SCAR Astronomy & Astrophysics from Antarctica (AAA)

Working Group B: Arctic Site Testing

Implementation Plan

DRAFT

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Overview

This document defines the implementation plan of the the Arctic Site Testing Working Group (AST), which reports to the Scientific Committee on Antarctic Research (SCAR) Astronomy & Astrophysics from Antarctica (AAA) Scientific Research Programme Planning Group. The AST has connections to the known site-testing activities in the Arctic, and seeks to be inclusive to all. Unlike the other three Working Groups, AST does not involve any specific activity in Antarctica, although there are several areas of overlapping interest. The intention here is to outline efforts already underway in the Arctic, to indicate similarities and differences with those undertaken in the Antarctic, and thereby facilitate improved communication and knowledge sharing. This can further assure the compatibility of datasets, and potentially guide cross-linked investigations or spur new activities of possible benefit for both Poles.

Background

The two major landmasses nearest the North Pole are Greenland (Denmark) and Ellesmere Island (Canada). Neither of these provide elevations as high as attainable on the Antarcitc plateau, but they are comparably cold and dry. A geographical parallel is provided by the Greenland icecap, reaching 3200 m at Summit (72N). At high northern latitudes, the polar vortex functions in the same way as in the Antarctic, although in detail there are differences. Away from the icecaps, a strong and stable surface-based thermal inversion peaked at about 1000 m develops and remains during much of winter. Several locations rise above this. One is Barbeau Peak (82N, 2600 m) within Quttinirpaaq National Park on Ellesmere Island, but mountains nearer the coast top 1400 m to 1900 m.

Meteorological records date back decades for several major bases and research stations in the Arctic. The most northern is the military outpost at Alert (82N), on Ellesmere Island. It is provided with broadband communications via microwave repeater stations linking to Eureka (80N), where geosynchronous satellites become visible. Eureka is accessible year-round by air, and by ship in summer. This is a manned weather station, providing among many other meteorological and atmospheric observations, twice-daily balloon aerosondes. Nearby is the Polar Environment Atmospheric Research Laboratory (PEARL) on a 600-m high ridge which is linked by a road. Another scientific base to the south is located at Resolute Bay (76N), which along with Eureka provides aircraft support for field logistics. On Greenland, the United States military base at Thule (76N) provides access to the Summit station (72N) via support from the National Science Foundation.

Serious interest in astronomical site testing in the High Arctic was initiated with the first conclusive evidence of excellent free-atmospheric seeing above the Antarctic glacial plateau (Lawrence et al. 2004). The analogy to the Greenland icecap initiated observations at Summit (Andersen & Rasmussen 2006, Andersen, Pedersen & Sorensen 2010). An independent investigation into the feasibility of observations from high and very remote mountain peaks on northwestern Ellesmere Island was also undertaken (Steinbring et al. 2008, Wallace et al. 2008), anticipating the avoidance of boundary conditions associated with the surface of an ice plateau (Hickson et al. 2010, Steinbring et al. 2010). A strong advantage for a high mountain site over the icecap has not yet been proved, and in the meantime a compromise afforded by the year-round logistics provided by the mid-elevation site at PEARL is also being investigated.

Astronomical Site-Testing Observations in the Arctic

Compared to the Antarctic, astronomical site testing in the Arctic is only in the early stages, with the first work commencing in 2006. Several university and government laboratory groups are collaborating to deploy various instruments, either of their own design or closely following standard ones. Observations are taking a path typical of mid-latitude sites. Initial meteorological and basic sky-quality measurements are now leading to more detailed studies, first with obervations obtained during brief campaigns. Characterziation of the scientific potential of the sites starts by deploying small semi-autonomous telescopes, desirably followed by fully robotic versions.

Instrumentation Deployment

Several investigations of which the AST is familiar have been undertaken or will be underway in the next two to three years:

- Basic meteorological and sky-clarity observations. Small autonomous weather stations and cameras were constructed by National Research Council of Canada Herzberg Institute of Astrophysics (NRC/HIA) and deployed on three mountains on northwestern Ellesmere Island. These data can be compared with manned sea-level stations, e.g. those of Environment Canada - counterpart to the US National Oceanographic and Atmospheric Organization (NOAO) - that have records dating back over 50 years.

- Sky-monitoring cameras. Data from existing atmospheric-science instrumentation at PEARL are being analyzed. Of key interest are all-sky camera images taken by the University of New Brunswick beginning in 2007. Some sky surface-brightness measurements have also been taken in the optical and near-infrared using instruments from the University of Toronto.

- Sub-mm radiometer. A commerial 225 GHz tipping radiometer provided by Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) in Taiwan was operated at PEARL in the winter of 2010/11, and re-deployment at Summit is planned.

- Specialized optical turbulence measuring instruments. A Polaris-tracking instrument was installed on a 39-m high mast at Summit by the University of Copenhagen. At Eureka, two Sound Detection and Ranging (SODAR) units surplus from TMT site testing have been operated nearby for two winters. And at the same time the Arctic Turbulence Profiler (ATP), a lunar scintillometer built by University of British Columbia, and similar to an instrument at Cerro Tololo Inter-American Observatory, has been undergoing field-readiness testing on the PEARL roof. The intention is to re-deploy it at a remote Ellesmere mountain site. Balloon-borne thermosondes are also being considered for Eureka in 2011/12.

- Small telescopes. A Differential Image Monitoring Measurement (DIMM), a clone of the unit at the Canada-France-Hawaii Telescope, was built by University of Toronto and utilized on a portable 0.35-m telescope. That, combined with Multi-Aperture Seeing Sensor (DIMM/MASS) is planned for 2012/13. This might be improved to include a variant of Single-Star Scintillation Detection and Ranging (SCIDAR).

Initial Results to be Followed Up

Preliminary Arctic results from these studies, either presented in the literature or known to the AST, are encouraging:

- Remote Ellesmere Island mountain sites are accessible by helicopter in summer and above the thermal inversion in winter, providing reliable logistics and good weather (Steinbring et al. 2010). Skies are clear 65% of the time or better, as expected from satellite measurements. All-sky camera measurements indicate that photometric conditions occur for a significant fraction of that time, typical of the best mid-latitude sites such as Mauna Kea, Hawaii.
- Skies are dark, as expected in the optical based on latitutude, and with indications that this follows into the near infrared consistent with atmospheric conditions. The atmosphere is extremely dry, with mean precipitable water vapour below 2-mm at sea level from Eureka in winter, allowing for good 225 GHz transparency at PEARL – possibily opening useful sub-mm windows.
- The boundary layer appears to be thin at PEARL, according to ATP measurements. For photometric conditions, the median boundary-layer seeing in winter below 10 m is better than 0.55”, improving to 0.45” at 20 m. The first wintertime data taken with DIMM are consistent with those results; seeing of 0.6” to 1.2” under clear skies from the 6-m high PEARL roof.
- Some Polaris-tracking seeing measurements taken at Summit in summer show seeing as good as 0.5” at 39 m, suggesting conditions comparable to the Antarctic icecap (Andersen, Pedersen & Sorensen 2010).

Future Steps

Clearly, more site testing is needed to fully realize the potential of Arctic sites. Within Canada this features as a priority among small projects within the 2010 Long Range Plan for Canadian Astronomy[1], which recommends that the conditions at the PEARL site be characterized, as well as at least one of the remote mountain sites. If justified by the site conditions, this would lead to the development and construction of a 1 to 4-m class optical/NIR telescope. That recommendation does not provide funding, although incentive could come with published results. Costs for Arctic logistics are relatively inexpensive, considering the remoteness of the locations. For example, transport from northern Canadian cities to Eureka is only approximately $20 per kilogram by air, and considerably less via the yearly sea voyage. The AST seeks to encourage the follow-up of initial results, along with the other items highlighted below:

- Carrying on with current instrumentation. Summit station can easily support field-readied autonomous instruments such as the ASIAA radiometer. Winter campaigns at Eureka take advantage of year-round logistics and existing atmospheric research programs underway. Coordination with groups there and elsewhere is sought, e.g., other site-testing groups or those in atmospheric or space physics research such as aurora observations and orbital-debris tracking.

[1] See the Canadian Astronomical Society webpage at http://www.casca.ca/ under Long Range Plan 2010 Documents

- Improvement in site-testing apparatus. Advancements in field-readying instrumentation for polar environments are always on-going, with some special aspects for the High Arctic – especially survivability under conditions of rime-icing and in high winds. Installation of a stand-alone 6-m tall site-testing tower near the PEARL facility is planned. This can reduce the deleterious effects of heat and turbulence associated with the PEARL building itself, and so provide more reliable seeing measurements.

- Further study of the high mountain sites on Ellesmere Island. That could include re-deployment of the ATP, although this would require a reliable source of power. Both wind-power and fuel-cell generators were investigated but not fully developed during the intial feasibility study. One possibility would be a PLATO-like system, similar to the compact unit being built for Ridge A.

- Initiation of scientific productivity. A 0.5-m wide-field optical imaging telescope – primarily for planet-hunting via transits - is being readied for PEARL as a collaboration between the Dunlap Institute, NRC/HIA, and other Canadian government departments. It takes advantage of the already excellent infrastructure in place at Eureka, and is not strongly dependent on the local seeing conditions near PEARL. It is to act as a pathfinder to future, larger instrumentation yet to be designed. Engineering studies for a 2-m class telescope comparable to those for the Antarctic Domes are to follow. The deployment of a sub-mm antenna for Very-Long Baseline Interferometry (VLBI) from Summit is being investigated.

SCAR can facilitate these advancements in a number of ways, all of which fall largely within the activities recommended under the 'Coordination' Section of the Working Group C Implementation Plan. Some key interactions of particular value for the Arctic are as follows:

- Provide a forum for increasing awareness among the Antarctic and broader scientific community of Arctic site-testing activities, the currently known conditions, and efforts to characterize those for scientific utility.

- Encourage interaction among users of the different polar research facilities, potentially leading to improved use of sites otherwise not considered. For example, the reversed seasons of the poles may provide opportunities for more rapid deployment or field-readying of instruments. Of particular note are the year-round logistics available at Eureka.

- Providing opportunities for the international astronomical site-testing community to meet and discusss methods and results. This might be in the form of sponsoring conferences and workshops, as well as encouraging or developing other web-based formats. This can help ensure complementarity of data, sharing of engineering or scientific resources, and possibly reveal new synergies between programs at various sites.

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