Variability of the Atmospheric Zero Trend Level

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Introduction

The current 2010 Quadrennial Defense Review Report and the 2010 National Security Strategy, primary strategic guidance for military operations ,dictates that climate change has national security implications[1][2]. To properly understand climate change it is imperative that we understand the cause and effect relationship of temperature changes in the atmosphere . The vertical profile of atmospheric temperature trends allows for the analysis of cause and effect relationship of temperature changes at different levels of the atmosphere. The majority of climate studies involving observed atmospheric temperature trends have been conducted over entire time periods of selected datasets or are analyzed over a trend in the early part of the dataset compared to a trend in the later part of the dataset. These datasets primarily consist of either radiosonde data or Microwave Sounding Unit (MSU) data from polar orbiting satellites.

Variability of many climate forcings (e.g., water vapor, stratospheric ozone, solar radiation, methane, regional land change/land use) has occurred over time periods shorter than the entire period of available atmospheric data or two long term trends, making it difficult, in some cases, to determine forcing effects on atmospheric temperature trends. Variability in atmospheric temperature trend profiles therefore need to be analyzed over shorter or limited time periods (LTP) to understand the complex feedback processes between atmospheric forcing and temperature change that may not be seen using one or two long term linear trends. Additionally, understanding the variability of the atmospheric temperature trend profile could aid in gaining greater understanding of atmospheric amplification theory, be a tool for validating climate models and has been shown to be instrumental in understanding complex differences in temperature database construction [3].

This study initiates the understanding of variability in atmospheric temperature trends by a top level analysis focusing on the level of the atmosphere where there is cooling above and warming below. This is the level where the trend is zero and is termed the zero trend level (ZTL). Examples as to why understanding variability in the ZTL and temperature trend profile is important to our understanding and interpretation of climate change are presented.

Data

The radiosonde data used here are based on the temporally homogenized data set described in [4] available at http://www.ncdc.noaa.gov/oa/cab/ratpac/index.php. We use RATPAC-A for our analysis. The RATPAC-B database was also used as a comparison. [5] found jumps and discontinuities in individual station records that are used in the RATPAC-B data causing a tendency for spurious cooling in stratospheric and tropospheric data. For this reason, only those radiosonde sites and times that were found to be "good" by this group are used, minimizing a long term cooling bias in the results of this study. This tailoring of the RATPAC data allows the radiosonde data to be in excellent agreement (variability and trend) with the MSU LS channel data [6]. While we used both datasets, our top level analysis of the variability of the ZTL was not impacted. Other radiosonde datasets have been analyzed and are similar to the results shown here but are not included on this poster.

References

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Analysis

LTP trends are created using least square linear trends over a moving window of 20 and 25-years at each radiosonde level. For example, Fig. 1 shows 20-year LTP trends for global(a) and tropics (20N-20S) (b) with the year indicating the end of the 20-year trend. The red line drawn through the year 1999 indicates the vertical trend profile for trends from 1979 to 1999.

The vertical distribution of temperature trends indicates mainly warming (variable magnitude) in the troposphere and strong cooling (variable magnitude) in the stratosphere over most LTP. In addition, results indicate a variability of the height of the ZTL over the defined LTP even in the longer 25-year LTP trends. The ZTL has a tendency to decrease over the temporal change of trends. The general tendency suggest that the ZTL decreases in height with strong cooling in the stratosphere, mainly in the later 20 and 25-year trends. However over some LTP trends the ZTL doesn't appear to depend on the magnitude of the cooling in the trends above the ZTL or the magnitude of the warming in the trends below the ZTL. The reduced RATPAC dataset shows global averaged ZTL varies from 20-year globally averaged LTP trends the ZTL varies over a range of ~75hPa-250hPa, and for the 25-year globally averaged LTP over a range of ~90hPa-250hPa. RATPAC-A does not show a significant departure from the reduced RATPAC results, however Fig. 2 shows results from the Ex Tropics((c) and (f)) and it indicates significant cooling over 20 or 25-year periods appear only after trends ending in ~1993. Results indicate the variability of the ZTL is independent of the tropopause, suggesting studies may have to view the atmosphere differently to understand trend. Instead of the tropopause, certain studies may need to use a variable boundary such as the ZTL. It is possible that causes of ZTL variability may be related to ozone depletion and recovery, water vapor variability or variability in the solar spectral output to name a few. However, a comprehensive study into the effects of these parameters over LTP would be necessary to confirm this hypothesis and in some cases vertical profiles of these forcings are not available.

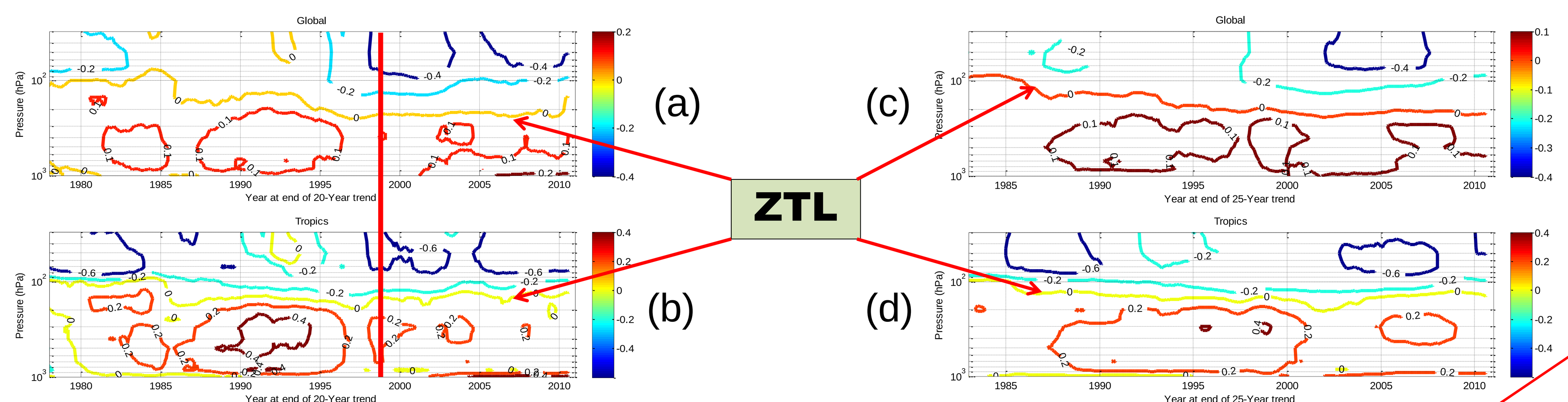

Figure 1: 20-year Limited Time Period trends (K/decade) on (a) globally averaged RATPAC(RW) data, (b) Tropical (20°N-20°S). Year indicates end of the 20-year trend, for example 1999 indicates trend data from 1979-1999. (c) and (d) are same as (a) and (b) over 25-year LTP.

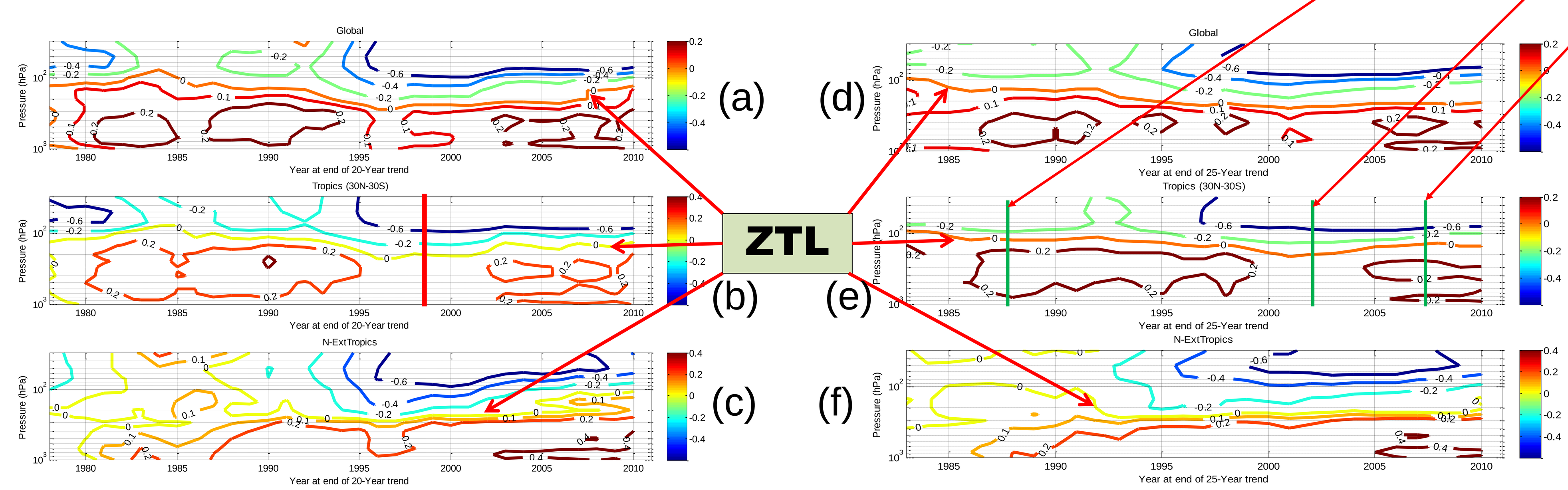

Figure 2: 20-year Limited Time Period trends (K/decade) on (a) globally averaged RATPAC-A data, (b) Tropical (30°N-30°S), (c) ExTropics. (d),(e) and (f) are same as (a), (b) and (c) over 25-year LTP.

Significance Examples

Here we present examples how understanding the variability in the ZTL and the vertical temperature trend profile may impact climate studies.

Trend Analysis Combining MSU MT and LS channels

[7] developed a method to analyze lower tropospheric temperature trends by combining MSU channel 2(MT) and channel 4(LS). Their method uses 25-year trends from radiosonde data to create coefficients to be used with MSU data.

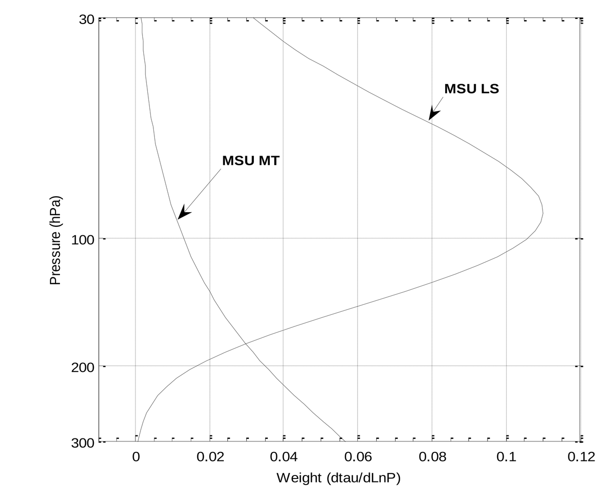

Figure 3: MSU channel 2(LS) and channel 4(LS) weighting functions. When combining channels the layer that has the greatest contribution from both channels is between 100mb and 200mb.

Note from Figs 1 and 2 that the majority of the ZTL variability is between 100mb and 200mb. This coincides with the layer that has the greatest contribution from both channels. We determined that the greatest errors using this method were seen during time periods the LS channel does not represent the MT channel layer above a chosen tropopause. This occurs when there is strong cooling in the stratosphere coincident with the predominate level of zero trend (ZTL) above the selected tropopause. We did not find this condition in any 25-year LTP in global or tropic averaged data, however studies that use this method in other regions or time periods (less than 25-year trends) may be introducing significant unaccounted errors[8].

Atmospheric Amplification Theory

Determining if tropical surface warming trends increase with height to the tropopause with a maximum trend in the middle to upper troposphere (Atmospheric Amplification)[9] could yield different results from using different trend time periods. Using Fig 2(e) as an example; Tropical (30N-30S) 25-year LTP trends.

- This temperature trend profile could give results showing atmospheric amplification with maximum warming around 300-400mb and warming until ZTL, close to 100mb.
- This temperature trend profile may not show any warming in the profile and the trends decrease after the 200mb ZTL well below the tropopause.
- This temperature trend profile may show two maximum levels (~850mb and 300-400mb) and then decreasing thru the ZTL (~150mb) to the tropopause (100mb)

Validating Climate Models - ZTL

[10] shows simulated 1979-1999 temperature trends from four different global climate models(see [10], figure 1). Each of those models depicted a ZTL at 100mb for the Tropics (30N-30S). Using Fig 2(b), Tropical (30N-30S) 20-year trends as a comparison indicates a difference. 20-year trend ending in 1999, Fig2(b) (red line) indicates a ZTL at or below 200mb. 200mb in the climate model figure indicates maximum warming (or close to it). The authors note that in this is an example and a detailed comparison needs to be accomplished, however, this comparison shows that the ***ZTL could be used as a novel tool to validate climate model output.***

Future Work

Our Significance Examples are not an exhaustive list, but does communicate the importance of understanding variability in the ZTL and temperature trend profiles. Future work will include: analysis of the ZTL with all available radiosonde datasets to include error analysis in the creation of the ZTL, analysis over different regions of the globe. Additional future work will include the necessary collaboration to create a new MSU channel to compare the ZTL region with satellite trends. We propose a new channel created from different scan angles of MSU channel 4(LS), sensing the lower region of the lower stratosphere (LLS).