

Contributions of animal-borne sensors to understanding broad-scale oceanographic-biological linkages

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Biologically relevant environmental observations

The wide-ranging animal migrations of many Arctic species make them ideal observing platforms for sampling environmental variables using globally-accepted standards for oceanographic data. Marine mammals in particular have contributed a significant number of oceanographic observations in the Antarctic (Figure 1) often providing observations in regions that would otherwise prove challenging for deploying observing instruments. Oceanographic sampling using marine mammals in the Arctic is significantly less common by comparison, with most contributions obtained using hooded seals (Fedak 2013). However the contributions from instrumented pinnipeds in the Arctic are expected to increase after the implementation of the MARES project begins collecting oceanographic data with instrumented bearded seals.

In addition to providing internationally-accepted standard oceanographic observations, animal-borne sensors (ABS) also provide information on biologically relevant oceanographic conditions. Unlike buoys that passively track currents, instrumented animals can sample water masses along preferred migratory routes and foraging locations. The use of ABS to monitor environmental variables and animal behavior provides an important link to understand how changes in the physical environment (that can also be monitored over broad scales using remote sensing technology) affects the biological components of Arctic ecosystems that is often harder to track. An improved understanding of the physical-biological linkages in polar waters is needed to explore more quantitative proxies for monitoring species change in the Arctic using remote sensing technology (Skidmore et al. 2015). In addition it provides an opportunity to test how migratory species affect the environment through transfer of energy or nutrients, thus acting as a biological conduit linking Arctic with non-Arctic ecosystems.

Challenges for sustainable observations

Coordination and data assimilation from disparate oceanographic sensors: Integration of oceanographic measurements from ABS to Arctic oceanographic observing programs can be particularly challenging if ABS oceanographic measurements are designed to maintain a tight coupling between environmental measurements and animal dive behavior, or habitat use. As an example of data integration challenges, international ocean observing systems, such as the International Arctic Buoy Program (IABP), often have established standards for collection of data. There may also be provisions for including additional data that are not required across the network of buoys. In contrast, ABS may only collect a subset of the required IABP measurements, and animal swimming behavior may violate data user needs to track sea ice and water masses that are typically recorded from drifting buoys. In the case of IABP there also are requirements for real-time data transmission and archiving. Programmed ABS sampling and data transmission rates based on animal dive depth thresholds or tradeoffs to improve battery longevity may make the format of ABS datasets unique and more challenging to incorporate into existing data processing frameworks that are used to serve real-time data.

Despite the challenges in integrating data across different sensor types, there are opportunities to improve coordination and build on existing data standards established for some ABS collected measurements. The level of precision and units of measurement could be informed by existing standards from global observing networks. Additional pre-processing and subsampling of ABS data may also provide more uniform observations that are not as heavily influenced by animal behavior. Establishment of data collection or processing standards to improve data interoperability will require commitment from a coordinating body that can represent the disciplinary interests of biologists and oceanographers.

The Integrated Ocean Observing System (IOOS) in the United States has established an Animal Telemetry Task Team to handle the unique ocean sampling regime of satellite tagged animals, and may provide a useful starting point for determining standards for oceanographic measurements from tagged animals (Moustahfid et al., 2014). The U.S. Arctic Marine Biodiversity Network (AMBON) may also be helpful partners in developing standards for ABS measurements in the Arctic that could account for the effects from different forms of sea ice that may be actively avoided or pursued by animals that are collecting oceanographic data. From a pan-Arctic perspective, the Marine Expert Network of the Circumpolar Biodiversity Monitoring Program (CBMP) may have the resources and coordination infrastructure in place to best lead an international effort to bridge the disciplinary divide that prevents active sharing of environmental data from ABS with the broader Arctic observing community. Establishing cooperative partnerships with existing funded entities with similar goals for integrating ABS data into ocean models should be a priority and would ensure that efforts are not duplicated.

Technological barriers: Long-term observations using animal-borne sensors will continue to prove challenging given the limitations in sensor technology, battery life, and attachment methods. Currently deployments are biased towards larger marine mammals capable of carrying satellite-linked instruments with minimal interference on behavior. Short battery-life limits the duration of data collection, and the annual molt of pinnipeds affects the duration that animals can carry instruments attached to fur. The high cost and effort involved in deploying instruments also limits sample size and may contribute to the difficulty in achieving sustainable funding for long-term ABS studies.

Supporting sustainable observations

In addition to technological advances that may improve the affordability and duration of observations from animal-borne sensors, a few implementation strategies are suggested for improving the sustainability of observations from animal-borne sensors:

- 1) *Coordination on data standards to maximize data interoperability:* Inclusion of ABS data on overlapping oceanographic variables should meet established data standards where applicable to improve data interoperability with the broader Arctic observing community. Such efforts to establish data standards should involve an international community of biologists and oceanographers. These efforts may build from some initial coordination support from the Marine Expert Network of the Circumpolar Biodiversity Monitoring Program, or national efforts that have complementary goals for integrating ABS data into ocean models or observing networks designed to detect environmental change.
- 2) *Rapid data access:* Oceanographic data with little or no embargo period are often most useful to the broader community, but animal tracking data are infrequently openly shared beyond derived mapped products. Commitment to providing a short QA/QC period prior to releasing oceanographic data through commonly-used ocean data access sites (e.g. sites where similar GEOSS observing data can be accessed) would increase the use and demand for ABS data. Currently support from national data archives (e.g., U.S. National Oceanographic Data Center,

ACADIS) provide a very flexible format for quality control and data archiving that do not always meet the need for rapid data access. Data sharing agreements and protocols for automation in the processing and serving of standardized data may need to be developed, and could begin by exploring ways to integrate data with existing operational Arctic observing networks (e.g., IABP) that have developed tools for data processing and rapid data access.

- 3) *Coordination with the modeling community*: Contributions from ABS towards validation of modeled oceanographic output may provide significant benefits. ABS data may help modelers gain additional insight into how species and ecosystems respond to environmental changes in the ocean. Such efforts would require conscientious coordination between modelers and biologists in order to develop, test, and validate hypotheses of physical-biological linkages in the Arctic.

Establishment of strong partnerships between the ocean-observing, and marine mammal research communities as well as a commitment to open data access are essential for promoting sustainable observations using ABS. However, the full value of using ABS on migratory species to improve understanding of oceanographic-biological linkages over broad scales has not yet been fully investigated in the Arctic.

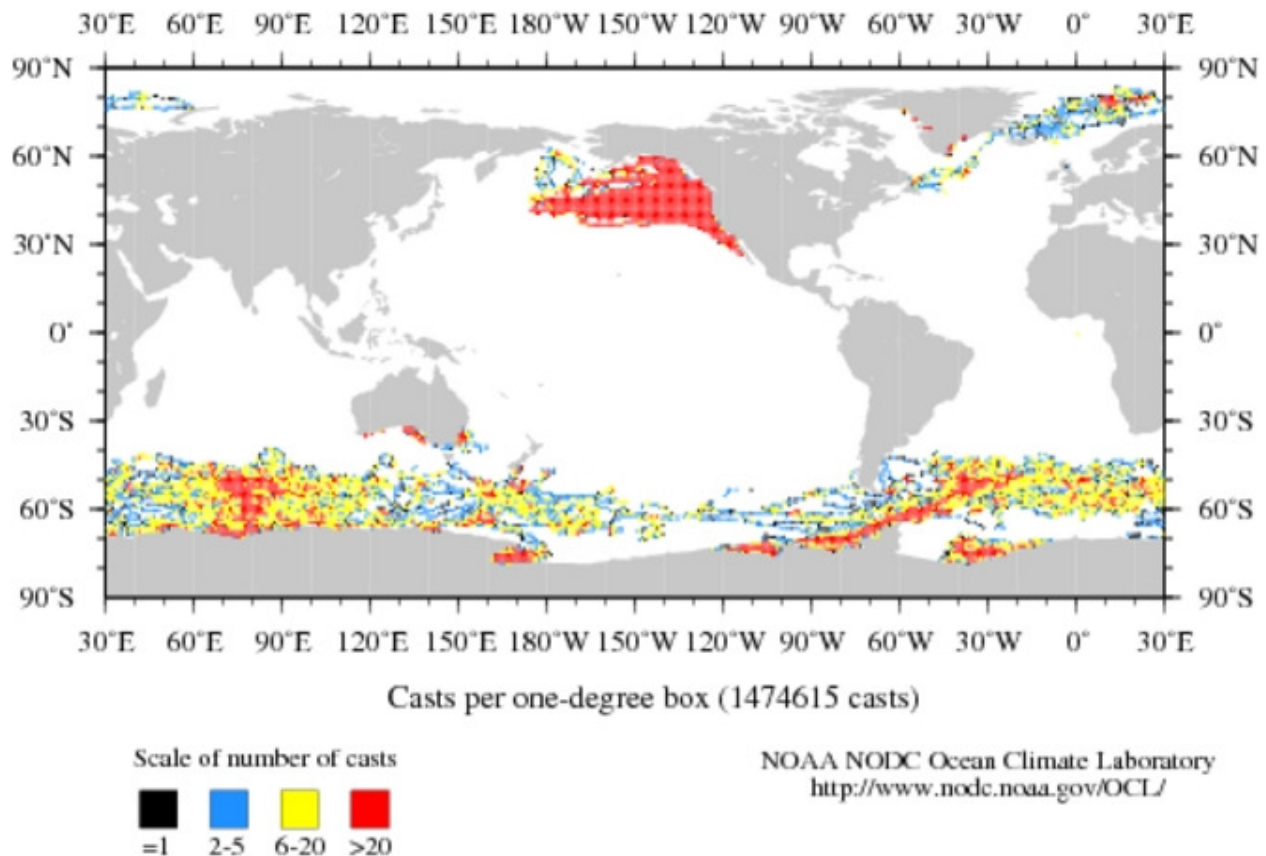


Figure 1. Distribution of CTD casts from animal-borne sensors. Source: National Oceanographic Data Center.

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