New satellite data and applications for tropical cyclone operations by 2025: Agency and Interagency plans

NRL Perspective

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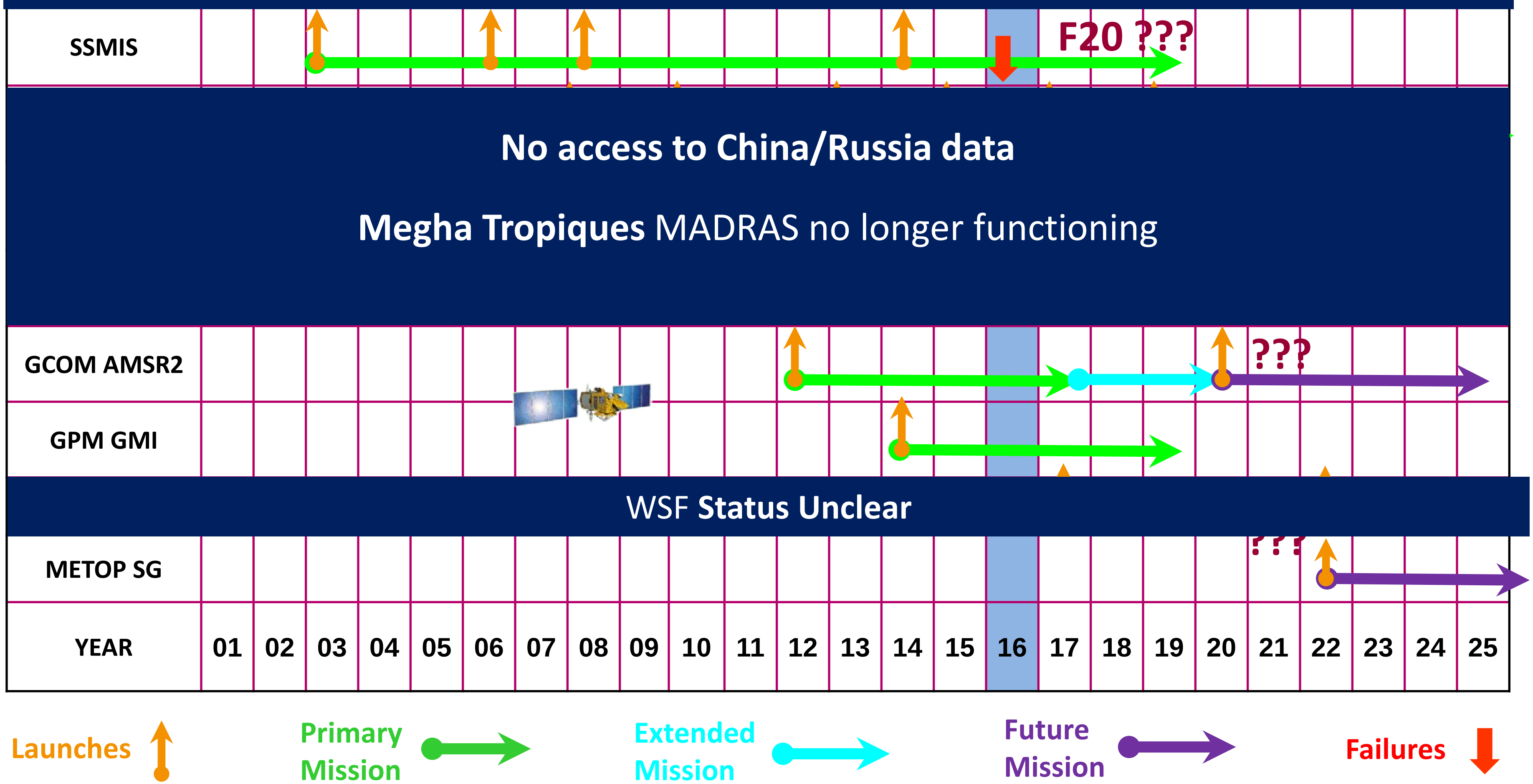
March 16, 2016

Satellite Tropical Cyclone Monitoring

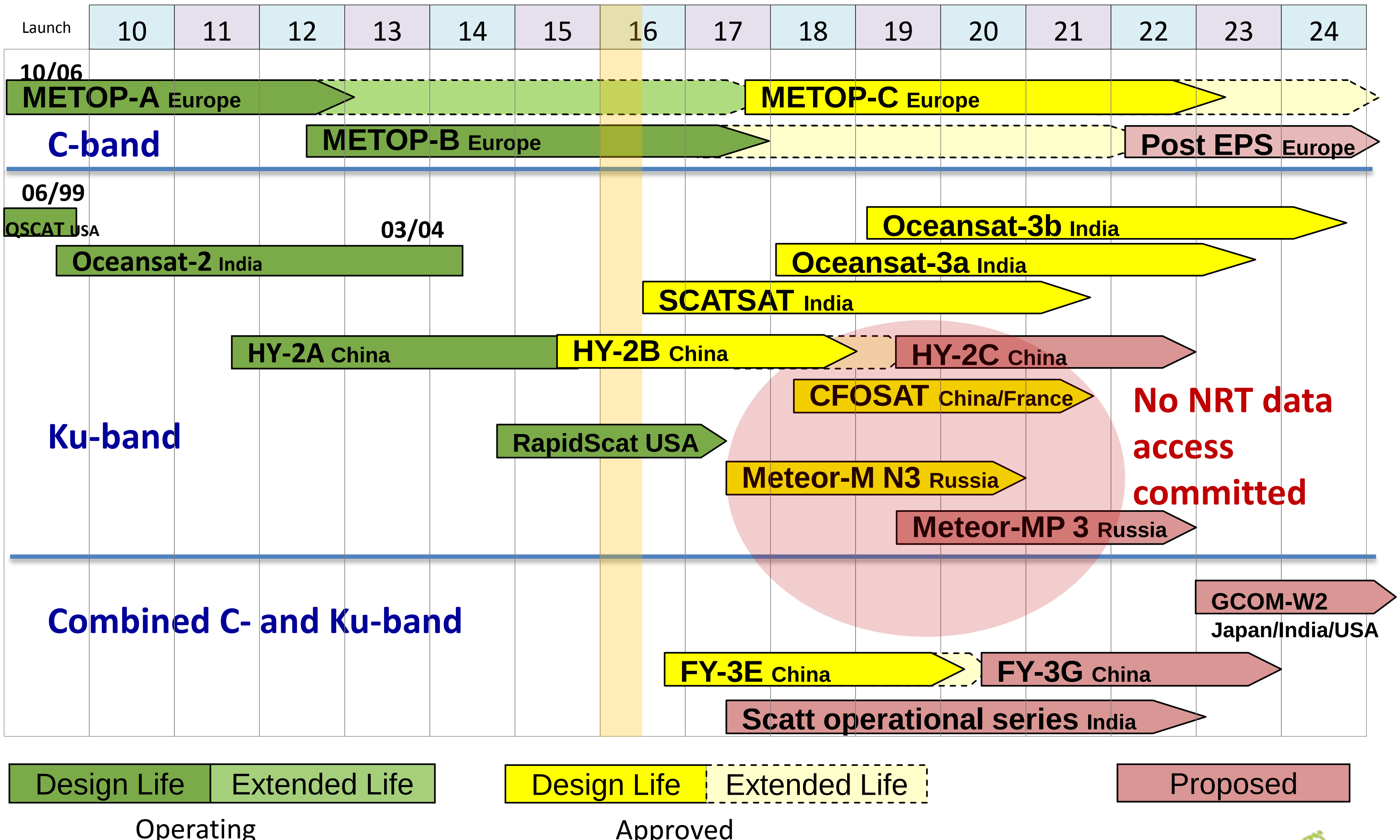
- **Problems:**
  - Aging constellation of LEO microwave imagers and sounders failing and not being replaced
  - Scatterometers not being funded by US for long term use
  - Legacy sensors often deemed too expensive for next generation
- **Solutions:**
  - Multi-national efforts (GPM), ESA, Korea?, etc.
  - Gap fillers (DMSP F-20?, COWVR/WSF?)
  - SmallSats and CubeSats as technology enables miniaturization
  - Data buys and ride “sharing”?

What's left in a few years after old R&D satellites fail



Ocean Vector Surface Vector Winds Constellation

Current status and Outlook – NRT data access



Courtesy: Dr. Mark Bourassa

Source: WMO OSCAR database and direct interactions with agencies

Committee on Earth Observation Satellites

SSMIS Constellation Status

- Loss of F-18 temperature sounding channels last year.
- Unable to communicate with F-19 since early February.
  - Orbit starting to degrade, may not be recoverable.
- Current capability:
  - F-17 partial temp sounder
  - F-18 partial humidity sounder
  - 3 functional imagers
- Status of F-20
  - Decision not to launch made near beginning of year.
  - However, recent F-19 loss may change perspective.

DoD COWVR and WSF

- DoD still searching for a low-cost weather satellite program
  - Ocean surface vector winds and tropical cyclone intensity are among top priorities
- Compact Ocean Wind Vector Radiometer (COWVR)
  - "Technology Demonstration Mission" to launch ~2017
  - JPL leverages Jason-3 AMR
  - 18.7, 23.8 , 33.9 GHz polarimetric radiometer
  - Full 360^{o} conical scans (2 looks)
- Weather System Follow-on (WSF)
  - Planned launches ~2022, ~2026
  - Exploring a WINDSAT-like solution

COWVR

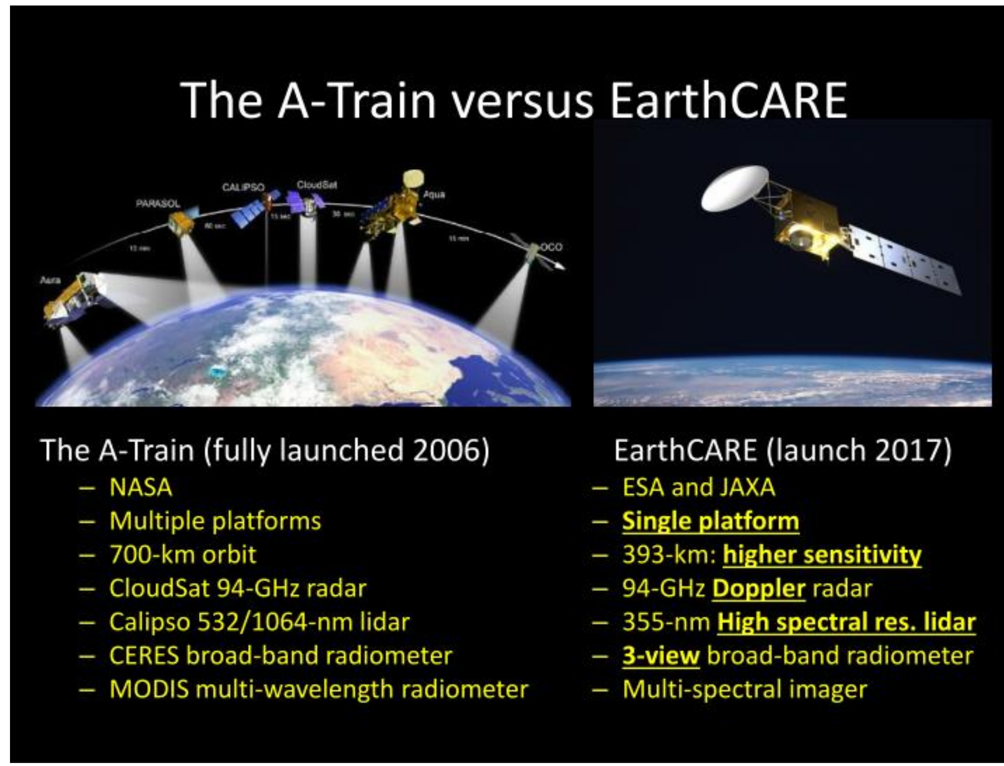
Latest Observing Capabilities

- NASA SMAP
  - Launched January 31, 2015
  - Radar stopped transmitting, but radiometer still working
- Jason-3
  - Launched January 17, 2016
  - Continues legacy of radar altimetry observations
- ESA Sentinal-3A
  - Launched February 16, 2016
  - Ocean/land color, topography
  - Sentinal-3B launch ~2017
  - Sentinal-3C launch ~2019

ESA Sentinal-3A ocean and land color instrument (March 2, 2016)

Near-Future Observing Capabilities

- ESA ADM-Aeolus
  - Launch ~2017
  - LIDAR vertical wind profiles
- ESA/Japan EarthCARE
  - Launch ~2018
  - Backscatter LIDAR, cloud profiling radar, passive radiometers
- DoD GFO-2
  - Geodetic Satellite Follow-On 2
  - Launch ~2019?
  - Altimetry similar to Jason series
  - Will be available to NOAA/NASA



Near-future: SmallSats and CubeSats

- CYGNSS: NASA, U. Michigan
  - 2016 launch
  - All weather ocean surface wind speeds (non-real time)
  - 8 sats, 350 inclined novel sampling winds
- MicroMAS: MIT
  - Two 3U sensors by 2017
  - Mini sounders building towards ATMS-type capability
- MISTiC: NASA, BAE systems
  - Cloud/moisture AMVs, temperature and humidity profiling (following AIRS legacy)
- TWICE: CSU, NASA
  - Tropospheric Water and Cloud ICE conical scans at 16 channels, 118-670 GHz
- RainCube: NASA-JPL
  - 6U constellation of profiling rain radars
  - 35.75 GHz, nadir, +10 dBZ, 250 m vertical, 5 km horizontal

Enabling the Next Generation: MicroMAS-1, MicroMAS-2, and MiRaTA

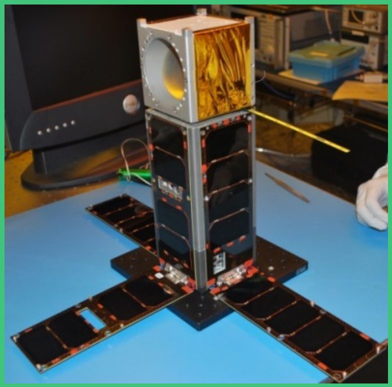
MicroMAS = Microsized Microwave Atmospheric Satellite
MiRaTA = Microwave Radiometer Technology Acceleration

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

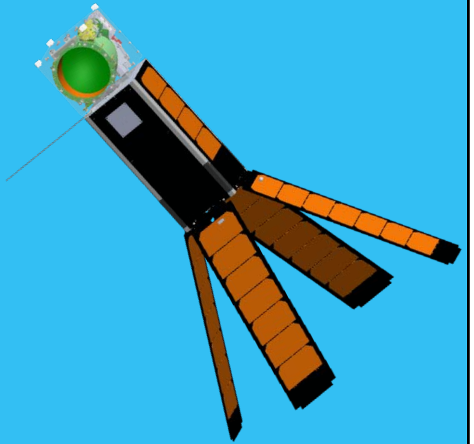


MicroMAS-2

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

12 channels for moisture and temperature profiling and precipitation imaging

Two launches in 2016/2017

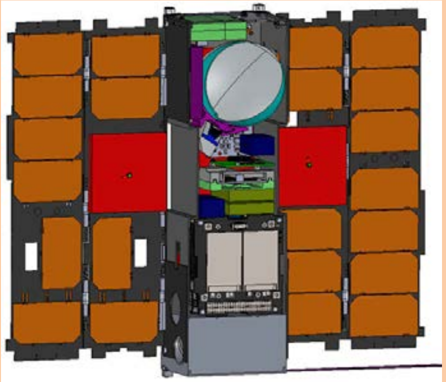


MiRaTA

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

10 channels for temperature, moisture, and cloud ice measurements

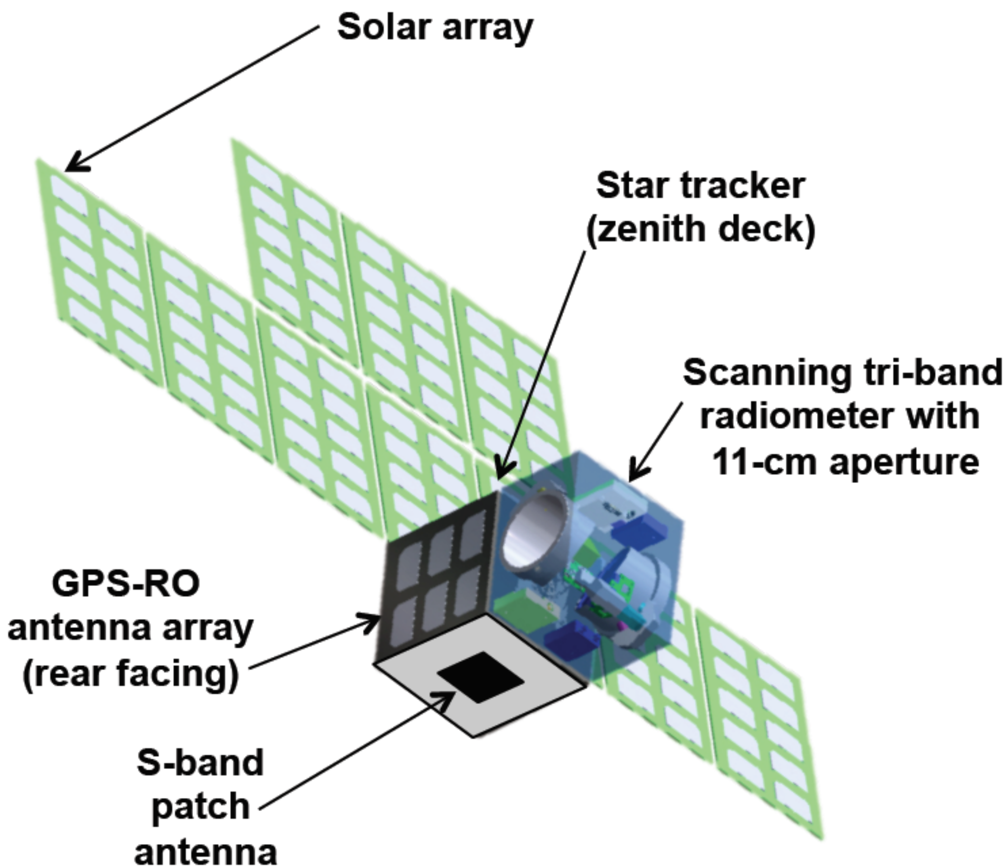
Nov 2016 launch on JPSS-1, or deployed from ISS



First CubeSat Constellation in Early 2017: Two MicroMAS-2's and MiRaTA

Courtesy: MIT/LL

Enabling the Next Generation: Earth Observing Nanosatellite (EON-MW)



EON

Earth Observing Nanosatellite

- All the features of MicroMAS (wide swath) and MiRaTA (sensitivity)
- 12U cubesat (21x21x34 cm)
- Larger aperture (improved spatial resolution)
- 23/31 + 50-60/88 + 166/183 GHz

  22 ATMS-equivalent channels
- 2-3 year mission lifetime
- Data downlink using S-band

Courtesy: MIT/LL

Far-future: Passive/Active Microwave

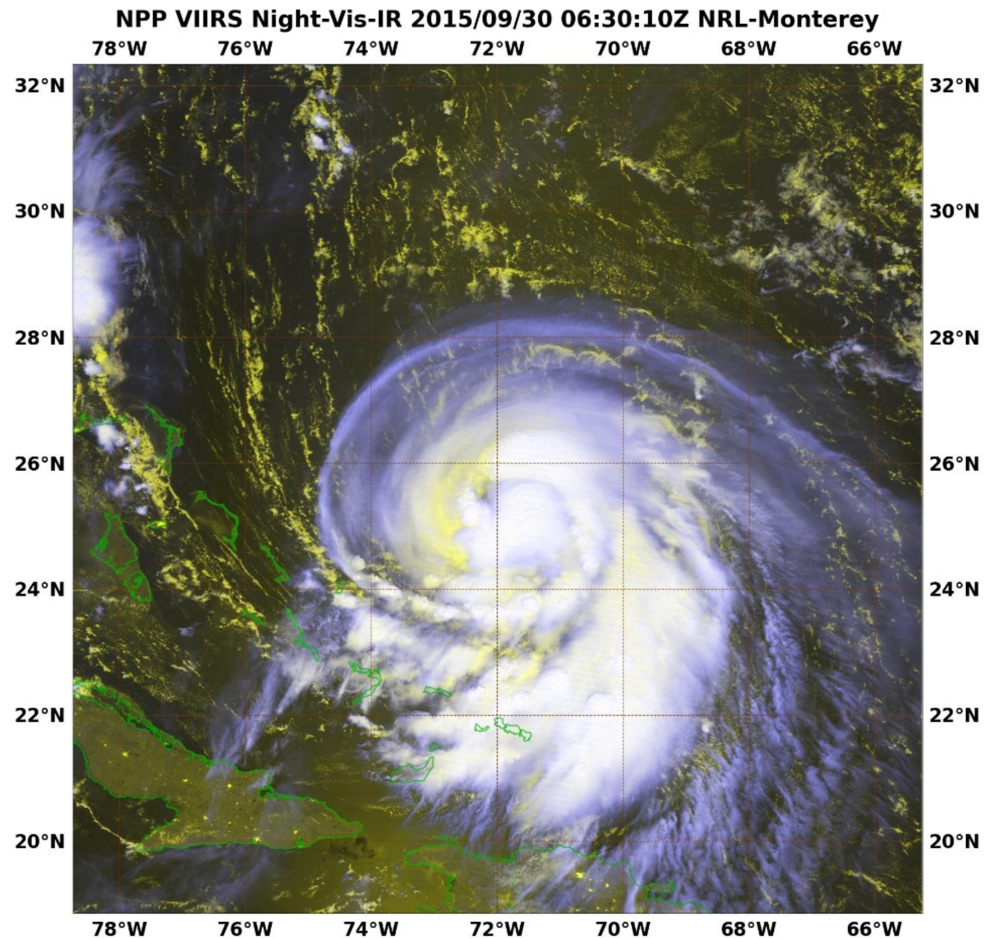
- ESA MetOp-SG
  - A Series
    - Launches in 2021, 2028, 2035
    - Multi-polarization Imager (3MI), IR Sounder (IASI-NG), UV-Vis-Near-IR sounder (Sentinal-5), Microwave Sounder (MWS) , Radio Occultation sounder (RO)
  - B Series
    - Launches in 2022, 2030, 2036
    - Ice Cloud Imager (ICI), Scatterometer (SCA), Microwave Imager (MWI), Radio Occultation sounder (RO)
- JAXA GCOM-W2
  - Launching in 2023?
  - AMSR-2 and high resolution scatterometer?
- KMA Future LEO
  - Launch ~2022?
  - One or two instruments similar to SSMIS, ATMS, GPM, and/or CRiS
  - Looking at international/joint development
- Plenty of CMA and Roscosmos plans
  - Currently reaching close to SSM/I level capabilities
  - CMA planning radar, scat, imager programs ~2020+

Satellite TC Monitoring Summary

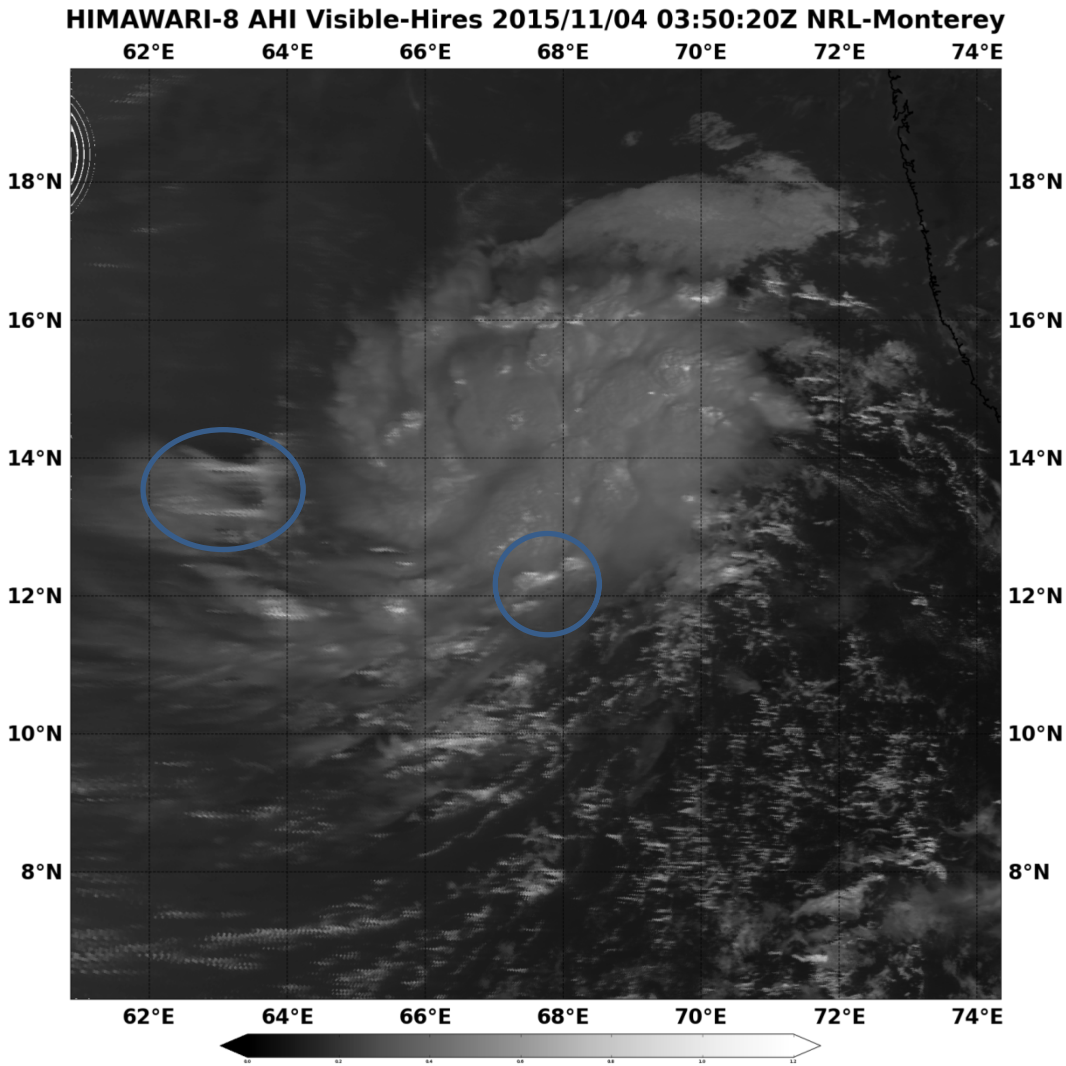
- Old school microwave imagers/sounders waning in numbers while next generation GEOs coming online
- Will DMSP F-20 SSMIS and WSF ever fly?
  - Do recent issues with SSMIS constellation (down to 1 partially functional sounder) influence course changes?
- Will CubeSats help fill the temporal issues in microwave sensing?
- Will METSATs begin ride sharing with “Com” satellites and will “data buys” enter the market long-term?

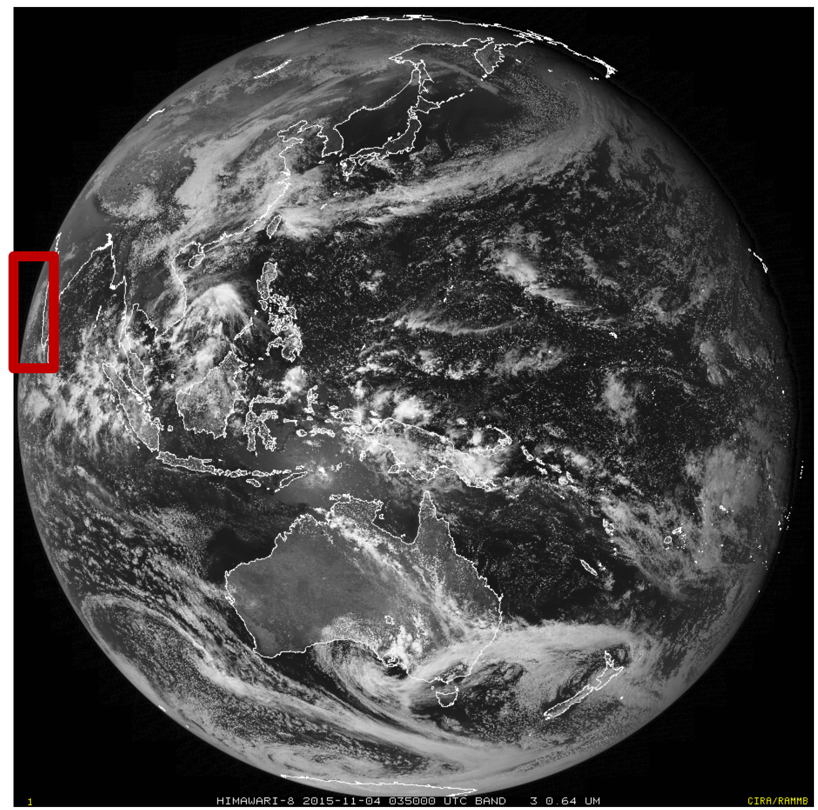
Future of NRL Satellite Applications

- Shift towards <u>research</u> and development of new guidance
- In-house development of new processing software
  - GeoIPS (Geolocated Information Processing Software)
  - Goal: process and visualize all meteorological and oceanographic data
  - Currently processes VIIRS, MODIS, geostationary vis/WV/IR, RapidSCAT
  - Processes 10-minutely Himawari data in real-time
  - Portability: processing products on 3 different clusters, and growing



Details seen in Himawari AHI: Cyclone Megh (2015)





Full disk image courtesy CIRA

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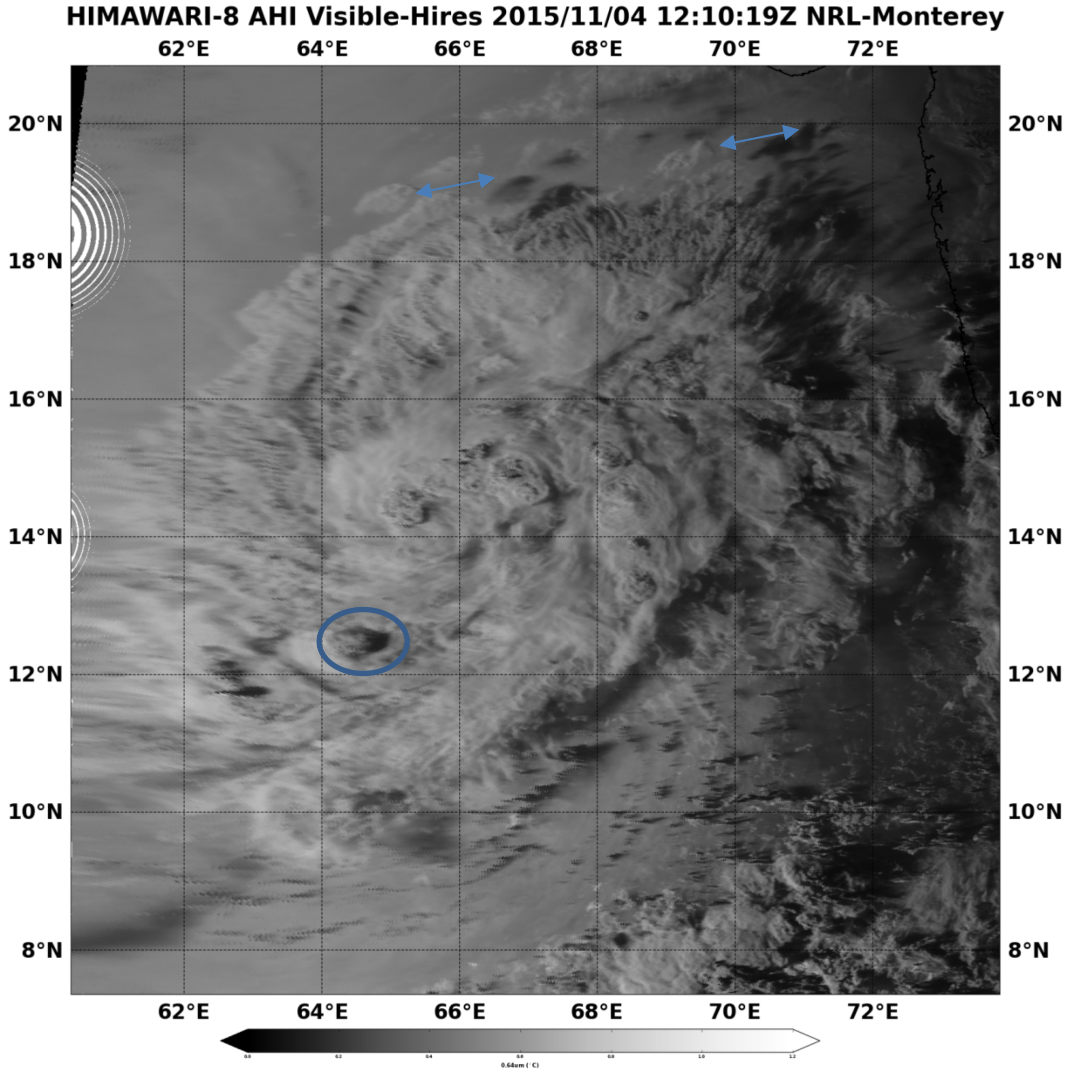
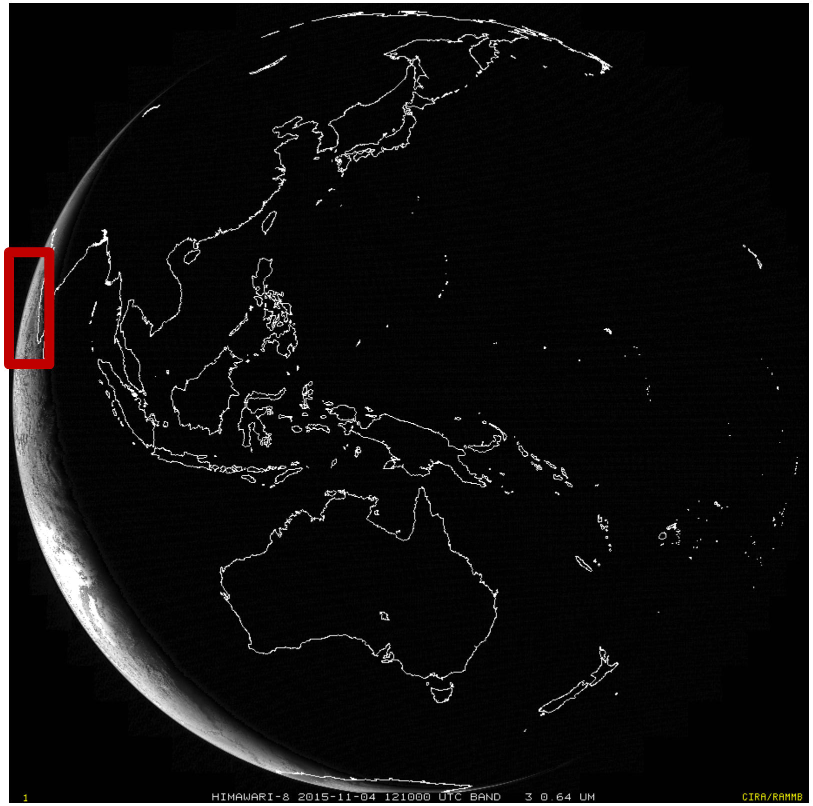
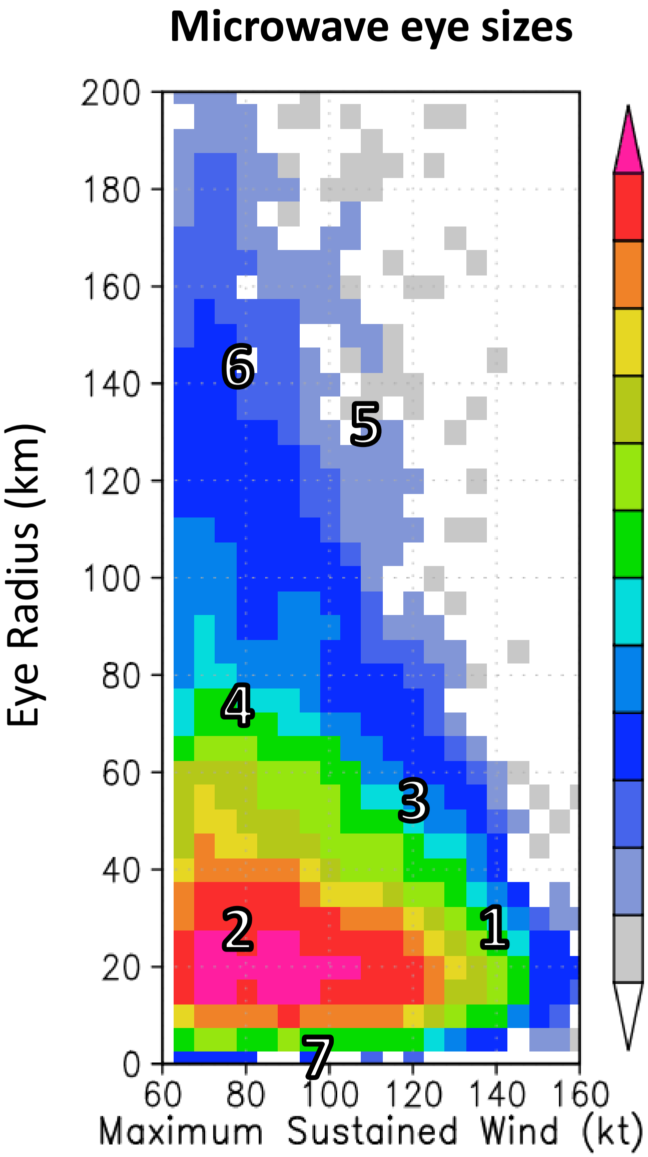
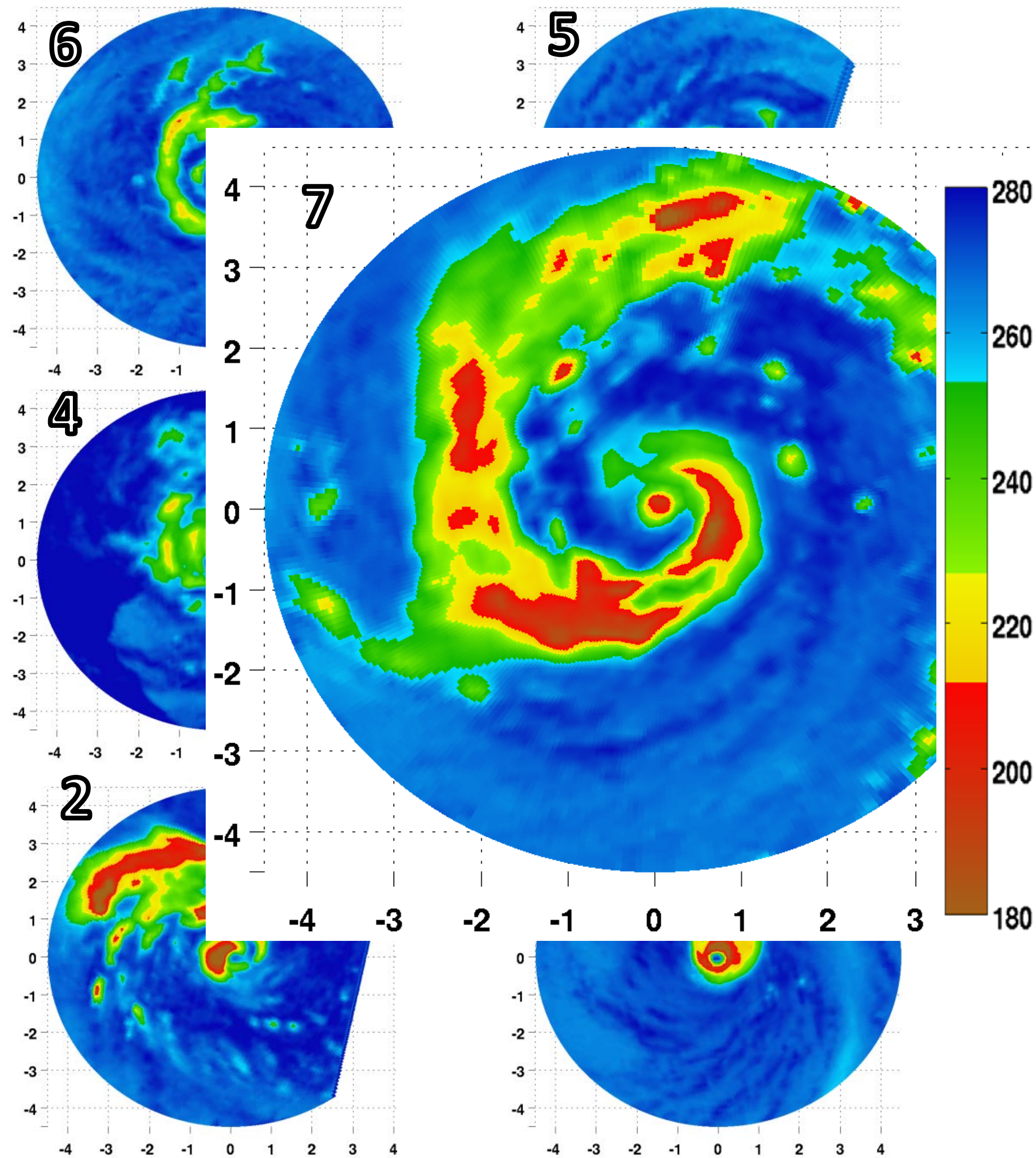




Full disk image courtesy CIRA

Future Products: Objective Structures





NRL Satellite Applications: To 2025

- Continue to advocate and acquire (near)real-time satellite observing capabilities for TC monitoring

- NRL TC web processing to transition to GeoIPS
  - In-house developed open-source python code
  - Allows more efficient data processing/exporting, easier transitions, upgrades, collaborations (e.g., FNMOC, NOAA)

- Strategy for next decade:
  - Support current and future satellite constellations by rapidly transitioning data into TC-centric products
  - Early adopters of cubesat data and investigate ability to help operations
  - Extract objective/automated metrics to inform TC intensity and structure analyses
    - Provide improved guidance of time evolution of microwave structures
    - Constrain structural state to improve model initialization, future potential