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# Formulating the ARkStorm Meteorology

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## BIOGRAPHICAL SKETCH

Dr. Michael Dettinger is a research hydrologist for the U.S. Geological Survey, Branch of Western Regional Research, and a research associate of the Climate, Atmospheric Sciences and Physical Oceanography Division at Scripps Institution of Oceanography, La Jolla, California. Dettinger has monitored and researched the hydrology, climates, and water resources of the West for almost 30 years, focusing on regional surface water and groundwater resources, watershed modeling, causes of hydroclimatic variability, and climatic-change influences on western water resources. He has authored over 75 scientific articles in scholarly journals and books, 20 government reports, and another 70 articles in outreach and less formal outlets.

Among other activities, he was the physical-sciences team leader for DOI-DOD ecosystem planning in the Mojave Desert, founding member of the multi-institutional CIRMONT Western Mountain Climate Sciences Consortium, climate advisor to the CALFED Bay-Delta Restoration Program, member of the Climate Change Technical Advisory Group for California Dept. of Water Resources' 2009 Water Plan Update and ongoing Central Valley Flood Protection Program workgroup, member of the external Science Steering Group for the federal Global Water Cycle Program, research advisor for USGS Surface-Water Discipline, and a member of the USGS Global Change Science Strategic Planning Team. He has degrees from the University of California, San Diego, Massachusetts Institute of Technology, and a Ph.D. from the University of California, Los Angeles (Atmospheric Sciences).

## ABSTRACT

The USGS Multi-Hazards Project is working with numerous agencies and experts to evaluate hazards that would be associated with a scientifically plausible series of extreme winter storms in California. The scenario consists of a storm sequence that impacts both Southern and Northern California in rapid succession, and that is more severe overall than any single 20<sup>th</sup> century storm, but that may rival the extreme storms of 1861-62. The atmospheric and hydrological characteristics of the storms are quantified to provide the basis for other teams to estimate human, infrastructure, economic, and environmental impacts. The scenario will be used to design emergency preparedness and flood planning exercises by federal, state and local agencies.

Recent storm episodes were "stitched" together to describe a rapid sequence of several major storms over the state, yielding precipitation totals and runoff rates beyond any that occurred during the individual (unstitched) historical events. This stitching approach is a new strategy that allowed the scenario-design team to avoid arbitrary scalings to achieve much greater-than-historical storm and flood totals, by instead allowing for the very real occasions when storms stall over parts of the state and when extreme storms have followed each other into the state over short periods of time. The scenario—called the ARkStorm—is quantified by a dynamical (regional weather-model) downscaling of historical observations of extreme winter storms of January 1969 and February 1986 to 6-km and 2-km grids over California. The weather model outputs were used to force a hydrologic model to estimate runoff, for comparison with historical runoff. The methods used to build this scenario, and key results, could also be applied to other, nonemergency or non-California applications.



*Formulating*  
**ARKSTORM**  
*Meteorology*

Mike Dettinger (USGS) and Marty Ralph (NOAA)

Mimi Hughes (NOAA), Tapash Das  
(SIO), Paul Neiman (NOAA), Dale Cox  
(USGS)





# USGS MULTI-HAZARDS DEMONSTRATION PROJECT

- **The Great Southern California Shakeout:** A week-long series of events to inspire SoCalifornians to improve earthquake readiness; >6 million participants thus far



- A scientifically plausible & detailed scenario of a major southern San Andreas earthquake was designed by the USGS scientists (and collaborators) and used as basis for California Office of Homeland Security's Golden Guardian exercises, Nov 2008, Oct 2009, Oct 2010, ...



California Earthquake Country Alliance  
www.earthquakecountryalliance.org

Shake  
Out

# ARkStorm METEOROLOGY TEAM

*In a new MutiHazards effort, we were tasked recently with formulating a similarly detailed & defensible scenario for an extreme-winter storm/flood episode(s) in California—eventually dubbed “ARkStorm”*



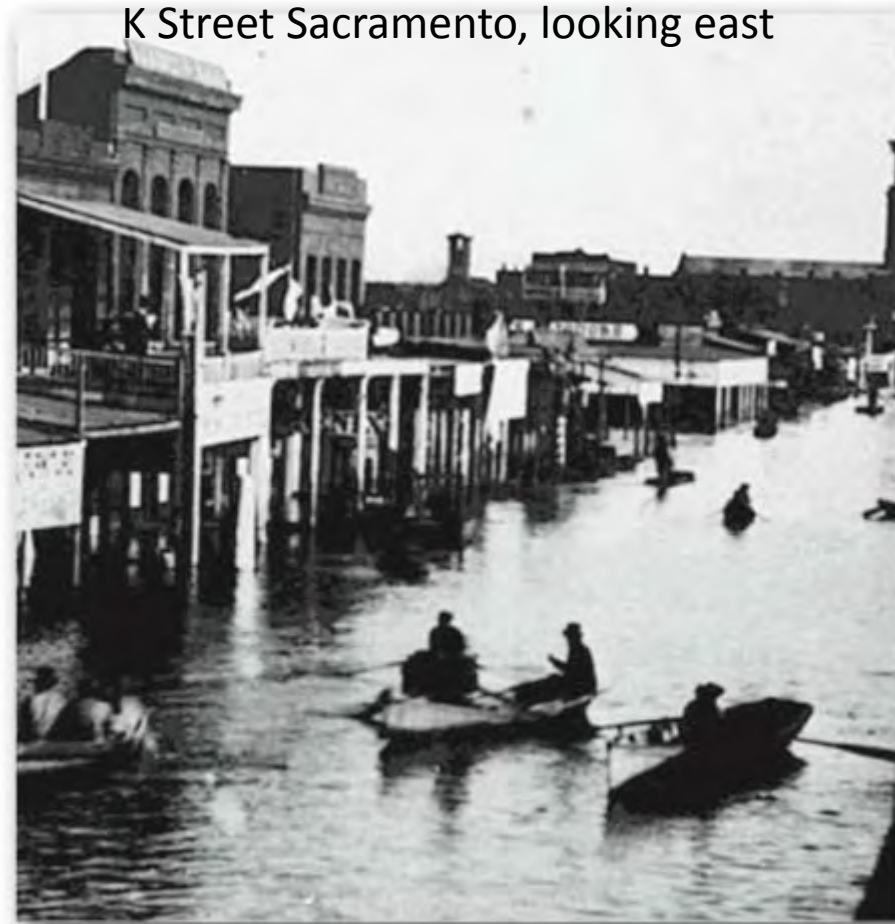
Name	Affiliation	Position
<b>Storm Design Team</b>		
F. Martin Ralph	NOAA/ESRL, Boulder	Team leader, Research meteorologist
Michael Dettinger	USGS, Scripps Institution of Oceanography, La Jolla	Team leader, Research hydrologist
Daniel Cayan	Scripps Institution of Oceanography, La Jolla	Research climatologist
David Danielson	NWS, Los Angeles	Hydrologist
Tapash Das	Scripps Institution of Oceanography, La Jolla	Postdoctoral researcher
Gary Estes	California Extreme Precipitation Symposium, Auburn	Scientist
Robert Hartman	NOAA/NWS CA-NV RFC, Sacramento	Hydrologist in charge
Mimi Hughes	NOAA/ESRL, Boulder	Postdoctoral researcher
Paul Neiman	NOAA/ESRL, Boulder	Research meteorologist
Jan Null	Golden Gate Weather	Consulting Meteorologist
David Reynolds	NWS, Monterey	Meteorologist in charge
<b>Review Team</b>		
Mark Jackson	NWS, Los Angeles	Meteorologist in charge
John Monteverdi	San Francisco State University, San Francisco	Meteorologist
Kelly Redmond	Western Regional Climate Center, Reno	Research climatologist
Maurice Roos	California Department of Water Resources, Sacramento	State hydrologist
<b>Project Management</b>		
Lucy Jones	USGS, Pasadena	Program chief
Dale Cox	USGS, Sacramento	Project chief
Suzanne Perry	USGS, Pasadena	Research geologist



# THE 1861-1862 FLOODS

- December 24, 1861 through Jan 21, 1862: nearly unbroken rains
- Central Valley flooding over about 300 mi long,  
12 – 60 mi wide
- Most of LA basin reported as “generally inundated”
- San Gabriel & San Diego Rivers cut new paths to sea
- 420% of normal-January precipitation in Sacramento in Jan 1862
- 300% of normal-January precipitation in San Diego in Jan 1862
- 500% of normal-January in San Francisco

K Street Sacramento, looking east



Another view of K Street from 4th Street looking east during the 1862 flood.

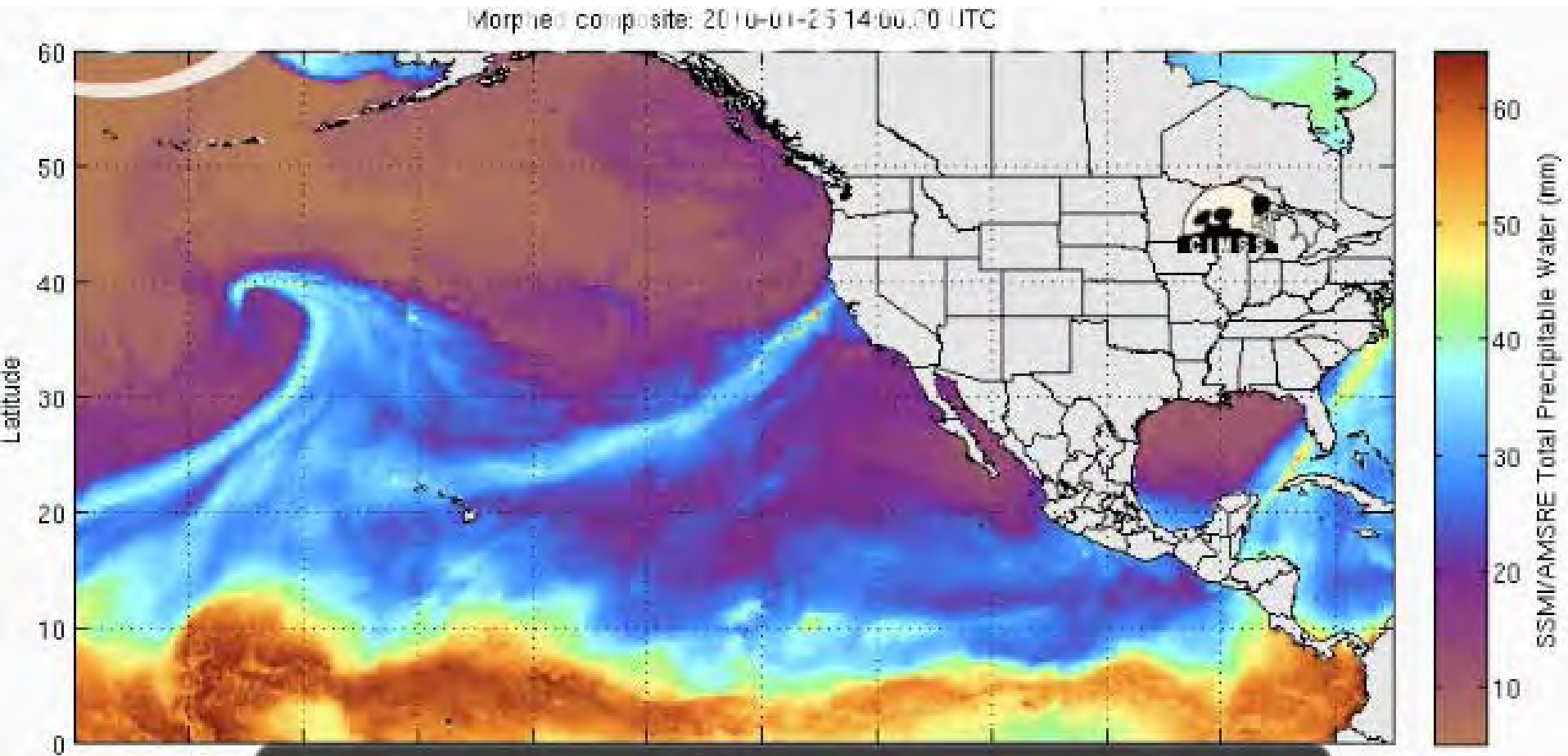


# THE 1861-1862 FLOODS

- No way of knowing how intense the rains were, but they were exceptionally large in total and prolonged.
- Lesson: Prolonged storm episodes are a plausible mechanism for winter-storm disaster conditions in California
- Lesson: **A combined NorCal+SoCal extreme event is plausible.** 12 days separated the flood crest in Sacramento from the crest in Los Angeles in Jan 1862



# AR in ARkStorm = Atmospheric River



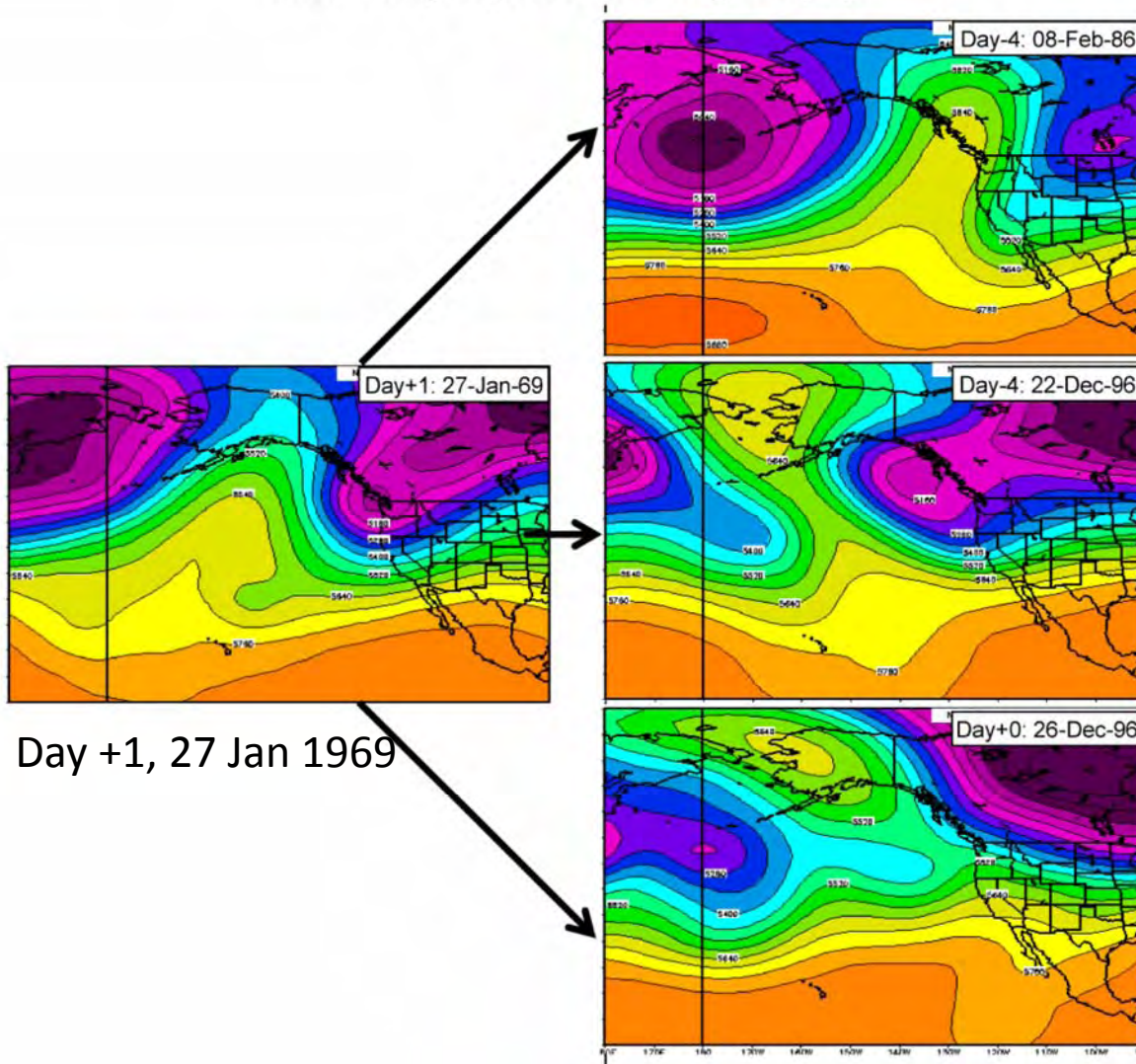
MIMIC-TPW from CIMMS @ Univ. Wisconsin Madison  
<http://cimss.ssec.wisc.edu/tropic/real-time/tpw2/epac/main.html>





# WHICH STORMS TO STITCH, WHEN?

500 mb geopotential heights (m)



Day -4, 08 Feb  
1986

Feb  
1986?

Day -4, 22 Dec  
1996

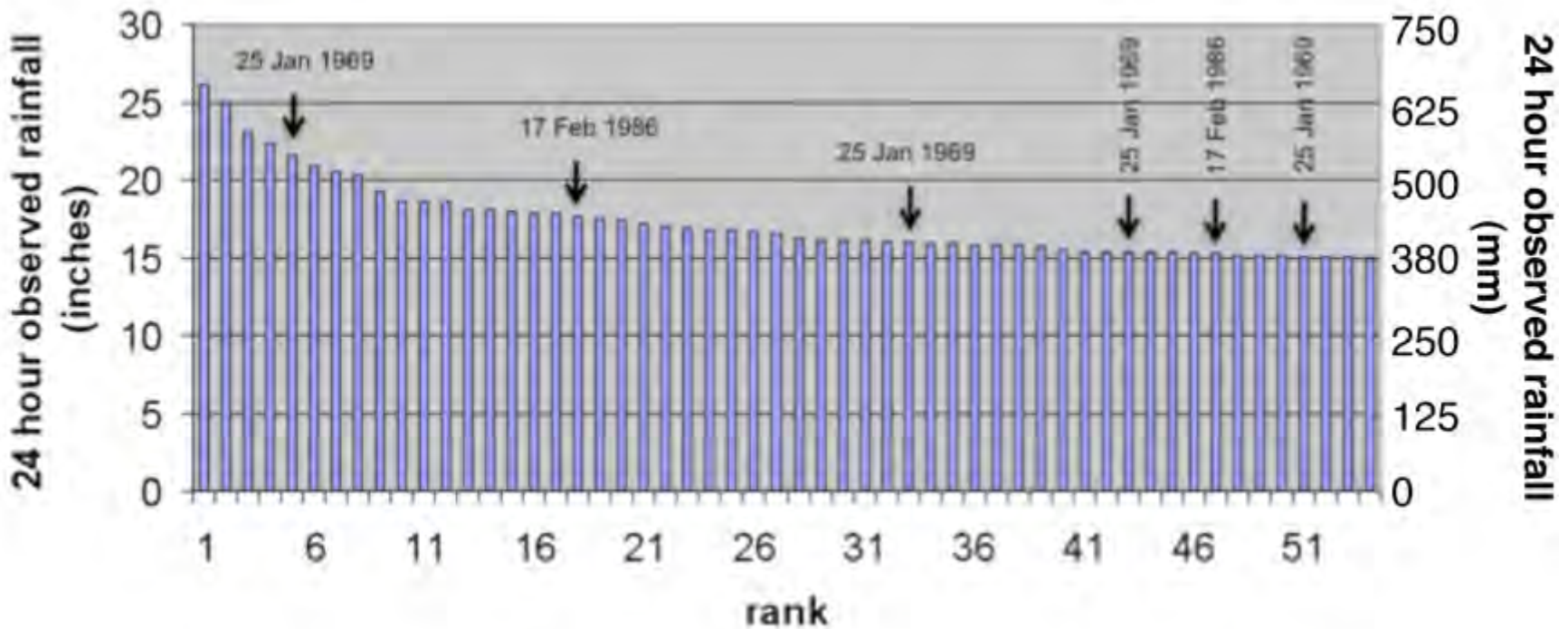
New  
Years, 1  
997?

Day 0, 26 Dec  
1996



# LARGEST HISTORICAL REPORTS OF DAILY PRECIPITATION IN CALIFORNIA

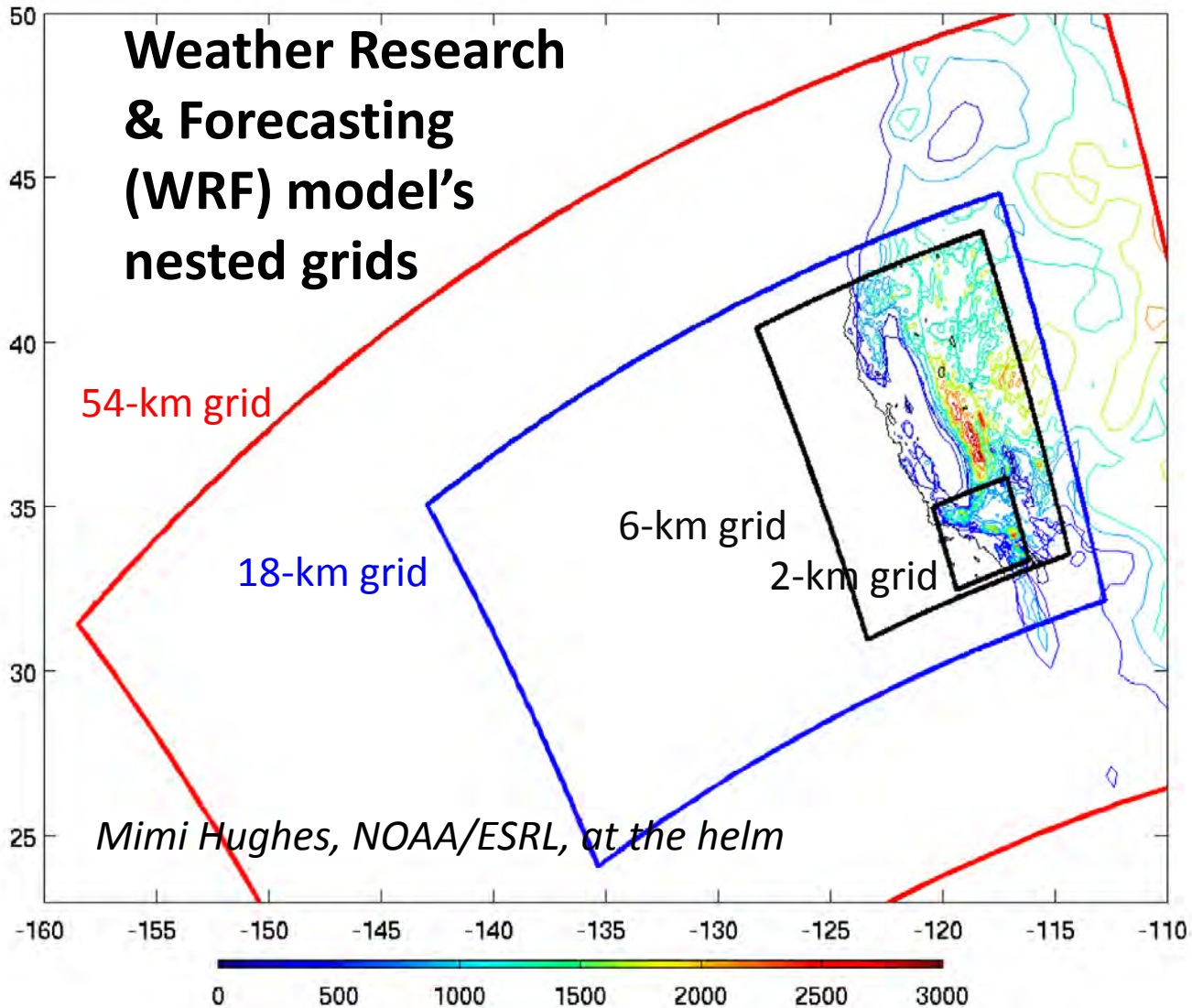
ALL reports of precipitation  $> 15$  in/day  
at sites in California, 1871-1998



Courtesy, Jim Goodridge, 2008

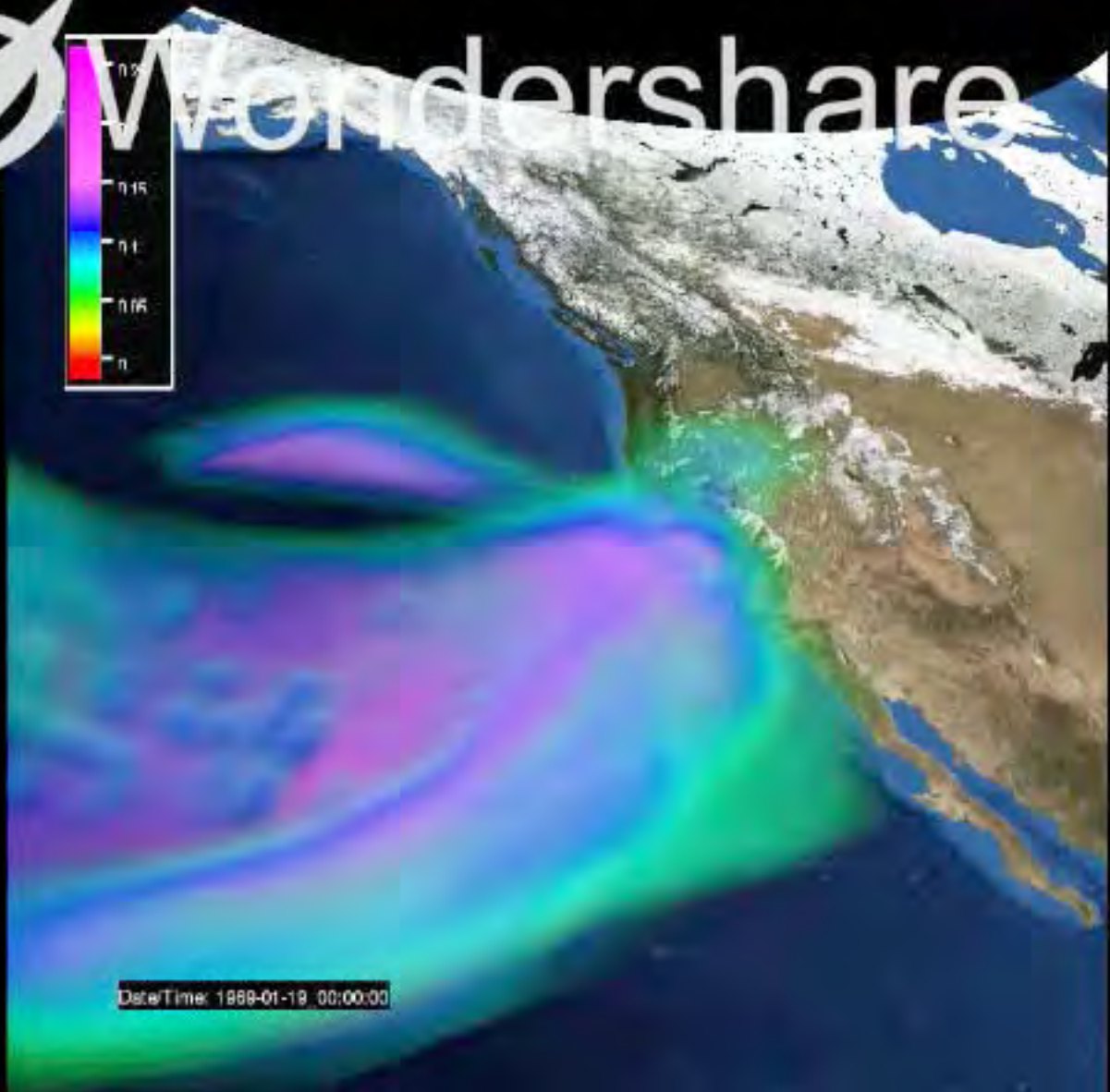


# SIMULATING THE SCENARIO

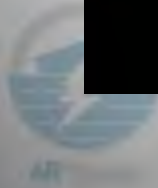




# Wondershare



DateTime: 1888-01-18 00:00:00

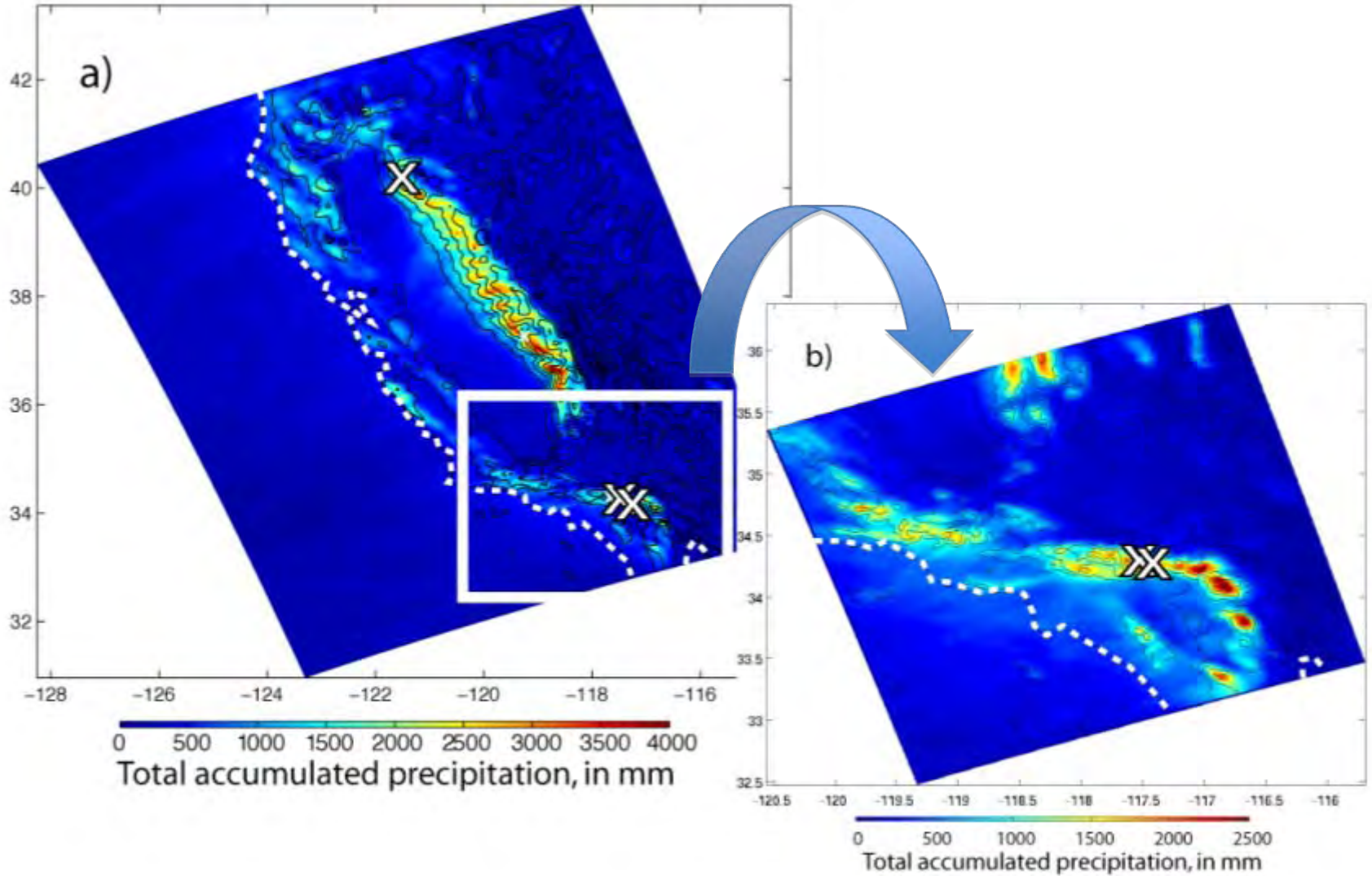


**NOAA**  
National Oceanic and Atmospheric Administration  
advance our knowledge of the world

From  
James Done, NCAR



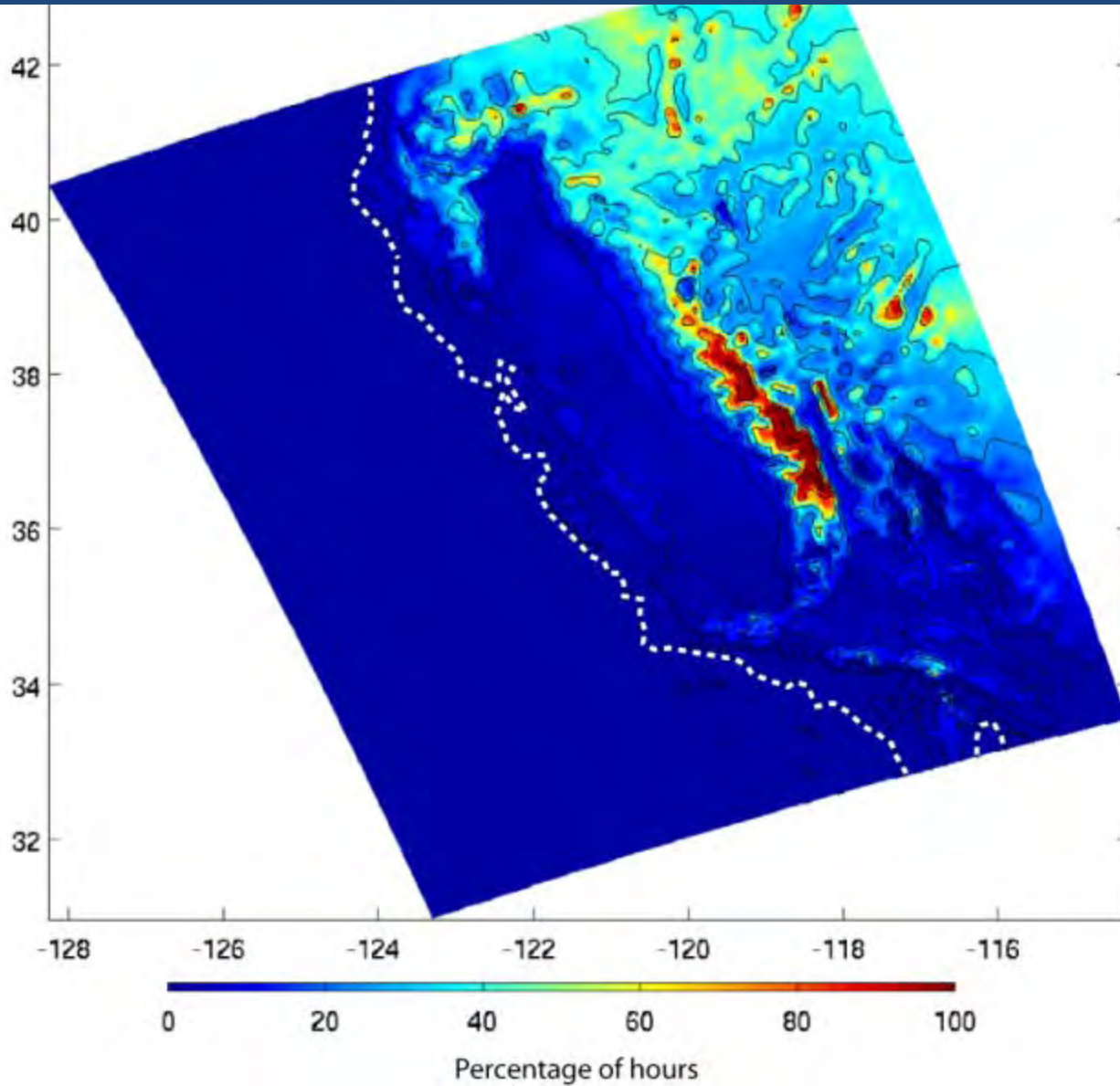
# ARkStorm PRECIPITATION TOTALS





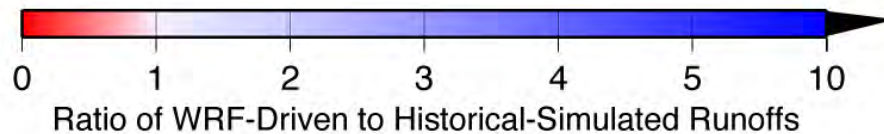
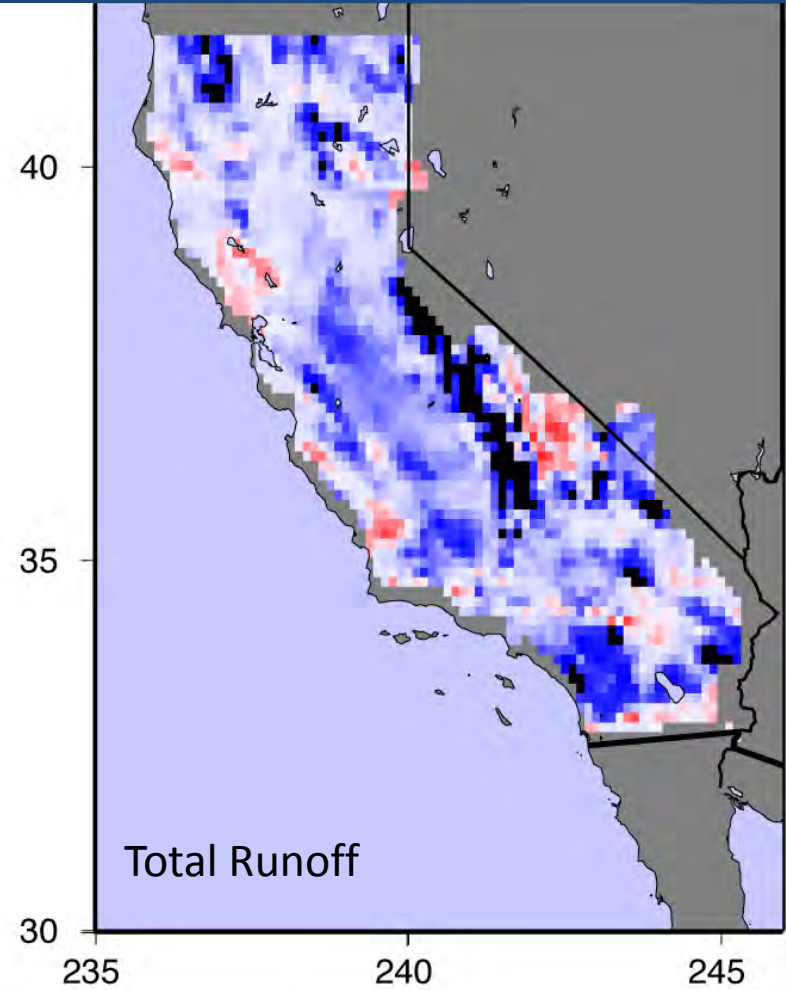
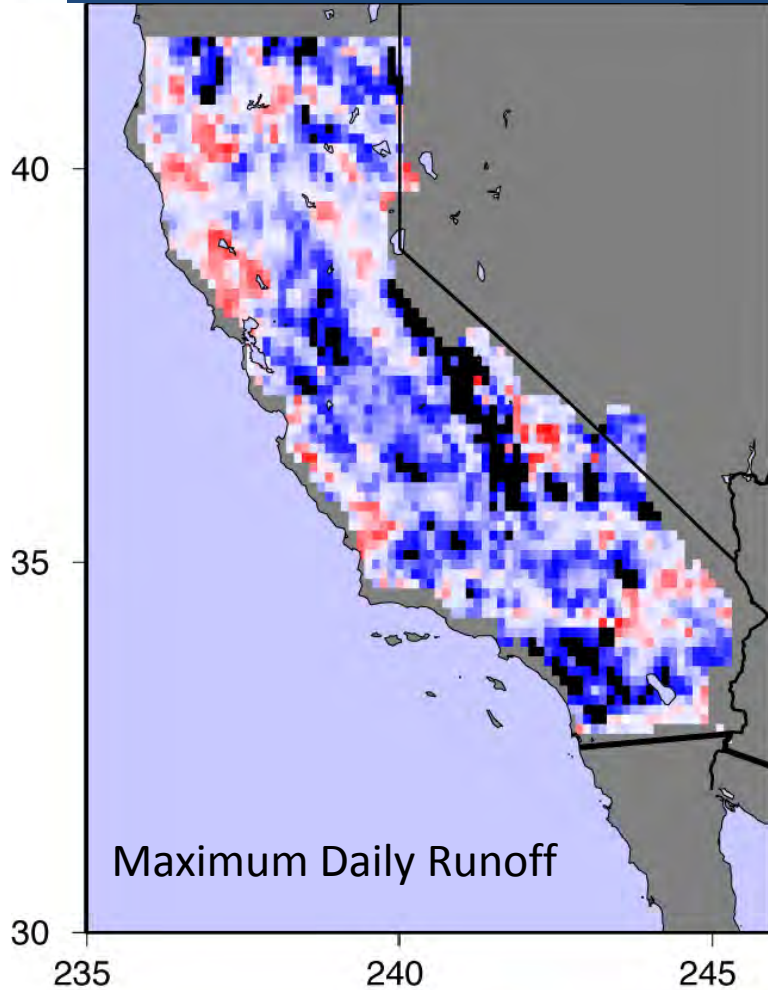


# PERCENTAGE OF ARkStorm SEQUENCE SPENT BELOW FREEZING



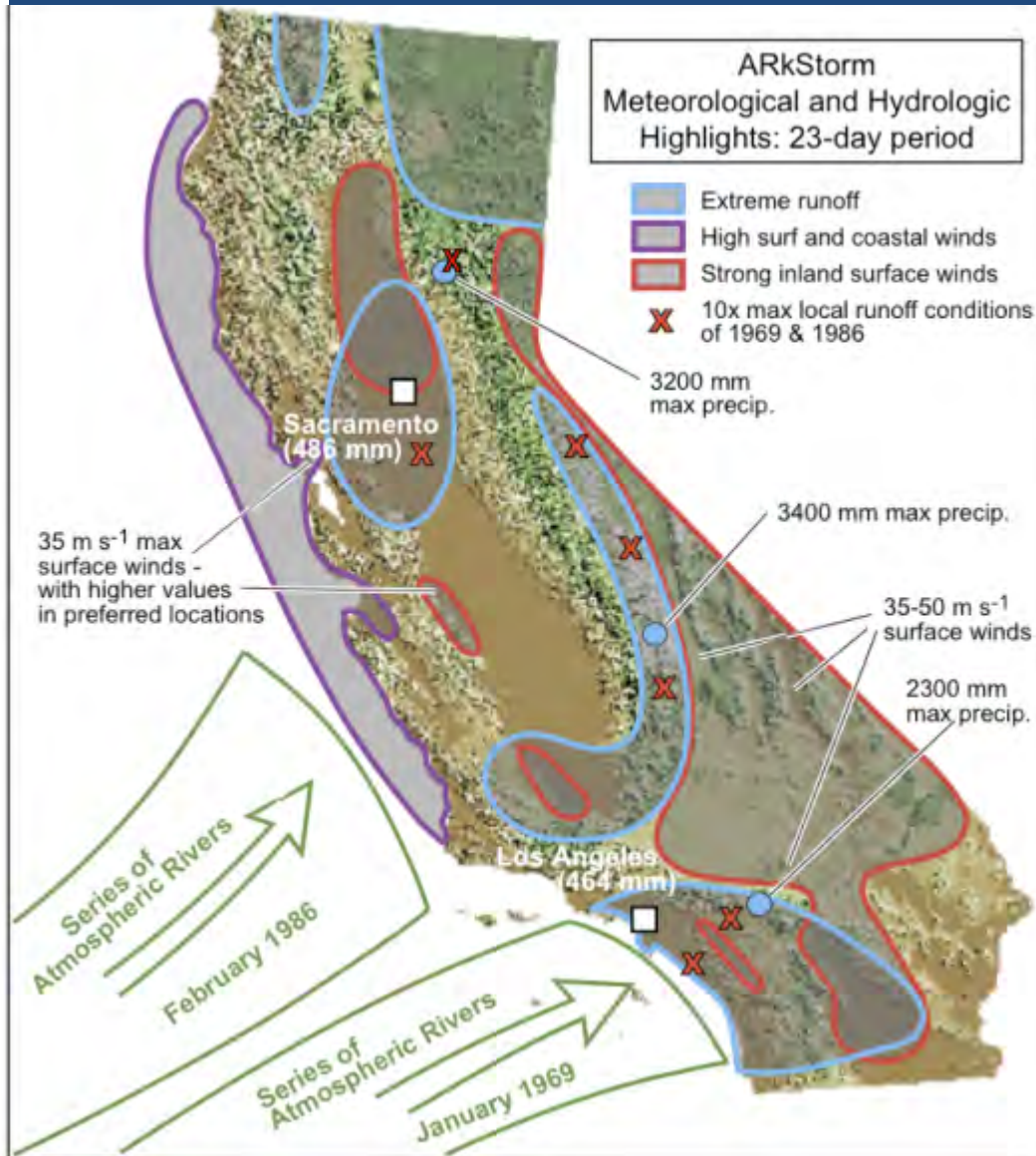


# COMPARISON OF ARKSTORM TO HISTORICAL SIMULATED-RUNOFF





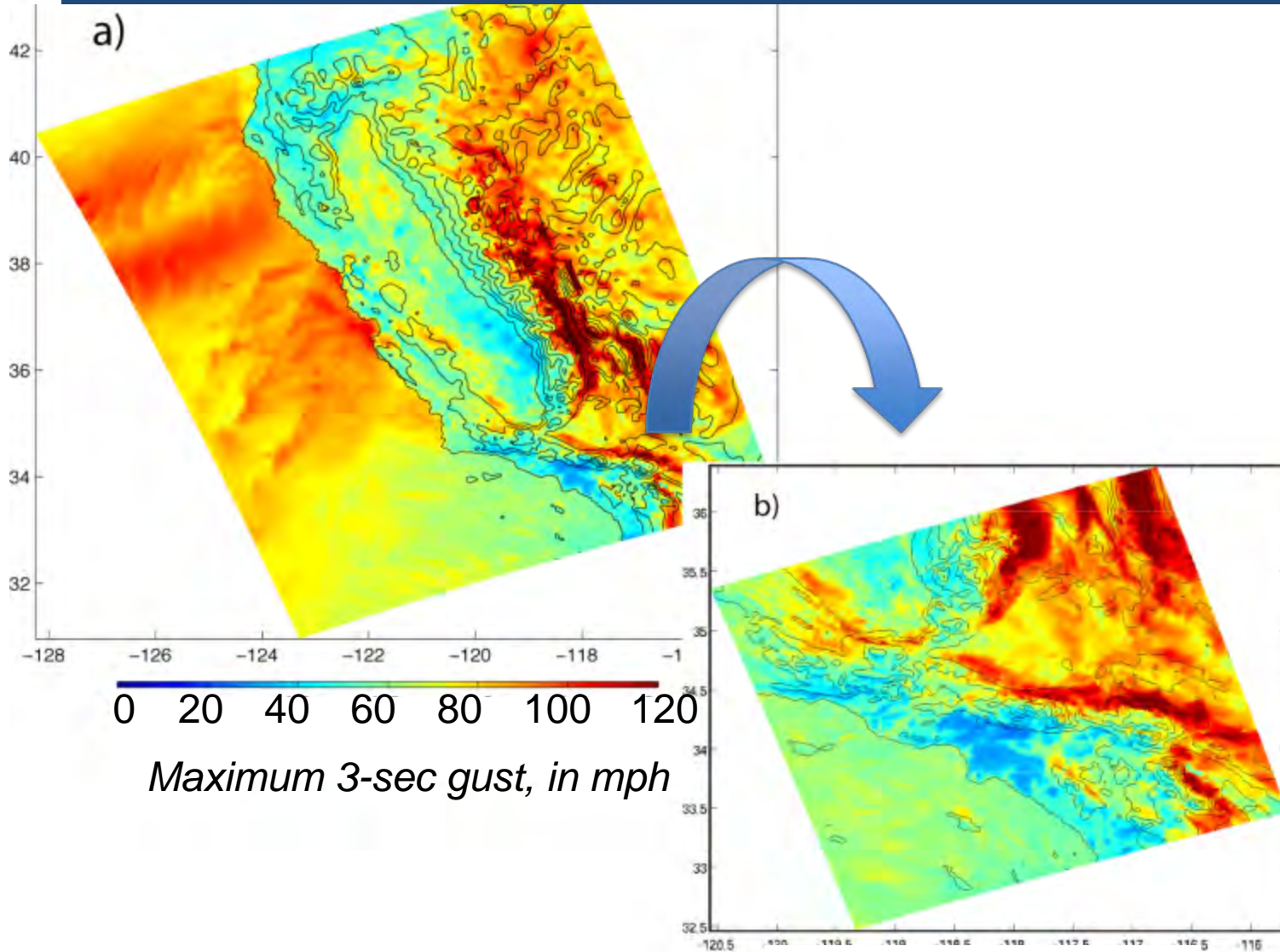
# SUMMARY OF ARkStorm METEOROLOGICAL EVENTS



*Dettinger, M.D., Ralph, F.M., Hughes, M., Das, T., Neiman, P., Cox, D., Estes, G., Reynolds, D., Hartman, R., Cayan, D., and Jones, L., submitted, Requirements and designs for a winter storm scenario for emergency preparedness and planning exercises in California: Journal of Hydrometeorology, 52 p.*

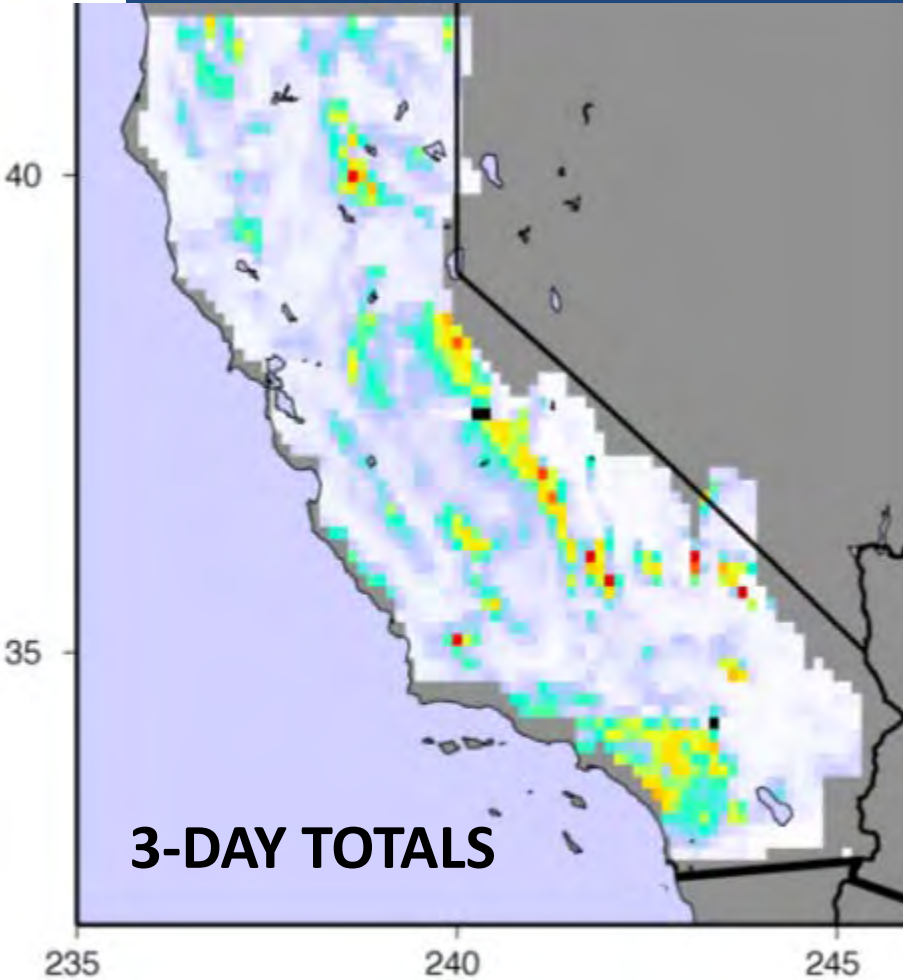


# MAXIMUM-GUST ARkStorm WINDS

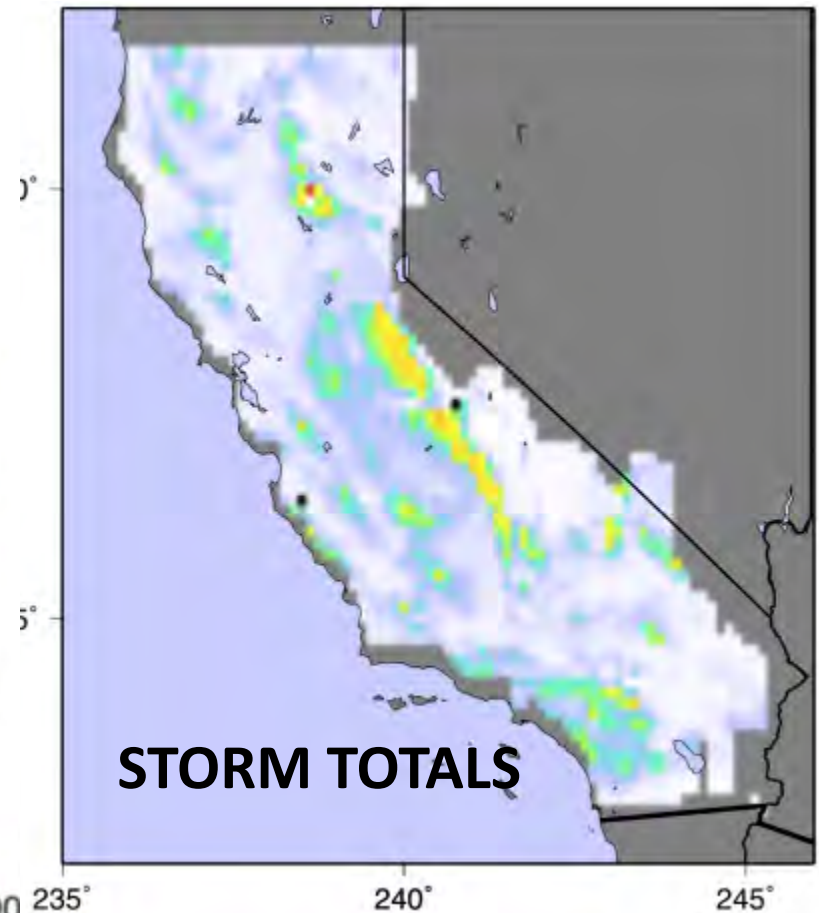








# 3- & 23-day MAXIMUM RUNOFF RETURN PERIODS OF ARKSTORM RUNOFF



*Based on comparisons to WY1916-2003 historical VIC runoff simulation*



ARkStorm  
 Meteorological and Hydrologic  
 Highlights: 23-day period

-  Extreme runoff
-  High surf and coastal winds
-  Strong inland surface winds
-  10x max lo of 1969 &

