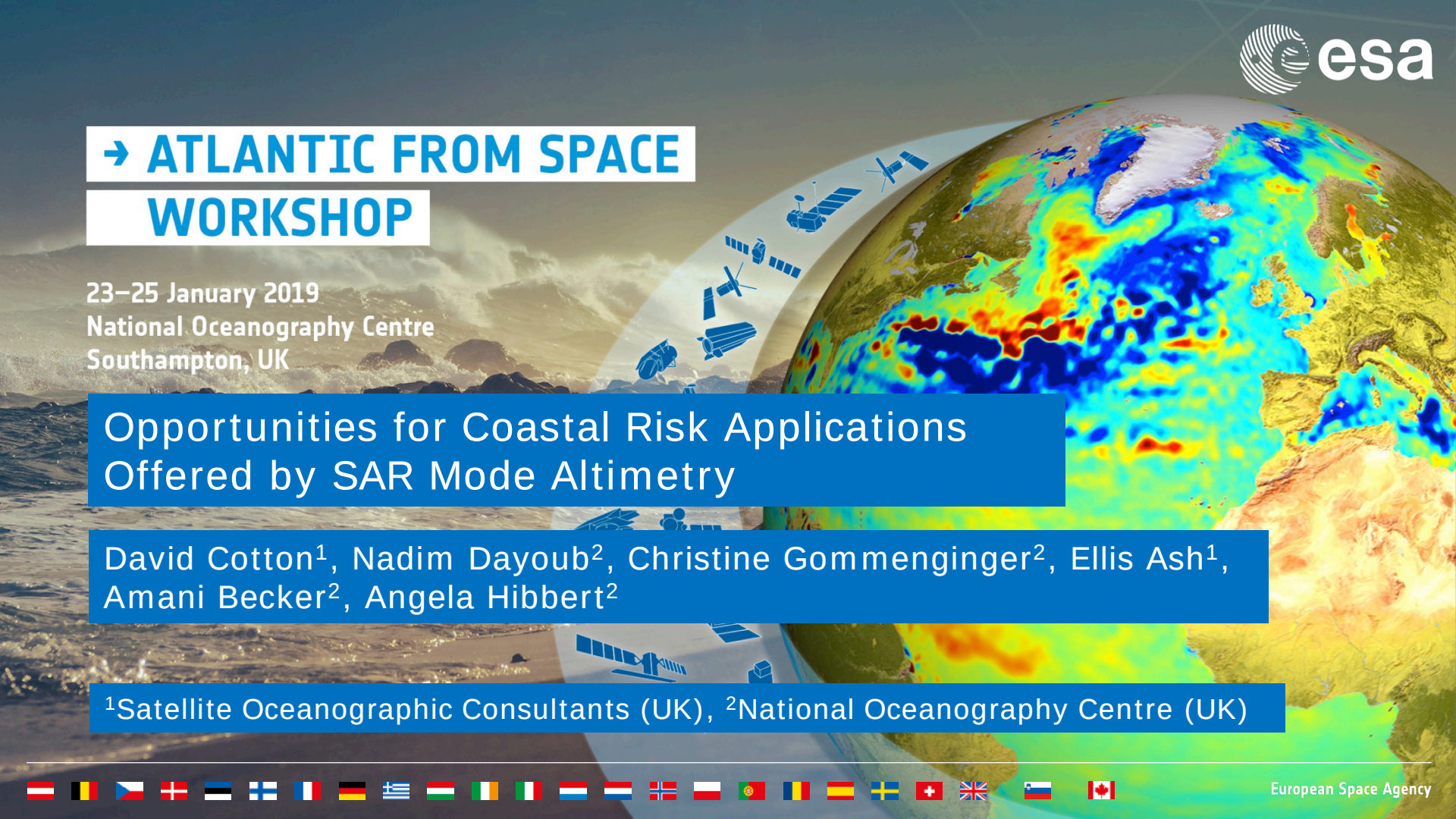

Opportunities for Coastal Risk Applications Offered by SAR Mode Altimetry

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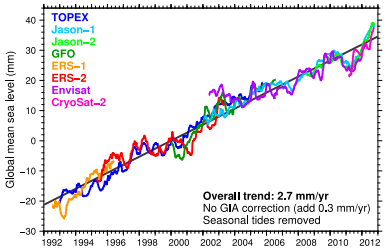
Introduction (1)

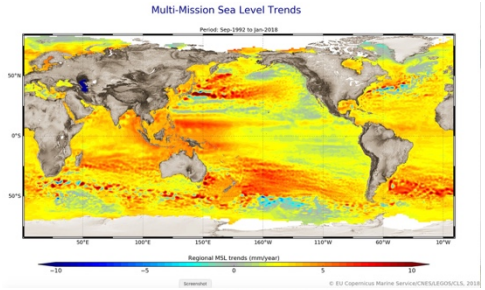
Global sea-level is increasing and large-scale weather patterns are changing.

Across large parts of the world, there is a lack of observational data on which to implement evidence-based approaches to coastal adaptation. Satellite altimetry provides decades of sea level, winds and waves data highly relevant to these problems.

The coastal zone presents significant challenges to altimetry that call for specialised processing.

This paper presents recommendations from recent projects that have developed and applied improved altimeter products for Coastal Risk applications.





Introduction (2)

Opportunities for Coastal Risk Applications Offered by SAR Mode Altimetry

Results and Recommendations from 3 projects:

SCOOP - SAR Altimetry in the Coastal and Open Ocean, funded by ESA under the Scientific Exploitation of Operational Missions (SEOM) Programme.

Sea Level Space Watch – Funded by the UK Space Agency under the Space for Smarter Government Programme (SSGP)

C-RISe – Coastal Risk Information Service – Funded by the UK Space Agency under the International Partnership Programme (IPP)

SCOOP – SAR Altimetry in the Coastal and Open Ocean

SCOOP (SAR Altimetry Coastal & Open Ocean Performance).

Aim is to provide answers to the two questions:

- What level of performance can we expect from Sentinel-3 SRAL data over the open ocean and coastal zone?
- Can we further enhance this performance with improvements to the processing schemes?

Partners: SatOC (UK), CLS (FR), isardSAT (ES and UK), National Oceanography Centre (UK), Noveltis (FR), TU Delft (NL), University of Bonn (DE), and University of Porto (PT).

SAR Altimetry

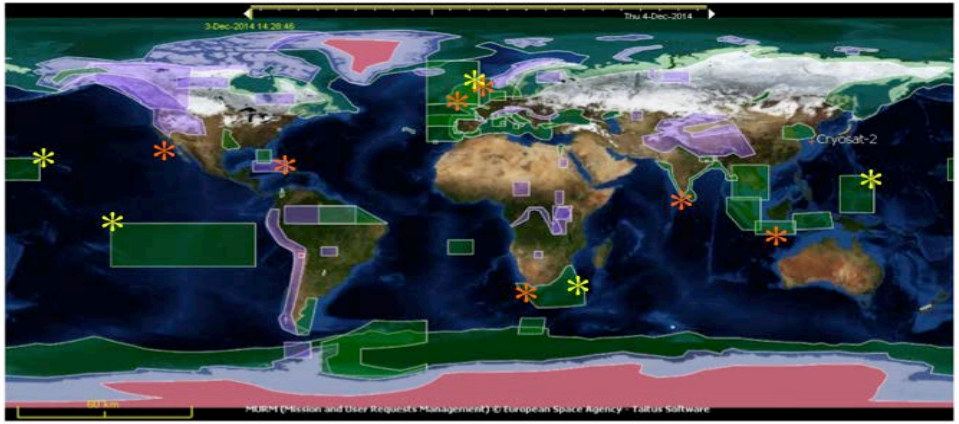
SAR Altimetry has been shown to offer important advantages over previous altimeter technology

- Improved along track resolution: 250m instead of 7km
    - Better data capture close to coastlines, and in complex coastal topography
    - Better resolution of mesoscale ocean features
- Reduced noise / improved precision
    - Sea Surface Height
    - Significant Wave Height
- Sentinel 3A and 3B are the first missions to offer global coverage in SAR Mode.
- But further improvements can be achieved - > The SCOOP project

SCOOP (2)

SCOOP Test Data Sets.

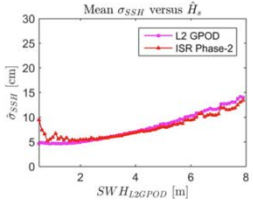
- TDS1: CryoSat FBR baseline C data –*Sentinel-3 SRAL baseline equivalent* processing.
- TDS2: Enhancements to S3 Baseline: SAR processing includes zero padding in range, and intra-burst Hamming windowing
- Enhanced Wet Troposphere Correction (U Porto): “GPD+”
- 10 Regions of interest (data sets available on request):
  - **NE Atlantic, N Sea;**
  - West, Central and Eastern Pacific;
  - Agulhas;
  - N Indian Ocean, Indonesia,
  - Cuba (SARin);
  - Harvest (California)



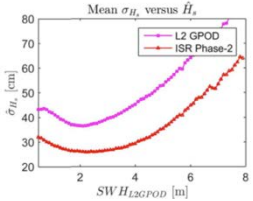
SCOOP Analysis Results – Open Ocean.

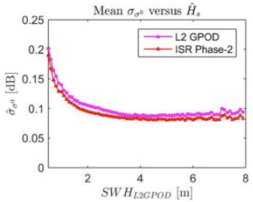
- *Sea Surface Height*: TDS2 noisier than TDS1 at low SWH, but better performing at high SWH
- *Significant Wave Height*: TDS2 improved on TDS1 for all SWH (10cm lower std)
- *Surface Backscatter*: σ^0: TDS2 slightly lower noise than TDS1 for all SWH.

SSH



SWH

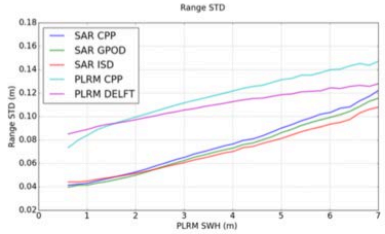




σ^0

IsardSAT Analysis

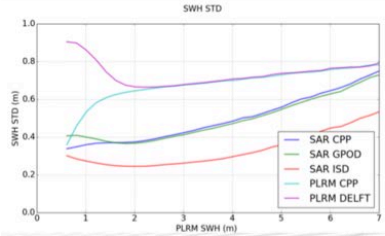
Range

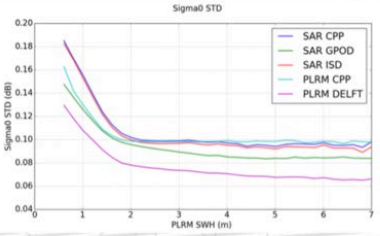


Alternative SARM algorithm:

- Range STD: improvement brought by Hamming window at medium/large wave height (but degraded at low swh)
- High noise reduction in SWH (> 35% @2m) better than CY2 Baseline B/C (also including zero-pading x2 and azimuth window)
- No improvement for sig0

SWH



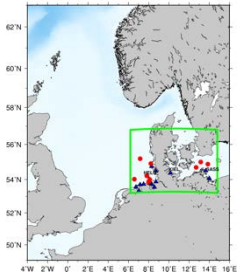


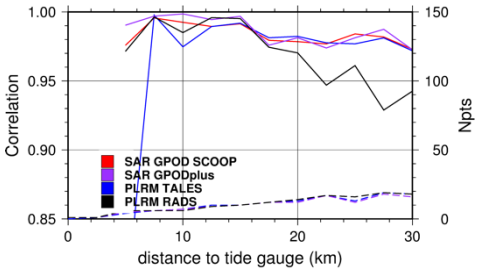
σ^0

CLS Analysis

SCOOP Analysis Results – Coastal Ocean.

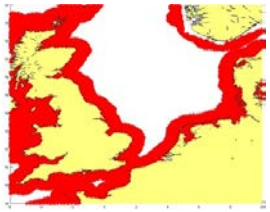
U Bonn Analysis (SAR and RDSAR)

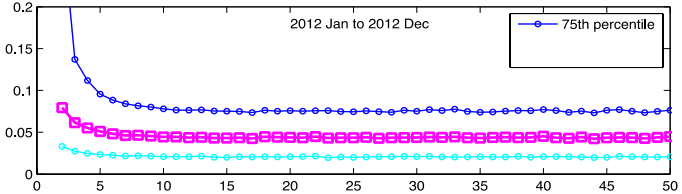




- TDS2 (SAR with Hamming window, and zero padding) shows improvement in both precision and accuracy compared to TDS1
- SAR better than RDSAR in coastal zone
- Dedicated coastal retrackers perform better (e.g. SAMOSA+ for SAR, sub-waveform for RDSAR)

SKYMAT Analysis (SAR product)





- Apparently different performance found for coasts in open and enclosed seas (SWH related?).
- More noise in TDS2 SWH at low SWH.
- Little difference in SSH in two products
- Need to filter data better?
- There may be more physical variability in SWH and SSH close to coast?

SCOOP (*Interim!*) Recommendations.

- From Analyses of SCOOP data sets:
  - SAR processing: Along track Hamming Window, Zero-Padding (factor -2), limit stack (< +/- 0.6°)
  - Significant improvement in open ocean performance in SSH and SWH, for SWH > 2m
  - Degradation in SWH performance at low SWH
  - Improved Wet Troposphere Correcion “GPD” outperforms model in open ocean and coastal regions
  - SAR product better than RDSAR at the coast
  - Coastal re-trackers for SAR and RDSAR products provide better results at coast

- Processing Modifications to investigate and further test
  - Maximise effective number of looks in processing
  - “ACDC” processing (Amplitude Compensation and Dilation Compensation)
  - Individual Doppler beam re-tracking
  - Antenna pattern compensation
  - Window range bin selection to remove waveform contamination
  - Coastal re-trackers for SAR echoes

- *Sea State Bias correction for SAR mode needed*

Scientific Roadmap with Final Recommendations to be published soon!

Sea Level Space Watch (1)

What information do coastal planners need?

- Mean Sea Level Change will strongly govern future flood probabilities.
- Improved information on sea level trends will support decisions on timing of high cost investment decisions.
- Many 100s hectares coastal habitat potentially at risk.
- How will sea level rise impact on shoreline management plans and coastal habitat?

For long-term planning of coastal defence management, UK agencies use UK CP projections

http://ukclimateprojections.metoffice.gov.uk.

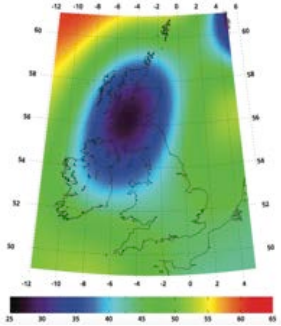


Figure: Projected changes in mean sea level from UKCP09: Relative sea level change around UK from 2000-2095 (medium emissions).

Table: Projected sea level rise since 1990. UKCP09 L/M/H scenarios

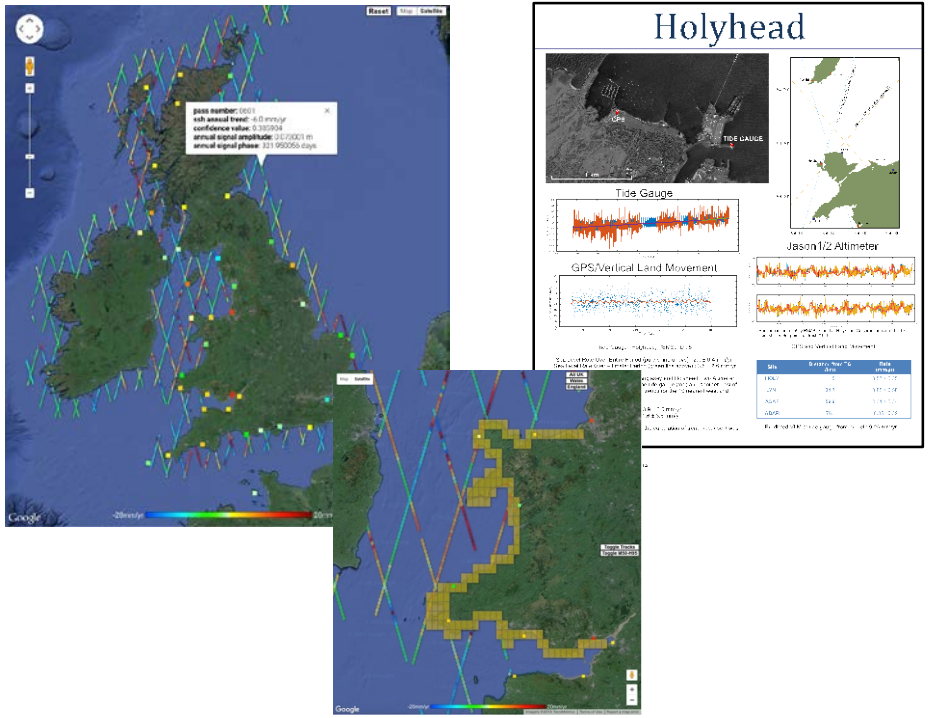
	London	Edinburgh	Belfast
2000	2.5/3.0/3.5	1.2/1.6/2.2	1.3/1.7/2.3
2020	8.2/9.7/11.5	4.3/5.7/7.5	4.6/6.0/7.8
2050	18.4/21.8/25.9	10.5/13.9/18.0	11.1/14.5/18.6

Models have limited input in terms of local oceanography, regional variability is primarily assigned to glacial isostatic adjustment.

- Can we get a better understanding of regional inter-annual sea level variability?
- Can satellite data provide useful information on the long-term trajectory of sea level change?

Sea Level Space Watch (2)

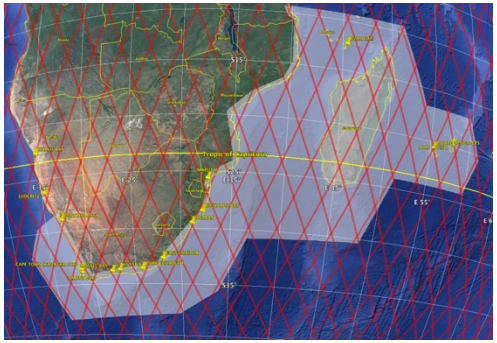
- UK Sea Level Space Watch is a web based sea level monitoring service for UK seas, sea level variability from space-borne altimeter data, combined with tide gauge data.
- To support national flood defence planning, by supplementing UK Climate Projections with information on seasonal & regional sea level variability.
- Satellite altimeter Sea Level data (2002-2015) generated by NOC ALES-based altimetry processor (Jason-1, Jason-2, Envisat, AltiKa)
- Total Water Level Envelope, Sea Surface Height Anomaly, annual cycle and long term trends
- Funded by UK Space Agency's "Space for Smarter Government Programme"
- Agencies interested in predicted change in extremes

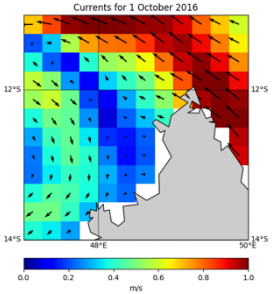


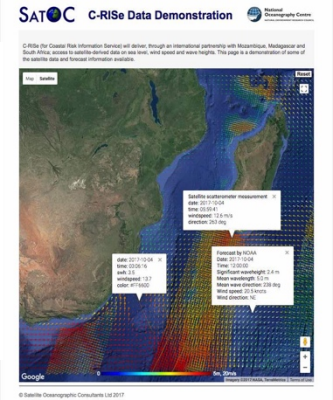
http://www.satoc.eu/projects/sealevelsw/test.html

C-RISe – Coastal Risk Information Service (1)

- C-RISe – Three year project funded by UK Space Agency under the International Partnership Programme (IPP)
- Developing countries in the South West Indian Ocean have significant coastal populations highly vulnerable to the consequences of climate variability and change.
- Local measurement capability very limited.
- With access to improved regional information on coastal risk factors (sea level, wave and wind extremes) plans to protect coastal communities and safeguard economic activity can be improved.







C-RISe – Coastal Risk Information Service (2)

C-RISe Data Products

- Reprocessed satellite sea level measurements: derived trends and variability
- Waves, winds and surface current climatologies
- Near real time waves, winds and currents

Use Cases

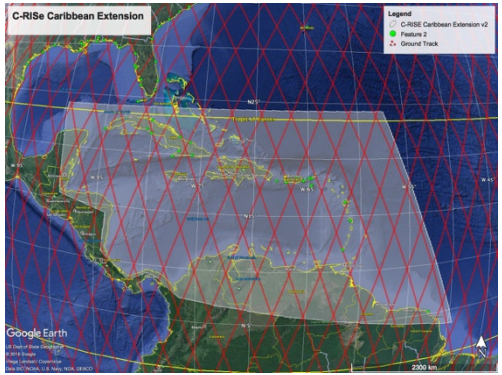
- Practical applications to implement use of C-RISe data
- 33 Use Cases in 5 themes: Marine Protected Area Management; Sea State Information, Sea Level Analyses; Wind and Wave Climate Variability; Climate Change Impact on Marine Ecosystems

Training Workshops

- Wind, Wave and Sea Level Information from Satellites
- Satellite Data for Coastal Risk Applications

C-RISe – Coastal Risk Information Service (3)

- Monitoring and Evaluation has been a key aspect
- Challenge is to build sustainable partnerships and maintain trajectory to impact
- Benefits to local population generally over the longer term – Impacts from development of coastal management strategies will be felt in 5-10 year timescale
- Aim is to support development of local capability through knowledge transfer and training
  - Training element has been very important and well received.
- Current implementation is in the South West Indian Ocean, but the issues are global and approach is transferable
- Investigating options to implement in Caribbean.



www.c-rise.info

Summary

- Coverage from satellite data vastly improved, and continuity of service for next ~20 years is secure.
- SAR mode altimetry offers improved precision, improved resolution, and better performance in complex coastal regions.
- Further improvements to processing are possible, and are being developed and tested.
- Have implemented and tested practical applications of satellite sea-level, wave and wind data in support of coastal managers planning against changing climate
- Consistent processing across different missions needed
- How to validate variability at small scales?