SUPPLEMENTARY MATERIALS FOR

Observing Ocean Boundary Currents

Lessons Learned from Six Regions with Mature Observational and Modeling Systems

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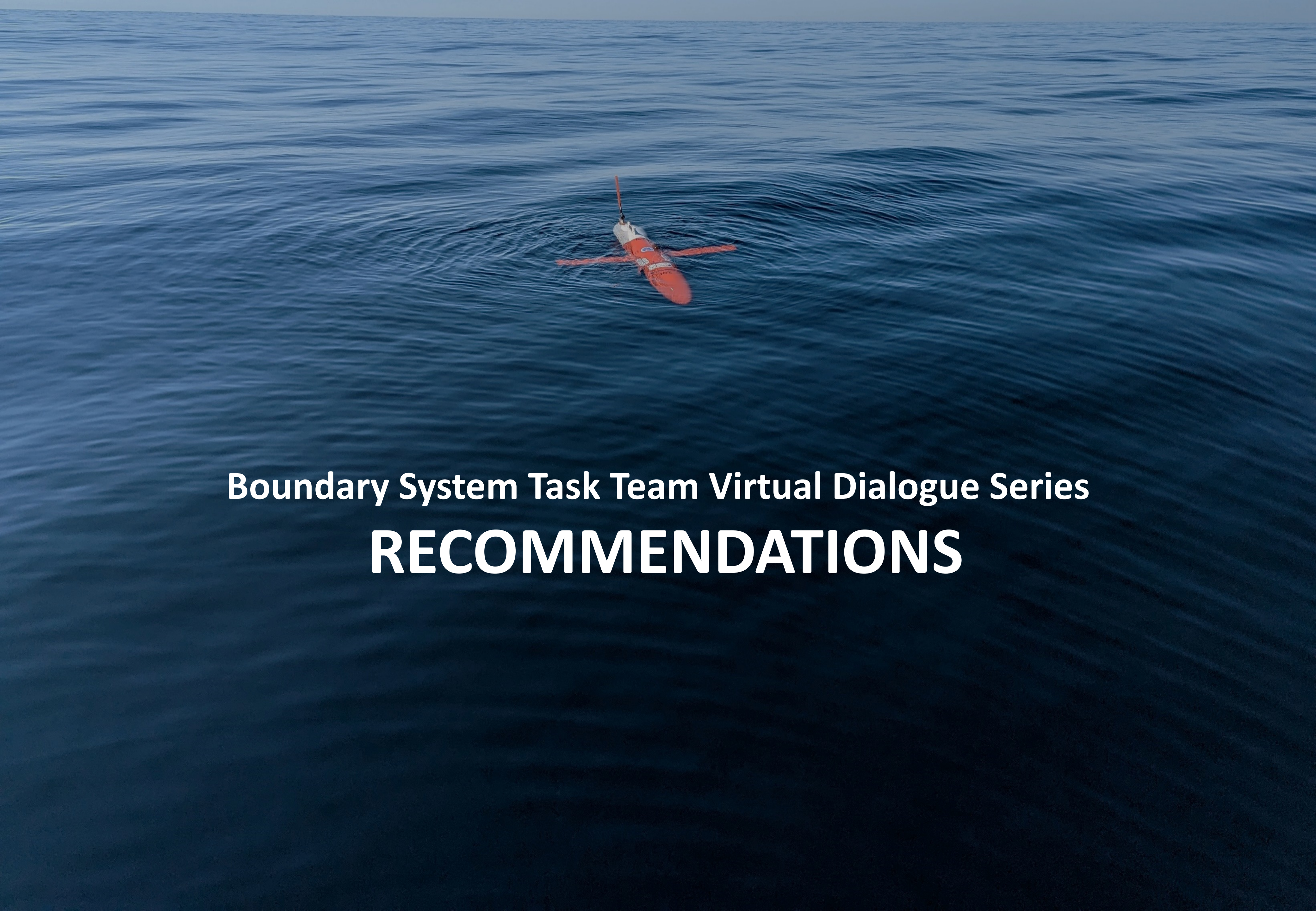
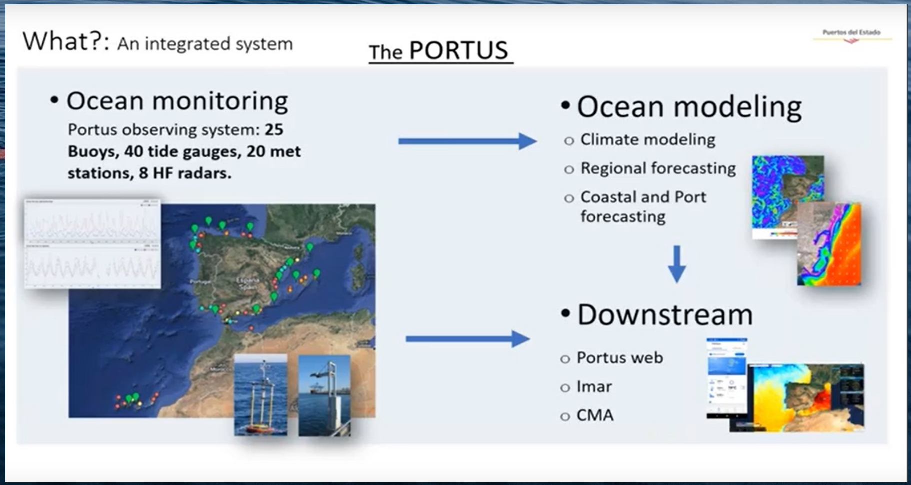


Boundary System Task Team Virtual Dialogue Series

RECOMMENDATIONS

Recommendation 1. Observing System Design

To ensure a fit-for-purpose and sustained observing system, a co-design approach should be adopted, gathering scientists, users, organizations, and funding agencies to define the objectives, to identify the essential observational targets and the appropriate sampling approach, to identify the needs and the strategy from observations to end products, and to set up a feedback loop between the observing system managers and the users. There is no need for operational and societal requirements to oppose research requirements in designing the observation network, as most observations are useful to both requirements. However, as all BCs are different in their physical characteristics and impacts on the coastal zone, there is no standard observing system that could be transferred from one BC region to another.



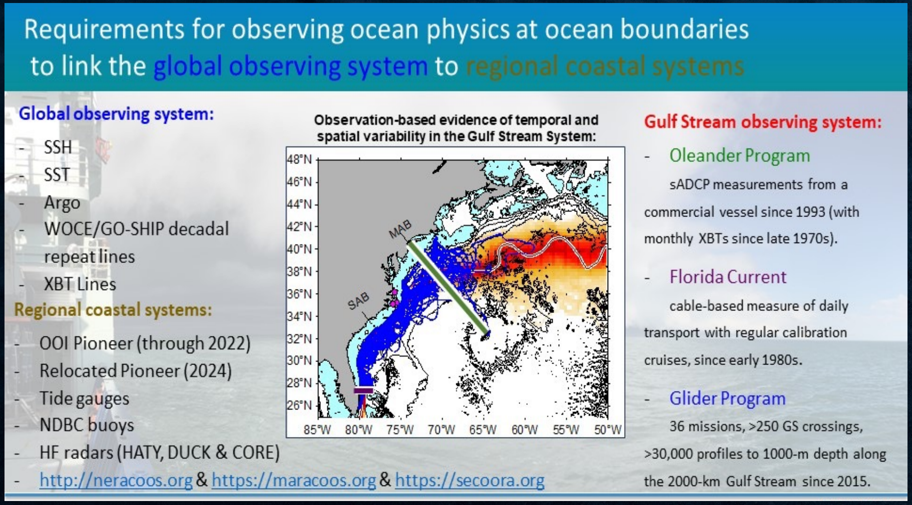
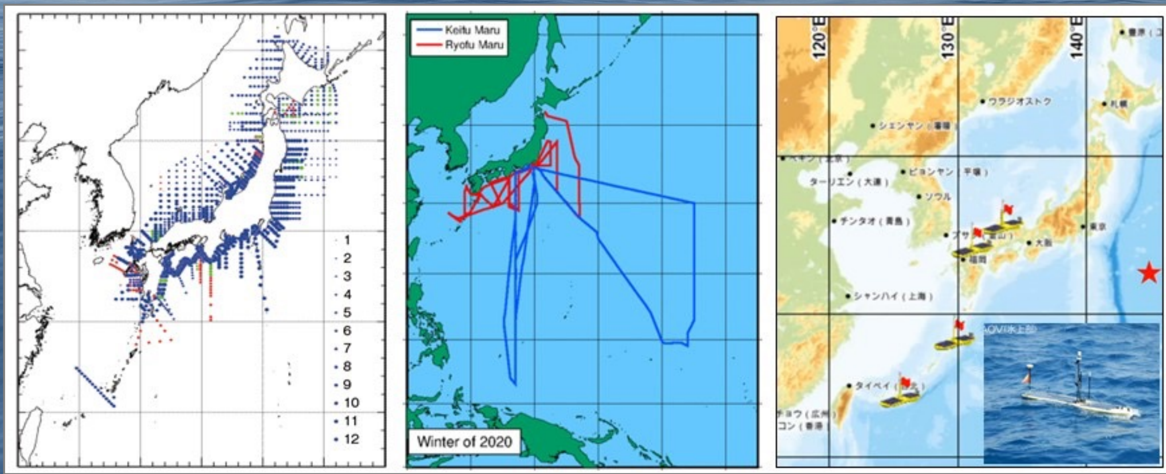


FIGURE. Portus (top) and GS (bottom) observing systems.
From the webinars of E. Alvarez-Fanjul and M. Andres

Recommendation 2. Observations



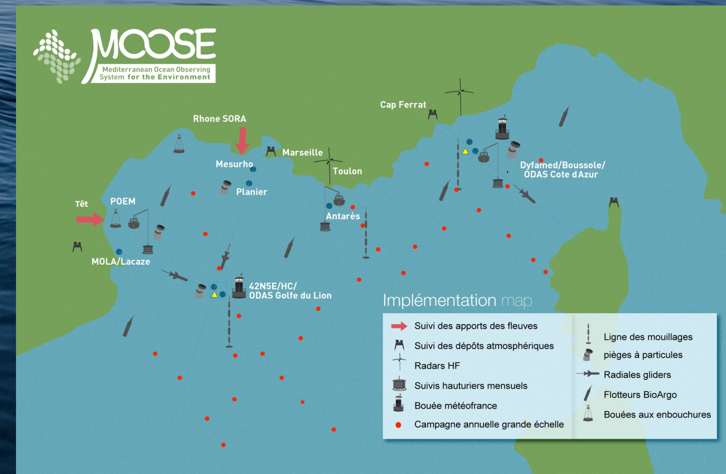


FIGURE. Observing systems for KC (left) and NWM (right). *From the webinars of E. Oka and A. Bosse*

The observing systems should consist of multidisciplinary observatories that provide essential physical, geochemical, and biological ocean and climate variables co-located in space and time. Measurements of air-sea fluxes (heat, water, momentum, CO_2) should be included, especially in western boundary currents. Long-term, sustained observations should be secured while allowing for regular reassessment and incorporation of new technologies as they reach more advanced stages of readiness. Diversified observing system composition that includes some level of redundancy, along with solid regional cooperation, could help to limit system vulnerability to various types of crises (e.g., war, pandemics, piracy, economic collapse). Finally, we advocate that sustainability issues and the impacts of observing systems on the environment and the climate should be central to consideration of the future of these systems.

Recommendation 3. Model-Data Integration

Each observing system should include a data center that distributes observations and products derived from the observations along with a modeling and forecasting center for ocean, weather, and subseasonal-to-seasonal predictions, where the observations are assimilated. Strong and continuous interactions between the observing and modeling communities should be encouraged; in particular, models or data assimilation can be used in the design of the observing network. Feedback from modelers should help to refine the data distribution strategy and evolution of the BC observing system. Additionally, modeling systems can lead to value-added data products that increase the use and uptake of the observations.

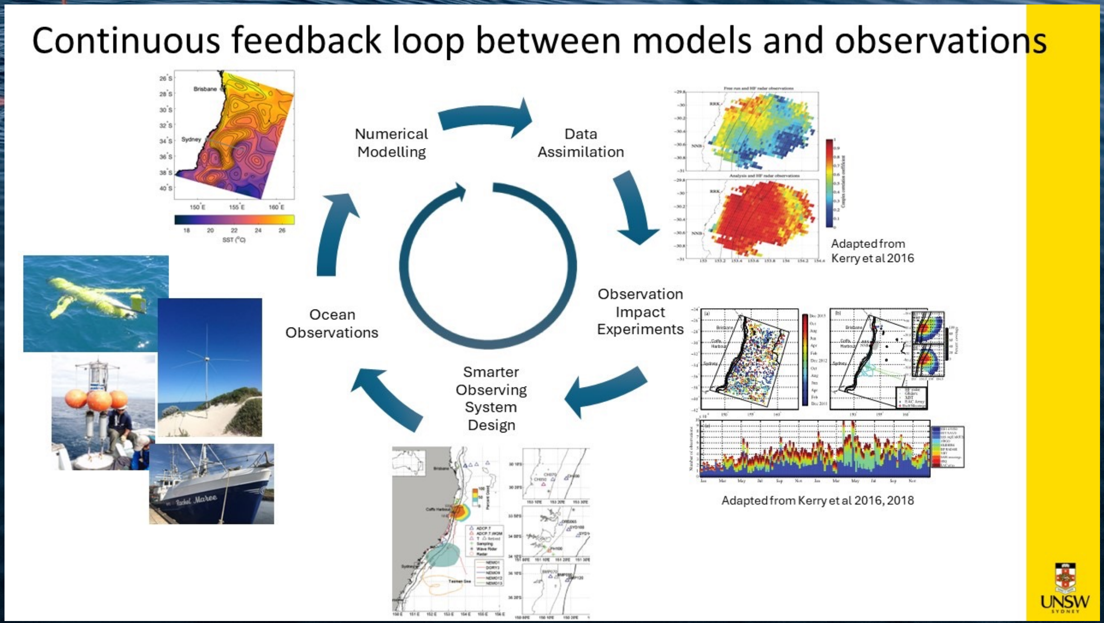
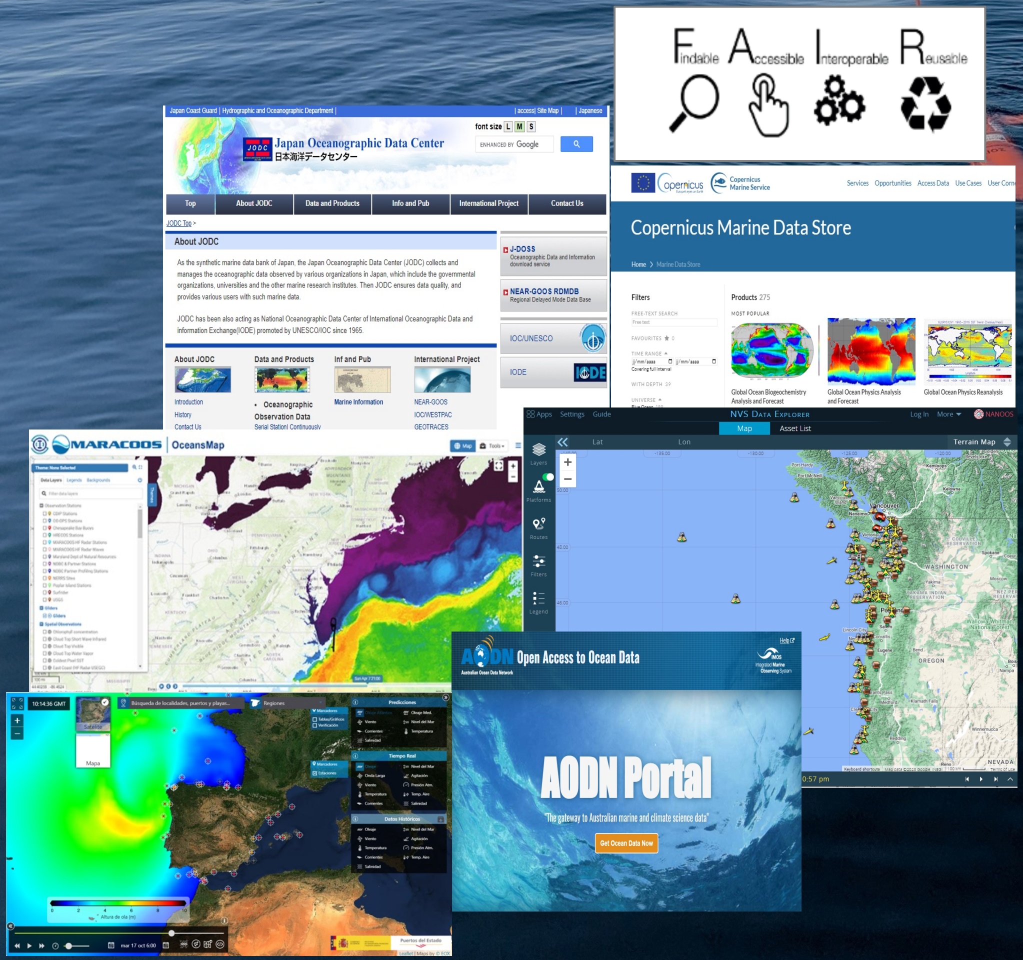


FIGURE. Schematic of the feedback loop between models and observations.
From the webinar of C. Kerry

Recommendation 4. Data Distribution and Products



Data distribution and products should rely on FAIR principles and on data portals designed to facilitate and reinforce the (re)use of the observations and products. Metadata and file formats should enable interoperability between data centers, while accurate error estimates for all measurements and derived products must be provided. Allocating financial and human resources is vital in order to move beyond data to products, but strengthening the evaluation of product usage by policymakers, the private sector, and the general public is crucial to ensure user uptake. A first step toward assessing how the observing systems can better meet user needs might be inspired by the concept of "checkpoints" developed by EMODnet (https://emodnet.ec.europa.eu/en/checkpoints).

Recommendation 5. Funding and Organization

Sustained government funding should be sought in order to ensure continuity of the observations and their use by different categories of users. In parallel, coordination among funders and regional partnerships should be established and maintained to ensure cohesion of the systems.

We advocate for international or trans-regional coordination; international funding and coordination mechanisms should be set up to facilitate the development of observing systems in countries with less developed infrastructure. Furthermore, we recommend the establishment of a task team, or the evolution of the Boundary System Task Team itself, to champion boundary current regions globally.

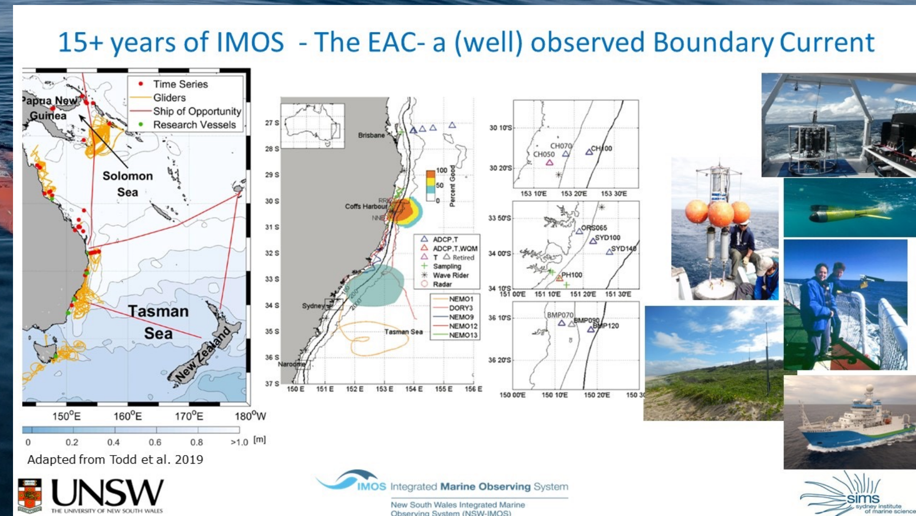
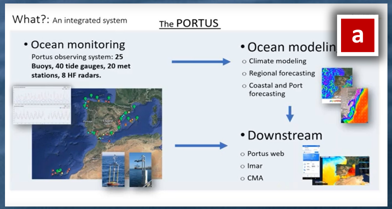
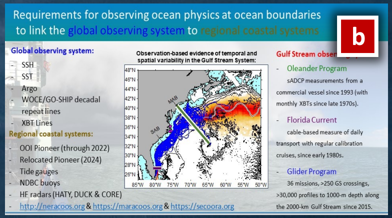


FIGURE. Observing systems for EAC (top) and CC (bottom).
From the webinars of M. Roughan and K. Zaba

Figure Info and Credits

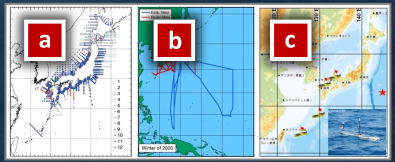


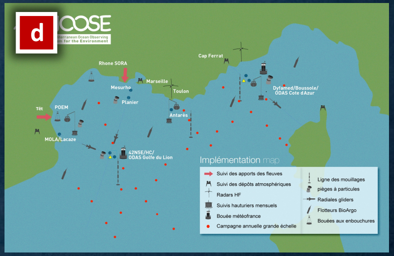


RECOMMENDATION 1

(a) The Portus system. Slide from the webinar of E. Alvarez-Fanjul. Credit: collage based on figures from the website of Puertos del Estado (https://www.puertos.es/).

(b) Requirements for observing ocean physics at ocean boundaries, the case of the Gulf Stream. Slide from the webinar of M. Andres. Credit: figure from M. Andres (WHOI)





RECOMMENDATION 2

(a) Coastal hydrographic stations by prefectural fisheries research institutes. Credit: https://www.jfa.maff.go.jp/j/kikaku/wpaper/h29_h/trend/1/t1_1_2_1.html

(b) Paths followed by the two research vessels (*Ryofu Maru* and *Keifu Maru*) of the Japan Meteorological Agency in the western North Pacific during winter 2020. Credit: https://www.data.jma.go.jp/gmd/kaiyou/db/vessel_obs/data-report/html/ship/ship_e.php?year=2020&season=winter#kisetsu

(c) Near-real-time location of autonomous ocean vehicles (wave gliders) operated by the Japan Coast Guard. Credit: https://www1.kaiho.mlit.go.jp/KAN11/aov/aov_realtime_msil/ (accessed June 2021)

(d) Implementation map of the MOOSE network. Credit: Cocquempot, L., C. Delacourt, J. Paillet, P. Riou, J. Aucan, B. Castelle, G. Charria, J. Claudet, P. Conan, L. Coppola, and others. 2019. Coastal ocean and nearshore observation: A French case study. *Frontiers in Marine Science* 6:324, https://doi.org/10.3389/fmars.2019.00324.

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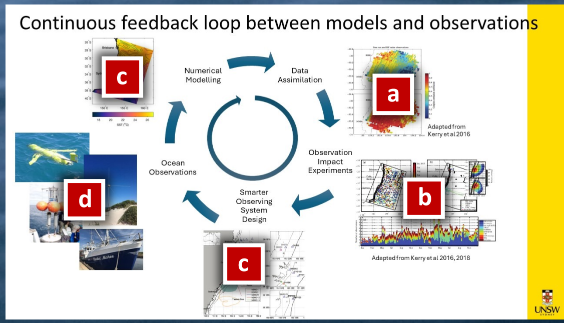


RECOMMENDATION 3

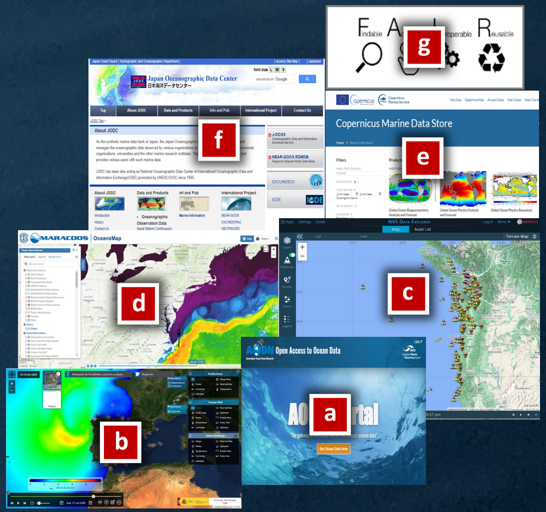
Schematic of the feedback loop between models and observations. Slide from the webinar of C. Kerry.

(a) Figures adapted from Figure 14 in: Kerry, C., B. Powell, M. Roughan, and P. Oke. 2016. Development and evaluation of a high-resolution reanalysis of the East Australian Current region using the Regional Ocean Modelling System (ROMS 3.4) and Incremental Strong-Constraint 4-Dimensional Variational (IS4D-Var) data assimilation. *Geoscientific Model Development* 9:3,779–3,801, https://doi.org/10.5194/gmd-9-3779-2016.

(b) Figures adapted from Kerry et al. (2016, 2018), their Figures 5 and 2, respectively. Kerry, C., M. Roughan, and B. Powell. 2018. Observation impact in a regional reanalysis of the East Australian Current System. *Journal of Geophysical Research: Oceans* 123(10):7,511–7,528, https://doi.org/10.1029/2017JC013685.

(c) Credits: C. Kerry (unpublished figures)

(d) Credits: Australia's Integrated Marine Observing System (IMOS)



RECOMMENDATION 4

(a) https://portal.aodn.org.au/

(b) https://portus.puertos.es

(c) https://nvs.nanoos.org/Explorer

(d) https://oceansmap.maracoos.org/

(e) https://data.marine.copernicus.eu/products

(f) https://www.jodc.go.jp/jodcweb/

(g) https://fr.wikipedia.org/wiki/Fair_data#/media/Fichier:FAIR_data_principles.jpg
Credits: SangyaPundir (2016) with CC BY-SA 4.0 license

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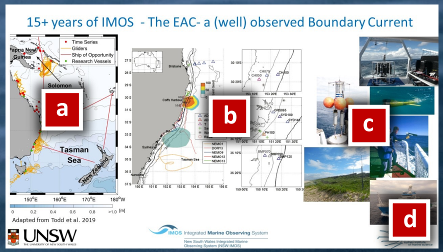

RECOMMENDATION 5

TOP. Representation of the IMOS observing system. Slide from the webinar of M. Roughan.

(a) Adapted from Todd et al., 2019; their Figure 7: Todd, R.E., F.P. Chavez, S. Clayton, S. Cravatte, M. Goes, M. Graco, X. Lin, J. Sprintall, N.V. Zilberman, M. Archer, and others. 2019. Global perspectives on observing ocean boundary current systems. *Frontiers in Marine Science* 6:423, http://doi.org/10.3389/fmars.2019.00423.

(b) Credits: C. Kerry (unpublished figures)

(c) Credits: IMOS

(d) Credit: R/V *Investigator*, courtesy of the Marine National Facility.

BOTTOM. Representation of the California Current System. Slide from the webinar of K. Zaba.