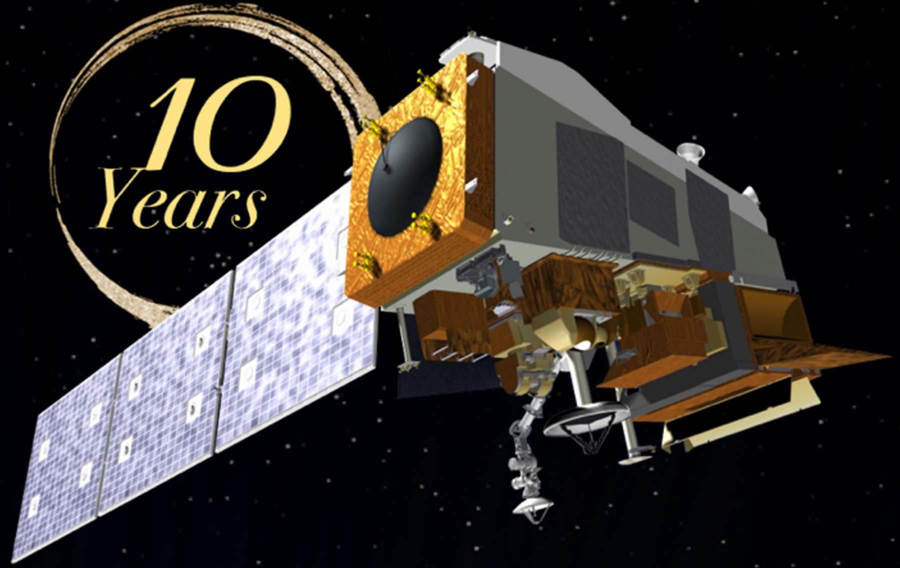
JPSS: Celebrating A Decade of Successful Operations of SNPP and Preparing for JPSS-2 Launch

Revolutionized Earth observations in LEO orbit



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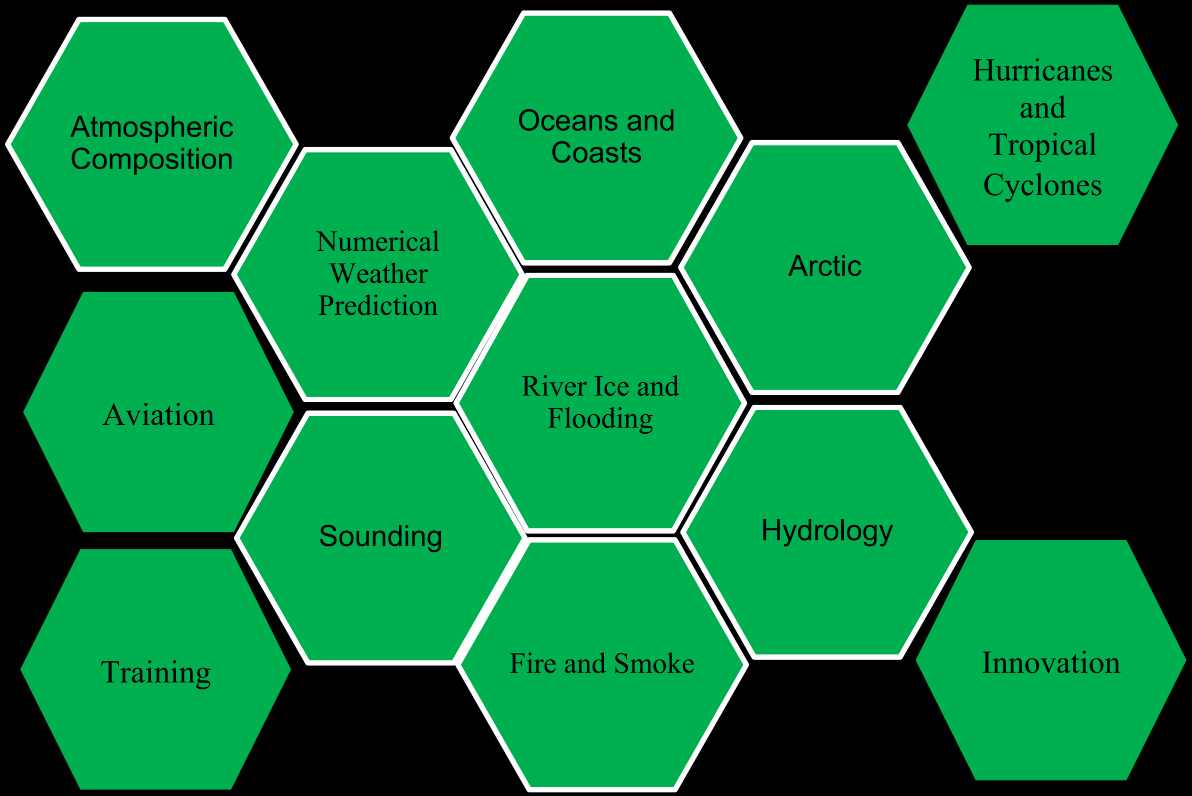
Outline

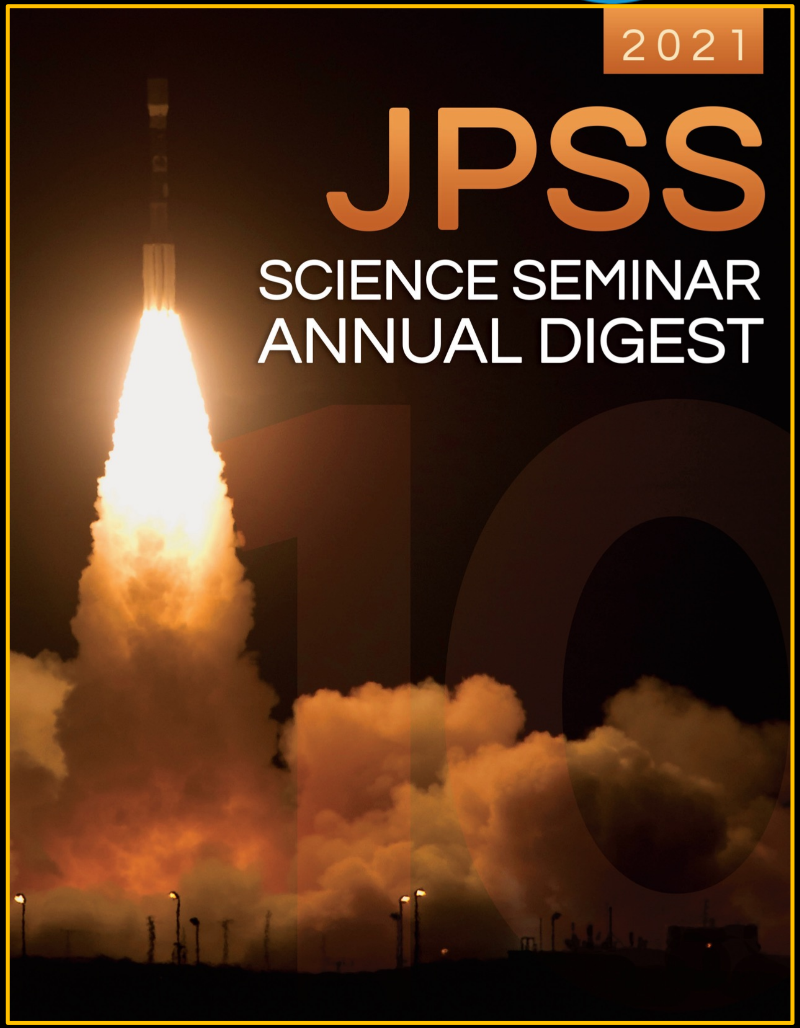
- 10 years of achievements of SNPP
- Status of the JPSS mission
- Introduction and status of LEO Program

SNPP Background

- October 28, 2021, marks the successful 10th anniversary of the SNPP satellite
- A a critical risk reduction and preparatory mission for the Joint Polar Satellite System (JPSS).
- CrIS and ATMS from SNPP were pathfinder and risk reduction activities for data assimilation of soundings from the new generation polar weather satellites within Numerical Weather Prediction (NWP) models.
- ATMS provides improvements from the heritage AMSU instruments that are still operating beyond their original mission like on legacy POES satellites.
- CrIS is NOAA’s first hyperspectral IR sounder.
- VIIRS provides improvements from its heritage on MODIS and ensures continuity to MODIS well in to 2040. A game changer for NOAA compared to AVHRR.
- OMPS fulfill the U.S. treaty obligation to monitor global ozone concentrations with no gaps in coverage and has heritage in TOMS and SBUV.
- All SNPP sensors operating nominally except CrIS that suffered an anomaly in May 2021 and has since been collecting SW and LW radiances only.

Data Exploitation and User Engagement





JPSS Proving Ground and Risk Reduction (PGRR) enables NOAA and Partner Stakeholder needs for data exploitation through:

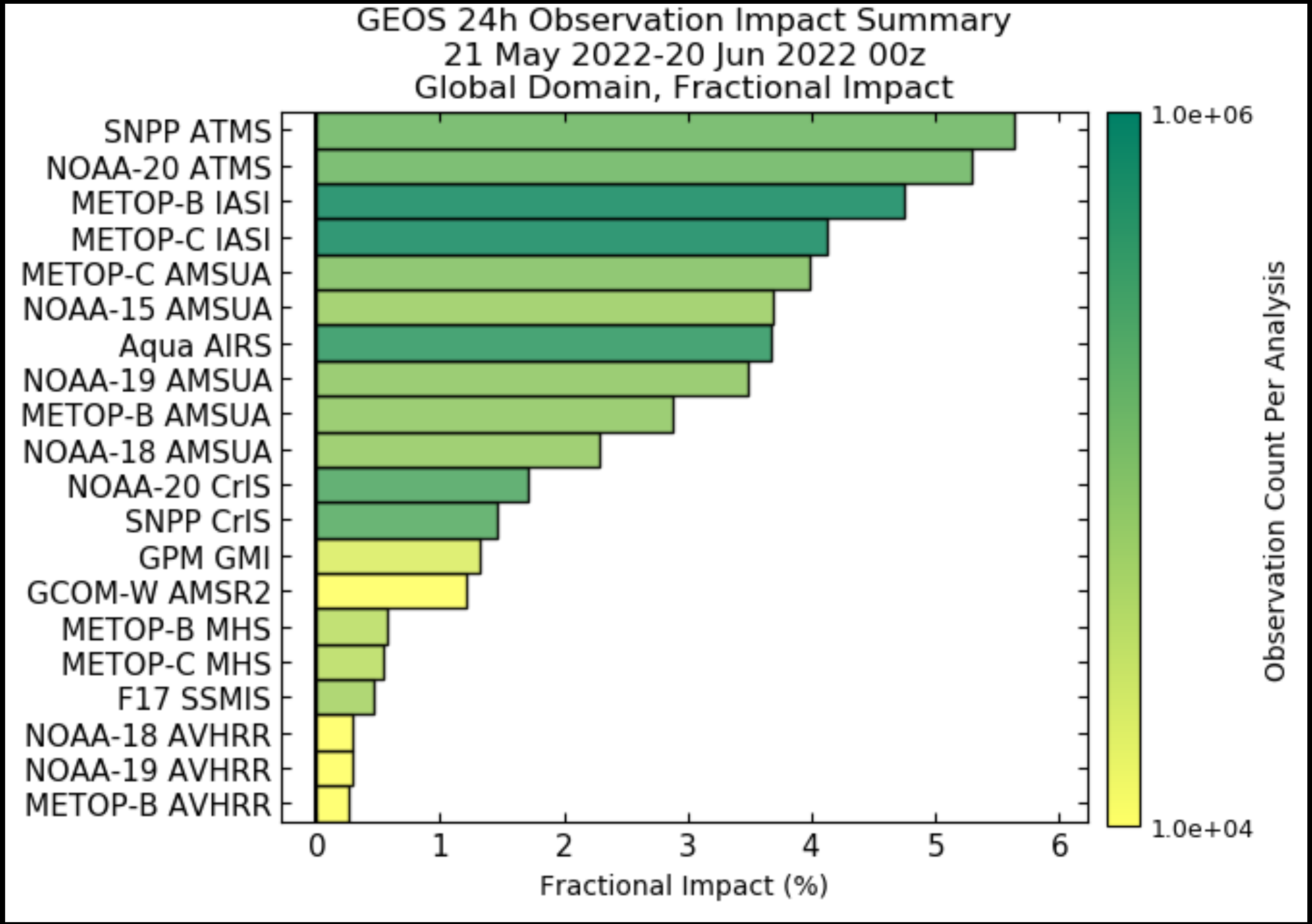
- Proving Ground: Demonstrations in user environments
- Risk Reduction: New research and applications to maximize mission benefits
- Innovation: Improvements/ Opportunities beyond the original mission objectives
- Training: Enabling effective use of the data

https://www.jpss.noaa.gov/assets/pdfs/science_publications/2021_science_seminar_digest.pdf

Important Milestones For SNPP

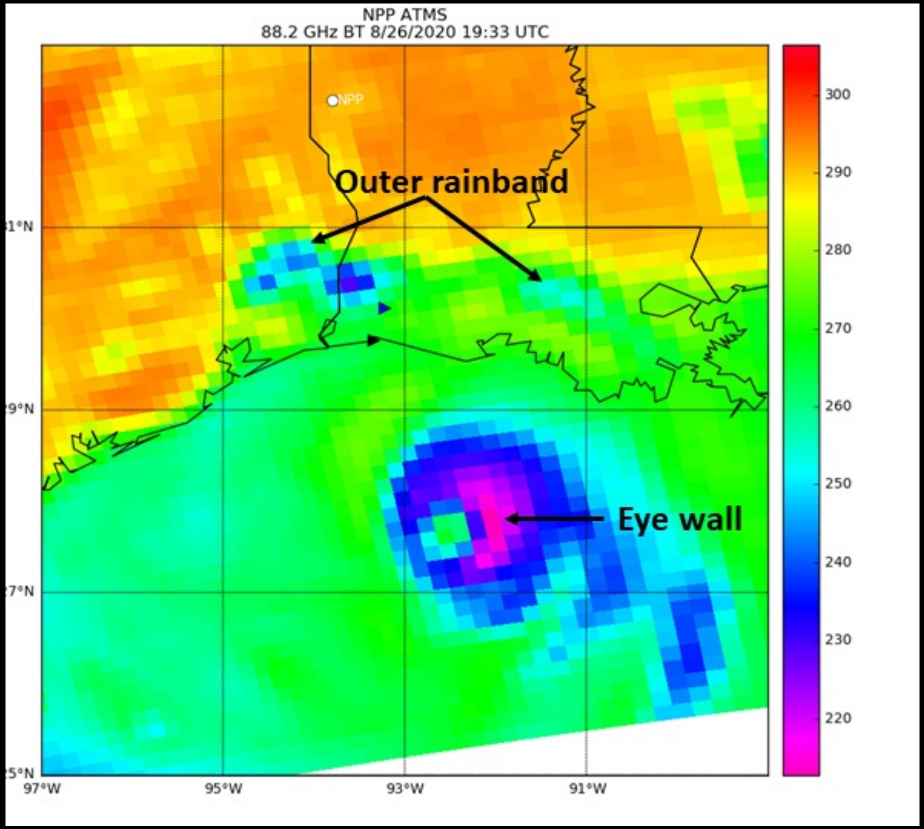
- May 1, 2012, VIIRS imagery used to support local warning and forecast operations throughout the NWS Alaska Region.
- May 22, 2012, ATMS radiances operationally assimilated in the National Centers for Environmental Prediction's (NCEP)/ NWS Global Forecast System (GFS).
- September 25, 2012, ATMS data assimilated operationally into the European Centre for Medium-Range Weather Forecasts (ECMWF) weather forecast models.
- April 2013, the United Kingdom Met Office began assimilating operational data from the Cross-track Imaging Radiometer Suite (CrIS) and ATMS into its weather forecast models.
- August 20, 2013, NCEP began incorporating S-NPP CrIS satellite data operationally into the GFS.
- October 31, 2013, NCEP/CPC started to use OMPS Ozone operationally.
- In November, 2013, NRL started to use ATMS operationally in their global forecast model.
- 2014 NUCAPS available in AWIS II
- December 2014, CrIS FSR turned on in operation

JPSS Impacts on NWP



NASA/GMAO

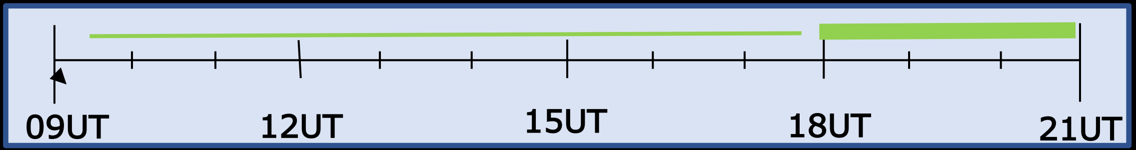
S-NPP ATMS 88 GHz brightness temperature (Kelvin) image at 1933 UTC 26 August 2020 over hurricane Laura

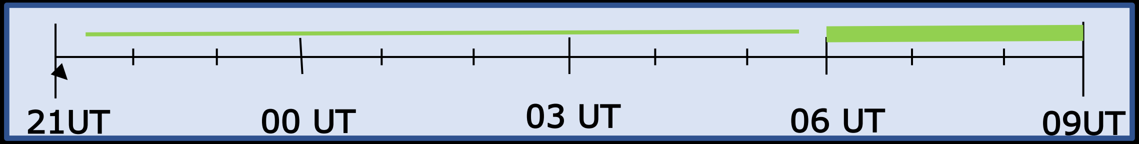


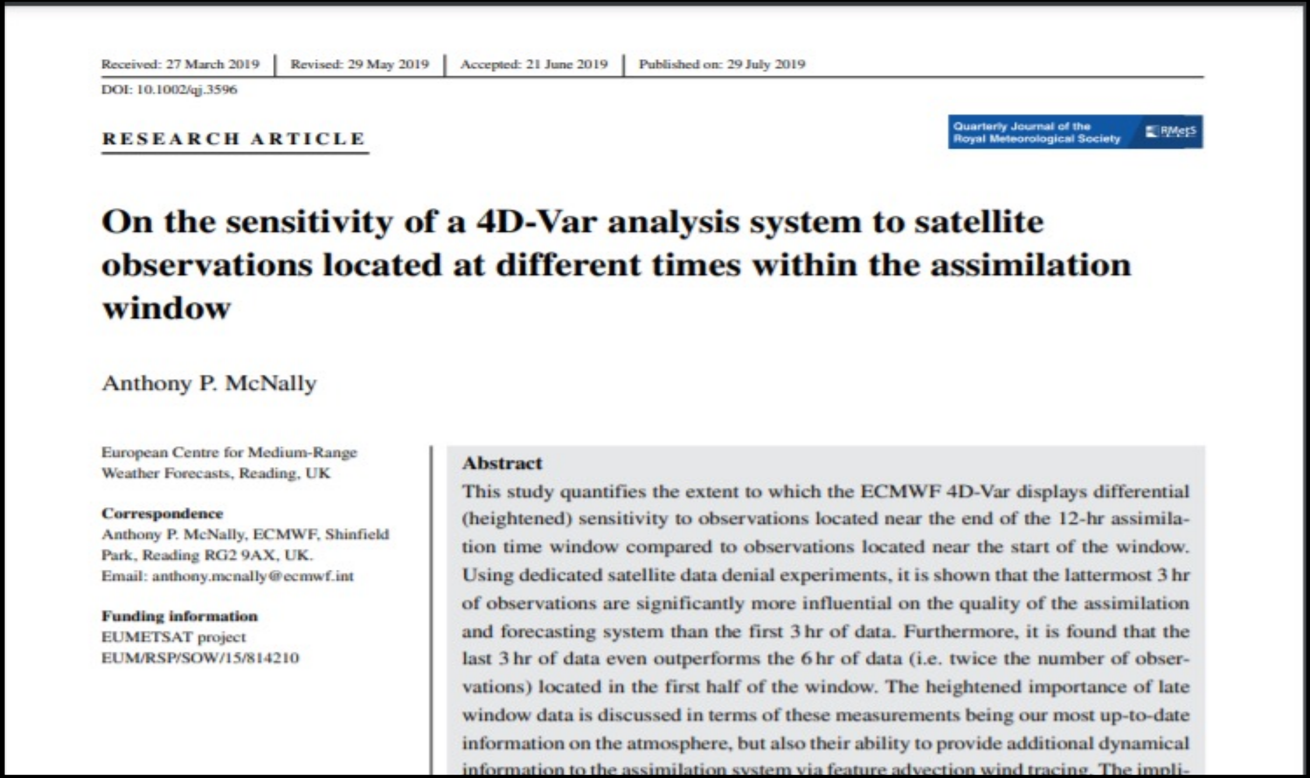
Ken Pryor/STAR

Importance of Low Latency Data to NWP

Observations located near the **end of the 12 hour window are significantly more influential** than observations located at the start of the window







Received: 27 March 2019 | Revised: 29 May 2019 | Accepted: 21 June 2019 | Published on: 29 July 2019

DOI: 10.1002/qj.3596

RESEARCH ARTICLE

Quarterly Journal of the Royal Meteorological Society RMetS

On the sensitivity of a 4D-Var analysis system to satellite observations located at different times within the assimilation window

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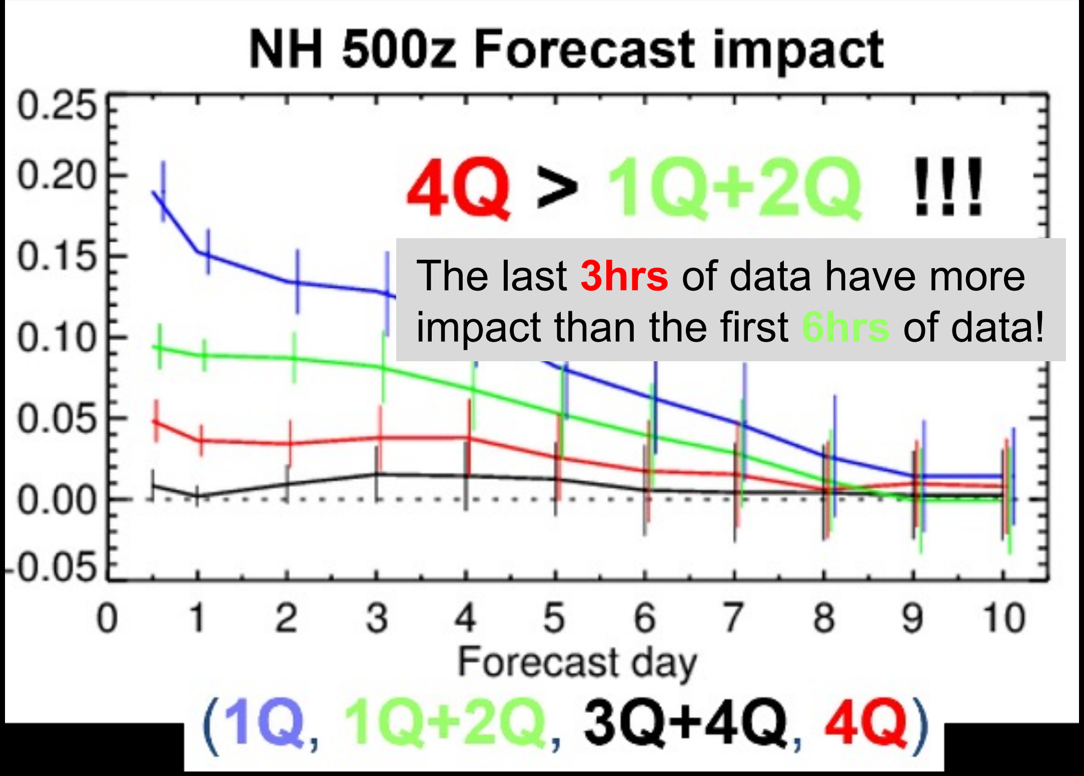
Funding information
EUMETSAT project
EUM/RSP/SOW/15/814210

Abstract

This study quantifies the extent to which the ECMWF 4D-Var displays differential (heightened) sensitivity to observations located near the end of the 12-hr assimilation time window compared to observations located near the start of the window. Using dedicated satellite data denial experiments, it is shown that the lattermost 3 hr of observations are significantly more influential on the quality of the assimilation and forecasting system than the first 3 hr of data. Furthermore, it is found that the last 3 hr of data even outperforms the 6 hr of data (i.e. twice the number of observations) located in the first half of the window. The heightened importance of late window data is discussed in terms of these measurements being our most up-to-date information on the atmosphere, but also their ability to provide additional dynamical information to the assimilation system via feature advection wind tracing. The impli-



Courtesy Anthony P. McNally, ECMWF

Latency of Measurements for Global NWP

Geophysical Variable	Units (Accuracy)	Geographic Coverage (dimensionless)	Horizontal Resolution (km)	Temporal Refresh (h)	Vertical Resolution (m)	Error Standard Deviation	Data Latency (h)
Air Temperature: Profiles	K	Global	[100,10,5]	[12,3,1]	[1000,500,100][1]	[2,1,0.5]	[6,1,0.25]
Cloud Liquid Water Path	g/m2 (%)	Global	[100,10,5]	[12,3,1]	[1000,500,100][2]	[10,5,2]	[6,1,0.25]
Cloud Top Temperature	K	Global	[100,10,5]	[12,3,1]	NA	[10,5,1]	[6,1,0.25]
Normalized Difference Vegetation Index	unitless	Global	[100,10,5]	[240,120,24]	NA	[0.25,0.15,0.1]	[240,24,3]
Specific Humidity: Profiles	%	Global	[100,10,5]	[12,3,1]	[1000,500,100][2]	[15,10,5]	[6,1,0.25]
Sea Ice Concentration	%	Global	[100,10,5]	[120,24,3]	NA	[25,15,10]	[120,24,3]
Sea Surface Temperature	K	Global	[100,10,5]	[120,24,3]	NA	[4,2,1]	[120,24,3]
Snow Cover	%	Global	[100,10,5]	[120,24,3]	NA	[25,10,5]	[120,24,3]
Snow Water Equivalent	cm	Global	[100,10,5]	[120,24,3]	NA	[8,4,2]	[120,24,3]
Soil Moisture: Surface Wetness	m3/m3	Global	[100,10,5]	[120,24,12]	NA	[0.2,0.1,0.05]	[120,24,3]
Surface Pressure	hPa	Global	[100,10,5]	[12,3,1]	NA	[1,1,0.5]	[6,1,0.25]
Wind Speed Profile: Eastward	m/s (%)	Global	[100,10,5]	[12,3,1]	[1000,500,100][1]	[20,10,5]	[6,1,0.25]
Wind Speed Profile: Northward	m/s (%)	Global	[100,10,5]	[12,3,1]	[1000,500,100][1]	[20,10,5]	[6,1,0.25]

* Current Geophysical Variable Need

NOAA Technical Report NESDIS 156

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Assessment of Solution-Agnostic Observational Needs for Global Numerical Weather Prediction (NWP)

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US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

NESDIS Office of System Architecture and Advanced Planning (OSAAP)
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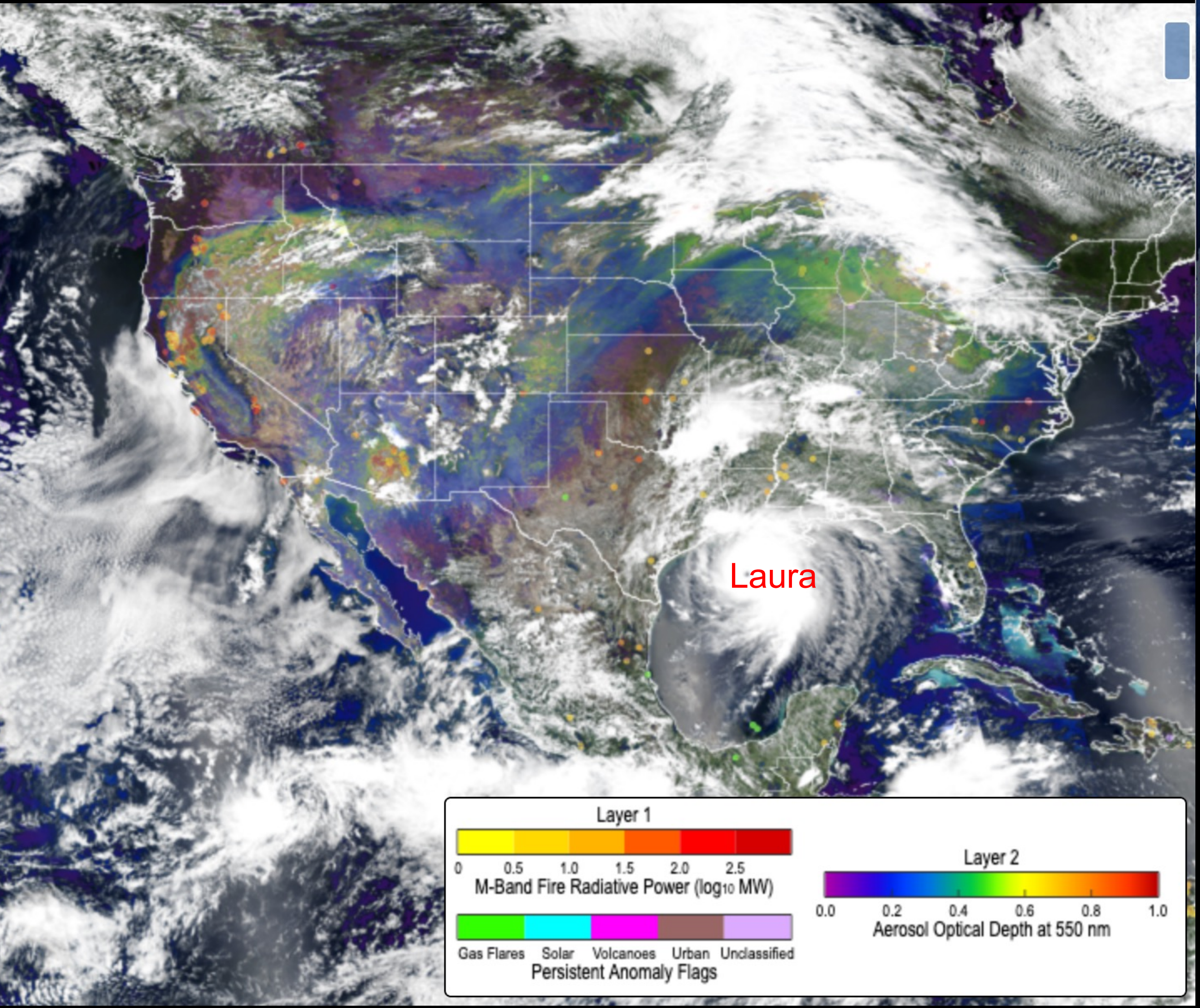
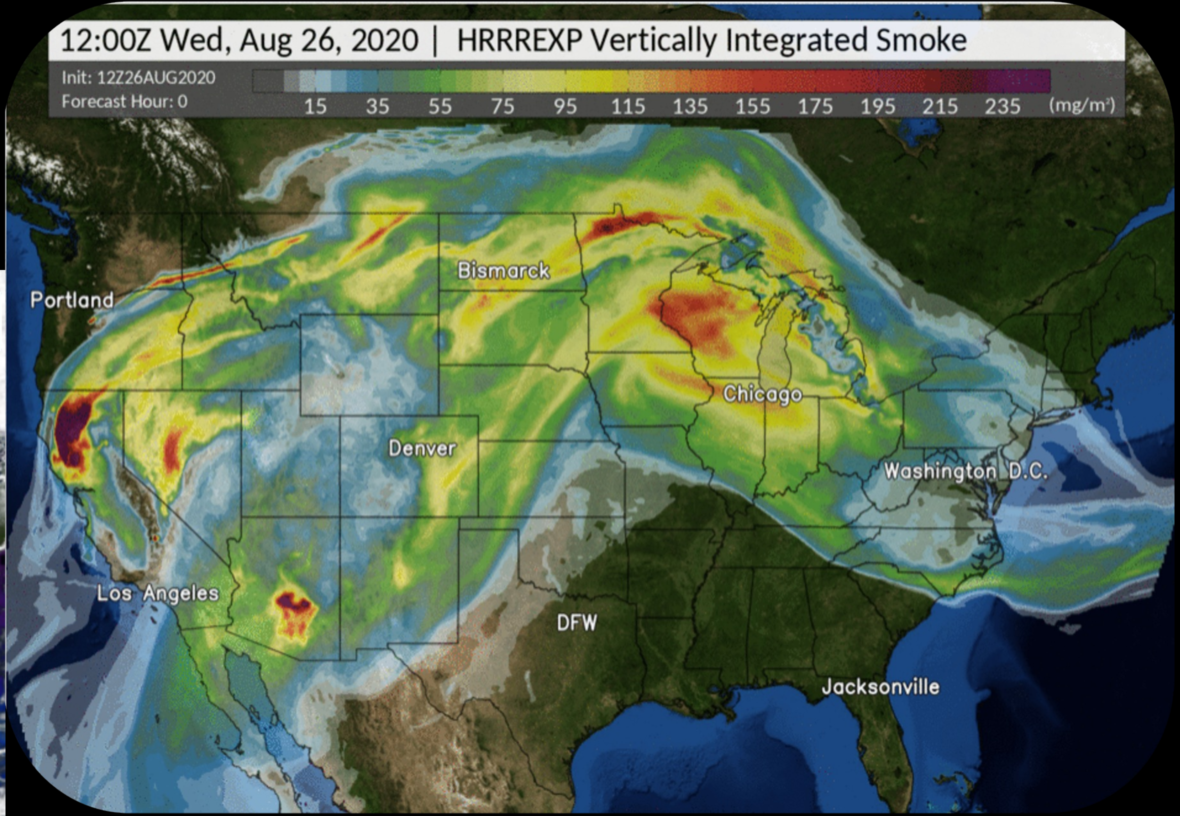
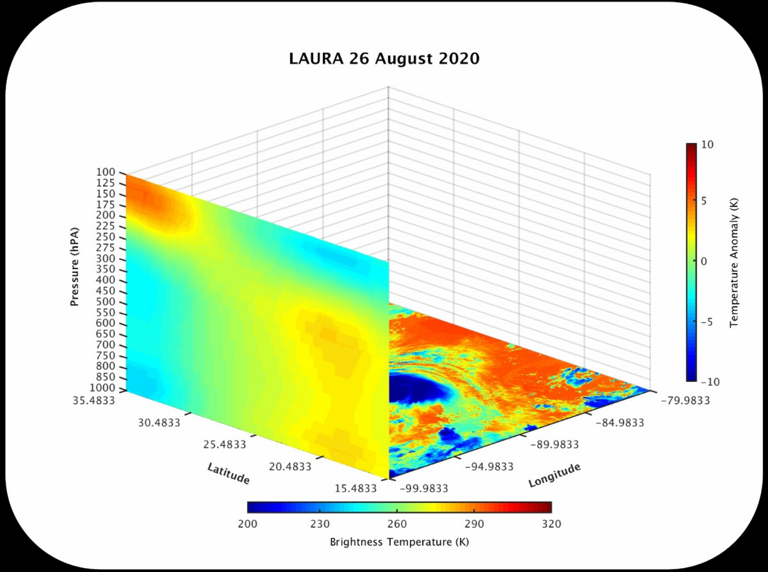
26 August 2020



NOAA/STAR



NOAA/GSL



Banghua Yan
STAR

Journey of an Iceberg in South Atlantic

ENVIRONMENT

NATIONAL GEOGRAPHIC

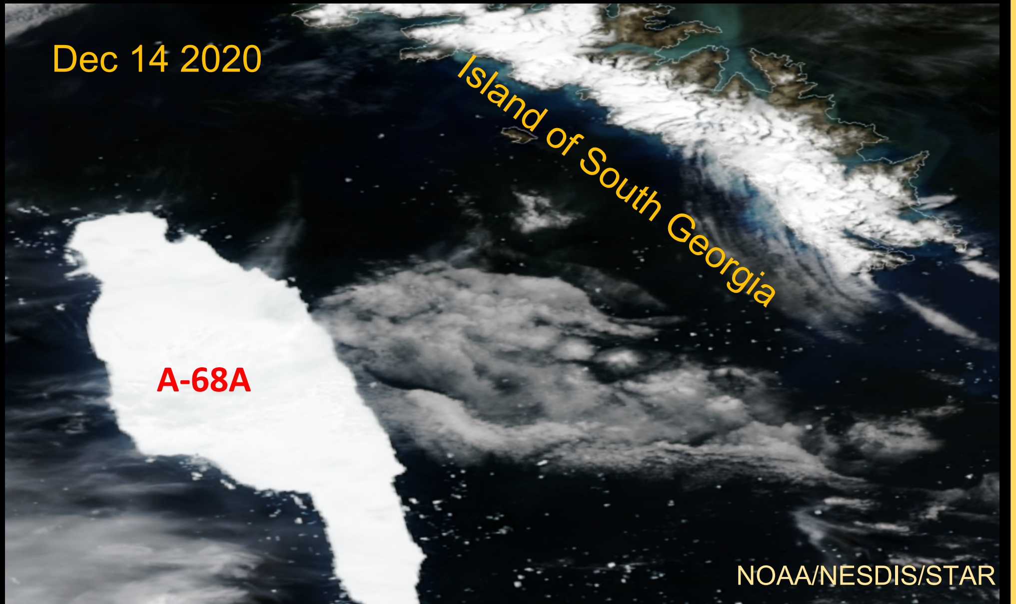
Huge iceberg breaking up off South Georgia Island is still a threat

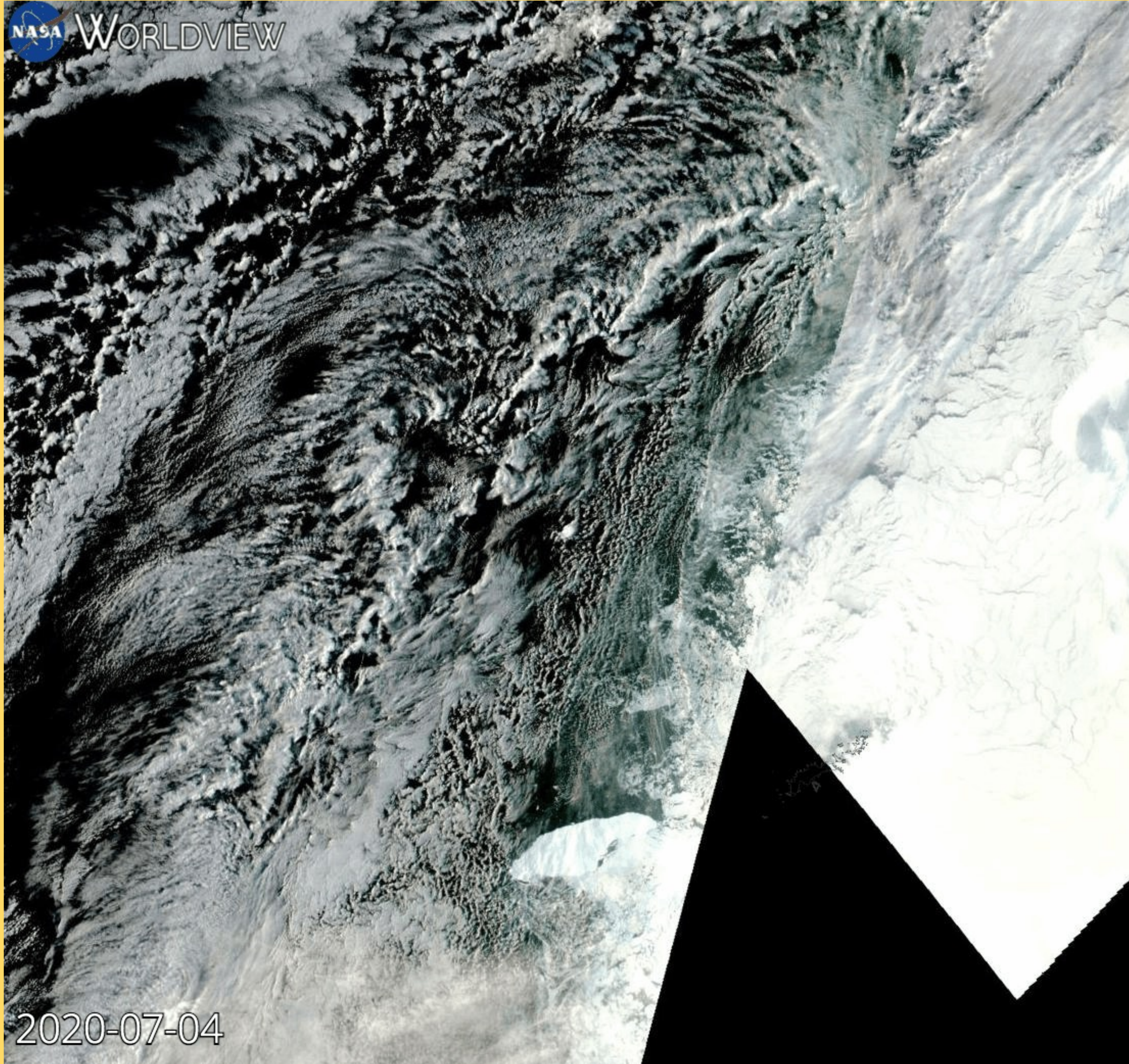
A68 iceberg on collision path with South Georgia

By Jonathan Amos
BBC Science Correspondent

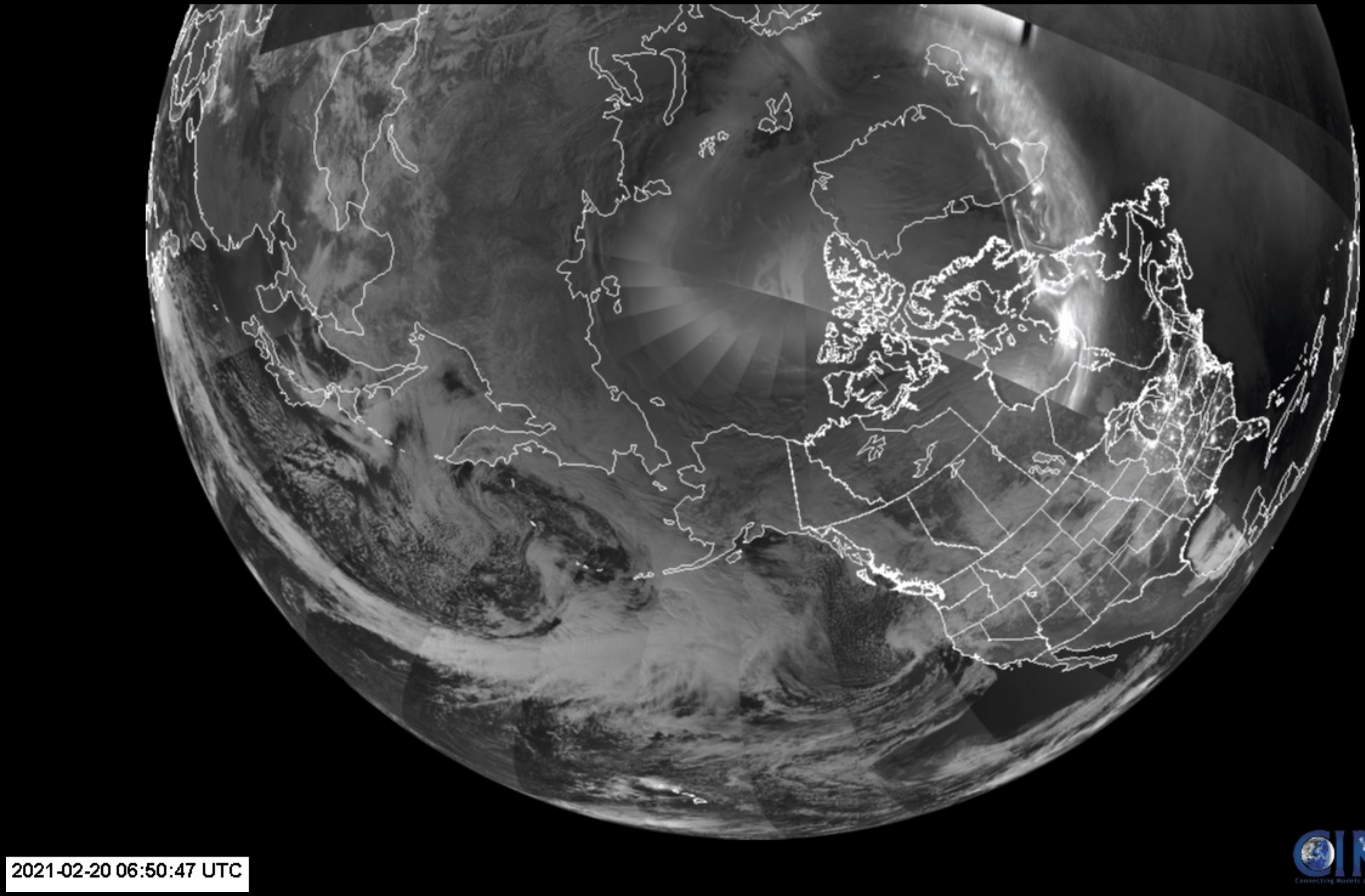
4 November 2020

BBC NEWS





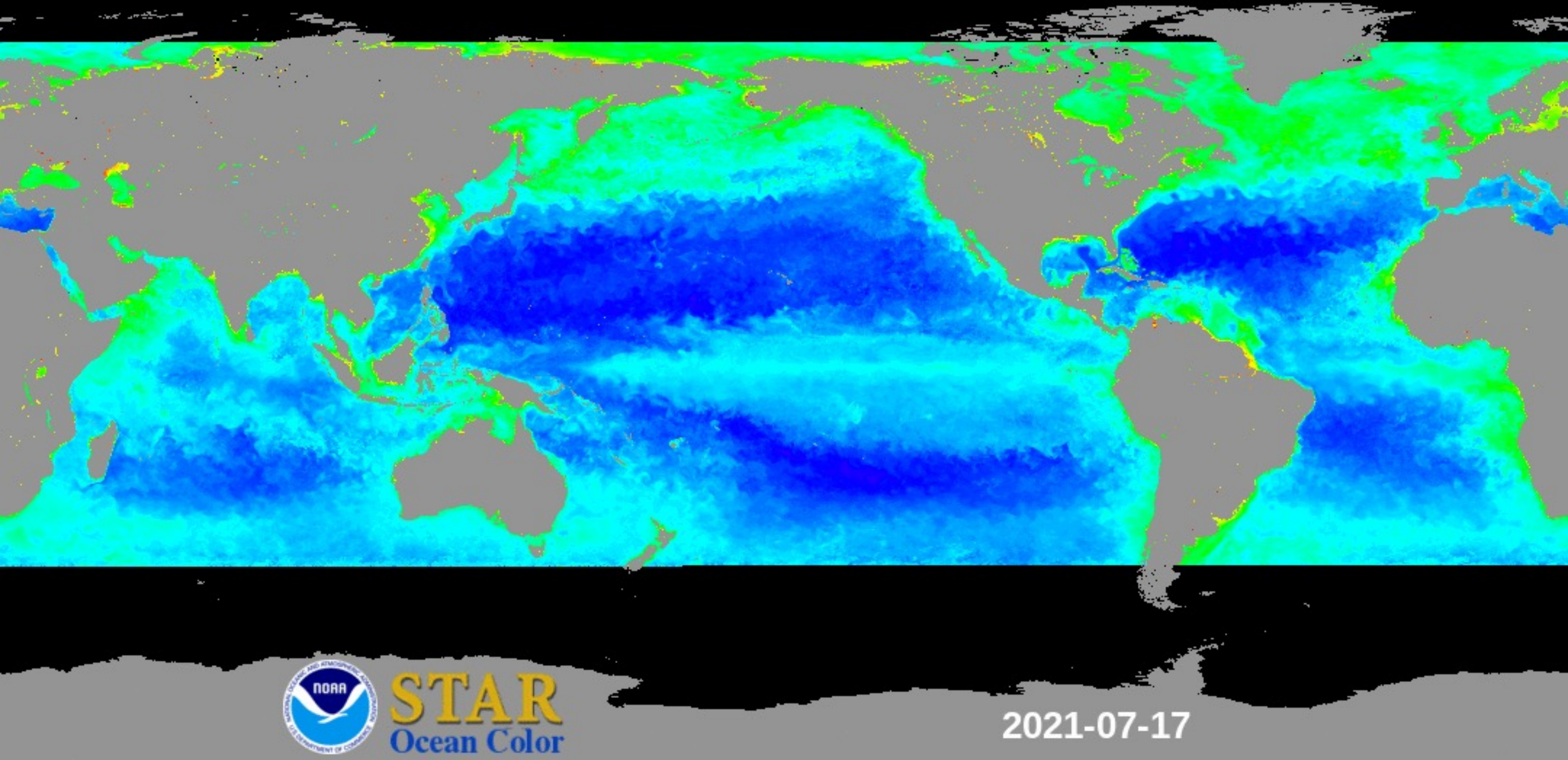
VIIRS Day Night Band (DNB)



The Day night Band on VIIRS built upon 40 years of experience with Operational Linescan System (OLS) revolutionized what we can see at night.

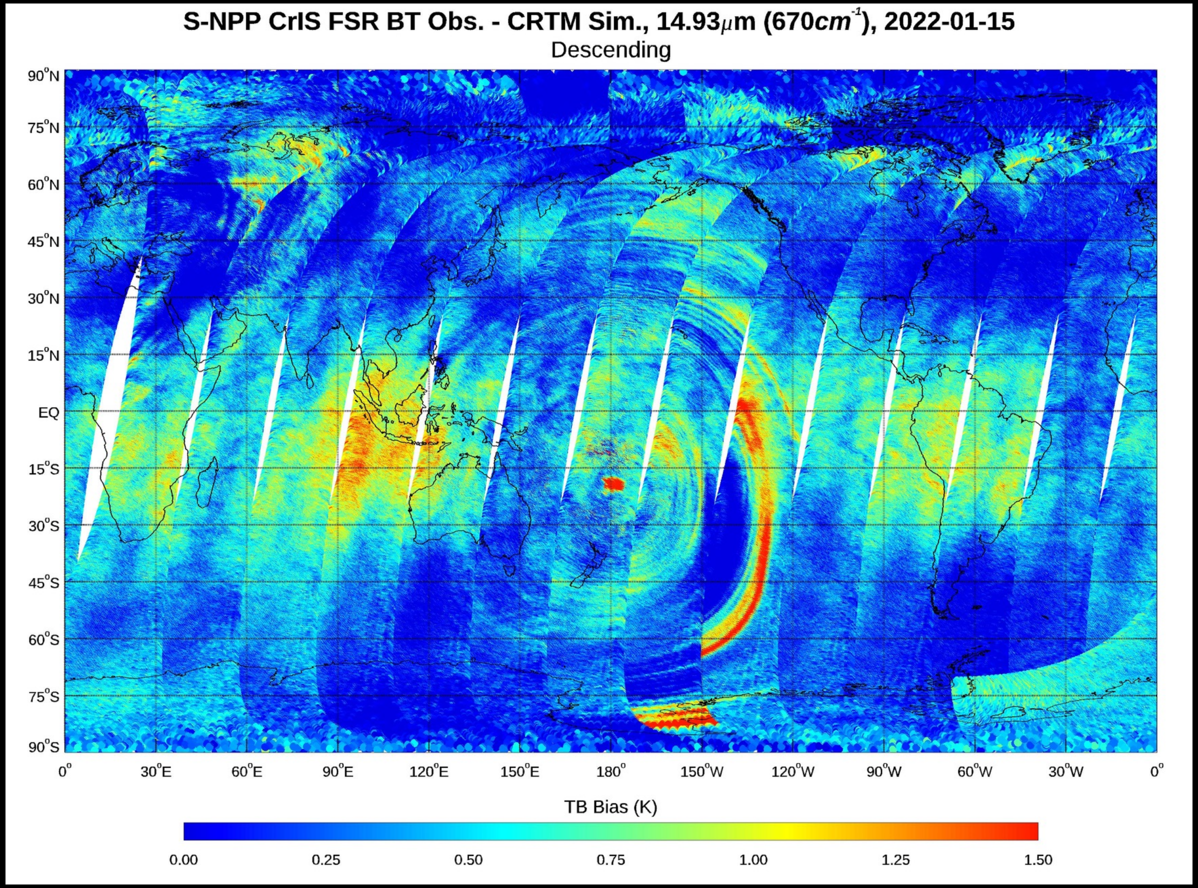
First capability on a NOAA mission.

Ocean Color Capabilities on SNPP - First on a NOAA Mission



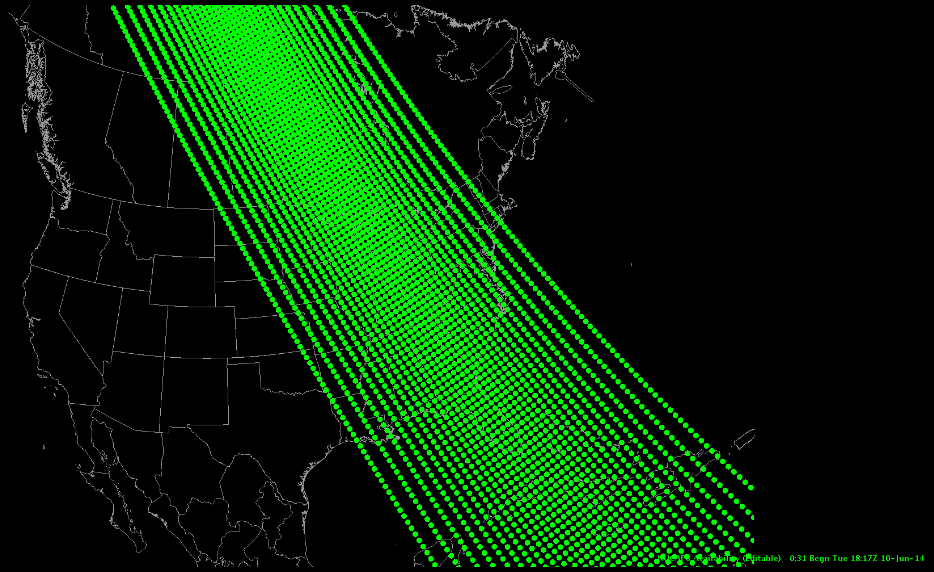
SNPP CrIS Applications

Ripples in temperature of the stratosphere caused by the Hunga Tonga eruption



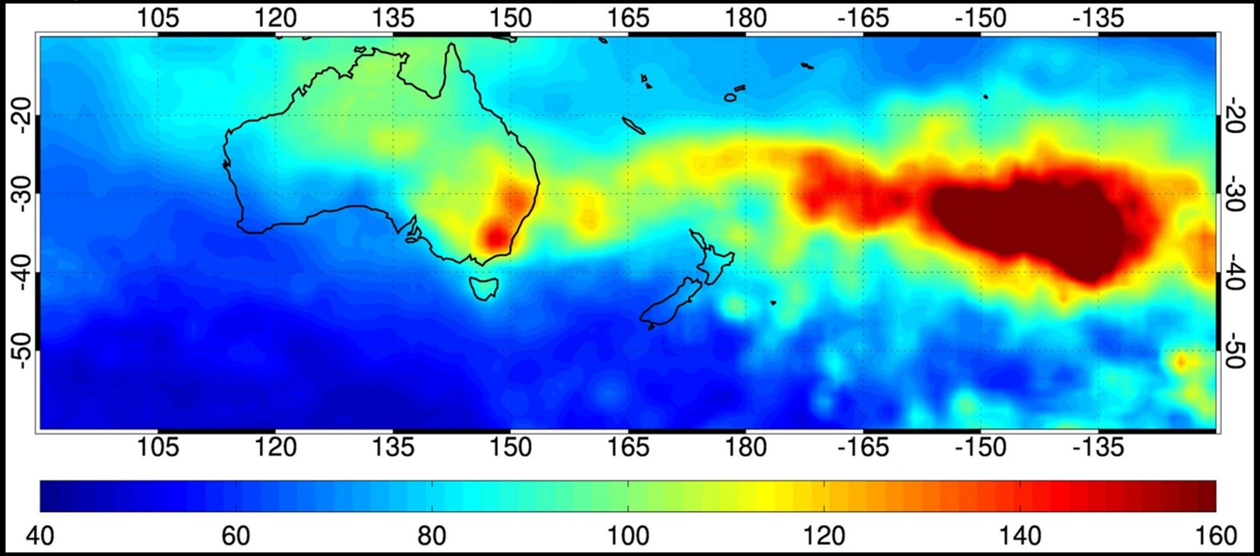
Ninghai Sun/STAR

SNPP NUCAPS available in AWIPS II since 2014

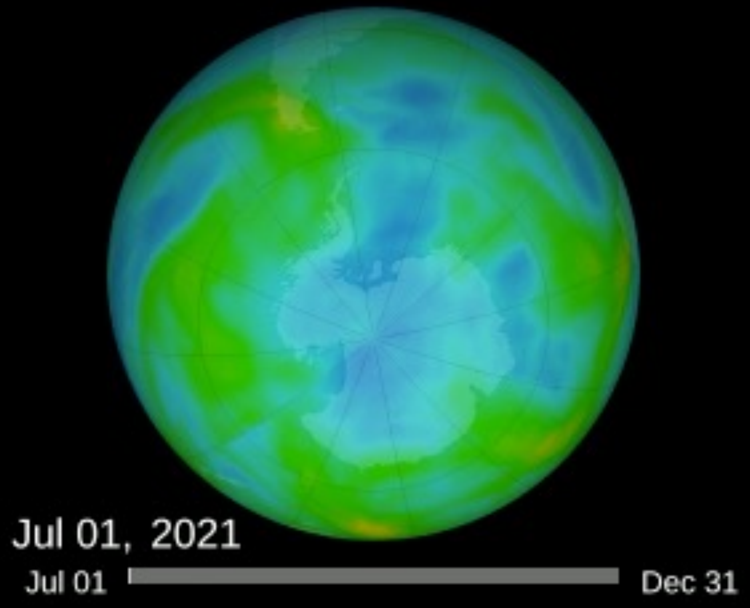


CIMSS

NUCAPS CO mixing ratios (ppbv) at 506 hPa from SNPP Jan 1-15, 2020

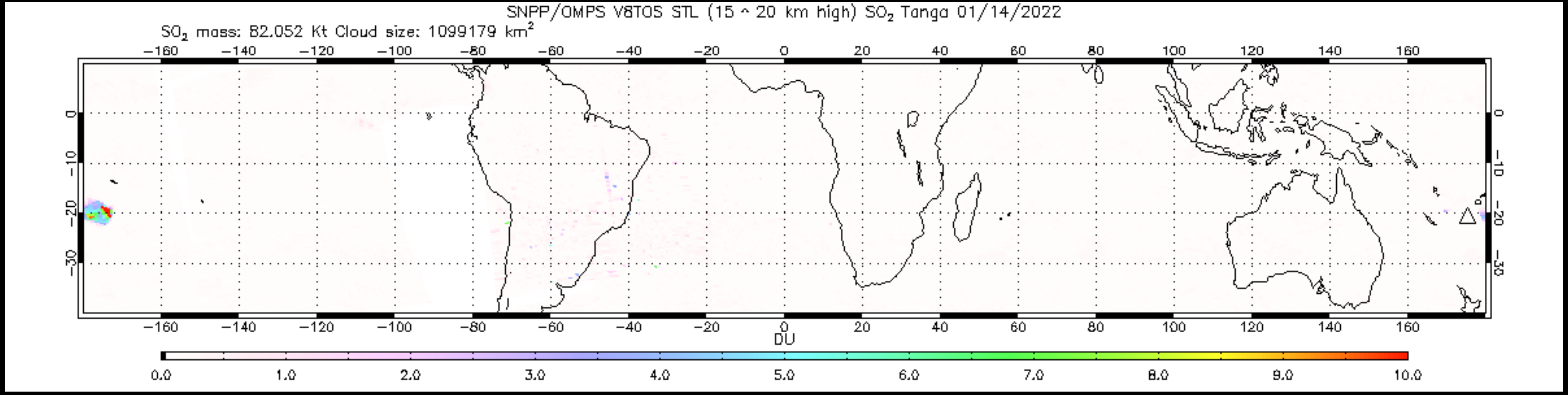


OMPS Provides Critical Measurements of Ozone and Atmospheric Chemistry



NASA Ozone Watch

SO2 from the Hunga Tong eruption captured by OMPS on SNPP



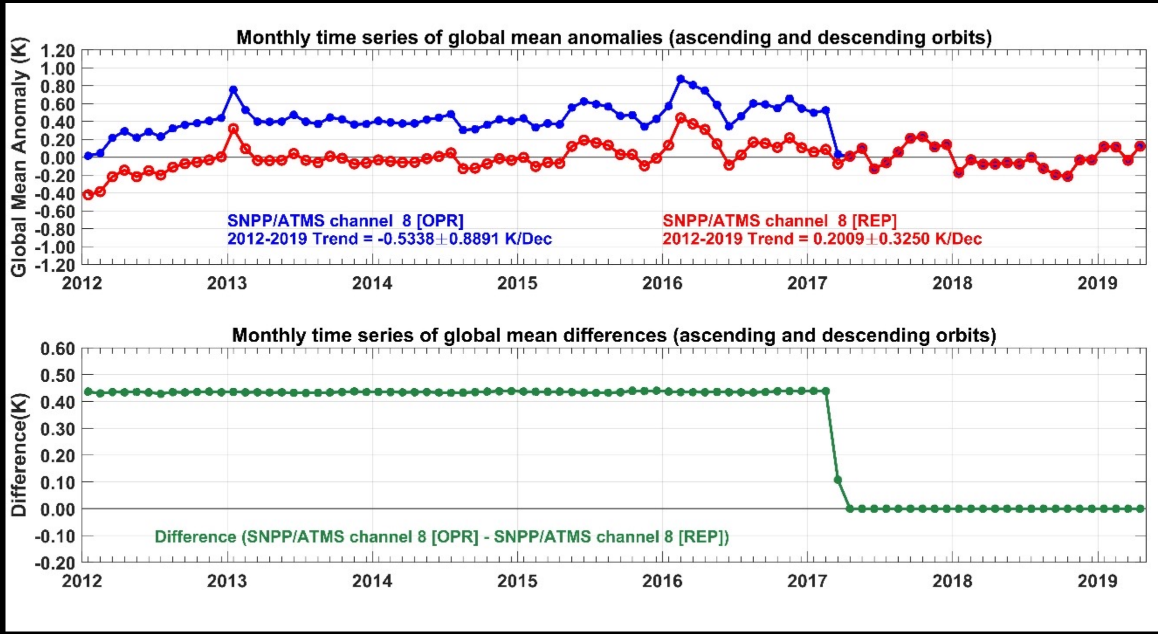
Jianguo Niu/NOAA/STAR

Reprocessing of SNPP Sensor Data Records

- SNPP Sensor Data Records (SDR) have been reprocessed for the following time periods:

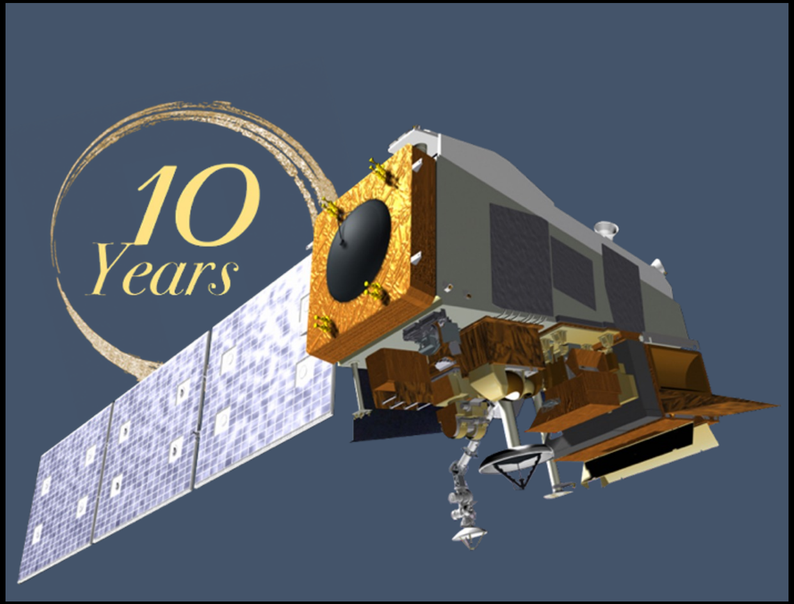
- ATMS SDR/TDR (2011-11-08 - 2019-10-15)
- CrIS SDR (2012-02-20 - 2020-01-29)
- OMPS SDR (2012-01-30 - 2020-05-30)
- VIIRS SDR (2012-01-02 - 2020-04-30)

Monthly global mean brightness temperature anomaly time series for ATMS channel 8



- Several improvements in reprocessed data: updates to calibration, stray light correction, terrain correction, nonlinearity and geolocation corrections and fixes to anomalies that have been observed in the data
- Reprocessed data available from NOAA/CLASS

JPSS Backbone Status



NOAA20 Operating Nominally

October 28, 2021, marks the successful

10^{th} anniversary of the SNPP satellite

JPSS-2 status

JPSS 2 successfully completed TVAC on June 2^{nd}

Pre-Ship Review is planned for August 1^{st}-4^{th}

JPSS 2 will arrive at Vandenburg on August 24^{th}

JPSS 2 will move to the Launch Pad on October 17^{th}

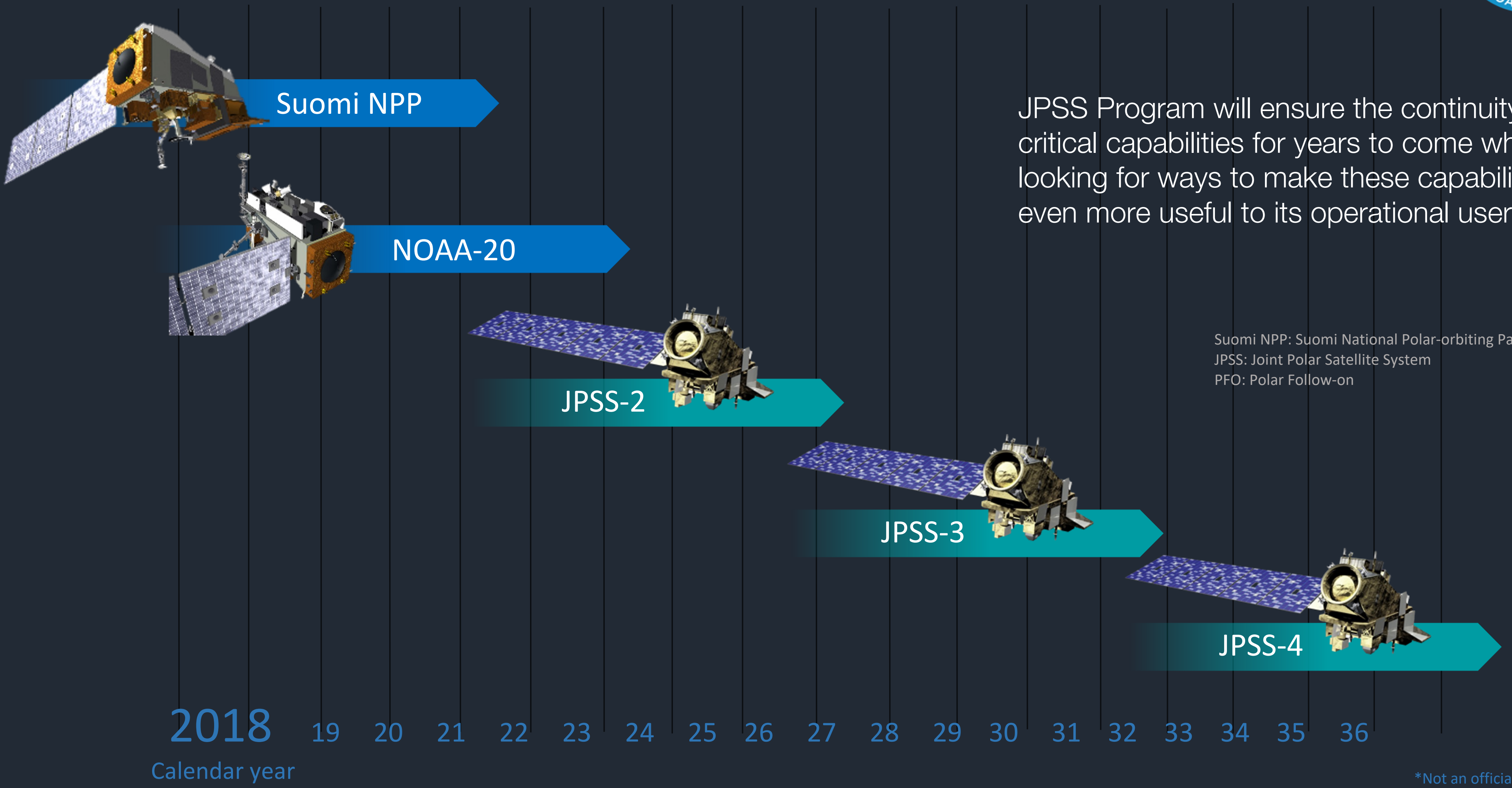
Launch is scheduled on November 1, 2022


JOINT POLAR SATELLITE SYSTEM PROGRAM
JPSS
NOAA • NASA
JPSS2
NOAA • NASA
JPSS 2 Satellite-level environmental completed.
Scheduled launch on November 1, 2022.

JPSS Continuity of Operations

JPSS Program will ensure the continuity of critical capabilities for years to come while looking for ways to make these capabilities even more useful to its operational users.

Suomi NPP: Suomi National Polar-orbiting Partnership
JPSS: Joint Polar Satellite System
PFO: Polar Follow-on



*Not an official fly-out chart

EUMETSAT Polar System-Second Generation or *EPS-SG*

Two satellite configuration

- **Metop-SG-A**
  - IASI-NG (IASI, AIRS)
  - METimage (AVHRR, MODIS)
  - MWS (AMSU-A, MHS)
  - 3MI (POLDER)
  - Sentinel-5 (GOME-2, SCIAMICHY, OMI)
  - RO (GRAS, COSMIC)
- **Metop-SG-B**
  - SCA (ASCAT, QUICKSCAT)
  - MWI (SSMI, AMSR-E)
  - ICI (AURA-MLS, Odin-SMR)
  - RO
  - ARGOS-4

Heritage

Joint Polar System (JPS) agreement between NOAA and EUMETSAT will provide observations from two complementary polar orbits till 2040

LEO Strategic Objective

1

Advance terrestrial observational leadership in geostationary and extended orbits

2

Advance space weather observational leadership in all applicable orbits to meet mission needs

3

Evolve LEO architecture to enterprise system of systems that exploits and deploys new observational capabilities

4

Develop agile, scalable ground capability to improve efficiency of service deliverables to support data from all sources

5 Provide consistent ongoing enterprise-wide user engagement to ensure timely response to user needs

6 Deliver the best value integrated suite of products and services responsive to user needs

LEO Sub-Objectives

Objective: Evolve LEO architecture to enterprise system-systems that exploits and deploys new observational capabilities

1 Backbone: Ensure and extend LEO observations through JPSS series and other current or planned missions

2 Exploitation: Institutionalize purchasing of weather data for operational use

3 Innovation: Adopt new technologies, concepts and architectures to evolve the LEO constellation in support of NOAA's future observational needs

Focus on observations, not platforms

Beginning of the LEO Program

- In FY 2022, NOAA was authorized to establish the Low Earth Orbit (LEO) activity, which will set the stage for managing future polar and other low earth and medium earth orbit satellite observations as loosely coupled programs.
- Future NOAA LEO missions are expected to be in a partially disaggregated architecture
- A disaggregated architecture is expected to exploit efficient and quick access to space ; Launch what we want, when we want, where we want it
- The first LEO-OP mission is the “QuickSounder” mission that will carry the Advanced Technology Microwave Sounder (ATMS) on a small satellite (Expected to launch in 2025)

NESDIS Level Requirements (NLR)

Foundational Products: Satellite Radiances and Satellite Imagery

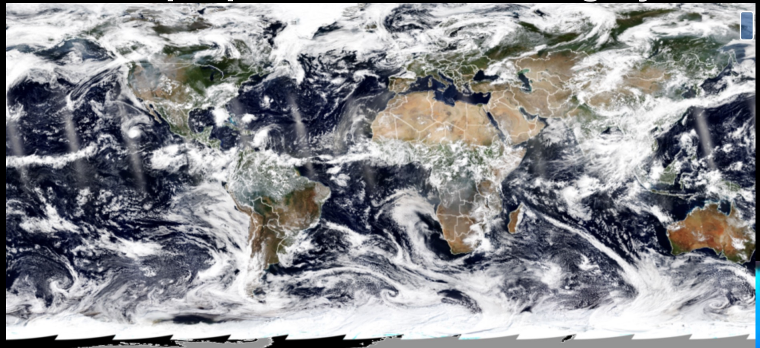
NESDIS Level Requirements – Geophysical Products

Atmosphere	Cryosphere	Land & Surface Hydrology	Ocean, Fresh Water & Coasts	Space

Analytical

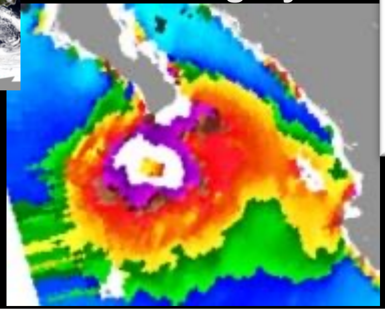
Climate | Weather | Ocean, Fresh Water & Coasts

Multipurpose VIS/NIR/IR Imagery

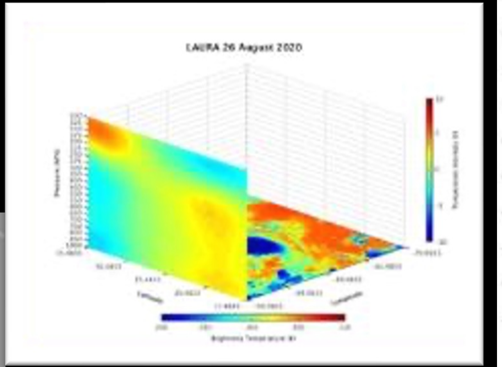


UV Imagery

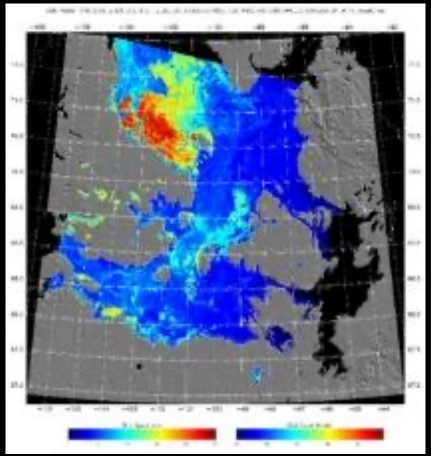
MW Imagery



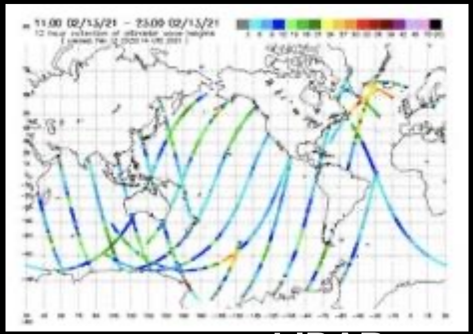
IR/MW/RO Soundings



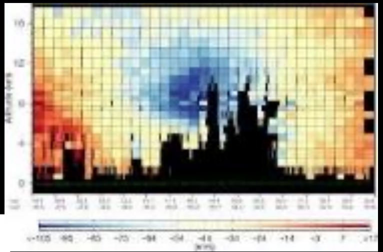
RADAR Imagery

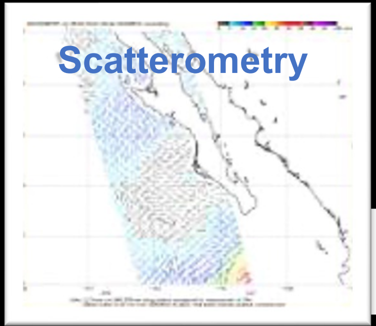


Altimetry



LIDAR





Nearly <u>every product category and subcategory</u> across the thematic areas described in the NESDIS Level Requirements relies on LEO observational measurements

LEO Measurements Activities NOAA

- NOAA relies on a family of LEO missions that we Manage (e.g. JPSS), Contribute under partnerships (e.g. Met Op) and Leverage (e.g. ESA/Sentinel missions)
- The Joint Polar Satellite System is the backbone of NOAA's polar-orbiting operational environmental satellite system and is the Program of Record (POR).
- NOAA relies on partner missions to supplement JPSS observations. ***Partnerships are critical!***
  - MetOp (EUMETSAT) – Provides continuity of mid-morning and afternoon LEO observations till end of next decade
  - GCOM-W (JAXA)
  - DMSP (DOD)
- LEO provides global measurements
  - Vice GEO definition of persistent regional measurements
- LEO is not bound by a specific orbit geometry or altitude
- It is expected that a disaggregated architecture would offer greater flexibility and agility to launch a variety of sensors on a constellation of satellites (compared to a single large spacecraft with multiple payloads).

Status of LEO Formulation Activities

User Needs Review and Gap Analysis

Review of each LEO measurement objective, incorporating NWS/NOS/OAR/NMFS and other community interests and requirements (requirements Gap)

Update of Measurement Categories to Minimum (current JPSS), Next Generation (2040 expected), and Maximum (major development)

Use to development of LEO Program L1 requirements

LEO Program of Record (POR)
Identification of expected "Partner" missions and instruments that may contribute to LEO Measurement objectives. Allows timing of LEO mission initiation

Instrument Definition Studies

Defining **notional instrument concepts** that address measurement objectives (different performance levels)

Incorporates information from earlier BAA and User Engagement Workshops, as well as from current "Instrument Catalogs"

Instrument characteristics (science and physical) needed for constellation and mission studies

Estimate instrument development costs (and schedules)

Constellation Studies

Use multi-element optimization tools to identify #s of instruments and/or orbital planes to meet measurement objectives

Each identified instrument, performance level, re-visit rate, and latency objectives (using notional Ground System)

Preliminary notional instrument(e.g. MW, IR soundings) constellations

Ground System Studies

Preliminary study of commercial and ground networks

Reviewing NESDIS ground system evolution plans

User Engagement Workshops

User Engagement (UE) through workshops, listening sessions at conferences, and proving ground & risk reduction activities enable us to better understand

- How is the current data used?
- What are the impacts of current data?
- What enhancements could we do current as well as future data?

Three workshops were held focused on MW and IR Soundings and atmospheric chemistry:

- https://www.jpss.noaa.gov/science_events/20210728-noaa-microwave-sounder-workshop/
- https://www.jpss.noaa.gov/science_events/20211206-noaa-virtual-infrared-sounder-workshop/
- https://cpo.noaa.gov/Divisions-Programs/Earth-System-Science-and-Modeling/Atmospheric-Chemistry-Carbon-Cycle-Climate-AC4/News/ArtMID/8741/ArticleID/2541/UV-VIS-NIR-Workshop

Multipurpose imagery (VIIRS) (June 29-30)

https://www.nesdis.noaa.gov/events/viirs-user-meeting-celebrating-10-years-of-snpp

BAA Studies

- NOAA awarded several contracts to industry via a Broad Agency Announcement in 2019 to explore integrated mission and instrument design concepts to form the basis for future acquisitions.
- SounderSat BAA Industry Studies
  - 15 LEO Sounder Studies
    - 4 Microwave Sounder, 3 Infrared Sounder, 8 Mission Concept studies
- SounderSat BAAs covered a wide trade space, setting Threshold, Target, and Objective requirements for Vertical Temperature and Moisture profiles.
  - TRL varied widely across the types of sensors that were studied

Overview of Sounder Studies From BAA

- Sounding instruments explored in the BAA span a range of capabilities, but generally fell into three classes based on waveband coverage:
  - MW HIGH – full ATMS channel set, and may include higher frequency bands
  - MW MID – reduced channels, drops lower frequency bands (K,Ka) in favor of higher frequency channels
  - MW LOW – limited channels, usually covering F, G, and W bands
  - IR-HIGH - SWIR, MWIR, LWIR (3.92 – 15.38 microns), hyperspectral
  - IR-MID – SW+MW, MW+LW
  - IR-LOW - Single band – range specific to science need
- Instrument calibration accuracy, spatial sampling, NEDT, and bandwidth correspond loosely to class
- As expected, High performance sensors have larger SWAP compared to with sensors with Low capabilities
- Can fly on a variety of smallsats and cubesats depending upon SWAP

QuickSounder Mission

- The QuickSounder Mission is an initial step toward NOAA's next generation LEO Program.
  - QuickSounder will fly an ATMS-EDU on a small commercial spacecraft using commercial mission operations, ground services, and data routing services.
  - A planned 3 year development cycle from authorization to launch
  - Completed Mission Concept Review in December 2021
  - Issued an RFI on March 7 to solicit input from industry on the implementation of "New Space" for the QuickSounder
  - DOC Milestone 1 planned for FY 2022
  - Launch Readiness Date ~ 2025
- By the end of the decade, LEO is expected to complete formulation of next generation MW and IR sounders and a multipurpose imager as a follow on to JPSS to assure continuity of key measurements

Some Ongoing Debates……

- What is an ideal LEO+GEO constellation?
  - LEO and GEO imagers are converging towards similar spectral bands
- How frequently do these measurements need to be made and what point do you see diminishing returns?
- Are more frequent limited set of spectral observations better than less frequent but large spectral range of observations?
- What is an ideal approach for conducting value assessments (e.g. societal, economic benefits etc.)
- How is the commercial market for remote sensing evolving? What is the quality of the commercial data? How reliable and cost effective is it?
- What are future partnership opportunities?

Summary

- NOAA-20 is the primary NOAA satellite in the 1330 orbit and is functioning nominally
- SNPP is operating nominally, and is the secondary backup to NOAA-20 (enables NOAA to have 2 gaps to a failure!)
- JPSS-2 is scheduled to be launched on November 1, 2022
- Low latency data (enabled via Direct Broadcast and CSPP) continues to be a critical capability for NWP users
- The LEO program will enable NOAA to be more agile and innovative in managing the portfolio of LEO measurements

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VIIRS 2011–2021: Ten Years of Success in Earth Observations

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Message from the Guest Editors

The new US polar orbiting system, JPSS, succeeds the heritage NOAA POES system, with the new generation VIIRS imager replacing the long-term POES AVHRR. The 1st VIIRS was launched onboard S-NPP in October 2011, and the 2nd sensor followed onboard JPSS-1/NOAA-20 in November 2017. Three more VIIRSs are planned to fly onboard JPSS-2, 3 and 4 satellites planned for launch in 2022, 2026 and 2031. This Special Issue aims to overview the initial VIIRS contributions during its first decade in space and place its products and performance in context of its historical counterparts (e.g., AVHRR, MODIS) and planned future sensors and data records (from, e.g., Metop-SG METImage and MTG FCI). Of special interest are Level 1 and derived Level 2–3 ocean, land, atmosphere and cryosphere data products, from VIIRS and other space sensors, and their use in downstream applications (such as, e.g., derivation of gap-free Level 4 analyses).

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Special Issue

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Hundreds of scientist and engineers in the government, industry and academia continue to contribute to the success of the JPSS mission and their passion and dedication to the mission are greatly appreciated!

Thank You!