NOAA GOES-R Office Hours

Satellite Data In the Cloud

Hosted by NOAA National Environmental Satellite, Data, and Information Service (NESDIS), NOAA Open Data Dissemination (NODD), and Microsoft

November 29, 2023 | 12-1:15 PM EDT | REGISTER HERE

- Connect with NOAA experts on GOES-R satellite data and information, with a focus on GOES-R cryosphere products
- Share experiences on use and access of NOAA GOES-R data via Microsoft
- Hear about open data access via NOAA Open Data Dissemination (NODD)

Tom Augspurger
Microsoft

Steve Superczynski
NOAA GOES-R Product Overview

Jeff Key
NOAA Cryosphere Product Overview

Yinghui Liu
NOAA Cryosphere PI (Ice concentration & extent)

Peter Romanov
NOAA Cryosphere PI (Snow cover)

Xuanji Wang
NOAA Cryosphere PI (Ice age & thickness)

Microsoft Azure

GoogleMeet Webinar - Recorded

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- If do not wish to be part of the recording, please feel free to drop off.
- Meeting summary and presentation slides will be available on the NODD website
  - **NOAA.GOV/NODD**

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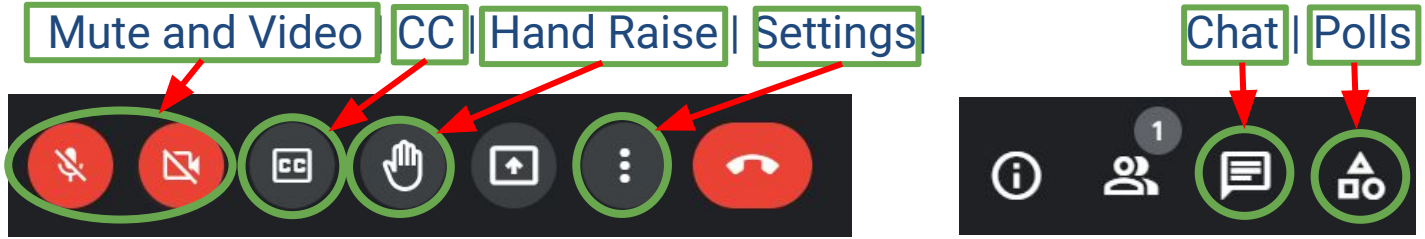
GoogleMeet Webinar Logistics

How to join the discussion!

- Keep yourself muted throughout (for call-in participants: to mute and unmute use *6) and videos off
- Raise your hand if you have a question and we'll respond in the order of the queue
- The following features of Google Meet:



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- You can also join by phone line only if you are having connectivity issues.
- (US) +1 508-687-4473 PIN: 297 789 966#

Guidelines for Discussion

- Keep it brief
- Keep it respectful
- Use the chat function for links, references and/or resources
- Submit questions through the chat function or raise your hand
- Identify who the question is directed to where possible

Quick Google Poll

POLL1

- How do you access GOES-R satellite data today?
  - On-prem via NOAA
  - Cloud
  - Both/Either
  - 3rd party/Web-based Viewer
  - None/Other

POLL2

- My primary goal for attending today is:
  - Technical use and access of GOES-R data
  - To learn about cloud access to data (e.g. NODD Program)
  - Meet and engage with NOAA staff scientists
  - Learn about Microsoft Cloud access and tools

Open & Free

NODD Disseminates NOAA Line Office Data

NOAA data is growing exponentially...

TECHNOLOGY MODERNIZATION

Reduces stress on NOAA's on-premise dissemination systems

Improves services for Users

FULL & OPEN PUBLIC ACCESS

Supports
Federal Data Strategy
& Evidence Act
Open Data Requirements

No egress costs

ENABLES & ENGAGES USERS

Catalyzes innovation in environmental services

Enables interoperability

- Open data with value to the public
- No use restrictions or user registration
- Appropriate Metadata included

Geostationary Operational Environmental Satellite-R (GOES-R) Series

- GOES-R (GOES-16) - Launched on November 19, 2016 at 6:42 p.m. EST
- Replaced GOES-13 as the operational GOES-East satellite on December 18, 2017
- Located at 75.2 degrees west

- GOES-S (GOES-17) - Launched on March 1, 2018 at 5:02 p.m. EST
- Replaced GOES-15 as the operational GOES-West satellite on February 12, 2019
- Relocated to storage at 104.7 degrees west following it's replacement as GOES-West

- GOES-T (GOES-18) - Launched on March 1, 2022 at 4:38 p.m. EST
- Replaced GOES-17 as the operational GOES-West satellite on January 4, 2023
- Located at 137 degrees west

- GOES-U scheduled to be launched in April 2024
- Carries a new sun-facing instrument called Compact Coronagraph (CCOR)
- Will be renamed GOES-19 and replace GOES-16 as the operational GOES-East satellite

GOES-R Series Instruments

Advanced Baseline Imager (ABI)

Geostationary Lightning Mapper (GLM)

Extreme Ultraviolet X-Ray Irradiance Sensor (EXIS)

Magnetometer (MAG)

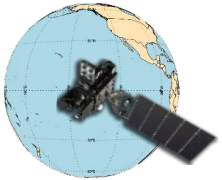
Space Environmental In-Situ Suite (SEISS)

Solar Ultraviolet Imager (SUVI)

GOES Constellation

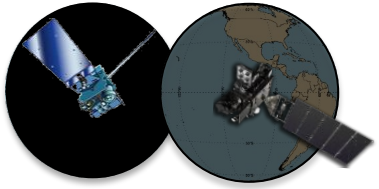
Current

GOES-West
GOES-18
137.0°W

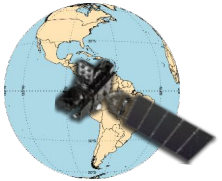


Co-Standby
GOES-14
108.2°W

Standby
GOES-17
104.7°W

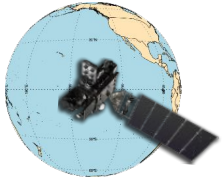


GOES-East
GOES-16
75.2°W



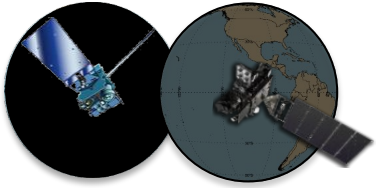
GOES-U Post-Launch Testing

GOES-West
GOES-18
137.0°W



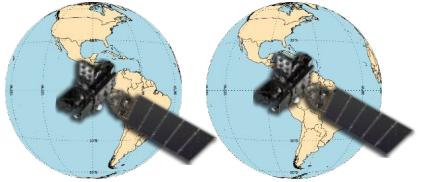
Co-Standby
GOES-14
108.2°W

Standby
GOES-17
104.7°W



Checkout
GOES-U/19
89.5° West

GOES-East
GOES-16
75.2°W



GOES-R Ground Segment Product Portfolio

Acronym	Meaning
GRB	GOES-R ReBroadcast
PDA	Product Distribution and Access
CLASS	Comprehensive Large Array Storage System
NODD	NOAA Open Data Dissemination
AWIPS	Advanced Weather Interactive Processing System (NWS)
HRIT	High Rate Information Transmission
EMWIN	Emergency Managers Weather Information Network
GNC-A	GEONETCast - Americas

ABI L1b in GRB, PDA, CLASS, NODD
Radiances
GLM L2 in GRB, PDA, CLASS, NODD
Lightning: Events, Groups, Flashes
SEISS L1b in GRB, PDA, CLASS, NODD
Energetic Heavy Ions
Magnetospheric e^-/p^+: Low Energy
Magnetospheric e^-/p^+: High Energy
Solar & Galactic Protons
EXIS L1b in GRB, PDA, CLASS, NODD
Solar Flux: EUV
Solar Flux: X-ray Irradiance
SUVI L1b in GRB, PDA, CLASS, NODD
Solar EUV Imagery
GMAG L1b in GRB, PDA, CLASS, NODD
Geomagnetic Field

Legend: * Enterprise Algorithm

Some products also delivered via HRIT/EMWIN and GNC-A

ABI L2+ Products in PDA, AWIPS, CLASS, NODD	
Cloud and Moisture Imagery (CMI) and Sectorized CMI (KPP)	Fire/Hot Spot Characterization
Aerosol Detection (Smoke & Dust)	Ice Age & Thickness *
Aerosol Optical Depth	Ice Concentration & Extent *
Clear Sky Mask *	Ice Motion *
Cloud Cover Layers *	Land Surface Albedo *
Cloud Optical Depth *	Land Surface Reflectance *
Cloud Particle Size Distribution *	Land Surface Temperature *
Cloud Top Height *	Legacy Vertical Moisture Profile
Cloud Top Phase *	Legacy Vertical Temperature Profile
Cloud Top Pressure *	Rainfall Rate/QPE
Cloud Top Temperature *	Reflected S/W Radiation: TOA
Derived Motion Winds	Sea Surface Temperature
Derived Stability Indices	Snow Cover *
Downward S/W Radiation: Surface	Total Precipitable Water

GLM L2+ Products in AWIPS
Gridded Flash Extent Density, Minimum Flash Area, Total Optical Energy





The Cryosphere




The **cryosphere** collectively describes elements of the earth system containing **water in its frozen state** and includes:

solid precipitation, snow cover, sea ice, lake and river ice, glaciers, ice caps, ice sheets, ice shelves, permafrost and seasonally frozen ground.

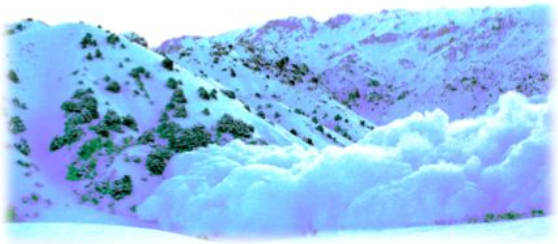
The cryosphere is **global**, ~100 countries

Impacts of a Changing Cryosphere

Changes in ice impact shipping, fisheries, coasts, wildlife, and weather

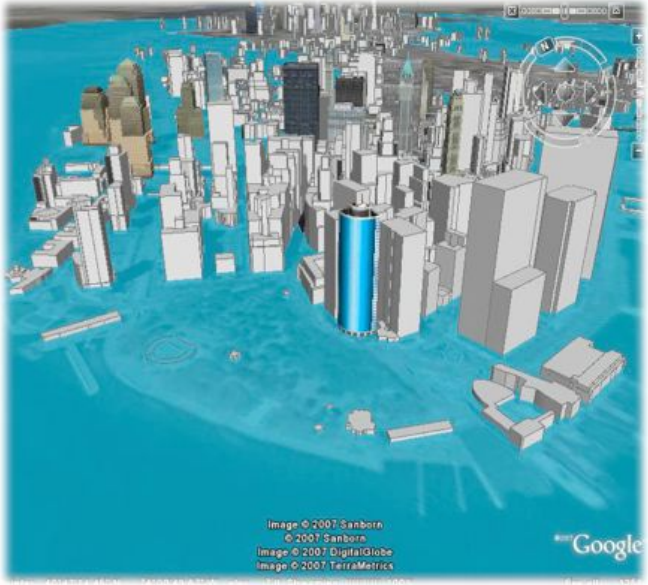
Impacts of a Changing Cryosphere

Changes in snow cover and temperature impact water supply, agriculture, infrastructure, wildlife, and weather

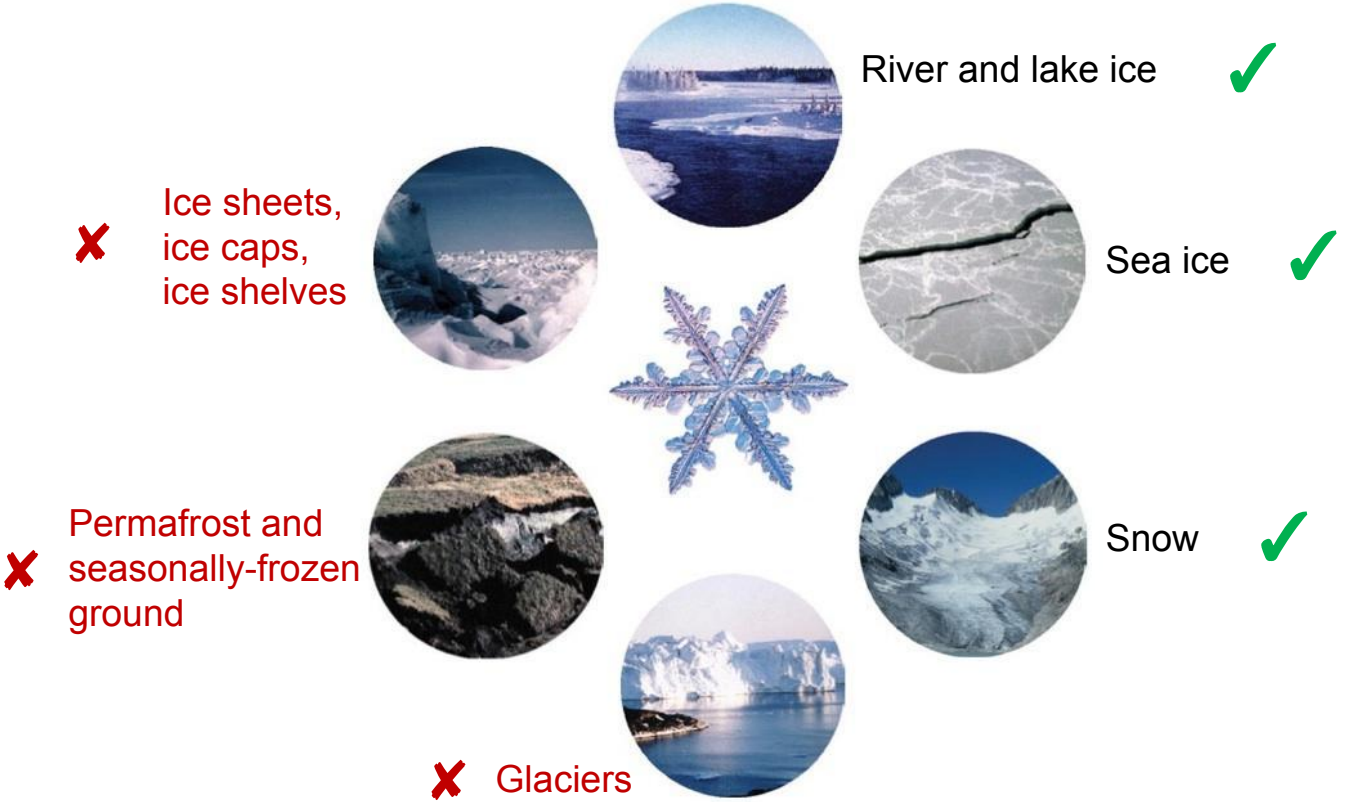


Impacts of a Changing Cryosphere

Changes in ice sheets affect sea level, which impacts coasts



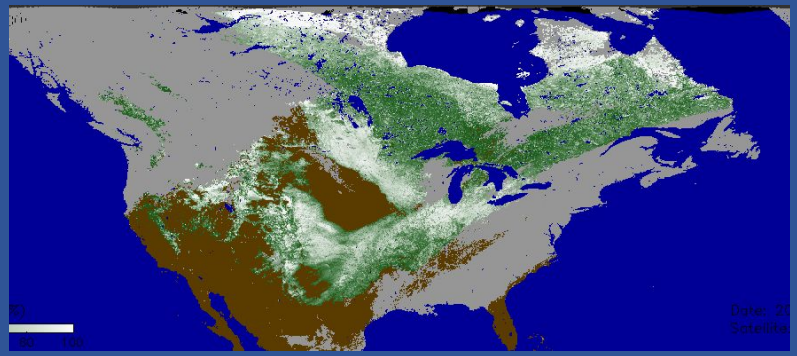
The Cryosphere in NOAA/NESDIS

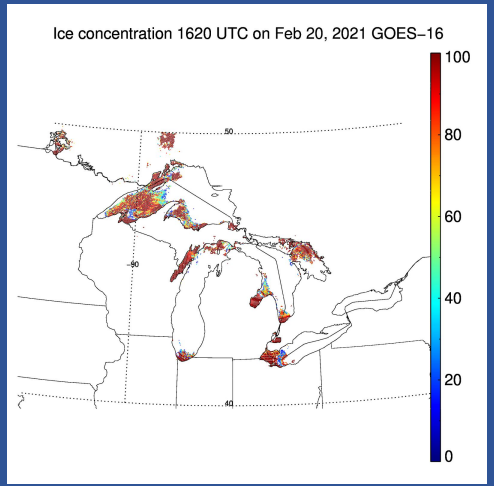


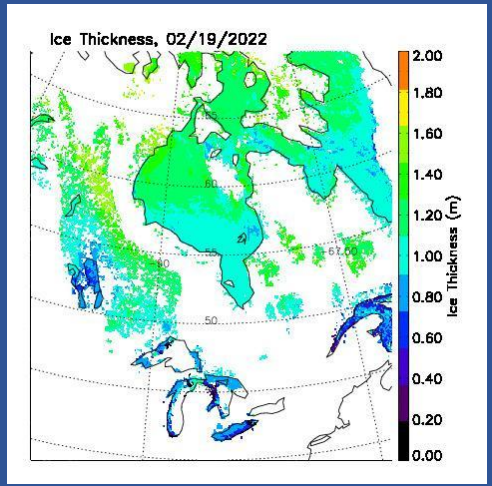
Operational ABI Snow and Ice Products

Products:

- Snow cover, binary (Peter Romanov)
- Snow fraction
- Ice concentration (Yinghui Liu)
- Ice surface temperature (intermediate product)
- Ice thickness and age (Xuanji Wang)
- Ice motion (not covered here)







GOES-R ABI Snow Products

Two Products: Binary Snow and Snow Fraction

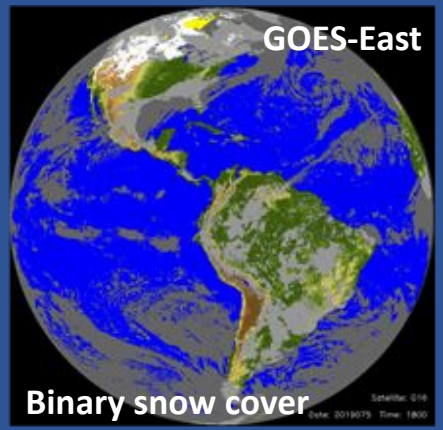
- Binary Snow: Yes/No characterization of snow cover
- Snow Fraction: Fraction of snow within sensor FOV (subpixel fraction)

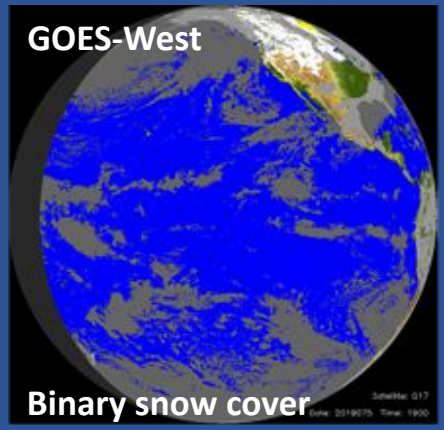
Produced hourly, at daytime, for clear-sky scenes, for GOES-East and -West

2 km spatial resolution at nadir (~4 km over midlatitudes)

Cover North and South America up to 65^0 -70^0 latitude N and S

Available from NOAA CLASS





Algorithm Details

Snow Identification (Binary Snow Mask):

- Threshold-based image classification + set of consistency tests
- External cloud mask used

Snow Fraction:

- Linear unmixing technique, uses reflectance in the visible band (0.6 µm)

$$SnowFraction = (R - R_{Land})/(R_{Snow} - R_{Land})$$

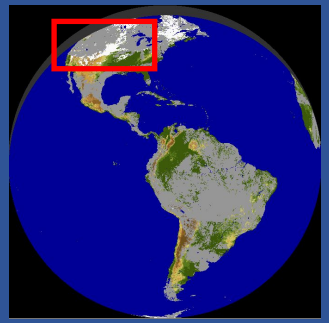
R **-** Observed TOA reflectance in the visible band

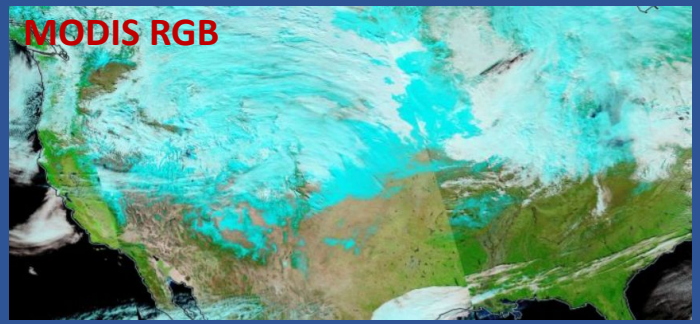
R_{Land} - Predicted TOA reflectance of snow-free land surface

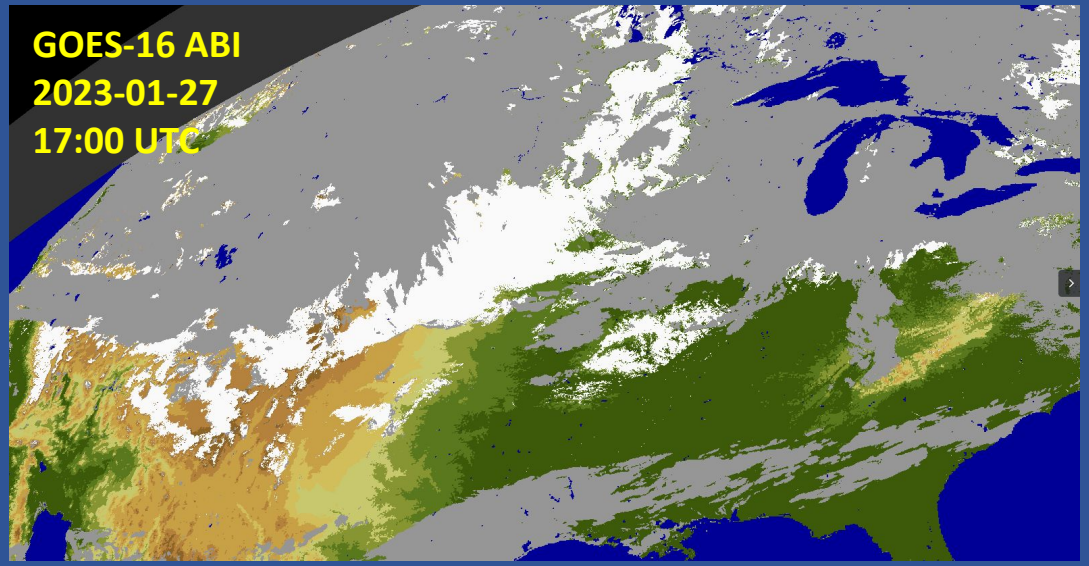
R_{Snow} - Predicted TOA reflectance of snow-covered land

This is “viewable” snow fraction, it is affected by tree canopy and is related to albedo

Product Example: Binary Snow



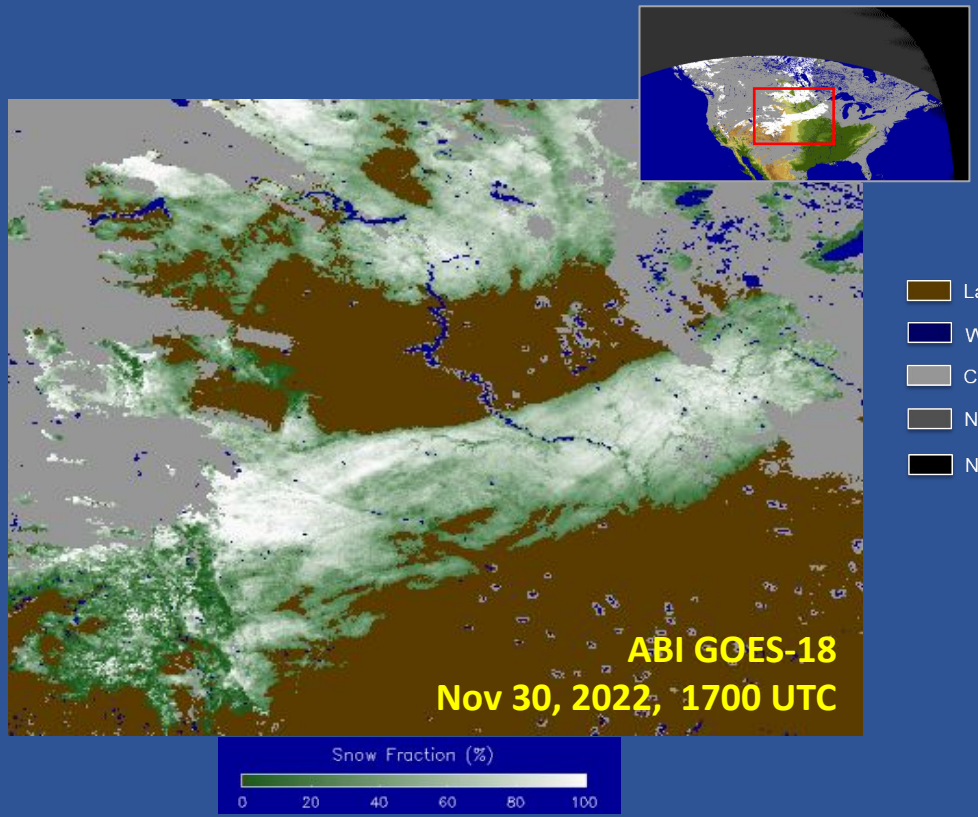




- Indicates presence of snow cover
- Gaps in coverage due to clouds
- Similar to products from MODIS, VIIRS, AVHRR
- 90-95% accuracy vs in situ obs.

Water
Cloud
No retrieval
No coverage

Product Example: Snow Fraction



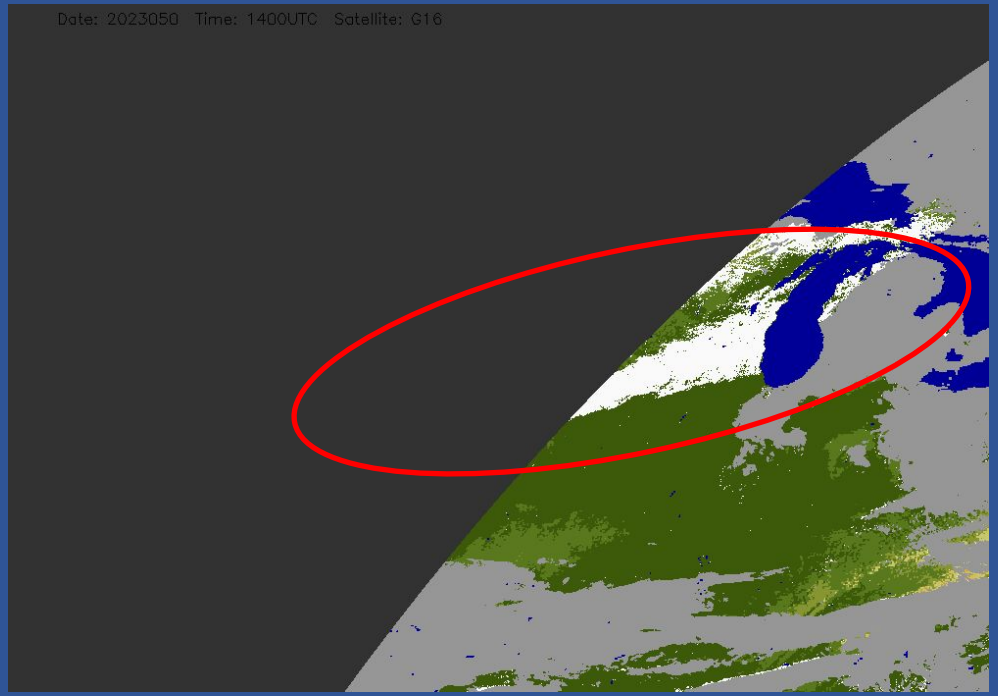
High snow fraction = High albedo
Reduced snow fraction indicates
- Patchy/shallow snow packs or
- Snow masking by tree canopy

Over non-forested areas snow fraction is directly related to the snow depth

25-30% accuracy

Extension of Product Applications: Animation

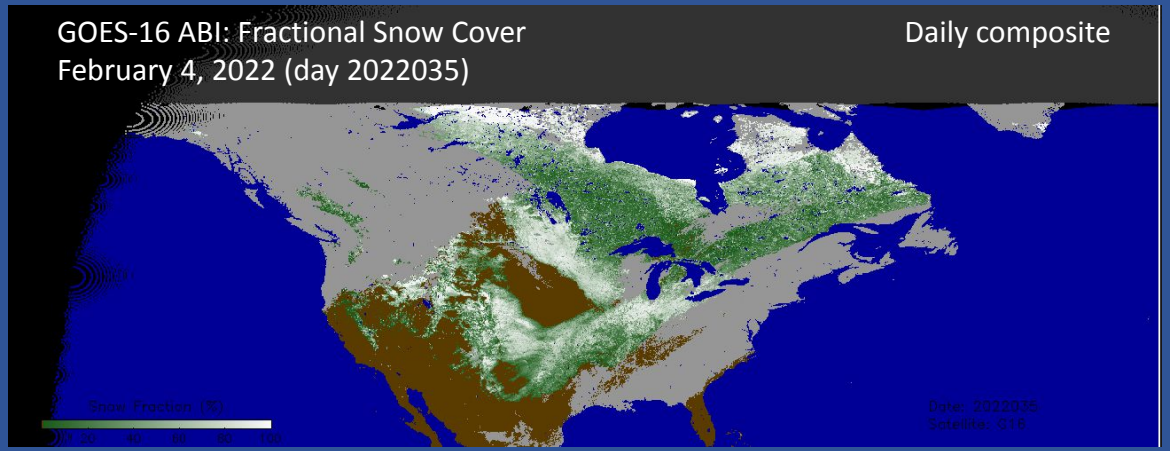
Daily snow product animation help visualizing and evaluating diurnal changes of the snow cover extent

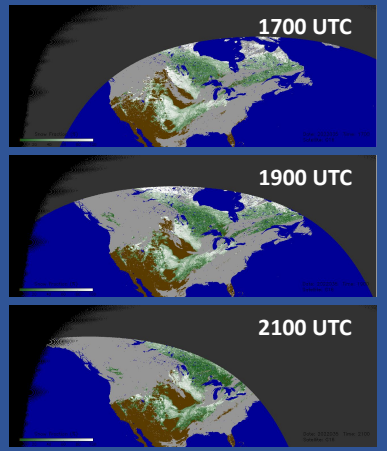


Extension of Product Applications: Daily Compositing

Daily clear-sky compositing provides daily snow products with reduced cloud contamination and improved effective area coverage. Diurnal variations are lost

Daily clear-sky compositing of hourly products results in ~ 5-20% improvement in the effective area coverage

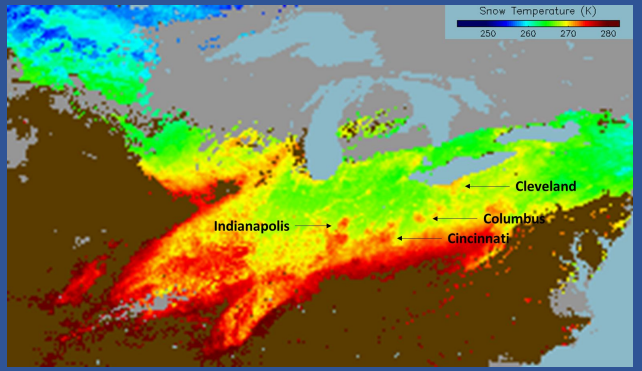


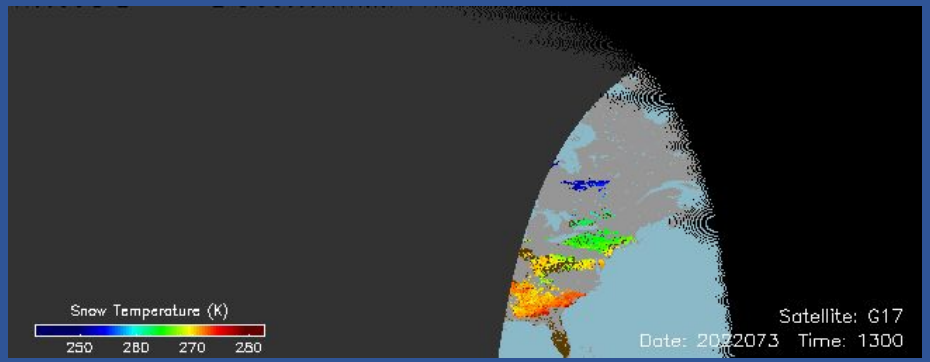


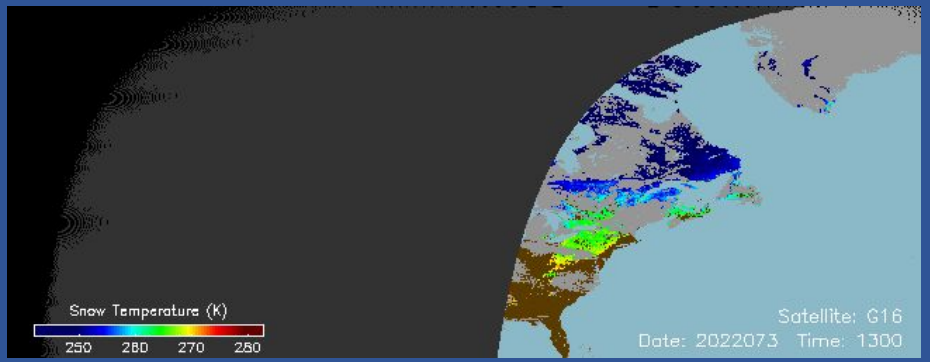
Extension of Product Applications: Snow Melt Identification

Combining ABI snow product with ABI observations in the infrared helps to identify areas of active snow melt.

Snow melt may not be captured by polar orbiting satellite sensors which provide only one daytime observation







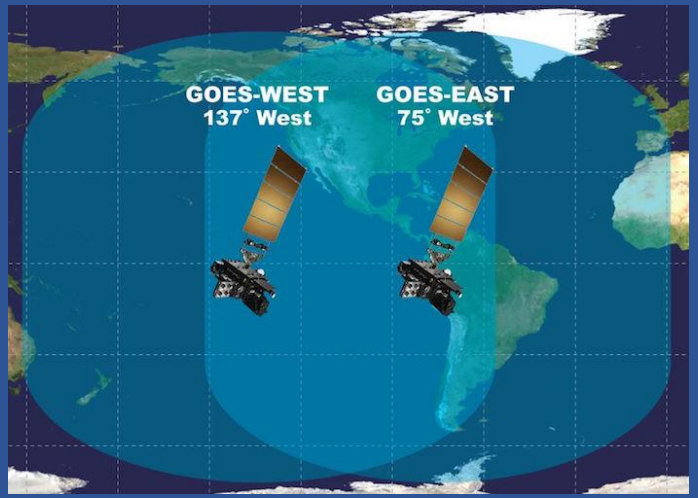
ABI Snow Temperature

ABI Snow Products: Summary

- Binary Snow and Snow Fraction are routinely generated from GOES-R ABI
- Hourly products are available from GOES-East and -West
- Limitations: clouds, nighttime, high latitudes
- Cloud gaps may be reduced by daily product compositing
- Products have been validated and accuracy estimates are available

GOES-R ABI Ice Concentration

- One Operational Product: Ice Concentration
  - Ice Concentration: Fraction of the sea or lake surface covered by ice
  - Ice surface temperature (Intermediate Product): Skin temperature of the ice-covered surface
  - Ice Map (Ice Mask): Yes/No an ABI pixel covered by ice
- Produced every 3 hours, day and night, clear-sky scenes, for GOES-East and GOES-West
- 2 km spatial resolution at nadir (~4 km over midlatitudes)
- Quantitative out to at least 67 degrees Local Zenith Angle and qualitative at larger LZA
- Cover up to 65^0 -70^0 latitude N and S
- Available from NOAA CLASS



GOES-East (GOES-16) and GOES-West (GOES-18) orbital positions.

Algorithm Details

- Read in the sensor data, ancillary data (land/sea mask), and derived product (cloud mask);
- Calculate the surface temperature using split-window approach

$$T_s = a + bT_{11} + cT_{12} + d\,[(T_{11} - T_{12})(\sec\theta - 1)]$$

T_s : estimated surface skin temperature (K),
T_{11} and T_{12} : brightness temperatures (K) at 11 μm and 12 μm bands,
θ : sensor scan angle,
a, b, c, and d : retrieval coefficients.

- Apply threshold tests to detect ice covered pixels based on NDSI (Normalized Difference Snow Index), reflectance at 0.86 μm, and surface temperature in daytime and surface temperature test at nighttime;
- Derive the ice concentration using a tie point algorithm.

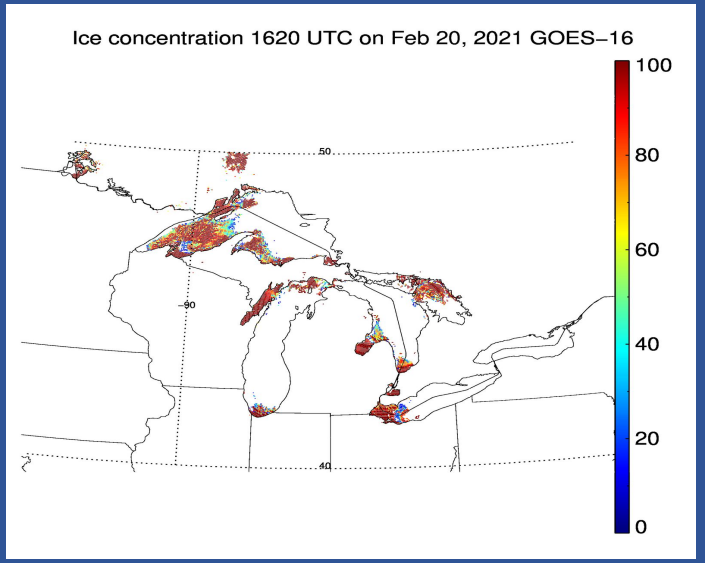
$$C_p = (B_p - B_{water})/(B_{ice} - B_{water})$$

c_p : ice concentration
B_{water} : reflectance or temperature of pure water pixels,
B_{ice} : reflectance or temperature of pure ice pixels (tie point reflectance or temperature),
B_p : observed reflectance or temperature of the pixel.

Product Example: Ice Concentration

GOES-16 true-color image

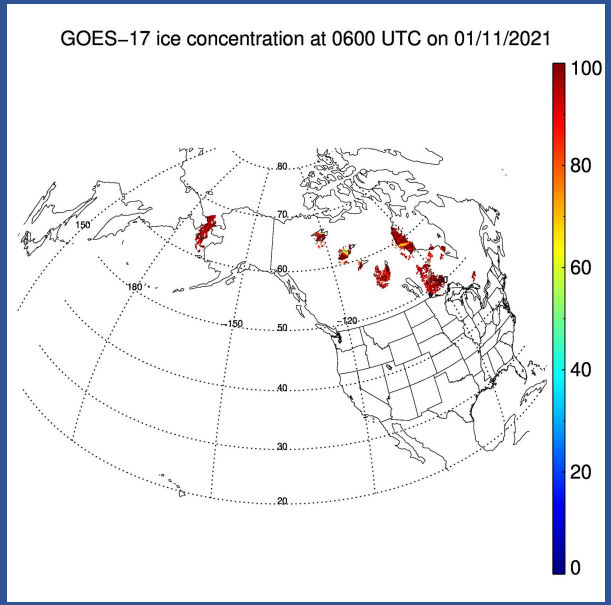
Derived ice concentration



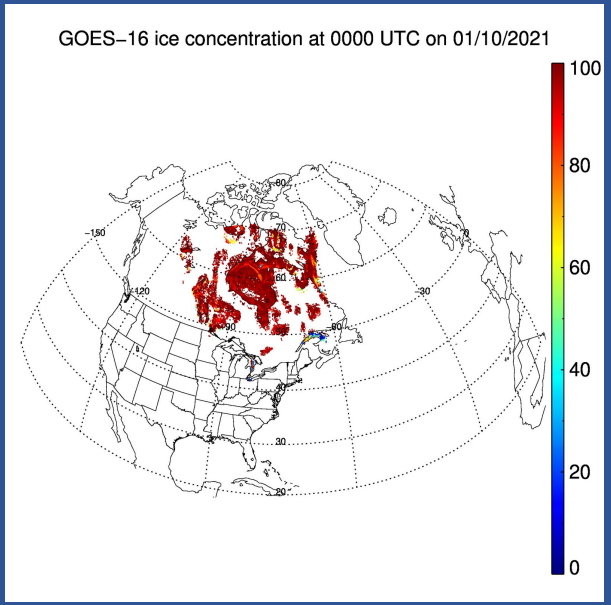
- Gaps in coverage due to clouds
- 10% accuracy
- 25% precision

Extension of Product Applications: Animation

Daily ice concentration animation help visualizing and evaluating diurnal changes of the ice concentration. Changes in the spatial coverages are due to changes in cloud cover.



GOES-17 FD ice concentration from Jan 10-18 2021



GOES-16 FD ice concentration from Jan 11-18 2021

GOES-R ABI Ice Concentration: Summary

- Ice concentration and Intermediate Product ice surface temperature are routinely generated
- Products are available every 3 hours for day and night at 2 km spatial resolution at nadir
- Products have gaps due to clouds and do not cover polar areas
- Cloud gaps may be reduced by daily product compositing

Ice Thickness and Age Product Overview

- Ice thickness is the vertical distance from the bottom to the top of the ice. Ice age is the time period of ice existence. The mission requirement is for ice age categories, not age per se. For ABI, the three categories are first-year ice, older ice, and ice-free.
- Ice thickness is retrieved by the One-dimensional Thermodynamic Ice Model (OTIM), which is based on energy budget theory at the ice/snow surface.
- Ice age is determined in terms of ice thickness.
- GOES-16,-17, and -18 ice thickness and age EDR is a Full Disk (FD) product.
- User needs:
  - One of the Essential Climate Variables (ECVs) in the Third version of the ECV Inventory by the Global Climate Observing System (GCOS) of the WMO
  - The Alaska Sea Ice Program request for monitoring ice conditions
  - Other applications: long-term global ice monitoring, hydrological monitoring, numerical model prediction, ecosystem monitoring, and climate studies, etc.

CIMSS SSEC WISCONSIN UNIVERSITY OF WISCONSIN-MADISON

Ice Thickness and Age Algorithm Overview

One-dimensional Thermodynamic Ice Model (OTIM)

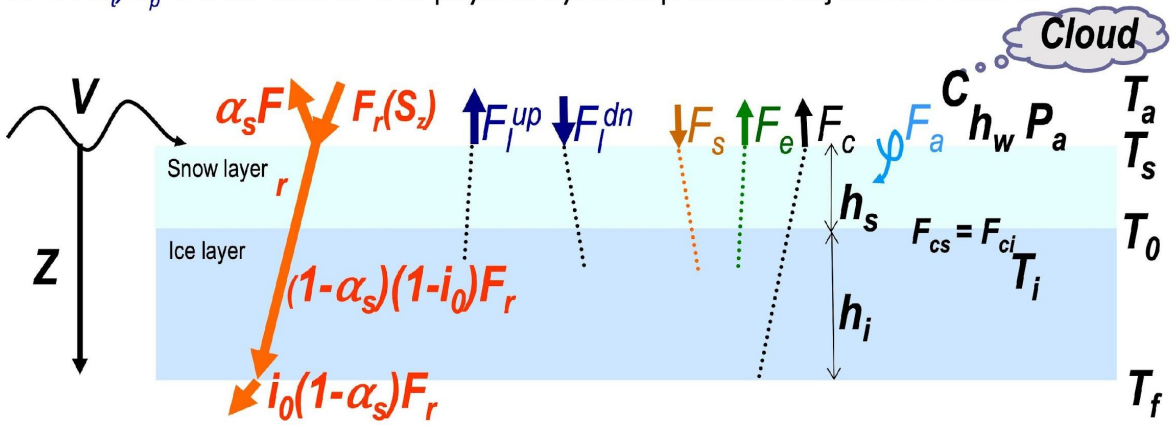
Based on the surface energy budget at thermo-equilibrium state, the fundamental equation is

$$(1-\alpha_s)(1-i_0)F_r - F_l^{up} + F_l^{dn} + F_s + F_e + F_c = F_a(\alpha_s, T_s, V, h_i, C, h_s, \ldots)$$

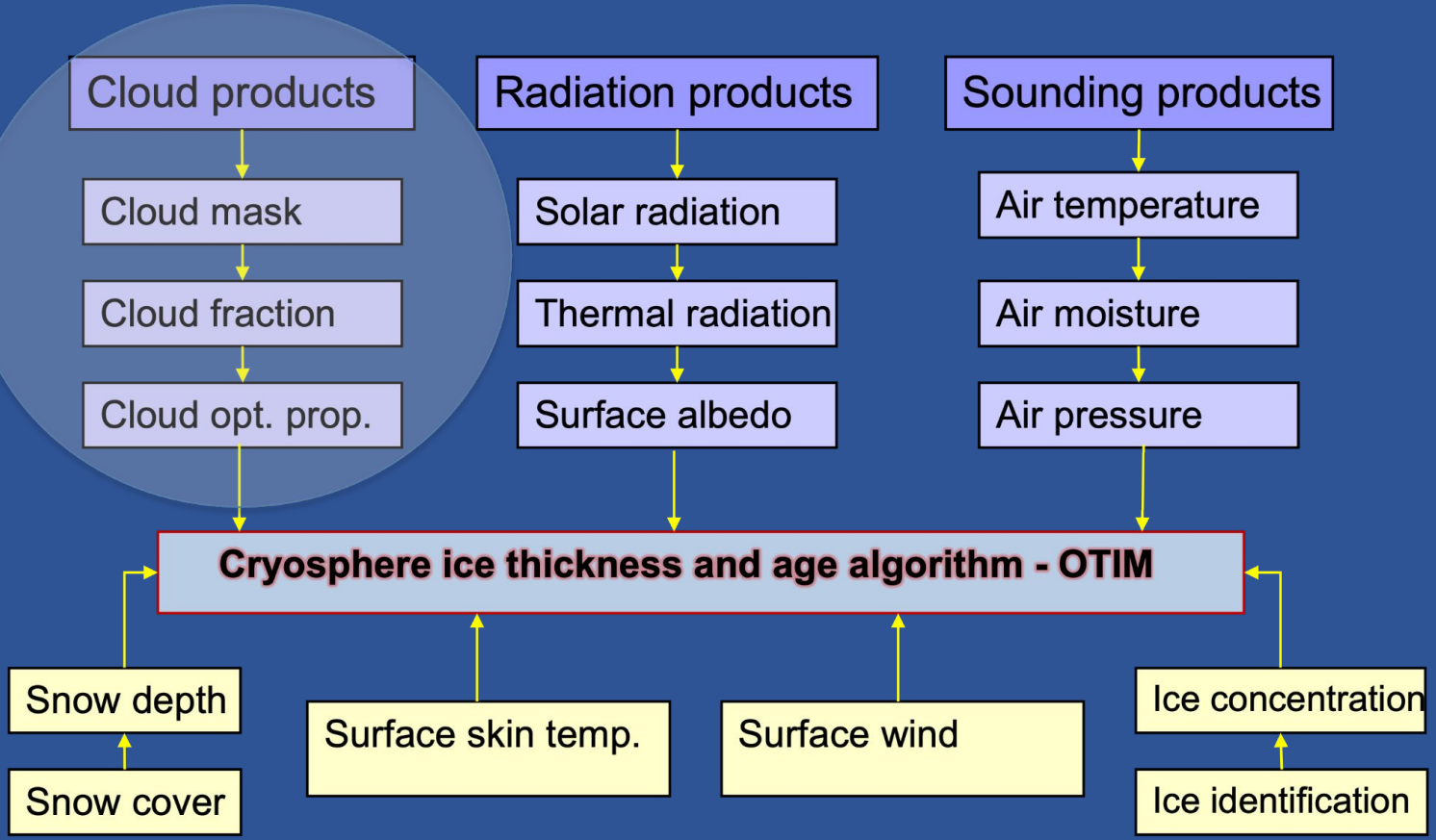
After parameterizations of thermal radiation (F_r, F_l^{up}, F_l^{dn}) and turbulent (sensible & latent) heat (F_s, F_e), ice thickness h_i becomes a function of 12 model controlling variables plus two factors:

$$h_i = f(\alpha_s, i_0, S_z, T_s, T_i, T_a, P_a, h_w, V, C, h_s, F_a, R_t, R_p),$$

where R_t, R_p are ice thermal and physical dynamic processes adjustment factors.



Ice Thickness and Age
Product Algorithm Dependencies



Product Quality Evaluation/Validation

ABI ice thickness is compared to National Ice Center ice charts (qualitatively), and other thickness data from other satellites such as NOAA-20, CryoSat-2, and SMOS directly and indirectly (quantitatively).

Note that the requirement is for correct classification in three categories: ice free, first-year ice, and older ice. In the Great Lakes and Hudson Bay, all ice is first-year ice! Meeting that requirement is relatively easy, so we have chosen to validate many more age categories as well as ice thickness.

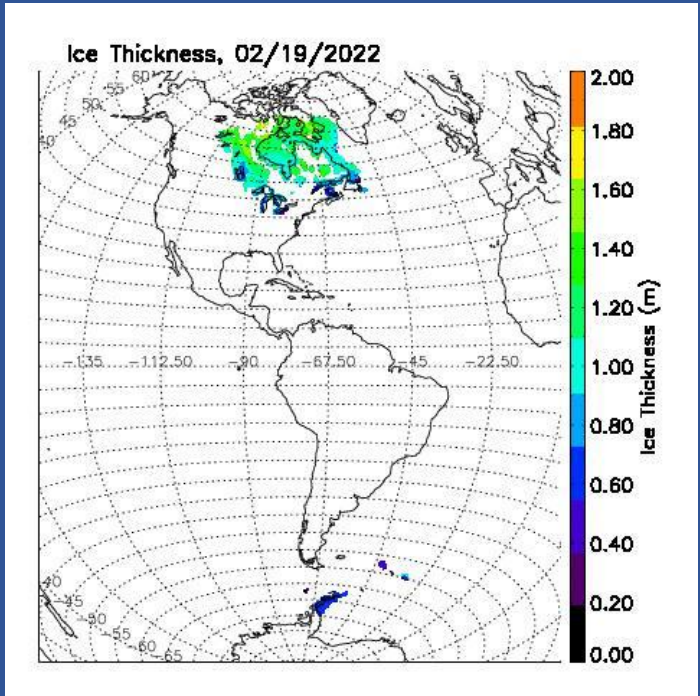
- Mission required ice age classification (3 categories) :

  Ice free (<0.1 cm), new/first year ice (0.1 ~ 180 cm), old ice (>180 cm).

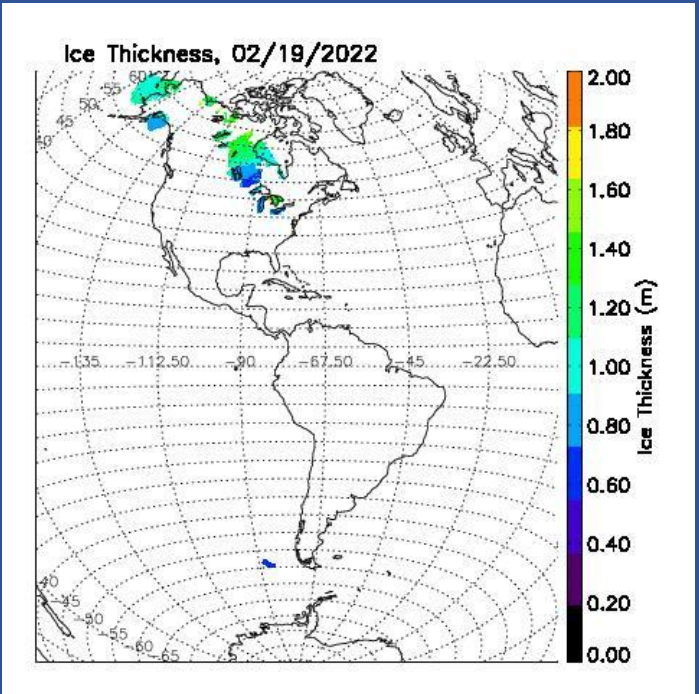
- More ice age classification (8 categories) :
  Ice free (<0.1 cm), new ice (0.1 ~ 10 cm), grey ice (10 ~ 15 cm), grey-white ice (15 ~ 30 cm), thin first ice (30 ~ 70 cm), median first year ice (70 ~ 120 cm), thick first year ice (120 ~ 180 cm), old ice (>180 cm).

Product Quality Evaluation/Validation

GOES-16, 2022-02-19, Ice Thickness



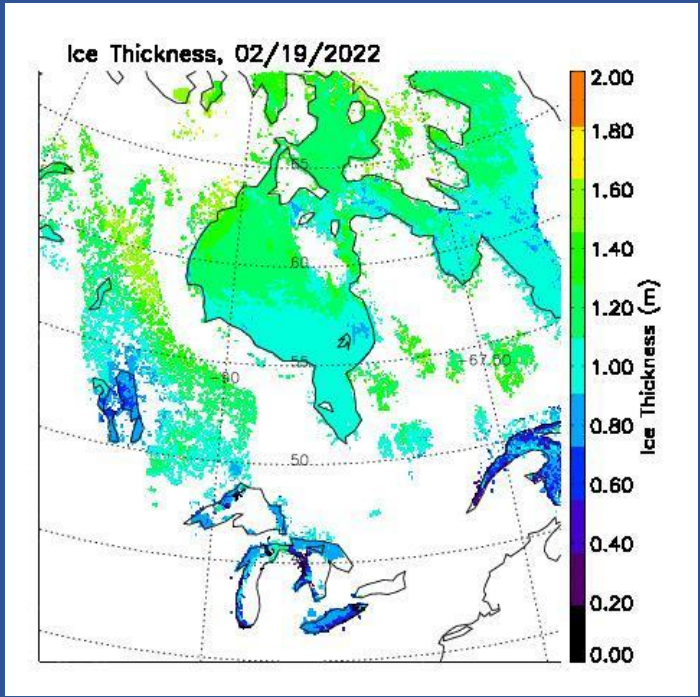
GOES-17, 2022-02-19, Ice Thickness



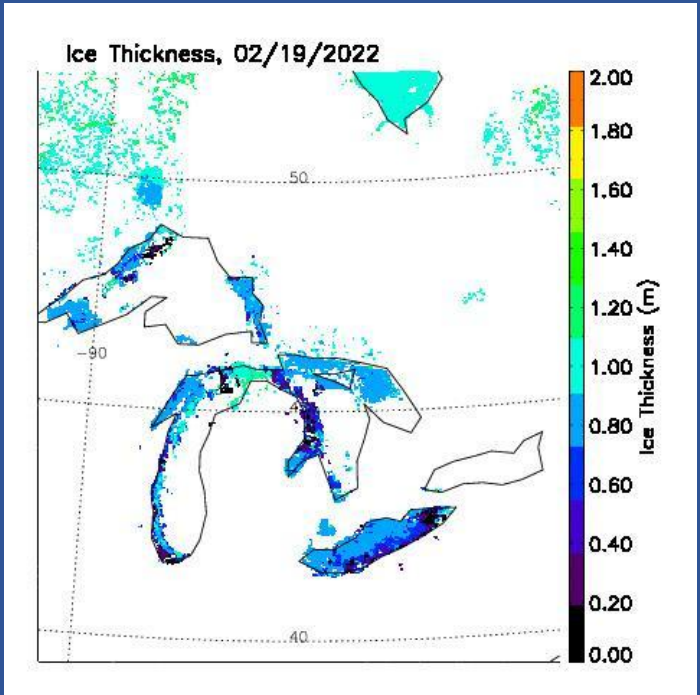
GOES-16 and -17 daily composite full disk ice thickness 0n Feb. 19, 2022.

Product Quality Evaluation/Validation

GOES-16, 2022-02-19, Ice Thickness



GOES-16, 2022-02-19, Ice Thickness



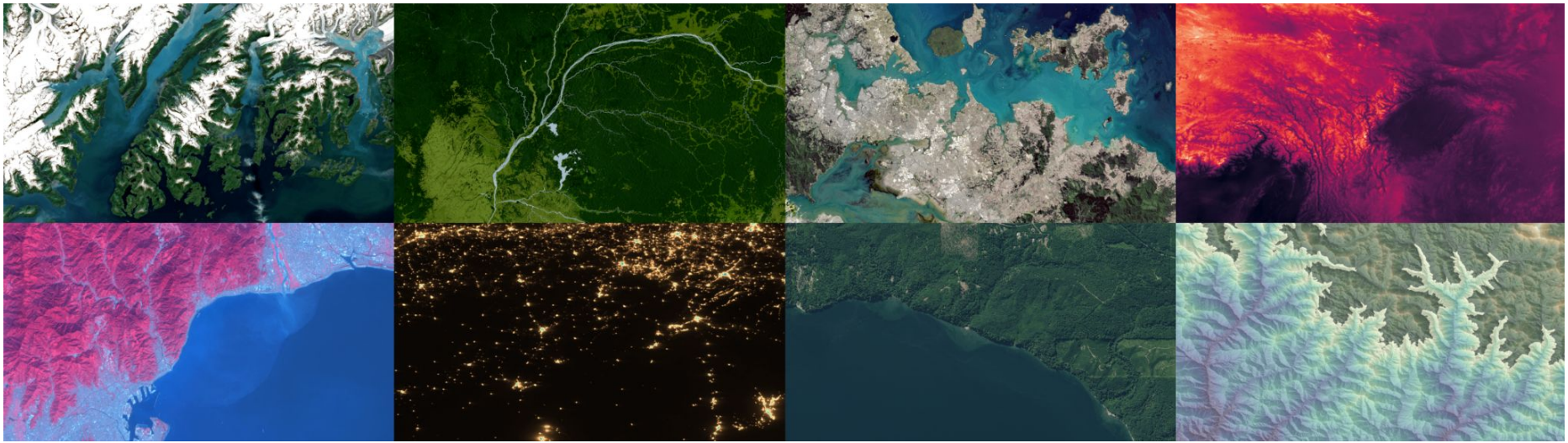
GOES-16 daily composite Hudson Bay (left) and Great Lakes (right) ice thickness on Feb. 19, 2022.

ABI Ice Thickness/Age: Summary

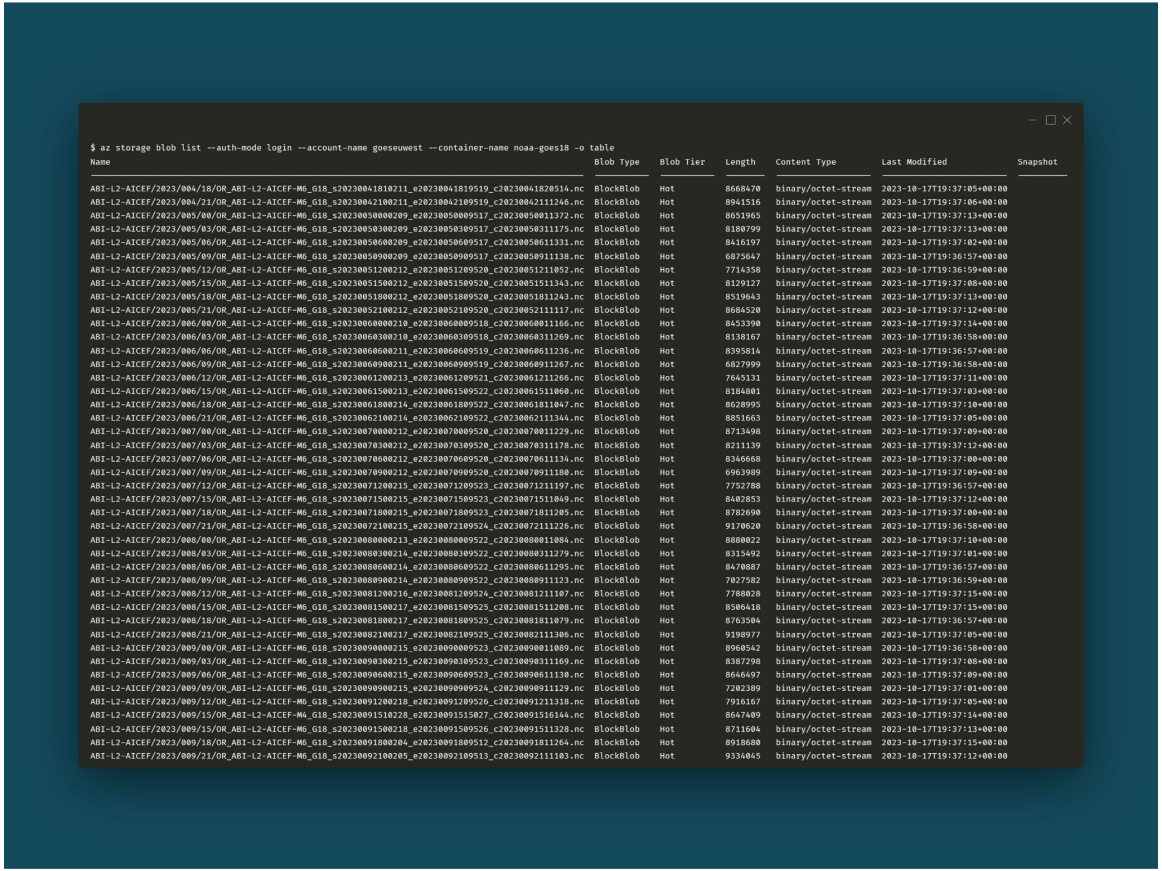
- With regard to the mission requirements, validating ice age categories (first-year and older ice) is simply a validation of the ice mask in the Great Lakes and Hudson Bay. Ice concentration validation showed that the ice mask has an accuracy well over 80%.
- Given that ice age is here defined in terms of ice thickness, we have gone beyond the basic requirement by validating ice thickness itself and additional age categories through comparisons to products from NIC ice chart, IceBridge ice thickness, VIIRS ice thickness, and more in the future.
- Overall, the GOES-R ice age/thickness product meets requirements. However, it appears that cloud contamination is still an issue.

Microsoft Planetary Computer

- About 60 PB of publicly available Earth Systems data
- STAC API for querying the data



What does 60 PB of data look like?



```
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Making data queryable

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)

search = catalog.search(
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    datetime="2022-07-23T01:00:00Z",
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)
items = search.item_collection()
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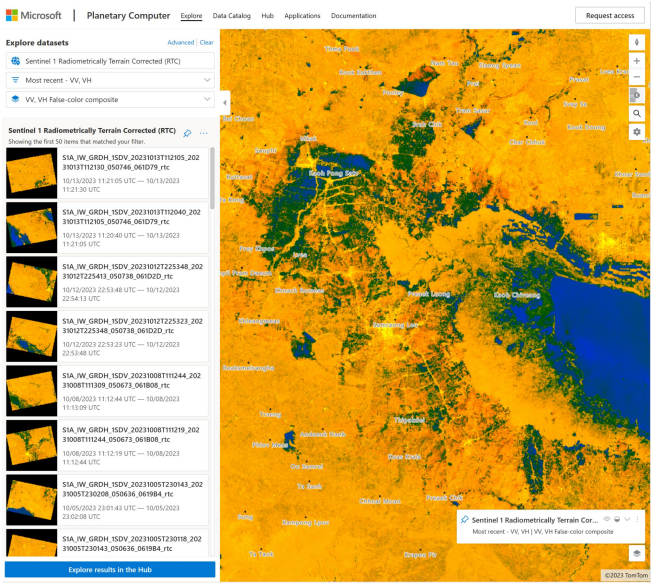
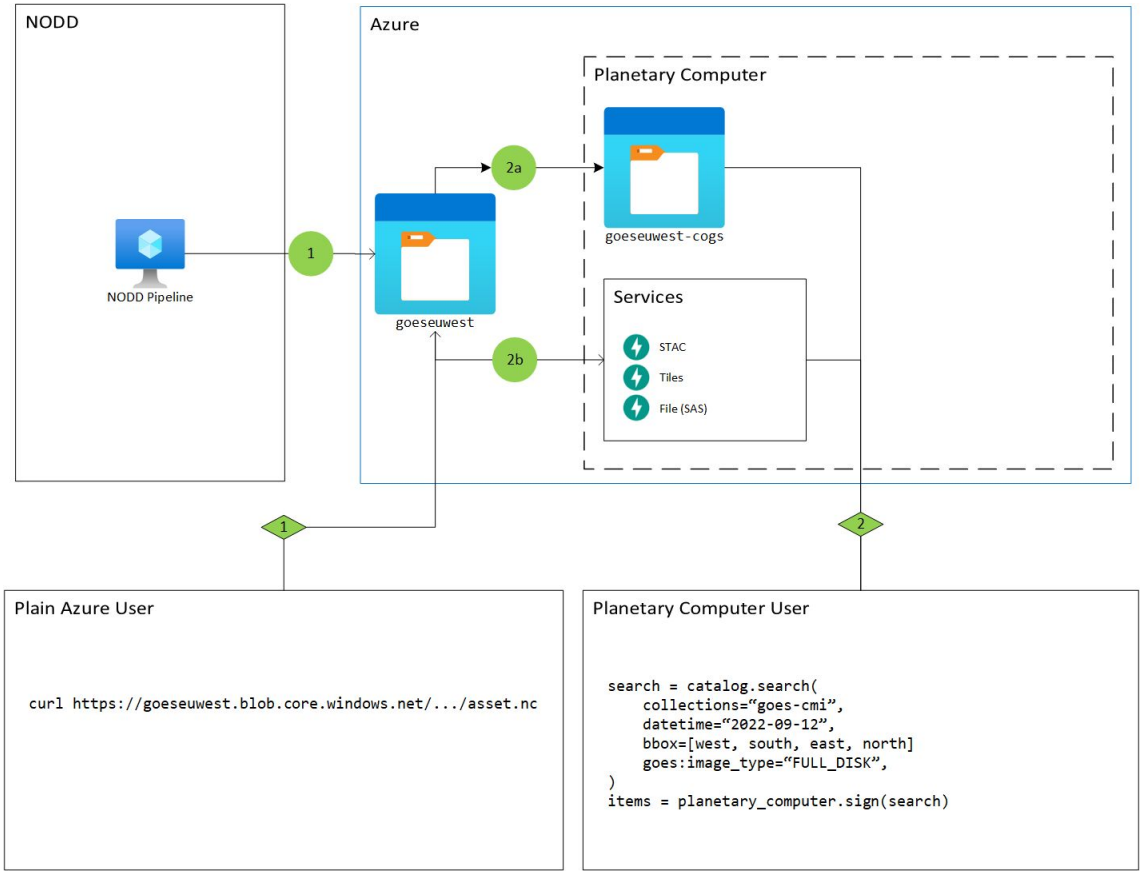
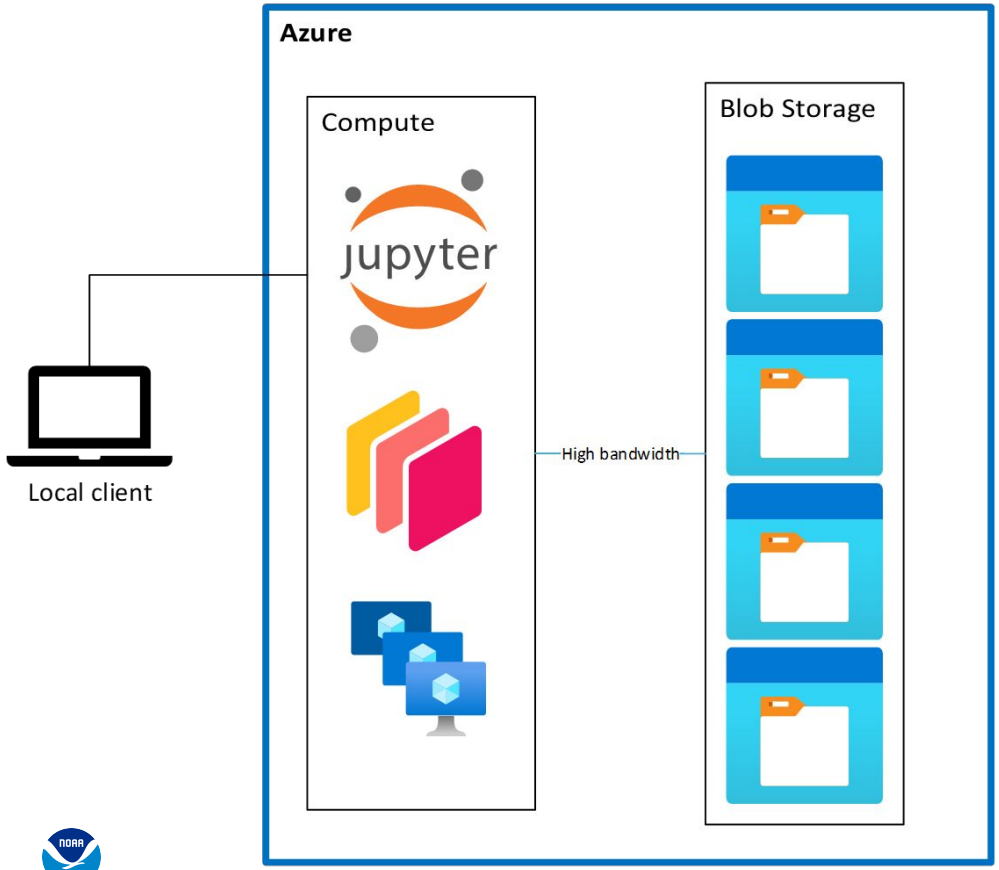


Planetary Computer & NODD



Cloud Native Geospatial



Demo

Questions and Discussion

- Please be brief in your questions / comments
- Use the chat or raise your hand for questions
- Identify who the question is directed to where possible
    - As questions are answered, we will go to the next in the chat queue and call on you to unmute yourself and ask your question.
    - We appreciate there may be questions that cannot be answered immediately and even those that we won't have an opportunity to get to: please be patient as we build our understanding and summary responses.

Resources

We invite you to stay engaged with NOAA!

- **NOAA GOES-R:**
  - https://www.goes-r.gov/
  - https://noaasis.noaa.gov/index.html
- **NOAA Open Data Dissemination:**
  - noaa.gov/nodd
  - Email: NODD@noaa.gov
- **Microsoft GOES-R:**
  - https://planetarycomputer.microsoft.com/
  - https://planetarycomputer.microsoft.com/catalog?filter=goes