Regional variation of heat transfer to deep sea and its implication for the recent warming hiatus based on long-term SST pattern characteristics

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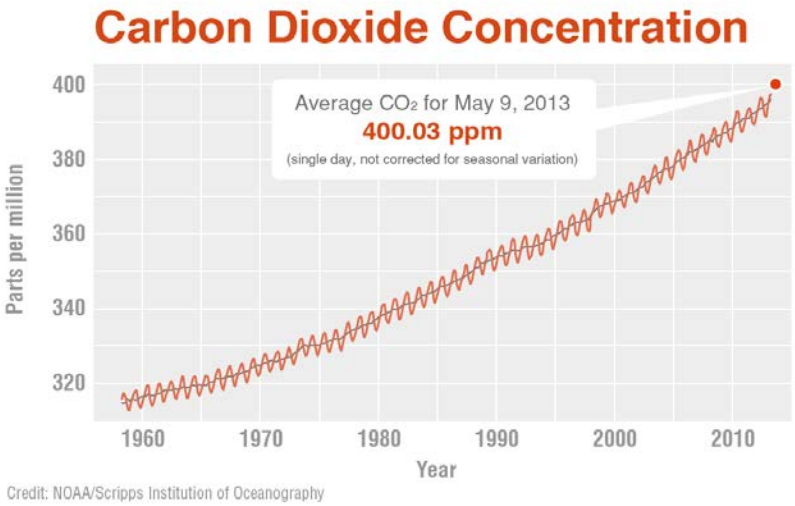
Contents

- Background & Introduction
- Method and Data
- Results
- Conclusions and discussion

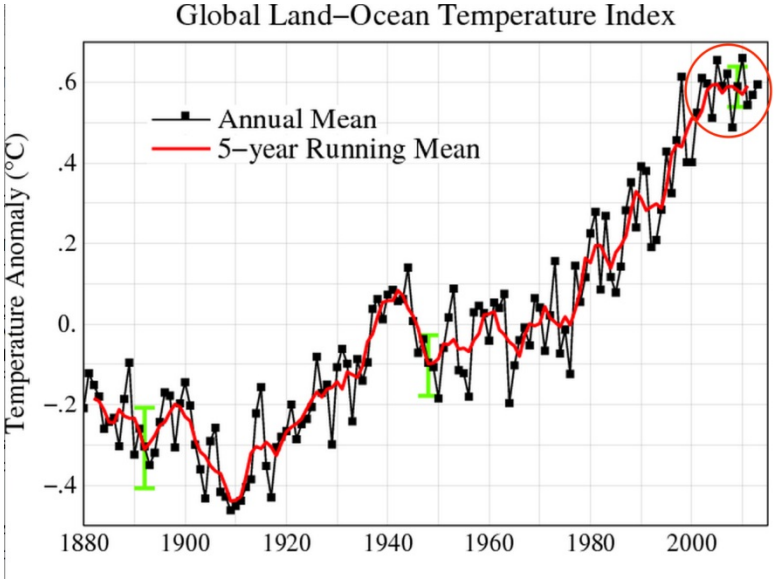
Background

Warming hiatus put climate scientists in great trouble



Climate change Skeptics: human induced climate change? Why does global surface temperature increasing rate slow down in the context of higher and higher atmospheric Co2 content? Why? Why? Just tell us why?

Scientists have long labored to explain what appeared to be a slowdown in global warming that began at the start of this century as, at the same time, heat-trapping emissions of carbon dioxide were soaring. The slowdown, sometimes inaccurately described as a halt or hiatus, became a major talking point for people critical of climate science.



To save themselves, What have Climate scientists done ?

1)Denying the hiatus
- Redefinition of hiatus
- Data problem (unreliable)
- Method problem

2) Explain the hiatus
- Volcanic eruption
- Air pollution
- Solar activities
- Scale-dependency
- Heat transfer to deep sea

Is There a Global Warming Pause? 翻译此页
isthereaglobalwarmingpause.com
The "pause" or "**hiatus**" in global **warming** Despite the continued increase in atmospheric greenhouse gas concentrations, the annual-mean global temperature has not ...

Possible artifacts of data biases in the recent ... 翻译此页
science.sciencemag.org/content/348/6242/1469 ▾
Karl et al. now show that temperatures did not plateau as thought and that the supposed **warming** "**hiatus**" is just ... 10.1126/science ... of **data** biases in the ...

On the definition and identifiability of the alleged ...
https://dash.harvard.edu/bitstream/handle/1/23845331/4657026.pdf?... · PDF 文件
On the **definition** and identifiability of the alleged **hiatus** in global **warming** (Article begins on next page) The Harvard community has made this article openly available.

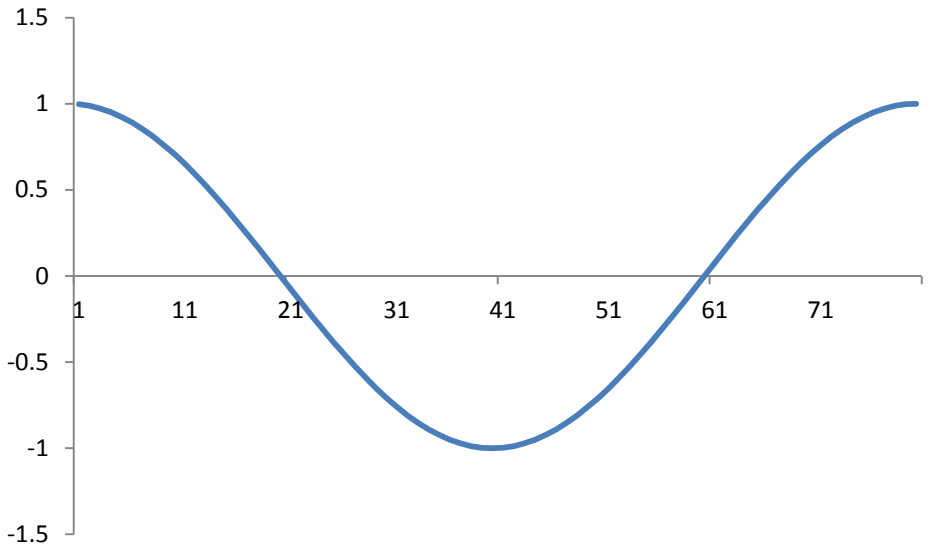
Debunking the climate hiatus - Springer
https://link.springer.com/content/pdf/10.1007/s10584-015-1495-y.pdf · PDF 文件
130 Climatic Change (2015) 133:129–140 We find compelling evidence that recent long-term record has been limited. We apply a rigorous, comprehensive statistical analysis of global temperature data that goes beyond simple linear models to account for temporal dependence and selection effects. We use this framework to test whether the recent period

Scale-dependency of the global mean surface temperature trend and its implication for the recent hiatus of global warming

Yong Lin & Christian L. E. Franzke

Warming hiatus and heat transfer to deep sea

heat transfer to deep sea, a long term (longer than 60 years)oscillation process, just in the positive phase in the hiatus period, is claimed as the key driver or the most possible cause of the global warming hiatus.



Problems with heat transfer to deep sea

- Inconsistent results
- data and tool

Inconsistent results

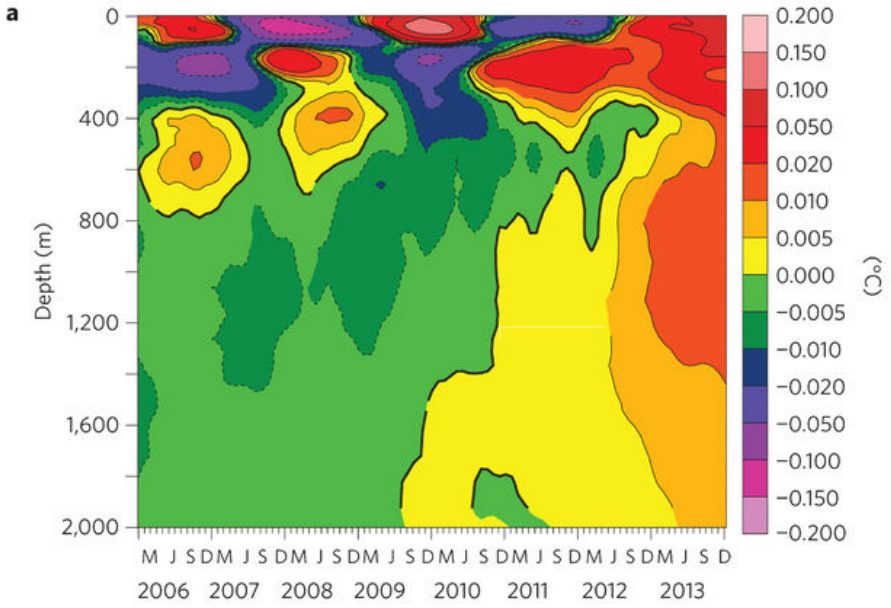
Some scientists found that Pacific Ocean is responsible for the recent hiatus[2] whereas other scientist claim that Atlantic Ocean contributes much to the recent hiatus and deny the role of Pacific at the same time[3]. In addition, it is reported that Indian Ocean[4-6] and Southern Ocean[3] also contribute to the recent hiatus. The inconsistence in which ocean is the main driver of the recent warming hiatus affects the validity and reliability of heat transfer to deep sea in explaining the warming hiatus to some extent.

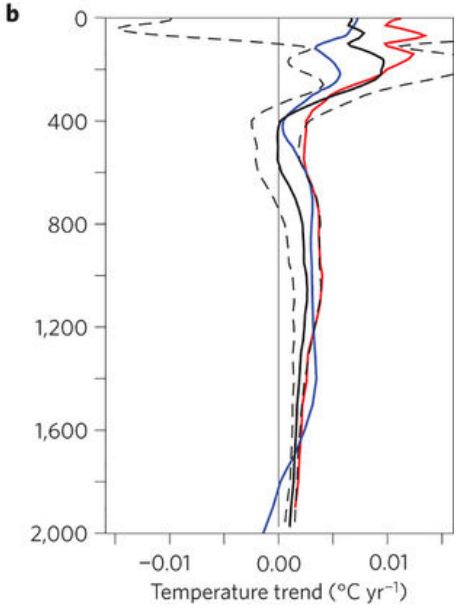
Just image how can you say that you know me well when you even do not know my name? Zhang san or Li Si ? You are not sure which one is right.

Method and data problem

The role of Heat transfer to deep sea (HTDS) in the recent hiatus is usually conducted by mean of model simulation[2,7,8] or ocean heat content (OHC)change estimation directly[9,10] or indirectly[11-13] (Domingues et al.,2008;Song & Colberg,2011,Llovel et al.,2014), which are constrained greatly by model reliability(due to data inputs and model assumption) and the sparsely spatial and temporal coverage of water sampling[14].

According to Durack et al[15], under-sampled areas, particularly located in southern hemisphere, may have significantly biased low the estimates of global OHC trends between 1970 and 2004. This is perhaps one of the main causes of the inconsistency in the study of heat transfer to deep sea at Ocean scale.





study a process of 60~80 years in duration with only 8 years data?

Time series is too short at least!

Why not use pre-2006 data?

Data quality is a problem.

a, Globally averaged temperature anomaly (colour scale) versus depth from the OI (ref. 14) estimate. **b**, Temperature trend versus depth, zonally averaged, for OI (black), RPF (ref. 15; red) and RSOI (ref. 16; dark blue) estimates. The 95% confidence interval (dashed) is shown for the OI alone(**Roemmich et al,2015, Unabated planetary warming and its ocean structure since 2006**)

What is way out?

The Use of long time series reliable data without resort to complex models !

Global SST data longer enough? Yes!

Much more reliable than Argo data? Yes!

Objectives

- Developing a new approach to study the role of heat transfer to deep sea
- Investigate which ocean (more specifically, sub-ocean) responsible for the recent hiatus

Long term SST pattern based approach for HTDS study

Seasonal pattern and its regional variation

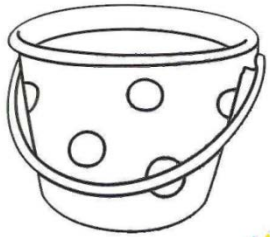
A simple question:
Q: how do you plan to quantitatively assess the influence of orbiting of the earth around the sun (OEAS) on land surface temperature(LST) and its regional variation?

Scientists: collecting data(distance, reflectivity, cloudiness and etc.) , developing models and then simulating under different inputs which are regional dependent.

Fisherman: I know nothing about models, but I know that tropical region is least sensitive to the seasonal change or the process of the orbiting of the earth around the sun.

Scientist : without any knowledge of the complex irradiation model, how does he know that?
Fisherman : just comparing LST fluctuation range.

$V=(4/3)\pi R^3$



Water inside

Model input R badly measured
Model parameter (4/3) highly uncertain

In that case, let us to measure the volume of the ball with simple tools

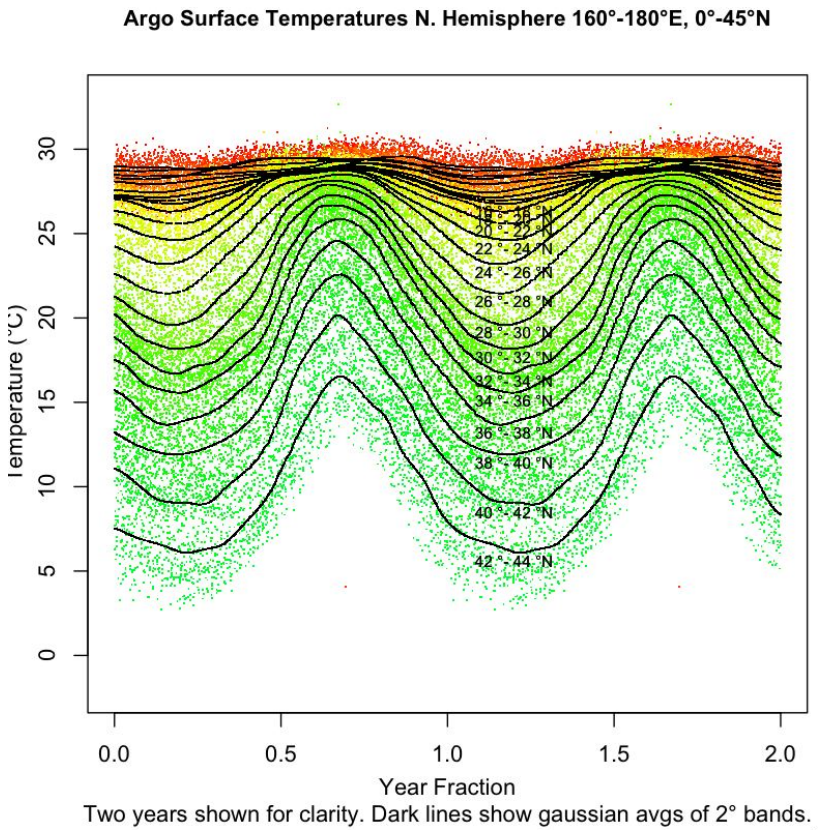
(W/m²)(4.6)
To f

HTDS related pattern vs. seasonal pattern

Lin Yong : what a clever fisherman !

I can do the same thing to study the process of heat transfer to deep sea and its regional variation by means of long-term dynamic pattern analysis of SST.

From pattern to process? A good idea!



Two years shown for clarity. Dark lines show gaussian avgs of 2° bands.

(W/m²)(4.6)
T

Still difficult to understand?

$$I_0 = I_{SC}\left[1 + 0.034\cos\left(2\pi\frac{n}{365.25}\right)\right](\cos\phi\cos\delta\sin\omega_S + \omega_S\sin\phi\sin\delta)$$

Where ϕ is the latitude (degrees) . Its value determines the amplitude of seasonal oscillation pattern and also the influence of earth orbiting on surface temperature. This means that we can infer the influence of the process of earth orbiting on surface temperature by means of surface temperature oscillation pattern characteristics(fluctuation amplitude or change speed)

- **Main assumption**

Periodic natural forcing or processes usually have a mark on climate time series in terms of oscillation pattern, which enable us to study the natural processes behind the corresponding climate dynamic patterns. More heat transferred to deep sea means less heat to warm sea surface and a cooling trend or reduced warming speed according to energy balance theory. The regional variation of the process of HTDS in intensity and speed are therefore reflected by the variation of SST change speeds or amplitude in the long term SST dynamic pattern. Naturally we can analyze the role of heat transfer to deep sea, an assumed periodic long-term physical process, in the recent warming hiatus by means of SST dynamic pattern.

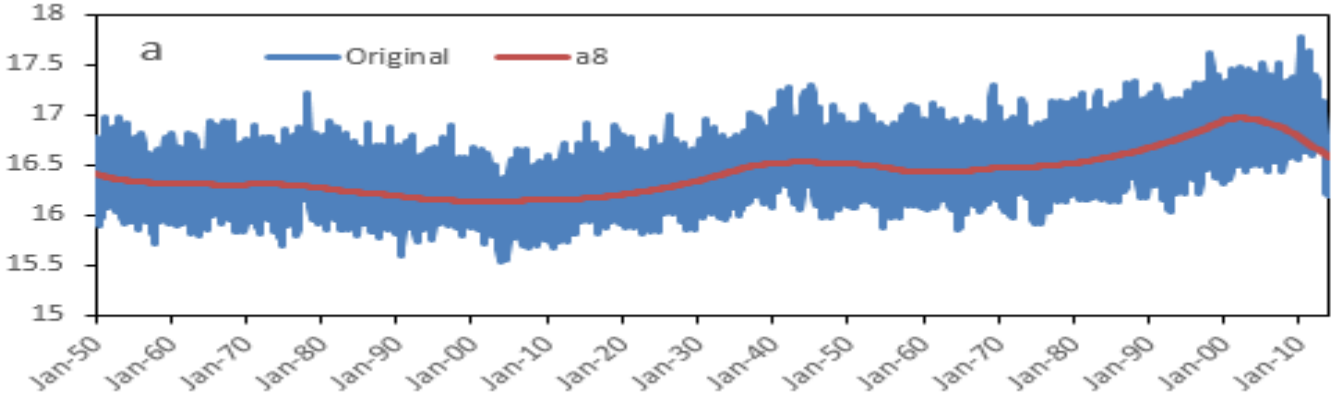
Method

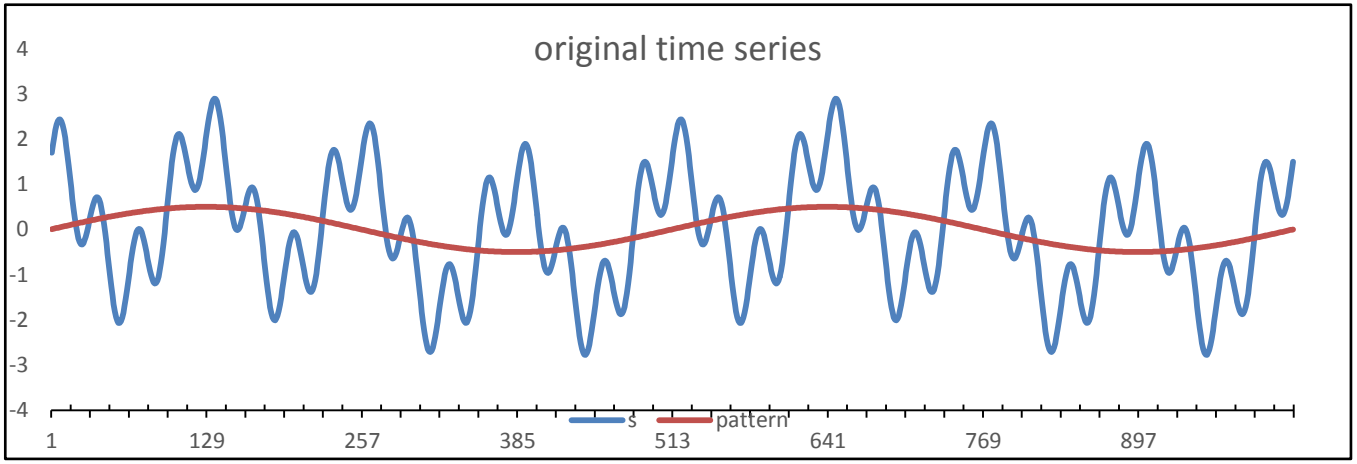
In this study wavelet transform is used to remove higher frequency oscillation components by means of multi-resolution analysis. we use the wavelet of Db4 to decompose each original SST time series above mentioned and to get the corresponding long term SST dynamic patterns at the levels of 7 and 8, which corresponds to 128 and 256 months scale with reference to Lin and Christian (2015).

In this study, SST change speeds and amplitudes of the long-term SST dynamic patterns in the hiatus period at the time scales of 256 months and 128 months for each spatial unit(hemisphere, latitude band, Ocean, sub-Ocean) are used to quantitatively assess the role of each spatial unit in driving the warming hiatus by means of HTDS. The Ocean (sub-ocean, hemisphere and latitude band) with higher cooling speed and bigger drop in SST long term dynamic pattern in the hiatus period are supposed to play a bigger role and to have more heat transferred to deep sea.

Long term dynamic pattern detection? Not easy!

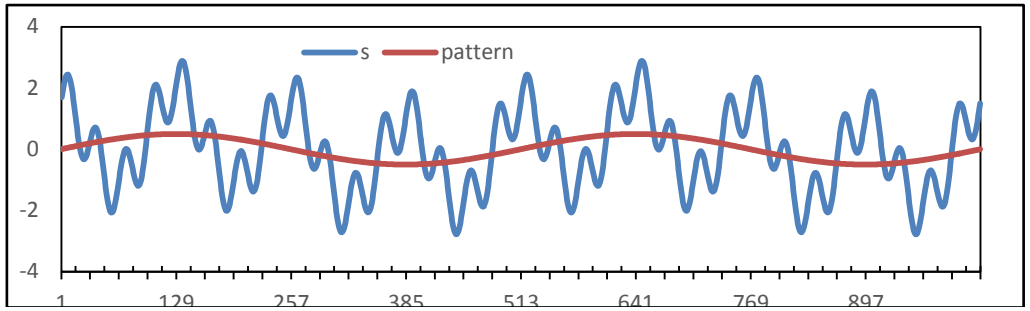
The existence of various high frequency oscillation components (regular or irregular) overshadows the dynamic pattern of interest to us (e.g. seasonal pattern or ENSO-like pattern).

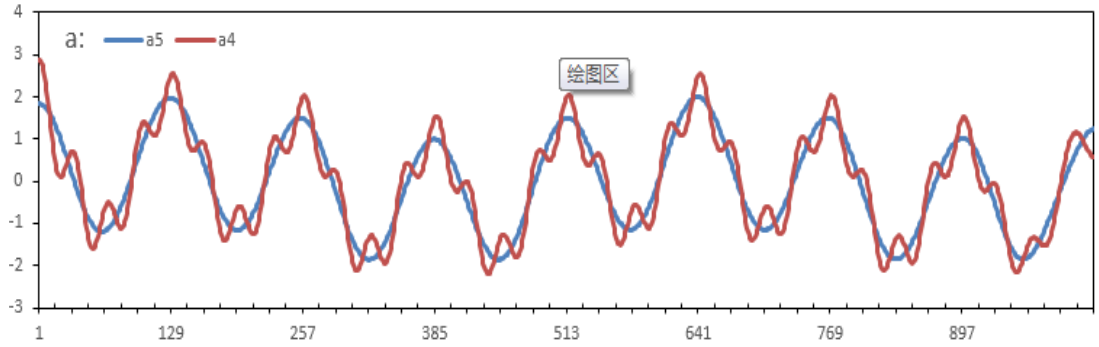


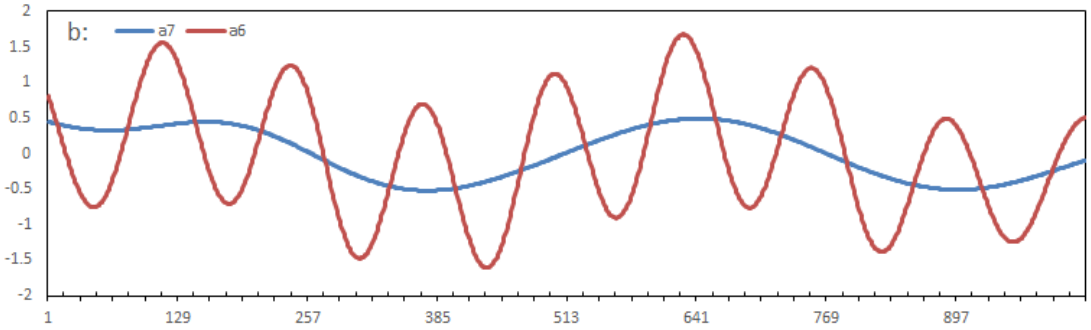


Dynamic pattern and its Intrinsic scales

According to ecology, any process or pattern has its own intrinsic scales and it is essential to match observation (or analysis) scales to intrinsic scales for the study on the pattern or process of interest

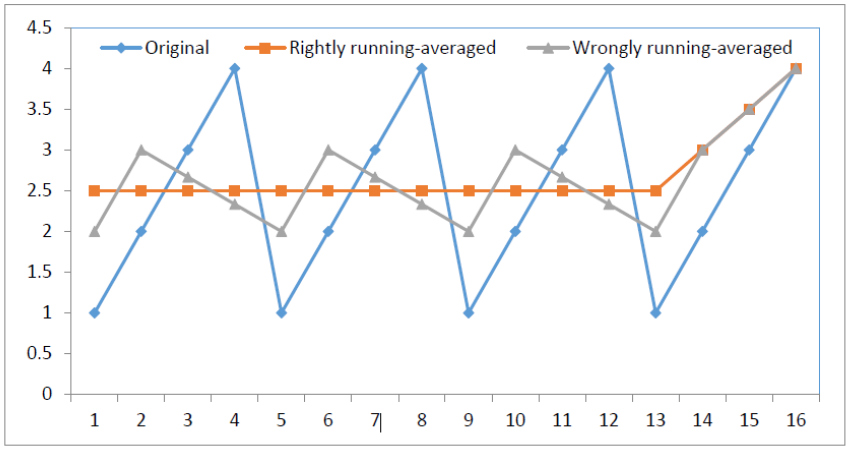




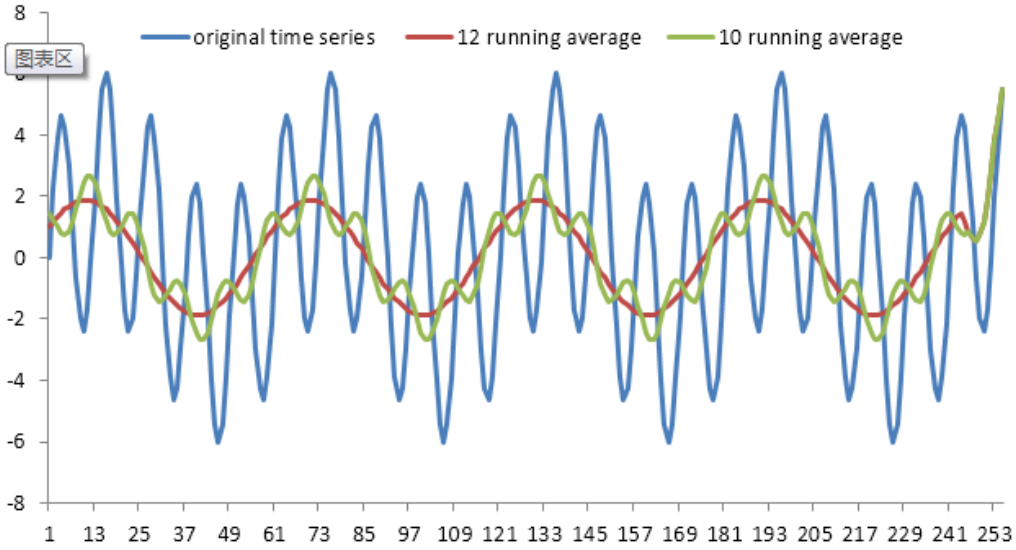


The issue is that we do not exactly know what is the intrinsic scale for HDTS . But we can study HTDS at multiple scales which increase the chance of scale match between analysis(observation) scale and intrinsic scale. This is why we study long term SST dynamic patterns at both 128 and 256 months scales.

Running –averaging approach to remove short term variability

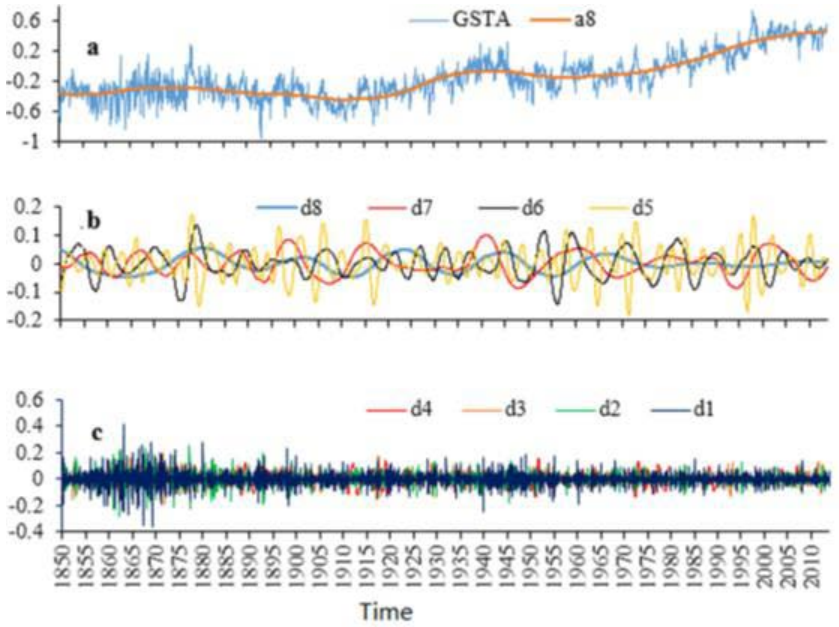


this approach only do a good job in removing well known regular climate variability such as daily and seasonal cycle and is of little help to eliminate the influence of irregular climate variability



Why wavelet based analysis?

In contrast, Wavelet based multi-resolution analysis (MRA) can decompose a climate time series into oscillation of low frequency and short-term variability of various high frequencies (whether regular or irregular) with minimum information loss, enabling us to study long term SST evolution patterns free of adverse influences of short term climate variability.



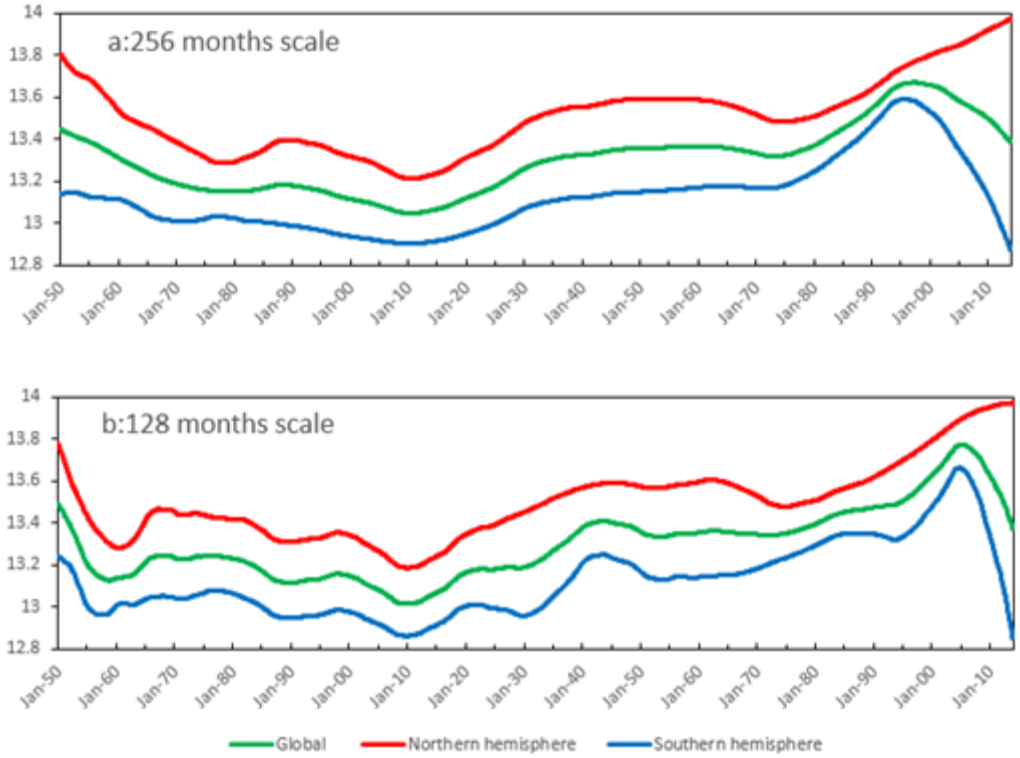
S=a8+d8+d7+d6+d5+d4+d3+d2+d1

long SST time series data

Global monthly Sea surface temperature at the resolution of 1.0 degree spanning from January 1850 to December 2013 (https://www.esrl.noaa.gov/psd/data/gridded/data.cobe2.html) are used in this study. The zonal mean monthly SST time series for each Ocean and Sub-ocean (namely, northern tropical, northern subtropical, arctic, southern tropical, southern subtropical and Antarctic), northern hemisphere, southern hemisphere and global are extracted and used in this study.

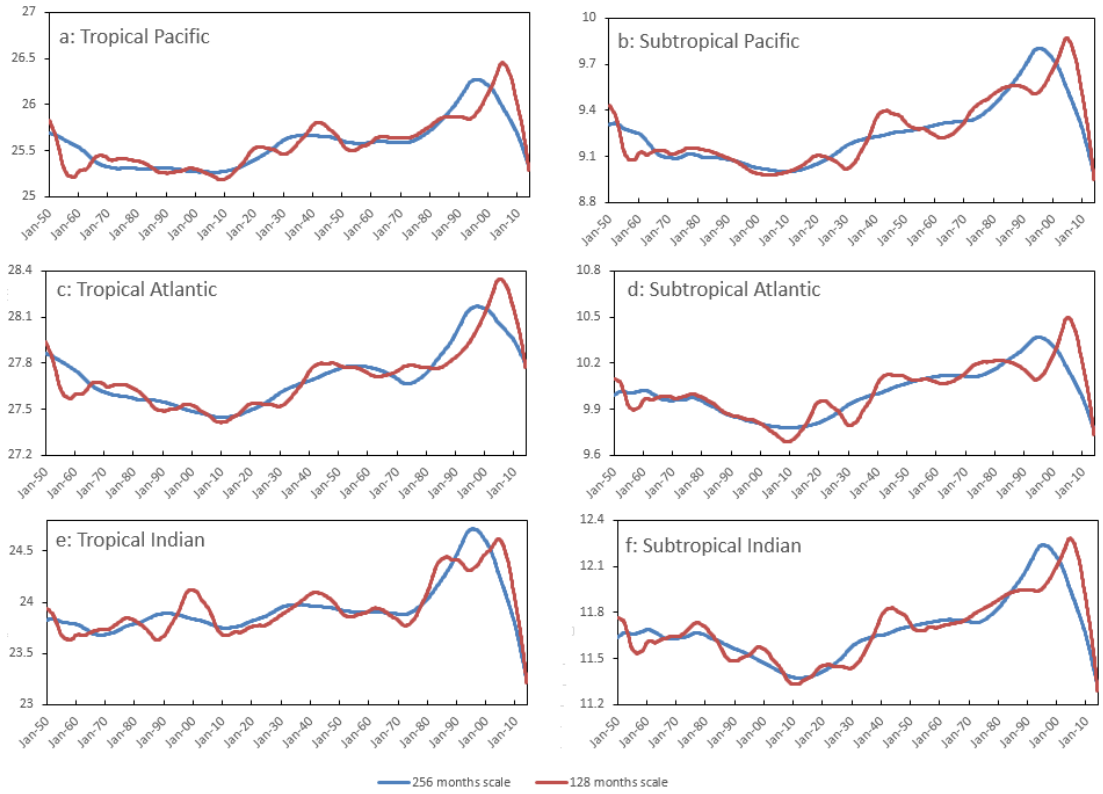
Results

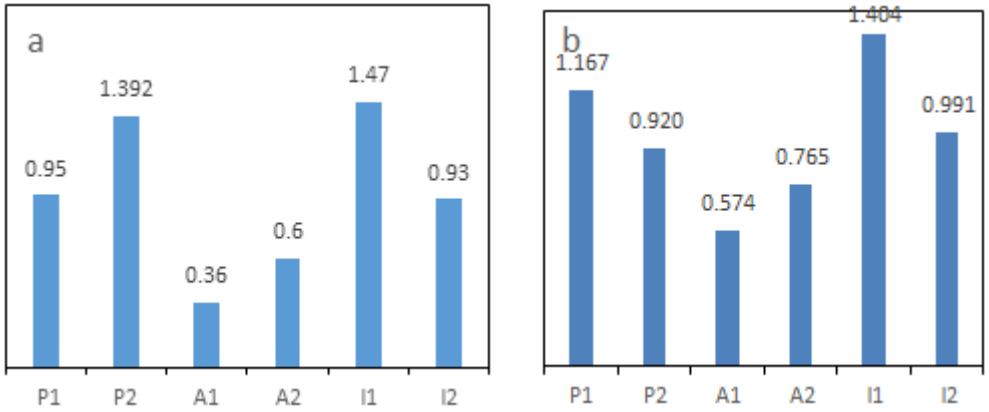
Hemisphere and globe scale



Global SST dynamic pattern from 1850 to 2013 at the scales of 256 months and 128 months show an obvious cooling trend in the recent hiatus period whereas hemisphere NH/SH shows an obvious upward /downward trend, suggesting the recent warming hiatus is mainly related to SH.

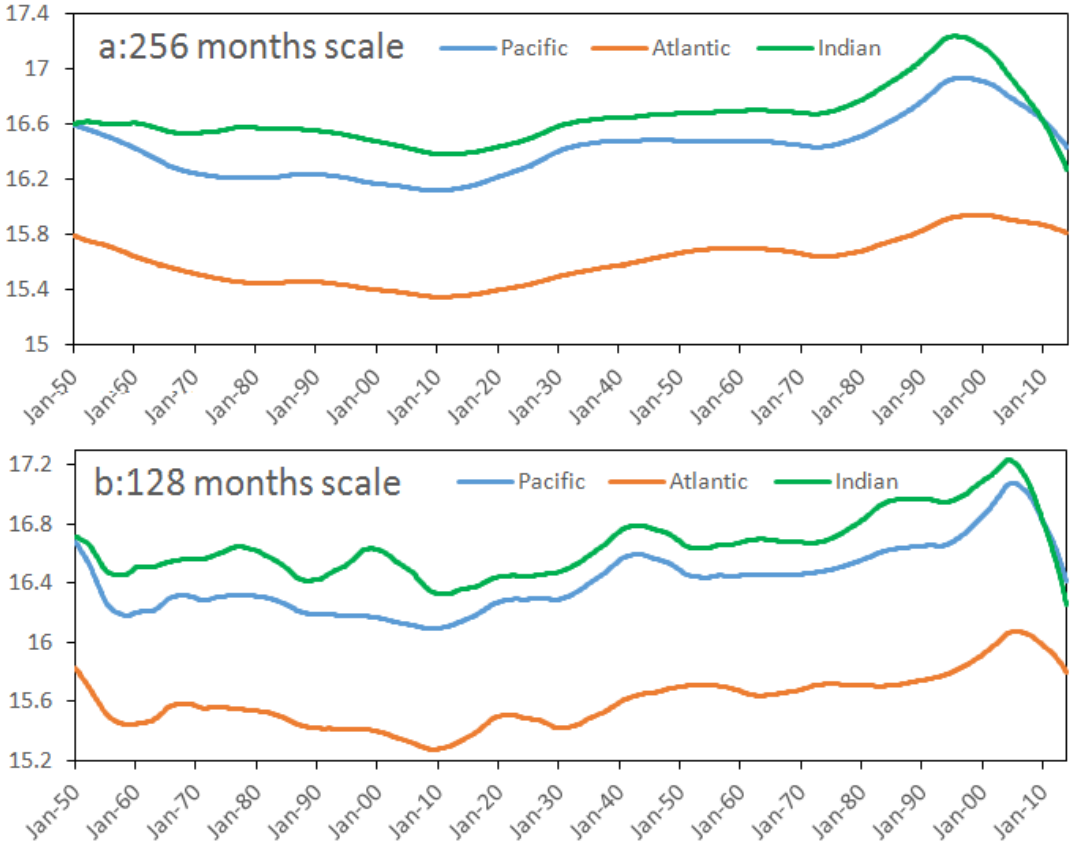
sub-basin scale(SH)





SST dropping amplitude(℃) in the warming hiatus period for long term SST evolution patterns of each sub-ocean in southern hemisphere at the time scales of 256 month(a) and 128 months(b). P1 and P2 are southern tropical Pacific and southern subtropical Pacific, respectively whereas A1 and A2 are southern tropical Atlantic and southern subtropical Atlantic ,respectively . Similarly, I1 and I2 are southern tropical and subtropical Indian.

Ocean scale



Indian Ocean has the biggest SST drop(0.962℃) in the recent hiatus period whereas the SST dropping amplitude of Atlantic Ocean is smallest(0.125℃) among the three Oceans at the scale of 256 months

Conclusion and discussion

Based on long-term SST dynamic pattern study at various spatial scales, we show that the recent warming hiatus is mainly related to HTDS in southern hemisphere and Indian Ocean and Pacific Ocean play a much bigger role than Atlantic Ocean. At both 256 and 128 months, southern tropical Indian Ocean show a much bigger cooling trend than other sub-oceans and worth more attention from climate scientists and Oceanographers in dealing with the oceanic mechanism for the recent warming hiatus.

Our results that Pacific and Indian Ocean are the main drivers of the recent warming hiatus is consistent with Nieves et al. who found that the recent hiatus is caused by decadal shift in Indo-Pacific heating[21]. In addition, our result that the recent warming hiatus is mainly related to southern hemisphere highlight the merit of our approach based on SST data rather than Argo based OHC data as southern hemisphere happens to have very sparse Argo coverage[14].

The long term SST dynamic pattern based HTDS study is free of the problems with OHC estimation models and sub-surface temperature data quality and coverage(in terms of time and space). But in fact I am not very sure of its validity despite that the logics behind it is no problem based on my academic level.

Thanks for your attention!