

# Climate Studies

introduction to climate science

## Chapter 2

# Observing Earth's Climate

# Essential Questions

- What are the essential climate variables?
- Why are essential climate variable important to monitor?
- How are observations of the essential climate variables collected?
- Where are observations of the essential climate variables monitored?
- Who observes the climate systems and its sub-systems?
- How are climatic observations used and by whom?

# What and why we observe Earth's climate system

- In order to understand how the climate works we need climatic observations
- Cannot prepare for changes in climate if we don't know what to expect
- **Global Climate Observing System (GCOS)** has aided in the collection and sharing of observations as they relate to the climate system
  - **GCOS** - a multinational collaboration that involves data from a multidisciplinary range of physical, chemical and biological properties, and atmospheric, oceanic and terrestrial processes

# What and why we observe Earth's climate system

## Essential Climate Variables

- **Essential Climate Variables (ECVs)** – those quantities with measurable values that define the current state of Earth's climate system, and allow us to study its processes and predict future states
  - Easy to measure and are fully monitored
  - Over 50 variables from all spheres
  - Help to paint a picture of what is going on

# What and why we observe Earth's climate system

## Essential Climate Variables

Domain	GCOS Essential Climate Variables
<p><b>Atmospheric</b> (over land, sea and ice)</p>	<p><b>Surface:</b> [1] Air temperature, wind speed and direction, water vapor, pressure, precipitation, surface radiation budget</p> <p><b>Upper-air:</b> [2] Temperature, wind speed and direction, water vapor, cloud properties, Earth radiation budget (including solar irradiance)</p> <p><b>Composition:</b> Carbon dioxide, methane, and other long-lived greenhouse gases [3], ozone and aerosol, supported by their precursors [4]</p>
<p><b>Oceanic</b></p>	<p><b>Surface:</b> [5] Sea-surface temperature, sea-surface salinity, sea level, sea state, sea ice, surface current, ocean color, carbon dioxide partial pressure, ocean acidity, phytoplankton</p> <p><b>Sub-surface:</b> Temperature, salinity, current, nutrients, carbon dioxide partial pressure, ocean acidity, oxygen, tracers</p>
<p><b>Terrestrial</b></p>	<p>River discharge, water use, groundwater, lakes, snow cover, glaciers and ice caps, ice sheets, permafrost, albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (FAPAR), leaf area index (LAI), above-ground biomass, soil carbon, fire disturbance, soil moisture</p>

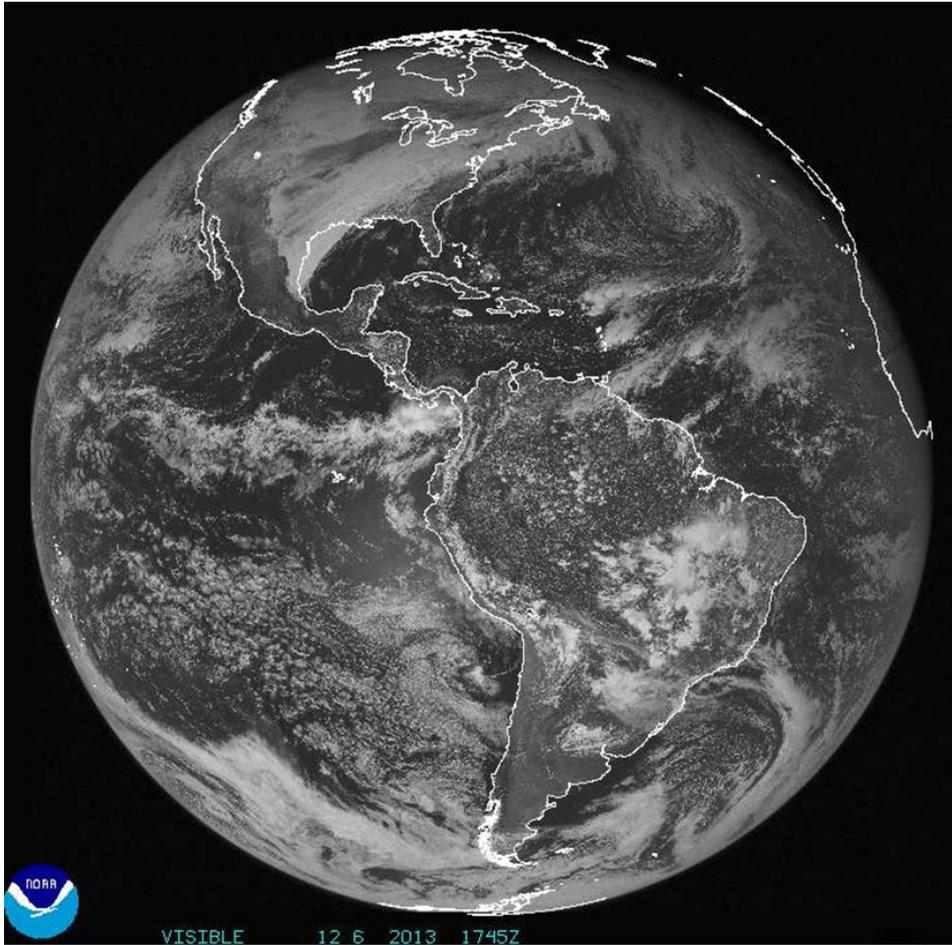
# What and why we observe Earth's climate system

## Acquisition of ECVs

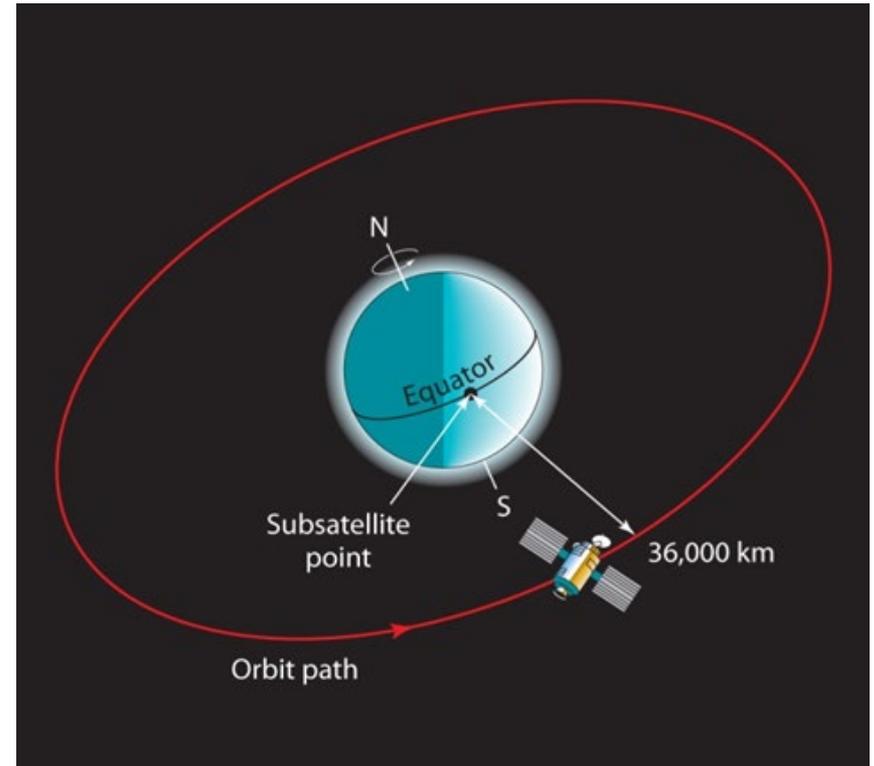
- Observations of ECVs fall into two categories:
  - **In situ** – measurements obtained by direct contact with the sample
    - Can be used to calibrate remotely sensed data
    - Considered to be more accurate
  - **Remote sensing** – measurements obtained from a distance



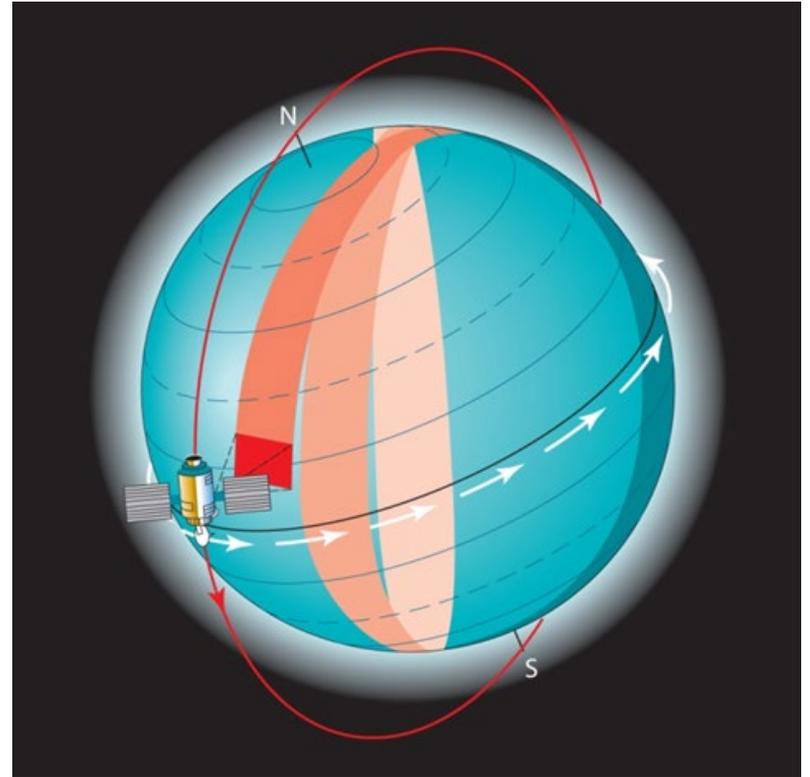
- Fastest growing class of remotely sensed observations is satellite data
  - Sensors on board monitor a variety of variables
  - Much more efficient at collecting data
- Two types of orbits:
  - **Geostationary** - a path, relative 36,000 km (22,300 mi.) high, through space that is at the same rate and direction as the rotation of Earth, thus staying directly above the same spot on Earth
  - **Polar** - a path through space, generally 800 to 1000 km (500 to 600 mi) high, that follows a fixed plane while Earth rotates on its axis within that plane.



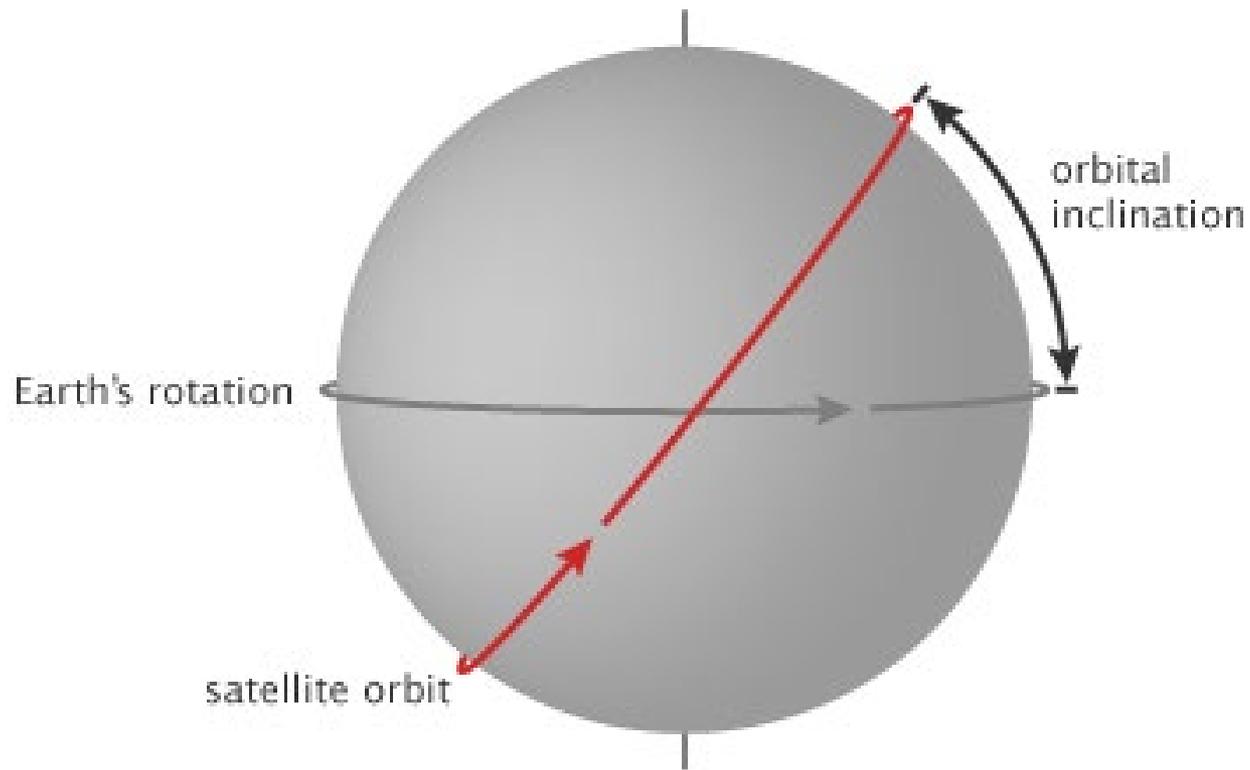
- **Geostationary Operational Environmental Satellites (GOES-East, GOES-West)** – geostationary weather satellites, one over South America near  $75^{\circ}$  W longitude and one over the eastern Pacific Ocean at  $135^{\circ}$  W longitude to provide a complete view of much of North America and adjacent portions on the Pacific Atlantic Oceans



- **Polar-orbiting satellites**
  - a satellite with a revolution that traces a fixed plane while Earth rotates on its axis positioned in the plane



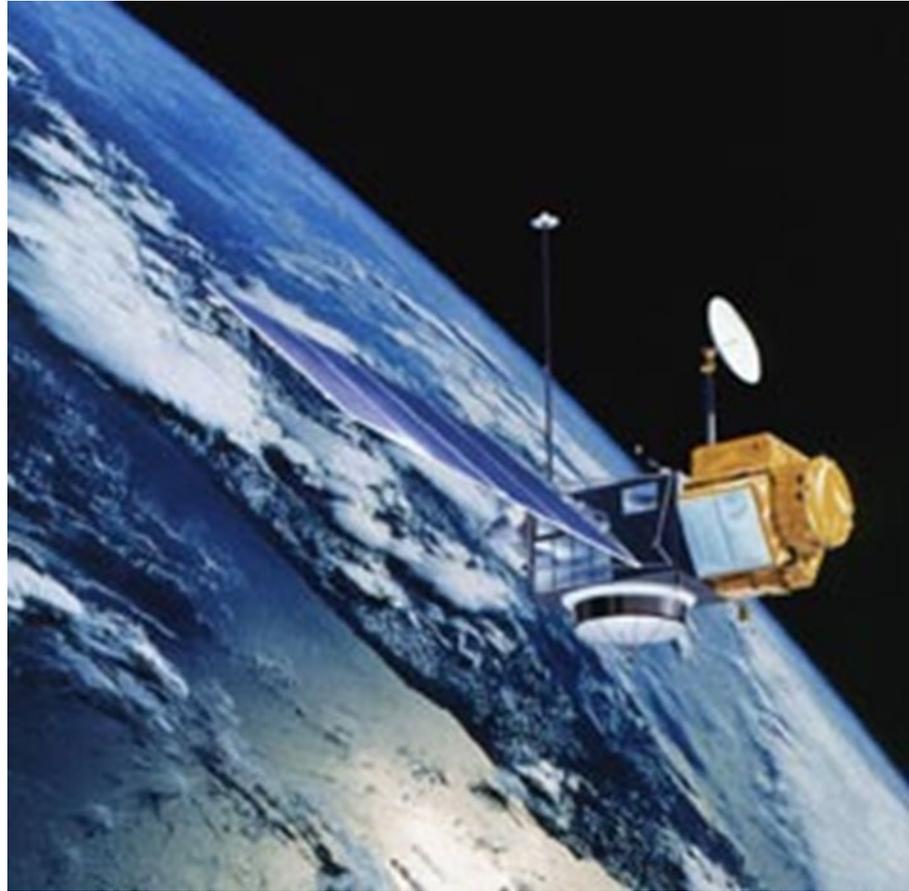
- NOAA's GOES satellites provide data for much of the globe, but cannot collect highly refined data near the poles
- Polar orbiting satellites miss the geographic poles due to the gravitational field of the Earth



- **Satellite Meteorology and Climatology Division (SMCD)** conducts research and develops new satellite products to improve and increase use of satellites in measuring ECVs
- Includes:
  - Atmospheric Variables
  - Land Surface Variables
  - Hydrological Cycle Variables
  - Environmental Hazards
  - Climate Variables

- **Satellite Climate Studies Branch (SCSB)** - a sub-organization of NOAA's SMCD that exploits the capabilities of Earth-observing satellites to investigate climate variations in the atmosphere, land and ocean
- **Cooperative Institute for Climate and Satellites (CICS)** - hosted by the University of Maryland to serve as a liaison between federal scientists and those in academia so that they may work together toward similar goals in utilizing satellite technologies for climate system investigations

- NASA also has many satellites that have been used for climate observations, including **TOPEX/Poseidon**
  - a joint venture between France's CNES and NASA, launched in 1992, that measured ocean surface topography
  - Eventually replaced with JASON/JASON2

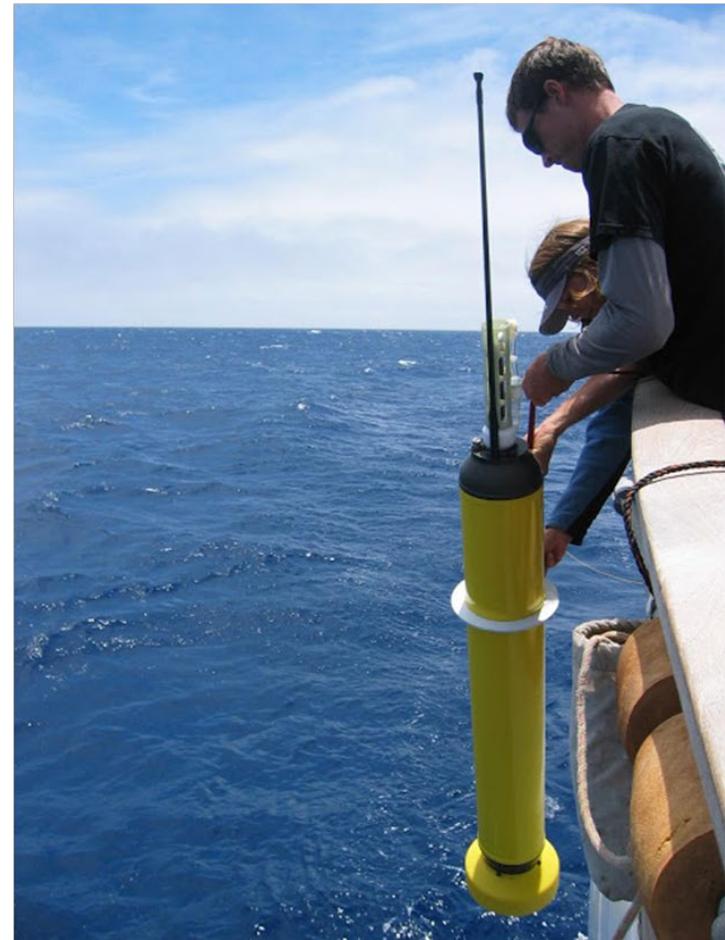
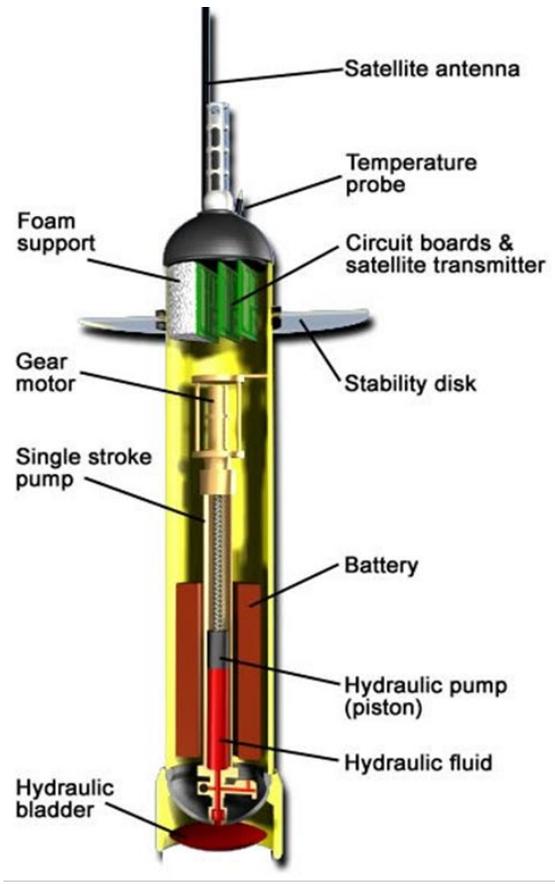


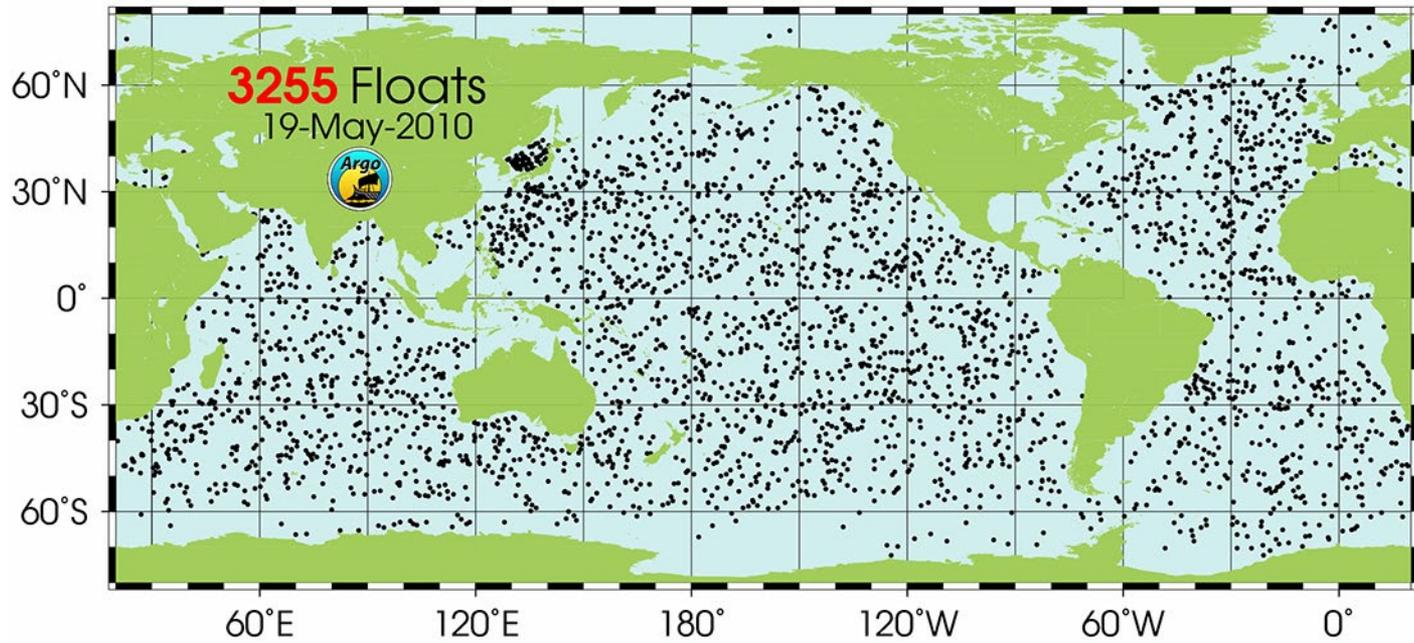
# What and why we observe Earth's climate system

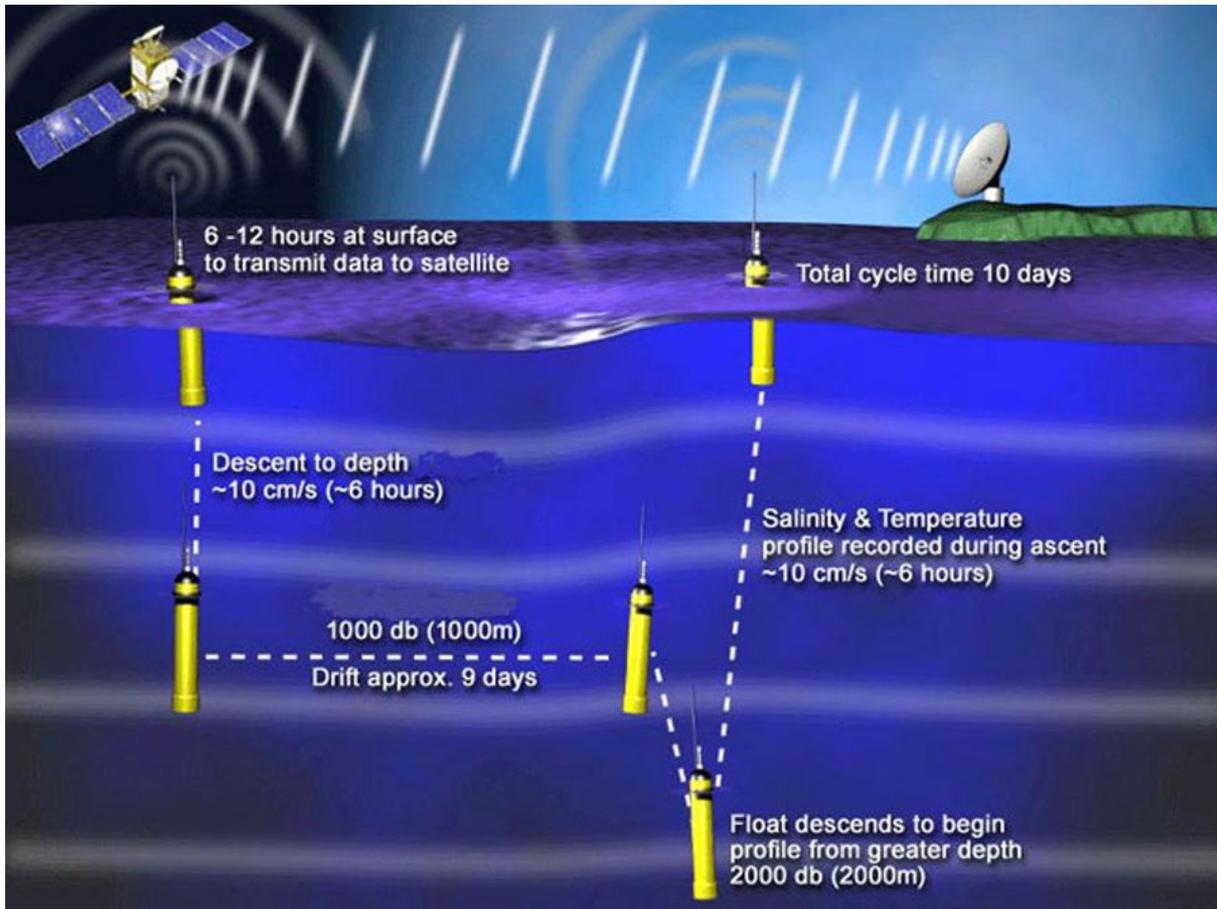
## Challenges in Sampling EVCs

- Challenges to maintaining instruments in orbit
- Varying observational capabilities needed
- Quality data is needed
  - Data obtained from accurate, high precision instruments
  - Analyzed and deemed to have little bias

- Oceans present a challenge both in obtaining measurements and ensuring quality
- **Argo** - a global-scale ocean observation network composed of small, drifting and diving robotic probes that measure conductivity and temperature profile and transmit data when at the surface







- Argo aids in calibrating remote sensing platforms and also is able to measure ECVs at the depths of the ocean
- Arrays such as Argo are being used in other scientific communities and to monitor additional climate variables

# What and why we observe Earth's climate system

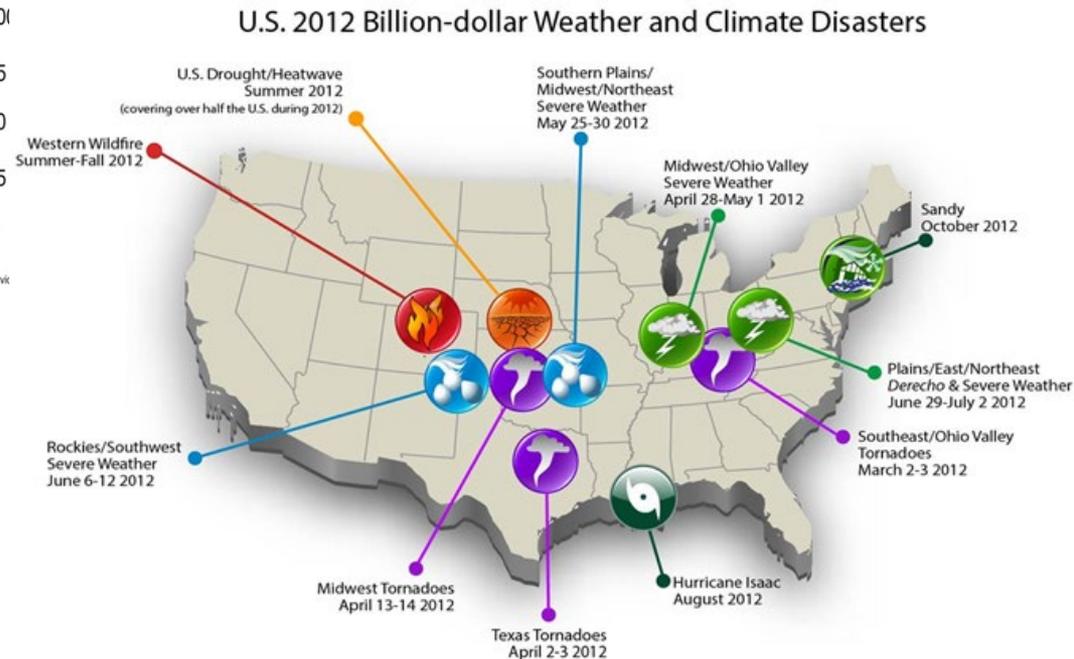
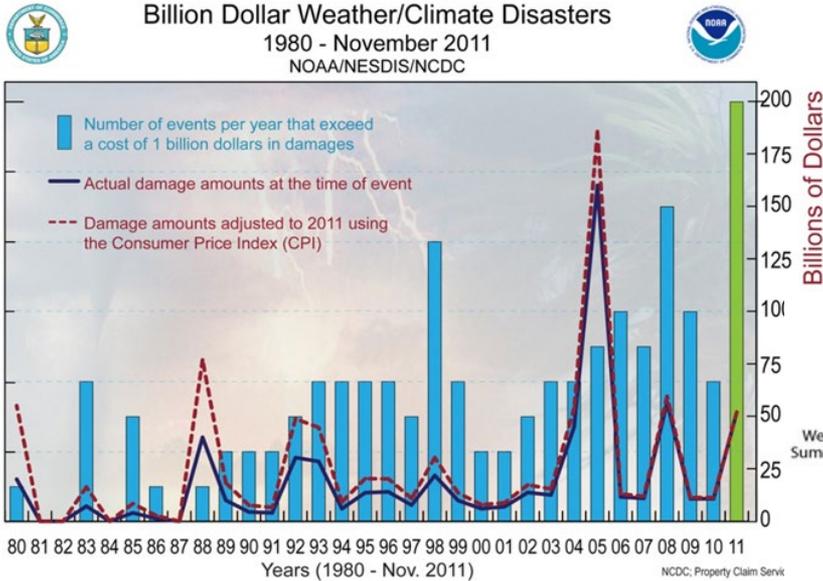
## Other ECV-Related Indicators of Climate

- **Climate Change Initiative (CCI)** – an open climate data record, created by the ESA, for 13 ECVs
- **Climate Data Record (CDR)** Project addresses the challenges of combining all past and present data together to make a long term record
- As sensors are replaced, they are replaced with sensors of better quality or with different observational capabilities

- **Environmental Protection Agency (EPA)**
  - a U.S. government agency that monitors the climate system by working with many other organizations to collect data on 26 environmental indicators, such as greenhouse gas emissions (using a CO<sub>2</sub> equivalency), U.S. temperatures and precipitation, sea surface temperatures, ocean acidity, Arctic sea ice, snow cover, ragweed pollen season, and heat-related deaths
  - The EPA's climate role fits into its broader purpose of protecting human health and the environment by monitoring, regulating and enforcing laws governing water, air, waste, pollution, pesticides and other environmental topics

Realm	Measurements
<b>Greenhouse gases</b>	U.S. greenhouse gas emissions Global greenhouse gas emissions Atmospheric concentrations of greenhouse gases Climate forcing
<b>Weather and climate</b>	U.S. global temperature High and low temperatures U.S. global precipitation Heavy precipitation Drought Tropical cyclone activity
<b>Oceans</b>	Ocean heat Sea surface temperature Sea level Ocean acidity
<b>Snow and ice</b>	Arctic sea ice Glaciers Lake ice Snowfall Snow cover Snowpack
<b>Society and ecosystem</b>	Streamflow Ragweed pollen season Length of growing season Leaf and bloom dates Bird wintering ranges Heat-related deaths

# How and Where we observe Earth's Climate System



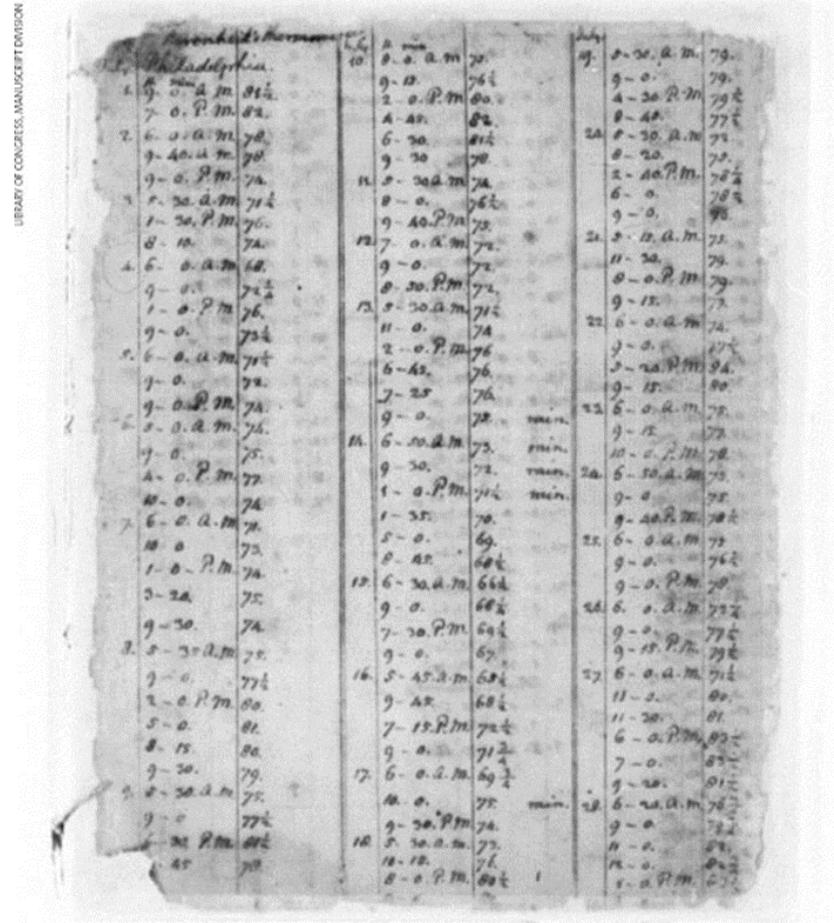
- Need for monitoring the climate is underscored by the amount of damage caused by weather related disasters

- Monitoring ECVs must be a consistent, continuum of observations to paint the big picture
- Predicting change requires a quality reference point on which to validate models

# Climate Observing Systems in the U.S

## Atmospheric Sampling on Earth's Surface

- **COoperative weather Observer Program** uses citizen observational data to construct a record of trends for temperature and precipitation
  - **National Weather Service** is the direct contact for collecting this information
- Dates back to Thomas Jefferson



## Cooperative Observer Program (COOP) Network



- COOP system has limitations
  - Require a person to make observations at the same time to the same degree of accuracy
- **Automated Surface Observing System (ASOS)**
  - an automated, electronic system that replaces the need for some of the COOPs manual observations
  - Data is considered cleaner since they are automated
    - First-order data



# NATIONAL WEATHER SERVICE ASOS SITES



- Though a large amount of data exists from COOP and ASOS sites, there is discontinuity in the data
- Changes in observational methodology, instrumentation and location have caused some differences in data
  - Requires more effort in using these data points in the climate record

- **U.S. Historical Climatological Network (USHCN)** is a sub-network of the COOP network to address specific climate concerns
  - Represent the best of the best COOP sites
  - Represented a usable dataset but was time-consuming to maintain
- **United States Climate Reference Network (USCRN)** began in 2002 to address inadequacies in data
  - Stations in areas likely to be unchanged so as to provide best chance at long term record

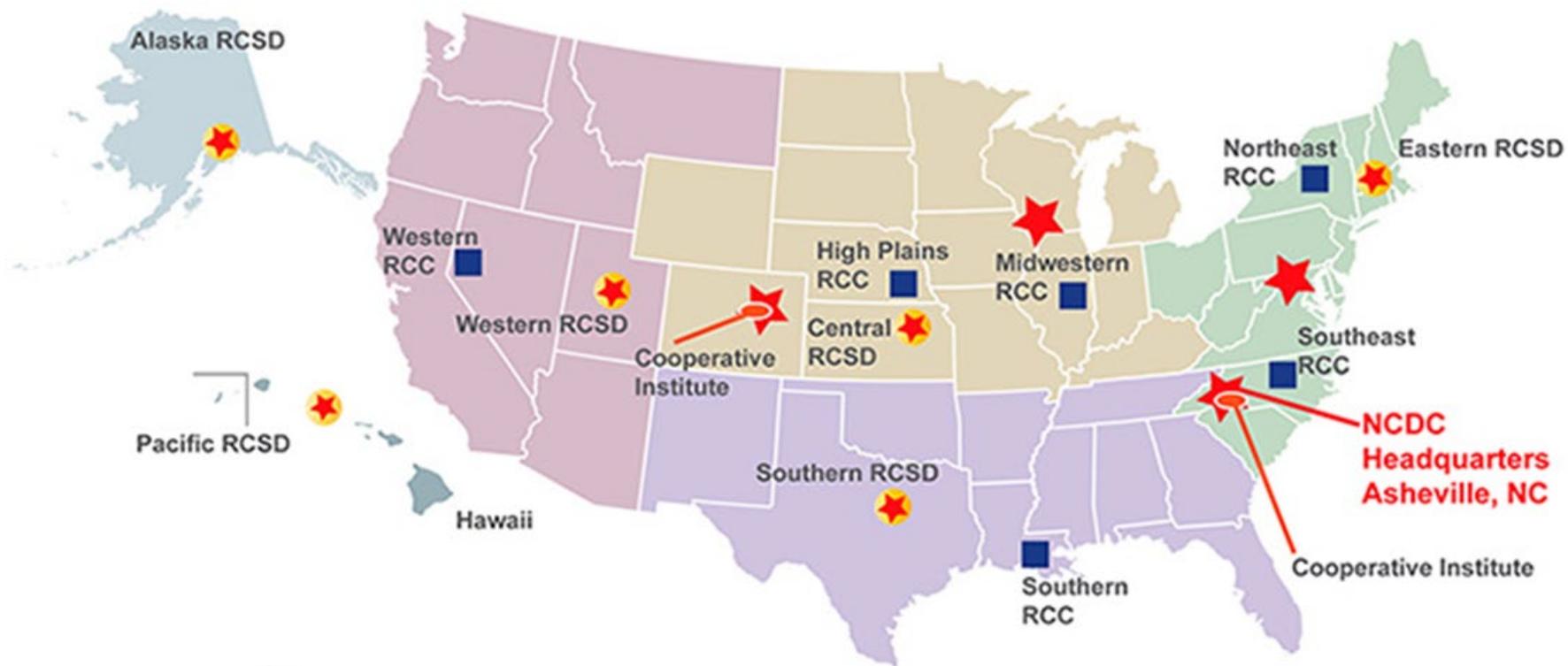
# Who Observes Earth's Climate System

- **Service climatologist** - a career that studies climate with the foremost goal to society of disseminating climate observation.
  - Also provides decision support with future climate conditions
  - Serves as a salesperson of climate data and assists with understanding of data
  - Understand instruments used and can recognize issues in data

# Who Observes Earth's Climate System

## Climate Data Centers

- **National Climatic Data Center** - the physical place where the collected climate observation and model products, as well as non-digital global records, are stored
- Regional climate centers support NCDC in data management
  - Linked with major universities
  - Allows for direct access for researchers and additional outreach in the community



 **NCDC staff location**

 **Cooperative Institute**

 **Regional Climate Center (RCC)**

 **NCDC Regional Climate Service Director (RCSD)**

- **State Climatologist** - a climate scientist, appointed by the state, that serves in one of the regional climate centers, often with a dual appointment at a faculty or state government, serving as an expert to the state government and its residents
- Climate scientists have a wide variety of duties
  - Requires cooperation from government, universities and private sector

# How Observations of Earth's Climate System are used and by whom

- International efforts to monitor climate exist
- **Intergovernmental Panel on Climate Change (IPCC)** tasked with evaluating scientific data and determining how it will impact the globe
  - The IPCC was formed by the U.N. Environmental Programme (UNEP) to evaluate the state of climate science as the basis for policy action, and informing scientists, public policy-makers and, ultimately, the public

- IPCC is politically neutral
  - Consists of three working groups and a task force
  - Examines all aspects of climate and impacts
  - Releases assessment reports that outline findings

# How Observations of Earth's Climate System are used and by whom

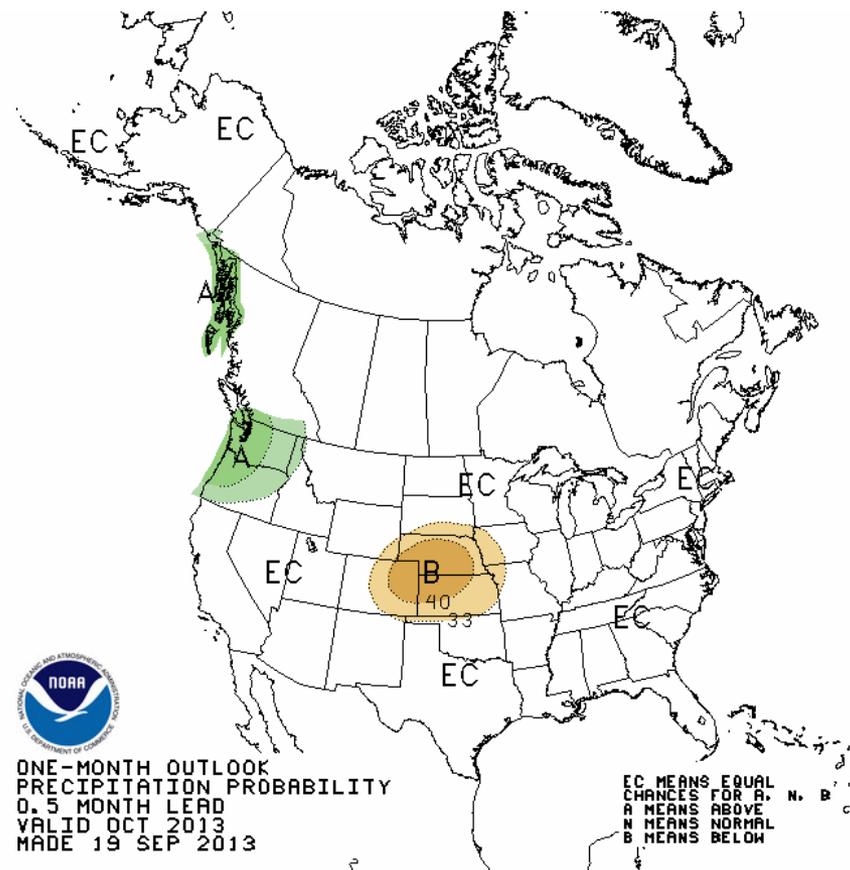
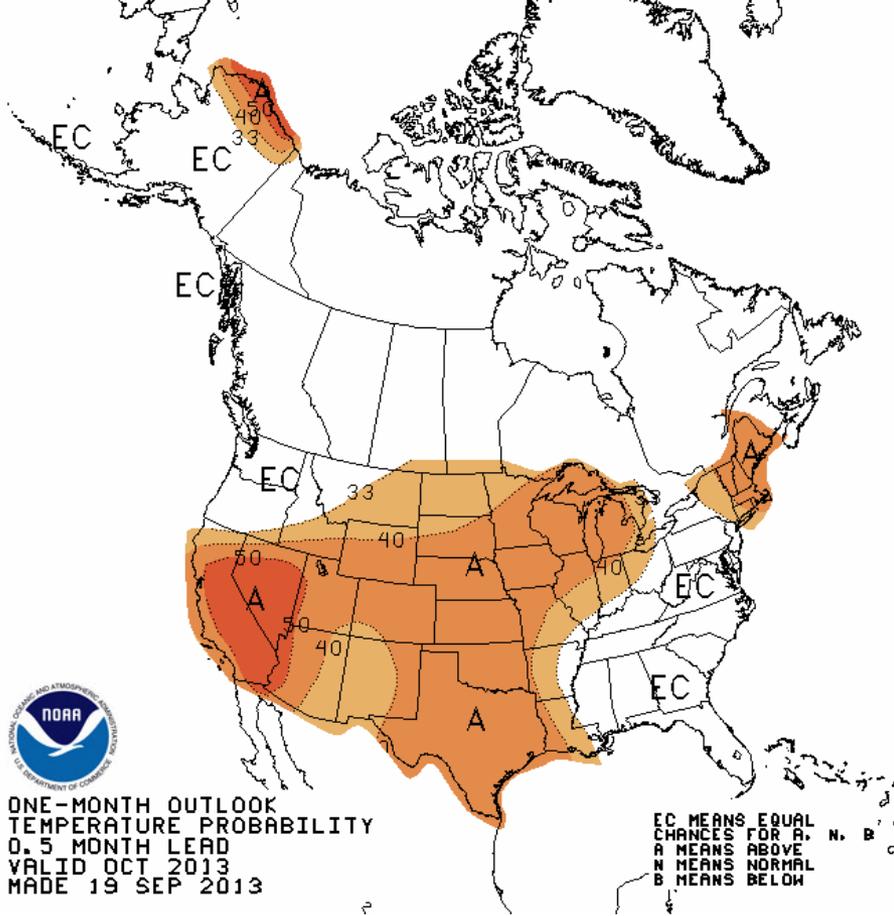
## Climate Modelers

- **Climate modelers** – climate scientists who not only use observational climate data but also create a whole new class of information by representing Earth's climate system virtually to experiment with different kinds of ECV observations and quantities
  - Come from throughout the scientific community
  - Play an important role in helping understand the climate system in terms of forecasting the future change
- **Primitive equations** - equations that quantify the motions of the atmosphere

# How Observations of Earth's Climate System are used and by whom

## Climate Forecasters

- Falls under the purview of the **National Center for Environmental Prediction (NCEP)**
  - part of NOAA that aims to deliver “analyses, guidance, forecasts and warnings for weather, ocean, climate, water, land surface and space weather to the Nation and the world.”
- **Climate Prediction Center (CPC)** delivers outlooks for climate variables for time periods of weeks to years with respect to normal values
  - Example: 30 day temperature



# Private sector applications of climate observations

- As much as \$4 trillion of the economy is sensitive to climate
- Use of climate data in business has expanded as data becomes more readily available

# Big Ideas

- Earth's climate has always and will always change.
- Related components of Earth's climate are not static.
- Some ECVs have changed drastically in the last million or so years.
- We do not know how these changes will impact humans.

# Key Terms

Global Climate Observing System (GCOS)

Essential Climate Variables (ECV)

In situ

Remote Sensing

Geostationary Orbits

Geostationary Operational Environmental Satellites (GOES)

National Aeronautics and Space Administration (NASA)

National Oceanic and Atmospheric Administration (NOAA)

Satellite Meteorology and Climatology Division (SMDC)

Satellite Climate Studies Branch (SMCD)

Topex/Poseidon

Jason2

ENVISAT

Argo

Climate Change Initiative (CCI)

Climate Data Record (CDR)

Cooperative Weather Observer Program (COOP)

National Weather Service (NWS)

Automated Surface Observing System (ASOS)

First-order network of climate observations

U.S. Historical Climatology Network (USHCN)

Service Climatologist

National Climatic Data Center (NCDC)

State Climatologist

Intergovernmental Panel on Climate Change (IPCC)

Primitive Equations

National Centers for Environmental Protection (NCEP)

Climate Prediction Center (CPC)

Weather Derivatives