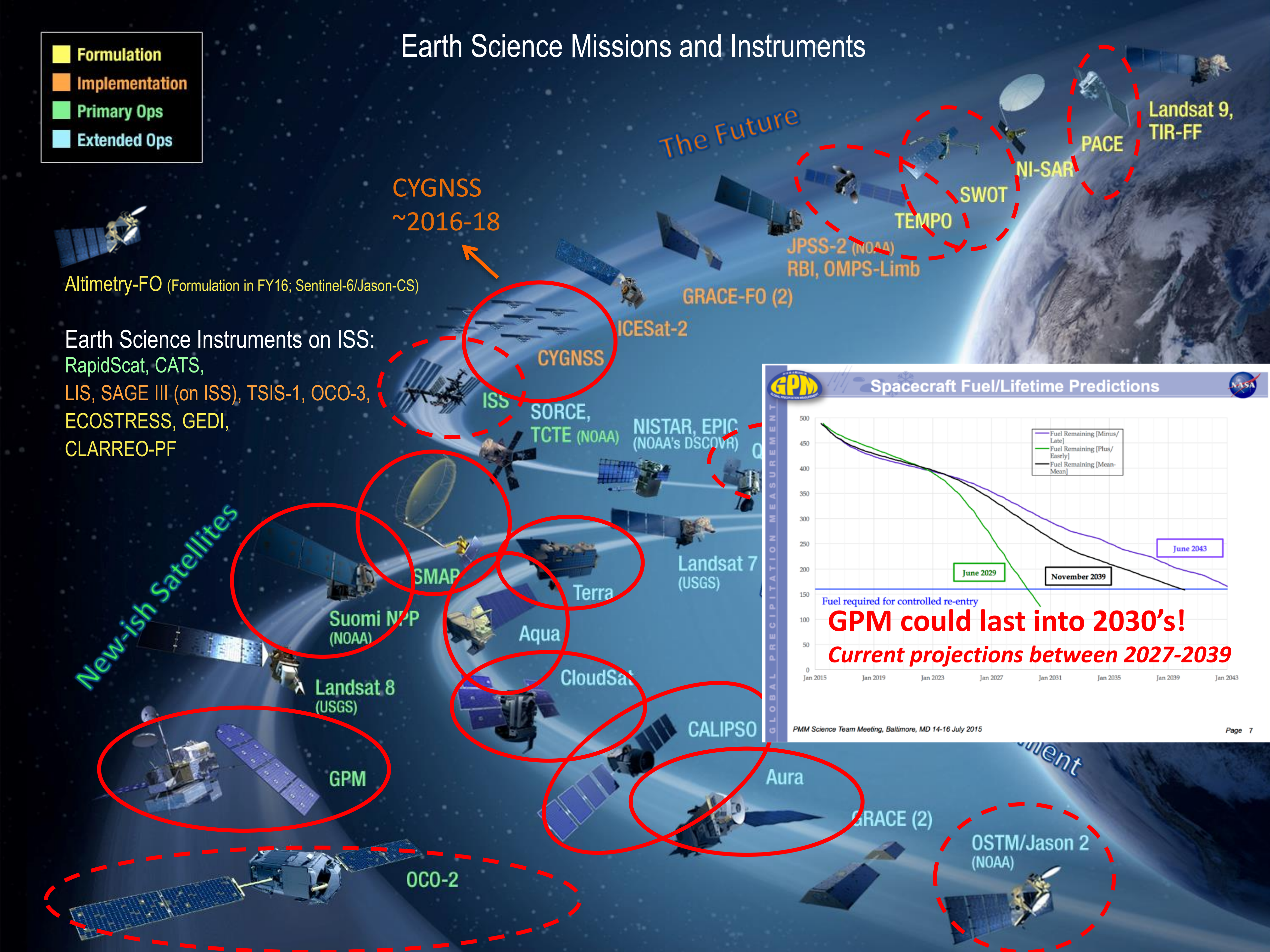
Potential Future NASA Satellite Data and Applications for Tropical Cyclones

Dan Cecil
NASA Marshall Space Flight Center
Daniel.J.Cecil@nasa.gov

With contributions from many others



Earth Science Missions and Instruments
Formulation
Implementation
Primary Ops
Extended Ops
The Future
CYGNSS
~2016-18
Altimetry-FO (Formulation in FY16; Sentinel-6/Jason-CS)
Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III (on ISS), TSIS-1, OCO-3,
ECOSTRESS, GEDI,
CLARREO-PF
Landsat 9,
TIR-FF
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA's DSCOVR)
Landsat 7
(USGS)
SMAP
Terra
Suomi NPP
(NOAA)
Aqua
CloudSat
Landsat 8
(USGS)
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2
New-ish Satellites
Spacecraft Fuel/Lifetime Predictions
GLOBAL PRECIPITATION MEASUREMENT
Fuel Remaining [Minus/Late]
Fuel Remaining [Plus/Early]
Fuel Remaining [Mean-Mean]
June 2029
November 2039
June 2043
Fuel required for controlled re-entry
GPM could last into 2030's!
Current projections between 2027-2039
500
450
400
350
300
250
200
150
100
50
0
Jan 2015
Jan 2019
Jan 2023
Jan 2027
Jan 2031
Jan 2035
Jan 2039
Jan 2043
PMM Science Team Meeting, Baltimore, MD 14-16 July 2015
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NASA's Role is Technology Development and Research

Earth Venture Mission *(full satellite missions) competed every 4 years*

- **CYGNSS selected in EVM-1**, launch NET Oct 2016
- ➢ Small sat constellation to measure ocean surface wind speed in hurricanes

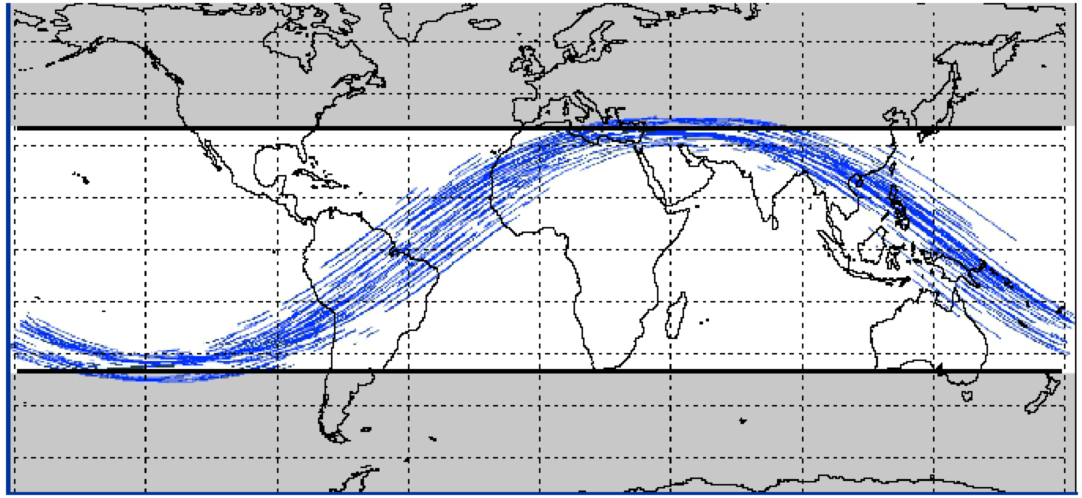
Earth Venture Instrument *(satellite instruments and cubesat missions) competed every 18 months*

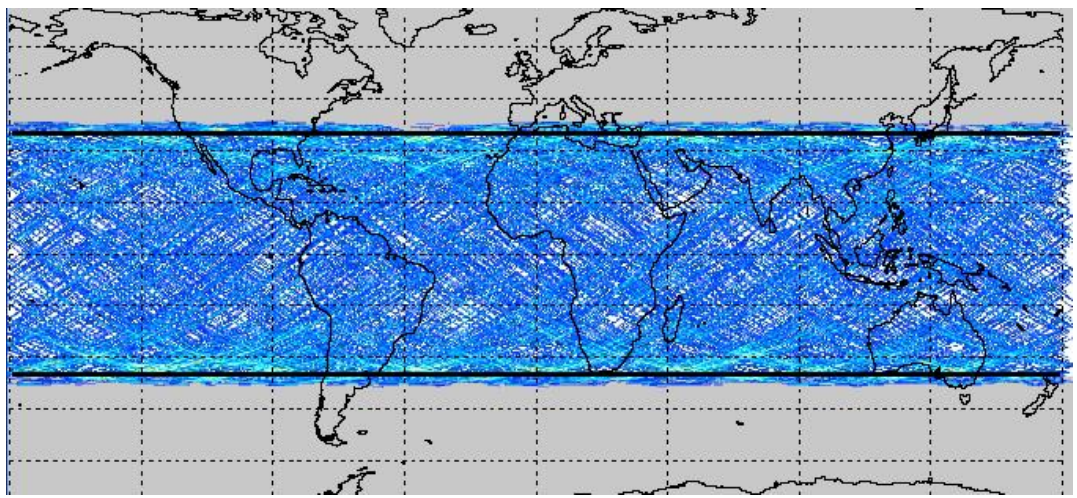
- ***TROPICS selected in EVI-3****, launch ~2019-ish*
- ➢ Cubesat constellation with sounding radiometers to measure thermodynamic and precip structure with frequent (~hourly?) re-visits

Other programs support initial instrument development, testing

CYGNSS Earth Coverage

- 90 min (one orbit) coverage showing all specular reflection contacts by each of 8 s/c
- 24 hr coverage provides nearly gap free spatial sampling within +/- 35 deg orbit inclination





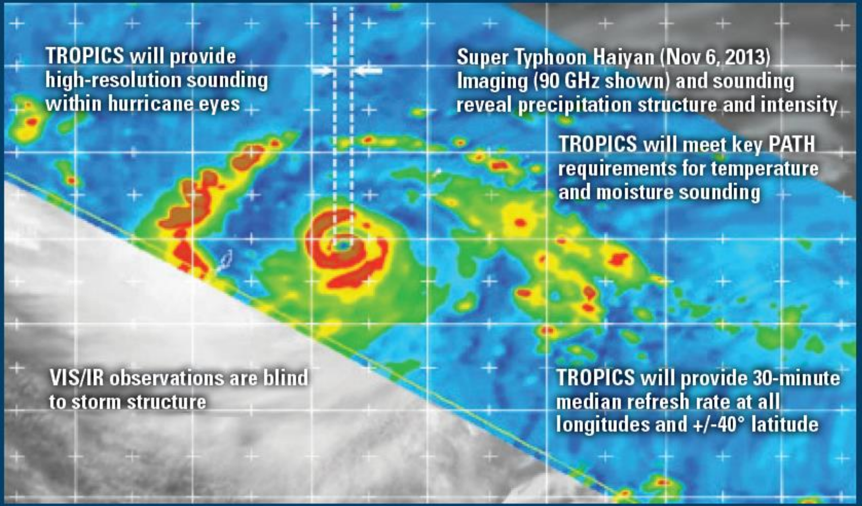
Courtesy Chris Ruf, University of Michigan, cruf@umich.edu

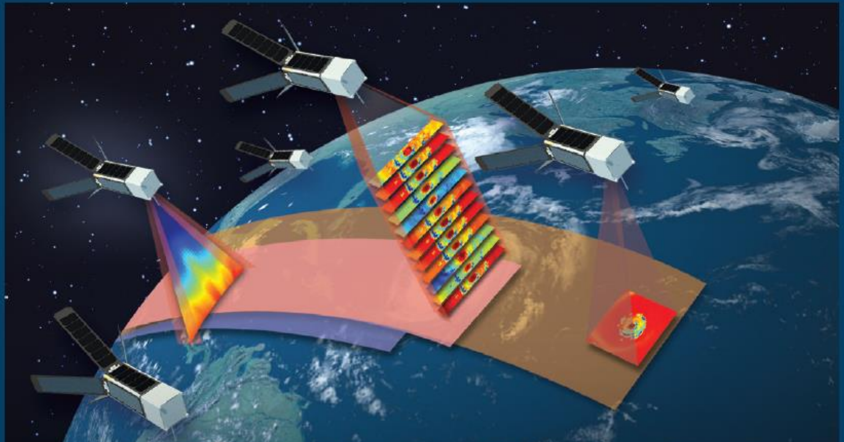
Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

Bill Blackwell, MIT-LL
wjb@ll.mit.edu

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





12 identical 3U CubeSats provide sounding (left CubeSat has a temperature profile of a simulated Tropical Cyclone (TC) from a Numerical Weather Prediction (NWP) model) and 12-channel radiometric imagery (center CubeSat has simulated radiances from NWP model and radiative transfer model and the near right CubeSat has a single channel radiance image of a TC) with 30-minute median revisit rate to meet most PATH requirements.

Significance to NASA

- First high-revisit microwave nearly global observations of precipitation, temperature, and humidity
- Fulfills most of PATH Decadal Survey mission objectives using a low-cost, easy-to-launch CubeSat constellation
- Complements GPM, CYGNSS, and GOES-R missions with high refresh, near-all-weather measurements of precipitation and thermodynamic structure
- Increases understanding of critical processes driving significant and rapid changes in storm structure/intensity

In-Space Validation of Earth Science Technologies (InVEST)

Not necessarily a complete list:

- The Microwave Radiometer Technology Acceleration (MiRaTA) CubeSat (Jan 2017, JPSS-1)
- Precipitation Profiling Radar in a CubeSat (RainCube – launch NET Aug 2017)
- Compact Infrared Radiometer in Space (CIRiS)
- CubeSat Infrared Atmospheric Sounder (CIRAS)

Concepts in Various Stages of Development

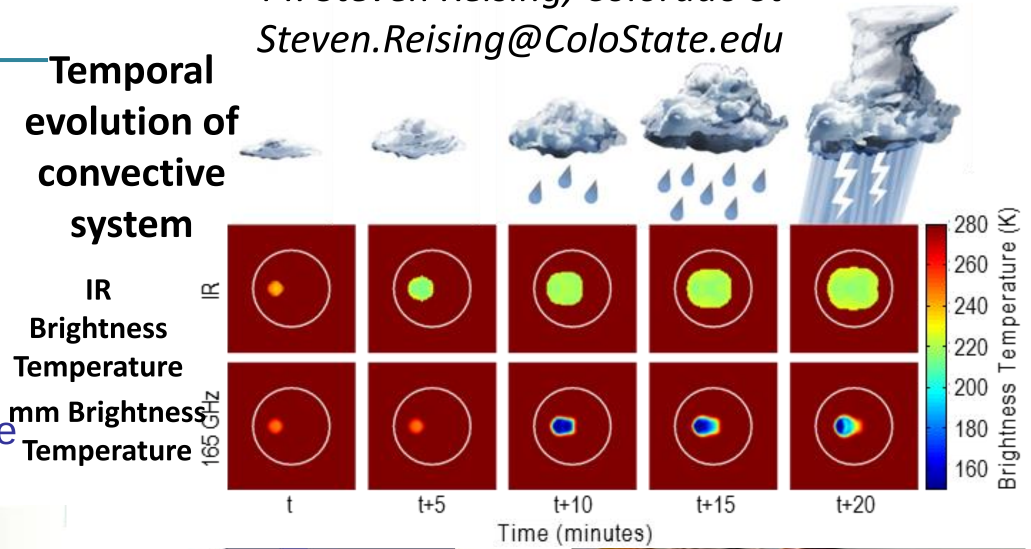
- Next slides cover some concepts I’m aware of that are relevant… *not all-inclusive*
- *This does not imply any official endorsement*

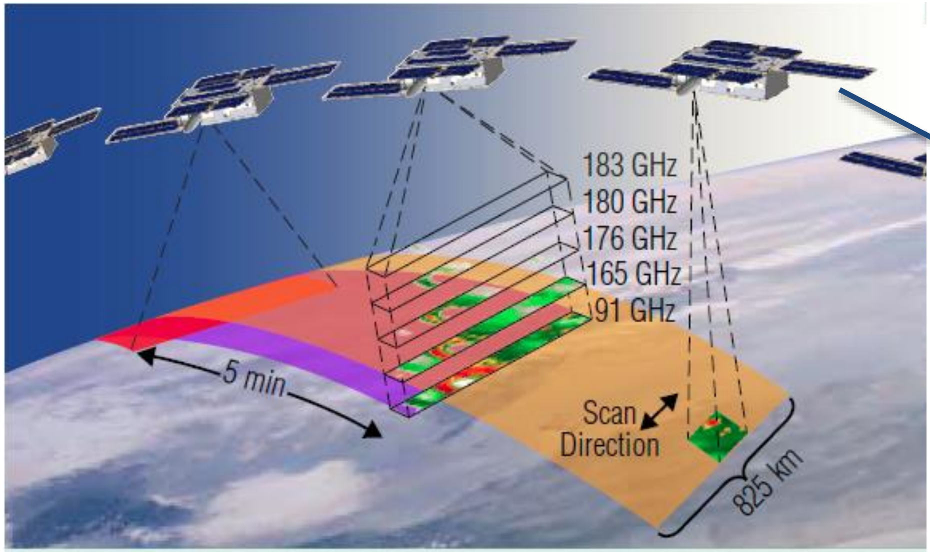
Temporal Experiment for Storms and Tropical Systems (TEMPEST)

PI: Steven Reising, Colorado St
Steven.Reising@ColoState.edu

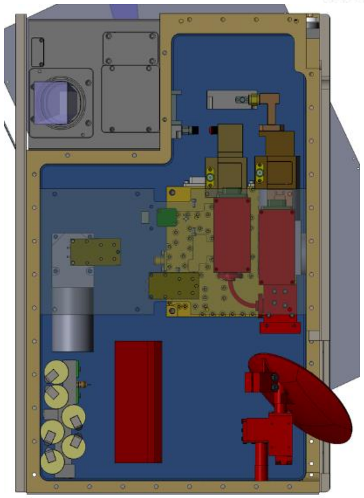
BENEFITS AND STRENGTHS

- First global observations of time evolution of precipitation
- Low-cost approach using 6U-Class satellites
- Unique data sets to enable improved weather and climate prediction models
- Significant impacts on agricultural forecasting, forest management and disaster preparedness
- Experienced collaborative team: Colorado State University (CSU), Caltech JPL and BCT





5 identical 6U CubeSats, each with an identical 5-channel radiometer, flying 5 minutes apart



MASC prototype
(S. Padmanabhan)

RainCube and MASC

RainCube & MASC are instruments developed at JPL for deployment in **6U CubeSats**.

They will enable **affordable LEO constellations** to observe **cloud and precipitation processes** as they evolve at the timescales needed to validate and improve weather and climate models.

RainCube

- nadir-pointing Ka-band precipitation radar (35.7 GHz)
- novel architecture to achieve the required sensitivity with low-power radar electronics that fit in 2U
- High performance pulse compression to reduce surface clutter contamination and achieve sensitivity and range resolution.
- Lightweight Deployable antenna stowes in 1.5 U (not included in airborne version, replaced by a horn-lens antenna).

MASC (Microwave Atmospheric Sounder on CubeSat)

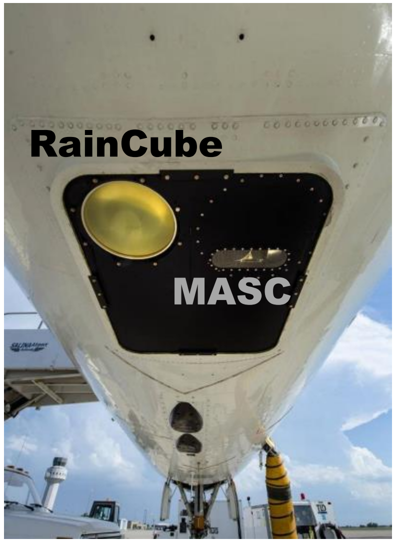
- 8 channel mm-wave radiometer (4 channels near 118GHz, 4 channels near 183 GHz)
- Cross-track scanning (±50˚)

MASC POC: Sharmila Padmanabhan, JPL
Sharmila.Padmanabhan@jpl.nasa.gov

Ongoing Developments for next decade:
Scanning Doppler radars in low earth orbit, to provide a swath of precipitation and vertical motion with acceptable (a few km) horizontal resolution

Both operated successfully on the NASA DC-8 for their **first airborne test and demonstration during PECAN (Jun. 28 – Jul. 11, 2015)**

Courtesy Simone Tanelli, JPL
simone.tanelli@jpl.nasa.gov

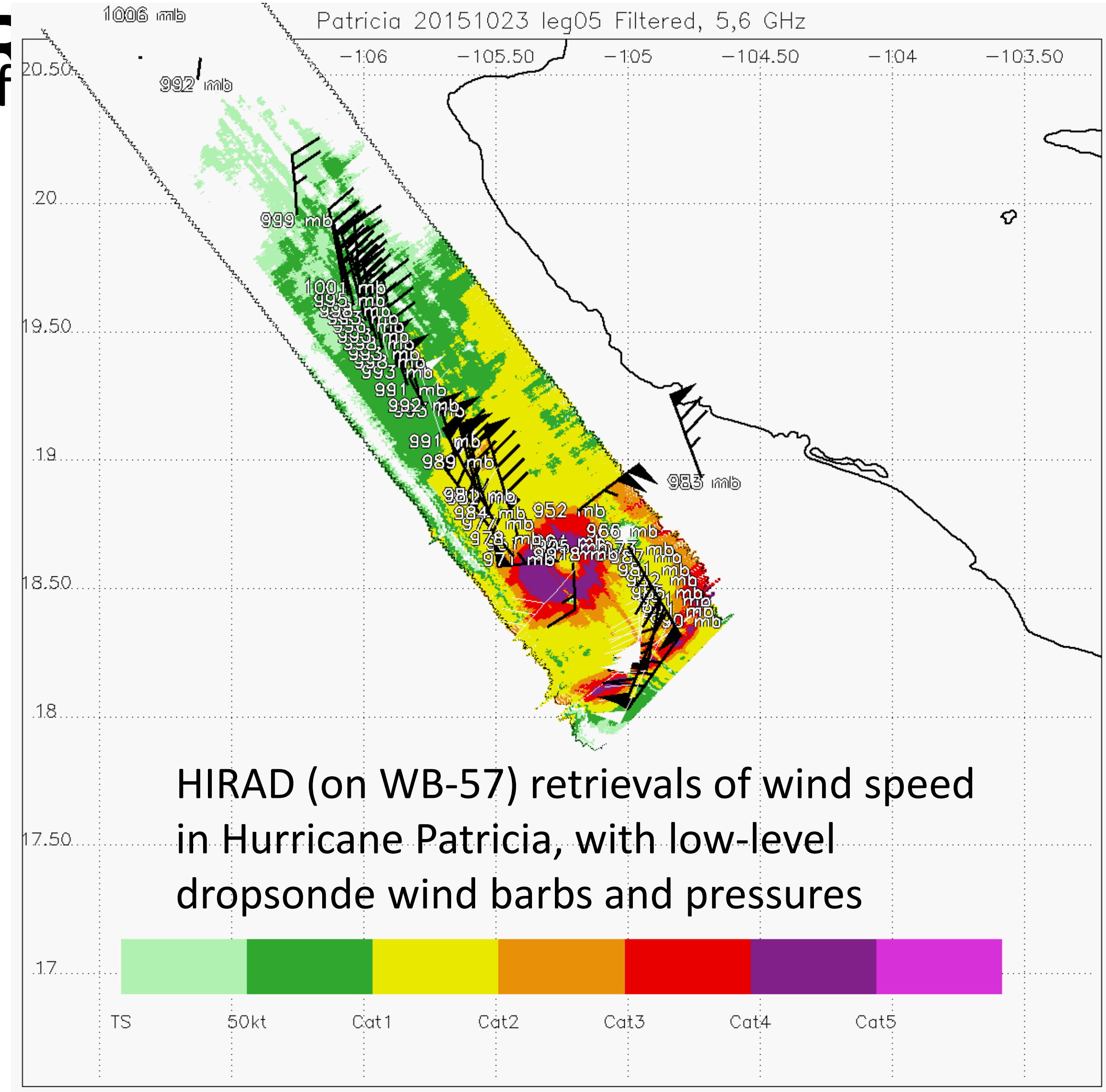


Hurricane Imaging Radiometer (HIR

Dual-polarization version of HIRAD to measure wind speed and direction from Low Earth Orbit

Want to develop airborne version of this capability first, then LEO

POC: Dan Cecil, NASA MSFC, Daniel.J.Cecil@nasa.gov



HIRAD (on WB-57) retrievals of wind speed in Hurricane Patricia, with low-level dropsonde wind barbs and pressures