SUMMARY

We present stratospheric observations of trace gases (methane, ozone) in the northern hemisphere by ENVISAT/MIPAS during the spring and summer 2003. Along-track, pole-centred cross-sections are used in conjunction with meteorological analyses to reveal several salient features: W-shaped CH$_4$ isopleths, long-lived “frozen-in” anticyclones circling the pole, and an Arctic low-ozone pool, that is involved in low column ozone episodes.

1 INTRODUCTION

The structure and evolution of the summer stratosphere in the Northern Hemisphere (NH) has been relatively little studied compared to stratospheric winter. A major motivation for studying the summer stratosphere is that changes in the thinner stratospheric ozone layer, and in particular low-ozone episodes, have a stronger effect on UV radiation reaching the ground, and impact on human health and ecosystems, than in the winter [1,2]. The summer mid-latitude stratosphere may also still carry signatures of the springtime polar ozone depletion [3].

In this paper, we follow the evolution of the MIPAS CH$_4$ during the spring-to-summer transition in 2003, using a pole-centred view [4]. We complement the satellite observations with meteorological analyses from the European Centre for Medium-Range Weather Forecasts. We report on a novel feature of the trace gas distribution during spring-summer, namely the W-shape in pole-centred CH$_4$ isopleths, which form from the raising of CH$_4$ isopleths at high latitudes. We also report on the first MIPAS observations of frozen-in anticyclones at high latitudes in summer, a phenomenon discovered by [5] using EOS/MLS observations in spring-summer 2005. Finally, we demonstrate that the meridional displacement of the summertime Arctic low-ozone pool is linked to the formation of an extreme, low-ozone episode over northern Europe in August 2003. The latter is described in more detail in [2]. The former results are part of a paper recently submitted [6].

2 METHANE DISTRIBUTION FROM MIPAS

Along-track, pole-centred cross-sections of MIPAS CH$_4$ on 10 selected orbits, during the period mid-April to mid-May are shown on Fig. 1. The main features are:

- W-shape pattern (i.e. raised CH$_4$ levels at the pole)
- Strong subtropical meridional gradients
- Vortex CH$_4$-poor filaments, lasting for 2-3 weeks after the breaking of the polar vortex (which started in mid-April).

3 “FROZEN-IN” ANTICYCLONES

Using data from MLS from the spring and summer 2005, [5] describe a frozen-in mid stratosphere anticyclone (FrIAC), which remains coherent while being slowly advected around the North Pole by the prevailing high latitude easterlies. Originating in the poleward transport of mid latitude air during the April final warming, the air masses confined in the anticyclone rotated around the Pole with a variable period of 2 or 3 weeks, before disappearing in August 2005. Frozen-in vortex remnants have been reported in models (e.g. [7]) and observations [8]. FrIACs can be regarded as the opposite of vortex remnants, as the former are long-lived anticyclonic vortices originating from low latitudes, whereas the latter are long-lived cyclonic vortices originating from high latitudes.
We see a FrIAC in 2003 developing out of the poleward transport of low-latitude air during the vortex breakdown in mid-April, and then as a low PV small-scale anomaly circling the pole until mid-May. This is clearly seen in the potential vorticity at 850K (ECMWF operational analyses) in Fig. 2, and can be traced in the corresponding MIPAS CH$_4$ along-track cross-sections.
Fig. 2. PV (PV units) at 850 K from ECMWF analyses for: (a) 16 April 2003; (b) 22 April 2003; (c) 25 April 2003; (d) 29 April 2003; (e) 6 May 2003; (f) 14 May 2003; (g) 15 June 2003; (h) 10 August 2003; (i) 15 September 2003; (j) 15 October 2003. The starting point of the viewing track is indicated by the solid circle. The PV values are normalized such that the highest value is denoted by red and the lowest value by blue.

4 LOW-OZONE ARCTIC POOL

A low-ozone pool of air resides over the Arctic in summer due to ozone photochemical (NOx) destruction during long insolation days. Summertime low-ozone episodes (LOEs) occur in conjunction with high-tropopause, anticyclonic conditions in the troposphere and the off-pole displacement of this pool of low-ozone Arctic air, aloft of the anticyclone as demonstrated in a case study of the summer 2000 [1]. We show another example during the notorious August 2003 European Heat wave, using TOMS column O3 and MIPAS mixing ratios in the stratosphere. Fig. 3 shows the TOMS column ozone at two locations in Scandinavia (Oslo and Kiruna) and the MIPAS 650K O3 averaged over a box (60N-70N, 0-36E) in AUG 2003. On August 10, during the peak of the Heat wave, column ozone reached
its summer minimum. The ozone lowering at 650K indicates that the stratosphere is implicated in the low ozone column (see [2]).

Fig. 3. (Left) Time series of column ozone from TOMS over Oslo (60N, 12E) and Kiruna (67N, 20E) in Scandinavia, in August 2003. Julian day 222 corresponds to August 10. (Right) Ozone mixing ratio (ppmv) in the stratosphere at 650K, over the same period from the binned NRT MIPAS data (60N-70N, 0E-36E). The dashed lines in (a) and (b) indicate the extent of 1 standard deviation envelope from the 2003 summer-mean in TOMS data over Oslo, and in the binned MIPAS data (60N-70N, 0E-36E). On the left, the circle on day 222 indicates the August mean over Oslo, based on TOMS data since 1978.

The tropospheric circulation is very disturbed by a persistent blocking over Europe, part of a prominent, quasi-stationary Rossby wave train across the Atlantic-Europe region. Its influence is felt up to 50-30 mb, where the stratospheric circulation is very disturbed, as can be seen from the ECMWF geopotential height maps (dam) at 250mb and 50mb on AUG 10. Note the split polar High at 50mb.

Fig. 4. (a) 8-day low-passed 250-mb geopotential for August 10, 2003. (b) Same for 50mb. Note the ridge extending south over Scandinavia and Northern Europe, and the high latitude cyclonic centre on the west-northern corner of Greenland. Units are dam, and contour intervals are 10 dam (a), 3 dam (b).
REFERENCES