Influence of processes in stratosphere upon the temperature at the tropopause and below

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Subject of the Study

Both total contents and vertical profiles of stratospheric aerosol and ozone are negatively correlated, which is caused by radiative processes that directly influence the temperature above the tropopause - an important climatic characteristic. The described interaction of the processes illustrating the influence of the stratospheric aerosol upon air temperature is under consideration in the presentation focused on climate changes in the temperature of the tropopause and below provided by balloon-borne radiosonde observations.

Interaction of Solar Radiation with Ozone

The accepted theory of solar radiation and its effects on the atmosphere is that incoming radiation from the sun passes through the atmosphere with little interaction, except at the ozone layer where ultraviolet radiation from the sun is absorbed by ozone and heats that layer. The ozone layer is considered to begin about 15 kilometers above the earth and contains 90 percent of the ozone. The region below the ozone layer is the troposphere, and it contains the remaining ten percent of the ozone.

Source of Information

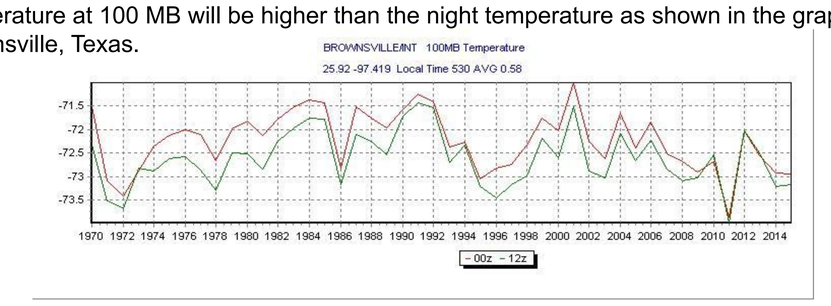
All data used in this article comes from balloon-borne radiosonde data obtained from https://www.ncdc.noaa.gov/data-access/weather-balloon/integrated-global-radiosonde-archive.
Most graphs are yearly average temperatures for the altitude indicated, and some are graphs of the difference between 00z and 12z observations. The temperatures at various levels vary widely from year to year, but the temperature differences between 00z and 12z are much more conservative and change little over the short term. For that reason, we use differences to determine the time of heating as it relates to the sun.
The National Weather Services measure the temperature aloft at regularly scheduled times of 0000z and 1200z. That is a standard launch time, but in actual practice, the balloons are routinely launched 45 minutes to an hour earlier than the standard time. It takes about 45 minutes for a balloon to get to 100 MB after launch, so the 12z - local time on the graphs below are approximate. There is evidence that indicates some foreign countries launch at times up to two hours later.
Because of the quality of the data, we will be using observational data primarily from the United States and Canada.

Dynamics of Temperature Changes in Upper Troposphere

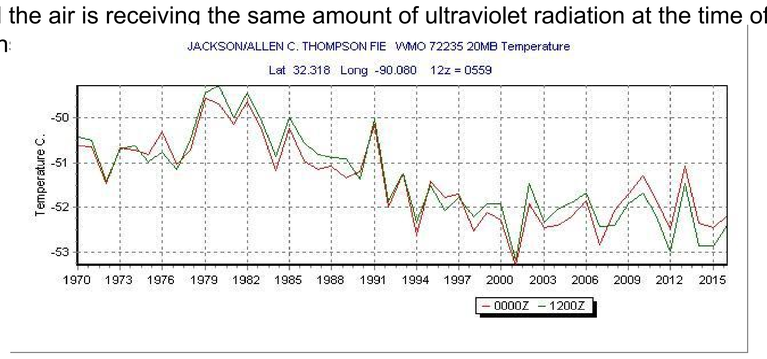
By comparing the temperature from the 0000z observation with the temperature from the 1200z observation, we can view the effects of the sun on different levels of the atmosphere in relation to time. In effect, we use year-long averages to detect changes that occur within minutes and hours.
The dynamics of temperature changes in the upper troposphere are very interesting and somewhat surprising. As the sun rises in the east, it immediately heats the atmosphere from 20mb down to about the 200mb level (85,0000 to 40,000 feet) and as the earth turns this heat wave moves to the west at 1,000 miles per hour. Of course, the amount of heat varies with latitude, the intensity of the radiation, and the amount of ozone.

Duirnal Temperature Changes and Sunrise

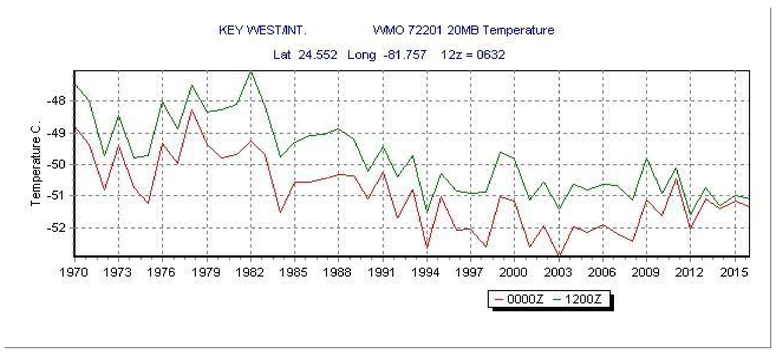
If one of the upper air observations coincides with day and the other at night, local time, the day temperature at 100 MB will be higher than the night temperature as shown in the graph for Brownsville, Texas.



If one of the observations coincides with sunrise, the difference between the day and night temperatures will be zero, since if one observation is at sunrise, the other is, on average, at sunset and the air is receiving the same amount of ultraviolet radiation at the time of the two observation:

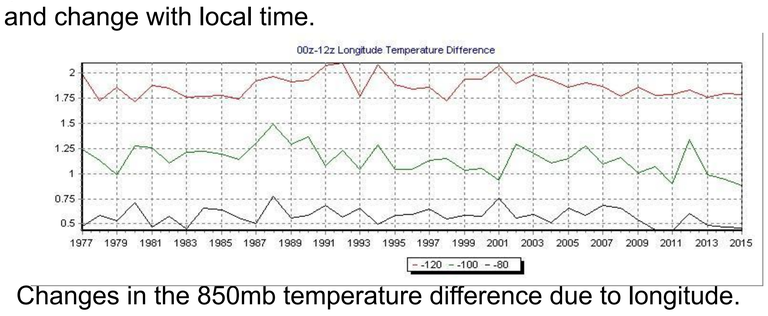


However, if we move to a station a little to the east, the 12z temperature rises substantially. Key West's local time at 1200z is 06:32, about 32 minutes after sunrise, and the temperature difference has climbed over one degree in 32 minutes. The 12z temperature is now higher than the 00z temperature.



Lower Troposphere

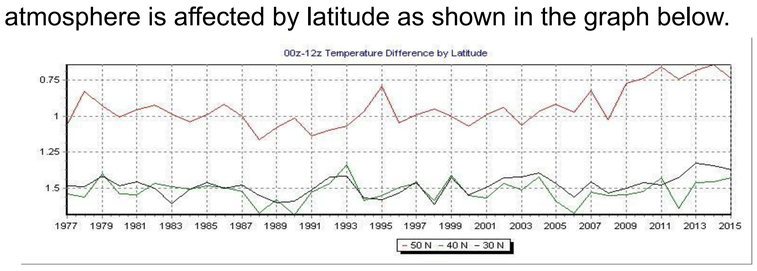
In the following we will be using the difference between the 12z and 00z temperatures rather than the temperatures themselves, the reason is that the differences are much more conservative and change with local time.



Changes in the 850mb temperature difference due to longitude.

The heating does not saturate as it does for the higher levels and continues to increase during the day.

Another aspect of this phenomenon is the difference due to latitude. As expected, solar heating of the atmosphere is affected by latitude as shown in the graph below.

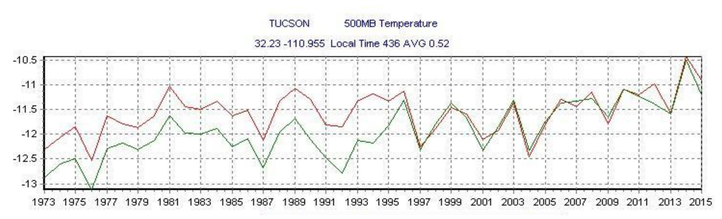


Changes in 850mb temperature difference due to latitude.

Day and Night Temperature Convergence

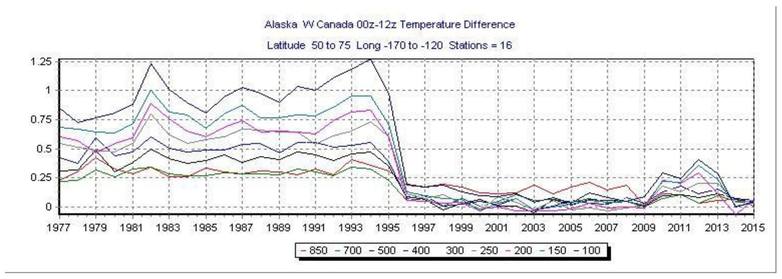
Changes in mean annual tropopause temperatures measured by radiosondes at 12z and 00z at more than 200 stations show that the day and night temperatures typically differing more than 0.5 degree for the 25 years (1977 through 1992) begin converging in the Post-Pinatubo period from 20mb down to the 500 or 700 MB level becoming equal to each other. For example, the convergence took place over the largest part of the United States in approximately 1993 (slightly later in Alaska and Western Canada) and in most cases 00z and 12z temperatures remain equal till present time.

It might be not easy to decide whether the daytime temperature fell to match the nighttime temperature or the nighttime temperature rose to meet the daytime temperature. If the difference between 12z and 00z was due to heating after sunrise then the convergence is simply a lack of heating because of a reduction in ultraviolet light from the sun or a reduction in the amount of ozone.



We have found that the beginning of convergence varies over wide geographic regions and most stations belong to a larger group. For example, almost all of Alaska stations experience similar years of convergence, 1995 to 1999. Other regions also exist such as Grand Junction, Albuquerque, Medford, Salem, Glasgow, Spokane, and Quillayute converge in the 2007 to 2010 time frame.

When the daytime temperature at the tropopause decreases, the air temperature in the upper part of the troposphere adjusts to lower temperature at 100 mb due to mixing spreading the convergence to 500 - 700 mb. In some cases mixing in the troposphere reaches at least the lowest level of observations at 850 mb. This can explain that the surface temperature in Greenland and its vicinity does not follow a predominant warming climate trend in air surface temperature.



Alaska and Western Canada 00z and 12z Temperature Differences.

This unusual graph is due to the latitude of the 16 stations and the fact they all have a similar date of convergence. Note that the 850mb curve after convergence also shows a slight decline.

Summary

The warming of the upper levels of the atmosphere, as measured by radiosonde, is caused by the absorption of ultraviolet radiation by ozone. The absorption at the 10mb down to the 200mb is very fast and can be measured a few minutes after sunrise, but the temperature continues to climb slowly for the next two hours. At the 850mb level, the temperature reaches its maximum sometime between 7 pm and 8 pm and a minimum just before sunrise.

If our atmosphere is entering a new and unknown era of climate change, where will it go from here?