



# Global Climate Change

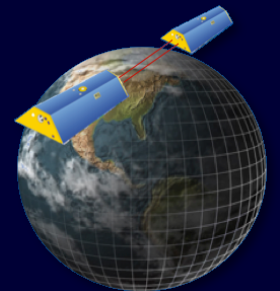
**Jianli Chen**

**(陈剑利)**

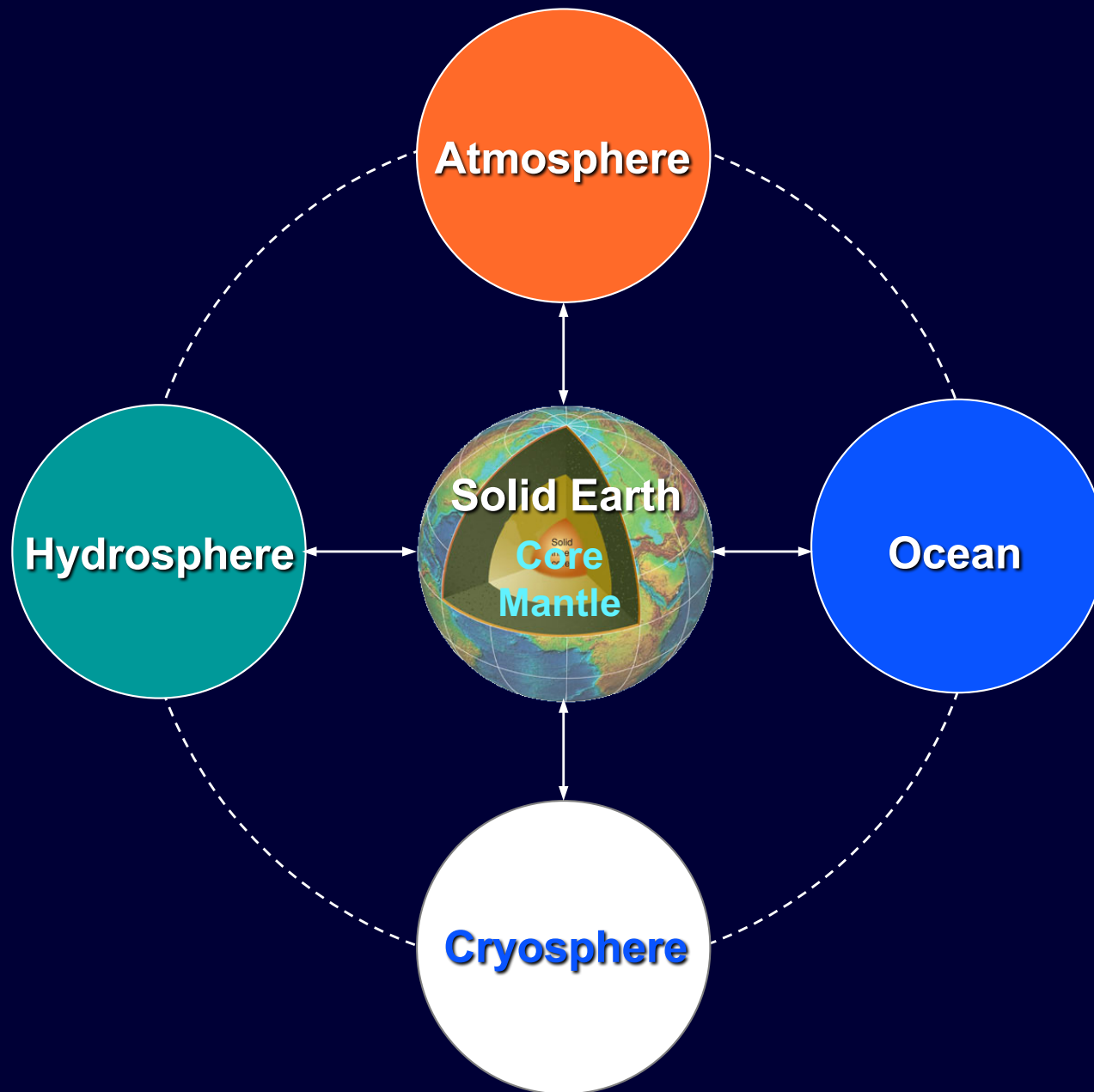
**Ph.D., Senior Research Scientist**

**Center for Space Research, University of Texas at Austin**

*2018 SEOGC Summer School 07/09-07/14, Shanghai, China*

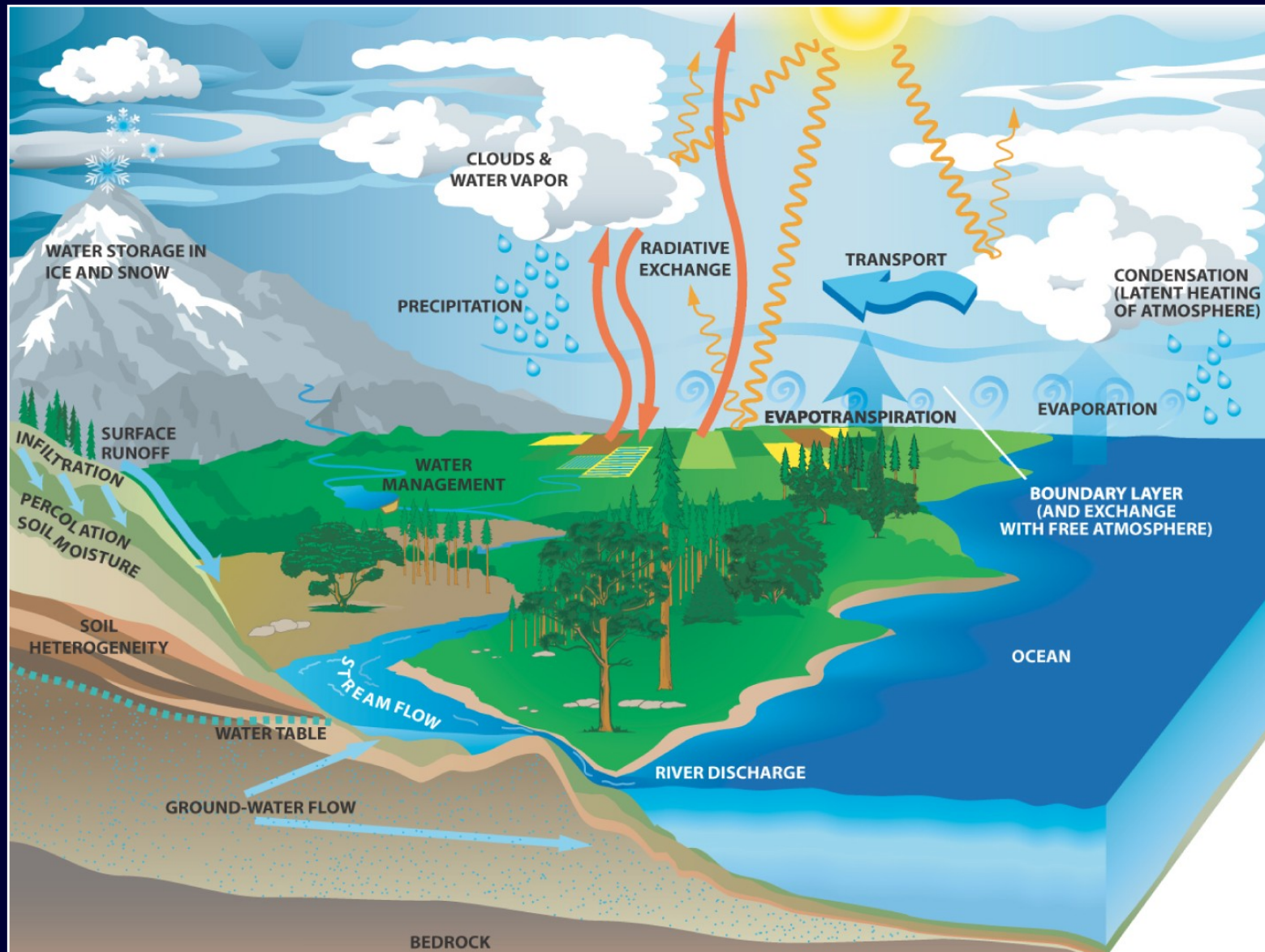


# The Earth System

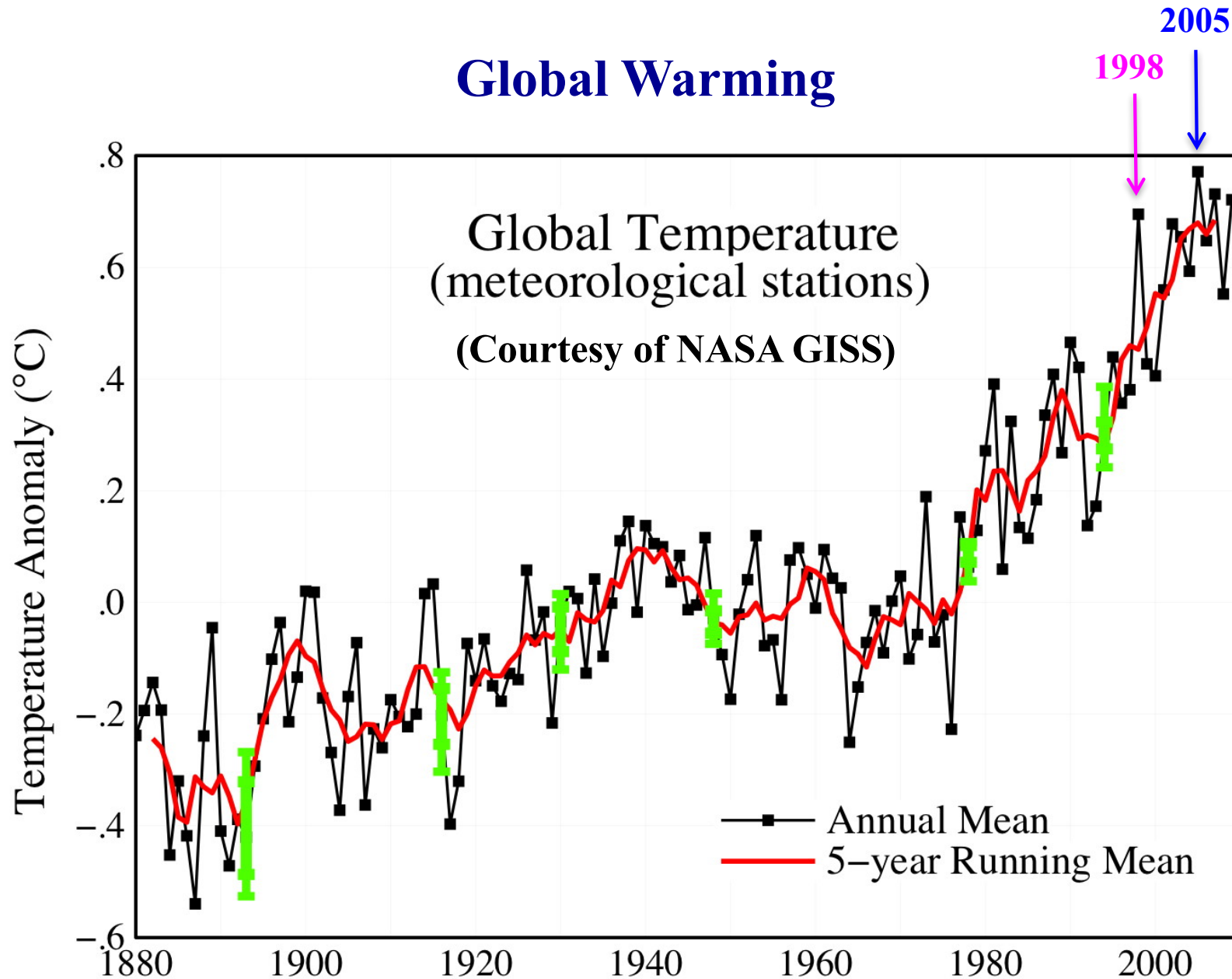




# Climate System and Global Water Cycle



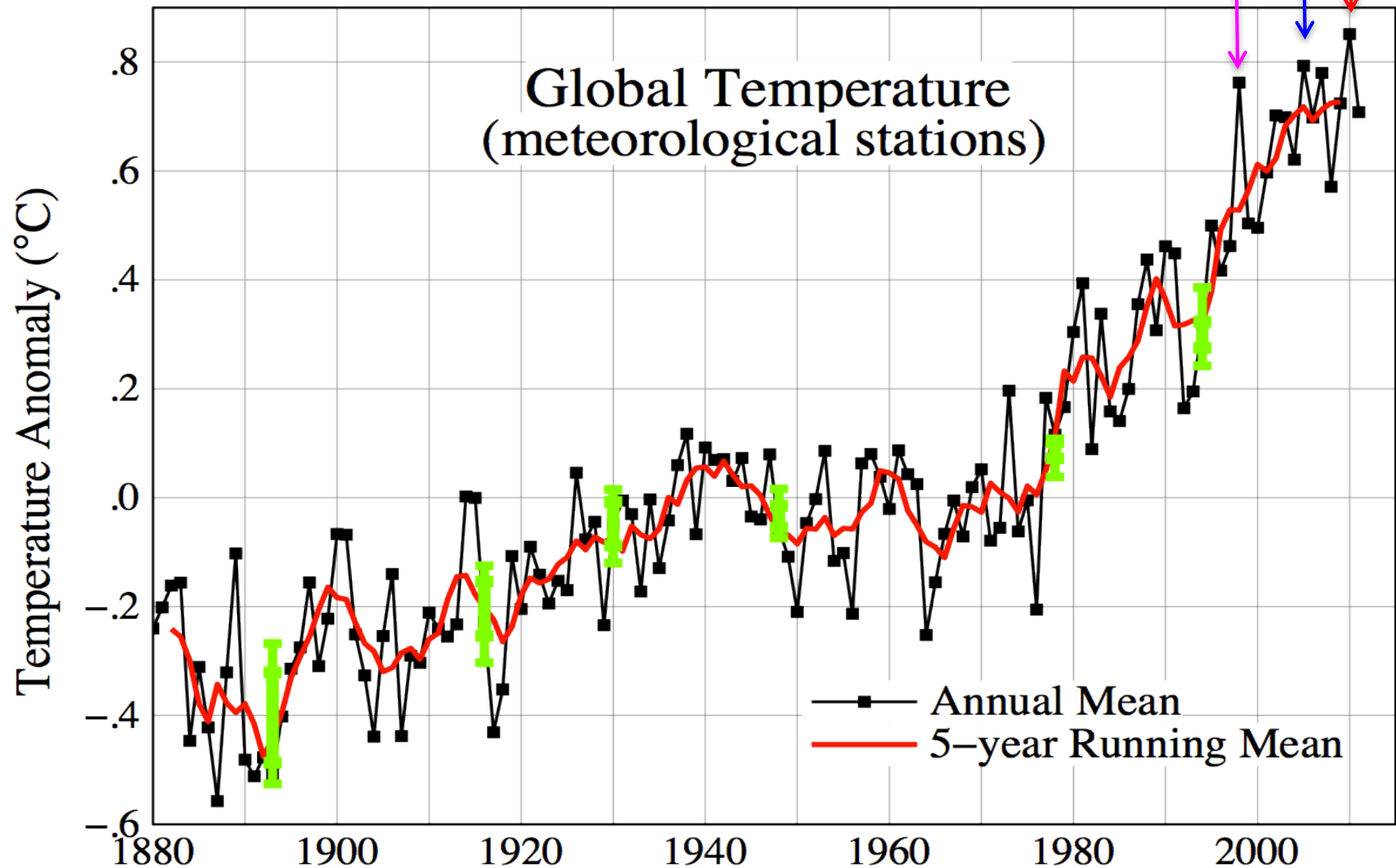
# Global Warming



**2005 was recorded as the warmest year in history.**

*(slide used in 2010)*

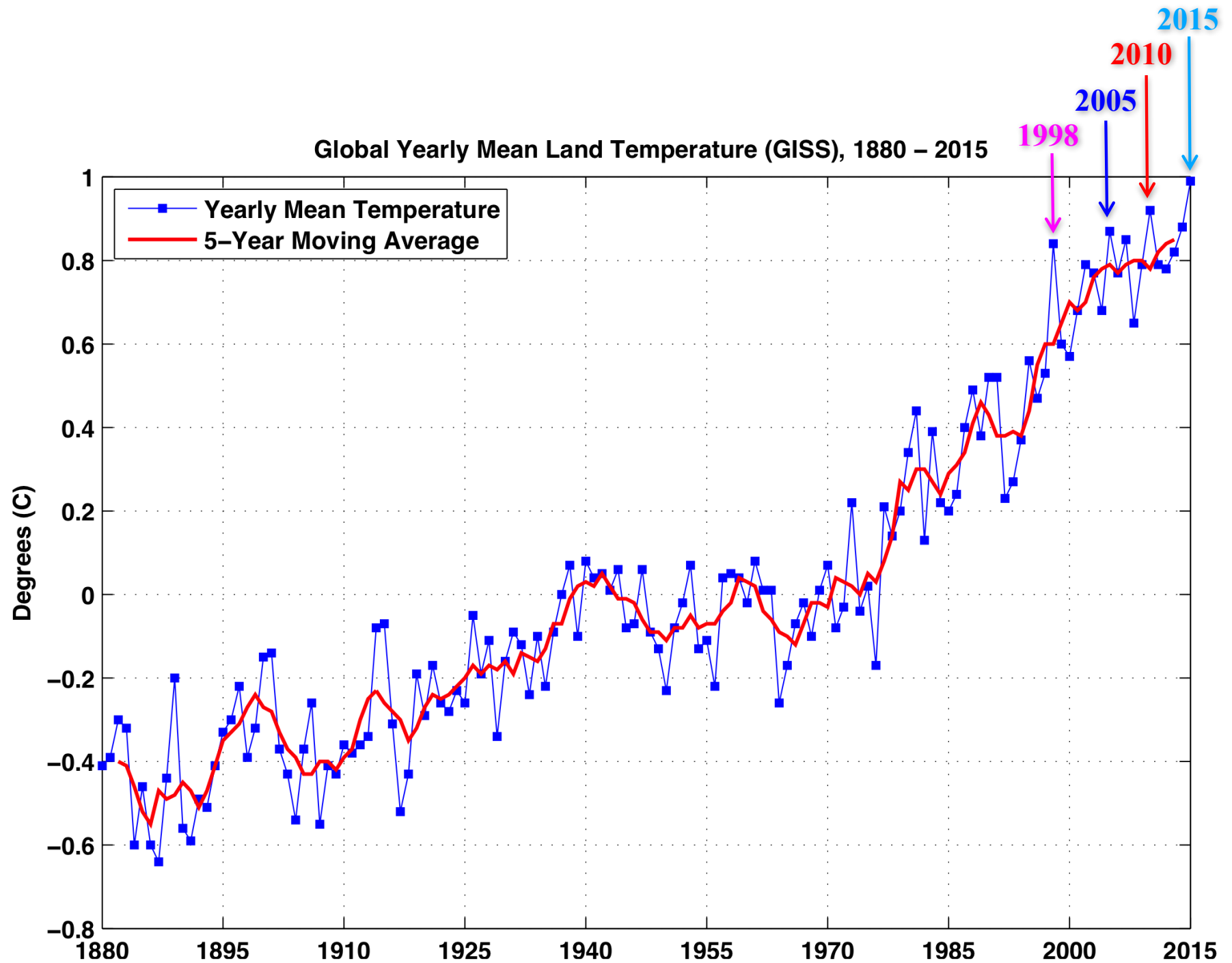
# Global Warming



**2010 was recorded as the warmest year in history.**

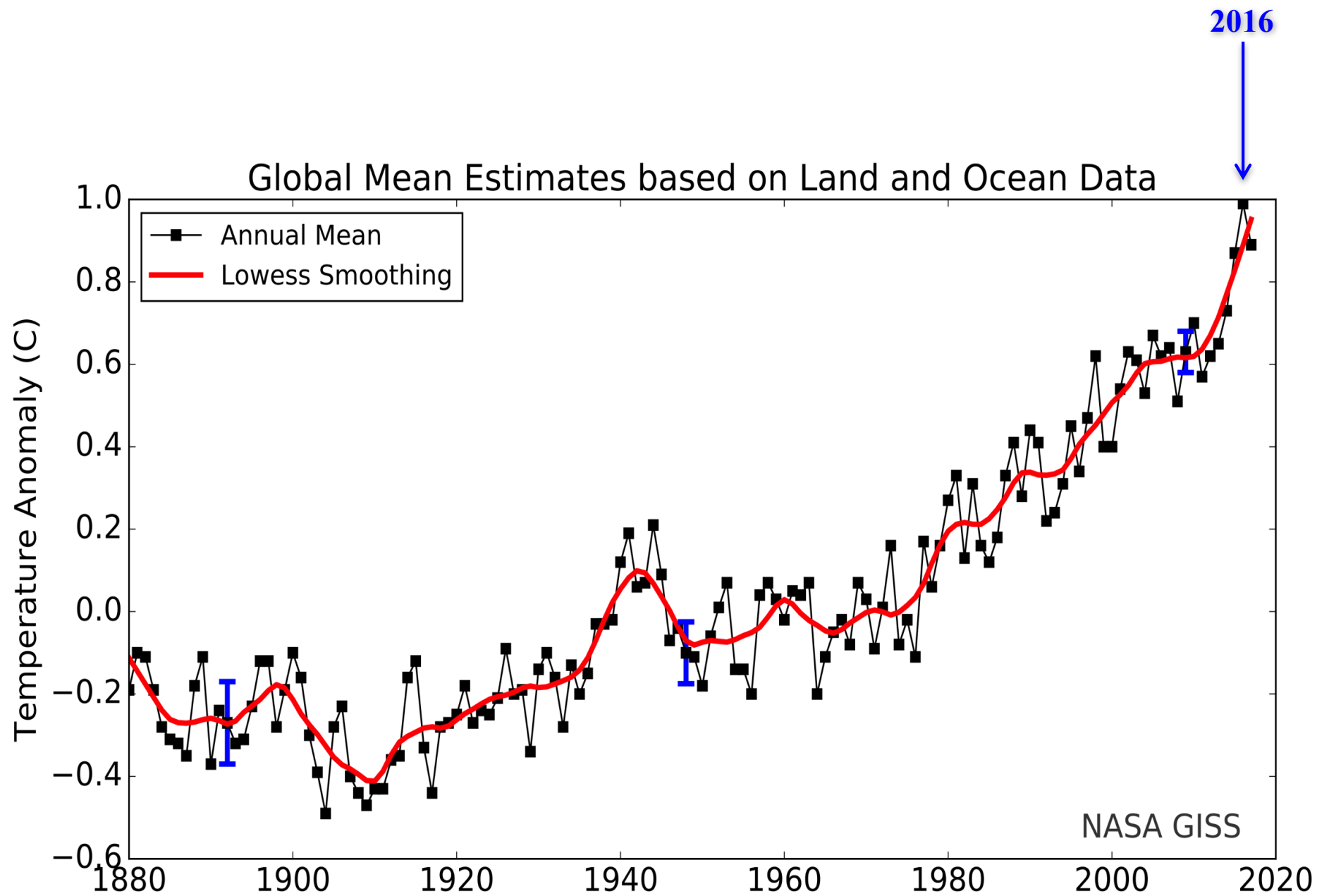
**(2005 as the 2<sup>nd</sup> warmest year in history)**

*(slide used in 2012 & 2014)*



(Courtesy of NASA GISS)

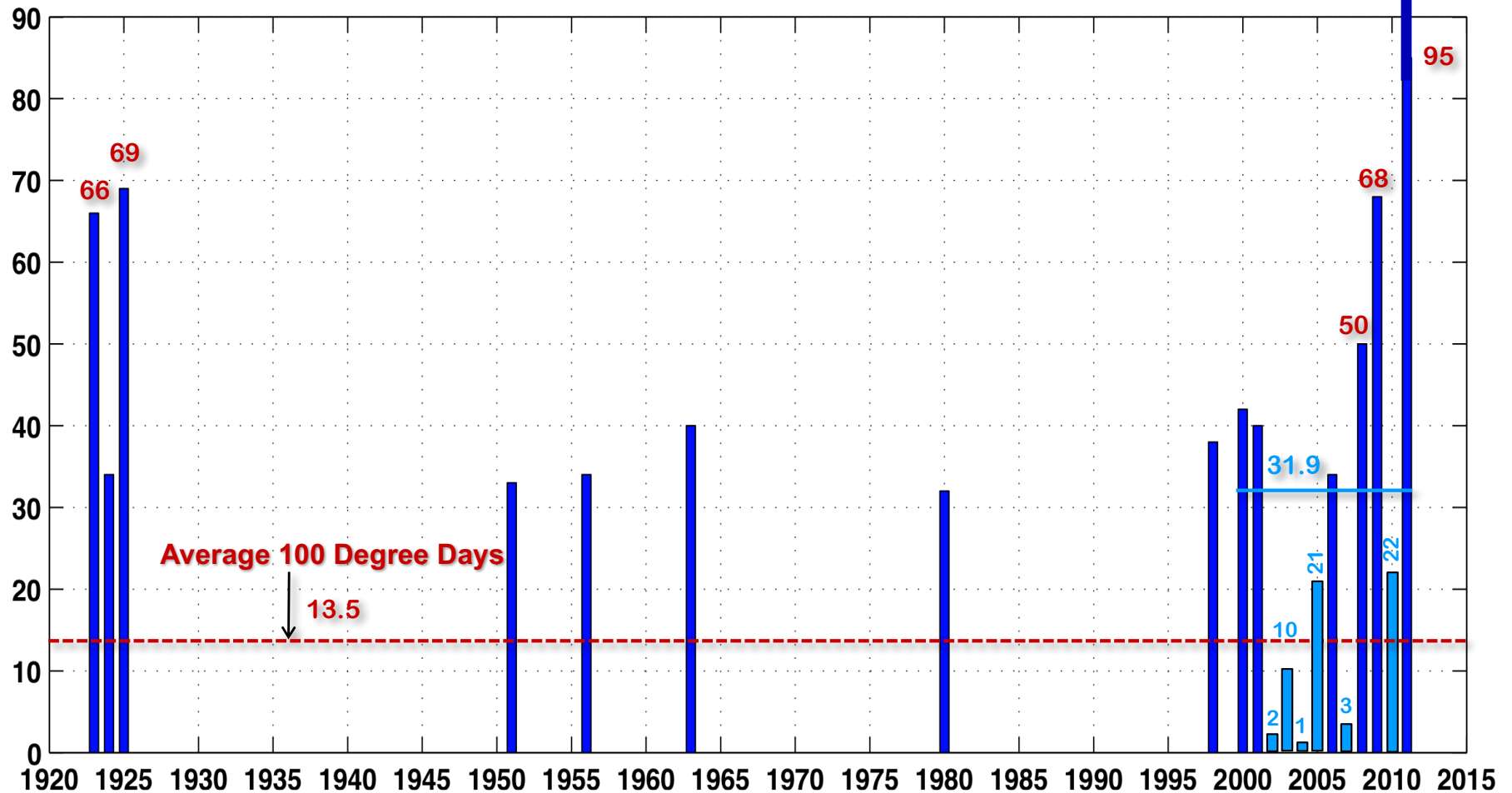
(slide used in 2016)



(Courtesy of NASA GISS)

***Well. How do I know global warming is real ?!***

**AUSTIN (CAMP MABRY) TOP 14 MOST 100 DEGREE DAYS IN A YEAR 1898 TO 2011**

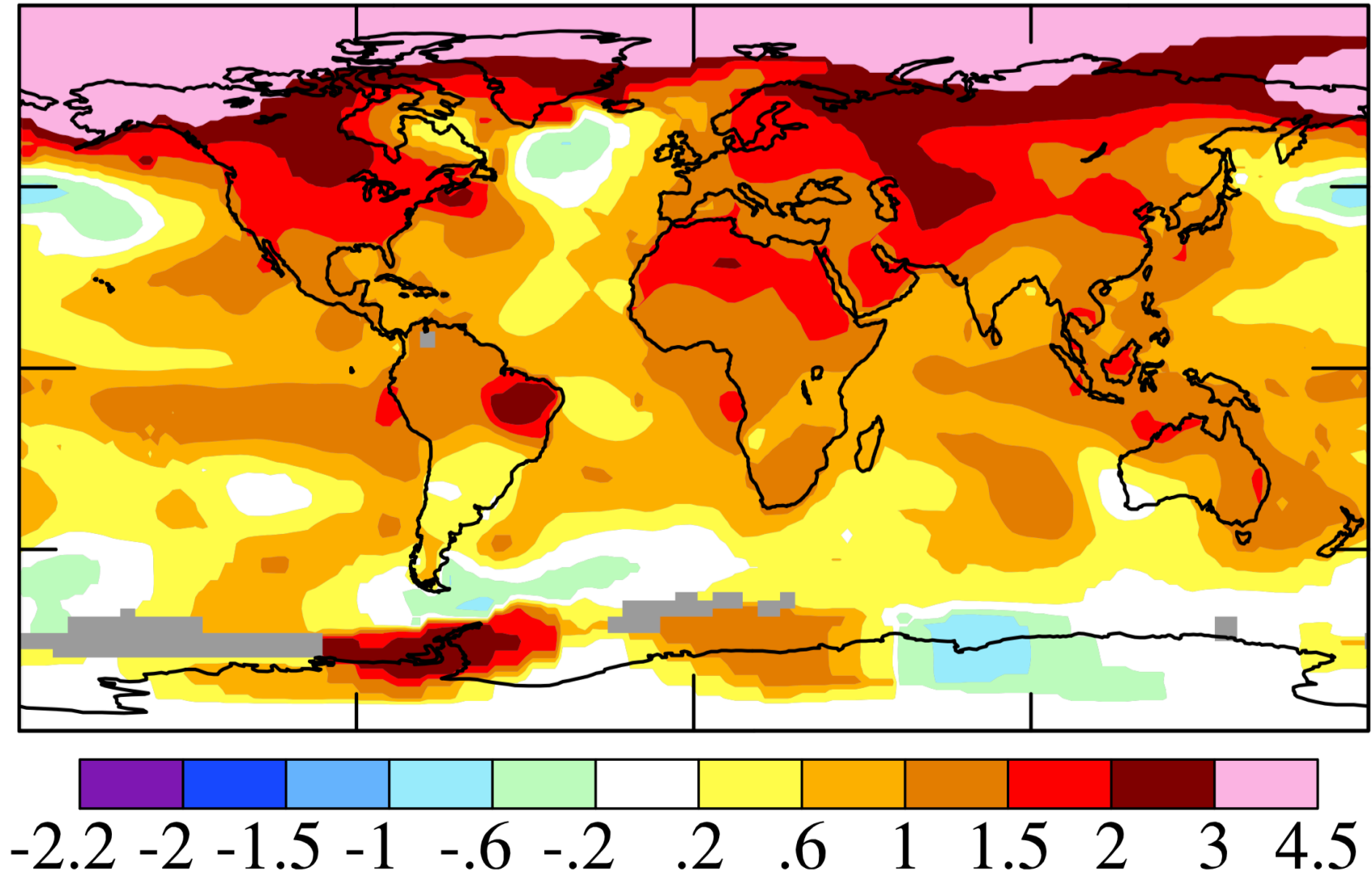


**(up to 09/29/2011)**



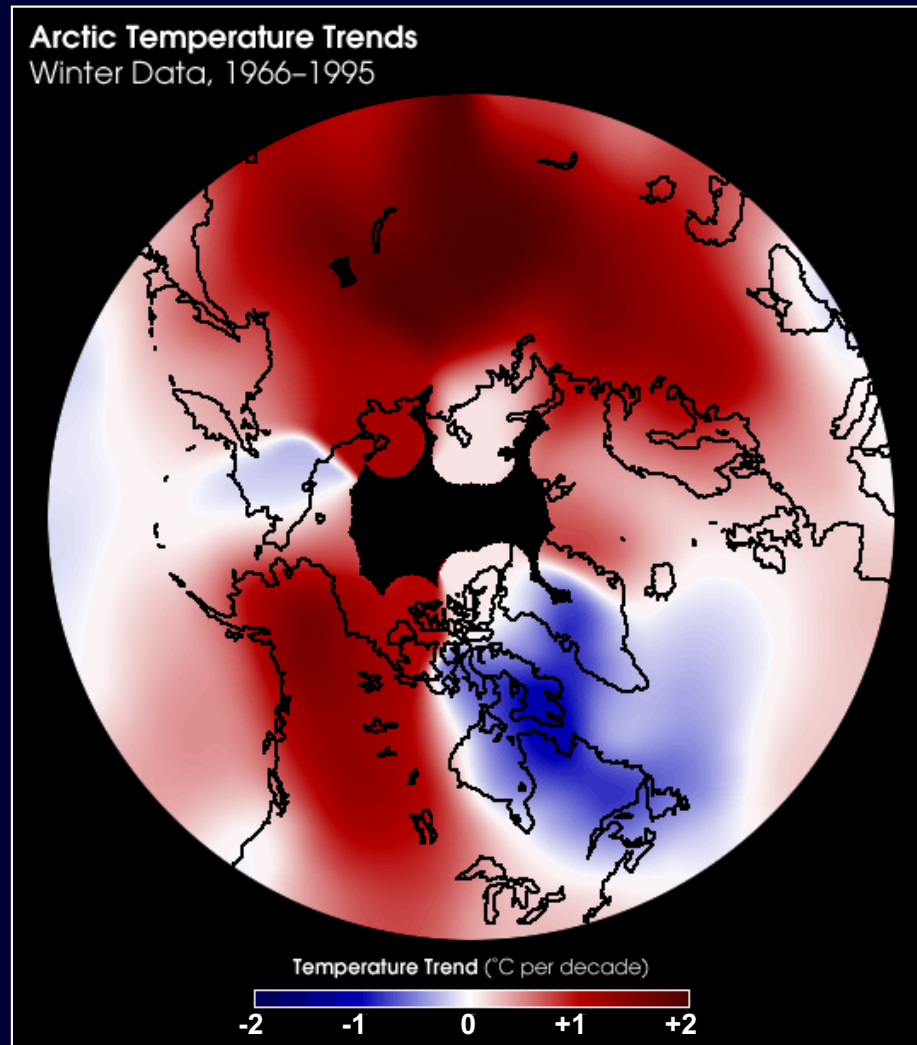
# Global Temperature Anomalies in 2016

(Relative to 1951-1980 Mean)



**Year 2016 was the warmest on record (by the end of 2017).**

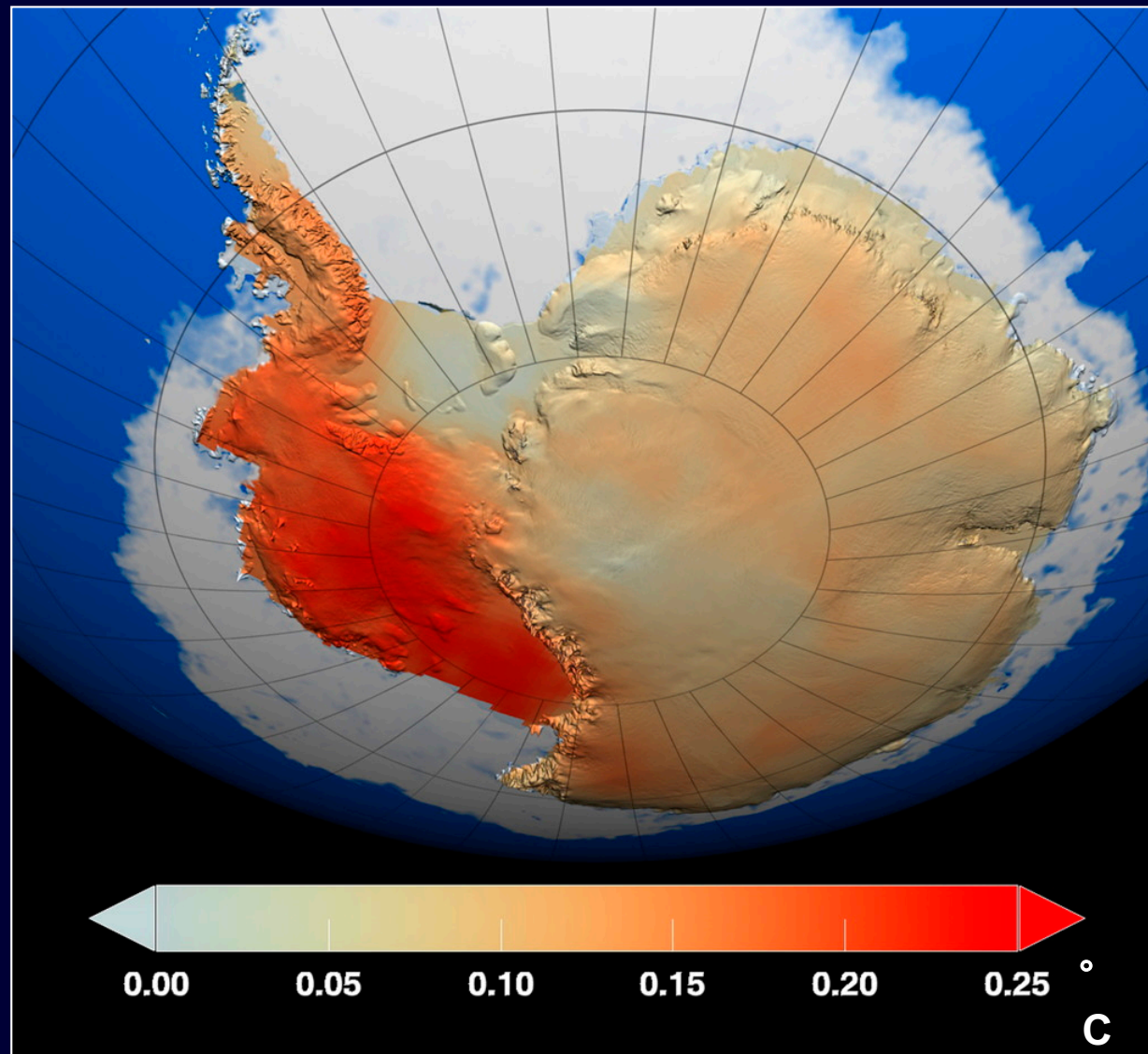
# Global Warming



Arctic Winter Temperature Trends (1966-1995, °C per decade)



# Global Warming



Antarctic temperature change per decade over the past 50 years.



2005 Melt  
Extent

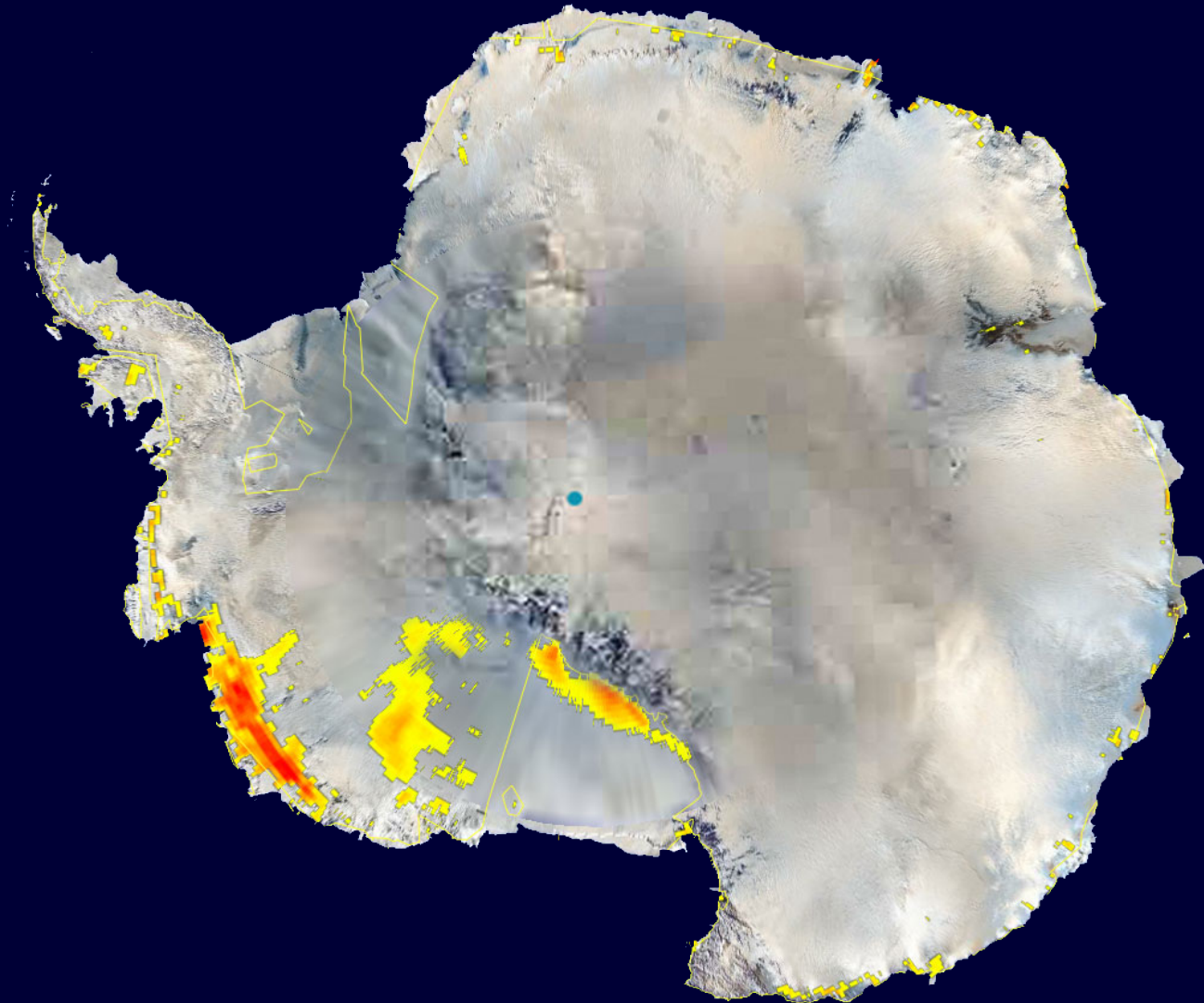
# Ice Sheets and Glaciers Melting

- Melted in 2005
- 1st Recorded Melt
- 2,000m Elevation

University of Colorado CIRES

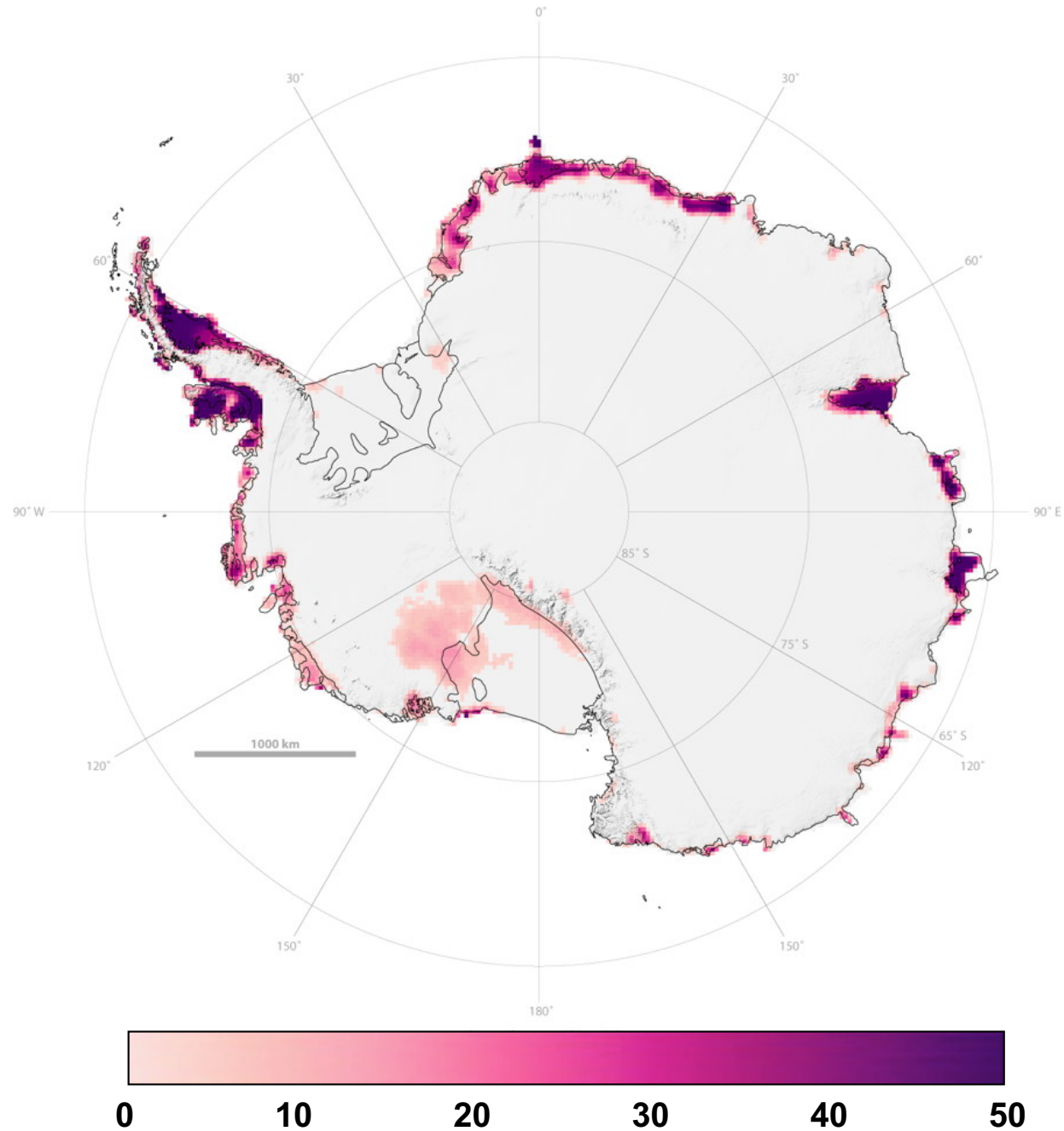
Courtesy Russell Huff and Konrad Steffen

# Antarctic Ice Sheet Melting

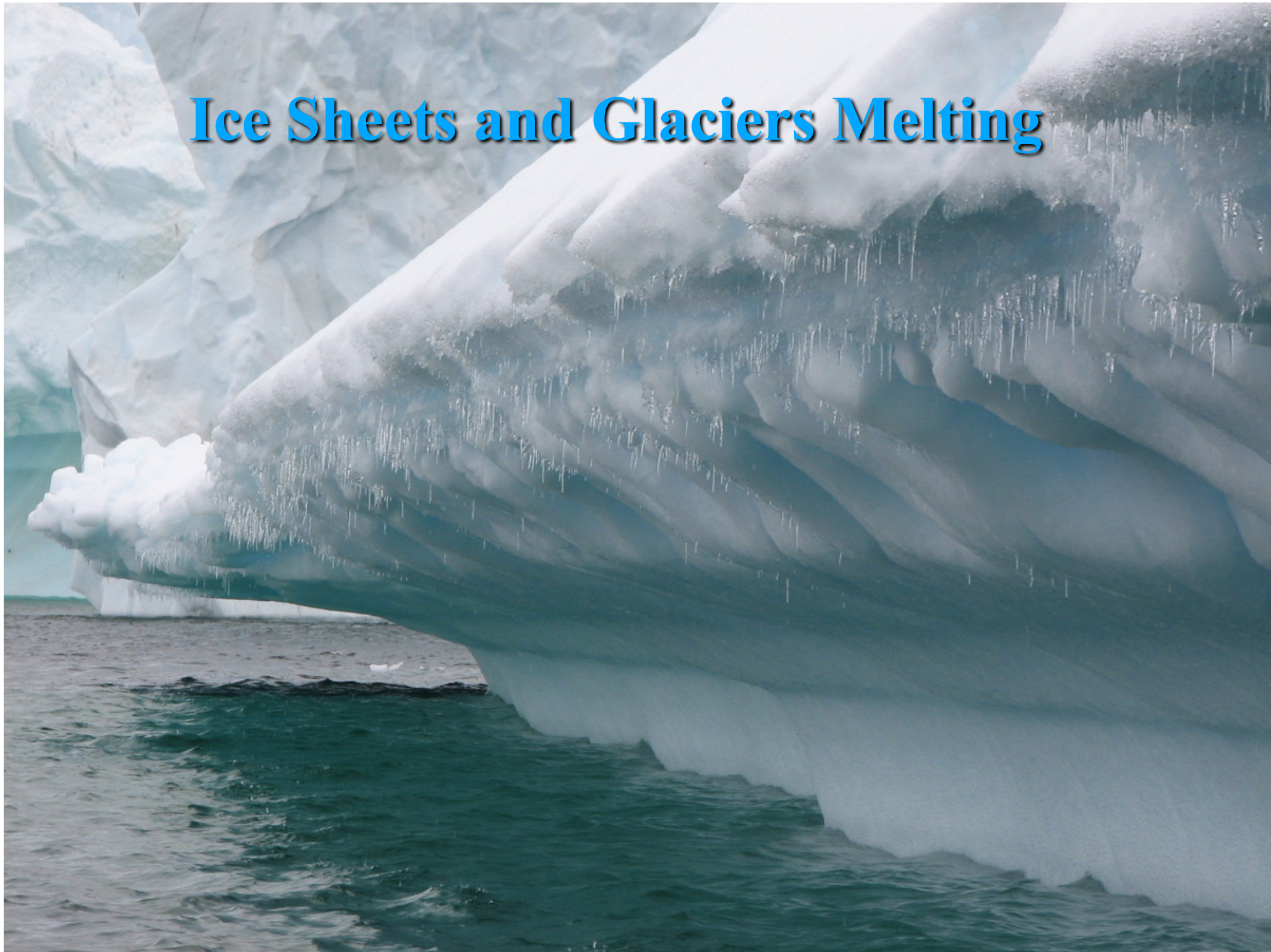




# Antarctic Melting Days in 2005



# Ice Sheets and Glaciers Melting

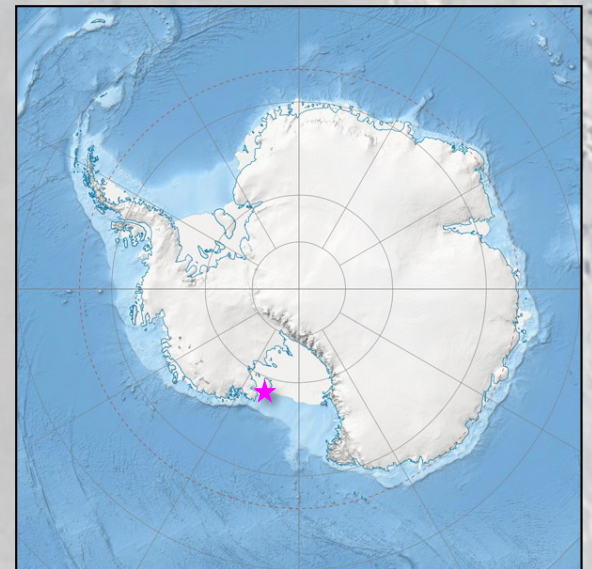




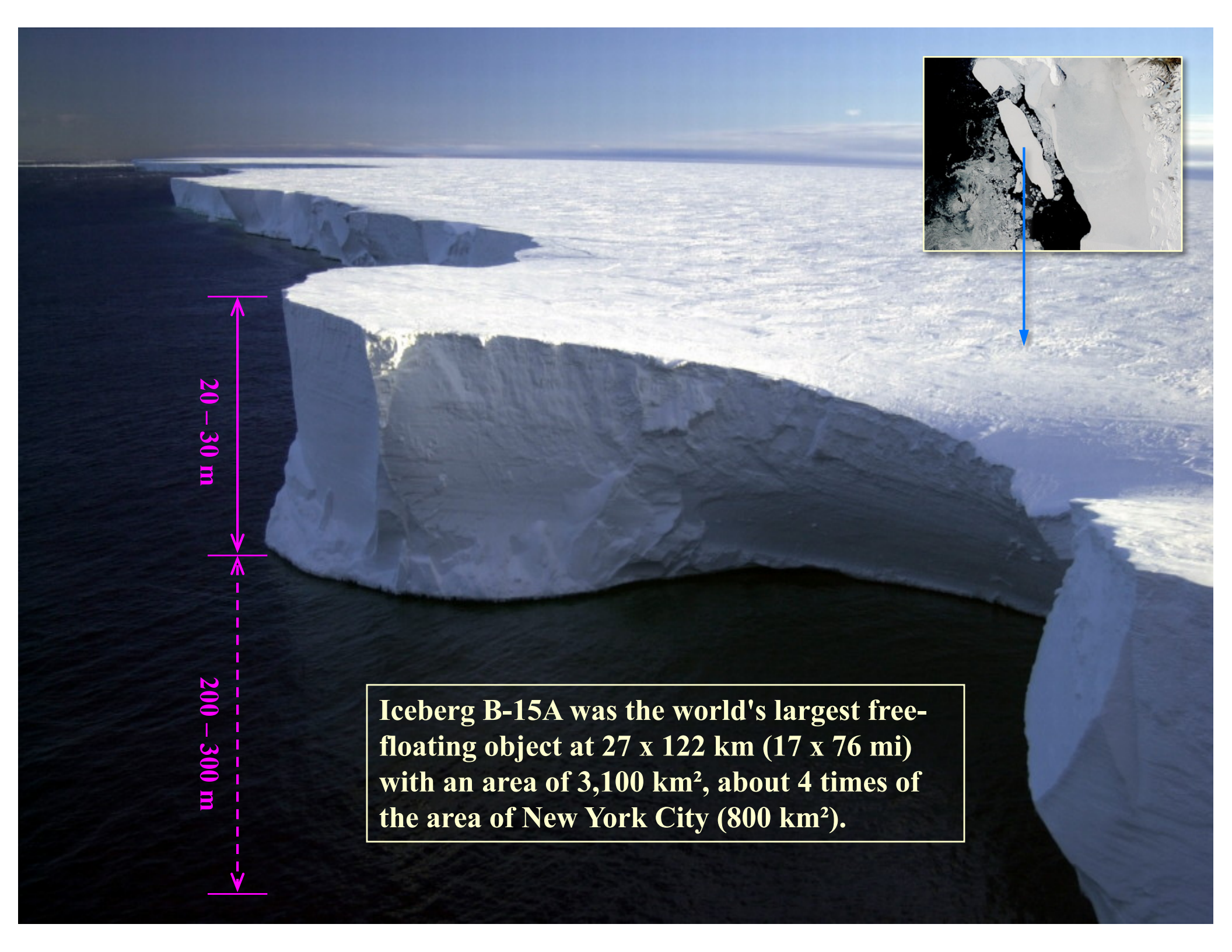
# Ice Calving (Breaking Up)

Originally calved from the Ross Ice Shelf near Roosevelt Island in March 2000, Iceberg B-15A was the world's largest free-floating object at 27 x 122 km (17 x 76 mi) with an area of 3,100 km<sup>2</sup>.

122 km







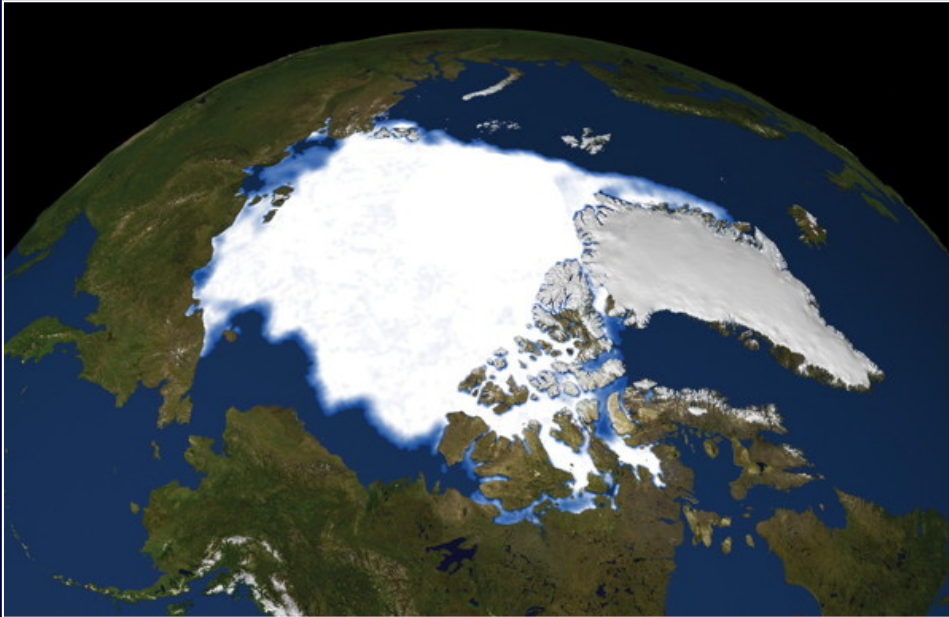
20 – 30 m

200 – 300 m

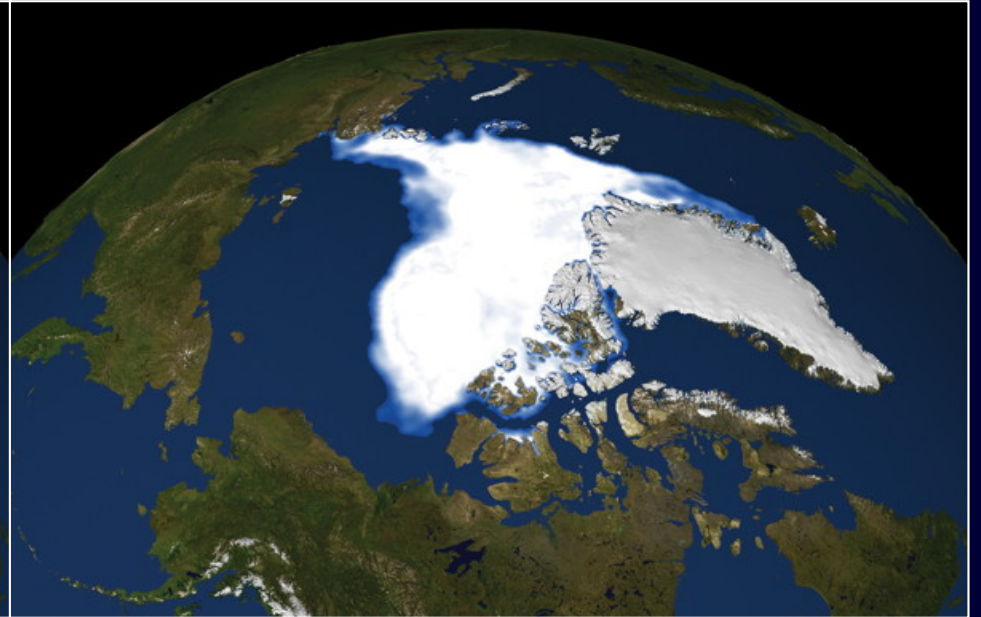
**Iceberg B-15A was the world's largest free-floating object at 27 x 122 km (17 x 76 mi) with an area of 3,100 km<sup>2</sup>, about 4 times of the area of New York City (800 km<sup>2</sup>).**



# Decreased Arctic Sea Ice Coverage

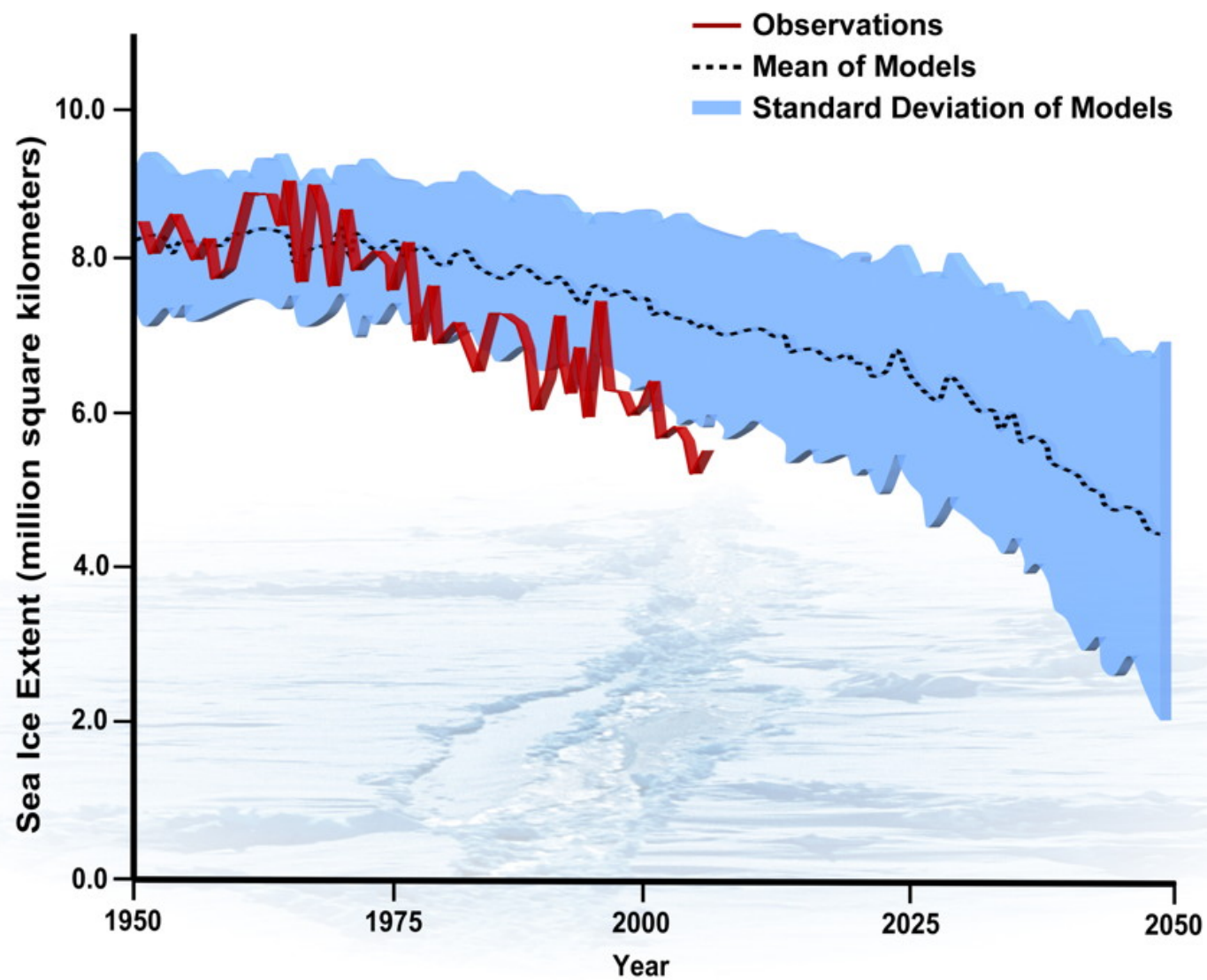


September 1979



September 2007

## Arctic September Sea Ice Extent: Observations and Model Runs



# Sea Level Rise

**Manhattan Skyline**

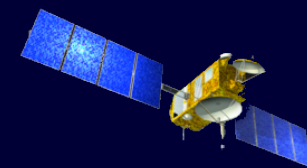
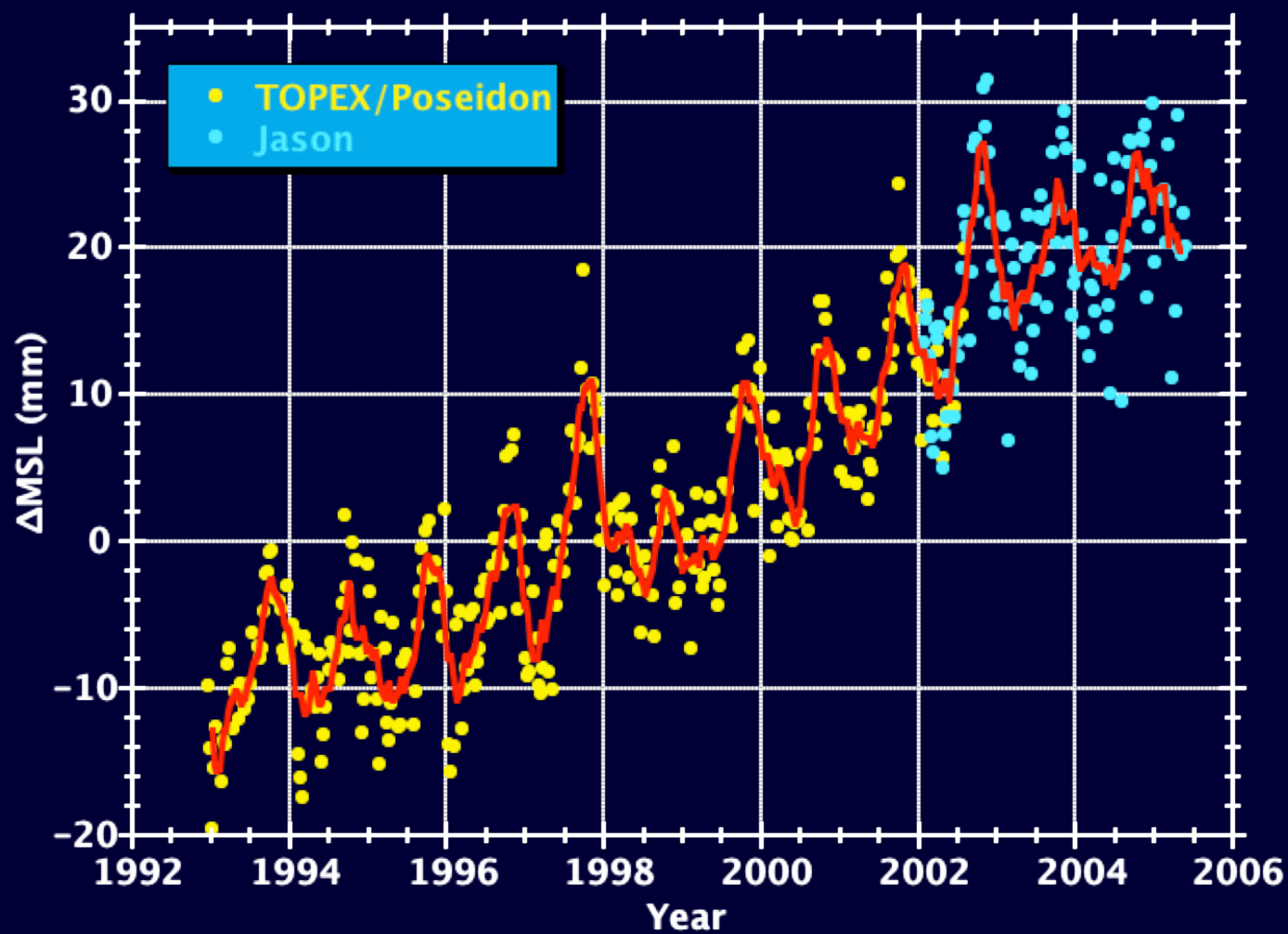






# Global Mean Sea Level Rise

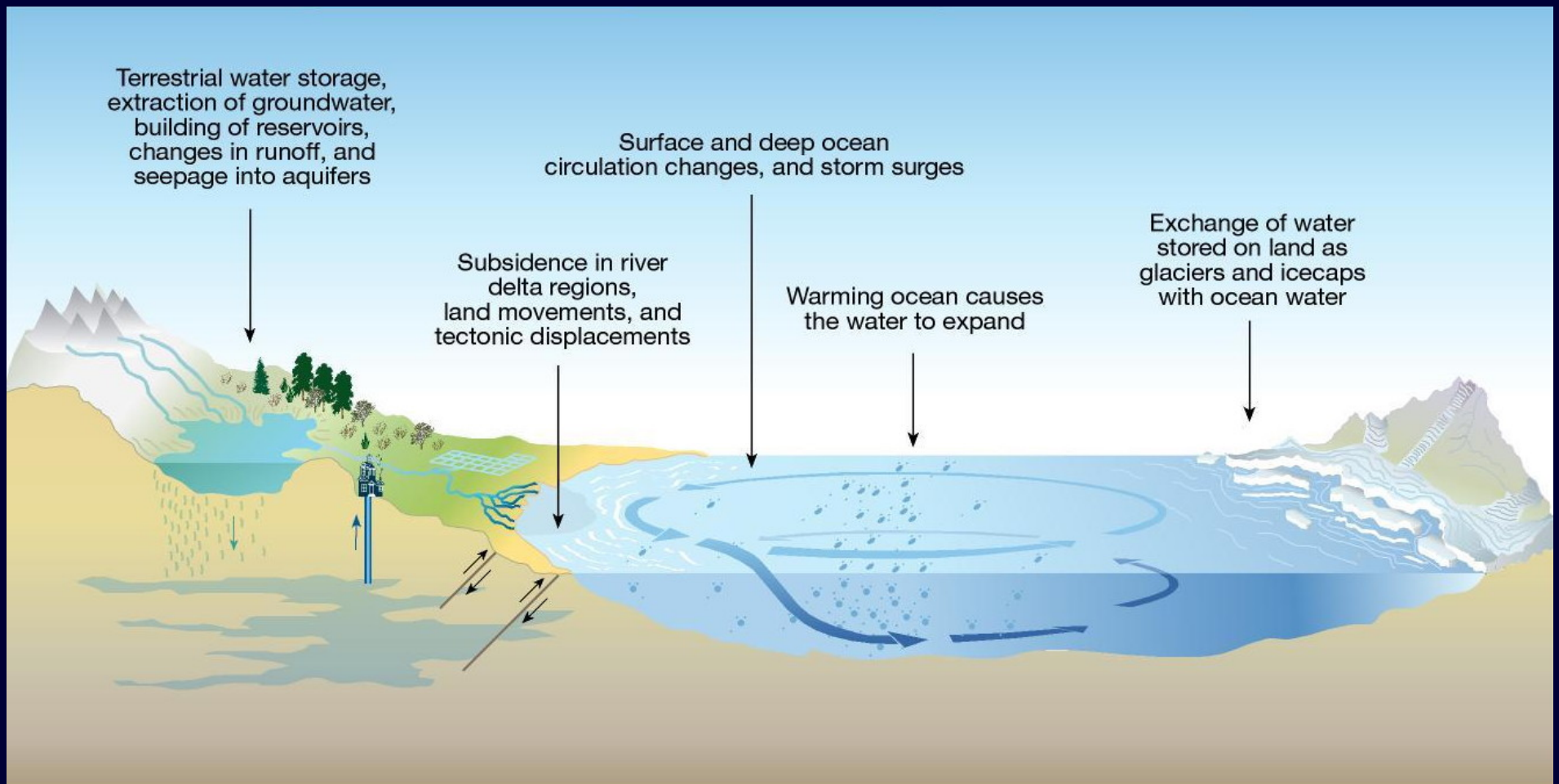
From Satellite Altimetry



# Why Does Sea Level Rise?



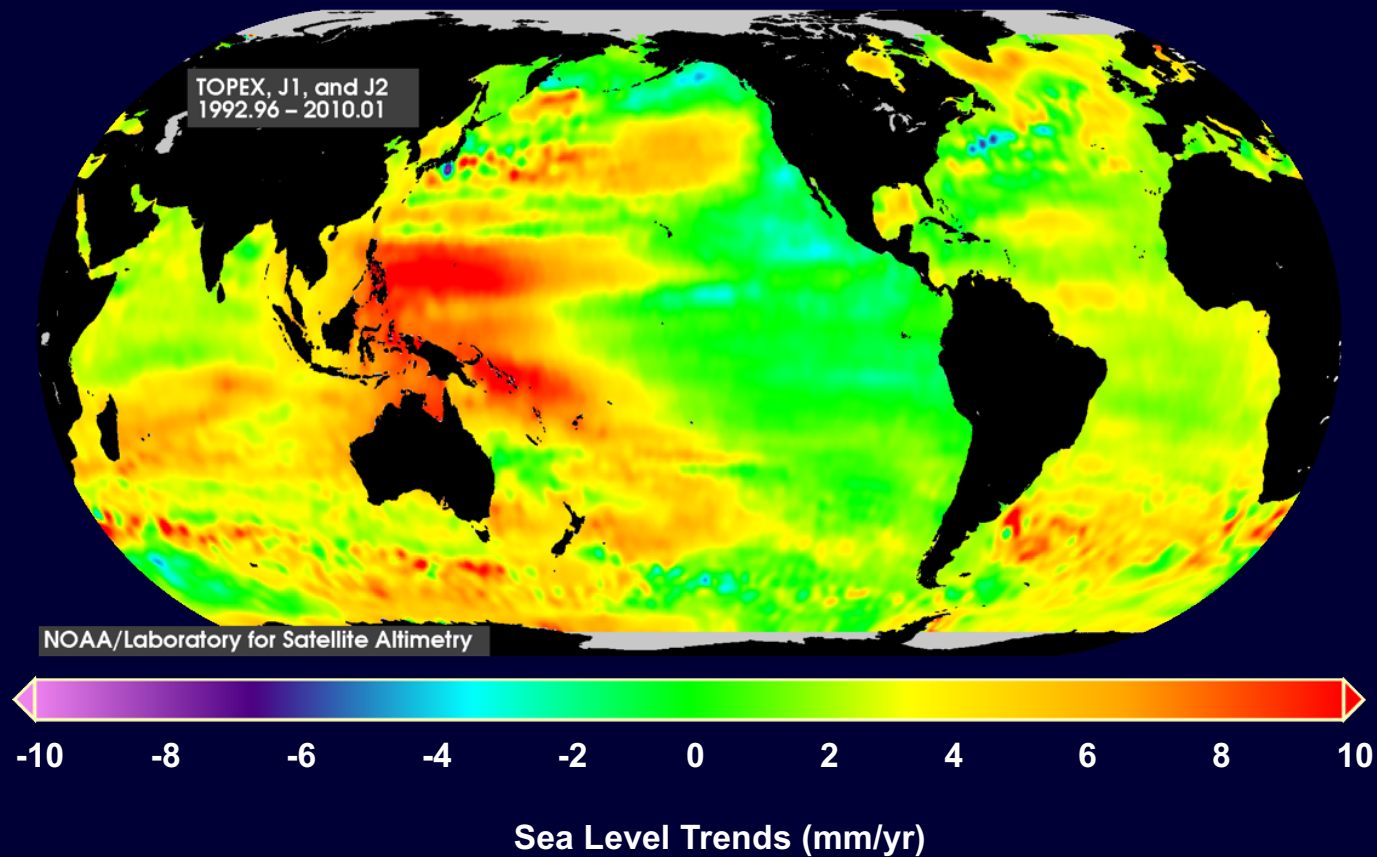
# Why Does Sea Level Rise?





# Global Mean Sea Level Rise

## From Satellite Altimetry

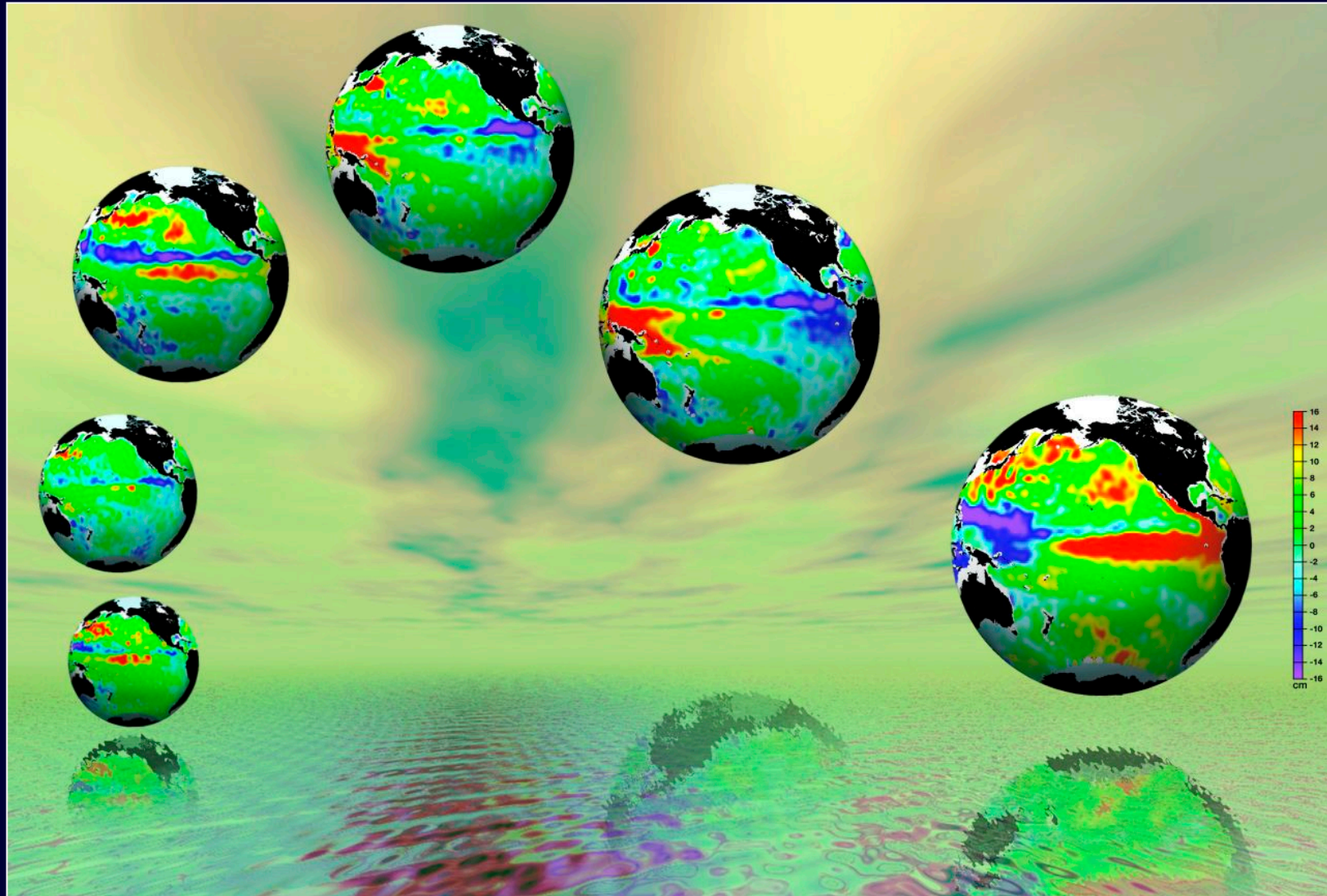


# **Impacts of Global Warming & Climate Change**



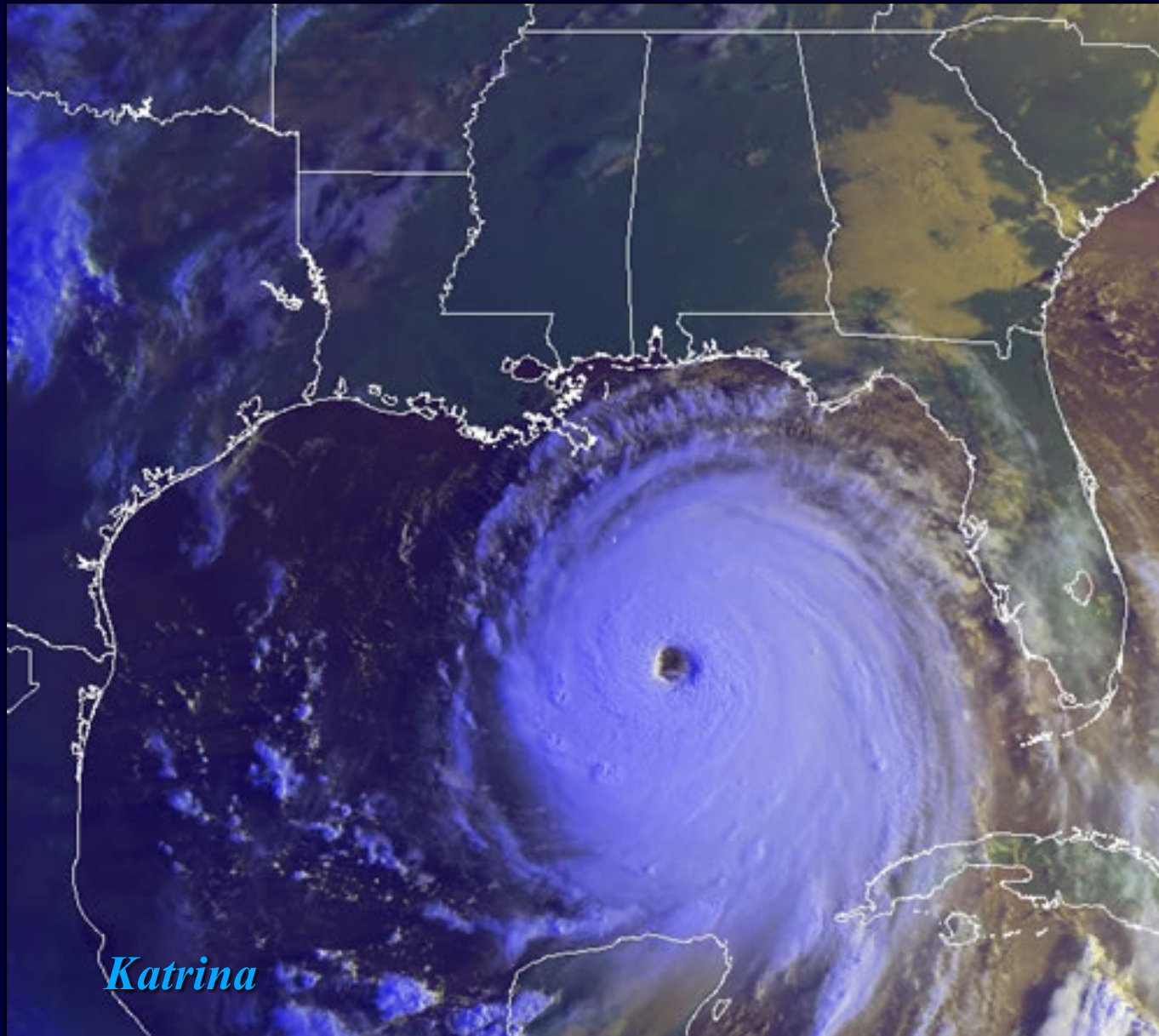


# El Niño/La Niña



*By courtesy of NASA*

# Increasing Number and Strength of Hurricanes



*By courtesy of NOAA*

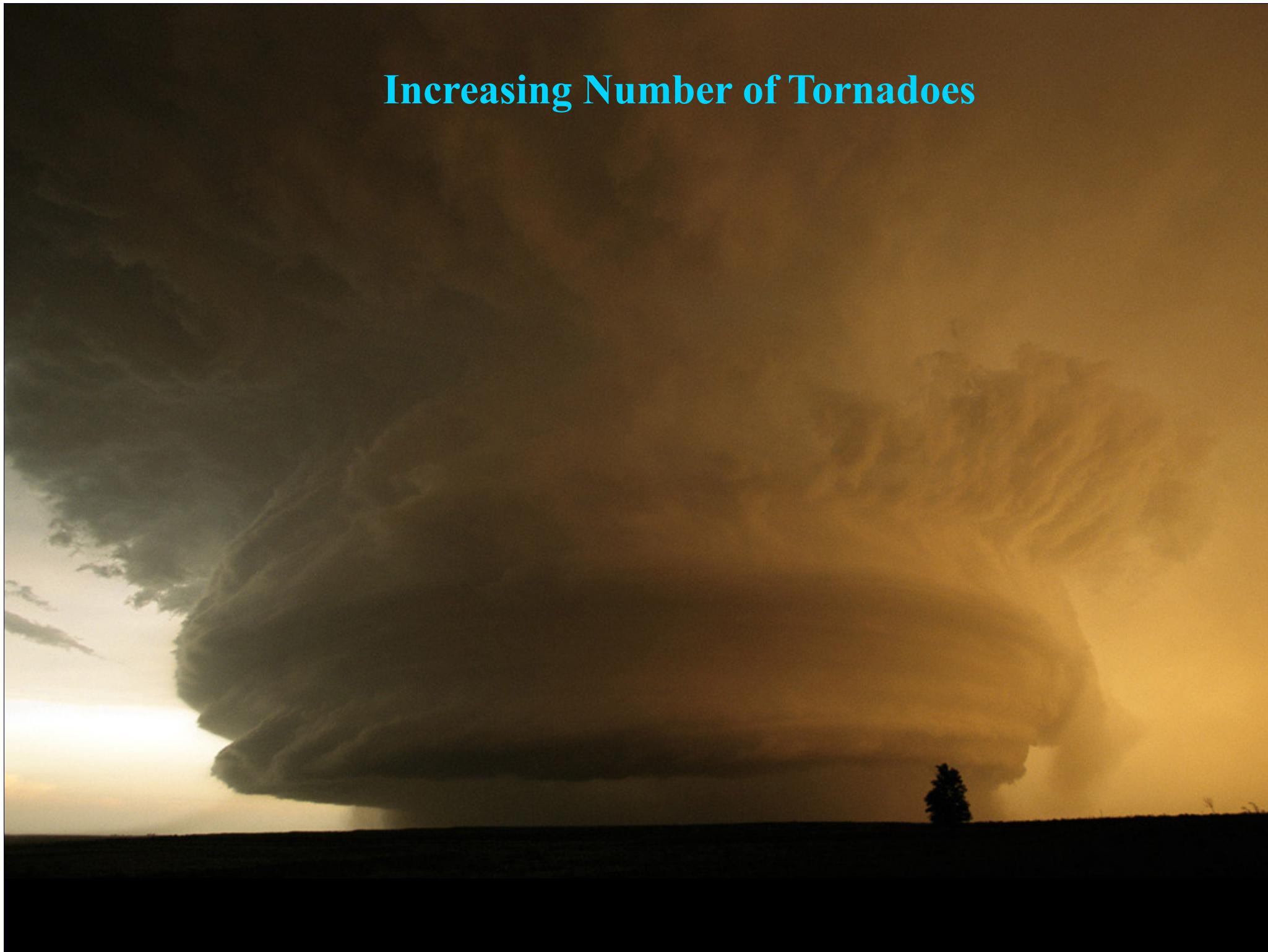
**Table 1. Change in the number and percentage of hurricanes in categories 4 and 5 for the two 15-year periods 1975–1989 and 1990–2004 for the different ocean basins.**

| Basin                | Period    |            |           |            |
|----------------------|-----------|------------|-----------|------------|
|                      | 1975–1989 |            | 1990–2004 |            |
|                      | Number    | Percentage | Number    | Percentage |
| East Pacific Ocean   | 36        | 25         | 49        | 35         |
| West Pacific Ocean   | 85        | 25         | 116       | 41         |
| North Atlantic       | 16        | 20         | 25        | 25         |
| Southwestern Pacific | 10        | 12         | 22        | 28         |
| North Indian         | 1         | 8          | 7         | 25         |
| South Indian         | 23        | 18         | 50        | 34         |

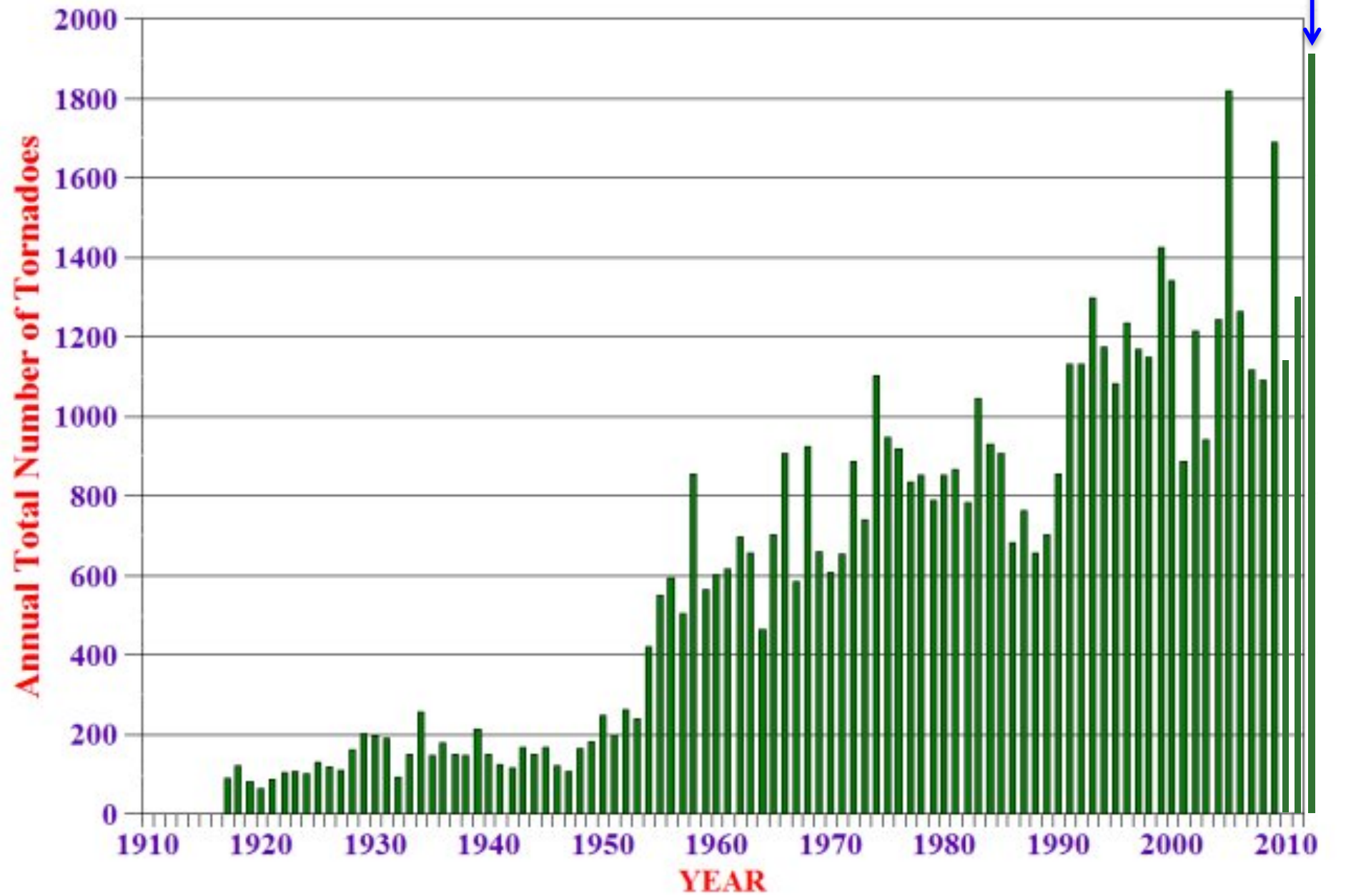
*Webster et al., 2005*



## Increasing Number of Tornadoes



# UNITED STATES TORNADOES 1916-2008



## **2011 Tornadoes Outbreaks in the US**

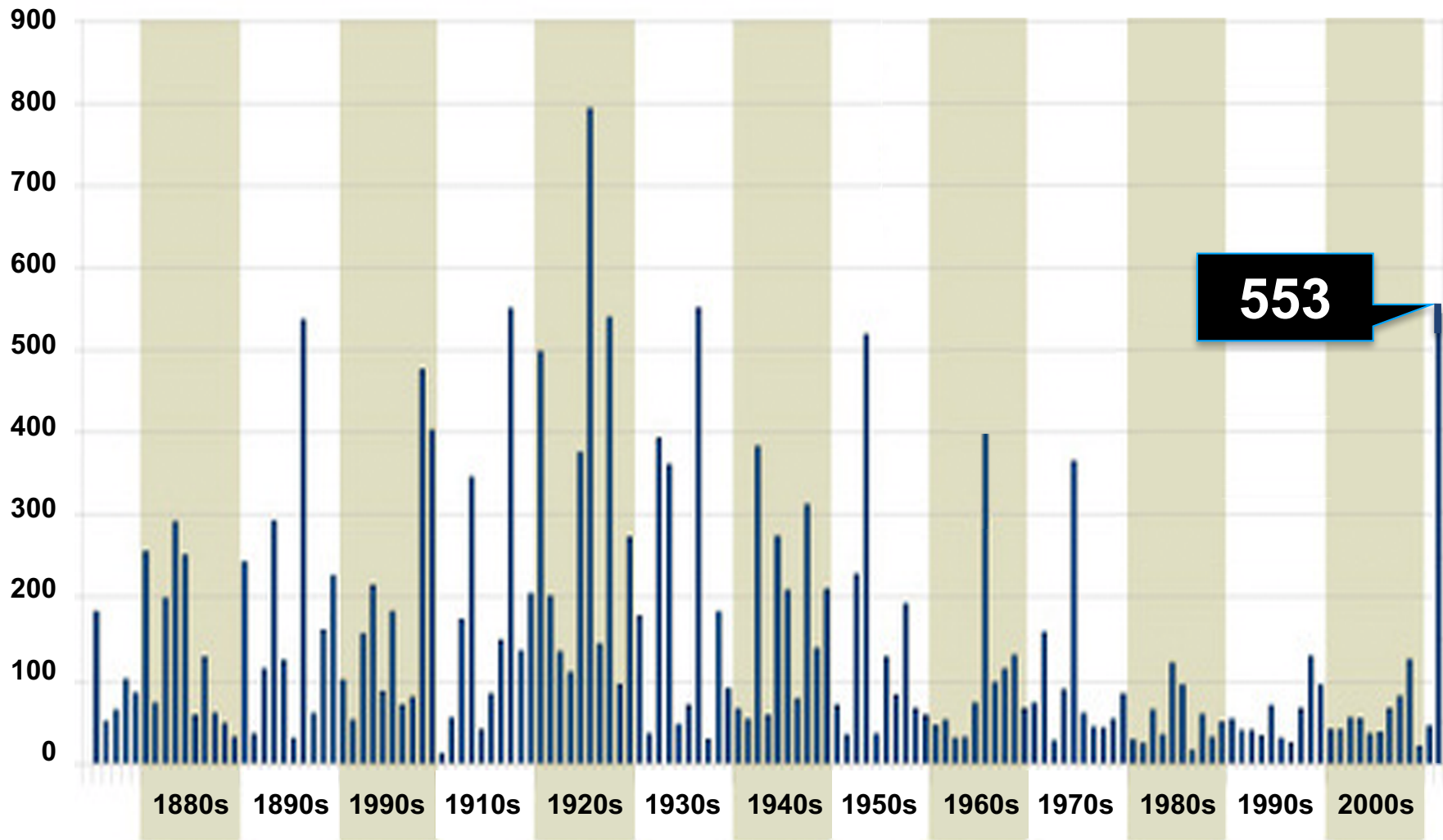
**There were 1,897 tornadoes reported in the US in 2011 (of which 1,704 were confirmed). 2011 had been an exceptionally destructive and deadly year for tornadoes; worldwide, at least 577 people perished due to tornadoes: 12 in Bangladesh, one in New Zealand, one in the Philippines, one in Russia, one in Canada, and an estimated 553 in the United States (compared to 564 US deaths in the 10 years prior).**

**Due in large part to several extremely large tornado outbreaks in the middle and end of April and in late May, It was also the deadliest year for tornadoes in the United States since 1936, due mostly to the 324 tornadic deaths that occurred during the April 27 outbreak across the Southeastern United States and the 158 tornadic deaths in the 2011 Joplin Tornado.**

*([http://en.wikipedia.org/wiki/Tornadoes\\_of\\_2011](http://en.wikipedia.org/wiki/Tornadoes_of_2011))*



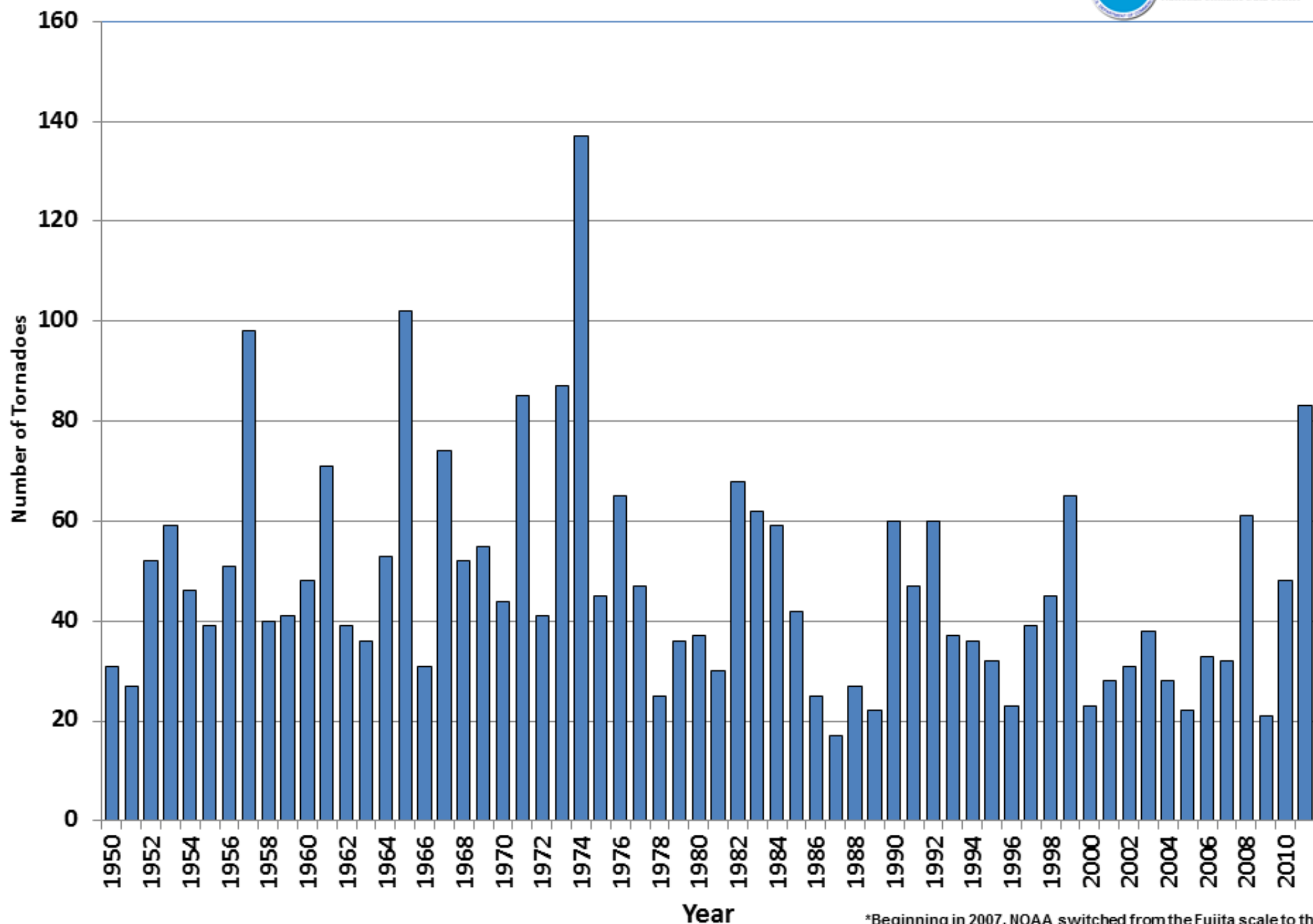
## Tornado Deaths in the United States, 1875 to present



# Number of Strong to Violent (EF3-EF5\*) Tornadoes

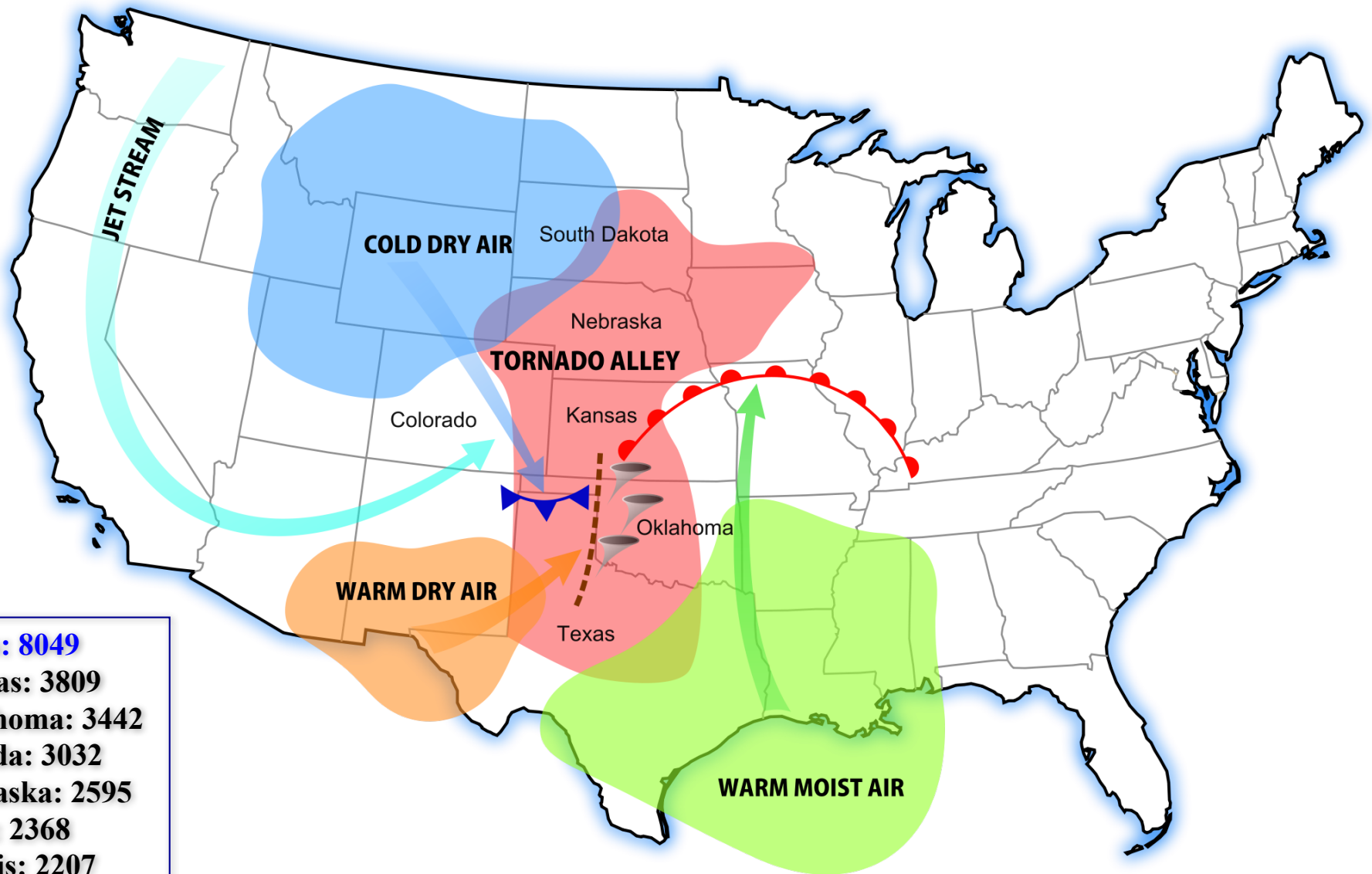


NOAA's  
National Climatic Data Center



\*Beginning in 2007, NOAA switched from the Fujita scale to the Enhanced Fujita scale for rating tornado strength.

# Tornado Alley in the United States



**Texas: 8049**  
**Kansas: 3809**  
**Oklahoma: 3442**  
**Florida: 3032**  
**Nebraska: 2595**  
**Iowa: 2368**  
**Illinois: 2207**  
**Missouri: 2119**  
**Mississippi: 1972**  
**Alabama: 1844**

**U.S. tornadoes per state: 1950-2009**

*By courtesy of NOAA*

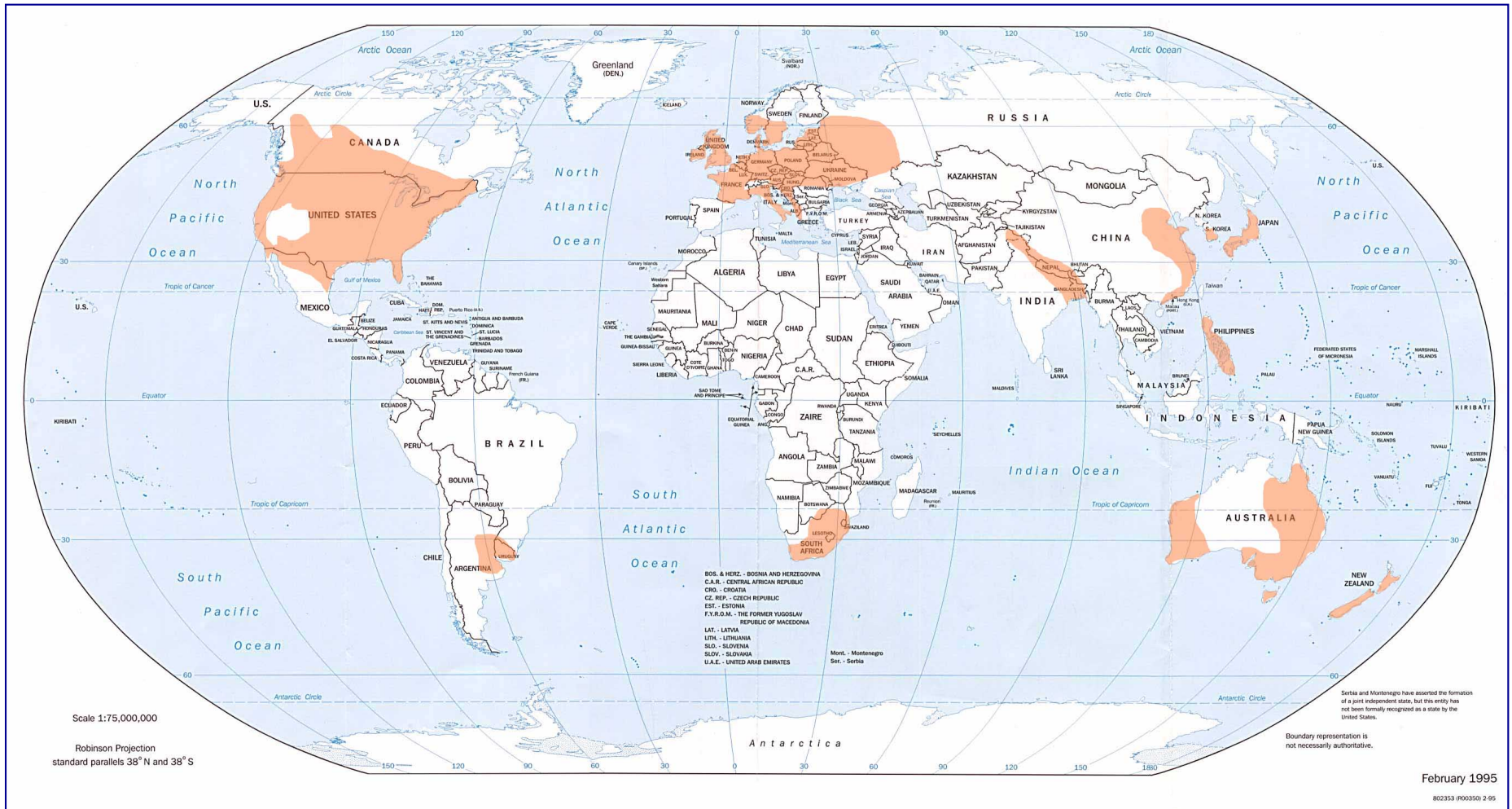


# Why is the United States so “special”?



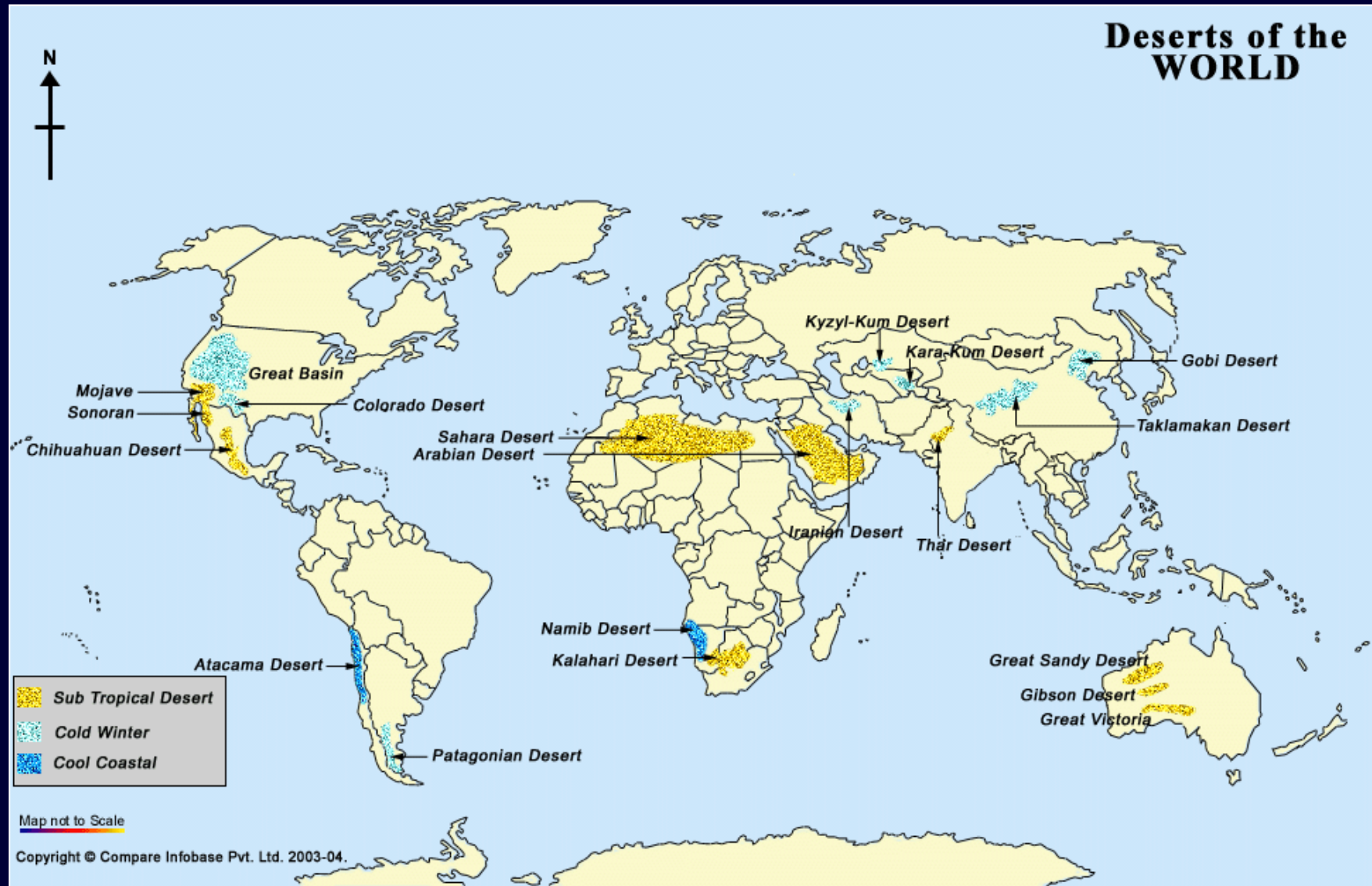
**The United States has the most tornadoes of any country, nearly four times more than estimated in all of Europe, excluding waterspouts. This is mostly due to the unique geography of the continent. North America is a large continent that extends from the tropics north into arctic areas, and has no major east-west mountain range to block air flow between these two areas. In the middle latitudes, where most tornadoes of the world occur, the Rocky Mountains block moisture and buckle the atmospheric flow, forcing drier air at mid-levels of the troposphere due to downsloped winds, and causing the formation of a low pressure area downwind to the east of the mountains. Increased westerly flow off the Rockies force the formation of a dry line when the flow aloft is strong, while the Gulf of Mexico fuels abundant low-level moisture in the southerly flow to its east. This unique topography allows for frequent collisions of warm and cold air, the conditions that breed strong, long-lived storms throughout the year.**

# Regions of the world with increased likelihood of experiencing tornadoes



By courtesy of NOAA

# Desert & Desertization





**Desert can be beautiful.**



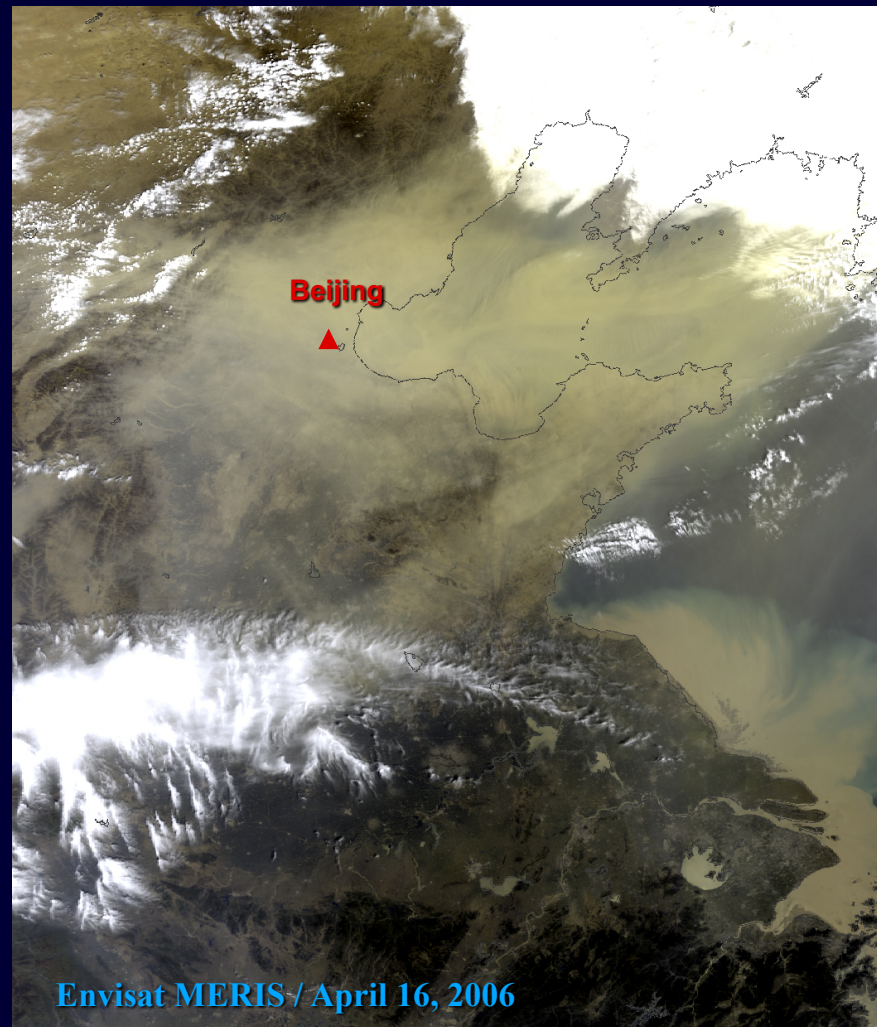


**Desert can be ugly as well.**



**The Infamous Sand Storm**

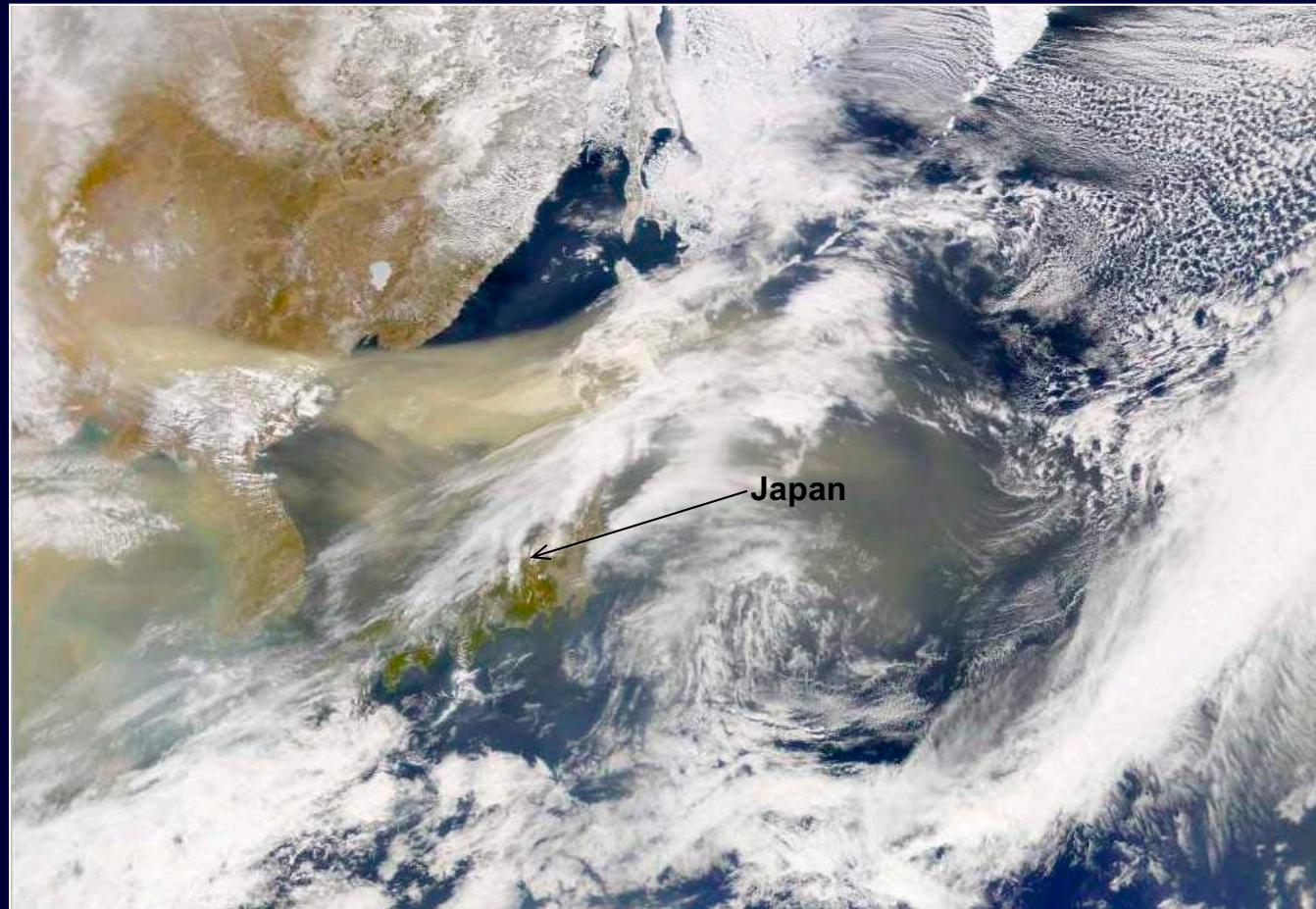
# Desert & Sand Storm



Envisat MERIS / April 16, 2006

*By courtesy of ESA*

## Sand Storm into the Ocean





# **Who is to Blame for Global Warming and Climate Change ?**

# The Greenhouse Effect

A T M O S P H E R E

S U N

- 1 Solar radiation passes through the clear atmosphere.  
Incoming solar radiation:  
343 Watt per  $m^2$

- 3 Some solar radiation is reflected by the atmosphere and earth's surface  
Outgoing solar radiation:  
103 Watt per  $m^2$

- 6 Some of the infrared radiation passes through the atmosphere and is lost in space

Net outgoing infrared radiation:  
240 Watt per  $m^2$

- 2 Net incoming solar radiation:  
240 Watt per  $m^2$

- 5 Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth's surface and the troposphere.

Surface gains more heat and infrared radiation is emitted again

- 4 Solar energy is absorbed by the earth's surface and warms it...  
168 Watt per  $m^2$

... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere

G R E E N H O U S E G A S E S

E A R T H



# 温室效应 - Greenhouse Effect

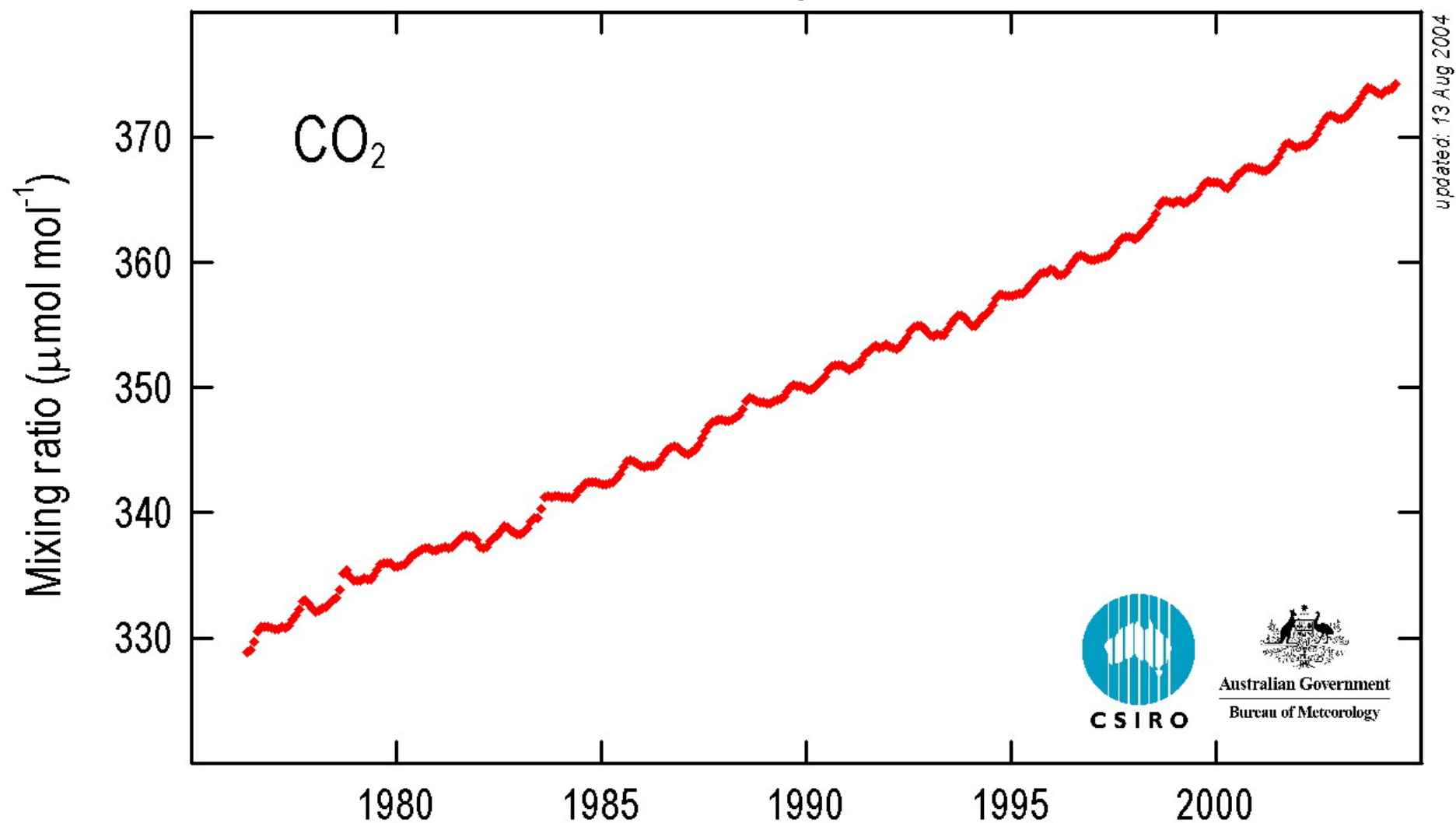




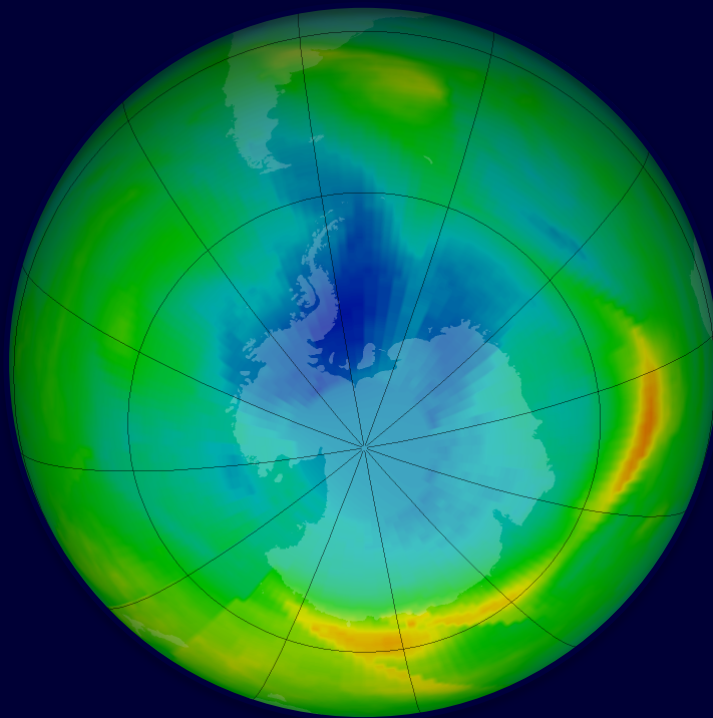
# Carbon Dioxide (CO<sub>2</sub>)



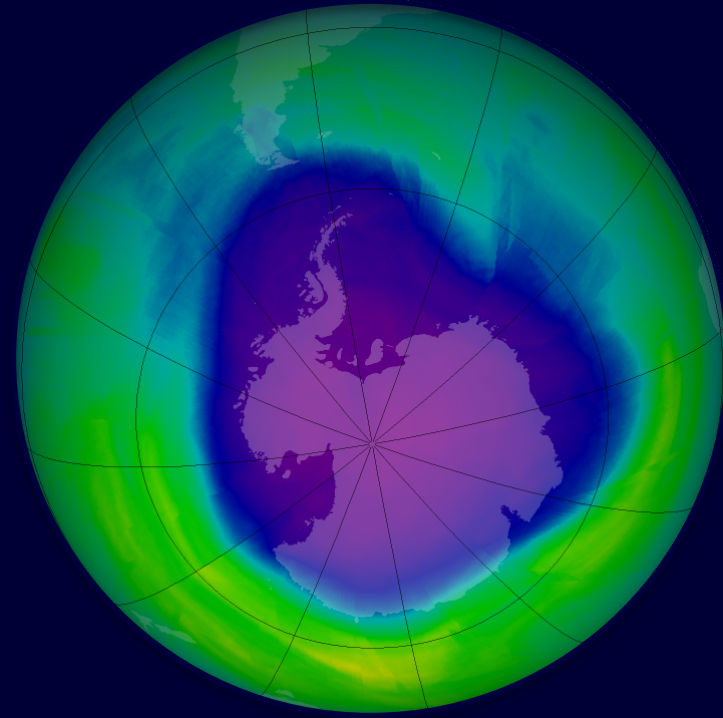
# Carbon dioxide at Cape Grim, Tasmania



# Ozone Hole Over the Antarctic Continent

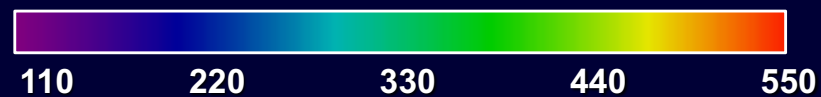


(1979)



(2008)

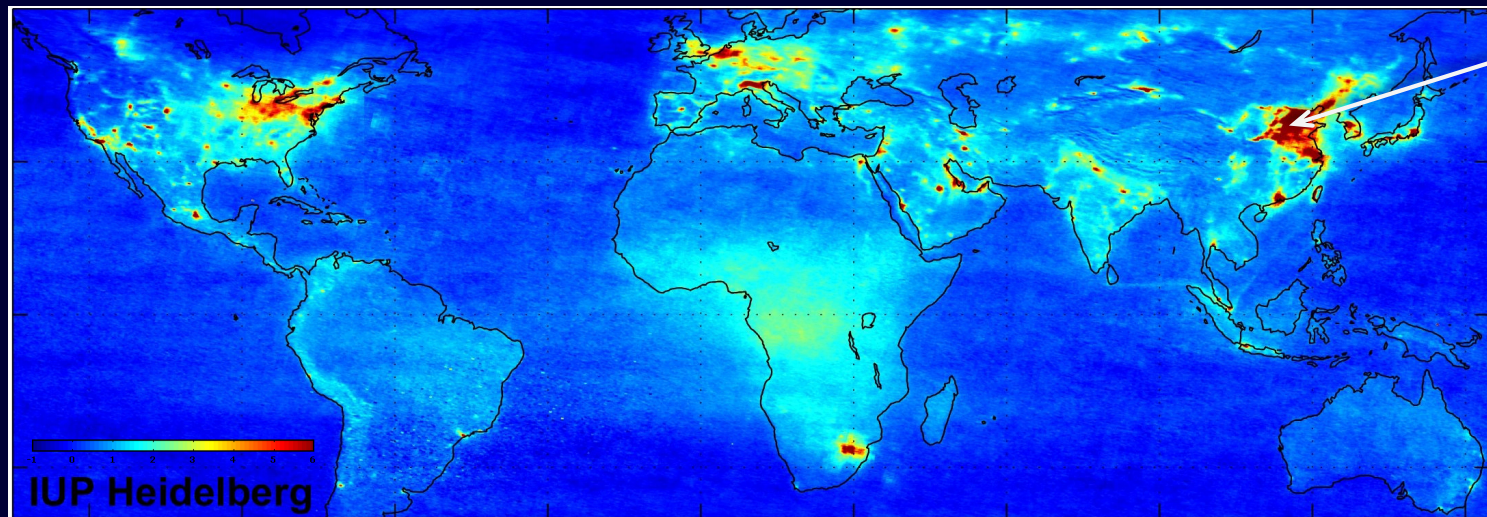
Ozone (Dobson Units)



The ozone ( $O_3$ ) layer, 15 - 50 km above the Earth, protects us from harmful ultraviolet rays.



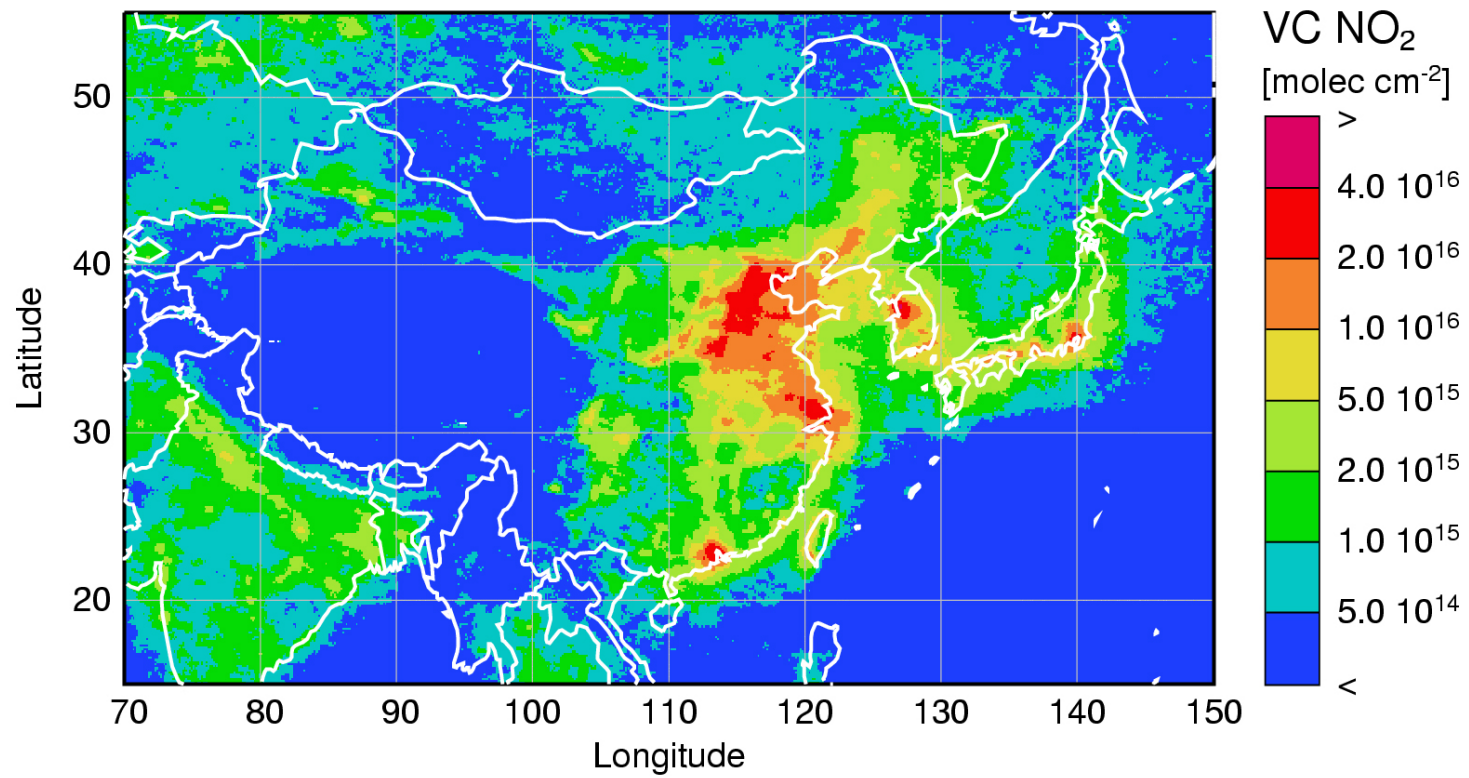
## Global Air Pollution Map Produced by Envisat's SCIAMACHY



*By courtesy of ESA*

**Nitrogen dioxide (NO<sub>2</sub>) is a mainly man-made gas, excess exposure to which causes lung damage and respiratory problems. It also plays an important role in atmospheric chemistry, because it leads to the production of ozone in the troposphere – which is the lowest part of the atmosphere, extending up to between 8 and 16 kilometers high.**

## Air Pollution Map Over China & East Asia



# Natural challenges:

- ✓ Global warming
- ✓ Polar ice sheet and glacial melting
- ✓ Global sea level rise
- ✓ El Niño/La Niña
- ✓ Hurricane/tornado/flooding
- ✓ Earthquake & tsunami
- ✓ Desert/desertization/sand storm
- ✓ & many others ...

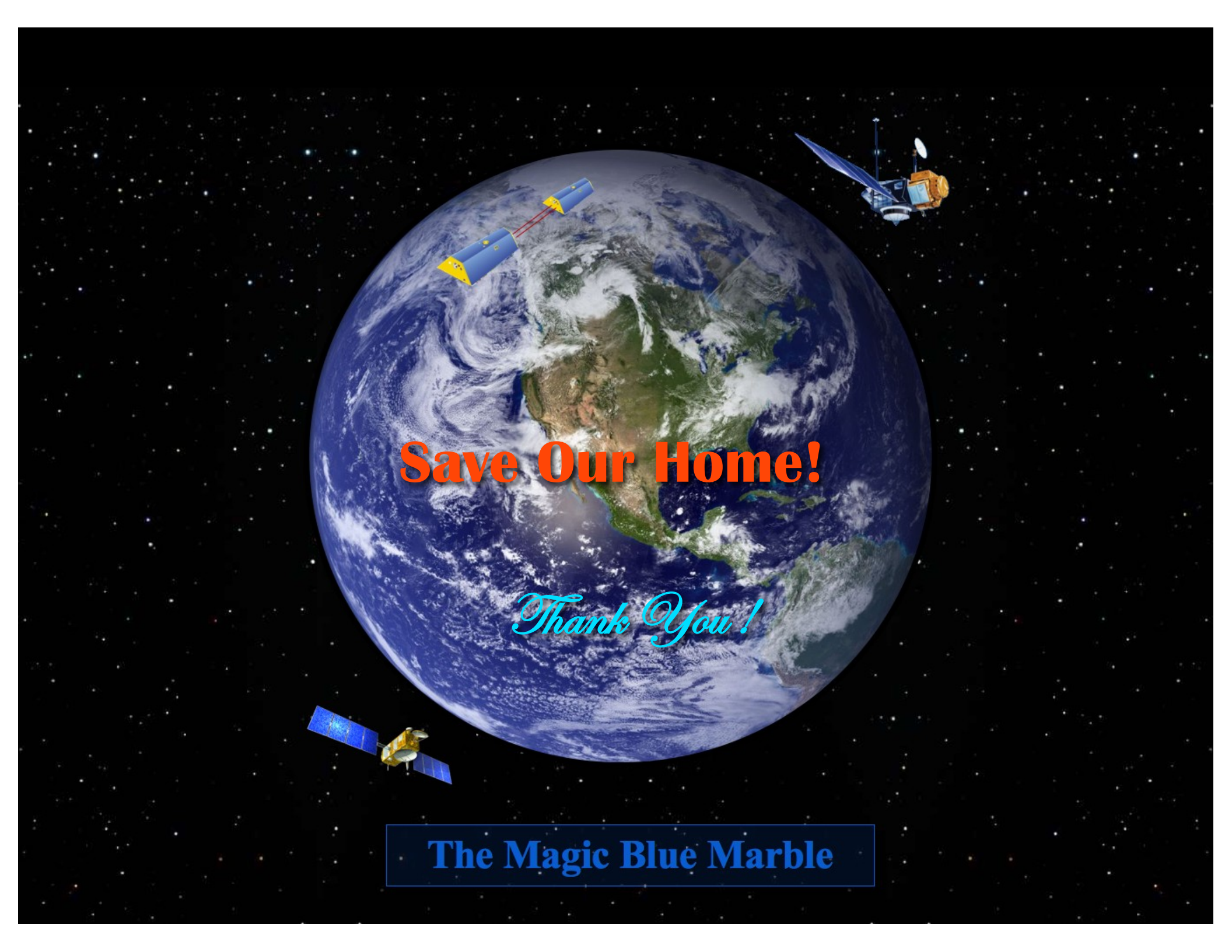
Enough or not?!



# Man-made Environmental Hazards:

- ❑ Green house effect & global warming
- ❑ Water pollution
- ❑ Air pollution
- ❑ Soil pollution
- ❑ Marine pollution
- ❑ Groundwater Scarcity
- ❑ Desertization
- ❑ Deforest
- ❑ Ozone hole
- ❑ Many others

We are feeling about these everyday.

A composite image of Earth from space, showing the Americas. Three satellites are visible: one in the upper left with two long solar panels, one in the upper right with a large dish, and one in the lower left with two rectangular solar panels. The background is a starry space.

**Save Our Home!**

*Thank You!*

**The Magic Blue Marble**