Forecast Informed Reservoir Operations (FIRO): Supporting Forecast Improvements through Targeted Data Collection

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FIRO at Lake Mendocino

Forecast Informed Reservoir Operations (FIRO) is a proposed alternative management strategy that aims to use data from watershed monitoring and state of the art weather and streamflow forecasting to improve water supply reliability without impairing flood protection. Lake Mendocino, located in northern California, US, is a current testbed for this strategy. The reservoir is managed for flood control by the U.S. Army Corps of Engineers and for water supply by Sonoma Water. The 1959 Lake Mendocino Water Control Manual (with minor updates in 1986), specifies reservoir elevations to control flooding and establishes the volume of storage that may be used for water supply (Fig. 1). This project was guided by the Lake Mendocino FIRO Steering Committee (SC), which consists of water managers and scientists from several federal, state, and local agencies, and universities. The SC shares a vision that operational efficiency can be improved by using monitoring and forecasts to inform decisions about releasing or storing water.

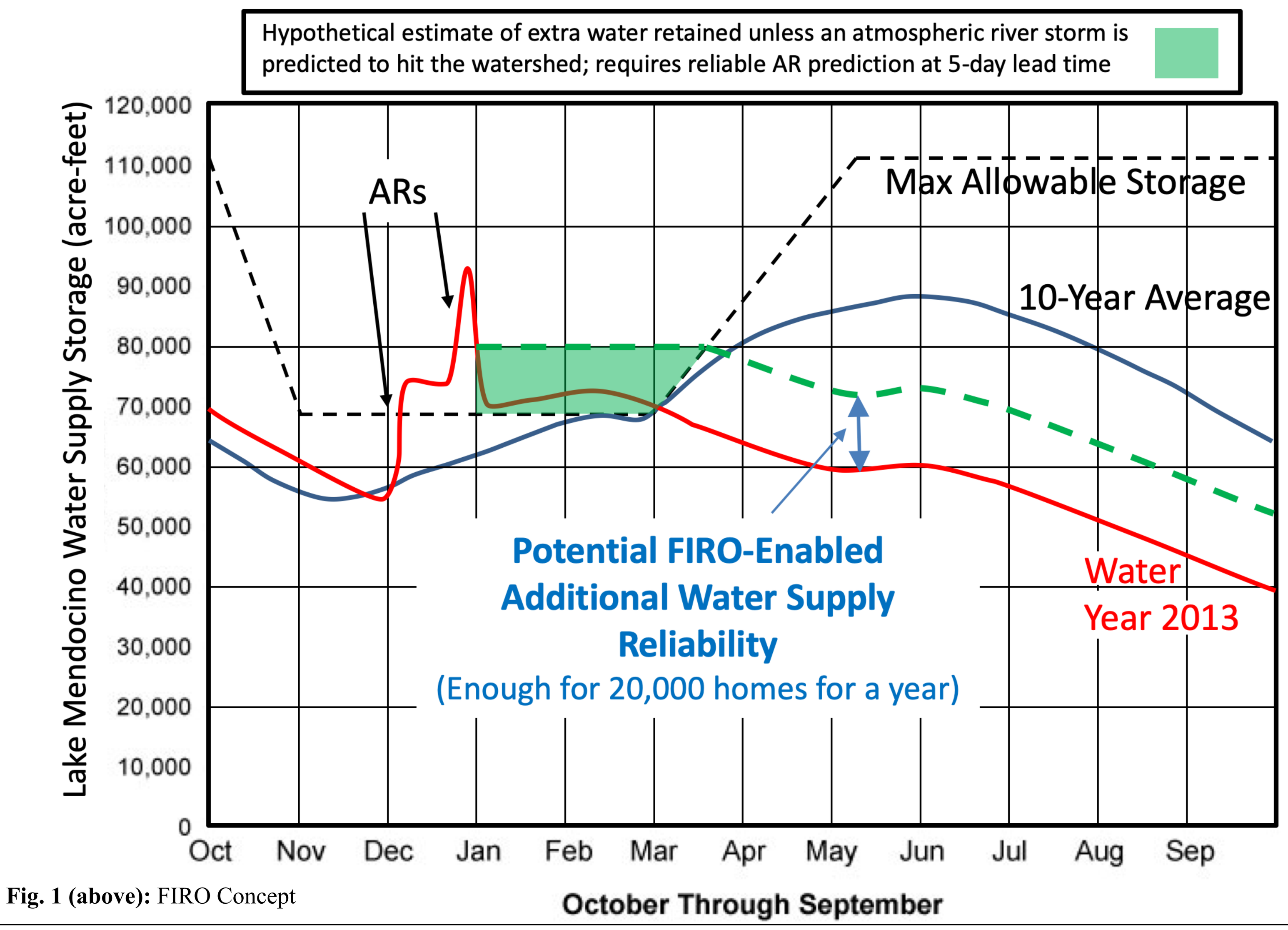
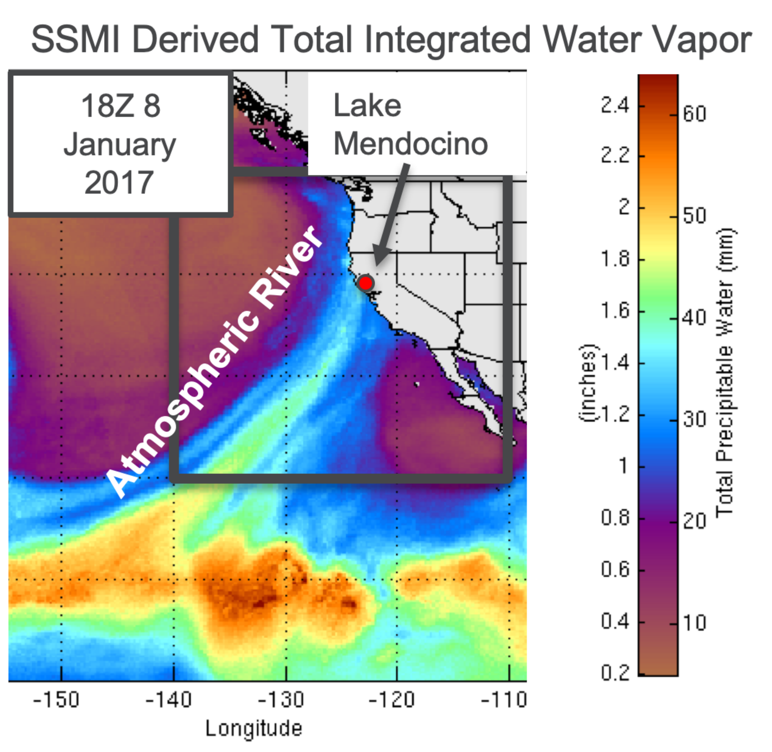
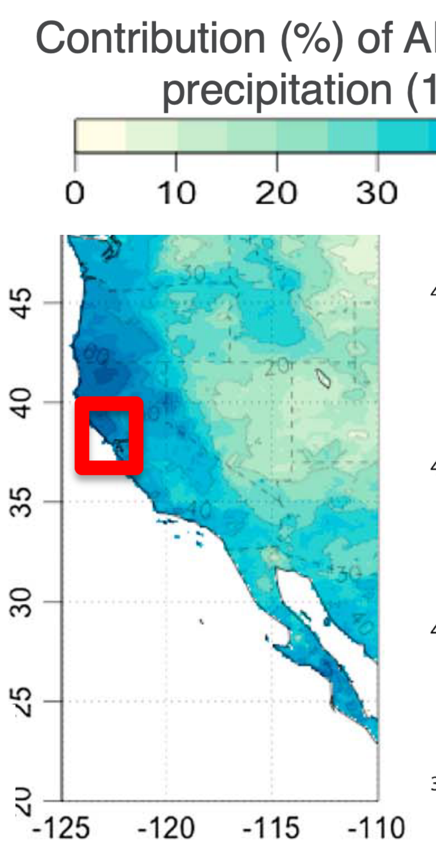


Fig. 1 (above): FIRO Concept

Role of Atmospheric Rivers





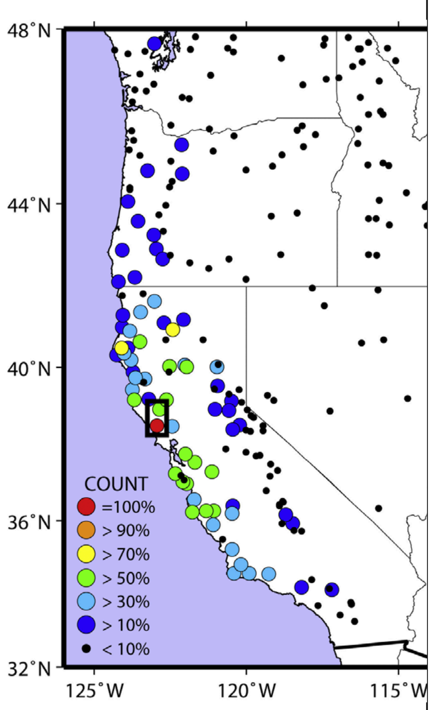
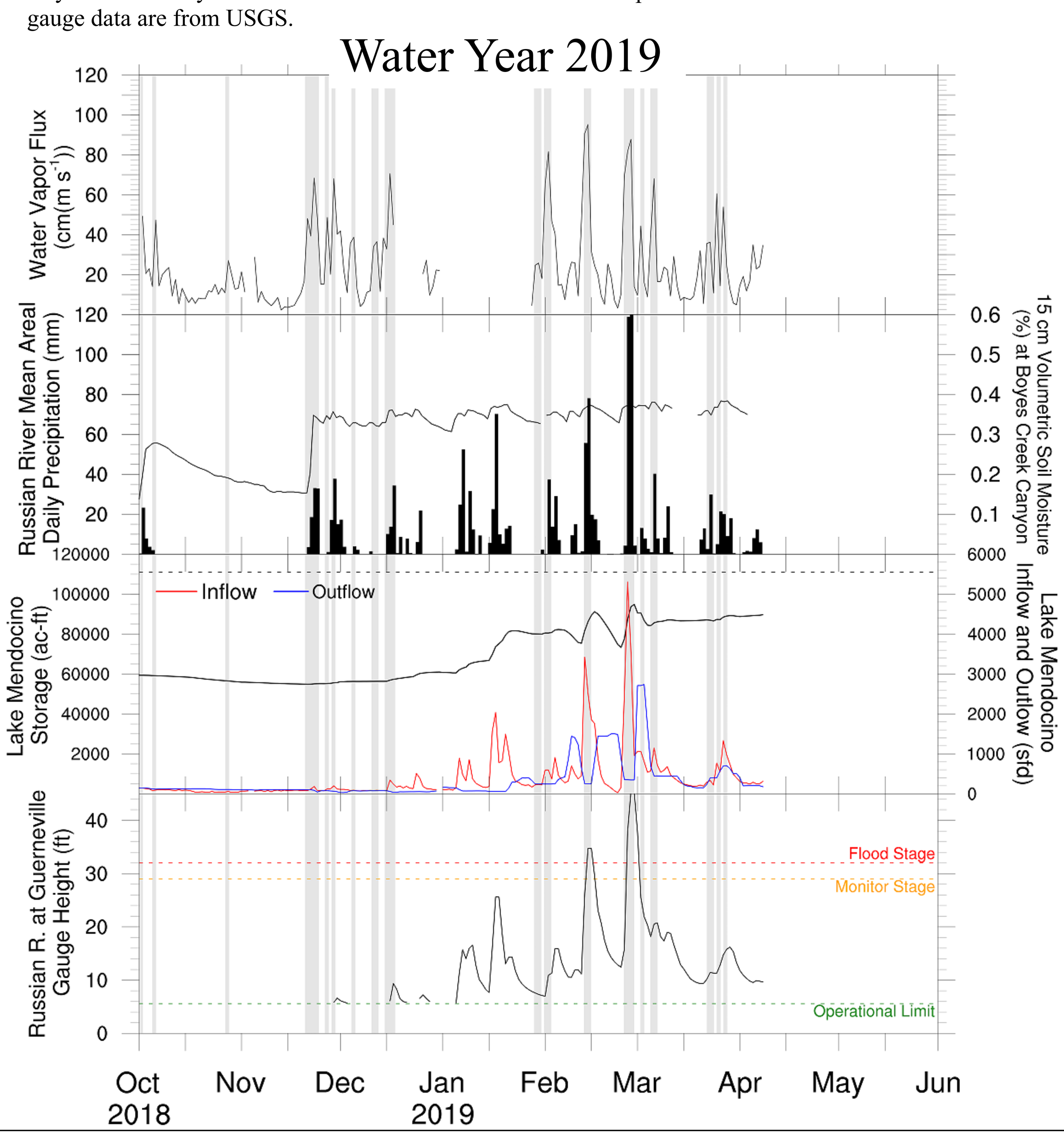


Fig. 2 (above): SSMI imagery of an atmospheric river; **Fig. 3 (right):** Fig. 2a from Gershunov et al., 2016; **Fig. 4 (far right):** Percent of floods during the period Oct 1997-Feb 2006 associated with ARs, fig. 6a from Ralph et al., 2006; **Fig. 5 (below):** Selected meteorological and hydrological variables plotted for the Russian River (see Fig. 6 for locations). Water vapor flux is computed at Bodega Bay, and ARs are identified whenever the ARO reports both water vapor flux above 20 cm m/s and IWV ≥ 2cm. Russian River MAP is from PRISM, soil moisture was recorded at Boyes Creek Canyon. ★ Data for Lake Mendocino reservoir operations are from CDEC and the Guerneville ★ gauge data are from USGS.



Water supplies rely on adequate precipitation, which in California is largely dependent on atmospheric rivers (ARs; Fig. 2-3). The absence of AR storms often leads to drought, whereas strong ARs can cause flooding (Fig. 4). ARs dominate the storage regimes in soils and reservoirs throughout the year in the Russian River (Fig. 5).

Goals for Observational Campaigns

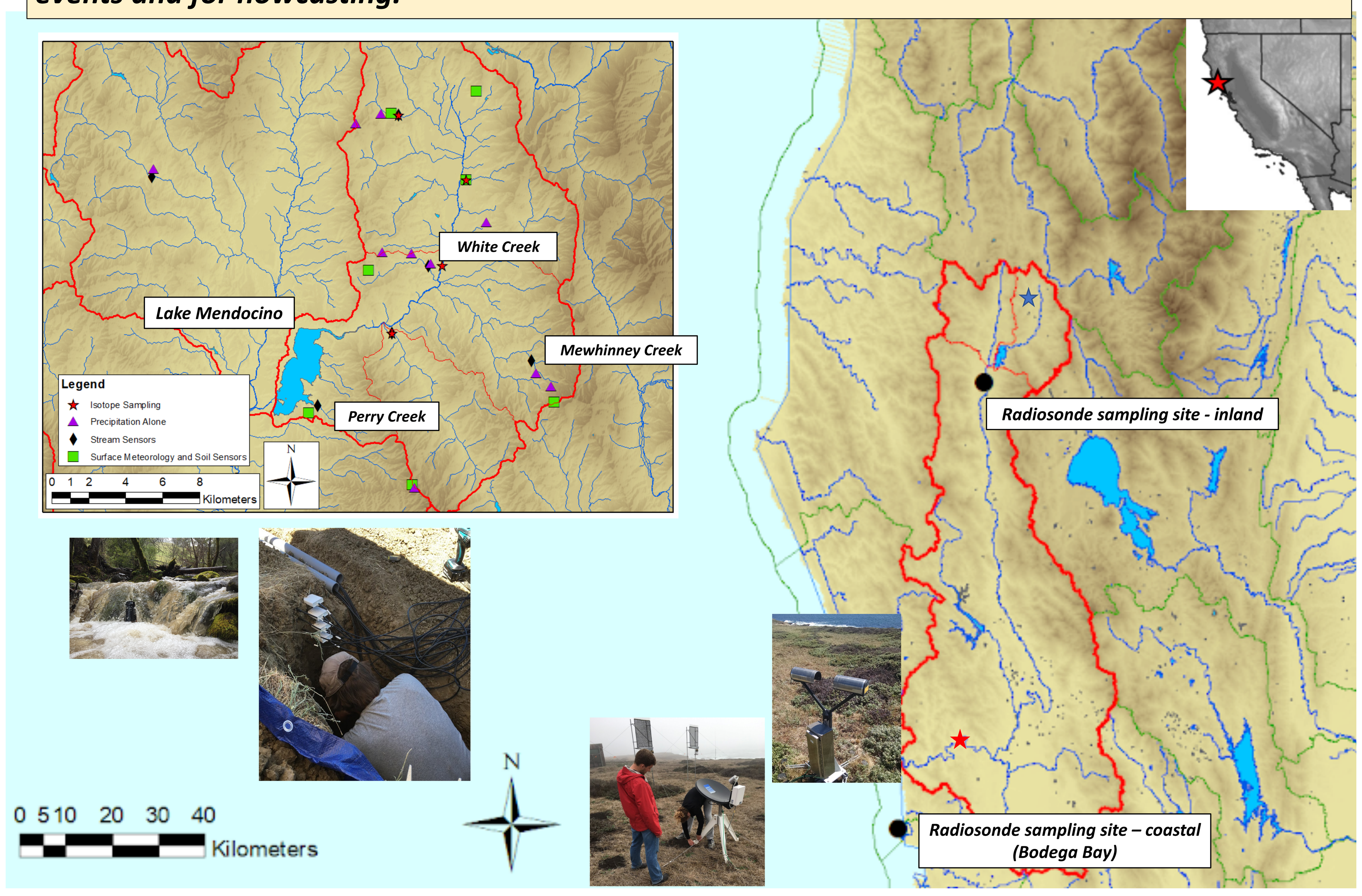
An extensive data collection campaign has been underway since January 2017, with the objective to **improve precipitation forecast skill** through improved understanding of atmospheric rivers (ARs).

Atmospheric Objectives:

- Improve understanding of AR structure and evolution:
  - What happens when the AR passes over the coastal ranges and/or is channeled by local valleys?
  - How do vertical variations in water vapor modulate AR transport?
- Support assessment of variance in the bulk upslope flux and precipitation relationship
- Improved predictions of ARs for the west, informing water managers, transportation sector, agriculture, etc.
- **Support West-WRF modeling** (both for verification, and for process studies)

Instruments: Radiosondes, Vertically Pointing Radars, Disdrometers

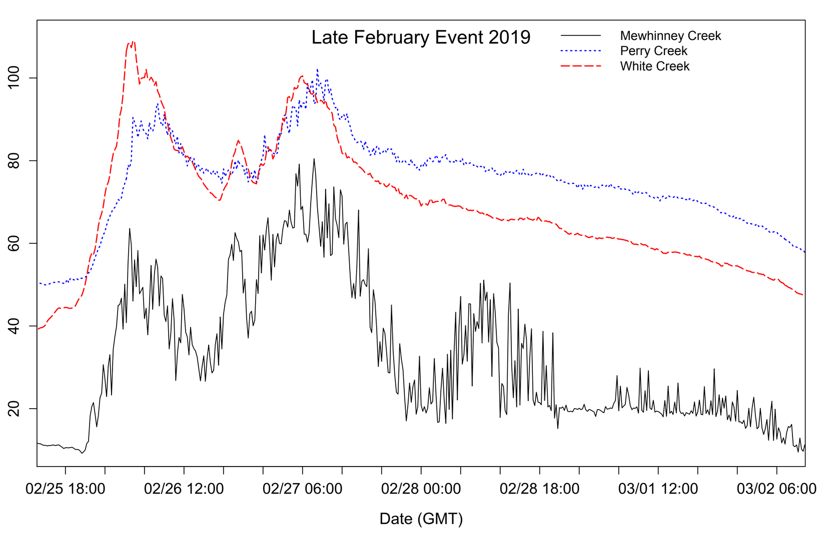
Since 2019, radiosonde data have been sent to the GTS in order to be assimilated into global operational numerical weather prediction models. Assessments will be undertaken to determine their impact. Radiosondes have also been used regularly for situational awareness through being provided in near real time to WFOs through the NWS Western Region; SOOs and WCMs report they are most frequently used to estimate how well models are performing in certain events and for nowcasting.



Hydrologic Objectives:

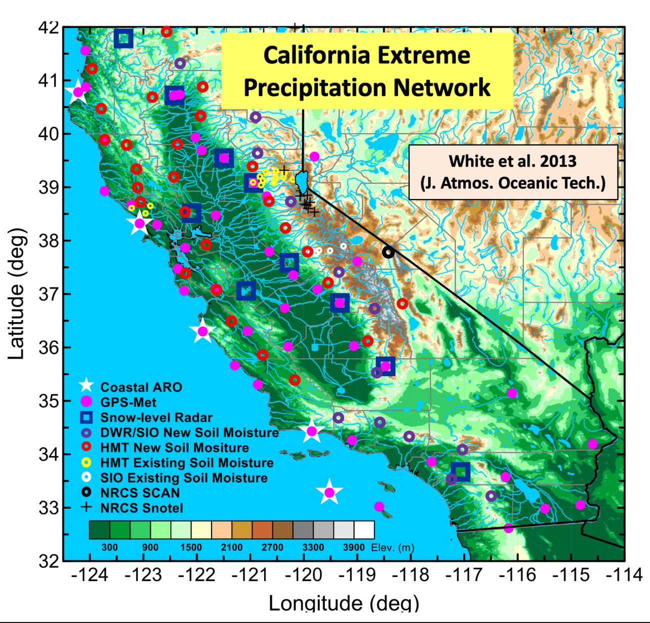
- Improve understanding of the spatial variability of precipitation, soil moisture, and streamflow **to inform hydrological modeling forecasts**
- Quantify runoff volumes and sources of runoff (e.g. surface vs. groundwater) to aid in understanding hydrologic response to ARs
- Observe the hydrometeorology of the watershed during events that provide inflows to Lake Mendocino at all relevant timescales

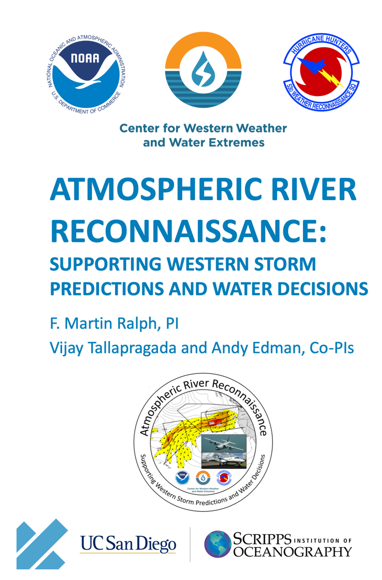
Fig. 6 (above): Map of CW3E FIRO stations; **Fig. 7 (below):** Three stage readings derived from level loggers deployed in the Lake Mendocino watershed for an event in Feb 2019, see Fig. 6 for locations.

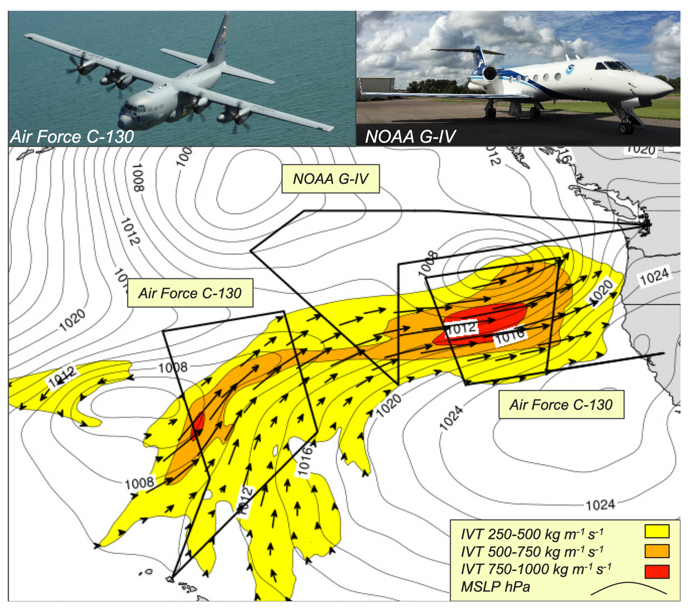


Instruments: Soil Moisture Reflectometers, Pyranometers, Various Surface Meteorology, Level Loggers, ISCOs

Leveraging Other Field Campaigns







Acknowledgements and References

Gershunov, A., T. Shulgina, F. M. Ralph, D. A. Lavers, and J. J. Rutz, 2017: Assessing the climate-scale variability of atmospheric rivers affecting western North America. *Geophys. Res. Lett.*, **44**, doi:10.1002/2017GL074175.

Ralph et al. 2006: Flooding on California's Russian River: The role of atmospheric rivers. *Geophys. Res. Lett.,* **33**, L13801.

CDEC data accessed from California Department of Water Resources, https://cdec.water.ca.gov/; NOAA HMT data accessed from NOAA Earth Systems Research Laboratory, Physical Science Division, https://www.esrl.noaa.gov/psd/data/obs/datadisplay/; PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004; U.S. Geological Survey, 2016, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), at URL [http://waterdata.usgs.gov/nwis/].

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