

**Operation IceBridge
Mid-Term Review Team (OIBMRT)
Land-Ice Group (LIG)**

RESPONSE FROM SCIENCE TEAM

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Introduction: The OIBMR-T LIG has conducted an extensive review of all aspects of the land-ice component of the Operation IceBridge Mission (OIB), including the goals and the level-1 requirements. The primary motivation behind OIB was to bridge the ice sheet altimetry record between ICESat and ICESat-2 missions. The OIBMR-T LIG concludes that OIG has made excellent progress in establishing an extended altimetry record of polar ice sheets and glaciers and it is on target to accomplish its main scientific objectives, and has proven to be much more valuable than originally anticipated. OIB has evolved into a complementary, not substitute, observing platform to satellite laser altimetry, measuring critical geophysical properties of glaciers and ice sheets that currently cannot be measured from space, e.g. ice sheet bedrock topography, basal and englacial characteristics and other crucial geophysical parameters, all of which are required for improving understanding of ice dynamics and for the development of 3-D time-dependent numerical ice-flow models.

RESPONSE: The ST is very thankful for this timely review.

The OIBMR-T has made several recommendations that would further strengthen the OIB mission as it moves into the second phase, summarized below:

- Revisit the science requirements so that the list is more concisely and clearly defined.

RESPONSE: Agreed. The ST will revisit and update the science requirement document to make the requirements leaner and revise goal IS14. We plan to have a revised document by early 2015, prior to OIB Greenland 2015.

- Revisit flight-planning priorities to enhance the capabilities of OIB to act as a bridge between satellite altimetry missions and to allow for cross-calibration between the altimeters.

RESPONSE: This has always been one of the underlying top priorities of OIB. Starting in 2014, however, to make this bridging and cross calibration more clear, the ST identified a set of “baseline” missions that will be flown systematically year after year or every other year, to establish a long-term reference of elevation

changes that will be measured systematically. In Antarctica, we established a “Pole Hole” mission for ICESat-2 that will cross all ICESat-2 tracks: a circle around the pole at 86°South. In addition, in Greenland, OIB will continue to fly ICESat-1 line near Summit Station that served as a long-term dh/dt ground validation site. An ICESat-2 calibration/validation site will be established at summit following the first reference flights conducted in Spring 2014.

- Include additional instruments for retrieval of snow radiative transfer properties critical for characterizing scattering of 532 nm wavelength laser altimeters and atmospheric forcing at the surface and for improved photogrammetric mapping of glacier topography.

RESPONSE: The ARISE program starting in September 2014 will address this issue.

- Publication of key review papers documenting the mission and its observing capabilities.

RESPONSE: The OIB web site (<http://icebridge.gsfc.nasa.gov>) includes comprehensive information about OIB mission and is continuously updated. A peer-review paper is a great idea but it would take time to assemble, it would not do well in the scientific literature if not accompanied by scientific analysis of the results and it may be out of date by the time it is published. Technical information about the instruments is available on the web site, and the ST will systematically post the final mission plans, i.e. flight lines in PDF format with description of science rationale and science objectives, and Google Earth kmz files of the missions. An example is already posted for Antarctica 2013. Antarctica 2014 will be posted in the coming weeks when finalized.

The OIBMR-T LIG recommends that efforts are made to secure funding for the continuation of OIB for at least the next decade.

RESPONSE: The ST agrees with this recommendation.

Detailed recommendations:

Science requirement document:

- Re-evaluate requirements for glaciers and ice shelves (IS8, IS9, IS11 and IS13).
- Prioritize the target regions (IS8, IS9, IS13)
- Reduced the number of glaciers for detailed monitoring (IS11)
- Observe large, non-polar glacier systems (Alaska, Patagonia).
- Re-evaluate IS14 (subglacial water distribution)
- Include ICESat-2 ground tracks over a range of conditions (elevation, roughness, melt).

RESPONSE: We agree to revise the science requirement document. This will take place in the fall of 2014 and early 2015. Alaska glaciers are part of OIB Alaska. There is no plan at this point to support an equivalent effort in Patagonia. We will re-evaluate IS14. All of our mission plans include ICESat-2 ground tracks over a range of conditions.

Technical requirements:

- Compare 532 nm (ICESat-2, ATM) with 1064 nm laser (ICESat, LVIS).
- Organize a targeted validation campaign over a wide range of ice surface to estimate biases between instruments.

RESPONSE: The ATM instrument team plans two upgrades for the ATM in the short and medium terms. The first upgrade incorporates a new laser transmitter, which operates at 10 kHz (the current transmitters operate at 3 kHz), has a pulse width of 1.3 ns (against 6 ns currently), and is air cooled where the current system is liquid cooled. The higher pulse rate will yield denser measurement coverage around the scan, the shorter pulse width will yield improved shot-to-shot range precision, and the simpler air-cooled design will yield more reliable operation. This new transmitter will arrive on-site in late July 2014 and incorporated into the ATM by spring 2015. It would constitute a modification to the wide-scan (15 deg) ATM transceiver, with the narrow scan ATM remaining unchanged. The second upgrade, now in the conceptual design stage, will include a transmitter modification to permit simultaneous transmission of 1064 nm (infrared) and 532 nm (green) laser radiation, paired with optical and digital upgrades on the receive side to allow simultaneous range measurements in both colors, from the same laser pulse. The science rationale for this latter upgrade is to provide answers to the question of differential firn penetration of 532 and 1064 nm laser light, which could introduce small range biases in airborne and spaceborne lidar data and for which little data is currently available. The ATM team expects spring 2016 to be the earliest potential deployment date for this system, assuming funding for the upgrade will occur.

Comparisons between ATM and LVIS elevation data over flat snow surfaces show random elevation differences at the few-cm level, which is consistent with the accuracy requirements for laser-altimetry measurements. It is not, however, sufficiently precise to allow assessment of green-vs-IR penetration biases, which are on the single-cm scale for fine-grained snow surfaces. The light-penetration problem will be best addressed by an instrument designed to make consistent measurements at the two wavelengths, such as the upgraded ATM.

Flight Planning:

- Need a clearer mechanism for community input and also for filtering community input to minimize the load on the science team.

RESPONSE: We agree. Starting with the Antarctic campaign of 2014, we will post on the web site (<http://icebridge.gsfc.nasa.gov>) the final mission plan including scientific rationale and objectives for each mission, and a description of our baseline missions and pole hole missions. We will continue to welcome comments and requests from the scientific community, as long as they fit with the stated mission objectives of OIB. We will note on the web site that users interested to provide comments or suggestions on the mission plan are invited to contact ST members directly. During the planning stages, the ST has always taken comments/requests, discussed them together with all ST members, and provided feedback to the initiators.

- OIB should adopt a more transparent method for selecting and coordinating land ice flight lines during future OIB campaigns. An example would be to hold semi-formal planning meetings amongst PIs to discuss flight planning.

RESPONSE: We agree. Posting the mission plan systematically as stated earlier will address the transparency issue. In addition, we will continue to solicit direct feedback from the community via two avenues: 1) the Fall AGU townhall meeting in San Francisco organized every year since 2009; and 2) the more science focused PARCA (Program for ARctic Climate Assessment) meeting organized every year at GSFC in late.

- OIB should acquire broader-scale coverage of the ice sheets.

RESPONSE: OIB is limited in spatial coverage by the aircraft range and airport location. In Greenland, OIB is already providing ice sheet wide coverage. In Antarctica, OIB is providing extensive coverage from Punta Arenas and McMurdo. If new possibilities were to open up in the future in the Antarctic, allowing the landing of a wheeled aircraft, the ST will be consider this opportunity to increase the survey area of OIB.

Instrumentation.

OIBMR-T LIG questioned the utility of the magnetometer.

RESPONSE: The magnetometer was included at a minor cost in prior deployments, and has been dropped of OIB deployments since 2013 because of its marginal usage.

OIBMR-T LIG recommends the addition of a 1064 nm laser altimeter

RESPONSE: This recommendation will be addressed with the new ATM instrument.

OIBMR-T LIG recommends the addition of a visible/NIR imaging spectrometer

RESPONSE: This recommendation will be addressed with ARISE starting in September 2014.

OIBMR-T LIG recommends a re-evaluation of DMS.

RESPONSE: Significant progress was reported on DMS processing at the OIB January 2014 meeting. Since then the DMS products have been made available at NSIDC. We will conduct a full evaluation of these products in the coming year.

OIBMR-T LIG recommends the addition of a low frequency radar or seismic methods for improved bed retrieval.

RESPONSE: OIB currently does not have a budget to enable a second aircraft dedicated to radar ice sounding, which would go early in the season and fly lower, slower; yet the ST has been exploring this option for Greenland Spring 2015 – and beyond - in case additional funds are made available to OIB. Seismic methods are outside of the scope of OIB.

Data Usability and Accessibility

OIBMR-T LIG recommends that ST conducts regular and frequent reviews of data usability and accessibility as these new products become available.

RESPONSE: A science committee designated to do this meets twice a year. It is not the role of the ST to review data usability and accessibility at large. The ST however stays informed of instrument/product/availability issues at its bi-annual meetings, during regular telecons, and through its own usage of OIB data. The January meeting often includes extensive reporting on instrument performance and data issues. In response to this comment, however, the ST agrees to designate some of his members to take a closer look at specific data sets to assess data usability, quality and accessibility to insure that OIB meets its stated science objectives.

OIBMR-T LIG recommends that funds be set aside to ensure that OIB data adheres to ESD approved Data System standards.

RESPONSE: The ST agrees with this recommendation, but it is beyond its role. The ESDIS (Earth Science Data and Information Systems) program (<https://earthdata.nasa.gov/esdis>) sets these requirements for OIB/NASA, and communicates those to OIB project and instrument teams; these requirements are already defined and captured in the OIB Data Management Plan. The OIB Project works with the instrument teams to make sure that they are compliant.

OIBMR-T LIG recommends that ST be tasked with ensuring that data providers / producers provide adequate quality assessments of all data products released by OIB.

RESPONSE: The project and an external committee review progress during the year. The ST has been making regular recommendations to the project for full documentation of the instrument performance and calibration online (NSIDC). For some instruments, the ST will request updates as needed, for instance once a major re-processing of OIB data has been performed with results posted at NSIDC.

OIBMR-T LIG recommends an overview paper.

RESPONSE: General overview papers summarizing OIB have been published (e.g. Koenig et al. 2011, EOS). As for a review of the science of OIB, the review team feels that this is premature due to the fact that OIB is only beginning its second phase and numerous OIB-related projects are in mid-progress. There is also the issue that OIB products have been used in a huge number and range of studies, making it difficult to include in a single overview paper. The ST plans to reconsider an overview paper at the end of phase 2.