Age of air and other timescales of transport in the New Dynamics Unified Model

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1 Introduction

In recent years the Unified Model (UM), the NWP and climate prediction tool of the U.K. MetOffice, has undergone an ambitious rejuvenation. The result, the "New Dynamics" UM, avoids many common approximations and compromises. It is the first non-hydrostatic climate model.

As a step towards turning the new UM into a fully coupled global environment model, the UCHEM project aims to add interactive chemistry and aerosol modules to the model. It is a joint project involving the MetOffice and Cambridge and Leeds Universities. At the start of the project is an assessment of transport timescales in the model.

2 Model characteristics

Version	V5.3L38 (HadGAM)
Vert coord.	hybrid-height
Advection	semi-Lagrangian
Model top	39 km
Hori. res.	$3.75^o \times 2.5^o$
Vert. res.	38 levels, 7 above 20 km
Timestep	30 min
Ocean	AMIPII SST

3 Model experiment

The model contains ^{222}Rn and ^{218}Pb tracers. Rn is emitted uniformly from non-frozen land points and decays with an *e*-folding time of 5.5 days. Removal of Pb is not included; hence Rn + Pb is an inert tracer with an invariant source totalling 10.9 and 4.1 kg/year in the two hemispheres. The experiment spans a total of 15 years, encompassing timescales of (a) interhemispheric exchange, and (b) stratospheric age of air. (c) Tracer conservation will be considered. The classical application of Rn as a tracer for tropospheric mixing has been considered in a preceding work [*Tan and Johnson*, 2002] upon which this experiment is based.

4 Results

(a) Interhemispheric exchange

In an idealized model the difference in tracer burden between the two hemispheres is described by

$$\Delta B(t) = \frac{\Delta S \cdot \tau}{2}\left[1 - \exp\left(-\frac{2t}{\tau}\right)\right] \qquad (1)$$

with ΔB representing the difference in burden, ΔS the difference in source, τ the mixing timescale and t time. From fig. 1 we infer a mixing timescale for tropospheric transport of 0.7 years.

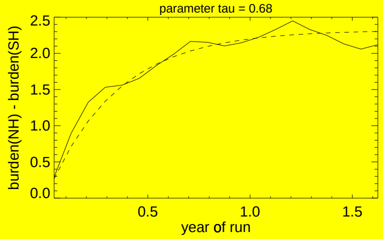

Fig. 1: (solid) Difference in Rn + Pb between the two hemispheres, in kg. (dashed) Least-squares fit according to Eq. 1 with $\tau = 0.68$ years.

(b) Stratospheric age of air

The constant rate of surface emission means that Rn + Pb is a good tracer for age of air with a tropospheric mixing ratio increasing nearly linearly with time. The results are displayed in figures 2 to 5.

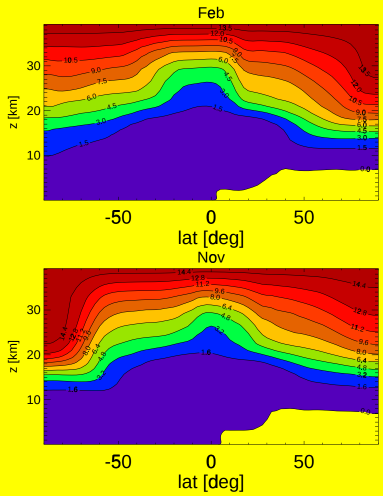

Fig. 2: Zonal mean age of air in years during the last year of the run for February and November.

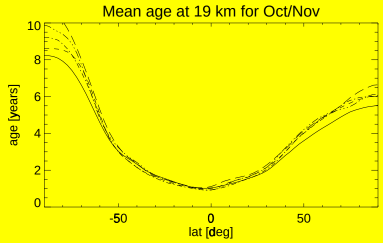

Fig. 3: Zonal-mean age of air at 19 km, averaged over October and November, for the last 5 years of the run.

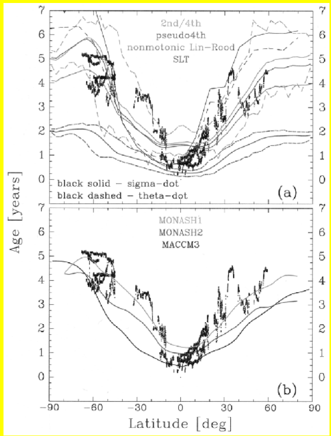

Fig. 4: Dots: Age of air inferred from CO_2 measurements [*Boering et al.*, 1996] Lines: Various model results. From *Eluszkiewicz et al.* [2000].

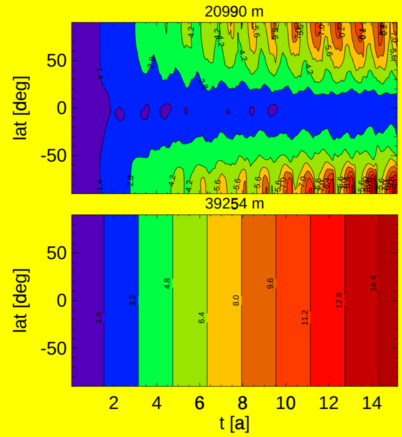

Fig. 5: Zonal-mean age of air at (top) 21 km (bottom) 39 km.

(c) Tracer conservation

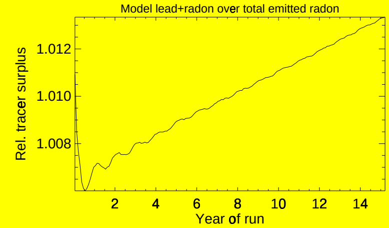

Fig. 6: Total Rn + Pb in the model, over total emitted Rn.

5 Summary

- Interhemispheric mixing timescale 0.7 years. Stratospheric mixing might lead to an underestimation of this number.
- The age-of-air diagnostic shows substantial subsidence over the winter vortices, suggesting that with chemistry a realistic Antarctic ozone hole will form.
- Age in the vortices and near the model top is too large. This is due to the low vertical resolution and the presence of a strong sponge layer. Future versions (L50 or L60) will hopefully fare better.
- For tracer conservation a positive trend of about 0.05% per year is found. For a planned century-scale integration this is a potential cause of concern.
- Tropospheric and stratospheric chemistries are coming soon.

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