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Stratospheric transport sensitivity to different assimilation systems in long-term CTM simulations

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Outline

¬ Motivation

- Assessment stratospheric (re)analyses for long-term studies
- Tests for ERA-Interim (new ECMWF DAS)

¬ Method and Data

- TOMCAT/SLIMCAT with ECMWF and UKMO (re)analyses

¬ Transport Results

- Mean-age-of-air, Age spectrum, Trajectories
- Reasons for improvements ?
- Effect on ozone distributions

¬ Conclusions

- New ECMWF assimilation improves stratosph. representation

Motivation

CTMs for analyses assessment

¬ **Stratospheric (re)analyses for long CTM runs**

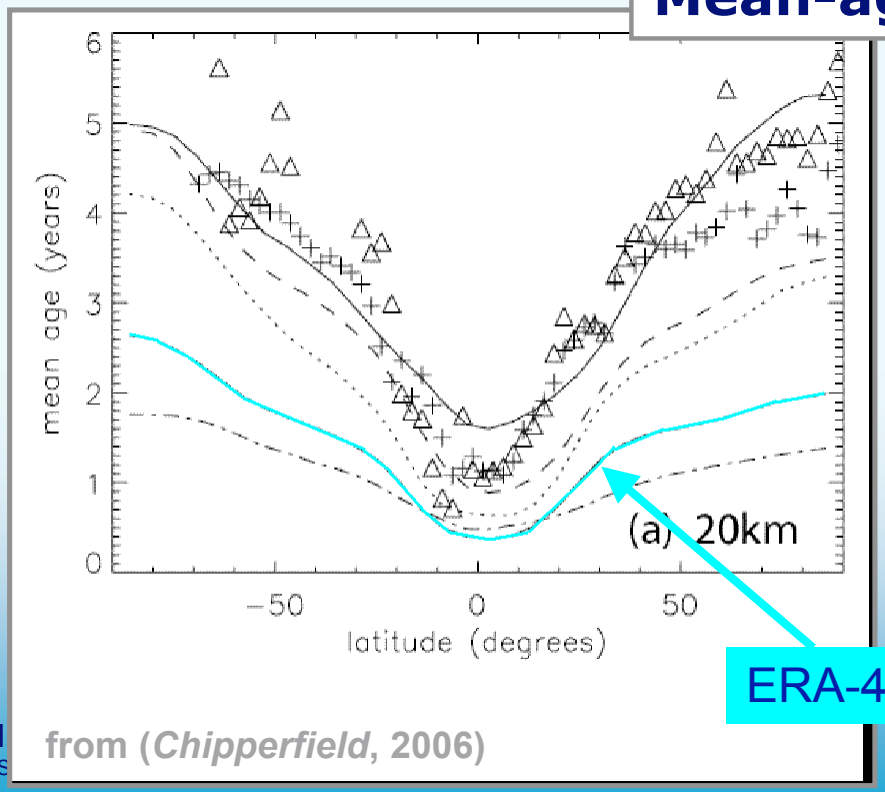
- **Off-line CTMs winds from GCMs or DAS analyses**
- **Analyses ◊ direct comparison with observations**
- **Accurate analyses ◊ accurate tracers distributions**
- **Long CTM stratosph. runs ◊ accurate Brewer-Dobson circul.**
- **CTMs reliance on analyses ◊ diagnostic tool for analyses age-of-air, trajectories…**
- **DAS too strong B-D circul. & not enough tropical isolation ◊ CTMs with DAS unrealistic tracers distributions**

Motivation DAS too strong Brewer-Dobson circ.

¬ Too strong B-D circulation: *problem with ERA-40, UKMO, NCEP…*

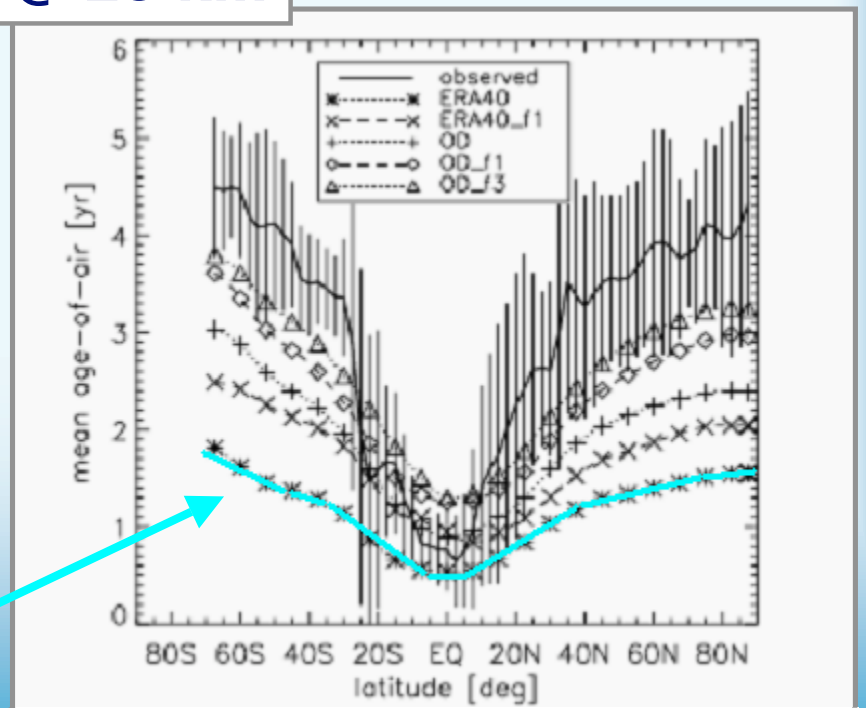
- **CTMs with ERA-40 underestimate mean-age-of-air**

Mean-age @ 20 km



from (*Chipperfield*, 2006)

ERA-40



from (*Meijer et al.*, 2004)

Some strategies

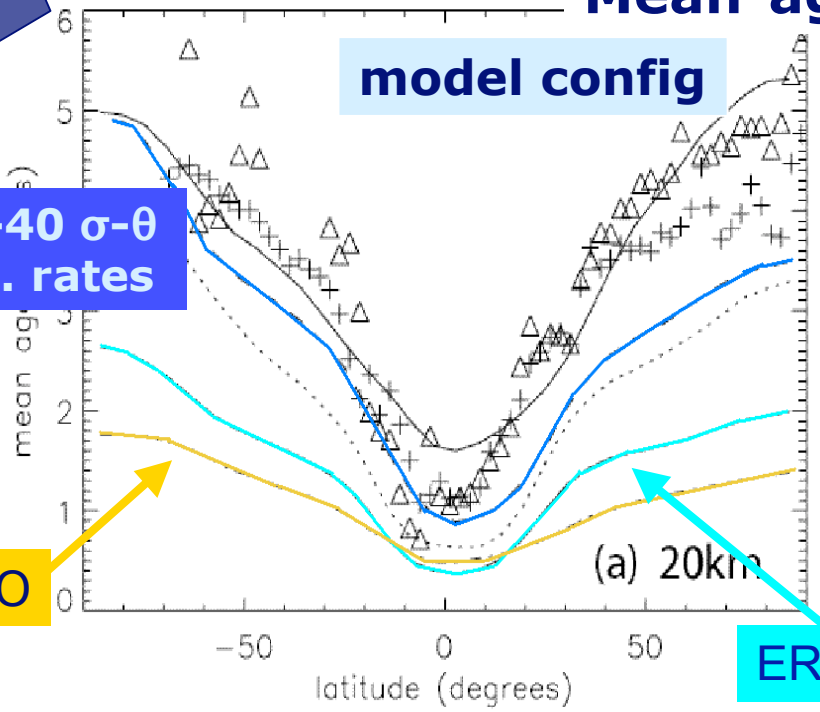
- **Isentropic vertical coordinate: σ-θ**
- **Derived vertical velocities: Heating rates**
- **Use of forecasts**

Mean-age @ [illegible] km

model config

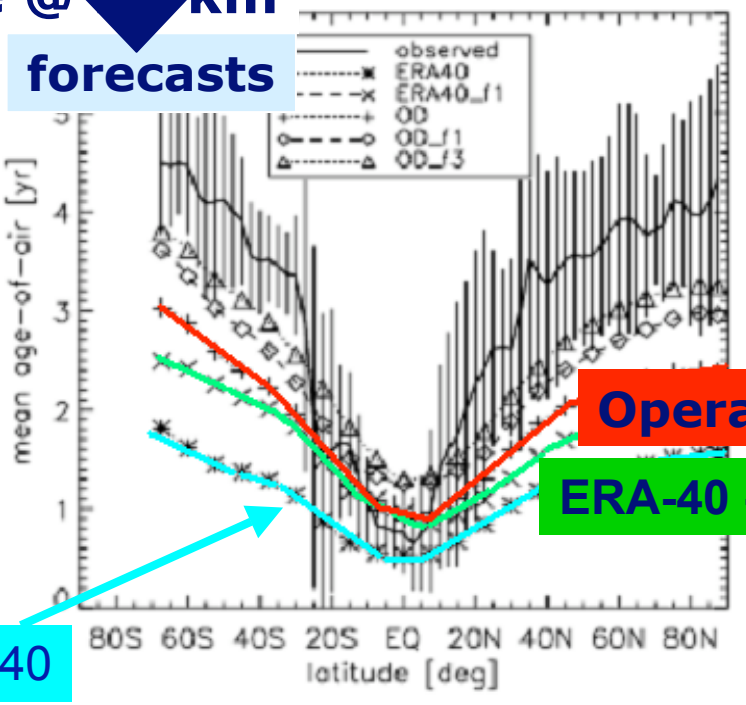
forecasts

ERA-40 σ-θ Heat. rates



UKMO

from (*Chipperfield*, 2006)



Operational

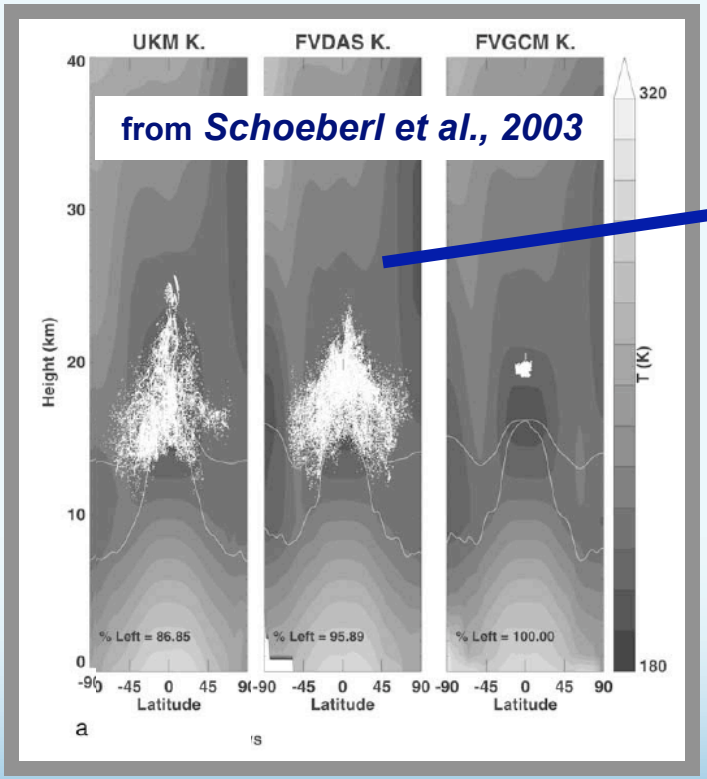
ERA-40 -24h fc

ERA-40

from (*Meijer et al.*, 2004)

Motivation DAS not enough tropical isolation

¬ Assimilated fields good enough for long-term stratospheric studies?



- Results from *Schoeberl et al., 2003* with UKMO and FVDAS suggest NO

- Results here with recent ECMWF winds suggest YES

↳ **ERA-Interim**

Motivation ERA-Interim tests

Improved Data Assimilation System
+ Improved forecast model
+ Improved observations

ERA-Interim

- **Much improved B-D circulation**
- **Much improved tropical isolation**

Data and Method

θ-levels, heating rates

p-levels, diverg.

- Off-line **C**hemistry**T**ransport**M**odel **SLIMCAT/TOMCAT**

- Data sets

ERA-40 analyses	**3D-Var**	**ECMWF**
Operational ⇄	**4D-Var**	
EXP471 (ERA-Interim exp)		
UKMO	**3D-Var**	**UK Met Office**

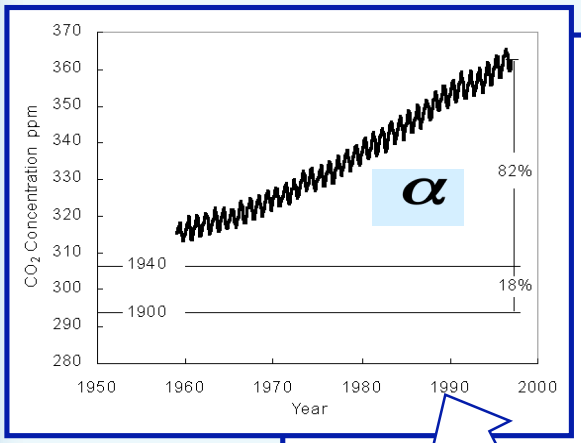
- **Brewer-Dobson** → Mean age-of-air, age-spectrum
  20-year simulations

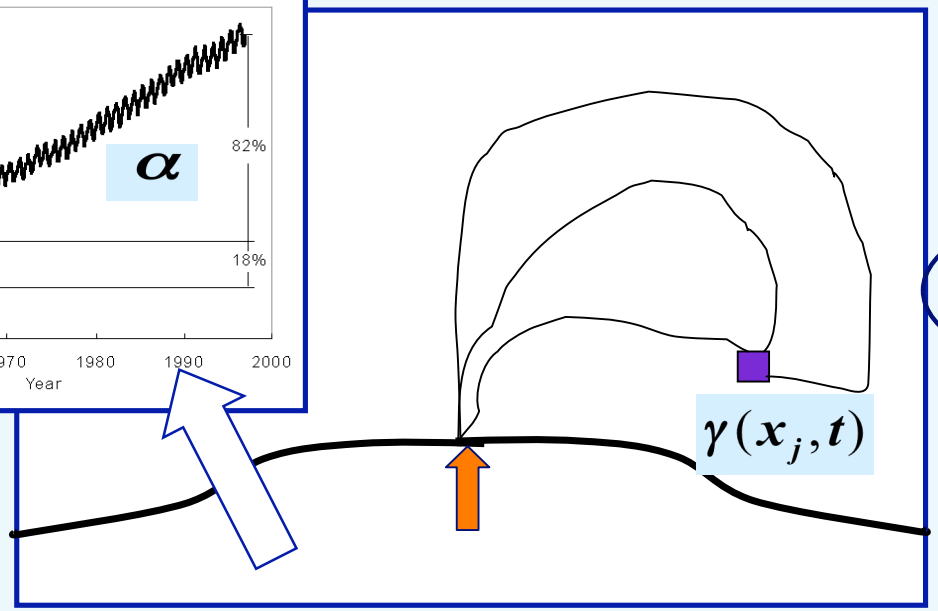
- **Tropical isolation** → Trajectories
  1-2 month simulations

Age of air

Age-of-air ◊ chemistry independent transport diagnostic

Observed conserved linear tracer ◊ mean-age $\Gamma(x, x_0)$





$$\Gamma(x, x_0) = t - \frac{\gamma(x,t)}{\alpha}$$

α : *mixing ratio trend*

CO_2, SF_6

- Sparse in-situ measurements (~20km)
- MIPAS SF_6 (G. Stiller, Karlsruhe Univ.)

Age of air: TOMCAT

cross sections annual mean

20-year meteorology 2000

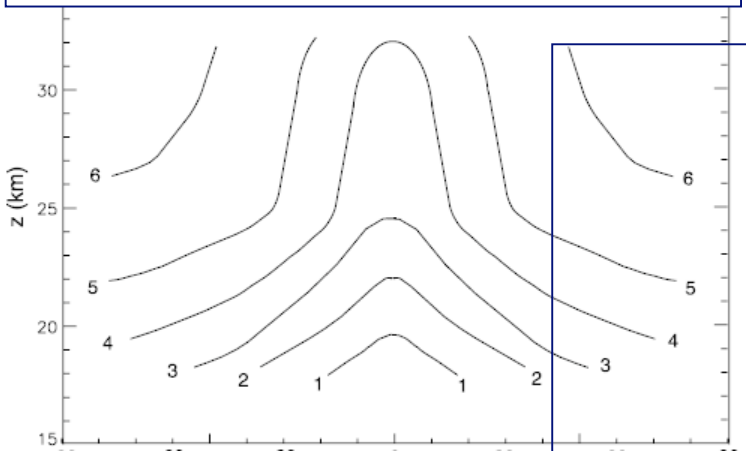
linear increasing tracer

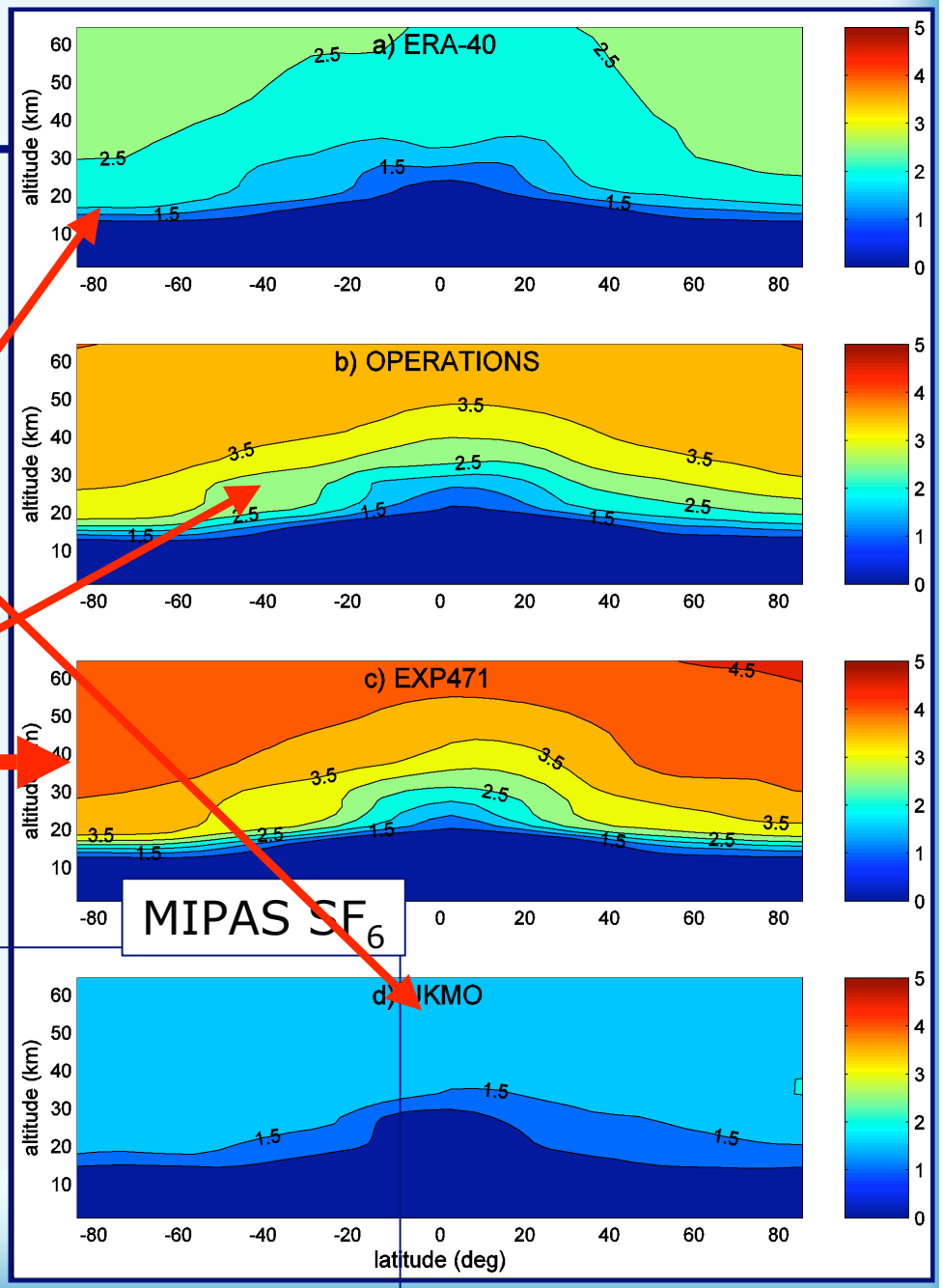
¬ ERA-40 & UKMO: too young, unrealistic

¬ Operations: still young, realistic

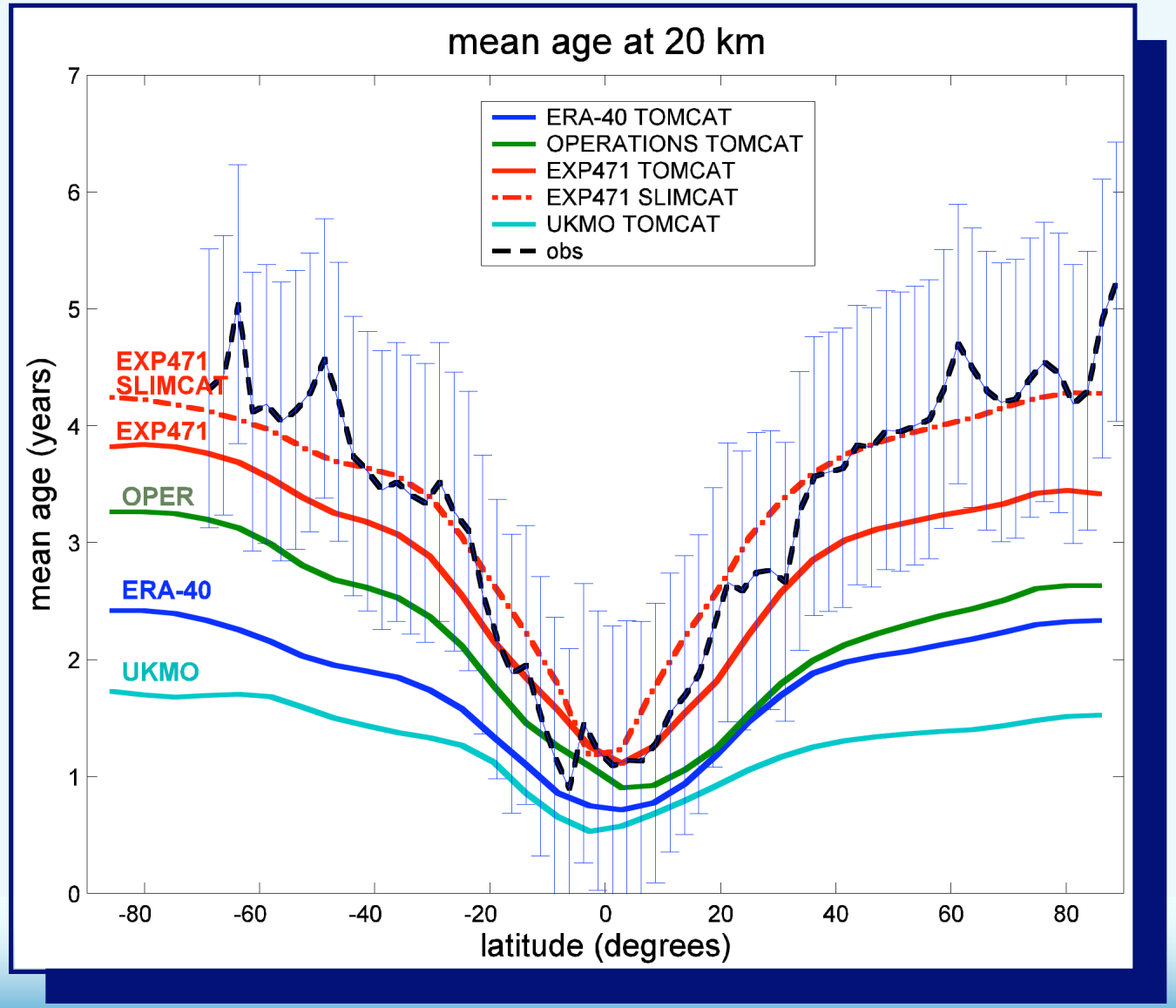
¬ EXP471: oldest, most realistic

Schematic annual mean mean-age, from (*Waugh and Hall, 2002*)





ERA-Interim: TOMCAT/SLIMCAT v. observations



OBSERV.

EXP471 SLIMCAT

EXP471 TOMCAT

OPER TOMCAT

ERA-40 TOMCAT

UKMO TOMCAT

Age of air

Age-of-air ◊ chemistry independent transport diagnostic

Observed conserved linear tracer ◊ mean-age

Our model ◊ linear tracer ◊ mean-age

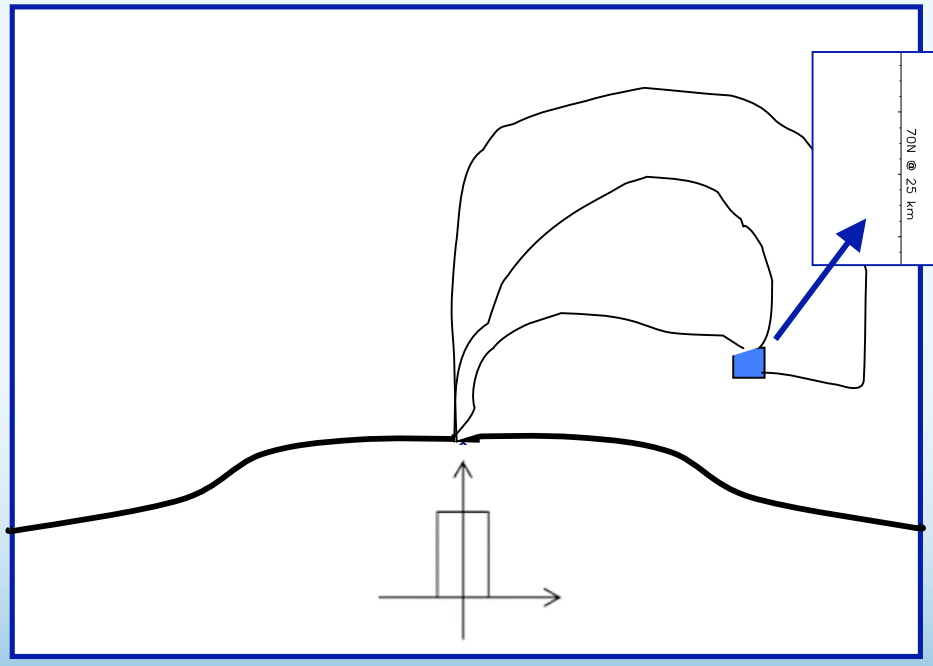
But mean-age not complete picture

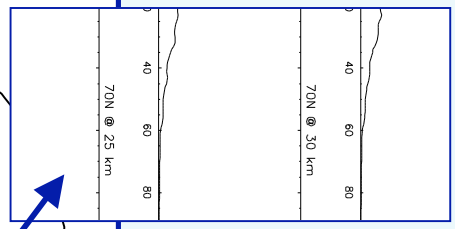
Our model ◊ pulse tracer ◊ age spectrum & mean-age

Age spectrum

For completeness: CTM pulse tracer ◊ age spectrum

¬ Age spectrum: distribution of transit times of an air parcel from a source to a certain location (in the stratosphere)



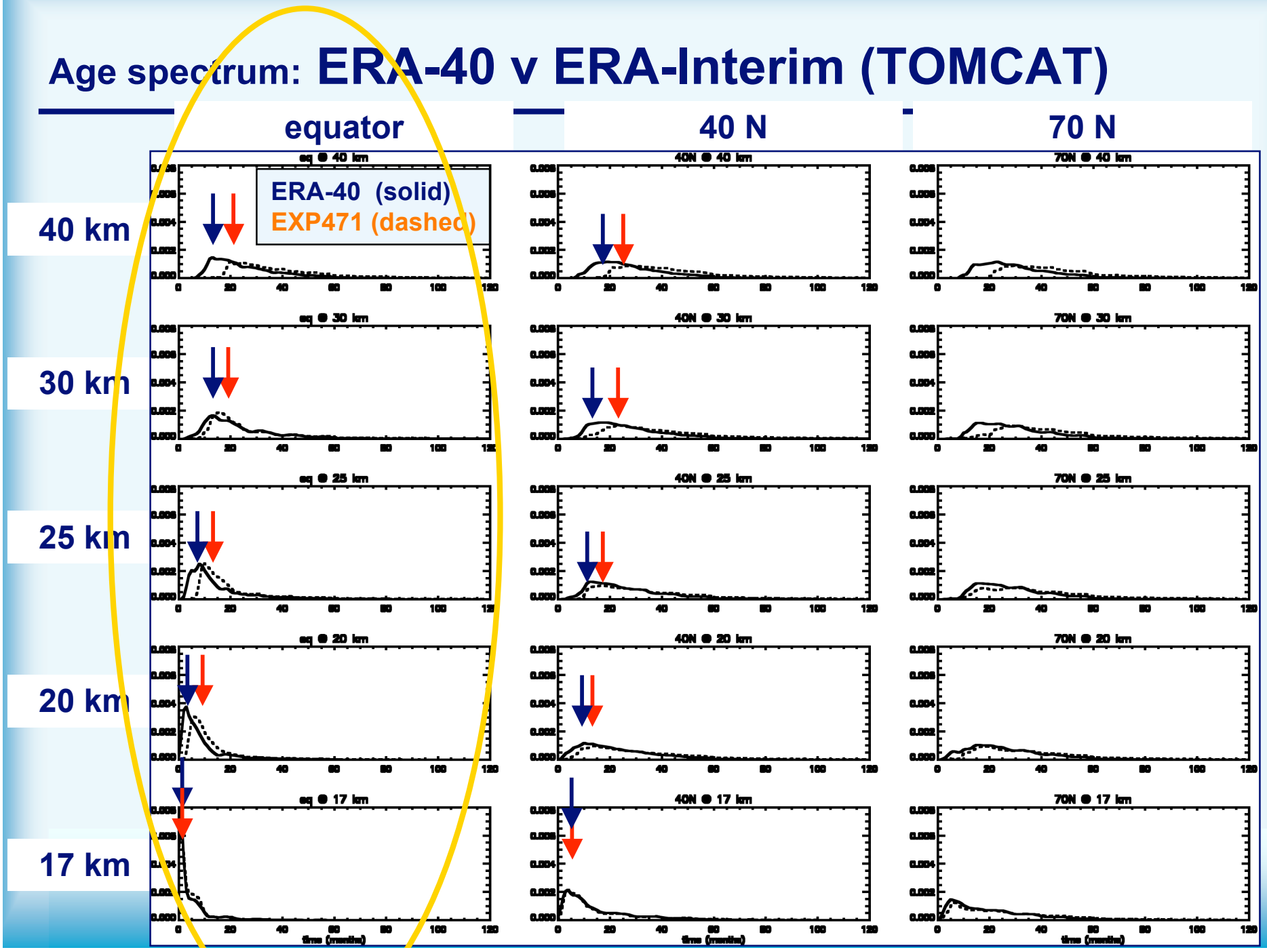


$$G(x,t)$$

$$\Gamma(x,x_0) = \int_0^\infty t\, G(x,x_0,t)\, dt$$

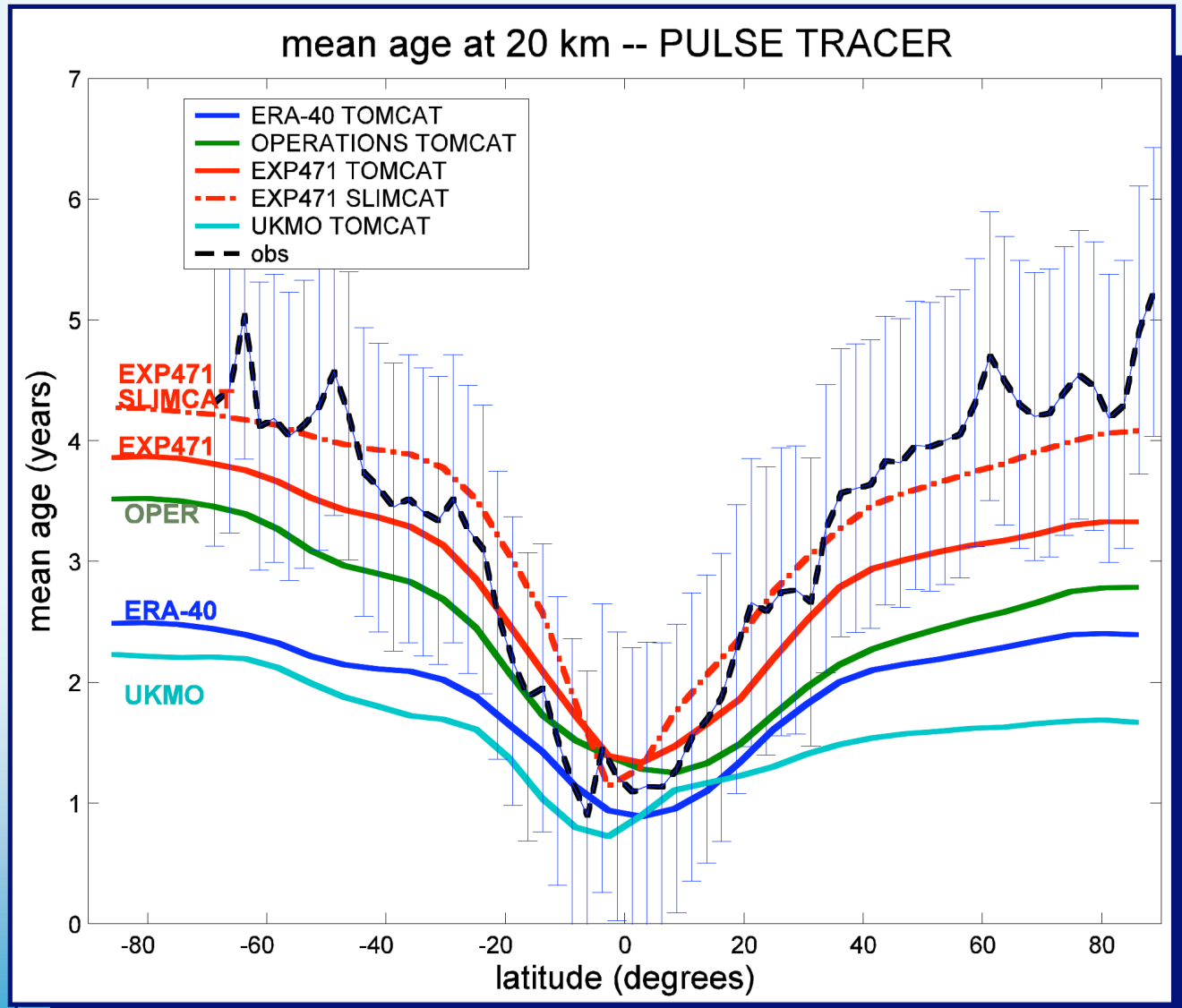
¬ Mean age-of-air: first moment of age spectrum

Age spectrum: ERA-40 v ERA-Interim (TOMCAT)



Age spectrum

Mean age 20 km PULSE TRACER



OBSERV.

EXP471 SLIMCAT

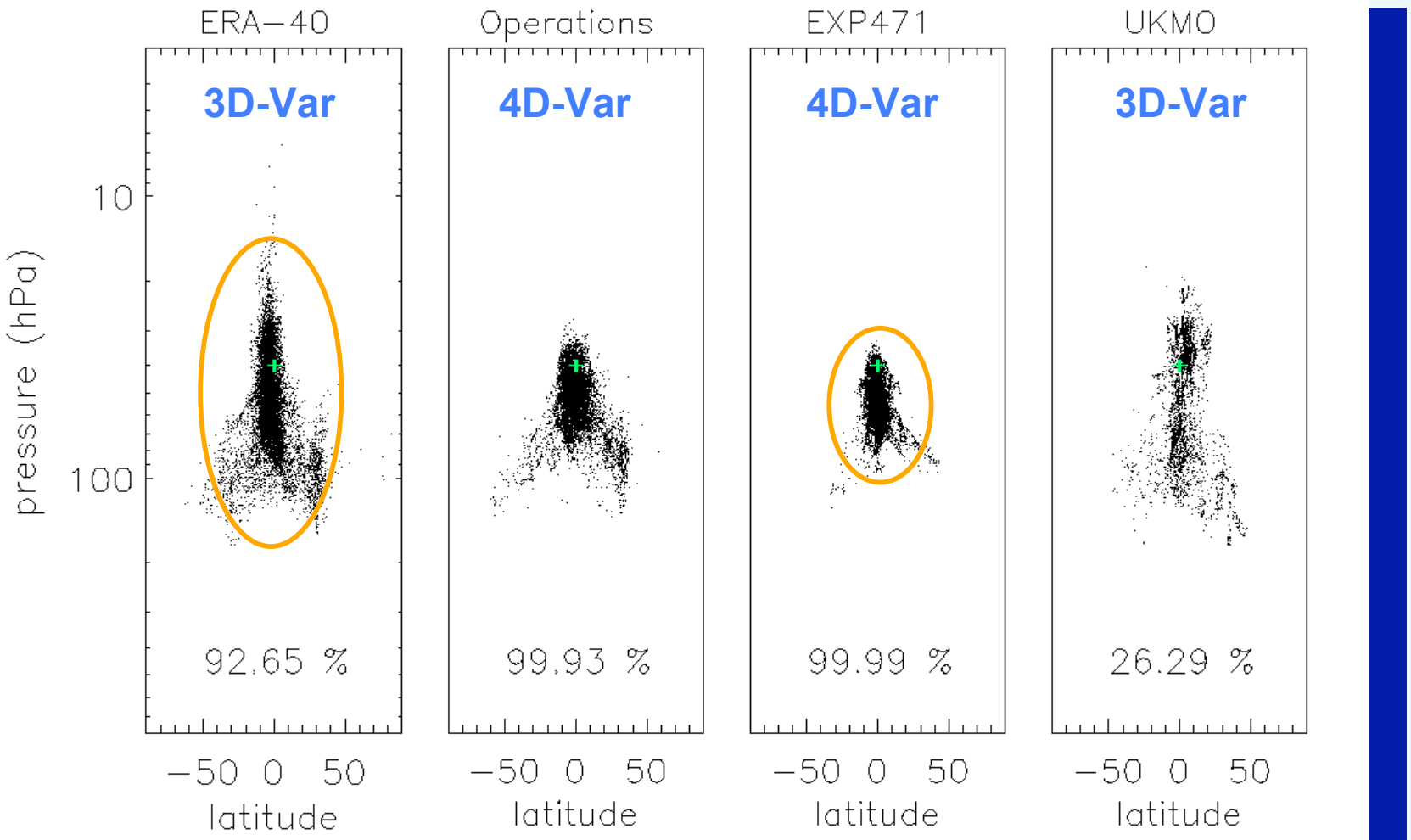
EXP471 TOMCAT

OPER TOMCAT

ERA-40 TOMCAT

UKMO TOMCAT

TOMCAT Trajectories



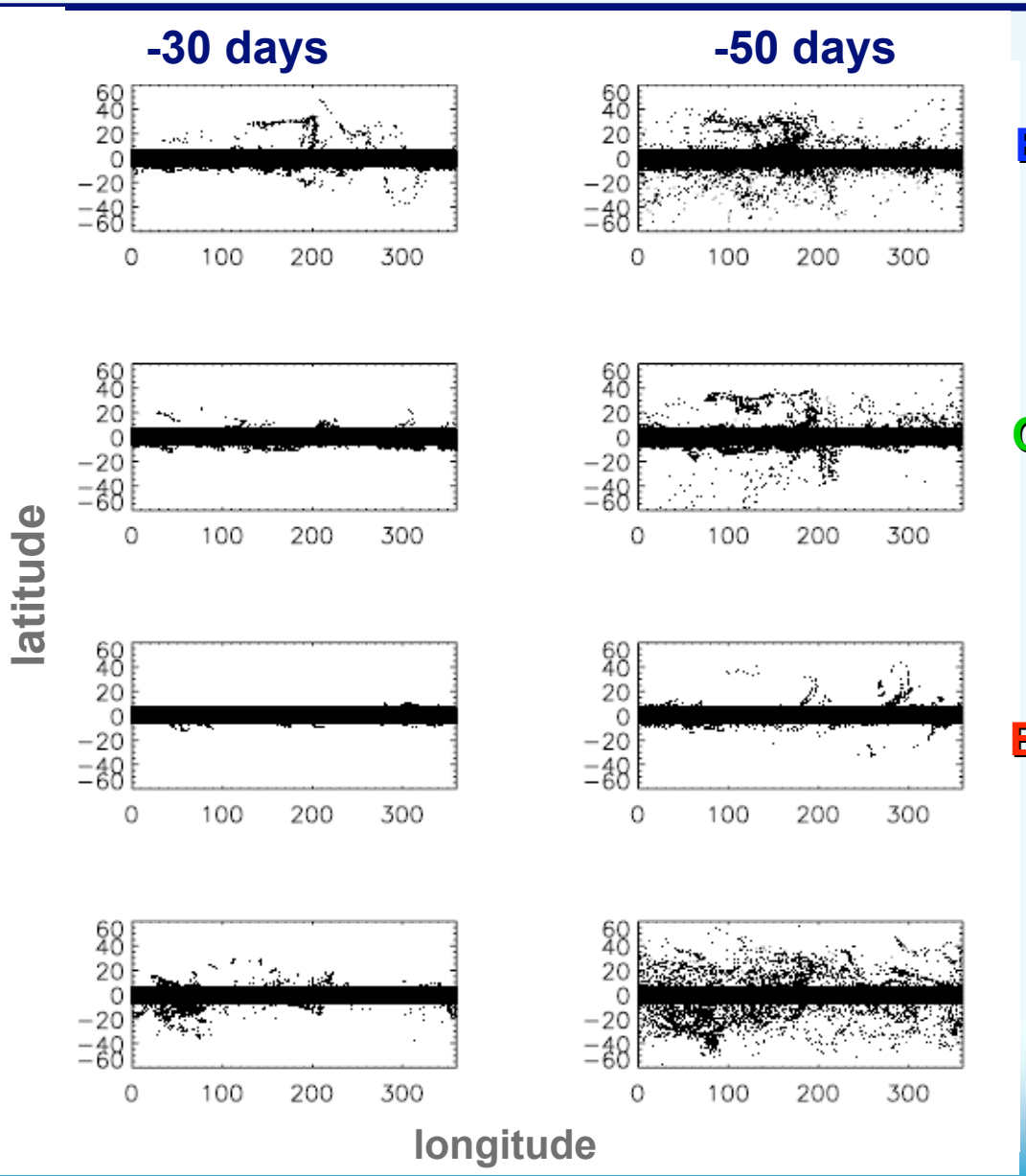
50-day backwards run: 1st Jan 2001

36.000 particles: 0º ± 1º

460K ± 5K

TOMCAT Trajectories

Density of particles



What causes the improvements ?

- *4D-Var instead of 3D-Var (ERA-40 vs OPER)*
- *12h cycling instead of 6h cycling (EXP471 vs OPER)*
- *better background error statistics (EXP471 vs OPER)*
- *Radiances biases corrections (EXP471 vs OPER)*
- *Better parameterisations …*

But, what causes what?

IMPOSSIBLE MISSION ?

¬ **Set of ERA-Interim experiments:**

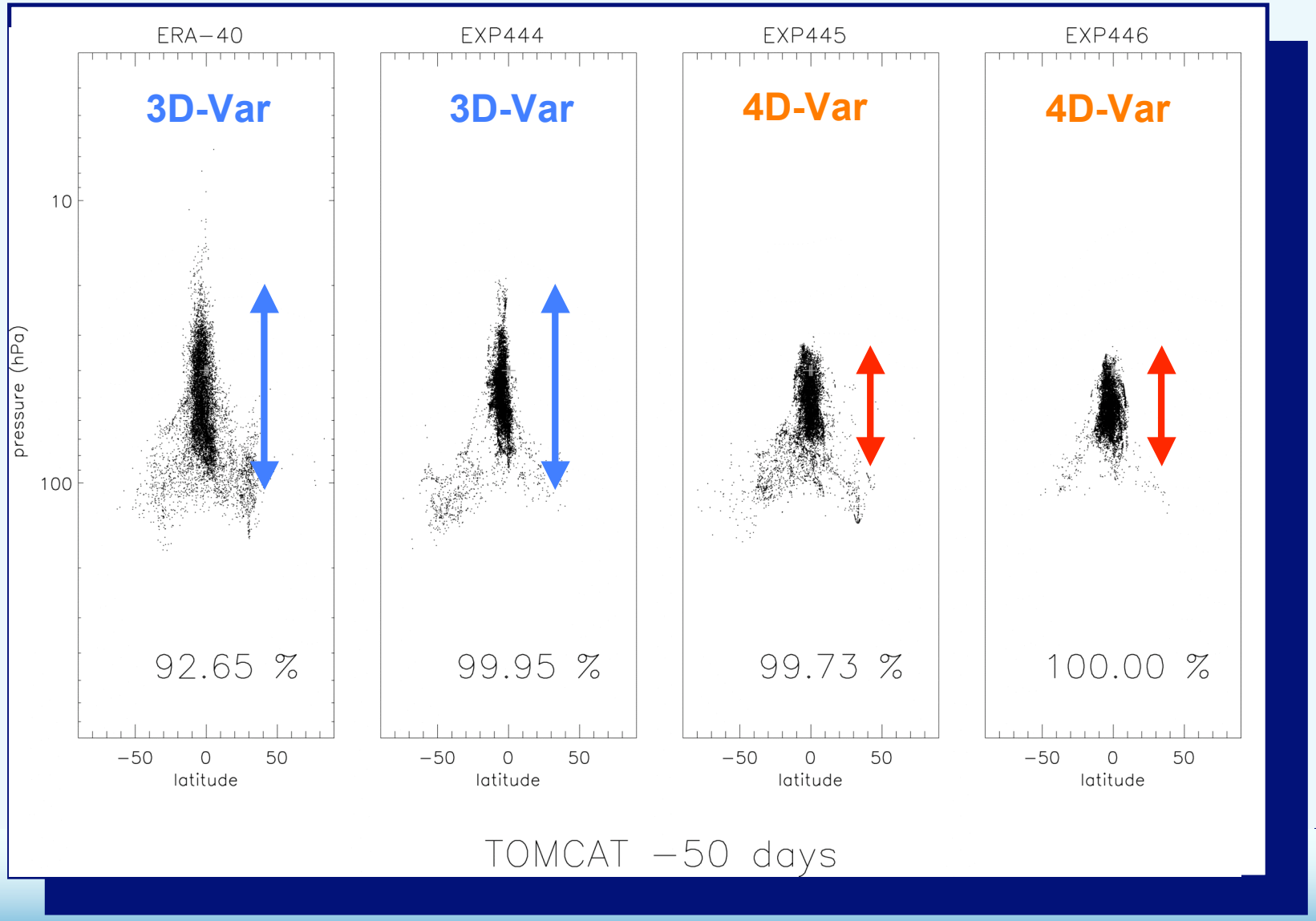
- **EXP 444: 3D-Var FGAT**
- **EXP 445: 4D-Var 12h**
- **EXP 446: 4D-Var 6h**

4D-Var v 3D-Var ?

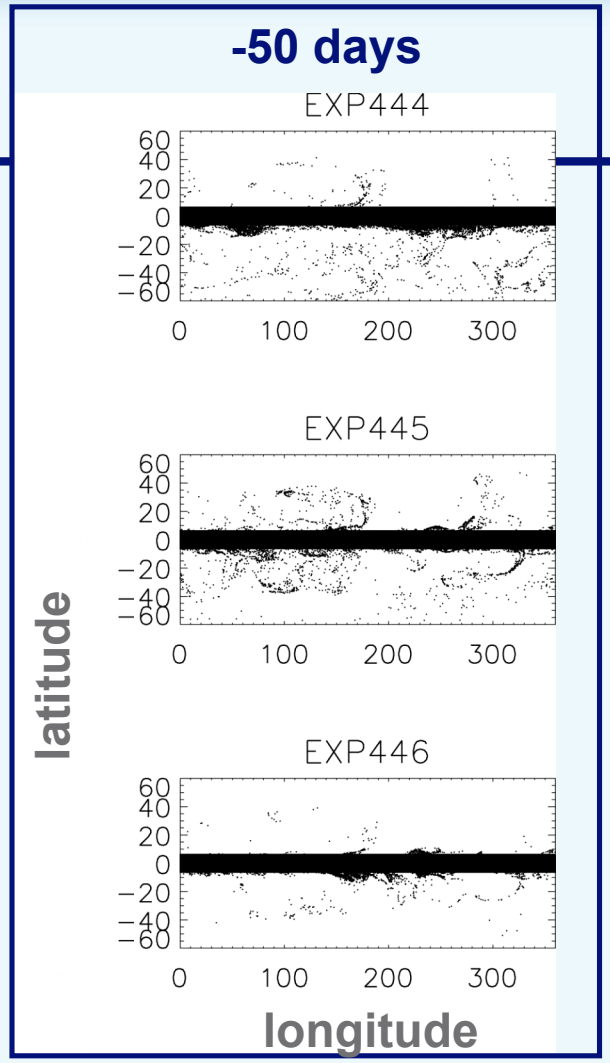
12h v 6h ?

TOMCAT 50-day backwards trajectories

TOMCAT Trajectories: sensitivity runs



TOMCAT sensitivity runs



EXP444 3D-Var

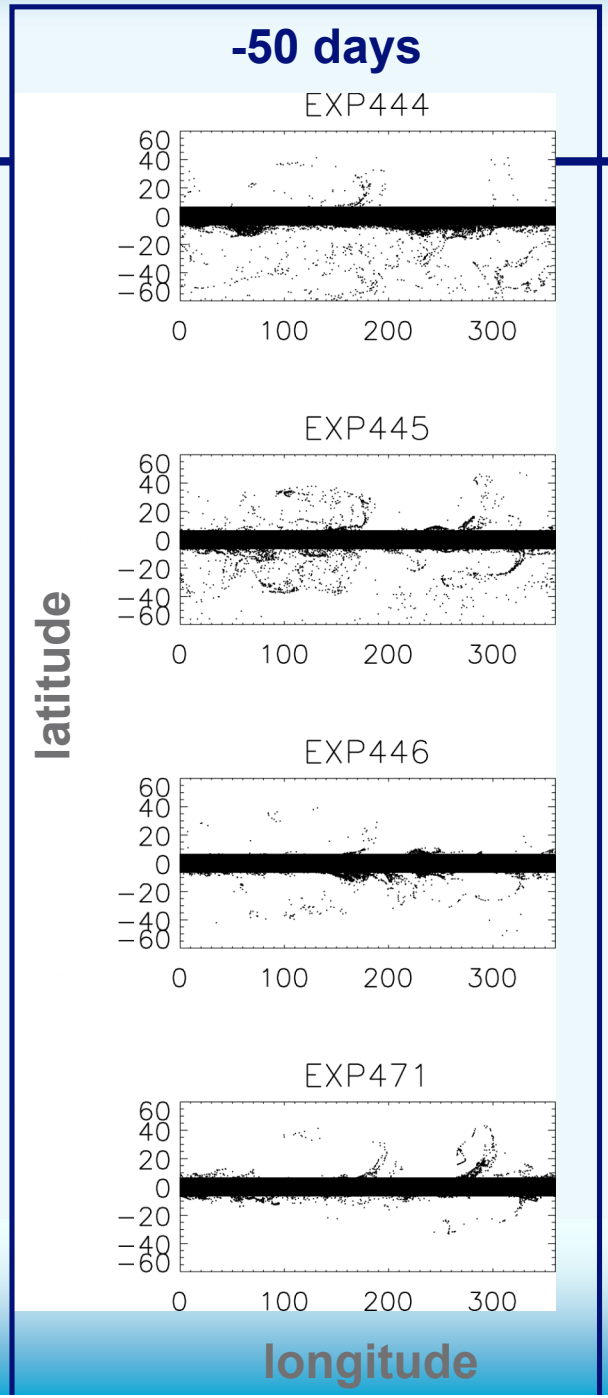
EXP445 4D-Var 12 h

4D-Var but more mixing ?

EXP446 4D-Var 6h

6h but less mixing ?

TOMCAT sensitivity runs



EXP444 3D-Var

EXP445 4D-Var 12 h

EXP446 4D-Var 6h

EXP471 4D-Var 12 h

improved IFS model ◊ positive impact on assimil. window

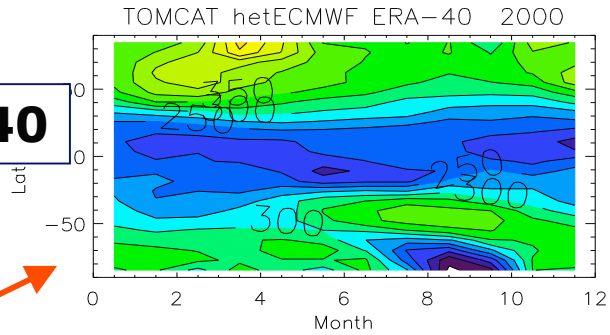
Ozone distributions

Ozone from TOMCAT with different ECMWF analyses 2000

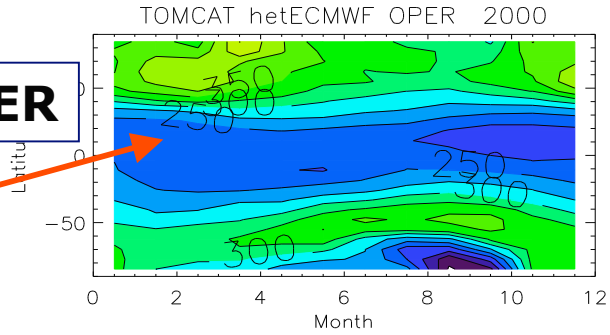
- **Problems with ERA-40**
- **Improvement with Operations**
- **Further improvement with ERA-Interim**

Not so much problem with SLIMCAT
(σ-θ and heating rates)

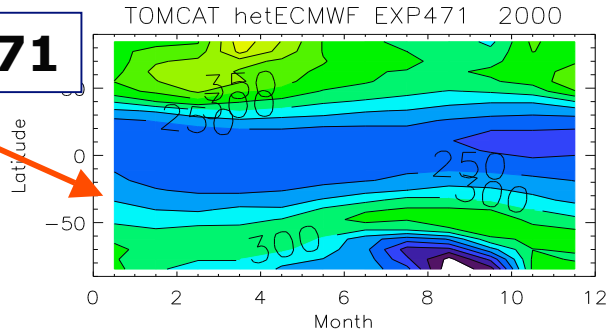
ERA-40



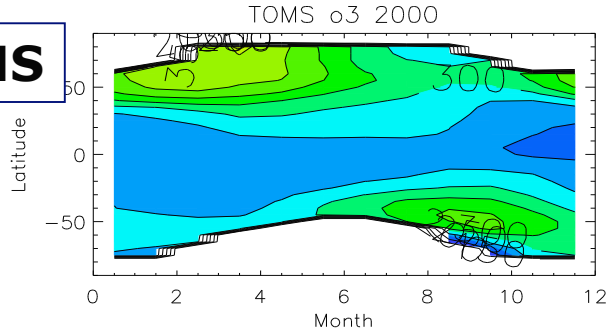
OPER



EXP471



TOMS



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Summary

- Age of air (spectrum and mean-age) ◊ Improved B-D circul. in ERA-Interim
- Trajectories ◊ More tropical isolation in ERA-Interim
- CTMs with ERA-Interim ◊ more realistic tracer distributions
- With the new improvements ECMWF (re)analyses expected to be very useful for long CTM runs
- Reasons for the improvements difficult to assess separately

¬ **Acknowledgements**

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¬ Submitted paper to GRL:

Monge-Sanz, B.M., Chipperfield, M.P., Simmons, A.J. and Uppala, S.M. Mean age of air and transport in a CTM: Comparison of different ECMWF analyses, *Geophys. Res. Lett.* (under review)

THANK YOU

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