Modelling of transport processes in the tropical upper troposphere and lowermost stratosphere.

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Introduction

As part of the EU-funded SCOUT-O3 (Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere) project, a model inter-comparison is being carried out, with the aim of assessing current shortcomings, and quantifying differences, in the representation of tropical tracer transport. The inter-comparison includes global offline chemistry-transport models, mesoscale models as well as coupled climate-chemistry models. Using idealised tracers with a range of lifetimes (2 hours – 20 days), the effects of processes such as boundary layer mixing, convective transport, advective transport, and wet deposition on tracer distributions are being compared.

Two rounds of model experiments have been carried out. Here, some preliminary results are presented.

Table 1. Information on the models which are participating in the inter-comparions. Models with a * are also participating in the second round of tracer experiments.

Name	Approx.resolution	Chem/advect. Δt	Met.Data/Forcing
Oslo CTM2*	2.8x2.8/40L	1 hour,900s (trop.)	ECMWF IFS
FRSGC/UCI CTM	2.8x2.8/37L	1 hour	ECMWF IFS
P-TOMCAT	2.8x2.8/31L	1800s,900s	ECMWF operational.
TOMCAT*	2.8x2.8/31L	1800s,900s	ECMWF operational
UMSLIMCAT	3.75x2.5/64L	1800s	
KASIMA	5.6x5.6/750m	900s	ECMWF operational
UM_CAM	3.75x2.5/19L	900s	2005 STT & ice
UKCA	3.75x2.5/38L		94/95 STT & ice
MOCAGE-climat	2.8x2.8/60L	1hour,900s	ECMWF operational
MOCAGE	2x2/47L	1hour,900s	Arpege
UMCAMUKCA*	3.75x2.5/60L	1200s	ECMWF op. (nudged)

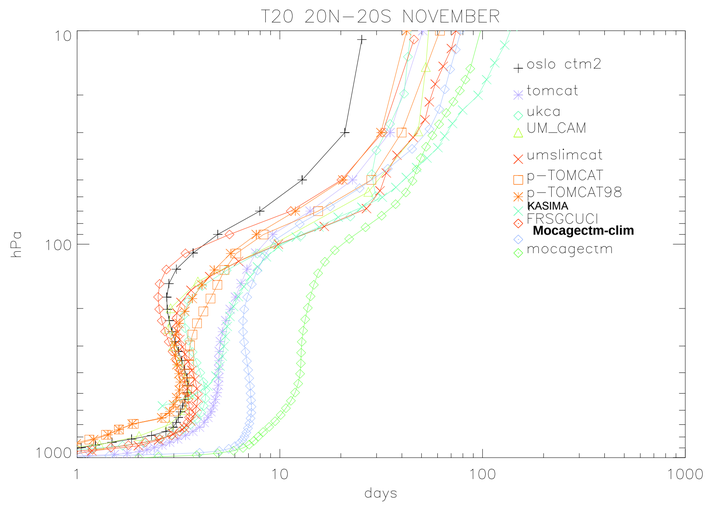
Tracers used in the second round of model experiments

	Tracer	Initial condition	Tracer source	Mean lifetime
1	T5	0	1pptv at the surface	5 days
2	T20	0	1pptv at the surface	20 days
3	idealised CO	0	mixing ratios prescribed at the surface to 700hPa	decay rate is function of pressure (1-3 months)
4	idealised ethane	0	mixing ratios prescribed at the surface to 700hPa	decay rate (2-3 months)
5	T20 wet removal	0	1pptv at the surface	20 days
6	T5 BL	0	1pptv from surface to 4km	5days
7	idealised H_2O	0	mixing ratios prescribed in the lower-mid trop.	
8	idealised O_3	O_3 climatology for initial month of the run	mixing ratio relaxed to O_3 climatology	Depends on altitude, see notes
9	T2	0	1ppbm Z<500m	2 days
10	T6H	0	1ppbm Z<500m	6 hours
11	Stratospheric	1ppbm Z>18km, in the region 20N-20S	mixing ratio reset to initial condition monthly	infinite

Notes on ozone tracer:

In order to constrain this ozone tracer it shall be relaxed to the relevant monthly mean, zonal mean ozone climatology with an e-folding time of:
2 days for 0<H<4km
20 days for 4<H<12km
360 days for H>12km
In this way we constrain the ozone mixing ratio a lot in the boundary layer, less so in the free troposphere and very little in the UTLS region. Therefore we allow for the effect of convective transport and strat-trop exchange to drive the ozone vertical distributions in the UTLS.

Variation in transport times between models

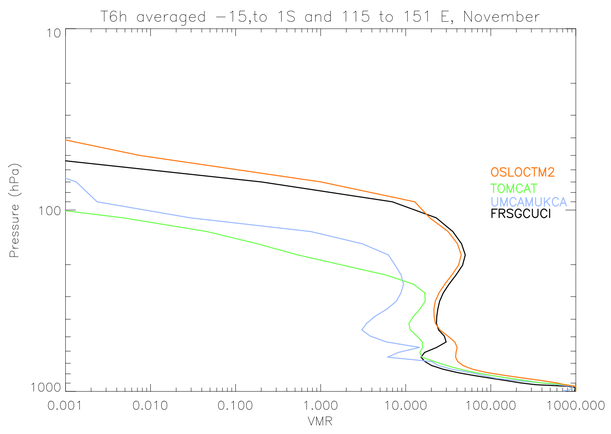


By using a tracer with a constant mixing ratio at the surface, and fixed lifetime (in this case 20 days), it is possible to calculate the mean transport time from the surface to a particular point in the model atmosphere.

This figure shows the mean transport time from the surface, as a function of altitude, averaged over 20S-20N, for November 2005. Especially around the tropical tropopause, there is a very large variation in the transport times between the different models, which will influence the concentrations of short lived species that each model predicts in the TTL.

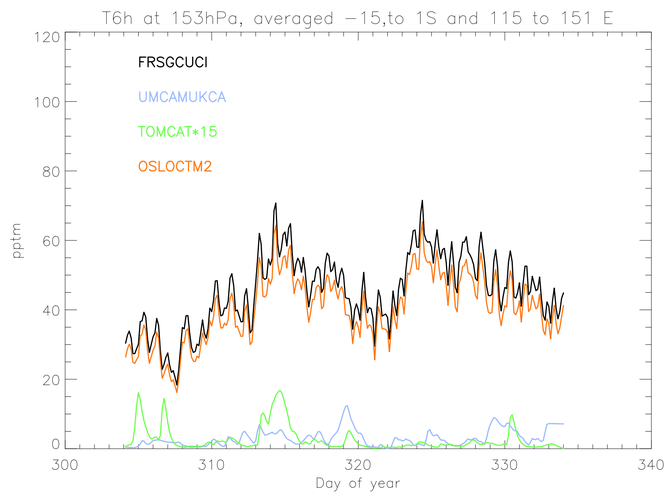
P-Tomcat was run for 2005, as were the other models, however an additional run was performed, where meteorological data for 1998 was used (p-TOMCAT98). The main differences between these two runs are in the mid to upper troposphere and the stratosphere.

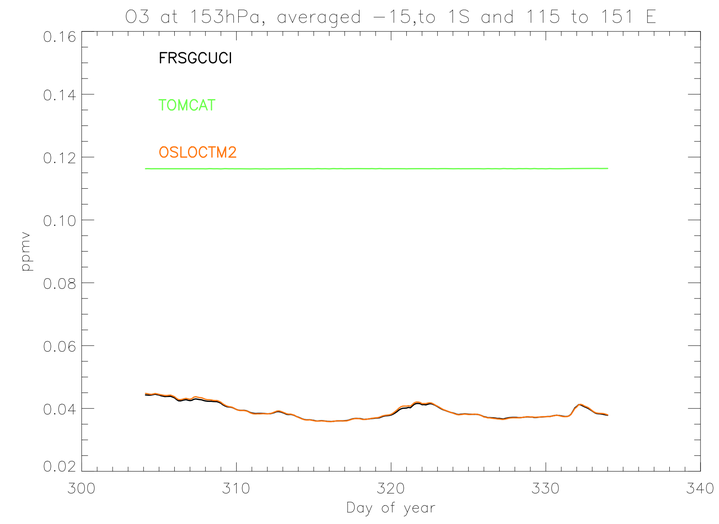
A very short lived convection tracer, and idealised O_3



To enable later comparison with mesoscale models, in the second round of experiments, a tracer with a 6 hour lifetime was included. Again, the mixing ratio was fixed at the surface. Here, differences between the models in the height of convective outflow are clearly visible. The 3 hourly output data was averaged for November 2005, from 15S to 1S and from 115E to 151E to construct these profiles.

Another factor that was investigated was the timing of the convective events. The plot on the right shows a time series of mixing ratios of the T6H tracer, at an altitude of 153 hPa, averaged over 15S to 1S and 115E to 151E. The timeseries for TOMCAT was increased by a factor of 15 to improve visibility, due to the lower concentrations at this altitude in the model (see plot above). The OsloCTM2 and FRSGCUCI models, which are very similar, and use identical circulation, show a well correlated transport influence on tracer concentrations. Although TOMCAT and UMCAMUKCA also use ECMWF data to drive the model (for the UMCAMUKCA as a nudging data set), the timing of the rapid transport events from the surface to 153hPa only coincide with that of the other models in a few places.





The idealised ozone tracer can be used to track stratospheric air. The plot on the left is analogous to the one above, and shows the mixing ratios of the ozone tracer. Corresponding to the dip in T6h concentrations around day 315-323, one sees a slight increase in the amount of ozone tracer at 153hPa, indicating downward mixing of air, in the OsloCTM2 and FRSGCUCI models. Lower concentrations in the T6H tracer correspond with higher ozone concentrations earlier in the time series.

Discussion

The comparison of tracer profiles and time series between several different models shows that even when the meteorological data is similar, there can be significant differences between the modelled concentrations of short lived tracers. This leads to significant differences in the concentration of short lived compounds in the tropical upper troposphere, between different models, with implications for the chemistry in this region. Heights of convective outflow differ between the models, but there is also little correlation in the timing of the rapid transport events from near the surface to the upper troposphere. This will affect how models predict the influence of short lived pollution events at the surface, on the upper troposphere.

It is difficult to quantitatively assess the transport parameterisations in a large scale model, as the most commonly measured tracers (CO, NOx, ozone, hydrocarbons etc. all undergo chemical reactions in the atmosphere. In order to model these species, transport as well as chemistry must be correct, and it is not possible to unambiguously describe a deviation of modelled data from measurements as being due to a shortcoming of the model transport scheme.

On the other hand, by applying these idealised tracers, differences between transport in the models can be found, and the reasons for these differences can later be determined.