Characterizing Warm-Season Heavy Precipitation in the HREF Means

Diana Stovern (NOAA/PSL), Janice Bytheway (NOAA/PSL), Kelly Mahoney (NOAA/PSL), Sarah Trojniak (CIRES/WPC), James Correia (CIRES/WPC), Ben Moore (NOAA/PSL), and Mimi Hughes (NOAA/PSL)

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WPC Flash Flood and Intense Rainfall Experiment

Motivation

Heavy precipitation from warm-season convection is one of the most challenging weather phenomena to forecast but can be the most impactful.

Convective allowing models (CAMS) are designed to capture the small-scale processes that lead to heavy precipitation rates.

The NCEP High Resolution Ensemble Forecast system (HREF) is an ensemble of CAMS that can give a range of possible outcomes and probabilistic information that cannot be provided by deterministic CAMS alone.

Motivation cont.

Ensemble means commonly used as a starting point in forecasting to characterize model agreement

Ensemble means smooth out high-amplitude features and increase the spread of low-amplitude features → gives a poor representation of extreme precipitation.

Probability-matched means (PMM) improve retention of local convective structures by replacing the ensemble mean amounts with amounts sampled from the distribution of ensemble member forecasts.

The PMM has been found to be more skillful than the individual members and the ensemble mean when forecasting heavy precipitation.

How are PMM and LPMM calculated?

Step 1

For both PMM and LPMM, calculate the traditional ensemble mean at each grid point

Step 2

PMM - sort the values of the ensemble mean from lowest to highest, storing the rank (i.e., numbered position of the sorted values; e.g., the fourth lowest value has a rank of 4) and location of each value

LPMM - within a 40-km radius of each grid point, sort the values of ensemble mean from lowest to highest and record the rank of the center point

Step 3

PMM - sort the values of all ensemble members from lowest to highest

LPMM - within a 40-km radius of each grid point, sort the values of all ensemble members from lowest to highest.

Step 4

PMM - select every nth (n = number of members) value from the array of ranked ensemble member values and swap the values from Step 2 with those from the ranked ensemble members (i.e., the grid point with the highest precipitation amount in the ensemble mean is replaced by the highest value in the distribution of ensemble members, and so on).

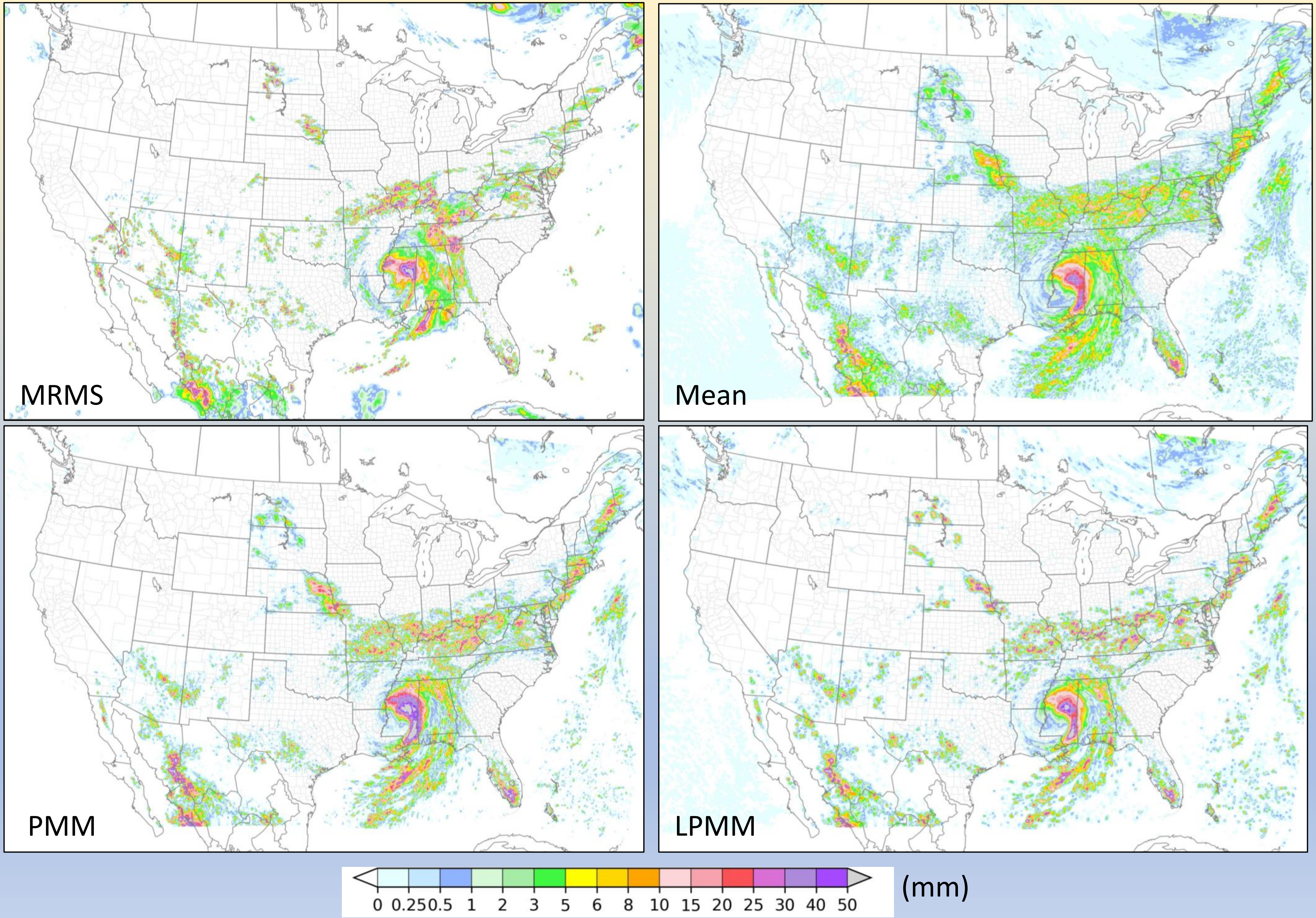
LPMM - replace the value of the neighborhood center point with the sorted ensemble member value ranked.

Example
Hurricane Ida
(2021)

MRMS for 3-hr period ending at 00 UTC on 20210831

vs.

HREF means for init time 20210830 at f=24 hr (3-hr accum
between 22-24 hr)



Data and Methods

HREF Quantitative Precipitation Forecasts (QPF)

- Forecasts for lead times 0–48 h
- ~3 km grid spacing
- 1-hourly temporal resolution
- Verifying 1-in QPF from June, July, August of 2021 and 2022 (static membership)

MRMS Multi-Radar Multi-Sensor Pass 2 (MRMS) Quantitative Precipitation Estimates (QPE)

- 1-km grid spacing
- The MRMS is regridded to the HREF grid using Earth System Modeling Framework's bilinear interpolation
- Comparing HREF to MRMS accumulated to 1-and 3-hourly amounts

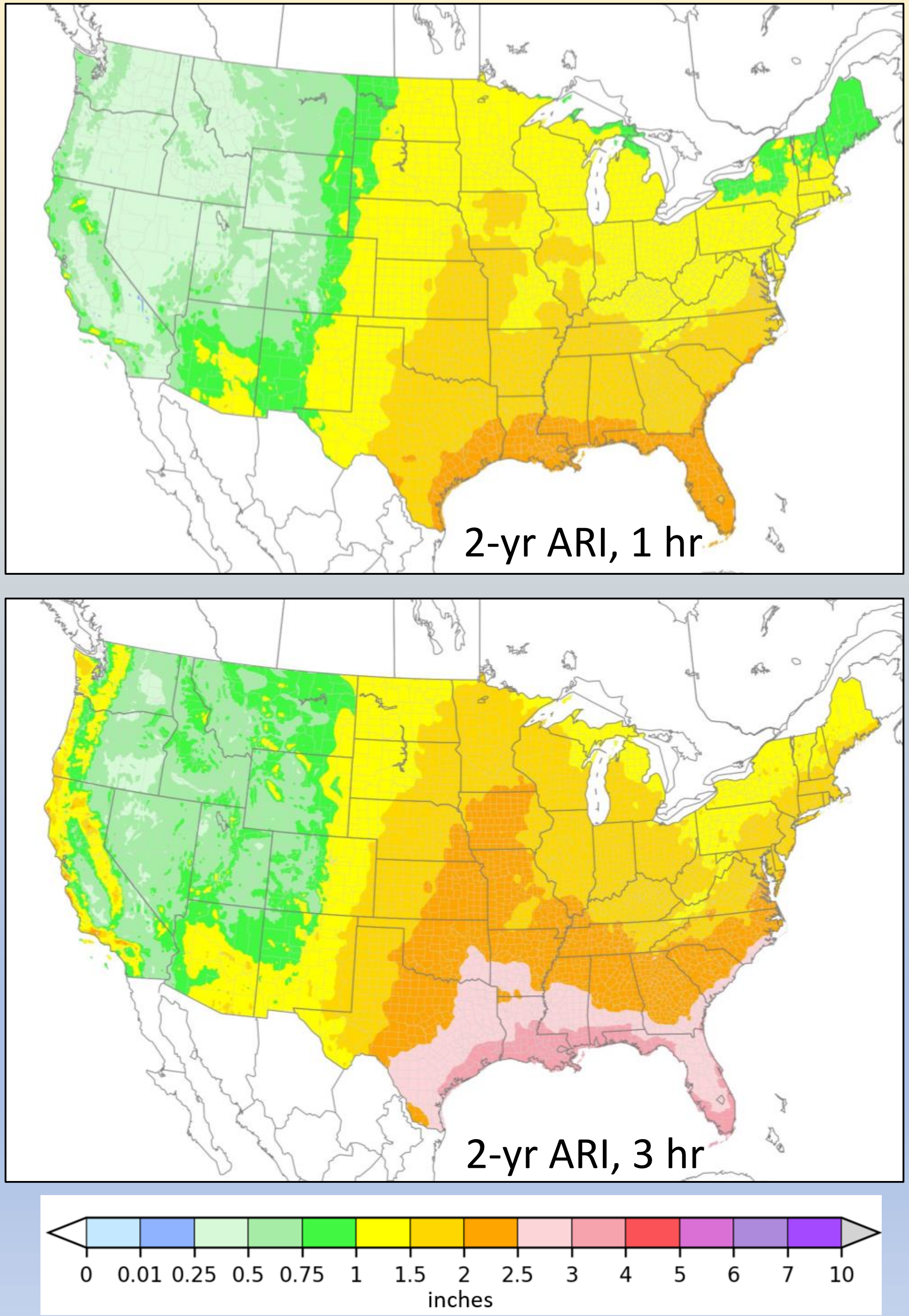
Average Recurrence Intervals (ARIs)

- NOAA Atlas-14 "stitched" with ARI-interpolated grids from Russ Schumacher
- Comparing to the 2-yr ARIs (ARI2) from 1- and 3-hourly duration rainfall

Configuration period: 2021-05-11 through present

Member	ICs	LBCs	Microphysics	PBL	dx (km)	Vert. levels	Included in HREF hours
HRRR	RAP -1h	RAP -1h	Thompson	MYNN	3.0	50	0 - 36
HRRR -6h	RAP -1h	RAP -1h	Thompson	MYNN	3.0	50	0 - 30
HRW ARW	RAP	GFS -6h	WSM6	YSU	3.2	50	0 - 48
HRW ARW -12h	RAP	GFS -6h	WSM6	YSU	3.2	50	0 - 36
HRW FV3	GFS -6h	GFS -6h	GFDL	GFS EDMF	3.0	60	0 - 60
HRW FV3 -12h	GFS -6h	GFS -6h	GFDL	GFS EDMF	3.0	60	0 - 48
HRW NSSL	NAM	NAM -6h	WSM6	MYJ	3.2	40	0 - 48
HRW NSSL -12h	NAM	NAM -6h	WSM6	MYJ	3.2	40	0 - 36
NAM CONUS Nest	NAM	NAM	Ferrier-Aligo	MYJ	3.0	60	0 - 48
NAM CONUS Nest -12h	NAM	NAM	Ferrier-Aligo	MYJ	3.0	60	0 - 48

Source: https://www.spc.noaa.gov/exper/href/#



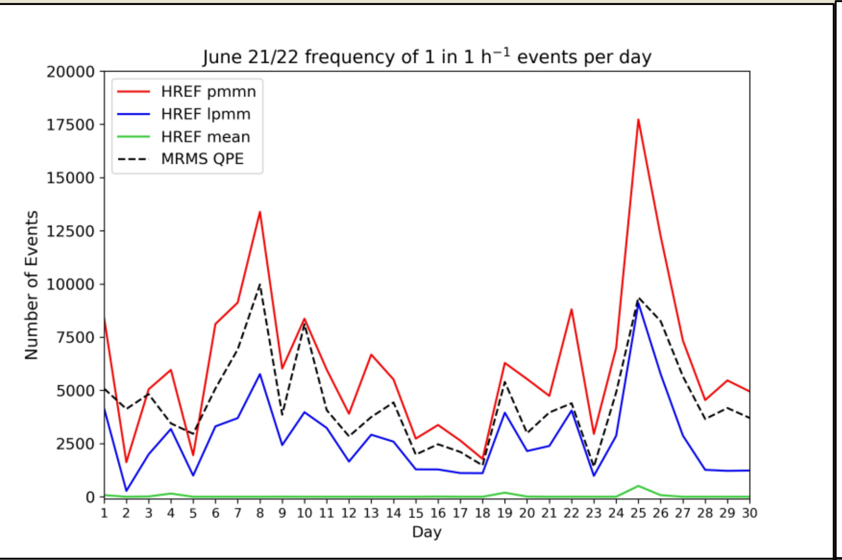
Skill Measures - CSI, POD, FAR

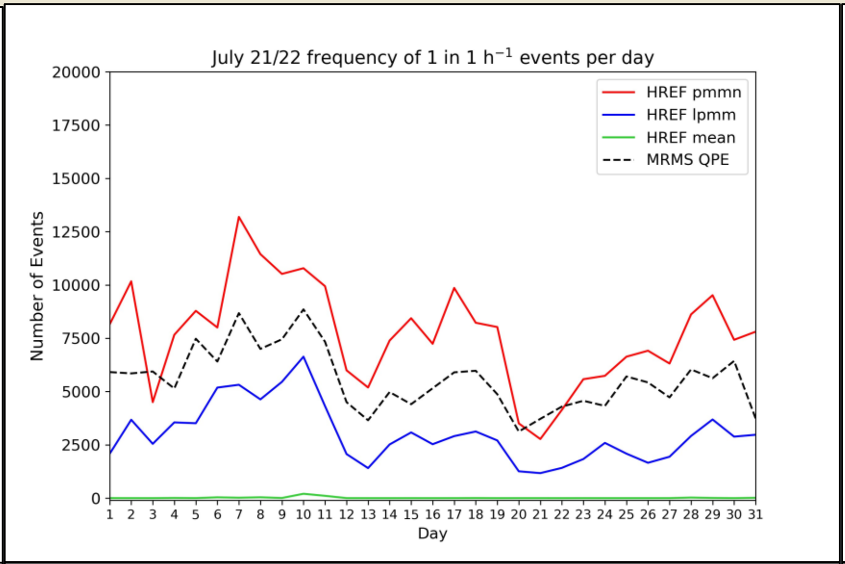
Critical Success Index (CSI) - equal to the total number of correct event forecasts (hits) divided by the total number of storm forecasts plus the number of misses (hits + false alarms + misses). The CSI is not affected by the number of non-event forecasts that verify (correct rejections) but is biased in that it is dependent upon the frequency of the event. Perfect skill is represented by CSI values of 1.0.

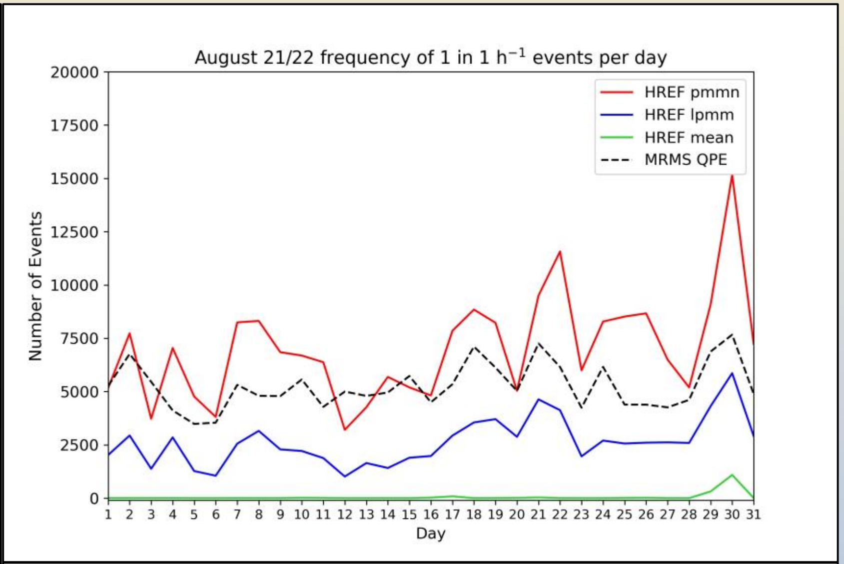
Probability of Detection (POD) - equal to the total number of correct event forecasts (hits) divided by the total number of events observed (i.e. percentage of events that are forecasted). Perfect skill is represented by POD values of 1.0

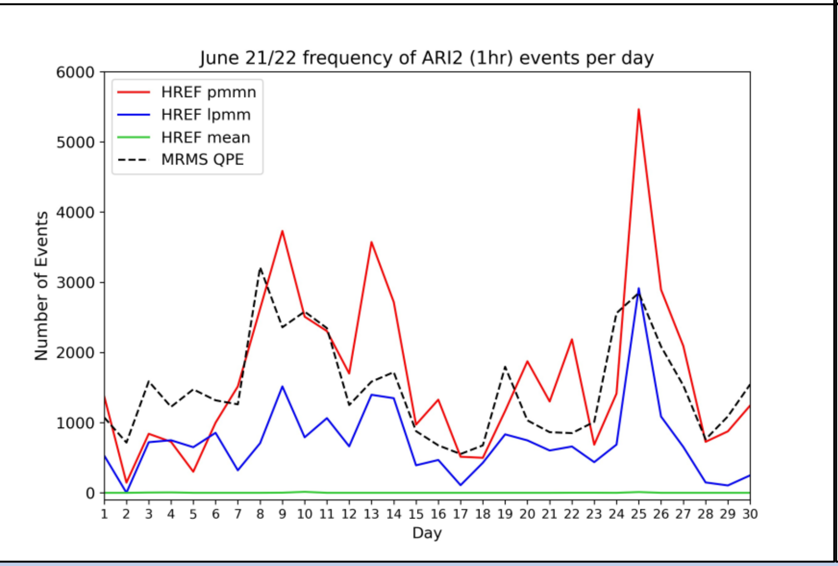
False Alarm Rate (FAR) - equal to the number of false alarms divided by the total number of event forecasts. Perfect skill is represented by FAR values of 0.0.

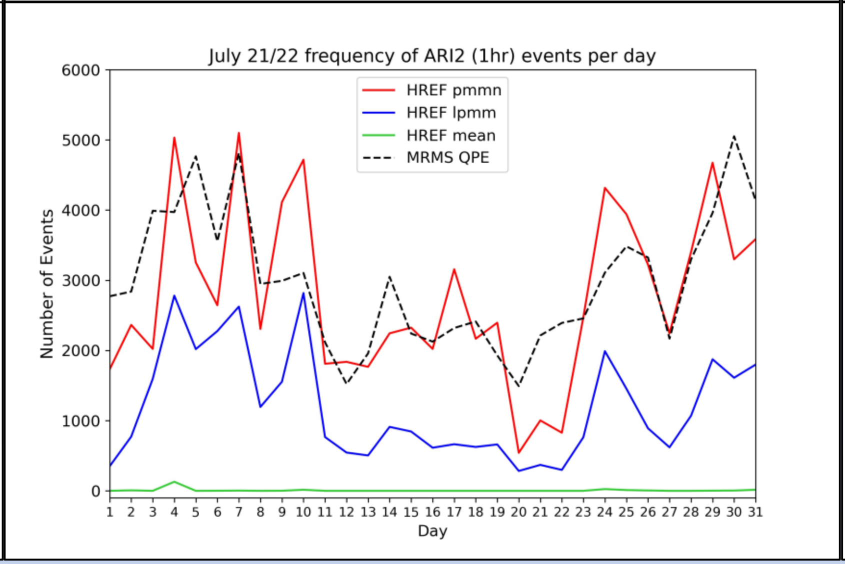
Frequency Analysis by month/day – 1hr

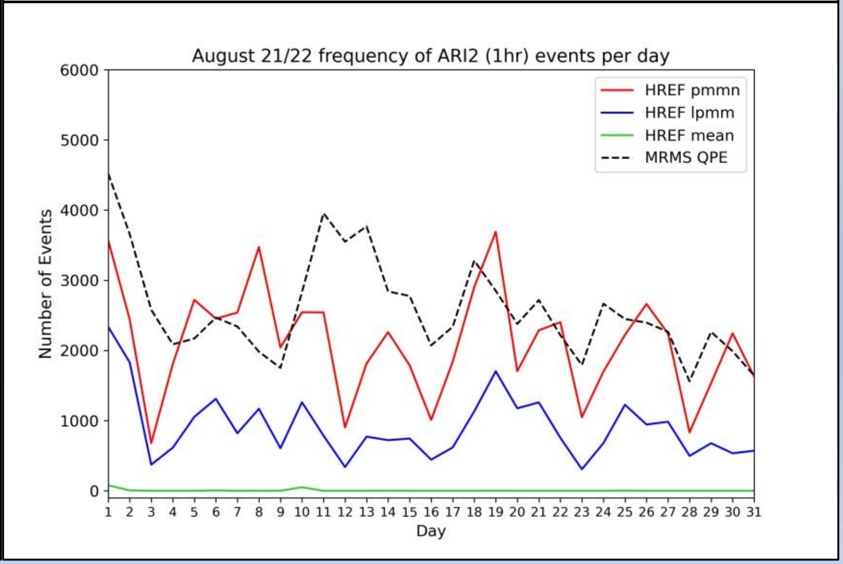




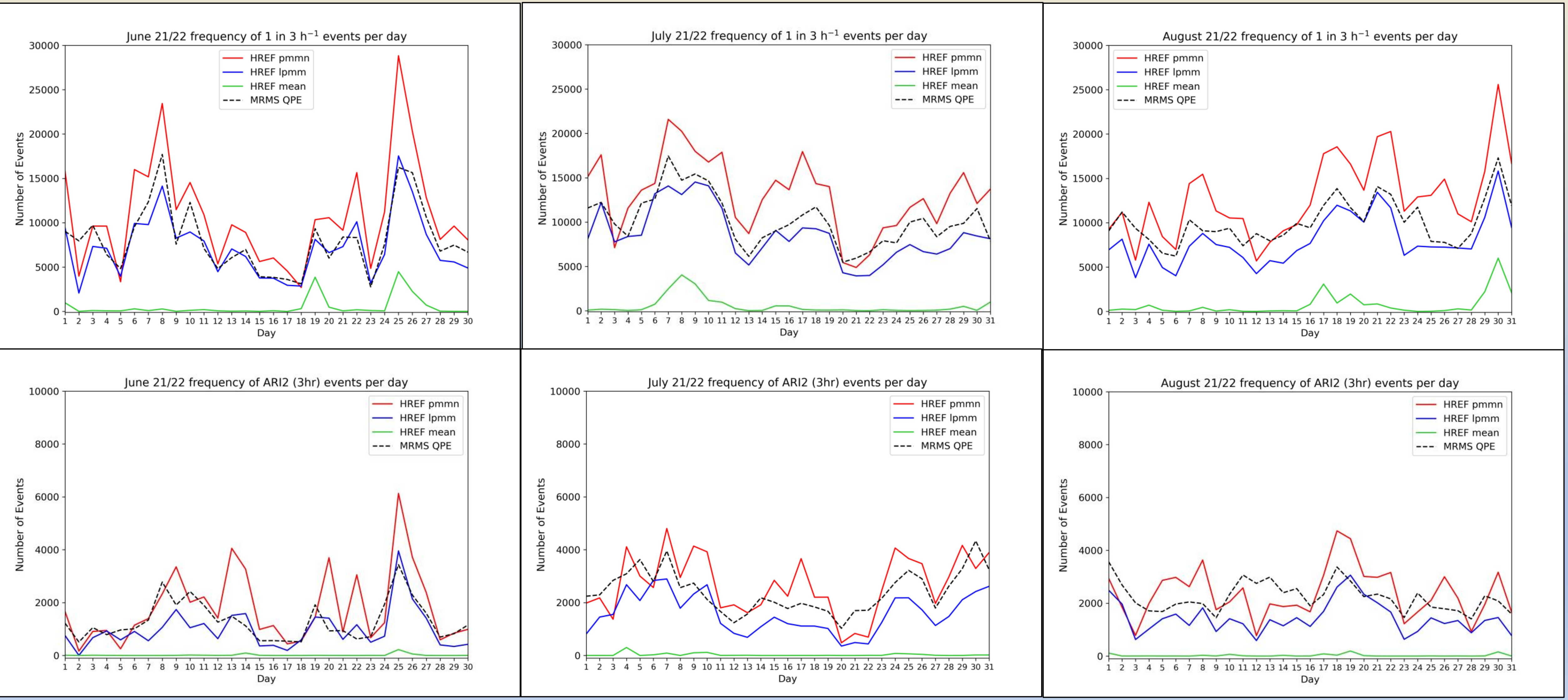


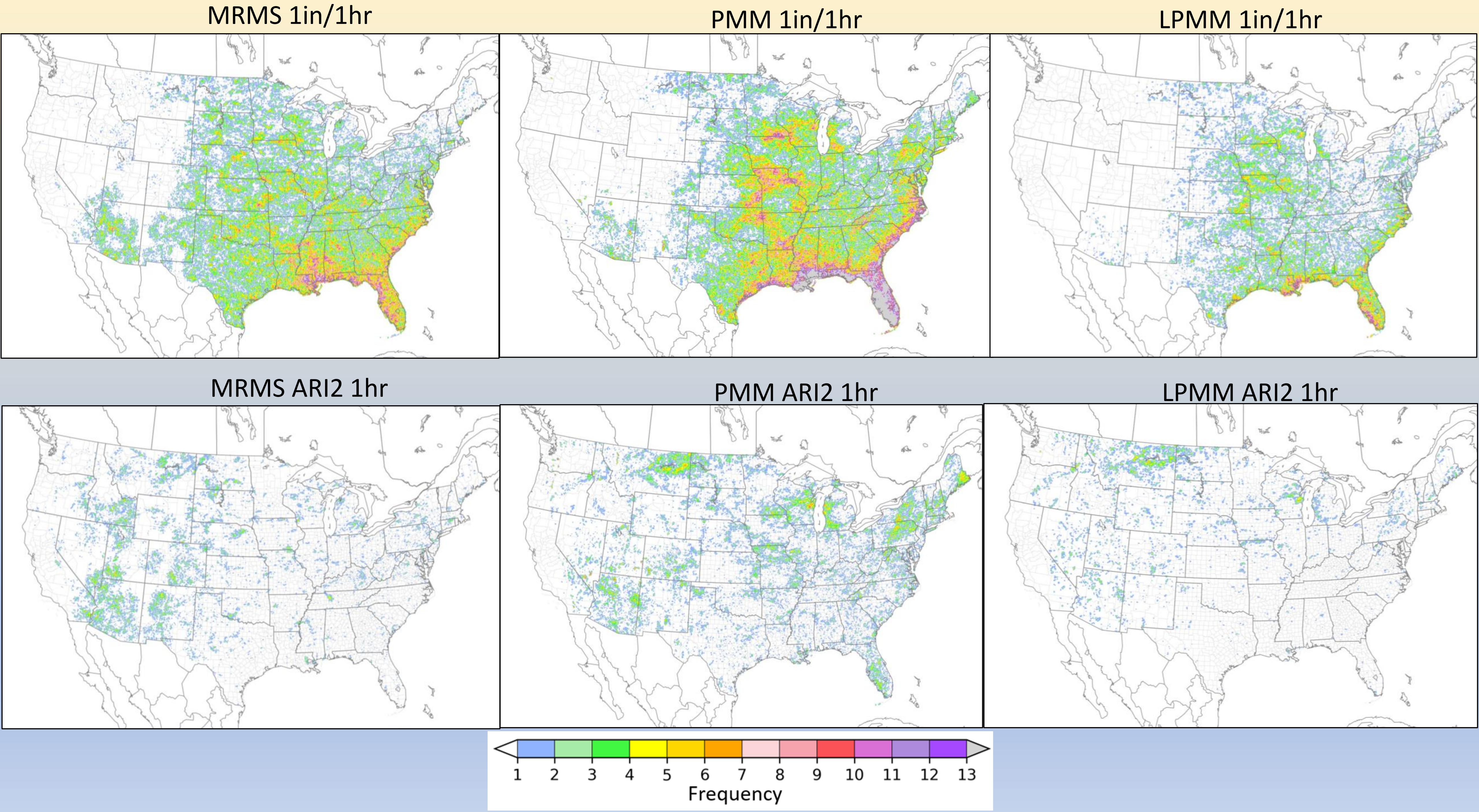




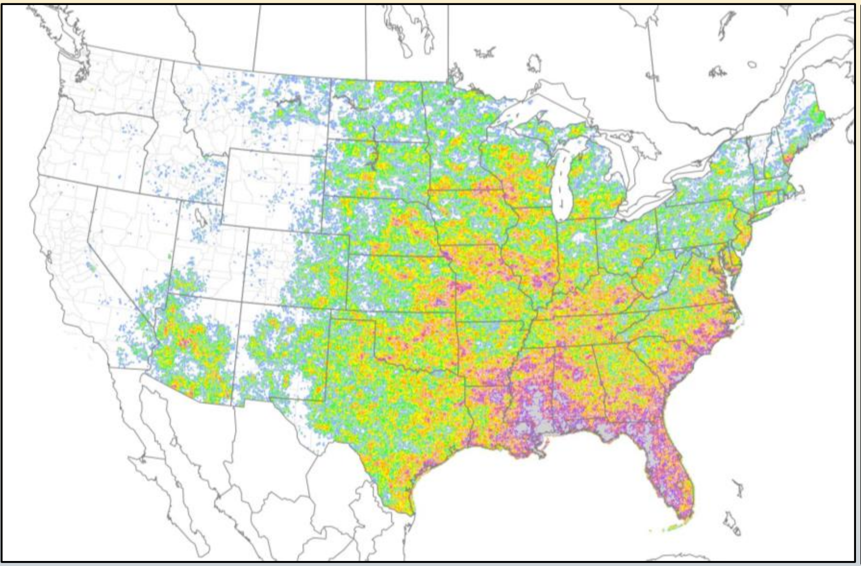


Frequency Analysis by month/day – 3hr

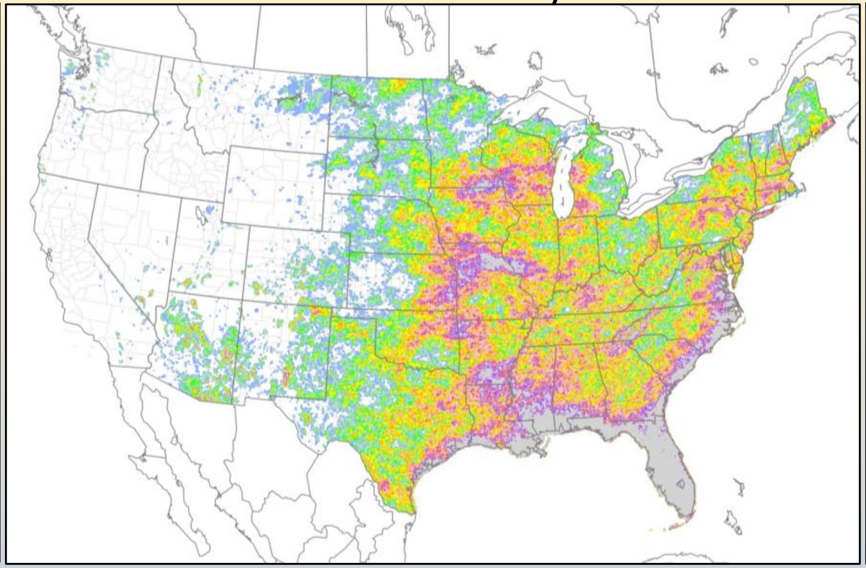



MRMS 1in/1hr
PMM 1in/1hr
LPMM 1in/1hr
MRMS ARI2 1hr
PMM ARI2 1hr
LPMM ARI2 1hr
1
2
3
4
5
6
7
8
9
10
11
12
13
Frequency

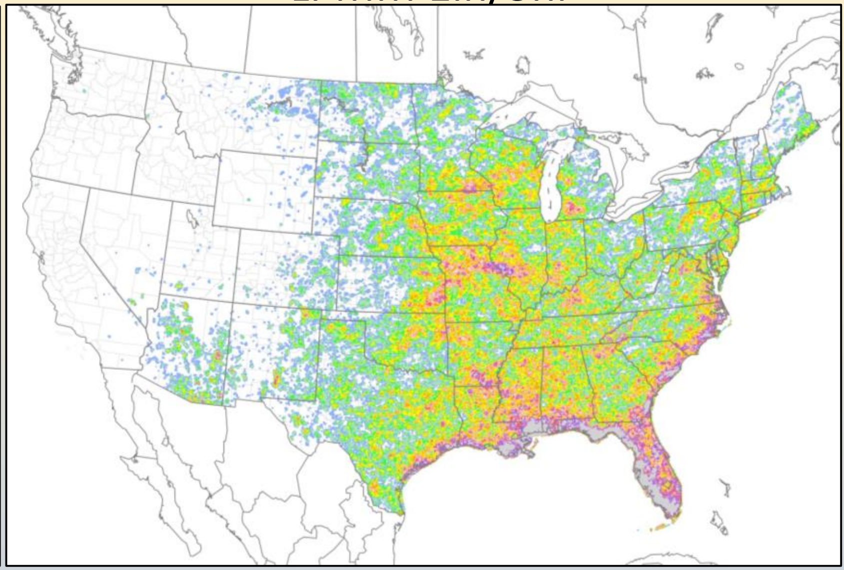
MRMS 1in/3hr



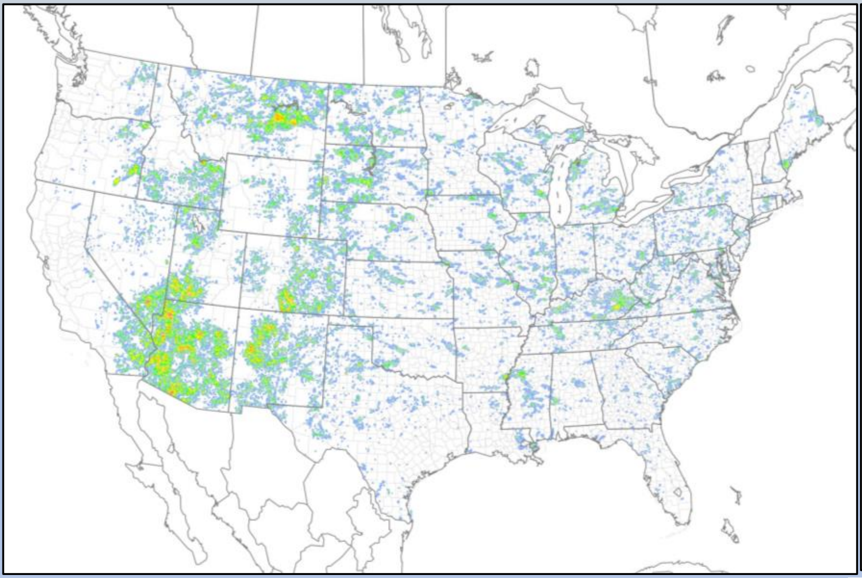
PMM 1in/3hr



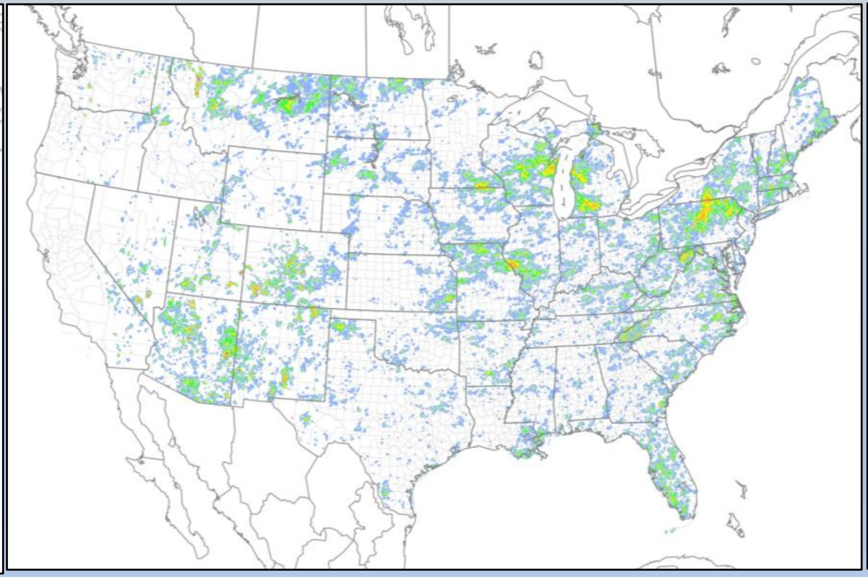
LPMM 1in/3hr



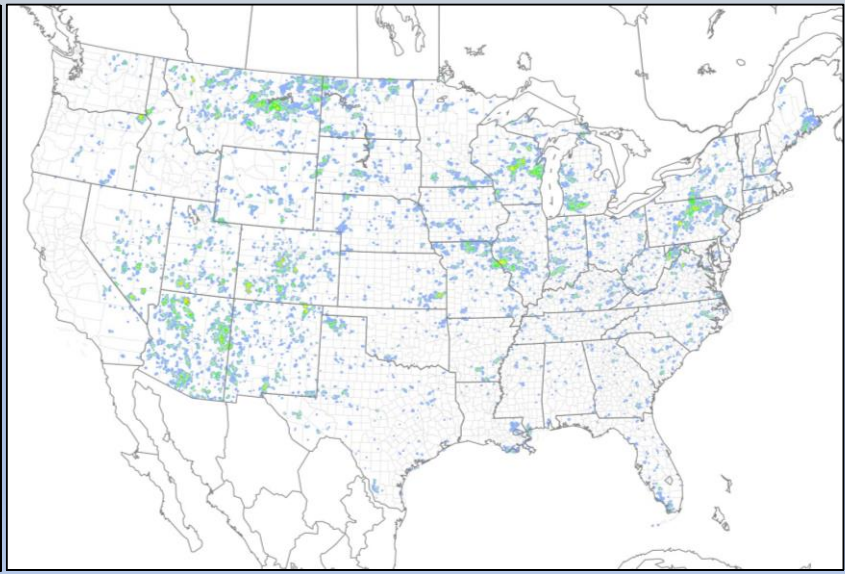
MRMS ARI2 3hr

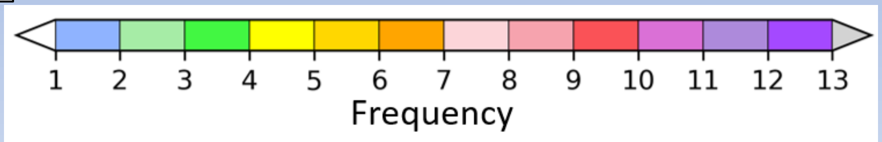


PMM ARI2 3hr



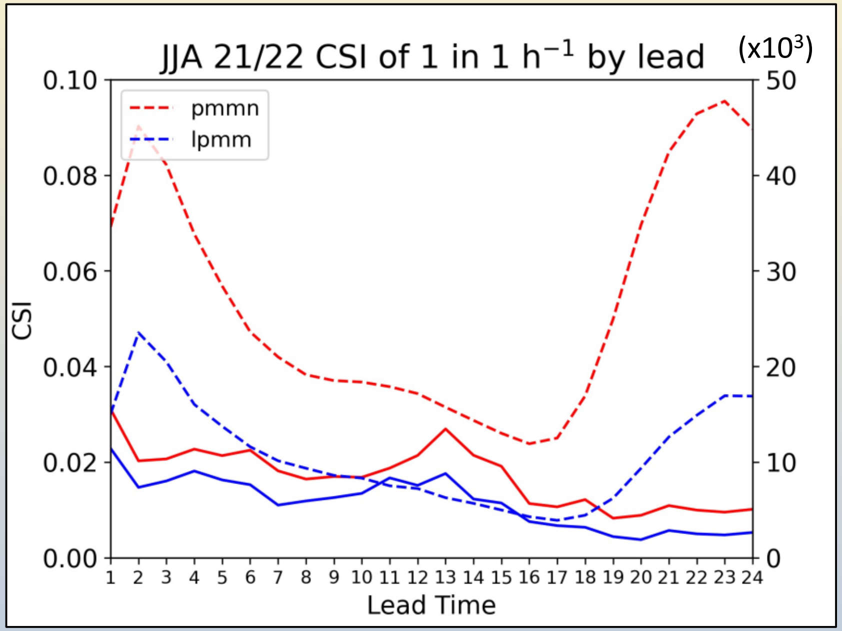
LPMM ARI2 3hr

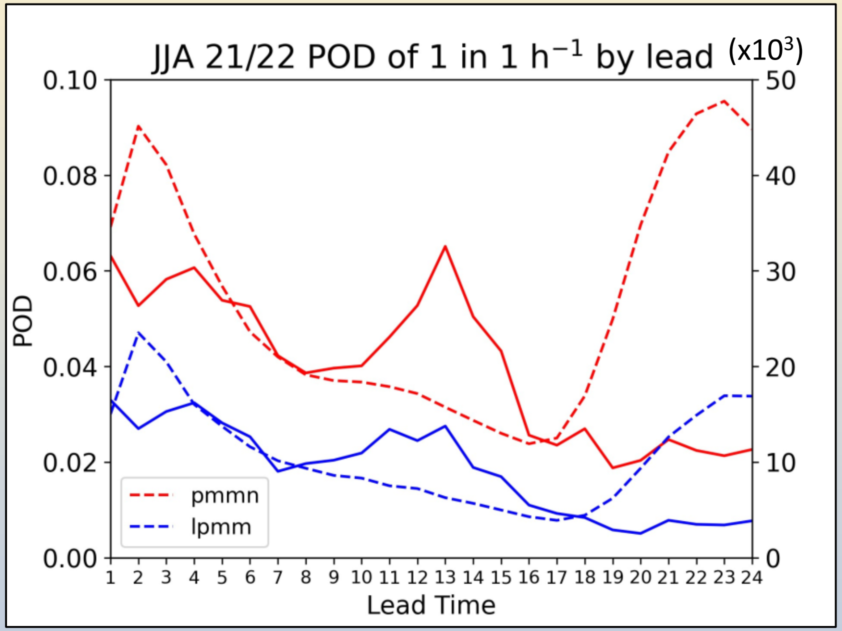


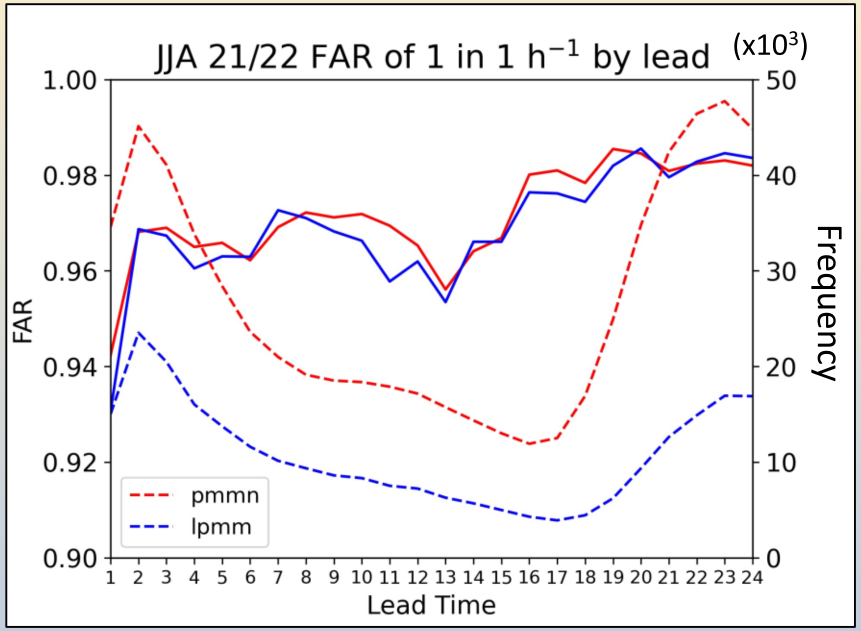


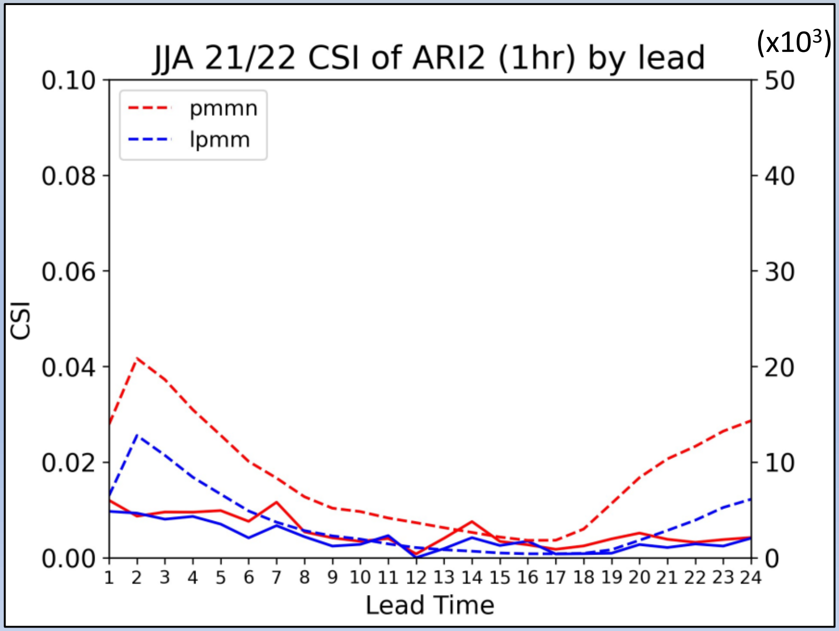
Dashed line - Frequency

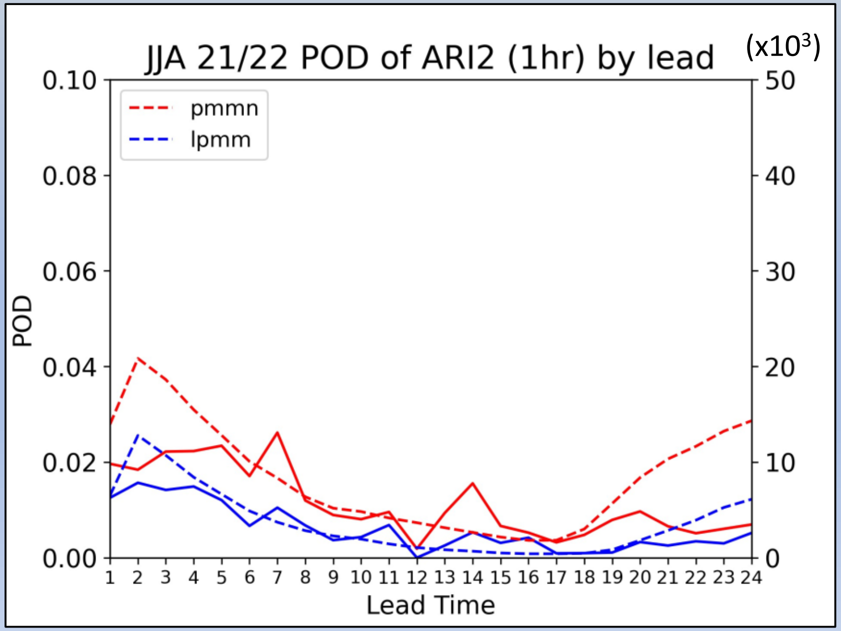
Solid Line - Skill

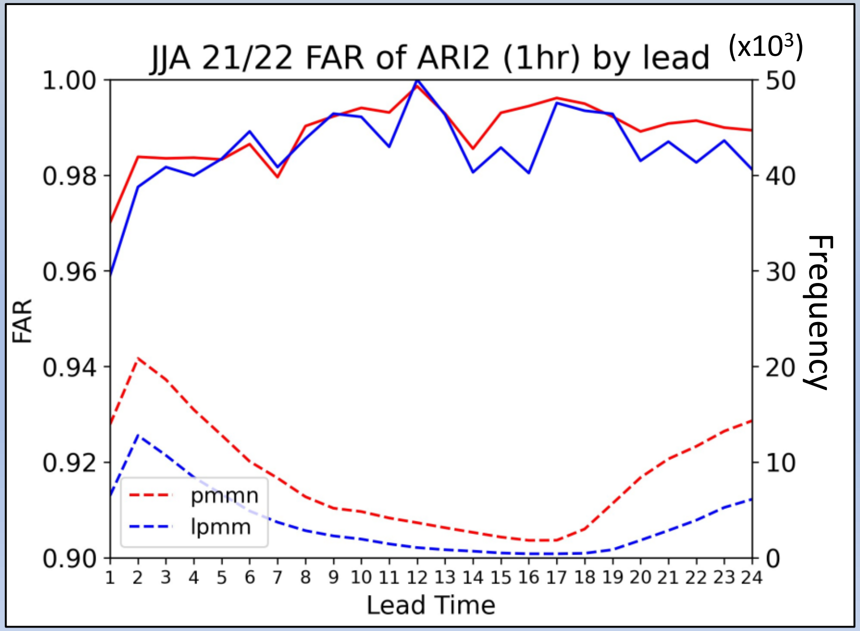




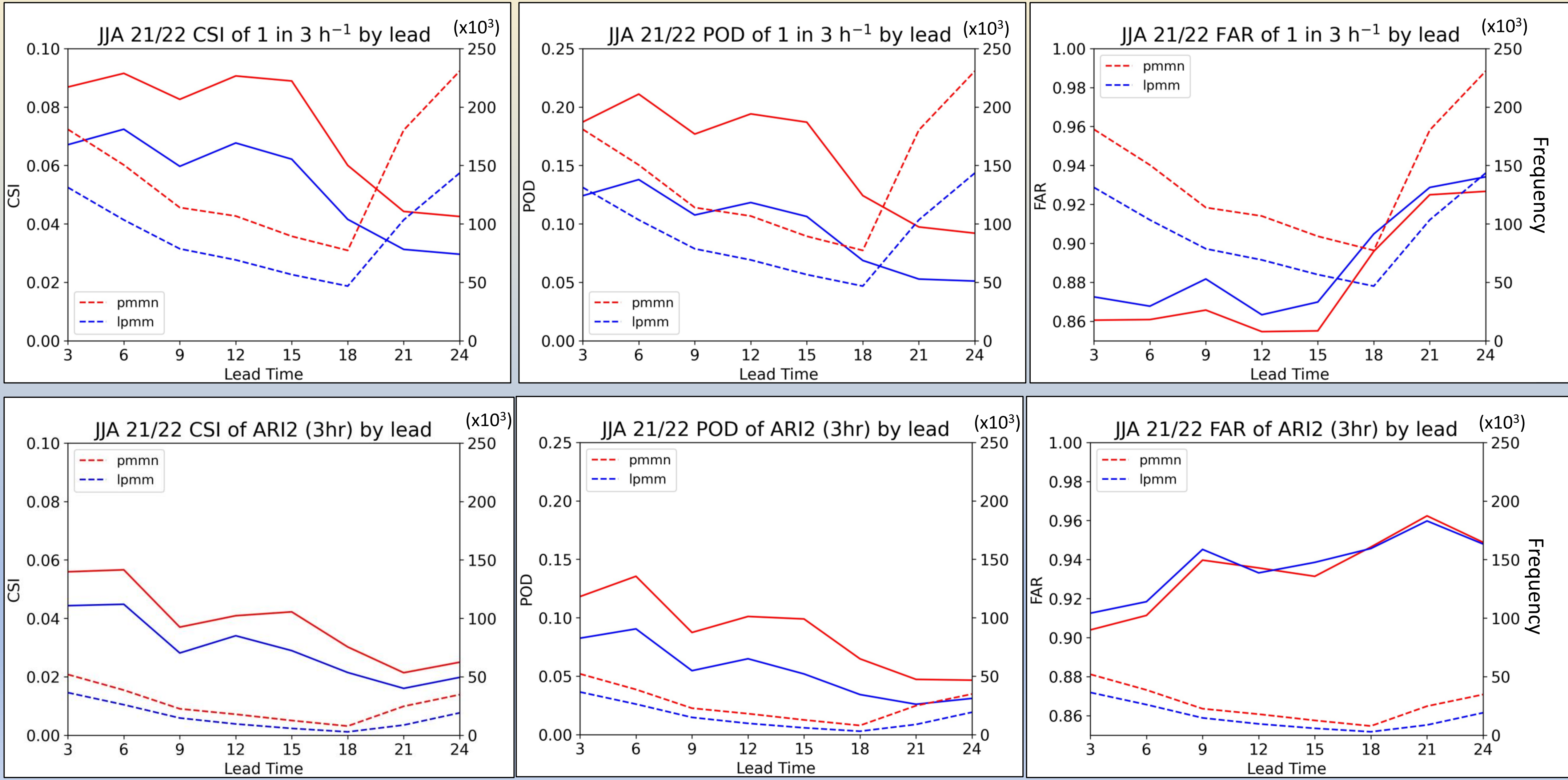








Dashed line - Frequency
Solid Line - Skill



Conclusions

- HREF mean has too infrequent heavy rainfall exceedances → not a good proxy for forecasting heavy, warm-season rainfall.
- PMM is more skillful than LPMM on a CONUS-wide scale.
- Both PMM and LPMM show a diurnal "bump" in skill for overnight convection.
- Skill is better for 1-in threshold compared to ARI2 threshold → likely due to more frequent 1-in threshold exceedances.
- Skill improves with increased duration.

Future Work

- Comparison to other durations (i.e., 6- and 24-hourly) and ARIs (e.g., 5, 10, 25, 50, and 100 years).
- Assess the Day 2 forecasts.
- Calculate regional skill (east vs. west), neighborhood skill, and bias.
- Event-based analysis → understand the precipitation systems where PMM and LPMM are most skillful (i.e., tropical cyclones vs. monsoon).
- Comparison with individual members and ensemble percentile amounts (i.e., 50th and 90th percentiles).