ARkStorm: California's Other Big One!

Understanding the Impacts of Massive Winter Storms

Mark Jackson
Meteorologist in Charge
NOAA/National Weather Service
Los Angeles/Oxnard

What is ARkStorm?

- Emergency-preparedness winter storm scenario for California
  - USGS Multi-Hazards Project
  - Analogous to the our massive winter storms
- One realistic outcome, giving granular detail of:
  - Environmental excitation
  - Physical damage and mitigation
  - Social and economic consequences and preparedness

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Origin of The Name "ARkStorm"

AR Atmospheric Rivers: They help drive the most threatening storms in California.

K Producing to 10- to 1000-year storm conditions.

ARk The visual pun to highlight the Noachian character of such storms, historical or hypothetical.

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Why do it?

Science can quantify how much bigger ARkStorm is than recent experience

ARkStorm challenges Californians and businesses to explore and enhance their resiliency to dangerous winter storms

Helping Californians Avoid, Withstand, and Recover!

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What we know can happen

- California winter storm of 1861-62
- January 1862 rainfall % of normal:
  - Sacramento 420%
  - San Francisco 519%
  - San Diego 300%
- Rain fell for 28 of 30 days from Dec 24, 1861 –Jan 21, 1862
- Santa Ana river flooded for 20 days
- Governor took row boat to inauguration
- A third of taxable land flooded

"The great central valley of the state is under water—the Sacramento and San Joaquin valleys—a region 250 to 300 miles long and an average of at least twenty miles wide, or probably three to three and a half millions of acres!"

- William Brewer, author of "Up and down California," January 19, 1862

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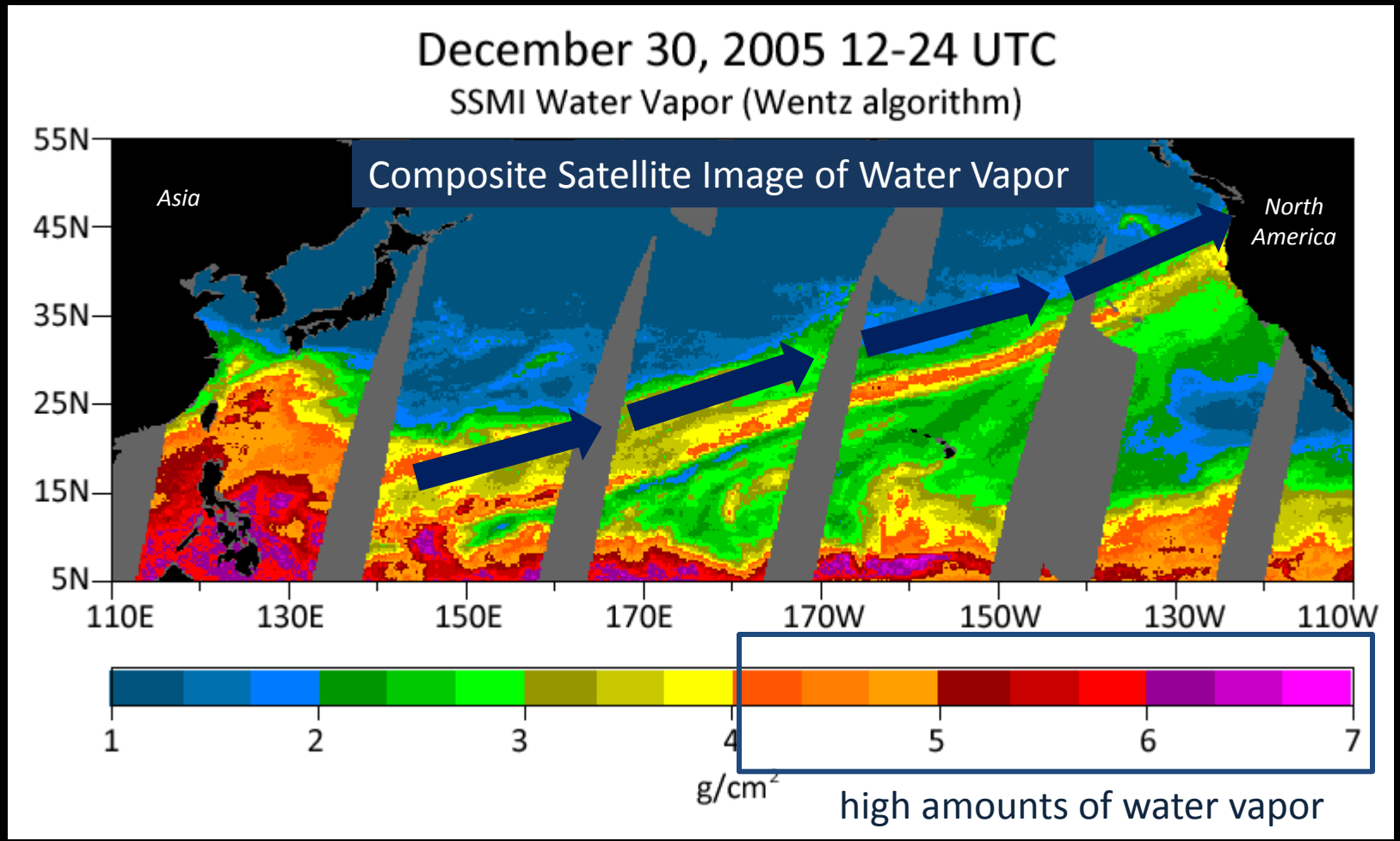
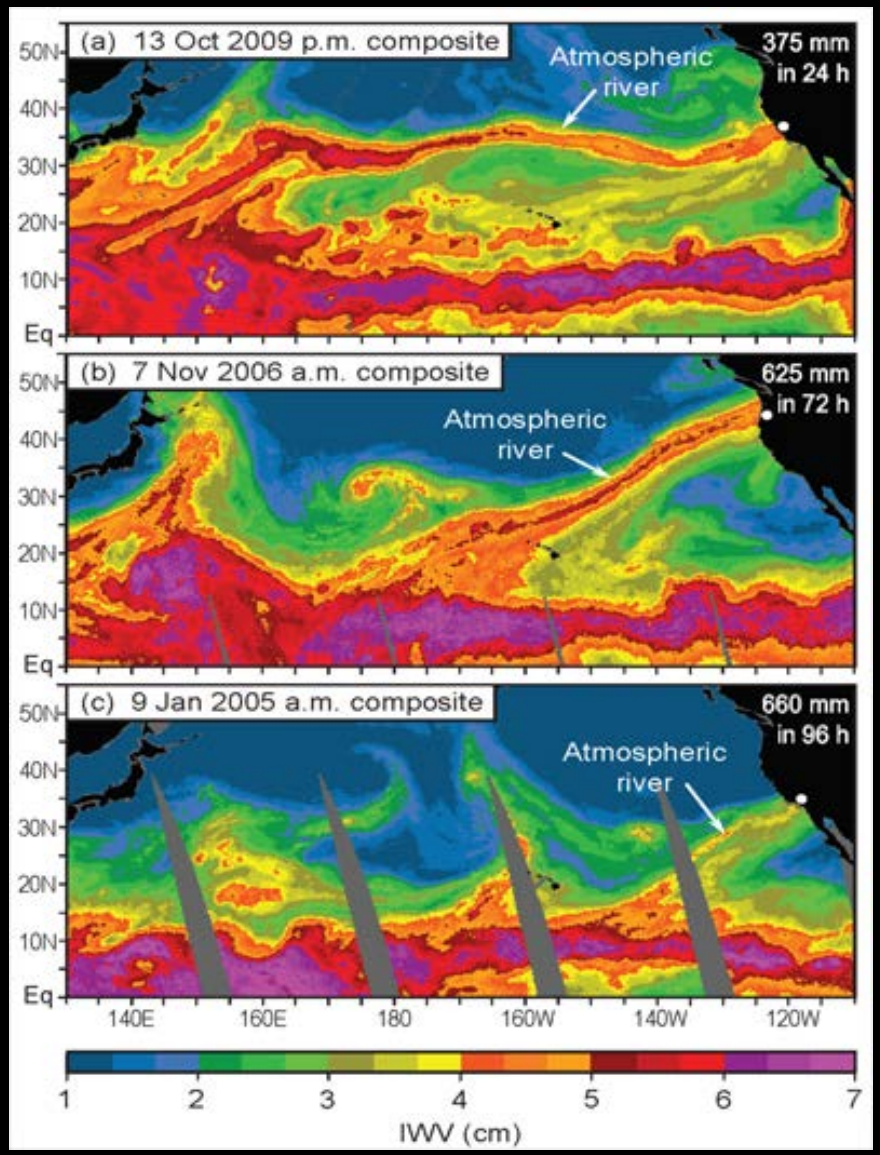
Atmospheric Rivers (AR)

Relatively narrow regions in the atmosphere that are responsible for most of the horizontal transport of water vapor outside of the tropics – The AR in ARkStorm

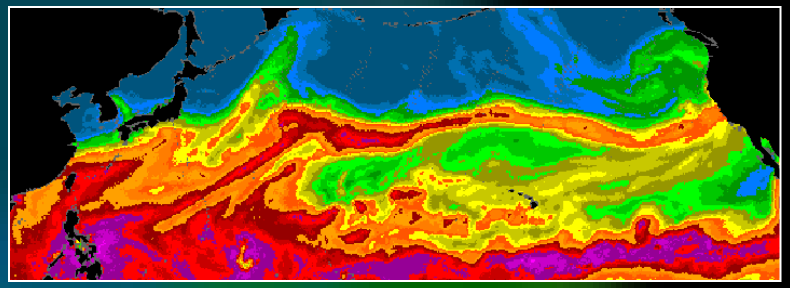




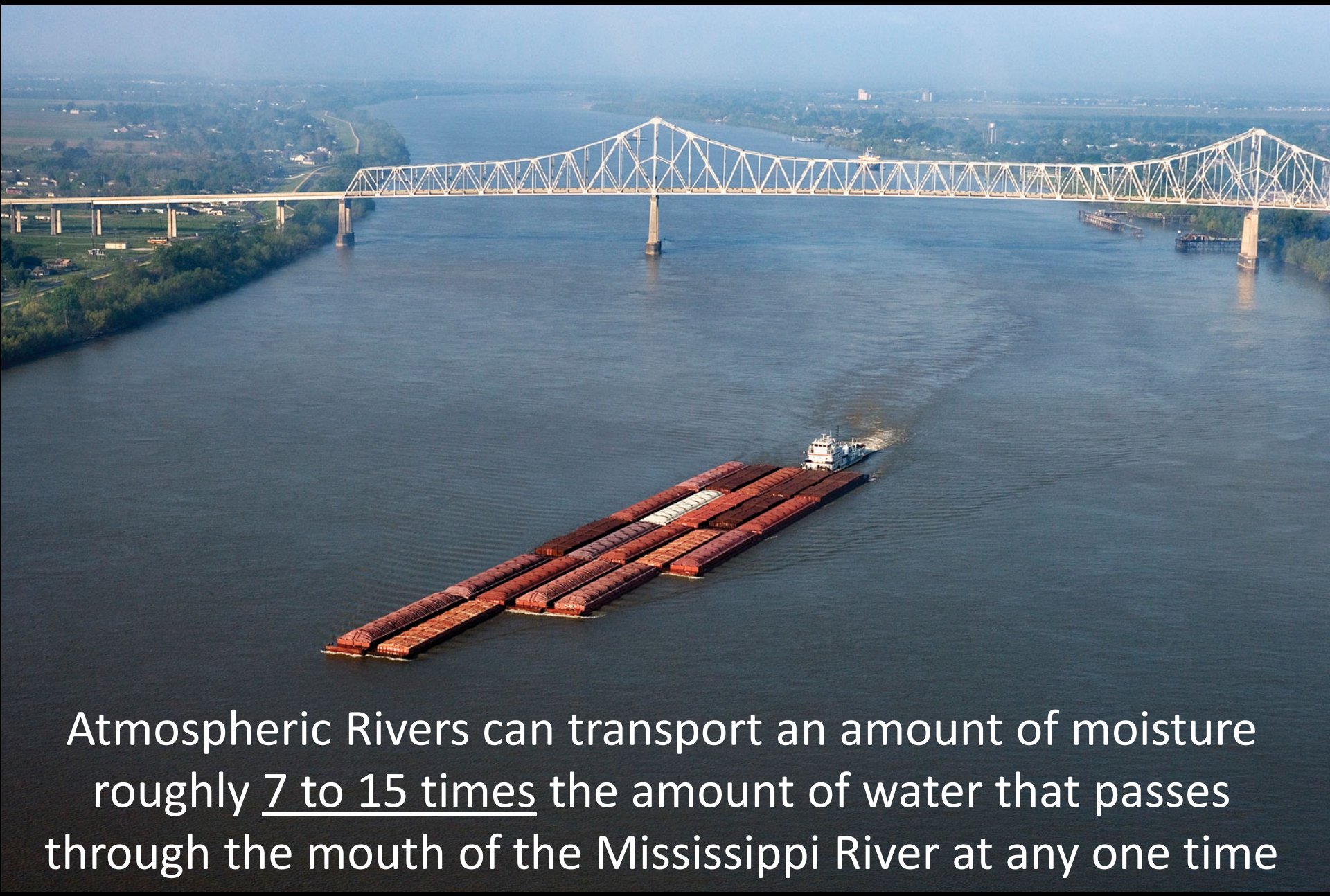
While ARs come in many shapes and sizes, those that contain the largest amounts of water vapor, the strongest winds, and stall over watersheds vulnerable to flooding, can create extreme rainfall and floods.

However, not all ARs cause damage – most are weak, and simply provide beneficial rain or snow that is crucial to water supply.

Quick Facts on ARs



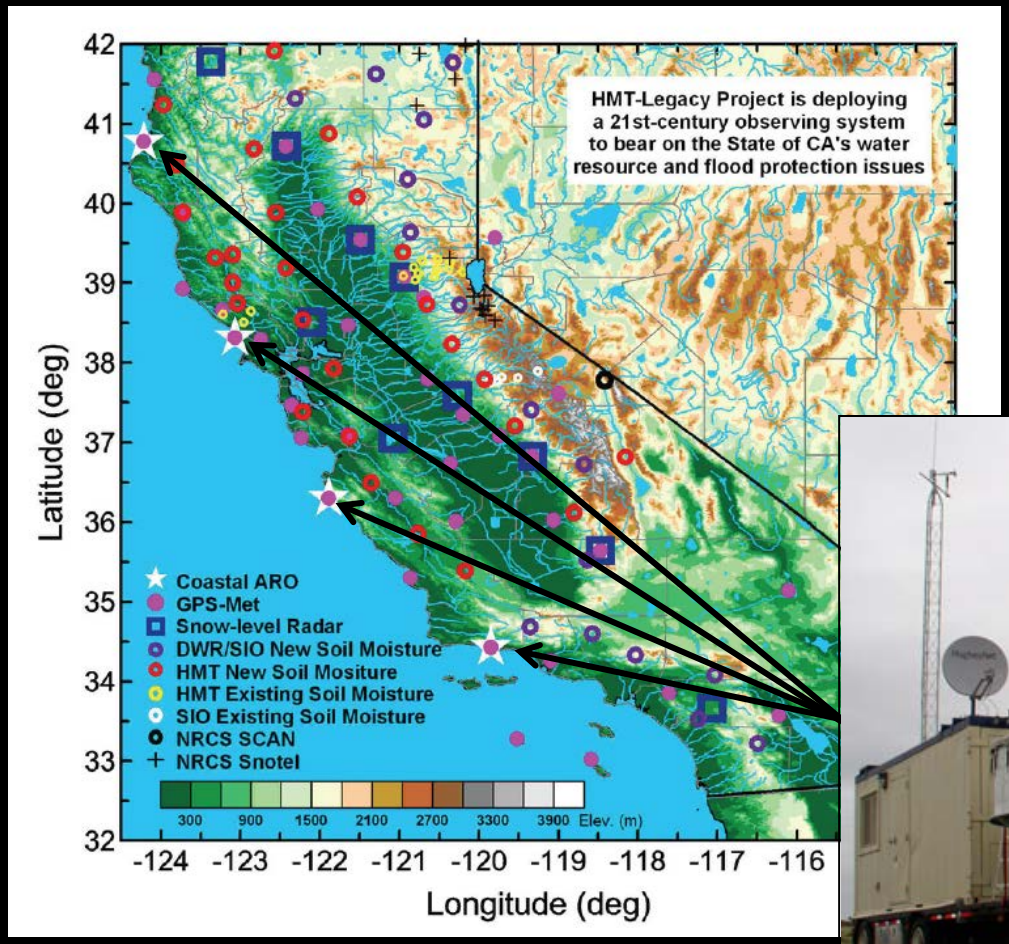
- ✓ On average, 250-400 miles wide
- ✓ 30-50% of annual precipitation in the west coast states occurs in just a few AR events
- ✓ ARs are a primary feature in the <u>entire</u> global water cycle, and are tied closely to both water supply and flood risks, particularly in the Western U.S.
- ✓ A “Pineapple Express” is just one kind of AR



Atmospheric Rivers can transport an amount of moisture roughly 7 to 15 times the amount of water that passes through the mouth of the Mississippi River at any one time

FROM RALPH AND DETTINGER, 2011, EOS, TRANSACTIONS AMERICAN GEOPHYSICAL UNION, VOL. 92, NO. 32

Atmospheric River Observatories (ARO)



Part of the Enhanced Flood Response and Emergency Preparedness (EFREP) program

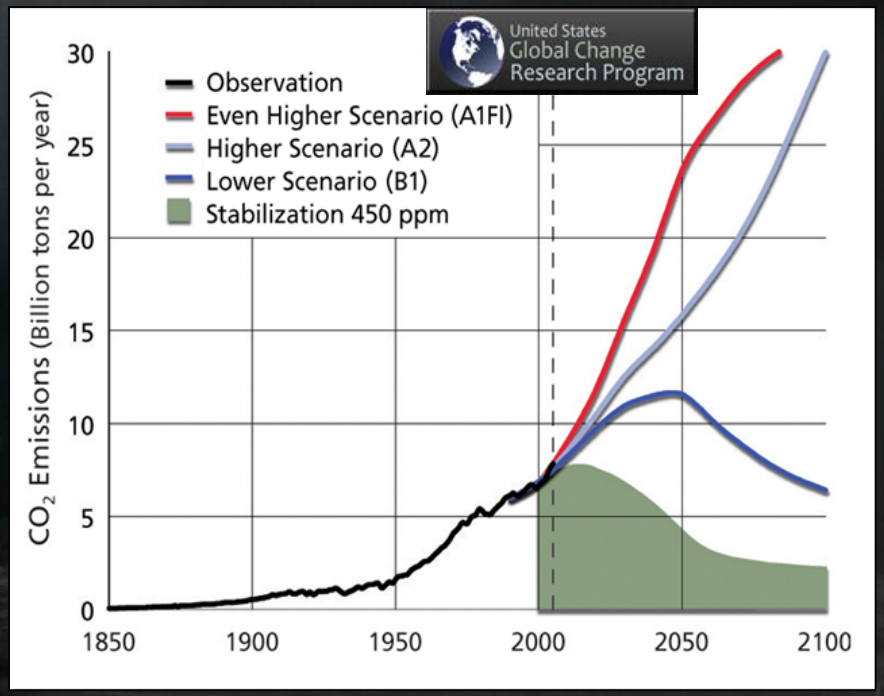
ARO Instrument Site

Improving understanding of ARs as they impact land

Atmospheric Rivers and Climate Change

Dettinger, 2011

- Using A2 emissions scenario
- 7 model (IPCC GCM) ensemble
- Average # of AR/year changes little
- Changes in extremes
  - Years with many AR episodes increases
  - Longer AR seasons possible



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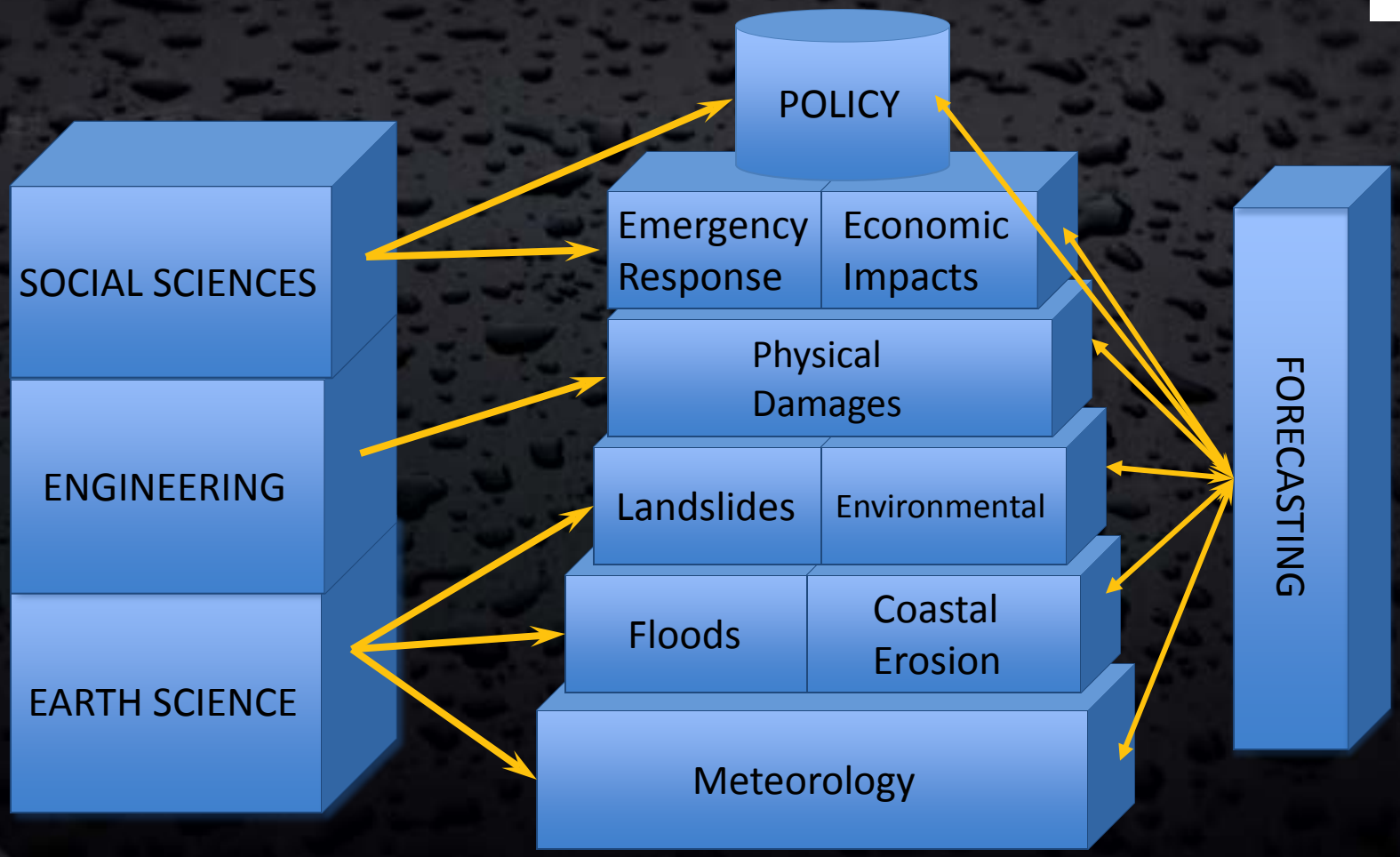
The ARkStorm Team

- Atmospherics: Mike Dettinger, *USGS Scripps;* Marty Ralph, *NOAA*
- Floods: Bill Croyle, *DWR Flood Operations Center;* Justin Ferris, *USGS;* Kathleen Schaefer, *FEMA;* Keith Porter, *University of Colorado*
- Landslides: Chris Wills, *California Geological Survey;* Jon Stock, *USGS*
- Coastal: Patrick Barnard & Dan Hoover, *USGS Coastal Marine Geology*
- Physical Damages: Keith Porter, *University of Colorado*
- Environmental: Geoff Plumlee and Charles Alpers, *USGS*
- Forecast: David Reynolds, *NOAA/NWS*
- Emergency Response: Mitch Miller, *Cal EMA;* Sue Perry, *USGS MHDP*
- Policy: Ken Topping, *California State Polytechnic, San Luis Obispo*
- Economics: Anne Wein, *USGS;* Adam Rose, *USC*
- Visualization: James Done, *National Center for Atmospheric Research*

BUILDING THE ARkSTORM SCENARIO



Modeling ARkStorm

Stitching together January ‘69 and February ‘86 storms to create an extended period of rainfall with substantial impacts

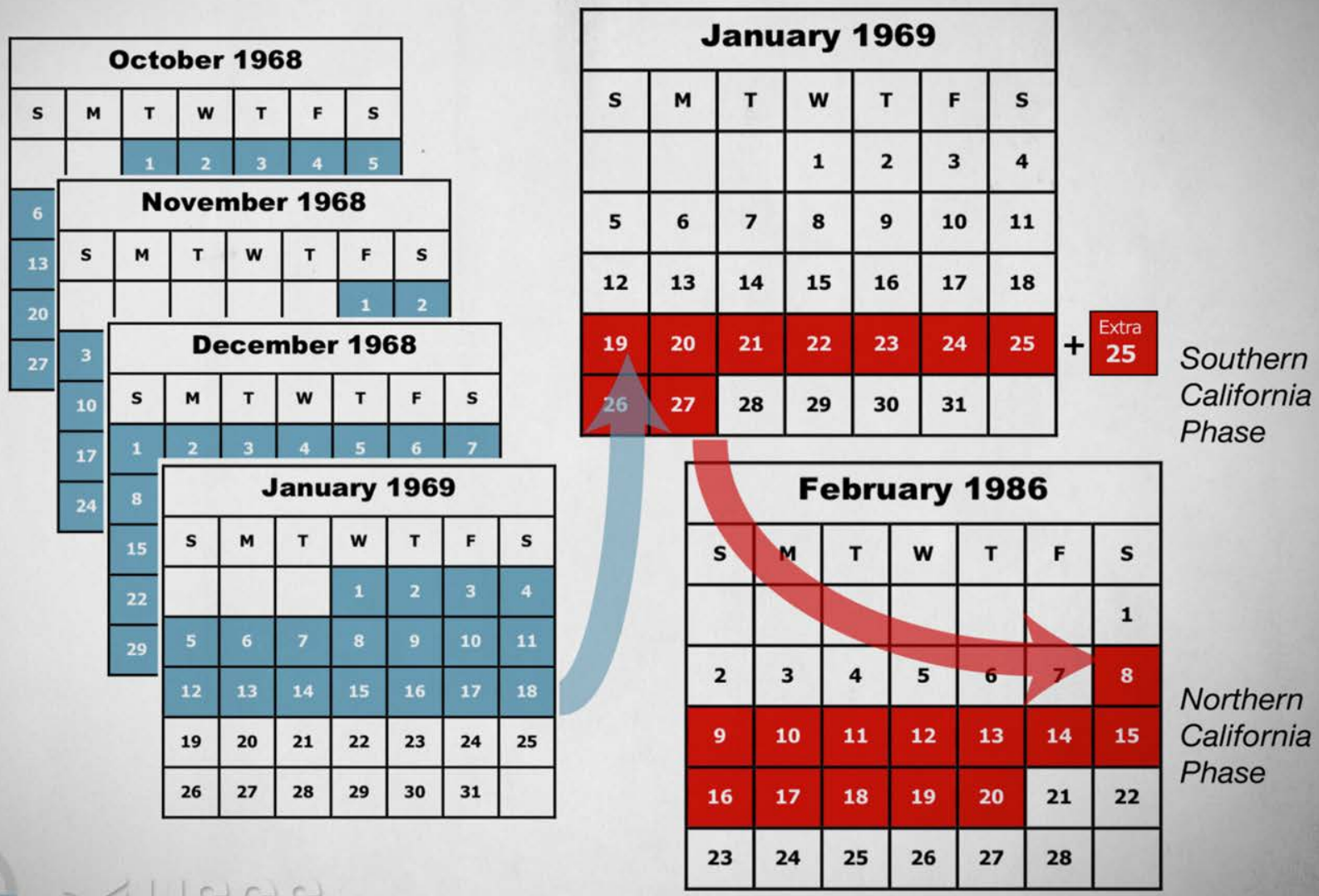
- January ’69 storm resulted in highest measured stream/river flows in recent decades across Southern California
- February ‘86 storm resulted in severe flooding in Northern California

Running numerical model with past data obtained from a reanalysis

See Dettinger et al, *Natural Hazards*, 2012, Volume 60, Number 3, Pages 1085-1111

PRECONDITIONING PERIOD

ARkStorm PERIOD



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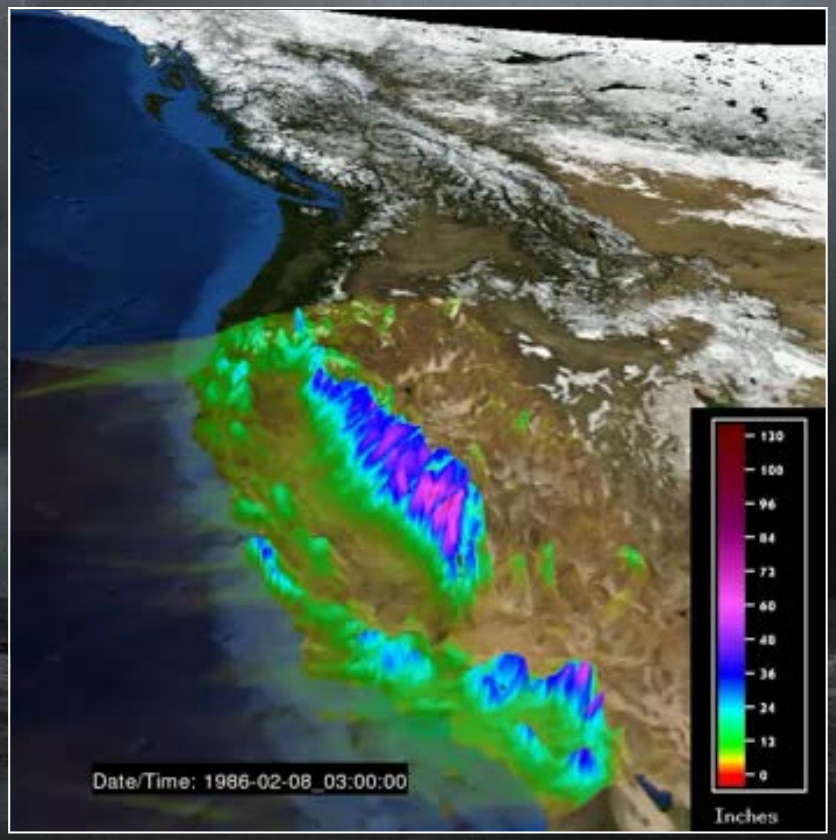
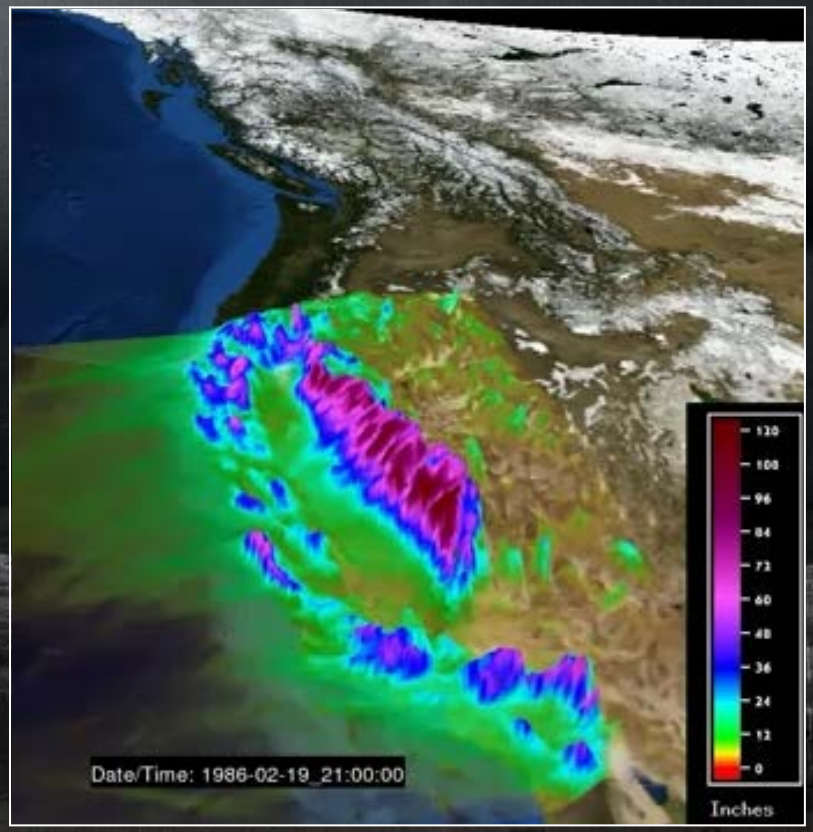
How Much Rain?



After Preconditioning Period



After ARkStorm Period

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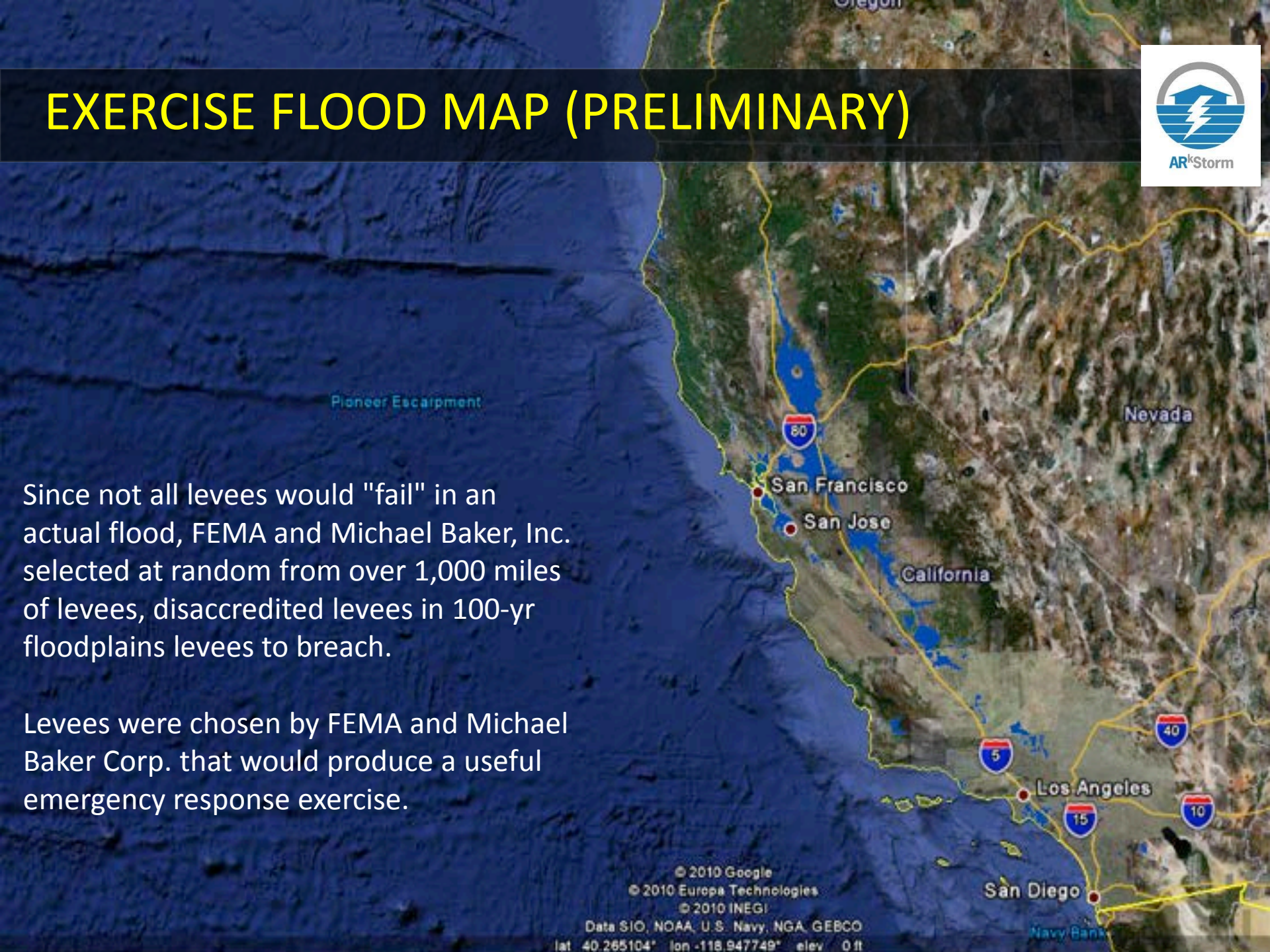
Estimating Flooding

- Hypothesized from linkages between:
  - Model precipitation
  - Simulated runoff rates
- Compared modeled ARkStorm runoff with 1916-2003 historical runoff
  - 1-, 3-, and 7-day runoff volumes per grid cell
  - Calculated ARkStorm return period (ave. number of years between events) varies from 10 to 1000 years

NOAA Photo

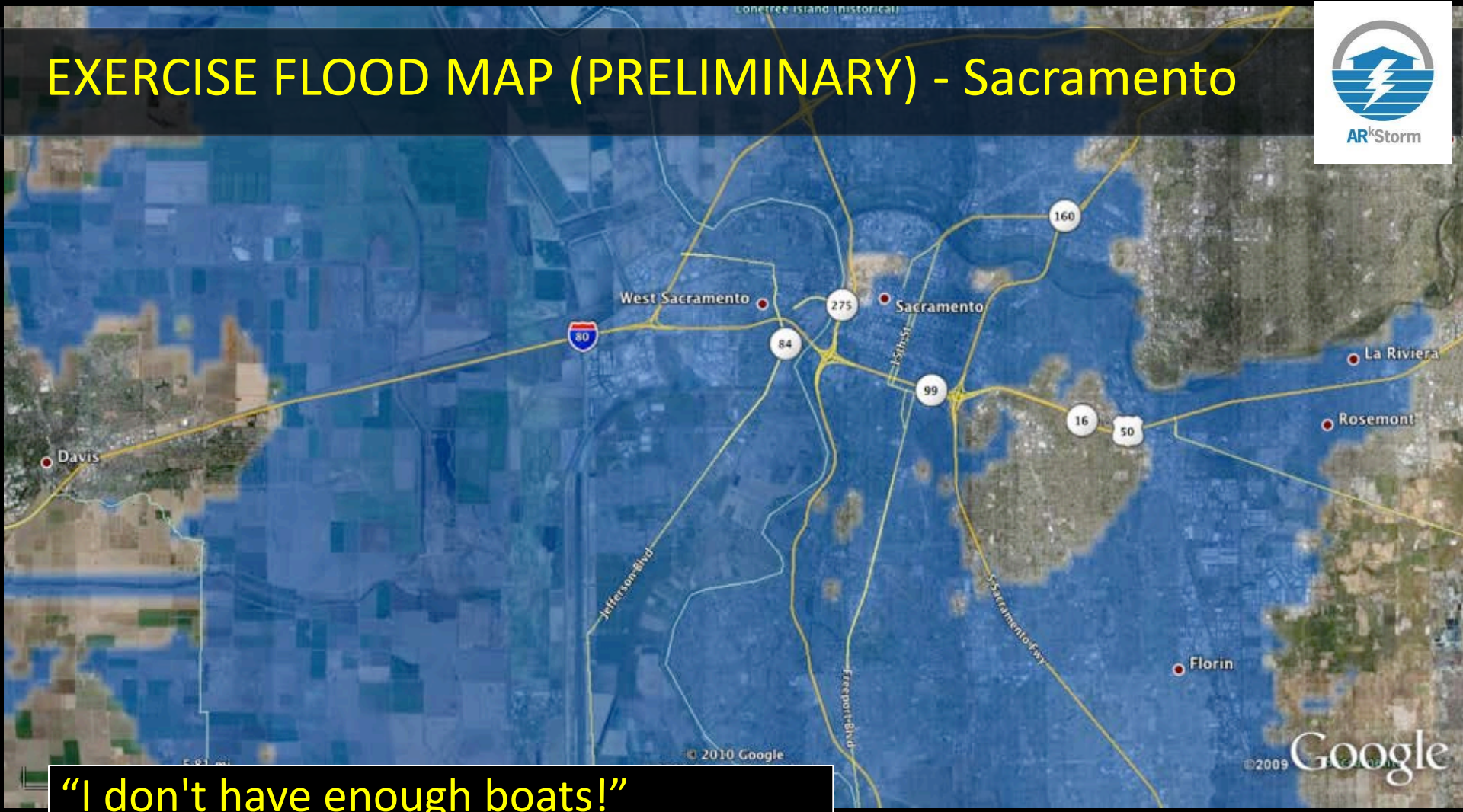
EXERCISE FLOOD MAP (PRELIMINARY)



Since not all levees would "fail" in an actual flood, FEMA and Michael Baker, Inc. selected at random from over 1,000 miles of levees, disaccredited levees in 100-yr floodplains levees to breach.

Levees were chosen by FEMA and Michael Baker Corp. that would produce a useful emergency response exercise.

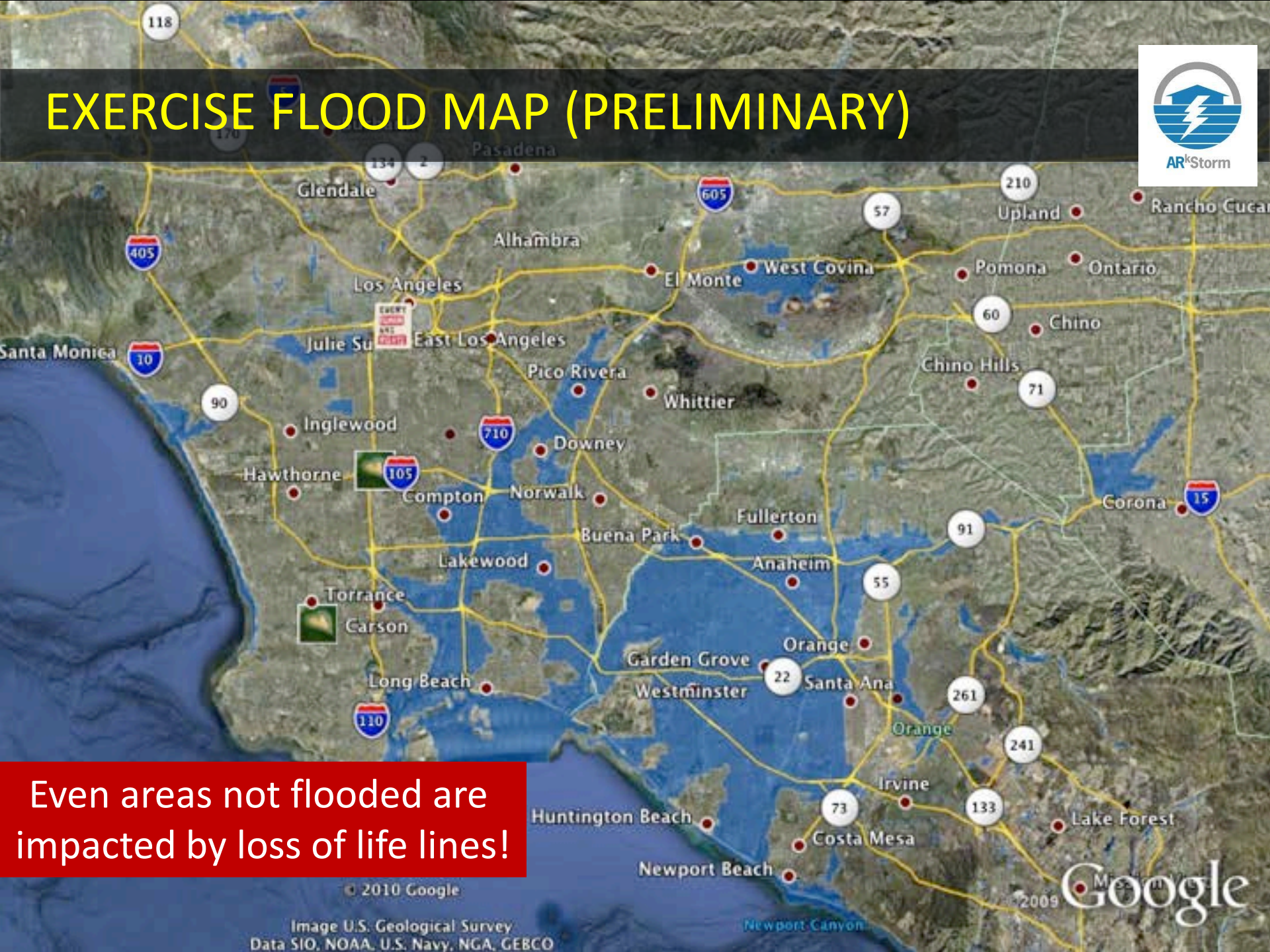
EXERCISE FLOOD MAP (PRELIMINARY) - Sacramento



"I don't have enough boats!"

Marc Bentovoja, Battalion Chief, Sacramento Urban Search and Rescue

EXERCISE FLOOD MAP (PRELIMINARY)



Even areas not flooded are impacted by loss of life lines!

Summary of Environmental Response

- Catastrophic flooding
  - Long term impact on fresh water sources
- Widespread landslides and debris flows
- Winds of 60 to 125 mph in some places
- Coastal erosion and high surf typical of El Niño storms

ARkStorm Impacts

- 25% of all buildings in state experience some sort of flooding
- $725 billion in damages
  - $400 billion in property damage (vs. $81-$105 billion for hurricane Katrina); $325 billion in business-interruptions
    - 3 times the estimated damage from the California Great ShakeOut earthquake scenario
    - Each has roughly same probability of occurrence
- 1,500,000 evacuations (more than Katrina)

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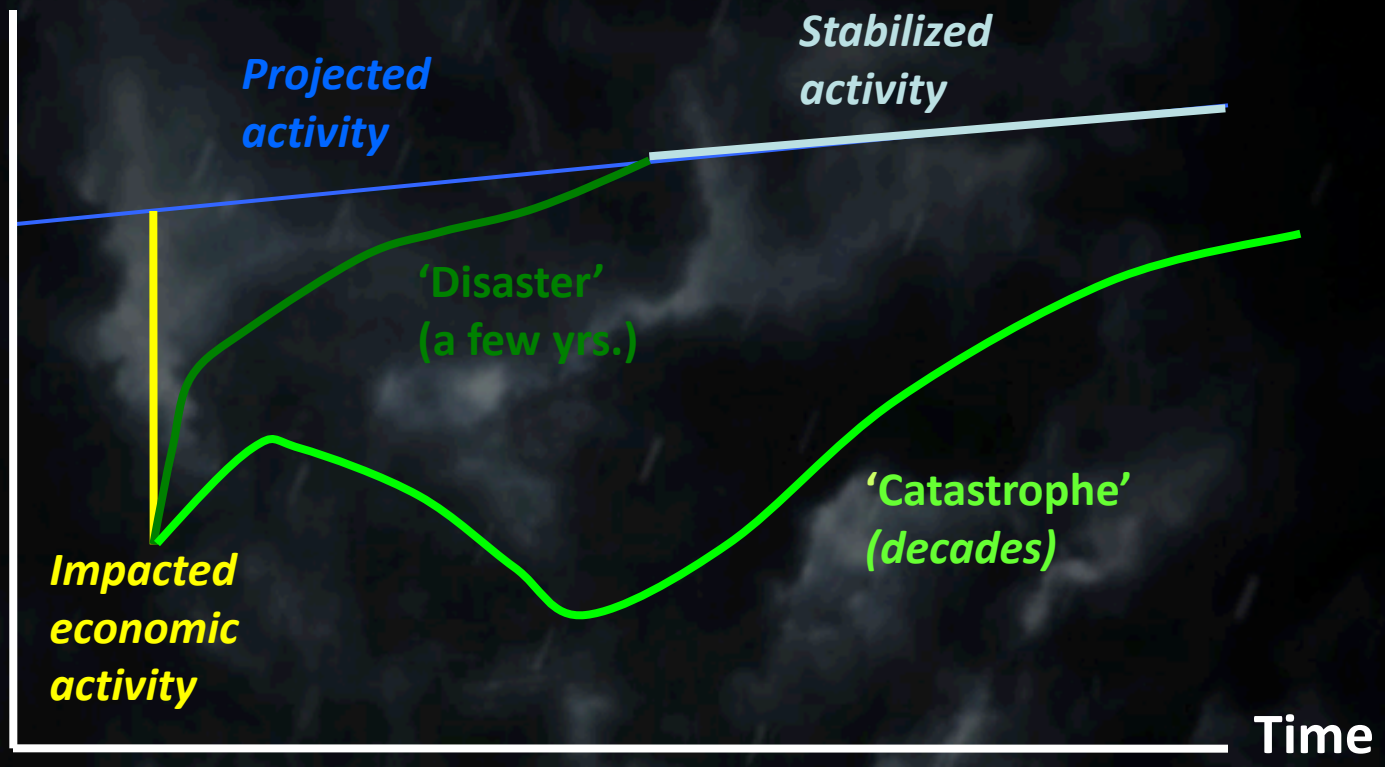
Economics of a Natural Disaster



The World Bank estimates that for every dollar spent on risk reduction, $7 is saved on relief and repairs

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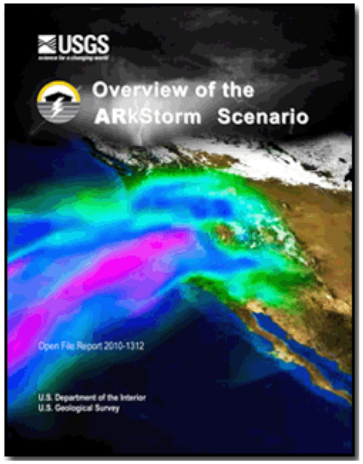
Multihazards Demonstration Project

Overview of the ARkStorm Scenario

By Keith Porter, Anne Wein, Charles Alpers, Allan Baez, Patrick Barnard, James Carter, Alessandra Corsi, James Costner, Dale Cox, Tapash Das, Michael Dettinger, James Done, Charles Eadie, Marcia Eymann, Justin Ferris, Prasad Gunturi, Mimi Hughes, Robert Jarrett, Laurie Johnson, Hanh Dam Le-Griffin, David Mitchell, Suzette Morman, Paul Neiman, Anna Olsen, Suzanne Perry, Geoffrey Plumlee, Martin Ralph, David Reynolds, Adam Rose, Kathleen Schaefer, Julie Serakos, William Siembieda, Jonathon Stock, David Strong, Ian Sue Wing, Alex Tang, Pete Thomas, Ken Topping, and Chris Wills; Lucile Jones, Chief Scientist, Dale Cox, Project Manager

ABSTRACT



The U.S. Geological Survey, Multi Hazards Demonstration Project (MHDP) uses hazards science to improve resiliency of communities to natural disasters including earthquakes, tsunamis, wildfires, landslides, floods and coastal erosion. The project engages emergency planners, businesses, universities, government agencies, and others in preparing for major natural disasters. The project also helps to set research goals and provides decision-making information for loss reduction and improved resiliency. The first public product of the MHDP was the ShakeOut Earthquake Scenario published in May 2008. This detailed depiction of a hypothetical magnitude 7.8 earthquake on the San Andreas Fault in southern California served as the centerpiece of the largest earthquake drill in United States history, involving over 5,000 emergency responders and the participation of over 5.5 million citizens.

This document summarizes the next major public project for MHDP, a winter storm scenario called ARkStorm (for Atmospheric River 1,000). Experts have designed a large, scientifically realistic meteorological event followed by an examination of the secondary hazards (for example, landslides and flooding), physical damages to the built environment, and social and economic consequences. The hypothetical storm depicted here would strike the U.S. West Coast and be similar to the intense California winter storms of 1861 and 1862 that left the central valley of California impassible. The storm is estimated to produce precipitation that in many places exceeds levels only experienced on average once every 500 to 1,000 years.

Extensive flooding results. In many cases flooding overwhelms the state's flood-protection system, which is typically designed to resist 100- to 200-year runoffs. The Central Valley experiences hypothetical flooding 300 miles long and 20 or more miles wide. Serious flooding also occurs in Orange County, Los Angeles County, San Diego, the San Francisco Bay area, and other coastal communities. Windspeeds in some places reach 125 miles per hour, hurricane-force winds. Across wider areas of the state, winds reach 60 miles per hour. Hundreds of landslides damage roads, highways, and homes. Property damage exceeds $300 billion, most from flooding. Demand surge (an increase in labor rates and other repair costs after major natural disasters) could increase property losses by 20 percent. Agricultural losses and other costs to repair lifelines, dewater (drain) flooded islands, and repair damage from landslides, brings the total direct property loss to nearly $400 billion, of which $20 to $30 billion would be recoverable through public and commercial insurance. Power, water, sewer, and other lifelines experience damage that takes weeks or months to restore.

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- **Report** PDF (9.8 MB)
- **Appendix A** PDF (2 MB)
- **Appendix B** PDF (598 kB)

- This report is available only on the Web.

Contact Information
USGS Multi-Hazard Demonstration Project
http://urbanearth.usgs.gov

Thank you!

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NOAA Photo