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Arctic Observing Mission (AOM) and international partnership

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1. Environment and Climate Change Canada,
2. Canadian Space Agency,
3. Natural Resources Canada

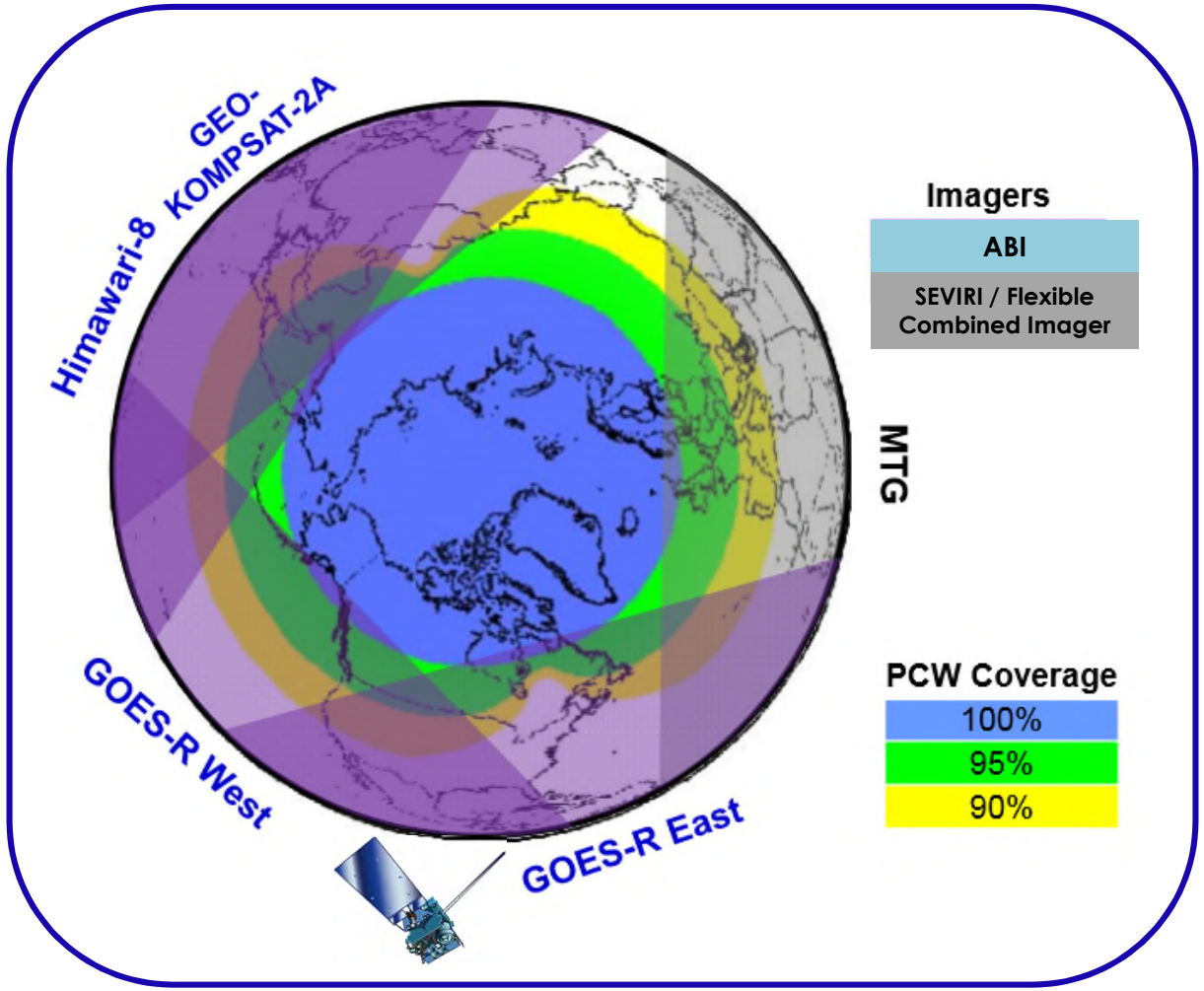
Community Meeting on NOAA Satellites
2020 October 1

CSA ASC

Canada

Existing weather, greenhouse gas, air quality satellites lack frequent coverage of the North

Meteorology has used LEO and GEO satellites together for decades and modern forecasting relies on this.
Air Quality is developing a GEO constellation in the 2020s and GHGs will follow.



Low Earth Orbit (LEO) satellites give global coverage but with low temporal revisit rates

Geostationary orbit (GEO) gives rapid revisit, but satellite coverage is limited to ~60ºS-60ºN due to viewing geometry from equatorial orbit

The Polar Communications and Weather (PCW)* mission was a Canadian highly elliptical orbit (HEO) mission proposed to address this gap.

Canada is now looking at a ***new*** HEO mission concept with a broader scope.

*Garand, Trishchenko, Trichtchenko, Nassar (2014), "The Polar Communications and Weather Mission: Addressing remaining gaps in the Earth Observing System" Physics in Canada.

On the Use of Satellites in Molniya Orbits for Meteorological Observation of Middle and High Latitudes

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Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado

18 August 1989 and 27 October 1989

ABSTRACT

Time and space sampling is an increasingly critical aspect of Earth observation satellites. The highly eccentric orbit used by Soviet Molniya satellites functions much like a high-latitude geostationary orbit. Meteorological instruments placed on a satellite in a Molniya orbit would improve the temporal frequency of observation of

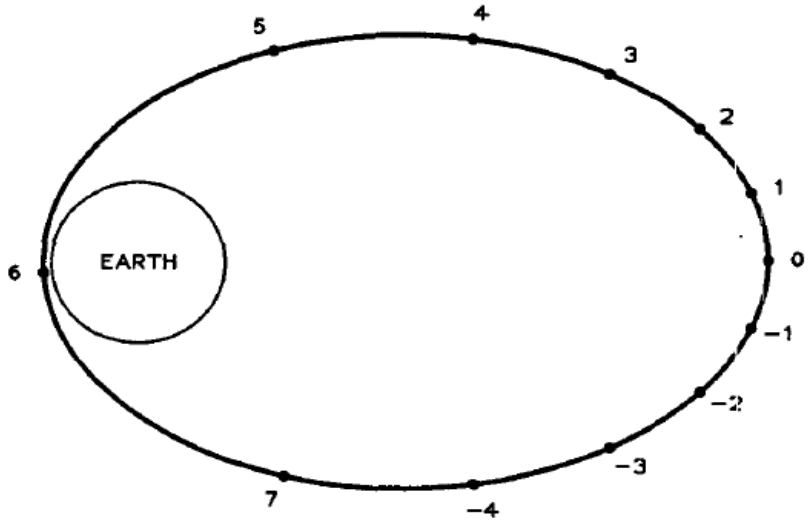


FIG. 4. A Molniya orbit (600 km perigee height) viewed perpendicular to the plane of the orbit. A dot is placed every hour. The labels are hours from apogee.

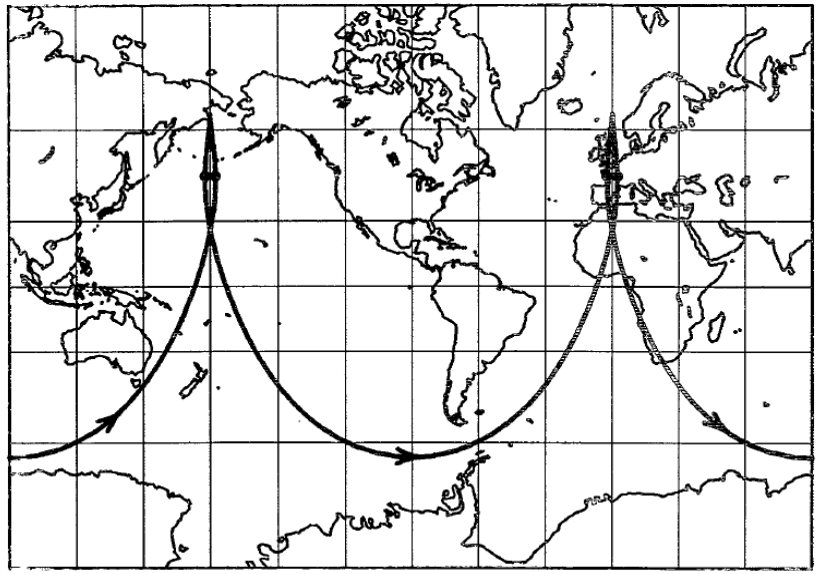
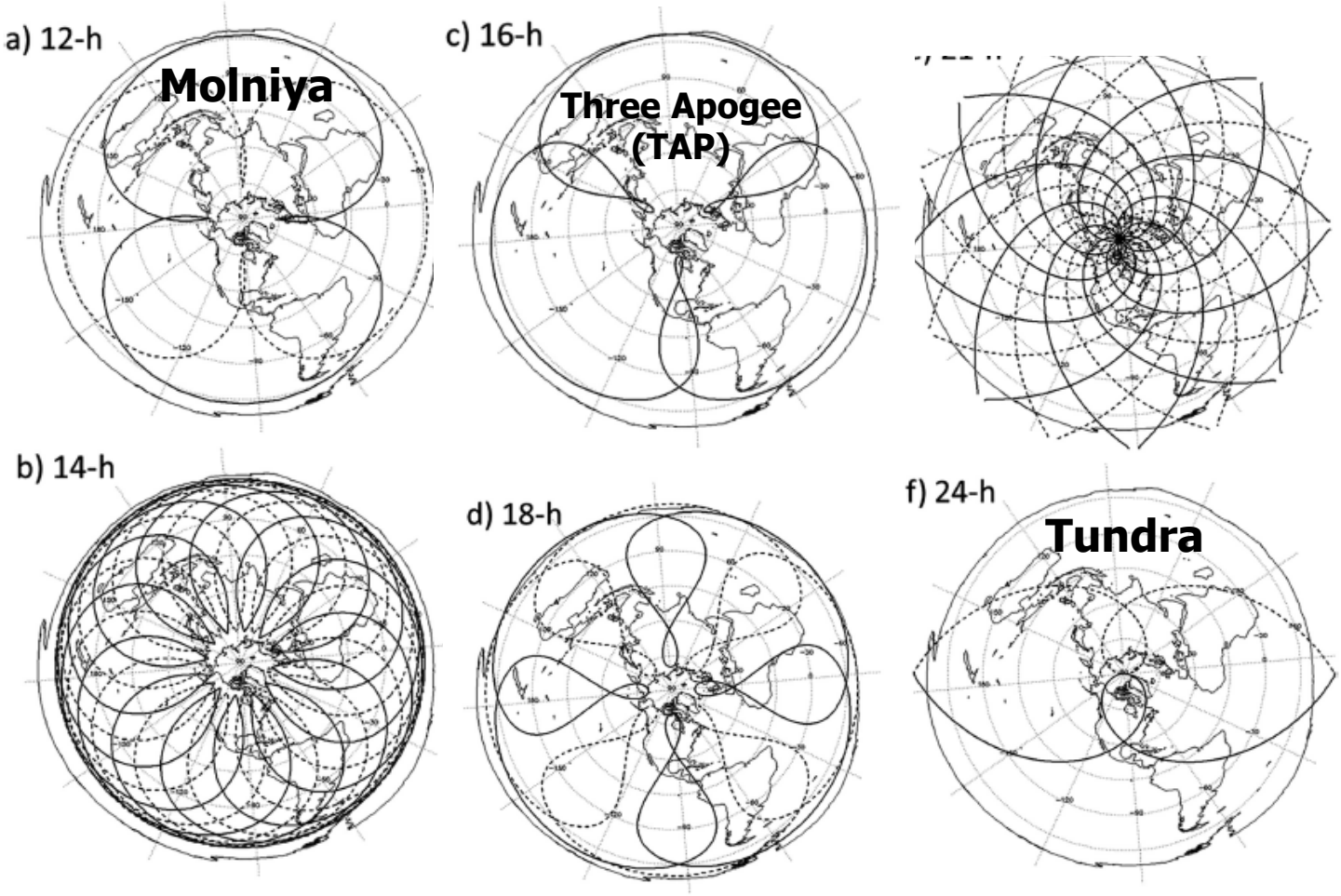
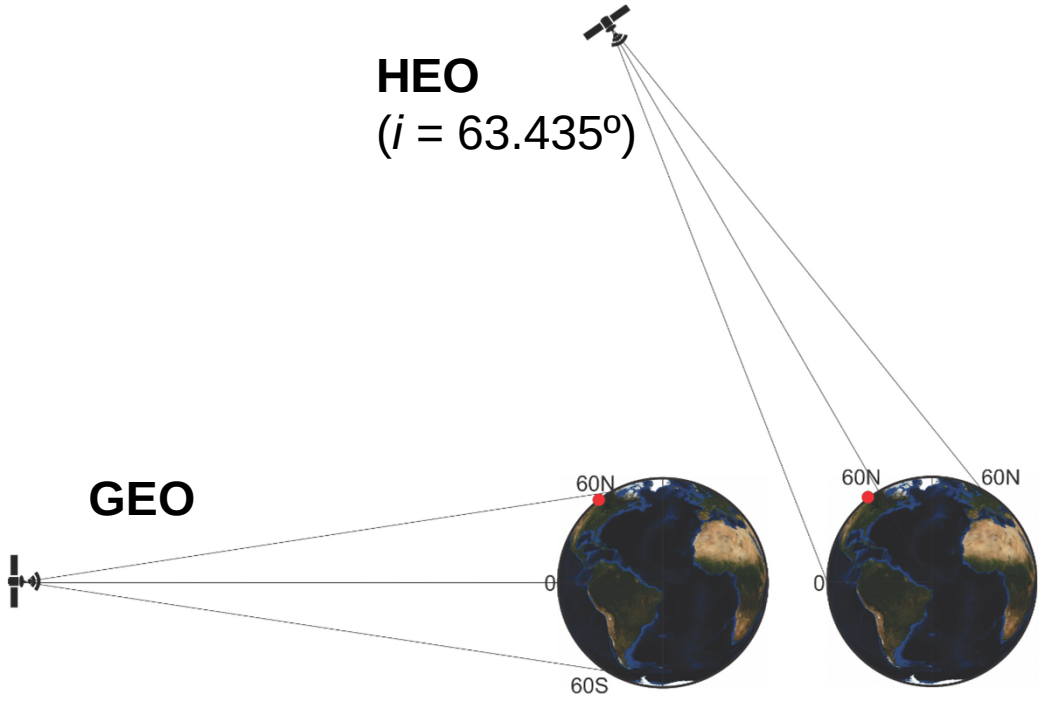


FIG. 5. Ground track of a satellite in a Molniya orbit with apogee at latitude 63.4°N and longitudes 0° and 180°. A dot is placed 4 h before and 4 h after apogee. The satellite spends two-thirds of its time north of the dots, which occur at 46.8°N and ±2.3° longitude from apogee.

Highly Elliptical Orbit (HEO) Possibilities for Earth Observation





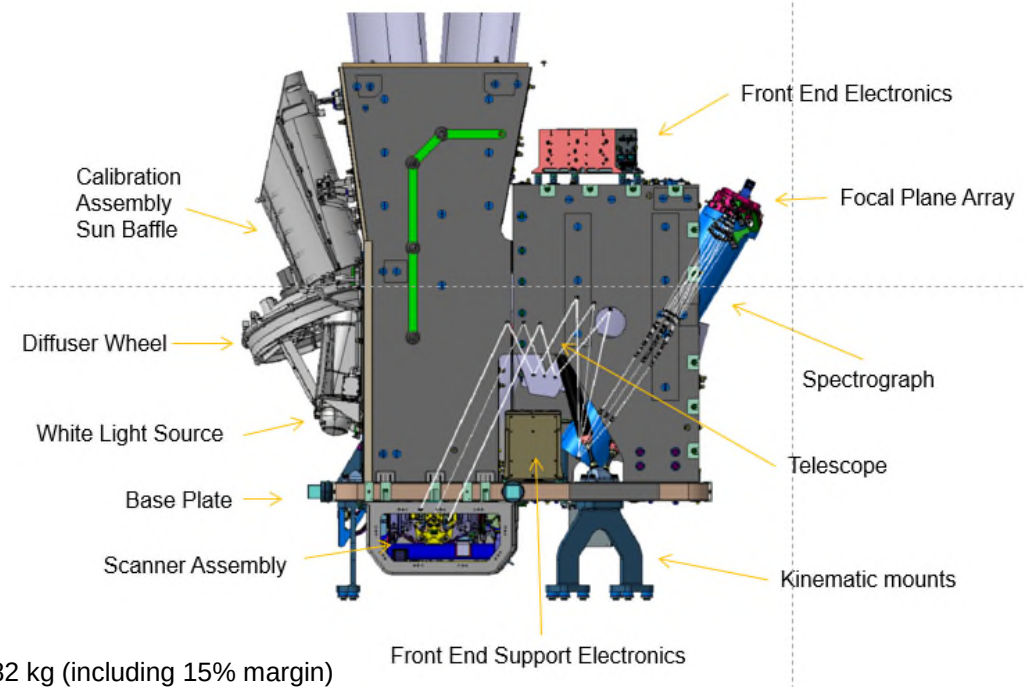
Numerous different periods, inclinations and eccentricities means more options (decisions to be made) than for GEO

Trishchenko and Garand (2011), *J. Atm. Ocean Tech., 28, 977-992.*
Trishchenko, Garand, Trichtchenko (2011), *J. Atm. Ocean Tech., 28, 1407-1422.*
Trichtchenko, Nikitina, Trishchenko, Garand (2014), *Adv. Space. Res. 54, 2398-2414.*
Garand, Trishchenko, Trichtchenko, Nassar (2014), *Physics in Canada*, 70, 4, 247-254.
Trishchenko, Garand, Trichtchenko, Nikitina (2016), *BAMS*, 19-24.
Trishchenko, Trichtchenko, Garand (2019), *Adv. Space. Res. 63, 12, 3761-3767.*

The Atmospheric Imaging Mission for Northern Regions (AIM-North)

Air Quality Spectrometer

NO_2, O_3, SO_2, BrO, HCHO, ClOClO, aerosols



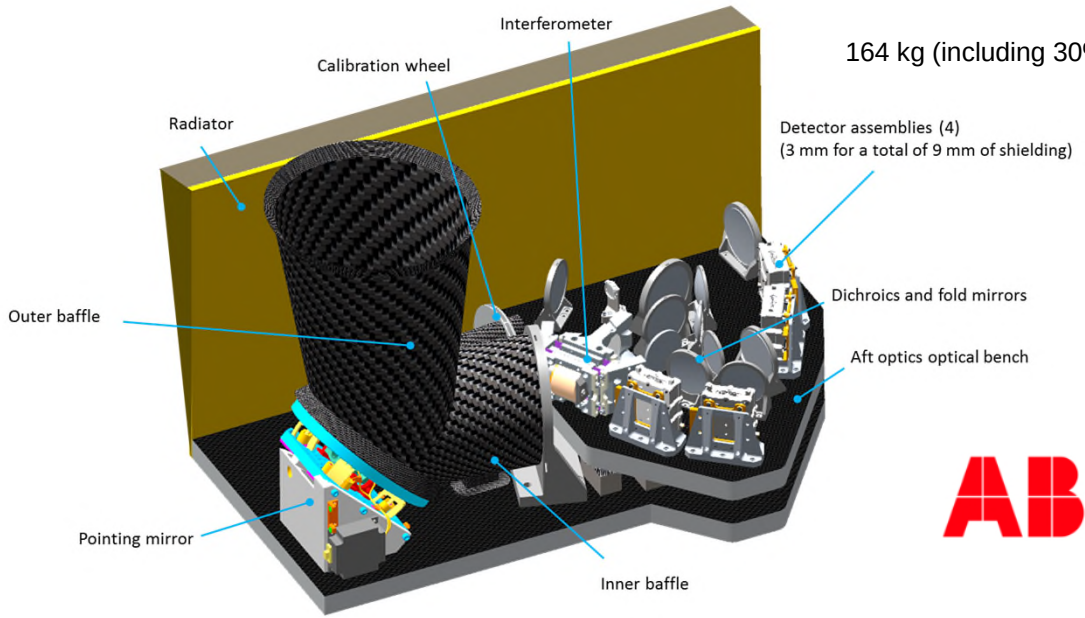
182 kg (including 15% margin)

AIRBUS DEFENCE & SPACE

Similar design to Copernicus/ESA Sentinel-4 AQ instrument

GHG Imaging Fourier Transform Spectrometer (IFTS)

CO_2, CH_4, CO, Solar Induced Fluorescence (SIF)



164 kg (including 30% margin)

ABB

Interferometers on Canada's SCISAT, Japan's GOSAT & NOAA CrIS series

Phase 0: AQ & GHG high precision imaging, ~4x4 km^2, hourly revisit for daylight cloud-free areas ~45-90°N

www.aim-north.ca

Nassar et al. (2019) https://doi.org/10.1080/07038992.2019.1643707

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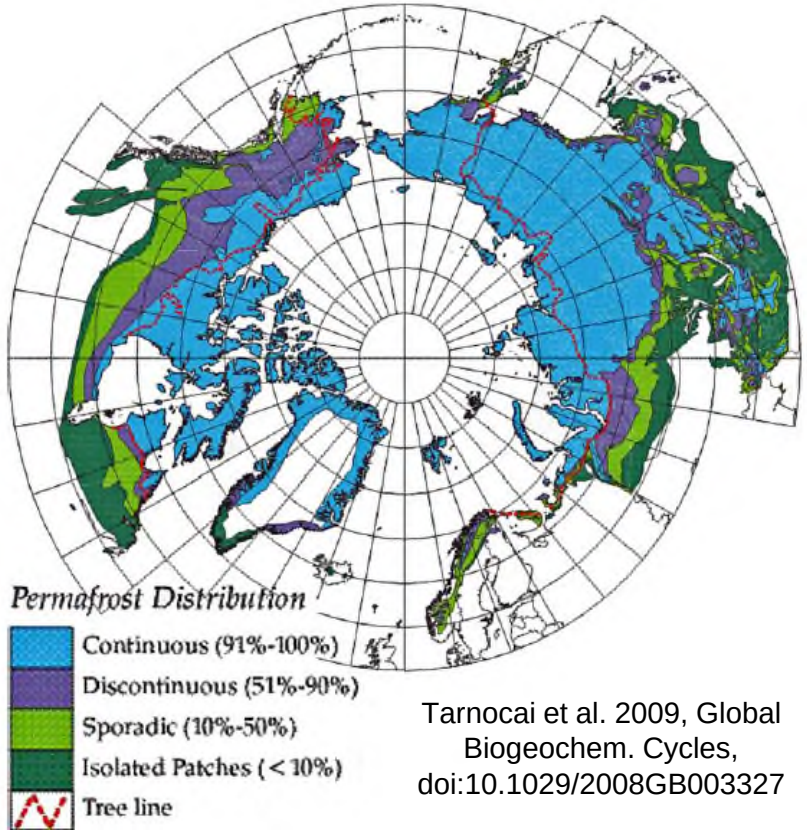
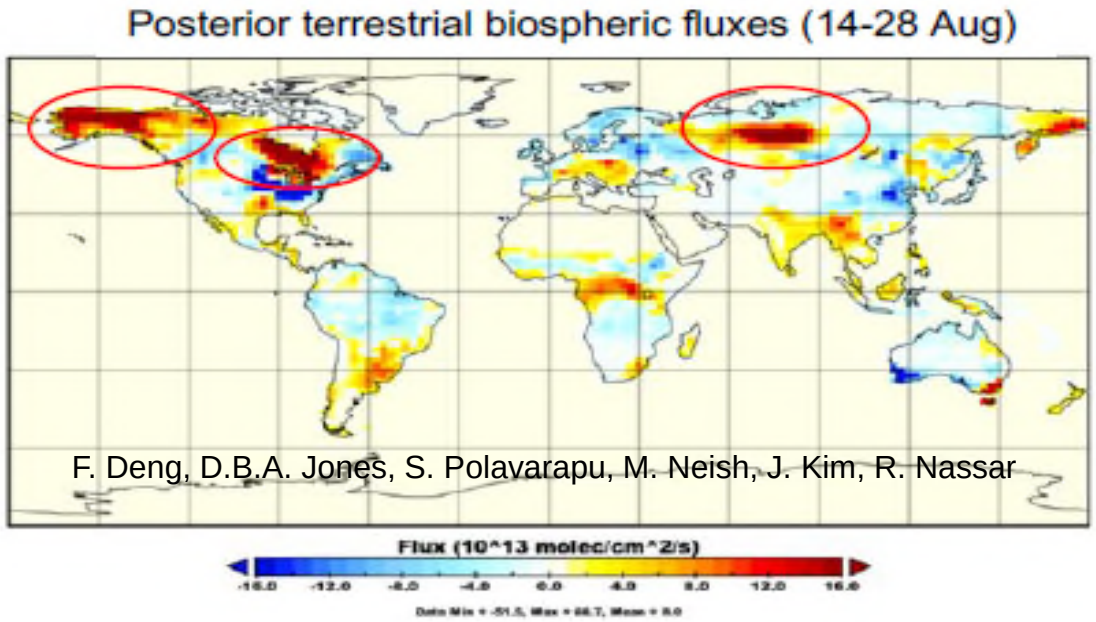
HEO Air Quality and GHG Applications

- Air quality observations of trace gases (NO_2, O_3, SO_2) and aerosols in near real-time would improve our ability to forecast AQ, with implications for human health and to monitor pollutant emissions (e.g. northern resource extraction) and transport from other regions
- Observations of CO_2, CH_4, CO and solar induced fluorescence (SIF) will lead to an improved understanding of the carbon cycle and the impacts of climate on northern forests and permafrost, and also support anthropogenic emission monitoring



Tarnocai et al. 2009, Global Biogeochem. Cycles, doi:10.1029/2008GB003327



F. Deng, D.B.A. Jones, S. Polavarapu, M. Neish, J. Kim, R. Nassar

Preliminary Observing System Simulation Experiment (OSSE) results show that AIM-North more easily detects the permafrost CO_2 emissions and more accurately determines northern high latitude CO_2 fluxes than a constellation of 3 LEO satellites.

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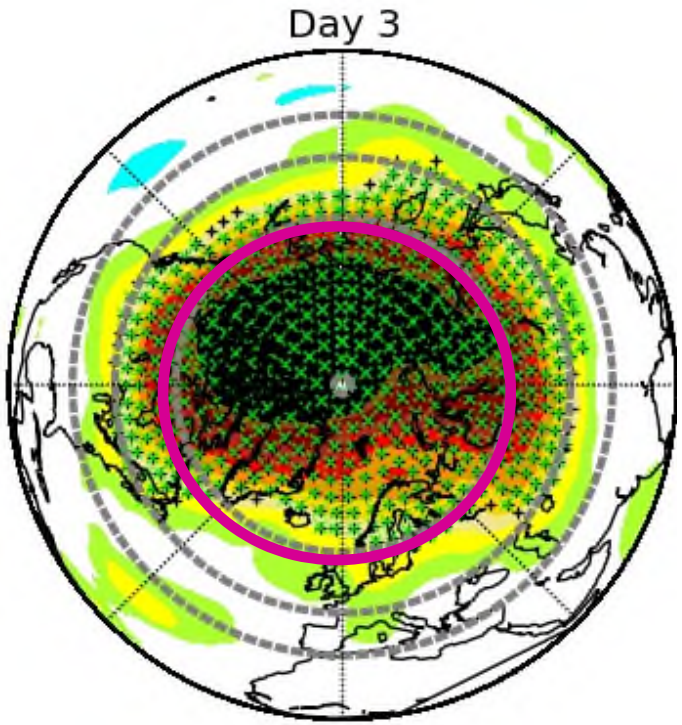
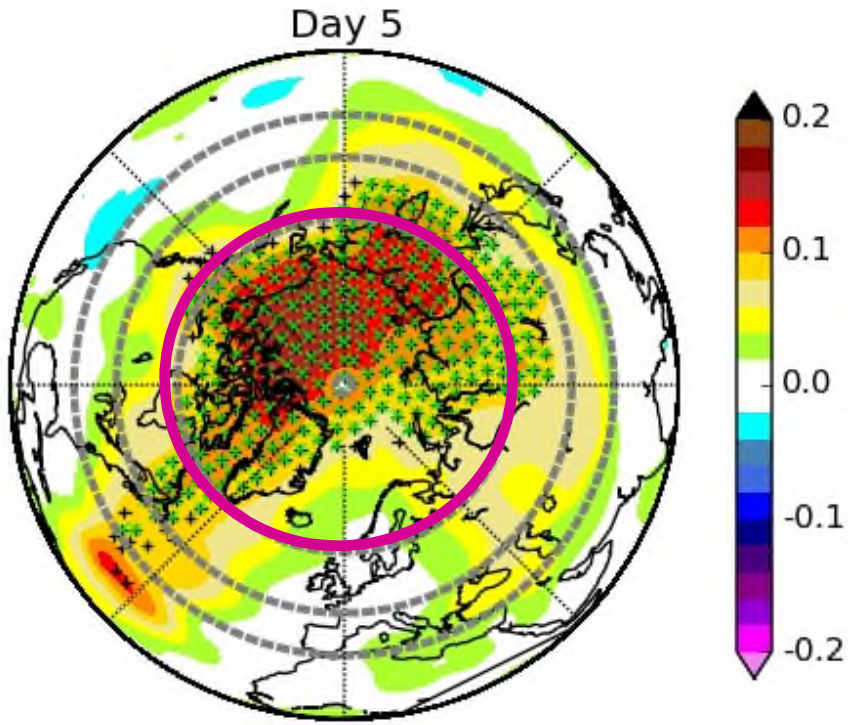
Potential Benefits of HEO Observations in Numerical Weather Prediction

Impact of all assimilated satellite data between 60-90ºN on global NWP



- Positive impact maximum within the area of interest (pink circle) but expanding throughout most of Southern Canada, especially in the East
- The signal decreases with time which suggest that HEO data would have the strongest impact on short-term forecast (0-72h)



✱ indicates 95% confidence interval

Study by Stéphane Laroche and Émmanuel Poan

International Partnership Discussions

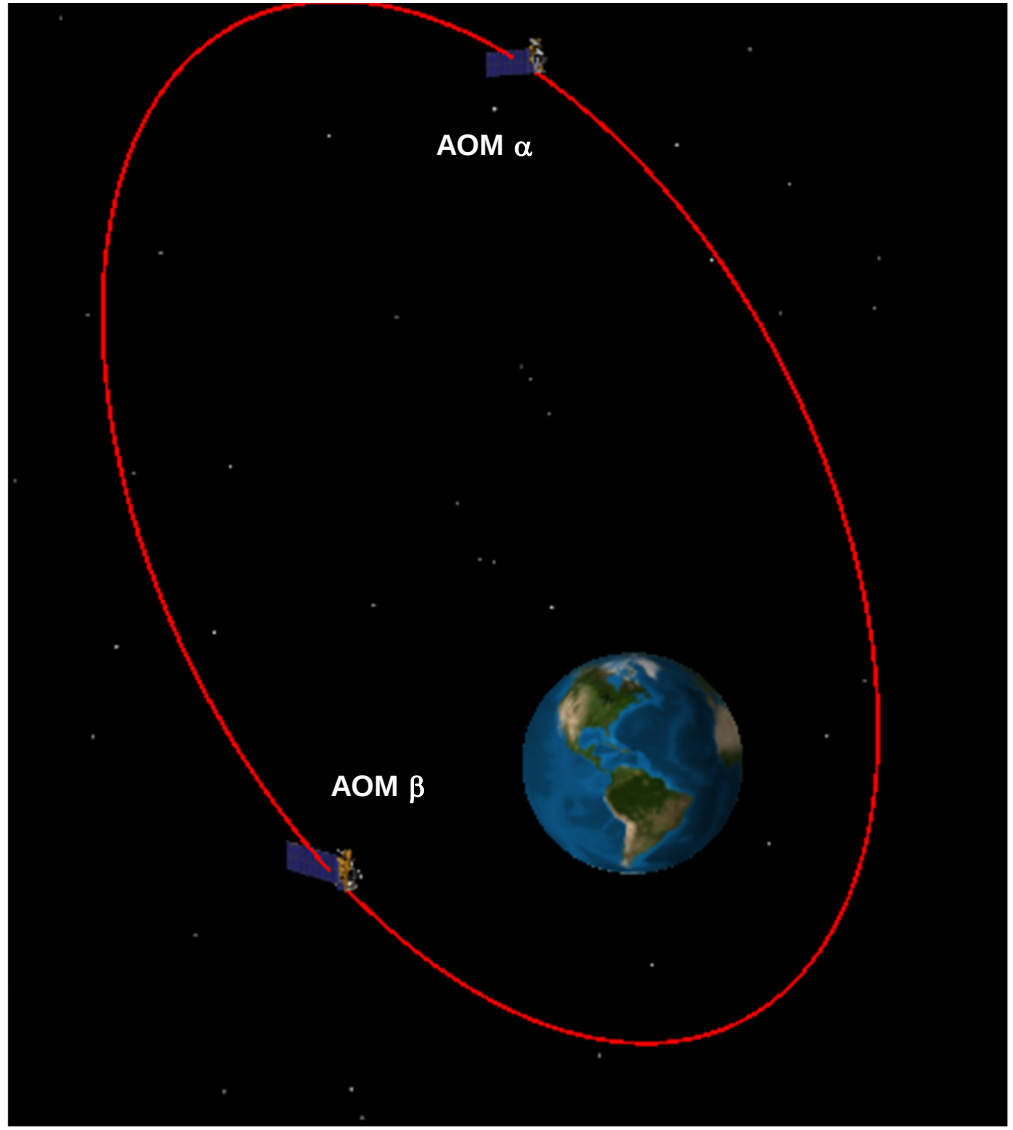
- ESA and EUMETSAT have studied an Arctic meteorological imager building off PCW work
- NOAA is considering making its next generation meteorological imager fully compatible for observing from both GEO and HEO under the GEO-XO program
- NOAA and NASA both have interests in space weather from HEO

- At high-level meeting in October 2019, ECCC, NOAA and EUMETSAT expressed mutual interest in exploring possibility of partnership on a HEO mission
- International expert team monthly teleconference with representatives from ECCC + CSA, NOAA + NASA, EUMETSAT + ESA explore common interests, technical and logistical discussion, as partnership could deliver overall cost savings relative to each partner pursuing separate HEO missions

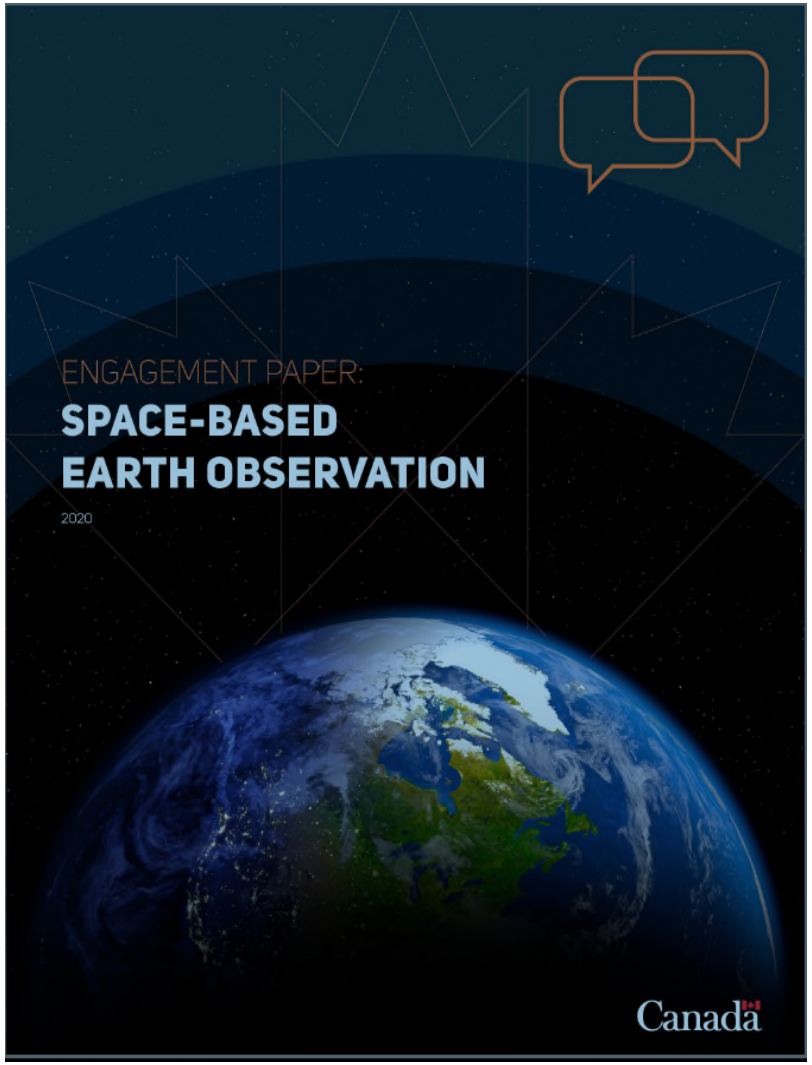
- AIM-North Phase 0 amended to study technical feasibility of adding meteorological and space weather instruments, expanding it to the *Arctic Observing Mission (AOM)*

Arctic Observing Mission (AOM)

- Proposed mission concept of 2 satellites in HEO
- Operational meteorological imager to follow ABI
- NIR-SWIR Greenhouse Gas (GHG) imaging spectrometer
- UV-vis Air Quality (AQ) imaging spectrometer
- Space weather in situ and imaging instrument suite
- Frequent coverage of ~45-90ºN to overlap with GEO
- Near real-time operational weather, AQ and space weather data for forecasting. Longer latency GHG data for flux monitoring and climate applications.
- Phase 0 scheduled for completion end of January 2021
- Canada has a strong interest in conducting a joint international study with NOAA beginning in 2021 to further explore technical questions and partnership possibilities to address our common interests



Although AOM is not yet approved, it aligns with Canadian priorities in SBEO Engagement Paper



Security, Sovereignty & Defence: Towards a 24/7 view of the Arctic and all Canadian territory for civilian and defense activities

Sustainable Agriculture & Food Security: Improved weather forecasts and land surface imagery for agriculture management

Healthy Canadians: Improved air quality forecasts impact health and save lives

Competitive Resource Sectors: Observations to support forest management for Canadian Forest Service and provinces

Clean Water: Measurements and improved predictions of precipitation (rain and snow) for better water management

Climate Change Action & Resilience: Tracking GHG emissions, Monitoring Essential Climate Variables (ECVs), Arctic Environmental Stewardship, Improved forecasts for societal resilience to climate change

International Satellite Constellations for Weather, Air Quality and GHGs

- **Weather:** LEO+GEO constellation, but WMO & CGMS vision for future includes HEO for northern coverage
- **AQ:** LEO+GEO constellation will be in place in 2020s, but extending coverage to north via HEO needed
- **GHGs:** CEOS vision for GHGs is LEO constellation in near term, followed by GEO+HEO later

The Arctic Observing Mission (AOM) would address the northern gap in these disciplines to generate dense and frequent northern weather, air quality and greenhouse gas observations from space

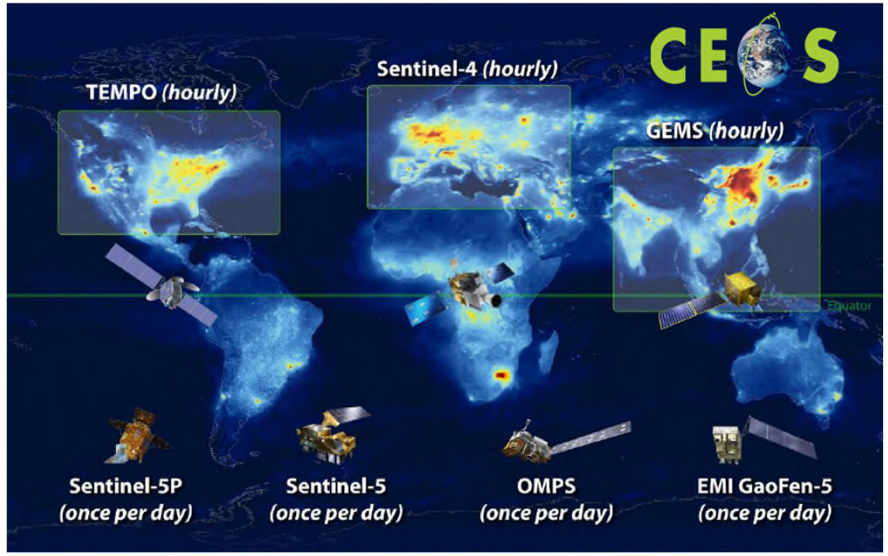
Weather

WORLD METEOROLOGICAL ORGANIZATION

CGMS

Coordination Group for Meteorological Satellites

Air Quality



Greenhouse Gases

CEOS Committee on Earth Observation Satellites

A CONSTELLATION ARCHITECTURE FOR MONITORING CARBON DIOXIDE AND METHANE FROM SPACE

6.1 A CO_2/CH_4 constellation architecture with LEO, GEO and HEO elements

A constellation of CO_2/CH_4 satellites that fully exploits the assets of the LEO, GEO, and HEO vantage points will be needed to meet the demanding GCOS requirements for precision, accuracy, spatial and temporal resolution and coverage summarized in Table 6.1. The following sub-sections describe a point design for a NIR/SWIR constellation architecture that addresses these requirements over continents, while providing somewhat lower resolution and coverage over the ocean. One or more of the LEO platforms would have to carry active CO_2 and CH_4 Lidars to provide useful constraints on XCO_2 and XCH_4 over the nighttime hemisphere. Lidar measurements could also provide global constraints on systematic biases in passive SWIR observations associated with variations in the solar illumination and viewing geometry.