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Measuring meteorological variables for studying the climate

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Measuring meteorological variables for studying the climate

The first instrumental weather measurements that have survived started in the 1660s from early thermometers, soon followed by rainfall and snowfall (precipitation) measured using early types of rain gauge placed on roofs. Starting in 1659, the longest surface temperature data set is the Central England Temperature (CET) dataset, which is supported with weather diary information. By 1850 weather instruments were widely operated in Europe, the eastern US and some other regions including, sparsely, the oceans. This is when some current global data sets commence. Other global temperature data sets start in 1880 when data became more widespread and the measurement methods more uniform.

Until World War II (WWII) most meteorological measurements were made using instruments read by people. After WWII atmospheric measurements up to the lower stratosphere (20km) were made electronically by a set of weather instruments attached to a balloon (known as radiosondes) with the number of these increasing very rapidly. These represent the first quasi-global set of remote measurements. Although originally made mainly for weather forecasting purposes, they provided a great increase in our ability to monitor climate and its variability from the late 1940s. Over land, automatic weather station (AWS) measurements started to be introduced in the 1980s, while semi-remote methods were developed for monitoring the depths of the oceans to around 1000m from the 1940s, though these measurements were not truly global.

A large step forward in our ability to monitor climate occurred in the 1970s with the advent of polar orbiting satellites, providing global coverage of our weather. These use infrared or microwave radiation to sample properties of the atmosphere, such as temperature and humidity and the amount of rainfall falling. These data are crucial for weather forecasting, but are now also sometimes used for climate studies where they are often combined with in situ data into amalgamated data sets. Satellites also provide data about the biosphere, including how the land surface is changing, for example whether forests are chopped down for agriculture.

A further increase in our ability to measure climate through the depth of the atmosphere, sometimes up to the lower mesosphere (50km), started in the 1990s through the method of "reanalysis". Here a fixed climate model assimilates diverse observations, including satellite data since the 1970s. Using advanced statistical methods this technique has been extended recently to allow climate and its changes to be usefully estimated through much of the depth of the troposphere (from the surface up to 20km) back to 1851, long before the advent of radiosondes or satellites.

Finally a large step forward in the remote monitoring the climate of oceans occurred in the early twenty first century with the advent of ARGO floats that periodically move up and down through the open oceans. Some 3000 of these now measure temperature and salinity in the top 2000m of the oceans worldwide and their impact on our understanding of, and ability to predict climate, has yet to be fully felt.

The importance of climate studies has been much increased by recent climate warming and its substantial attribution to human activity[1]. Thus global mean surface temperatures have increased by about 1°C since the late nineteenth century, and substantially more in the Arctic. 2015 has been the warmest in the instrumental record globally, though it was also influenced by an important mode of climate variability, El Niño. In fact the interaction of human induced climate change and regional natural climate variability is now a key topic, emphasising the need for more detailed regional observations and regional "reanalyses". The widespread climate changes being observed are consistent with the latest estimates of the enhanced radiative forcing of climate by greenhouse gases since 1750[2], around 2.9W/m^2.

Not surprisingly measurements of the geographical distribution of the various greenhouse gases using satellites and in situ methods (including carbon dioxide, methane, nitrous oxide and others) has become a key component of climate measurements. In fact the variables discussed in this text and many others are now identified by the Global Climate Observing System[3] as "Essential Climate Variables" (ECV). One ECV, ocean subsurface temperature, has become crucial to understanding how the global climate is being warmed by enhanced radiative forcing. Different analyses of ocean heat content now consistently show that about 90% of this enhanced heating is occurring in the upper global oceans at a rate consistent with the many other prominent and diverse indications of climate change. These include worldwide glacier, ice sheets, snow cover, permafrost and sea ice melt, sea level rise, changes in nature and agriculture, warming of lakes and rivers, increases in heat waves and decreases in cold extremes and increases in average and severe precipitation, and atmospheric moisture content.

Notes, further reading and references:

1. Intergovernmental Panel on Climate Change, 2014: Climate Change 2013. Cambridge University Press
2. Blunden, J. and D. S. Arndt, Eds., 2015: State of the Climate in 2014. Bull. Amer. Meteor. Soc., 96, S1– S267.
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Measuring the climate; an illustrated extension to the briefing paper by Ian Strangeways [www.rmets.org/sites/default/files/Measuring%20the%20Climate%20presentation%20by%20Ian%20Strangeways.pdf]