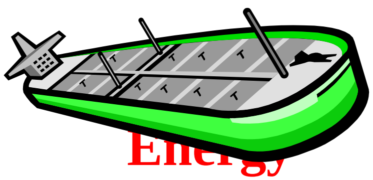
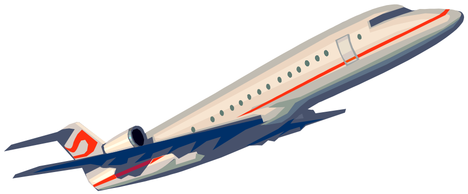
Climate Change, Livestock and the Inevitability Of Adaptation



Energy



Mitigation

Climate Change Effects

Adaptation

Bruce A. McCarl

Distinguished Professor of Agricultural Economics

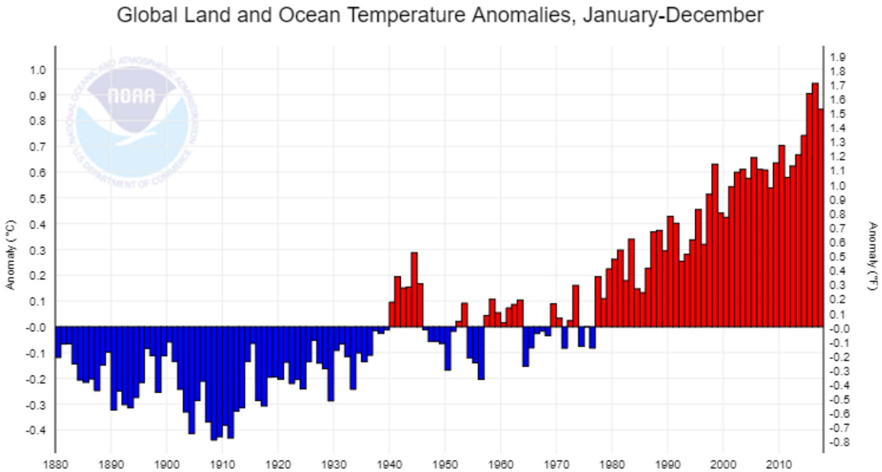
Presidential Impact Fellow

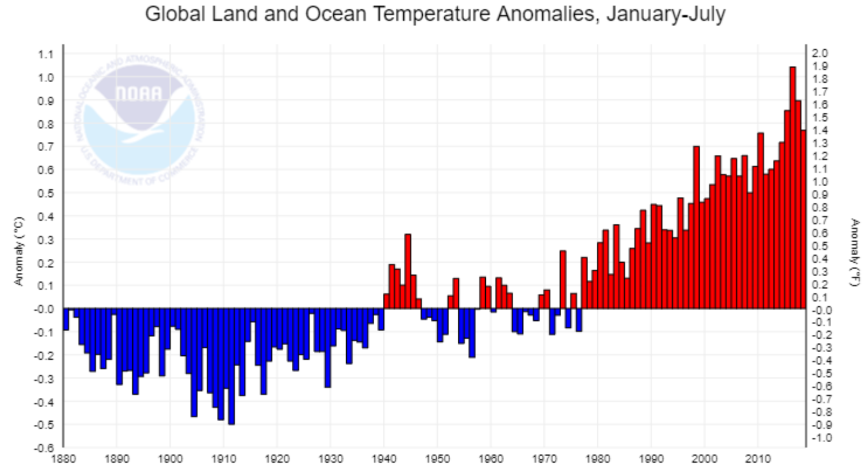
Texas A&M University

Presented at Agri-Food & Biosciences Institute Belfast, Northern Ireland Aug 2018

What have we seen

Temperature history



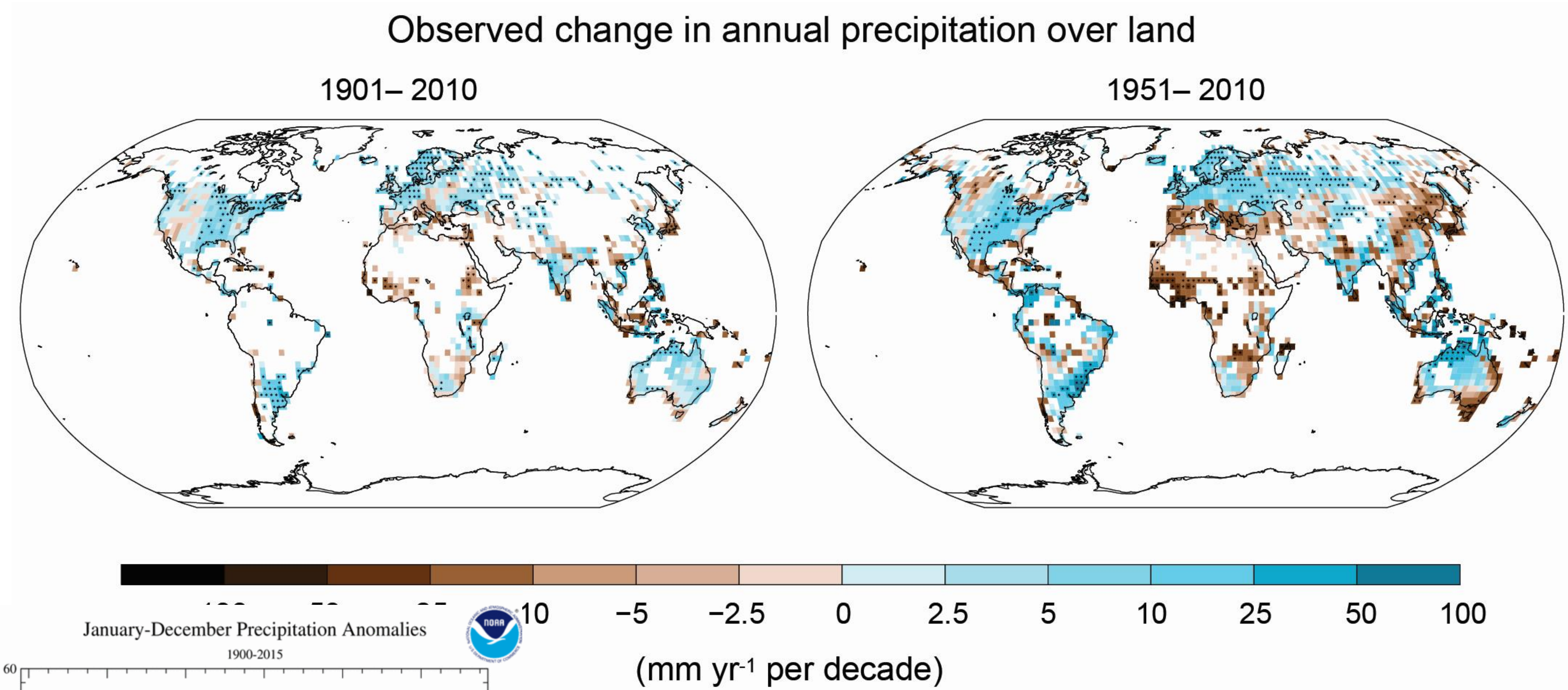


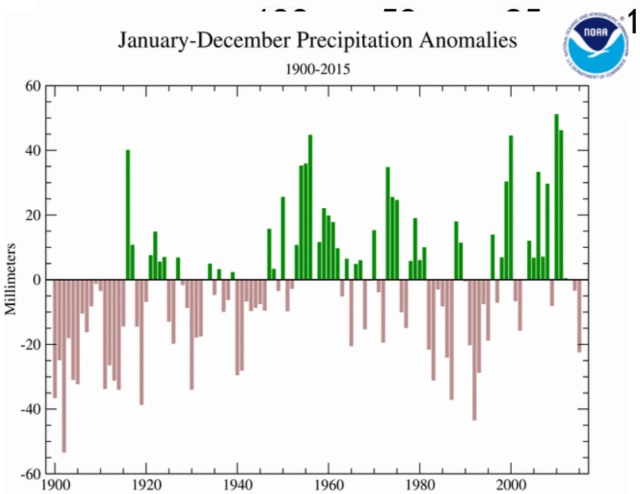
https://www.ncdc.noaa.gov/sotc/global/201613

- **2017 was the third warmest year in NOAA's 138-year series.**
- **41ht consecutive year (since 1977) that annual temperature is above 20th century average.**
- **All 17 years of 21st century rank are among seventeen warmest on record (1998 is ninth)**
- **Six warmest years have all occurred since 2010**
- **Four warmest have been last 4**
- **Temperatures in 2015-2016 were majorly influenced by strong El Niño**
- **Increased 0.07°C (0.13°F) per decade since 1880 and 0.17°C (0.31°F) since 1970**

year	Change from 20th Century Average	Annual Rank out of 138 years
2014	0.74°C	135
2015	0.90°C	137
2016	0.94°C	138
2017	0.84°C	136

Precipitation changes



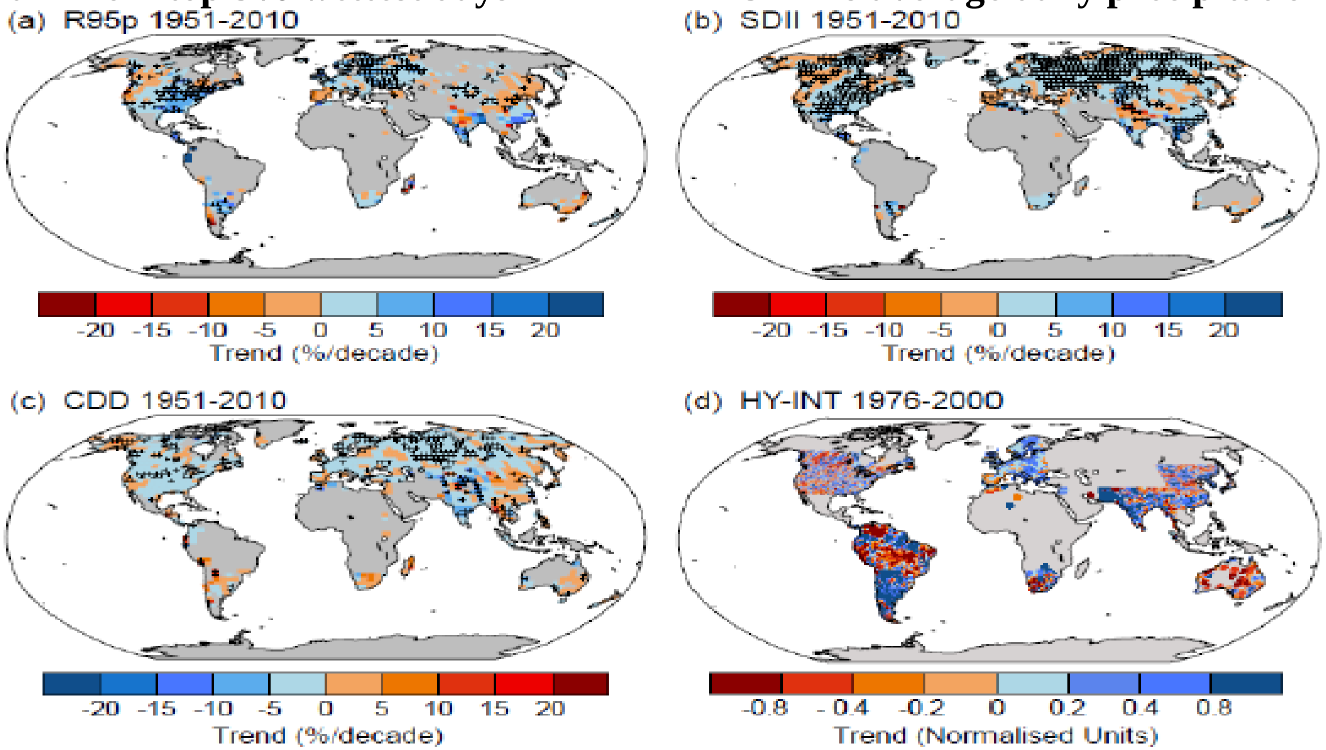


IPCC WGI AR5 Summary for Policy Makers and NOAA state of the Climate

Rainfall is increasing (ocean evaporation)

Precipitation Intensity

R95 is rain from top 5% wettest days **SDII is average daily precipitation intensity**

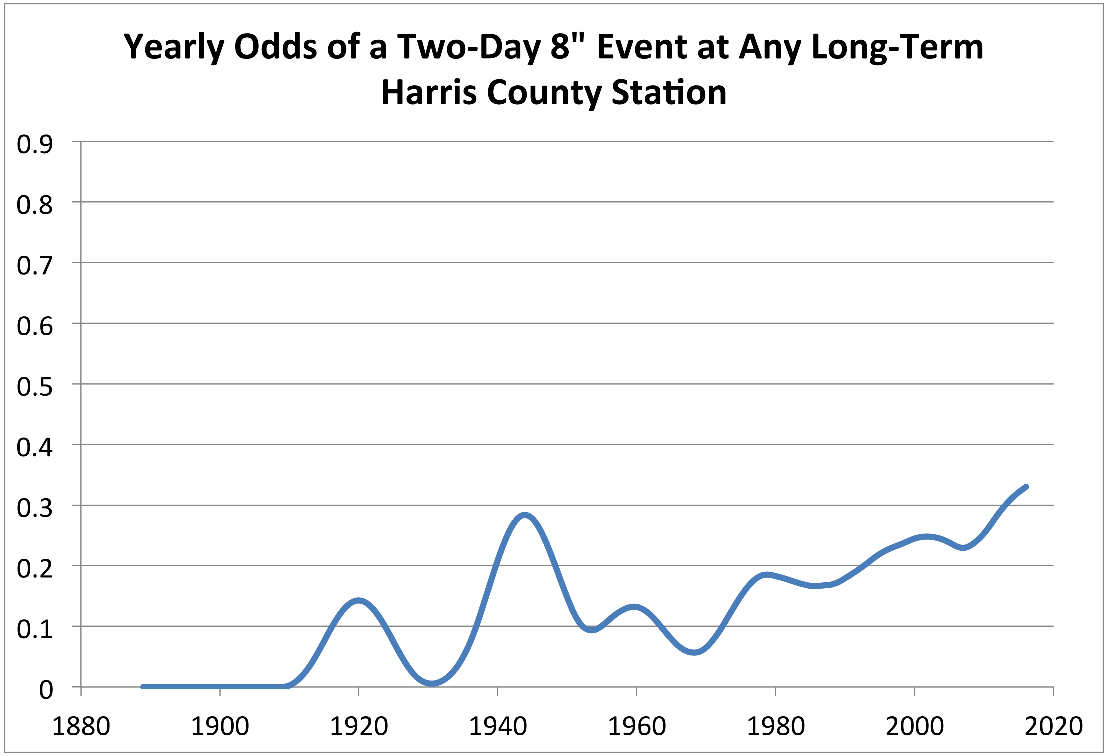


CCD is frequency of consecutive dry days **HY-INT reflects length of drought or extreme precip events**

Rainfall has become more concentrated

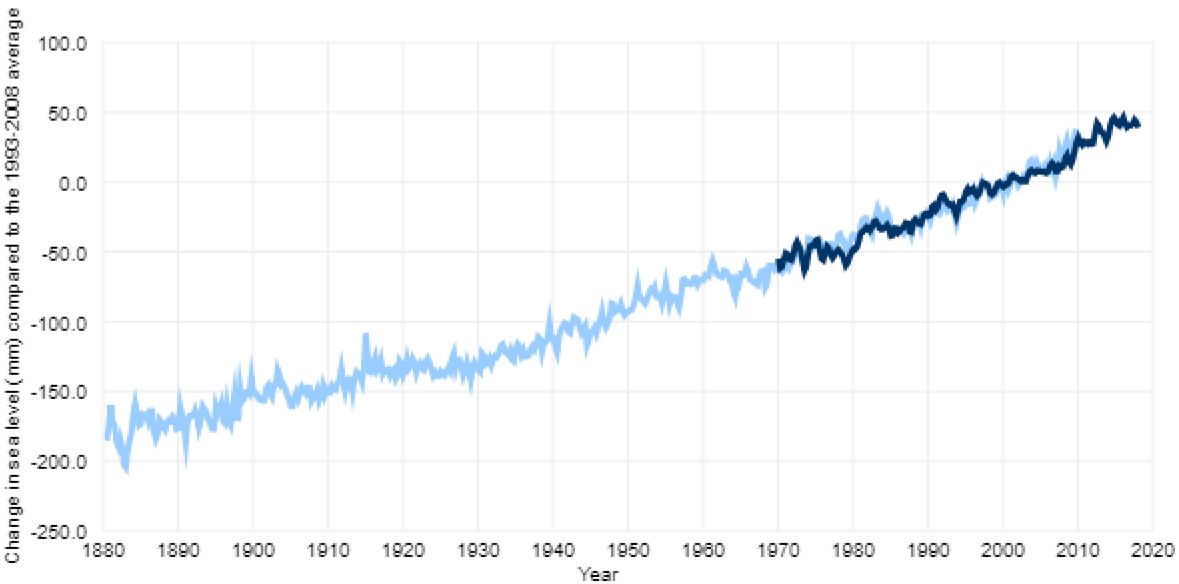
AR5 WGI chapter 2 figure 2.33

Precipitation Intensity - Flooding



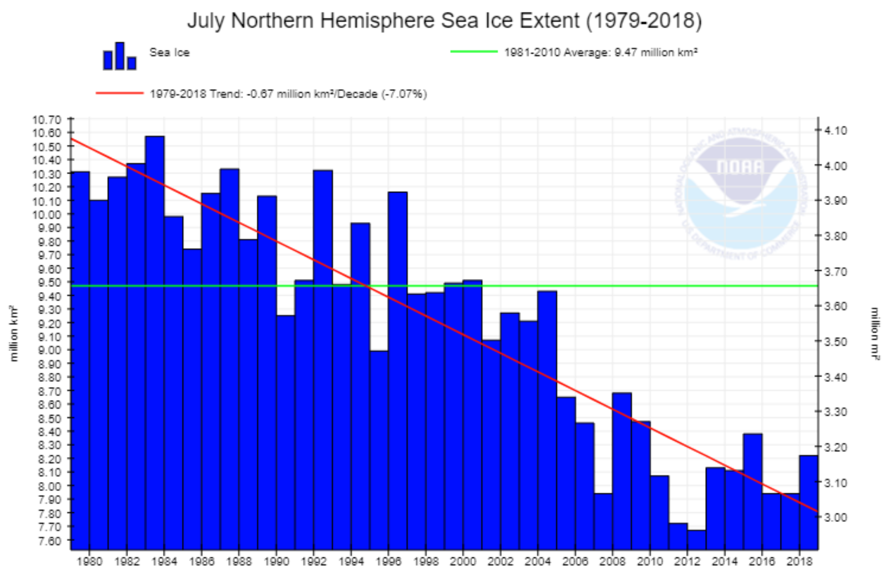
A Preliminary Examination of Heavy Rainfall Changes
in Harris County, John Nielson Gammon TAMU

Ocean and Ice/Snow



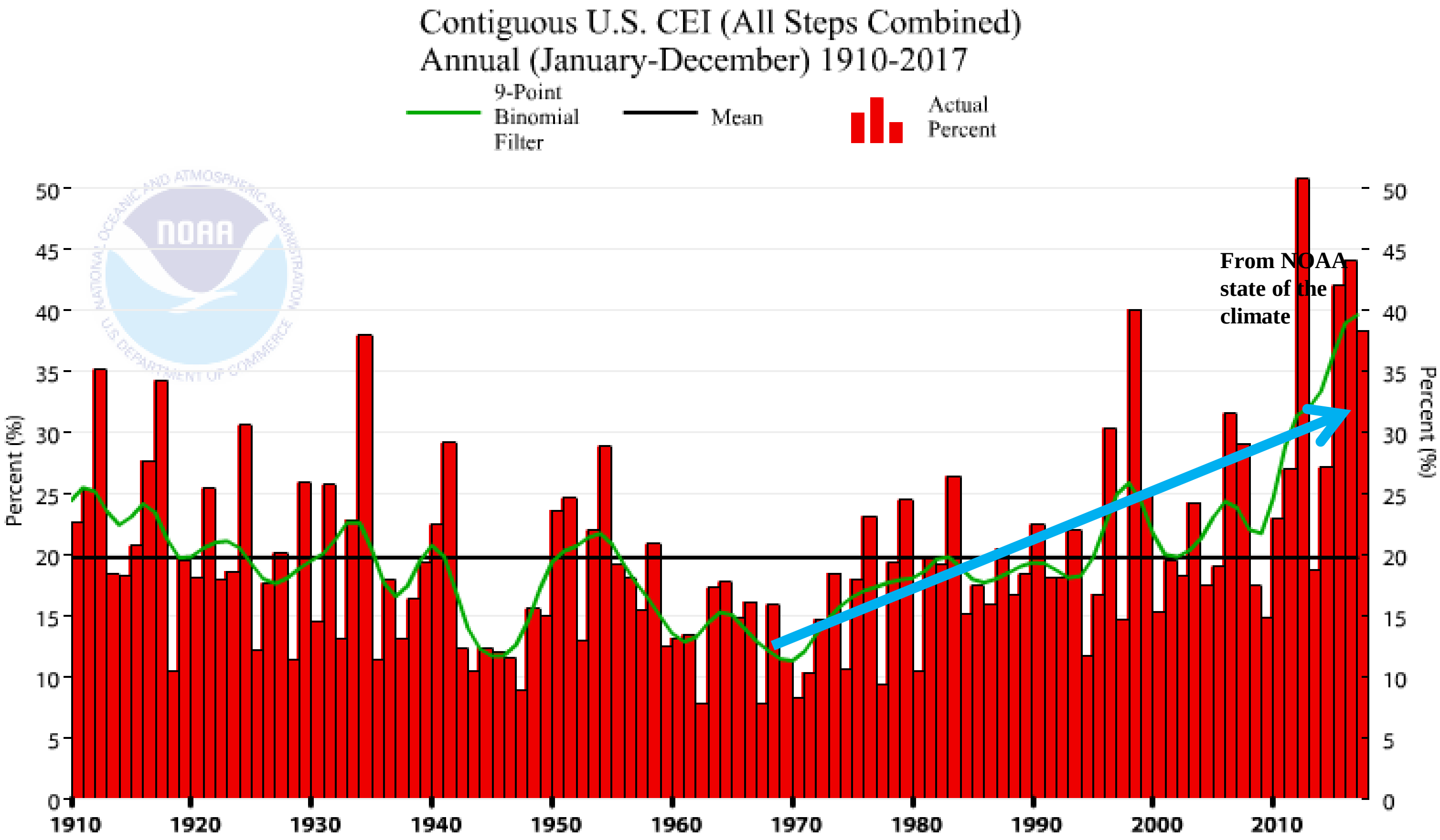
https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

Ice and Snow Melting, Oceans rising (77mm since 1993, – thermal expansion and ice melt)



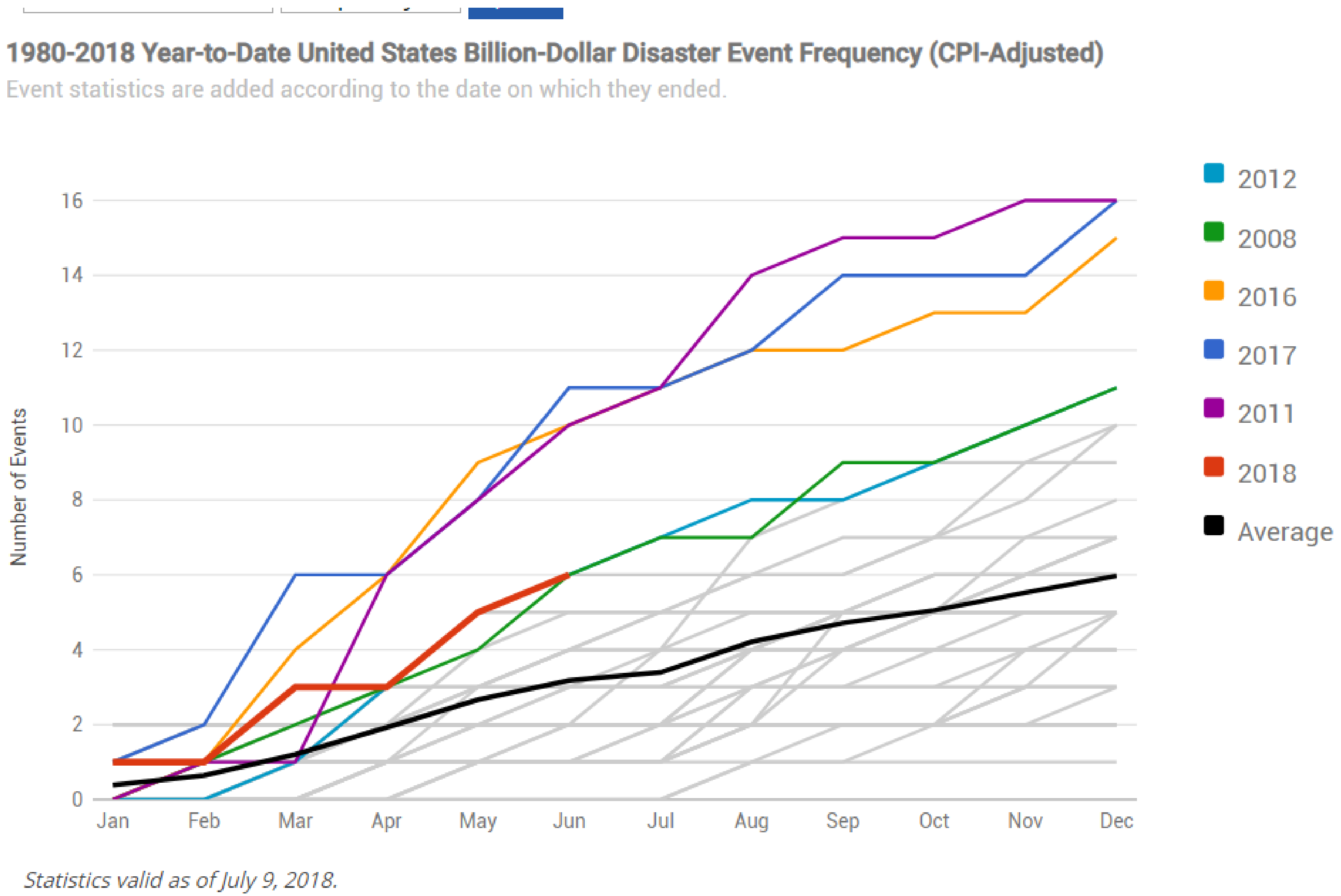
https://www.ncdc.noaa.gov/snow-and-ice/extent/

Index of Extremes



- Maximum temperatures much below normal and much above normal.
- Minimum temperatures much below normal and much above normal.
- Land in severe drought - lowest 10th % PDSI and severe moist. surplus highest 10th %
- Land with greater than normal share of precip from highest 10th % 1-day events.
- Land with a much > than normal days with precip and much > of days without.
- Landfalling tropical storm and hurricane wind velocities.

Billion Dollar Extremes



https://www.ncdc.noaa.gov/billions/

Why is this happening

Why are we seeing climate change?

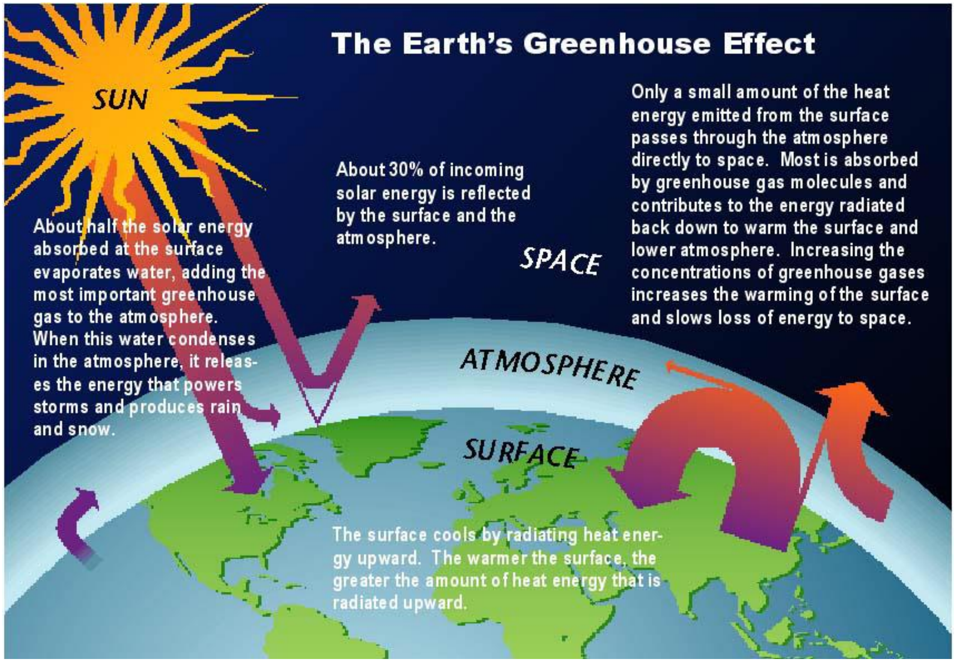
IPCC (1995) "The balance of evidence suggests a **discernible human influence** on global climate."

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.

Greenhouse effect

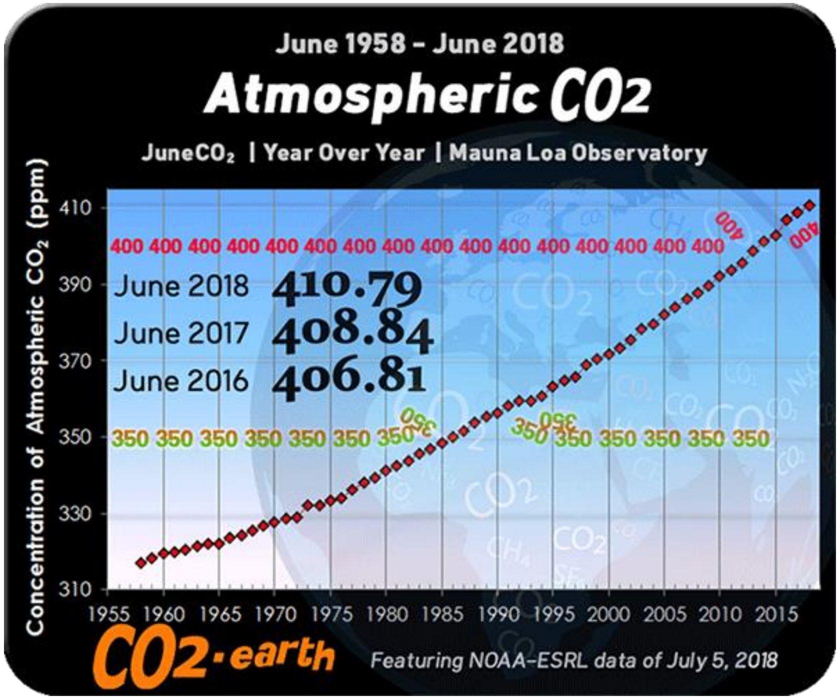


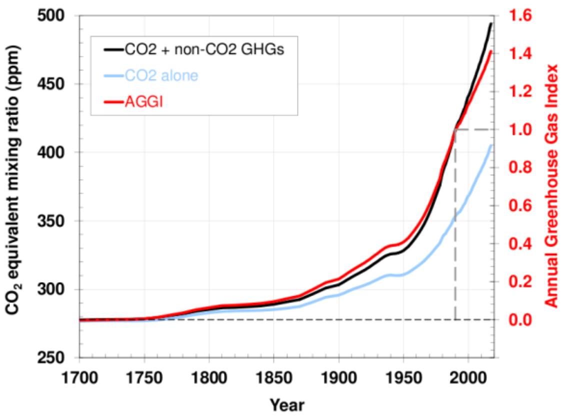
Some gases, like carbon dioxide (CO), trap heat in the atmosphere by absorbing longwave radiation not letting the Sun's energy pass through. A greenhouse allows in sunlight while keeping in heat. Since the gases act similarly in atmosphere, we name them **greenhouse gases**.

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

Why is this happening

GHG Concentration





Pre industrial - 275

2018 - 411

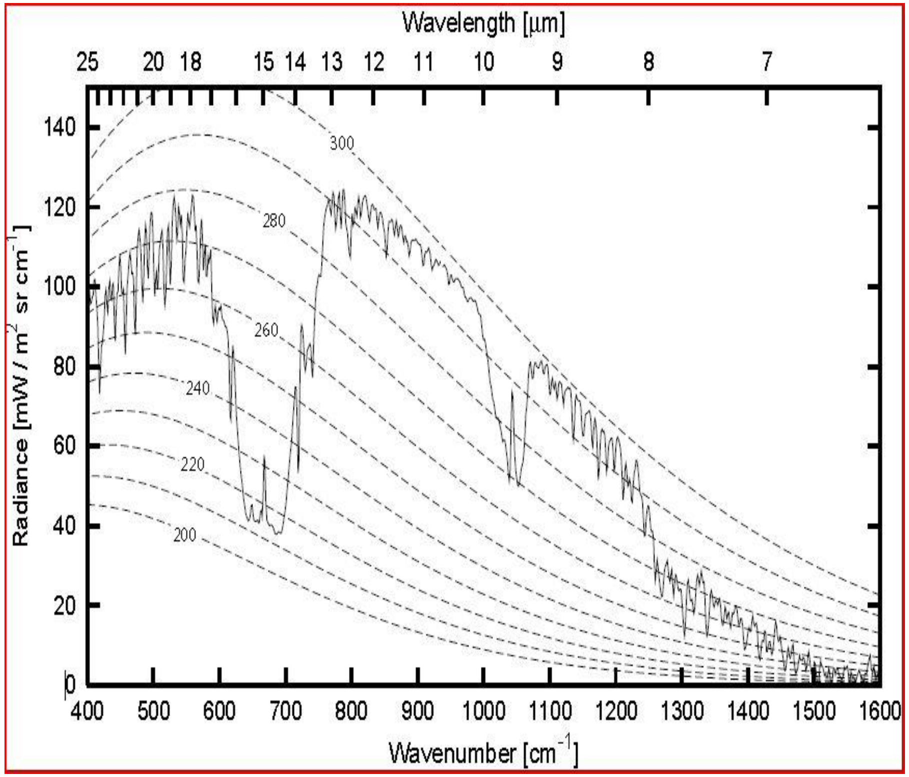
http://co2now.org/

- The AGGI in 2017 was 1.41, which means that we've turned up the warming influence by 41% since 1990.
- It took ~240 years for the AGGI to go from 0 to 1, i.e., to reach 100%, and 26 years for it to increase by another 41%.
- In terms of CO_2 equivalents, the atmosphere in 2017 contained 493 ppm, of which 405 is CO_2 alone. The rest comes from other gases.

https://www.esrl.noaa.gov/gmd/aggi/

Radiation Being trapped

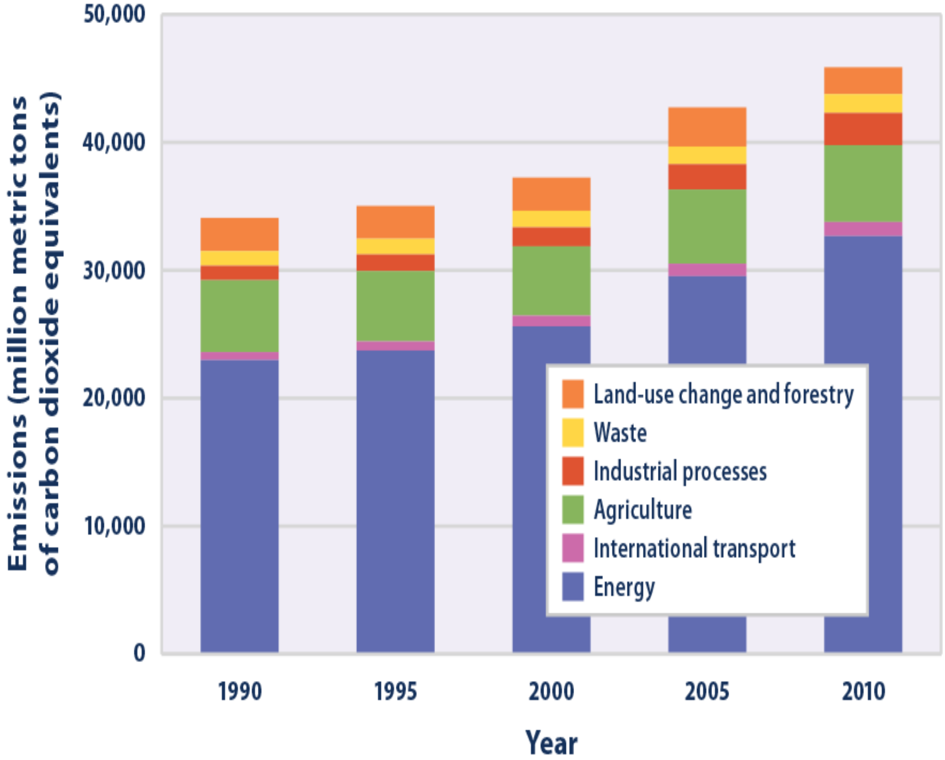
Satellite observations show radiation being retained in number of bands along with heat content



co_2

https://wattsupwiththat.com/2011/03/10/visualizing-the-greenhouse-effect-emission-spectra/

Global GHG Emissions By Source



Globally energy is big one – about 75%

https://www.epa.gov/climate-indicators/climate-change-indicators-us-greenhouse-gas-emissions

What is Projected

Yet more could happen

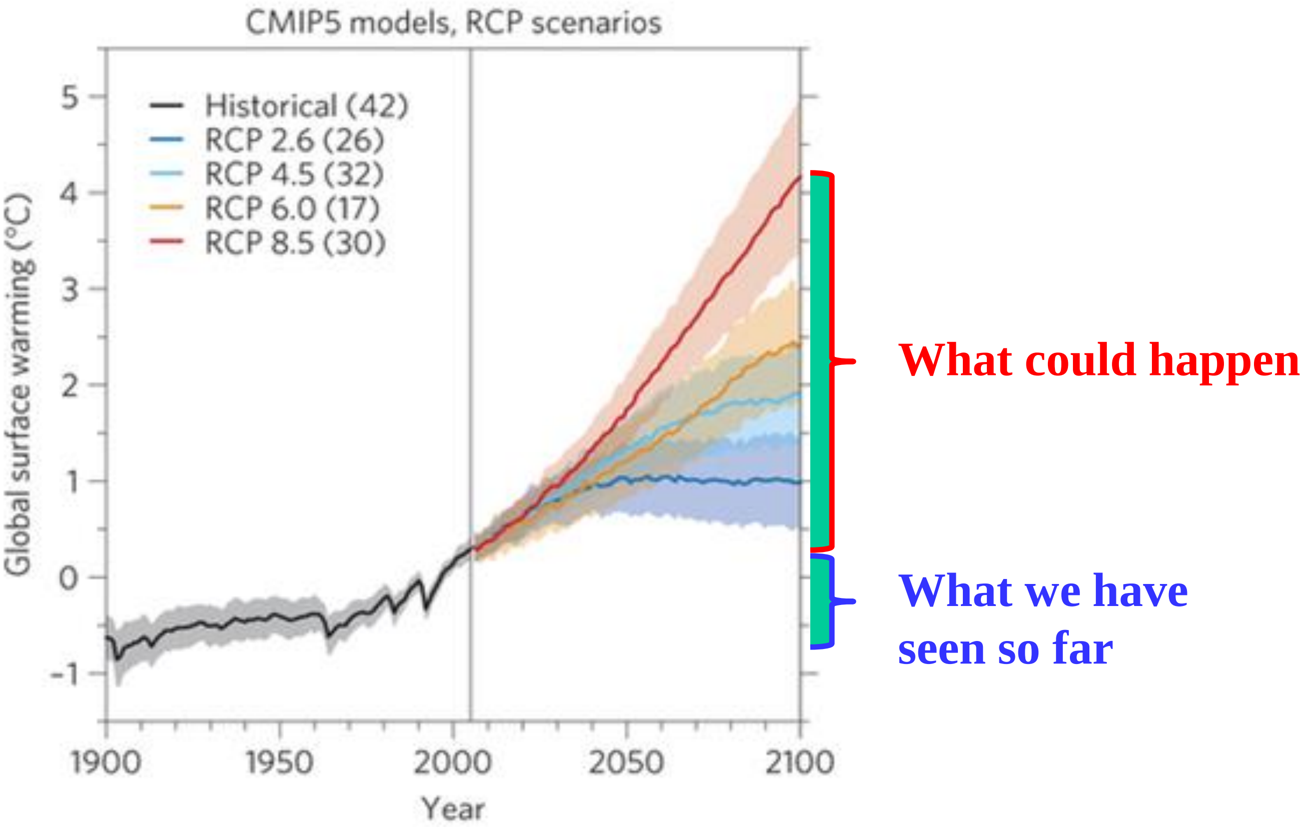
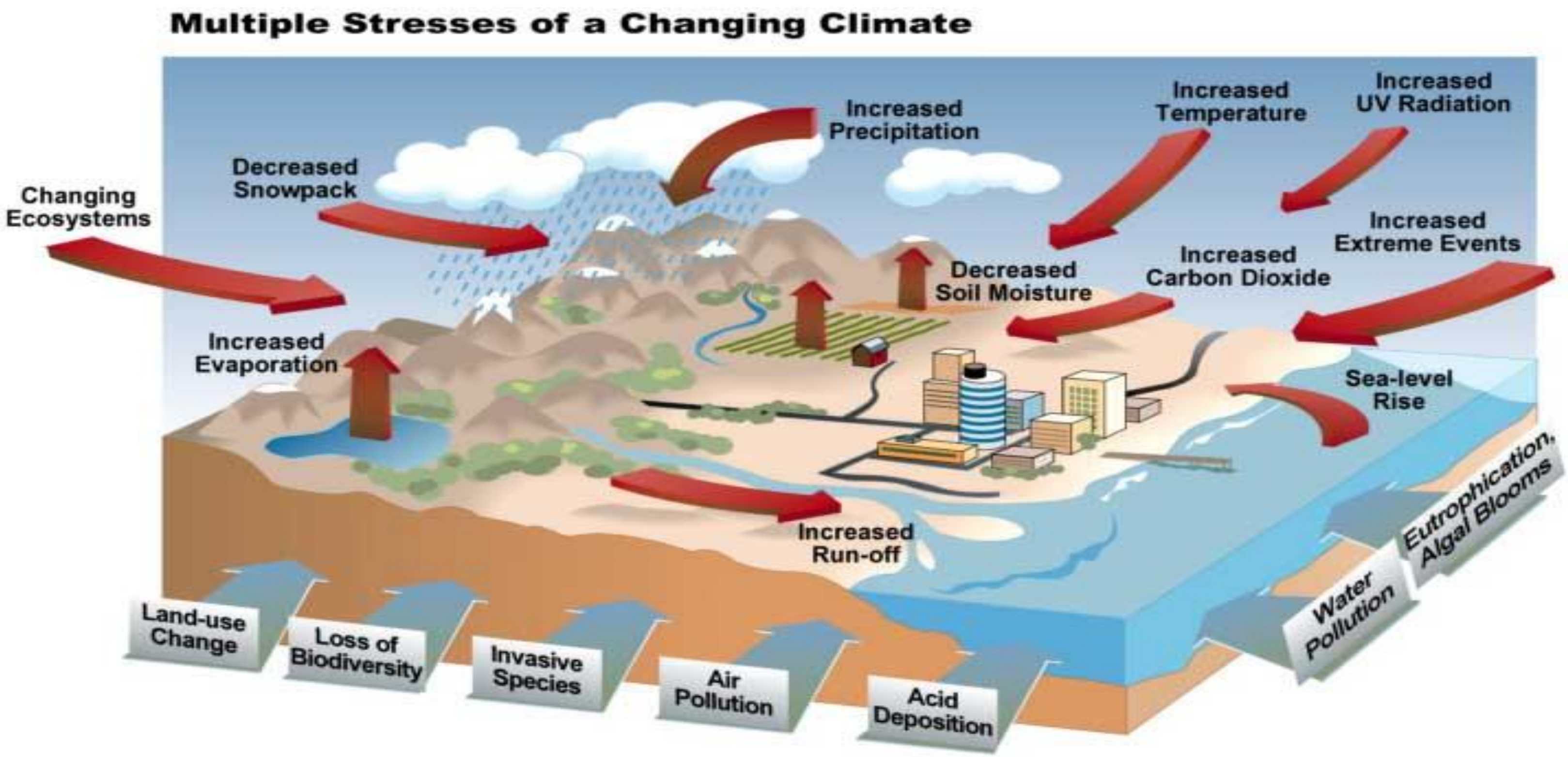


Figure 1: Global temperature change and uncertainty. From Robustness and uncertainties in the new CMIP5 climate model projections Reto Knutti & Jan Sedláček, Nature Climate Change 3, 369–373 (2013) doi:10.1038/nclimate1716,

Effects on Ag

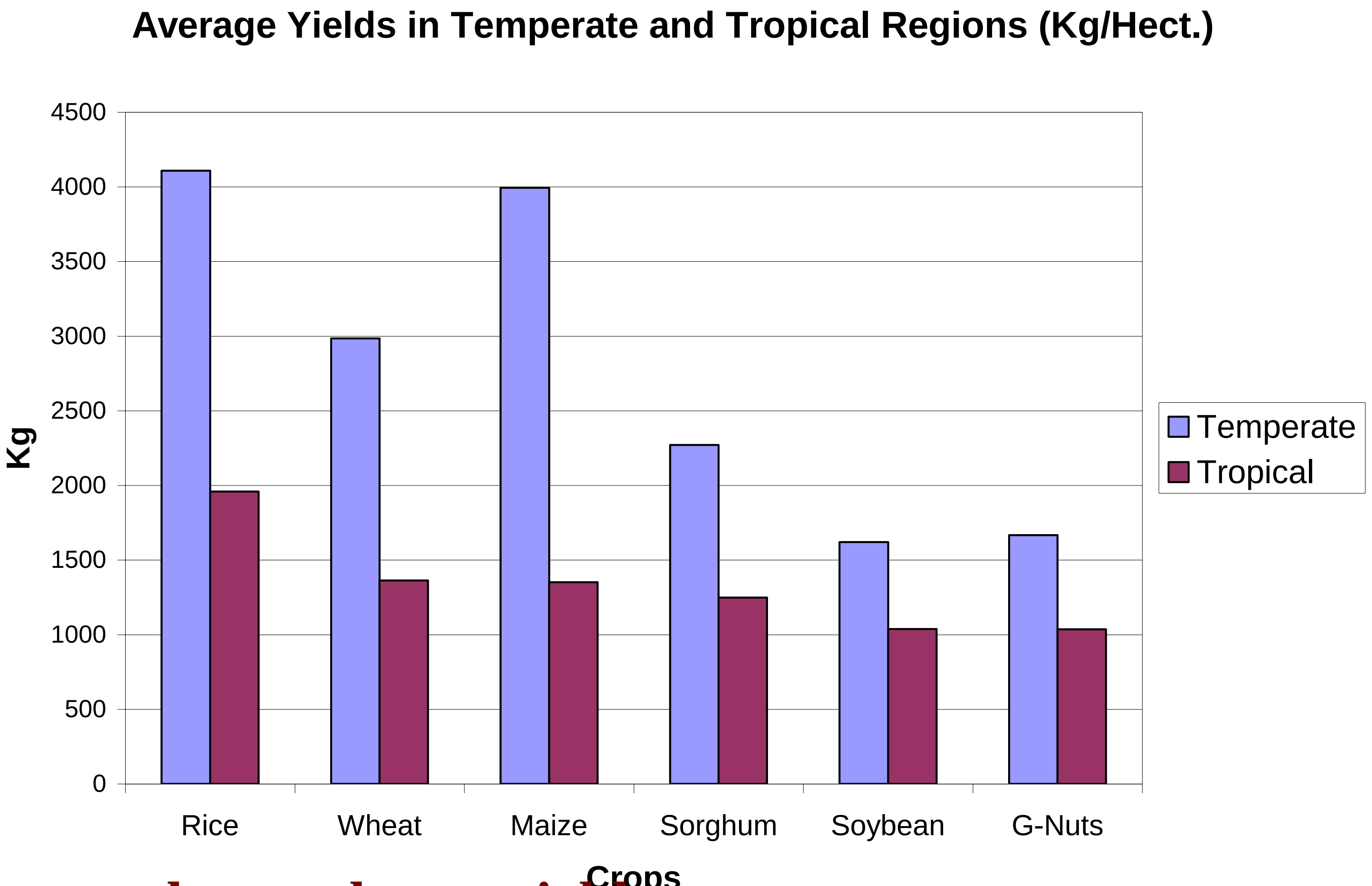
Climate Change can be disruptive



Lots of effects

Source :2001 US National Assessment

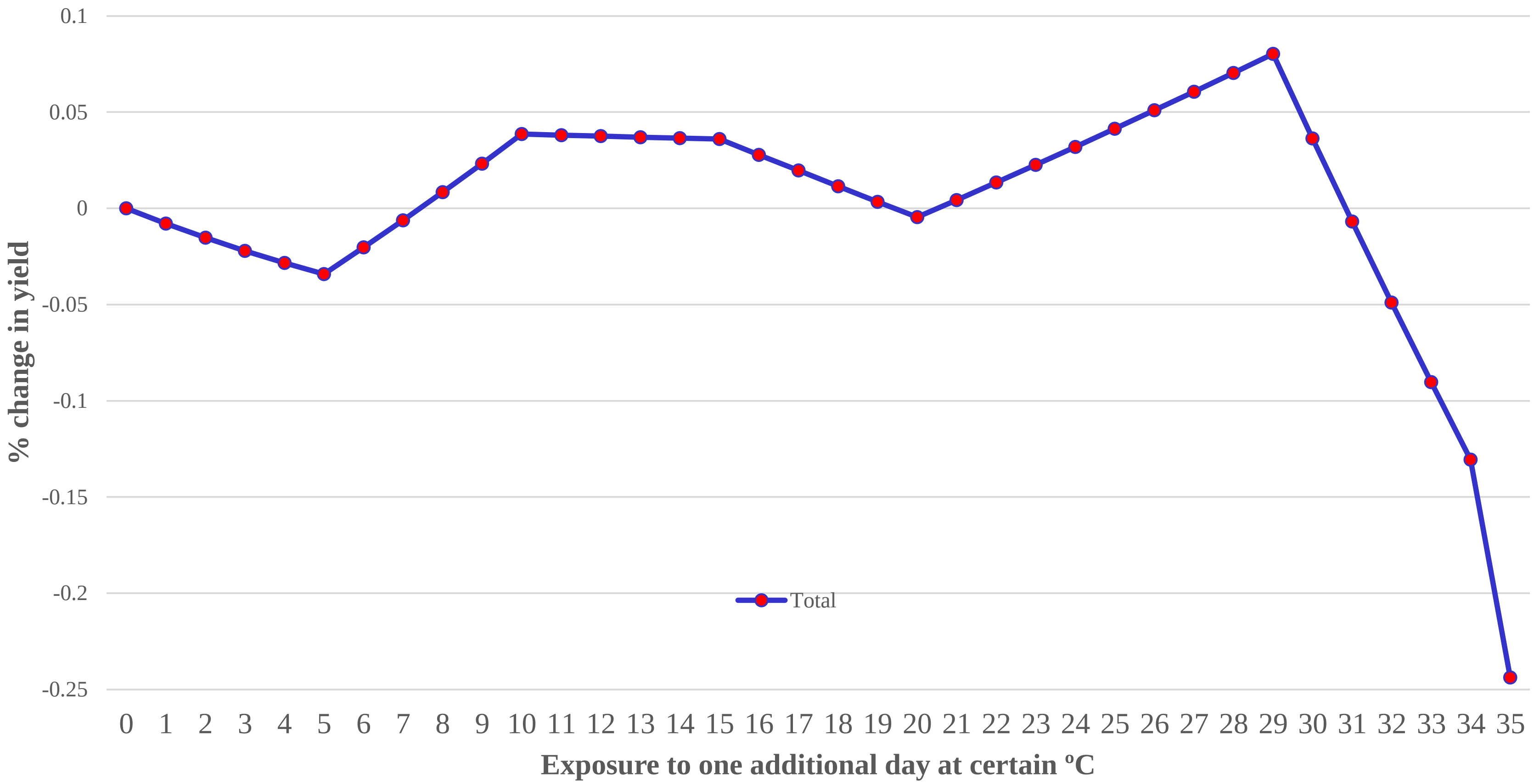
Climate change and agriculture



Hotter places – lower yields

Kaynak: Rosenzweig & Hillel, pg. 189

Projected temperature impact on corn yield



U shaped effects – critical points

Zidong Wang, THREE ESSAYS ON CLIMATE CHANGE, RENEWABLE ENERGY AND AGRICULTURE IN THE US, TAMU PhD thesis, 2018

Climate Change is making things non stationary

POLICYFORUM

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a

that has emerged from climate models (see figure, p. 574).

Why now? That anthropogenic climate change affects the water cycle (*9*) and water supply (*10*) is not a new finding. Nevertheless, sensible objections to discarding stationarity

Water - Can we use 100 year flood?

Milly, PCD, J. Betancourt, M. Falkenmark, 2008. Climate Change: Stationarity Is Dead: Whither Water Management?, Science, Vol. 319. No. 5863, pp. 573 – 574.

Climate Change and Future Analysis: Is Stationarity Dying?

Bruce A. McCarl, Xavier Villavicencio, and Ximing Wu

Economists often do risk analysis in support of management decisions. Commonly, such analyses are based on probability distributions arising from historical data where the distributions developed are based on at least a partial assumption of stationarity. For example, in water-based risk analysis one typically assumes the distribution is stationary, and uses the 100 year drought. In yield-related analyses analysts typically assume the mean is changing with time (proxying for technological progress along with monetary inflation) but that the variance is stationary.

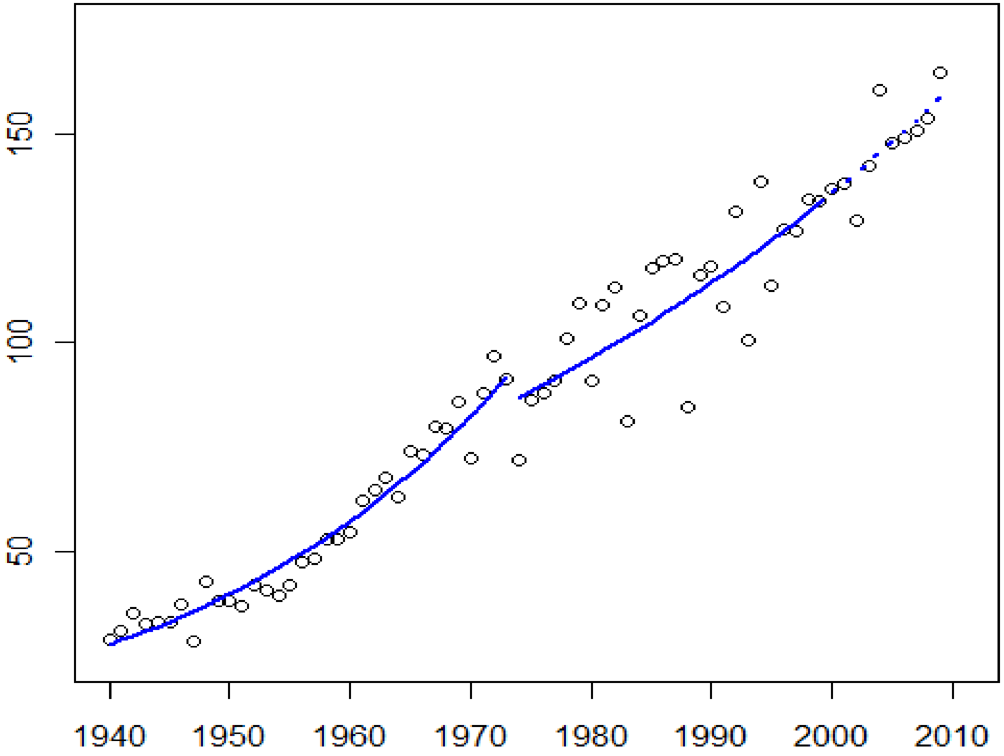
assessments (2007, 2001) or the U.S. National Assessment (Reilly et al. 2002). Many studies indicate that climate change alters mean yields (e.g., Adams et al. 1990; Reilly et al. 2002; Deschenes and Greenstone 2007) and/or land values (Mendelsohn, Nordhaus, and Shaw 1994). Chen, McCarl, and Schimmelpfennig (2004) also indicate that in addition to climate change affecting mean yields, it will contribute to a change in crop yield variability, while Mearns, Rosenzweig, and Goldberg (1992) provide crop simulation results to the same point.

Ag yields - Can we history to assess risk?

McCarl, Bruce A., Xavier Villavicencio, and Ximing Wu. "Climate change and future analysis: is stationarity dying?." American Journal of Agricultural Economics 90.5 (2008): 1241-1247.

Effects- Technological progress

- **US corn yields**



Technical progress is slowing down

Work shows part due to climate

Will we prioritize Biofuels?

What about food needs?

Villavicencio, X., B.A. McCarl, X.M. Wu, and W.E. Huffman, "Climate Change Influences on Agricultural Research Productivity", <u>Climatic Change, Volume 119, Issue 3-4, pp 815-824, 2013.</u>

Baker, J.S., B.C. Murray, B.A. McCarl, S.J. Feng, and R. Johansson, "Implications of Alternative Agricultural Productivity Growth Assumptions on Land Management, Greenhouse Gas Emissions, and Mitigation Potential", <u>American Journal of Agricultural Economics, 95: 435-441, 2013.</u>

CO2 Enrichment Empirical results

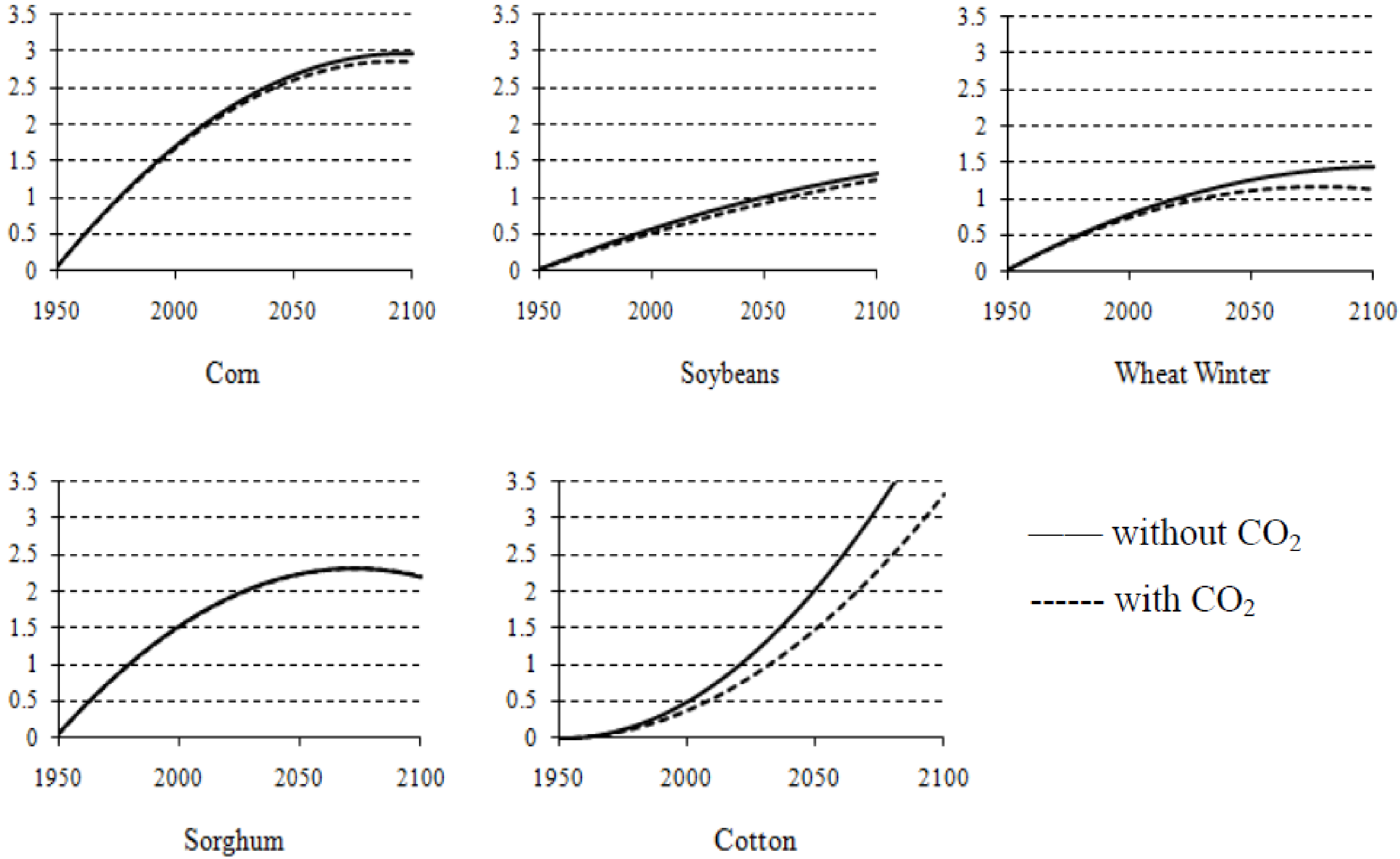
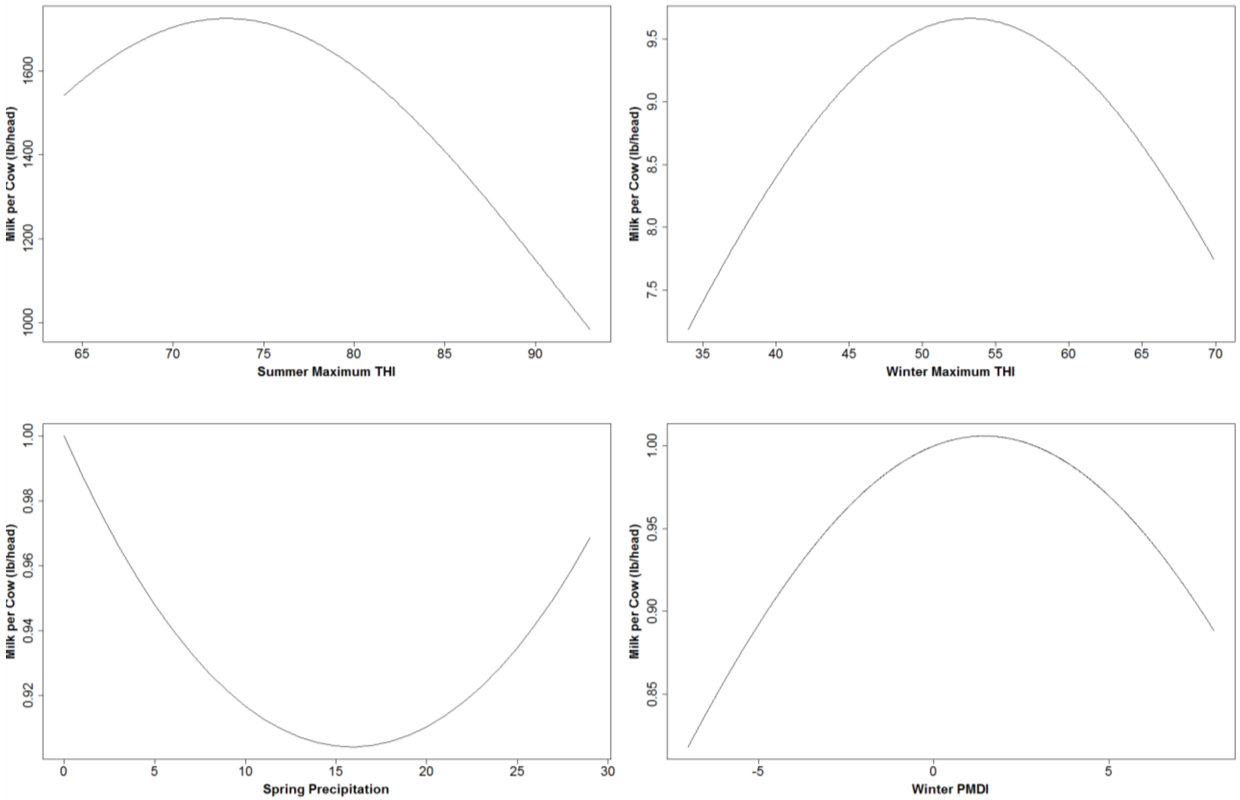


Figure 1. Marginal effect of crop production technology

Wheat and cotton enhanced

Livestock performance- milk



Milk yields have optimal point declines after

Projections show many declines

- **Summer maximum THI, winter maximum THI and winter PMDI: inverse U-shaped relationships, respectively with a critical value of 72, 55, 1.5**
- **Spring precipitation: U-shaped relationship with a threshold value of 15**

XinXin Fan, An Integrated Analysis of Federal Milk Marketing Order Price Differential Policy and Climate Change Effects in the U.S Dairy Industry, TAMU PhD dissertation, 2018

Projected temperature impact on cattle sale weight

Scenarios	Sale Month	Texas	Kansas	Nebraska	Iowa	Colorado	California	Wisc
Base Scenario:								
Actual Average Sale Weight Between 1993 and 2010	Jun.	1122	1203	1234	1196	1218	1268	1297
	Dec.	1106	1175	1234	1203	1213	1271	1290
A1F Scenario: 2020								
Projected Sale Weight for Period 2010-2039	Jun.	1125	1187	1219	1220	1214	1262	1239
	Dec.	1128	1185	1217	1213	1225	1262	1237
A1F Scenario: 2050								
Projected Sale Weight for Period 2040-2069	Jun.	1127	1187	1222	1224	1213	1263	1243
	Dec.	1129	1188	1216	1214	1220	1265	1236
A1F Scenario: 2080								
Projected Sale Weight for Period 2070-2099	Jun.	1133	1189	1225	1227	1214	1267	1248
	Dec.	1134	1194	1220	1220	1217	1271	1241

Livestock yields lower in places

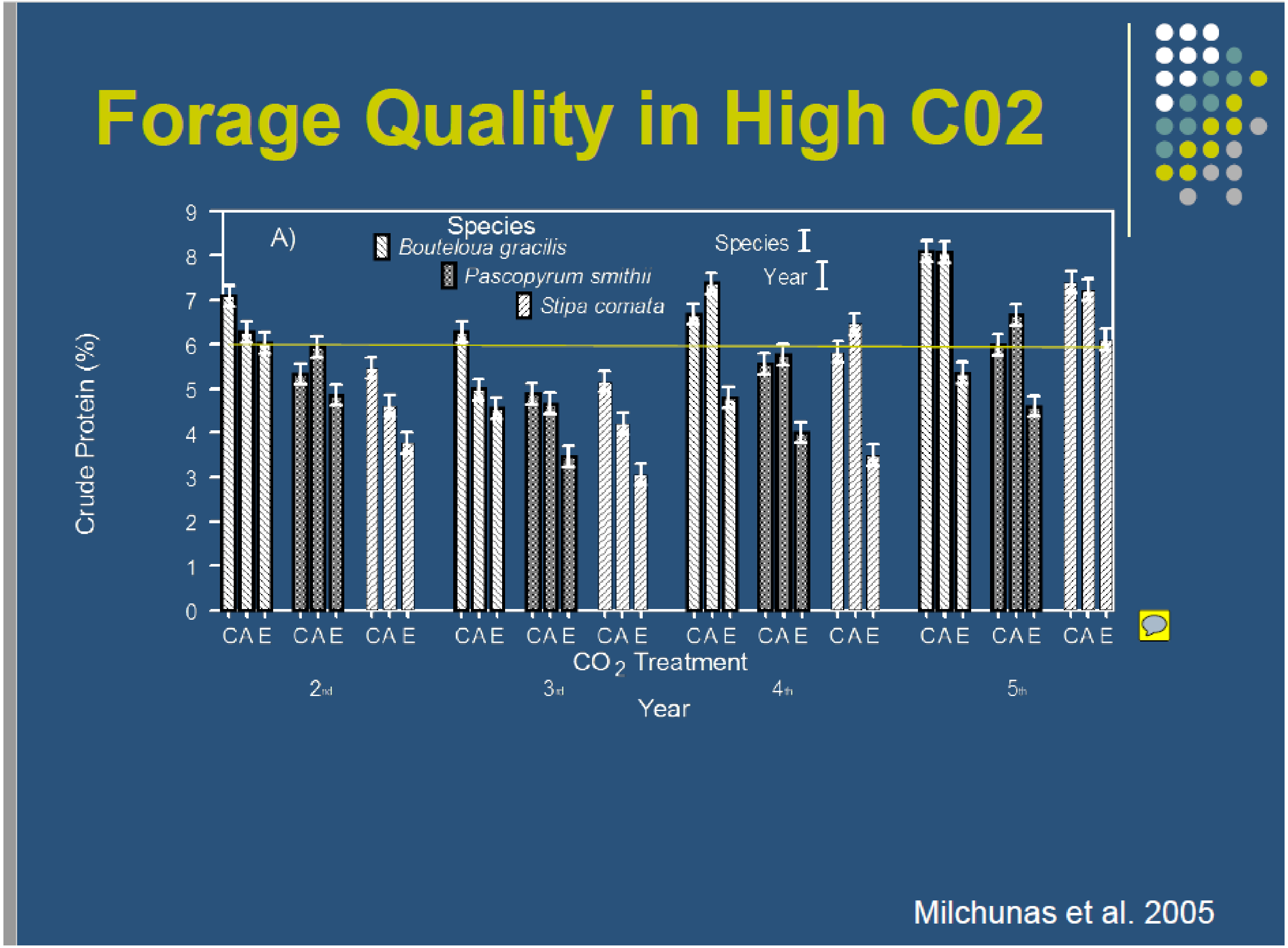
Feedlots, Climate Change and Dust: Economic Vulnerability and Adaptation Chin-Hsien Yu, Bruce A. McCarl Seong C. Park

Observations - Livestock

Hotter climate in south

- **Increases time to grow beef cattle and swine to a given weight**
- **Decrease calving rate**
- **Decreases milk production**
- **Decreases grass growth**

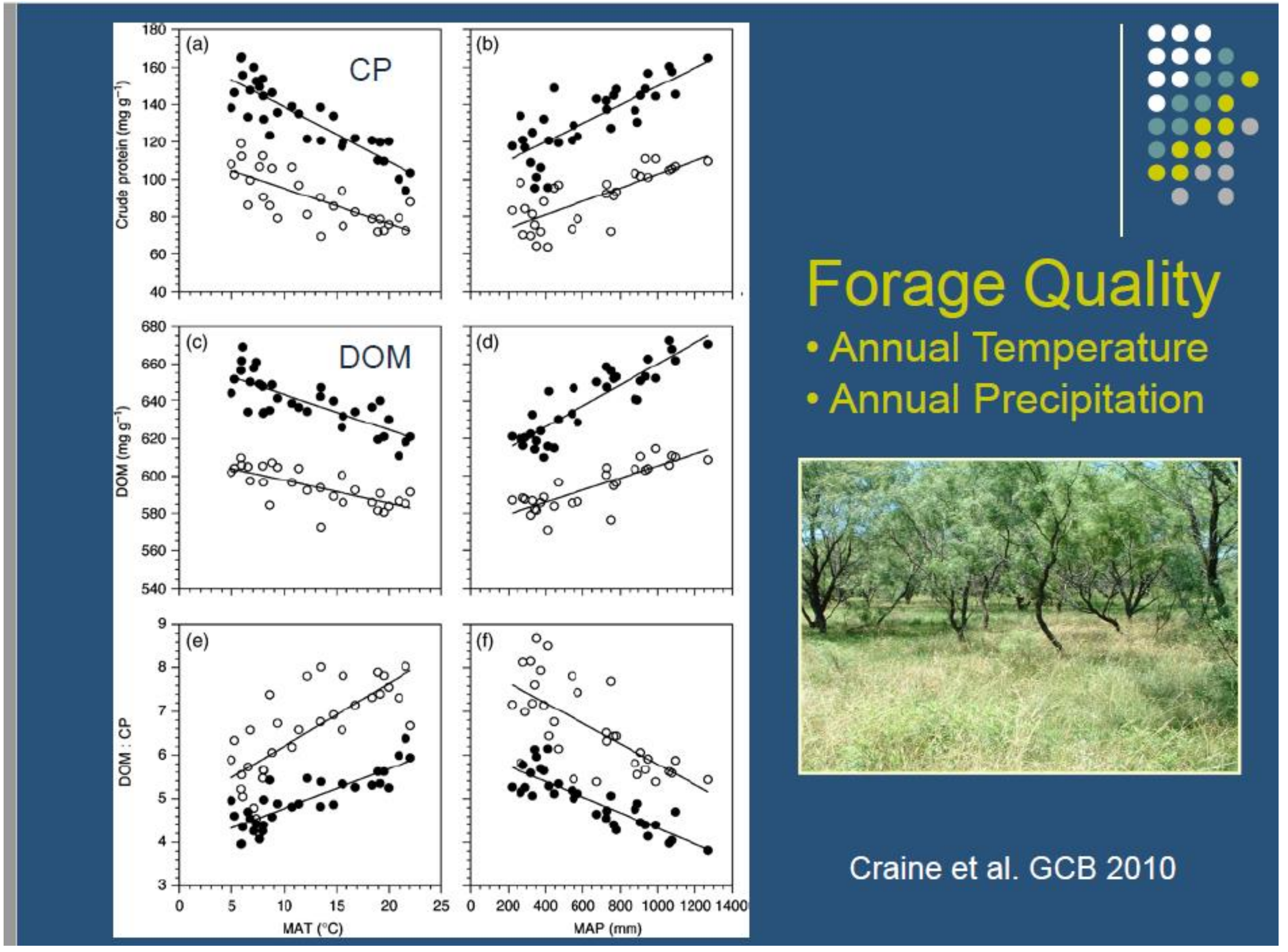
Beach, R.H., Y.W. Zhang, J.S. Baker, A.D. Hagerman, and B.A. McCarl, "U.S. Livestock Production under Climate Change: Implications for International Trade", Presented at the 2012 USDA ERS Conference: Emerging Issues in Global Animal Product Trade in Washington DC September 27-28, 2012.
Reilly, J.M., J. Hrubovcak, J. Graham, D.G. Abler, R. Darwin, S.E. Hollinger, R.C. Izaurralde, S. Jagtap, J.W. Jones, J. Kimble, B.A. McCarl, L.O. Mearns, D.S. Ojima, E.A. Paul, K. Paustian, S.J. Riha, N.J. Rosenberg, C. Rosenzweig, and F. Tubiello, Changing Climate and Changing Agriculture: Report of the Agricultural Sector Assessment Team, US National Assessment, prepared as part of USGCRP National Assessment of Climate Variability, Cambridge University Press, 2002.
Mader, Terry L., Katrina L. Frank, John A. Harrington, G. Leroy Hahn, and John A. Nienaber. 2009. Potential climate change effects on warm-season livestock production in the great plains. Climatic Change 97 (3-4): 529 - 541.



Briske, D.D. , L.A. Joyce, H.W. Polley, J.R. Brown, K. Wolter, J.A. Morgan, B.A. McCarl, and D.W. Bailey, "Climate Change Adaptation: Linking Regional Exposure with Diverse Adaptive Capacity", Frontiers in Ecology and the Environment, Volume 13 (2015) Issue 5 (June), 249-256, 2015.

Joyce, L. A., Briske, D. D., Brown, J. R., Polley, H. W., McCarl, B. A., & Bailey, D. W. (2013). Climate change and North American rangelands: assessment of mitigation and adaptation strategies. *Rangeland Ecology & Management*, *66*(5), 512-528.

Polley, H. Wayne, David D. Briske, Jack A. Morgan, Klaus Wolter, Derek W. Bailey, and Joel R. Brown. "Climate change and North American rangelands: trends, projections, and implications." *Rangeland Ecology & Management* 66, no. 5 (2013): 493-511.



Briske, D.D. , L.A. Joyce, H.W. Polley, J.R. Brown, K. Wolter, J.A. Morgan, B.A. McCarl, and D.W. Bailey, "Climate Change Adaptation: Linking Regional Exposure with Diverse Adaptive Capacity", Frontiers in Ecology and the Environment, Volume 13 (2015) Issue 5 (June), 249-256, 2015.

Joyce, L. A., Briske, D. D., Brown, J. R., Polley, H. W., McCarl, B. A., & Bailey, D. W. (2013). Climate change and North American rangelands: assessment of mitigation and adaptation strategies. *Rangeland Ecology & Management*, *66*(5), 512-528.

Polley, H. Wayne, David D. Briske, Jack A. Morgan, Klaus Wolter, Derek W. Bailey, and Joel R. Brown. "Climate change and North American rangelands: trends, projections, and implications." *Rangeland Ecology & Management* 66, no. 5 (2013): 493-511.

Climate Effects on Pests

Impacts of rainfall on total pesticide usage cost for corn, cotton, soybeans and wheat are positive. mixed effect of temperature.

% Change in Pesticide Cost for a % Change in Climate

	Precipitation	Temperature
CORN	-0.0292	0.2284
COTTON	0.3100	0.6607
POTATOES	-0.0777	0.2998
SOYBEANS	-0.0435	-0.1042
WHEAT	-1.1579	1.8678

Pest and pest cost expansions

Chen, C.C. and B.A. McCarl, "Pesticide Usage as Influenced by Climate: A Statistical Investigation", Climatic Change, 50, 475-487, 2001.

Projections are for altered river flow

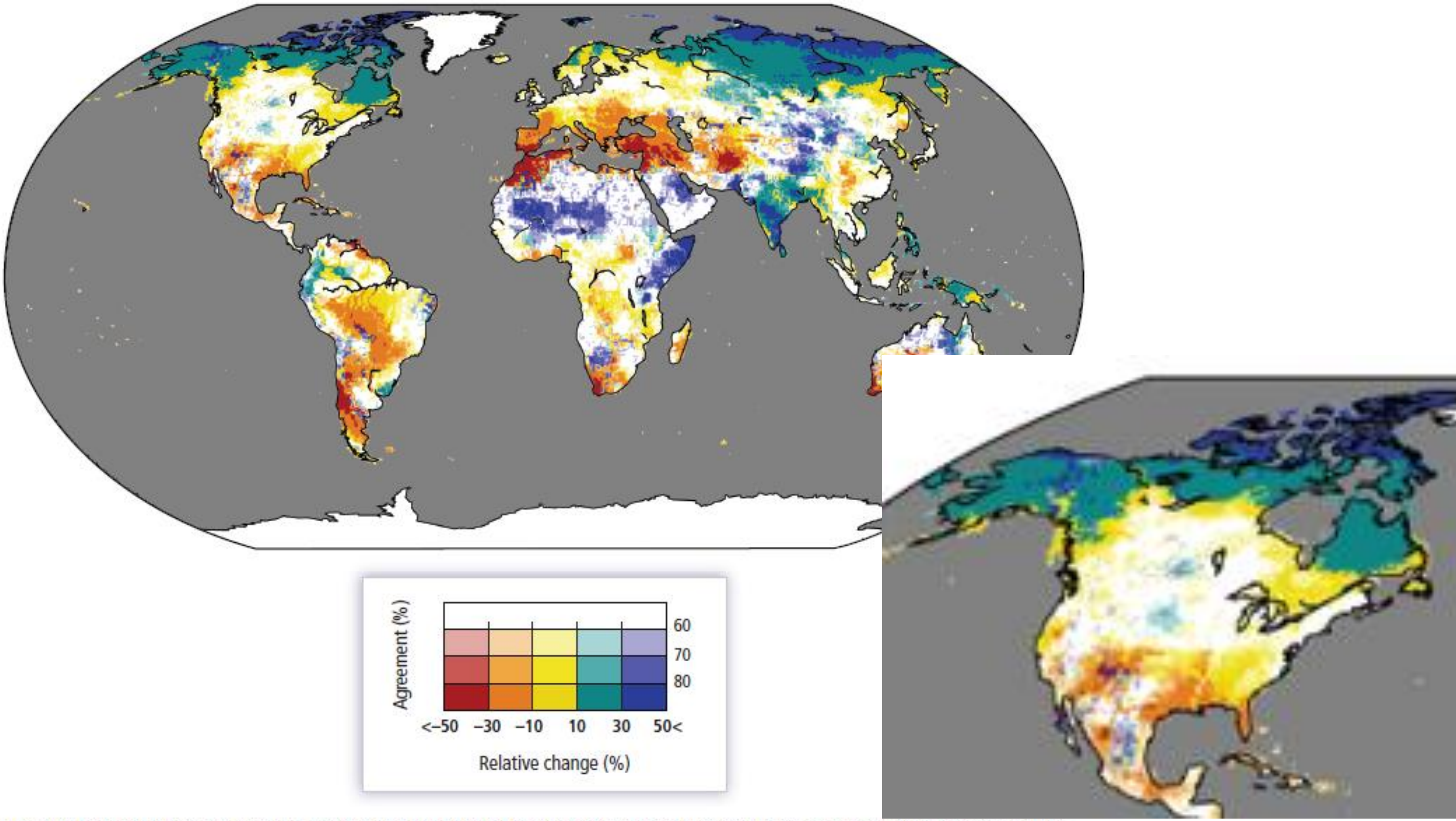


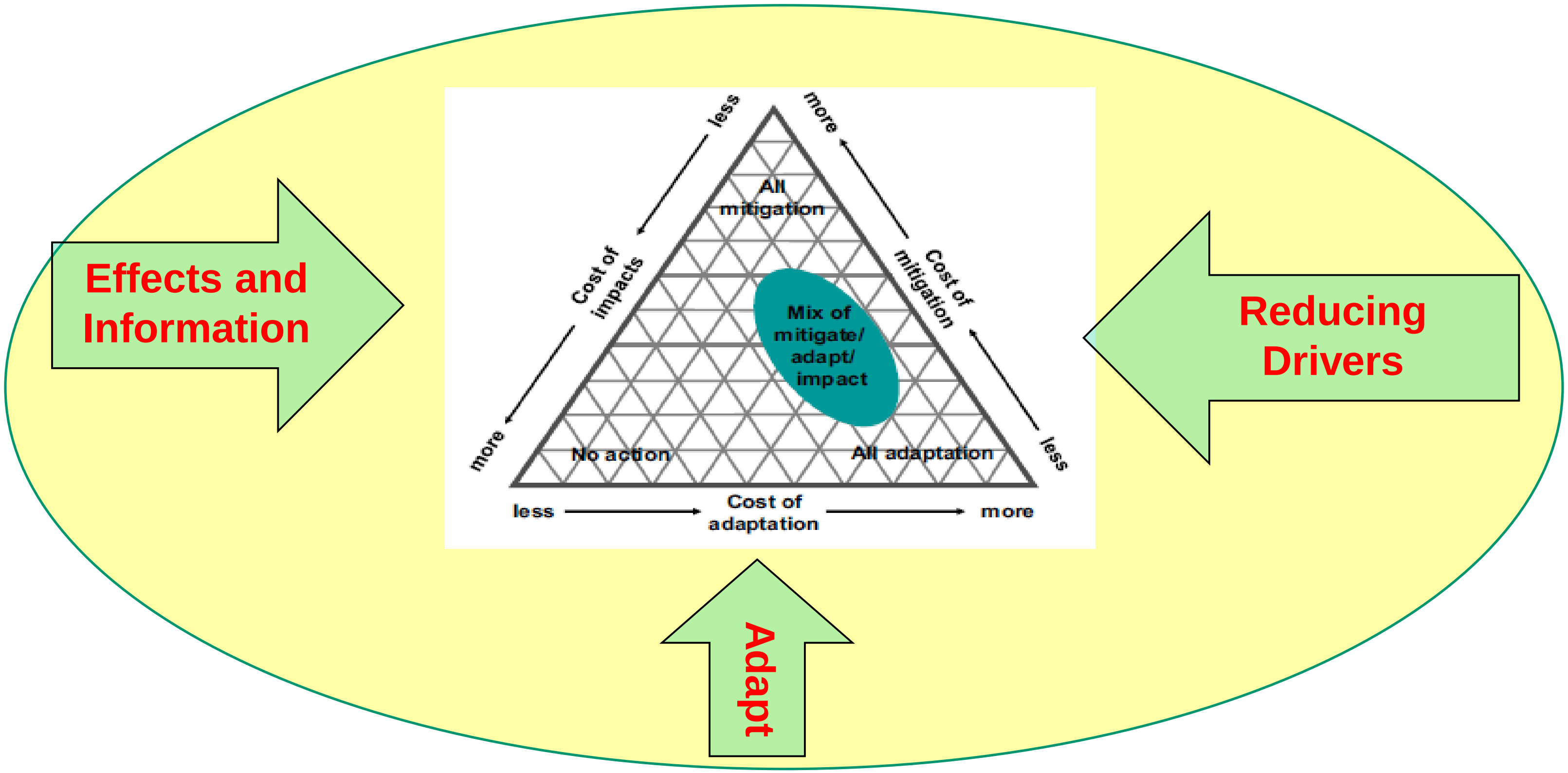
Figure 3-4 | Percentage change of mean annual streamflow for a global mean temperature rise of 2°C above 1980–2010 (2.7°C above pre-industrial). Color hues show the multi-model mean change across 5 General Circulation Models (GCMs) and 11 Global Hydrological Models (GHMs), and saturation shows the agreement on the sign of change across all 55 GHM–GCM combinations (percentage of model runs agreeing on the sign of change) (Schewe et al., 2013).

Less water in many regions

IPCC, WH2 AR5 chapter 3

What do we do

Meeting the Challenge
Basics of Climate Change Action



- Climate shift alters growing conditions and productivity - **Effects**
- Alter operations reduce future extent by limiting drivers **Mitigation**
- Alter management to reduce impact of change - **Adaptation**

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.

Policy Challenge

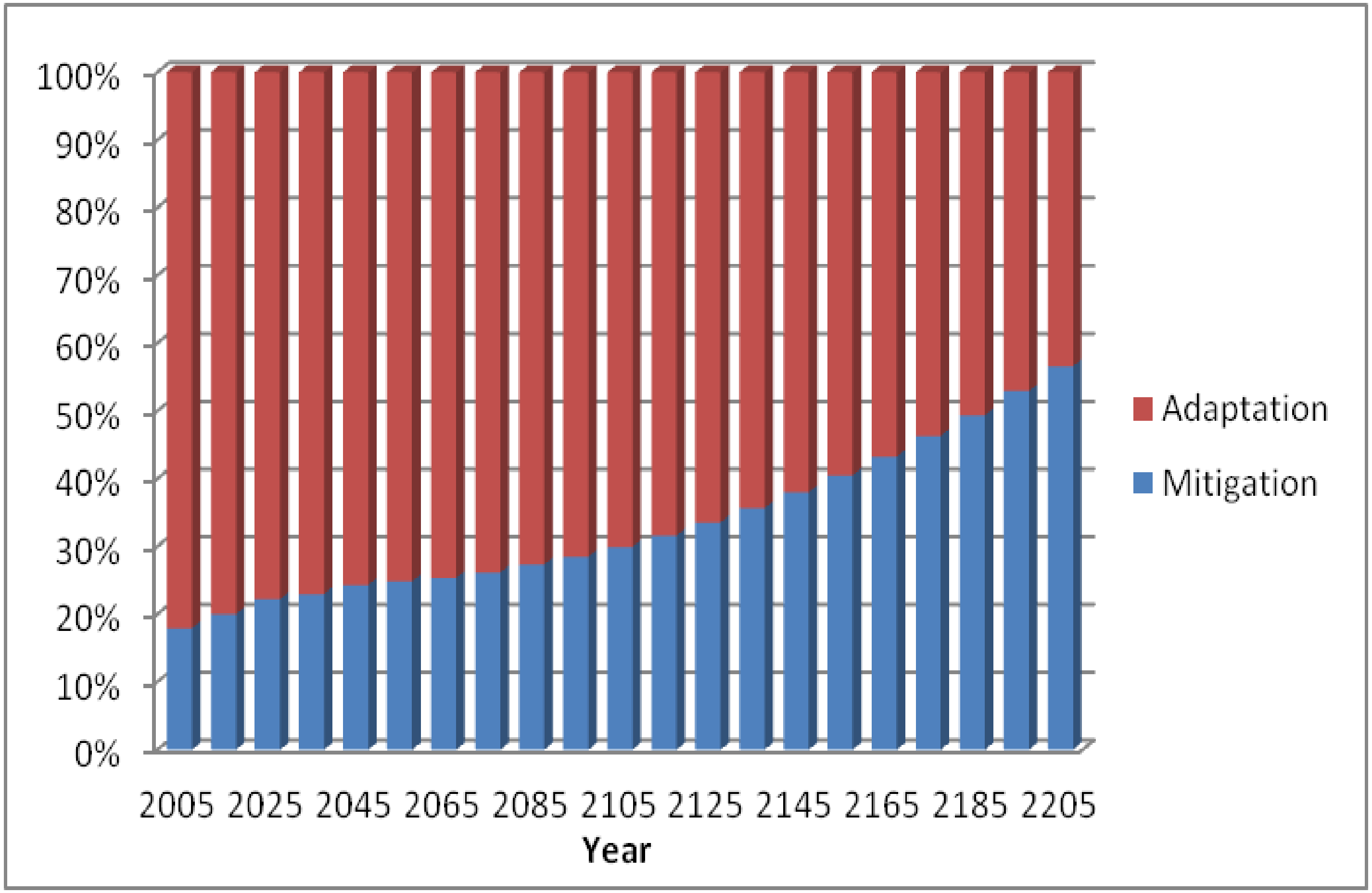
- Most effects in future but much of Mitigation and adaptation costs now
- Exact nature of effects and effectiveness of adaptation and mitigation are uncertain
- Unilateral action on mitigation not effective but collective no action means nothing gets done
- Resource and investment competition between current production/R&D and mitigation/adaptation

So grand challenge is

How much to invest now in mitigation and adaptation in interest of future parties at likely cost of current?

Here I focus on adaptation

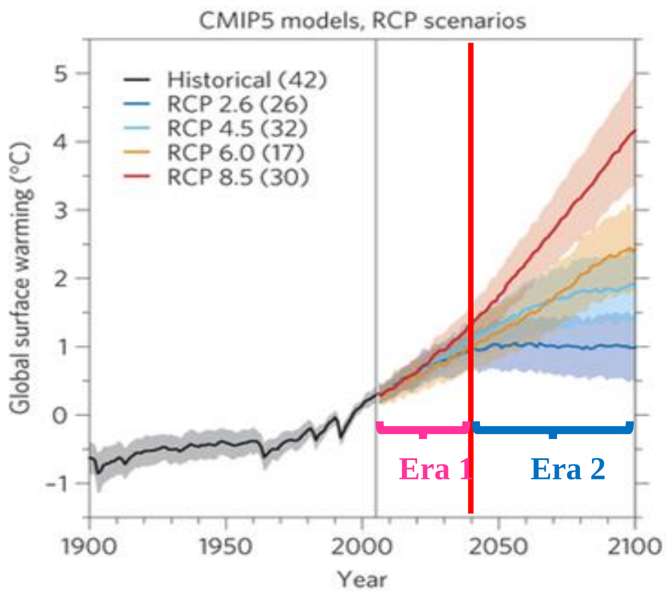
Adaptation Share Over Time



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.

Adaptation – Inevitability



4°

2°

Inevitable amount

What we have seen so far

Era 1 For now until 2040-2050 there is not much contribution from limiting emissions with an inevitable amount of climate change of about 1 degree C. Need adaptation plus mitigation

Era 2 – In this time period (2050-2100) mitigation has effects and the climate is warming the question is how much

Huge Ag Challenge -- Need to adapt to accommodate 1 degree change

McCarl, B.A., "Elaborations on Climate Adaptation in U.S. Agriculture", Choices, 2nd Quarter 30(2) http://www.choicesmagazine.org/magazine/pdf/cmsarticle_432.pdf, 2015.
McCarl, B.A., A. Thayer, and J.P.H. Jones, "The Challenge of Climate Change Adaptation: An Economically Oriented Review", Journal of Agricultural and Applied Economics, forthcoming, 2015.

Huge Ag Challenge

Need to adapt to accommodate 1 degree change

Forms of Adaptation

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 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 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 Possibilities

Ag/Ecosystem items

- **R&D** - Heat tolerant crops, Low water using crops, Pest and disease resistance/treatment, Heat tolerant livestock breeds
- **Risk management assistance**
  - Variability insurance
- **Information Dissemination**
  - Adaption practices
  - Altered enterprises
- **Infrastructure investment -** water control, migrated processing
- **Managing previously unmanaged items** – ecosystems,

Aisabokhae, R.A., B.A. McCarl, and Y.W. Zhang, "Agricultural Adaptation: Needs, Findings and Effects", Handbook on Climate Change and Agriculture, Edited by Robert Mendelsohn and Ariel Dinar, Published by Edward Elgar, Northampton, MA, pp 327-341, 2011.

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

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.

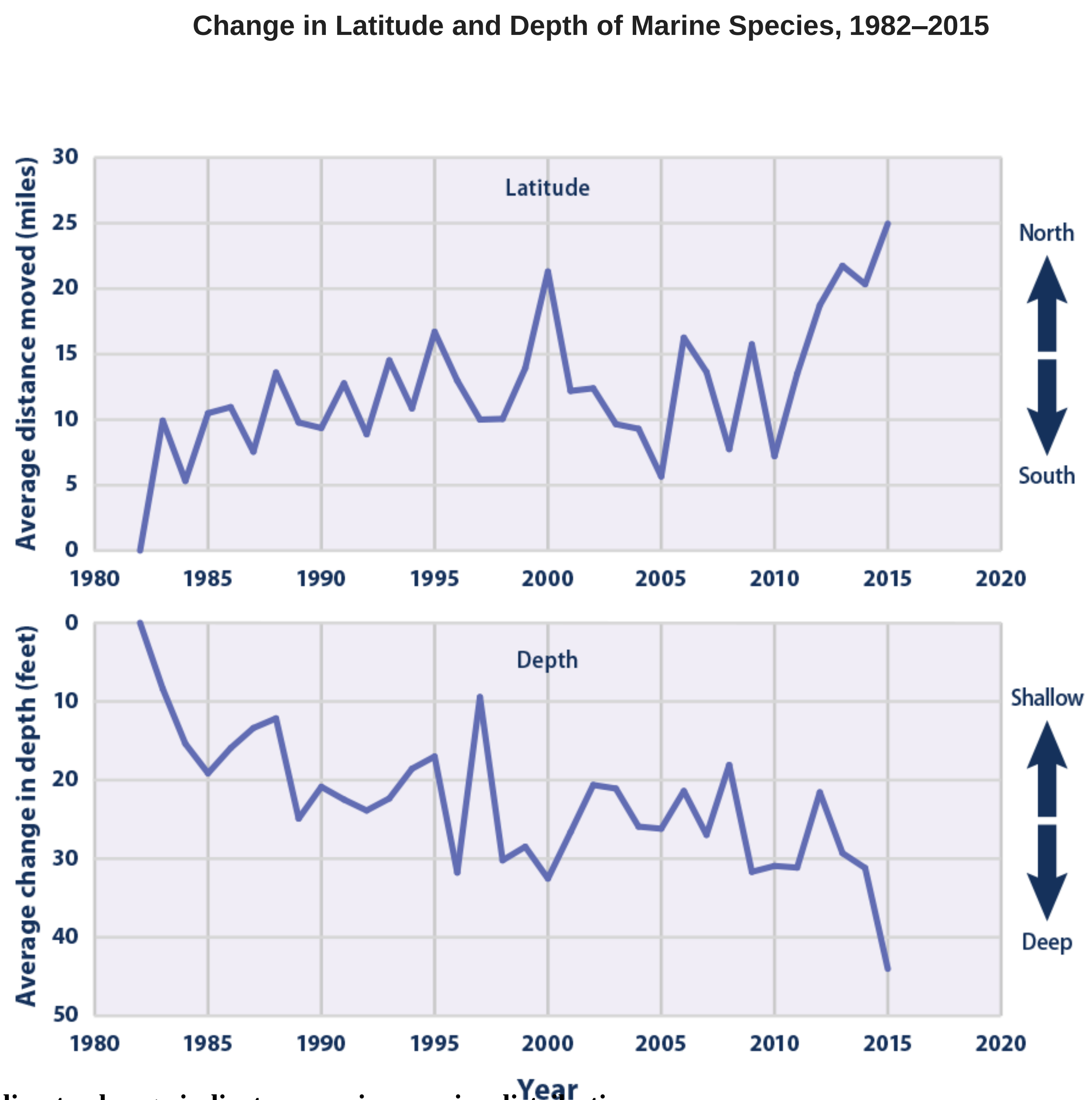
Adaptation Economics Key Concepts

- **We will have residual damages - damages that remain after adaptation actions are taken. Likely because of diminishing returns to adaptation effort.**
- **We face a current and will face future Adaptation deficit a gap between current state and a state that minimizes adverse impacts from climate.**
- **We will see Maladaptation Actions improving local adaptation leading to increased vulnerability here , elsewhere or future. (may be economically rational)**
- **We will need to choose additional, permanent, certain non leaking adaptations**

McCarl, B.A., A. Thayer, and J.P.H. Jones, "The Challenge of Climate Change Adaptation: An Economically Oriented Review", Journal of Agricultural and Applied Economics, forthcoming, 2016.

Observed Ag Adaptations

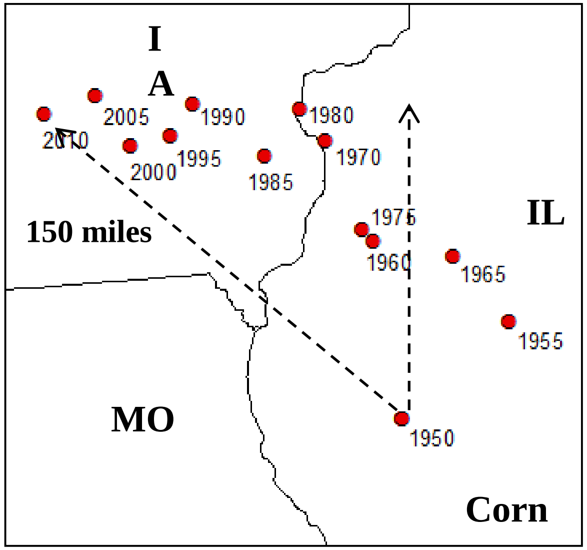
Observed Natural Adaptation

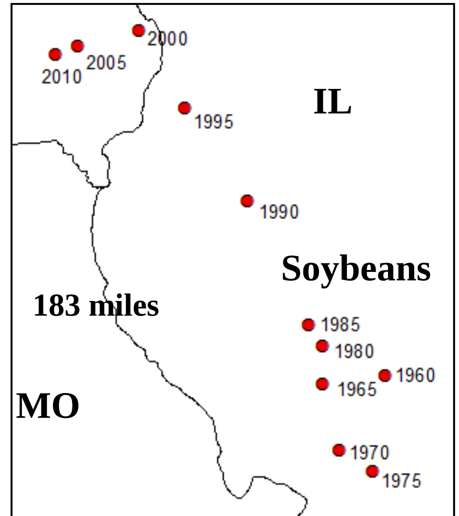


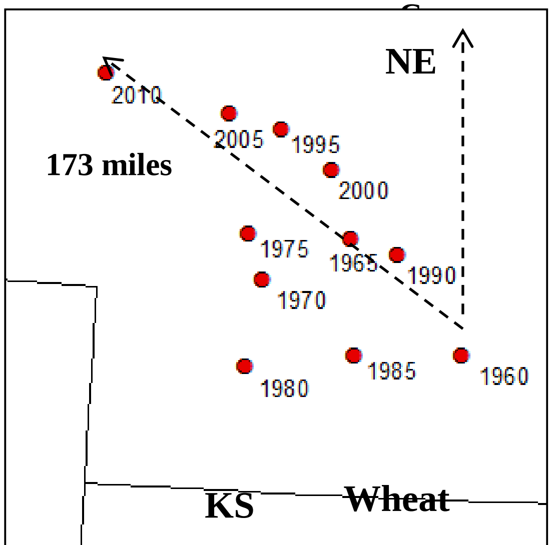
Observations show natural patterns changing

https://www.epa.gov/climate-indicators/climate-change-indicators-marine-species-distribution

Observed Autonomous Adaptation – Crop mix shift





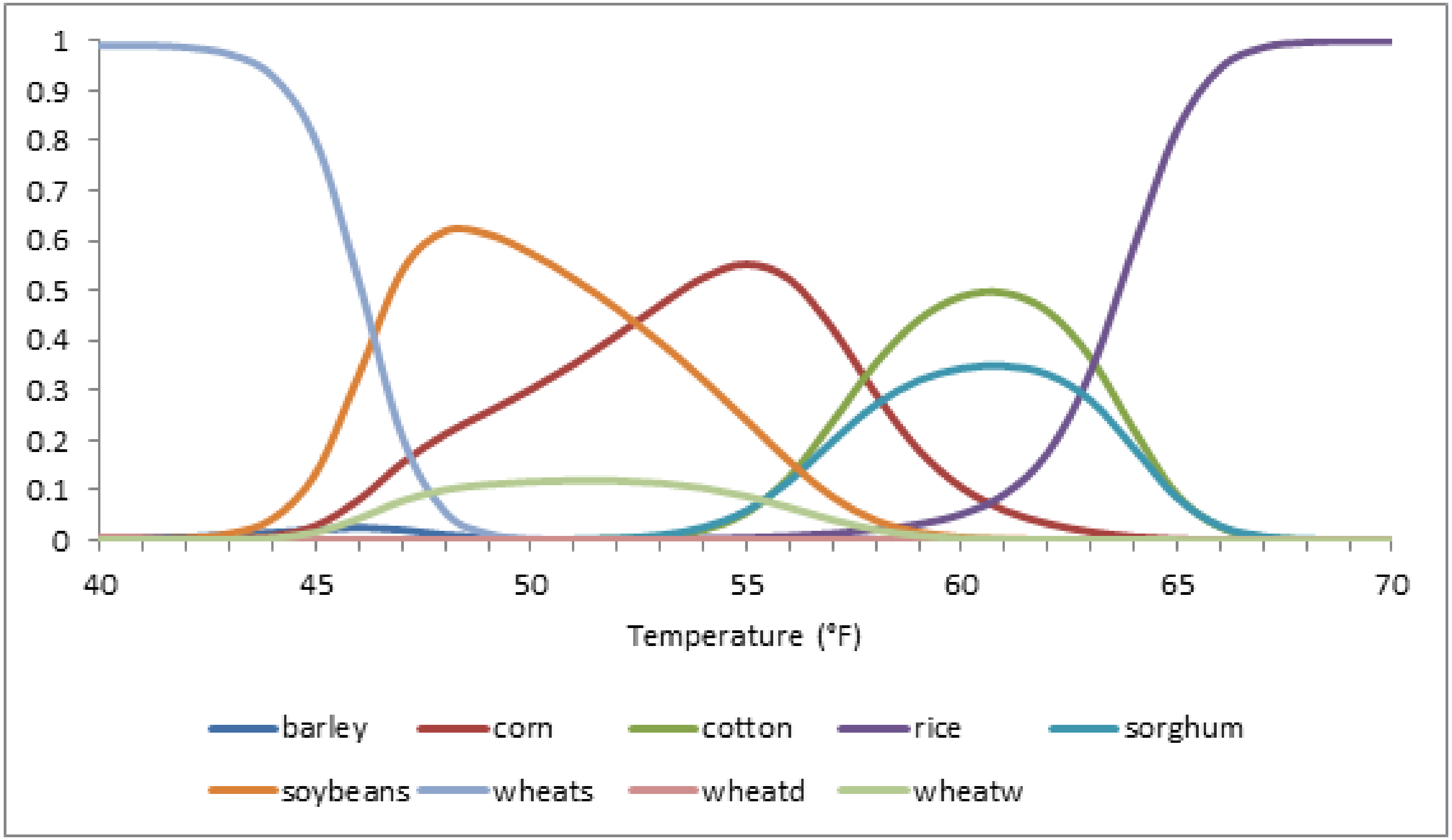


- Shifts have already happened
- Greater yield has transport implications
  - wheat yields 44 bu/acre
  - corn yields 165 bu/acre
- More demands for transport and grain movement in the north

Witsanu Attavanich PhD Thesis

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.

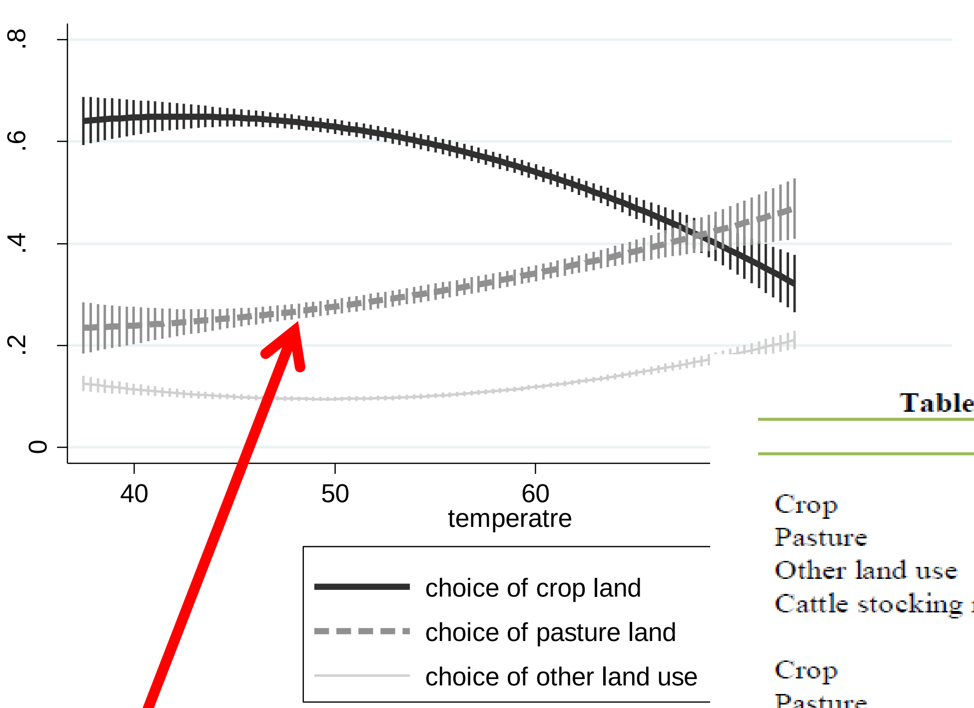
Observed Adaptation – Crop Choice



Farmer autonomously adopt crops reflects optimal growing conditions

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

Observed Adaptation – Land use and stocking rate



Cropland to pasture/range

Decreased stocking rate

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", <u>Mitigation and Adaptation Strategies for Global Change, doi:10. 1007/s11027-012-9384-4, 2012.</u>

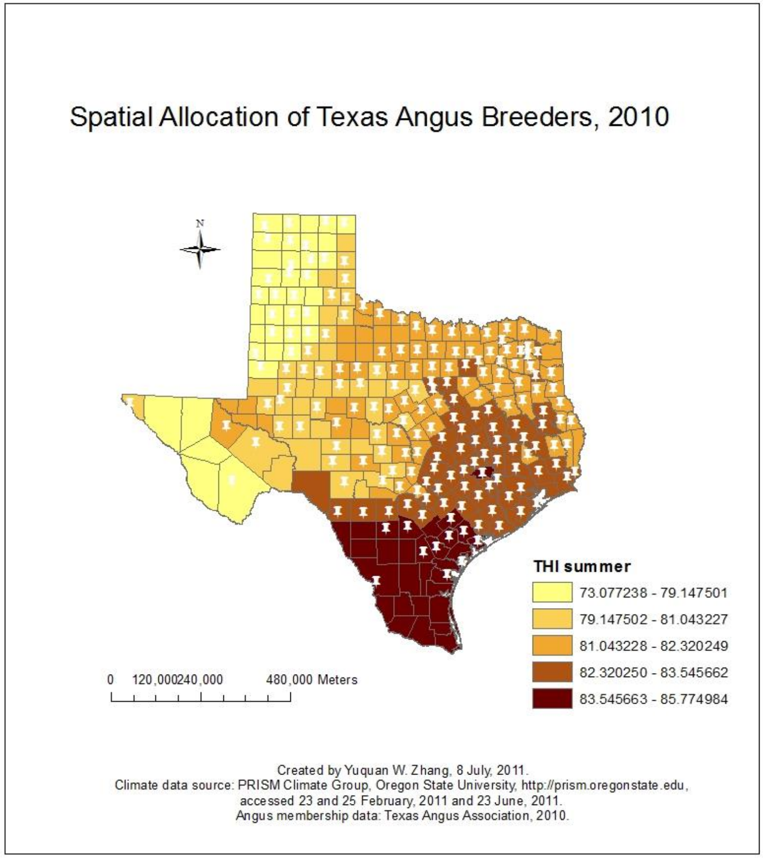
Table 5 Changes of Land Use Allocation and Cattle Stocking Rate

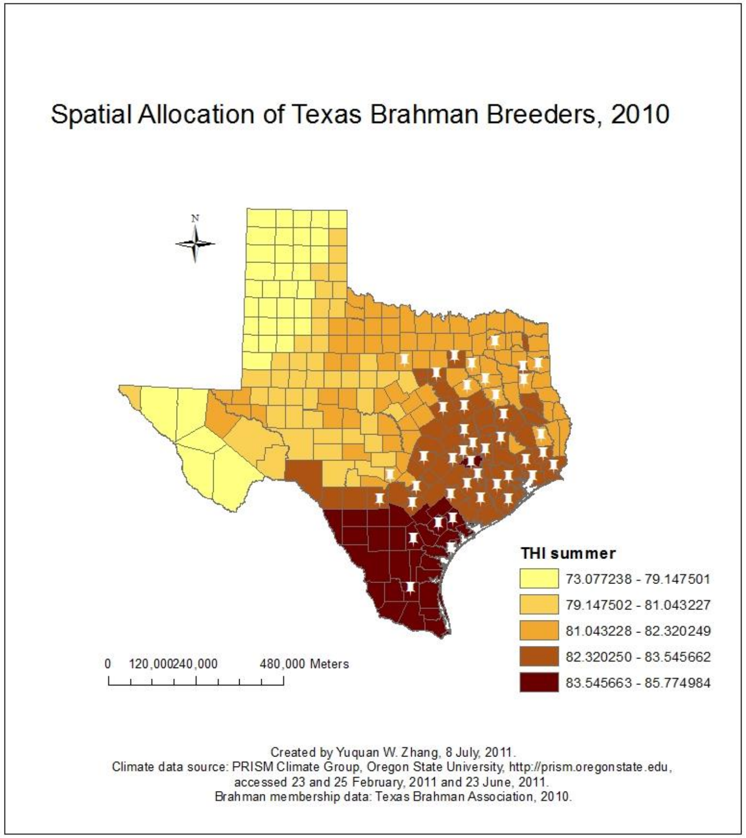
	Base	2010-2039	2040-2069	2070-209
		HadCM3-B1 emission scenario		
Crop	0.60	-0.22	-0.28	-0.3
Pasture	0.29	0.28	0.35	0.4
Other land use	0.11	0.06	0.07	[illegible]
Cattle stocking rate*(animal/acre)	0.25	-35.48	-41.86	-48.8
		HadCM3-A1B emission scenario		
Crop	0.60	-0.31	-0.38	-0.4
Pasture	0.29	0.39	0.46	0.5
Other land use	0.11	[illegible]	[illegible]	[illegible]
Cattle stocking rate*(animal/acre)	0.25	-49.89	-58.01	-66.3
		HadCM3-A2 emission scenario		
Crop	0.60	-0.28	-0.35	-0.4
Pasture	0.29	0.35	0.43	0.5
Other land use	0.11	[illegible]	[illegible]	[illegible]
Cattle stocking rate *(animal/acre)	0.25	-47.72	-54.63	-70.2

Note: For land use allocation, this table shows the changes of predicted probabilities that are calculated from the FMNL model with pooled sample and sub-regional dummies;

For cattle stocking rate, this table shows the predicted changes of cattle stocking rate that are derived from the OLS model with pooled sample.

Observed Adaptation – Cattle breed location





Angus breeders spread across Texas.

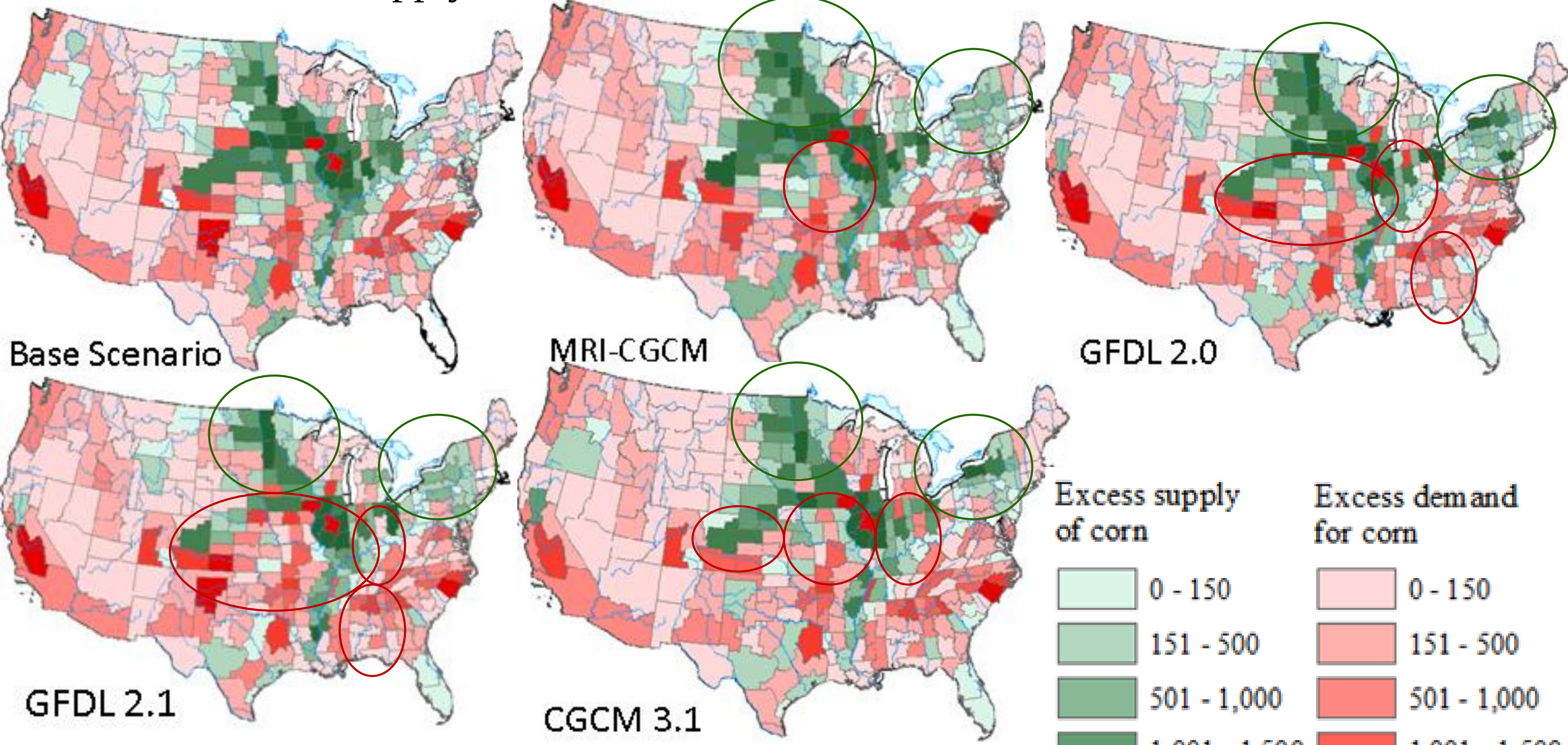
Brahman breeders are located in Southeast Texas, where the temperature-humidity index (THI) values for summer are high.

Animal choices shift with climate

Zhang, Y.W., A.D. Hagerman, and B.A. McCarl, "How climate factors influence the spatial distribution of Texas cattle breeds", Climatic Change, Volume 118, Issue 2, 183-195, 2013.

Model Results: Spatial Mapping (CRD level)

Excess supply and demand for corn under base and climate scenarios

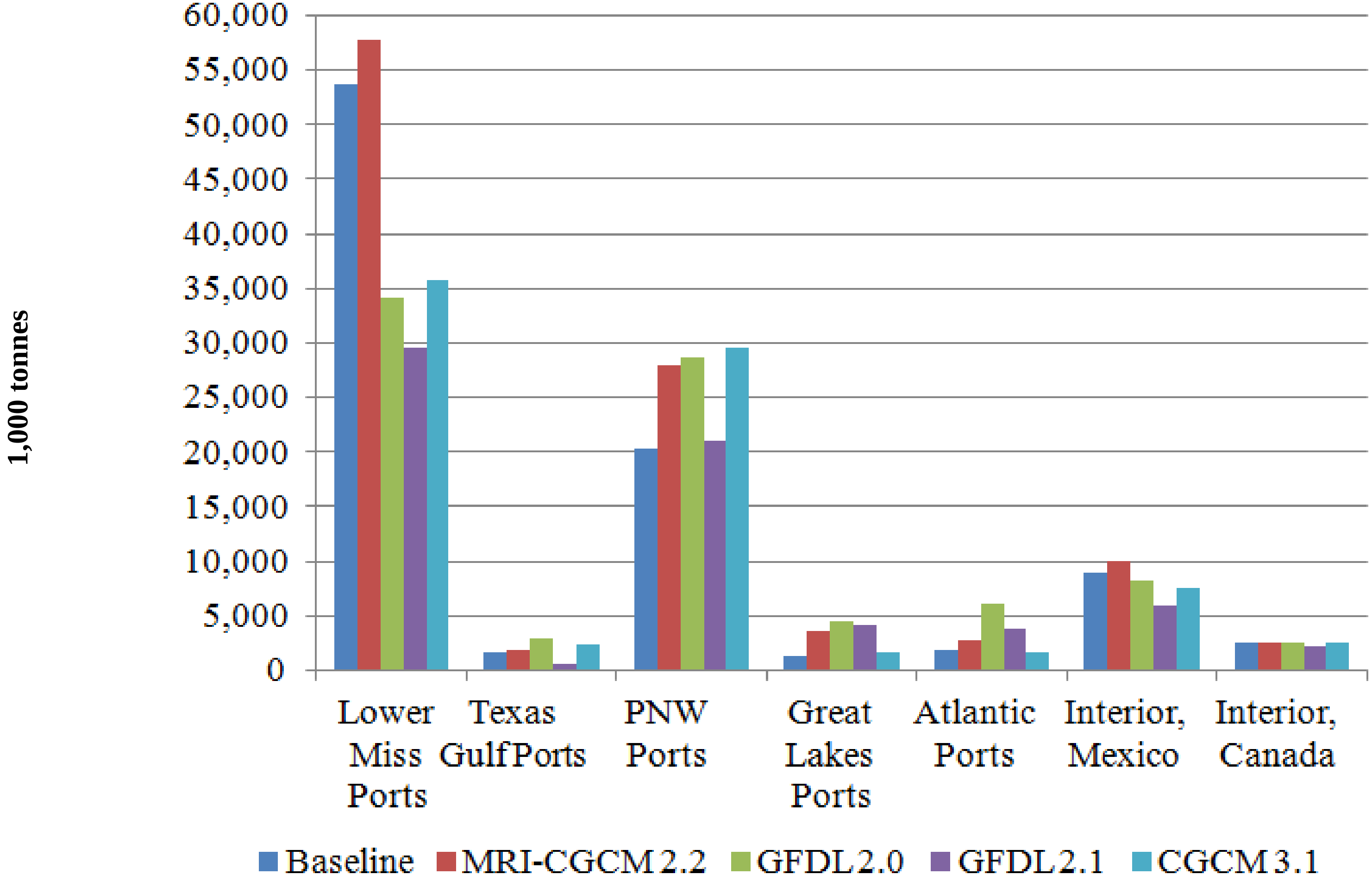


Note northward shifts in excess supply plus southern/central shifts in excess demand

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.

Transport effects of Crop mix shifts

Total grain shipments to port areas for export



- **More generally affects location of infrastructure – transport, processing , facilities**

Livestock adaptations

Conservation/drought planning
Supplemental feeding i.e., protein
Stocking rates
Cow body size
Ectoparasite control
Livestock breeds and species
Use of novel communities
Location of operations
Alternative production systems
Income diversification
Fire policy –fuel management

Concluding comments

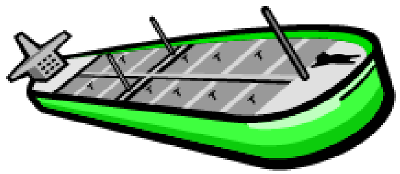
- Climate change has multidimensional implications
- Yield and tech progress effects raise risks
- Food production is at risk in many places
- Production is shifting and will shift more
- Extremes are of concern
- Will be a continuous process for sometime

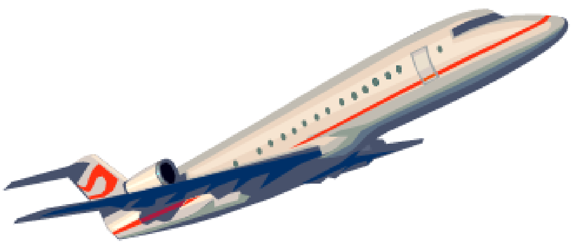
Concluding comments

- Adaptation will be a continuous force and may move opportunities plus influence industry location
- Public role needed for some but not all adaptation
- Industry will need to fund some adaptation
- Identify responses to vulnerability
- Need to observe emerging adaptations
- Value adaptation actions now and in future
- Examine income distribution effects
- Look at market conditions – altered prices, production, locations of production, risk distributions
- Design adaptation incentives

The onset and exact effects of climate change are uncertain

Energy





Adaptation

Mitigation

Effects

Food Supply is **Vulnerable**
Some Regions will be Squeezed

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