Our Changing Climate From Space
A Global Perspective

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Changes in our Environment

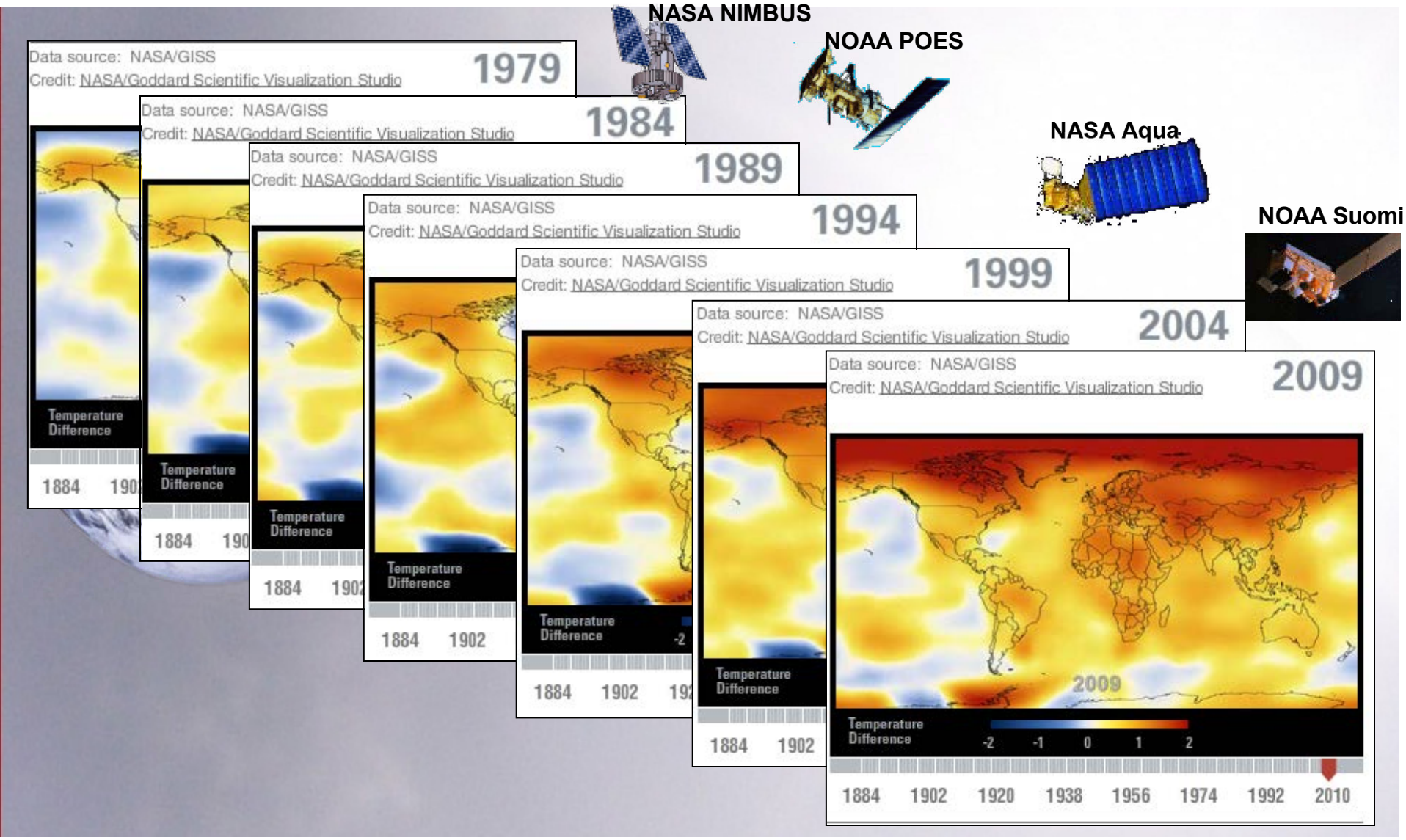
Big Questions

- How is our planet's environment changing?
- How big are these changes and where are they occurring?
- How will our environment change in the future?
- How can we limit or adapt to these changes?

NASA collects global, space-based measurements to address these questions

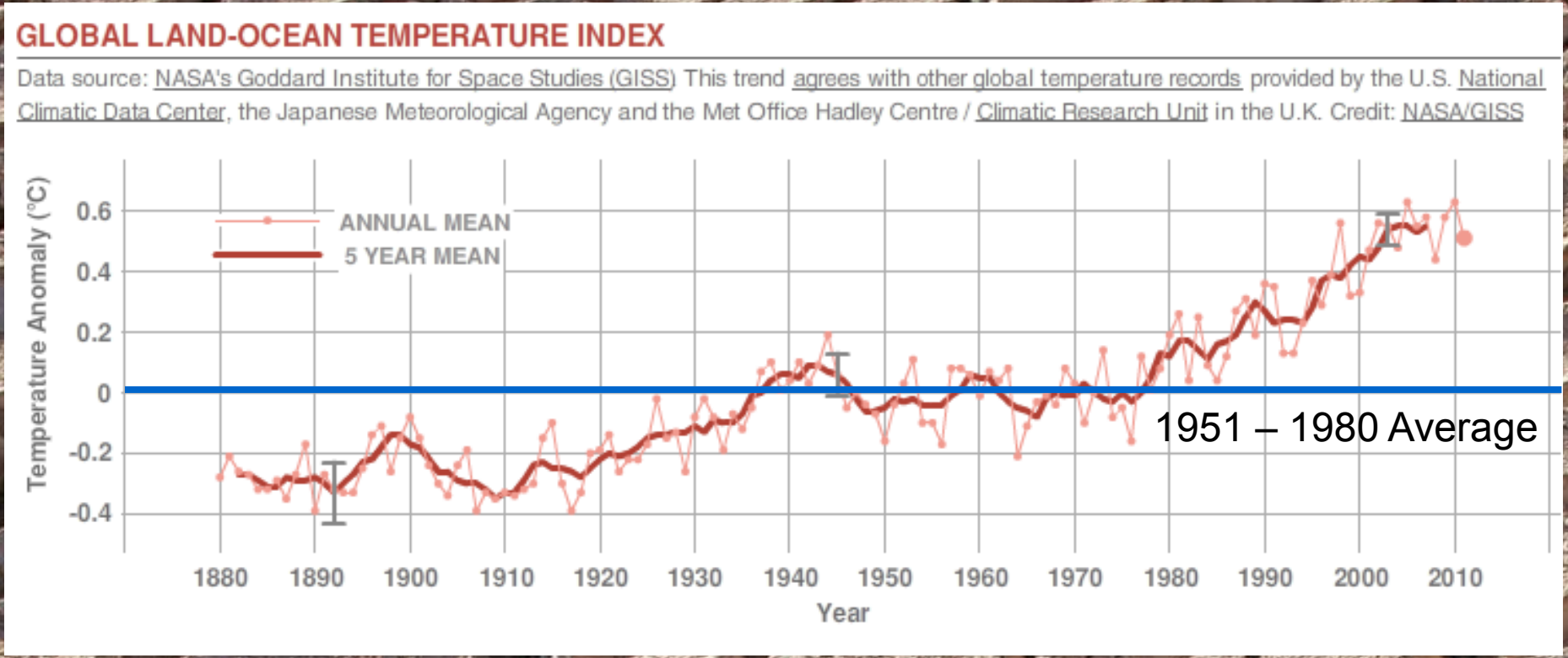
NASA's Role: Space Based Observations

Measuring the Earth's Temperature



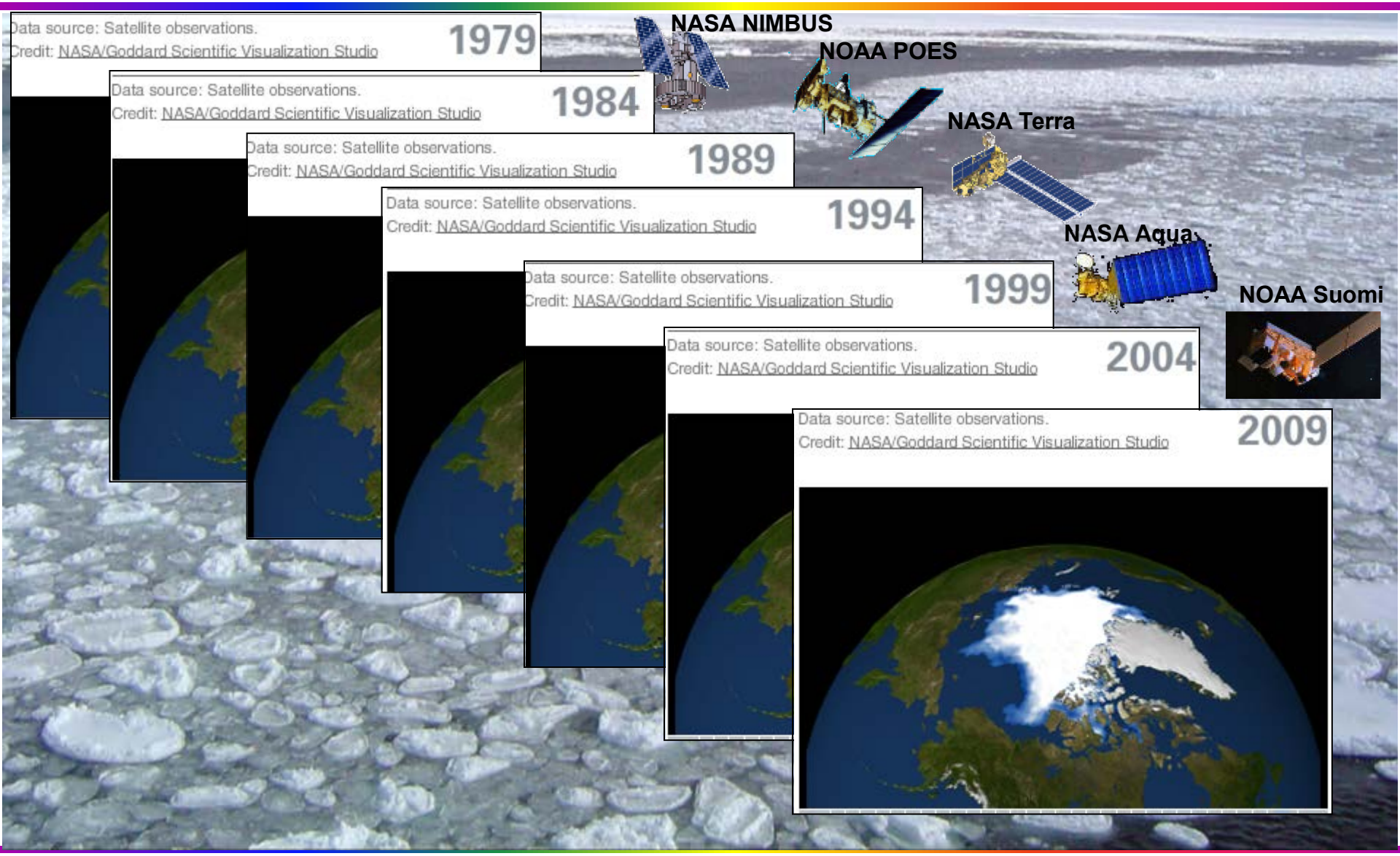
Global Surface Temperatures are Increasing

The years 2005 and 2010 are tied as the warmest years on record (Source NASA GISS).

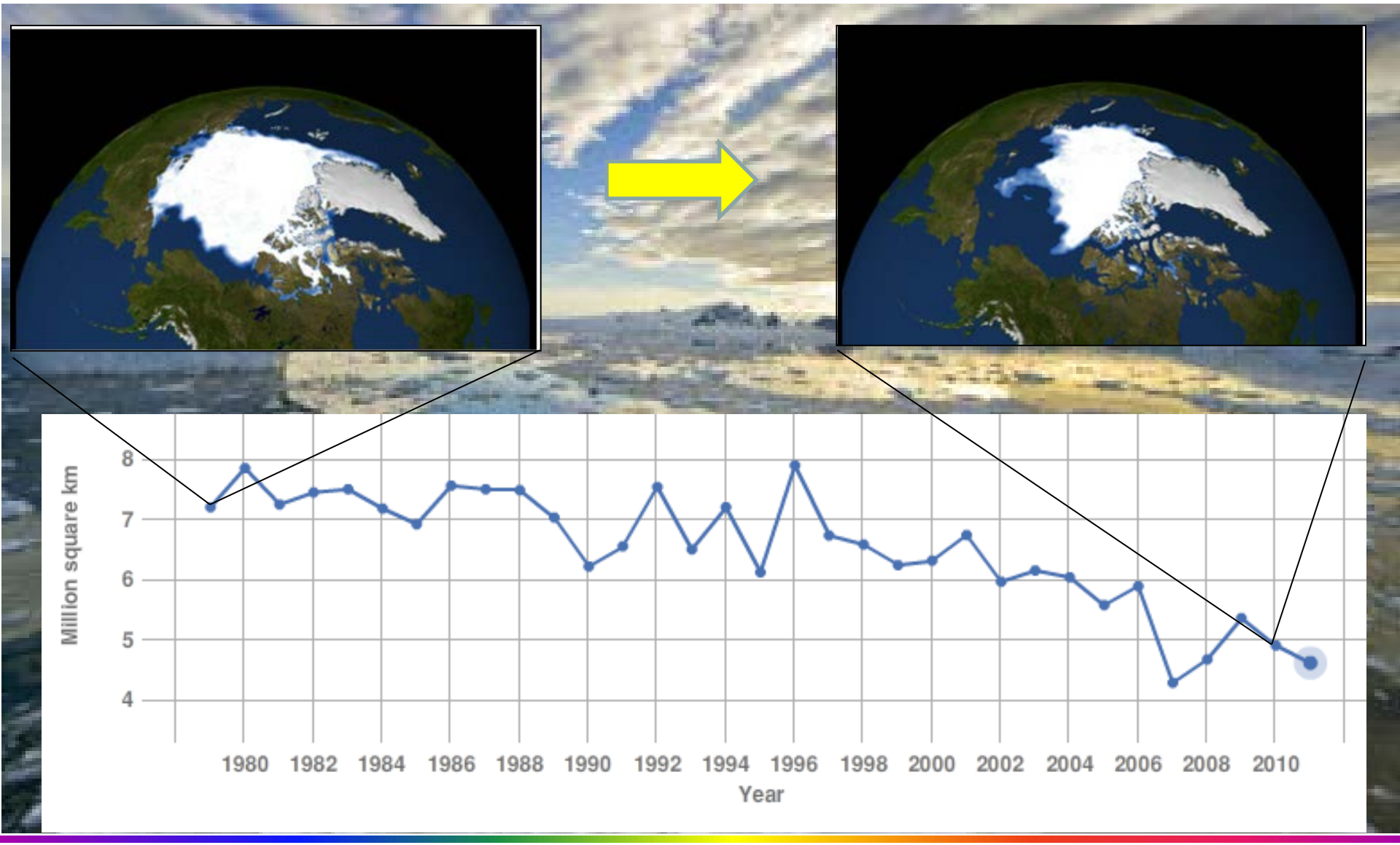


Impacts of Rising Temperatures: Drought, Dust Storms, Fire

Other Impacts of Rising Temperatures: Melting Polar Ice

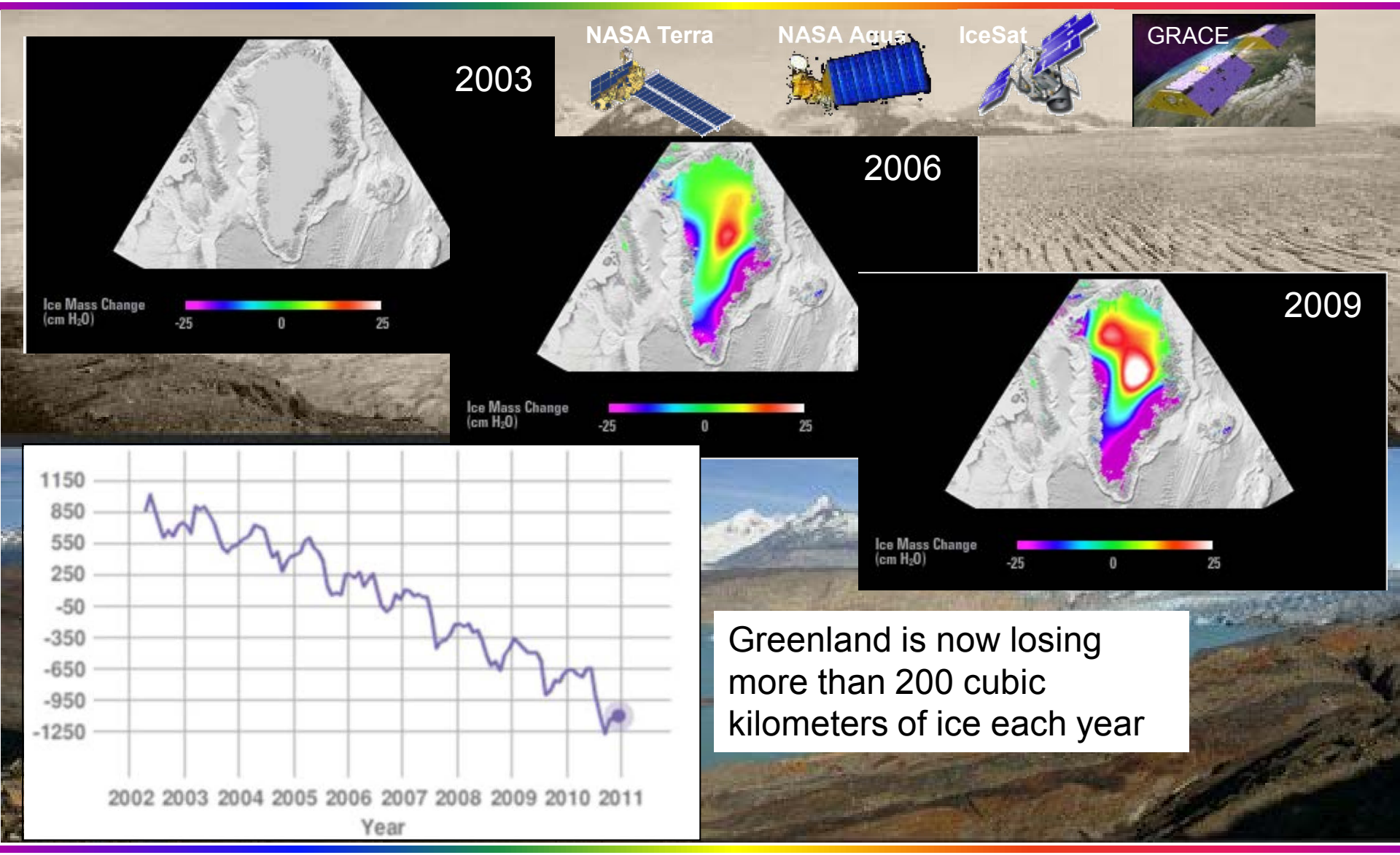


Arctic Sea Ice Extent is Decreasing



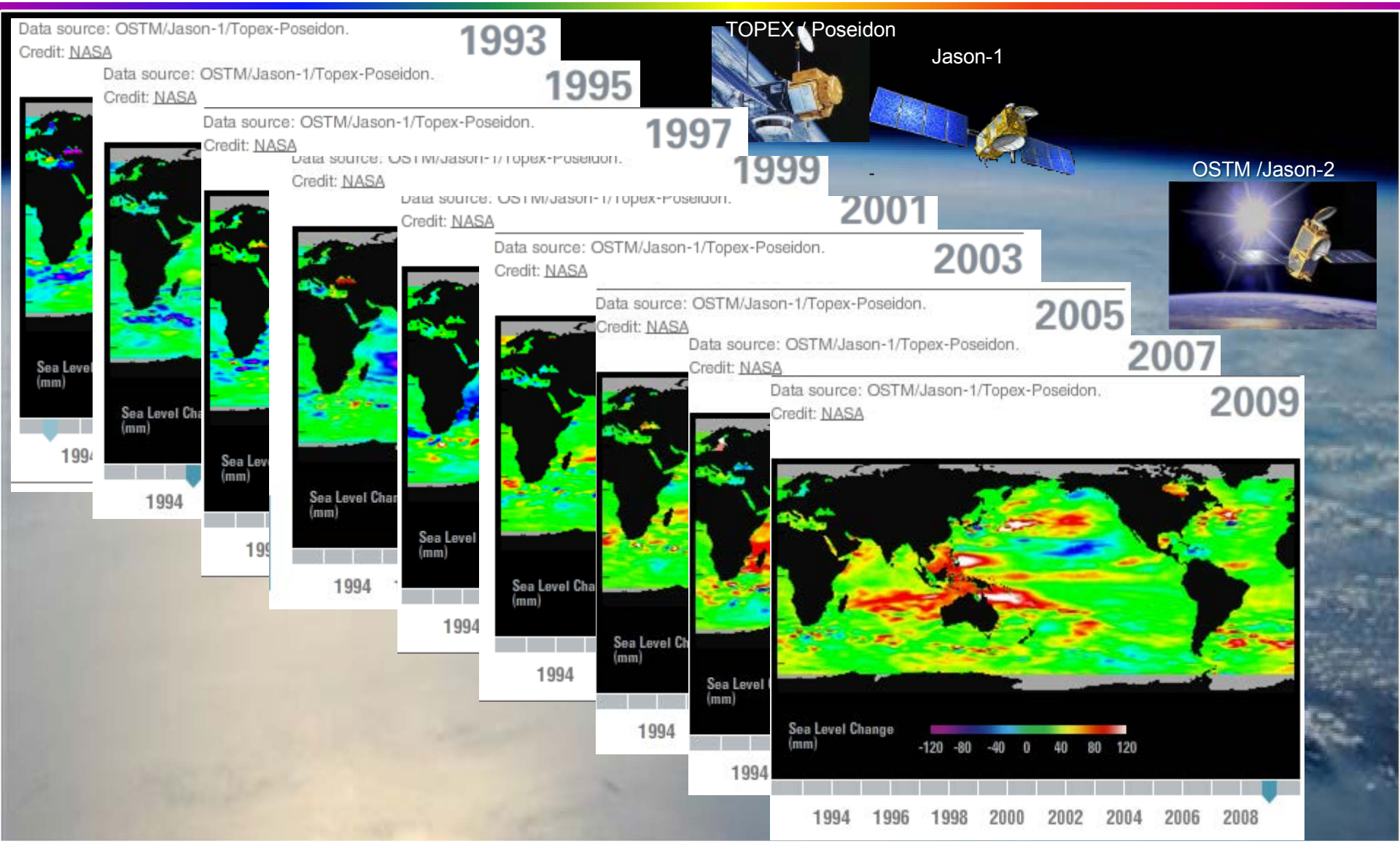
Crisp, NASA Climate

Land Ice

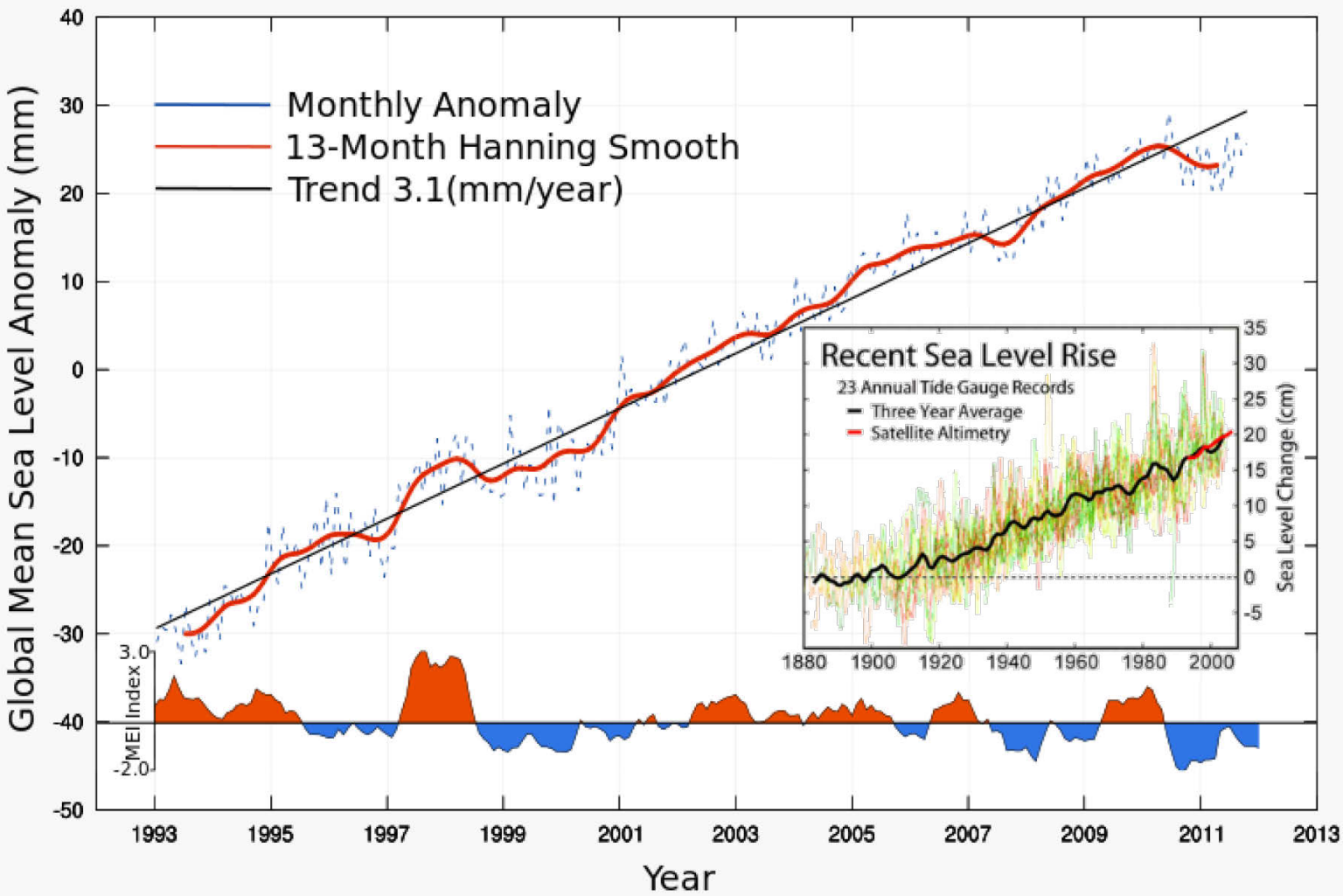


Greenland is now losing more than 200 cubic kilometers of ice each year

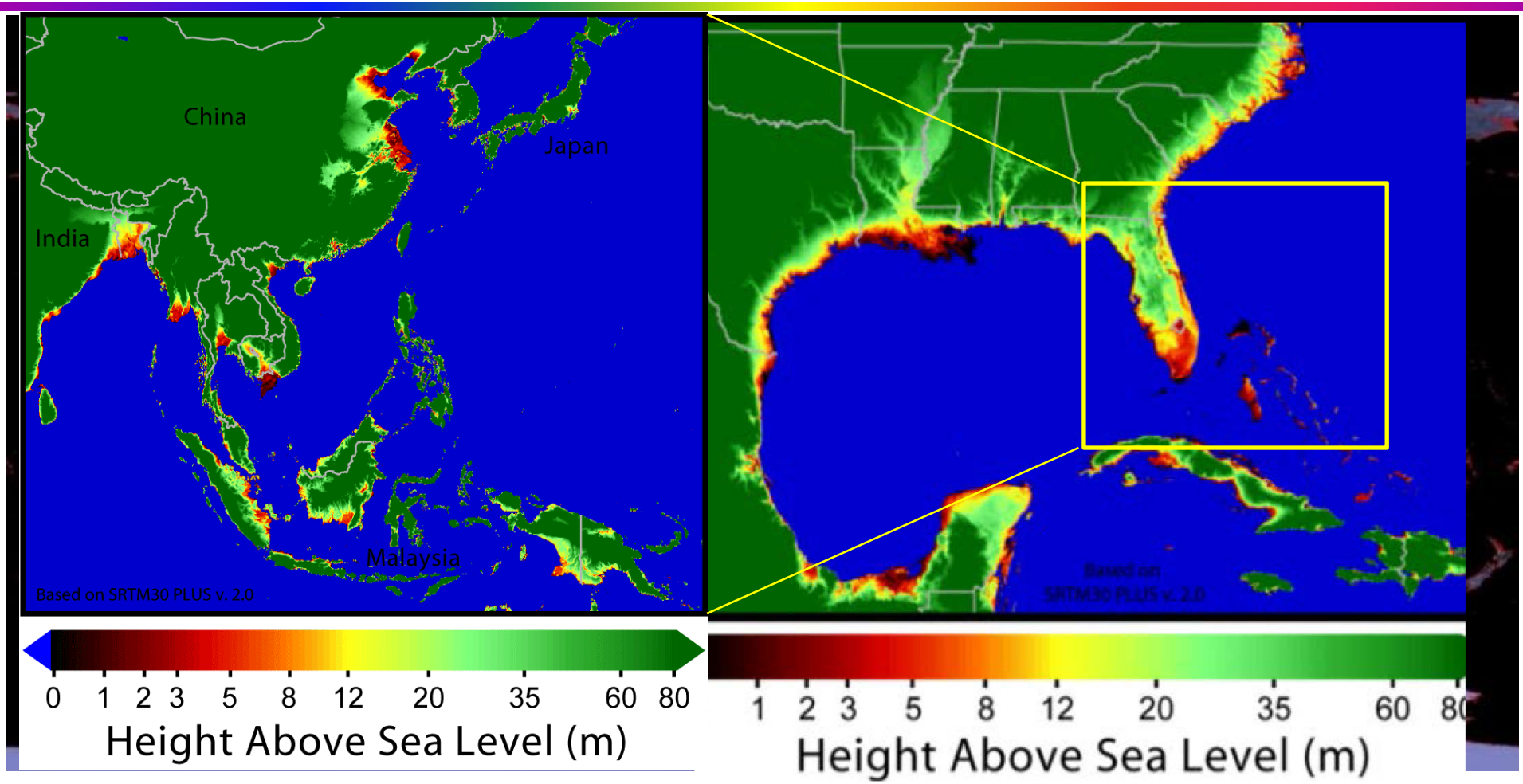
Monitoring Sea Level from Space



Sea Level is Rising over the Globe



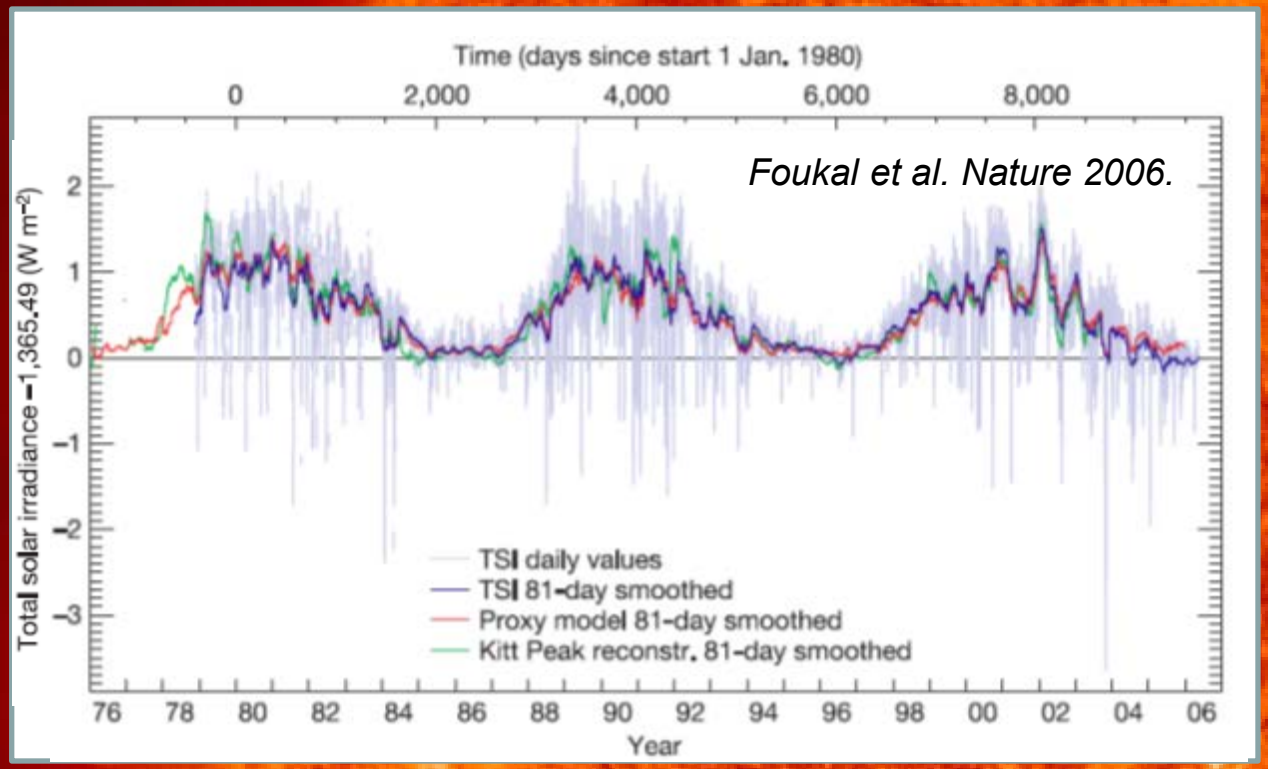
Regions Vulnerable to Sea Level Rise



- Over 600 million people live in coastal areas that are less than 10 meters above sea level
- Two-thirds of the world's cities with populations over 5 million are in these at-risk areas

Could the Sun be Causing These Climate Changes?

The Earth receives all of its energy from the sun. Could the sun be heating up?

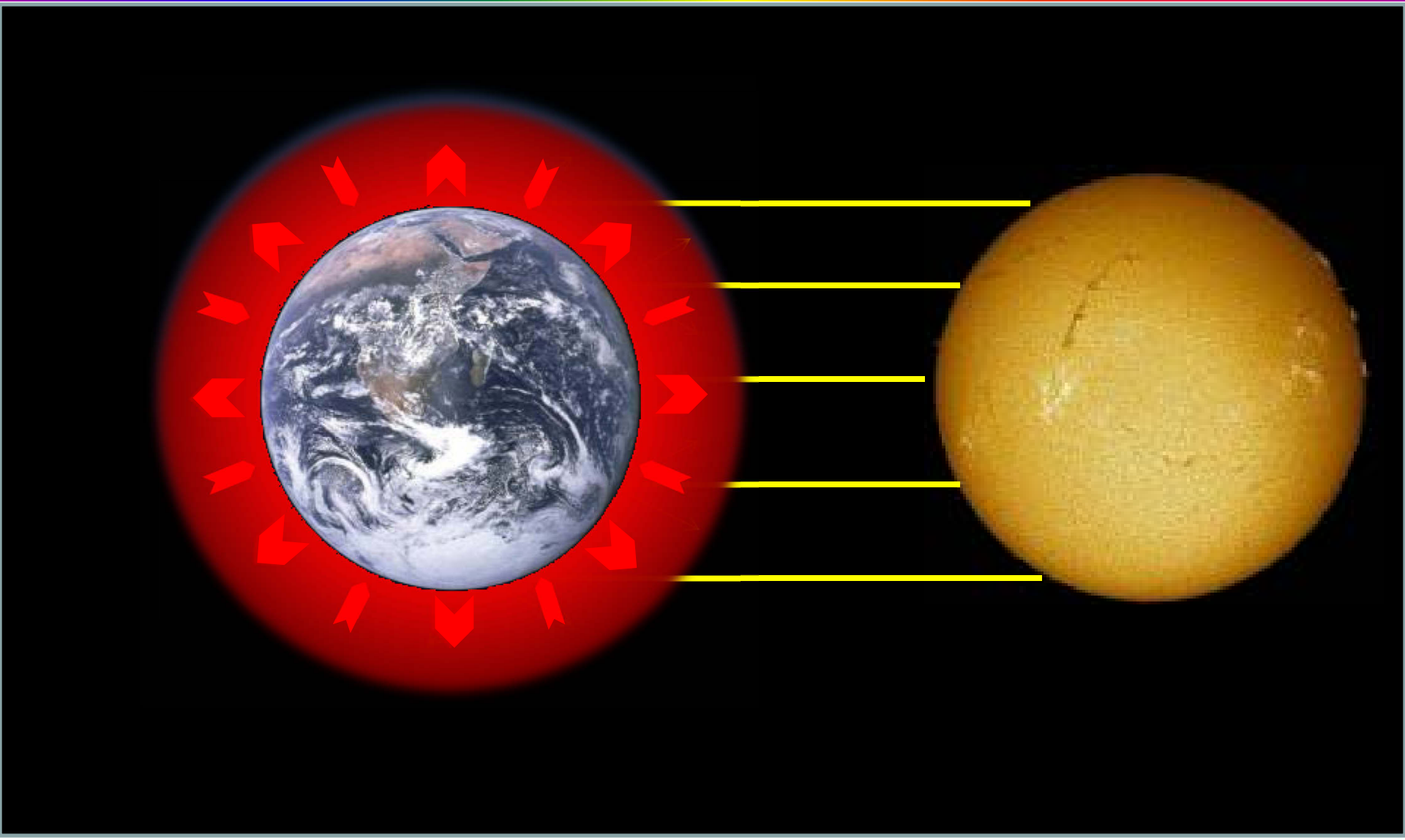


NASA has been monitoring the sun closely. There is no evidence that its output has increased.

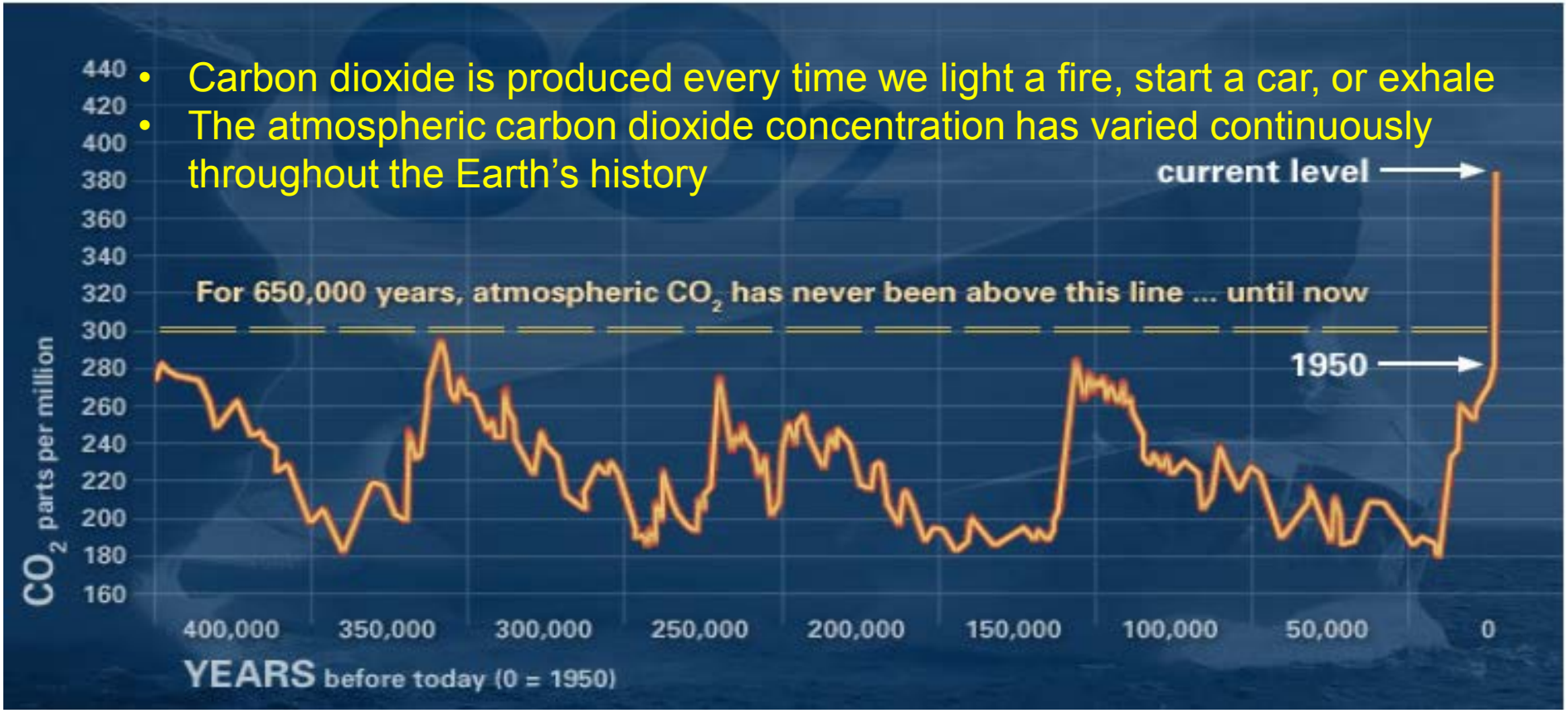
Greenhouse Effects and Global Warming

- The existing evidence indicates that the observed temperature increases are primarily due to heat trapping by greenhouse gases
- These gases act as a blanket for the Earth, absorbing heat and warming the surface to a life-supporting average of 15 degrees Celsius.
- The primary greenhouse gases are water vapor, carbon dioxide, and ozone. Methane, nitrous oxide and other gases contribute to greenhouse warming
- Recently, carbon dioxide (CO_2) increases have been contributed primarily by human activities, including fossil fuel combustion, deforestation, and other land use practices

Atmospheric Greenhouse Effects

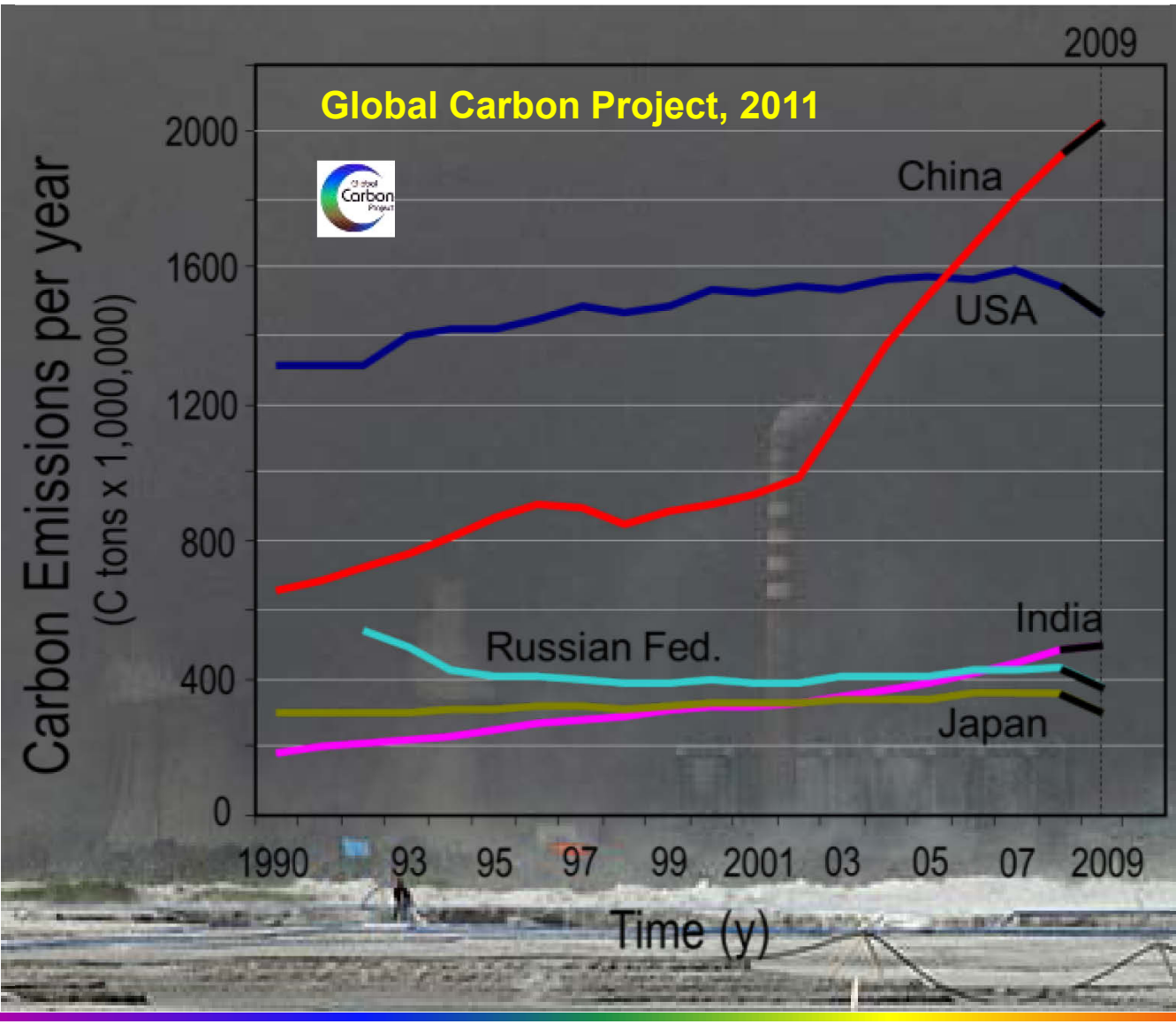


Atmospheric Carbon Dioxide – The primary Man-Made Greenhouse Gas



Since the 1950's, atmospheric carbon dioxide (CO_2) concentrations have risen to levels not seen for the past 650,000 years.
They are now increasing … *RAPIDLY*

Fossil Fuel CO_2 Emissions: Top Emitters



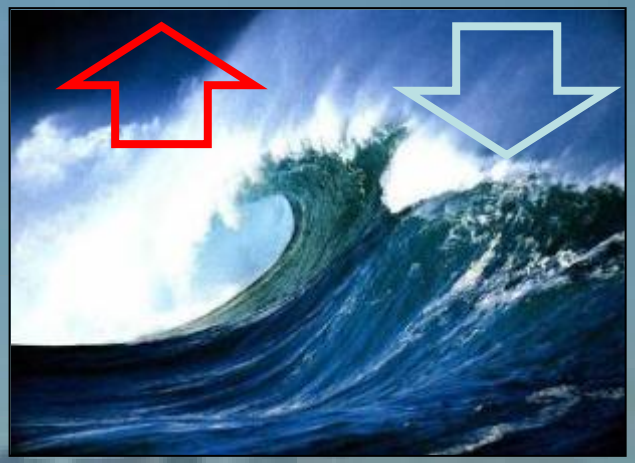
Human Activities are adding more than 30 billion tons of carbon dioxide to the atmosphere each year.

In recent years, the largest increases in fossil fuel emissions have occurred in developing countries.

China is now the largest single emitter, but its per capita emissions are still well below those in the U.S.

What Controls Atmospheric Carbon Dioxide?

- Natural systems including the ocean and plants on land both absorb and emit carbon dioxide to the atmosphere



- Currently, these natural systems are
  - absorbing about half of the carbon dioxide emitted by human activities
  - limiting the rate of carbon dioxide buildup and its impact on the Earth's climate

- Fundamental questions:
  - What processes are responsible for absorbing this CO_2?
  - Why does the sink strength vary dramatically from year to year?
  - Will the nature, location and strength of these CO_2 sinks change in the future?

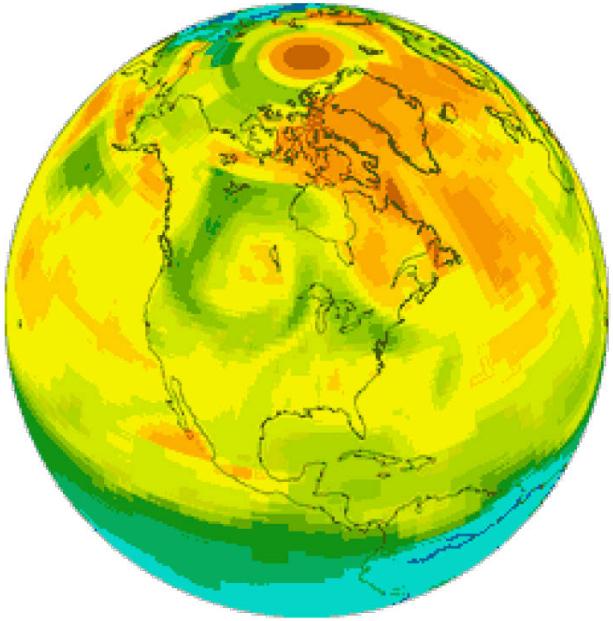
Global Measurements from Space are Essential for Monitoring Atmospheric CO_2

To limit the rate of atmospheric carbon dioxide buildup, we must

- Control emissions associated with human activities
- Understand & exploit natural processes that absorb carbon dioxide

We can only manage what we can measure

Plumes from medium-sized power plants (4 MtC/yr) elevate X_{CO2} levels by ~2 ppm for 10's of km downwind [Yang and Fung, 2010].

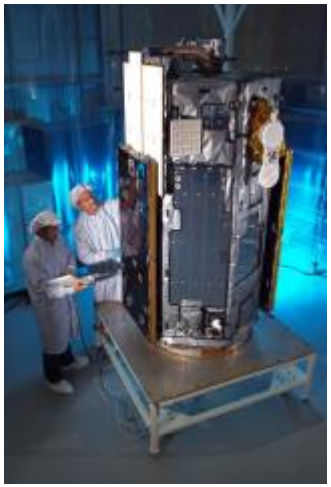


These variations are superimposed on a background of "**CO_2 weather**"

Monitoring Carbon Dioxide from Space: The Japanese GOSAT and NASA OCO Mission

Because of the importance of carbon dioxide to the climate system, both Japan and the US have developed satellites to monitor this gas over the entire globe

- **GOSAT, (nick-named Ibuki)**
  - Joint Project of JAXA, MoE, and NIES
  - Launched in January 2009
  - Optimized for spectral and spatial coverage
  - Collects 10,000 soundings every day



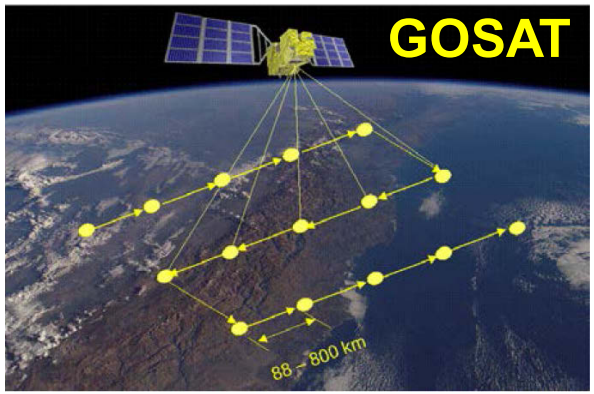
- **NASA Orbiting Carbon Observatory**
  - Optimized for high sensitivity and resolution
  - Designed to collect up to a million soundings each day

GOSAT-OCO Collaboration

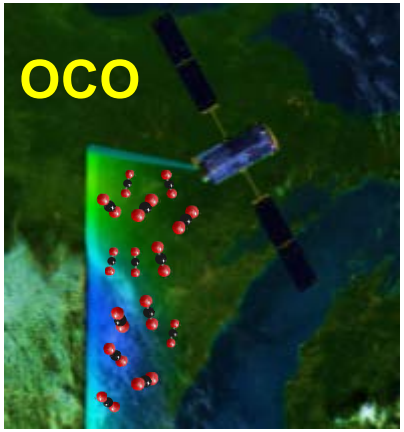
The OCO and GOSAT teams formed a close partnership during the implementation phases of these missions

The objectives of this partnership were to:

- Accelerate understanding of this new data source
- Facilitate combining results from GOSAT and OCO



3-day ground track repeat cycle resolves weather



Continuous, high resolution measurements along track

The Launch of GOSAT & Loss of OCO

GOSAT launched successfully on 23 January 2009

OCO was lost a month later when its launch system failed

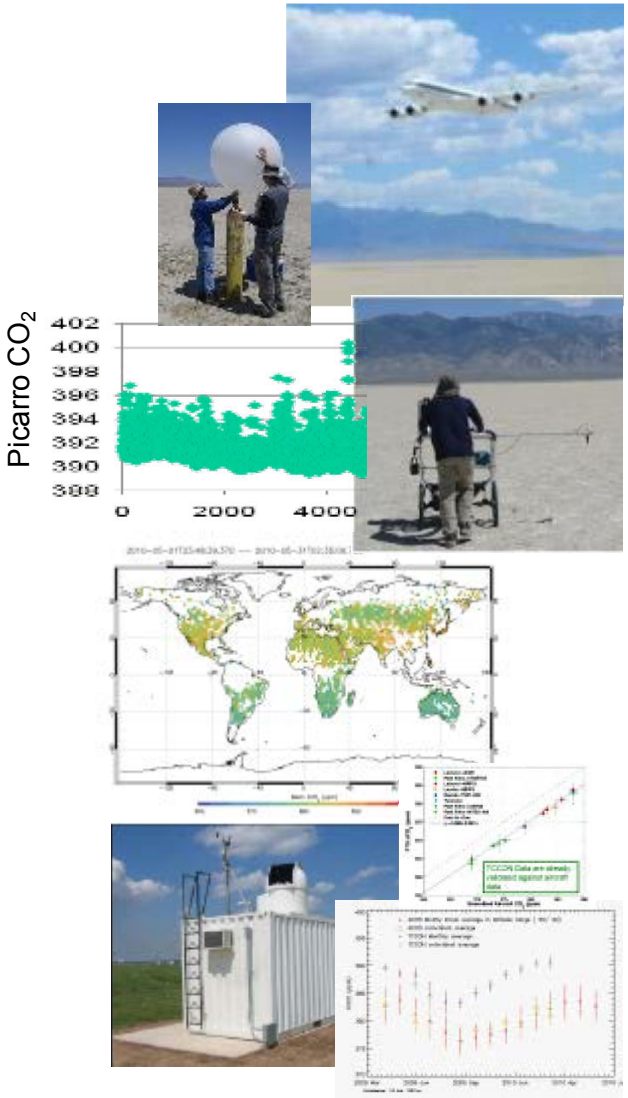
The ACOS/GOSAT Collaboration

- Immediately after the loss of OCO, the GOSAT Project manager invited the OCO Team to participate in GOSAT data analysis

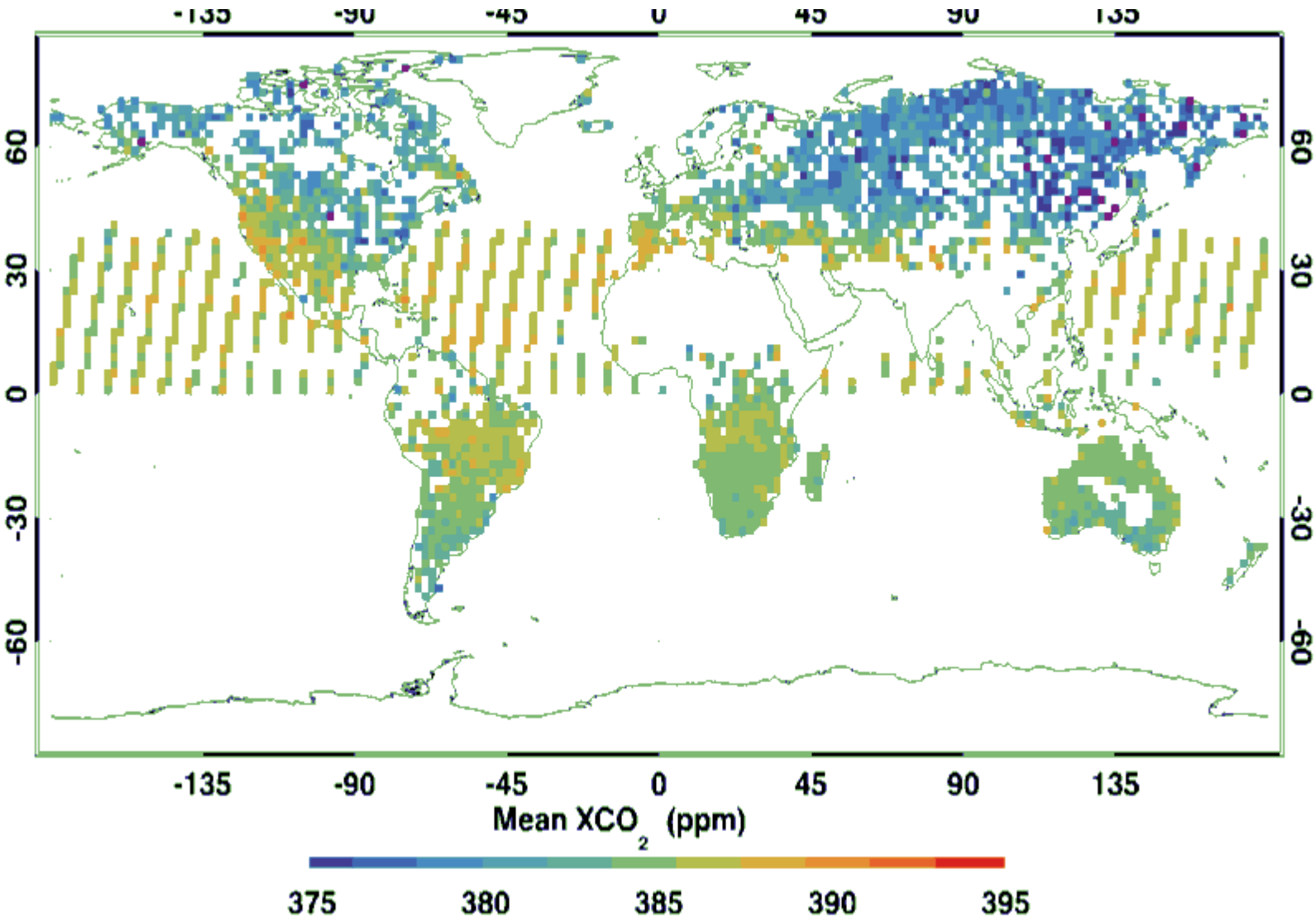
- The ACOS team is collaborating closely with the GOSAT teams at JAXA and NIES to:
  - Conduct calibration campaigns
  - Retrieve X_{CO2} from GOSAT spectra
  - Validate GOSAT retrievals against established standards

- A replacement for the NASA OCO mission, called OCO-2 is now under Development

- Participation in the GOSAT project is expected to accelerate the delivery of data from OCO-2.

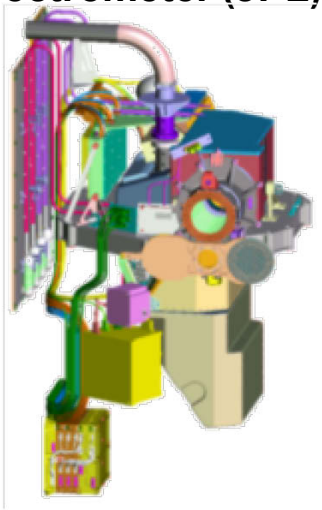


Global Maps of CO_2 from GOSAT, produced by the OCO Team

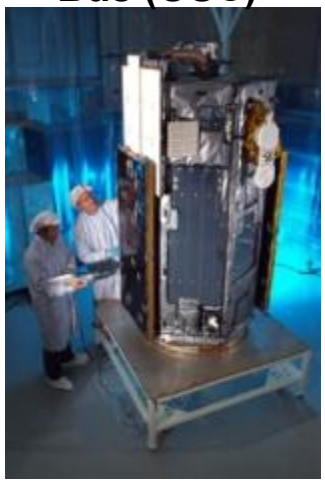


The OCO-2 Mission is Under Development

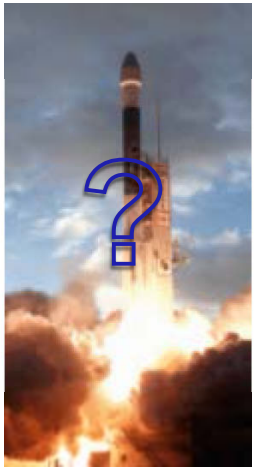
3-Channel Spectrometer (JPL)



Dedicated Spacecraft Bus (OSC)



TBD Launch Vehicle

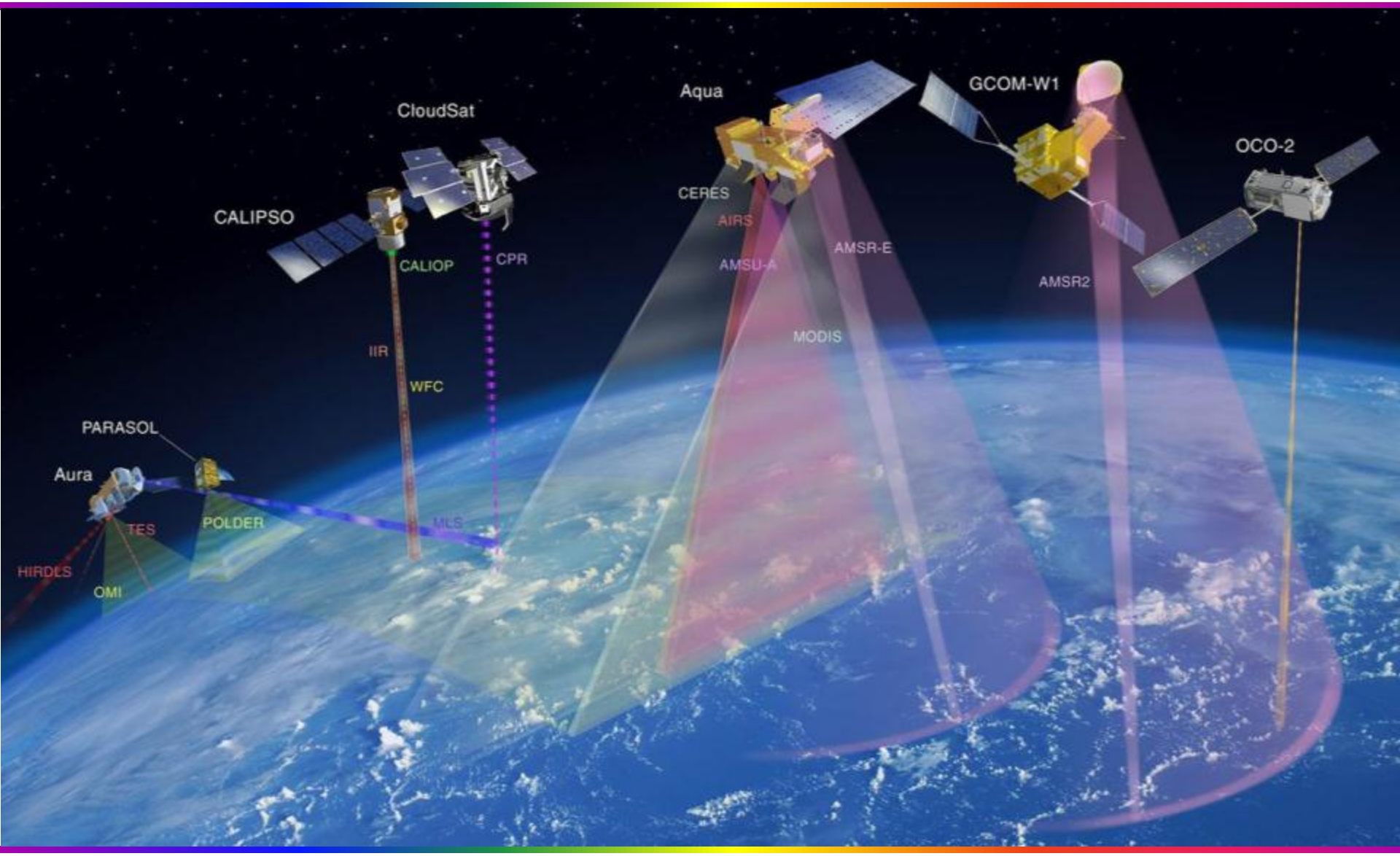


Mission Operations (OSC)

Formation Flying as Part of the A-Train Constellation

NASA NEN (GSFC) and SN (TDRSS)

OCO-2 Will Fly in the A-Train



More Information

- NASA and its partners are currently operating more than a dozen spacecraft in orbit around the Earth to monitor the health of its climate, and more are under development
- You can learn more about these and other NASA Earth Science missions at the web sites:

http://climate.nasa.gov/

and

http://science.nasa.gov/earth-science/

Thank you for your attention