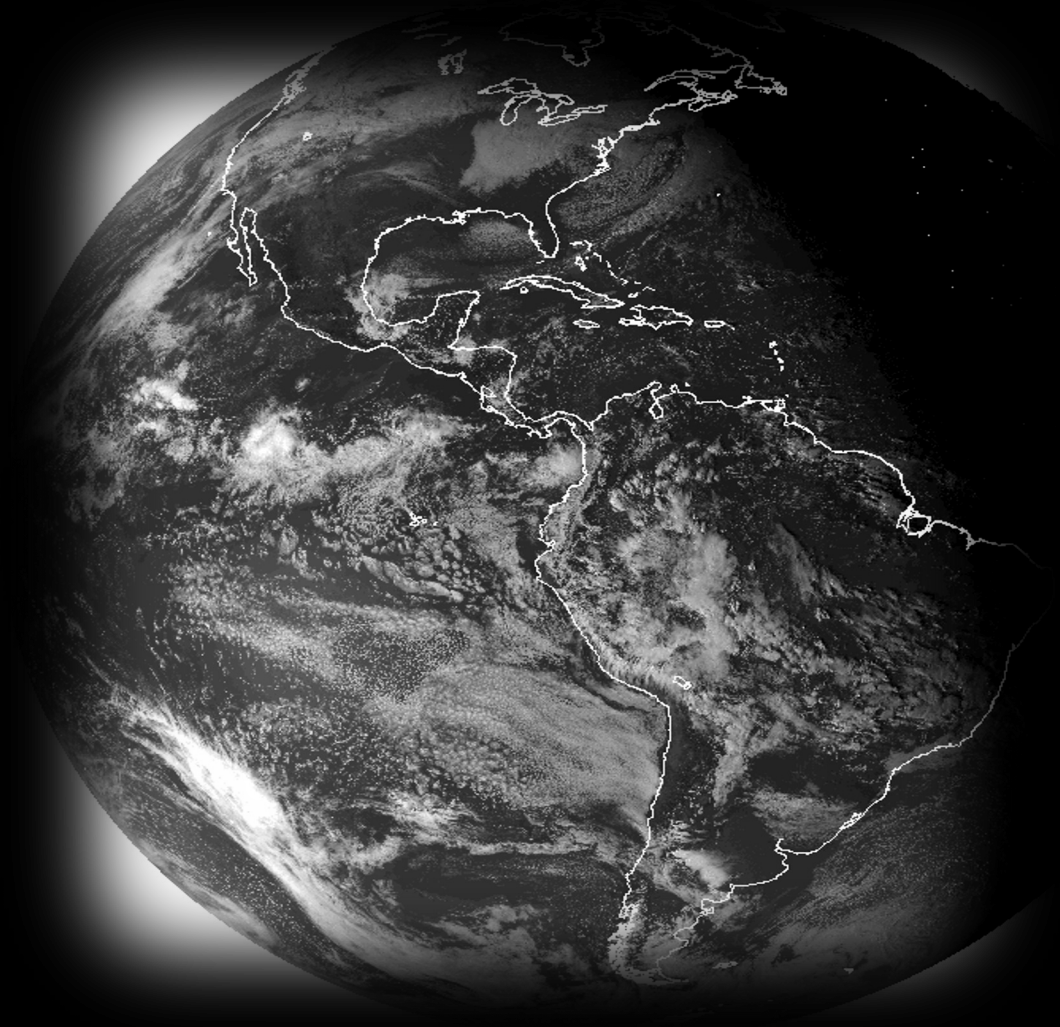
NASA Langley SatCORPS Global Cloud Composites from GEO and LEO



McIDAS User Group Meeting
Sept 25-26, 2023

Louis Nguyen, William Smith Jr.,
Douglas Spangenberg,
and rest of SatCORPS Team

NASA Langley Research Center
Hampton, VA, USA

The Satellite ClOud and Radiative Property retrieval System (SatCORPS)

SatCORPS team operates and utilizes a LEO and GEO imager data production and visualization system with global real-time and historical capabilities

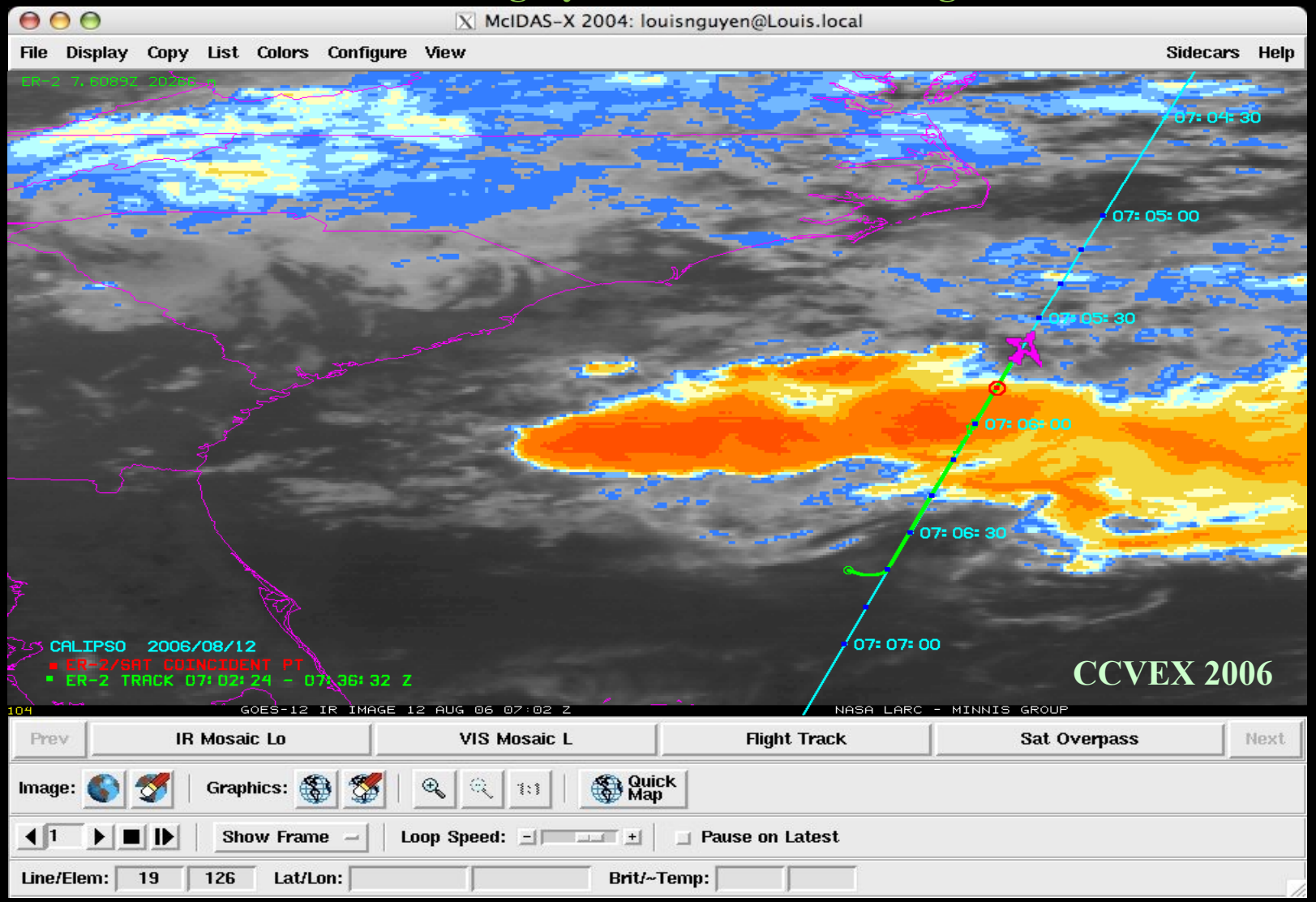
Conceived in 1990's to support climate programs

- NASA CERES (ERB), requires global
- DOE ARM

Near real-time and historical cloud analyses for research and operations

- Support field campaigns
- Cloud process research & model development (cloud parameterizations)
- Weather forecasting (e.g. cloud datasets sent to GSL/NCEP for assimilation)

Real-time full-res Imagery and Aircraft Tracking via McIDAS



The Satellite ClOud and Radiative Property retrieval System (SatCORPS)

Unique SatCORPS Data Products

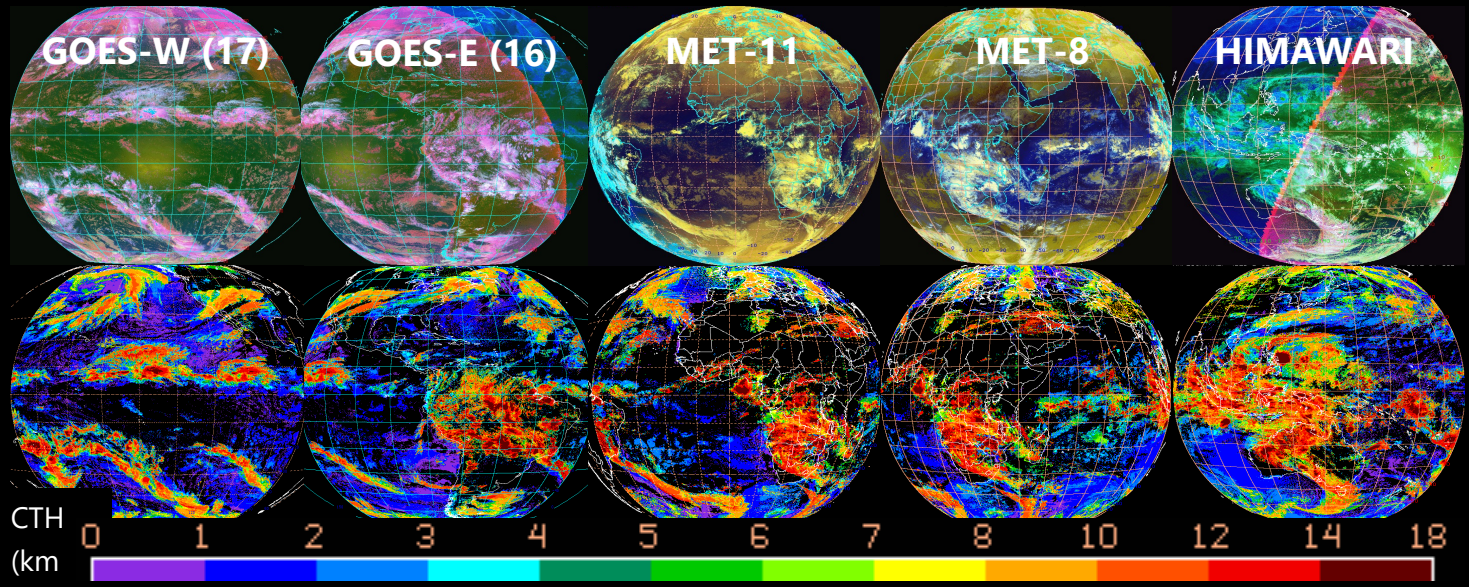
Traditional Standard Cloud Products

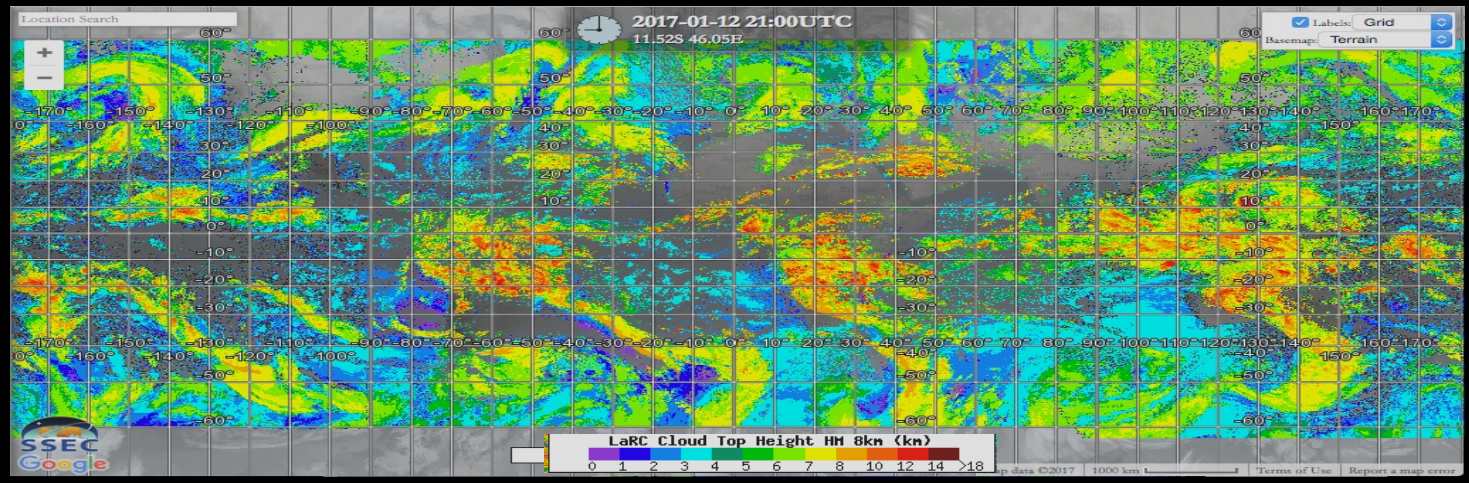
Channels: 0.65, 3.7, 10.8, 12.0 μm

- Cloud Mask, Thermodynamic phase
- Cloud Temperature, Height, Pressure
- Optical Depth, Effective Radius, Water Path
- Droplet number concentration

Innovative SatCORPS Data Products

- Cloud optical properties at Night
  - Physical retrieval for thin cloud optical properties
  - Machine learning for thick clouds (diurnally consistent)
- Cloud vertical structure
  - Cloud layering, thickness, base heights
  - Cloud water content profiles
- Radiative Fluxes (TOA and SFC)
- Surface Skin Temperature
- Aviation weather hazards & climate impacts
  - Icing and convection
  - Contrail optical properties, radiative effects

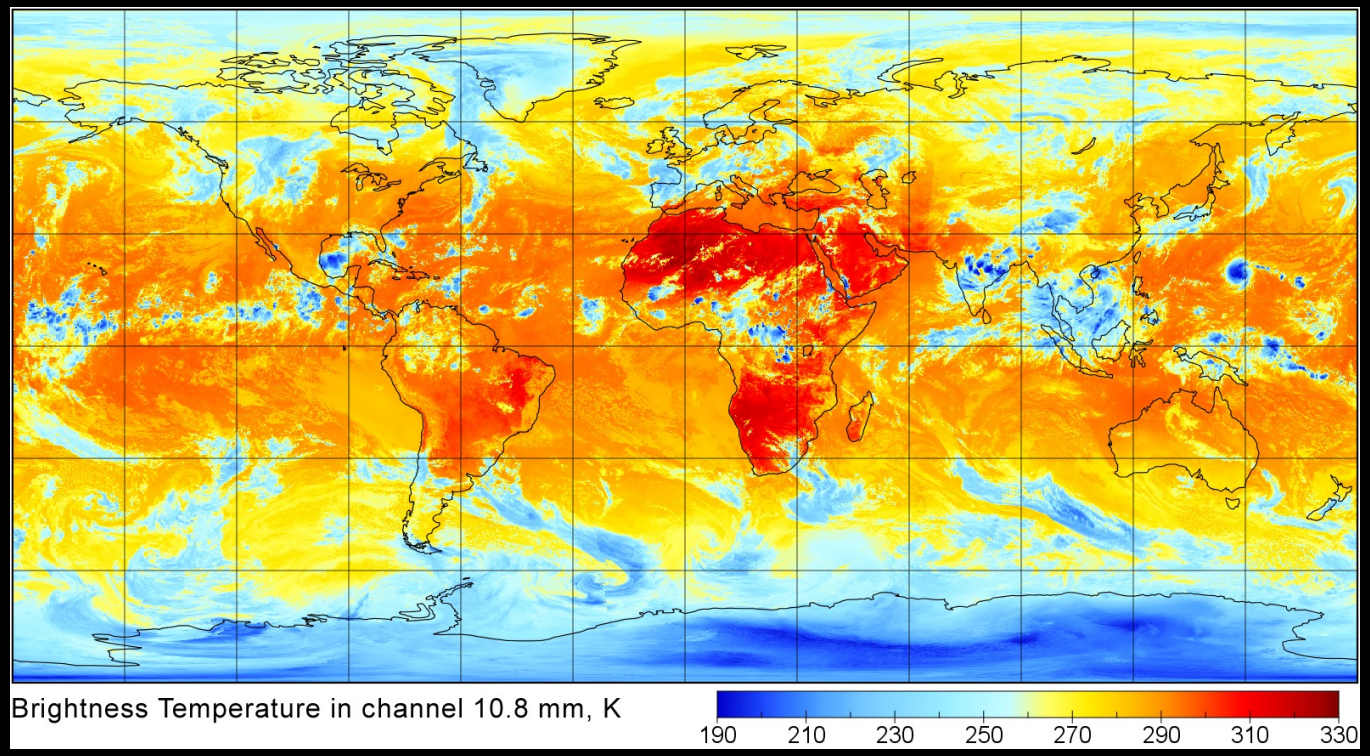




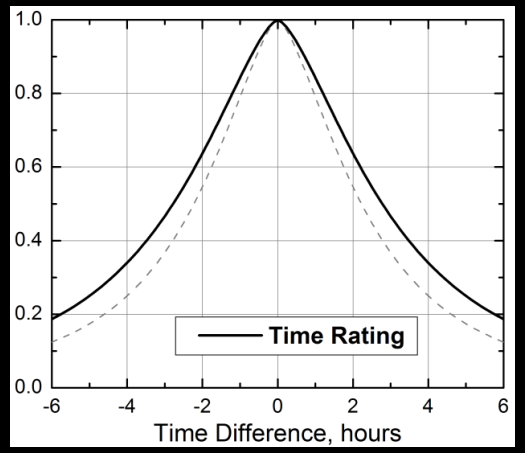
NRT half-hourly **GEO** Cloud Composite, 3km subsampled data products

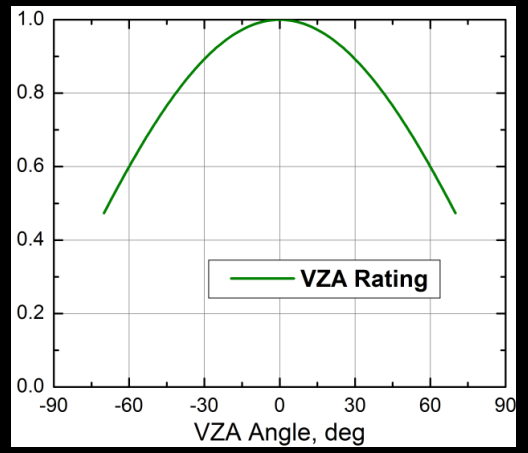
Pixel Ranking for Global Cloud Composite

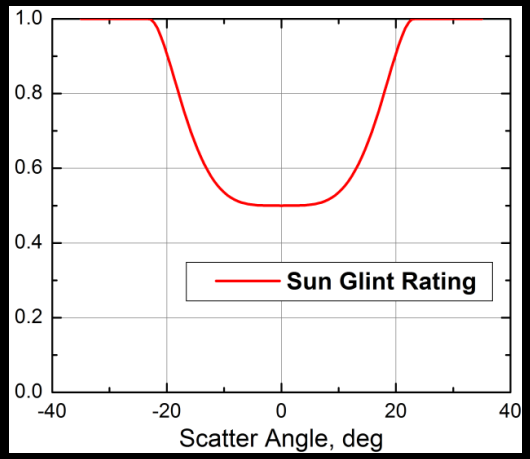
Global composite image of BT in 11 μm

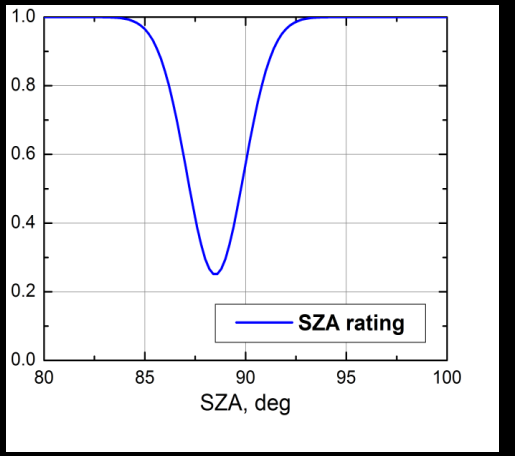


$$R = F_{\text{resolution}}\ F_{\text{terminator}}\ F_{\text{glint}}\ \frac{F_{\text{VZA}}}{\left(1+(\Delta t/\tau)^{1.5}\right)^2}$$



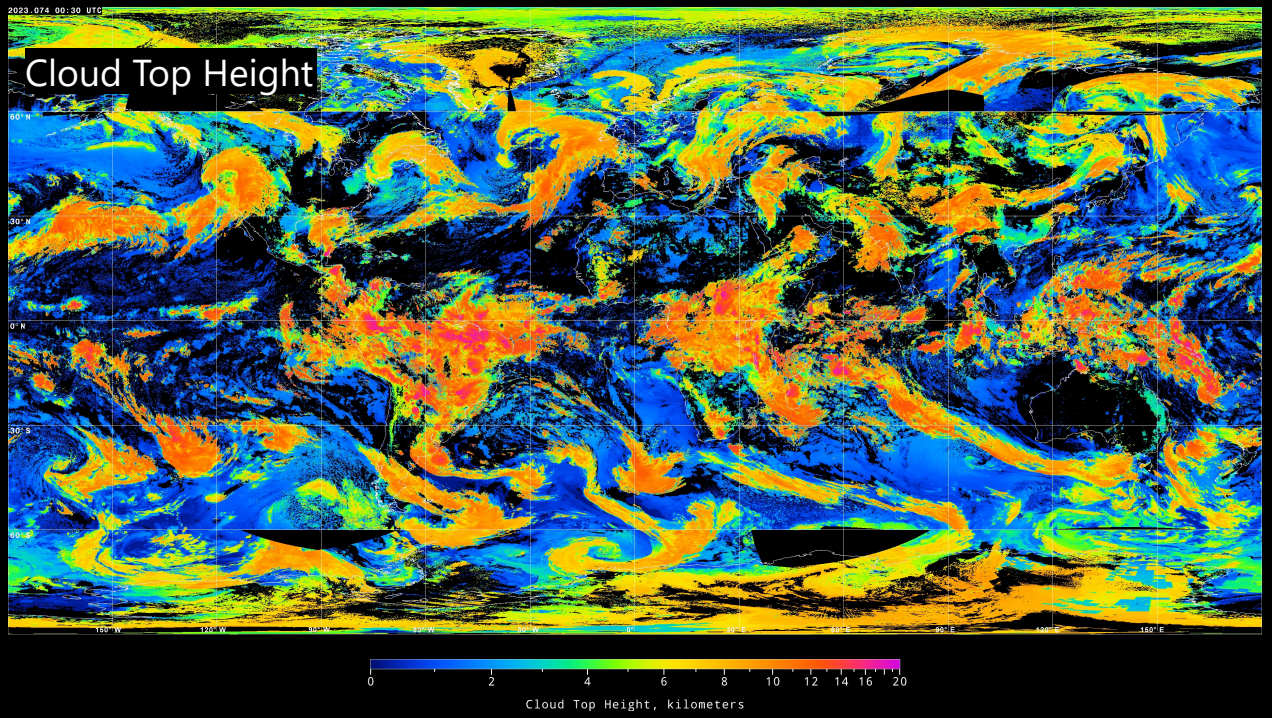


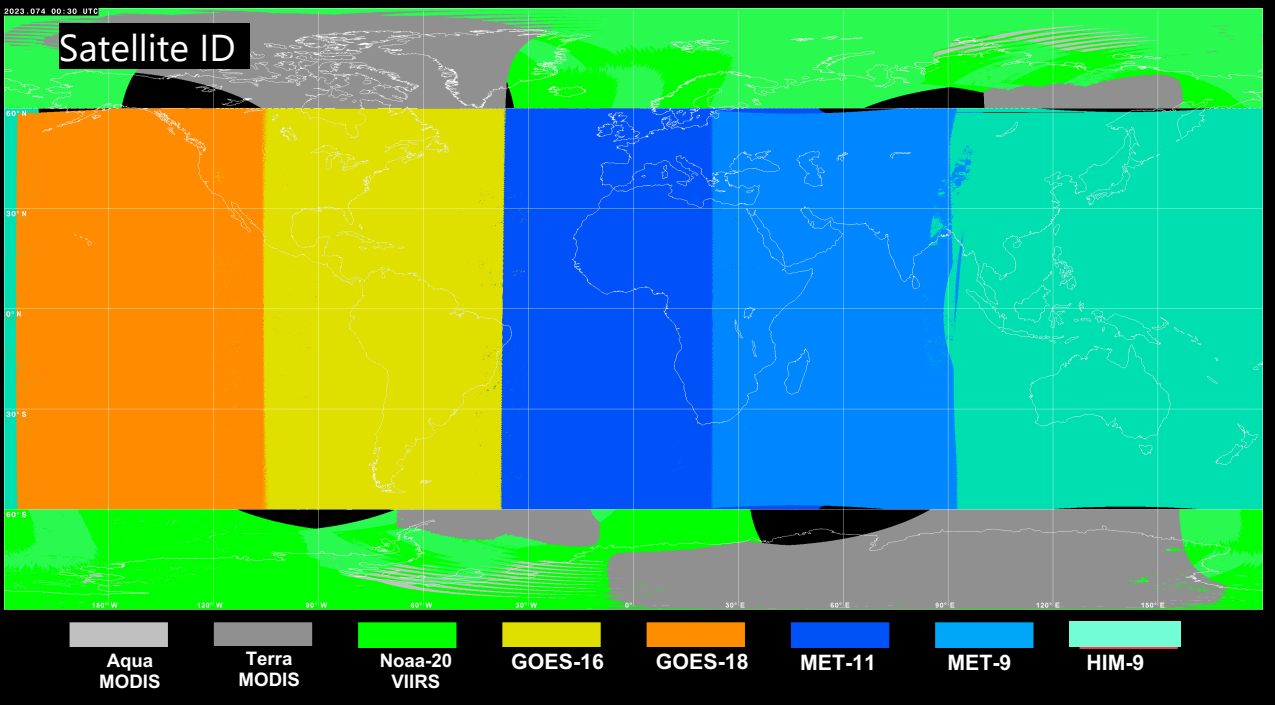




This rating approach allows merging of multiple input factors into a single number to be compared and enables higher flexibility in choosing between two candidate pixels.

Konstantin Khlopenkov et al.





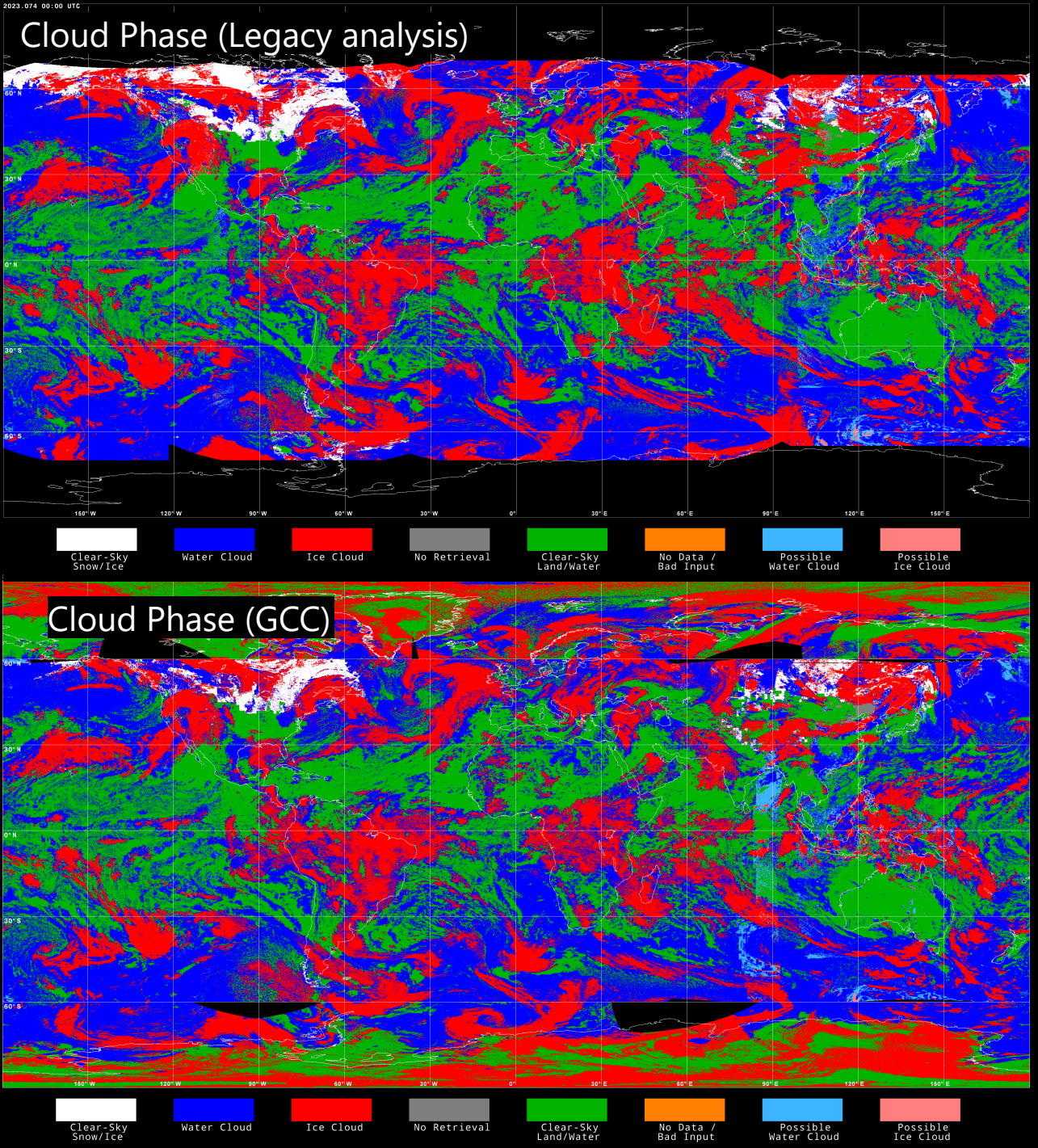
Global Cloud Composites (GCC) from Satellites

Objective: Optimally combines GEO and LEO radiances and derived products (cloud properties and radiative fluxes) as seamlessly as possible into a unified global data product

Legacy system is complex with many independent regional processes to support various applications.

New GCC system is streamlined enabling one overarching global data production system for most needs (Operational implementation in progress)

- 3-km gridded cloud properties every 30 minutes
- Many new cloud algorithm enhancements are being implemented that improve accuracies, cross-platform consistency, and reduce artifacts
  - New atmospheric corrections (satellite dependent)
  - Improved clear sky radiances & cloud detection
  - Reduction of solar terminator & sunglint artifacts
  - Improved day/night consistency



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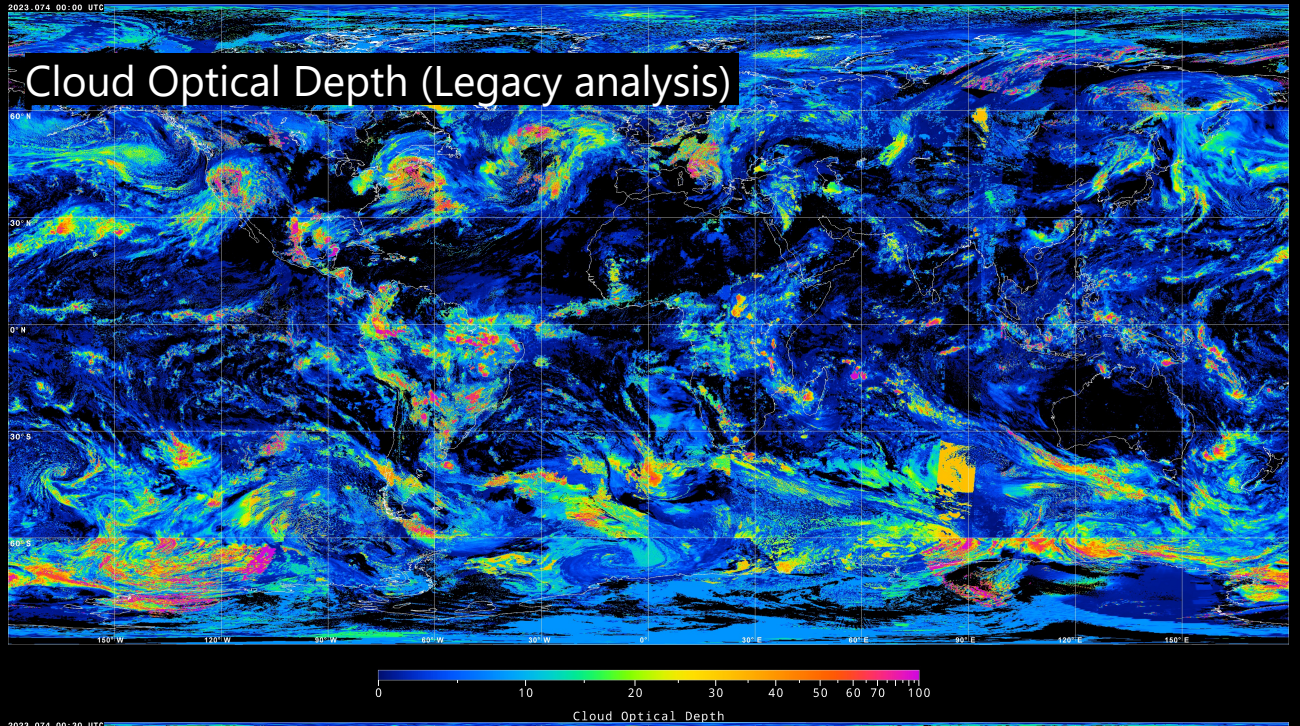

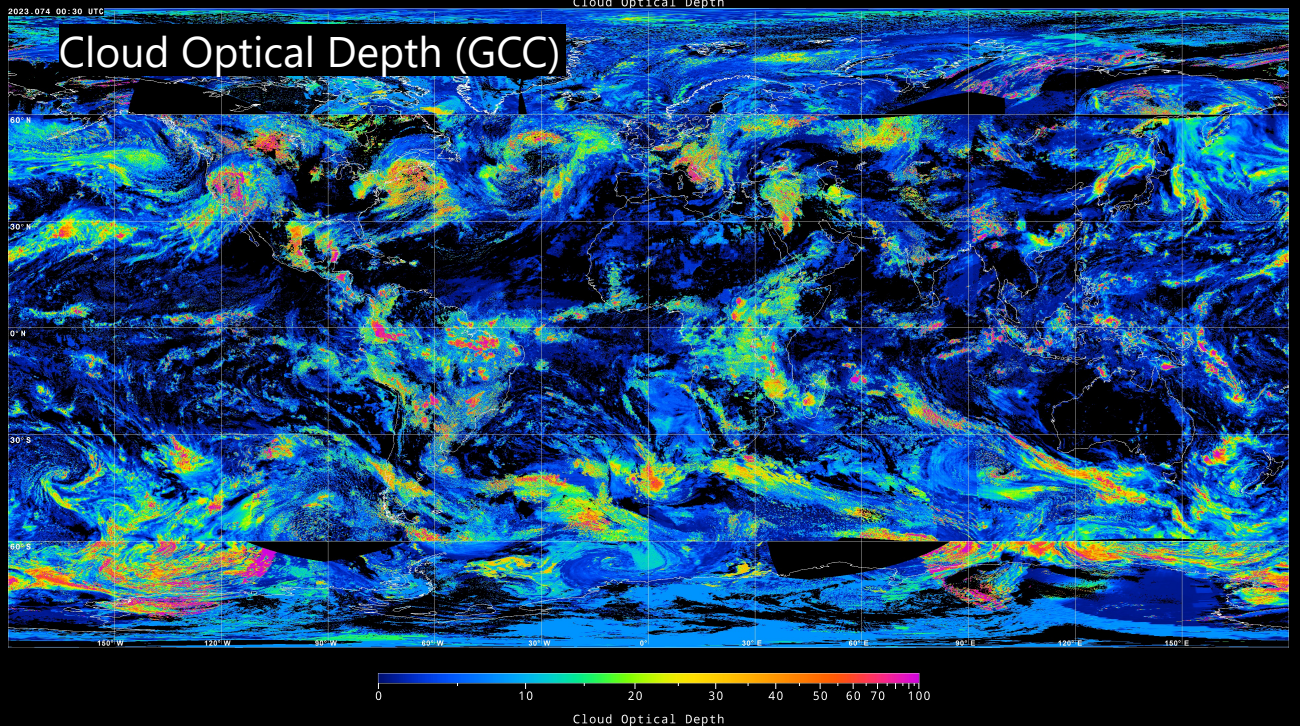

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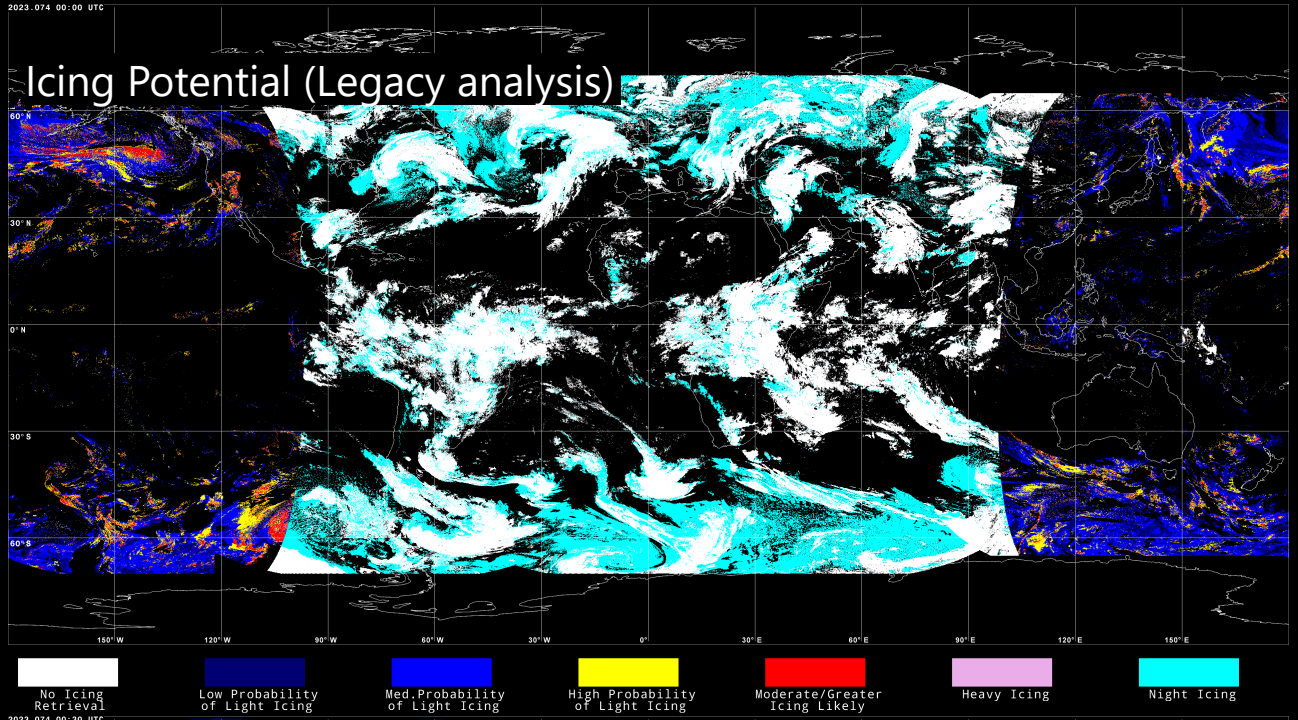

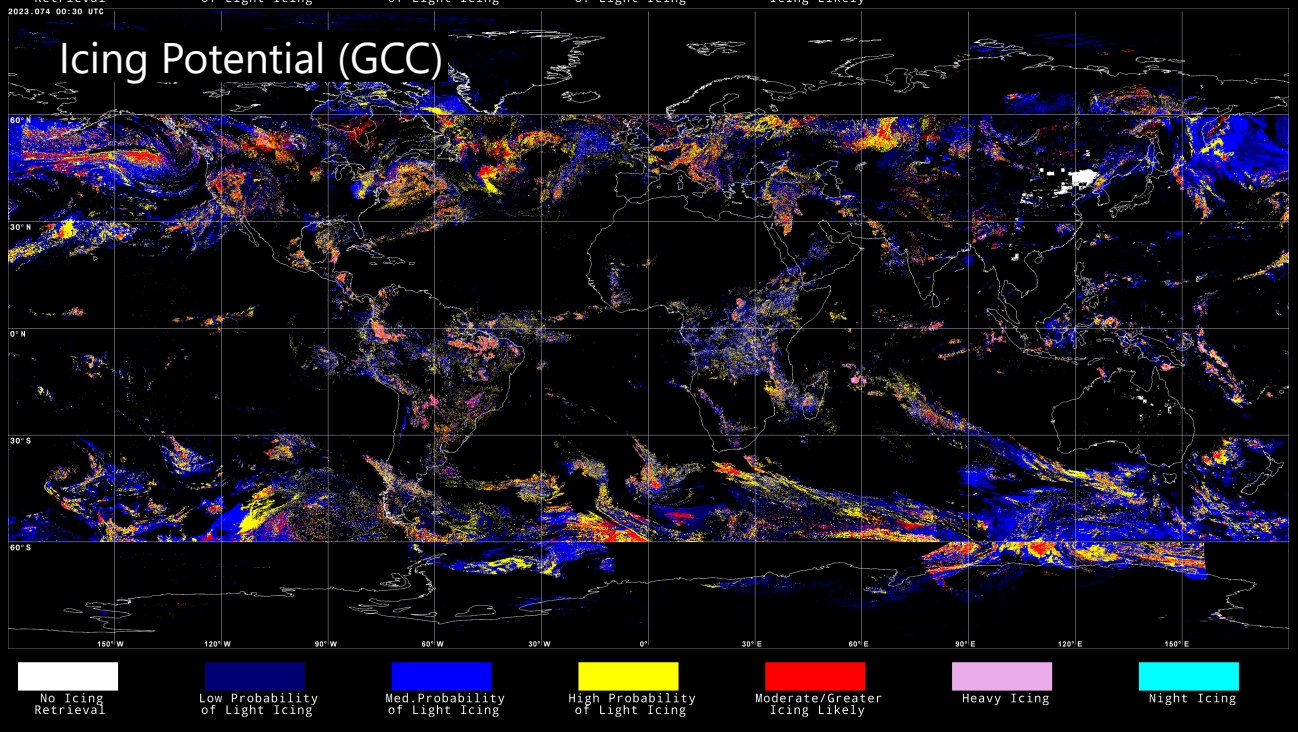

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Satellite Cloud/Icing Remote Sensing Challenges Being Addressed with **AI/ML**

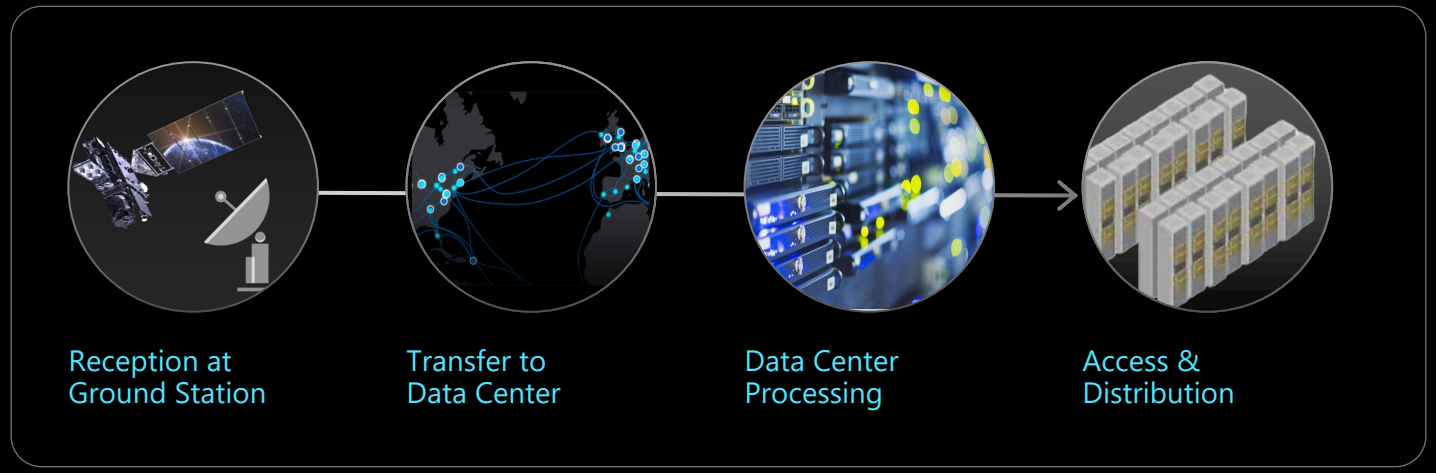
Problem Areas	AI/ML Approach
Image quality – bad scan lines in radiance imagery	Apply human visual or **CNN** QC for most cases and satellites; apply radiance reconstruction using **KNN** for severely corrupted images
Day/Night Consistency (cloud optical properties)	**ANN** to help overcome theoretical limits due to IR blackbody limit; **KNN** to extrapolate optical properties from daytime
Data products in the solar terminator and sun-glint	**KNN** to extrapolate information from surrounding space/time domain
Assumption that clouds are single-layer and have vertically homogeneous phase and PSD's	New IWP/LWP parameterizations that better account for cloud vertical structure; **ANN** for multi-layer cloud retrieval methods
Poor knowledge of land surface emission temperature (affects cloud mask and retrievals)	**DNN** to correct model reanalysis skin temperature based on correlations with satellite-derived values in clear conditions
Nighttime cloud detection in polar regions	**ANN** trained with CALIPSO data for application to MODIS/VIIRS
Cloud thickness and ceiling	Parameterizations based on CloudSat/CALIPSO groundtruth**;** **KNN** for satellite/ceilometer data fusion over U.S.

Active research areas to reduce uncertainties and improve the utility of data products

Reduced Latency LEO Satellite Data Processing using Ground Station Observation Network (GSON) Framework

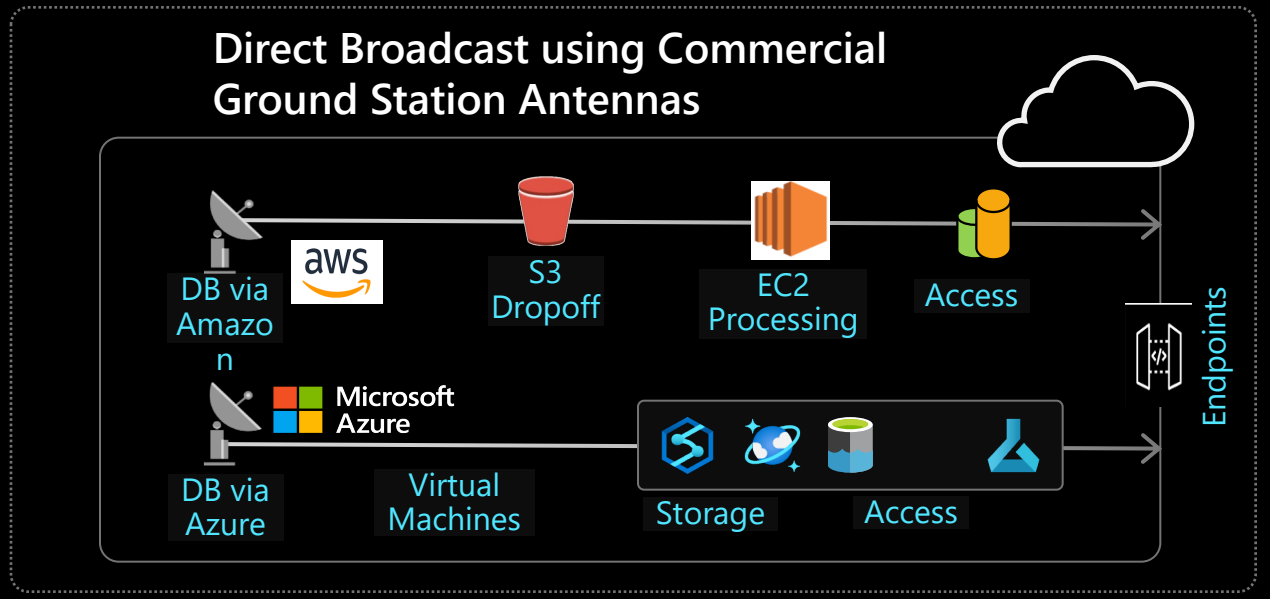
LEO data latency problem (3-6 hours) poses a significant impact on data product optimal use due to delay

Need to **improve data latency** to better support weather diagnoses and forecasting, disaster management (FIRMS), airborne science research, and other Earth Science applications



Solution to Improving Latency:

1. Use cloud-based open framework for satellite processing system
2. Use direct broadcast data capabilities using Amazon and Azure ground stations (15 min latency)
3. Use AWS Open Data Registry (global LEO coverage, 15-55 min latency)



Using Cloud Services to Reduce Latency

GSON Architecture Overview

LEO Data via AWS Cloud

SNPP

JPSS-1/ NOAA-20

Amazon Open Data Repo

GEO Data via RT Feed

GOES-W, GOES-E, MET-11, MET-8, HIM-8

GSON Processing Framework

LEO Data via Direct Broadcast

TERRA

AQUA

SNPP

JPSS-1/ NOAA-20

Amazon Ground Station

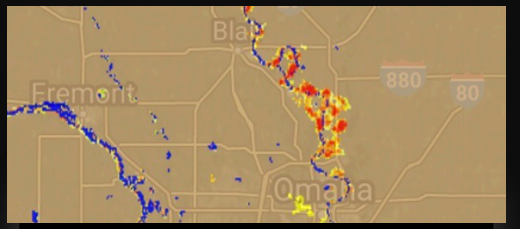
KSAT + Azure Orbital Ground Station

NASA SMCE Amazon Cloud

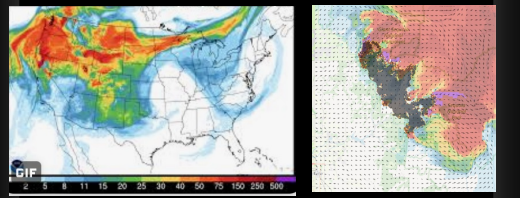
Microsoft Azure

Near Real-time Science Data Products

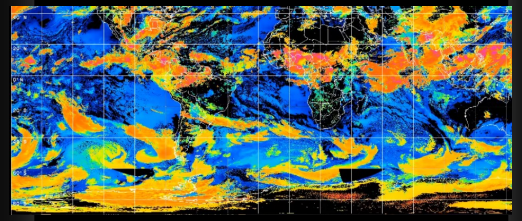
VIIRS Active Fires ~12min



VIIRS Flood Detection ~25min



4D Data Assimilation Forecast

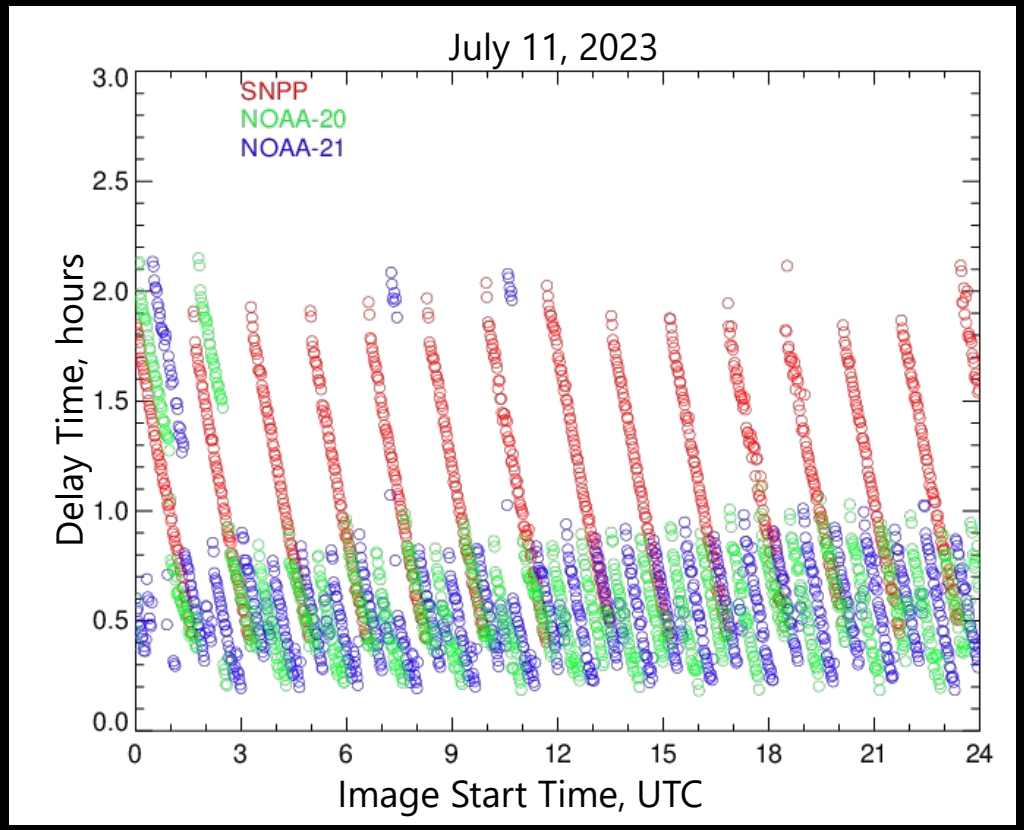


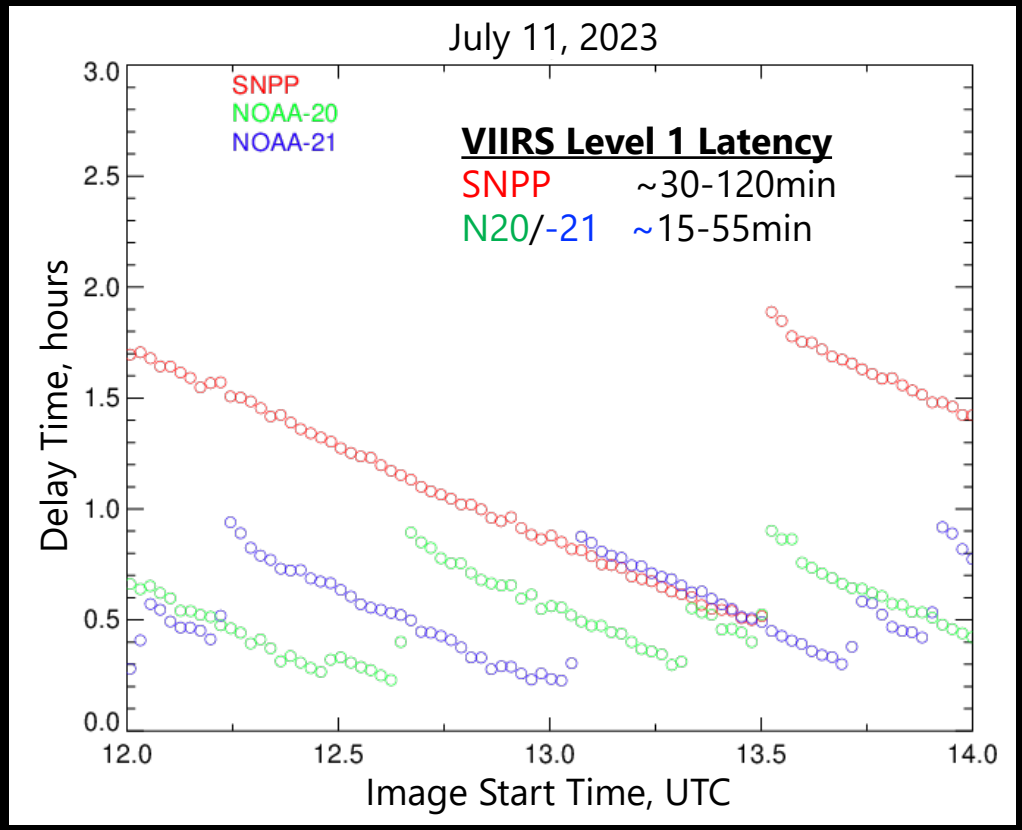
SatCORPS GEO+LEO Global Cloud

Use Amazon Open Data Registry to Reduce Latency

- Global access to VIIRS data:
  - https://registry.opendata.aws/noaa-jpss/

Data Latencies of SNPP/N20/N21 VIIRS L1 Granule on NOAA S3 Buckets





Granule Prediction Service for LEO Satellites

Authenticated User

Prediction

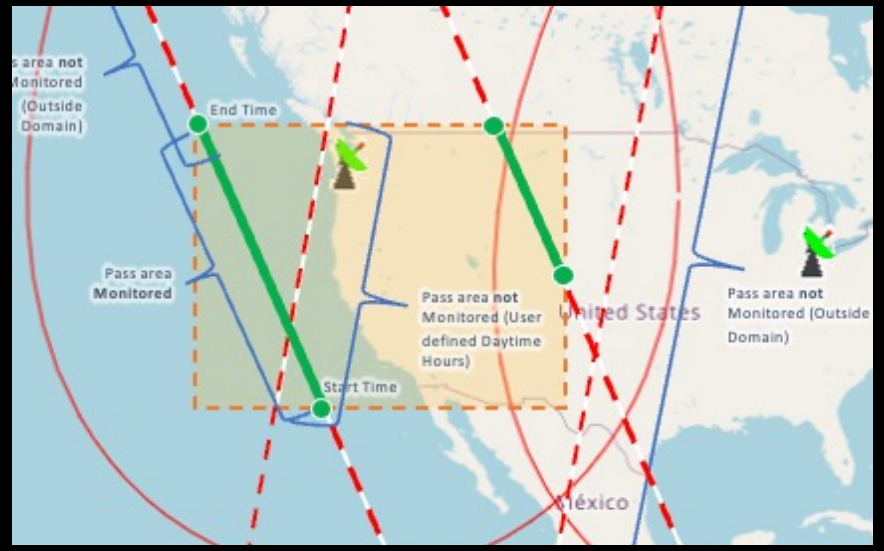
S3

Reservation

Subscription

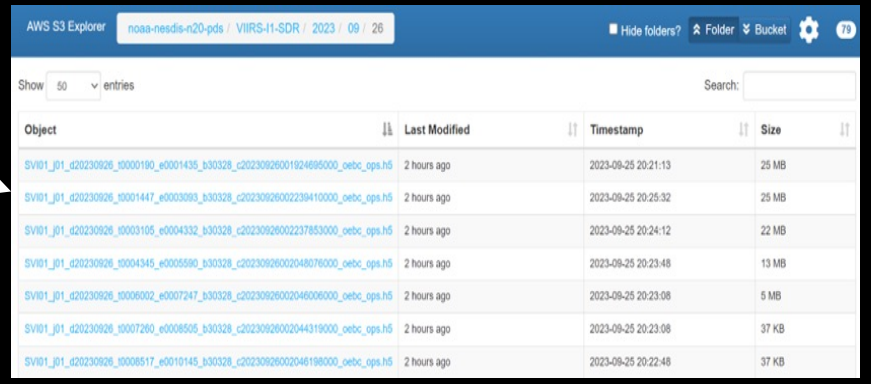
GSON API Service for matching Satellite Granules

- order with pass requirements (date range, vza, ROI, etc)



Supports Large Repositories (S3)

- Any event or instruments (VIIRS/MODIS, etc)
- S3 Lambda Event Monitoring Files



Returns List of Matches (JSON: File Names, URLs)

- System evaluates matches and orders on behalf of user

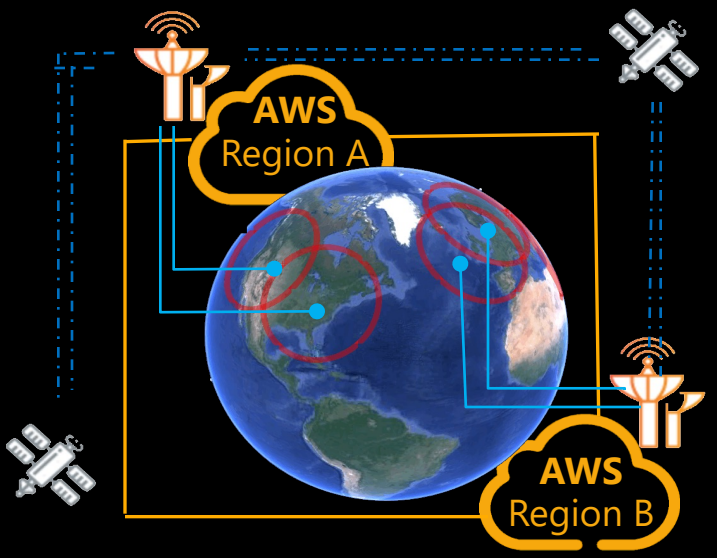
Subscription Service for Monitoring Real-Time Data

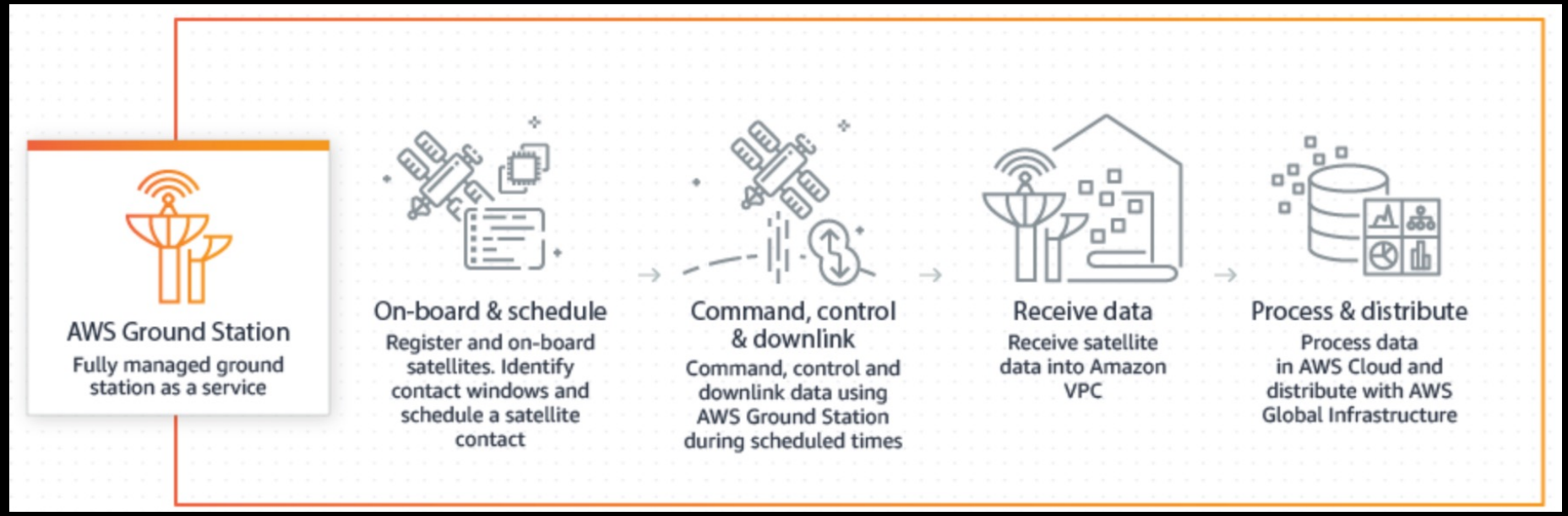
- Multiday request
- Dispatch message via SNS/SQS or Message Broker

Use Commercial Ground Stations to Reduce Latency

How Amazon Ground Station as a Service works

- Provides global network of ground stations
- On-boarding and Scheduling
- Downlink direct broadcast data
- Allows uplink for command and control
- DB data received by VPC instance
- Data delivered to S3 for processing/distribution



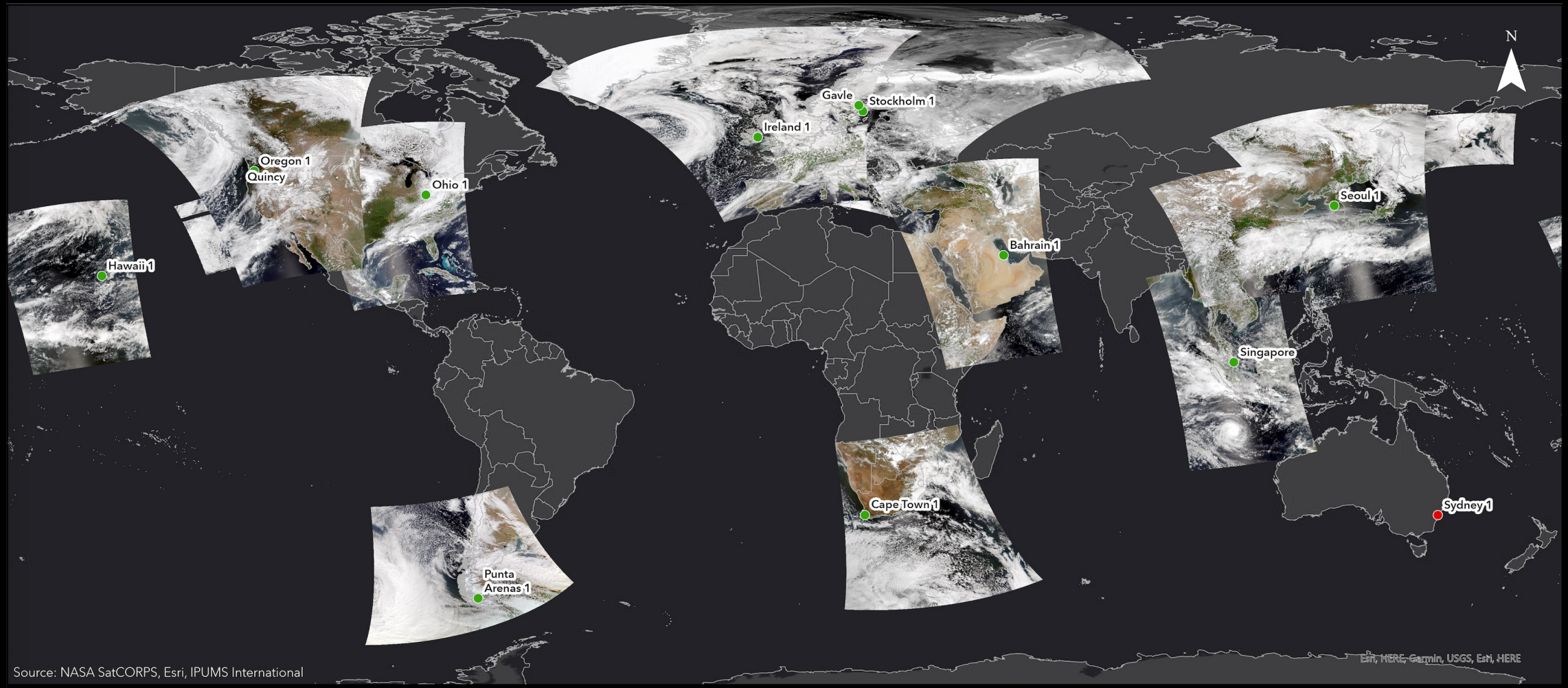


Ground Station Coverage from Amazon and Azure

Successful VIIRS Direct Broadcast Capture using GSON System

Amazon
- Ohio
- Oregon
- Bahrain
- Stockholm
- Dublin
- Hawaii
- Cape Town
- Seoul
- Punta Arenas
- Sydney

Azure
- Quincy,
- Gavle,
- Singapore
- S. Africa



0 1,500 3,000 6,000 Kilometers

GSON VIIRS Sample Products

Ground Station Observation Network (GSON) | NASA Langley Research Center

February 2023

- World Boundaries
- On-Boarded Ground Station
- To Be On-Boarded Ground Station

SatCORPS GIS | Transformation & Distribution

Analysis Ready Data (ARD)

- Rolling 2-week data parameters stored in cloud-optimized format and full archive access
- Built with transpose to provide more-efficient time series retrieval
- Global composite and regional mosaic availability

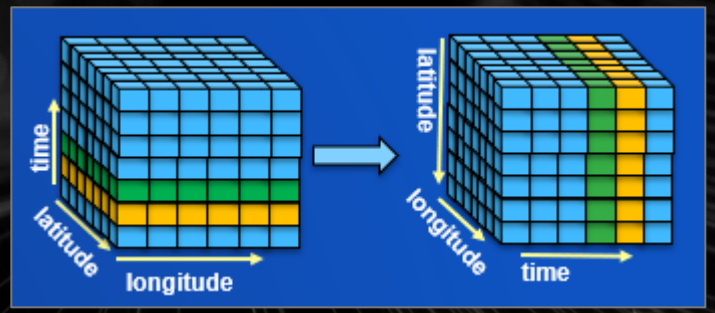
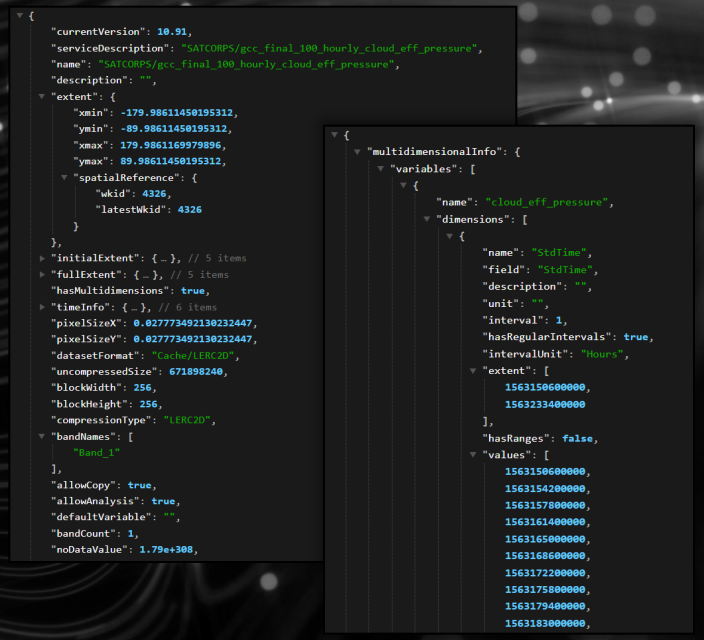


Image Source: Esri

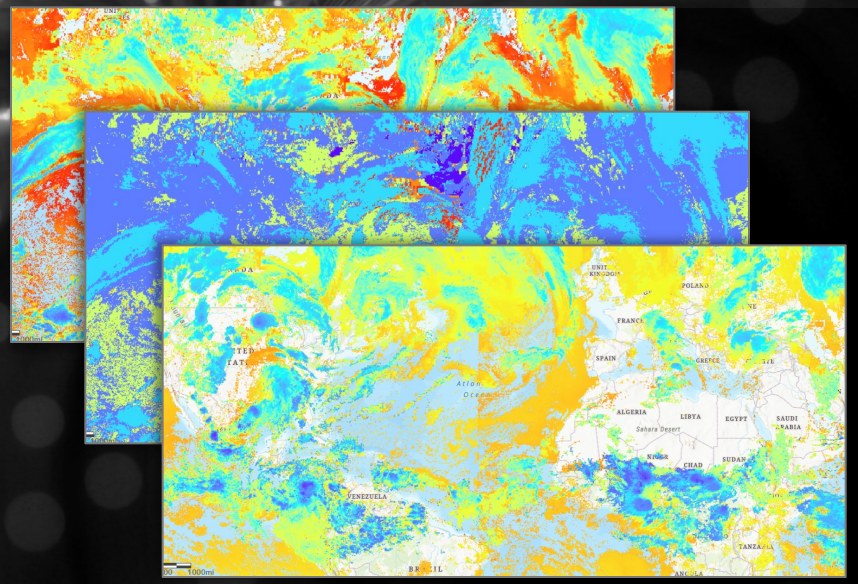
Cloud Raster Format with Transpose

Geospatial Services

- ~28 Multidimensional (time-enabled) parameter-level geospatial services as global and regional composites
- Exposed as RESTFul APIs, ArcGIS Image Services, & Open Geospatial Consortium (OGC) Web Mapping Services/Web Coverage Services, OpenDAP, ADDE



RESTful API Endpoint



ArcGIS Image Services & OGC WMS/WCS

SatCORPS GIS | Visualization & Analysis

- Currently Under Development -

Data Layer Manipulation

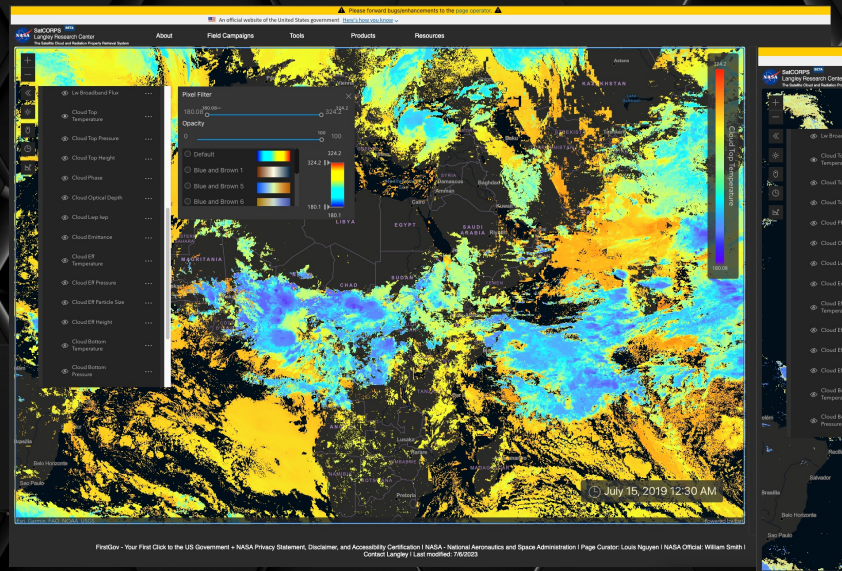
- Layer transparency settings and raw pixel value identification
- On-the-fly filtering of pixel values to identify areas of interest

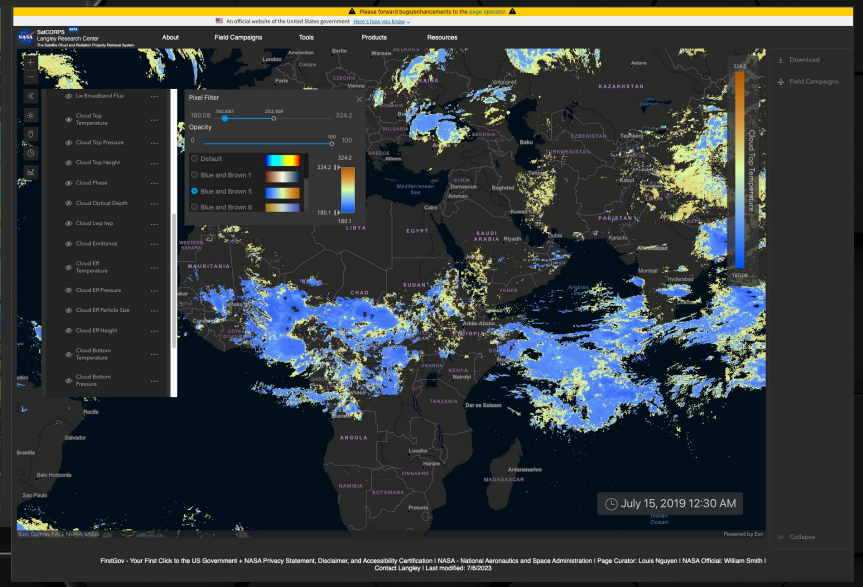
Multidimensional Analysis

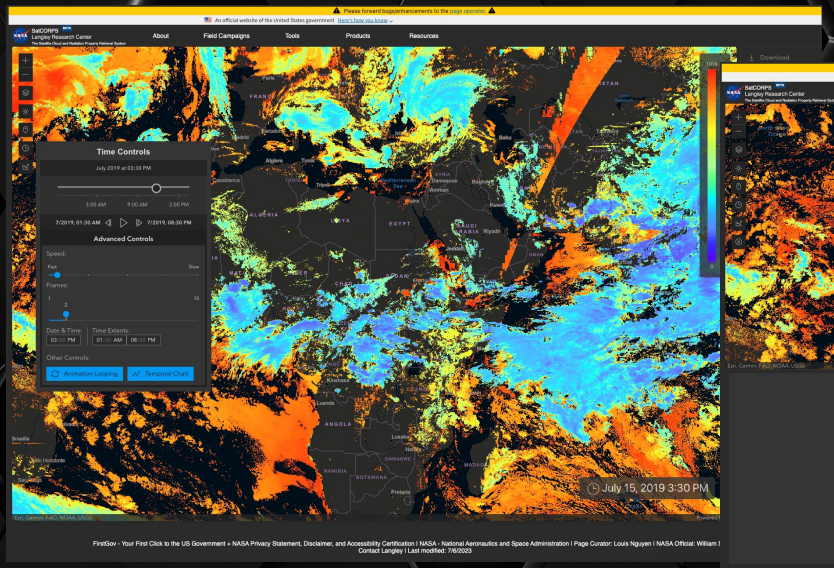
- Single point time series across 2 week rolling ARD service
- Time slider and user-defined animation functionality

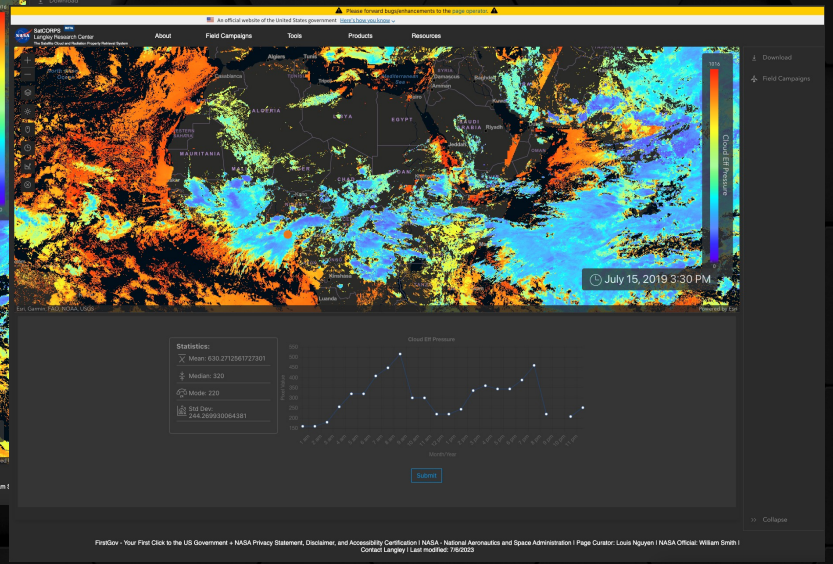
Parameter Subsetting

- Regional bounding-box subsettting delivering customized NetCDF/JSON









Questions? Thank you!

- SatCORPS Website: https://satcorps.larc.nasa.gov/indexV2.html
- Near Real-time SatCORPS Global Cloud Composites expected to go into production by end of C2023