Stratosphere-troposphere exchange study in the Southern subtropics using experimental data, trajectory and Reverse Domain Filling calculations

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INTRODUCTION

The analysis of a vertical profile of a tropospheric species like ozone is frequently complex because of the interlacing and mixing of layers originating from different regions and influenced by different sources. The analysis of long series of data requires to know the origin of air masses and their mixing to understand the contributions of each source. We have then developed LACYTRAJ, a trajectory code to explicit the origin of the air masses.

RDF (Reverse Domain Filling, Dritschel, 1988) is a mapping technique based on trajectory and advection of a parameter assimilated to a tracer : Potential vorticity, water vapor or else. If the time of trajectory is adjusted to the lifetime of the tracer, this technique allows to build sub-grid fine scale structures of a profile, horizontal field or vertical cross section. This kind of tool can be used for the characterisation of the influence of biomass burning or pollution on tropospheric ozone, stratosphere-troposphere exchange and for a better understanding of the causes of long-term trends.

METHODOLOGY AND ALGORITHM

LACYTRAJ is a new kinetic trajectory code written in C++ using ECMWF data (horizontal resolution of 1.125 degrees, 21 or 23 vertical pressure levels and a time resolution of 6 hours). The user defines a start grid in three dimensions Each grid points is advected by using a bilinear interpolation for horizontal wind fields and time and a log-linear interpolation for vertical wind field, and with a time step between 5 and 30 minutes. After the back trajectories calculations, tracers are advected along each trajectory. Runs of LACYTRAJ can be done using all type of data (reanalyses, forecast) in GRIB format, and it can be configured to different resolutions in space and time.

The intercomparison between LACYTRAJ and FLEXPART (version 4.3, 60 vertical model levels, horizontal resolution : 1°, time resolution 3h, Stohl et al., 1998) is shown in figures 1 and 2.

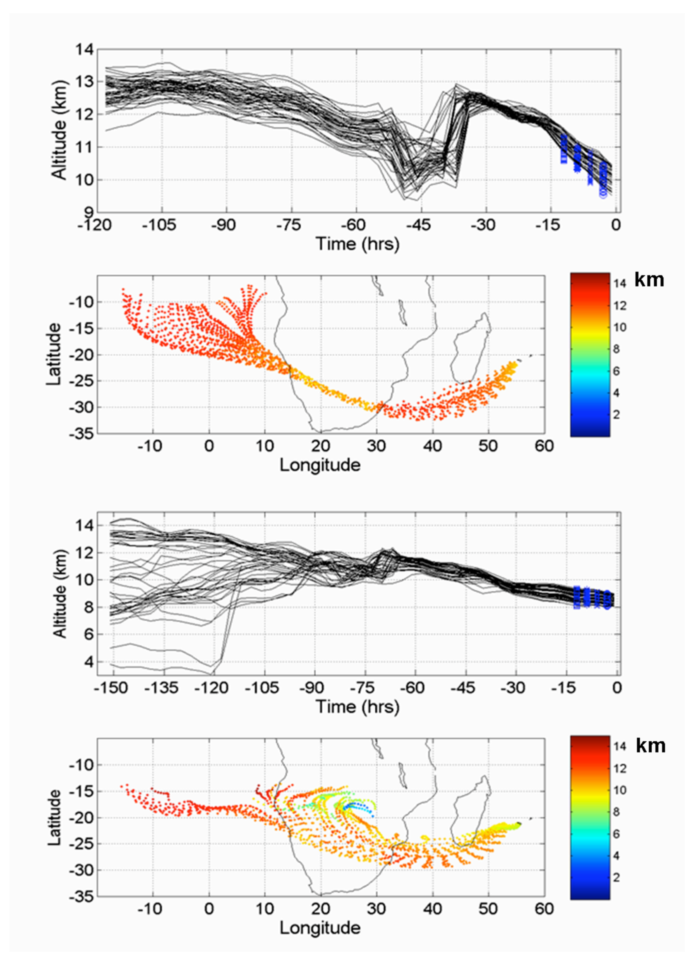

Figure 1. *FLEXPART cluster back trajectories ending on 15 (top) and 19 February 2002 (bottom) over Reunion Island (From Leclair de Bellevue et al., 2006).*

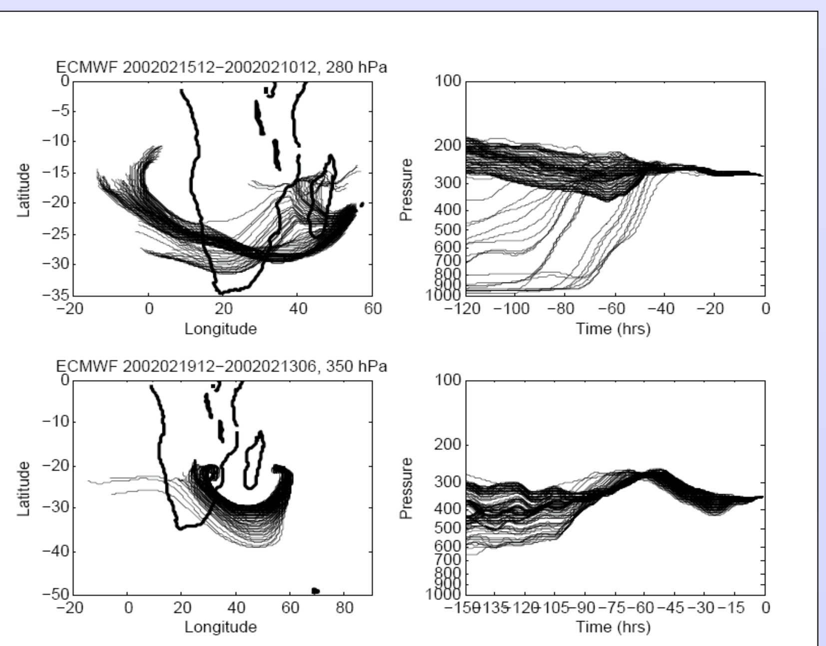

Figure 2. *LACYTRAJ cluster back trajectories ending on 15 (top) and 19 February 2002 (bottom) over Reunion Island.*

RESULTS

The figure 3 presents the comparison between two ozone profiles obtained by lidar with the PV profiles obtained directly by ECMWF, and reconstructed by RDF-LACYTRAJ on 24 and 48 hours backtrajectories on 4 December 1999, 00 UT. In the two ozone profiles, we have a tropospheric layer with high ozone values, between 5 and 11 km on 3 December, and between 6 and 12 km on 4 December. The reconstruction of PV shows a peak, more important with a reconstruction of 48 hours (2.5 PVU) than 24 hours (1 PVU). The altitude of the PV peak is between 500 and 350 hPa, corresponding to the lower part of the enhanced ozone layer. The stratospheric origin suggested by this RDF-PV peak, not well captured by the PV profile given directly by ECMWF, has contributed to a part of the ozone enhancement observed by lidar, in addition to the biomass burning influence.

The code allows to advect tracers not only on a profile, but on a 3D domain, and then on a vertical cross section or on a horizontal field. The figure 4 presents vertical cross sections of potential vorticity (48 hours) and water vapor mixing ratio (6 hours) for the 3 December 1999, 18 UT, compared to ECMWF. The RDF reconstruction evidences a stratospheric filament constituted by dry and high PV air, where the ozone peak was observed over Reunion island, especially visible on 3 December. In cases of downward movement from the stratosphere, the RDF reconstruction is able to produce realistic potential vorticity distribution, and enhance the gradients of dry structures in the tropopause fold, with wet air in the frontal areas around it, if the time of trajectories is not too long.

The comparison between an upper tropospheric horizontal field of water vapor reconstructed by RDF and the water vapor channel of Meteosat on 12 January 2007 shows that, despite the short time of the trajectories (6 hours), the RDF methods gives little scale water vapor structures with a good agreement Meteosat, for the wet and dry areas (figure 5).

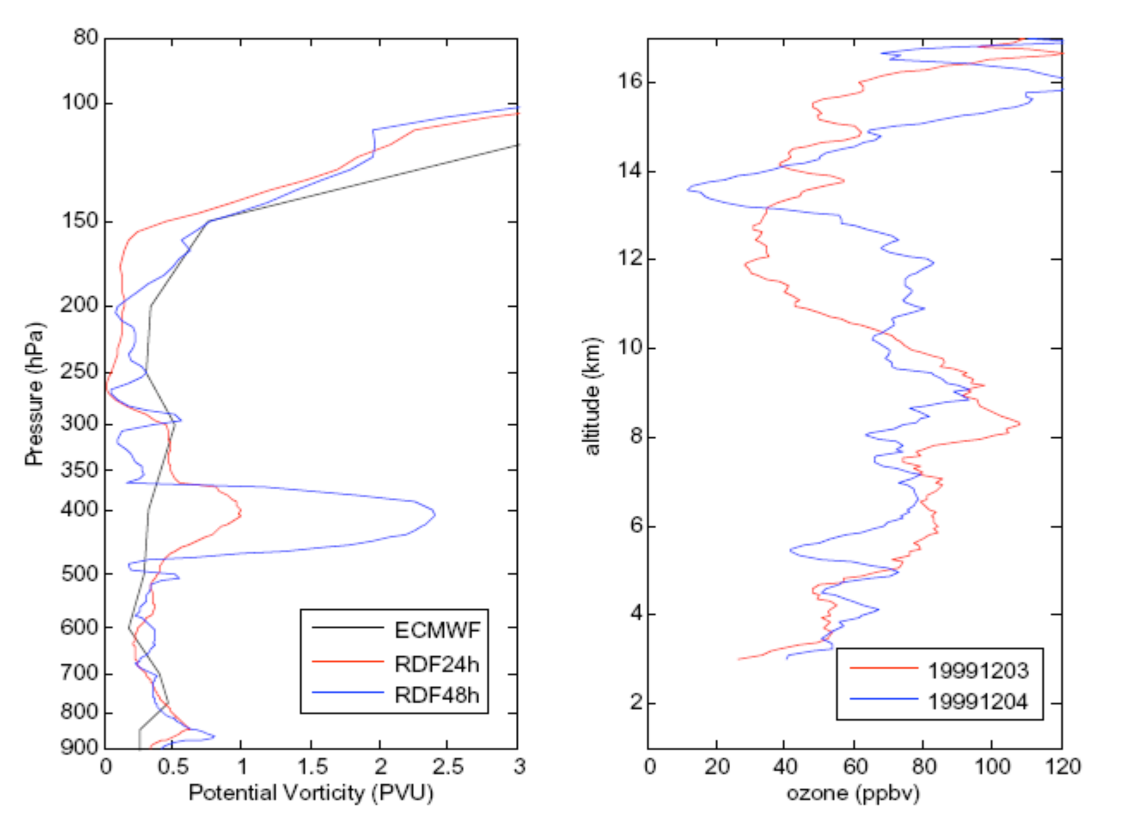

Figure 3. *Potential vorticity over Reunion Island on 4 December 1999, 00 UT given by the ECMWF model and by RDF reconstruction during 24 and 48 hours with LACYTRAJ (left), and ozone profiles obtained by lidar on 3 and 4 December 1999, 18 UT (right).*

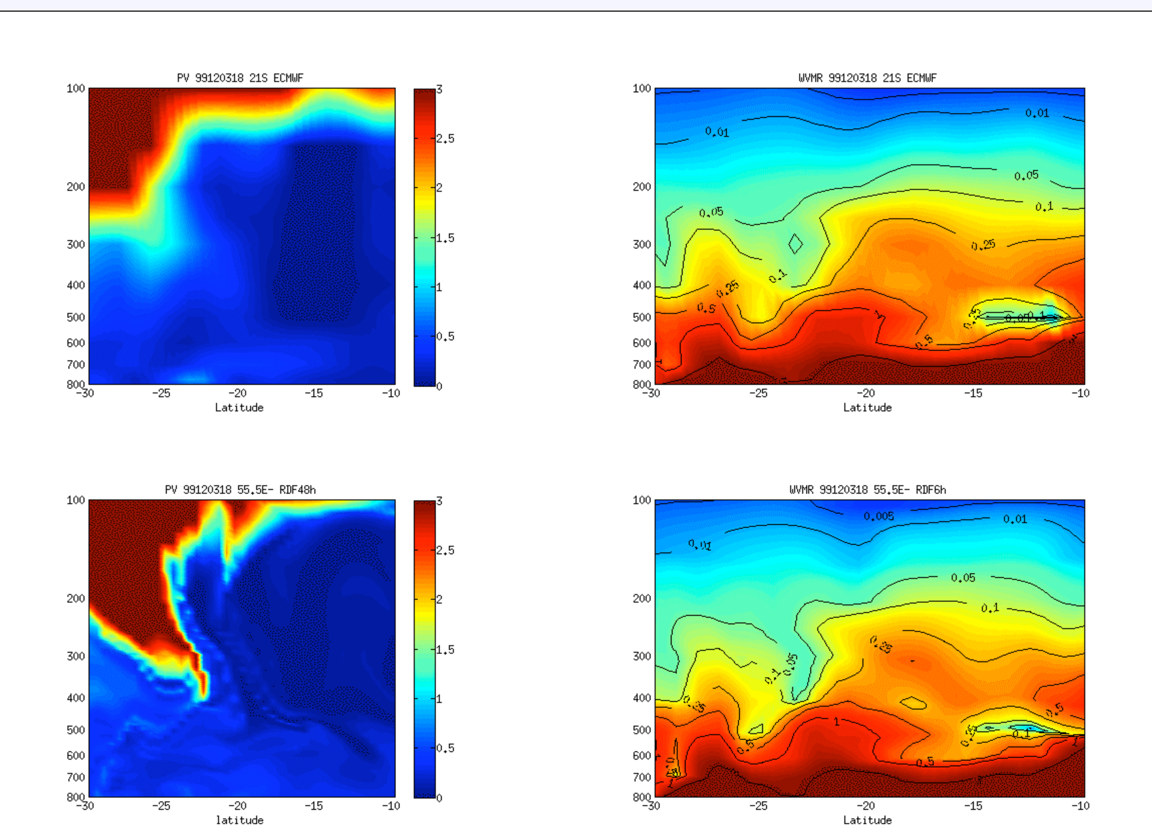

Figure 4. *ECMWF (top) and RDF (bottom) vertical cross section of potential vorticity (left) and water vapor mixing ratio (right) on 03 December 1999, 18 UT. The RDF figures have been obtained on 48 hours (PV) and 6 hours (Water Vapor) with LACYTRAJ. The color scale for water vapor is logarithmic from 0.001 (blue) to 3 g/kg (red).*

ACKNOWLEDGEMENTS

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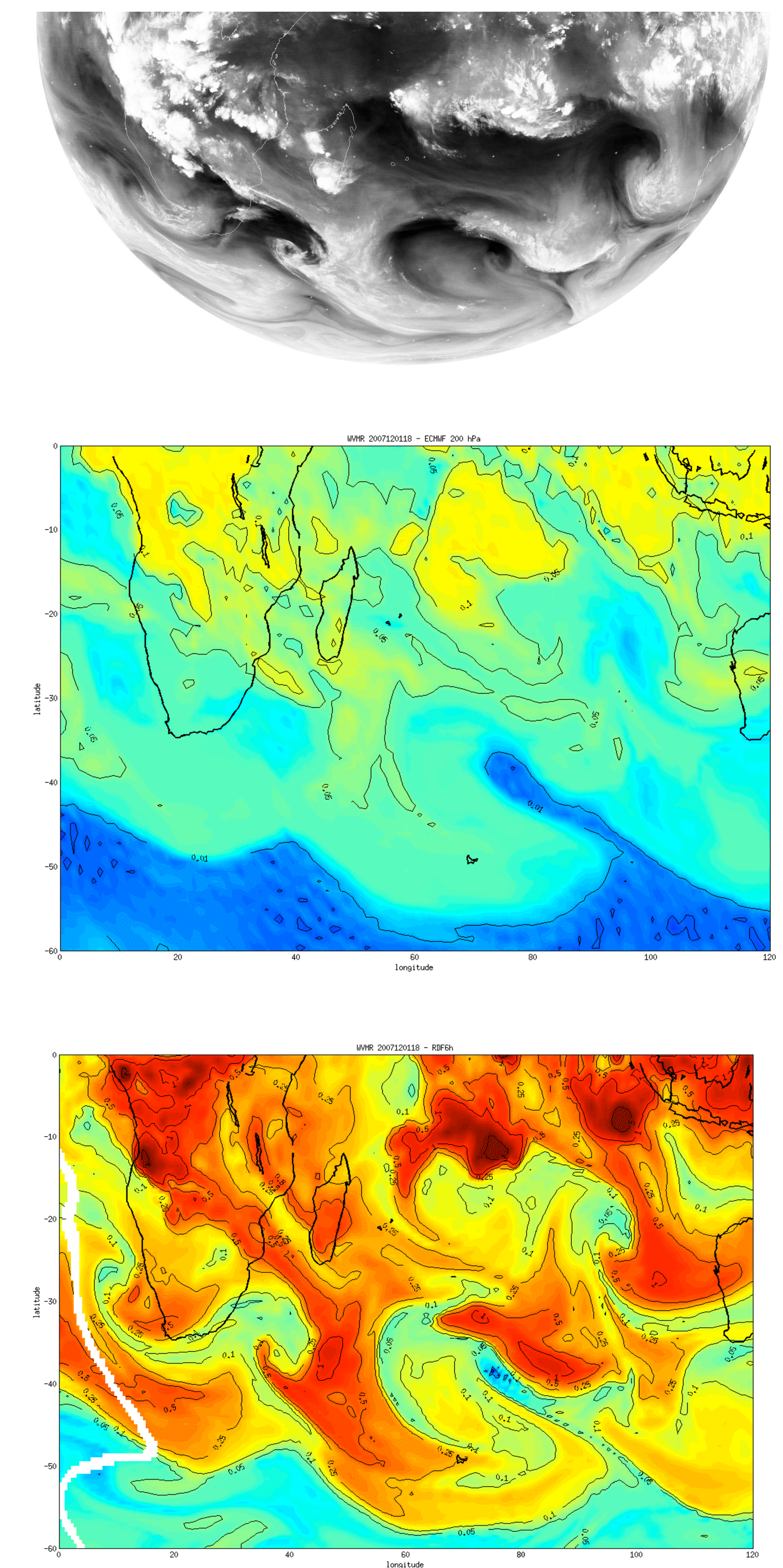

Figure 5. *Meteosat image in the water vapor channel on 1 December 18 UT (top), ECMWF water vapor mixing ratio field at the level 200 hPa (middle) and obtained by RDF reconstruction during 6 hours (bottom).*

CONCLUSION AND PERSPECTIVES

We have presented LACYTRAJ, a new code of trajectory-Reverse Domain Filling advection of tracers, and first results in terms of stratosphere-troposphere studies.

The trajectories have been intercompared with existing codes like FLEXPART.

- Further comparisons with existing codes to validate the trajectory code are needed.
- The code has good performance for the PV RDF reconstruction : Systematic application to the ozone database of Reunion Island (see poster of G. Clain).
- For the water vapor tracer, the little scale structures of water vapor given by RDF calculations seems realistic, but two problems remain : The short time life of this tracer in the troposphere, which means short times for the trajectories (6 hours), and the under-estimation of water vapor in the UTLS in the ERA-40 ECMWF data.
- We plan to improve the first point using longer trajectories with a micro-physic scheme developed in the MIMOSA code (Hauchecorne et al., 2002) for the study of water vapor in presence of cirrus.
- The way to improve the second point is to initialise the calculation with other data for the UTLS (new products of ECMWF ERA-INTERIM , satellite data like those of AIRS/AMSU, SAGE-II, HALOE, MIPAS or GOMOS).

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