Climate Change and Adaptation

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Energy **Adaptation**

Mitigation **Effects**

Presented at the
American Institute of Aeronautics and Astronautics Meeting
Climate Change Engineering, Science & Public Policy
Houston, Nov 3, 2015

Plan of talk

Will Cover 4 items

- **Some recent Climate Change Evidence**
- **What is causing this and what are future prospects**
- **What about vulnerability under projections?**
- **What about adaptation?**
  - ➢ **The adaptation imperative**
  - ➢ **What we have seen happen so far**
  - ➢ **Some elements of adaptation program design**

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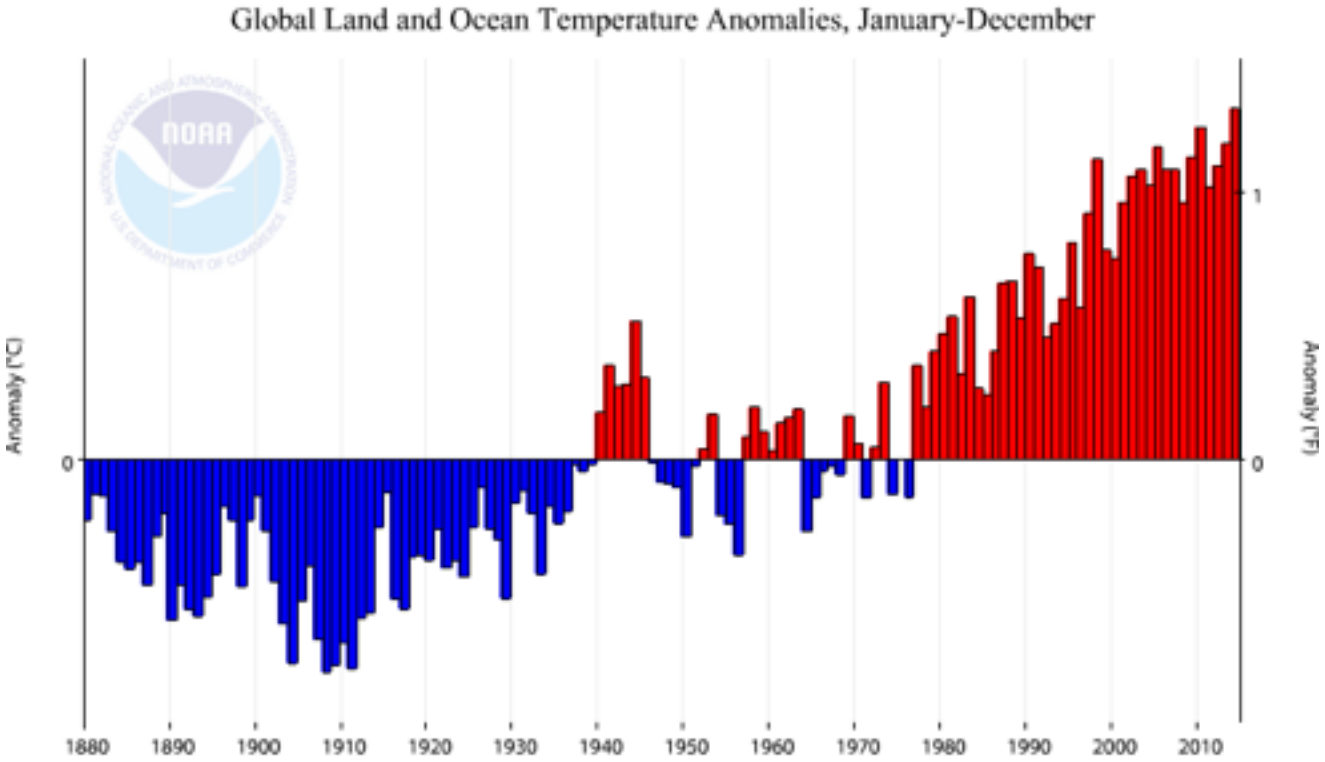
What have we seen

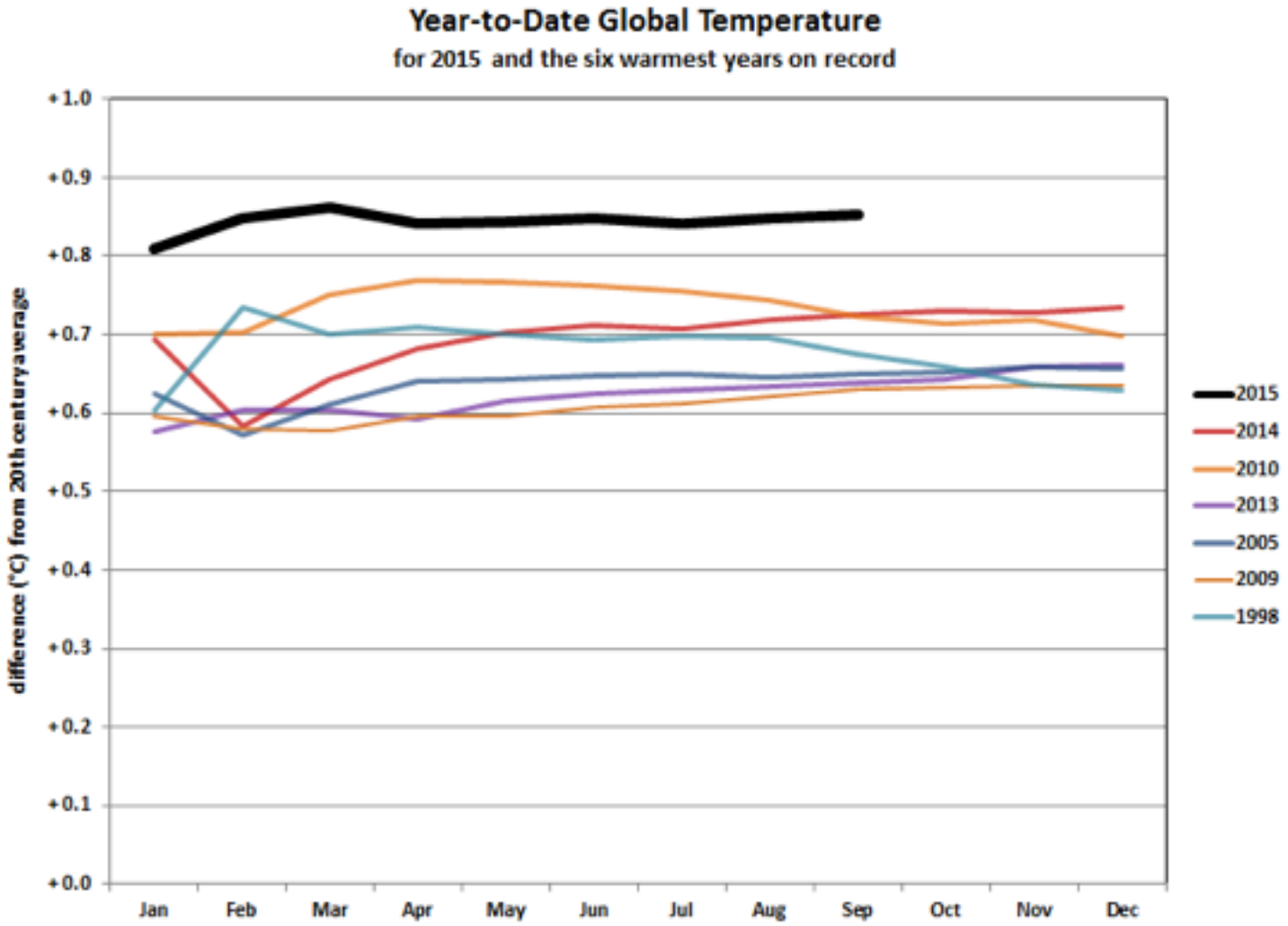
Climate Change Evidence



2014 was the warmest since records began in 1880.
temperature was 0.69°C (1.24°F) above 20th century average
38th consecutive year that the global temperature was above historic average.
14 of the 15 warmest in 135-year record occurred in 21st century.
1998 is the other one.

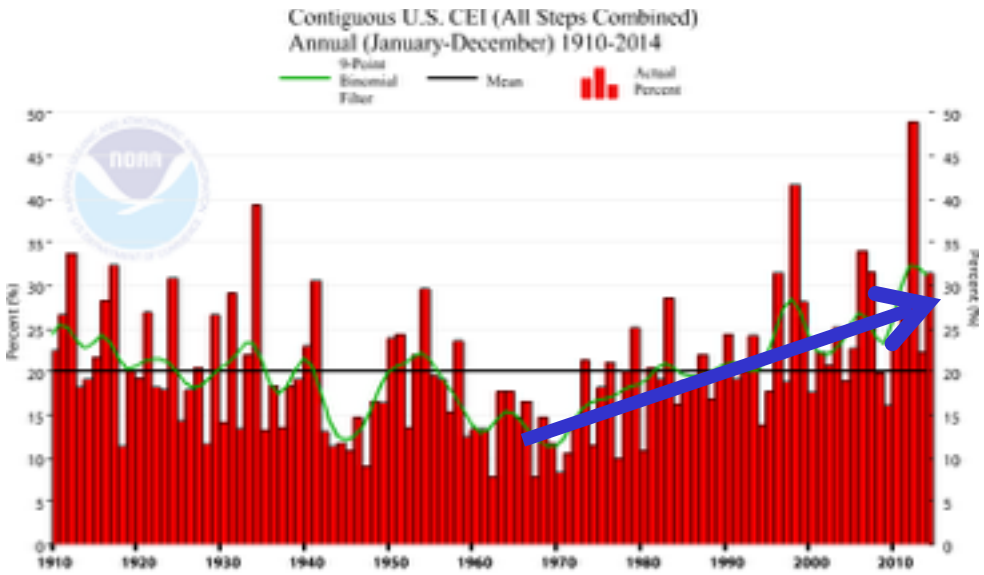
From NOAA State of the Climate
http://www.ncdc.noaa.gov/cag/time-series/global/globe/land_ocean/ytd/12/1880-2015

Climate change Evidence 2015

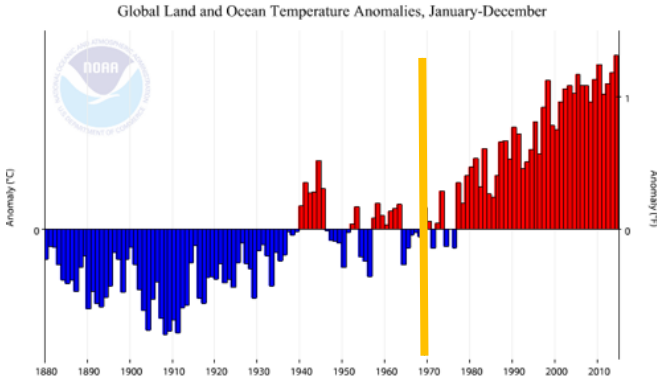


From NOAA State of the Climate
https://www.ncdc.noaa.gov/sotc/global/2015/9/supplemental/page-2

Incidence of Extremes



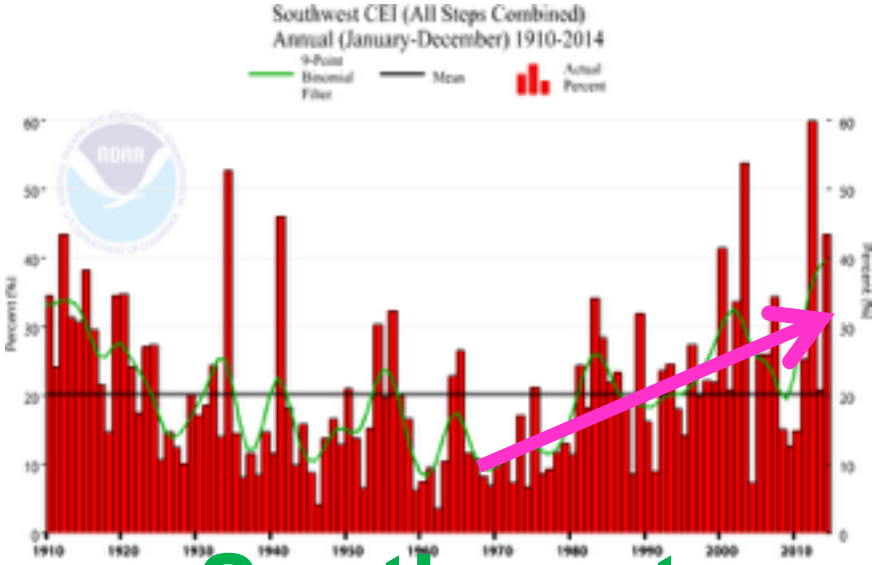
US



We see an increase in events and variability since about 1970 when warming began

From noaa climate extremes index
http://www.ncdc.noaa.gov/extremes/cei/introduction

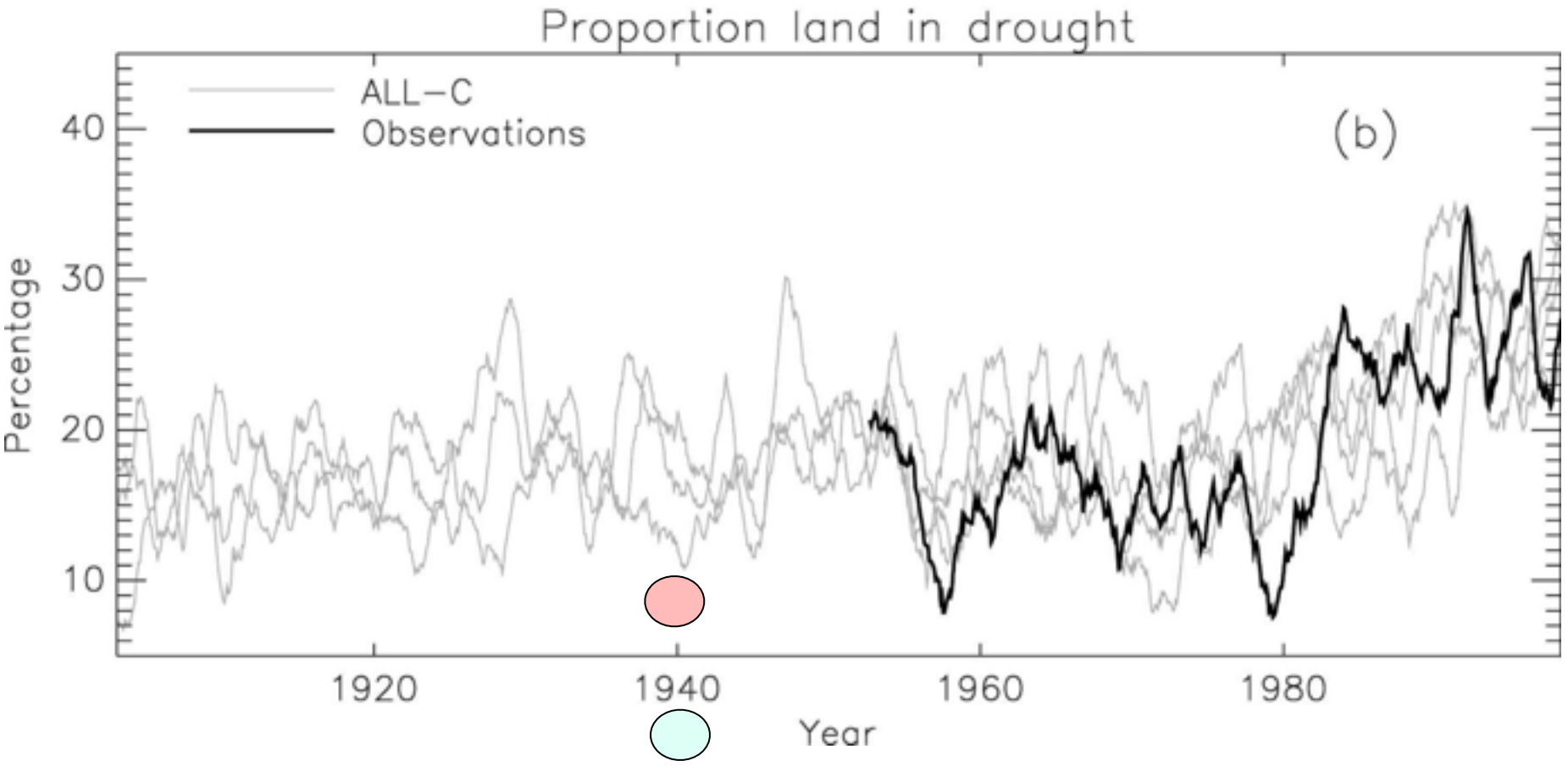
average of percentage of conterminous U.S. area:
- with maximum temperatures much below or above normal
- with minimum temperatures much above or below normal.
- under severe drought
- with severe moisture surplus
- with a much greater than normal precipitation from extremes
- with a much greater than normal number of days with precipitation
- with much greater than normal days without precipitation.



Southwest

Degree of climate change

What is happening up to now -- Drought



Doubled frequency

ELEANOR J. BURKE, SIMON J. BROWN, AND NIKOLAOS CHRISTIDIS ,
Modeling the Recent Evolution of Global Drought and Projections for the Twenty-First Century with the Hadley Centre Climate Model

Why are we seeing this

Why are we seeing climate change?

IPCC (1995) "The balance of evidence suggests a **discernible human influence** on global climate."

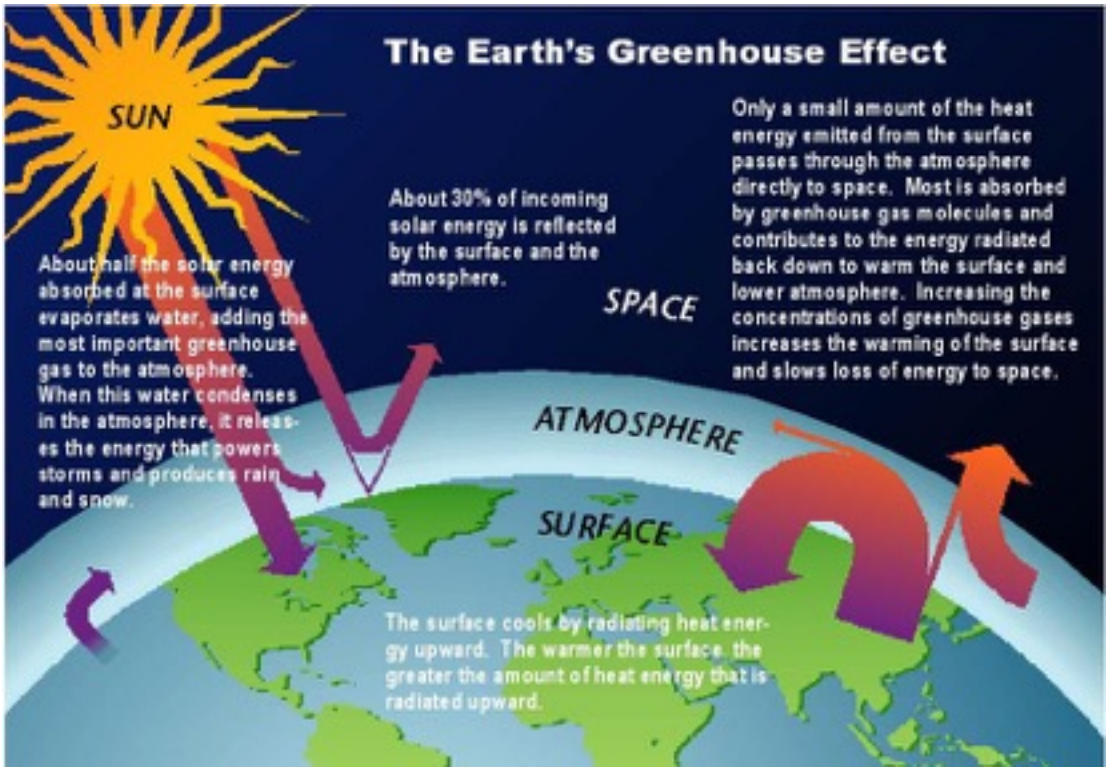
IPCC (2001) "Most of the warming of the past 50 years **is likely (>66%) to be attributable to human activities**."

IPCC (2007) "Most of the observed increase in global average temperatures since the mid-20th century **is very likely (>90%) due to the observed increase in anthropogenic (human caused) greenhouse gas** concentrations."

IPCC (2013) It is **extremely likely (95–100% probability) that human activities caused more than half** of the observed increase in global average surface temperature from 1951 to 2010.

Degree of climate change

Why is this happening

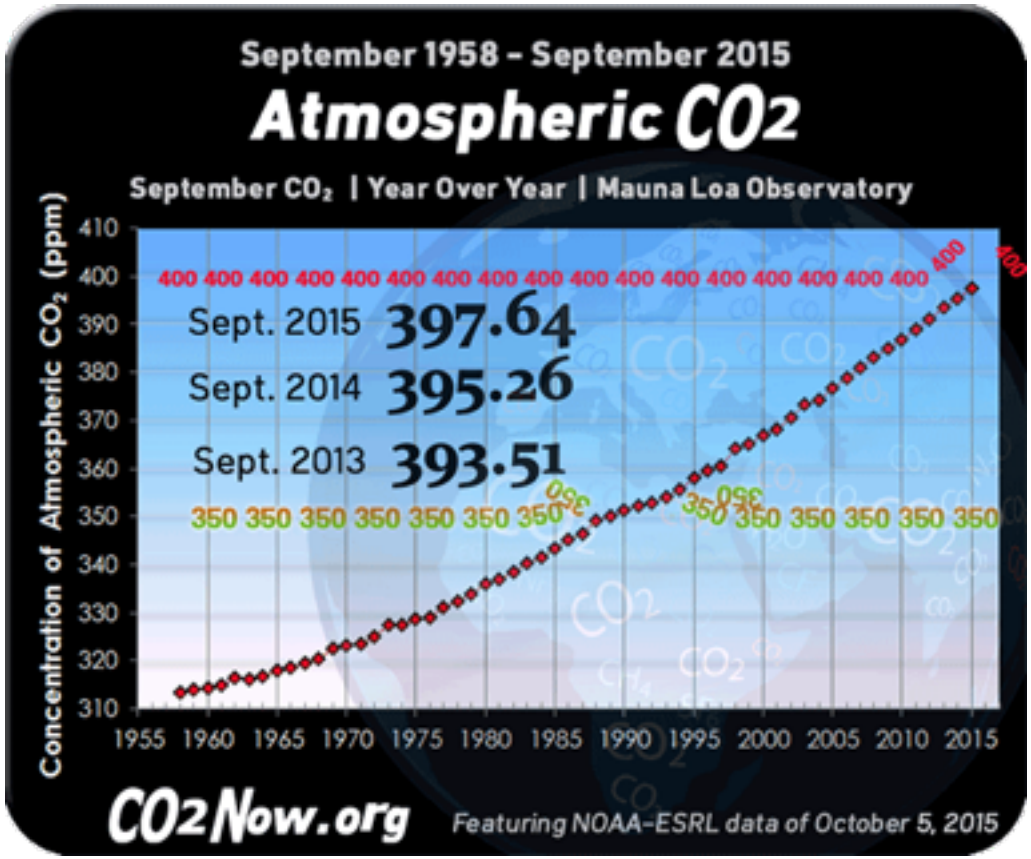


Some gases, like carbon dioxide (CO), trap heat in the atmosphere by absorbing longwave radiation while letting the Sun's energy pass through. The transparent roof and walls of a greenhouse allow in the sunlight while keeping in the heat. Since these gases act similarly in the atmosphere, we call them **greenhouse gases**.

Source : U.S. National Assessment http://www.usgcrp.gov/usgcrp/Library/nationalassessment/images/Greenhouse-s.jpg.

Why is this happening

GHG Concentration



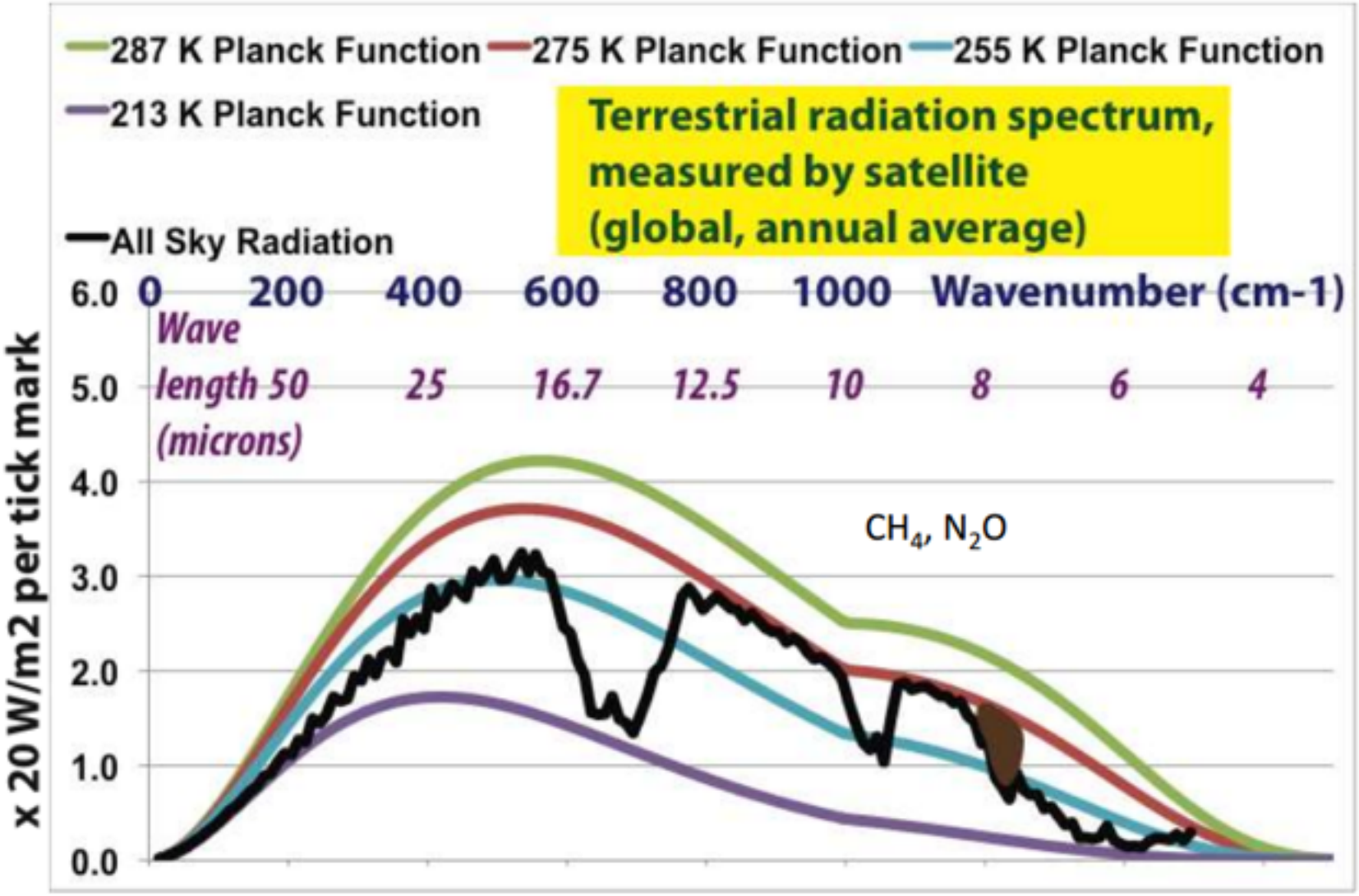
Counting Non CO_2 this increase exceeds 480ppm

For the past ten years (2005 - 2014), the average annual rate of increase is 2.11 parts per million (ppm). This rate of increase is more than double the increase in the 1960s.

Pre industrial - 275
1985. - 345
2014 average - 399

http://co2now.org/

Why Vulnerable -Temperature and Extremes



Will it go on

Why is this Happening - Emissions growing

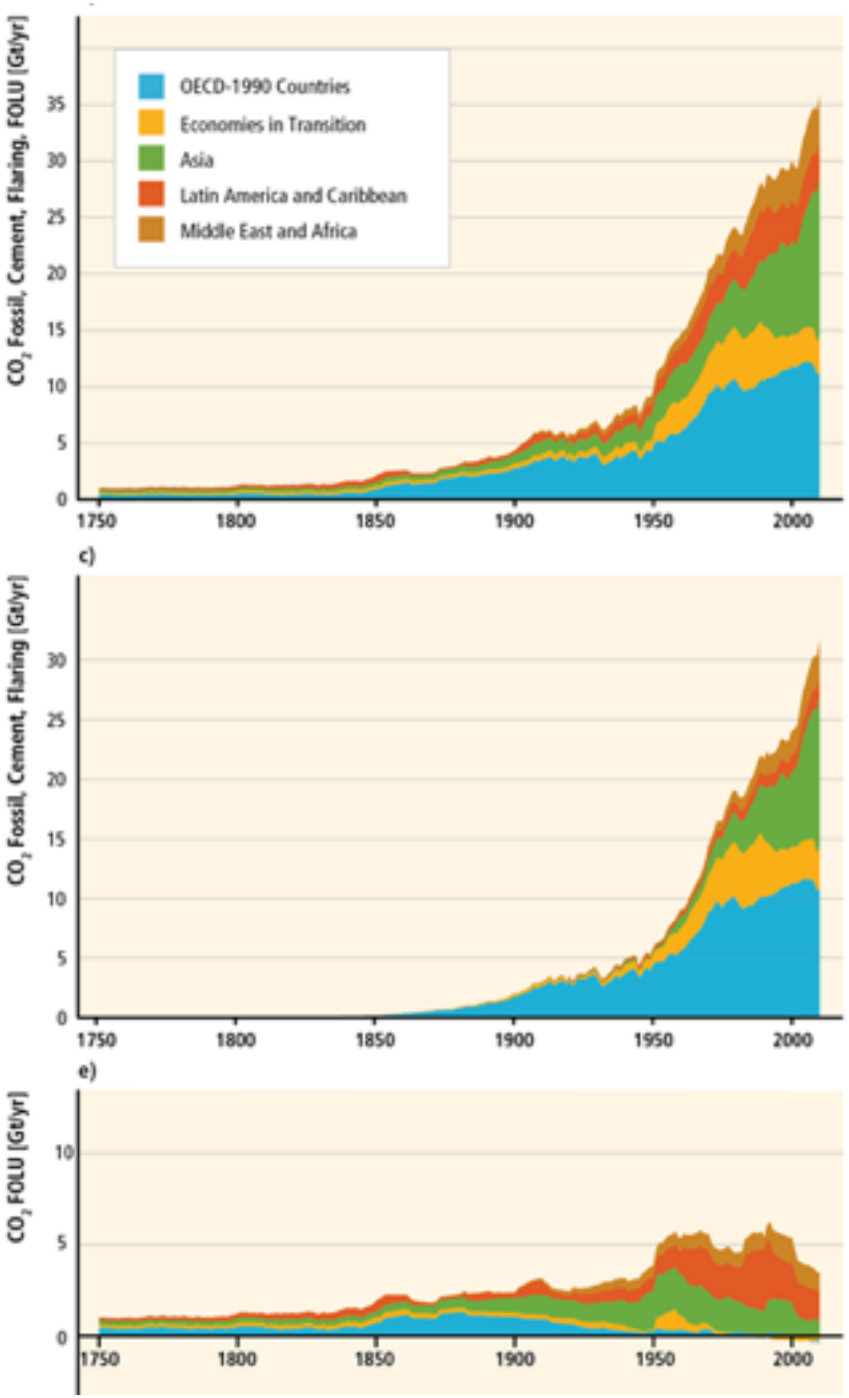
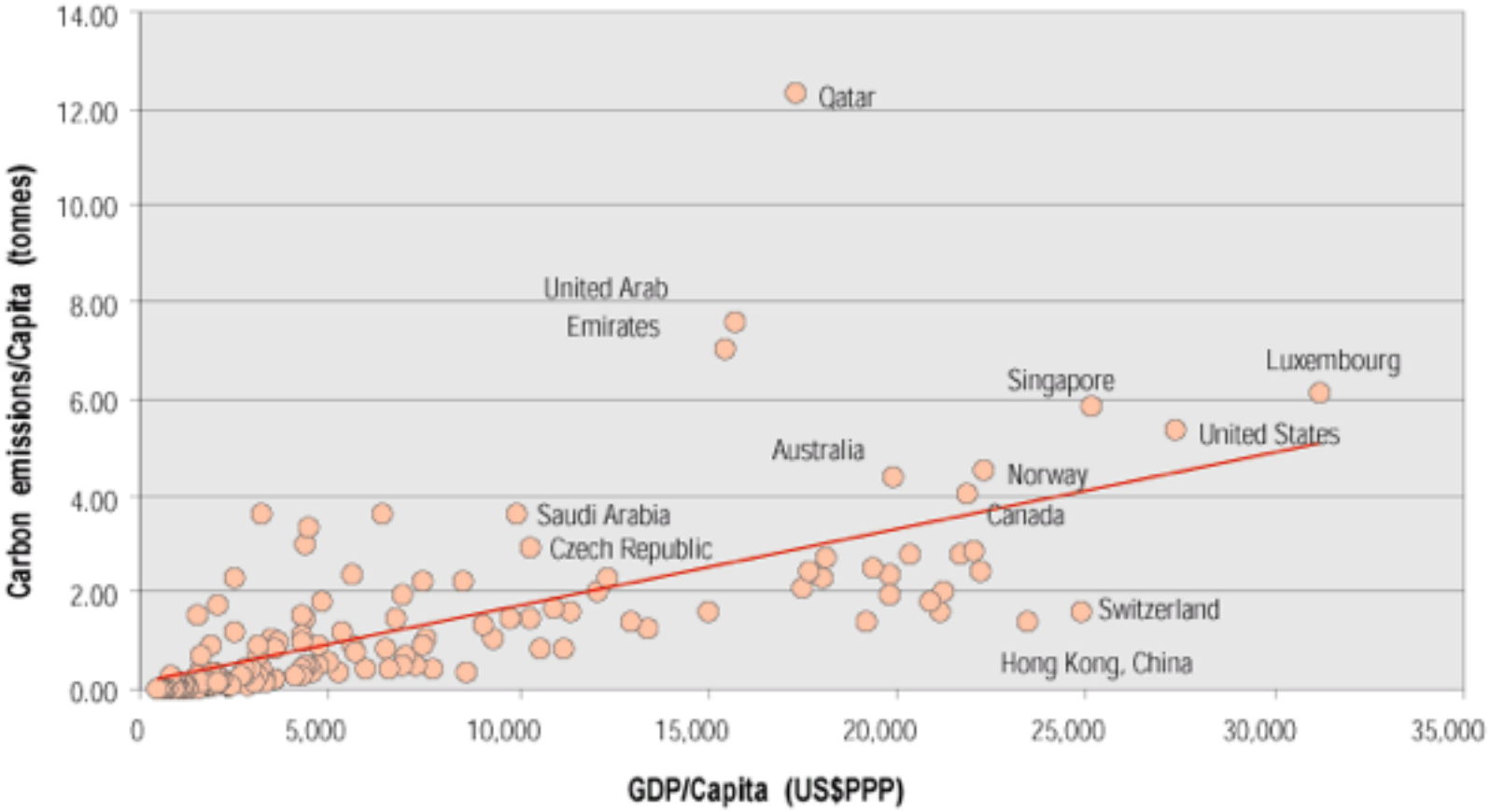
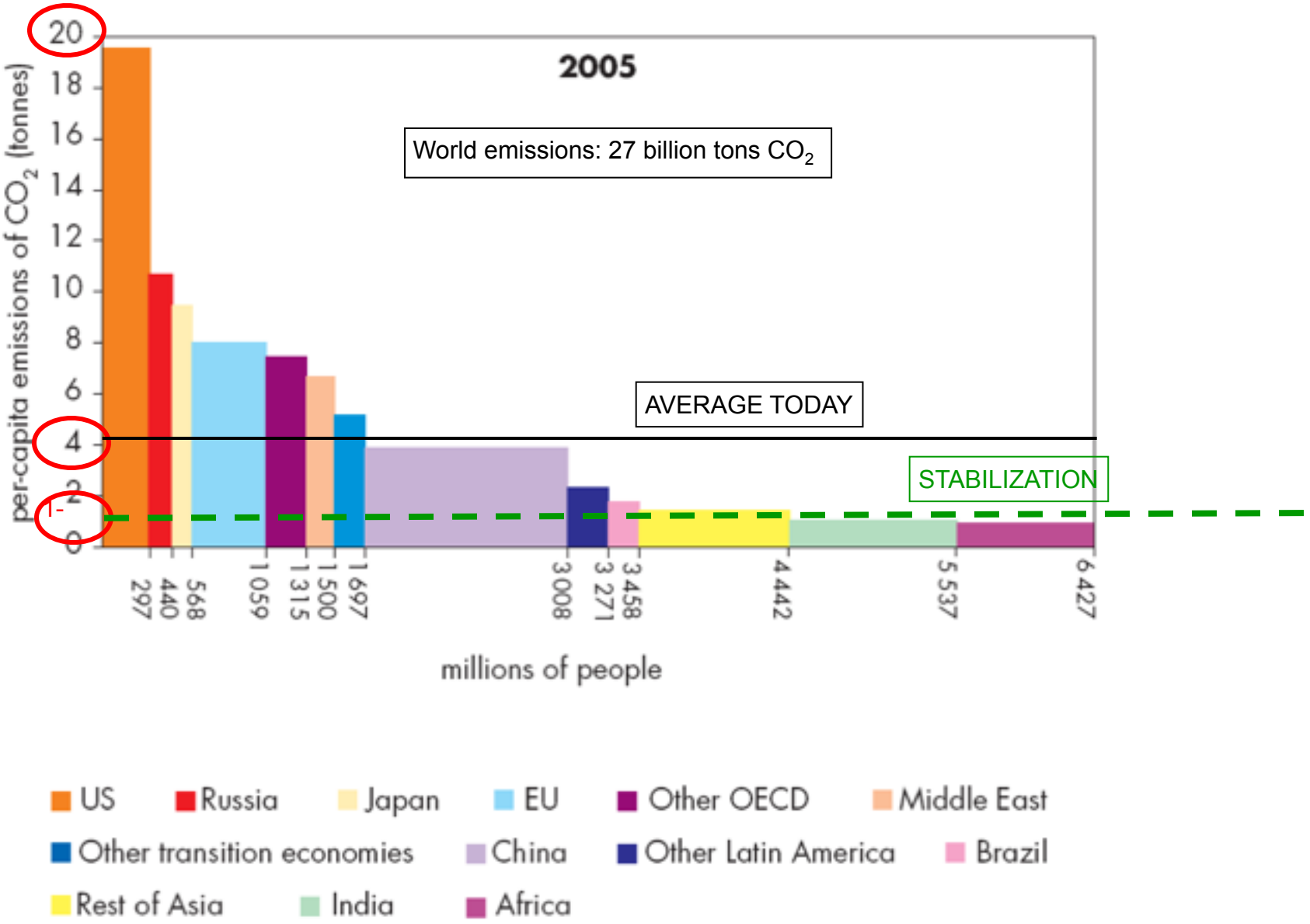


Figure TS.2. Historical anthropogenic CO2 emissions from fossil fuel combustion, flaring, cement, Forestry and Other Land Use (FOLU) in five major world regions: OECD1990 (blue); Economies in Transition (yellow); Asia (green); Latin America (red); Middle East and Africa (brown). Panels show regional CO2 emission trends 1750-
6 2010 from: (a) all sources (c+e); (c) fossil fuel combustion, flaring and cement; (e) FOLU.

Who Emits


14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Carbon emissions/Capita (tonnes)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
GDP/Capita (US$PPP)
Qatar
United Arab Emirates
Luxembourg
Singapore
United States
Australia
Norway
Canada
Saudi Arabia
Czech Republic
Switzerland
Hong Kong, China

Per-capita fossil-fuel CO2 emissions, 2005



Source: IEA WEO 2007 and Socolow presentation at Americas Climate Choices

"Stabilization": 1 ton CO2/yr per capita

It is *not* sufficient to limit emissions in the prosperous parts of the world and allow the less fortunate to catch up. Such an outcome would overwhelm the planet.

The emissions of the future rich must eventually equal the emissions of today's poor, …

…not the other way around.

What is projected

Climate Change can be much larger

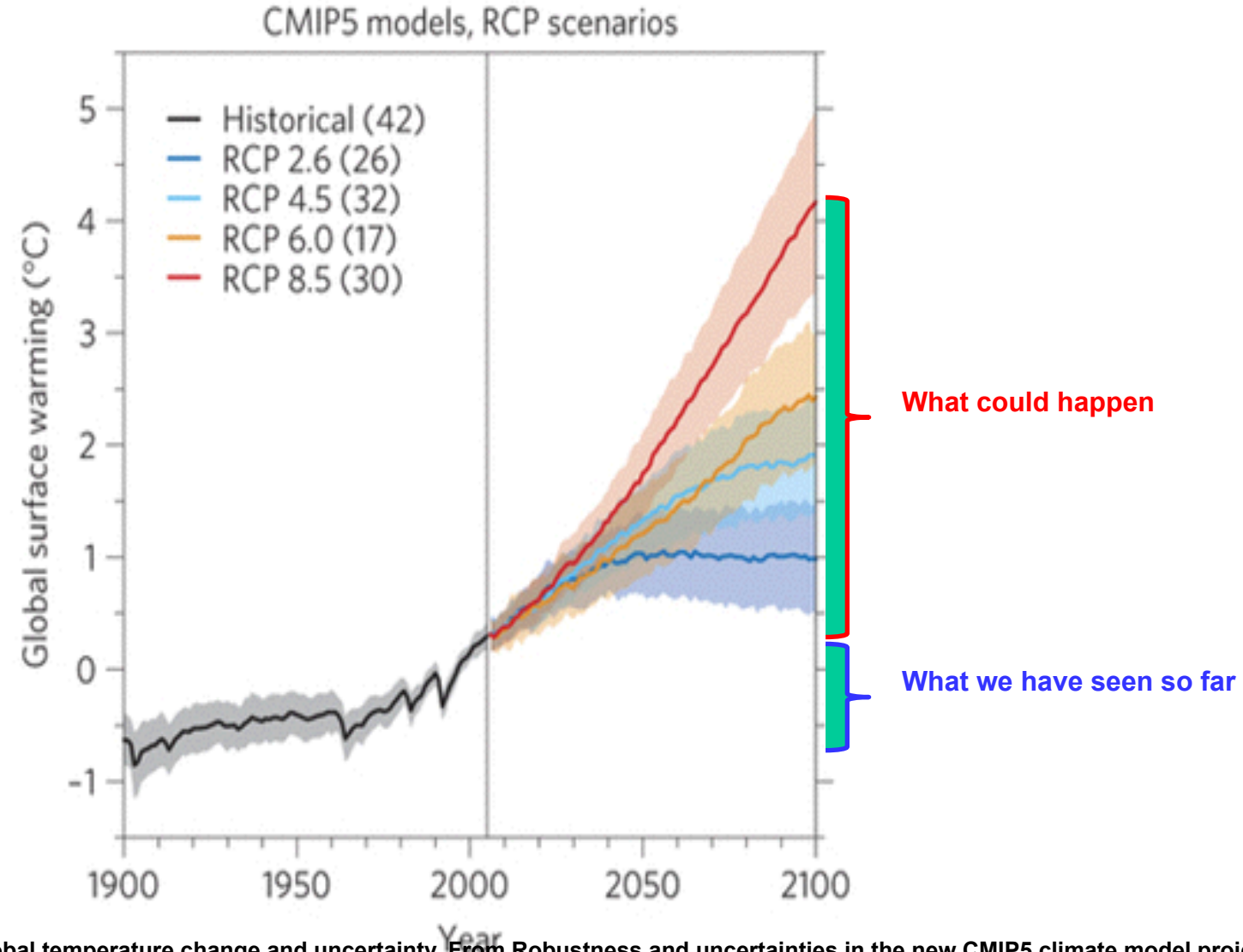
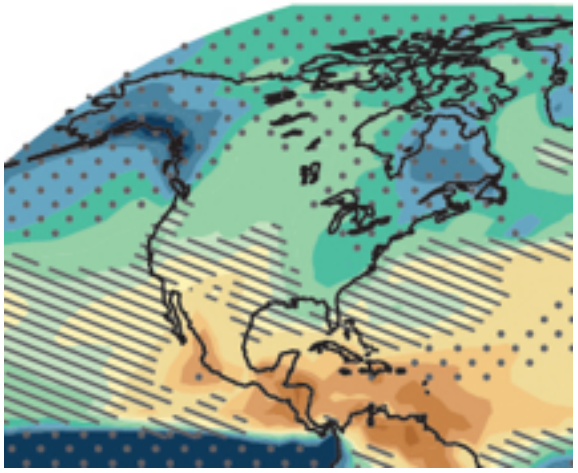


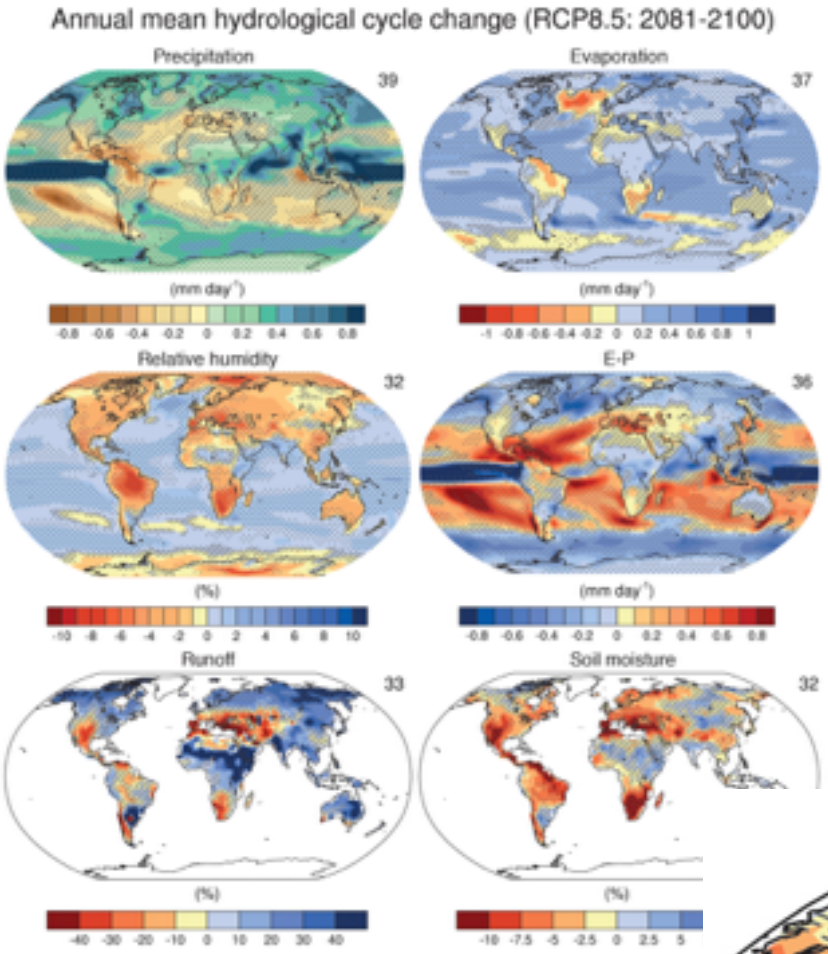
Figure 1: Global temperature change and uncertainty. From Robustness and uncertainties in the new CMIP5 climate model projections Reto Knutti & Jan Sedláček, Nature Climate Change 3, 369–373 (2013) doi:10.1038/nclimate1716,

What about water

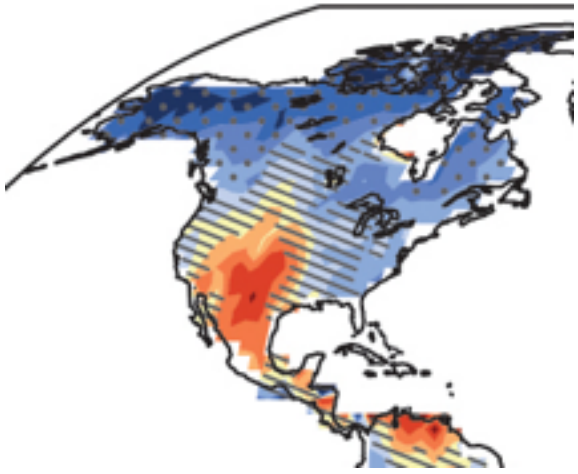
Precipitation



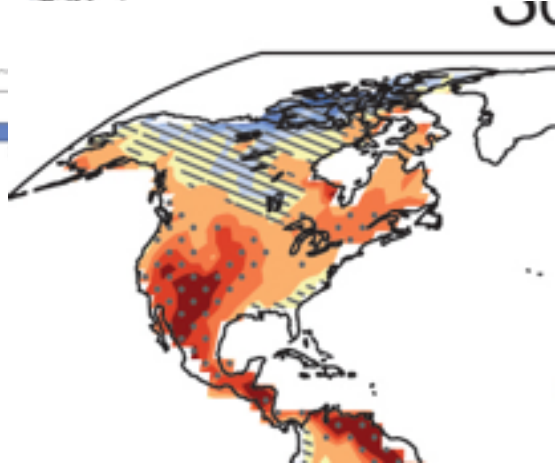
Precipitation varies with northern gains, subtropic drying



Runoff



Soil Moisture

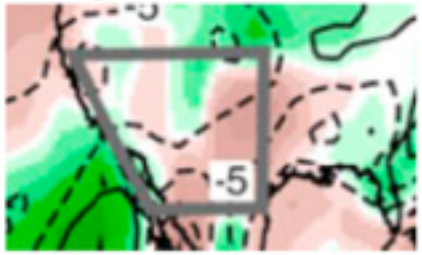


Source IPCC 2013, WGI http://www.ipcc.ch/report/ar5/wg1/

Southwest US water

Climate Model Results: Future SW Moisture

Region Included



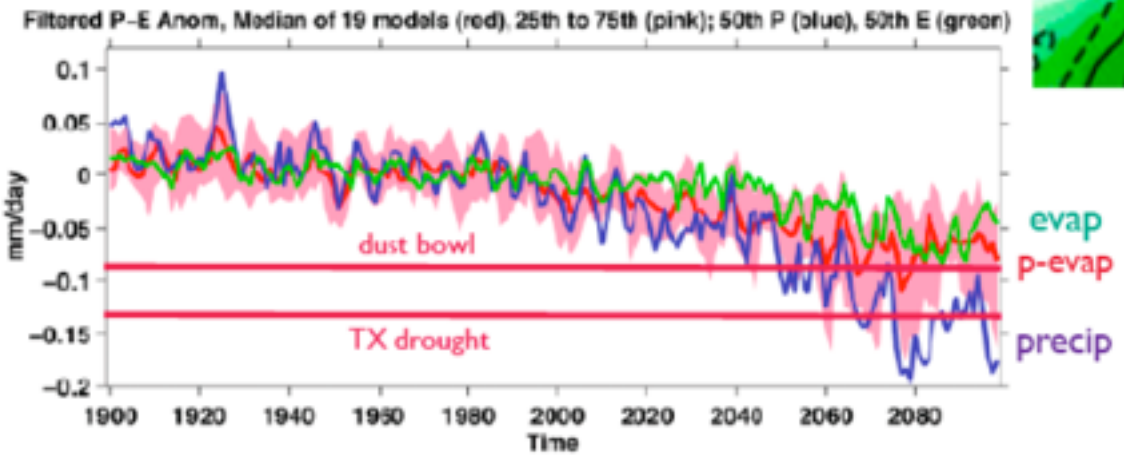


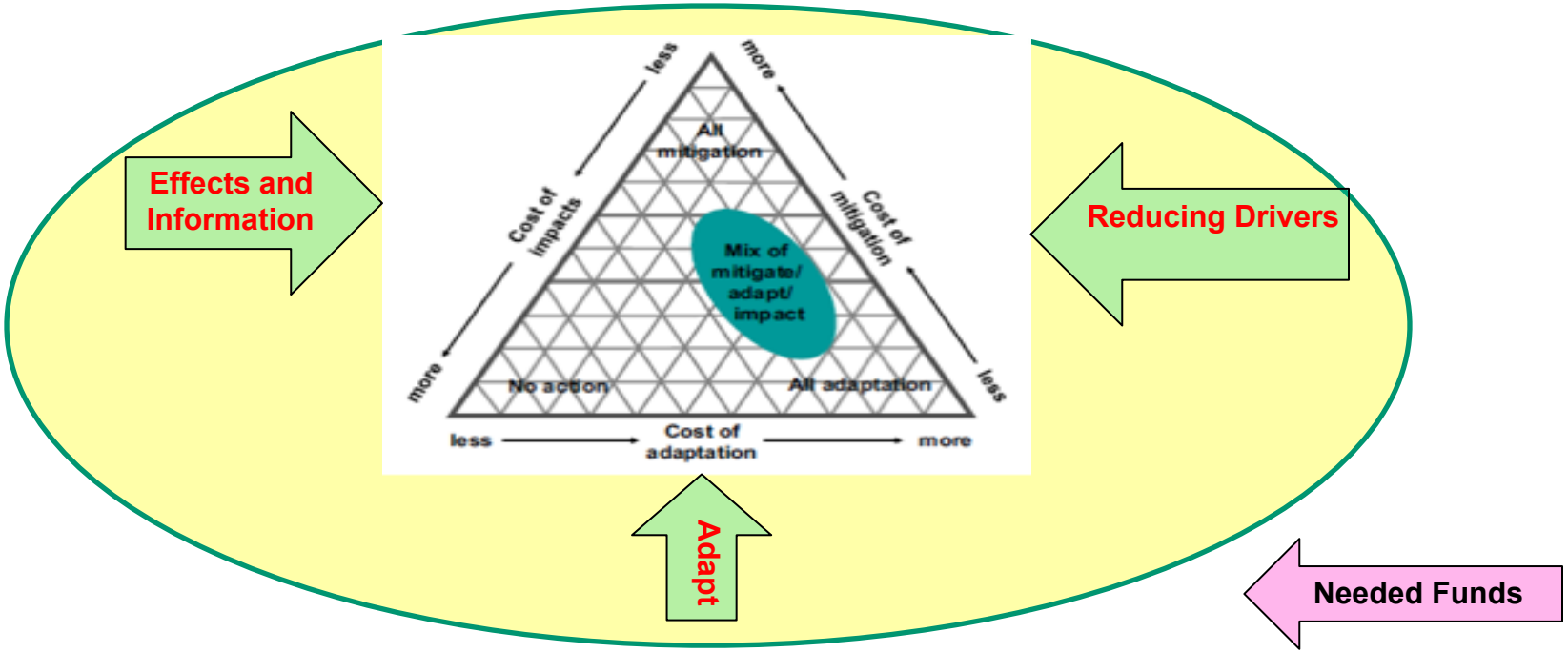
Fig. 1. Modeled changes in annual mean precipitation minus evaporation over the American Southwest (125°W to 95°W and 25°N to 40°N, land areas only), averaged over ensemble members for each of the 19 models. The historical period used known and estimated climate forcings, and the projections used the SResA1B emissions scenario. The median (red line) and 25th and 75th percentiles (pink shading) of the $P - E$ distribution among the 19 models are shown, as are the ensemble medians of P (blue line) and E (green line) for the period common to all models (1900–2098). Anomalies (Anom) for each model are relative to that model's climatology from 1950–2000. Results have been 6-year low-pass Butterworth-filtered to emphasize low-frequency variability that is of most consequence for water resources. The model ensemble mean $P - E$ in this region is around 0.3 mm/day.

SEAGER et al., *Science*, 2007

BOTTOM LINE: MUCH LESS WATER IN THE SOUTHWEST

So what can we do

So What could we do?



Reactions to climate change basically consist of four directions:

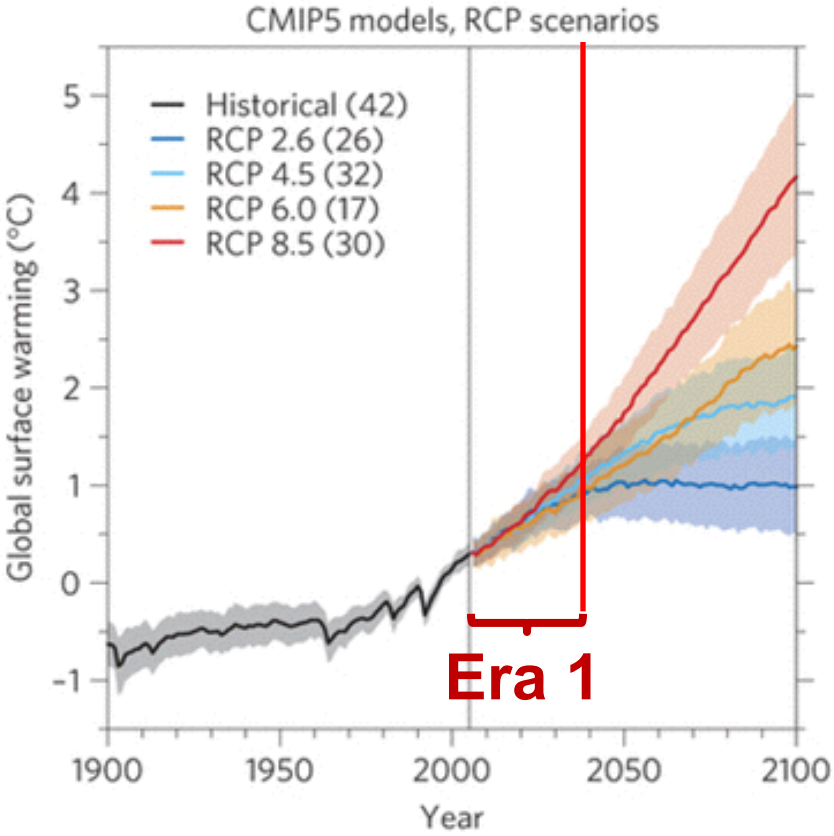
- Live with the effects – do little
- Reduce future extent by limiting drivers Mitigation
- Alter management to reduce impact of change - Adaptation
- Monitor and forecast effects- Effects and Information

Last three compete with traditional investment

McCarl, B.A., "Some Thoughts on Climate Change as an Agricultural Economic Issue", Journal of Agricultural and Applied Economics, vol 44 no 5, 299-305, 2012.

Adaptation *Is* Inevitable

Given the emission growth – Action Eras, Possible Climate Goals and Inevitability



4°

2°

Inevitable amount

ACTION ERA 1 – In this time period (now until 2040-2050), there is not much contribution from limiting emissions with an inevitable amount of climate change.

Climate Goals - Requires adaptation plus mitigation.

Types of Adaptation Actions

Adaptation can be "natural" or "autonomous" or "planned."

Natural adaptations are actions in ecosystem stimulated by species reacting to climate

Autonomous adaptations are actions taken voluntarily by decision-makers (such as farmers or city leaders)

Planned adaptations are interventions by governments to address needs unlikely to be met by autonomous actions (Public goods)

A public good is an item where individuals cannot be effectively excluded from use and where use by one individual does not reduce availability to others like a sea wall or a new cropping practice

Public goods include NASA findings fresh air, , flood control systems, lighthouses, and street lighting.

Public goods problems are often closely related to the "free-rider" problem, in which people not paying for the good may continue to access it. Thus, the good may be under-produced, overused or degraded. Many adaptation actions fall here

Adaptation can be "natural" or "autonomous" or "planned."

Public sector may play important roles in all cases.

- **Support autonomous adaptation providing information, shaping market conditions , developing technologies**
- **Act directly by developing strategies, providing resources, and carrying out projects (infrastructure development).**
- **Influence natural adaptation by managing the unmanaged**

Government scientists and policy makers are in the public sector group and would address public goods

Key Concepts

Throughout history, people and societies have adapted to and coped with climate, climate variability, and extremes, with varying degrees of success particularly in agriculture.

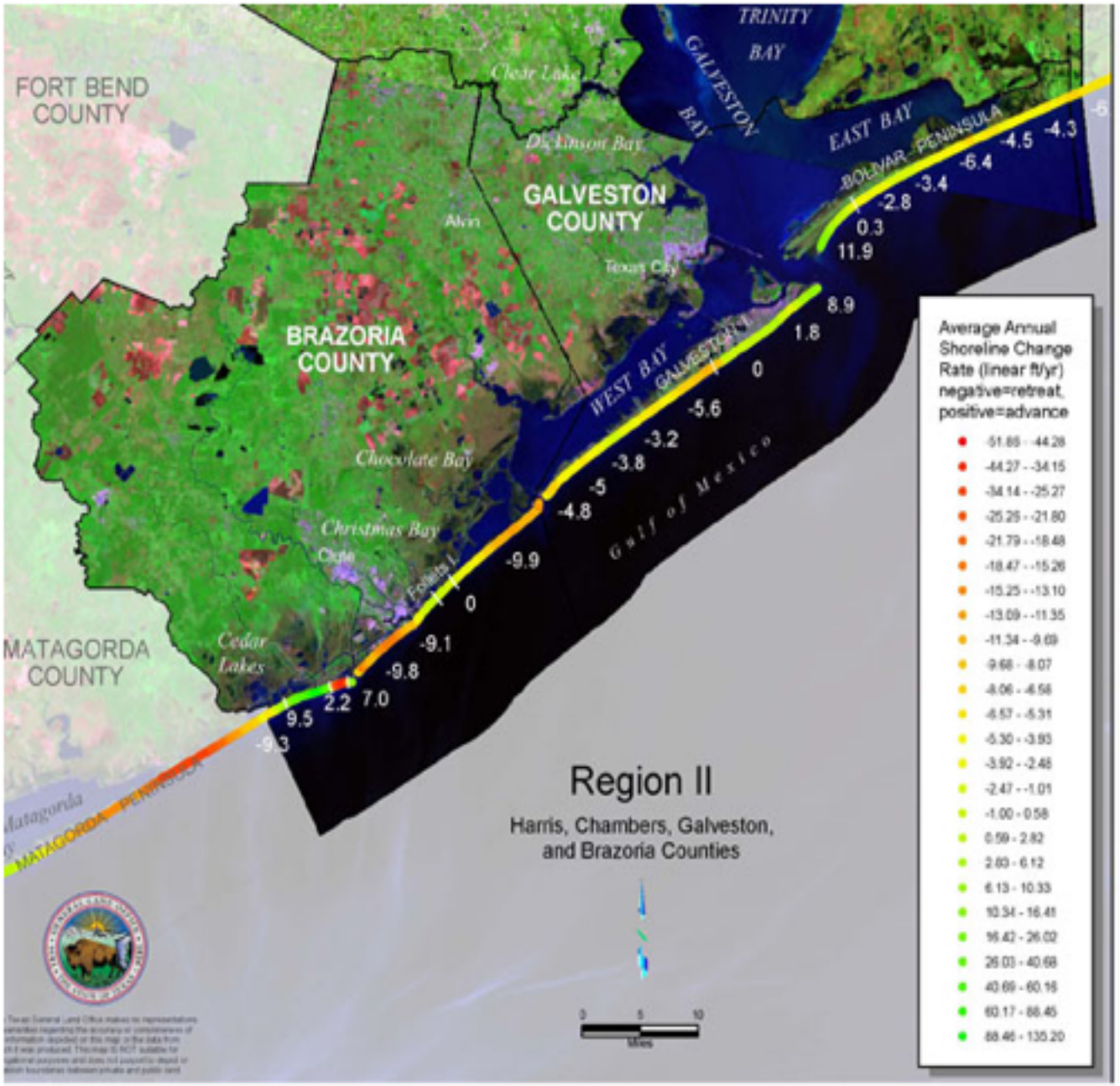
But the pace of adaptation may be unprecedented. We may be on the treadmill requiring almost constant adaptive actions.

Adaptation is place- and context-specific, with no single approach for reducing risks appropriate across all settings.

Adaptation is Happening

Natural Adaptation

Measurements of Galveston shore level retreat averaging 6 feet per year



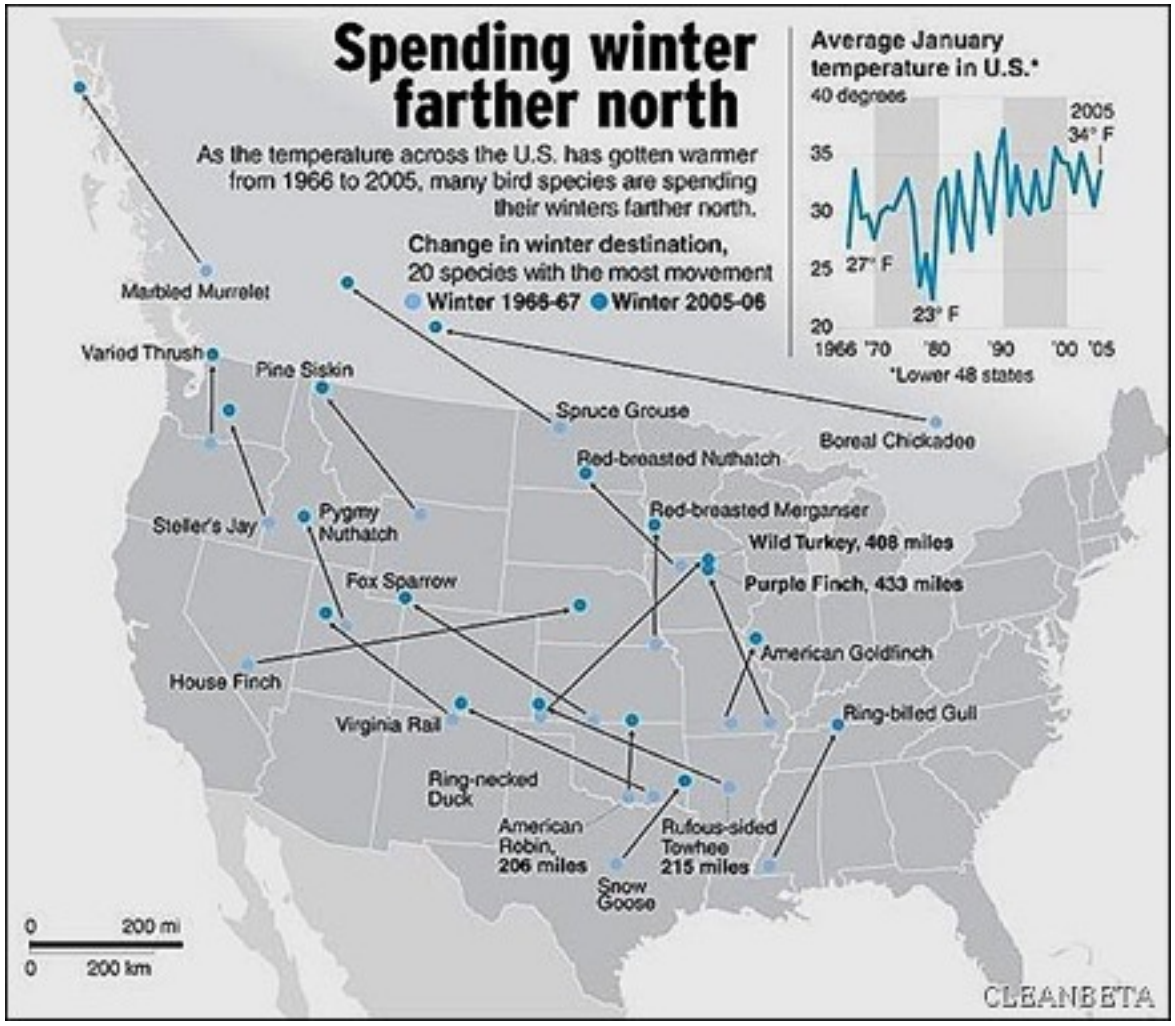
Natural Adaptation

We also have seen

- Melting glaciers
- More pests
- Sea level rise
- Coastal retreat

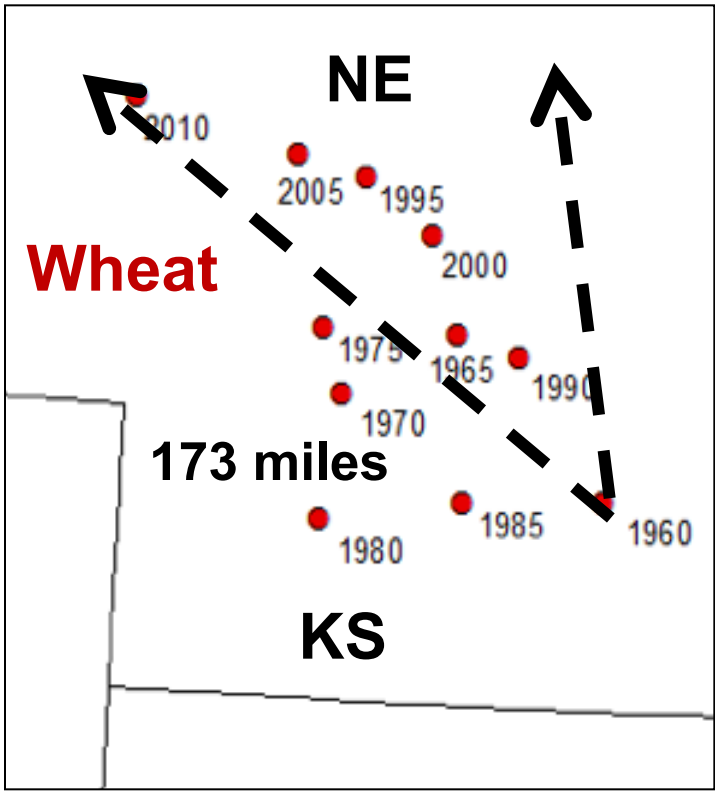
Pictures over time of glacial water supply source, for Boulder CO

Natural Adaptation

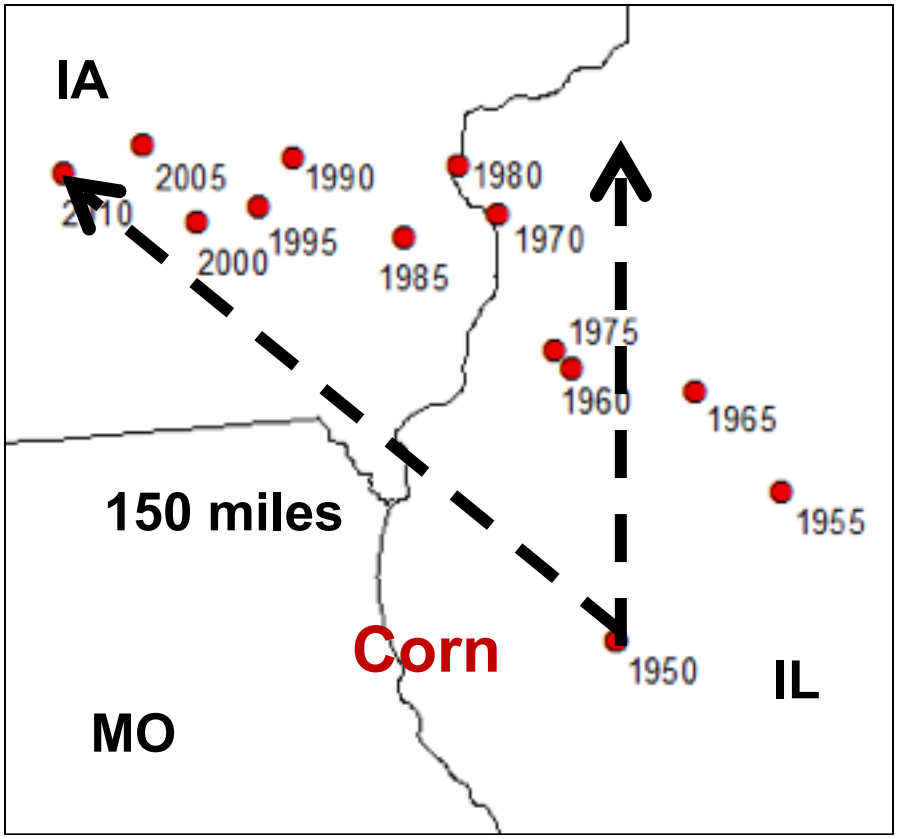


Pentland, William, 2009. Bird-Strikes Bringing Down More Airplanes, Global Warming Changing Bird Migration Patterns – Linked? Retrieved on 11 March 2010 from http://cleantechlawandbusiness.com.

Autonomous Adaptation

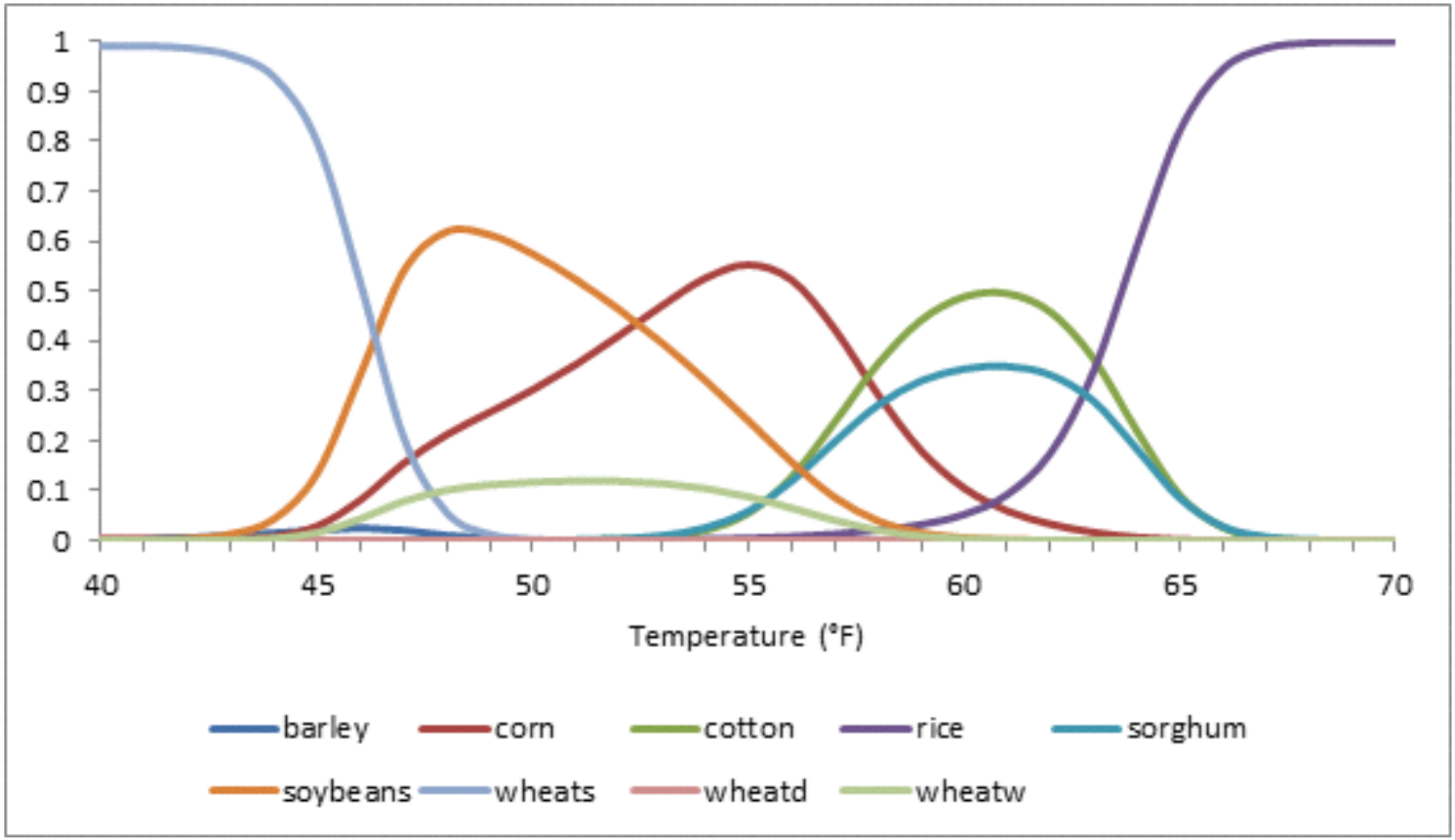


Production Weighted Centroid 1950-2010



Attavanich, W., B.A. McCarl, Z. Ahmedov, S.W. Fuller, and D.V. Vedenov, "Climate Change and Infrastructure: Effects of Climate Change on U.S. Grain Transport", Nature Climate Change, on line at doi:10. 1038/nclimate1892, VOL 3 JULY 2013, 638-643, 2013.

Autonomous Crop Choice

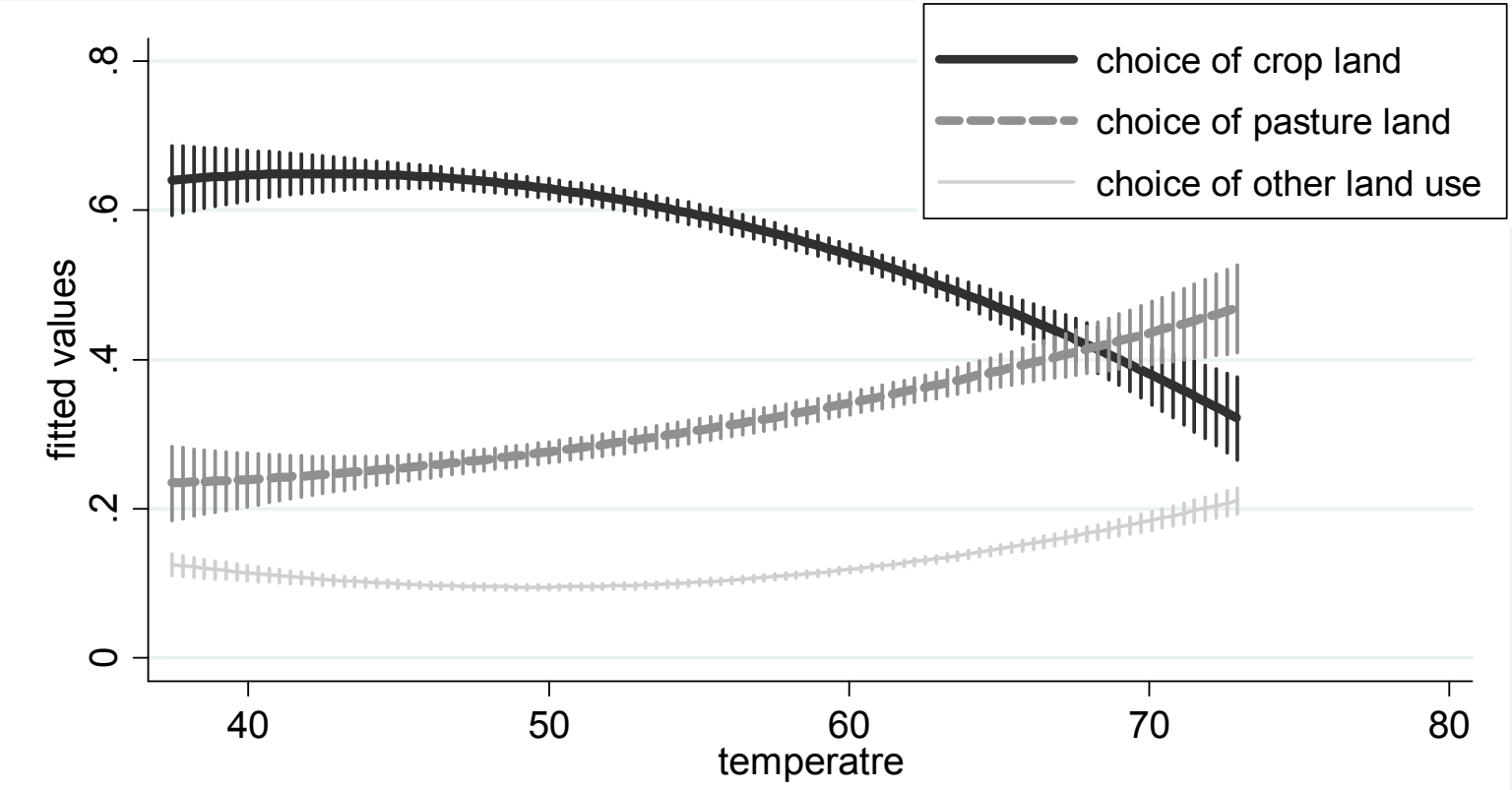


Crop mix shift as climate warms - wheat at low end rice at upper. Neglects grasslands

Park, J.Y., B.A. McCarl, and X.M. Wu, "The Effects of Climate on Crop Mix and Climate Change Adaptation", 2013.

Autonomous Land Use

- **Farm gate adaptations include changes in irrigation, crop mix, land use and to a lesser extent irrigation methods.**



Crop land moves to pasture

Mu, J.E., B.A. McCarl, and A.M. Wein, "Adaptation to climate change: changes in farmland use and stocking rate in the U. S", Mitigation and Adaptation Strategies for Global Change, doi:10. 1007/s11027-012-9384-4, 2012.

Autonomous Stocking Rates

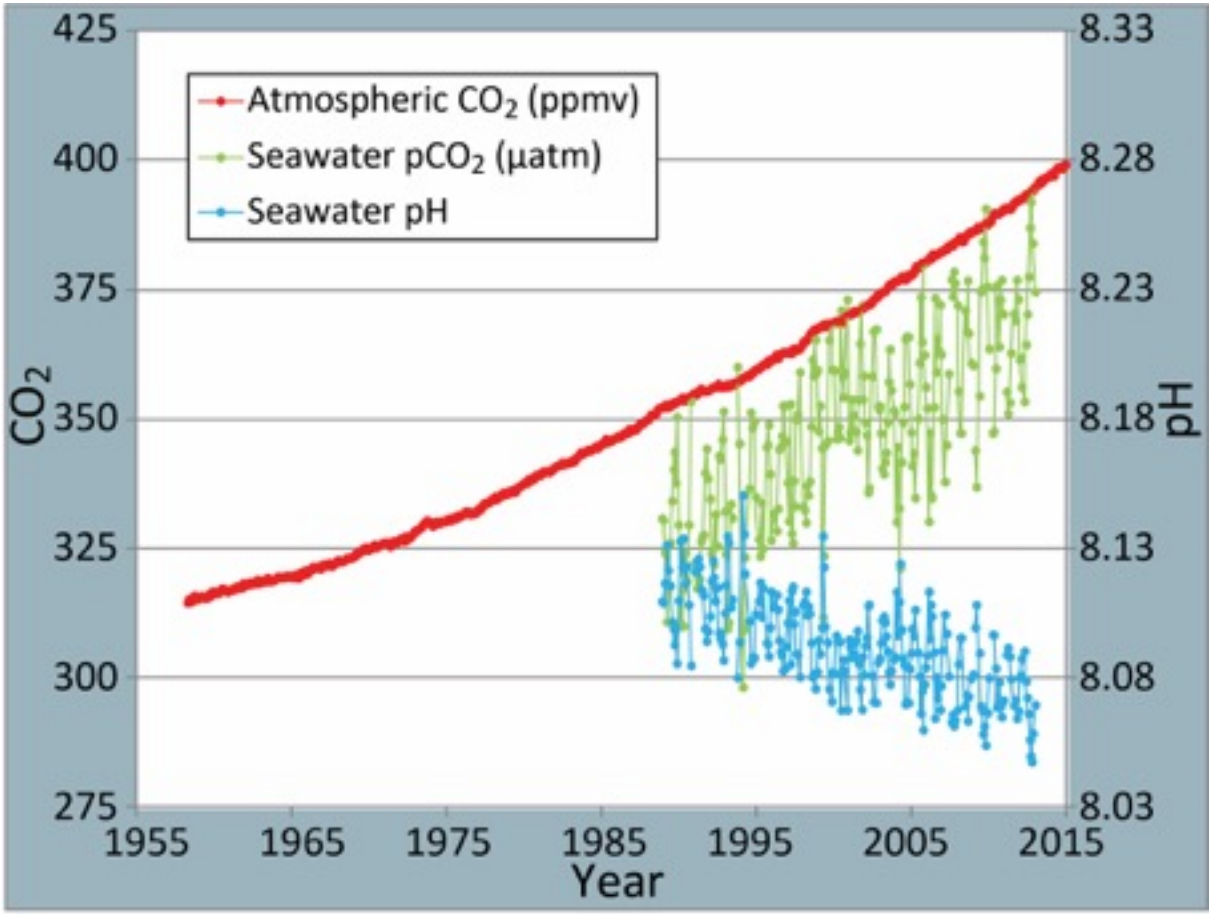
Table 5 Changes of Land Use Allocation and Cattle Stocking Rate

	Base	2010-2039	2040-2069	2070-2099
		HadCM3-B1 emission scenario		
Crop	0.60	-0.22	-0.28	-0.33
Pasture	0.29	0.28	0.35	0.41
Other land use	0.11	-0.06	-0.07	-0.08
Cattle stocking rate*(animal/acre)	0.25	-35.48	-41.86	-48.87
		HadCM3-A1B emission scenario		
Crop	0.60	-0.31	-0.38	-0.43
Pasture	0.29	0.39	0.46	0.52
Other land use	0.11	-0.07	-0.09	-0.09
Cattle stocking rate*(animal/acre)	0.25	-49.89	-58.01	-66.34
		HadCM3-A2 emission scenario		
Crop	0.60	-0.28	-0.35	-0.44
Pasture	0.29	0.35	0.43	0.53
Other land use	0.11	-0.07	-0.08	-0.09
Cattle stocking rate *(animal/acre)	0.25	-47.72	-54.63	-70.27

Stocking rates decrease

Mu, J.E., B.A. McCarl, and A.M. Wein, "Adaptation to climate change: changes in farmland use and stocking rate in the U. S", Mitigation and Adaptation Strategies for Global Change, doi:10. 1007/s11027-012-9384-4, 2012.

Ocean Acidification



This graph shows the correlation between rising levels of carbon dioxide (CO_2) in the atmosphere at Mauna Loa with rising CO_2 levels in the nearby ocean at Station Aloha. As more CO_2 accumulates in the ocean, the pH of the ocean decreases. (modified after R. A. Feely, Bulletin of the American Meteorological Society, July 2008).

Adaptation Cost and Design

Adaptation and the treadmill

Climate change and its continual progression raises a new demand on agriculture research and extension

Traditionally in agriculture we did research on yield improvement and some maintenance for say pest resistance

We could count on weather being stationary but now this is likely not so.

So we must devote resources to technological adaptation in maintaining productivity at a spot

Adaptation Limits

A few words from the IPCC (WGII 2014)

Adaptive capacity is uneven across and within societies
There are substantial limits and barriers to adaptation.

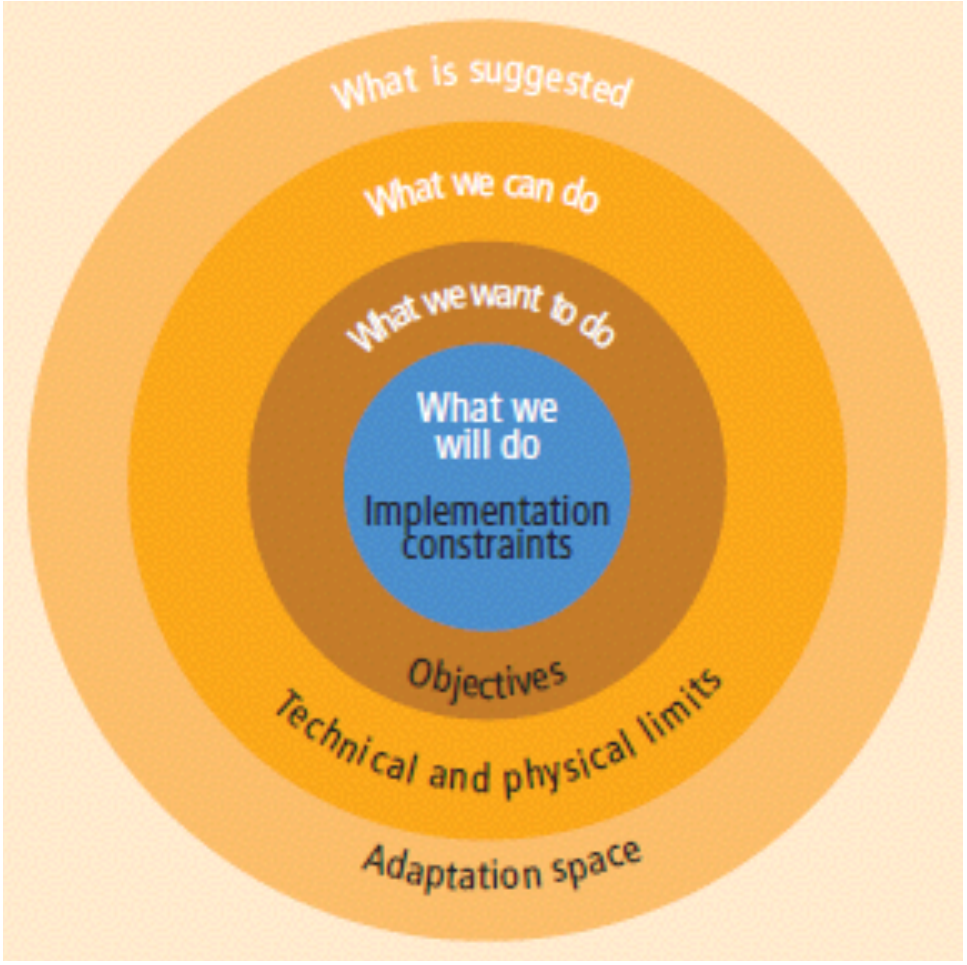


Figure 17-1 | The narrowing of adaptation from the space of all possible adaptations to what will be done. Forces causing the narrowing are listed in black.

Burden of Adaptation

Investment is the cost of adaptation.

Always assumed people would just adjust, but we may need improved varieties, practices, as well as additional facilities for irrigation and land development.

Adaptation Occurs in Three Quarters

1. **Research**
2. **Extension**
3. **Capital investment**

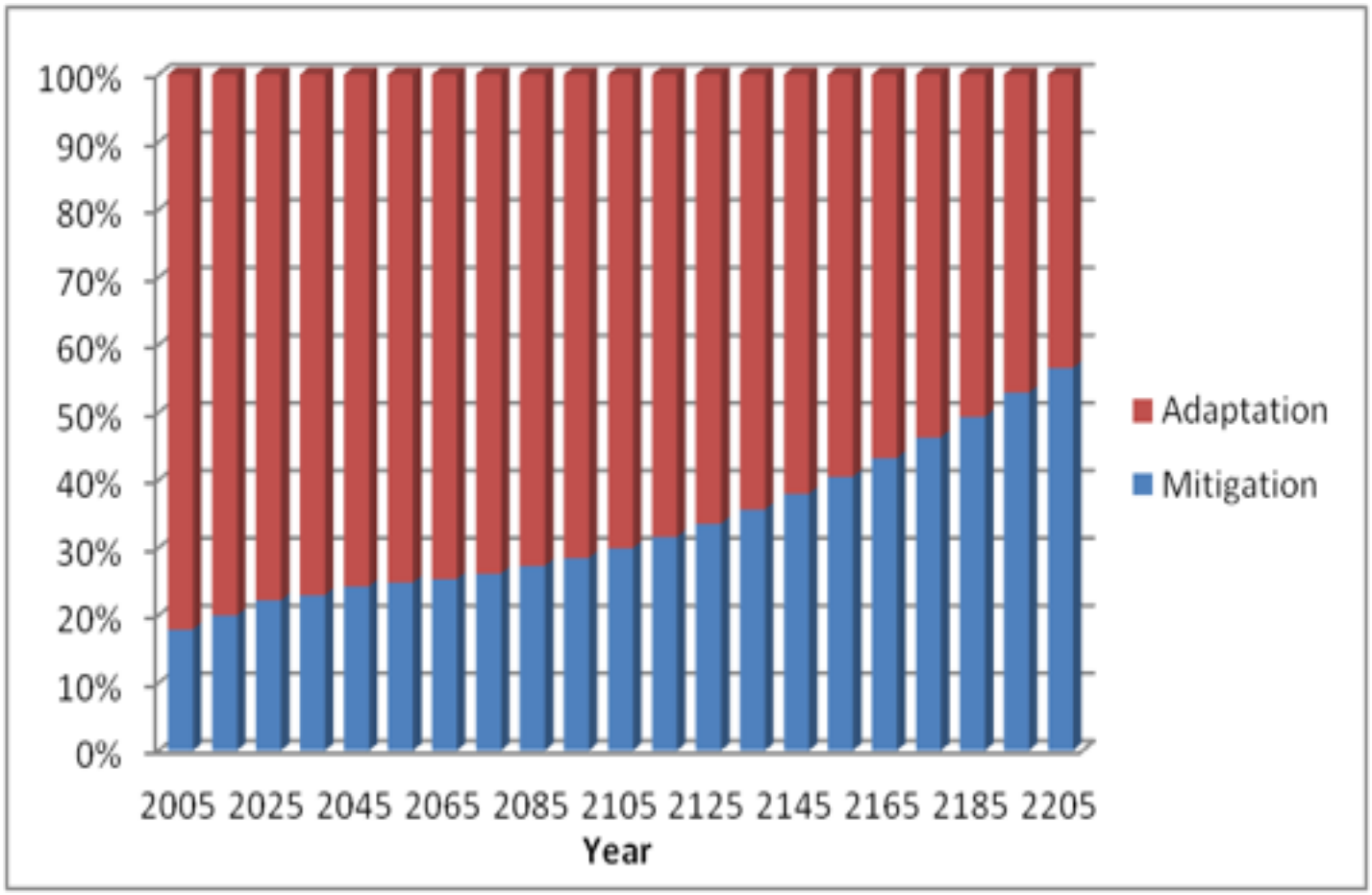
McCarl, B.A., Adaptation Options for Agriculture, Forestry and Fisheries, A Report to the UNFCCC Secretariat Financial and Technical Support Division, 2007. http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/mccarl.pdf

Burden of Adaptation

			Primary Only		Plus processing	
	Today	BAU Gain	CC Add	Mitig CC ADD	CC Add	Mitig CC ADD
AFF Research	$35,959	$30,075	$3,007	$2,632	$3,007	$2,632
AFF Extension	$6,426	$547	$55	$48	$55	$48
AFF Capital Formation	$124,658	$118,995	$2,380	$2,082	$9,795	$8,570
Total	*$167,043*	*$149,617*	*$5,442*	*$4,762*	*$12,857*	*$11,250*

Climate change adaptation could mean an investment of $5 - $13 billion per year globally.

Adaptation Share Over Time



Adaptation dominates for first 100 years

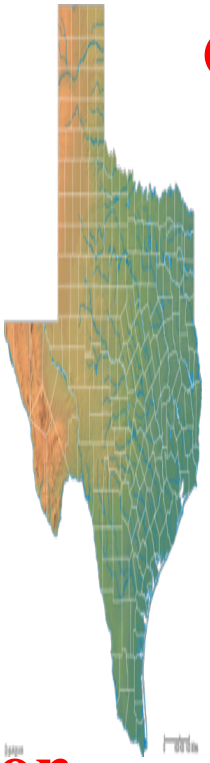
Wang, W.W., and B.A. McCarl, "Temporal Investment in Climate Change Adaptation and Mitigation", Climate Change Economics, Vol. 4, No. 2, 1350009, DOI: 10. 1142/S2010007813500097, 2013.

Concluding Remarks About Adaptation

- Agriculture will have to adapt at unprecedented rates
  - 1º C by 2040
  - 2-4º C by 2100
- Requires public and private roles
  - Public fosters those that create public goods
  - Private role to offer traditional investment
  - Many possible strategies
  - Adaptation will require large investments
- Adaptation may dominate over mitigation for some time
  - Adaptation is happening now
  - Adaptation has its limits

The onset and exact effects of climate change are **uncertain**

Energy



Climate Change Adaptation

Climate Change Mitigation

Climate Change Effects

Texas is v**ulnerable and** We will be squeezed

If you want to know more come take AGEC/ GEOS 489/689 this spring