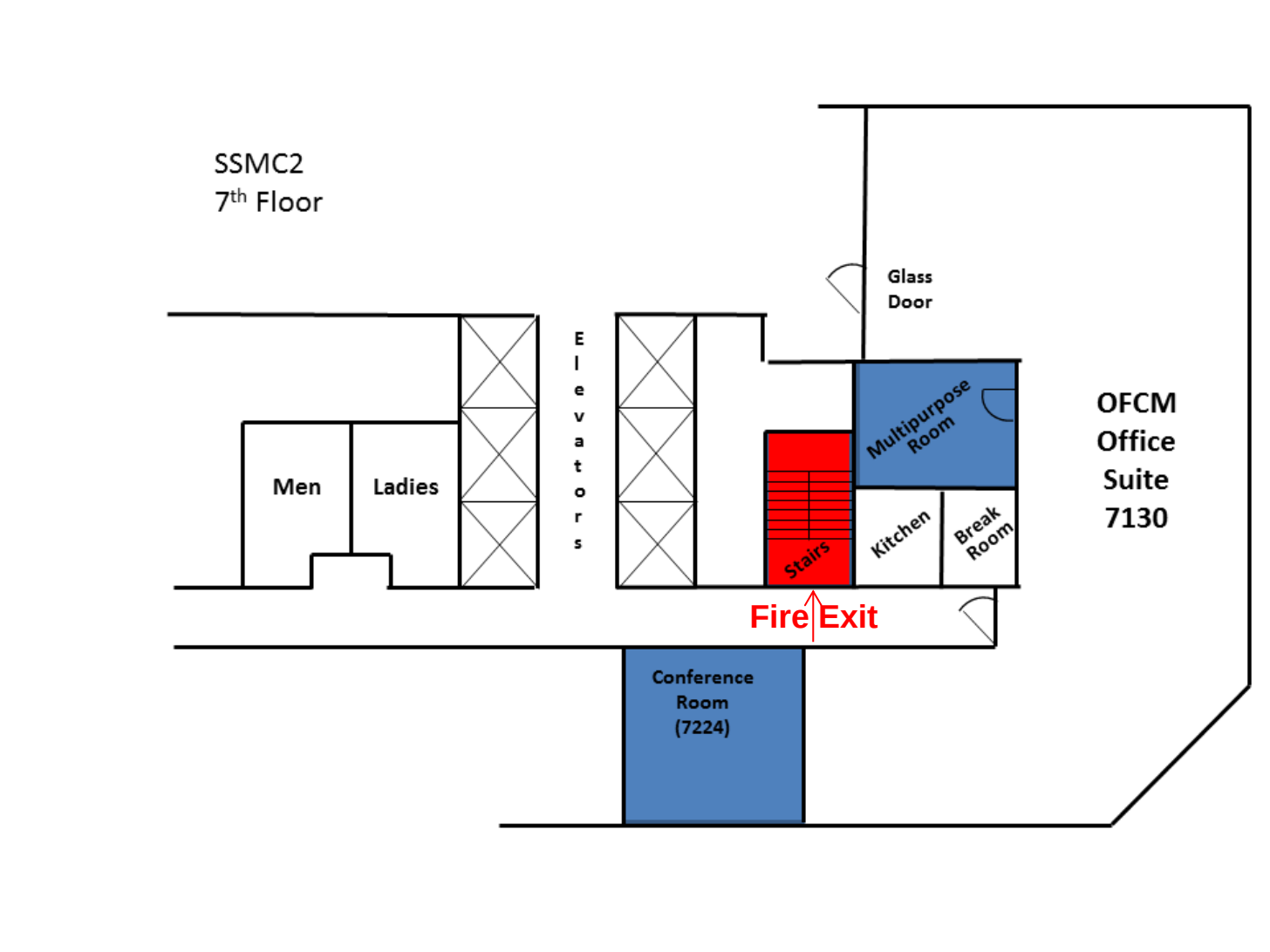
# *Committee on Operational Environmental Satellites*

# *Meeting 2017-1*

**March 17, 2017**

***Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM)***

# OFCM Floor Plan



# Opening Remarks

**COES Co-Chairs:**

- **Dr. Thomas Burns (NOAA-NESDIS)**
- **Col Michael Gremillion (DOD-USAF)**
- **Mr. David McCarren (DOD-USN)**
- **Mr. Joseph Pica (NOAA-NWS)**

**COES Executive Secretary:**

- **Mr. Michael F. Bonadonna (OFCM)**

**Meeting is being recorded to help produce an accurate Record of Action (ROA)**

# Agenda

- Opening Remarks: COES Cochairs
- Action Item Review: Executive Secretary
- Strategic Plan For Federal Weather Enterprise Coordination:
  Dr. Bill Schulz (OFCM)
- COES Terms of Reference (ToR): Executive Secretary
- JPSS Update: Dr. Mitch Goldberg (NOAA-JPSS)
- NASA's TROPICS Cubesat Mission: Dr. William Blackwell (MIT-LL)
- Open Discussion: COES Members.
- Action Item Review / Next Meeting: Executive Secretary
- Adjourn: The meeting is expected to end by 3:00 PM EDT.

# Action Item Review

| AI # | Text | Responsible Office | Comment | Status | Due Date |
|---|---|---|---|---|---|
| 2016-3.1 | Draft and coordinate a letter from the Federal Coordinator to NTIA describing the impact of spectrum allocation reduction on the Federal Weather Enterprise. | OFCM, COES Members | 11/29: Letter has been drafted and coordinated. Pending approval. Will be statused at the March COES mtg | In progress | 03/17/17 |
| 2016-4.1 | Review the draft COES Terms of Reference (ToR) document. Provide any recommendations for changes to the Executive Secretary | COES Members | 1/6/17: a few comments received and incorporated | Closed | 01/06/17 |
| 2016-4.2 | Collect and adjudicate any comments received on the draft COES ToR and provide a final version for approval at the next COES meeting in March 2017. | ExecSec | 2/27/17: Comments collected and adjudicated. Final version sent to COES | Closed | 02/23/17 |
| 2016-4.3 | Schedule next meeting for March 2017; include update briefings on JPSS and GOES-16. | ExecSec | Scheduled for 3/17 @ 1-3p. JPSS brief on agenda. | Closed | 02/02/17 |

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# Strategic Plan for Federal Weather Coordination

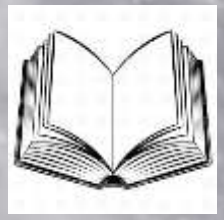
## Revising the annual Federal Plan for Meteorological Services

# New Federal “Plan”

## Old:


- Single publication
- Produced annually
- 200+ pages
- Multiple detailed spreadsheets
- Released in October
- No formal review

## New (proposed):



**First publication:**

- Strategic Plan
- Published every four years
- Composed by interagency group
- Approved by FCMSSR

**Second publication:**

- Annual Report
- Smaller (~50 pages)
- Few spreadsheets (satisfies PL 87-843)
- Progress towards Strategic Goals and Objectives (Agencies, Committees)
- Released in March
- OMB Review

# Strategic Plan: Goals and Objectives

1. Improve the resolution, frequency, information content and sustainability of global observing capabilities.
   a) Enable interagency discussions of observation system acquisition at the capability planning stage
   b) Conduct development, deployment and sustainment of common-use systems through formalized interagency processes.
   c) Coordinate data formatting, processing, communication, management and stewardship standards to optimize the exchange, timeliness, usability and value of earth observations.
   d) Coordinate the development of technology to extract information from observations.

# Strategic Plan: Goals and Objectives

2. Make Federal forecasting processes more resilient for all relevant time and spatial scales.
   a) Strengthen interoperability among interagency forecasting centers in producing accurate, timely, and precise weather products, information and services.
   b) Ensure interagency utility (data types, precision, etc.) of intraseasonal-to-interannual and longer-term forecasts.
   c) Support agency efforts to plan and develop the cooperative use of processing resources to increase the Nation's computing power for enhancing data assimilation and modeling systems.

3. Ensure availability of effective and consistent decision support products, information and services.
   a) Coordinate interagency outreach efforts to identify weather and water related information needs for decision making and risk management.
   b) Improve the consistency of decision support and risk management products, information and services.
   c) Crossfeed processes and lessons learned between agencues to improve decision support tools.

# Strategic Plan: Goals and Objectives

4. Conduct productive, synergistic interagency research efforts.
   a) Exercise leadership in coordinating U.S. efforts in international weather research priorities including the current WMO Grand Challenges.
   b) Foster interagency collaboration of research initiatives starting at the planning stage.
   c) Support efforts among FWE participants to coordinate task definition and sponsorship of National Academies research initiatives.
   d) Expand interagency use of data and information for research.

5. Develop, recruit, and sustain a professional diverse federal workforce.
   a) Coordinate OPM definitions and requirements for meteorology-related positions to ensure appropriate education and experience of the FWE workforce.
   b) Coordinate opportunities to leverage outreach, including education efforts, recruiting, and diversity inclusion initiatives.
   c) Crossfeed information on career path planning, training opportunities, diversity and inclusion, professional development, and retention programs.

# Strategic Plan: Goals and Objectives

6. Coordinate messaging about FWE priorities and needs.
   a) Coordinate input about FWE priorities to the Executive and Legislative branches, including communicating these priorities to federal agencies that are not FWE participants.
   b) Coordinate input about FWE priorities to academia, professional associations, non-federal government entities, and the general public.

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**Joint Polar Satellite System**

# THE NATION'S ADVANCED SERIES CIVILIAN POLAR ORBITING ENVIRONMENTAL SATELLITE SYSTEM

**Mitch Goldberg, Chief Scientist**

Joint Polar Satellite System
National Environmental Satellite, Data, and Information Service
U.S. National Oceanic and Atmospheric Administration
U.S. Department of Commerce

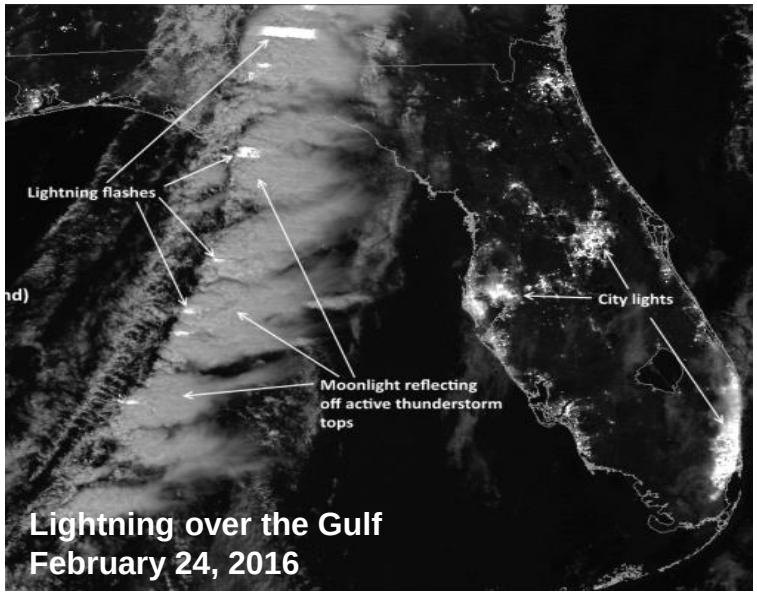
March 17, 2017


# Program and Mission

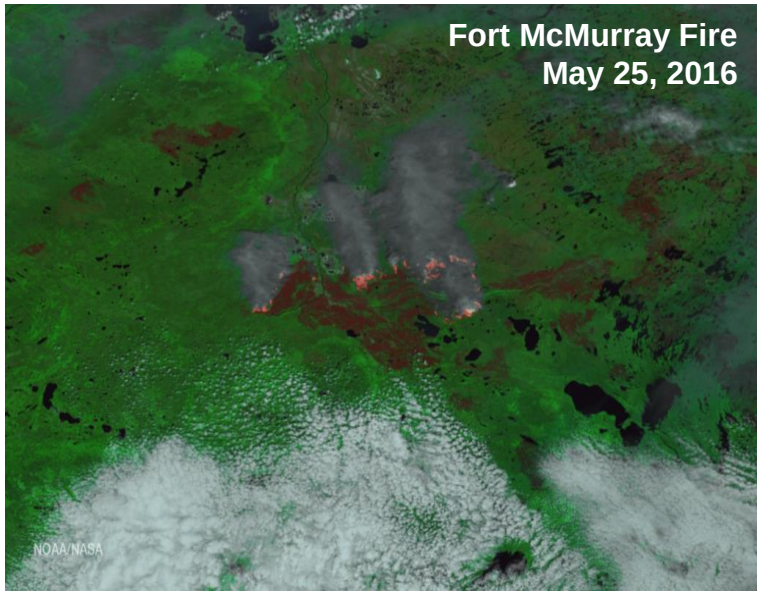
# Advantages of JPSS

## JPSS provides:

- Critical data to enable accurate medium-term forecasts, 3–7 days in advance of severe weather events
- Observations for Alaska and Polar Regions operational forecasting
- Global coverage and unique day and night imaging capabilities

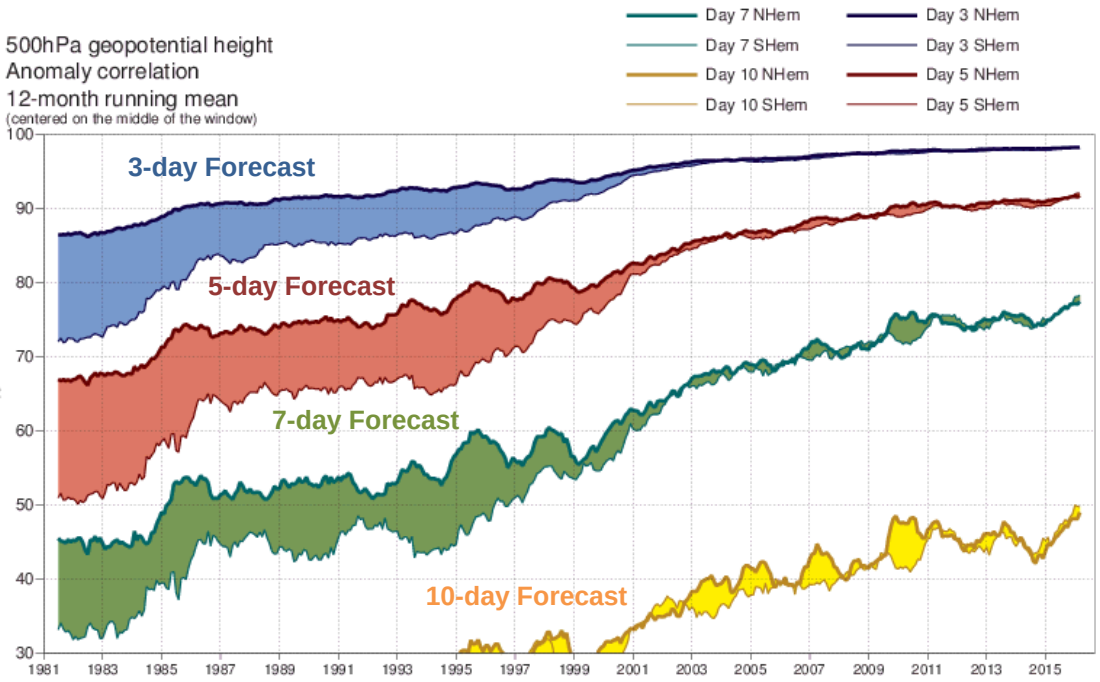


Lightning over the Gulf
February 24, 2016



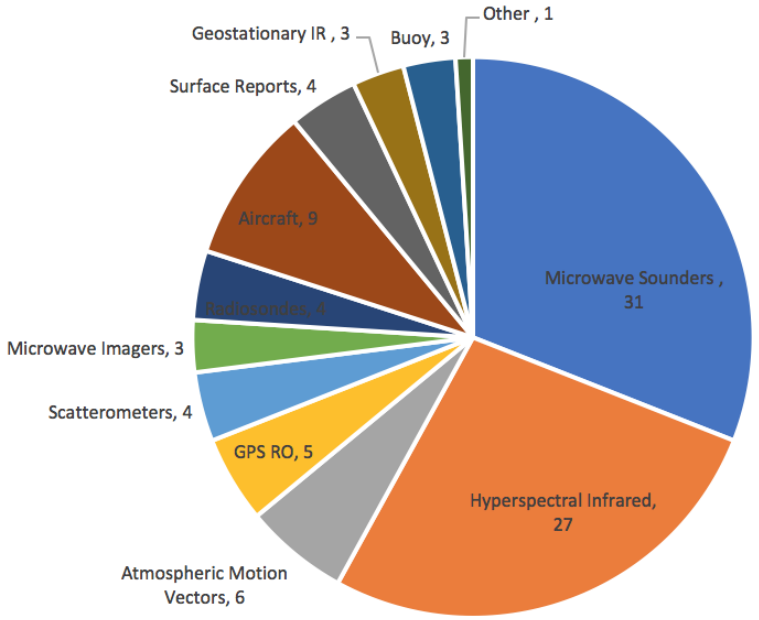

**Without JPSS, the U.S. would experience immediate degradation in the weather forecast model performance.**

# Why polar? Why JPSS?




Credit: ECMWF

Observation Type and % Impact to Reducing Forecast Errors

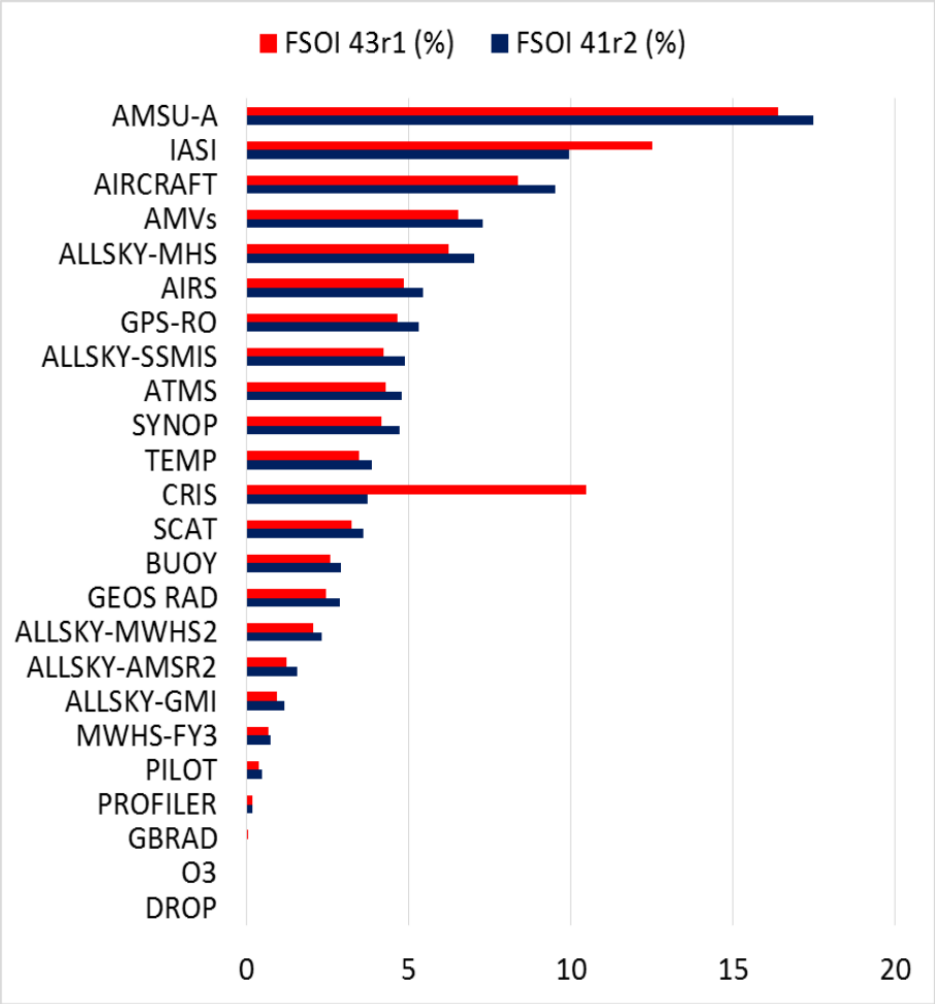


# Nov. 2016 Significant improvement in CrIS NWP assimilation by ECMWF

→Two major changes in the use of CrIS:

1) 50% increase in the number of active channels
2) Observation error covariance set consistently with diagnostics

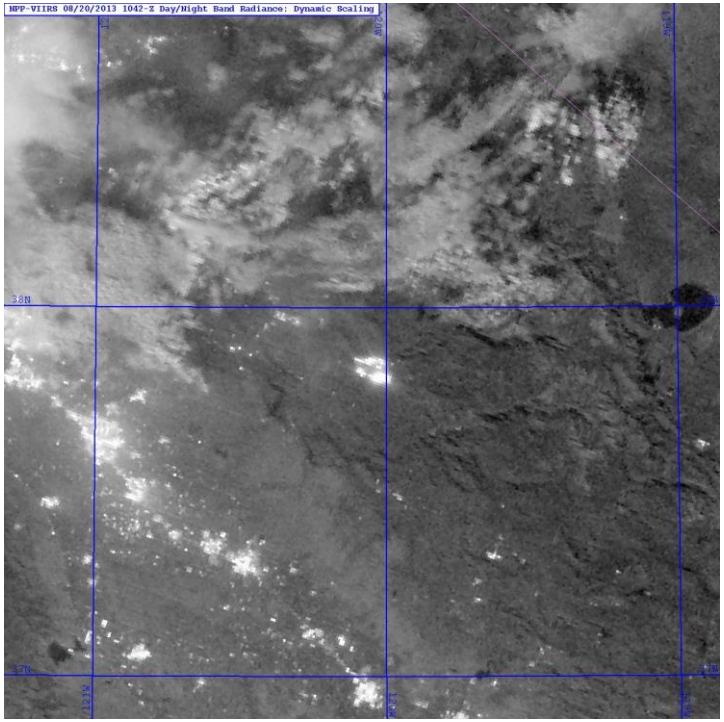
→*A large increase in the **apparent** forecast impact based on diagnosed forecast sensitivity*




ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

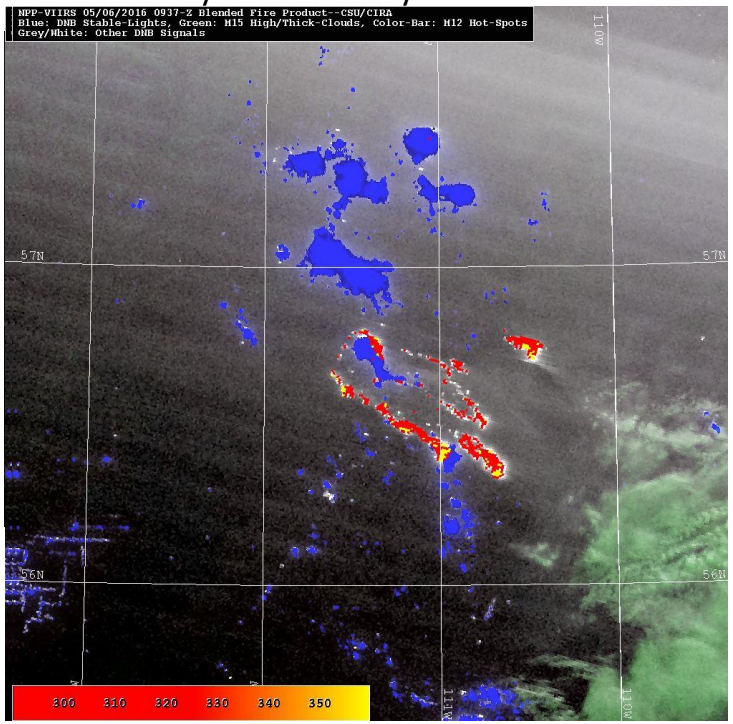
# New capabilities

Rim Fire: ~Aug 2013




Help firefighters monitor the status of nocturnal fire lines,

Ft. McMurray Fire: 4-6 May 2016




Detection of lights from small/nascent fires (e.g., lightning triggered) initially undetected by thermal infrared bands.

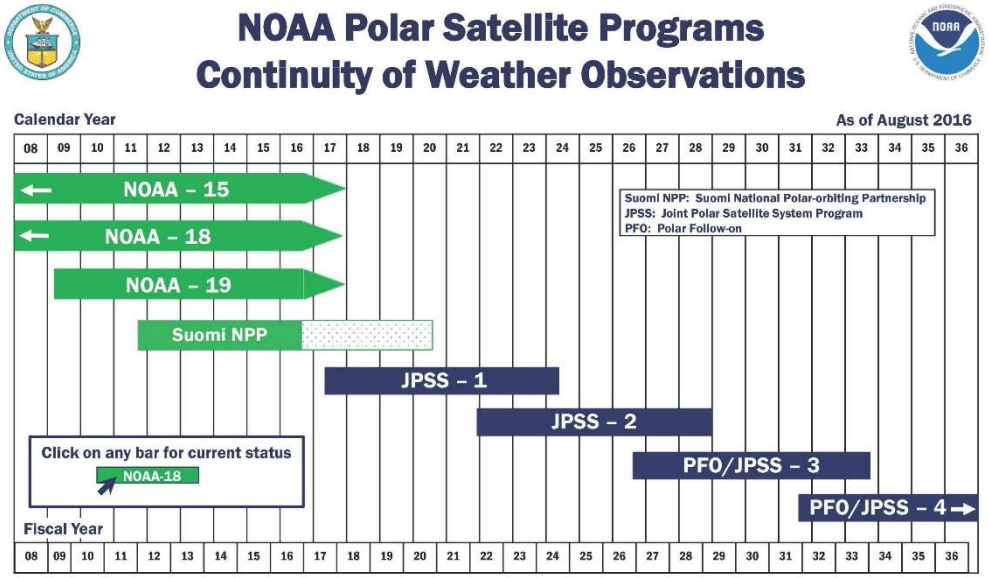
# Program Status: PFO and Partnerships

## JPSS-3 and JPSS-4 approval and funding received from Congress

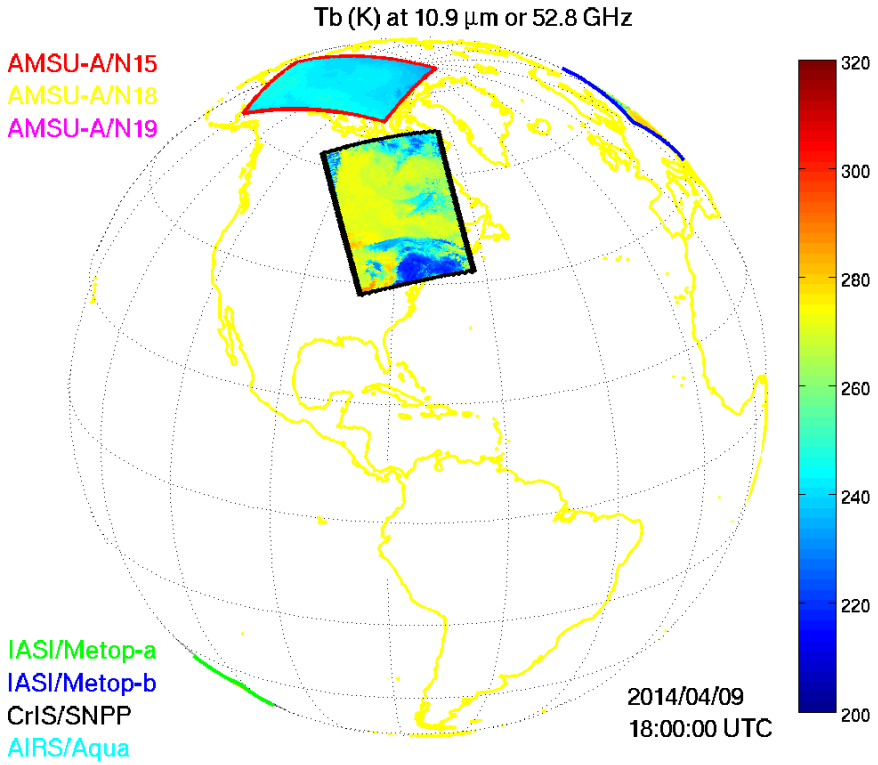
- Program life cycle baseline through 2038
- Establishing a robust architecture for a fault tolerant observing system

## JPSS and EUMETSAT signed partnership agreement

- Joint Polar System Program Implementation Plan outlines details of cooperation
- Share ground assets at McMurdo and Svalbard

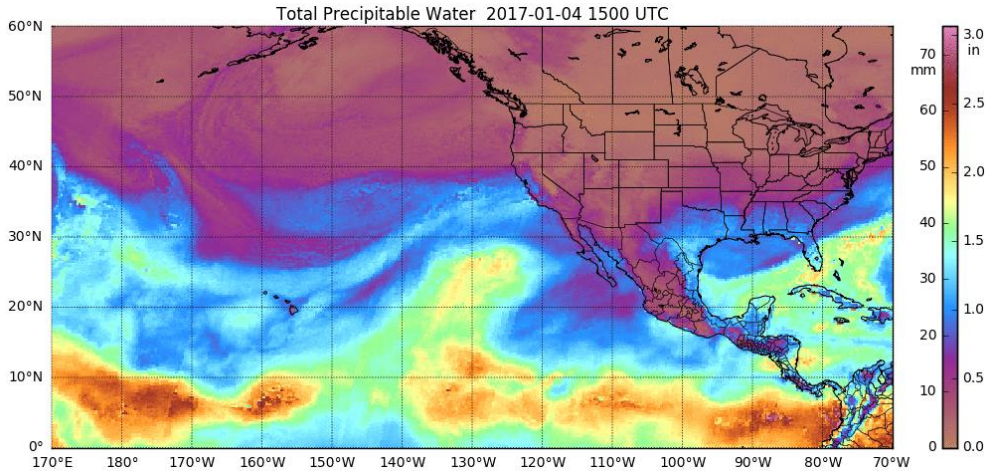


# Multiple Orbits Create Better Coverage



## Suomi NPP is producing outstanding data

- The satellite is healthy and producing a high availability of data (~99.99%)
- Operations of the satellite transferred from NASA to NOAA in 2013
- Suomi NPP is the primary operational polar-orbiting satellite for NOAA
- The satellite has been on-orbit for more than 5 years




Los Angeles Times

LOCAL / L.A. Now

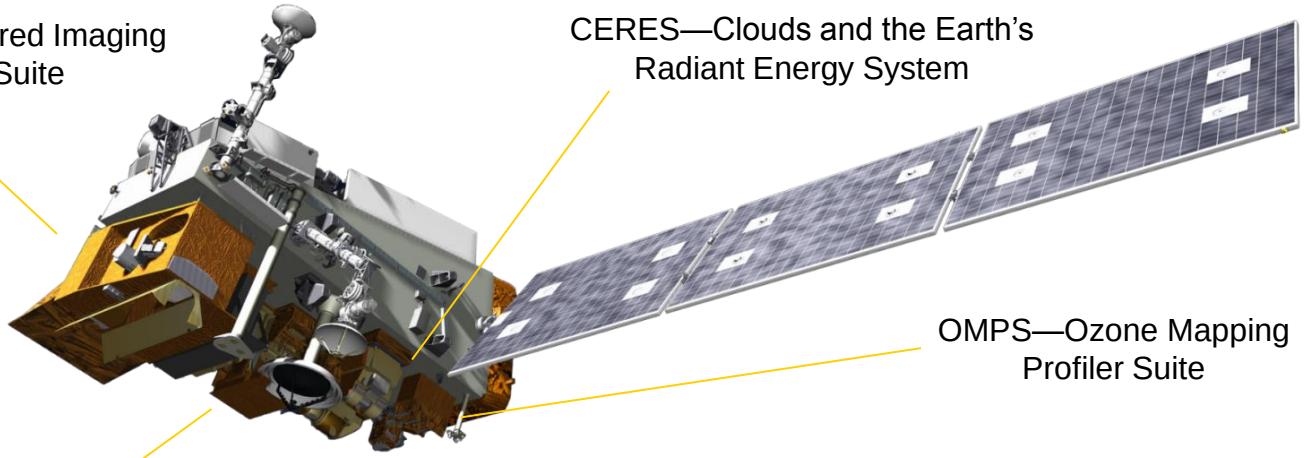
This article is related to: Droughts and Heat Waves, California Drought

# How California went from drought to dangerous rain and snow

# Program Status: JPSS-1 – Satellite

## JPSS-1 is proceeding well

- Instruments are assembled and spacecraft bus is built
- Satellite integration completed—working issue with one instrument
- Planned for launch in 4th Quarter FY 2017

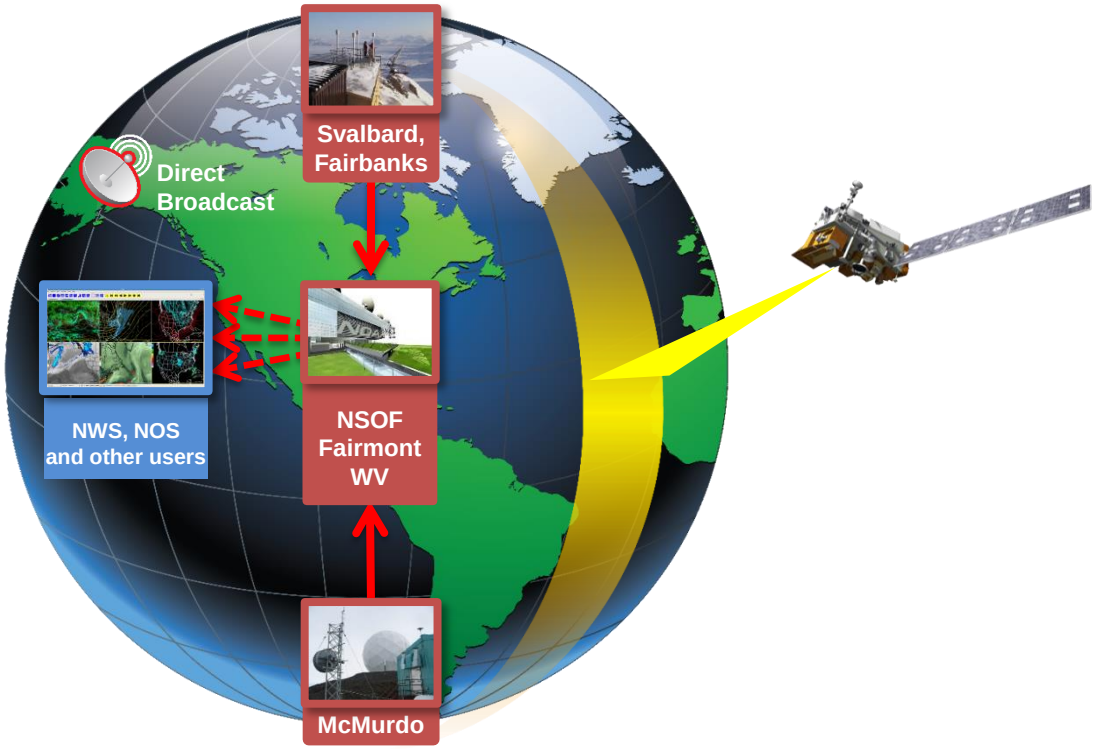



Ball Aerospace & Technologies Corp.

# Program Status: JPSS-1 – Ground System

## JPSS-1 is proceeding well

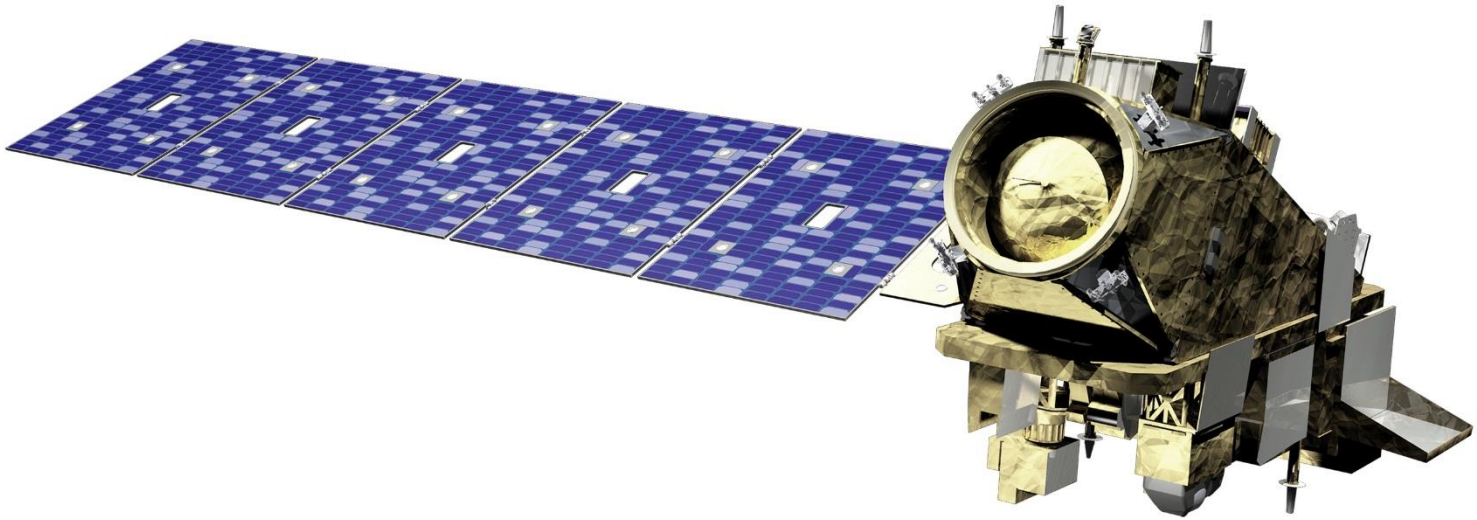
- Developments and implementation of the new ground data processing system are underway
- Addition of JPSS-1 will improve latency
- Ground stations at Svalbard and McMurdo receive data (agreement with EUMETSAT)
- Users can receive data via CLASS, PDA or DB stations



# Program Status: JPSS-2

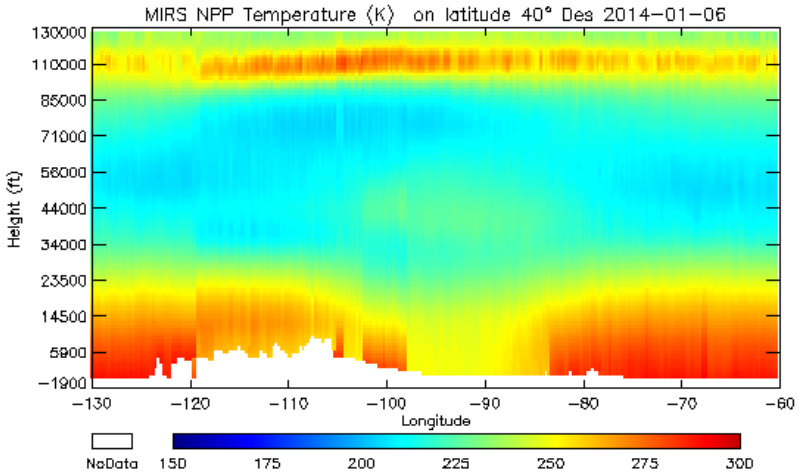
## JPSS-2 procurement activities are progressing well

- The VIIRS, OMPS, CrIS, ATMS and Radiation Budget Instruments are under contract
- The spacecraft contract awarded
- Developing ground requirements to accommodate change in spacecraft
- Launch scheduled for 1st Quarter FY 2022

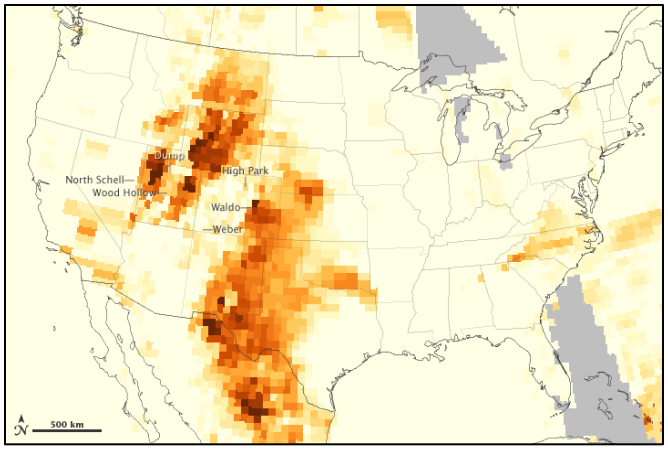



# Science and Applications

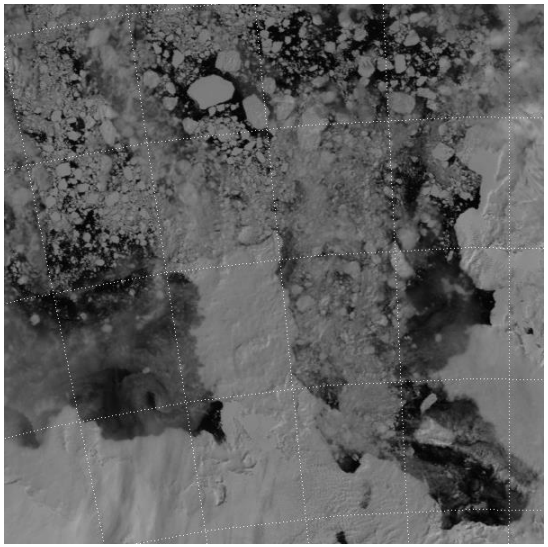
# Wide Range of Capabilities



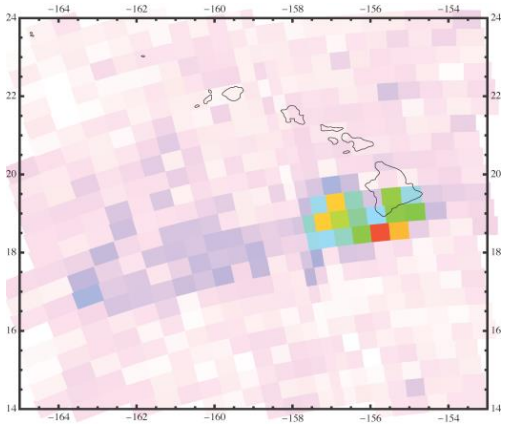

Temperature X-Section Polar Vortex




Aerosols from Fires



Day/Night Band Ice detection



Volcano $SO_2$ degassing

Algae in Lake Erie

# Operational Use of JPSS Data

## NOAA real-time users of JPSS data include:

- National Weather Service
  - ATMS and CrIS for weather forecasts
  - VIIRS nowcasting imagery and products
  - VIIRS environmental products for modeling and assessments
  - OMPS ozone for ozone monitoring and UV forecasts
- National Ocean Service
  - Coastal water quality alerts
  - Harmful algal bloom alerts
- National Marine Fisheries Service
  - Marine resources/ecosystems
- NOAA Satellite and Information Service
  - Hazard mapping system
  - COASTWATCH

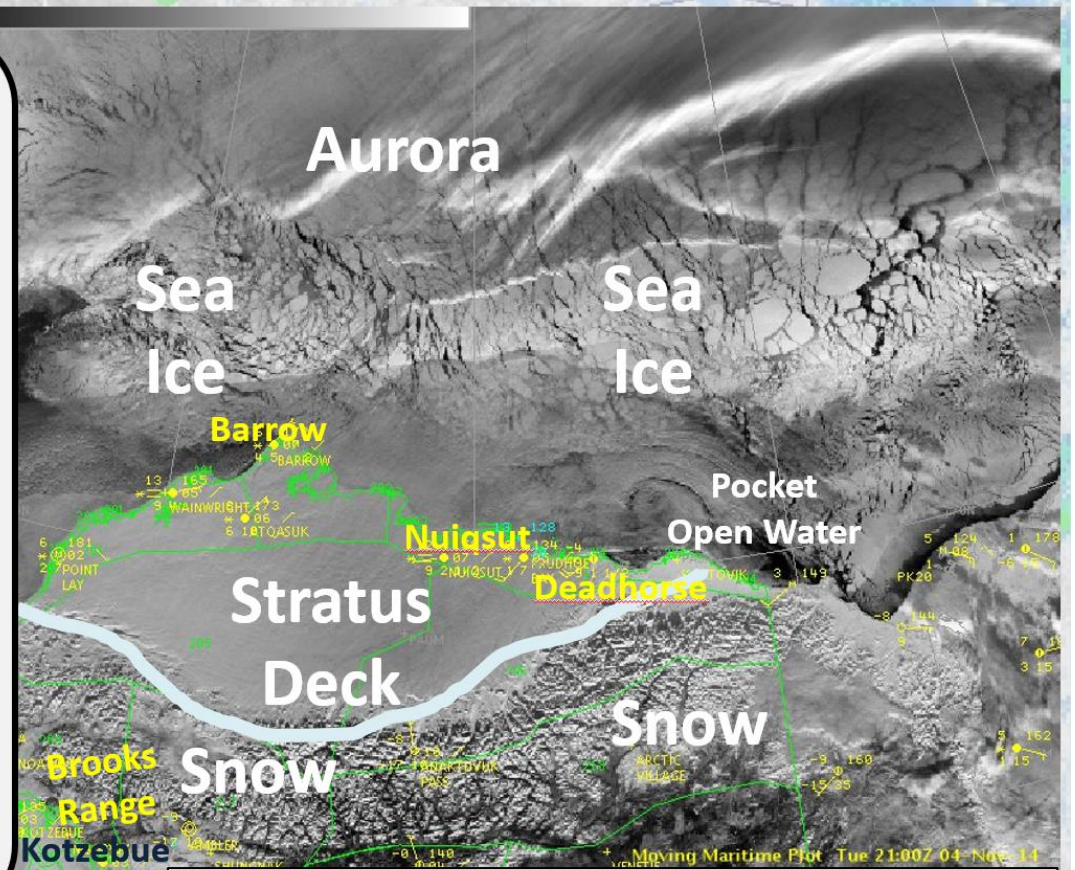

## Partner real-time users of JPSS data:

- DoD forecast agencies
- EUMETSAT member meteorology services
- Other Met agencies around the world

# NWS utilizing JPSS Data

## Satellite in Operations

- Sea Ice Analysis
- Land Impacts
  - Fog/Stratus
  - Coastal ice
  - Snow
  - Combined Winds and Satellite data: Blowing Snow
- Marine Impacts
  - Coastal Erosion

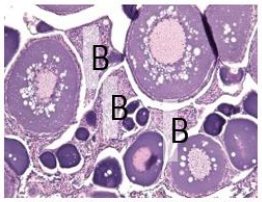



*SNPP VIIRS Day Night Band (DNB) at 2110z on Nov 4, 2014*

# NOAA Fisheries utilizing JPSS Data

## Temporal variability in rockfish reproductive parameters in the Gulf of Alaska

NOAA FISHERIES
AFSC
Kodiak Laboratory
Christina Conrath

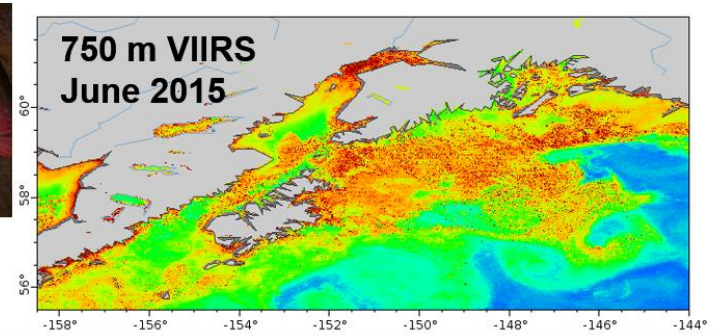


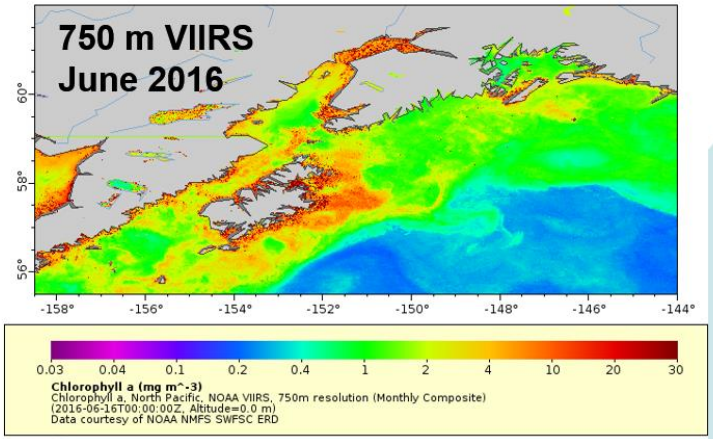

A histological section of a non-spawning adult shortraker rockfish. There is evidence of a prior spawning (B) but no current development.

A histological section of a spawning adult shortraker rockfish. The embryos within this section were at the eyed stage of development.

### Objective

Examine temporal variability in reproductive parameters (maturity, fecundity, reproductive success, and the strength of maternal effects) to see how these changes may be related to environmental variability including sea surface temperature and primary productivity.




These charts show the variability in chlorophyll a concentrations on the same day during two different years (2015 and 2016).

# User Engagement: PGRR

**The Proving Ground and Risk Reduction program enhances user applications of JPSS data, algorithms and products by stimulating interactions between technical experts and key user stakeholders.**

**Initiatives include:**

- River Ice and Flooding
- Fire and Smoke
- Sounding Applications NOAA Unique CrIS/ATMS Processing System (NUCAPS)
- OCONUS and NCEP Service Centers—AWIPS
- ★ Hydrology
- ★ Atmospheric Chemistry
- Ocean and Coastal
- Severe Weather/NWP/Data Assimilation
- ★ Arctic
- Innovation and Training

★ *New in 2016*

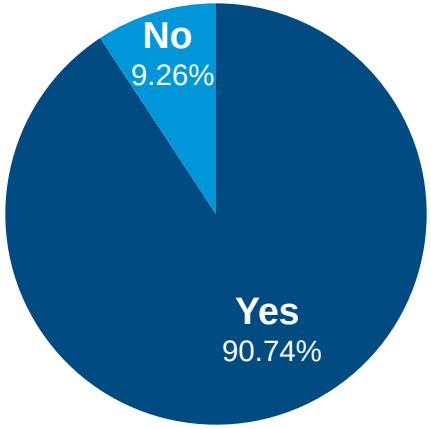
# User Engagement: PGRR

## Key updates

- Fire and Smoke
  - New smoke windows for Alaska/Western U.S. in HRRR model
- Sounding Applications NUCAPS
  - NUCAPS was evaluated during the 2016 Atlantic Tropical Cyclone Season—positive feedback demonstrated value of product
- Hydrology
  - New atmospheric water vapor applications being tested
  - ATMS Snowfall rate widely used by NWSFO's
- Arctic
  - Ice products made available to NWS Sea Ice Program
- Innovation and Training
  - Created the 'Satellite Foundational Course—JPSS' training module

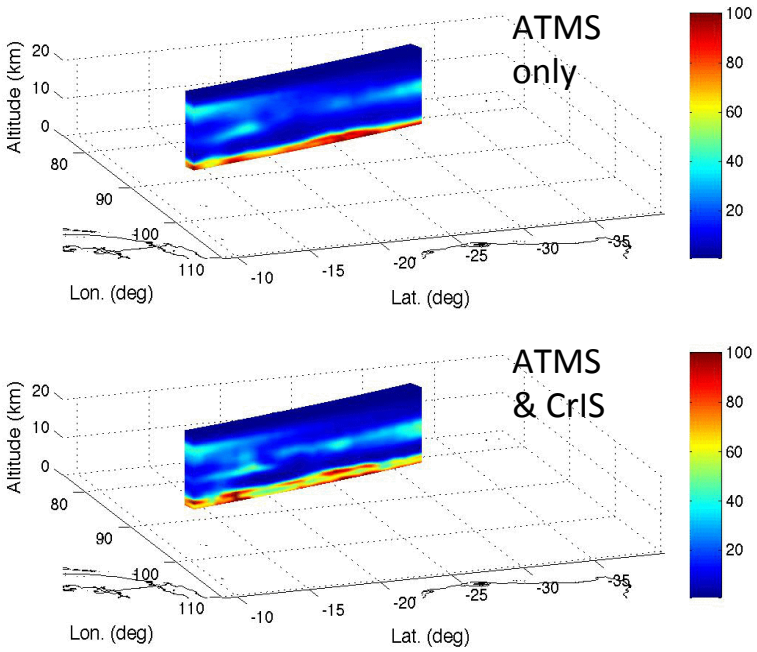
Did the NUCAPS soundings provide an effective update on the current state of the thermodynamic environment?

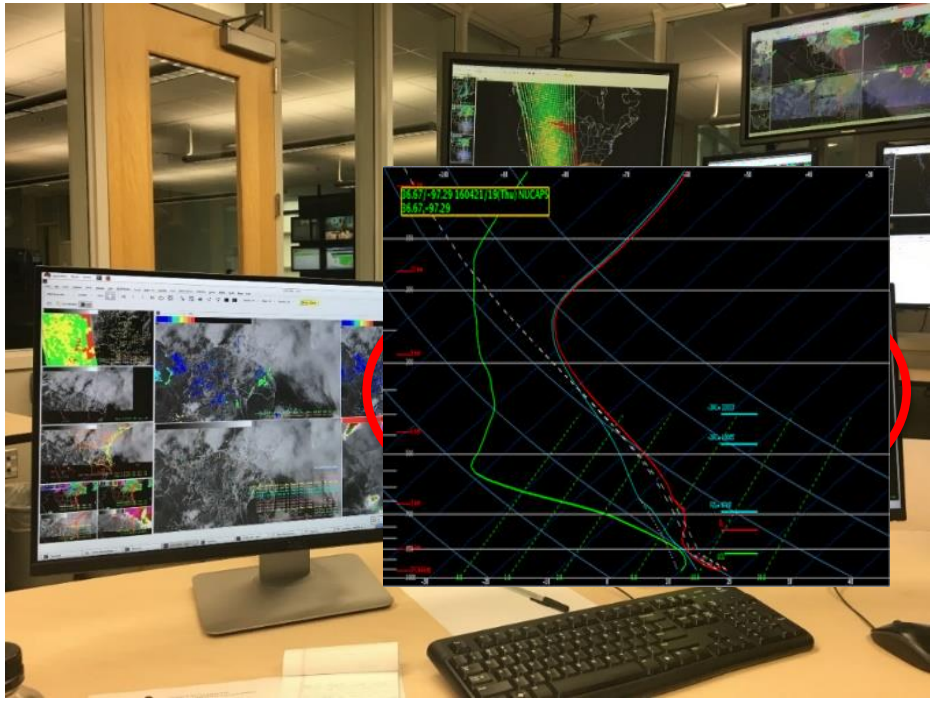
Answered: 54 Skipped: 9



# Combine CrIS and ATMS in AWIPS

Relative Humidity Vertical Slice



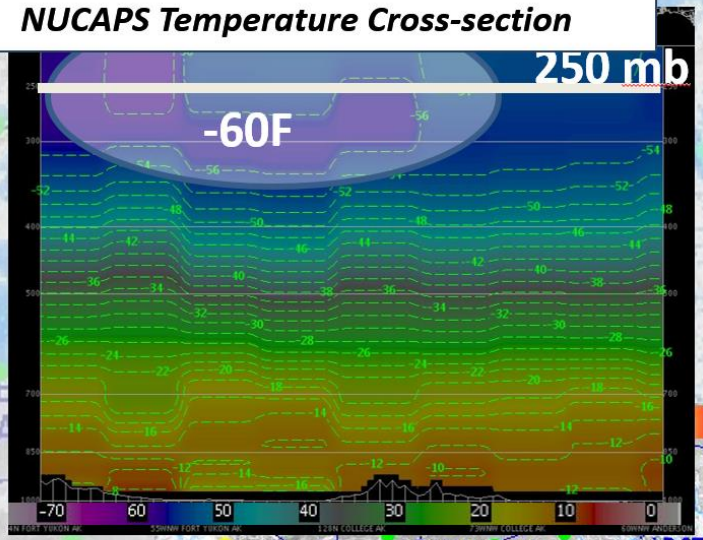



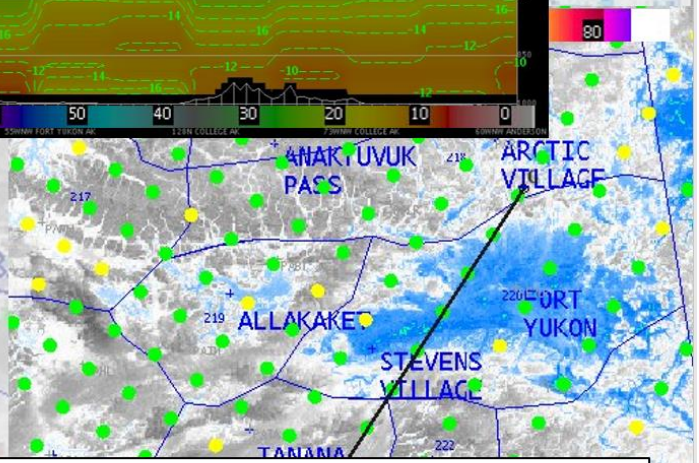
# NWS utilizing JPSS Data

## NUCAPS

- NOAA Unique Combined Atmospheric Processing System (NUCAPS)
  - CrIS
  - ATMS
- 2014 JPSS Proving Ground Risk Reduction Project
  - Aviation hazards for Cold Air Aloft events and potential freezing fuel
  - Visualization of data over large area

*NUCAPS Temperature Cross-section*




*SNPP IR 10.8um and NCAPS at 1400z on December 9, 2016*

# NWS River Forecast Centers utilizing JPSS Data

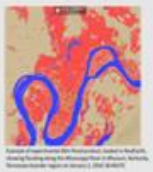
## A Case Study of the 2015-2016 Mississippi River Basin Flood Using Suomi-NPP VIIRS Flood Products

*Mike DeWeese*
*NWS North Central River Forecast Center*
*Chanhassen, MN 55317*

### Background

Historic flooding from an unusual winter rainfall event impacted Missouri in December 2015. Rain amounts of 8-10 inches fell along a 60 mile-wide band across the Meramec and lower Missouri Rivers, and into the Illinois River basin. The heavy rain event fell on saturated ground due to rainfall over the previous week, causing widespread major to record flooding. Rivers spilled into the flood plain as numerous levees were breached and water backed up into tributaries. River forecast models were adjusted in real time, based on observed information, to account for these dynamic conditions as they occurred during this event.

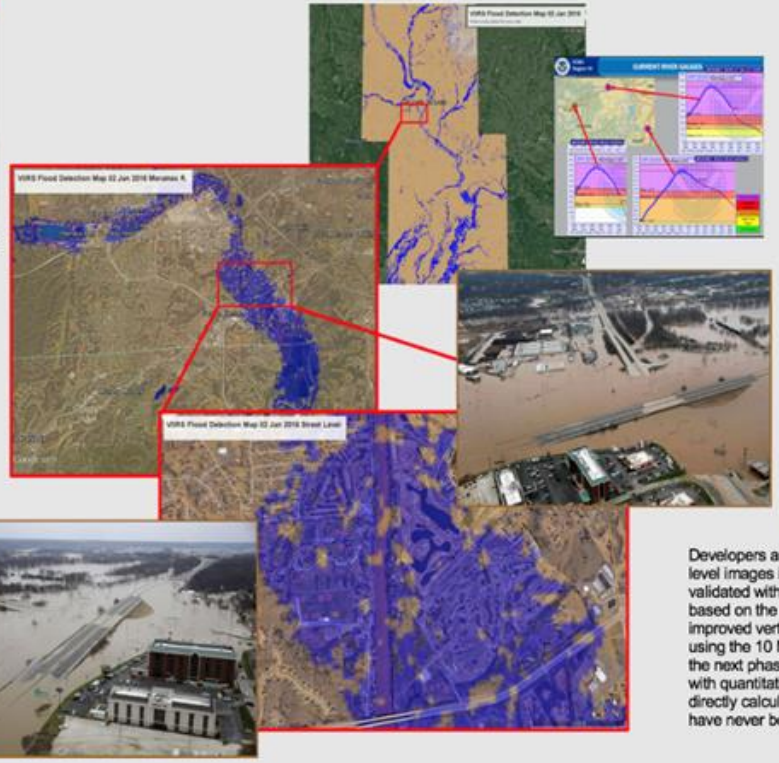
One new source of observed data utilized was the **Flooded Area imagery from the Suomi-NPP VIIRS satellite**, developed by George Mason University. This experimental product has been under development since 2014 and proved valuable in determining the flood inundated areas, providing forecasters and decision makers with detailed inundation imagery over extensive areas.

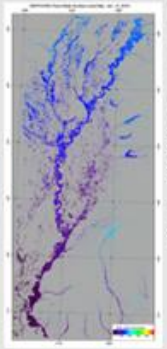


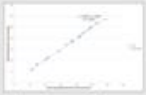
US Army Corps of Engineers made a map book using VIIRS 30-m flood maps along the Illinois River during the Midwest flood event in January 2016.

### Downscaling and Operational Applications

River forecasters used the imagery to adjust models for extensive flood plain storage effects, thereby improving model simulations of river levels at downstream points. The images were also provided to the FEMA Region VII Regional Response Coordination Center (RRCC) for daily briefings and high level response planning. The USACE Rock Island District used the images to develop a flood playbook for Emergency Managers to monitor levee conditions on the Illinois River. Finally, the images were provided to the Ohio and Lower Mississippi River Forecast Centers (OHRFC and LMRFC) for their use as the flooding progressed to other regions.





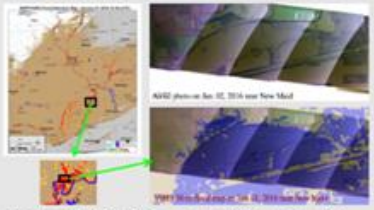


Above: Scatter plot between VIIRS retrieved water surface levels and water levels from river gauge observations during 2016's Midwest flood event.

Left: VIIRS 375-m flood water surface level map along the Mississippi River Basin on Jan. 12, 2016.

### VIIRS Processing and Dissemination

The VIIRS floodwater fraction product has been available routinely at five River Forecast Centers in the USA since 2014, under the support of the Joint-Polar Satellite System Proving Ground and Risk Reduction Program (JPSS/PGRR). The 375 meter resolution VIIRS images are processed initially at GMU, then sent to the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin. From there the images are repackaged for dissemination in AWIPS. The images are also downscaled from the native 375 M resolution to 30 M high resolution images available in the web based Real Earth viewer at CIMSS.



The downscaled 30-m flood maps present a lot more inundation details than the original VIIRS 375-m flood maps.

**VIIRS near-real-time flood maps:**

- ✓ **Coverage:** any regions between 80° S and 80° N.
- ✓ **Spatial resolution:** 375-m
- ✓ **Flood types:** supra-veg/bare soil flood and supra-snow/ice flood.
- ✓ **Classification types:** Cloud, Snow, River/Lake Ice, Shadow (cloud shadow and terrain shadow), Supra-snow/Ice, Normal Open Water, and Flooding Water fractions of supra-veg/bare soil floods.
- ✓ Daytime 375-m resolution JPSS VIIRS Flood Products are distributed to forecasters in AWIPS and to the general pubic via RealEarth (a web-based mapping service).
- ✓ Products available online or via mobile app

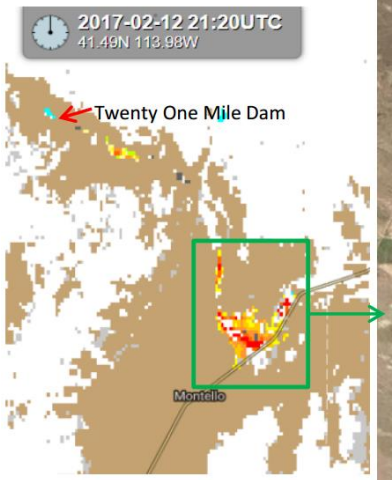
http://realearth.ssec.wisc.edu/

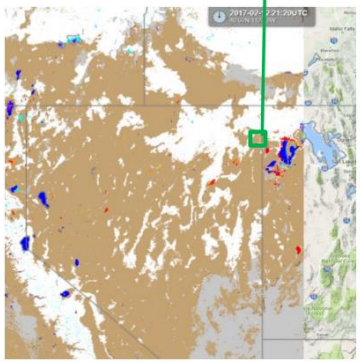
### Future Development

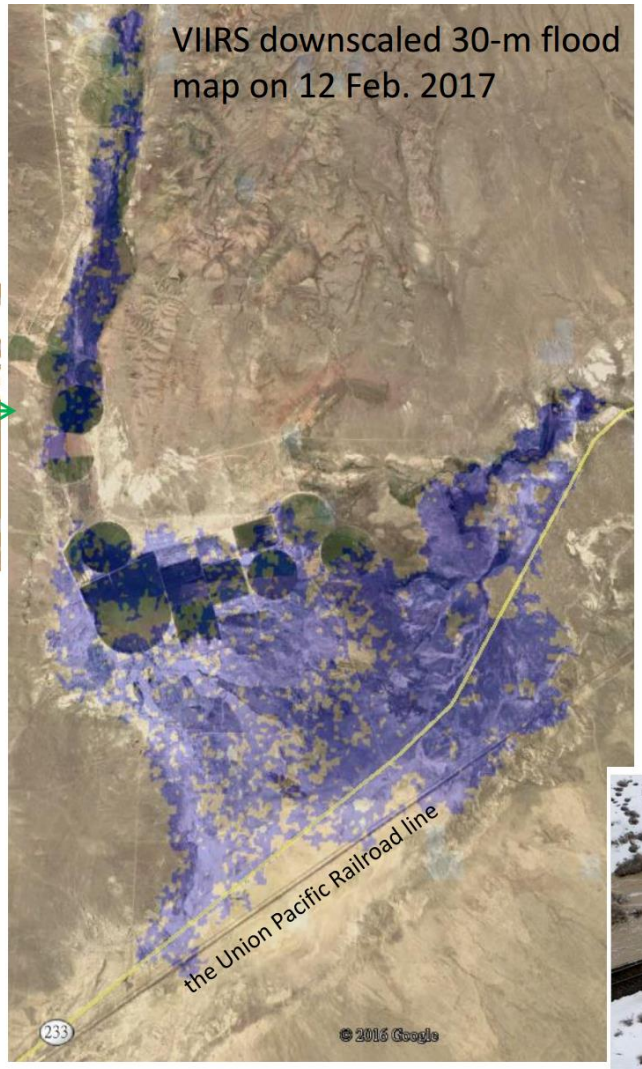
Developers are working with the NCRFC to create water level images in addition to flood areas. Results have been validated within one meter accuracy for several events based on the 30 M STRM DEM dataset. The potential for improved vertical accuracy within one foot or less is high using the 10 M NED dataset, which will be completed in the next phase of the project. This will provide forecasters with quantitative gridded forcings that can be used to directly calculate storage volumes in river models, which have never been available before.

# Image of the Month - JPSS Proving Ground Success Stories

VIIRS flood maps are routinely provided to NWS River Forecast Centers and FEMA during extreme events as part of the JPSS Flood Initiative to help mitigate disasters due to flooding.



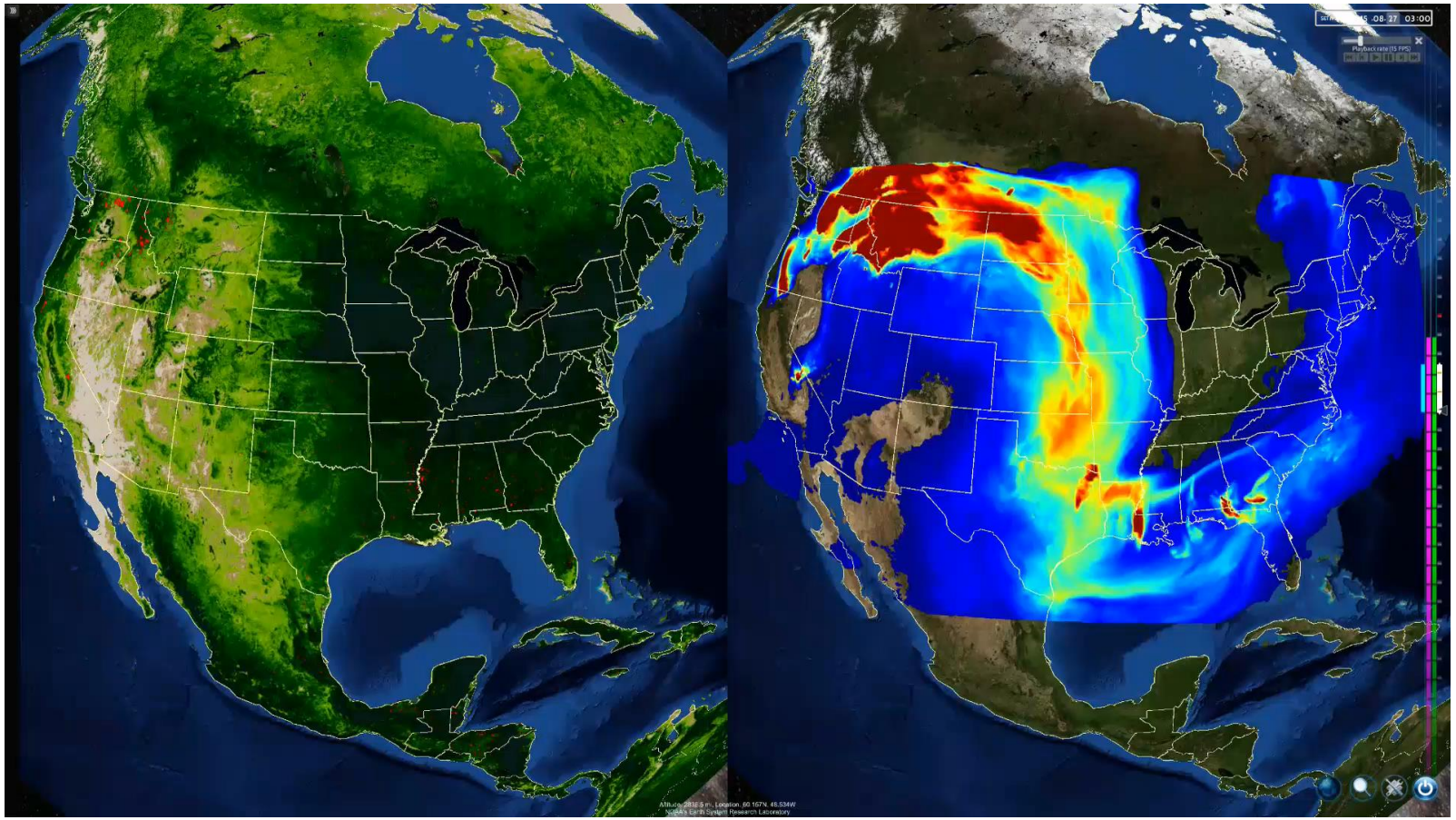






Abnormal water was found after Twenty One Mile Dam was damaged around 8 Feb. 2017.
Part of highway 233 and the Union Pacific Railroad line near Montello were inundated.


Train tracks are flooded Wednesday, Feb. 8, 2017, after the 21 Mile Dam near Montello, Nevada, broke and caused flooding to the Union Pacific railroad line near

# Dangerous Phenomena: Smoke



# Summary

- Healthy and operational Suomi NPP still producing outstanding data
- JPSS-1 launching 4th Quarter FY 2017
- Polar-orbiting satellites provide a wide range of data products supporting environmental monitoring and providing the 3–7 day weather forecast
- Ensured data continuity through 2038
- Continual focus on user engagement, feedback and improvements

# Thank You

**For more information visit**

**www.jpss.noaa.gov**

 **/NOAANESDIS**

 **/NOAASatellites**

 **@NOAASatellites**

# Agenda

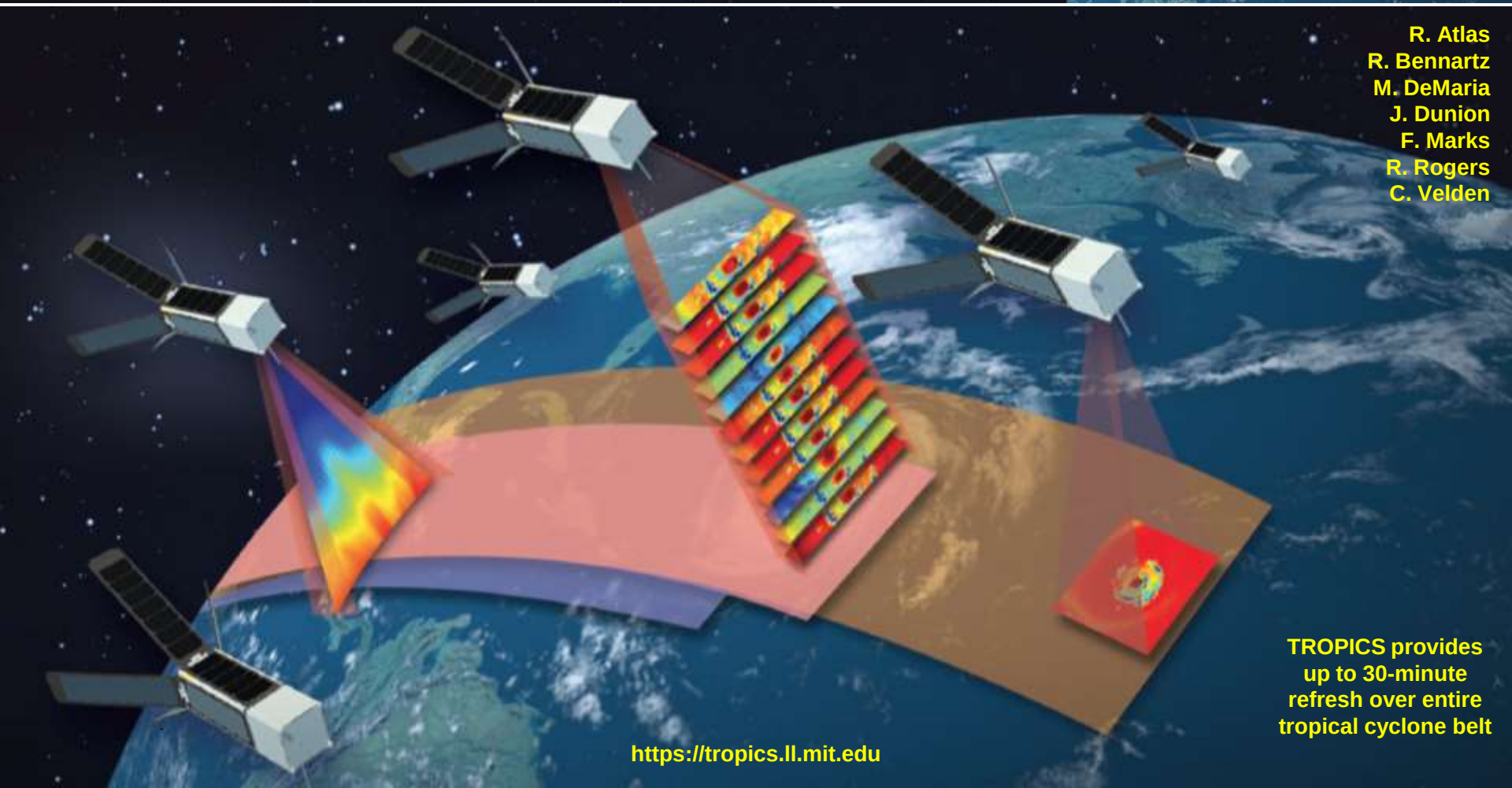
- Opening Remarks: COES Cochairs
- Action Item Review: Executive Secretary
- Strategic Plan For Federal Weather Enterprise Coordination:
  Dr. Bill Schulz (OFCM)
- COES Terms of Reference (ToR): Executive Secretary
- JPSS Update: Dr. Mitch Goldberg (NOAA-JPSS)
- NASA's TROPICS Cubesat Mission: Dr. William Blackwell (MIT-LL)
- Open Discussion: COES Members.
- Action Item Review / Next Meeting: Executive Secretary
- Adjourn: The meeting is expected to end by 3:00 PM EDT.

# Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

**MIT Lincoln Laboratory** (lead organization)

William J. Blackwell, Principal Investigator. Scott Braun (NASA GSFC), Project Scientist

R. Atlas
R. Bennartz
M. DeMaria
J. Dunion
F. Marks
R. Rogers
C. Velden



TROPICS provides up to 30-minute refresh over entire tropical cyclone belt

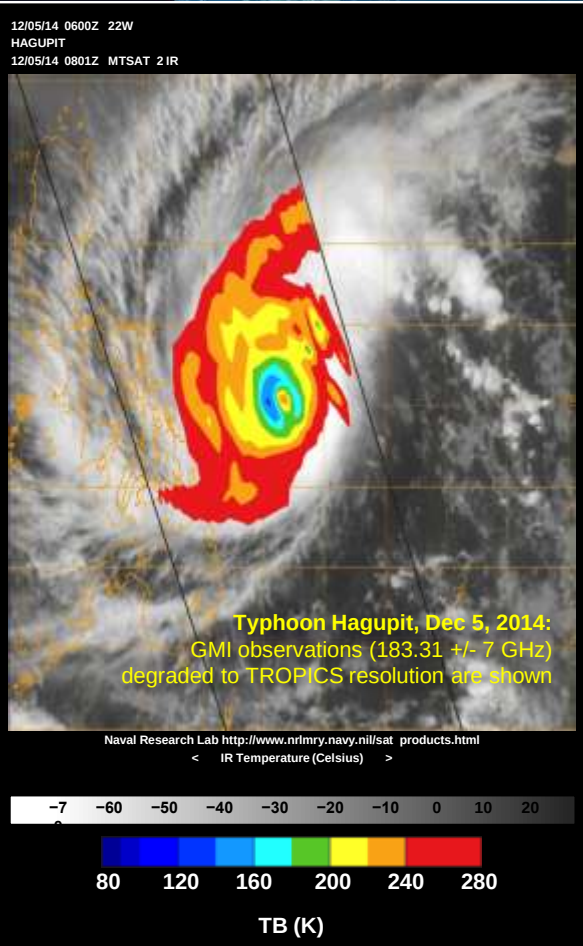
https://tropics.ll.mit.edu

# Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

**MIT Lincoln Laboratory** (lead organization)

William J. Blackwell, Principal Investigator. Scott Braun (NASA GSFC), Project Scientist

- **TROPICS will be the first demonstration that science payloads on low-cost CubeSats can push the frontiers of spaceborne monitoring of the Earth to enable system science.**
- **TROPICS will fill gaps in our knowledge of the short time scale—hourly and less—evolution of tropical cyclones. Our current capabilities are an order of magnitude slower.**
- **TROPICS will complement CYGNSS by making direct measurements of temperature, humidity and precipitation, in rapidly developing tropical cyclones.**
- **TROPICS has the potential to make frequent precipitation measurements, expanding on the coverage of the GPM mission.**




https://tropics.ll.mit.edu

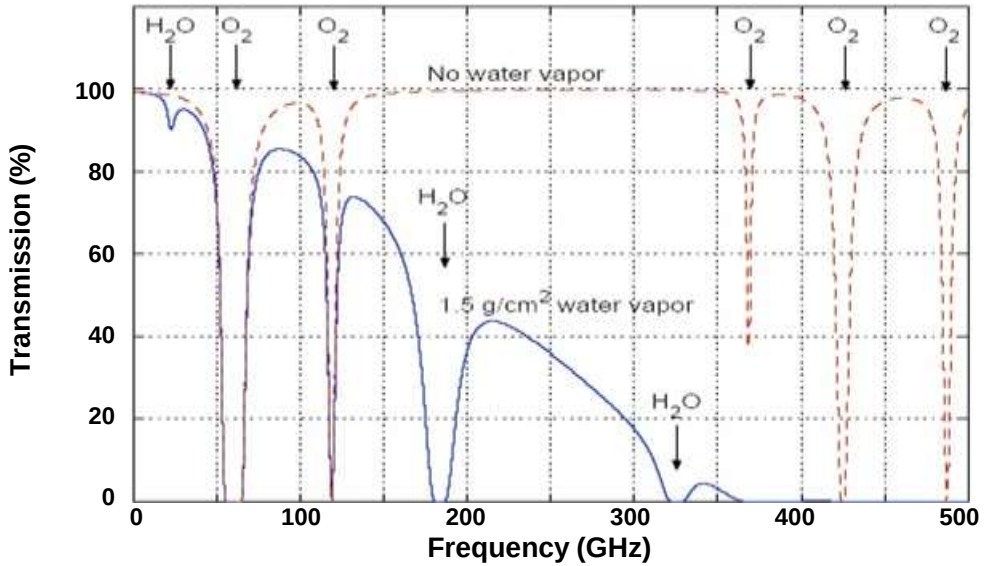
# Outline

- New CubeSat approach for Microwave Sounding enables constellations
  - Innovative instrument technologies
  - Exploding commercial sector for CubeSat buses, components, launch services, and mission operations
- TROPICS overview
  - Science objectives
  - CubeSat constellation observatory
  - Mission implementation
- Summary and path forward

# Microwave Atmospheric Sensing

| Wavelength (meters) | Radio | Microwave | Infrared | Visible | Ultraviolet | X ray | Gamma Ray |
|---|---|---|---|---|---|---|---|
| | $10^{3}$ | $10^{-2}$ | $10^{-5}$ | $.5 \times 10^{-6}$ | $10^{-8}$ | $10^{-10}$ | $10^{-12}$ |

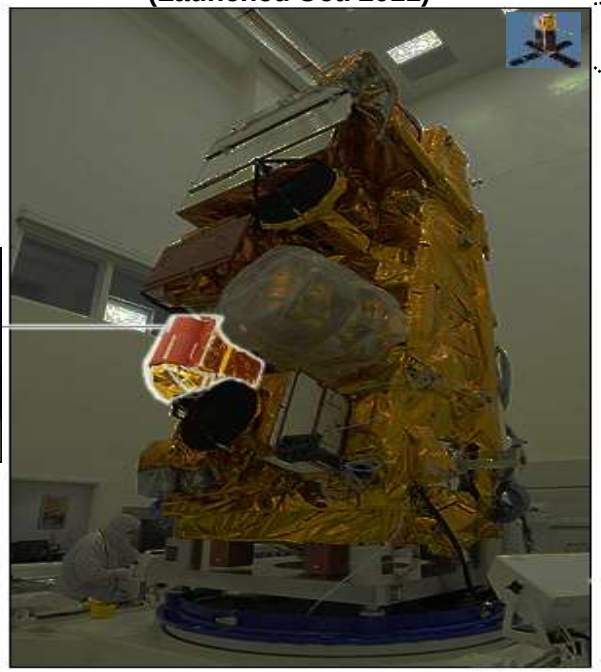
**Cloud Penetration; Highest Forecast Impact**




**The frequency dependence of atmospheric absorption allows different altitudes to be sensed by spacing channels along absorption lines**

# New Approach for Microwave Sounding

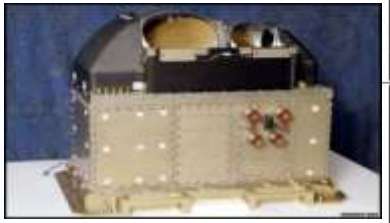
**Suomi NPP Satellite (Launched Oct. 2011)**



**2100 kg**

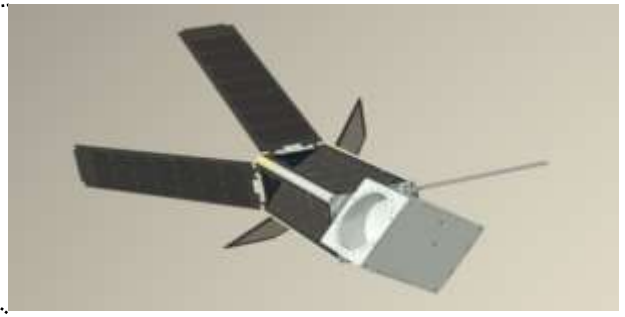
NASA/GSFC

**Advanced Technology Microwave Sounder (ATMS)**



**100 kg, 100 W**

**MicroMAS Satellite**



**4.2 kg, 10W, 34 x 10 x 10 cm**

- **Microwave sensor amenable to miniaturization (10 cm aperture)**
- **Broad footprints (~50 km)**
- **Modest pointing requirements**
- **Relatively low data rate**

**NPP: National Polar-orbiting Partnership**

# TROPICS Pathfinders: MicroMAS-1, MicroMAS-2, and MiRaTA

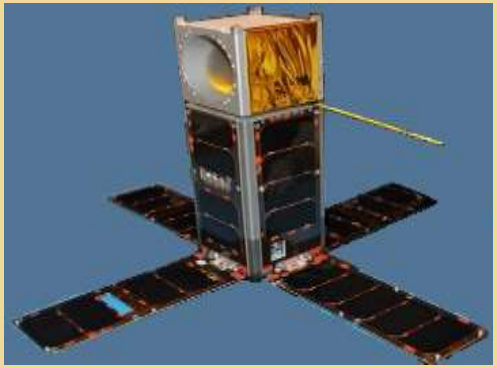
**MicroMAS = Microsized Microwave Atmospheric Satellite**
**MiRaTA = Microwave Radiometer Technology Acceleration**

## MicroMAS-1

**3U cubesat with 118-GHz radiometer**

**8 channels for temperature measurements**

**July 2014 launch, March 2015 release; validation of spacecraft systems; eventual transmitter failure**

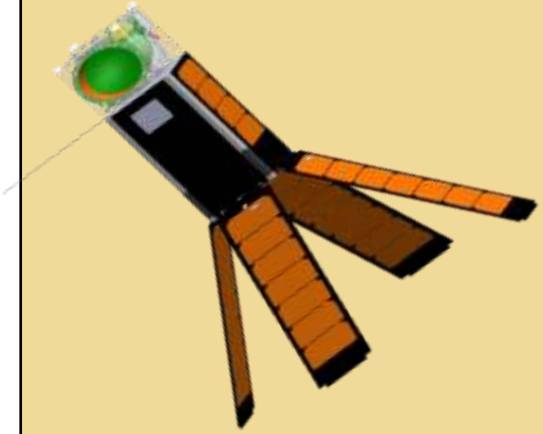


## MicroMAS-2

**3U cubesat scanning radiometer with channels near 90, 118, 183, and 206 GHz**

**Channels for moisture and temperature profiling and precipitation imaging**

**Two launches in 2017**



## MiRaTA

**3U cubesat with 60, 183, and 206 GHz radiometers and GPS radio occultation**

**10 channels for temperature, moisture, and cloud ice measurements**

**2017 launch on JPSS-1**

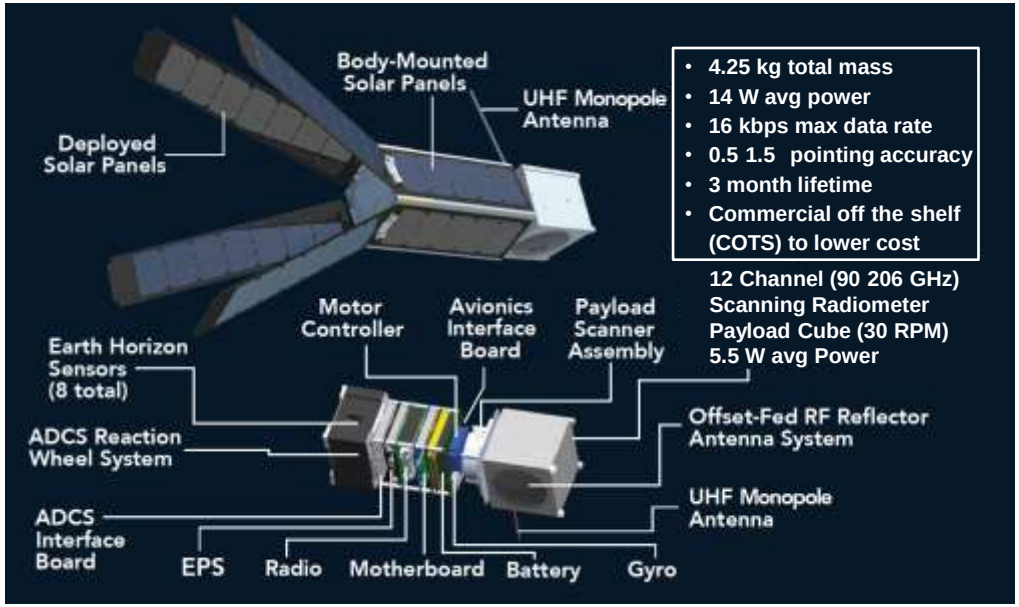
# MicroMAS-2 CubeSats Reduce Risk for TROPICS

**3U CubeSat (2U spacecraft bus, 1U radiometer)**

**12-channel passive microwave radiometer**

- **90 & 206 GHz imaging channels**
- **Temperature sounding near 118 GHz**
- **Moisture sounding near 183 GHz**

**Bus with solar panels in launch position 10 cm × 10 cm × 34 cm**




**MicroMAS-2 is a 3U CubeSat with heritage from MicroMAS-1 and MiRaTA flight designs**

# TROPICS Will Leverage Rapidly Maturing Commercial Capabilities for CubeSat Spacecraft

## Tyvak Nanosatellite Systems

**Tyvak has been the leading expert in nanosatellite technology for over 10 years, dating back to the original CubeSat**

**Multiple CubeSats on orbit, several more slated for 2017**

**Endeavor platform supports 3U to 12U missions and provides high power, precision pointing, radiation tolerance, high communication data rates, and fault handling**


## Blue Canyon Technologies

**Blue Canyon founders have over 100 years of combined experience designing and building spacecraft for the DOD, NASA, and commercial aerospace organizations.**

**BCT specializes in small spacecraft design and development. This includes satellite components for classes of small, micro, nano, pico, and cubesats.**

**30 space systems are in operation, with many more in production**


**Down-selection of bus provider in Spring 2017**

# Outline

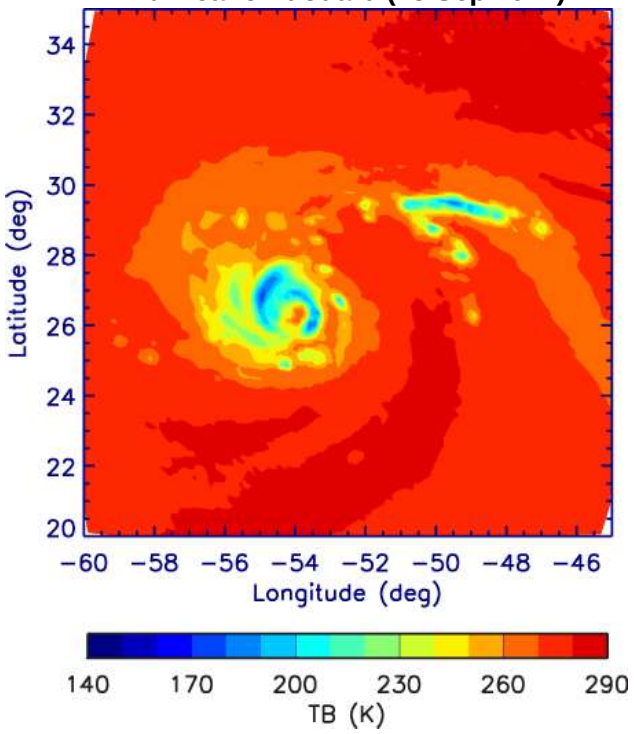
- New CubeSat approach for Microwave Sounding enables constellations
  - Innovative instrument technologies
  - Exploding commercial sector for CubeSat buses, components, and launch services
- **TROPICS overview**
  - **Science objectives**
  - **CubeSat constellation observatory**
  - **Mission implementation**
- Summary and path forward

# TROPICS Science Objectives

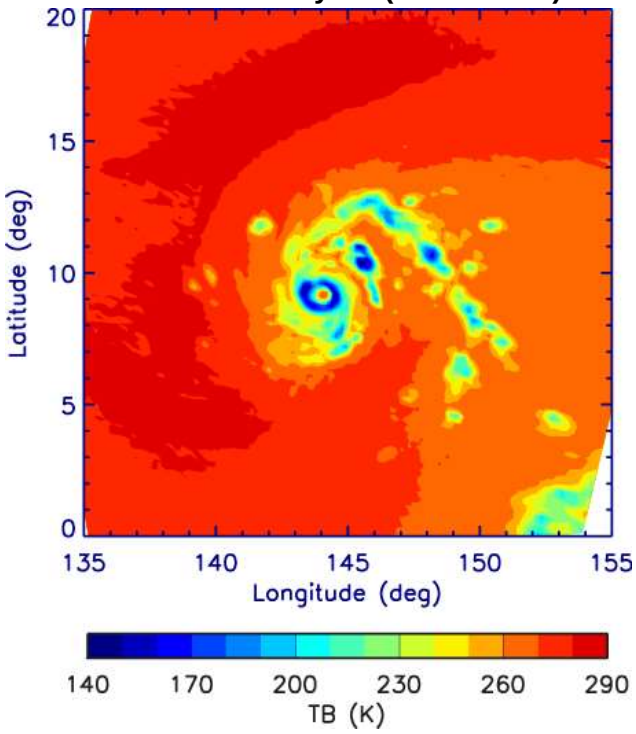
- **Relate precipitation structure evolution, including diurnal cycle, to the evolution of the upper-level warm core and associated intensity changes**
- **Relate the occurrence of intense precipitation cores (convective bursts) to storm intensity evolution**
- **Relate retrieved environmental moisture measurements to coincident measures of storm structure (including size) and intensity**
- **Assimilate microwave radiances and/or retrievals in mesoscale and global numerical weather prediction models to assess impacts on storm track and intensity**

# Representative TROPICS 183-GHz Images (ATMS Data Shown, Similar Spatial Resolution)

**Hurricane Edouard (15 Sep 2014)**




**Hurricane Maysak (30 Mar 2015)**



# TROPICS Channels

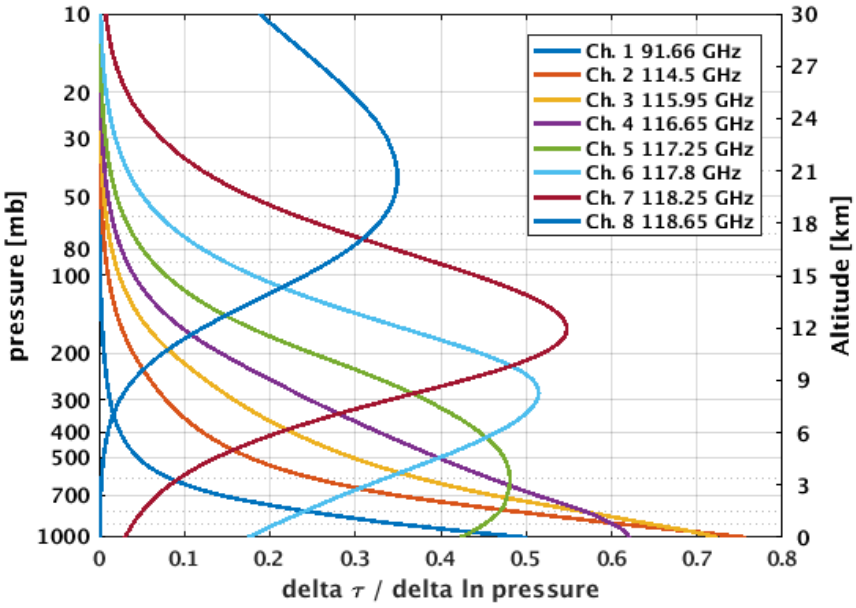
| TROPICS Ch. | W-band Ch. | Center Freq. (GHz) | Bandwidth (GHz) | RF Span (GHz) |
|---|---|---|---|---|
| 1 | 1 | 91.655 ± 2 | 1.000 | 89.155-90.155, 93.155-94.155 |

| TROPICS Ch. | F-band Ch. | Center Freq. (GHz) | Bandwidth (GHz) | RF Span (GHz) |
|---|---|---|---|---|
| 2 | 1 | 114.50 | 1.000 | 114.00-115.00 |
| 3 | 2 | 115.95 | 0.800 | 115.55-116.35 |
| 4 | 3 | 116.65 | 0.600 | 116.35-116.95 |
| 5 | 4 | 117.25 | 0.600 | 116.95-117.55 |
| 6 | 5 | 117.80 | 0.500 | 117.55-118.05 |
| 7 | 6 | 118.25 | 0.400 | 118.05-118.45 |
| 8 | 7 | 118.65 | 0.400 | 118.45-118.85 |

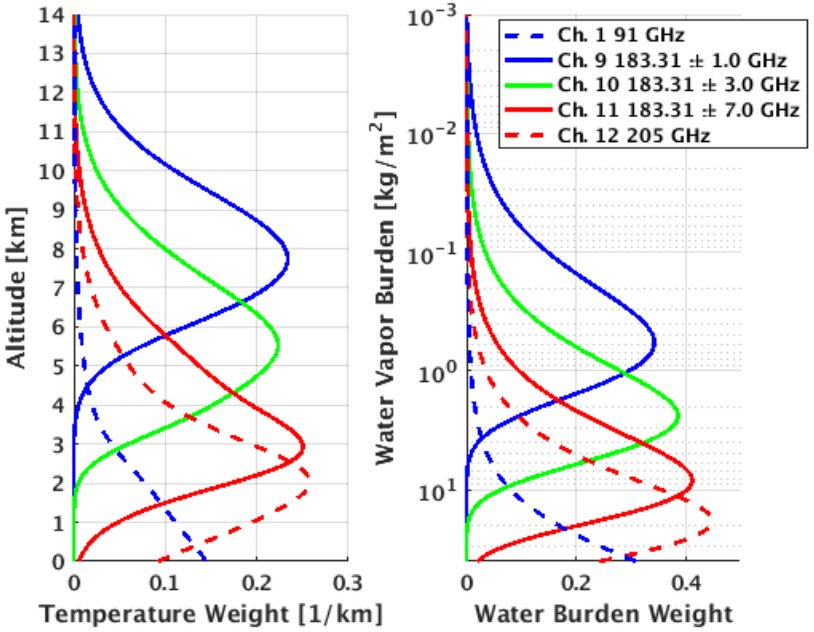
| TROPICS Ch. | G-band Ch. | Center Freq. (GHz) | Bandwidth (GHz) | RF Span (GHz) |
|---|---|---|---|---|
| 9 | 1 | 183.31 ± 1.0 | 0.500 | 182.06-182.56, 184.06-184.56 |
| 10 | 2 | 183.31 ± 3.0 | 1.000 | 179.81-180.81, 185.81-186.81 |
| 11 | 3 | 183.31 ± 7.0 | 2.000 | 175.31-177.31,189.31-191.31 |
| 12 | 4 | 204.8 | 2.000 | 203.8-205.8 |

# TROPICS Channel Characteristics

## Temperature

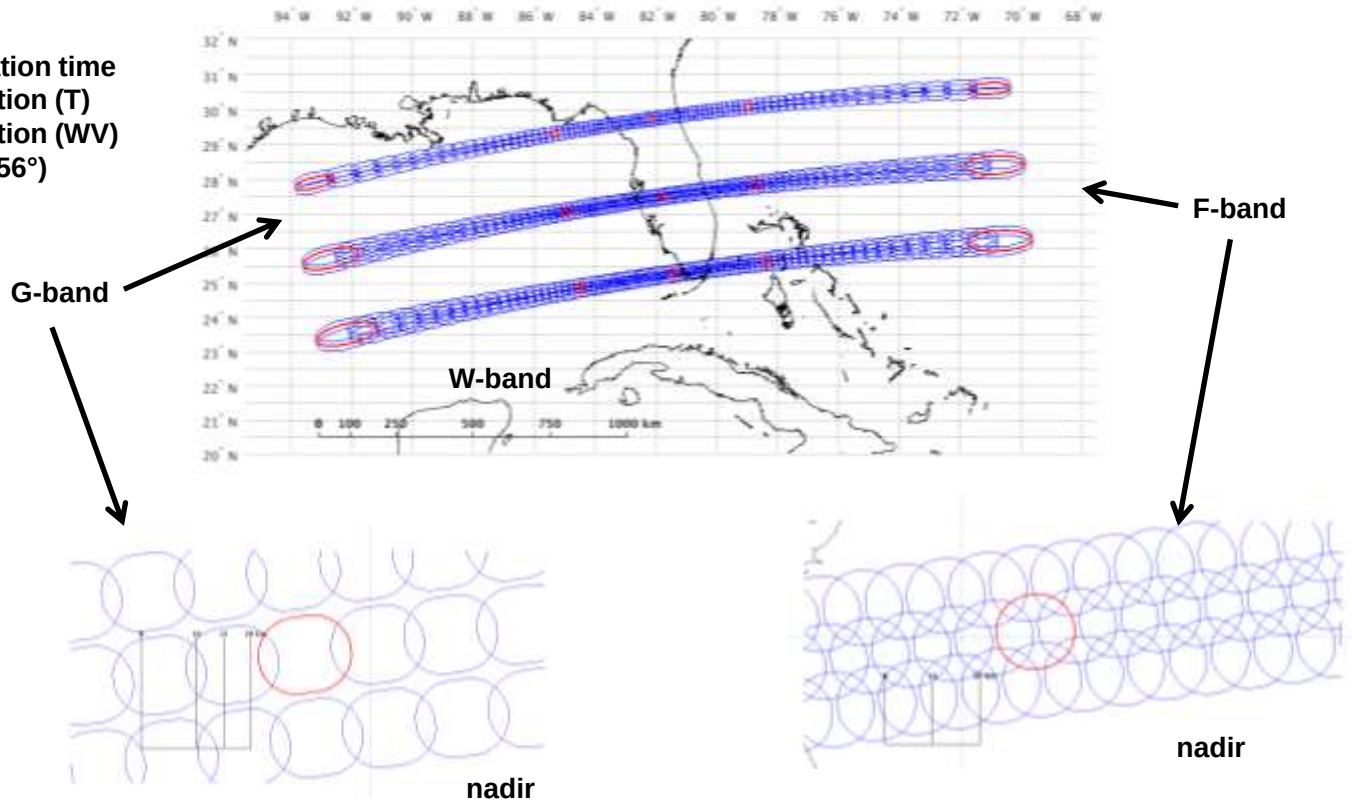



## Water Vapor



# TROPICS Swath & Footprints

**30 RPM scan rate**
**8.333 msec integration time**
**25 km nadir resolution (T)**
**15 km nadir resolution (WV)**
**>2000 km swath (±56°)**




**Altitude of 500 km**

# TROPICS Spatial and Temporal Resolution

| | ATMS Nadir/Avg (km) | TROPICS Nadir/Avg (km) |
|---|---|---|
| Temperature | 33/44 | 27/40 |
| Moisture & Precipitation | 17/24 | 17/24 |
| Swath width | 2250 (±50.5°) | 2025 (±56°) |

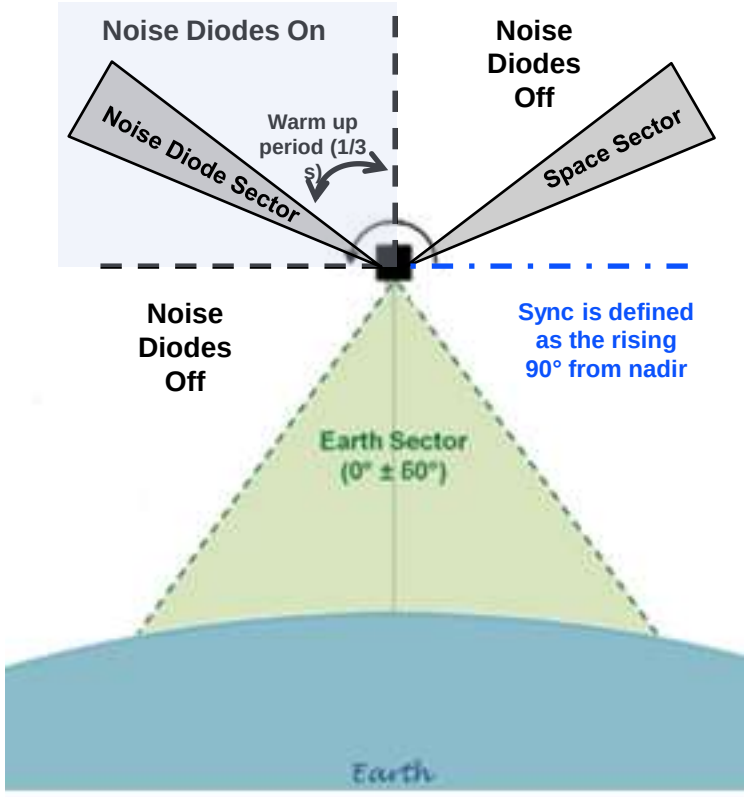
**TROPICS resolution comparable to ATMS**

**TROPICS will provide frequent revisits**

| | Average (min) | Median (min) | Frequency of gaps <2 hr |
|---|---|---|---|
| Baseline 9-12 satellites | 45 | 30 | 60% |
| Threshold 6-9 satellites | 90 | 60 | 50% |

# Scan Profile for TROPICS

- Rotation rate is 30 RPM (2 sec. period)
- 81 Earth Sector samples per scan
- 10 samples each in Space & ND Sectors
- Integration time: 8.333 msec
- Spatial Information (at 500 km):
  - Beamwidth (FWHM):
    - W-band 3.0° (3.2° CT)
    - F-band 2.7° (2.88° CT)
    - G-band 1.6° (1.95° CT)
    - Sample spacing: 1.5°
  - Swath: ~2000 km
  - Nadir footprint diameter
    - W-band: 26-km DT, ~28-km CT
    - F-band : 23.5-km DT, ~26-km CT
    - G-band : 14-km DT, ~17-km CT






DT = down track CT = cross track

# TROPICS Products and Expected Performance

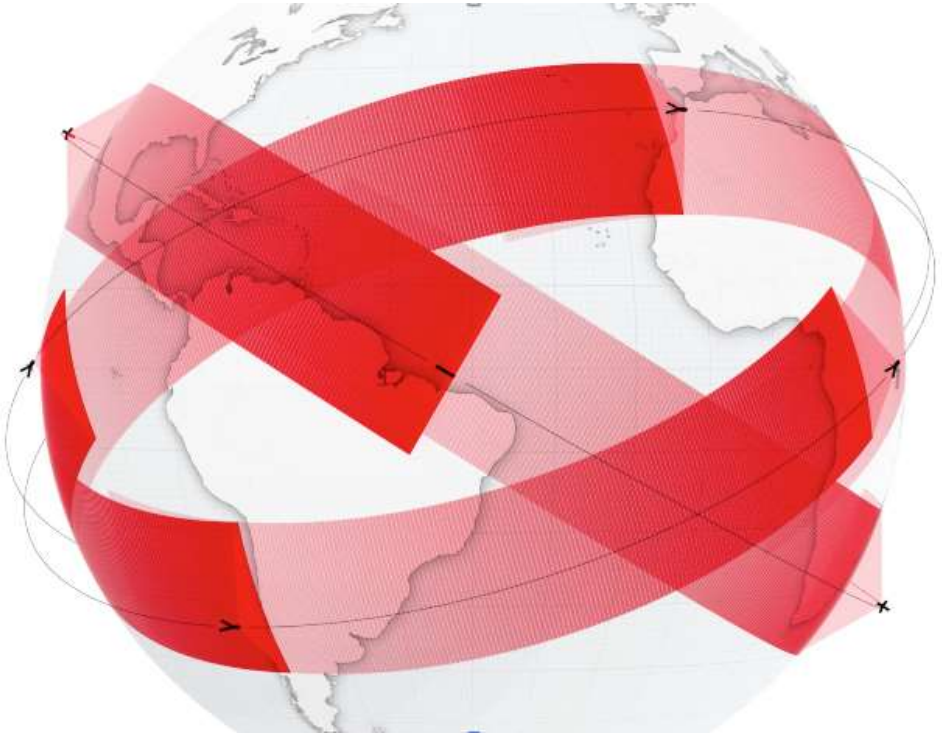
| Product | Threshold Requirement (Uncertainty) | Baseline Requirement (Uncertainty) | Expected Performance (Uncertainty) |
|---|---|---|---|
| Temperature Profile | 2.5 K | 2.0 K | 1.9 K |
| Moisture Profile | 35 % | 25 % | 22 % |
| Rain Rate | 50 % | 25 % | 25 % |
| Min Sea-Level Pres. | 12 hPa | 10 hPa | 10 hPa |
| Max Sustained Wind | 8 m/sec | 6 m/sec | 6 m/sec |

# TROPICS Orbital Characteristics

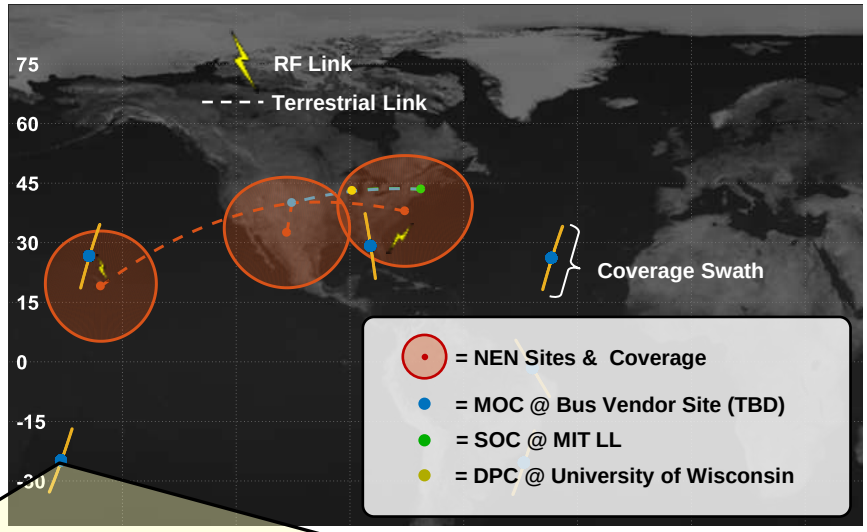
**Multiple CubeSats in each of three orbital planes**

**Altitude of 600 km, 30° inclination**

**Sweet spot in: swath width, revisit rate, and spatial resolution**



# TROPICS Mission Overview




Science Community

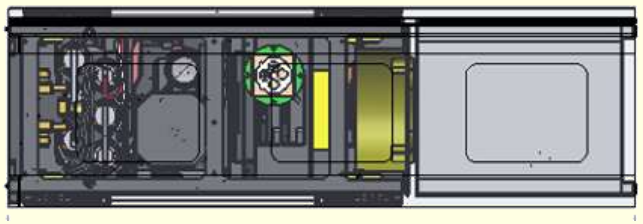
TROPICS Science Team

NASA Distributed Active Archive Center

## Space Vehicle

**BUS**
(Commercially Procured)

**Payload**
(MIT LL)



## Ground

**Ground Network**
(NEN Baseline)

**Mission Operations**
(Bus Vendor Baseline)

**Data Processing Center** (U. Wisconsin)

**Science Operations Center** (MIT LL)



NEN = NASA Near-Earth Network
MOC = Mission Operations Center
SOC = Science Operations Center
DPC = Data Processing Center

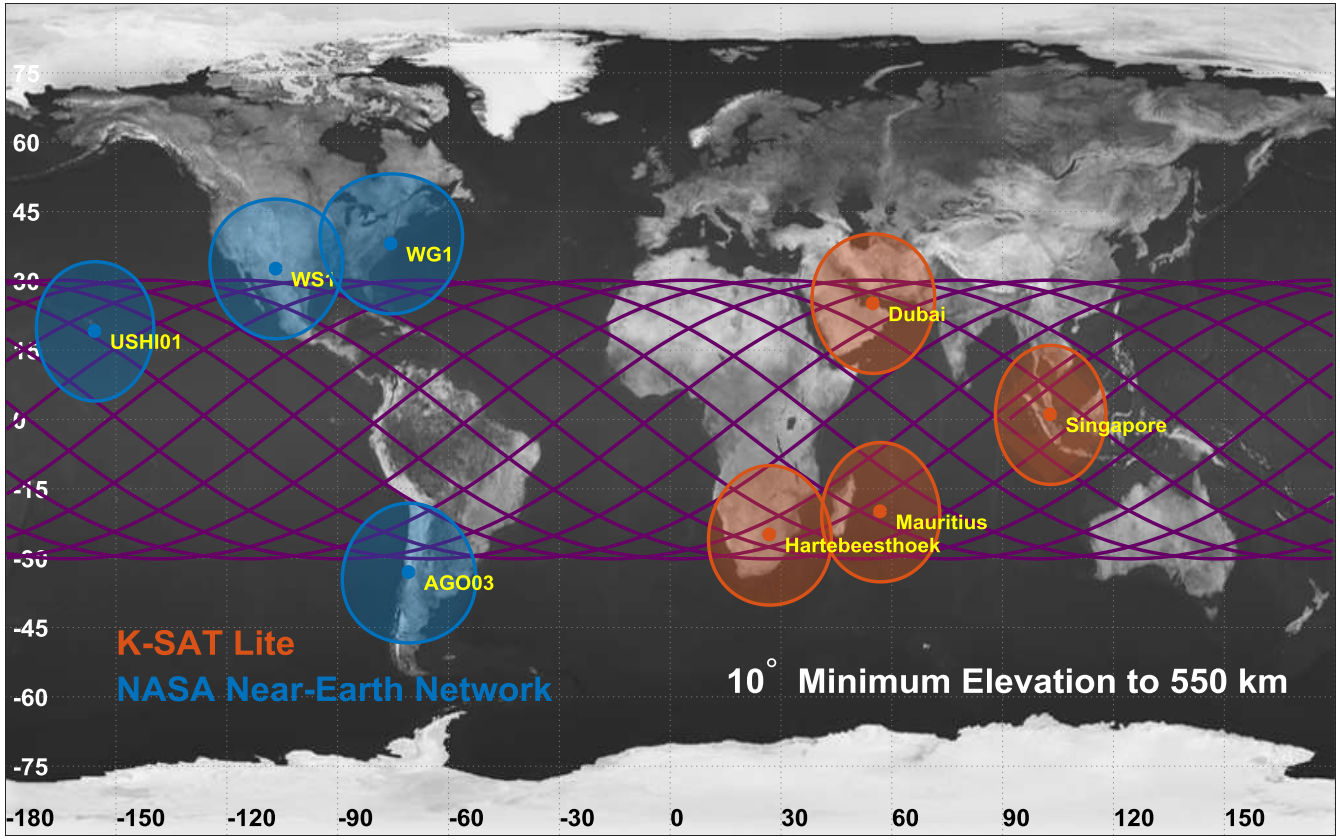
# Conceptual Data Flow

RF
TCP/IP

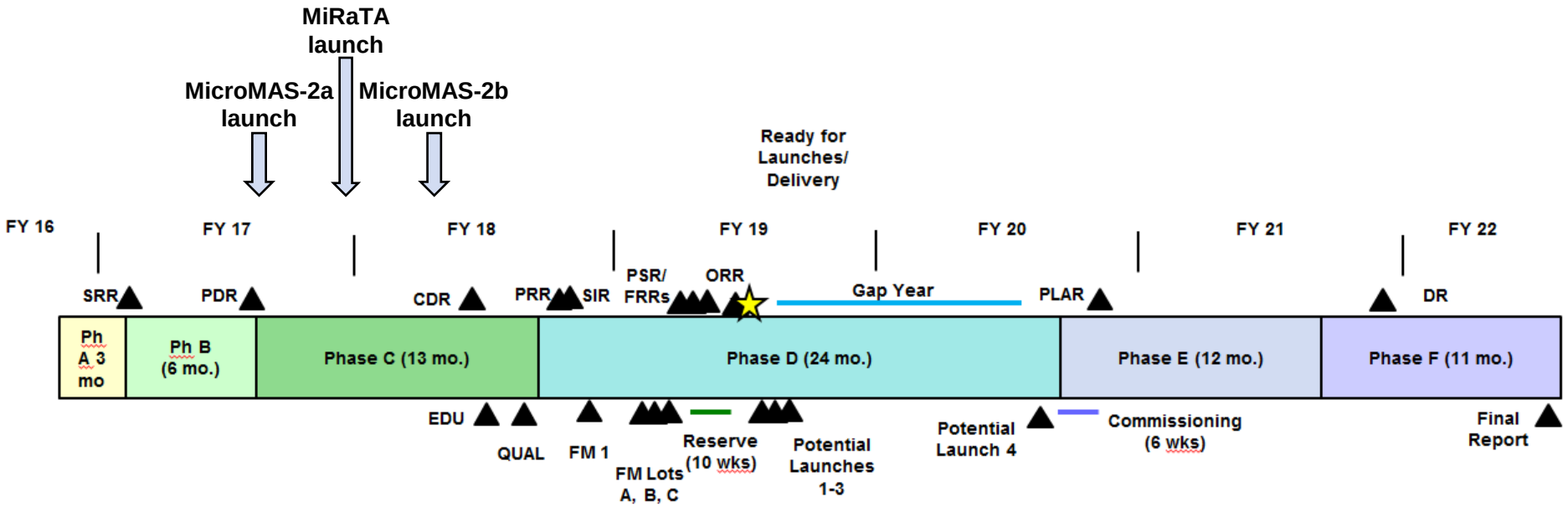
| Ground Station Network | Mission Operations Center | Science Operations Center | Data Processing Center |
|---|---|---|---|
| **NEN** | **Bus Vendor** | **MIT LL** | **UW-SSEC** |
|  | BLUE CANYON TECHNOLOGIES<br>tyvak A Terran Orbital Corporation |  |  |
| • Antenna commanding<br>• Data demodulation<br>• Temporary data storage | • Antenna scheduling<br>• SV Command & Control<br>• Health and Status monitoring<br>• Anomaly resolution | • Payload Monitoring<br>• Payload long-term trending<br>• Commanding support | • Data Processing (Lvl-0 to Lvl-2b)<br>• Data formatting & archiving<br>• Web Interface |

# Ground Network Considerations

- **Mission Operations will consider:**
  - **Ground Station Access (Lat/Lon)**
  - **Minimum elevation requirement**
  - **Network availability (congestion)**



# TROPICS Mission Timeline



# Summary and Path Forward

- **We can now use a global constellation of CubeSats to determine the dynamic and thermodynamic relationships in rapidly evolving storms**
- **TROPICS will provide the first high-revisit microwave observations of precipitation, temperature, and humidity on a near-global scale**
- **TROPICS addresses PATH Decadal Survey mission objectives using a low-cost, easy-to-launch CubeSat constellation**
- **Measurements will complement GPM, CYGNSS, and GOES-R missions with high refresh, near-all-weather measurements of precipitation and thermodynamic structure**
- **TROPICS will increase our understanding of critical processes driving significant and rapid changes in storm structure/intensity**
- **Program ramping up now for 2020 launch readiness**

# Save The Date

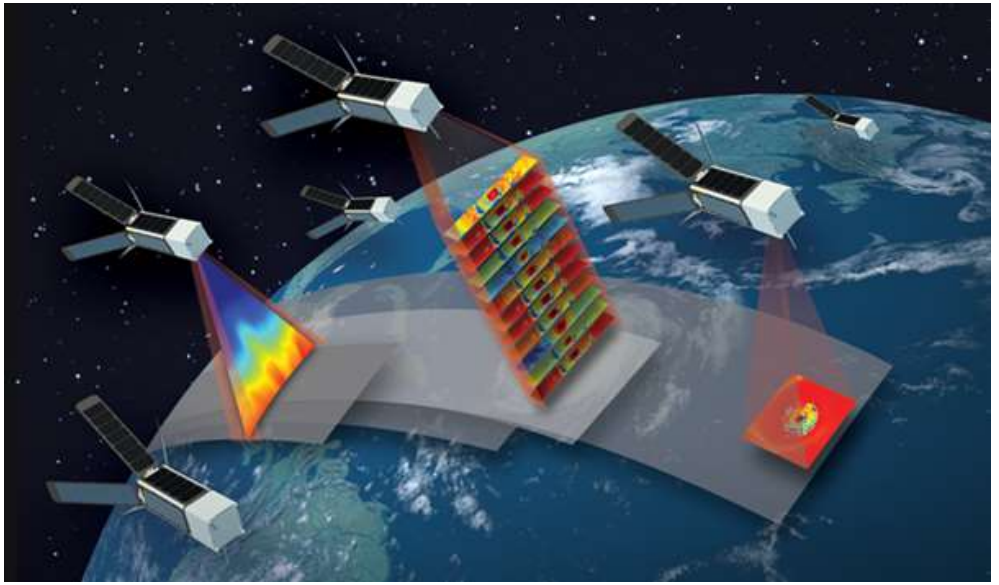
## 1st TROPICS Applications Workshop

**May 8-10, 2017**

**University of Miami, Miami, Florida**

Meeting Objectives:

- Introduce end-users to expected value of TROPICS by reviewing mission specifications and status
- Engage the end-user community to learn how TROPICS observations could be used by their organizations and barriers to data use
- Establish an early adopter community to accelerate post-launch application through access to TROPICS mission scientists and proxy datasets



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For more information or to participate, contact brad.zavodsky@nasa.gov or jason.dunion@noaa.gov

# Agenda

- Opening Remarks: COES Cochairs
- Action Item Review: Executive Secretary
- Strategic Plan For Federal Weather Enterprise Coordination:
  Dr. Bill Schulz (OFCM)
- COES Terms of Reference (ToR): Executive Secretary
- JPSS Update: Dr. Mitch Goldberg (NOAA-JPSS)
- NASA's TROPICS Cubesat Mission: Dr. William Blackwell (MIT-LL)
- Open Discussion: COES Members.
- Action Item Review / Next Meeting: Executive Secretary
- Adjourn: The meeting is expected to end by 3:00 PM EDT.

# Action Item Review / Next Meeting

- **The Executive Secretary will document any action items taken during the meeting**
- **The Executive Secretary will coordinate with the cochairs and schedule the next meeting.**
  - **Our goal is to conduct 4 COES meetings in 2017 (March, June, September, and December)**
    - Jun 2, 2017, 1-3pm (TBD)
    - Sep 8, 2017, 1-3pm (TBD)
    - Dec 8, 2017, 1-3pm (TBD)

# BACK-UP