ICE-POP and the NASA Global Precipitation Measurement (GPM) Mission

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KMA ICE-POP Meeting

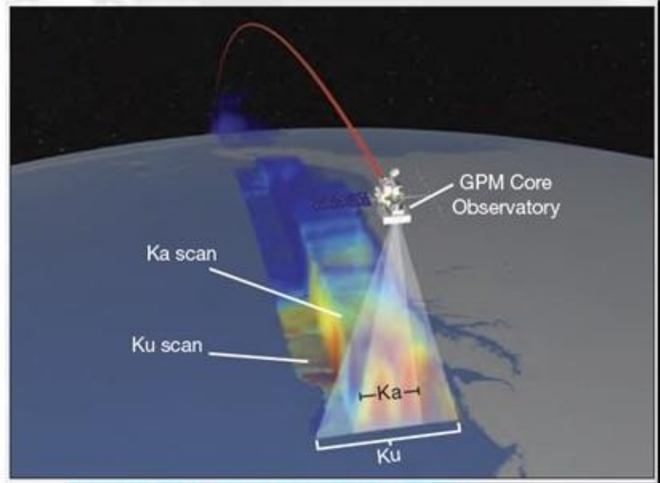
8-11 November 2016

Broader Framework for NASA ICE-POP Involvement

- Physical and direct validation of Global Precipitation Measurement (GPM) Mission satellite remote sensing retrievals in orographic snow
- NuWRF short range forecasts in complex terrain
- Test/improve cloud model representation of snow microphysics and application to satellite remote sensing
- NASA Short Term Prediction and Operational Research Transition (SPoRT)- field product testing, utility
- Development of satellite-based ocean latent heat fluxes and potential impacts for nowcasting and NWP

GPM: "Flagship" Core Observatory

Carries **two instruments** that can view precipitation (rain, snow, ice) in new ways; serves as a standard to calibrate measurements made from partner satellites



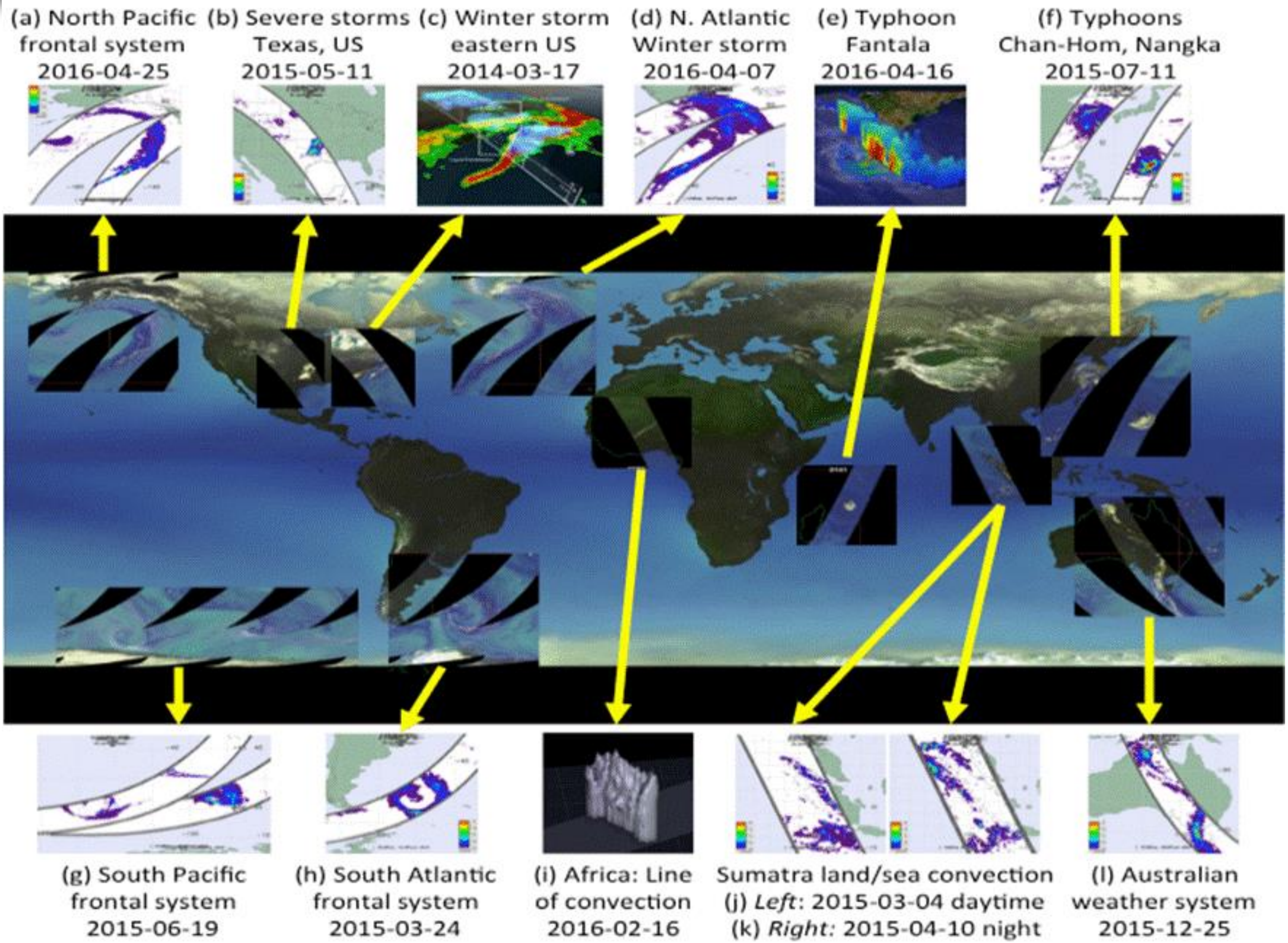
GPM Microwave Imager (GMI): 10-183 GHz

13 channels that provides an integrated picture of energy emitted and scattered by precipitation

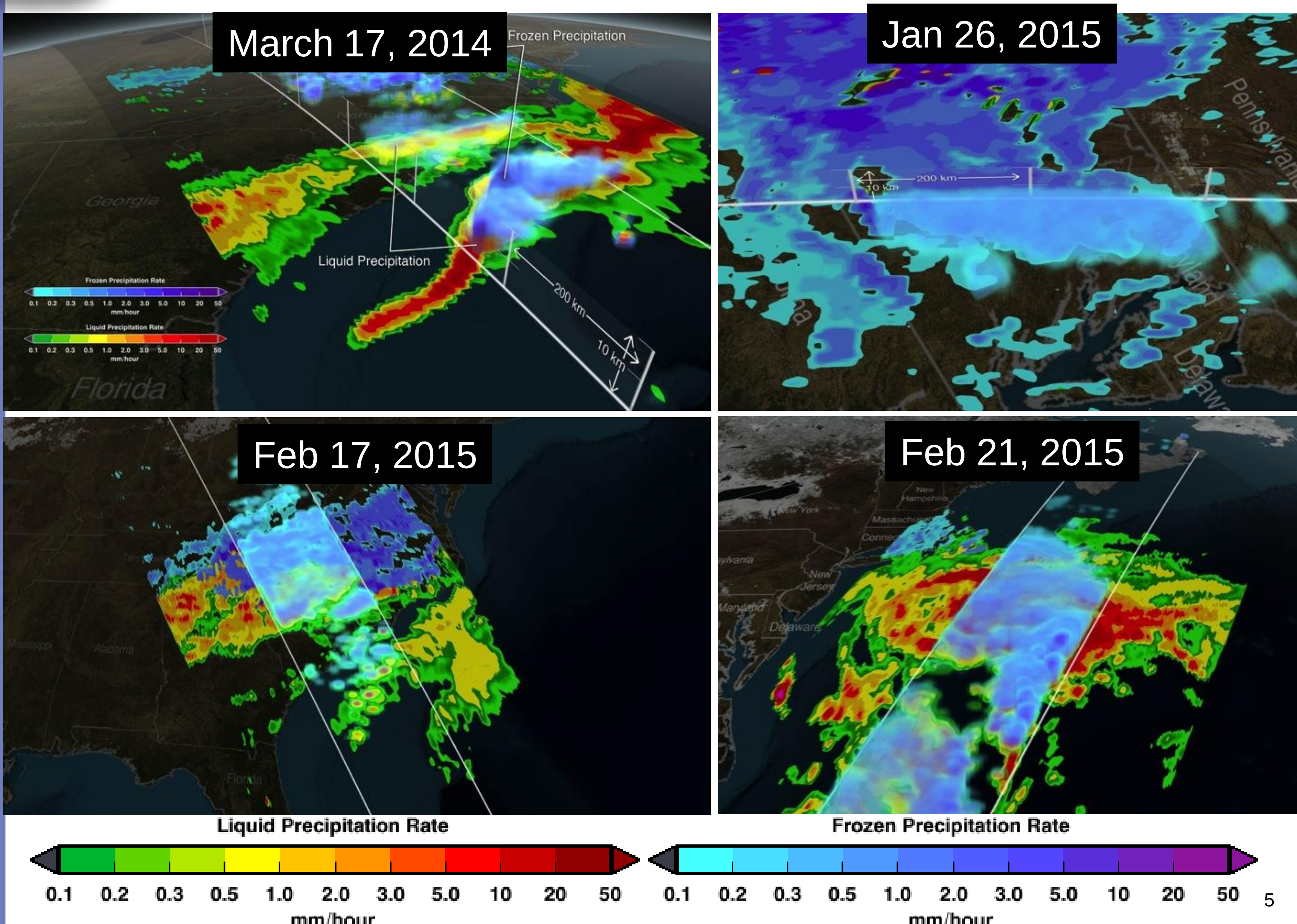
Dual-frequency Precipitation Radar (DPR): Ku-Ka bands

Two different radars with different frequencies that look at precipitation in 3-D throughout the atmospheric column

GPM Observations – Provide a Global View

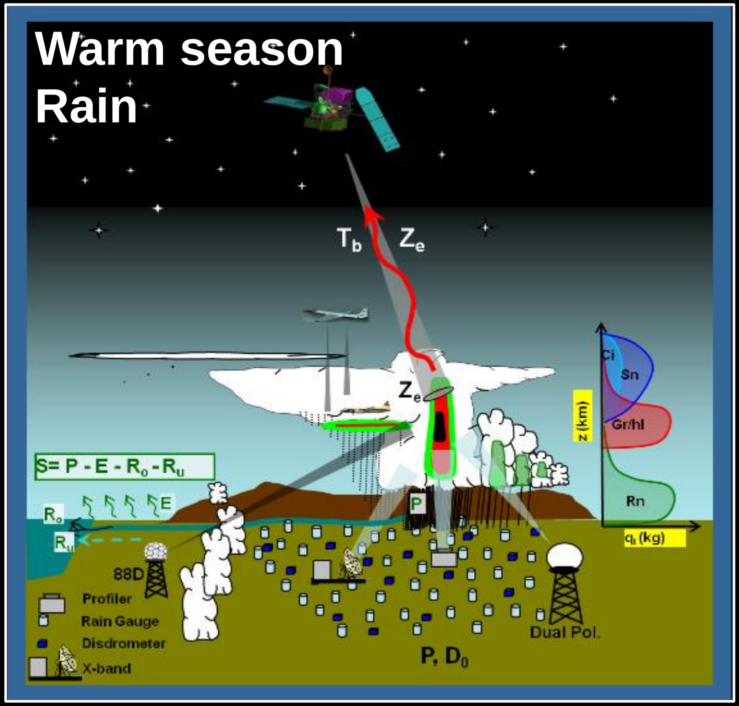


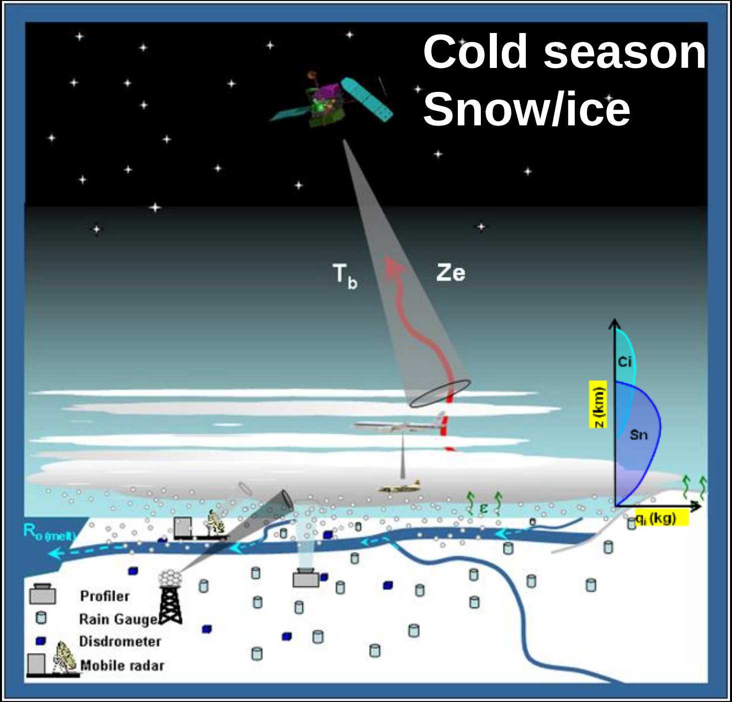
GPM Detects and Estimates Falling Snow Rates



Ground Validation

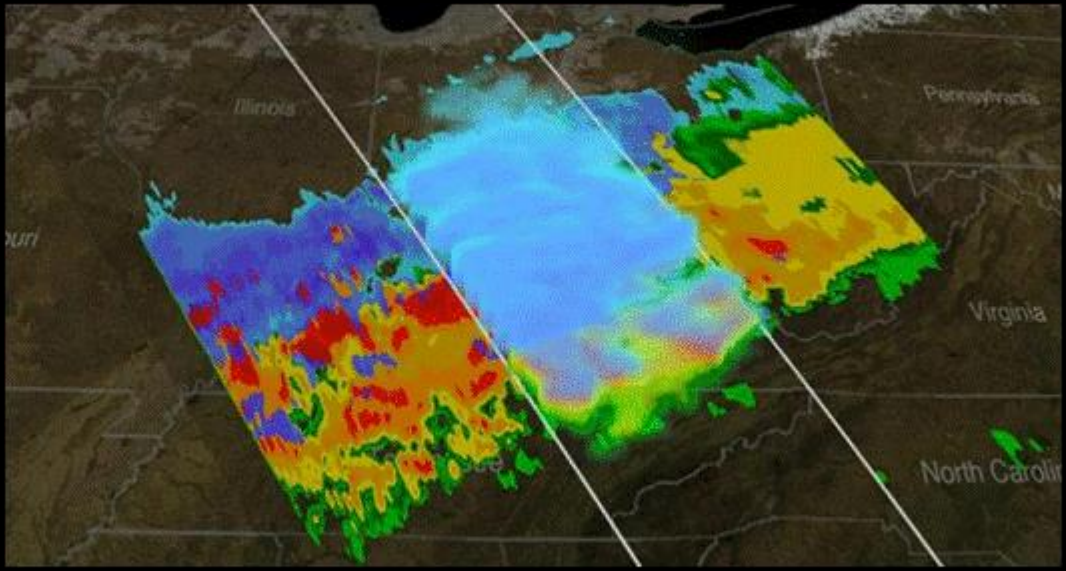
Direct, Physical, and Integrated Approaches
Goal: Convergence between space and ground-based measurments





- **Fundamentally, GPM must produce accurate precipitation estimates over a broad range of warm *and* cold season conditions- difficult proposition!**

GPM's Level 1 Requirement: Detect snow!

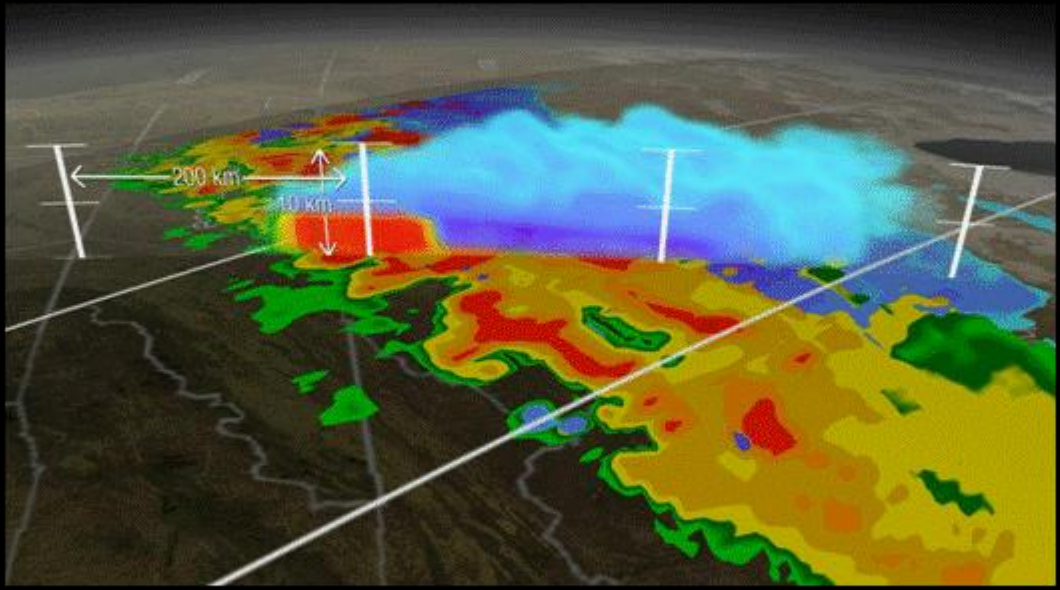


Winter storm with mix of liquid, freezing, frozen precipitation

GPROF and D3R delineate snow and rain..So, *we can* detect it

But not always uniformly-

Vision: Unambiguously capture physical variability and reliably estimate liquid equivalent rates over all terrain types



NASA GPM Objectives

GPM Ground Validation (ICE-POP Field Campaign - RDP)

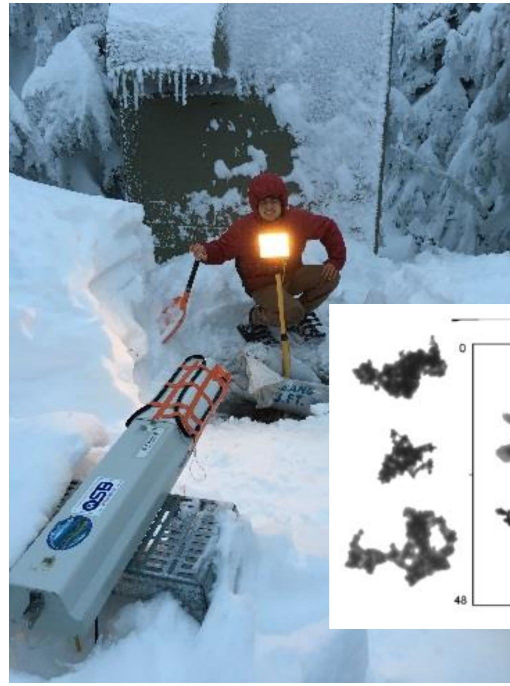
- Direct/physical validation of satellite-based snowfall retrieval algorithms (radar, radiometer, merged satellite algorithms) over coastline and mountains; melting layer interaction with terrain also of interest.
- Physics of snow, coupling to SWER and satellite remote sensor retrieval algorithm assumptions
- Model + Observational analyses: Movement toward level IV products leverage intensive and multi-faceted NWP component.
- Support current PMM/GPM collaboration with KMA- leverage significant international observational science/data effort.
- Cloud/precipitation model processes (liquid, mixed phase and frozen) testing and improvement in orographic natural laboratory and under satellite coverage. Builds model testing database for further remote sensing algorithm development

Specific Measurement Interests

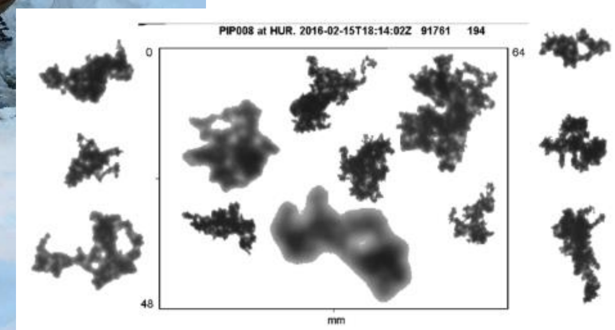
- Storm Type/Regime: Shallow, deep, synoptic, terrain-forced……
- Physical process and structure responsible for snow in the column
- Snow size distribution
- Snow habit, density, fall speeds, liquid eq. rate, and spatial variability
- Measurement quality and limitations (sensitivity, calibration, viewing angle…. other artifacts…..)
- Determining and developing a ground “reference” for liquid equivalent snow rate measurement

NASA Instruments for ICE-POP: D3R, PIP, Pluvio, MRR

Dual Frequency Dual Polarimetric Doppler Radar (D3R)



Precipitation Imaging Package (PIP) x 2



Pluvio$_2$ x 3

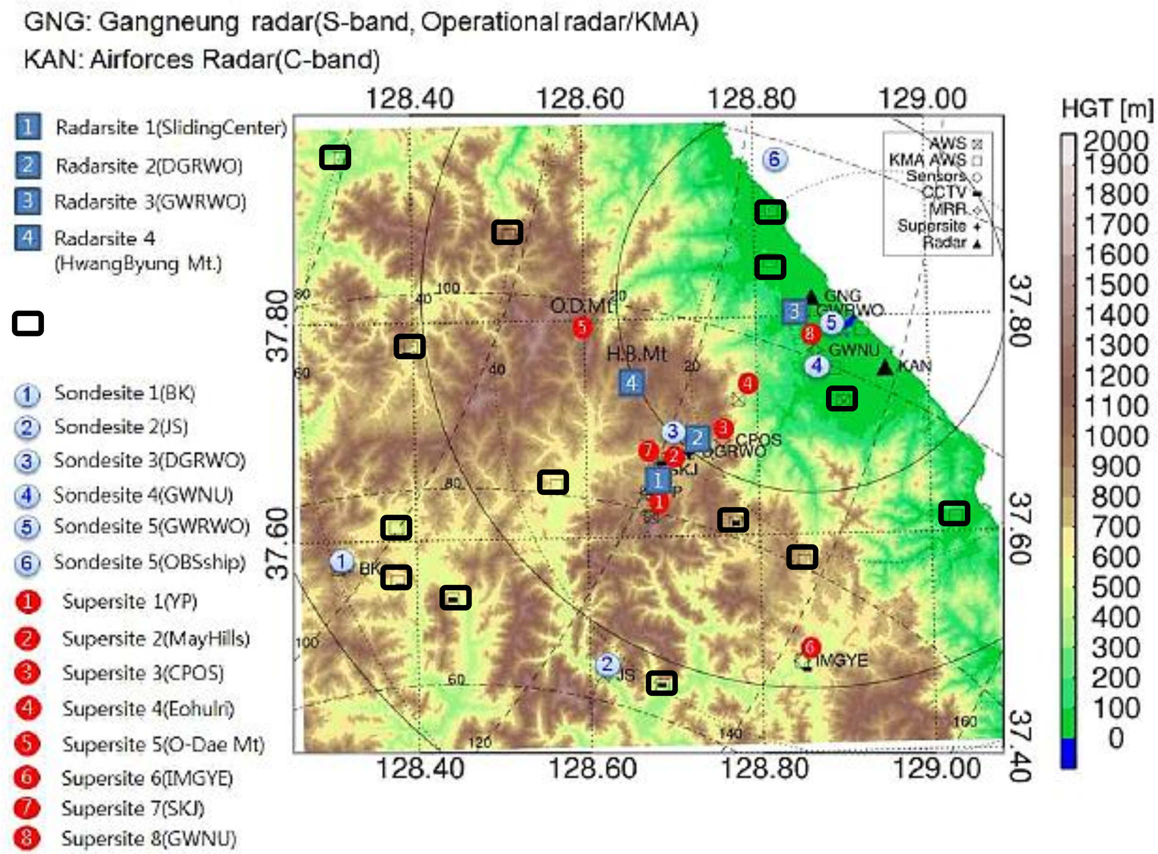
MRR x 2

Parsivel disdrometer (APU) x 3

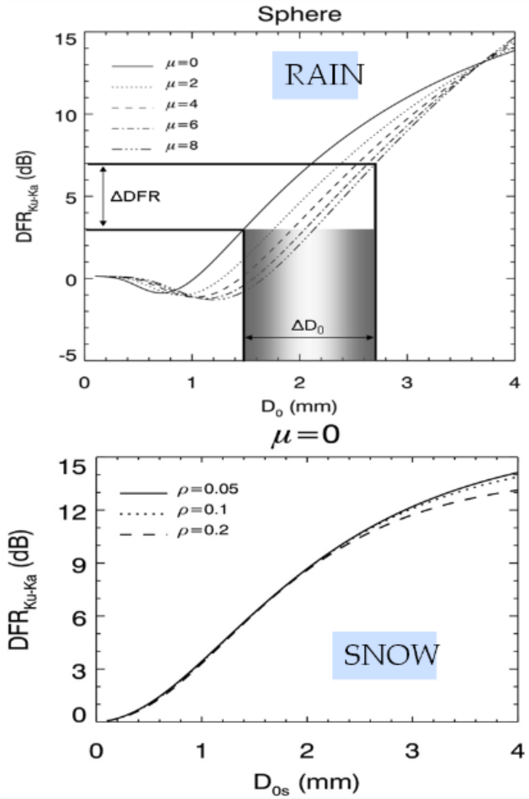
PyeongChang Area: Instrument layout

NASA: 3 Pluvio 400 + APU (Fall 16), 2 PIP, 2 MRR (Fall 17)

(YongPyeong cloud physical observatory)	128°40'13.65"/ 778m	PIP-NASA1 POSS-EC1 Pluvio-NASA LSND-NIMS1 PWD-NIMS
Supersite 2 (Mayhill)	37°39'54.87"/ 128°41'58.65"/ 788m	VertiX-KNU 2DVD-KNU MASC-CSU MRR-KNU Par-KNU Par-UCLM(8) POSS-KNU DFIR-KNU1 Pluvio-EC1 Geonor-KNU
Supersite 3 (Cloud Physics Observation Site)	37°41'10.72"/ 128°45'32.52"/ 837m	MRR-NIMS3 Par-NIMS3 PIP-NASA2 POSS-EC2 Pluvio-NIMS1 Vis-NIMS MWR-NIMS CLM-NIMS1 CSAT-NIMS BYL-NIMS ACOS-NIMS
Supersite 4 (Eohulri community center)	37°43'13.51"/ 128°47'43.63"/ 209m	W-band Radar(WMcGill) 2DVD-NCU MASC-EPFL MRR-EC Par-EC POSS-EC Vis-EC DFIR-KNU2 POSS-EC3 Pluvio-EC2
Supersite 5 (O.D.Mt)	37°50'06.41"/ 128°38'53.70"/ 271m	MRR-NIMS4 Par-NIMS4 LSND-NIMS2
Supersite 6 (IMGYE)	37°29'40.97"/ 128°51'09.92"/ 508m	MRR-NIMS5 Par-NIMS5 LSND-NIMS3
Supersite 7 (SKJ)	37°39'38.98"/ 128°40'44.10"/ 837m	MRR-NIMS2 Par-NIMS2 CLM-NIMS2 GNS-NIMS1 ORG-NIMS1
Supersite 8 (GWNU)	37°46'14.82"/ 128°52'00.48"/ 38m	CLM-NIMS3 AWS



Observation site name	Lat/Lon/Height	Available instruments in year
Radarsite 1 (Sliding Center)	37°39'07.62"/ 128°40'40.18"/ 922m	X-band Radar(XUCLM) Ka-Ku band Radar(D3RNASA)
Radarsite2 (DGRWO)	37°40'38.79"/ 128°43'07.86"/ 776m	K-band Radar (KMcGill) Wind Lidar(LEC) MRR-NASA Par-NASA CLM-KMA1 VIS-KMA1
Radarsite3 (GWRWO)	37°48'17.80"/ 128°51'16.93"/ 83m	X-band Radar (XEPFL) K-band Radar (KEPFL) MRR-CSU Par-CSU MWR-KMA CLM-KMA2 WPR-KMA VIS-KMA2
Radarsite 4 (H.B. Mt.)	37°45'27.20"/ 128°39'42.34"/ 1378m	X-band Radar (XKMA)



Retrieving snowfall from DPR

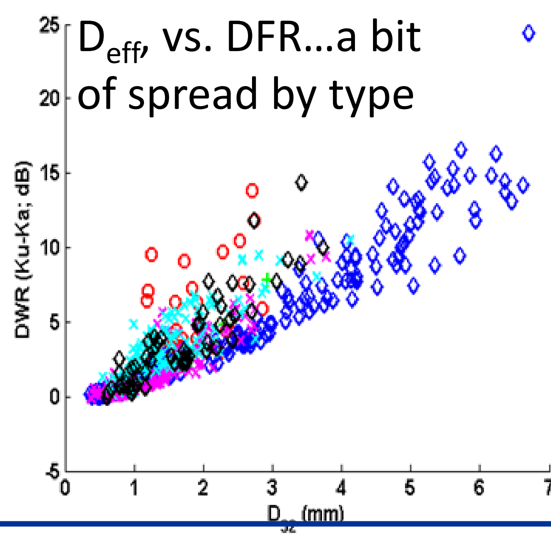
Lookup tables of DFR to estimate D_o

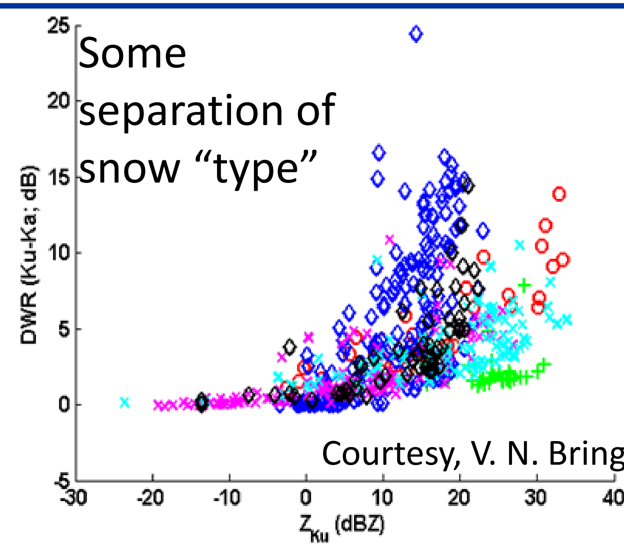
Use with Z_{Ku} to estimate N_w with μ = fixed (ambiguities in assumed ρ and μ).

Integrate to get contents.

CMB additionally uses the GMI scattering to constrain total column IWP (at say, 166 GHz).

Dual-Frequency Approach tested with GV data

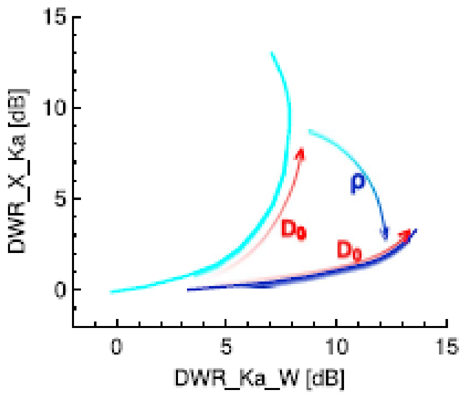




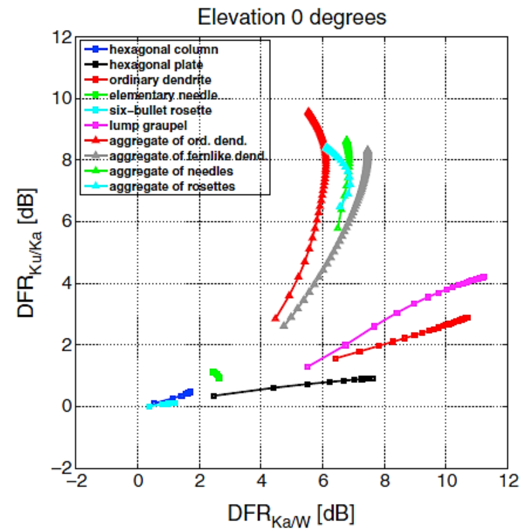
D3R: [Dual-Freq., Dual-Pol., Doppler Radar]

System	
Frequency	Ku- 13.91GHz ± 25MHz; Ka- 35.56GHz ± 25MHz
Minimum detectable signal (Ku, Ka)	-8 dBZ, -2 dBZ noise equivalent at 15 km, at 150m range resolution
Minimum operational range	450 m
Operational range resolution	150 m (nominal)
Maximum range	30 km
Angular coverage	0-360° Az, -0.5-90° El (full hemisphere)
Antenna	
Parabolic reflector –Diameter	6 ft (72 in.) (Ku), 28 in. (Ka)
Gain	45.6 dBi (Ku), 44.3 dBi (Ka)
HPBW	0.89° (Ku), 0.90 (Ka)
Polarization (Ku, Ka)	Dual linear simult. and alternate (H and V)
Maximum side-lobe level (Ku, Ka)	~ -25 dB
Cross-polarization isolation (on axis)	< -30 dB
Ka-Ku beam alignment	Within 0.1 degrees
Scan capability	0-24°/s Az, 0-12°/s El
Scan types	PPI sector, RHI, Surveillance, Vertical pointing
Transmitter / Receiver	
Transmitter Architecture	Solid State Power Amplifier Modules
Peak Power / Duty cycle	200 W (Ku), 40 W (Ka) per H and V channel, Max duty cycle 30%
Receiver Noise figure	4.8 (Ku), 6.3 (Ka)
Receiver dynamic range (Ku, Ka)	~ 90 dB
Clutter Suppression	GMAP
Data Products	
Standard products	- Equivalent reflectivity factor (Z_h) (Ku, Ka) - Doppler velocity (unambiguous: 26 m/s)
Dual-polarization products	- Differential reflectivity (Z_{dr}) (Ku, Ka) - Differential propagation phase (φ_{dp}) (Ku, Ka) - Copolar correlation coefficient (ρ_{hv}) (Ku, Ka) - Linear depolarization ratio (LDR_h, LDR_v) (Ku, Ka) *(in alternate mode of operation)*
Data format	NETCDF

Snow Physics with Multi-Frequency Polarimetric Radar



DFR (X/Ka, Ka/W)



DFR (Ku/Ka, Ka,W)

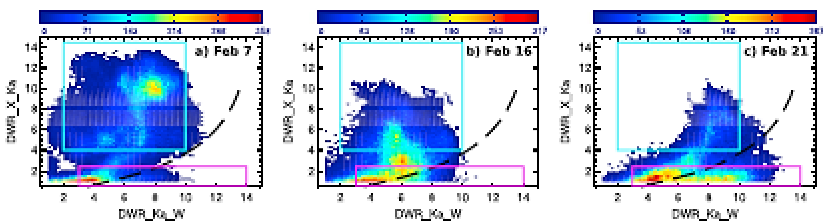
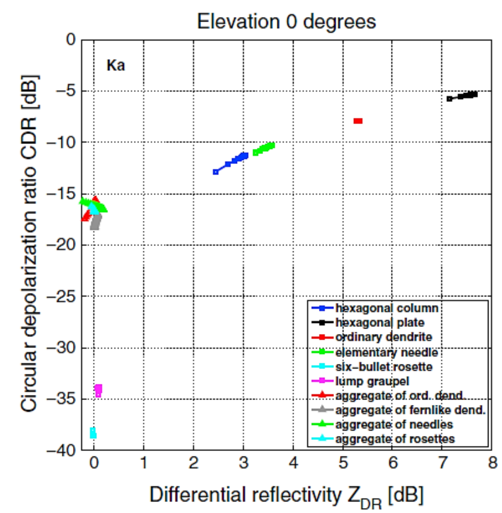


Figure 16. Two-dimensional histograms of triple-frequency signatures from all three cases including all heights below 4 km AGL. The color represents the absolute number of observations per pixel. The colored frames represent approximate areas in the triple-frequency space that were found to be related to the presence of large aggregates (light blue) or rimed particles (purple) in the surface in situ observations.

Pol (CDR, ZDR)



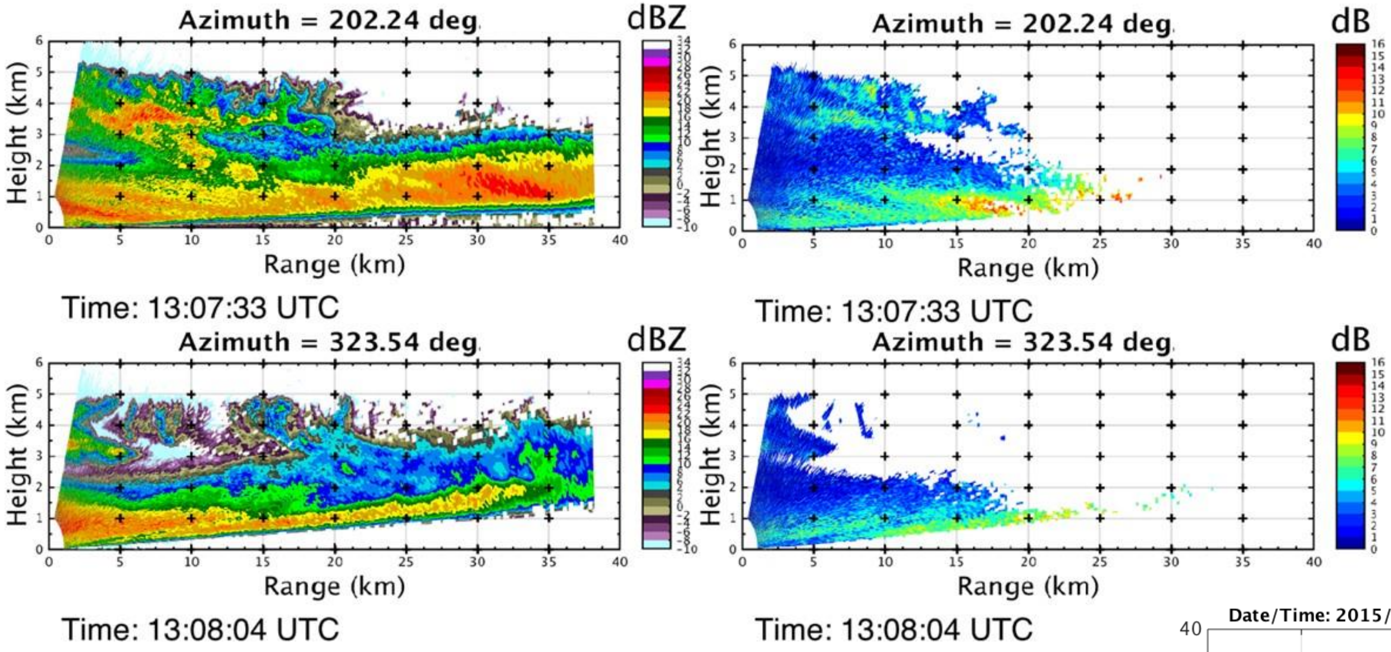
Kniefel et al., 2015 JGR

Tynella and Chandrasekar (2014, JGR)

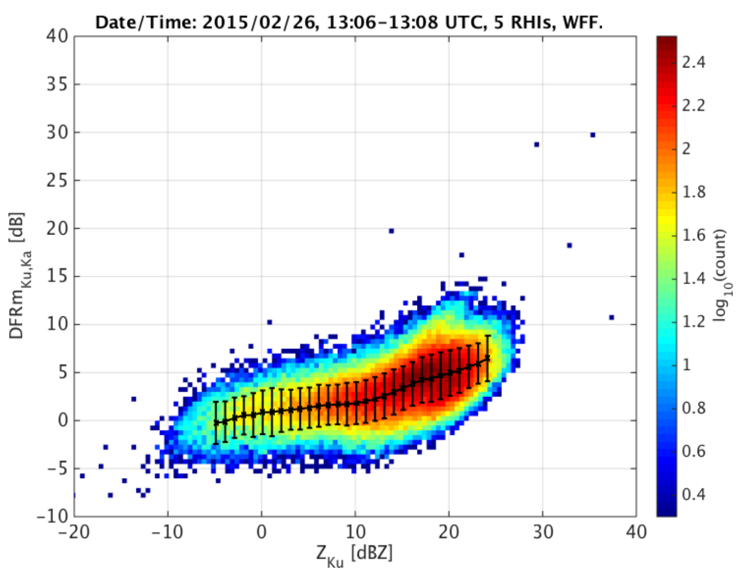
D3R February 26, 2015 Snow in Virginia

13:00 UTC RHIs

Z_e DFR



Growth of large aggregates and some mixed phase



ICE-POP GPM GV Summary

GPM Physical Validation of Retrievals (databases, forward models etc.)

- Direct/physical validation of satellite-based snowfall retrieval algorithms over complex terrain; melting layer interaction with terrain also of interest.
- Physics of snow, retrieval algorithm assumptions and cloud model parameterizations of ice processes
- Model + Observational analyses: Movement toward level IV products leverage intensive and multi-faceted NWP component.
- Support current PMM/GPM collaboration with KMA- leverage significant international observational science/data effort.

GPM GV Deployment

- **D3R Radar IOP 2018**
- **Supporting snow measurement instruments including PIP, MRR2, Parsivel, Pluvio (partial winter 2016, remainder IOP 2018)**

EXTRA

Summary D3R Deployment Requirements (Current Configuration)

- Power: 208-240 V, 60 Hz, 50A (D3R does have a propane generator, requires LP gas for setup and backup operations during short power loss (2-4 hours))
- Cell communications for remote instrument monitoring, control, display (or wire/fiber hook-up), just one fixed IP address required
- On board servers/processing/storage (RAID), graphical user interface setup in remote operator location through internet connection to instrument
  - Antennas and transceiver + IF electronics boxes shipped separately from trailer
  - Towing vehicle required for transport and local set up
  - Forklift required to assemble antennas and transceiver + IF electronics boxes
  - Typically ready to operate within 1-2 days

High Level Assembly Procedure