Study of the PSC Evolution in Antarctica in August 2007 during IPY by combining Lidar Measurements, the Lagrangian MATCH Approach, and Microphysical Modelling

Montoux[1], N. ; Klekociuk[2], A. ; Pitts[3], M. ; Keckhut[4], P. ; Di Liberto[5], L. ; Snels[5], M. ; Larsen[6], N. ; Noël[7], V.

1. Laboratoire de Météorologie Physique (France) ; 2. Australian Antarctic Division (Australia) ; 3. NASA Langley Research Center (United States) ; 4. Laboratoire Atmosphères, Milieux, Observations Spatiales (France) ; 5. Institute of Atmospheric Sciences and Climate (Italy) ; 6. Danish Meteorological Institute (Denmark) ; 7. Laboratoire de Météorologie Dynamique (France)

1. Introduction

Three major types of particles forming the Polar Stratospheric Clouds (PSC) (Lowe and McKenzie, *JAST*, 2008) :

- type 1a: solid nitric-acid trihydrate (**NAT**) particles
- type 1b: supercooled ternary solution (**STS**) of $HNO_3/H_2SO_4/H_2O$
- type 2: ice (**ICE**) particles

Chlorine activation and thus ozone destruction depend of the particles formed

Aims:

- Better **understand the formation and evolution of the particles** in consideration of the thermodynamical conditions of the air mass
- **Assess the ability of PSC microphysical models to reproduce the observations**

Method: "**MATCH**" (Von der Gathen et al., *Nature*, 1995) to follow the evolution of the optical properties/type of PSCs recorded by lidar in Antarctica with pressure and temperature evolution along Lagrangian trajectories

Project: ORACLE-O3 ("Ozone layer and UV RAdiation in a changing CLimate Evaluated during **IPY**")

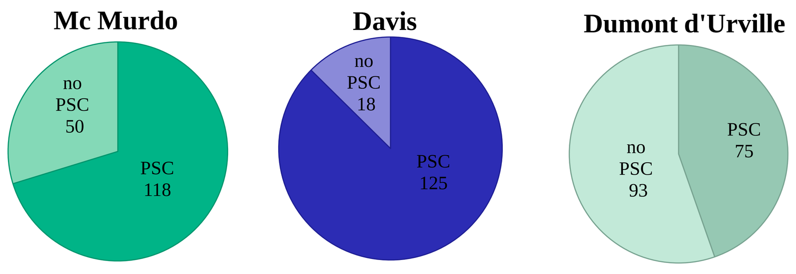
Dates: 2006 to 2008 from May to September

Lidars involved:

- Ground-stations: **Davis** (68.6°S ; 78°E), **Dumont D'Urville** (DDU: 66.7°S ; 140°E) and **McMurdo** (McM: 77.9°S ; 166.5°E)
- spaceborne lidar **CALIOP/CALIPSO** (Pitts et al., ACP, 2007)

2. Overview of the campaign

Number of days of ground-based measurements during the three years:



Less PSC observed at Dumont D'Urville :

- DDU closer from the vortex edge,
- lower energy per pulse and telescope diameter compared to Davis ⇒ lower signal to noise ratio ⇒ less PSC detections

Trajectory calculation:

- Initial time: mid-time of the individual lidar observing sessions
- Altitude: 10 vertical levels between 13 and 25 km
- Model: GSFC server with two meteorological assimilations (NCEP and DAO)

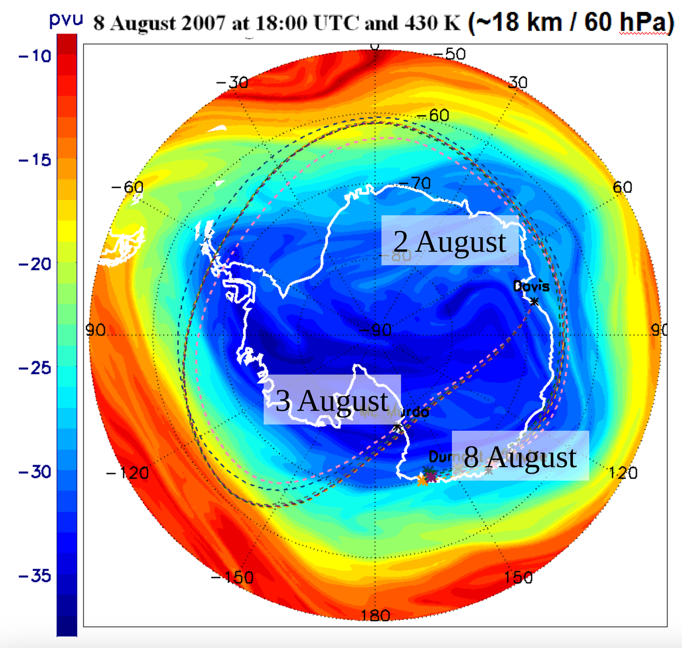
⇒ 4790 forward trajectories with NCEP and 3240 with DAO (not available for 2008)

Match criteria:

- Trajectories passing **less than 200 km** away from several ground-stations observing PSC and with **potential vorticity variation (PV) less than 40 %** have been selected
  ⇒161 trajectories with NCEP and 85 trajectories with DAO
- CALIOP observations (obtained by the algorithm of Pitts et al., ACP, 2009) complement the evolution of the PSC optical properties along the trajectories (Δt< 2.5 min and Δd<200 km)

3. Presentation of a case study

A. Trajectory

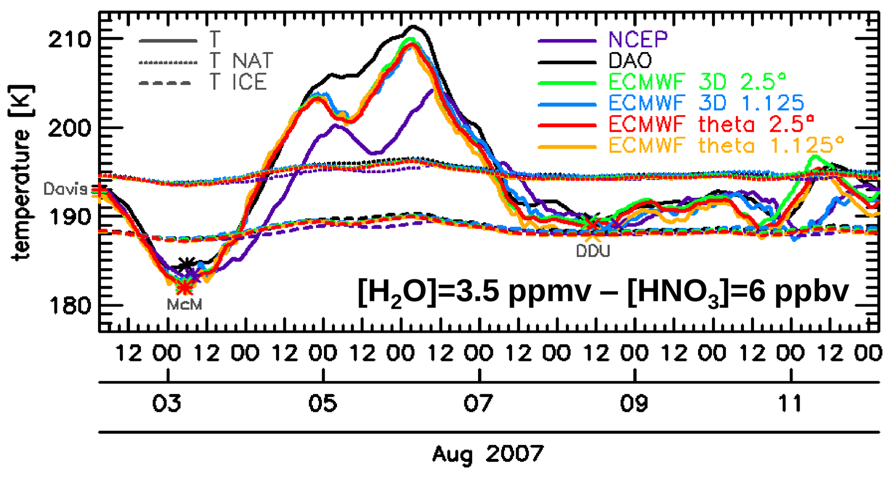


Trajectories BADC:
--- ECMWF 3D – 1.125°
--- ECMWF 3D – 2.5°
--- ECMWF θ – 1.125°
--- ECMWF θ – 2.5°

Trajectories GSFC :
--- NCEP ftraj – diabatic
--- DAO ftraj – diabatic

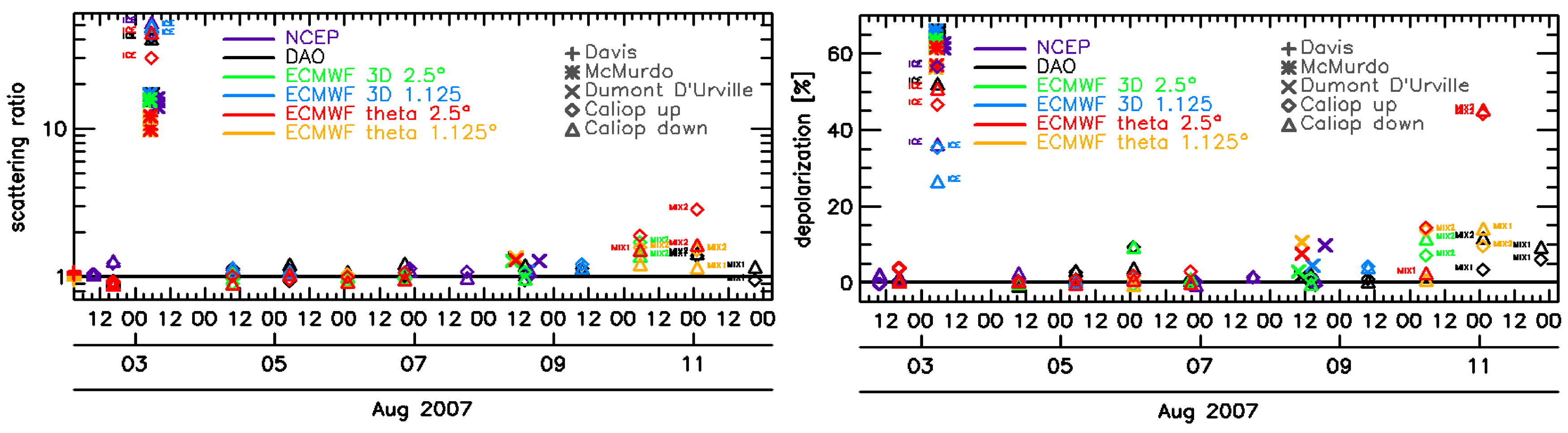
- **The trajectories follow similar paths and appear to track the same air mass**
- **On closer inspection, there are differences in location between the different trajectories** (all trajectories pass close to Dumont D'Urville but with time differences as large as 10 hours (~1100 km))

B.Temperature evolution



- **The differences are smaller for the colder temperatures where PSC are expected to be formed**
- Based on the trajectory temperatures and assumed nitric acid and water vapour abundances, we would expect to observe a NAT PSC at Davis (+), an ICE PSC at McMurdo (✱) and possibly a NAT PSC at Dumont D'Urville (×)

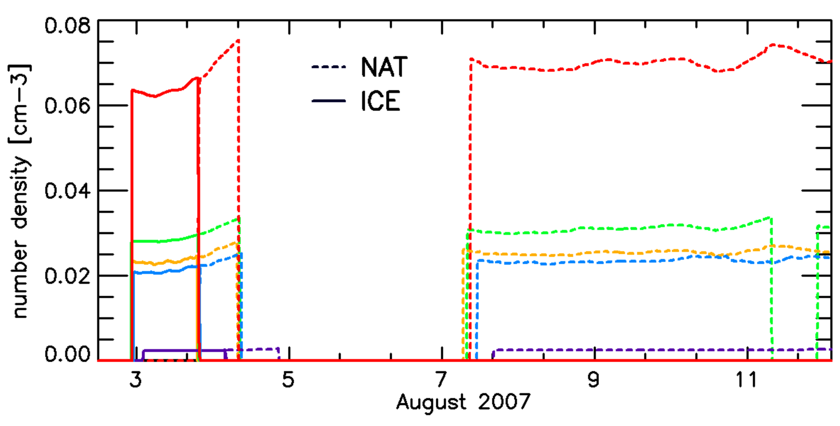
C. Optical properties observed by the lidars along the trajectories

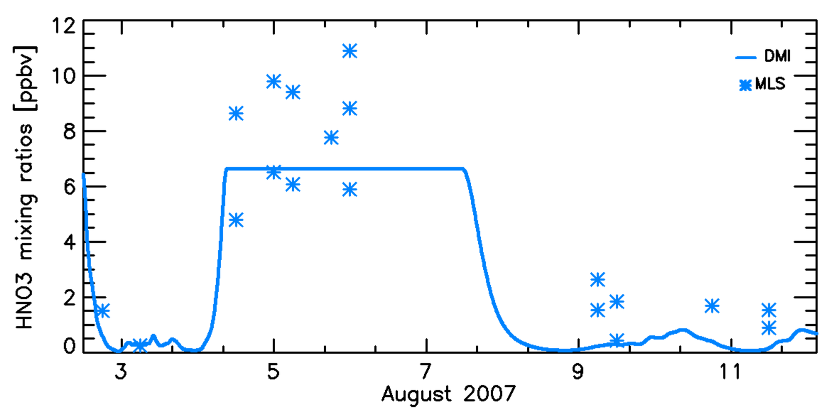


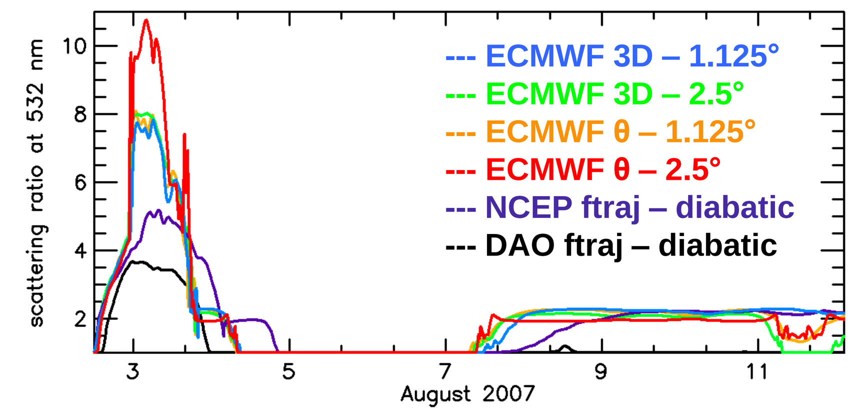
- On 3 August, **great scattering ratio and depolarisation** characteristics of a ICE PSC but **quantitative disagreement** between ground station and CALIOP measurements (due to the presence of **mountain waves** ?)
- **Temperature alone could not explain PSC existence at a given location but rather temperature evolution** (09 August 9:51 UTC, T=191.5 K : no PSC and 11 August 21:10 UTC, T=194.2 K : STS+NAT PSC)

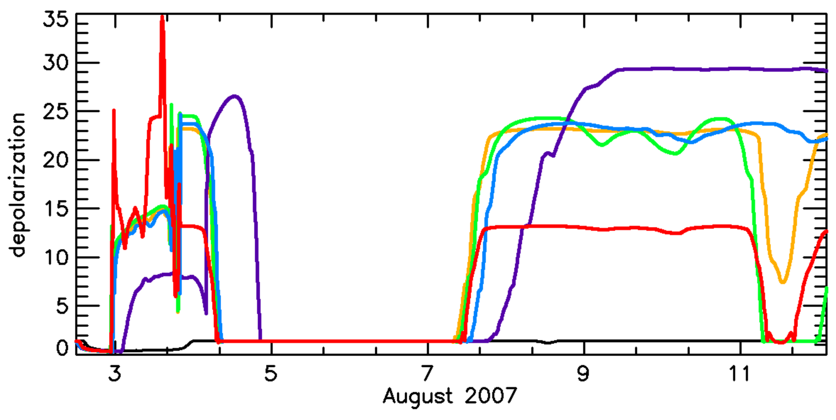
D. Modelling with the Danish Meteorological Institute (DMI) microphysical model

- Input: trajectory (P,T) and MLS HNO_3 and H_2O mixing ratios (V3.3)
- Output: microphysics (particles distributions), chemistry (HNO_3 and H_2O mixing ratios) and optics (scattering ratio and depolarisation).





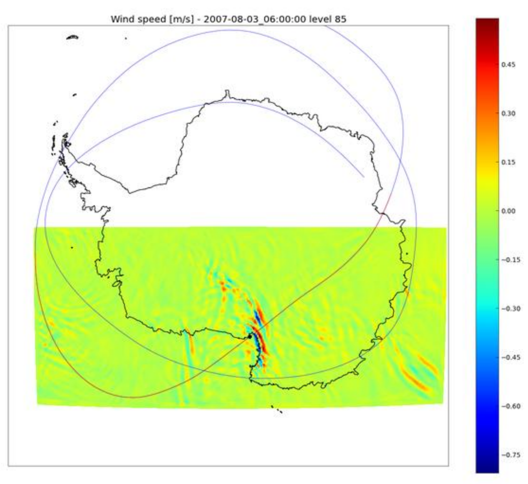


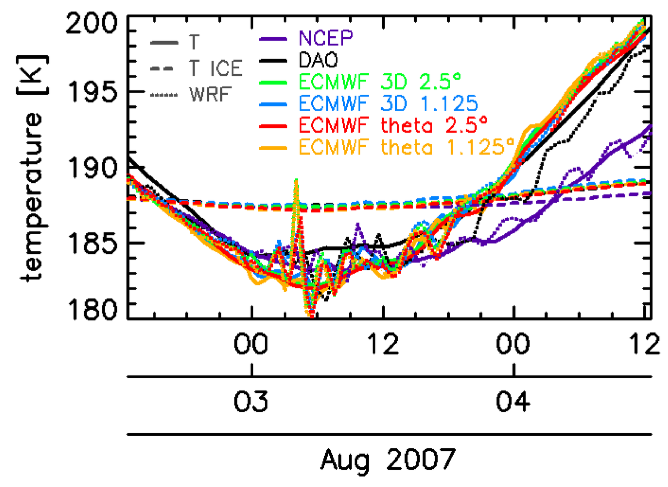


- **Between the different trajectories, the number density of particles varies by a factor ~3**
- **Good agreement** between the DMI model **chemistry and temperature evolutions** and MLS (criteria : Δt< 30 min and Δd<200 km, closer pressure level)
- The modelled optical signals are smaller than those observed with the lidars: due to mountain waves not reproduced in the trajectories ?

E. Modelling with the Weather Research & Forecasting (WRF) model

- Input: NCEP Final analysis (http://www2.mmm.ucar.edu/wrf/users/download/free_data.html) : 1° horizontal resolution every 6 hours.
- Output: vertical wind, temperature every hour with a horizontal resolution of 20 km on 120 vertical levels up to 10hPa.





- **Variation up to 7 K in the area of McMurdo due to the presence of gravity waves**

4. Conclusions and future plans

- Strong variations in the optical properties on small space scales
  Mountain waves could induce up to 7K of rapid variation according to WRF simulations
  ⇨ useful to test if it could explain the differences observed between CALIOP, the ground based lidars and the DMI model simulations
- The history of the air mass and notably the temperatures encountered along the trajectories seems important to explain the presence of some particles observed by lidars
- A statistical study with 10 cases already selected (different months, years and types of PSC) will de done to test the robustness of the DMI model to reproduce different types of PSC produced by different thermodynamical conditions
- Necessity of particle counters to test if the difference observed between lidar data and optical simulations are due to optical parameters not well adjusted (refractive index, aspect ratio) in the optical module or to the microphysical module itself (particles distributions)

Acknowledgements

The Davis measurements used here were obtained under Australian Antarctic Science project 737, and we thank the Davis wintering lidar scientists for collecting these data. We are grateful too for the provision of trajectory information from GSFC and BADC, and extend thanks to Leslie Lait of GSFC for assistance with the Goddard Automailer. CALIOP data were supplied by the Langley Research Center of the National Aeronautics and Space Administration