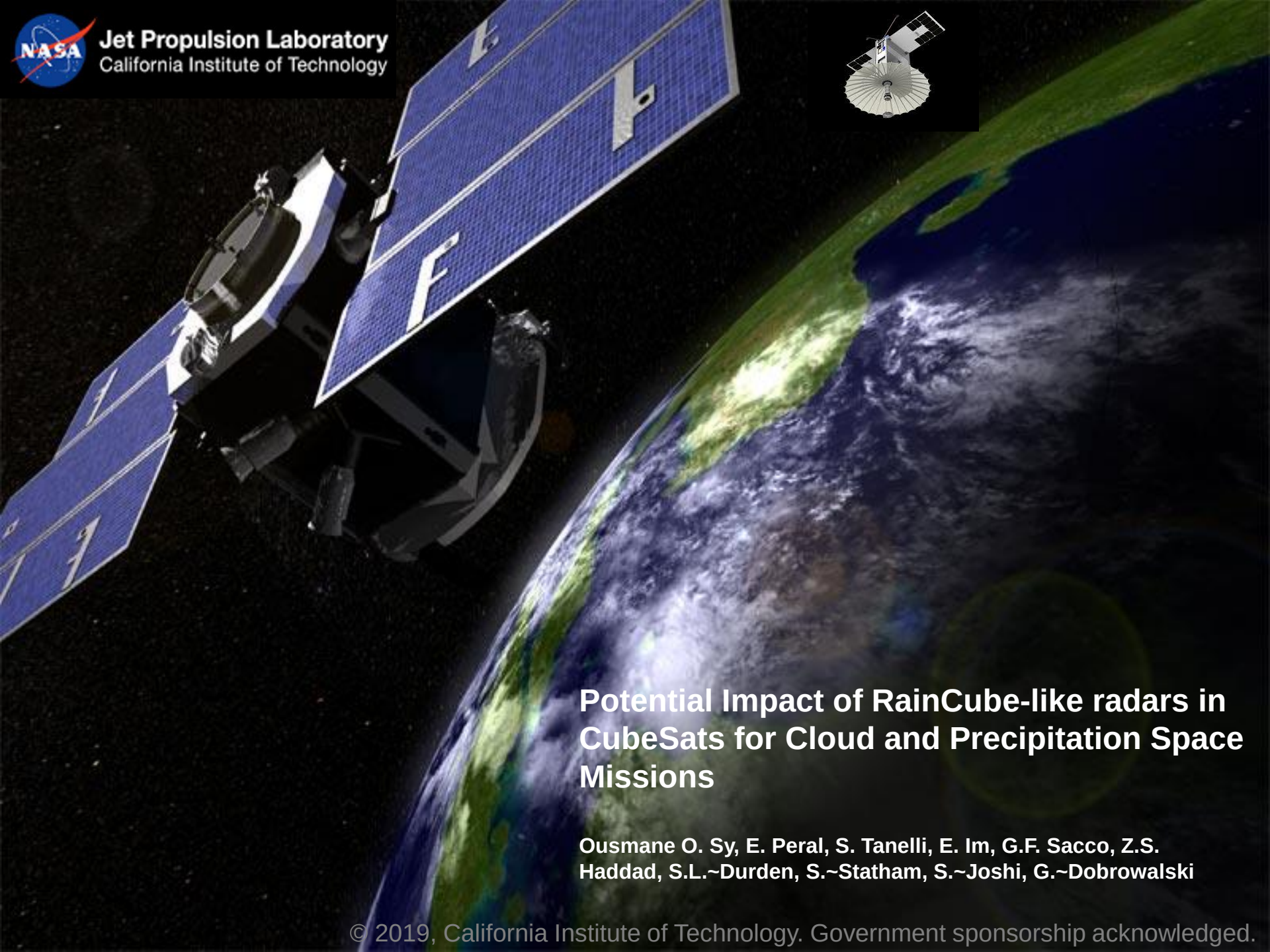
Jet Propulsion Laboratory
California Institute of Technology



Potential Impact of RainCube-like radars in CubeSats for Cloud and Precipitation Space Missions

Ousmane O. Sy, E. Peral, S. Tanelli, E. Im, G.F. Sacco, Z.S. Haddad, S.L.~Durden, S.~Statham, S.~Joshi, G.~Dobrowalski

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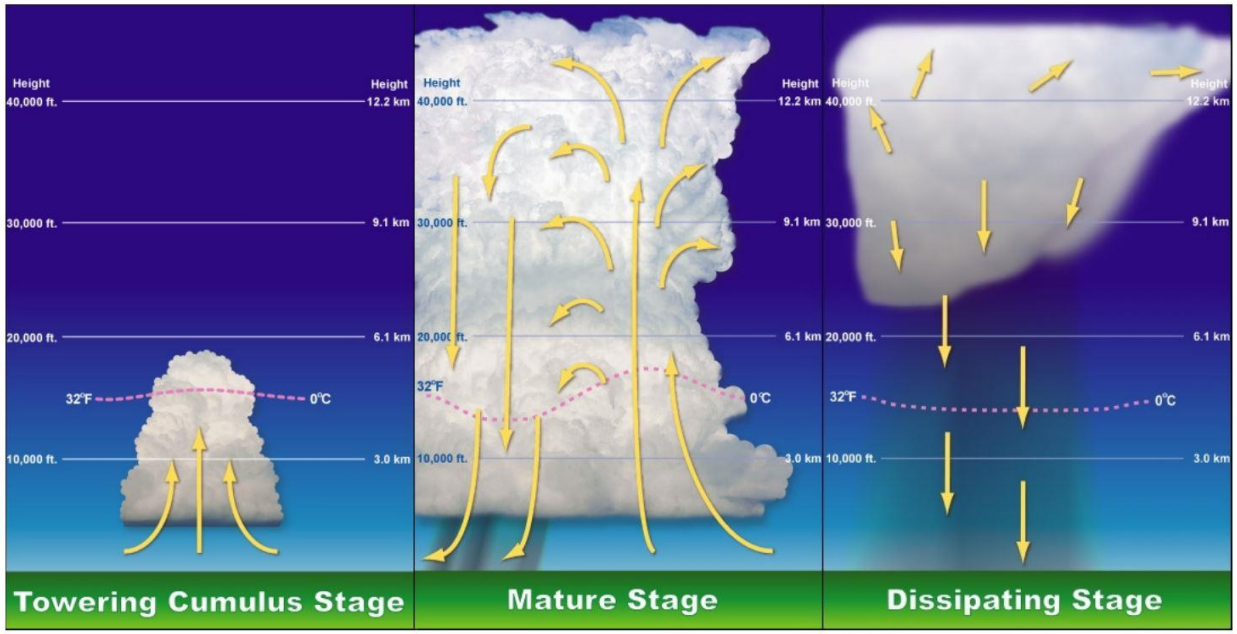
Spaceborne cloud radar and time



(Lifecycle of a thunder storm). Credit: NOAA

	Cloudsat (2006)	GPM (2014)
Max size/ weight	5.1 m/995 kg	13 m/3850 kg
Swath [km]	nadir	125–250
I_{orbit} [°]	98	65
Altitude [km]	705	407
Revisit time	$\sim$ 16 days	$\sim$ 3 hours

Lifetime

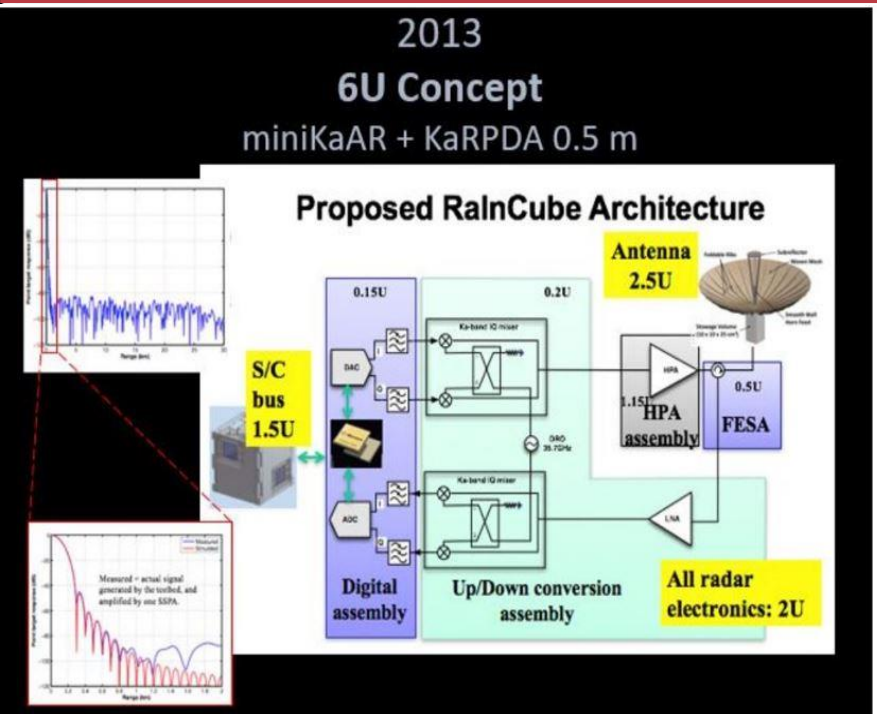
Single cell 30 mins

Multi-cell: few hours

Possible options

- GEO
- Doppler in space
- Constellation of radars

RainCube: 1st Radar in a CubeSat: Dr. Eva Peral (PI, JPL)



- NASA ESTO InVEST program
- NASA Earth Science Division's Flight and R&A Programs

Technology demonstration

Frequency	35.75 GHz
Antenna size	0.5 m
Volume	6U ($10 \times 20 \times 30$ cm^3)
Mass	5.5 kg
RF Power	10 W
Processing	PC & Offset (I,Q) modul.
Beams	1 (nadir)
Hor. Resolution	8 km
Range Res	250 m

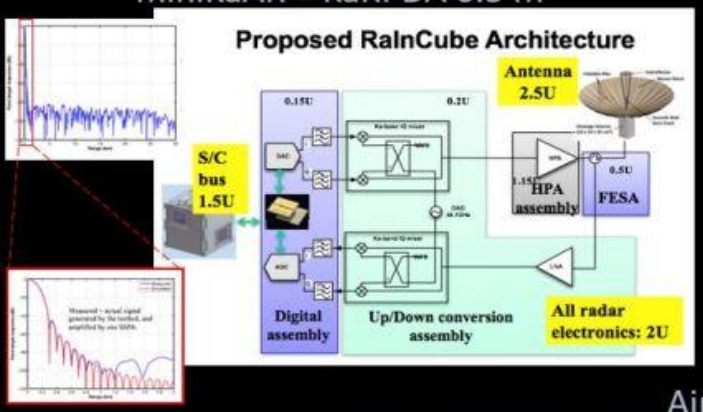
E. Peral et al., "Radar Technologies for Earth Remote Sensing From CubeSat Platforms," in *Proceedings of the IEEE*, vol. 106, no. 3, pp. 404-418, March 2018

RainCube development

2013

6U Concept

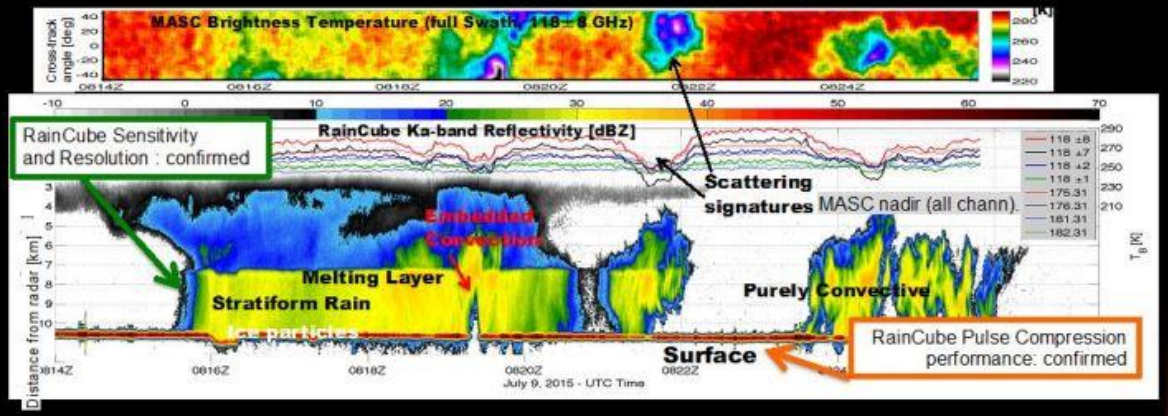
miniKaAR + KaRPDA 0.5 m



2015

PECAN

Airborne Demo of miniKaAR

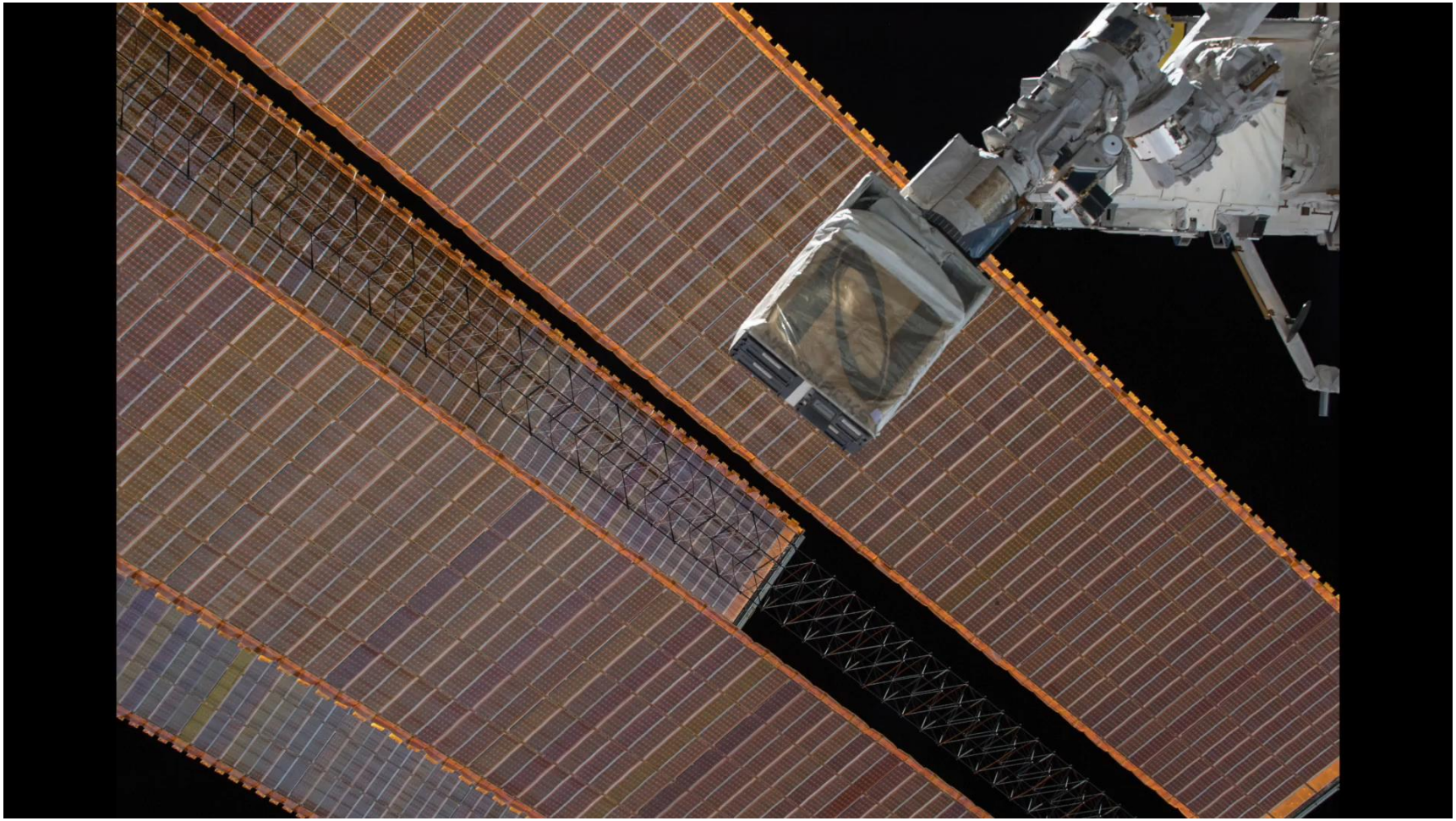


May 2018

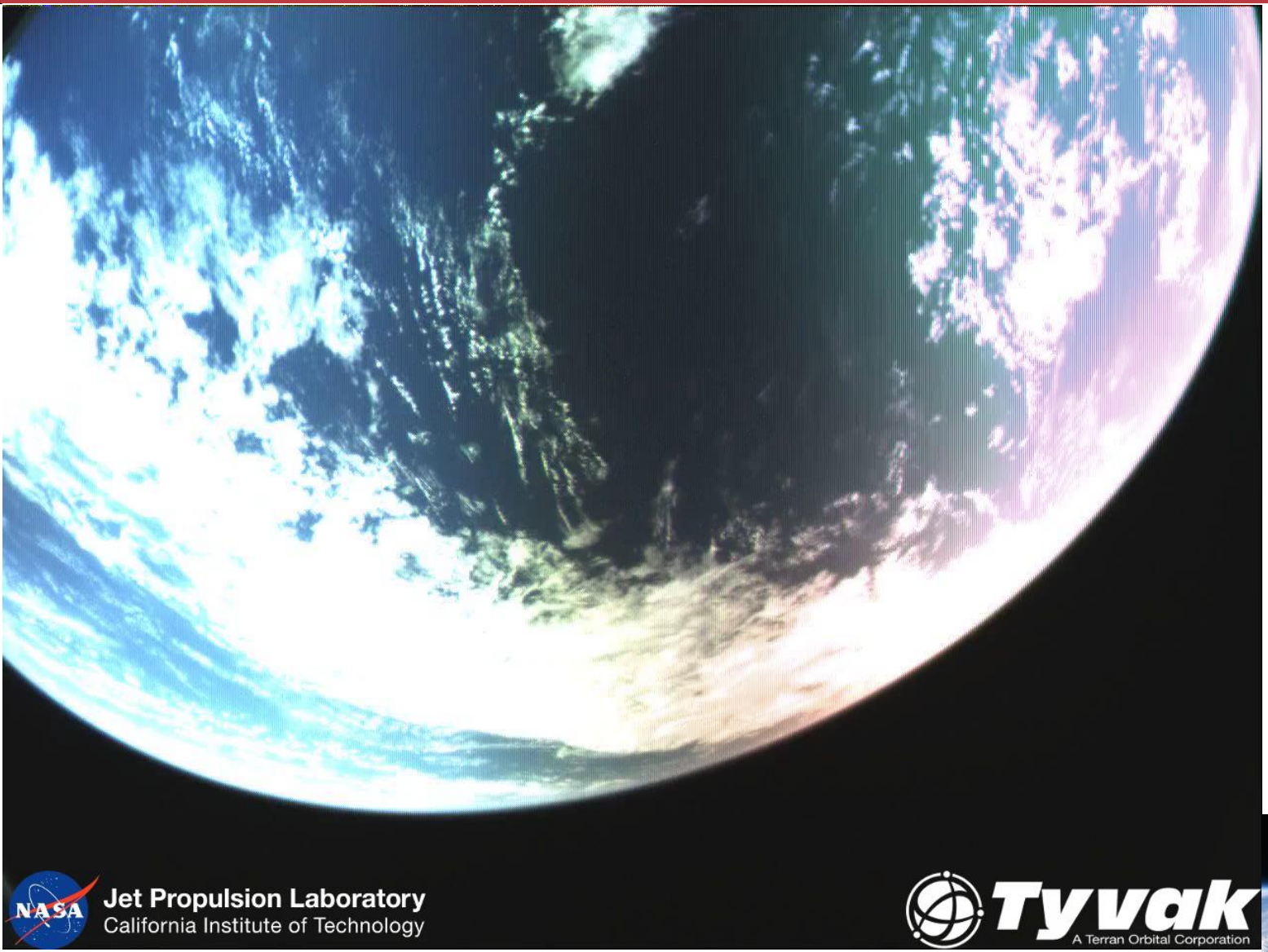
RainCube 6U

Launched to ISS

ISS Deployment: July 13th, 2018

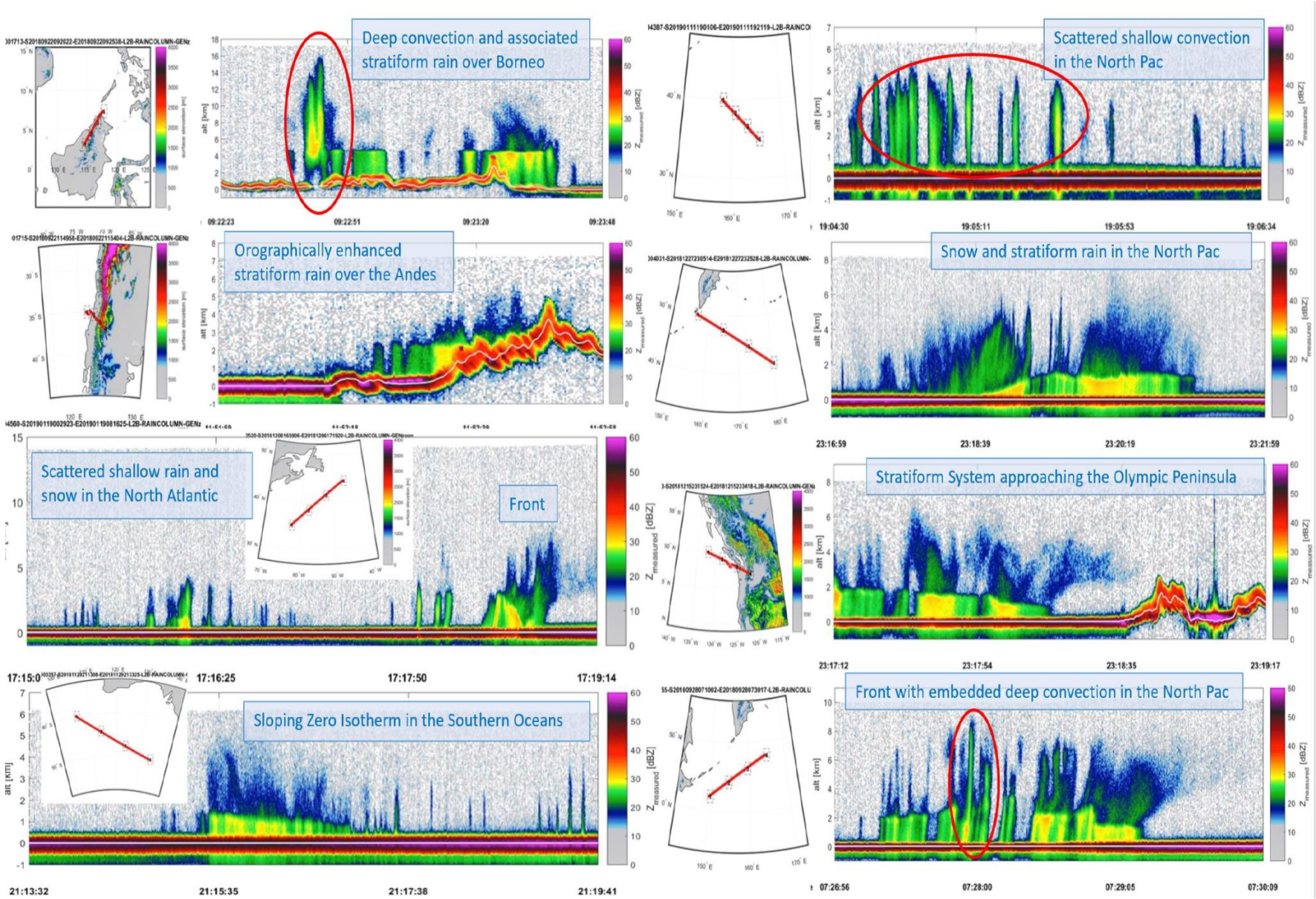


Antenna Deployment: July 28th, 2018

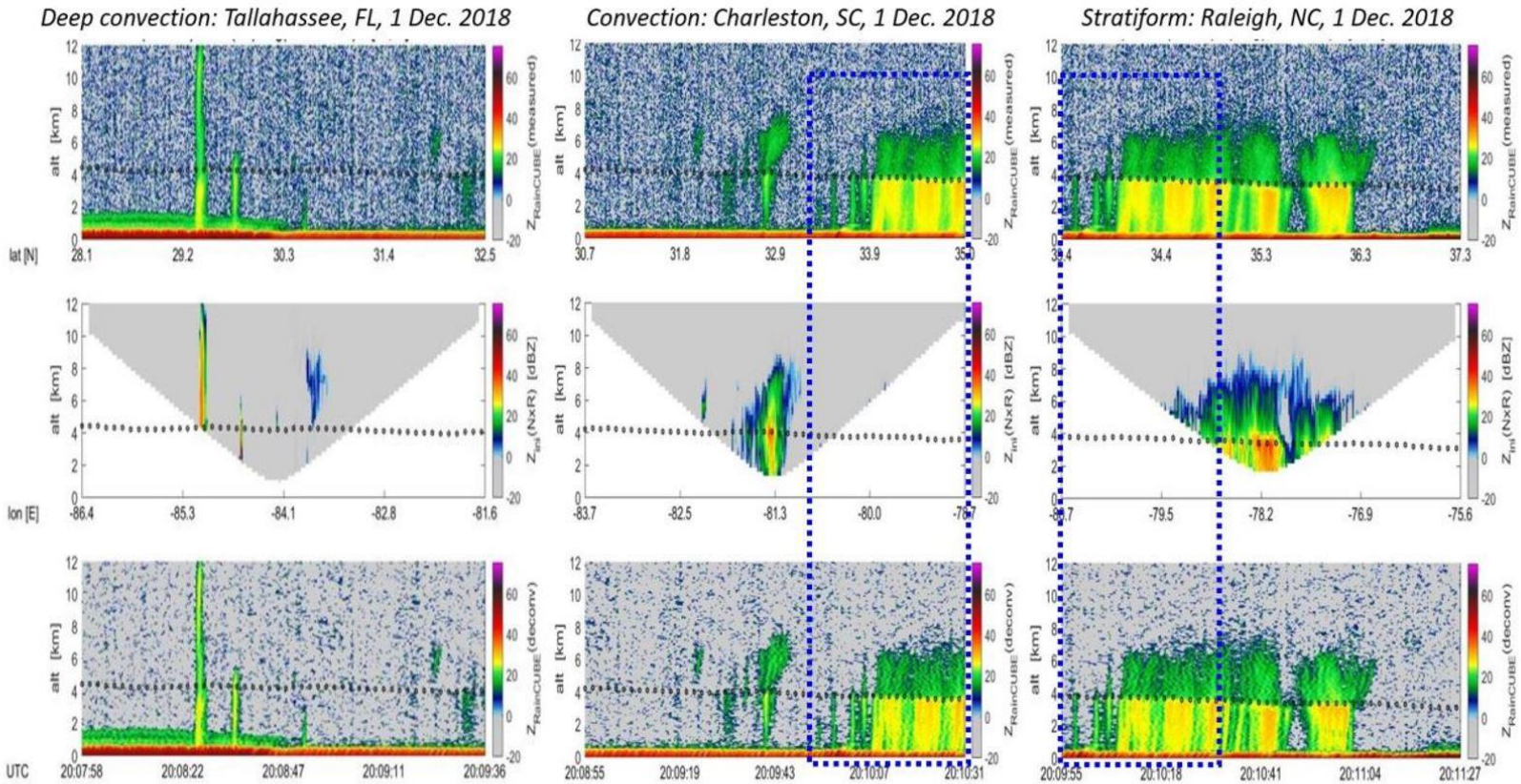


Artist concept

A Collection of RainCube Storms



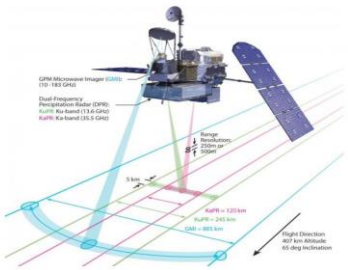
Co-location to NexRAD (NOAA, NWS)

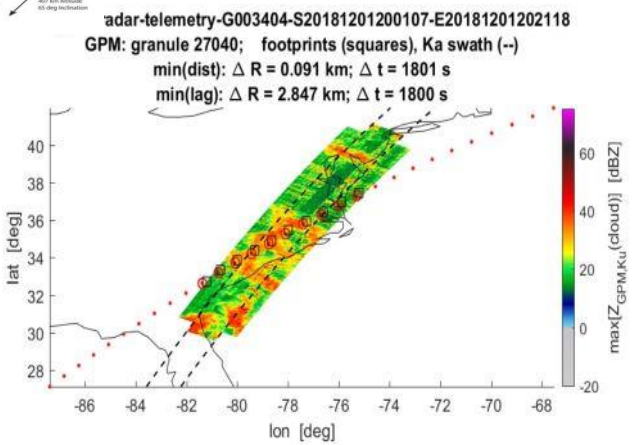


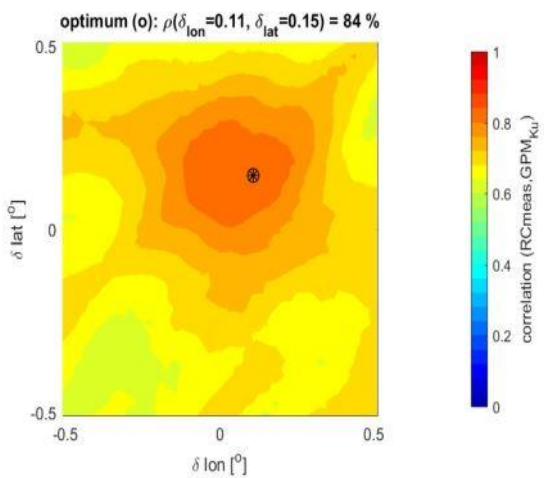
Complementarity $\neq$ viewing geometries, $\neq$ frequencies

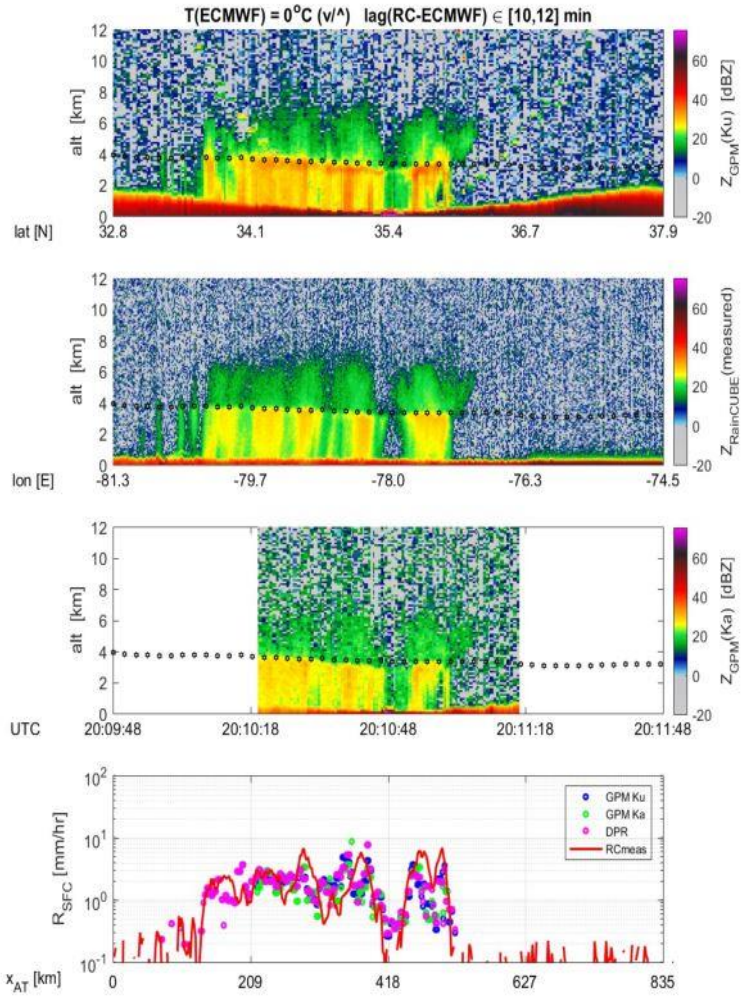
Co-location to GPM DPR (NASA-JAXA)

https://pmm.nasa.gov/gpm









GPM(Ku)

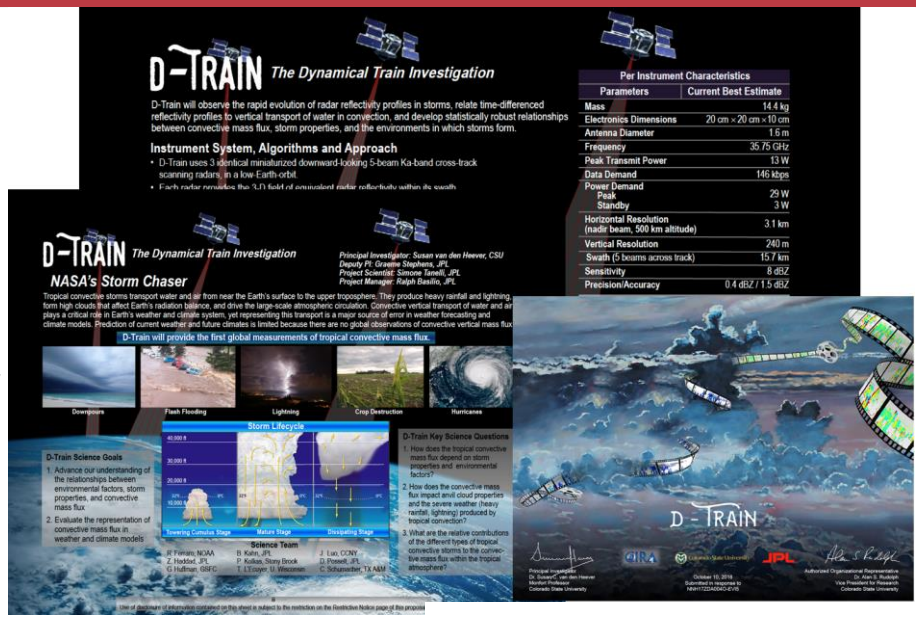
RainCube

GPM(Ka)

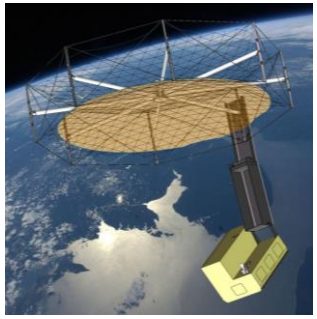
R_{SFC}

RainCube: Constellation mission concepts

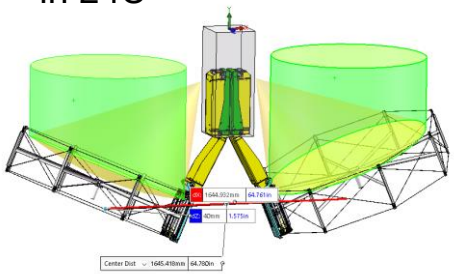
- Constellation with
  - → RainCube's "as is"
  - → with improved antennas & electronics:
    - * Extension to **W** and **G band**
    - *** DPCA** for Doppler, scanning, improved resolution & sensitivity



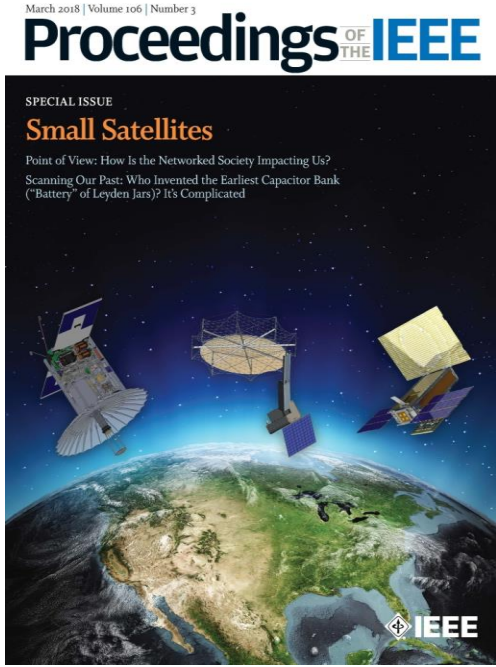
RainCube 1.0 m
in 12 U



RainCube 1.0 m DPCA
in 24U



TENDEG



- → with **Radiometers**

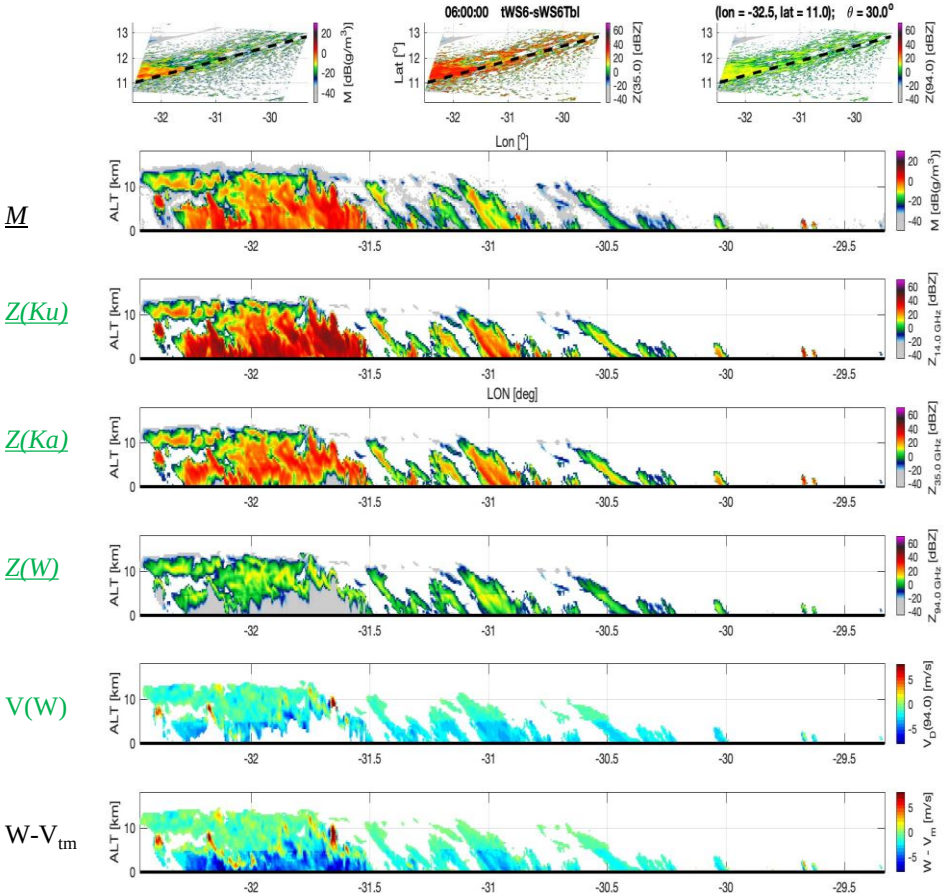
Ka-band ESTO InVEST and ACT programs

	6U	12 U	50 kg
Antenna size [m]	0.5	1.0	2.0
Sensitivity [dBZ]	15	5-10	0-5
Hor Resolution [km]	8	4	2
Range Res [m]		250	
Beams	1	1-3	1-5
RF Power [W]	10	10-20	10-40

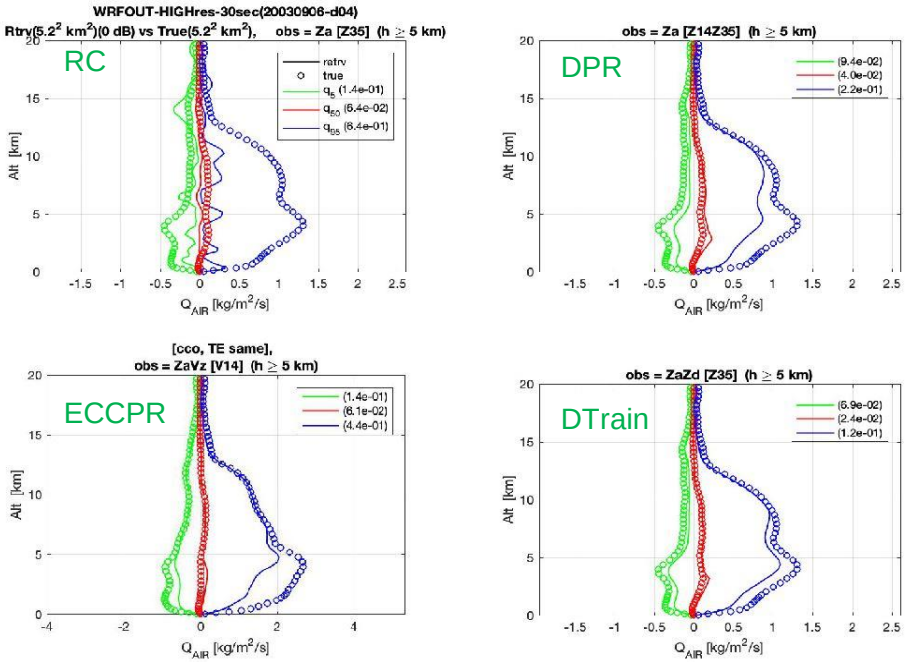
A. QuickS3: Quick Statistical Scattering Simulator

- *In:* cloud-resolution model simulations at *high-temporal resolution* (10s, 30s)
- Simplified *radiative transfer* over entire domain (attenuation, Doppler)
- *Retrieval* operator based on *Bayesian-interpolation* [Sy *et al.* 2017, IEEE TGRS]
- *Statistical analysis of skill of instruments (radar (multi-freq, Doppler), radiometer), etc*

Example: Tropical Storm Isabel Cabo Verde, (6th Sept 2003),



Assessing ability of various instruments to retrieve vertical air mass fluxes



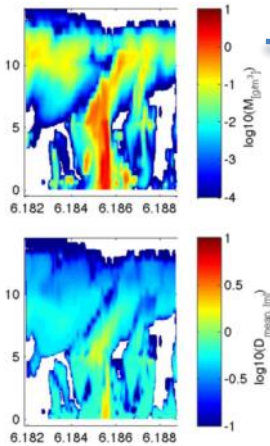
Poster #8: *Observation of Atmospheric Dynamics from Spaceborne radars: Added value of Doppler capability and sequence of "Z-only" observations*

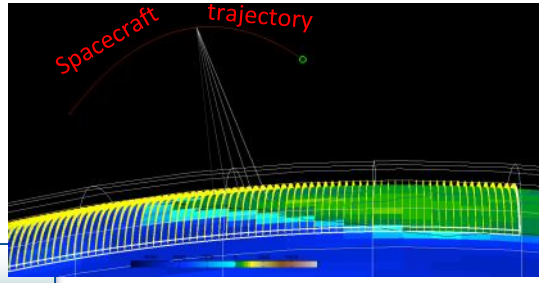
B. NEOS3: NASA Earth Observing Systems Simulator Suite

Now available online to US investigators: https://neos3.jpl.nasa.gov

Account requests: simone.tanelli@jpl.nasa.gov

Beta testing phase





IRM Geophysics

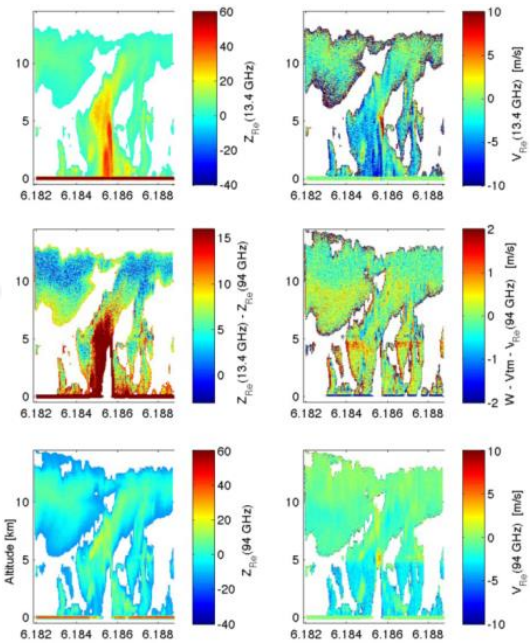
SEAM Electromagnetic signatures

ISM Propagation & Instrument/platform specs

Mass Size Shape
Orientation
Composition
Temperature
Pressure
Wind speed
Surface roughness
Sand fraction
Grain size Density
Soil moisture
Salinity SWE WRF
LIS DHARMA SAM

Refractive index
Extinction
Absorption
Polarization
Scattering Phase function Albedo
DDSCAT Rayleigh
SNOWFAKE T-Matrix
Geometric Optics
HITRAN FASTEM
Emissivity NRCS

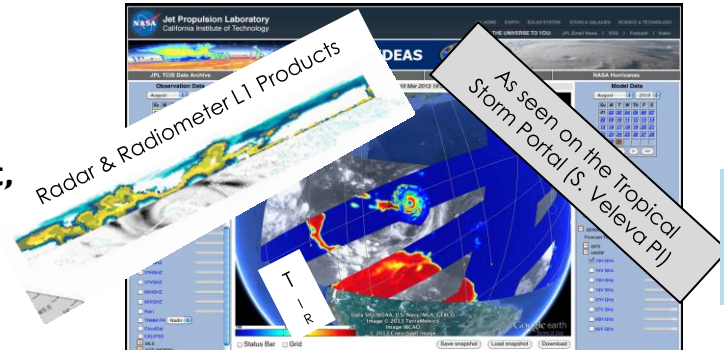
Instrument type
Antenna pattern
Scanning Orbit
Pulse integration
Conical Cross-track
Inclination Angle
Elevation angle
Filters DOMUS
SHDOM Radiative Transfer Model
Monte-Carlo RTM
SOI



a service-based tool suite providing simulated measurements for a wide range of instruments aimed at remote sensing of the atmosphere, on missions such as EarthCARE, ACE, GPM, A-Train, Nexrad in Space, and others, based on input from atmospheric models.

Allows user to

- **select simulated storm,**
- **specify instrument(s) and orbit,**
- **specify calculation modules and produces expected measurements**



This tool is developed and available. It needs a user base for beta testing, customization, and improvements.

Thank you!

For more information:

ousmane.o.sy@jpl.nasa.gov simone.tanelli@jpl.nasa.gov

- **RainCube:** Eva.Peral@jpl.nasa.gov
- **D-Train:** zsh@jpl.nasa.gov (Ziad Haddad)

RainCube data sets

https://tcis.jpl.nasa.gov/data/raincube/