NOAA RESEARCH • ESRL • PHYSICAL SCIENCES DIVISION

Science of Arctic Change- Implications for Central US Water and Agriculture

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With

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UN-Lincoln School of Natural Resources
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What is Known About Arctic Change?

- Larger Surface Warming of the Arctic Than Rest of World: *Arctic Amplification*

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- **Larger Surface Warming of the Arctic Than Rest of World : *Arctic Amplification***

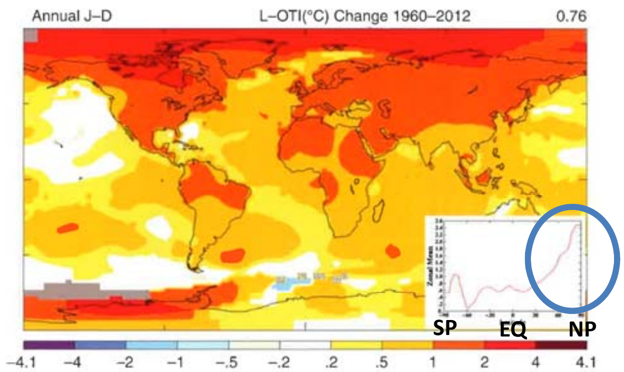

Figure 1.5. Linear trends in annual averages surface air temperature over the 1960–2012 period. The inset shows linear trends averaged by latitude. The larger trends over the Arctic region (Arctic amplification) are obvious (based on the National Aeronautics and Space Administration Goddard Institute for Space Sciences [NASA GISS] temperature analysis) (http://data.giss.nasa.gov/gistemp).

From Serreze and Barry, 2014: The Arctic Climate System

What is Known About Arctic Change?

- **Arctic Surface Warming Accelerated as Sea Ice Melted**

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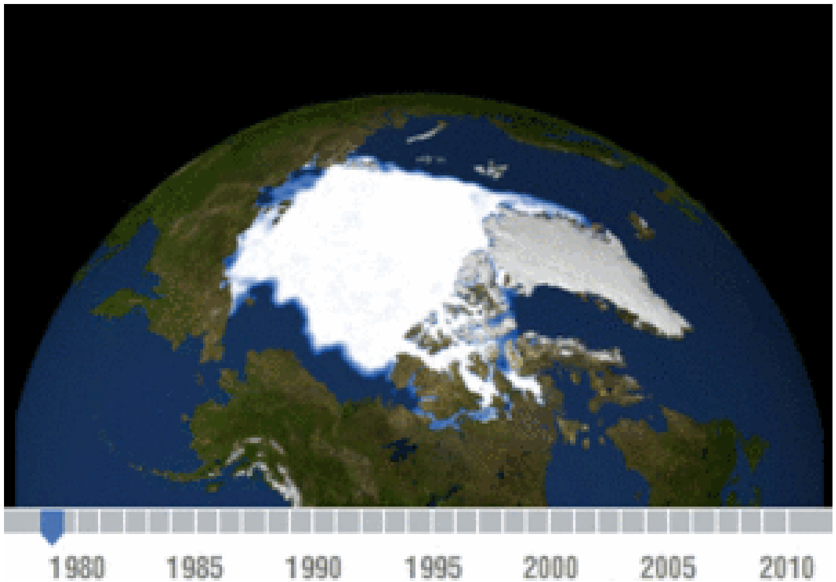

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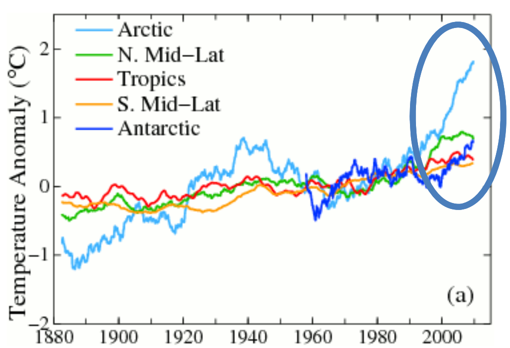
• Arctic Surface Warming Accelerated as Sea Ice Melted



Data based on the NASA GISS analysis

What is Known About Arctic Change?

• Arctic Sea Ice Loss Largely Due to Human-Induced Change

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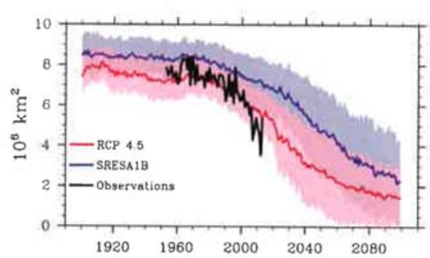
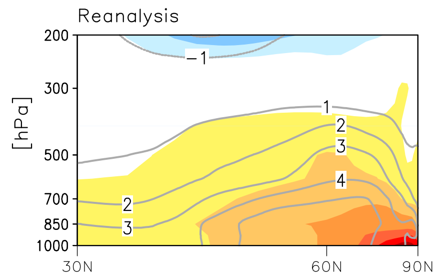


Figure 9.13. Multimodel ensemble mean sea ice extent based on observations (black line), the CMIP5 models (red line for the ensemble mean and red shading for the +/– 1 standard deviation) and the CMIP3 models (blue line for the ensemble mean and red shading for the +/– 1 standard deviation) (courtesy of J. Stroeve, NSIDC, Boulder, CO).

From Serreze and Barry, 2014: The Arctic Climate System

What is Known About Arctic Change?

- **The Arctic Has Warmed Throughout the Troposphere**
  (Recent Decade Compared to 1980s)

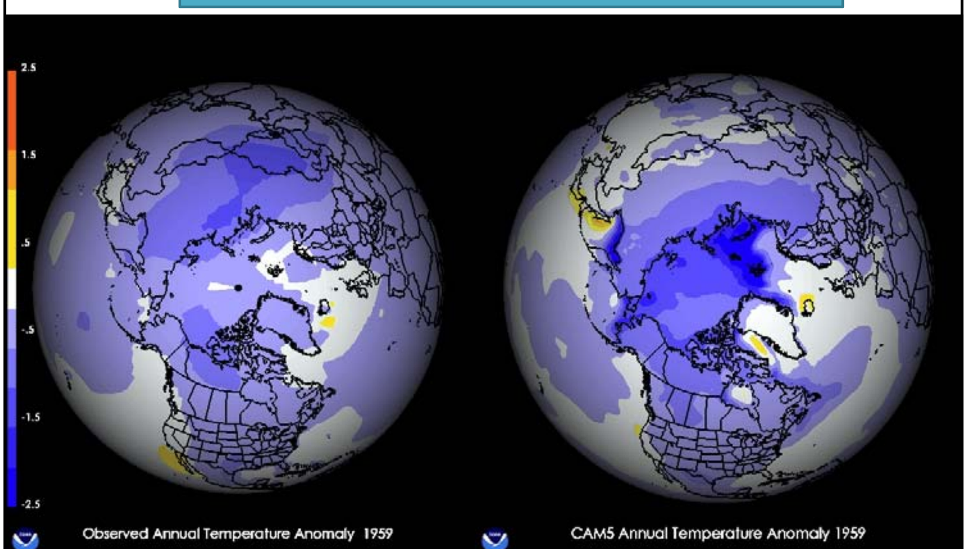


Little or No Arctic Amplification in the Middle and Upper

from Perlwitz et al , 2015 : Assessing Why the Arctic Has Warmed and Linkages to Lower Latitudes

What is Known About Arctic Change?

- **Arctic Sea Ice Loss is A Major Cause for Arctic Surface Warming**



Interpretation of Observed Recent Arctic Change

[see also NOAA's Arctic Report Card http://www.arctic.noaa.gov/reportcard]

° Late Summer Arctic Sea Ice is Declining ~13%/decade, in the Recent Era Post-1990s.

° Much (>50%) of Arctic Sea Ice Decline is Likely Due to Human-Induced Climate Change.

° Arctic Surface Temperatures Have Warmed.

° Arctic Surface Warming Is Faster (~2x) Than Warming Over the Rest of the World.

° Little or No Arctic Amplification of Deep Tropospheric Warming.

What is Known About Arctic Change Impacts?

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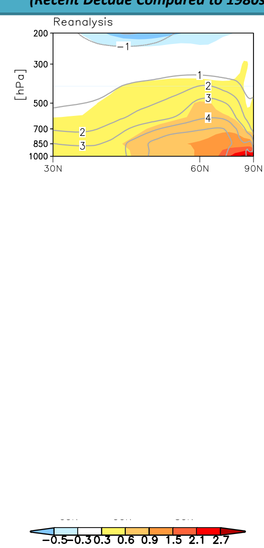
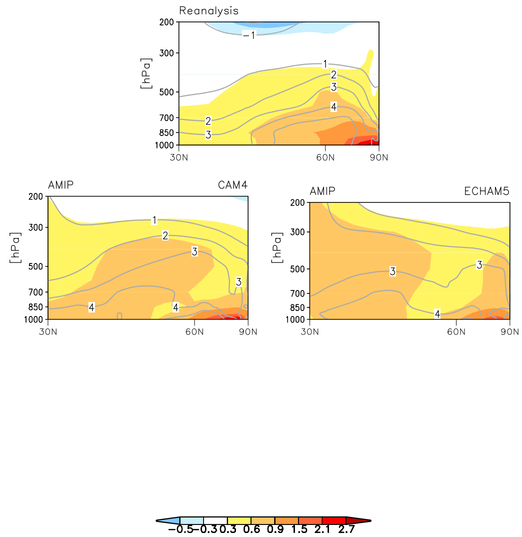


from Perlwitz et al , 2015 : Assessing Why the Arctic Has Warmed and Linkages to Lower Latitudes

What is Known About Arctic Change Impacts?

• Climate Models Reproduce the Tropospheric Warming Pattern



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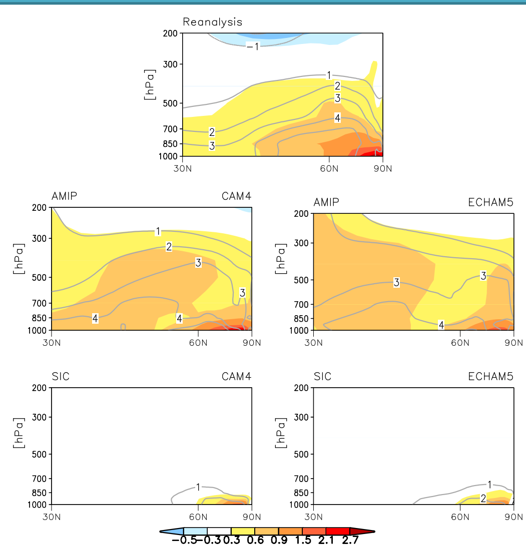
What is Known About Arctic Change Impacts?

• The Deep Tropospheric Warming is *Mostly Unrelated* to Sea Ice Loss



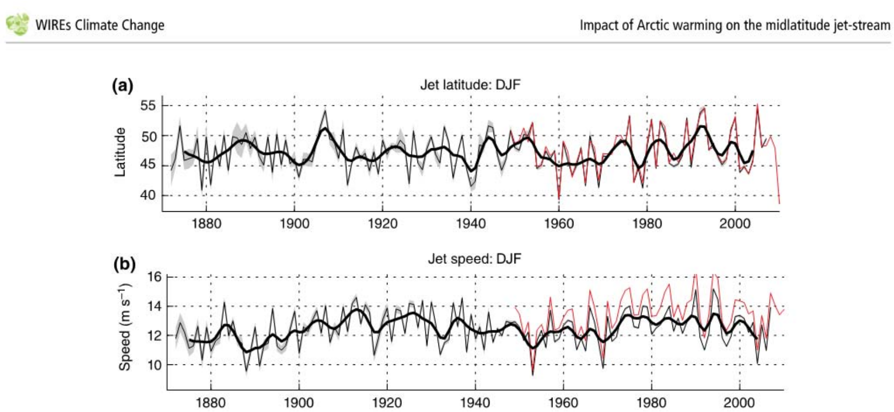
from Perlwitz et al , 2015 : Assessing Why the Arctic Has Warmed and Linkages to Lower Latitudes

"It has been suggested that sea ice losses have been a primary driver of Arctic tropospheric warming which, through a cascade of processes, has led to more persistent and extreme weather conditions in mid-latitudes (Francis and Vavrus, 2012). Perlwitz et al. (2015) results provide an alternate interpretation of Arctic-midlatitude interactions that may have occurred during recent years.

In contrast to Francis and Vavrus (2012), Perlwitz et al. findings suggest that over the recent decade the Arctic troposphere has been more responding to changes in lower-latitude weather and climate than forcing them. Their analysis also suggests that the main drivers for mid-latitude regional circulation differences observed between the decades of 1979-1988 and 2003-2012 are more likely to have resulted from internal variations in the atmosphere-ocean system rather than as a forced response to global climate change."

from Perlwitz et al , 2015 : Assessing Why the Arctic Has Warmed and Linkages to Lower Latitudes

Detectability of Arctic Change Impacts on the Jet Stream



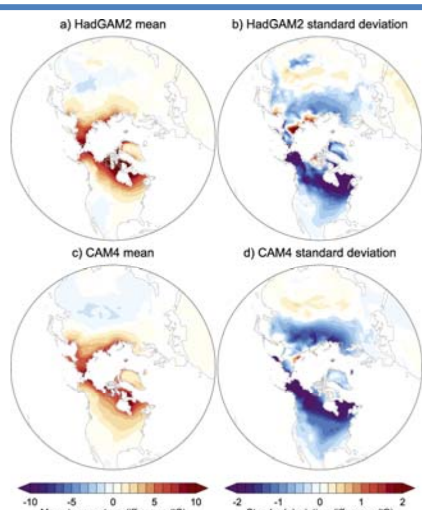
From Barnes and Screen 2015 : Impact of Arctic Warming on the Mid-latitude Jet Stream: Can it?, Has it? Will It?

Detectability of Arctic Change Impacts on the Jet Stream

Screen et al.[22] analyzed the midlatitude circulation in an ensemble of model simulations where sea ice concentrations were reduced at the observed rate, and they concluded that if only Arctic sea ice were changing, it would take 50 years or more for the forced signal in the large-scale winds to be distinguishable from internal variability.

see Screen, Deser, Simmonds, and Thomas, 2014: Atmospheric Impacts of sea ice loss, 1979-2009, separating forced change from internal atmospheric variability.

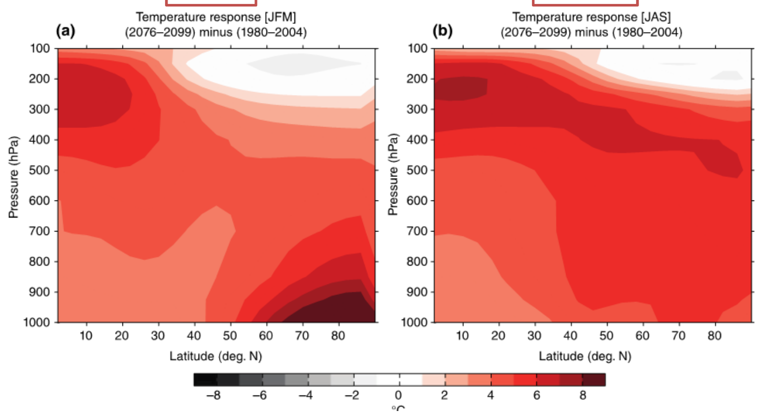
Impacts of Arctic Change on Weather Extremes



see Screen et al., 2015: Reduced Risk of North American Cold Extremes Due to Continued Sea Ice Loss (BAMS)

Overall Global Climate Change: Arctic vs Tropics

Winter **Summer**

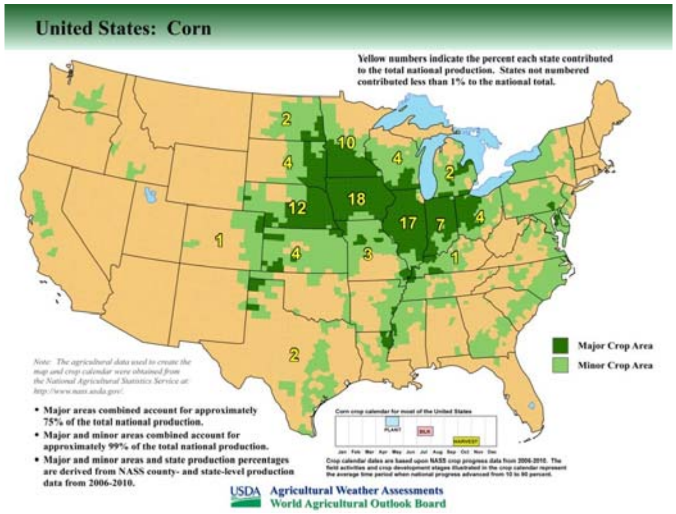


from Barnes and Polvani 2015: CMIP5 Projections of Arctic Amplification, of the North American/North Atlantic Circulation, and of Their Relationship.

Interpretation of Science on Arctic Change & Impacts

- **Sea Ice Loss is the Main (But Not Sole) Cause for Arctic Amplification of Surface Warming**
- **Sea Ice Loss Does Not Drive Deep Arctic Tropospheric Warming**
- **The Critical First Link in the Chain Proposed to Connect Arctic Amplification to Mid-latitude Weather Extremes is Weak**
- **Extreme Weather Responds to Arctic Amplification: Reduced Risks of Cold Extremes**
- **Arctic Change Impacts on Mid-latitudes are Mostly Undetectable, at This Time**

What Features of GP Climate Matter Most for Corn Production?



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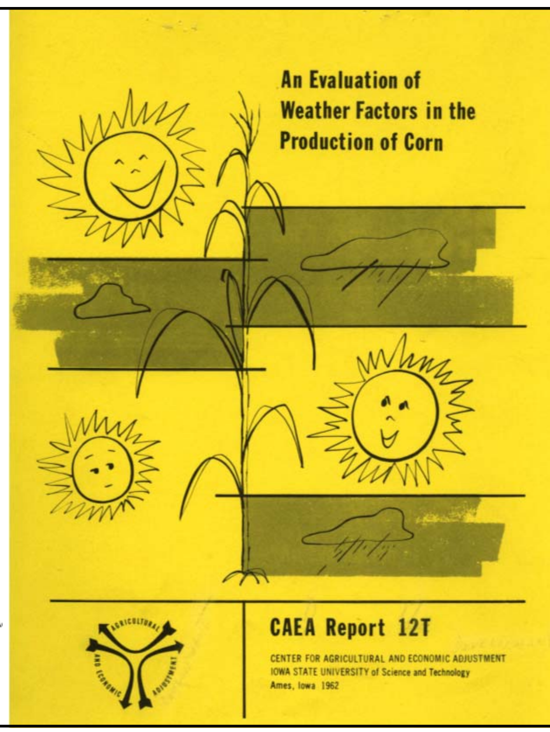
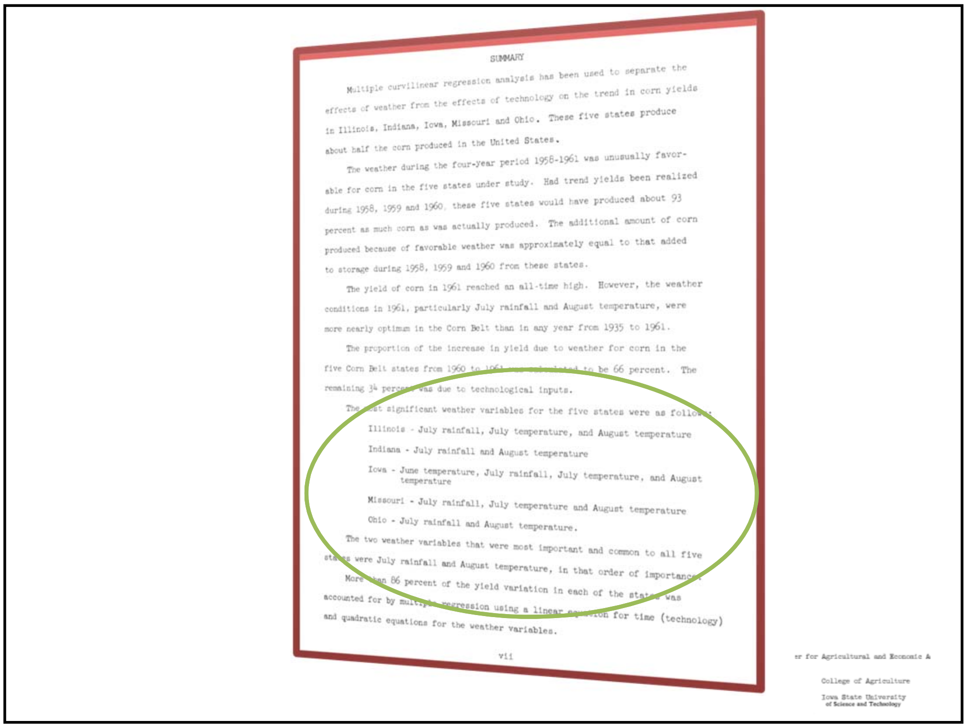
Iowa State University
of Science and Technology





SUMMARY

Multiple curvilinear regression analysis has been used to separate the effects of weather from the effects of technology on the trend in corn yields in Illinois, Indiana, Iowa, Missouri and Ohio. These five states produce about half the corn produced in the United States.

The weather during the four-year period 1958-1961 was unusually favorable for corn in the five states under study. Had trend yields been realized during 1958, 1959 and 1960, these five states would have produced about 93 percent as much corn as was actually produced. The additional amount of corn produced because of favorable weather was approximately equal to that added to storage during 1958, 1959 and 1960 from these states.

The yield of corn in 1961 reached an all-time high. However, the weather conditions in 1961, particularly July rainfall and August temperature, were more nearly optimum in the Corn Belt than in any year from 1935 to 1961.

The proportion of the increase in yield due to weather for corn in the five Corn Belt states from 1960 to [illegible] to be 66 percent. The remaining 34 perc[illegible] was due to technological inputs.

The [illegible]st significant weather variables for the five states were as follo[illegible]:

Illinois - July rainfall, July temperature, and August temperature

Indiana - July rainfall and August temperature

Iowa - June temperature, July rainfall, July temperature, and August temperature

Missouri - July rainfall, July temperature and August temperature

Ohio - July rainfall and August temperature.

The two weather variables that were most important and common to all five st[illegible]s were July rainfall and August temperature, in that order of importance.

More [illegible]an 86 percent of the yield variation in each of the stat[illegible] was accounted for by multi[illegible] regression using a linear [illegible]on for time (technology) and quadratic equations for the weather variables.

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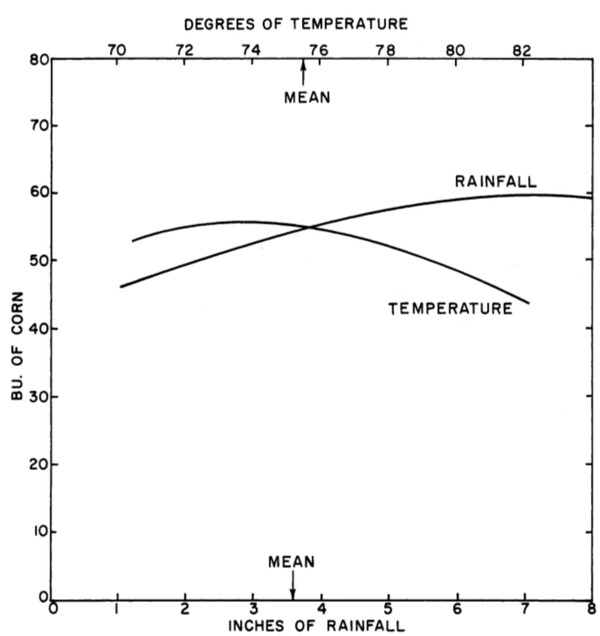
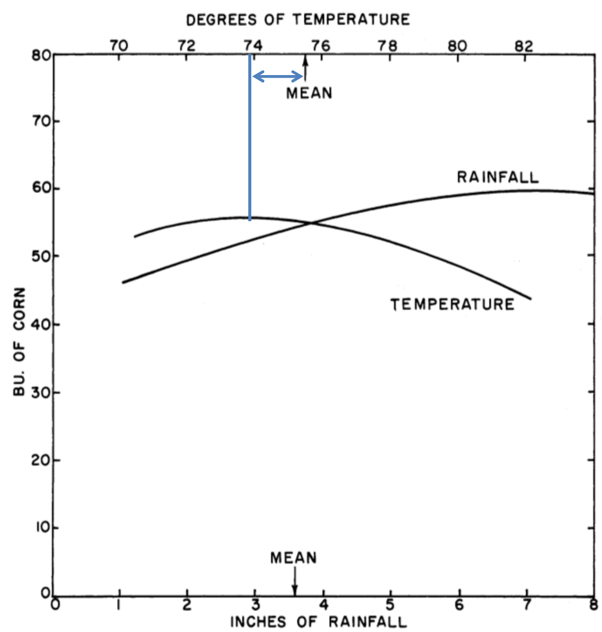


FIGURE 8. JULY RAINFALL AND AUGUST TEMPERATURE CURVES FOR ILLINOIS



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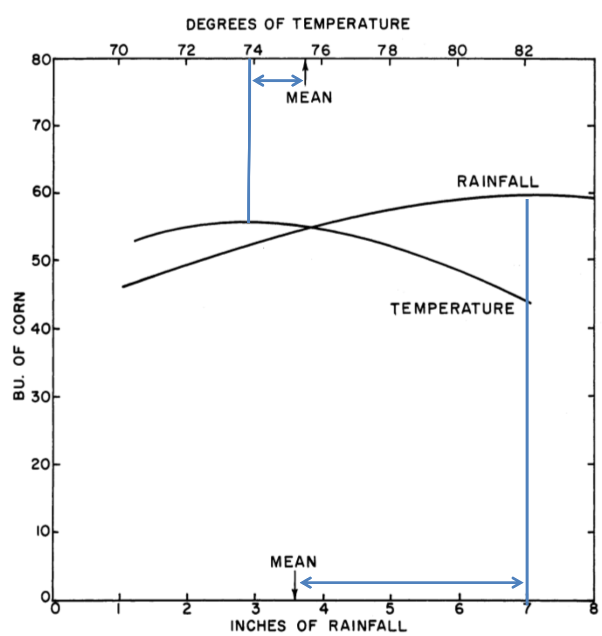

FIGURE 8. JULY RAINFALL AND AUGUST TEMPERATURE CURVES FOR ILLINOIS

How Has OBS Climate Changed During GP Growing Season?

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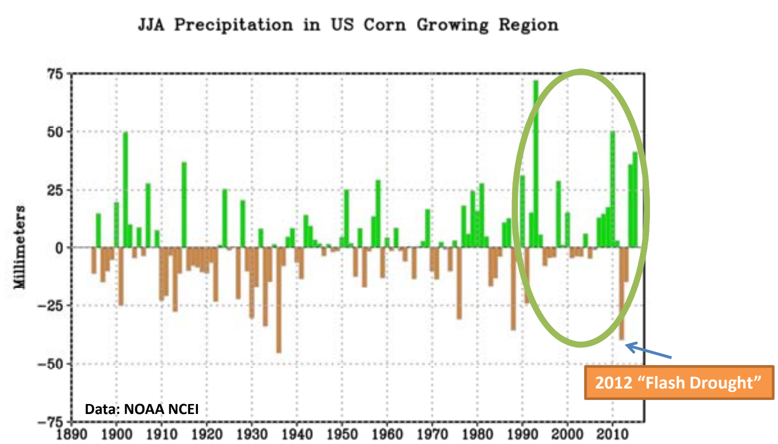
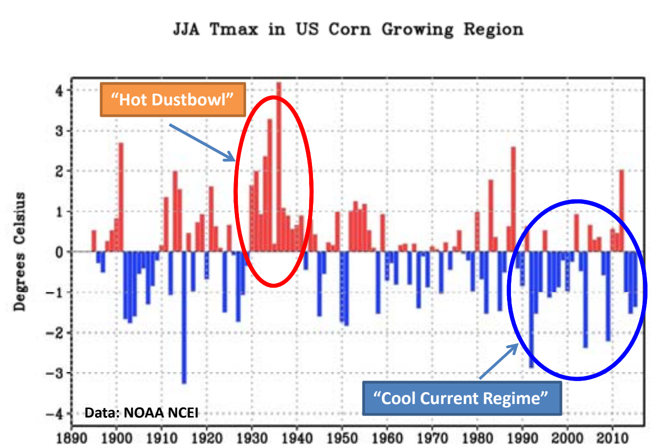
Since the Early 20th Century, GP Climate Has Become *More Favorable* for Corn Production

Summers Have Become Wetter Over the Corn Belt



Summer Daytime Temperatures Have Become Cooler in the Corn Belt



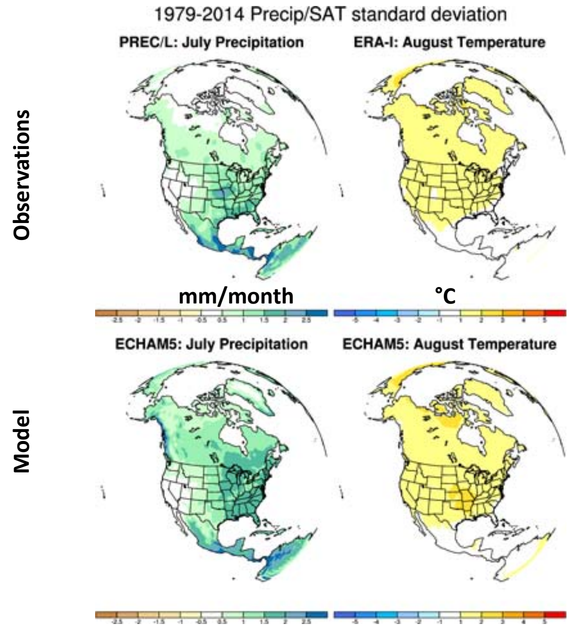
Has *Arctic Change* Caused the More Favorable GP Climate?

Historical and *Counterfactual* Climate Model Simulations

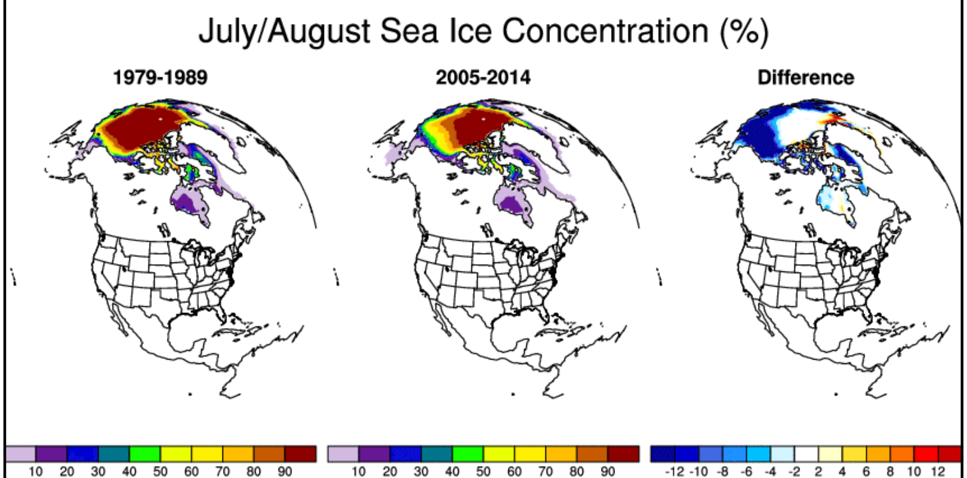
- **Atmosphere Model*** driven by observed monthly varying sea ice, sea surface temperatures, and GHGs since 1979. (***Historical AMIP***)
- **Atmosphere Model*** driven by observed monthly varying sea surface temperatures, GHGs since 1979. Polar sea ice held fixed, according to 1979-1989 climatology. *(**Counterfactual CLIM_POLAR**)*
- **ΔICE = AMIP – CLIM_POLAR**

*ECHAM5, global model ~85km spatial resolution, 30-member ensembles
see Perlwitz et al. 2015
also Screen et al. (2013a,b); Screen et al. (2015); Mori et al. 2014 for other modeling studies

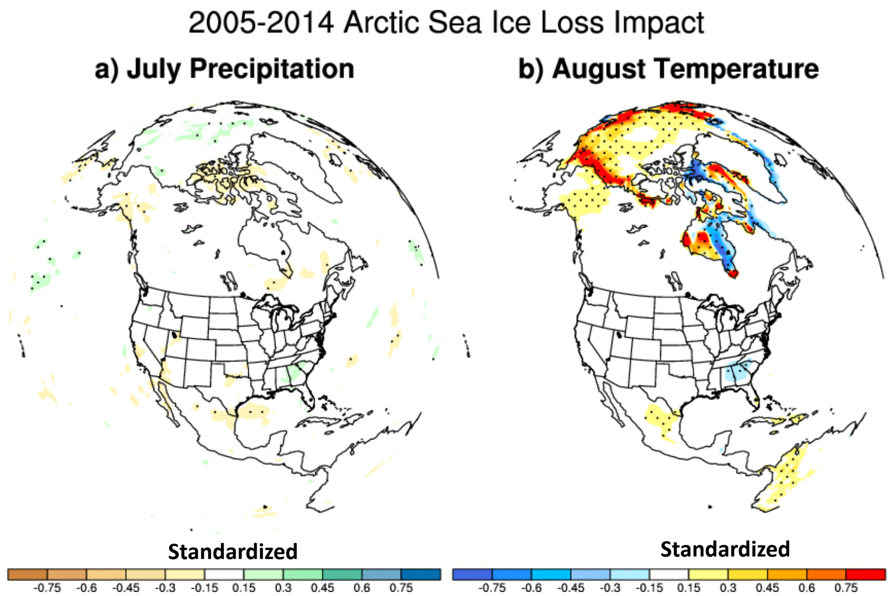
July and August Climatological Variability



Observed July/August Sea Ice Change



Simulated Impact of Sea ice Change on July/August Climate



Interpretation

° **Arctic climate response to sea ice loss is relatively small in summer:**

Physical reason: *° small air-sea contrast at that time of year*
° small summer heat exchange between ocean/atmosphere
° limited thermodynamic response to summer sea ice loss (different from winter; see also Deser et al. 2010)

° **No detectable effect of Arctic change on continental US summer rainfall/sfcT:**

Physical reason: *° Little remote dynamical response in summer to Arctic sea ice loss*
° Monthly/daily summertime GP variability insensitive to Arctic change
° Typical summertime GP variability an order of magnitude larger than sea ice related impacts
° Dynamic and thermodynamic links are ineffective.

Summary

° Sea Ice Change is Currently a Major Climate Change Driver *in the Arctic*

° A Significant Factor Causing Arctic Change is Human-Induced GHG Emissions

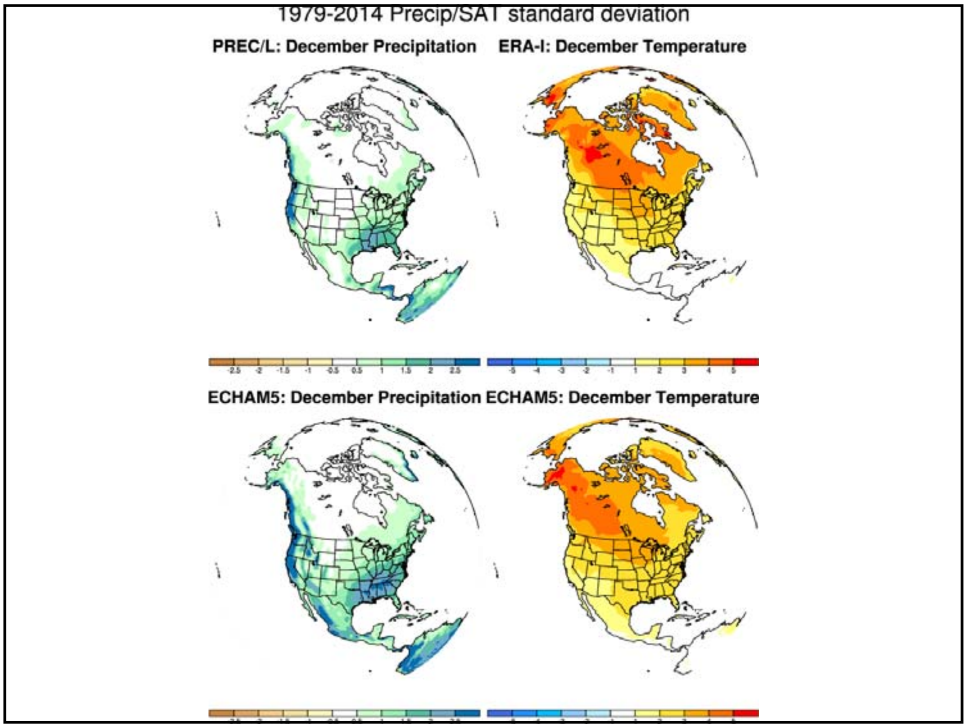
° Natural Variability Also Causes Arctic Change on Multi-Decadal Scales

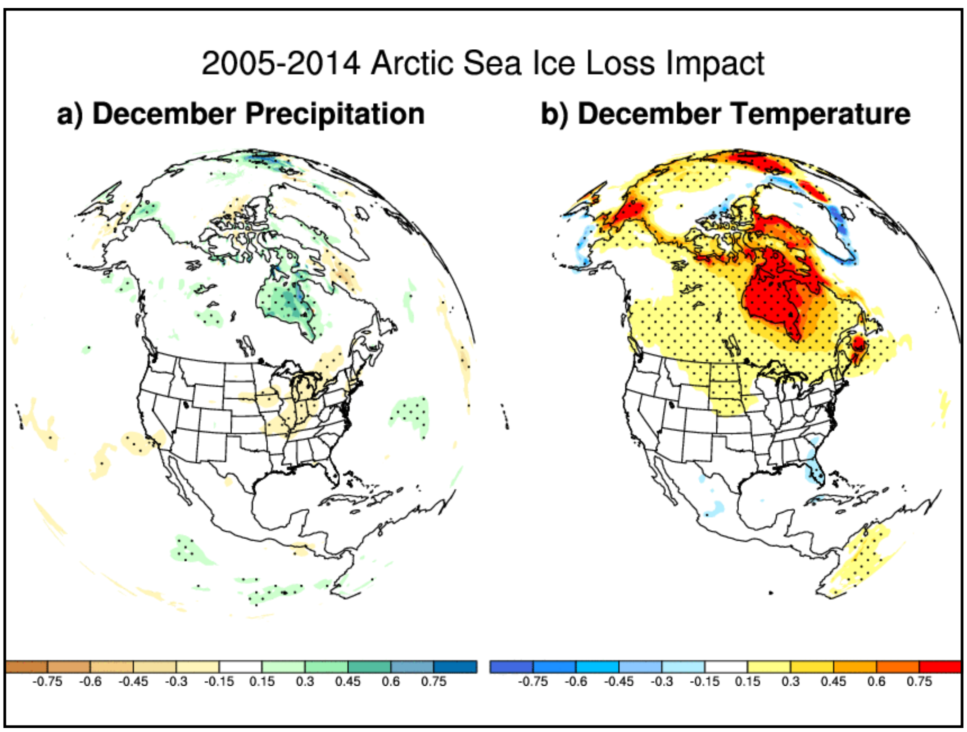
°A Changing Arctic is Not Materially Affecting Ag/Water Resources in the Central U.S.

° Climate in the Corn Belt Has Become More Favorable for Yields over the Last Century

° A Changing Arctic Is Not The Cause for The More Favorable Summer GP Climate

Extra Slides


1979-2014 Precip/SAT standard deviation
PREC/L: December Precipitation
ERA-I: December Temperature
ECHAM5: December Precipitation
ECHAM5: December Temperature


2005-2014 Arctic Sea Ice Loss Impact
a) December Precipitation
b) December Temperature
-0.75 -0.6 -0.45 -0.3 -0.15 0.15 0.3 0.45 0.6 0.75
-0.75 -0.6 -0.45 -0.3 -0.15 0.15 0.3 0.45 0.6 0.75