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Contribution of stratospheric warmings to temperature trends in the middle atmosphere as revealed by the lidar series obtained at Observatory of Haute-Provence (44°N)

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Temperature trends in the middle atmosphere based on investigations of monthly mean temperature changes suffer from numerous backsides including the high winter variability, which make trends more difficult to interpret. Middle atmosphere temperature variability is not only driven by radiative processes but also in northern winter by wave-mean flow interactions unambiguously noticeable through large events like Sudden Stratospheric Warmings (SSW). This study describes a method to calculate long-term temperature trends, as an alternative to the ones based on monthly mean temperatures. This method avoids the strong influence of SSW and provides background temperature trend estimates which are in better agreement with expected direct radiative effects due to atmospheric composition changes. The data set used results from lidar measurements which have been performed above south of France continuously since late 1978 and combined with daily radiosonde profiles located in the same region. Using this new methodology the long-term trends during winter at 40 km shows a larger cooling (-2 K/decade) than when the monthly mean temperature is used (-0.4 K/decade). The cooling of the background temperature is then closer to the summer trend estimates, which are similar whatever the temperature proxy used due to the absence of SSW. The temperature anomalies associated with dynamical disturbances like SSWs show an increase in both their intensity and occurrence that leads to partly cancel out the apparent long-term trends on monthly mean series. Based on this background temperature evolution, mean winter anomalies have been calculated: they show colder stratospheric temperature when no major SSW happens. A composite evolution has also been displayed using the measurements obtained each winter, with the time reference shifted according to the dates of the major SSWs, which correspond to the only events clearly documented. Similar evolutions for both vortex-displacement and vortex-splitting SSWs are observed: in both cases the largest warming occurs at the time of the SSW as expected, around the altitude of 40-50 km, and with mean amplitudes of more than 10 K. However, a warm signal in the upper mesosphere could suggest a potential pre-conditioning role of gravity waves. In addition, colder ground temperatures are noticed during and before the SSW with a stronger signal for split-type events.