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On the stratospheric aerosol budget at Northern mid-latitudes from 21 years of ground-based lidar and satellite observations

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The paper presents a new high-quality 21-year series of continuous stratospheric aerosol observations at Observatoire de Haute-Provence (OHP, 44°N, 6°E) in Southern France using two powerful and well-maintained lidar systems. In contrast to previous studies making use of the observations by aerosol-dedicated lidars operating within the Network for Detection of Atmospheric Composition Change (NDACC), we exploit the backscatter measurements from the off-line 355 nm channel of stratospheric ozone lidar (LiO_3S) and low-gain 532 nm channel of stratospheric temperature lidar (LTA). The presented series of stratospheric aerosol backscatter and extinction at 532 nm, spanning from January 1994 through 2016, include on average 10-11 lidar acquisitions per month after careful quality screening.

The OHP lidar observations are compared with global space-borne measurements of zonal-mean stratospheric extinction by SAGE II, GOMOS, OSIRIS and CALIOP instruments, altogether covering the time span of OHP lidar data sets. Both ground-based and satellite monthly-mean stratospheric Aerosol Optical Depth between 17 and 30 km altitude ($sAOD_{1730km}$) series are in good cross-agreement with discrepancies well below the measurement errors, thereby ensuring the quality and coherency of all data sets exploited for our study. The global satellite observations are then used to identify the drivers of stratospheric aerosol variability observed locally by the OHP lidars.

The 21-year aerosol series reflect two essential periods in the global volcanic activity over the past two decades. The first one, a long volcanically-quiescent period of low aerosol burden ($0.002 < sAOD_{1730km} < 0.003$) starts after the complete removal of Pinatubo aerosol in late 1996 and extends until late 2003. This 'background' period is followed by a volcanically-active one, dominated by several moderate and strong $sAOD_{1730km}$ enhancements up to 0.008 after tropical and Northern mid-latitude volcanic eruptions of VEI 4. We note that $sAOD_{1730km}$ values tend to drop to 0.003 level or below within several months after each eruption-induced aerosol outbreak.

The annual cycle of aerosol scattering ratio profile, as seen by both ground-based and satellite observations during both volcanically quiescent and active periods, shows a minimum between 15-19 km altitude during late spring – early summer season. This minimum is argued to be due to quasi-isentropic poleward transport of tropical air processed by overshooting convection, as the latter acts to transport clean tropospheric air into the tropical lower stratosphere. The convective 'cleansing' process, described in detail by Vernier et al. (2011), takes place mainly during the southern tropics convective season, which together with the timescale of poleward transport is compatible with the observed seasonality of aerosol in the mid-latitude stratosphere.