Evaluation of the LMDz-INCA chemistry-climate model in the extratropical tropopause region

F. Jégou (1) , I. Pisso (2), K. Law (1) , S. Bekki (1), I. Bouarar (1), D. Hauglustaine (3), S. Szopa (4), A. Cozic (4), F. Lott (5), F. Lefèvre (1), M. Marchand (1), P. Hoor (5), the AMMA science team, the SCOUT-O3 science team

(1) Service d'Aéronomie, Université Paris VI, Tour 45, boite postal 102, 4 place Jussieu 75252 Paris, France, (2) DAMTP, Centre for Mathematical Sciences, University of Cambridge, Wilberforce Road, Cambridge, U.K., (3) Eur o pean Science Foundation, 1 quai Lezay-Marnésia, BP 90015, 67080 Strasbourg, France, (4) LSCE, 91191, Gif sur Yvette, France (5) LMD, Université Paris VI, Tour 45, boite postal 99, 4 place Jussieu 75252 Paris, [...] Germany

LMDz-INCA

LMDz-INCA is a coupled Climate-Chemistry Model developed to study the interactions between dynamical, physical and chemical processes in the troposphere and stratosphere and in particular the upper troposphere and lower stratosphere. The stratospheric version uses 50 vertical levels from the surface to 76 km and a horizontal resolution of 2.5° in latitude and 3.75° in longitude. 63 chemical species are treated with this model.

REF2 CCM-val nudged simulation

Our reference simulation was to reproduce the 1980-2006 period (REF2 CCM-Val simulation). This simulation is designed to reproduce the well-observed period of the last 25 years during which ozone depletion is well recorded, and allows for a more detailed investigation of the role of natural variability and other atmospheric changes important for ozone balance and trends. This transient simulation includes all anthropogenic and certain natural forcings based on changes in trace gases, and sea surface temperatures (SSTs). SSTs and emissions in this run are based on the HadISST1 and RETRO databases respectively. ECMWF climatology is used to nudge the winds and the temperature.

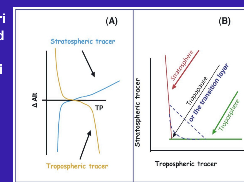
Diagnostic of the transport in the extratropical tropopause region

In this study, we evaluate LMDz-INCA by making comparisons with in situ observations of ozone, carbon monoxide, water vapour and N_2O profiles obtained, during 6 campaigns: POLARIS (1997), STRAT (1995-1997), SPURT (2001-2003), Crystal-Face (2002), SCOUT-O3 (2005) and AMMA (2006). Three related diagnostics are used to evaluate the chemical transport processess in the extratropical upper troposphere and lower stratopsphere (UTLS). The first diagnostic compares the observed and modeled UTLS trace gas profiles in a relative altitude coordinate. The second one compares the observed and modeled UTLS tracer relationships. The third one compares observed and modeled thickness of the tropopause transition layer. These diagnostics were defined and used by L.L. Pan et al. (2004, 2007) to evaluate the extratropical tropopause region. Model data were selected in a ±5° lat-lon box around the coordinates and days observed to match the campaigns.

Schematic illustrating the concept of identifying the tropopause location using tracer relationship

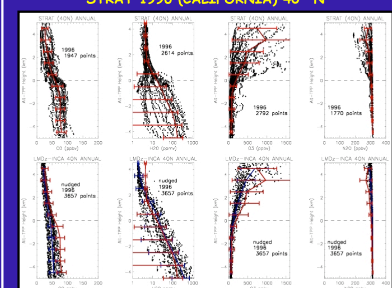
(A) stratospheric tracer and a tropospheric tracer in altitude space

(B) and their relations in tracer-tracer space

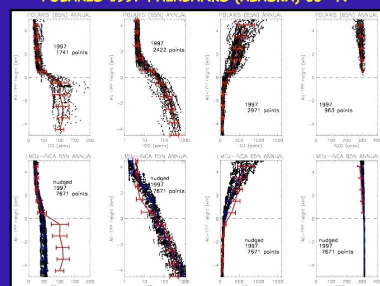


Profile comparisons using relative altitude coordinates

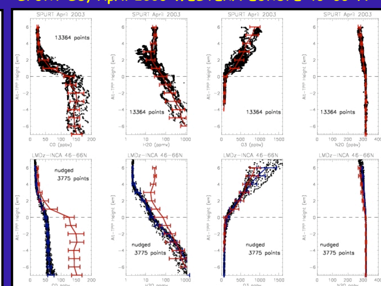
STRAT 1996 (CALIFORNIA) 40 °N



POLARIS 1997 FAIRBANKS (ALASKA) 65 °N



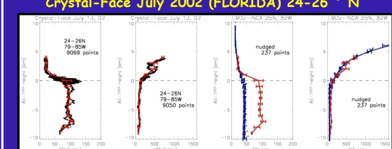
SPURT S8, April 2003 WESTERN EUROPE 46-66°N



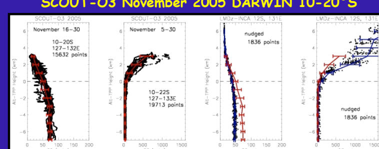
Top figures: CO, H_2O, O_3, N_2O profiles from POLARIS, STRAT and SPURT campaigns in relative altitude coordinates. The solid lines are the mean and standard deviation for each 2 km.

Bottom figures: CO, H_2O, O_3, N2O profiles from REF2 LMDz-INCA simulations in relative altitude coordinates. The red and blue solid lines are the mean and standard deviation for each 2 km, for measurements and simulations data, respectively.

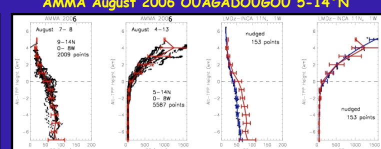
Crystal-Face July 2002 (FLORIDA) 24-26 ° N



SCOUT-O3 November 2005 DARWIN 10-20°S



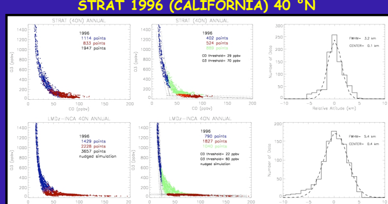
AMMA August 2006 OUAGADOUGOU 5-14°N



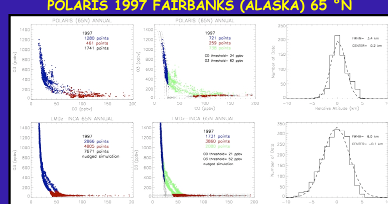
Left figures: same figures for CO, O3 profiles from Crystal-Face, SCOUT-O3, and AMMA campaigns in relative altitude coordinates. **Right figures**: same figures for CO, O3 profiles from REF2 LMDz-INCA simulations in relative altitude coordinates.

Tracer-Tracer correlations

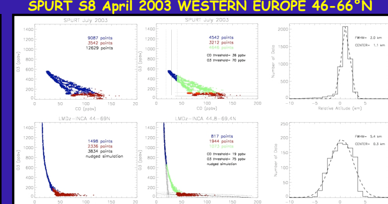
STRAT 1996 (CALIFORNIA) 40 °N



POLARIS 1997 FAIRBANKS (ALASKA) 65 °N



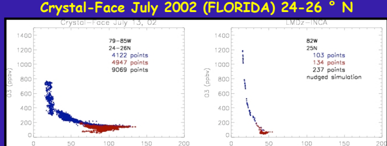
SPURT S8 April 2003 WESTERN EUROPE 46-66°N



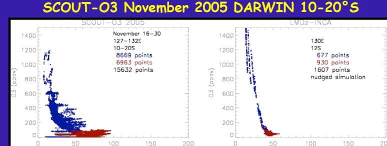
Tracer-Tracer correlations (Top left figures and 6 figures below) : comparisons of O3 –CO relationship between observations and the results of the LMDz-INCA model nudged simulation, blue (red) points are above (below) the thermal tropopause.

Sharpness of the chemical transition (Top right and middle figures) : the solid and dotted lines are fit to the stratospheric and tropospheric points, respectively, and the range of 3 sigma standard deviations. The selection criteria for the points in the fit are calculating for each comparisons. The CO and O3 thresholds correspond of the average values in the region 3 km away from the thermal tropopause. Blue and red points are identified as stratospheric and tropospheric, respectively (within 3s from the fit). The green points are identified as transitional points, produced primarily by mixing of stratospheric and tropospheric air. Light red and light blue points are data within a strato(tropo) branch but identified as tropo(strato) points. Histograms show the distributions of the green points in relative altitude space, providing a quantitative measure of the sharpness of the chemical transition across the tropopause.

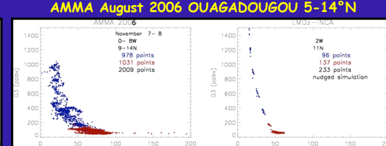
Crystal-Face July 2002 (FLORIDA) 24-26 ° N



SCOUT-O3 November 2005 DARWIN 10-20°S



AMMA August 2006 OUAGADOUGOU 5-14°N



Discussion and perspectives

The model tropospheric CO profiles show a low bias, in the Crystal-Face, POLARIS, and SPURT comparisons but not in the START, SCOUT and AMMA comparisons. This could be due to lack of deep convection in the model or an underestimation of forest fire emissions. The omission of NMHC (which are significant sources for tropospheric CO) is another bias in the simulation. The H_2O profiles show a systematically low bias at all latitudes possibly due to a lack of deep convection in the model. The O_3 and N_2O distributions are well representing in the model. Modelled correlations are generally consistent with the observations. The histograms show that the distribution of the transitional points from the LMDz-INCA model are centred near the thermal tropopause. The modelled transition layer, is much broader, reflecting a limitation of the model's ability to simulate sharp changes in tracer gradients across the tropopause. Difference factors could contribute to the broader transitions layer by the models: the vertical resolution used to represent the tropopause region or the wind field. We plan to make specific study with different idealized tracer simulations to investigate the troposphere-stratosphere exchange.

Reference

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