ships4sst

shipborne radiometers for sea surface temperature

The Copernicus Imaging Microwave Radiometer (CIMR) sea surface temperature validation with ship-borne infrared radiometers

W. Wimmer, T. Nightingale, J. Høyer, R. Wilson, S. Skarpalezos

esa RAL Space University of Southampton DMI Vejr, klima og hav Space ConneXions

Motivation

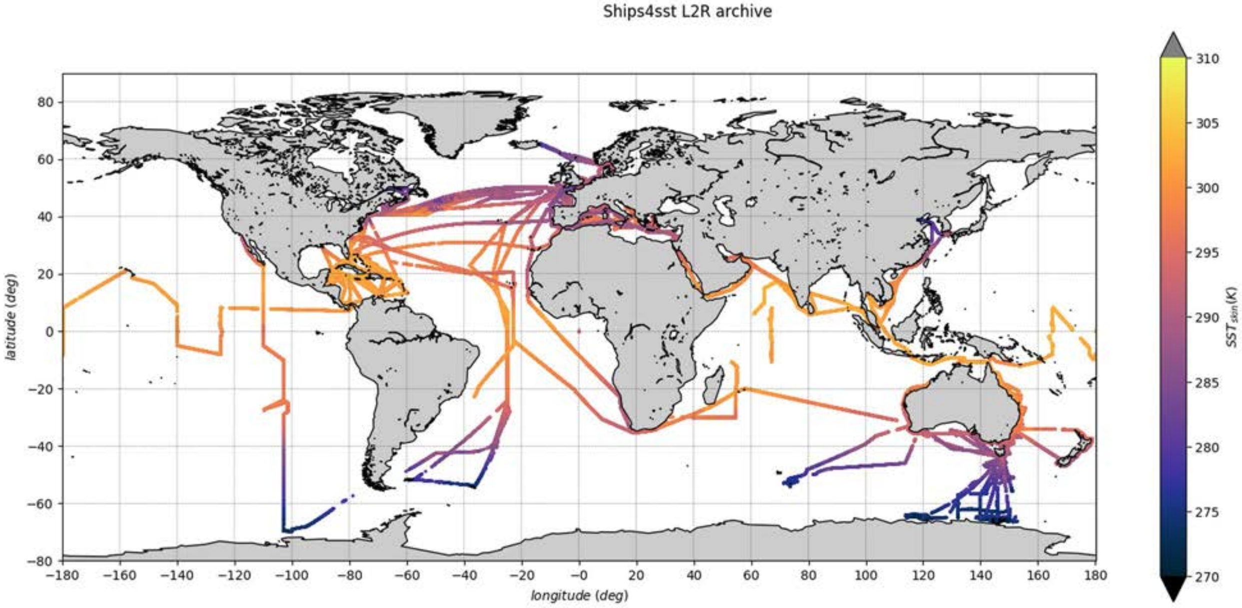
The Copernicus Imagining Microwave Radiometer (CIMR) mission objective for Sea Surface Temperature (SST) is to provide continuity to the passive microwave measurement capability in synergy with other missions, for non-precipitating atmospheres at an effective spatial **resolution of ≤ 15 km**, with a total **standard uncertainty of ≤ 0.2 K**, and with a focus on sub-daily coverage of polar regions and daily coverage of adjacent seas. The uncertainty requirement of ≤ 0.2 K poses a particular challenge to achieve with the proposed NEDT figures of the channels used for SST.

Fiducial reference measurement data

- In order to **evaluate the performance of CIMR** once in orbit it will need a high quality reference dataset such as that provided by the International SST Fiducial Reference Network (ISFRN) which is currently funded by the European Space Agency's (ESA's) Fiducial Reference Measurements for Sea Surface Temperature (**FRM4SST**) project.
- The ISFRN has a **proven track record** in the validation of infrared satellite sensors such as the Advanced Along Track Scanning Radiometer (AATSR), the Sea and Land Surface Temperature Radiometer (SLSTR) and the Advanced Very High Resolution Radiometer (AVHRR).
- The advantages of using ISFRN data over other datasets is that the data provide not only SST measurements in a variety of regions where there are few drifting and moored buoys, including part of the Arctic and Southern Oceans, but also provides **per-SST uncertainties**. The data and uncertainties are traceable to National Metrological Institute (NMI) standards such as those provided by National Physical Laboratory, Teddington, UK (NPL) and National Institute of Standards and Technology, USA (NIST).

Fiducial reference measurement data (2)

- FRM data for SST is mainly acquired with Infrared Shipborne Radiometers:
  - Infrared Sea surface temperature Autonomous Radiometer (ISAR)
  - Scanning Infrared Sea surface Temperature Radiometer (SISTeR)
  - Marine Atmospheric Emitted Radiance Interferometer (M-AERI)
- The ships4sst project provides a platform to coordinate the collection and storage of FRM data sets in a standardised **netCDF** format. The figure below shows a map of the shisp4sst archive data.



esa RAL Space UNIVERSITY OF Southampton DMI Vejr, klima og hav Space ConneXions

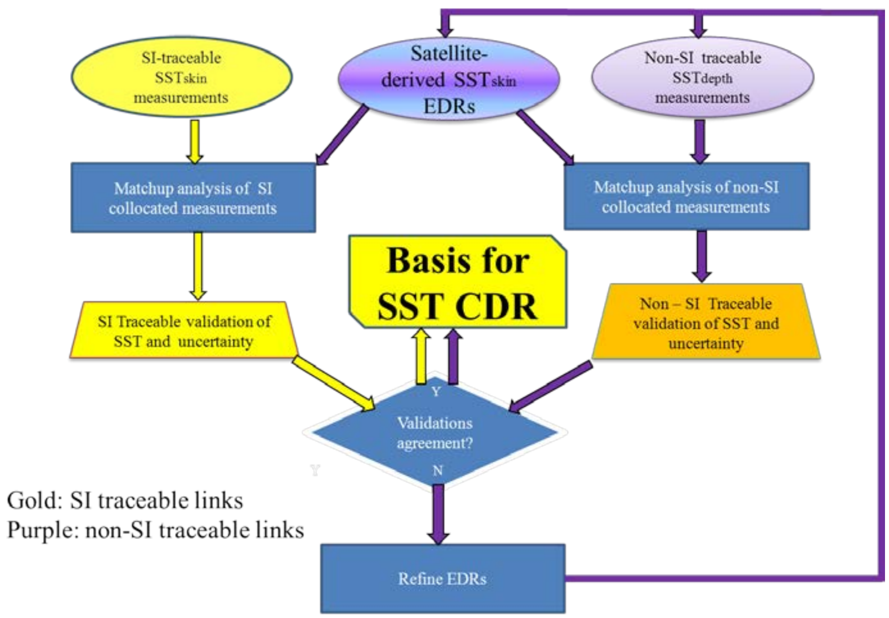
Validation challenges

- The challenges for the L2 CIMR validation are:
  - **Footprint**. The large and frequency dependent footprint of the CIMR L2 data potentially introduces aliasing and point in area sampling errors.
  - **SST sensitivity**.
    - Compared to the TIR, MW **sea surface emissivity** is relatively low and dependant on temperature and surface roughness, including orientation. Consequently the sensitivity to non-radiometric measurements and SST model fidelity is much higher.
    - **dB/dT** is relatively low in the longwave part of the Planck function so classical two-point calibrations are harder as the black body (BB) temperatures need to be a sensible distance apart to resolve the instrument radiometric gain. Similarly for external BBs. LN2 BBs generate significant radiances at 20 GHz

Validation challenges (2)

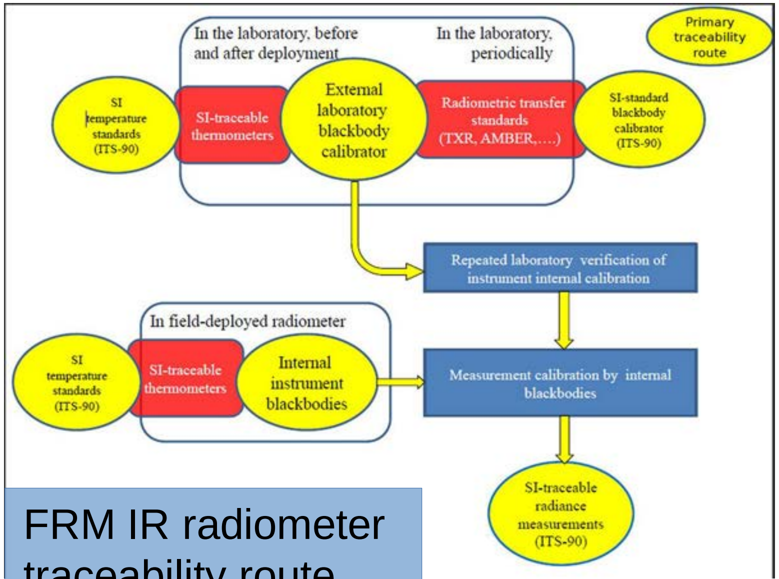
- **Traceability chain**.
  - This is fairly straightforward and established for infrared (IR) instruments
    - See FRM4STS (www.frm4sts.org) and traceability slide (slide 7).
  - More complex and challenging for microwave (MW) instruments.
    - MW validation instruments have small **antennas**/feedhorns and extensive **antenna patterns**. Consequently, they integrate a large range of measurement angles into a measurement. This means both that it's not generally possible to put black bodies at the very end of the instrument chain (so antenna radiances have to be calculated out) and that the sea surface measurement contains information from a large range of directions. This all has to be modelled out of a satellite inter-comparison.
    - It's hard to build high quality **MW black bodies** and consequently hard to validate the instrument calibration. MW black **coatings** are thick and not very black so the correspondence between thermometric and emitting temperatures may not be the best if there's a significant heat load on the BB surface, the resulting potential poor blackness has obvious consequences for the overall BB emissivity. The aperture will likely have to be quite large, particularly at the longest wavelengths, to reduce antenna pattern issues. This exacerbates both the emissivity and heat load issues.
    - **Emissivity** (mentioned in SST sensitivity – previous slide**)**, needs a traceability route too.

Traceability route for IR instruments

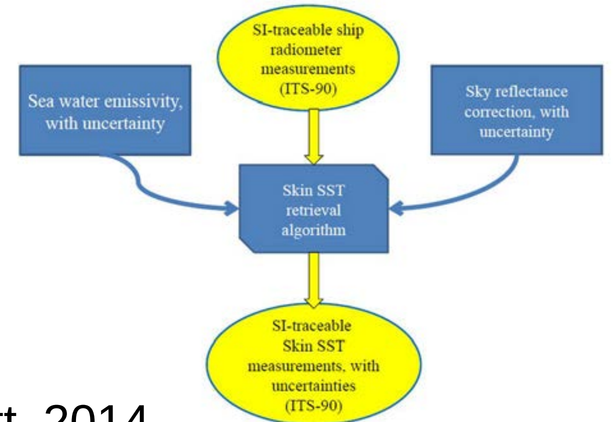


If all conditions satisfied, satellite SST data set suitable for CDAF assessment.

Satellite traceability route, when in orbit



FRM IR radiometer traceability route

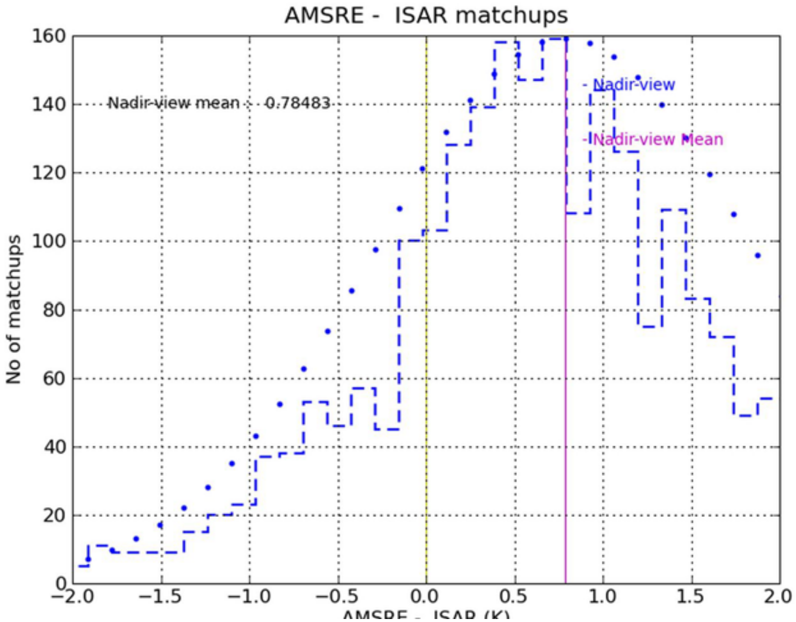


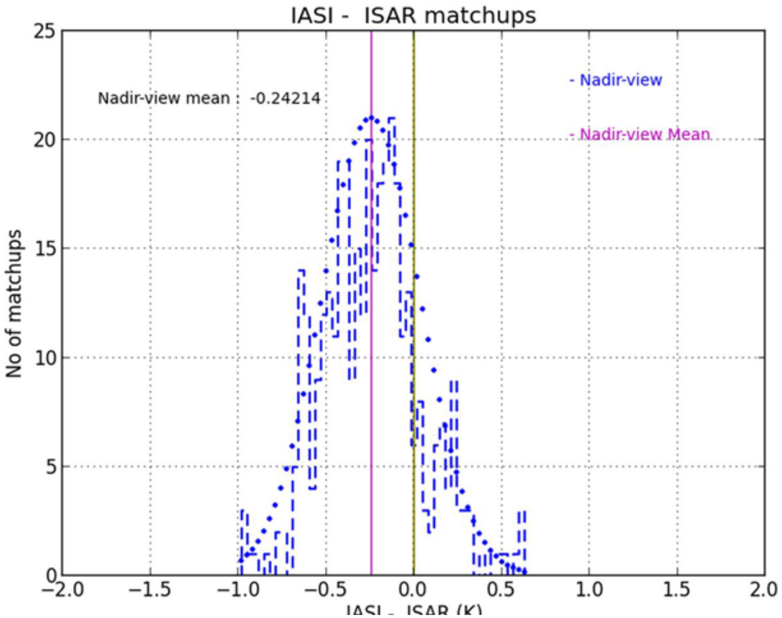
From ISSI, Project Group Minnett, 2014

esa RAL Space University of Southampton DMI Vejr, klima og hav Space ConneXions

Validation of MW sensors

- As an example for MW validation with ships4sst data, the left figure shows the validation of the Advanced Microwave Scanning Radiometer - EOS (AMSR-E) which shows a much wider spread in the histogram and an offset compared to the Infrared Atmospheric Sounding Interferometer (IASI) shown in the right figure.





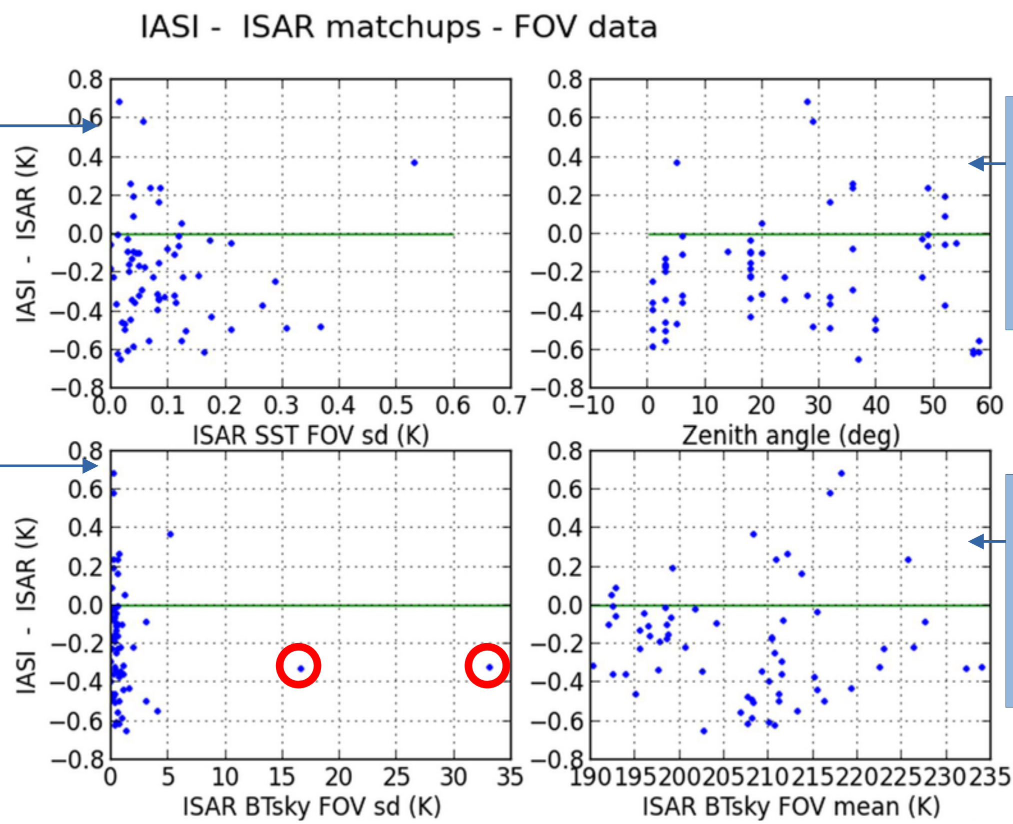
DMI
Vejr, klima og hav

Validation of large field of view sensors

IASI field of view (FOV) analysis comparing various parameters against the IASI to ISAR difference. IASI has a FOV of approximately 15 km.

IASI - ISAR mean difference vs. the standard deviation of the ISAR SST data in the IASI pixel.

IASI - ISAR mean difference vs. the satellite zenith angle.



IASI - ISAR mean difference vs. the standard deviation of the ISAR sky Brightness Temperature (BT), Red circles are likely sub pixel cloud.

IASI - ISAR mean difference vs. mean of the ISAR sky BT data.

Validation of MW and IR satellite senors

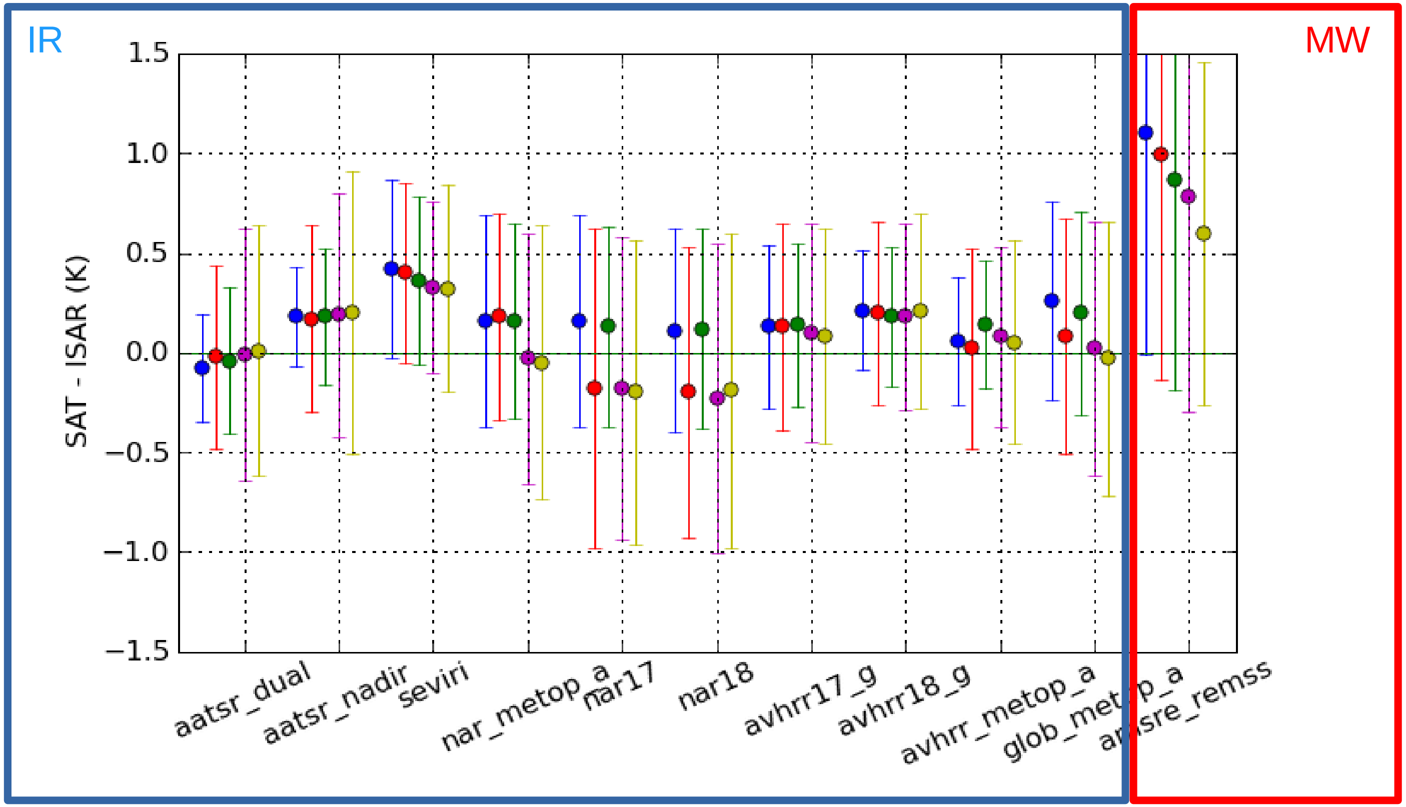
Group for High Resolution Sea Surface Temperature (GHRSST) L2 SST product validation.

Validation data is one year (2009), the circle represents the mean of the difference and the error bar the standard deviation.

Infrared satellite sensors are framed blue, Microwave satellite sensors are framed red.

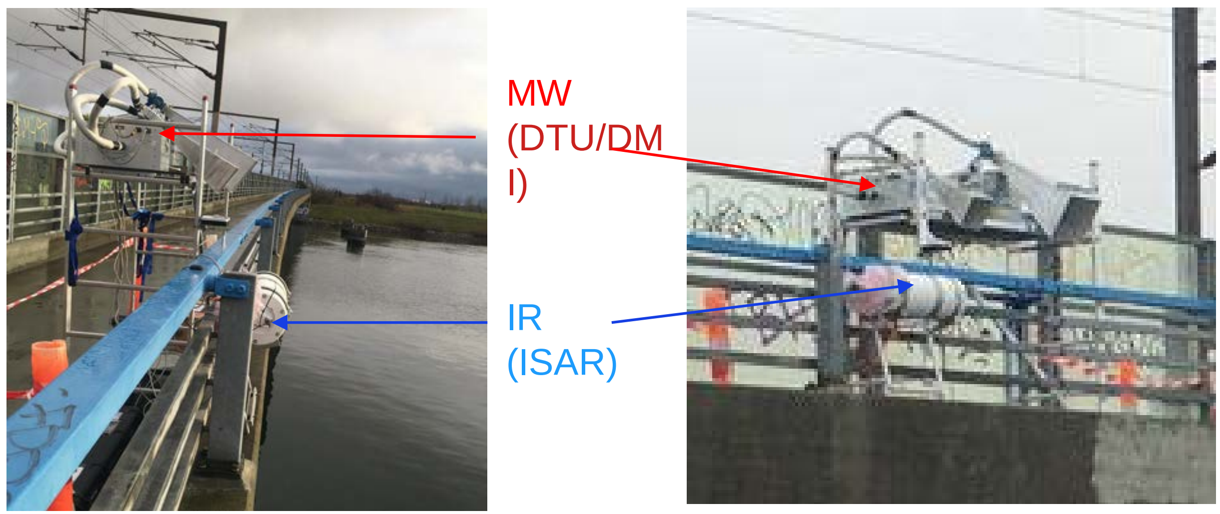
The colours represent different match-up windows:

- Blue: 0.5 h and 1 km
- Red: 0.5 h and 20 km
- Green: 2 h and 1 km
- Magenta: 2 h and 20 km
- Yellow: 6h and 25 km



Conclusion

- Validation of CIMR at L2 SST with FRM data will be a great asset to the CIMR campaign allowing the SST product to be traceable and a route to a climate data record .
- Comparison of field of view data from IASI and AMSR-E shows variability and that great care has to be taken choosing validation data and procedures to avoid point in area sampling errors.
- Work has been under way in comparing in situ IR and MW data to show the how they can be used as validation data for CIMR. A first side by side comparison was carried out in late 2020 near Copenhagen as shown below.



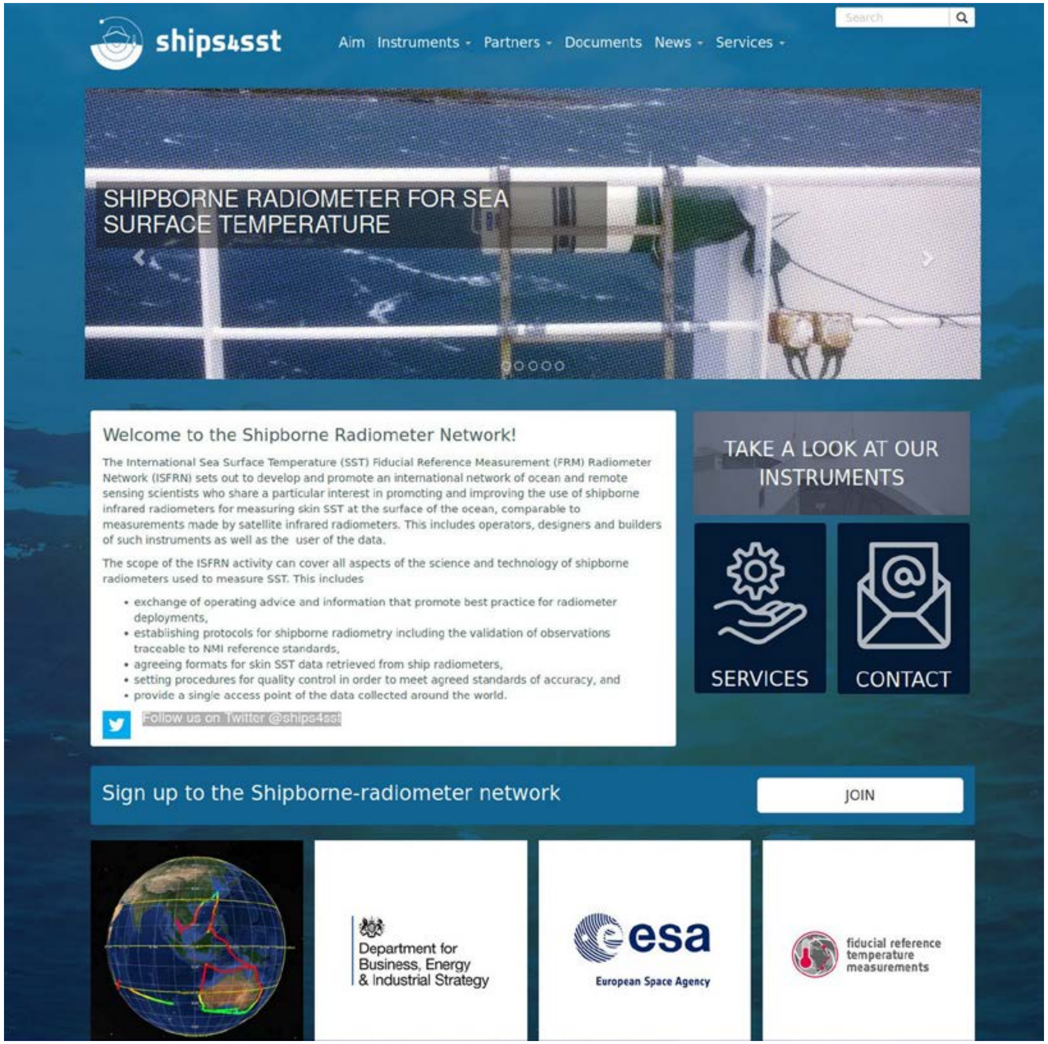
Further information

Thank you for your attention !

www.ships4sst.org

Follow us on Twitter @ships4sst

Or email : w.wimmer@soton.ac.uk



esa RAL Space UNIVERSITY OF Southampton DMI Vejr, klima og hav Space ConneXions