Evaluation of Summer 2018 Quantitative Precipitation Estimations for the CONtinental United States from Model, Satellite and Radar

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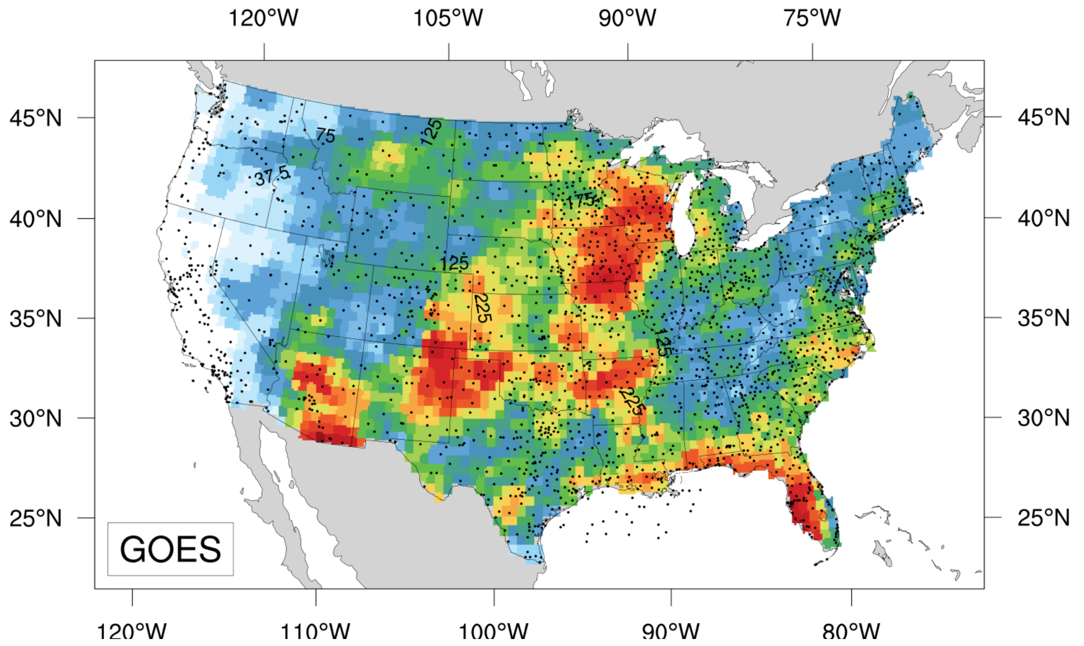
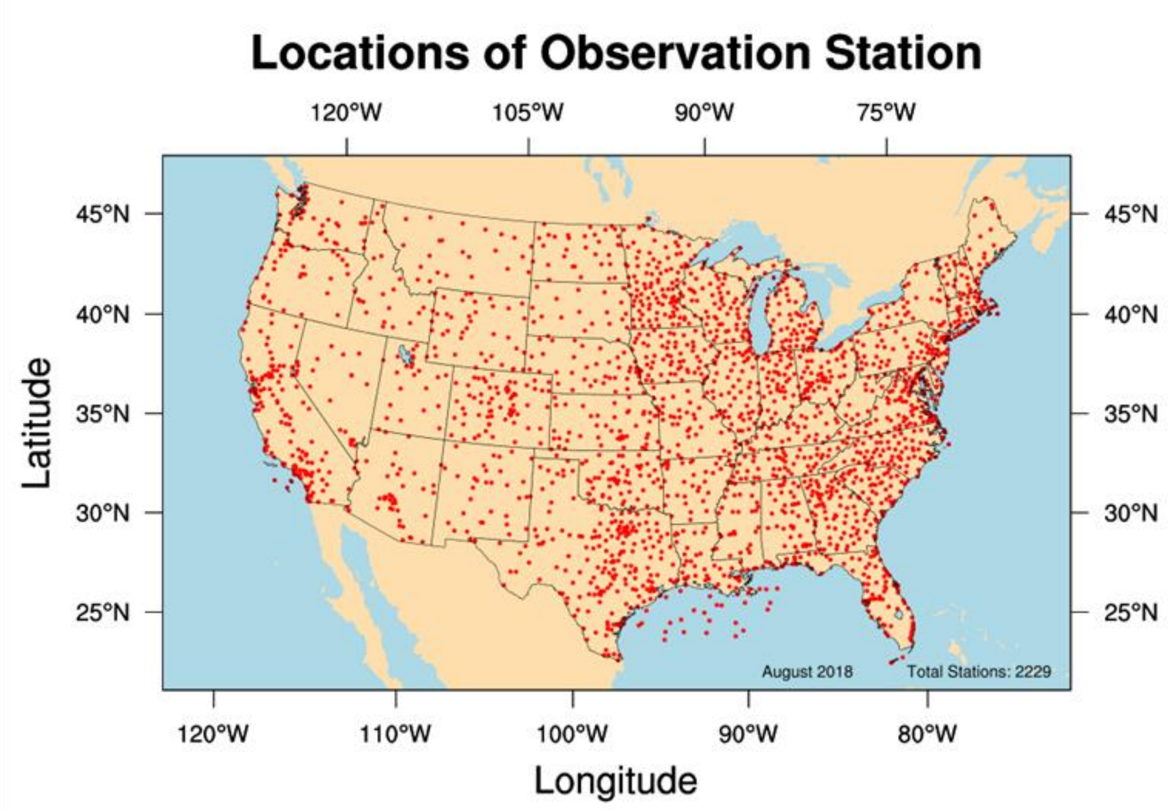
Precipitation is a relatively difficult meteorological quantity to forecast, estimate or measure. In this study, we look at Quantitative Precipitation Forecasts or Estimates (QPF/QPE) by the High-Resolution Rapid Refresh (HRRR) model, the **GOES-16** satellite product, the NCEP Stage IV multisensory data and measured values from the Automated Surface Observing System (ASOS/METAR) network.

We base our evaluation on comparisons with station-based observations for the continental USA (CONUS), in the summer of 2018. Results show that compared with the ASOS/METAR observations, the other three data sets over-predict/over-estimate the rainfall and have an overall wet bias. GOES-16 satellite estimation has the largest bias.



Total Monthly rainfall, August 2018, from GOES data, interpolated onto METAR site locations



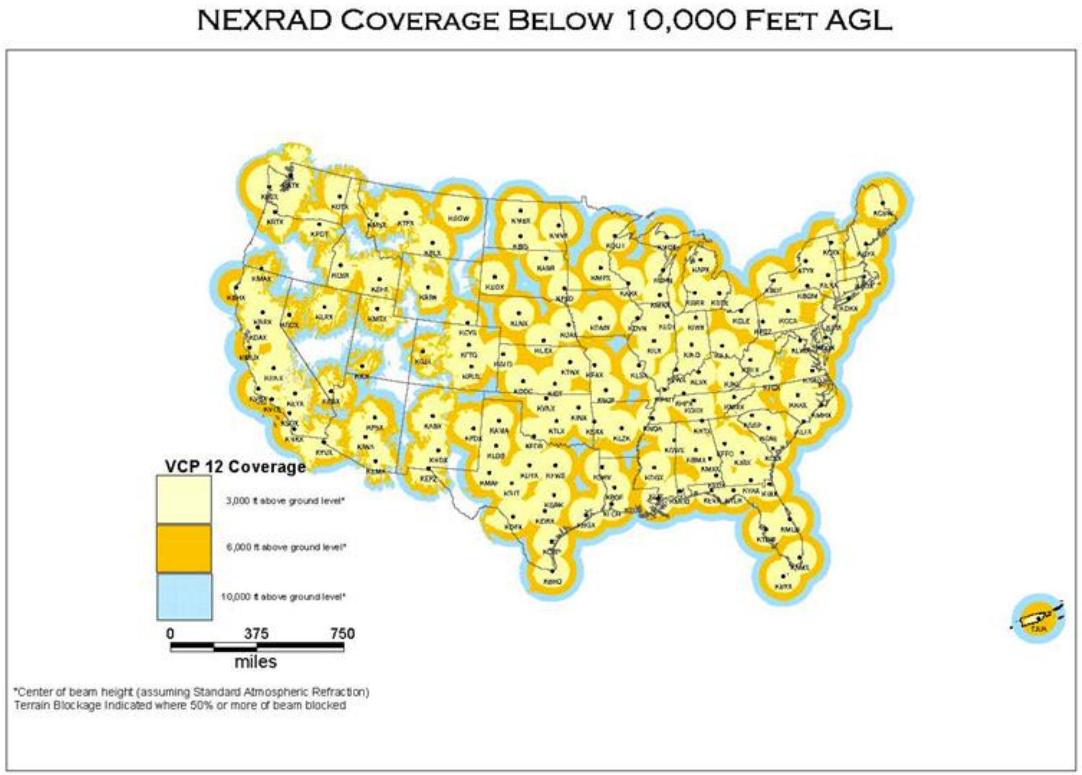


Figure 1. Our motivation was to see whether we could use GOES-16 and HRRR estimates of summer rainfall rates over Canada, where in situ and radar measurements are limited. Pelmorex/The Weather Network use a “Virtual Observation Engine” to estimate current meteorological parameters, including precipitation, at locations where measurements (including radar) are not available. Will GOES-16 precipitation estimates help?

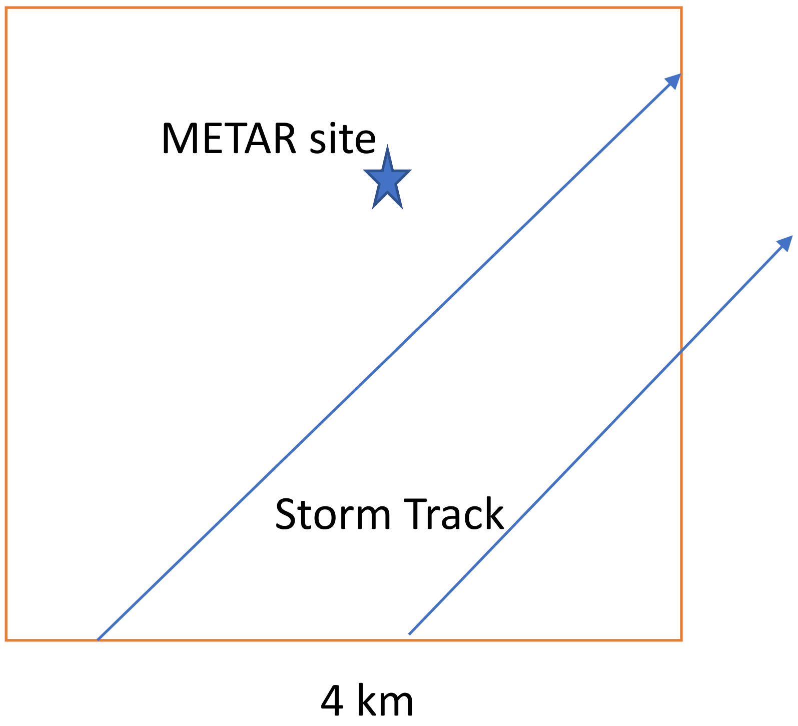
Point Measurements and Gridded Data/Model output

The downloaded CONUS model and remote sensing data sets are on different spatial grids. The HRRR provides output on a 3km grid while the GOES and Stage IV data sets respectively are considered to have a 4km resolution. PRISM data are available on a 4km grid.

The METAR data are at relatively coarse resolution (~ 50 km). The number of METAR stations used in this analysis are 2214, 2217 and 2229 for June, July and August respectively. Other data are "interpolated" to the METAR locations. Closest grid point was found to be as good and linear interpolation.

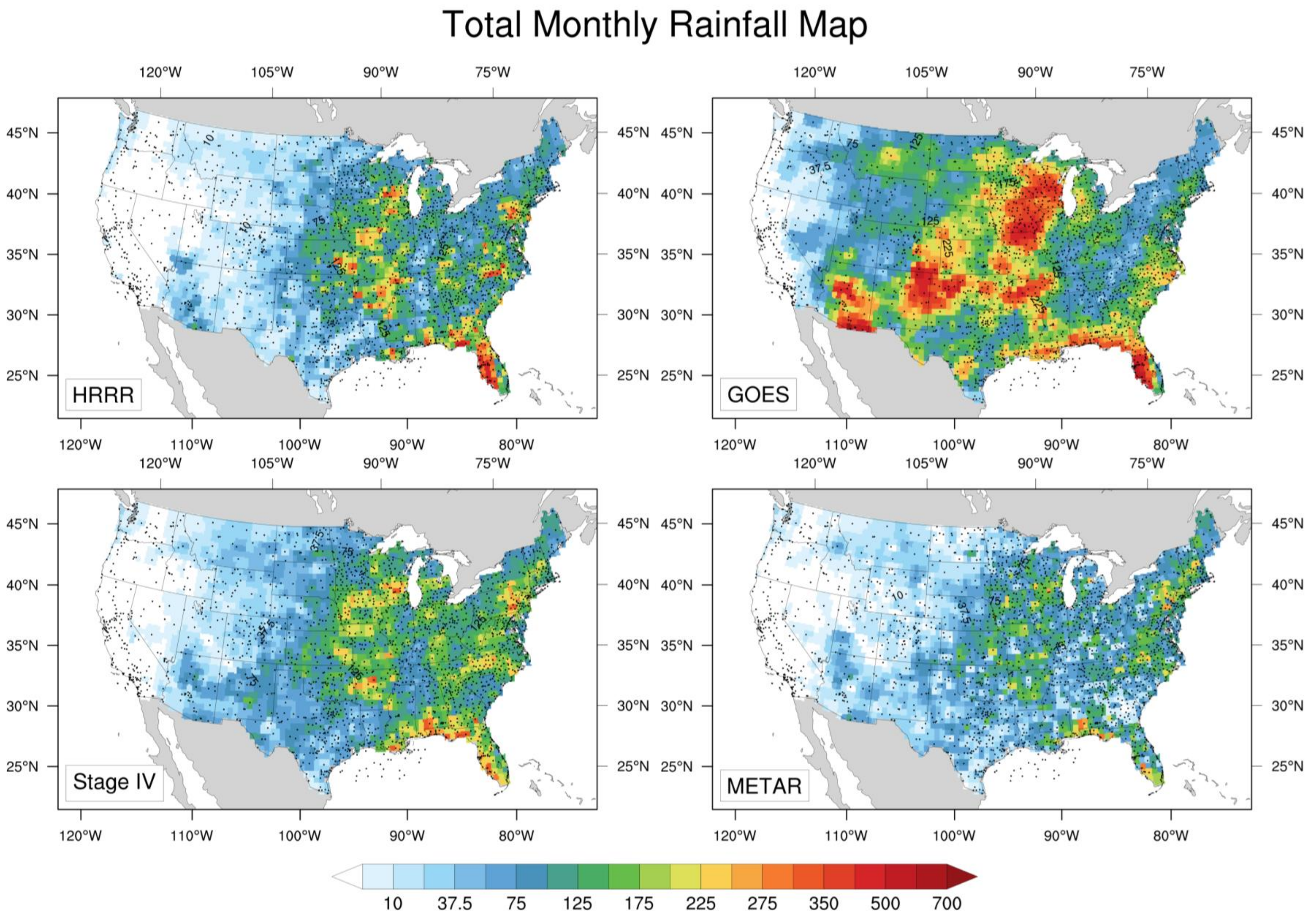
Summer precipitation is often convective. Let's assume a 50% convective/stratiform ratio. The typical horizontal scale of convective precipitation can vary considerably but 1-2 km is a plausible scale to use. Translations speeds are typically 10s of km/h so one guess of the likelihood of a cell passing over a specific point in a 4km x 4km grid cell in an hour would be in the 25-50% range and the ratio of hourly precipitation amount at the fixed METAR site relative to the grid square average would range from 0 to about 4

Averaging over a month should remove this variability, and so would averaging over 2000+ locations at a particular hour. But histograms of hourly precipitation rate will differ and site-specific Rain/No Rain forecasts will be a problem.



Forecast/Estimated/Measured total monthly rainfall (mm) maps from the HRRR, GOES, Stage IV and METAR data sets (land surface only, after interpolation to the METAR sites) for August 2018.

Sum of 31X24 hourly values at each site.



Forecast/Estimated/Measured averaged hourly rainfall rate from the HRRR, GOES, Stage IV and METAR data sets for August 2018. Average over all 2219 METAR locations, no area weighting.

There is an overall wet bias, i.e. over estimations of QPEs by HRRR, GOES and Stage IV data sets compared with the METAR observation. The QPE of the GOES satellite data has the greatest wet bias. A notable feature is a strong diurnal cycle, especially in the GOES data set.

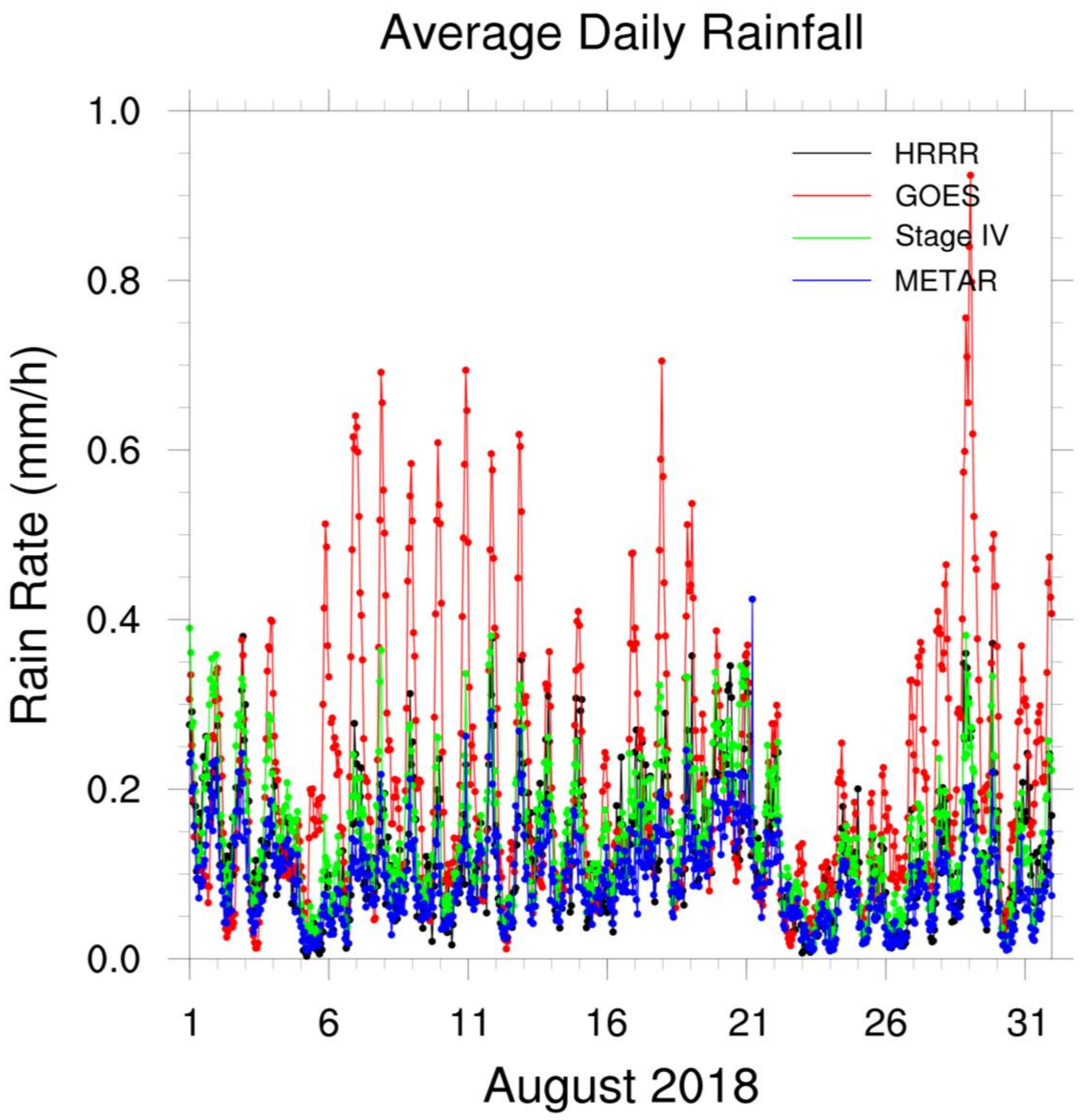


Table 2: a) Total monthly precipitation (Total ppt, mm) averaged over all stations reporting data and missing data (MD, %) for Summer 2018. HRRR, GOES, Stage IV and PRISM data are interpolated to METAR sites and then accumulated and averaged.

Data Set	June		July		August	
	Total ppt	MD	Total ppt	MD	Total ppt	MD
HRRR	155.26	0	110.64	0	90.47	0
GOES	177.71	0.016	156.27	0.404	155.19	0.134
Stage IV	103.95	0.972	100.78	0.898	105.56	1.244
METAR	69.50	2.919	65.06	3.244	69.96	3.628
PRISM	102.94	0	95.88	0	104.13	0

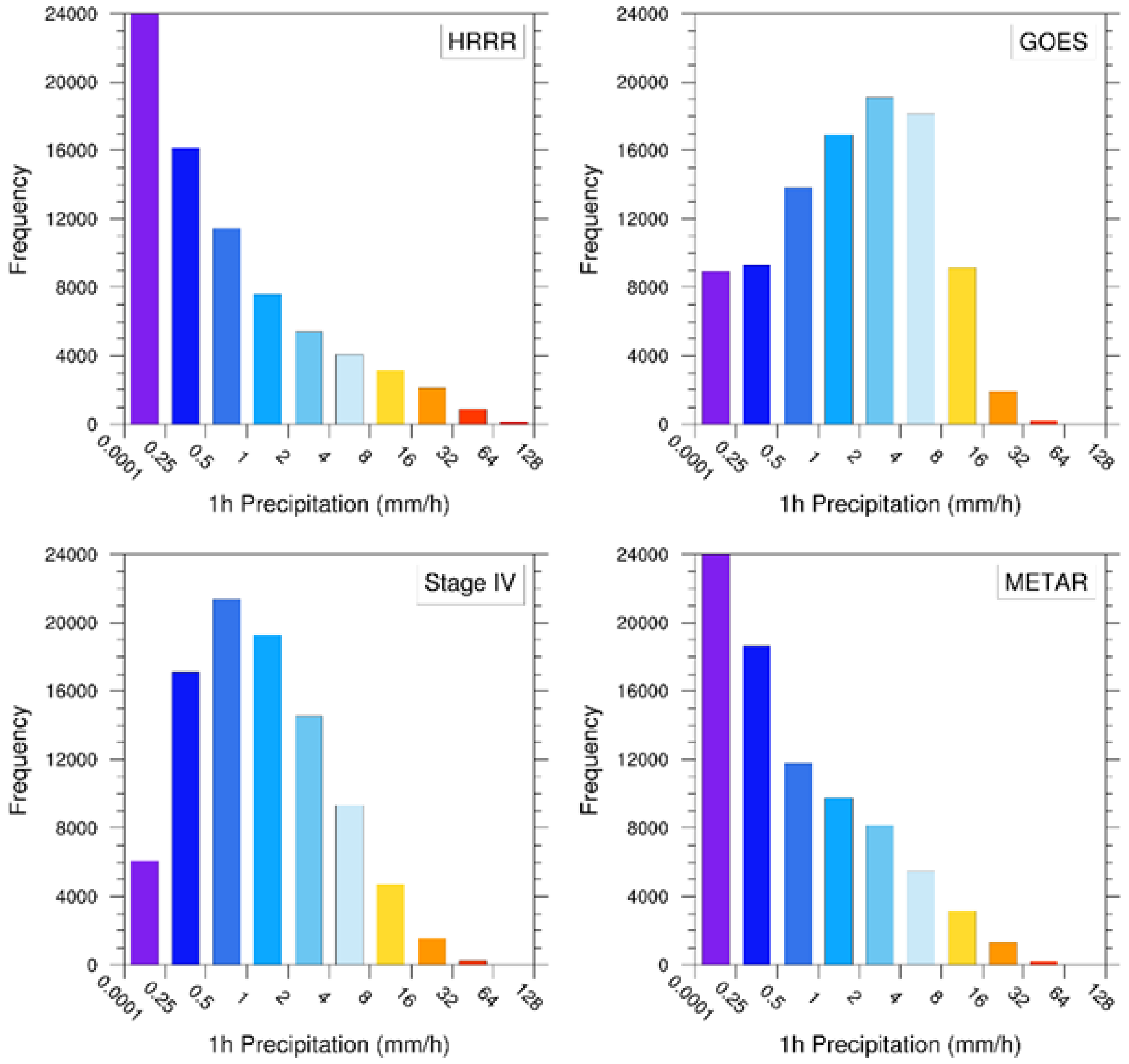
Table 5: Contingency table of hourly rainfall rate at METAR locations for August 2018.

METAR	HRRR		GOES		Stage IV	
	Yes	No	Yes	No	Yes	No
Yes	21,875	17,959	20,054	19,751	35,393	4,379
No	26,616	1,531,748	65,393	1,490,852	40,340	1,498,392
Totals	1,598,198		1,596,050		1,578,504	

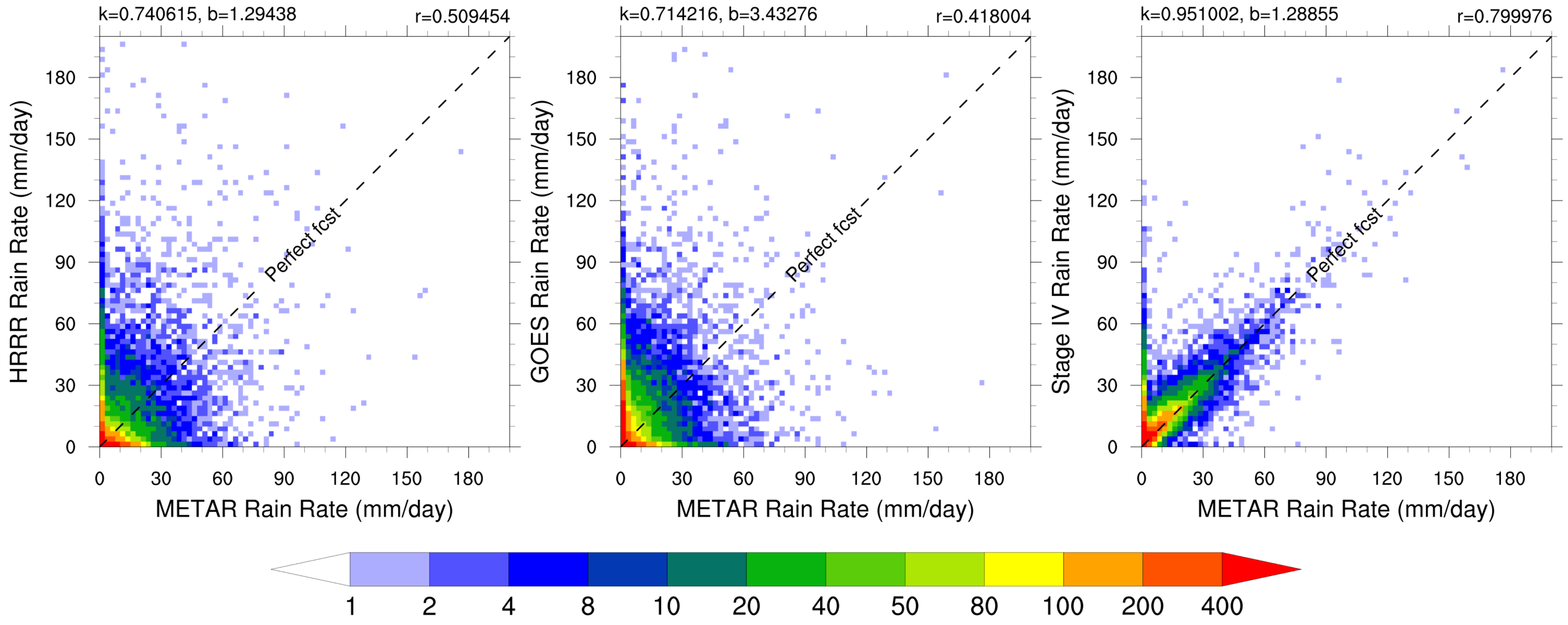
Key point is that HRRR, GOES and Stage IV report precip in their grid squares when METAR stations in the grid boxes have none. YES ≡ precip ≥ 0.254 mm/h

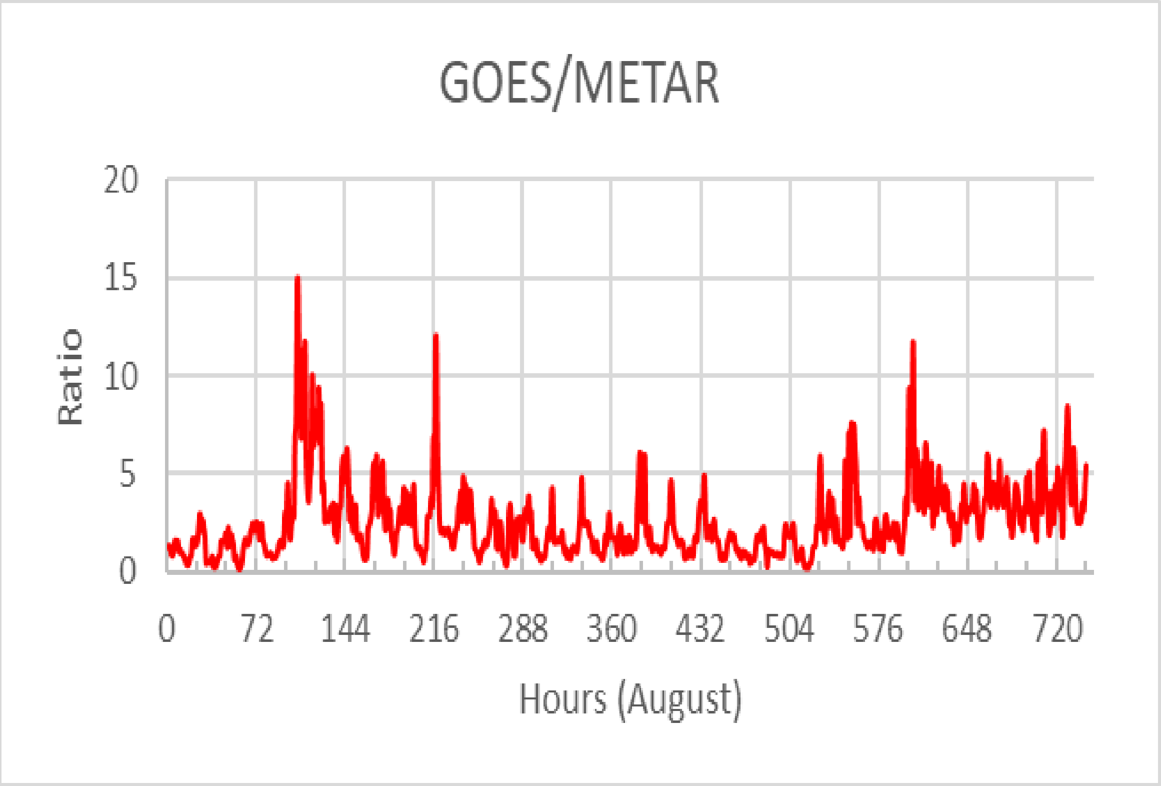
Rainfall rate histograms, Aug 2018.
Note log scale of precipitation rate bins. GOES data have fewer low precip rate cases. HRRR and METAR are off-scale at lowest rate bin. Total possible occurrences, zeros included, are 1,68,376 from 2219 METAR sites

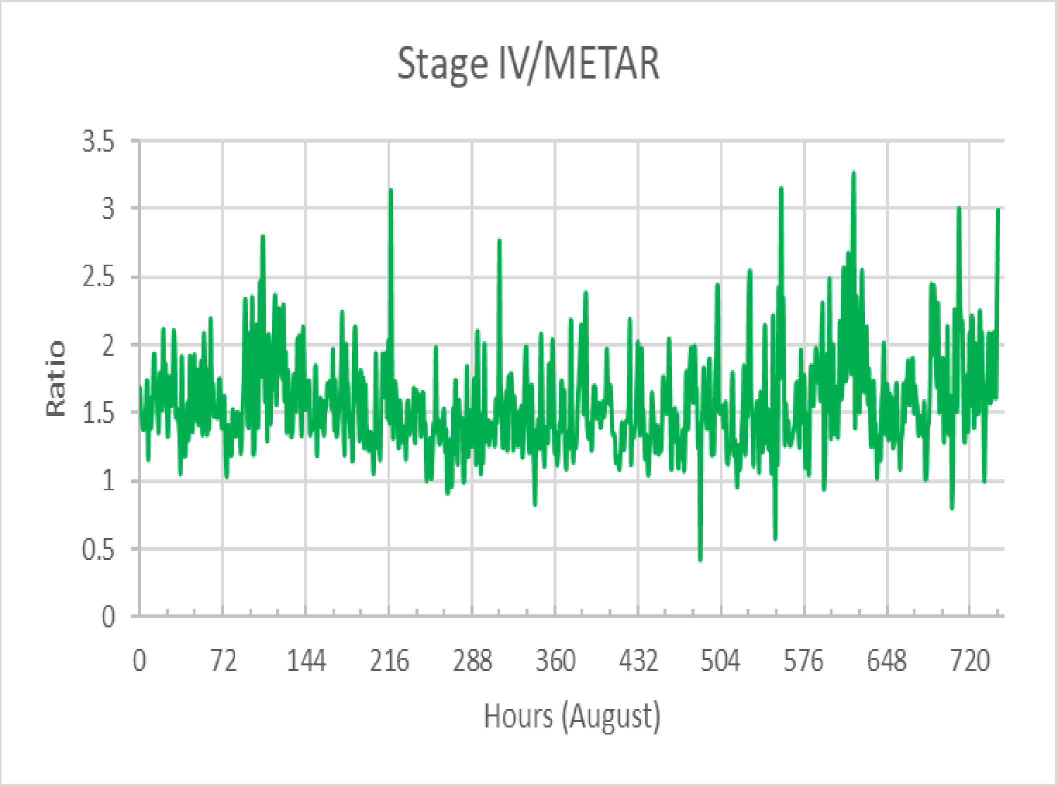
METAR data have far more low precipitation cases than HRRR or Stage IV. Zero precip cases are not shown but again METAR has more that Stage IV. METAR sites report fewer cases in ranges from 0.5 to 16 mm/h.



Correlation plots, daily precipitation totals, Aug 2018 over CONUS METAR sites. Total numbers 2219 x 31 = 68,789 comparison points. Note large number of low METAR values.



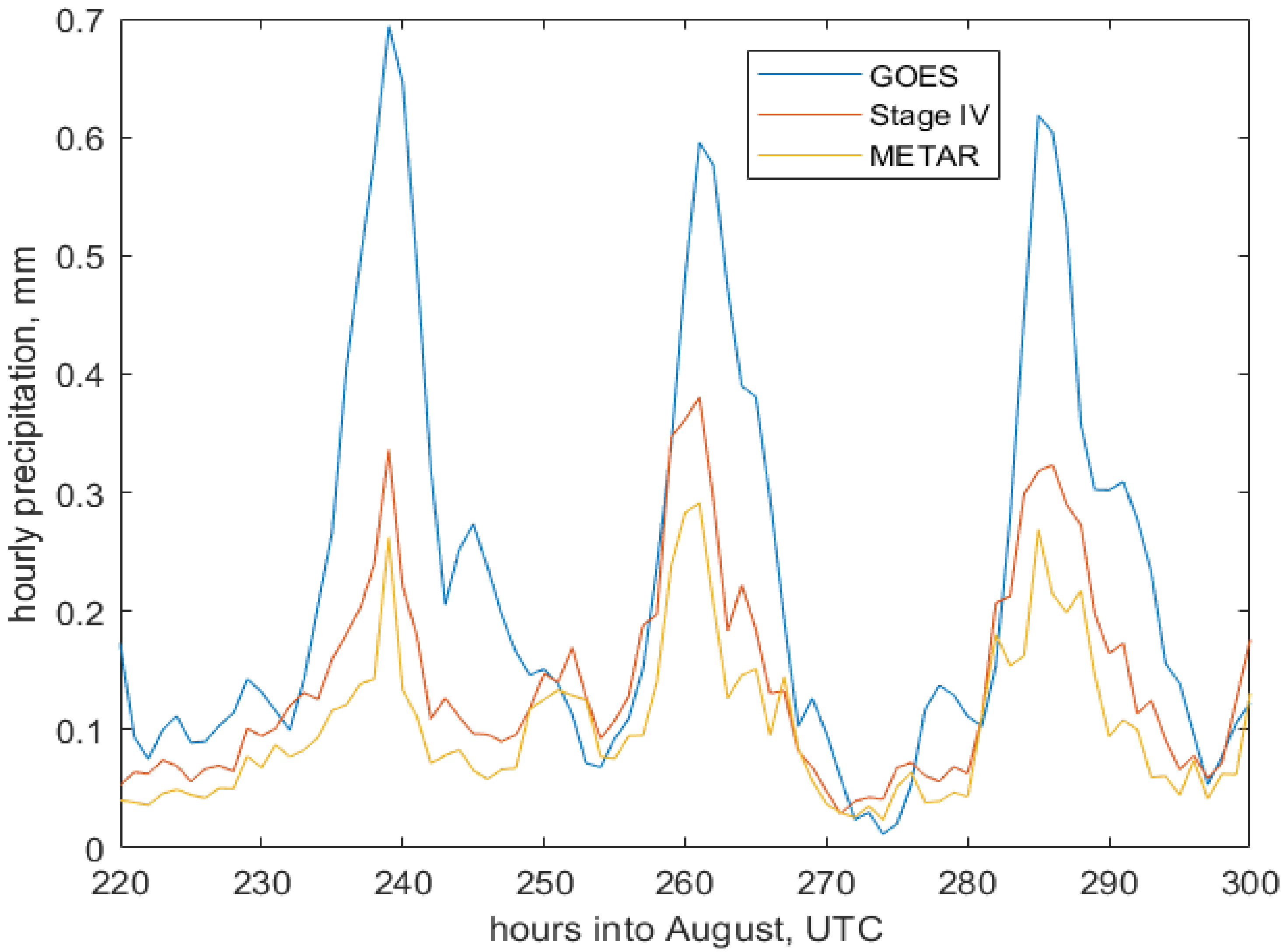


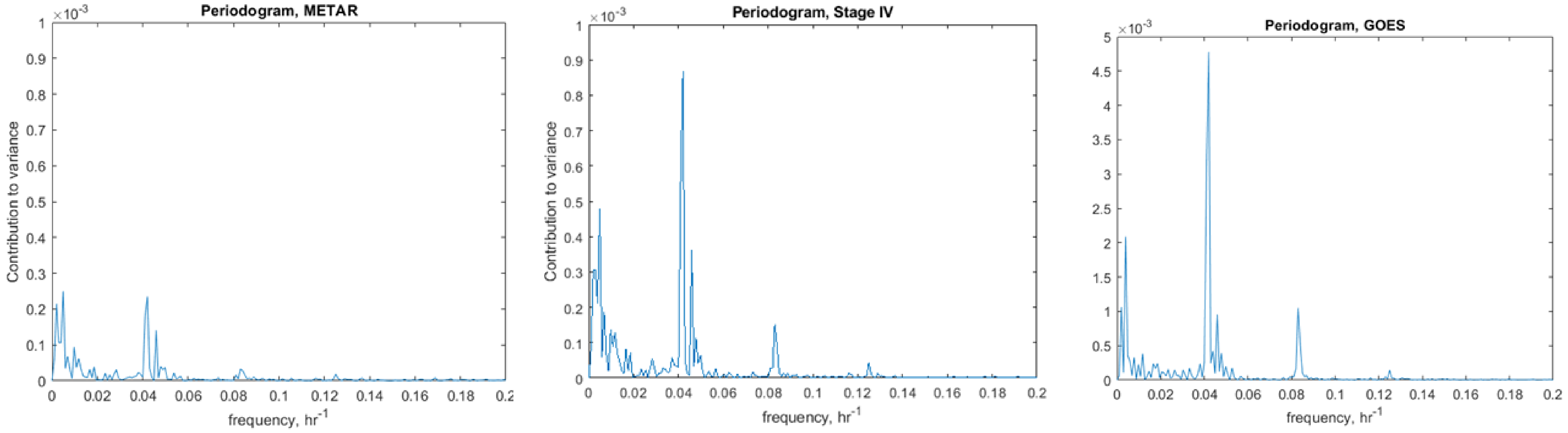


Hourly ratios of precipitation rates averages over all METAR stations in CONUS during August 2018. Note different ratios GOES and Stage IV. GOES/METAR ratio has a strong diurnal variability. Stage IV/METAR ratio close to 1.5, as in Table 2 (Slide 6).

Figure 12: Averaged hourly precipitation at METAR sites across CONUS during 3 days in August 2018. METAR measurements, Stage IV analyses and GOES estimates.

All have maxima at about 2300 UTC, so 1700 CST, 1800 CDT.

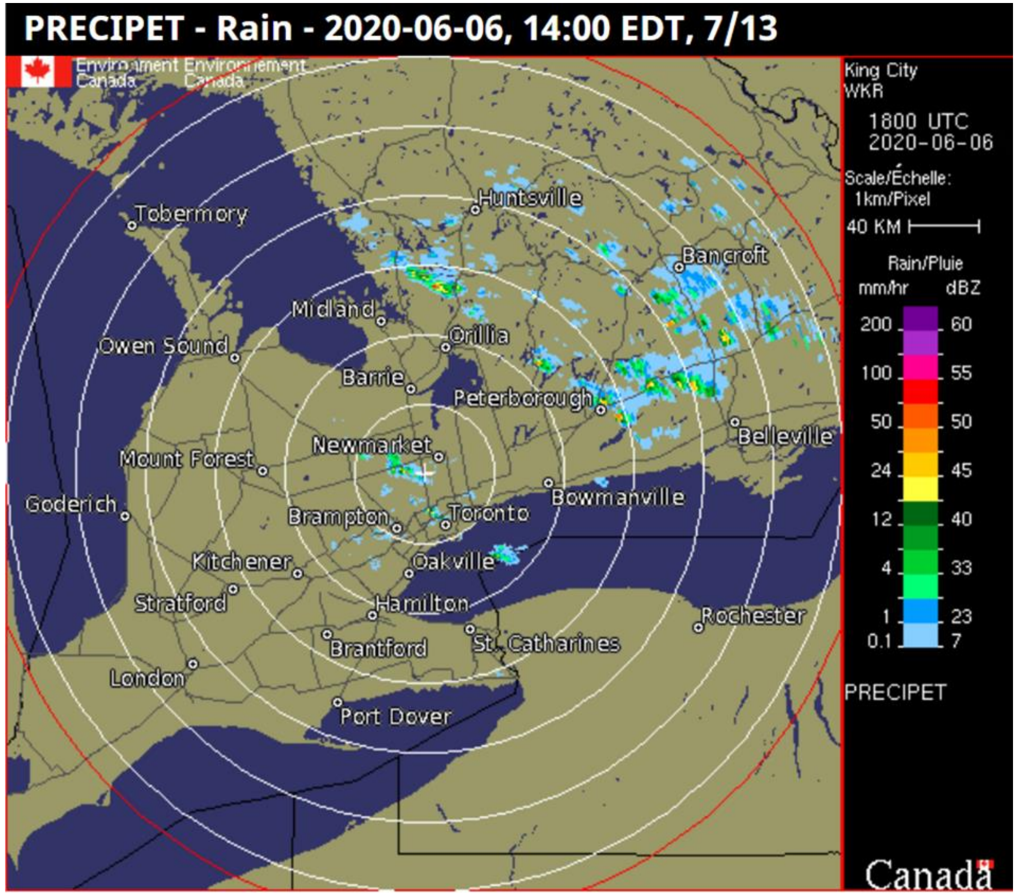


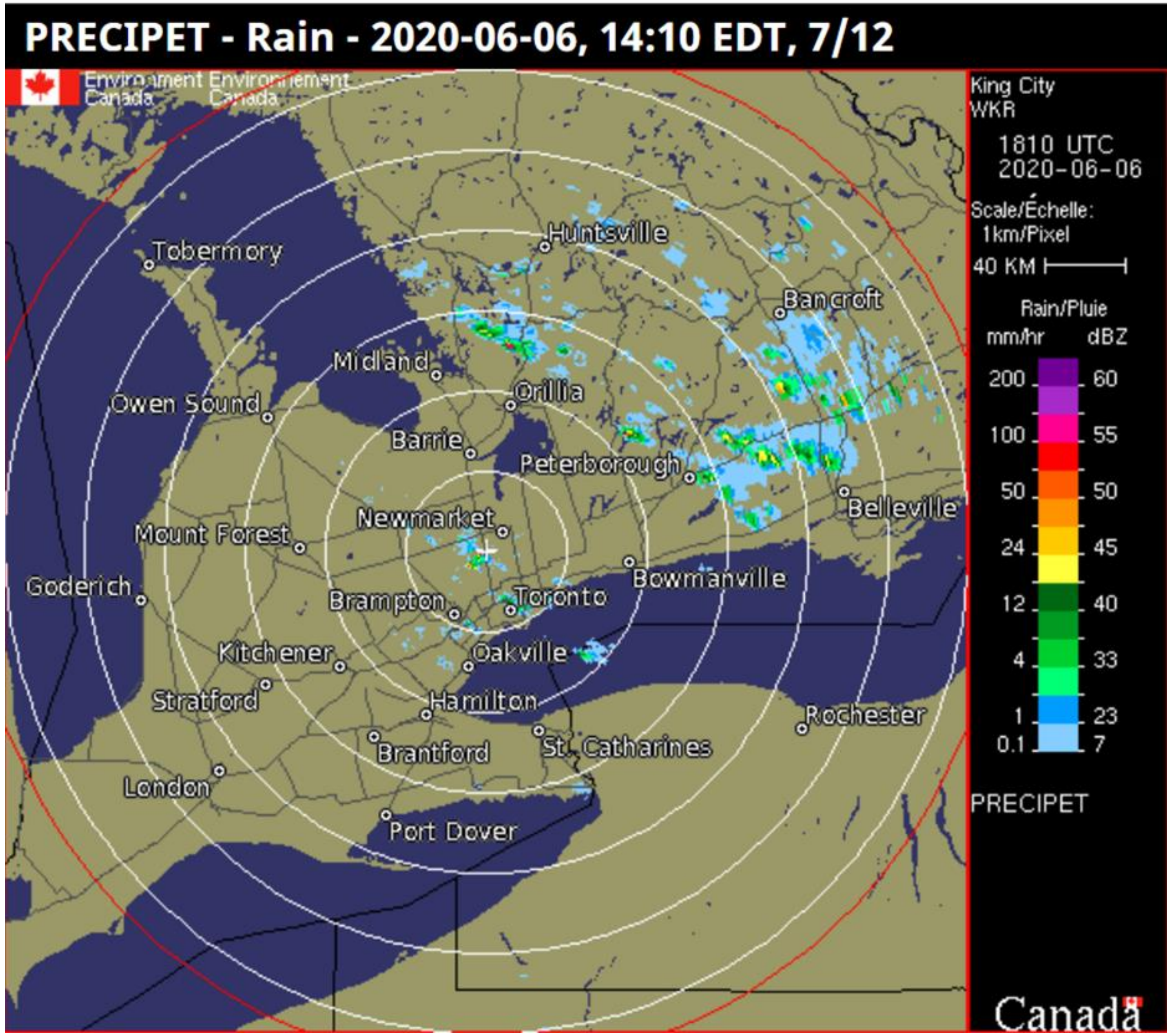


Periodograms of hourly precipitation rates summed over the CONUS METAR locations in August 2018. Note 1/24 = 0.0417 hr^{-1}. Peak frequencies are slightly offset by Matlab's periodogram/FFT with zero filling from our 744 records to 2^{10}=1024 data points. Note the stronger diurnal component in Stage IV rates and the different (x5) scale on the GOES plot.

Thankyou for listening. Slides are posted at: http://www.yorku.ca/pat/CMOS20-PAT2.pdf

Saturday's rainstorm near home.





The five data sets were downloaded from the following sites:

- HRRR – https://rapidrefresh.noaa.gov/hrrr/HRRR/Welcome.cgi;
- GOES – https://www.ncdc.noaa.gov/airs-web/; and search GOES-R, ABI L2+ product data, RRQPE. See also GOES-16 ABI L2+ Rainfall Rate / QPE (RRQPE) Release at https://www.ncdc.noaa.gov/sites/default/files/attachments/ABI_L2_RRQPE_Provisional_ReadMe.pdf
- Stage IV –See https://www.emc.ncep.noaa.gov/mmb/research/stage4.FAQ.html
- METAR – https://mesonet.agron.iastate.edu/rainfall/obhour.phtml
- PRISM - http://www.prism.oregonstate.edu/