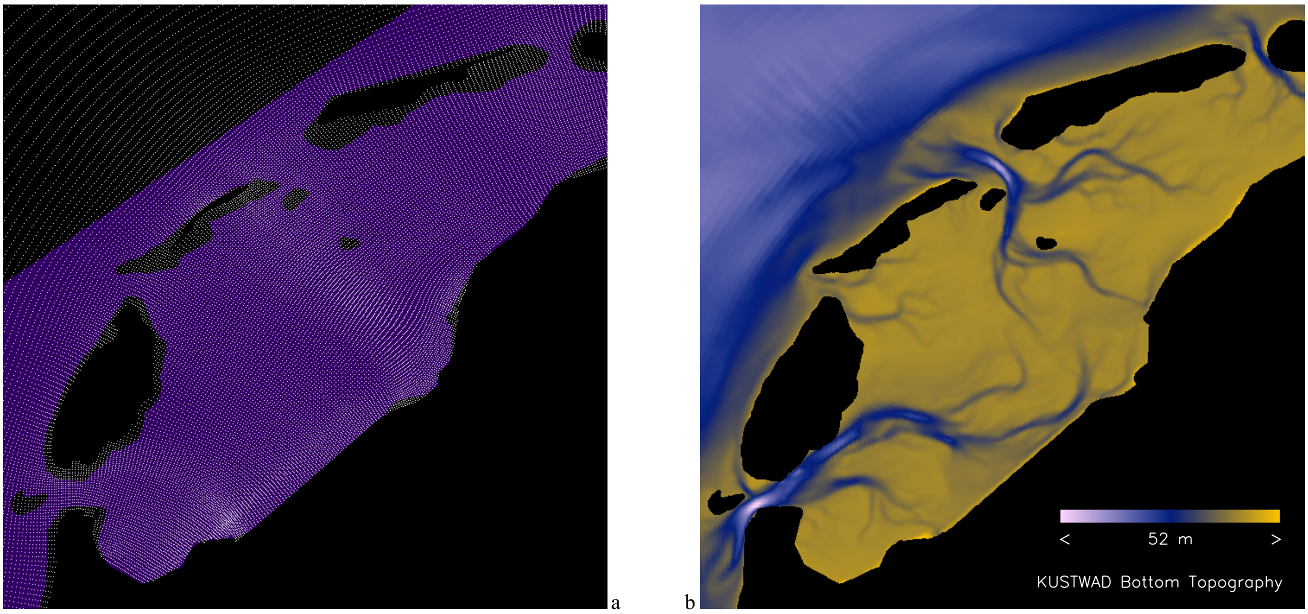


Figure 1. KUSTWAD model grid points and SRTM swath and land mask (a) and KUSTWAD bottom topography (b) in the 70 km × 70 km test area.

III. General Validation of SRTM-Derived Currents

Figure 2 shows the line-of-sight current field derived from the SRTM data and a corresponding current field derived from the KUSTWAD result for the tidal phase 20 minutes before the SRTM overpass. The qualitative and quantitative agreement of the two datasets appears to be quite good. In particular, the topography-guided strong currents in relatively narrow channels exhibit very similar flow patterns and have very similar magnitudes.

Figure 3 shows a corresponding scatter plot of SRTM-derived vs. KUSTWAD-derived line-of-sight currents. The correlation coefficient between the two datasets is 0.558, the regression coefficient is 1.011, and the rms difference is 0.24 m/s. The mean difference is found to be 0.02 m/s. In view of the fact that the SRTM phases were not absolutely calibrated and that the bias of the SRTM-derived current field was manually adjusted such that the line-of-sight current becomes 0 in the vicinity of the Ijsselmeer dam [2], this is a quite good result.

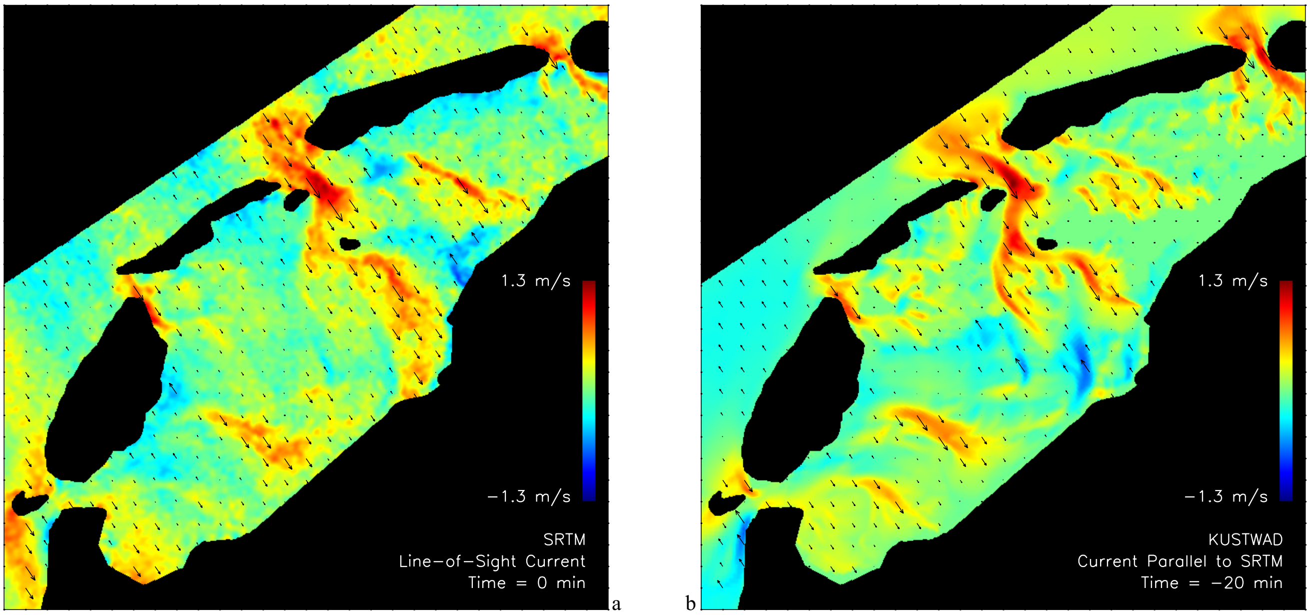


Figure 2. Line-of-sight current field in the test area as derived from the SRTM data (a) and as obtained from KUSTWAD for the tidal phase 20 minutes before the SRTM overpass (b); grid resolution is 100 m × 100 m; only datapoints with valid currents from SRTM and KUSTWAD are shown.

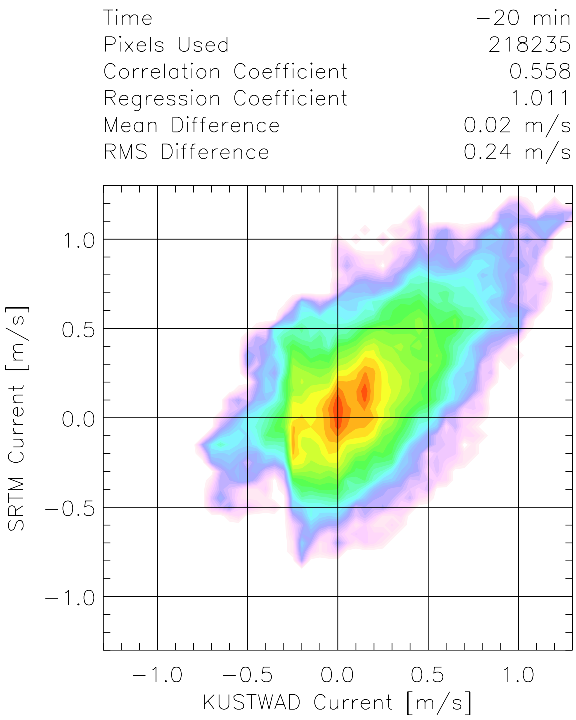


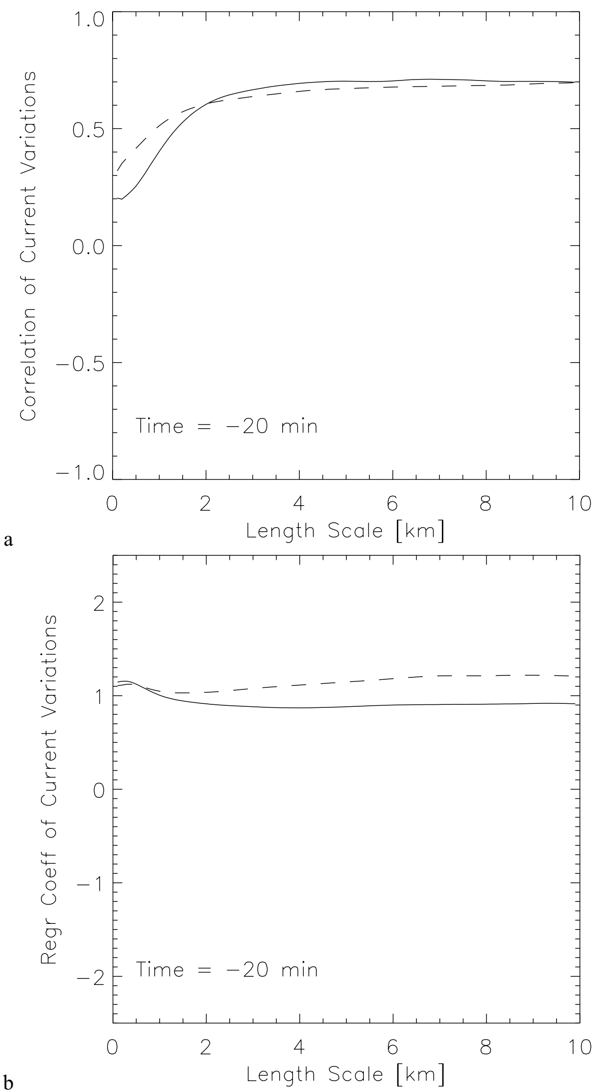
Figure 3. Scatter diagram showing the distribution of SRTM-derived vs. KUSTWAD-derived current components in the SRTM look direction, as well as corresponding statistical quantities, for the tidal phase 20 minutes before the SRTM overpass.

IV. Comparison of Current Variations on Different Spatial Scales

To compare spatial variations in the SRTM-derived line-of-sight current field and the corresponding KUSTWAD-derived current field, we have computed correlation and regression coefficients of the differences in the two current fields on different length scales. For example, differences between pixels in the SRTM current field which are separated by 1 km were correlated with the corresponding differences between pixels in the KUSTWAD current field to obtain regression and correlation coefficients for variations on a length scale of 1 km. This analysis was performed for distances of 100 m (1 pixel length) to 10 km parallel and perpendicular to the look direction of SRTM. Results are shown in Figure 4. They indicate that the correlation and regression coefficients are almost constant down to spatial scales on the order of 1 to 2 km.

V. Conclusions

The results of our analyses indicate that the SRTM-derived line-of-sight current field agrees quite well with the corresponding KUSTWAD result down to spatial scales of 1 to 2 km. The correlation is between 0.5 and 0.7, and the regression coefficient is close to 1. In view of the fact that SRTM was not designed for current measurements and that the KUSTWAD model does not necessarily provide perfect reference data, this is a quite positive and promising result.



a

b

Figure 4. Correlation (a) and regression coefficient (b) of variations in the SRTM and KUSTWAD currents at different spatial scales parallel (solid lines) and perpendicular (dashed lines) to the SRTM look direction.

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