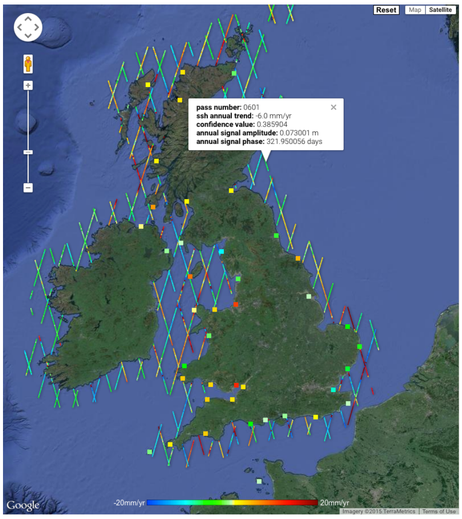
Sea Level Space Watch – An Operational Service to Monitor Seasonal and Inter Annual Sea Level Variability from Space

Report on: A Workshop to Review Requirements and Options for an Operational Service

Tuesday 22nd March
National Oceanography Centre, Southampton

Introduction
UK Sea Level SpaceWatch is a service designed to support agencies responsible for the management and planning of national flood defences and programmes that relate to the effects of sea level change. Initial development for feasibility assessment and provision of an operational ready service has been funded by the UK Space Agency under the Space for Smarter Government Programme.



Using data from satellite altimeters in combination with tide gauge data, Sea Level SpaceWatch provides the latest observed sea levels around the UK through an easy to use web-interface. The data are supported by careful analyses of long-term trends, regional variability and confidence intervals showing the lower and upper limit for the current mean sea levels. The service complements and supplements the sea level change scenario information available from UK Climate Projections[1], offering coastal practitioners the opportunity to verify the regional variability of sea level around the UK at multiple time scales, and observe the presence of any significant inter-annual changes and therefore discern trends on sea levels that may affect coastal investment decisions.

Workshop Aims
The objective of the workshop was to present the Sea Level Space Watch service, review its capability in the context of users needs, and present a business plan for implementation of an operational sea level advice service aimed at supporting long term planning and risk management. The workshop also considered the potential for implementation overseas at key locations at high risk from flooding / sea level rise.

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[1] http://ukclimateprojections.metoffice.gov.uk

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Workshop Report

1. Introduction

In this report we will provide a summary of the key points of the workshop presentations and the main conclusions identified in the discussion session. The presentations are available on the project website:
(http://www.satoc.eu/projects/sealevelsw/phase2_workshop.html)

To open the meeting, David Cotton (SatOC) welcomed all participants and provided an introduction to the meeting, noting that Sea Level Space Watch Phase 2 was a 3 month project, funded by the UK Space Agency's "Space for Smarter Government Programme", aimed at developing an implementation ready sea level monitoring service for the UK seas combining satellite altimeter and tide gauge data. The Sea Level Space Watch service makes use of recent developments at the National Oceanography Centre that provide accurate altimeter measurements, closer to the coastline than previously possible. The service provides regional information on the seasonal and inter-annual variability of the non-tidal sea level, to support the agencies responsible for planning the UK coastal flood defences.

Session 1: The need for monitoring sea level rise in a changing climate

The first session included a number of presentations of recent work summarising what is currently known about sea level variability in the UK coastal region, followed by contributions from the user agencies outline their requirements for improved sea level information.

1. What we know about sea level variability around the UK:

UK Sea Level Variability from Tide Gauge Data: Angela Hibbert (NOC, Liverpool)

Angela presented an overview of what is known about sea level variability around the UK, based on analyses of tide gauge data.

- Sea level varies on different time-scales, driven by different processes, e.g. (waves, tides, seiches, surges, seasonal changes, atmospheric variability and long-term trends.
- A large part of the longer term components of this variability is coherent, at least regionally.
- The long term trend average sea level trend for the UK over the 20th century (1900-2000) was 1.4 mm/yr, analysis of recent altimeter sea level data (1990 onwards) indicates a consistent trend.
- Land movement (post glacial rebound) makes a significant contribution, with the land sinking in the South East of England, and rising in Scotland, Wales, Ireland and North-Western England
- Once the long-term trend is removed, there remains coherent inter-annual variability, which is linked to atmospheric variability (sea level pressure, winds and climate models.
- An observed increase in extreme sea levels is largely due to increased mean sea level, though it has also been observed that the mean tidal range is also increasing.
- The nature of the observed changes in tidal range varies significantly regionally, with the cause not yet completely understood.

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Spatial Footprint and temporal clustering of storm surges around the UK: Ivan Haigh (The University of Southampton)

Ivan presented recent work looking at specific characteristics of storm surge events, the "footprint" (the area of the coastline affected), and the temporal clustering.

- More information on this work, and the data used, are available at www.surgewatch.org
- Using water level data from the UK National Tide Gauge network the study has identified 310 high water events (> 1 in 5 year return level), and 96 storm events, since 1915.
- Based on storm surge levels, i.e. water level above predicted tide, the study has identified 261 "skew surge" events and 111 storms, since 1915.
- Although data return is uneven across the years, a large proportion of all events (~7-8%) occurred in the 2013-14 winter.
- There appears to be four types of events in terms of footprint; SW Coast, W Coast, N-NE Coast, E Coast, which in turn can be related to different tracks followed by the storms causing the events. Individual storms can have footprints on two stretches of coastline.
- Clustering in time is reasonably rare. High water level events are not found to occur within 4-8 days of each other, because of the spring/neap tidal cycle.

2. User Needs:

Environment Agency (EA): Owen Tarrant.

Owen Tarrant presented an overview of the information requirements for the EA Flood and Coatsal Risk Management (FCRM) programme

- Coastal flooding is the 2nd highest priority on the National Risk Assessment, behind only behind Pandemic Flu.
- 1 in 5 properties are estimated to be at risk from flooding (from rivers, sea and surface water).
- Critical infrastructure is also at risk (electricity, roads, railways, water pumping stations/ treatment works, gas …)
- £30bn of FCRM assets in England, with 1537km of tidal defences, and 1013km of coastal defences.
- The EA is planning to spend £2.3 bn in England in the next 6 years to reduce risk of flooding and coastal erosion, and expect an increase in this spend will be needed because of climate change.
- The aim is to manage risk by applying management at appropriate times: A "managed adaptive approach".
- Sea Level information is needed because:
    - Mean Sea Level (MSL) change will strongly govern future flood probabilities.
    - This will affect all assets (walls and embankments as well as "active" structures)
    - To identify adaptable solutions a good understanding of sea level trends is needed.
    - Large investment decisions necessitate long lead times. Its essential to monitor changes in trends to provide early indication of accelerations
    - Reducing uncertainty in the future trajectories can allow "expensive" decisions to be deferred with more confidence.

Natural Resources Wales (NRW): Richard Park

Rick Park presented an oral summary of NRW's needs for improved sea level information

- Rick advised that NRW has similar basis of requirements for sea level as the EA in terms of management and planning of coastal defences.

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- There are also statutory obligations to preserve sensitive habitats (Natura 2000) from sea level rise and associated flood impacts achieved through compensatory measures to manage EU infraction risks, at the risk of infraction.
- Important to have information about the impact of sea level rise on shoreline management plans and coastal habitat – "coastal squeeze".
- Area of coastal habitat at risk from "coastal squeeze" is in the order 1000s hectares. It costs £50k-£200k per hectare to create replacement compensatory habitat.
- NRW strategic planning is based on UKCP09 median (95 percentile) profile and PAG3 sea level rise scenario.
- The NRW flood and operational risk management department would require ongoing monitoring of real sea level rise against these trajectories. This information will help manage both their flood risk management of Wales and their provision of adequate compensation habitat.
- Can Sea Level Space Watch feed information into the climate projections?

Scottish Environment Protection Agency (SEPA): Kat Ball
Kat Ball presented a short summary of SEPA's responsibilities regarding coastal flood risk management, and the related requirements SEPA has for sea level information.

- SEPA has similar basis of requirements for sea level as the EA for flood risk management purposes
- In Scotland estimated annual damages are £252 million, 21% due to coastal flooding (coastal figures based on still water projection model)
- However, SEPA is not responsible for funding, building and maintaining flood defence schemes, which falls to local authorities. SEPA's responsibility is rather to provide guidance to the local authorities with this responsibility.
- SEPA produce national flood hazard and risk maps and undertake a national appraisal process to identify the most sustainable actions to reduce flood risk in Potentially Vulnerable Areas. These are outlined in the Flood Risk Management Strategies and provided to Scottish Government to help inform allocation of money to local authorities for flood risk management purposes. A total of 42millon will be allocated to local authorities next year for flood schemes and studies).
- SEPA use Coastal Flood Boundary method to inform sea levels and UKCP09 high (95 percentile) for climate change.
- SEPA also has a role for providing planning advice.
- It is important to have access to best sea level information and rates of sea level rise to provide good advice and use appropriate climate change scenarios.
- Scottish Natural Heritage is primarily responsible for Natura 2000 site management in Scotland, but these areas have to be considered in flood protection schemes.
- SEPA is also responsible for operational flood warnings.

Jim Hansom (University of Glasgow) is providing support to Scottish Government on erosion risk mapping, working closely with SEPA. The Flood Risk Management (Scotland) Act 2009 does not include any reference to erosion but SEPA recognise that consideration of erosion is important for sustainable flood risk management. In Scotland the 1949 Coast Protection Act is still the most relevant legislation which gives local authorities permissive powers to protect eroding coastlines.

Committee for Climate Change: Kathryn Humphrey (Information provided earlier and presented by David Cotton)

- The Committee for Climate Change (CCC) has information on global and UK sea level but wants to know how this translate this large scale information to regions around the UK.

- The CCC needs indicators of present, and possible future, trends.
- The CCC is responsible for providing 5-yearly updates to the Climate Change Risk Assessment (CCRA), which has the following objectives:
    - Assess current vulnerability to climate, adaptation
    - Assess future risks and adaptation
    - Summarise priorities for 2018-22 (including evidence gaps)
    - The next CCRA evidence report (CCRA 2017) is due to be presented to government in July 2016.
- The types of sea level information the CCC needs, ideally in the form of a synthesized expert analysis of evidence with links to the supporting data, are:
    - Regional trends in mean sea level around the UK.
    - Regional trends in peak tides (e.g. highest tide level per annum).
    - Number of times tide level thresholds are exceeded.
    - Number of times coastal defences are breached per annum, and location.
    - Comparison of current trends in sea level with future projections; which pathway are we currently following

Space for Smarter Government Programme Showcase – 7th June: John Vesey (SSGP)

- The UK Space Agency will be holding a showcase event for all projects supported by the Space for Smarter Government Programme at Westminster Hall, London, on 7th June. The meeting is intended for UK public sector agencies, and is an invitation only event.

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Session 2: Sea Level SpaceWatch: Variability in UK Coastal Sea Level from Satellite Altimetry and Tide Gauges

In the second session presentations looked firstly at the basis of modelled projections for sea level change, and then reviewed the work that had been done within the Sea Level SpaceWatch project in terms of processing satellite altimeter and tide gauge data, and using these data to carry out analyses of sea-level variability around the UK

1. *Constructing model projections of century-scale change in extreme sea level for UKCP09 and UKCP18: Tom Howard, Met Office*

Tom presented the ongoing work at the Met Office, Hadley Centre constructing projections of long-term change in extreme sea-levels for UKCP09 and now UKCP18.

- The projections of mean sea level add together the contribution of thermal expansion, ice melt from different regions, and additional land water. Global and regional projections are generated.
- New developments within the latest projections include a pattern scaling approach to oceanographic sea level, new approaches in providing uncertainty estimates, estimates of regional variability through a combination of tide gauge data and models, and projections beyond 2100.
- The H++ scenario is based on the worst possible case. The basis of these ranges from process based models, expert narratives, to a simple calculation of the amount of land ice available.
- UKCP09 included the effect of storm surge – using an ensemble model approach. The changing contribution of storm surge was found to have a significant effect in project extreme levels in the Eastern N Sea, but not at the UK Coast.
- For UKCP18, the work has looked at projected changes in storm tracks and in strength of storms, again through an ensemble analysis. A range of outcomes was seen across different models, some indicating an increase in strength and a northward latitudinal shift of the storm track, others showing a reduction in strength and a southward shift in the latitude of the storm track. It is planned is to include the outcome of this work in UKCP18.
- Uncertainties on projected extreme water levels are still very high at some locations
- It was noted that in some areas (e.g. South Coast) a higher frequency occurrence of average storms could have as large an impact as in increase in the strength of rarer extreme events.

2. *Sea Level Data from satellites and tide gauges*

Tide Gauge Data Processing for Sea Level SpaceWatch (Angela HIbbert, NOC)

Angela provided an overview of the processing applied at NOC to the Tide Gauge data for the project

- NOC has generated two sets of data, high frequency data for direct comparison against satellite data, and monthly averages for long-term trends and seasonal variability.
- Non tidal residuals of Maximum Total Water Levels were calculated.
- Data from 46 tide gauges in the UK Tide Gauge network, and 11 from the Channel Coast Observatory Tide Gauges were included. Data from the CCO tide gauges is not currently included in calculation of Long-Term trends as only ~10yrs data available.
- There was particular appreciation of the Southend TG data made available to the project, and consequently PSMSL, courtesy of the Port Of London Authority. Access to these data enabled confirmation of the reliability of the Sheerness TG data, against which there had previously been some question marks.

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Processing of coastal altimetry data for Sea Level SpaceWatch (Paolo Cipollini, NOC)
Paolo provided an overview of the satellite altimeter processing carried out at NOC for the project

- Recalled the starting point, 8 years of Envisat data already processed (2002-2010) in Sea Level SpaceWatch Phase 1.
- Revised the need for specialised altimeter data processing at the coast, and gave some details of the processing approach.
- The sea level analysis is based on two sea level parameters: Total Water Level Envelope and Sea Surface Height Anomaly. The former supports analysis of extreme sea level, the latter for long term trends and seasonal /regional variability.
- In Phase 2, the processing of 14 full years' Jason-1 / Jason-2 data, on a 10 day repeat orbit, as been completed. Processing of (AltiKa) data on the 35-day repeat orbit to complete the (Envisat) time series from 2002 to 2015 is underway but not yet complete.
- Paolo discussed the key issue of ensuring consistent corrections across the data sets.
- The long term-trends from the longer Jason time series (2002-2015) were seen to be more coherent then had been found from the shorter Envisat time series (2002-2010).
- There is preliminary evidence of a geographical structure in the long-term trend, larger on the South and East than in the North-West.
- The choice of tidal model chosen has an impact on the outcome of the analyses and the errors in the identified characteristics of sea level variability, so it is important to consider this choice carefully.
- The analysis of the fitted annual sea level cycle confirmed previous work from Phase 1, showing the peak of the annual cycle occurs ~30 days later in the NW (~day 310) than in the SE (~day 280)
- Conclusions:
    - Results from combined Jason-1/Jason-2 are improved (longer time series, 14 yr), 'less noisy'.
    - AltiKa processing still being fine-tuned.
    - Consistency of corrections crucial for reliable estimates of characteristics of sea level variability.
    - Significant regional variations can be seen, supporting the objectives of the Sea Level SpaceWatch concept.
    - Data from **Jason-3** (launched Jan 16) will be fully compatible with the system, and will continue the time series on the 10-day repeat tracks.
    - Early examples of (SAR) Altimeter data **from Sentinel-3** (launched Feb 16) are very promising but Sentinel-3 will provide data on a different set of ground tracks tracks to Envisat / AltiKa (27 day repeat orbit).,
- There could be scope to extend the time series backward in time to 1992, but there are some technical difficulties. It will be easier to achieve this for the "Envisat" 35 day repeat tracks (from the ERS-1, ERS-2 missions), than for the "Jason" 10 day repeat tracks (from the Topex-Poseidon mission).

3. *Analysis: Variability (in time and space) and errors / confidence levels (12:20 – 12:50)*

Product Analysis and Validation (Francisco Calafat, NOC)
Francisco presented the results of his work on assessing the performance of the coastal altimetry data, and at characterizing the annual and inter-annual variability

- The performance assessment was based on a comparison of the altimeter data against tide gauge data for the same period (2002-2015)

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- The different processes leading to changes in global and coastal sea level were summarised
- The amplitude and phase of the annual cycle derived from altimeter and tide gauge data were compared. There was clear consistency between the annual cycle parameters (amplitude and phase) from tide gauge and altimeter data, with some localised differences. The annual cycle peaks between early October in the south-east and early November in the west coast and has an amplitude ranging from 5 to 9 cm
- It was noted that the annual cycle is not constant and varies from year to year (as seen from tide gauge data).
- The inter-annual variability derived from tide gauge and altimeter data was also compared.
- There is good agreement between the de-trended de-seasoned sea level from altimetry and from the tide gauges, with a mean correlation of 0.57, and RMSD of 5.3 cm.
- The need to take into account the atmospheric contribution to the sea level (by applying the inverse barometer correction), was demonstrated. In the case of Holyhead this increased the correlation from 0.57 to 0.75, and reduced the Root Mean Square Difference from 7.7 cm to 3.3 cm.
- Tide Gauge data (1985-2015) was used to characterize regional patterns of inter-annual variability, using EOF (Empirical Orthogonal Function) analysis. The first mode explained 52% of the variance, and was coherent across most of the UK
- Finally, Francisco recalled the importance of being aware of the impact of inter-annual variability on decadal trends

Stochastic modelling of the tide gauge, altimeter and GPS time series for realistic uncertainties in derived parameters (Simon Williams, NOC)

Simon presented the results from his analysis of uncertainties/errors in the parameters derived from the altimeter and tide gauge sea level time series data sets.

- The frequency characteristics of different types of noise were reviewed, and it was noted that the choice of noise model can have a significant affect on the uncertainties in derived parameters.
- For the analysis, a power law noise model and white noise model were applied to the Tide Gauge data time series, and consequent the difference in uncertainties in the derived long term trend from the two models could be seen.
- The correlation in variability across different Tide Gauges was analysed and two populations were identified, which were internally well correlated: Tide Gauges on the English E Coast from Whitby to Sheerness; and all the other Tide Gauges from Dover, round the S Coast and SW coast of England, Wales, NW England and Scotland.
- Simon then looked at altimeter data using three noise models: White noise, power law, and auto-regressive.
- Combining the TG and altimeter data sets for a single site (North Shields), it was found that differently sampled data sets can be seen to obey different models. The analysis indicated that the 14 year altimeter time series is not yet long enough to accurately model the longer term variability.
- In summary:
    - Tide gauge data exhibit a power law noise power spectrum with a spectral index of approximately -0.5.
    - The Altimeter data appear to show smaller spectral indices or AR(1) model
        - Partly because the inverse barometer effect is removed in the

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altimeter data (and is not for the tide gauge data)
        - Partly length of time series
    - GPS data shows a power-law noise with a spectral index of -0.7
- Interpretation is that long-term trends estimated from altimeter data gathered over a 15 year period could give an erroneous trend as they could interpret shorter term decadal scale variability as a long term signal.
- A question from the meeting asked how many years would be needed in a time series to bring errors down to a practically useful level?
    - This varies from site to site. The PSMSL web site has calculated the length of time series needed to bring errors down to given levels (1.0 mm/yr, 0.5 mm/yr, 0.1 mm/yr). See
    - (http://www.psmsl.org/products/trends/trends.txt)
    - For GB tide gauges the length of time series needed to provide estimates of long term trend accurate to 1.0 mm/yr ranges from 21 years at Dunbar to 45 years for Sheerness. Most lie in the range 21-34 years

Session 3: Sea Level SpaceWatch Implementation – Business Plan

1. *The Sea Level SpaceWatch Service Offering and Business Plan David Cotton, SatOC*

David provided an overview of the proposed operational Sea Level Space Watch service, designed to support flood defence planning and coastal management, summarized below.

- Public SLSW web-service
    - Sea level trend information, derived from analyses of satellite altimeter and tide gauge data.
    - Download Access to processed altimeter data and derived metrics on trends and variability
- Detailed Site Specific Analyses - Accessible to Funders
    - Two sites per partner
    - Chosen on basis of data availability / strategic interest
    - Trends, uncertainties, statistics
    - Comparisons between Satellite and Tide Gauge data
    - Levelling / GPS derived information (e.g. land movement)
    - UKCP 09/18 projections
    - Example possible layout for Holyhead demonstrated
- Further on Request Site Specific Analyses
    - As above. On request - additional cost
- Technical Guidance
    - Results of validation study between satellite altimeter and tide gauge data
    - Assessment of regional patterns of variability / coherence.
    - Analysis of errors
    - Advice on the correct usage and interpretation of the sea-level information provided in Sea Level Space Watch
- Funding basis
    - Consortium funding
    - User Board, with funding partner representatives, service manager, other members as agreed, meets annually to review service and consider possible developments.
    - Subscription covers general service & site specific at analyses at 2 locations (per customer).

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- Customer benefits
  - Provision of measured sea level trends alongside projections provides greater confidence for planning investment on coastal defences, and coastal habitat management.
  - Cost recouped if the service results a 0.01% efficiency improvement in the management of flood and erosion risks (derived from the PCv estimate for this cost of £25bn over 100 years).
  - Further savings could result from potential reduction in costs of compensatory coastal marine habitat creation
- Demonstration version of the service available at http://www.satoc.eu/projects/sealevelsw/test.html

There was then an open discussion on the service as proposed, with the following issues being raised:

- Site Analyses:
  - The key messages should be highlighted at the top of the page: What the measured sea level trend rate is, what the projections are.
- Regional Analyses:
  - It would be useful to have regional analyses that cover a larger area, and/or at key sites, with trend data available in downloadable tabulated form
  - The display should provide some indication of the spatial scale over which the signal varies.
- General Points

  Q What do we get from satellite altimetry that we cannot get from Tide Gauges?

  A Measurement at Tide Gauge is very dependent on localized conditions within the estuary, river mouth, etc, and most likely not representative of the situation even a few km away along the coast. The satellite measures close to the coast, but also out from the coast, without any such localized effects and so can give the wider picture, as well as linking the coastal measurements to the open ocean.

  - NRW – What is really needed is high confidence sea level trend information that can be considered alongside the sea level change projections from climate models.
  - Have seen there is good coherence between the inter-annual variability signals from tide gauges and satellite data, question is how best to combine information from the two sources.
  - Climate models do not perform well in the coastal zone, so a best comparison between the climate model projections and measurements may be best done with the trends from satellite data out in the open ocean.
  - MCCIP Annual scorecard approach could be a useful model (see http://www.mccip.org.uk/annual-report-card/
  - Could step back through Tide Gauge data, increasing the length of time series to establish what length of record is needed for the long term trend signal to be seen above shorter scale variability.
  - Can a similar approach be taken to average data spatially to reduce uncertainty?
  - General recommendation to adopt an approach with trends calculated at different scales, e.g. 4 sets of scales:
    - National: (Scotland, England, Wales, N Ireland)

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- Large coherent regions: S Coast England; SW Coast England; S, Central Wales, N Wales and NW England; W Scotland; E Scotland; E England.
- Shoreline Management Plan Regions (England and Wales), Local Plan Districts (Scotland)
- Localised Analysis where there is high volume of reliable data to support it.

- How often should the service be updated?
- DC will plan to review with all interested parties in the next few months.

2. Possible Future Developments: Extensions outside UK

There was a short discussion on the potential for implementing the Sea Level SpaceWatch concept outside UK seas.

European implementation: North Sea, plus other areas?

The North Sea is one possible region, also possibly the Mediterranean Sea

- A North Sea implementation could link to the iSTORM project, which is a consortium of storm surge barrier managers across the North Sea.
- One funding option could be through the ESA Integrated Application Programme, which DC has been investigating
  - Two different satellite technologies must be involved (this could be satellite altimeters for sea level, and GPS for Tide Gauge precise leveling / land movement.
  - ESA IAP is 50% funded (for feasibility studies / demonstration projects)

Beyond Europe: Low lying / Vulnerable Regions

- Possible locations were discussed, with the Indian Ocean (coastal zones and offshore islands) thought to be the place where greatest benefits could be realized.
- It was noted that in many areas there is not the infrastructure in terms of in situ measurements so the contribution of altimeter data will be more critical.
- Potential sources of funding include the UKSA International Partnership Space Programme, the Global Collaborative Space Programme, and more general aid programmes.
- NOC is part of a small project to spread UK Marine Science to island states. The first stage has very limited funding to establish what level of interest there may be. If interest is established, UK Govt. may provide increased funding in subsequent years.
- Any implementation in new locations would need to include local validation of the sea level products. It would also be important consider other aspects, e.g. the best tidal model for different regions.

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Annexes
Workshop Agenda

Welcome - Introduction to the Sea Level SpaceWatch Project (09:30)

Session 1 – The need for monitoring sea level rise in a changing climate (09:35-11:00)

1. What we know about sea level variability around the UK. (09:35 – 10:15)
   - UK Sea Level Variability from Tide Gauge Data (Angela Hibbert, NOC)
   - Spatial footprint and temporal clustering of storm surges around the UK (Ivan Haigh, University of Southampton)
2. User Needs: (10:15 – 11:00)
   The Environment Agency, Natural Resources Wales, The Climate Change Committee, Scottish Environment Protection Agency
   (10 minutes each)

   Announcement of SSGP Showcase – 7th June

Break (11:00 – 11:30)

Session 2 - Sea Level SpaceWatch: Variability in UK Coastal Sea Level from Satellite Altimetry and Tide Gauges 11:30 – 13:00

4. Constructing model projections of century-scale change in extreme sea level for UKCP09 and UKCP18. (Tom Howard, Met Office) (11:30 – 11:50)

5. Sea Level Data from satellites and tide gauges (11:50 – 12:20)
   - Tide Gauge Data Processing for Sea Level SpaceWatch (Angela HIbbert, NOC)
   - Processing of coastal altimetry data for Sea Level SpaceWatch (Paolo Cipollini, NOC)
6. Analysis: Variability (in time and space) and errors / confidence levels (12:20 – 12:50)
   - Analysis of seasonal to interannual sea level variability from altimetry and tide gauge data (Francisco Calafat, NOC)
   - Stochastic modelling of the tide gauge, altimeter and GPS time series for realistic uncertainties in derived parameters (Simon Williams, NOC)
7. Example of a possible Site Specific Analysis - Discussion

Lunch (13:00 – 14:00)

Session 3 – Sea Level SpaceWatch Implementation – Business Plan
14:00 – 16:00

1. The Sea Level SpaceWatch Service Offering and Business Plan
   David Cotton, SatOC (14:00 – 14:30)
2. User response and Discussion (14:30 – 15:30)
   a. Identification and discussion of options
   b. Further developments necessary before implementation
3. Possible Future Developments: Extensions outside UK (15:30 - 15:40)
   a. Within Europe
   b. Internationally – identification of vulnerable regions
4. Round up and next steps (15:40 – 16:00)

Close 16:00

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Workshop Attendees:

At NOC, Southampton

Valborg Byfield	National Oceanography Centre
Paolo Cipollini	National Oceanography Centre
David Cotton	Satellite Oceanographic Consultants Ltd
Bill Cooper	ABPMER
Neil Counsell	Natural Resources Wales
Uwe Dornbusch	Environment Agency
Christine Gommenginger	National Oceanography Centre
Ivan Haigh	University of Southampton
Angela Hibbert	National Oceanography Centre
Tom Howard	Met Office
Jack Eade	National Oceanography Centre (CCO)
Francisco Mir Calafat	National Oceanography Centre
Richard Park	Natural Resources Wales
Andrew Shaw	SkyMat
Owen Tarrant	Environment Agency
John Vesey	UK Space Agency (SSGP)
Thomas Wall	University of Southampton

Remotely

Kathryn Ball	Scottish Environment Protection Agency
David O'Brien	Scottish Environment Protection Agency
Jim Hansom	University of Glasgow
Claire Harley	Scottish Environment Protection Agency
Darroch Kaye	Scottish Environment Protection Agency
Marcello Passaro	Technical University of Munich
Simon Williams	NOC, Liverpool

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