How to measure climate change?

Andy May

In the draft of AR6, due out later this year, the IPCC calls **temperature a key indicator of changing climate.**

They mean the global mean surface temperature or **GMST, or their *new* global surface atmospheric temperature or GSAT.**

Global Mean Surface Temperature (GMST)

- Average of land weather stations and Sea Surface Temperatures (SST), it has been the official *IPCC measure* of climate change
- Solar and orbital effects on climate are regional, so focusing on global averages is misleading. Both orbital precession and orbital obliquity affect temperature by latitude, only CO_2 is quasi-global.
- Surface Weather is chaotic at all time scales, the "climate" limit of 30 years is arbitrary.
- July Vostok Station, Antarctica average low air temp is -95°F/-70 °C
- July Doha average high air temp is 106°F/41°C
- What does a July global mean of +41C and -70C tell us?
- In the AR6 the IPCC plans to replace GMST with GSAT (Global Surface Air Temperature) from a *model*. They have no dataset, only a model.

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The IPCC currently measure climate change with global mean surface temperature, this number is a mixture of air temperatures on land and SSTs in the oceans, which cover **71% of Earth**.

This is appropriate **only** if there is just one global force to consider, for example a well-mixed gas like CO2. The Sun and Earth's orbit tend to affect the Northern and Southern Hemispheres differently, they also affect different latitudes differently. Thus, only focusing on the global average temperature is misleading, it puts the focus on CO2! CO2 has a global impact of **3 to 4 W/m^2**. Orbital forces can have a **100 W/m^2** impact at 65 degrees North, 25 to 30 times higher!

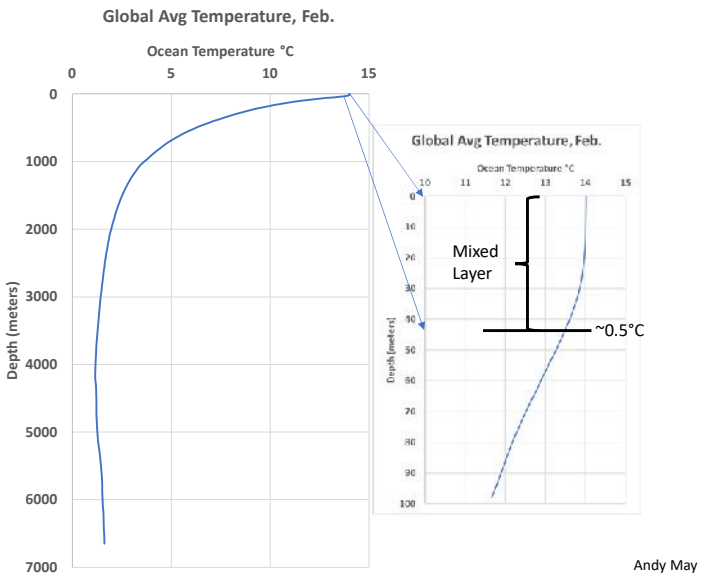
The Earth's surface is never at equilibrium and all climatic factors, temperature, precipitation, winds all change rapidly and continuously. Measuring climate change there is like measuring a man's shoe size while he is riding a bicycle at top speed.

The extreme temperatures on the surface, in any given month can be over 100°C different! Yet we pretend that a monthly average that increases a few hundredths of a degree is significant!

The IPCC is now making things worse. There are serious quality problems with GMST, but at

least there are an organized databases that GMST can be computed from. In AR6 the IPCC is planning to introduce “GSAT” the global surface atmospheric temperature. It is computed from GMST, using a model. It increases the GMST warming rate by 4%, yet there is no data that supports this increase. The only justification is from models.

Ocean Temperature Profile



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- The Ocean mixed layer is in constant communication with the surface, oceans cover 71% of the surface.
- Defined as a turbulent zone with nearly constant temperature and density (within ~0.5°C of surface)
- Below the mixed layer the age of the temperature increases with depth, dependent upon ocean current speed and direction
- Model needed; it could be the best record of past ocean surface temperatures.
- Data from University of Hamburg

Temperatures in the ocean are more stable than in the atmosphere and the oceans cover 71% of the Earth, they dominate climate. Historically, we have known very little about ocean temperatures, especially below the surface.

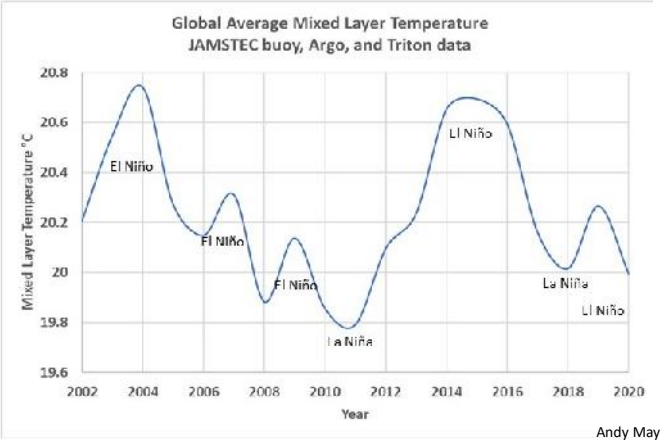
The ocean mixed layer is in constant communication with the surface, it averages 72 meters in thickness, and is only a small fraction of the ocean. The mixed layer always reflects surface temperatures, but usually with a small lag of a few days. **Surface extremes are not seen if they are short-lived**. The mixed layer temperatures are an excellent record of short term (say **one month**) climatic changes.

The mixed layer is defined as a zone of nearly constant temperature and density. A common definition of the base of the mixed layer, is the point where the temperature is 0.5°C different from the surface.

The deeper part of the ocean has older temperature data. Generally, the deeper you go in the ocean the more insulated you are from surface variability.

A 3D model of ocean temperature by depth and location may be able to tell us what surface temperatures in the past were. **I seriously doubt models of the atmosphere will ever work**, but I see possibilities in an ocean model.

Ocean Mixed Layer



- On average, the upper 72 meters of the ocean
- 27x the heat capacity of the whole atmosphere
- Atmosphere temperature increases 27° > mixed layer 1°
- Constant communication with atmosphere
- Current temperature trend is down
- Only good data from ~2005 to 2020

JAMSTEC, the **Japanese Agency of Marine-Earth Science and Technology**, has created a database that computes a global grid of mixed layer temperatures. It goes back to 2001, but the data does not get comprehensive until about 2005.

Surface events, like ENSO events (La Niñas and El Niños) are clearly seen in the mixed layer temperature record

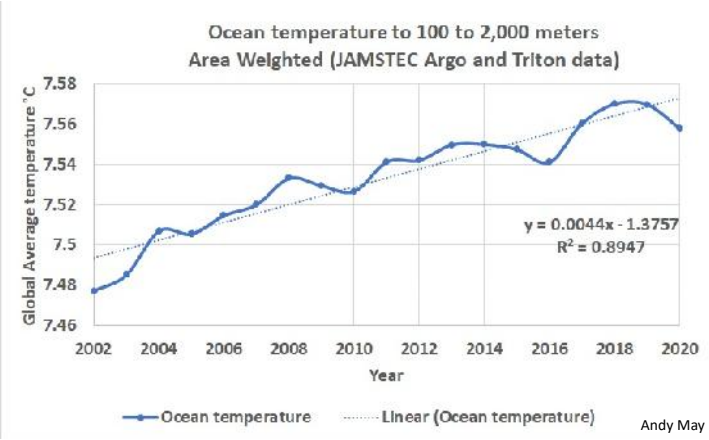
The global heat capacity of the mixed layer is 27 x the heat capacity of the entire atmosphere. Heat capacity tells us how much thermal energy is required to heat a body 1 degree. Thus, if the atmosphere warmed 27 degrees and transmitted all this heat to the mixed layer it would go up only one degree.

While the mixed layer temperature is trending down, this is highly dependent upon the data prior to 2005, when the global coverage was not so good. Since the data got better, the trend has been flat.

The depth of the mixed layer varies by season and atmospheric wind speed. The wind provides most of the force mixing the layer. There is a delay in transferring atmospheric temperatures to the mixed layer due to its large heat capacity and wild temperature swings in the atmosphere are dampened in the mixed layer. The delay is a matter of days, a few

weeks at most. The mixed layer current temperature trend is down about 0.6 degrees C per century, but this is suspect.

The Deeper Ocean



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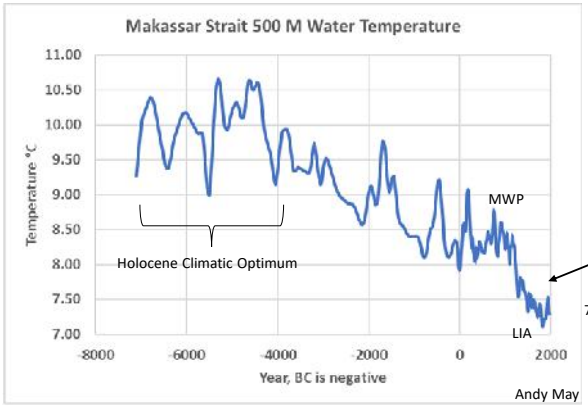
- No ENSO events
- Little and/or slow communication with the surface
- Age of temperature increases with depth
- Temperature increase very linear
- Warming at 0.44°C/century
- Probably this warming is all natural
- Age of temperatures function of currents and depth
- Model needed

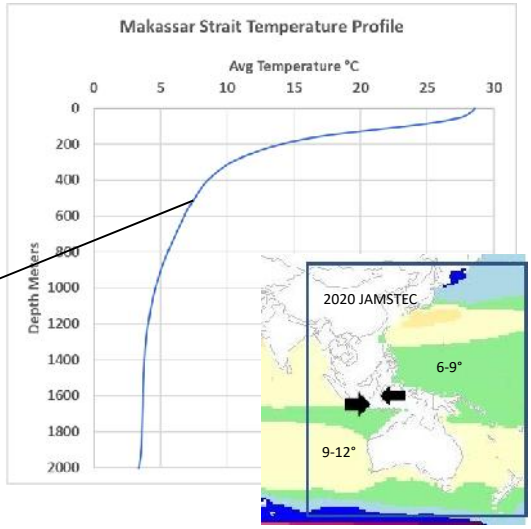
The deeper ocean (100 meters to 2,000 meters) has little communication with the surface, so it is a **record of older temperatures**. It shows a strong linear trend of warming that is probably natural. This trend varies from region to region. The trend shown is the global trend. Possibly a model of world ocean temperatures that takes into account current speed and direction could unravel ancient temperatures and provide a history of natural temperature trends.

Anthropogenic effects may influence the upper part of this zone, but not the deeper part, below 1,000 meters.

Rosenthal, et al., 2013, *Science,* 10,000 yr. Temperature Reconstruction of 500 m water in the Makassar Strait.



U. Of Hamburg temperature profile, ~2004-2016



The left-hand graph shows a temperature reconstruction by **Yair Rosenthal** and colleagues in their 2013 paper in *Science*. They use **bottom-dwelling foraminifera** in the Makassar Strait, between **Sulawesi and Borneo in Indonesia**. The water at about 500-meters, where the forams live, is sourced from the Southern Ocean near Antarctica, the southern Indian Ocean and the North Pacific. This location is ideal for checking the 500-meter water temperature for much of the Southern Hemisphere and a portion of the Northern Hemisphere.

On the right we see a location map and a temperature profile for the Makassar Strait from the University of Hamburg database. The University of Hamburg database is a high resolution (0.25° latitude and longitude) monthly series that uses all available data from whatever year. This profile gets most of its data from 2004-2016. It shows an average temperature at 500 meters of about 7.7°C. **Thus, this area, at this depth, warms about 0.5°C from the depths of the Little Ice Age, here about 1810, until ~2010**. This is less than estimated at the surface.

In summary, the data we need to reconstruct Holocene, and older temperatures is in the oceans and in ocean sediments. Ocean temperature reconstructions represent much more of Earth's surface (defined as from the ocean floor to the top of the atmosphere) than any land- or ocean-based measurements in the atmosphere. The atmosphere is far too chaotic

and unstable. The ocean temperatures are more stable, usable, and easier to compare to paleo-temperatures.

Reference:

Rosenthal, Y., Linsley, B., & Oppo, D. (2013, November 1). Pacific Ocean Heat Content During the Past 10,000 years. *Science*. Retrieved from http://science.sciencemag.org/content/342/6158/617