Space-Based Observations for Understanding Changes in the Arctic-Boreal Zone

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Short Statement: Satellites play a critical role in monitoring changes in the Arctic-Boreal Zone (ABZ), which often occur in remote and inhospitable regions. However, satellites face a number of unique challenges when observing high latitudes, including persistent cloudiness, lack of sunlight for months at a time, sea ice, snow and ice covered land surfaces, and poor thermal contrast between the surface and air above. While suitable for detecting overall change, the current observational suite is inadequate for systematic monitoring and for improving process-based and large-scale understanding of the integrated components of the ABZ , which includes the cryosphere, biosphere, hydrosphere, and atmosphere. Such knowledge will lead to improvements in Earth system models, enabling more accurate prediction of future changes and development of informed adaptation and mitigation strategies.

A recent, interdisciplinary survey of more than 40 international remote sensing experts reviewed the strengths and limitations of current space-based observational capabilities and made recommendations for improving upon these current capabilities (Duncan et al., 2019).
General recommendations focused on the complementarity of sub-orbital and satellite observations, the need for measurement continuity, and the importance of stakeholder engagement. The development of a comprehensive and robust sub-orbital portion of an ABZ observing network can act to fill some temporal gaps in satellite coverage, provide detail unobtainable from space, and is necessary for validation and interpretation of satellite data. The establishment of international and multi-disciplinary observing ground sites and other platforms (e.g., aircraft), would help to constrain and distribute the costs of building and maintaining observational platforms.

A priority across all types of observations is the continuation, enhancement, and/or creation of long-term, multi-satellite, climate-quality, and self-consistent data records of ABZ components, such as surface temperature, energy fluxes, or sea ice extent and volume, for improved determination of trends. Long-term passive satellite observations currently represent the only feasible option for monitoring change of the ABZ at broad spatial scales required to address pressing science challenges. Application of consistent retrieval algorithms to multiple data sets, as well as careful characterization of satellite instruments and their temporal evolution, helps to ensure data quality and consistency.

Earth scientists must work in parallel with policy and other stakeholders to formulate strategies that pursue innovative, informed, and practical uses for Earth science data in decision-making. A high degree of technical skill is often required to access, process, and properly interpret ABZ satellite datasets and model output. As a result, some governmental and non-governmental entities, such as the NASA Applied Sciences Program, have initiated programs to foster capacity building. At the same time, we understand that governments, non-governmental agencies, and private companies have existing structure under which decisions are made. The goal is to integrate Earth science data into stakeholder organizations as seamlessly as possible, so that mitigation and adaptation decisions are based on sound, comprehensive science.

Following the methodology of the 2017 Decadal Survey for Earth Sciences (NAS, 2018), authors were also asked to rank observational needs as most important, very important, and important, which allowed for consensus recommendations of the highest priority observational needs across the Earth system. Among the needs ranked as "Most Important" are those associated with gaining a process-based understanding of the ABZ carbon cycle and hydrologic cycle (which includes sea level rise) as they have the potential to affect a large portion of Earth's population.

Recommendations for the carbon cycle include the use of methane and carbon dioxide lidar instruments to observe their atmospheric concentrations. Such measurements allow for the inference of fluxes from ABZ wetlands, permafrost, and wildfires in the low-light conditions that are typical of the ABZ. Complementing atmospheric greenhouse gas measurements, improvements in spatial resolution and/or spectral range would support better characterization of wetland inundation regimes, ocean biology and biogeochemistry, and permafrost degradation. For the hydrologic cycle, key recommendations focused on improving the spatial resolution of passive microwave instruments to better define the coast and sea ice edge. New technology is also needed to better observe ice and snow albedo and snow-water equivalent. Scientists often rely on more than one satellite dataset to thoroughly understand processes, which means that having contemporaneous observations of certain parameters is critical and must be considered by space agencies.

This review recommends an interdisciplinary, stepwise approach to developing an ABZ observing network, beginning with an focus on observing networks designed to gain process-based understanding for individual ABZ components while keeping early development efforts feasible in recognition of financial constraints. This approach should help lay the foundation for observing networks for more complex ABZ subsystems (e.g., the hydrological cycle) that could, at some point in the future, serve as the building blocks for a comprehensive observing network. The authors emphasize that a systems approach to observing is necessary to support a predictive understanding of Earth system science and to ensure a strong return on investment for future missions.

References

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