25th International SST Users' Symposium and GHRSST Science Team Meeting (GHRSST25)

25th International SST Users' Symposium and GHRSST Science Team Meeting

# Book of Abstracts

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The Group for High Resolution Sea Surface Temperature (GHRSST) is an open international science group that promotes the application of satellites for monitoring sea surface temperature (SST).
The 25th International SST Users' Symposium and GHRSST Science Team Meeting (GHRSST25) will take place in Montreal, Canada and online from June 10th to 14th, 2024.
The event is co-hosted by the Environment and Climate Change Canada and the Université du Québec à Montréal (UQAM) and organised in collaboration with the GHRSST Project Office, located at the Danish Meteorological Institute.

The GHRSST Project Office is funded by the European Union Copernicus Programme and is hosted by the Danish Meteorological Institute, Sankt Kjelds Plads 11, 2100 Copenhagen, Denmark.

# Aim of the Symposium

The primary objective of this symposium is to foster discussion and collaboration among experts in the field and promote the utilization of satellite sea-surface temperature (#SST) data products for oceanographic research and applications.

# Target Audience

Researchers, scientists, students, and practitioners working with satellite sea-surface temperature, SST users, SST producers.

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The GHRSST Project Office is funded by the European Union Copernicus Programme and is hosted by the Danish Meteorological Institute, Sankt Kjelds Plads 11, 2100 Copenhagen, Denmark

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# Science Session S1 – Coupled Data Assimilation

Coupled ocean-ice-atmosphere models have been largely used for the Numerical Weather Prediction (NWP) and ocean forecast for many years already. They have demonstrated a significant improvement in the forecast quality with respect to uncoupled systems. However, coupled models often get initialised by distinct uncoupled data assimilation systems for the ocean and ice and for the atmosphere, that leads to initialization shocks and thus, suboptimal performance. Hence, the analyses produced within coupled ocean-ice-atmosphere data assimilation systems may be beneficial for an accurate initialization of the coupled forecasts. Most NWP centers are already developing coupled data assimilation systems for NWP or reanalyses. This session is open to presentations related to the actual progress in coupled data assimilation, with emphasis on the coupling between atmosphere, ocean, and ice. Presentations on a wide range of topics, from observation operators for SST and ice, direct assimilation of L1 satellite data, status of the operational systems and applications are welcomed.
The session will focus on the following:

- Advances and challenges in coupled data assimilation systems for operational applications or reanalyses
- Applications of direct data assimilation
- Research on observation operators for SST and ice

**Keywords:** coupled data assimilation, direct assimilation, observation operators

# Abstracts: Science Session 1 – Coupled Data Assimilation

## 4-S1: Flux to Flow: A Clearer View of Earth's Water Cycle via Neural Networks and Satellite Data

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**Abstract**

Water continuously cycles throughout the land, ocean, and atmosphere. Accordingly, it is important for hydrological analyses to consider water as it moves throughout the entire hydrosphere, and not just a single facet of the process. We use neural networks as a device to transform geospatial observations of water quantity and quality into forecasts of ground truth streamflow measurements. Two very large transboundary basins, the Columbia River and Yukon River, are subjects of this investigation. We first describe the basins. Then we create two datasets for each basin: one with coupled surface flow, subsurface flow, and sea surface temperature of the basin adjacent oceans; and another with simply the surface and subsurface flow land measurements constrained to the definitive boundaries of the delineated watershed. Finally, we load these datasets into Flux to Flow (F2F), our neural network test platform. Our results indicate that, even with the smallest neural network we try (four neurons only), use of sea surface temperature greatly improves forecasting of monthly streamflow from up to two years lag between the input images and the output gauged streamflow measurements. We see the future use of the F2F pattern having more output targets and likely requiring multiple compute nodes to scale the work. We discuss and identify drought monitoring as a suitable next step. We believe this work has only scratched the surface regarding the integration of land and ocean parameter datasets to fields devoid of non-numerical observations.

## 15-S1: Using skin temperature increments from microwave observations in a coupled atmosphere-ocean model

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**Abstract**

ECMWF plans to move to a coupled atmosphere-ocean system in the near future, as the accuracy of the surface temperature of the ocean is critical for ensuring high quality forecasts. This presentation will summarise work to fully exploit information on the ocean surface temperature available from passive microwave imagers directly in a coupled atmosphere-ocean system.

The new RADSST method allows the incremental update of the SST using skin temperature increments derived in the atmospheric 4DVar using a sink variable approach. The utility of this method has already been demonstrated for IR clear-sky radiances. Here, we investigate its application to microwave radiances processed under all-sky conditions, which allows a greater temporal and spatial coverage than IR.

This microwave-based SST derivation benefits from the inclusion of lower frequency microwave channels around 6 and 10 GHz. Work has been ongoing to ensure the inclusion of these lower frequency channels provides the best available information, requiring the implementation of coastal, sun glint and RFI screening.

The skin temperature increments generated from these microwave imagers help to account for known deficiencies in the background skin temperature used within the ECMWF-IFS without compromising the atmospheric analysis. Furthermore, inclusion of these in the coupled system result in a better fit of the ocean analysis to in-situ observations.

# 23-S1: Sea Surface Temperature products useful for Global Atmosphere-Ocean-Ice Coupled NWP at the Bureau of Meteorology

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**Preferred participation:** Online

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**Abstract**

The Australian Bureau of Meteorology (Bureau) is currently developing a global Atmosphere-Ocean-Ice Coupled Numerical Weather Prediction (NWP) system, based on the UK Met Office's global coupled NWP model.

This presentation will focus on recently developed, and future planned, high-resolution remotely sensed sea surface temperature (SST) products that have potential to benefit the Bureau's future operational Atmosphere-Ocean-Ice coupled NWP forecast systems. We will discuss how we assimilate existing SST data from polar-orbiters into the Bureau's operational ocean models. This includes Global Area Coverage (GAC) Advanced Very High-Resolution Radiometer (AVHRR) aboard MetOp-B and MetOp-C, Visible Infrared Imaging Radiometer Suite (VIIRS) aboard Suomi-NPP and NOAA-20, and Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard GCOM-W. We will also examine the potential benefits for coupled model forecasting in the future, of assimilating infrared SST from Sea and Land Surface Temperature Radiometer (SLSTR) aboard Sentinel-3A and Sentinel-3B, VIIRS onboard NOAA-21, and the Advanced Himawari imager (AHI) on Geostationary satellite Himawari-9.

# 26-S1: Global daily SST analysis at Environment and Climate Change Canada

**Submitting author/speaker (Name and Surname):** Sergey Skachko

**Preferred type of contribution:** Talk

**Preferred participation:** In-person (Montreal)

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**Abstract**

A new global daily foundation SST variational (2D-Var) analysis that aims to provide SST products for all current operational atmospheric and ocean prediction systems at Environment and Climate Change Canada (ECCC) was recently implemented within Modular and Integrated Data Assimilation System (MIDAS). The objective in developing a new SST analysis system is to replace the existing outdated SST analysis employed at ECCC with a more modern system using updated data assimilation method, background quality control and bias estimate methods as well as computationally efficient environment. As MIDAS already has atmospheric and ocean data assimilation algorithms, the general functionality of the SST analysis can be used to work on full three-dimensional ocean data assimilation using the same observations. The perspectives in using the new SST analysis within the future fully-coupled ocean-ice-atmosphere data assimilation system are also discussed.

# 27-S1: Towards Strongly Coupled Data Assimilation at Environment Canada

**Submitting author/speaker (Name and Surname):** Mark Buehner

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**Abstract**
The operational global numerical weather prediction systems at Environment and Climate Change Canada have employed fully coupled atmosphere-ocean-ice models for several years. However, the data assimilation (DA) systems for each of these Earth system components is still mostly independent of each other. To facilitate future research on the potential benefit of strongly coupled DA methods, the functionality needed for sea ice and sea surface temperature analysis has been integrated into the same software used for atmospheric DA: the Modular and Integrated Data Assimilation System (MIDAS). The current functionality of MIDAS will briefly be described, including the deterministic and ensemble DA algorithms that are implemented in a sufficiently general way to allow application to atmosphere, sea ice or ocean. These DA algorithms rely on ensemble covariances to represent short-term forecast error. Consequently, it is relatively straightforward to perform strongly coupled DA by using the coupled model to produce ensemble forecasts and then combining the DA for all Earth system components within a single procedure. In this way, the ensemble covariances used for DA include the connections between variables of the different components, for example, between sea surface temperature and either sea ice concentration or near-surface atmospheric temperature. Plans for the future development and testing of such strongly coupled DA systems will be outlined.

# 49-S1: Importance of ocean observations, including SST, in ECCC's Global Ocean Analysis: The SynObs Project

**Submitting author/speaker (Name and Surname):** Andrew Peterson

**Preferred type of contribution:** Poster

**Preferred participation:** In-person (Montreal)

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**Abstract**

The Synergistic Observing Network for Ocean Prediction (SynObs) project (https://oceanpredict.org/synobs) seeks to find synergies between ocean observations and ocean prediction through a multi-system approach to an Observing System Experiment (OSE). Best estimates and predictions of the location of eddies, ocean sound speed profiles, ocean currents and ocean water masses are important ocean diagnostics for a variety of ocean and/or coupled NWP applications. Skillful estimates of these diagnostics is presumably determined by the quantity and quality of ocean observations used in the ocean state estimation, but the exact value of the observations, and in particular, which observations are most crucial is unknown. Through OSE experiments performed by Environment and Climate Change Canada's (ECCC) system the Global Ice Ocean Prediction System (GIOPS) for the SynObs project, we will investigate the effect of observation withholding experiments on these diagnostics.

The SynObs project was particulary concerned with the importance of sub-surface observations, especially ARGO --- but other experiments only assimilating SST, or withholding altimeter observations were also performed with some novel results.

In the process of demonstrating the importance of each observation withholding experiment, we will present results showing the role of SST observations in capturing observed eddies and predictions of near surface currents in the ECCC GIOPS system.

# 62-S1: Radiance assimilation at ECMWF for SST and Sea Ice Concentration

**Submitting author/speaker (Name and Surname):** Philip Browne

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**Preferred participation:** Online

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**Abstract**

At ECMWF we are striving to extract more information from existing observations we have in our data assimilation system. In the next few upgrades we will see the ocean model playing a larger role, allowing us to expand our coupled DA methodologies.

Exactly how to use interface observations in a coupled DA setup with separate minimisations had until recently been quite ad hoc. A simple, implementable formalism for this will be presented. This allows us to see precisely where parametrisations, such as the cold skin, enter the methodology.

We will show the structure of increments we can achieve from both IR and MW data, into the 3D ocean and sea ice models in preparation for an operational implementation.

# 69-S1: Use of near-real-time SST analyses for ENSO prediction and analyses with a coupled ocean-atmosphere model of intermediate complexity

**Submitting author/speaker (Name and Surname):** Alexey Kaplan

**Preferred type of contribution:** Talk

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**Abstract**

The El Nino - Southern Oscillation (ENSO) is the dominant mode of global interannual climate variability and seems to be the principal mode for which seasonal-to-interannual prediction methods are more skillful than climatology or persistence. Operational ENSO predictions with the Zebiak-Cane coupled ocean-atmosphere model of intermediate complexity started almost 40 years ago. Its current operational version LDEO5 is one of the skillful members of the IRI operational multi-model ENSO predictions ensemble and remains competitive with all the coupled GCMs in this ensemble, despite their continuing evolution. The operational forecasts with the LDEO5 model are performed at the end of each month. Model initialization for the forecast involves its coupled run with data assimilation by nudging of available SST, sea surface height, and surface wind stress observations up to the present month, when data availability ceases; the extension of the same run into the future produces the forecast. Until its sudden termination in January 2023, weekly 1 degree NCEP OI SST analysis product was used for the forecast initialization. Since then we switched to the NOAA Daily 0.25 degree OI product, v2.1 (OISST2.1) The final OISST2.1 fields are produced with two-week latency, however the latency of their "preliminary" version is less than a day. Therefore, in the month preceding the forecast, the ingested SST are based in half on the OISST2.1 preliminary fields. The analysis of the SST error caused by this approximation and the effect of the SST product replacement on the forecast initialization will be presented.

## 80-S1: Coupled Data Assimilation Experiments in CNR ISMAR

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**Preferred participation (in-person or online)**: in-person

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**Abstract**

Coupled data assimilation in regional climate models is still largely unexplored, besides few pioneering applications, but represents a high potential for regional predictability gain, linked, among several factors, to the correction of imbalances at initial time and/or at the lateral boundaries, and the maximization of the benefits of the regional observing networks. Here, we present initial works and results relative to extending a variational data assimilation system in the ocean to include atmospheric parameters and observations. First, the concept is illustrated in an idealized atmosphere-ocean single-column model augmented with data assimilation, which indicates the benefits and advantages of the strongly coupled assimilation paradigm in a controlled environment. Sensitivity to the choice of the coupled background-error covariances is, however, large. Second, we show preliminary results in a realistic regional climate model over the Mediterranean region including state-of-the-art numerical models (NEMO, WRF, HD). Weakly coupled assimilation experiments indicate the importance of ocean data assimilation in the prediction of the intensity of individual medicane events. A roadmap and initial results from the strongly coupled scheme are also presented.

# Science Session S2 – Climate Change and Variability in Global and Regional SST

Global and regional climate SST reanalyses and climate data records are essential for monitoring and characterisation of the climate system and its change. Sustained monitoring provides an observational basis for our understanding of climate change and variability, and enables us to place current events into the context of the past. It draws upon information from in situ and satellite observations as well as dynamical reanalyses and climate models. This session aims to highlight the recent advancements in SST climate data records and reanalyses with a particular focus on the observed trends, variabilities and the corresponding uncertainties. This session also welcomes contributions on the use of SST products in climate models for assimilation as well as model evaluations. Comparison and validation of climate simulations using different SST datasets are welcome, in order to provide information to producers to enable them to improve their products for specific applications.
The session will focus on the following:

- Advances in observational climate and reanalysis SST products
- Applications of SST observations and reanalyses in global and regional assessments of climate change and variability
- Applications of SST observations for assimilation, evaluation and inter-comparisons of climate models and dynamical reanalyses.
- Comparison and validation of climate simulations using different SST datasets

**Keywords:** Climate monitoring, climate data records and reanalyses, climate change and variability, trends, climate-indicators, dynamical reanalyses, climate model simulations.

# Abstracts: Science Session 2 – Climate Change and Variability in Global and Regional SST

## 2-S2: Analysis of the Global Marine Heat waves based on CMA Ocean Data Analysis System for Sea Surface Temperature (CODAS-SST) Datasets

**Submitting author/speaker (Name and Surname):** Zhihong Liao
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**Abstract**

The sea surface temperature(SST) products from China Meteorological Administration(CMA) Ocean Data Analysis System(CODAS) were used for analyzing the distribution of global Marine Heat Waves(MHW) from 1982-2023, and the MHW's characteristics such as the duration, frequency, intensity and number of days are calculated with the de-trended SST data that obtained by using the Singular Spectrum Analysis(SSA) method. Additionally, the NOAA OISST product is selected for the comparison to analyze the difference between it and the CODAS SST product in the application of ocean heat waves. The differences between the NOAA OISST and CODAS SST products in the application of ocean heat waves are currently being analyzed.

## 6-S2: Analysis of the Global Marine Heat waves based on CMA Ocean Data Analysis System for Sea Surface Temperature (CODAS-SST) Datasets

**Submitting author/speaker (Name and Surname):** Zhihong Liao
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**Abstract**

The sea surface temperature(SST) products from China Meteorological Administration(CMA) Ocean Data Analysis System(CODAS) were used for analyzing the distribution of global Marine Heat Waves(MHW) from 1982-2023, and the MHW's characteristics such as the duration, frequency, intensity and number of days are calculated with the de-trended SST data that obtained by using the Singular Spectrum Analysis(SST) method. Additionally, the NOAA OISST product is selected for the comparison to analyze the difference between it and the CODAS SST product in the application of ocean heat waves. The differences between the NOAA OISST and CODAS SST products in the application of ocean heat waves are currently being analyzed.

## 9-S2: Enhanced Driving Data for Regional Climate Models: Assessing the Systematic Improvements with GCM Run-time Empirical Bias Correction

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**Preferred type of contribution:** Talk
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**Abstract**

The novel run-time empirical bias correction (EBC) developed and applied to enhance the global Earth system model CanESM5 demonstrate significant improvements in the representation of the historical climate. It provides enhanced driving data for dynamical downscaling through regional climate models (RCMs). This study aims to assess the impact of the bias-corrected driving data with EBC on two RCMs, namely CRCM5 (Ouranos) and CanRCM5 (CCCma).
Three 10-member ensembles are used to examine the added value of driving RCMs simulations of North America with the EBC driving data. Three different configurations of CanESM5 are used as driving data: the original CanESM5 (no correction); CanESM5 where only the sea surface temperature (SST) and sea ice concentration (SIC) are corrected; and CanESM5 where the atmosphere, SST, and SIC are corrected. All ensembles are compared against evaluation runs, where the RCMs are driven with ERA5.
Results indicate a clear advantage of using EBC driving data, particularly in regions where the initial biases are substantial. For instance, there are significant improvements in the representation of key meteorological phenomena, notably the North American monsoon and the nor'easters (extratropical cyclones). These improvements can be attributed not only to the refinement in addressing climatological biases in land and ocean data but also to the enhanced representation of cyclonic activities due to a more accurate depiction of the circulation in the region. Ultimately, this research seeks to provide a methodology to mitigate uncertainties in downscaled projections of future climate change through the application of EBC.

## 14-S2: Verification of CMIP6 SST data against gridded observations over the ocean regions around Canada

**Submitting author/speaker (Name and Surname):** Housseyni SANKARE
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**Abstract**

Climate change impacts ocean ecosystems in diverse ways, altering both the physical environment and biogeochemical cycles. Coastal communities and ecosystems must adapt to these changes. One outcome of climate change is the change in sea surface temperature (SST). Estimating future values of SST is crucial for implementing mitigation and adaptation strategies within a sustainable development framework. In this poster, we will present results from the evaluation of twenty-eight Global Climate Model (GCM) outputs from the Coupled Model Intercomparison Project phase 6 (CMIP6) concerning their ability to reproduce historical SST patterns in ocean regions around Canada. To evaluate the models, we utilize observational data from the Group for High Resolution Sea Surface Temperature (GHRSST) Level 4 AVHRR_OI Global and the Hadley Centre Sea Ice and Sea Surface Temperature data set (HadiSST v1.1). Statistical metrics such as mean bias, correlation coefficient, and Perkins skill score are employed to assess each model's performance in reproducing SST patterns. These results will allow us to verify the ensemble's performance across oceanic regions around Canada during the historical period, identify problematic areas, and propose potential solutions.

# 24-S2: CONTRASTING RATES OF COOLING IN THE ARABIAN SEA AND THE BAY OF BENGAL DURING WINTER MONTHS

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**Abstract**

In this study, we try to analyze and explain the possible mechanisms behind the contrast in the cooling rates observed in the Arabian Sea (AS) and the Bay of Bengal (BoB) during fall and winter season. To this end, we make use of climatological SST derived from satellite observations for 1990-2018. It is observed that both AS and the BoB observe cooling during October to January, but the rate of cooling differs significantly between these domains. The rate of cooling is quantified using two selected 5x5-degree boxes from both basins, situated in the same latitude belt. Despite receiving the similar solar insolation, the BoB is warmer than AS, the BoB cools faster (with cooling rate of 1.46ºC/month ) as compared to the AS (cooling rate of 1.12ºC/month ) during the winter months. In order to understand the mechanisms behind this contrast in the cooling rates, we have made use of the background atmospheric conditions like the winds, fluxes and the subsurface oceanic conditions. Preliminary analysis suggest that the ocean stratification that plays a dominant role in this contrasting cooling of the two basins. Some factors like vertical, mixing, thermal inversion and barrier layer formation seem to be the main factors responsible for this change in the rate of cooling in the two basins. Details of the analysis will be presented in the conference.

# 33-S2: THE STRANGE CASE OF THE PERSISTING MEDITERRANEAN HEATWAVE

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**Abstract**
The last Marine HeatWave (MHW) in the Mediterranean Sea started on May 2022 and, after two years, still ranges on the waters of this mid-latitude semi-enclosed marginal sea. We have analyzed this event in the context of the variability of the basin sea surface temperature (SST) over the last four decades using data produced and distributed by the Copernicus Marine Service. The product used provides a stable and consistent long-term time series developed for climate applications.
(https://data.marine.copernicus.eu/product/SST_MED_SST_L4_REP_OBSERVATIONS_010_021/description). The analysis of the Mediterranean MHW time series is of crucial interest because this basin is a hot spot region for climate change, where a strong mean SST increasing trend (0.045 °C/year) has been observed in the last 40 years.

Our main finding, deduced from the analysis of the time series, is that, besides a general linear trend in the SST signal and in the frequency of MHW events, since May 2022 the system appears to have abruptly shifted into a new equilibrium state characterize by a jump of 1°C, which, following Hobday's criteria, can be interpreted as a persistent MHW.
The evolution of this exceptional MHW is also discussed in relation to the corresponding atmospheric events occurred over the western portion of Europe and of the Mediterranean Sea. The discussion is complemented with the analysis of in situ data acquired at the ENEA Climate Laboratory in Lampedusa (a small island located to the south of Sicily) which allowed us to investigate the vertical penetration of the signal and the corresponding mixing events.

## 35-S2: Impact of resolution on observed SST climatology and variability

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**Abstract**
Some traditional, climate-oriented sea surface temperature (SST) observational datasets do not generally include satellite data and are typically based on in-situ observations with a coarser spatial resolution (1 to 2 degrees), prominent examples being the Extended Reconstructed SST from NOAA (ERSST) and the Hadley Centre SST, version 3 (HadSST3). Other datasets combine both, in-situ and satellite observations, such as the Hadley Centre Sea Ice and Sea Surface Temperature dataset (HadISST).
The main objective of this work is to globally characterize and compare SST climatology and variability at grid-point level, considering seasonal averages (DJF, MAM, JJA, SON), between two standard, climate-oriented datasets, HadISST (1º resolution) and ERSST v5 (2º resolution), with the GHRSST product developed by the European Space Agency Climate Change Initiative (CCI) (0.05º resolution). The study spans over 1982-2016 (35 years) that corresponds to the temporal coverage of the satellite product (CCI).
Preliminary results show that the coarser datasets (ERSST, HadISST) overall have a warmer mean-state, except in the more dynamically-active oceanic regions such as the western boundary currents where they yield a colder SST climatology. On the other hand, the high-resolution dataset (CCI) markedly displays larger SST variability in these dynamically-active oceanic regions, which is consistent along the seasonal cycle.

## 36-S2: Ongoing reprocessing of Meteosat/SEVIRI 0° sea surface temperature data record at OSISAF

**Submitting author/speaker (Name and Surname):** Tourandre Benoit
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4. *Stéphane Saux Picart, Centre National de Recherches Météorologiques, Avenue de Lorraine, B.P. 50747, 22307 Lannion cedex, France, benoit.tournadre@meteo.fr*

**Abstract**
Imagery from meteorological satellites can be used to derive sea surface temperature (SST). Geostationary satellites like Meteosat Second Generation (MSG) can also inform us on diurnal variations of SST, a useful information for deriving foundation SST and building multisensor-based analyses. EUMETSAT's Ocean and Sea Ice Satellite Application Facility (OSISAF) operationally produces SST estimates from MSG's Spinning Enhanced Visible and Infrared Imager (SEVIRI) observations. We present here ongoing activities for its reprocessing into a climate data record covering the period from 2004 to 2024 for sensors at longitude 0°, on a 0.05° regular grid and with hourly resolution. Hosted by the European Weather Cloud, the reprocessing will notably rely on improved radiance calibration, reprocessed input datasets (cloud mask, climatologies of maximum SST gradients, atmospheric temperature and humidity profiles, a priori SST...) and on consistent radiative transfer simulations from the version 13 of the RTTOV model.

## 42-S2: A new global, combined SST and IST CDR from 1982 to 2024, for the Copernicus Climate Change Service

**Submitting author/speaker (Name and Surname):** Ioanna Karagali
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**Abstract**
The Danish Meteorological Institute, a Production Unit for the Copernicus Marine Service (CMS) and Copernicus Climate Change Service (C3S), is releasing a new, global, gap-free (L4) dataset of climate-equivalent sea surface temperature (SST) at 20cm and sea-ice surface temperature (IST) at 0.05 degrees for C3S covering the period 1982-2022. The new product, GBL SST/IST Climate Data Record (CDR), is using ESA SST-CCI L3U v3 data, and the AASTI/C3S IST CDR along with sea ice information from multiple sources. For the first time in a global CDR dataset, Passive Microwave (PMW) SST data are also included to enhance coverage especially in the polar regions. This presentation demonstrates the methodologies for generating the global SST/IST CDR, validation with in situ data and comparison with the ESA SST CCI L4 product. Preliminary validation results for 2015 show a median (robust standard deviation) of -0.03 0C (0.27 0C) with ARGO, -0.06 0C (0.25 0C) with drifters and 0 0C (0.2 0C) with the Global Tropical Moored Buoy Array indicating very promising results. Applications of the CDR for climate monitoring will be investigated in terms of Ocean Monitoring Indicators.

## 48-S2: The record-high sea surface temperature and marine heatwaves in 2023

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**Abstract**

Globally (90ºS−90ºN) averaged sea surface temperature (SST) was 18.81ºC on March 31, 2023, which broke the historic record (18.78ºC) set on March 6, 2016 after a historically strong 2015−16 El Niño event. The unusualness of the record-breaking SST is that it happened immediately after the triple-dip 2020−23 La Niña event when SSTs were low, while SST record was usually broken after El Niño events. The record-breaking SST raised a lot of medium interests and public concerns on the reasons for the high SSTs, their impacts on climate, extreme weather, and marine environment, as the record SST may increase further as the on-going 2023−24 El Niño event becomes stronger in later 2023 and early 2024. As expected, the new record was broken again and again during July 13−22 (18.82º−18.87ºC), July 27−31 (18.88º−18.94ºC), August 6 (19.95ºC). These record-breaking SSTs are mostly attributed to the record high SSTs in the eastern North Atlantic, northern North Pacific, eastern equatorial Pacific, and the Southern Ocean. The record high SSTs result in active marine heatwaves (MHWs) in those regions during the time when SSTs were in record-high. Our analyses show that two factors are attributed to the series record high SST in 2023: One is the warming SST due to the transition from the triple-dip 2020−23 La Niña event to the 2023−24 El Niño event; the strength and duration of the on-going 2023−24 El Niño event may directly contribute the future record high SST since the globally averaged SSTs are usually high after El Niño events. The other is the overall warming trends of SSTs in the global oceans associated with increasing greenhouse gases.

## 53-S2: A 42-year Sea Surface Temperature Climate Data Record from the ESA Climate Change Initiative

**Submitting author/speaker (Name and Surname):** Owen Embury
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**Abstract**
ESA's Climate Change Initiative (CCI) has released the third major version of the SST CCI Climate Data Record (CDR) which now spans over 40 years, using data from Advanced Very High Resolution Radiometer (AVHRR), Along Track Scanning Radiometer (ATSR), Sea and Land Surface Temperature Radiometer (SLSTR) instruments, Advanced Microwave Scanning Radiometer (AMSR)-E and AMSR2. The dataset includes both single-sensor products plus a Level 4 SST analysis generated using the Met Office Operational Sea Surface Temperature and Ice Analysis (OSTIA) system.
Version 3 of the SST CCI CDR is the first to make use of data from AVHRR/1 instruments carried on board NOAA-6, -8, and -10 platforms. This increases data coverage in the 1980s and extends the dataset back to 1980. The quality of the AVHRR retrievals has been improved by using a new bias aware optimal estimation (BAOE) technique and updated radiative transfer modelling which significantly reduces the SST biases due to dust aerosols seen in previous CDRs. Additionally, the dataset also includes passive microwave AMSRE and AMSR2 data, MetOp AVHRR now at full resolution, and dual-view SLSTR data.
Complementary to the ESA CCI CDR we are producing an Interim CDR (ICDR) to proving an ongoing extension in time of the SST-CCI CDR at short delay (approx. 2 weeks behind present). The ICDR was funded by the Copernicus Climate Change Service (C3S) for 2022 and is now funded by the UK Earth Observation Climate Information Service (EOCIS) and Marine and Climate Advisory Service (MCAS) for 2023 onwards.

# 56-S2: Two decades of global ocean biophysical dynamics from NASA's MODIS mission: A retrospective analysis

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**Abstract**
The MODIS sensor onboard Aqua and Terra platforms has been acquiring data for more than two decades. It provides a unique opportunity to identify seasonal patterns and long term trends in ocean biophysical dynamics at global and regional scales, through the analysis of Sea Surface Temperature (SST) and Chlorophyll-a concentration (Chl-a) gradients.
In this study, ORBTY's Multidimensional Dynamic Data Fusion System (M3DFS) is applied to 20 years of daily MODIS Level 3 products to generate Level 3 monthly maps of SST and Chl-a for the period from 2002 to 2022. This dataset is compared to conventional time-averaged composite maps and shown to provide a more consistent representation of the spatial distribution and temporal variability of biophysical gradients associated with ocean processes.

## 63-S2: Inter-Comparisons of Long-term Global Trend of Sea Surface Temperatures for the Past Four Decades (1982-2021)

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**Abstract**
To ensure inter-comparisons of well-known SST analyses, we adjusted for natural climate variability on interannual and seasonal scales, incorporating indices such as ENSO, NAO, AAO, PDO, and DMI into our analysis. The comparative study revealed a general agreement among the datasets, with global SST trends predominantly ranging between -0.1 to 0.1°C/year. Despite this overarching consistency, discrepancies were observed: OISST data frequently suggested slightly higher warming rates compared to OSTIA, particularly in the higher latitudes of the Northern Hemisphere. Conversely, ESA CCI trends aligned more closely with OSTIA, except in the equatorial and arctic regions, where OSTIA recorded more significant warming, notably around the Antarctic region. Further examination using the high-resolution MURSST dataset for a more condensed timeframe (2003-2021) highlighted an even more pronounced warming trend, approaching 0.1°C/year. This dataset also unveiled specific regions experiencing divergent trends, such as cooling in the south of Greenland and significant warming in the western Pacific near North America. This analysis highlights the fundamental agreement on the global SST warming trend among different datasets, while also drawing attention to notable variances that underscore the complexities inherent in measuring and interpreting SST changes. These findings advocate for ongoing scrutiny into the methodologies underlying SST analyses, emphasizing the need for continued exploration of oceanic thermal structure to refine our understanding of global climate change.

## 68-S2: Assembling user needs for the advancement of the NOAA/NESDIS next generation SST product suite

**Submitting author/speaker (Name and Surname):** Elyse N. Bonner
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**Abstract**
National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) Sea Surface Temperature (SST) data products are used internally to serve NOAA missions and are available freely and without registration to everyone. NOAA uses SST in applications such as coral reef conservation, climate adaptation research, severe weather predictions, ocean forecasting, ecosystem-based management, and harmful algal bloom forecasting. To aid data use in these and other applications, NOAA CoastWatch Program exists to help people find, access, evaluate, and use satellite remote sensing data and data products for ocean, coastal and inland water applications. CoastWatch facilitates the use of SST by NOAA and by external users including academic, commercial, federal and state government agencies for operational uses such as monitoring of climate change, estuarine pollution and water quality. At the recent NOAA CoastWatch Annual Science Meeting , a user discussion session documented NOAA's and others' needs for SST that will guide the design and development of the next-generation NOAA/NESDIS SST product suite, initially proposed by the NOAA/NESDIS SST Working Group in January 2022, and provide a clear and compelling case for the agency resource support needed to execute its vision. Results from the session include guidance on: spatial coverage, accuracy, consistency, increased spatial resolution at the coast, historical bias-correction, and needs for Level 2, Level 3, and Level 4 data. This presentation will highlight the results of that CoastWatch meeting SST user discussion session.

## 72-S2: Covariation of long-term trends in surface water temperature and bio-optical indicators across the Great Lakes

**Submitting author/speaker (Name and Surname):** Prasanjit Dash
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**Abstract**

With satellite-based climate data records (CDRs) spanning 1998-2022, we preliminarily explored instantaneous and noninstantaneous synchronous covariations of lake surface water temperature (LSWT) with bio-optical water-state indicators in the Great Lakes, the world's most extensive inland freshwater system. The LSWT is the key indicator of lakewater's physical state, while chlorophyll-a (Chl-a) and the diffuse attenuation coefficient at 490 nm (Kd490) capture the bio-optical and optical aspects. In addition to these indicators, potential coupling with other dynamic parameters, such as 10m wind speed (WS) and column-integrated total precipitation (TP), is also investigated. Windspeed was sourced from NOAA National Centers for Environmental Information's (NCEI) blended seawinds. Other CDRs are available from ESA/C3S's Climate Change Initiative. Seasonal responses to climate and meteorological forcings vary disproportionately among parameters. Hence, slow-oscillating noninstantaneous trends, rather than instantaneous time series, may be more suitable for such cross-correlation studies. To test this assumption, we utilized the Multiple Seasonal-Trend decomposition using the Locally estimated scatterplot smoothing (MSTL) method and spectral analysis to derive time-varying trend lines and per-grid trend rates. Water depths affect ecological processes. For example, depths exceeding a few meters can lead to thermal stratification, particularly in low wind conditions, and not well-mixed bottom waters can become depleted of dissolved oxygen. Considering these effects, we stratified the analysis for the five lakes by deep versus shallow regimes using clustering-based thresholds.

Preliminary results demonstrate temporally covarying trends among the water quality parameters. We are investigating further to understand the cross-correlations better and look forward to potential collaboration with experts.

## 76-S2: Exceptional global sea surface temperatures associated with the 2023 and 2024 El Nino

**Submitting author/speaker (Name and Surname):** Christopher Merchant
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**Abstract**
The anthropogenic rise in global sea surface temperature (SST) is not steady, but reflects chaotic internal variability as well as variations in external forcing. The warm global mean SSTs observed in 2023 and early 2024 were not only recording-breaking in the observational era, but exceptional in the degree to which they exceeded previous records (by up to 0.3 K). In accounting for this, there are roles for internal variability (El Nino and ocean heat redistribution, ice variability) and external forcing (accelerating greenhouse gas concentrations, solar and other variability, aerosol trends). The contributions of these factors will be presented in an attempt to explain why 2023 and 2024 were years in which global SST warming appeared to accelerate. Implications will be drawn regarding the future trajectory of global SST.

# Science Session S3 – Challenging Regions: The Coastal Margin and The Arctic

This session is dedicated to challenging regions for SST retrieval and analysis, with particular focus on coastal regions and the Arctic, which has been recognized as a user-driven priority for the upcoming year. Coastal regions are challenging due to proximity to land, turbidity, tidal motion / mixing, upwelling or high gradients. In the Arctic, challenges arise due to a persistent cloud cover and the mix of open water and sea ice (and the temporally varying sea ice cover). Recent efforts have been made to get Sea Ice Surface Temperature (IST) homogenised with SST as an uniform

variable (X-ECV) in order to define the boundaries between ocean/sea-ice, and there is a growing need to get these connected with the global L4 SST counterparts. Both the coastal and Arctic regions are lacking satellite and in situ observations, which limits the possibilities for algorithm training and/or validation purposes. Improved SST coverage and accuracy in the coastal regions will benefit the forecast performance of operational ocean models. Ocean forecasting will also benefit from improvements in satellite SST cloud clearing algorithms to preserve cool ocean features, such as coastal upwelling.
The goal of this session is to provide an overview of satellite and in-situ data available for these challenging regions and provide examples on how these data are used for monitoring and/or ocean applications.
The session will focus on the following:

- Advances in SST retrievals, in situ observations and products for challenging regions
- Applications of SST observations in regional assessments of climate change and variability in challenging regions
- Comparison and validation of SST products in challenging regions
- Advances in the representation of the marginal ice zone SST and combined SST/IST estimates

**Keywords:** Coastal regions, Arctic, sea ice, remote areas, boundaries, X-ECVs

# Abstracts: Science Session 3 – Challenging Regions: The Coastal Margin and The Arctic

## 5-S3: Validation and Algorithm Development of R2019 MODIS-derived Sea Surface Temperature at High Latitudes

**Submitting author/speaker (Name and Surname):** Chong Jia
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**Abstract**
MODIS-derived sea surface temperatures (SSTs) have larger uncertainties at high latitudes where the atmosphere is very dry and cold, an extreme of global conditions. The current MODIS R2019 skin SST products have latitudinally and monthly dependent algorithm coefficients including an additional band above 60°N to better represent Arctic atmospheres. However, the accuracy of MODIS SST still has room for refinement. We use 21-years (2002-2022) of collocated, simultaneous satellite brightness temperature (BT) from MODIS on Aqua and in situ subsurface SST from iQuam for validation. Unlike elsewhere, the 11 μm and 12 μm BT differences are poorly related to the column water vapor at high latitudes, resulting in poor atmospheric water vapor correction. Anomalous BT difference signals are identified, caused by the temperature inversion in the lower troposphere, especially significant during the summertime. Although the existence of negative BT differences is physically reasonable, it makes the retrieval algorithm lose effectiveness. The statistics of MODIS SST when compared with iQuam SST show large difference

for the matchups at the northern Atlantic and Pacific sides of the Arctic due to the disparity of in situ SST measurements and distinct surface and vertical atmospheric conditions. Additionally, we further optimize the emissivity effect correction presented in Jia and Minnett (2020) primarily by introducing the parameterization of atmosphere-sea temperature difference. We aim to improve the algorithms to obtain more accurate MODIS SST for climate change research and to study surface ocean processes in the Arctic.

## 8-S3: Evolution of Copernicus Marine Surface Temperature Products in Coastal Regions and High Latitudes

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**Abstract**
Accurate long-term measurements of marine surface 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 Copernicus Sea and Land Surface Temperature Radiometer (SLSTR) is a multi-spectral dual-view radiometer with two on-board blackbodies and cooled detectors ensuring accurate radiometric measurements for the estimation of sea surface temperature (SST) and sea-ice surface temperature (sea-IST).
Operational retrieval of SST from satellite thermal infrared (TIR) radiances relies on a pre-processing step to identify and discard cloud-affected observations. Coastal regions offer particularly challenging regimes for cloud detection owing to an increased frequency of turbid waters modifying ocean colour and SST fronts generating sharp gradients in the TIR. Here we present new approaches for cloud detection prior to SST retrieval from SLSTR and illustrate the benefits using case studies in coastal zones covering optically bright waters and around strong ocean fronts.
The evolution also includes a new high-latitude combined SST and sea-IST product implemented at the nominal SLSTR TIR resolution (1 km) and routinely processed for SLSTR-A/B over the high latitude regions (>50° poleward in both the Northern and Southern hemispheres). Sea-IST cloud masking is provided by the EUMETSAT NWC SAF PPS cloud and cloud probability algorithms. Initial validation results indicate the sea-IST performance for SLSTR-B in particular is very good and already close to the Essential Climate Variable (ECV) goal of 1 degree Celsius. Moreover, the challenging cases of winter / night-time performance is also of good quality and not too far from daytime performance.
Pre-operational products in GHRSST L2P format will be available to users from the Copernicus WEkEO DIAS reference service for evaluation from April 2024, with operational implementation expected from Spring 2025.

## 13-S3: Multi-scale variations of ocean temperature off the coast of Nova Scotia: Analyses in situ and remote sensing observations and high-resolution ocean models towards applications in ecosystem and fishery

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**Abstract**
Ocean temperature variations off the coast of Nova Scotia are quantified through analyses of data from in situ and satellite remote sensing observations, and high-resolution numerical ocean models. The analyses reveal significant variations at various time-space scales, including: 1) rapid cooling in nearshore waters associated with extreme cold-air outbreaks; 2) frequent cold spells at seabed along the coast from late fall to early spring; 3) large-scale cooling or warming spanning over a season or longer; 3) extensive upwelling along the coast from late-spring to fall; 4) space-time (seasonal and interannual) variations of marine heat waves and cold spells at surface and in the water column; and 5) interannual variations of upwelling along the coast. The forcing mechanisms and predictability of these variations are explored through analysis of atmospheric forcing and ocean model solutions. The potential relevance to applications in marine ecosystems and fishery is discussed.

## 16-S3: Validation and Application of Satellite Derived Sea Surface Temperature Gradients in the Bering Strait and Bering Sea

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**Abstract**
The Arctic is one of the most important regions of the world's oceans for understanding the impacts of a changing climate. Yet, it is also difficult to measure because of extreme weather, as well as ice conditions. In this work we directly compare four data sets from the Group for High Resolution Sea Surface Temperature (GHRSST) with a NASA Saildrone deployment along the Alaskan Coast and the Bering Sea and Bering Strait. The four data sets used were the Remote Sensing Systems Microwave Infrared Optimally Interpolated (MWIR) Product, the Canadian Meteorological Center (CMC) product, the Daily Optimally Interpolated Product (DOISST) and the Operational Sea Surface Temperature and Ice Analysis (OSTIA) product.
Gradients were derived for both the Saildrone deployment and the GHRSST products, with the GHRSST products collocated with the Saildrone deployment. Overall, statistics indicate that the OSTIA product had the best correlation of 0.79 and a root mean square difference of 0.11C/km when compared with Saildrone. Differences increased at latitudes > 65N were sea ice would have a greater impact. A trend analysis was then performed on the gradient fields. Overall positive trends in gradients occurred in areas along the coastal regions. A negative trend occurred at approximately 60N. A major result of the study indicates that future work needs to revolve around the impact of changing ice conditions on SST gradients.

## 18-S3: Saildrone Arctic field campaign and dataset, 2019-2022

**Submitting author/speaker (Name and Surname):** Marisol Garcia-Reyes
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**Abstract**
Sea surface data that can be used to validate satellite data and improve retrieval algorithms are limited, particularly in the Arctic, given the challenging conditions oceanographers and instruments endure. New technologies and increased field campaigns are helping to reduce this limitation. Saildrone, uncrewed vehicles that collect surface ocean and atmospheric continuous data, is one of these new technologies, by providing data that cover both difficulties. Saildrone vehicles can help better validate satellite retrievals as they provide data from the surface layers of the ocean and the ocean-air boundary. Also, due to their autonomy and by being powered by solar and wind energy, Saildrone can collect data in challenging regions like the Arctic, where crewed field campaigns either cannot go, or cannot be out for long periods of time. The NASA funded Multi-Sensor Improved SST (MISST) project funded three summers of Saildrone campaigns in the Alaskan Arctic. Here, we present the highlights of this open access dataset, aiming to promote its use by the scientific community. Data collected extends beyond sea surface and air temperature to also include salinity, winds, currents, and dissolved oxygen. Furthermore, the period of the Saildrone campaigns, 2019-2022 includes an Arctic Marine Heatwave in 2019, and two summers of subsurface temperature data that provide data for the study of diurnal warming.

## 19-S3: SST trends and extreme events across L4 SST datasets at 23 globally significant coastal habitats for top marine predators

**Submitting author/speaker (Name and Surname):** Marisol Garcia-Reyes

**Preferred type of contribution**: Talk
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**Abstract**
Ocean temperature is a critical environmental driver of habitat suitability, biodiversity, and health of natural populations. SST products are among the best resources available to study ocean change, and have been widely applied to assess climate change impacts on marine ecosystems. There are areas, however, where SST accuracy needs improvement. Cloudiness limits the observations of small-scale processes, and data accuracy is reduced in coastal and (sub)polar areas due to land- and ice-ocean interactions. Coastal marine areas are where a large portion of marine life is found, specifically due to the land-ice-ocean dynamics. Land provides breeding habitat for marine species, and also leads to processes such as upwelling that fuel marine productivity by bringing nutrients to the surface. Therefore, to accurately investigate biophysical relationships in cloudy coastal regions it is important to understand the strengths and limitations of different SST products in representing key changes in conditions like secular trends and extreme events. Here, we compare L4 and reanalysis SST products in coastal areas (<200 km from land) around the world that are notable for their rich communities of top predators. In particular, we focus on 23 coastal sites that serve as breeding habitat and feeding areas for well-monitored colonies of seabirds and marine mammals, as they are of great interest as sentinels of how ocean change impacts the marine food web upon which they, and scores of other species, rely. We discuss agreement among datasets and the tradeoffs between high-resolution and effort to acquire and analyze SST data.

## 22-S3: Comparisons of satellite-derived sea surface temperature with in situ temperature in the Arctic Ocean: Impacts of oceanic surface stratification

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**Abstract**

Remotely sensed sea surface temperature (SST) retrieval is essential to assess the thermal condition of the Arctic Ocean, where routine in situ measurement is hampered by limited accessibility. However, the retrieved value represents skin SST affected by diurnal solar insolation and has a gap with the temperature at the surface mixed layer (so-called foundation SST) when the oceanic structure is strongly stratified. In lower-latitude oceans, the gap becomes negligibly small when radiative cooling during the night or wind-driven vertical mixing occurs. However, this cannot be applied to the Arctic Ocean because the solar incoming continuously occurs during the midnight sun, and the strong stratification due to melt water and river water supplies tends to inhibit the mixing. This highlights the importance of understanding the relationship between the SST gap and the oceanic condition in the Arctic. This work compares skin and foundation SST values obtained from satellite-based retrievals and in situ observations. In the presentation, we will show detailed results of the comparisons and discuss a relationship between the vertical SST gap and oceanic structure in the Arctic Ocean.

## 28-S3: New observational thermal stress and marine heatwave monitoring tools for the Australian coasts

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**Abstract**
Monitoring the warming ocean in Australian regions is essential for understanding extreme events such as marine heatwaves (MHWs) and their potential impacts on marine ecosystems. Advances in satellite technology have made it possible to monitor sea surface temperatures (SST) at resolutions, crucial for research, climate modelling, and understanding coastal processes. The Bureau of Meteorology is developing a state-of-the-art remote sensing application to monitor ocean surface temperatures around Australian coasts (100-165oE, 7-46oS) using satellite SST observations.
The 10-minute temporal resolution of the newly developed Himawari-8/9 SST data enables a daily composite with enhanced spatial coverage, effectively filling in SST gaps caused by transient clouds. Skin SST retrievals from infra-red radiometers on Himawari-8 and polar-orbiting satellites are composited over multiple swaths/scenes and gridded on a 0.02o rectangular grid over the Australian domain and are used to develop thermal stress and MHW monitoring tools. The new tools are compared with the Bureau's existing operational ReefTemp Next Generation system which has provided heat stress monitoring tools for the Great Barrier Reef region since 2012. Further, MHW monitoring metrics such as MHW duration and intensity are developed. We will demonstrate some examples of new metrics along with case studies.

Ongoing near real-time monitoring of SST across Australian waters will equip marine managers and researchers with tools to inform decision making, assessment and prioritisation of marine ecosystems at risk of thermal stress. It will have utility across conservation, reef management, aquaculture and fisheries sectors, supporting effective management of marine heatwave impacts in a warming ocean.

## 37-S3: When is Wind Speed Not Enough for Characterizing the Cool Skin?

**Submitting author/speaker (Name and Surname):** Sandra Castro, Andrew Jessup and Gary Wick
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**Abstract**
Theoretical approaches have long suggested that the temperature change across the oceanic cool skin layer (T) is a function of multiple parameters including the wind stress and heat flux. Given the challenges in obtaining sufficiently accurate measurements of the heat flux outside of dedicated research studies, however, data from many cruises distributed throughout the oceans have suggested that T can be approximated with a simple wind speed dependence that asymptotes to a value near 0.17 K at high wind speeds. This approach is widely utilized in the retrieval of satellite sea surface temperature values and the generation of blended L4 analyses.

Several recent datasets demonstrate specific conditions where observations of T deviate significantly and systematically from the simplified assumed wind speed dependence. Measurements from the recent Submesoscale Ocean Dynamics Experiment (S-MODE) off the coast of California near San Francisco demonstrate large modulation of T across strong submesoscale temperature fronts that correlate with the change in the heat flux. Additionally, independent measurements from the EPIC experiment and collocated satellite and TRUSTED buoy measurements at higher latitudes show a significant deviation from the asymptotic high wind speed limit in the presence of large air-sea heat fluxes. This presentation examines the behavior exhibited by these data sets and evaluates the ability of other theoretical skin layer models to reproduce the observations. Analyses specifically examine the relative accuracy of estimates of T from simplified and theoretical approaches given heat flux estimates with varying uncertainty to assess where improved predictions of T may be possible.

## 44-S3: Updated OSI-SAF Near Real Time Sea Ice Concentration products

**Submitting author/speaker (Name and Surname):** Suman Singha
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**Abstract**
The retrieval of sea ice concentration (SIC) through passive microwave satellite sensors has become a well-established field over several decades. Various algorithms, employing slightly different approaches, such as utilizing diverse microwave satellite channels with the ability to combine frequencies and polarizations, have been tested in prior studies to assess the reliability and accuracy of SIC retrievals. The underlying algorithm for the OSISAF SIC products is a well established hybrid SIC retrieval algorithm and the retrieved SIC can be used for data assimilation and as an essential auxiliary input for other geophysical parameter retrievals (e.g. SST). Although the core algorithm remains the same, we recently upgraded the EUMETSAT OSI SAF Near Real Time (NRT) processing chain to perform Radiative Transfer (RT) calculations by means of the NWP SAF RTTOV package. These calculations are necessary in the algorithm processing logic because they determine the magnitude of the atmospheric correction which is applied to observed microwave brightness.
Although the skills of the SIC retrievals remain comparable, the use of RTTOV allowed to redesign the NRT algorithm and make it a more general framework to facilitate the ingestion of observations from different passive microwave sensors. The new NRT algorithm, operationally released in April 2023 (for SIC retrievals from AMSR2 and SSMIS), represent the essential technical framework which will be adopted to guarantee the continuity of the SIC retrievals which we will derive from new satellite missions (e.g., EUMETSAT's Metop-SG MWI, JAXA's AMSR-3, and ESA's CIMR).

## 46-S3: Developing surface temperature retrievals for CIMR

**Submitting author/speaker (Name and Surname):** Jacob L. Høyer
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**Preferred participation:** In-person (Montreal)

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**Abstract**
Observations of sea surface temperature (SST) from passive microwave (PMW) sensors are important complements to traditional infrared (IR) observations. However, the resolution of the current microwave imagers are not enough to capture subscale to mesoscale variability. Furthermore, they suffer from coastal and sea ice contamination. The Copernicus Imaging Microwave Radiometer (CIMR) is currently being prepared by the European Space Agency (ESA) as a part of the Copernicus Expansion program for the European Union, with an expected launch in 2029. CIMR is designed to observe high-resolution and high-accuracy PMW measurement of a select range of geophysical variables, such as SST, Sea Ice, IST and Lake Surface Water Temperature (LSWT). Currently, retrieval algorithms for CIMR Level-2 products are being developed within the ESA funded project CIMR-PAD and this poster will give an overview of the development activities with focus on the temperature retrievals for Polar Oceans, sea ice and lakes. The CIMR SST retrieval algorithm is a statistically-based model for retrieving both SST and associated uncertainty, using satellite brightness temperatures and derived wind speed. The CIMR Level-2 SST algorithm also involves re-sampling and re-mapping. The CIMR Level-1b brightness temperatures need to be re-mapped on common location and resolution before application of the SST algorithm. The prototype retrieval algorithm is developed and validated using simulated L1b CIMR data. The performance is assessed using demonstration reference scenario scenes, consisting of typical brightness temperatures for different surface types arranged in artificial patterns corresponding to real world scenarios, such as ocean-land and ocean-sea ice transitions.

## 47-S3: Using satellite-derived surface temperatures to benchmark climate models and reanalyses in the Arctic

**Submitting author/speaker (Name and Surname):** Pia Nielsen-Englyst
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**Abstract**

Arctic surface temperatures are heavily under-sampled in terms of both satellite and in situ observations, causing large uncertainties in current gridded observational datasets, dynamical renanalyses as well as in global climate models. Currently, no satellite-observed surface temperatures are included over the sea ice in reanalyses and global gridded observational datasets, and the near-surface air temperature (T2m) estimates are thus derived using only a very limited number of in situ observations. This study takes advantage of the newly generated Arctic combined sea and sea-ice surface temperature climate data record produced for the Copernicus Marine Service (CMS), which is based on infrared satellite observations. The dataset offers a much better spatial resolution than the sparse in situ network and brings a new possibility for benchmarking climate models and reanalyses in the Arctic Ocean. To further facilitate the usage of the dataset, efforts have been made to convert the satallite-observed ice surface temperatures into near-surface air temperatures. Here, we present an evaluation of ERA5 and the latest generation (phase 6) of the Coupled Model Inter-comparison Project (CMIP6) historical simulations using the satellite-derived T2m as benchmark. It is evident that ERA5 has a warm offset throughout the period (1982-2020), while the CMIP6 ensemble mean is in closer agreement with satellite-derived T2m in the central Arctic Ocean. It is also found that both ERA5 and CMIP6 underestimate the T2m trend (by –0.23degC per decade and –0.18degC decade, respectively) compared to the satellite-derived T2m estimate. The results highlight the importance of having accurate and absolute reference fields evaluating and assessing the current as well as the next generation of dynamical reanalyses and global climate models (CMIP7) in the Arctic Ocean.

## 52-S3: Arctic Marine Heatwaves: Assessing the Impacts on Marine Primary Producers

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**Abstract**
The Arctic region has undergone profound environmental transformations, characterised by a significant loss of multiyear sea ice, a reduction in sea ice concentration, and an elevation in Sea Surface Temperatures. Notably, the frequency of Arctic marine heat waves (MHWs) has surged, posing potential repercussions on marine ecosystems owing to the thermal sensitivities of aquatic organisms. Presently, the effects of MHWs upon Arctic primary producers has been relatively understudied. However, historically, warming in the Arctic has led to heightened phytoplankton productivity, attributed to greater open water regions and prolonged growth seasons. Still, there exists ongoing debate regarding the sustainability of enhanced productivity amidst escalating temperatures. Here, we investigate SST trends across various Arctic regions to pinpoint areas where MHWs have had the most significant impacts, while also examining patterns in their occurrence, duration, and intensity. To understand how primary producers might respond to future warming, we assess the relationship between satellite-derived chlorophyll a concentrations and SST during MHW events. By examining these relationships, we aim to provide valuable insights into the potential ecological ramifications of intensified warming in the Arctic.

## 57-S3: Status of the Ice and Sea Surface Temperature activities at MET Norway and DMI

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**Abstract**
The Norwegian (MET Norway) and Danish Meteorological Institute (DMI) have in cooperation developed a combined retrieval of Ice and Sea Surface Temperature including the (IST+SST) in polar regions through different projects, such as EUMETSAT OSI SAF, Copernicus Sci4MaST and C3S, using both AVHRR, SLSTR and VIIRS data. The retrieval set up will be presented. The latest advances in this work will be presented, including improved masking of sea ice using the PPS v2021 cloud processor and OSI SAF sea ice products, including improved cloud mask over sea ice and improved temperature algorithm. Some first results of using buoys with four thermistors for validation of IST/MIZT temperatures will also be presented.
The IST monitoring also includes a climate perspective and the combined use of climate data records of sea ice surface temperature and sea ice extent for studying the decay of polar sea ice extent.

## 58-S3: Improving Copernicus L4 SST regional products with CIMR observations

**Submitting author/speaker (Name and Surname):** Mattia Sabatini
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**Abstract**
In the Mediterranean Sea (MED), a hot spot for climate change, the operational monitoring of sea surface temperature (SST) is uniquely based on infrared (IR) satellite measurements. IR sensors provide high spatial resolution (~1 km) observations, although unable to see through clouds. Passive microwave (PMW) sensors, on the contrary, are able to sense the sea surface through non-precipitating clouds at a coarser resolution (~25 km).
The Copernicus Imaging Microwave Radiometer (CIMR) mission (2029+ timeframe) will provide observations at higher spatial resolution (~10 km), frequent coverage in polar regions, and almost all-weather capabilities.
We present an observing system simulation experiment (OSSE) to assess the impact of CIMR observations within the gap-free (L4) MED products of the Copernicus SST Thematic Assembly Center (SST-TAC). Based on Copernicus numerical model outputs (our ground truth SSTs), we generated a time series of synthetic CIMR collated (L3C) and IR merged multi-sensor (L3S) SSTs. These data were ingested by an optimal interpolator (OI) considering only IR or a combination of IR and CIMR L3 fields. A preliminary comparison of the ground truth SST with the "IR only" and the "IR+CIMR" OI SSTs suggests that CIMR observations can improve the accuracy of the MED L4 SSTs by reducing the root mean squared error (RMSE) up to 0.3 °C.

# 59-S3: Variability in sea surface temperature from a coastal ice-ocean model and observations over the Northwest Atlantic and Gulf of St. Lawrence

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**Abstract**
Sea surface temperatures from a multi-decadal (1993-2018) simulation using the Coastal Ice-Ocean Prediction Systems for the East Coast of Canada (CIOPS-E) are compared to satellite-derived SST products, in situ observations to evaluate the simulated variability from seasonal to interannual timescales. Areas of high variability are identified, and representation of the physical processes such as radiative fluxes from the atmosphere and shortwave absorption in the water column are investigated in the model and compared to available observations. Comparisons with the operational implementation of the CIOPS-E forecasting system for the overlapping years are also used to understand sensitivity to changes in the experimental configuration and error growth in the system.

## 64-S3: A new global multi-source sea ice concentration composite

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**Abstract**
Sea ice concentration is a headline climate indicator, serving as one of the most evident indicators of climate change. Various climate data records for sea ice concentration exist and they provide an essential tool for monitoring and evaluating long-term climate trends in sea ice coverage.
The accuracy and spatial resolution of existing sea ice concentration climate data records vary depending on the satellite sensors and frequency subsets used in retrieval algorithms. Typically, these records rely on data from a single sensor to maintain long-term consistency, although this approach fails to gain the full potential from improving satellite sensors.
At the Danish Meteorological Institute (DMI), we have developed a new global multi-source sea ice concentration composite by integrating existing climate data records and sea ice chart information. This composite aims to provide the most reliable sea ice information from 1982 to 2023, and various filtering methods have been applied to ensure long-term consistency. The sea ice concentration fields are currently being implemented for the second generation of the Copernicus Arctic Regional Reanalysis (CARRA) system as well as the new global, combined sea and sea-ice surface temperature climate data record for the Copernicus Climate Change Service (C3S).
This presentation offers an overview of the multi-source sea ice concentration composite, outlining key aspects of the methodology. Additionally, it will compare the results with other climate data records including the OSI SAF Global Sea Ice Concentration climate data record (SMMR/SSMI/SSMIS) release 3 and the NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 4.

## 67-S3: Apples to Oranges? Exploring the sufficiency of thermal stress products for coral reefs

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**Abstract**
Coral reefs harbor the highest biodiversity of any ecosystem globally, directly support hundreds of millions of people worldwide, and are key indicators of global ecosystem health. It is incontrovertible that many coral reefs are in various stages of decline and may be unable to withstand the consequences of global climate change, including a long-term oceanic warming signal. Further, the frequency and intensity of extreme marine temperature events (i.e., marine heatwaves) are increasing as a consequence of anthropogenic climate change and can drive rapid bleaching and mortality on the order of weeks in comparison with progressive degradation on the order of several months from canonical events. As a result, the tropics have observed more frequent and intense mass coral bleaching events in the last twenty years. This presentation will explore the sufficiency of thermal stress products for coral reefs. Specifically, we will provide a comparison of "gold standard" 5 km products from Coral Reef Watch (OSTIA / NOAA Geo-Polar Blended SST) with higher resolution ocean temperature products on the order of 1 km (Multi-scale Ultra-high Resolution SST) and 70-90 m (Landsat and ECOSTRESS) for the main Hawaiian Islands and northern Great Barrier Reef. Benefits and limitations will be discussed towards the goal of improved understanding of the relationship between reef functional diversity and its environment to better manage, conserve, and predict this vital ecosystem.

## 71-S3: A satellite-data-driven coastal awareness framework: CEOS COAST Application Knowledge Hub (AKH)

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**Abstract**
Routinely evaluating changes in coastal regions is essential due to the substantial global population residing in these areas, where the bulk of goods and services are generated, accompanied by notable social and ecological concerns. Coastal zones, however, pose observational challenges owing to their dynamic nature, intricate ecosystems (comprising physics, biology, and biogeochemistry), interconnected transboundary elements (such as the land-sea interface), and multifaceted trans-disciplinary interactions (environmental and social aspects). An array of factors (mixed-pixel effect, tidal actions, boundary currents) makes the coasts uniquely challenging for retrieving and applying satellite data. However, combining various satellite data offers a valuable overarching perspective, however, their effectiveness is further enhanced when combined with sub-orbital and field measurements, as well as a diverse array of socio-economic data.
To address some of these challenges and maximize the use of satellite retrievals for coastal monitoring and awareness, the CEOS Coastal Observations Applications Services and Tools (COAST) Team, co-led by NOAA and ISRO, is leading an initiative to establish a knowledge repository for characterizing events and the overall condition of coasts: the COAST Application Knowledge Hub (AKH). In this presentation, we will report on the status and updates on the CEOS COAST AKH that was alpha-released in June 2023.

## 79-S3: Observations and simulations of Yukon River discharge variability and its impacts on Norton Sound and Gulf of Alaska

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**Abstract**
Using synoptic scale means of SST–the Group for High Resolution Sea Surface Temperature, 0.09° gridded, level-4 dataset (GHRSST-MWIR) as proxy for river temperature in the Norton Sound [1], we ask how Yukon River discharge volume and temperature impacts Norton Sound and Gulf of Alaska SST, salinity, and vertical mixing. An SST Daily point time series at the Yukon River Mouth, [1] is used as a substitute for river mouth temperature. In the time series above, SST is variable over periods of 5-7 years, and by location. We take similar means of sea surface salinity with the optimally interpolated sea surface salinity dataset (OISSS) with 1/4° gridding. Salinity time series show the seasons may cause changes in freshwater, having implications for vertical mixing, biodiversity, and ocean circulation [2;3]. Phase diagrams of in-situ Yukon River headwaters temperature vs. Yukon River mouth freshwater flux [3;5] indicate July is the month when most of the river discharge occurs while August and September are river shutdown months. Modeled sea surface temperature (1992-2020), and observed SST (2003-2017) [1;6], show that similar patterns exist in the later years of the study and provide a basis for longer model-data comparisons. Modeled salinity (1992-2020) juxtaposed with observed salinity (2003-2017) [7;3] illustrates that the observed data has coarser gridding. Reanalysis MERRA-2 precipitable water vapor [8] averages suggest that rainfall is a reason for the large variation in river flux volume and headwaters temperature, providing conjecture for physical links between the river temperature and ocean temperature.
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# Science Session S4 – Calibration, Validation, and Product Assessment

This session aims to highlight recent advancements in sea-surface temperature (SST), with a particular focus on the calibration and validation of satellite-derived SST products and the assessment of their quality and applicability, and a focus on in-situ/FRM datasets and inter-comparisons.
The session will focus on the following:

- Calibration and inter-calibration of satellite instruments.
- Validation of satellite-derived SST products.
- Comparisons between satellite data products and in situ measurements.
- Inter-comparisons of satellite data products from various platforms and sensors.
- Quality control and quality assurance of satellite data products.
- Evaluation of uncertainties and error sources in SST products.

**Keywords:** calibration, intercalibration, validation, product assessment, inter-comparison, quality control, quality assurance, uncertainties, evaluation, error sources

# Abstracts: Science Session 4 – Calibration, Validation, and Product Assessment

## 1-S4: Examination of the performance of 22 CMIP6 ESMs on large scale changes in the atmosphere and oceans (North Atlantic, Arctic and North Pacific)

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**Abstract**

This study examines the performance of 22 CMIP6 models. Sea level pressure and 2m air temperature of the atmosphere component are compared with those from a reanalysis product. Sea surface temperature and sea ice from an observation-based ocean product are used to investigate the performance of the ocean component in these models. This study finds that the performance varies substantially between models and also between variables within one model. In general, these models do not represent sea level pressure well which is strongly related to the atmospheric circulation (winds), however, they well represent the 2m air temperature in terms of its long-term warming tendency over the historic time period. The multi-decadal variations of the sea surface temperature in the North Atlantic Ocean are captured by the majority of the models, however, they mostly fail to represent the dominant changes in the sea surface temperature in the North Pacific Ocean. This study suggests that the North Atlantic Ocean appears to be more predictable than the North Pacific Ocean. The declining trend in the summer Arctic ice area is reproduced, and some models have trends close to the observations. UKESM1-0-LL, CNRM-ESM2-1 and CESM2 are the three models with overall good performances for atmosphere, ocean and ice components.

# 3-S4: Historical and Near-real Time Geostationary ACSPO SST Products from GOES and Himawari Series Satellites

**Submitting author/speaker (Name and Surname)**: Victor Pryamitsyn

**Preferred type of contribution:** Poster

**Preferred participation:** In-person (Montreal)

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## Abstract

Satellite SST products from geostationary and low earth orbit satellites are produced at NOAA using the Advanced Clear Sky Processor for Oceans (ACSPO) enterprise system. In 2023 we released ACSPO v2.90 with updated SST algorithms and clear-sky mask for geostationary satellites. The new version has been used for the SST production from the ABI and AHI sensors flown onboard the operational satellites GOES(G)-18 and Himawari(H)-9. Full mission ACSPO SST datasets from both G18 and H09 are available at NOAA CoastWatch and JPL PODAAC with new data added in near-real-time. The G16 SST is continued to be produced with ACSPO v.2.70. We performed a full mission SST Reanalysis (RAN) of G16 and the inactive H08 with ACSPO v2.90. During reprocessing of the 8-year H08 mission we identified a -0.17 K/decade drift of the global mean SST bias relative to various references. For the 6-year G16 mission we found an analogous larger drift of -0.27 K/decade. The G18 and H09 missions are too short to accurately estimate the presence of such drifts. We have attributed the SST drifts to gradual degradation of the AHI and ABI emissive band calibration during the satellite missions. In this presentation we present the ABI/AHI ACSPO SST datasets and evaluate the possibilities of the mitigation of such

bias drifts and also the origins and possible mitigations of the seasonal periodical global biases of the amplitude of ~0.2 K observed in ACSPO SST for all ABI/AHI sensors.

## 7-S4: Fiducial Reference Measurements for SST and sea-ice

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**Abstract**

Fiducial Reference Measurements (FRM) are high-quality, calibrated and SI-traceable reference in situ measurements needed for the validation of climate-quality or reference satellite Sea and sea-Ice Surface Temperatures (SST/IST), such as from Copernicus Sentinel-3 Sea and Land Surface Temperature Radiometers (SLSTR).
Since 2018, within the frame of the Copernicus TRUSTED (www.eumetsat.int/TRUSTED) project, over 177 drifting buoys have been deployed worldwide, providing high quality in situ SST measurements towards FRM quality. Recent achievements have been the definition of an uncertainty diagram for the buoy SST measurements providing traceability to SI and updates of the platform and measurement metadata and quality control processes. Since 2022, activities have begun towards developing high quality sea-ice measurements from drifters with a newly developed prototype probe by NKE, with 16 equally spaced thermistors, now completed and under calibration and testing by the SHOM and DMI. This year sees the development of the IST drifting buoy platform which is planned to be further calibrated and tested in Qaanaaq, Greenland in winter 2024/2025. An operational service of IST measurements is expected to follow in 2026 / 2027 to support the upcoming availability of operational Day-1 IST products from SLSTR.
The presentation will give an overview of the status and details of TRUSTED FRM drifting buoys for SST and IST at high-latitudes and over sea-ice, including the status of the availability of current measurements and definitions, development of new platforms / sensors, progress with uncertainty diagrams and metadata / quality control and future steps and recommendations.

## 11-S4: NOAA Super Collated SST Products From Low Earth Orbit Satellites (L3S-LEO)

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**Abstract**

NOAA produces a global 0.02° Super Collated high resolution family of SST products from low earth orbit satellites (L3S-LEO) using the Advanced Clear Sky Processor for Oceans (ACSPO) enterprise system. The L3S-LEO family includes the PM, AM and Daily lines of products. The PM line includes MODIS and VIIRS SSTs from satellites in afternoon 'PM' orbit (Aqua, NPP, N20 & N21) and is available back to Jul 2002 (earliest Aqua MODIS SST). The AM line includes AVHRR SSTs from mid-morning orbit satellites (Metop-A, -B & -C) and is available back to Dec 2006 (earliest Metop-A data). Both AM and PM products are reported separately for day and nighttime. The L3S-LEO-Daily SST combines both daytime and nighttime PM, AM and Terra MODIS SST into one daily file with diurnal variations adjusted to 1:30am local time (nighttime PM) viewing conditions. The Daily L3S product is available back to Feb 2000 (earliest Terra MODIS SST). Complete timeseries of L3S-LEO products is available at NOAA CoastWatch and NASA PO.DAAC. In this presentation we give an overview of the L3S-LEO family of products and highlight their relative merit and advantages over uncollated L3U SSTs in terms of SST quality and data volume. We highlight updates in the recently released ACSPO L3S-LEO v2.81 PM and Daily datasets which succeed v2.80. Updates include the addition of Aqua and Terra MODIS SSTs which improve global coverage and significantly extend the L3S-LEO PM and Daily availability back in time. Updates also include detrending of the VIIRS daytime SST prior to collation to correct for residual calibration drift.

## 12-S4: On Potential Contribution of TICFIRE on HAWC/AOS Mission for SST Validation and Applications

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**Abstract**
Reliable data of Sea Surface Temperature (SST) is essential, not only for weather predictions and climate studies, but also for the accurate retrieval of aerosols, clouds and precipitation, especially over ocean. A new spectroradiometer, the Thin Ice Cloud and Far IR Emission (TICFIRE) is in preparation to join NASA's AOS satellite constellation in 2031. Design to be part of the principal observatory, AOS-Sky, a polar orbiter on a similar sun-synchronous orbit than EarthCARE and the A-Train, TICFIRE aims to measure on 8 bands from 4 to 73 µm wavelengths as an imager at about 2 km resolutions, over a swath larger than 50 km. Two other Canadian instruments, the Aerosol Limb Imager (ALI) and the Spatial Heterodyne Observation of Water (SHOW) will join as a companion satellite (HAWC) to focus on the UTLS water vapor, aerosols and tenuous clouds. There will be strong synergies between active (lidar and Doppler radar) and passive instruments (polarimeter, microwave and Far IR radiometers) to accurately probe radiation, clouds, aerosols, and precipitation. The relevance with SST is multifold. Primarily, the detailed retrieval of extensive and tenuous ice clouds and aerosols might help improve surface IR brightness temperature (mostly around 11 µm), which may serve either as a complementary information for SST or as a verification application on data quality. Alternatively, SST will be used to better constrain lower boundary conditions for atmospheric variable retrieval. We expect that closure experiments will be enhanced between multiple instruments observations and model reconstructions of SST.

# 17-S4: Assessing the impact of additional L4 analyses in the Met Office GMPE product

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**Abstract**
The Met Office GHRSST (Group of High Resolution Sea Surface Temperature) Multi-Product Ensemble (GMPE) product has been developed to provide the median and standard deviation of the participating L4 SST analyses and a form of intercomparison between those analyses: the anomaly field for each L4 analysis relative to the GMPE median is provided on consistent grid and also SST gradient fields. Recent work has investigated the impact of three proposed changes to the participating L4 analyses: the re-inclusion of NCEI AVHRR OI, the addition of Ifremer ODYSSEA analyses from CMEMS, and the potential replacement of MUR 0.01 with MUR 0.25. The quality of the GMPE median and the participating L4 analyses are assessed using Argo observations. Argo data from the SIRDS (SST CCI Independent Reference Data Set), which is extracted from the Met Office HadIOD dataset, are used. Statistical analysis using Argo data is performed for two pre-operational trials in December 2022 – February 2023 and June – August 2023 to account for seasonal variabilities. Differences in the SST gradients are investigated and the potential impact of using Argo in L4 analysis production will be discussed. It is intended that the changes will eventually be added to the operational GMPE product.

# 20-S4: SOFS SST applications: validation of IMOS nighttime Geo-Polar Multi-Sensor L3S skin SST and investigation of SST fronts in the Southern Ocean

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**Abstract**

The Southern Ocean Flux Station (SOFS) is currently the only operating mooring in the Southern Ocean (142°E, 47°S) which is known for extremely windy and harsh conditions. As part of the Southern Ocean Time Series (SOTS) project funded by the Australian Integrated Marine Observing System (IMOS), SOFS has been collecting near-surface met-ocean observations, including sea surface temperature (SST) at ~ 1 m depth, since March 2010. The high-quality, longer than a decade time series of SST were used to validate the IMOS nighttime Geo-Polar Multi-Sensor L3S skin SST reprocessed by the Australian Bureau of Meteorology. The L3S SST product is constructed using composition of the skin SST retrievals from infra-red radiometers on various geostationary and polar-orbiting satellites and is available on the 0.02 degree grid over the Australian domain for 2015-2022. The location of SOFS is within the Sub-Antarctic Zone (SAZ), which is defined as the area between the Subtropical Front (STF) and Sub-Antarctic Front (SAF) with active ocean fronts. Spatial-temporal variations of SST were studied in detail using the high resolution (1-minute) SOFS data in search of SST frontal activities. Preliminary results indicate that SST may differ by up to 3.5°C across a region as narrow as 35 km, as illustrated by the concurrent SST data from two nearby moorings.

## 21-S4: Cross-calibration of Himawari-9 SST for improved assessment of AMSR2 SST

**Submitting author/speaker (Name and Surname):** Yukio Kurihara
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**Abstract**

The AMSR series, a series of micro-wave sensors developed by JAXA, plays an important role in remote sensing of SST, as well as optical sensors onboard satellites. The strongest advantage of the AMSR is the observations less affected by clouds. Meanwhile, it has a weak point of a low spatial resolution. Although the nominal spatial resolution of the AMSR2, currently operating, is about 50 km at 6 GHz, the actual spatial resolution of the retrieved SST could be lower than this; this is due to retrieval uncertainty and so on.

Knowing the actual spatial resolution is essential for the utilization of SST by the AMSR series for studies of a phenomenon with a wide range of temporal-spatial scales. We are currently assessing the actual spatial resolution of the AMSR2 by comparison with Himawari SST which is observed via Japanese geostationary meteorological Himawari satellites. The assessment accuracy depends on three main factors, i.e., the assessment method, the random noise and striping noise in the AMSR2 SST, and the accuracy of the Himawari SST. To improve the assessment accuracy, we are now studying the method for denoising and destriping of AMSR2 SST and the way for improving Himawari SST.

The Himawari satellite was switched from Himawari-8 to -9 in 2023. However, the initial Himawari-9 SST was slightly lower than buoy data. As a part of the improving Himawari SST, we calibrated Himawari-9 thermal infrared data by using SGLI as a reference observation. The result shows that the cross-calibration improves the SST.

## 30-S4: Derivation and Validation of over two decades of skin SST retrievals from MODIS on Terra and Aqua

**Submitting author/speaker (Name and Surname):** Peter Minnett

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**Abstract**

Over two decades ago, NASA launched a series of satellites in the Earth Observing System, including Terra and Aqua, each of which carries a MODerate Resolution Imaging Spectroradiometer (MODIS). These instruments are still functioning well and thus provide long time series of skin sea-surface temperature (SSTskin), although the original orbits are no longer maintained and are drifting slowly impacting the time of day of the measurements. To facilitate the assessment of the accuracy of the SSTskin derived from the MODIS measurements, which is limited by the accuracy with which the effects of the intervening atmosphere can be corrected, NASA supported the development and deployment of a series of high-accuracy ship-board Fourier-Transform Infrared interferometers to take near-surface measurements for the derivation of SSTskin. The ship-board instruments, the Marine-Atmospheric Emitted Radiance Interferometers (M-AERIs) have been deployed at sea essentially continuously through the MODIS era. In addition, In addition, the validation of MODIS retrievals by comparisons with the greater number of drifters and moorings has continued throughout the missions..

During the COVID pandemic, many ships were idled, and updates on the post-COVID deployments of the M-AERIs will be given.

We will cover the accuracies of the SSTskin derived from the MODIS data, including regional and temporal characteristics.

# 31-S4: Monitoring of radio frequency interference (RFI) signals in AMSR2 C-band brightness temperature and preparation for future AMSR3

**Submitting author/speaker (Name and Surname):** Misako KACHI
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**Abstract**

JAXA has operated a series of microwave imagers, the Advanced Microwave Scanning Radiometer (AMSR) series, with 6.925-GHz band, which has a sensitivity to SST and soil moisture at the surface since May 2002. The 6.925-GHz band is not primarily allocated for Earth Observation but is defined as the primary band for ground-to-satellite radio communications. Therefore, AMSR-E on board the NASA's Aqua satellite, the first generation of AMSR series, had frequently experienced large radio frequency interference (RFI) signals in 6.925-GHz brightness temperatures, especially over land area. These RFI signals in 6.925-GHz channels have impacted not only to estimation of soil moisture content but also to SST retrievals near the coast and over open ocean. In AMSR2 on board the GCOM-W satellite, the second generation and launched in 2012, we introduced new 7.3-GHz channels to help mitigate RFI influences in C-band. Simple RFI/possible RFI detection method is introduced to Level 1 Ver.2 algorithm in 2013, and we continued monitoring of RFI signals in C-band brightness temperature using 6.925- and 7.3-GHz channels more than 11-year. Variation of RFI occurrence and distribution during 2012-2023 will be reported at the meeting. JAXA is currently preparing the launch of AMSR3 onboard the GOSAT-GW satellite in JFY2024. AMSR3 will have additional 10.25-GHz channels with better NEDT along with original 10.65-GHz channels. The 10.25-GHz channels are expected to help detection of RFI signals in both C- and X-band brightness temperature as well as improved SST retrievals using 10.65-GHz channels with higher resolution compared to that by 6.9-GHz channels.

# 34-S4: Improved Surface Currents from Altimeter-Derived and Sea Surface Temperature Observations: Application to the North Atlantic Ocean and intercomparison of the OSTIA L4 NRT and REP products

**Submitting author/speaker (Name and Surname):** Daniele Ciani
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**Abstract**

The marine currents are key for understanding the ocean–atmosphere system, impacting its short-term and long-term dynamics. Monitoring the ocean currents is crucial for understanding heat and salt transport, aiding predictions on the marine ecosystems and supporting maritime activities such as safe navigation and the monitoring of marine debris.

In this study, we introduce a methodology for reconstructing ocean surface currents by merging Level-4 (L4, gap-free) geostrophic currents derived from altimetry data and satellite-derived sea surface temperatures (SST). Building upon prior research on the multivariate reconstruction of geostrophic currents from satellite observations, we regionalized and optimized an algorithm to improve the altimeter-derived surface circulation estimates in the North Atlantic Ocean. This involved a comparative assessment of the Copernicus OSTIA near real-time and reprocessed L4 SSTs.

A ten-year-long surface currents time series (2010–2019) is presented and validated by means of in situ observations. The newly optimized algorithm allowed us to improve the currents estimate along the main axis of the Gulf Stream and in correspondence of well-known upwelling areas in the North Eastern Atlantic, with percentages of improvement around 15% compared to standard operational altimetry products (quantified via inter comparisons with in-situ measured currents). In general, such methodologies constitute an indirect validation tool for L4 SST products. Our findings indicate improved overall performances with the inclusion of OSTIA L4 reprocessed SSTs.

# 38-S4: Selection, in-situ calibration, and minimum coverage of a GHRSST product for the monitoring of the Canadian Atlantic Zone

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## Abstract

SST from AVHRR is routinely used in climate state of ocean reporting, as is done by Fisheries & Oceans Canada's Atlantic Zone Monitoring Program. Criteria for selection of an SST product are presented (long term climatology, real-time availability, no filtering out of regional upwelling or mixing). Day and night composites are combined into daily composites that are adjusted against in-situ observations from oceanographic buoys. The 0.2 to 0.4C adjustment is necessary in order to blend two products in order to achieve a long term climatology close to the standard 30 years. Since AVHRR SST data have many spatial and temporal gaps, a common difficulty is establishing how much data are sufficient to yield useful estimations of temperature anomalies. A statistical Monte Carlo method showed that monthly regional averages composed of as little as 7% of possible data still yield useful results, resolving half the standard deviation of interannual variability. Results are shown for Canada's Atlantic zone, showing a warming trend and strong inter-annual correlation with air temperature.

# 39-S4: NOAA ACSPO V2.80 THERMAL FRONTS PRODUCT

**Submitting author/speaker (Name and Surname):** Irina Gladkova
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**Abstract**

NOAA produces thermal front products from high-resolution low earth orbit (LEO: NPP/N20/N21 VIIRS, Terra/Aqua MODIS, Metop-A/B/C AVHRR FRAC) and geostationary (GEO: G16/17/18 ABI; H08/09 AHI) sensors in L2P (swath) projection and 0.02o gridded Level 3 products of various types: uncollated, collated, and super-collated. Two fields are reported in ACSPO v2.80 – the binary front position and the rate of temperature change in physical K/km units.

The subject of thermal front detection is not new, but the conventional front detection approaches assume clear sky conditions. In ACSPO, a set of tests was developed, which use gradients of brightness temperature bands as well as logical decisions based on the local shape and complexity of the gradient ridge throughout the estimated connected path along the thermal front, to distinguish oceanic thermal features from temperature contrasts at the cloud boundary. The rate of change is calculated using a 5x5 differential filter designed for noisy imagery.

The quantitative evaluation of SST gradients derived from noisy satellite measurements is a challenging task. A dense network of in situ SST data from traditional ships provide the measurements on both sides of the thermal fronts but these in situ measurements are usually at a coarser spatial resolution than satellite-derived, also noisy, and recorded at a coarse quantization level. NOAA has been deploying newer technology like SailDrones, which have potential for higher spatial resolution in situ measurements across SST fronts. We will present a quality assessment of the matchups between ASPO L3S-LEO-AM/PM products and in situ data in the vicinity of the thermal fronts and show comparison examples when in situ paths intersect dynamic regions with strong thermal variations.

## 40-S4: Simplifying and Improving in situ Skin Temperature Measurements

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**Abstract**

Some two decades ago, the need for in situ measurements to validate satellite-based SST products led to the development of reliable shipboard radiometer systems with a nominal accuracy of ± 0.1 °C. The general approach has been to use a single radiometer with a mirror to measure both the sea and sky and provide a two-point calibration using hot and ambient temperature blackbodies. However, the complexity and expense of this approach have resulted in relatively limited observations. The improved stability of commercially-available radiometers over the past two decades suggests that a simplified design may be feasible.

Results are presented using IRISS (Infrared Instrument for Sea Surface Temperature), a new instrument design which eliminates the need for a mirror by using separate radiometers to measure the sea and sky and a one-point ambient temperature calibration of the sea radiometer only. In addition to reduced complexity and cost, this approach allows measurements in conditions of rain and sea spray. IRISS is compared to measurements using two ROSRs (Remote Surface Ocean Radiometer) on the 2022 S-MODE cruise 100 km off the coast of California near San Francisco. IRISS is shown to agree with the ROSRs to ± 0.1 °C.

Also, results are presented using a version of IRISS with a spectral band in which the reflected sky radiation is from a few kilometers of the ship and thus minimally affected by clouds. This approach minimizes the difference between the brightness and skin temperatures, which reduces the effect of uncertainty in the emissivity.

## 41-S4: ECOSTRESS Calibration and Bias Correction by In-Orbit Comparison with CrIS and IASI

**Submitting author/speaker (Name and Surname):** David Wethey
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**Abstract**

ECOSTRESS is a push-whisk instrument with 5 infrared bands centered on 8.28, 8.78, 9.20, 10.49, and 12.09 μm. Radiance calibration on orbit is achieved with two onboard black bodies at temperatures of 293 K and 319K that are imaged on each mirror rotation. ECOSTRESS Collection 1 data has ~1 K temperature bias relative to in-situ land and ocean observations and VIIRS retrievals. The bias was partially corrected with linear gain and offset coefficients applied to the channel radiances in ECOSTRESS Collection 2, but biases still exist in Collection 2, among individual detectors along the focal plane array.

Hyperspectral data from collocated Crosstrack Infrared Sounder (CrIS) and Infrared Atmospheric Sounding Interferometer (IASI) observations were used to improve on-orbit calibration of individual pixels in the ECOSTRESS focal plane array. Sounder spectra were convolved with the spectral responses of ECOSTRESS channels and compared to retrieved radiances of pixels within the Sounder fields of view (FOV). We used only homogeneous FOVs where the standard deviation among ECOSTRESS brightness temperatures (BT) was less than 0.3 K. The negative parabolic distribution of 10.49 μm BT bias along the focal plane is consistent with the pattern of retrieved temperature bias. Correction of the 10.49 μm BT bias pattern should reduce striping and checkerboard artifacts in ECOSTRESS SST, supporting our plan to produce a split-window GHRSST compatible SST for archiving at PODAAC.

## 43-S4: A reprocessing of 1km Level 1 data from AVHRR HRPT archives and of the (A)ATSR series

**Submitting author/speaker (Name and Surname):** Jonathan Mittaz
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**Abstract**
From early 2024 two new projects are starting which will provide reprocessed data at 1km resolution from both the AVHRR as well as the (A)ATSR sensor series with the aim of providing uniformly processed data records together with pixel level uncertainties (random and systematic) as well information on other error correlations such as channel-to-channel covariances. The AVHRR data itself comes from 1km HRPT archives over Europe and will also include HRPT archives from Kenya, South Africa and Argentina which have been recovered by ESA. Updates to pyGAC, a python package to read AVHRR data, will also be made which will enable users to access uncertainty information from their own AVHRR data. The second project is to undertake a further reprocessing of the complete (A)ATSR Level 1 archive which will also include uncertainty information as part of the output. This project will also recover and assess the (A)ATSR pre-launch data which is needed to provide traceable uncertainties. Here we will show the planned improvements and updates for both sensor series along with the planned uncertainty analysis.

## 45-S4: Contribution of SLSTR datasets from Sentinel 3A and Sentinel 3B to CMC SST analysis

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**Abstract**
The SLSTR instrument on bord Sentinel 3A and Sentinel 3B provides data continuity from previous instruments ATSR on ERS-1, ATSR-2 on ERS-2 and the AATSR on Envisat. At CMC, data from ATSR, ATSR-2 and AATSR have been used for CMC reanalysis produced for the period 1991-2011 and available from PO.DAAC.
Compared to his predecessors, SLSTR provides equivalent or better performance such as an increased dual view swath, a nadir improved resolution and a higher lifetime design. SLSTR data used in CMC SST analysis are obtained from EUMETSAT in L2P GHRSST format.
Experiments are carried out to assess the potential contributions of SLSTR datasets onboard Sentinel 3A and Sentinel 3B satellites to the quality of global sea surface temperature (SST) analyses. The new datasets are assimilated both separately and together AVHRR, VIIRS and AMRS2 satellite retrievals. Verification against independent data shows that the analysis performs well compared with the operational version. The impact of the new datasets in coastal regions and over the continental waters are also measured.

## 50-S4: Relative Performance Assessment of the Operational SST Products from INSAT-3D and 3DR Imagers

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## Abstract

India launched two geostationary satellites INSAT-3D and 3DR on July 2013 and September 2016, respectively. Both satellites have two identical meteorological payloads namely 6-channels Imager and 19-channels Sounder operating in the optical and infrared regions of the electromagnetic spectrum. Currently, more than 30 important geophysical parameters like sea surface temperature (SST), precipitation, cloud motion vectors, fog, smoke, fire, etc. are being generated operationally from Imager observations of both satellites, which are disseminated regularly through Meteorological and Oceanographic Satellite Data Archival Center (MOSDAC) portal of Space Applications Centre, Ahmedabad, India. The present study aims to assess the relative performances of the operational SST products from INSAT-3D and 3DR Imagers. The evaluation is carried out by comparing the yearlong SST products of INSAT-3D with INSAT-3DR SST for 2023. The inter-comparison shows the negligible errors between the two SST products with 0.4K uncertainty for the entire period. It infers that the operational SST products from INSAT-3D and 3DR are consistent with each other and may be used for further applications and marine process studies.

## 51-S4: SST and Combined SST/IST Products Overview: DMI's Contribution to Copernicus Marine and Climate Change Services

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**Abstract**
The Copernicus Marine Service (CMS) and Copernicus Climate Change Service (C3S) are responsible for complementary reprocessing activities using satellite ocean observations. CMS encompasses reprocessing at global and regional scales of all satellite observations including all observations available at a given time (reprocessing of Essential Ocean Variables, EOVs). C3S fosters climate reprocessing, typically at global scale, with special focus on the most accurate observations and homogeneous time series (reprocessing of Essential Climate Variables, ECVs). The Danish Meteorological Institute (DMI) serves as a Production Unit (PU) for the Sea Surface Temperature (SST) and Sea Ice (SI) Thematic Assembly Centers (TAC) of CMS and the SST ECV of C3S. Within both frameworks, a suite of L3S and L4 SST and combined SST/IST products for the Baltic and North Sea (CMS), Pan-Arctic (CMS) and Global Ocean (C3S) are produced. Nearing the end of Phase 2 of the project at the end of 2024, a range of evolutions have been implemented over the last three years, from releases of new products to improvements on existing ones.
The aim of this presentation is to provide an overview of the existing and new products and their quality and applicability, along with a summary of the recent advancements on the products implemented during the period 2022-2024.

## 55-S4: Multidimensional dynamic data fusion of satellite geophysical datasets: Application to Level 3 Sea Surface Temperature from MSG/SEVIRI and impact on derived gradients

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**Abstract**
To study Sea Surface Temperature (SST) variations over a broad range of timescales, synoptic datasets are typically time-averaged into daily, weekly or monthly Level 3 composite maps. While particularly beneficial for high temporal resolution sensors such as MSG SEVIRI, such compositing methods may introduce artifacts due to the SST temporal variability, undetected clouds, persistent cloud coverage or uncertainties in Level 2 retrieval algorithms. The resulting spatial discontinuities affect downstream applications such as the spatio-temporal analysis of SST gradients . In this study, ORBTY's Multidimensional Dynamic Data Fusion Systen (M3DFS) was applied to MSG SEVIRI hourly SST to generate daily single-sensor Level 3C SST. In addition to statistical validation with in situ measurements, we illustrate the impact of using the M3DFS on the spatial distribution and temporal variability of SST gradients.

## 60-S4: Observations of Oceanic Skin and Bulk Temperatures in the Seas Surrounding the Korean Peninsula and the Northwest Pacific Using ISAR

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**Abstract**

Temporal variations in oceanic surface temperatures are influenced by a myriad of factors emanating from both the marine environment and the atmosphere, presenting a complex vertical dynamic that has been the focus of extensive research over recent decades. Efforts to elucidate the underlying mechanisms and structural variations of these temperature shifts have led to significant advancements in observational methodologies, notably through the deployment of the Infrared Sea surface temperature Autonomous Radiometer (ISAR). Despite the global scope of such research endeavors, the regions surrounding the Korean Peninsula have hitherto been underrepresented in observational data. Addressing this gap, our study utilizes the ISABU, a representative Korean research vessel, to conduct comprehensive ISAR-based observations of skin surface temperatures. This endeavor spanned from October 27 to November 16, 2023, planning a cruise from the southern coast of Korea, across the East Sea, through the Tsugaru Strait into the Northwest Pacific, subsequently traversing the Kuroshio Current, veering westward past southern Japan, and circling back through the East China Sea and Korea Strait. Accompanying these ISAR observations were simultaneous recordings of wind speed, direction, and atmospheric conditions, alongside thermosalinograph-observed temperature data, thus providing a view of the oceanic and atmospheric interactions. Comparative analyses with AMSR2 SST datasets further enriched our understanding, unveiling the intricate interplay between wind-induced effects and the diurnal variations of the skin-bulk temperature differences. This study is expected to not only help understand the process of skin-bulk temperature change in Northeast Asia and the Northwest Pacific, but also improve sea surface temperature retieval studies using Korea's geostationary satellite data. It highlights the need for continued ISAR observations in line with ISABU 's upcoming cruises.

# 70-S4: Error models for ICOADS SST from ships and moorings based on ESA CCI SST Analyses

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**Abstract**
Previously reported (at GXXIII) method for constructing error estimates of 1x1 degree monthly bin averages of SST observations from ships (ICOADS, Release 3.0) was tested and generalized by its application to the SST observations from moored buoys. Recall that the method is based on the in situ data comparison with daily 6x6 km fields of the ESA Climate Change Initiative (CCI) SST Analysis product (CCI SST) and takes advantage of this product's high spatial resolution, reliable uncertainty estimates, and its independence from the concurrent in situ data. A principal difference between typical sampling schemes of global SST data sets from ships (irregularly distributed observations concentrated along ship tracks) and moorings (regular observations at a relatively small number of spatial locations) required some methodological modification. While in the previous work ship observations were successfully treated as if they were quasi-randomly distributed within the volume of 1x1 degree monthly bins, this assumption could not be used with the moorings data. However, by varying bin sizes between 0.05 degree (the CCI SST resolution) and 5 degree and by estimating separately temporal and spatial SST variability within bins (further use of the CCI SST analysis), measurement error estimates for the SST observations from moorings, as well as the estimates of the error in their bin averages were constructed. The obtained estimates were validated by their consistency checks with previously obtained error estimates for bin averages of ship SST data.

## 74-S4: A Cloud-Native SST Monitoring Pipeline and Dashboard

**Submitting author/speaker (Name and Surname):** Garrett Graham
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**Abstract**
Sea surface temperatures (SSTs) are a critical environmental parameter in Earth system science, influencing meteorological and climate models. Many nations generate SST datasets using diverse data assimilation techniques and differing data sets, leading to discrepancies among these high-quality products. Real-time statistical intercomparisons are essential to understand these differences. However, the computational complexity of such analyses increases significantly with the number of datasets. Cloud computing provides a scalable solution with its on-demand compute power, storage, and networking capabilities.
We present an automated SST intercomparison pipeline built using serverless compute instances within Amazon Web Services (AWS). Our pipeline computes difference statistics for six internationally recognized global gridded SST products (CMC, GAMSSA, GeoPolar-Blended, MUR, OISST, OSTIA) against in situ data, supporting both native and unified 0.25° resolutions. This cloud-native AWS pipeline serves as a valuable tool for the SST community and a potential template for researchers facing limitations with on-premises computational resources.

## 61-S4: A new parameterization for oceanic diurnal warming

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**Abstract**

The ocean surface undergoes a diurnal cycle of heating which may be several kelvin in magnitude under conditions of high insolation and light winds. Oceanic diurnal warm layers have been extensively studied over the years due to their important role in a variety of geophysical disciplines. Much of this research has been dedicated to the development of predictive models of varying complexity to calculate the spatiotemporal magnitude of the effect. Optimal combination of sea surface temperature data from different satellite instruments requires accounting for the magnitude of the cycle at each observation time throughout the day. We present results which show that significant variability can be accounted for by addressing the combined impacts of atmospheric water vapor and solar zenith angle on both the spectral distribution of insolation energy at the water surface and its subsequent absorption within the water column. Comparisons with satellite-observed diurnal amplitudes on the basin-scale show that the new scheme provides notable improvements over one with a fixed insolation parameterization. The improved model will be integrated into the operational processing chain for the Geo-Polar Blended SST, and the code and documentation will also be made available to Eumetsat under the EUMETSAT-NOAA Science cooperation project. Finally, model output and satellite diurnal warming observation datasets will be made available to the wider scientific community, along with model code and documentation.

# Science Session S5 – Advances in Computing and Products

This session is dedicated to new and evolving approaches of computing techniques for GHRSST data product formulation, validation and scientific investigation.
Results using methodology and workflows applying Artificial Intelligence and Machine Learning for SST products and analysis are encouraged.
This session will also emphasise cloud computing and storage, optimization of formats and processing software for the cloud, and parallel computation approaches.
The session will focus on the following:

- Challenges and advances in various computing techniques
- Artificial Intelligence and machine learning applications
- Challenges and advances cloud computing and storage technologies

**Keywords:** Computing, parallel computing, cloud computing, cloud storage, data formats, SST products and validation, Artificial Intelligence, Machine Learning

# Abstracts: Science Session 5 – Advances in Computing and Products

## 10-S5: Improvements to the NOAA iQuam System: Enhancing Data Completeness and Quality

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**Abstract**

The in situ SST Quality Monitor (iQuam; currently version 2.1) was established at NOAA in 2009 to support the Cal/Val of NOAA satellite SST products. The iQuam gathers in situ SSTs from various sources, performs quality control (QC), monitors the QC'ed data online, and provides the data to users. For each platform, iQuam collects data from several independent sources, to provide redundancy and maximally complete coverage. This presentation outlines planned iQuam v2.2 updates, which include additional sources of in situ SST data and revised QC algorithm.
The iQuam 2.2 adds support for two new data sources, International Comprehensive Ocean-Atmosphere Data Set (ICOADS) and Copernicus Marine Environment Monitoring Service (CMEMS). This greatly improves data completeness for drifting buoys, ships, coastal moorings, and tropical moorings, addressing several notable data gaps observed in iQuam v2.1. Support of NCEP GTS in iQuam was discontinued due to its omission of recent drifter data with 7-digit IDs.
The iQuam 2.2 QC incorporates the Diurnal Reference Check (DRC), designed to address the overscreening in areas experiencing intense diurnal warming and in dynamic regions. The DRC applies to the platforms whose sampling frequency is high enough to capture the diurnal signal in in situ SST. This includes the majority of drifting and moored buoys and a number of ships. In contrast to the previous QC methodology, the DRC utilizes the 'foundation' Level 4 (L4) SST

analysis exclusively for QC'ing nighttime SSTs, while daytime SSTs are checked against the median nighttime SSTs.
NOAA plans public release of the iQuam v2.2 in late 2024.

# 25-S5: Deep learning methods for Super Resolution of satellite derived Sea Surface Temperature data over the Mediterranean Sea

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**Abstract**
Sea surface temperature (SST) is an essential variable within the Earth's climate system and its accurate estimation and systematic monitoring from space are of crucial importance. Despite the superior coverage provided by satellite infrared measurements compared to in situ platforms, their inability to observe the sea surface under cloudy or rainy conditions results in significant data gaps even in merged multi-sensor satellite products. To obtain gap-free (L4) images various statistical strategies have been proposed, primarily relying on the Optimal Interpolation algorithm. However, these techniques tend to filter out signals below the considered space-time decorrelation scales, thereby smoothing out most of the mesoscale and submesoscale features. In this context, we explore the achievements and the limitations of applying deep learning models, originally developed for single-image Super Resolution, to enhance the effective resolution of SST products and improve the accuracy of SST gradients. A dilated convolutional multi-scale learning network, including an adaptive residual strategy and a channel attention mechanism, is employed to reconstruct features of SST data at spatial resolution of 1/100°, starting from 1/16° data over the Mediterranean Sea. Subsequently, we compare these findings with those obtained using a Generative Adversarial Network (GAN) solving the same task. Here, the generative convolutional neural network is pitted against a discriminator model, whose only job is to distinguish true samples from the reconstructed images. The competition between the two networks drives them to improve their outputs until the super-resolved samples are indistinguishable from the real ones.

## 29-S5: Recent Advances in Applications of Cloud Computing and Cloud Data Optimization

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**Abstract**
GHRSST sea surface temperature (SST) data served from the NASA PO.DAAC have found a new permanent home in the Amazon Web Services (AWS) Cloud. As we have gained more experience working with SST and other oceanographic data in the cloud we present a follow-on to last year's presentations with the latest applications of cloud computing and data container optimization strategies. First, we present new material demonstrating parallel computing methods to process GHRSST data in the cloud. While the method utilizes Dask along with a cluster of AWS EC2 instances, the details are abstracted using a third party software library called Coiled. Coiled has shown to be an easier user pathway for leveraging cloud parallel computing, although there is some cost to incur. Secondly, we will also update on our experiences and roadmap using AWS Lambda and related services to perform large scale SST cross-comparison time series calculations. Finally, there are new advances in understanding how to optimize the netCDF container for cloud object store and computing that will be important for new and on-going GHRSST datasets. A set of recommendations and best practices for data producers will be presented on this topic. Other competing strategies like Zarr and Kerchunk will also be discussed. The cloud is a rapidly evolving compute environment and the GHRSST community should stay abreast of this new frontier to take better advantage of its capabilities.

## 31-S5: Updates to the PO.DAAC Cloud Data and Services Ecosystem

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**Abstract**
Given that the PO.DAAC has 100% transitioned into the NASA Earthdata Amazon Web Services Cloud, establishing a new era for NASA's earth data archiving and distribution system, it is imperative that the GHRSST community adopt the growing tools and services within the Earthdata Cloud ecosystem into their science workflows. In this presentation we will inform on the latest improvements and capabilities of this services stack including updates to the podaac-data-downloader/subscriber tool, new harmony services for data manipulation and transformation, and updates to other legacy interfaces like SOTO, MCC and HiTIDE. Harmony is a NASA enterprise collection of services that enable users to discover and access Earth observation data from 12 different NASA data centers. The Harmony APIs encompass services for subsetting, Zarr reformatting, regridding, and more. Many of these services are documented in the PO.DAAC cookbook (https://podaac.github.io/tutorials/) , an online repository of data recipes and tutorials that can be directly utilized in typical science workflows, and serve as a foundation for learning and cloud adoption. The cookbook also contains specific recipes using GHRSST data (see https://podaac.github.io/tutorials/quarto_text/GHRSST.html).

# 54-S5: 4DVarNet-SST: Neural Data assimilation schemes for the production of L4 NRT SST product on the North Sea/Baltic Sea

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**Abstract**
The Danish Meteorological Institute (DMI) serves as a Production Unit (PU) for the Sea Surface Temperature (SST) Thematic Assembly Center (TAC) of the Copernicus Marine Service. Within this framework, a suite of L3 and L4 SST products for the Baltic and North Sea are produced daily and as multi-year products. The L4 Near-Real-Time (NRT) SST SST_BAL_SST_L4_NRT_OBSERVATIONS_010_007_b is a daily, multi-sensor, level 4 optimally interpolated product using night time SST at high resolution (0.02°), covering the Baltic and North Sea, generated with the operational Optimal Interpolation system at DMI (DMIOI). It is based on the SST_BAL_SST_L3S_NRT_OBSERVATIONS_010_032 which uses various satellite SST level 2 data as input, that have passed a significant number of quality controls, and are inter-calibrated and bias corrected.
The 4DVarNet Deep Learning algorithm, backboned on variational data assimilation and already used with model-based training for SSH applications, and also applied on realistic datasetswas, was trained directly using the L3S SST product for the years 2019-2020 with the aim to finally generate the L4 SST product for the year 2021. A benchmarking experiment with the L4 SST product generated using the standard DMIOI system is built in which SLSTR, i.e. a sensor originally used the L3S and L4 SST products, is kept for validation. Preliminary results indicate that 4DVarNet is able to reproduce the physical features on the SST field, may locally improve the OI-derived interpolation while considerably speeding up the production of the L4 SST products, which paves the way to fast analysis, NRT and and short-term forecasting products in the near future.

# 65-S5: Bias Correction of Satellite Sea Surface Temperature using Machine learning algorithms

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**Abstract**
Within the atmosphere-ocean coupled Earth system, sea surface temperature (SST) is a fundamental oceanic parameter for understanding and forecasting the ocean weather system. As global warming increases, consistent long-term SST data is essential both for accurate monitoring of climate change and observations of anomalies in near-real-time.
Since the early 1980s, satellites have been used to measure SST in areas around the world. The Advanced Very-High-Resolution Radiometer (AVHRR) instrument is the only sensor covering the entire satellite era, thus being able to estimate and correct for biases in the data is critical for the long-term record. Recent advances in knowledge, ancillary data, and improvements in the in situ network allow the development of bias correction methods that may then be adapted to earlier periods where direct adjustment of the data is more challenging due to the sparsity of in situ data. Aside from the greater availability of in situ and other ancillary data, the Meteorological Operational Satellite Program (MetOp) platforms maintain a consistent equator crossing time orbit through active orbit control, thereby reducing effects seen in earlier NOAA platforms. The superior stability of MetOp AVHRR data allows our initial research to focus on addressing more fundamental aspects of retrieval error. The results of this study suggest that the application of machine learning algorithms, in combination with appropriate predictors from ancillary data, can be effective in accounting for the various causes of bias that are enmeshed in empirically derived SST algorithms and products.

## 66-S5: Progresses in NCEI's Sea Surface Temperature Products

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**Abstract**
NCEI produces two kinds of sea surface temperature (SST) products. One is based on historical in-situ observations and named as Extended Reconstructed Sea Surface Temperature (ERSST). ERSST has the time resolution of monthly and a spatial resolution of 2x2-degree global grid. It is a centennial scale time scale product for long term climate monitoring and research, starting from 1854 to present. The in-situ data are from observations of ships, surface drifting buoys, moored buoys and Argo floats. The 2nd SST product NCEI produces is the higher resolution SST, utilizing integrated use of satellite and in-situ observations, named as the Daily Optimum Interpolation Sea Surface Temperature (OISST or DOISST). Satellite observations provide higher spatial resolutions while high quality in-situ observations provide ground truth for long term climate consistency. In this presentation, we describe our recent progress in both ERSST and OISST. On the methodology side, AL/ML methods have been investigated to improve the accuracy and spatial variability over the long used traditional EOF/EOT methods, which showed promising results. On the data side, we expanded data from AVHRR satellite observations to multiple-sensor multi-satellite observations. We are also making our data output as AI/Cloud ready for the ease of the user community. Details will be discussed at this presentation.

# 73-S5: A Deep Learning Approach to Satellite Bias Correction in Level 4 Data Assimilation SST Products

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**Abstract**
Data assimilation algorithms for global sea surface temperature (SST) estimation depend on both in situ and satellite observations. Satellite-derived SSTs exhibit biases that necessitate correction using various statistical methods. NOAA's Optimum Interpolation Sea Surface Temperature (OISST) v2.1 utilizes empirical orthogonal teleconnections (EOTs) for large-scale bias correction. However, EOTs may be less effective in correcting localized biases, particularly in regions of sparse in situ coverage. Deep learning offers a promising alternative for bias correction. In this work, we present a ResNet-ConvLSTM deep learning network designed to correct gridded satellite SST observations for use within SST data assimilation algorithms. We benchmark its performance against other deep learning architectures employed in similar in-painting and super-resolution tasks.

# 75-S5: Fast Simulation of Infrared Atmospheric Optical Depth Based on Neural Network

**Submitting author/speaker (Name and Surname):** Mingkun Liu
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**Abstract**

Atmospheric radiation transfer model (RTM) is the foundation and core of the physical retrieval of atmospheric and surface parameters in remote sensing as well as the assimilation of satellite observation data. Infrared RTM is widely used in the retrieval of Earth surface temperature, cloud detection, and water vapor remote sensing. This paper is committed to exploring the fast and accurate simulation of atmospheric radiation transfer over the ocean using deep learning algorithms, with the key issue being the fast calculation of atmospheric optical depth. We have constructed a Neural Optical Depth Model (NODM) for atmospheric radiation transfer simulation from thermal infrared channels, and applied it for VIIRS M15 and M16 channels. The multilayer perceptron (MLP) is used to predict OD. We employ more sophisticated predictors as features for the MLP input. These predictors include a total of 46 elements encompassing water vapor, carbon dioxide, and ozone. They are combined into a 46-dimensional vector, which is input into the MLP and used to predict OD. The comparison results with the line-by-line radiative transfer model (LBLRTM) indicate that the algorithm achieves fast and precise simulation of atmospheric radiation transfer, with the simulated brightness temperature accuracy better than 0.1K.

## 77-S5: Restoring SST gradients in level 4 GHRSST products

**Submitting author/speaker (Name and Surname):** Christopher Merchant
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*Christopher Merchant, NCEO University of Reading, Reading, UK, c.j.merchant@reading.ac.uk*
**Abstract**
Many users want gap-filled data ("level 4"). As observations are not continuous in space, because of clouds and rain and swath limits, creating gap-filled data implies interpolation. Interpolation methods propagate information across space and/or time, and therefore inevitably smooth the SST relative to the resolution of the data inputs. This is a disbenefit, but optimal interpolation systems also add benefits of reconciling (at least to some degree) the differing observational biases of different sensors in the constellation, etc, when creating a global continuous field. Nonetheless, it is unsatisfactory to see smoothed SST fields in areas where clear skies enabled much sharper ocean features to be observed at level 2 or 3. Multi-scale analysis has been one response to this, with its own strengths and weaknesses. Experiments with machine-learning downscaling have also been undertaken. This poster presents a new method of restoring gradients to a level 4 product in areas where spatially continuous observations at full resolution are available, without changing the bias properties of the SST analysis or introducing temporal smoothing.

## 78-S5: Usage trends, cloud access options, and future of GHRSST Data Holdings at PO.DAAC

**Submitting author/speaker (Name and Surname):** Suresh Vannan
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**Abstract**
The Physical Oceanography Distributed Active Archive Center (PO.DAAC https://podaac.jpl.nasa.gov/) is NASA's data center for the GHRSST datasets (https://podaac.jpl.nasa.gov/GHRSST). In this poster, we will cover GHRSST data usage trends, cloud access details, and summarize the future of GHRSST data at PO.DAAC. The usage trend details will include dataset citation metrics. We will also provide details on getting help on GHRSST datasets through tools such as user forum, cookbook etc. A key aspect of this poster is to highlight the future of data holdings at NASA/PO.DAAC. The future of GHRSST holdings needs active discussion as sensors such as MODIS will eventually cease operations. An active conversation on future of GHRSST data holdings is needed to ensure the needs of the SST research and applications community are met.
We will also provide details specific to accessing GHRSST data within the Earthdata cloud. In 2022, PO.DAAC completed its migration of the entire GHRSST data collection to the Cloud hosted in Amazon Web Services (AWS). The vision for PO.DAAC's cloud capabilities is to enable new frontiers in SST research and applications. Users now can explore SST data directly in the cloud and also interface with the data using Application Programming interfaces (API). Transformation, Visualization, and Analysis services are available for users to explore SST data and their characteristics. A getting started tutorial using a cloud playground will be provided. While data is being delivered from the cloud all SST data from PO.DAAC will remain free and open to discover and access.