Efforts to Address AR and Precipitation Forecasting Challenges in FIRO Watersheds

Forest Cannon

Center for Western Weather and Water Extremes

Bodega Bay, CA
(Location of CW3E Field Campaign Installation & NOAA ARO)

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

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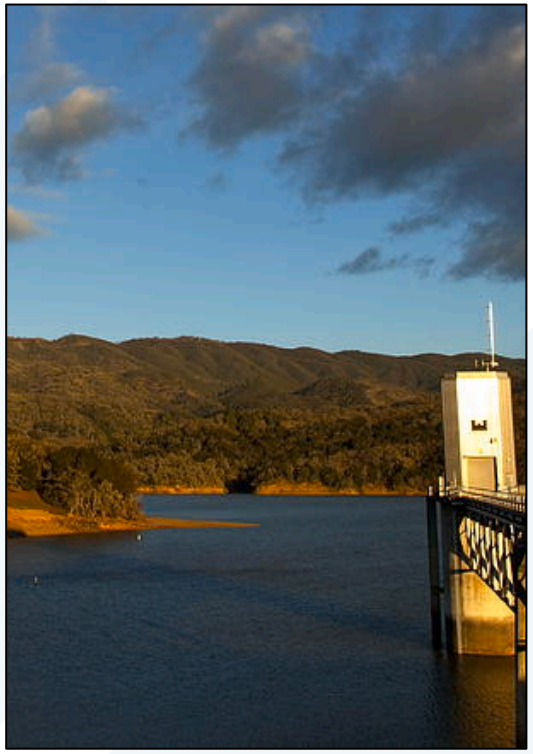
UC San Diego

OVERVIEW OF METEOROLOGICAL RESEARCH FOR FIRO PROJECTS



Lake Mendocino

- FVA
- AR Skill Assessment
- Precipitation Proc.

Prado

- PVA
- WRF Development
- Snow Processes

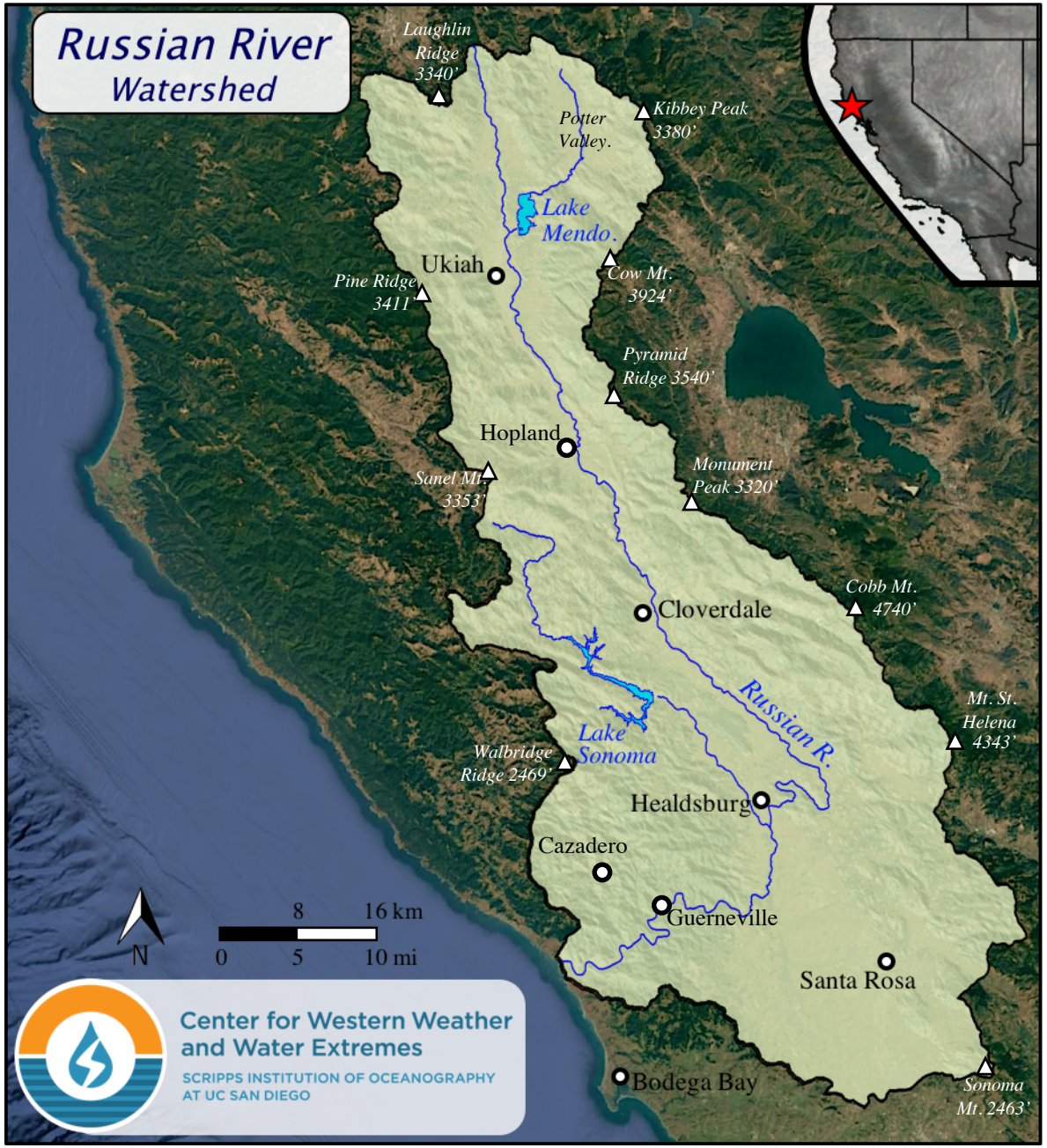
Yuba/Feather

- Workplan
- WRF Development
- Snow Processes

Howard Hanson

- New Project
- HH Extreme Events
- WRF Considerations

Lake Mendocino



FVA summarizes meteorological studies executed over a 5+ year period in support of FIRO

MENDO FINAL VIABILITY ASSESSMENT: RESEARCH & ENHANCED OBSERVATIONS

2.2 Enhanced Monitoring

- 2.2.2: AR Recon
- 2.2.3: Ground-based Atmospheric Sensor Network
- 2.2.4: Russian River Hydromet Observing Network

2.3 Week 1 Forecast R&D

- 2.3.2: Assess QPF and Stramflow/Inflow for Lake Mendo
- 2.3.3: Establish West-WRF
- 2.3.4: Forecast Sensitivities to Physical Processes
- 2.3.5: Reforecast, Machine Learning, Post-Processing
- 2.3.6: West-WRF Uncertainty Quantification (Ensemble)
- 2.3.7: NWP Data Assimilation Research

2.4 Subseasonal Forecast R&D

- 2.4.2: Dynamical Model S2S R&D
- 2.4.3: Statistical Models S2S R&D
- 2.4.4: Role of Ocean Atmosphere Coupling in S2S

2.5 Hydrologic Model Improvement

- 2.5.2: GSSHA Model
- 2.5.3: WRF Hydro

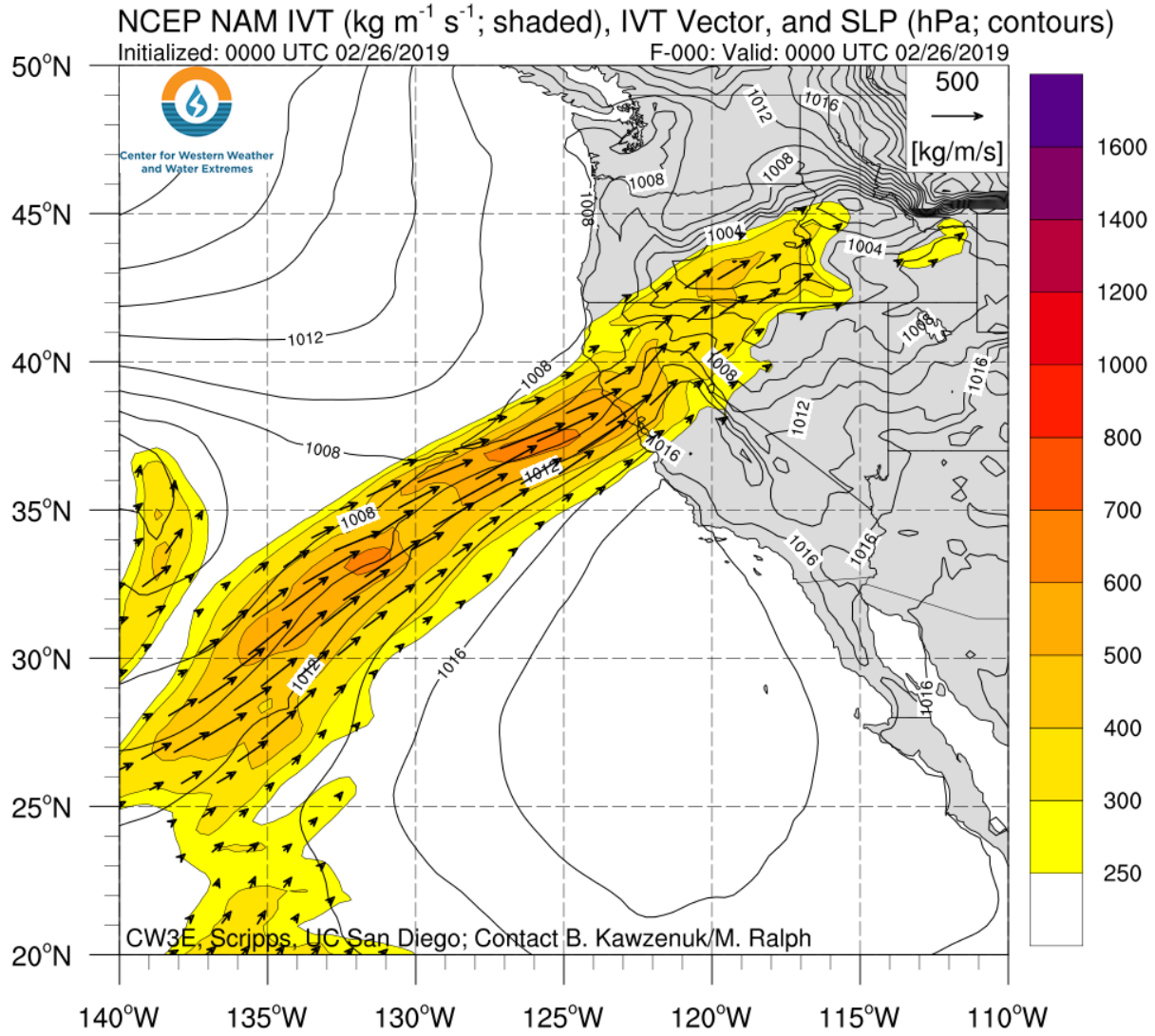
2.6 AR Forecasting Products and Situational Awareness

- 2.6.2: Deterministic (Control) Products
- 2.6.3: Probabilistic Forecast Products
- 2.6.4: Forecast Evaluation
- 2.6.5: The AR Scale
- 2.6.6: Integration and Improvement of Products

2.7 Reservoir Management Tools

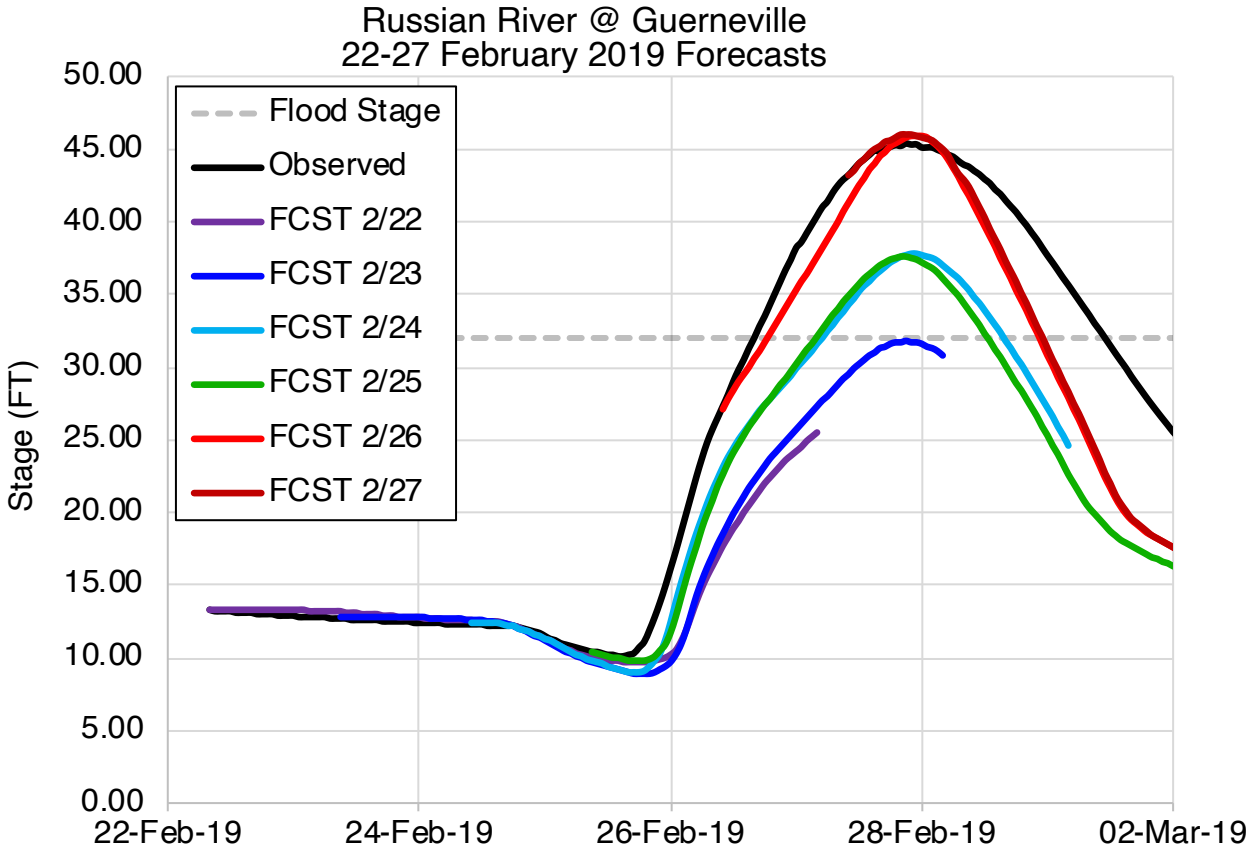
- 2.7.2: Improvements to the EFO Model
- 2.7.3: Scaling of Historical Events
- 2.7.4: Risk Curve Refinements and Evaluations
- 2.7.5: Multi-Objective Hybrid Alternative

The Role of Atmospheric Rivers: 27 Feb. 2019 Example

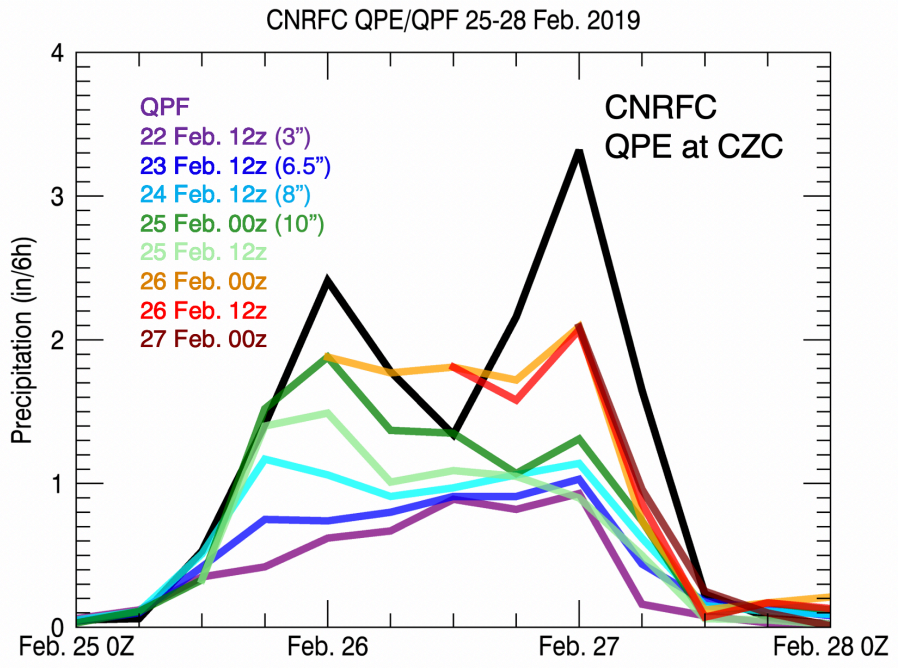


- FIRO project on Russian River at Lake Mendocino
- Atmospheric River landfall drives regional water supply and flooding hazards (Ralph et al. 2006)
- WRF provides improved representation of the physical processes driving precip within ARs (Martin et al. 2018)

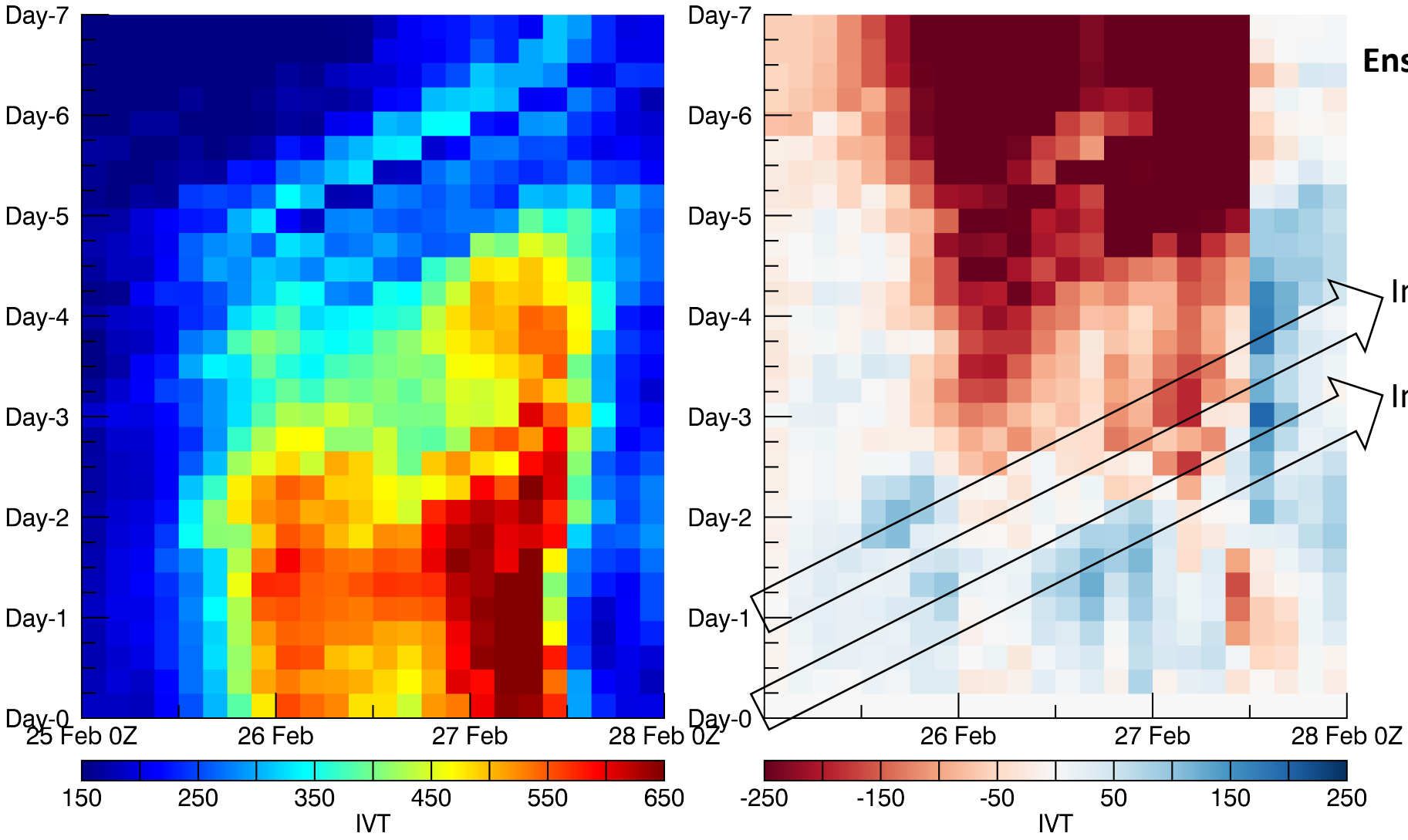
FLOOD FORECASTING CHALLENGES DURING EXTREME EVENTS:
27 FEB. 2019 EXAMPLE



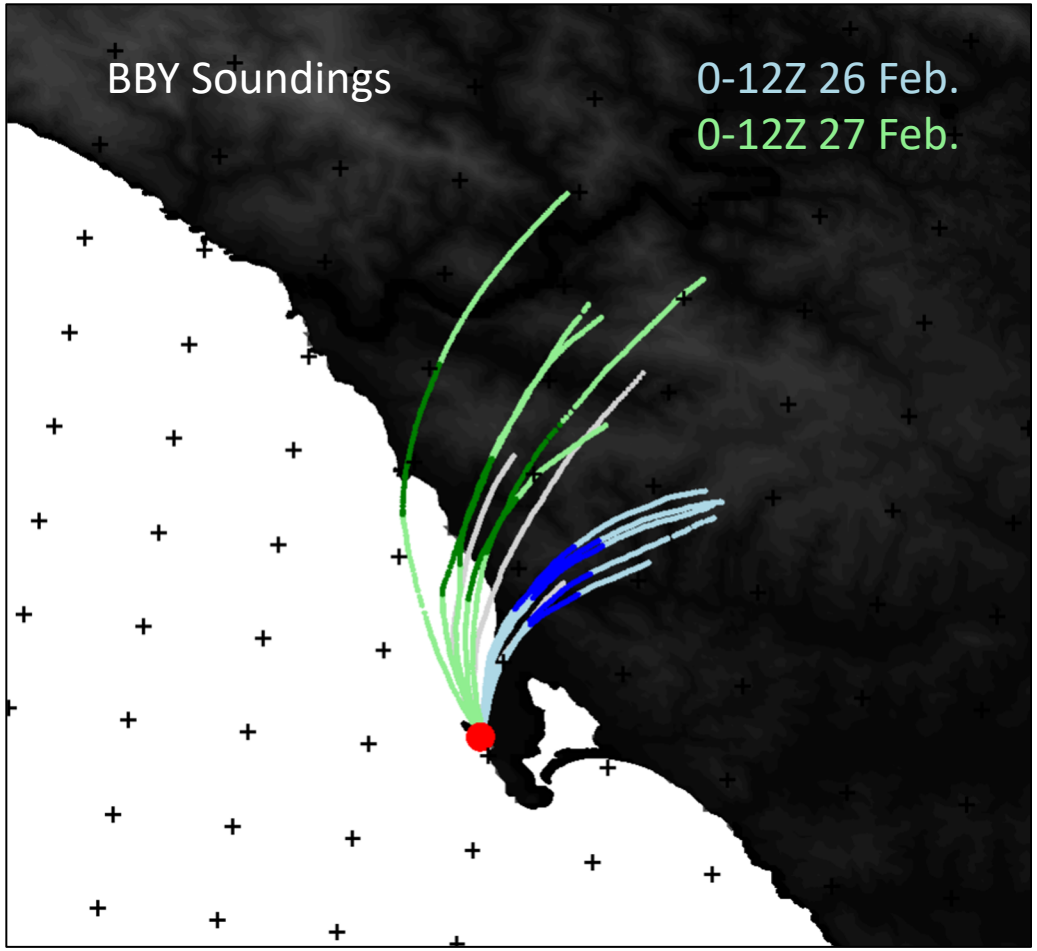
- Operational hydro forecasts are largely informed by coarse-resolution ensemble mean precipitation (GEFS)
- Rapid stage height forecast changes are frequently seen in extreme events at < 5 day lead time



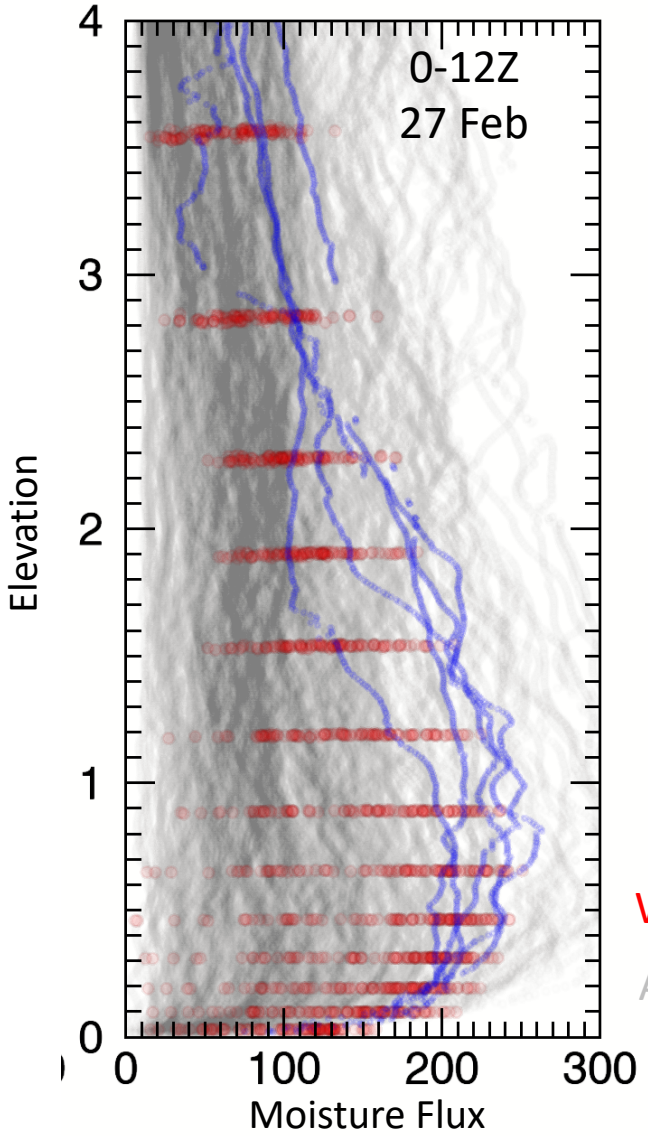
GEFS Evaluation of Forecast Error Source (38.5N, 123W (BBY))



Field Campaign to Support Forecast Evaluation: WRF vs. Sondes



0-2000m profile w/ 750-1250m in dark shading
+ denotes WRF 3km Grid Cells



Forecasted upslope flux was deficient.

Precipitation efficiency was also very important for underforecast.

Soundings

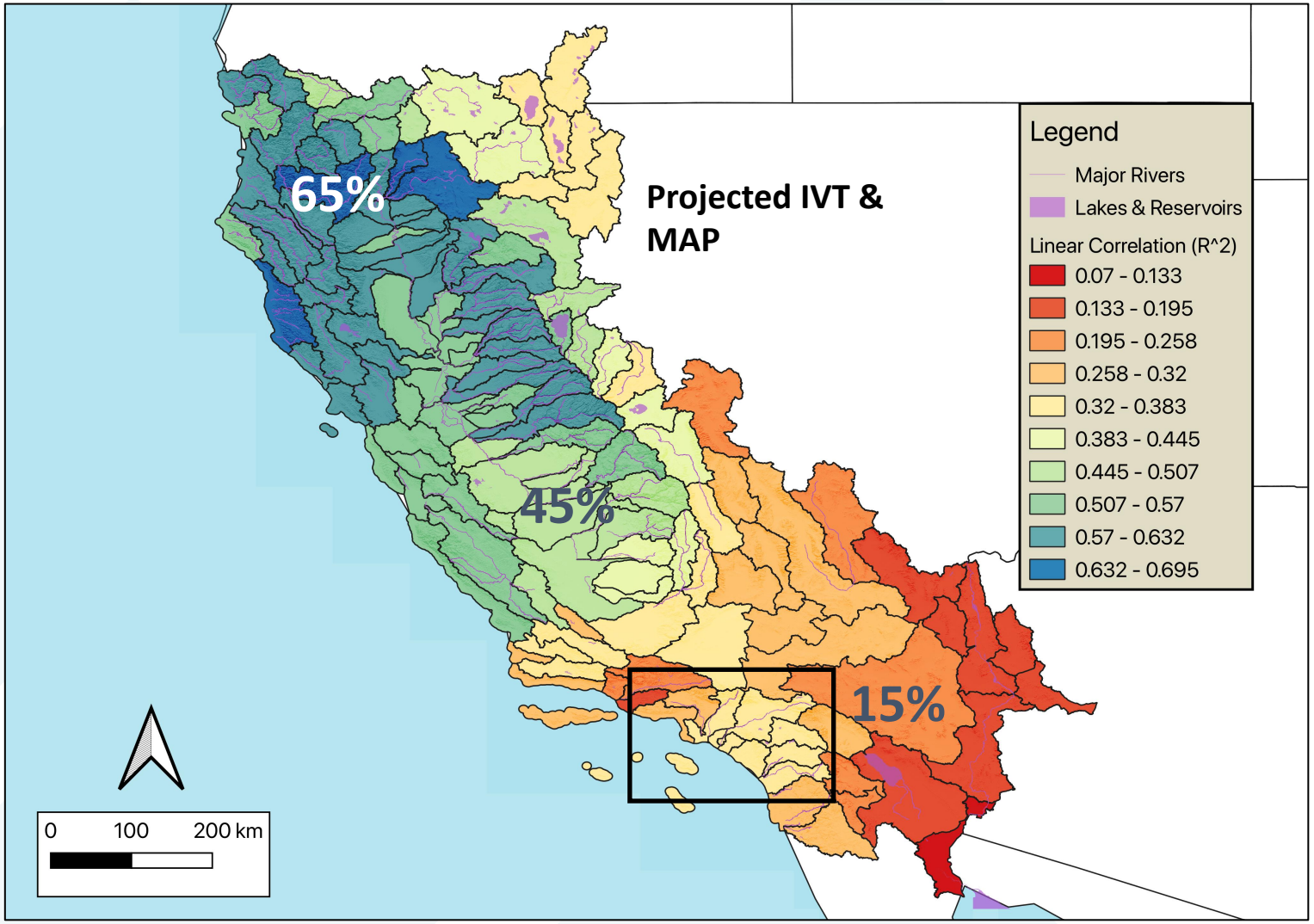
WRF Ensemble Members

All Soundings 2016-2020

Forecast Informed Reservoir Operations: Prado Dam

Currently wrapping up PVA

RELATIONSHIP B/W WATER VAPOR TRANSPORT AND PRECIPITATION



Ricciotti and Cordeira

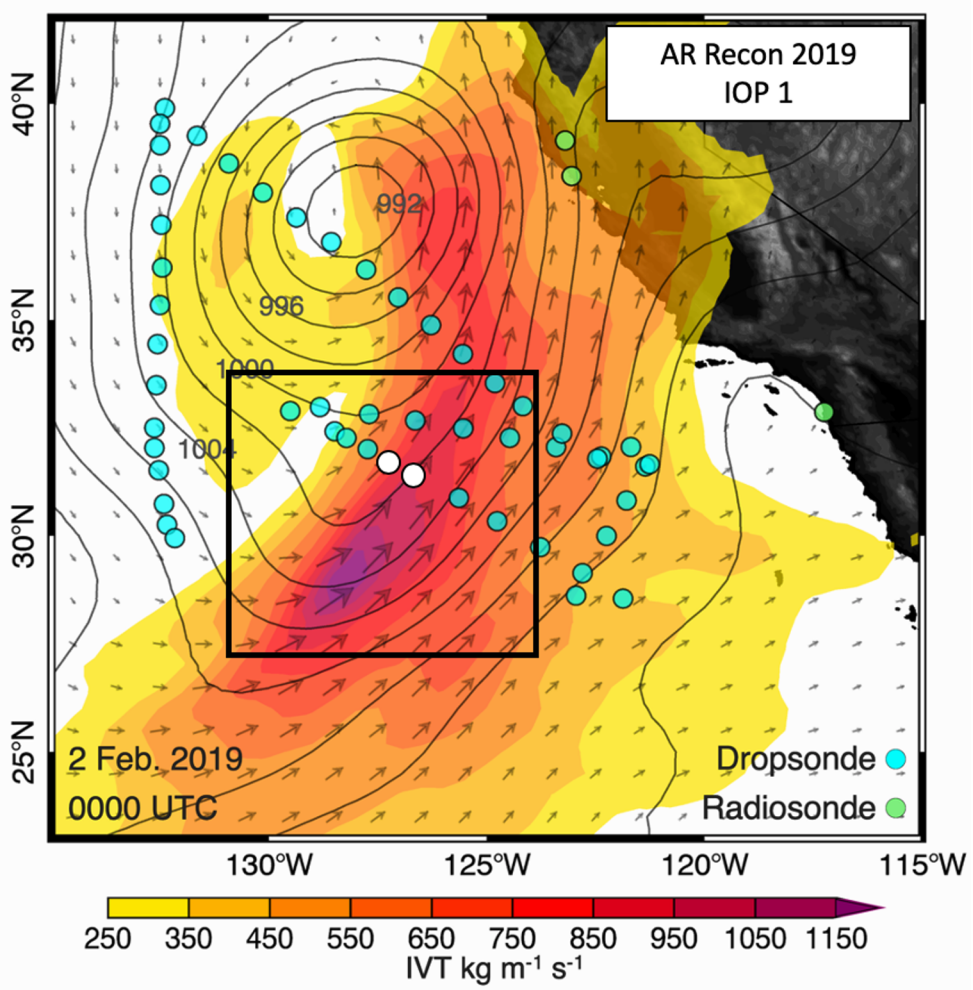
- Projected IVT explains ~45–65% of variance in daily MAP across northern two-thirds of California
- Projected IVT helps highlight role of upslope moisture flux across Coastal and Sierra Nevada mountains
- **Southern CA and Santa Ana basin, specifically, has a different relationship**
- **Fewer events are a challenge to meteorology and hydrology evaluation**
- **ARs still dominate, but require additional considerations**
- **Physical process research to define precipitation mechanisms and forecast skill**

Physical Sources of AR and Precipitation Forecast Uncertainty

Physical Sources of AR and Precipitation Forecast Uncertainty

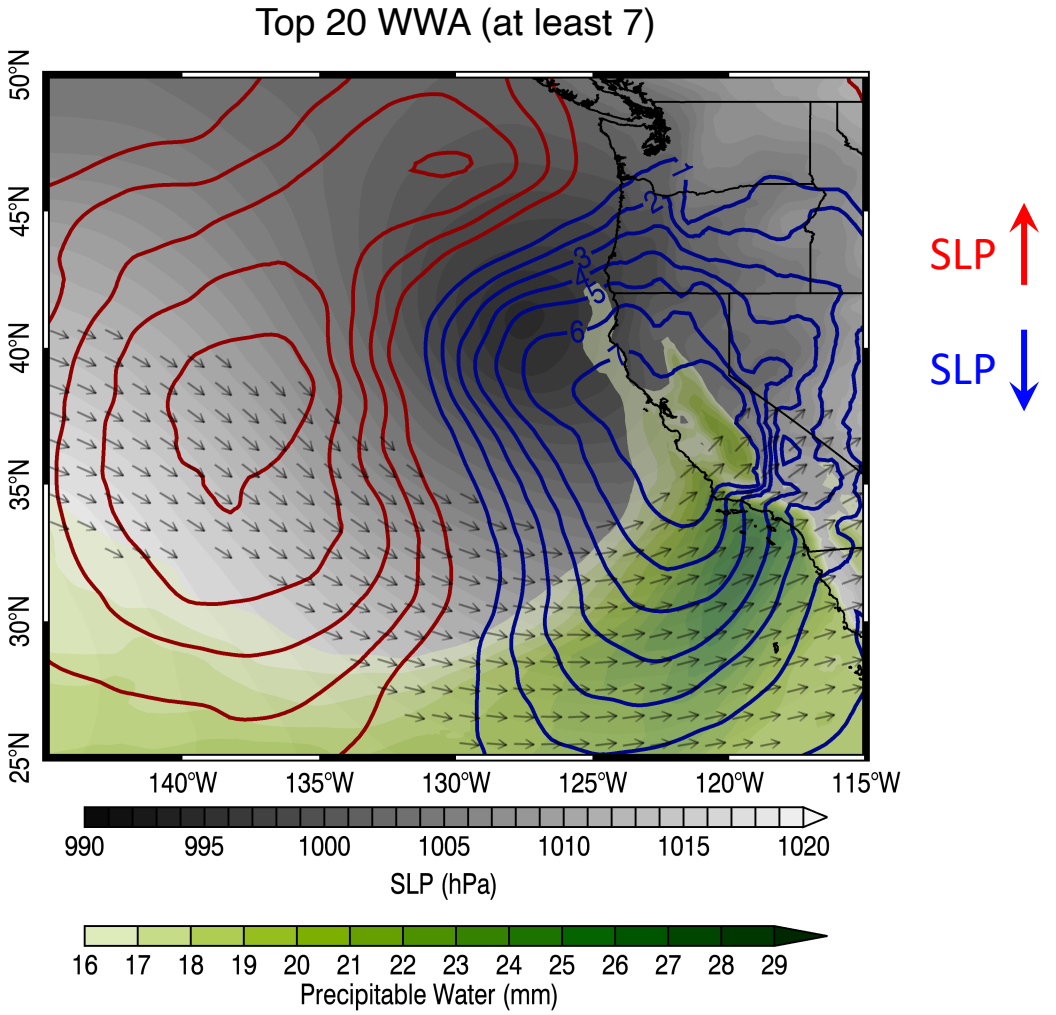
Evaluation of Precipitation Forecast Uncertainty during AR Landfall in Southern California Watersheds

- A 21-member WestWRF ensemble
- Cannon et al. evaluated WestWRF ability and limitations in short-duration, high-intensity precipitation predictability via NCFR characteristics in dropsonde and radiosonde observations.
- WestWRF sensitivity research is also guiding the development of an NRT Ensemble that is aimed at improving precipitation and freezing level forecast uncertainty estimates in AR events



A Climatology of Narrow Cold-Frontal Rainbands in Southern California

- A composite of SLP and SLP tendency for the top 20 events with the most warnings (at least 7)
- The SLP tendency demonstrates a set of extreme events driven by common meteorological processes (e.g. a deepening cyclone)
- The behavior of any individual NCFR, the intensity of its precipitation and its regional impacts exist on a spectrum.
- Case studies have favored the more intense events, but the same processes are observed in weaker cyclones.



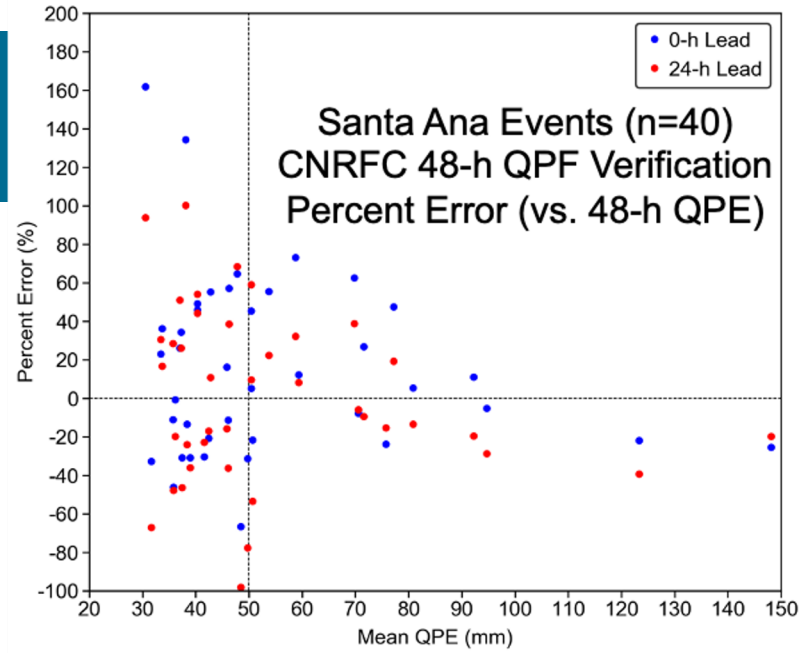
deOrla-Barile et al. 2020

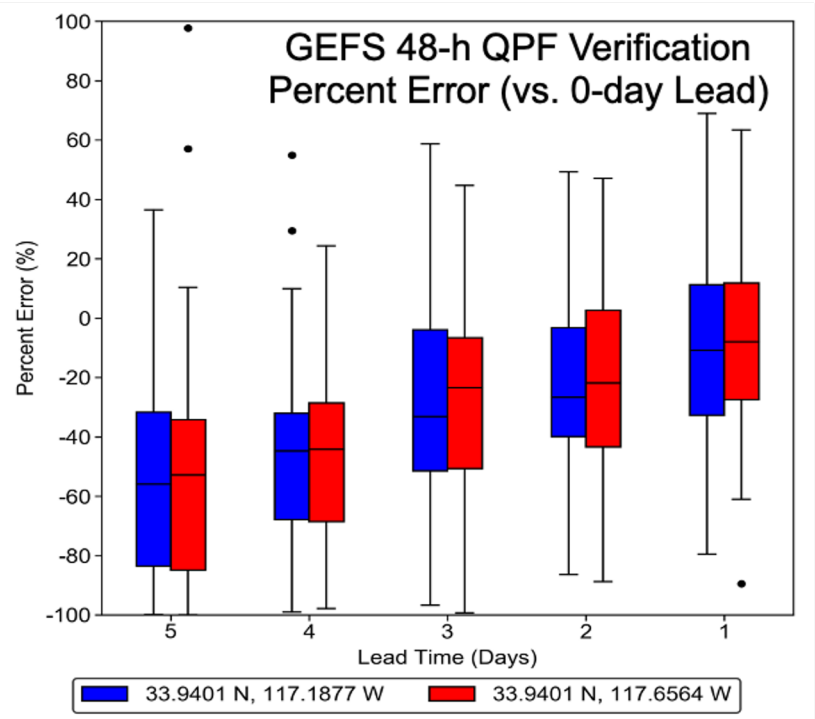
Forecast Evaluation and Development

Physical Sources of AR and Precipitation Forecast Uncertainty

Historical CNRFC and GEFS precipitation forecasts were evaluated for extreme events in each of the FIRO watersheds to determine forecast error and biases.

- Events were categorized according to their forecast skill and are currently being evaluated for commonalities in the synoptic weather features that lead to either good or poor precipitation predictability.
- Identical analyses were performed using West-WRF to determine whether there are events whose forecast skill benefits more or less from dynamical downscaling.





Caption – Precipitation percent error for 40 extreme events impacting the Santa Ana watershed in the CNRFC record extending from 2002 to present (top) and GEFS precipitation forecast error for the same events at 1-5 day lead time

Provided by C. Castellano

CW3E Prado FIRO Field Campaign: Catalina Island

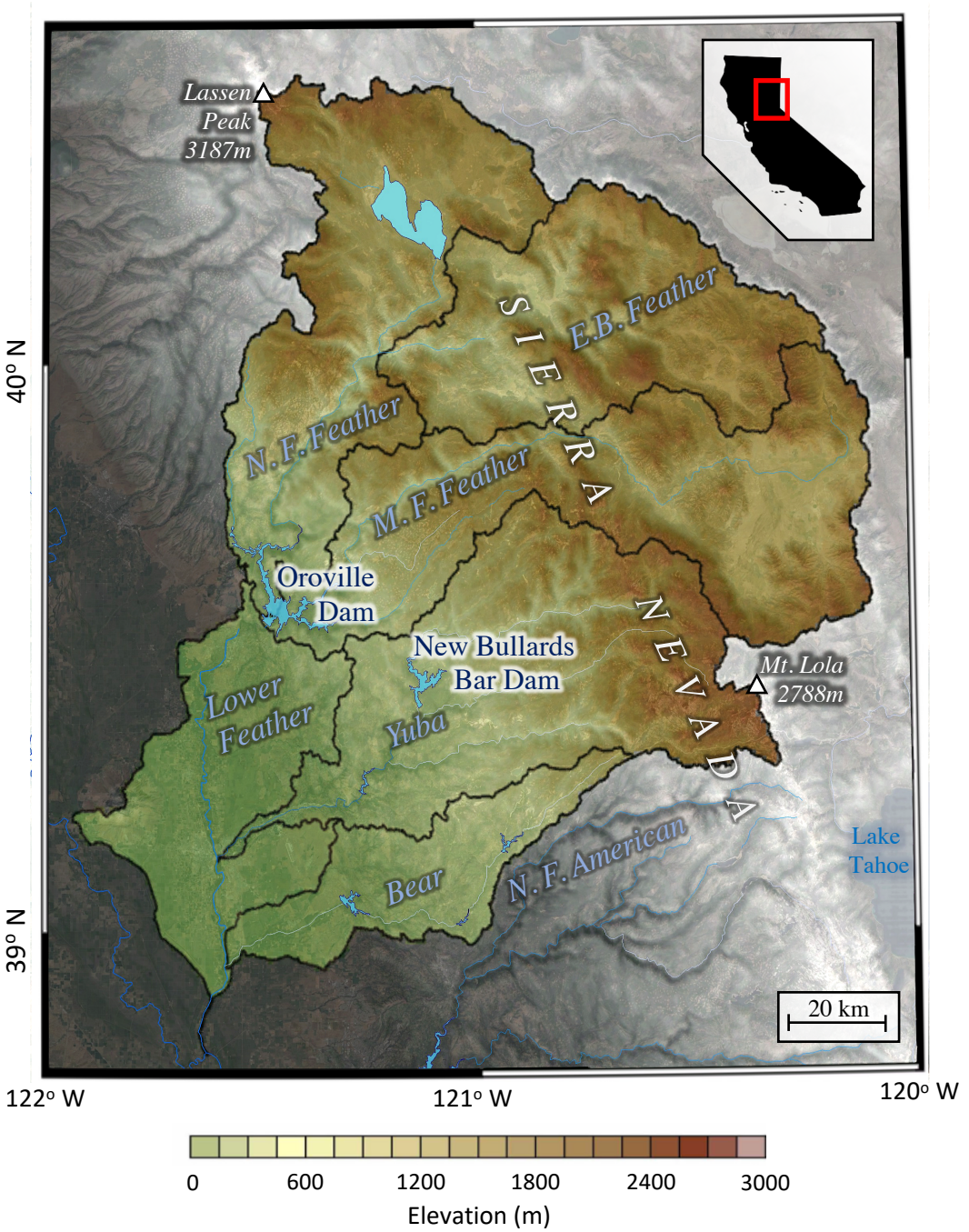
Field site is positioned upstream of Santa Ana Watershed

- Weather radiosonde launches provide observations in atmospheric rivers that generate precipitation and runoff into Prado Reservoir
- The observations are assimilated into global forecast models and are essential for research into precipitation mechanisms and forecast skill

Radiosonde

YUBA / FEATHER FIRO

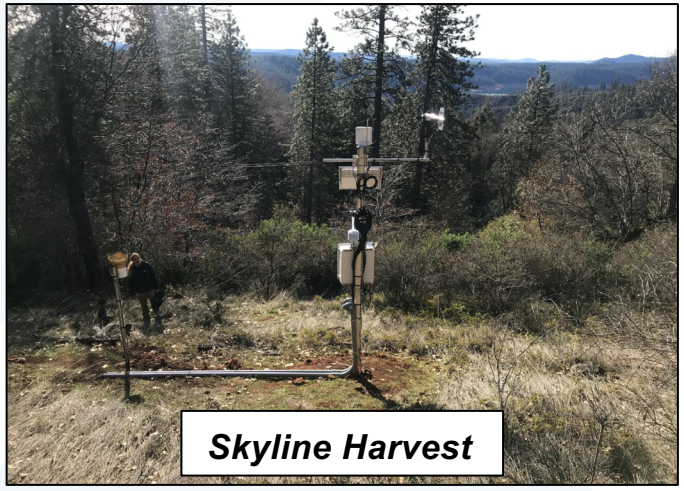
Recently completed workplan

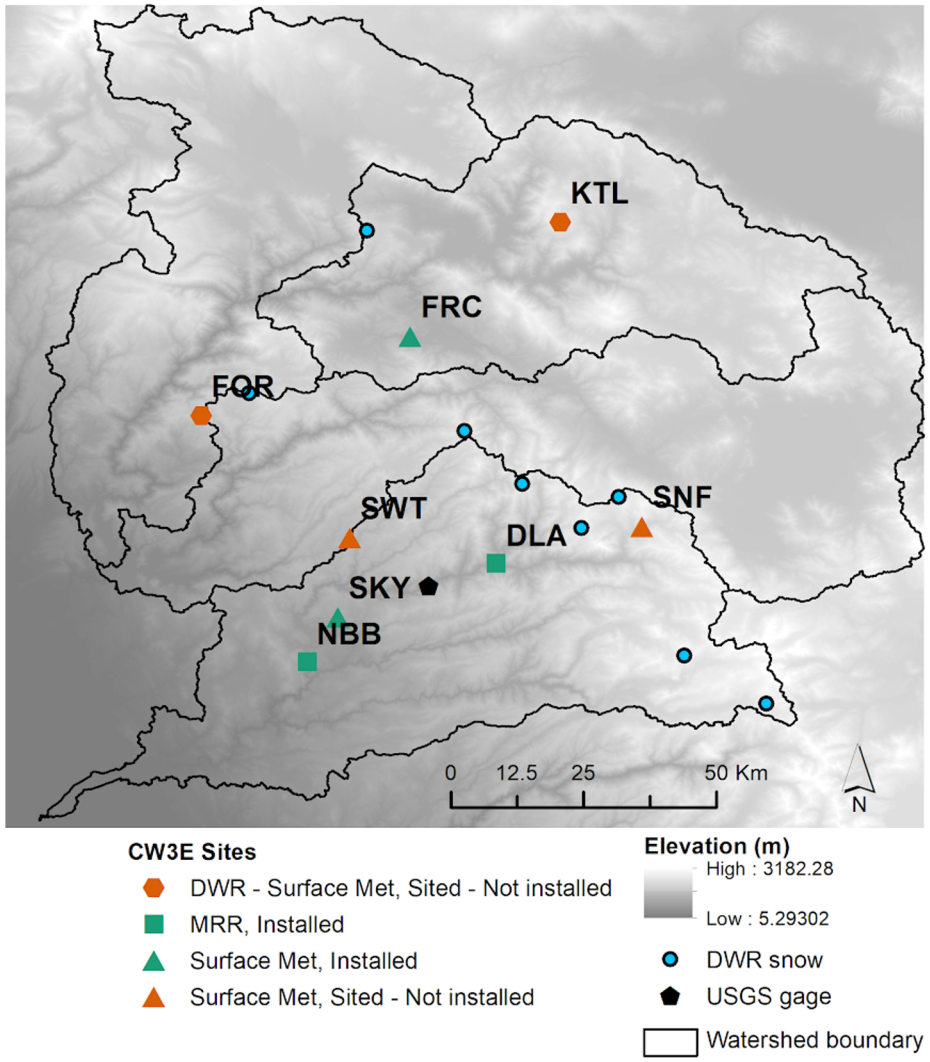


HYDROLOGY - SOIL MOISTURE AND SURFACE METEOROLOGY SITES

Site Name (Code)	Site Type	Latitude (°)	Longitude (°)	Elevation (m)	Install Status
Skyline Harvest (SKY)	SMOIL	39.47	-121.09	829	installed
Feather River College (FRC)	SMOIL	39.95	-120.97	1048	Installed
Downieville (DLA)	RadMet	39.56	-120.58	901	Installed
New Bullards Bar (NBB)	RadMet	39.40	-121.14	634	Installed

All sites have: air temperature, relative humidity, solar radiation, wind speed and direction, precipitation, and air pressure. Measurements are recorded every 2 minutes.
SMOIL sites have: soil moisture and temperature at 6 depths (5, 10, 15, 20, 50, and 100 cm).
RadMet sites have: Micro Rain Radar, disdrometer, and GPS, but no soil measurements


Skyline Harvest



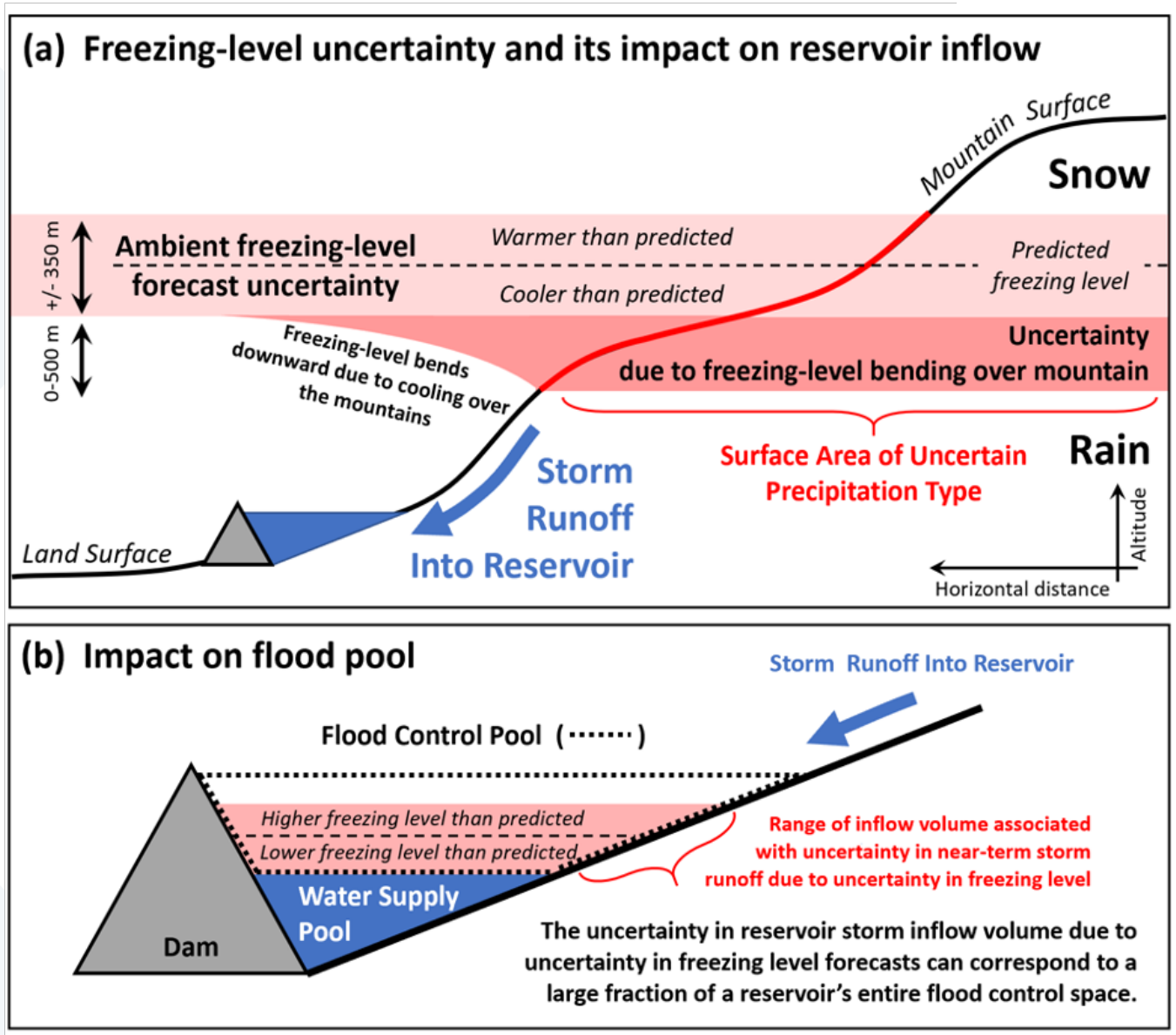
Provided by: H. McMillan, A. Cooper, K. Paulsson, E. Sumargo, R.Weihs

Importance of Rain/Snow Transition for Regional Forecasts

Schematic description of the impact of freezing level (Z_{FL}) forecast uncertainty on (a) storm runoff from a watershed and (b) the associated inflow to the reservoir flood pool.

The ±350 m average Z_{FL} forecast uncertainty in (a) is based on Henn et al. (2020) and valid up to a 72-hour forecast lead time. The 0–500 m downward bending of Z_{FL} over the mountain topography in (a) is based on the results of Minder and Kingsmill (2013).

Sumargo et al., 2020

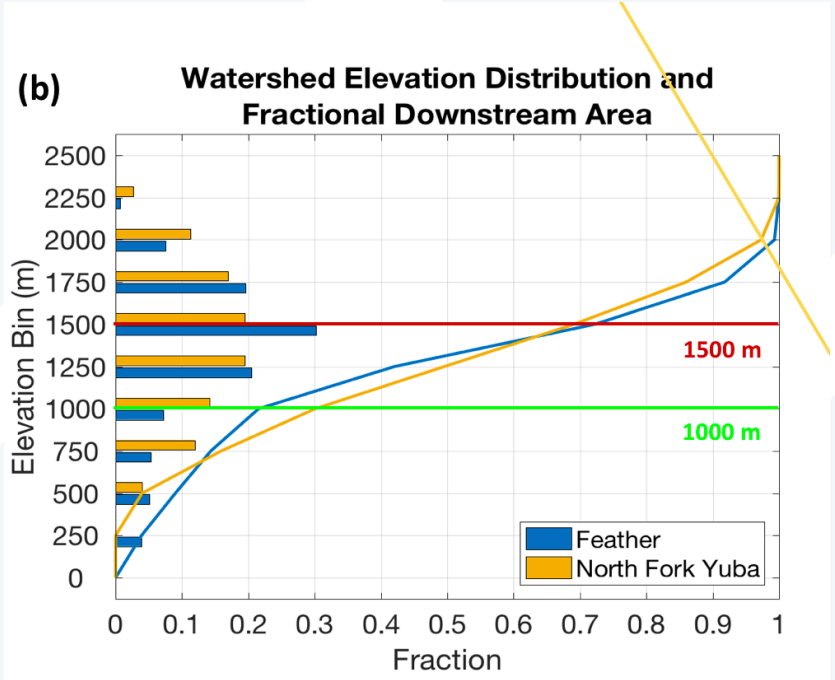


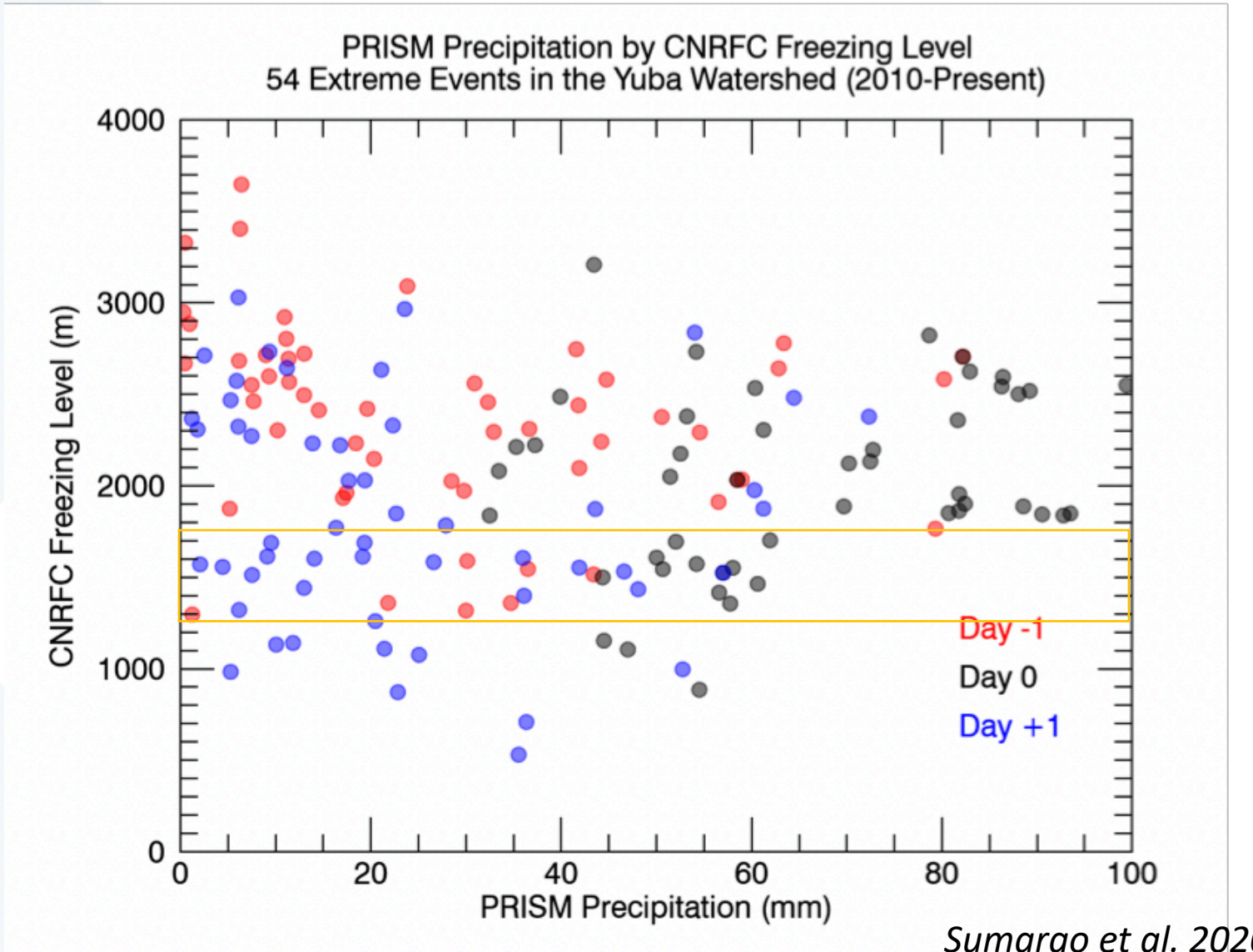
Schematic by F.M. Ralph

Rain/Snow Transition: Extreme Event Frequency by Z_{FL}

Extreme event freezing level is generally above the watershed maximum elevation during the most extreme precip periods associated with ARs,

However, an important fraction of precipitation during these events does fall when freezing level elevation is in a sensitive elevation band (1250-1750m).



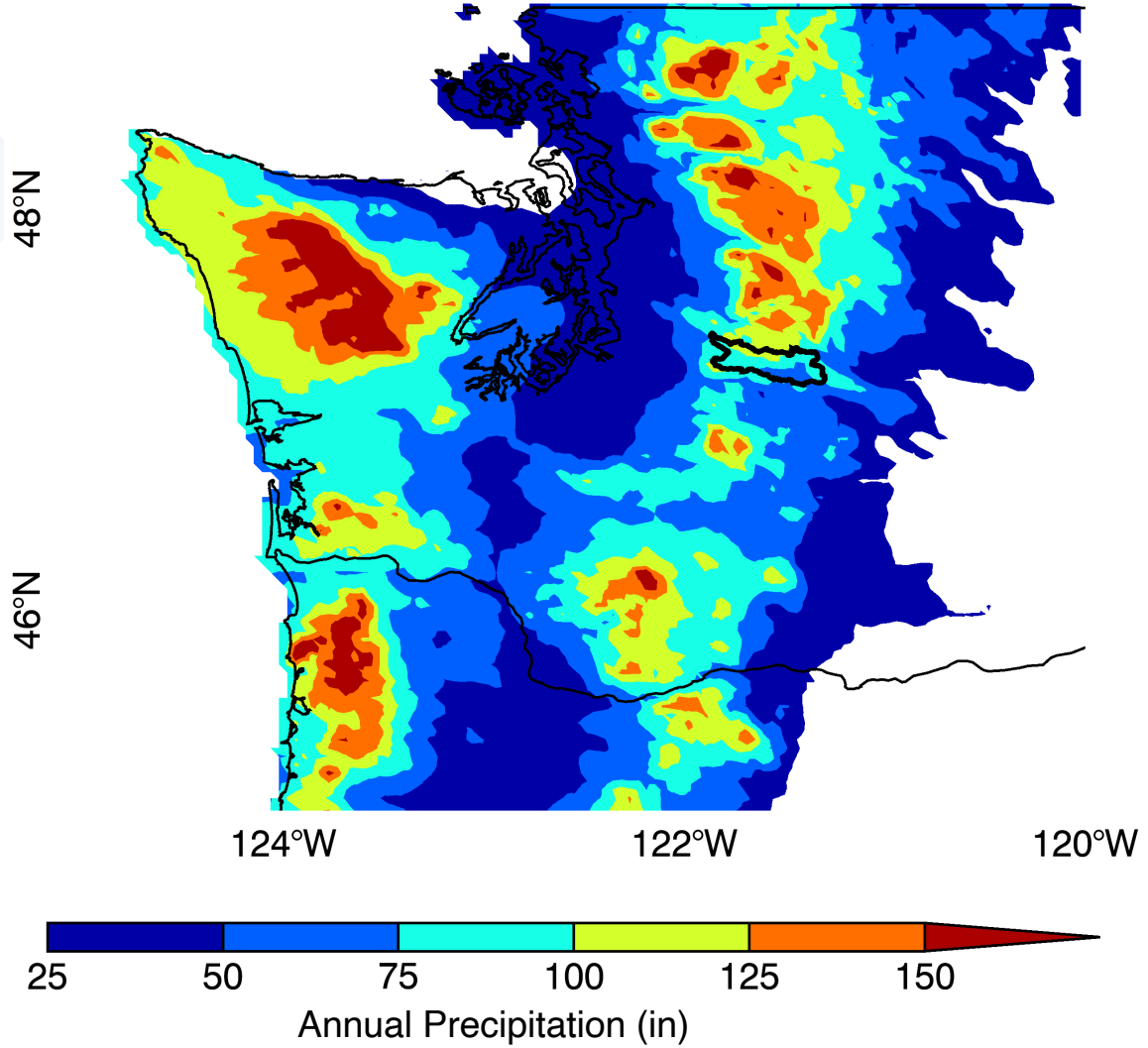


Sumargo et al. 2020

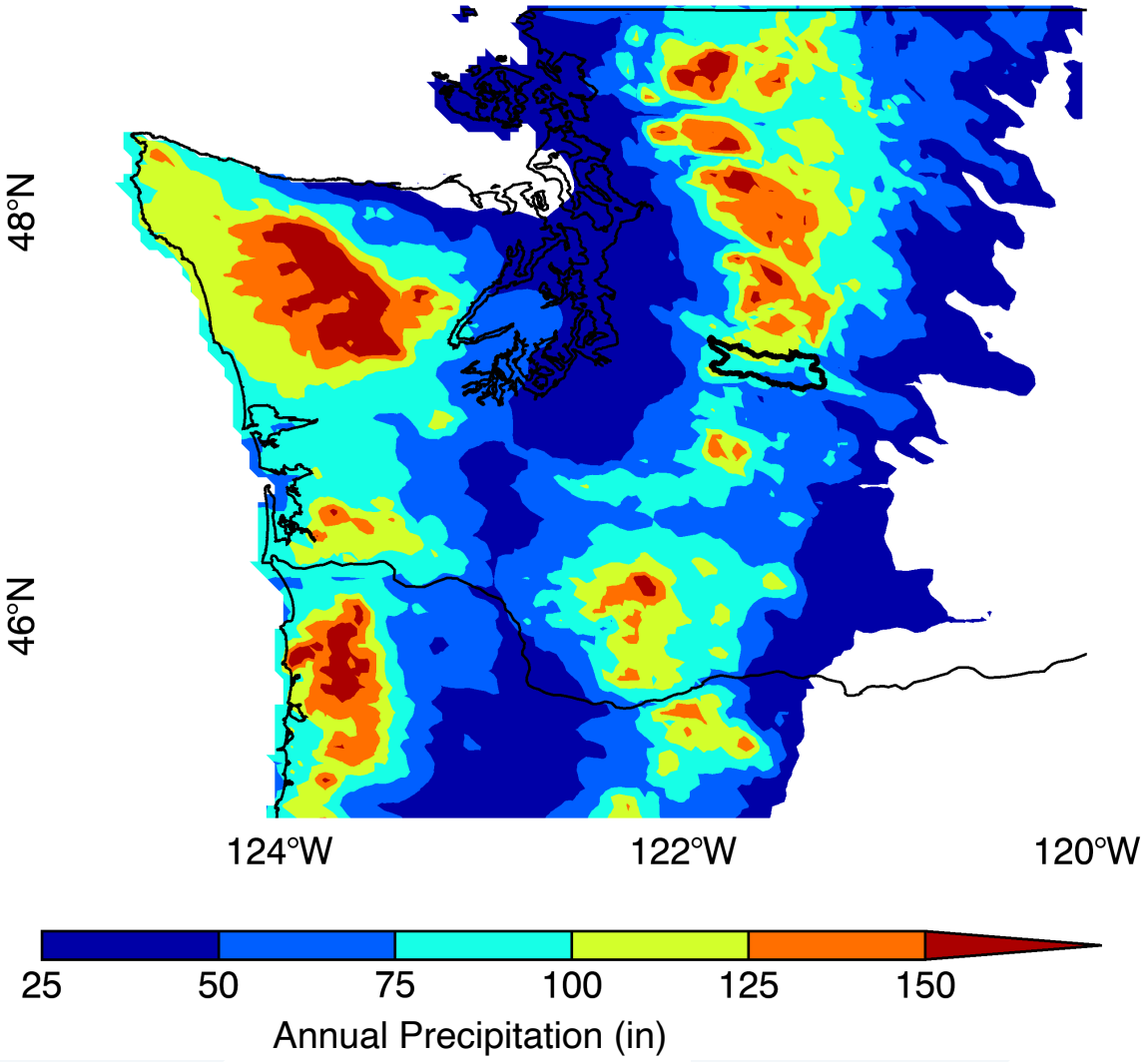
FIRO Phase II: New Project in PacNW (Howard Hanson)

Howard Hanson

- New Project
- HH Extreme Events
- WRF Considerations



New FIRO Project in PacNW (Howard Hanson)



Top50 Events 1981 --> 2020

Events/Month	Duwamish
Oct	4
Nov	15
Dec	8
Jan	9
Feb	9
Mar	2
Apr	1
May	0
Jun	0
Jul	0
Aug	0
Sep	1

Duwamish Above Howard Hansen				
Date of Max Precip During Max Independent 3-day MAP				
Year	Month	Day	3-day MAP	Rank
1982	1	23	6.4	11
1982	2	14	6.0	13
1982	12	4	4.7	37
1983	1	5	5.4	20
1983	11	3	4.5	42
1986	2	24	4.9	30
1986	11	24	5.9	14
1987	12	10	5.6	16
1988	10	16	5.4	19
1989	12	4	4.7	38
1990	1	10	6.4	10
1990	2	11	5.1	27
1990	11	10	4.8	35
1990	11	25	7.0	8
1991	2	20	5.0	29
1991	4	5	4.7	39
1994	10	27	4.3	48
1994	11	30	4.8	32
1995	2	19	5.5	18
1995	11	8	4.8	31
1995	11	29	8.4	3
1996	2	7	7.1	6
1997	3	19	6.1	12
1998	11	21	4.8	34
1998	12	28	5.2	24
1999	11	13	4.6	41
1999	11	25	5.2	26
1999	12	16	4.7	36
2000	10	1	4.3	47
2003	2	1	4.4	44
2004	1	30	4.5	43
2005	1	18	6.7	9
2005	9	30	4.6	40
2006	1	10	5.6	15
2006	11	7	11.2	1
2007	12	4	5.3	22
2008	2	9	4.8	33
2008	11	7	4.0	50
2008	11	13	7.0	7
2009	1	8	9.5	2
2011	1	17	5.3	23
2011	3	31	5.2	25
2012	2	22	5.6	17
2013	9	29	4.3	49
2015	1	6	4.4	46
2015	11	1	7.8	4
2015	11	18	5.1	28
2015	12	9	7.1	5
2017	10	22	5.4	21
2017	12	30	4.4	45

WEST-WRF NRT

Objectives

Near real time (NRT) production of West-WRF model forecasts, including tailored model output visualizations and analysis, to support California water decisions

Key Accomplishments To Date

- West-WRF improves upon other models for IVT magnitude and precipitation forecasts
- West-WRF forecasts using ECMWF operational forecast as input added this past season
- Daily production of three different simulations during water year 2020
- Reforecast Completed
- Ensemble in Development
- Development of efficient I/O strategies
- Workflow code available on 2 backup systems

Provided by: D. Steinhoff

WY Forecast Tools Updates: ECMWF Forecasts

Landfall Tool with Probability of IVT>250 kg/ms

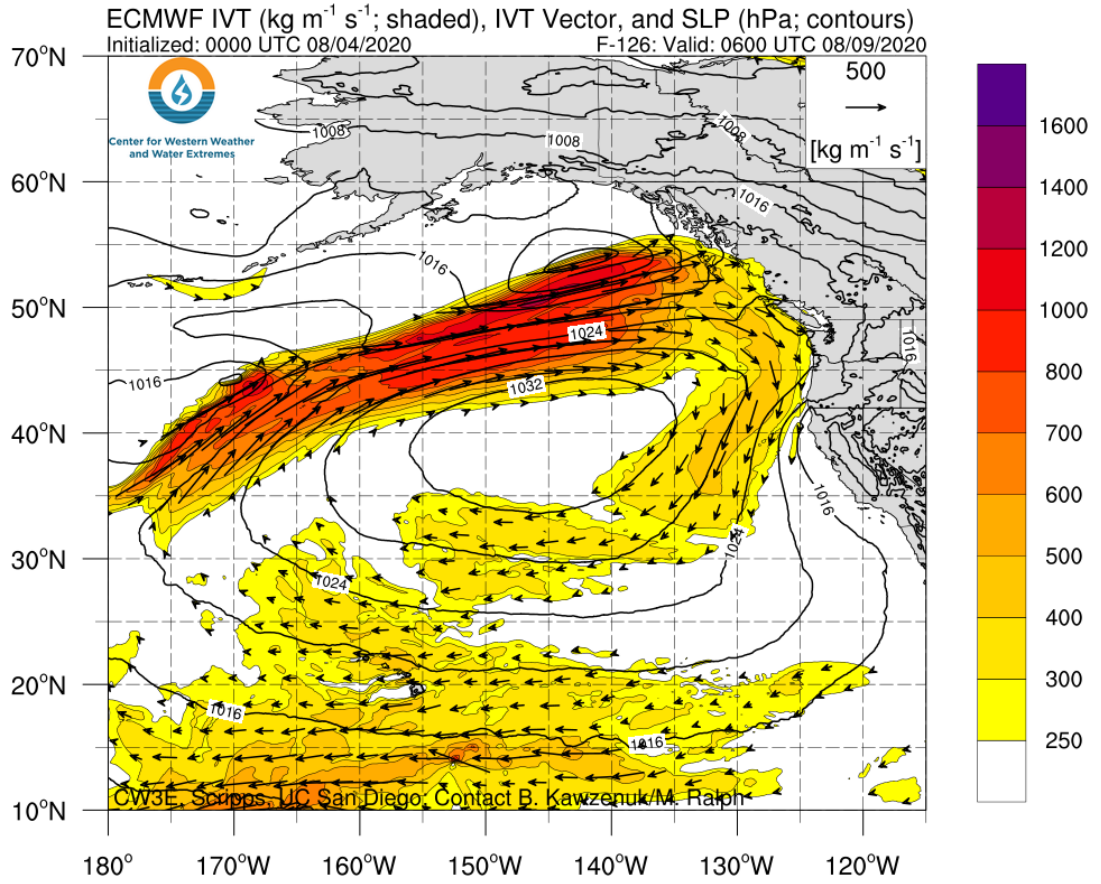
Landfall Tool with Ensemble Mean

Landfall Tool with Ensemble Control

Both coastal and inland

With differences from GEFS

IVT plumes for 7, 10, and 16 (really 15) days for coastal transect.



Provided by J. Cordeira

PROGRESS AND ONGOING WORK

The research presented for each project represents the cumulative efforts of a large number of individual scientists

A lot of ongoing work that is instrumental to successfully executing the meteorology portion of FIRO is not presented here