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TEMPERATURE CLIMATOLOGY WITH RAYLEIGH LIDAR ABOVE OBSERVATORY OF HAUTE-PROVENCE: DYNAMICAL FEEDBACK

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ABSTRACT

Rayleigh lidar in synergy with satellite observations (SSU and AMSU) allow insuring an efficient monitoring and showing that cooling has continued. New approach for trend detection has been developed allowing a better estimate of changes due to radiative forcing. Stratospheric Warmings and gravity waves contribute to insure a dynamical feedback of the long-term changes.

1. INTRODUCTION

Rayleigh lidar measurements were performed continuously since 1979 at Observatory of Haute-Provence in south of France (44°N) allowing detecting temperature trends in the stratosphere and mesosphere.

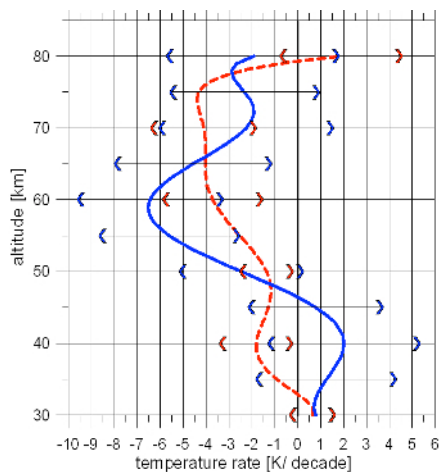


Figure 1. Temperature trends derived from the OHP lidar for winter (blue) and summer (red) periods with a multi-function linear regression.

Time evolution reveals a general cooling during the 1995-2005 period, and a slowdown of the cooling that is not yet understood and coincides

with the end of SSU series with a questionable continuity between the successive instruments [1]. Some differences with other lidar series have been reported [2] as well as differences between summer and winter estimates (Figure 1).

In addition to radiative forcing induced by ozone decrease and greenhouse gas increase, dynamic feedbacks are investigated while the variability of the middle atmosphere is driven by waves propagation and their interaction with the mean flow mainly through Sudden Stratospheric Warming and mesospheric dissipation.

2. SSU AND AMSU CONTINUITY

The SSU experiment has provided the unique temperature series from space. While the continuity suffers from tidal effect due to the orbit changes from the successive satellites and their time drifting [2], the continuity is now insured by AMSU. Comparisons between lidar and AMSU reveal very good agreements when data obtained on the same days are considered and partial sampling appear critical [3].

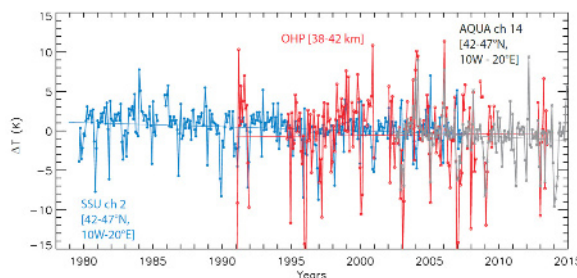


Figure 2. Temperature series in the upper stratosphere given by SSU (blue), OHP lidar (red), and AQUA-AMSU (grey).

For some AMSU similar drifts and tide effects occur [4], however some platforms like METOP

do not exhibit drift and the combinations of some of them avoid the tidal effects. Lidars and SSU series have shown a temperature plateau [2] during the period 1995-2005 and AMSU series have confirmed that cooling has continued and that the plateau was a transitory effect (Figure 2).

3. EFFECT OF STRATOSPHERIC WARMINGS

Stratospheric warmings are the main cause of temperature variability during winter-time (Figure 3). The breakdown of the vortex induces a large warming in the upper stratosphere associated with a cooling in the mesosphere.

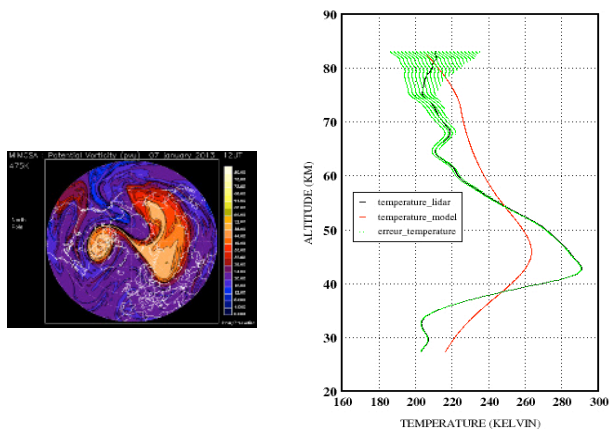


Figure 3. Temperature profile during a stratospheric warming on January 2013 (right panel) and the corresponding PV map in the stratosphere at 475 K.

While their occurrence can be forced by the mean state of the atmosphere and could be modified with climate change, it is important to estimate temperature change due to radiative effect alone. This estimate has been performed in tracking the main mode of the temperature distribution instead of the mean (Figure 4). In applying such methodology the warming observed in December-February period due to stratospheric warming seasonal cycle have been removed [4] and trends during winter and summer reduced. The impact of different sampling is probably the main cause of differences between the different lidar and rocket series with satellite data while the impact of stratospheric warming is not zonal.

Stratospheric warmings were associated with cooling at ground and some mesospheric effect

more than a month before the breaking is also noticed suggesting a potential role of gravity waves.

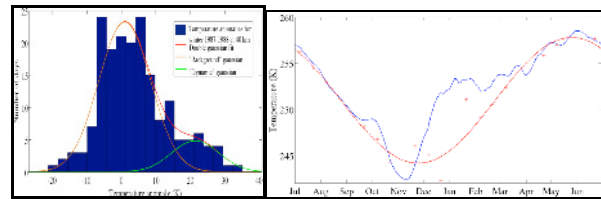


Figure 4. Histogram of stratopause temperature (left panel) and seasonal cycle (right panel) estimated from the mean temperature and the maximum of the main mode.

4. EFFECT OF GRAVITY WAVES

Gravity waves potential energy has been derived from COSMIC GPS and Rayleigh lidar providing consistent information between the both methods. The observed seasonal variations of stratospheric gravity waves activity is found mainly driven by the wind filtering process [6].

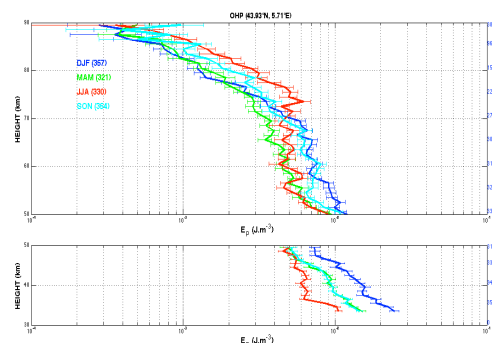


Figure 5. Vertical profiles of potential energy per unit mass (in $J \cdot kg^{-1}$ top) in the upper stratosphere and mesosphere averaged over winter (December-January-February, blue line), spring (March-April-May, green line), summer (June-July-August, red line), and autumn (September-October-November, cyan line). The horizontal error bars indicate the $\pm 1\sigma$ uncertainty of the median.

Dramatic increases of gravity waves activity in the upper stratosphere above OHP have been observed before and during the SSW event in early January 2013. This is attributed to planetary wave activity, which strongly perturbs the zonal winds in the middle atmosphere, resulting in wave

generation by adjustment of the unbalanced flow. The gravity wave potential energy has been derived using a variance method on the raw signal [7]. We observed night-to-night variations in the lidar measurements, and inter-annual variability in gravity wave activity based on 16 years of Rayleigh lidar data (30–85 km). This method provides additional information on the vertical structure and on the interactions of the gravity waves with the mean flow. Because the energy is constant with altitude when there is no interaction with the mean flow, it is possible to investigate the altitude where the largest energy exchange occurs. This analysis shows that wave energy dissipates in the background atmosphere depending on the altitude and the season above OHP (Figure 5). Gravity waves are dissipating above ~70 km during all seasons and a little bit higher during summer, but there is relatively little dissipation at lower altitudes. Below 40 km there are also some interactions that have been also confirmed by the COSMIC observations when the flow is highly perturbed as it can happen during stratospheric warmings.

5. CONCLUSIONS

Lidar temperature series obtained since 1979 allow monitoring long-term changes due to anthropogenic change. Global estimate can be performed in synergy with satellite series. The plateau observed during 1995-2005 period was a temporary anomaly and our investigation shows that the cooling has continued with similar amplitude as during the 1980s. The new approach to analyze temperature trends reveals the dynamical feedback associated with stratospheric warmings and may explain differences between estimates from different lidar sites and between winter and summer. Gravity waves analysis allows identifying altitude where interactions with the mean flow are the largest. Their potential feedback on the long-term still needs to be estimated. Synergy of lidar and GPS technique could be used.

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