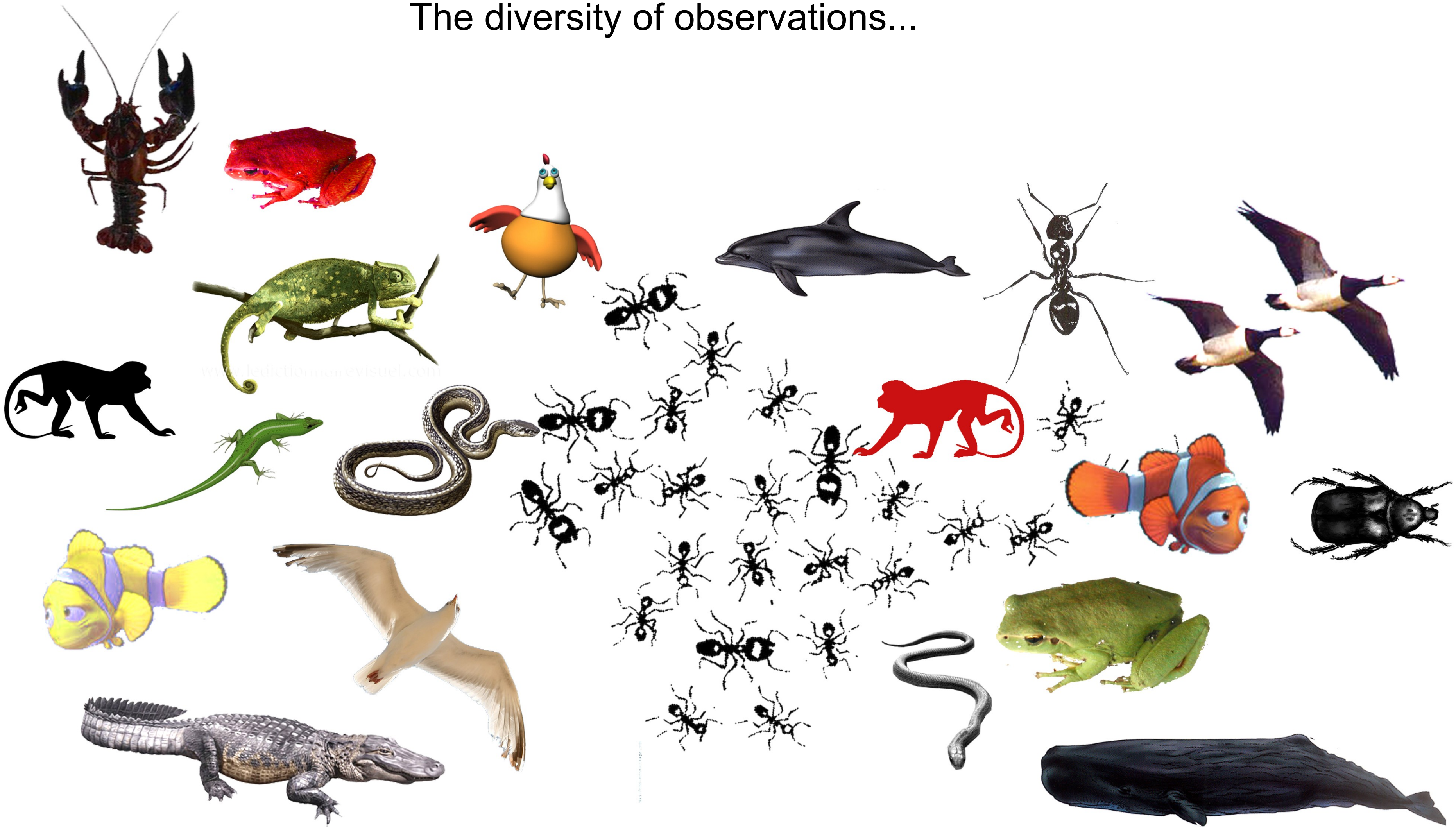
Mixing processes and exchanges across the tropical and subtropical tropopause layer

R. James & B. Legras

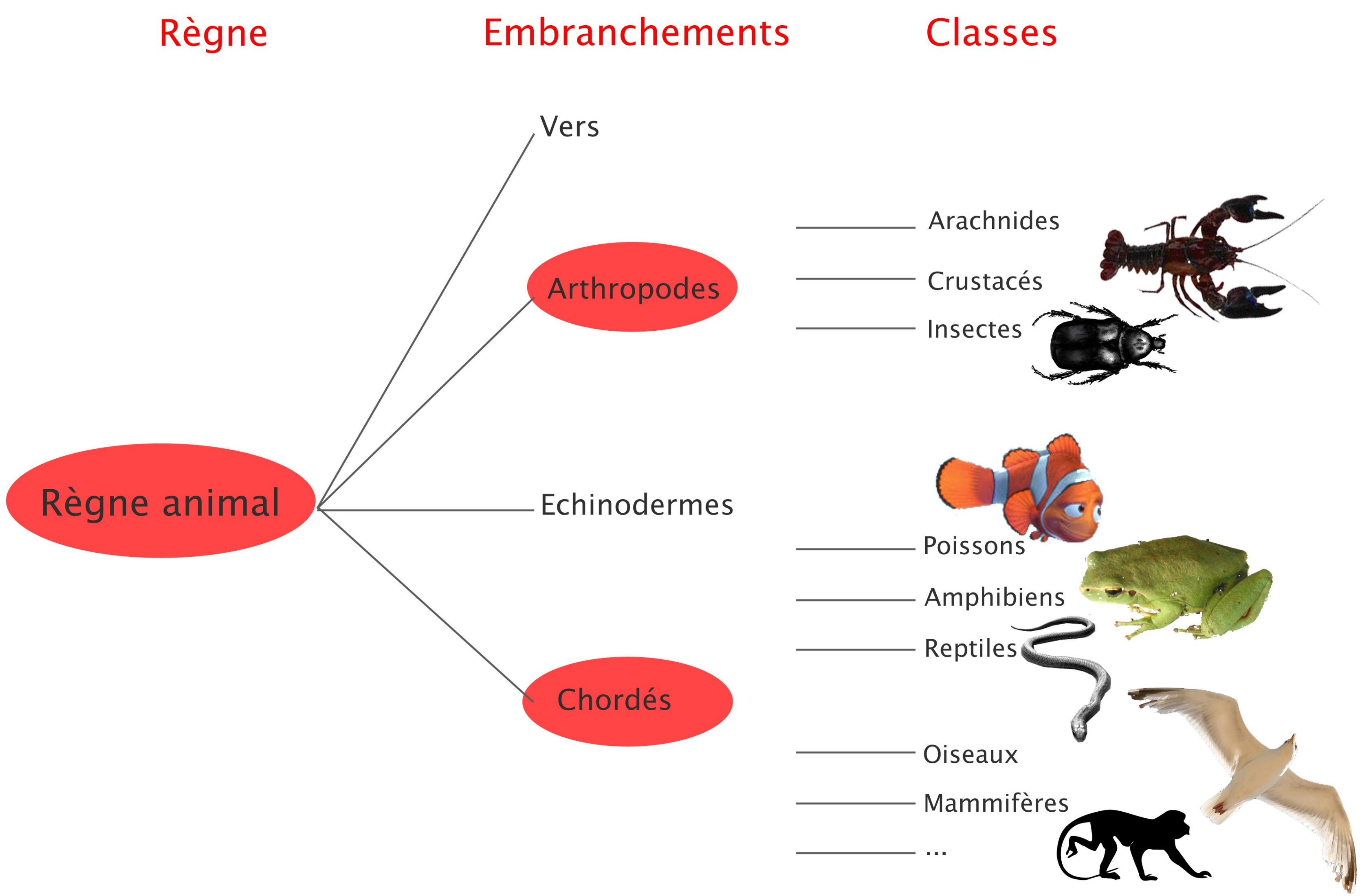
Mixing processes at the tropical and subtropical tropopause layer, R. James, and Legras, B., Atmos. Chem. Phys., 2009

Classify to reduce
The diversity of observations...



Classify ro reduce

The diversity of observations...



1. Mixing in the UT/LS

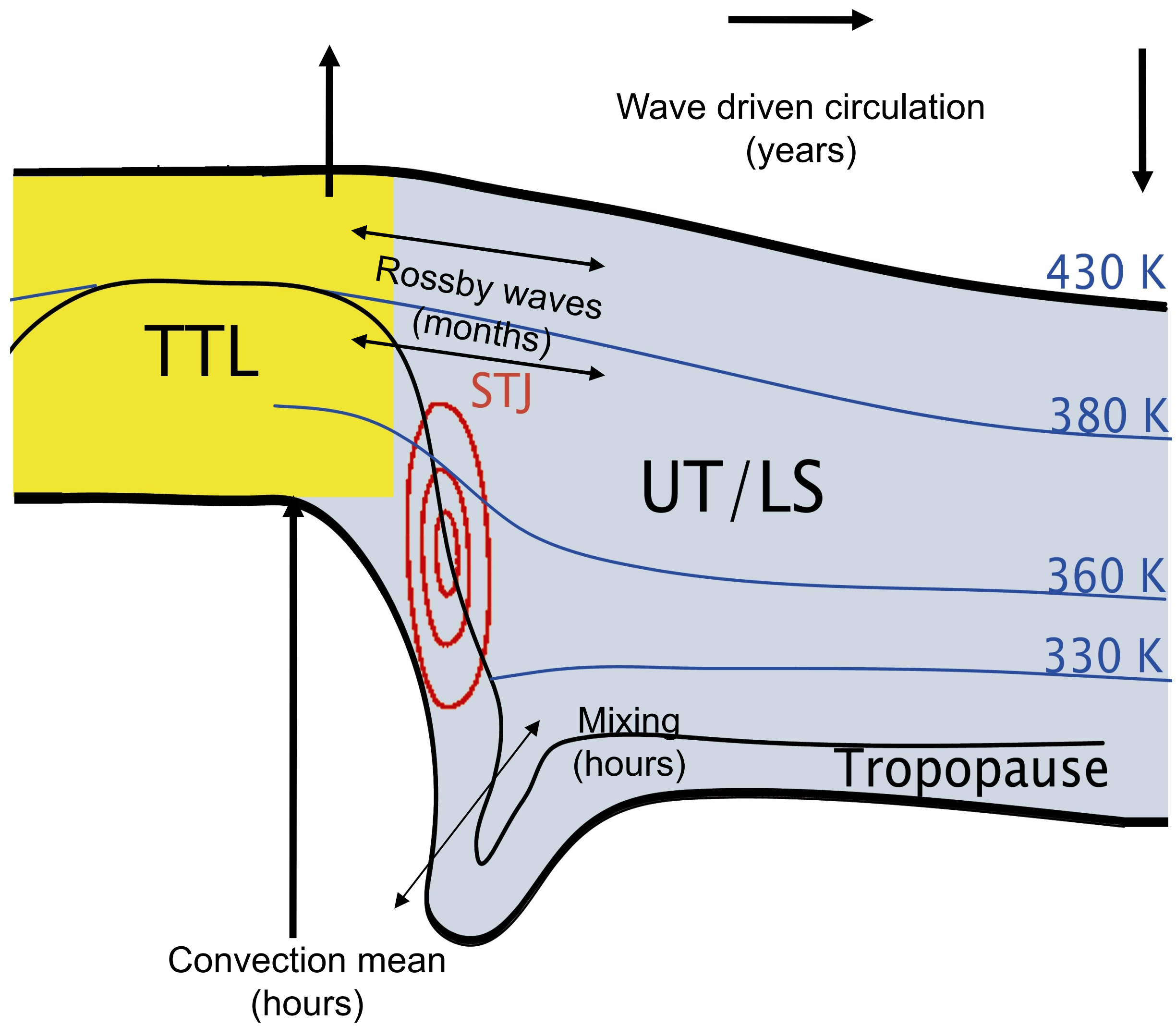
1.1 Exchanges in the UT/S : Structures and time sclales

Role of mixing in 3 regions

<u>Trop. Meridional Exchanges :</u>
Rosenlof 1995, Andrews 2001

<u>Subtrop. Transport Barrier :</u>
Hintza 1994
Chen 1995, Haynes 2000

<u>Extratrop. Mixing Layer :</u>
Hoor 2002, Pan 2006
Shapiro 1980, Wernli 2002)



Which method to study the TS mixing impact ?

Accurate in-situ measurements (WB-57 aircraft) in the UT/LS :

- Campaigns : Pre-AVE and Costa Rica-AVE
- 12 tropical flights (latitude < 10°)
- 2 subtropical flights (latitude > 30° N)

Lagrangian analyse with back trajectories representing mixing effects :

- ECMWF wind fields + Diffusion
- Dynamical tropopause definition (PV and θ)

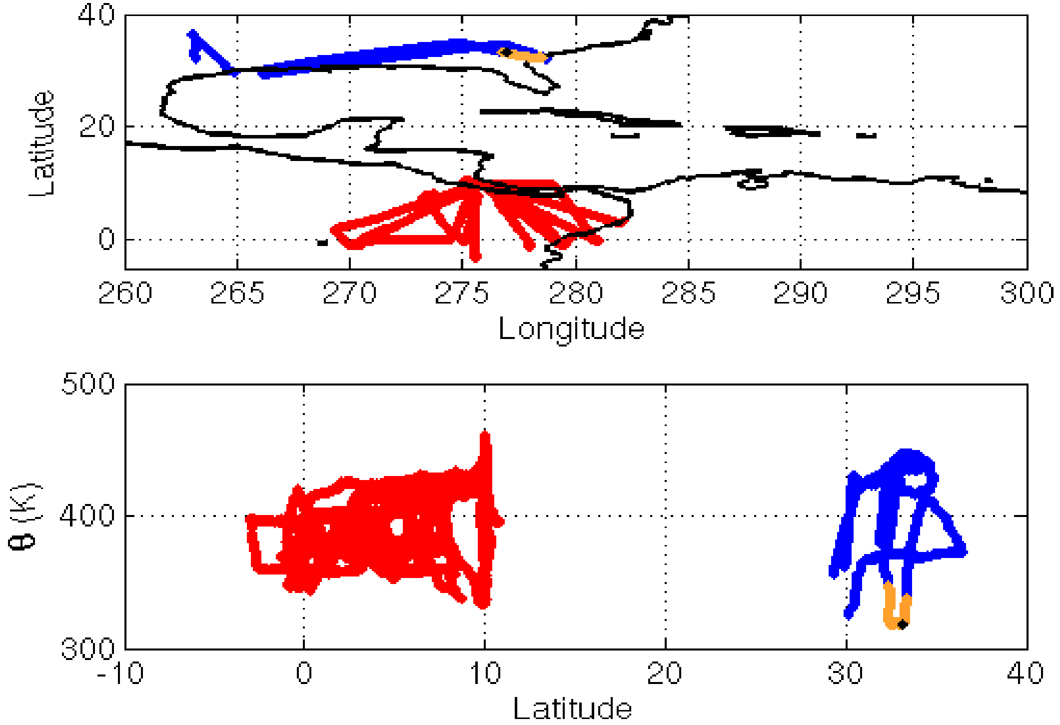
Aims of the study :

- Test mixing hypothesis
- Provide time scales
- Identify pathways

2. Data and Methods

2.1 In-situ measuremts: Pre-AVE and CR-AVE campaigns

Species : O_3, CO and CO_2
Instuments : UV-NOAA, ALIAS, ARGUS
Resolutions : 1-2 sec/250m/10m

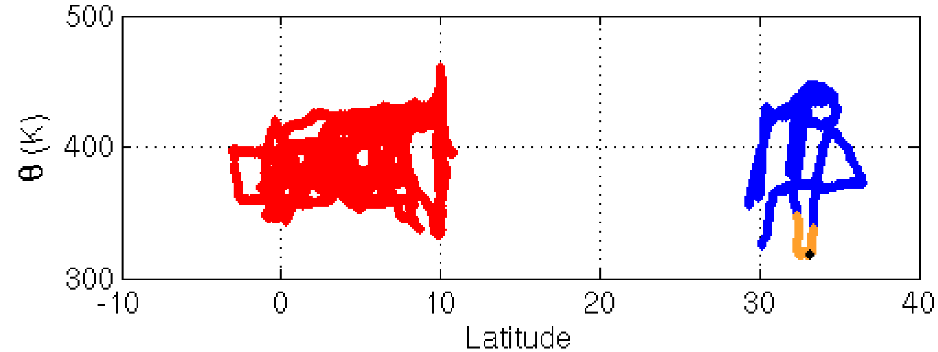


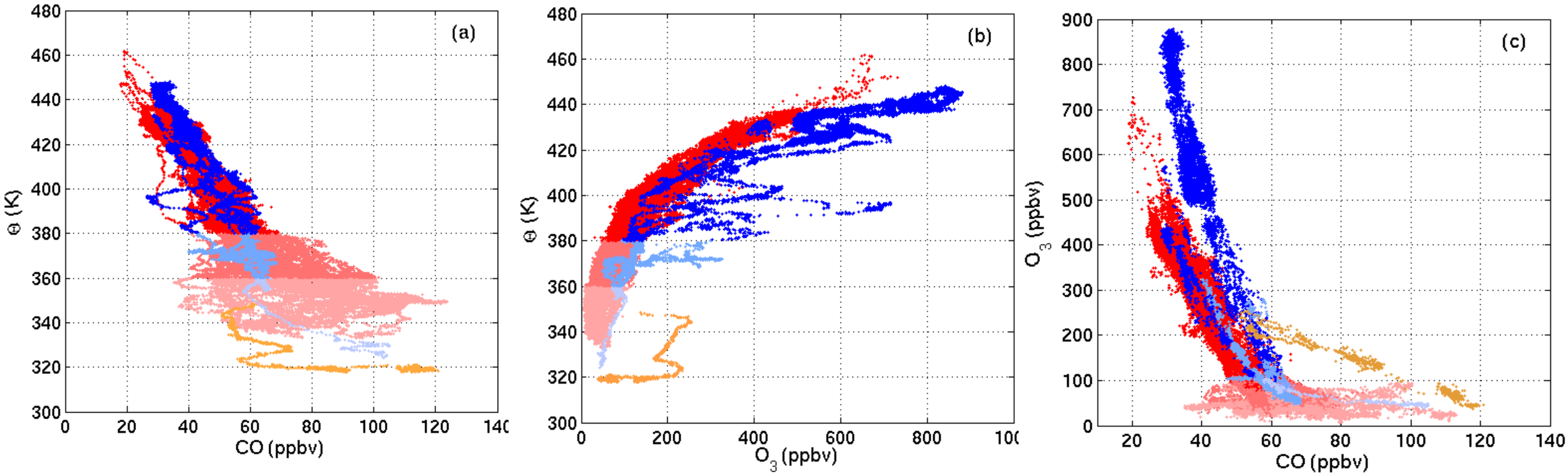
Analysed flights :

1. 19 jan 2004
2. 27 jan 2004
3. 29 jan 2004
4. 30 jan 2004
5. 19 jan 2006
6. 21 jan 2006
7. 22 jan 2006
8. 25 jan 2006
9. 27 jan 2006
10. 30 jan 2006
11. 2 fev 2006
12. 6 fev 2006
13. 7 fev 2006
14. 9 fev 2006

2. Data and Methods

2.2 Vertical profils and CO/O3 relations

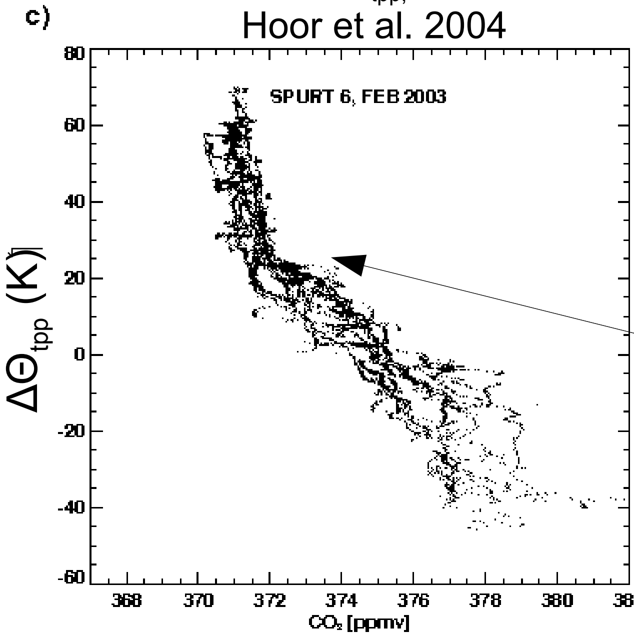




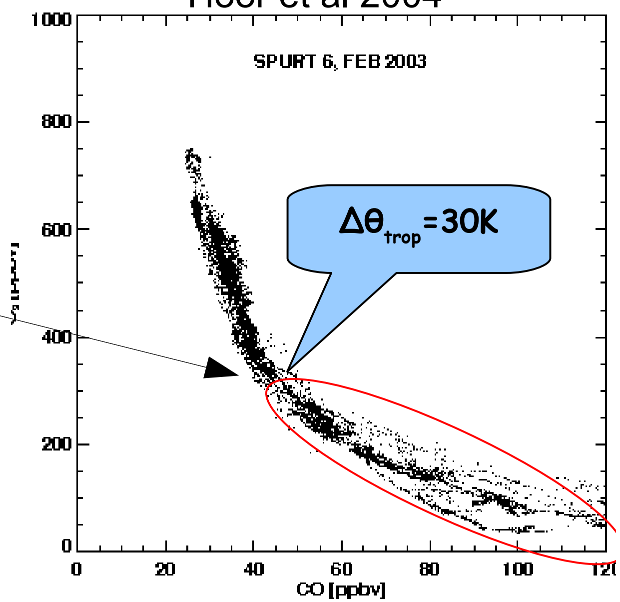
2. Data and Methods

2.2 Profils verticaux et relations CO/O3 : Mixing interpretation

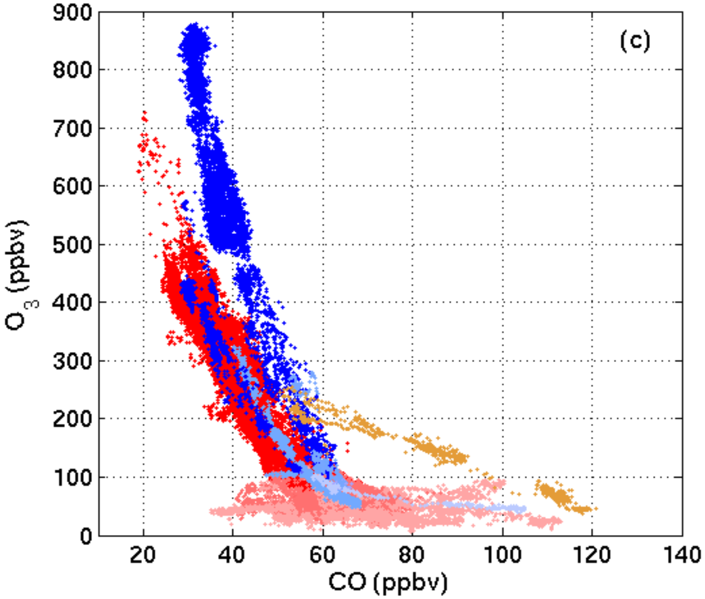
CO2 profils $\Delta\theta_{tpp,}$(SPURT)
Hoor et al. 2004



CO/O3 (SPURT)
Hoor et al 2004



CO/O3 (Pre et CRAVE)
James et al 2009



Tracer-Tracer correlations in the ELS :

. Vicinity of the tropopause : local TS mixing local generate mixing lines

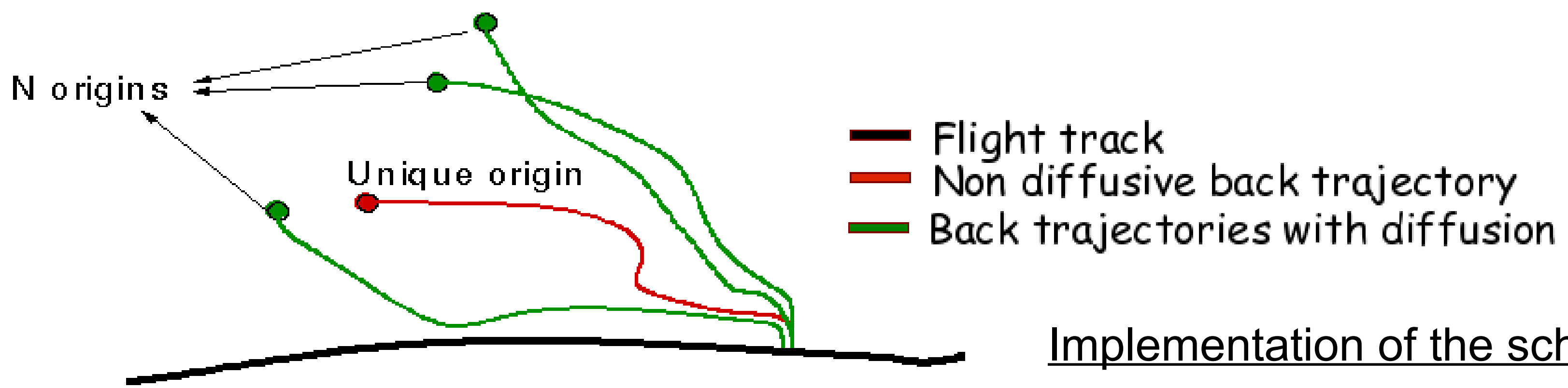
. 30K above the tropopause : CO2 profils et CO/03 relationships

suggest the existence of distincts mecanisms.

2. Data and Methods

2.3 Origines of air mass parcels and back-trajectory ensembles

Shematic of diffusive back-trajectories principle



Implementation of the scheme :

$$\Delta\mathbf{x}=\mathbf{v}(\mathbf{x},t).\Delta t + \mathbf{k}.\eta(t).$$

ECMWF + Diffusion

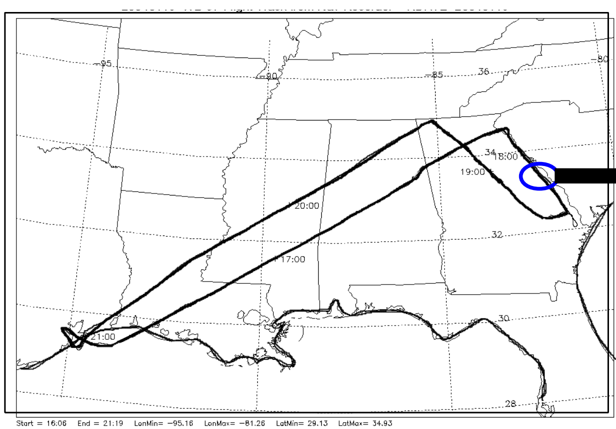
▪Each measured parcel = One particles ensemble

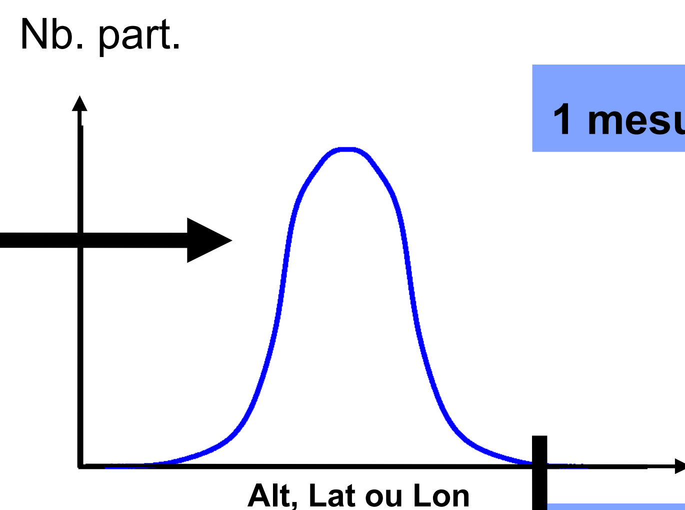
(Legras et al., ACP, 2005)

2. Méthodes et données

2.4 Back trajectories : diffusion and mixing processes

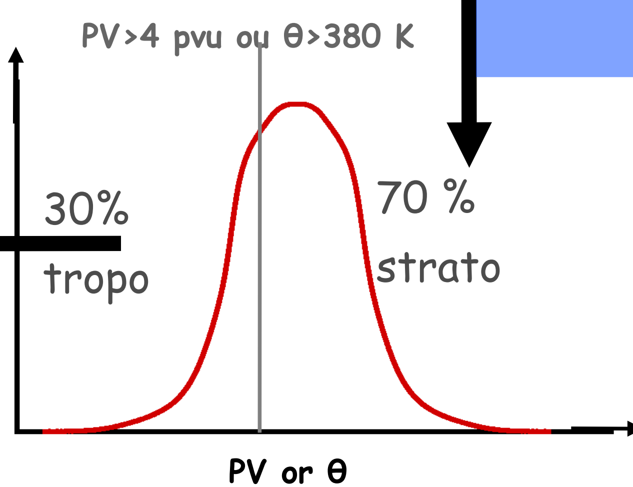
Spectrum of origines





1 mesure = 1 origines specta

1 spectra = 1 tropospheric part
+ 1 stratospheric part

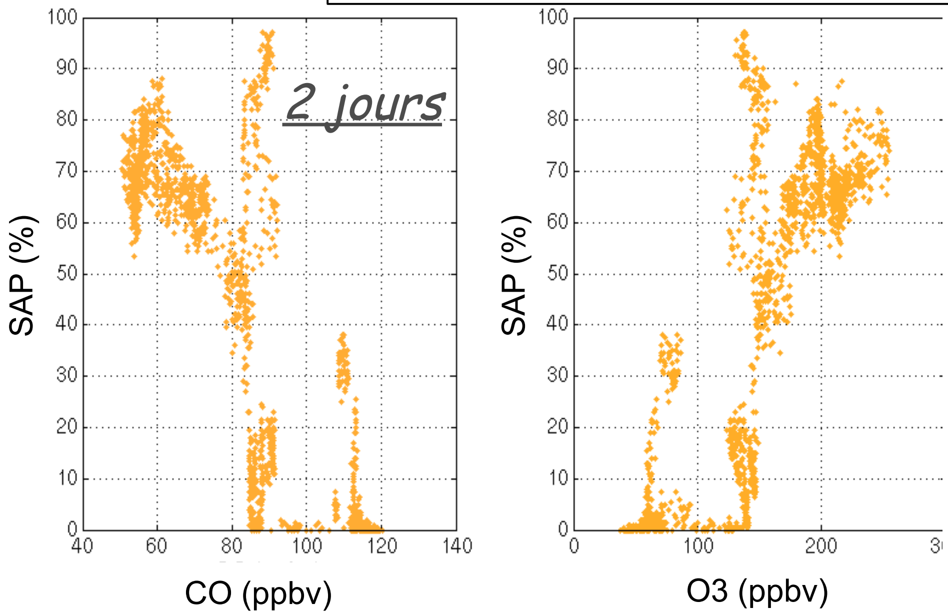


Stratospheric Air Proportion (SAP)

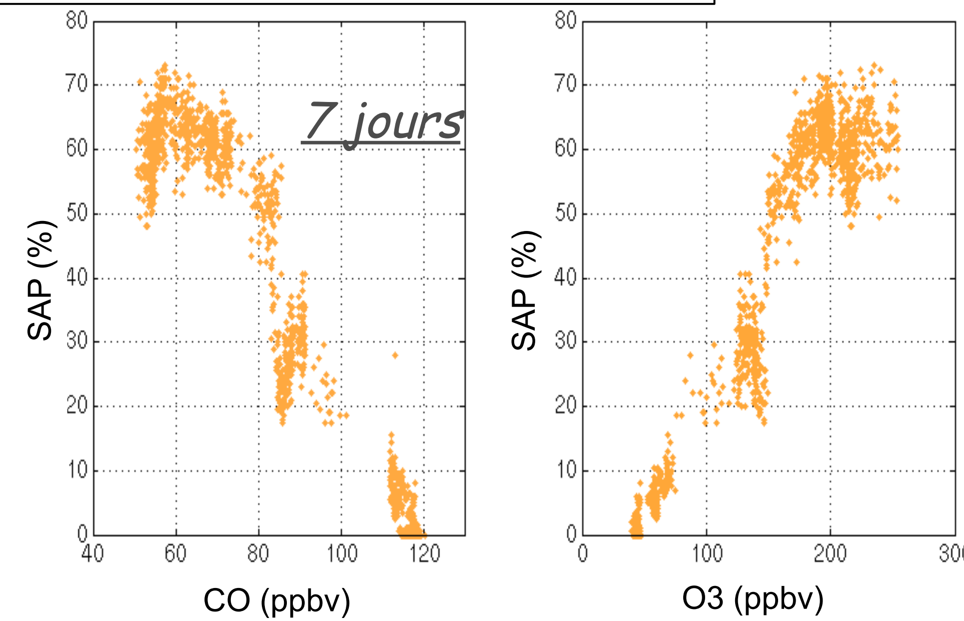
3. Mixing in the ELS

3.1 Validation of mixing lines

Comparison between in-situ mesurements and calculated SAP



Non coherent relations



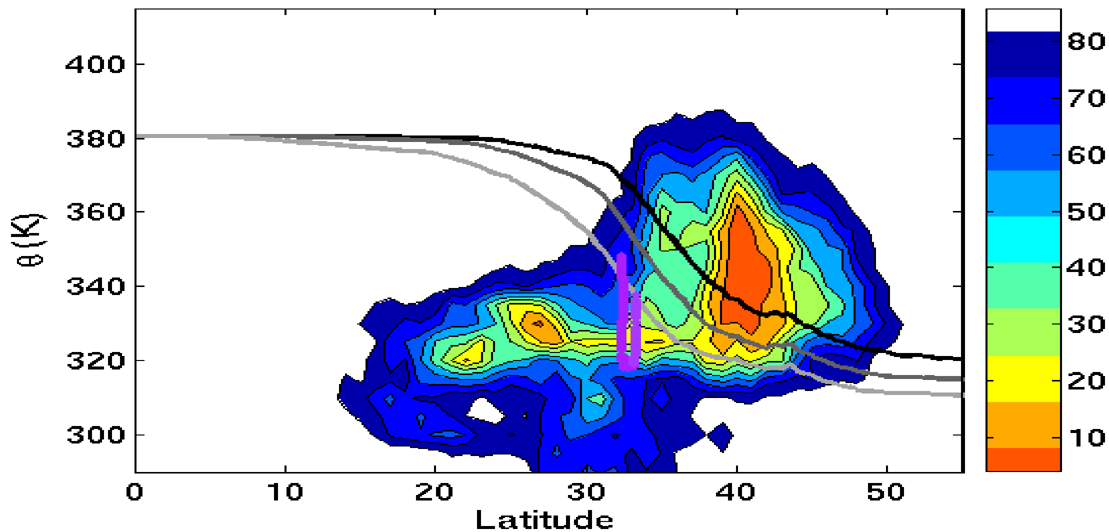
Quasi-linear relations

Over a period of a week, the mixing between tropospheric and stratosheric air determines tracers values.

3. Mixing in the ELS

3.2 TS exchanges : Involved processes

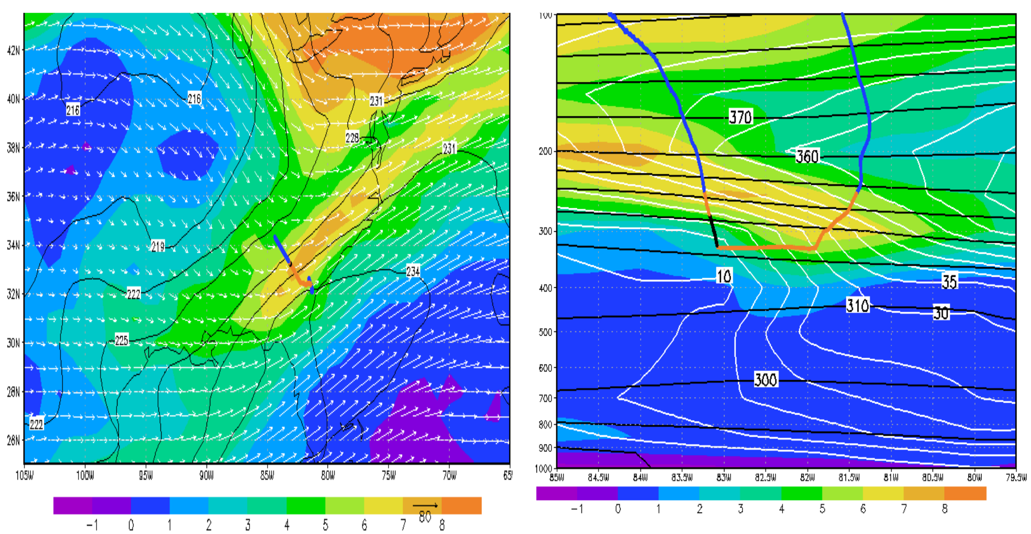
Parcels distribution after 1week (PDF)



=>Tropospheric and stratospheric ensembles are clairly separateds (D=Rossby radius).

=> Results from mixing of air masses of distinct origins and compositions.

Meteorological conditions along the flight (PV maps)

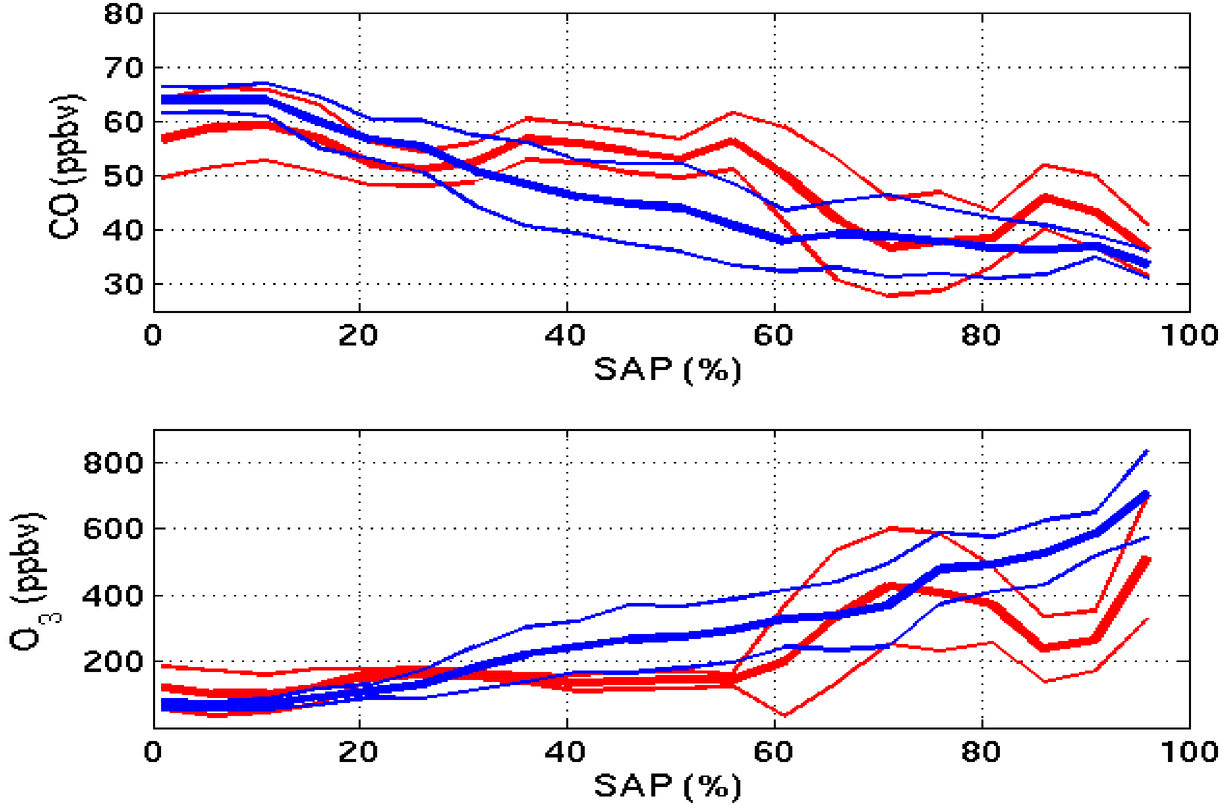


=> Identification of the baroclinic perturbation.

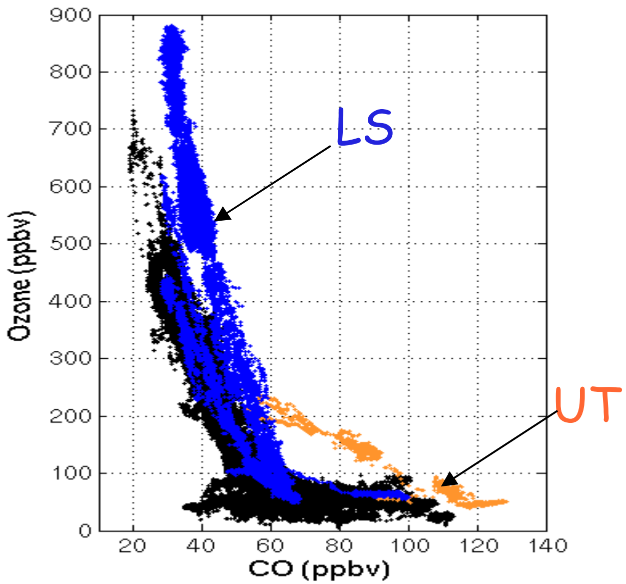
1. The baroclinic perturbations allow TS exchanges across the jet.
2. Small scale turbulence leads to irreversible exchanges

3. Mixing in the ELS

3.4 Validation of the mixing hypothesis



Rouge= 1 week
Bleue = 1 month



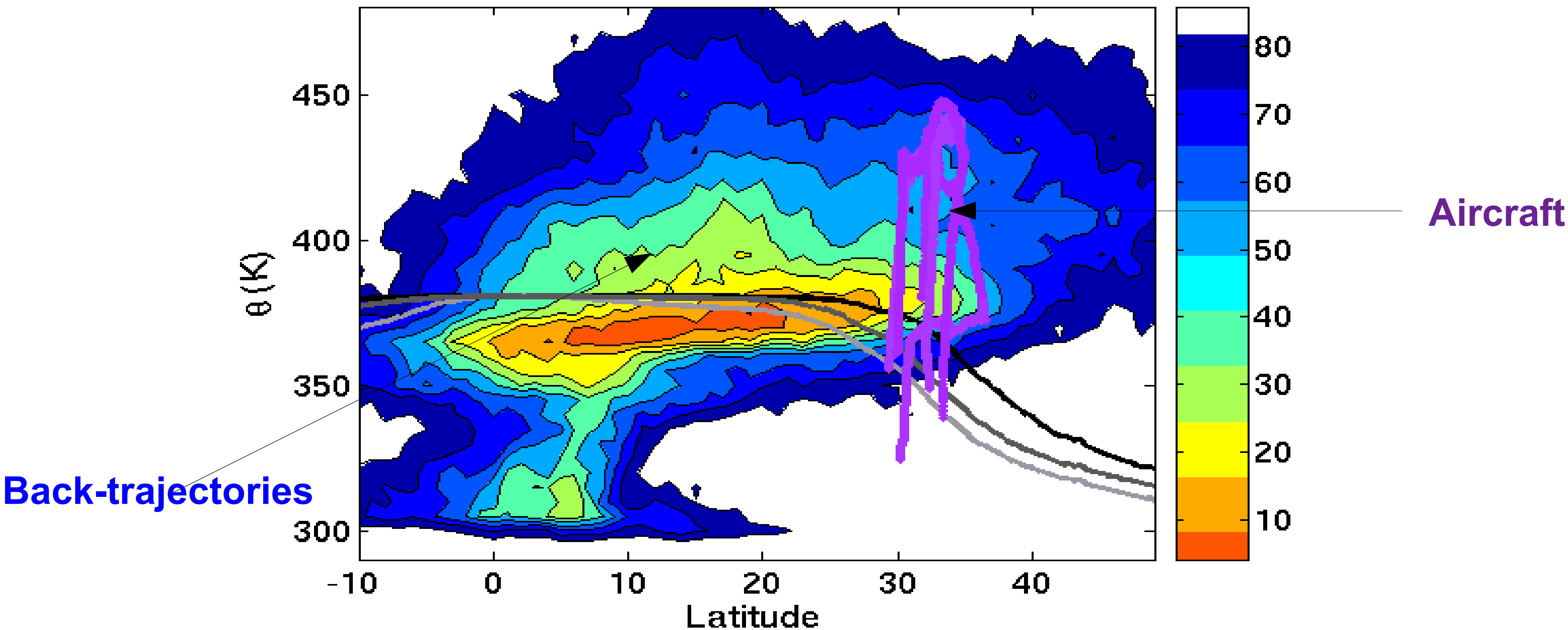
After 1 month, the parcels retrieve a quasi-linear relations.

Above 350 K, TS mixing acts on the time scale of 1 month to determine the tracers concentrations;

3. Mixing in the ELS

3.4 Validation of the mixing hypothesis

Sub-tropical particles distribution after 1 month



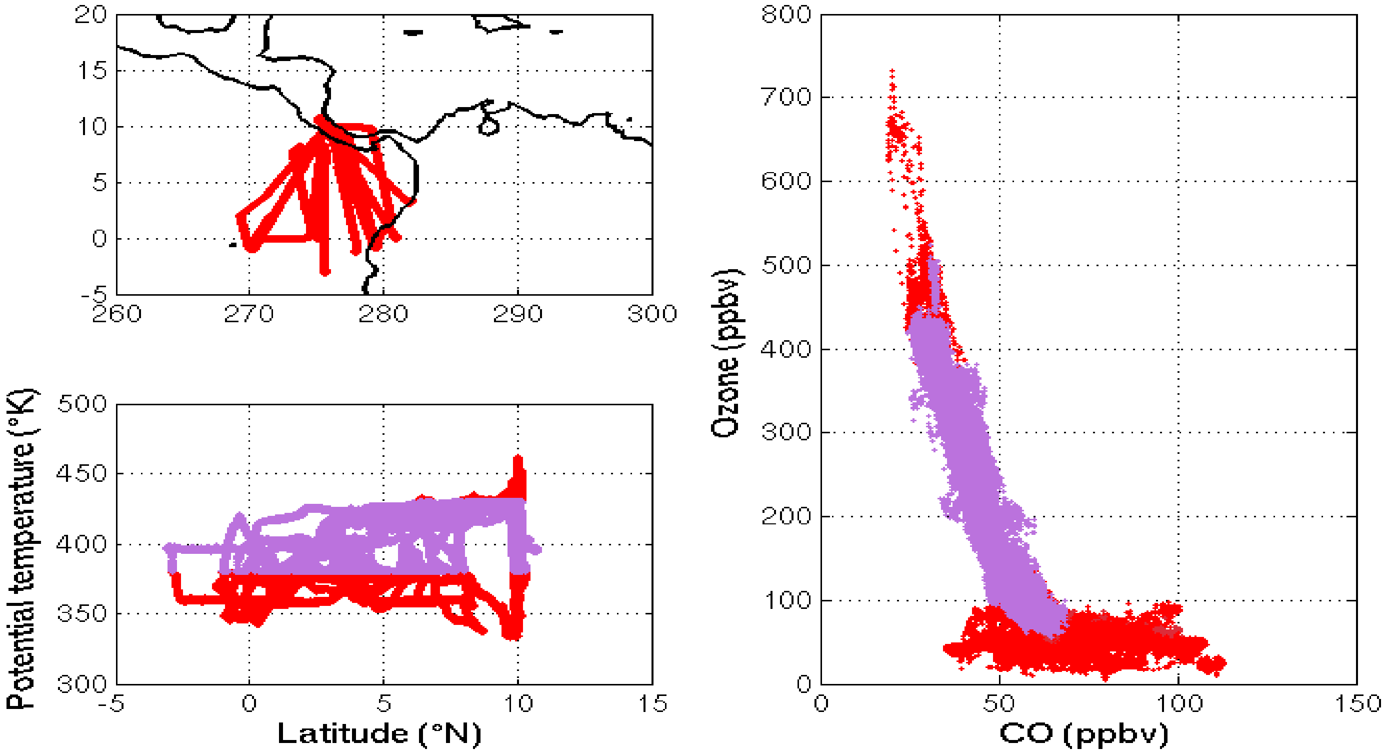
Tropospheric particules come from trhe tropics.

=> The importance of meridional exchanges from the TTL into the ELS

4. Mixing in the TTL

4.1 CO/O3 relations

12 tropical flights

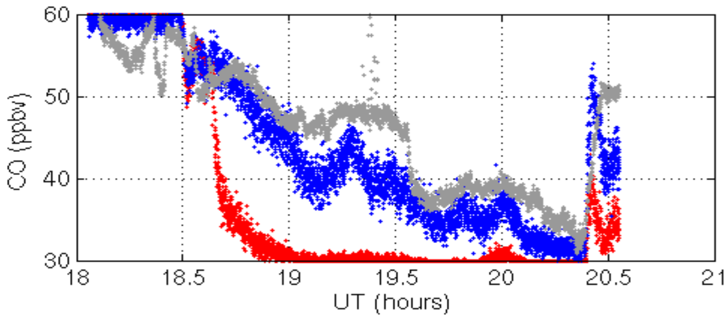


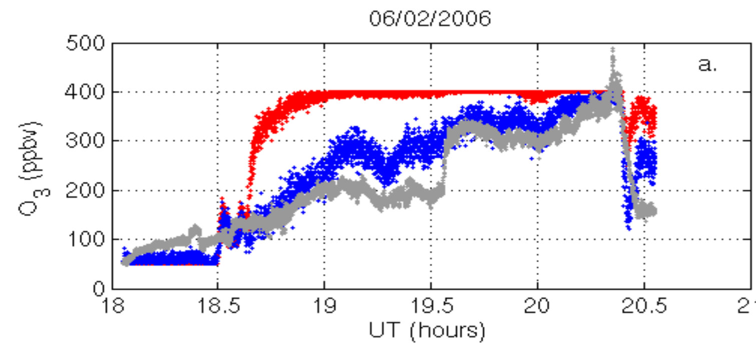
.Flights until 450 K
.Between 380 et 430 K : linear relation in CO/O3 space

4.2 Measured profils (grey) v.s. Reconstructions from SAP calculations

Rouge= 1 week
Bleue = 1 month

$$X_{(t)} = (1-SAP_{(t)})*X_{Trop} + SAP_{(t)}*X_{Strat}$$





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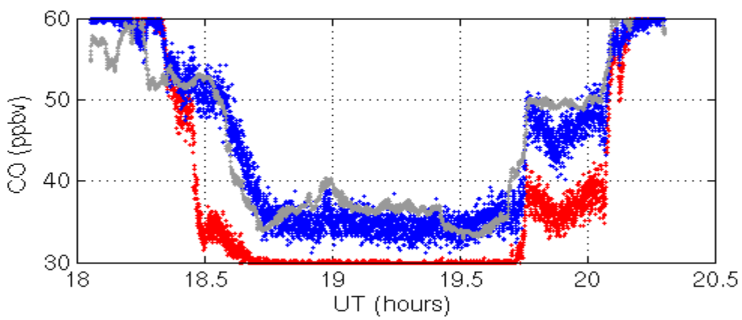

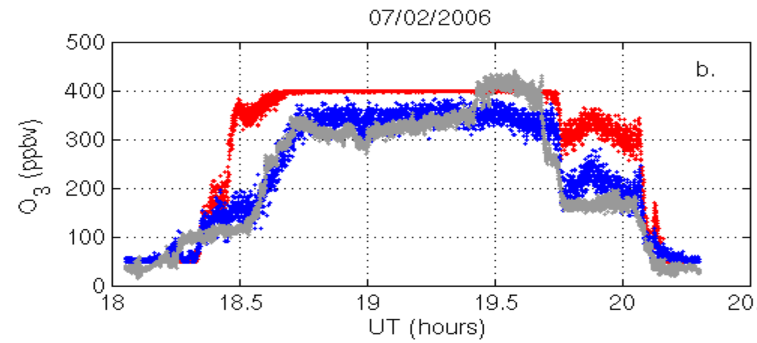

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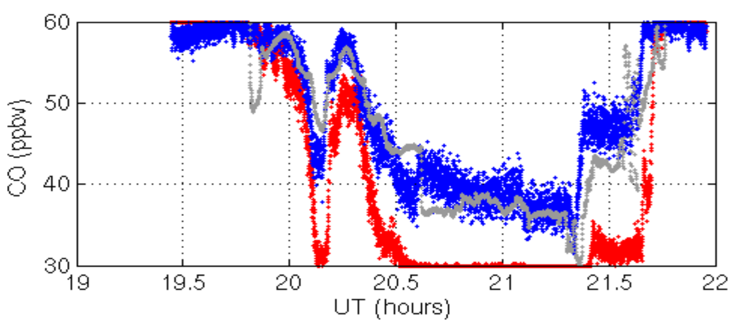

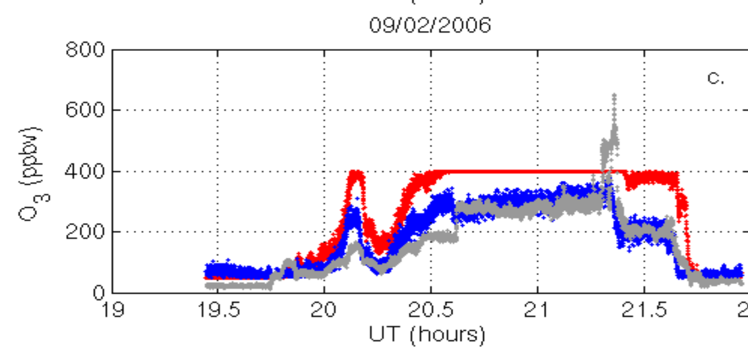

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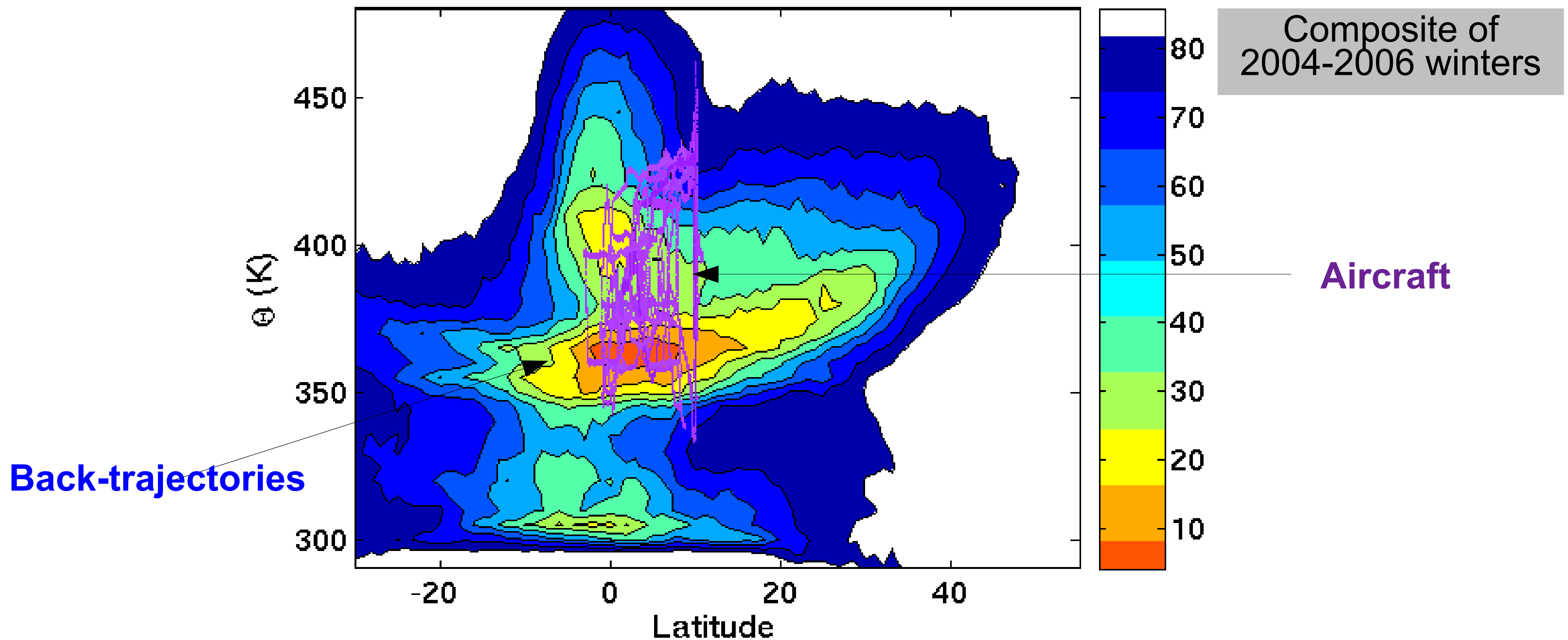
Over a period of a 1 month, TS mixing determine the vertival distribution of chemical tracers in the TTL

4. Mixing in the TTL

4.3. Entrainment and mixing in the TTL

Tropical parcels distribution after 5 weeks



Between 380 et 430 K, meridional exchanges are efficient in the Northern hemisphere. => Impact of Rossby waves

In the tropics, tropospheric air is progessively mixed in the TTL on the time scale > 1 month

V. Summary and conclusions

Diffusive back-trajectories allow to **quantify the impact** of mixing across the tropopause, and simultaneously **assess the origins** of air parcels measured during aircraft campaigns.

Our results :

1. Show that synoptic perturbations mix air from distant regions in latitude and chemical composition. The **bi-modality** of air masses origins demonstrate that those observations correspond to a well defined mixing line.

2. Validate the **tropical origin** of the tropospheric source in the ELS above a transition of 30 K (Hoor et al., 2005)

3. Identify the impact of the **two-way irreversible exchanges** between the TTL and the sub-tropical LS on irreversible mixing.