ESA'S DUE ESURGE PROJECT: IMPROVING STORM SURGE MODELLING WITH ADVANCED SATELLITE DATA PRODUCTS

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Abstract

Storm surges, where sea water is pushed onto the shore by extreme weather conditions, are one of the deadliest and most destructive natural hazards. Satellite data already play an important role in storm forecasting, however more could be done. In particular advanced satellite products, such as coastal altimetry and high resolution scatterometry, are not currently widely used but have great potential to improve the modelling and forecasting of storm surges. ESA's eSurge project aims to improve the uptake of such data, by providing new data products of particular use to modellers, by making it easier to access such data, by running experiments to demonstrate the usefulness of the data, and by providing training and support to help users utilise the available data.

STORM SURGES AND THE ESURGE PROJECT

Storm surges, where sea water is pushed onshore by extreme weather conditions, are one of the deadliest and most devastating natural hazards, with large parts of the world's coastlines at risk. Well known examples include the 1953 North sea floods, Cyclone Sidr in Bangladesh, Cyclone Nargis in Myanmar, and Hurricanes Katrina and Sandy in the Caribbean and USA. As sea levels rise, such events are expected to become more frequent.

Any improvement in modelling and forecasting such surges has the potential to save lives and money. Satellite data already play an important role in storm forecasting, however much more could be done. In particular, advanced satellite products such as wind speed and direction from high resolution scatterometry and sea state information from coastal altimetry are not yet widely used in storm surge forecasting. Such data can be used both for assimilation or ensemble pruning during an event, or for post-event assessment of the accuracy of models. Because storm surges are so destructive, even a small improvement has the potential to save lives and money.

Recognising this, ESA has initiated the eSurge project through its DUE programme, with the aim of improving the uptake of such satellite products by storm surge modellers and forecasters. The project is led by CGI (formerly Logica), (UK), with NOC (UK), DMI (Denmark), CMRC (Ireland) and KNMI (Netherlands) as scientific partners.

To achieve its objective, the project brings together a wide variety of relevant data types into a single online portal, at www.storm-surge.info. These include scatterometry, wave measurements, altimetry, sea surface temperature and in-situ data. Some of these data are already available; however by bringing them together we can facilitate their use by the modelling community. Data are available for a wide selection of historic storm surge events since 1992, as well as for live events (see below).

However it is not enough just to make data available; to aid users the project also provides a selection of training material to ensure they can utilise the data, and also runs a training course in the use of satellite data for surge modelling. The consortium also performs experiments to demonstrate the usefulness of adding the data to surge models.

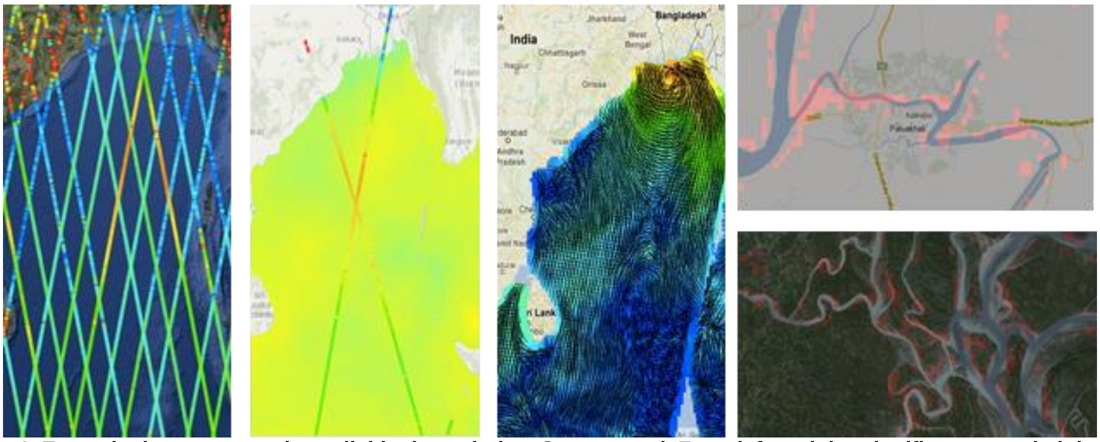

Figure 1: **Example data types made available through the eSurge portal. From left to right: significant wave heights (from GlobWave), Sea Surface Temperature, Scatterometry winds and two different inundation maps showing the resulting inundation. (All for Cyclone Sidr, 2007.)**

COASTAL ALTIMETRY

In recent years, there has been a lot of work done in the field of coastal altimetry, analysing radar altimeter (RA) data which had previously been rejected as contaminated by the presence of land. Using these techniques, measurements of total water level elevation (TWLE) can be obtained in the coastal zone, i.e. within about 50km of the shore. Since TWLE is the most important parameter for coastal flooding, using coastal altimetry techniques for storm surges is a natural application.

Within eSurge, a dedicated coastal altimeter processor has been developed, building on work previously done in other projects, particularly the ESA-funded COASTALT project and the CNES-sponsored PISTACHE project. This processor is called ALES (Adaptive Leading Edge Subwaveform retracker), as it uses only a portion of the waveform (the sub-waveform) and adapts the fitting window (i.e. the window selecting that portion) in order to give a very good fit of the leading edge, which is the the part that matters for estimation of the key parameters.

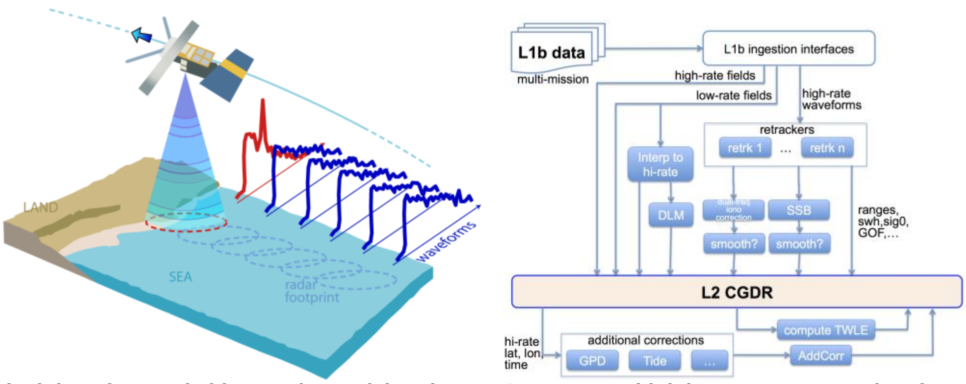

Figure 2: **Principles of coastal altimetry: by applying the ALES processor (right), we can recover data from the coastal strip previous rejected as corrupted (left).**

ALES has been validated both by comparison to other retrackers, and using in-situ data in the Adriatic sea. It has been shown to be a clear improvement over other retrackers available, works well both in the coastal zone and open ocean, and is well suited for assimilation into numerical models. Currently, ALES has been used to reprocess 10 years of Envisat altimetry data for a wide selection of surges. Data from other satellites will be added later.

In addition, eSurge is looking at making coastal altimetry data available in near real time. Since May 2013, ESA has been making Cryosat SAR altimetry available in NRT for a coastal strip around the Indian coastline. This modification to the Cryosat Mode Mask was implemented specifically for the eSurge project, and allows us to prove the feasibility of proving SAR coastal altimetry in NRT, and to investigate how much data can best be used. This experiment is a pathfinder for the Sentinel-3 mission, which will provide SAR ocean altimetry worldwide.

The first event analysed with this processor was Cyclone Mahasen, which hit the Bay of Bengal in May 2013, shortly after the initiation of this service. The results show that the ALES processor worked well, right up to the coast. Unfortunately the tracks of Cryosat did not directly cross over the storm surge. However the provided data are still useful for modellers, as they allow ensemble pruning based on TWLE away from the main track. Currently this is done using tide gauges, however in many parts of the world such physical infrastructure is lacking, and coastal altimetry can replace this.

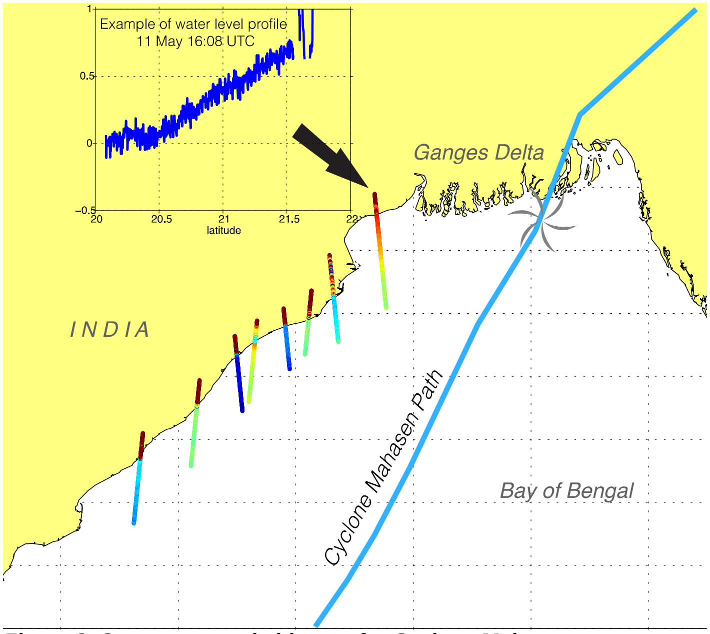

Figure 3: **Cryosat coastal altimetry for Cyclone Mahasen**

In summary, coastal altimetry has a natural application in measuring storm surges. It is currently handicapped by the limited sampling due to the low number of available radar altimeters. However this should be improved as eSurge brings other altimeters into our processing chain. In the future, Sentinel-3 will greatly improve the amount of usable altimetry for storm surge applications.

DATA ASSIMILATION INTO NUMERICAL MODELS

To demonstrate the usefulness of coastal altimetry, DMI have studied assimilating it into numerical models of the North and Baltic seas. First, coastal altimetry and tide gauge measurements are combined to give a blended 2D field of sea surface. This is then assimilated into DMI's storm surge model, which is a HIROBM-BOOS model using a hydrostatic 3D circulation model, and forced using the regional climate model HIRHAM. Simulations are made using a free model run and with assimilation of the blended product every 24 hours using an Ensemble Optimal Interpolation approach.

Although preliminary, the first indications are that assimilating such data gives a clear improvement in the model's accuracy, as determined by comparing to tide gauges which were excluded from the original blending. If confirmed, this will be a clear indicator of the usefulness of altimetry data in forecasting models.

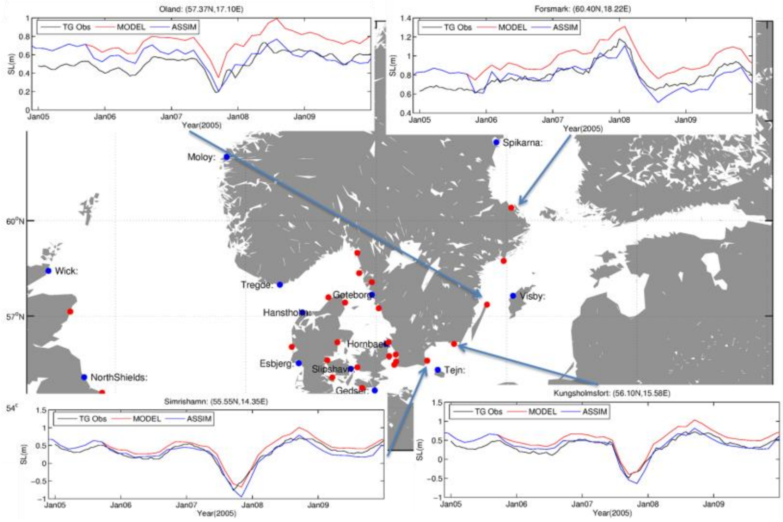

Figure 4: **Preliminary results of comparing tide gauge observations (block) to simulations performed with (blue) and without (red) assimilating altimetry data**

During the remainder of the project, more assimilation experiments will be conducted in other areas, including looking at how to improve surge models in the North Indian Ocean by using the coastal altimetry data from the Cryosat SAR.

CONCLUSION

In summary, we believe that we have shown that new types of satellite data products can be used to improve the modelling and forecasting of storm surges. The project will continue to work with end users of the data (i.e. modellers and forecasters) to investigate how the new products available can be optimally used. We welcome contributions and inputs from all such parties, with the ultimate aim being to bring such products within improved operational systems.

REFERENCES

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