# MFE659 Lecture 5a: Heat waves, Drought, Dust Storms, and Wild Fires



# Weather, Climate & Finance

A preview of what of what Brendan may cover next.

- Purchasing, planting, routing etc. decisions
- Conventional “casualty insurance” (e.g. crop, flood, hurricane insurance) & reinsurance
- Weather index insurance
- Commodity futures (energy, agricultural..)
- Weather derivative contracts
- Catastrophe bonds
- Carbon permits, climate change planning



# Why is finance concerned with climate change?

- Climate change contributes to trends seen in historical weather data – of relevance to using past data to value weather derivative contracts
- Climate change may affect the severity of catastrophic weather-related losses – of interest to insurance industry and for market-traded catastrophe hedges
- Climate change will affect many aspects of business operation and required financial disclosures now need to account for anticipated impacts of climate change
- Climate change can affect long-term business planning
- Climate change may drive markets in pollution credits



# Weather, Climate & Finance

Purchasing, planting, routing etc. decisions

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Carbon permits, climate change planning .

U.S. Securities and Exch

**SEC Issues Interpretive Guidance on Disclosure Related to Business or Legal Developments Regarding Climate Change**

FOR IMMEDIATE RELEASE
2010-15

*Washington, D.C., Jan. 27, 2010* -- The Securities and Exchange Commission today voted to provide public companies with interpretive guidance on existing SEC disclosure requirements as they apply to business or legal developments relating to the issue of climate change.

Federal securities laws and SEC regulations require certain disclosures by public companies for the benefit of investors. Occasionally, to assist those who provide such disclosures, the Commission provides guidance on how to interpret the disclosure rules on topics

Video: Open Meeting

Chairman Schapiro Discusses the Interpretive Guidance: Windows Media Player QuickTime

Text of Chairman's Statement

Chicago plans based on long-term forecast.

The New York Times

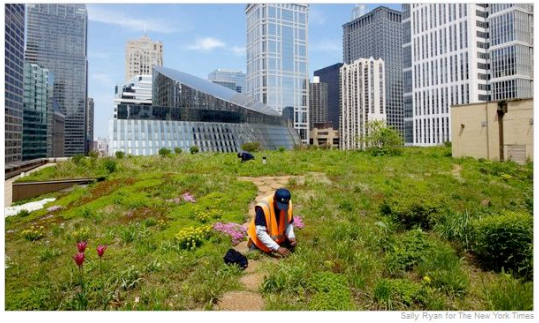
## Environment

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

ENVIRONMENT | SPACE & COSMOS


CHANGES IN THE AIR

### A City Prepares for a Warm Long-Term Forecast



Sally Ryan for The New York Times

Leroy Ledbetter tending a rooftop garden created to reduce energy use by Chicago's City Hall.

By LESLIE KAUFMAN
Published: May 22, 2011

CHICAGO — The Windy City is preparing for a heat wave — a permanent one.

Changes in the Air

Climate scientists have told city planners that based on current trends,

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## Regional Greenhouse Gas Initiative

an initiative of the Northeast and Mid-Atlantic States of the U.S.

RGGI, Inc. | RGGI Benefits | $CO_2$ Auctions, Tracking & Offsets | Program Design | News & Updates | Key Documents

Welcome

**Upcoming Auctions**

Auction 11
March 09, 2011
Auction 12
June 08, 2011
Auction 13
September 07, 2011
Auctions RSS Feed

### Welcome

The Regional Greenhouse Gas Initiative (RGGI) is the first mandatory, market-based effort in the United States to reduce greenhouse gas emissions. Ten Northeastern and Mid-Atlantic states have capped and will reduce $CO_2$ emissions from the power sector 10% by 2018.

States sell nearly all emission allowances through auctions and invest proceeds in consumer benefits: energy efficiency, renewable energy, and other clean energy technologies. RGGI is spurring innovation in the clean energy economy and creating green jobs in each state.

This website provides a portal for official user platforms, state applications, and materials for participants in RGGI, as well as current information about the status of RGGI auctions and state rules.

Countdown to Auction 11
March 09, 2011:

Days to go:
69




**RGGI Spotlight**

**Auction 10 Results:**
Current Control Period: $1.86

Future Control Period: $1.86

Read the news release and market monitor report

View comments & materials from the RGGI stakeholder meetings

Sign up for our mailing list

Read recent RGGI success stories

See detailed auction results

RGGI Inc.

RGGI Inc. is a nonprofit corporation created to provide technical and administrative services to the Regional Greenhouse Gas Initiative $CO_2$ budget trading programs of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont.



# CHICAGO CLIMATE EXCHANGE

CCX Chicago Climate Exchange

Search | Contact Us | Login: select...

Market Info / CCX CFI 2003 $0.05

- ABOUT CCX
- MEMBERSHIP
- MARKET
- OFFSETS

Quick Links:
- Join the Exchange
- Register Offsets
- Trade on CCX
- Resources and Fees
- Member List
- News

Affiliated Exchanges:
- European Climate Exchange (ECX)
- Insurance Futures Exchange (IFEX)
- Montréal Climate Exchange (MCeX)
- Tianjin Climate Exchange (TCX)
- Envex

The World's First and North America's Only
Greenhouse Gas Emissions Registry, Reduction, & Trading System

**Exchange Overview**

Welcome to CCX: We are a financial institution whose objectives are to apply financial innovation and incentives to advance social, environmental and economic goals through the following platforms.

Chicago Climate Exchange (CCX) is North America's only cap and trade system for all six greenhouse gases, with global affiliates and projects worldwide. (learn more)

Chicago Climate Futures Exchange (CCFE) is a landmark derivatives exchange that currently offers standardized and cleared futures and options contracts on emission allowances and other environmental products. CCFE is a wholly owned subsidiary of CCX. (Visit CCFE's website)

**Market Overview**

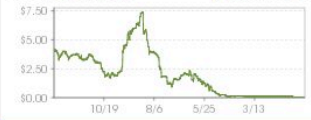
CCX | CCFE | ECX

December 30, 2010 — Updated end of day.

| CCX CFI | CLOSE | CHANGE |
|---|---|---|
| CFI 2003 | $0.05 | $0.00 |
| CFI 2008 | $0.05 | $0.00 |
| CFI 2010 | $0.05 | $0.00 |

Electronic Prices | OTC Prices

CCX CFI Vintage 2010 (Quoted in mt CO2)






# CHICAGO CLIMATE EXCHANGE

http://www.chicagoclimatex.com/content.jsf?id=821

# CHICAGO CLIMATE EXCHANGE

Chicago Climate Exchange (CCX) was established in 2003 as a voluntary greenhouse gas reduction and offset trading platform. Market participants included major corporations, utilities and financial institutions with activities in all 50 United States, 8 Canadian provinces and 16 countries. The total program baseline covered 700 million metric tons CO2 - equal to roughly one-third the size of Europe's cap and trade program.

Founded by Richard L. Sandor, the exchange sought to help businesses and markets prepare for potential regulations at the international, federal, and regional levels. By establishing a market-based price for reducing emissions of carbon and other greenhouse gases, CCX facilitates investment in new technologies and innovative products and helps companies to build the skills and institutions needed to manage environmental risks.



# CHICAGO CLIMATE EXCHANGE

The commodity traded on CCX is the Carbon Financial Instrument® (CFI®) contract, which represents 100 metric tons of CO2 equivalent. CFI contracts consist of exchange allowances and offset credits. Allowances were issued to members in accordance with their emission baseline and reduction schedule during Phases I and II of the program. Offsets are generated by qualifying offset projects. The offsets program includes participation by more than 15,000 farmers, ranchers and foresters who conduct mitigation practices on more than 25 million acres of land.



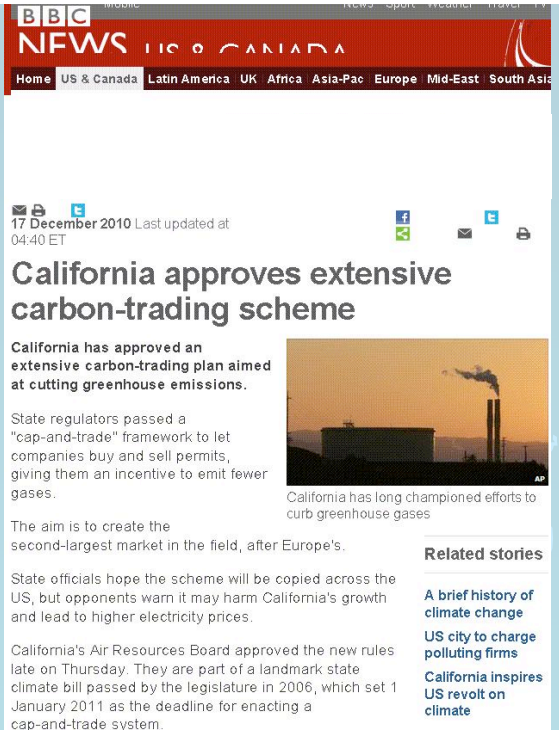
# CHICAGO CLIMATE EXCHANGE

CCX members made a legally-binding commitment to meet annual reduction requirements. All emission baselines and annual emission reports receive independent verification. Members reducing beyond their targets receive surplus allowances to sell or bank; those who do not meet the targets comply by purchasing CFI contracts. Independently verified emission reductions have totaled nearly 700 million metric tons of CO2 since 2003 - the equivalent of taking approximately 140 million cars off the road for a year.

IntercontinentalExchange, a leading operator of global regulated futures exchanges, clearing houses and over-the-counter markets, acquired CCX and its global affiliates in July 2010.



Carbon cutting plan approved in California.



BBC NEWS US & CANADA

Home | US & Canada | Latin America | UK | Africa | Asia-Pac | Europe | Mid-East | South Asia

17 December 2010 Last updated at 04:40 ET

**California approves extensive carbon-trading scheme**

**California has approved an extensive carbon-trading plan aimed at cutting greenhouse emissions.**

State regulators passed a "cap-and-trade" framework to let companies buy and sell permits, giving them an incentive to emit fewer gases.

The aim is to create the second-largest market in the field, after Europe's.

State officials hope the scheme will be copied across the US, but opponents warn it may harm California's growth and lead to higher electricity prices.

California's Air Resources Board approved the new rules late on Thursday. They are part of a landmark state climate bill passed by the legislature in 2006, which set 1 January 2011 as the deadline for enacting a cap-and-trade system.

California has long championed efforts to curb greenhouse gases

Related stories

A brief history of climate change

US city to charge polluting firms

California inspires US revolt on climate

## For US there is already a "voluntary" greenhouse pollution permit trading market

http://www.chicagoclimatex.com

## Example of offsets for sale

http://co2offsets.sustainabletravelinternational.org/ua/offsets/



## MFE659 Lecture 5a: Heat waves, Drought, Dust Storms, and Wild Fires



## Heat Stroke and Heat Disorders

At temperatures above the body's core temperature (37°C) heat must be dissipated. ~90% of heat loss occurs through skin; sweating becomes less effective at high RH, hence the increase in "apparent temperature". If heat gain exceeds heat loss, body core temperature rises, and heat disorders occur.

Sunburn can retard the body's ability to shed heat, and may increase the severity of the heat disorder.

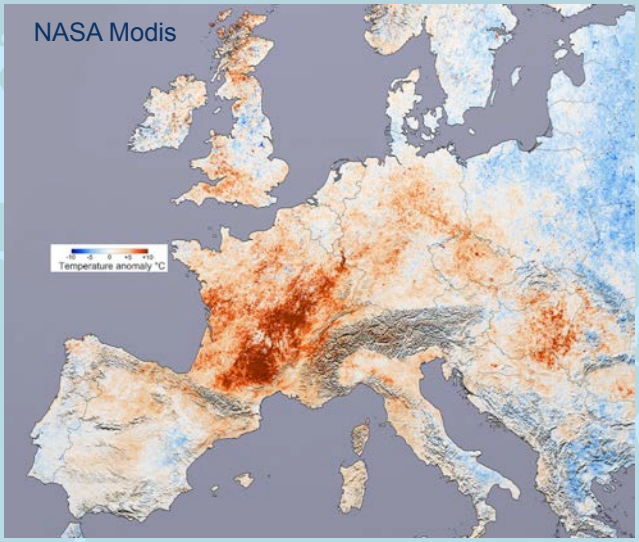


## Heat Waves and Deaths

| Rank | Death toll | Event | Location | Date |
|---|---|---|---|---|
| 1. | 56,000 | 2010 Russian heat wave | Russia | 2010 |
| 2. | 40,000 | 2003 European heat wave | Europe | 2003 |
| 3. | 5,000–10,000 | 1988 United States heat wave | United States | 1988 |
| 4. | 1,700 | 1980 United States heat wave | United States | 1980 |
| 5. | 1,500 | 2003 Southern India heat wave | India | 2003 [21] |
| 6. | 946 | 1955 Los Angeles heat wave | United States | 1955 |
| 7. | 891 | 1972 New York City heat wave | United States | 1972 |
| 8. | 739 | 1995 Chicago heat wave | United States | 1995 [22] |
| 9. | 503 | 2010 Japanese heat wave | Japan | 2010 [23] |

- Several thousand people die each year worldwide from heat stress.
- Most deaths in North America occur in inner cities & in the southeastern US.
- Severe urban pollution may be a contributing factor.

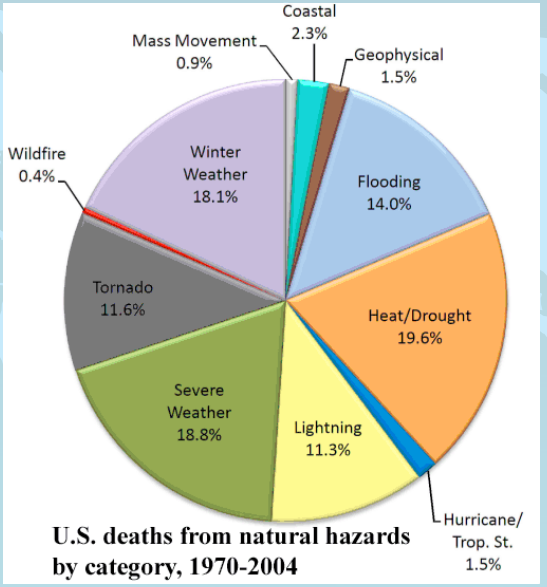
# Heat Waves and Deaths




Europe 2003 – 40,000 deaths

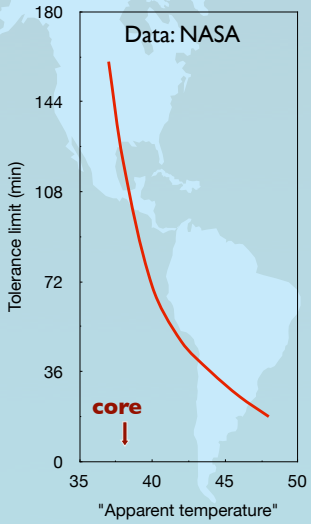


# Heat Waves and Deaths






# Human Tolerance of High Temperatures




**Heat Index chart: apparent temperature**

| Air temperature (°C) \ Relative humidity (%) | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43 (110°F) | 58 | | | | | | | | | | | | |
| 42 | 54 | 58 | | | | | | | | | | | |
| 41 | 51 | 54 | 58 | | | | | | | | | | |
| 40 | 48 | 52 | 55 | 58 | | | | | | | | | |
| 39 | 46 | 48 | 51 | 54 | 58 | | | | | | | | |
| 38 | 43 | 46 | 48 | 51 | 54 | 58 | | | | | | | |
| 37 (100°F) | 41 | 43 | 45 | 47 | 51 | 53 | 57 | | | | | | |
| 36 | 38 | 40 | 42 | 44 | 47 | 49 | 52 | 56 | | | | | |
| 34 | 36 | 38 | 39 | 41 | 43 | 46 | 48 | 51 | 54 | 58 | | | |
| 33 | 34 | 36 | 37 | 38 | 41 | 42 | 44 | 47 | 49 | 52 | 55 | | |
| 32 | 33 | 34 | 35 | 36 | 38 | 39 | 41 | 43 | 45 | 47 | 50 | 53 | 56 |
| 31 | 31 | 32 | 33 | 34 | 35 | 37 | 38 | 39 | 41 | 43 | 45 | 47 | 49 |
| 30 | 29 | 31 | 31 | 32 | 33 | 34 | 35 | 36 | 38 | 39 | 41 | 42 | 44 |
| 29 | 28 | 29 | 29 | 30 | 31 | 32 | 32 | 33 | 34 | 36 | 37 | 38 | 39 |
| 28 | 27 | 28 | 28 | 29 | 29 | 29 | 30 | 31 | 32 | 32 | 33 | 34 | 35 |
| 27 | 27 | 27 | 27 | 27 | 28 | 28 | 28 | 29 | 29 | 29 | 30 | 31 | 31 |

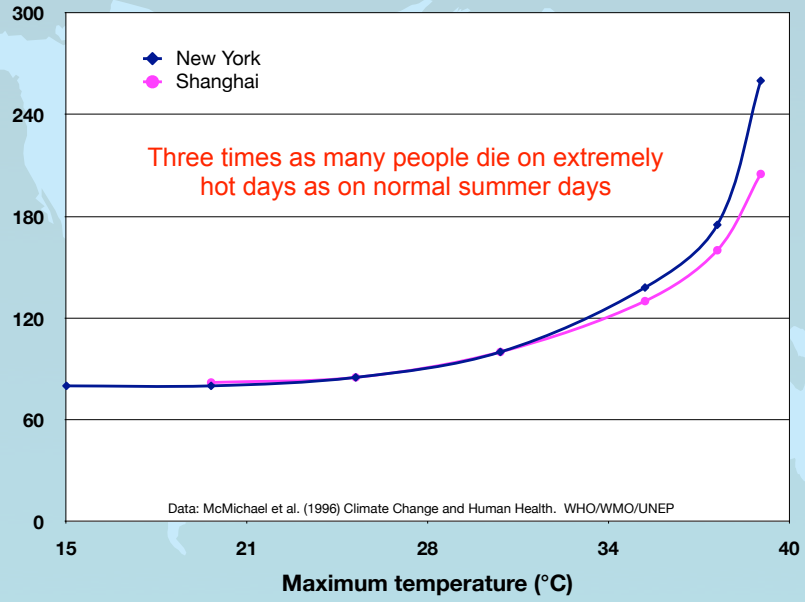
extreme danger
danger



# Heat Disorders and Apparent Temperature

- >50°C: heatstroke/sunstroke highly likely with continued exposure
- 40-50°: sunstroke, heat cramps likely, and heatstroke possible with prolonged exposure and/or physical activity
- 35-39°: sunstroke, heat cramps and heatstroke possible with prolonged exposure and/or physical activity
- 30-34°: fatigue possible with prolonged exposure and/or physical activity
- Heat disorders increase with age – 20yr - heat cramps; 40yr - heat exhaustion; >60yr - heat stroke

# Mean Daily Mortality






# Heat Waves, Drought and Wildfires
## frequently occur together

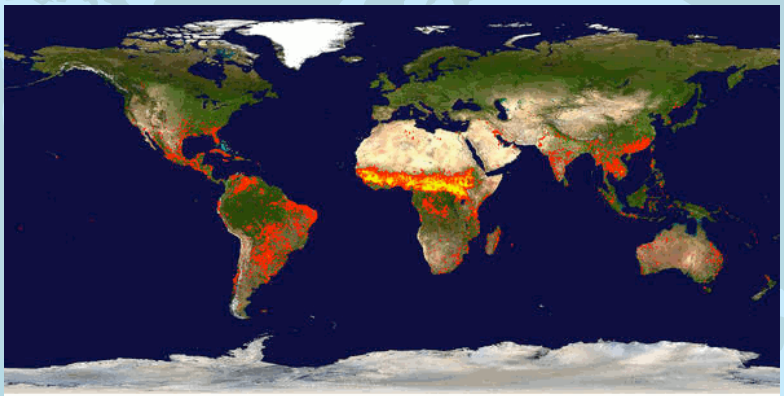
Desiccated sunflowers, France, 2003

Wildfires, Portugal, 2003

Photos: Munich Re

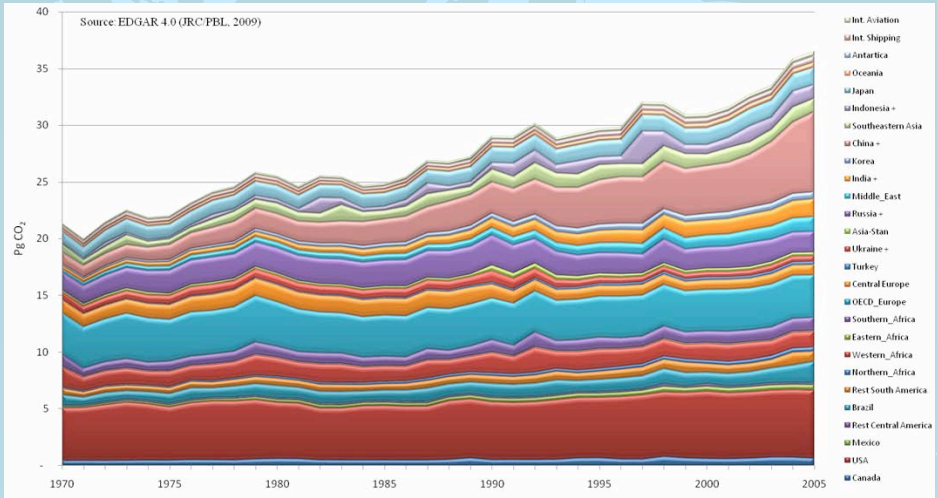


# Global Wildfires





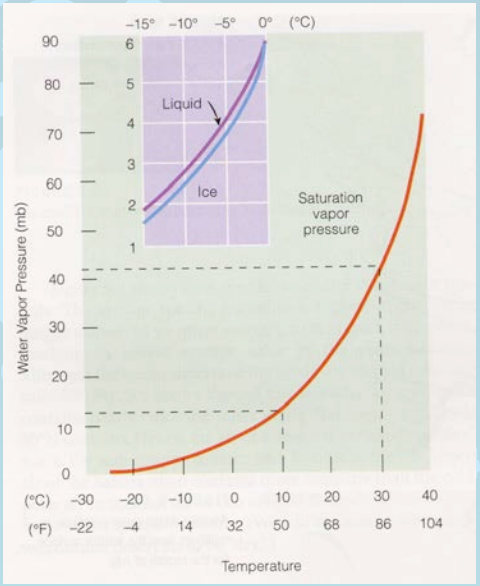

# Global Wildfires




Wildfires increased by 75% between 1970 and 2005.

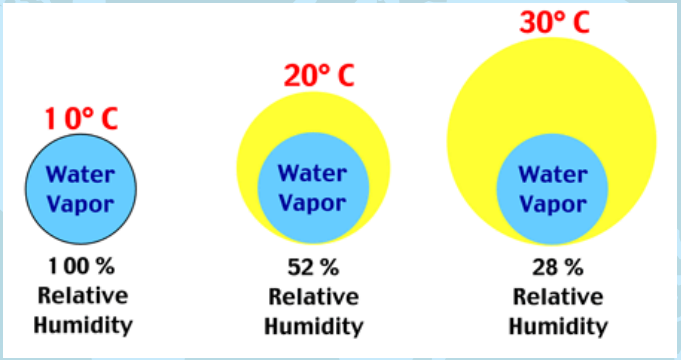
# Warmer Air: Floods and Droughts

There is a non-linear increase in the amount of water vapor in the air at saturation as the temperature increases. Thus, given a source of vapor from the ocean, the amount of water available in the air to rain out increases rapidly with warmer ocean temperatures.






# Warmer Air: Floods and Droughts

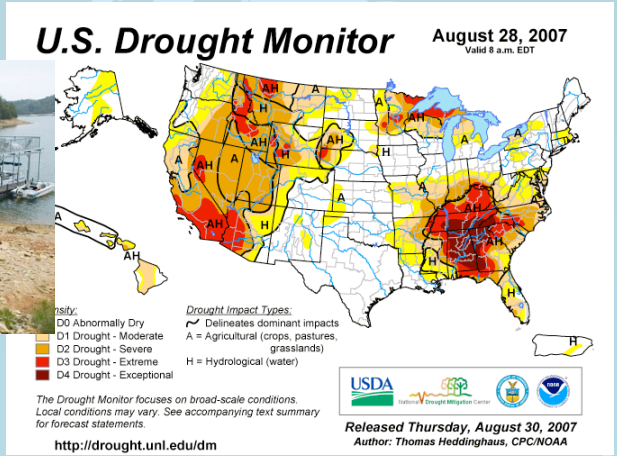



If the amount of water in the air is limited as it is over inland areas, but the temperature increases, then the relative humidity drops. Lower relative humidity means drier conditions are experienced, e.g., droughts.



# More Intense Hydrological Cycle

Lake Lanier, GA



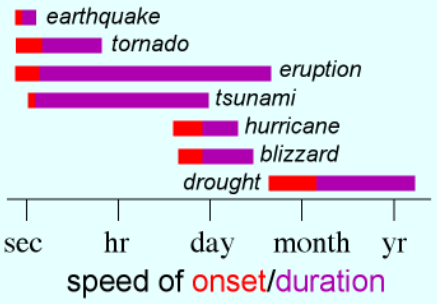

Severe drought in SE US

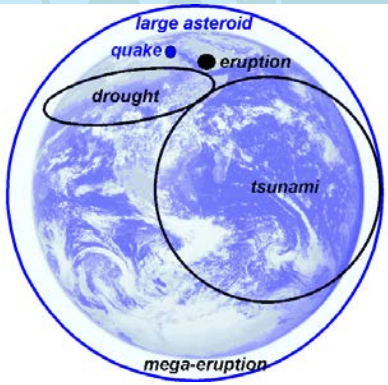


# Drought

A **drought** is an extended period of months or years when a region notes a deficiency in its water supply whether surface or underground water.

- Desertification and habitat damage
- Impacts crops and livestock
- Dust storms, Erosion and Dust bowls
- Famine due to lack of water for irrigation
- Malnutrition and dehydration
- Mass migration, resulting in internal displacement and international refugees
- Social unrest
- War over natural resources, including water and food
- Wildfires, such as bushfires, are more common during times of drought.
- Reduced electricity production due to reduced water flow through hydroelectric dams
- Shortages of water for industrial users



# Strategies for Drought Mitigation

- Dams
- Cloud seeding
- Desalination of sea water for irrigation or consumption.
- Drought monitoring
- Land use - Carefully planned crop rotation can help to minimize erosion and allow farmers to plant less water-dependent crops in drier years.
- Outdoor water-use restriction
- Rainwater harvesting
- Recycled water
- Transvasement - Building canals or redirecting rivers as massive attempts at irrigation in drought-prone areas.



# Drought: some early operational definitions

- Great Britain (1936): 15 consecutive days with daily precipitation totals of less than .25 mm
- India (1960): actual seasonal rainfall deficient by more than twice the mean deviation
- Bali (1964): a period of six days without rain
- Libya (1964): annual rainfall less than 180 mm

*Note: locally-specific criteria*



# Drought Indices

- The Palmer Drought Index (PDI) – now called the Palmer Drought Severity Index (PDSI) is a measurement of dryness based on recent precipitation and temperature (Wayne Palmer 1965).

http://www.math.montana.edu/~nmp/materials/ess/mountain_environments/intermediate/ystone/palmer_more.html

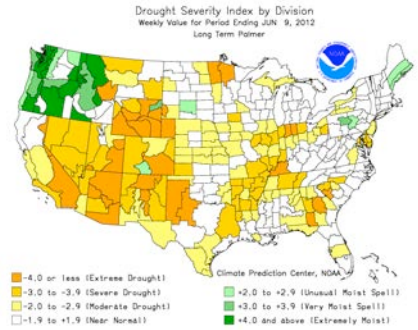


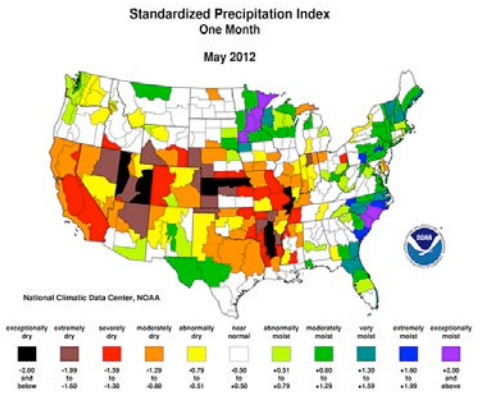
# Drought Indices

Standardized Precipitation Index (SPI) – a probabilistic index based on rainfall amount compared to normals for the same period using a gamma distribution. Technically, the SPI is the number of standard deviations that the observed value would deviate from the long-term mean, for a normally distributed random variable. Since precipitation is not normally distributed, a transformation is first applied so that the transformed precipitation values follow a normal distribution.

http://climatedataguide.ucar.edu/guidance/standardized-precipitation-index-spi

# SPI and PDSI maps (North America)




http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/spi.html

http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml

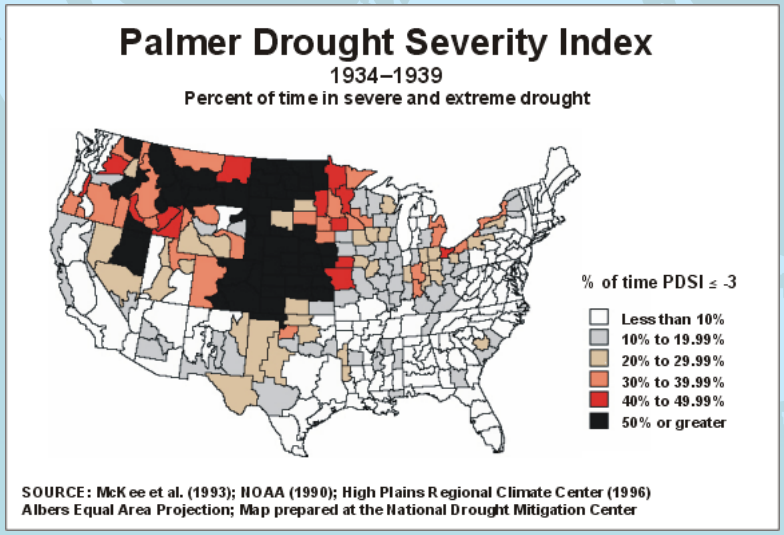


# The Dust Bowl

Boise City, Oklahoma, April 15, 1935.



# The drought of the 1930's: the Dust Bowl

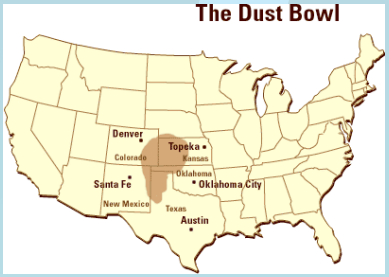





# DUST BOWL

Precursors

- Ten times increase in population in OK,TX,AK from 1860 - 1920.
- Deep ploughing and wheat monoculture destroyed soil structure and increased soil erosion potential
- Drought (1931-1940)
- world economic slump in 1930's; virtually no federal funds for prairie farmers
- economic disaster - outmigration of "Okies"

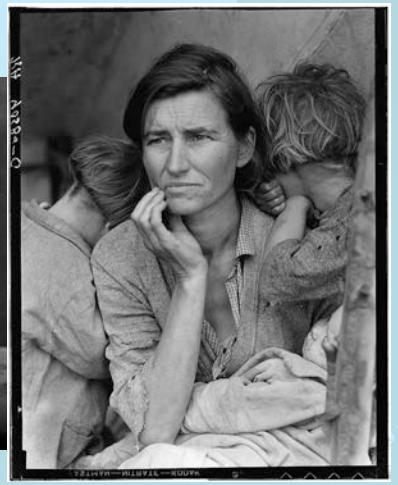



Cimarron County, Oklahoma. Date April 1936

## Dust Bowl Kansas 1936



## Dust storm during the 1930's drought in the southern Great Plains





## The Dust Bowl: Contributing Factors

overgrazing

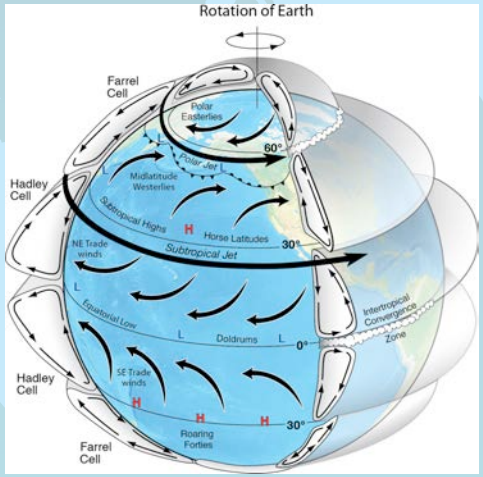
cropping of marginal soils

soil erosion

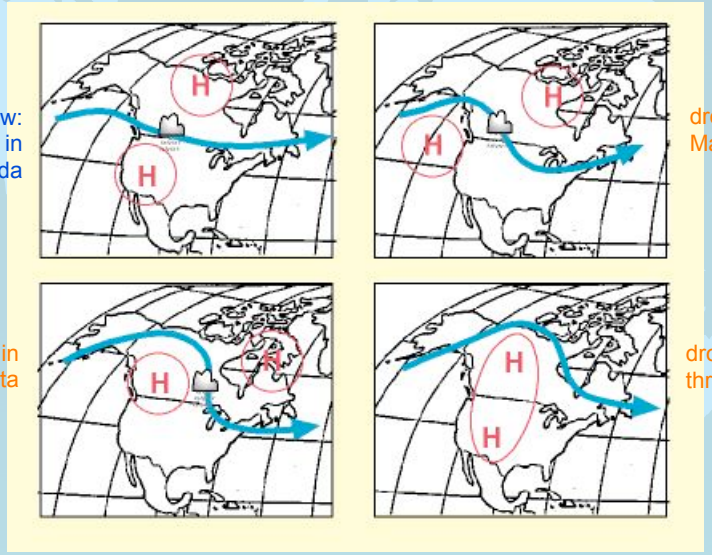


## Drought climatology

- Temperate climates - blocking highs in zone of westerlies (Rossby waves)
- Seasonal tropical climates - ITCZ position on monsoon penetration
- Humid tropical climates - El Niño - Southern Oscillation (ENSO)



# Storm tracks, blocking highs and drought in the US and Canadian Prairies






# Sahel Drought

1980's Drought

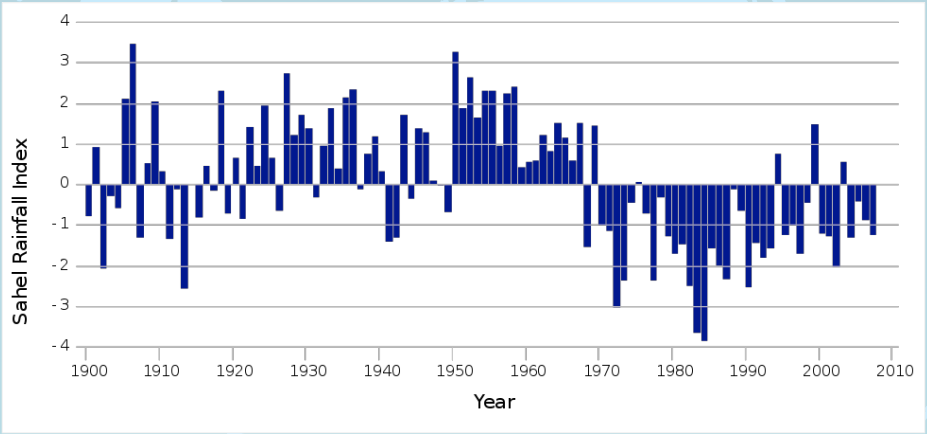
5M people affected; >200K died from malnutrition and associated diseases

Livestock herds decimated (80% died)

Loss of livestock ⇒ loss of wealth ⇒ massive social dislocation and emigration to urban areas

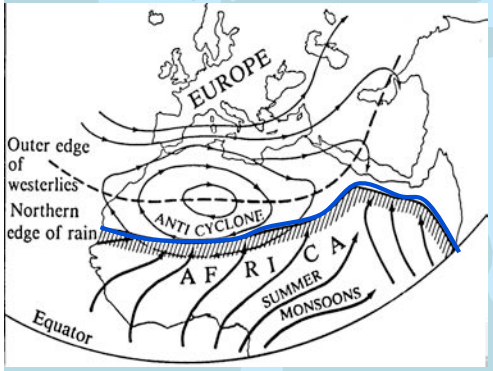


# Changing rainfall patterns in the Sahel region

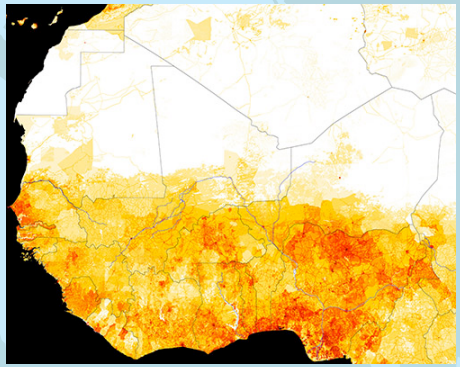





# Drought in Monsoon Climates: the Sahel

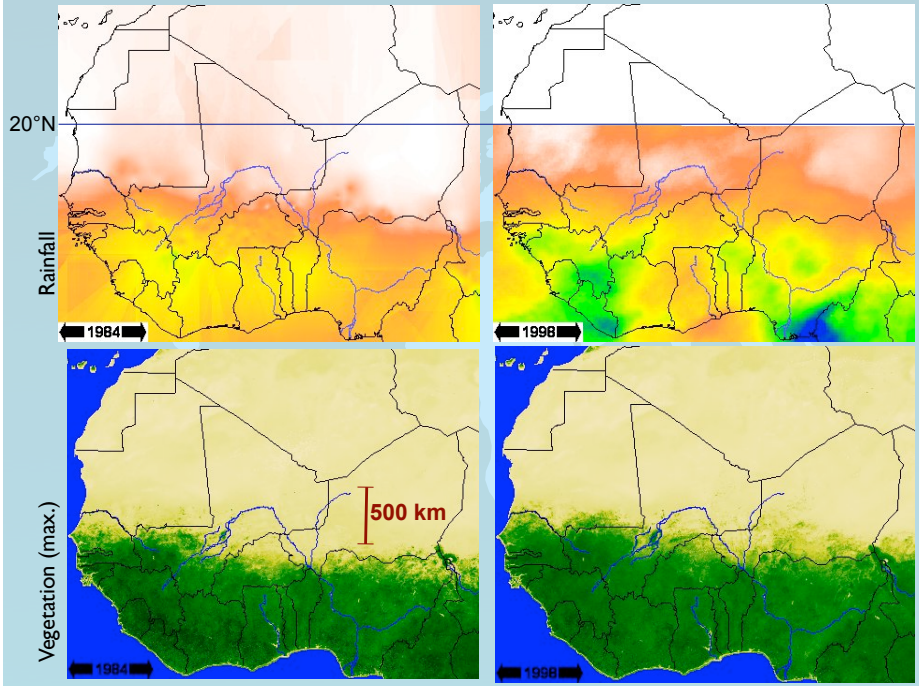



Inter-Tropical Front / Inter-Tropical Convergence Zone



Population density (orange >25 people km$^{-2}$)

Source: www.mapjourney.com/sahel/

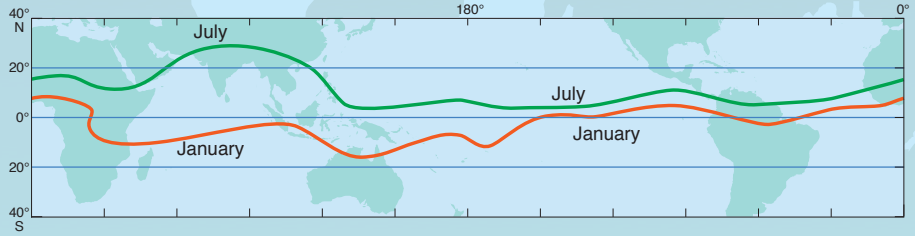





# Hypotheses to explain Sahelian drought

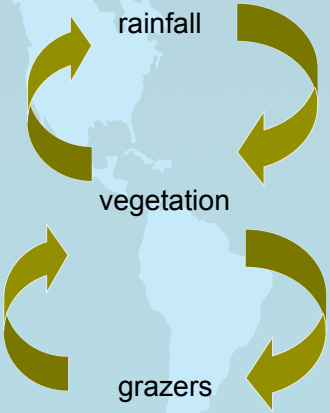
"Climatological" - northward penetration of ITCZ controlled by variations in atmospheric temperature in northern tropics, due to:

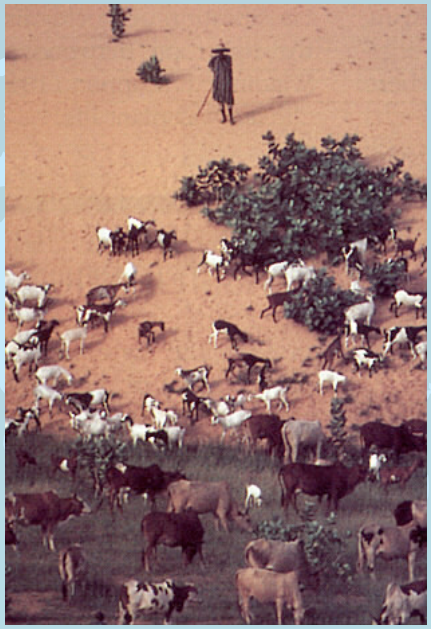
- SST anomalies in northeastern Atlantic linked to general circulation (especially El Niño/La Niña), or
- Industrial pollution (particularly $SO_2$ aerosols) from N.America, Europe and Asia (intense drought of 1970-85).
- "Anthropogenic" - changes in vegetation and surface albedo caused by varying land-use result in changes in regional climate.
- These may be influenced by global warming





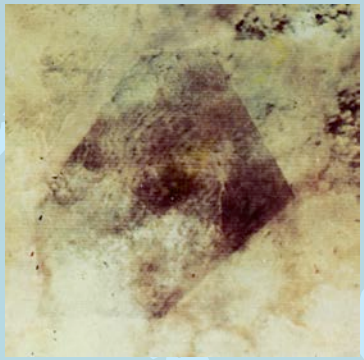

# Rapp's albedo feedback model



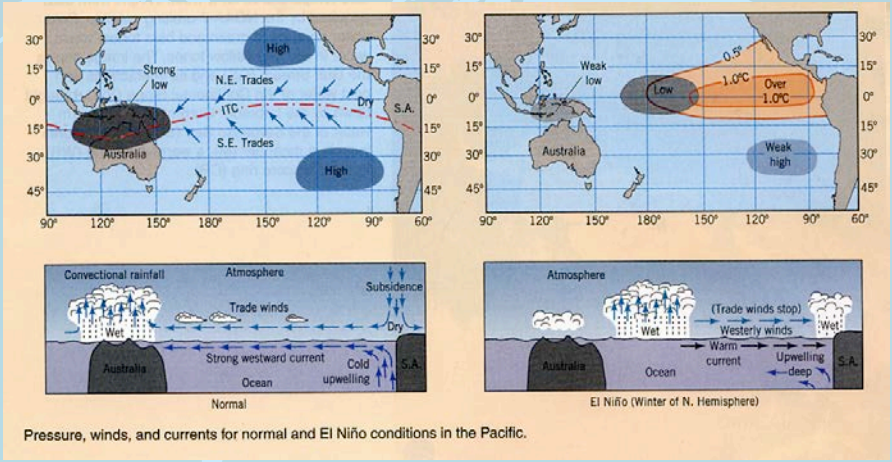





# Evidence for Rapp's Model



# ENSO and drought in western Pacific (Indonesia and N. Australia)

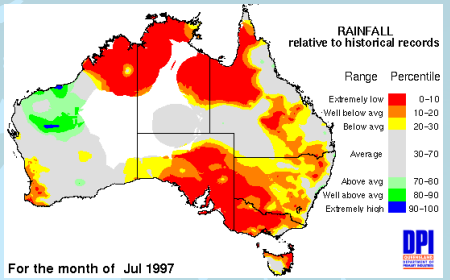



Pressure, winds, and currents for normal and El Niño conditions in the Pacific.

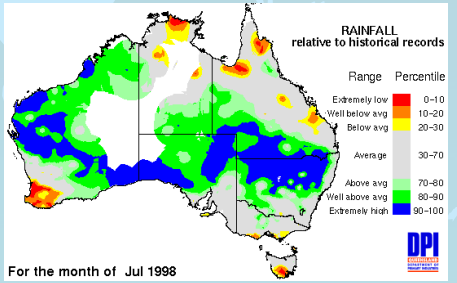


# ENSO and Australian Drought

July, 1997 (El Niño)




July, 1998 (La Niña)




Rainfall relative to historical records



# Dust storm, E. Australia, 2002



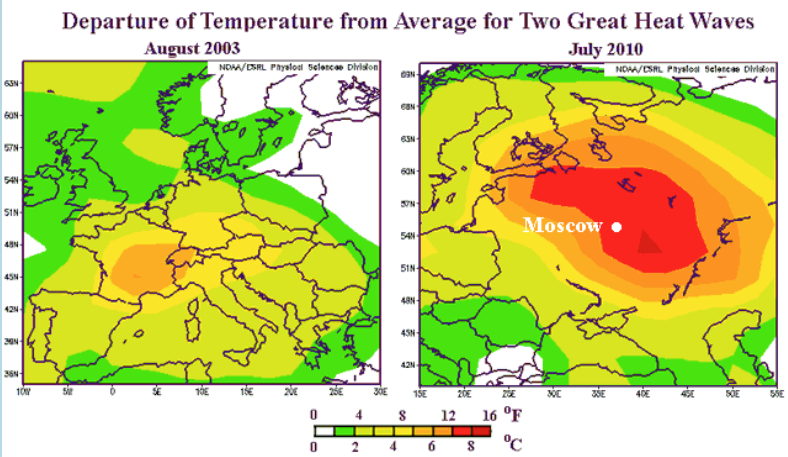

# Effects of 1997-98 drought in Indonesia

Agricultural production:

- 20 - 30% reduction of rice crop in eastern Indonesia (parts of Kalimantan, Sulawesi and Irian Jaya.
- Markedly lower yam production in Irian Jaya.
- In some villages in the latter 20-30% of people died from malnutrition
- 95% incidence of malaria reported.

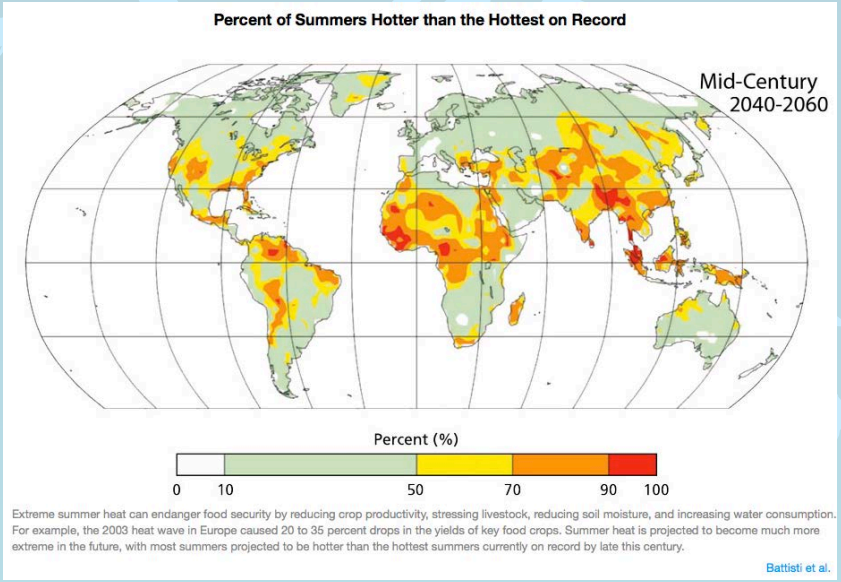
# Future Heat Waves and Climate Change

During the summer of 2010, Russia recorded the warmest temperatures in 1000 years. This was a 1 in 1000 year heat wave.
What will the recurrence time be in the "x2 $CO_2$" summers of the mid-21st century?



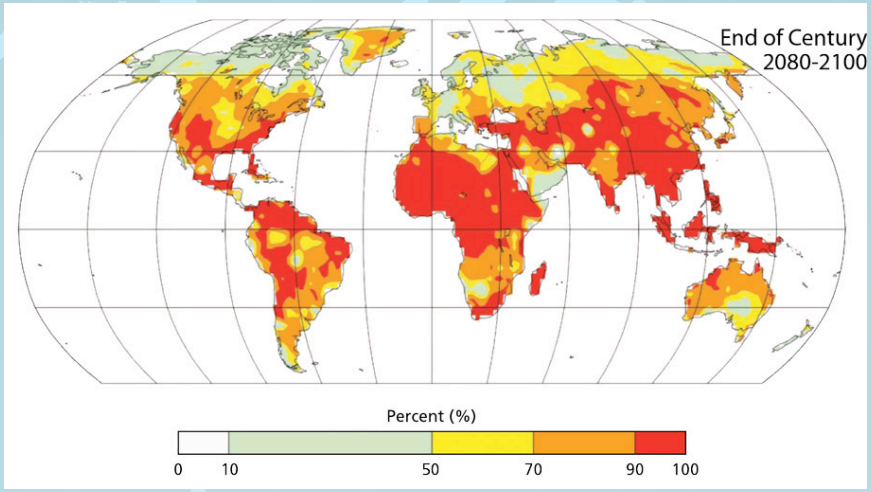



# Future Heat Waves and Climate Change






# Future Heat Waves and Climate Change




Percentage of summers hotter than the hottest on record.



# Questions?