Operation IceBridge
Mid-Term Review Team (OIBMR-T)
Sea Ice Group (SIG)

RESPONSE FROM ICEBRIDGE SEA ICE SCIENCE TEAM

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Introduction: The OIBMR-T SIG reviewed the goals and level-1 science requirements (L1SR) of Operation IceBridge (OIB) and evaluated how OIB's activities and products have addressed the goals relevant to sea ice and marine snow cover at the mid-term of the program. In summary, the OIBMR-T SIG reports that the mandated programmatic goals and broad scientific goals of OIB are important and appropriate. Progress toward the goals is substantial at the mid-term of the program. OIB has produced and made available estimates of sea ice thickness and snow depth that are being used by the research community to document changes in the state of the marine cryosphere, understand the physics of sea ice and snow, improve predictive models, and improve methods of remote sensing. At least 23 OIB-related articles concerning sea ice and marine snow cover have been published since 2010.

The OIBMR-T SIG has made several recommendations that would further strengthen the OIB mission as it moves into the second phase. The recommendations are listed below, in priority order, along with responses from the OIB Sea Ice Science Team:

1) Establish a working group charged with estimating snow depth and errors, from snow radar, altimeter, and other remote and in-situ measurements and models.

Response:

Already motivated by concerns similar to those voiced by the OIBMR-T SIG, Dr. Tom Wagner has directed the formation of a Snow Thickness on Sea Ice Working Group (STOSIWIG). The STOSIWIG is scheduled to convene its first meeting at U of Kansas on 17-18 Sept 2014. The meeting will be hosted by CReSIS, and will focus on the interpretation of snow radar data and data quality. The group will consider the radar instruments, data processing techniques, and application of in situ data for validation. This meeting is expected to be the first in a series.

(2) Pursue additional opportunities to expand the seasonal and spatial coverage of OIB sea ice and snow measurements, and strengthen connections between OIB and in-situ measurement programs.

Response:

Expanding seasonal and spatial coverage: In response to community comments, the IceBridge Sea Ice Science Team has already provided priority recommendations to the IceBridge Project and NASA Program Manager regarding the seasonal and spatial

expansion of OIB measurements. As a result, efforts are already underway on both fronts. For instance:

- *Seasonal*: OIB has extended temporal sampling of the Arctic sea ice pack beyond winter-time surveys by embarking on new surveys during the early growth and late melt seasons. In late October/early November 2013, sea ice elevation was measured with NASA's Land, Vegetation, and Ice Sensor (LVIS) scanning laser altimeter. In late August to early October 2014, LVIS will collect another set of sea ice measurements during the new Arctic Radiation-IceBridge Sea & Ice Experiment (ARISE) mission with the specific aim to observe conditions in the late summer when melt ponds are expected to be ubiquitous. ARISE is a unique opportunity combining the interest of IceBridge with those of the cloud radiation community. The OIB Project Office is responsible for processing data from both missions. Work will be required to evaluate the applicability of algorithms developed for sea ice conditions in March/April, prior to melt. In addition to these collection opportunities, in 2014 new instrumentation was installed on the NASA OIB aircraft to measure albedo. The primary motivation for measuring sea ice albedo was the anticipation of extended temporal sampling of the polar ice pack. The new albedo instruments were flown during the 2014 Arctic campaign. The OIB instrument and sea ice science teams are working with the OIB Project Office to evaluate the quality and utility of these measurements.

- *Spatial:* OIB has increased the coverage of the Arctic sea ice cover since the first mission was flown in March 2009. This includes a now-routine, temporary relocation of the NASA aircraft to Fairbanks, to provide better access to the Beaufort and Chukchi Seas. As a result, the current compilation of measurements acquired during the series of sea ice missions flown in a given campaign provides comprehensive mapping of snow depth and sea ice thickness distribution across the western Arctic region in winter, at the end of the growth season. Particular attention is paid to the collection of observations in regions that exhibit significant ice thickness gradients (i.e. northern coast of Greenland and edge of the perennial ice pack). The OIB sea ice science team and broader sea ice community encourage extending coverage to the eastern Arctic, but such requests have thus far been denied due to the inability to attain the necessary diplomatic clearance to operate in Russian airspace. Until such clearance is obtained sampling will be limited to the western Arctic region.

  During the 2013 southern hemisphere winter campaign, the base of operations moved from Punta Arenas to McMurdo Station. As a result, OIB collected its first sea ice observations in the Ross Sea. Plans are to rotate the base of operations between Punta Arenas and McMurdo on an annual basis, thus providing the opportunity to collect measurements of the wintertime sea ice pack in both the Weddell/Bellingshausen Seas area and in the Ross Sea on an every other year basis.

Strengthen connections with in-situ measurement programs: The OIB Sea Ice Science Team has made it a priority to seek out opportunities to coordinate OIB sea ice flight lines with planned in-situ measurement programs in the Arctic and Southern Ocean, paying particular attention to programs whose goals are synergistic with those of the OIB Science Requirements. Such opportunities for coordinated efforts are discussed by the OIB Sea Ice Team and members of the sea ice community during the annual Sea Ice

Workshop, typically held in January of each year. The successful implementation of these coordinated efforts relies on the development of thorough logistics plans, involving parties from a variety of agencies, programs and countries. For instance, during the 2014 Arctic campaign, OIB overflew in-situ measurements campaigns supported by ESA, CSA, ONR and NRL. In anticipation of the 2014 Antarctic campaign, an effort is underway to coordinate observations with the planned Polarstern cruise in the Weddell Sea. Publications and presentations at major national and international conferences demonstrate that the measurements made during the numerous coordinated campaigns are being used by members of the research community to improve the quality and utility of airborne and satellite-based sea ice observations. OIB's commitment to identify and coordinate with planned in-situ measurement programs will continue. The OIB Sea Ice Science Team also expects that the upcoming STOSIWIG (Item #1) will provide valuable guidance to the community regarding the design of future in-situ measurement plans for further assessment of OIB data quality.

(3) Update the L1SR document and clarify how the baseline requirements follow from the science goals, especially the goals related to climate dynamics and forecasting.

Response:

The OIB Sea Ice Science team will provide assistance to the OIB Project and Program Managers as needed, reviewing the OIB Level 1 Science Requirements and, if warranted, providing suggested revisions. The need and schedule for this review will be determined by the NASA HQ.

(4) Formally establish the annual open meeting to enhance the effectiveness of input to OIB from the sea ice/snow research community on flight lines, instruments, data access and other topics.

Response:

As the OIBMR-T SIG acknowledges in their report, the OIB Sea Ice Science Team has welcomed and actively sought community participation in the OIB science team meetings, which are held twice yearly. Since 2011, the OIB Sea Ice Science Team has led a 1-day open science meeting in late January at NASA GSFC, in conjunction with the PARCA and OIB Science Team meetings. A broad invitation has gone out to the community for participation in this 1-day sea ice meeting. Attendance has grown each year with representation by the OIB Science and Instrument Teams, the Project Office, national and international agencies (including ONR, NOAA, NIC, ESA, Environment Canada), and academic institutions. This meeting has provided a forum to discuss the quality and utility of OIB data among those collecting, processing and interpreting the measurements. The outcome of these discussions has significantly influenced the OIB sea ice program. For instance, the development of the Arctic sea ice quick look product was a response to the strong interest in the ability to access OIB sea ice products in a time frame that was significantly shorter than the standard timetable for data delivery to NSIDC. Community input is also reflected in the flight line recommendations, the instrument suite, coordination between OIB and other planned activities, data processing and product accessibility.

To further engage the sea ice/snow research community, the OIB Sea Ice Team, in coordination with the OIB Project Office, will take advantage of the momentum established by the January 1-day open science meeting at NASA GSFC. The current invitation list will be reviewed and expanded, with possible use of established scientific distribution lists (e.g. FAMOS). Consideration will also be given to expanding the length (e.g. 2 days versus 1 day) and the scope of the meeting (e.g. increased opportunities to present work related to the production or use of OIB sea ice products). Efforts will also be made to increase community awareness of the public documentation of meeting summaries and presentations. These efforts will be implemented for the January 2015 meeting.

(5) Establish a working group charged with estimating sea ice thickness and errors from altimeter, radar and other remote and in-situ measurements and models, spanning the ICESat-ICESat2 era.

Response:

The OIB Sea Ice Science Team sees high value in establishing this working group. However, we recommend that it be convened on a timeline that can build upon both the momentum and outcomes of the planned STOSIWIG (Item #1). A key input for estimating sea ice thickness and deriving errors relies first on a thorough understanding of the sources and level of uncertainty in the snow depth measurements.