Avoid the Unmanageable, Manage the Unavoidable
Eight Interdisciplinary Lectures on Climate Change
Charles F. Kennel
Monday Evenings, 5:30-7 pm, Martin Johnson House
Scripps Institution of Oceanography, University of California San Diego

Dec 1: California Prepares to Adapt
The El Nino cycle, today and in the past; atmospheric rivers, floods and droughts; water resources and management; how California learned from air pollution; California’s regional assessments; Impacts on regional natural systems, regional technical systems, and populations
The history of California is written in water, not ink, in great swings between abundance and dearth, the *El Nino* and *La Nina*. Their cycle is as important to Western North America as the monsoon is to India.
Proxies tell us that El Niño events were extreme but infrequent in the period 12-8,000 years ago. A long paleoclimate record from this alpine lake in Ecuador shows a systematic change in El Niño activity during the Holocene. Between 8,000 and about 5,000 years ago, winters were dry. Starting around 5,000 years ago, around the end of the holocene climate optimum, *El Niño* floods became more frequent and the intervals about 3,000 and after 2,000 years ago were particularly stormy.
In a review of multiple long tree-ring reconstructions of past drought (Palmer Drought Severity Index) conditions in North America, Cook et al. find evidence of "a number of unprecedented mega-droughts over the past millennium that clearly exceed any found in the instrumental records," including an amazing "epoch of significantly elevated aridity that persisted for almost 400 years over the AD 900-1300 period."

All major historical droughts of North America were caused by "the development of cool 'La Niña-like' SSTs in the eastern tropical Pacific"...They report that "La Niña-like conditions were apparently the norm ...during much of the Medieval period," during which time the truly unprecedented 400-year mega-drought held sway.

The Great California Mega-Flood Of 1862

Rain began Dec 24, 1861 and continued for 43 days
8.6 inches in December, 24 inches in January, 1862, and 7.5 inches in February

K Street, Sacramento
Jan. 10, 1862
A strong AR transports an amount of water vapor roughly equivalent to 7.5–15 times the average flow of liquid water at the mouth of the Mississippi River. On average, about 30-50% of annual precipitation in the west coast states occurs in just a few AR events.
Atmospheric Rivers
A little bit of the tropics in the temperate zone

Atmospheric Rivers present on 28 Dec 2011

Precipitable Water

CIMSS/SSEC/The COMET Program
An Atmospheric River Streams Across Northern California

December 20, 2010

Water Vapor Content
An Atmospheric River Encounters California’s Coast
Mouth of Russian River
Storms Hit Sierra Nevada
More than 10 feet of snow in places
The Press Democrat, Dec 20, 2010
Lack of Sierra snowmelt prompts drastic State cutbacks

State officials announced they will not be able to make any deliveries from the State Water Project this year unless California receives significant additional rain and snowfall. It would be the first time in the system’s 54-year history that there isn’t enough water in reservoirs or in anticipated snowmelt to deliver supplies to agencies serving 25 million Californians and 1,000 square miles of farmland, said Mark Cowin, director of the Department of Water Resources.

“This is not a coming crisis. This is not an evolving crisis. This is a current crisis,”

Sacramento Press-Enterprise, Jan 31, 2014
Sacramento River Delta Catchment

In *El Nino* years, 1-in-20 storms provide almost as much as all other rain events.

Continuing decline in Pineapple Express storms during today’s extended *La Nina*.

M. Dettinger and D.R. Cayan, Drought and the California Delta-A matter of extremes, June 2014.

University of California e=Scholarship, http://escholarship.org/uc/item/88f1j5ht
2014 Drought in US Western States

Drought 2014: 240 Gigaton Water Deficit in Western USA

10 cm. or 4 inch layer over entire region
Equivalent to annual mass loss rate of Greenland Ice Sheet

Western USA Water Load (left) and Uplift (right) between March 2013-March 2014
771 GPS Sensor Network, NSF Plate Boundary Observatory

A.A. Borsa, D. Agnew, and D. Cayan, Ongoing drought-produced uplift in the western United States, Science 2014;345:1587-1590
Wildfire Burn Area Increased During “Hiatus”

Figure 1. Total Number of Wildfires and Acres Burned (1983-2012)

Source: NIFC.
What can we say about California’s Climate Future?
The horizontal line marks the precipitation level of the 2000 - 2004 drought, the worst of the past 800 years. Droughts of this intensity are predicted to be the new normal by 2030, and will be considered an outlier of extreme wetness by 2100.

"This impending drydown of western North America is consistent with present trends in snowpack decline as well as expected increases in aridity and extreme climate events, including drought, and is driven by anthropogenically forced increases in temperature with coincident increases in evapotranspiration and decreases in soil moisture. Although regional precipitation patterns are difficult to forecast, climate models tend to underestimate the extent and severity of drought relative to available observations. As such, actual reductions in precipitation may be greater than shown. Forecasted precipitation patterns are consistent with a probable twenty-first century megadrought."

Sierra Nevada Snowmelt
The single most persuasive impact examined by the 2006 Assessment


Follow the Water
Where water flows, prosperity goes

The Bay-Delta Watershed and Major Water Projects

70% of Southern California’s water originates in the Sierra Nevada, transits the Bay-Delta watershed, and flows south and over the Tehachipis in aqueducts
Declining Colorado Flow to Southern California

50% chance by 2021 of a season when Lake Mead goes dry, due to upstream withdrawals, declining average rainfall, and Rocky Mountain snowmelt, together with La Nina

Water for Imperial Valley Agriculture and San Diego

Electricity for Las Vegas

17% of Capacity in 2008

Heat Waves

“Extremely hot” days in Sacramento (at least 105°F) will become more common. By 2050, their number could increase fivefold (up to 20 days). By 2100, under business as usual, they could occur as much as ten times more often.
Electricity Demand

Higher emissions scenario, end of this century compared to historical average, in percent
California Wildfires

Climate change, population growth, urban-wildland development

October 27, 2003
3,600 structures

October 23, 2007
1500 Structures
650,000 evacuated
Wildfire Risk: Structures

Number of buildings lost from the 25 most destructive wildland-urban interface fires in California history from 1960–2007

Building Loss by Fires at California Wildland-Urban Interfaces

2085 Predicted burned area as a multiple of 1971-2000 predicted area burned. Panels show SRES A2 scenarios with the location of fire regimes fixed. All scenarios show large increases in burned area in forests of the Sierra Nevada, northern California Coast, and southern Cascade ranges. A value of “1” indicates burned area is unchanged, while 4+ indicates that burned area is 400% or more of the reference period.

Our Changing Climate 2012: Vulnerability & Adaptation to the Increasing Risks from Climate Change in California  
A Summary Report on the Third Assessment from the California Climate Change Center
Rising Sea Level

2006 projection for 2100: 6-30 inches
2012 projection for 2100: 31-55 inches
Coastal Infrastructure At Risk

Capital Assets Only

2009 California Climate Assessment

National Climate Assessment, 2013
The Big Gulp

San Francisco Bay-Delta
Dark Red: 39 inches SLR

Weiss and Overpeck, 2011

California’s Second Biggest Nightmare

Levee failure during storm surge at high tide leading to salt water intrusion
California
The most thoroughly assessed state in the Union
Smog Prepared California for Climate Change

In 1960s, California had the highest ozone levels (600 ppb) ever recorded anywhere  
Stage 1 alerts (O3>200 ppb) more than half the time

Since then, California’s population doubled and economy grew dramatically  
Number of vehicles up 170%, vehicle-miles tripled

Last stage 1 alert was in 1998  
Peak CO down by 87%, NO2 83%, SO2 90% since 1968, when CARB was founded

Bart E. Croes, Atmos. Environment, 47, 562-563, 2012
California agencies work intimately with the science community

- 2001 - California Climate Action Registry
  - California industry, universities and agencies report GHG emissions
  - Registry provides methodology and certifies result
  - Transitioned to The Climate Registry (North America) in 2010

- 2003 - California Climate Change Center founded
  - First US state-funded climate change research program
  - Focus on mitigation strategies and California impacts

- 2005 - California Climate Action Team
  - Multi-Agency working groups (Agriculture, Biodiversity, Energy, Forestry, Land Use, Oceans, Public Health, Research, State Government Operations, Water) collaborate with Climate Change Center scientists
  - "Polycentric" governance mechanism thereby established

- 2005 - Executive order S-3-05 requires adherence to goals of Kyoto Protocol (80% below 1990 by 2050)

- 2006 - First Assessment, *Our Changing Climate*, identifies risks to California

- 2006 - California Legislature passes *Global Warming Solutions Act (AB 32)*

- 2008 - Executive order S-13-08 requires adaptation planning

- 2009 - Second California Assessment proposes adaptation strategies

- 2012 - Third California Assessment focuses on regions
California Climate Action Team

Polycentric* decision-making

Why a Climate Action Team is Needed

Inter-sector interactions require polycentric decision-making

2009 California Climate Adaptation Strategy
Regional Diversity

Polycentric Decision Making

Each environmental issue has its own natural region.
Rigorous science respects natural boundaries.
Spans of authority do not match natural regions.
Regional Decision Support

Complex information potentially enabling adaptive management
Locale by locale, county by county, town by town
Knowledge Action Partnerships
Scientists working directly with polycentric decision consortia

The State of Bay-Delta Science

Consortium of Federal and State Agencies with jurisdictions in the bay-delta system
CALFED science program

2009 California Climate Adaptation Strategy
California Climate Action Team, a council of resource management agencies
California Climate Change Center
Repeated Assessment

The key to adaptive management

Executive Order S-3-05 charged the Secretary of the California Environmental Protection Agency to report to the Governor and the State Legislature by January 2006 and periodically thereafter on the impacts of global warming to California.
Think Globally, Assess Regionally, Act Locally

Prospects of Local Impacts Inspire Community Action

San Diego Foundation

San Diego, 2050 Is Calling. HOW WILL WE ANSWER?

FACING THE FUTURE:
How Science Can Help Prepare San Diego Regional Leaders for Climate Change
“38501. The Legislature finds and declares all of the following: Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snowpack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems.”

California Assembly Bill 32, 2006
The Impact of Impact Assessments

The Western Climate Initiative, 2007, 15% below 1990 by 2020

Coalition of the Willing

WCI Partners and Observers

U.S. Partner jurisdictions comprise 19% of the total U.S. population and 20% of the U.S. GDP.
Canadian Partner jurisdictions comprise 79% of the total Canadian population and 76% of the Canadian GDP.

Manitoba

Ontario
GDP: 592,119 Million C$  Population: 12,800,000  Largest Source of Emissions: Transportation

British Columbia
GDP: 190,214 Million C$  Population: 4,300,000  Largest Source of Emissions: Transportation

Quebec

Washington
GDP: 311,270 Million U.S.$  Population: 6,642,824  Largest Source of Emissions: Transportation

Montana

Oregon

Utah
GDP: 105,668 Million U.S.$  Population: 2,640,330  Largest Source of Emissions: Electricity

California
GDP: 1,812,968 Million U.S.$  Population: 36,552,715  Largest Source of Emissions: Transportation

New Mexico
GDP: 76,178 Million U.S.$  Population: 1,960,915  Largest Source of Emissions: Electricity

Arizona

Observers

CANADA: Nova Scotia, Saskatchewan, Yukon; UNITED STATES: Alaska, Colorado, Idaho, Kansas, Nevada, Wyoming; MEXICO: Baja California, Chihuahua, Coahuila, Nuevo Leon, Sonora, Tamaulipas

* Includes vital oils
What will happen to me?

The most important question in environmental science
Answering it is the key to progress on adaptation
Wildfire Risk:
Transmission Lines
Changing probability in fire risk by end of century compared to 1961-1990, higher emissions scenario

Our Changing Climate 2012: Vulnerability & Adaptation to the Increasing Risks from Climate Change in California

Wildfire Risk:
Structures
Number of buildings lost from the 25 most destructive wildland-urban interface fires in California history from 1960–2007