Sudden Stratospheric Warmings seen using underground muons in Soudan Minnesota

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***Abstract*. There is a well known correlation between atmospheric muon rates and seasonal temperature variations. Other effects related to weather can also affect the muon rate on shorter time scales. This poster will discuss the previously reported results on Sudden Stratospheric Warmings from MINOS using data from 2003-2007, and data from the Soudan 2 detector in the same location, if it becomes available, from 1995.**

***Keywords*: muons, sudden stratospheric warmings**

I. Introduction

Upper-air temperature data have been provided by the British Atmospheric Data Centre (BADC). This comprised the 4-daily Operational Analysis data from the ECMWF. These data combine a range of environmental data in a meteorologically consistent fashion using a process known as data assimilation[1]. In the atmosphere, planetary Rossby waves can have horizontal wavelengths of several thousand kilometers. These waves propagate up from the troposphere to the stratosphere during winter and have an association with high-latitude vortex structures in the upper atmosphere. In analogy to water waves, these waves can break causing temperatures in the polar stratosphere to rise by over 50 K in a few days. These events are known as Sudden Stratospheric Warmings (SSW) and appear as a displacement or splitting of a large persistent low pressure system which resides over the pole, known as the wintertime stratospheric polar vortex.

II. Muons from MINOS

The MINOS detector observes about 0.5 Hz of atmospheric muons with a surface energy of 700 GeV or more.[2] The detector has been operational from August 2003 to the present with a live-time percentage above 90%. The variation in the muon rate and the corresponding effective temperature are shown as a function of time in Figure 1. To better highlight covariations in the muon rate and temperature, a 5-day rolling average is applied twice to each time series[3]. A strong correlation between R and T is clearly seen. A conspicuous feature in both the muon rate and the temperature can be seen in February 2005; both show a sharp rise followed by a fall over a period of 2-3 weeks during which the muon rate changes by $(4 \pm 1)\%$. This behavior is consistent with Rossby wave activity. Following this warming and cooling, temperatures and muon rate are seen to increase once more, coinciding with an early final warming (and break-up) of the vortex on March 10, with the transition from winter to summer conditions. This was reported in Reference [3] as the first time that daily variations in secondary cosmic rays from an underground muon detector were shown to be associated with planetary-scale meteorological phenomena in the stratosphere.

III. Muons from Soudan 2

Seasonal Variations in both the trigger rate and the muon rate were also seen in the Soudan 2 detector, which was located about 20 meters from the current location of MINOS in the Soudan mine[4]. Data for the complete Soudan 2 detector is available from 1995 to 2000. During 1999, there were two SSWs in the Northern Hemisphere. Muon data from Soudan 2 is currently being analyzed and will also be compared with data from the ECMWF database.

References

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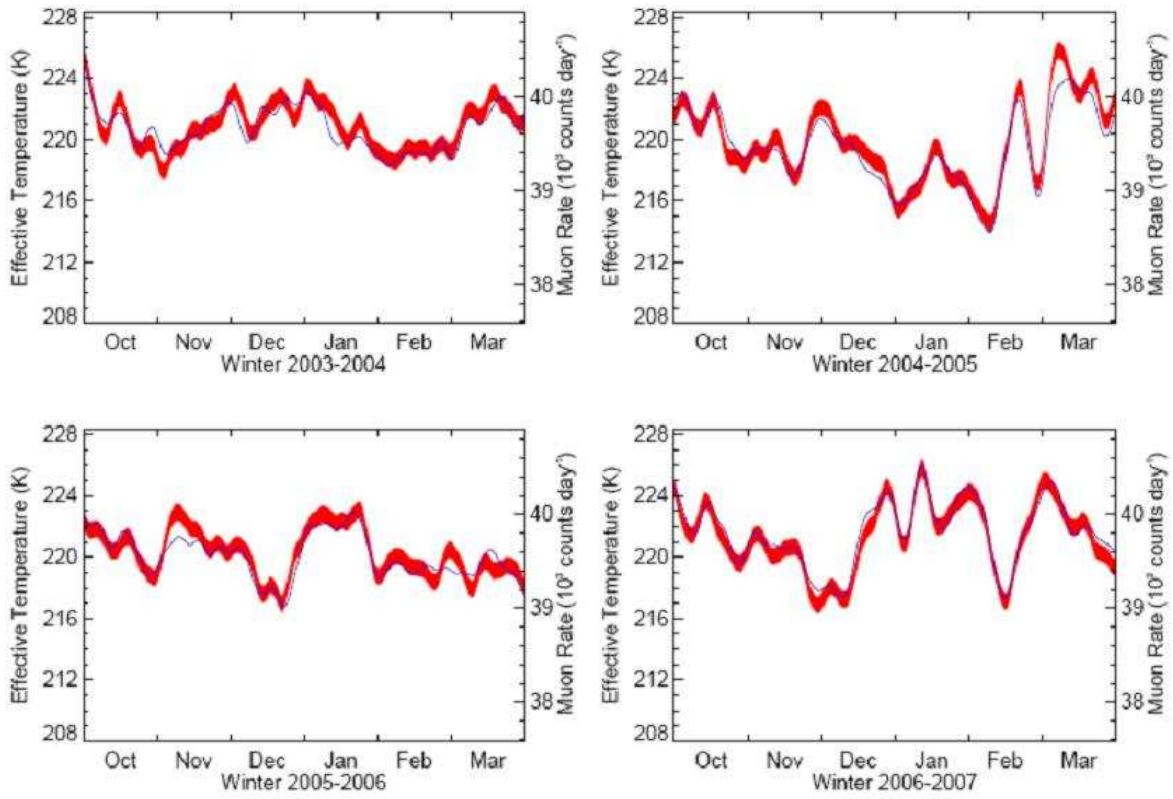

Fig. 1. Time series of effective temperatures for winters 2003-2007 (small blue line) from ECMWF and daily muon rate ± 1 standard deviation registered at MINOS Far Detector (thick red line). A five day smoothing has been twice applied to both data. The ticks on the horizontal axis correspond to the start of the labeled month.