COMMENTARY

# The Need for a Community of Practice for Air-Sea Flux Observations


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Development and widespread adoption of community-recommended practices are fundamental to the sustained global ocean observing efforts and are increasingly being called for within existing and emerging observing systems. As an example, the Observations Coordination Group (OCG) of the Global Ocean Observing System (GOOS) outlines 10 attributes of mature global observational networks (GOOS report No. 266, 2021). Included in these attributes is the existence of a "*Community of Practice*" that "*provides a means of developing a multi-year strategy and implementation plan.*" Another of these attributes emphasizes the development of standards and recommended practices. Specifically, the attribute "*Develops and follows Standards and Best Practices*" focuses on ensuring accessibility, development, documentation, and adherence to the recommended practices, as well as regular updates of these practices across the observation life cycle. Further, the OCG states that these recommendations should cover *"Deployment and sampling/standard operating procedures/operations, pre-mission preparation (e.g., calibration and validation), data retrieval and formatting, primary quality control, and secondary quality control."* Community-recommended practices have often been referred to as "best practices". However, we argue that the term "community-recommended practices" better represents the evolving nature and advancement of the various observational techniques and, therefore, of the practices themselves.

In many cases, standards and recommended practices are adopted by multiple observing networks, each with different challenges and requirements. This is particularly true for air-sea interactions observed with a variety of platforms within different OCG networks, such as the long-term fixed stations of OceanSITES, coastal and real-time moorings, as well as surface drifters of the Data Buoy Cooperation Panel platforms, ship-based observations within the Ship Observation Team (SOT), emerging and other networks, and by individual groups that are not yet affiliated with the GOOS networks.

The Observing Air-Sea Interactions Strategy (OASIS; Cronin et al., 2023), a program of the *UN Decade of Ocean Science for Sustainable Development (i.e., the "UN Ocean Decade")*, has established a task team dedicated to identifying, developing, and promoting community-recommended practices for observing air-sea interactions. Within the *UN Ocean Decade* framework, this task team aims to contribute to expanding the global ocean observing systems (Challenge 7 of the *UN Ocean Decade,* UNESCO-IOC, 2021) and develop skills, knowledge, and technology for all (Challenge 9 of the *UN Ocean decade*: UNESCO-IOC, 2021) through an integrated and practical approach to observing air-sea interactions. Here, we will outline the scope of this task team.

## Scope of Practices

Recommendations from the community of practice must cover the entire process from instrument selection, instrument siting, and setup to quality control and data management. Further, effective recommendations must ensure applicability to both well-resourced groups using state-of-the-art new technologies as well as groups facing limitations related to, for example, power supply, maintenance schedules, data transmission, and access to equipment and materials. This approach acknowledges the potential for increased uncertainties associated with lower resource availability. Lastly, the recommended practices must be suitable for a full range of applications, field conditions, and be relevant for a variety of platforms and networks.

Thoroughly documented and widely accessible recommendations, including target uncertainty specifications, are particularly important for industry. Often, scientists engage with engineers too late in the development process, after fundamental decisions have been made that "bake in" features that increase uncertainty in measurements. Likewise, including engineers' perspectives while developing the community-recommended practices can help frame the practices from a broader standpoint that allows for innovative solutions. Community-recommended practices and standards can help guide technology development and result in solutions that further meet the needs of OASIS, as well as the broader scientific community. Having well-documented, community-recommended practices will also lead to better quality observations when data are provided as a service from an industrial partner. By specifying these recommended practices within the contract, ambiguities in the data collection process can be reduced for scientists and service providers alike.

## Essential Ocean and Climate Variables of Concern

Air-sea turbulent and radiative fluxes, and the surface ocean variables necessary to estimate them are Essential Ocean Variables (EOVs; Lindstrom et al. 2012). Most of these EOVs are also supported as Essential Climate Variables (ECVs) defined by the Global Climate Observing System (GCOS), as are the near-surface meteorological variables required for air-sea flux calculations. Air-sea fluxes depend upon several co-located EOVs and ECVs to be measured simultaneously and often rely on multiple community-developed algorithms. Therefore, the potential for error and uncertainties is high in both flux measurements and bulk flux estimates. To reduce these uncertainties, OASIS seeks to galvanize community-recommended practices for air-sea interaction observations.

The current status of recommended practices for direct flux observations and key variables for bulk flux calculations are presented in Table 1

**TABLE 1**

Status of recommended practices for direct air-sea fluxes.

| Variable name | Status | Available in public repository | Endorsed by expert panel | Relevant references★ |
|---|---|---|---|---|
| Latent heat flux | ● ◐ ◐ ○ | ✓ | | 1, 2 |
| Mass flux: | | | | |
| • Carbon dioxide ($CO_2$) flux | ● ◐ ◐ ○ | ✓ | | 1, 3, 4 |
| • Dimethylsulphide (DMS) flux | ● ○ ● ○ | | | |
| • Other gas fluxes | ● ◐ ○ ○ | | | |
| Momentum flux | ● ● ● ○ | ✓ | | 1, 2 |
| Sensible heat flux | ● ◐ ◐ ○ | ✓ | | 1, 2 |

**Symbology:** ● practices exist, ● practices exist and are adequately documented, ● existing practices are suitable for air-sea interaction studies, ● existing practices are updated and represent the current state-of-the art for air-sea interaction studies. Half-circles indicate partly fullfiled conditions. ✓ Some documentation is publicly available.

**References:** 1. Aubinet et al., 2012; 2. Cronin et al. 2019; 3. SOLAS Report No.37, 2024; 4. Yang et al., 2022.

★ This is not a comprehensive literature review. Nevertheless, these references cover---to the extent possible---work relevant for air-sea interaction observations.

and Table 2, respectively, followed by current community efforts focused on advancing recommended practices for air-sea interaction observations. OASIS recommends that the community review the recommended practices for all variables on a regular basis.

Uncertainties in both flux measurements and key variables used for bulk calculations represent a challenge for resolving air-sea interaction processes at relevant temporal and spatial scales. Factors related to the platform and instrument capabilities and setup (sensor accuracy and precision, platform motion, flow distortion, etc.), and environmental conditions (e.g., bulk sea surface temperature (SST) differences from skin SST, sea state, and salt contamination) are major sources of uncertainty. In addition, uncertainties intrinsic to the bulk parametrization are also major contributions to uncertain air-sea fluxes. Overall, understanding and reducing uncertainties in these observations is critical to provide more consistent air-sea flux estimates, relevant for accurate and timely ocean, weather, and climate predictions needed for early warning systems, extreme weather forecasts, and ecosystem health assessments.

Of the EOVs and ECVs used for air-sea flux calculations, SST is critical. SST is necessary for freshwater, sensible heat, and mass flux calculations, and it strongly impacts the stability of the atmospheric and oceanic boundary layers, affecting turbulent fluxes at the air-sea interface. For

## TABLE 2

Status of recommended practices for in-situ EOVs and ECVs needed to parameterize air-sea fluxes.

| Variable name | Status | Needed for | Available in public repository | Endorsed by expert panel | Relevant references★ |
|---|---|---|---|---|---|
| Atmospheric pressure | ● ● ● ○ | Momentum, sensible heat latent heat and mass fluxes | ✓ | | 1, 2, 3 |
| Air temperature* | ● ● ● ○ | Sensible and latent heat fluxes | ✓ | | 1, 2, 3 |
| Concentration gradients: | | Mass flux | | | |
| • Atmospheric $CO_2$ and other greenhouse gases | ● ● ● ● | | ✓ | | 4 |
| • Seawater CO2 conc. | ● ● ◐ ○ | | ✓ | | 5 |
| • Other gases in seawater | ● ○ ○ ○ | | | | |
| Currents†, * | ● ◐ ● ● | Momentum, sensible heat and latent heat fluxes | ✓ | | 2, 6 |
| Humidity | ● ● ● ○ | Latent heat flux | ✓ | | 1, 2, 3 |
| Long-wave radiation | ● ● ● ● | Net radiation | ✓ | ⏳ | 7 |
| Precipitation | ● ● ● ○ | Freshwater flux | ✓ | | 1, 2 |
| Sea state† | ● ● ● ● | Mass flux (optional) | ✓ | | 8, 9 |
| Sea surface salinity† | ● ◐ ◐ ◐ | Freshwater and mass fluxes | ✓ | | 2, 10, 11 |
| Sea surface temperature†, * | ● ● ◐ ○ | Freshwater, sensible heat and mass fluxes | ✓ | | 1, 2 |
| Short-wave radiation | ● ● ● ● | Net radiation | ✓ | ⏳ | 7 |
| Skin temperature†† | ○ ○ ○ ○ | (preferred over SST) | | | |
| Wind speed * | ● ● ◐ ○ | Momentum, sensible heat latent heat and mass fluxes | ✓ | | 1, 2, 3 |

**Symbology:** ● practices exist, ● practices exist and are adequately documented, ● existing practices are suitable for air-sea interaction studies, ● existing practices are updated and represent the current state-of-the-art for air-sea interaction studies. Half-circles indicate partly fullfiled conditions. ✓ Documentation is publicly available, ⏳ endorsement process is in progress.

**References:** 1. Bradley and Fairall, 2006; 2. Venkatesan et al., 2018; 3. Kent et al., 2019; 4. Crotwell et al., 2019; 5. Dickson et al., 2007; 6. Mantovani et al., 2020; 7. Riihimaki et al., 2024; 8. Ardhuin et al., 2019; 9. Swail et al., 2010; 10. HELCOM; 11. GOSUD.

★ This is not a comprehensive literature review. Nevertheless, these references cover---to the extent possible---work relevant for air-sea interactions.
* Variables necessary to estimate the stability of the atmospheric boundary layer.
† Essential Ocean Variable (EOV) specification sheets available from GOOS (https://goosocean.org/what-we-do/framework/essential-ocean-variables/).
†† Skin temperature is defined by GOOS as a sub-variable of sea surface temperature (SST).

bulk flux parametrization, SST representing the conditions at the interface (i.e., skin temperature) is necessary; however, in-situ measurements of skin temperature are challenging and constraining the uncertainty of the measurement techniques is still necessary.

## Skin Temperature: A Key Variable to Improve

The temperature at the air-sea interface (i.e., skin temperature) is necessary in air-sea bulk flux parametrization. However, in-situ measurements are typically several meters deep, representing instead the subsurface ocean temperature and this bulk SST can differ from the skin SST through both a cool skin effect and a daytime stratification. For this reason, state-of-the-art bulk algorithms include techniques for extrapolating bulk temperatures to the skin temperature (e.g., Fairall et al., 1996). The efforts to make automated measurements of the skin temperature from vessels (e.g., the Infrared SST Autonomous Radiometer, Donlon et al., 2008; the Marine Atmosphere Emitted Radiance Interferometer, Kearns et al., 2000), including Voluntary Observing Ships (VOS), are examples of how to increase access to this type of observation and increase their availability over the global ocean. While commercial-off-the-shelf (COTS) infrared temperature sensors are available, their use for observing the skin temperature of the ocean is challenging. Skin temperature observations are easily contaminated by reflected sky temperature, effects of the platform structure (e.g., ship wakes), and sun glint. These uncertainties could be reduced through development and adoption of community-recommended practices. Development of these recommended practices is a high priority for OASIS as proper use of COTS sensors could potentially lead to both lower cost and higher quality air-sea interaction measurements.

## The Surface Radiation Case, An Example of How to Move Forward

The OASIS-led, community-recommended practices for observing ocean surface radiation (Riihimaki et al., 2024) provides a roadmap for developing recommended practices for EOVs and ECVs associated with air-sea fluxes. Initial conversations were started at GCOS/GOOS meetings between leaders in the ocean radiation measurement community and the Baseline Surface Radiation Network (BSRN)—a primarily land-based network—about better integrating the land and ocean communities. This led to a series of four virtual meetings at the Intergovernmental Oceanographic Commission (IOC)-Ocean Best Practices System (OBPS) fall workshop, iterating between the communities to develop recommended practices for ocean radiation measurements, eventually resulting in Riihimaki et al. (2024) in the special issue of Frontiers in Marine Science associated with the OBPS archive. The recommendations have been presented at BSRN, OceanSITES, American Geophysical Union, and American Meteorological Society Radiation meetings for feedback from the wider community. The practices were endorsed by the OceanSITES network, and we are now seeking GOOS endorsement (Hermes, 2020). The next steps are to start developing a path forward to create a joint ocean/land network of networks, both scientifically and logistically. Such a community-wide process and interaction is an example of how recommended practices for other air-sea flux variables and related ECV/EOV measurements could be followed in the future.

## The Grandest Idea of All—A Collaborative Effort for *The Ocean We Want*

While community-recommended practices evolve as technology and knowledge advance, having vetted practices clearly documented and widely shared is critical for creating and sustaining interoperable global observing networks. Even though air-sea interactions from in-situ observations are the focus of this commentary, we acknowledge that a community of practice built from collaborative efforts across disciplines and areas of expertise is necessary. Early on, the IOC-OBPS community-building meeting established a global group to synthesize the fragmented knowledge on radiation measurements into recommended practices. In this process, the IOC-OBPS offered other tools, in particular, the production and archiving of open-access and citable (via Digital Object Identifiers (DOIs)) manuals and standard operating procedures.

Having Findable, Accessible, Interoperable, and Reusable (FAIR) data (Tanhua et al., 2019) is central to the OASIS theory of change (Cronin et al., 2023). Agreement on data formats, (meta)data standards, persistent and unique (meta)data identifiers, and protocols for documenting flux algorithms and uncertainty methodology requires community input and deliberation, and guidance from data scientists. To achieve the goal of making air-sea flux observations FAIR, the community needs to develop and adopt standards (e.g., standardizing air-sea flux parameter vocabularies, work that is already underway in OASIS) and recommend practices to address the FAIR principles (Wilkinson et al. 2016). All of these efforts will enhance the data management of air-sea flux observations and expand community access to well-documented datasets with better defined error and uncertainty characteristics.

Satellite remote sensing plays an important role in providing complementary global coverage to in-situ observations for air-sea flux estimates. Satellites collect data globally and have the potential to provide measurements of multiple critical parameters as well as simultaneous measurements of co-varying parameters needed for air-sea buoyancy flux (e.g., a "Butterfly"-like mission, Gentemann et al., 2020) or for air-sea momentum exchange (e.g., global winds and currents coverage from the proposed Ocean Dynamics and Surface Exchange with the Atmosphere mission (ODYSEA), Rodríguez et al., 2019; high-resolution winds, waves, and currents via Synthetic Aperture Radar measurements from Harmony or SeaStar, López-Dekker et al., 2021; Gommenginger et al., 2019). However, to be interpreted in full, remotely sensed data depend on in-situ observations (e.g., for calibration and validation) and on modeling and process studies to unravel the physics underpinning the observed systems. In community-recommended practices, satellite observations are released, as open access data, following FAIR principles. Because of their global scope and open access status, remotely sensed observations play a valuable role in supporting scientists, especially early career scientists from all nations, and in building capacity within the air-sea flux community.

The mission of OASIS is to develop a practical, integrated approach to observing air-sea exchanges associated with the Energy, Water, Carbon, and Life Cycles. In OASIS, we are working to implement grand ideas associated with in-situ and remotely sensed observations of air-sea interactions and with a full hierarchy of Earth System models. As a *UN Ocean Decade* program, OASIS strives to build a broad community that includes Early Career Ocean Professionals (ECOPs), practitioners from the Global South and Small Island Developing States (SIDS), and to connect engineers, scientists, and practitioners within the Blue Economy. This pool of expertise constitutes a Community of Practice that is ideal for developing recommended practices for air-sea interactions and air-sea fluxes. To join the OASIS community, please get involved at: http://airseaobs.org/get-involved.

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## References

**Ardhuin**, F., Stopa, J.E., Chapron, B., Collard, F., Husson, R., Jensen, R.E., … Young, I. 2019. Observing sea states. Frontiers in Marine Science. 6(124). https://doi.org/10.3389/fmars.2019.00124.

**Bradley**, E.F., & Fairall, C.W. 2007. A guide to making climate quality meteorological and flux measurements at sea. Technical Memorandum OAR PSD-311, Physical Science Division, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO.

**Cronin**, M.F., Gentemann, C.L., Edson, J., Ueki, I., Bourassa, M., Brown, S., … Zhang, D. 2019. Air-sea fluxes with a focus on heat and momentum. Frontiers in Marine Science. 6(430). https://doi.org/10.3389/fmars.2019.00430.

**Cronin**, M.F., Swart, S., Marandino, C.A., Anderson, C., Browne, P., Chen, S., … Yu, L. 2023. Developing an observing air-sea interactions Strategy (OASIS) for the global ocean. ICES Journal of Marine Science. 80(2):367–73. https://doi.org/10.1093/icesjms/fsac149.

**Crotwell**, A., Lee, H., & Steinbacher, M. (Eds.) 2019. 20th WMO/IAEA meeting on carbon dioxide, other greenhouse gases and related measurement techniques (GGMT-2019). GAW Report No. 255, 151 p.

**Dickson**, A.G., Sabine, C.L., & Christian, J.R. 2007. Guide to best practices for ocean CO2 measurements. PICES Special Publication 3, p. 191.

**Donlon**, C., Robinson, I.S., Wimmer, W., Fisher, G., Reynolds, M., Edwards, R., & Nightingale, T.J. 2008. An Infrared Sea Surface Temperature Autonomous Radiometer (ISAR) for deployment aboard Volunteer Observing Ships (VOS). Journal of Atmospheric and Oceanic Technology. 25:93–113. https://doi.org/10.1175/2007JTECHO505.1.

**Fairall**, C.W., Bradley, E.F., Godfrey, J.S., Wick, G.A., Edson, J.B., & Young, G.S. 1996. Cool-skin and warm-layer effects on sea surface temperature. Journal of Geophysical

Research: Oceans. 101(C1):1295–308. https://doi.org/10.1029/95JC03190.

**Gentemann**, C., Clayson, C.A., Brown, S., Lee, T., Parfitt, R., Farrar, J.T., … Zlotnicki, V. 2020. FluxSat: Measuring the ocean-atmosphere turbulent exchange of heat and moisture from space. Remote Sensing. 12(1796). https://doi.org/10.3390/rs12111796.

**Gommenginger**, C., Chapron, B., Hogg, A., Buckingham, C., Fox-Kemper, B., Eriksson, L., … Burbidge, G. 2019. SEASTAR: A mission to study ocean submesoscale dynamics and small-scale atmosphere-ocean processes in coastal, shelf and polar seas. Frontiers in Marine Science. 6(457).

**GOOS Report No. 266, Observations Coordination Group**. 2021. Network attributes, commitments, and benefits—What it means to be an OGC Network. https://goosocean.org/document/24002.

**GOSUD**. n.d. Measuring sea surface salinity with thermosalinometers. https://www.gosud.org/Standards-and-best-practices/Measuring-Sea-Surface-Salinity-with-thermosalinometers.

**Hermes**, J. (Ed.) 2020. GOOS Best Practices Endorsement Process. Version 1. Global Ocean Observing System, p. 7.

**Kearns**, E.J., Hanafin, J.A., Evans, R.H., Minnett, P.J., & Brown, O.B. 2000. An independent assessment of pathfinder AVHRR sea surface temperature accuracy using the Marine Atmosphere Emitted Radiance Interferometer (MAERI). Bulletin of the American Meteorological Society. 81:1525–36. https://doi.org/10.1175/1520-0477(2000)081<1525:AIAOPA>2.3.CO;2.

**Kent**, E.C., Rayner, N.A., Berry, D.I., Eastman, R., Grigorieva, V.G., Huang, B., … Willett, K.M. 2019. Observing requirements for long-term climate records at the ocean surface. Frontiers in Marine Science. 6(441). https://doi.org/10.3389/fmars.2019.00441.

**Lindstrom**, E., Gunn, J., Fischer, A., McCurdy, A., & Glover, L.K. 2012. A Framework for Ocean Observing. By the task team for an Integrated Framework for Sustained Ocean Observing. UNESCO. https://doi.org/10.5270/OceanObs09-FOO.

**López-Dekker**, P., Biggs, J., Chapron, B., Hooper, A., Kääb, A., Masina, S., … Rommen, B. 2021. The Harmony mission: End of phase-0 science overview. In: 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS (pp. 7752–5). IEEE. https://doi.org/10.1109/IGARSS47720.2021.9554896.

**Mantovani**, C., Corgnati, L., Horstmann, J., Rubio, A., Reyes, E., Quentin, C., … Griffa, A. 2020. Best practices on high frequency radar deployment and operation for ocean current measurement. Frontiers in Marine Science. 7(210). https://doi.org/10.3389/fmars.2020.00210.

**Pearlman**, J., Bushnell, M., Coppola, L., Karstensen, J., Buttigieg, P.L., Pearlman, F., … Whoriskey, F. 2019. Evolving and sustaining ocean best practices and standards for the next decade. Frontiers in Marine Science. 6(277).

**Riihimaki**, L.D., Cronin, M.F., Acharya, R., Anderson, N., Augustine, J., Balmes, K.A., … Zhang, D. 2024. Ocean surface radiation measurement best practices. Frontiers in Marine Sciences. 11.

**Rodríguez**, E., Bourassa, M., Chelton, D., Farrar, J.T., Long, D., Perkovic-Martin, D., & Samelson, R. 2019. The winds and currents mission concept. Frontiers in Marine Science. 6(438). https://doi.org/10.3389/fmars.2019.00438.

**SOLAS Report No. 37**. 2024. Eddy covariance (EC) air/sea gas flux best practices workshop. https://www.solas-int.org/files/solas-int-2019/3%20Publications/Event%20Reports/SOLAS%20Event%20Report_Issue%2037.pdf.

**Swail**, V., Jensen, R., Lee, B., Turton, J., Thomas, J., Gulev, S., … Warren, G. 2010. Wave measurements, needs and developments for the next decade. In: Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference 21-25, September 2009 (ESA Publication WPP-306), eds. Hall, J., Harrison D.E. & Stammer, D. Vol. 2, Venice, Italy.

**Tanhua**, T., Pouliquen, S., Hausman, J., O'brien, K., Bricher, P., De Bruin, T., … Zhao, Z. 2019. Ocean FAIR data services. Frontiers in Marine Science. 6(440). https://doi.org/10.3389/fmars.2019.00440.

**UNESCO-IOC**. 2021. The United Nations Decade Of Ocean Science For Sustainable Development (2021–2030) implementation plan, Vol. 20. UNESCO.

**Venkatesan**, R., Ramesh, K., Kishor, A., Vedachalam, N., & Atmanand, M.A. 2018. Best practices for the ocean moored observatories. Frontiers in Marine Science. 5(469). https://doi.org/10.3389/fmars.2018.00469.

**Wilkinson**, M.D., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., Baak, A., … Mons, B. 2016. The FAIR Guiding Principles for scientific data management and stewardship. Scientific data. 3(1):1–9. https://doi.org/10.1038/sdata.2016.18.

**Yang**, M., Bell, T.G., Bidlot, J.R., Blomquist, B.W., Butterworth, B.J., Dong, Y., … Zavarsky, A. 2022. Global synthesis of air-sea CO2 transfer velocity estimates from ship-based eddy covariance measurements. Frontiers in Marine Science. 9(826421). https://doi.org/10.3389/fmars.2022.826421.