Environment and Climate Change Canada / Environnement et Changement climatique Canada

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

GHG & Air Quality Observations from a Highly Elliptical Orbit (HEO)

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Environment and Climate Change Canada

CEOS Atmospheric Composition Virtual Constellation Meeting

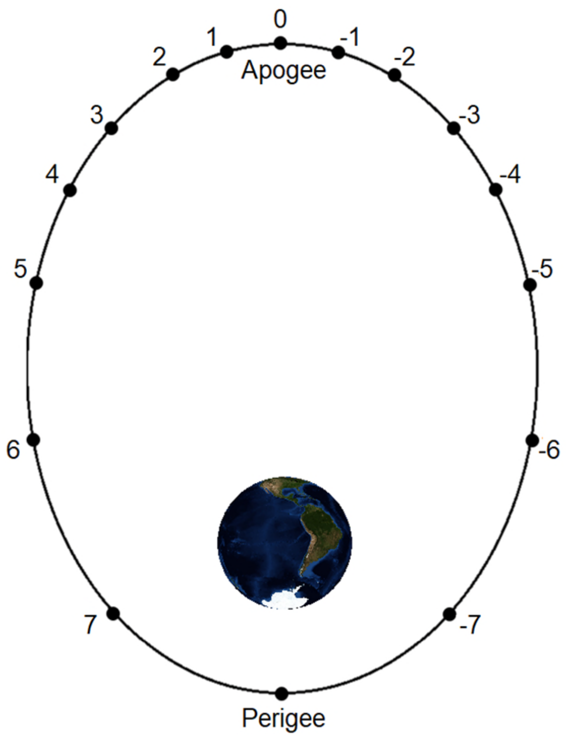
June 2020

Canada

The Highly Elliptical Orbit (HEO) Class

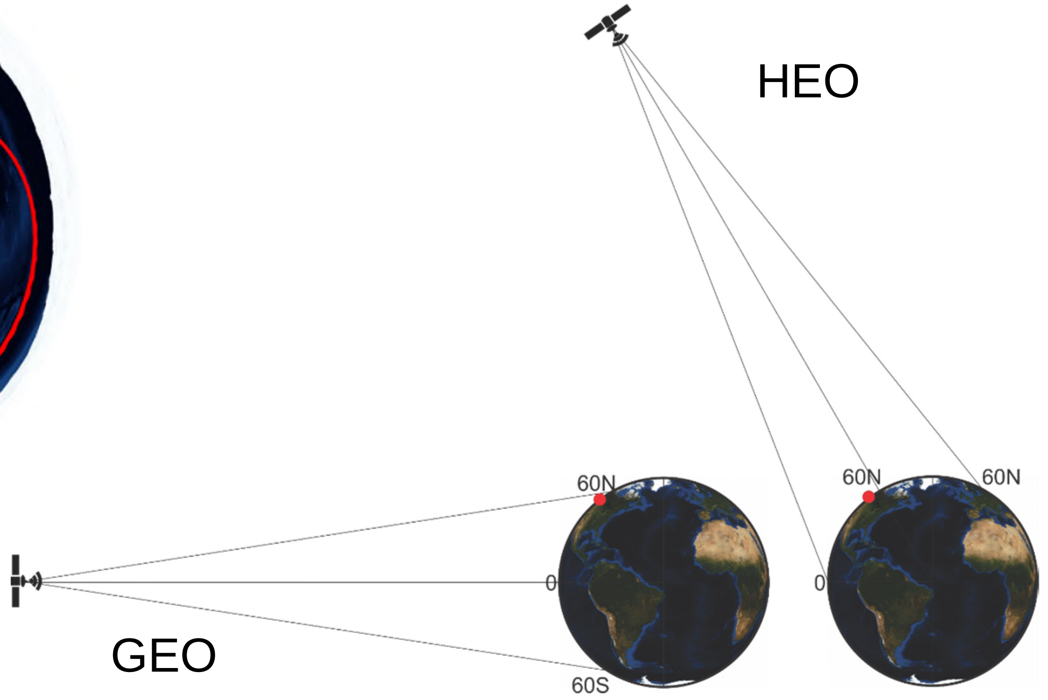
- Highly elliptical orbits can be used for quasi-geostationary high latitude Earth observations
- Multiple Canadian-led studies into HEO orbit variations. Example:

a) 16-hour elliptical orbit



b) Three apogee orbit ground track

c) Viewing angle from HEO (i = 63.435º)



www.aim-north.ca

AIM-North

THE ATMOSPHERIC IMAGING MISSION FOR NORTHERN REGIONS

OVERVIEW | SCIENCE | ORBIT | INSTRUMENTS & DATA | TEAM | RELEVANCE | PUBLICATIONS

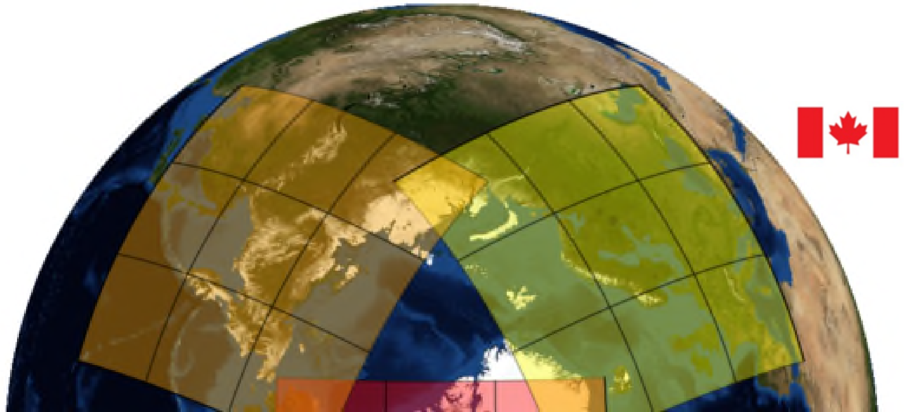
AIM-North is an innovative satellite mission concept that is under consideration by the Canadian Space Agency (CSA). The mission is currently undergoing Phase 0 studies.

AIM-North would provide observations of unprecedented frequency, density and quality for monitoring greenhouse gases (GHGs), air quality (AQ), clouds and solar induced fluorescence (SIF) from vegetation in northern regions. AIM-North would use a constellation of two satellites in a highly elliptical orbit (HEO) configuration, enabling observations over land from about 40-80°N, multiple times per day. Enhancing the mission with additional spectral bands could provide complementary observations for weather, climate and AQ research and operations. The project is a collaborative effort between Environment and Climate Change Canada (ECCC), CSA, other federal and provincial government departments, Canadian academia, Canadian industry and international scientists.

ABB

AIRBUS DEFENCE & SPACE

MDA



Environment and Climate Change Canada

CSA ASC

CANADIAN JOURNAL OF REMOTE SENSING
https://doi.org/10.1080/07038992.2019.1643707

The Atmospheric Imaging Mission for Northern Regions: AIM-North

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ABSTRACT

AIM-North is a proposed satellite mission that would provide observations of unprecedented frequency and density for monitoring northern greenhouse gases (GHGs), air quality (AQ) and vegetation. AIM-North would consist of two satellites in a highly elliptical orbit formation, observing over land from ~40°N to 80°N multiple times per day. Each satellite would carry a near-infrared to shortwave infrared imaging spectrometer for CO_2, CH_4, and CO, and an ultraviolet-visible imaging spectrometer for air quality. Both instruments would measure

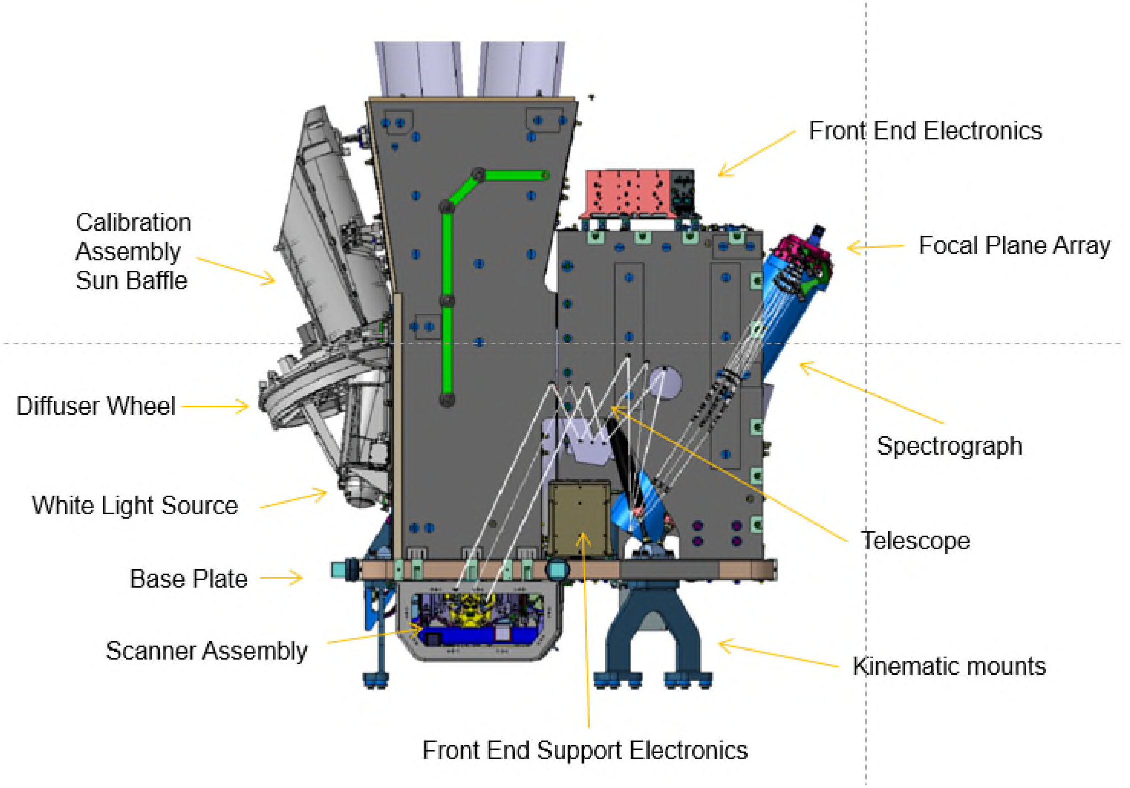
ARTICLE HISTORY
Received 2 January 2019
Accepted 11 July 2019

Published Sept 2019
Over 1100 views and counting

Canadian Journal of Remote Sensing 2019
Paper of the Year

Air Quality Spectrometer

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

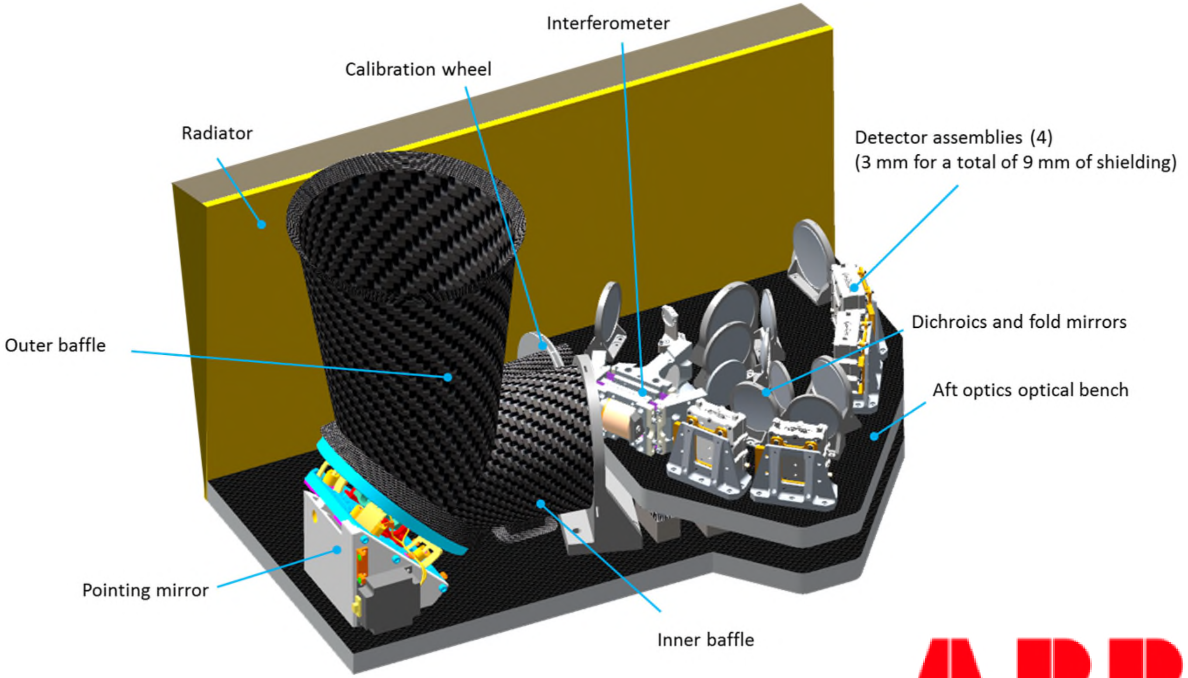


Similar design to Copernicus/ESA Sentinel-4 AQ instrument

GHG Imaging Fourier Transform Spectrometer (IFTS)

CO_2, CH_4, CO, SIF

Selected for adequate precision performance, high commercialization potential and superior cloud avoidance potential (intelligent pointing)



Interferometers on CSA SCISAT/ACE, JAXA GOSAT/GOSAT-2 & NOAA CrIS

AIM-North GHG Observing Requirements & Options

	Single Sounding Precision*	Multi-sounding maximum bias (after bias correction)
XCO_2	1 ppm (G) = 0.25% 3 ppm (T) = 0.75%	0.2 ppm (G) = 0.05% 0.6 ppm (T) = 0.15%
XCH_4	9 ppb (G) = 0.5% 27 ppb (T) = 1.5%	2 ppb (G) = 0.10% 6 ppb (T) = 0.30%
XCO	5% (G) 15% (T)	5% (G) 15% (T)
	Multi-sounding Precision	
Solar Induced Fluorescence (SIF)	0.30-0.90 $W\ m^{-2}\ \mu m^{-1}\ sr^{-1}$	

G = Goal, T = Threshold

*AIM-North requirements converted from % assuming 400 ppm XCO_2 and 1.8 ppm XCH_4

	IFTS	Grating Spectrometer
Field of View (FOV)	128 x 128 (step-and-stare)	480 x 1 (sweep scanning)
Pixel Size	4x4 km^2	4x4 km^2
Integration time	60 s	1.75 s
Aperture diameter	20 cm	10 cm
Mass	164 kg	203 kg
Power	187 W	202 W
Raw # obs / h	~900,000	~900,000

Simulated instrument performance using modified OCO-2 retrieval algorithm:

Precision achieved based on current IFTS and grating spectrometer design options for a reference scene (SZA = 45°, VZA = 0.1°, AOD = 0.1 and forest albedo).

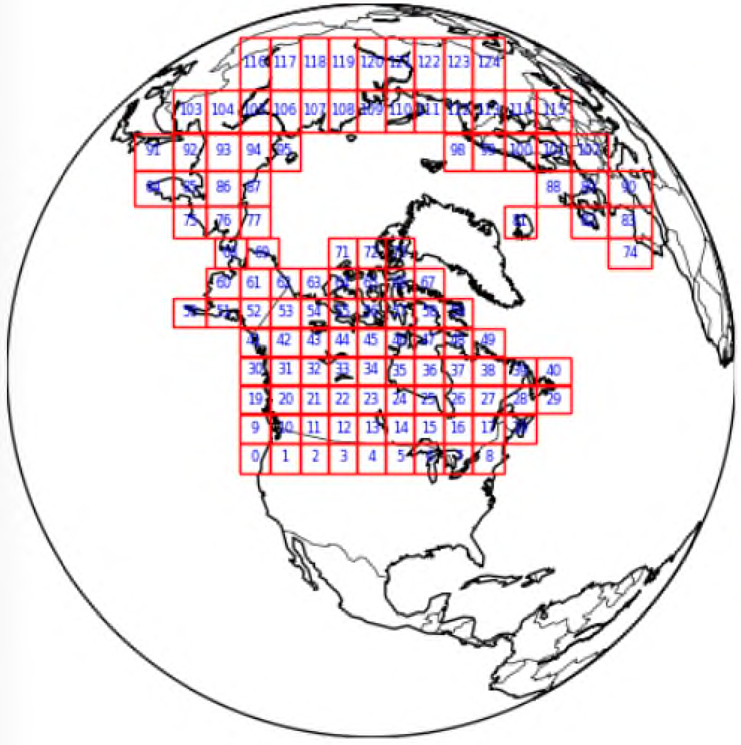
(%)	XCH_4	XCO	XCO_2
Grating	0.53	7.63	0.40
FTS	0.62	8.56	0.42

J. Mendonca, S. Roche, D. Wunch, K. Strong, R. Nassar

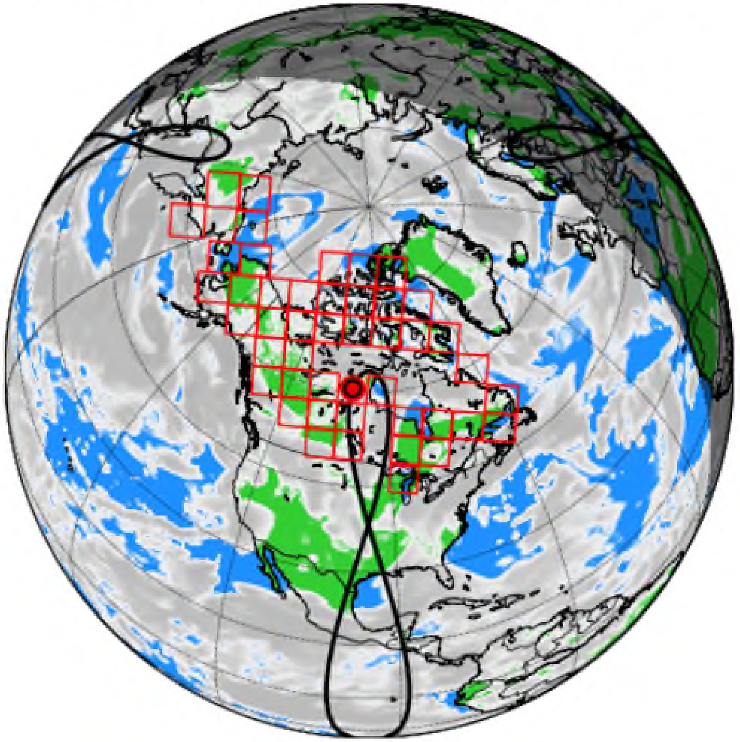
AIM-North Intelligent Pointing

- About 70% of Earth is covered by clouds at any moment, resulting in loss of most observations with standard pointing
- Plan for *Intelligent Pointing* building off pioneering work of GOSAT-2 (Japan) from LEO
- With real-time cloud information, 128x128 pixel FOV could be pointed at cloud-free regions every ~60 s
- Hourly revisit rate for cloud-free land regions spanning daylight (SZA ≤ 80°) portion of the diurnal cycle

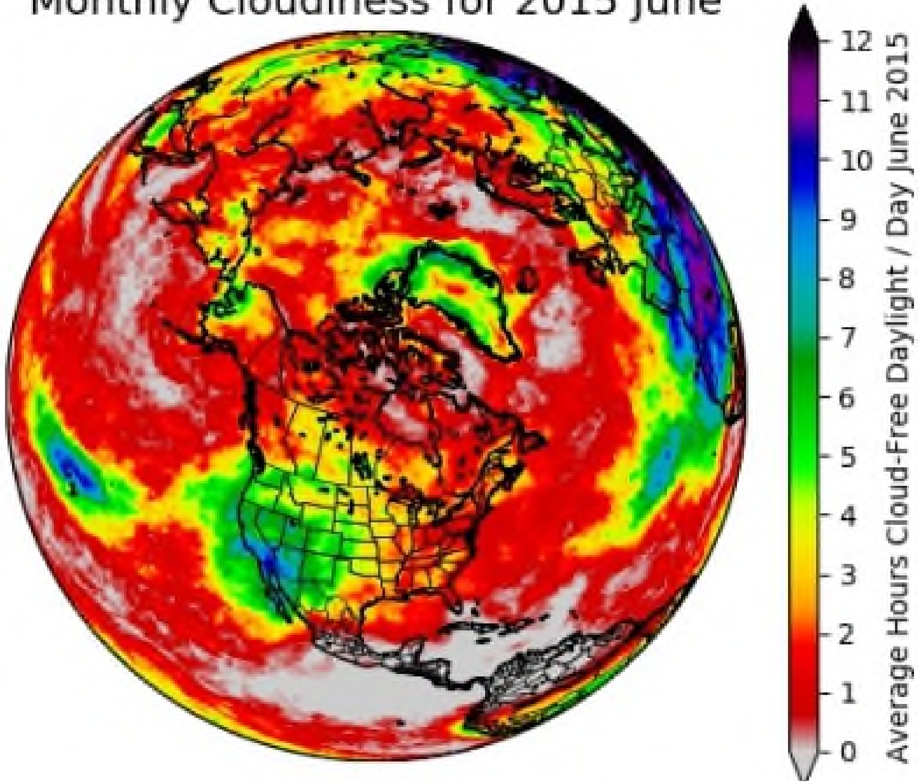
Potential FOV locations



FoV Selections 01 June 2015 19:29 - 20:59 UTC



Monthly Cloudiness for 2015 June



Although a dispersive spectrometer can cover similar area in same time, aspect ratio of FOV matters!
IFTS with square FOV gets factor ~2.0 increase in successful observations with intelligent pointing,
but dispersive only gets factor ~1.6, since harder to fit through holes in cloud cover.

Baseline Products from the GOES-R Advanced Baseline Imager (ABI)

Table 4. List of GOES-R ABI-derived baseline products. Also included are other attributes, such as the geographical coverage, horizontal resolution, and product refresh rate.

Baseline product	Product geographic coverage	Product horizontal resolution	Refresh rate/coverage time (mode 3)
Aerosol detection (including smoke and dust)	CONUS FD Mesoscale	2 km	CONUS: 15 min FD: 15 min Mesoscale: 15 min
Aerosol optical depth	CONUS FD	2 km	CONUS: 5 min FD: 15 min
Volcanic ash: Detection and height	FD	2 km	FD: 15 min
Cloud and moisture imagery	CONUS FD Mesoscale	2 km, with finer daytime observations	CONUS: 5 min FD: 15 min Mesoscale: 30 s
Cloud optical depth	CONUS: for optical depth > 1 FD: for optical depth > 1	CONUS: 2 km FD: 4 km	CONUS: 15 min FD: 15 min
Cloud particle size distribution	CONUS FD Mesoscale	2 km	CONUS: 5 min FD: 15 min Mesoscale: 5 min
Cloud-top phase	CONUS FD Mesoscale	2 km	CONUS: 5 min FD: 15 min Mesoscale: 5 min
Cloud-top height	CONUS FD Mesoscale	CONUS: 10 km FD: 10 km Mesoscale: 4 km	CONUS: 60 min FD: 60 min Mesoscale:5 min
Cloud-top pressure	CONUS FD	10 km	CONUS: 60 min FD: 60 min
Cloud-top temperature	FD Mesoscale	2 km	FD: 15 min Mesoscale: 5 min
Hurricane intensity	FD	2 km	FD: 30 min
Rainfall rate/quantitative precipitation estimation (QPE)	FD	2 km	FD: 15 min
Legacy vertical moisture profile	CONUS FD Mesoscale	10 km	CONUS: 30 min FD: 60 min Mesoscale: 5 min
Legacy vertical temperature profile	CONUS FD Mesoscale	10 km	CONUS: 30 min FD: 60 min Mesoscale: 5 min
Derived stability indices [convective available potential energy (CAPE), lifted index, *K* index, Showalter index, total totals]	CONUS FD Mesoscale	10 km	CONUS: 30 min FD: 60 min Mesoscale: 5 min
Total precipitable water	CONUS FD Mesoscale	10 km	CONUS: 30 min FD: 60 min Mesoscale: 5 min
Clear-sky masks	CONUS FD Mesoscale	2 km	CONUS: 15 min FD: 15 min Mesoscale: 5 min
Radiances	CONUS: clear and above cloud regions only FD: clear and above cloud regions only Mesoscale: clear and above cloud regions only	Individual channel resolutions (0.5, 1.0, and 2.0 km)	CONUS: 15 min FD: 15 min Mesoscale:5 min
Downward shortwave radiation: Surface	CONUS FD Mesoscale	CONUS: 25 km FD: 50 km Mesoscale: 5 km	CONUS: 60 min FD: 60 min Mesoscale: 60 min
Reflected shortwave radiation: TOA	CONUS FD	25 km	CONUS: 60 min FD: 60 min
Derived motion winds	CONUS FD Mesoscale	Band dependent	CONUS: 15 min FD: 60 min (based on a single set of three sequential images 5 min or more apart) Mesoscale: 5 min
Fire/hotspot characterization	CONUS FD	2 km	CONUS: 5 min FD: 15 min
Land surface (skin) temperature	CONUS FD Mesoscale	CONUS: 2 km FD: 10 km Mesoscale: 2 km	CONUS: 60 min FD: 60 min Mesoscale: 60 min
Snow cover	CONUS FD Mesoscale	2 km	CONUS: 60 min FD: 60 min Mesoscale:60 min
Sea surface temperature (skin)	FD	2 km	FD: 60 min

Schmidt et al. (2017), A Closer Look at the ABI on the GOES-R series, Bulletin of the American Meteorological Society, doi:10.1175/BAMS-D-15-00230.1

GEO-XO Industry Concept Analyses

NESDIS Update to the Committee on Earth Science and Applications from Space

NOAA Satellite and Information Service

March 31, 2020

Dr. Stephen Volz

Assistant Administrator for Satellite and Information Service

From the BAA, FY20 funds are being used to partner with industry for options to **replenish GOES-R data by 2030:**

Instruments

- Regional, real-time weather imagery
- Space weather data
- High latitude observations – highly elliptical orbits (Tundra) for Arctic observations
- Lightning mapping; hyperspectral sounding to support

Implementation solutions

- Standard satellite bus, including GEO/Tundra shared
- Hosting services, for NOAA instruments on others' platforms and for partners to fly on NOAA satellites
- Small satellites for space weather instruments
- Commercial data and services

2020: Complete pre-Phase A studies, ready for detailed trades
2021: Phase A start, focused industry design trades

Letter of Support from NOAA, Stephen Volz (2020)

Canada is now exploring partnership possibilities with:
NOAA,
EUMETSAT,
ESA,
NASA (heliophysics),
for an expanded international HEO mission:

Arctic Observing Mission

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 delivering a major improvement in capacity for Northern observation from space

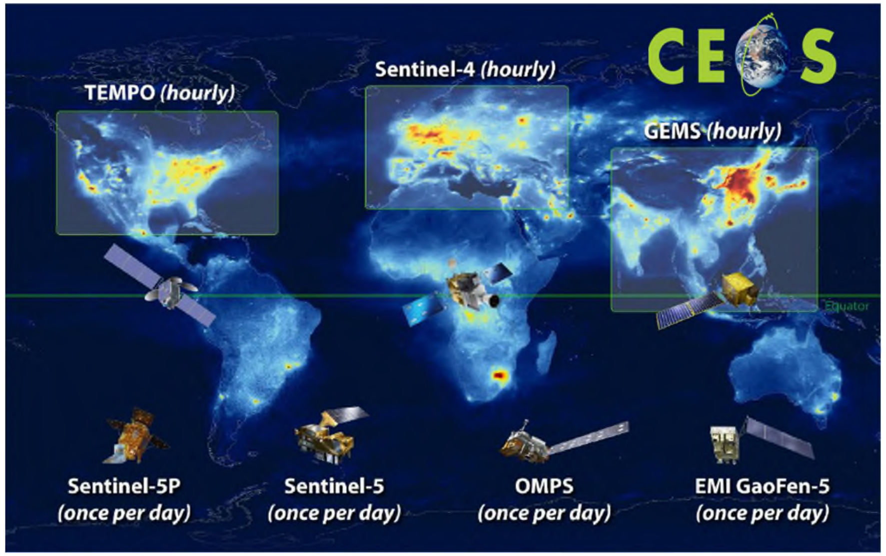
Weather

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.