RainCube and MASC in PECAN
(status report March 2016)

S. Tanelli, S. Padmanabhan, E. Peral,
O. Sy, S.L. Durden, D. Price, B. Ortloff, C. Parashare, F.J. Turk,
R. Stachnick, J. Munger

Jet Propulsion Laboratory, California Institute of Technology

Copyright 2016, California Institute of Technology. Government Sponsorship acknowledged.

RainCube and MASC in PECAN

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

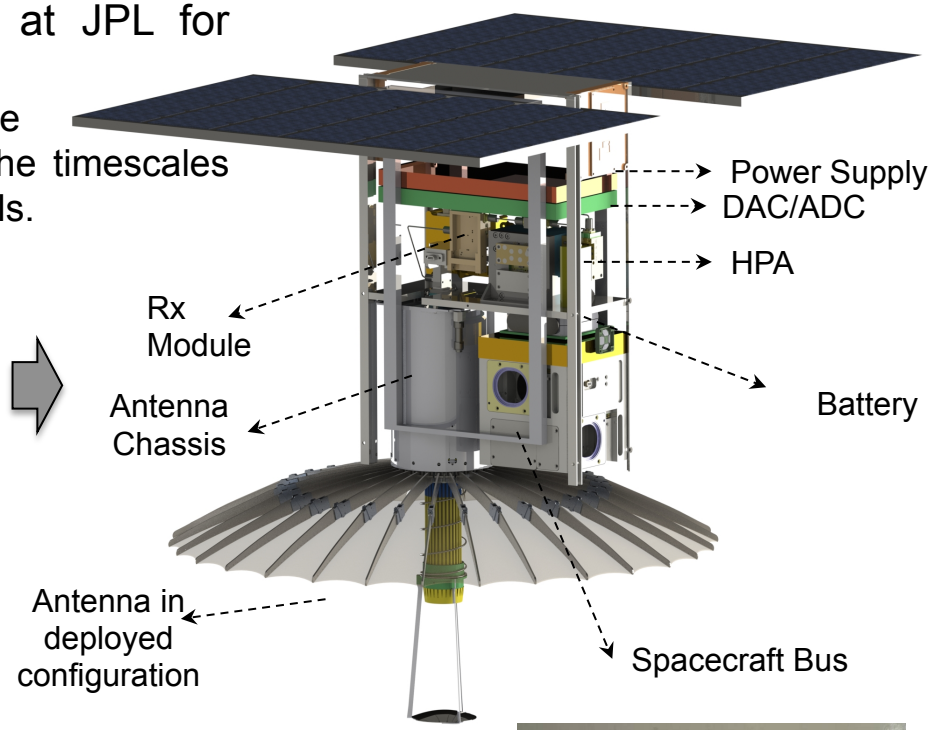
(PI: E. Peral, JPL)

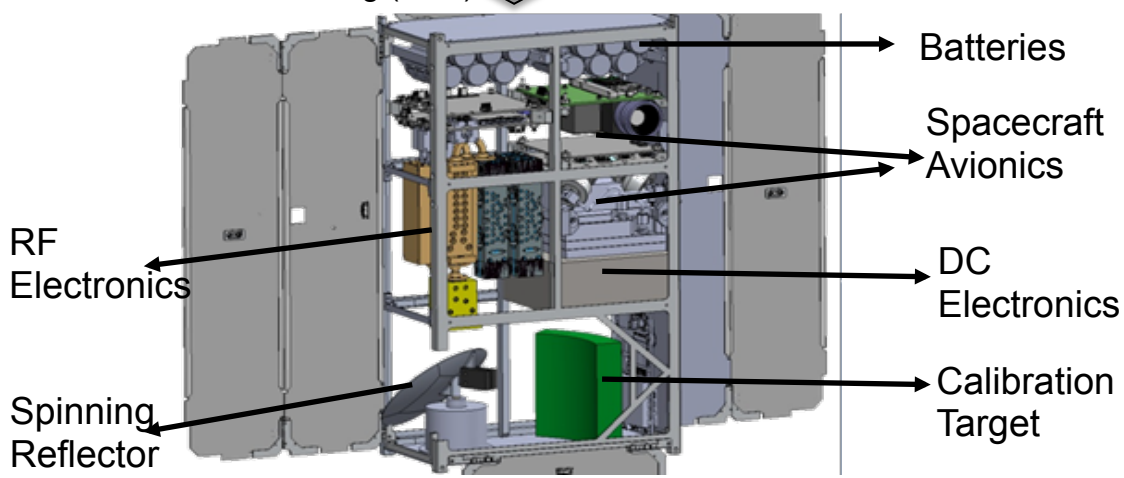
- nadir-pointing Ka-band precipitation radar (35.7 GHz)
- novel architecture to achieve the required sensitivity with low-power radar electronics that fit in 2U
- High performance pulse compression to reduce surface clutter contamination and achieve sensitivity and range resolution.
- Lightweight Deployable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

MASC (Microwave Atmospheric Sounder on CubeSat)

(PI: S. Padmanabhan, JPL)

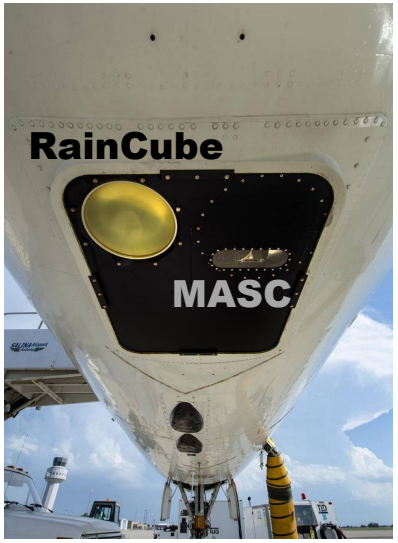
- 8 channel mm-wave radiometer (4 channels near 118GHz, 4 channels near 183 GHz)
- Cross-track scanning (±50˚)



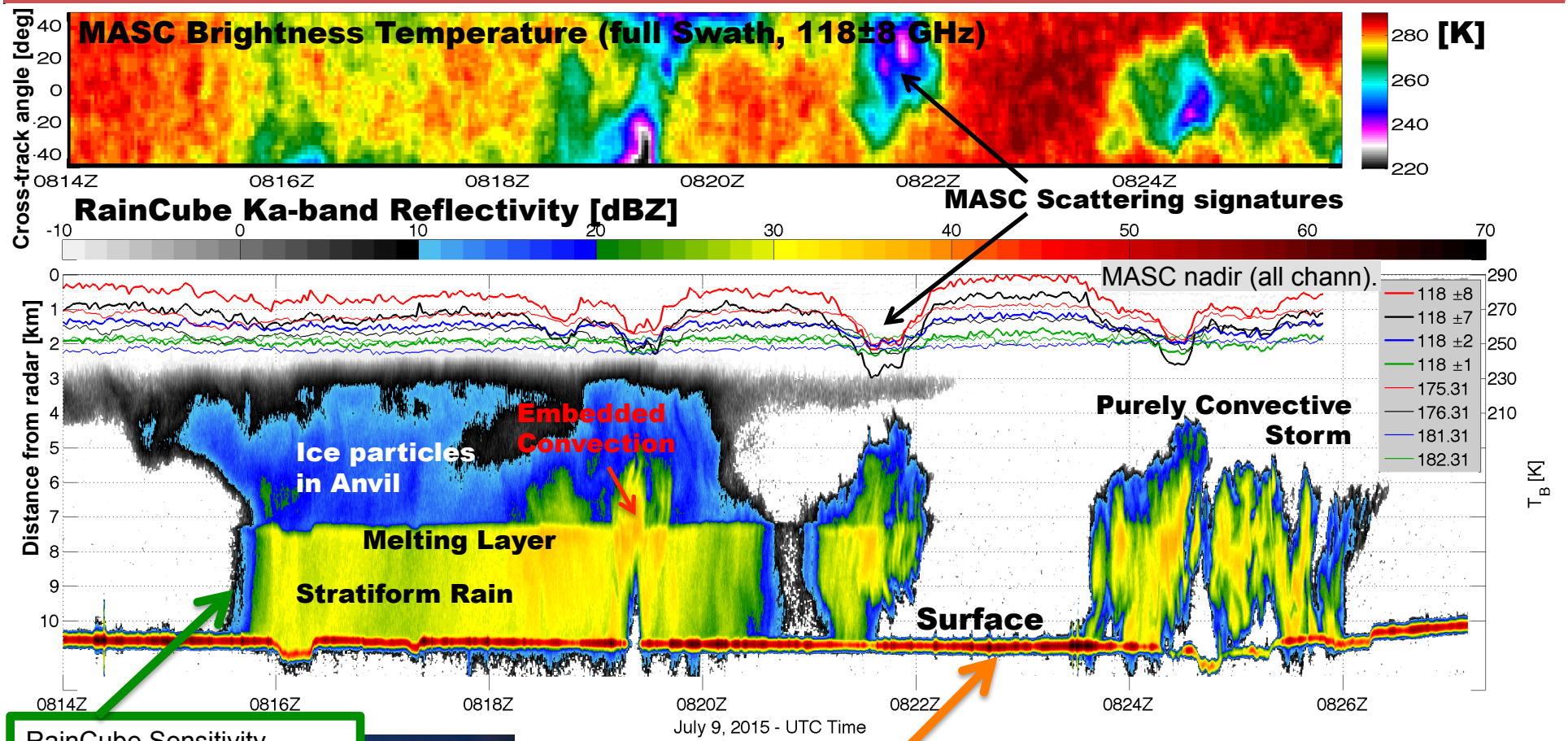


Both operated successfully on the NASA DC-8 for their **first airborne test and demonstration during PECAN (Jun. 28 – Jul. 11, 2015)**

They share the nadir #2 port



Radar-Sounder observations of PECAN storms



RainCube Sensitivity and Resolution : confirmed

RainCube Pulse Compression performance: confirmed

- No faults or glitches from first flight to last flight.
- Fine calibration and science analysis: in progress.
- Coordinated operations with ground based weather radars

Acknowledging:

- **AFRC**: excellent coordination and rapid implementation
- **PECAN** Science Leadership: outstanding flexible and creative collaboration
- **OU ARRC**: coordinated deployment of X-band ground based weather radars
- **Weather Focus Area** Leads: additional flight hours to PECAN for RainCube and MASC

Summary of Progress & Accomplishments

In the field

Demonstrated **Pulse compression performance** that generates acceptable surface clutter.

Demonstrated that **novel architectures** produces data of quality equivalent to classical less compact approaches (e.g., APR-3 Ka for RainCube)

Demonstrated **reliability of actual prototypes** in the DC-8 environment

Captured **structure of PECAN precipitation** at high vert. resolution (complement ground based radars)

Current Progress and immediate outcomes

Proof of measurement in relevant environment paved the way for **RainCube selection in the InVEST program**

Preliminary proof of coordination btw RainCube and MASC paved the way to **MASC deployment in OLYMPEX/RADEX'15**

Preliminary **algorithms** to **collocate** MASC and RainCube data, and **geolocate** RainCube to ground weather radars

FY 16/17 goals

Have RainCube at launch readiness by **August 2017**. No launch date available at this time but was selected as #2 priority in the CSLI.

Integrate MASC measurements in **OLYMPEX/RADEX'15 science analyses**

Provide validation of experimental mW sounder **retrieval algorithms**

Support PECAN team in defining details of the nature of the observed storms based on observations

Perform unsupervised retrievals and validate with ground based radar and other assets

LEGEND **Technology Focus** **Science Focus**

Dedicated funds

Best effort. No dedicated funds. Only synergy with other projects.

① RainCube + ground based radar

RainCube "Curtain plots" acquired during PECAN have been collocated to NEXRAD data for initial validation. Same approach to be applied to PX-1000 and DOW.

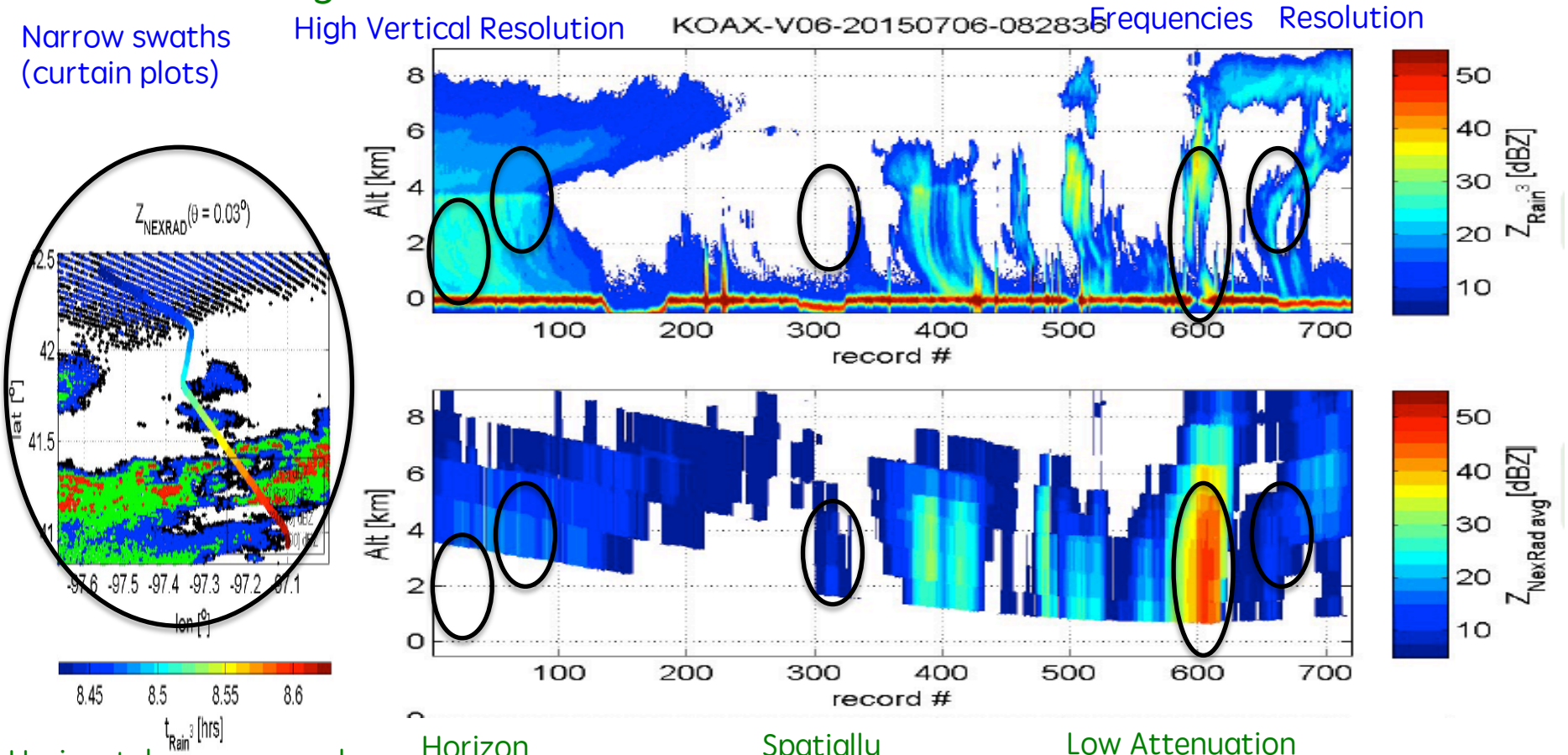
This example of snapshot is good to illustrate several of the key differences between the airborne and ground based radars

Narrow swaths (curtain plots)

High Vertical Resolution

Attenuated Frequencies

High Resolution



Horizontal coverage and temporal sampling

Horizon shadow

Spatially contiguous

Low Attenuation

Images Courtesy of: Ousmane Sy (JPL)

Recent GPM/ACE joint Experiments

The GPM GV program and the ACE Science Working Group have successfully completed two joint projects where **multi frequency cloud-precipitation radar** data were acquired:

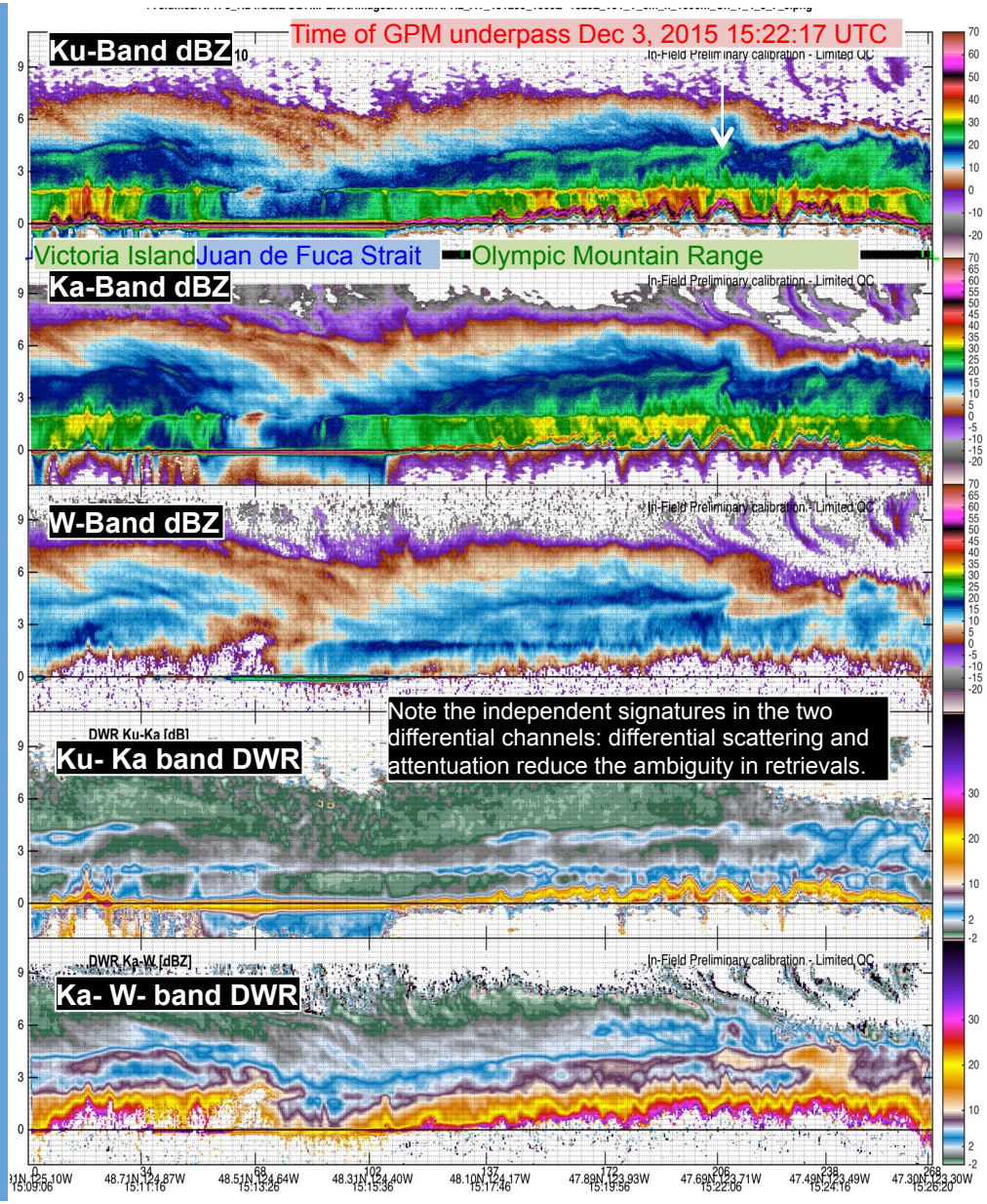
- **IPHEX/RADEX'14**, N. Carolina, May/Jun 2014
- **OLYMPEX/RADEX'15**, Washington, Nov/Dec 2015.

W. Petersen, M. Schwaller, J. Mace, R. Marchand. A. Barros, R. Houze, L. McMurdie and many other.

GPM exploits the multi frequency radar data to better constrain the validation of GPM retrievals.
ACE seeks to demonstrate and refine the definition of the radar for the ACE mission.

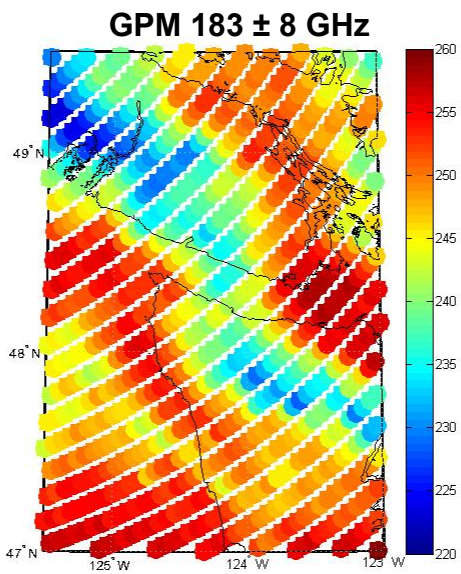
APR-3 (S. Durden, PI, ESTO/AITT Program) is the first 3-frequency (Ku, Ka, W), scanning, Doppler, airborne radar. APR-3 was due for completion in June 2016, but was successfully demonstrated in OLYMPEX/RADEX'15 onboard the NASA DC-8.
One example of the data acquired (preliminary calibration) is shown from a direct GPM/DPR underflight on Dec 3, 2015.
APR-3 is an airborne proxy to 3CPR.

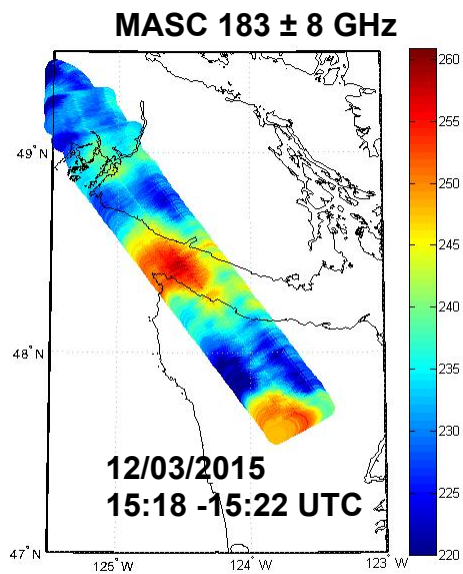
MASC (S. Padmanabhan PI) was added as host payload after the successful demonstration in the PECAN experiment.

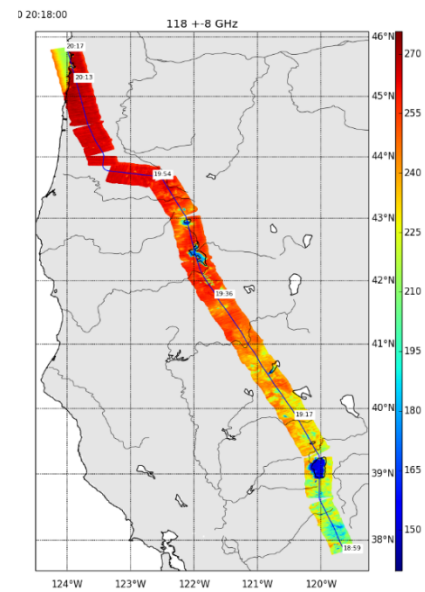


MASC in OLYMPEX

MASC was deployed on the NASA DC-8 from Nov 10 to Dec 22, 2015 for OLYMPEX The Olympic Mountains Experiment (OLYMPEX) is a ground validation field campaign designed to verify and validate satellite measurement of precipitation from the constellation of satellites known as the Global Precipitation Measurement (GPM).







Recent updates

- Received notification from OU that PX-1000 data completed their QC in February 2016. Thank you Jim Kurdzo, Boon Leng Cheong, Robert Palmer & team.
  - Tools ready for further analysis but no dedicated funds to support this specific activity.
- Received notification from LaRC that LASE data completed their QC in January 2016. Thank you Susan Kooi, Rich Ferrare & Amin Nehrir, & team.
  - Tools ready for further analysis but no dedicated funds to support this specific activity.
- More general work on retrievals & science analysis will continue under GPM STM, ACE SWG, TEMPEST-D and other related projects. Not tailored to the specific PECAN needs under current funding, but synergy on various fronts.

Acknowledging again

Because it was truly outstanding how this came to pass.

AFRC: excellent coordination and rapid implementation

PECAN Science Leadership: outstanding flexible and creative collaboration.

A special thank you to Rich Ferrare and Amin Nehrir because they truly owned the addition of these two last-minute instruments and helped on all aspects.

OU ARRC: coordinated deployment of X-band ground based weather radars.

A special thank to PX-1000 team for their great flexibility in adapting plans and extending their original commitments to maximize the collocations.

Weather Focus Area Leads (Tsengdar Lee and Ramesh Kakar): additional flight hours to PECAN for RainCube and MASC were the key to enabling this target of opportunity. Great strategic vision!

The backup slides following this one contain the full set of imagery collected by RainCube and collocated to NEXRAD (by O. Sy, September 2015).