Temperature
Trend, Variability and Global Warming

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Overview

- Global Climate Change
- Greenhouse effect
- Watch Climate change mitigation Video
- Group Activity
  - Plan of action

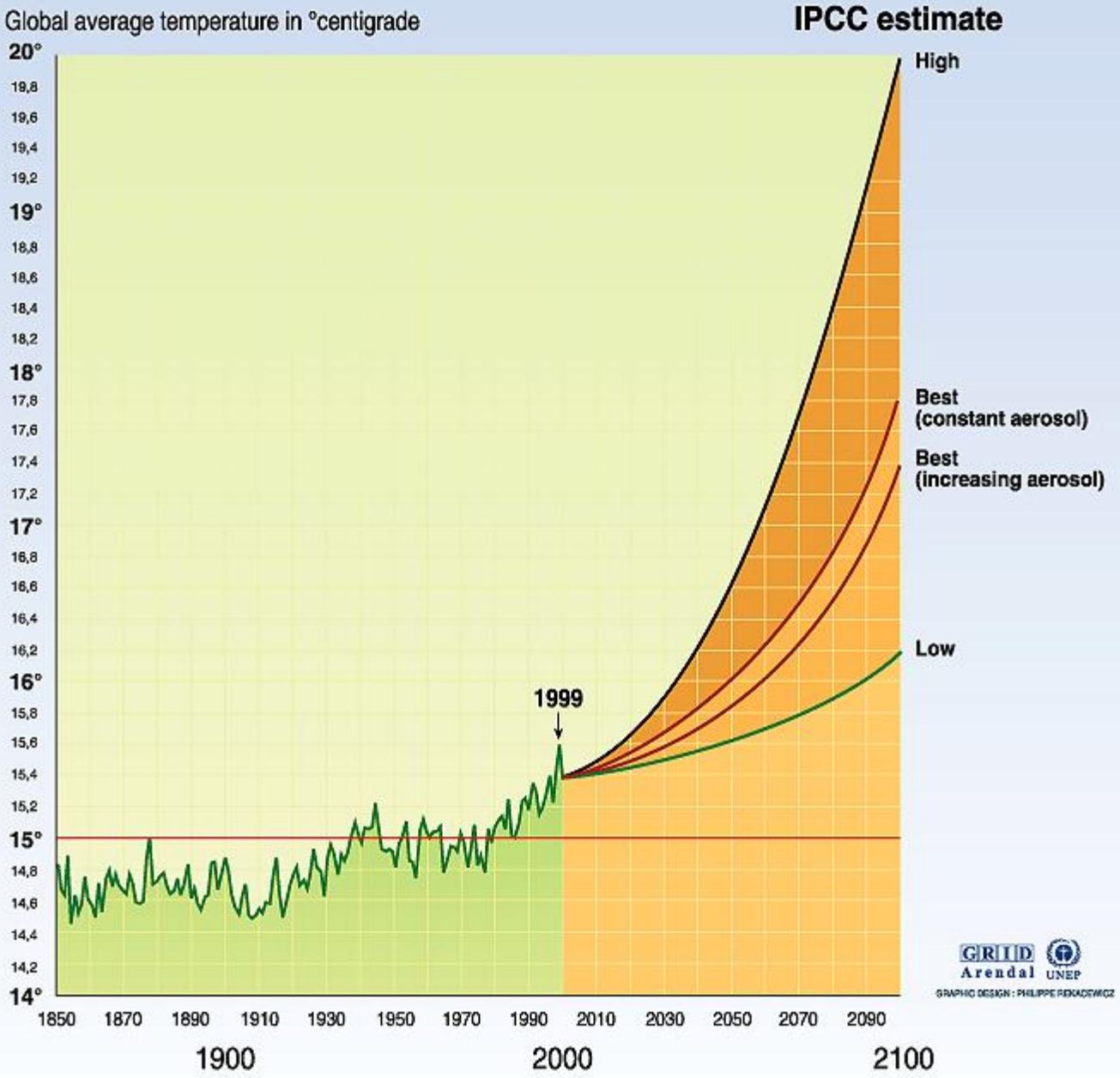
Global Warming

Global warming is the increase in the mean surface temperature of the Earth. In the last century, the Earths' average temperature has increased by 1° to 1.5°. The last 30 years has seen a 10% reduction in the polar ice caps.

- Causes for global warming include:
  - Burning of fossil fuels
  - Removal of trees and plants
- Effects of global warming include:
  - Rise in the sea level
  - Precipitation pattern and amount changes
  - Increase in size of subtropical desserts

Projected changes in global temperature:

global average 1856-1999 and projection estimates to 2100

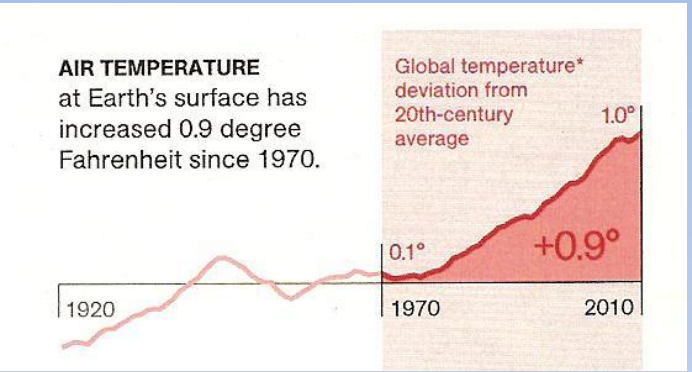


Source : Temperatures 1856 - 1999: Climatic Research Unit, University at East Anglia, Norwich UK. Projections: IPCC report 95.

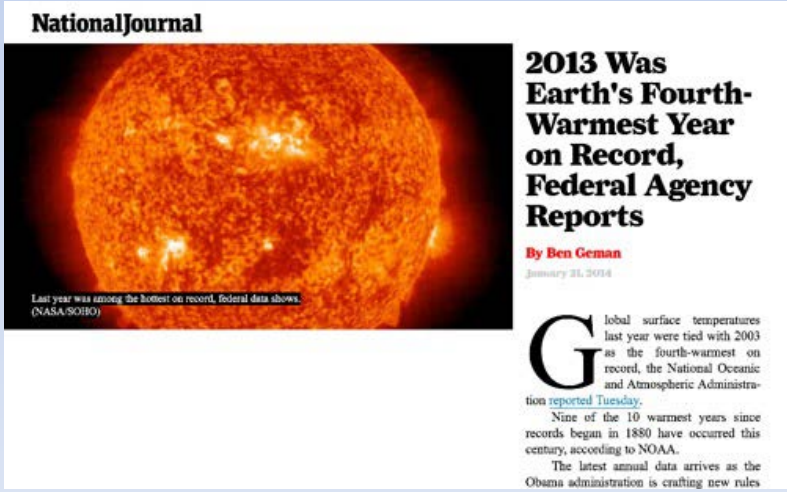
Global Warming Evidence

- There is firm evidence that the greenhouse effect is being enhanced and that we are entering a global warming period

- This evidence includes:
  - 29 of the highest world average annual temperatures ever recorded (since 1880) recorded from 1976-2013; with the exception of 1998, the nine hottest years have occurred since 2001 (2013 was the fourth hottest global year on record, 2005 and 2010 the hottest);
  - about a 50% reduction in European Alps glacier ice in the last 100 years;



Source: National Geographic, Sept. 2012



NationalJournal

Last year was among the hottest on record, federal data shows. (NASA/SOHO)

2013 Was Earth's Fourth-Warmest Year on Record, Federal Agency Reports

By Ben Geman

January 31, 2014

Global surface temperatures last year were tied with 2003 as the fourth-warmest on record, the National Oceanic and Atmospheric Administration reported Tuesday.

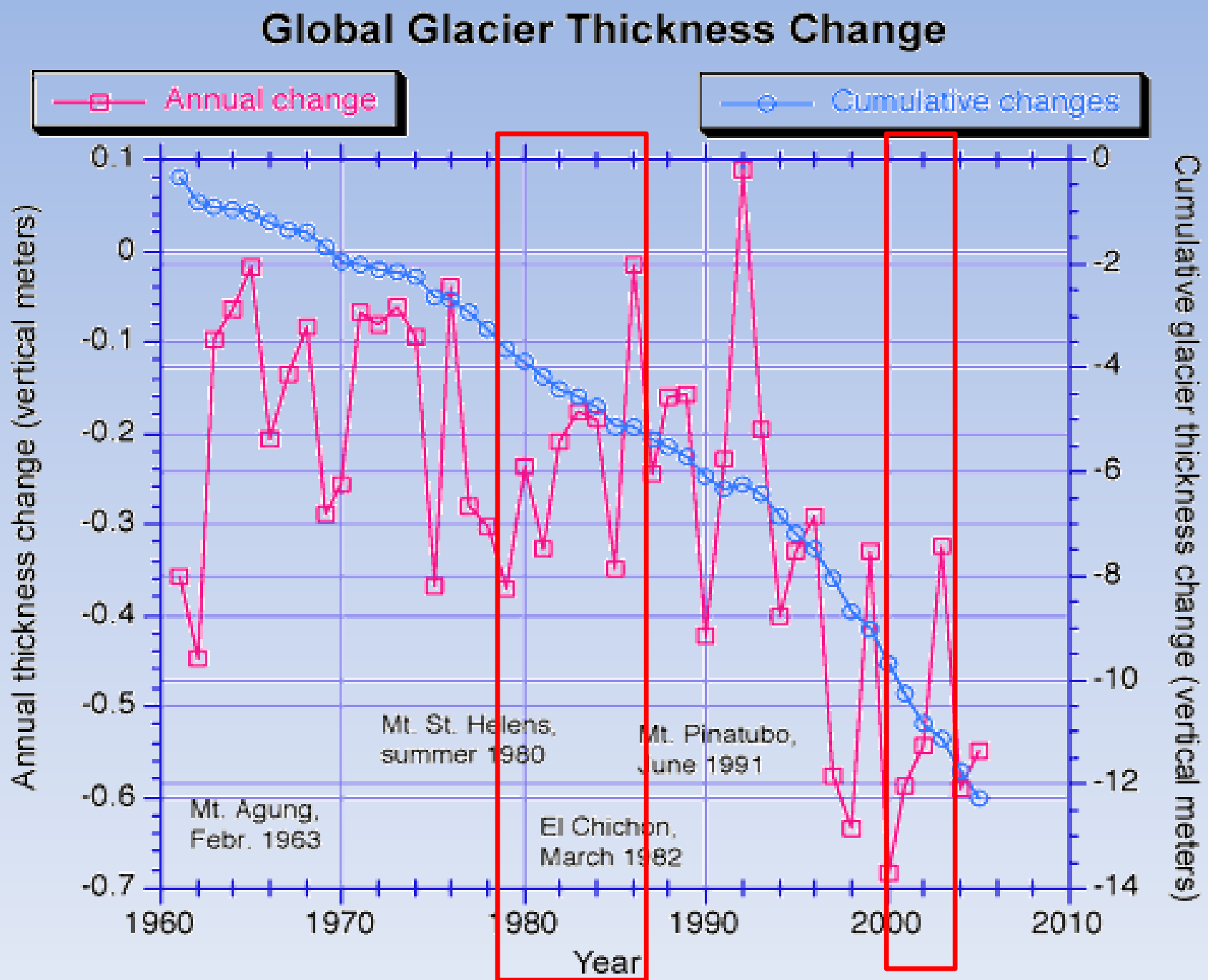
Nine of the 10 warmest years since records began in 1880 have occurred this century, according to NOAA.

The latest annual data arrives as the Obama administration is crafting new rules

Global Warming Evidence

- an average rise in world sea levels of about 1 foot during the last century;
- a decline of about 42% in Arctic sea ice volume in the last 30 years; and the quick melting of portions of the Greenland and Antarctic ice sheets and Antarctic ice shelves (1995, 2002 and 2008 – in March 2002 a portion of the Larsen ice shelf the size of Rhode Island (1250 mi^2) collapsed into the Antarctic Ocean)

Change in Arctic Sea Ice Minimum 1979-2007

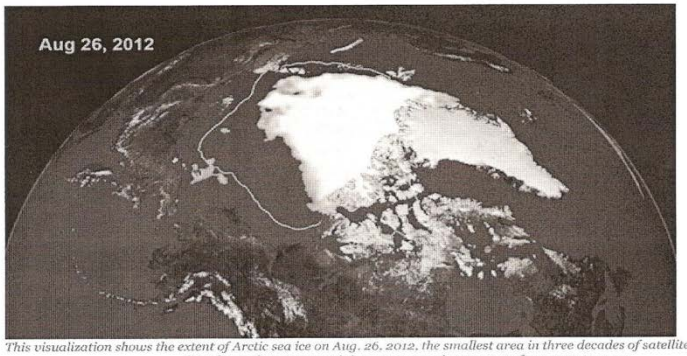

Global Glacier Thickness Change
Annual change
Cumulative changes
Annual thickness change (vertical meters)
Cumulative glacier thickness change (vertical meters)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
0
-2
-4
-6
-8
-10
-12
-14
1960
1970
1980
1990
2000
2010
Year
Mt. Agung, Febr. 1963
Mt. St. Helens, summer 1980
El Chichon, March 1982
Mt. Pinatubo, June 1991

Global Warming Evidence

'A less polar pole': Arctic sea ice at record low

By Miguel Llanos, NBC News
August 28, 2012, 7:23 am

NBCNews.com



This visualization shows the extent of Arctic sea ice on Aug. 26, 2012, the smallest area in three decades of satellite records. The yellow line shows the average minimum summer ice coverage from 1979 to 2010.

The amount of summer sea ice in the Arctic has reached a record low in three decades of satellite data, scientists reported Tuesday, with one of them describing recent warm years there as creating a "less polar pole." The decline was expected to continue for at least several more days before cold weather sets in and creates new ice through fall and winter.

The area of Arctic waters covered by sea ice was measured at 1.58 million square miles on Sunday, the National Snow and Ice Data Center (NSIDC) reported. That's below the previous record low of 1.61 million square miles set on Sept. 18, 2007, and in line with earlier expectations for the season.

"Including this year, the six lowest extents in the satellite record have occurred in the last six years," the center noted on its website.

npr morning edition

Scientists say they have put together a record of global temperatures dating back to the end of the [read more...]

Past Century's Global Temperature Change Is Fastest On Record

by CHRISTOPHER JOYCE

Past Century's Globa...
NPR Morning Edition

There's plenty of evidence that the climate has warmed up over the past century, and climate scientists know this has happened throughout the history of the planet. But they want to know more about how this warming is different.

Now a research team says it has some new answers. It has put together a record of global temperatures going back to the end of the last ice age — about 11,000 years ago — when mammoths and saber-tooth cats roamed the planet. The study confirms that what we're seeing now is unprecedented.

What the researchers did is peer into the past. They read ice cores from polar regions that show what temperatures were like over hundreds of thousands of years. But those only reveal changes in those specific regions; cores aren't so good at depicting what happened to the whole planet. Tree rings give a more global record of temperatures, but only back about 2,000 years.

Shaun Marcott, a geologist at Oregon State University, says "global temperatures are warmer than about 75 percent of anything we've seen over the last 11,000 years or so." The other way to look at that is, 25 percent of the time since the last ice age, it's been warmer than now.

You might think, so what's to worry about? But Marcott says the record shows just how unusual our current warming is. "It's really the rates of change here that's

March 08, 2013 2:22 AM

Page 1 of 2

theguardian

Doubling of Antarctic ice loss revealed by European satellite

Continent shedding 160 billion tonnes a year, CryoSat-2 shows, just days after warning over western ice sheet's collapse

Damian Carrington

Antarctica is shedding 160 billion tonnes a year of ice into the ocean, twice the amount of a few years ago, according to new satellite observations. The ice loss is adding to the rising sea levels driven by climate change and even east Antarctica is now losing ice.

The new revelations follows the announcement last week that the collapse of the western Antarctica ice sheet has already begun and is unstoppable, although it may take many

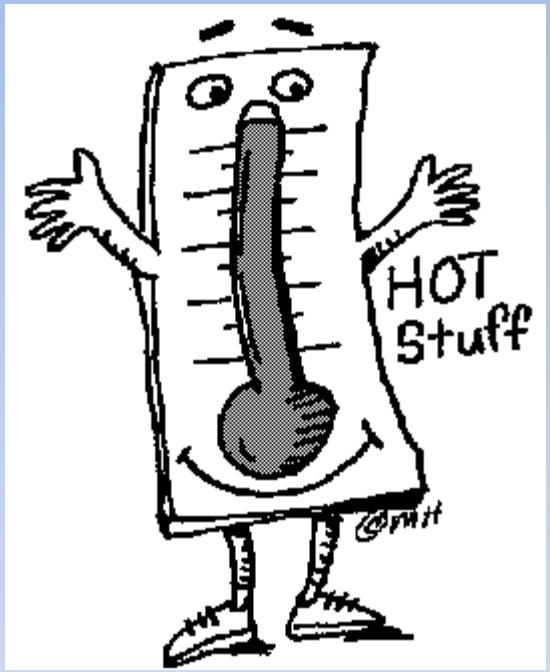
Three years of measurements from CryoSat show that the Antarctic Ice Sheet is now losing 159 billion tonnes of ice each year, enough to raise global sea levels by 0.45 mm Read More...

May 29, 2014

Page 1 of 2

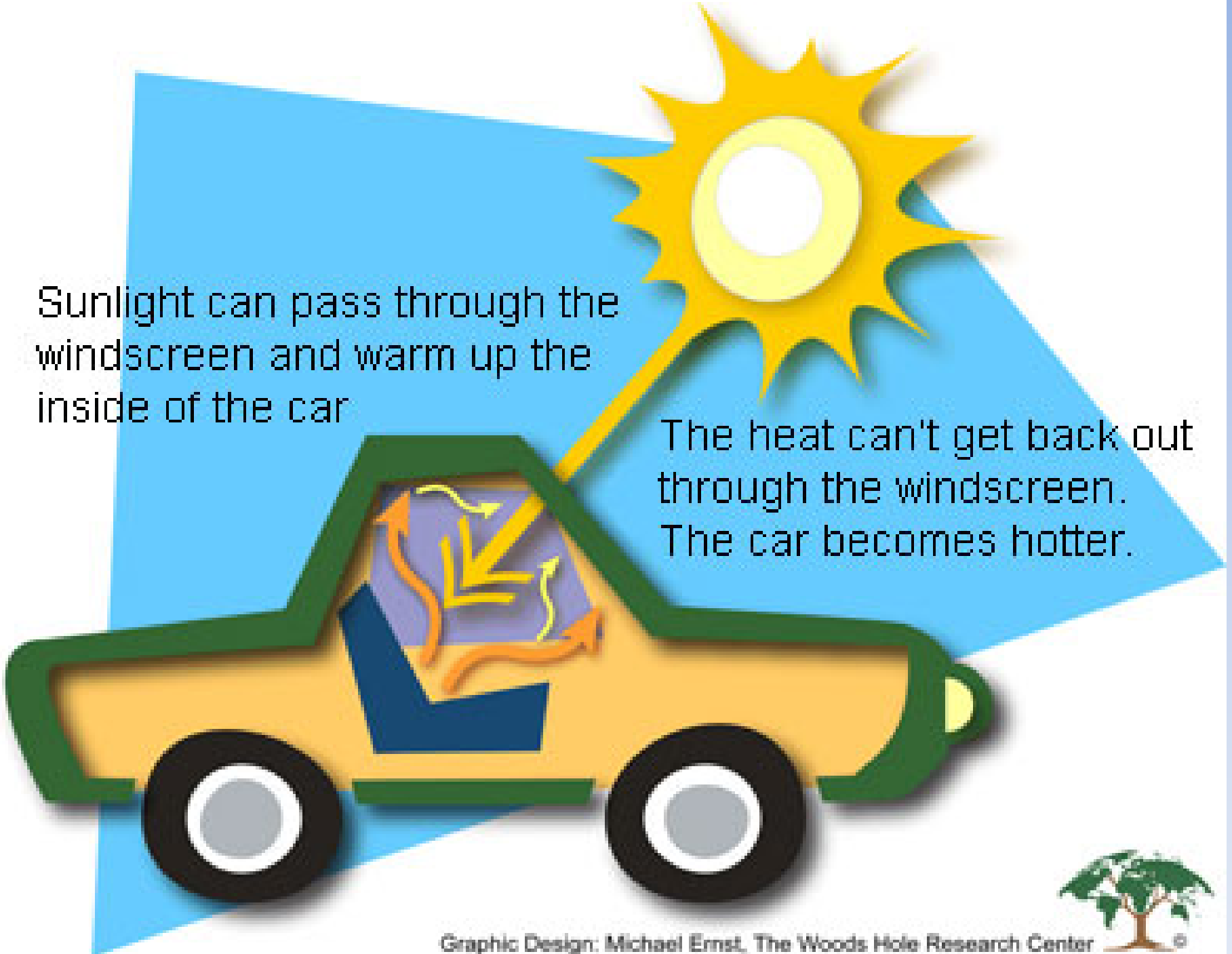
Global Climate Change

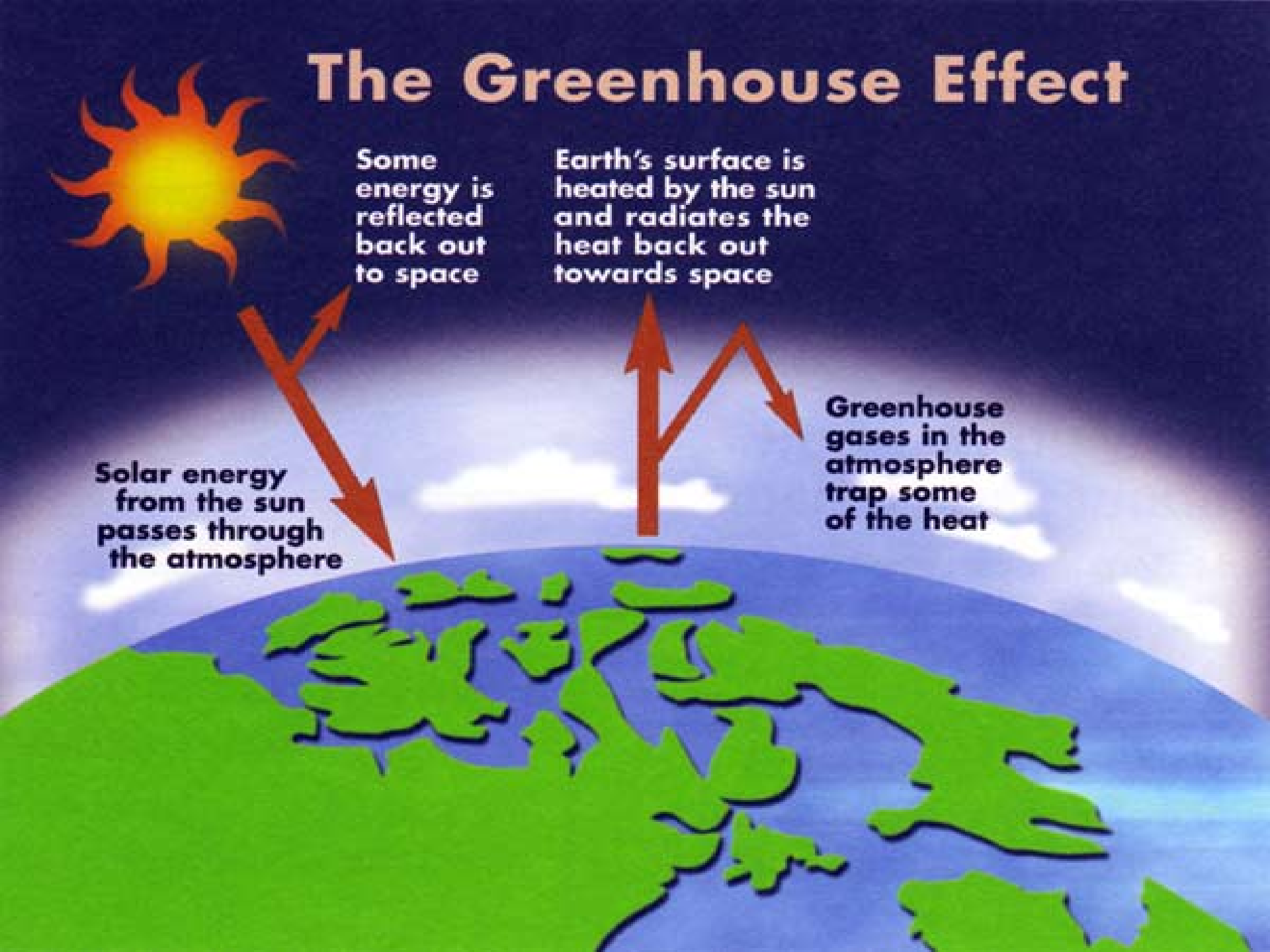
- Identifiable change in the climate of Earth as a whole that lasts for an extended period of time (decades or longer)
  - When due to natural processes, it is usually referred to as global climate variability
  - Usually refers to changes forced by human activities that change the atmosphere



What causes Earth's climate to change?

- Natural processes
  - Volcanoes
  - Tectonic plate movement
  - Changes in the sun
- Human activities – any activity that releases "greenhouse gases" into the atmosphere


Sunlight can pass through the windscreen and warm up the inside of the car
The heat can't get back out through the windscreen. The car becomes hotter.
Graphic Design: Michael Ernst, The Woods Hole Research Center ©


The Greenhouse Effect
Some energy is reflected back out to space
Earth's surface is heated by the sun and radiates the heat back out towards space
Greenhouse gases in the atmosphere trap some of the heat
Solar energy from the sun passes through the atmosphere

Which gases in the atmosphere trap heat?

The atmosphere is made of 78% Nitrogen and 21% Oxygen.
But these gases **don't** trap heat and cause global warming or climate change.
What % of the atmosphere is left?

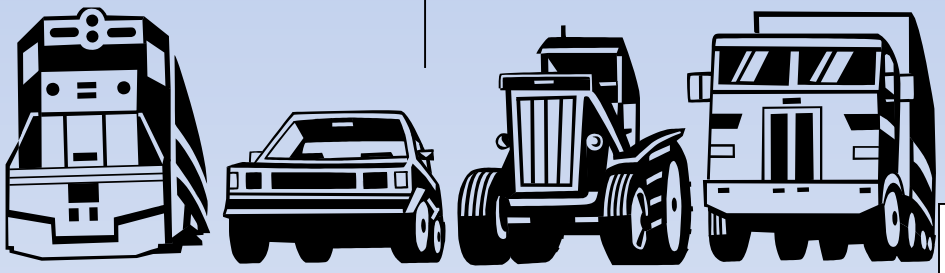
The gases which trap heat make up less than 1% of the atmosphere! They are called the 'greenhouse gases'.

The main greenhouse gases are:
Carbon dioxide
Methane
Nitrous oxide
Ozone
Water vapour
Halocarbons

Human activity increases the amount of these gases in the atmosphere

How do humans increase carbon dioxide levels in the atmosphere?

Burning **fossil fuels** releases the carbon dioxide stored millions of years ago. Most of the increased carbon dioxide comes from fossil fuels



Deforestation releases the carbon stored in trees. Less trees also means less **carbon dioxide** can be removed from the atmosphere.

How do humans increase methane levels in the atmosphere?

Methane is produced when bacteria rot **organic matter**

Increased rice growing

Increased livestock farming

Increased rubbish in landfill (gas)

Methane is also released when **fossil fuels (coal mines) are extracted**

The amount of **methane** in the atmosphere has increased by two and a half times since the Industrial Revolution.

Nitrous Oxide (N2O) Emissions

- Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

Perfluorocarbons (PFC's)

- Aluminum production
  - perflorometh**a**ne (CF4)
    - GWP = 6500
  - perfloroethane (C2F6)
    - GWP = 9200

Sulfur Hexafluoride (SF6) Emissions

- Insulator for electrical equipment
- Fugitive emission from semiconductor manufacture
- Cover gas for magnesium production
  - prevents the oxidation of molten magnesium in presence of air


EXIT

GLOBAL CLIMATE CHANGE

Who's researching it?

Research

- Almost 1000 studies dealing with different aspects of climate change have been conducted and published
- So… how do we make sense of all this?

Intergovernmental Panel on Climate Change (IPCC)

- Why was it created?
  - Created in 1988 by the United Nations Environmental Program
  - Established to provide policy-makers with an objective source of information about climate change

Intergovernmental Panel on Climate Change (IPCC)

- Who is it?
  - Governments
    - Members of the UN
    - Participate by naming experts and reviewing the reports before they're published
  - Scientists
    - Close to 1000 scientists
    - Climatologists, ecologists, atmospheric physicists, and others

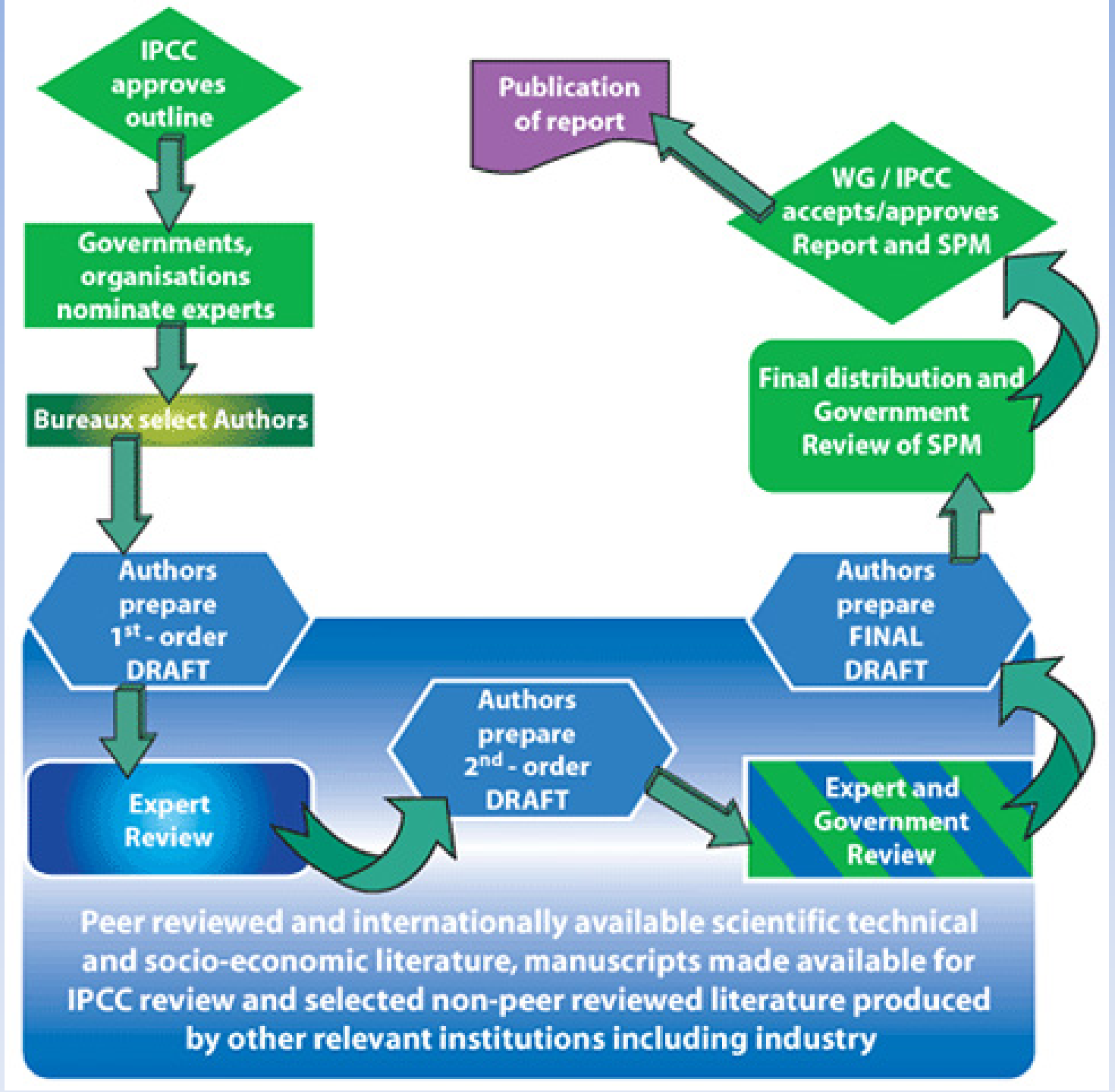
Dr. Susan Solomon, a NOAA atmospheric chemist, an IPCC member and one author of IPCC summary

Intergovernmental Panel on Climate Change

- What do they do?
  - Review current scientific and technical literature relevant to global climate change
  - Provide reports on their findings at regular intervals
  - Reports are designed to be politically neutral and of high scientific and technical standards

How do they create their reports?

It’s a multi-step process…


IPCC approves outline
Governments, organisations nominate experts
Bureaux select Authors
Authors prepare 1st - order DRAFT
Expert Review
Authors prepare 2nd - order DRAFT
Expert and Government Review
Authors prepare FINAL DRAFT
Final distribution and Government Review of SPM
WG / IPCC accepts/approves Report and SPM
Publication of report
Peer reviewed and internationally available scientific technical and socio-economic literature, manuscripts made available for IPCC review and selected non-peer reviewed literature produced by other relevant institutions including industry

IPCC – Words Used in Reports

- When they discuss data:
  - Very high confidence to very low confidence that the data is accurate
- When they discuss the likelihood of something occurring:
  - Virtually certain to exceptionally unlikely

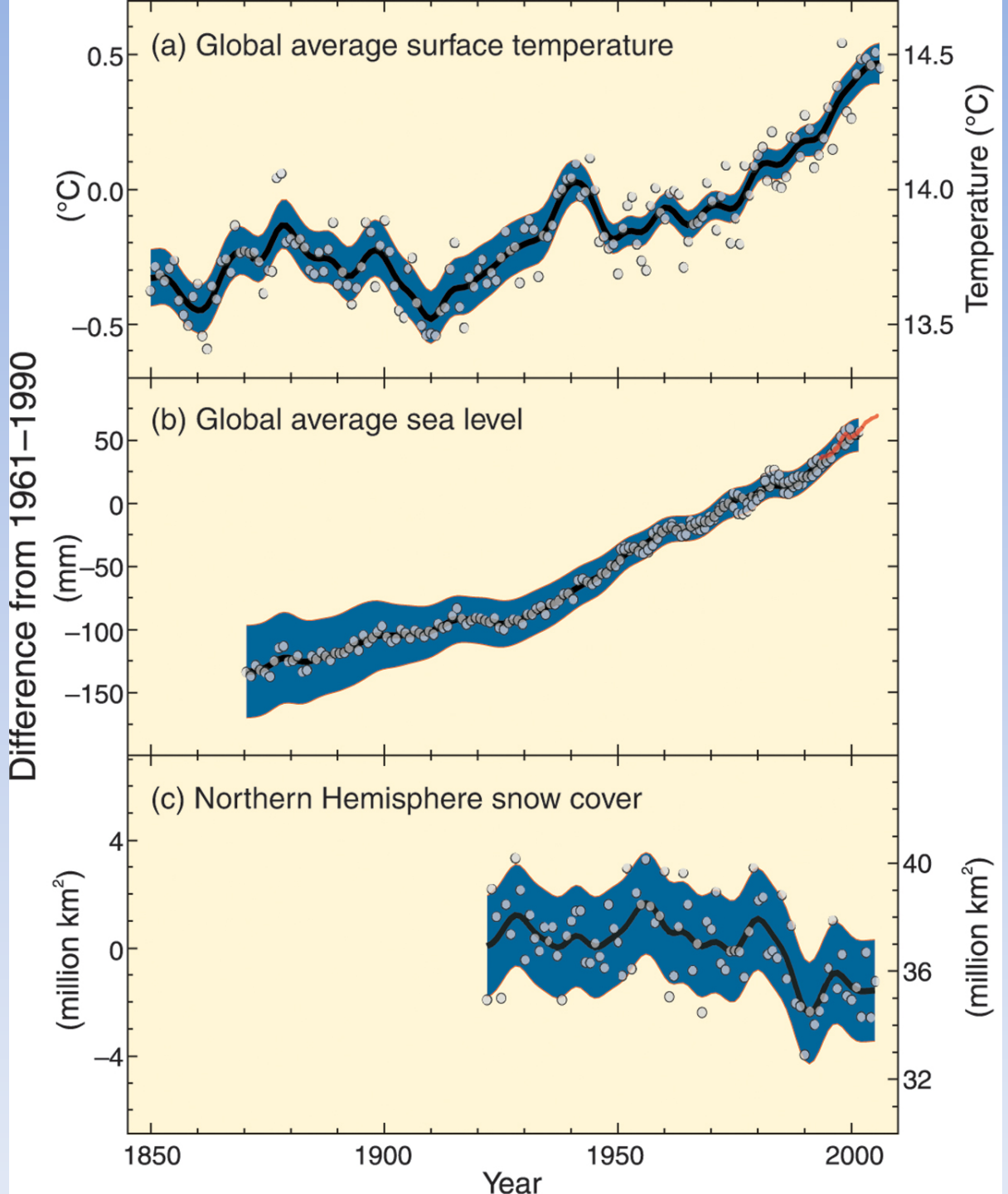
GLOBAL CLIMATE CHANGE

Well, what does the data say?

Observed Changes and Effects

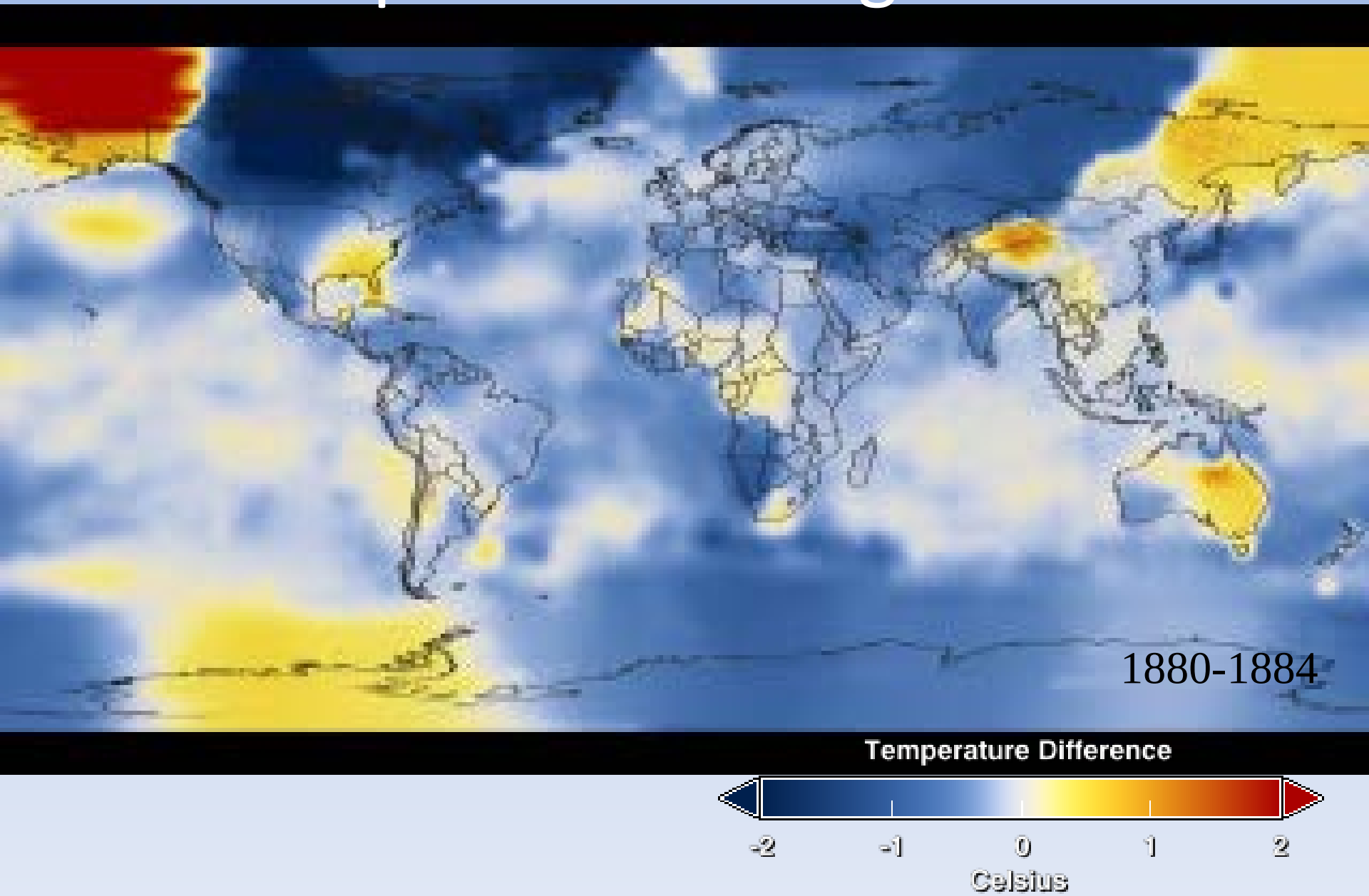
Warming of Climate

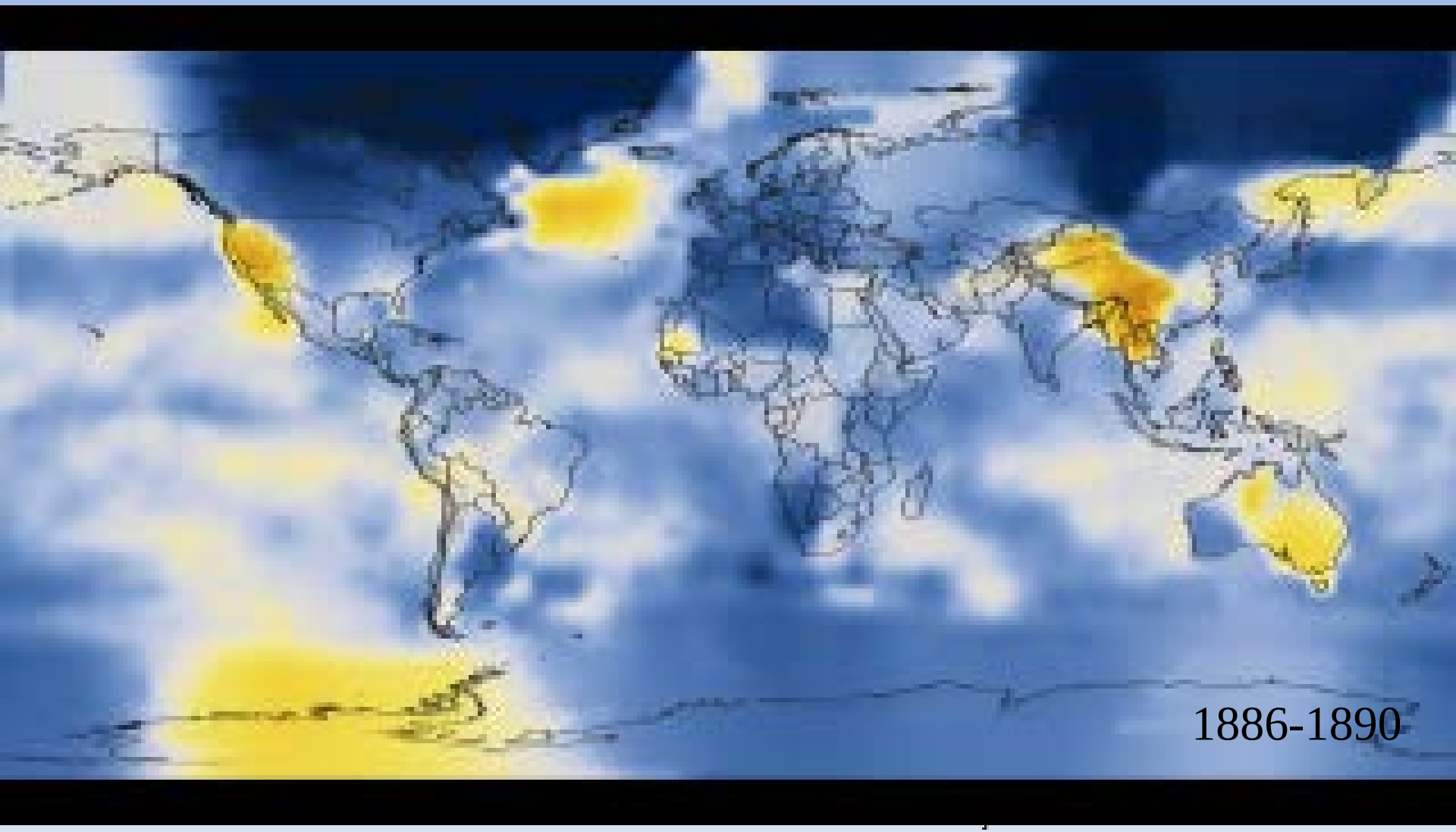
- Warming of the climate is definitely occurring and can be observed by the:
  - Increases in global sea and air temperatures
  - Widespread melting of snow and ice
  - Rising global sea level

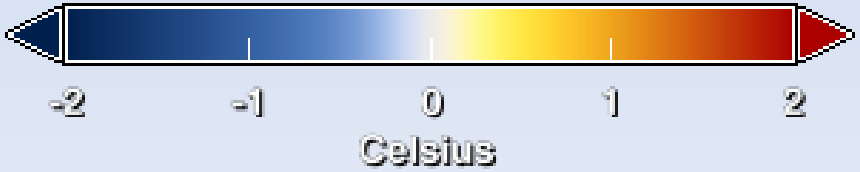


Source:
IPCC 2007

Temperature Change Data




1886-1890


-2
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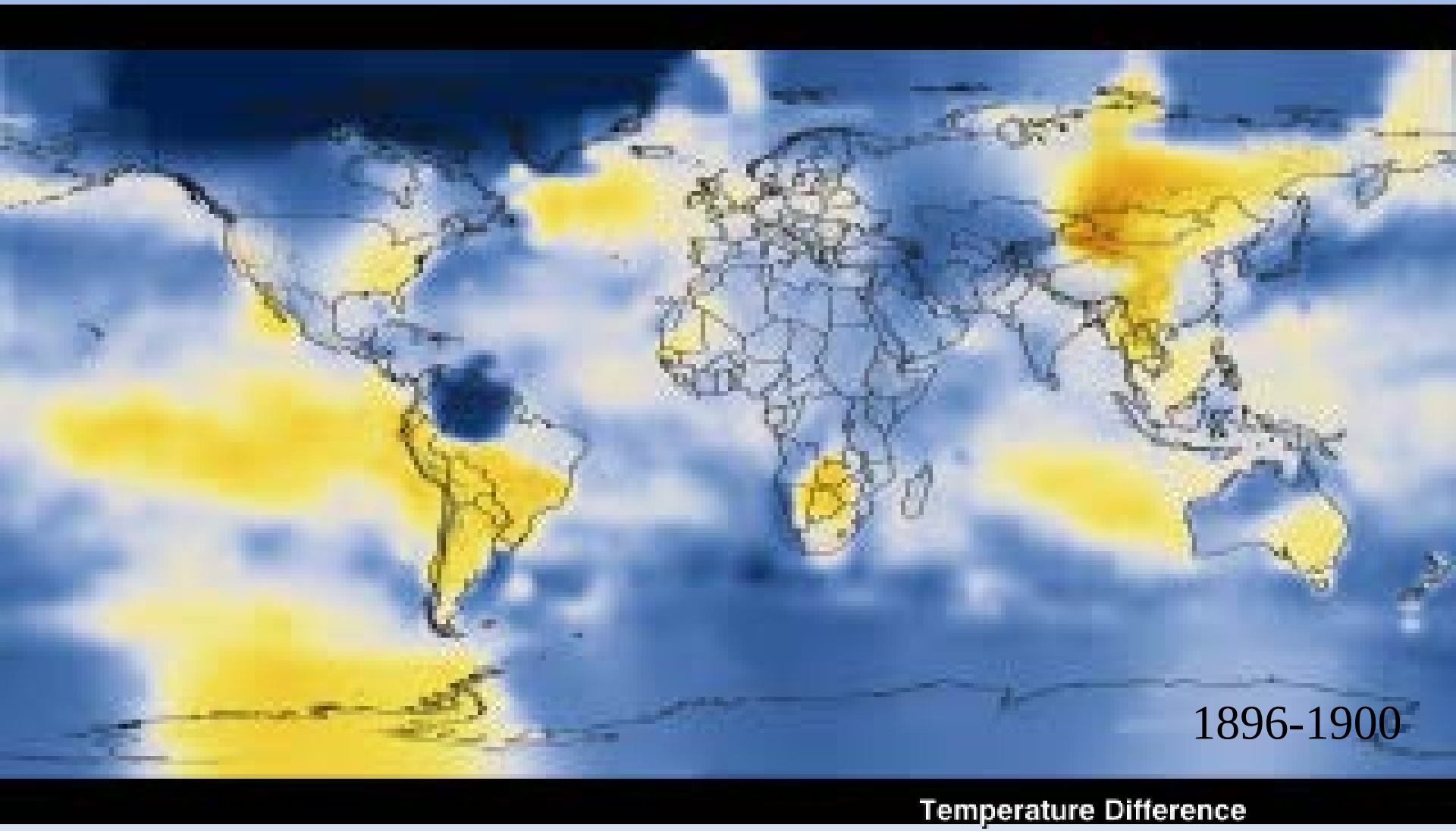
Celsius


1896-1900
Temperature Difference
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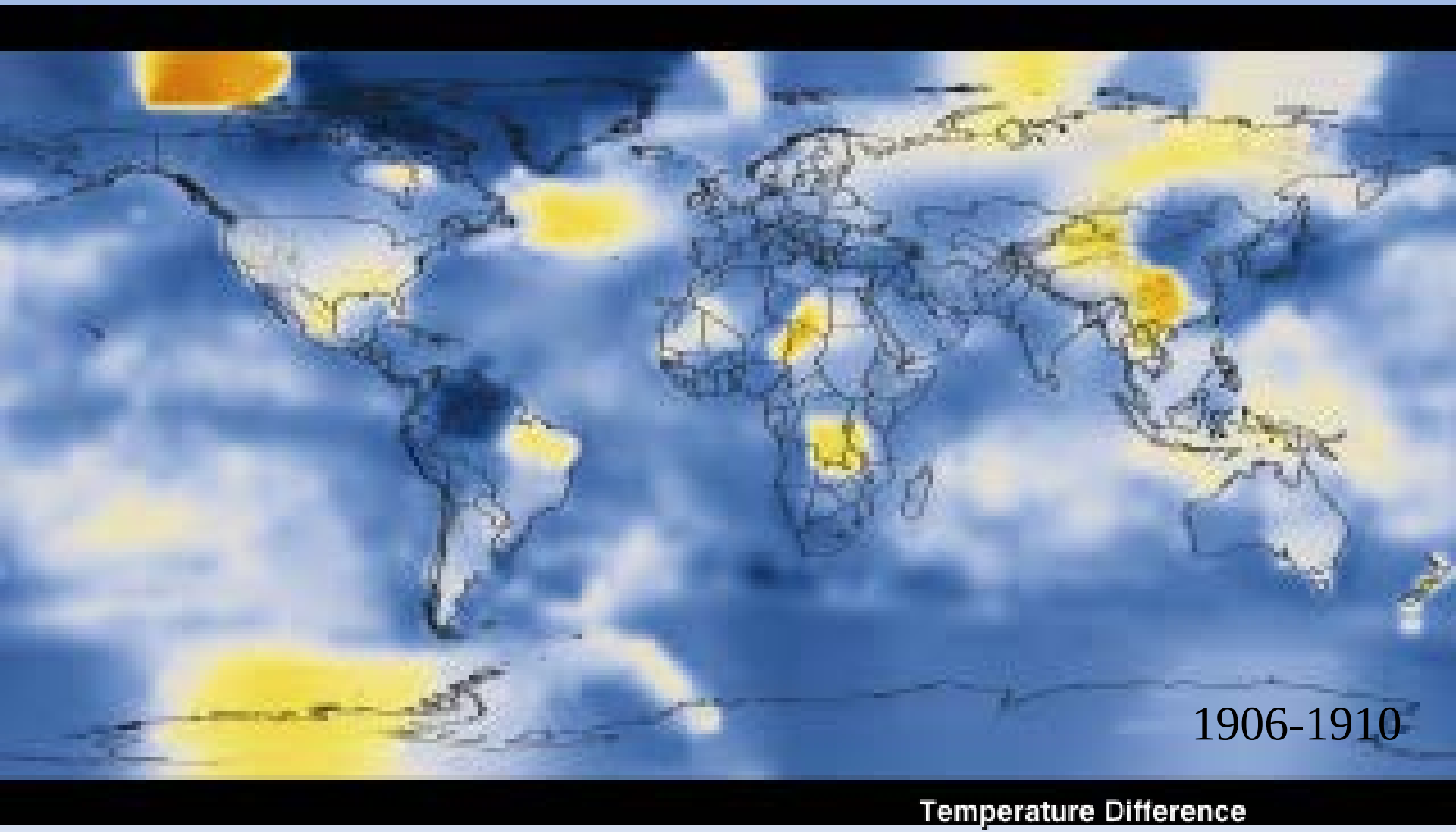
Celsius


1906-1910
Temperature Difference
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-1
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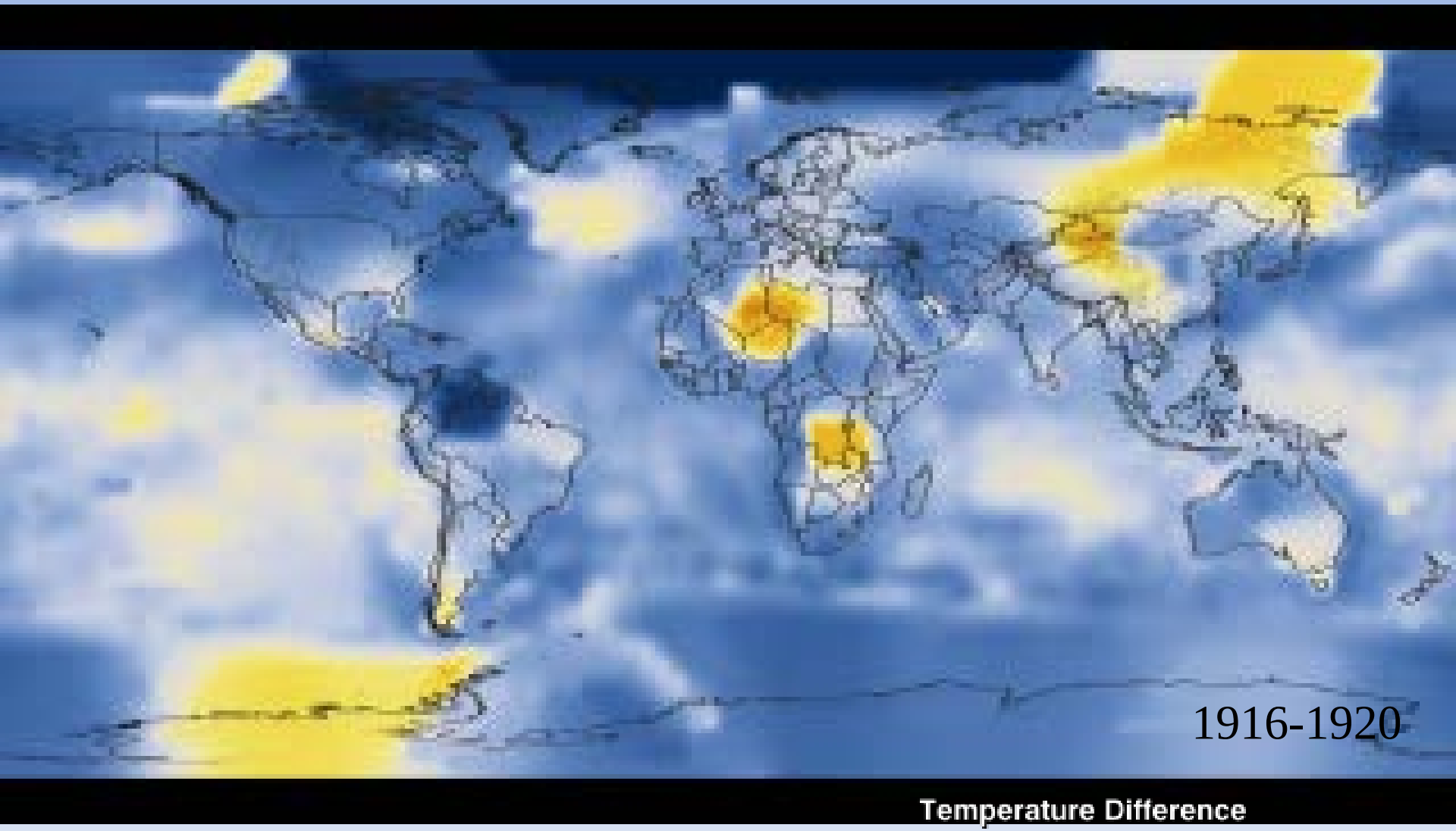
Celsius


1916-1920
Temperature Difference
-2
-1
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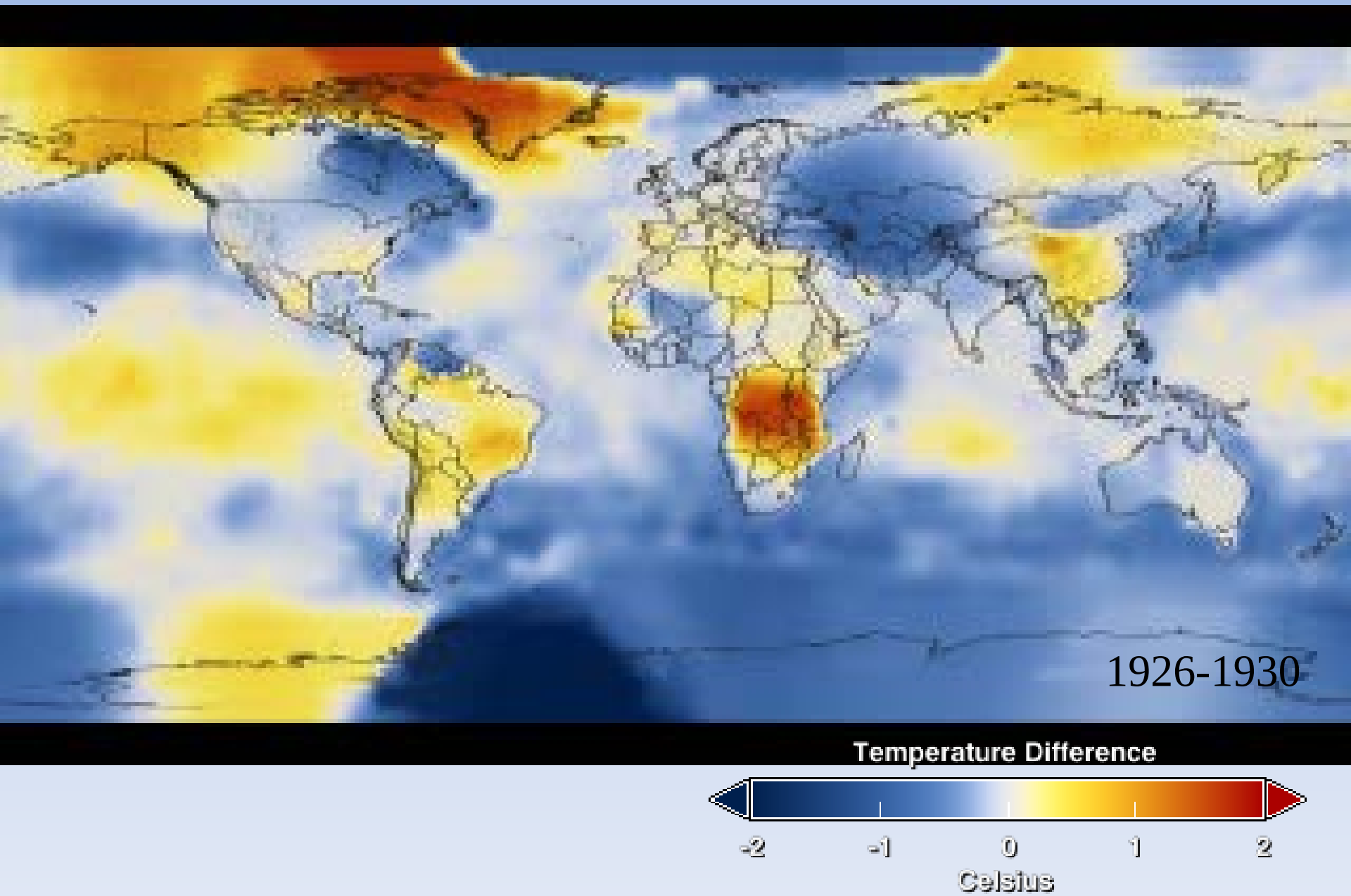
Celsius


1926-1930
Temperature Difference
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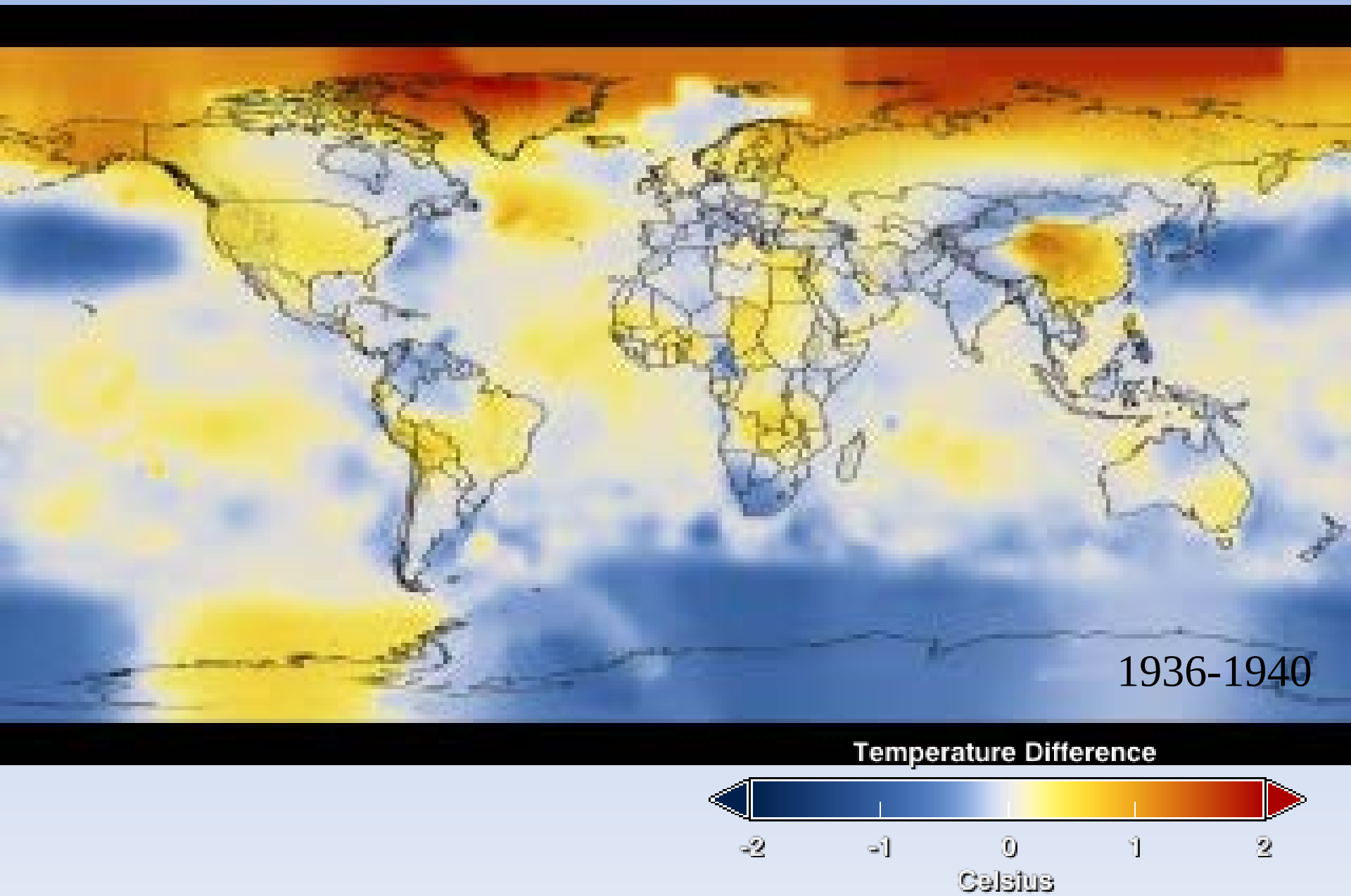
Celsius


1936-1940
Temperature Difference
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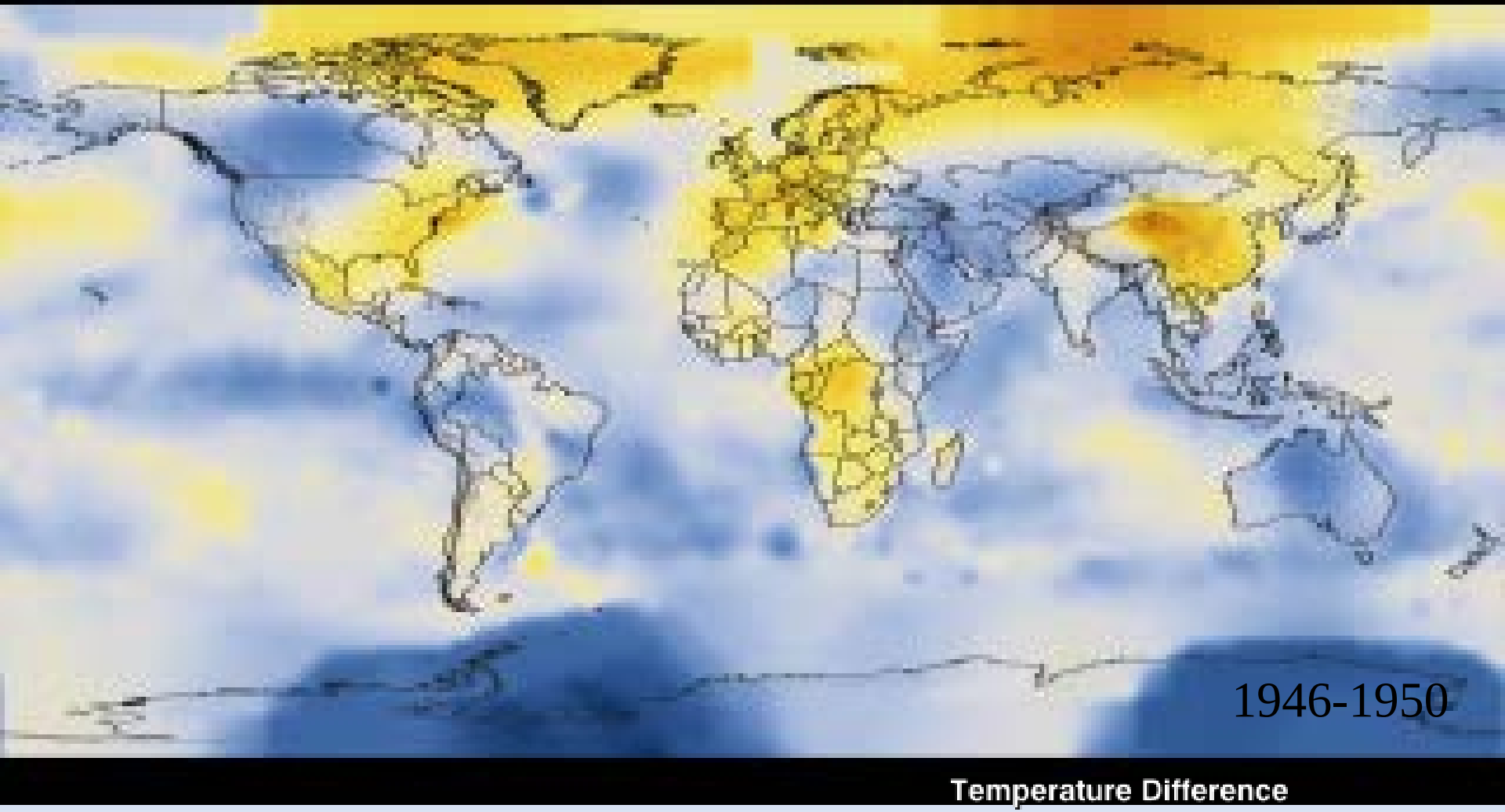
Celsius


1946-1950
Temperature Difference
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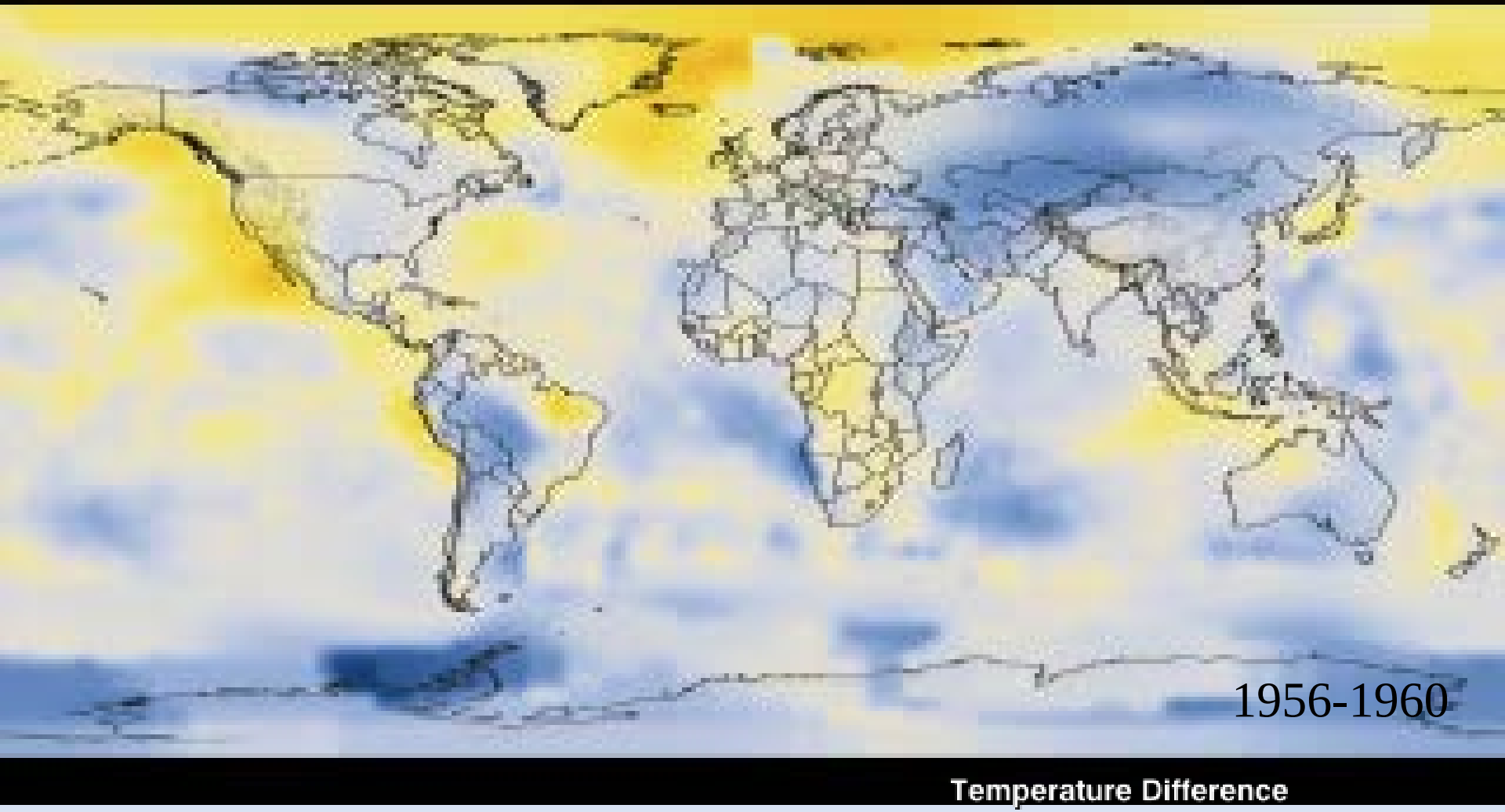
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Temperature Difference
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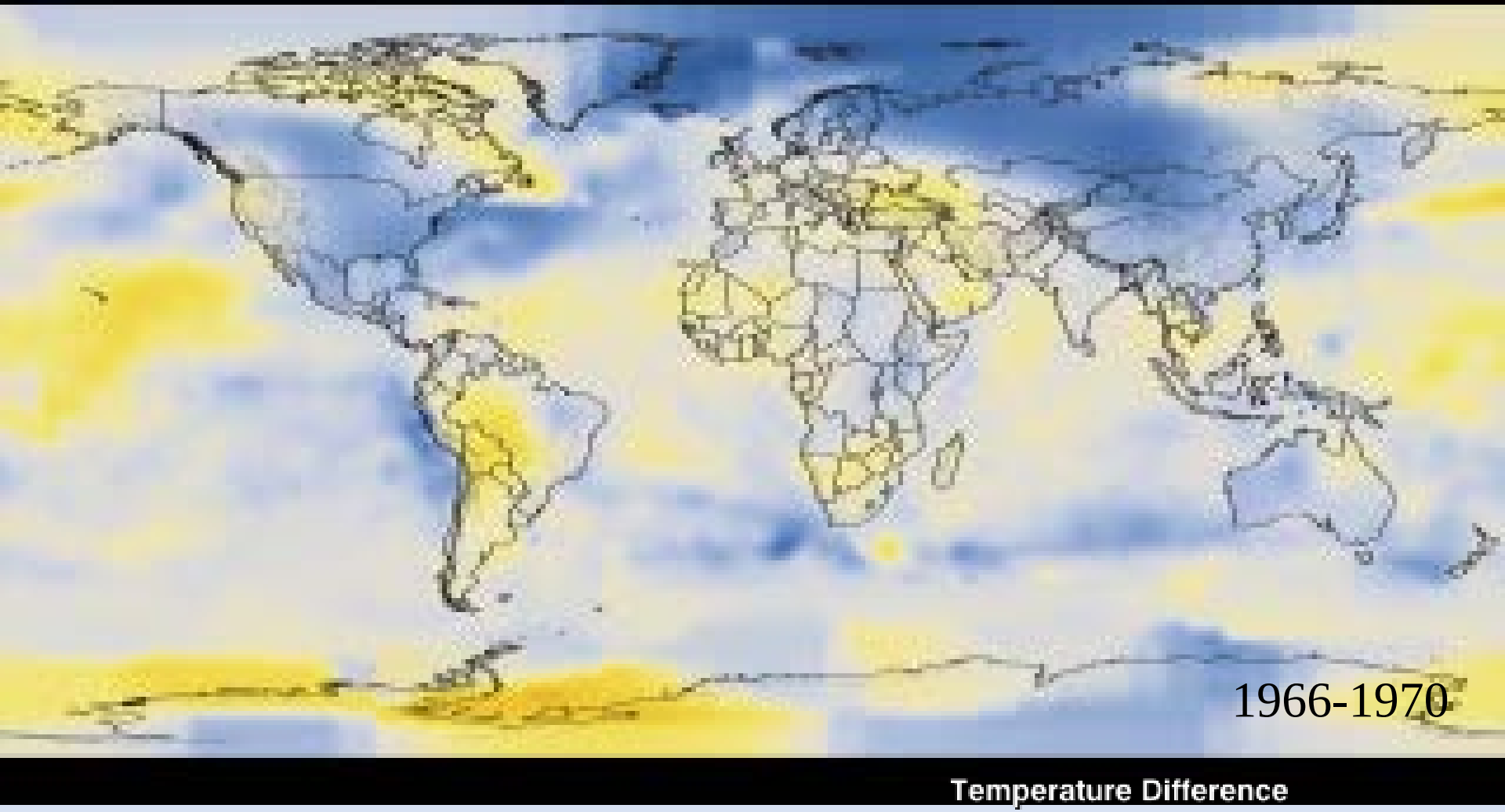
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Temperature Difference
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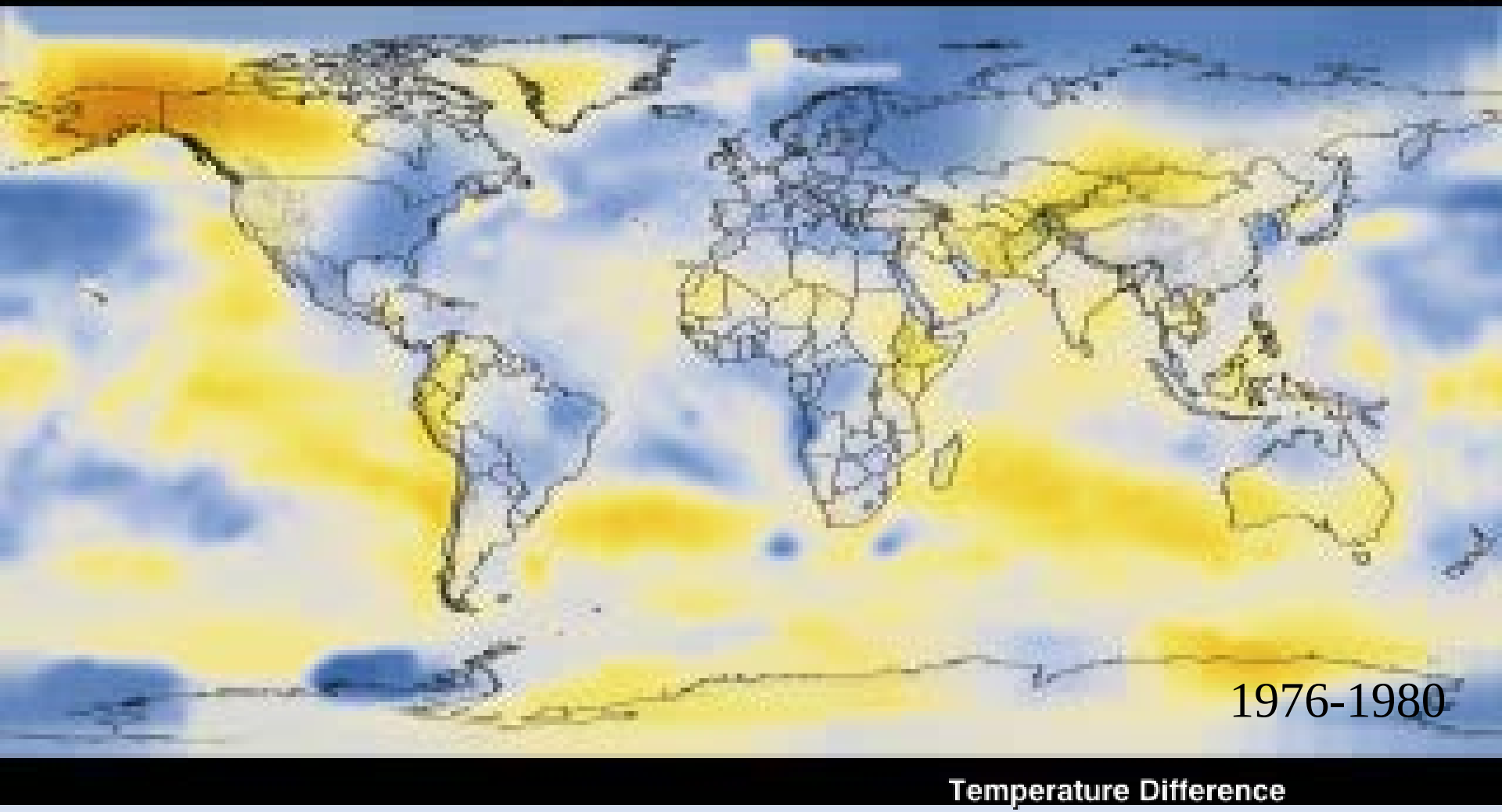
Celsius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Temperature Difference
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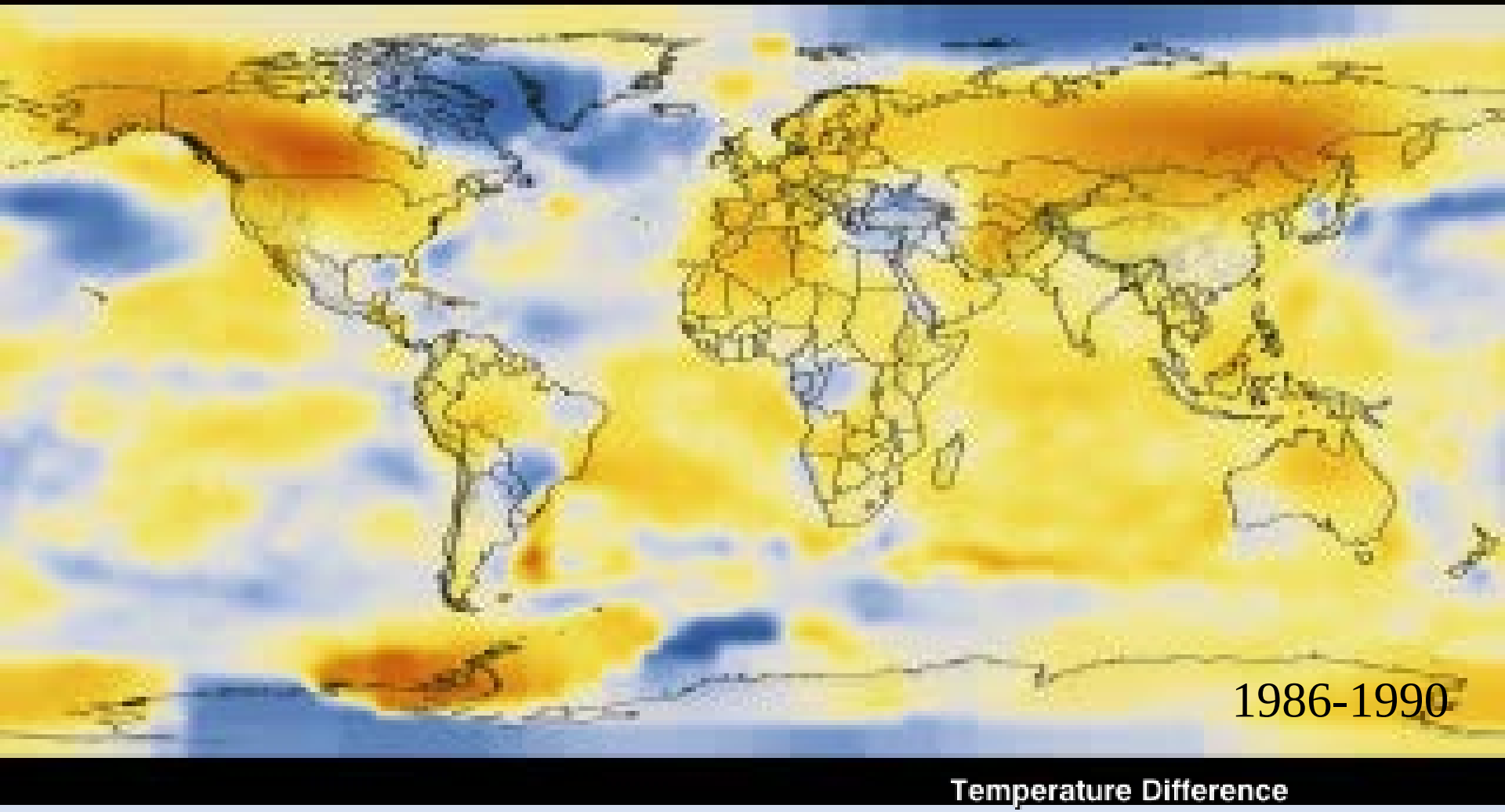
1986-1990
Temperature Difference
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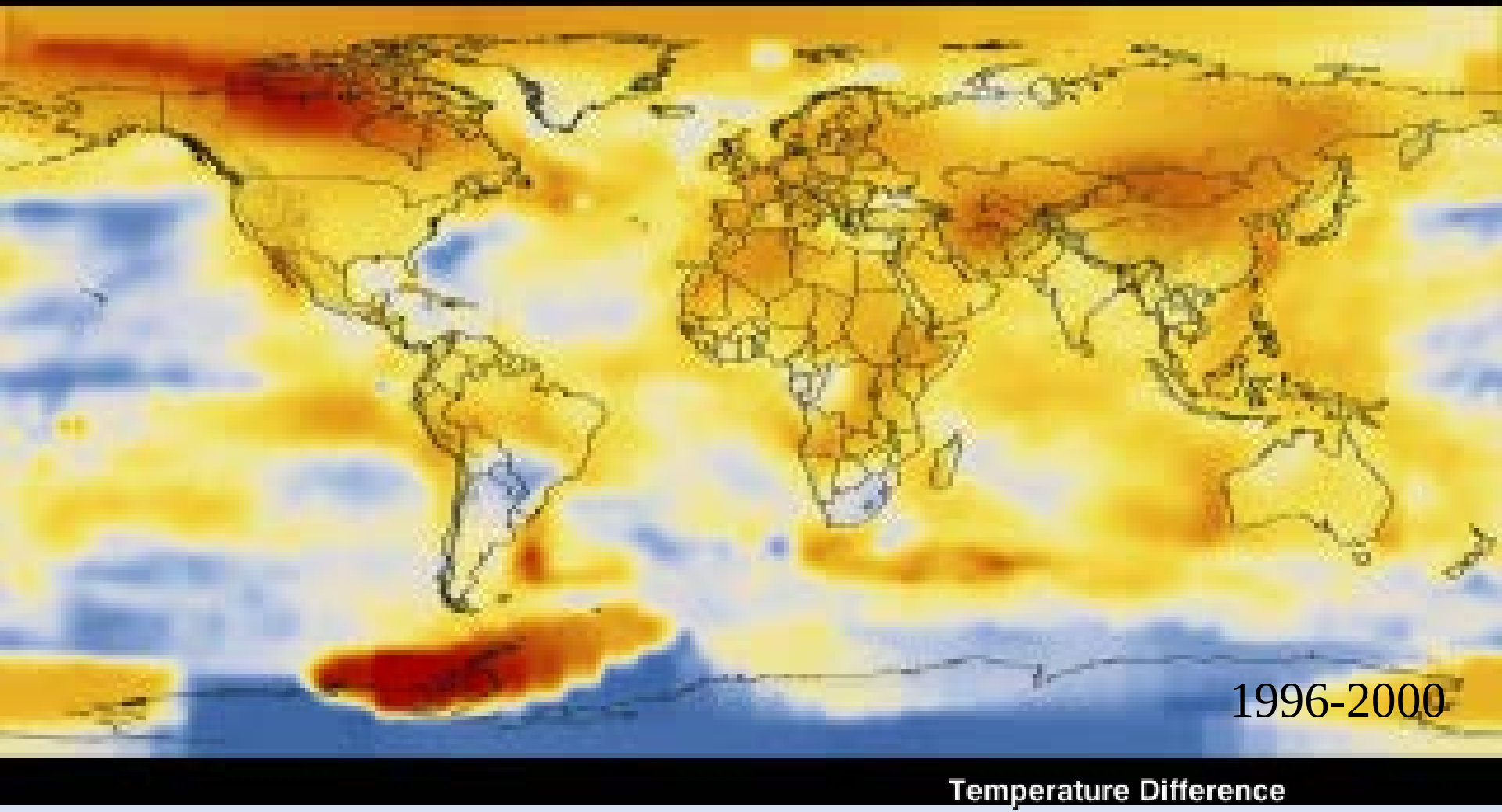
1996-2000
Temperature Difference
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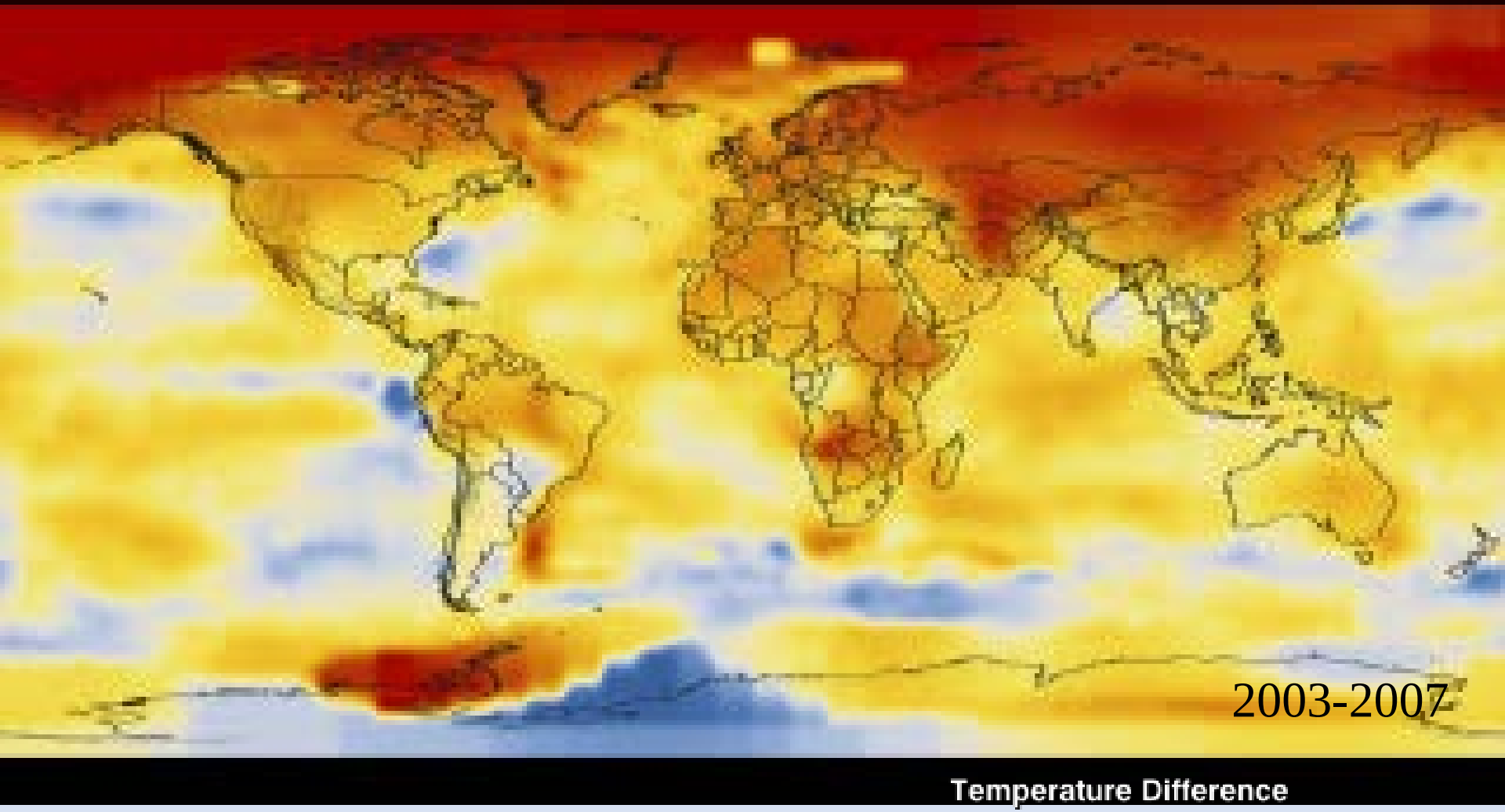
2003-2007
Temperature Difference
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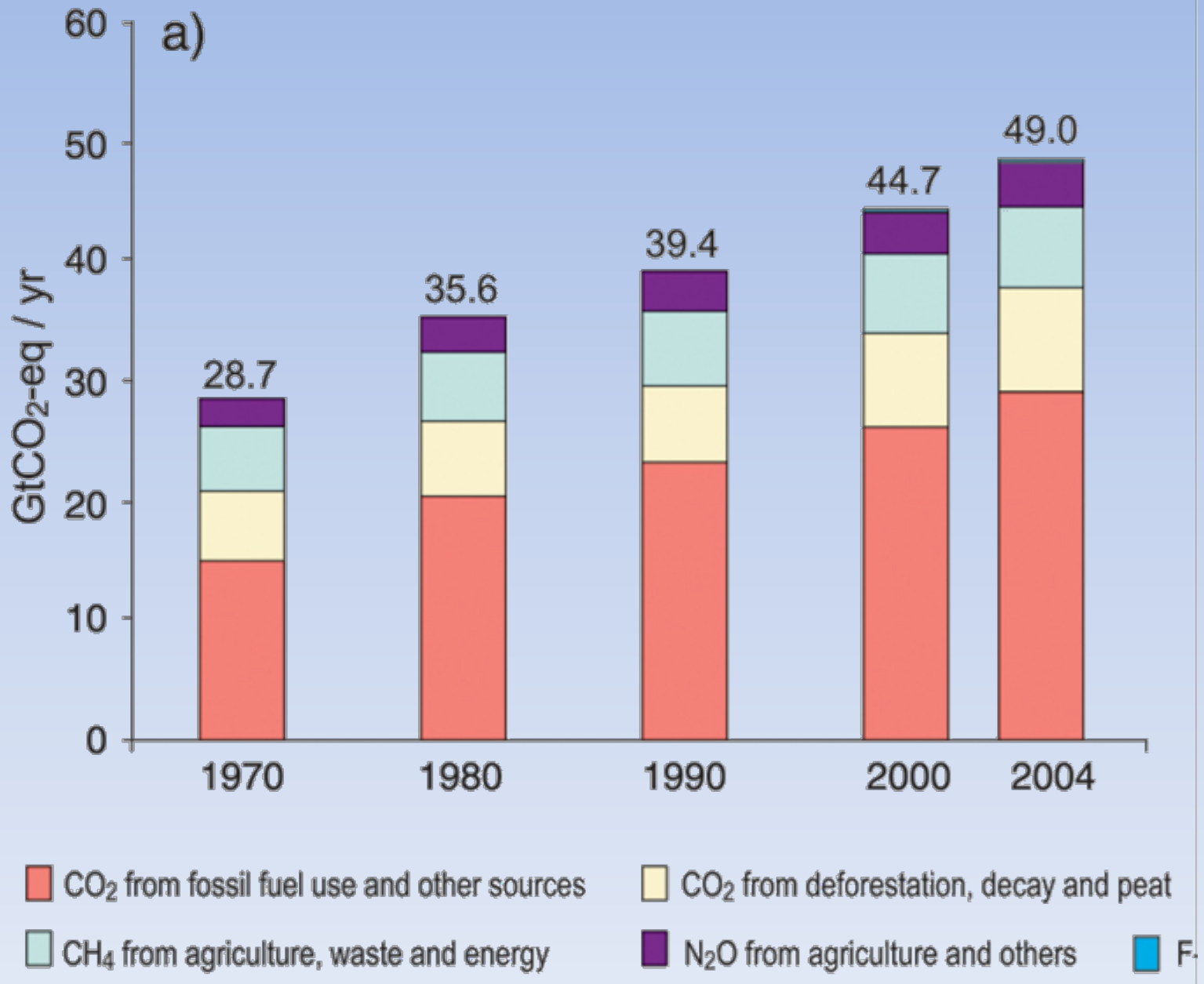
Celsius

Other Observed Changes and Effects

- 89% of current changes in ecosystems are consistent with changes expected due to global climate change
- Carbon dioxide, methane, and nitrous oxide levels in atmosphere have increased greatly due to human activities since 1750 and now far exceed previous levels
- Carbon dioxide has increased by approximately 80% since 1970

Human-Produced Greenhouse Gas Levels



New York’s Urban Heat Island

Project by: Brian Vant-Hull

Health Impacts of Temperature

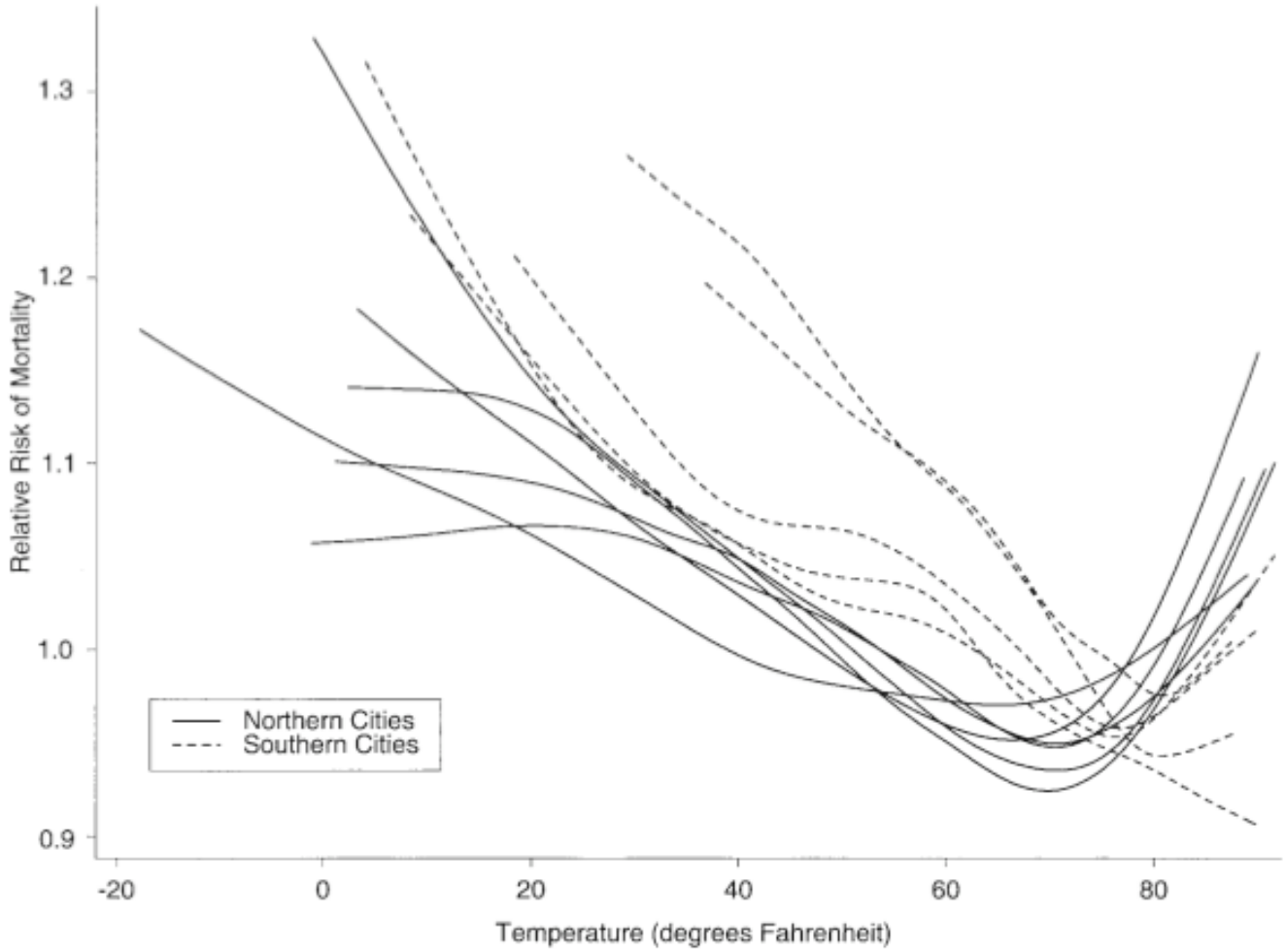
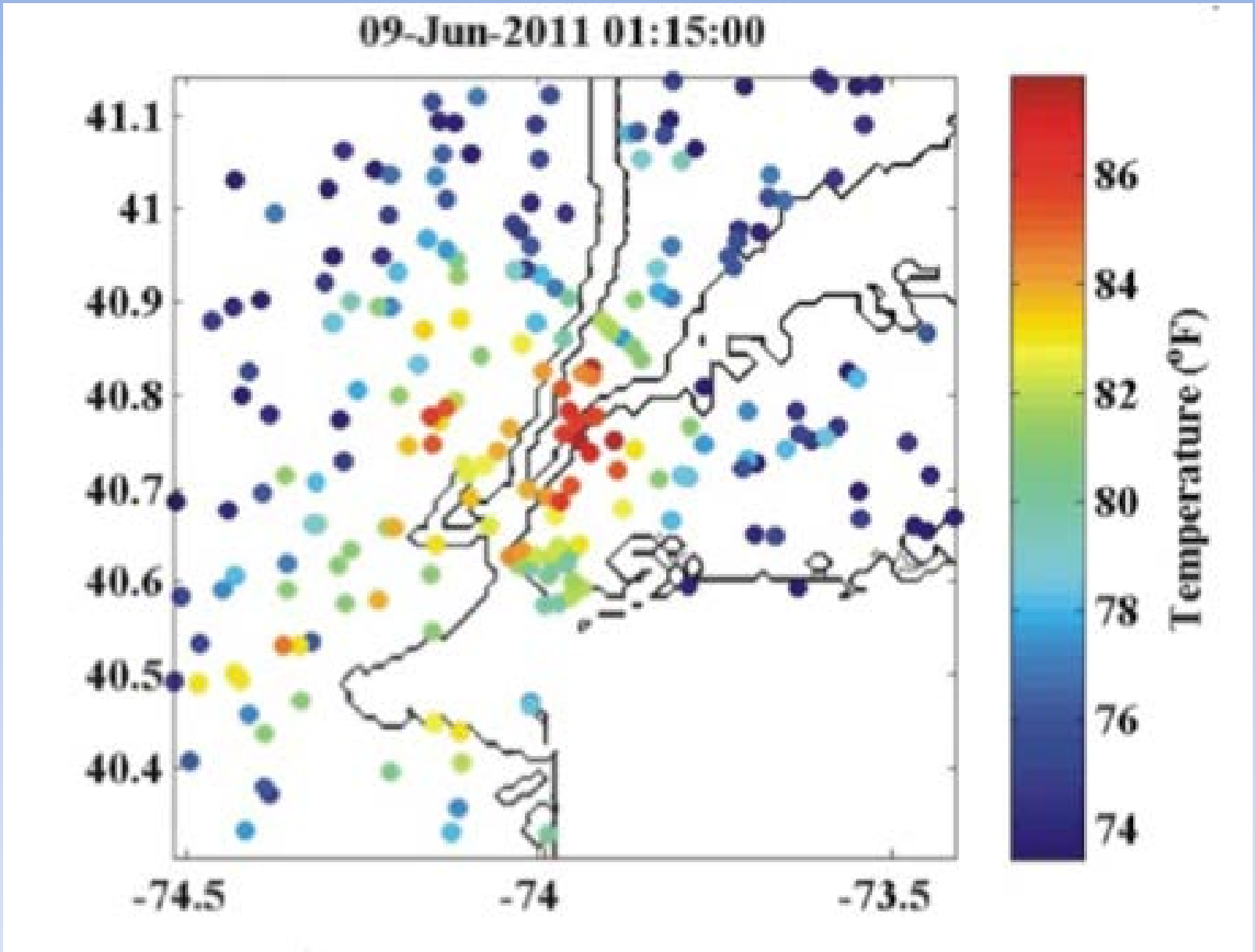


FIGURE 1. Temperature-mortality relative risk functions for 11 US cities, 1973–1994. Northern cities: Boston, Massachusetts; Chicago, Illinois; New York, New York; Philadelphia, Pennsylvania; Baltimore, Maryland; and Washington, DC. Southern cities: Charlotte, North Carolina; Atlanta, Georgia; Jacksonville, Florida; Tampa, Florida; and Miami, Florida. °C = 5/9 × (°F − 32).

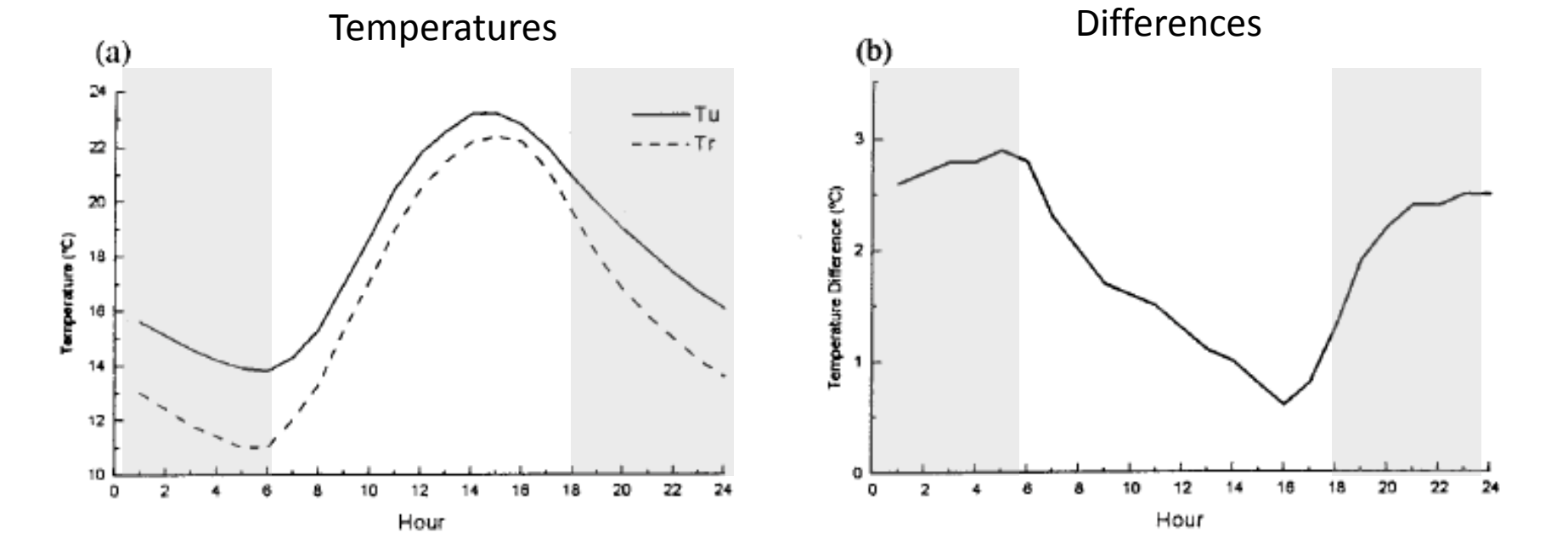
Vulnerable populations:
- Elderly
- Sick
- Poor, no AC

Curriero et al, 2011, American Journal of Epidemiology



"Forecasting the New York City urban heat island and sea breeze during extreme heat events". Meir, Orton, Pullen, Holt, Thompson and Arend, 2013. *Weather and Forecasting.* AMS.

UHI intensity = T_{urban} - T_{rural}



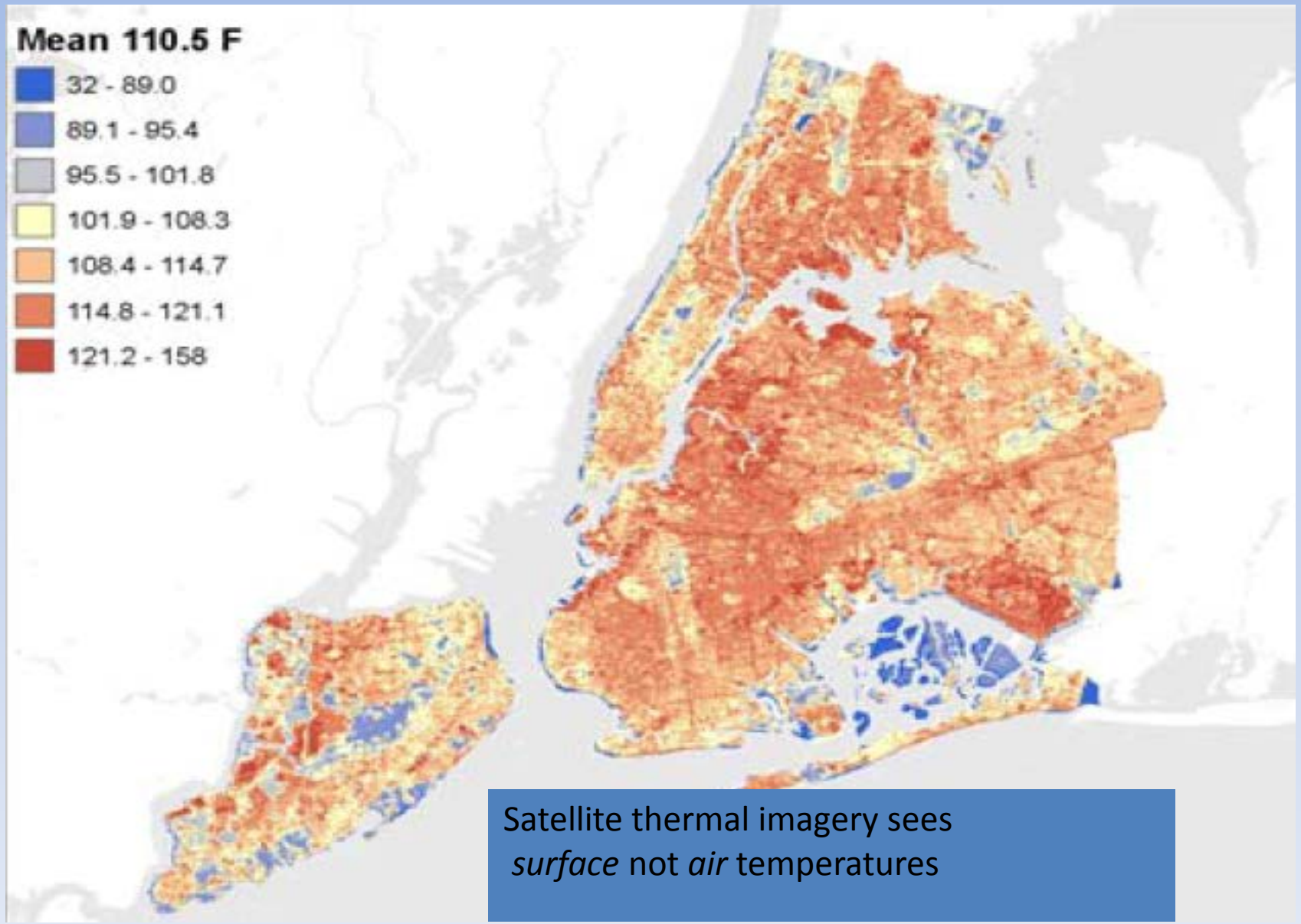
Diurnal Variation in Urban vs Rural Temperatures
(Granada) Montavez, Rodriguez, Jimenez, Int. J. of Climatology, 2000.

Change of Temperature with Time

$$\text{Slope} = \frac{\text{Heat Flow}}{\text{Heat Capacity}}$$

	Day	**Night**
Heat Flow	Sun: ***high***	Thermal radiation: ***low***
	Buildings	**Vegetation**
H. Capacity	***High***	***Low***

Complexity in the Urban Environment



Satellite thermal imagery sees *surface* not *air* temperatures

Sensor Deployment

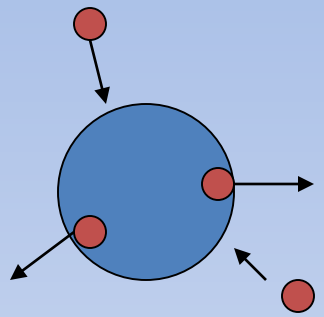
- Thermocouple and relative humidity sensors attached to interface that allows time based sampling

- Mounted on backpack to be isolated from body and also inside foam cup to avoid further heat transfer except from the air.

Currently up to 8 sensor packs can be deployed concurrently.

Dewpoint calculated from RH and T

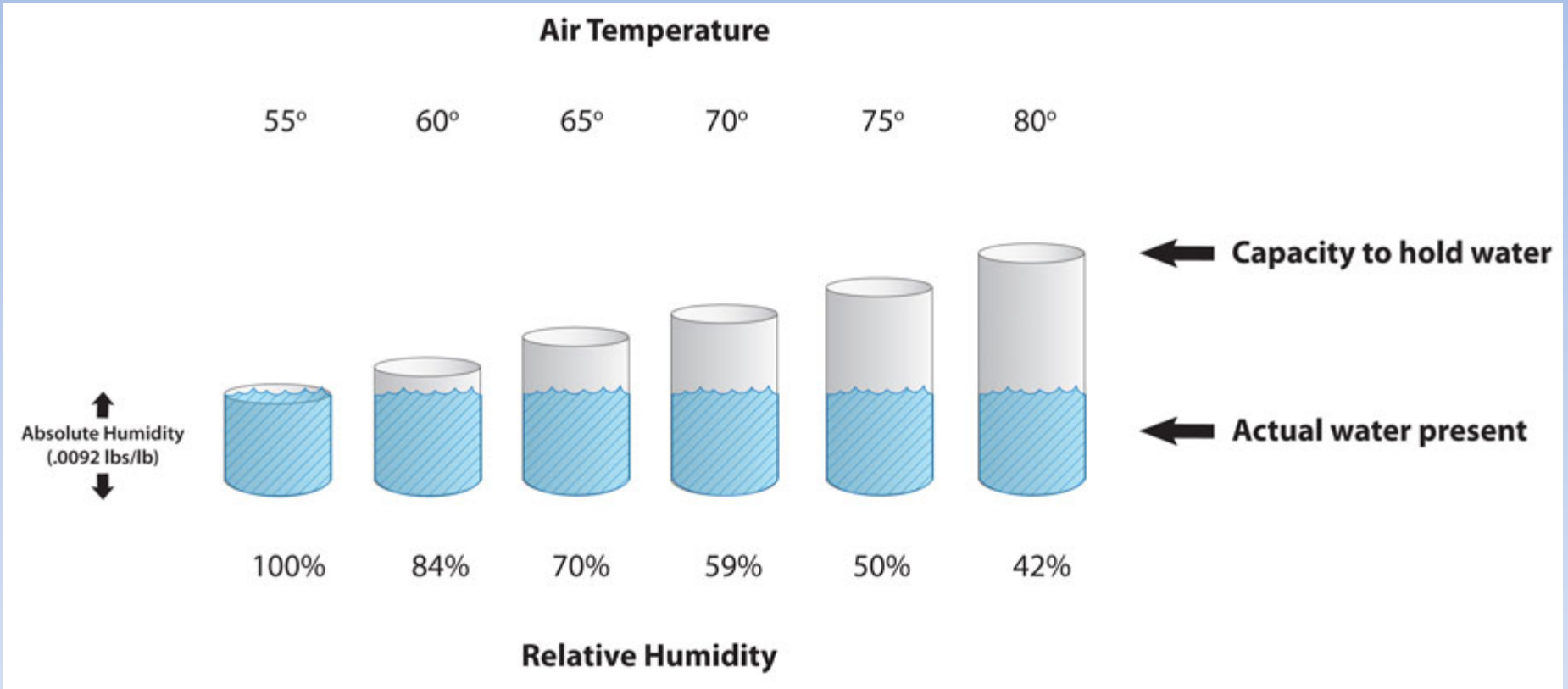
Why Dewpoint?



Dewpoint is the temperature at which
Evaporation balances **Capture** for water.

Evaporation rate depends on Temperature.
Capture rate depends on water vapor Density.

So Dewpoint Temperature reflects water vapor Density


Air Temperature
55°
60°
65°
70°
75°
80°
Capacity to hold water
Absolute Humidity
(.0092 lbs/lb)
Actual water present
100%
84%
70%
59%
50%
42%
Relative Humidity

Color Scheme for all Measurement Units

Black	< -1.75 units
Blue	-1.25 to -1.75 units
Light blue	-0.75 to -1.25 units
Green	-0.25 to -0.75 units
Yellow	+/- 0.25 units; neutral
Orange	+0.25 to +0.75 units
Red	+0.75 to +1.25 units
Purple	+1.25 to +1.75 units
White	> + 1.75 units

Bluer is lower: Yellow is Neutral: Redder is higher

Temp Avgs

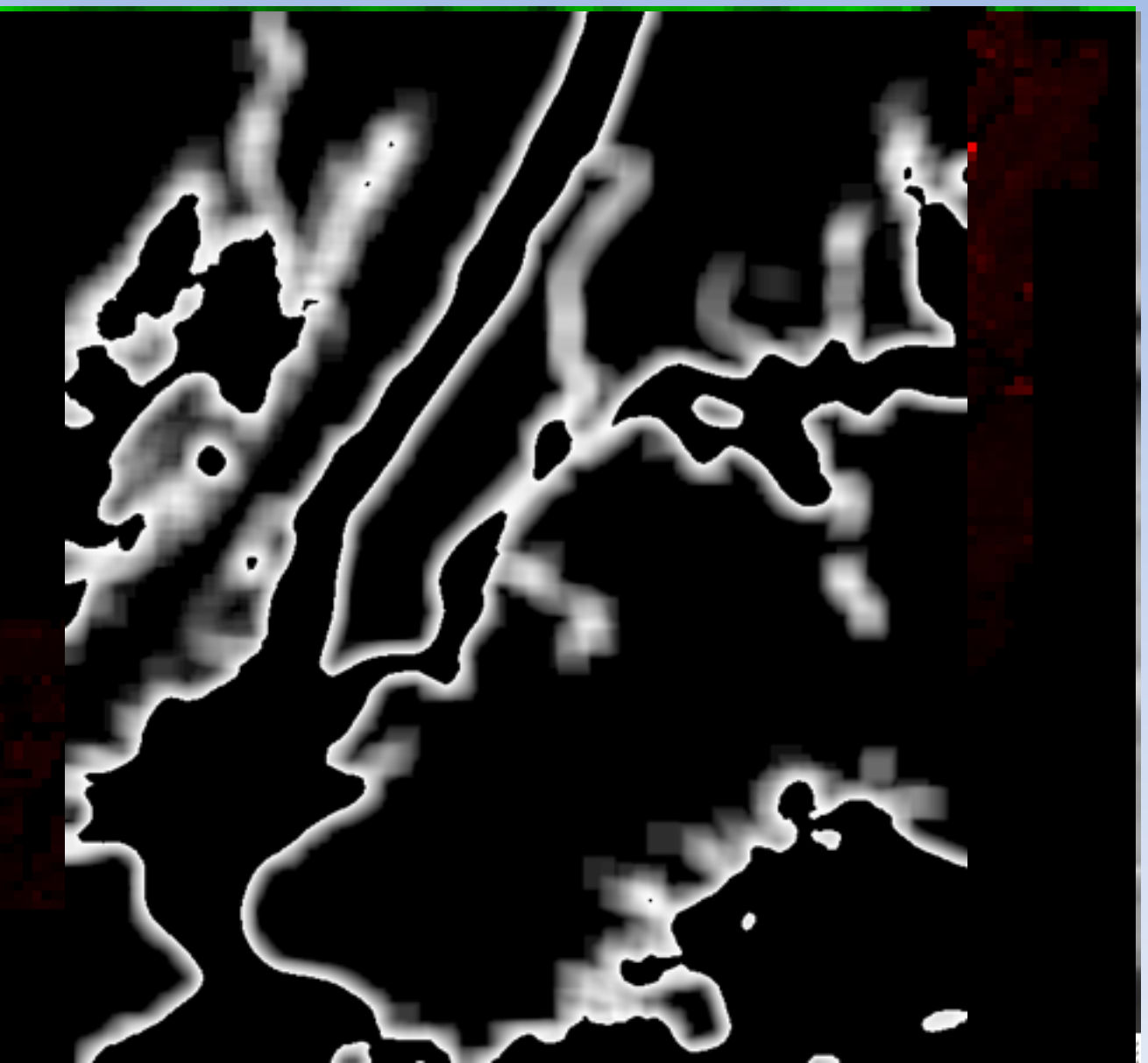
< In the shaded street data, low buildings are warmer, vegetation and higher elevations are cooler.

In the sunny avenues > high buildings are warmer, proximity to water is cooler. There is also a patchwork effect between routes.


2.25
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
-2.25
Tdev
HR=14


2.25
1.75
1.25
0.75
0.25
-0.25
-0.75
-1.25
-1.75
-2.25
DPdev
HR=14

Inputs to statistical model



Albedo

vegetation

Building Area fraction

Building Height

Elevation

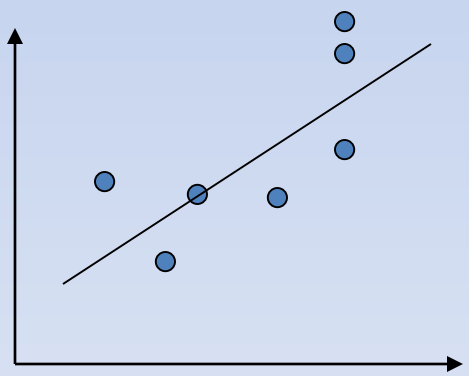
Water fraction

…and nonlinear combinations thereof…

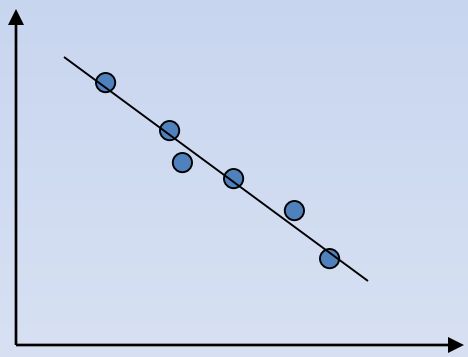
Multi-variable Linear Regression

$$Y = k + aX + bW + cZ + \ldots.$$

$$T = T_0 + a \bullet Albedo + b \bullet Vegetation + c \bullet Buildings + \ldots$$

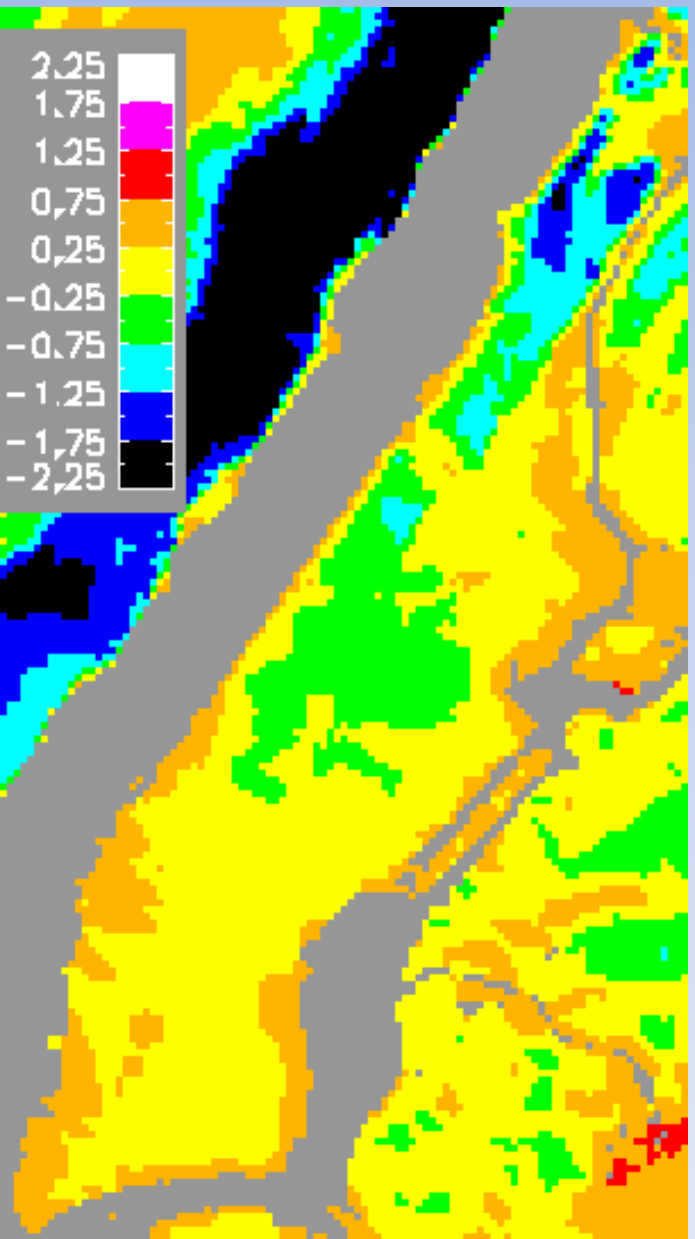


Low positive correlation



High negative correlation

Temperature Anomalies based on Surface Characteristics

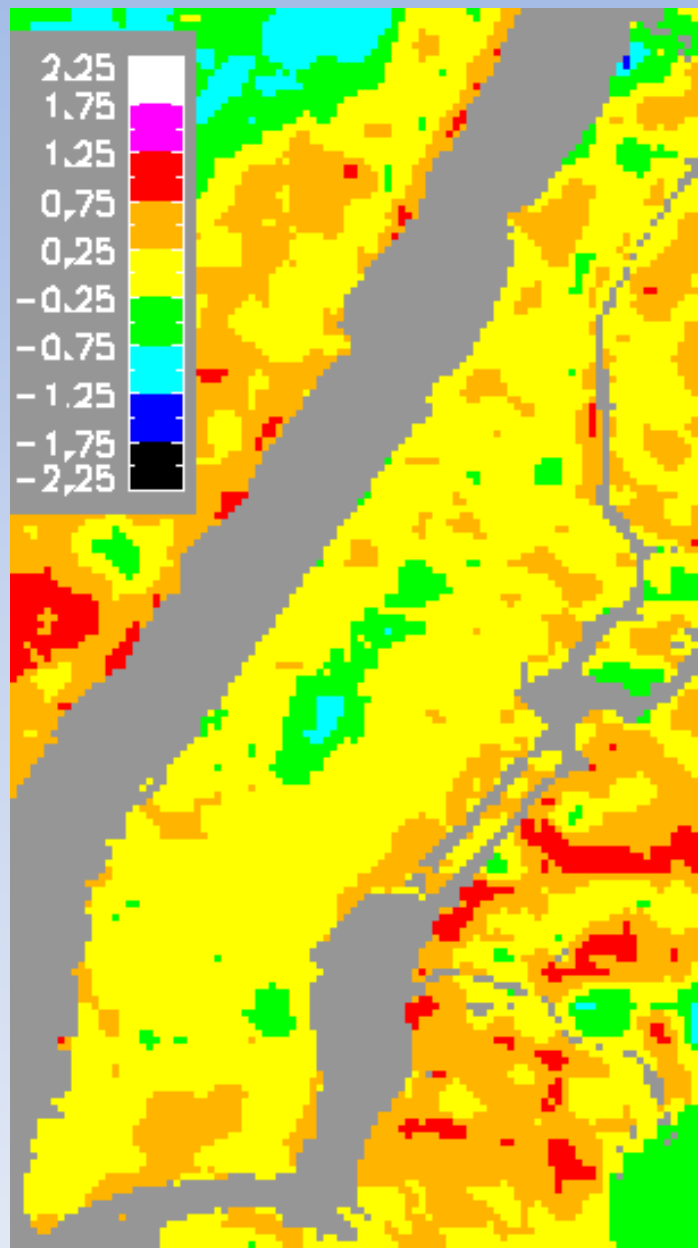


Streets
(shadow)

Multivariable
Correlations
< 0.6 0.5>

Avenues
(sun)

Increasing building height, albedo cools in shade, heats in sun



Sunny versus Shady Regression Coefficients (corr)

Surface variable	Shady	Sunny
Vegetation	-0.76 (-0.24)	-1.3 (-0.16)
Albedo	5.3 (0.16)	-4.9 (-0.21)
Building area fraction	-1.4 (-0.12)	~~5.6 (0.04)~~
Building Height	~~0.03 (-0.09)~~	1.2 (-0.12)
Elevation	-0.02 (-0.42)	~~0.01 (0.05)~~

GLOBAL
CLIMATE CHANGE

So.. What can we do?

There are several types of options…

- Reduce emissions of greenhouse gases
- Attempt to develop alternatives energies
- Allow emission to continue, but prepare for global climate changes
- Allow emissions to continue as normal and leave preparations up to individual countries
- Combine any of these ideas
- Come up with your own unique plan!

Global Warming Video

- Climate Change: The State of the Science
  https://www.youtube.com/watch?v=_EWOrZQ3L-c
- Climate Change 2013: The Physical Science Basis
  https://www.youtube.com/watch?v=6yiTZm0y1YA
- IPCC Fifth Assessment Report Synthesis Report
  https://www.youtube.com/watch?v=F-Hcu3jH8G4
- Climate Change 2014: Mitigation of Climate Change
  https://www.youtube.com/watch?v=gDcGz1iVm6U
- “Home" 2009 documentary by Yann Arthus-Bertrand
  https://www.youtube.com/watch?v=jqxENMKaeCU
- Saving Planet Earth & Stop Climate Change - Documentary
  https://www.youtube.com/watch?v=YwzqO13WiVc
- The Science Behind Global Warming (Documentary)
  https://www.youtube.com/watch?v=T-sy6rPJBj4