

## **The Distributed Biological Observatory: Linking Physics to Biology in the Pacific Arctic Region**

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### **Introduction**

In 2009, in response to dramatic seasonal sea ice loss and other physical changes influencing biological communities, a Distributed Biological Observatory (DBO) was proposed as a change detection array to measure *biological responses* to physical variability along a latitudinal gradient extending from the northern Bering Sea to the Beaufort Sea in the Pacific Arctic sector (Grebmeier et al. 2010). By design, DBO sampling was focused on five regions of demonstrated high productivity, biodiversity and rates of change (<http://www.arctic.noaa.gov/dbo/>). The DBO concept was vetted at numerous scientific meetings and has been included in various US arctic research planning documents, including the National Oceanographic and Atmospheric Administration (NOAA) Arctic Strategic Plan, the United States Geological Survey (USGS) 'Science Needs' Report, the Bureau of Ocean Energy Management (BOEM) Alaska Region Research Plan, the Interagency Arctic Research Policy Committee (IARPC) 5-Year Research Plan, the National Ocean Policy Strategic Plan, and the National Strategy for the Arctic Region (NSAR).

### **Pilot Phase, 2010-2014**

In 2010, a pilot DBO program was initiated focused on developing standardized sampling in regions 3 and 5. International participation was coordinated by the Pacific Arctic Group (<http://pag.arcticportal.org/>) and national participation was coordinated by NOAA (<http://www.arctic.noaa.gov/dbo/>). In 2012, the National Science Foundation/Arctic Observing Network (NSF/AON) program awarded a 5-year research grant to a collaborative team from the University of Maryland Center for Environmental Science (UMCES), Clark University and the Woods Hole Oceanographic Institution (WHOI) to provide support for standardized sampling in all five DBO regions. That same year, the IARPC developed a 5-year plan focused on seven research themes (<http://www.iarpccollaborations.org/plan/index.html>). The DBO Collaboration Team (CT) was formed under the first theme, *Sea Ice and Marine Ecosystems* and has been meeting via teleconference to complete ten milestones intended to guide the DBO from a pilot phase to the implementation of decadal-scale sampling; more details at: <http://www.iarpccollaborations.org/teams/Distributed-Biological-Observatory-milestones>.

### **International Cruise Planning and Reporting**

Support from the Pacific Arctic Group (PAG) has been essential to the success of the DBO pilot phase. PAG is a consortium of international institutions and individuals having a Pacific perspective on Arctic science (<http://pag.arcticportal.org/>). Organized under the aegis of the International Arctic Science Committee (IASC), the PAG has as its central mission to serve as a Pacific Arctic regional partnership to plan, coordinate, and collaborate on science activities of mutual interest. The PAG meets each spring and autumn and has taken a leadership role in

coordinating international and industry-based contributions to DBO sampling, including the provision of ship time at no-cost. These international contributions to DBO sampling have provided an unprecedented capability to track inter- and intra-annual variability in DBO regions. An annual listing of DBO cruises is developed each year at the PAG spring meeting and is available on both the PAG and NOAA DBO websites (<http://www.arctic.noaa.gov/dbo/cruise-data>). The results of each year's sampling are reported at the PAG autumn meeting and form the basis for national and international science presentations given at various national and international forums.

### **US Interagency, Academic and Industry Partners**

The DBO CT has benefitted from strong support and collaboration from a number of US agencies and academic partners. An abbreviated listing of contributions is provided below, accompanied by web links to sources of additional information.

**NSF AON:** Conduct standardized sampling in all five DBO regions, 2012-2017  
<http://arctic.cbl.umces.edu/>; also, contributions to DBO sampling from other AON-supported projects, various NSF-research platforms and the provision of a physical oceanographic data portal at WHOI

see Lee Cooper presentation to the DBO CT  
<http://www.iarpccollaborations.org/members/documents/2164>

**UCAR:** Provision of a DBO Data Agreement and Data Archive at the University Corporation for Atmospheric Research (UCAR), Earth Observing Laboratory (EOL)  
[https://www.eol.ucar.edu/field\\_projects/dbo](https://www.eol.ucar.edu/field_projects/dbo)

see Jim Moore presentation to the DBO CT  
<http://www.iarpccollaborations.org/members/documents/1576> and

see Don Stott presentation to the DBO CT  
<http://www.iarpccollaborations.org/members/events/2319>

**NASA** The development of DBO-focused satellite visualizations products as part of the Cryosphere Science Research Portal  
<http://neptune.gsfc.nasa.gov/csb/index.php?section=270>

see Joey Comiso presentation to the DBO CT  
<http://www.iarpccollaborations.org/members/documents/1318>

NASA also contributed to DBO sampling during the 2010 ICESCAPES program  
<http://www.nasa.gov/topics/earth/features/icescape2010.html>

**NOAA OAR:** Coordination of international contributions to the DBO, via the PAG, and contributions to DBO sampling during the RUSALCA program - the only program to sample in the Russian Exclusive Economic Zone <http://www.arctic.noaa.gov/rusalca/>

**NMFS:** Chair of the IARPC DBO CT, and contributions to DBO sampling during various multidisciplinary research programs in the northern Bering and Chukchi seas, e.g. BASIS: [http://www.afsc.noaa.gov/abl/mesa/mesa\\_basis.php](http://www.afsc.noaa.gov/abl/mesa/mesa_basis.php), Arctic Eis: <https://web.sfos.uaf.edu/wordpress/arcticeis/>

**NOS:** Opportunistic contributions to DBO sampling via NOAA ship *Fairweather* and coordination of the Arctic Marine Biodiversity Observing Network (AMBON). NOTE: AMBON is co-supported by BOEM through the National Oceanographic Partnership Program (NOPP) and by industry partner Royal Dutch Shell. <http://ambon-us.org>

**BOEM Alaska Environmental Studies Program:** Contributions to DBO sampling, via support of research projects conducted by NOAA OAR and NMFS, in the Chukchi and Beaufort Seas (e.g. CHAOZ, ArcWest), and via awards to numerous academic partners in support of studies such as ANIMIDA, cANIMIDA, ANIMIDA III, COMIDA, Hanna Shoal, AMBON;

see Dan Holiday presentation to the DBO CT  
<http://www.iarpccollaborations.org/members/documents/1956>

for research project summaries, see DBO 2<sup>nd</sup> Data Workshop final report  
[http://www.arctic.noaa.gov/dbo/sites/default/files/atoms/files/2nd%20DBO%20data%20workshop%20report\\_Final-2.pdf](http://www.arctic.noaa.gov/dbo/sites/default/files/atoms/files/2nd%20DBO%20data%20workshop%20report_Final-2.pdf)

also see BOEM Alaska Region Environmental Studies page:  
<http://www.boem.gov/About-BOEM/BOEM-Regions/Alaska-Region/Environment/Environmental-Studies/Index.aspx>

Future contributions to sampling in DBO Beaufort Sea regions are anticipated, via the Marine Arctic Ecosystem Study (MARES) program  
see Guillermo Auad presentation to the DBO CT  
<http://www.iarpccollaborations.org/members/documents/2533>

**AOOS** Provision of web-based assets mapping and a password-protected DBO Data Workspace  
<https://workspace.aos.org/group/23134/projects>

AOOS also provides link to the IOOS, including with both national (17 Fed agencies) and global (GOOS) outreach <http://www.aos.org/>

Partial support for long-term biophysical mooring (UAF) in the NE Chukchi Sea, and potential for future support for moorings in the N. Bering and Beaufort seas as ‘anchors’ to DBO transect lines.

**NPRB** Support for long-term biophysical mooring (UAF) in the NE Chukchi sea, and potential for future contributions to sampling in DBO Chukchi Sea regions, via the Arctic Program <http://www.nprb.org/arctic-program>

### **Key Products: Workshops, Data Agreement, Data Archive, Presentations and Papers**

There have been numerous special sessions and presentations on the DBO at multiple science and policy venues since the inception of the pilot phase. While a full-listing goes beyond the scope of this document, some of the key meetings (including two DBO Data Workshops) are provided here: <http://www.arctic.noaa.gov/dbo/workshop-products>. Several significant products have resulted from these meetings, including:

- DBO Data Policy and Release Guidelines: [http://dbo.eol.ucar.edu/data\\_policy-dbo.html](http://dbo.eol.ucar.edu/data_policy-dbo.html)
- UCAR/ACADIS DBO Data Archive: [https://www.eol.ucar.edu/field\\_projects/dbo](https://www.eol.ucar.edu/field_projects/dbo)
- Satellite products for the DBO: <http://neptune.gsfc.nasa.gov/csb/index.php?section=270>
- AOOS DBO Workspace <https://workspace.aos.org/group/23134/projects>
- Presentations: AGU & OSM Meeting(s) 2012, 2014 & Alaska Marine Science Symposiums
- Peer-reviewed publications: Itoh et al. (2015); Grebmeier et al. (2015); NOTE – planning is underway for DBO Special Issue of *Deep Sea Research II*.

## **Decadal Implementation Phase, 2015-2024**

### **Expansion to Eight DBO Sampling Regions: 2 Bering + 3 Chukchi + 3 Beaufort**

In 2013, increasing interest in the DBO led to the initiation of discussions within the IARPC CT to extend DBO sampling to regions in the Beaufort Sea. Primary contributors to these discussions were NSF/AON-UMCES, BOEM/Alaska Region, NOAA/NMFS & OAR and Canada Department of Fisheries and Oceans. To the extent possible, Beaufort Sea sampling transects and regions were centered on areas of high productivity and biodiversity, as in the Chukchi Sea. Other factors considered in selection of the new regions included: (i) availability of long-term data; (ii) linkages to other programs; and (iii) willingness of IARPC CT and other partners to participate in DBO sampling and data sharing. In 2014, draft maps of provisional DBO sampling sites were prepared and circulated among the IARPC CT and other interested colleagues for discussion and revision. By 2015, three new DBO regions were agreed upon for the Beaufort Sea, with locations embedded in a web-accessible map, (<http://www.arctic.noaa.gov/dbo/dbo-stations>). The IARPC DBO CT agreed that expansion of standardized sampling into the Beaufort Sea was a significant step in the process of developing a decadal-scale implementation plan.

**Annual Cycle for Field Season Planning, Data Sharing and Reporting: 5 steps**

Since the inception of the DBO, the PAG semi-annual meetings have been essential to field season planning, provisional data exchange and collaboration on science products on an international basis. The annual cycle for of DBO activities proceeds in five steps:

- (i) PAG Spring Meeting: coincides with the Arctic Science Summit Week (ASSW) of IASC, and includes a review of ongoing studies in the Pacific Arctic region and the initiation of the annual DBO Sampling Table where *planned* DBO sampling is tabulated and auxiliary research projects that can provide DBO-related data are identified.
- (ii) DBO Cruises: ship-based sampling is completed on various cruises from July-October, and DBO-related sampling is completed on various auxiliary projects.
- (iii) PAG Fall Meeting: often coincides with related arctic science meetings and provides an opportunity to report *actual* DBO cruise sampling and related outcomes from auxiliary projects. During the implementation phase, a new goal of submission of metadata to the UCAR/ACADIS website will be established.
- (iv) DBO Data Workshops: two DBO Data Workshops have provided an opportunity for presentation of provisional results, multi-disciplinary discussions and planning for the data archiving (<http://www.arctic.noaa.gov/dbo/workshop-products>). During the implementation phase, an annual DBO Data Workshop has been identified as a key activity in support of data integration, analysis and archiving.
- (v) DBO Products: this has included science presentations and community outreach at various annual science meetings (e.g. AGU, OSM, AMSS) and during informal discussions with agency and academic leaders. During the implementation phase, the goal of augmenting community outreach to include active participation by local observers of biological change will be sought, via linkages with established community observing networks (e.g. CONAS, ELOKA, C2O2, A-OK).

This annual cycle of DBO activities has proven very effective during the pilot phase and is anticipated to foster success during the DBO implementation phase. As noted above, three important additions to the cycle for the implementation phase include: (1) a requirement for all DBO contributors to upload metadata to the ACADIS DBO data archive before or immediately after the PAG autumn meeting; (2) the conduct of an annual DBO Data Workshop, and (3) the goal of building connections with existing community-based observation programs, as described below.

**Building Connections with Existing Community-based Observation Programs**

The development of a decadal implementation plan seems an opportune time for the DBO to foster connections to existing community-based observation programs in an effort to link offshore observations of biological change to local observations and traditional knowledge. One approach to this goal would be to identify communities close to existing DBO transect lines where local observations are already underway: e.g., Gambell, Savoonga, Wales, Diomedea,

Point Hope, Point Lay, Wainwright, Barrow and Kaktovik. A second step would be to initiate dialog with existing local observing programs to explore areas of synergy between coastal and DBO sampling, which could be identified and acted upon.

Over the past decade of rapid environmental change, several community-based programs have been initiated to foster the inclusion of local knowledge and observations in assessments of shifts in Arctic ecosystems (e.g., Sigman, 2015). Three examples include the US-based CONAS and ELOKA programs, and the Canadian-based CACCON program:

- The Community Based Observation Network for Adaptation and Security (CONAS) consists of systematic observations made by subsistence hunters, fishermen and other leaders from eight coastal communities in the Bering Sea (<http://www.bssn.net>). The existing network is comprised of 3 villages in Chukotka and 5 in Alaska, including Gambell and Savoonga on St. Lawrence Island (near DBO regions 1 and 2). The CONAS is funded by the NSF, and is now planning to expand northwards, to include coastal villages along the Chukchi and Beaufort seas, and has expressed an intention to partner with the DBO and AOOS. <http://www.uidaho.edu/caa/programs/research/crc/research/conas>
- The Exchange for Local Observations and Knowledge of the Arctic (ELOKA) was launched during the 2007-09 IPY, with funding from NSF/Arctic Social Science program, to facilitate the collection, preservation, exchange, and use of local observations and knowledge of the Arctic. ELOKA continues to support a number of community-based observations and includes a long list of partner organizations including AOOS (<http://eloka-arctic.org/>).
- The Circumpolar Arctic Coastal Communities Observatory Network (CACCON ~"Catch-ON") is a new initiative aiming to build knowledge hubs to support, sustain and share adaptation for coastal communities (<http://caccon.org/>).

There are many other community-based programs (e.g., LEO, SIWO, C2O2 etc.) where synergistic connections to the DBO might be fostered. In particular, a new initiative to support community observations and information sharing is the Alaska Arctic Observatory and Knowledge Hub (A-OK). This 5-year program will focus initially on the cryosphere and likely include aspects of several local observation programs already underway in the Alaskan arctic. The upcoming Arctic Observing Open Science Meeting (17-19 November 2015; <http://www.arcus.org/search-program/meetings/2015/aosm>) might provide an opportunity to discuss steps toward developing synergistic connections between existing community-based observations and the DBO.

### **Periodic Assessment of the State of the Pacific Arctic Marine Environment**

The overarching goal of a decadal-scale DBO implementation plan is to establish guidelines for the *periodic assessment of the physical and ecological state of the Pacific Arctic marine*

*environment* (ref: Milestone 3.1.3h). The DBO was launched in 2010 with just such a goal in mind; that is, to assess how bio-diverse ‘hotspots’ of marine organisms are responding to rapid physical changes in the Pacific Arctic region. As mentioned earlier, an annual DBO workshop is considered an essential activity in support of this goal. Annual workshops would serve as forum where assessment guidelines could be developed, discussed and approved. All US agencies involved in the DBO effort should explicitly recommend and financially support the participation of their Principal Investigators in this annual DBO workshop.

A general timeline for steps in the development of a periodic Pacific Arctic Regional Marine Assessment (PARMA) are provided here for discussion and revision:

<b>PRODUCT</b>	<b>Target Date</b>
<b>Annual DBO Workshop</b>	2016-2023
PARMA Guidelines: development & vetting	2016-2017
Special Issue of DSR II: “the DBO – results since 2010”	2017
 <b>Produce the 1<sup>st</sup> Pacific Arctic Regional Marine Assessment</b>	 2018
Revise PARMA @ 3-year intervals	2021, 2024
 <b>Long-term Future of the DBO – National and International Linkages</b>	 2019
IARPC-IASC Panel Review @ 3-year intervals	2020, 2023

Some ideas on how the DBO Implementation phase might be supported include:

#### **US Agency Contributions**

- **NSF** – continue support of DBO sampling in all regions, *and* support of the DBO Data Archive; initiate a DBO Program Office &/or as a DBO-LTER (Long Term Ecological Research) framework.
- **NASA** – further refinement of DBO Cryosphere products, as needed. Note that satellite sea surface height and sea surface salinity are currently being added to augment existing data products. Also, NASA may provide coordination of sampling from shipboard programs (e.g. Arctic-COLORS), which may be developed over the next decade.
- **NOAA** –continue DBO sampling during the RUSALCA and AMBON cruises, on AFSC cruises *and* with NOS-charting assets (e.g. *Fairweather*) whenever possible; support and host an annual DBO workshop; publish the Executive Summary of the PARMA as a contribution to the Arctic Report Card.
- **BOEM** – continue support of DBO sampling during all research programs in the Pacific Arctic whenever possible.

- **AOOS** – continue support of long-term biophysical mooring in the NE Chukchi Sea and initiate support for biophysical moorings in the Beaufort and northern Bering Seas; enhance DBO Workspace and linkages to DBO Data Archive; assist in the development of visualization products; support State of the PAME assessment.
- **NPRB** – continue support of long-term biophysical mooring in the NE Chukchi Sea, as part of the Long-Term Monitoring Program; initiate DBO sampling during research programs funded via the Arctic Program.
- **ONR** – initiate DBO sampling during physical research programs in the Pacific Arctic whenever possible.
- **Industry Contributions**  
NOPP – following the AMBON example, development of an inter-agency + industry call for a 10-year program of DBO support, in response to Integrated Ecosystems Assessment (IEA) goals common to all contributors.
- **Academic Contributions**  
Universities – research & provision of peer-reviewed science, via support from US Agencies; streamline funding processes through programs such as the NOPP, LTER, and NOAA/Cooperative Institutes.
- **International Support and Coordination**  
PAG – continued support of semi-annual meetings  
IASC – initiate inclusion of DBO review @ annual meeting of IASC-Marine Working Group  
Arctic Council – CAFF/CBMP, PAME, other WGs

### **Contributions to the National Strategy for the Arctic Region**

The National Strategy for the Arctic Region (NSAR) Implementation Plan<sup>1</sup> identifies three lines of effort, **two** of which are particularly germane to the implementation phase of the DBO, specifically: *Pursue Responsible Arctic Region Stewardship*, and *Strengthen International Cooperation*.

The DBO directly supports responsible stewardship of the arctic region by providing science-based observations as a basis for effective management and policy decisions. Activities of the DBO are summarized in the NSAR report under the 'Stewardship' line of effort, demonstrating the key nature of systematic observation of biophysical properties to the goals of integrated ocean resource management.

The DBO also strengthens international cooperation by providing the foundation for countries to engage in a common approach to oceanographic observations. The activities of the DBO, coordinated by the PAG, directly support the 'One Arctic' theme, at the foundation of goals established by the US during the Chairmanship of the Arctic Council. In addition, the fact that DBO regions are 'embedded' in the US contribution to the Arctic Council CAFF/CBMP program further strengthens international cooperation.

### References

Grebmeier, J. M., Moore, S. E., Overland, J. E., Frey, K. E., and Gradinger, R. 2010. EOS Trans. AGU, 91, 18, doi:10.1029/2010EO180001.

Grebmeier, J.M., Bluhm, B.A., Cooper, L.W., Danielson, S.L. + 13 additional authors. 2015. Ecosystem characteristics and processes facilitating persistent macrobenthic biomass hotspots and associated benthivory in the Pacific Arctic. *Progress in Oceanography* 136: 92-114.

Itoh, M., Pickart, R.S., Kikuchi, T., Fukamachi, Y. + 9 authors. 2015. Water properties, heat and volume fluxes of Pacific water in Barrow Canyon during summer 2010. DSR I 102: 43-54.

Sigman, M. (ed). 2015. Community-based monitoring of Alaska's coastal and ocean environment: best practices for linking Alaska citizens to science. Alaska Sea Grant, UAF ISBN 978-1-56612-181-1.

<sup>1</sup>[www.whitehouse.gov/sites/default/files/docs/implementation\\_plan\\_for\\_the\\_national\\_strategy\\_for\\_the\\_arctic\\_region\\_-\\_fi....pdf](http://www.whitehouse.gov/sites/default/files/docs/implementation_plan_for_the_national_strategy_for_the_arctic_region_-_fi....pdf)