Working Group Proposal Submitted to SCOR:

Developing an Observing Air-Sea Interactions Strategy (OASIS)

May 2020

SUMMARY

This SCOR Working Group (WG) will harmonize observational strategies of several dozen OceanObs'19 community papers to create a unified vision for an Observing Air-Sea Interaction Strategy (OASIS). While OceanObs'19 led to consensus recommendations within communities, this effort will bring previously siloed communities together, under the umbrella of SCOR, to work towards the larger *UN Decade of Ocean Science for Sustainable Development* outcomes: "a predicted ocean, predicted marine weather & predicted climate"; "a safe ocean"; "a healthy & resilient ocean"; and "a sustainable & productive ocean". The strategy will follow the Framework for Ocean Observing for designing networks to meet stakeholder requirements for ocean information. Likewise, the strategy will identify where short-duration process studies are needed to advance understanding, parameterizations, and modeled and satellite representation of Essential Ocean and Climate Variables used for estimating air-sea fluxes. Focusing on air-sea fluxes of heat, momentum, moisture, important greenhouse gasses, and biogenic trace gases, and their boundary layers, the strategy will identify gaps in the current observation network and opportunities for leveraging multidisciplinary activities. Capacity will also be built through inclusion of developing countries, by identifying leveraged opportunities that connect local scales to regional scale networks. OASIS will consider air-sea-biosphere coupled processes holistically to integrate the observing system. At the strategy's core will be community building, training, and promotion of standardized methods to ensure Findable-Accessible-Interoperable- and-Reusable (FAIR) observational best practices. Ultimately, the WG will develop a practical, integrated approach to observing air-sea interactions that will allow near-realtime quantification of air-sea exchanges, with breakthrough accuracy, throughout the global ocean.

SCIENTIFIC BACKGROUND AND RATIONALE

The surface of the ocean is the portion of the ocean felt by the atmosphere, viewed from space, and experienced most directly by people and most other life on Earth. The ocean modulates the Earth's weather and climate through exchanges of heat, moisture, momentum, greenhouse gasses, aerosol precursor gases, and aerosols at the air-sea interface. Air-sea exchange can even influence the stratosphere; e.g., N_2O is now considered a major threat to the ozone layer and approximately a third of the N_2O source to the atmosphere is from the ocean. The influence of air-sea fluxes on the Earth's water cycle, carbon cycle, and energy cycle is a critical element of the support of life on Earth.

It is therefore imperative that the air-sea exchanges of heat, moisture, momentum, important greenhouse gasses, and biogenic trace gasses be monitored globally. Furthermore, because air-sea fluxes can depend upon feedbacks and interactions across disciplines and scales, to understand these air-sea exchanges and how they couple the atmosphere, ocean and biosphere, it is vital to also observe the oceanic and atmospheric boundary layer's chemical, biological, physical and geological components. These do not need to have independent observational networks. Because these different types of air-sea fluxes depend upon many of the same variables (e.g. winds, sea surface temperature,...), and upon similar turbulent and radiative processes, there is potential for considerable leveraging of observations through integration of the observing system.

The surface of the ocean is observed by satellites and a set of regional and thematic *in situ* ocean observing networks that provide essential data for addressing critical scientific, societal, policy, and economic issues. Despite many successes, the need for this oceanic and atmospheric surface and boundary layer information, across different temporal and spatial scales for different disciplines, has outstripped the capabilities of these individual networks. Making matters worse, in some regions, observations are seasonal (e.g., summer bias in polar regions), and/or have minimal integration of sensors for monitoring relevant feedbacks, and have severe funding difficulties. Indeed, whole swaths of the world's oceans do not have any *in situ* surface observations.

This WG will build on the work leading up to and following the OceanObs'19 Conference, which assembled more than 1,500 ocean scientists, engineers, and users of ocean observing technologies from 74 countries and across many disciplines. The ocean observing community submitted 140 community white papers (CWPs) with over 2500 contributing authors to OceanObs'19. More than three dozen CWPs addressed concepts associated with surface observing (see **KEY REFERENCES**), but were largely siloed by discipline, region, network, Essential Ocean Variable of interest, or stakeholder need. The proposed OASIS Working Group will integrate these recommendations into a unified vision for a multifunctional, multidiscipline, integrated observing system that allows near-realtime quantification of the air-sea exchanges, with breakthrough accuracy, throughout the global ice-free ocean.

The initial core drivers for the strategy include:

(1) **monitoring and predicting the ocean's influence on global weather and climate on timescales of days-seasons-decades** [This addresses the *UN Decade of Ocean Science for Sustainable Development* outcomes of "a safe ocean", "a predictable ocean"]. This requires improved coupled ocean-atmosphere models and sustained observations to constrain and validate their forecasts, including observations of the heat, freshwater, and momentum exchange between the ocean and atmosphere, and boundary layer processes affecting these fluxes. Model development may also require short-duration, intensive observations of processes, such the impacts of currents and waves on the turbulent fluxes and feedbacks between phytoplankton blooms, biogenic aerosol fluxes and radiative fluxes.

(2) **monitoring and predicting marine weather in the ocean and atmosphere** [*Decade* outcomes: "a safe ocean", "a predicted ocean","a clean ocean", "a sustainable productive ocean"]. This requires a subset of the same EOVs, but observed and studied at higher frequency and resolution. Improved marine weather information, including better ocean eddy, surface wave, and atmospheric boundary layer characterization would lead to improved monitoring of fisheries, open ocean biodiversity, debris (e.g., microplastics) and other pollutants; as well as better tracking for search and recovery, and protection of nearshore Marine Protected Areas.

(3) **tracking ocean uptake of carbon dioxide and oceanic deoxygenation and denitrification** [*Decade* outcomes: “a healthy & resilient ocean”, “a sustainable productive ocean”]. This effort will provide insights on the ocean’s uptake potential of atmospheric CO_2, as well as the potential of oceanic deoxygenation and denitrification over the next decade. These processes, together with consequent ocean acidification (OA), depend upon not only on the physics and chemistry of the ocean, but also interact with the biology, ecosystem and biodiversity in the ocean. Thus a core driver also includes collocating multidiscipline measurements that consider the full suite of interactions that feedback on OA and influence the development of oxygen minimum zones.

(4) **studying how biology, biodiversity, and the surface ecosystems relate to changes in surface concentrations and fluxes of CO_2, DMS, and N_2O** [*Decade* outcomes: “a healthy & resilient ocean”, “a sustainable productive ocean”]. The goal will be to provide information needed to better understand air-sea exchanges of properties and how those properties influence phytoplankton community structure and propagate throughout the marine food web. As food web models and process understanding become more sophisticated the propagation of physical feedbacks into food web interactions will need to be parameterized and accounted for. Improved predictions in this domain influence stakeholder products for harmful algal blooms, pathogens, ocean acidification, hypoxia, and fisheries impacts. This effort will be a step toward the ultimate goal of sound management of human activities to maximize societal benefits, including a robust blue economy, improved human health, protection of property, and the wise conservation of marine resources.

A system-as-a-whole approach is called for. We envision a multi-scale integrated observing system, with satellites that are optimized for marine boundary layer observations, tuned and validated against a global network of regional *in situ* platforms. Global coverage of air-sea fluxes will be achieved through consolidation and expansion of the existing networks and introduction of new sustainable ocean technologies, such as autonomous surface vehicles and a new generation of chemical, biological and physical sensors. Gridded fields at the desired spatial and temporal resolution, and required accuracy will be achieved by constraining coupled models with these observations.

This would result in a <u>sea-change increase of surface and boundary layer data</u> that would lead to revolutionary improvement in understanding of air-sea interactions and its representations in forecast models and would be used to constrain these improved numerical models for ocean, weather, and climate prediction. To realize the value of this “Big Data”, the OASIS must also build the community for making and using these data via new techniques, such as machine learning or community-based data processing software packages. The OASIS thus must also include strategies for training data providers and data users, promoting standardized methods, and ensuring Findable-Accessible-Interoperable-and-Reusable (FAIR) observational best practices.

OceanObs'19 provided an opportunity for scientists to come together to form strategy papers that would propel their communities forward over the next decade. We now want to take this a step further. Through this SCOR Working Group, we want to bring these previously siloed communities together, under the umbrella of SCOR, and as a unified ocean community, work towards *UN Decade of Ocean Science for Sustainable Development* outcomes of "a predictable ocean, predictable marine weather, and predictable climate", "a safe ocean", "a clean ocean", "a healthy and resilient ocean", "a sustainably harvested ocean", and "a transparent ocean". This can only be done by a diverse, international, multidisciplinary group of scientists, working together. We believe that this SCOR Working Group is the ideal way, and maybe the only way, to achieve this long-term legacy.

TERMS OF REFERENCE

1. **Harmonize the recommendations from the OceanObs'19 CWPs into a unified Observing Air-Sea Interaction Strategy (OASIS)** by identifying and ranking overlaps and resolving apparent contradictions, focusing on global air-sea exchanges of heat, moisture, momentum, important greenhouse gasses, biogenic trace gasses, and the multidisciplinary boundary layer variables associated with these air-sea exchanges.

2. **Produce a capacity building strategy that enables developing nations (including least developed nations and island nations) to actively participate in and benefit from local-to-global air-sea interaction observations.** This will involve a training strategy, as well as identification of opportunities for leveraging contributions by new partners.

3. **Develop and assess network designs that optimize air-sea interaction observations,** following the Framework for Ocean Observations, in coordination with OceanPredict, and other working groups focused on optimizing network design.

4. **Develop a strategy for air-sea interaction process studies** to address knowledge gaps; to improve model and satellite representation of Essential Ocean Variables (EOVs), Essential Climate Variables (ECVs), and Essential Biological Variables (EBVs) associated with air-sea interaction processes; and to develop parameterizations to relate variables that are difficult to measure with variables that can be broadly observed.

5. **Develop a strategy for assessing interoperability of surface observing platforms**. This will include intercomparisons of EOV, ECV, and EBVs observed from different platforms; development of best practices; and development of procedures to increase Technical Readiness Levels and expand technology solutions.

6. **Build community and capacity for using, operating, and developing air-sea interaction observational platforms that allow collaborative partnerships** with existing national and international air-sea interaction working groups and observational coordination groups.

WORKPLAN & 3-YEAR TIMELINE

Review of ongoing activities and OceanObs19 community recommendations (desk studies, 3-12 months): Consolidate, summarise and rank air-sea flux related recommendations delivered from the OceanObs19 CWPs. Recommendations will be grouped by topic in order to highlight commonalities. Rankings made within each CWP will be preserved and contribute to the overall ranking of the synthesized recommendation. <u>Prioritization and rankings of recommendations requires understanding the science behind the recommendation and can only be done successfully by a diverse working group of scientists, such as we have proposed here.</u>

Curriculum development for Capacity Building Institutes (3-36 months): Our members have extensive experience with capacity building activities, and one WG member will be organizing SOLAS Summer Institutes in the 2021-2023 timeframe. Thus the WG will develop a curriculum for these, that will include background science lessons, data handling and engineering training and information/training needed for participation in air-sea interaction fieldwork. In particular, the WG will develop software toolboxes and "How To" manuals for making air-sea flux observations, for calculating fluxes, and for using the fluxes. For more detail on this, see the **CAPACITY BUILDING** section below.

Assessment of recommendations addressing gaps in knowledge requiring process study research (6-24 months): This will synthesize recommendations from OceanObs19 publications, from ongoing regional and global research activities, and from gaps identified by the WG. High-resolution (e.g. hourly, <10 km), global air-sea fluxes with breakthrough accuracy will only be possible by using numerical models that combine remotely-sensed and in situ surface observations. Thus it is not sufficient to just improve the in situ observing network. We must also improve the satellite observations of surface ocean and atmospheric boundary layer variables. Likewise, we must improve numerical models. Coordinated experiments are needed to understand air-sea interactions and feedbacks, across scales and disciplines, that are currently not well resolved in numerical models. These experiments are also needed to relate remotely sensed variables to in situ environmental conditions. <u>These 'Big Science' challenges can only be undertaken through broad community interaction, consensus and sharing of resources.</u>

Assessment of interoperability of different observing platforms (12-24 months): There are a wide range of *in situ*, upward-looking remote sensing and downward-looking satellite platforms for measuring EOVs, and even within each type of platform, the technologies can be diverse. Assessments of platform intercomparisons are needed to ensure specification of their measurement uncertainty, a key factor when determining appropriate platforms for a given sampling strategy. These assessments are likely to be ongoing, but are required for developing the OASIS implementation plan. Development of Best Practices will be done in coordination with the IOC's Ocean Best Practices System (OBPS).

Assessment of existing air-sea flux observing systems (12-18 months): Before implementing the OASIS, the existing regional and global initiatives must be assessed to identify existing capability gaps. As a SCOR Working Group, our primary focus will be to identify areas for potential collaboration, and opportunities for leveraging new partners, including early career scientists, scientists from developing nations, and citizen scientists. This assessment of existing air-sea interaction observations will extend throughout the global ocean (including at ice margins and coastal zones), and include the ability of developing nations' weather, climate, and ocean services to provide and access air-sea exchange information.

Assessment of network designs (12-24 months): Following the Framework for Ocean Observing, array designs will begin by first assessing stakeholder needs for ocean information. This will then set the baseline requirements for prioritizations of phenomena needing monitoring and evaluation of the network's ability to (1) measure key phenomena, (2) constrain uncertainties in budgets, (3) have appropriate scales and accuracy for calibration/validation of satellite measurements. Other array design methods may also be used to optimize the OASIS both regionally and globally, including Observing System Simulation Experiments/Observing System Experiments to assess the impact of observations. This effort will work with existing regional groups (e.g. TPOS-2020, CLIVAR basin panels, SOCCOM, SOOS and SOFLUX) to provide recommendations that take into consideration unique conditions for each region, and different requirements for applications with different objectives.

Strategy Document (24 - 36 months): Develop a unified vision for the global, integrated air-sea interaction observations that identifies gaps in the present system, activities required for implementation, and potential leveraging opportunities that would accelerate implementation, and enable participation from developing countries. The strategy will also explain how these data will be Findable-Accessible-Interoperable-and-Reusable (FAIR). To the extent possible, the strategy will include costs and prioritizations for implementing recommendations.

Virtual WG meetings (monthly or bi-monthly) and Face-to-Face Workshops (6 months, 24 months, and 36 months): The WG will have regular virtual meetings focused on specific deliverables (see DELIVERABLES). These will be supplemented with three larger workshops that will consider the full workplan, and showcase deliverables as they become finalized. WG workshops will be open meetings and scientific and resource manager representatives from different air-sea interaction communities, including from private, public and academic sectors, will be encouraged to participate. Funds will be sought to support early career scientists and scientists from developing nations.

Some travel will be supported through the Consortium for Ocean Leadership (COL) as an OceanObs'19 Research Coordination Network (RCN) activity. Further support by the US Interagency Ocean Observation Committee (IOOC) is under consideration. We may consider holding one of the workshops in conjunction with an OceanObs RCN annual meeting, as these are generally coordinated with a large international science meeting, and many of our invited guests and CWP original authors, would likely already be planning to attend this meeting.

Communications (Ongoing, pending COL support): With web-support from COL, the WG could develop an independent OASIS website that will highlight the OASIS recommendation rankings and rationale; will maintain a calendar of relevant workshops, meetings, and other activities; will act as a portal to the air-sea flux toolbox and curriculum; and will host an electronic newsletter that will solicit engagement, promote coordination activities, highlight scientific results, and new publications.

DELIVERABLES

1. **Consolidated recommendation report (TOR #1; 6-months):** This synthesis report, based upon more than three dozen OceanObs19 CWP (see **KEY REFERENCES**) will be made publicly available and will guide all activities undertaken by the WG.
2. **OASIS publication (TOR #1-6; 36-months):** The OASIS will be published as an open-access peer-reviewed publication.
3. **Best practice papers (TOR #2-5; 18-36-months)** for ocean surface flux measurements, platforms, standards, analysis, array design for publication as part of the special Section Ocean Best Practices of Frontiers in Marine Sciences.
4. **Air-sea flux toolbox (TOR #2, 4-6; 12-36-months)** will be made available as open source code through github and published in code-themed journals (where needed) that includes well-documented, easy-to-use bulk flux algorithms, asset mapping, direct covariance flux code for physical fluxes with the possibility to extend to trace gas fluxes (especially CO_2 and DMS), and numerical 1-D (vertical) model codes.
5. **Air-sea flux curriculum (TOR #2, 4-6; 12-36-months)**, including a library of How-To manuals relevant to air-sea fluxes, will be geared towards early career scientists and Summer Institute students in developing nations.
6. **Website, webinars and newsletter (TOR #1-6; Ongoing):** Focused webinars (1-2 per year) will allow the community to 'meet' and discuss WG's deliverables. Pending COL support, an OASIS website will be launched that will host an electronic newsletter, sent out to email subscribers, that will highlight OASIS news (e.g., flux-related publications, upcoming meetings and training opportunities, new observational capabilities and career opportunities). The newsletter format has proven very popular and valuable in other flux initiatives (e.g. SOFLUX).

CAPACITY DEVELOPMENT & COMMUNITY BUILDING

To promote the practice and understanding of air-sea interactions over the next decade or even longer, the OASIS working group will also dedicate itself to long-lasting capacity development in this field (explicitly stated in TOR 2 and 6). Our main capacity development tools will be a curriculum that will include background science lessons, Best Practice guides and "How To" manuals for making air-sea flux observations and calculating fluxes from either state variables using a bulk algorithm, and an open-source (e.g via GitHub) well-documented air-sea flux toolbox. Capacity development will also be achieved by shifting the observing system culture towards partnerships, collaboration and mentorships by identifying leveraged observing opportunities.

The "How To" manuals will include Best Practice guides for making air-sea flux observations (from ships, buoys, autonomous surface vehicles and drifting platforms) and for calculating fluxes from either state variables using a bulk algorithm, or directly using covariance techniques. Air-sea flux toolboxes, provided openly (e.g. via GitHub), will allow for easier access to scripts to process level 1 data in order to derive 'science-ready' flux estimates for a variety of applications (from research to operations). The curriculum will also include some examples of how these fluxes could be used within the context of large general circulation models as well as simple 1-d models that show how different surface physical and biogeochemical fluxes can result in different water column physical and biochemical tracers and processes (mixed layer, primary and secondary production).

This curriculum and tool-box development activity is well suited for a SCOR WG, which can facilitate interactions between members who are experts in the model and parameterization development, members who are experts in the methodological handling of field data, members who can implement these methods into new and well documented (via well-explained code and publications in code-themed journals) processing language and packages (e.g. Python) to be made openly available, and members familiar with the broad spectrum of potential users of this toolbox, including ECS and scientists and students in developing countries. <u>We wish to emphasize that these tools will make it significantly easier for all users (students to established researchers, current operators to developing nations, etc) to make and work with air-sea flux observations</u>. The tools will include modules that enhance data standardization easing downstream data storage and discoverability. Its community-driven approach ensures these tools remain up-to-date and all-encompassing. Such tools will work in parallel with best practice guidelines and papers.

Our first opportunity to test the curriculum will be at the 2021 SOLAS summer school, which is directed by one of our group members. While the development of the toolboxes and guides will have just started, background concepts and early versions of lesson plans could be implemented by the program as early as 2021. The participants are asked at the end of every SOLAS summer school to evaluate the content and it can be retested at the next school (either 2022 or 2023). This feedback will be integral in shaping the final version of OASIS curriculum. In addition, the 2021 school will be held in Cape Verde, with the potential to return there for subsequent schools. The location is ideal to bolster capacity to early career scientists in Africa, especially on the Cape Verde Islands and in coastal nations, who are primarily interested in fisheries and biodiversity, but must understand how surface fluxes in a changing ocean will impact their research and their community.

Air-sea fluxes are challenging to compute as they rely upon many co-located, high resolution, high quality surface EOV and ECV. Air-sea heat fluxes, as an example, require more than 8 EOV/ECV: surface winds, surface currents, surface humidity and air temperature, sea surface skin temperature, downwelling solar and longwave radiation, and surface albedo and emissivity estimates. Modern bulk air-sea heat flux algorithms also depend upon sea state. Several of these variables are also needed for other air-sea fluxes, such as for carbon dioxide fluxes. This complexity means that partnerships are often needed to make air-sea flux observations, with one partner being responsible for the platform and a subset of EOV/ECV measurements, and other partners being responsible for other EOV/ECV. This provides a leveraging opportunity for new partners. New partners may join an observing team to help with a single EOV without needing to be responsible for engineering and operating the entire platform. New sensors, of course, must be carefully tested and integrated into platforms to ensure interoperability and non-interference with other measurements. However by developing best practices, and technical readiness level advancement procedures, and by developing a culture of mentorship and partnership, the capacity of the observing system could be significantly expanded. Developing such a culture requires a diverse working group, such as we have formed here, and terms of reference that mandate this. The result of this cultural shift would be a broader base of users, operators, and technological solutions.

MEMBERSHIP & REPRESENTATION

Full Members (*co-chairs)

Name	Gender	Place of work	Expertise
1 Meghan Cronin*	F	NOAA Pacific Marine Environmental Laboratory, **US**	Heat, momentum, moisture fluxes; Operating longterm surface observing platforms; emerging technologies; Optimizing observing systems (TPOS2020, OOPC)
2 Sebastiaan Swart *	M	University of Gothenburg, **Sweden**	Heat, momentum and CO2 fluxes; Mixed layer physics; Operating autonomous surface platforms; Southern Ocean fluxes (SOFLUX)
3 Nadia Pinardi	F	University of Bologna, **Italy**	Numerical ocean forecasting systems, surface air-sea fluxes in

			the Mediterranean Sea for coupling with atmospheric forecasts
4 R. Venkatesan	M	National Institute of Ocean Technology, **India**	Physics, Operational met, Capacity Building
5 Phil Browne	M/ECS	ECMWF, **UK**	Operational, Coupled DA
6 Warren Joubert	M/ECS	South African Weather Service, **South Africa**	BGC, Capacity Building, Operational
7 Ute Schuster	F	University of Exeter, **UK**	Ocean carbon cycle variability and biogeochemical drivers; operating long-term observational platforms; member of European ICOS observational infrastructure, SOCONET, AtlantOS programme; past memeber of SCOR WG 133, CARBOOCEAN, CARBOCHANGE; co-author of OceanObs19 papers of Steinhoff et al., Wanninkhof et al., Smith et al.
8 Christa Marandino	F	GEOMAR, **Germany**	Climate-relevant trace gas air-sea exchange and surface ocean cycling, short-lived biogenic trace gases (e.g. DMS), SOLAS
9 Shuangling Chen	F/ECS	Second Institute of Oceanography, **China**	BGC, satellite estimation of air-sea CO2 flux, Chen et al.
10 Clarissa Anderson	F	Scripps Institution of Oceanography, **US**	Biological oceanography, integrated ocean observing, stakeholder capacity building

Associate Member

Name	Gender	Place of work	Expertise
1 Jim Edson	M	Woods Hole Oceanographic Institution, **US**	Physics, direct flux measurement & parameterization, novel technology & observing systems
2 Zhaohui Chen	M	Ocean University of China, **China**	ECVs/EOVs and Heat fluxes using surface fixed/mobile observing platforms, Centurioni et al.
3 Juliet Hermes	F	South African Environmental Observation Network, **South Africa**	Physics, observing systems, modelling, IORP, GOOS OCG, IOC/GOOS Ocean Best Practices steering group, Capacity Building
4 Fabrice Ardhuin	M	University Brest, CNRS, IRD, Ifremer, Laboratoire d'Ocèanographie Physique et Spatiale (LOPS), IUEM, **France**	Physics, Satellite observations of winds, waves, and surface currents
5 Oscar Alves	M	Bureau of Meteorology, **Australia**	Coupled modelling, coupled DA, sub-seasonal to seasonal prediction, WGNE Member
6 Anne O'Carroll (Pending Approval)	F	European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), **Germany**	GHRSST, satellite observations

WORKING GROUP CONTRIBUTIONS

Meghan Cronin was lead author of the OceanObs19 paper "Air-Sea Fluxes with a Focus on Heat and Momentum", and co-author on four other CWP. With her system's experience as co-chair of the Tropical Pacific Observing System (TPOS)-2020 Planetary Boundary Layer Task Team and member of Ocean Observations for Physics and Climate (OOPC) panel, and experience maintaining reference station moorings and using novel surface observing technologies, she will act here as Co-Chair.

Sebastiaan Swart was lead author of the OceanObs19 strategy paper "Constraining Southern Ocean air-sea-ice fluxes through enhanced observations". He brings expertise in air-sea flux field observations with a focus on the Southern Ocean (former Co-Chair of SOOS) and will act here as Co-Chair.

Nadia Pinardi was the lead author for the OceanObs19 review paper "The Joint IOC (of UNESCO) and WMO Collaborative Effort for Met-Ocean Services" and she was leading the design and the implementation of the Mediterranean Forecasting System from the operational observing system to the numerical modelling and data assimilation. She now serves as vice-president of the WMO Infrastructure Commission.

R Venkatesan has designed, developed, installed, and established Indian moored buoy systems in the Indian Ocean (OMNI), contributes to the RAMA network and global OceanSITES network, and is responsible for Indian Arctic Observatory; with particular expertise in flux data measurements and validation. He serves as a Chair of GOOS Regional Alliances of IOC UNESCO

Phil Browne is the lead developer of coupled ocean-atmosphere data assimilation for numerical weather prediction at the European Centre for Medium-Range Weather Forecasts (ECMWF). He brings expertise in the operational use of surface observations and the pathways to impact through weather forecasting.

Warren Joubert, an ECS, has expertise in air-sea CO_2 fluxes through field observations in the Southern Ocean. He is currently responsible for a Global Atmosphere Watch long term atmospheric observations station in South Africa.

Ute Schuster has expertise in ocean carbon cycle variability, including air-sea CO_2 flux and interior ocean anthropogenic carbon transport and storage, including underlying biogeochemical and physical drivers of variability, from seasonal through multi-decadal time scales. She is executive group member of the European ICOS OTC (https://otc.icos-cp.eu/), leading the North Atlantic section of the global Surface Ocean CO2 ATlas (SOCAT; www.socat.info), and co-author of three OceanObs'19 papers.

Christa Marandino uses eddy covariance to measure trace gas air-sea exchange. She is active within SOLAS (German national rep, summer school director, science and society co-lead).

Shuangling Chen, an ECS, brings expertise in air-sea CO2 flux, especially its remote estimation from satellites. She is passionate about the future potential of the ocean in absorbing anthropogenic CO2.

Clarissa Anderson was lead author of the OO'19 CWP, "Scaling up from regional case studies to a global harmful algal bloom observing system" and a newly elected member to the IOC-SCOR GlobalHAB Scientific Steering Committee, the U.S. National HAB Committee (NHC), the OO'19 RCN "Impacts and Applications" Working Group, and the OO'19 Ecosystem Health and Biodiversity Planning Team. She brings expertise in biological oceanography, harmful algal blooms, and integrated ocean observing systems.

RELATIONSHIP TO OTHER INTERNATIONAL PROGRAMS AND SCOR WORKING GROUPS

1. Other SCOR Working Groups

OASIS has synergies with SCOR Working Group 153 FLOTSAM. In developing a strategy for FAIR data, with automated quality control, OASIS will benefit from SCOR Working Group 148 IQuOD. OASIS will also benefit from SCOR Working Group 133 OceanScope for ship-based observations, and from SCOR Working Group 143 on dissolved N_2O and CH_4 measurement. Their OceanObs'19 paper will contribute to OASIS's synthesis recommendations. SCOR Working Group 152 ECV-Ice standardized protocol for gas exchange measurements over sea ice are relevant to OASIS goals for open waters. Finally, SCOR Working Group 154 global plankton observations will inform the OASIS for EBVs.

2. Global and regional networks

OASIS will help integrate the air-sea interaction observations across the patchwork of GOOS Regional Alliances (**GRAs**), and from emerging systems, such as the Southern Ocean Observing System (**SOOS**), to mature systems, such as Tropical Pacific Observing System (**TPOS-2020**). OASIS will take work with their surface flux task teams (e.g. SCOR/SCAR's **SOOS SOFLUX)**.

The Observations Coordination Group (**OCG**) is charged to review, advise on, and coordinate across the global ocean observing networks to strengthen the effective implementation of a global ocean observing system (**GOOS**). OASIS will provide a vision for integrating air-sea interaction observations across networks, and disciplines. OASIS will also consider leveraging opportunities for multidisciplinary observations that could bring new partners, including early career scientists, scientists from developing countries, and citizen scientists.

Several **GOOS OCG** networks observe air-sea interaction (e.g. **OceanSITES**, **DBCP network** (Centurioni et al. 2019), etc.). In addition, there are several discipline-specific flux networks, e.g. **Integrated Carbon Observation System** (ICOS -OTC; https://otc.icos-cp.eu/), **Surface Ocean CO2 NETwork** (SOCONET; Wanninkhof et al., 2019). OASIS will identify common ground across discipline, where leveraged observations could contribute to an integrated observing system.

OASIS will also develop community endorsed best practices which can be shared, with support of the **Ocean Best Practices** steering group.

3. UN Decade of Ocean Science for Sustainable Development

It is hoped that OASIS will be embraced as a Decade Project and in this way have its strategy implemented.

4. OceanObs Research Coordination Network (RCN)

OASIS is a community effort, resulting from OceanObs19 and therefore has close affinity with the **OceanObs RCN**.

5. International programs

The **WCRP**, **CLIVAR, SOLAS,** and **IMBER** programs will benefit from OASIS. For example, Core Theme 2 of SOLAS focuses on surface fluxes and each of the remaining four Core Themes contain important elements related to air-sea exchange. The International Ocean Carbon Coordination Project (**IOCCP**), promotes the development of a global network of ocean carbon observations; http://www.ioccp.org/. OASIS WG members are closely linked to **IOCCP** activities.

OASIS will be informed by **OceanPredict**'s array design studies.

Working Group on Numerical Experimentation (**WGNE**) is expanding its remit, from a focus on atmospheric/weather models to a focus on coupled models of the earth system, and therefore has a priority to improve air-sea fluxes in coupled models of the earth system for weather and climate studies and prediction. **WGNE** is currently undertaking a surface flux intercomparison project, that involves collecting and evaluation surface fluxes from operational weather forecast models.

KEY REFERENCES from OceanObs19 Frontiers in Marine Science Collection, unless otherwise noted

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