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Using Ancillary Zero Trend Levels as a Means to Elucidate Microwave Sounding Unit Derived Tropospheric Temperature Trends Methods

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ABSTRACT

Accurate assessment of temperature trends in the atmosphere is an important tool in our understanding of climate change. Currently there are three databases derived from satellite based Microwave Sounding Unit (MSU) radiance measurements. The three separate databases produce different results in the middle troposphere (termed MT) temperature trends, with two of the databases producing lower troposphere (termed LT) trends with differing results, introducing uncertainty which prevents the community from deriving distinct conclusions. Comparison studies have been performed using ancillary data to discriminate which method of database construction represents the closest actual climate evolution without success.

This study introduces the concept of the zero trend level (ZTL) which allows the globally averaged atmosphere to be analyzed as a dichotomous system, one cooling layer and one warming layer over a chosen time period. The ZTL concept together with shorter MSU derived trend time periods are used as a means to elucidate between trend method construction by comparing consistency of the different methods with the latest data available.

Results from the ZTL analysis show an important insight into the evolution of the atmospheric temperature trends over the last four decades. Combined with shorter time period analysis the ZTL analysis provide evidence that the University of Alabama-Huntsvilee (UAH) derived database is more self consistent than the Remote Sensing Systems (RSS) database over the 1988-2003 time period within the uncertainty, validity and accuracy of the latest radiosonde data available. NOAA-11 and NOAA-14 uncorrected MSU hot plate anomaly signatures are

visible in the RSS-UAH brightness temperature monthly anomaly time series in the LT channel only, indicating this to be source of the inconstancy.

KEYWORDS: Atmospheric temperature trends, MSU derived temperature trends, Climate

1. Introduction

Accurate assessment of temperature trends in the atmosphere is an important tool in our understanding of climate change. Currently there are three databases derived from satellite based Microwave Sounding Unit (MSU) radiance measurements [*Christy and Spencer*, 2005; *Christy, et al.*, 2003; *Mears, et al.*, 2003; *Vinnikov, et al.*, 2006] which will be referred to as (UAH) (RSS) and (UMd) respectively. The three separate databases produce different results in the middle troposphere (termed MT) temperature trends, with two of the databases (UAH, RSS) producing lower troposphere (termed LT) trends with differing results, introducing uncertainty which prevents the community from deriving distinct conclusions when incorporating tropospheric trends in determining how the atmospheric climate has evolved. The major differences in the methods use to create these temperature trends are in the hot target calibration and diurnal drift corrections for the different satellites that have been used to produce the database [*Mears, et al.*, 2006]

Due to the discrepancies, comparison studies have been performed using ancillary data to discriminate which method of database construction represents the closest actual climate evolution, yet conclusions have yet to be determined.

Uncertainties that existed in the stratospheric region of the globally homogenized data available at the time lead to one study using only the tropospheric part of the radiosonde data with inconclusive results [*Christy and Norris*, 2004].

Fu and Johanson (2004) and Christy and Norris (2006) use simple statistical retrieval (SSR) methods to eliminate the influence of lower stratosphere (LS) on MT, however, complete elimination of the influence from LS cannot be accomplished [*Christy and Norris*, 2006] nor is the actual cooling influence from the lower stratosphere/upper troposphere on MT, which can be deeper into the atmosphere than LS senses, eliminated.

Additionally, Fu *et al.,* (2004) process produced a trend for the 800-350hPa layer which was compared to LT and/or MT channels from UAH and RSS. This caused ambiguity due to the fact that although the MSU channels produce a broad average layer trend the LT and MT layers do not coincide with the 850-350hPa layer, thus any comparison is inconclusive and needs further investigation.

This work introduces the ancillary derived zero trend level (ZTL) as a means to evaluate the evolution of the atmosphere. It allows the atmosphere to be analyzed as a dichotomous system with one distinct cooling layer and one warming layer on either side of the ZTL, over a chosen time period. The cooling layer is used to calculate the temperature trend in the warming layer as it would be seen by MT, using an MT static weighting function. This control warming layer can be compared to the tropospheric warming produced by the MSU derived temperature methods. Ancillary derived ZTL comparisons are made to MSU derived temperature trends with the purpose of elucidating one method that provides the closest evolution of the atmosphere based on the current radiosonde data available. Shorter MSU derived trend time periods are analyzed as means to elucidate method trend construction by comparing self consistency of the different methods.

Section 2 of this work will describe the data use, introduce the ZTL, and describe methods created to compare MSU derived temperature trends. Discussion and results are provided in section 3 and conclusions in section 4. It is important to note that this is not an attempt to create a new database and trend is used solely as a means to investigate differences between methods. The purpose of this study was entered into with the spirit of looking at the data in a different way to see which data is closer to the "truth" so we can advance our understanding of causal mechanisms behind observed climate change [*Thorne, et al.*, 2005a] and to open a window of comprehension to find steps to thoroughly assess and improve methods to remove time varying basics that are responsible for these discrepancies [*Lanzante, et al.*, 2006].

2. Data/Methods

2.1 Data

The radiosonde data used here are based on the temporally homogenized data set described in Free *et al.* (2005), available at http://www.ncdc.noaa.gov/oa/cab/ratpac/index.php and Thorne *et al.* (2005b), available at http://www.hadobs.org . These data (hereafter called RATPAC-A and HadAT) are the newest temporally homogenized data sets available and have corrected many of the problems that have plagued homogenized radiosonde data set in the past. While both products incorporate a common building-block data [*Lanzante, et al.*, 2003] their methods of construction differ considerably [*Lanzante, et al.*, 2006] and are used in this work as two independent sources of ancillary data to which comparison studies are done. The RATPAC data includes the levels; Sfc, 850hPa, 700hPa, 500hPa, 300hPa, 250hPa, 200hPa, 150hPa, 100hPa, 70hPa, 50hPa and 30hPa. The HadAT data includes the levels; 850hPa, 700hPa, 500hPa, 300hPa, 200hPa, 150hPa, 100hPa, 50hPa and 30hPa. Here 1965-2005 data are used for introducing the ZTL and 1979-2004 (or subsets within this time period) are considered for MSU comparison analysis.

Satellite observations with the MSU instrument provide measurements of mean temperatures over vertical layers, from surface to 400-500hPa for LT and surface to 75hPa for MT. The MT has a contribution from cooling in the upper troposphere and lower stratosphere that ranges from 0.5% to 30%, depending on the level of the ZTL (discussed in section 2.3), for the last four decades. The LT channel was created [*Spencer and Christy*, 1992b] in order to minimize the contribution to MT from the upper troposphere and lower stratosphere. Here we consider results based on two different MSU data sets. One produced by Remote Sensing Systems and sponsored by the NOAA Climate and Global Change Program. Data are available at www.remss.com and described in Mears *et al.* (2003) and Mears and Wentz (2005). The other from the University of Alabama at Huntsville (UAH), available at http://vortex.nsstc.uah.edu/, and described in [*Christy and Spencer*, 2005; *Christy, et al.*, 2003]. Published results from the University of Maryland's (UMd) recently developed MT data, described in Vinnikov et al., (2006), are not used in this work as there is not an LT database to use for consistency comparisons.

2.2 MT static weighting function sensitivity

To accomplish the methods described in this work, radiosonde data at specific layers needs be weighted as the MSU would sense the atmosphere. Therefore this study uses the MT static weighting function method to generate the simulated satellite temperature trends from the radiosondes [*Spencer and Christy*, 1992b]. Fig. 1 shows the fractional contribution of a layer (surface to height of the layer) to the total simulated MT trend. From this fractional contribution, it is possible to calculate the contribution of any atmospheric layer's temperature trend to the total MT trend. If any inclusive layer contribution is necessary to be used a simple subtractions of the fractional contribution derived from two different layer heights would give the fractional contribution from that layer to the total simulated MT trend. Creating the metric in this way is the same as vertically integrating the radiosonde temperatures to the MT weighting function, but allows the versatility of finding the fractional contribution from any layer needed to do the analysis.

2.3 Zero Trend Level (ZTL)

Current literature [*Davey, et al.*, Submitted; *Free, et al.*, 2005; *Seidel, et al.*, 2004; *Sherwood, et al.*, 2003; *Thompson and Solomon*, 2005; *Thorne, et al.*, 2005b] show global average radiosonde/reanalysis derived temperature trends. These studies show that the atmosphere is divided into two layers, one layer with a positive temperature trend (lower troposphere) and the other layer with a negative temperature trend (lower stratosphere/upper troposphere).

The "transition" level between positive and negative temperature trends will be termed the zero trend level (ZTL). To find the ZTL, trends at each reported level in the ancillary data are created over a chosen time period. The two levels are found where the upper level (lower pressure level) has a negative temperature trend and the lower level (higher pressure level) has a positive temperature trend. Linear interpolation between these two levels is used to find the pressure level at which the temperature trend is zero. If the trends are all positive the ZTL is considered 30hPa (constrained by the database). Fig. 2 shows an example created using trends derived from RATPAC-A data for 1979-2004, with the ZTL at about 230hPa.

All temperature trends discussed and calculations of layers are accomplished and weighted by the MT static weighting function.

Using the derived ZTL as a reference and the fact that the microwave region lies in the Rayleigh-Jeans portion of the Plank's Black Body Function, the MSU brightness temperature (Tb) is directly proportional to the physical temperature [*Spencer and Christy*, 1992a]. A relationship for changes in temperature (i.e. temperature trends) in the layer above the ZTL (AZTL), the layer below the ZTL (BZTL) and the MT, using a static MT weighting function is derived (Fig. 3)

$$\Delta T_{BZTL} = \alpha(\Delta T_{MT} - \Delta T_{AZTL}) + \Delta T_{AZTL} \qquad \text{or}$$

$$\Delta T_{BZTL} = \alpha(\Delta T_{MT}) + (1-\alpha)(\Delta T_{AZTL}) \quad (1)$$

Where $\alpha = \frac{1}{\beta_{BZTL}}$ and β_{BZTL} = The fractional contribution of the BZTL temperature trend to the MT trend (Fig. 1).

As stated in this definition, the level depends on the time period used and on the data used to find the level. However, temperature trends from any data source will depend on the time period of interest or the data that is being used. As the purpose of this work is to elucidate trends from different MSU database construction processes, multiple time periods are analyzed. Each comparison is done with a consistent time period across both MSU and radiosonde data, with trends and ZTLs derived for each period.

Why create a new reference level? The main motivation is to find a way to eliminate the influence of the lower stratosphere and/or upper troposphere on the MT trend and create a control layer to use in MSU comparison studies. This layer (BZTL) is not influenced by the upper troposphere / lower stratospheric cooling (over chosen time period). Fu and Johanson (2004) and Christy and Norris (2006) use simple statistical retrieval (SSR) methods to eliminate the influence of LS on MT, however, complete elimination of the influence from LS cannot be accomplished [*Christy and Norris*, 2006] nor is the actual cooling influence from the lower stratosphere/upper troposphere on MT, which is deeper into the atmosphere than LS senses, eliminated. To show this, a 15-year trend starting each year from 1965 to 1990 was computed for each reported level in the ancillary data. The corresponding ZTL is calculated for each time period and results are shown in Fig. 4. Analysis from the RATPAC-A data is shown, however, the HadAT data gave similar results. This different view of cooling and warming in the atmosphere does not provide magnitude, but indicates that the lower boundary of the cooling layer has significant variability; from 30hPa to 270hPa over a four decade time period. The cause of this variability is left to further investigation, but the tendency indicates that linear statistical combinations using LS trends, which have significant spatial (vertical) and temporal variability cannot be used to negate influence from the lower stratosphere/upper troposphere in MT, when monitoring tropospheric temperature trends. This supports Spencer et al., (2006) findings. In addition, variability of this nature gives further strength that LT channel is the robust satellite channel to monitor tropospheric trends as there is very little influence from the lower boundary of the cooling layer in the atmosphere. Using just the MT channel trend will not provide true nature of the tropospheric temperature evolution. In light of these issues with LS the elucidation method using the ZTL analysis uses the radiosonde data to completely eliminate the cooling influence of the lower stratosphere and upper troposphere on TM.

Furthermore, comparison studies tend to compare "tropospheric" temperature trends with different definitions of "troposphere". One example; the Fu and Johanson (2004) method results in a trend of the 850mb-300mb layer where UAH and RSS create the LT trend that is from surface to 400-500hPa [*Spencer and Christy*, 1992a]. Comparison of the two trends cannot lead to any conclusions as any variability in temperature in one layer that is outside of the other layer being compared will lead to different trends. The ZTL method creates a clearly defined warming layer to analyze, the BZTL; the layer that is warming over the chosen time period, and therefore is used as the control layer in which to compare data, alleviating any ambiguity arising from trends created from different layers and layers that are within or outside of a different warming layer created by a alternate construction methods.

Debate on the robustness of surface trends [*Parker*, 2004; *Pielke and Matsui*, 2005] is also addressed by this method. The elucidation method using ZTL analysis works with a top-down approach using radiosonde data down to (at most) 500hPa, alleviating any ambiguity with the surface or surface influenced layers in the ancillary data.

Uncertainties in stratosphere are relatively large [*Free, et al.*, 2005; *Thorne, et al.*, 2005b]. The process is completed by including the relatively large uncertainties in the stratosphere into the process. Even though there are relatively large uncertainties in the data the approach used here provides valuable information that would not otherwise have been found.

2.4 The control ($\Delta T_{BTZL(con)}$)

An overview of the procedure to create a control temperature trend in the BTZL layer ($\Delta T_{BTZL(con)}$) is as follows:

1. Choose time period; calculate trends at each reported level of radiosonde data.
2. Find the ZTL, then corresponding trend in the AZTL layer weighted by TM weighting function.
3. From equation (1) all possible solutions for $\Delta T_{BTZL(con)}$ based on any ΔT_{MT} are then calculated.

This provides the trend in the warming layer (BZTL), over the chosen time period, based on removal of the influence of the cooling layer (AZTL) from the MT, all weighted by the MT weighting function. Stated differently, this provides what the warming should be in the BZTL when the lower stratospheric/upper tropospheric cooling influence is eliminated, as seen by the MSU MT weighting function. Fig. 5 shows the relationship between the MT temperature trend and the BZTL temperature trend based on the constraints (ZTL, AZTL trend) of the 1979-2004 time period from the RATPAC-A data.

The uncertainty on either side of the line is created from the uncertainties in the radiosonde data. Two sources of uncertainty are considered. The ZTL is found by linear interpolation between two levels where the upper level (lower pressure level) has a negative temperature trend and the lower level (higher pressure level) has a positive temperature trend. The first source of uncertainty is in the calculation of the ZTL and is found by using the upper and lower uncertainty bounds of the trends in the radiosonde data at these two layers. The other source of uncertainty is calculated from the uncertainties in each of the radiosonde level trends within the AZTL. These uncertainties where calculated for each time period and level used, and was found to never be beyond ±0.16 °K/decade so this is the number that was used in all calculations. It is likely that conclusions presented in this paper show an overestimation of the actual uncertainty in calculating the trend in the AZTL. The bounds in Fig. 5 include both sources of errors.

At this point only the radiosonde data has been used and a control $\Delta T_{BTZL(con)}$ exists. The next step is to use the $\Delta T_{BTZL(con)}$ to compare the MSU derived trends. In order to do so, two pieces of information are necessary from the MSU derived products to see if the trends created by the different processing methods are self consistent with the radiosonde data being analyzed; the MSU MT temperature trend and the MSU BTZL temperature trend.

2.5 MSU comparison methods

The MSU MT is easily found from the data over the time period chosen. However, to compare MSU trends a weighted trend in the BTZL layer must be calculated. This is done from the LT data, and requires a small correction layer (CL).

The LT layer has been described as approximately representing the average temperature trend from surface to 400-500hPa. [*Spencer and Christy*, 1992b], however a more accurate layer to represent the LT is important to the way this process calculates temperature trend. Therefore, to ensure the results where not dependent on the layer chosen to represent LT temperature trends the calculations where completed separately with the temperature trends from the LT assumed to be the average temperature trend for the surface to 300hPa layer, surface to 400hPa layer and surface to 500hPa layer for the RATPAC-A data, the surface to 300hPa layer and surface to 500hPa layer for the HadAT data. This results in any distinguishable conclusions having the LT layer representing a surface to, somewhere, between 500hPa and 300hPa. The contribution from above the 300mb level is extremely small, therefore the channels representative layer would not lay outside of the surface to 300hPa layer.

The weighted trend in the BZTL created from the LT ($\Delta T_{BTZL(LT)}$) is found by the following equation:

$$\Delta T_{BZTL(LT)} = \frac{\beta_{CL}(\Delta T_{CL}) + \beta_{CL}(\Delta T_{LT})}{\beta_{BZTL}} \quad (2)$$

Where $\beta_{CL}, \beta_{TLT}, \beta_{BZTL}$ = fractional contribution (Fig. 1) to MT from $\Delta T_{CL,} \Delta T_{LT}, \Delta T_{BZTL}$ respectively (see Fig. 6)

The $\Delta T_{BTZL(LT)}$ is then compared to the $\Delta T_{BTZL(con)}$ to assess the consistency of the different MSU derived temperature trend methods with the radiosonde data and uncertainties.

3. Results

We start by comparing the 1997-2004 time period. Fig. 7 displays this comparison and it can be seen that the results are inconclusive within the uncertainties of the method, or the UAH and RSS time series are consistent with themselves within the uncertainty, validity and accuracy of the radiosonde data. The way this method is accomplished the cooling eliminated from the MT static weighting function is constant over the time period used in the comparison. This allows the possibility that both methods could be consistent within the validity and accuracy of the radiosonde data yet still offer differing trends in each channel. This would indicate, as it does in this particular comparison, that the MT trend and the LT trend from both methods are consistent with each other, within the uncertainty, validity and accuracy of the radiosonde data.

a. Shorter time period constraint

In order to create a constraint to the data, to be able to elucidate the methods, a filter was accomplished on the MSU data and the radiosonde data, creating 15-year running trends. As long as the MSU data and the radiosonde data are analyzed over the same time period the analysis is valid, however using any relationship derived over any other time period than the one used in deriving the calculations will not be valid. 15-year trends were used as it represents a long enough time period to get accurate trends, while smoothing out any short term temperature increases or decreases.

Fig. 8 displays 15-year running trends of RSS - UAH, at each channel (termed RMU_{MT} and RMU_{LT}) and was used to assess the best 15-year time period to use for comparison purposes. Two regions of interest were investigated. The 1982-1997 time period was considered because the magnitude of RMU_{MT} and RMU_{LT} was the greatest and the 1988-2003 time period was considered because the magnitude of RMU_{MT} - RMU_{LT} was the largest. The lower dashed line in Fig. 8 is RMU_{MT} - RMU_{LT} and indicates the magnitude of separation between the different MT trends decreases at a slower rate than the magnitude of separation between the different LT trends.

Two features in Fig 8 require further analysis and comment at this time. The tendency of RMU_{MT} and RMU_{LT} to decrease from the trend starting in 1982 to the trend starting in 1988 can be explained by the difference in RSS and UAH's satellite merging method with respect to the NOAA-9 satellite. To further understanding, Fig. 9 shows the UAH - RSS monthly brightness temperature anomaly time series from 1979 to 2004 for the MT and LT channels. This time series shows differences in RSS and UAH time series, and shows a discontinuity around 1985-1987. It is known this difference is due to correction methods used for the NOAA-9 satellite and is discussed further in Mears et al., (2003) and Christy and Norris (2004). The magnitude of RMU_{MT} and RMU_{LT} will decrease as the influence of this discontinuity becomes less, and should be the lowest after the trend is not influenced by the discontinuity. It can be see that the trends starting in 1987,1988 and 1989 have the smallest RMU_{MT} and RMU_{LT} as the 1985-1987 discontinuity is no longer an influence in the trend.

The second feature is the fact that the magnitude of RMU_{MT} - RMU_{LT} starts to increase beginning around the trend starting in 1982 (see lower dashed line in Fig. 8) and continuing to maximum in the trend starting in 1988. This shows that the RMU_{MT} and RMU_{LT} trends decrease, as should, due to the 1985-1987 NOAA-9 merging method discontinuity, but the magnitude of the RMU_{LT} trends decrease at a faster rate. Because of the relationship between MT and LT this anomaly cannot be due to any physical properties (i.e. temperature trends) in the atmosphere but would only happen if the portion of the atmosphere being sensed changed (weighting function changed) or there was something in the processing of the methods that effected one channel but not the other.

The magnitude of RMU_{MT} - RMU_{LT} is maximum in the trend starting in 1988, but close to maximum in trends starting in 1987 and 1989. This would indicate a distinct discrepancy between the MT and LT data in the 1994 to 1997 time period (corresponding to the center of the 15-year time series). Further inspection of the UAH - RSS monthly brightness temperature anomaly time series (Fig. 9) indicates uncorrected instrument body temperature effect signatures for the NOAA-11 time period and the NOAA-12 time period in the LT channel only. This includes the signature of the distinctive decrease in warm target temperature in the 1994 time period. AMSU data included in UAH LT data but not in RSS LT data was thought of as a possibility for this anomalous effect, but the anomaly time series does not indicate any distinctive signatures starting around 1998-1999 when the AMSU data started to be included in the UAH LT data.

Uncorrected signatures in LT only explain why there is a difference in the tendency of RMU_{MT} and RMU_{LT}. The fact that the signatures themselves are seen in the LT channel and not the MT channel invoke the need for further investigation into the methods of corrections in these two satellites. This analysis shows the differences between the two methods and cannot point to one method or combination of both as causing the anomaly found, however, comparing them using the elucidation method from ZTL analysis shows an inconsistency.

The elucidation method using ZTL analysis for the 1982-1997 time period (where the magnitude of RMU_{MT} and RMU_{LT} was the greatest) does not indicate inconsistency within the uncertainties of the method (not shown). However the 1988-2003 time period (Fig. 10) (where the magnitude of RMU_{MT} - RMU_{LT} was the largest) shows that the RSS method relationship between the MT and BTZL is not consistent within the uncertainty of the radiosonde derived BTZL trend. The inconsistency, explained by aforementioned discussion on uncorrected signatures in the LT channel only, lead us to conclude that the majority of the uncorrected signatures arise from the RSS data.

4. Summary and conclusions

On ZTL

Introduction of ZTL is accomplished as a means to look at the atmosphere in a temporal and spatial (vertical) way. It shows that the cooling layer in the atmosphere is highly variable over the last four decades with the ZTL ranging from 30hPa to 270hPa. Further investigation is warranted to explain the physical processes behind this unique variability.

The variability of the ZTL indicates that the MT has a 0.5% to 30% contribution from cooling in the upper troposphere/lower stratosphere. Therefore, any linear combination of LS, which does not sense the depth of the cooling layer, cannot be used in any statistical sense to subtract the effects of cooling in the upper troposphere/lower stratosphere, supporting findings by Spencer *et al.*, (2006).

The variability of the ZTL also indicates cooling is either extremely small or non existent in the LT channel (over any 15-year trend) and should be considered the best satellite channel to use for tropospheric trend analysis, based on the last 4 decades of radiosonde data. Thus, using any method or dataset that is solely MT as tropospheric trends or to validate methods used to derive tropospheric trends will not show an accurate evolution of the atmospheric temperature and should be discouraged.

On Elucidation

Our elucidation method using the ZTL analysis completely eliminates the cooling contribution from the upper troposphere/lower stratosphere on the MT to find a distinct warming layer (BTZL) over the time period chosen. The BTZL is used as a control metric in which comparison studies are done while alleviating issues regarding surface/near surface trend ambiguity and discrepancies created as the result of comparing different tropospheric defined layers.

MSU analysis on shorter time periods (15-year running trends) leads to the discovery that there are uncorrected instrument body temperature effect signatures for the NOAA-11 time period and the NOAA-12 time period in the LT channel only. This includes the signature of the distinctive decrease in warm target temperature in the 1994 time period.

Combined with the inconsistency outcome of our elucidation method using the ZTL analysis over the 1988-2003 time period leads us to conclude that the uncorrected signatures in the LT arise from the RSS data and are the basis of warranted continued investigation.

Further scientific inquiry is continued to determine how the uncorrected signatures can be seen in the LT channel difference only in order to determine the proper correction.

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Figure Legends

Figure 1 Fractional contribution , from surface to Top of Layer, to MT temperature trend weighted by the MT static weighting function.

Figure 2 Fractional contribution , from surface to Top of Layer, to MT temperature trend weighted by the MT static weighting function.

Figure 3. Zero Trend Level(ZTL) for RATPAC-A, 1979-2004. Trends are calculated for each reporting level. The ZTL is found by linear interpolation between the levels that change from positive trend to negative trend. This ZTL is 230hPa. AZTL is the layer cooling over the time frame and the BZTL is the layer that is warming over the timeframe

Figure 4 The total MT temperature trend is a linear combination of the (BZTL temperature trend * BTZL fractional contribution to MT trend) + (AZTL temperature trend * AZTL fractional contribution to MT trend)

Figure 5. 15-year running trend ZTL for RATPAC-A

Figure 6. The relationship between the MT temperature trend and the BTZL. This is derived with two constraints (1) AZTL for given time period, (2) ZTL for given time period. This relationship is derived from RATPAC-A 1979-2004 time period

Figure 7. To calculate BZTL from LT channel a Correction layer is need. A linear relationship exists between BZTL, LT and CL.

Figure 8 Comparison of UAH and RSS MT trend vs $BZTL_{(LT)}$ trend. RATPAC-A; 1979-2004. Top of LT representative layer is 500hPa(*),, 400hPa(x), 300hPa(O).

Figure 9. 15-year running trend of RSS - UAH for MT(offset by 0.8) and LT(offset by 0.4)

Figure 10. RSS-UAH monthly brightness temperature anomaly time series from 1979 to 2004

List of Figures

Figure 1

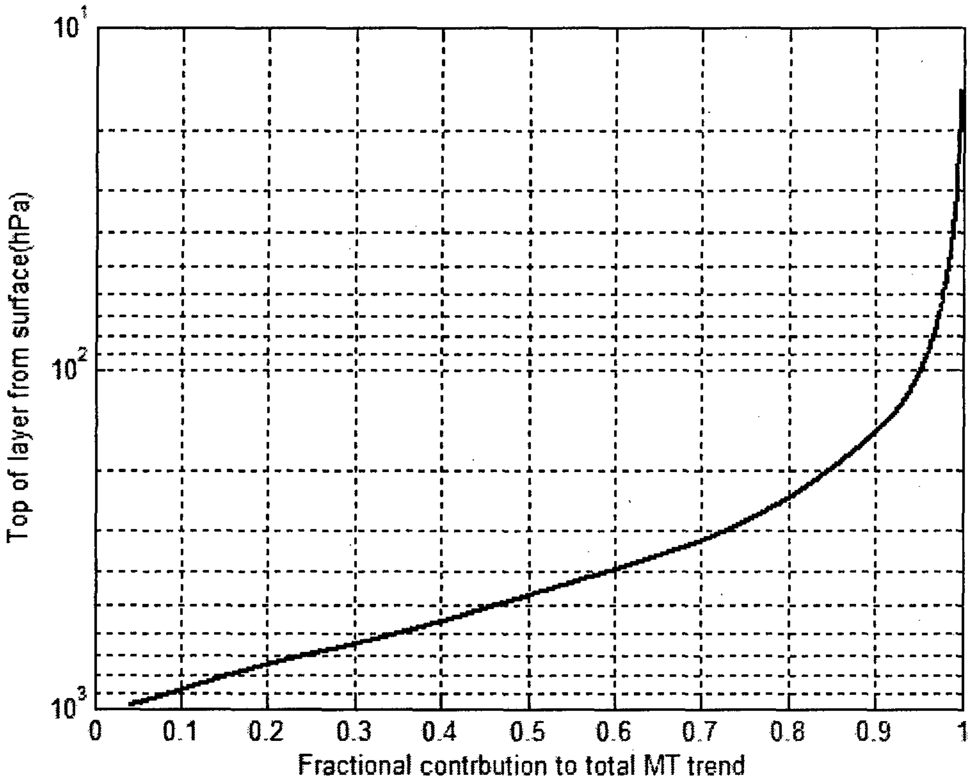
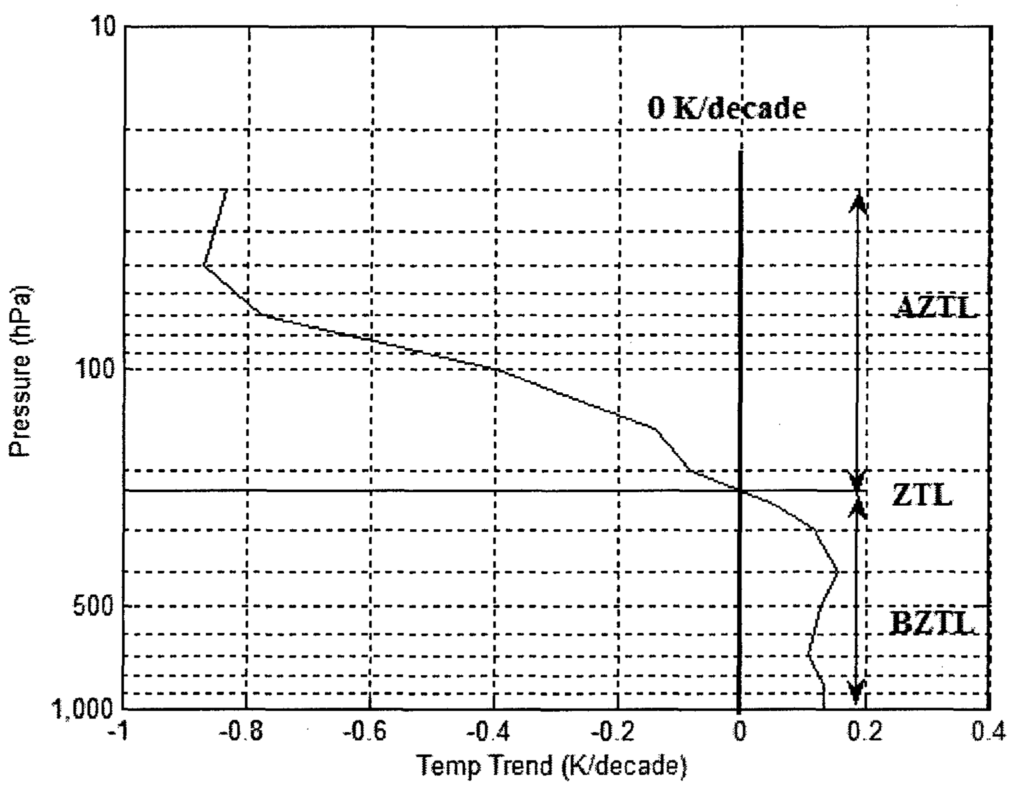
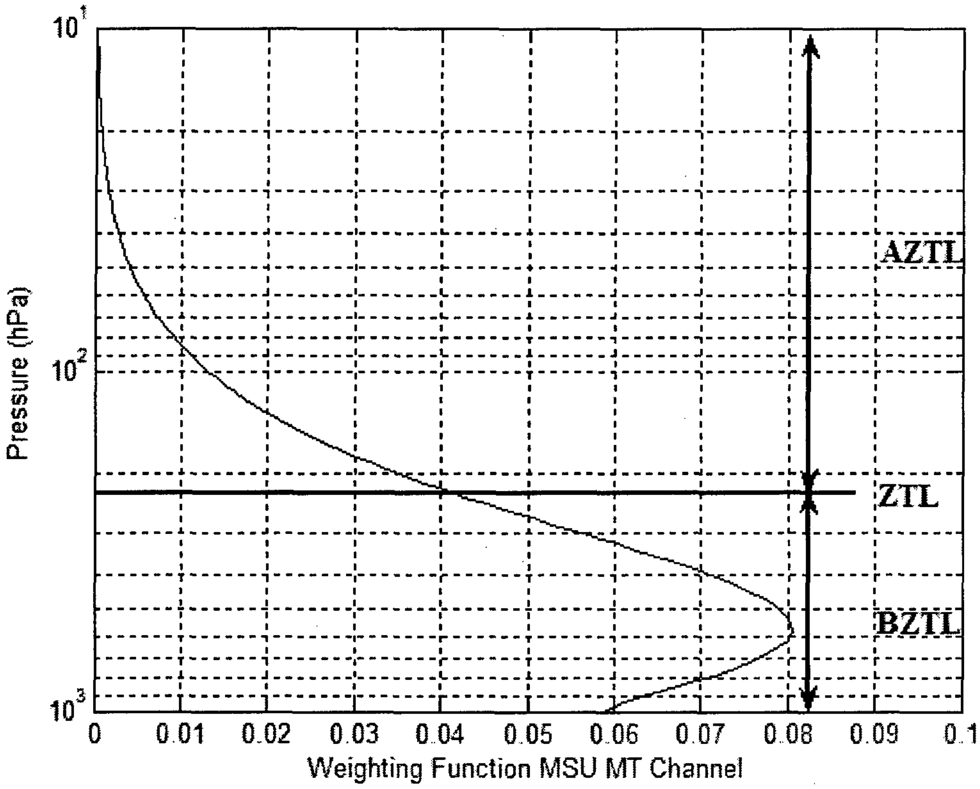


Figure 2



0 K/decade
AZTL
ZTL
BZTL
Pressure (hPa)
10
100
500
1,000
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
Temp Trend (K/decade)

Figure 3



Pressure (hPa)
10¹
10²
10³
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Weighting Function MSU MT Channel
AZTL
ZTL
BZTL

Figure 4

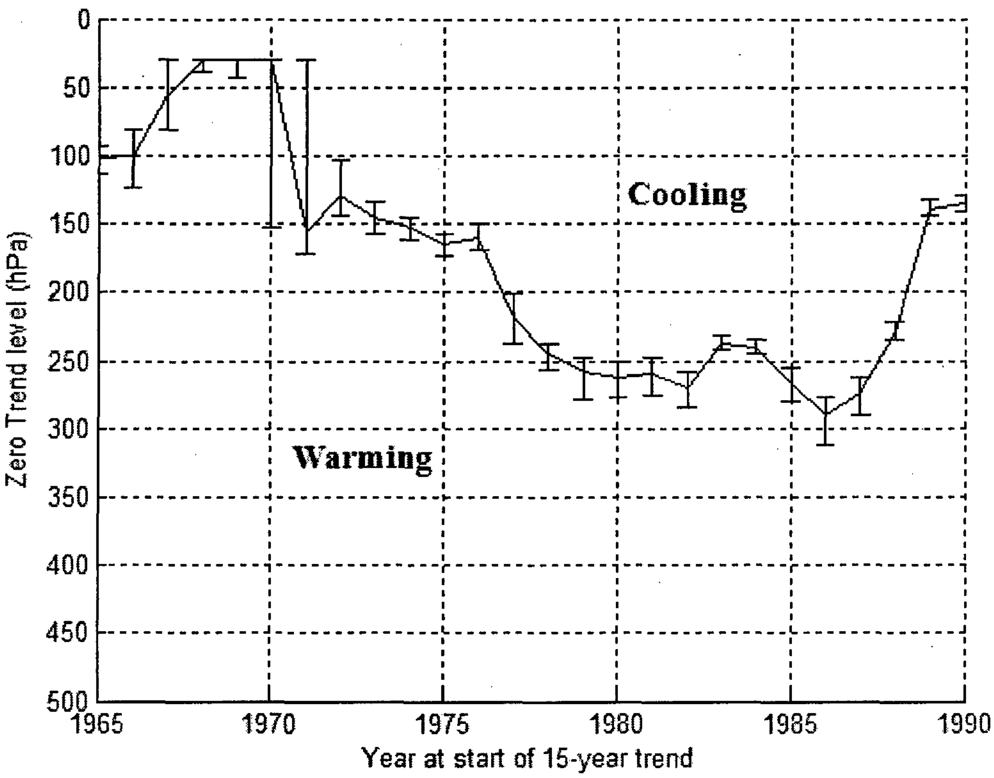
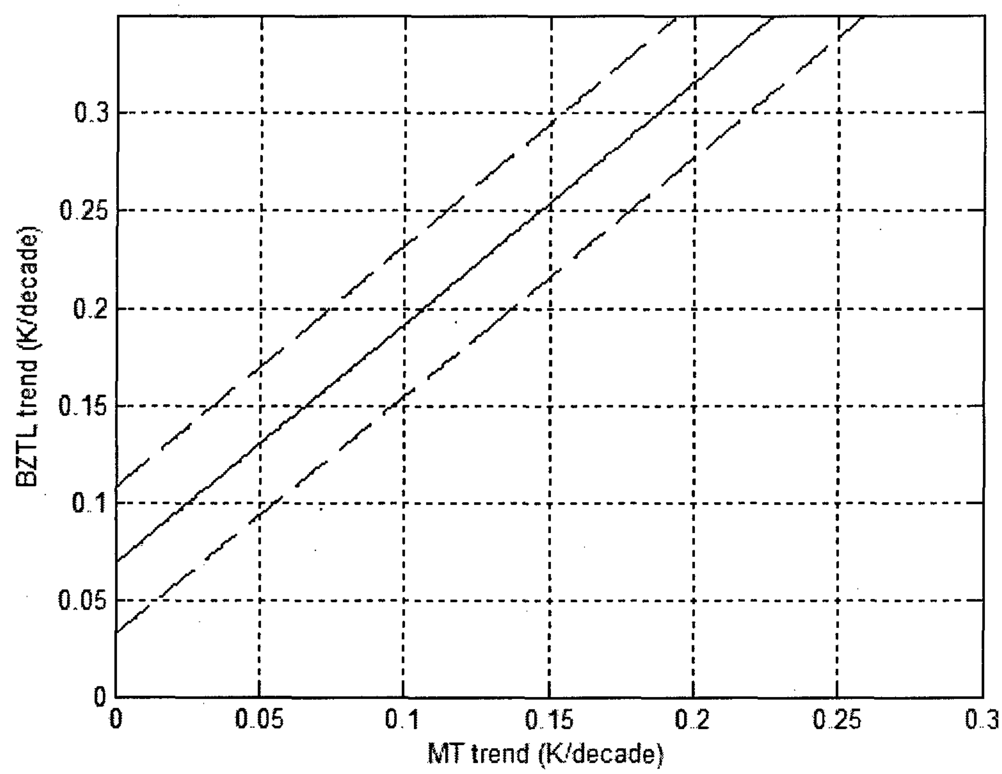
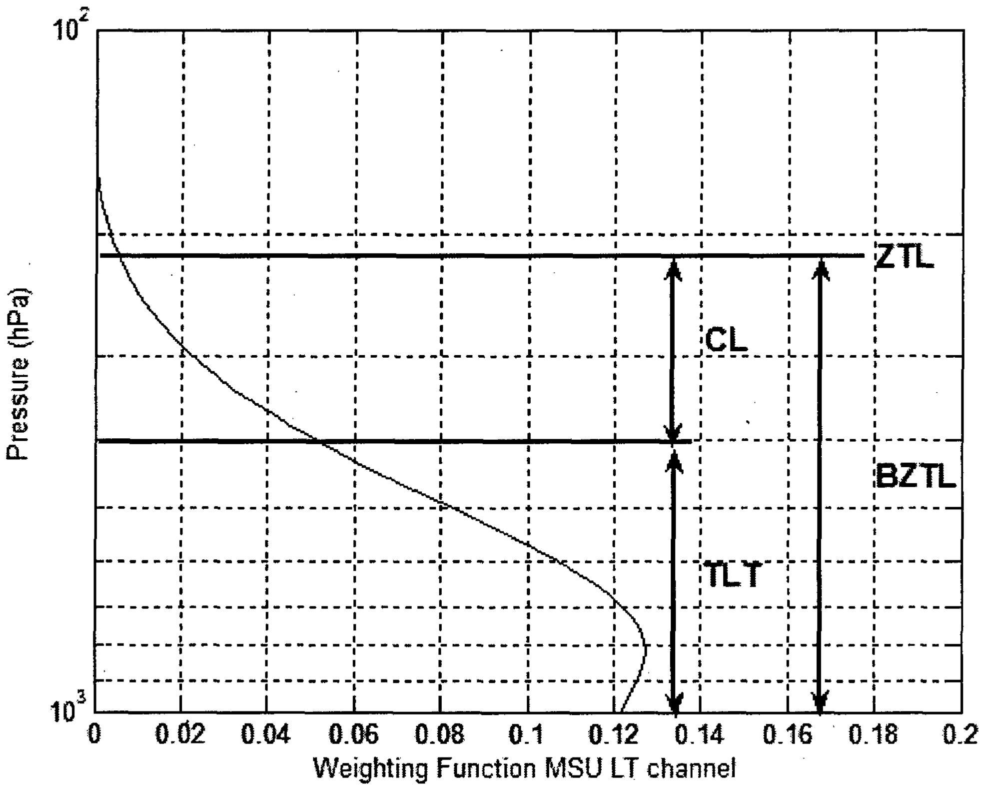

Cooling
Warming
Zero Trend level (hPa)
Year at start of 15-year trend
0
50
100
150
200
250
300
350
400
450
500
1965
1970
1975
1980
1985
1990

Figure 5



0.3
0.25
0.2
0.15
0.1
0.05
0
BZTL trend (K/decade)
0
0.05
0.1
0.15
0.2
0.25
0.3
MT trend (K/decade)

Figure 6



10^2
10^3
Pressure (hPa)
ZTL
CL
BZTL
TLT
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Weighting Function MSU LT channel

Figure 7

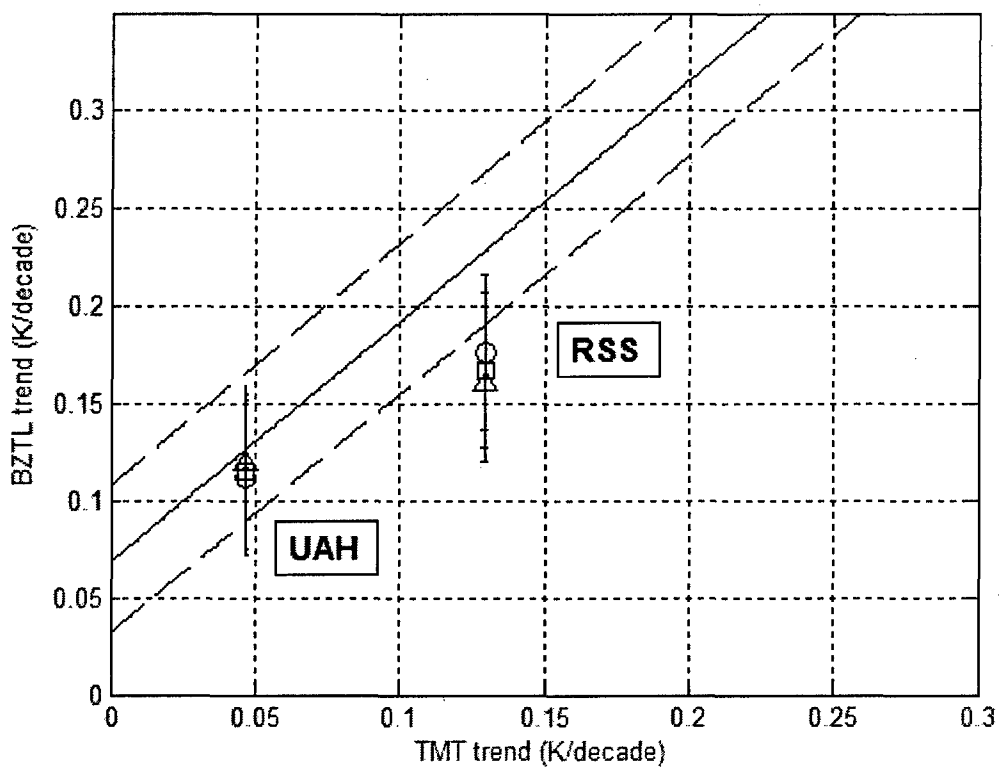
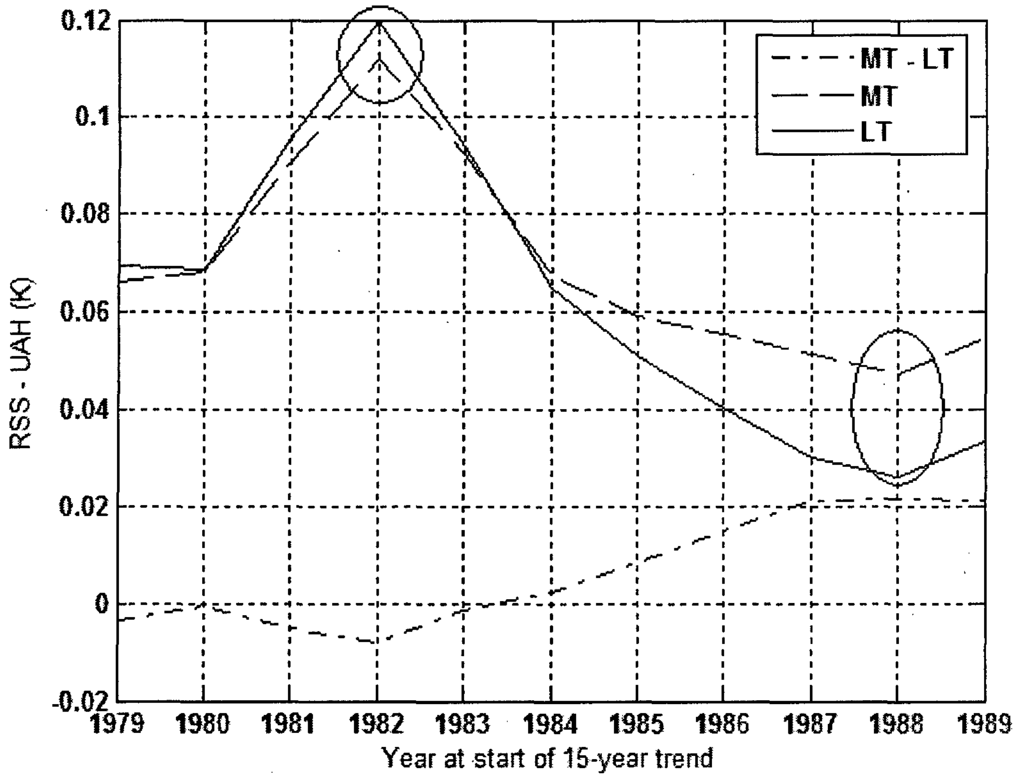

RSS
UAH
BZTL trend (K/decade)
TMT trend (K/decade)
0
0.05
0.1
0.15
0.2
0.25
0.3

Figure 8



MT - LT
MT
LT
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
RSS - UAH (K)
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
Year at start of 15-year trend

Figure 9

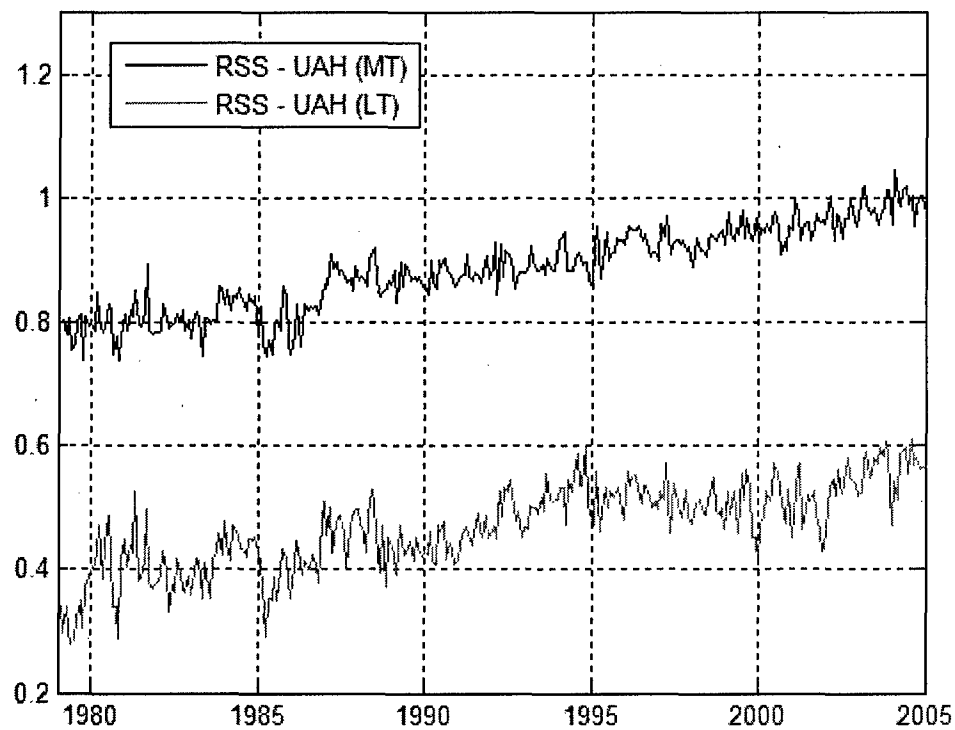
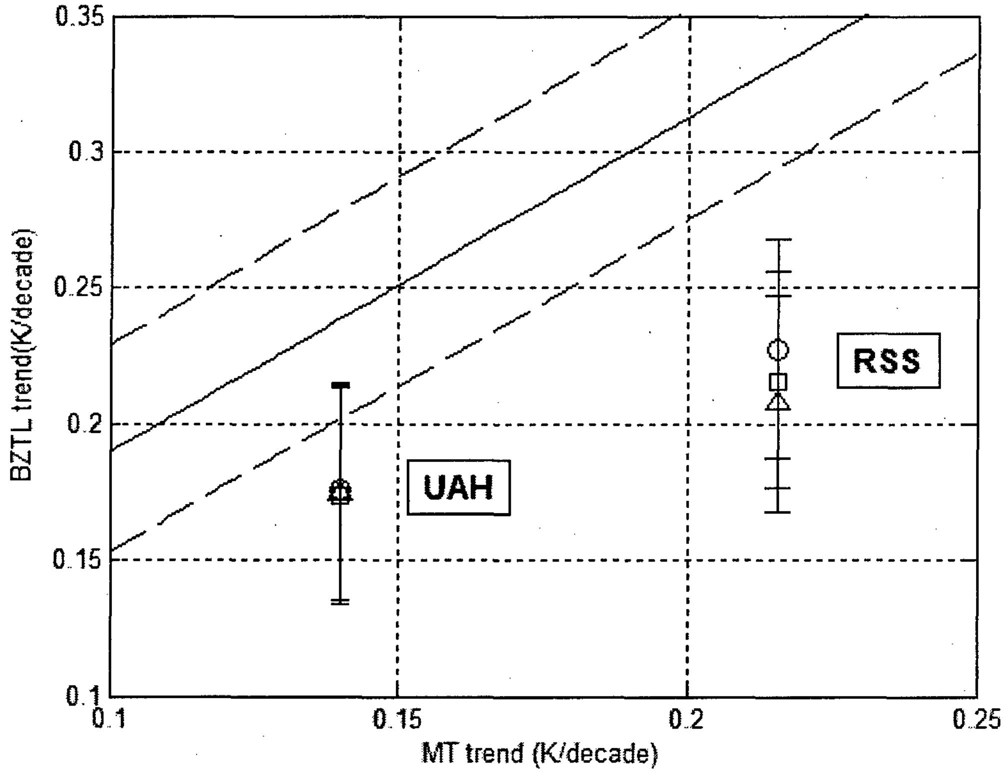

RSS - UAH (MT)
RSS - UAH (LT)
1.2
1
0.8
0.6
0.4
0.2
1980
1985
1990
1995
2000
2005

Figure 10


0.35
0.3
0.25
0.2
0.15
0.1
BZTL trend(K/decade)
0.1
0.15
0.2
0.25
MT trend (K/decade)
UAH
RSS