The Global Mean Surface Temperature Series: A Review

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Abstract

In this review, the development of the science of the measurement of Global Mean Surface Temperature (GMST) of the Earth is studied by considering different Global data sets related with Climate Change. The review studies the problems and issues faced by various researchers in constructing a Global dataset for the Global Mean Surface Temperature (GMST) of the Earth. It is concluded in this study that the Global Mean surface temperature (GMST) of the Earth is a very important parameter to understand the Climate Variability and Climate Trends of the Earth. A proper analysis of the past data along with the knowledge of the errors involved in the construction of the data set is essential to estimate the climate variability and to predict the climate trend in the future. Moreover, a systematic mechanism should be developed in order to maintain a high quality Global dataset with the least possible error in the near future by combining all the available global datasets.

Keywords: *Climate Change, Climate variability, Data Sets, Earth, Global, Temperature*

1. Introduction

A proper study of Global Mean Surface Temperature (GMST) is very important for assessing the climate change and variability. The application of global mean temperature on various research fields is well established. One of the vital indicators of climate change is the Global Mean Surface Temperature (GMST) of the Earth.

Fourier (1827) explained that the planetary energy balance is directly related to the surface temperature of a planet which in turn affects the cumulative green house gas emission (IPCC, 2013). Arnell et al. (2014) indicated that climate impacts and risks are related with the Global Mean Surface Temperature (GMST) of the Earth. Thus, the cause of Climate Change and Global Warming can become clearer when the trend of Global Mean Surface Temperature (GMST) of the Earth is accurately estimated.

2. Methodology

The review started with the identification of literature related with climate variability and climate change. The selected literatures were reviewed and the topics related with the Global Mean Surface Temperature (GMST) of the Earth were selected for further research. Some of important topic in the chosen areas was prioritized from the selected literatures which include:

(a) History and growth of the science of the measurement of Global Mean Surface Temperature (GMST) of the Earth.
(b) Methods and process in the measurement of Global Mean Surface Temperature (GMST) of the Earth.
(c) Technique involved in constructing the past data sets of Global Mean Surface temperature of the Earth.
(d) Review of the Different Global data sets pertaining to Global Mean Surface Temperature (GMST) of the Earth.

For each of the prioritized topics, the relevant literatures related with the trend of Global Mean Surface Temperature (GMST) of the Earth were searched for the study. The search was narrowed to peer- reviewed and grey literature published in English.

3. Development of the Science of the Measurement of Global Mean Surface Temperature(GMST)

Daniel Gabriel Fahrenheit invented the mercury thermometer around the year 1714. Meteorologist gradually started observing parameters of Climate Variability like temperature and rainfall. The observation of temperature and rainfall helped the farmers in the scientific growth of Agriculture. The

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proper documentation of weather data initially started in Europe which gradually expanded to other parts of the globe.

In the initial years, Scientist in different parts of the world started documenting and analyzing temperature of a local place or a region. Gradually, the researchers made an effort to do collectively for a global data set in the measurement of Global Mean Surface Temperature (GMST) of the Earth. The initial stage in constructing the past Global Mean Surface Temperature (GMST) of the Earth temperature was difficult due to the constraints and backwardness in instrumentation and communication science. The weather stations were neither densely located nor uniformly distributed. The interaction and coordination between researchers was poor.

Most of the observations were done in Western Europe and it was impossible to rationalize the idea of a Global Mean Surface Temperature (GMST). Although the study of the Global Mean Surface Temperature (GMST) of the earth extended to most part of the northern hemisphere and some part of the southern hemisphere, the meteorological stations did not have a uniform frequency of observation. Most of the meteorological stations initially started with the concept of just concentrating in their own local areas and could not relate much with the other surrounding stations to streamline the sharing of weather data among themselves. Moreover, most of the meteorological stations were documenting the surface temperature in terms of months rather than days. These were some of the major setbacks for estimating the global climate trend in the initial stage. A good network of weather station reduces error in prediction of temperature trend (Willmott et al.1994). With all its limitation, the World weather Record (WWR) started in 1923 in an attempt to document global climate trend (Clayton 1927).

With the advancement in science and technology, the documentation of data started in the late 19th century. Scientist started using proxy evidence from sources like tree rings, corals, ocean sediments, cave deposits, ice cores, bore holes, glaciers, and documentary evidences from different locations. Like for example; the study on Alpine glacier length is obtained from paintings and other historical records. The method has progressed to a stage where scientist can now reconstruct the Global Mean Surface Temperature (GMST) of the Earth. The research based in proxy evidence by Michael Mann, Raymond Bradley and Malcolm Hughes (1998 &1999) predicted that the Northern Hemisphere was warmer during the late 20th century than any other time during the last millennium.

Most of the meteorological stations initially were situated at the land surface of the northern hemisphere. With the passage of time, Scientists started accruing more accurate methods of predicting the temperature trend with the help of new statistical methods. Researchers in climatology started constructing the global mean temperature series in order to study the Global Mean Surface Temperature (GMST) of the Earth with time resolutions of one year. Mitchell (1961) divided the earth into six parts comprising of 30 degree latitudinal belt. The result of the six zones was combined to estimate the mean temperature of the earth's surface and it was compared with a 5 year average temperature ranging from 1880 to1884. He showed that 1940s was the beginning of a warming period. The areas without temperature records were considered as places without any temperature by the Gandin (1963) method while the other methods considered those areas with the same temperature change as its adjoining areas. Hansel et al. (1987) found that the second method out of the two methods yield a better result.

The study and documentation of the Global Mean Surface Temperature (GMST) of the Earth improved appreciably from 1980s with the introduction of the World weather records and monthly climatic data for the world by constructing different global temperature datasets. The ocean surface temperature based on ship data was observed by many scientists (Palttidge and Woodruff 1981; Barnett 1984; Folland et al., 1984). Barnett (1984) concluded that the accuracy of a result enhances on estimating the land and ocean data sets individually and combing the two results to obtain the final global picture. Radiosonde stations started measuring the temperature through the troposphere and lower stratosphere from 1953which proved to be quite helpful (Angell and Korshover, 1983).

Jones et al. (1986a; 1986b) considered around 3276 meteorological stations spread across different places and applied the area weighted grid point estimates method by considering discrete station data into 5 º latitude by 10º longitude grid. He estimated the hemispheric and the Global Mean Surface Temperature (GMST) of the Earth but there was an absence of observational data for area south of 60ºS. Hansen and Lebedeff (1988) first partitioned the data into eighty equal area regions and calculated separately the temperature time series for each region which was then combined to estimate the global mean temperature series. Vinnikov et al. (1990) initially considered an area of 30º latitude and then calculated Global Mean Surface Temperature (GMST) of the Earth. Vinnikov et al. (1990) also could not include the data south of 60 º S in his estimation. The global mean temperature series obtained by the three group of scientist had a good correlation with one another although the statistical method employed and the stations to collect the data were different from each other.

Many scientists also started to construct their own Global Mean Surface Temperature (GMST) data according to the needs of their research (Wernstedt 1972; Bradley et al.1985 etc.). Hansen et al. (1981) studied the global, northern latitude, southern latitude, and low latitude temperature change for the year ranging from 1880 to 1978. Hansen et al. (1987) predicted a global temperature increase by around 0.5º C between 1880 to 1940 while there was a decrease in global temperature by about 0.2 º C between 1940 and 1965 and then an increase in global mean temperature by about 0.3 º C between 1965 to 1980.The maximum of 1981 increased by around 0.2º C when compared to the maximum of 1940.

With the pace of time, new and relevant statistical methods were employed to study the temperature trends which produced improved homogenized quality data (Peterson et al. 1988a).Rayner et al. (2003) concluded that the surface temperature over the oceans have a better accuracy by considering the data of Sea Surface Temperature(SST). Thus, the mean surface temperature has to be estimated by considering both the land surface temperature and the Sea Surface Temperature (SST).Rayner et al. (2006) found that the uncertainties involved decreases appreciably with the inclusion of more observations. Ljungqvist (2009) mainly concentrated on the reconstruction of Climate dataset in tropical zones.

Foster and Abraham (2015) studied the NASA GISTEMP data for years ranging from 1970 to 2013 and could not predict a trend change with statistical significance. Rajaratnam et al. (2015) predicted no proper trend, where four Global Mean Surface Temperature data sets till the year 2014 were considered. Cahill et al. (2015) used change point analysis statistical technique and concluded that there is no established trend in global temperature since 1970. Lewandowsky et al. (2016) found that there is no trend in global mean surface temperature for the years ranging from 1970 to 2014.However, Fyfe et al. (2016) established that the surface warming rate for the baseline 1972 to 2000 is different as compared to the baseline 2001 to 2014.

4. Different Global Mean Surface Temperature (GMST) Data Sets

Scientist tried to construct the Global Mean Surface Temperature (GMST) data sets to monitor and assess the climate variability and climate change. In the initial years, the scope of the global surface temperature data sets was used for predicting and forecasting weather reports which were mainly helpful for farmers and the soldiers in times of wars. Now, the field of Climate Variability and Climate Change has emerged as one of the vital research field for the scientific community because it has practical application that ranges from agriculture to communication, recreation to travel, marine to air and so on. The study of all the important Global Mean Surface Temperature (GMST) data sets is beyond the scope of this paper. Therefore, the study will restrict to some of the relevant Global Temperature data sets.

The Hadley centre of the United Kingdom Meteorological Office and the Climatic Research Unit of the University of East Anglia since 1987 maintains Global Mean Surface Temperature (GMST) data by combining the sea surface temperature and the land surface air temperature. This particular collection of the Global Mean Surface Temperature (GMST) data is termed as HadCRUT. The 5 º x 5 º grid average temperature weighted by grid were considered from 4167 meteorological stations to study the Global Mean Surface Temperature (Jones et al 2001). HadCRUT2 was subsequently revised to HadCRUT3 by rectifying the old data and combining with the improved Sea Surface Temperature (SST) data of Hadley Centre (Brohan et al. 2006).

The National Climate Data Centre (NCDC) and the Carbon Dioxide Information Analysis Centre (CDIAC) constructed the Global Historical Climatology Network (GHCN) around 1990 from 6039 land based temperature stations spread in all part of the globe (Vose et al. 1992). The primary dataset along with the derived product became an important resource for the studies in climate change (Jones 1994; Karl et al 1994; Gutzler 1996) and a Global Baseline Data set of the World Meteorological Organization (WMO).The version 2 of Global Historical Climatology Network (GHCN) contains data from 31 diverse sources. The data quality improved a lot by increasing the number of stations and eliminating duplicate stations. Discontinuities of data were checked by introducing a multifaceted quality control approach (Peterson T.C. et al.1997).This data set consists of 4.7 million station month of temperature records starting from 1701 and consists of mean monthly maximum, minimum and mean temperature. The National climatic Data center's (NCDC) and the World Weather Record (WWR) also jointly published the World Monthly Surface Station Climatology dataset (Spangler and Jenna 1992).

The Global Climate Observing System (GCOS) was established in 1992 comprising of different observing networks to provide a comprehensive data on the global climate system. Jones et al. (2001) constructed a temperature data set for Antarctica

from 3900 temperature observations, of which 2961 stations were used in the gridding (Jones et al. 2003). The National Ocean and Atmospheric Administration (NOAA) started in 1970 provides weather data for research and other applied fields. Other global temperature data sets are NASA's GISTEMP, Cowtan and Way, Berkeley Earth etc.
The Intergovernmental Panel on Climate change (IPCC) is an international organization established in 1988 by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP). The fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) was published in 2013. The fifth Assessment Report of the Working Group I Intergovernmental Panel on Climate Change (IPCC) observed that the warming of the climate system is unequivocal and many of the climate changes are unprecedented over decade to millennia. There is a rise in sea level due to melting of ice. The year spanning from 1983 to 2012 was found to be the warmest 30 year period of the last 1400 years in the Northern Hemisphere. There is a warming of the earth from 0.65 ºC to 1.06 ºC over the period 1880 to 2012 (IPCC 2013).

5. Result and Discussion

The above study shows that there is definitely a change in the Global Mean Surface Temperature (GMST) of the Earth. But there is still no clear evidence to prove whether the change is short term variability or a long term change in temperature. The study of course indicates that global temperature is related to solar activity, volcanism and human activities. Most of the climate data are accessed from reliable resources centers like NOAA, NASA, NCDC, Hadley Centre etc. However, there are still rooms for improvement in obtaining high quality resolution data to enable a proper study in the trend of Global Mean Surface Temperature (GMST) of the Earth.
Most of the global temperature dataset have recently incorporated historical observations of near surface air temperature at land stations with the Sea Surface Temperature. This review found that we need to design a method to check on whether it is more relevant to study the global temperature trend either from the land and ocean climate data separately and combine the two sets together for the final analysis or combine the two sets at the primary level as a single entity. The acquisitions of global climate temperature data sets still have many constraints which have to be dealt in a more systematic manner. The minimum or critical time duration required to predict the global temperature trend has to be clearly defined.

6. Conclusion

It is now proved that man made activities can cause a change in Surface Temperature of the Earth. A proper understanding of the relationship between Global Warming and the Global Mean Surface Temperature (GMST) of the Earth is very important to tackle the issues of Global Warming. Thus, we need to Construct a high quality homogenized global data set for the Global Mean Surface Temperature (GMST) pooled from the entire international agency. The reconstruction of a high quality past temperature record is very essential to understand the future trend of the Global Mean Surface Temperature (GMST) of the Earth.

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