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Title : Service Roadmap

Abstract : This document contains the Service Roadmap for the Copernicus Sentinel-3 Sea and Land Surface Temperature Radiometer (SLSTR) Sea Surface Temperature (SST) Validation using Fiducial Reference Measurements (FRM) Service.

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CONTRACT REPORT

The work described in this report was done under ESA contract. Responsibility for the contents resides in the author or organisation that prepared it.

AMENDMENT RECORD

This document shall be amended by releasing a new edition of the document in its entirety. The Amendment Record Sheet below records the history and issue status of this document.

AMENDMENT RECORD SHEET

ISSUE	DATE	REASON FOR CHANGE
A	28/03/2019	Draft for first internal review
B	05/04/2019	Further updates
C	01/04/2019	Draft for review by project team
1	16/04/2019	Issued to ESA

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1. INTRODUCTION

Satellite remote sensing of the Earth has become an essential tool in increasing our understanding of the climate, weather patterns and the impact of climate change. It has, and continues to, assist scientists in their analysis of climate change and world leaders in the formation of policies to adapt to or mitigate the effects of climate change. For this reason, remote sensing data must be as accurate as possible as well as long-term; i.e. creating a reliable data series by linking different satellite sensors to common reference standards. To this end, *in situ* Thermal Infrared (TIR) radiometers are deployed on vessels across the globe to collect SST data, which is then used to validate and verify satellite measurements, ensuring optimal accuracy. The ISAR and SISTeR instruments used on this project are two such TIR radiometers and have been used in deployments since 1998 and 1996 respectively.

The project team work daily with shipborne radiometer colleagues and other climate scientists worldwide. They therefore have useful personal networks within the climate and shipborne radiometer user community, and a deep appreciation of the concerns and perspectives of the radiometer network community regarding *in situ* climate data. This knowledge has been combined following an in-depth discussion at the ISFRN Review meeting on 28 February 2019 to produce a service roadmap, complete with implementation strategies and priorities**.**

This report presents the service roadmap for the Ships4sst contract. The main aim of this roadmap is to:

- provide a critical analysis of the feedback from participants and institutions working in the service, including feedback from the ISFRN Review meeting;
- articulate lessons learned by the service providers;
- identify potential strategies for integrating the service outcomes into existing initiatives and operational institutions;
- identify priority areas to be addressed in potential future activities to support SLSTR validation activities.

2. PROJECT OVERVIEW

This project, which is funded by the European Space Agency (ESA), started on 1 April 2018, and is due to run until 31 March 2019 with an option for an extension for a further year. The aim of this project is to validate Copernicus Sentinel-3A and Sentinel-3B SLSTR Sea Surface Temperature (SST) data products using Fiducial Reference Measurements (FRM). This aim is being fulfilled through the collection, processing, analysis, publication and reporting of *in situ* FRM field measurements made using the Infra-red SST Autonomous Radiometer (ISAR) and the Scanning Infra-red SST Radiometer (SISTeR) instruments, that are near-contemporaneous with satellite data from the Sentinel-3A and Sentinel-3B SLSTR instruments.

Providing reliable and timely Fiducial Reference Measurements to support the validation of SLSTR SST involves the use of three unique European activities and data sets:

- Continuation of the English Channel and Bay of Biscay ISAR radiometer deployments, ISAR 002 and 003,
- Continuation of SISTeR A deployments on the *Queen Mary 2* liner between Southampton and New York, and round the world,
- Deployment on Smyril-line Denmark–Faroe Island-Iceland, ISAR 008, in synergy with the Ferrybox project and instrumentation,

The work to be carried out by the project team is also:

- To support a collaborative network that enables other users of ship radiometers worldwide to contribute to the *in situ* SST Reference Database and which disseminates the data to the wider community. This includes maintenance of FRM protocols.

The Ships4SST project also provides and maintains an International SST FRM Radiometer Network (ISFRN) website that makes information and data available on all aspects of the radiometer deployments to users and the project team, as appropriate. This includes; a Campaign Implementation Plan (CIP), a Campaign Actions and Risk Log (CARL), the most recent radiometer data and calibrated skin SST with associated uncertainties, validation plots, reports and links to scientific papers, an ISFRN data description and user manual, and details of the ISFRN Service Review Meeting.

3. ROADMAP DEVELOPMENT

3.1 ISFRN Workshop

On the 27th February 2019 the project hosted the first international ISFRN workshop, with scientific and operational users and producers of *in situ* radiometer SST data from the UK, Denmark, America, Australia, Italy and France attending. The aim of the workshop was to present and discuss ship-borne satellite SST validation activities and results, and to share the findings of the partners in the ISFRN service.

The ESA-sponsored workshop was hosted at the National Oceanography Centre (NOC) in Southampton and consisted of two days of presentations, posters and interactive sessions, designed to review progress, results and advances in deployments, calibration and validation as well as a discussion on a service roadmap. The workshop consisted of the following sessions:

- Session 1: Experiences of Radiometer Operators
- Session 2: Developing the Radiometer Network
- Session 3: Radiometer Performance and Uncertainties
- Session 4: Validation of Satellite SST Measurements
- Session 5: Software and Tools

Following on from the final session, a group breakout commenced in which detailed discussions on the future of the service took place. The project team had summarised a number of areas that could be developed and had prepared questions for participants of the workshop prior to the session. Attendees discussed a number of these and strategies for implementing future requirements were developed. This included possible impacts and difficulties that may ensue.

3.2 Service Roadmap

Table 3-1 shows the results of the service roadmap discussions. Requirements and suggestions have been met with strategies for implementation and/or comments. Each suggestion has been rated 1 to 5 for impact and difficulty and, if possible, a target date for implementation was given.

Requirement / suggestion	Strategies for implementation / Comments	Impact (5 high, 1 low)	Difficulty (5 high, 1 low)	Target Date
Add more data and metadata to ISFRN database	Encourage more radiometer operators to join the network. New routes and reprocessing of existing data to L2R	5	being done routinely	ongoing
Improve information on observational methods	Write papers Publish more papers/reports/etc.	5	5 (because of time restraints)	April 2019 (2 papers by the ships4SST team)
Ensure adequacy and continuity of the observing system	Performing more intercomparison exercises will help confirm the validity of uncertainty budgets, show the validity, equivalence and traceability of the measurements. This is actually quite hard to do in the field as there is a geophysical component we don't necessarily know. But we need to try to achieve this in the field.	5 - how we understand uncertainties	3 (have the knowledge, funding and time is limited)	2021
Improve openness and access to information	Increase the number of online documents on the Ships4sst webpage	5	2	2020
Quantified fully broken down uncertainties and sources of error in respect to SI	Source of errors might be tricky, and quantifying them, as if we can quantify them we correct for errors, otherwise they are uncertainties. Verification of uncertainty model (out at field).	5	5	ongoing
Push for more radiometers on ships of opportunities.	Radiometers can be more readily made traceable to SI than buoys Groups are starting to take up ISARS so this is increasing	5 (have better stats with more radiometers)	1	ongoing

Requirement / suggestion	Strategies for implementation / Comments	Impact (5 high, 1 low)	Difficulty (5 high, 1 low)	Target Date
Develop new routes	The most important areas for new route would be: 1. Reference ship tracks in cloud free regions; this could be on a ship or fixed platform. This would fulfil the need for long-term consistency. 2. More radiometers going out into problem areas (Arctic and islands) and the whole of the southern area. 3. Aerosol regions (P&E) 24° west – there are 6/7 cruises ready to go. Aerosols sometimes vary a lot so it is good to go to a few times. Money, time and experience are what are needed!	4-5	2-3 (could use existing infrastructure)	Now
A database of information, including QA, on all radiometers to support validation	Documentation of processing versions, instrument maintenance etc. is there, just needs to be links to reference sites, websites populated etc. A link from the ships4sst to QA3O information will be put online.	4-5	2-3	ongoing
Promotion of community protocols and best practises	Data submitted to the L2R archive should/must follow the ships4sst protocols. Mandatory requirement to be L2R (like GHRSST) There may be some more work to do on protocols and metadata as protocols are followed within the ships4sst project (therefore easier) but not always used by everyone else. Is there evidence that people follow the protocols? The FRM4STS website needs to be linked to the ships4sst site.	4	2-4	ongoing

Requirement / suggestion	Strategies for implementation / Comments	Impact (5 high, 1 low)	Difficulty (5 high, 1 low)	Target Date
Measurements at a range of sea depths	We can only measure at the surface (skin), so should there be a range of oceanographic regimes, or do we want to include other sensors? Most ships already measure bulk temperature so it could be combined with skin temp tracks. Merge drifter data with radiometer data for SI link. Most ships are now measuring a range of data depths - is there an interest for more range? The impact on validation is believed to be small but impact on science large. A platform in the Mediterranean would be more useful than more depths on ships because ships do not have FRM standards (difficult to do at depths due to temp gradient etc.) Several months' worth of data of diurnal variability on various platforms would be useful. Peter Minnett has a spare ISAR, perhaps it could put it on a platform that Helen Beggs uses.	Unknown	5 - doable but difficult to do with ship operators	
Sampling of coastal variability	Is already done, but we exclude most of the data for validation. Not necessarily an issue for climate studies. Interesting for high resolution missions. Sensing of bulk areas can be good with *in situ* radiometers. Large birds could be instrumented (e.g. on albatrosses and boobies feet) – Peter Minnett commented that the data was remarkably good when birds were used.	1	1	

Requirement / suggestion	Strategies for implementation / Comments	Impact (5 high, 1 low)	Difficulty (5 high, 1 low)	Target Date
Where would people like to see the focus of ships4sst.	Climate focus important - service to operational validation of SST. Getting other members to contribute so that more data records could be included. Develop, consolidate and maintain a network to provide data of sufficient quality to allow optimal validation. Actively engaging with other operators. Telecons with international partners/operators to get them more involved? 0900 or 1530 telecons manages to get most people (globally). A simplified next generation radiometer that could go on fixed platforms (might not be as robust as something on a vessel but could make a lot of instruments). These may not be as reliable which is putting people off. This has also been thought of before and there did not seem to be a big gain from the report.	Various	Various	Various

Table 3-1 – Service Roadmap

3.3 Summary

The discussions identified a number of areas to target that were both High Impact and Low Difficulty, leading to a high likelihood that these suggestions will come to fruition in the near future. One of these is the need to improve openness and access to information. Strategies for implementing this included increasing the number of online documents on the ships4sst webpage, and the FRM4STS study provides an opportunity to do this. Linking the ships4sst project website to relevant sources of information was suggested several times. Whilst there are already a number of links online, it is clear that more links with more information and details are required. Again, this will be addressed in the FRM4SST study.

One of the highest priority areas was to increase the understanding of, and improving the uncertainties associated with radiometer SST measurements. There were several suggestions for this; for example, performing intercomparison exercises help to confirm the validity of uncertainty measurements on radiometers. Past intercomparison exercises have proved successful and with funding, time and international cooperation, future intercomparison exercises could be performed. Whilst there are geophysical factors that can make improving uncertainties in field measurements tricky, the need for increased time and funding to perform the intercomparison experiments and analyse the data seems to be the main factor increasing the difficulty level of uncertainty-related requirements to the highest rating of 5.

When specifically asked where participants would like the project to focus on, there were a number of suggestions including:

- Focussing on the operational validation of SST is important for climate studies.
- Consolidating the network and encouraging new members to contribute data and information by actively engaging with other radiometer operators.
- Maintain a network to provide data of sufficient quality to allow optimal validation.
- Looking into creating a cheaper, simplified radiometer that can go on fixed platforms. It need not be as robust as an instrument on a vessel but there could be opportunities to deploy more fixed instruments.

Looking into a cheaper and simplified radiometer has been thought of before according to several participants but there did not seem to be a big gain, which is putting people off making them.

Plans to promote the ISFRN and actively engage with the community will continue into the FRM4SST study.

4. CONCLUSION

This service roadmap has provided the project with excellent feedback to take into the ESA-funded FRM4SST study. The recommendations, which are backed up by strategies for implementation, difficulty and impact ratings, will facilitate this project in focussing on the high priority areas that are doable within the framework of the contract. More importantly, the service roadmap details a number of goals that are needed to ensure that *in situ* radiometers fulfil the role of validating and verifying SLSTR SST data to the best of its ability, which is the fundamental aim of this contract.