TEMPERATURE LIDAR NETWORK AND SSU/NOAA SYNERGY FOR THE MIDDLE ATMOSPHERE MONITORING

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ABSTRACT

The global long-term changes can be deduced from space but requires ground-based references. Several temperature data sets are now available within the Network of the Detection of Stratospheric Changes (NDSC). Successive satellite adjustments can be validated as well as the continuity of lidar series. In the mesosphere lidars can give an unique information on trends in this altitude range.

1. INTRODUCTION

In the middle and upper stratosphere, model results suggest that the increases in the well-mixed greenhouse gases and changes in ozone will contribute to temperature changes of around 1 Kelvin per decade [1]. These changes are a magnitude larger to what is expected at ground level. However, at altitudes above the lower stratosphere, there are major quantitative differences between the modeled and observed cooling [1]. Also, the reduction of the anthropogenic chlorine loading in the atmosphere let us expected an ozone recovery and then changes on the cooling rates.

2. TEMPERATURE SERIES FROM SPACE

The temperature evolution of the middle atmosphere is an important parameter as a fingerprint of different anthropogenic forcing and also because the temperature plays a key role in the atmospheric composition and on the dynamics that can directly or indirectly impact on the climate. However, the only global source of temperature, in the middle atmosphere, on a long-term basis (decades), is provided by the TIROS/NOAA operational vertical sounders (TOVS). A series of TOVS instruments (which includes MSU and SSU) has been put into orbit onboard a succession of operational satellites since late 1978. These instruments do not yield identical radiance measurements for a variety of reasons, and derived temperatures may change substantially when a new instrument is introduced [2]. Temperature is derived with different techniques and tools.

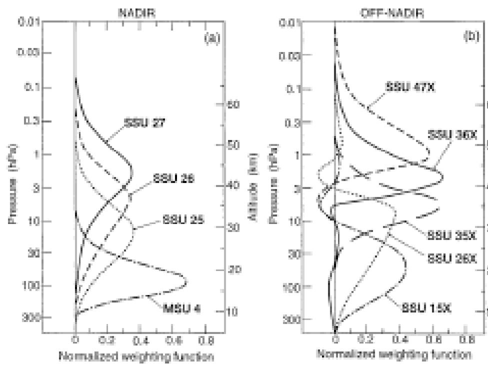


Fig. 1. Weighting function of the SSU/TIROS experiments

Finger et al. [3] have compared the operationally derived temperatures with collocated rocketsondes and lidar observations and find systematic biases of the order of 3–6 K in the upper stratosphere. These biases furthermore change with the introduction of new operational satellites, and Finger et al. [3] provide a set of recommended corrections to the temperature data, which have been used by NOAA. In spite of the application of the adjustments recommended by Finger et al. [3], time series of temperature anomalies from the NOAA analyses still exhibit significant discontinuity near the times of satellite transitions due to tidal interferences [4]. Other uncertainties associated with the satellite data, in general, include the effects due to longitudinal drifts that cause i/ spurious trends as the diurnal cycle is sampled at earlier or later times for a single satellite, and ii/ changing solar shadowing effects on the instrument, in turn causing heating or cooling of the radiometer. While estimates for the correction and attempts to remove the biases are made, this factor does introduce a potential uncertainty in the trend determination.

The "Nash" [2] data set consists of brightness temperatures from observed (25, 26, and 27) and derived (47X, 36X, 35X, 26X, and 15X) channels of the Stratospheric Sounding Unit (SSU) and High-Resolution Infrared Sounder (HIRS) 2 instruments on these same satellites. The weighting function for the SSU channels are typically 10–15 km thick (Figure 1), illustrating the thick-layer nature of the measurements. One complication with satellite data is the discontinuities in the time series owing to the measurements being made by different satellites monitoring the stratosphere since 1979. Adjustments have been made in the Nash channel data to compensate for radiometric differences, tidal differences between spacecraft, long-term drift in the local time of measurements, and spectroscopic drift in channels 26 and 27. More recently, the second generation of instrument AMSU has been launched with a thinner weighting functions.

3. LIDAR GROUND-BASED TEMPERATURE REFERENCE

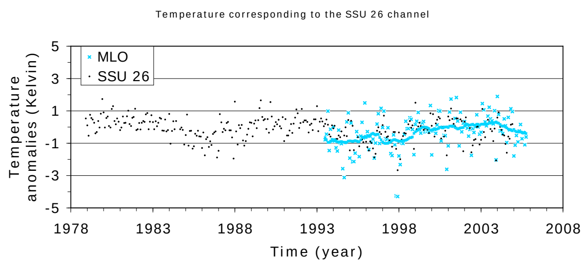
Up to now there were very few ground-based measurements to insure the continuity and quality of such measurements. The rocket network was used for such a purpose but launches had decreased dramatically since 1980 and is now not operant.

Station	Latitude	Longitude	Date of first operation
Hohenpeissenberg	47,80°N	11,02°E	1987
Observatory of Haute-Provence	43,93°N	5,71°E	1979
Table Mountain Facility	34,04°N	117,70°W	1988
Hawaï	19,54°N	155,58°W	1993
La Réunion	21,80°S	55,5°E	1994

Table 1. List of stations used in this study

Since 1991, a network dedicated to the stratosphere; the Network for the detection of Stratospheric Changes (NDSC) has been implemented [5] and provides now decadal series of temperature obtained from lidar that can be used to check the consistency of measurements obtained from space and mainly their continuity and can also allow to derive trends at different latitudes.

Rayleigh lidar data cover the altitude range from about the middle to the upper stratosphere and mesosphere. In a pure molecular atmosphere, the temperature profile obtained from Rayleigh scattering does not required any external calibration [6]. The lidar measurements provide good vertical resolutions. Since 1979, lidar measurements of stratospheric temperatures are available from the Observatory of Haute-Provence (OHP) in southern France. Several other lidar sites have initiated operations and are now available over more than a decade and can provide temperature trends and satellite series assessments at very different place (table 1).



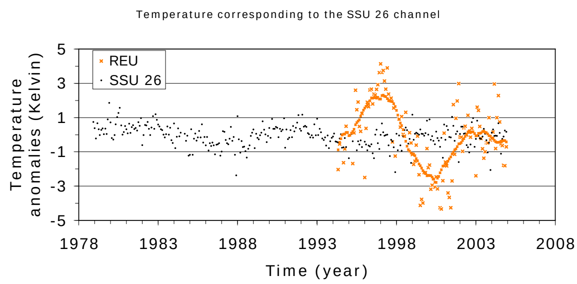


Fig. 2. Zonal monthly mean temperature derived from SSU channel 26 compared to corresponding monthly mean of weighted lidar profiles at Hawaï (top) and La Réunion (bottom).

However on several decades of continuous operations, lidars know some modifications and improvements. These changes as well as mis-functioning can be the source of discontinuities in the temperature series. The lidar series from the Hohenpeissenberg Observatory are very valuable because this station is closed to OHP and the both stations can provide a ground-based reference with a stronger consistency. Table Mountain Facility is also at mid-latitudes further south and 120° in longitude apart that is quite very different regarding time of the measurements and tidal effects. The two other locations included in this study are located in tropics in each hemisphere where the daily variability is the smallest.

Since its inception, the NDSC has provided systematic lidar measurements of ozone and temperature at several places around the world that are well adapted for satellite validations. Regular exercises have been organized to ensure the data quality at each individual site. These exercises can be separated into three categories: large scale inter-comparisons using multiple instruments, including a mobile lidar; using satellite observations as a geographic transfer standards to compare measurements at different sites; and comparative investigations of the analysis software. NDSC is a research network, so each system has its own history, design, and analysis, and has participated differently in validation campaigns.

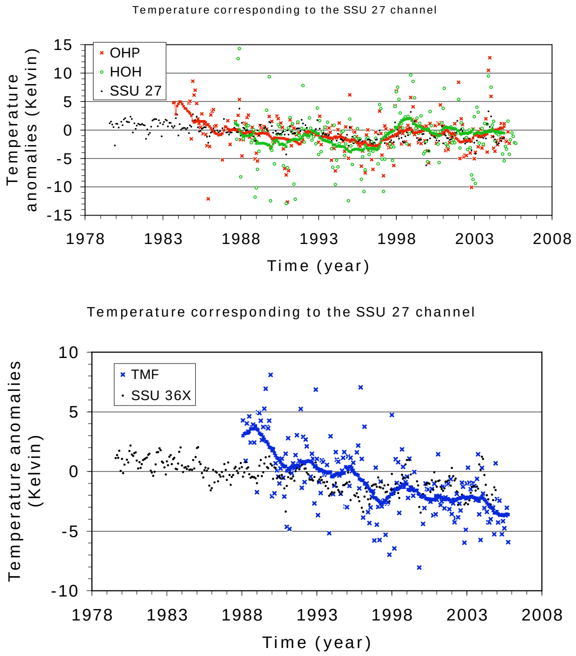


Fig. 3. Zonal monthly mean temperature derived from SSU channel 27 compared to corresponding monthly mean of weighted lidar profiles at mid-latitude in Europe at 2 sites OHP and Hohenpeisenberg (top) and Table Mountain in California (bottom).

There are still some technological differences that may explain different accuracies. However, the comparison campaigns performed over the last decade have always proved to be very helpful in improving the measurements. To date, more efforts have been devoted to characterizing ozone measurements than to temperature observations. The synthesis of the published works shows that the network can potentially be considered as homogeneous within ±1 K between 35-60 km for temperature [7]. In the lower stratosphere, Nitrogen Raman channels seem to improve comparisons but such capabilities were not implemented on each site and use different techniques [8]. The vibrationnal branch that is the easiest to implement, requires corrections to take into account aerosols and ozone attenuations [9].

4. LIDAR SSU COMPARISONS

The temperature series show cycles that can be associated to seasonal changes, to the Quasi Biennal Oscillation (QBO) and to the 11-year solar cycle. Trends are also clear at some levels. However, SSU reveal a plateau after 1998 when AMSU where introduced and careful examination are required. The comparison of lidar and SSU temperature series show a good overall agreement. However some differences need to be further investigated. The comparisons of temperature at tropical latitudes reveal very different behavior. While the Hawaï site on the northern hemisphere is in good agreement with SSU, La Réunion station on the southern hemisphere presents larger deviations that appear to be associated with QBO (Figure 2).

At mid latitude some differences are also reported (Figure 3). For the two alpine stations differences can only be due to sampling and time of measurements (tidal effects) and large residual trends according to SSU are derived. While the trend reduction is reported for the both alpine stations, continuing trends are reported for the Californian station (TMF)

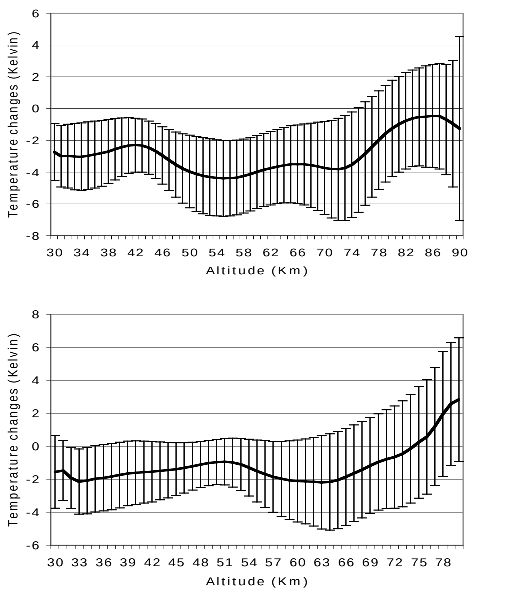


Fig. 4. Linear trend profiles as seen above California (top) and France (Bottom).

Linear trends of the middle atmosphere temperature have been derived in using multi-regression analyses that take into account the main part of the natural component of the inter-annual variability such as the solar cycle, the QBO and aerosols injected in the stratosphere after major volcanic eruptions. Trends derived from lidar stations inform also on the mesospheric part that is poorly documented [10]. Linear temperature trends observed on the OHP data series are smaller than the one derived previously because of the zero-trend since 1998 and show a maximun cooling of 2K. Trends are also derived at TMF with amplitude twice the one observed at OHP, and the main difference occurs during the last 10 years.

5. DISCUSSIONS AND CONCLUSIONS

The temperature lidars deployed at very different location around the globe, within the NDSC, with a long-term commitment show their great value for the validation of the temperature series assembled with the successive SSU/AMSU experiments. These comparisons reveal very different behaviors compared to SSU/AMSU series. Long-term evolutions present large differences that can be continuous drifts or can be the result of successive changing bias. Further analyses are required to understand the source of discrepancies and if the time of measurements and orbit change and drift can be one of the reasons, because of tidal effects. Also the lidar series exhibit their own history of instrumental changes that may affect the continuity.

The shift from SSU to AMSU that provides a better vertical resolution, can be also the source of discontinuity that need to be checked while the date of the AMSU inclusion in the series is close to the date of the observed changes on the cooling rates.

The temperature evolution shows that linear trends are not pertinent while the cooling rate appears to strongly slow down around 1998.

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