Assimilation of Surface Current Data from SAR and HF Radar Data into a Shelf-Seas Model

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New approach to SAR analysis promises surface current estimates useful for assimilation into predictive ocean models.

INTRODUCTION

Recently, Office Of Naval Research International Field Office (ONRIFO) conducted a site visit to Proudman Oceanography Laboratory (POL) to assess a proposal to assimilate surface current data from SAR and HF Radar data into a Shelf-Seas Model, as well as, exchange requirements, capabilities and interests between POL, Vexcel UK and the Met UK Office. The result of the meeting was a confirmed interest in further collaboration. It was decided that the SAR data were complementary to the HF radar in coverage (the latter being appropriate for the littoral zone, the SAR data being appropriate further from the coast); the POL shelf-seas model was considered an appropriate environment for assimilation; the POL plans were consistent with the timing and objectives of such a project (in particular, the planned deployment of HF radar network and interest in

assimilation of such data fitted well with the project). This Newsletter is designed to inform national and international scientists, research and governmental institutions and international organizations about potential research collaboration.

LONG-TERM GOALS

The long-term goal is to improve our ability to monitor and predict the ocean environment at the scales of variability provided by satellite data, by combining observations with models using the framework of data assimilation. A broad vision for this work is a complete suite of models, from deep ocean (assimilating altimetry SSH data) through the "Atlantic Margin" ~12km grid crossing the shelf break into the shelf seas, then with nested 1NM coastal (e.g. Irish Sea) resolution, with nested ~500m resolution Liverpool Bay (or nearshore / estuarine scale) as the ultimate "littoral" model. These would make full use of available remote sensing data.

OBJECTIVES

Surface currents are extremely important to a range of operational activities in and close to the littoral zone. The objectives of this proposed effort are (a) to demonstrate and assess the use of *existing* synthetic aperture radar (SAR) and HF radar data in improving now-casting and prediction of ocean surface currents in a shelf-seas model; (b) to demonstrate and assess the use of data assimilation as a framework for this activity; (c) to demonstrate and assess the Proudman Oceanographic Laboratory (POL) shelf-seas model (POLCOMS) as an operational model for littoral and near-littoral processes (Figure 1) and (d) to build on previous ONR funded research involving forward modeling of the SAR spectrum as described below. The POLCOMS model is already used operationally at the Met Office and the Royal Navy use its forecasts of current, temperature etc.

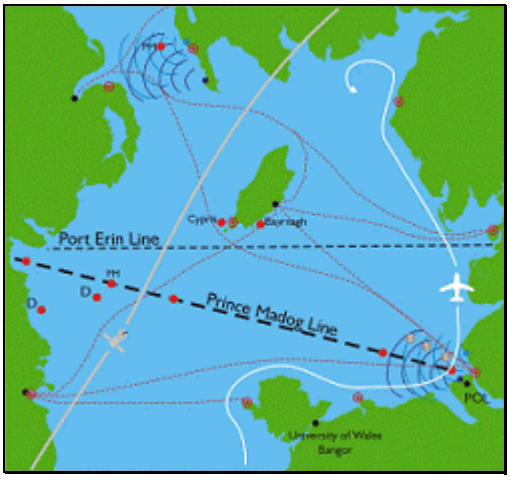

Figure 1. Schematic showing the area of the POL NE Irish Sea coastal observatory including HF radar coverage (some planned), and airborne and sea-borne observation transects.

APPROACH

The approach involves two phases. The first includes the demonstration and optimization of SAR-derived one-dimensional surface ocean currents using conventional SAR data and their assessment against HF radar data, along with the parallel definition of the most appropriate data assimilation technique that will be able to ingest both SAR and HF radar-derived velocities into the POL Shelf-Seas model. It has been said, loosely, that 80% of the work in data assimilation lies prior to implementation as a result of a need to understand the input data sources correctly, and hence we feel it is appropriate to divide the project into two phases with the second only proceeding following successful conclusion of the first phase.

The SAR-derived surface ocean currents utilize the Doppler information in SAR systems. The algorithm has been developed as an option within the operational SAR processor developed by Atlantis Scientific of Canada and so is fully operational in a basic form, providing a current precision estimated at 0.2 m/s, but we propose to optimize the technique by predicting spectral information available from the POL model via forward modeling of the spectrum based on model estimates of ocean current and waves. This will avoid the need for any arbitrary assumptions about wind/wave effects on the spectrum, so we would plan eventually to use modeled waves as well as winds (planned to be brought together in POLCOMS over the next 18 months or so). We expect to significantly improve the precision and accuracy of the technique using this method. We plan also to build on other funded ONR work in this area (Walker and Lyzenga, 2001). At the end of Phase 1, we will assess the “optimized” surface velocity estimates against independent HF radar observations in Liverpool Bay area to determine whether the resulting velocity estimates are of an operationally useful quality. We will also estimate the errors in sufficient detail to support the use of these products in a data assimilation environment.

At the end of Phase 1, we will assess the “optimized” surface velocity estimates against independent HF radar observations in Liverpool Bay area to determine whether the resulting velocity estimates are of useful quality for operational Navy purposes. We will also estimate the errors in sufficient detail to support the use of these products in a data assimilation environment. We will carry out an assessment of the SAR ocean currents both on and off the shelf break (to test the technique with different ocean features, such as non-tidal but slower moving eddies filaments and gyres circulation) using results from the POL "Atlantic Margin Model" which is POLCOMS applied over 40N-65N, 20W - 13E on a ~12km grid. (The Met Office is preparing to implement this version in their daily operational suite with nesting into their deep ocean model, FOAM). A small Phase 1 activity will also look into the error characteristics of HF radar observations as a pre-cursor to their use in data assimilation.

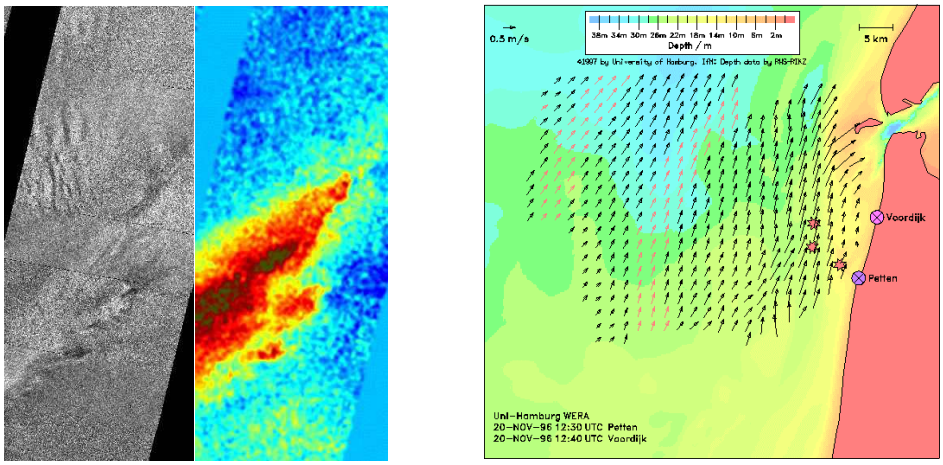

Figure 2. (a) Ocean currents derived from RADARSAT-1 data across the Gulf Stream (Van der Kooij et al., 1999, swath width 500km, resolution 1 km) and (b) HF radar observations from the University of Hamburg system which is being implemented by POL in the Liverpool Bay region of the Shelf-Seas model domain (range: 50km from coast, resolution 1.2 km).

The parallel Phase 1 activity on data assimilation will consider the most appropriate data assimilation technique for both HF radar and SAR observations of surface velocity. This will account for such features as the one-dimensional nature of the SAR-derived velocity estimates (consecutively in different directions as a result of the ascending and descending orbits), the non-uniform temporal sampling, the estimated error characteristics of the velocity estimates from both sensors and computational costs of implementation in an operational environment. Phase 1 will end with a review of whether the input data sources are of sufficient quality, and available in an appropriate form, to justify data assimilation and also a consideration of whether the data assimilation can be implemented operationally with available resources.

Phase 2 involves the implementation of the most appropriate data assimilation technique and "offline" evaluation using the SAR and HF radar products. Evaluation will take place using procedures of data-withholding, internal consistency (the physics not being violated by the introduction of the assimilation) and operational utility (issues of computational efficiency, etc.). A successful conclusion to the study would involve a set of techniques and an implementation that will be available for operational use and potentially transferable to new shelf-seas domains.

Relevant organizations include the Proudman Oceanographic Laboratory, who would have responsibility for the model and assimilation activities and the HF radar; Vexcel UK who would have responsibility for the SAR product development and product assessment activities; Atlantis Scientific, sister company to Vexcel UK, who would be consultants in the development of the SAR products (having developed the original technique) and the Met Office, who would be able to advise on operational requirements from a UK perspective.

IMPACT/APPLICATIONS

As well as having application to shelf and littoral region environmental monitoring in general, this work will also have direct relevance for, and provide preparation for, data that may eventually be available from space-borne along-track scanning interferometers. This also uses the Doppler information but has some distinct advantages over the use of conventional SARs and is currently being investigated by a few researchers. This technique suffers from similar issues related to spectrum effects on the phase related to surface velocity and would also require assimilation into a model to be of most benefit operationally. POL have some involvement in research into this technology in the UK and so would provide a useful link.

TRANSITIONS / FUTURE RESEARCH INITIATIVES

ONR will, potentially, be able to influence the transition of the 'portable' POL Shelf-Seas model to other domains and use the techniques and products demonstrated through this project in other domains. The work is related to research carried out by Walker and Lyzenga (2001) that involved the SWAN model and variational SAR assimilation. In principle, other products from SAR, such as vessel detections, could also be explored downstream for assimilation into regional models.

Activities involving investigation into Along-track interferometry as a future technology for ocean surface current monitoring will benefit from this study, by addressing many of the common technical issues. One such project in the UK is: "Along-track SAR interferometry for ocean currents and swell", BNSC NEWTON project managed by QinetiQ, Contract CU009-017539, started Jan 2002. This is led by BAE SYSTEMS ATC, with Southampton Oceanography Centre, Proudman Oceanographic Laboratory, Satellite Observing Systems Ltd. and Astrium.

ASSESSMENT AND POTENTIAL COLLABORATION

The project could potentially improve the predictive capability for marine conditions in the littoral zone and the shelf zone more generally. It could provide an opportunity for ONR to evaluate the POL Shelf-Seas model that has been demonstrated to have promising capabilities with regard to ONR's littoral zone interests. It could expand the range of information used from satellites and from SAR in particular, which is atmosphere and daylight-insensitive. A challenge, however, would be to demonstrate that the SAR data are sufficiently precise and accurate to add value to the particular currents within the existing domain of the POL shelf-seas model. This means that key technical tasks of the project will be to refine very carefully the SAR technique using forward modeling of the spectrum and to assess the scope for assimilation to refine the effective precision by exploiting the larger number of degrees of freedom in the SAR data.

As part of this proposal, it would be useful for the group to meet with US investigators involved in this area, for example Walker and Lyzenga in Michigan and those involved in the SWAN model.

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