The Arctic Observing Mission (AOM): A high priority candidate mission for the Government of Canada

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Keywords: satellites, Arctic, weather, climate, greenhouse gases, air quality.

Abstract

The Arctic Observing Mission (AOM) is a satellite mission concept under study by the Canadian Space Agency (CSA), in partnership with Environment and Climate Change Canada (ECCC) and Natural Resources Canada (NRCan). AOM would use two satellites in a highly elliptical orbit (HEO) to enable frequent observations of meteorological variables, greenhouse gases (GHGs), air quality (AQ) and space weather over northern regions, reaching beyond the usable viewing range of geostationary satellites. These new rapid-revisit observations over the North would address key spatio-temporal gaps in the Global Observing System so that services similar to those available from geostationary satellites would then be extended to the circumpolar Arctic region. AOM observations are important for operational activities, environmental monitoring and prediction, and scientific research aligned with the Government of Canada priority of enhancing Arctic and northern situational awareness and security. This paper reviews some technical, policy and programmatic aspects of AOM, describing the proposed orbit and expected coverage, the instrument payloads and main data products, and ends with a brief discussion on the path to space.

1. Introduction

1.1 Overview

The Arctic Observing Mission (AOM) is a satellite mission concept under study by the Canadian Space Agency (CSA), in partnership with Environment and Climate Change Canada (ECCC) and Natural Resources Canada (NRCan). AOM would use two satellites in a highly elliptical orbit (HEO) to enable frequent observations of meteorological variables, greenhouse gases (GHGs), air quality (AQ) and space weather over northern regions, reaching beyond the usable viewing range of geostationary satellites to address key spatio-temporal gaps in the Global Observing System. Services similar to those available from geostationary satellites would then be extended to the circumpolar Arctic region. These observations are important for operational activities, environmental monitoring and prediction, and scientific research aligned with the Government of Canada priority of enhancing Arctic and northern situational awareness and security.

1.2 Orbit and Coverage

Low Earth Orbit (LEO) satellites can provide global coverage with low revisit rates (typically daily or less per satellite, depending on the observable). Geostationary orbit (GEO) satellites use an equatorial orbit, synchronized with Earth's rotation to give a continuous view of a portion of the Earth. Typical GEO revisit rates are ~10 minutes for meteorological imagery and every ~30-60 minutes for atmospheric sounding observations, but GEO data quality degrades for high latitudes (beyond ~55°N/S) due to viewing geometry and cannot be used for polar regions. A highly elliptical orbit (HEO) offers a method to make geostationary-like observations of the polar regions.

AOM proposes to use two satellites in a HEO with a 16-hour period called a Three Apogee (TAP) orbit (Trishchenko et al., 2011) for near-continuous observations north of ~40°N. With both satellites in the same orbital plane, they share a ground-track with three apogee (highest point in the orbit) locations, which is repeatable every 48 hours. With an orbital eccentricity of 0.50, the apogee height is 41,885 km, ~17% higher than GEO. A satellite in HEO moves slower near apogee, and an orbit at the critical inclination of 63.435° is most stable and repeatable, giving a vantage point for which rapid revisit observations can be focused on northern regions. The ground track and viewing opportunities from the proposed AOM TAP orbit are shown in Figure 1.

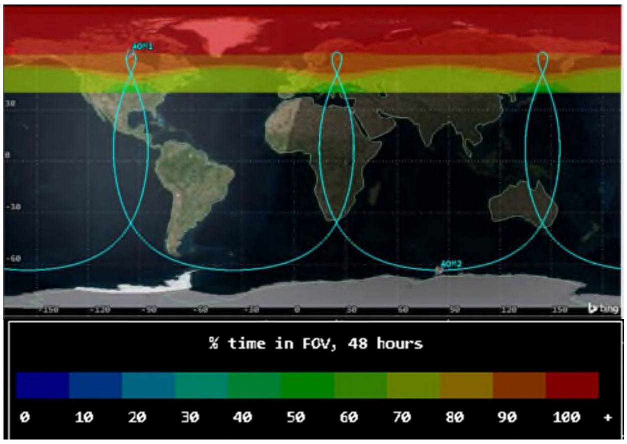

Figure 1. Percent of time that a given location north of 40° is in the field of view (FOV) of at least one of the two AOM satellites, assuming a view zenith angle cutoff of 70° and the proposed AOM TAP orbit.

2. AOM Payloads and Applications

2.1 Meteorological Imager

The benefits of meteorological imager observations from HEO, have been recognized for many years (Garand et al., 2014; WMO, 2019). These new observations would complement the ring of GEO meteorological satellites and are required to achieve continuous global image coverage at any one time. The overarching benefit of meteorological imager observations from a HEO constellation is the ability to acquire continuous pan-Arctic imagery. The addition of the HEO orbit will provide 24/7 situational awareness north of the useable limit of GEO meteorological satellites, and fill in the substantial temporal and spatial gaps in mid to high northern latitude coverage provided by LEO meteorological satellites. The hemispheric scale coverage provided by a two-satellite TAP HEO constellation also simplifies image analysis relative to interpreting data from multiple LEO satellites by providing data at a regular cadence and eliminating the need to stitch together image swaths from multiple satellites/instruments acquired at varying times to achieve circumpolar coverage. Additionally, imagery acquired from HEO provide improved viewing geometry (reduced satellite viewing zenith angle (VZA), and thus reduced parallax effects and increased spatial resolution) relative to GEO imagery for substantial portions of the day at locations above ~40°N, and at all times for locations above ~65°N.

To maximize interoperability with existing and planned GEO sensors, AOM would use a meteorological imager of comparable capability to Europe's Flexible Combined Imager (FCI) or the planned National Oceanic and Atmospheric Administration (NOAA) GeoXO Imager (GXI). With 16 or more bands spanning the visible to infrared (~0.4 to 13.3 μm), near real-time imagery would be acquired with a ~10 to 15 minute full-disk scan cadence. The imager would provide data at ~0.5 to 2 km spatial resolution at nadir, depending on the image channel, and the satellite's altitudinal position in orbit. As the altitude of the satellite will be changing throughout the satellite's orbit, the AOM meteorological imager will have a slightly coarser spatial resolution than GEO satellites as AOM approaches apogee (approximately ±3.3 hours from apogee), which is slightly beyond the altitude of GEO satellites. Level 1 and Level 2 data products would be produced in near real-time to support operational meteorological and related environmental programs and services that have strict latency requirements (typically ≤ 15 minutes). Key requirements linked to the AOM meteorological imager are presented in Table 1.

Meteorological Imager Characteristic	AOM Requirement
Full-disk scan cadence	≤ 15 minutes (Goal: 10 minutes)
Spatial coverage	Coverage provided 100% of the time above 65°N, still > 67% of the time at 40°N, with a view zenith angle cutoff of < 70°
Spectral coverage	≥ 16 channels, with central wavelengths from 0.4 to 13.3 μm
Spatial resolution	Ground sampling distance (GSD) of VIS channels: 1.5 km (Goal: 0.5 km) IR channels: 3.0 km (Goal: 2.0 km)
Key derived products	Atmospheric motion vectors (winds), cloud cover/type, cloud top height/phase/temperature, fog, aerosol optical depth, aerosol detection mask (smoke/dust), volcanic ash, forest fire hot spots and radiative power, land/sea surface temperature, albedo, emissivity, ice/snow cover.

Table 1. Summary of key user requirements and derived products for AOM's meteorological imager payload.

The proposed meteorological imager would provide multi-purpose imagery of the Earth's atmosphere in all weather, as well as land and oceans in cloud free areas, measuring key variables for weather and environmental monitoring, modelling and prediction. These data would improve nowcasting, forecasting of severe weather and general Numerical Weather and Environmental Prediction (NWEP) over the Arctic and northern mid-latitudes, along with other environmental applications. Forecasters routinely leverage Level 1 cloud and moisture imagery directly, including RGB colour composites, to carry out a variety of tasks such as identifying cloud types/heights, identifying airmasses, and detecting convective initiation. Some key use cases where AOM imagery are expected to provide substantial improvements for forecasting operations at mid to high northern latitudes include identification and characterization of blowing snow and blizzards, low lying fog, thunderstorm activity, wildfires and associated smoke plumes, tracking of polar lows, and sea spray.

Additionally, derived Level 2 products (Table 1) support a wide range of applications, including nowcasting on grid, air quality monitoring and prediction (including wildfire smoke plumes), and characterization of sea/lake ice conditions. For example, retrieval of aerosol optical depth (AOD) from the meteorological imager data will be used to derive estimates of fine particulate matter ($PM_{2.5}$) concentrations. Obtaining quantitative spatial maps of $PM_{2.5}$ in near real-time would support improvements to air quality forecasting such as Canada's Air Quality Health Index (AQHI), a growing concern as emissions from Canadian wildfires have increased in recent years.

In addition to supporting nowcasting operations, AOM is expected to contribute to NWEP forecast skill primarily due to the improved coverage of atmospheric motion vectors (AMVs) that HEO can provide at high latitudes, particularly in the ~55 to 70°N range between the existing dense AMV coverage from GEO and LEO meteorological satellites, and the continuous availability of radiance observations at the pan-Arctic scale. Additional data of value for NWEP will be provided by AOM’s infrared (IR) sounder (next section).

AOM’s meteorological imager and IR Sounder represent transformative meteorological capabilities that would enable Canada, and other northern countries, to deliver substantially improved nowcasts and severe weather warnings, as well as increased skill in medium-range weather predictions across the circumpolar Arctic region, with benefits extending well into mid-latitude regions, improving national weather services and contributing to international commitments (e.g. METAREAS, Volcanic Ash Advisory Centre). These observations are expected to provide substantial socio-economic benefits for weather impacted sectors (e.g. aviation, marine navigation, tourism, forestry, insurance) along with significant enhancements to forecast products provided to northern and indigenous communities across the circumpolar Arctic region.

2.2 Infrared (IR) Sounder

The AOM IR Sounder would use Imaging Fourier Transform Spectrometer (IFTS) technology for rapid revisit spectroscopic observations from six spectral bands: one near-infrared (NIR) band, three shortwave infrared (SWIR) bands, one mid-wave infrared (MWIR) band and one longwave infrared (LWIR) band as shown in Table 2. To span this wide spectral range, an innovative dual-interferometer design is proposed, with a common set of fore optics, then a dichroic would split the beam for the two interferometers such that one interferometer and its aft optics would be optimized for NIR-SWIR and the other for MWIR-LWIR. This design also enables the possibility of simultaneous observations from the two interferometers operating at two different spectral sampling intervals.

The NIR-SWIR bands would record spectra of solar radiation reflected off Earth’s surface for retrieval of high precision column-averaged dry-air mole fractions of CO_2, CH_4 and CO (referred to as XCO_2, XCH_4 and XCO). The idea of GHG observations from an IFTS in HEO was first described in Nassar et al. (2014) and later in Nassar et al. (2019). The NIR band observes the oxygen *A* band spectral feature, giving information on surface pressure and aerosols. This spectral region also contains solar lines that are perturbed by fluorescence from vegetation, enabling retrieval of solar induced fluorescence (SIF), which is used as a proxy for photosynthetic activity from forests, tundra or agricultural areas. The three SWIR bands observe the spectral signatures of CO_2, CH_4 and CO.

Band	Wavelength (μm)	Wavenumber (cm^{-1})	Key Observables
1	0.758 – 0.772	12,953 – 13,192	surface pressure, aerosols, SIF
2	1.598 – 1.618	6180 – 6258	CO_2
3	2.042 – 2.079	4810 – 4897	CO_2
4	2.301 – 2.380	4195 – 4345	CH_4, CO
5	~7.1 – 14.7	~680 – 1400	H_2O, Temperature, CO
6	~4.44 – 6.25	~1600 – 2250	H_2O, Temperature, O_3, NH_3, CO_2, CH_4

Table 2. Summary of AOM IR Sounder bands and key observables or applications.

In an amendment to the AOM pre-formulation study mission design contract, the IFTS industrial contractor (ABB) confirmed the feasibility of adding LWIR and MWIR bands to enhance the IFTS. These bands are now included in the baseline design for future phases as the MWIR and LWIR emission spectra enable retrieval of vertical profiles of N_2O, NH_3, O_3, CO_2, CH_4 and CO during day/night, summer/winter and over land/water, and provide enhanced vertical information on temperature, water vapor and 3D winds for meteorology. These capabilities have been developed from LEO sounding missions and are planned for the emerging GEO-ring of IR Sounders: China’s Fengyun-4B Geostationary Interferometric Infrared Sounder (GIIRS, Yin et al., 2025), Europe’s Meteosat Third Generation Infrared Sounder (MTG-IRS, Holmlund et al., 2021), Japan’s future Himawari Sounder (Okamoto et al., 2020) and the future NOAA GeoXO Sounder (GXS, McGrath-Spangler et al., 2024).

The spectral sampling requirement for all bands is 0.625 cm^{-1} (goal) and 0.700 cm^{-1} (threshold). It is highly desirable for MWIR-LWIR observations to be made at the goal of 0.625 cm^{-1} for consistency with the ring of GEO IR sounders. For NIR-SWIR, the more challenging frame rate requirements for the focal plane arrays may require the slight relaxation of spectral sampling to 0.700 cm^{-1}.

IFTS observations would be made with a *Step-and-Stare* approach in which the IFTS stares or dwells over a location for some time, then steps or repoints to the next location. Prior to inclusion of the MWIR-LWIR bands in the baseline, an intelligent pointing approach (Nassar et al., 2023) was planned, where cloud information from the meteorological imager would inform IFTS pointing to focus on the least cloudy regions, since NIR-SWIR observations do not penetrate clouds and those obscured by clouds would later be discarded. With this approach, using a 60-second dwell, cloud-free sunlit land regions could be observed with hourly revisit.

For meteorological applications, intelligent pointing is not desired, since observations over clouds, bodies of water and non-sunlit areas can be made by observing MWIR-LWIR emission and these observations are just as valuable as those over land, sunlit and cloud-free areas. The feasibility of modifying the IFTS design to improve the revisit rate to better align with meteorological applications was explored. These recent findings suggest that by resizing the IFTS, an improved revisit rate is achievable. Moving forward, the requirement would be for a stare or dwell to last for ~20 seconds. The pointing mirror would then step to the next position (and settle) in under 2.0 s for a subsequent dwell. Each dwell would consist of 160 x 160 pixels observed simultaneously in the 6 spectral bands. Combining the observations from both satellites together as shown in Figure 2, the circumpolar area north of 45°N, along with southern regions of Canada, would be observed with a revisit rate of ~40 minutes.

The IR sounder threshold requirement for ground pixel size is 4x4 km^2 at nadir from a reference altitude of 40,000 km (95.5% of apogee height). The nadir pixel size would change over the observable fraction of the orbit from ~2.3x2.3 to 4.1x4.1 km^2. Pixel size also increases with VZA over the range from 0-60°. A small fraction of AOM IR sounder data (~1-2%) in bands 1-4 could potentially be made available at the higher native spatial resolution of IFTS focal plane array pixels, which is desirable for applications that benefit from spatial resolution more than high precision, such as the quantification of northern anthropogenic CO_2 and CH_4 point sources. However, the potential for these high spatial resolution measurements (~1x1 km^2) depends on the ability to reach the pointing stability goal of ~500 m during a dwell. This will likely not be possible near

https://doi.org/10.5194/isprs-archives-XLIX-B3-2026-1465-2026 |

the beginning or end of the observing period for each satellite, but perhaps near apogee (where satellite ground speed approaches a minimum) and will be explored in future studies.

A sub-orbital demonstration of an IFTS developed by ABB was conducted by CSA, ECCC and a science team led by University of Saskatchewan. The IFTS flew on a stratospheric balloon launched from Timmins, Ontario, Canada in August 2022 for a 13-hour flight that reached 37-km altitude as it made CO_2 and CH_4 observations over the Boreal forests of Northern Ontario (Qian et al., 2024). Although the balloon IFTS demonstration did not use the same bands or focal plane arrays proposed for AOM, the flight demonstrated IFTS technology for GHG measurement and also highlighted design aspects to be improved for a future satellite version of the instrument.

HEO observations of GHGs would improve the capability to detect and monitor changes in the Arctic and boreal carbon cycles, including CO_2 and CH_4 from permafrost and northern vegetation under a changing climate. A recent observing system simulation experiment (OSSE) demonstrated that HEO XCO_2 observations would improve the ability to track seasonal transitions in Arctic-boreal ecosystems (Parazoo et al., 2024).

Spaceborne monitoring of permafrost CH_4 or CO_2 emissions is a very challenging task. New research shows that the current generation of satellites offer limited capability to detect permafrost CH_4 emissions under some circumstances (Nassar et al., 2026). In the future, operational monitoring of CH_4 and CO_2 emissions from permafrost thaw may become possible with improvements in sensitivity, coverage and revisit rate from AOM, combined with the advances in permafrost modelling and the intensification of permafrost CH_4 and CO_2 emissions driven by climate change.

By assimilating AOM CO_2 and CH_4 observations in an atmospheric data assimilation system, higher level GHG products would be developed, including hourly 1°x1° 3D fields of CO_2 and CH_4 (Level 3) and monthly 1°x1° CO_2 and CH_4 surface fluxes (Level 4). These products align with World Meteorological Organization (WMO) Global Greenhouse Gas Watch (G3W) programme requirements and would be shared openly for the benefit of all.

AOM’s IR sounder would also provide detailed vertical information on the state of the atmosphere (temperature, ozone and humidity profiles, and 3D wind retrievals) from its MWIR-LWIR sounding channels that will complement the coverage of existing and planned LEO and GEO hyperspectral IR sounders. The rapid revisit of AOM’s IR Sounder will greatly increase the volume of radiance and 3D wind data available to NWEP systems at mid to high northern latitudes, which is expected to improved NWEP skill as these data sets that have been shown to have significant positive impacts on NWEP models (McGrath-Spangler et al., 2025; Li et al., 2025; Holmlund et al., 2021).

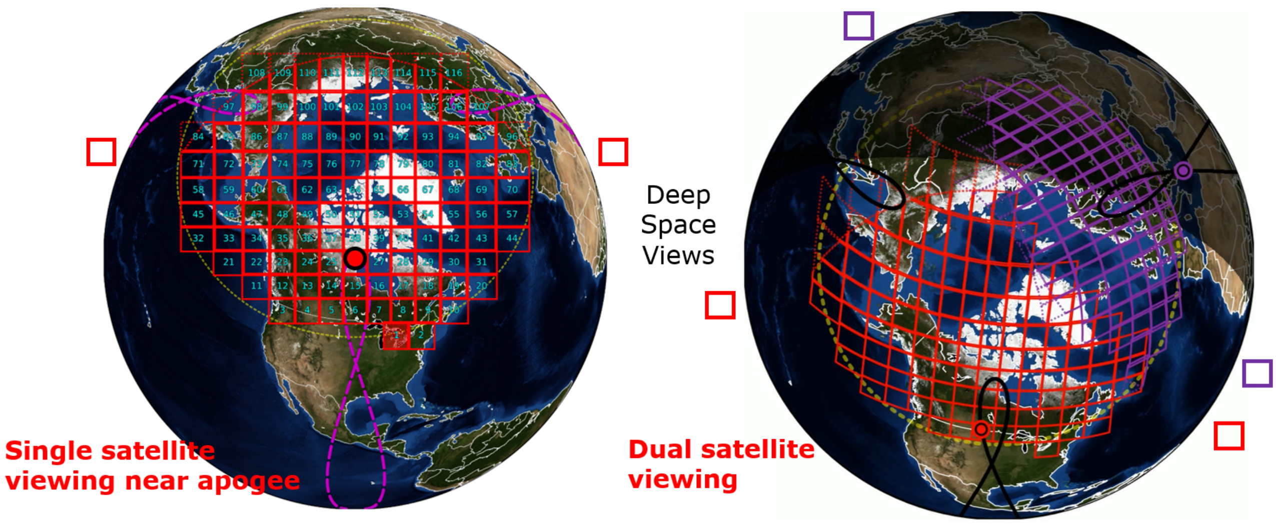

Figure 2. AOM IR Sounder pointing with FOVs directed at areas north of 45°N along with southern parts of Canada. Each FOV consists of 160x160 binned pixels, with a nominal pixel size of 4x4 km^2 at nadir from a reference altitude of 40,000 km. The IR Sounder would also make periodic deep space observations for the purpose of calibration. For about 16 hours/day, only one of two satellites is in position to observe the north, requiring slightly more than 40 minutes to step-and-stare scan over the area of interest. For about 8 hours/day, simultaneous dual-satellite viewing is possible. Although dwells and individual pixels are smaller during dual satellite viewing opportunities, revisit rates of better than 40 minutes can be achieved.

2.3 Space Weather Instrument Suite

HEO provides a unique vantage point for both in situ and remote sensing observations of space weather. Such space weather observations are of interest to NRCan and Canada’s Department of National Defence (DND). Although the configuration of the AOM space weather instrument suite is less mature than other payloads, it is proposed to consist of:

- an Auroral Imager observing in the far-UV
- a magnetometer on a 1-2 m boom
- an energetic particle (electron, proton, ion) detector
- plasma analysers

These observations would improve forecasting of space weather and its effects on processes in Earth’s upper atmosphere, while also improving our scientific understanding of solar-terrestrial interactions.

2.4 UV-Visible Spectrometer

An ultraviolet-visible dispersive spectrometer, with capabilities similar to those of current GEO air quality instruments, has also been considered for AOM. This payload would observe air quality trace gases, especially NO_2, but also O_3, SO_2, HCHO and others with approximately hourly revisit. HEO AQ observations would enhance the capability to monitor emissions from resource extraction in the North and the transport of pollution from mid-latitudes, improving air quality forecasts with implications for human health. Although the value of these observations is recognized, observations from the other payloads are ranked as a higher priority for Government of Canada and our potential international partners.

3. Partnerships and the Path to Space

AOM is envisioned as a Canadian mission with potential for international collaboration in areas such as science support and data processing algorithms. With Phase 0 now completed, the AOM proposal is continuing to be developed with an aspirational launch target of 2037 followed by commissioning and 10 years of operations.

4. Conclusions

The proposed Arctic Observing Mission would address observation gaps in the northern hemisphere by leveraging the unique vantage point provided by a highly elliptical orbit. It would make observations of key variables for weather, climate, air quality and space weather, enhancing services across these domains. By doing so, AOM would become the most comprehensive weather and climate satellite mission for the North ever flown.

Acknowledgements

Thanks to Matthew Boland (University of Waterloo) for conducting AOM IR Sounder scanning simulations and his contribution to Figure 2.

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