Development of an Operational Cross-track Precipitation Retrieval Scheme

Chris Kidd & co-workers

UMD/ESSIC and NASA/GSFC

Background

- Sounders now form the majority of passive microwave radiometers;
- Exploitation of their observations critical to achieve the temporal sampling required for observing precipitation;
- Resolutions comparable with imagers, often better at nadir.

But there are challenges:

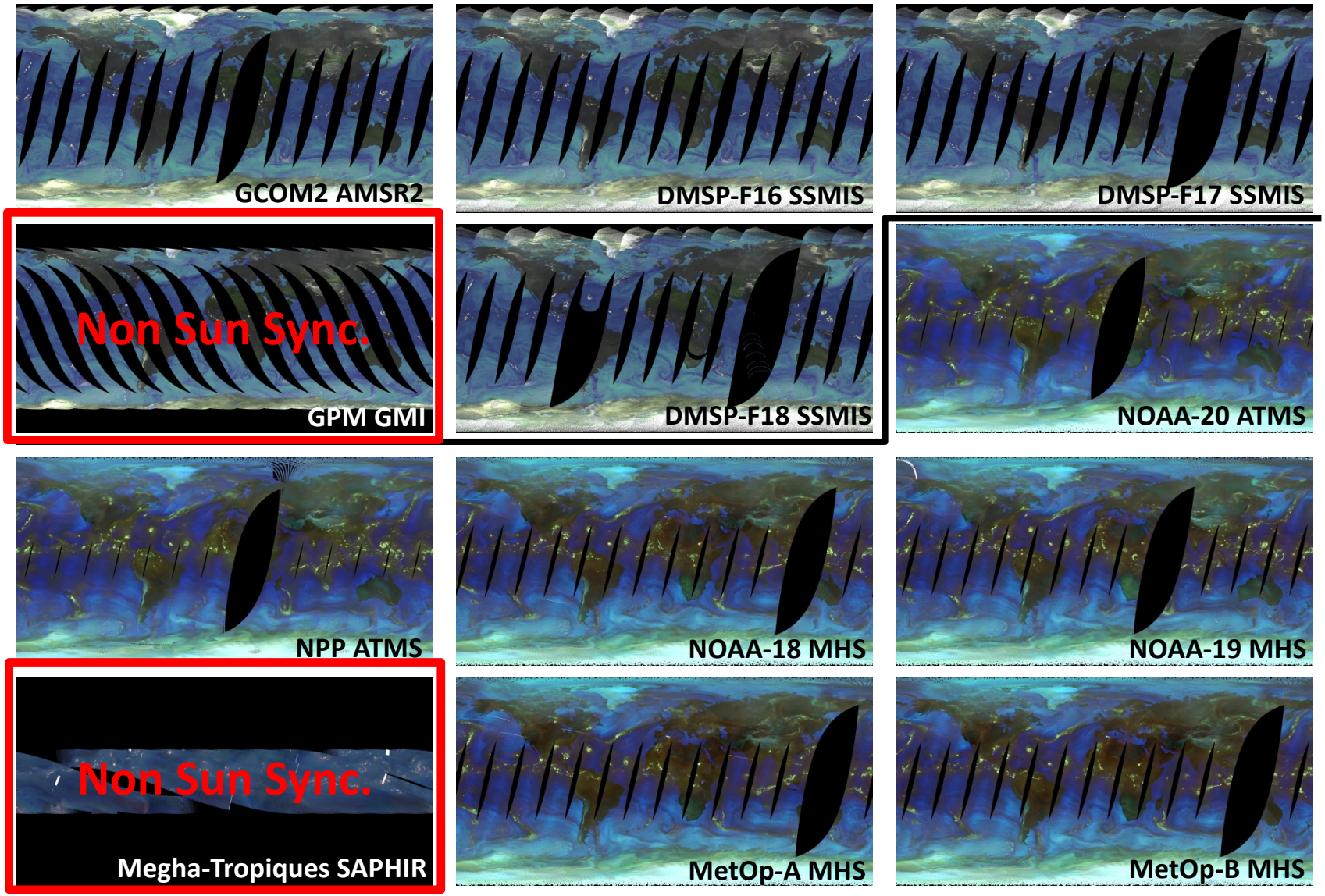
- Instruments were not designed for precipitation;
- Cross-track scanning, resulting in variable Earth Incidence Angle, impacting resolution, atmospheric path length and altitude of maximum sensitivity.

Retrieval schemes – incl GPROF – but not for SAPHIR

GPM & international partner satellites

Imager/conical

Sounder/cross-track



Descending overpasses: 11 Sept. 2018

Sounders now form the majority of sensors

Passive Microwave Sounding Instruments

AMSU-B	MHS	ATMS	SAPHIR
89.9 ± 0.9	89.0	89.5*	
150 ± 0.9	157.0	165.5	
			183.31 ± 0.2
183.31 ± 1.0	183.31 ± 1.0	183.31 ± 1.0	183.31 ± 1.1
		183.31 ± 1.8	
183.31 ± 3.0	183.31 ± 3.0	183.31 ± 3.0	183.31 ± 2.7
		183.31 ± 4.5	183.31 ± 4.2
183.31 ± 7.0	190.31	183.31 ± 7.0	183.31 ± 6.6
			183.31 ± 11.0
16 km	16 km	16 km (*32km)	10 km
1998-2014	2005-pres.	2011-pres.	2013-pres.

Precipitation Retrieval and Profiling Scheme (PRPS)

Database

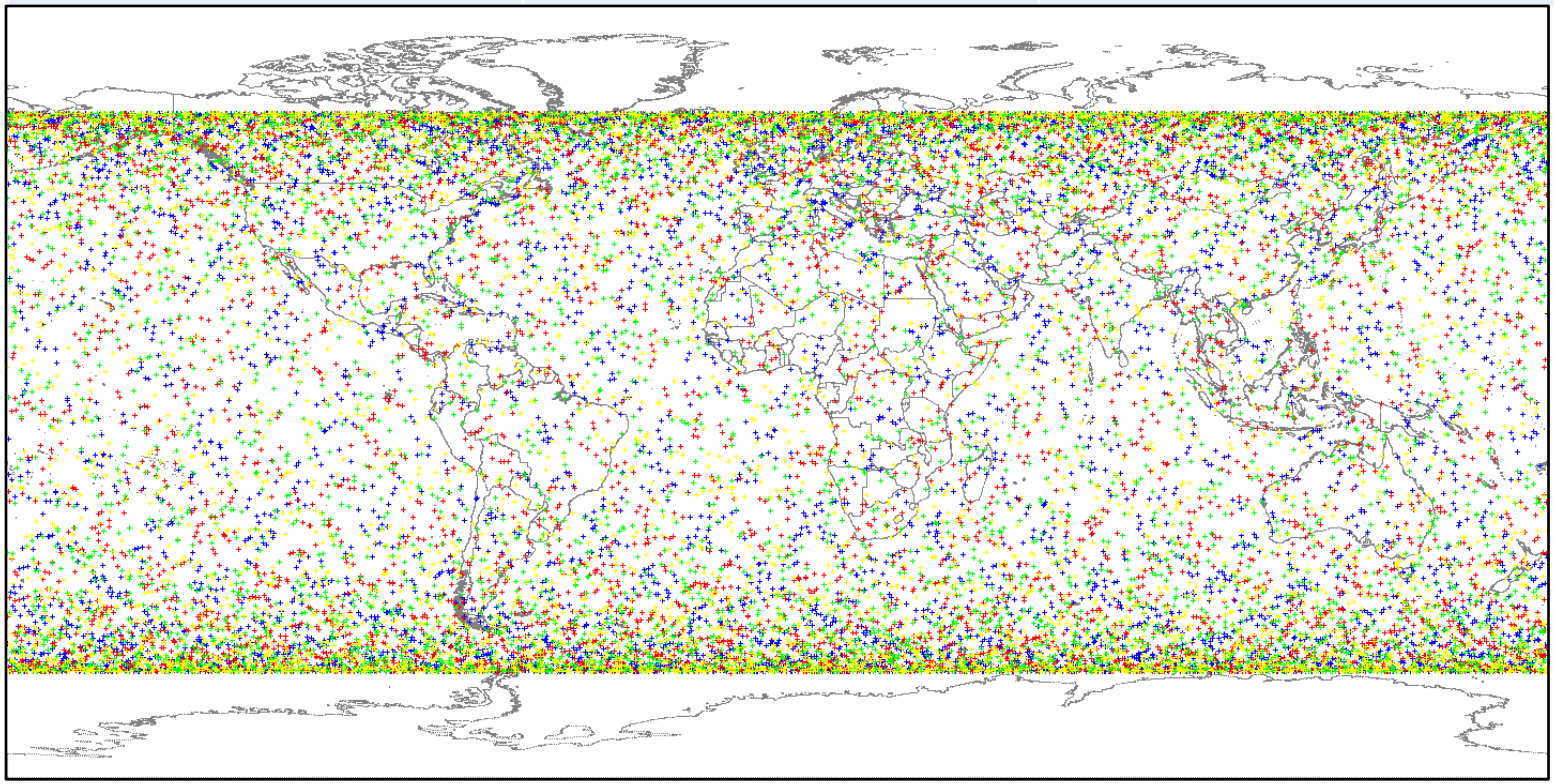
- Database entries generated from matched DPR-sensor footprints – small enough for memory;
- Database sorted and indexed (by most disparate Tc/Tc combination) for computational efficiency;

Retrieval

- Land/sea mask and altitude used, but NO DYNAMIC ANCILLARY DATA;
- Precipitation retrieval based upon the six closest observation:database matches;
- Scan position correction (SAPHIR v01-02 only);
- Outputs of <u>precipitation</u>, <u>error</u>, <u>fit</u> and <u>quality</u>.

DPR-MHS intersects, 2014/03-2018/07

Satellite	Intersects	FOV matchups
METOPA	5580	8029736
METOPB	5806	8353189
NOAA18	5770	8255956
NOAA19	5783	8168129



‘Full’ database – one per overpass matchup

Source filenames

crossing lat/lon (and resolution)

One entry per matched fov

```
ex1C.NOAA19.MHS.XCAL2016-V.20170428-S190725-E204925.042368.V05A.dat
ex1C.GPM.GMI.XCAL2016-C.20170428-S190846-E204121.017987.V05A.dat
ex2A.NOAA19.MHS.GPROF2017v1.20170428-S190725-E204925.042368.V05A.dat
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exNSMSHS.GPM.DPR.V7-20170308.20170428-S190846-E204121.017987.V05A.dat
   6.277  103.559    5.000
 17  4 28 20 18 36  19.365   98.006 1602  85 283.32 281.98 242.26 257.39 267.37 17  4 28 20 11 34  19.338   98.001 2010 105 279.49 276.72 281.50 278.65 283.62 281.03 279.34 284.81 284.81 17
 17  4 28 20 18 38  19.210   97.975 1603  85 282.94 281.27 242.45 256.00 267.21 17  4 28 20 11 36  19.210   98.000 2011 104 278.67 276.92 280.75 279.88 283.64 281.90 280.54 284.73 284.60 17
 17  4 28 20 18 38  19.128   98.691 1603  83 278.30 273.71 232.75 251.53 261.06 17  4 28 20 11 42  19.129   98.695 2014 115 275.34 273.81 278.14 276.09 279.08 275.83 275.70 276.00 274.28 17
 17  4 28 20 18 41  19.098   97.554 1604  86 285.79 283.77 246.93 262.02 271.43 17  4 28 20 11 36  19.073   97.583 2011  96 280.40 276.89 282.26 280.79 284.65 282.90 281.58 285.94 285.63 17
 17  4 28 20 18 44  18.989   97.110 1605  87 285.29 285.36 249.60 264.70 274.22 17  4 28 20 11 36  18.965   97.100 2011  87 281.15 279.03 281.88 282.17 282.67 282.05 281.02 284.39 283.45 17
 17  4 28 20 18 44  18.944   97.523 1605  86 285.62 283.63 246.83 261.06 270.90 17  4 28 20 11 38  18.9[illegible]                                                                    285.83 17
 17  4 28 20 18 44  18.818   98.627 1605  83 278.79 274.97 233.65 252.25 262.17 17  4 28 20 11 46  18.8                                                                              277.11 17
 17  4 28 20 18 49  18.549   98.217 1607  84 280.91 279.68 234.76 254.70 264.99 17  4 28 [illegible]                                                                                  280.24 17
 17  4 28 20 18 52  18.436   97.819 1608  85 284.97 284.56 243.58 259.60 270.91 17  4 28 20 11 47  18.4                                                                              285.15 17
 17  4 28 20 19  2  17.694   98.732 1612  82 279.75 272.46 235.53 249.29 259.65 17  4 28 20 12  2  17.7[illegible]                                                                    281.44 17
 17  4 28 20 19 10  17.119   99.530 1615  79 267.33 250.34 229.86 248.51 248.11 17  4 28 20 12 16  17.139   99.523 2032 114 272.52 262.93 278.15 270.50 280.70 277.67 273.14 261.74 256.66 17
 17  4 28 20 19 13  16.999   99.212 1616  80 271.28 255.77 232.94 249.91 253.43 17  4 28 20 12 16  17.002   99.230 2032 108 279.34 271.84 282.60 278.41 283.68 283.23 279.75 274.44 272.94 17
 17  4 28 20 19 16  16.844   99.180 1617  80 272.08 256.92 236.38 250.59 254.78 17  4 28 20 12 17  16.851   99.178 2033 106 276.31 267.51 279.68 273.41 282.16 279.94 276.31 267.20 263.97 17
 17  4 28 20 19 16  16.741  100.000 1617  77 259.32 236.18 239.12 247.40 244.59 17  4 28 20 12 25  16.722   99.998 2037 119 254.33 228.34 266.56 253.04 275.54 271.53 264.09 265.99 262.56 17
 17  4 28 20 19 26  16.153   99.604 1621  78 280.90 275.78 229.05 251.70 261.24 17  4 28 20 12 31  16.127   99.612 2040 108 259.98 233.97 267.86 251.53 277.41 271.99 259.75 282.25 279.62 17
 17  4 28 20 19 24  16.180  100.630 1620  74 268.12 251.21 238.08 244.93 244.50 17  4 28 20 12 38  16.157  100.644 2044 126 262.29 242.09 273.52 263.91 277.20 268.84 263.16 255.30 250.30 17
 17  4 28 20 19 29  16.105   98.719 1622  81 280.35 275.88 238.23 252.07 262.14 17  4 28 20 12 27  16.081   98.697 2038  92 276.28 273.54 280.23 277.64 279.90 278.75 277.96 280.51 280.64 17
 17  4 28 20 19 29  16.068   99.015 1622  80 278.69 275.08 236.39 251.08 261.71 17  4 28 20 12 29  16.038   99.006 2039  97 277.43 274.58 278.23 277.16 279.15 276.41 275.78 276.88 275.94 17
 17  4 28 20 19 29  15.964   99.832 1622  77 281.14 278.13 237.68 252.05 262.04 17  4 28 20 12 34  15.974   99.855 2042 111 258.78 233.23 266.08 244.49 276.20 270.52 254.75 282.17 278.17 17
 17  4 28 20 19 32  15.877   99.266 1623  79 280.81 276.15 237.29 252.58 262.31 17  4 28 20 12 32  15.867   99.257 2041 100 276.84 274.17 281.00 280.75 282.38 282.38 280.25 281.92 281.04 17
                                                                                   28 20 12 44  15.828  100.785 2047 126 268.21 251.01 276.41 270.09 281.16 278.62 275.10 275.01 273.55 17
                                                                                   28 20 12 34  15.741   99.254 2042  99 277.85 275.53 280.01 279.08 282.01 280.82 280.33 280.35 280.25 17
 17  4 28 20 19 45  15.101   99.100 1628  79 283.70 280.77 238.87 252.87 264.49                                                                                                  3 283.81 17
                                          74 284.30 276.93 239.91 252.01 259.94                                                                                                  9 285.30 17
                                          72 285.62 283.04 245.78 258.70 268.39                                                                                                  3 121 270.81 255.66 280.08 272.56 284.91 285.18 278.80 287.23 286.14 17
                                          73 284.35 279.99 234.58 255.10 264.67                                                                                                  3 116 270.53 251.35 279.10 268.67 283.49 281.12 274.32 285.56 284.09 17
 17  4 28 20 19 58  14.070  100.845 1633  71 281.27 278.84 248.45 260.91 267.73                                                                                                  114 265.70 242.03 275.92 262.61 283.1                                  6.12 17  4
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yr mo dy hr mn sc lat lon scanline/pos Tc(1:5)

MHS L1C data

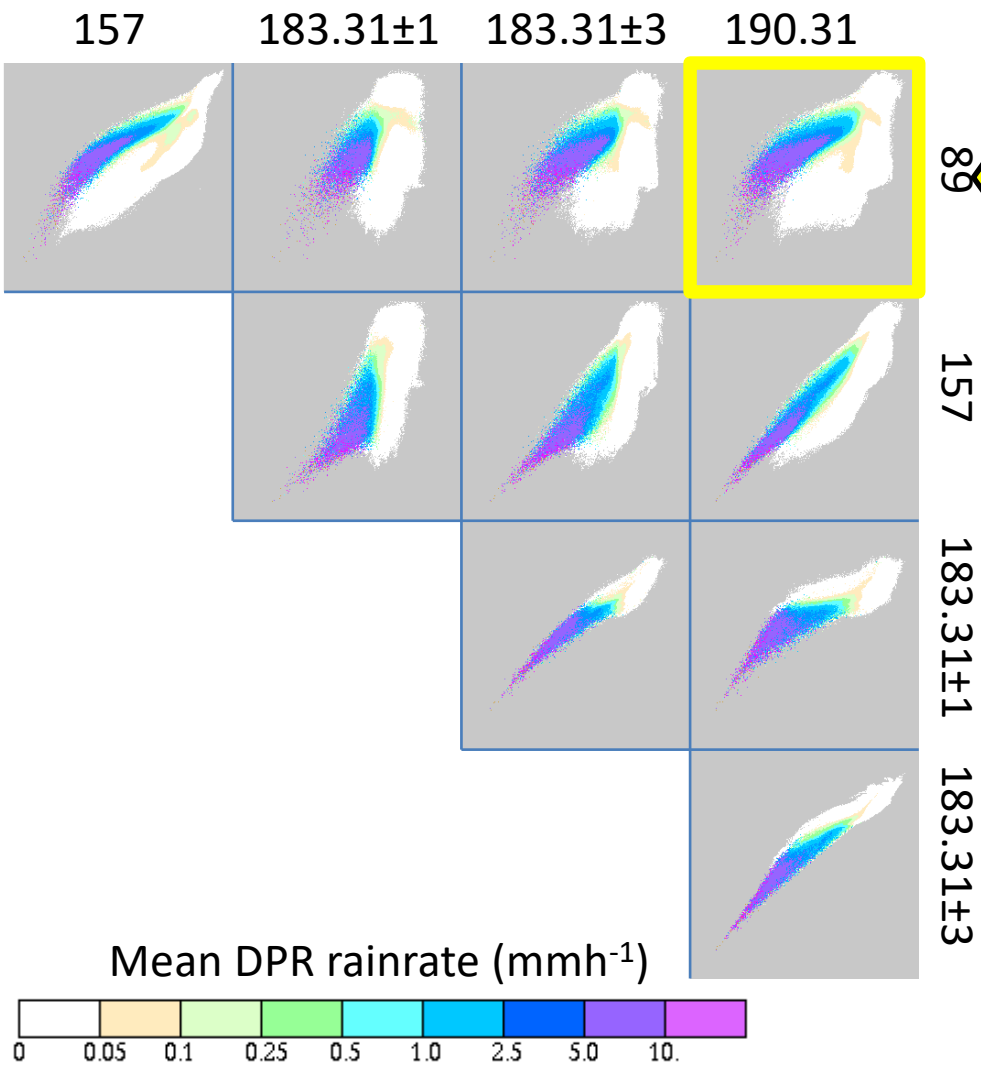
yr mo dy hr mn sc lat lon scanline/pos Tc(1:9) Tc(1:4)

GMI L1C data

…..etc….

GMI information is only included for comparisons at the research level – and not for any retrieval

Database index (MHS)



Tc1/Tc5 used as index to database to identify suitable entries (x2 for land & sea).

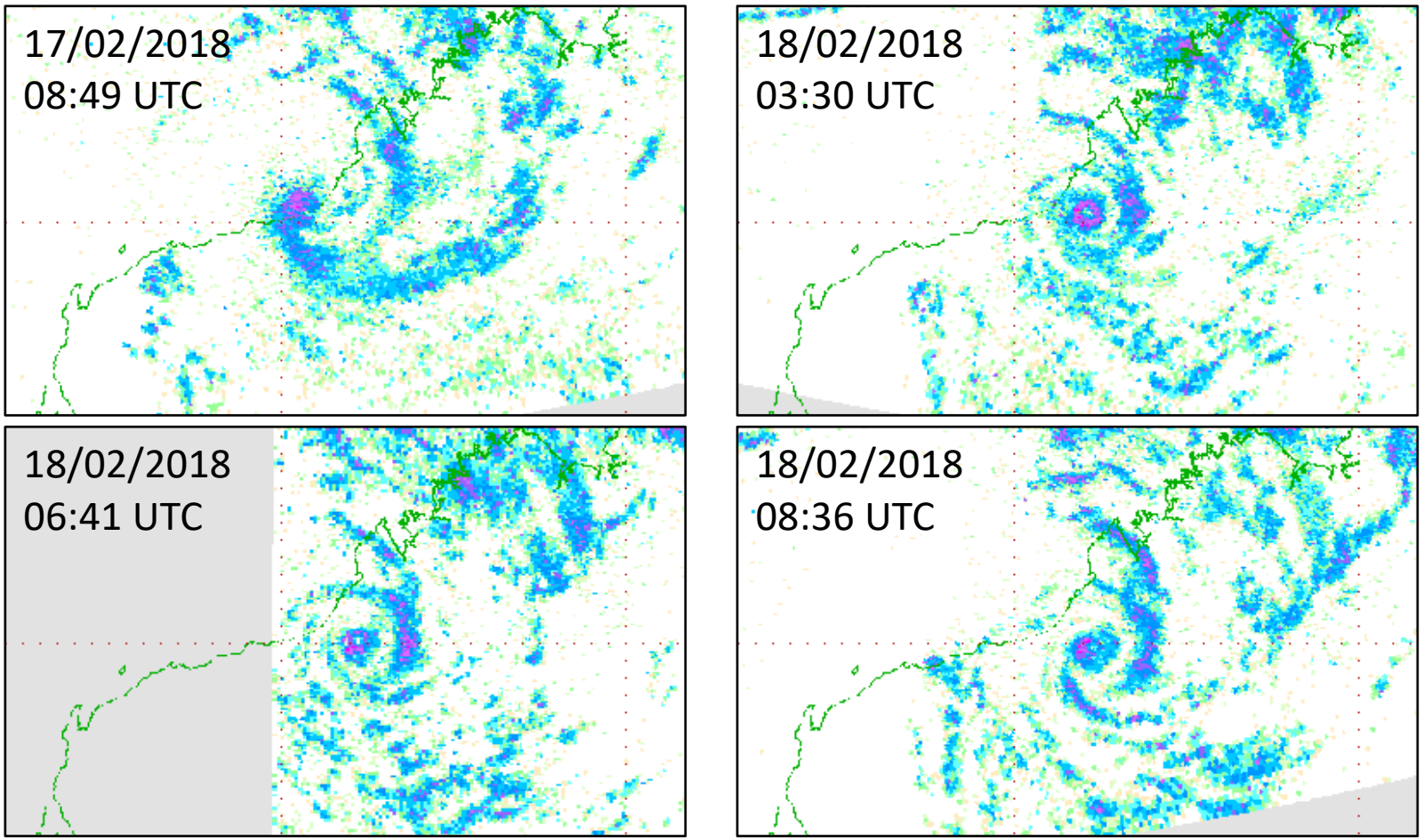
Each index bin contains <u>start/end location</u> of database entries

Mean rain rate per Tc/Tc may also be used as a benchmark to assess more complex retrievals

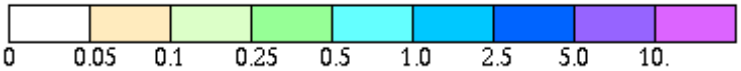
Tropical Cyclone Kelvin WA (12-23 February 2018)

Eye formed over land – 'brown ocean'. Broome Airport – 376.8 mm in 24 hours; 1506.0 mm of rain 1 Jan-19 Feb. (ann. mean 607.4 mm/yr)

SAPHIR PRPS_V01-02

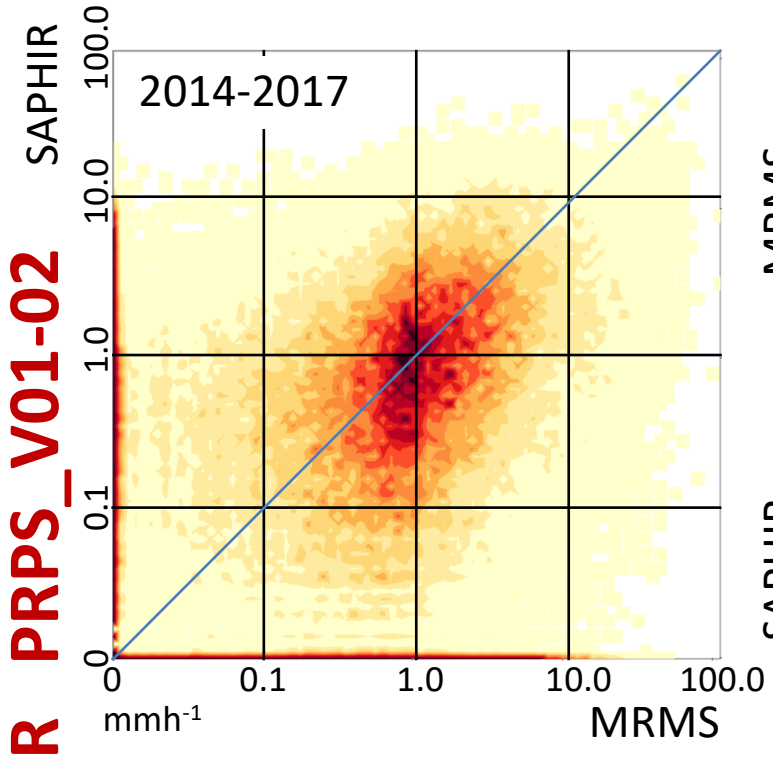


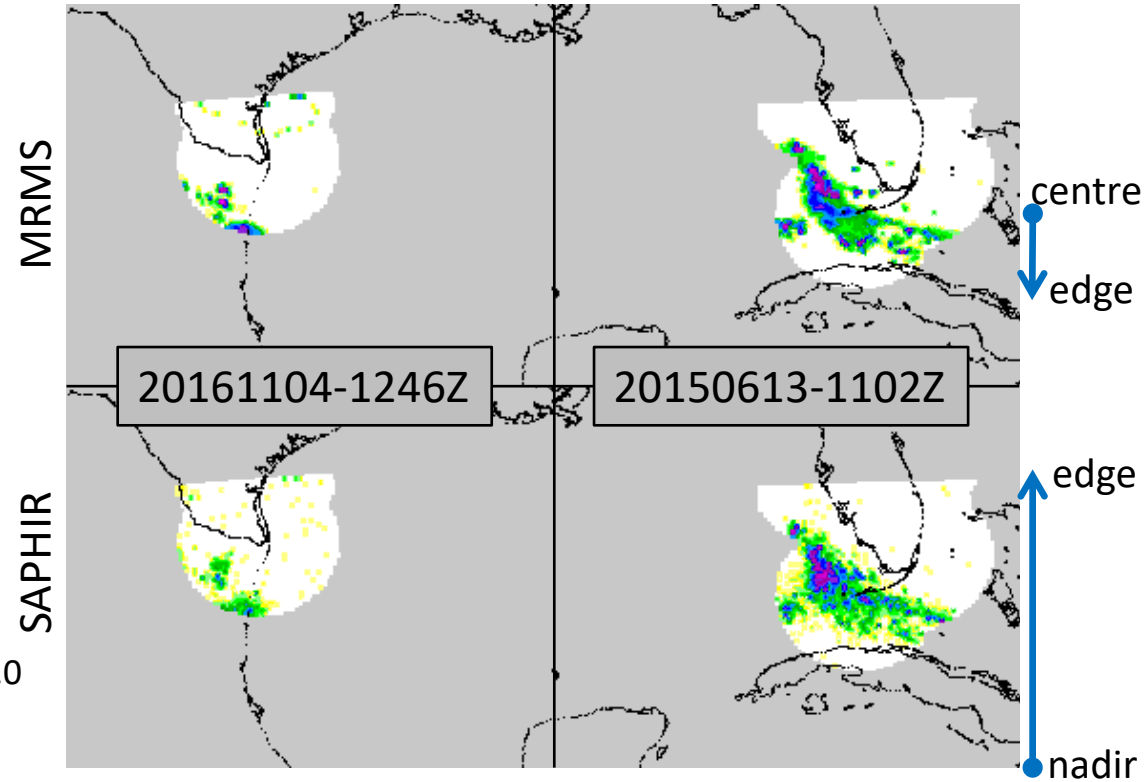
PRPS SAPHIR retrievals



mmh^{-1}

Instantaneous validation (US radar)





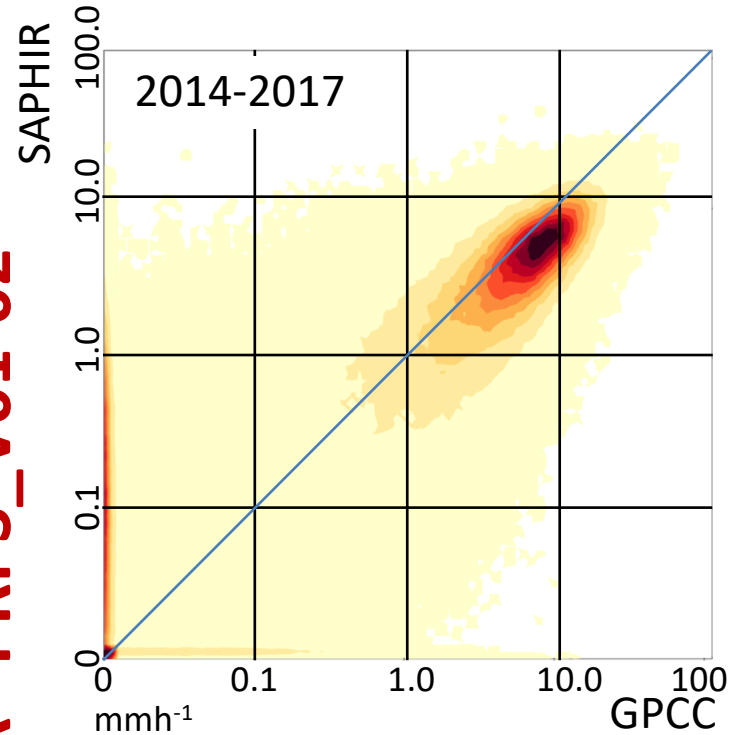
SAPHIR PRPS_V01-02

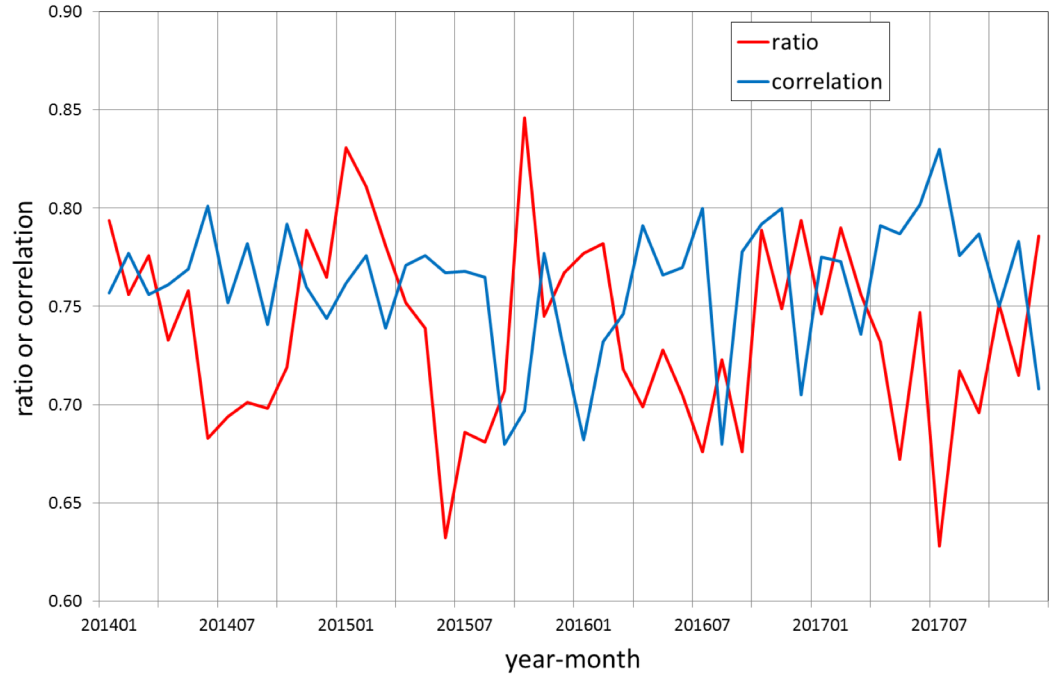
The US radar network (MRMS) extends to Southern Florida, but is at the northern-most SAPHIR coverage, consequently:

- The radar beam is at higher elevations, and;
- SAPHIR observations are at the edge of scan = poorer resolution.

Monthly 1 degree validation (GPCC)

SAPHIR PRPS_V01-02

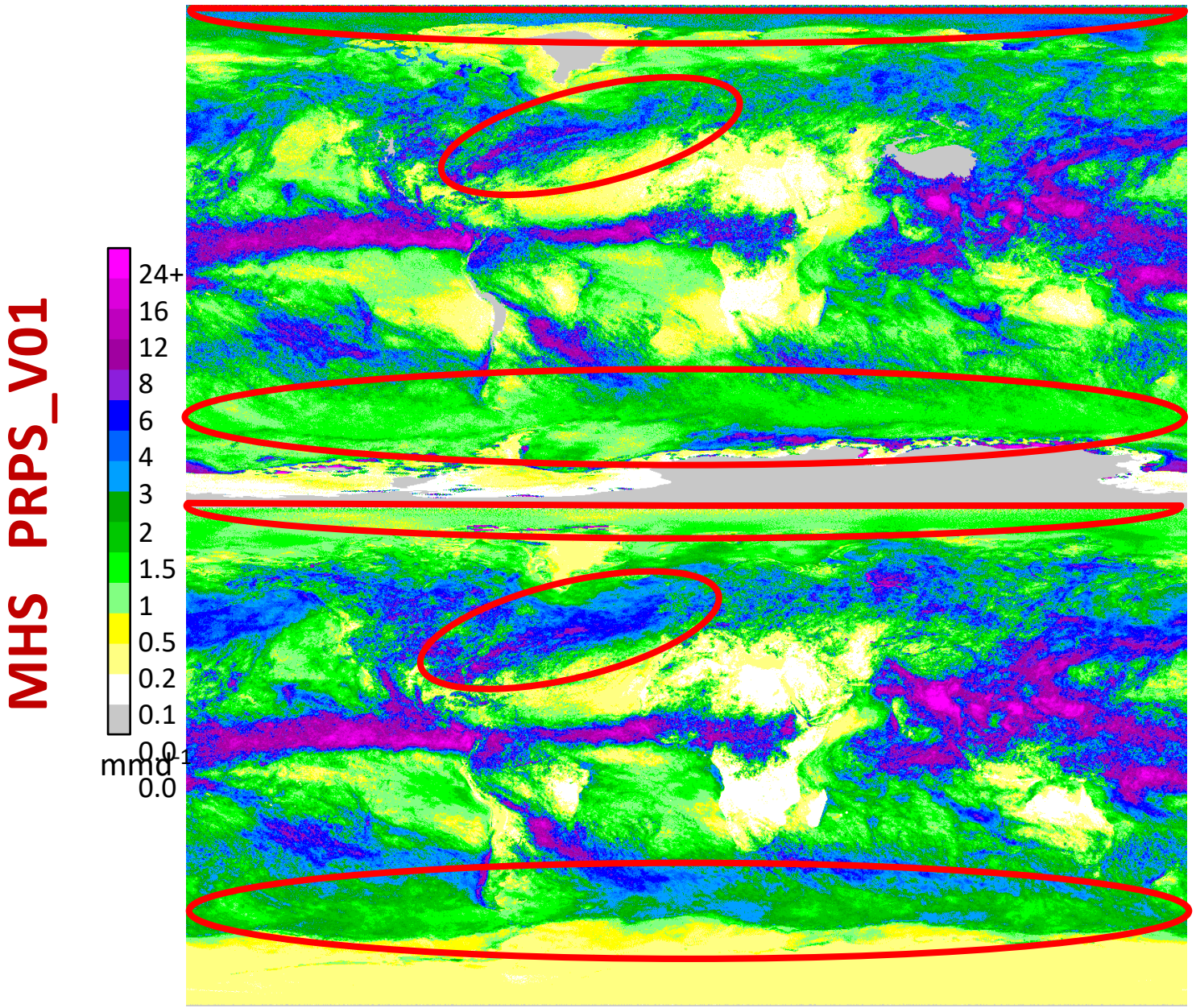




Use of GPCC 1 degree monthly (v5) dataset - 'Land' only (GPCC extent), and 28°N-28°S (SAPHIR extent):

- Much better relationship;
- Correlations generally 0.75-0.80, but ratios <1.0 (c. 0.65-0.80)

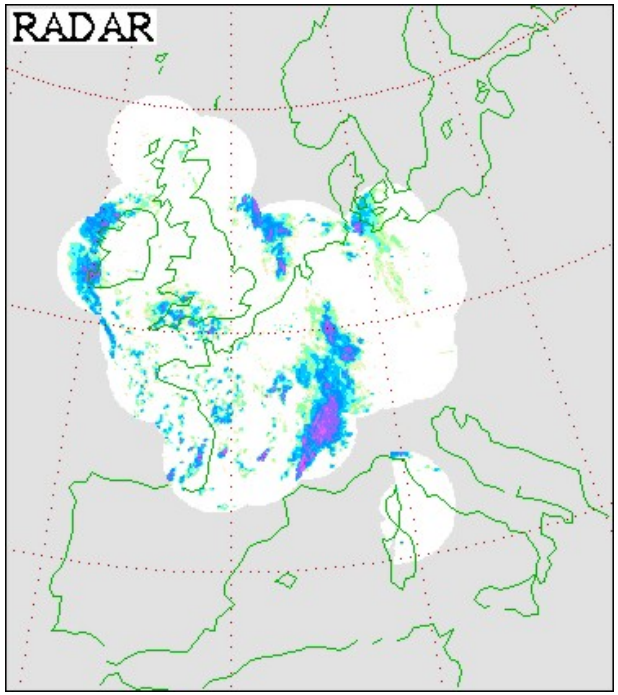
Monthly Mean Precipitation (July 2015)



July 2015

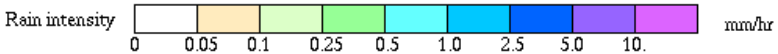
PRPS-MHS

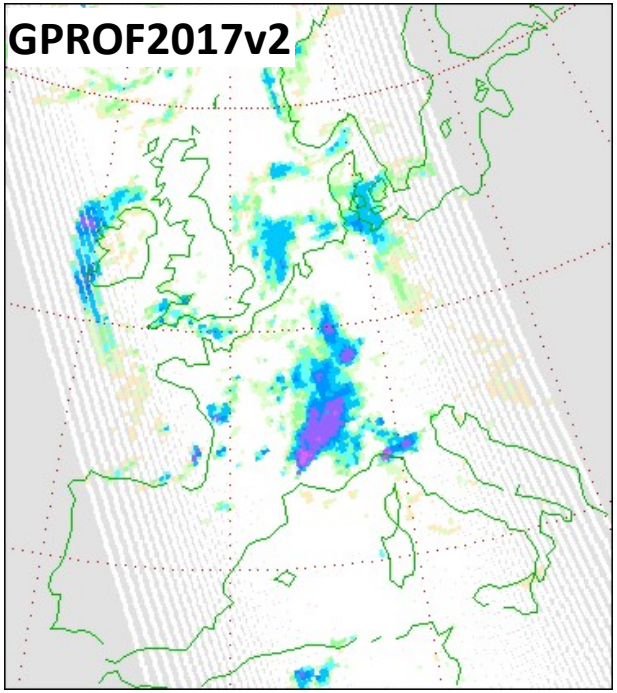
GPROF 2017v2 (V05)

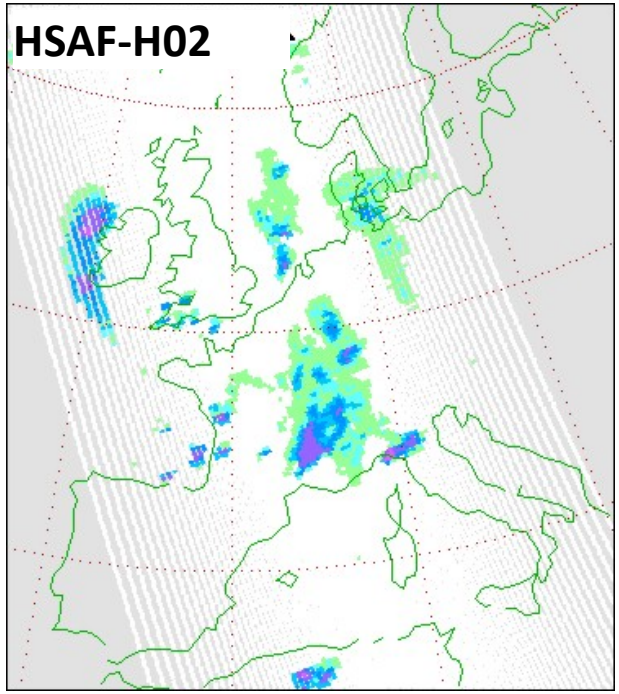


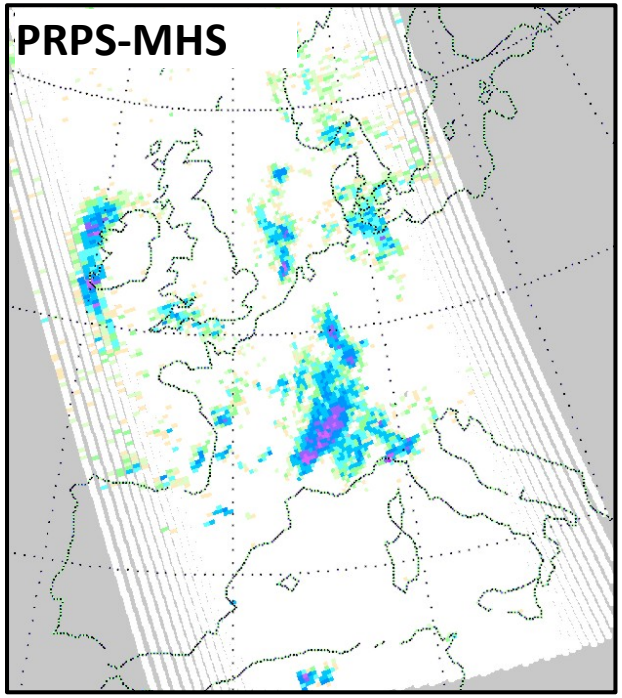
2015-09-13 20:34UTC

- PRPS-MHS quite similar to GPROF but with slightly less rain area;
- PRPS-MHS more dynamic than HSAF-H02 product;
- All ‘reasonable’ w.r.t. surface radar product







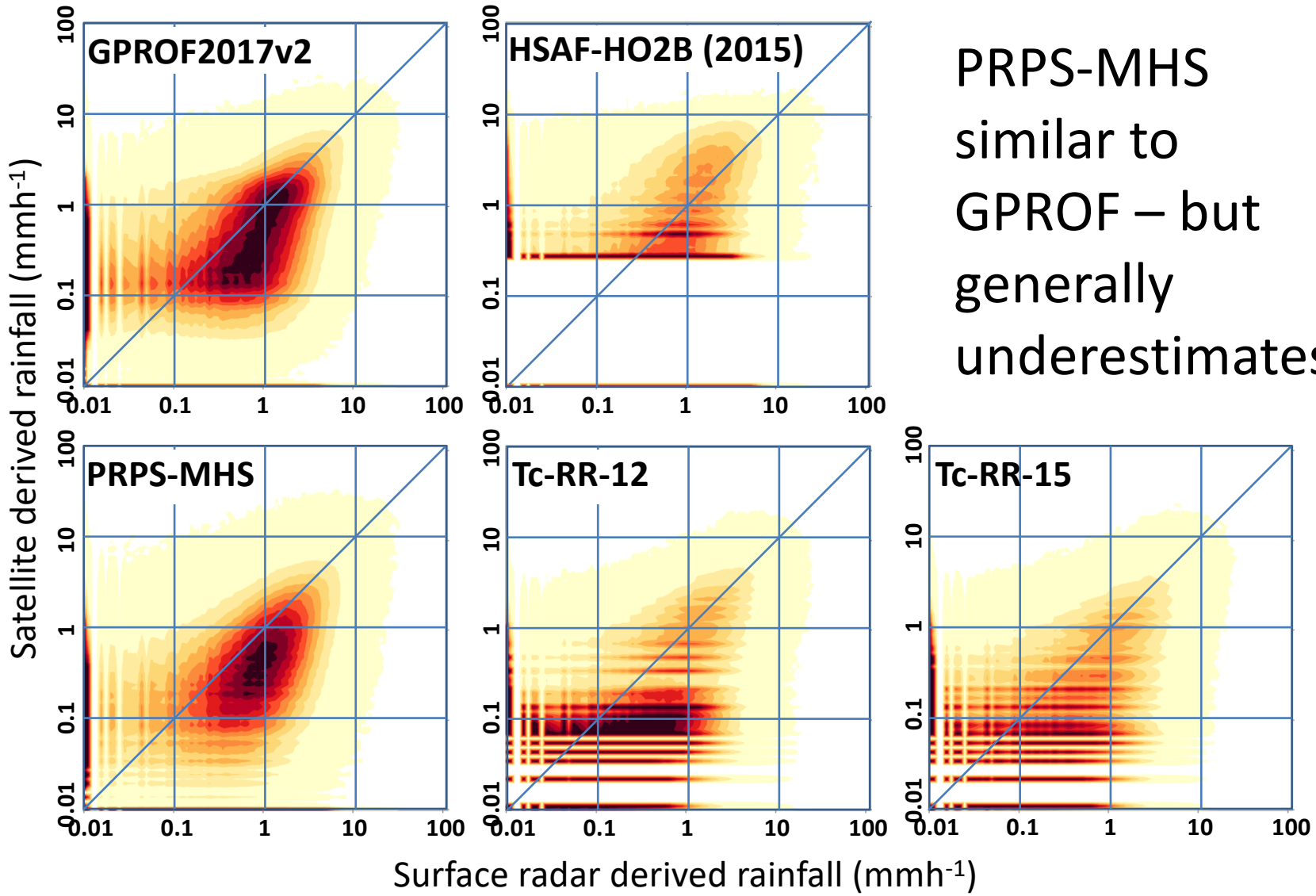


Statistical performance (2015)

Algorithm	ME	Ratio	RMSE	CC	nobs	POD	FAR	HSS
GPROF 2017v2	-0.04	0.647	**0.429**	**0.572**	11954361	0.450	0.383	0.352
HSAF-H02	-0.02	0.776	0.521	0.466	7767360	0.269	0.371	0.287
PRPS-MHS	-0.06	0.497	0.460	0.507	11907427	0.410	**0.269**	**0.367**
Tc1/Tc2	*-0.02*	*0.825*	*0.437*	*0.543*	*11913431*	*0.970*	*0.756*	*0.284*
Tc1/Tc5	***-0.01***	***0.888***	*0.451*	*0.507*	*11913382*	***0.980***	*0.767*	*0.274*

- GPROF has 'best' correlation and lowest RMSE
- PRPS-MHS has 'best' FAR and HSS
- Tc1/Tc5 has 'best' ME, ratio and POD

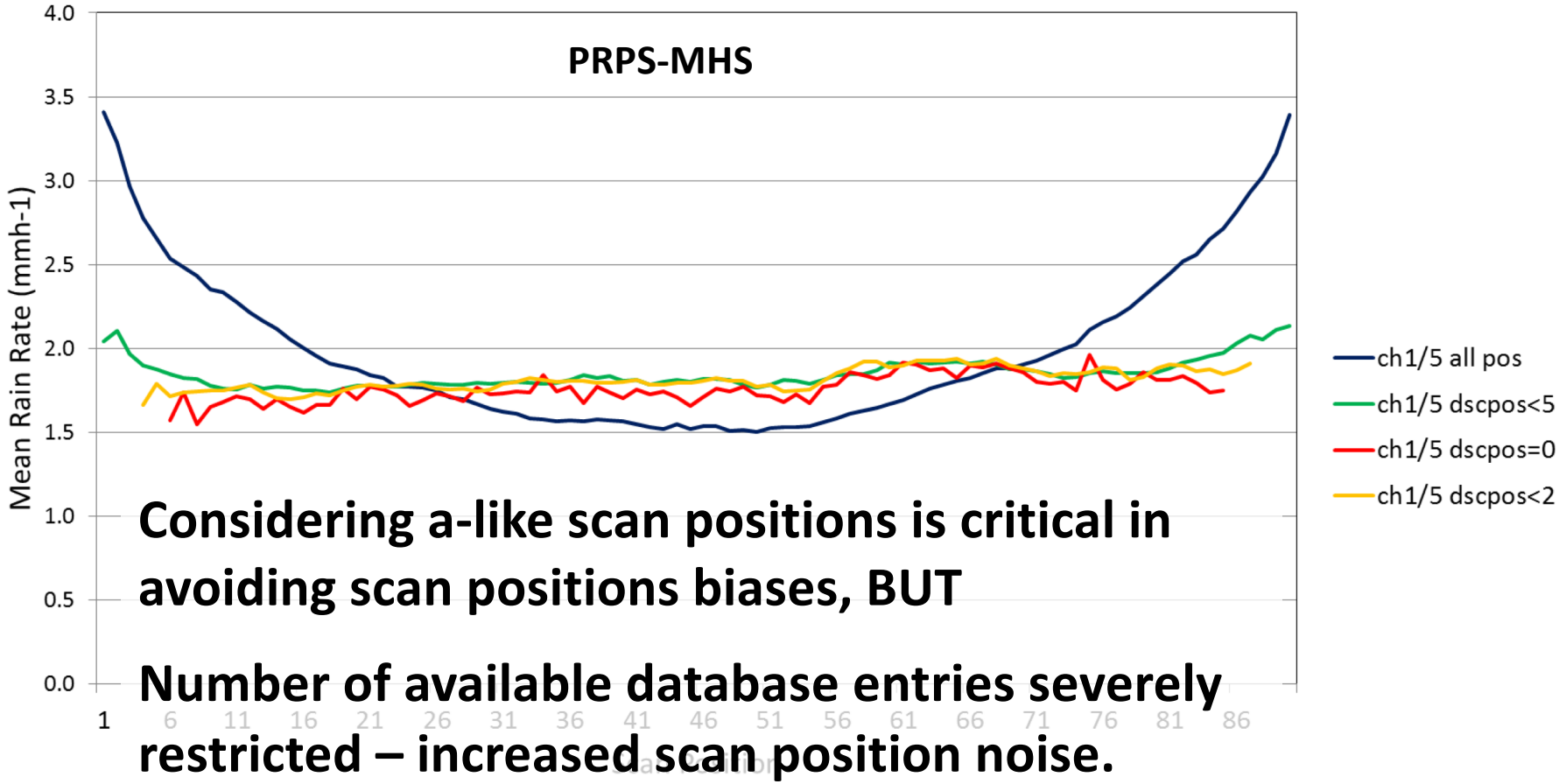
MHS 2D density scatterplots (2014-2018)*



PRPS-MHS similar to GPROF – but generally underestimates

Scan position biases

Due to the variable EIA, scan positions biases are a problem; PRPS-SAPHIR has a correction, PRPS-MHS_v01 has no correction:



Considering a-like scan positions is critical in avoiding scan positions biases, BUT

Number of available database entries severely restricted – increased scan position noise.

Future Directions

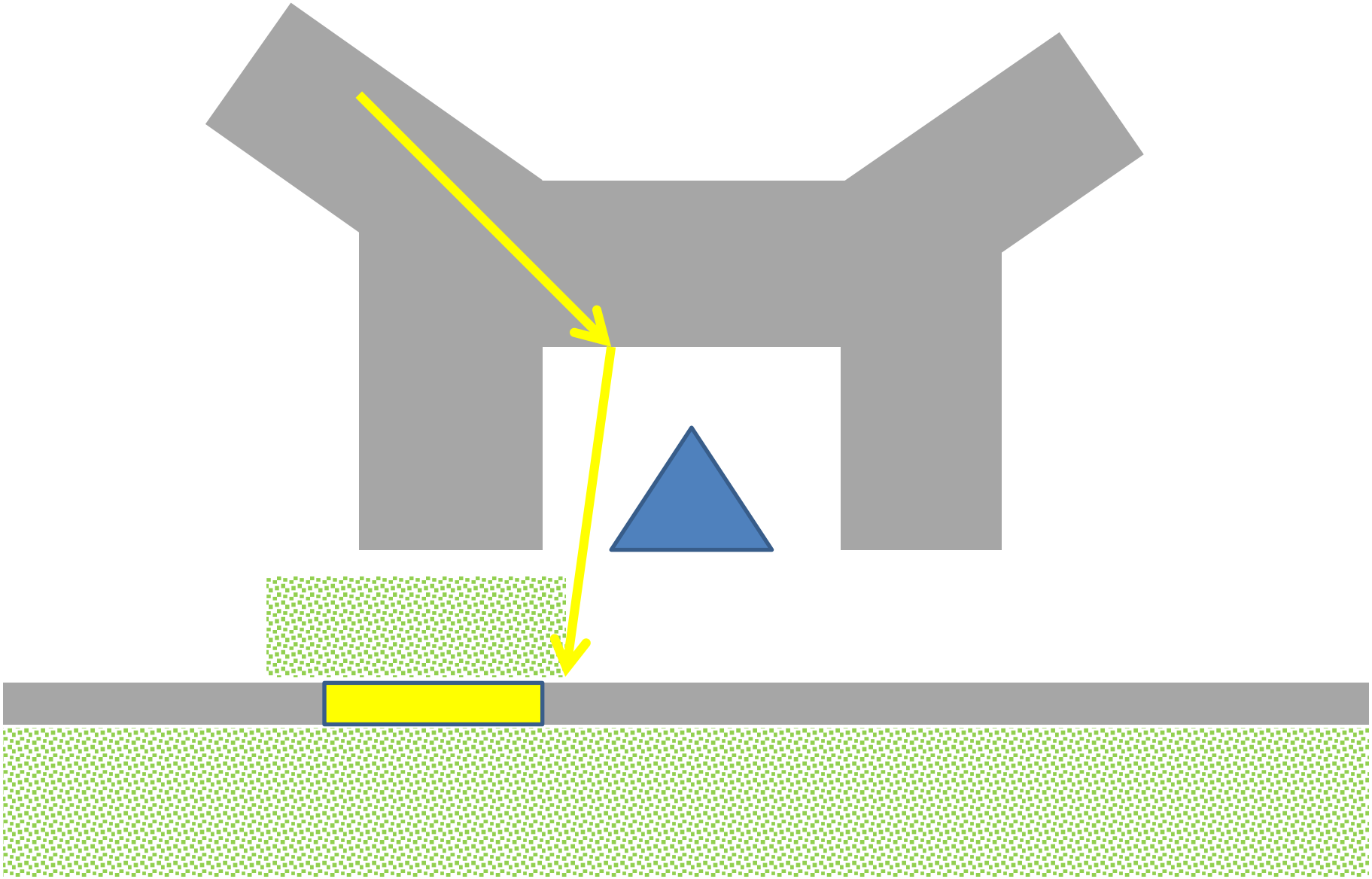
- PRPS-SAPHIR V01-02 is currently generated by the PPS;

Kidd, C. 2017: last updated 2018: GPROF CNES/ISRO Megha-Tropiques SAPHIR radiometer Precipitation Retrieval and Profiling Scheme, Level 2A precipitation product. NASA/GSFC, Greenbelt, MD, USA.

doi=10.5067/GPM/SAPHIR/MT1/PRPS/2A/05

- PRPS-MHS V02 nearly done and will be implemented by the EUMETSAT CM-SAF;
- Extension of PRPS to ATMS, to AMSU-B, and to future sensors, such as TROPICS;
- Ongoing work to ensure better representation of the database through 'noise' removal and modelling work.

…and finally…

- 30 years since my PhD on "*Passive microwave retrieval of rainfall over land*"
- Don't forget what the observations represent – the natural world, not some mathematical exercise;
- Overland we (generally) observe frozen precipitation – ice/snow, we <u>infer</u> rainfall from the ice, and therefore the linkages between the ice aloft and rainfall is critical;
- Also possible to <u>infer</u> precipitation from increased water vapour, but again, *not directly*.

Group Photo at end of THIS SESSION!