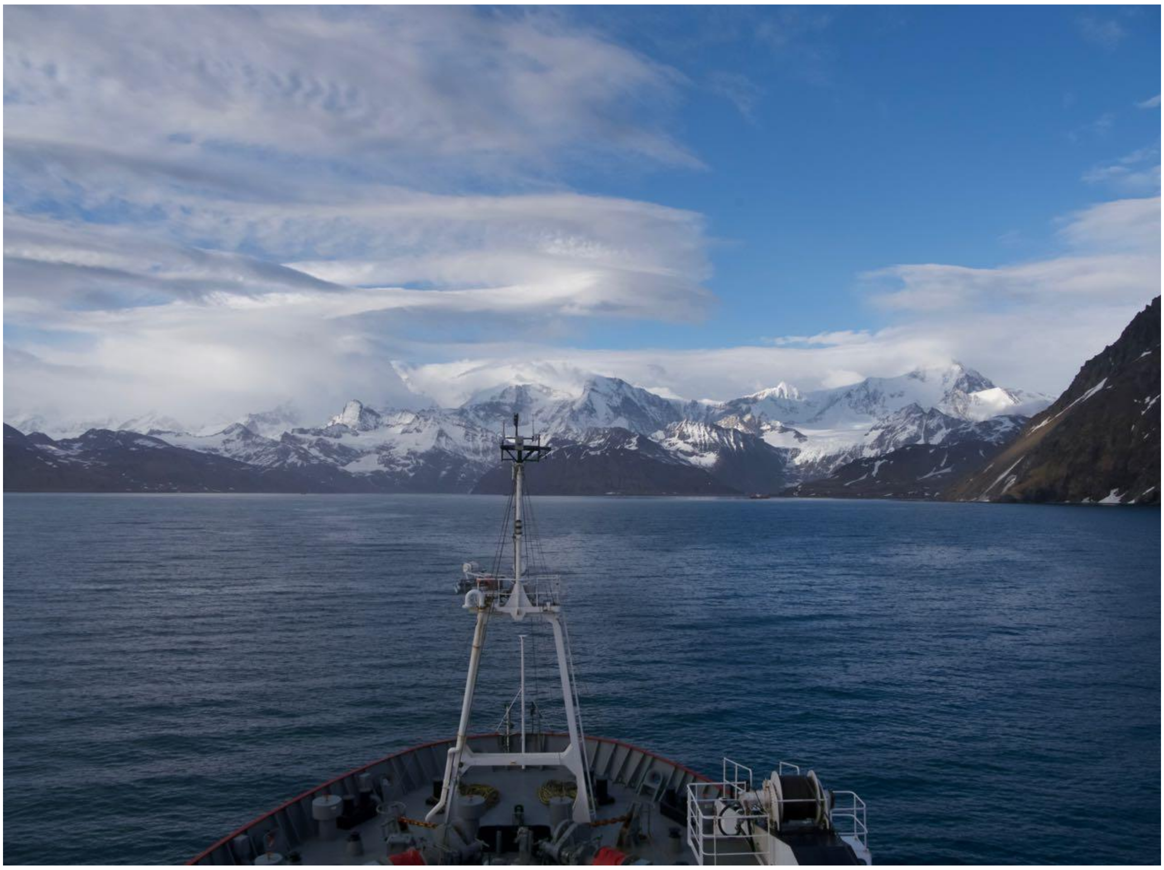
FRM4SST Project

ISFRN Workshop Book of Abstracts



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INTRODUCTION

The FRM4SST project is funded by the European Space Agency (ESA) and, through various activities, aims to sustain and evolve the International Sea Surface Temperature (SST) Fiducial Reference Measurement (FRM) Network (ISFRN). One way that this aim is fulfilled is through the annual ISFRN Workshop, which aims to bring together scientific and operational users and producers of *in situ* radiometer SST data to review progress, achievements and developments within the radiometer community. The meeting this year is held in-person and online, and is open to anyone actively involved and interested in SST science, satellite validation and the uses of *in situ* radiometer measurements.

The objectives for the FRM4SST project are:

- OBJ-1: Deploy and maintain shipborne thermal infrared (TIR) FRM radiometers and necessary supporting instrumentation to validate satellite SST products.
- OBJ-2: Maintain FRM protocols for satellite SST measurements and uncertainty budgets.
- OBJ-3: Process, quality control, archive and deliver approved FRM4SST data sets following documented FRM procedures and approve their use for FRM satellite validation.
- OBJ-4: Validate satellite SST products to FRM standards and publish monthly results.
- OBJ-5: Promote the FRM4SST outputs and maintain the International SST FRM Radiometer Network (ISFRN).

This report contains abstracts from the talks at the 2026 ISFRN Workshop.

1. SESSION 1: THE ISFRN NETWORK

1.1 Status of the ISFRN and the ships4sst data archive

Speaker: Dr Werenfrid Wimmer

Institute name: University of Southampton

Email address: w.wimmer@soton.ac.uk

Abstract

W. Wimmer[1], T. Nightingale[2], J. Høyer[3], H. Kelliher[4], R. Wilson[4], J-F. Piolle[5], C. Donlon[6]

[1]University of Southampton , [2]RAL Space, [3]DMI, [4]Space ConneXions, [5]Ifremer, [6]ESA

The International Shipborne Fiducial reference Radiometer Network (ISFRN) represents the shipborne infrared radiometer operators and data users around the world. Its aim is to maintain and deploy Infrared Radiometers of fiducial reference measurement (FRM) quality which are necessary to validate Sentinel-3 SLSTR SST products. Furthermore, all data are processed, archived, formatted and quality controlled following documented FRM procedures and protocols.

We will give an update of the current status of the ISFRN, the data providers and the users. Furthermore, we explore some the central archive (hosted by IFREMER), which due to the common data format, allows common tools to be used for the data exploitation. Examples of the data usage will be demonstrated, however the main use of the ships4sst data is for the SLSTR validation, which is shown in separate talk.

2. SESSION 2: EXPERIENCES OF RADIOMETER OPERATORS

2.1 ISAR UK

Speaker: Dr Werenfrid Wimmer

Institute name: University of Southampton

Email address: w.wimmer@soton.ac.uk

Abstract:

W. Wimmer[1], I. Robinson[1], R. Holmes[1], J.Marin[1], G. Fisher[1], C. Donlon[2]

[1]University of Southampton , [2]ESA

The Infrared Sea surface temperature Autonomous Radiometer (ISAR) is a self-calibrating instrument capable of measuring in situ sea surface skin temperature (SSTskin) to an accuracy of better than 0.1 K. The ISAR instrument has been developed for satellite SST validation and other scientific programs. The ISAR can be deployed continuously on ships of opportunity without any service requirement or operator intervention for periods of up to 3 months. The ISAR instrument is a single channel radiometer with a spectral band pass of 9.6 µm – 11.5µm to be adapted for autonomous use. The entire instrument infrared optical path is calibrated by viewing two blackbody reference cavities at different temperatures in order to maintain high accuracy while tolerating moderate contamination of optical components by salt deposition. During bad weather, an innovative storm shutter, triggered by a sensitive optical rain gauge, automatically seals the instrument from the external environment. Data are presented that verify the instrument calibration and functionality in such situations. A watchdog timer and auto-reboot function support automatic data logging recovery in case of power outage typically encountered on ships.

The University of Southampton ISARs have completed nearly 100 deployment over the last 25 years used for validating the Advanced Along Track Scanning Radiometer (AATSR) on Enivsat, the Sea Land Surface Temperature Radiometer on Sentinel 3 and the AVHRR on Metop and NOAA satellites. Examples of the deployments and experience will be shown together with lessons learned and the improvements made to ISAR over the years.

2.2 Update on the deployments of the Marine-Atmospheric Emitted Radiance Interferometers (M-AERIs)

Speaker: Dr Peter J Minnett

Institute name: Rosenstiel School of Marine, Atmospheric and Earth Science, University of Miami

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Abstract

Peter J Minnett, Miguel Angel Izaguirre, and Goshka Szczodrak

Prior to the COVID-19 pandemic we had three Marine-Atmospheric Emitted Radiance Interferometers (M-AERIs) installed on cruise ships of the Royal Caribbean Group and one on the NOAA Ship *Ronald H Brown*. The ships were idled while travel restrictions were imposed but once these were lifted, we began the refurbishment of the instruments and reinstallation on the ships. At present, we have one system on *Celebrity Equinox*; data transmissions restarted on August 19, 2023. On March 31, 2024, we completed the installation on the R/V *Neil Armstrong* of the Woods Hole Oceanographic Institution and the M-AERI took measurements for a period of one year. All the M-AERI data processed to SSTskin and near-surface air temperature are available. The presentation will give an update on our situation with an outlook on the future.

2.3 Modulation of the Ocean Surface Skin Temperature and Heat Flux in the Presence of Strong SST Fronts

Speaker: Dr Andy Jessup

Institute name: Applied Physics Laboratory, University of Washington, Seattle, WA

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Abstract

This talk examines direct sea surface temperature (SST) measurements of the skin (SSTskin) and near-surface SST (SSTdepth), and wind speeds measured during the Sub-Mesoscale Ocean Dynamics Experiment (S-MODE) along with derived bulk fluxes. We evaluate the modulation of the net heat flux, wind speed, and skin cooling across SST fronts and the ability of the COARE bulk flux algorithm to reproduce this variability. Bulk flux computations can be performed directly from a radiometric SSTskin, or more commonly, from the SSTdepth provided that the depth of the SST measurement is corrected for cool skin and diurnal warming effects. Both types of SST were measured during S-MODE allowing for 1) an assessment of the importance of having a SSTskin for a direct flux evaluation in frontal regions, and 2) an evaluation of the accuracy of the cool skin corrections within COARE for the indirect bulk flux computation. Testing of the COARE algorithm suggested that indirect bulk fluxes had sufficient accuracy to close the heat budget over the front.

3. SESSION 3: ENSURING HIGH-ACCURACY MEASUREMENTS

3.1 ASTeRN: A Next Generation In-Situ Radiometer

Speaker: Dr Dave Smith

Institute name: STFC, UK

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Abstract

SST validation is supported by a number of autonomous self-calibrating ship-borne radiometers deployed by a number of institutes. The current UK in situ radiometer designs (ISAR, SISTeR) are now 20+ years old. Hence, a new generation of radiometers are required to enhance and maintain capability for next decade.

The Advanced Surface Temperature Radiometer Network (ASTeRN) is a project to design and manufacture radiometers with the capability for measuring sea, land and ice surface temperatures with high accuracy and precision. The radiometers will be an evolution of existing designs with the same basic measurement approach as existing instruments but drawing on lessons learned and incorporating modern components. The design includes: additional spectral channels for atmospheric characterisation, extended capability for measuring Land Surface Temperatures, address obsolescence issues, and to improve manufacturability and maintainability. We present the status of the radiometer development and plans for deployment.

3.2 An update on the FRM buoys of The TRUSTED Project

Speaker: Dr Marc Lucas

Institute name: CLS

Email address: mlucas@groupcls.com

Abstract

The Copernicus TRUSTED project aims to provide high quality sea surface temperature data in order to help improve the calibration and validation of the sentinel 3 radiometers. It is articulated around 4 pillars, namely hardware, Procedures, Data Management and Documentation to ensure that each data point collected can be classified as a Fiducial Reference Measurement.

In this presentation, we will look at the maturity level of each of these pillars and how this breakdown translates into the project activities such as calibration, deployment and data collection. We will also look at current and forthcoming activities for Ice Surface Temperature retrieval that have recently been included within the project objectives.

4. SESSION 4: SST DATA IN PRACTICE

4.1 Sea surface temperature measurements are now needed for climate quality ocean carbon assessments to support the UN G3W, and the aims of CEOS and the IPCC

Speaker: Prof Jamie Shutler

Institute name: University of Exeter

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Abstract

The ocean is one of two observational constraints within the global carbon assessments used to guide policy on the emission reductions that are urgently needed to stabilise our climate. Within these observation-based ocean sink estimates, sea surface temperature is a strong controller of ocean carbon concentrations and its exchange with the atmosphere. This talk will discuss recent developments around these issues, which includes how the wider carbon community have now begun to embrace the need for precise temperature measurements and handling. The talk will also demonstrate how the impact of seemingly small differences in sea surface temperature can ripple through the global carbon assessments used to guide policy. This will show that fiducial measurements are now needed to support ocean and global carbon assessments; something the ocean community are now calling for. The talk will show examples of our first attempts for collecting relevant near-fiducial measurements for all key carbon parameters which includes temperature, and how these can be used to support the development of an ocean carbon climate data record that is in development.

4.2 In Situ Observations from the PIRATA Program in the Tropical Atlantic Used to Estimate Air–Sea Heat Fluxes with COARE 3.6 and ERA5

Speaker: Dr. Ronald Buss de Souza

Institute name: National Institute for Space Research (INPE), Brazil

Email address: ronald.buss@inpe.br

Abstract: L. Stachelski[1], R. B. de Souza[1], G. Fisch[2], R. Moura[1], L. Pezzi[1], B. T. Steffen[1] [1] National Institute for Space Research, [2] University of Taubaté

The exchanges of sensible (*Hs*) and latent (*Hl*) heat between the ocean and the atmosphere in the tropical region are essential for controlling cloud formation, the ocean–atmosphere–continent moisture transport, and the warming or cooling of the atmosphere. In this study, we focus on a targeted comparison between ERA5 and COARE 3.6 in representing air–sea turbulent heat fluxes at the PIRATA moorings across the Tropical Atlantic Ocean (TAO) using monthly time series (1997–2023). ERA5 is treated as a widely used, globally consistent reanalysis product that provides gridded surface fluxes derived from the ECMWF surface-layer framework. In contrast, COARE 3.6 is adopted here as the reference against which ERA5 is evaluated, because it is a state-of-the-art bulk algorithm specifically designed and extensively validated for tropical open-ocean conditions and, in this application, it is computed offline using the in situ meteorological and oceanic variables measured directly at the buoys (e.g., near-surface wind, air temperature and humidity, and SST).

Overall, ERA5 reproduces the dominant seasonal phasing of *Hs* and *Hl* linked to trade-wind modulation and the seasonal migration of the ITCZ, indicating that the reanalysis captures much of the large-scale forcing controlling air–sea exchange in the TAO. However, relative to the COARE 3.6 reference, ERA5 exhibits systematic magnitude differences, which are more pronounced for *Hl* than for *Hs*. In particular, ERA5 commonly shows a tendency toward stronger latent heat loss (enhanced evaporative cooling) at several buoy sites, even when the temporal variability remains well correlated with COARE 3.6. This behaviour is consistent with the fact that, in tropical regimes, *Hl* is highly sensitive to near-surface humidity gradients, stability-dependent transfer coefficients, and the effective wind used by the bulk formulation elements that differ between a gridded reanalysis framework and a buoy-forced bulk algorithm optimized for marine boundary-layer conditions. These results underscore that, while ERA5 is highly valuable for diagnosing regional-to-basin-scale variability, biases in turbulent flux magnitude, especially *Hl*, remain climatologically meaningful when evaluated against a physically grounded, buoy-forced reference such as COARE 3.6 at TAO moorings.

4.3 Coastal Monitoring Service from Copernicus LAC Chile for Latin America and the Caribbean

Speaker: Lucas Amézquita Toledo

Institute name: Copernicus LAC–Chile

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Abstract:

The Copernicus Regional Hub for Latin America and the Caribbean (Copernicus LAC–Chile) is developing a Coastal Monitoring Service aimed at regional needs. This initiative integrates satellite observations from multiple sensors with available in-situ measurements to improve the monitoring of coastal ocean variability and support the development of regional SST Climate Data Records.

In this presentation we describe the processing workflow used to generate regional SST products, including quality control of night-time infrared observations, multi-sensor compositing, and the construction of daily and monthly datasets following the GHRSST data standards. Particular emphasis is placed on the use of in-situ measurements from drifting buoys and other observing systems for validation and bias assessment of the satellite-derived SST fields.

The resulting datasets contribute to strengthening regional climate monitoring capabilities and provide a foundation for the development of consistent SST Climate Data Records in the LAC region.

This work highlights the importance of expanding in-situ observations in the Southern Hemisphere and demonstrates how regional services can complement global SST initiatives by bridging *the gap between satellite observations, validation datasets, and operational coastal applications.'*

DAY 2 – INTRODUCTION TO CIMR-AIR

CIMR-Air Instrument Status and Capabilities

Speaker: Martin Suess

Institute name: ESA

Email address: martin.suess@esa.it

Abstract:

Martin Suess(1), Craig Donlon(1), Juha Kainulainen(2), Tapio Saarinen(2), Josu Uusitalo(2), Tommi Häkkilä(2), Taylan Yesilurt(2), Janne Lahtinen(2), Juha Lemmetyinen(3), Kimmo Rautiainen(3), Marko Mäkynen(3), Patrik Ahola(3), René Forsberg(4)

(1) European Space Agency, (2) Harp Technologies Oy, (3) Finnish Meteorological Institute, (4) Technical University of Denmark

The Copernicus Imaging Microwave Radiometer (CIMR) mission of the European Space Agency will deploy two identical satellites, scheduled for launch in 2029 and 2035, to provide long-term passive microwave observations of key oceanic and terrestrial geophysical variables. Operating across L-, C-, X-, K-, and Ka-bands, the mission delivers high-resolution data products—including sea surface temperature, sea ice concentration, sea surface salinity, soil moisture, and snow water equivalent—to support climate and environmental monitoring. To complement and validate the satellite mission, ESA initiated the development of the airborne CIMR-AIR system in 2023, led by Harp Technologies. CIMR-AIR replicates the essential radiometric characteristics of the spaceborne instrument and is designed for field campaigns aimed at algorithm development as well as calibration and validation activities

The CIMR-AIR system comprises five fully polarimetric radiometers, visual and thermal infrared cameras, an infrared sky thermometer, autonomous attitude and heading reference instrumentation, and an operator display unit. Its radiometers achieve footprint sizes from approximately 1.2 km (L-band) to below 200 m (Ka-band) at 1 km altitude, with full Stokes vector measurements and channel-dependent sensitivities and sampling characteristics. The system is installed as a side-looking payload on aircraft such as the Twin Otter, with adjustable mechanics ensuring correct observation geometry during various flight maneuvers. Key design features include high-efficiency custom antennas extending outside the aircraft fuselage, comprehensive thermal stabilization, noise-injection radiometer architecture for stability, digital backends with RFI detection, and internal calibration references.

MAIN CHARACTERISTICS OF CIMR-AIR RADIOMETERS

Parameter	**Unit**	**Channel**				
		L-band	**C-band**	**X-band**	**K-band**	**Ka-band**
Centre freq.	GHz	1.425	6.875	10.65	18.7	36.5
Bandwidth	MHz	50	400	100	200	300
Footprint size (1 km altitude)	m	1220	445	445	195	194
Observation zenith angle	°	55				
Polarization	Full Stokes vector					
Total Standard Uncertainty (requirement)	K	0.5	0.5	0.5	0.6	0.8
L1A data sampling (nominal)	ms	500	200	200	100	100
L1B footprint dwell time	s	11.4	4.5	4.5	2.0	2.0
L1B NEDT	K	0.08	0.04	0.07	0.28	0.16

Data processing is conducted using the FMI-developed L1&L2 Processor, which converts raw measurements into L1A engineering data, georeferenced L1B Stokes vectors, and L2 estimates of sea ice concentration and sea surface temperature. All products are provided in netCDF format. As of late 2025, system integration is nearing completion, with the first flight campaign planned for 2026.

The CIMR-AIR instrument is currently under integration and testing. The presentation will give an overview of the CIMR-AIR instrument and its capabilities, present the current status and the planned flight testing.

5. SESSION 5: EXPERIENCES OF RADIOMETER OPERATORS

5.1 ISAR Korea : Recent ISAR Observations of Skin–Bulk Temperature Differences in the Seas around the Korean Peninsula and in the Northwest Pacific (2024–2025)

Speaker: Prof Kyung-Ae Park

Institute name: Department of Earth Science Education, Seoul National University, Korea

Email address: kapark@snu.ac.kr

Abstract: **Kyung-Ae Park**[1], **Ji-Won Kang**[2], **Hee-Yong Kim**[1], **Hye-Jin Woo**[1]

[1]*Department of Earth Science Education, Seoul National University, Korea*

[2]*Department of Science Education, Seoul National University, Korea*

This study presents a comprehensive analysis of sea surface skin temperature (skin SST) observations obtained since 2018 using an Infrared Sea Surface Temperature Autonomous Radiometer (ISAR) installed aboard the research vessel ISABU, covering the waters surrounding the Korean Peninsula as well as the Indian Ocean and the Northwest Pacific. Particular emphasis is placed on intensive observations conducted during the summers and autumns of 2024 and 2025, when sea surface temperatures were anomalously high. These observations focus on the coastal waters of the Korean Peninsula, the Kuroshio region, and the Northwest Pacific between 10°N and 30°N. To quantify the characteristics of skin–bulk SST differences, ISAR-derived skin SST measurements are compared with bulk SST observations obtained from a shipborne thermosalinograph (TSG). The results demonstrate that the temperature differences between ISAR skin SST and bulk SST reproduce the well-known diurnal variability reported in previous studies. In addition, comparisons with satellite-derived SST products from GK-2A are presented to assess the consistency, strengths, and limitations of satellite SST estimates under various oceanic and atmospheric conditions. Future work will continue ISAR observations in accordance with the operational schedule of the research vessel ISABU, with the aim of building a long-term, high-quality in situ dataset to support studies of extreme high sea surface temperature events and air–sea interactions.

5.2 Bridging In-Situ FRM Observations and Copernicus Coastal SST Data Products

Speaker: Dr Guisella Gacitua

Institute name: DMI

Email address: gga@dmi.dk

Abstract

Guisella Gacitúa, Alexander Hayward, Jacob Høyer

The Danish Meteorological Institute contributes to the FRM4SST initiative, providing traceable Fiducial Reference Measurements (FRM) of Sea Surface Temperature (SST) for satellite validation. High-accuracy observations from Infrared Sea Surface Autonomous Radiometers (ISARs) onboard the ferry *Norröna* have been collected since 2016 along the route between Denmark, Norway, the Faroe Islands, and Iceland, covering both open-ocean and coastal environments in the North Sea, Nordic Seas and Arctic regions.

Within the EU Horizon Europe project FOCCUS, efforts are underway to integrate ISAR FRM observations into coastal validation and data assimilation workflows to enhance Copernicus Marine coastal services. Preliminary analysis compares the 2016–2025 FRM dataset with the multi-sensor SST Climate Data Record from the ESA Climate Change Initiative as a function of distance from the coast. Results quantify coastal bias, error variance, and critical nearshore distances where satellite performance declines, and evaluate SST CCI uncertainty representation.

This analysis demonstrates how FRM observations can support bias correction, uncertainty characterization, and optimised assimilation, ultimately enhancing coastal SST products for forecasting and climate applications.

5.3 SISTeR

Speaker: Dr Tim Nightingale

Institute name: STFC, UK

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Abstract

The SISTeR (Scanning Infrared SST Radiometer) is a chopped, autonomous, self-calibrating infrared filter radiometer that can measure IR brightness temperatures to high accuracy (~30mK). It is split into three compartments, the inner being the calibration enclosure which hosts two blackbodies and a rotating scan mirror. SISTeR measures the upwelling radiance from the sea surface and corrects for the reflected sky component with measurements of the downwelling sky radiance. The blackbody thermometer calibrations are traceable to ITS-90. SISTeR generates level 0 data and a dedicated processor unpacks this data.

SISTeR was first deployed in 1997 and since 2010 has been deployed on the Cunard Queen Mary 2 (QM2) liner where it is mounted on a dedicated platform above the starboard bridge wing.

The usual routes are sailings between Southampton and New York with additional Caribbean, Canadian and European trips, and historical data have included an annual world cruise.

6. SESSION 6: SST DATA IN PRACTICE

6.1 From Radiometric Intercomparison to Skin SST Retrieval: Algorithm Development Using INSAT- 3DR andMeteosat-8 TIR Observations

Speaker: Swadhin Satapathy

Institute name: Swadhin Satapathy, National Institute of Science Education and Research, Bhubaneswar, India

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Abstract:

Accurate skin-SST retrieval with high temporal resolution from satellites presents a persistent challenge in remote sensing inversion, which is often neglected due to the inherent limitations in in-situ observations and with many algorithms prioritizing bulk SST. By leveraging the continuous monitoring capability of the geostationary satellites, we developed a robust methodology for skin-SST retrieval using observations from INSAT-3DR and Meteosat-8. To ensure the quality of the input observations in the retrieval framework, we performed a detailed intercomparison of the Brightness Temperatures (BTs) of the thermal infrared window channels using more than 1.5 billion collocated clear-sky observations over the Bay of Bengal. We found that INSAT-3DR observations are 1.21 K (at 10.8 μm) and 0.83 K (at 12 μm) warmer than the Meteosat-8 observations, with corresponding mean model BT differences of 0.96 K and 0.84 K, respectively. A sensitivity test linked these systematic differences to viewing geometry and atmospheric total column water vapor. We applied a bias-correction scheme, significantly improving the consistency of observations and bringing mean observation-minus-model (O-M) differences to zero, thus preparing high-quality inputs for the inversion process. We address this inverse problem by integrating prior knowledge from a large ensemble of 11 years of ERA5 cloud-free atmospheric and surface datasets and using the RTTOV radiative transfer model to generate an extensive lookup table (LUT), mapping the physical states to the corresponding simulated BTs. We then implemented a Bayesian 1D-Var framework and developed a machine learning (ML) model utilizing the LUT to learn complex patterns for improved retrieval. We obtained a correlation of 0.99 with an RMSE of 0.23 in the algorithm training and testing phase, which shows the robustness of the ML model. By successfully leveraging a physically constrained dataset, our method significantly advances the accuracy of skin-SST retrieval, enabling improved monitoring of the ocean from geostationary platforms.

6.2 Usage of ISAR for very high-resolution coastal SST validation

Speaker: Jean-François Piollé

Institute name: Ifremer

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Abstract:

Existing (Landsat-9, ECOSTRESS) and upcoming (TRISHNA, LSTM, SBG) very high resolution thermal infrared missions provide unprecedented view of sea surface temperature dynamics in coastal and estuarine regions but come with serious challenges for the validation of the sea surface temperature : their narrower swath (compared to current operational missions), lower revisiting time and acquisition mask restricted to near-shore areas, where in situ measurements are scarce, result in a limited amount of available observations for the validation when using traditional in situ platforms like drifters or moored buoys. In situ radiometers onboard ferrylines or research vessels can, on the opposite, balance lower temporal coverage with several continuous measurements over a single satellite pass, providing also in addition to absolute SST value information on the gradients and dynamics. Ifremer has a acquired an ISAR that will complement the existing ISFRN network and the other various in situ systems used for the cal/val of the mentioned upcoming missions. Assessment of the complementarities between the available reference measurement sources will be presented in this talk.

7. SESSION 7: RADIOMETER PERFORMANCE AND UNCERTAINTIES

7.1 TIRCALNet – Top of Atmosphere Thermal Infrared Vicarious Calibration Network

Speaker: Steffen Dransfeld, Aimé Meygret

Institute name: ESA, CNES

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Abstract:
The coming years will see an increase in the development and preparation for higher spatial resolution thermal imaging missions. While the sector for high resolution optical visible imagery has been a large focus of space agencies and many commercial players around the world, thermal imagery at high resolution is still lagging behind largely due to the increased complexity of instrumentation required. CNES, NASA and ESA with the TRISHNA, SBG and LSTM missions aim to launch in the current decade thermal imaging missions of 50 - 60m spatial resolution to address this current gap and various commercial enterprises are emerging with their own plans of operation HR thermal imaging missions. This increase of thermal missions provides an unprecedented opportunity to monitor frequently and at high detail at global level the thermal status of our planet. It is thus becoming essential to ensure data intercomparability to allow understanding of measurement biases that may affect one mission with respect to the others. Independent anchoring points on ground are a means to provide a reference measurement that can be propagated to the top of atmosphere allowing satellite operators to compare it to what their satellite instrument measures and thus to reveal any biases of the satellite measurement. For high resolution visible optical sensors such on-ground measurements are provided by the RadCalNet initiative consisting of a network of ground-instrumented sites that provide ground-based reflectance measurements propagated to Top of Atmosphere spectrally resolved reflectances. This network has had an enormous impact in terms of providing satellite operators with an independent reference framework that allows to calibrate at ToA their various satellite instruments and also intercompare them to each other, an essential pre-cursor to any application making use of combined and fused data from more than one mission.

Such a network providing ToA reference measurements does not yet exist for TIR (Thermal InfraRed) missions and based on the RadcalNet experience it would provide key data to allow intercalibration and harmonization of thermal data across missions and hence their combined synergistic exploitation.

Providing accurate ToA TIR signals is even more challenging than for reflectances in the visible domain since thermal behavior of the ground is impacted by significantly varying emissivity and actual surface temperature. Moreover, the composition of the atmospheric column over the site affects the ToA signal. BoA and atmospheric parameters need to be precisely known inclusive of their related measurement uncertainties to provide a ToA derived signal that can be of effective use. Ideally the uncertainty of the derived ToA Brightness Temperature provided by such a network should not surpass 0.5 K. This is a hugely challenging task and currently only provided by sites of stable and homogeneous emissivity and temperature as well as with known atmospheric profiles typically present in aquatic environments. While these sites are providing key measurements for the radiometric assessment and also calibration of ToA TIR sensors there is a need to be providing these measurements for other surfaces corresponding more to the extremes of the calibration range to cover the dynamic range of the satellite instruments. This presentation will introduce the current studies that are being done to build such a network and provide a plan towards a roadmap to an operational network status.

7.2 Radiometer uncertainty models

Speaker: Dr Werenfrid Wimmer

Institute name: University of Southampton

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Abstract

When reporting the result of a measurement of a physical quantity, it is obligatory that some quantitative indication of the quality of the result be given so that those who use it can assess its reliability. Such an indication of quality is essential for any measurement but especially for Fiducial Reference Measurements (FRM) to comply with metrological and QA4EO standards.

To show how and uncertainty model can be derived for self-calibrating infrared radiometers the example of the Infrared Sea surface temperature Autonomous Radiometer (ISAR) uncertainty model will be shown. To develop the ISAR uncertainty model all the sources of uncertainty in the instrument are analysed and an uncertainty value is assigned to each component. Finally, the individual uncertainty components are propagated through the ISAR Sea Surface Temperature skin (SSTskin) retrieval algorithm to estimate a total uncertainty for each measurement. The resulting ISAR uncertainty model applied to a 20-year archive of SSTskin measurements from the Bay of Biscay shows that 77.6 % of the data are expected to be within ± 0.1 K and a further 17.2 % are within 0.2 K.

8. SESSION 8: VALIDATION OF SATELLITE SST AND IN SITU SST MEASUREMENTS

8.1 Sentinel-3 SLSTR SST Validation using Fiducial Reference Measurements (FRM).

Speaker: Dr Werenfrid Wimmer

Institute name: University of Southampton

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Abstract

W. Wimmer[1], T. Nightingale[2], J. Høyer[3], H. Kelliher[4], R. Wilson[4], J-F. Piolle[5], C. Donlon[6]
[1]University of Southampton , [2]RAL Space, [3]DMI, [4]Space ConneXions, [5]Ifremer, [6]ESA

ESA is building on over 20 years of continuous Fiducial Reference Measurements (FRM) from UK-funded shipborne radiometers by establishing a service to provide historic and ongoing FRM measurements to the wider sea surface temperature (SST) community through an International SST FRM Radiometer Network (ships4sst). The ships4sst is open for partners around the world, currently compromising of partners from the UK (University of Southampton, Rutherford Appleton Laboratory, Space ConneXions), Denmark (Danish Meteorological Institute) and France (Ifremer) and not only collects shipborne radiometer data but also uses the data to validate satellite SST products.

Ships4sst not only provides FRM SST measurements, put also includes a long term data archive of the FRM datasets at Ifremer where the data are stored in the ships4sst netCDF L2R format. Furthermore, a validation service based on the ESA felyx match-up database (MDB) hosted at EUMETSAT is provided. The ships4sst data is freely available to anyone, as are the validation results. At ships4sst we organise and participate in regular inter-comparisons at the National Physics Laboratory (NPL) in the UK and the National Institute of Standards and Technology (NIST) in the USA, to ensure not only the SI (International System of Units) traceability of our remeasurements but also the validity of the per SST value uncertainties.

To demonstrate the value of the FRM SST, we will first show some examples of the ships4sst data around the world and second show the most recent validation results from SLSTR A and B from the ships4sst network regions. This will not only demonstrate that SLSTR A and B are preforming to specification and at least as well as their predecessor AATSR, but also show a potential route for SI-traceability for SLSTR SST measurements.

8.2 Comparison (of shipborne radiometers) with other in situ measurements

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Abstract

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Accurate long-term measurements of ocean temperatures are required to understand key physical processes at the ocean-atmosphere interface and any changes that may occur to these processes over time. The first Copernicus Sentinel-3A Sea and Land Surface Temperature Radiometer (SLSTR-A) was launched on 16th February 2016. SLSTR-A is a multi-spectral dual-view radiometer with two on-board blackbodies and cooled detectors ensuring accurate radiometric measurements. SLSTR-A was joined in orbit by its twin, SLSTR-B, on 25th April 2018. SLSTR-A SST products were released operationally from the EUMETSAT marine centre on 5th July 2017 and SLSTR-B products were released operationally on 12th March 2019.

SLSTR provides high-quality dual-view SSTs that are used as a reference sensor in several operational systems. In this presentation we summarise how SLSTR SSTskin measurements are validated using a range of in situ measurements at various depths including Fiducial Reference Measurements (FRM) from shipborne IR radiometers and recently deployed Copernicus drifting buoys. We describe the validation process as well as the concept of a validation space and show that the combination of in situ measurement and FRM provides high confidence in the quality of all datasets, as well as models of the skin-layer and diurnal variability required to adjust the temperature measurement from various depths.

9. ACRONYMS AND ABBREVIATIONS

AATSR	Advanced Along-Track Scanning Radiometer
ASTeRN	The Advanced Surface Temperature Radiometer Network
ATSR	Along-Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BB	Blackbody
CDR	Climate Data Record
CCI	Climate Change Initiative
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DMI	Danish Meteorological Institute
DTU	Danish Technical University
ECV	Essential Climate Variable
EDS	Engineering Data System
EGSE	Electrical Ground Support Equipment
EO	Earth Observation
ESA	European Space Agency
ESL	Expert Support Laboratory
ESOC	European Space Operations Centre
EU	European Union
FPA	Focal Plane Assembly
FRM	Fiducial Reference Measurements
FRM4STS	Fiducial Reference Measurements for validation of Surface Temperature from Satellites
FTP	File Transfer Protocol
GHRSST	Group for High Resolution SST
GTMBA	Global Tropical Moored Buoy Array
HTTP	HyperText Transfer Protocol
IPCC	Intergovernmental Panel on Climate Change
IR	Infra-Red

ISAR	Infrared SST Autonomous Radiometer
ISFRN	International SST FRM Radiometer Network
ISSI	International Space Science Institute
KIT	Karlsruhe Institute of Technology
L0	Level 0
L1	Level 1
L2	Level 2
LST	Land Surface Temperature
M-AERI	Marine-Atmospheric Emitted Radiance Interferometer
MODIS	Moderate Resolution Imaging Spectroradiometer
NOCS	National Oceanography Centre, Southampton
OP	Operational Processor
RAL	Rutherford Appleton Laboratory
RP	Reference Processor
RSD	Robust Standard Deviation
SCL	Space ConneXions Limited
SISTeR	Scanning Infrared Sea surface Temperature Radiometer
SLSTR	Sea and Land Surface Temperature Radiometer
SST	Sea Surface Temperature
ST	Surface Temperature
STFC	Science and Technology Facilities Council
TIR	Thermal Infra-Red