Equatorial Transport from the Troposphere to the Stratosphere as diagnosed from N$_2$O Variability

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Scientific Issues

- Horizontal and vertical transports in the Tropical Tropopause Layer (TTL) based upon global-scale satellite observations

- The time evolution of long-lived and tropospheric-origin nitrous oxide ($N_2O$) in the equatorial troposphere, UTLS and stratosphere is examined by combining satellite measurements (ODIN and IASI) and 3D CTM results (MOCAGE and SLIMCAT).

- Particular attention is given in the Equatorial UTLS over different regions (Western Pacific vs. Africa) where Troposphere-to-Stratosphere Transport might be more intense e.g. over Africa during the March-May 2002-2004 season (Ricaud et al., ACP, 2007).

- Seasonal variations are now considered in the present study.
  - 400, 450, 500, 550 K (ODIN) and Troposphere (IASI)
  - 10°S-10°N
  - Western Pacific (120°E-210°E) and Africa (30°W-60°E)
  - Ricaud et al., ACPD, 2009 and ACP, 2009.
Data Sets

- **N$_2$O Measurements**
  - Limb-viewing microwave SMR instrument on the ODIN platform
    - 2001-2005 in V222 (ETHER data base)
    - 100-1 hPa
  - Nadir-viewing IR IASI instrument on MetOp-A
    - Tropospheric column from EUMETSAT in MAM 2008

- **3D off-line CTMs**
  - SLIMCAT
    - Univ. Leeds, UK
    - 7.5°x7.5°, 24 levels from the surface to about 60 km
    - Detailed stratospheric chemistry
    - Vertical advection from diabatic heating rates
    - ECMWF : 1977-2001 (ERA 40) and after (operational analysis)
  - MOCAGE
    - Météo-France, Toulouse, France
    - 2000-2005
    - 5.6°x5.6°; 60 layers from the surface to about 0.07 hPa
    - Detailed tropospheric and stratospheric chemistry
    - Vertical velocities calculated from the ECMWF forcing analyses
**MAM season**

- At 400 K, all measured gases ($\text{N}_2\text{O}$, $\text{CH}_4$ and $\text{CO}$) show significant longitudinal variations, not captured by the model (Ricaud et al., ACP, 2007).

- The maximum amounts are primarily located over Africa in MAM 2002-2004.

- The suggestion is of strong overshooting over land convective regions, particularly Africa, very consistent with the TRMM maximum overshooting features over the same region during the same season.

Overshooting Probability Function (*Liu and Zipfser, JGR, 2005*)
AO, SAO and QBO

Model underestimation of the AO in the UTLS

Non-negligible measured SAO at 100 hPa
Variations of N$_2$O vs. Vertical Winds

N$_2$O variation correlated with $\Omega$ and $W_Q$ in the LS but 1-2 month shift

Upwelling $W_Q$

Vertical winds $\Omega$
Longitudinal gradients in N$_2$O vanishes above 500 K whatever the month considered.

At and below 500 K, a maximum in N$_2$O is observed over Africa peaking in:
- May-July at 400 K
- May at 450 and 500 K

(Max in May)

(Ricaud et al., ACPD, 2009)
Contribution of overshootings above 14 km (Liu and Zipser, JGR, 2005.)

Adapted from Liu and Zipser (2005)

Maximum in March-May
Variations of $\text{N}_2\text{O}$ vs. Zonal Winds

Minimum of horizontal mixing in May-June in the LS
Tropospheric distribution of $\text{N}_2\text{O}$ from MOCAGE @ 340 K (~11 km)

- Maximum of $\text{N}_2\text{O}$ over Africa whatever the season considered whilst emissions are the strongest over South America.
Vertically distribution of $N_2O$ from MOCAGE (0-20 km)

- Due to the Walker (longitudinal) and Hadley (latitudinal) cells, Africa appears to be a Convergence Zone all over the year with maxima of $N_2O$ in the middle troposphere.

- What about actual measurements of tropospheric $N_2O$ along the equatorial band?
  - Check with IASI data.
N$_2$O Column:

- OLR MAM 2002–2004: 10S–10N (W m$^{-2}$)
  - South America
  - Africa
  - Indonesia
  - Western Pacific

MOCAGE N$_2$O Emissions: 10S–10N (x 10$^{-12}$ mole s$^{-1}$)

(Ricaud et al., ACP, 2009)
A Stratospheric “Drain” over the Maritime Continent

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Conclusions

- The equatorial $\text{N}_2\text{O}$ variations measured above 32 hPa are generally well captured by the 3D CTMs (AO, SAO and QBO).
- In the UTLS, the observed variations are shown to be mainly seasonal with peak amplitude at 400-450 K (~17.5-19 km), but totally missed by the models.
- The minimum $\text{N}_2\text{O}$ in June is out of phase by 1-2 months with the known minimum seasonal upwelling and amplified over the Western Pacific compared to Africa.
- In the troposphere, models and measurements show important effects of the Walker and the Hadley cells on the distribution of $\text{N}_2\text{O}$ by producing a local maximum above the African continent.
- The observed $\text{N}_2\text{O}$ annual cycle in the lower stratosphere might also be amplified by the existence of a downward time-averaged mass flux (stratospheric drain) above specific regions e.g. over Indonesia (Sherwood, 2000).
- The coincidence of the WP-AF contrast with the maximum overshooting volume in May measured by TRMM suggests a strong influence of deep convection on the chemical composition of the tropical LS up to 500 K (~21 km).