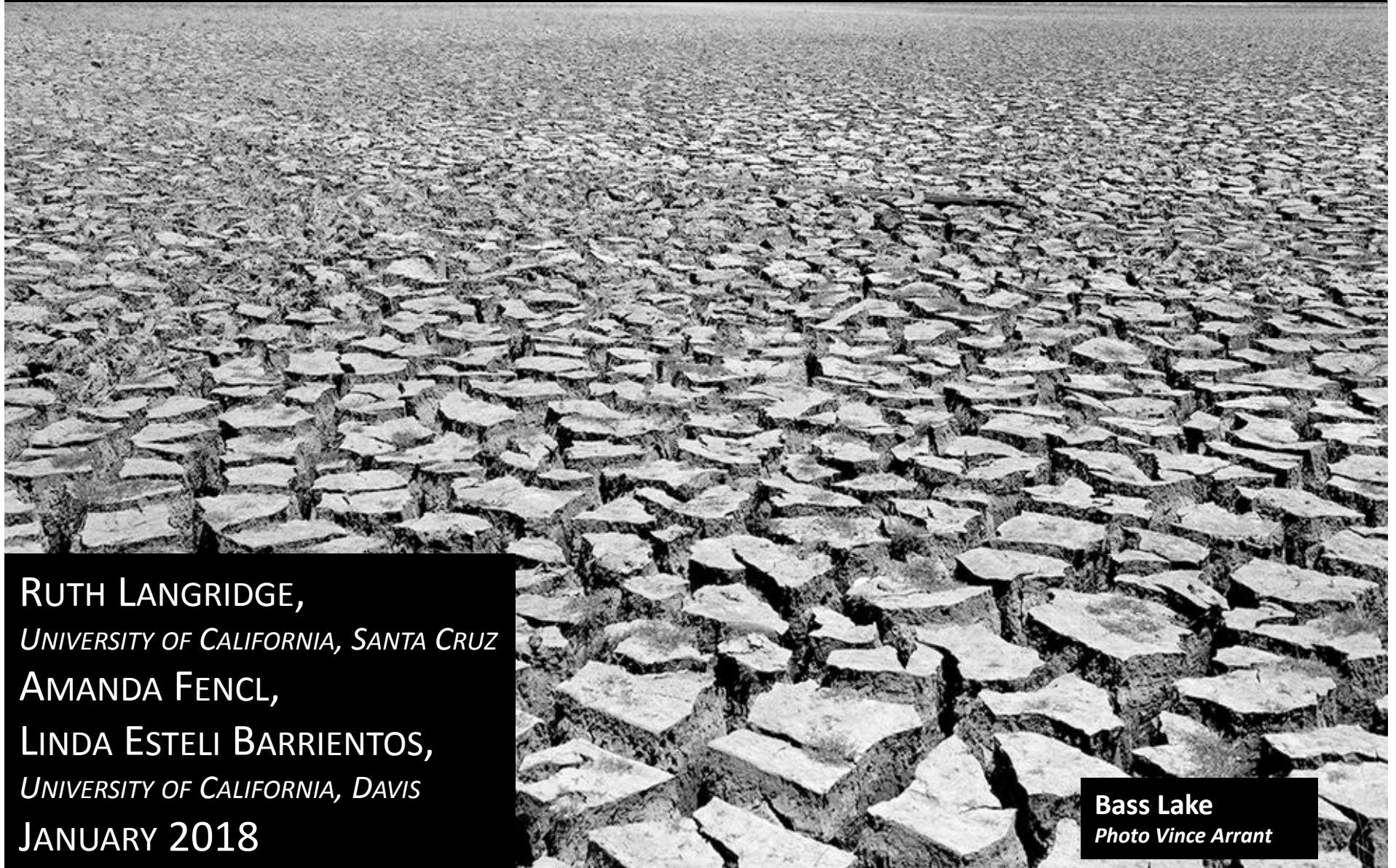


Science Policy Research Report

Groundwater Security Under Drought

Synthesis and Analysis of Information and Knowledge Gaps



RUTH LANGRIDGE,
UNIVERSITY OF CALIFORNIA, SANTA CRUZ
AMANDA FENCL,
LINDA ESTELI BARRIENTOS,
UNIVERSITY OF CALIFORNIA, DAVIS
JANUARY 2018

Bass Lake
Photo Vince Arrant

Groundwater Security Under Drought

I. Importance

I. Our Approach

II. Physical Science

III. Social Science

IV. Law and Policy

V. Interdisciplinary Relationships between
Groundwater, Drought and Climate Change

VI. Knowledge Gaps



I. Importance

Groundwater



- An essential resource, especially where surface water supplies are limited
- Many cities, rural communities and agriculture rely on groundwater
- Groundwater can have a higher storage capacity than surface water

Groundwater is a critical backstop during drought

AND Drought Affects Groundwater



Less Precipitation

Surface water shortages

Increased groundwater pumping

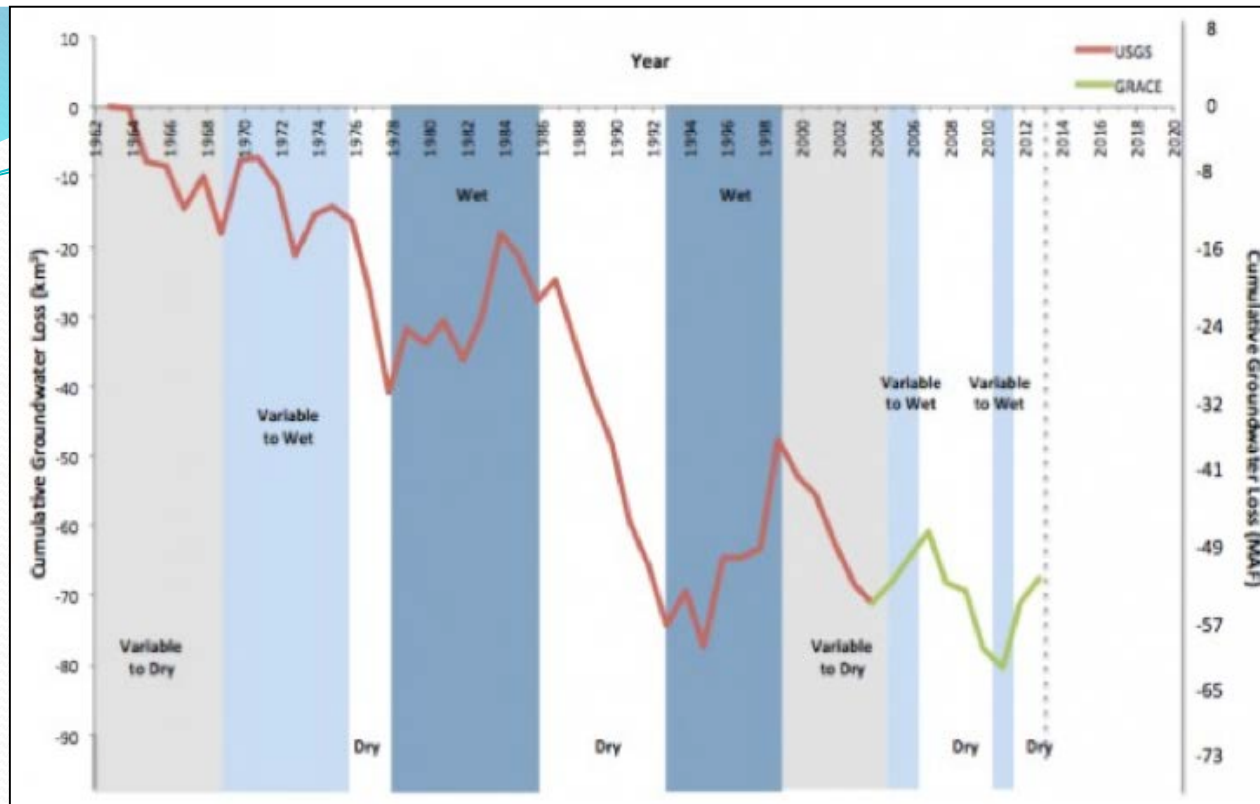
Groundwater storage reduced



AND even during non-drought years....
Extraction rates often exceed natural recharge rates



Groundwater storage reduced



USGS data, Claudia Faunt. Satellite data, NASA and the National Center for Atmospheric Research.
Posted by Jay Famiglietti, UC, Irvine in Water Currents, 2014

TAKE HOME

Increased pumping during drought
Insufficient recharge during normal or rainy periods



Long-term groundwater level declines

Groundwater depletion is already extensive in many parts of the world & coming under increasing strain as the result of intensive agriculture, urban development & climate change



The Conundrum

Water in the aquifers continues to be the most effective strategic weapon against drought.

ACE – Lessons Learned From the
California Drought **(1987-1992)**

AND

Climate scientists predict more extreme drought events and higher temperatures by the end of the 21st century

Impacting

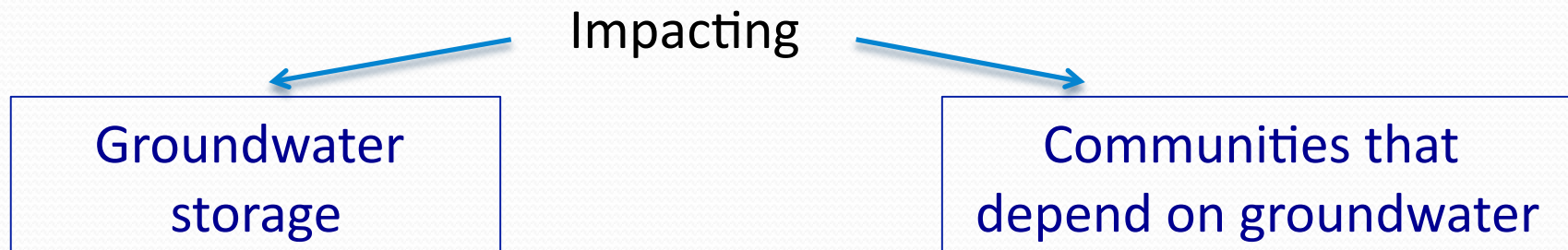
```
graph TD; A[Climate scientists predict more extreme drought events and higher temperatures by the end of the 21st century] --> B[Impacting]; B --> C[Groundwater storage]; B --> D[Communities that depend on groundwater];
```

Groundwater
storage

Communities that
depend on groundwater

AND

Climate scientists predict more extreme drought events and higher temperatures by the end of the 21st century



Studies on the impacts of drought and climate change on groundwater are limited compared to surface water

Evaluating long-term relationships between drought and groundwater is crucial to generate effective strategies to mitigate future negative impacts



II. Our Approach

Interdisciplinary Research

<i>Physical Sciences</i>	How do the hydrogeophysical characteristics of a basin affect groundwater use and management and overall water supply security?
	What is the impact of future droughts under climate change on water supplies in different regions of California?
<i>Social Sciences</i>	How are decisions made regarding groundwater use and management in the face of competing interests and climate uncertainty? Who is excluded and why?
	What are the benefits and impacts of particular management approaches and how are they distributed?
<i>Law and Policy</i>	What legal and policy programs exist to improve groundwater security and sustainability?
	What incentives can reduce resource degradation and promote more equitable access?



Data Sources	Physical Sciences	Social Sciences	Policy and Law
Academic journals, peer reviewed research	X	X	X
IPCC; CA Climate Assessments	X		X
Law journals			X
Geography, Governance journals		X	
Reports by NGOs i.e. Resources for the Future	X	X	X
Water, administrative, statutory law			X
Technical Reports by Gvt.	X	X	X
State agency research, reports, i.e. DWR	X		
Federal agency research, reports i.e. USGS, US Climate Assessments	X		X



California is an ideal case study

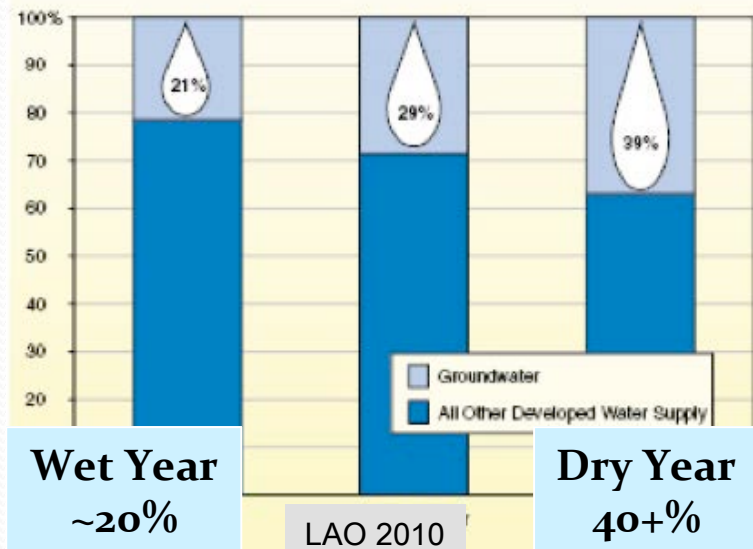
Significant land use diversity, demographics & water management approaches



California is an ideal case study

Significant land use diversity, demographics & water management approaches

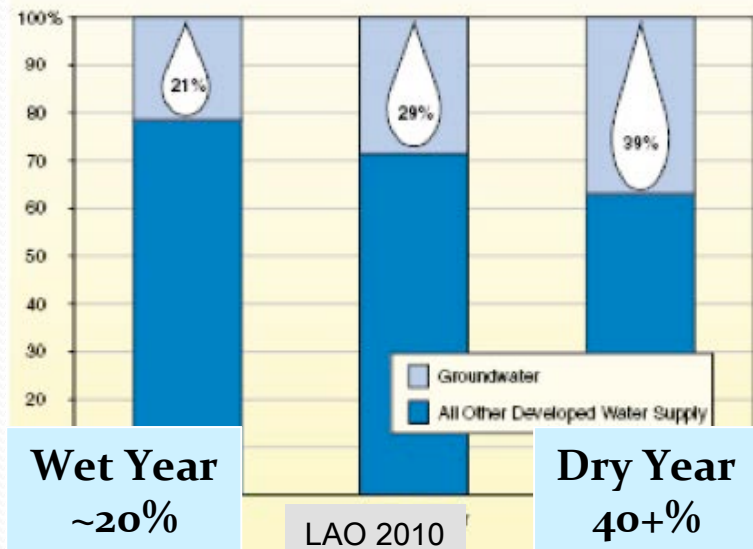
Groundwater Use is Extensive, particularly in dry years



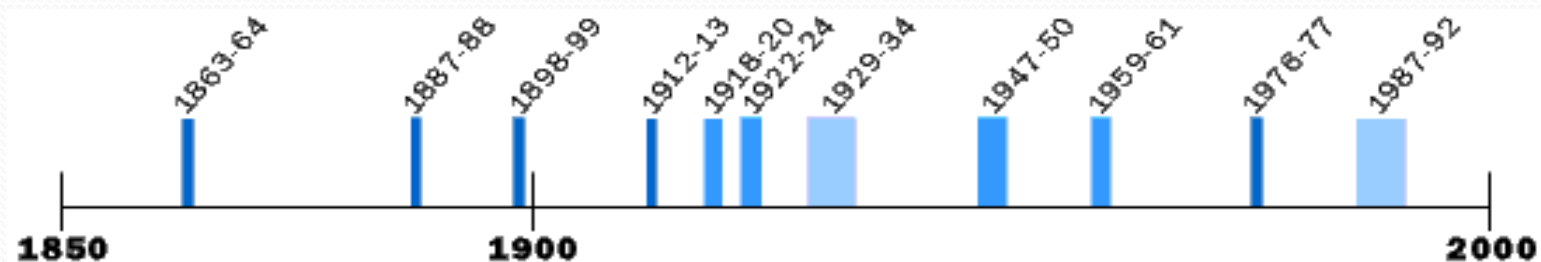
California is an ideal case study

Significant land use diversity, demographics & water management approaches

Groundwater Use is Extensive, particularly in dry years



Characterized by periodic and multi-year droughts

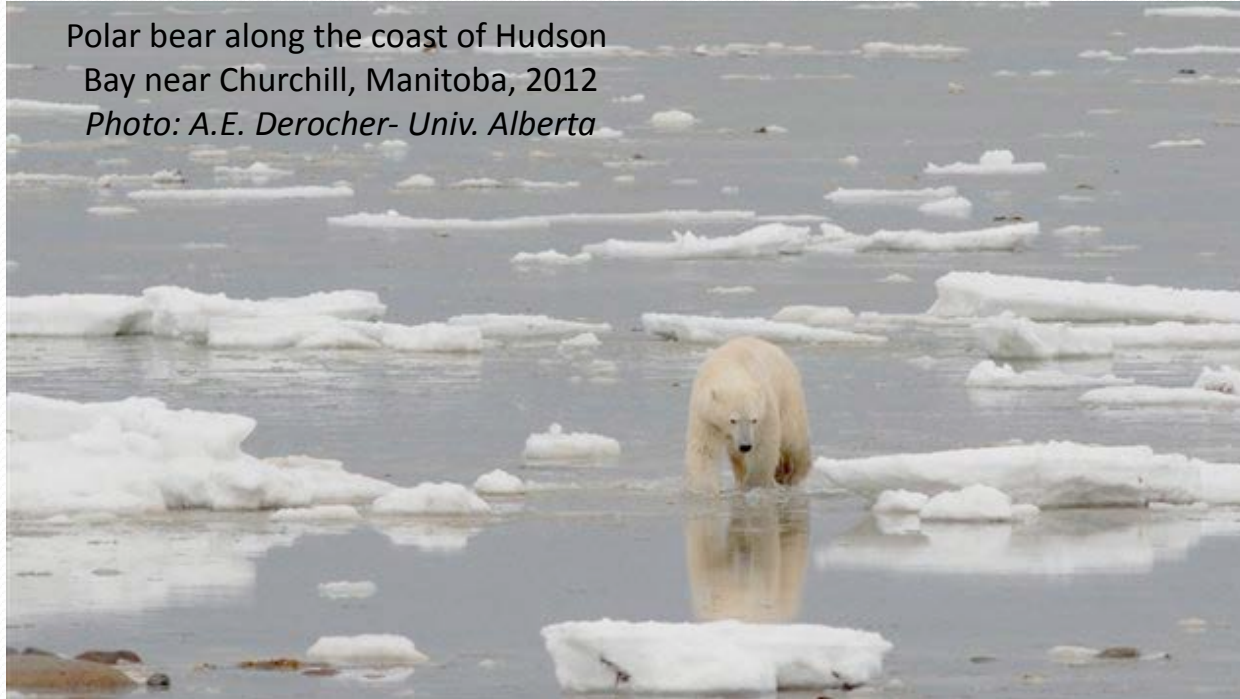




III. Physical Science

Drought

Polar bear along the coast of Hudson
Bay near Churchill, Manitoba, 2012
Photo: A.E. Derocher- Univ. Alberta



Droughts are
driven by
anomalies in
precipitation and
temperature

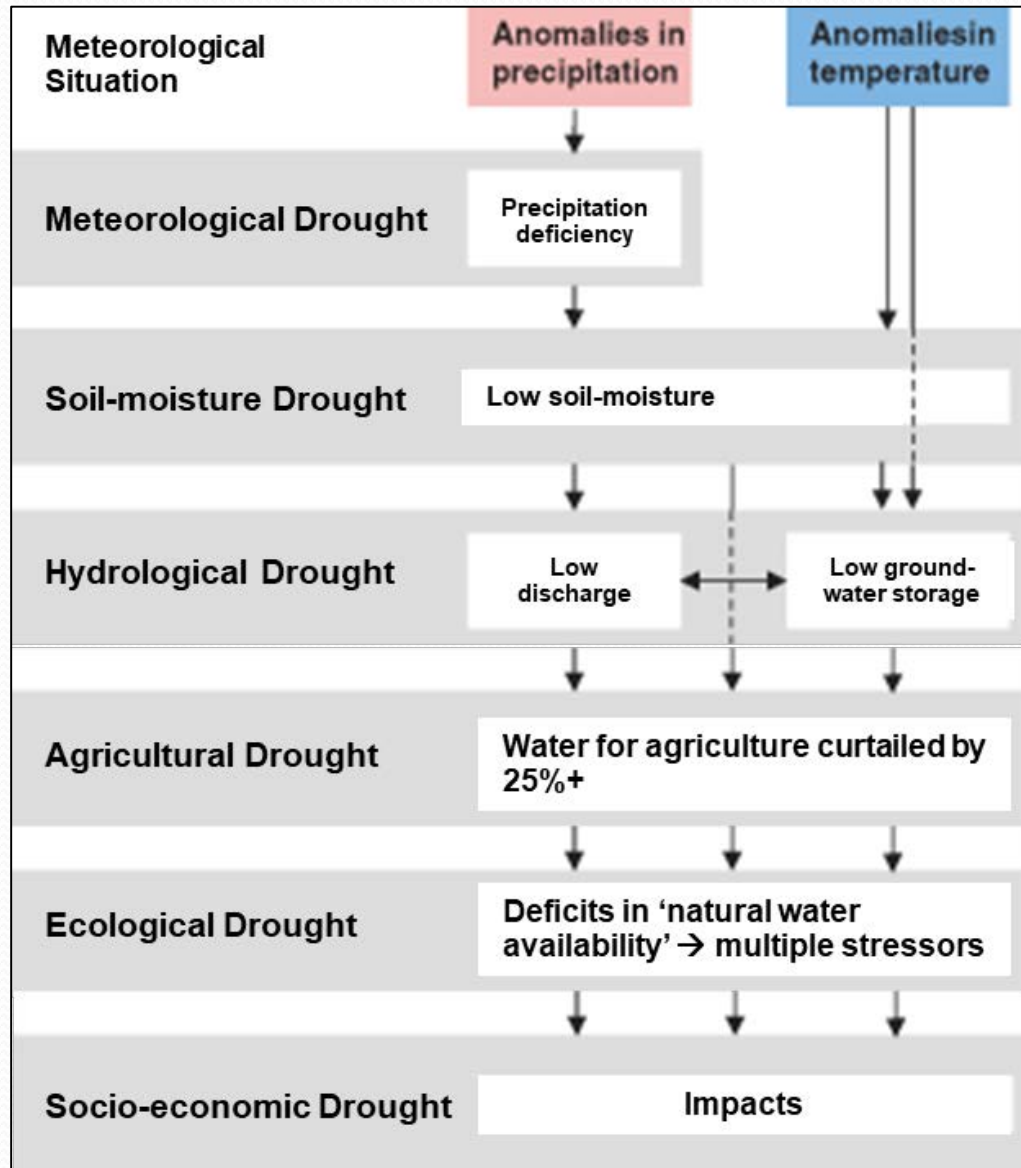
“teleconnections”
global processes like arctic sea ice loss, sea-surface temperature warming,
and atmospheric warming impact local weather patterns

High confidence that extreme
temperatures in the U.S. are
projected to increase more than
the averages (Vose et al. (2017))

Drought

Categories and Interactions

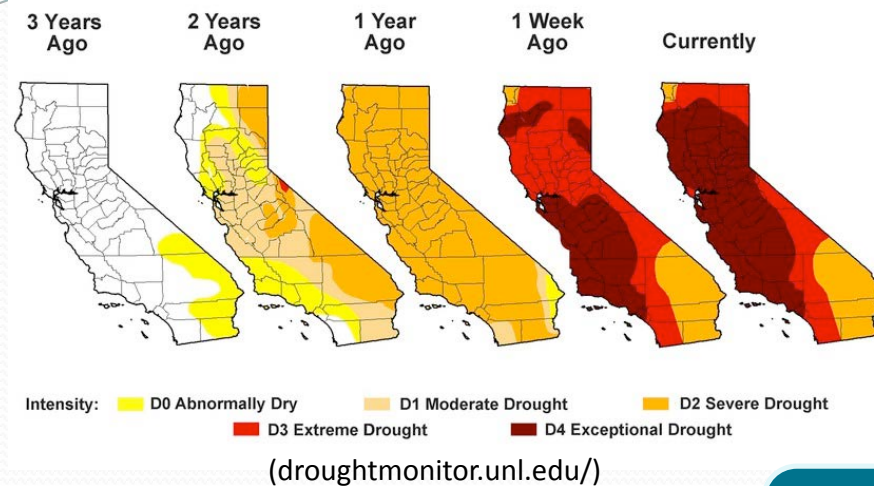
(adapted from Van Loon 2015; USGS 2017)



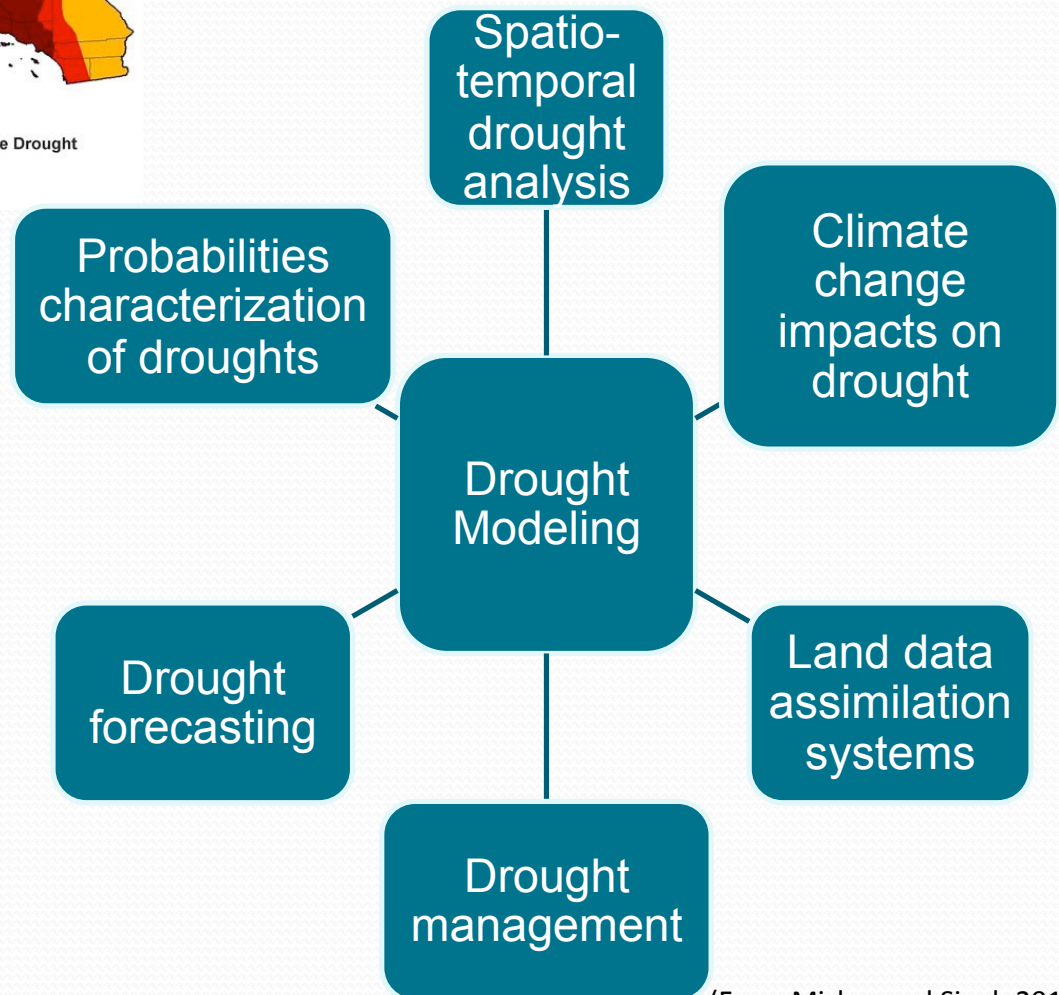
No mention of groundwater droughts, but while less visible, they are a “very severe hazard”

Groundwater droughts are understudied, less modeling, less indexing

Drought Indices



Drought Modeling



(From Mishra and Singh 2011)

Drought in California

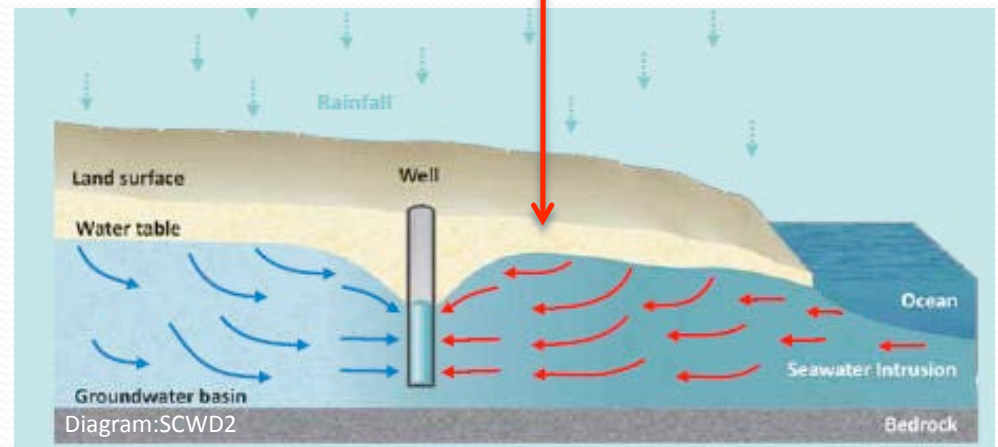
More reliance on groundwater during drought

Insufficient Recharge results in groundwater impacts



Subsidence

Seawater intrusion



But - Groundwater Recharge is partially controlled by local climate



IV. Social Sciences

Drought Governance

Difficult to establish a governance framework

Drought's effects accumulate slowly over a considerable period of time, and may also linger for years after it is over

Strategic Drought
Risk Management
(SDRM)

Goal

To plan for,
respond to and
recover from
drought



- Data and information gathering;
- Risk analysis and evaluation;
- Appraisal of options;
- Making, implementing, and reviewing decisions to reduce, control, accept, or redistribute drought risks

Groundwater Governance



Common Pool Resource

Multiple entities can withdraw groundwater from a basin. Exploitation by one user can reduce the quantity or quality available to others. Unlimited use by all can exceed the upper limits of the resource.

Governing common pool resources is challenging

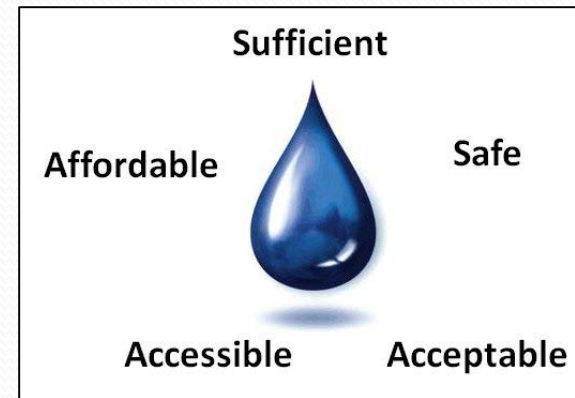
While participatory decentralized management can be effective, a combination of local authority with the support of a state or national government is posited to facilitate good groundwater management

Decision Making and Equity

Equity Framework

- ***Distributive equity** - the distribution of the resource and its benefits;
- ***Procedural equity** - decision- making processes and procedures;
- ***Contextual equity** - pre-existing conditions and power relations

**WATER IS A
HUMAN RIGHT**



2012 - California adopts a Human Right to Water

“every human being has the right to safe, clean, affordable and accessible water adequate for human consumption, cooking & sanitary purposes” (AB 685).

Imposes on state agencies a duty to consider HRTW
as they establish policies and regulations

Groundwater Governance in California - *pre-2014*

Local Agencies - Districts:

Some districts could fix and collect fees, regulate extraction & overdraft

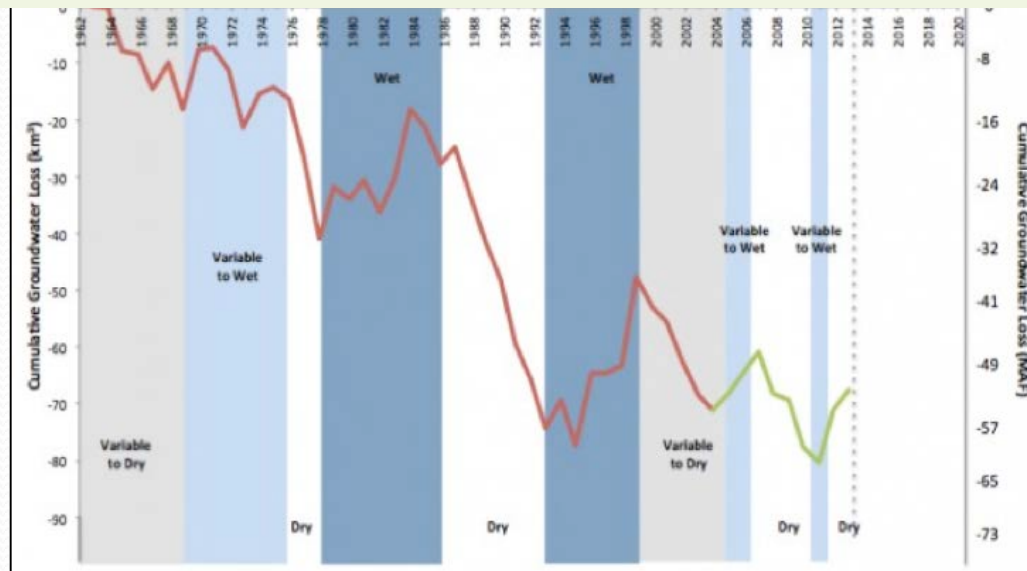
City and County Ordinances:

Cities and counties may adopt ordinances to manage groundwater

The Courts:

Adjudicated Basins

A long-term decline in groundwater levels



USGS data, Claudia Faunt. Satellite data, NASA and the National Center for Atmospheric Research.
Posted by Jay Famiglietti, UC, Irvine in Water Currents, 2014

THE SUSTAINABLE
GROUNDWATER
MANAGEMENT ACT



2014 Sustainable Groundwater Management Act

GSAAs **must** adopt plans to manage groundwater

“without causing undesirable results”

-Chronic lowering of groundwater levels

-Significant and unreasonable:

Reduction in storage

Saltwater intrusion

Degraded water quality

Subsidence

Reduced flows in surface streams

**But No Incentives to Establish Pro-Active
Strategies to Reduce Drought Vulnerability**



V. Law and Policy

Legal Frameworks

Drought

Since 1980s-global conventions to address climate change and drought

These are weak and generally reactive

In US responses are primarily state and local

Groundwater

In contrast, groundwater law developed over centuries through customary rules institutionalized in legal systems
In the US responses are also primarily state and local

Drought – Policy Strategies

“...the worst time to respond to a drought is in the midst of one. At that point, there are few, if any, good options available to avoid the worst impacts of drought, and combined with inflamed passions and politics, reaching consensus on solutions is nearly impossible....” (The Nature Conservancy and others, open letter to US Senate, 5 Oct. 2015)



Vulnerability
and Impact
Assessment



Monitoring
and Early
Warning
Systems



Mitigation
and Response



The law frames how groundwater is allocated

Overlying Landowners

Correlative Rights/Reasonable Use
Each overlying property owner has
common right to the reasonable,
beneficial *use* of a basin's supply
Place of Use Restrictions

Municipalities

Generally have appropriative rights
to groundwater for their customers

Exporters

First in Time, First in Right
Reasonable Use

Groundwater – Policy Strategies

Supply Side Approaches	Demand Side Approaches
• Increase storage capacity by building reservoirs and dams • Desalinate seawater • Expand rain-water storage • Remove invasive non-native vegetation from riparian areas • Expand imported water • Increase recycled water • Develop artificial recharge for ASR/MAR using recycled or imported water • Facilitate water transfers • Increase conservation including pricing • Increase efficiency including drip-feed irrigation technology	• Reduce water demand for irrigation by changing the cropping calendar, crop mix, irrigation method and area planted • Expand use of economic incentives including metering and pricing to encourage reduced withdrawals • Introduce drip-feed irrigation technology • Develop groundwater reserves • Develop groundwater protection strategies to avoid loss of groundwater resources from surface contamination • Manage soils to avoid land degradation to maintain and enhance groundwater recharge



VI. Interdisciplinary Relationships between Groundwater, Drought & Climate Change

Physical Science Relationships

Aquifers May Be Latest Casualty of Drought

U.S. water aquifer levels have been dropping at an accelerating rate for decades

Drought is the new normal

Drought dries rural wells, residents carry water in buckets

2011



2014



Feb 2017



Lake Oroville, CA

Photos: CA Department of Water Resources

Social Science Relationships

- Limited links between physical and social science research
- Limited links within social science research between groundwater and drought
- Disproportionate impacts of drought and groundwater depletion
- Existing disparities frequently exacerbated



The California Towns Without Safe Drinking Water

Bitter disputes in the municipal politics of California's drought-ridden San Joaquin Valley have kept the poorest areas from consolidating water systems.

Severe water shortages

State health officials on Tuesday identified 17 small community water districts in 10 counties that are at risk of running out of water in 60-120 days due to the drought.



Source: California Department of Public Health

BAY AREA NEWS GROUP

Law and Policy Relationships

Recharge and Water Rights

Recharge = type of *storage*, not a beneficial use

→ Capturing and storage water in a groundwater basin for use later, requires a water right permit

Special Situations

- Projects covered by an existing water right
- Projects using *recycled* water
- Projects designed solely for flood control



VII. Knowledge Gaps

Physical Science Knowledge Gaps

- Mismatch between global/regional scale climate models and small-medium scaled hydrologic processes
- How teleconnected processes drive California's warming
- Uncertainty in climate change impacts



Social Science Knowledge Gaps

- Limited drought frameworks and integration into groundwater policies
- Insufficient groundwater governance analyses



Law and Policy Knowledge Gaps

- Insufficient groundwater data for crafting groundwater policy, including recharge
- Insufficient information about proactive processes, in contrast to reactive
- Unknown effectiveness of past laws, policies and management approaches to reduce groundwater vulnerability to drought



Interdisciplinary Knowledge Gaps

- Accounting for integration of multiple climatic/drought interactions, human uses, and law and governance regimes
- Understanding of considerable uncertainties throughout every discipline

Questions?

Ultimately, actions taken in response to lessons learned through interdisciplinary research have the potential to reduce the negative impacts to groundwater from drought and climate change—
both by increasing our understanding of the relevant geophysical and social risks and knowledge gaps, and
by optimizing groundwater management strategies that increase resilience to future droughts and a changing climate.

Thank you!

Dr. Ruth Langridge: rlangrid@ucsc.edu

Amanda Fencl: alfencl@ucdavis.edu