Use of coincident GPM/CloudSat dataset for GMI snowfall observation assessment

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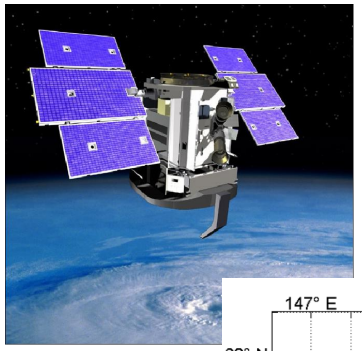
Why CPR?
GPM-DPR vs. CloudSat CPR

(Casella et al., Atmos. Res., 2017, under review)

GPM-CO

CloudSat

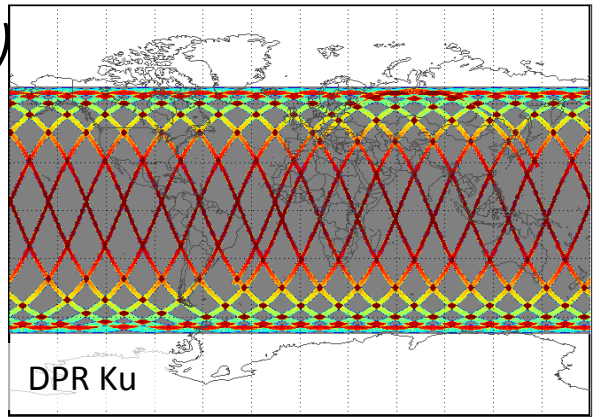


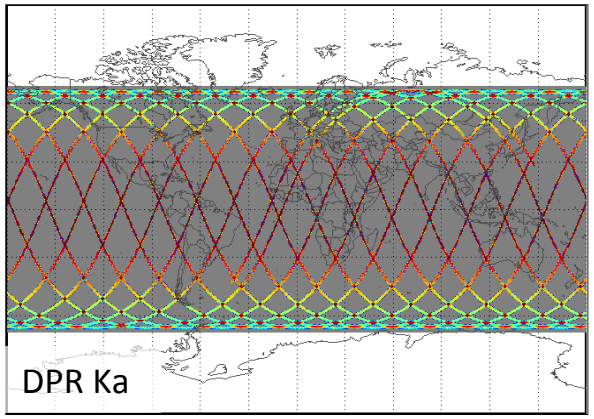
We collected 74750 coincident DPR-CPR snowfall observations from 2B-CSATGPM (**Joe Turk**) product for the period March 2014 to May 2015

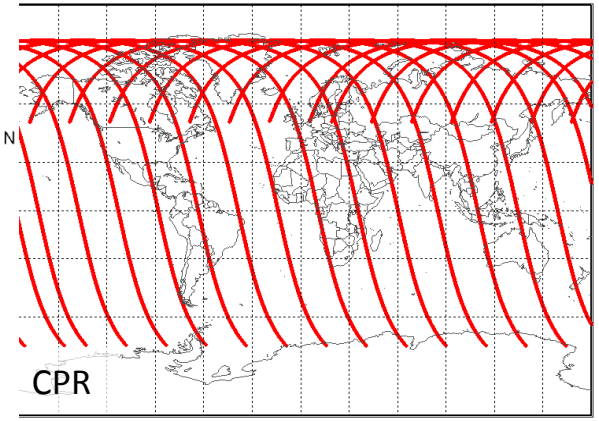
Selected coincidences within:

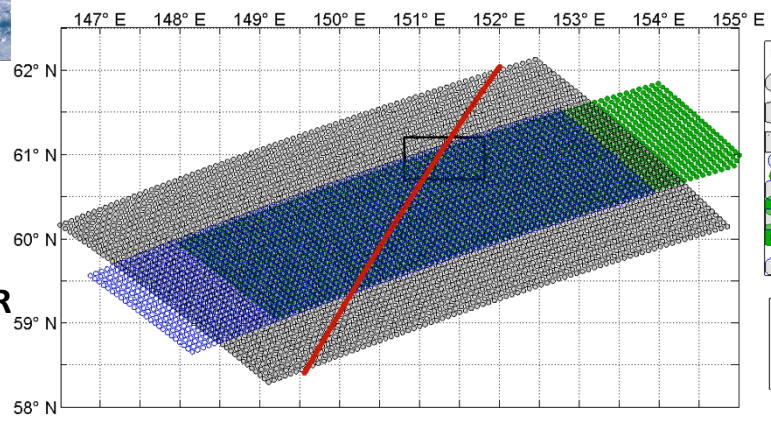
5 minutes and 2.5 km.

The dataset was enriched with various CludSat-GPM products

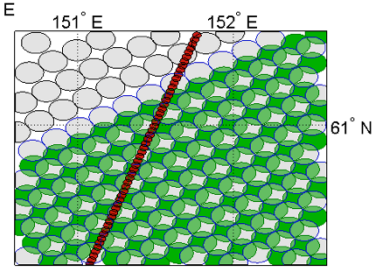








CloudSat-DPR coincidence segment



DPR-CPR footprint mismatch

Assessment of snowfall rates in DPR L2 (V04) products

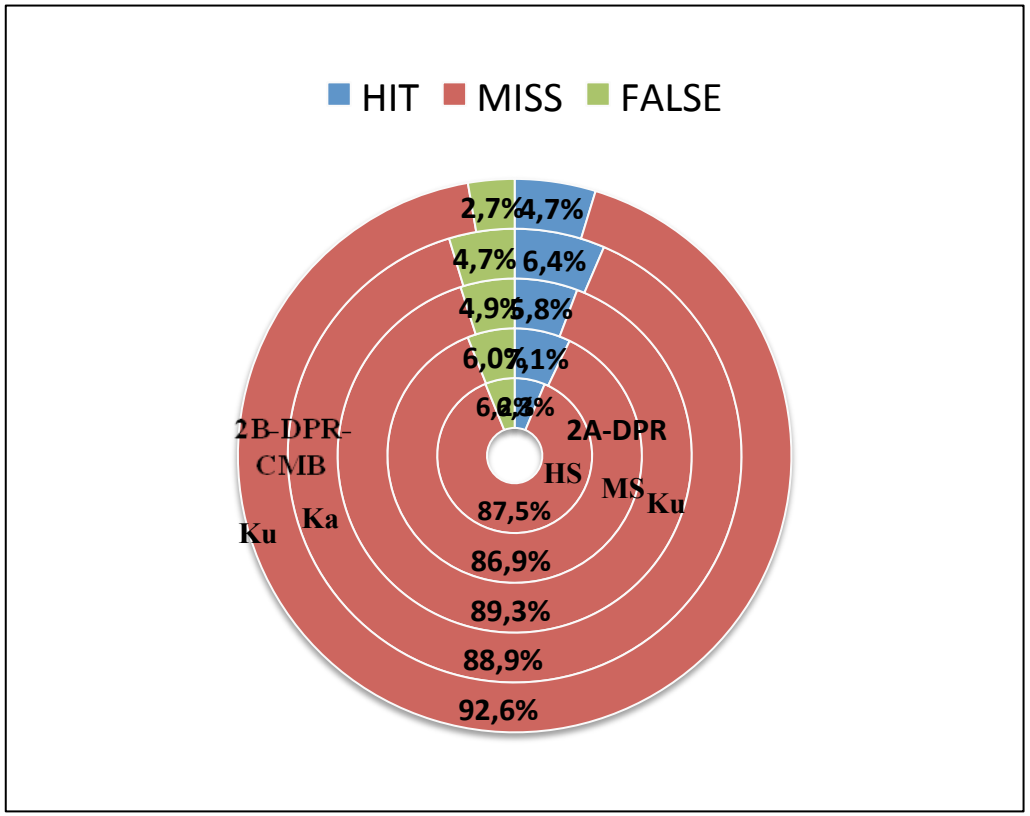
In bold, solid and mixed precipitation (melted fraction <=0.1); in italics solid-only precipitation (melting fraction =0 or full temperature profile < 0 °C)

(*Continuous statistics computed for HITS only*)

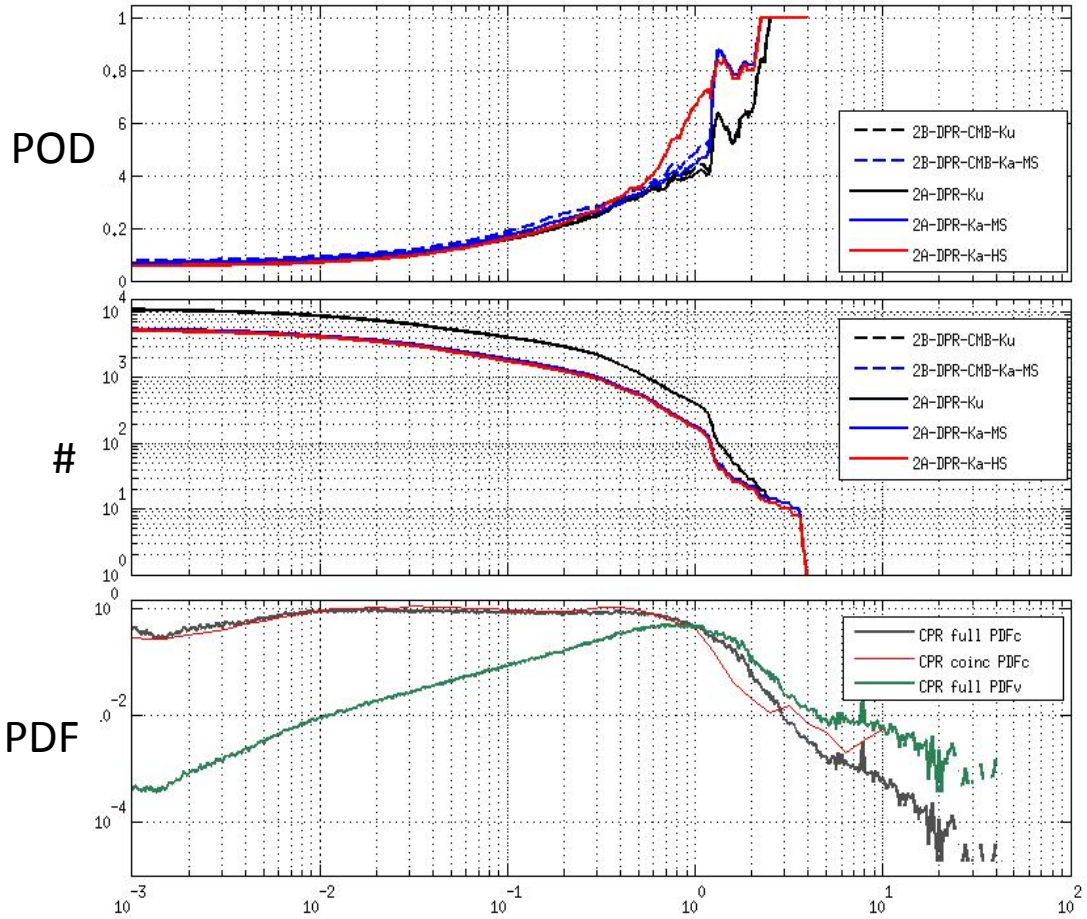
	2B-DPR CMB Ku	2B-DPR CMB Ka MS	2A-DPR Ku	2A-DPR Ka MS	2A-DPR Ka HS
*ME** *[mm h^{-1}]*	**-0.320** *-0.375*	**-0.261** *-0.315*	**-0.099** *-0.120*	**-0.075** *-0.075*	**-0.519** *-0.615*
*RMSE** *[mm h^{-1}]*	**0.611** *0.701*	**0.650** *0.775*	**0.633** *0.712*	**0.682** *0.786*	**0.819** *0.947*
*ARMSE** *[mm h^{-1}]*	**0.520** *0.593*	**0.595** *0.708*	**0.625** *0.702*	**0.678** *0.782*	**0.634** *0.720*

Cloudsat snowfall rate at the surface from 2C-SNOW-PROFILE product is used at reference.

False Alarms *mostly due to inconsistencies in the precipitation phase between DPR and CPR products (Free Clutter Bean Height and in the Freezing Level Height)*



DPR Products Snowfall Detection Capabilities



POD of the 2B-DPR-CMB and 2A-DPR for a varying minimum threshold of CPR snowfall rate.

Number of pixels for each GPM product considered

PDF by occurrence (PDFc) and by volume (PDFv) from 2 years (2014-2015) of global CPR snowfall observations (in red the PDFc in the CPR-DPR coincidence dataset).

Estimate of snowfall mass detected by DPR vs. CPR

2B-DPR-CMB Ku	2B-DPR-CMB Ka MS	2A-DPR Ku	2A-DPR Ka MS	2A-DPR Ka HS
29.94%	34.35%	29.14%	32.76%	32.41%

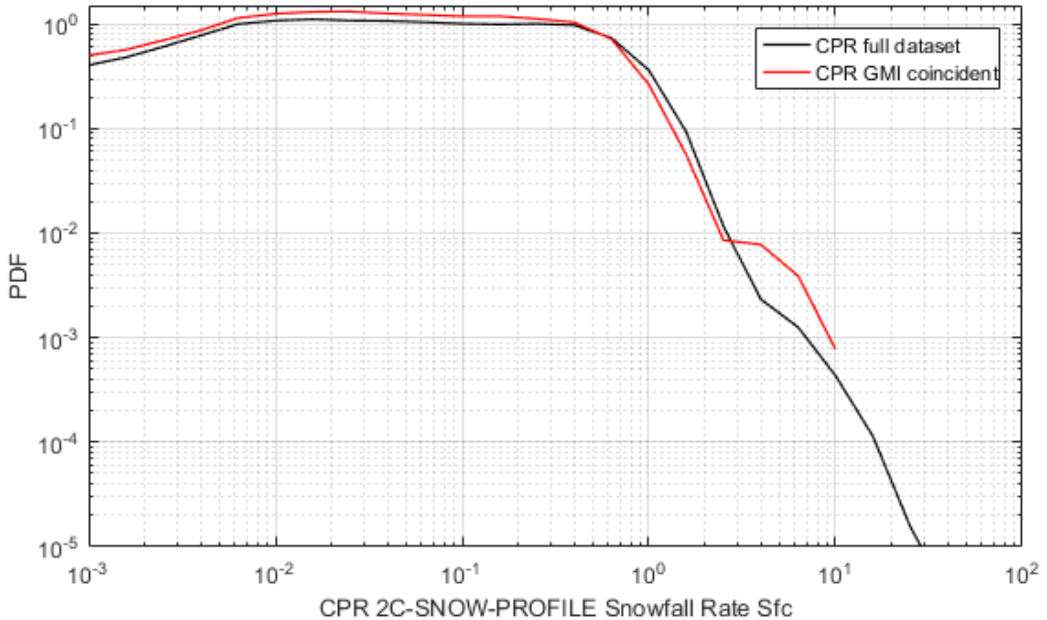
Inspite of POD = 6-7%

Analysis GMI snowfall detection capabilities

	GMI–DPR–CPR ***(snowfall-only)***
Period	08/03/14 21/05/16
Averaged pixels	465.300
Snowfall Pixels	44.131
Products used	2B-CSATGPM 2B-CMB 2A-DPR 1C-GMI 2B-GEOPROF 2C-SNOW-profile, 2C-PRECIP-COLUMN 2B-CLOUD-CLASS ECMWF-AUX
Ancillary variables (ECMWF)	T2m Surf Pres Specif.Hum. T500m TPW

GMI-DPR-CPR coincidences within 5 minute time interval;
Dataset generated at two spatial resolutions: IFOV 10 GHz and 89 GHz

Other variables related to the co-location/ averaging procedure are provided: minimum distance, mean distance, number of CPR pixels within GMI pixel.



All-sky surface classification scheme for GMI

- Spatial resoution 32 km (10 GHz);
- Input: T_{2m} and TB at 10 GHz, 23.8 GHz, 18.7 GHz, 36.5 GHz;

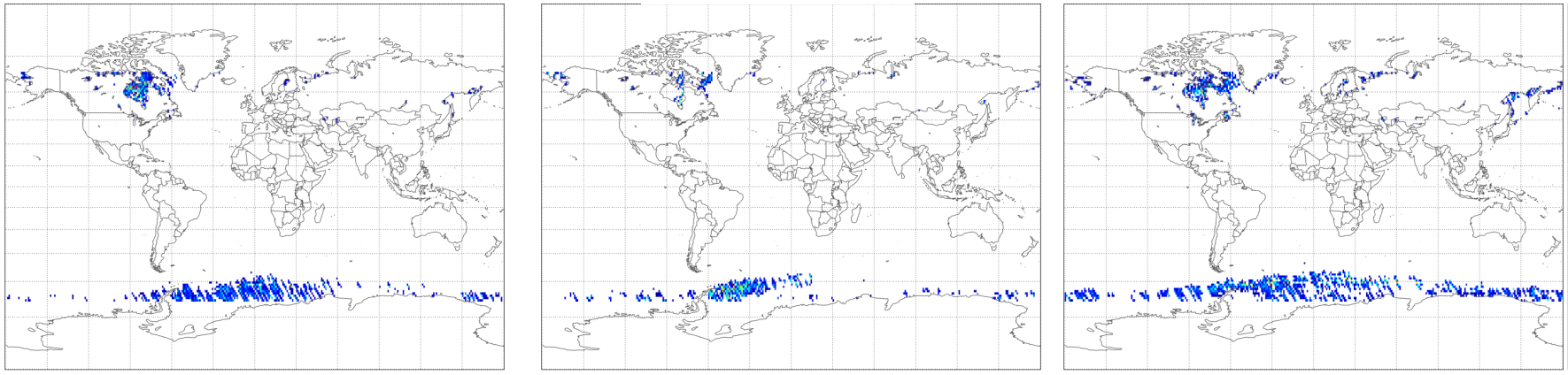
1. Land/Sea map: Strict criteria for Land (% land = 1) Ocean (% land = 0) (the rest is “Coast”);
2. Identifies Snow over land and Ice over Ocean
   - Snow cover: discriminant function based on TB 10 GHz T_{2m}, vs. Snow depth from ECMWF Era-I analysis;
     POD 93% FAR 1%
   - Ice over ocean: (discriminant function based on TB10 GHz, T_{2m}, vs. Surface_Type in CPR 2C-PRECIP-COLUMN);
     POD 85% FAR 3%;
3. Unsupervised classification algorithm identifies three categories of Ice over Ocean (based on Hewison and English 1999, and pseudo emissivities); and three categories of snow cover;

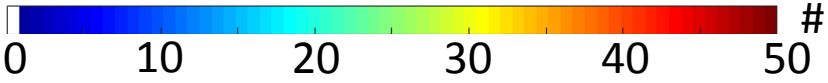
GMI/CPR dataset: frozen surface classification

New Sea Ice

Multilayer Ice

Broken Ice

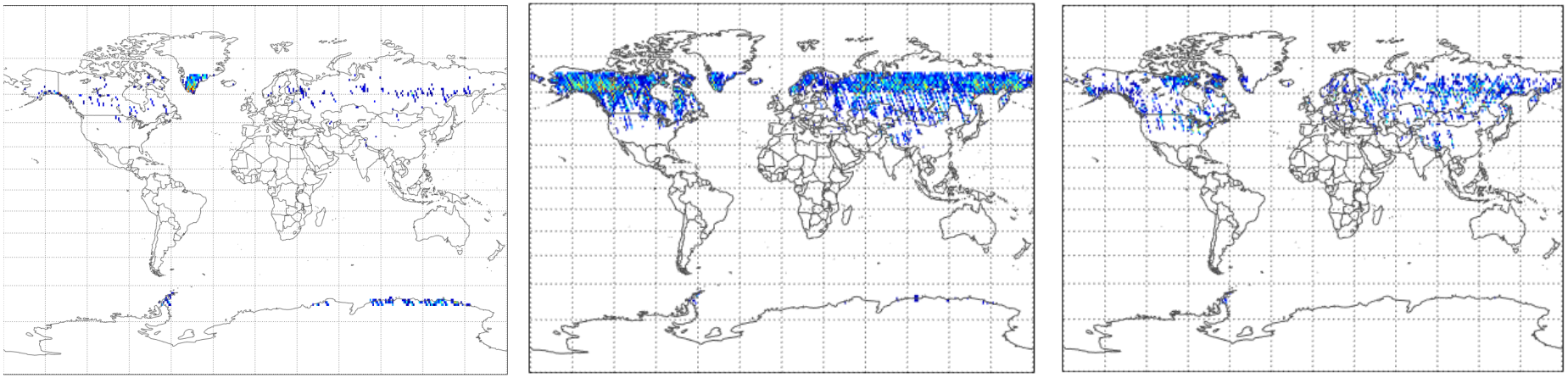


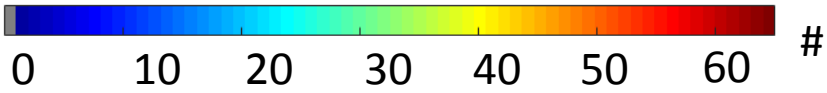


Snow A1

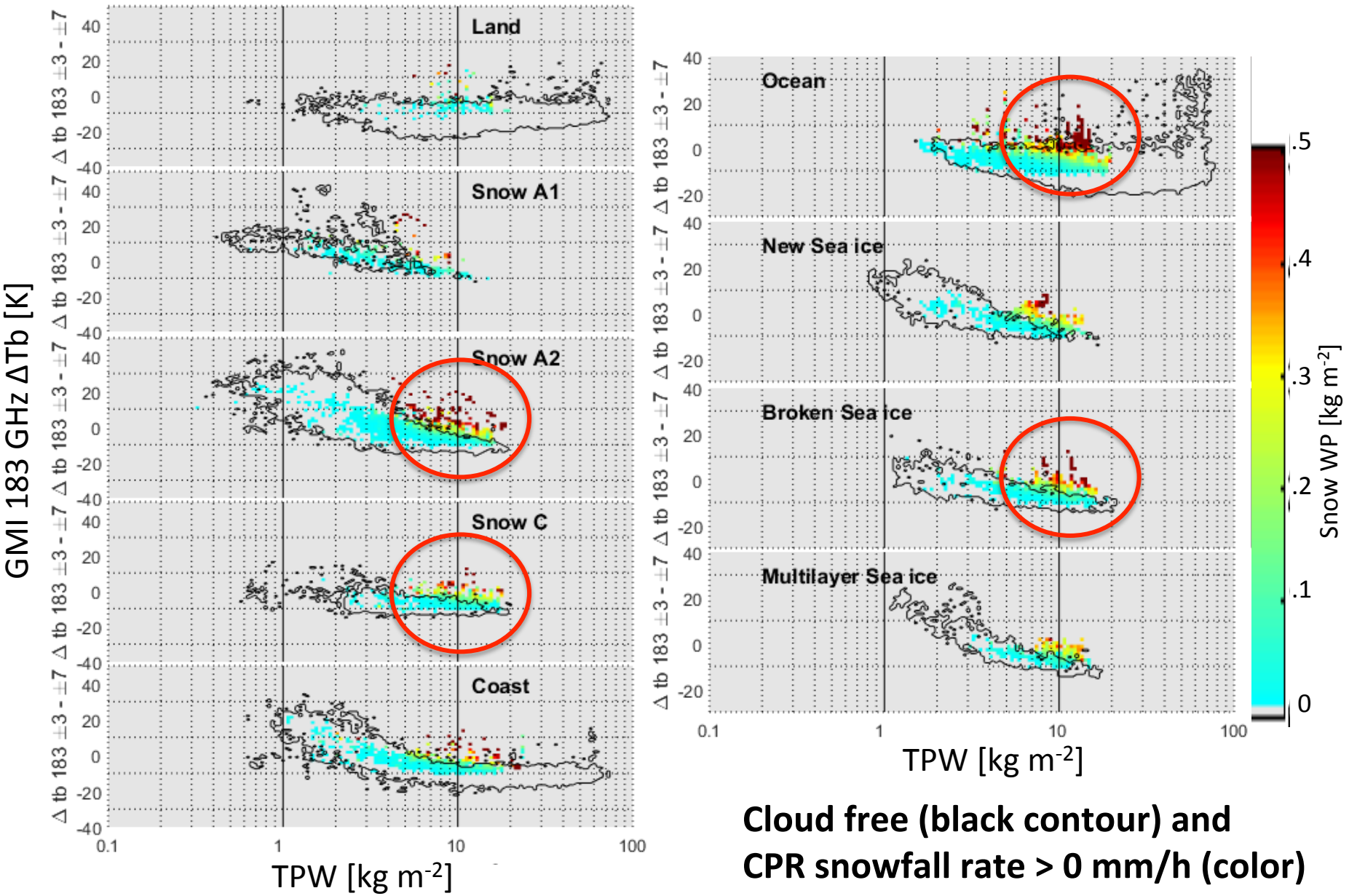
Snow A2

Snow C



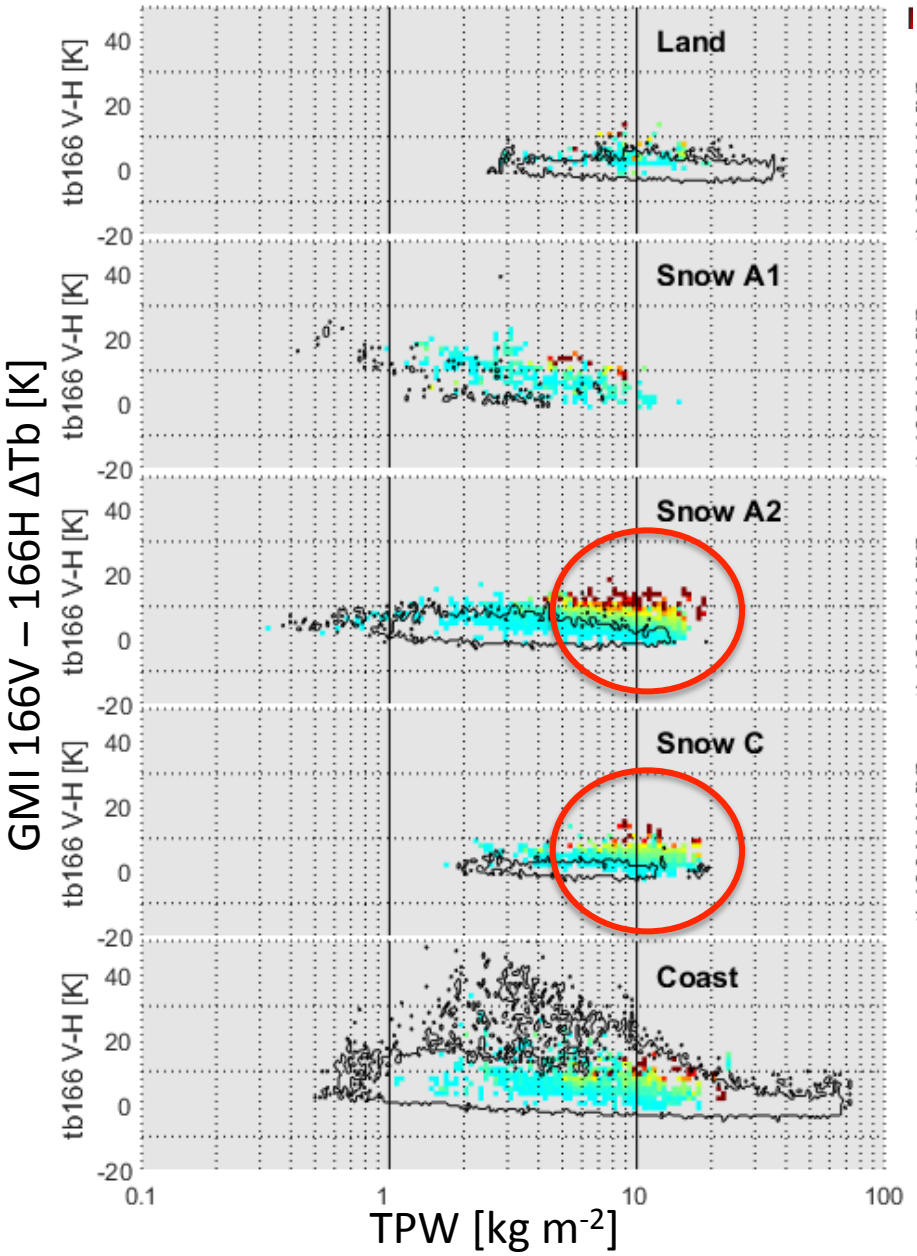


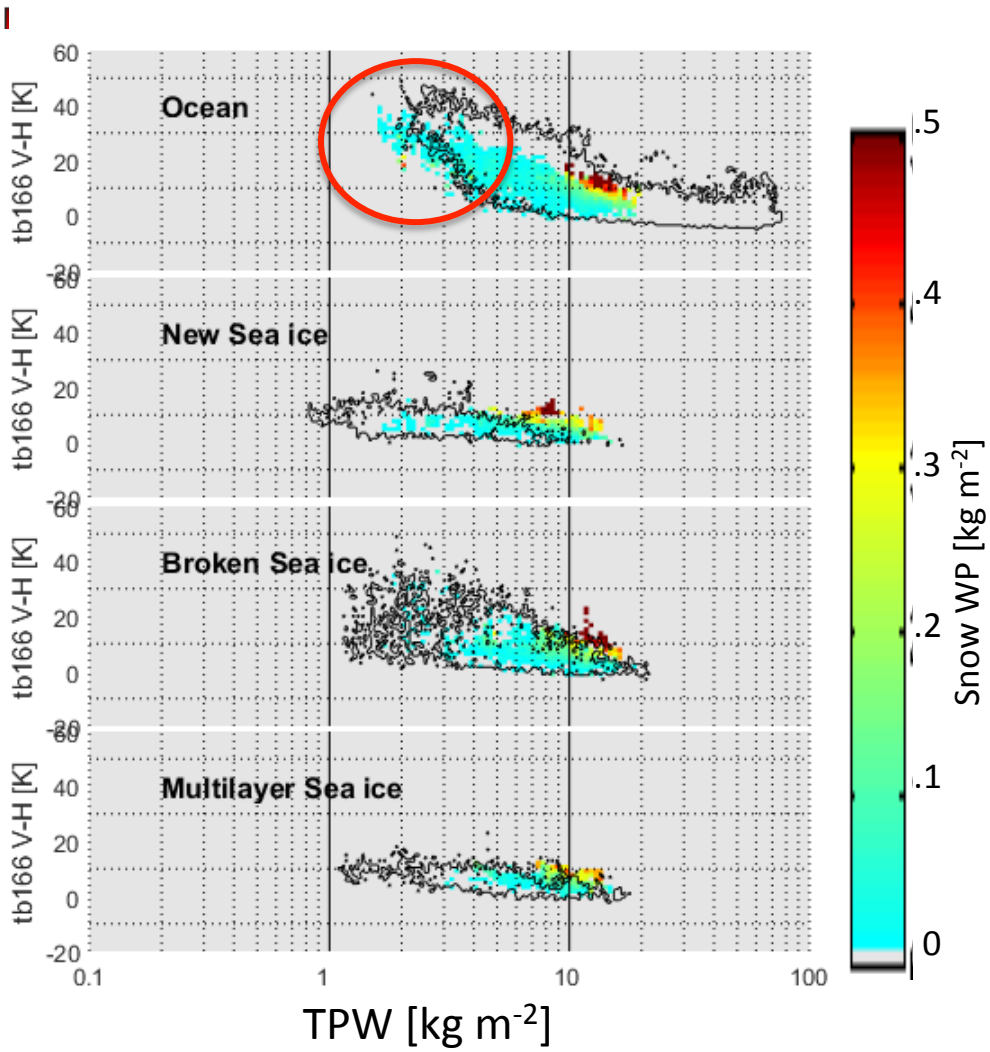
Analysis of snowfall signal for different surface types: GMI 183 GHz ΔTb



Cloud free (black contour) and CPR snowfall rate > 0 mm/h (color)

Analysis of snowfall signal for different surface types: GMI 166 GHz V-H





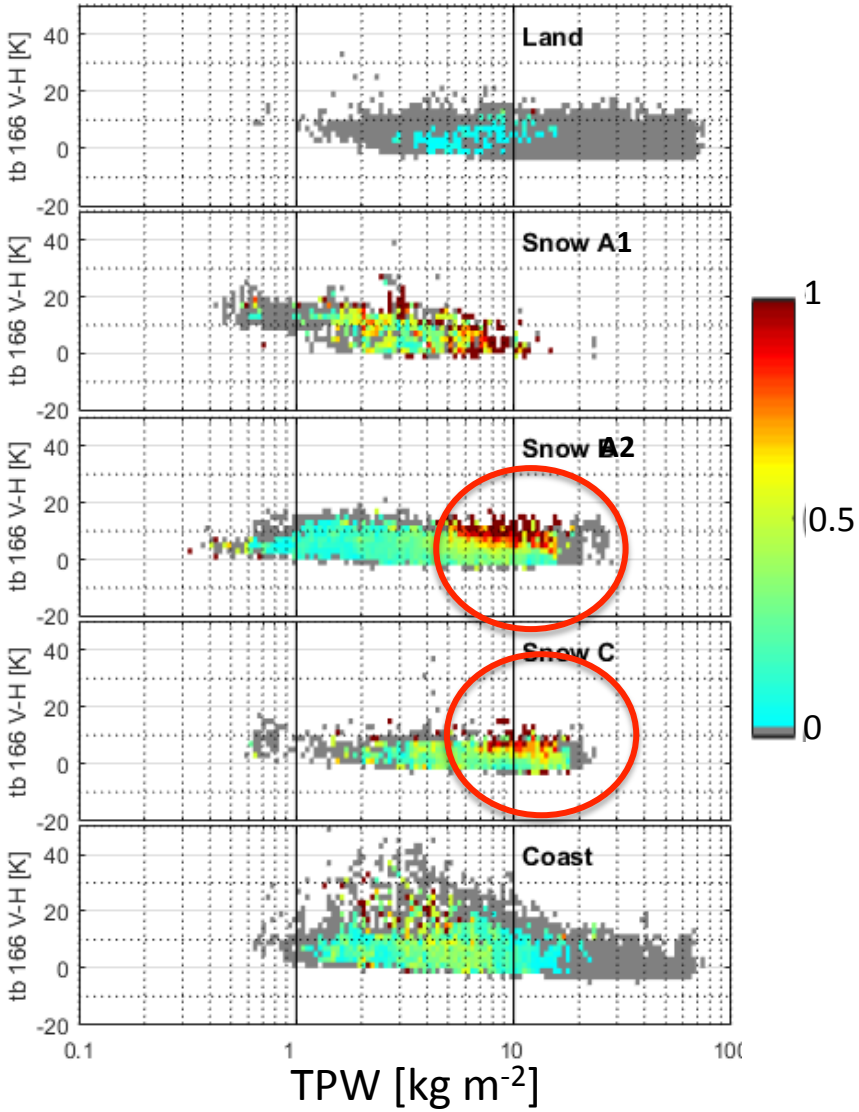
Cloud free (black contour) and CPR snowfall rate > 0 mm/h (color)

GMI snowfall probability based on GMI/CPR coincidence dataset

Snowfall probability (color scale) is calculated as: Ns/(Ns+N0) for a given combination (bins) of ΔTB and TPW

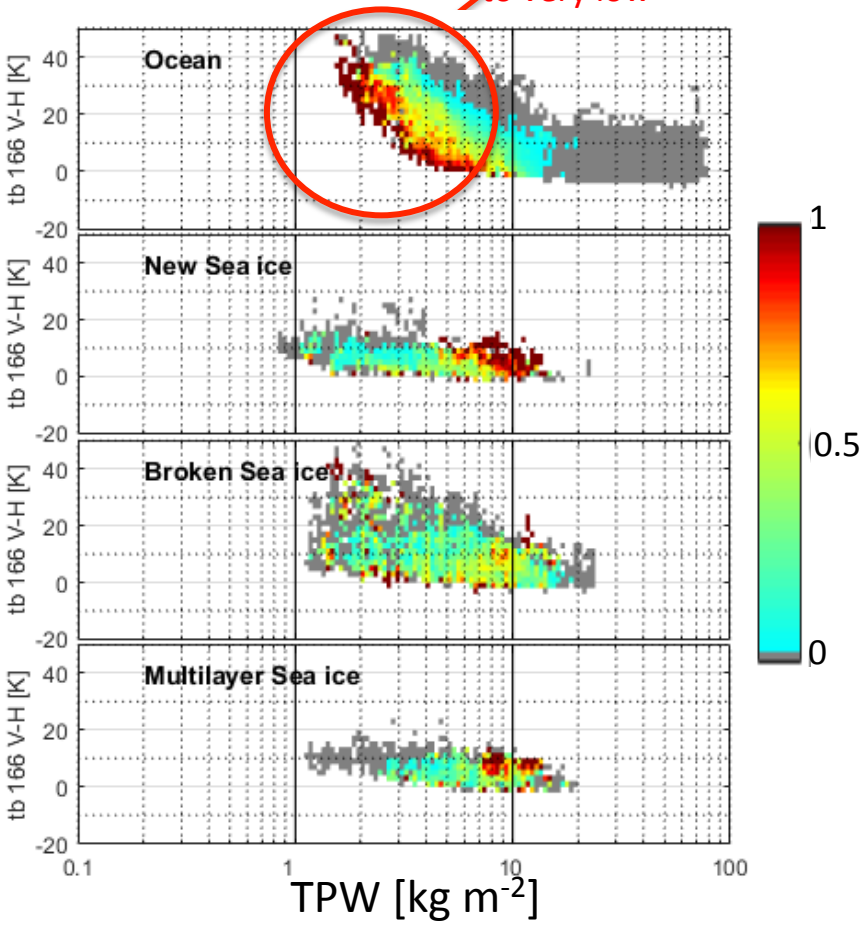
Ns is the number of CPR observations with snowfall
N0 is the number of CPR observations without snowfall

LAND



OCEAN

Corresponsing to very low



GMI snowfall detection algorithm based on GMI/ CPR coincidence dataset

Prototype algorithm based on lookup tables

1. First step determines the probability of snowfall from a 3-dimensional look-up table based on environmental variables (Sims and Liu, 2015]:
   - TPW (50 bins, linear scale)
   - T2m (50 bins, log scale)
   - Lapse rate 2-500 m (20 bins, linear scale)

2. A second step determines the probability of snowfall based on a 4-dimensional look-up table (only if the environmental probability of snowfall is higher than 10%):
   - Surface type
   - TPW
   - Tb 166 GHz V-H
   - Tb 183±3 -183±8 GHz

Note that:

- The computation of the environmental lookup tables is based on the full CPR database (2006-2011) (day and night);
- The computation of the look-up table in the second step is based on the GMI/CPR coincident observation dataset.

Snowfall probability is calculated as: Ns/(Ns+N0) (Ns occurrences of CPR 2C-SNOW surface snowfall, N0 occurrences without CPR 2C-SNOW surface snowfall)

GMI/CPR test dataset

- GMI-CPR coincidences between 06/06/2016-29/10/2016 ~5 months- 2C-SNOW product not available yet.
- As ground truth:
  - CPR PRECIP Precipitation Flag Snow or Mixed (Possible or Certain)
  - if mixed precipitation is found only melted fraction <=0.1 is considered.
  - A test (using the development dataset) confirms that this conditions are almost equivalent to surface snowfall rate >0 mm/h (POD=0.9985, FAR=0.08, HSS=0.953);
- GPM product are considered as snowfall at the surface if:
  - DPR CMB (Ku NS) surface precipitation >0 precipitation liquid fraction <0.1
  - GPROF v4 surface precipitation >0, precipitation liquid fraction <0.1
  - GPROF v5 surface precipitation >0, precipitation liquid fraction <0.1

	Ocean'	'New Sea ice '	'Broken Sea ice'	'Multilayer Sea ice'	'Land'	'Snow A'	'Snow B'	'Snow C'	'Coast'
total number of GMI pixels	23664	336	1123	180	13488	62	353	291	2195
GMI pixels with snow (looking at precip flag)	1919	120	454	58	73	32	85	111	72

Statistical Scores

The new GMI snowfall detection algorithm performs well over Ocean Coast
Acceptable over new sea ice and Snow B

Detection of snowfall over Land seems very difficult for all algorithm.
The new GMI algorithm has many False alarms

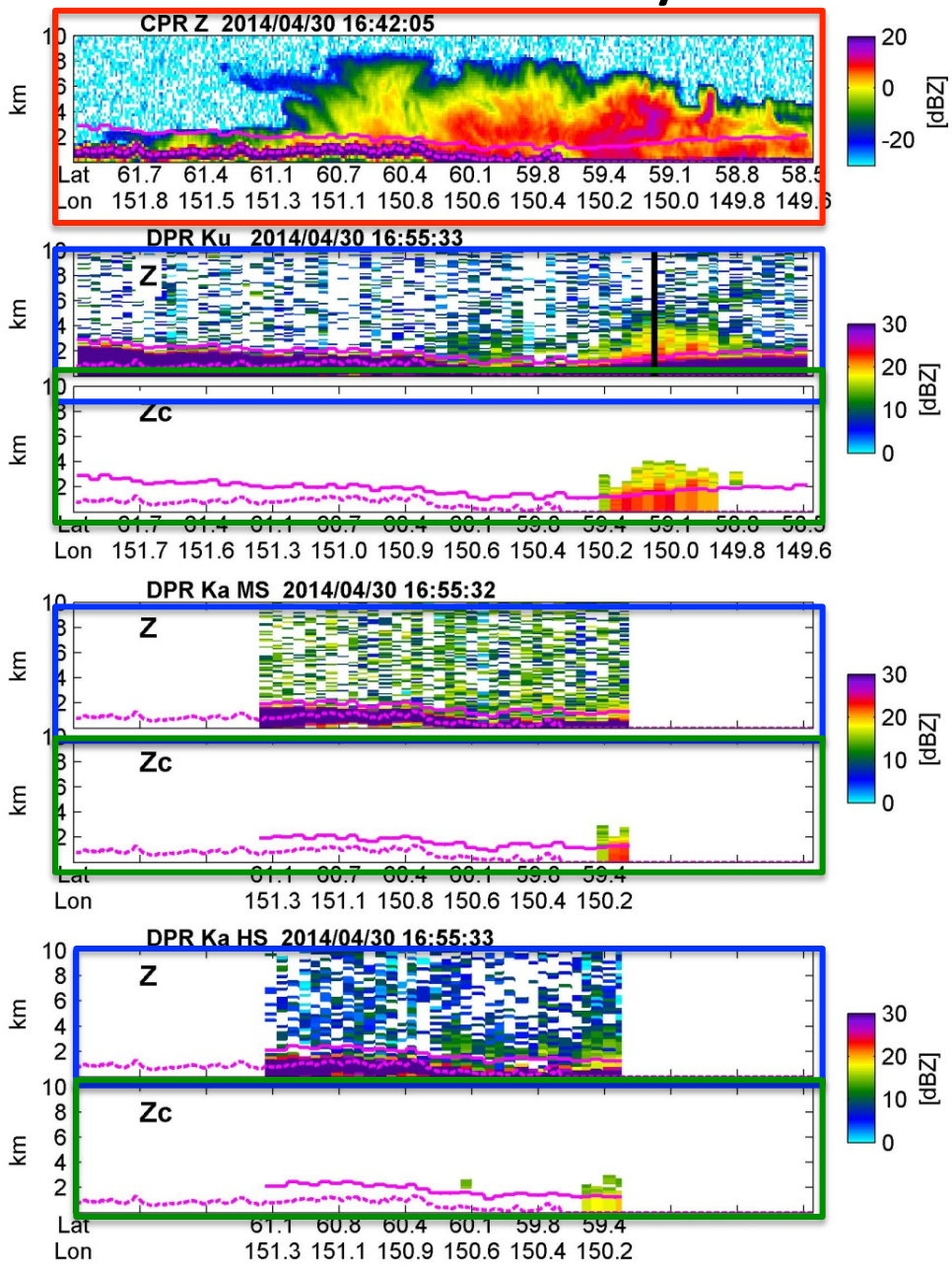
		GMI tables	DPR CMB	GPROF v4	GPROF v5
'Ocean'	POD	0.80	0.13	0.57	0.11
	FAR	0.40	0.86	0.44	0.12
	HSS	0.65	0.06	0.53	0.19
'New Sea ice '	POD	0.60	0.02	1.00	0.90
	FAR	0.35	0.00	0.64	0.50
	HSS	0.43	0.02	0.02	0.34
'Broken Sea ice'	POD	0.83	0.08	0.96	0.51
	FAR	0.47	0.35	0.58	0.42
	HSS	0.31	0.06	0.04	0.26
'Multilayer Sea ice'	POD	0.72	0.05	1.00	0.34
	FAR	0.54	0.00	0.68	0.33
	HSS	0.28	0.07	0.00	0.30
'Land'	POD	0.19	0.34	0.19	0.05
	FAR	0.74	0.97	0.87	0.56
	HSS	0.22	0.04	0.15	0.10
'Snow A'	POD	0.31	0.22	1.00	0.00
	FAR	0.09	0.00	0.47	0.00
	HSS	0.27	0.21	0.07	0.00
'Snow B'	POD	0.54	0.08	0.76	0.24
	FAR	0.36	0.13	0.77	0.39
	HSS	0.47	0.11	-0.02	0.24
'Snow C'	POD	0.74	0.18	0.63	0.18
	FAR	0.49	0.26	0.62	0.64
	HSS	0.28	0.17	-0.01	-0.02
'Coast'	POD	0.74	0.36	0.67	0.10
	FAR	0.37	0.84	0.69	0.53
	HSS	0.67	0.19	0.40	0.15

The new GMI detection algorithm “”works better than Gprof (v4 or v5) over all surfaces but multilayer sea ice (looking at HSS)

The Gprof v5 improves (w.r.t. v4) the snowfall detection over most surfaces, but not over ocean

Extra slides

Case study: extensive frontal snowfall



Widespread frontal snowfall event occurred over Eastern Russia north of the Sea of Okhotsk on 30 April 2014

CPR:

- Typical maximum CPR Z: 10-15 dBZ
- maximum cloud top heights between ~5-8 km
- shallower cloud structures with cloud top heights less than ~2 km

DPR Measured Reflectivity (Z)

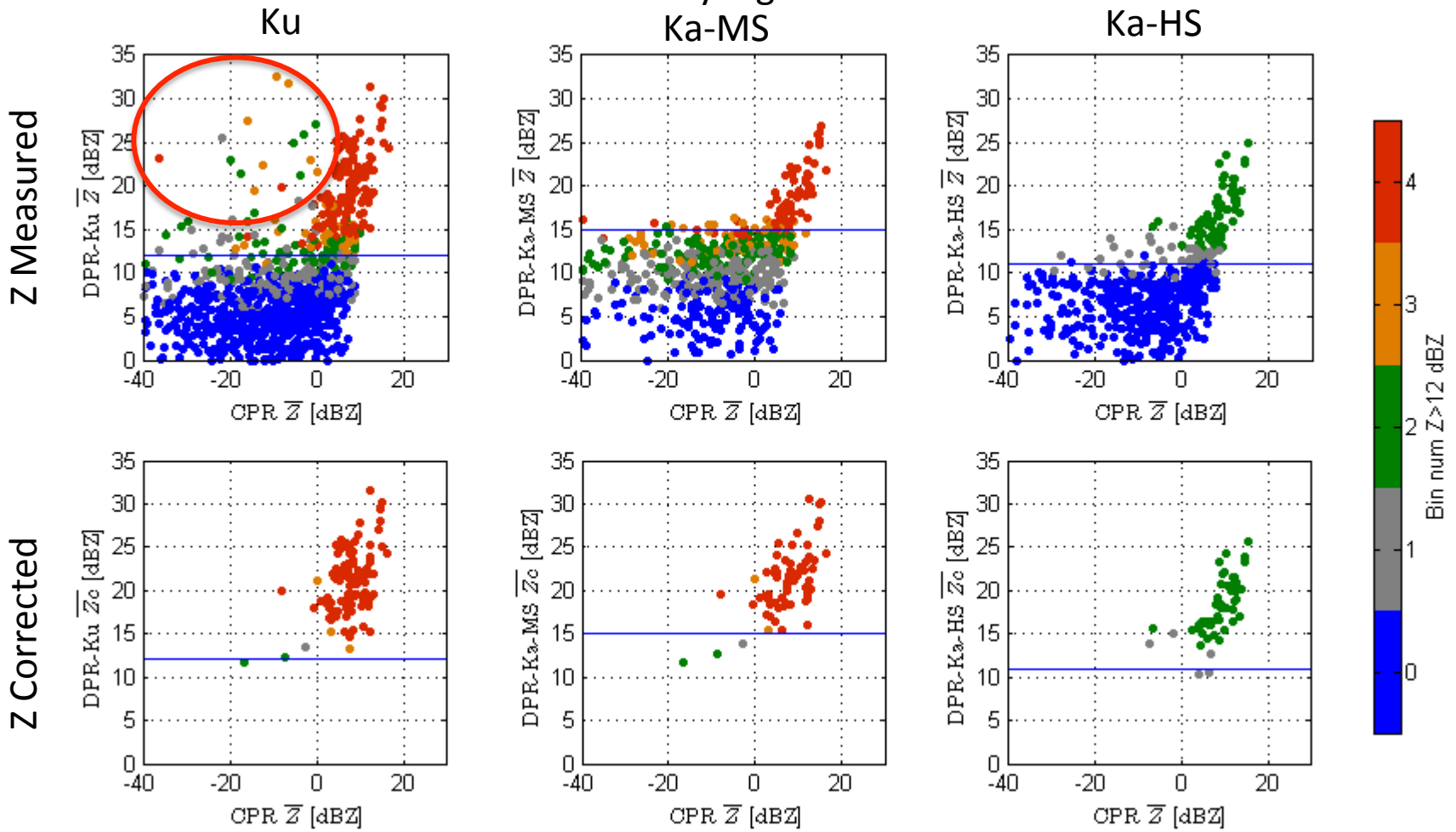
- Ku and Ka-HS uncorrected Z some structure below ~4 km in the deeper snowfall segment
- most of the event north of 60° latitude and at higher altitudes is missed
- significant random noise around 12 dBZ (Ku and Ka HS) or 16 dBZ (Ka MS)
- Side lobe clutter signal in the Ku

DPR Corrected Reflectivity (Zc) (2A-DPR)

- Complete suppression of random noise and side lobe clutter
- Attenuation correction below the free-clutter level
- Part of the weak signal related to snowfall is also eliminated

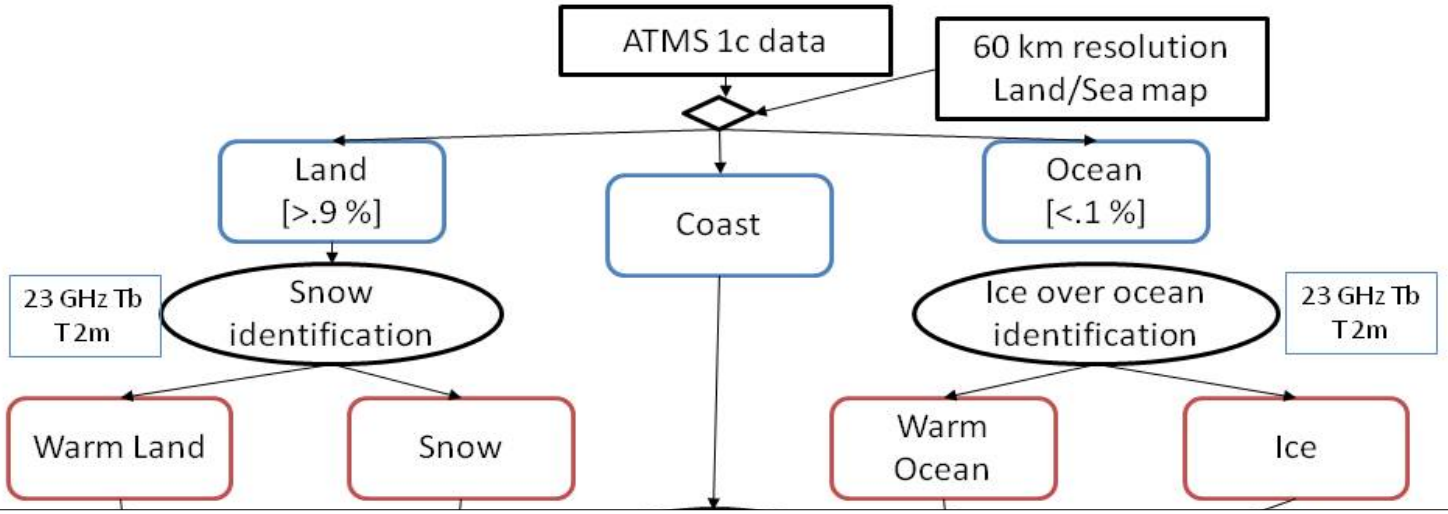
Assessment of DPR sensitivity to snowfall: DPR-CPR Low Level Reflectivity Comparison

Mean reflectivity from DPR compared to the mean CPR reflectivity in a layer 500 m thick above the DPR clutter-free bin. The color scale depicts the number of pixels in the 500 m layer with DPR reflectivity higher than 12 dBZ.



Z correction (V4) removes noise and side lobe clutter effect; however, many observations with relatively weak echoes close to the sensitivity threshold are also eliminated.

All-sky surface Classification scheme for ATMS (and GMI)



Verified against:
Snow depth ECMWF Era-I analysis;
POD 93% FAR 10%

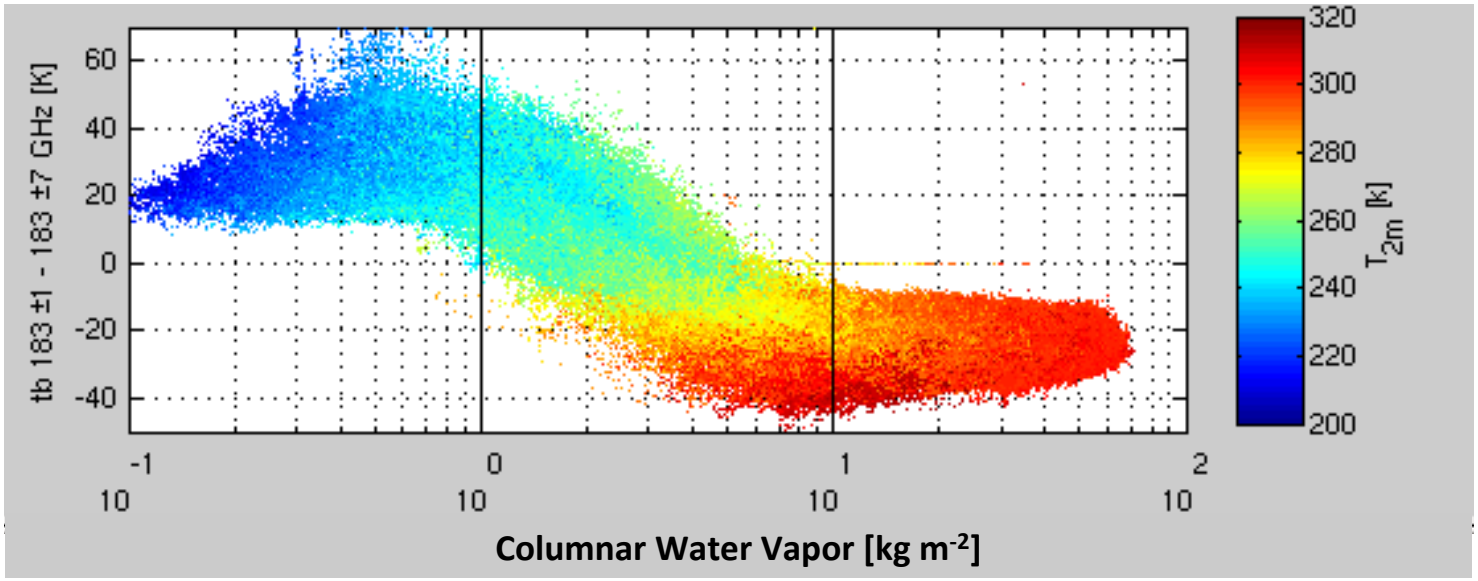
Verified against
Surface_Type in CPR 2C-PRECIP-COLUMN;
POD 93% FAR 1%

based on
Hewison and English (1999)

see Panegrossi et al., 2016 (FA_15_01 Mid-term report)

Analysis of snowfall signal: ATMS 183 GHz ΔTb

Cloud Free



Cloud free (black contour) and CPR Surface Snowfall rate >0 mm/h (color)