Ocean Current Retrievals From TerraSAR-X and TanDEM-X Data

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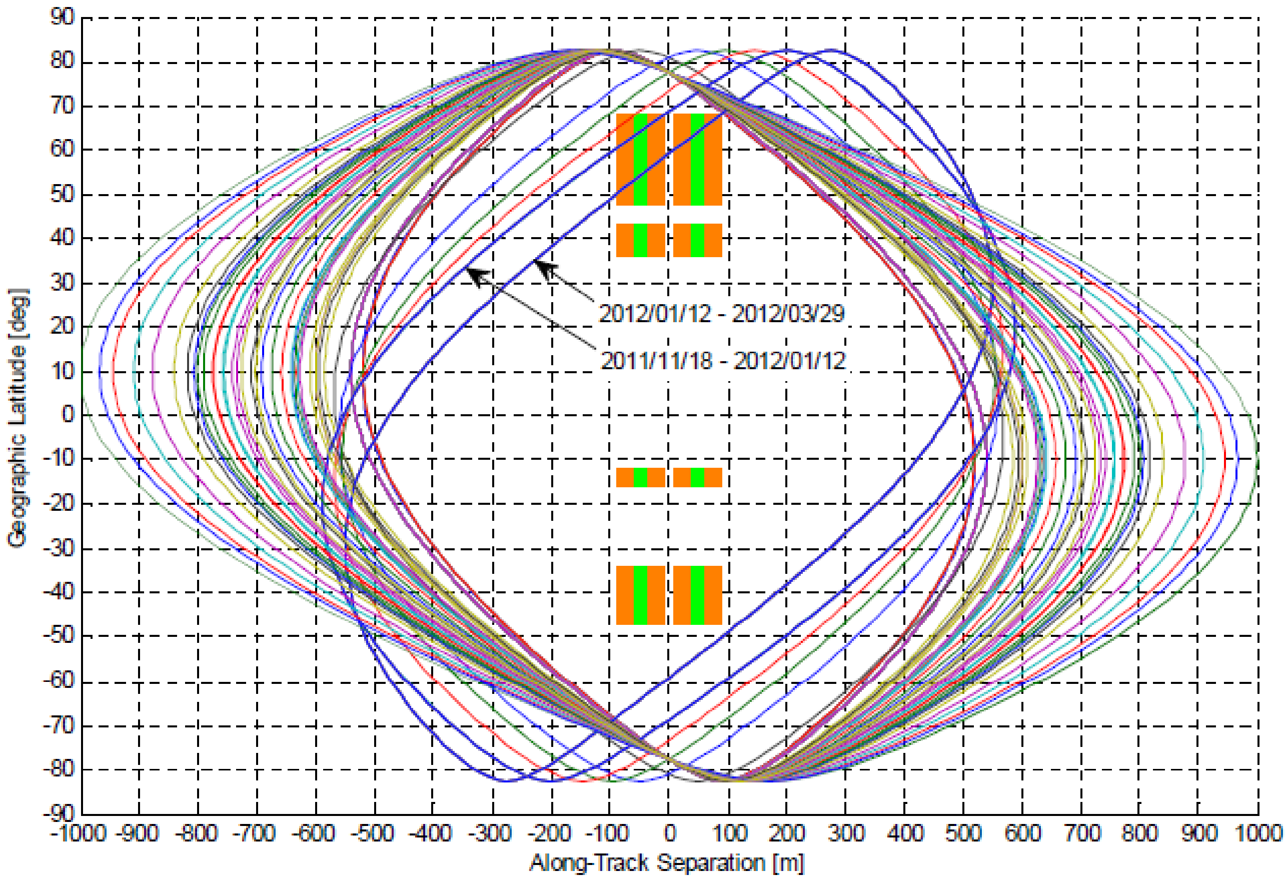
TanDEM-X Orbit Geometry



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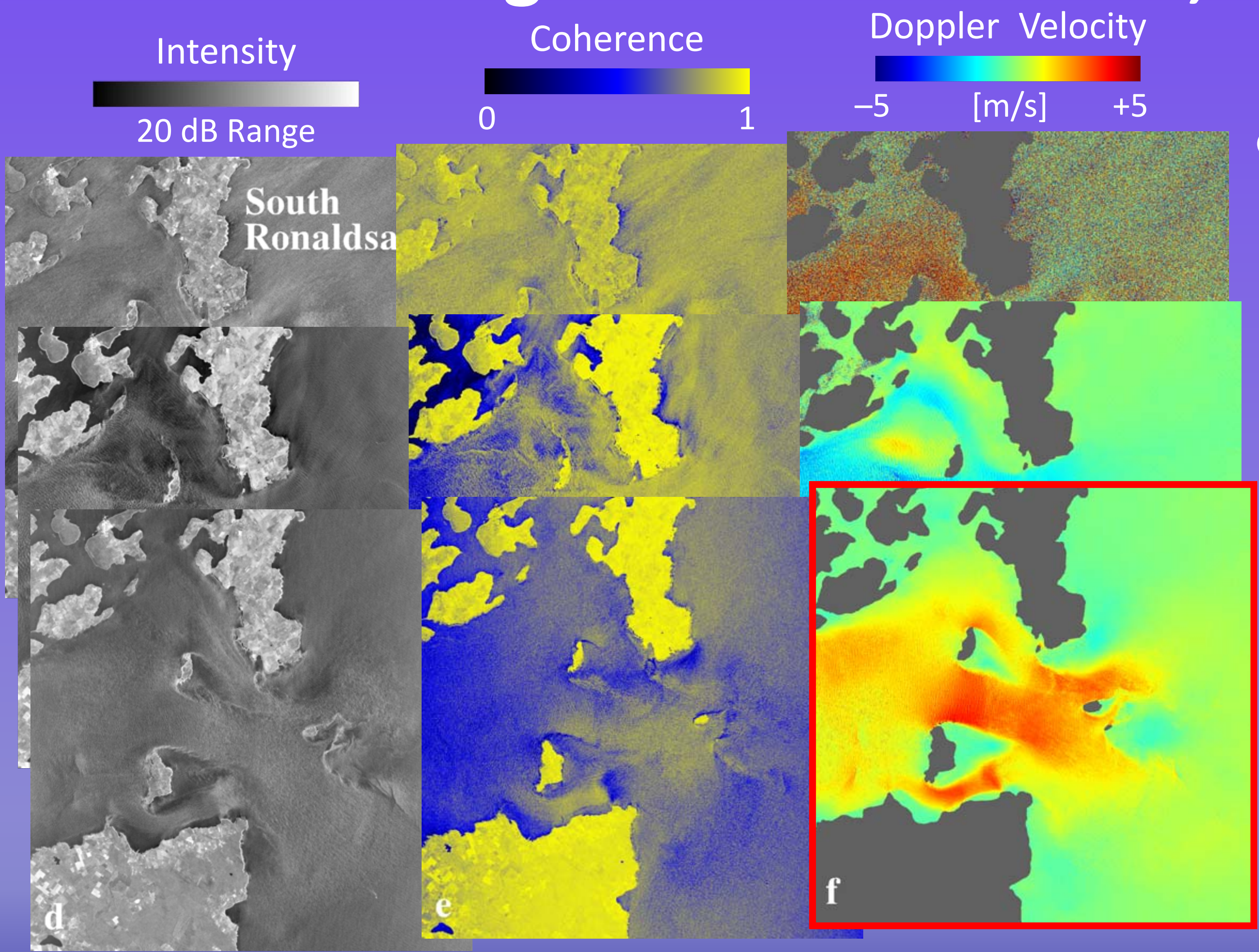
Three ATI Images of Pentland Firth, Scotland



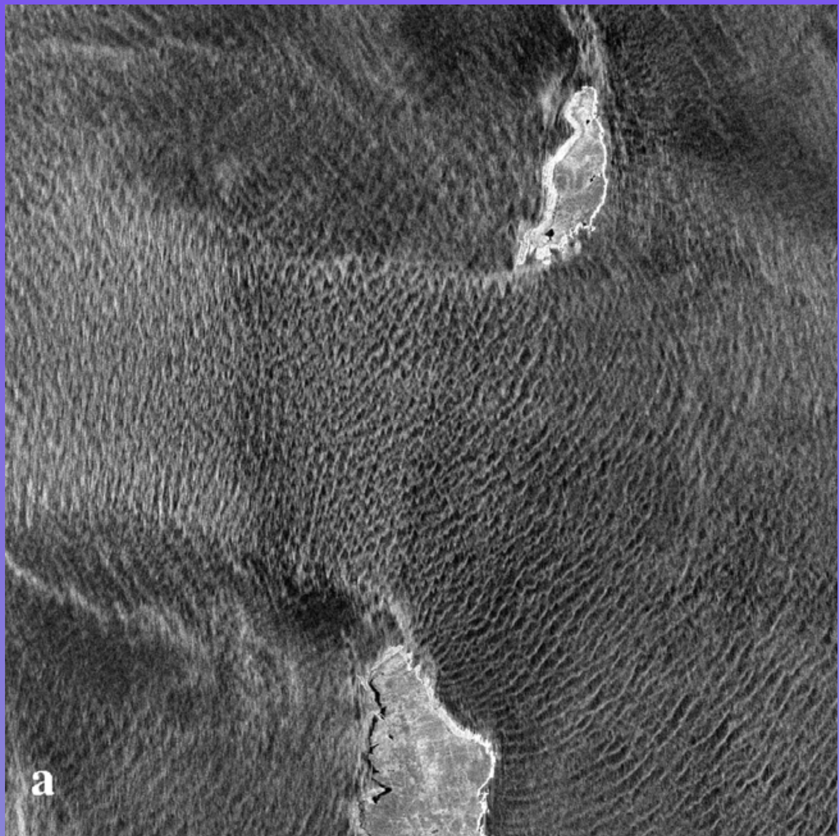
❶ TerraSAR-X DRA
2010-04-26
BL_{AT} = 1.15 m
200 m/s / 2π

❷ TanDEM-X
2012-02-26
BL_{AT} = 25 m
9.14 m/s / 2π

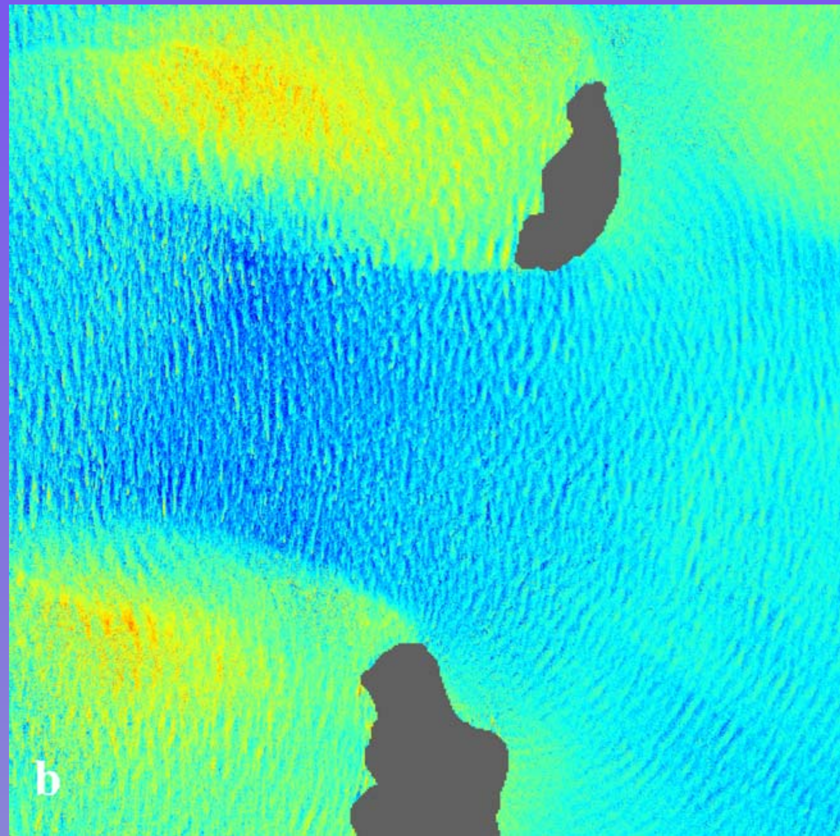
❸ TanDEM-X
2012-03-19
BL_{AT} = 40 m
5.69 m/s / 2π

Shown area =
30 km × 30 km;
pixel size =
25 m × 25 m

Effective Spatial Resolution Analysis



20 dB Range
Intensity



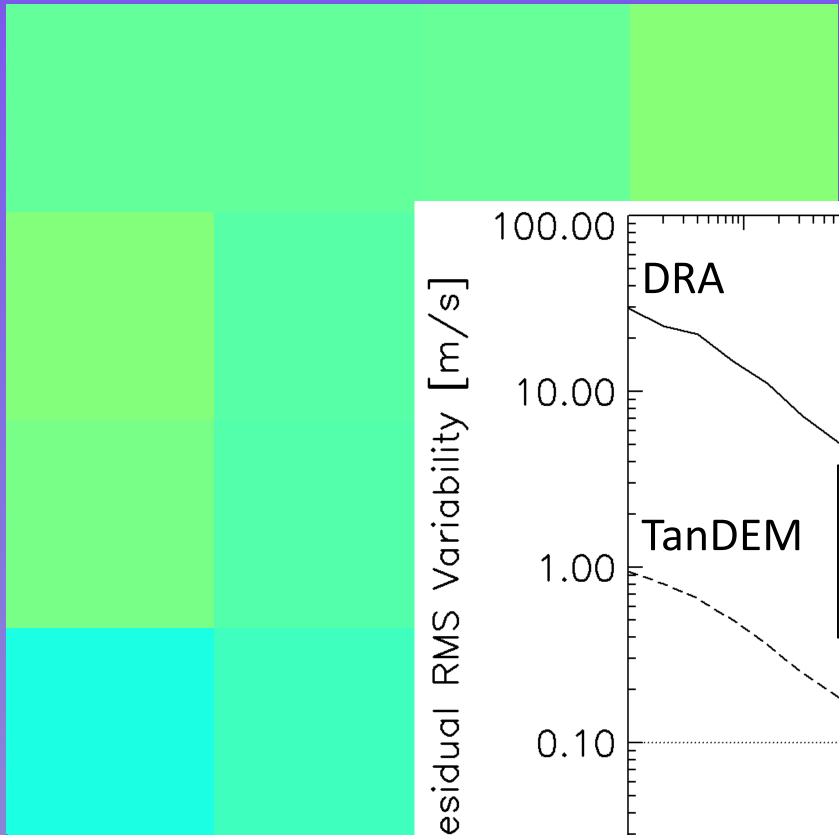
–5 [m/s] +5
Doppler Velocity

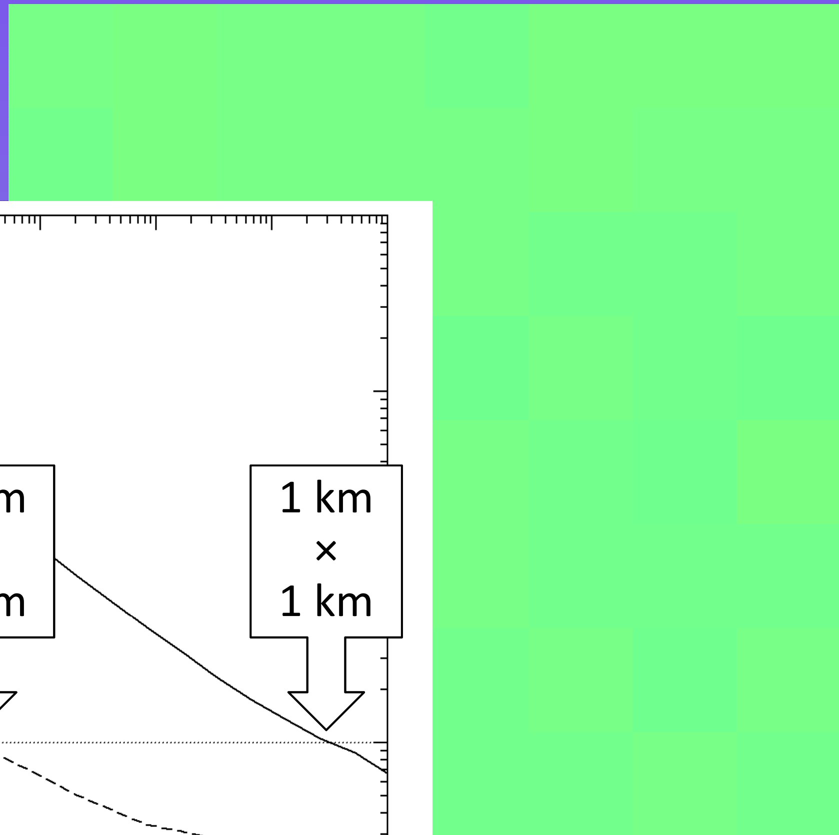
10 km × 10 km subsection of the TanDEM-X image from 2012-02-26, pixel size = 8.40 m × 8.46 m

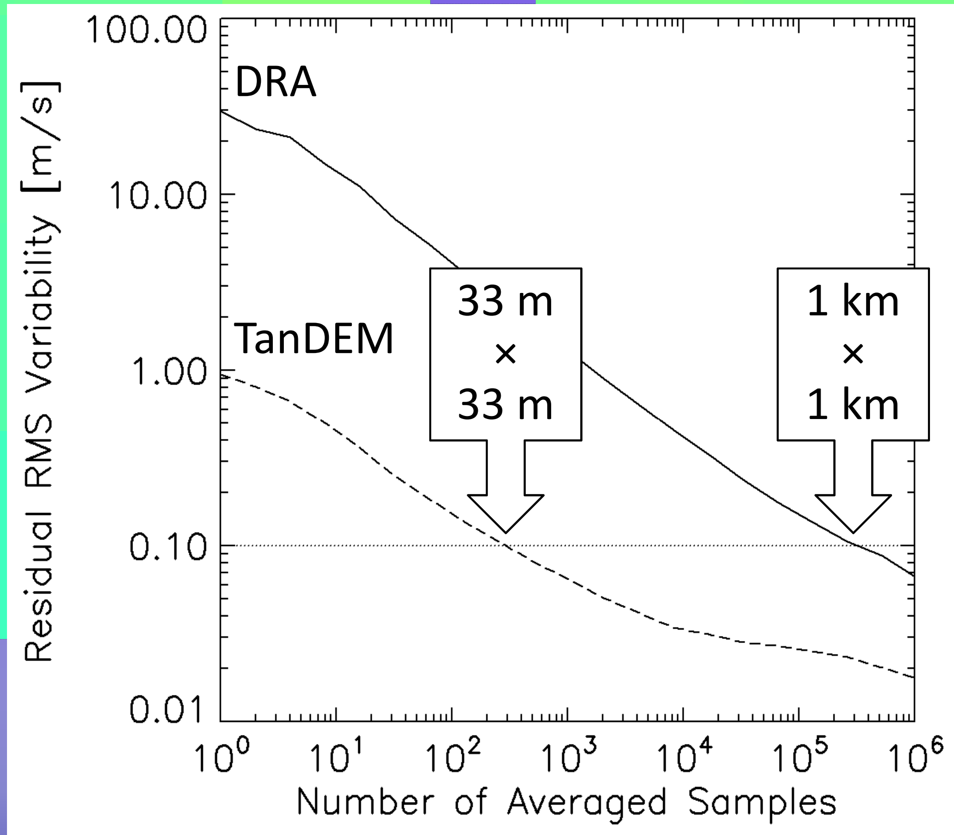
RMS Uncertainty Analysis

TerraSAR-X DRA

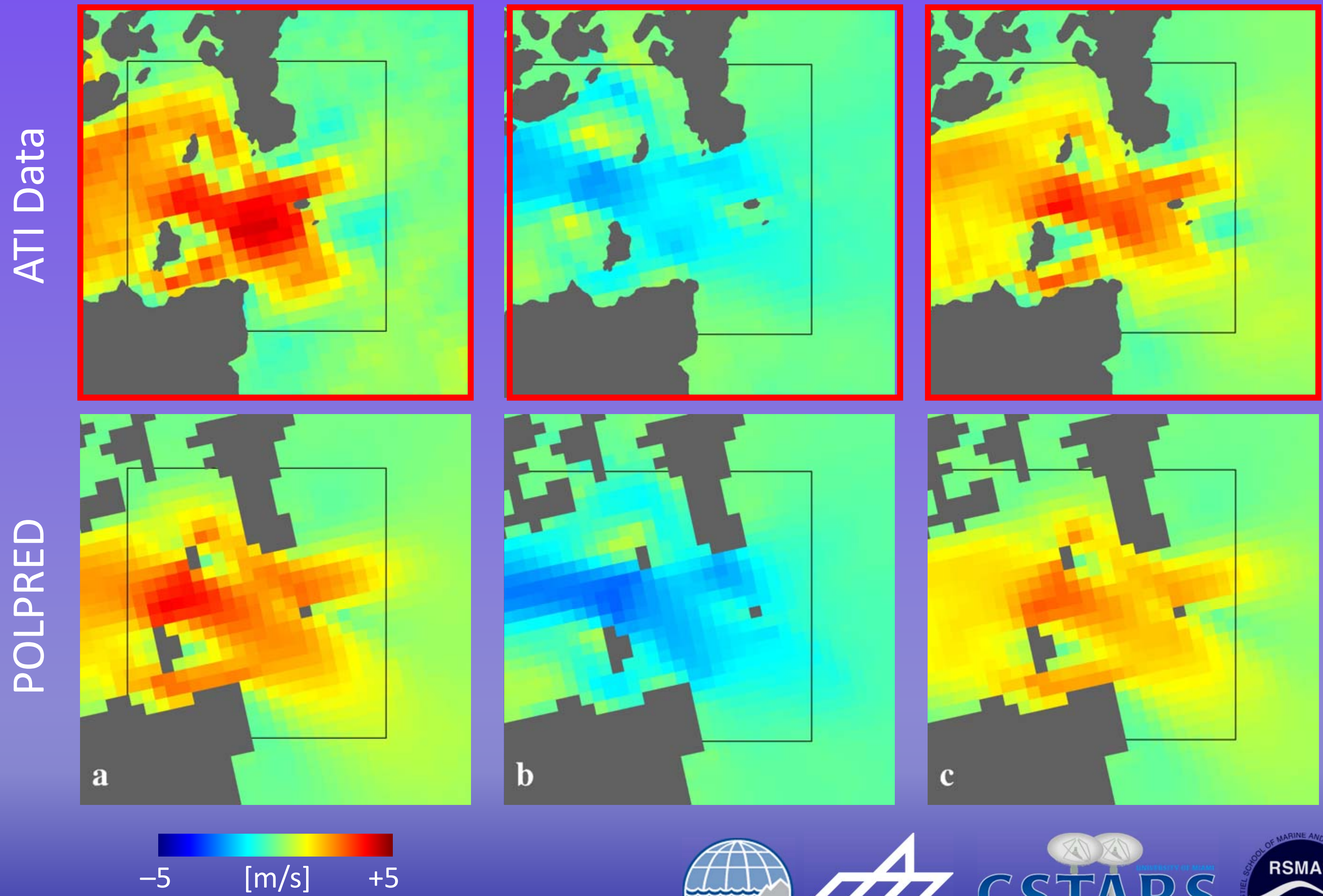
TanDEM-X



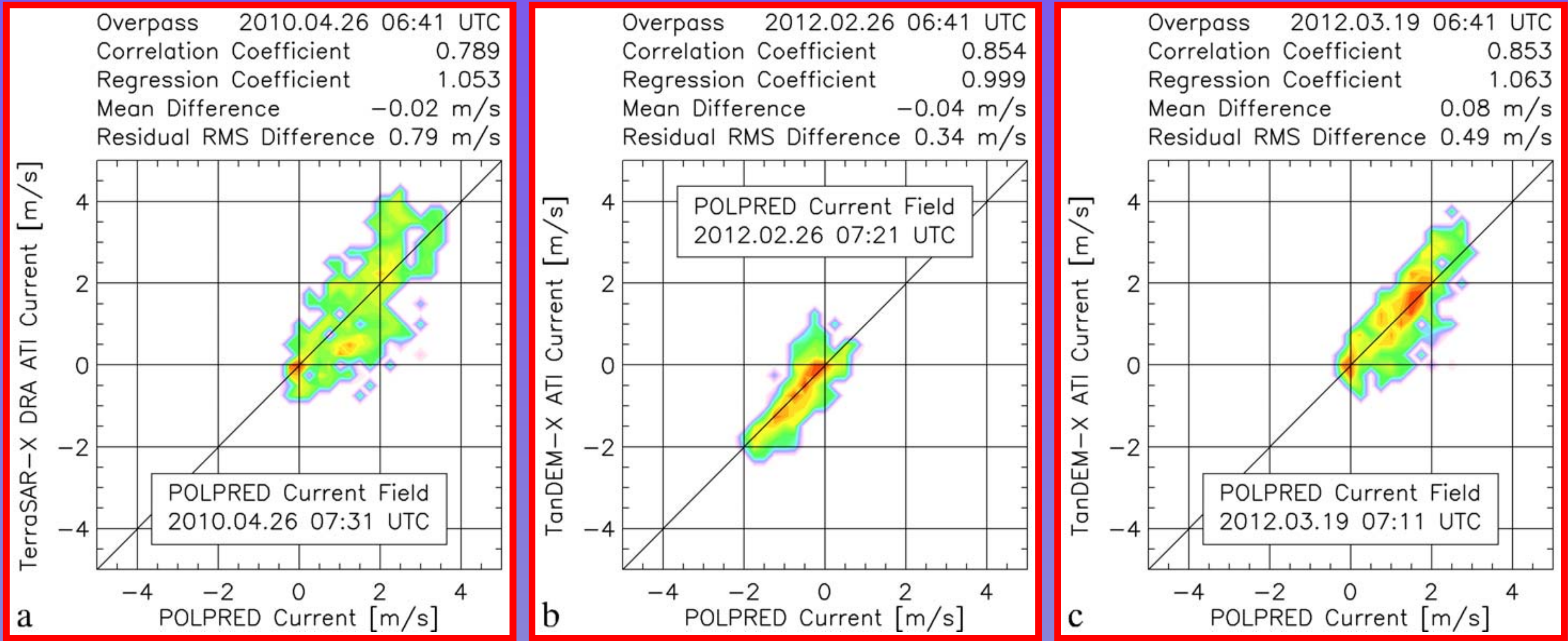




From Doppler Velocities to Current Fields



Statistical Analysis of ATI Results



- Observed currents seem to be ahead of POLPRED by 30-40 min
- Good general agreement, better for TanDEM-X than TerraSAR-X DRA
- Limitation: 1-km resolution of POLPRED

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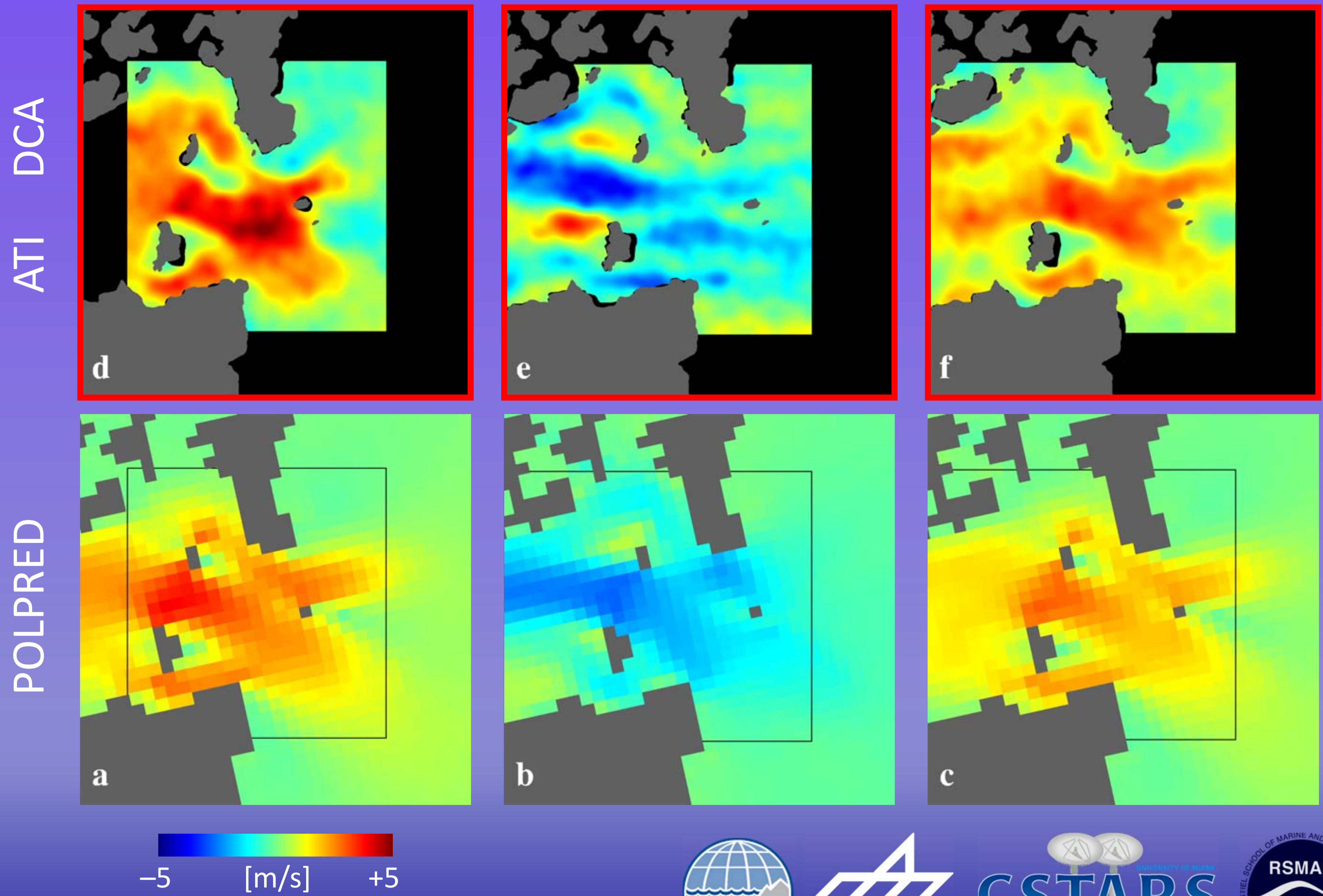
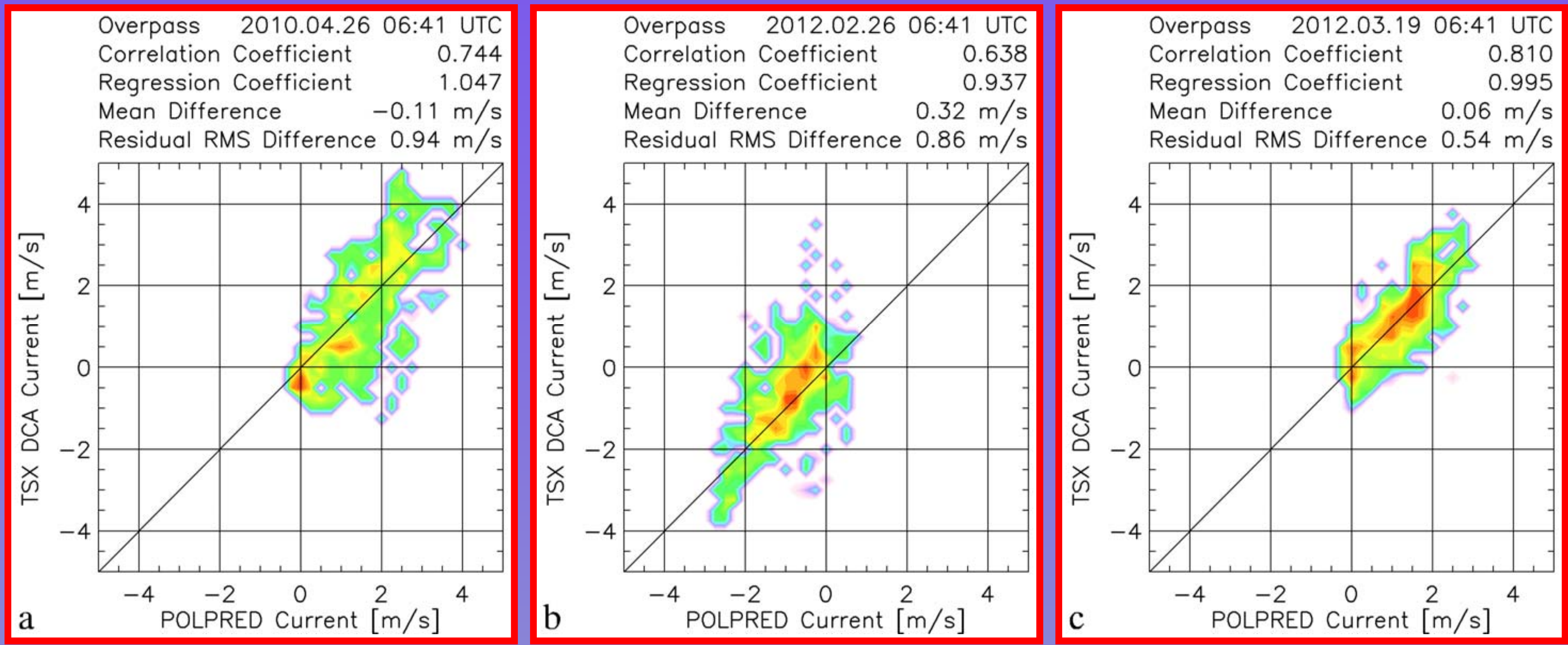
Another Test: Doppler Centroid Analysis



Statistical Analysis of DCA Results



- DCA results are found to be generally less accurate than ATI results, but almost as good as DRA-mode and AS-mode ATI results

Summary and Outlook

- A special TanDEM-X orbit constellation in early 2012 gave us an opportunity to test ATI at optimal baselines (approx. 30 m)
- Pentland Firth test site: Strong tidal currents, known from earlier TerraSAR-X ATI tests, good availability of reference data
- Analyzed one DRA mode dataset and two TanDEM-X datasets
- Performed Doppler centroid analysis (based on single-antenna data) for comparison, for all three cases
- Found good agreement of all SAR-based current fields with 1-km resolution tide computation system POLPRED
- Found TanDEM-X data to be very good, resolving 200 m waves, consistent with theoretical expectations
- Found Doppler centroid analysis results to be almost as good as split-antenna along-track InSAR data from TerraSAR-X
- Planning to obtain additional TanDEM-X acquisitions with better reference data (nautical radar, in-situ, higher-resolution models)
- Planning to analyze wave signatures, coherence vs. time lag, etc.

For Further Reading...

Quality Assessment of Surface Current Fields From TerraSAR-X and TanDEM-X Along-Track Interferometry and Doppler Centroid Analysis

Roland Romeiser, *Member, IEEE*, Hartmut Runge, Steffen Suchandt, Ralph Kahle, Cristian Rossi, and Paul S. Bell

***Abstract*—All existing examples of current measurements by spaceborne synthetic aperture radar (SAR) along-track interferometry (ATI) have suffered from short baselines and corresponding low sensitivities. Theoretically, the best data quality at X band is expected at effective baselines on the order of 30 m, i.e. 30 times as long as the baselines of the divided-antenna modes of TerraSAR-X. In early 2012, we had a first opportunity to obtain data at near-optimum baselines from the TanDEM-X satellite formation. In this paper we analyze two TanDEM-X interferograms acquired over the Pentland Firth (Scotland) with effective along-track baselines of 25 m and 40 m. For comparison we consider a TerraSAR-X Dual Receive Antenna mode interferogram with an effective baseline of 1.15 m, as well as velocity fields obtained by Doppler centroid analysis (DCA) of single-antenna data from the same three scenes. We show that currents derived from the TanDEM-X interferograms have a residual noise level of 0.1 m/s at an effective resolution of about 33 m × 33 m, while DRA-mode data must be averaged over 1000 m × 1000 m to reach the same level of accuracy. A comparison with reference currents from a 1-km resolution numerical tide computation system shows good agreement in all three cases. The DCA-based currents are found to be less accurate than the ATI-based ones, but close to short-baseline ATI results in quality. We conclude that DCA is a considerable alternative to divided-antenna mode ATI, while our TanDEM-X results demonstrate the true potential of the ATI technique at near-optimum baselines.**

***Index Terms*—Interferometry, radar velocity measurement, remote sensing, synthetic aperture radar (SAR).**

I. Introduction

A little more than 25 years ago, Goldstein & Zebker described the concept of ocean surface current measurements by synthetic aperture radar (SAR) along-track interferometry (ATI) and presented a first example result [1]. Since then, the feasibility of current measurements by this technique has been demonstrated in a number of further experiments, using interferometric SAR (InSAR) systems on aircraft (e.g. [2]–[5]), on a space shuttle [6],[7], and on the first ATI-capable satellite, the German TerraSAR-X [8]. Furthermore, some theoretical studies have been performed to understand the ATI imaging mechanism of current and wave fields and to find out how the ATI data quality depends on radar frequency, incidence angle, along-track (AT) baseline, etc., and what parameter combinations are most promising for accurate high-resolution current measurements (e.g. [9],[10]). According to these studies, optimal AT baselines, defining the time lag between the two SAR images that form an interferogram, should be on the order of 20–30 m for satellite-based X band ATI systems. Here we always refer to the "effective" AT baseline, which is half the physical AT distance between the two antennas if only one of them is used for transmitting and both for receiving, as it is the case with the TerraSAR-X and TanDEM-X data considered in this work.

Unfortunately, the Shuttle Radar Topography Mission setup (used in [6],[7]) and the divided-antenna modes of TerraSAR-X (explained in [10]–[12] and used in [8]) have offered effective AT baselines of only 3.5 m and approx. 1 m, respectively, resulting in a clearly suboptimal sensitivity to target velocities and the requirement to average the interferograms over thousands of full-resolution pixels to reduce phase noise. This degrades the effective spatial resolution to several 100 m at best. In contrast to this, the AT baselines between the TerraSAR-X satellite (launched in June 2007) and its companion TanDEM-X (launched in June 2010) are too long over most ocean regions of interest: With the standard helical orbit pattern, the two satellites have an AT distance between 0 at the northern- and southernmost points of the orbit and about 550 m over the equator [13], limiting the region of useful baselines for inter-satellite interferometry over water to narrow latitude bands far in the north and south. In regions of longer AT baselines, the data quality suffers from temporal decorrelation of the backscattered signal.

However, the TanDEM-X formation geometry gets modified from time to time to optimize the cross-track interferometry (XTI) performance in certain regions or for certain applica-

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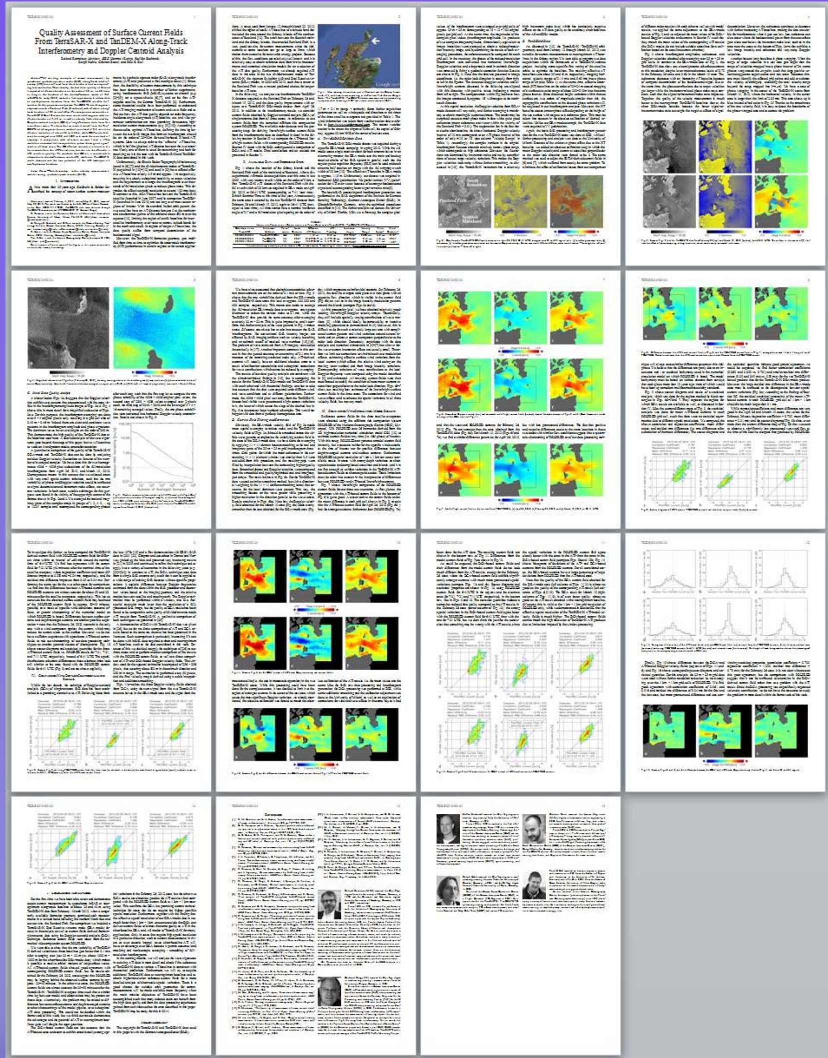
Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.



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END OF PRESENTATION

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