Mixing processes and exchanges across the tropical and subtropical tropopause layer

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Classify to reduce
The diversity of observations...
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Règne | Embranchements | Classes
--- | --- | ---
| Vers | Arachnides | Oiseaux
| Arthropodes | Crustacés | Mammifères
| Echinoderms | Insectes | ...
| Chordés | Poissons | Reptiles

Règne animal
1. Mixing in the UT/LS

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

Role of mixing in 3 regions

Trop. Meridional Exchanges:

Subtrop. Transport Barrier:
Hintza 1994
Chen 1995, Haynes 2000

Extratrop. Mixing Layer:
Hoor 2002, Pan 2006
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 measurements: Pre-AVE and CR-AVE campaigns

Species: $\text{O}_3$, CO and CO$_2$

Instruments: 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 profiles and CO/O3 relations
2. Data and Methods

2.2 Profils verticaux et relations CO/O3 : Mixing interpretation

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.

\[ \Delta \theta_{tpp} = \text{30K} \]
2. Data and Methods

2.3 Origins of air mass parcels and back-trajectory ensembles

Shematic of diffusive back-trajectories principle

- 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 spectra

1 spectra = 1 tropospheric part + 1 stratospheric part

Stratospheric Air Proportion (SAP)

30% tropo
70% strato
Over a period of a week, the mixing between tropospheric and stratospheric air determines tracers values.

3. Mixing in the ELS

3.1 Validation of mixing lines

Comparison between in-situ measurements and calculated SAP

Non coherent relations

Quasi-linear relations

Over a period of a week, the mixing between tropospheric and stratospheric air determines tracers values.
3. Mixing in the ELS

3.2 TS exchanges: Involved processes

Parcels distribution after 1 week (PDF)

=> Tropospheric and stratospheric ensembles are clearly separated (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

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

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 the 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 profiles (grey) v.s. Reconstructions from SAP calculations

Over a period of a 1 month, TS mixing determine the vertical distribution of chemical tracers in the TTL.
4. Mixing in the TTL

4.3. Entrainment and mixing in the TTL

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

In the tropics, tropospheric air is progressively 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.