Khosrawi et al.: Assessment of the interannual variability and impact of the QBO and upwelling on tracer-tracer distributions of N_2O and O_3 in the tropical lower stratosphere

Electronic supplement

Latitudinal occurrence of $N_2O > 320$ ppbv:
In Figure 1 the N_2O mixing ratios 650±25 K that are larger than 320 ppbv are plotted on a map for January, April, July and October 2003. These high N_2O mixing ratios occur solely in the tropics.

Odin/SMR:
Considering the maximum N_2O mixing ratios of the averaged bins for the years 2003 to 2010 a higher occurrence of these high N_2O values is found in 2003, 2004, 2007 than in the other years (Table 1). High N_2O mixing ratios are found in 2003 during all winter months (January to March and October to November), but in 2004 only at the begin of the year (January to March), in 2005 and 2007 only at the end of the year (November to December), in 2006 and 2010 only in two months (January and October and January and March, respectively) and 2008 and 2009 only in one month (February and November, respectively). Lowest maximum N_2O values are found during summer months (June and July in 2004-2005, June to August in 2006, May to July 2007, May to August 2008 and 2009 and July to August 2010). One exception, however, of this scheme is found in 2007, when the lowest value was found in January.

Aura/MLS:
Though the highest N_2O averages from Aura/MLS are $\sim$ 20 ppbv lower than the monthly averages from Odin/SMR, a similar structure of higher N_2O values during winter months is found (Table 2). The summer minima, however, are not as strongly pronounced in the Aura/MLS data as in Odin/SMR data (see paper for more details).

ENVISAT/MIPAS:
In 2003 and 2004, before the intermission in the ENVISAT/MIPAS operation, maximum N_2O mixing ratios of 330 ppbv are found between February and April. From 2005 onwards when ENVISAT/MIPAS continued its operation with a lower spectral resolution much lower N_2O mixing ratios (Table 3) are found than in 2003 and 2004.

SD-WACCM:
No structure as pronounced as in the satellite data sets showing higher

maximum N_2O mixing ratios of the averaged bins during winter months are found Table 4. However, higher values are found during Mai 2007, February 2009 and from January to June 2010. The QBO in SD-WACCM is realistically simulated and in good agreement with the QBO derived from Odin/SMR (not shown). However, in WACCM the QBO does not propagate as far down as in Odin/SMR. This may explain why we do not see the structure of higher N_2O values in winter than in summer that pronounced in SD-WACCM than in the satellite data.

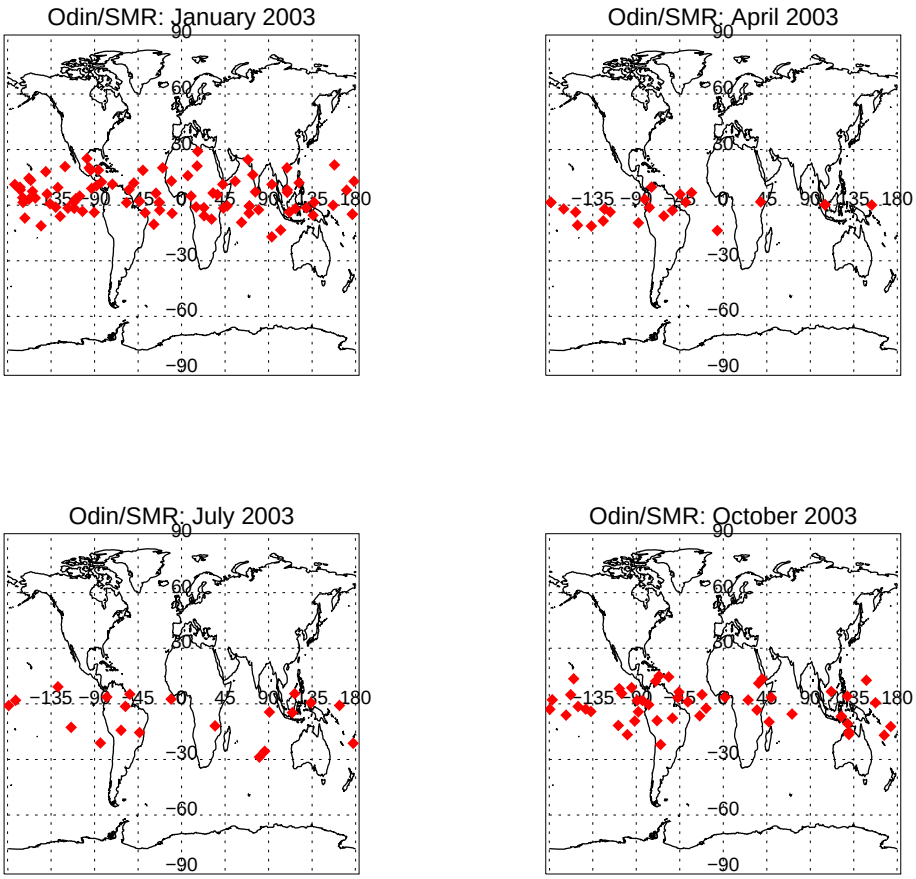

Figure 1: Locations where Odin/SMR N_2O mixing ratios greater 320 ppbv are observed at 650±25 K during 2003 (NH). Shown is every third month, thus January (top, left), April (top, right), July (bottom, left) and October (bottom, right).

Table 1: Odin/SMR: Maximum monthly averaged N_2O mixing ratios (averaged mixing ratio of the last N_2O bin) at 650±25 K. Maxima and Minima are marked in bold face.

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010
January	**330**	**330**	310	**330**	**290**	310	310	**330**
February	**330**	**330**	310	310	310	**330**	310	310
March	**330**	**330**	310	310	310	310	310	**330**
April	310	310	310	310	310	310	310	310
May	310	310	310	310	**290**	**290**	**290**	310
June	310	**290**	**290**	**290**	**290**	**290**	**290**	310
July	310	**290**	**290**	**290**	**290**	**290**	**290**	**290**
August	310	310	310	**290**	310	**290**	**290**	**290**
September	310	310	310	310	310	310	310	310
October	**330**	310	310	**330**	**330**	310	310	310
November	**330**	310	**330**	310	**330**	310	**330**	310
December	**330**	310	**330**	310	**330**	310	310	310

Table 2: Aura/MLS: Maximum monthly averaged N_2O mixing ratios (averaged mixing ratio of the last N_2O bin) at 650±25 K. Maxima and Minima are marked in bold face.

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010
January	-	-	**310**	**310**	**310**	290	**310**	**310**
February	-	-	**310**	**310**	**310**	290	**310**	**310**
March	-	-	**310**	290	**310**	290	**310**	**310**
April	-	-	290	290	290	290	290	**310**
May	-	-	290	-	290	290	290	**310**
June	-	-	290	**270**	290	290	290	-
July	-	-	290	**270**	290	290	290	-
August	-	-	290	290	290	290	290	-
September	-	290	290	290	290	290	290	-
October	-	290	290	290	290	290	**310**	-
November	-	290	290	-	**310**	290	**310**	290
December	-	290	290	290	290	290	**310**	290

Table 3: ENVISAT/MIPAS: Maximum monthly averaged N_2O mixing ratios (averaged mixing ratio of the last N_2O bin) at 650±25 K. Maxima and Minima are marked in bold face.

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010
January	310	310	**250**	270	270	**290**	**290**	-
February	**330**	310	270	-	270	**290**	270	-
March	**330**	310	270	270	270	**290**	270	-
April	**330**	-	**250**	-	270	270	270	-
May	310	-	**250**	270	270	270	270	-
June	310	-	270	**250**	270	270	270	-
July	310	-	**250**	270	270	270	**290**	-
August	310	-	270	270	**290**	270	**290**	-
September	310	-	-	270	270	270	**290**	-
October	310	-	-	270	270	270	**290**	-
November	310	-	-	270	270	270	**290**	-
December	310	-	270	270	**290**	270	**290**	-

Table 4: WACCM: Maximum monthly averaged N_2O mixing ratios (averaged mixing ratio of the last N_2O bin) at 650±25 K. Maxima and Minima are marked in bold face.

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010
January	-	-	270	270	280	270	280	**290**
February	-	-	280	270	280	270	**290**	**290**
March	-	-	280	270	280	280	280	**290**
April	-	-	280	270	280	270	280	**290**
May	-	-	280	270	**290**	280	280	**290**
June	-	-	280	270	280	280	280	**290**
July	-	-	280	270	280	280	270	280
August	-	-	280	270	280	280	**260**	270
September	-	-	280	270	280	270	270	270
October	-	-	270	270	270	270	270	-
November	-	-	280	270	270	270	280	-
December	-	-	270	280	270	280	280	-