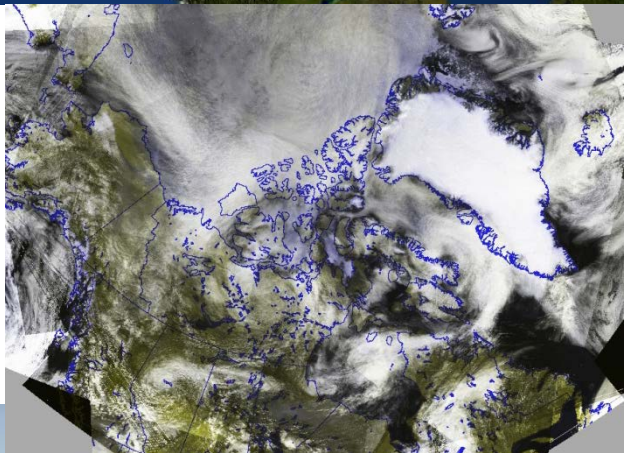


Polar Communications and Weather Mission: Status and potential contribution to the space- based architecture for climate monitoring



Environment Canada
CM-12
21 June, 2014





Background

- Mission concept to support Canadian interests in the Arctic developed by Canadian Space Agency (CSA)
- in partnership with Environment Canada (EC) and Department of National Defence (DND)
- Requirements
 - civil and military broadband communications
 - weather imaging
 - space weather
- CSA Phase A studies completed - 2012
 - 2-satellite, HEO (Molniya) concept
- Military narrowband communications (UHF) requirements added – DND + Allies
- Approval by Government required to proceed





Request for Information (RFI)

- RFI released to industry - November 2013
 - response date – January 2014
- Purpose
 - Inform industry of the proposed PCW initiative
 - Seek industry comments on the requirements, feasibility, cost, risk and business models
 - Inform the development of a business case for consideration by Government
- High-Level Requirements (capabilities) vs. specifications
 - seeking innovation and diversity of technical and business solutions
 - target: 2020-2022 launch



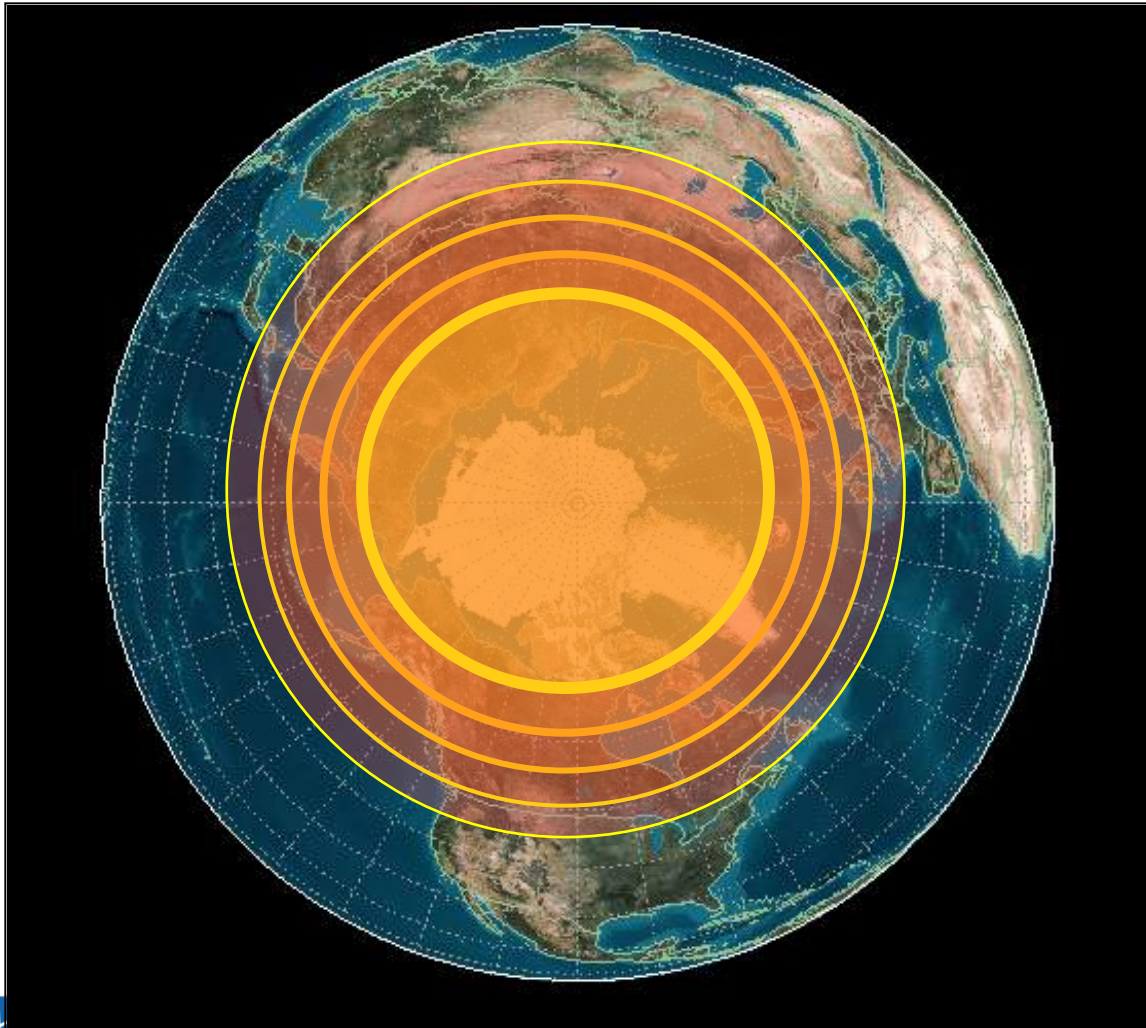
Weather

High-Level Requirements

- ‘GEO-like’ continuous imaging of Arctic circumpolar region
- ‘GEO-like’ spatial and temporal resolution
- ‘next-generation’ meteorological imager
- near-real time processing for delivery to Environment Canada
- compatibility with GEO imagers as part of WMO Global Observing System
 - end-to-end implications to achieve this class of performance
 - e.g., radiometric/geometric/spectral instrument performance, calibration, etc



Weather Spatial Coverage



Viewing Angle $\leq 70^\circ$

Continuous Imaging
- 24 hours
- ≤ 20 min refresh
(goal: ≤ 15 min)

Spatial Coverage
100% - 65°N - 90°N
 $\geq 95\%$ - 60°N - 65°N
 $\geq 90\%$ - 55°N - 60°N
 $\geq 80\%$ - 50°N - 55°N
 $\geq 70\%$ - 45°N - 50°N
Best effort - $<45^\circ\text{N}$

On-demand Imaging
(optional)
- user-selected sub-
regions
- ≤ 10 min refresh



Status

- RFI Outcomes
 - 20+ respondents, incl. several complete system solutions
 - technical feasibility confirmed
 - variety of orbits, space and ground segment architectures proposed
 - variety of procurement and service models proposed
 - little cost information
- Weather
 - all weather requirements can be met or exceeded
- Next Steps
 - Autumn 2014 - options and business case development for consideration by Government



Potential PCW contribution to climate monitoring

Contribution in two key areas:

- Fundamental Climate Data Records in circumpolar area 50-90N
 - to support a variety of Essential Climate Variables
 - 15 years at spatio-temporal resolution similar to GEO
 - from calibrated imagery and PCW Level 2/Level 3 products
- Contribution to inter-calibration with LEO and GEO satellites
 - PCW will overlap significantly with all
 - contributes to continuity of products between GEO and LEO in polar areas



Essential Climate Variables (ECV) potentially supported by PCW

Domain	Variable
Atmosphere (over land, sea, ice/snow)	<ul style="list-style-type: none"> • Earth radiation budget at surface and TOA • Upper-air temperature (via radiance assimilation) • Wind speed and direction • Water vapour (via radiance assimilation or retrieved optical depth) • Cloud properties • Ozone (total optical depth) • Aerosol properties (type and optical depth)
Oceanic	<ul style="list-style-type: none"> • Sea-surface temperature • Sea ice
Terrestrial	<ul style="list-style-type: none"> • Albedo • Fire disturbance • Fraction of absorbed photosynthetically active radiation (fAPAR) • Land cover (including vegetation type) • Leaf area index (LAI) • Surface Temperature • Snow/ice cover • Evapotranspiration (ET) • Net Photosynthesis (GPP) • Net Primary Productivity (NPP) • Net Ecosystem Exchange (NEE) <div style="text-align: right; margin-top: 10px;"> <p>level 3 model-based products</p> </div>



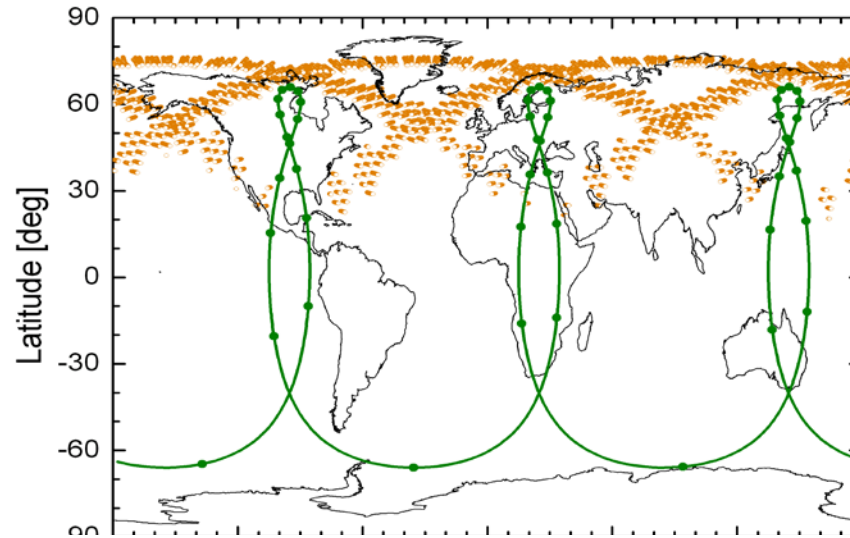
PCW Inter-calibration with GEO and LEO as Part of WMO GSICS Project

- PCW is planned be part of the WMO Global Space-based Inter-Calibration System (GSICS)
- The PCW HEO observing system will provide frequent and diverse opportunities for inter-calibration with polar LEO systems
- The inter-calibration between HEO and GEO also possible

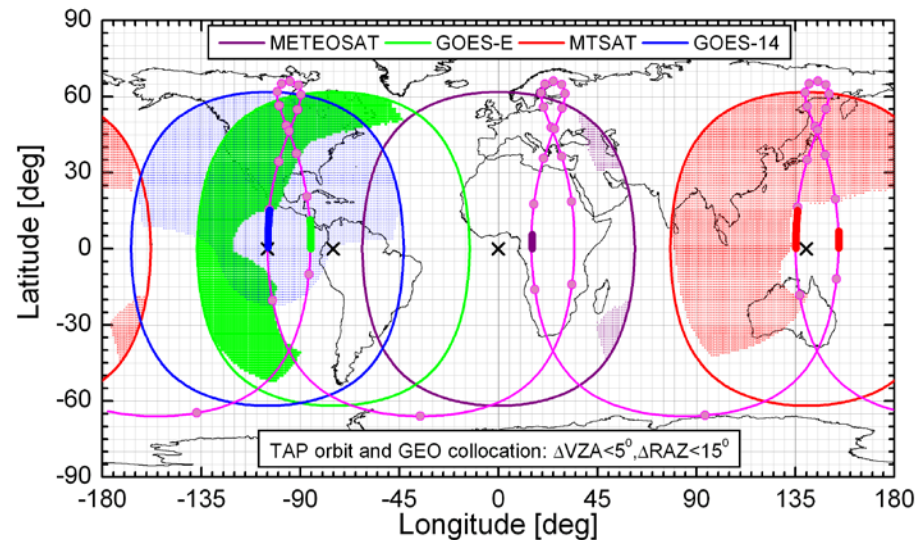


Example of PCW Geometry Matching [16-hr TAP Orbit]

VIIRS/SNPP



GEO





Extra slides



Imager Requirements

Band No.	Wavelength (microns)	Heritage	Priority	GSD (km)		Main applications
				Goal	Max	
1	0.45-0.49	ABI,FCI	1	0.5	1.5	Surface, clouds, aerosols
2	0.59-0.69	ABI, FCI	1	0.5	1.5	Wind, clouds, ice mapping
3	0.704-0.714	MERIS-09	2	0.5	1.5	Water quality, chlorophyll
4	0.85-0.89	ABI, FCI	1	0.5	1.5	Wind, aerosols, vegetation
5	1.04 – 1.06	SGLI SW1	2	1.0	3.0	Snow grain and clouds
6	1.37-1.39	ABI, FCI	2	1.0	3.0	Cirrus detection
7	1.58-1.64	ABI, FCI	1	0.5	1.5	Snow-cloud distinction, ice cover
8	2.22-2.28	ABI, FCI	1	1.0	3.0	Aerosol, smoke, cloud phase
9	3.80-4.00	ABI, FCI	1	2.0	3.0	Fog, fire detection, ice/cloud separation, wind, phase.
10	5.77-6.60	ABI, FCI	1	2.0	3.0	Wind, high level humidity
11	6.75-7.15	ABI, MTSAT	2	2.0	3.0	Wind, mid level humidity
12	7.24-7.44	ABI, FCI	1	2.0	3.0	Wind, low level humidity,SO ₂
13	8.30-8.70	ABI, FCI	1	2.0	3.0	Total water, cloud phase
14	9.42-9.80	ABI, FCI	2	2.0	3.0	Total ozone
15	10.1-10.6	ABI, FCI	2	2.0	3.0	Cloud, surface, cirrus
16	10.8-11.6	ABI, HIRS	1	2.0	3.0	Cloud, SST, ash
17	11.8-12.8	ABI, FCI	1	2.0	3.0	Ash, SST
18	13.0-13.6	ABI, FCI	1	2.0	3.0	Cloud height
19	13.5-13.8	MODIS,HIRS	2	2.0	6.0	Cloud height, low level temperature
20	13.8-14.1	MODIS,HIRS	2	2.0	6.0	Cloud height, mid level temperature
21	14.1-14.4	MODIS,HIRS	2	2.0	6.0	Cloud height, high level temperature

Advanced 'Next-Gen' Imager (MTG, GOES-R class)

Channels

Priority 1 (req'd) -12

Priority 2 (desirable) – 9

Ground Sampling Distance

(+/- P/8 hrs from apogee)

Max. 1.5km-6.0km

Goal 0.5km-2.0km

Desirable (for INR)

1 x 0.5km channel

1 x high-res. IR (Arctic night)

Calibration

-pre-launch and on-orbit characterization appropriate to support GSICS* practices

*Global Space-based Inter-calibration System





Weather

Ground Segment

- Continuous real-time downlink
 - simultaneous reception from all visible satellites
 - required: Arctic Area of Interest (AOI)
 - *goal: areas of processable imagery outside Arctic AOI*
- Products
 - Level 0, Level 1
 - routine processing to L1c to standardized grid for Arctic region
 - routine processing to L1b or L1c outside Arctic region (tbd)
 - latency - 20 min
 - *goal: ≤ 15 min or \leq image refresh frequency*
- Image quality, monitoring, and calibration tools
- L2+, user services, long-term preservation outside scope of RFI



Baseline List of PCW Products (1)

PRODUCT	Repeat Cycle	Latency	COMMENT
Level 1c imagery	15 min	15 min	Calibrated, mapped to standard grid (15 min refresh)
Level 2 imagery	15 min	30 min	Composite of 2 satellites
AMV: Atmospheric Motion Vectors	1 hour	1 hour	Latency is w.r.t. oldest image of triplets/duos used for tracking
Cloud mask	15 min	30 min	Important for direct assimilation of radiances
Cloud height, amount, emissivity, temperature	15 min	30 min	Important for AMV
Volcanic ash height (optical depth)	15 min	30 min	When active. Done at Dorval volcanic ash advisory center. Could develop a SO2 product as well.
Fog and surface visibility	15 min	30 min	
Forest fires. Hot spots	3 hours	1 hour	Product elaborated either, or both at CCRS and CFS, NRCan

Baseline List of priority 1 products from PCW Imager



Baseline List of PCW Products (2)

PRODUCT	Repeat Cycle	Latency	COMMENT
Ice motion vector	TBD	TBD	To be defined (e.g. Canadian Ice Service)
Snow/ice mapping (cover and depth)	6 hours	6 hours	Derived from 15 min. Resolution 2 km. May include snow grain size.
SST: sea surface temperature	1 hour	2 hours	Resolution 4 km
LST: land surface temperature	1 hour	2 hours	Resolution 4 km
Surface albedo	6 hours	6 hours	Resolution 10 km. Could be done at CCRS
Aerosol optical depth	3 hours	6 hours	Resolution 10 km
Atmospheric stability index	1 hour	1 hour	Resolution 10 km
Aircraft icing threat	1 hour	15 min	Resolution 10 km
Total ozone	1 hour	1 hour	Resolution 10 km

Note: Level 2 products are retrievals made from Level 1c. Level 3 products defined at a coarser resolution. Surface parameters are only available in clear air (mask =0) or when the sun angle allows. In areas devoid of observations, the pixels are either left blank or replaced by a previously obtained value.

Baseline List of priority 2 products from PCW Imager



Baseline List of PCW Products (3)

PRODUCT	Repeat Cycle	Latency	COMMENT
Vegetation Index	1 day	1 day	Resolution 1 km
FPAR	1 day	1 day	Fraction of Absorbed Photosynthetically Active Radiation. Resolution 1 km
LAI: Leaf Area Index	1 day	1 day	Resolution 2 km
Radiative fluxes	1 hour	1 day	Resolution 10 km (SW, LW, PAR at surface and TOA)
Land surface emissivity	1 day	1 day	4km consistent with LST product

Archive Products: Levels 0, 1c and 2 are archived forever at CMC, and Level 1b for 5 years. In addition rotating archive of Level 0 at ground receiving station.

**Baseline List of Climate Essential Variable (ECV) products from PCW Imager
Priority 2 - Level 3 climate essential variables products and archive
Products can be elaborated by EC or Other Government Department**