



ARKSTORM

California's Other "Big One"

Understanding the Impacts of Massive Winter Storms

Most people know that California is at risk from large earthquakes, like the magnitude 7.8 temblor in the ShakeOut scenario (USGS OFR-2008-1150). Relatively few people realize that California needs to be ready for another "Big One," a massive, statewide winter storm. The last such storms occurred in the 19th century, outside the memory of current emergency managers, officials, and communities. Yet massive storms are a recurring hazard in California and a source of costly disasters. Scientists have created a model of a megastorm similar to the storm of the winter of 1862 (described in USGS OFR-2010-1312) and concluded that such a storm could cause more damage than even a big earthquake on the San Andreas Fault.

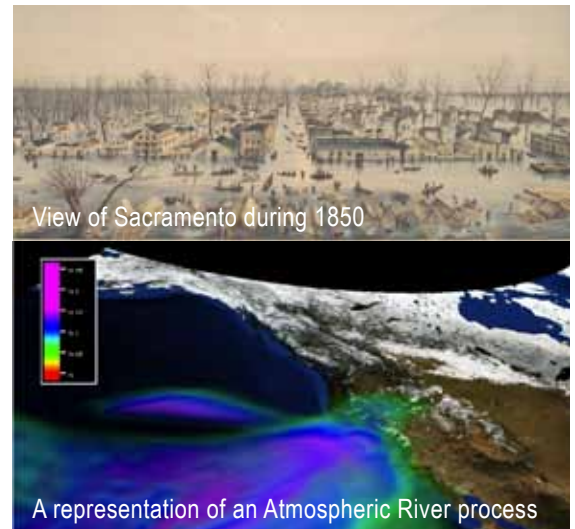
What is an ARkStorm?

An ARkStorm is a major West Coast winter storm caused by an atmospheric river. These are narrow regions (roughly 240-480 kilometers or 150-300 miles wide) of very moist and fast moving air that carry much of the moisture from the tropics to California. Meteorologists have used recent advances in satellite imagery to study these features. Forecasters can now track the formation of the Atmospheric Rivers and recognize the approach of these storms a week in advance. Because atmospheric rivers bring intense storms that rival hurricanes in the intensity of the rainfall, we call these storms "A(tmospheric)R(iver)k(1,000) Storms," where the k or 1,000 is an indicator of storm size.

Like earthquakes, the biggest storms are very rare events. Similar (though smaller) storms caused significant damage in southern California in 1934, 1938 and 1969 and in northern California in 1986 and 1997. The last great statewide megastorm happened in 1861. Geologic studies of deposits offshore of California's big rivers suggest that storms even bigger than 1861-62 have happened six times in the last 1800 years.

The Storms of 1861-62.

Beginning in early December 1861 and continuing 45 days into 1862, an extreme series of storms struck California. The storms caused severe flooding, turning the Sacramento Valley into an inland sea, requiring Governor Leland Stanford to take a rowboat to his inauguration, and ultimately causing the state capitol to be moved temporarily from Sacramento to San Francisco. Lakes formed in the Los Angeles Basin, Orange County and the Mojave Desert. The mouth of the Santa Ana River moved six miles and the largest community between Los Angeles and New Mexico, ironically named Agua Mansa (Smooth Water) was completely destroyed. The storms destroyed almost one-third of the taxable land of California, bankrupting the state.



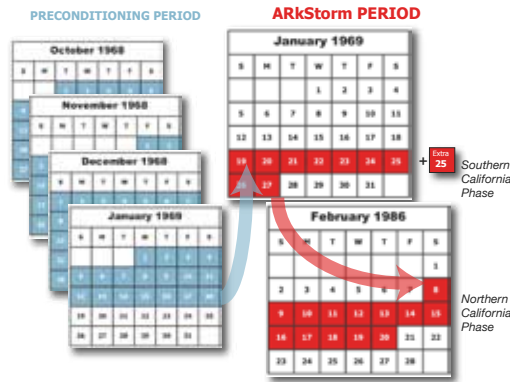
View of Sacramento during 1850

A representation of an Atmospheric River process

The ARkStorm Scenario (USGS OFR-2010-1312) was a major scientific study that brought together 120 experts from dozens of agencies to model a great atmospheric river storm on the same scale as the storm of 1861-1862. Many physical scientists, engineers and social scientists worked together to create a synthetic storm, estimate its impact and evaluate the consequences to modern society. The bottom line is that a storm like this one, which only happens once every century or two, could cause damage several times greater than a big San Andreas Fault earthquake.

HOW THE ARKSTORM SCENARIO WAS MADE

Eleven teams were assembled to model different aspects of the storm.



The ARkStorm scenario was created by combining two major CA storms, 1969 and 1986, in a scientifically plausible way.

Meteorology Led by **Dr. Marty Ralph** of NOAA's Earth System Research Laboratory and **Dr. Mike Dettinger** of the USGS's National Research Program, this team created a comprehensive model for the rainfall, air temperature, air pressure and wind speed across California by combining the January 1969 and February 1986 storms in a scientifically plausible way. The result is rainfall of as much as ten feet in some areas of California.

Flooding Led by **Kathleen Schaefer**, Regional Engineer with FEMA Region IX's Floodplain Management program, **Dr. Justin Ferris** of the USGS's California Water Science Center, and **Prof. Keith Porter** of the University of Colorado at Boulder, this team estimated the extent of flooding in this storm by estimating the runoff return periods for each watershed, and then associating runoff return period with flooding return period. From this, the team assigned each watershed to <100 year, 100-year or 500-year flooding categories and used the relevant FEMA Digital Flood Insurance Rate Map to determine the extent of flooding.

Landslides Led by **Dr. Christopher Wills** of the California Geological Survey and **Dr. Jonathon Stock** of the USGS's Earth Surface Processes Science Center, this team compiled data for landslide susceptibility across California and developed a relationship between rainfall and rate of failure in susceptible areas to estimate the total losses from landslides. The team also estimated the rate of fire-related shallow landslides, considering the fires from 2009.

Coastal Erosion Led by **Dr. Patrick Barnard** and **Dr. Dan Hoover** of the USGS's Coastal and Marine Geology Science Center, this team developed a model to predict wave heights from windspeeds and coastal bathymetry. They used that information to estimate coastal erosion effects. This model is now being applied to predict wave and current patterns for incoming storms.

Physical Damages Led by **Prof. Keith Porter** of the University of Colorado at Boulder, this team used both FEMA's HAZUS-MH methodology and expert opinion with panels of lifeline operators and government agency representatives to estimate lifeline service interruption, property damage, and property repair costs from wind and floods.

Environmental Damage Led by **Dr. Geoffrey Plumlee** and **Dr. Charles Alpers** of the USGS Crustal Imaging and Characterization Science Center and California Water Science Center, this team evaluated the plausible environmental and human health issues that would arise from the flooding and its impact on EPA-regulated facilities.

Forecasting and Emergency Response Led by **Dr. David Reynolds** of the National Weather Service and **Mitch Miller** of the California Emergency Management Agency, this team developed a series of plausible forecasts and other tools that can be used in emergency exercises about an ARkStorm and is continuing to work with the Meteorology team to develop a scaling system to represent the size of future ARkStorms.

Economics Led by **Dr. Anne Wein** of the USGS's Western Geographic Science Center, this team used the direct losses determined by the physical damages team to estimate the costs of the flooding and then an analysis to estimate the indirect losses from business interruption.

Policy Led by **Dr. Ken Topping** of California Polytechnic Institute at San Luis Obispo, this team investigated the policy implications and identified six policy options that could be used to enhance community resiliency.

Visualizations **Dr. James Done** of the National Center for Atmospheric Research created imagery of the ARkStorm's windspeeds and precipitation. These visualizations helped other ARkStorm authors to understand and convey the meteorological effects of the storm.

KEY FINDINGS

1. Megastorms are California's other "big one." A severe California winter storm could realistically flood thousands of square miles of urban and agricultural land, result in thousands of landslides, disrupt lifelines throughout the state for days or weeks, and cost on the order of \$725 billion. This figure is more than three times that estimated for the ShakeOut scenario earthquake, that has roughly the same annual occurrence probability as an ARkStorm-like event. The \$725 billion figure comprises approximately \$400 billion in property damage and \$325 billion in business-interruption losses. An event like the ARkStorm could require the evacuation of 1,500,000 people. Because the flood depths in some areas could realistically be on the order of 10-20 ft, without effective evacuation there could be substantial loss of life.

2. An ARkStorm would be a statewide disaster. Extensive flooding is deemed realistic in the California Central Valley, San Francisco Bayshore, Los Angeles and Orange Counties, several coastal communities, and various riverine communities around the state. Both because of its large geographic size and the state's economic interdependencies, an ARkStorm would affect all California counties and all economic sectors.

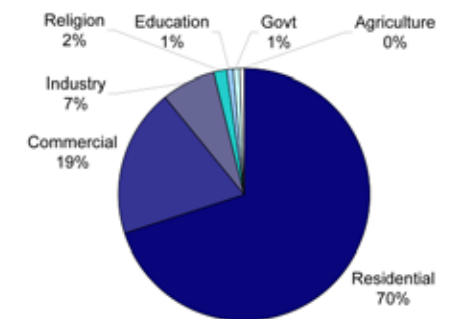
3. An ARkStorm could produce an economic catastrophe. 25% of buildings in the state could experience some degree of flooding in a single severe storm. Only perhaps 12% of California property is insured, so millions of building owners may have limited or no ability to pay for repairs. That degree of damage would threaten California with a long-term reduction in economic activity, and raise insurance rates statewide—perhaps nationwide or more—afterwards.

4. An ARkStorm is plausible, perhaps inevitable. Such storms have happened in California's historic record (1861-1862), but 1861-1862 is not a freak event, not the last time the state will experience such a severe storm, and not the worst case. The geologic record shows 6 megastorms more severe than 1861-1862 in California in the last 1800 years, and there is no reason to believe similar events won't occur again.

5. The ARkStorm is to some extent predictable. Unlike for earthquakes, we have the capability to partially predict key aspects of the geophysical phenomena that would create damages in the days before an ARkStorm strikes. Enhancing the accuracy, lead time, and the particular measures that these systems can estimate is a great challenge scientifically and practically.

6. Californian flood protection is not designed for an ARkStorm-like event. Much has been done to protect the state from future flooding, but the state's flood-protection system is not perfect. The existing systems are designed among other things to protect major urban areas from fairly rare, extreme flooding. The level of protection varies: some places are protected from flooding that only occurs on average once every 75 years; others, on average every 200 years. But the levees are not intended to prevent all flooding, such as the 500-year streamflows that are deemed realistic throughout much of the state in ARkStorm.

7. Planning for ARkStorm would complement planning for earthquakes. The ShakeOut exercise has become an annual activity in California, with more than 7 million people participating each year. Many of the same emergency preparations are useful for a severe winter storm: laying in emergency food and water, shelter preparations, exercising emergency corporate communications, testing mutual aid agreements, and so on.



Fraction of \$370 billion in flood- and wind-related building and content property loss, by economic sector, including demand surge. Figure does not include lifeline repair costs, landslide-related costs, or business interruption.

Photo credit: (top) D.Saville for Federal Emergency Management Agency; (middle) J.Augustino for Federal Emergency Management Agency; (bottom) California Department of Water Resources



Photo credit: (top and bottom) Courtesy Captain Larry Collins; (middle) K.Galvin for Federal Emergency Management Agency



WHAT CAN BE DONE ABOUT THE ARKSTORM?

California has made great advances over the years in finding engineering solutions to our flood control problems. The network of dams, levees and flood control channels is one of the great engineering feats. But no flood control could or should be built to handle every imaginable flood. We engineer up to a fiscally responsible level and use emergency management after that. So planning for future ARkStorms means making sure the flood control system is as good as it should be and that the emergency responders are prepared for events beyond that.

Photo credit:
(left) D.Hunsinger for Federal Emergency Management Agency; (right) National Oceanic and Atmospheric Administration/ Department of Commerce



On October 1, 2010, a team of stakeholders participated in a day-long workshop to start addressing the outcomes of the scenario. This process and continued discussions highlight the value of the USGS scenarios.

Keep on Talking

Several groups of flood managers, scientists, and emergency managers have been meeting to discuss the implications of the ARkStorm. On October 1, 2010, 25 top decision makers spent a day in brainstorming possible approaches to reducing losses. On January 13-14, 2011, USGS, FEMA, and CalEMA are hosting a two-day event to engage hundreds of stakeholders from across California to take action as a result of the ARkStorm scenario's findings, which will be officially released at the Summit.

Advance the Science

Scientists from the National Weather Service, NOAA, and USGS are meeting with emergency managers to develop a scaling system to better communicate the possible sizes of different storms and predict their potential impact. Researchers have also identified several products that could improve resiliency including improved hydrologic modeling of flood runoffs, better elevation data and historical landslide maps, and better databases of at risk essential facilities.

Consider ARkStorm in flood mitigation decisions

Governments, businesses, public and private utilities, and individuals have the opportunity now to explore the costs and benefits of physical improvements to their infrastructure to reduce future damage. Flood risk mitigation can be highly cost effective, with benefit-cost ratios on the order of 5.0 or more. Enhancing urban sections of the state's flood protection system to 500-year levels could realistically cost \$10s of billions. Not doing so could realistically cost \$100s of billions when such a storm occurs.

Remember Katrina

Hurricane Katrina is a relevant, cautionary experience. Just under one year before Katrina, the USACE requested \$4 million from Congress for a study on how to protect New Orleans from a category-4 hurricane, which would have cost on the order of \$30 billion. Congress deemed the cost of the study to be too high at the time. The storm ultimately cost the federal government in excess of \$100 billion, resulted in perhaps \$150 billion in total economic loss, and killed 1800 people.

