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

Jason M. English[1,2], David D. Turner[1], Melinda Marquis[1], Trevor I. Alcott[1], William R. Moninger[1,2], Janice L. Bytheway[1,2], Robert Cifelli[1]

[1]NOAA Earth Systems Research Laboratory, Boulder, CO [2]CIRES, University of Colorado, Boulder, CO

2020 AMS Mountain Meteorology Meeting (Virtual)

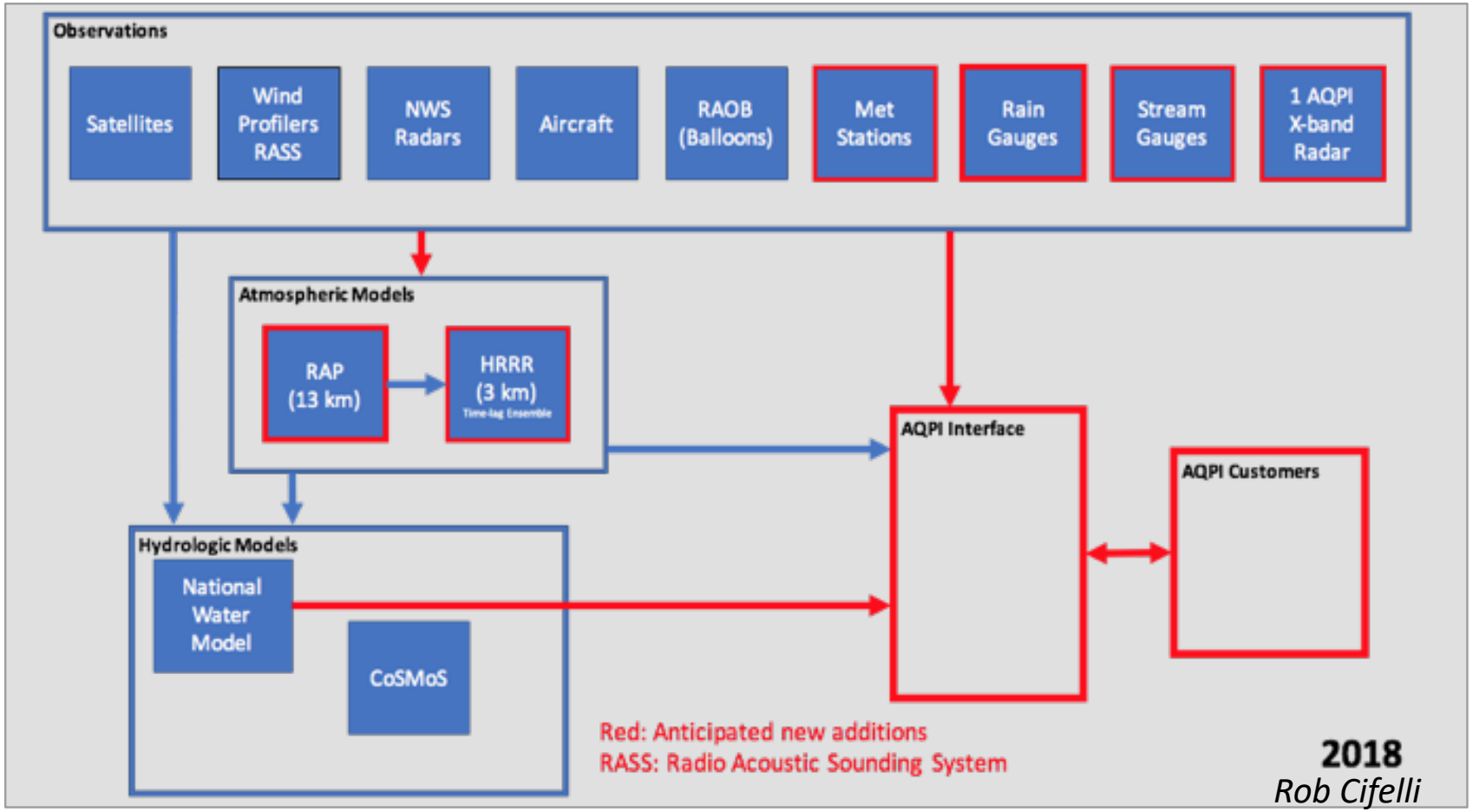
Introduction / AQPI Project

Problem: AR events are highly impactful, yet many aspects of these events can be poorly predicted or communicated

AQPI Goal: improve California early warning through research transition, monitoring, and prediction of precipitation, streamflow, and storm surge

Actions: Deploy & assimilate AQPI radar & sfc met instruments; evaluate model predictions of precipitation, streamflow, and storm surge

AQPI = Advanced Quantitative Precipitation Information



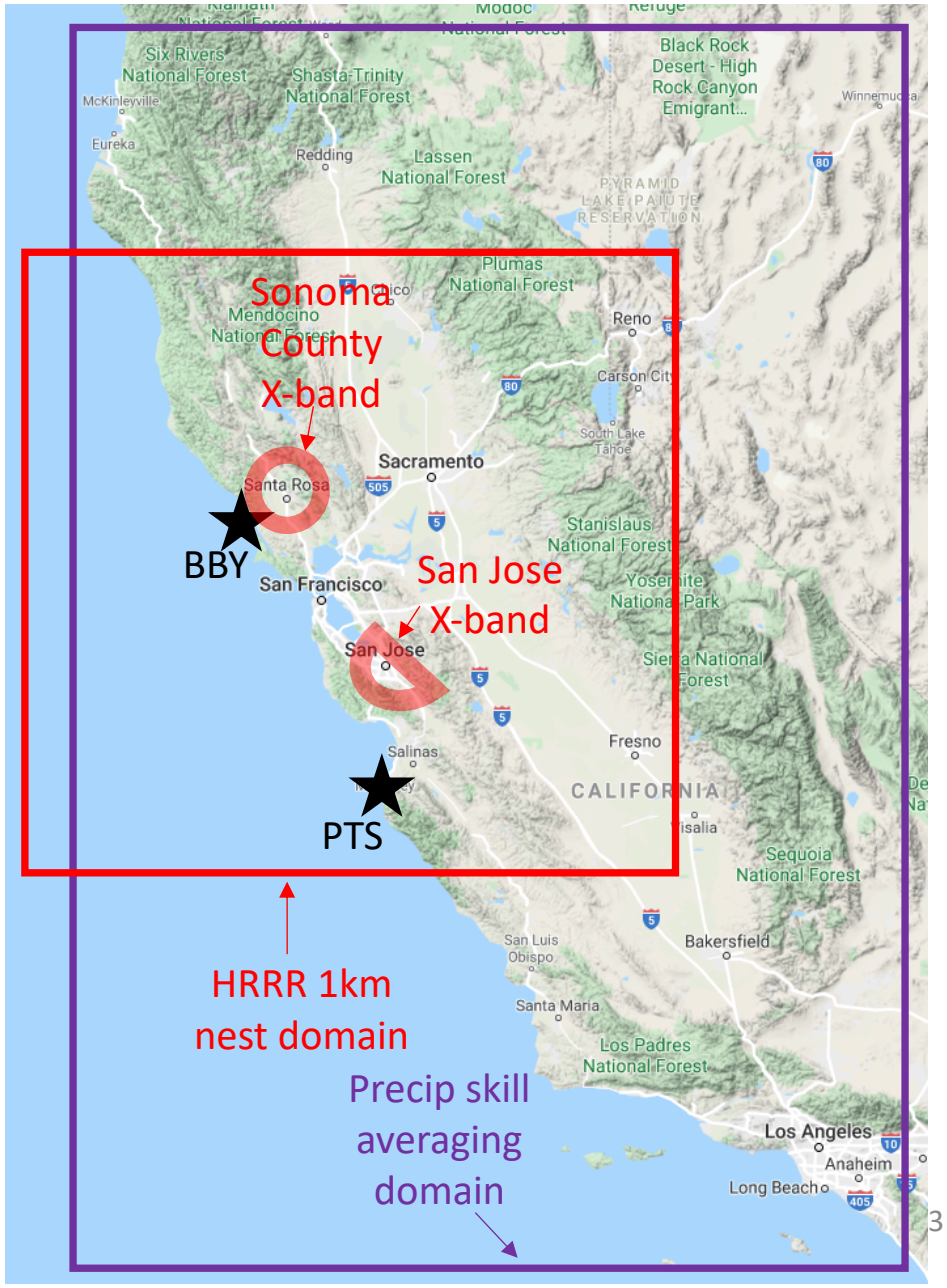
4-year grant awarded by the DWR to NOAA, CSU, USGS, DWR, and NWS

NOAA Global Systems Lab (GSL) Research Plan

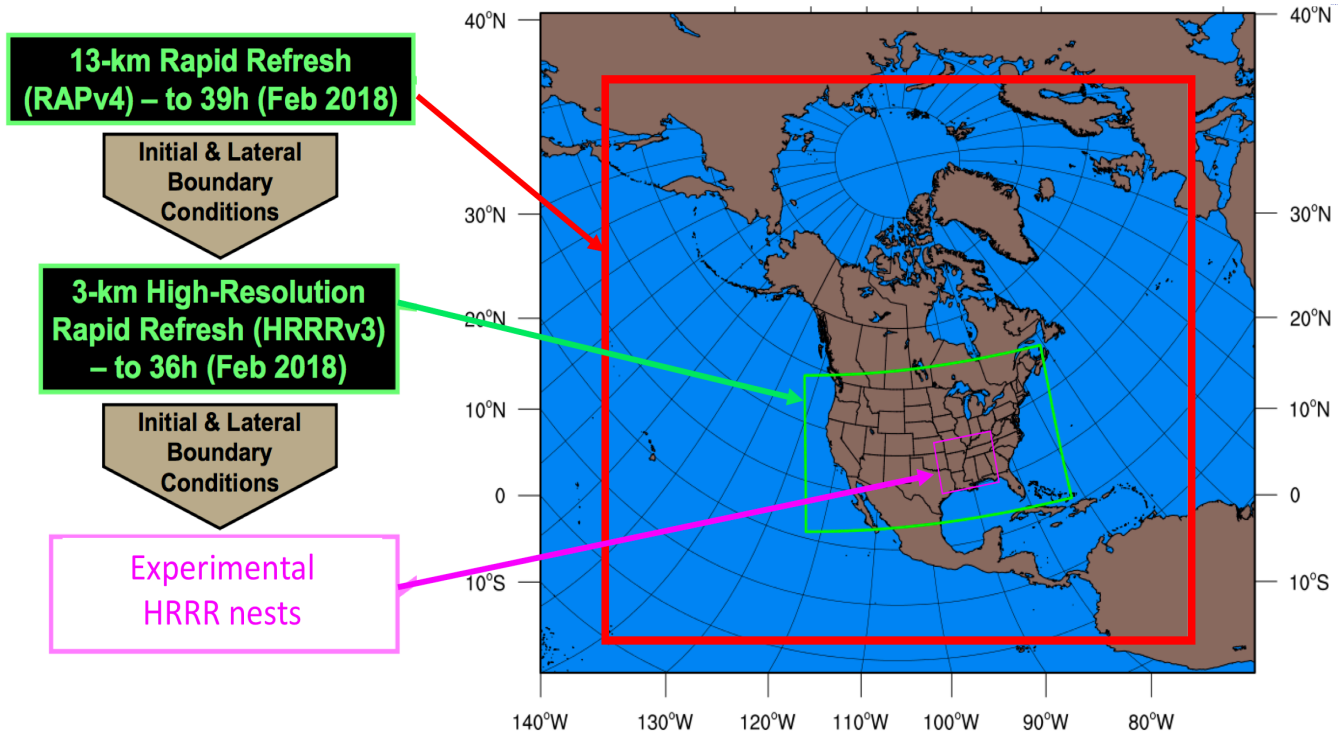
Overall NOAA GSL Goal:
Evaluate/improve RAP/HRRR forecasts of AR events in California

Approach:

- Select six AR events that have occurred
- Download/run retrospective simulations of HRRR operational/experimental models
- Quantify/understand HRRR forecast accuracy by comparing QPF (Quantitative Precipitation Forecasts) to QPE (Quantitative Precipitation Estimates) and other fields
- Evaluate impacts of experimental HRRR 1km nest on precip skill
- Evaluate impacts of adding new X-band radars to HRRR DA



The RAP/HRRR Model



- RAP/HRRR is a high-resolution mesoscale model for short-term weather forecasts (0-48h)
- NOAA/ESRL/GSL develops improved versions of RAP/HRRR and release them to NCEP operations every ~2 years
- RAPv5/HRRRv4 is currently being released to NCEP

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	Mid-late 2020	Latest Grell-Freitas convection (RAP only), MYNN PBL updates, enhanced GW drag, HRRRDAS mean for HRRR IC and BEC, some new obs/DA methods

AR events studied

Event	HRRR op	HRRR exp
21-23 Mar 2018	HRRRv2	HRRRv3
2-4 Feb 2019	HRRRv3	HRRRv4
13-15 Feb 2019*	HRRRv3	HRRRv4
25-27 Feb 2019	HRRRv3	HRRRv4
2-3 Mar 2019	HRRRv3	HRRRv4
5-6 Mar 2019	HRRRv3	HRRRv4

*Additional 13-15 Feb 2019 runs:

- HRRR 1km nest
- HRRR Without X-band (ctl)
- HRRR With X-band (exp)

Evaluation methods

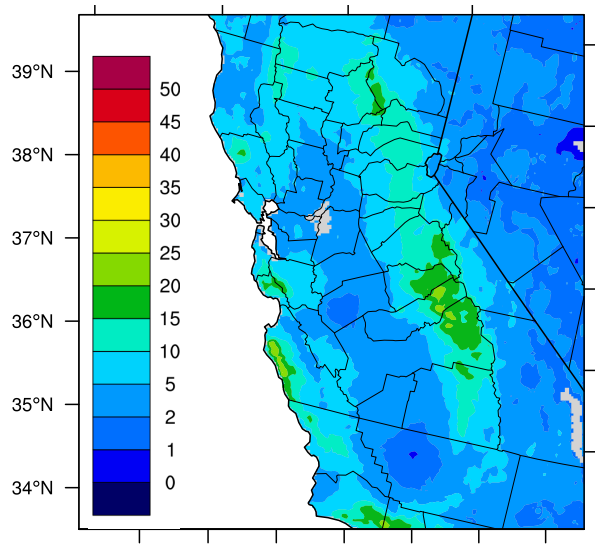
Challenge	Solution(s)
QPE products disagree due to errors, blockage, spatial/temporal limitations, etc	Compare multiple products (Stage-IV and Mesonet)
Inconsistent treatment of snow in QPE products	Use HRRR rain-only QPF; Discard data when T < 3C
Precip timing/location errors makes it hard to fairly quantify skill – esp when comparing to gauges or different model resolutions	Utilize Neighborhood Max (NM) Technique (*Schwarz 2017*) in addition to point-point comparisons

AR event: 2-4 Feb 2019

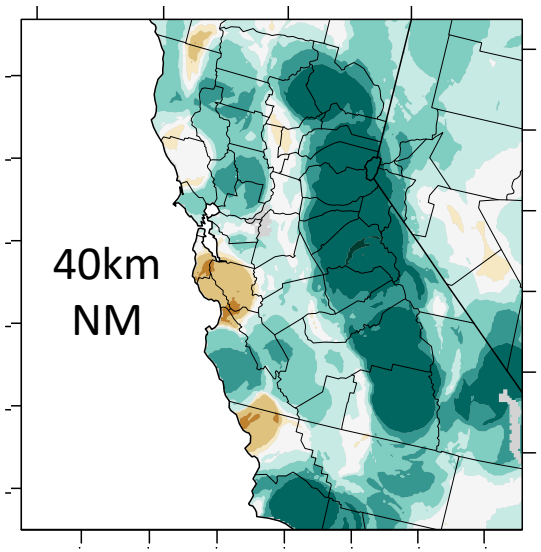
HRRR wet bias in mountains, dry bias in Bay Area/coast, HRRRv4 slightly better than HRRRv3

6h acc (mm)

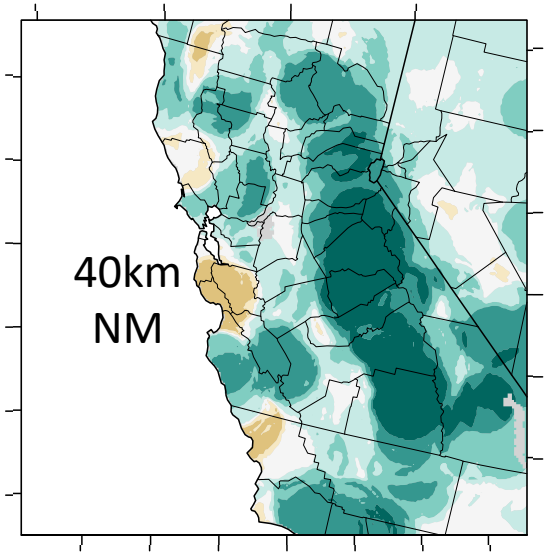
Stage-IV

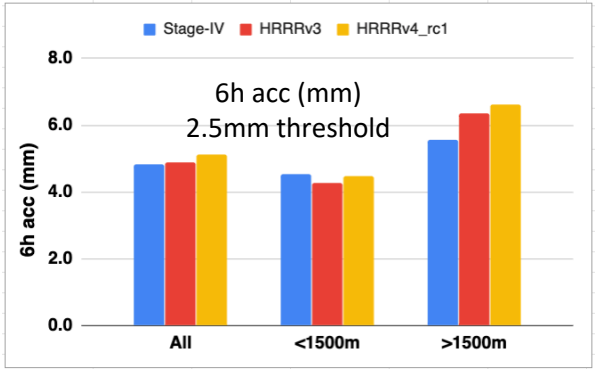


HRRRv3 (op) fchr 6



HRRRv4 (exp) fchr 6

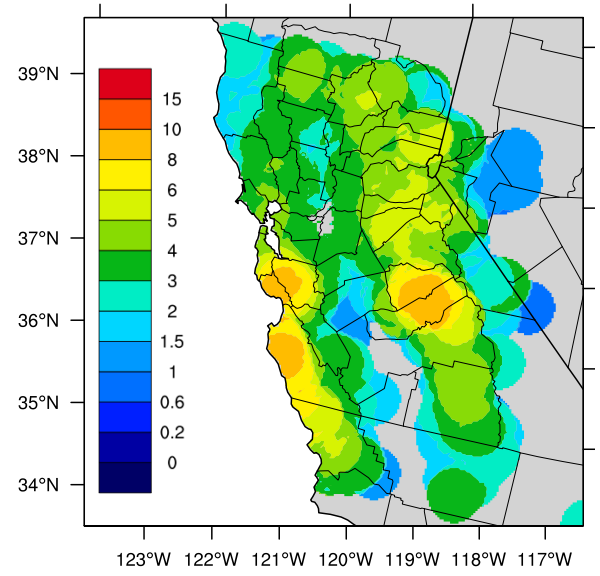




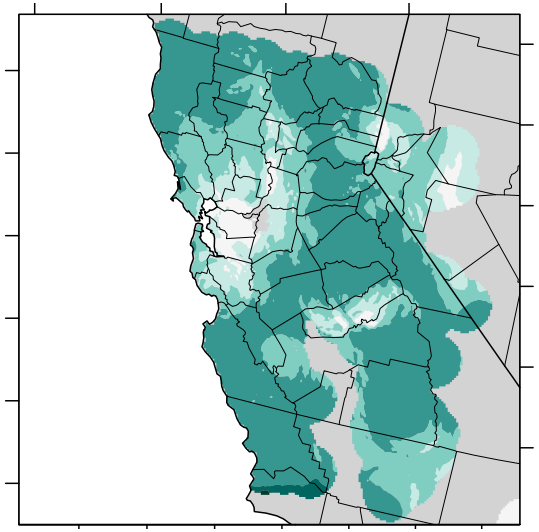
CSI	All	<1500m	>1500m
HRRRv3	0.69	0.68	0.71
HRRRv4	0.70	0.69	0.72

1h acc (mm) [40km NM]

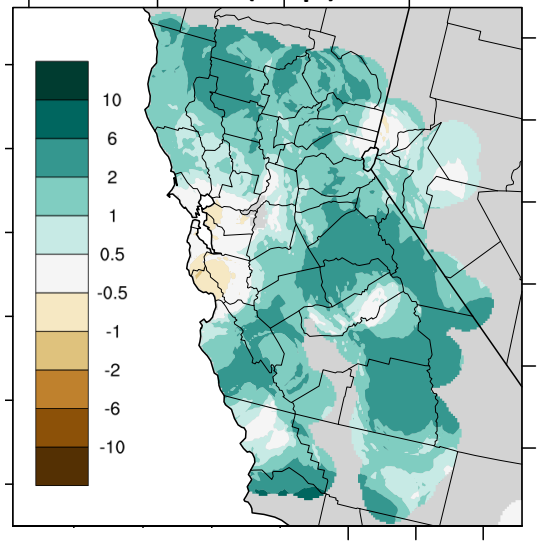
Mesonet

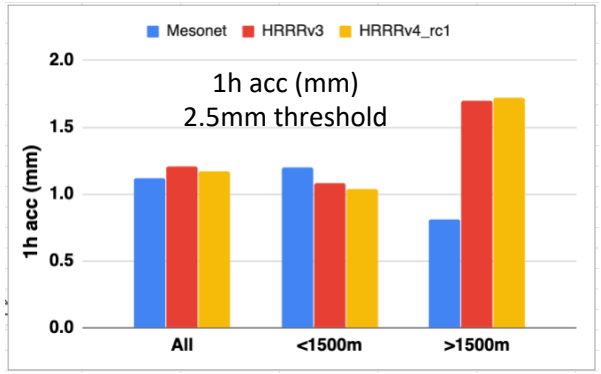


HRRRv3 (op) fchr 1



HRRRv4 (exp) fchr 1





CSI	All	<1500m	>1500m
HRRRv3	0.45	0.45	0.46
HRRRv4	0.45	0.43	0.47

Valid times 20190212-020412 (3km grid)

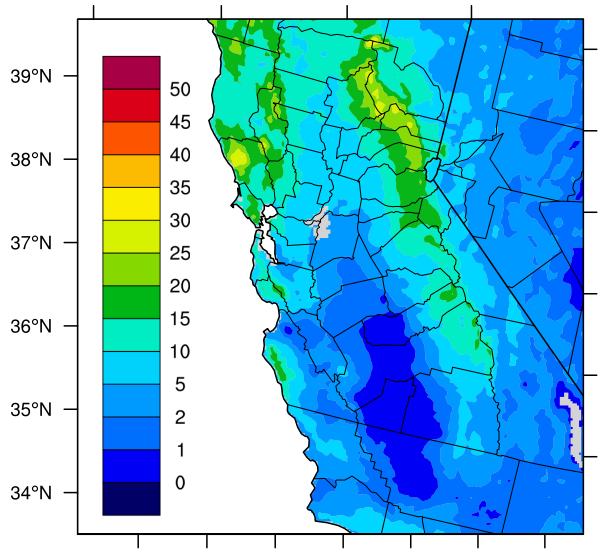
33.2-41.4 °N 118.1-124.9 °W

AR event: 13-15 Feb 2019

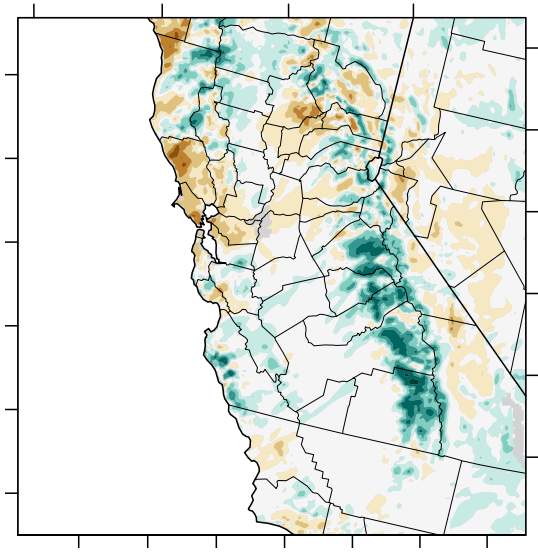
HRRR wet bias in mountains, dry bias in Bay Area/coast, HRRRv4 slightly better than HRRRv3

6h acc (mm)

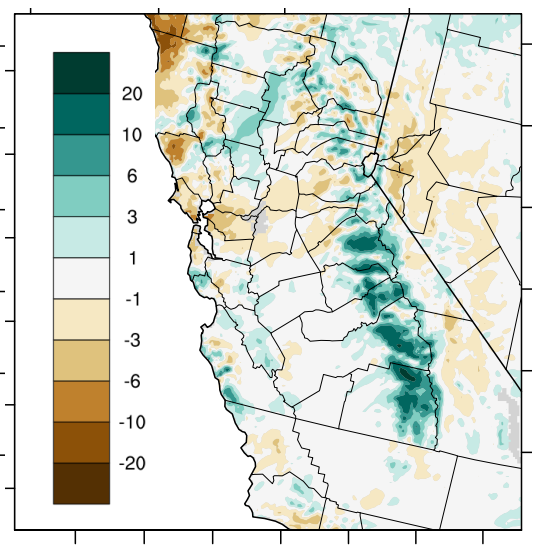
Stage-IV

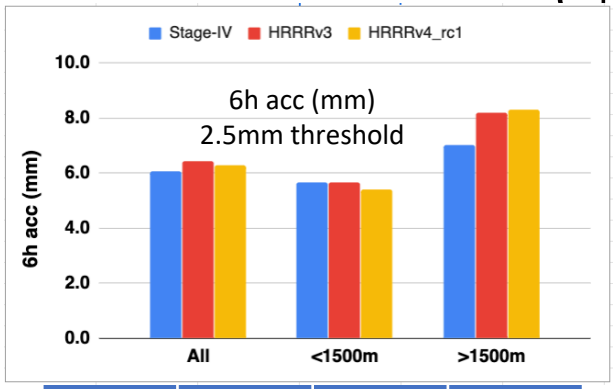


HRRRv3 (op) fchr 6



HRRRv4 (exp) fchr 6

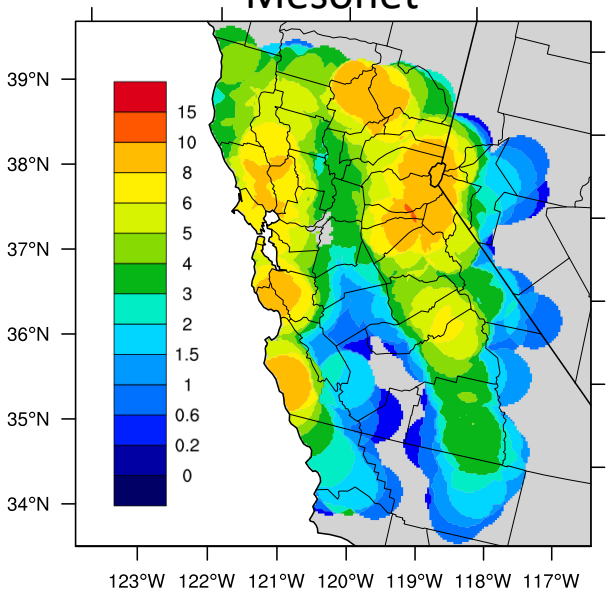




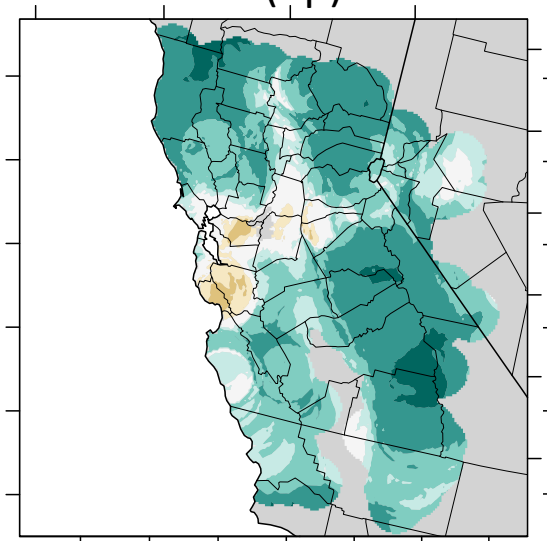
CSI	All	<1500m	>1500m
HRRRv3	0.74	0.74	0.73
HRRRv4	0.75	0.75	0.74

1h acc (mm) [40km NM]

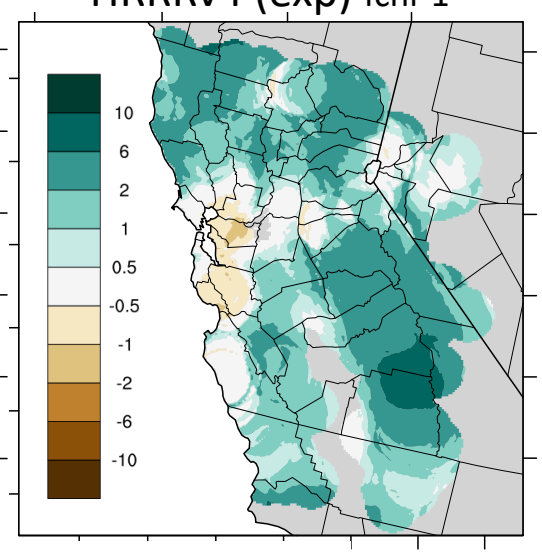
Mesonet

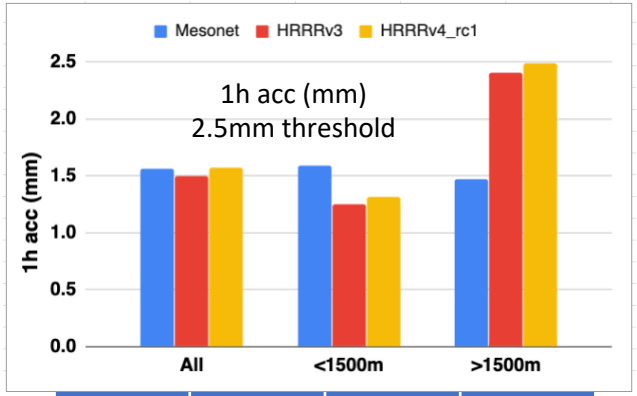


HRRRv3 (op) fchr 1



HRRRv4 (exp) fchr 1





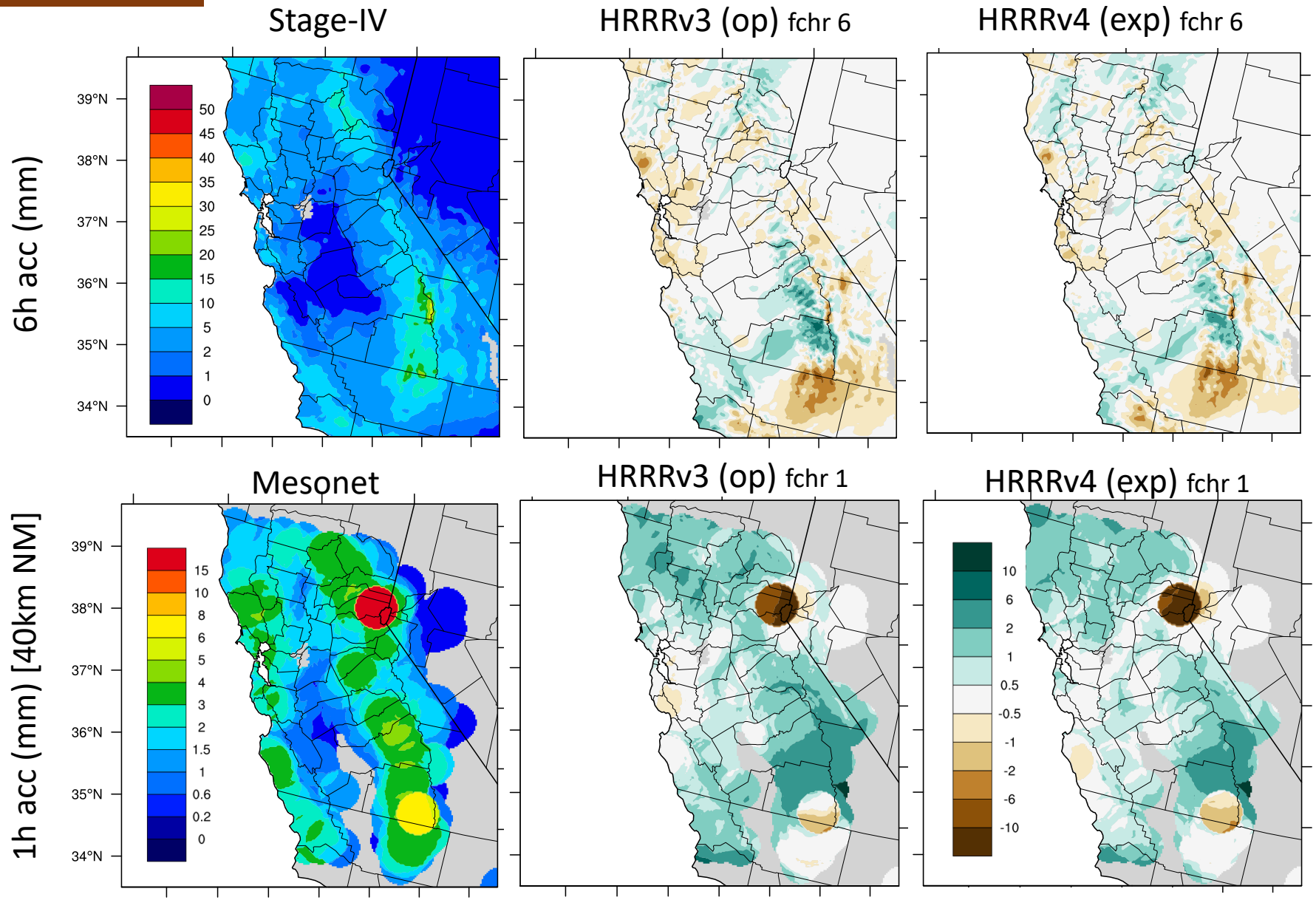
CSI	All	<1500m	>1500m
HRRRv3	0.62	0.63	0.62
HRRRv4	0.64	0.64	0.62

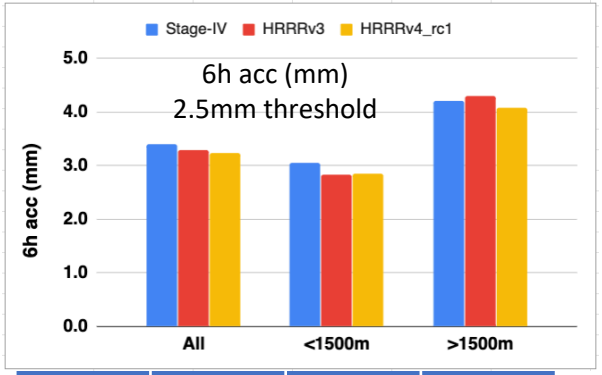
Valid times 2019021306-021506 (3km grid)

33.2-41.4 °N 118.1-124.9 °W

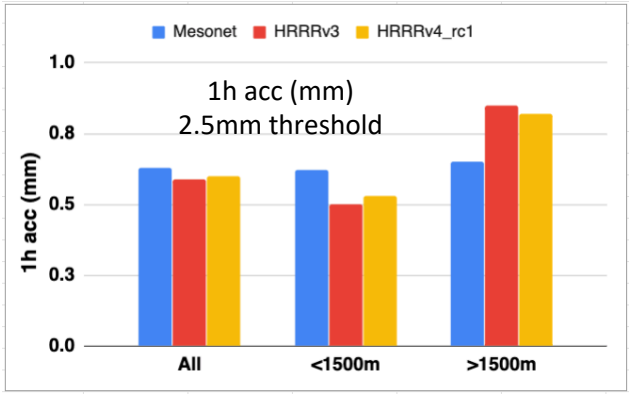
AR event: 5-6 Mar 2019

HRRR wet bias in mountains, dry bias in Bay Area/coast, HRRRv4 slightly better than HRRRv3





CSI	All	<1500m	>1500m
HRRRv3	0.66	0.65	0.68
HRRRv4	0.68	0.67	0.71

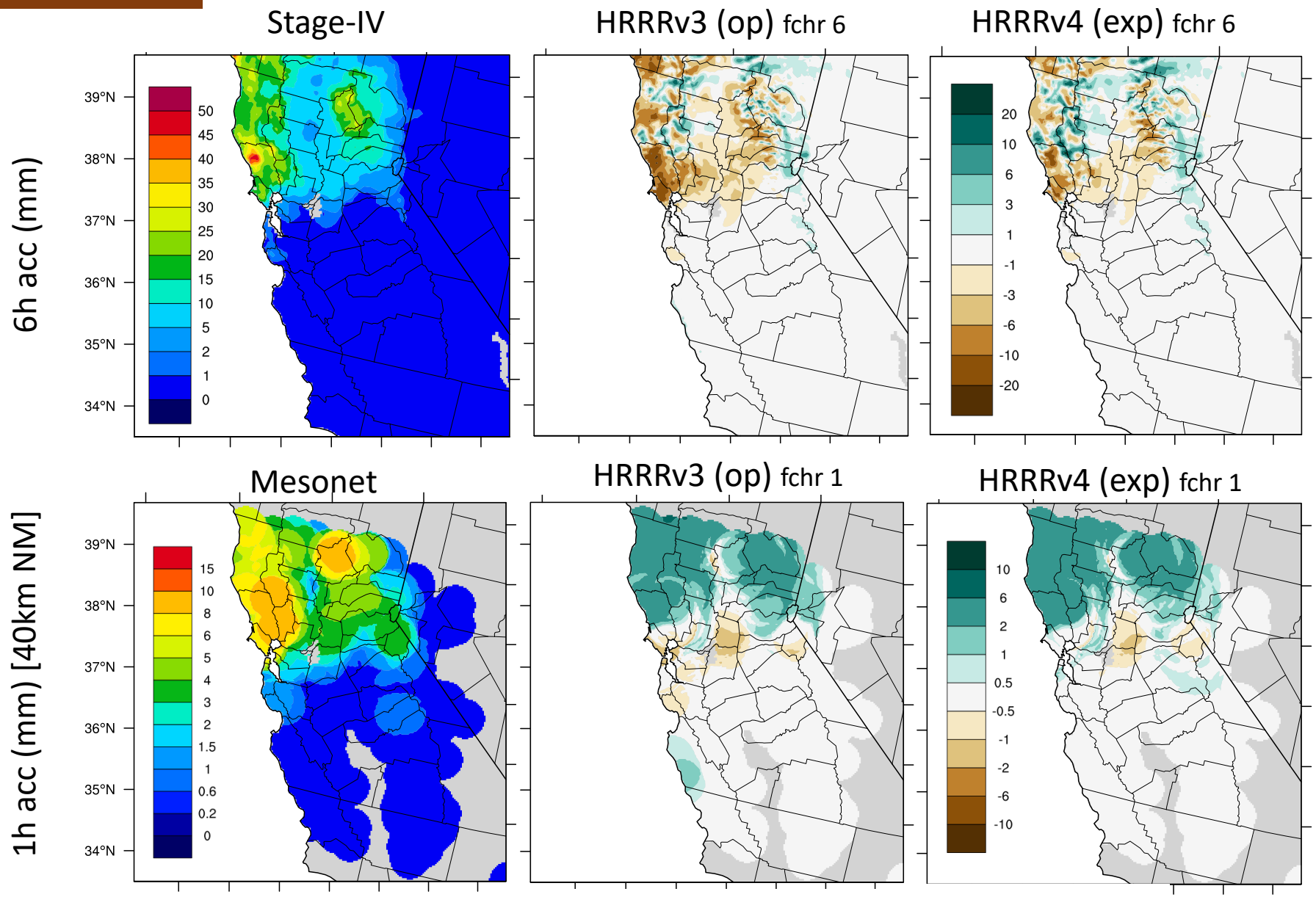


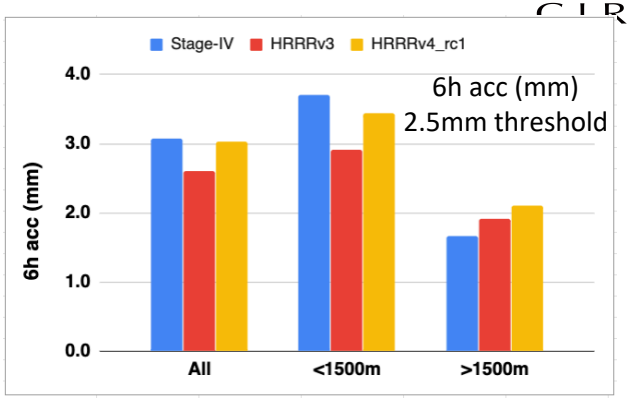
CSI	All	<1500m	>1500m
HRRRv3	0.22	0.23	0.19
HRRRv4	0.28	0.33	0.22

33.2-41.4 °N 118.1-124.9 °W

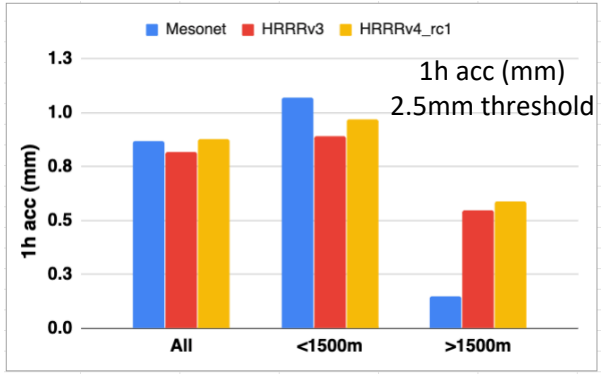
AR event: 25-27 Feb 2019

HRRR dry bias in Bay Area; Stage-IV & Mesonet disagree to the North, HRRRv4 slightly better than HRRRv3





CSI	All	<1500m	>1500m
HRRRv3	0.78	0.82	0.66
HRRRv4	0.81	0.85	0.68

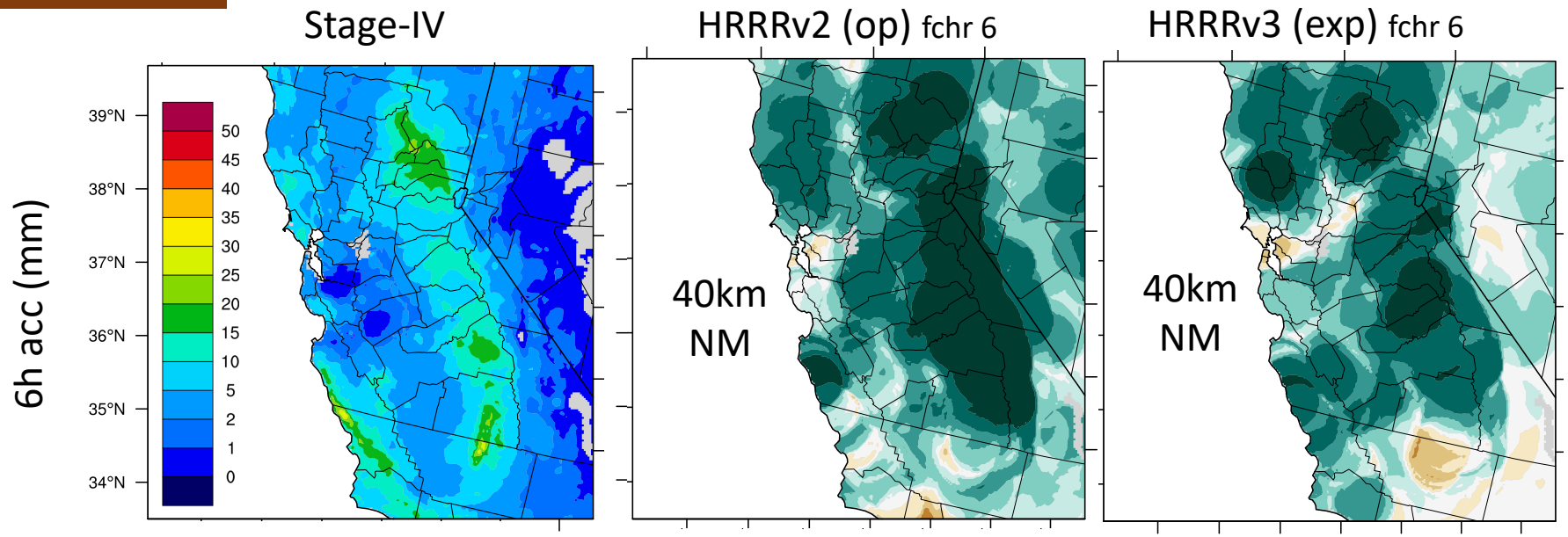


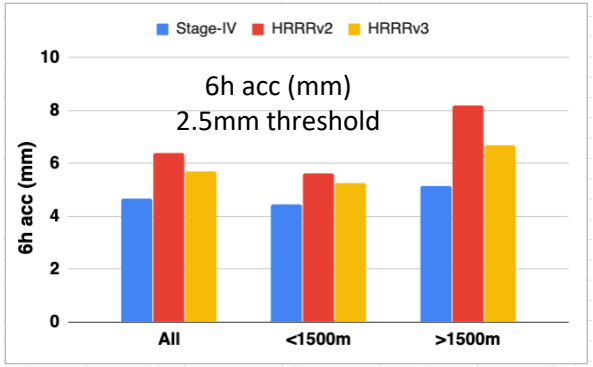
CSI	All	<1500m	>1500m
HRRRv3	0.69	0.75	0.46
HRRRv4	0.69	0.77	0.46

33.2-41.4 °N 118.1-124.9 °W

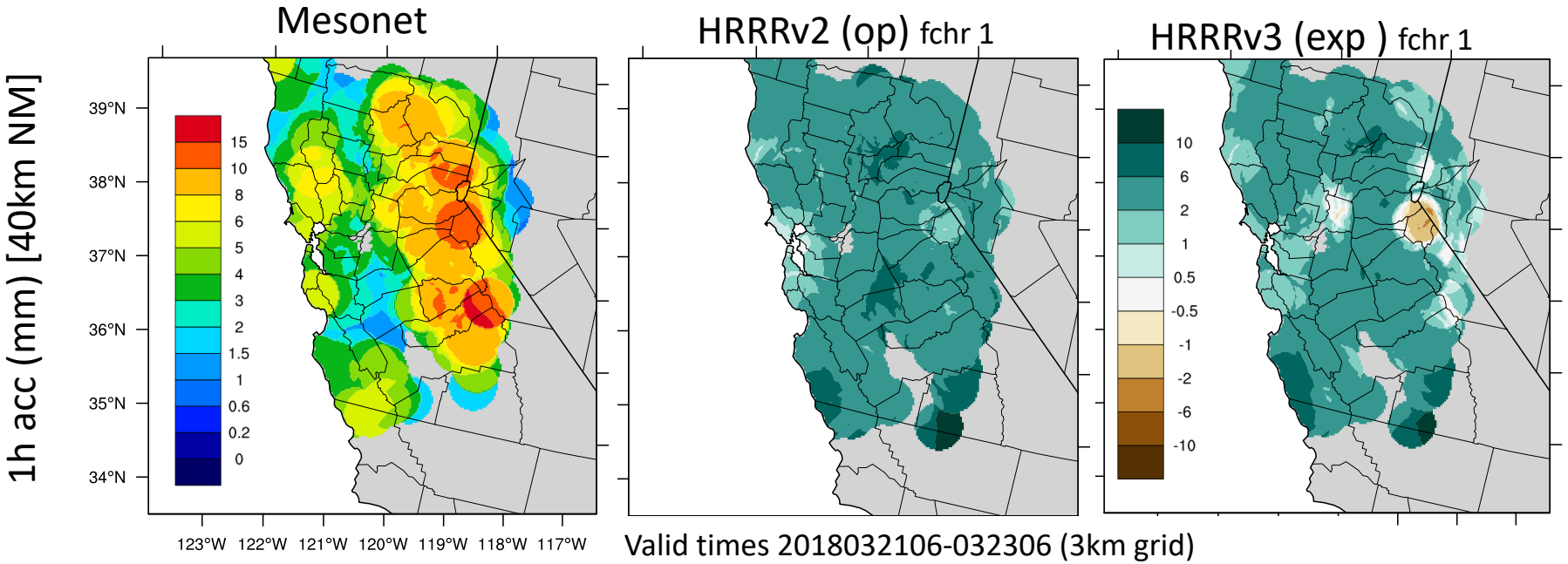
AR event: 21-23 Mar 2018

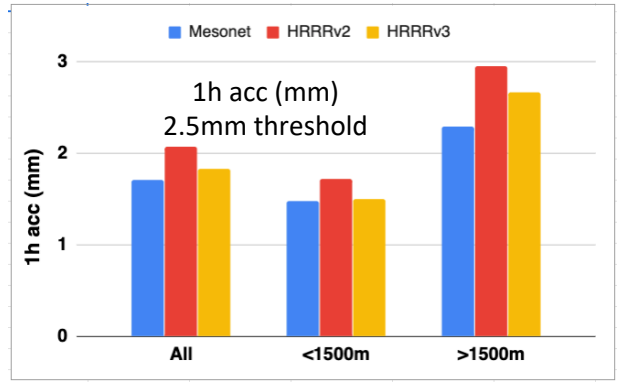
HRRR has a wet bias across most of the region
HRRRv3 improves over HRRRv2





CSI	All	<1500m	>1500m
HRRRv2	0.49	0.46	0.56
HRRRv3	0.53	0.50	0.60





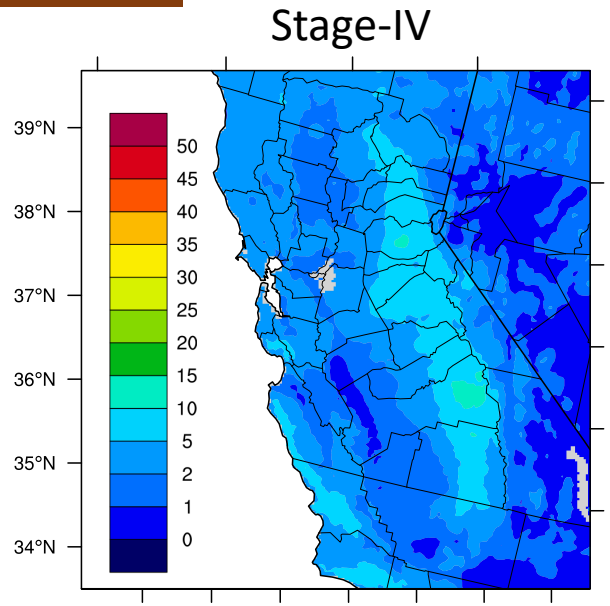
CSI	All	<1500m	>1500m
HRRRv2	0.61	0.54	0.79
HRRRv3	0.63	0.57	0.78

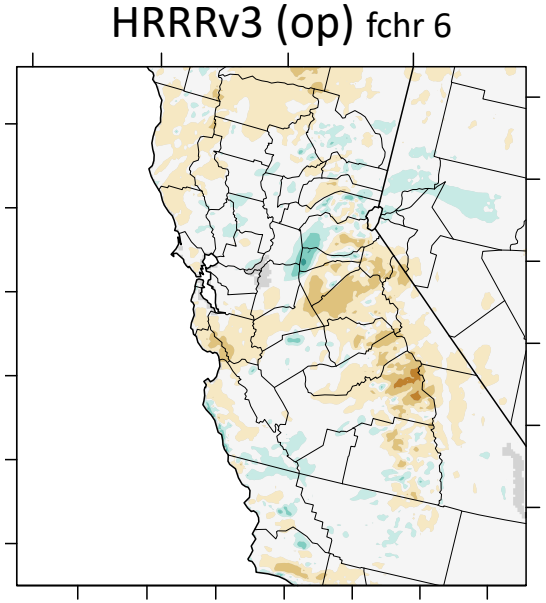
33.2-41.4 °N 118.1-124.9 °W

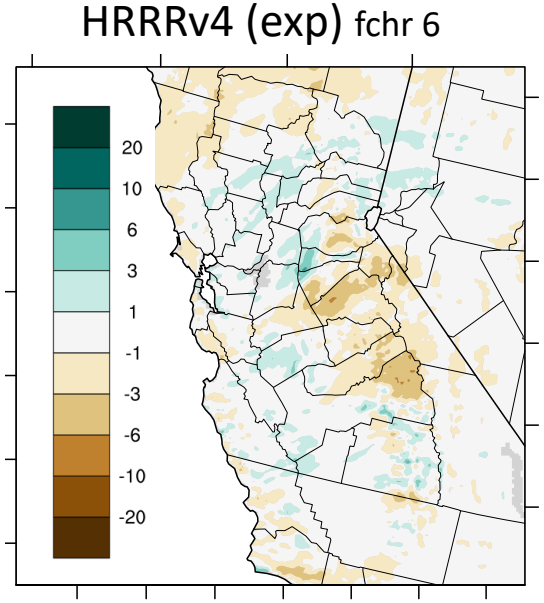
AR event: 2-3 Mar 2019

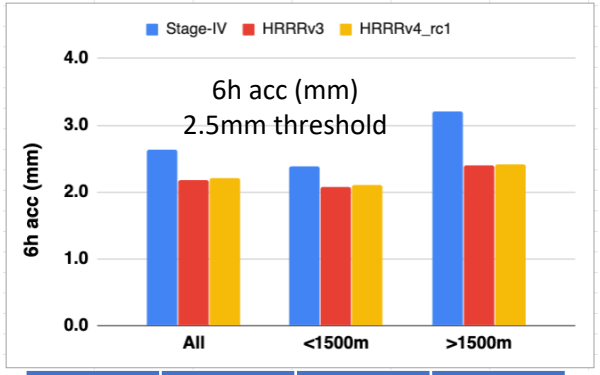
Stage-IV & Mesonet disagree at high altitude, HRRRv4 slightly improved over HRRRv3

6h acc (mm)



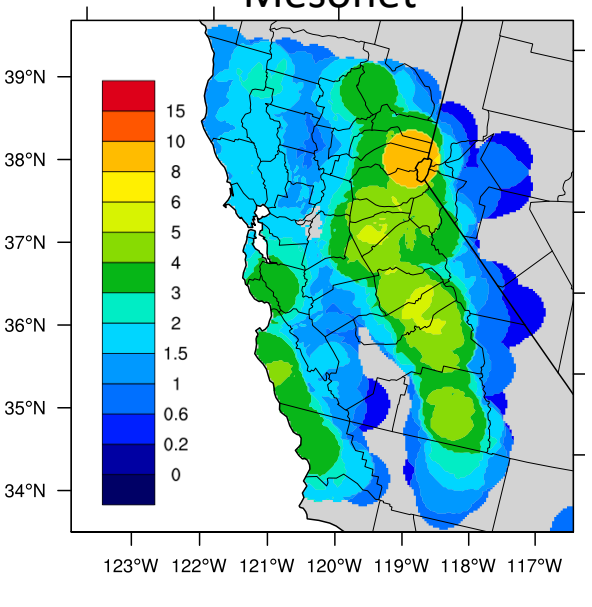


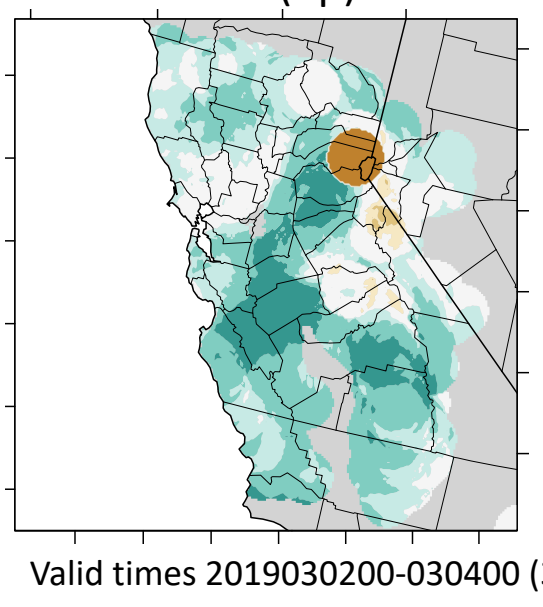


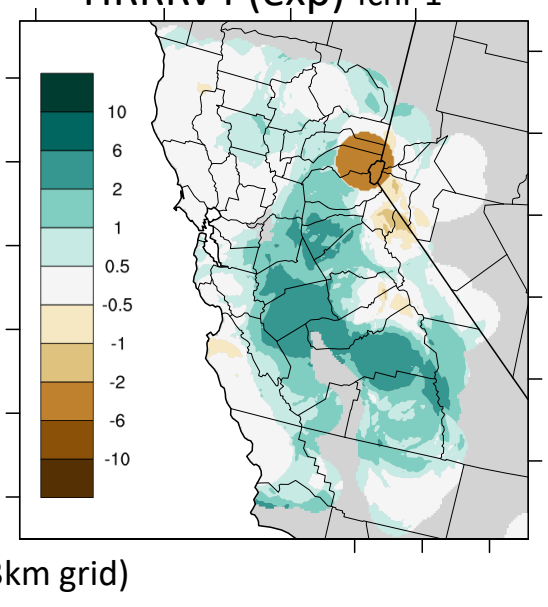


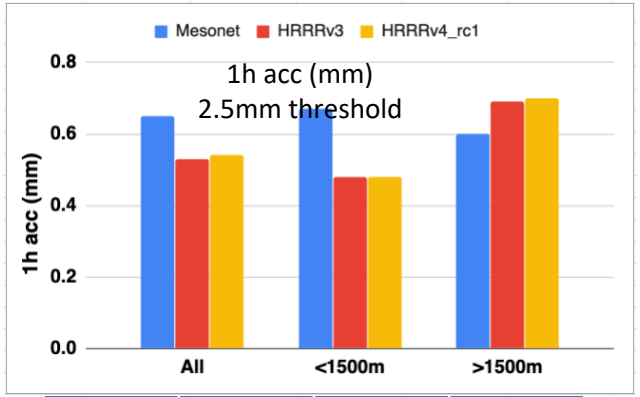
CSI	All	<1500m	>1500m
HRRRv3	0.52	0.52	0.53
HRRRv4	0.55	0.55	0.55

1h acc (mm) [40km NM]









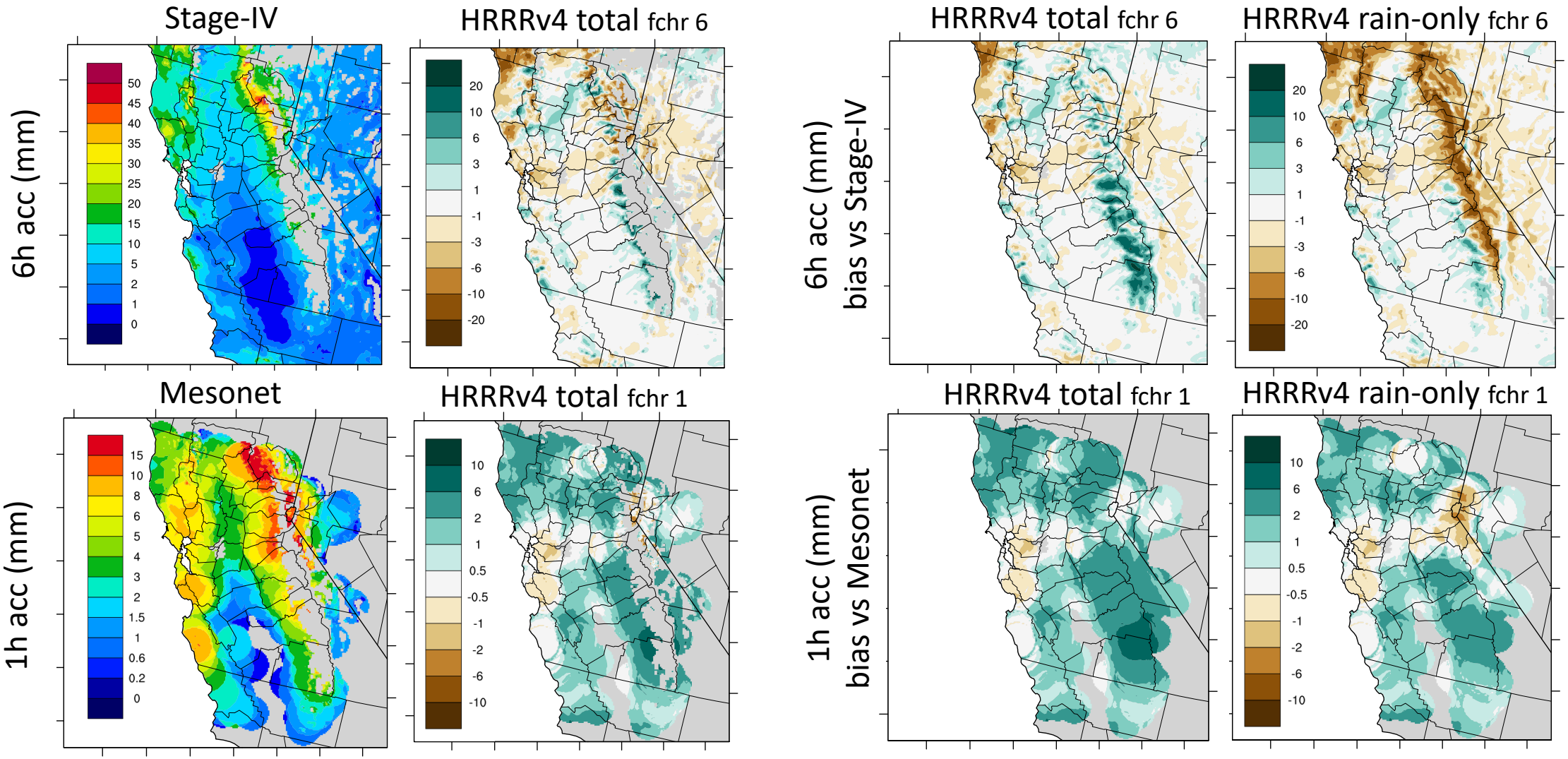
CSI	All	<1500m	>1500m
HRRRv3	0.46	0.43	0.52
HRRRv4	0.50	0.49	0.52

Valid times 2019030200-030400 (3km grid)

33.2-41.4 °N 118.1-124.9 °W

AR event: 13-15 Feb 2019

Snow explains some of the wet bias (esp vs Mesonet)



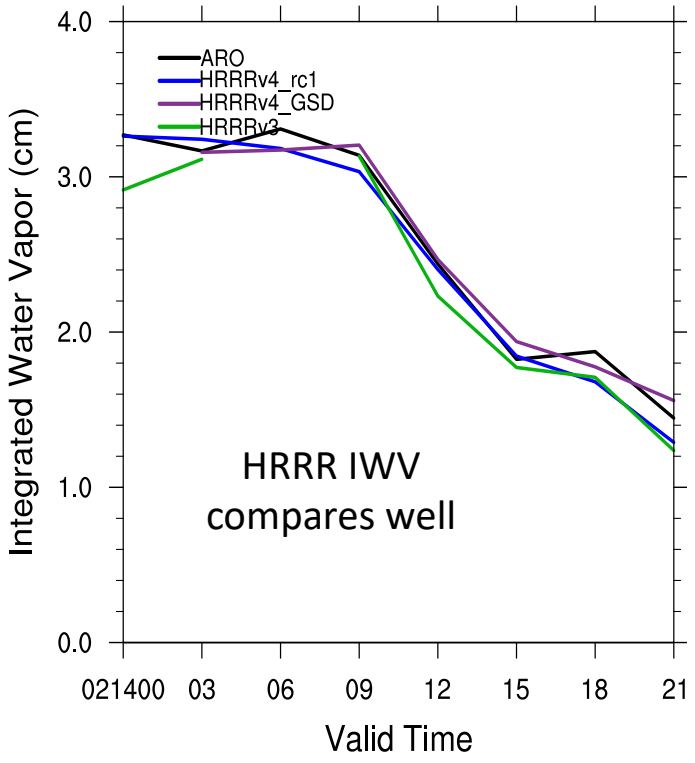
Largest wet biases are eliminated where temperatures are below 3 C

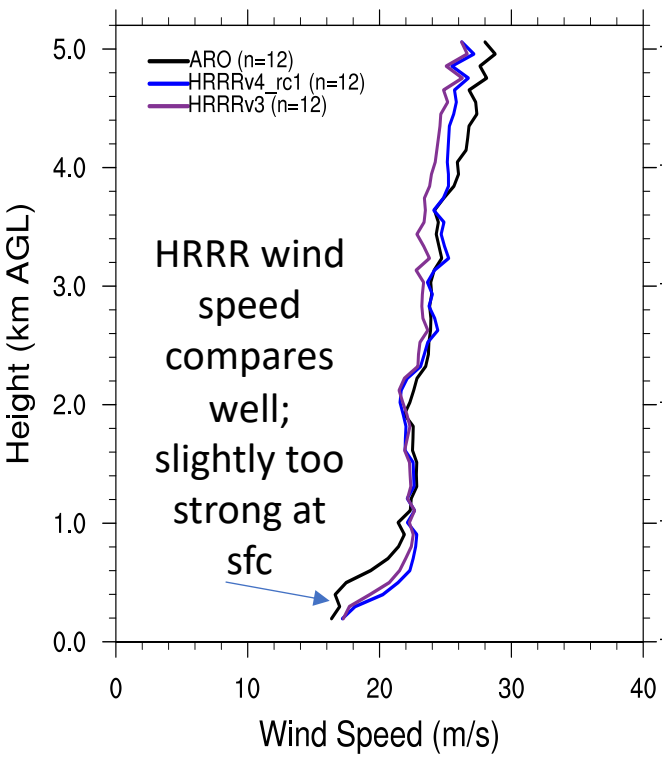
HRRR rain-only compares better to Mesonet than Stage-IV

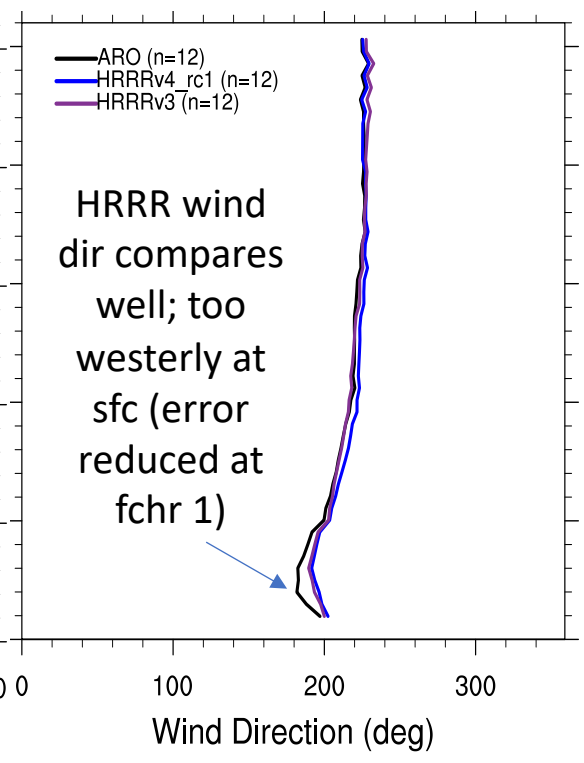
Valid times 2019021306-021506 (3km grid)

AR event: 13-15 Feb 2019

HRRR winds & IWV compare well to measurements at BBY (and PTS, not shown)





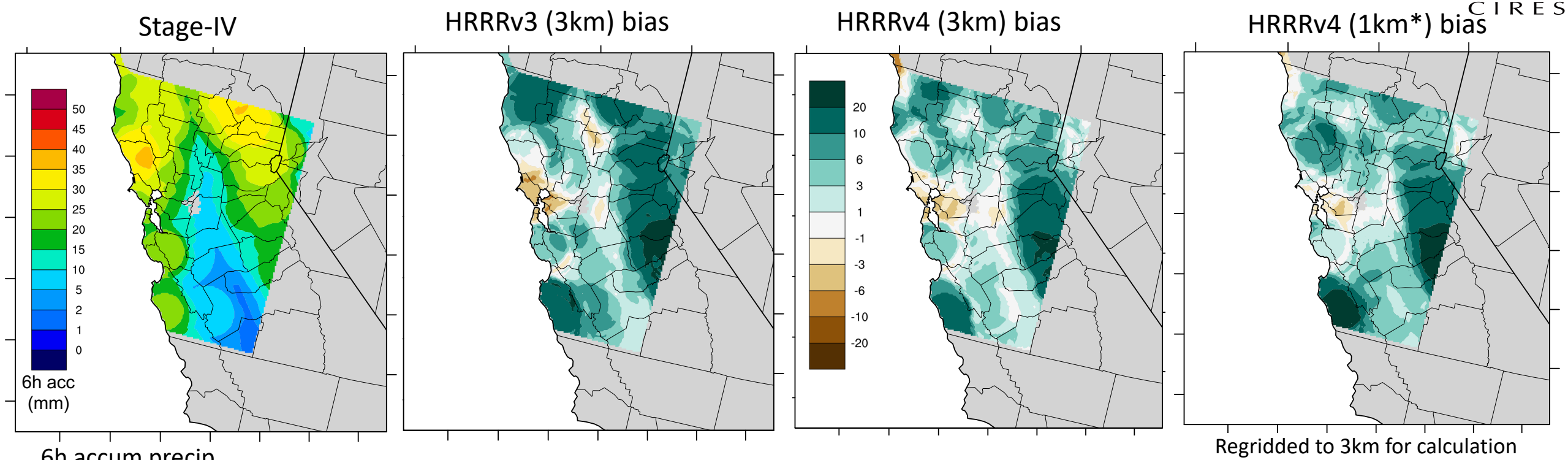


6h forecasts; 2019021306-021506 (48h avg); matched

- Why does HRRR have a dry bias at low altitude?
  - Bay Area QPF bias does not appear to be due to IWV or wind errors nearby (two locations)

AR event: 13-15 Feb 2019

HRRR 1km nest: CSI / ETS / bias similar to 3km suggesting HRRR terrain/lower atmosphere resolution not the problem



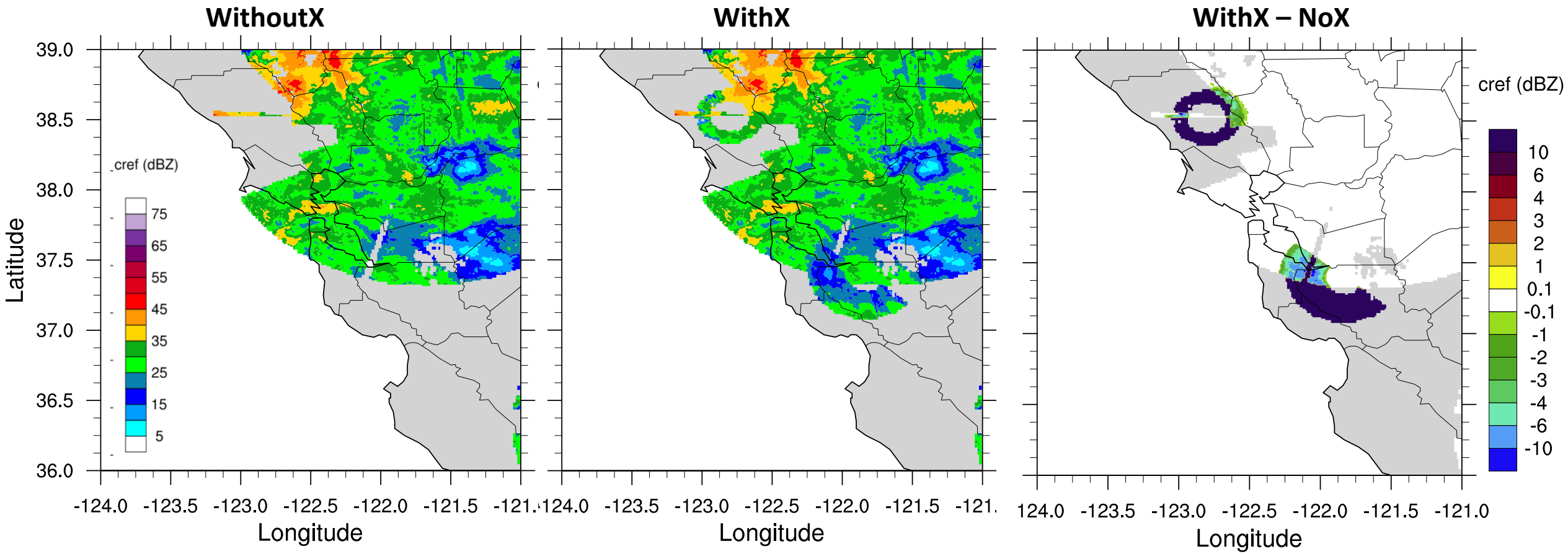
6h accum precip
(fchr 6, vstep 6, 40km NM, 3km grid)
Valid times 2019021306-021506

Regridded to 3km for calculation

CSI (40km NM)	All	<1500m	>1500m
HRRRv3	0.89	0.88	0.89
HRRRv4	0.90	0.90	0.90
HRRRv4_1km nest	0.89	0.89	0.89

AR event: 13-15 Feb 2019

Adding X-band radar to HRRR DA: Grids including X-band radar have noticeable reflectivity differences at their radar locations at specific times

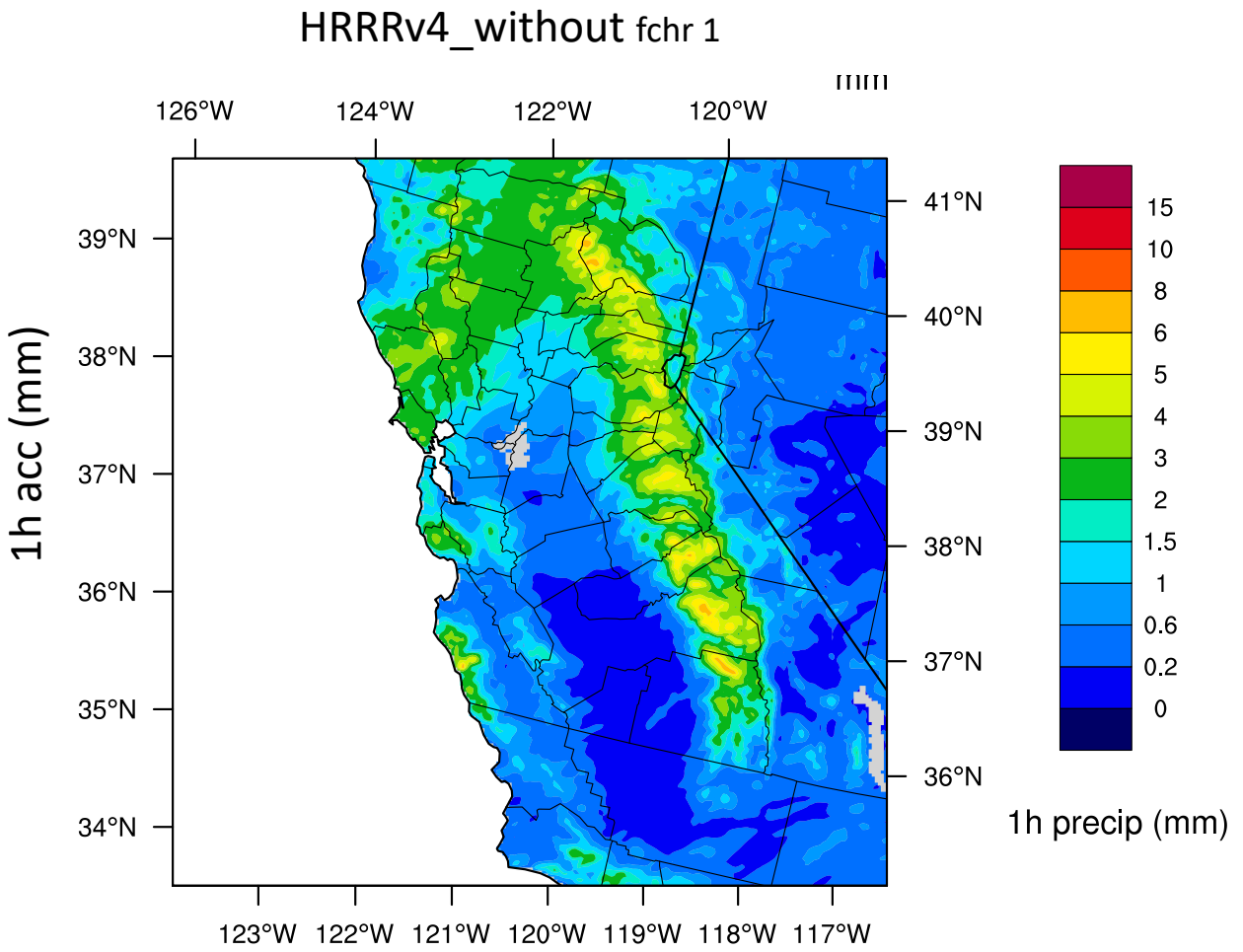


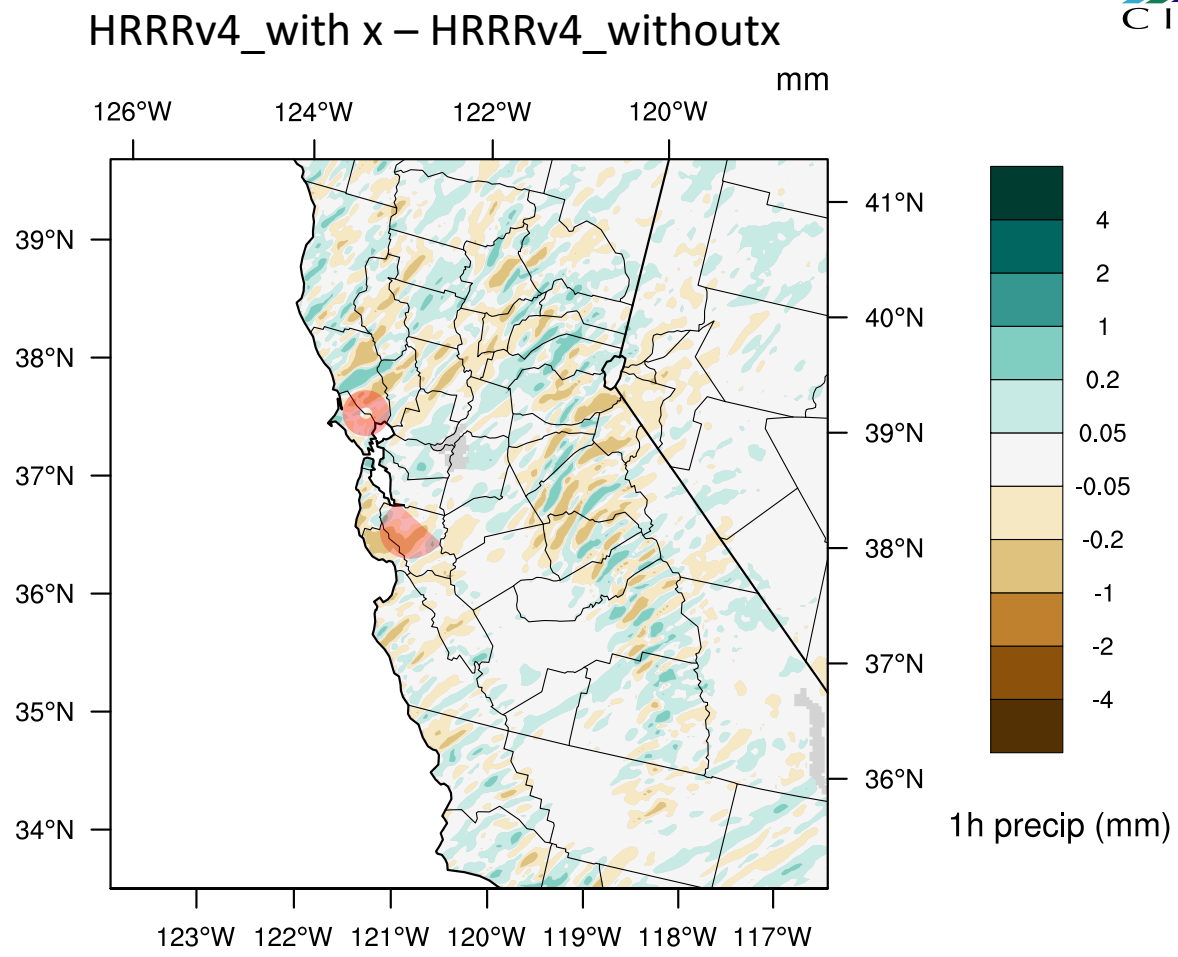
WithoutX missing values set to zero for difference calculation

Val Time: 13-Feb-2019, 13hr 14min
Lev: 1km

AR event: 13-15 Feb 2019

However, QPF is similar
Average precip / CSI / ETS are similar





Valid times 2019021306-021506 (3km grid)

CSI	All	<1500m	>1500m
Without X	0.75	0.75	0.74
With X	0.75	0.76	0.74

Summary

- Evaluated QPF from HRRR op/exp for six AR events:
  - Overall, HRRR QPF compares reasonably well to QPE measures (new HRRR usually better)
  - HRRR usually has a wet bias at high altitude and a dry bias near the Bay Area / coast
    - High altitude wet bias is partly due to snow
    - HRRR temperature/wind/IWV compares favorably to Bay Area observatories
    - HRRR 1km nest has similar CSI/ETS to 3km HRRR, suggesting grid resolution not the issue
  - Stage-IV and mesonet agree fairly well, but they weren't directly compared
  - HRRR has more wet bias via 40 km NM technique than grid-grid comparisons
  - Incorporating X-band radar reflectivity into HRRR DA does not significantly impact forecasts

Next Steps

- Compare HRRR state variables to more ARO sites, Oakland soundings, satellite PW
- Extend rain/snow analysis to the other five AR events
- Further explore grid-grid vs Neighborhood Max
- Submit a journal manuscript on this work