GOMO's Impact and Output measures

As GOMO and observing systems mature, there is a need to better quantify the real impact of these systems and the information they provide beyond the AOP (Annual Operating Plan) milestones and measures. Without continuous valuation of the systems, there will not be any improvement or increased benefit to the range of end-users including societal benefits. GOMO chose several output and impact measures in order to capture some of the higher level benefits and other areas of active study including the economic valuation of ocean data and information. GOMO is still developing ways to best track and measure these. Below are a few examples of these measures.

Examples of Output Measures

1. **Quality-controlled data or products**
    ● All of the observing systems have practices in place to quality control the data. Examples are the Global Drifter Program (https://gdp.ucsd.edu/ldl/data/), Argo (https://argo.ucsd.edu/data/), and Sea Level (https://uhslc.soest.hawaii.edu/datainfo/).

2. **Publications by PIs that utilize observations or products (from a total of ~350 in FY21)**
    ● Zhu, J., G. Vernieres, T. Sluka, S. Flampouris, A. Kumar, A. Mehra, M. Cronin, D. Zhang, S. Wills, J. Wang, and W. Wang, 2021: Roles of TAO/TRITON and Argo in tropical Pacific observing system: An OSSE study for multiple time scale variability. J. Clim., 34, 6797-6817. https://doi.org/10.1175/JCLI-D-20-0951.1
    ● Miles, T.N., D. Zhang, G.R. Foltz, J. Zhang, C. Meinig, F. Bringas, J. Triñanes, M. Le Hénaff, M.F. Aristizabal Vargas, S. Coakley, C.R. Edwards, D. Gong, R.E. Todd, M.J. Oliver, W.D. Wilson, K. Whilden, B. Kirkpatrick, P. Chardon-Maldonado, J.M. Morell, D. Hernandez, G. Kuska, C.D. Stienbarger, K. Bailey, C. Zhang, S.M. Glenn, and G.J. Goni. 2021. Uncrewed ocean gliders and saildrones support hurricane forecasting and research. Pp. 78–81 in Frontiers in Ocean Observing: Documenting Ecosystems, Understanding Environmental Changes, Forecasting Hazards
    ● E.S. Kappel, S.K. Juniper, S. Seeyave, E. Smith, and M. Visbeck, eds, A Supplement to Oceanography 34(4), https://doi.org/10.5670/oceanog.2021.supplement.02-28

3. **Data used in models and improved data assimilation**
    ● GOMO initiated a pilot (in collaboration with WHOI) in the 2021 hurricane season. 50 Argo floats were providing data on a 'rapid cycle' (every 2.5 days as opposed to their normal 10 days). Now researchers at Rutgers University Rutgers are currently working to assess the impact of these rapidly cycled floats on the Real-Time Ocean Forecast System, which is used to initialize the coupled operational hurricane forecast models.
    ● The OceanPredict project collects information on ocean data assimilation systems from around the world. This includes information on assimilated data and products. The data does not capture all ocean models (for example it doesn't include NOAA/NCEP GODAS, NOAA/GFDL models, etc which are used for climate predictions and projections). Nor does it capture ocean platform data (e.g. from moored and drifting buoys) used in atmospheric models.

4. **Data or products used in assessments to inform science and management**
   - Development and maintenance of delivery of ocean monitoring and forecast products to the operational and research community: the Global Ocean Data Assimilation System (GODAS) website (http://www.cpc.ncep.noaa.gov/products/GODAS), hosted by NOAA's Climate Prediction Center, serves a global user community with real-time ocean monitoring and ocean prediction products. The website also provides access to the GODAS data sets that can be used for (a) improved understanding of ocean climate variability, and (b) validating data from different in situ ocean observing systems.

5. **Highly cited GOMO-supported observational products and authoritative assessments**
   - World Ocean Database (https://www.ncei.noaa.gov/products/world-ocean-database)

6. **Field tests/demonstrations of new technologies or methodologies.**
   - TPOS-2020: Technology projects to address observational requirements and gaps in the tropical Pacific Ocean. Projects included Argo floats equipped with rainfall, wind speed and biogeochmical sensors; Saildrone as a low-cost platform for observing the planetary boundary layer and surface biogeochemistry; and Enhancement of NDBC TAO Moorings to enable boundary layer sampling that can be easily integrated into the current array.
   - Saildrone in the Arctic - ARP has collaborated with Saildrone, the Pacific Marine Environmental Laboratory's (PMEL) Innovative Technology for Arctic Exploration (ITAE), and the National Ocean Service, and others to develop instruments such as an air-sea carbon dioxide flux sensor and collect data in the data sparse Arctic. Saildrone measurements extend and enhance the spatial coverage of the measurements made on traditional ship-based platforms for ARP programs including the Distributed Biological Observatory (DBO) and Ecosystem Fisheries-Oceanography Coordinated Investigations Programs (EcoFOCI).

7. **GOMO PIs, personnel, and/or key partners in critical leadership roles.**
   - Sid Thurston
     - WMO Vice-Chair, Standing Committee on Earth Observing Systems and Monitoring Networks (SC-ON), Data Buoy Cooperation Panel (DBCP)-Lead, International Cooperation and Partnerships, IOC-WMO Joint Collaborative Board (JCB) - WMO Observations Lead
   - Kathy Tedesco
     - Co-Chair, USGCRP Carbon Cycle Science Interagency Working Group
   - Kelley Uhlig
     - Chair of the cross-NOAA Arctic Action Team
   - Brittany Croll
     - lead US negotiator for UNFCCC research and systematic observations, periodic review and global stocktake

Examples of Impact Measures

1. **Transition of mature technologies into sustained observing**
   - In progress.

2. **Partner engagement and leveraging of resources**
   - GOMO has participated in RAMA bilateral Partnerships with India's Ministry of Earth Sciences (MoES) and Indonesia's Agency for Meteorology, Climatology and GeoPhysics (BMKG) for over 15 years. During this long-term collaboration GOMO's partners have delivered a combined annual average of 80 ship-days to service NOAA's Indian Ocean RAMA moorings located in the central and eastern Indian Ocean. The price of this shiptime is US$4M/year using a typical day rate of $50K for a research vessel. This does not include the savings of not having to transit a NOAA "White Hull" Research Vessel away from its intended US Mission to the Indian Ocean. In exchange for this critical shiptime, GOMO provides annual in-country capacity building workshops with NOAA and US Subject Matter Experts, modeling and forecast training at NOAA's Climate Prediction Center (CPC) International Desk, Graduate Fellowships at the US Universities and joint monsoon and climate models development.

3. **Publications by others that utilize GOMO data/products**
   - Many of the publications listed in our dataset are written by others utilizing the data from our observing systems (see the GOMO overview presentation).

4. **Model and/or forecast improvements**
   - A variety of GOMO-supported observations (Argo, drifters, Gulf Stream gliders, etc.) are being leveraged during hurricane seasons. These observations are being evaluated for their impact on the experimental and operational hurricane forecast models, especially from the 2021 season.
   - A data denial impact study (Centurioni et al., 2017) demonstrated the impact of drifter-based surface pressure observations, noting that these drifter observations are the most valuable per-observation contributor of the global ocean observation system to numerical weather prediction.

5. **Specific knowledge advancements/monitoring**
   - [Tropical Pacific Observing System](#) (TPOS) 2020 was a focused, finite-term project, beginning in 2014 and completing in 2021, with its primary outcome being an internationally-coordinated and supported sustainable observing system for the tropical Pacific ocean. TPOS 2020 set out to deliver a new integrated TPOS design to improve coupled weather and subseasonal forecasting capabilities.

6. **Ocean data contributing to the blue economy**
   - GOMO co-funded a study that estimates the potential economic value of improved information about three areas of active research within the NOAA Research portfolio, namely: 1) Ocean acidification (OA), focusing on users in the US shellfish industry, 2)

Arctic sea ice, focusing on users in the global maritime transportation industry and 3) Ocean carbon uptake, focusing on climate policy decisions. Areas 1 and 3 are strongly tied to GOMO's support of ocean carbon research.