[*Climate Data Collection and Forecasting Element*]

floodER
Department of Water Resources
Flood Emergency Response Program

An Advanced Monitoring Network In Support of the FloodER Program

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FloodSAFE
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Introduction

Extreme precipitation and the resulting flooding events cause death and disruption to California. Although uncertainties abound, such events may become more commonplace or extreme as a result of warmer ocean temperatures related to climate change. Quantitive Precipitation Forecasts (QPF) provide an estimate of short-term precipitation that is used in flood forecasting. By using existing technologies and providing additional observations we can improve information and accuracies in forecasting these events. The National Oceanic and Atmospheric Administration's Earth System Research Laboratory (NOAA-ESRL) and Scripps Institution of Oceanography (Scripps) have developed a tiered program of observations to help California respond to extreme precipitation events with tiers of observations segregated according to increasing technical complexity and cost. The four tiers range from proven technologies that are available today at relatively low costs and are ready for rapid deployment, to high-cost technologies that still require development. An overview of the contents of the tiers is presented in this document.

Over the next five years, NOAA-ESRL, in partnership with the California Department of Water Resources (DWR) and Scripps, will begin implementing elements of the first and second tiers of observation equipment along with associated data processing, modeling, data display, and decision support tools for an integrated information package. Data streams from these new observations will be made available to the public through the California Data Exchange Center (CDEC). To the extent possible, other partners will be identified to provide additional support for this effort called the 21st Century Extreme Precipitation Observation Network.

A combination of the Tiers I and II observing components will greatly improve the ability to track and, ultimately, to predict the evolution and severity of extreme precipitation events.

Recent research has shown that extreme precipitation in California is most often a result of land-falling atmospheric rivers. Figure 1 shows an atmospheric river that impacted California and the associated flooding that occurred on the Russian River in 2004. Land-falling atmospheric rivers focus concentrated plumes of water vapor at the coast (hence their name) resulting in intense and orographically enhanced rainfall. Offshore, atmospheric rivers are monitored by polar-orbiting satellites, which provide twice-daily snapshots of the total amount of water vapor in the atmosphere. However, satellite based techniques do not work over land. Tiers I and II observations extend offshore satellite observations of atmospheric rivers over land so that moisture plumes can be tracked as they cross the coastal mountains and impact the Sierra Nevada. Tier I adds soil moisture observations that play a critical role in both flood forecasting (precursor) and long-term drought monitoring, and small radars designed to track time variations of the altitude of the rain-snow transition at many locations along the Sierra. Accurate estimation of the melting (freezing) altitude is critical to forecast runoff and the potential for flooding. Over time, these observations will create an important climate record and data sets with which models can be verified and forecasts improved.

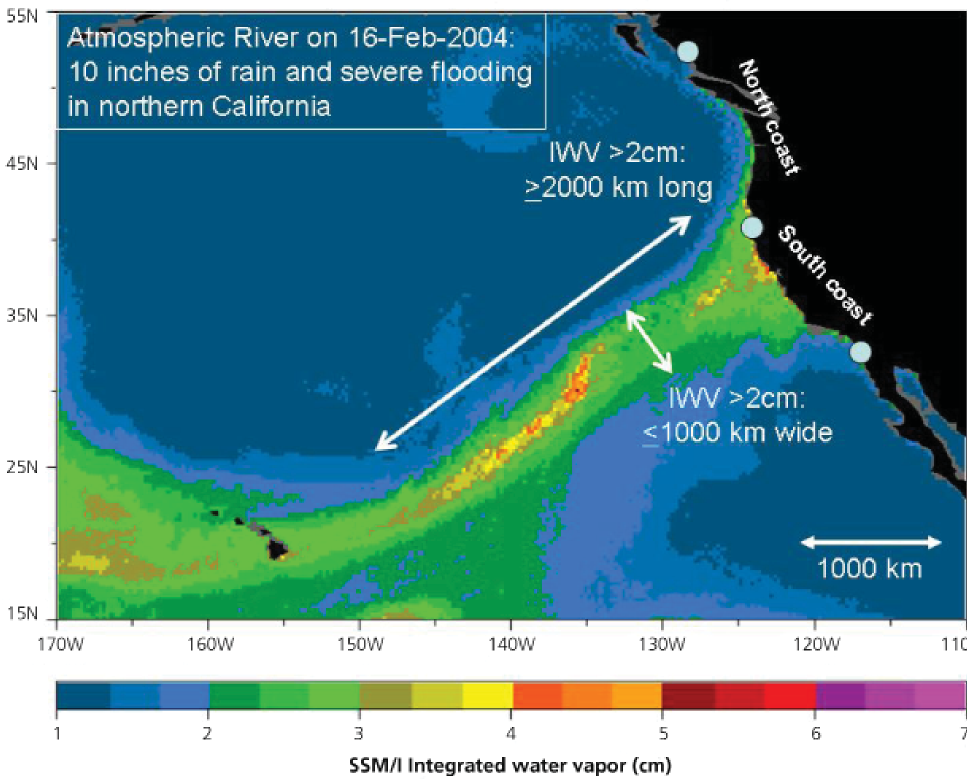

Figure 1. An atmospheric river, which impacted California on February 16, 2004. Warm colors indicate more water vapor.

The full value of these observations will only be realized if, from the onset, assimilation and modeling systems are developed to take full advantage of the resulting data streams. Tools that bring the new observations into a coherent depiction of the pre storm and evolving storm-time environments will enhance quantitative prediction of precipitation. Thus, as the program is advanced through the observational tiers, a complementary effort in assimilation, modeling, and display will be necessary to ensure maximum benefit for the investment in observational infrastructure.

Decision support tools will be developed to integrate information (knowledge, modeling, observations) into rapidly accessible and understandable indicators and thresholds. These will provide frameworks for probabilistic threat assessments and decision-making regarding extreme precipitation and flood potentials over a variety of time scales.

The immediate benefit comes in the operations arena where the new data will inform forecasting and flood management. Placing the data on CDEC will enable broad use of the data by outside agencies and the public. Over time the data collected from this network will provide valuable information for the description of California's climate and its long-term evolution.

A Tiered Approach Investment in the Observation Program

NOAA-ESRL and Scripps developed the concept of the 21st Century Observations Program for California based on a recognition that several new observational technologies have become available in the past decade, that offer marked enhancements and complements to existing observational networks developed in the later half of the 20th Century. Some of these new technologies are already being used in experimental settings and need only the support to extend them into sustained operational networks; other technologies are more expensive or more speculative at present. Consequently, the program of new observations was conceived in terms of a sequence of steps or tiers of observations of increasing complexity and cost.

A four tiered program has been developed to improve information for flood forecasting:

Tier I builds on existing networks using proven, relatively low-cost technologies.

Tier II continues the use of proven technology, with more costly equipment.

Tier III adds higher cost technologies whose operational merit may not yet have been demonstrated conclusively.

Tier IV observations use technologies that are optimistically anticipated but that remain speculative.

DWR has identified Tiers I and II as significant elements of upgrades for California's observation network that will benefit flood control and water supply in the short term and climate monitoring efforts in the long term. Figure 2 shows the locations and types of instruments in Tier I. The instruments include:

- GPS-Met stations that continuously monitor variations of the total amount of water vapor in the atmosphere above the stations
- Soil moisture monitoring at Remote Automated Weather Stations (RAWS) and DWR California Cooperative Snow Survey (CCSS) sites
- Vertically pointing radar at reservoir sites to continuously monitor how much of the contributing catchments are receiving rain versus snow during storms.

Map of Tier I

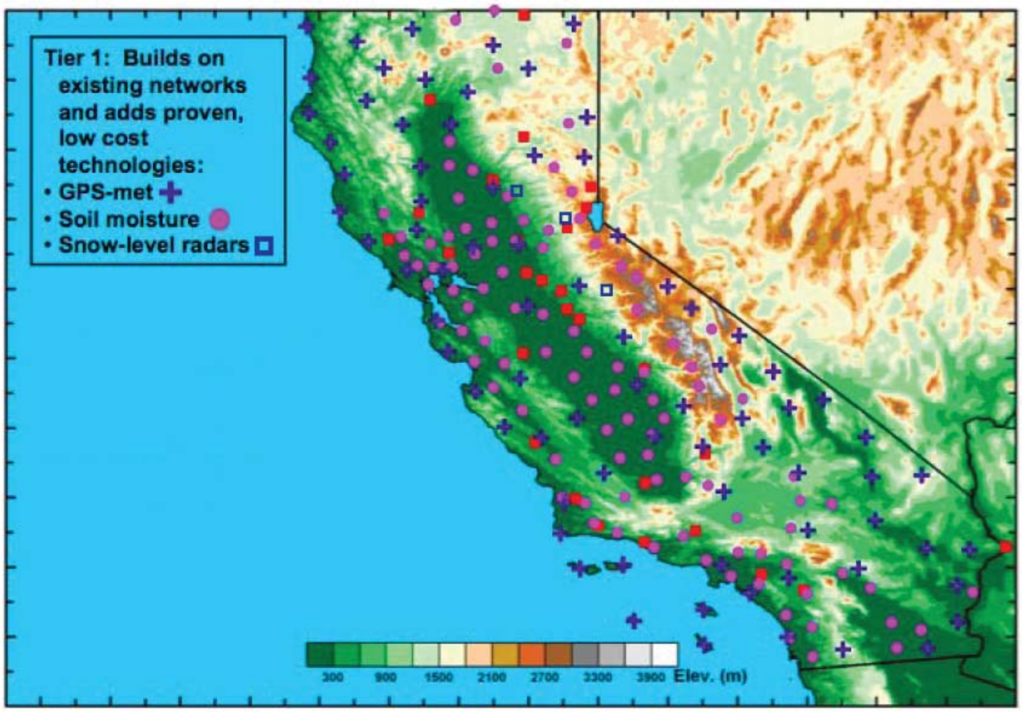

Figure 2. Map of California showing location and distribution of Tier 1 instrumentation (figure courtesy of Mike Dettinger and Allen White).

The GPS-Met component of Tier I economizes by using existing networks of telemetered, ultra-precise GPS receivers maintained by the United States Geological Survey (USGS) and Scripps for monitoring tectonic movements. In order to use these tectonic monitors for water-vapor observations, relatively minor meteorological equipment needs to be added to provide for key atmospheric water vapor information. Similarly, the soil-moisture component of Tier 1 builds upon the existing telemetry at monitoring sites of two of the State's existing meteorological and snow monitoring networks. Finally, the rain-snow radars are a new development that was largely motivated by the discussions that spawned the 21st Century Observations Program, extracting a low-cost solution from more complete but more expensive technologies that will be deployed more sparingly as part of Tier II.

Tier II builds upon Tier 1 instrumentation, adding several Atmospheric River Observatories along the coast to the observation network. Whereas Tier I sites provide surface or integrated observations, Tier II sites profile the atmosphere to provide detailed information aloft. The location of these elements and their relative position to Tier I instrumentation is shown in Figure 3.

Map of Tier II

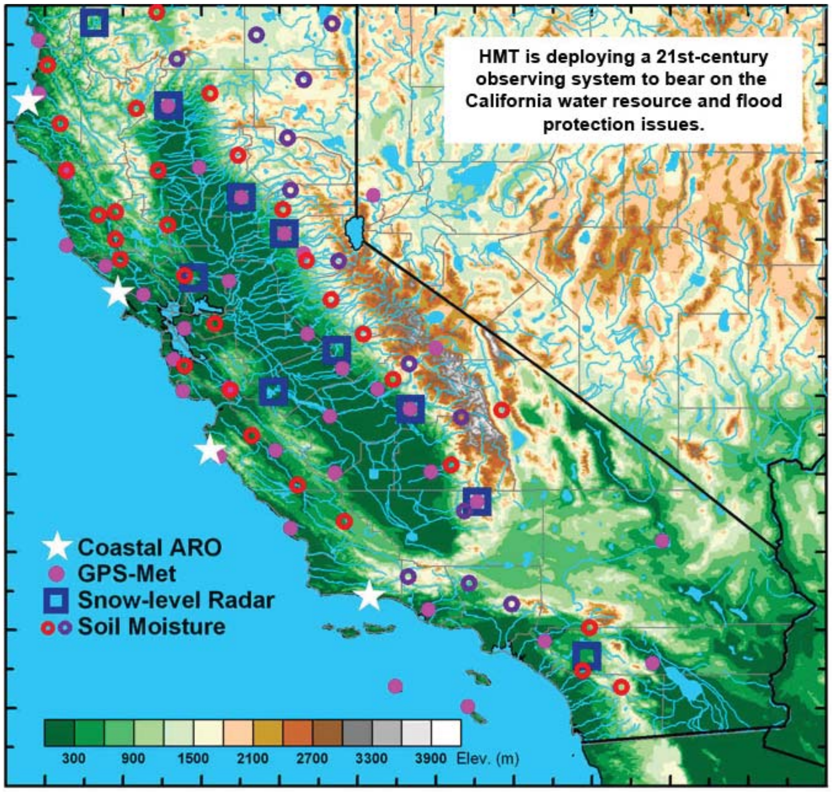

Figure 3. Location of Tier II instrumentation in California

Tiers III and IV are more speculative but give indication of strategies that would take advantage of some key developing technologies in coming years. Tier III adds offshore monitoring of the atmosphere using an ocean buoy network, and gap-filling radars across the state. Tier IV adds an offshore aerial-reconnaissance program to directly monitor the strength and location of atmospheric rivers approaching California by using unpiloted aerial vehicles.

Data Assimilation, Forecasting, and Decision Support Displays

The first two tiers of the enhanced observing system provide advanced forecasting products. The National Weather Service (NWS) global and national scale numerical modeling will allow deciphering impacts of large (Pacific) scale atmospheric processes on small-scale California river basins of concern over a 0- to 5-day period. The advanced observations will be used to create highly detailed depictions of existing weather that when used as model, initial conditions will significantly enhance the precipitation forecasts for day 0-2; the global-regional nested system will allow detailed forecasts out in the 3-5 day period. The combination of high resolution data-driven forecasts and globally influenced longer term forecasts will provide water managers sound guidance to drive decisions out to 5 days and beyond. By running multiple versions of the regional models probabilistic, 5-day forecasts can be produced to aid water managers in their decision making.

Five-Year Implementation Program

The implementation of all Tier I and Tier II instrumentation are planned for 2008 through 2013. A year-by-year breakdown of instrumentation installations are outlined in table below. Details of the locations of each year's installation will be coordinated among DWR, NOAA and the Scripps personnel.

Table 1. Year-to-year breakdown of Tier 1 & Tier 2 instrumentation implementation

Tier 1	Proposed	Year 1	Year 2	Year 3	Year 4	Year 5	Total
GPS-Met Sites	84	8	16	20	20	20	84
Soil Moisture Sites	100	10	20	20	25	25	100
Snow Level Radars	24	2	2	6	7	7	24
Tier II	**Proposed**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Atmos. River Obs.	3	0	0	1	1	1	3
Wind Profilers	8	0	0	2	3	3	8

Data streams from the field sensors will be made available to the research community and public through DWR's California Data Exchange Center.

Points of Contact

DWR:
Jon Ericson
Mike Anderson
California Department of Water Resources
Division of Flood Management
3310 El Camino Avenue Rm 200
Sacramento, CA 95821
Phone (916) 574-2830
jericson@water.ca.gov (Jon)
manderso@water.ca.gov (Mike)

USGS/Scripps/UCSD:
Mike Dettinger and Dan Cayan
USGS/Scripps Institution of Oceanography
UC San Diego, Dept 0224
9500 Gilman Drive
La Jolla, CA 92093-0224
Phone: (858) 822-1507
mdettinger@ucsd.edu or dcayan@ucsd.edu

NOAA:
Principal Contact:
Timothy Schneider
325 Broadway, R/PSD2

For additional information, contact
Mike Anderson
(916) 574-2830
manderso@water.ca.gov

Or visit us on the Web at www.water.ca.gov

Arnold Schwarzenegger
Governor

Lester A. Snow
Secretary of Resources

Mark Cowin
Director
Department of Water Resources

Prepared by GEI Consultants, Inc. for
The California Department of Water Resources
Naser Bateni, Program Manager (PE 36128)