AGU Fall Meeting 2019

H33P-2238

AQPI: RAP/HRRR Model Forecasts of Atmospheric River Events over the San Francisco Bay Area

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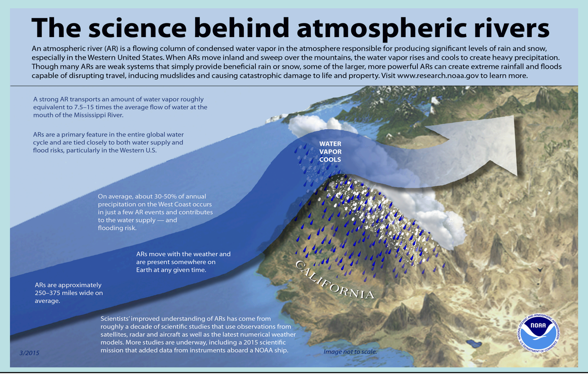
1. Introduction

- Atmospheric Rivers (ARs) transport moisture from the tropics and bring heavy rain to higher latitudes
- ARs are responsible for roughly 40% of California's annual precipitation
- Better forecasts of rain timing/intensity, streamflow, reservoirs, and storm surge can minimize human, ecosystem, & economic impacts



2. The AQPI Project

- Goal of AQPI (Advanced Quantitative Precip. Info): improve California early warning through research transition, monitoring, and prediction of precipitation, streamflow, and storm surge
- Deploy & assimilate AQPI radar & sfc met instruments; evaluate model predictions of precipitation, streamflow, and storm surge
- 4-year grant awarded by the DWR to multiple partners: NOAA, CSU, USGS, DWR, and NWS

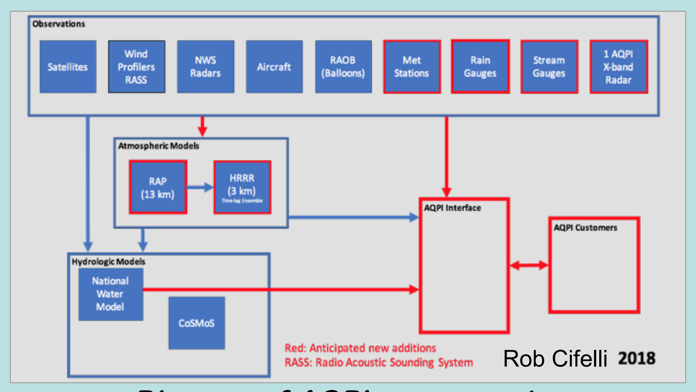


Diagram of AQPI components

3. NOAA GSD Research Plan

NOAA GSD Role: Evaluate/improve QPF from RAP/HRRR model over AQPI region

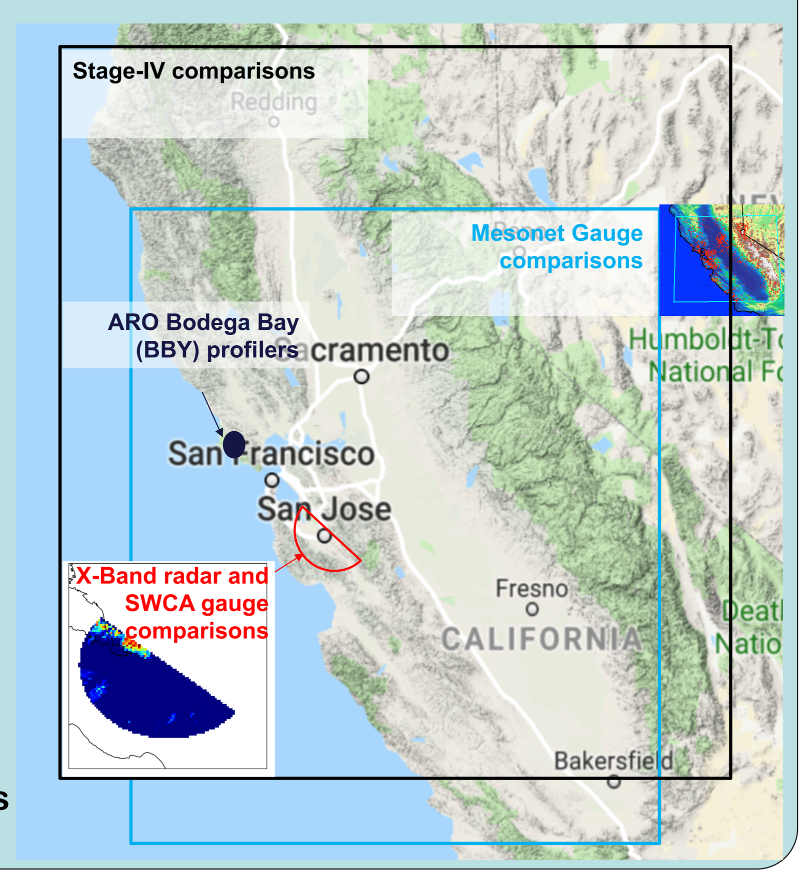
Science Question: How well do different versions of the RAP/HRRR model forecast various AR events over California?

Approach:

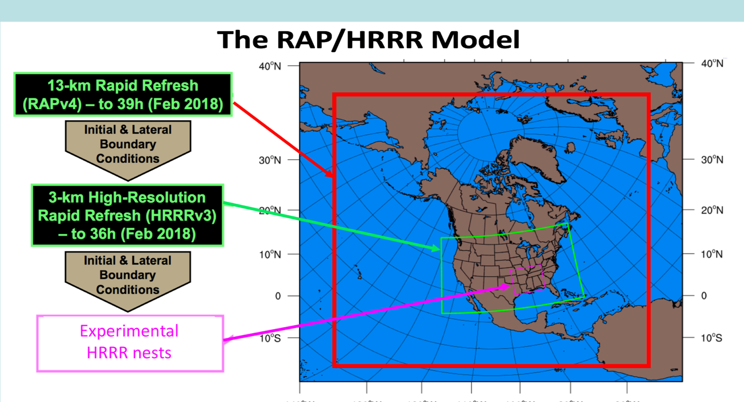
- Select 6-8 AR events that have occurred
- Download operational & real-time-X RAP/HRRR output, & run retrospective simulations with the latest RAP/HRRR model version
- Compare model forecasts of precip and other metrics to available observations

Metrics:

- Precip (Model QPF vs Observed QPE): Stage-IV; Mesonet contingency tables; San Jose X-band domain
- Winds, T, water vapor: PSD ARO Profilers (Bodega Bay, Pt Sur)



4. RAP/HRRR Model Versions



- RAP/HRRR is a high-resolution mesoscale model for short-term weather forecasts (0-36h)
- NOAA/ESRL/GSD develops improved versions of RAP/HRRR and release them to NCEP operations every ~2 years
- Currently RAPv4/HRRRv3 is operational; RAPv5/HRRRv4 is under development

Model Version	Operational Dates	Notable Improvements
RAPv3/HRRRv2	Aug-2016 to Jul-2018	Aerosol Thompson Microphysics, MYNN PBL updates, RUC Land Sfc Model, RRTMG Radiation, Grell-Freitas cumulus, improved 2m T/Td background est.
RAPv4/HRRRv3	Jul-2018 to Present	Hybrid vertical coordinates, Thompson microphysics (UL clouds), MYNN PBL updates, full geometric diffusion (better winds/temp in terrain), some new obs/DA methods
RAPv5/HRRRv4	Scheduled Jun-2020	Latest Grell-Freitas convection (RAP only), MYNN PBL updates, enhanced GW drag, some new obs/DA methods

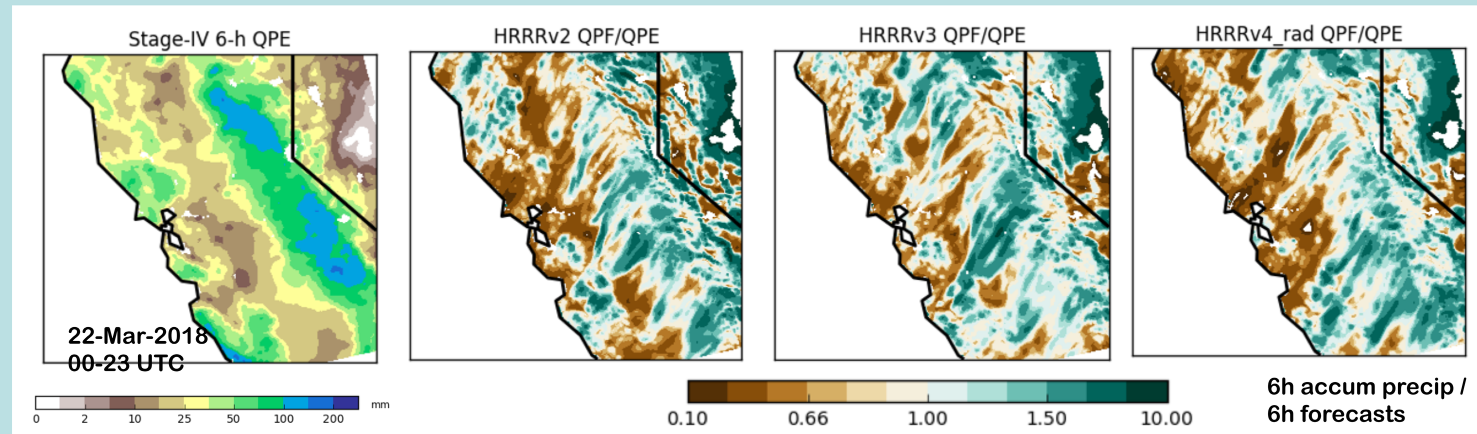
Experimental Design (AR Events Studied)

Event	Operational Case Name	Real-Time X Case Name*	Final-X Case Name*	Additional X Retros*
22-Mar-2018	HRRRv2	---	---	HRRRv4_rad
2-Feb-2019	HRRRv3	HRRRv4_GSD	HRRRv4_rc1	---
14-Feb-2019	HRRRv3	HRRRv4_GSD	HRRRv4_rc1	HRRRv4_feb19
26-Feb-2019	HRRRv3	HRRRv4_GSD	HRRRv4_rc1	---

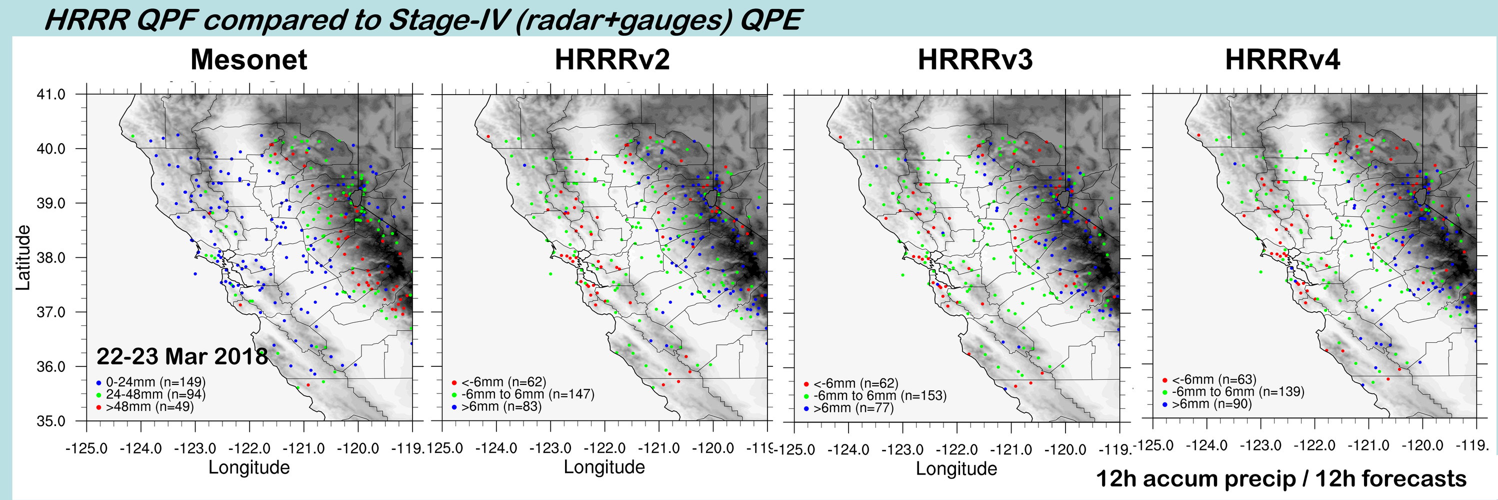
*Real-time X is continuously evolving. Final-X is the frozen version for NCEP implementation which occurred Fall 2019. Additional X retros were based on Fall 2018 code and assimilation dependent upon obs available for each event (22-Mar-18 has 5 radiance types; 14-Feb-19 has 16)

5. Case Study: 22-Mar-2018

A. QPF/QPE Comparions (Stage-IV & Mesonet)



HRRR QPF compared to Stage-IV (radar+gauges) QPE



HRRR QPF compared to Mesonet gauges (closest model grid point) (292 gauges included)

Contingency Tables (vs Mesonet)

time_acc (h)	threshold (mm)	Domain	Model	avg (mm)	TS/CSI	ETS/GSS
6	20	All	Mesonet	18.2	1	1
			HRRRv2	19.7	0.572	0.391
			HRRRv3	19.1	0.581	0.402
			HRRRv4	20.1	0.546	0.355
6	20	0-1000m	Mesonet	14.8	1	1
			HRRRv2	12.6	0.437	0.323
			HRRRv3	13.6	0.466	0.348
			HRRRv4	14.0	0.402	0.273
6	20	1000-3000m	Mesonet	23.1	1	1
			HRRRv2	29.7	0.664	0.358
			HRRRv3	27.0	0.663	0.368
			HRRRv4	28.7	0.654	0.348

Given categories	Observed	
Model	Yes	No
Yes	Hits (A)	False alarms (B)
No	Misses (C)	Correct negatives (D)

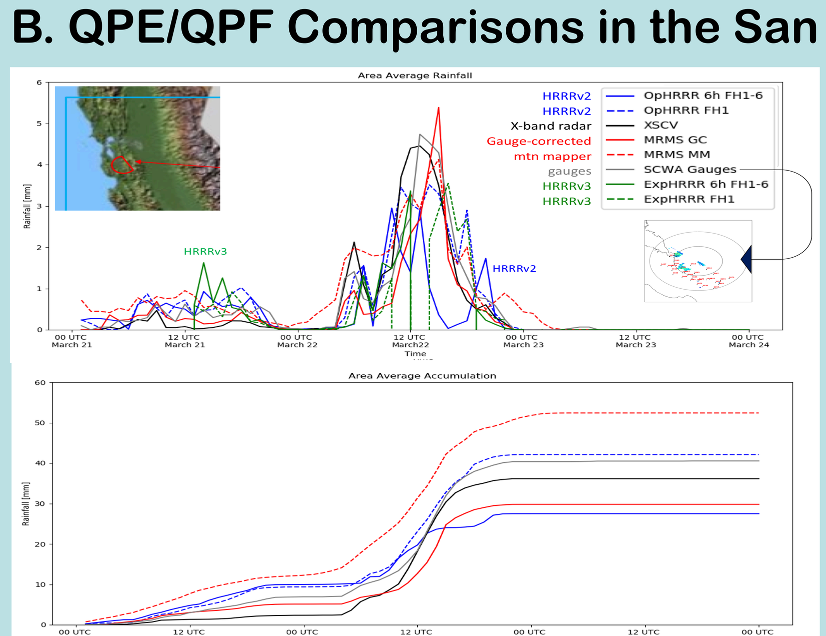
The A, B, C and D are represent the number of occurrences for which model precipitation or observed precipitation did (yes) or did not (no) reach or exceed a given threshold

Threat Score (Critical Success Index) = Hits / (hits + misses + false alarms)

Equitable Threat Score (Gilbert Skill Score) = (Hits – random_hits) / (hits + misses + false alarms + random_hits)

- NWS Stage-IV and Mesonet gauges measure significant rainfall over the Pacific Coast and Sierra Nevadas
- All HRRR versions generally capture the spatial extent, but predict too little rainfall in the Bay Area, and too much rainfall over the Sierra Nevadas
- Threat Score (TS) and Equitable Threat Score (ETS) are higher (better) at higher elevations, because the large-scale forcing is easier to model
- HRRRv3 seems to perform the best, but differences are small

B. QPE/QPF Comparisons in the San Jose Area

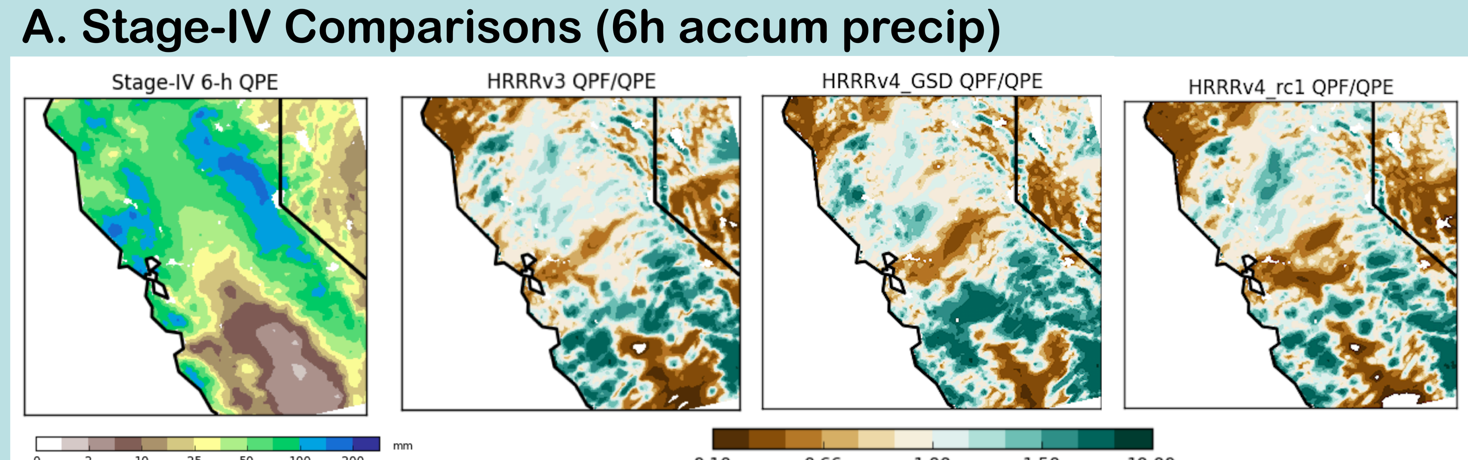


QPE/QPF estimates in the San Jose radar domain

- Both HRRRv2 and HRRRv3 overestimate rainfall in the first event (21-Mar); underestimate the "main event" (22-Mar)
- Area average accumulation varies widely between various QPE (Quantitative Precipitation Estimation) sources, highlighting the challenges with trying to understand precip
- QPE from the Sand Jose X-band radar falls in the middle of the pack of QPE estimates

6. Case Study: 14-Feb-2019

A. Stage-IV Comparisons (6h accum precip)



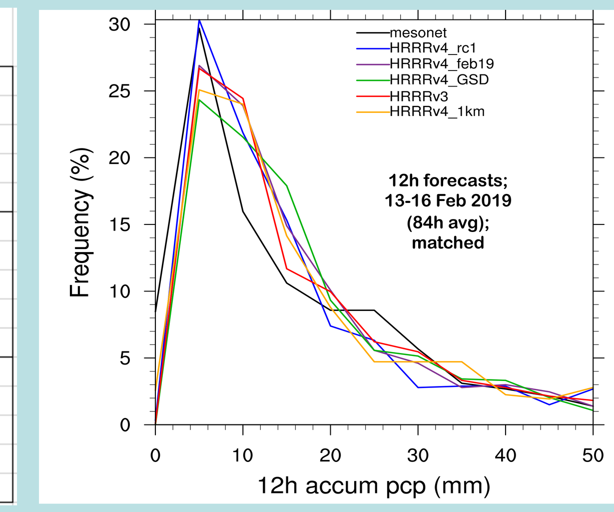
HRRR precip compared to Stage-IV 6h accumulations from 14-15 Feb 2019 (radar+gauges)

- All HRRR versions predict rainfall very well in the north, but in the south tend to overpredict rainfall at high elevation, and underpredict at low elevation, similar to the 22-Mar-2018 case
- Small differences between the HRRR versions. The newest HRRR-X (HRRRv4_rc1) is drier than previous versions, improving comparisons in some regions while degrading in others

6. Case Study: 14-Feb-2019 (cont'd)

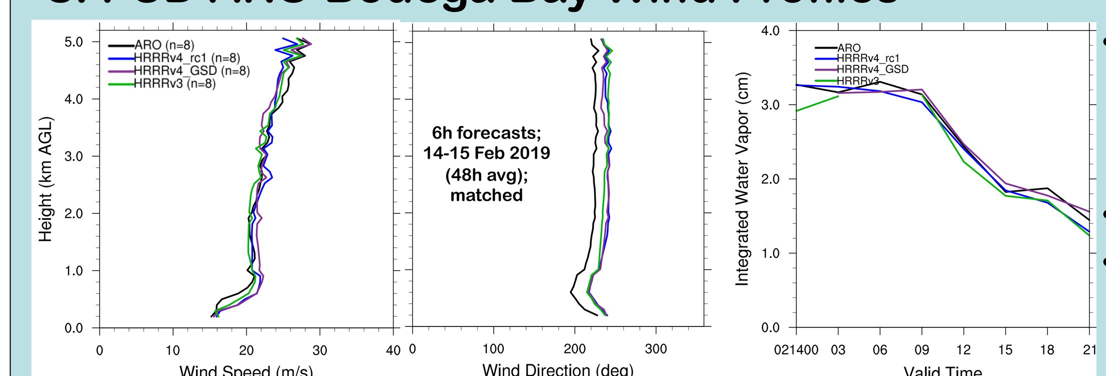
B. Mesonet Gauge Comparisons

time_acc (h)	threshold (mm)	Domain	Model	avg (mm)	TS/CSI	ETS/GSS
12	10	All	Mesonet	13.4	1	1
			HRRRv3	15.5	0.627	0.416
			HRRRv4_GSD	15.8	0.626	0.410
			HRRRv4_feb19	15.6	0.607	0.388
			HRRRv4_rc1	16.4	0.611	0.389
12	10	0-1000m	Mesonet	12.3	1	1
			HRRRv3	11.5	0.667	0.508
			HRRRv4_GSD	12.1	0.671	0.508
			HRRRv4_feb19	11.6	0.642	0.475
			HRRRv4_rc1	12.7	0.646	0.476
12	10	1000-3000m	Mesonet	16.1	1	1
			HRRRv3	25.8	0.564	0.215
			HRRRv4_GSD	25.4	0.554	0.198
			HRRRv4_feb19	25.9	0.553	0.195
			HRRRv4_rc1	26.3	0.556	0.195



- As with the 22-Mar-2018 event, all HRRR versions have a wet bias at high elevations
- Small differences between HRRR versions
- Evaluations with 6h acc have similar results (not shown)
- Gauge spatial plots also show small differences (not shown)
- A PDF of accumulated precip shows that all HRRR versions underpredict <10mm thresholds and overpredict 15-20mm thresholds
- All HRRR versions are similar (including the 1km HRRR nest) (standard HRRR is 3km)

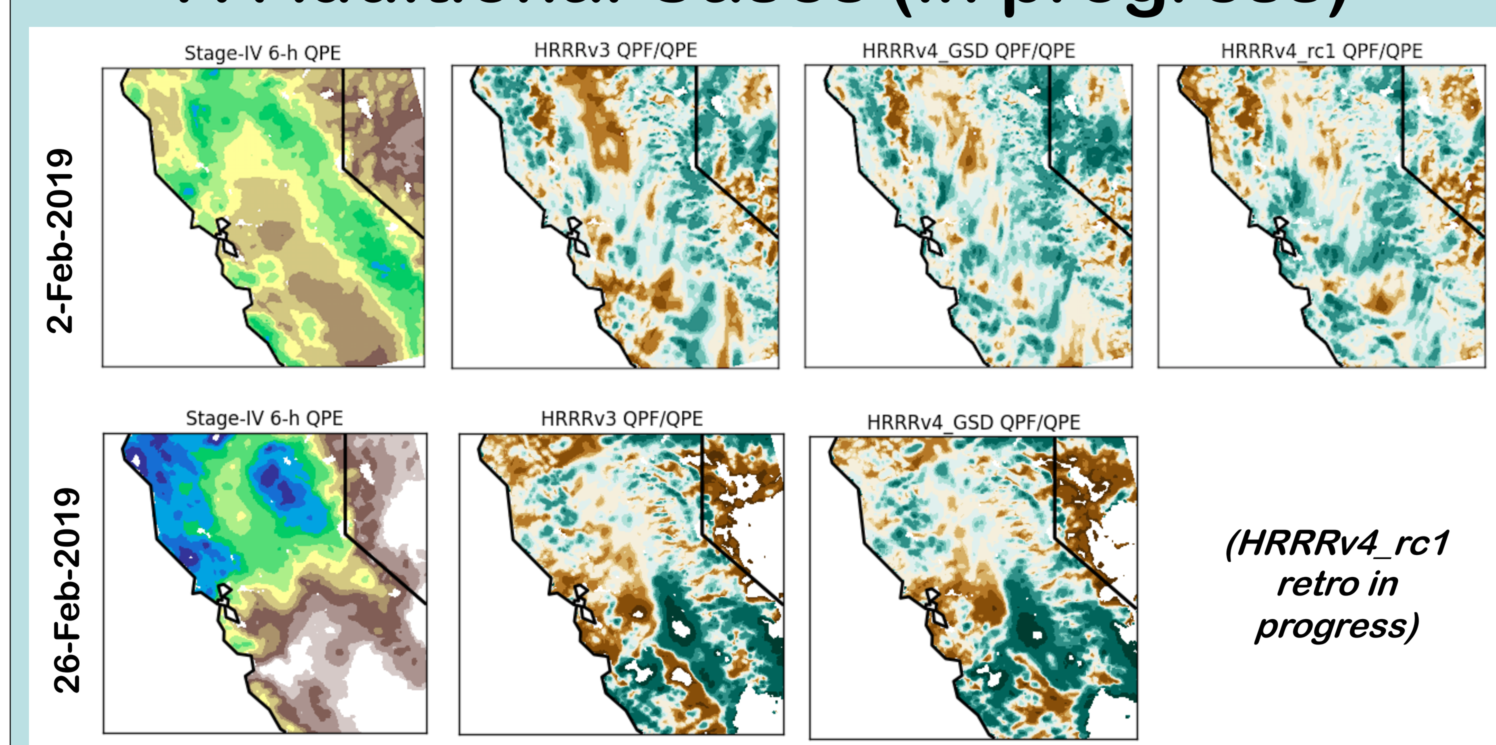
C. PSD ARO Bodega Bay Wind Profiles



Vertical profiles of wind speed & direction (48h avg); and IWV over time (24h)

- Winds too strong near the surface; too weak aloft; too easterly, but mostly compare well
- IWV compares well
- Biases are similar across all three versions of the HRRR evaluated

7. Additional Cases (in progress)



(HRRRv4_rc1 retro in progress)

- For 2-Feb, QPF for both HRRR versions compare favorably to Stage-IV; HRRRv4 better
- For 26-Feb, QPF for both HRRR versions compare well in the north but a wet bias in the south
- As with previous cases, HRRR generally has a wet bias at high altitudes and dry bias at low altitudes (with some exceptions)

8. Summary

- QPF evaluated for four AR events for multiple models (HRRRv2, HRRRv3, HRRRv4) against multiple precip measurements (X-band & MRMS radars, Mesonet & SWCA gauges, Stage-IV) and Bodega Bay Profilers
- All versions of the HRRR generally predict rainfall spatial distribution and accumulation well, but tend to overpredict high altitude regions and underpredict low altitude regions
- HRRRv4 outperforms HRRRv3 in some but not all cases
- QPE measures vary widely, highlighting challenges with evaluating models

9. Next Steps

- Further explore causes of model biases; compare to additional observations (More ARO sites; Oakland soundings; satellite precipitable water)
- Conduct HRRR retros with and without local X-band radar in the data assimlmiation to understand its value for improving HRRR forecasts
- Evaluate an additional 2-4 cases to understand statistics