

# Guide to the Science of Climate Change in the 21<sup>st</sup> Century

## Chapter 14 Modern Instrumental Period

David H. Manz  
PhD., P. Eng., AOE, FCAE  
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[https://www.nasa.gov/mission\\_pages/GPM/overview/index.html](https://www.nasa.gov/mission_pages/GPM/overview/index.html)

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<https://airs.jpl.nasa.gov/#:~:text=AIRS%2C%20the%20Atmospheric%20Infrared%20Sounder,gases%2C%20surface%20and%20cloud%20properties.>

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## Chapter 14.0 Modern Instrumental Period

### 14.1 Introduction

The instrumental period refers to the time when weather observations, meteorological observations, were performed using equipment that directly measured temperature and precipitation. The instrumental period of climate history began in the 19<sup>th</sup> century with the commencement of routine weather observations at fixed sites. Data collected from 1900 to the present is used to calibrate and evaluate global circulation models (GCM's) that would ultimately be used to predict future climate changes.

The type and frequency of meteorological observations has steadily grown to include temperature (actual, minimum and maximum), precipitation (type and rate), dew point, humidity, wind speed and direction, radiation (incoming and reflected short wave, incoming long wave and outgoing long wave, hours of bright sunshine), barometric (air) pressure and visibility. The observations are made at a variety of elevations above the Earth's surface. Observations acquired using equipment and techniques endorsed by the World Meteorological Organization (WMO) are collected and archived by the WMO and made available to the public.

Advances in data collection over recent decades have enabled high quality computer modelling of the global climate system. This is evident in the complexity of the atmosphere ocean global climate models or AOGCM's. It was argued that there was insufficient theory and data to support such modelling initiatives. These criticisms are not valid, particularly with the availability of global scale information made available from recently launched satellite platforms and the inevitable fine tuning and development of theoretical considerations themselves. Modelling initiatives can only evolve if they have the data they need. Computational capacity has improved to the point where it has disappeared as a major constraint. The IPCC AR5 clearly reflected this trend.

### 14.2 Instrumental temperature record

The instrumental temperature record, considered the most reliable record for estimating global average temperature, is considered to start in the mid 19<sup>th</sup> century when in situ global coverage started to become available. The global average temperature change from 1850 to present is shown in Figure 14.1. The most striking observation about the graph is how well the results from different contributors agree. Equally striking is the steady climb in temperature from 1975 on. The data sets used in Figure 14.1 are available from the various contributors.

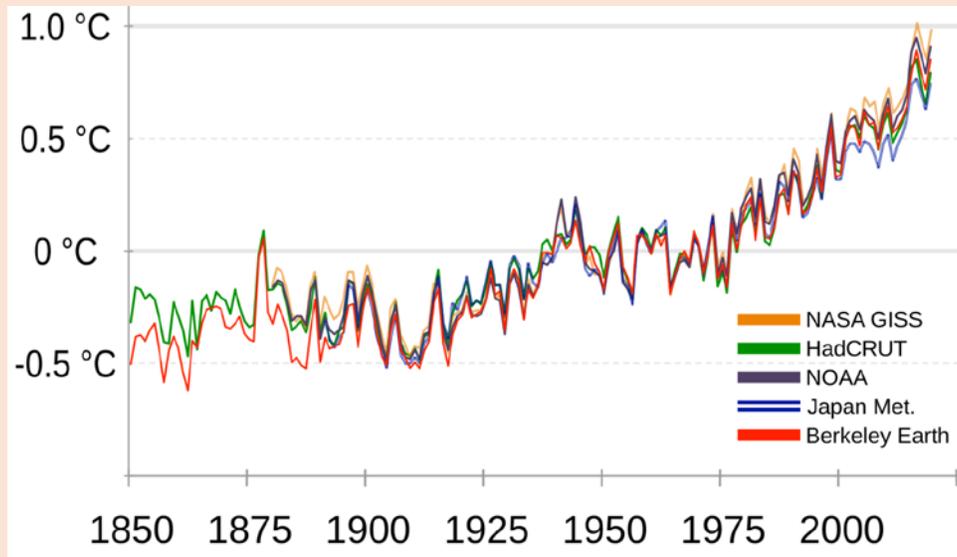


Figure 14.1 Global average temperature change – 1850 to present.

### 14.3 Modern instrumentation

The instrumentation and platforms used to make the meteorological observations have evolved dramatically in recent years to take advantage of advances in electronics, communication, data collection and management, computational capabilities and satellite technology. Many agencies, universities, research organizations and countries have contributed to the advances, in particular the United States National Aeronautics and Space Administration (NASA) and the United States National Oceanographic and Atmospheric Administration (NOAA). The European Union, Japan, Canada, Australia and several other countries have several satellite programs as well.

The Global Observation System managed by the World Meteorological Organization, WMO, (187 member states and 6 member territories) is shown in Figure 14.2. The observation system includes a variety of land based, ocean based, airborne, and satellite platforms that monitor continuously or intermittently as required. There are a variety of other information gathering systems presently active (including weather balloons and pilot balloons) which are also able to observe air chemistry (greenhouse gases) including ozone. Most types of aerosols can be detected and monitored. Much of the data managed by the WMO is available to users directly or through the bureaucracy of the member state. WMO maintains quality control over the data collected by providing guidelines for the type of technology used and how it must be employed. These guidelines must be followed before data collected can be accepted and published. See WMO-No. 8, Guide to Meteorological Instruments and Methods of Observation <https://www.weather.gov/media/epz/mesonet/CWOP-WMO8.pdf>.

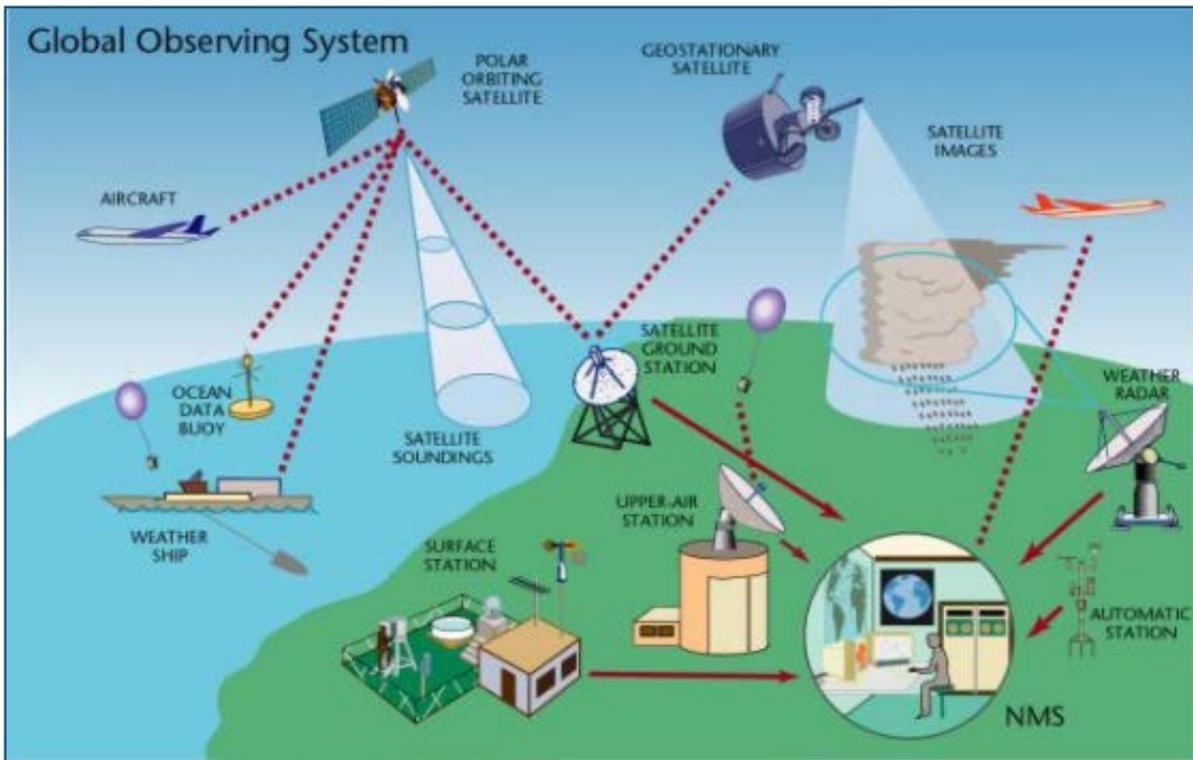


Figure 14.2 Global Observing System – WMO <https://public.wmo.int/en/programmes/global-observing-system>

Images of the various observation platforms are shown in Figures 14.3 to 14.9, land based, ship and buoy. Figure 14.10 illustrates use of weather balloons.



Figure 14.3 Modern surface weather station, U.S. Climate Reference Network Station, Ithaca, New York.



Figure 14.4 Weather ship MS Polarfront at sea – decommissioned in 2009. Note that weatherships are no longer used.

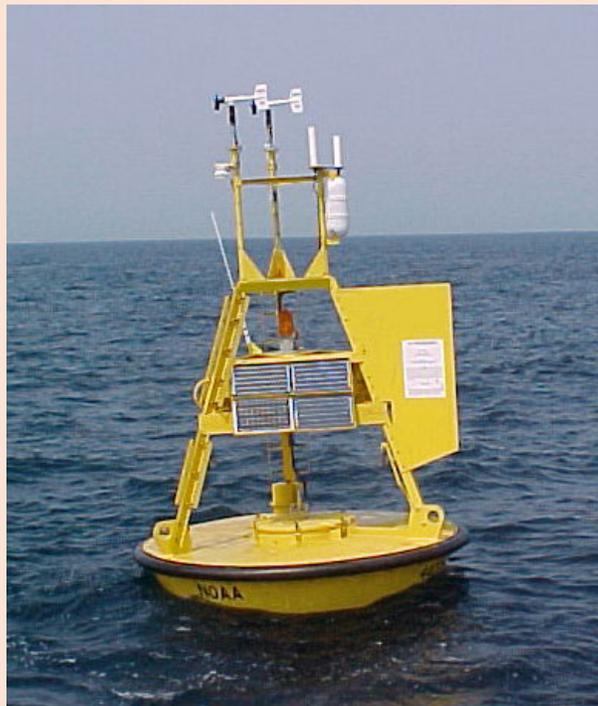


Figure 14.5 Weather buoy operated by the NOAA National Buoy Center.



Figure 14.6 Weather Station – remote land based.

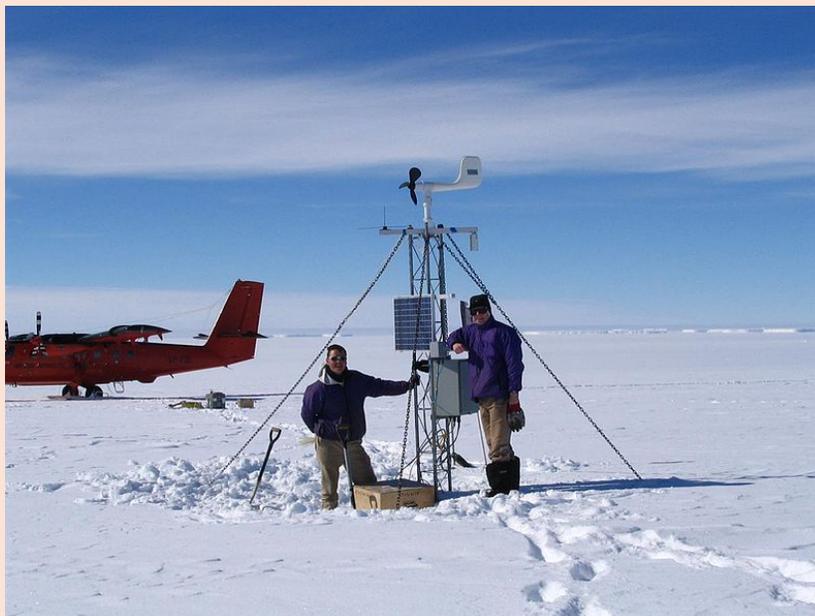


Figure 14.7 Antarctic automatic weather station – part of the automatic weather stations project AWS in Antarctica.

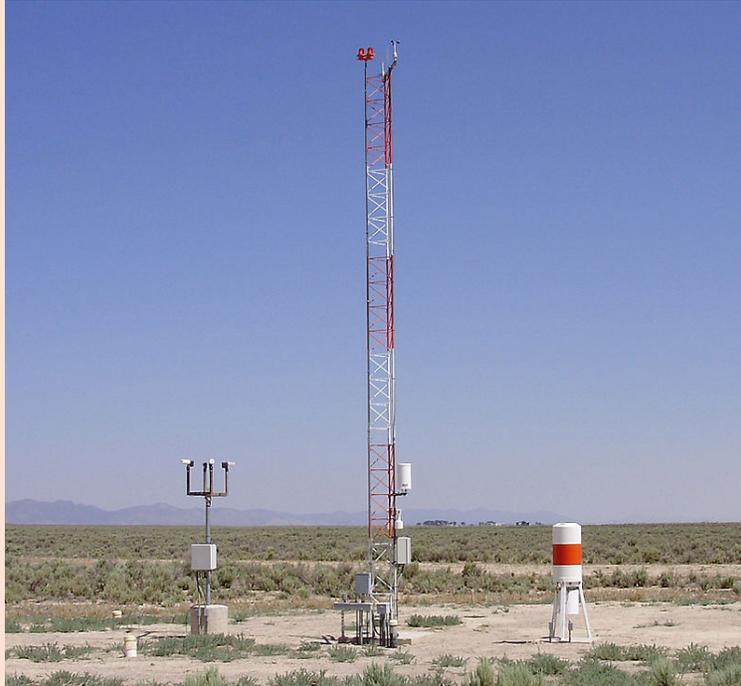


Figure 14.8 Commercial automatic weather observation station AWOS.



Figure 14.9 Remote manned weather stations.

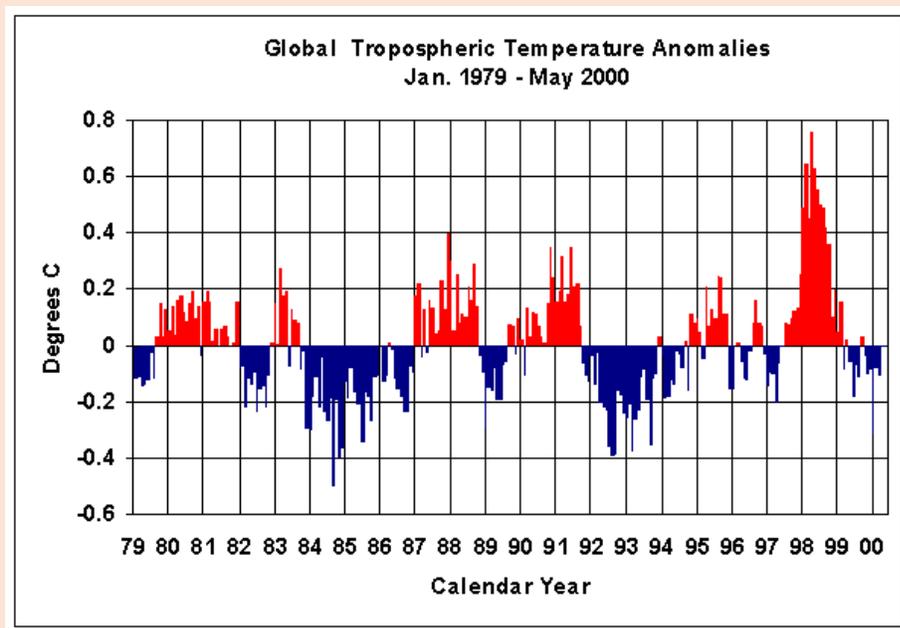
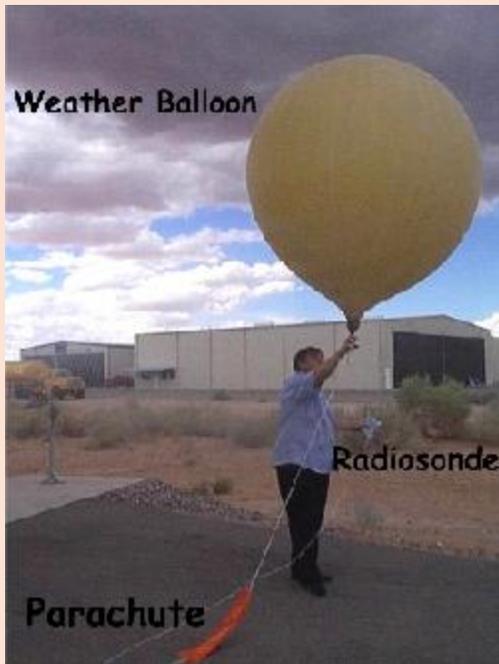


Figure 14.10 Weather balloons with radiosonde.

## 14.4 Satellites

Satellites are able to collect many meteorological observations on a global scale. The NASA Earth fleet is illustrated in Figure 14.11. Satellites are now providing most of the data required for climate modelling. A list of some of the data available is shown in Table 14.1 taken from <https://modis.gsfc.nasa.gov/data/dataproduct/index.php>. Examples of the types of satellites are shown in Figures 14.12 to Figure 14.15. Internet searches will identify which satellites are available to collect the information of interest. Most of the data is available from NASA.



Figure 14.11 NASA Earth science spacecraft and instruments in orbit.

**Level 1**

MODIS Raw Radiances  
MODIS Calibrated Radiances  
MODIS Geolocation Fields

**MODIS Atmosphere Products**

MODIS Aerosol Product  
MODIS Total Precipitable Water  
MODIS Cloud Product  
MODIS Atmospheric Profiles  
MODIS Atmosphere Joint Product  
MODIS Atmosphere Gridded Product  
MODIS Cloud Mask

**MODIS Land Products**

MODIS Surface Reflectance  
MODIS Land Surface Temperature and Emissivity (MOD11)  
MODIS Land Surface Temperature and Emissivity (MOD21)  
MODIS Land Cover Products  
MODIS Vegetation Index Products (NDVI and EVI)  
MODIS Thermal Anomalies - Active Fires  
MODIS Fraction of Photosynthetically Active Radiation (FPAR) / Leaf Area Index (LAI)  
MODIS Evapotranspiration  
MODIS Gross Primary Productivity (GPP) / Net Primary Productivity (NPP)  
MODIS Bidirectional Reflectance Distribution Function (BRDF) / Albedo Parameter  
MODIS Vegetation Continuous Fields  
MODIS Water Mask  
MODIS Burned Area Product

**MODIS Cryosphere Products**

MODIS Snow Cover  
MODIS Sea Ice and Ice Surface Temperature

**MODIS Ocean Products**

MODIS Sea Surface Temperature  
MODIS Remote Sensing Reflectance  
MODIS Chlorophyll-a Concentration  
MODIS Diffuse Attenuation at 490 nm  
MODIS Particulate Organic Carbon  
MODIS Particulate Inorganic Carbon  
MODIS Normalized Fluorescence Line Height (FLH)  
MODIS Instantaneous Photosynthetically Available Radiation  
MODIS Daily Mean Photosynthetically Available Radiation

Table 14.1 Data products available from NASA, Moderate Resolution Imaging Spectroradiometer, MODIS. <https://modis.gsfc.nasa.gov/data/dataproduct/index.php>



Figure 14.12 GOES-8, a United States weather satellite of the meteorological-satellite service.  
[https://en.wikipedia.org/wiki/Weather\\_satellite](https://en.wikipedia.org/wiki/Weather_satellite)

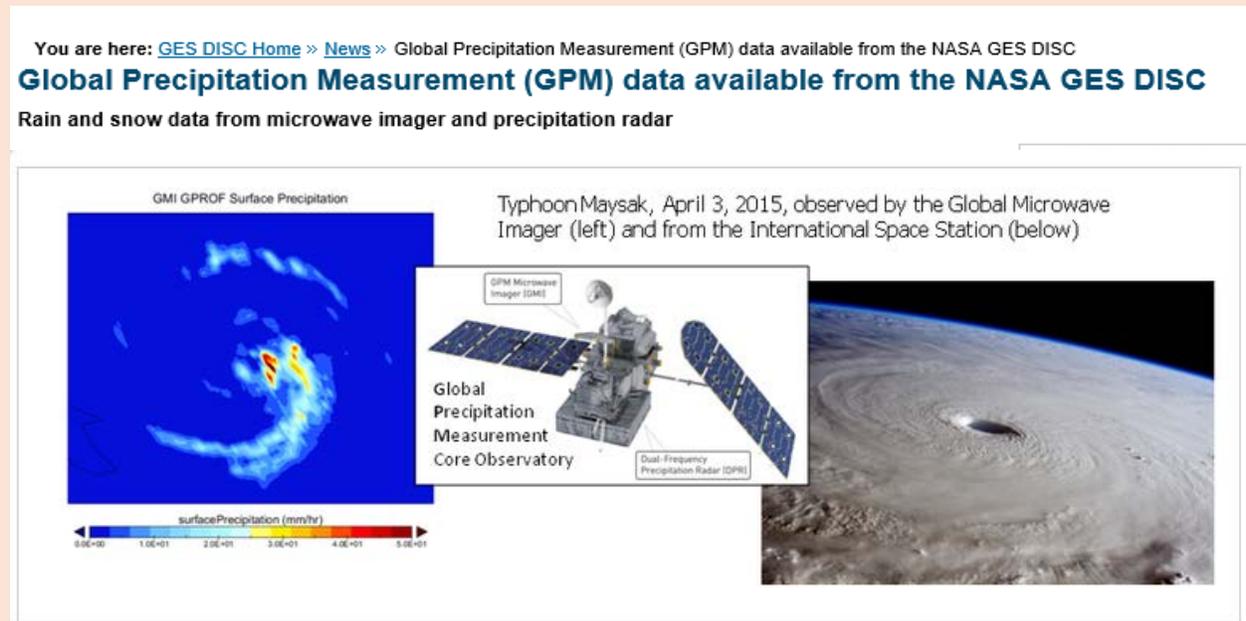


Figure 14.13 Global precipitation measurement from NASA GES DISC satellite  
[https://www.nasa.gov/mission\\_pages/GPM/overview/index.html](https://www.nasa.gov/mission_pages/GPM/overview/index.html)

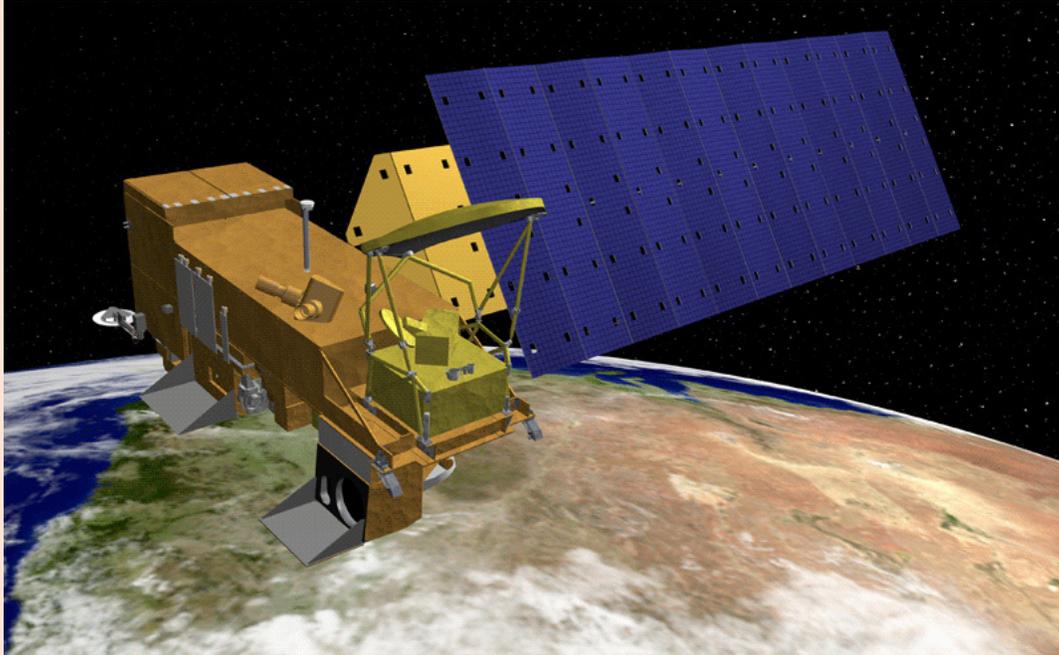


Figure 14.14 Infrared Sounder on NASA's Aqua Satellite.

<https://airs.jpl.nasa.gov/#:~:text=AIRS%2C%20the%20Atmospheric%20Infrared%20Sounder,gases%2C%20surface%20and%20cloud%20properties.>

ICESat-2's laser is split into six beams, to better measure Earth's surface. Find out more [here](#).

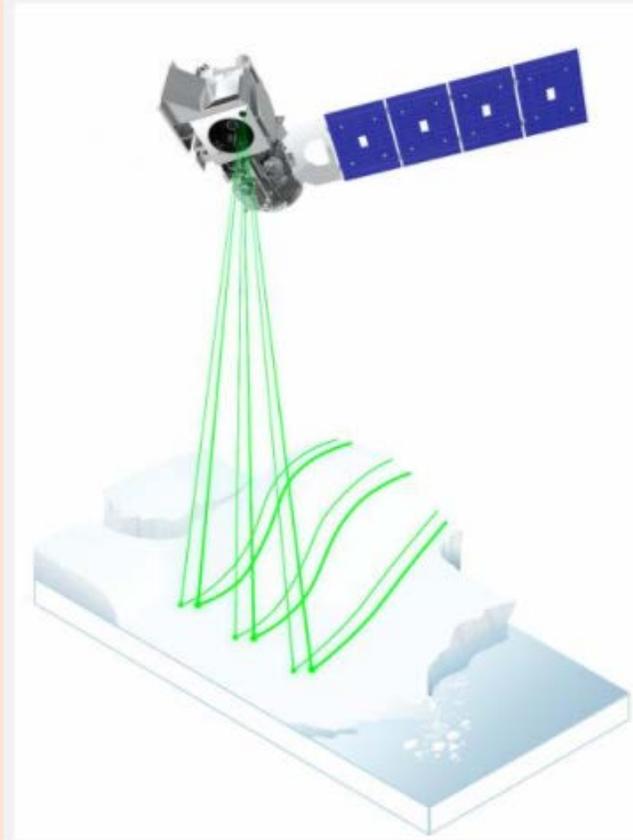


Figure 14.15 Ice thickness. <https://icesat-2.gsfc.nasa.gov/>

## 14.5 Information support

### Key web sites:

1. Instrumental temperature record.  
[https://en.wikipedia.org/wiki/Instrumental\\_temperature\\_record](https://en.wikipedia.org/wiki/Instrumental_temperature_record)
2. Observed climate variations and change.  
[https://www.ipcc.ch/site/assets/uploads/2018/03/ipcc\\_far\\_wg\\_i\\_chapter\\_07-1.pdf](https://www.ipcc.ch/site/assets/uploads/2018/03/ipcc_far_wg_i_chapter_07-1.pdf)
3. Global observing system. <https://public.wmo.int/en/programmes/global-observing-system>
4. WMO member states and territories. <https://public.wmo.int/en/about-us/members>
5. Guide to meteorological instruments and methods of observation.  
<https://www.weather.gov/media/epz/mesonet/CWOP-WMO8.pdf>
6. Global historical climate network. <https://www.ncdc.noaa.gov/ghcn-daily-description>
7. Climate data online. <https://www.ncdc.noaa.gov/cdo-web/>
8. National Centers for Environmental Information. <https://www.ncdc.noaa.gov/>
9. Weather station. [https://en.wikipedia.org/wiki/Weather\\_station](https://en.wikipedia.org/wiki/Weather_station)
10. Automatic weather station.  
[https://en.wikipedia.org/wiki/Automatic\\_weather\\_station](https://en.wikipedia.org/wiki/Automatic_weather_station)
11. GOES-16 Space weather station.  
<https://www.spaceweatherlive.com/en/news/view/399/20191209-welcome-goes-16.html>
12. Weather satellite. [https://en.wikipedia.org/wiki/Weather\\_satellite](https://en.wikipedia.org/wiki/Weather_satellite)
13. Global precipitation measurement.  
[https://www.nasa.gov/mission\\_pages/GPM/overview/index.html](https://www.nasa.gov/mission_pages/GPM/overview/index.html)
16. Atmospheric Infrared Sounder on NASA's Aqua Satellite.  
<https://airs.jpl.nasa.gov/mission/overview/>

17. NASA taking a global perspective on Earth's climate.  
[https://climate.nasa.gov/nasa\\_science/history/](https://climate.nasa.gov/nasa_science/history/)
18. ICESat-2. <https://icesat-2.gsfc.nasa.gov/>
19. NASA Moderate Resolution Imaging Spectroradiometer data products.  
<https://modis.gsfc.nasa.gov/data/dataproduct/index.php#atmosphere>

Videos:

Measuring ice thickness with ICESAT-2.

[https://www.youtube.com/watch?v=S1-3uu1Vlw&feature=emb\\_rel\\_end](https://www.youtube.com/watch?v=S1-3uu1Vlw&feature=emb_rel_end)