Transitions and transformations- Climate extremes, hotspots, and adaptation, in semi-arid regions

Roger S. Pulwarty, Doug Kluck

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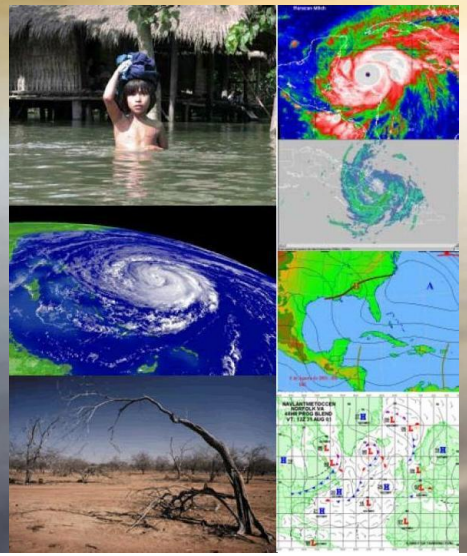
NOAA

[1] Senior Advisor Climate Research and Director, NIDIS
[2] Central Regional Climate Services Director
(J. Porter, B. Rippey, R. McNider, A. Hoell, J. Verdin, others)

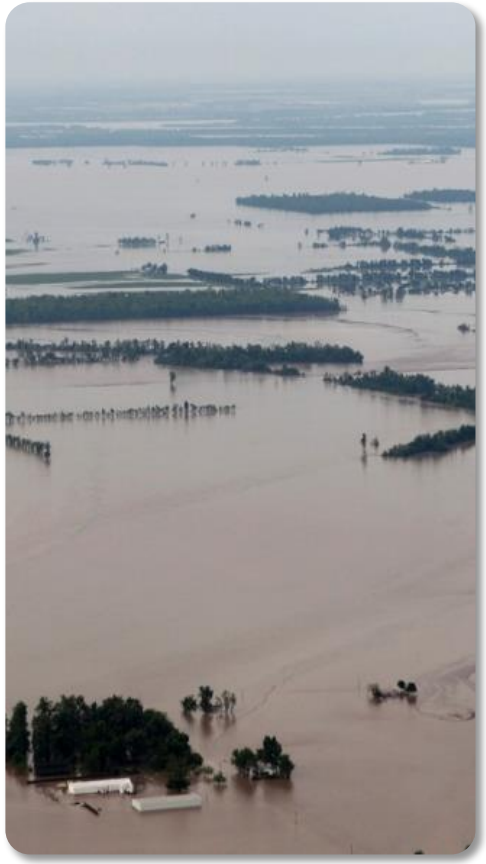


Climate Change and Cereal Production in Semiarid Regions

Increasing food production has been one of the major triumphs of the human enterprise over the last century

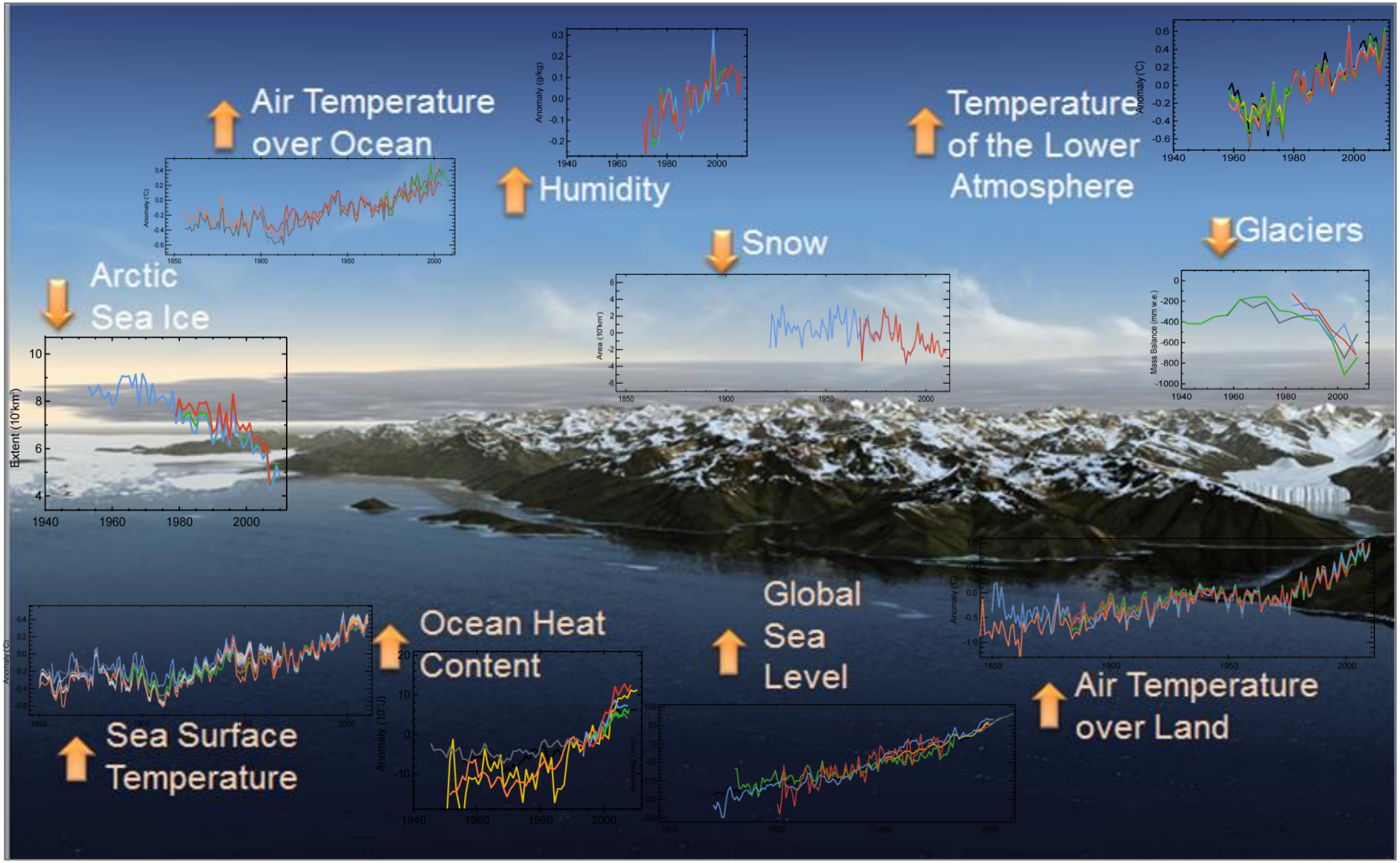
Traditionally emphasis has been placed on production, the availability aspect of food security, the elements of accessibility and stability, are under increasing scrutiny

A changing climate leads to changes in extreme weather and climate events



What do we know?

Ten Indicators of Changing Conditions:



Source: National Climatic Data Center

The Romans Ignored The AD 305 IPCC Report (and apparently several National Climate Assessments) !

Source: InfoRoma, 2004. www.inforoma.it

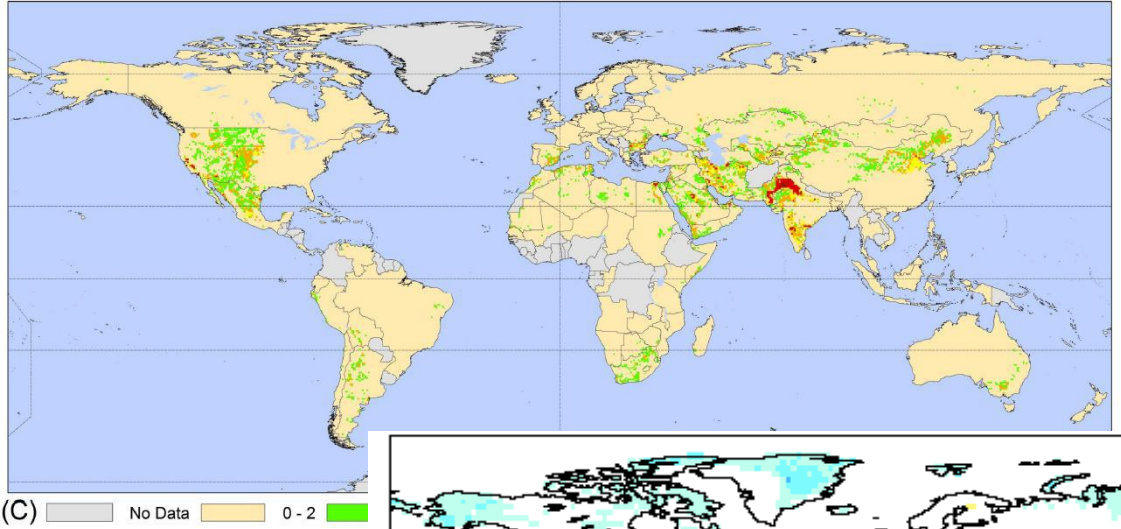
DEFERRED MAINTENANCE?

“Hotspots”

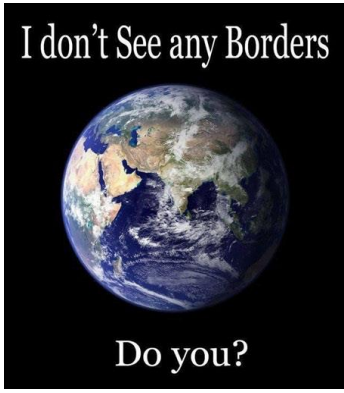
S*ystem, region - unit* of analysis (what is vulnerable?), *valued attributes* of concern (why is it important?), *external hazard* (to what is the system vulnerable?), a *temporal reference* (when?)

Developed to target conservation efforts- maps explicitly developed to help aid organizations in priority setting and strategic planning with regards to climate adaptation projects

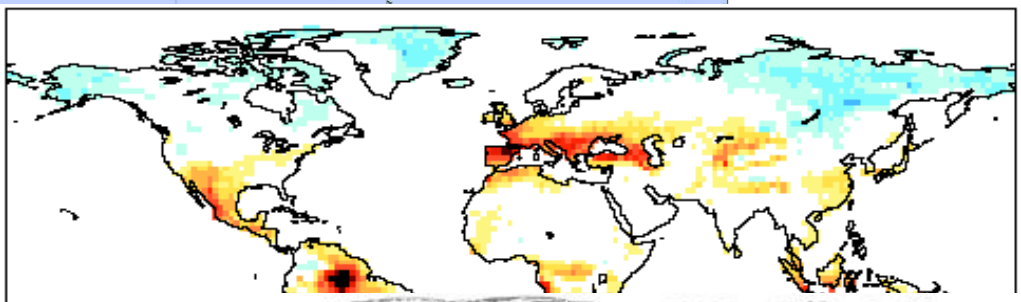
- High exposure, high sensitivity, rates of change and low adaptive capacity, to suffer significant impacts
- Identify likely climate change impacts and conveying with strong visual elements



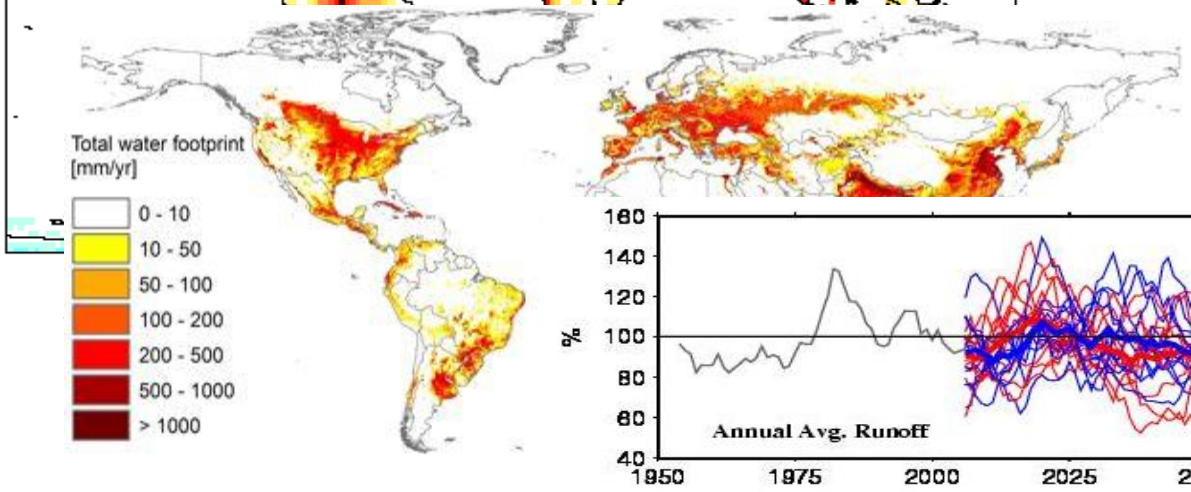
Ground water depletion



Model agreement (2050)



Water footprint

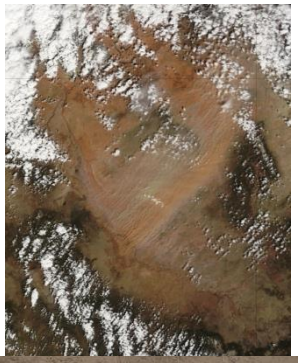


Many potential futures:

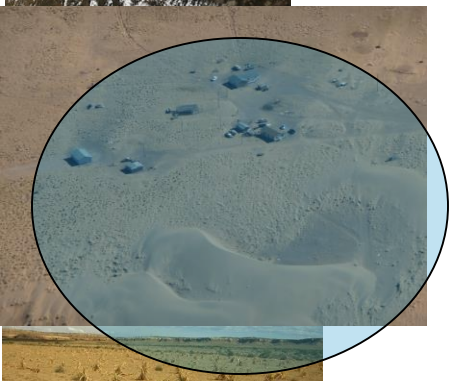
Adaptation requires science that analyzes decisions, identifies vulnerabilities, improves foresight, and develops options

Landscape changes
Dryland Farming in the Four-Corners Region (USGS, NIDIS)

Sand Dune Mobility = W/(P/PE)



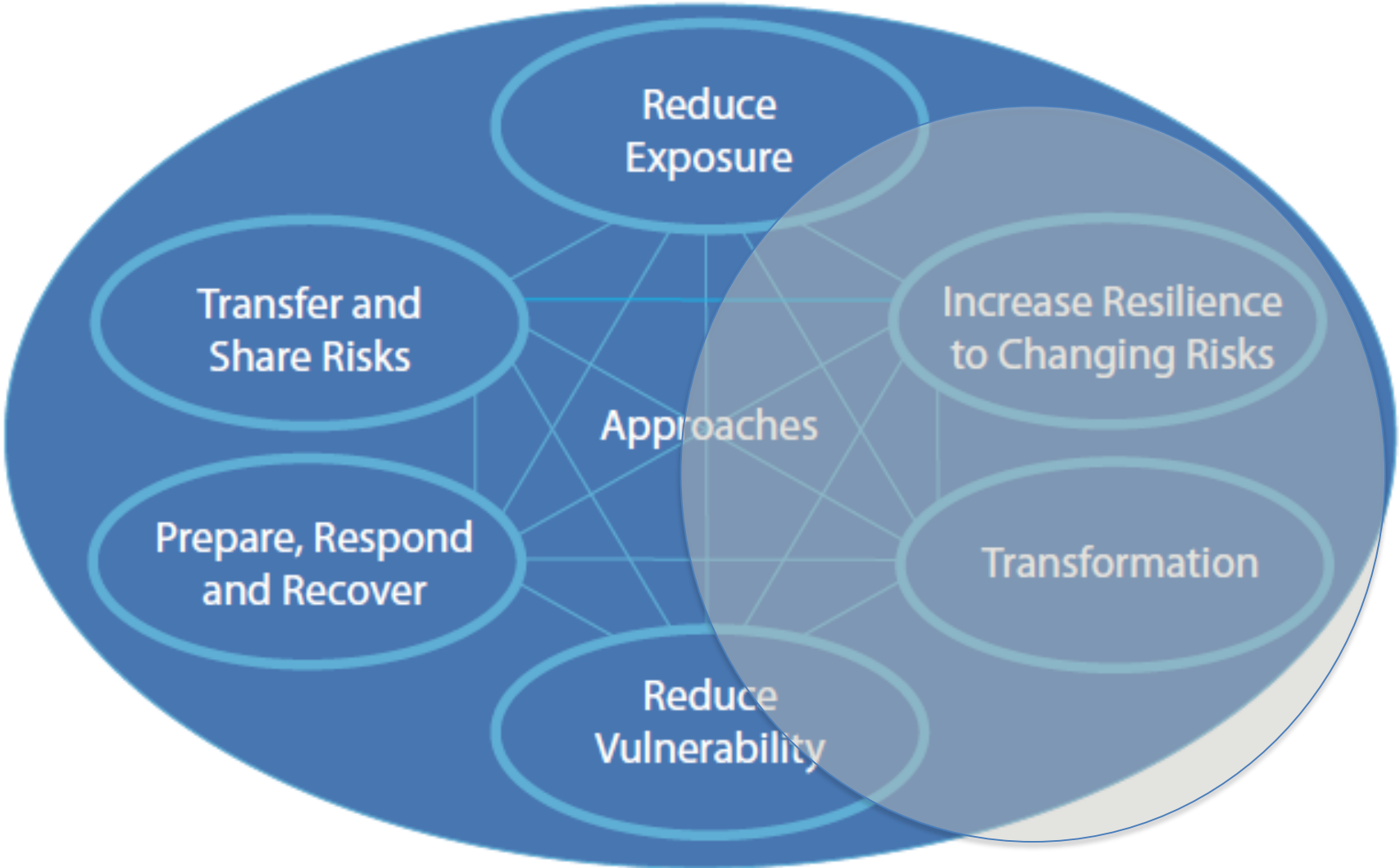
Stable Sand Dunes
= P/PE > 0.31 ⟶



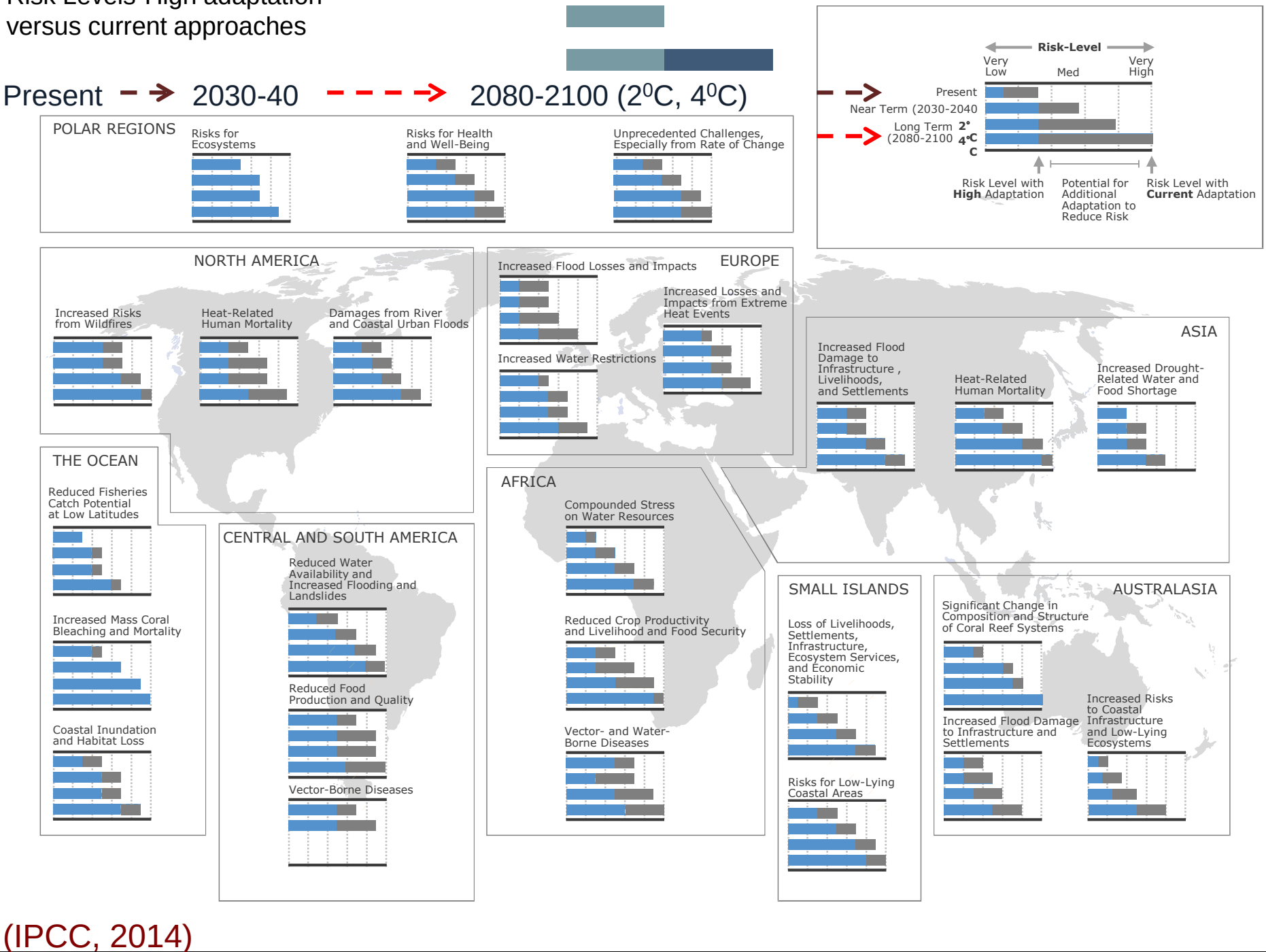
Partly Active Dunes ⟶

Fully Active Dunes
= P/PE< 0.125 ⟶

The adaptation solution space



Risk Levels-High adaptation versus current approaches



(IPCC, 2014)

Hotspots:
Soil moisture reductions combined with reduced adaptive capacity:

For Wheat: southeastern U.S., southeastern South America, the northeastern Mediterranean, and parts of central Asia,
For Maize: southeastern South America, parts of southern Africa, and the northeastern Mediterranean

'No or low regrets' practices with demonstrated evidence of having integrated observed trends in disaster risks to reduce the effects of disasters

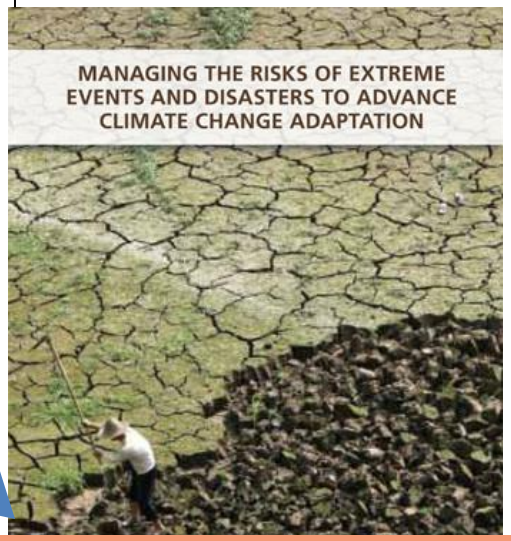
- Effective early warning systems and emergency preparedness (*very high confidence*)
- Integrated water resource management (*high confidence*)
- Rehabilitation of degraded coastal and terrestrial ecosystems (*high confidence*)
- Robust building codes and standards reflecting knowledge of current disaster risks (*high confidence*)
- Ecosystem-based/nature-based investments, including ecosystem conservation measures (*high confider*
- Micro-insurance, including weather- indexed insurance (*medium confide*
- Vulnerability-reducing measures suc pro-poor economic and human development, through for example improved social services and protec employment, wealth creation *(very confidence)*

Practices that enhance resilience to projected changes in disaster risk

- Integrated coastal zone management integrating projections of sea level risk and weather/climate extremes (*medium confidence*)
- National water policy frameworks and water supply infrastructures, incorporating future climate extremes and demand projections *(medium high*

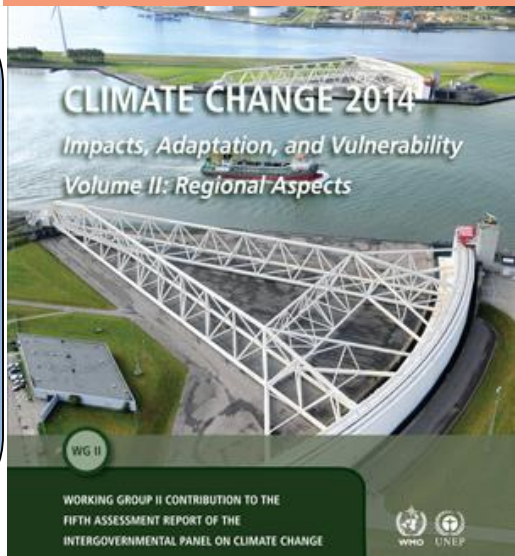
Effective early warning systems and emergency preparedness

Vulnerability reducing measures such as pro-poor economic and human development, through improved social services and protection

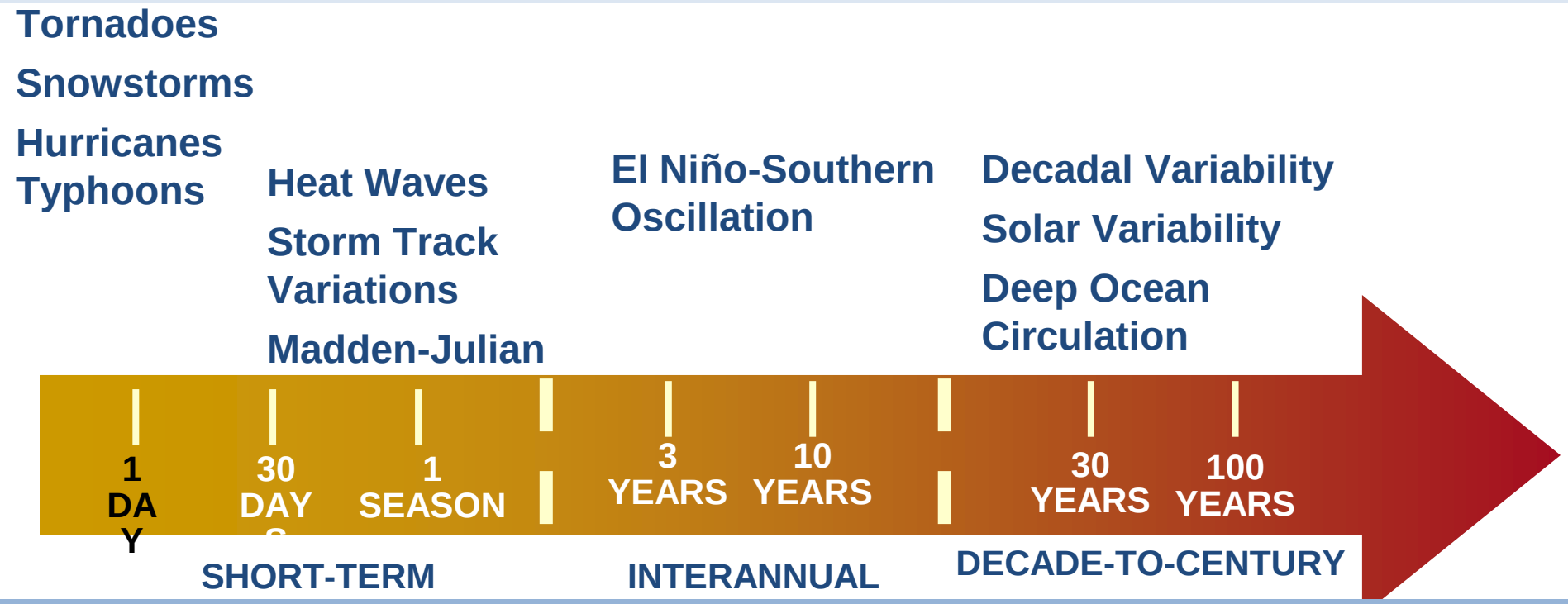


Risk Management

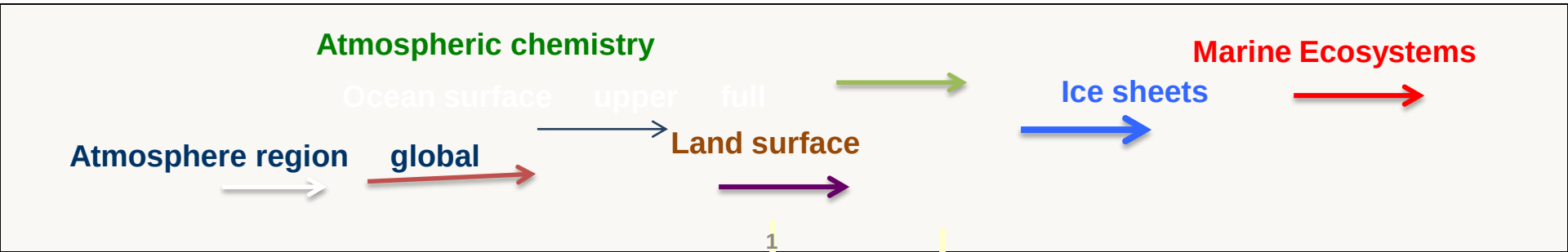
Resilience



Weather-Climate-a Continuum and an adaptation deficit…..

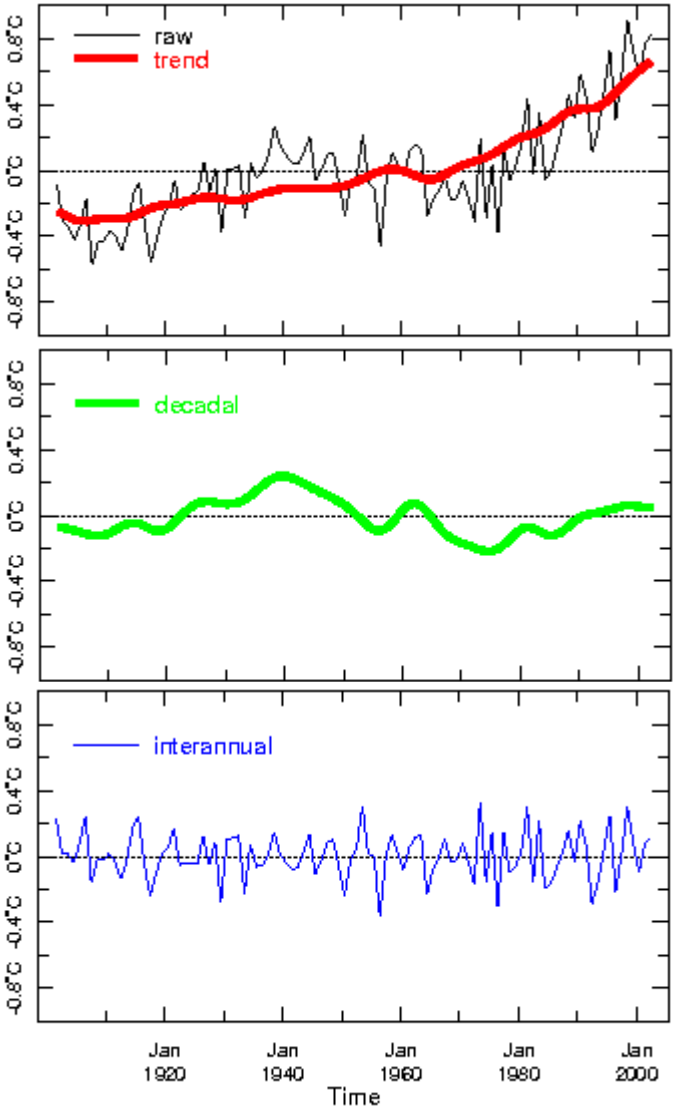


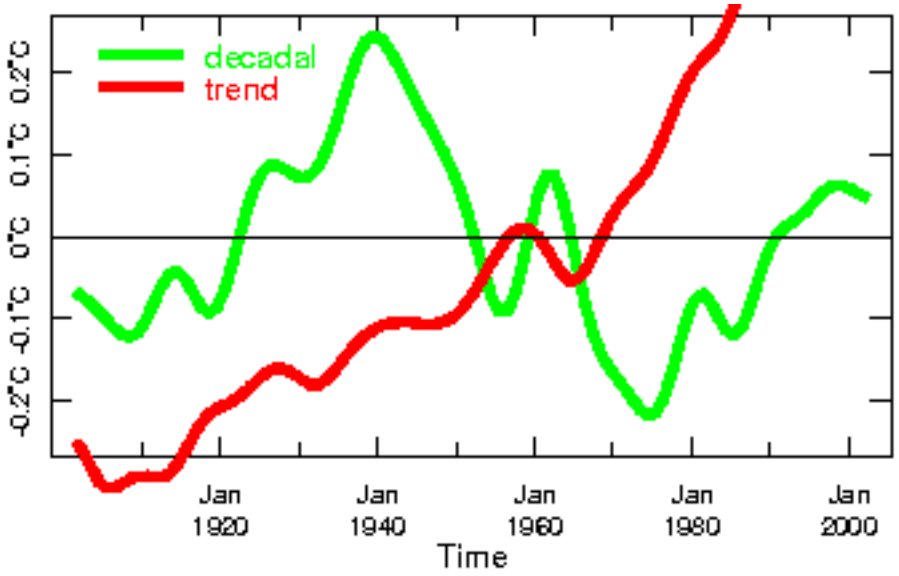
Early warning....resource allocation…. Infrastructure Design



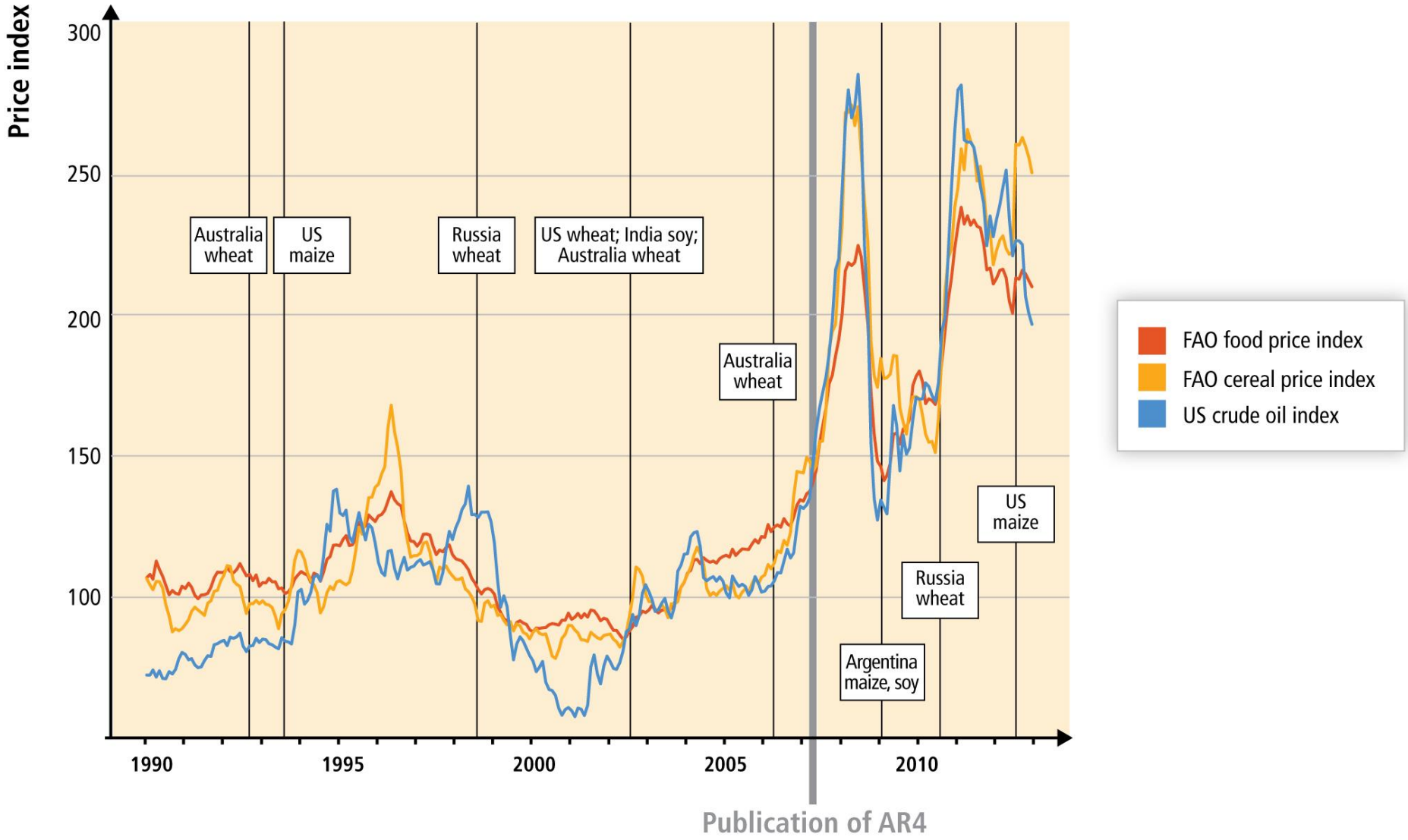
Global Variability and Variance

Annual Mean Temperature





What should we be trying to predict? (assuming some measure of skill)

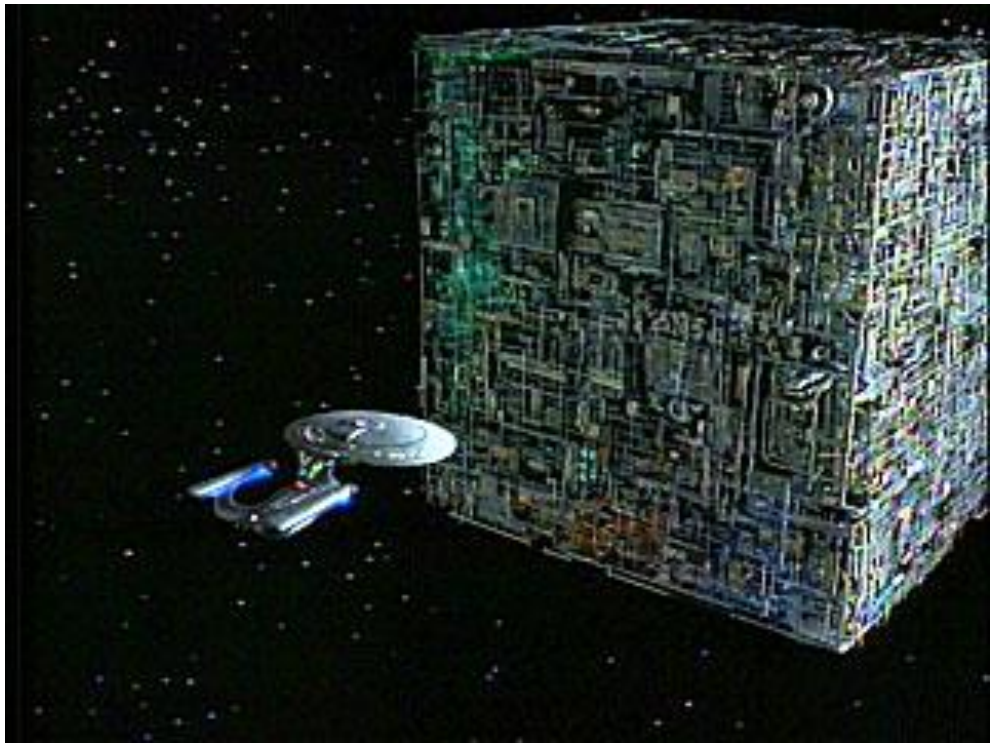


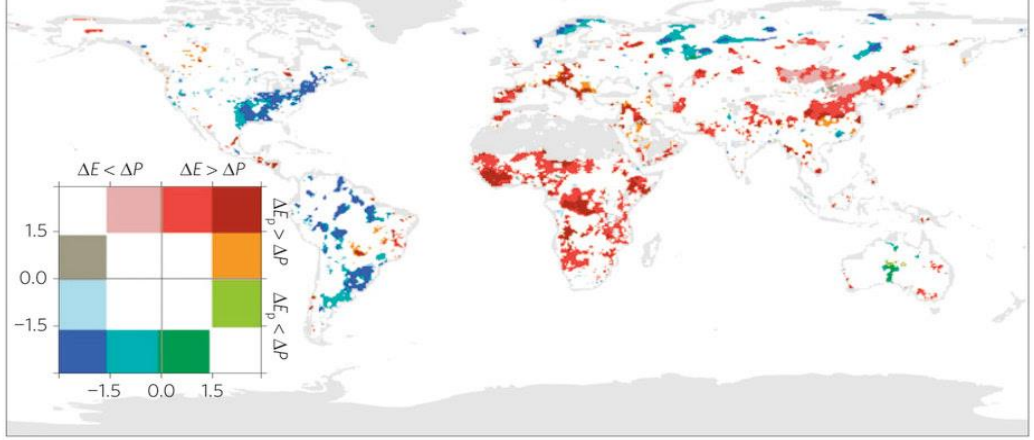
Since the AR4, international food prices have reversed historical downward trend. . (Porter et al, 2014 IPCC WGII AR5)

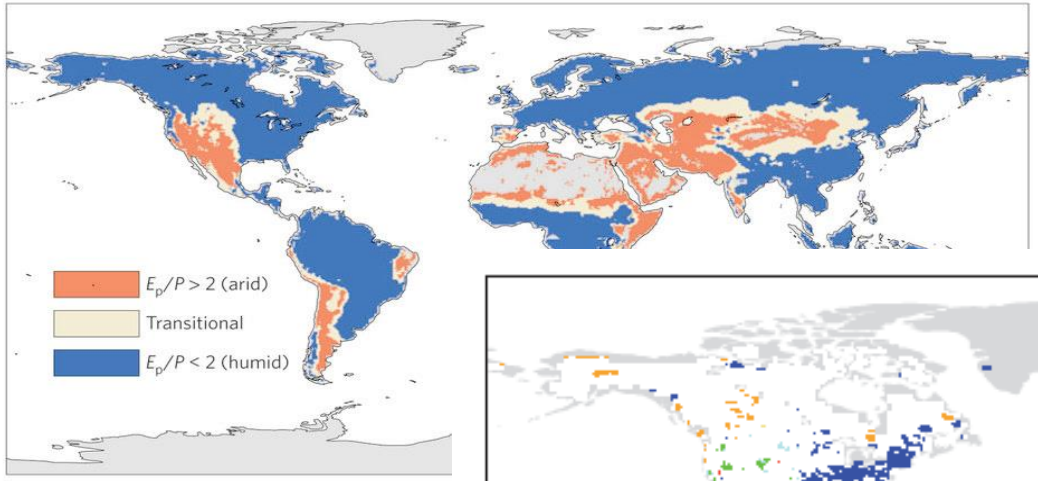
If it’s so easy why is it so hard?

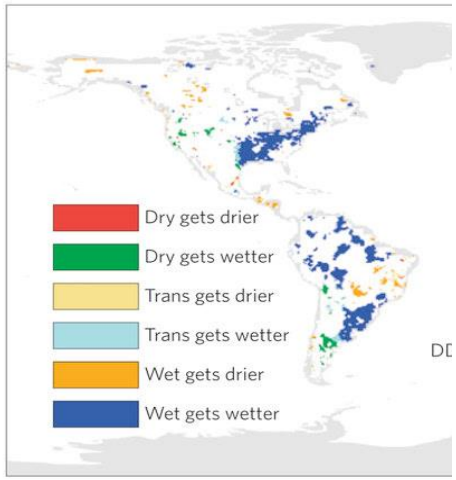
Dreadnaught-class Starship

Meet “The Borg”







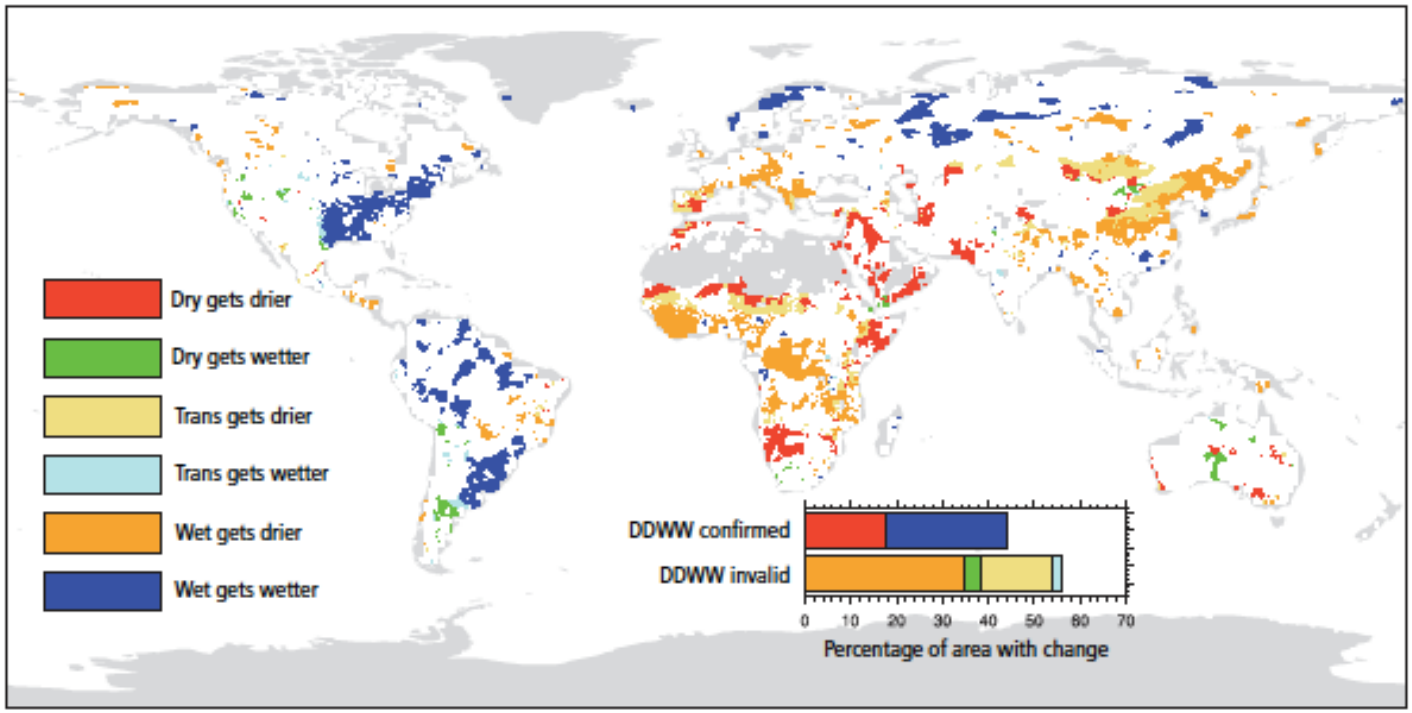


"Dry gets drier"

"Wet gets wetter"

Not necessarily

(Greve and Seniveratne 2014)



Recent Studies of Mid-century Climate Change Impacts on Colorado River flows (Lee's Ferry)

The future is already here. It's just not very evenly distributed. -- William Gibson

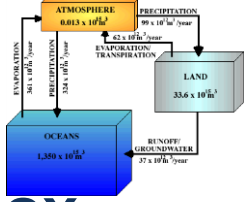
Recent Studies	Projected Annual Flow Reductions
Christensen et al., 2004	~18%
Christensen and Lettenmaier, 2007	~6%
Milly et al., 2005	10 to 25%
Hoerling and Eischeid, 2007	~45%
Seager et al., 2007	"an imminent transition to a more arid climate"
McCabe and Wolock, 2008	~17%
Barnett and Pierce, 2008	assumed <10 to 30%

Response One: "These are so different, we can't trust any of them…"

Response Two: "We need to resolve these differences!"
" Are the differences due to climate uncertainty or different models and methods?"

Response Three: "None of these studies show increasing flows"
"Any decrease is a source of concern"

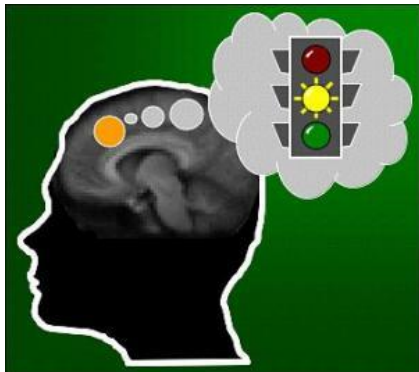
Usually requested…..

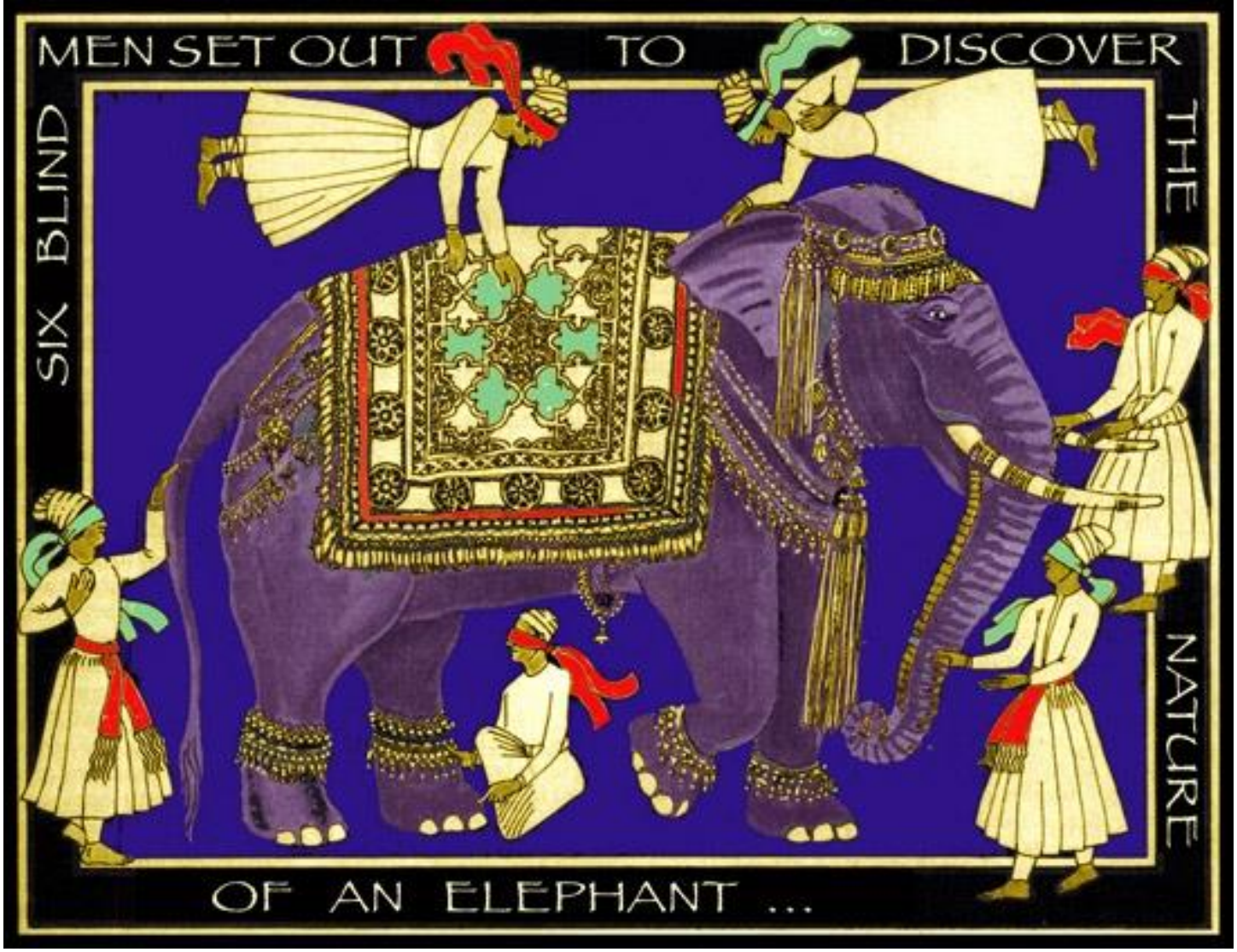


- **model agreement –convergence (not just at the grid-box scale)-**
- **narrowing the projection range**
- **higher-resolution spatial and temporal scales, and improved shorter**
- **time-horizon projections**

Influenced by choice of forcing data, calibration scheme, objective function etc.

The state of the practice is improving but in many cases does not fully recognize fundamental uncertainties – many adaptation studies are likely 'overconfident'





Model agreement/convergence?

Observational agreement

What is the Message?

- ***Despite advances to date, predicting the future hydro-climate variables will remain a major challenge:***

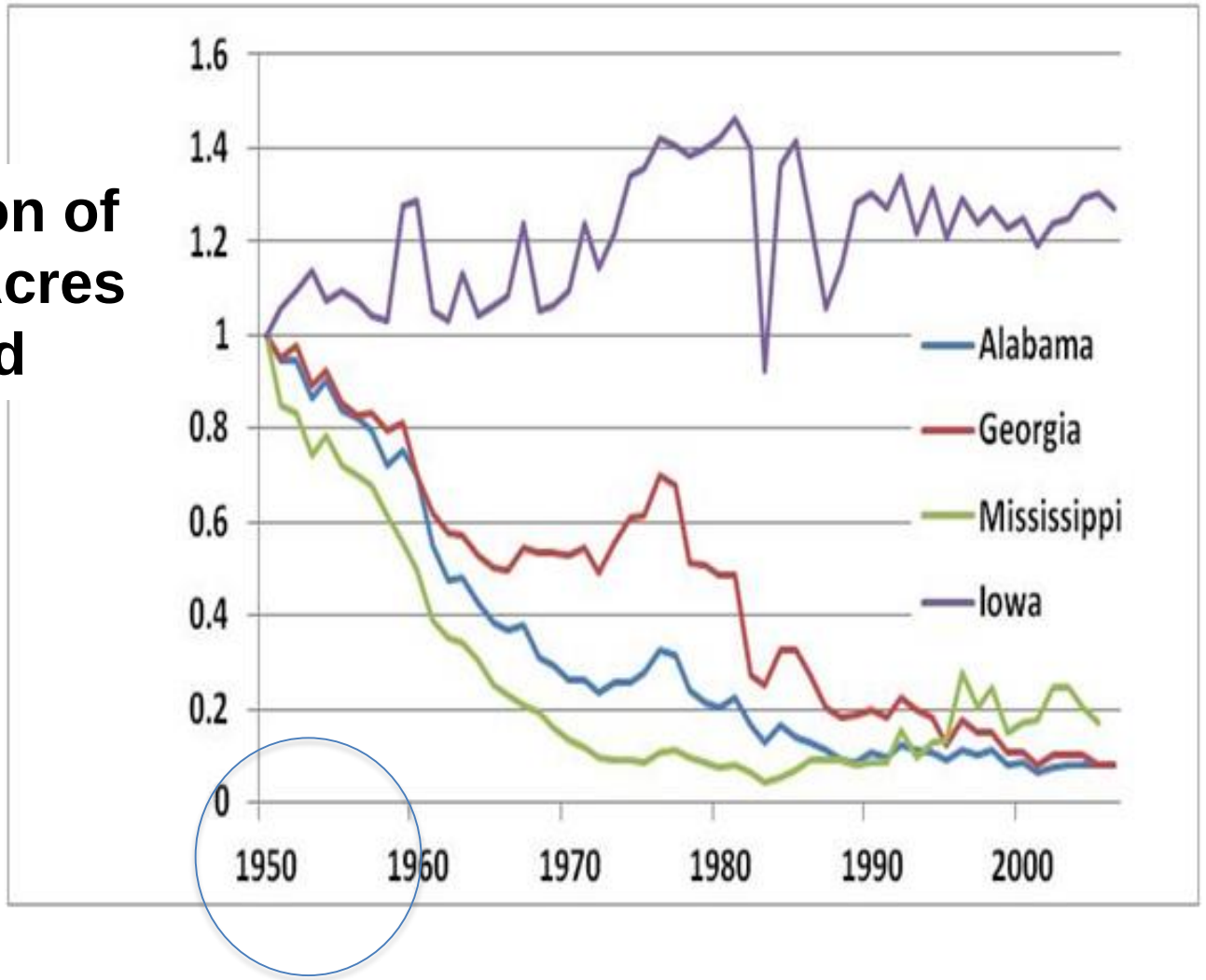
Factoring in Resiliency in water resources system's design and planning is still the safest approach!

observing and modeling its norm… "have a will to doubt" the credibility models.

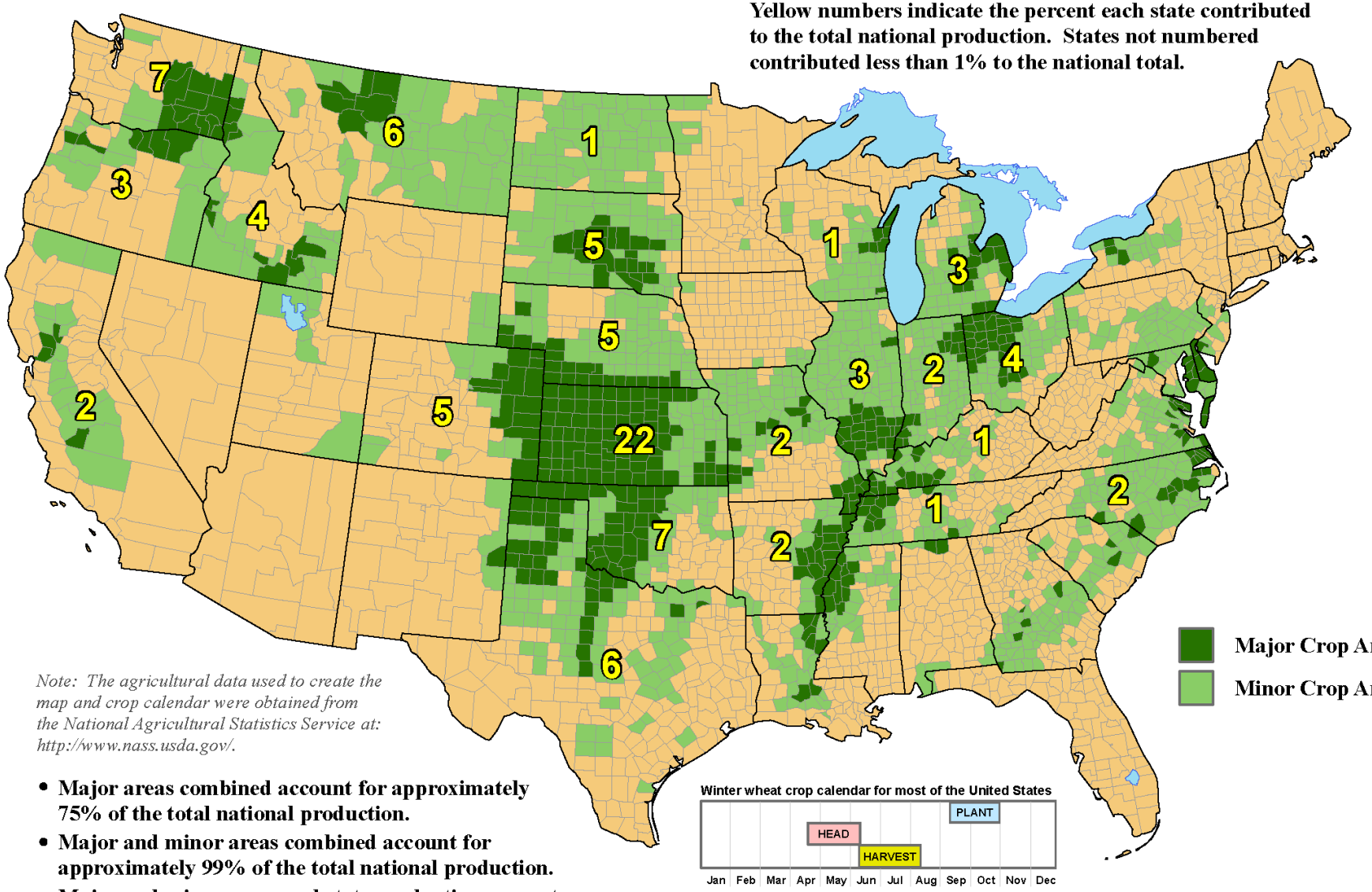
- ***Long-term and sustained observation programs are critical, especially for model verification.*** ***Without some degree of verifiability, hard to expect their use***

Midwest yields (and rise of center-pivot irrigation and other technology). Areas like the Southeast gave up on corn.

Fraction of 1950 Acres Planted



United States: Winter Wheat



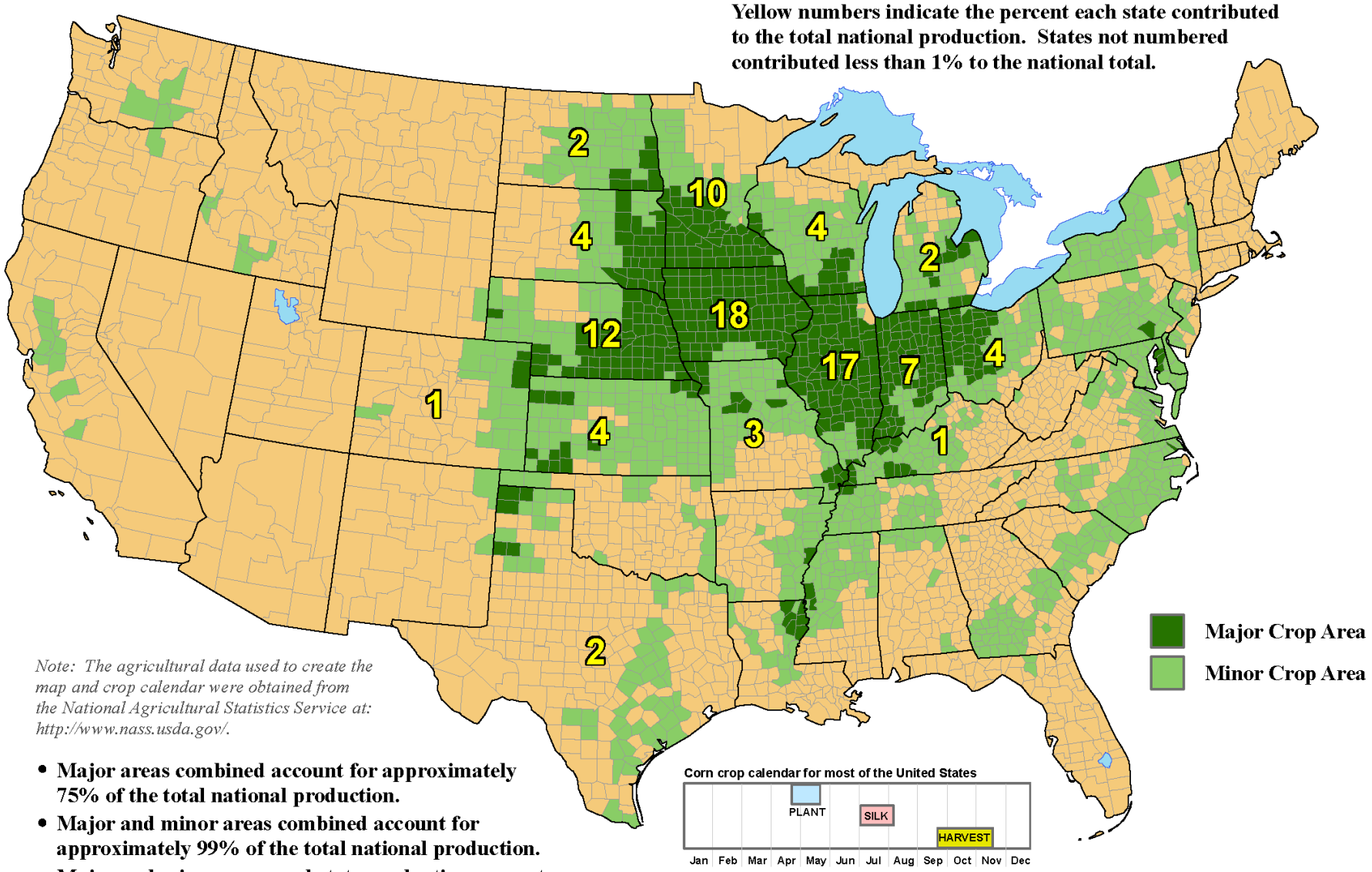
Note: The agricultural data used to create the map and crop calendar were obtained from the National Agricultural Statistics Service at: http://www.nass.usda.gov/.

- **Major areas combined account for approximately 75% of the total national production.**
- **Major and minor areas combined account for approximately 99% of the total national production.**
- **Major and minor areas and state production percentages are derived from NASS county- and state-level production data from 2006-2010.**

Crop calendar dates are based upon NASS crop progress data from 2006-2010. The field activities and crop development stages illustrated in the crop calendar represent the average time period when national progress advanced from 10 to 90 percent.

USDA Agricultural Weather Assessments
World Agricultural Outlook Board

United States: Corn



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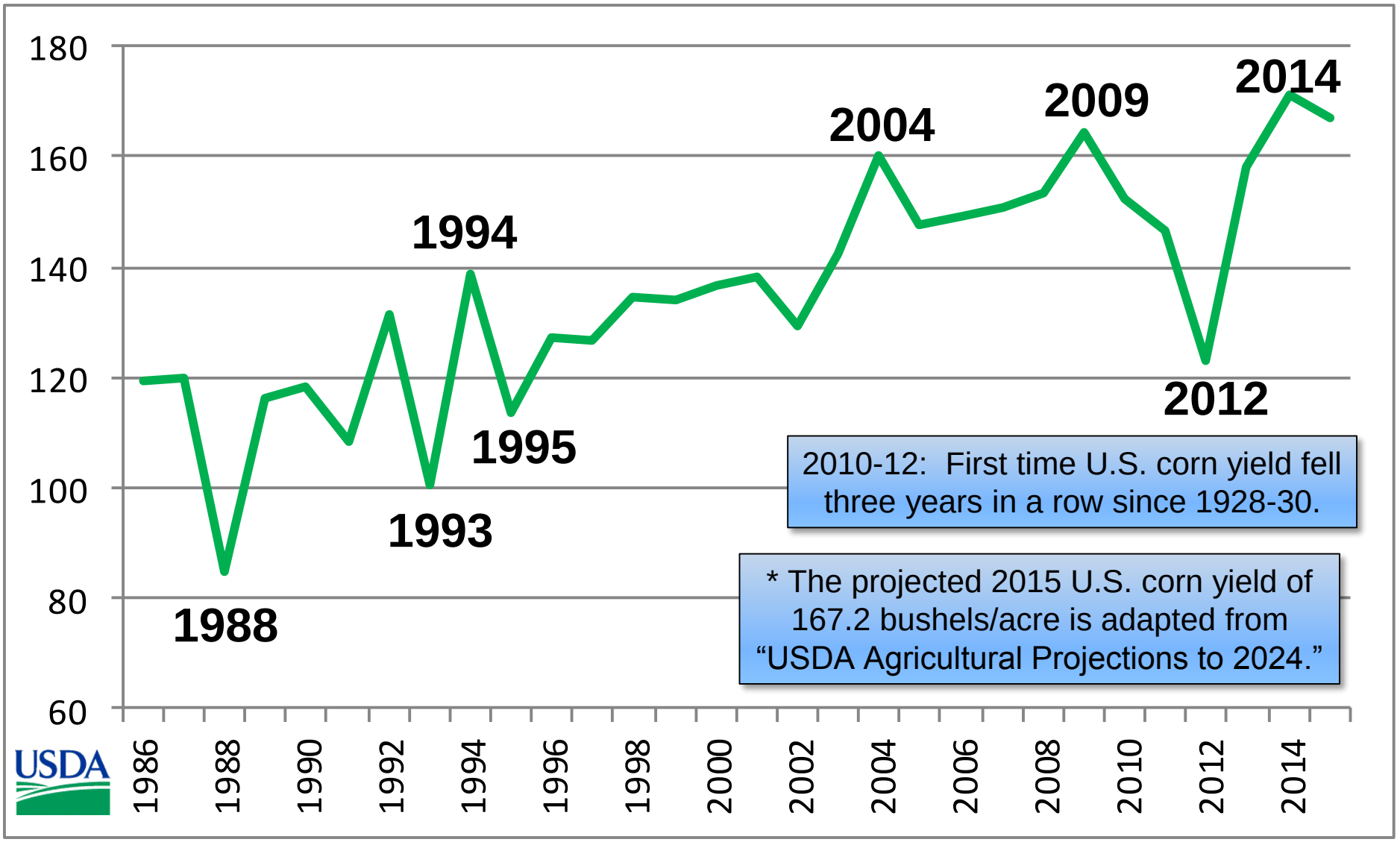
USDA Agricultural Weather Assessments
World Agricultural Outlook Board

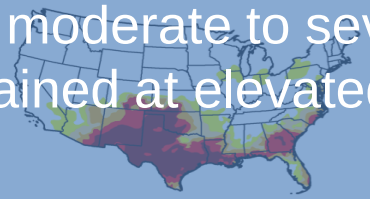
U.S. Corn Yield, Bushels Per Acre
1985-2015*



The weather-climate continuum

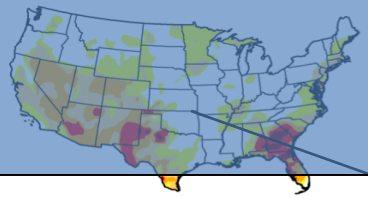
The percent of the U.S. experiencing moderate to severe drought suddenly increased and remained at elevated levels during the first decade of the 21st Century

July 2010
to exceptional

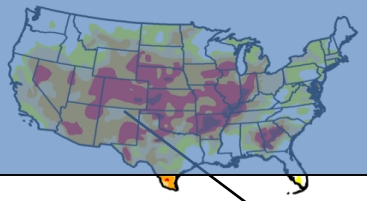


July 2011
to exceptional

Even a perfect SST prediction would "likely" capture much less than half the total variance in annual precipitation over North America

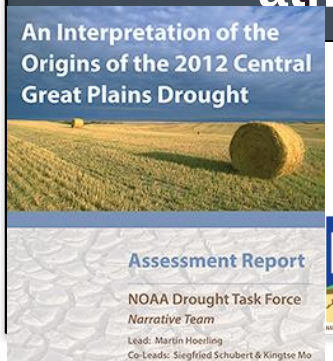


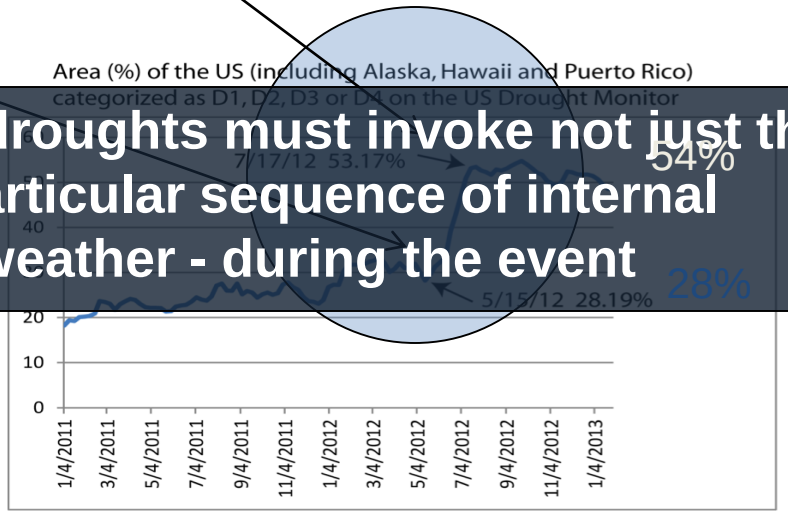
May 2012
35% moderate
to exceptional



July 2012
64% moderate
to exceptional

A complete explanation of these droughts must invoke not just the ocean forcing but also the particular sequence of internal atmospheric variability - weather - during the event





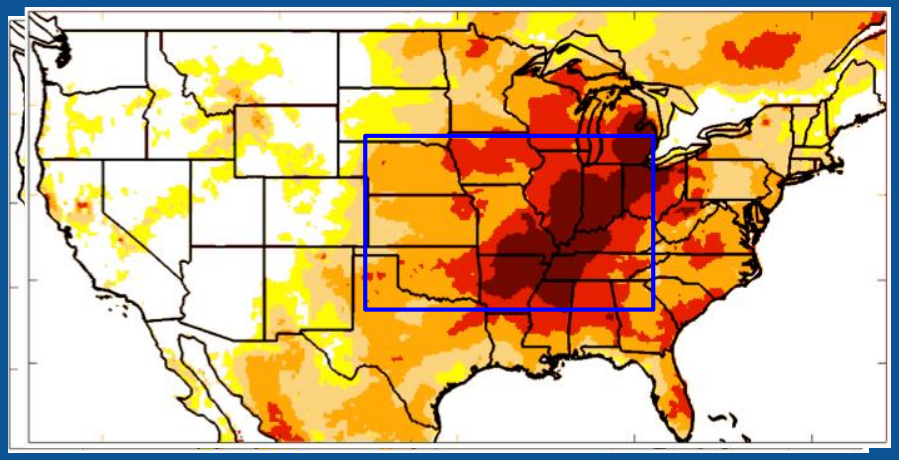
Evaporative Demand Drought Index

EDDI shows strong early warning potential-2012

May 31 August 7

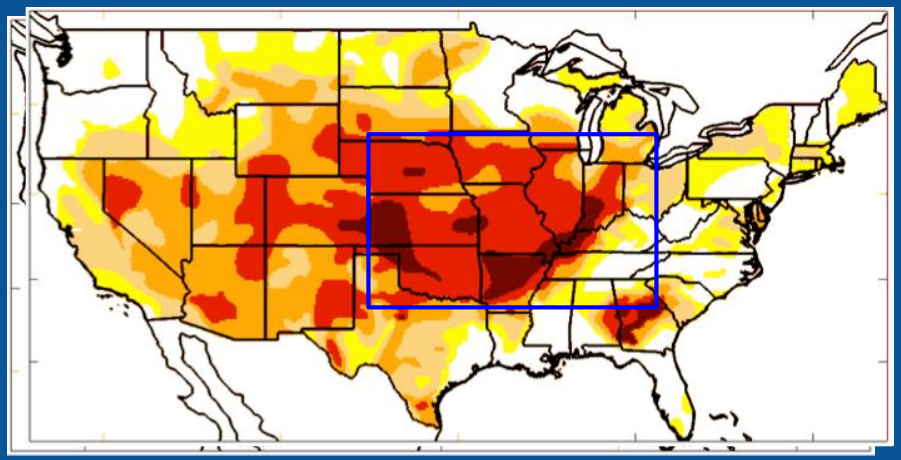
$$EDDI_j = \frac{\sum_{t=i}^{j}\left(ET_{0_t} - \overline{ET_{0_t}}\right)}{\sigma_{\overline{ET_{0_t}}}}$$

2-week *EDDI*



flash drought in MO, AR, KS, IL
drought developing in entire region
note little drought in western US

US Drought Monitor



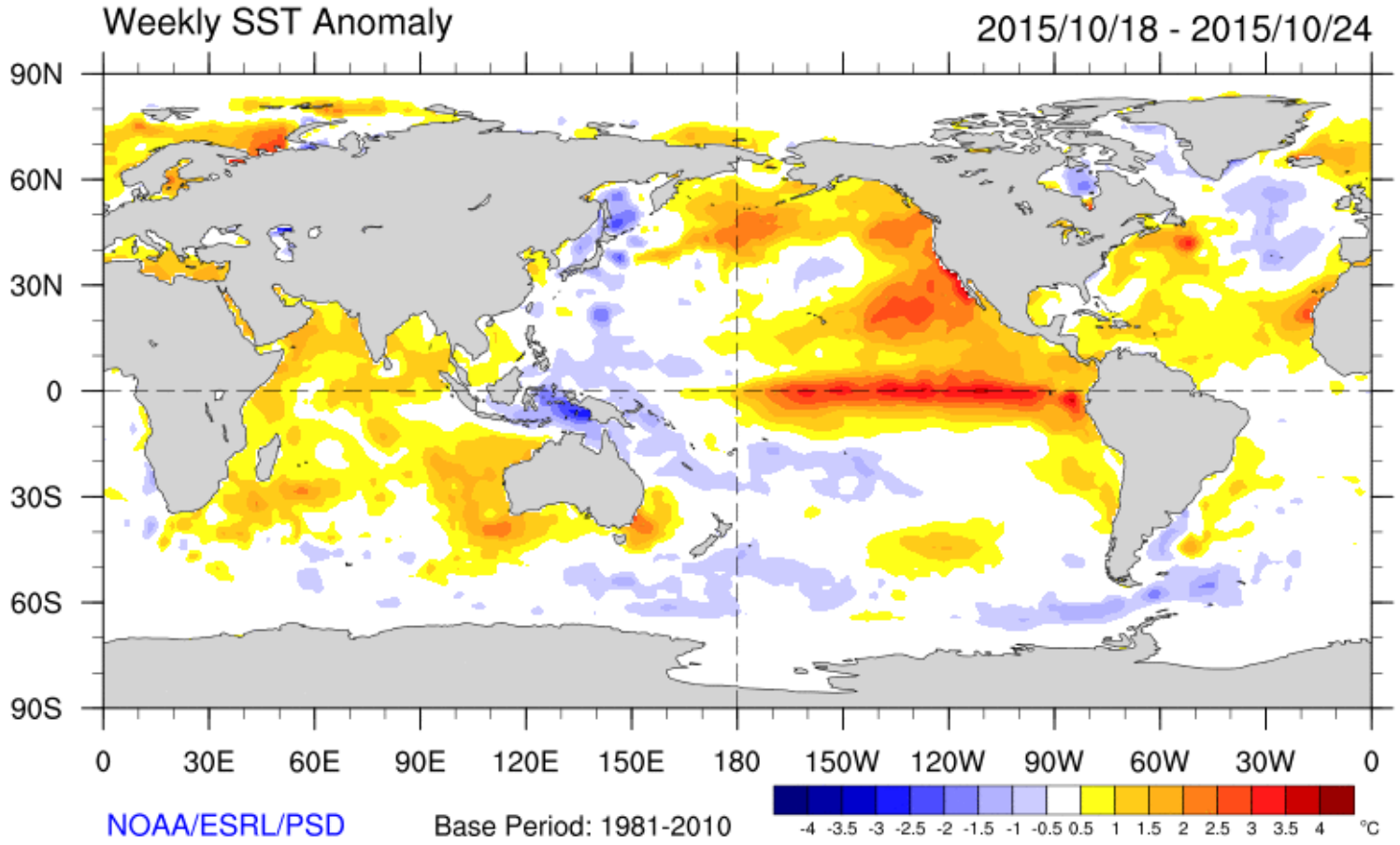
drought expanded to D3 over much of region;
D0, D1, D2, D3, D4;
drought in NY, PA, and VA 2 months after *EDDI*
no drought in MO, AR, OK, NE

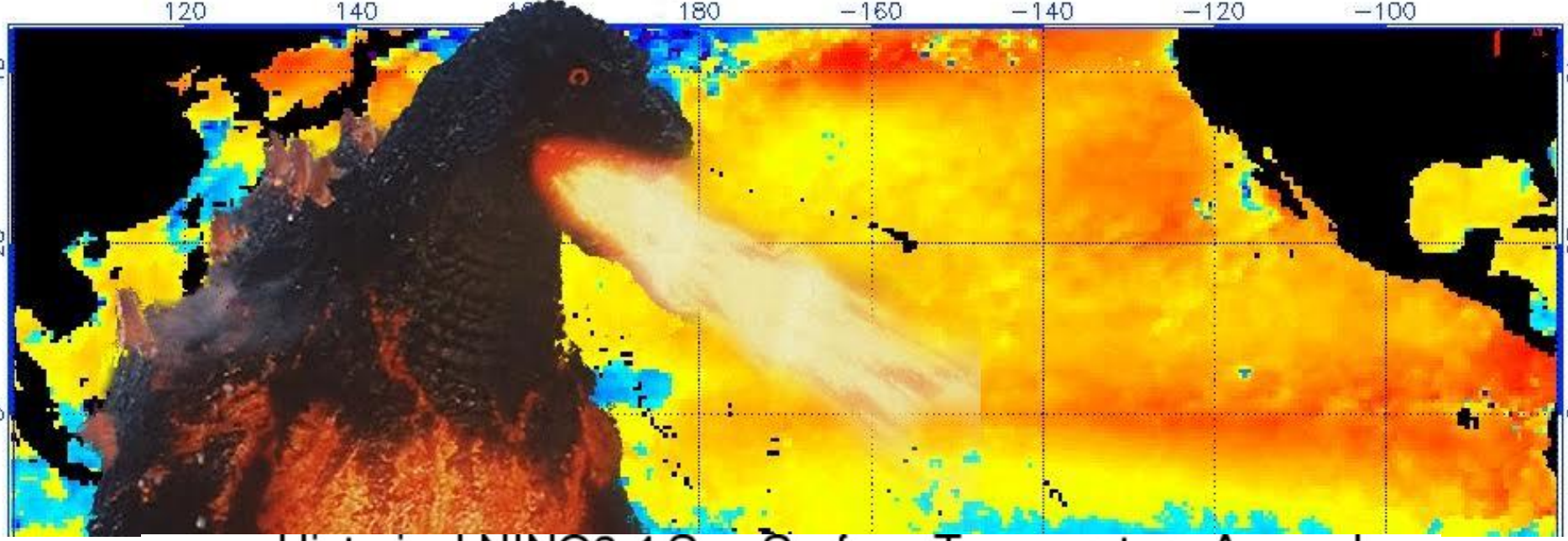
- Due to land-atmosphere feedbacks, evaporative demand (E_0) reflects surface moisture conditions, *often before ET does*,
  - responds positively to both flash droughts and sustained droughts.

Crop	Unit	USDA projection/ estimate as of:		Change	Percent change
		5/10/2012	1/11/2013		
Corn	$/bu	4.60	7.40	2.80	60.9
Soybeans	$/bu	13.00	14.25	1.25	9.6
Sorghum	$/bu	4.25	7.30	3.05	71.8
Rice	$/cwt	15.8	14.9	-0.9	-5.7
Wheat	$/bu	6.10	7.90	1.80	29.5
Cotton	Cts/lb	75.0	68.5	-6.5	-8.7

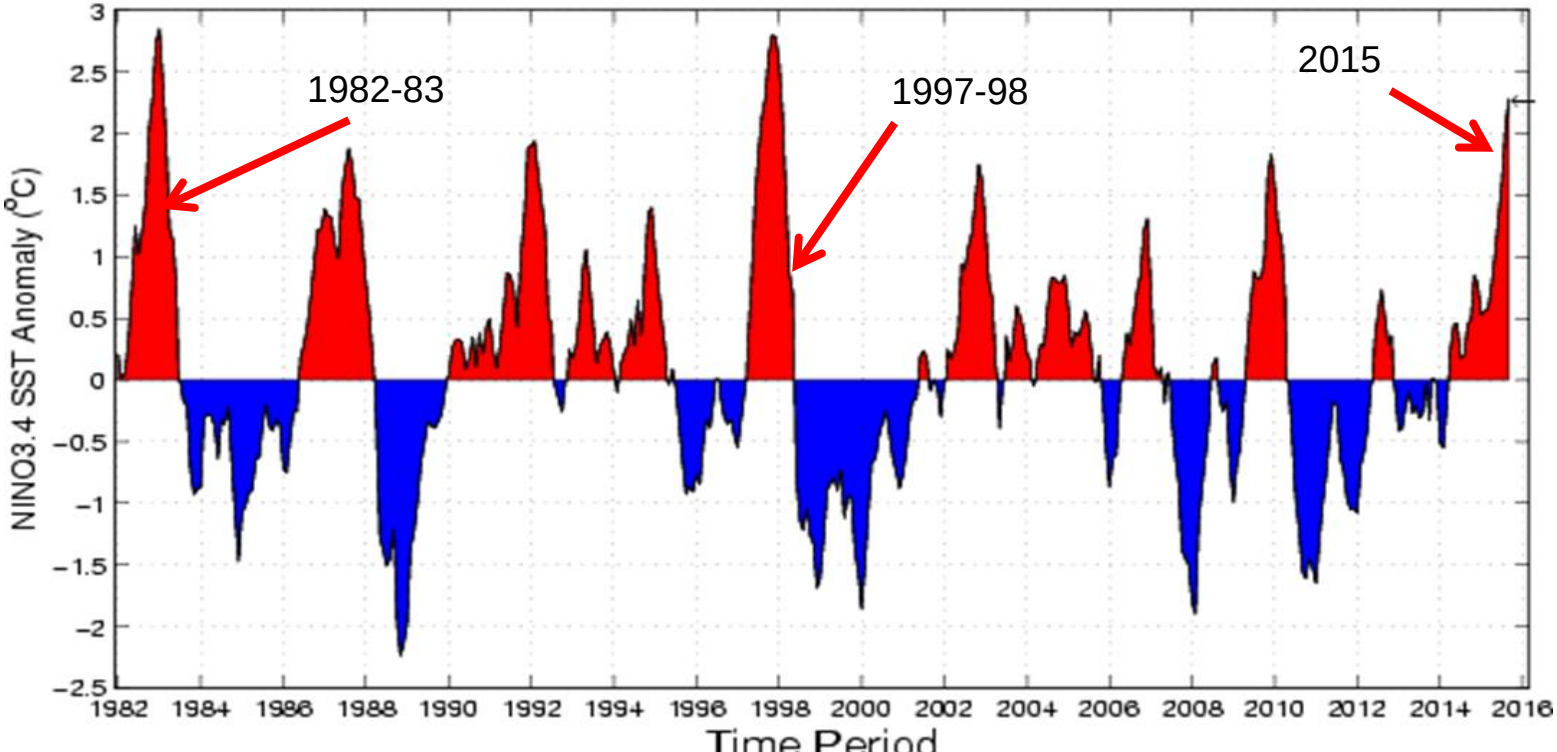
El Niño

Anomalous oceanic and atmospheric conditions in the Pacific that influences climate around the world



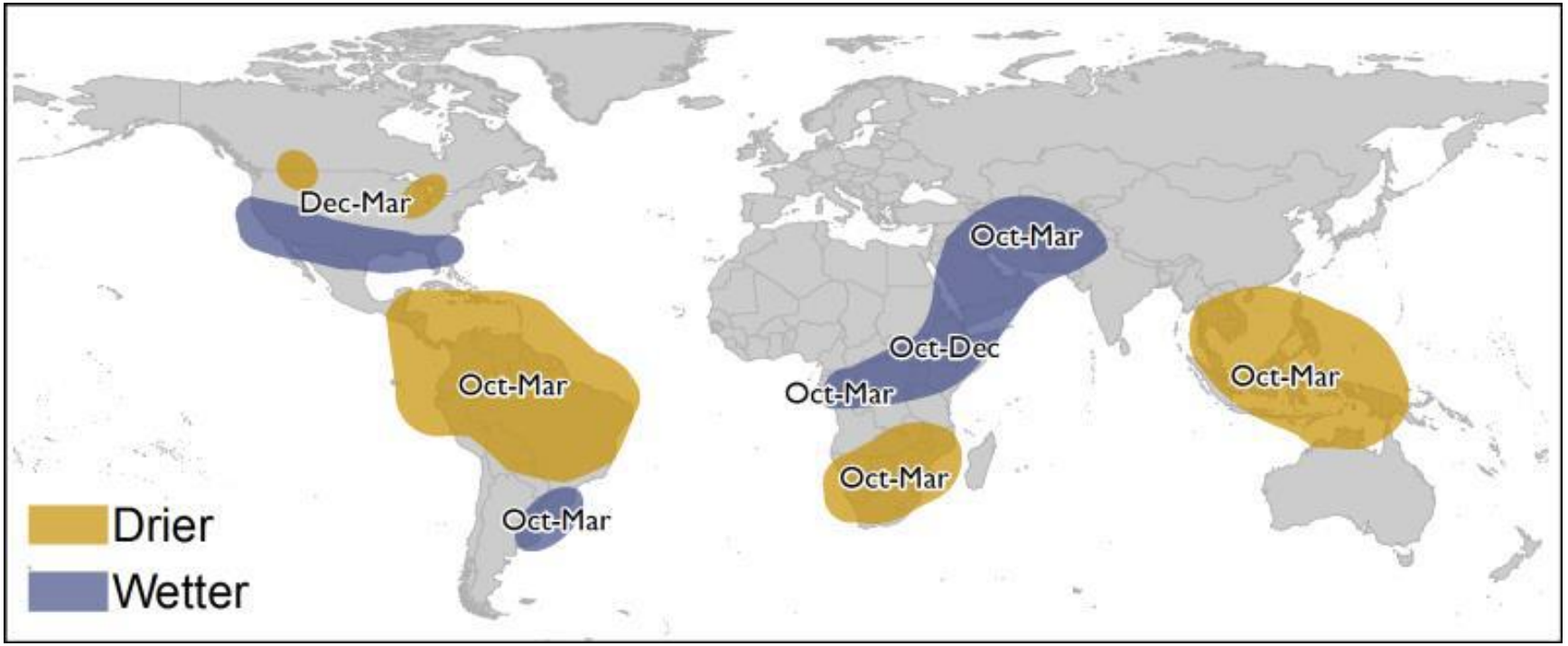


Historical NINO3.4 Sea Surface Temperature Anomaly

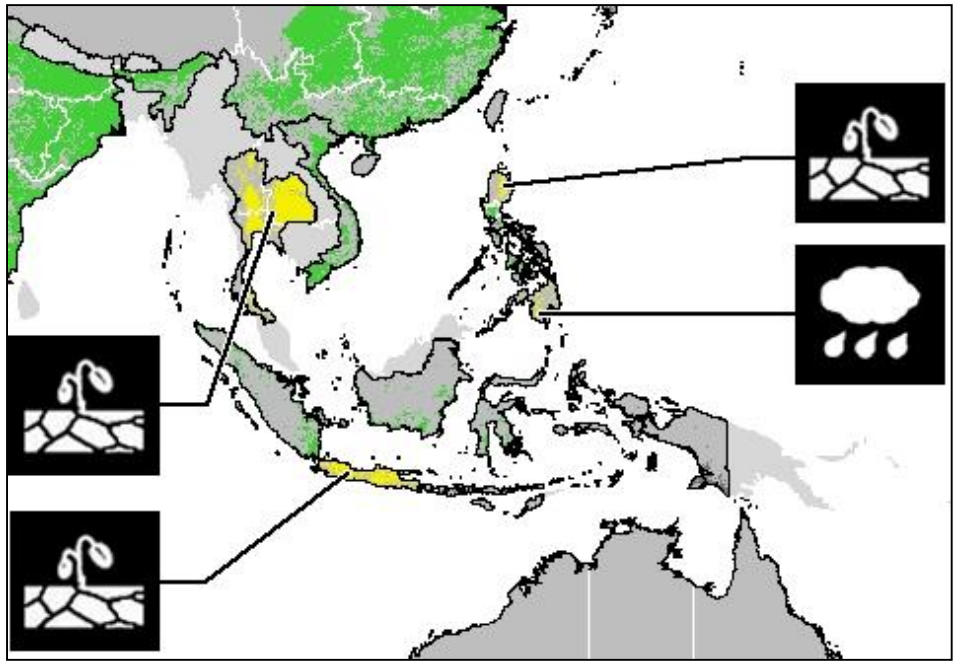


Forecasting El Niño impacts

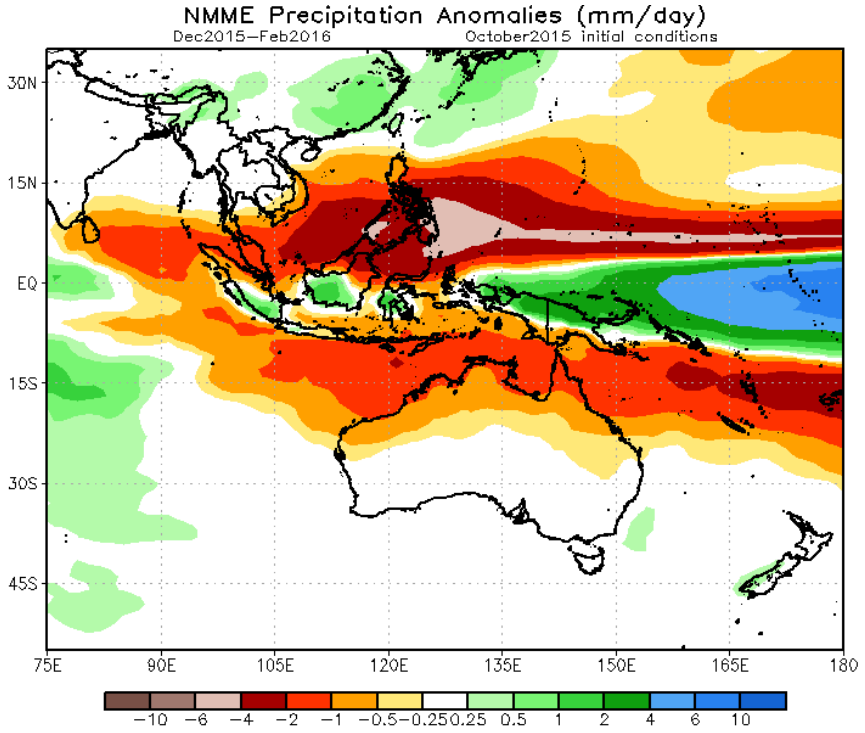
October 2015 – March 2016



SE Asia Rice Producing Countries



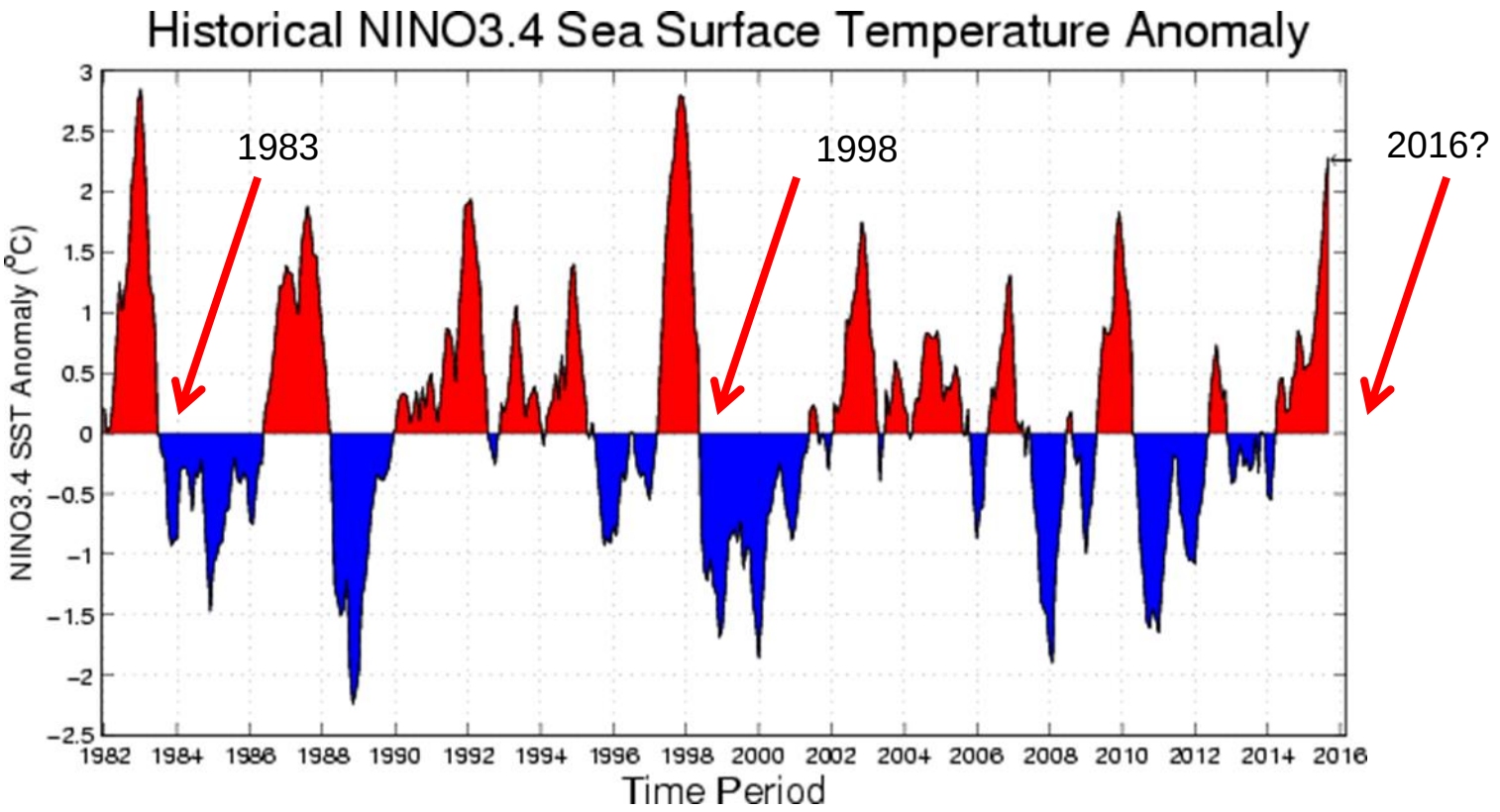
GEOGLAM AMIS Crop Monitor – Oct 2015



Forecast DJF 2015-2016

Drought Impact on Rice Crops:
Thailand, northern Philippines, southern Indonesia

Rapid Transition to La Niña?



U.S. Winter Wheat Abandonment: The Ten Worst Years, 1909-2009

1.	1917	34%	1916-17 Cold Phase
2.	1933	32%	Neutral
3.	1935	29%	Neutral
4.	2002	29%	1998-2001 Cold Phase
5.	1951	29%	1949-50 Cold Phase
6.	1989	25%	1988-89 Cold Phase
7.	1936	24%	Neutral
8.	1955	24%	1954-57 Cold Phase
9.	1928	24%	1928-29 Cold Phase
10.	2001	24%	1998-2001 Cold Phase

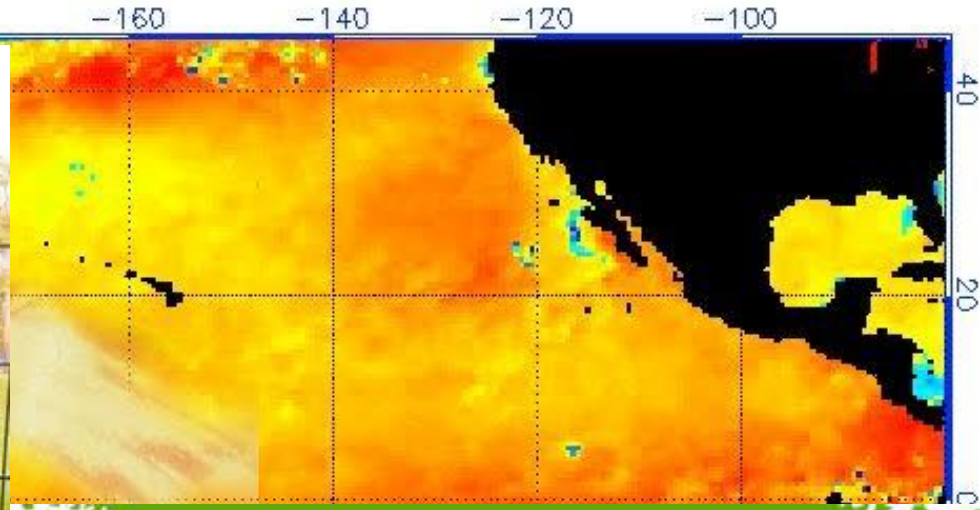
USDA

- La Niña increases the risk of winter wheat abandonment on the Great Plains (e.g. 1951, 1955, 1989, 2001), often the year following development

- La Niña is not a consistent indicator of low corn yields, but low yields sometimes do occur (e.g. 1954, 1964, 1974, 1988)—often during the year of onset

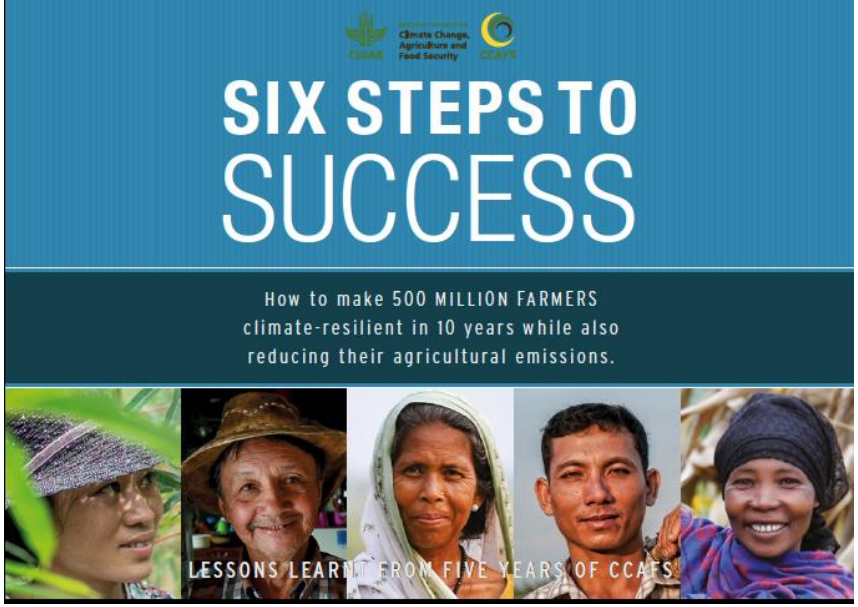
- Hot, dry Midwestern conditions immediately following a wet El Niño regime (e.g. 1983, 1995) can be devastating to corn because shallow-rooted crops suffer as previously soggy soils are baked into concrete.

Using the forecast



“Hotspots”

- Increasing pressure on Federal agencies, donors and development organizations to show that scarce public resources are being used in a responsible manner
- Spatial indicators and hotspots maps hold the promise of transparent, “scientific”, and defensible priority setting
- Many hotspots mapping efforts are affected by the spatial scale and uncertainties in the available global data sets. e.g. inconsistent patterns for water security



CGIAR
Climate Change, Agriculture and Food Security
"Climate-smart agriculture"

- Expanding the evidence base and assessment tools to identify agricultural growth strategies for food security
- Integrate adaptation and potential mitigation
- Building policy frameworks and consensus to support implementation
- Strengthening national and local institutions to enable farmer management of climate risks Adoption of context-suitable agricultural practices, technologies and systems
- **Enhancing financing options to support implementation, linking climate and agricultural finance**

Oscar Selfie Worth as Much as $1 Billion
Oscar photo of host DeGeneres with **Bradley Cooper**, **Jennifer Lawrence**, **Julia Roberts**, **Brad Pitt**, **Meryl Streep, Kevin Spacey** and others

World's highest net worth selfie? $1 trillion in one shot

Walmart's Sustainability Product Expo

Global Framework for Climate Services

Goal:

Enable better management of the risks of climate variability and change and adaptation to climate change at all levels, through development and incorporation of science-based climate information and prediction into planning, policy and practice.

World Meteorological Organization
Weather • Climate • Water

WORLD CLIMATE CONFERENCE - 3

Geneva, Switzerland

31 August–4 September 2009

Characteristics of decisionmaking

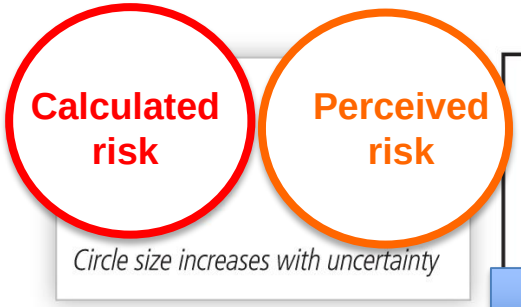
Calculated risk

Perceived risk

AR5 identified a lack of progress in developing implementation pathways for adaptation: in essence noting the need to move from assessment to adaptation action

Characteristics of decisionmaking

Circle size increases with uncertainty



Characteristics of decision making	Simple Risk	Complicated Risk	Complex Risk
Methodology	Linear, cause and effect	Top down and/or bottom up, iterative	Iterative and/or adaptive, ongoing and systemic
Approach	Analytic and technical	Collaborative process with technical input	Process driven. Frame and model multiple drivers and valued outcomes
Stakeholder strategy	Communication	Collaboration	Deliberation, creating shared understanding and ownership
Mental models	Common model	Negotiated and shared	Contested initially and negotiated over project
Values and outcomes	Widely accepted	Negotiated over project by user perspectives and calculated risk	Contested initially and negotiated over project
Monitoring	Straightforward	With review and trigger points	As real-time as possible, adaptive with management feedback and trigger points

AR5 also identified a lack of progress in developing implementation pathways for adaptation: in essence noting the need to move from assessment to adaptation action

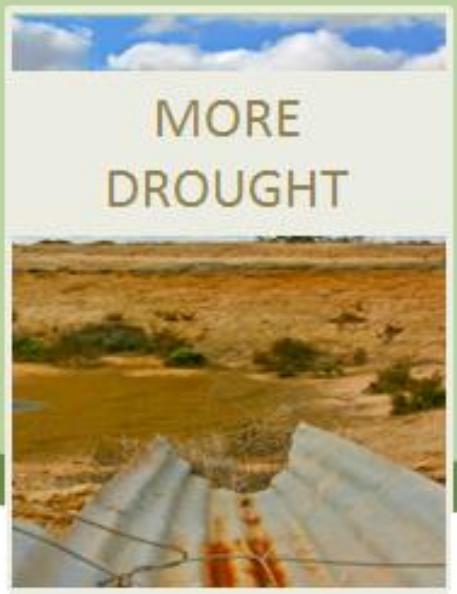
RAIN

Apathy

DROUGHT

"Hydro-Illogical" Cycle

Panic

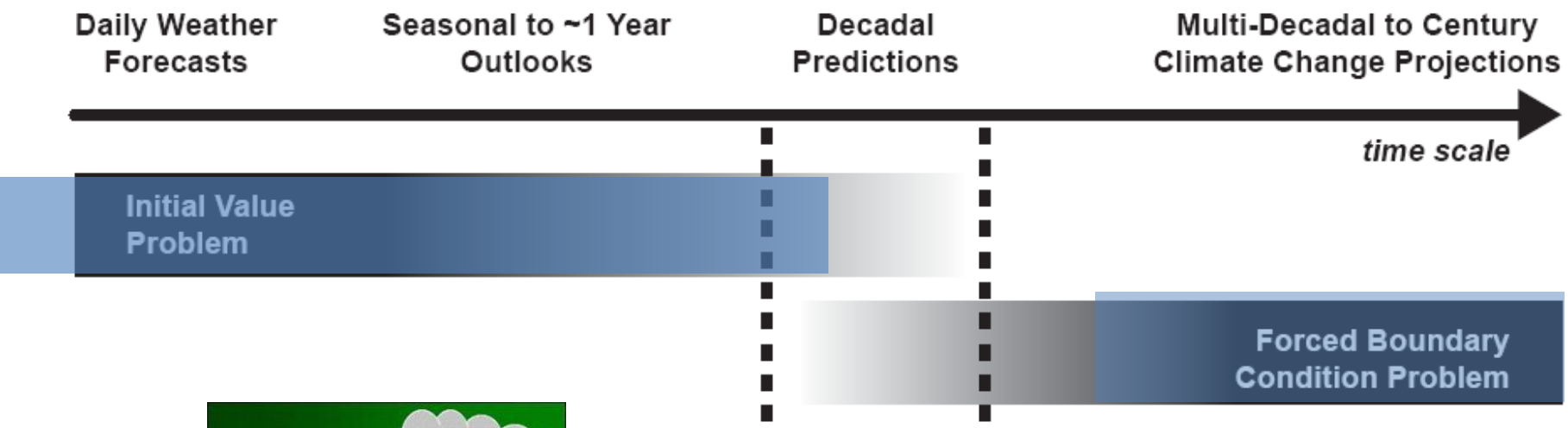


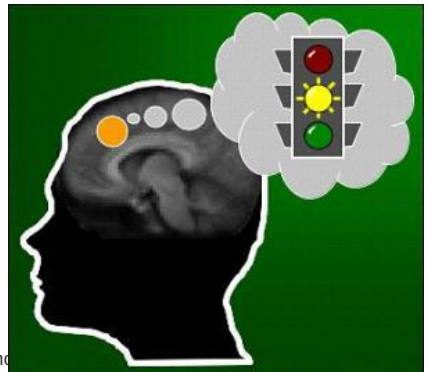
MORE DROUGHT

Concern

1. Acknowledge the cross-timescale nature of climate and of early warning information

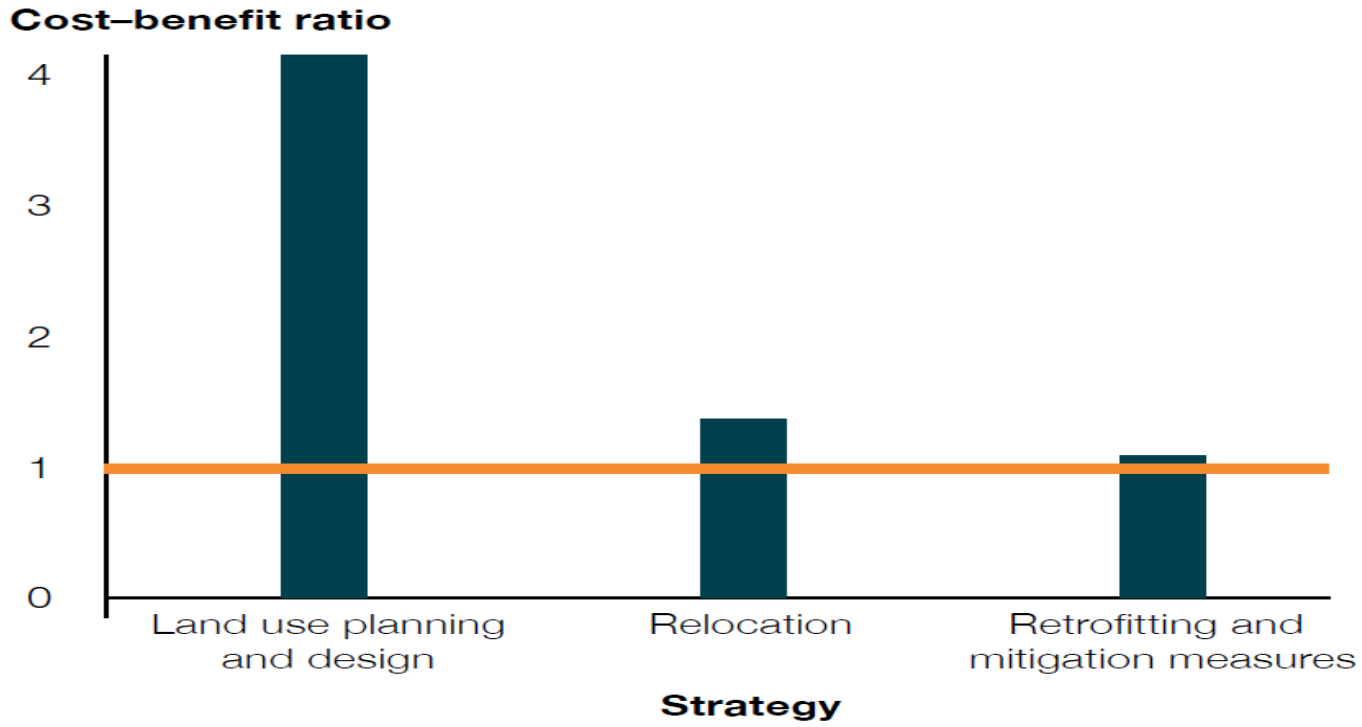
Improved understanding of long-term variations of largest storms-dictate the occurrence of droughts in California



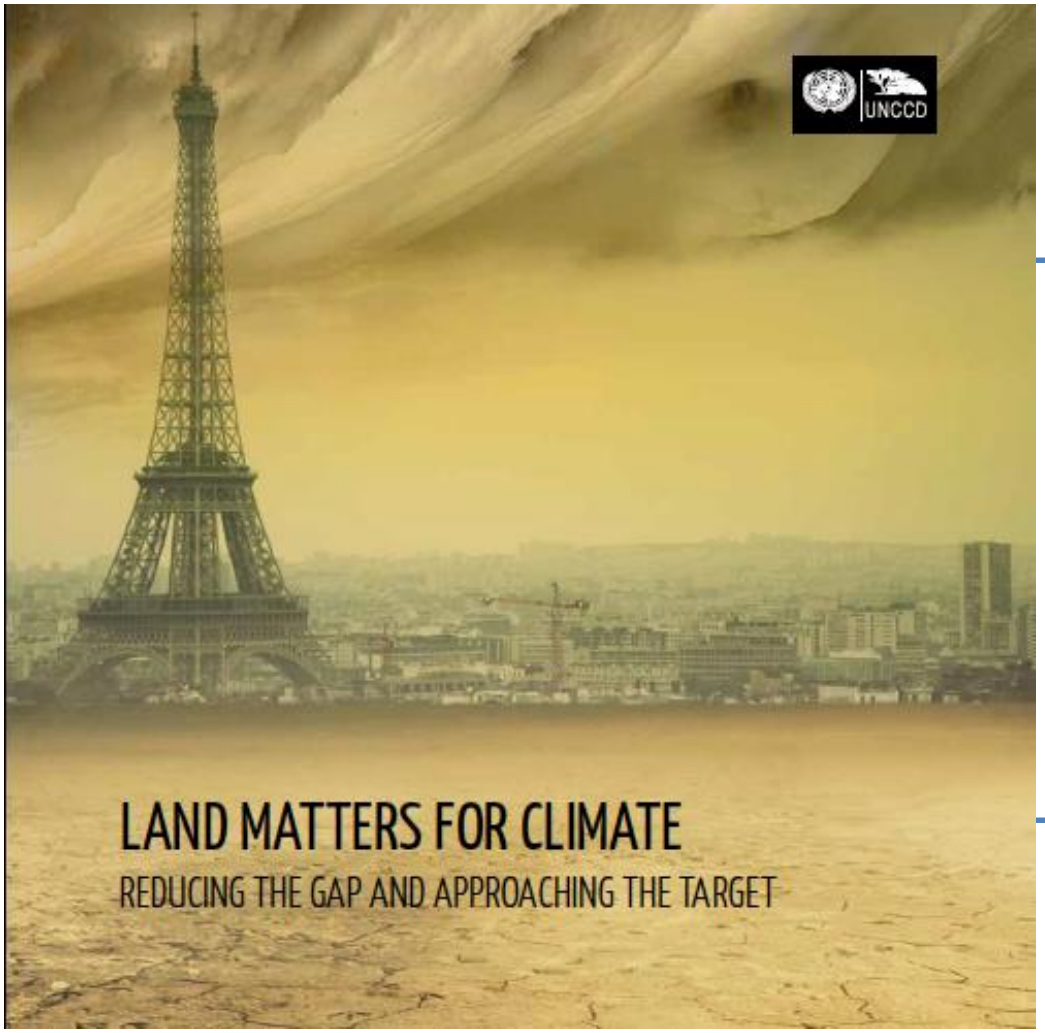


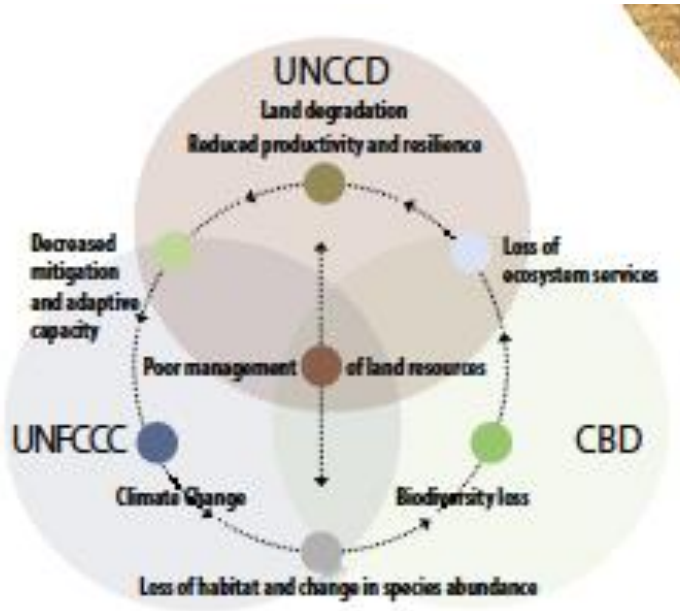
Multi-year droughts are, at present, not addressed by any forecast system, clearly a gap in our capabilities

2. Recognize alternative means of addressing water security Best adaptation practices may be novel configurations of efficiency and land and water resources



SMART Growth Conservation costs savings on 22 water city and district water plans in Colorado-water obtained by conservation is still the cheapest option per AF for development (Kenney et al 2010)


UNCCD
LAND MATTERS FOR CLIMATE
REDUCING THE GAP AND APPROACHING THE TARGET

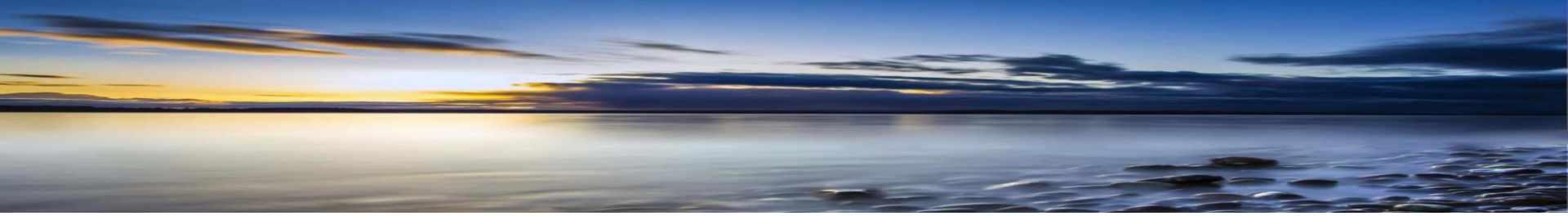

UNCCD
Land degradation
Reduced productivity and resilience
Decreased mitigation and adaptive capacity
Loss of ecosystem services
Poor management of land resources
UNFCCC
CBD
Climate change
Biodiversity loss
Less of habitat and change in species abundance

3. Recognize "communication" as critical but not sufficient

Broad societal processes that create dynamic pressures and unsafe conditions are not easy to change, yet are fundamental to human vulnerability

A social process -beyond one and even "two-way" communication

More challenging is an understanding the socialization of lessons learned by particular individuals and organizations through their own, direct trial and error experiences



If we only knew the “tradeoffs”…….

Revenue produced by using an acre-foot of water for:

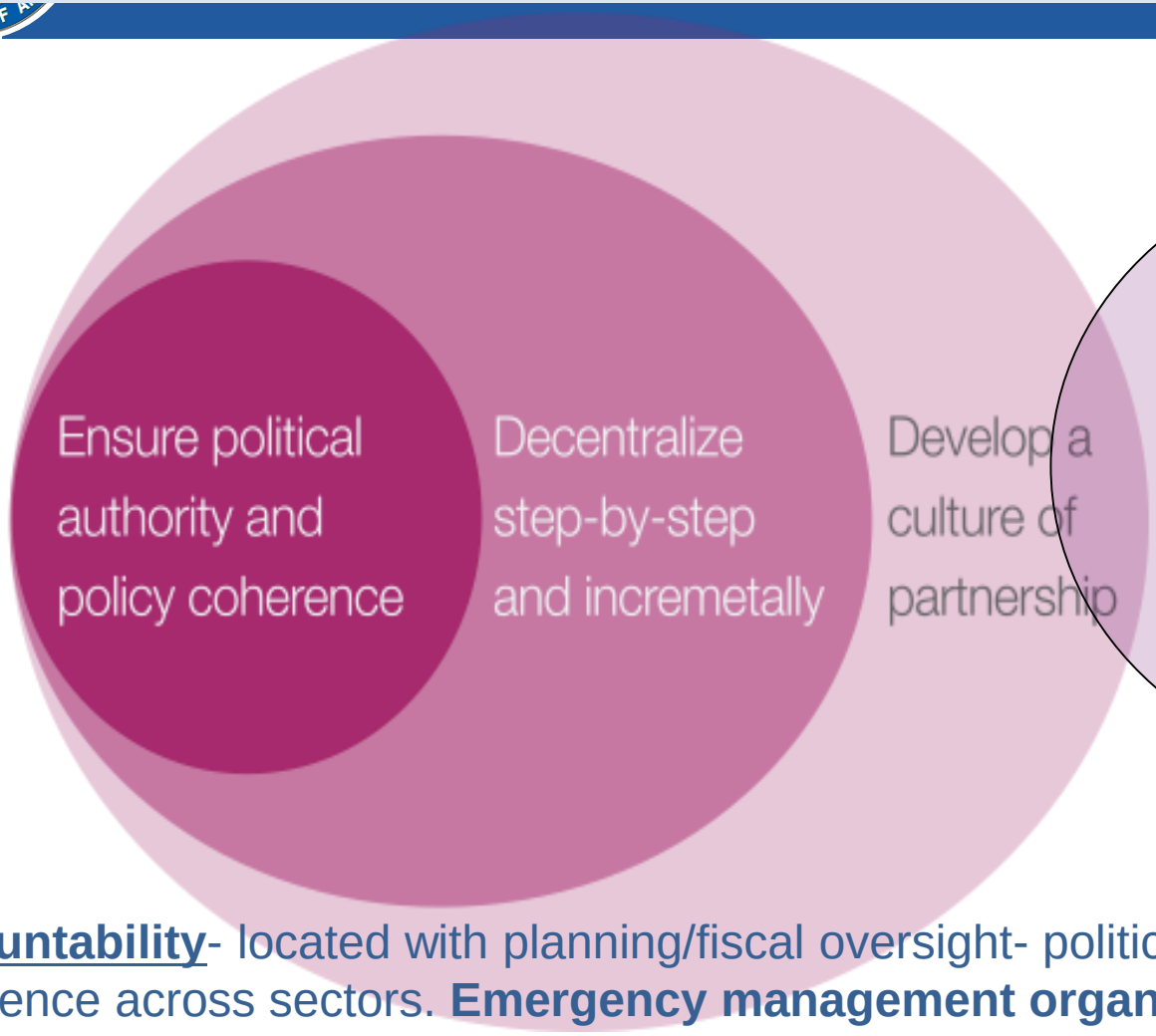
1. Alfalfa: $920
2. Lettuce: $6,000
3. Intel to manufacture core 2 duo chips: $13 million

(Glennon, 2015)

If only we could assess future risks with greater…… certainty……

Damon Winter
The New York Times
April 4, 2015

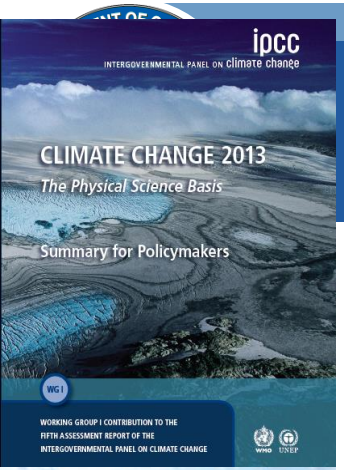
4. Focus on institutions and capacity: risk management governance

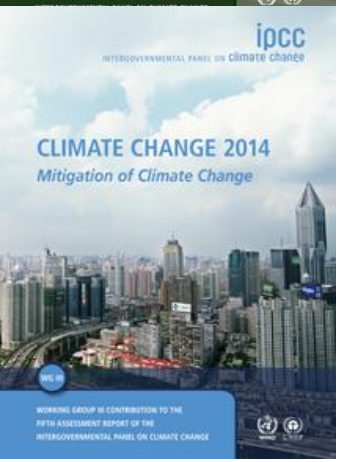


Partners do not just share information-they also share risks and responsibilities

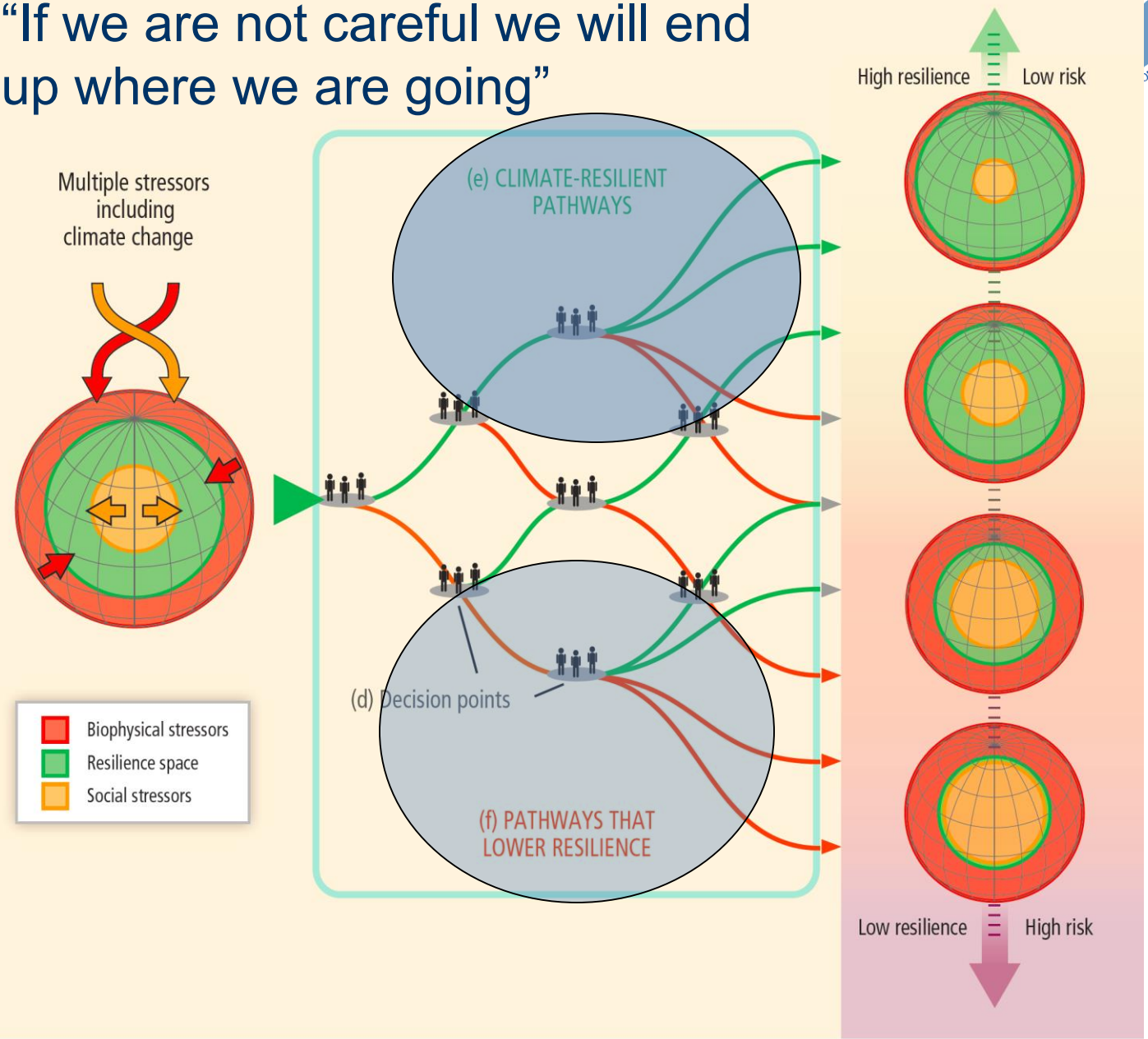
Accountability- located with planning/fiscal oversight- political authority and policy coherence across sectors. **Emergency management organizations can rarely play that role**

Efficiency- achieved in partnership with at-risk sectors and local communities and organizations that represent them-

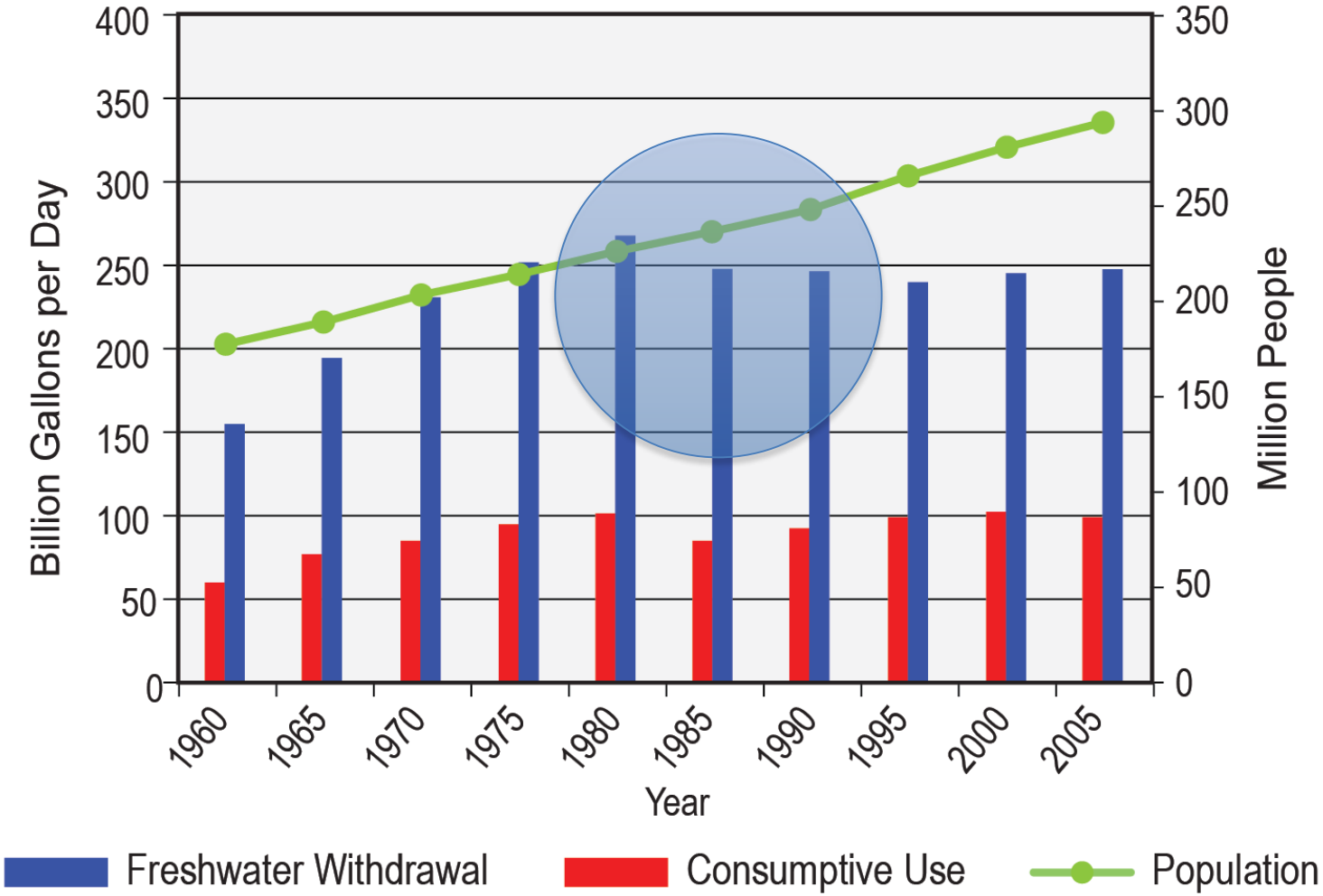


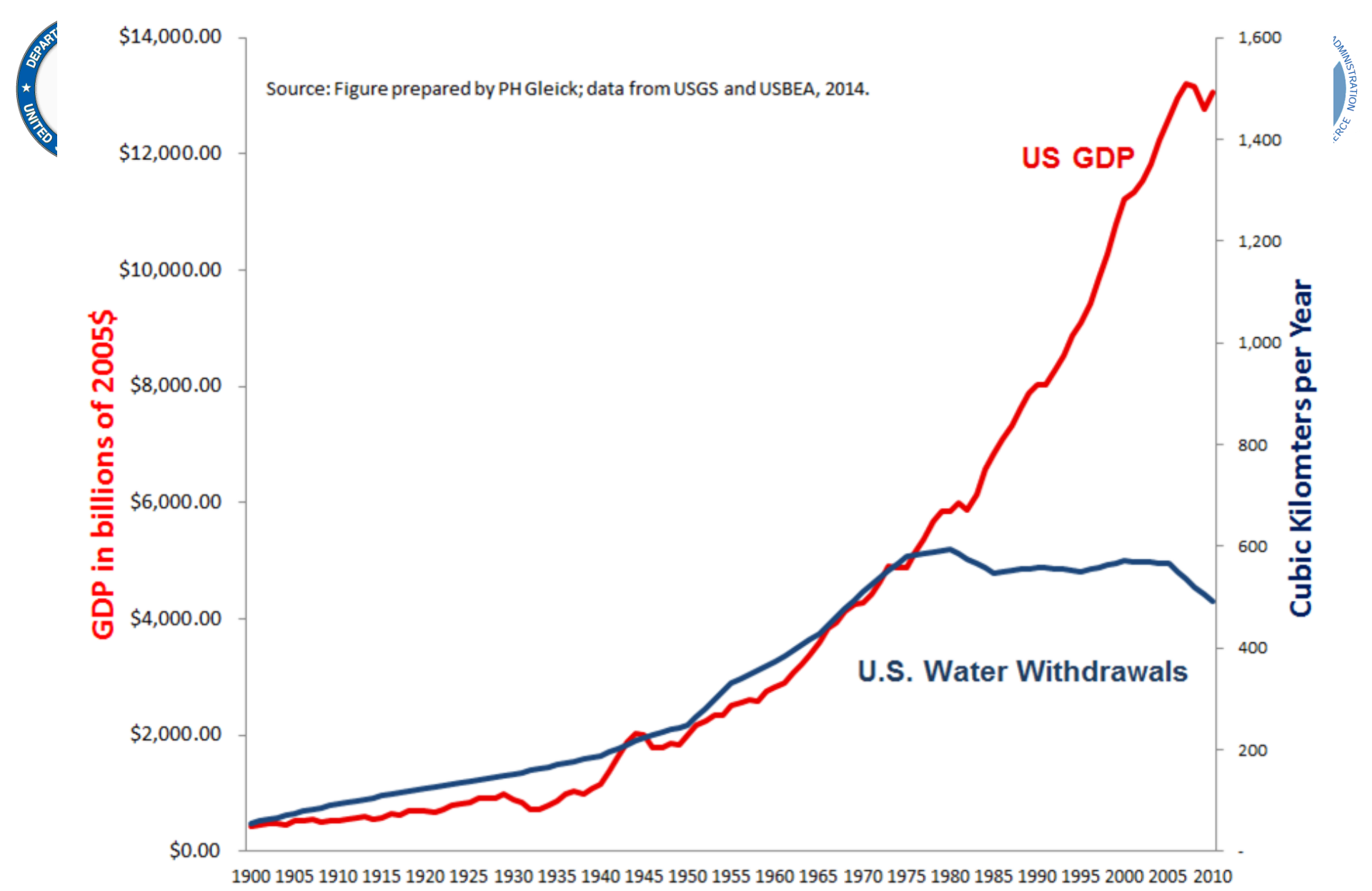


"If we are not careful we will end up where we are going"



U.S. Freshwater Withdrawal, Consumptive Use, and Population Trends




Source: Figure prepared by PH Gleick; data from USGS and USBEA, 2014.
US GDP
U.S. Water Withdrawals
GDP in billions of 2005$
Cubic Kilomters per Year
$14,000.00
$12,000.00
$10,000.00
$8,000.00
$6,000.00
$4,000.00
$2,000.00
$0.00
1,600
1,400
1,200
1,000
800
600
400
200
-
1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010

- Drought driven by natural variability (sea surface temperatures, soil moisture conditions), climate change (increases in temperature and regional shifts in precipitation), and increased human water demand

- Temperature increases are projected to be a continuing and increasing factor in the changing hydroclimate

- Significant, valuable research enterprise involving federal agencies, and academic partners to improve understanding, monitoring, predictions, and projections of drought e.g. GEOGLAM, NSMN

http://earthobservatory.nasa.gov/IOTD/view.phpid=85887

The fundamental adaptation question: When/How often should we revise our assumptions?

Improving scientific and institutional knowledge, agility and alignment: Regional Research Collaboration Networks

:

- Food production assessments linked with food security assessments
- Information services to support adaptation in changing environments
- Empirical evidence on the effectiveness of technological interventions and social adaptations at all levels of the food system

Most critical will be development of sustained networks across institutions to ensure that lessons being learned, as risks and opportunities emerge, become embedded in practice, and inform the choice of pathways for resilience.

When was the Summer of Love? Watergate?-

The year is 2015

We are closer to 450 ppm and 9 000 000 000 000 people than to either of these

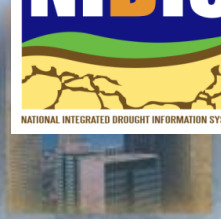
Thank you

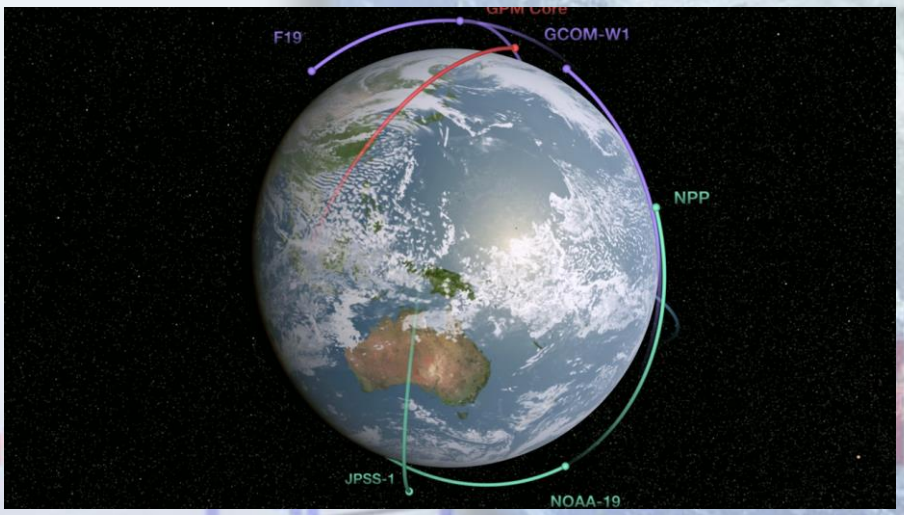
drought.gov











Drought.gov

Coordination

Transitioning Cereal Systems to Adapt to Climate Change

REACCH
Regional Approaches to Climate Change –
PACIFIC NORTHWEST AGRICULTURE

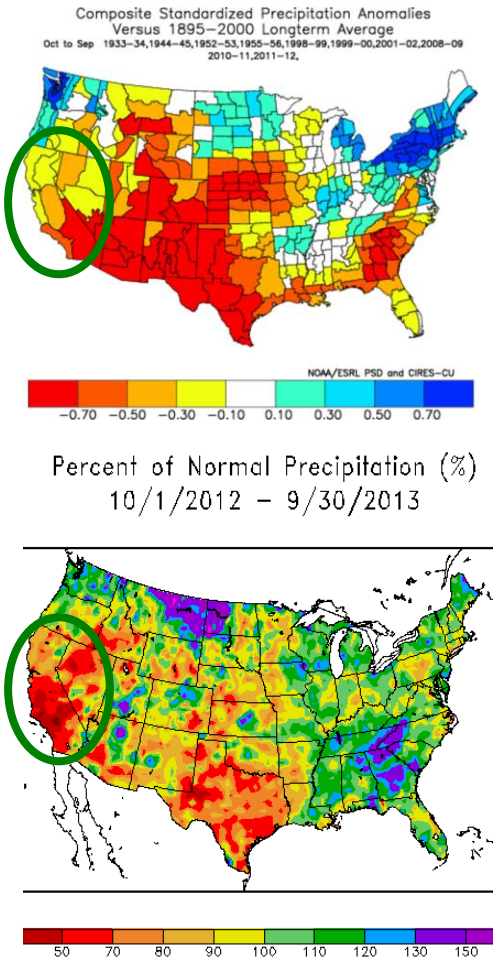
Thank you

You cannot solve the problem with the same kind of thinking that created the problem

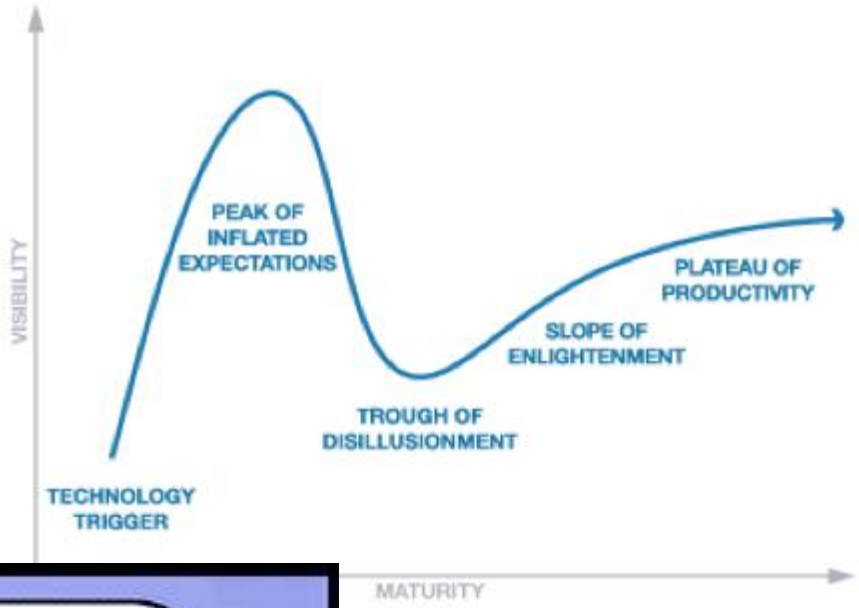
Albert Einstein

Forecasts of Opportunity – 'Analogues'

- Summer of 2012 had the most extreme combination of negative PDO and positive AMO in over a century
- This spelled continued drought conditions for CA-was a successful forecast

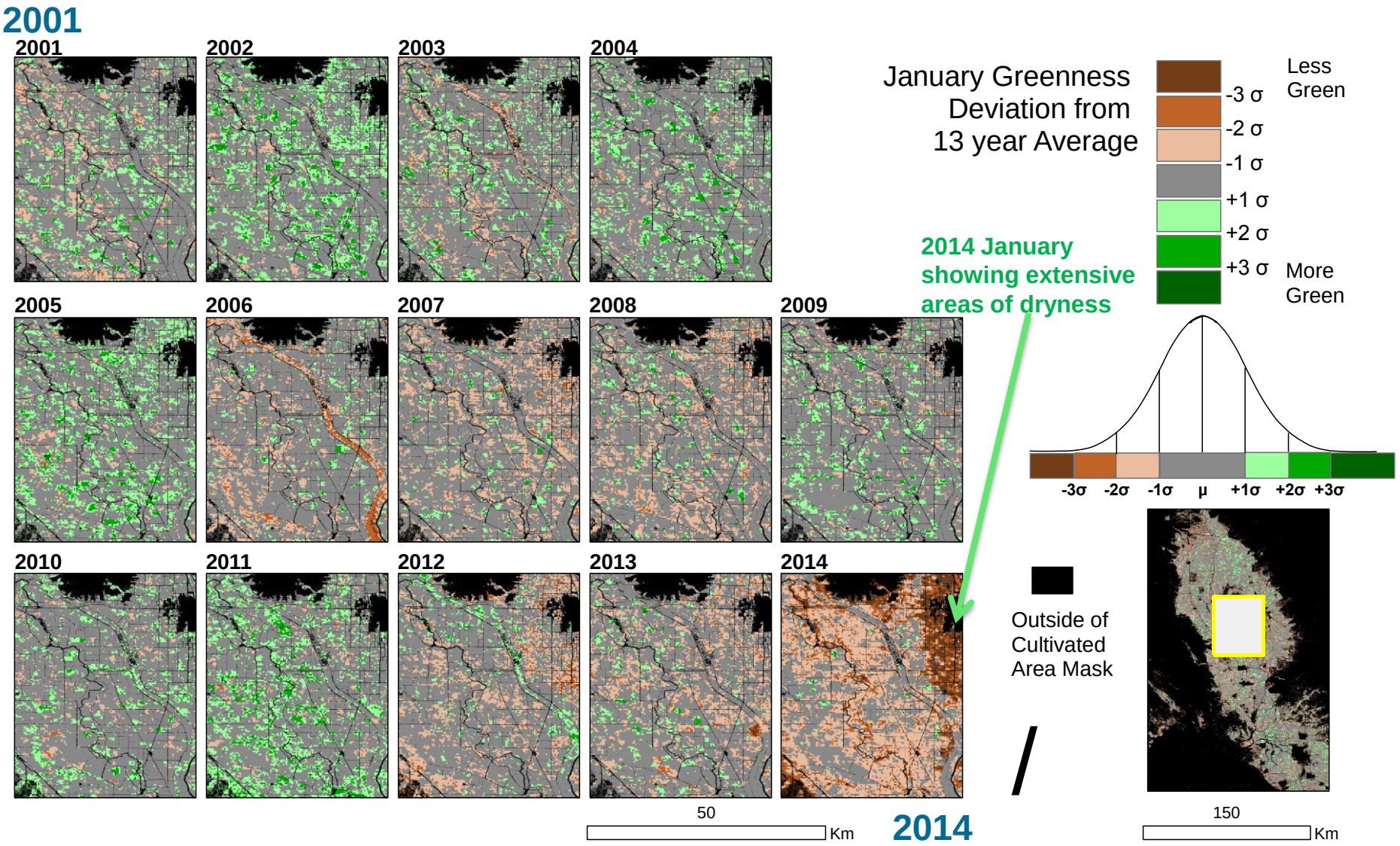


Wolter, 2015

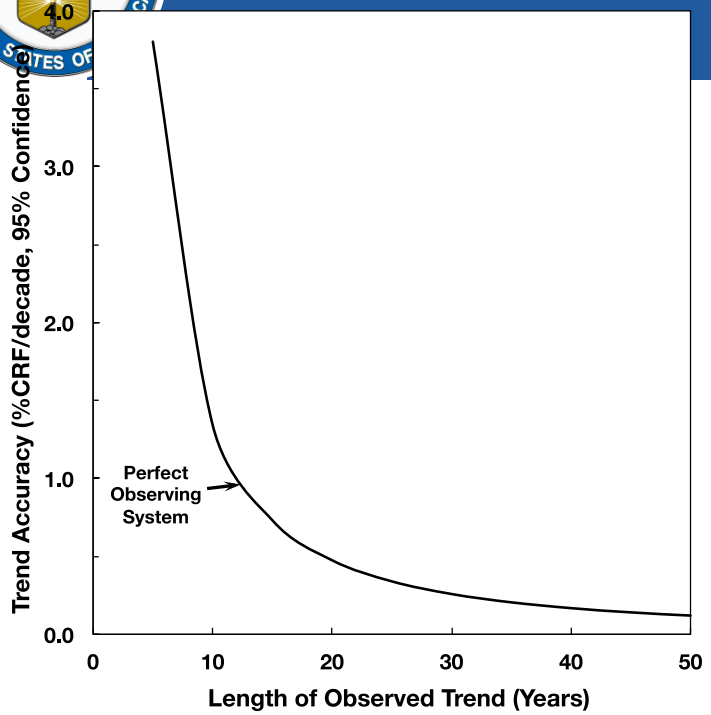

VISIBILITY
PEAK OF INFLATED EXPECTATIONS
PLATEAU OF PRODUCTIVITY
SLOPE OF ENLIGHTENMENT
TROUGH OF DISILLUSIONMENT
TECHNOLOGY TRIGGER
MATURITY


USING IT
IS THE HARDEST PART.
BIG
DATA

A 35% (400,000 acre) increase in fallowing was observed in 2014 relative to 2011, a year of normal water availability-state resources for county food banks



NIDIS, NASA, USDA, USGS, NOAA and the California Department of Water Resources,



The length of time required to detect and attribute a climate trend caused by human activities is determined by:

- **Natural variability**
- **The magnitude of human driven climate change**
- **The accuracy of the observing and modeling systems**

The year in which we become 90% certain depends on our Earth observations, their accuracy, and their completeness

The economic value of advanced climate observing systems is dramatically larger than their cost
(Wielicki, Cooke et al, 2013)

We lack a comprehensive climate observing system capable of testing climate predictions with sufficient accuracy or completeness

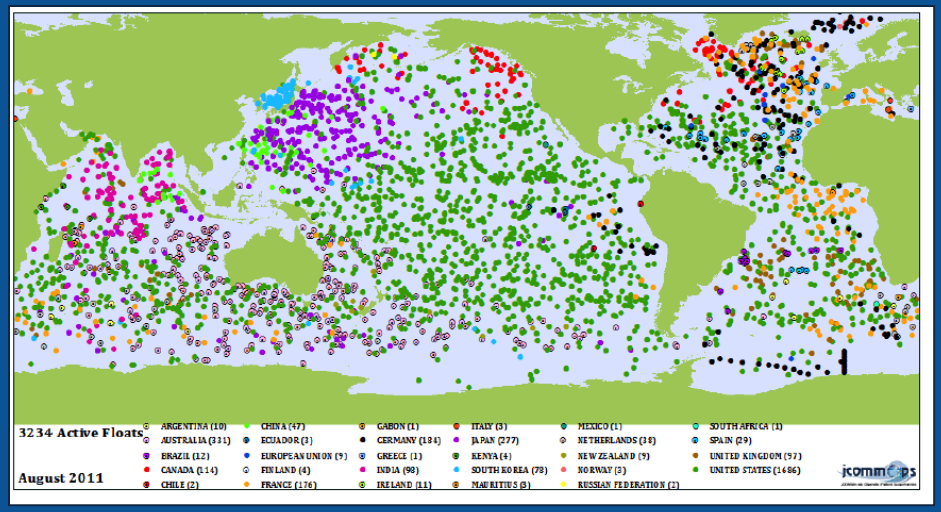
Improving cultivar tolerance to high temperature is a frequently identified adaptation for almost all crops and environments worldwide as high temperatures are known to reduce both yield and quality noting that a new cultivar usually takes between 8 and 20 years to deliver

- Breeding additional drought-tolerant crop varieties for enhanced storage and access to irrigation water, more efficient water delivery systems, improved irrigation technologies such as deficit irrigation, more effective water harvesting, agronomy that increases soil water retention through
- practices such as minimum tillage and canopy management,
- agroforestry, increase in soil carbon, and more effective decision support

There is medium confidence (limited evidence, high agreement) that crop adaptations can lead to moderate yield benefits (mean of 10 to 20%) under persistently drier conditions and that irrigation optimization for changed climate can increase yields by a median of 3.2% as well as having a range of other beneficial effect

Observations and Monitoring: **the current availability and quality of climate observations and impacts data to support adaptation appear inadequate for large parts of the globe**

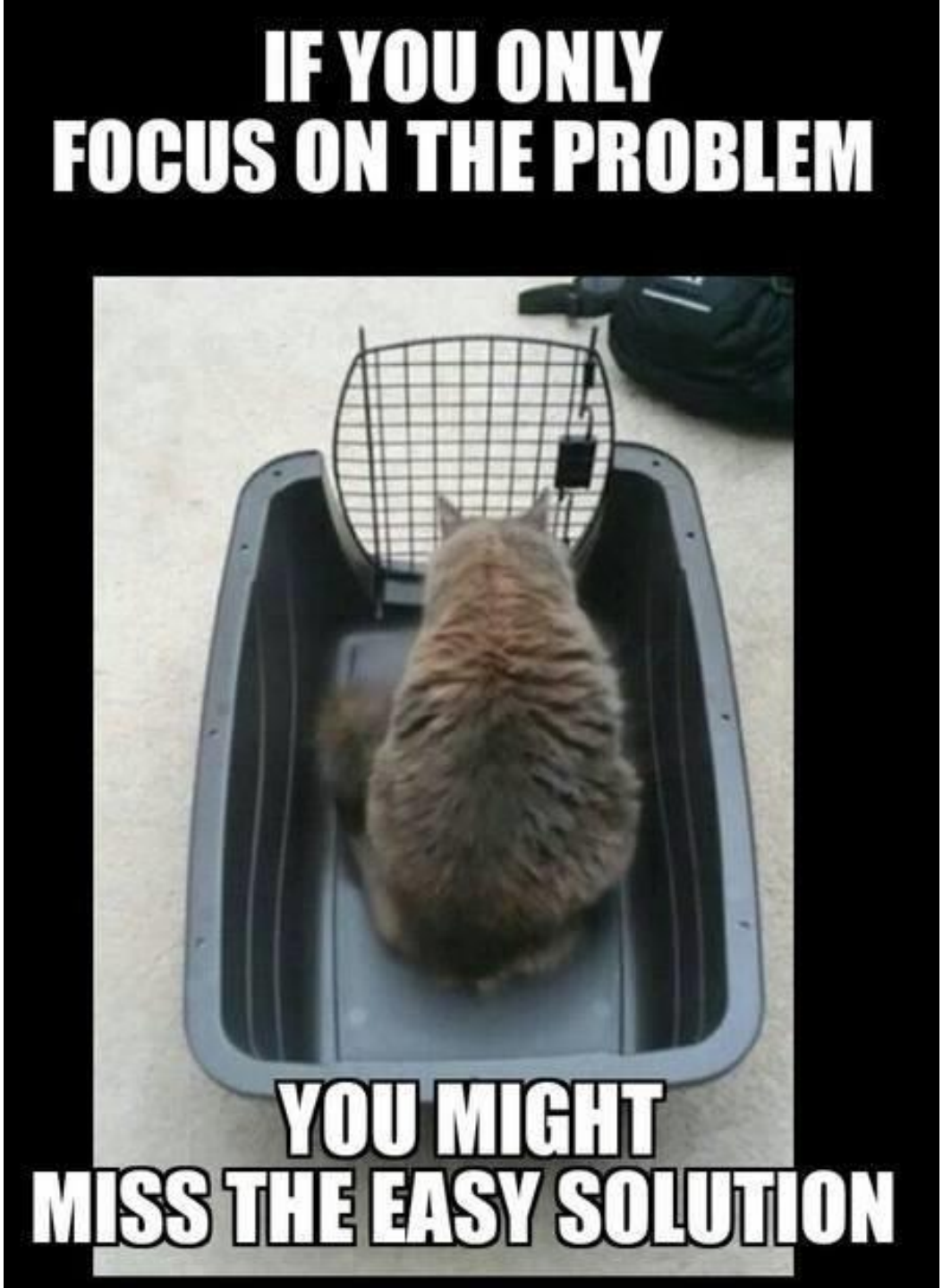
- Ocean
  - Global coverage
- Satellites
  - Weather and Climate
- Atmospheric
  - Global and domestic
- Capacity Building
  - WMO/IOC JCOMM



- Global Climate Observing System (GCOS)

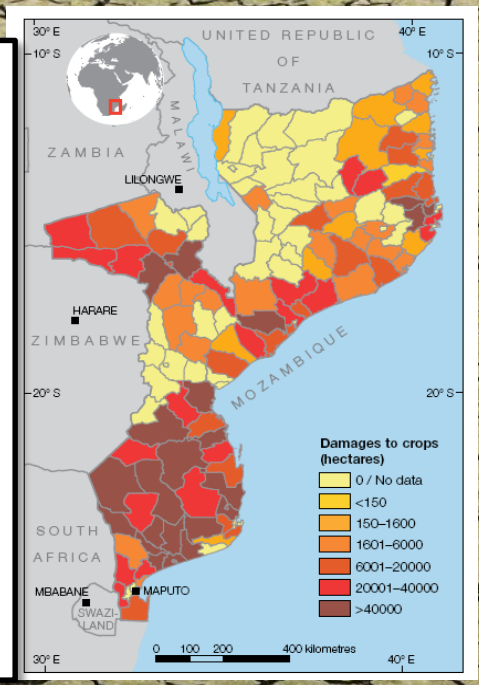
Improving scientific and institutional knowledge, agility and alignment: Regional Research Collaboration Networks

- Integrate into existing knowledge networks
- Quality: climate observations, research and information services that match user requirements
- Assess impediments to the flow of knowledge among existing components
- Policies and practices that can limit or facilitate research-partner networks working as a system
- Opportunities for learning and institutional innovation and identifying priorities back up the research chain-gaming scenarios


IF YOU ONLY
FOCUS ON THE PROBLEM
YOU MIGHT
MISS THE EASY SOLUTION

Most estimates of disaster losses exclude indirect losses – livelihoods, informal economies, intangible losses including ecosystem services, quality of life and cultural impacts

In some areas drying due to climate change will be overlain on the periodic events/droughts those areas have always experienced



Short-term actions do not always provide long term risk reduction-can reduce or increase longer-term risks

For exposed and vulnerable communities, even non-extreme weather and climate events can have extreme impacts

ISDR

ipcc
INTERGOVERNMENTAL PANEL ON climate change