Polar Stratospheric Clouds formation and evolution in Antarctica by applying the "MATCH" method to Lidar investigations within the International Polar Year

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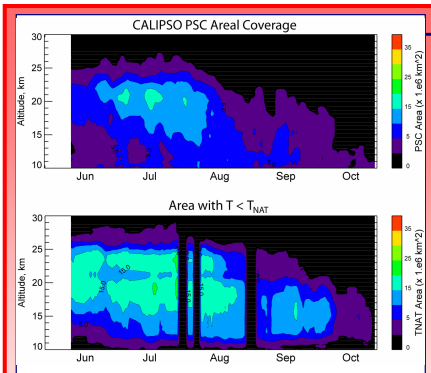
INTRODUCTION

As well known, anthropogenic halogenated gases have contributed to the decrease in stratospheric ozone. This depletion is expected to gradually disappear as a result of reductions of emissions of these gases as imposed by the Montreal Protocol (1987). Meanwhile, since 1980 the amount of major greenhouse gases has increased, which not only affects climate but makes ozone recovery highly problematic. ORACLE-O3 is a collaborative project within the third International Polar Year (IPY) designed to extensively study the amplitude and time extension of ozone recovery. Owing to their key role in ozone depletion, Polar Stratospheric Clouds (PSC) studies are part of the project. Particle type is largely influenced by temperature and the thermal history of the air masses in which PSCs occur. However, substantial uncertainties about these processes still remain. Understanding how PSCs form and evolve is a critical issue in quantifying the impact of climate change on their frequency and, further, on chlorine activation and subsequent ozone depletion.

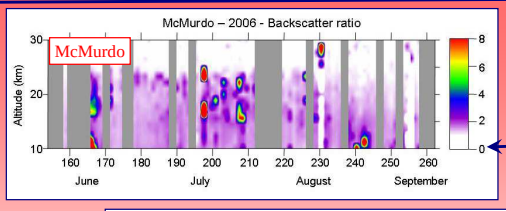
METHODOLOGY

For the first time, the "MATCH" method [Rex et al., 1998] is applied to lidar observations of PSC. This leads to combined ground-based and space-borne lidar observations, with Lagrangian trajectory calculations, to infer information on formation processes of each PSC type and assess our ability to predict PSCs for various environmental conditions. The campaigns took place in Antarctica during winters 2006, 2007 and 2008. Microphysical model calculations are performed for analysing the data and testing PSC formation scenarios along the trajectories.

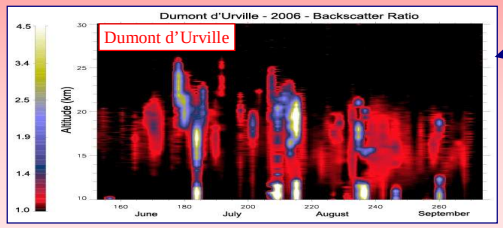
I – OVERVIEW OF THE 2006 WINTER

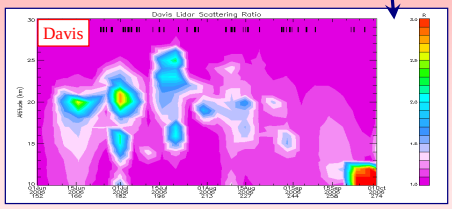


CALIPSO PSC area integrated over latitudes poleward of 50°S compared with the time series of potential PSC area calculated as area with T < Tnat for 2006 winter [Pitts et al., 2007].



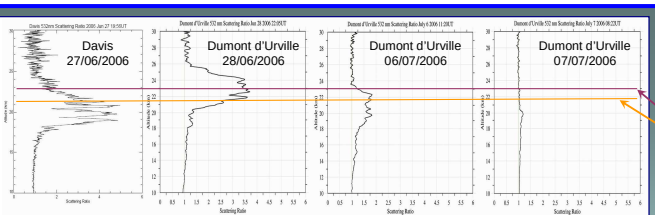
Time series Backscatter Lidar at λ= 532 mn

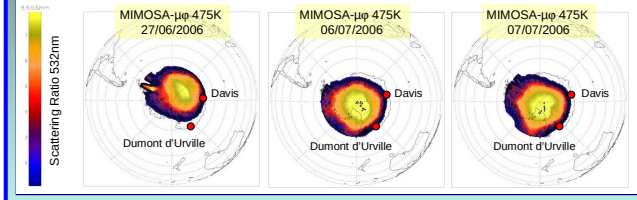




Three ground-based lidar : Davis (68.58°S, 77.97°E), Dumont d'Urville (66.67°S, 140.01°E), and McMurdo (77.86°S, 166.48°E)
Space-borne lidar : CALIOP on board CALIPSO

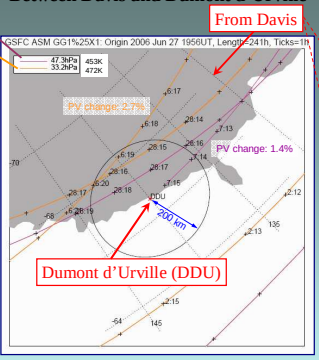
Lidar scattering ratio profiles from Davis on June 27 2006 (initial profile) [Innis and Klekociuk, 2006] and from Dumont d'Urville on June 28, July 6 and 7 2006 [David et al., 1998]

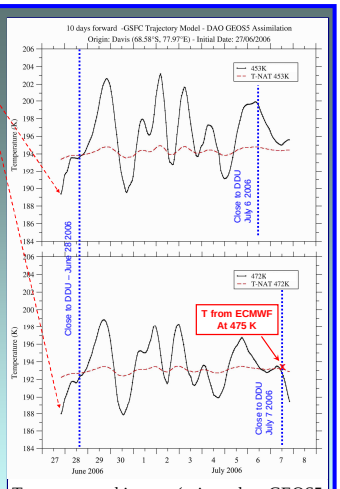




High advection contour model MIMOSA, coupled with microphysical and optical codes, simulates scattering ratio fields at 532nm over Antarctica (ECMWF initialization) [Hauchecorne et al., 2002 ; Jumelet, 2007]

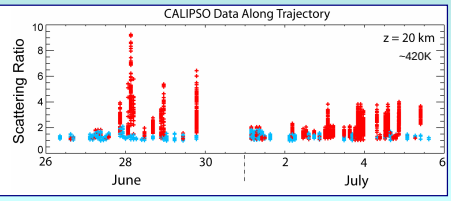
II – EXAMPLE : A MATCH CASE Between Davis and Dumont d'Urville





Temperature history (using the GEOS5 Data Assimilation System from GSFC) along the 10 days forward trajectories at 453K and 472K starting over Davis on June 27th, 2006 ; blue lines indicates the closest points to Dumont d'Urville.

CALIPSO scattering ratio observations along the trajectory between Davis and Dumont d'Urville, at ~20km, within 250 km of the trajectory intersection ; in red, points where PSC are identified.



10 days forward trajectories are performed (GSCF trajectory model with GEOS5 DAS) from each lidar station, when PSCs are detected. The trajectories initialized over Davis on June 27, at 33.3 hPa (~453K) and 47.2 hPa (~472K) have the selected MATCH criteria with DDU: distance less than 200 km, PV change less than 40%, on June 28 (both levels) and on July 6 (453K) and 7 (472K). The air masses experience large temperature fluctuations, with $T>T_{NAT}$ (10 ppbv HNO_3, 5 ppmv H_2O) several times. The initial PSC is disappearing gradually over DDU, less on CALIPSO data.

CONCLUSION and PERSPECTIVES

A preliminary study on a selected MATCH case between Davis and DDU shows that the evolution of a PSC can be followed on a 10 days trajectory and related to the temperature (T) history along this trajectory. Persistence of a type 1 cloud seems to be closely linked to the fluctuations of T above and below T_{NAT}. Ground-based observations provide initial and final stages, while CALIPSO gives PSC properties in between. Microphysical 3D simulations of PSC optical properties fit well the local measurements. Trajectory selection still has to be refined, as well as their intersections with CALIPSO tracks. For quantitative analysis, differences between instruments and inversion algorithms have to be accounted for.
Throughout winters 2006 and 2007, numbers of MATCH cases between two or three lidar stations have been identified. Other cases will be extracted for winter 2008. From a statistical study of the evolution of PSC properties along trajectories, some conclusions on the type of cloud formed according to classes of surrounding environmental conditions (i.e. HNO_3, HO_2 content evolution, local temperature and temperature history) should arise.

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