Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

CW3E Field Campaigns to Support Hydrometeorological Forecasting in the northern Sierra Nevada

Forest Cannon

Center for Western Weather and Water Extremes (CW3E)

Scripps Institution of Oceanography, UCSD

SCRIPPS INSTITUTION OF OCEANOGRAPHY

OUTLINE

- Yuba/Feather Forecast Informed Reservoir Operations
- Freezing Level Observations
  - Physical Process Studies (West-WRF)
  - Reforecast project
- Additional Observations
- Atmospheric River Reconnaissance

YUBA/FEATHER FIRO

FIRO researches opportunities to improve reservoir operations and reduce flood risks by improving weather and runoff forecasts.

Understanding and better predicting regional rainfall and snow processes is fundamental to establishing forecast confidence.

For More Information:

https://cw3e.ucsd.edu/firo_yuba_feather/

FIRO Steering Committee Members

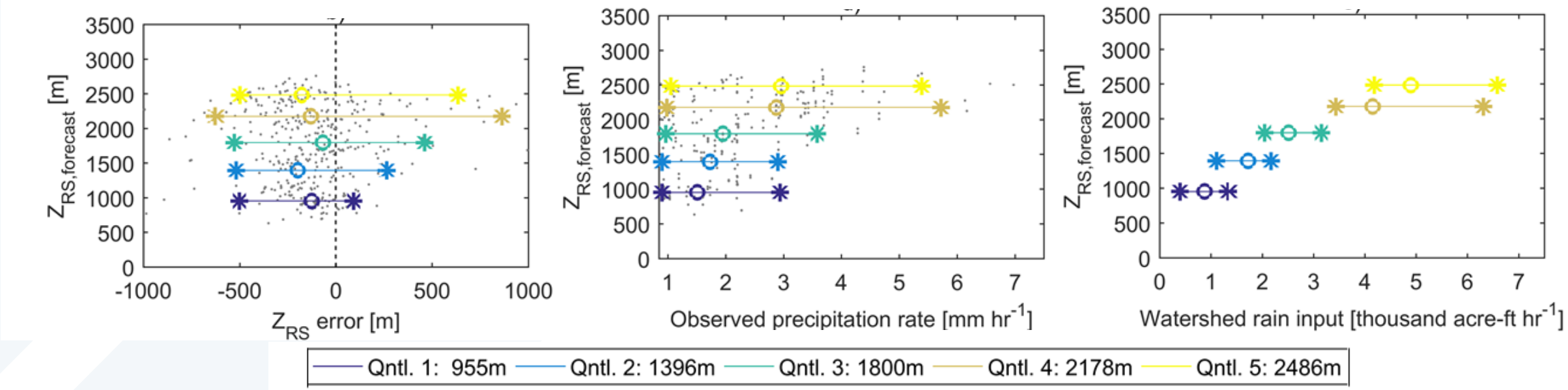
- Co-Chair F. Martin Ralph — *Director, CW3E, UC San Diego Scripps Institution of Oceanography*
- Co-Chair Curt Aikens — *General Manager, Yuba Water*
- Co-Chair John Leahigh — *Water Operations Executive Manager, DWR*

Lake Oroville

NBB Reservoir

SKILL OF RAIN-SNOW LEVEL FORECASTS FOR LANDFALLING ATMOSPHERIC RIVERS
HENN ET AL. (IN PRESS)

Lake McClure (Merced River) watershed topography and precipitation and New Exchequer (ner) profiling radar observations illustrate sensitivity of flood risk to freezing level height and its forecast errors
(West-WRF forecasts with 27-72hr lead times are shown)

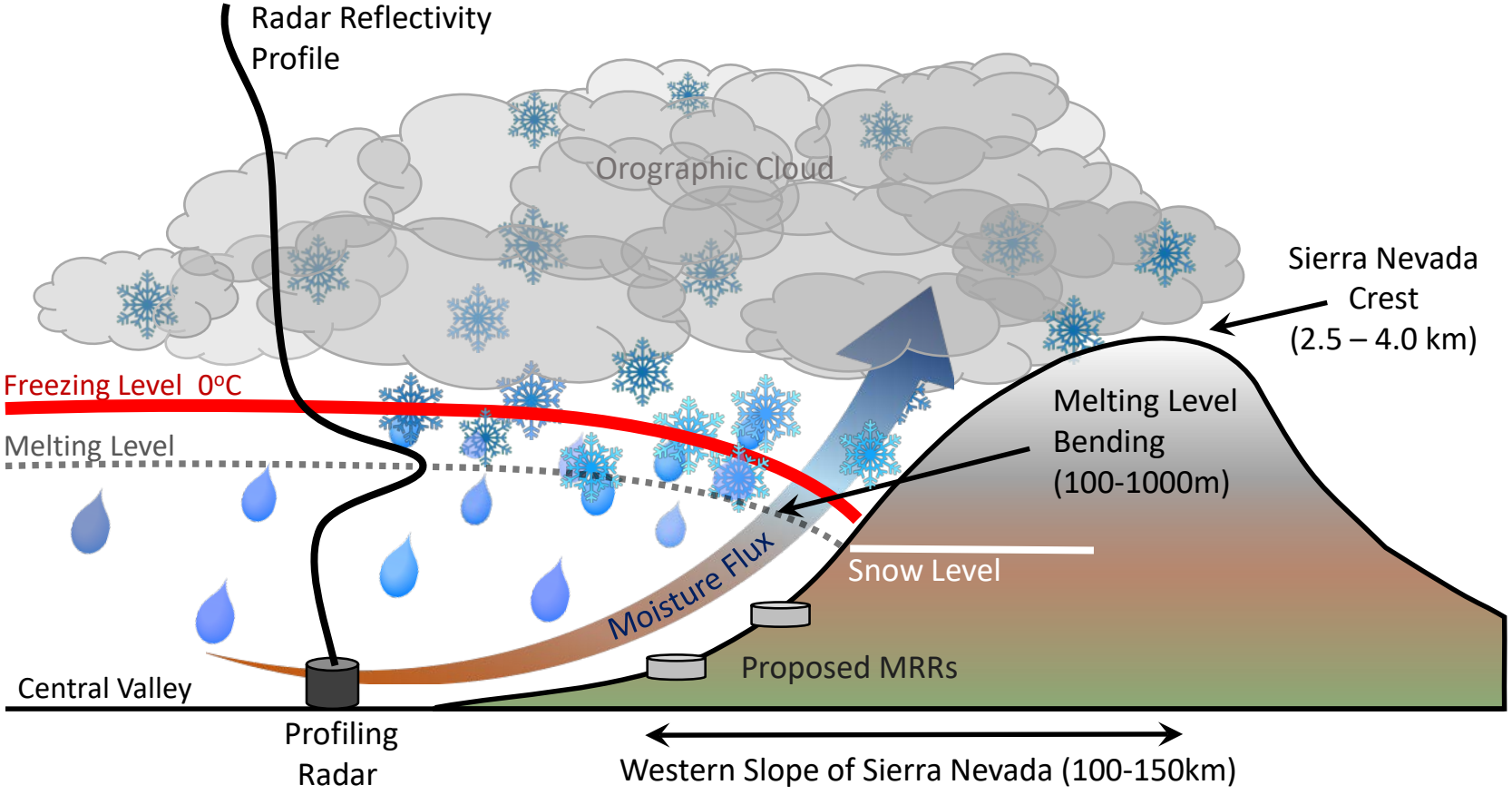


Freezing level forecast uncertainty at 24-hour lead time according to storm temperature

The biggest precipitation events (typically from ARs) generally have higher freezing levels

The watershed rain input is very sensitive to storm freezing level height

Physical Processes Driving Freezing Level Forecast Uncertainty: Melting Level Bending



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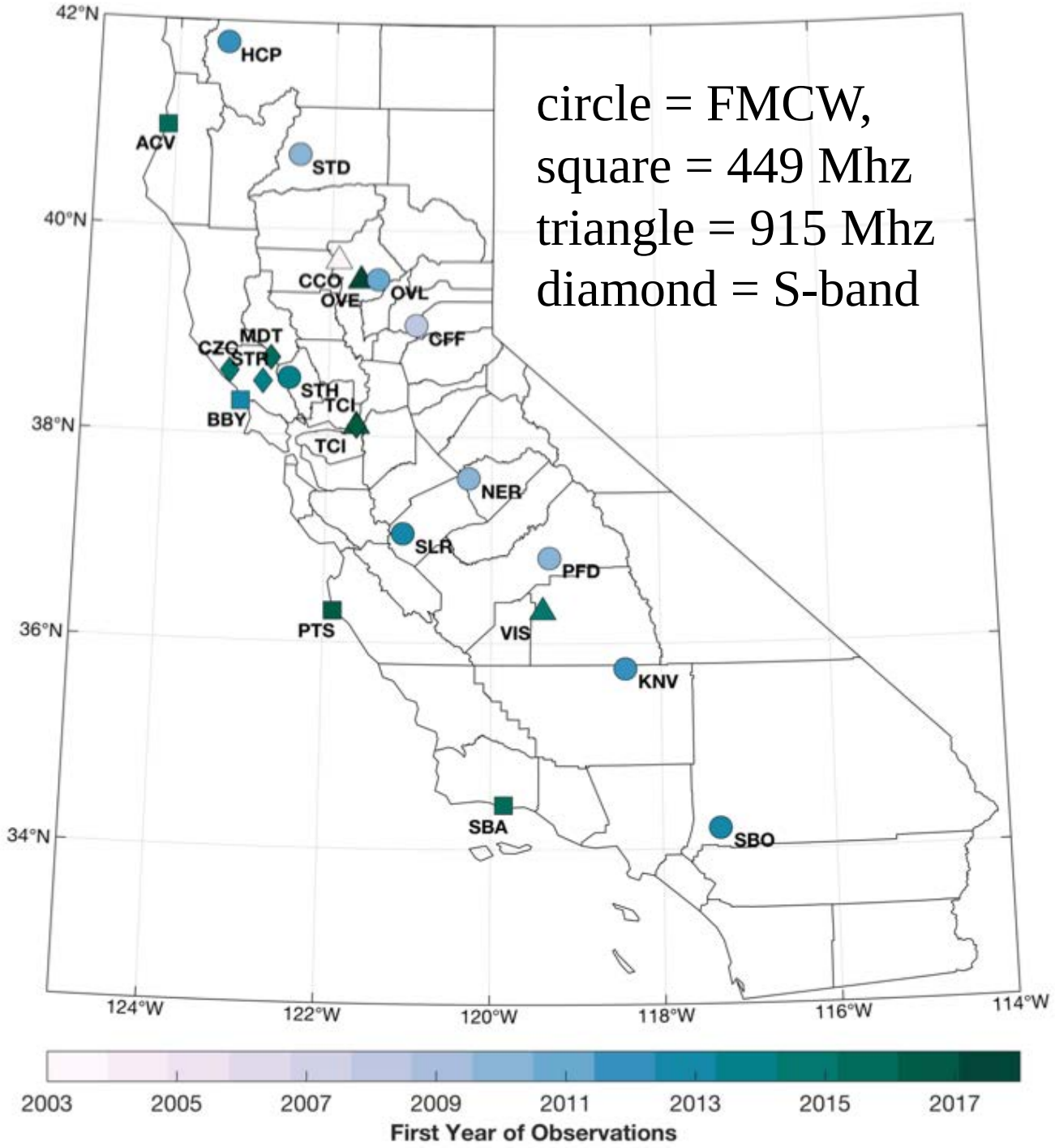
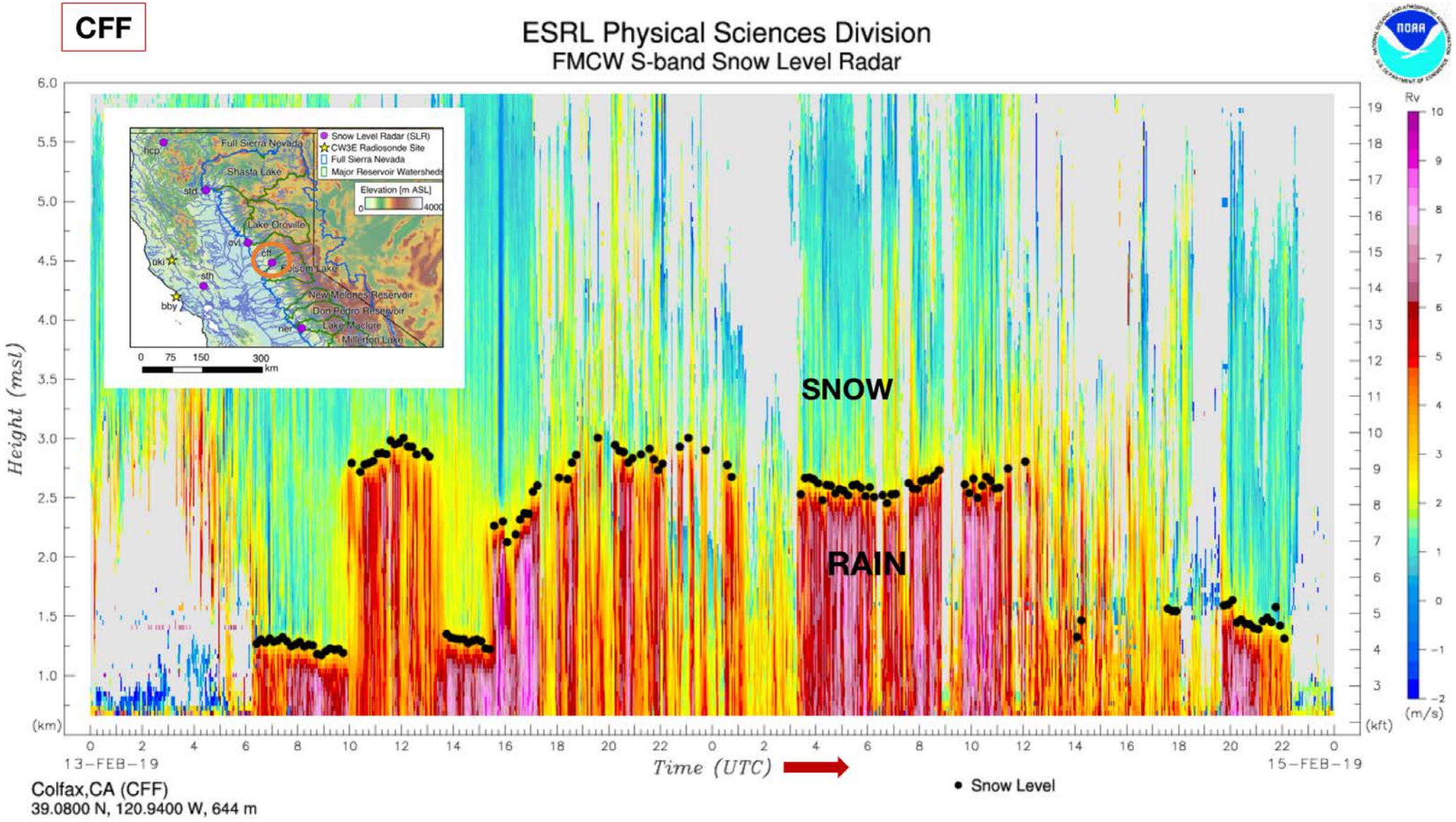


CA NETWORK OF PROFILING RADARS

- jointly supported by the NOAA Earth Systems Research Laboratory and the California Department of Water Resources.
- Network designed to provide novel observations of hydrometeorological processes relevant to water management during extreme events.
- provides data to support hydrologic forecasting and water resource operations, as well as research efforts aimed at evaluating characteristics of freezing levels in mountainous terrain.

EXAMPLE OF FORECAST CHALLENGE

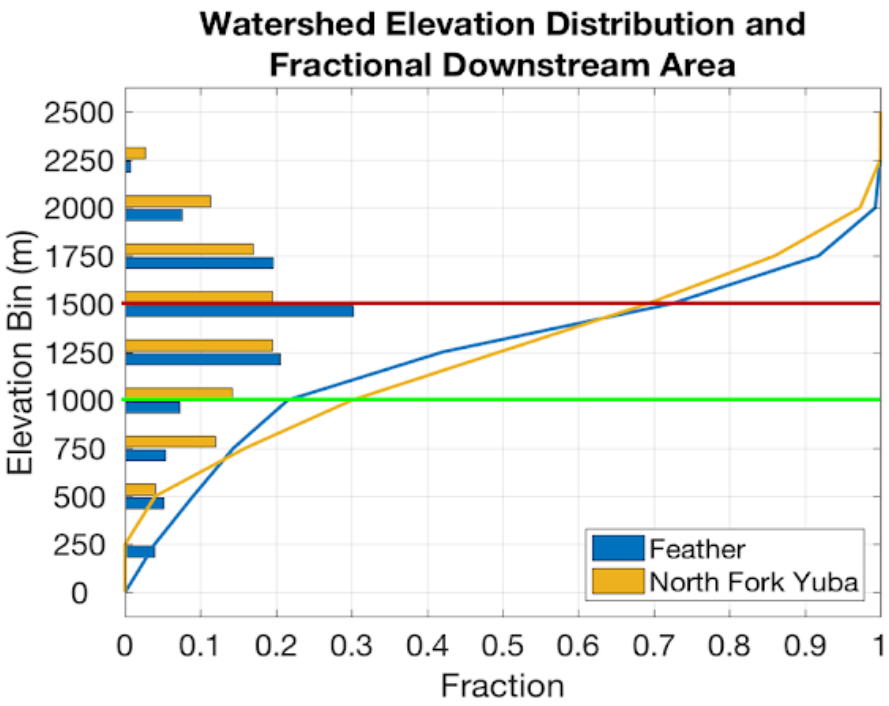


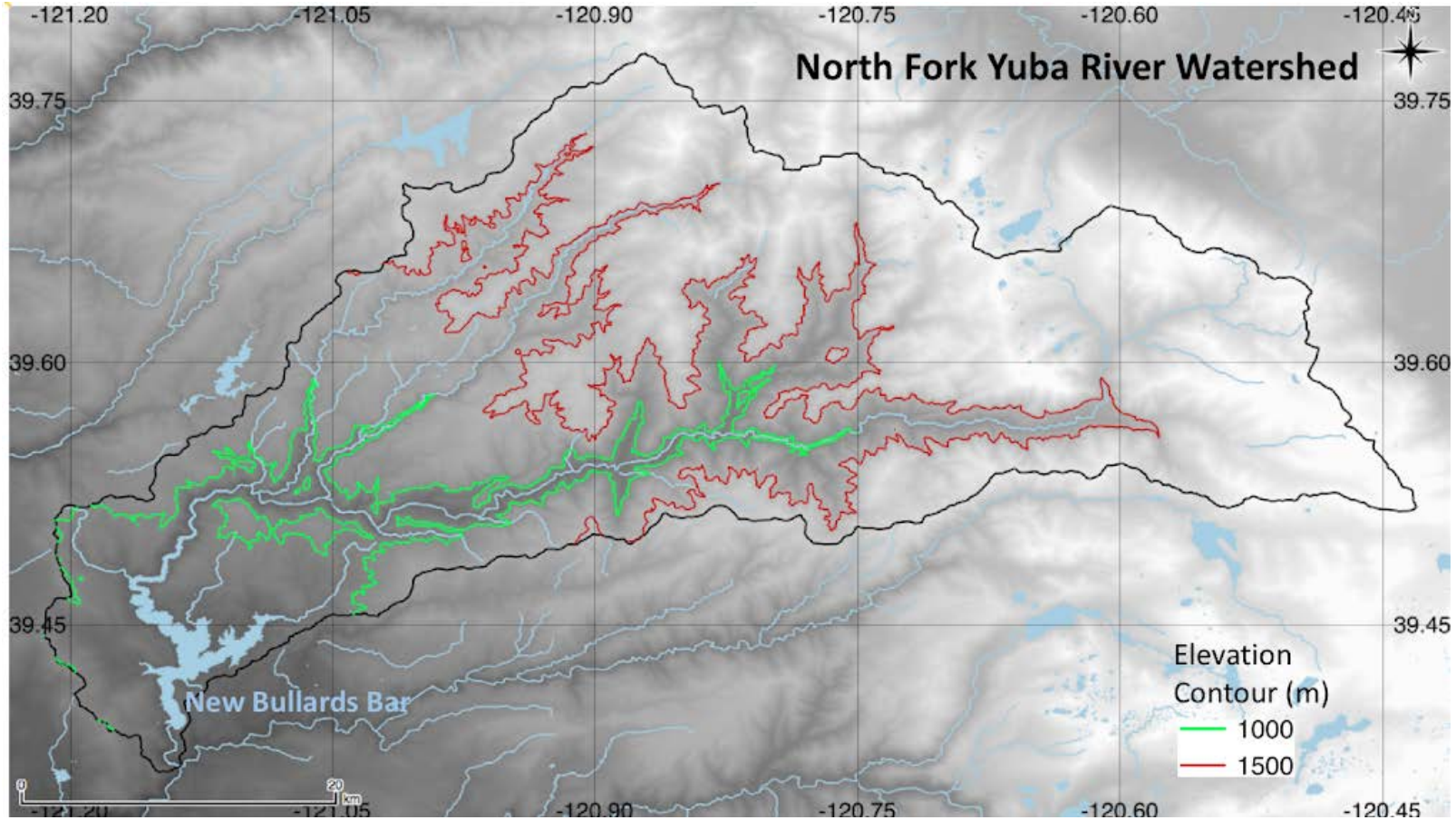
Slide Provided by Tashiana Osborne

USES OF HMT NETWORK

- Monitoring snow levels during storms
- Predicting runoff from watersheds receiving frozen and liquid precipitation that affects flooding, flood control systems, and reservoir operations
- Identifying abrupt changes in snow levels and evaluating the physical processes controlling snow level variability
- Investigating and documenting climate change trends
- Validating numerical weather model forecasts

Importance of Basin Hypsometry in Freezing Level Uncertainty Impacts





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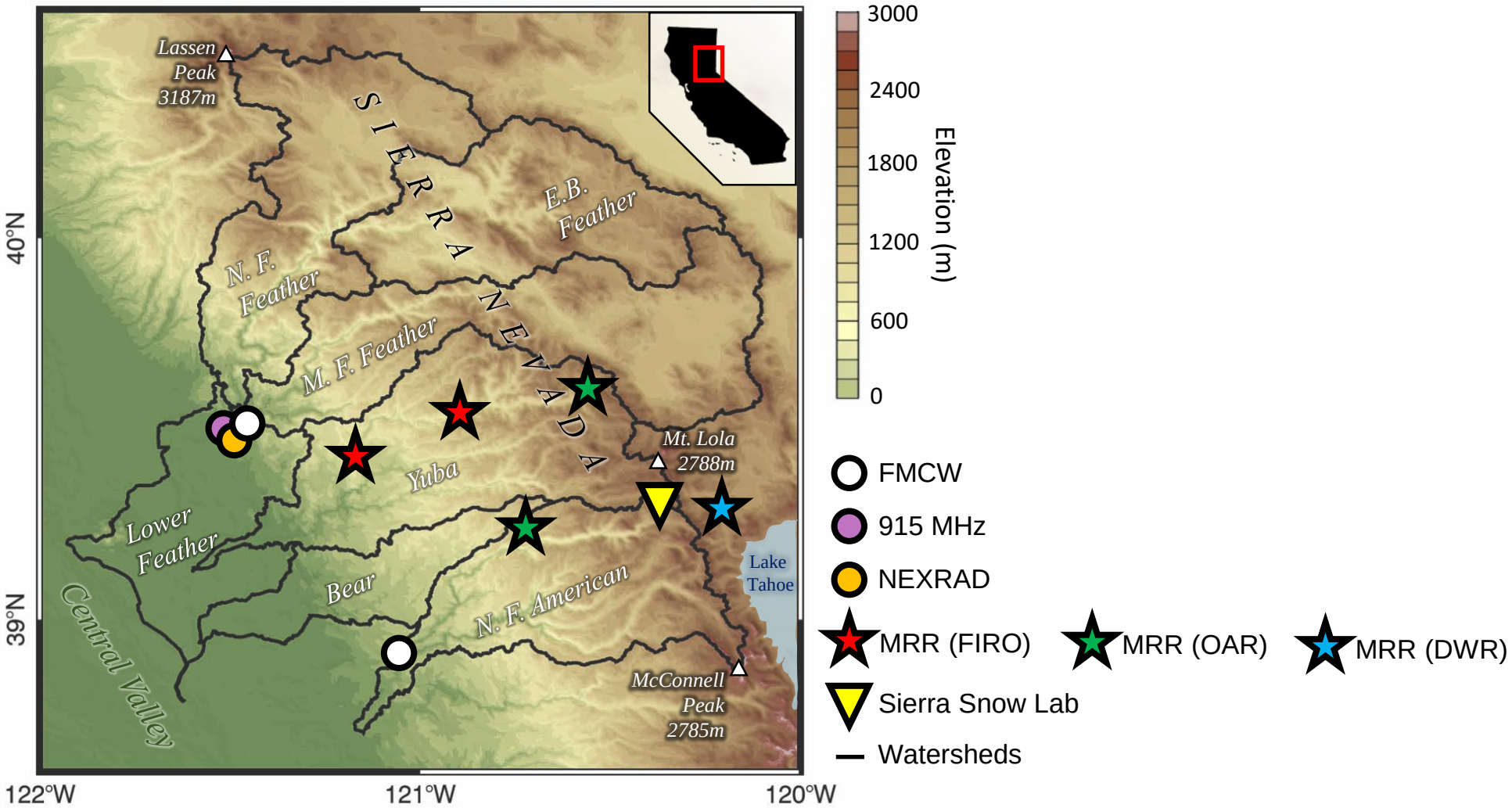
Yuba/Feather Forecast Informed Reservoir Operations (FIRO) Field Campaign



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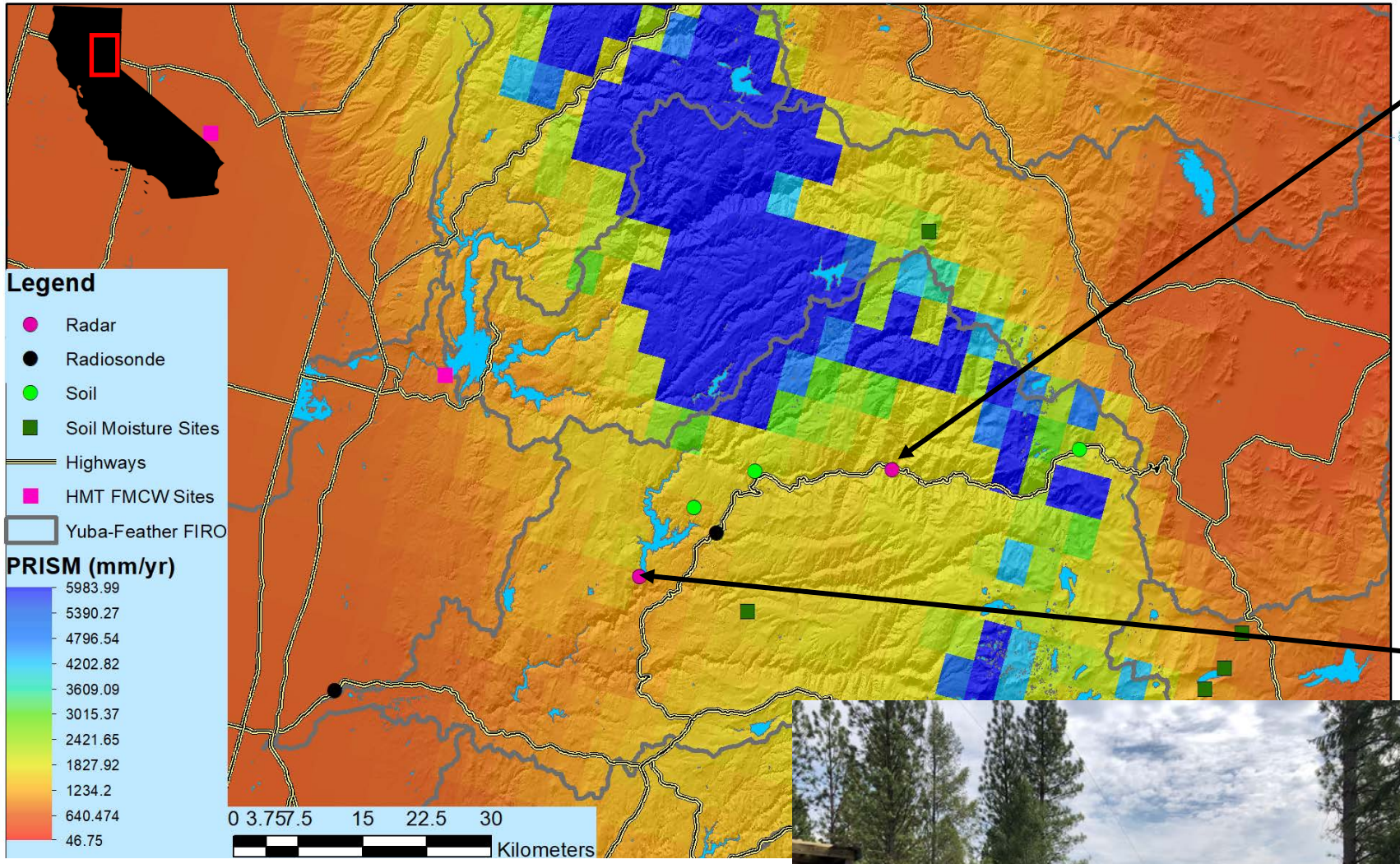
w/ support from Yuba Water Agency, US Army Corps and CA DWR



Downieville MRR site. Local landowner (connection through Yuba Water Agency); ~900m

New Bullards Bar dam – MRR location, on roof of spill gate house OR at storage building above marina. Working out details. ~500m

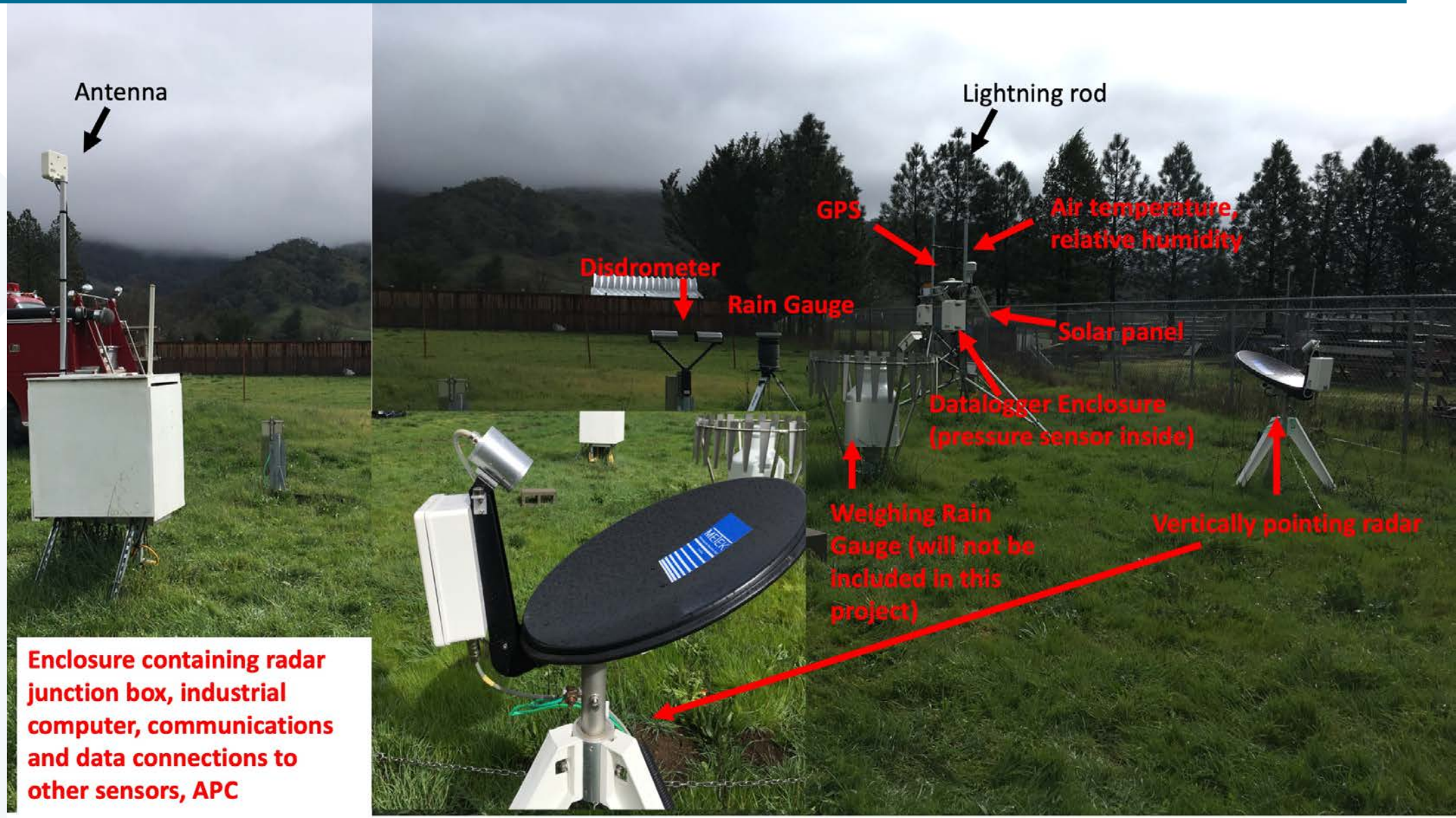
MRR straight line distances – 32km over elevation difference of 400m (500m first site; 900m second)

PROPOSED ADDITIONAL SNOW LEVEL STATIONS

Micro Rain Radar- signal to noise ratio, fall velocity – hydrometeor profiles, and snow level.

GPS-Met: provides integrated water vapor

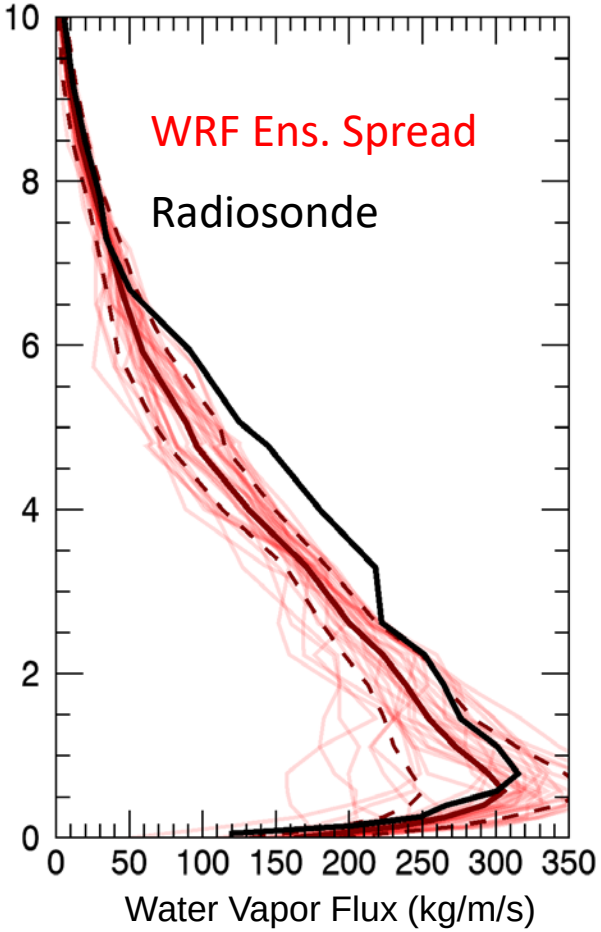
Others: surface measurements



Provided by C. Ellis, A. Cooper, D. Alden, & A. Wilson

Additional Co-Located Observations

Radiosondes



Observation-based evaluation of model representation of physical processes.

Ensemble enables model uncertainty to be evaluated separately.

CW3E Stream Discharge and Isotope Measurements

- Currently only deployed in the Russian River basin
- Preliminary plans to add sites in the Yuba/Feather

Comprehensive observations to identify and understand sources of precipitation variability and runoff impacts

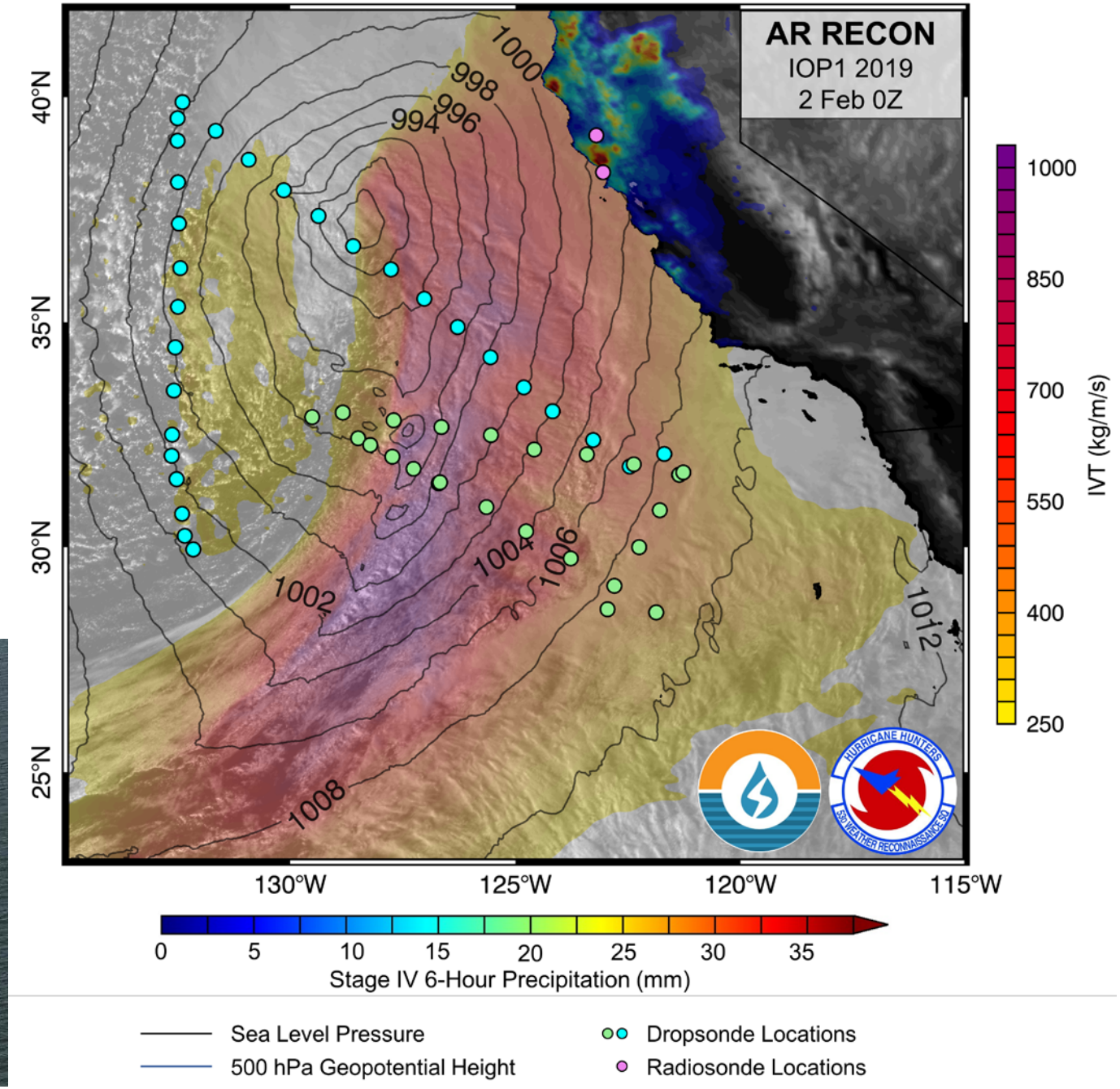
Taking Advantage of Unique Observations

AR Recon (PI: F. Marty Ralph – CW3E)

AR Recon = opportunity to collect unique data on AR structure ahead of landfall

Data support global numerical weather prediction

Data can be also used to evaluate physical processes and their representation in WestWRF



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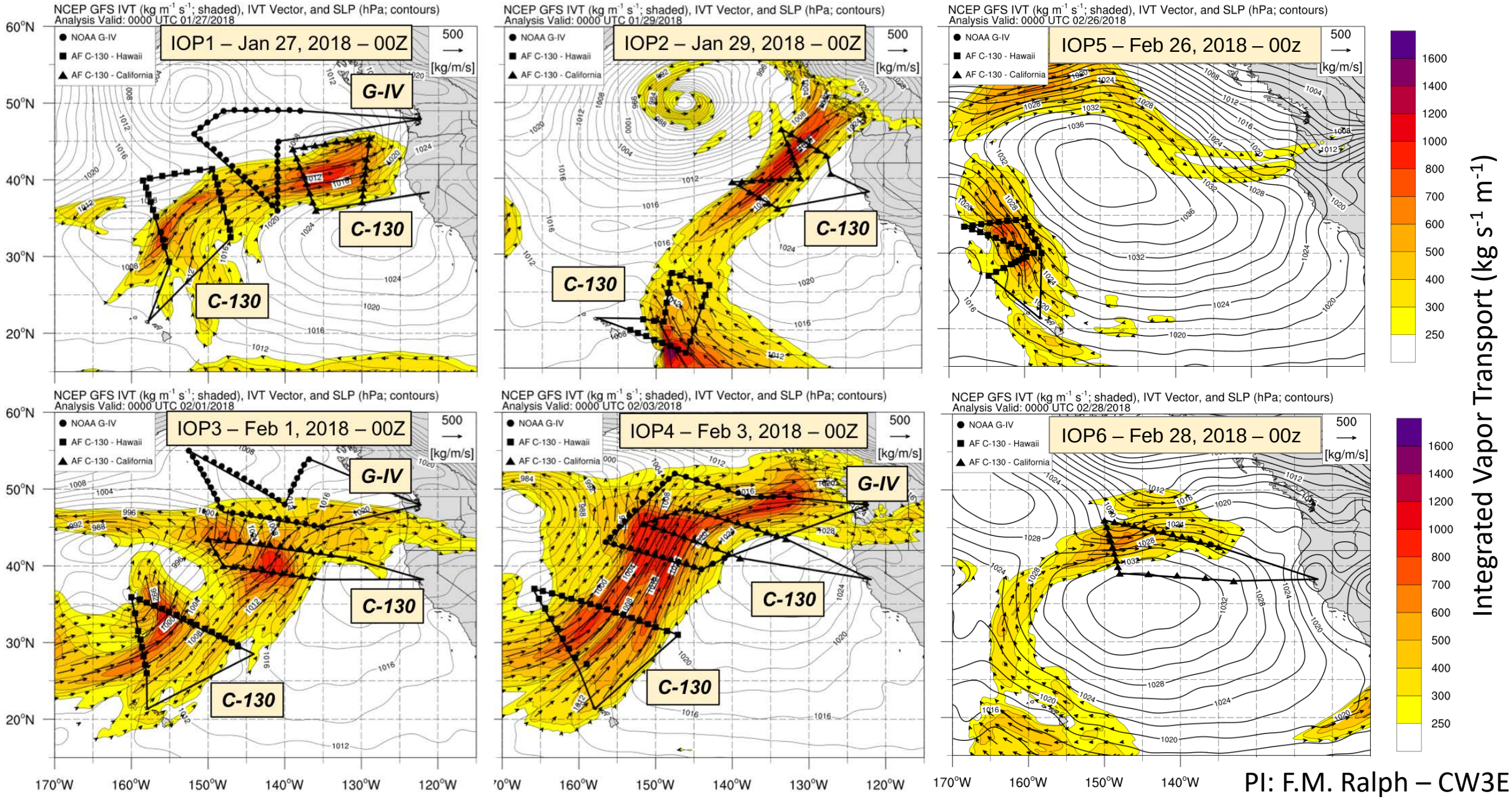
Atmospheric River Reconnaissance 2018

U.S. AIR FORCE



PI: F.M. Ralph – CW3E

Dropsonde Observations

Temperature
Humidity
Pressure
Winds

AR Recon Assimilated Dropsonde Data (2016-2019)

Date	AF C-130	AF C-130	NOAA G-IV	Dropsondes	Dropsondes Assimilated		
2016					NCEP	ECMWF	Navy
00 UTC 14 Feb. 2016	X	X	*	99	69	**	**
00 UTC 16 Feb. 2016	X	X	*	80	42	**	**
00 UTC 22 Feb. 2016	X	X	*	95	46	**	**
2018							
00 UTC 27 Jan. 2018	X	X	X		87	80	87
00 UTC 29 Jan. 2018	X	X			47	41	47
00 UTC 1 Feb. 2018	X	X	X		88	79	88
00 UTC 3 Feb. 2018	X	X	X		86	86	86
00 UTC 26 Feb. 2018	X				0	0	0
00 UTC 28 Feb. 2018	X				25	25	25
2019							
00 UTC 2 Feb. 2019	X	X			58	52	53
00 UTC 11 Feb. 2019	X				24	24	24
00 UTC 13 Feb. 2019	X	X			47	48	40
00 UTC 24 Feb. 2019	X	X			45	44	45
00 UTC 26 Feb. 2019	X	X			35	35	35
00 UTC 1 Mar. 2019	X	X			47	54	59

* During 2016 the NOAA G-IV and NASA Global Hawk conducted research flights as part of the NOAA El Nino Rapid Response (ENRR) field campaign. The Global Hawk partially sampled ARs in coordination with the AR Recon C-130s. The G-IV sampled tropical conditions south of Hawaii based on ENRR's primary airborne objectives, which focused on tropical convection.

** The number of assimilated drops in the ECMWF and Navy models is not available for the 2016 season.

PI: F.M. Ralph – CW3E

AR Recon Updates and Plans for 2020

Table 1. Timeline of AR Recon IOPs, aircraft staging locations, flights and dropsondes released.

Year	No. of IOPs	Aircraft	Location	No. of Flights	Total No. of Sondes
2016	3	USAF C-130 USAF C-130	Hickam AFB, Hawaii McChord AFB, California	3 3	272
2018	6	USAF C-130 USAF C-130 NOAA G-IV	Hickam AFB, Hawaii Travis AFB, California Paine Field, Washington	5 5 3#	361
2019+	6	USAF C-130 USAF C-130	TBD (Hawaii) TBD (CA, WA or AK)	4 5	291
Annual+	12*	USAF C-130 USAF C-130 NOAA G-IV	TBD (Hawaii) TBD (California) TBD (Washington)	12* 12* 12*	720*

#GPS radio occultation measurements taken aboard the NOAA G-IV
+32 Drifting barometer buoys deployed from USAF C-130 in two flights ahead of IOP1
*Planned

PI: F.M. Ralph – CW3E

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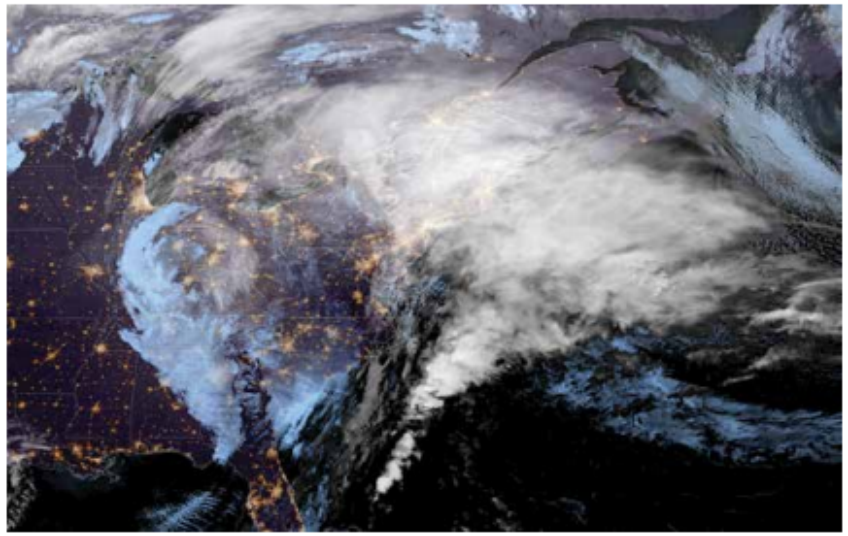
U.S. DEPARTMENT OF COMMERCE/ National Oceanic and Atmospheric Administration

OFCM

OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

National Winter Season Operations Plan

FCM-P13-2019

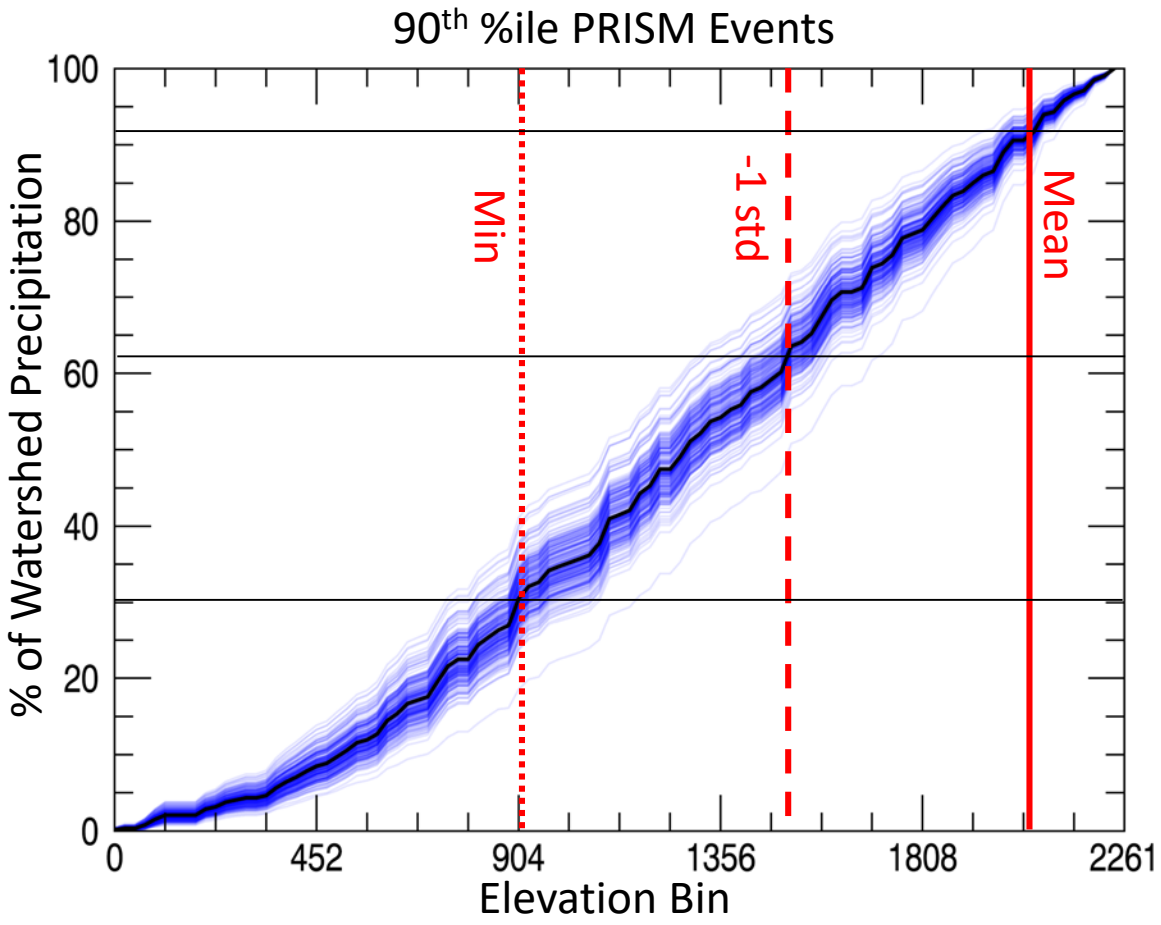


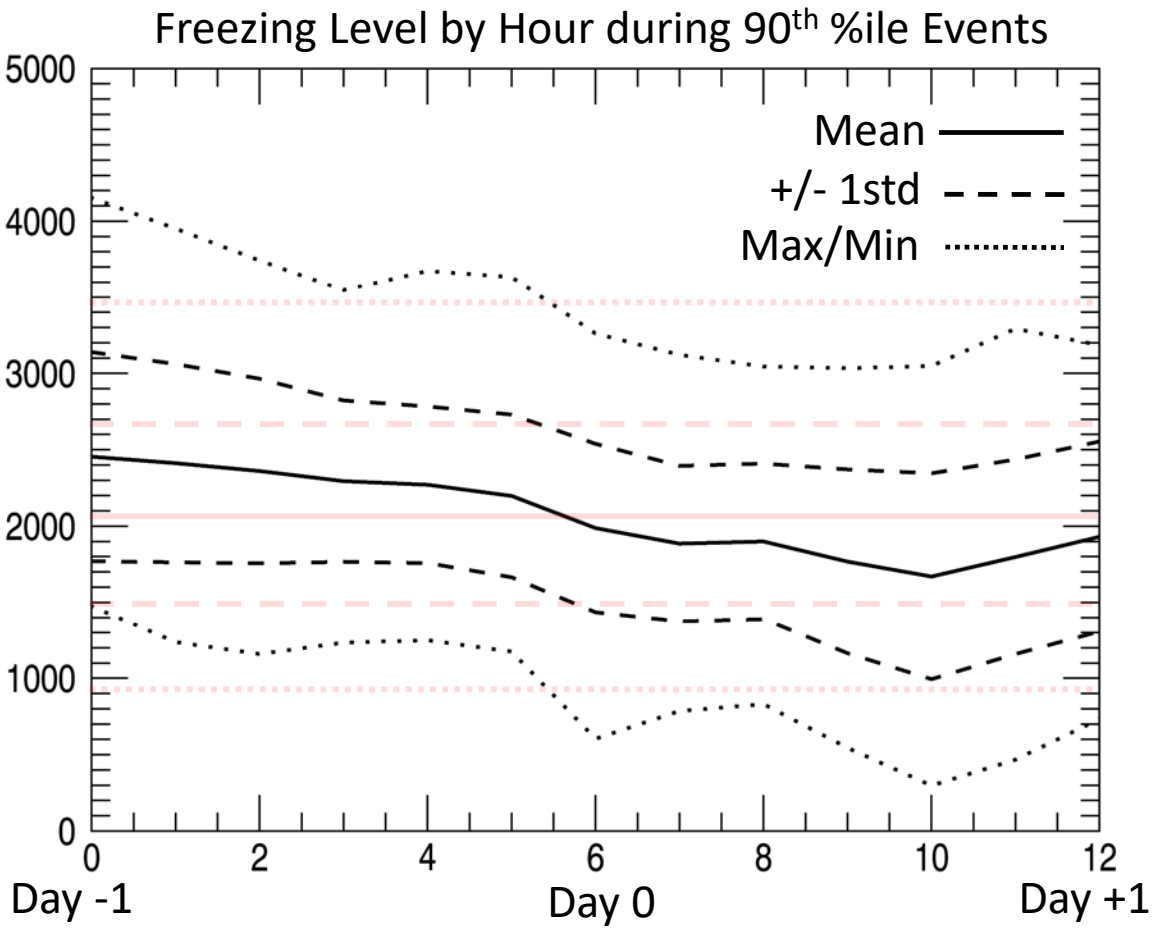
Washington, DC
June 2019

SUMMARY

- Yuba/Feather FIRO field campaign is underway
- Freezing Level Observations for:
  - Real-time monitoring
  - Physical Process Studies (West-WRF)
  - Forecast development
- Additional Observations are being sited to support these efforts
- AR Recon now part of WSOP w/ 12 Storms Planned for 2020

Yuba River Watershed Precip by Elevation and Basin Freezing Level (241 Events = 50%)





CNRFC 6-hour Observation Period

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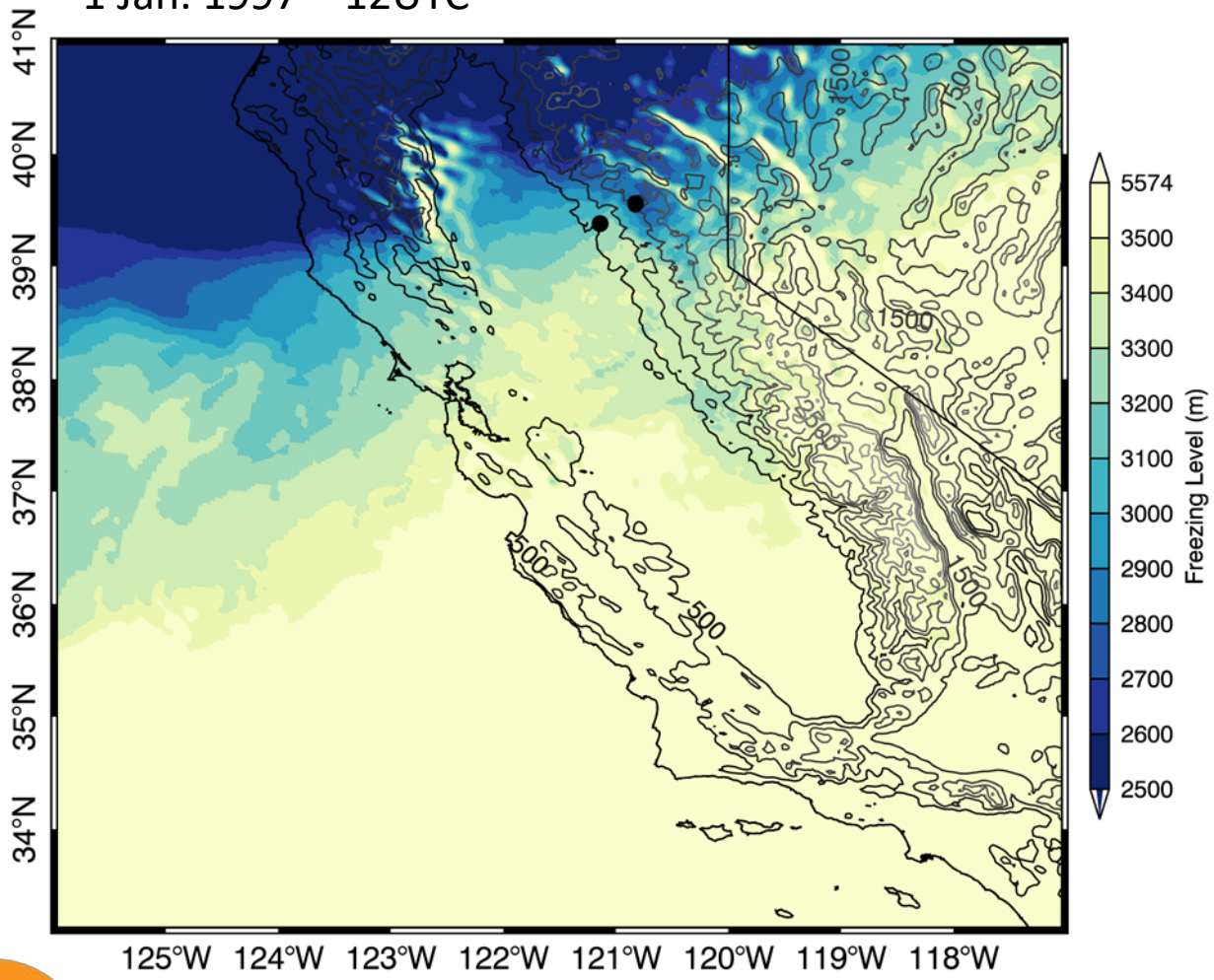
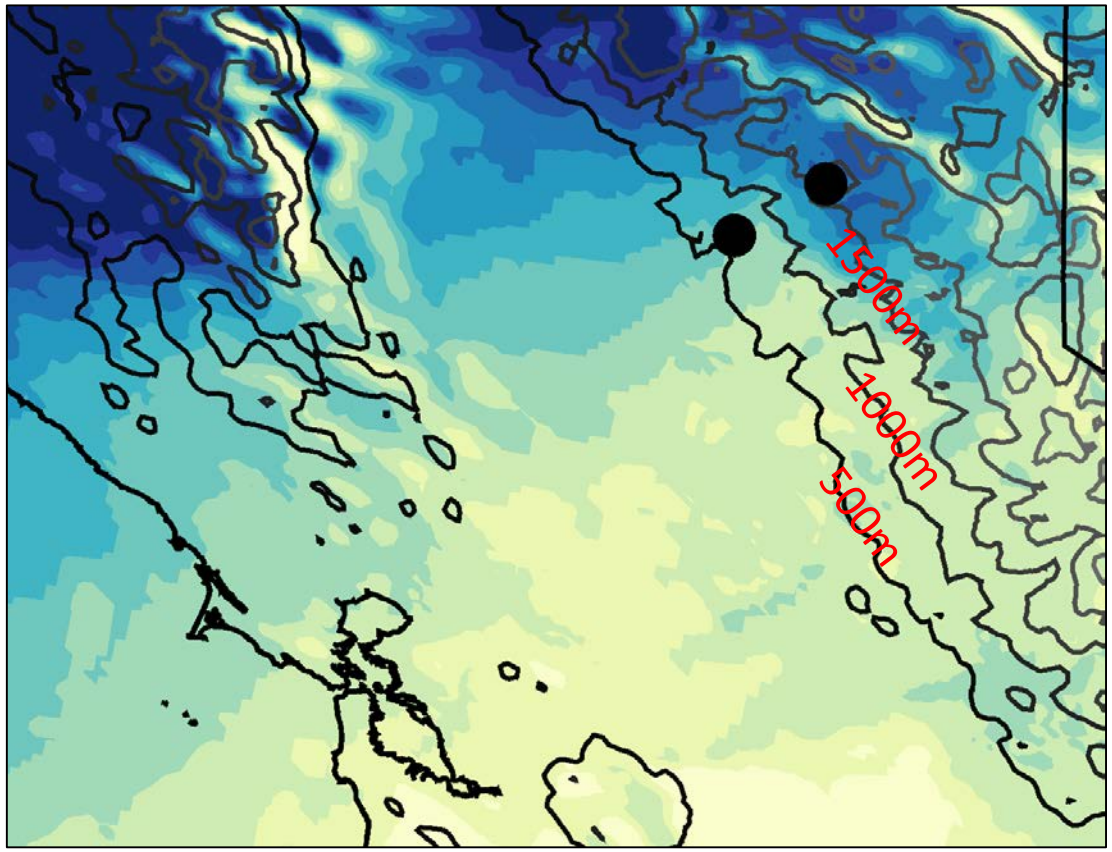
WestWRF Reforecast Freezing Level Height Example

1 Jan. 1997 – 12UTC





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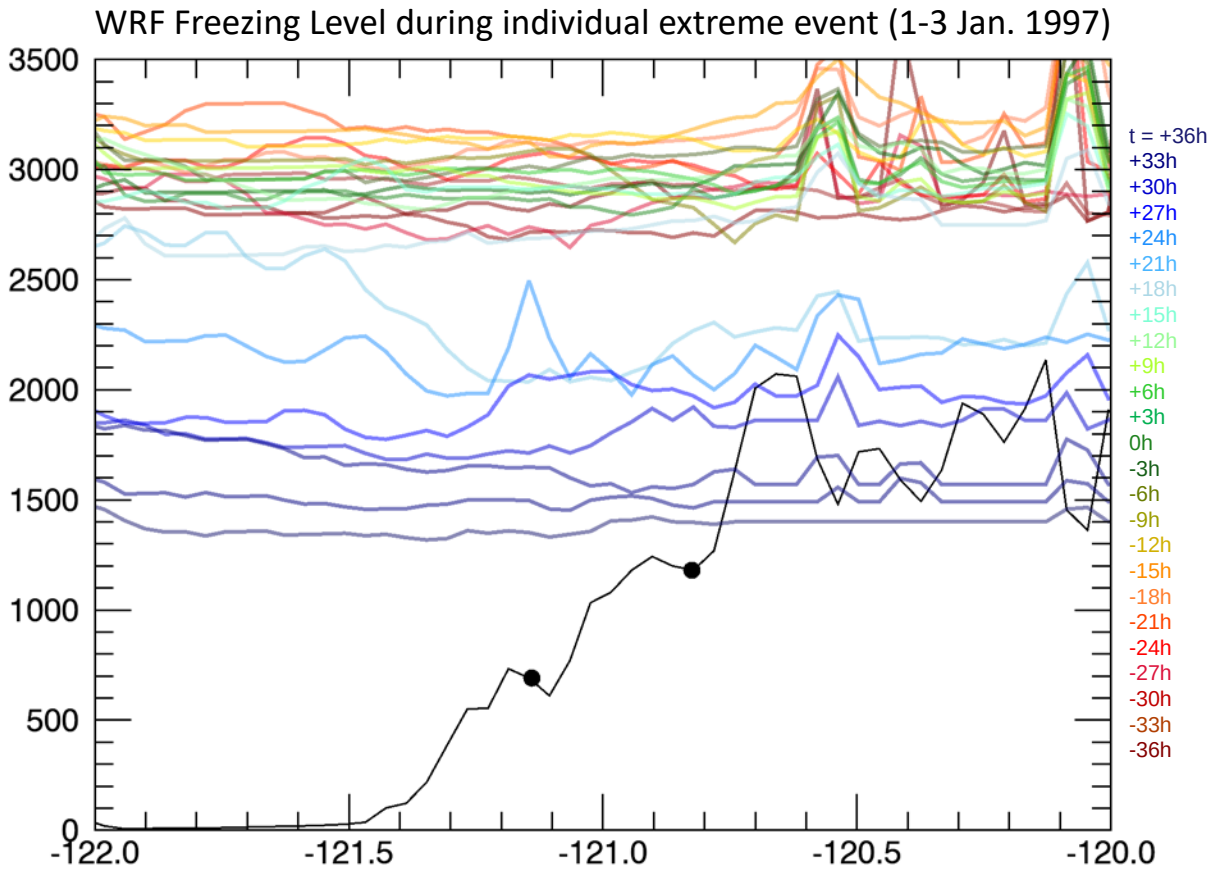
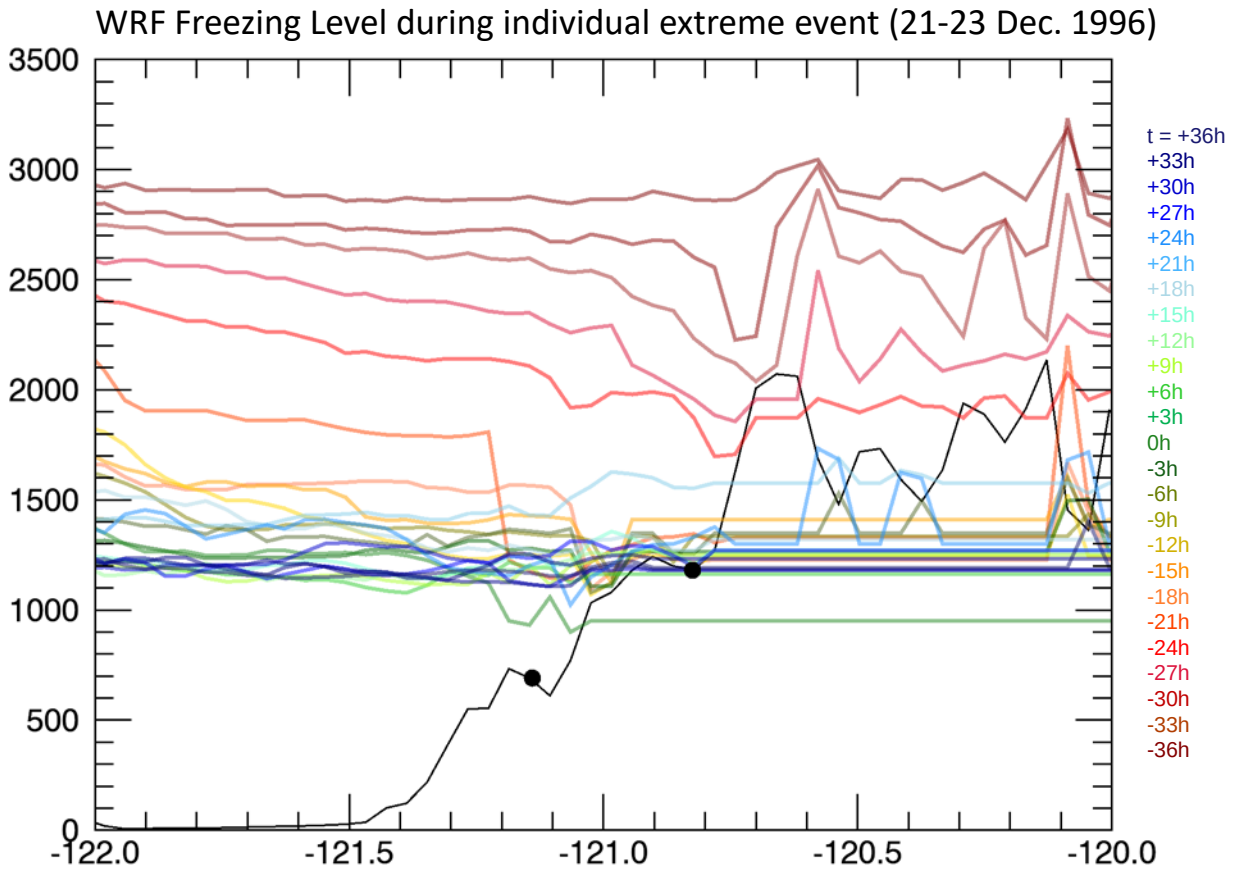
WestWRF Reforecast Freezing Level Height Example Inter/Intra – event variability





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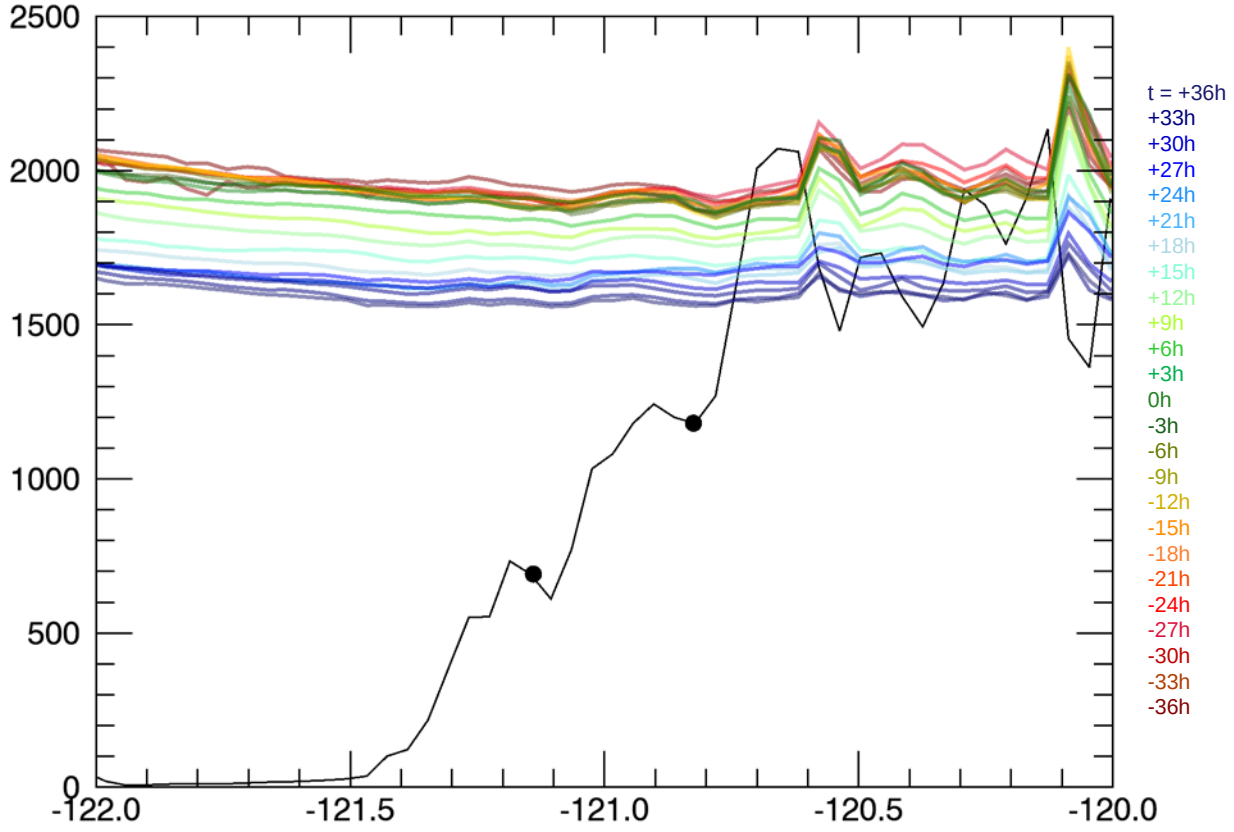
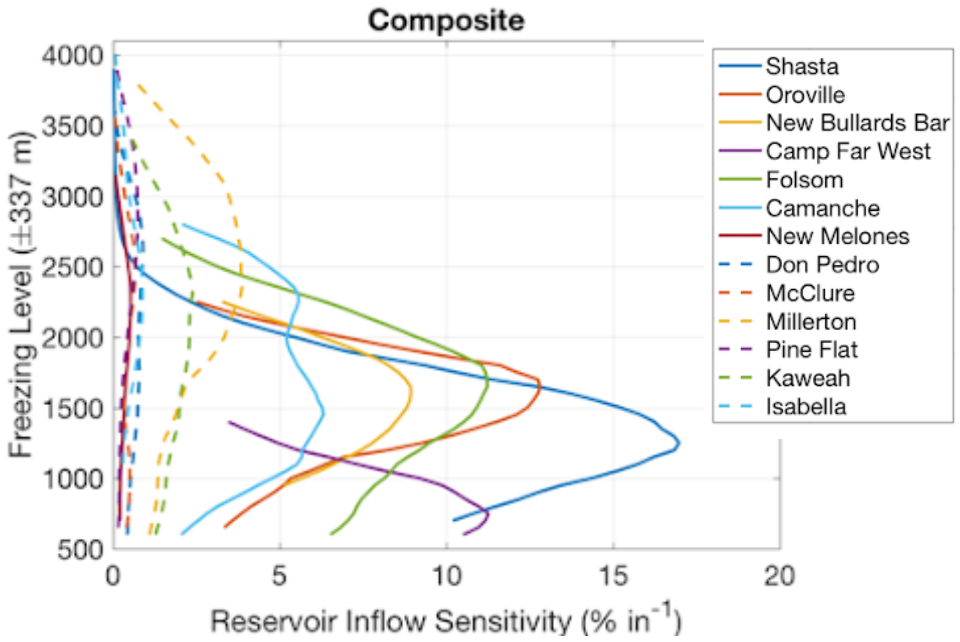
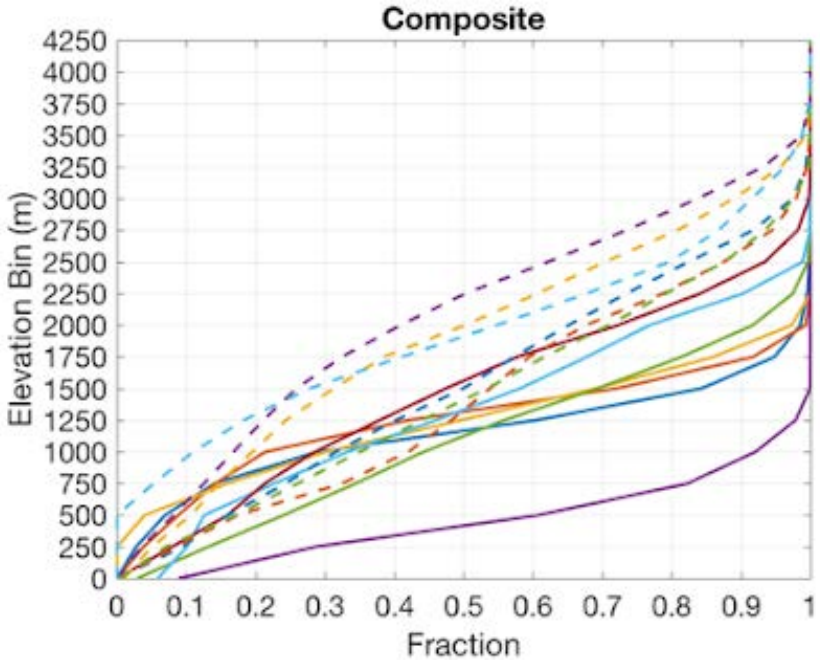
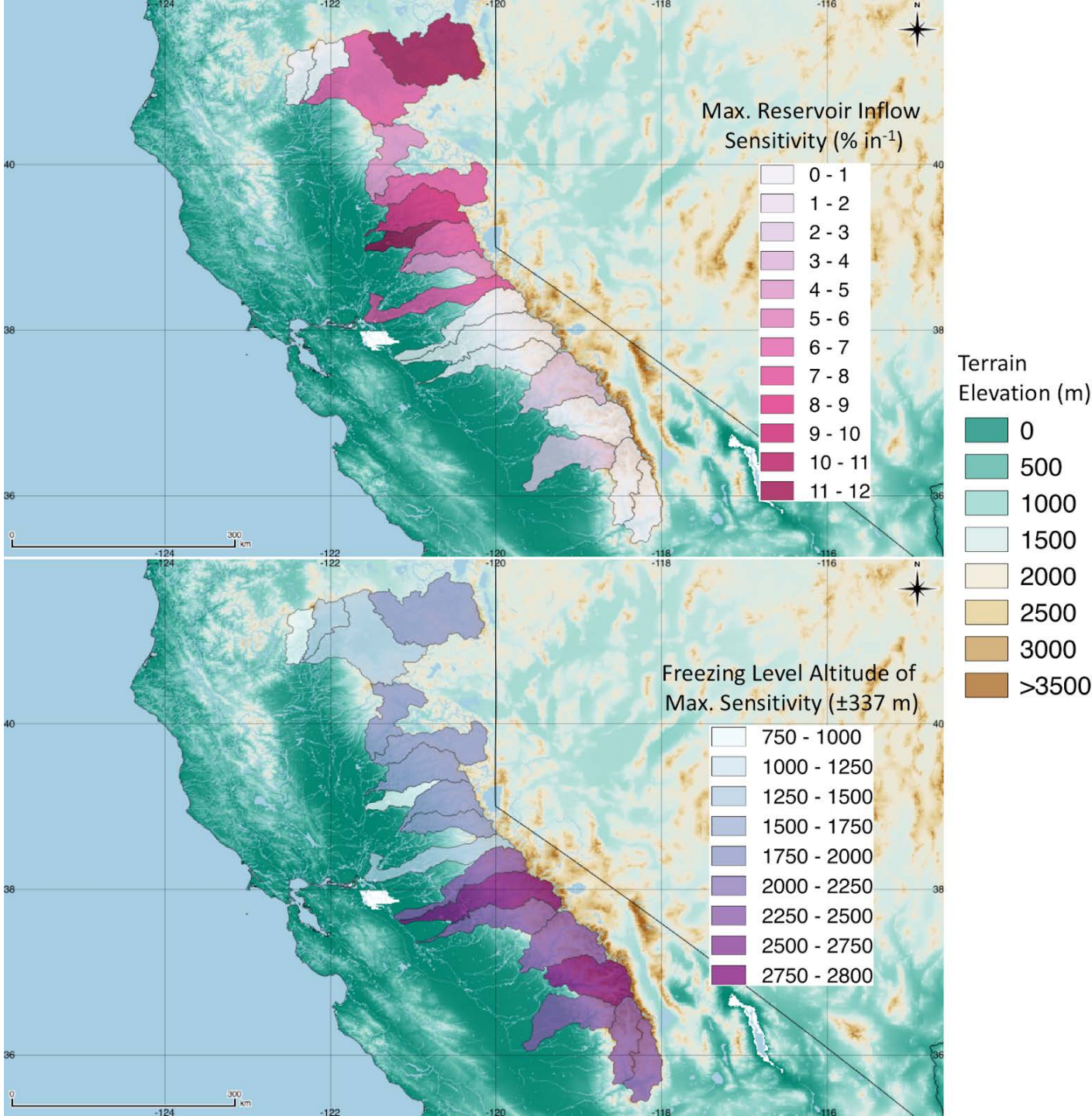
WRF Freezing Level during all extreme events (1986-2006)



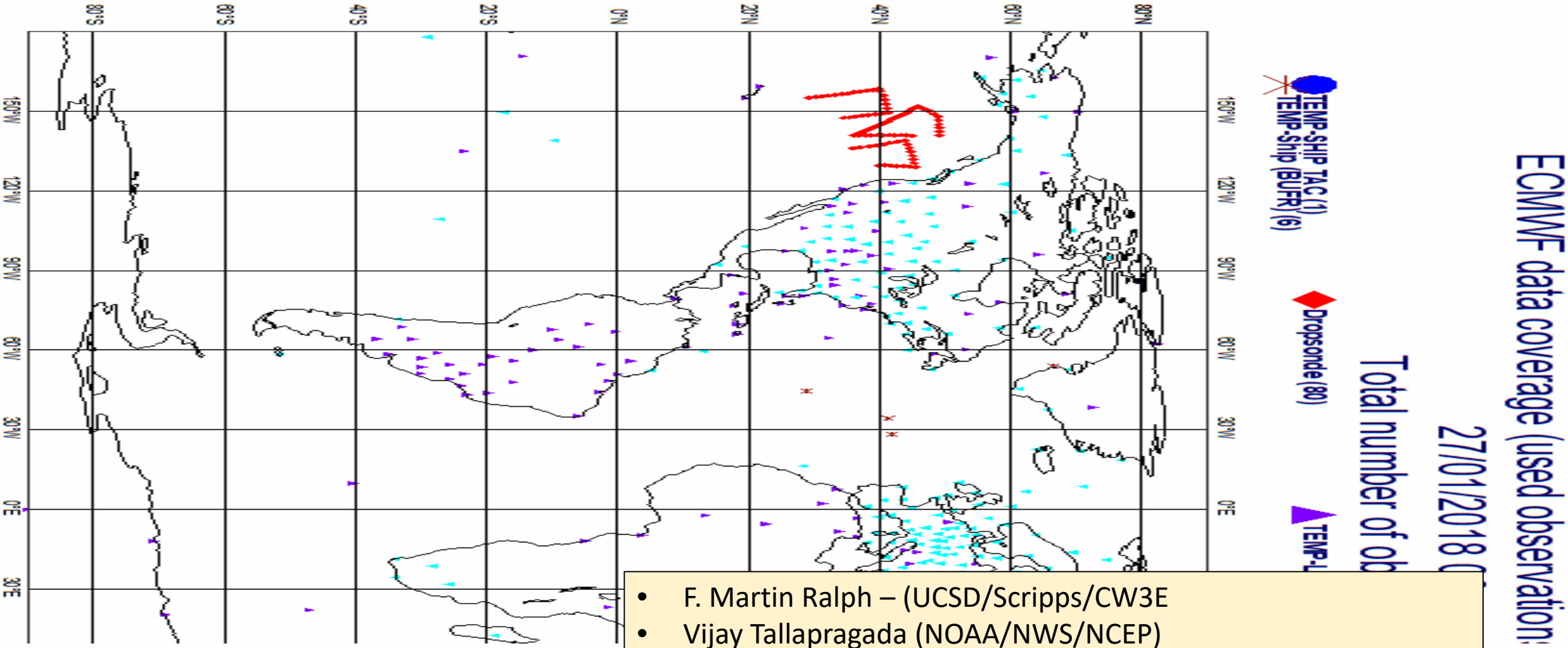
/Users/fcannon/Google Drive/BURO/PRISM_Event_WRF_FreezingLevel_Yuba_transect.pro


Composite
Freezing Level (±337 m)
Reservoir Inflow Sensitivity (% in^{-1})
Shasta
Oroville
New Bullards Bar
Camp Far West
Folsom
Camanche
New Melones
Don Pedro
McClure
Millerton
Pine Flat
Kaweah
Isabella


Composite
Elevation Bin (m)
Fraction

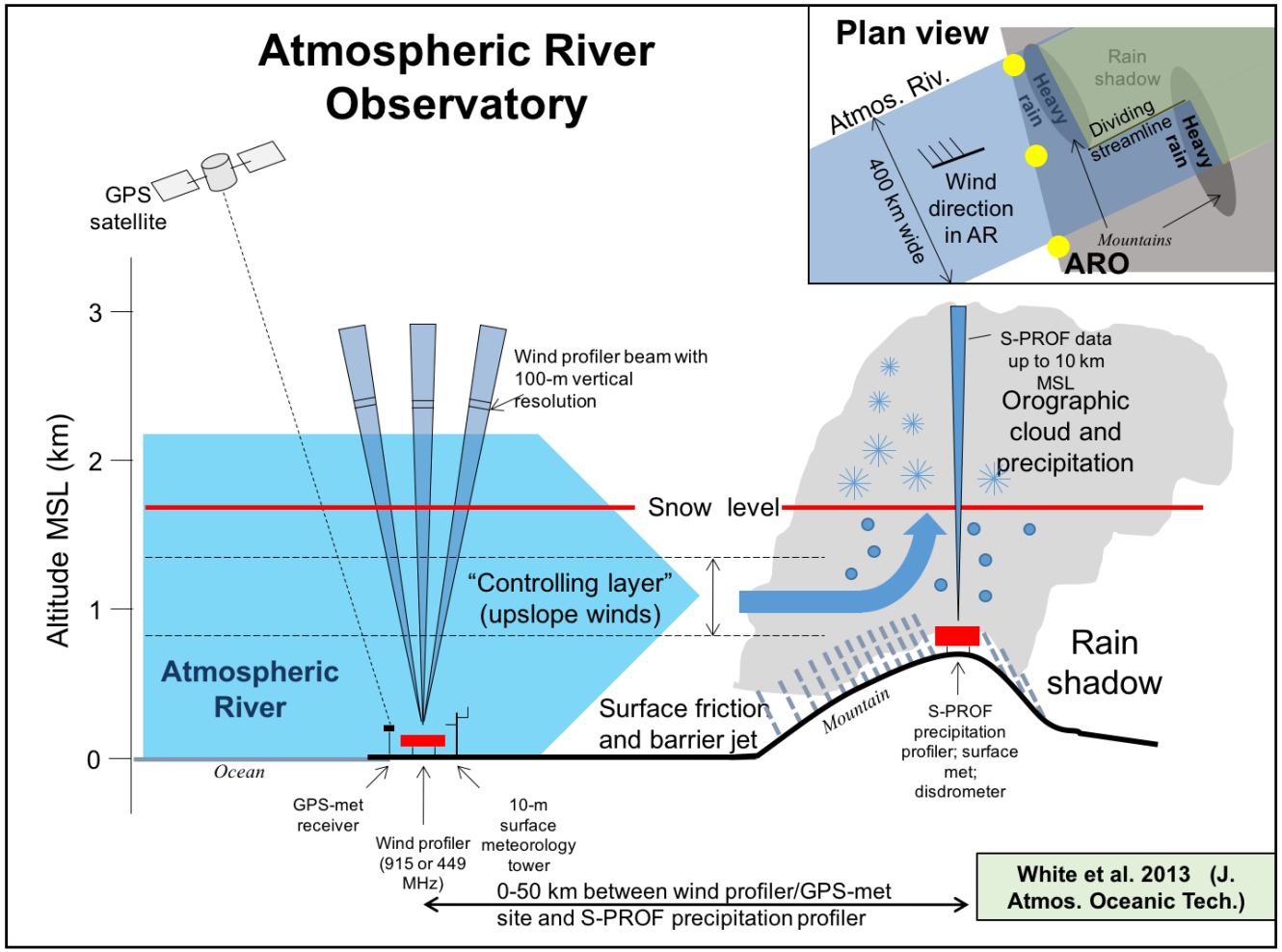

Max. Reservoir Inflow Sensitivity (% in^{-1})
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
Freezing Level Altitude of Max. Sensitivity (±337 m)
750 - 1000
1000 - 1250
1250 - 1500
1500 - 1750
1750 - 2000
2000 - 2250
2250 - 2500
2500 - 2750
2750 - 2800
Terrain Elevation (m)
0
500
1000
1500
2000
2500
3000
>3500

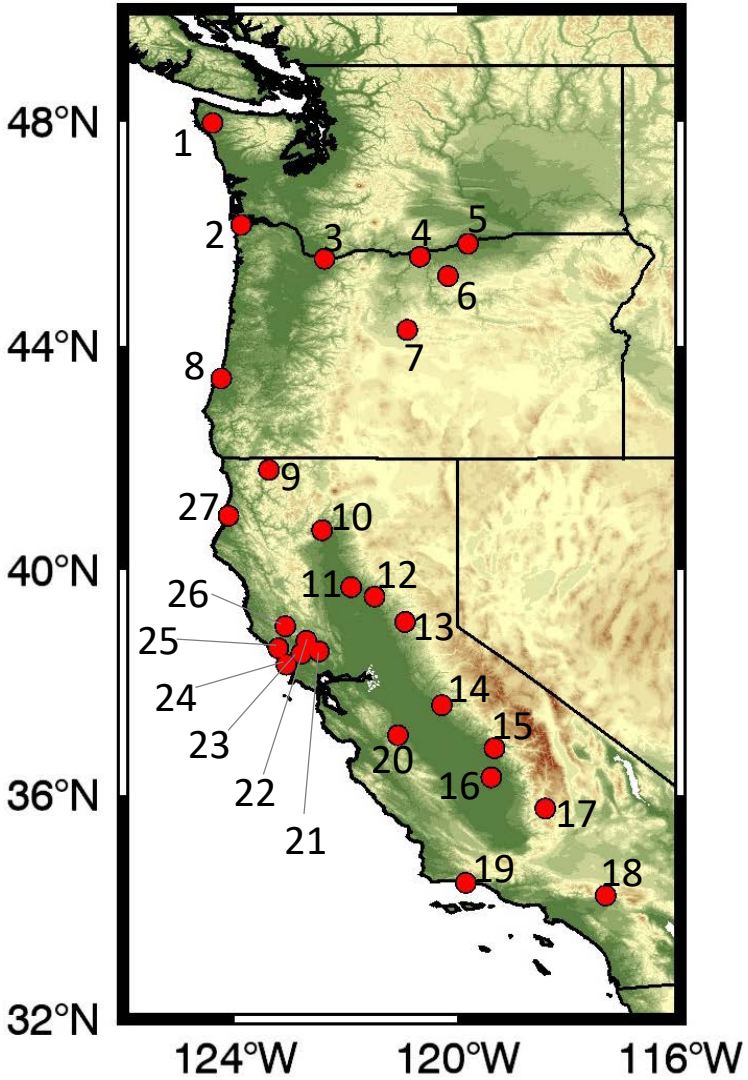
AR Recon Modeling and Data Assimilation Steering Committee



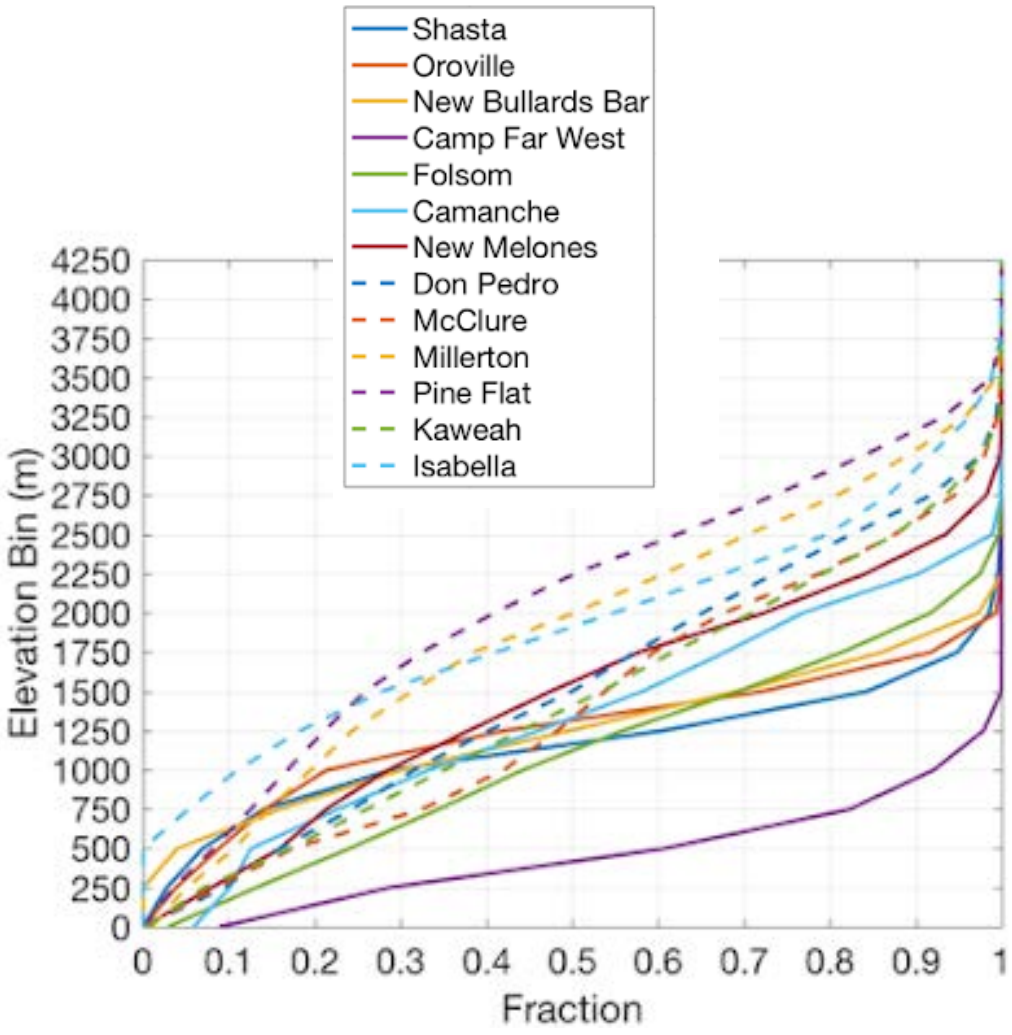
- F. Martin Ralph – (UCSD/Scripps/CW3E
- Vijay Tallapragada (NOAA/NWS/NCEP)
- Jim Doyle (NRL)
- Aneesh Subramanian (UCSD/Scripps/CW3E)
- Chris Davis (NCAR/MMM)
- Florian Pappenberger (ECMWF)

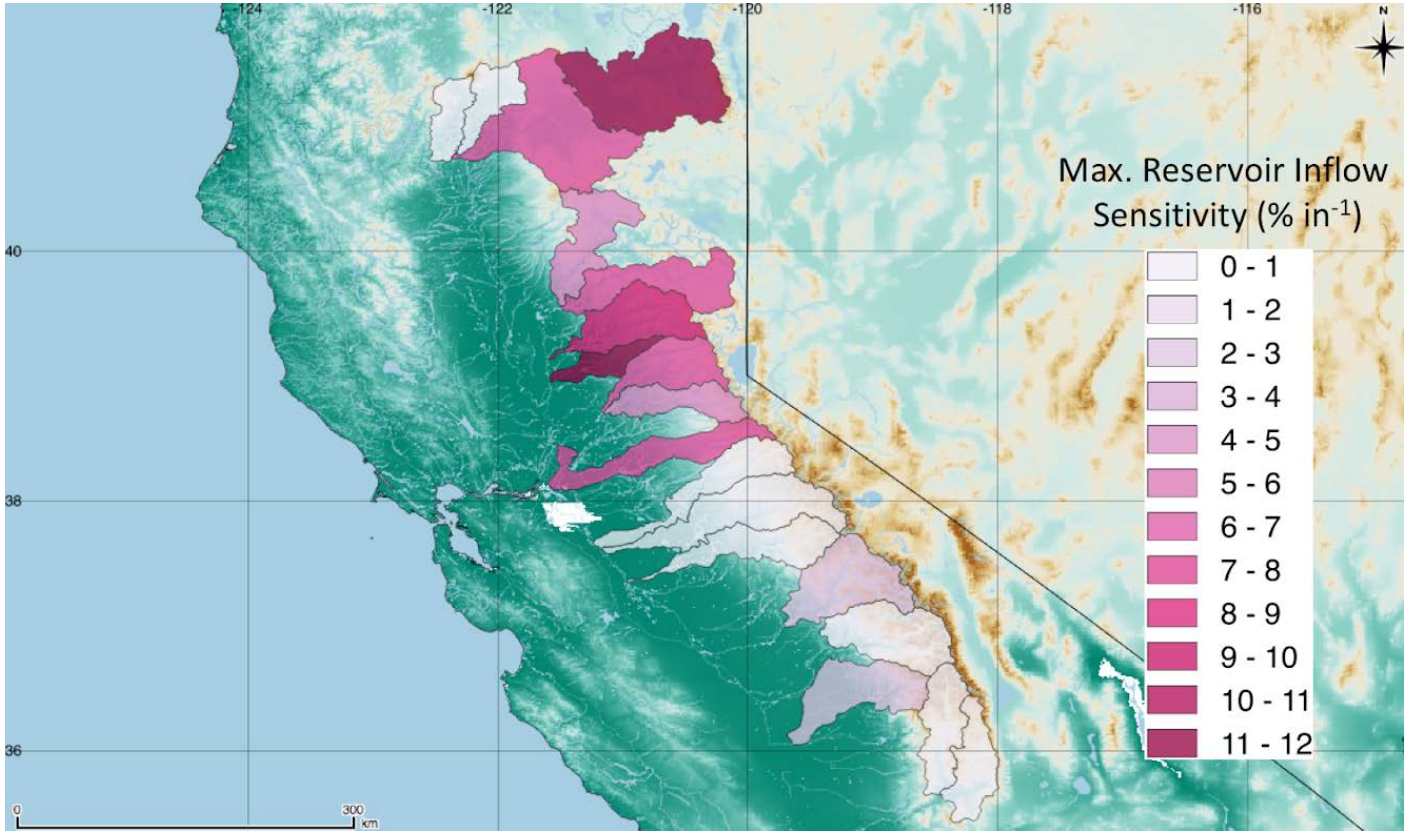
Improved observations of AR Characteristics





Terrain Profiles and their sensitivity to typical freezing level uncertainty





Northern Sierra seems to respond more due to narrow elevation bands with large watershed area