JGR Space Physics

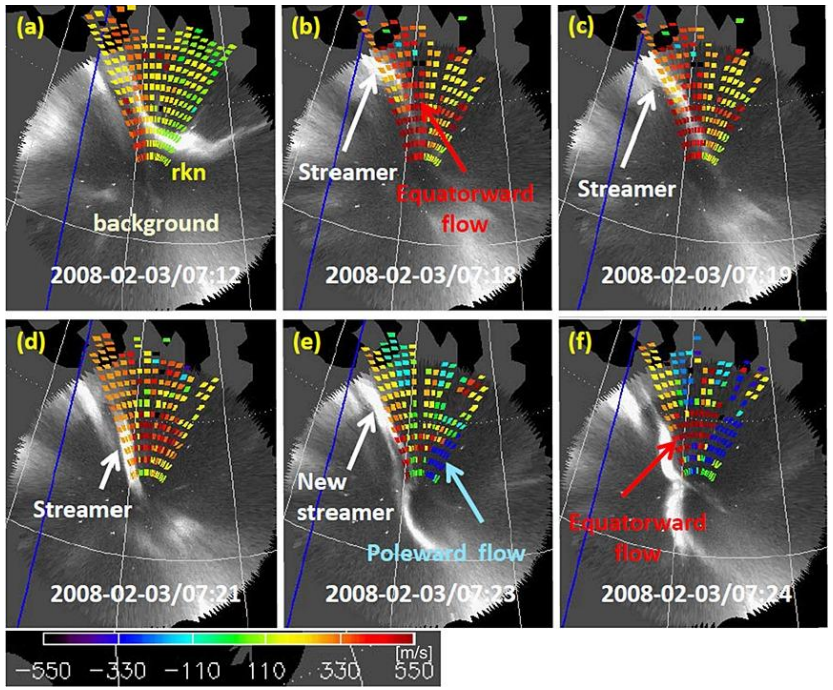
Research Article | Free Access

Coordinated SuperDARN THEMIS ASI observations of mesoscale flow bursts associated with auroral streamers

Bea Gallardo-Lacourt, Y. Nishimura, L. R. Lyons, S. Zou, V. Angelopoulos, E. Donovan, K. A. McWilliams, J. M. Ruohoniemi, N. Nishitani

First published: 10 December 2013 | https://doi.org/10.1002/2013JA019245 | Citations: 61

[Gallardo-Lacourt et al., 2014]



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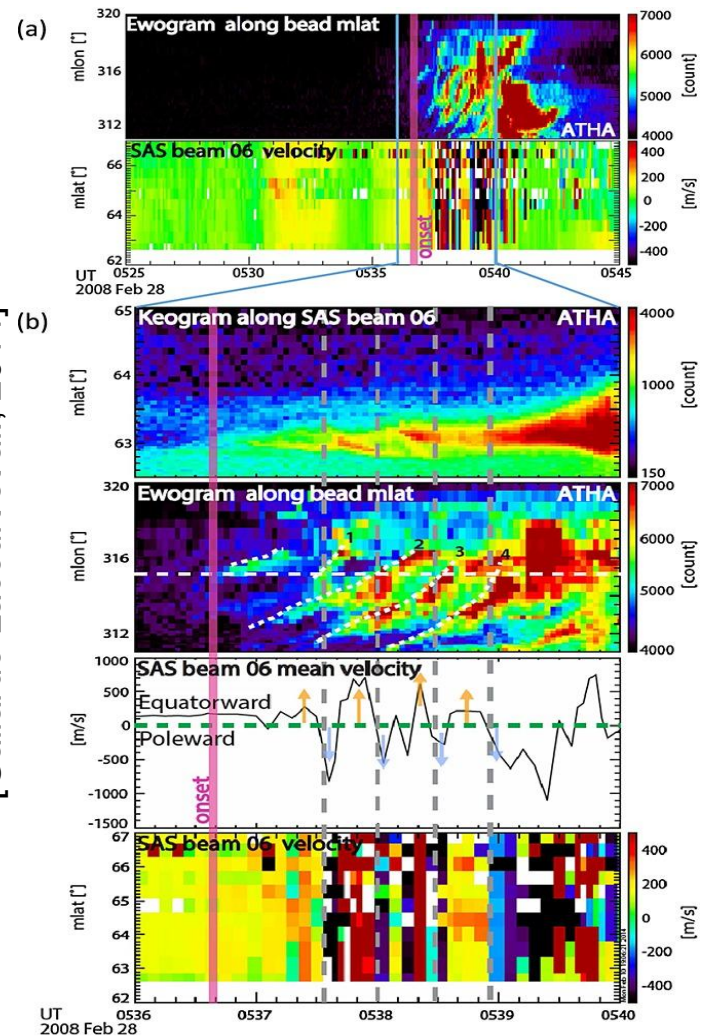
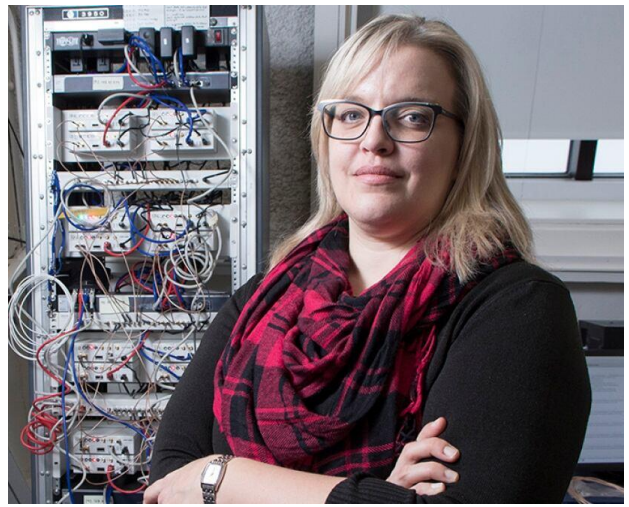
Ionospheric flow structures associated with auroral beading at substorm auroral onset

Bea Gallardo-Lacourt, Y. Nishimura, L. R. Lyons, J. M. Ruohoniemi, E. Donovan, V. Angelopoulos, K. A. McWilliams, N. Nishitani

First published: 30 October 2014 | https://doi.org/10.1002/2014JA020298 | Citations: 22

[Gallardo-Lacourt et al., 2014]





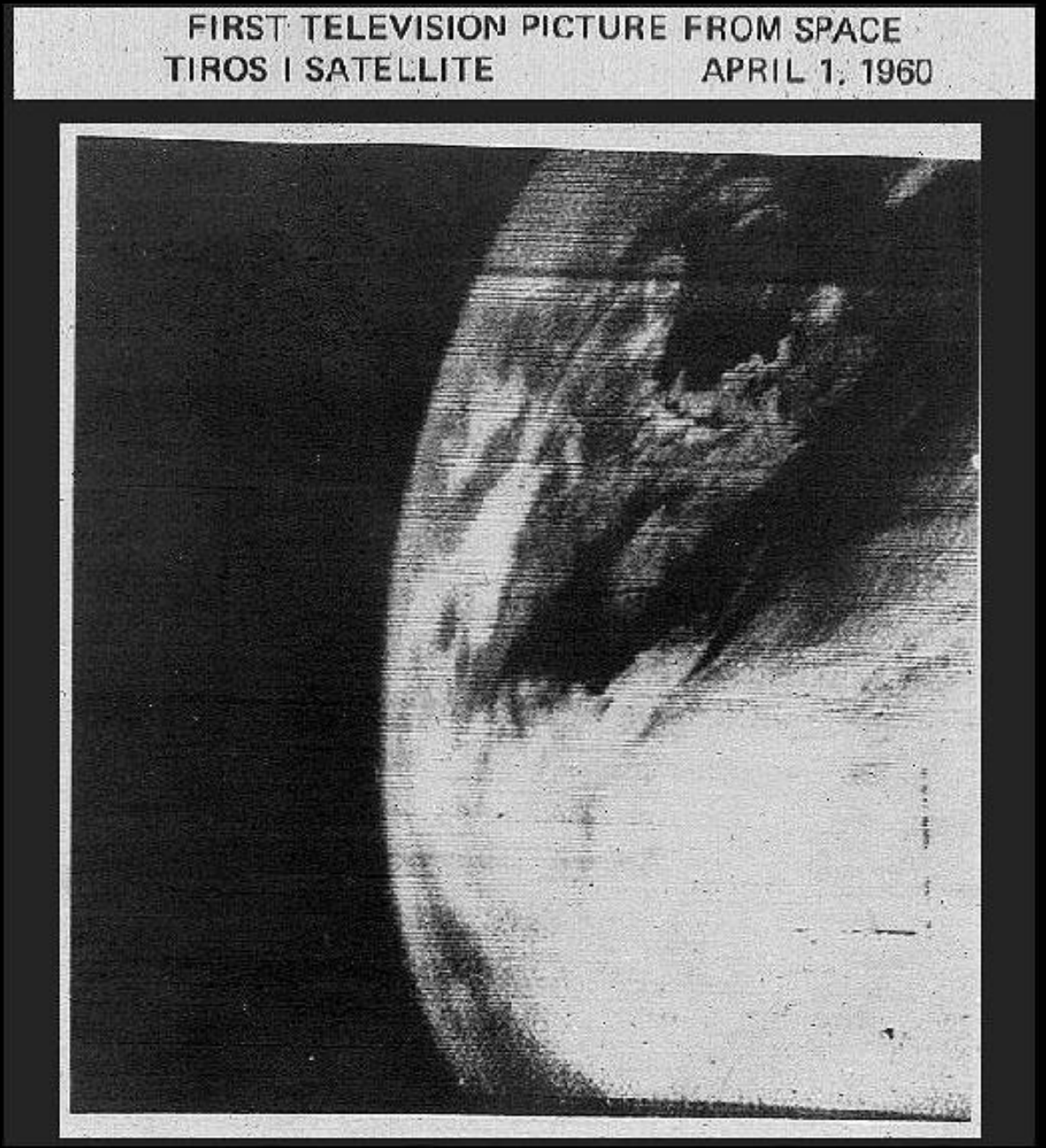
Thank you, Kathryn!

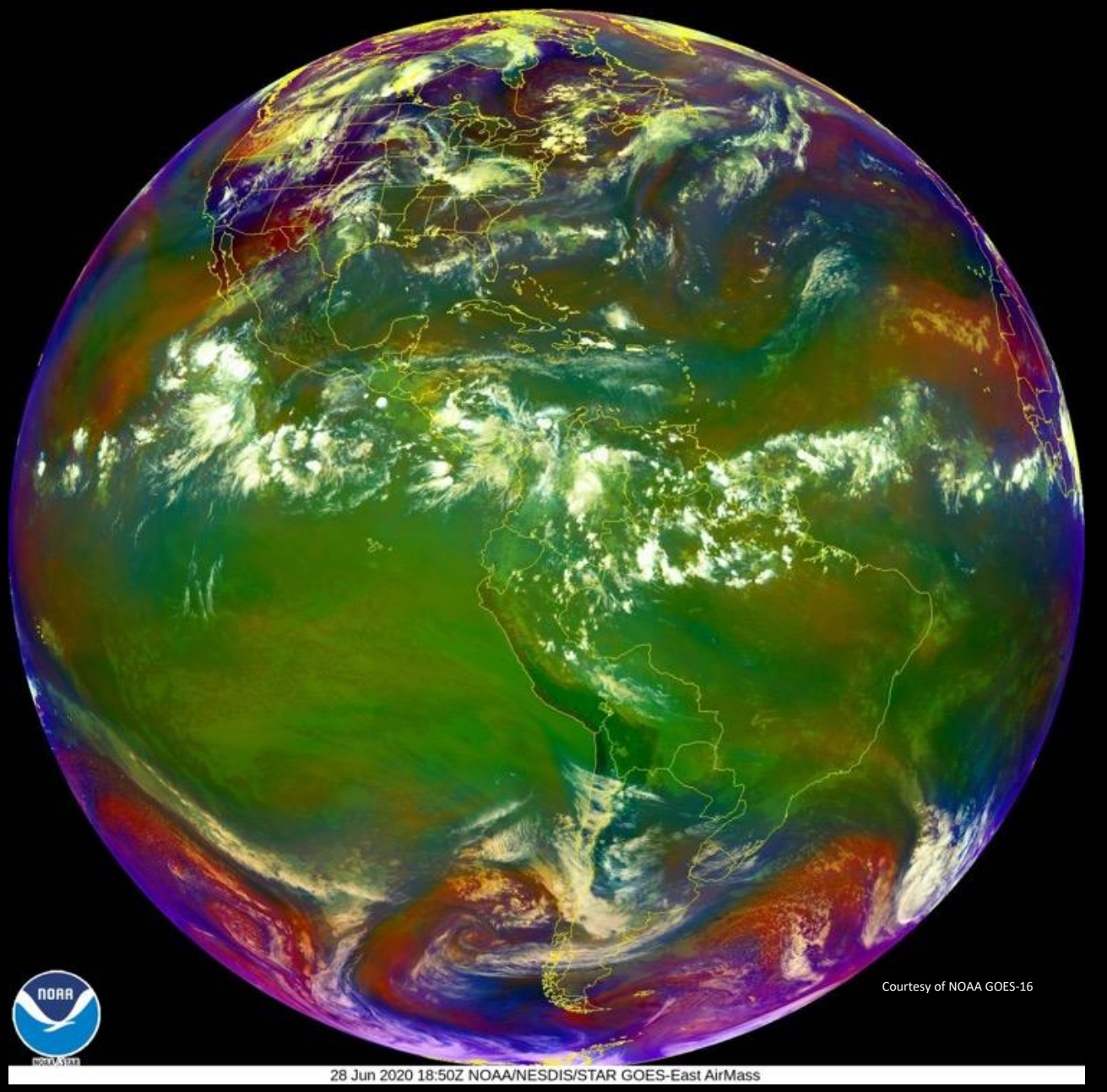
Exploring the prospects for a vivid collaborative science between the GDC mission and the Ground-Based community

Bea Gallardo-Lacourt, Doug Rowland, Katherine-Garcia Sage, Larry Kepko, and the GDC Science Team

SuperDARN Workshop 2025, Roanoke, VA – June 2025

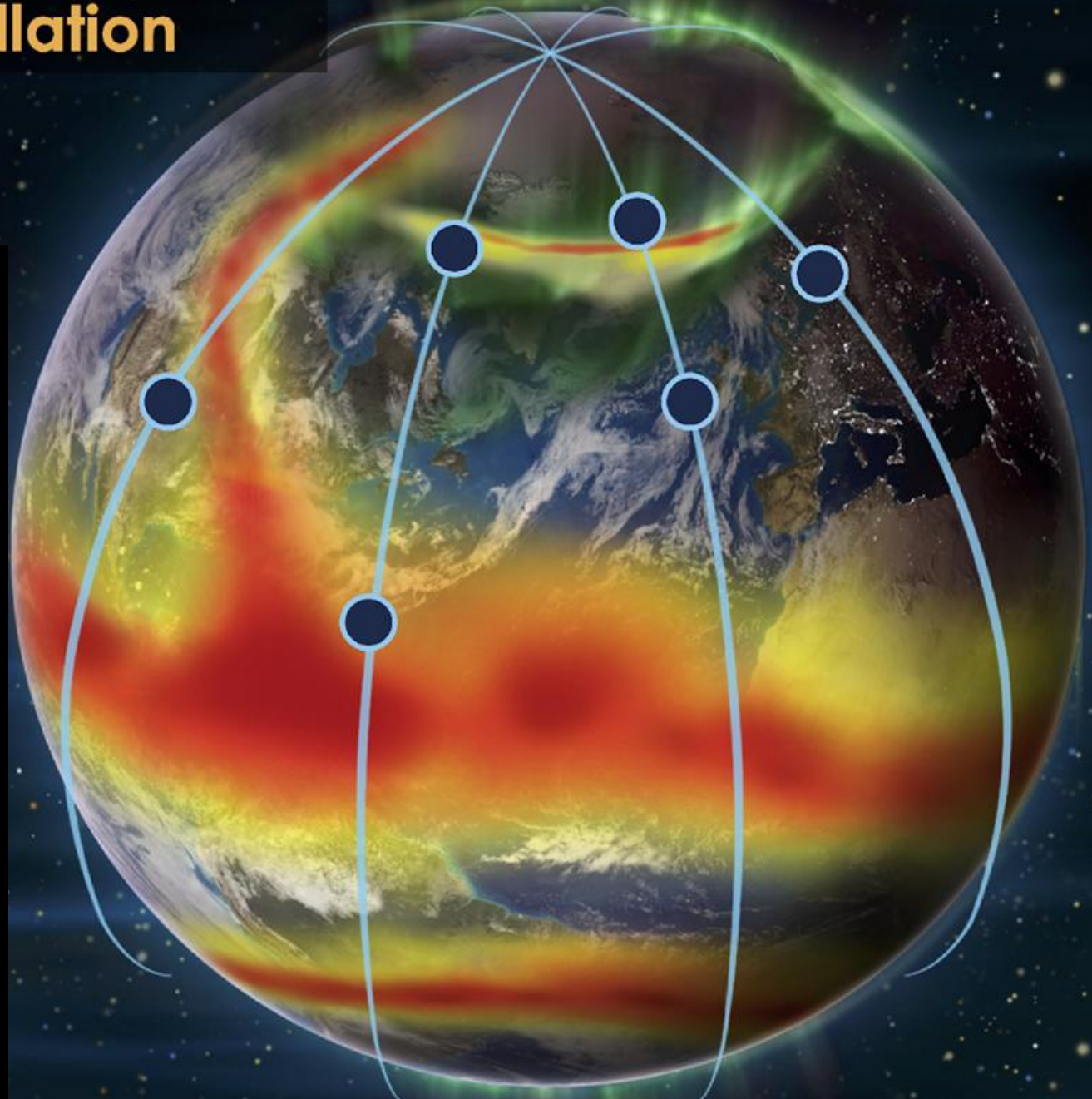
Weather satellites have given us a truly global view of tropospheric / stratospheric weather, leading to a scientific and forecasting revolution. Ultimate energy source is solar VIS / IR radiation



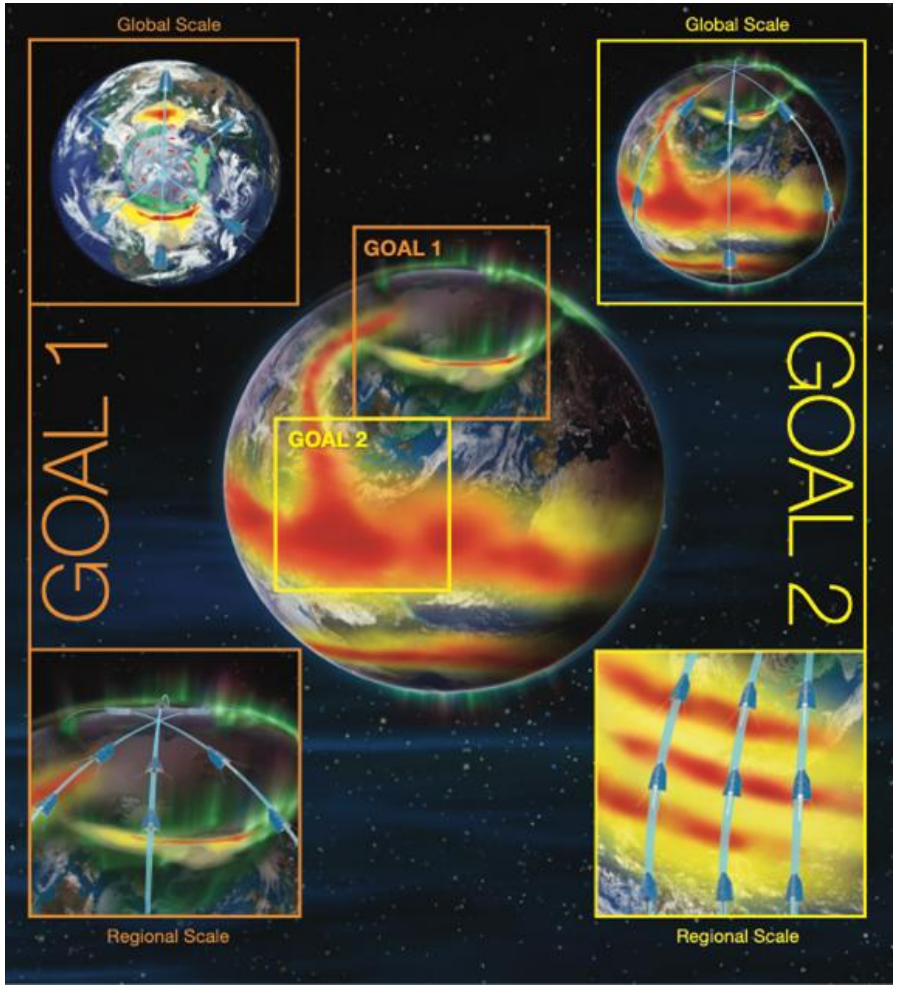


Geospace Dynamics Constellation

- 6 identical satellite mission to study the transition between Earth's atmosphere and the space environment
- First comprehensive measurements in this region, including energy inputs from the space environment above and the variable upper atmosphere response
- Interdisciplinary study of fundamental processes of planetary upper atmospheres, to understand the space environment role in the planetary habitability
- Provides critically-needed space weather observations of the low earth orbit (LEO) region, enabling characterization of the orbital drag environment and understanding of space weather processes



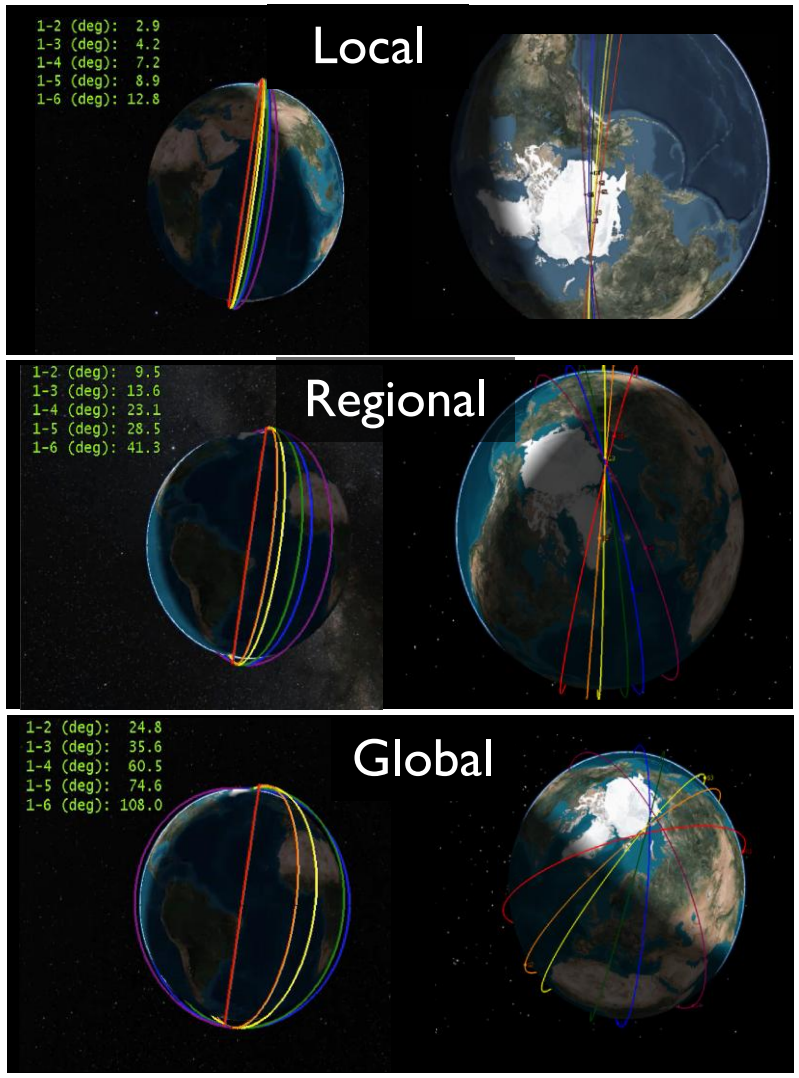
Geospace Dynamics Constellation: Two Overarching Goals



GDC Goal 1
Understand how the high latitude ionosphere-thermosphere system responds to variable solar wind/magnetosphere forcing

GDC Goal 2
Understand how internal processes in the global ionosphere-thermosphere system redistribute mass, momentum, and energy

Geospace Dynamics Constellation: Phases

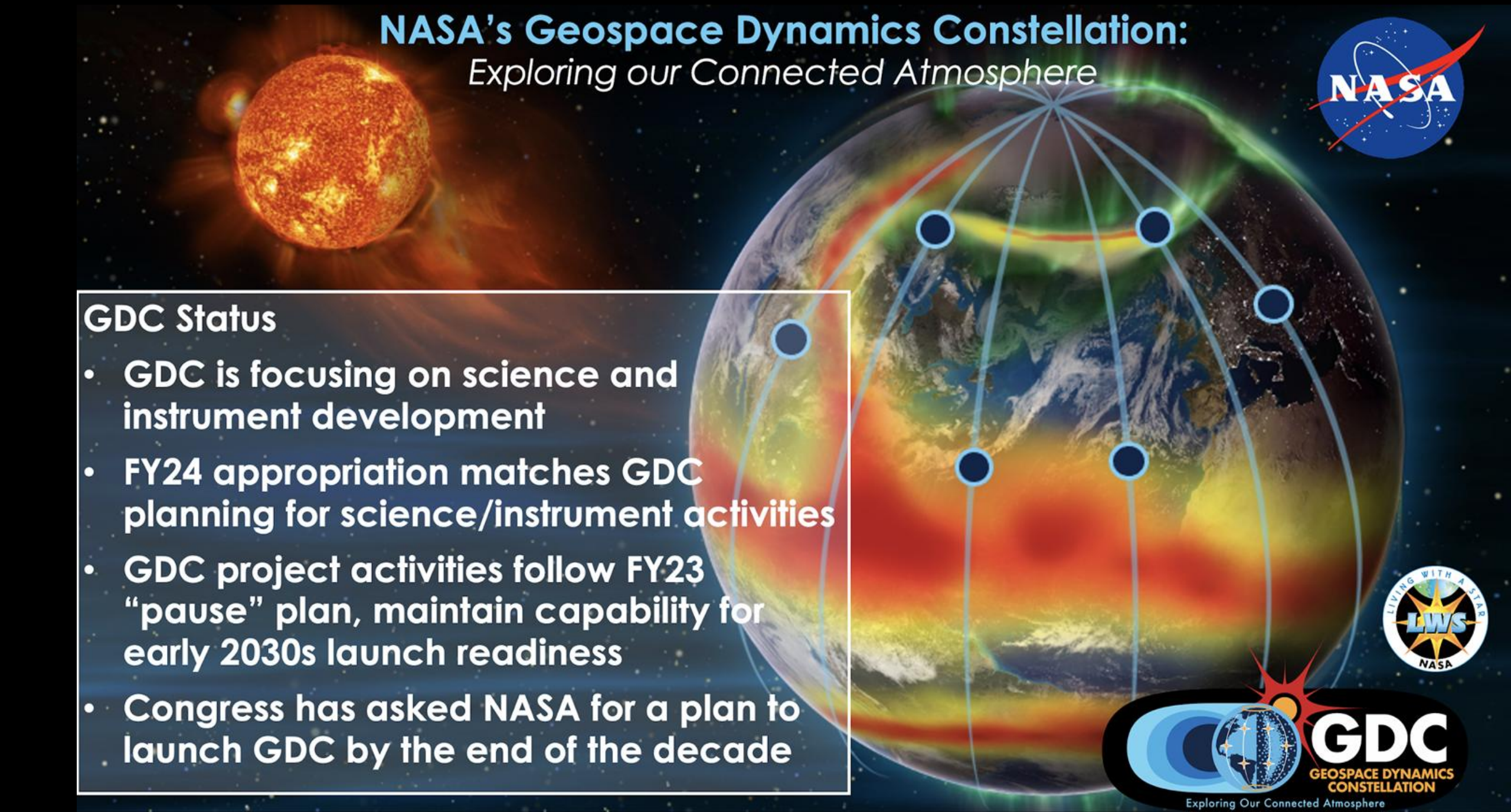


- Partner mission (DYNAMIC) will study how upper atmosphere and ionosphere respond to energy inputs from below (terrestrial weather)
- GDC will use six identical satellites in high-inclination, circular, low earth orbits to measure **local, regional, and global-scale** dynamics
- GDC will fly through a critical part of this region, where the ionized gas of the ionosphere and the neutral gas of the thermosphere exhibit complex coupled dynamics and chemistry
- Critical national infrastructure resides in this poorly studied region, and our predictive models are insufficient to protect these assets
- GDC's orbit, at **350-400 km,** is just below the International Space Station

GDC ephemeris can be downloaded from:
https://ccmc.gsfc.nasa.gov/mission-planning/GDC/

NASA's Geospace Dynamics Constellation:

Exploring our Connected Atmosphere



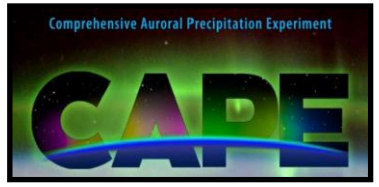
GDC Status

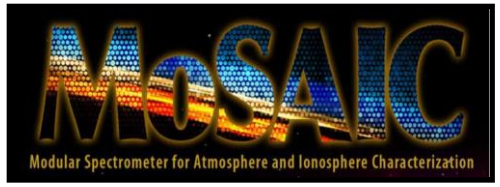
- GDC is focusing on science and instrument development
- FY24 appropriation matches GDC planning for science/instrument activities
- GDC project activities follow FY23 "pause" plan, maintain capability for early 2030s launch readiness
- Congress has asked NASA for a plan to launch GDC by the end of the decade

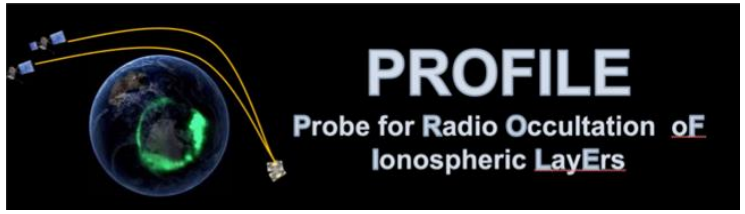
GDC
GEOSPACE DYNAMICS CONSTELLATION
Exploring Our Connected Atmosphere

Geospace Dynamics Constellation: Instruments

Instruments



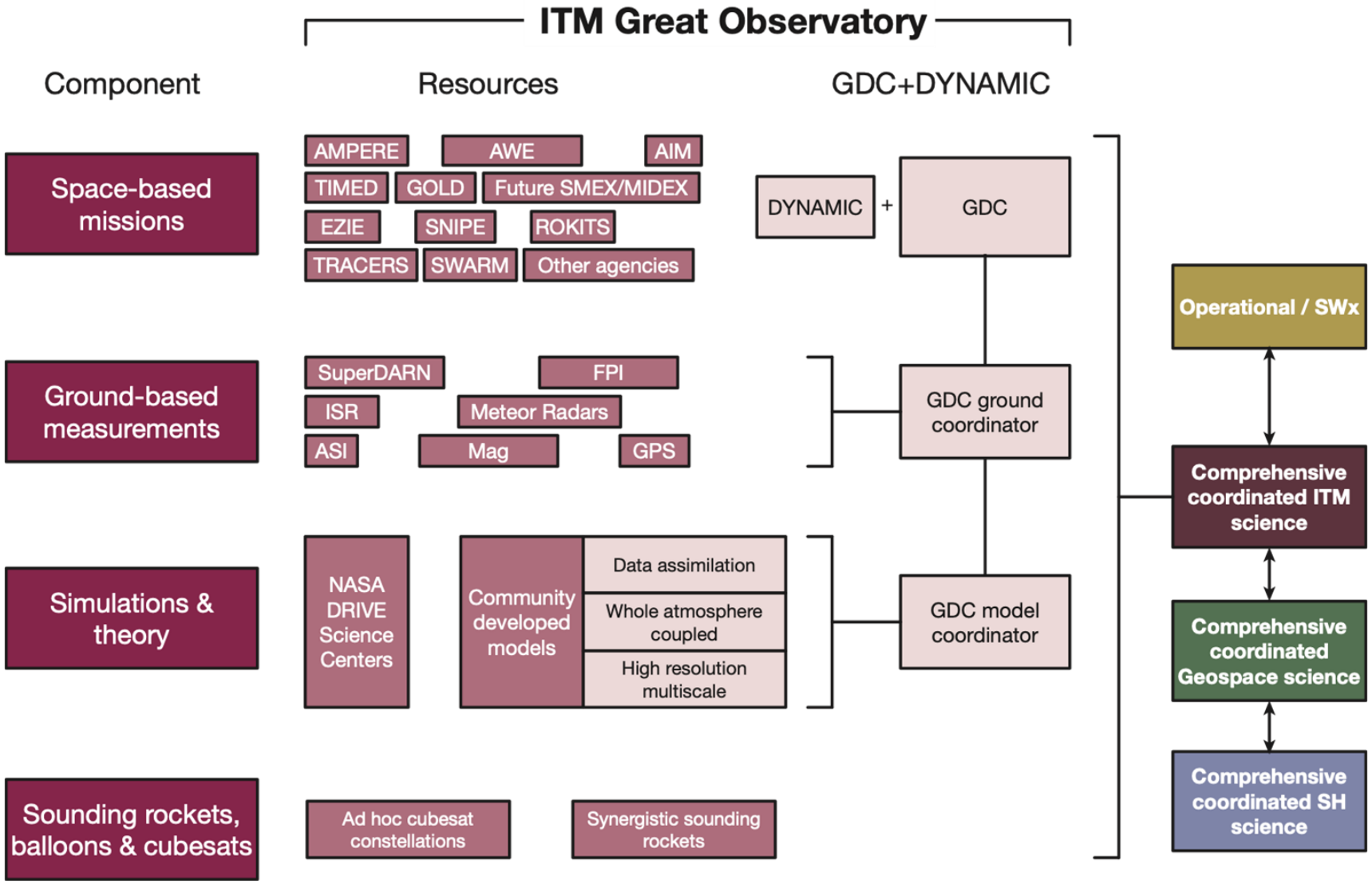




GDC's measurement parameters

	Selected GDC instruments (P: prime; S: support)					
Physical Parameters	**MoSAIC**	**CAPE**	**AETHER**	**NEMISIS**	**TPS**	**PROFILE**
Thermal ion velocity, horizontal (vector)	S				P	
Thermal ion velocity, vertical	S				P	
Thermal plasma density	S		P		S	
Thermal ion temperature	P				S	
Thermal Ion Composition	P				S	
Neutral wind, horizontal (in-track)	P					
Neutral wind, horizontal (cross-track)	P					
Neutral wind, vertical (cross-track)	P					
Neutral gas number density	P					
Neutral gas temperature	P					
Neutral gas composition	P					
Auroral electrons energy / pitch angle distribution		P				
Auroral ions energy / pitch angle distribution*		P				
Small scale electric field (0.1-25 km)			P			
Small scale plasma density (0.1-25 km)			P			
Thermal electron temperature			P			
Magnetic field (DC field, vector)				P		
HmF2						P
NmF2						P

GDC is a strategic hub



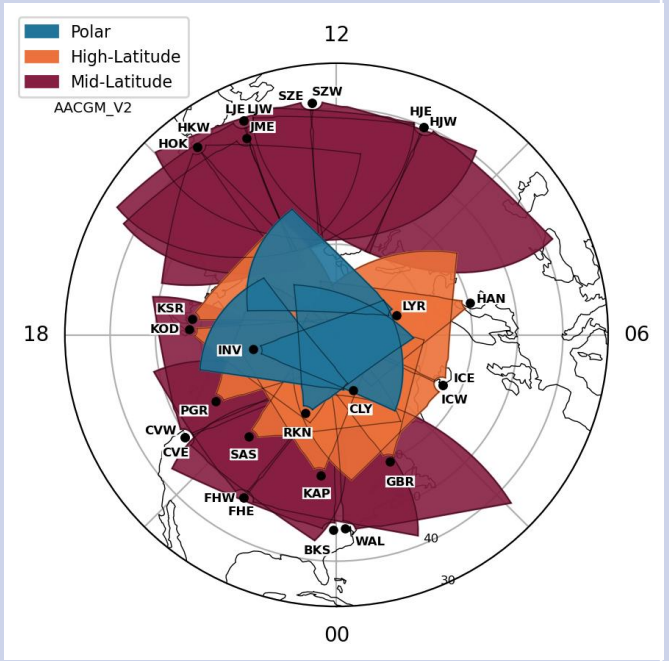
GDC: A Community Mission

GDC Community Ground-based Coordination Group
Potential for additional science outcomes

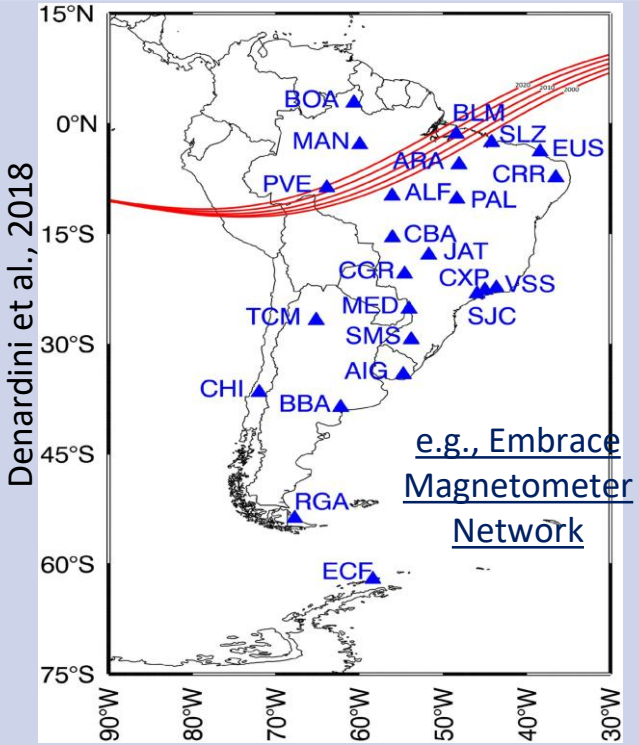
Conjunctions between ground-based instruments around the world and GDC measurements present a unique opportunity to further our understanding of the Ionosphere-Thermosphere-Mesosphere system

Some examples of ground-based assets and facilities around the world

Northern and Southern Hemisphere SuperDARN radar



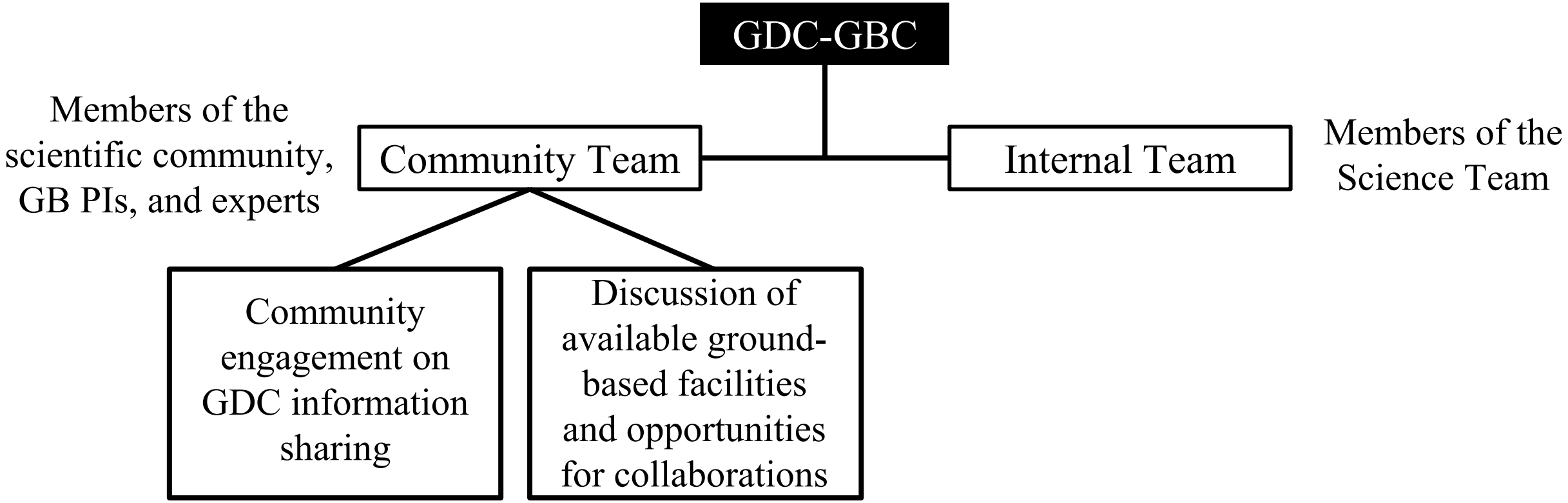
Arrays of GB Magnetometers



Chinese Meridian Project

GDC Ground-based coordination

1. GDC Internal Ground-based Coordination Group



GDC Ground-based coordination

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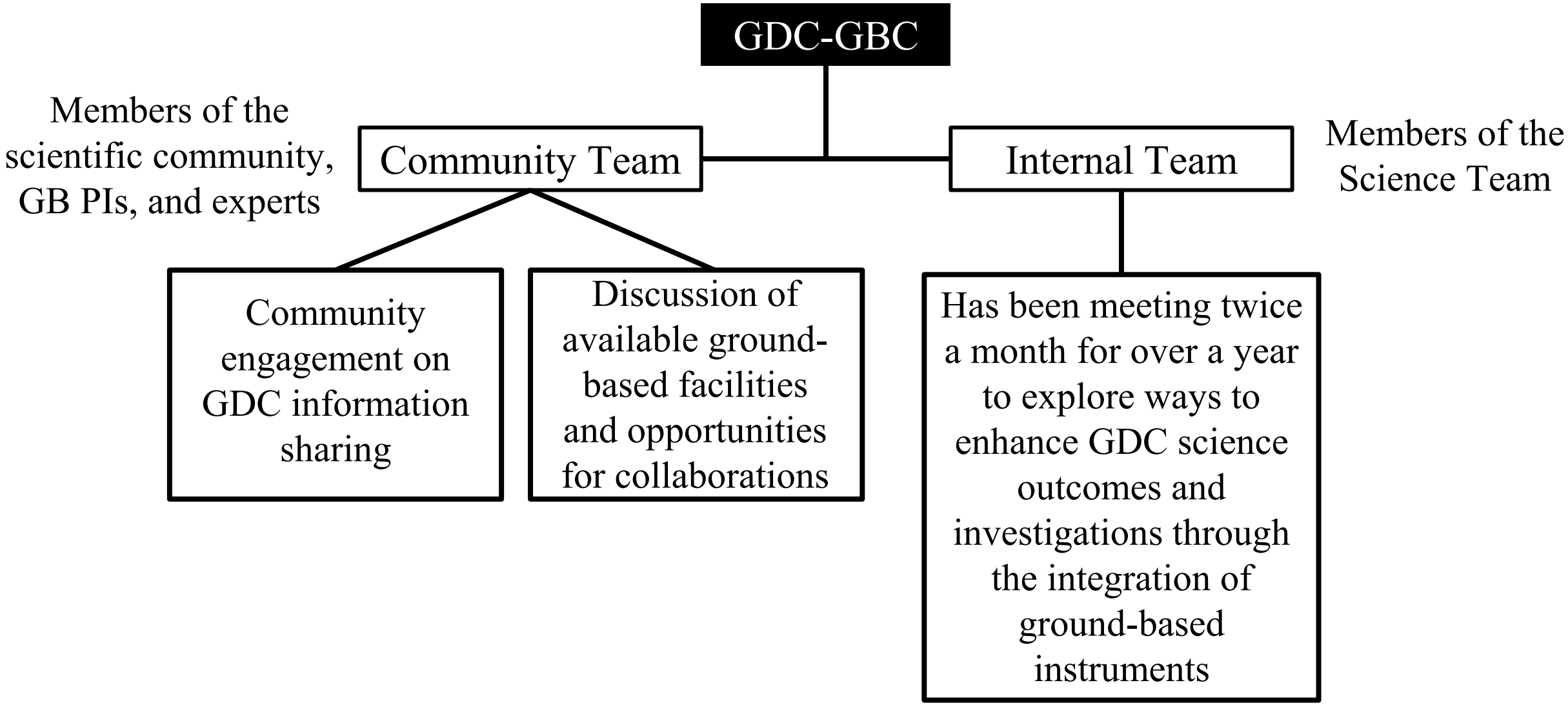


GDC Ground-based coordination

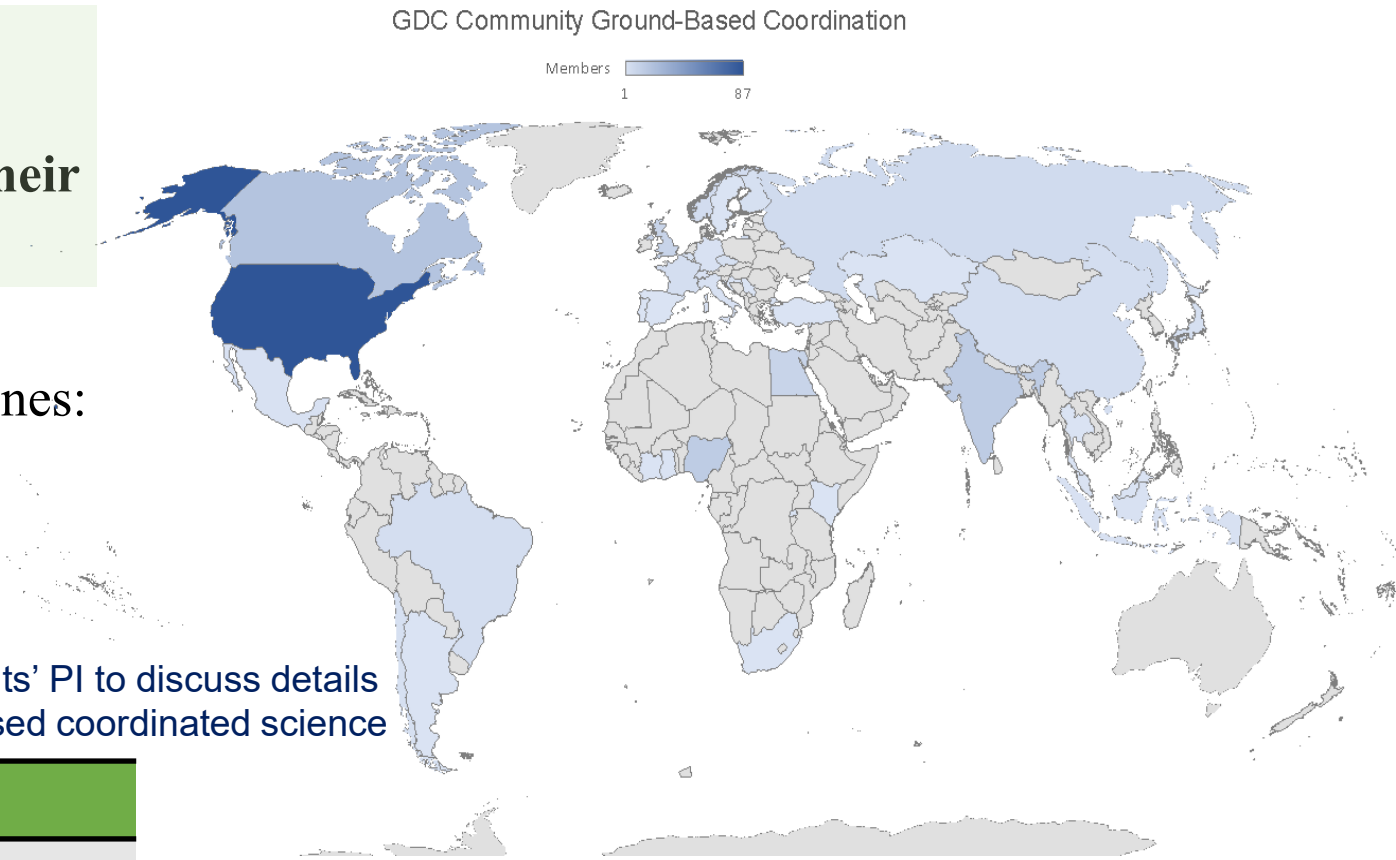
The Ground-Based STM

			Ground-based Instrumentation											
			FPI	ASI	MSP	CSR	ISR	Magnetometers	Ionosondes	LiDAR	Meteor Radars	Riometers	GPS TEC	Photomete
Goal 1 Understand how the high-latitude ionosphere-thermosphere system responds to variable solar wind/magnetosphere forcing.	**Objective 1.1: Determine how high-latitude plasma motion, particle precipitation, and electromagnetic energy inputs drive thermospheric neutral winds.**	**Subobjective 1.1.1**												
		Subobjective 1.1.2												
		Subobjective 1.1.3												
	Objective 1.2: Determine how coherent plasma density structures arise and evolve in response to high-latitude plasma motion, particle precipitation, and electromagnetic energy inputs.	**Subobjective 1.2.1**												
		Subobjective 1.2.2												
		Subobjective 1.2.3												
	Objective 1.3: Determine how high-latitude magnetospheric energy inputs, plasma motion, and neutral dynamics drive the generation and evolution of high-latitude neutral density structures.	**Subobjective 1.3.1**												
		Subobjective 1.3.2												
		Subobjective 1.3.3												
Goal 2 Understand how internal processes in the global ionosphere-thermosphere system redistribute mass, momentum, and energy.	**Objective 2.1: Determine the efficiency of electromagnetic drivers and ion-neutral coupling in driving plasma density variations at mid- and low latitudes.**	**Subobjective 2.1.1**												
		Subobjective 2.1.2												
		Subobjective 2.1.3												
	Objective 2.2: Identify the processes that create and dissipate horizontally propagating ionosphere and thermosphere structures	**Subobjective 2.2.1**												
		Subobjective 2.2.2												
		Subobjective 2.2.3												
	Objective 2.3: Determine the connections between winds, temperature, and major neutral species density variations at mid and low latitudes	**Subobjective 2.3.1**												
		Subobjective 2.3.2												
		Subobjective 2.3.3												
	Objective 2.4: Determine how seasonal variations and asymmetries in Earth's magnetic field and magnetospheric input affect the	**Subobjective 2.4.1**												
		Subobjective 2.4.2												
		Subobjective 2.4.3												
		Subobjective 2.4.4												

GDC: A Community Mission

2. GDC Community Ground-based Coordination Group

- Group open to the international community
- **Goal: Help coordinate the ground-based community to leverage GDC measurements to extend and enhance their science, and achieve their science goals**
- First meeting in February 2023
- Meeting ~once a month with three rotating time zones:
  - US-centered
  - Asia-centered
  - Europe-centered



247 members from around the world!

We are currently organizing presentations by instruments' PI to discuss details about GDC instruments and possibilities for ground-based coordinated science

Phase 1	Phase 2
Learning about the GDC mission and instruments	Learning about ground—based community assets, facilities, and collaboration opportunities

GDC: A Community Mission

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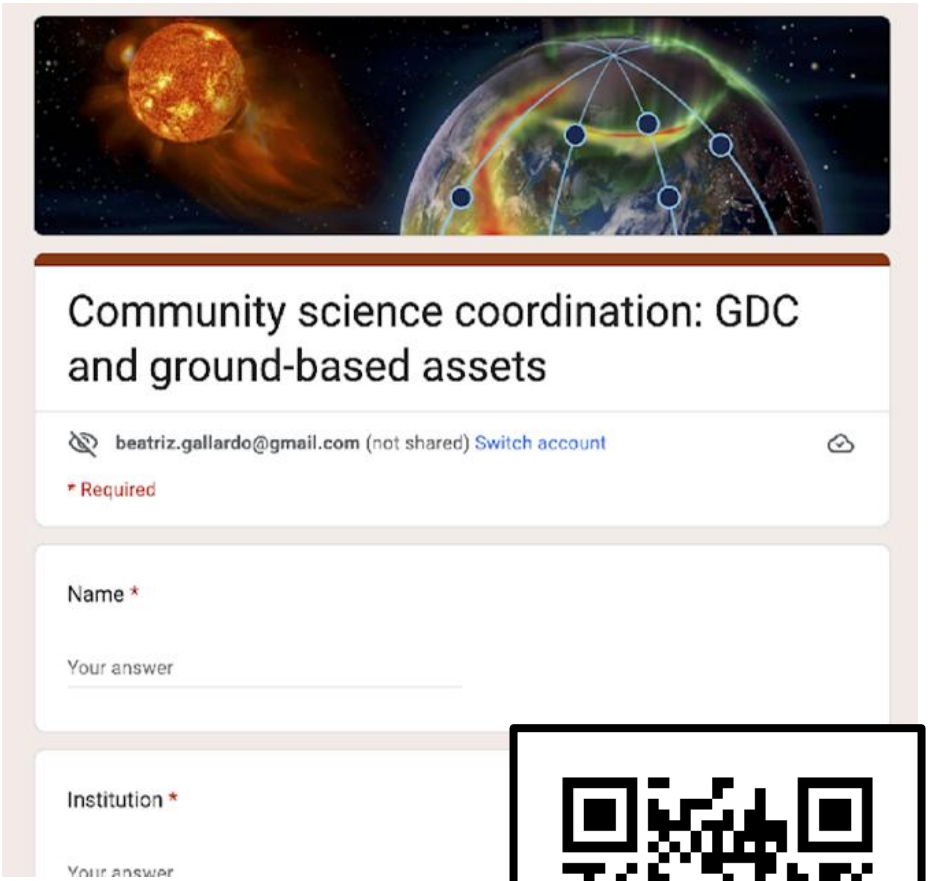

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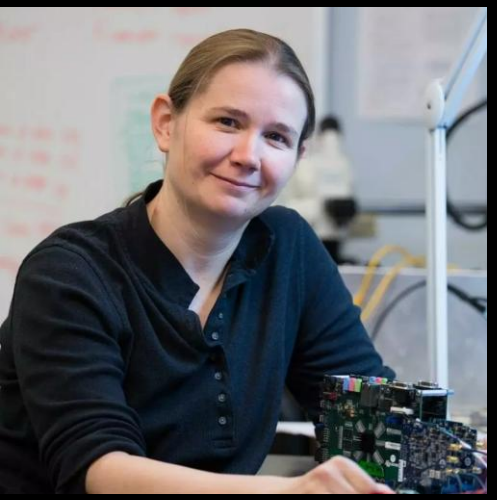
Phase 1	Phase 2
Learning about the GDC mission and instruments	Learning about ground—based community assets, facilities, and collaboration opportunities

Submit the form to get updates **and Join the group!**

GDC-G (ground)

27 Mags (fluxgate)
27 Riometers
23 RGB ASI
8 Spectrographs
16 Red ASI
27 GNSS
6 FPI

134 instruments across 27 sites

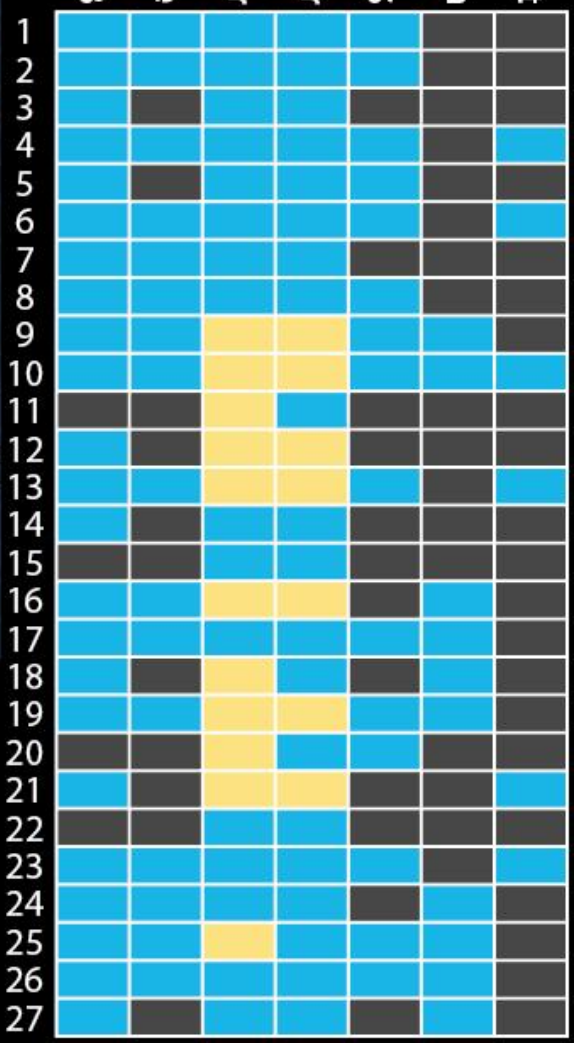


PI: Emma Spanswick

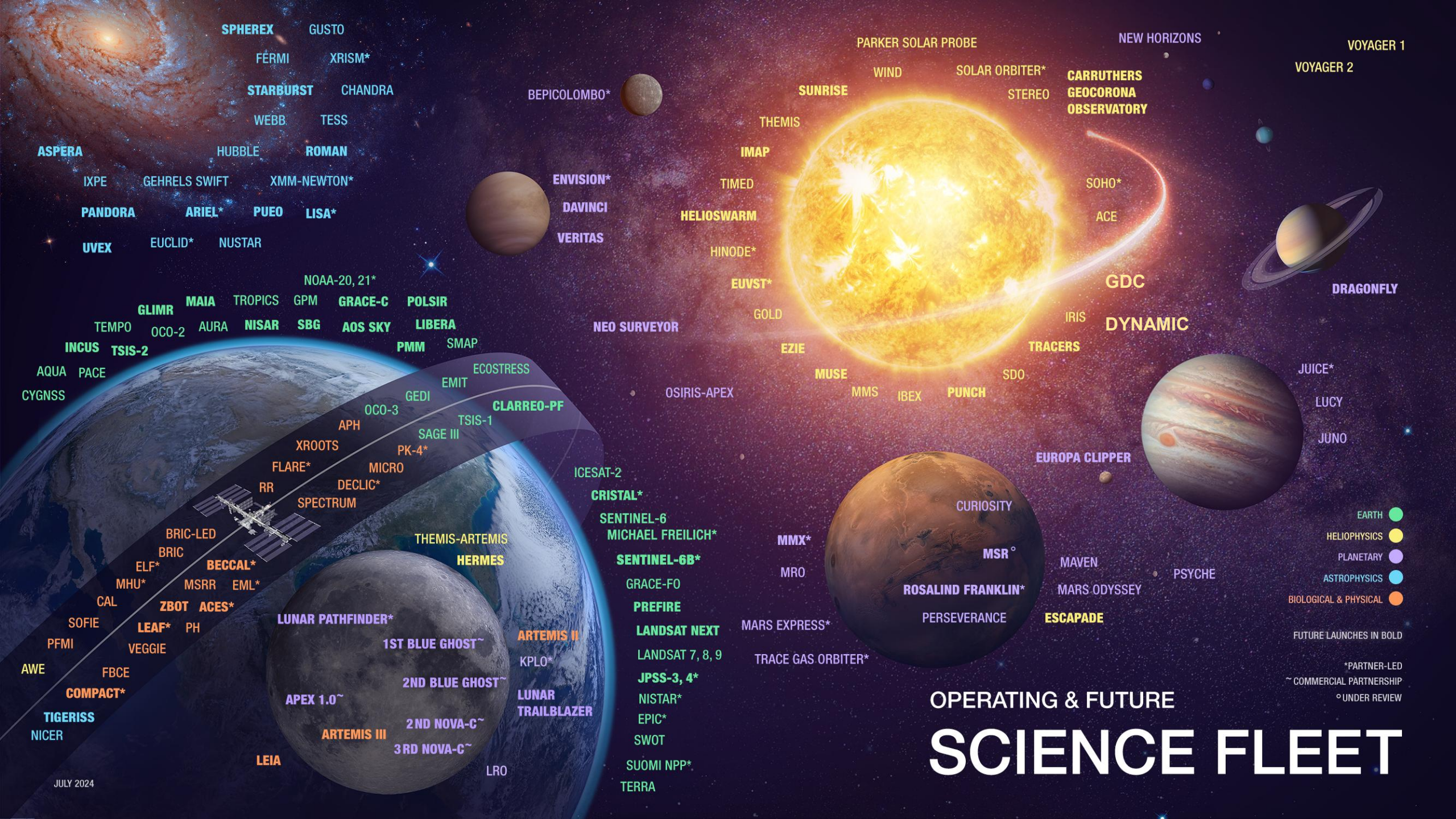
University of Calgary

1. Eureka, NU
2. Resolute Bay, NU
3. Clyde River, NU
4. Iqaluit, NU
5. Kuujjuaq, QC
6. Labrador City, NL
7. Sanikiluaq, NU
8. Kapuskasing, ON
9. Pinawa, MB
10. Gillam, MB
11. Churchill, MB
12. Rankin Inlet, NU
13. Taloyoak, NU
14. Cambridge Bay, NU
15. Contwoyto, NU
16. Rabbit Lake, SK
17. Lucky Lake, SK
18. Athabasca, AB
19. Fort Smith, NWT
20. Prince George, BC
21. Fort Simpson, MWT
22. Normal Wells, NWT
23. Sachs Harbour, NWT
24. Inuvik, YK
25. Whitehorse, NWT
26. Poker Flat, AK
27. Toolik, AK

New Sensor
Existing

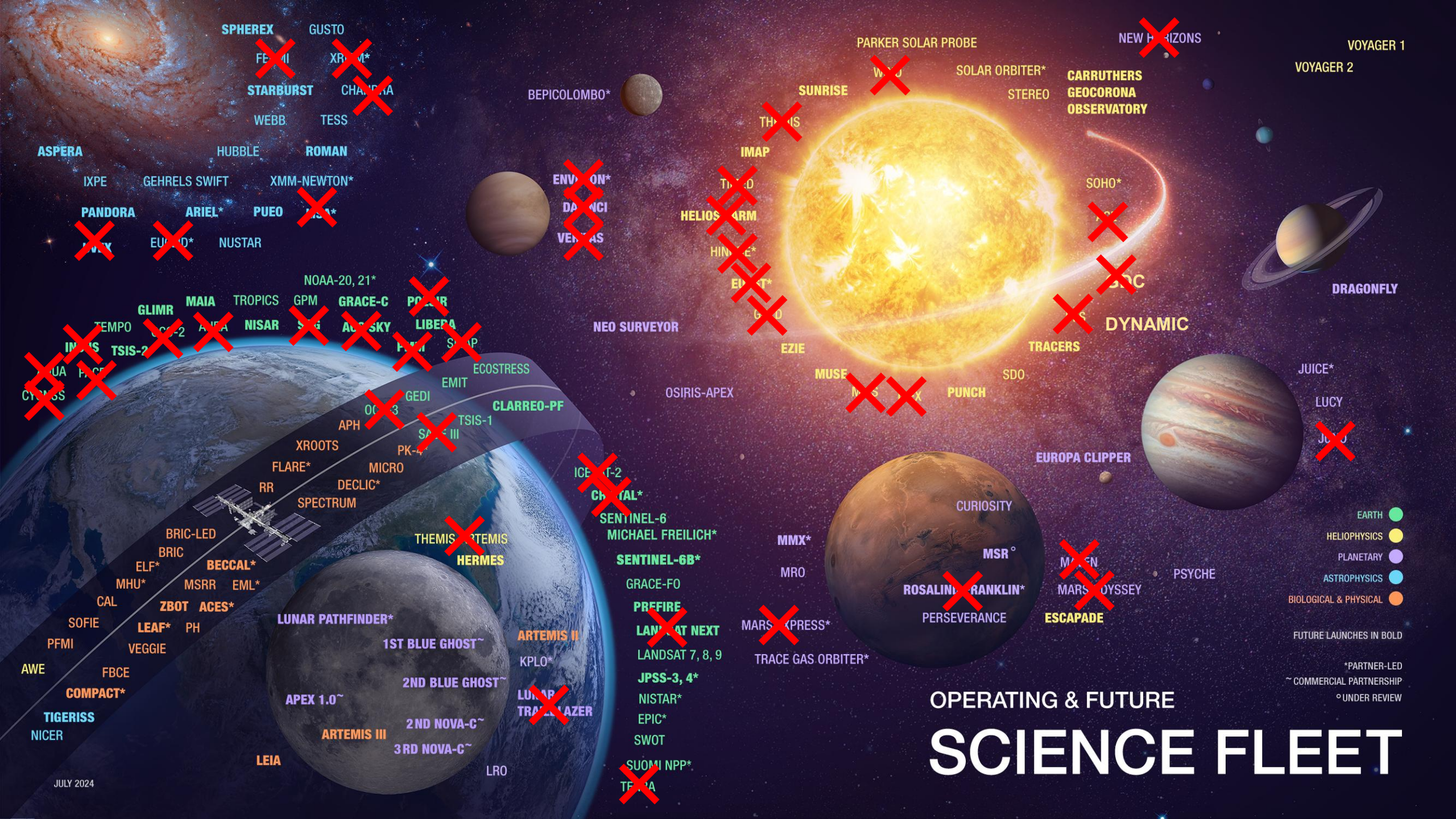


Normally my presentation would end around here, but…..



OPERATING & FUTURE

SCIENCE FLEET


SPHEREX
GUSTO
FERMI
XRISM*
STARBURST
CHANDRA
WEBB
TESS
ASPERA
HUBBLE
ROMAN
IXPE
GEHRELS SWIFT
XMM-NEWTON*
PANDORA
ARIEL*
PUEO
EUCLID*
NUSTAR
BEPICOLOMBO*
ENVISION*
DAVINCI
VERITAS
PARKER SOLAR PROBE
SOLAR ORBITER*
SUNRISE
STEREO
IMAP
HELIOSWARM
HINODE*
EUVST*
NEO SURVEYOR
EZIE
CARRUTHERS GEOCORONA OBSERVATORY
NEW HORIZONS
VOYAGER 1
VOYAGER 2
SOHO*
SDC
DYNAMIC
TRACERS
DRAGONFLY
NOAA-20, 21*
GLIMR
MAIA
TROPICS
GPM
GRACE-C
POLAR
TEMPO
NISAR
AURORASAT
LIBERA
TSIS-2
ECOSTRESS
EMIT
GEDI
CLARREO-PF
APH
TSIS-1
XROOTS
PK-4
FLARE*
MICRO
RR
DECLIC*
SPECTRUM
BRIC-LED
BRIC
ELF*
BECCAL*
MHU*
MSRR
EML*
CAL
ZBOT
ACES*
SOFIE
LEAF*
PH
PFMI
VEGGIE
AWE
FBCE
COMPACT*
TIGERISS
NICER
THEMIS
ARTEMIS
HERMES
LUNAR PATHFINDER*
1ST BLUE GHOST~
2ND BLUE GHOST~
APEX 1.0~
ARTEMIS III
2ND NOVA-C~
3RD NOVA-C~
LEIA
LRO
ARTEMIS II
KPLO*
LUNAR TRAILBLAZER
ICESAT-2
CRYOSAT*
SENTINEL-6
MICHAEL FREILICH*
SENTINEL-6B*
GRACE-FO
PREFIRE
LANDSAT NEXT
LANDSAT 7, 8, 9
JPSS-3, 4*
NISTAR*
EPIC*
SWOT
SUOMI NPP*
TERRA
OSIRIS-APEX
MUSE
PUNCH
SDO
JUICE*
LUCY
EUROPA CLIPPER
CURIOSITY
MMX*
MSR°
MRO
ROSALIND FRANKLIN*
PERSEVERANCE
MARS EXPRESS*
TRACE GAS ORBITER*
MAVEN
MARS ODYSSEY
ESCAPADE
PSYCHE
EARTH
HELIOPHYSICS
PLANETARY
ASTROPHYSICS
BIOLOGICAL & PHYSICAL
FUTURE LAUNCHES IN BOLD
*PARTNER-LED
~ COMMERCIAL PARTNERSHIP
° UNDER REVIEW
JULY 2024
OPERATING & FUTURE
SCIENCE FLEET

FY 2026 PRESIDENT'S BUDGET REQUEST SUMMARY

Access all PBR documents:

Budget Authority ($ in millions)	Op Plan 2024	Enacted 2025	Request 2026	Fiscal Year 2027	2028	2029	2030
Heliophysics	**805.0**	**--**	**432.5**	**422.5**	**432.5**	**432.5**	**432.5**
Heliophysics Research	**247.4**	**--**	**134.0**	**136.0**	**135.0**	**130.0**	**130.0**
Heliophysics Research and Analysis	55.8	--	40.2	40.2	40.2	40.2	40.2
Sounding Rockets	73.1	--	30.0	30.0	30.0	30.0	30.0
Research Range	26.9	--	10.0	10.0	10.0	10.0	10.0
Other Missions and Data Analysis	91.6	--	53.9	55.8	54.8	49.8	49.8
Living with a Star	**107.4**	**--**	**70.5**	**67.5**	**77.0**	**72.8**	**72.8**
Other Missions and Data Analysis	107.4	--	70.5	67.5	77.0	72.8	72.8
Solar Terrestrial Probes	**191.7**	**--**	**42.4**	**26.1**	**18.0**	**17.5**	**17.5**
Interstellar Mapping and Acceleration Probe (IMAP)	137.4	--	39.5	23.9	15.3	15.0	15.0
Other Missions and Data Analysis	54.3	--	2.9	2.2	2.7	2.5	2.5
Heliophysics Explorer Program	**206.2**	**--**	**125.2**	**128.8**	**121.4**	**119.7**	**129.2**
Multi-Slit Solar Explorer	74.7	--	66.9	78.0	15.6	11.7	0.6
Other Missions and Data Analysis	131.5	--	58.4	50.8	105.8	108.0	128.6
Space Weather	**40.5**	**--**	**54.9**	**59.1**	**76.1**	**87.5**	**78.0**
Heliophysics Technology	**11.8**	**--**	**5.4**	**5.0**	**5.0**	**5.0**	**5.0**

Geospace Dynamic Constellation

Conclusions

- GDC will study how the upper atmosphere and ionosphere response to energy inputs from above

- GDC, via the *ITM great observatory,* wants to serve as a strategic hub for the international ITM science community

  Help coordinate the ground-based community to leverage GDC measurements to extend and enhance their science and achieve their science goals

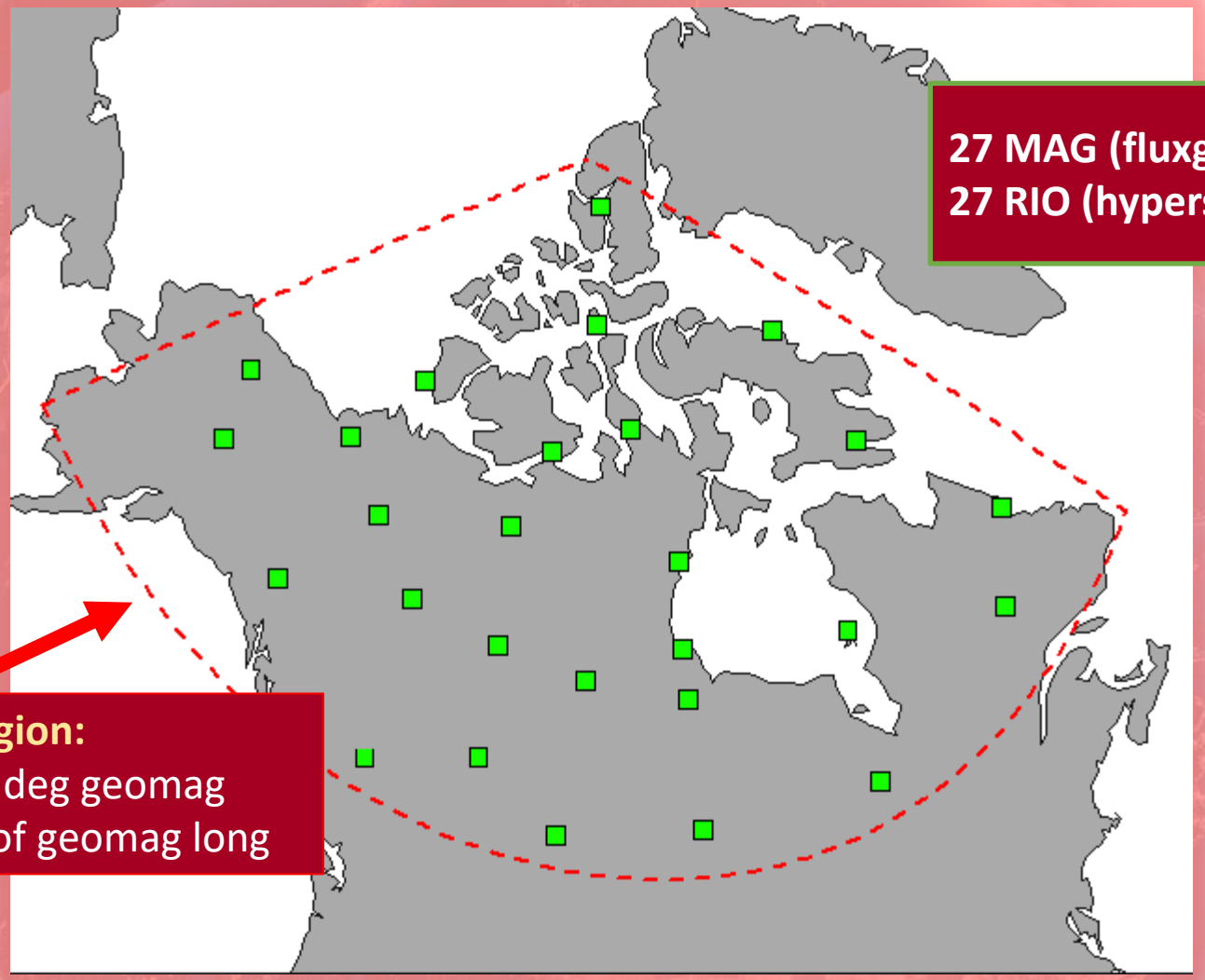
- Join the group!

Join the GDC Ground-based community

For more information contact:
Bea Gallardo-Lacourt (NASA/CUA)
bea.gallardolacourt@nasa.gov

Extra slides

GDC-Ground Infrastructure

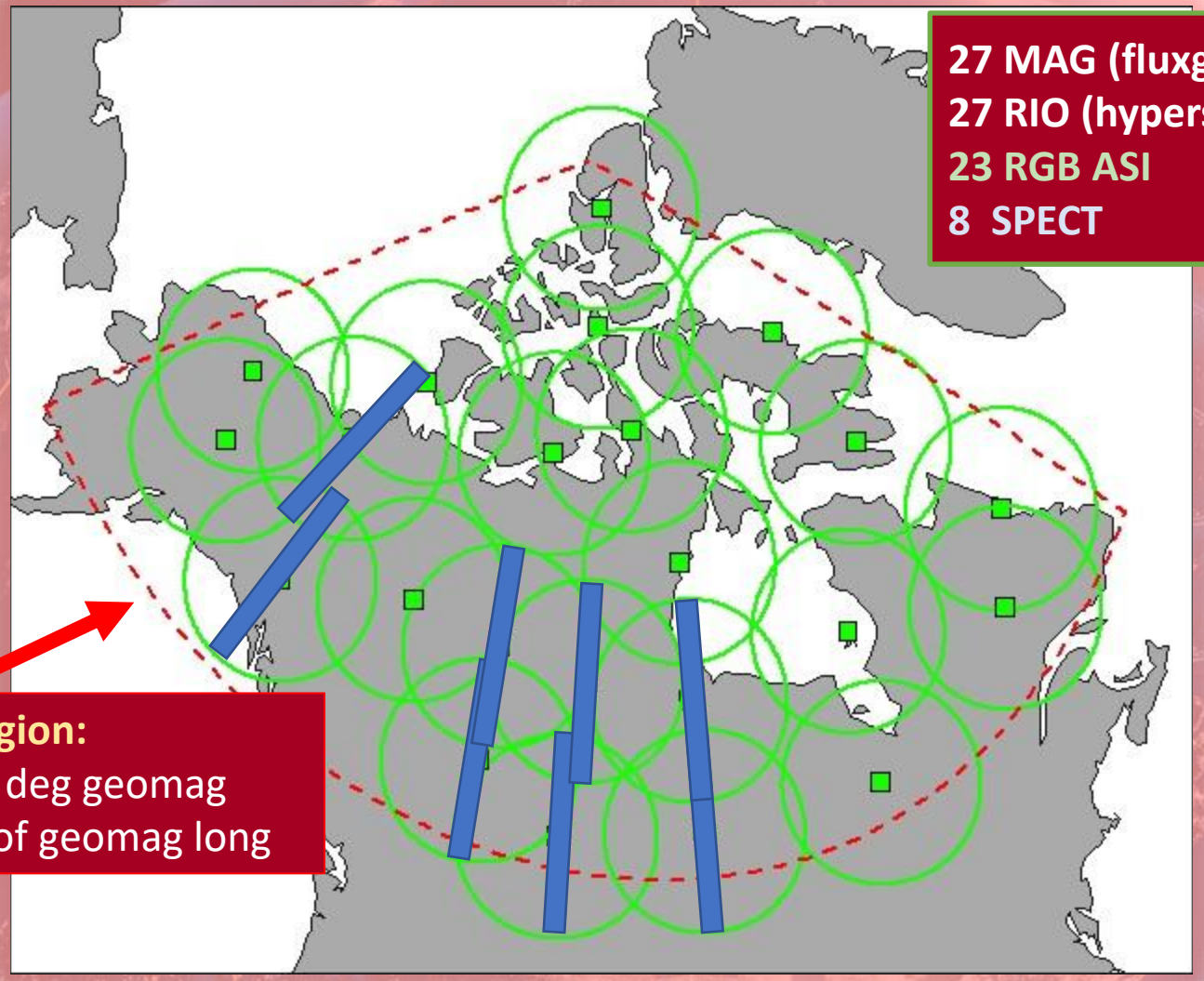


27 MAG (fluxgate)
27 RIO (hyperspectral)

Target Region:
~58 to 90 deg geomag
>120deg of geomag long

27 “core sites”

GDC-Ground Infrastructure



27 MAG (fluxgate)
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23 RGB ASI
8 SPECT

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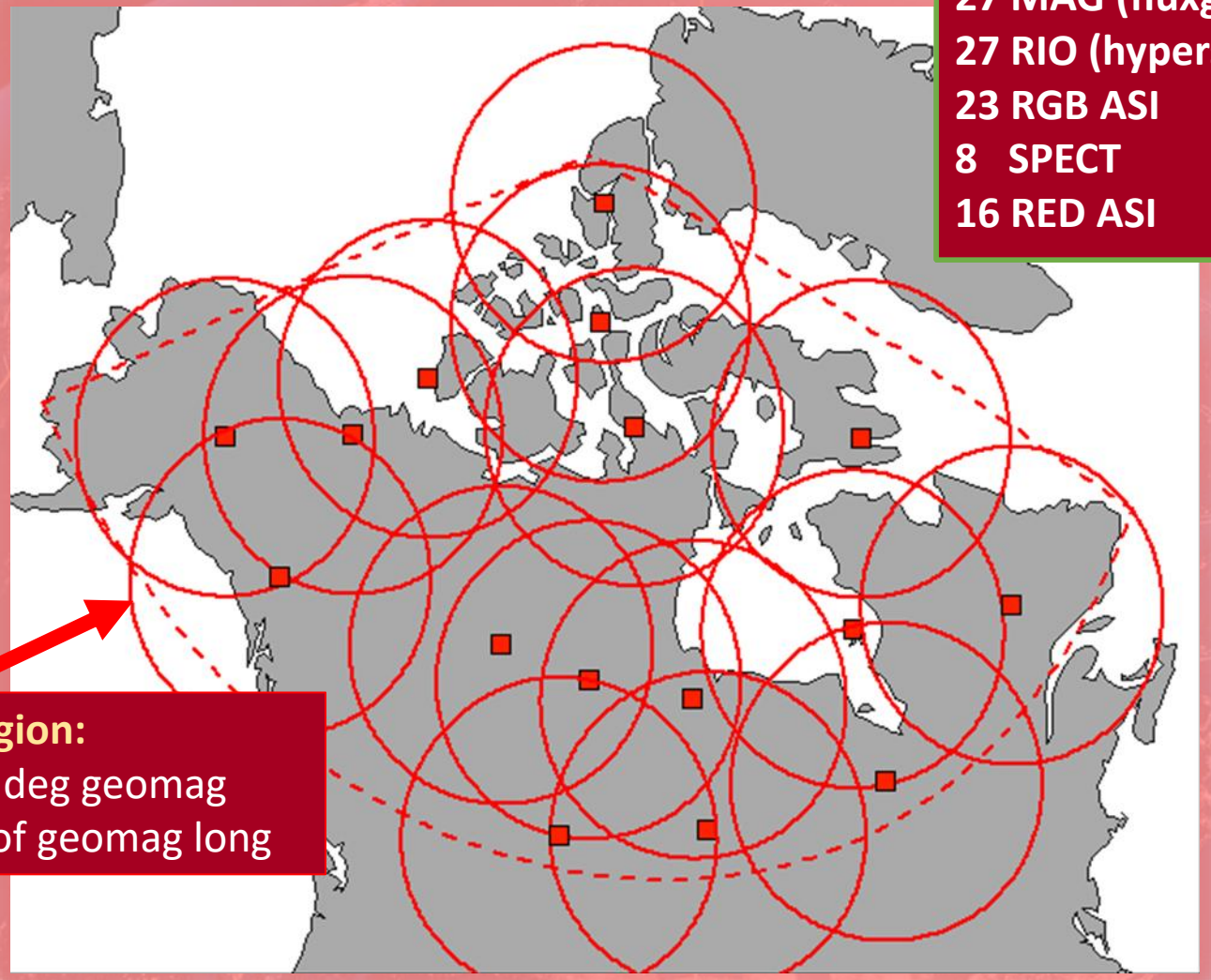
GDC-Ground Infrastructure



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GDC-Ground Infrastructure

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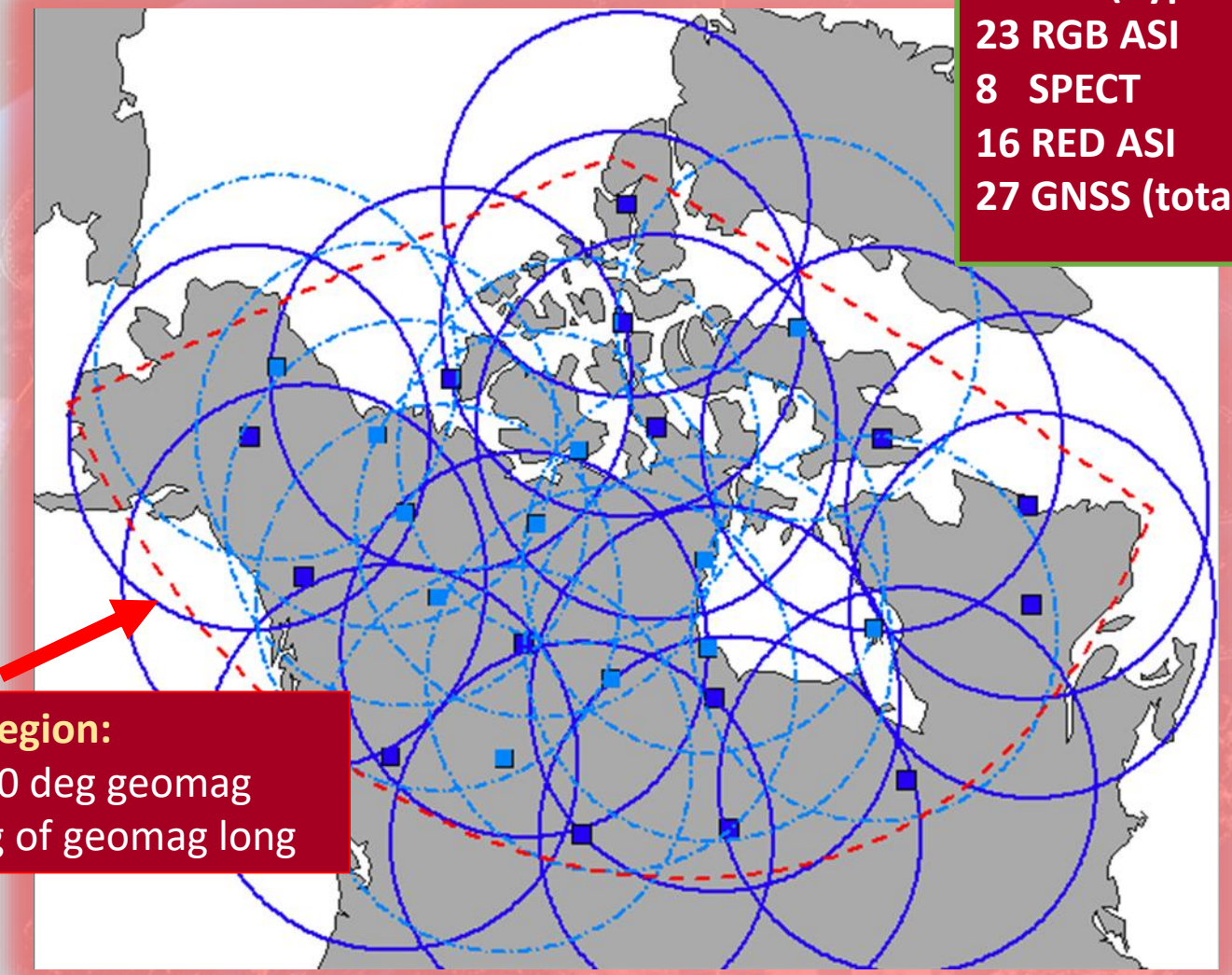
16 RED ASI
27 GNSS (total)

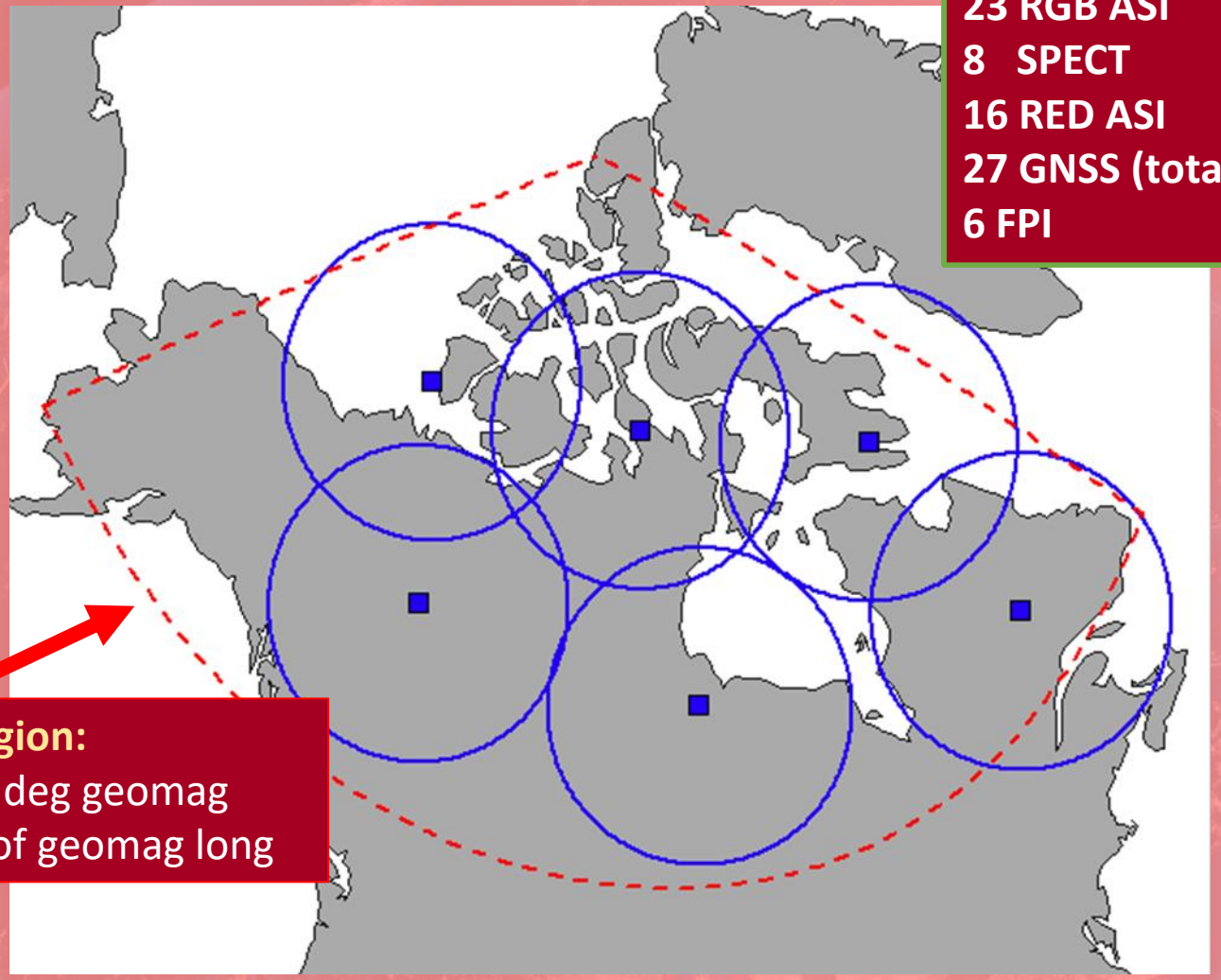


Target Region:
~58 to 90 deg geomag
>120deg of geomag long

27 “core sites”

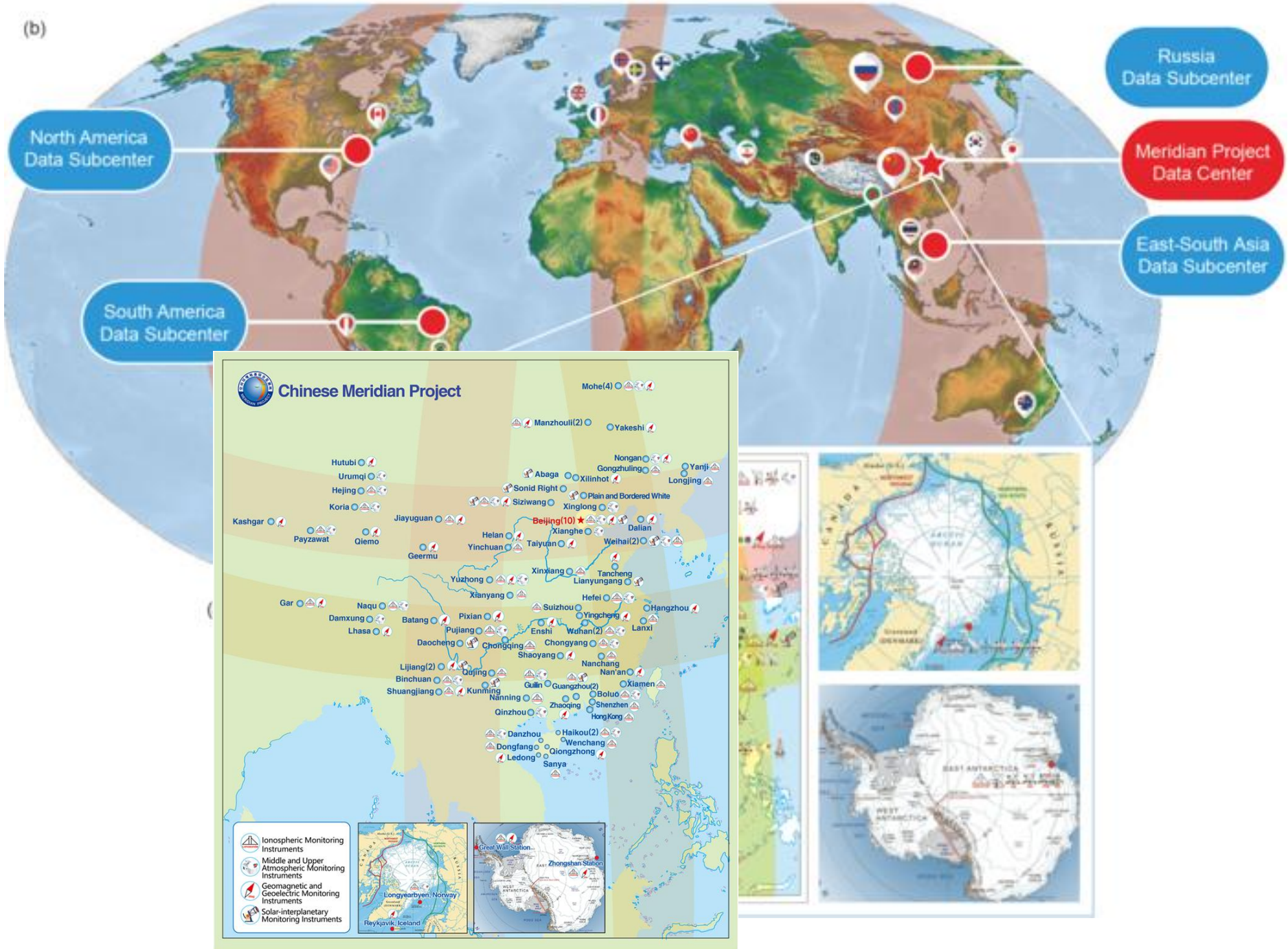
GDC-Ground Infrastructure

27 MAG (fluxgate)
27 RIO (hyperspectral)
23 RGB ASI
8 SPECT
16 RED ASI
27 GNSS (total)
6 FPI



Target Region:
~58 to 90 deg geomag
>120deg of geomag long

27 “core sites”


(b)
North America Data Subcenter
South America Data Subcenter
Russia Data Subcenter
Meridian Project Data Center
East-South Asia Data Subcenter
Chinese Meridian Project
Mohe(4)
Manzhouli(2)
Yakeshi
Hutubi
Urumqi
Hejing
Koria
Kashgar
Payzawat
Qiemo
Jiayuguan
Geermu
Abaga
Xilinhot
Sonid Right
Plain and Bordered White
Siziwang
Xinglong
Beijing(10)
Xianghe
Dalian
Helan
Yinchuan
Taiyuan
Weihai(2)
Nongan
Gongzhuling
Yanji
Longjing
Xinxiang
Tancheng
Lianyungang
Yuzhong
Xianyang
Hefei
Suizhou
Yingcheng
Hangzhou
Lanxi
Gar
Naqu
Damxung
Lhasa
Batang
Pixian
Pujiang
Enshi
Wuhan(2)
Daocheng
Chongqing
Chongyang
Shaoyang
Nanchang
Nan'an
Lijiang(2)
Qujing
Binchuan
Shuangjiang
Kunming
Guilin
Guangzhou(2)
Xiamen
Nanning
Zhaoqing
Boluo
Shenzhen
Hong Kong
Qinzhou
Danzhou
Haikou(2)
Wenchang
Dongfang
Qiongzhong
Ledong
Sanya
Ionospheric Monitoring Instruments
Middle and Upper Atmospheric Monitoring Instruments
Geomagnetic and Geoelectric Monitoring Instruments
Solar-interplanetary Monitoring Instruments
Longyearbyen, Norway
Reykjavik, Iceland
Great Wall Station
Zhongshan Station

GDC Status

- GDC definition began in 2018 with the Science and Technology Definition Team. The STDT report was issued Nov 2019.
- In Nov 2019, NASA GSFC was directed to perform a pre-Phase A study to define the scientific and technical scope of GDC. This resulted in a successful Mission Concept Review in July 2020 and a subsequent KDP-A in Aug 2020
- The IDS teams were selected by NASA HQ in fall 2021
- Independent Review Board affirmed GDC's importance in summer 2022
- The first three instruments (AETHER, CAPE, MoSAIC) selected by NASA HQ in spring 2022
- TPS, NEMISIS, and PROFILE instruments selected by NASA HQ Jan 2023
- Spacecraft procurement process underway

- March 2023: President's Budget proposed a 3-year "pause" or slowdown of GDC funding to better align the Project's needs with available funding. Through Sept 30, 2026, GDC expects to have a primary focus on science and instrument development, with full development expected to start Oct 1, 2026.

- GDC is looking forward to the National Academies' Decadal Survey report, expected in 2024, and anticipates continued strong support from the community

Geospace Dynamics Constellation Overview

- **GDC will study the region where our upper atmosphere transitions to space.** This transition region between neutral atmosphere and ionized space is where energy input from the Sun and magnetosphere is deposited, altering the chemical composition, plasma density structure, and neutral winds of our upper atmosphere, leading to profound space weather effects such as increased atmospheric drag, geomagnetically induced currents, and GPS errors.
- This region is where all our low-earth orbit (LEO) satellites live, including the ISS. **Critical national infrastructure resides in this poorly studied region, and our predictive models are insufficient to protect these assets.** We do not have sufficient measurements needed to understand and predict the temporal and spatial scales over which these interactions occur.
- GDC, in combination with its partner mission DYNAMIC, will capture the full breadth of energy input from above (GDC) and below (DYNAMIC). This mission combination will allow us to understand the full response of the ITM system to these energy inputs.

- **GDC Facts**:
  - NASA's next Living With a Star (LWS) strategic mission

GDC: A Community Mission

- GDC has a *scientific* focus as a NASA investigation of Earth's upper atmosphere
- GDC has a major *system-science* focus as the next NASA LWS mission, providing a critical "missing link" in the Heliophysics System Observatory (of high interest to ITM and magnetospheric researchers) and a critical window into the science of space weather phenomena that have by far the most impact on our technological society
- GDC is a *strategic* focus as a "**community mission**" that will lay the groundwork for future science investigations and capabilities. GDC can serve as an "anchor / hub" to provide synergistic opportunities for a range of related and complementary Heliophysics and partner agency / international investigations and missions.
- GDC's data, science, and tools are meant to be **open, accessible, reproducible, and extensible** by the community. The same tools used by the science team will be available for use, extension, modification, etc. GDC is the first strategic Heliophysics mission to be developed under SMD's "open science" policies from day 1.
- As a Center-led strategic mission with independent PI-led investigation and IDS teams, GDC is inherently open and democratic, and well suited for community engagement and open dialog and coordination. Think of GDC as an "observatory" that will produce tremendous science output for a wide range of scientific problems, both deep and broad, and including excellent opportunities for secondary science and R2O2R activities.
- GDC will help to strengthen, rebuild, recruit, and retain a NASA-funded community of ITM researchers, which has not had a new **strategic** mission in over two decades (TIMED / remote sensing, launch 2002) or four decades (Dynamics Explorer-2 / in situ sampling, launch 1981).