The Arctic Observing Mission (AOM): Update on Pre-Formulation Study Progress and Partnerships

Ray Nassar[1], Alec Casey[1], Geneviève Gariépy[2], Kurtulus Yilmaz[2], Matt Arkett[1], Chris Sioris[1], Chris McLinden[1], Joseph Mendonca[1], Josep Aparicio[1], Shen-En Qian[2], Isabelle Jean[2], Kiernan McClelland[2], Alexander Trishchenko[3]

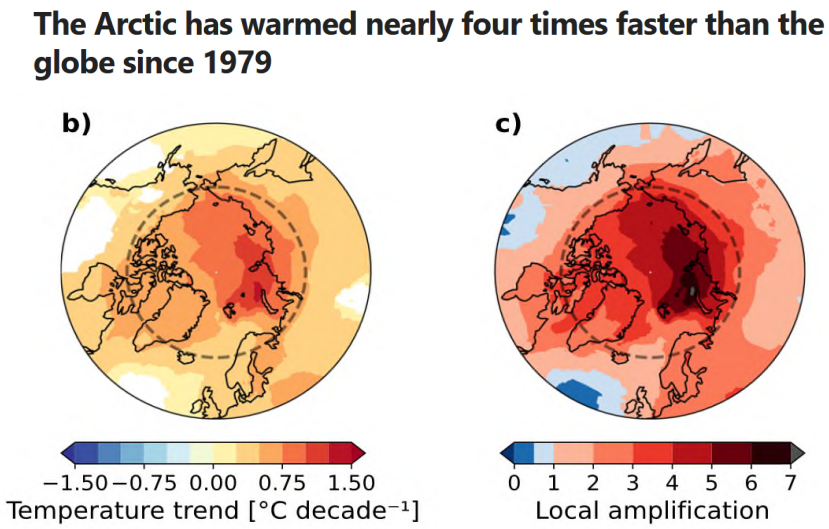
1) Environment and Climate Change Canada (ECCC)
2) Canadian Space Agency (CSA)
3) Natural Resources Canada (NRCan)

American Meteorological Society (AMS) Annual Meeting
2024 January 31

Canada

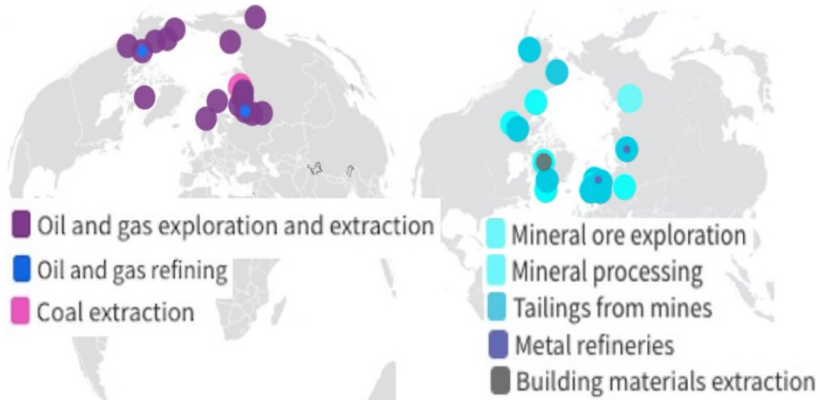
The Changing Arctic

Weather & Climate



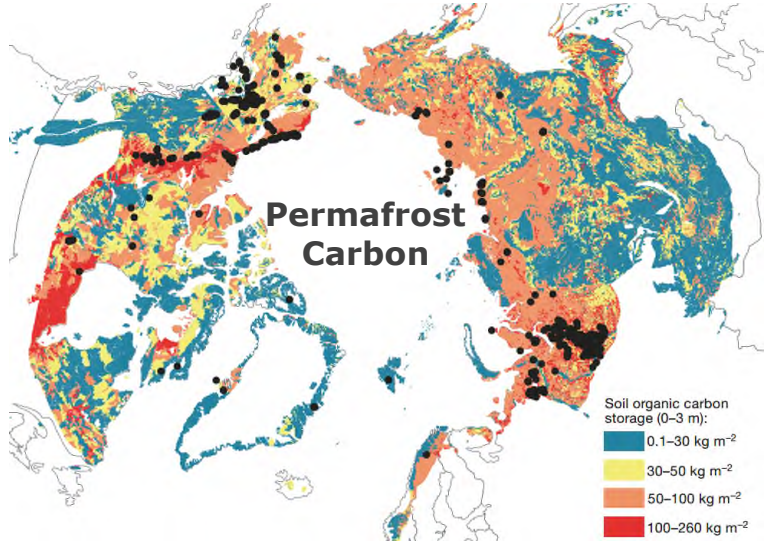
Rantanen et al. 2022, Comm. Earth & Env.

Resource Extraction



Hanaček et al. 2022, Ecological Economics

Climate Feedbacks



Schuur et al. 2015, Nature

- Arctic temperatures have increased 3-4 times global average and this trend is expected to continue
- Changes occurring in multiple Arctic systems (land, atmosphere, ocean, cryosphere) are linked to climate and other anthropogenic drivers

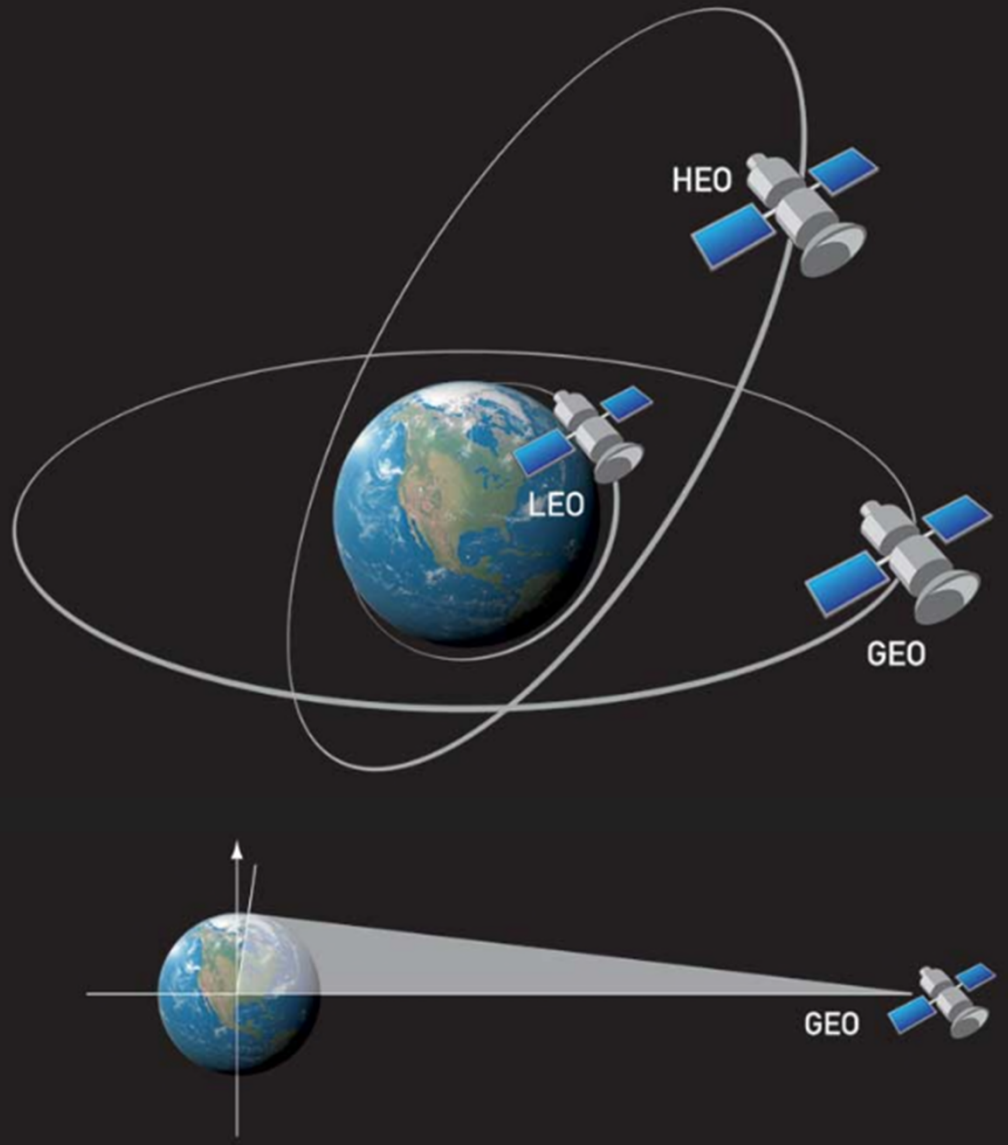
- New, enhanced observations are needed over the Northern high latitudes to improve weather prediction, situational awareness and environmental science and monitoring for societal benefit

Satellite Orbits

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

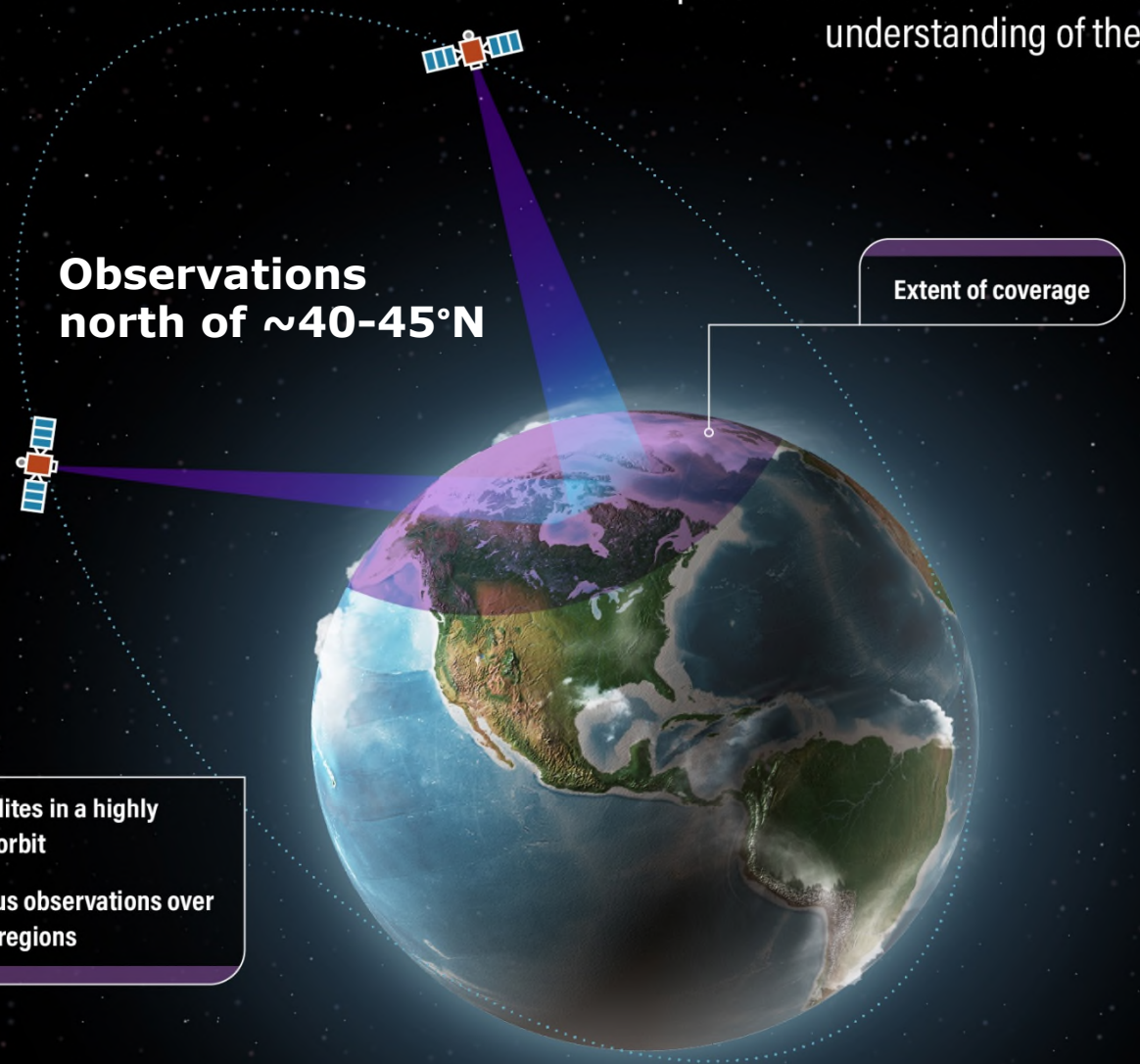
Geostationary Orbit (GEO) gives rapid revisit, but satellite coverage is limited to ~60ºS-60ºN due to viewing geometry from equatorial orbit

A **Highly Elliptical Orbit (HEO)** can address the spatial/temporal gap over the North



ARCTIC OBSERVING MISSION

Proposed Canadian-led international satellite mission to provide a better understanding of the effects of climate change in the North



METEOROLOGY

Support weather and environmental predictions for the North

GREENHOUSE GASES

Detect and monitor greenhouse gas emissions from natural and human activity

AIR QUALITY

Monitor air pollutant emissions and improve air quality forecasts

SPACE WEATHER

Improve space weather forecasts and protect satellites and ground-based infrastructures

Canadian Space Agency | Agence spatiale canadienne

Canada

AOM Timeline and Partnerships

2022-2025 (Pre-formulation Studies – Phase 0)

- GHG instrument sub-orbital demonstration stratospheric balloon flight: August 2022
- NOAA-funded meteorological imager adaptation study with L3Harris: Completed December 2022
- AOM CO_2/NO_2 science study (Univ. of Toronto): Started January 2023, planned completion March 2024
- Socio-economic benefits study (EuroConsult): Completed June 2023
- GHG observing strategy manuscript: Published October 2023
- **AOM Mission Design Contract (MDA, ABB, Airbus): Started June 2023, planned completion fall 2024**
- GHG instrument Focal Plane Array (FPA) study: Started September 2023, planned completion fall 2024
- Various other science/application studies (AOM CO_2 OSSE, orbit studies, ….) in progress

2026-2034 (Phases A-D)

- If funded, detailed design, build and launch

2034-2044 (Phase E)

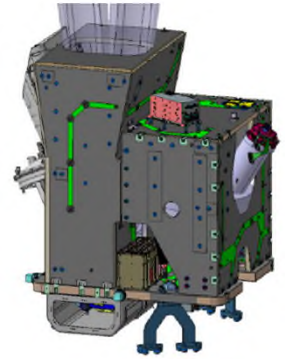
- AOM operations (10-year mission)

Canada

- Envision a Canadian-led international mission, where international partnership is essential to secure Canadian funding and overall success
- Discussions with NOAA, NASA & EUMETSAT on potential contributions are progressing well
- We are also exploring contributions from other international space/meteorological agencies

Possible Arctic Observing Mission (AOM) Payloads and Partnerships

UV-Vis Air Quality Spectrometer



~100 kg

Meteorological Imager

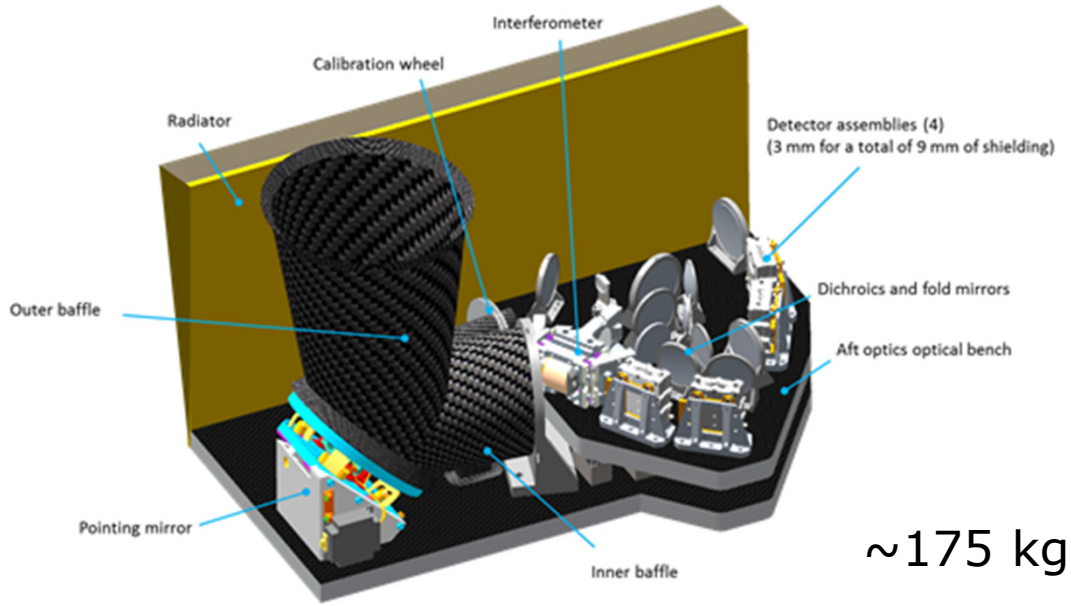
Advanced Baseline Imager (ABI)

~350 kg

NIR-SWIR GHG Imaging Fourier Transform Spectrometer (IFTS)

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

Canada



~175 kg

Space Weather Instruments

~95 kg

EUMETSAT

Potential contributions in data reception & data processing

Other potential partners ???

FINNISH METEOROLOGICAL INSTITUTE

JPL Jet Propulsion Laboratory

UK SPACE AGENCY

AOM Configuration Options

Option	# Satellites	Meteorology	GHG	Air Quality	Space Weather
A	2	ABI	IFTS	AQ	SpW
B	2	ABI	IFTS	-	-
C	1	ABI	IFTS	AQ	SpW
D	1	ABI	IFTS	-	-

Notes:

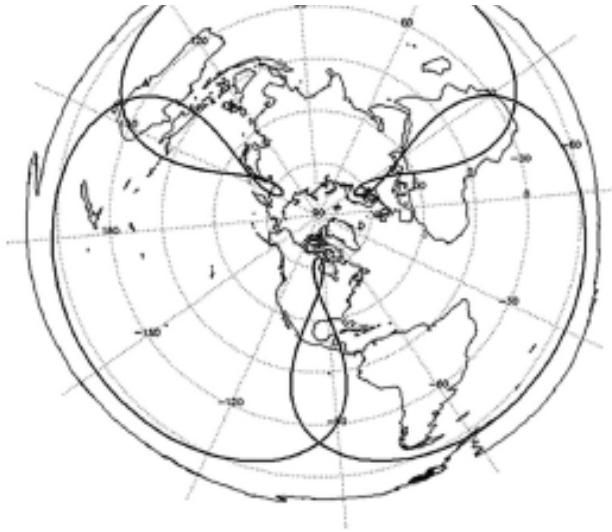
1. Expectation is that cost will decrease stepwise from Option A to D
2. Including only one of AQ or space weather instrument suite are variations in which costing will be estimated by interpolation.

Orbit recommendation from Requirements and Orbits Review (ROR)

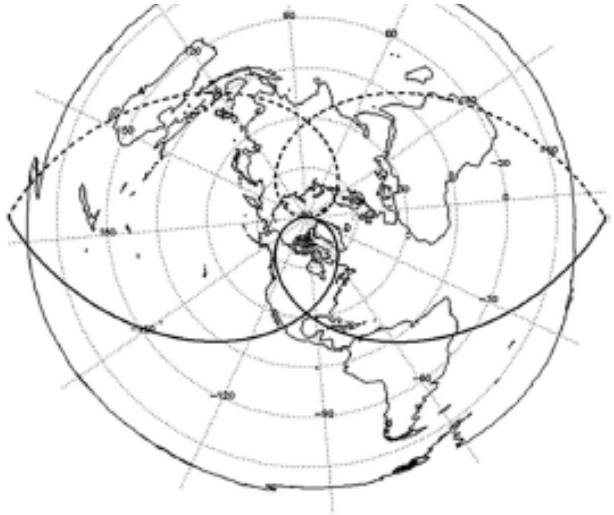
Orbit	Eccentricity	Apogee Height	Inclination	Period
TAP	0.50	41,885 km	63.435°	16 hours
Tundra 0.30	0.30	48,434 km	63.435°	24 hours
Tundra 0.22	0.22	45,061 km	63.435°	24 hours

- Many science and technical implementation factors considered & weighed in orbit assessment process.
- **TAP recommended for 2 satellite scenario** due to lower apogee height for GHG observation SNR and since it best satisfied requirements for continuous meteorological observations near 60°N.
- **Tundra *e* = 0.30 recommended for single satellite case** due to focused coverage over Canada and Alaska (although very limited European & Russian coverage).

Three Apogee (TAP)



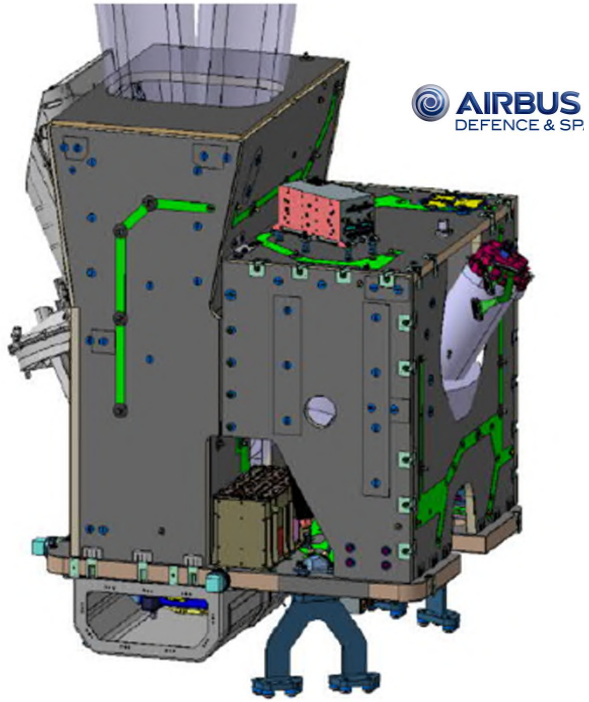
Tundra

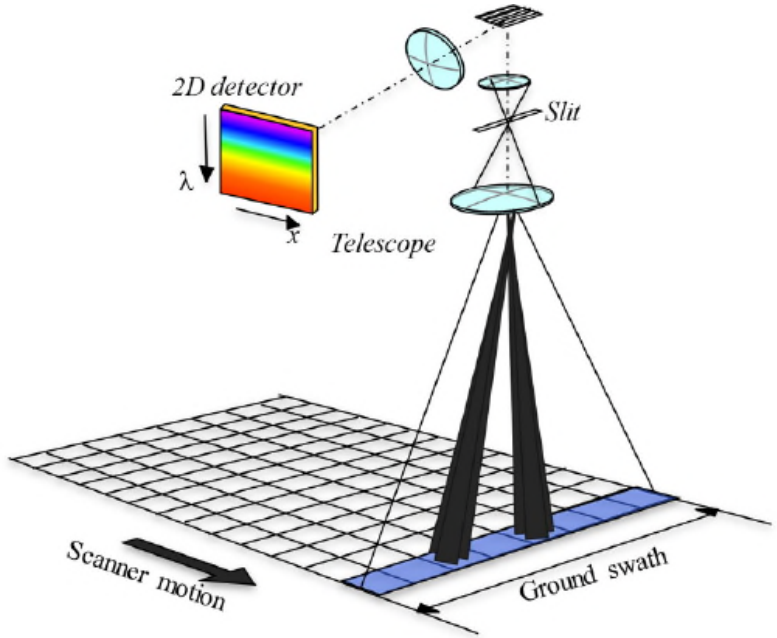


AOM Air Quality Instrument

"Full Capability AQ instrument": similar design to Copernicus/ESA Sentinel-4 GEO AQ instrument was previously studied

- Pushbroom scanning
- 4x4 km^2 (while Sentinel-4 is 8x8 km^2)
- 290-780 nm, 0.25 nm spectral sampling, 0.8 nm spectral resolution
- Addition of line imager for sub-pixel (500x500 m^2) cloud and aerosol data
- Mass 182 kg (including 15% margin)





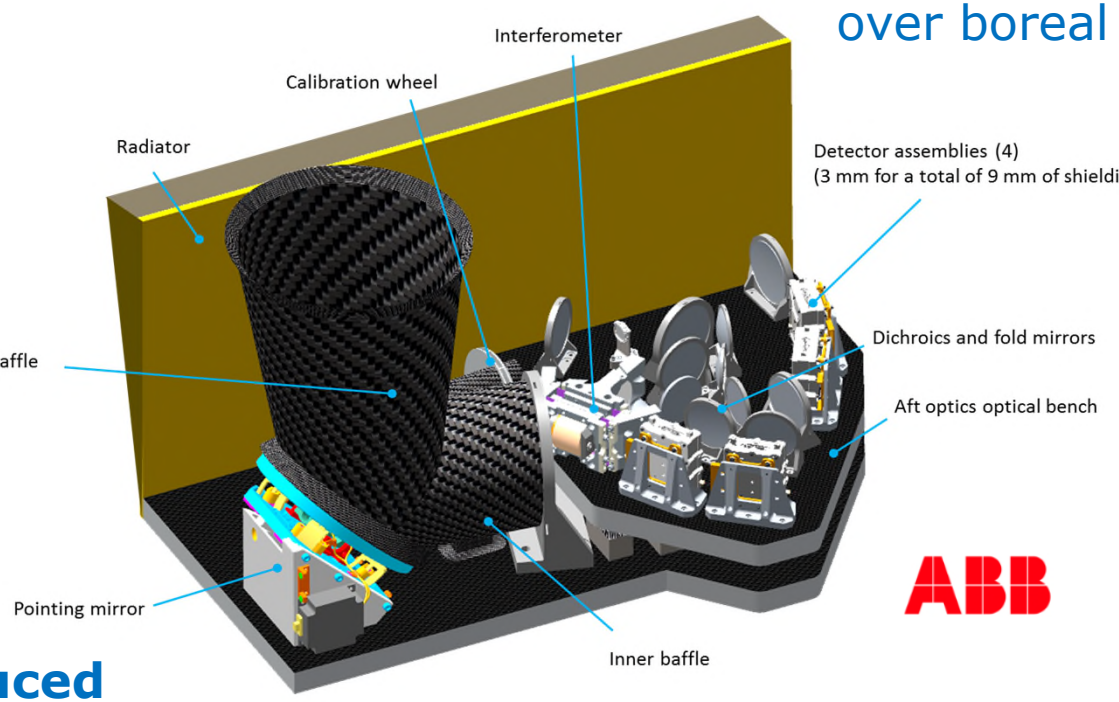
- Pre-formulation study exploring a "Reduced Capability AQ instrument" using dispersive spectrometer technology, 100 kg maximum and cost-capped, UV-vis observations (~325-480 nm, 1 nm spectral resolution) for NO_2 (top priority for synergy with CO_2), O_3 (next priority), some capability for BrO, HCHO, OClO
- Relaxing revisit rate to ~3 hours, but reducing data latency to < 1 hour
- Combined with aerosol data from ABI, would support improved Air Quality forecasts

Greenhouse Gas Imaging Fourier Transform Spectrometer (IFTS)

IFTS technology for CO_2 and CH_4 measurement demonstrated on sub-orbital balloon flight (~37 km) over boreal forest in August 2022.

Using 2D focal plane array (FPA), IFTS will generate spectra in 128x128 pixels every 60 seconds.

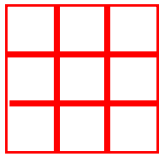
Wavelength range (nm)	Wavenumber range (cm^{-1})
758 - 772	12,953 - 13,192
1598 - 1618	6180 - 6258
2042 - 2079	4810 - 4897
2301 - 2380	4195 - 4345



CO_2, CH_4, CO and solar induced fluorescence (SIF) over land during daylight.

Assessing FPA candidates and refining IFTS concept in Pre-formulation mission design contract (and a parallel technology development study).

3x3 binning



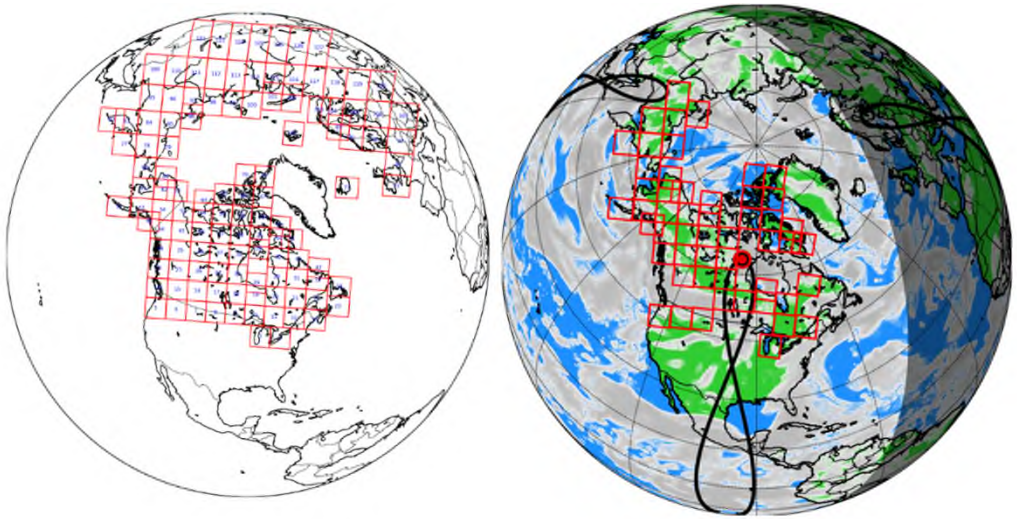
	Binned Pixel	Unbinned Pixel
At 40,000 km	3.6 km	1.2 km
Three Apogee Orbit average	~ 3.0 km	~ 1.0 km

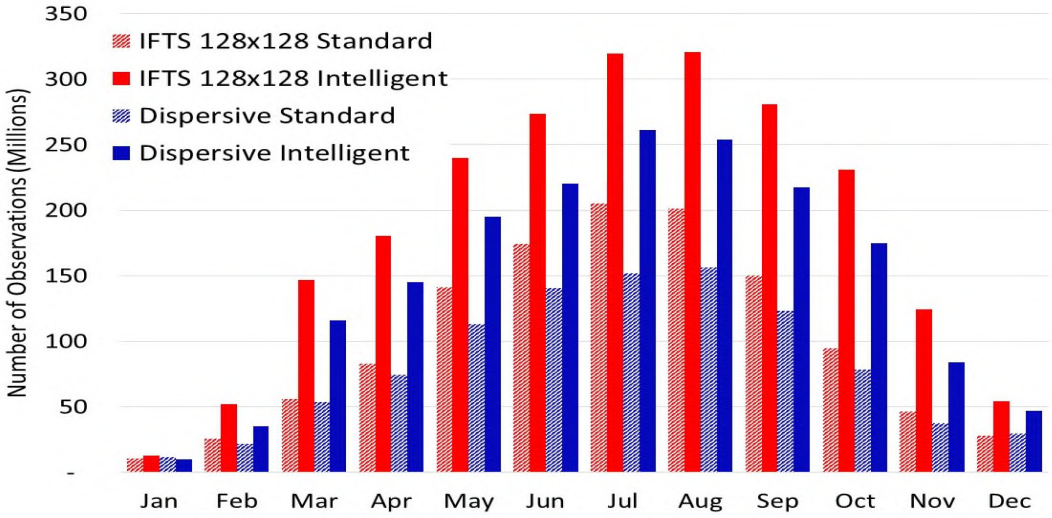
*Only binned pixels will meet precision & accuracy requirements

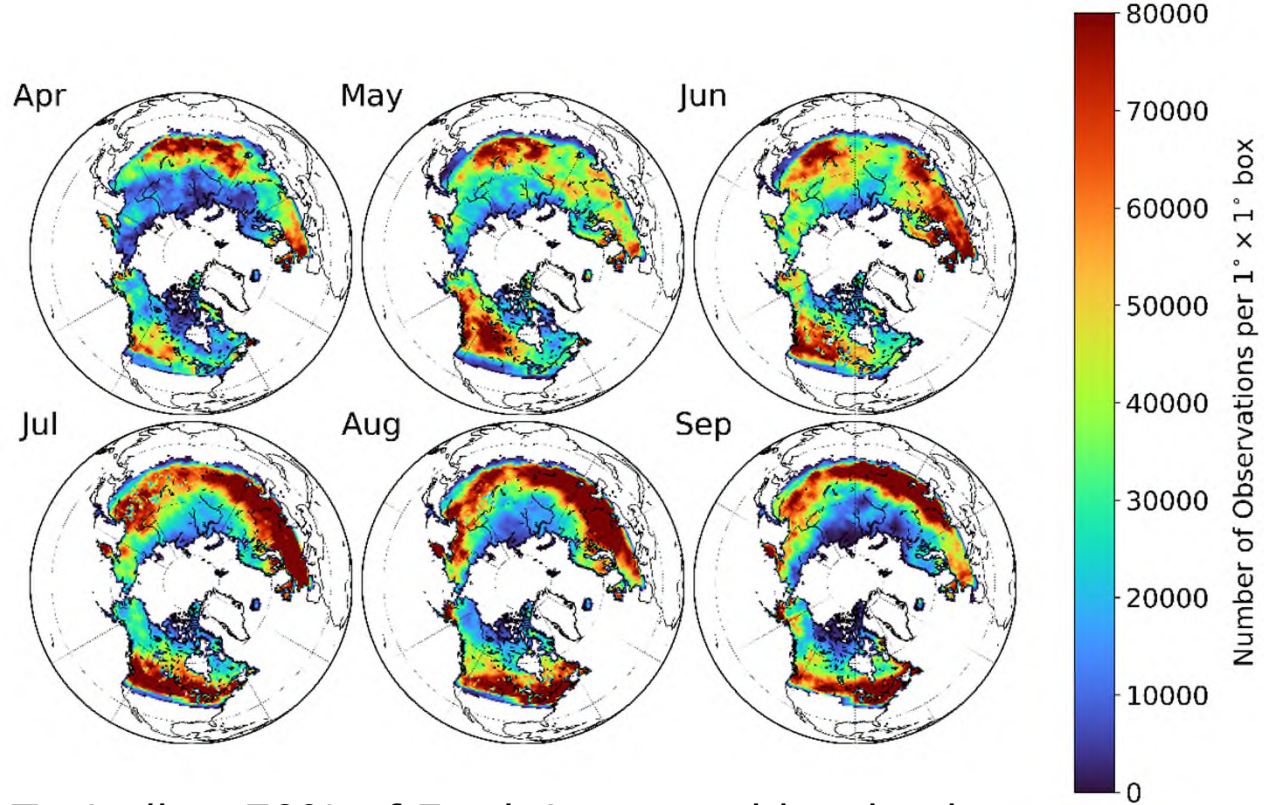
Intelligent Pointing increases the fraction of cloud-free CO_2 and CH_4 observations from space

frontiers | Frontiers in Remote Sensing *Published October 2023*

R. Nassar, C.G. MacDonald, B. Kuwahara, A. Fogal, J. Issa, A. Girmenia, S. Khan, C. Sioris https://doi.org/10.3389/frsen.2023.1233803







- Typically ~70% of Earth is covered by clouds
- *Intelligent Pointing* pioneered by GOSAT-2, but simulations suggest it is more effective from HEO and GEO than LEO
- With real-time cloud information from ABI to guide IFTS pointing, AOM could obtain hourly revisit during daylight for cloud-free land north of ~42°N for most of the year

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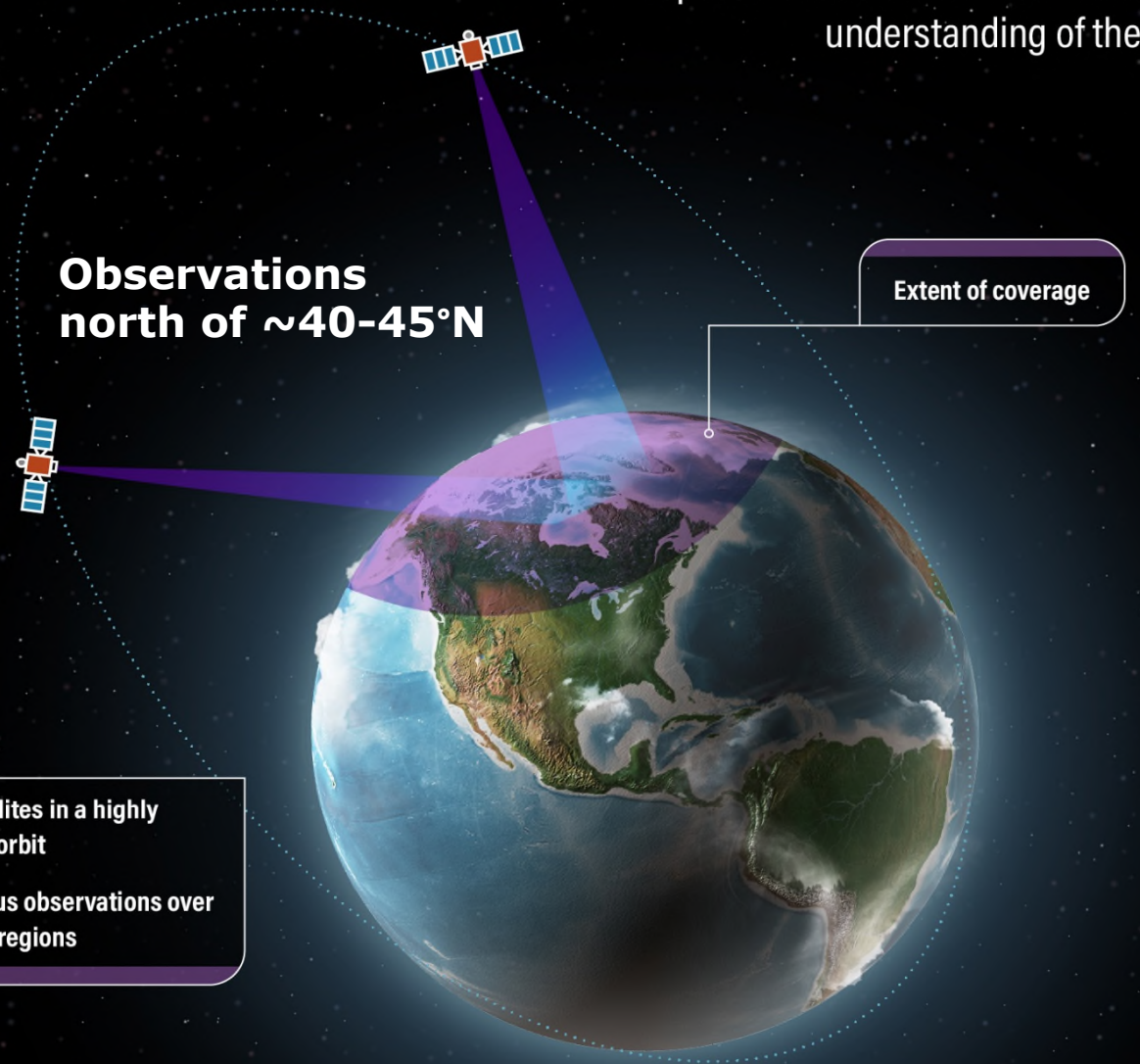

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