On the dynamical evolution of the polar stratosphere after the vortex breakdown

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A. ABSTRACT

During winter, the polar vortex forms in arctic stratosphere a dynamical barrier which prevents large scale exchanges between high latitude and tropical regions. However, thin tropical air mass intrusions at the edge of the polar vortex have already been detected and modelled. These structures could play an important role for the knowledge of the balance between chemistry and dynamical processes associated with ozone budget.
During springtime, after the final stratospheric warming, the breakdown of the polar vortex occurs and the summer circulation start to develop. Air mass intrusions from the tropics can be trapped into the polar latitudes in an anticyclone which can persist until August, advected by summer easterlies. These structures, named "Frozen In Anticyclones" (FrIAC's), have already been observed in 2003 and 2005 by MIPAS-ENVISAT (*Lahoz et al, 2007*) and MLS-AURA (*Manney et al., 2006*) instruments.
We present here a new case of FrIAC in 2007 highlighted using MLS-AURA measurements. Time evolution of N_2O and H_2O mixing ratios in the core of this FRIAC are compared with the 2005 similar event. These two cases are also studied using potential vorticity advection model MIMOSA in order to understand associated dynamical processes.
In addition, we perform a climatology of tropical air mass intrusions during the last decade based on MIMOSA results and MLS-AURA measurements. This climatology reveals a favourite path for exchanges between polar and tropical stratosphere.
This study is made in the framework the STRAPOLETE project which has started on January 2009 to study the Arctic stratosphere in the summertime.

B. TOOLS

• **AURA-MLS (Microwave Limb Sounder,** *Livesey et al. (2006)* **)** is an instrument aboard AURA satellite which makes measurements of thermal microwave emission from Earth's 'limb'. MLS produces profiles of several species every ~25 seconds from the ground to ~90 km. The data version 2.2 is used in this study.

• **MIMOSA (Modélisation Isentrope du transport Méso-échelle de l'Ozone Stratosphérique par Advection,** *Hauchecorne et al. (2002)* **)** is a semi-Lagrangian high resolution model of advection of potential vorticity (PV). PV is advected on several isentropic levels [350 K; 950 K] by the horizontal wind components on a x-y grid centred at the North Pole with a resolution of either 3 or 6 points per degree. Initialisation and assimilation data come from winds, pressure and temperature re-analysis fields of the ECMWF (ERA-INTERIM). PV grids are advected then re-interpolated on the original grid every 6 hours in order to keep the distance between two adjacent points approximatively constant. The regridding process is based on the preservation of the second order momentum of PV perturbation which allows to minimize the numerical diffusivity to 1350 $m^2.s^{-1}$

D. COMPARISON 2005/2007

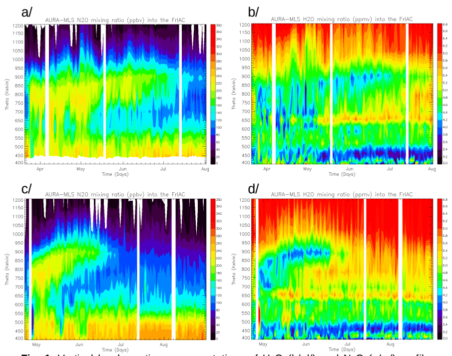

Fig. 1. Vertical levels vs time representations of H_2O (b/,d/) and N_2O (a/,c/) profiles from AURA-MLS in 2005 (a/,b/) and 2007 (c/,d/). Profiles are taken at the N_2O maximum at 10 hPa and northward of 60°N.

N_2O and H_2O tracers are **well correlated**. The vertical extension is approximatively similar in 2005 and 2007 decreasing in time due to vertical winds shear, tilting the structure.
H_2O tracer persists more than N_2O showing **dynamical and chemical (photolysis) competition on the FrIAC lifetime**.

E. MODELLING FrIACs & VORTEX REMNANTS

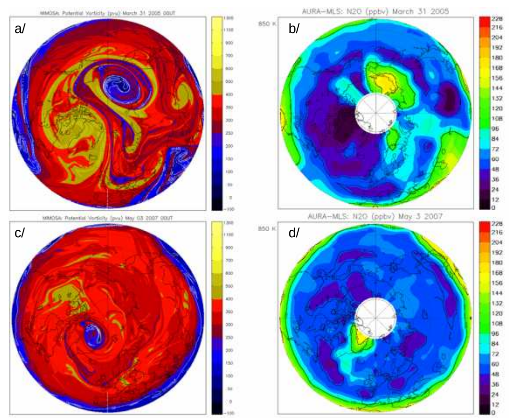

Fig. 2. Plate of potential vorticity from MIMOSA (a/,c/) and N_2O from AURA-MLS (b/,d/) the 31th March 2005 (a/,b/) and the 03rd May 2007 (c/,d/) at 850K isentropic level. MIMOSA is initialized on the 1st January of each year and works with a 1/3°/1/3° (latitude/longitude) grid resolution. N_2O plate is obtained by vertical interpolation of each profile on a chosen isentropic level. Then an horizontal interpolation is done on a 3°/3° (Lon/Lat) grid using the three closest points.

MIMOSA simulations show a very **good agreement** between PV and N_2O AURA-MLS tracer fields in 2005 and 2007. Vortex remnants (low N_2O and high PV) are well located as well as FrIAC's structures (high N_2O and low PV). The very high resolution of MIMOSA allows a **fine definition of anticyclonic's shapes of the FrIAC's**.
FrIAC's can be followed in PV fields until June if diabatic effects on PV are taken into account.

Tropical air masses intrusions tracks are well represented in MIMOSA PV fields allowing a detailed study on the required dynamical conditions leading in the FrIAC formation.

C. FrIAC's CLIMATOLOGY

At 850K		2003	2005	2007
Start		April 15th	March 27th	April 28th
N_2O (ppbv)	Max	-	~225	~225
	Surrounding	-	~50	~50
O_3 (ppmv)	Max	-	~9	~8
	Surrounding	-	~6	~5
CH_4 (ppbv)	Max	> 1000	-	-
	Surrounding	~800	-	-
HCl (ppbv)	Min	-	~2.0	~2.0
	Surrounding	-	~2.5	~2.4
H_2O (ppmv)	Min	-	4-4.4	4-4.4
	Surrounding	-	~6.0	~5.5
PV (pvu)	Min	150	100	100
	Surrounding	300-400	400-500	350-400

Tab. 1. FrIAC's chemical and potential vorticity features in 2003, 2005 and 2007 at 850K.

FrIAC's are the result of tropical air mass intrusions in arctic polar region occuring during the transition between winter westerlies and summer easterlies wind phases. They are characterized by high (low), N_2O, CH_4 (PV,H_2O) in comparison with the surrounding air.
2003 FrIAC has been reported by *Lahoz et al. (2007)* using MIPAS-ENVISAT data.
2005 FrIAC has been reported by *Manney et al. (2006)* using MLS-AURA data.
AURA-MLS data allowed us to report a **new FrIAC case** at the end of April 2007.

F. INTRUSIONS CLIMATOLOGY

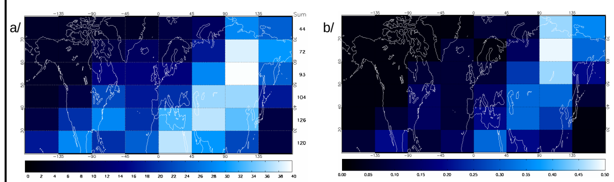

Fig. 3. Location of tropical intrusions going from January 2000 to May 2009 based on MIMOSA model. Only intrusions which start southward of 40°N were taken into accou nt. a/ represents number of intrusions per grid square and b/, the probability of location per 10°latitude range.

The **favourite path** of tropical intrusions is located above **east of Asia** at mid-latitudes.

G. ZONAL WIND DIAGNOSTIC

The favourite region for tropical air mass intrusions (Fig. 3.) is located in the [90;135]°E longitude range and at 49.5°N. It is associated with **zonal wind convergence** from January to May which is more intense during years with FrIAC's cases. This observation is verified for 2003 and 2005 (not shown).

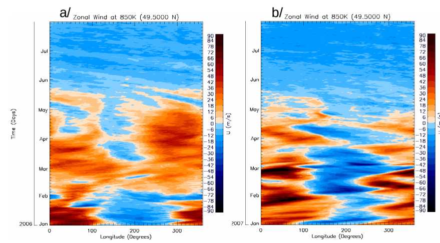

Fig. 4. Hövmoller (Time vs Longitude) plots of zonal wind (ERA-INTERIM) at 850K and latitude 49.5 N for the years 2006, a/ (no FrIAC's) and 2007, b/ (FrIAC's)

CONCLUSION

A new case of FrIAC has been reported and compared with the two known cases of 2003 and 2005. They show very similar features as vertical extension and evolution in time. MIMOSA is an useful tool for modelling such dynamical structures and to investigate stratospheric dynamical conditions associated with this phenomena. It allows us to determine a favourite area above east Asia crossed by most of the tropical intrusions. This region corresponds to the interface between the edge of the polar vortex and the edge of the associated anticyclone.
Currently, we investigate possible links between tropical intrusions and other phenomena as :
• Quasi Biennial Oscillation.
• Several types of waves.
• Final Stratospheric Warming.
• Asiatic Monsoon.

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Acknowledgments

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