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# A Preliminary Survey of Cold Season Precipitation from Planetary Scale to Mesoscale

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## I. INTRODUCTION

The GPM mission is designed to better quantify precipitation characteristics at middle and high latitudes. During cold season, precipitations are often associated with frontal cyclones that evolve through a life cycle. Using the first year GPM data, we conduct a preliminary survey in order to categorize precipitation characteristics and their relationship with the associated frontal cyclones.

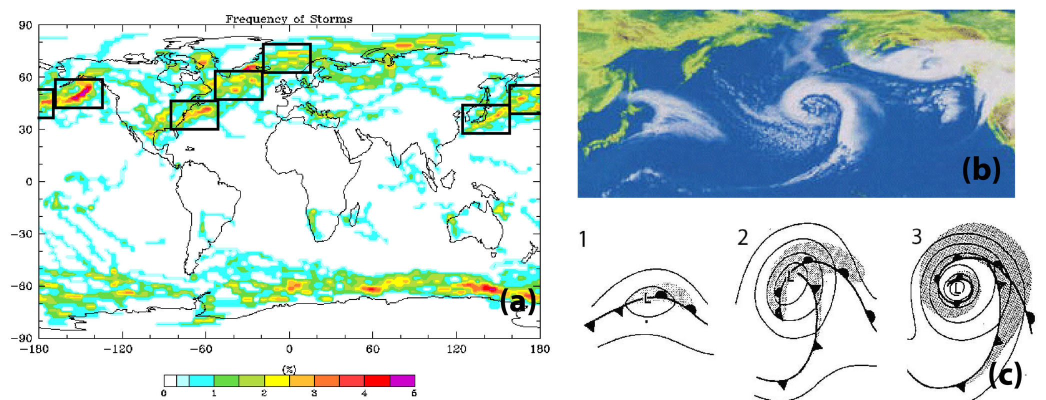


*Fig. 1: (left) Cyclone frequency (Courtesy: Dr. Mark Chandler at GISS); (right top) Cloud water of simulated cyclones in the Northern Pacific basin (Fig. A1 in Orlanski 2005); (right bot.) Schematic of cyclone life cycle (adapted from Shapiro and Keyser 1990)*

## II. NORTHERN PACIFIC

Cyclones often undergo a 5-7 days life cycle. Precipitations are classified to different bands/clusters based on their location in relation to fronts and cyclones.

| Type | Subtype | Definition | References |
|---|---|---|---|
| Cold-frontal band | Wide (WCFR) | A band parallel to and in the vicinity of the cold front | HH1982; Locatelli et al. 1994; Han et al. 2009 |
| | Narrow (NCFR) | A band (~ 10 km wide) with high reflectivities collocated with the surface cold front | HH1982; Braun et al. 1997; Han et al. 2009 |
| Comma-head band | – | A band associated with a curved front to the west of the cyclone center | SK1990; Browning 2005; Han et al. 2007 |
| Post-frontal precp. | – | A group of open- or closed-cellular convective cells, or organized precip. behind the cold front | Monteverdi 1976; Reed 1979; HH1982; Reed and Blier 1986; Braun and Monteverdi 1991; Stevens et al. 2005 |
| Spiral band | – | A nearly circular band collocated with a closed low and associated with weak temperature gradients | HH1982; SK1990 |
| Warm-frontal band | – | A band in the vicinity of the warm front | HH1982; Han et al. 2007 |
| Warm-sector band | – | A band in the warm sector | Nozumi and Arakawa 1968; HH1982 |

*Table 1: Precipitation bands/clusters*

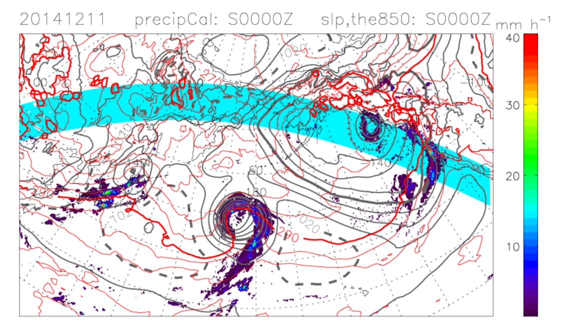


*Fig. 2: IMERG precip. rate (color shade), MERRA sea level pressure (SLP, gray contour), 850 potential temperature (theta850, red contour) and GMI orbit (cyan belt)*

### *Four examples of precipitation bands/clusters in the Northern Pacific*

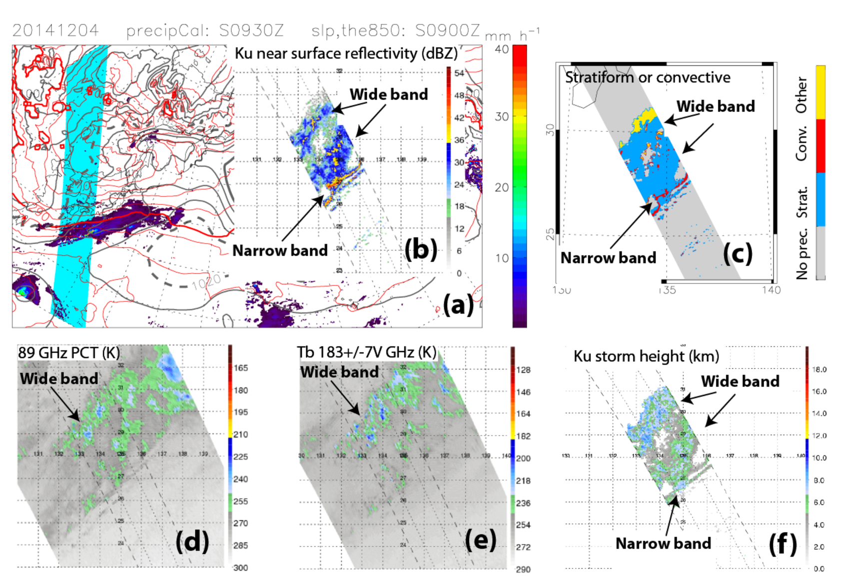


*Fig. 3 (left) : Cold-frontal band*

- Cyclone 1 at its incipient frontal wave stage on Dec 4, 2014.
- Convective nature – narrow band (NCFR)
- Abundant ice and higher storm height – wide band

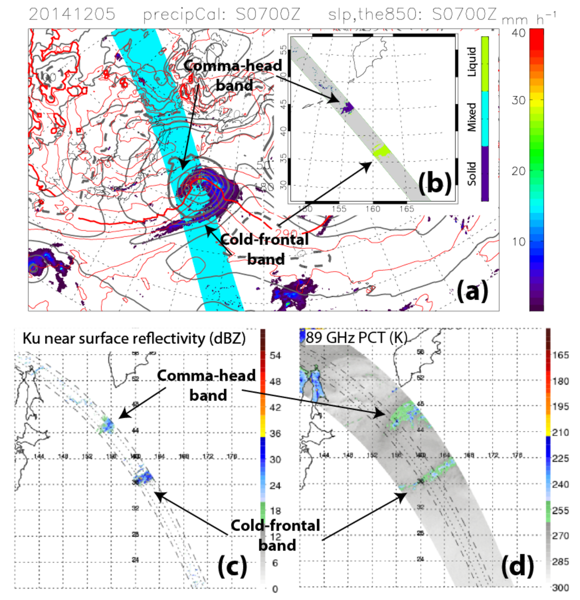
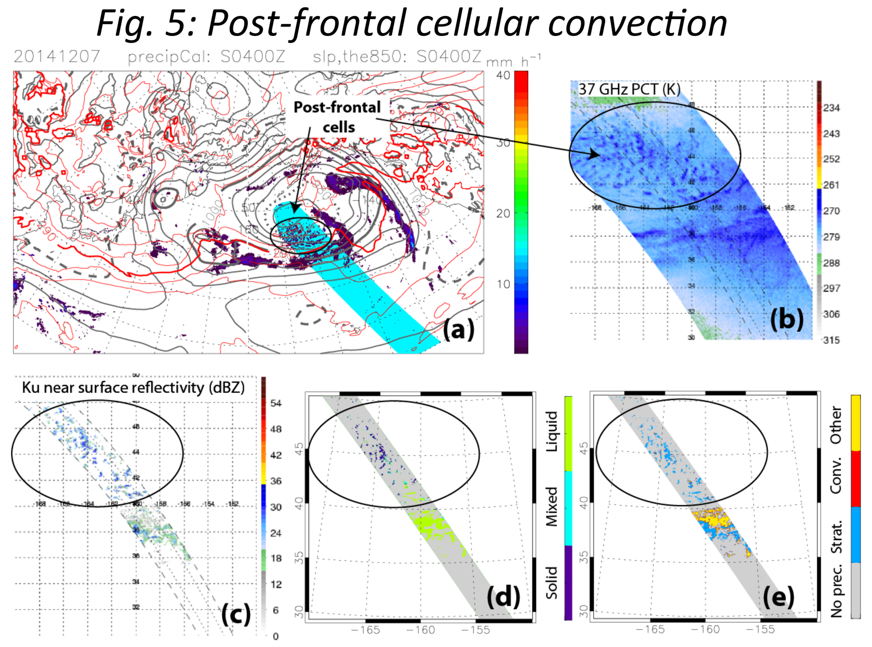


*Fig. 4: Comma-head band*

- Cyclone 1 at its "t-bone front" stage on Dec 5
- Wrapped-around snow vs. cold frontal rain

*Fig. 5: Post-frontal cellular convection*



- (Fig. 5) Cyclone 1 at a time after "t-bone front" stage on Dec 7
- (Fig. 5) Post-frontal snow shower – shallow convection is categorized as stratiform by DPR

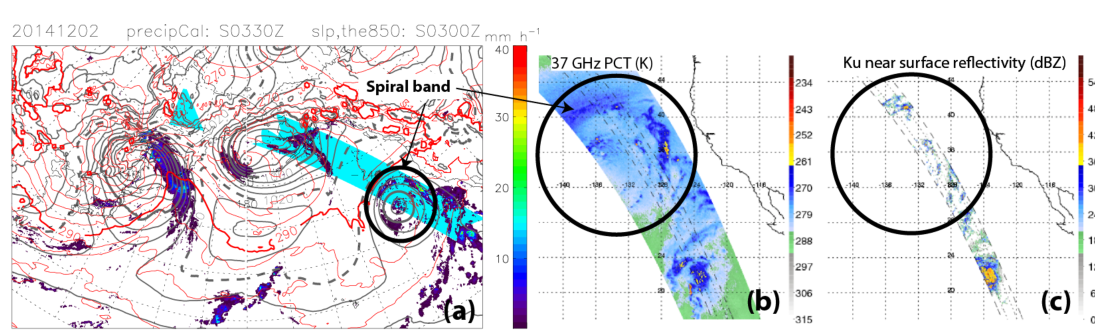


*Fig. 6 (left): Spiral band*

- Cyclone 2 at its "warm-core frontal seclusion" stage on Dec 2
- Precipitation at the culmination of a frontal cyclone evolution (Shapiro and Keyser 1990)

## III. CONTIGUOUS UNITED STATES (CONUS)

It is a challenge for the GPM Microwave Imager (GMI) and the Dual-frequency Radar (DPR) to detect falling snow. In order to better understand the question, we select a snowstorm case after GPM's launch and a GPM Cold-season Precipitation Experiment (GCPEx) case to examine the dynamical, physical, and radiative properties of the snowstorm.

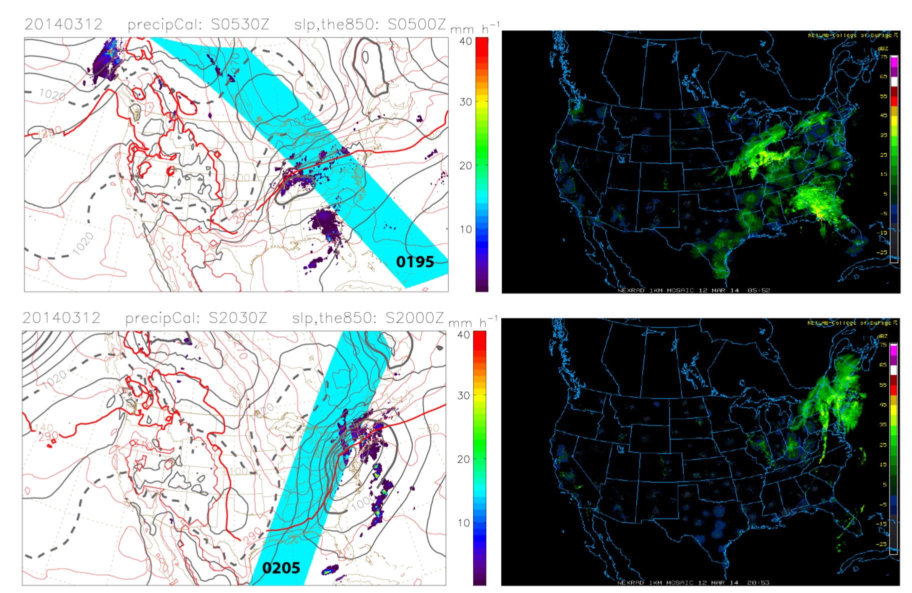


*Fig. 7 (left): A snowstorm in the Midwest and Northeast U.S. on Mar 12, 2014*

- MERRA data show GPM orbits passing through a cyclone warm-frontal and comma-head sectors
- Limited detection of snow in IMERG vs. NEXRAD
- GMI and KuPR orbital views (Figs. 8 and 9, below) show limited detectability

*Fig. 8: Orbit 0195*

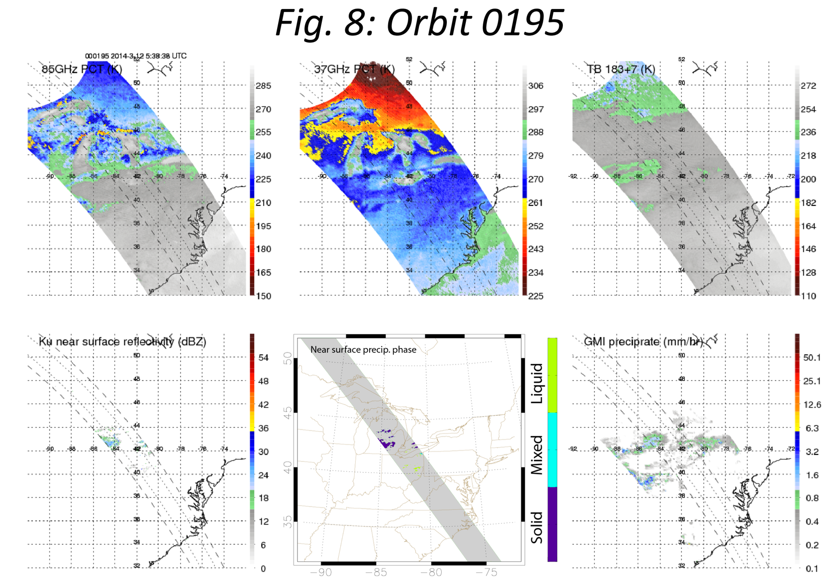
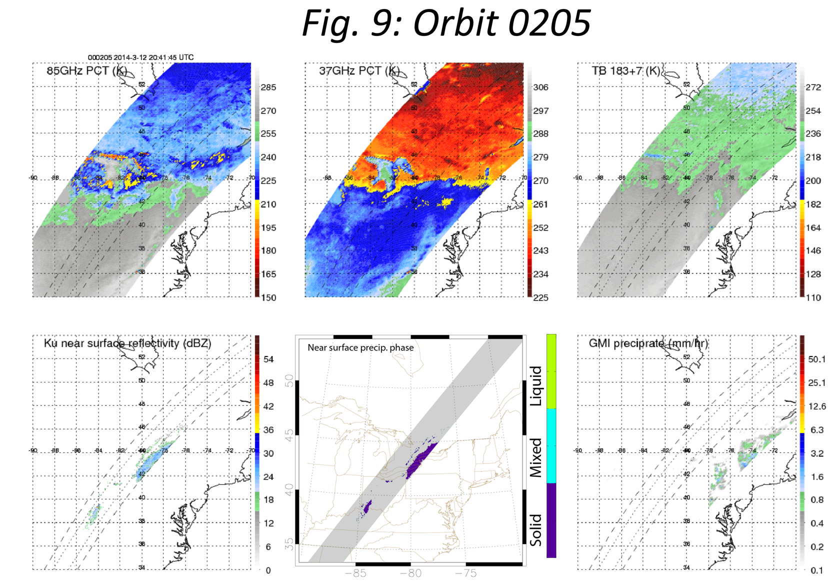


*Fig. 9: Orbit 0205*



### *Observations and Simulations of the Feb 24 GCPEx case*

The GCPEx case over the Great Lakes region on Feb 24 2012 is examined with CloudSat and MRMS observations. Simulate radar reflectivity *(attenuation-corrected)* and Doppler velocities (with WRF and G-SDSU) at four frequencies, W-band (94 GHz), Ka (35 GHz), Ku (13 GHz), and S-band (3 GHz) are compared. (The minimum detectable echo are -28, 13, 17, and 0 dBZ for the 4 frequencies, respectively.)

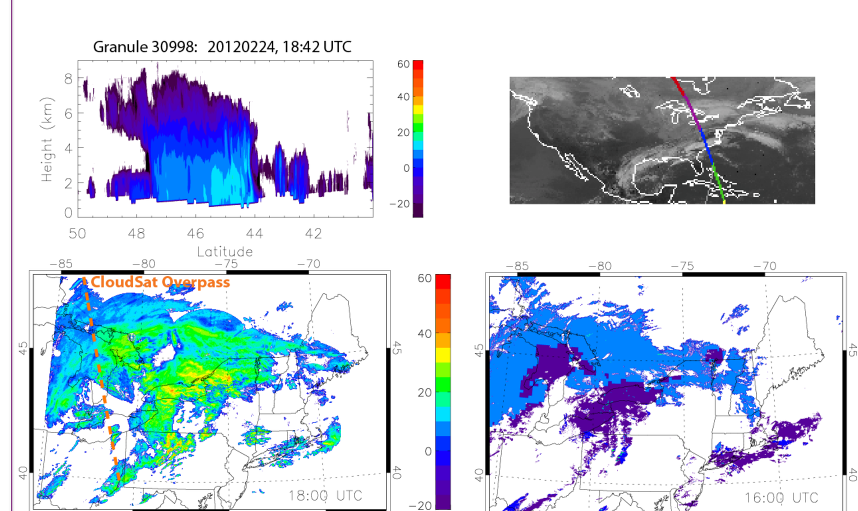
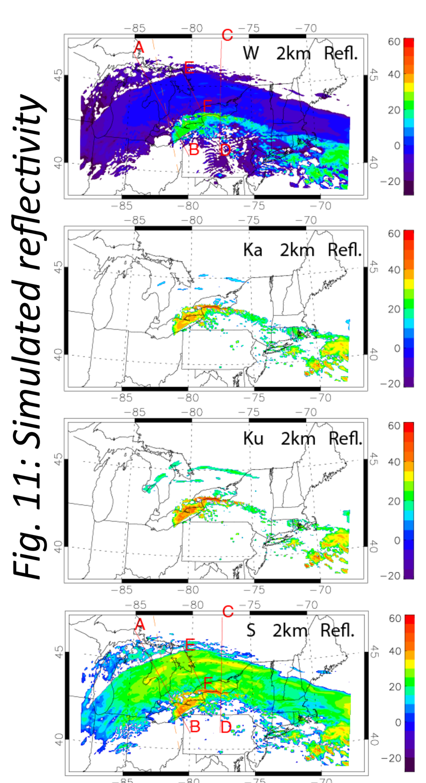


*Fig. 10: A cloudSat overpass (top left: W-band reflectivity) and MRMS 3-D mosaic (bottom left: S-band radar reflectivity at 2 km ASL; right: surface precip. Phase)*

- CloudSat W-band: Reflectivity in the sampled snow region is up to 15 dBZ
- MRMS: Reflectivity with snow may be up to 35 dBZ

*Fig. 11: Simulated reflectivity*



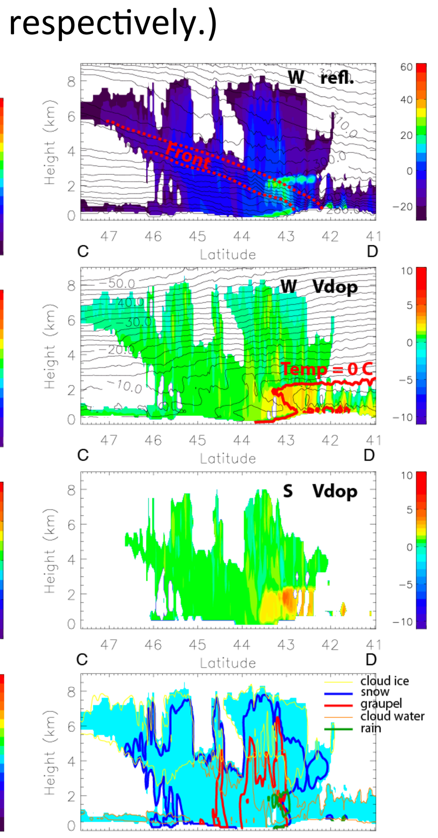


*Fig. 12: Cross-sectional view of (top) simulated reflectivity, (middle two) Doppler velocity, and (bot.) hydrometeors.*

- Ku and Ka band only captured small patches of snow due to the minimum detectable reflectivity threshold
- Simulated W-band reflectivities were about 10 dBZ less than the CloudSat observations
- A deep layer of mixed phase particles near the interface of cold and warm air

## IV. NORTHERN ATLANTIC

The GPM Core Observatory could provide observations with high temporal resolution near the north edge of its orbit (68° N). Here we show an example of a precipitation system that was sampled by 12 orbits in two days. It was associated with a cyclone that originated over the Labrador Sea and traveled across Greenland to the north of the UK.

*Fig. 13: IMERG and MERRA SLP and theta850*

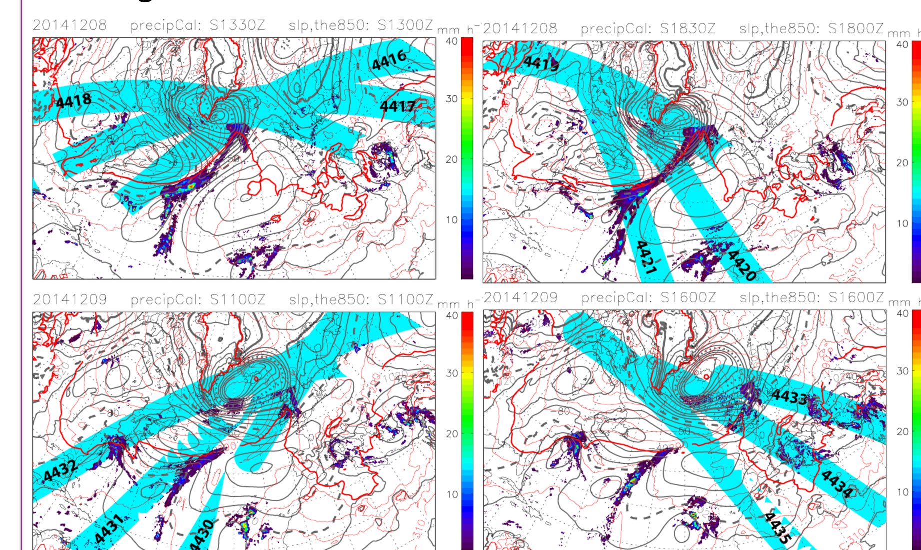
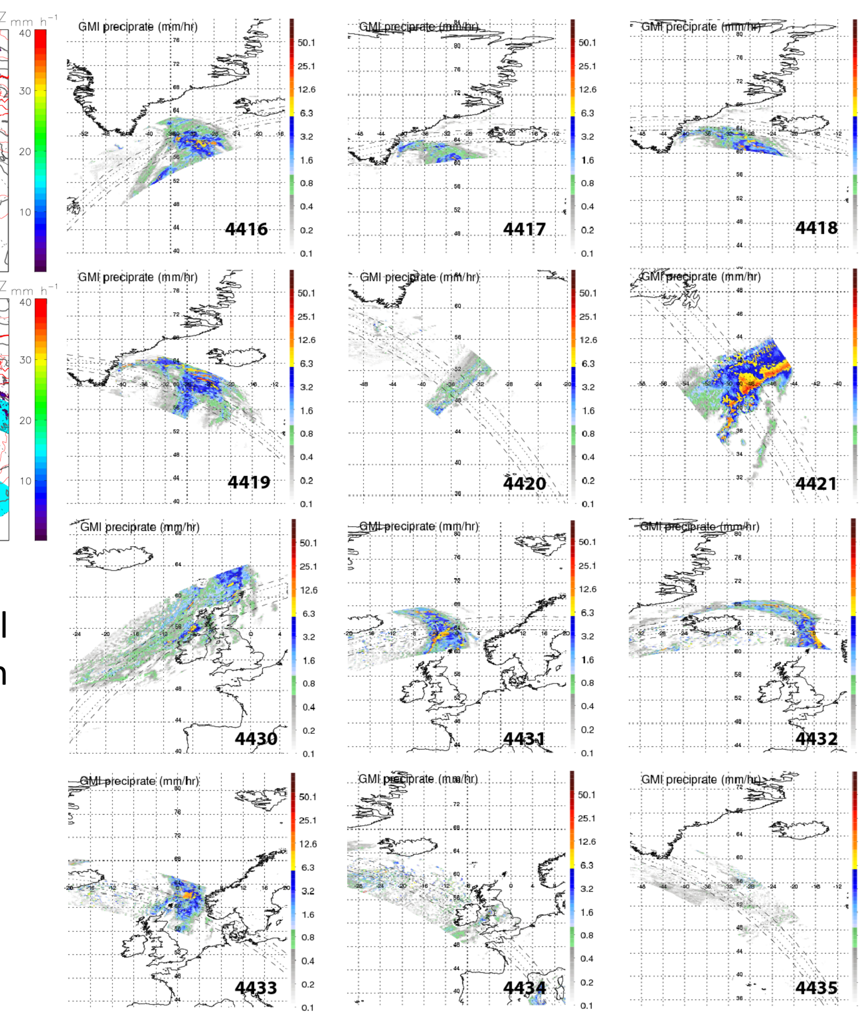
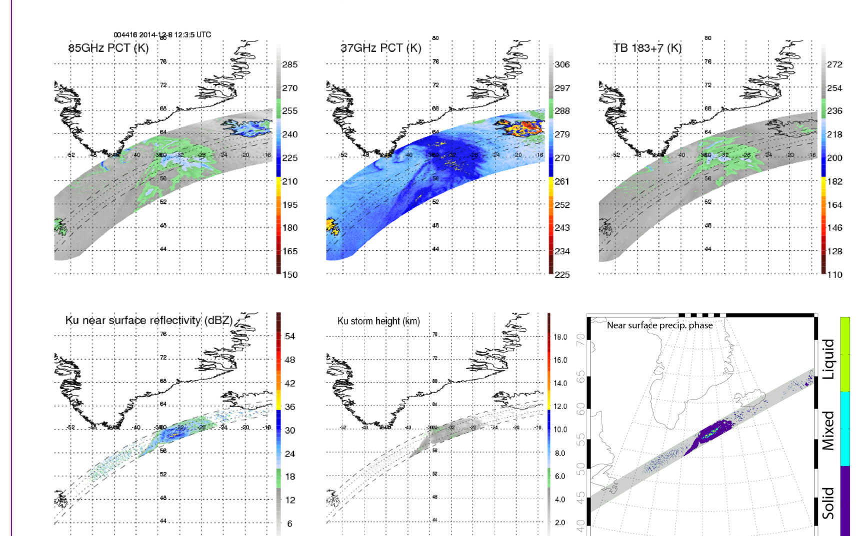


*Fig. 14: GMI precipitation rate from 12 orbits*



- IMERG covers up to 60° N
- Precipitation characters are revealed by orbital data in Figs. 14-17, some of that is not included in IMERG

*Fig. 15: Orbit 4416*



- Frontal bands/clusters show similar structures to those in the Northern Pacific. Identified types Include cold-frontal band, comma-head band, and post-frontal cells.

*Fig. 16: Orbit 4421*

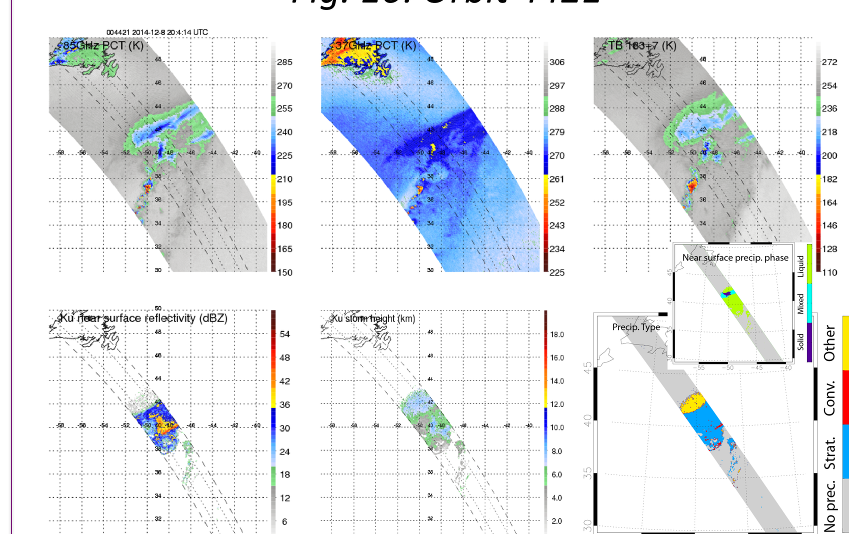
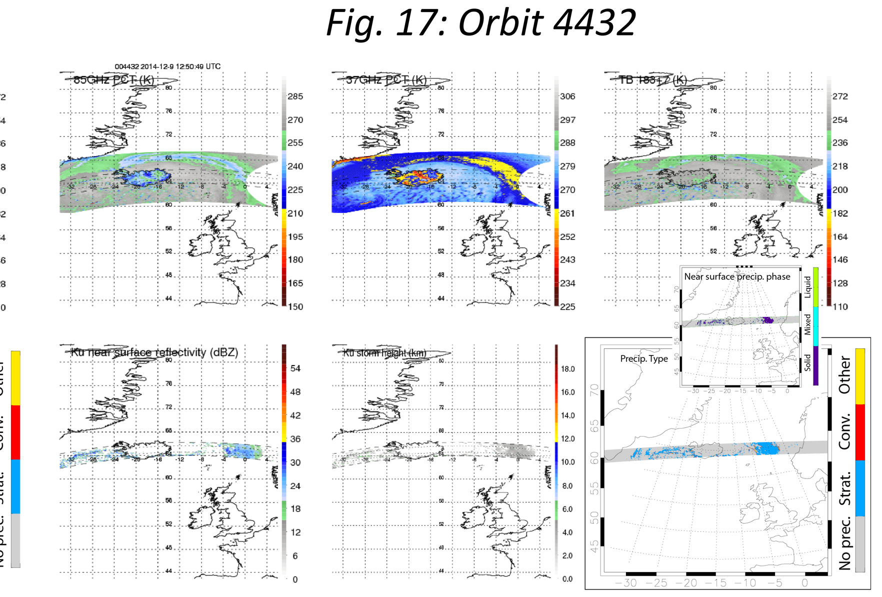


*Fig. 17: Orbit 4432*



## V. SUMMARY

Using data obtained during the first year of the GMP mission, a preliminary survey of the precipitation in the cold season was conducted. With MERRA and IMERG data, precipitation systems were identified with their associated cyclones and fronts along the northern oceanic storm tracks and over the CONUS.

It is demonstrated that precipitation sampled by the GPM core satellite over the open oceans can be classified to different categories of bands/clusters in a way similar to their coastal and land counter parts documented in early literatures. This survey is toward a comprehensive study of precipitation characteristics and hydrometeor properties associated with different types of precipitation bands/clusters.

Two similar snowstorm cases over land show limited capabilities of the GPM observations and current algorithms on detecting snowfall near the Great Lakes region.