UNIVERSITY OF CAMBRIDGE

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Nudged Version of the UM

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Introduction

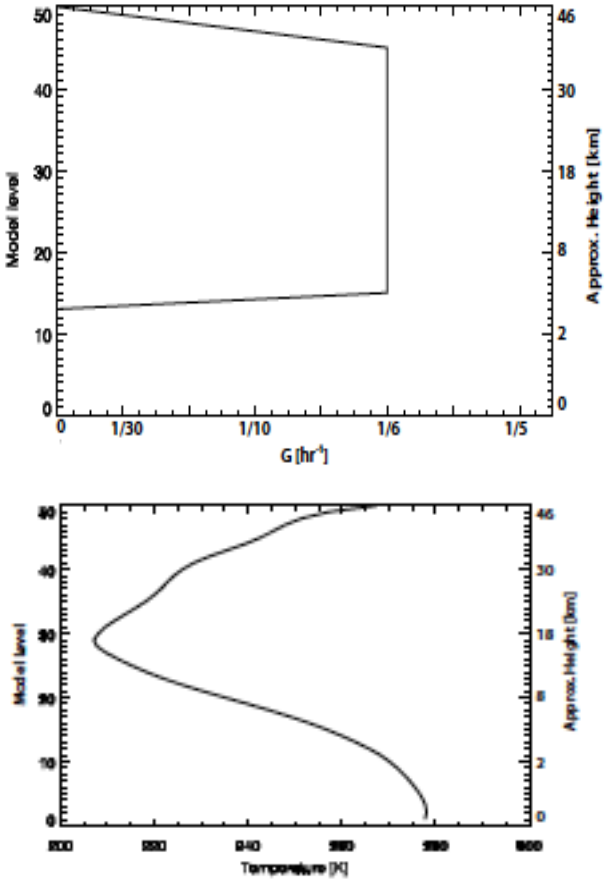
- Nudging (or Newtonian Relaxation) is the 'poor mans data assimilation'
- Constrain free running GCMs using meteorological analyses such as ECMWF/ JRA/ UM
- Quick and simple method that allows these models to represent a particular short period time
- Expands data sets that can be used for validation and allows us to concentrate on certain limited aspects of model (eg chemistry)
- Useful for hindcasting (e.g. compare to events such as volcanic eruptions)

Model Set-Up

- Model used is N48L60 Met Office UM
- 3.75° x 2.5° lon x lat and 60 levels from the surface to 84km
- Add nudging as an extra term

$$\Delta X = F_{mt}(X) + (G\Delta t)(X_{\text{ana}} - X),$$

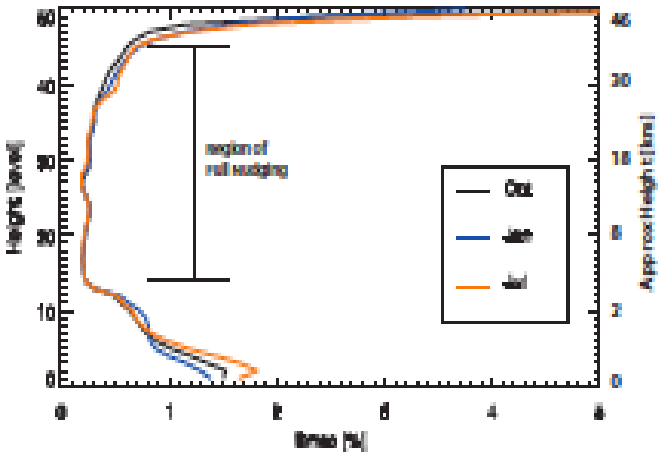
- Adjust temperature & horizontal winds
- Relaxation parameter (G) is 1/6 hr
- Nudge from 2km to 45 km
- Default use ECMWF ERA-40/ECMWF-Ops

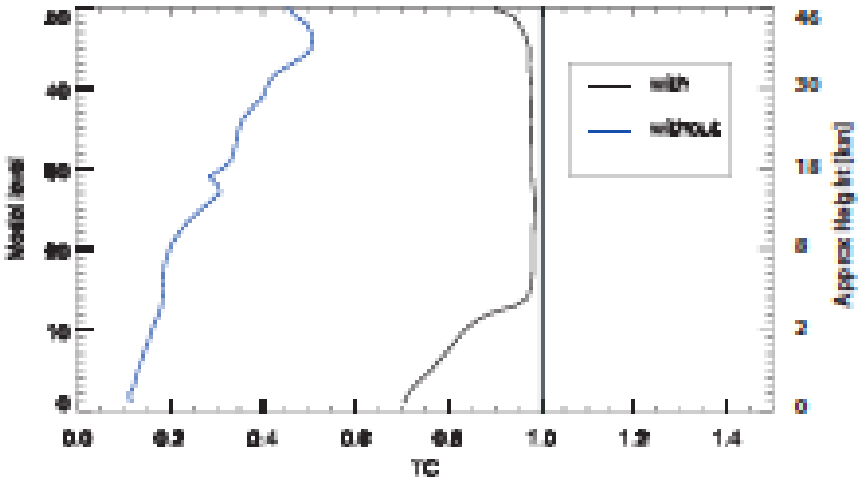


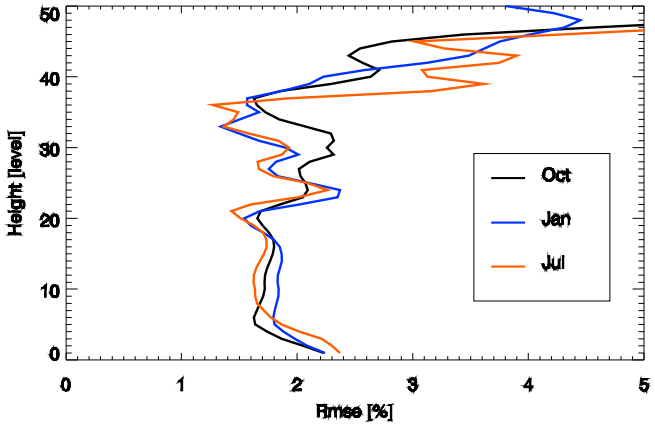
Telford et al, ACP 2008

Model Validation

- Validate the performance quantitatively
- Compare biases, RMSE & correlations
- Use analyses as baseline
- Use October 1999 as main test case



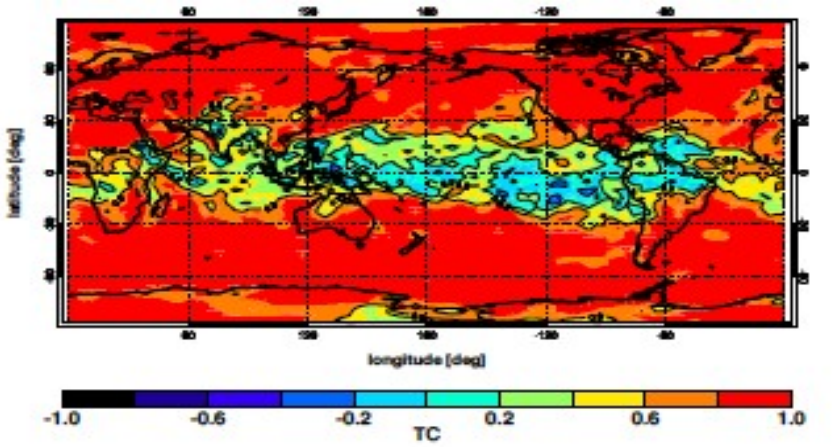


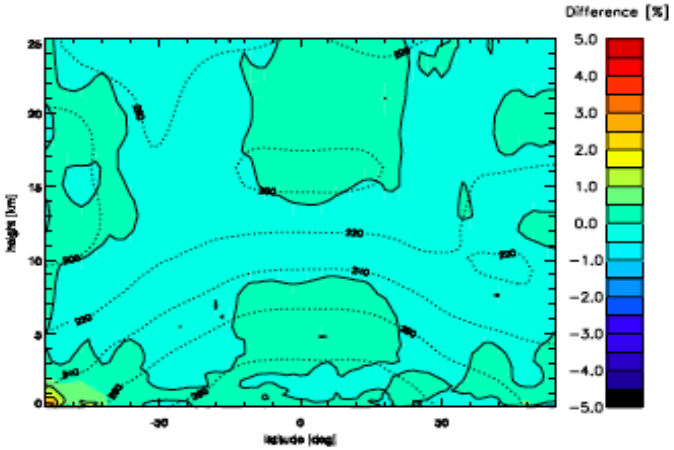


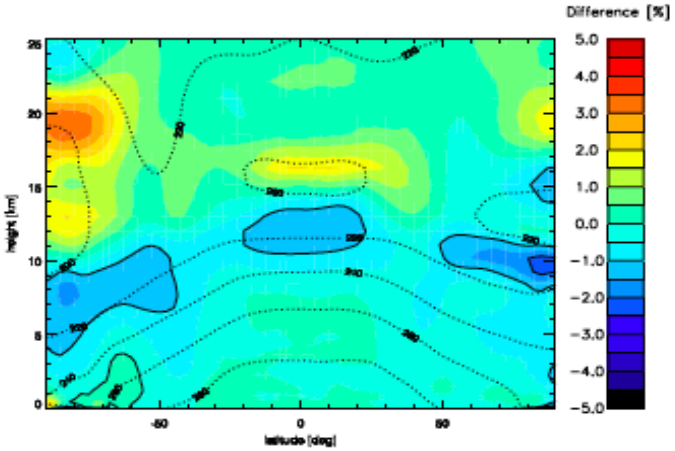
Telford et al, ACP 2008

Spatial Distribution

- Resolve comparisons in space
- See improvements everywhere
- Lower correlations in tropics
- In agreement with other nudged models



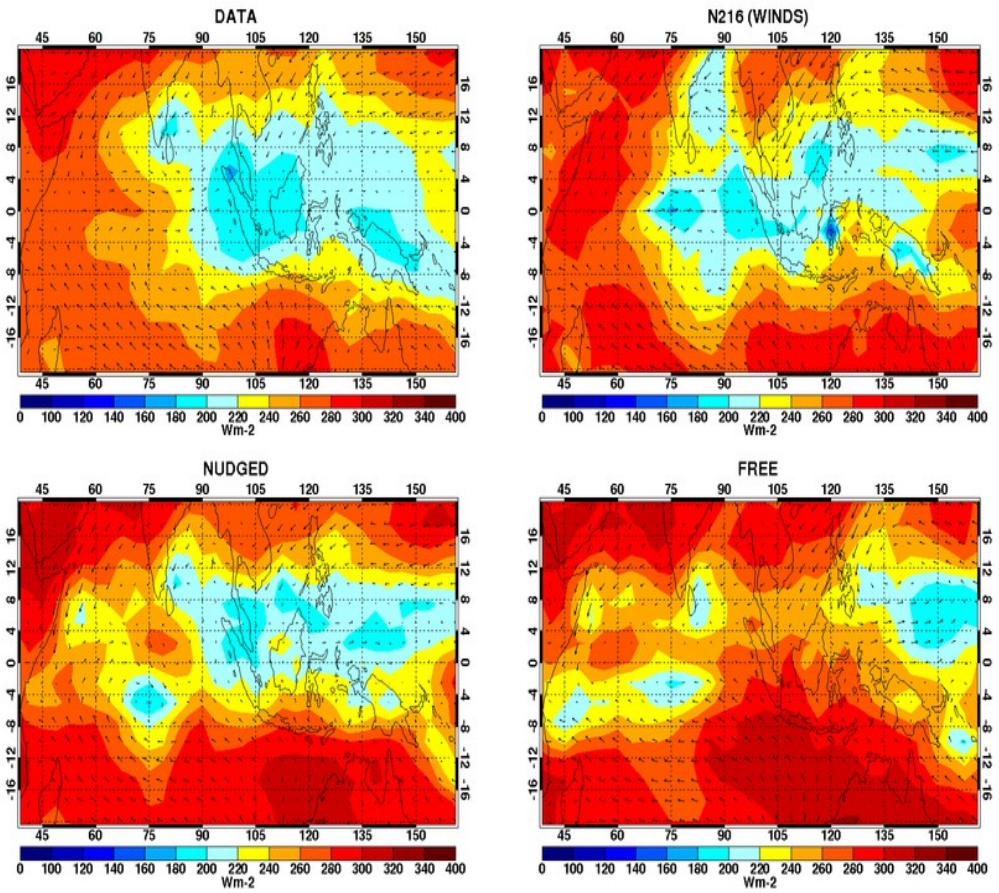




Telford et al, ACP 2008

Validation in Tropics

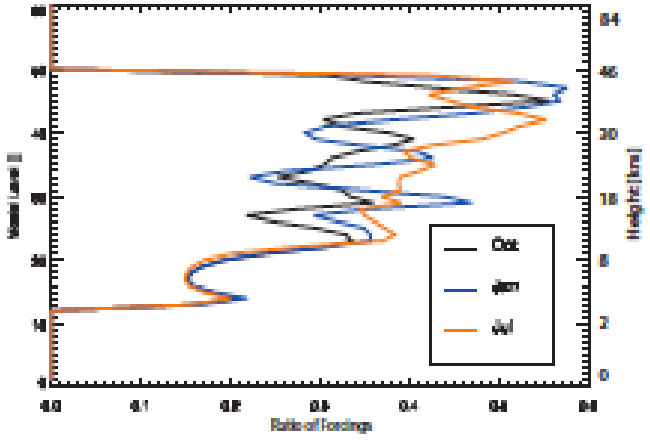
- Correlating time series of daily values correct metric in tropics?
- Investigate how well model describes convection
- Use NOAA satellite OLR to locate convection
- Nudging greatly improves description of where convergence occurs



Russo et al, prep., ACP. 2010; Russo et al, in prep. 2010

Sensitivity Studies

- Compare ratio of tendency from nudging to that from all other sources
- Increases with model height
- Pattern looks similar throughout the year
- Vary strength of nudging by factors of 10
- Any weaker and agreement begins to deteriorate
- Any stronger and nudging begins to predominate
- Justifies natural choice of timescale

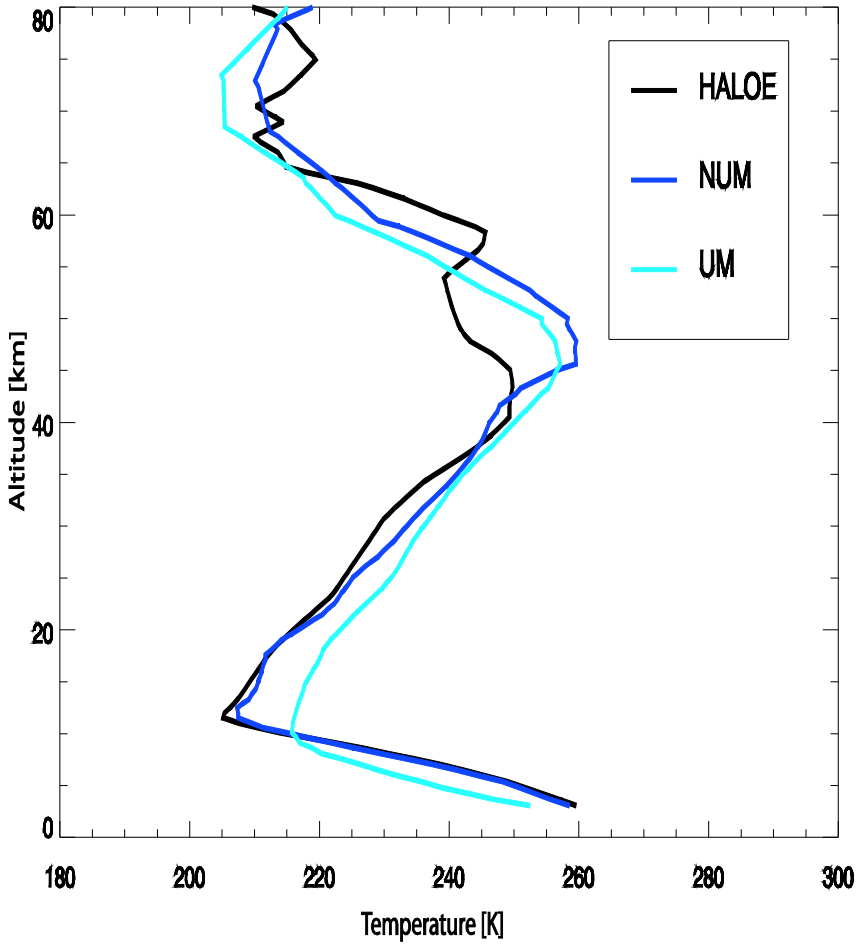


Level	θ		u	
	strong	weak	strong	weak
16 (~5 km)	0.61	0.09	0.83	0.15
29 (~15 km)	0.92	0.14	1.02	0.18
35 (~20 km)	1.01	0.10	1.11	0.09

Telford et al, ACP 2008

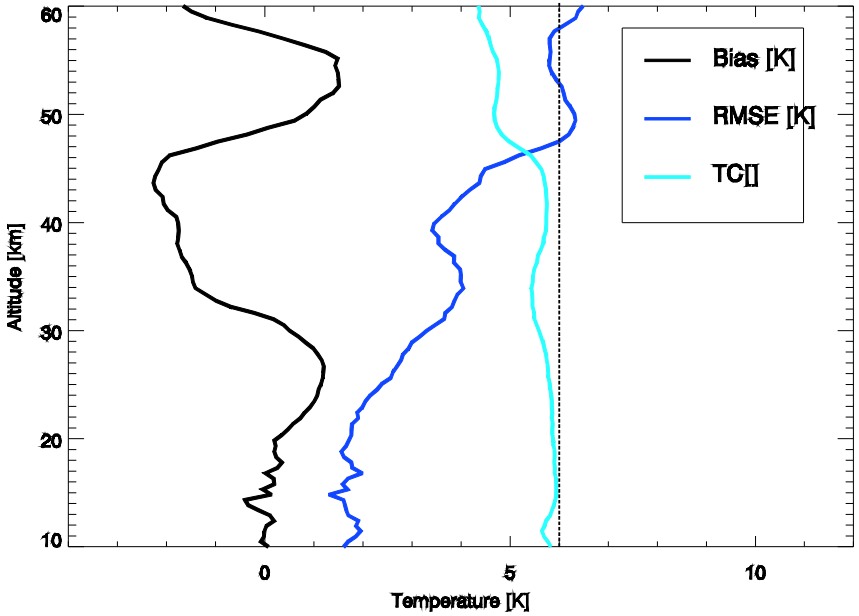
Comparisons to Satellite Data

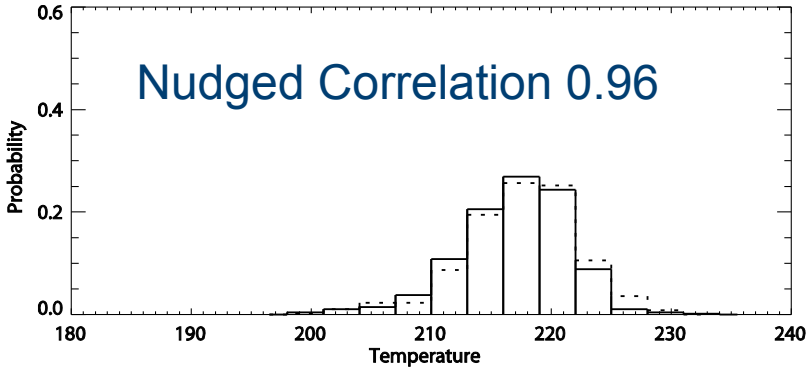
- Representing the atmospheric conditions on a given day allows us to make more specific comparisons to satellite profiles
- Show example comparison with HALOE data in Sep 1999
- Large tropopause difference between free running model & data
- Differences still above nudged region

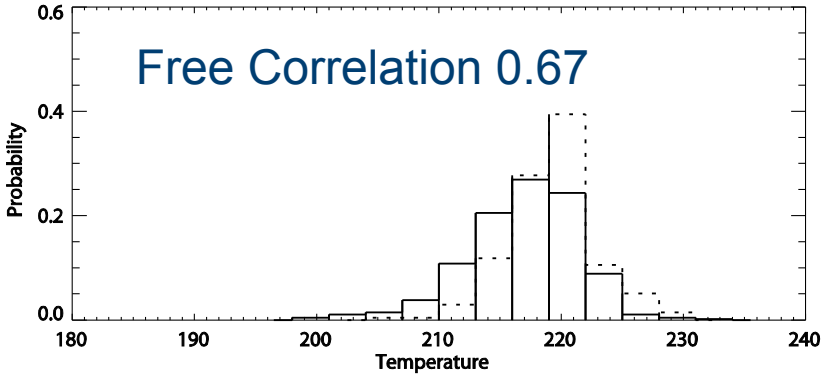


Quantitative Comparisons

- Make more quantitative comparisons with HALOE T
- Use Bias, RMSE & Correlation
- Compare PDFs at 30hPa for N Extra-tropics (> 30 N)
- Improvements in other regions

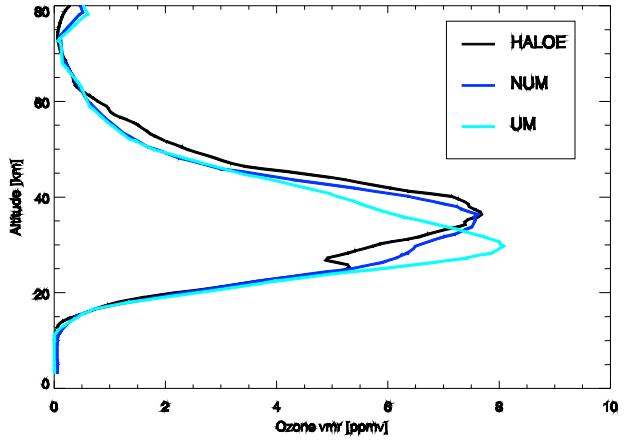


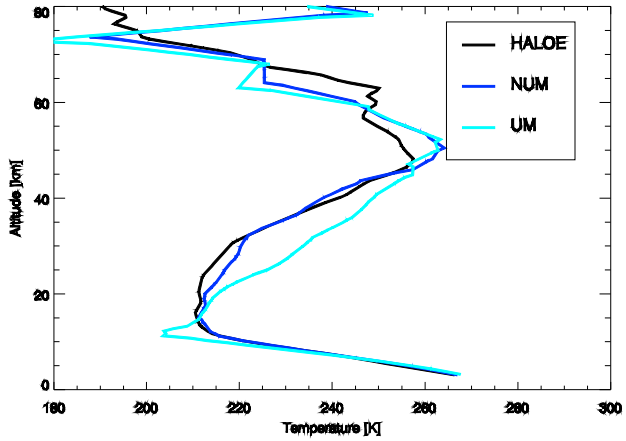




Comparisons to Satellite Ozone

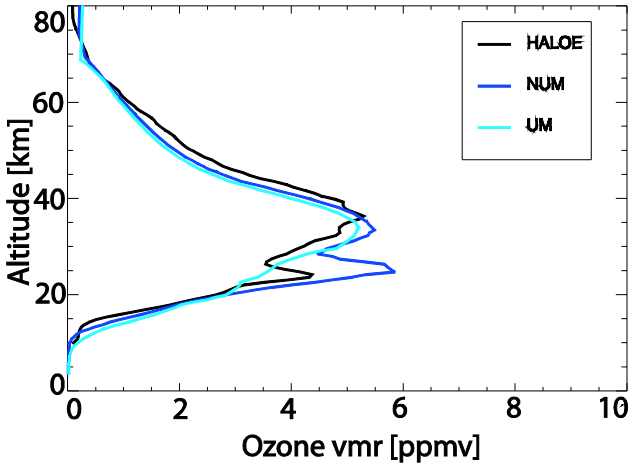
- Can use the nudged model to investigate the performance of the chemistry
- Compare model profile (nudged & free) with HALOE ozone
- Include T profiles for reference (below)
- When represent atmosphere well, then ozone looks better

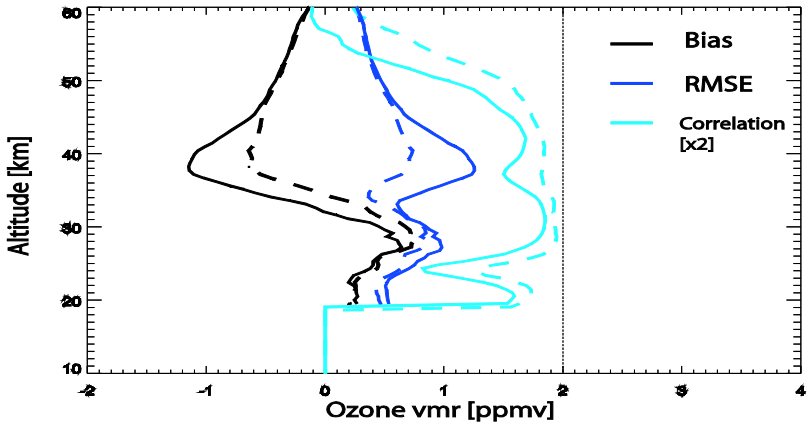




Quantitative Comparisons

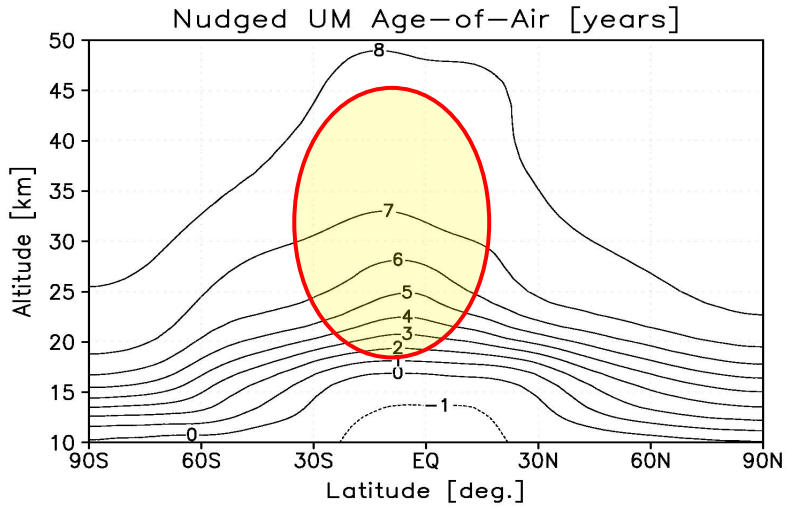
- Nudging doesn't always improve the description (see left)
- Nudging picks up the structure better but overall high biased
- Look at more quantitative assessments
- Compare Bias, RMSE and correlations
- In general nudging improves
- High bias in lower stratosphere

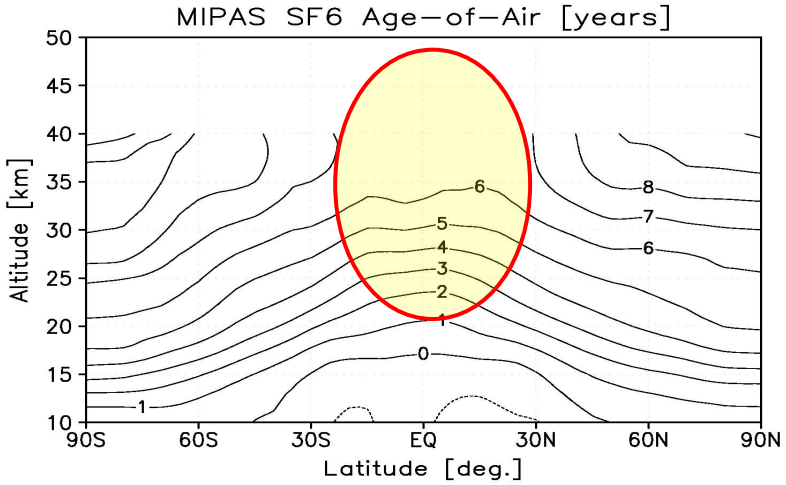




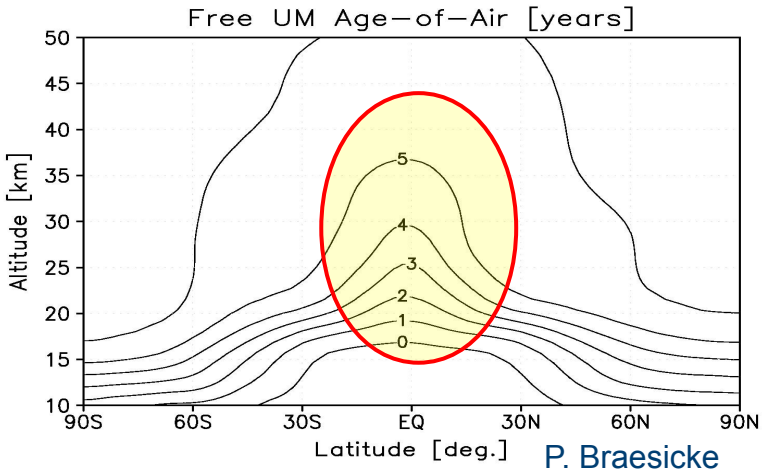
Stratospheric Circulation

- Investigate effect of nudging on Brewer Dobson Circulation
- Nudging produces more realistic width of tropical pipe
- Highlights problem in lower stratosphere





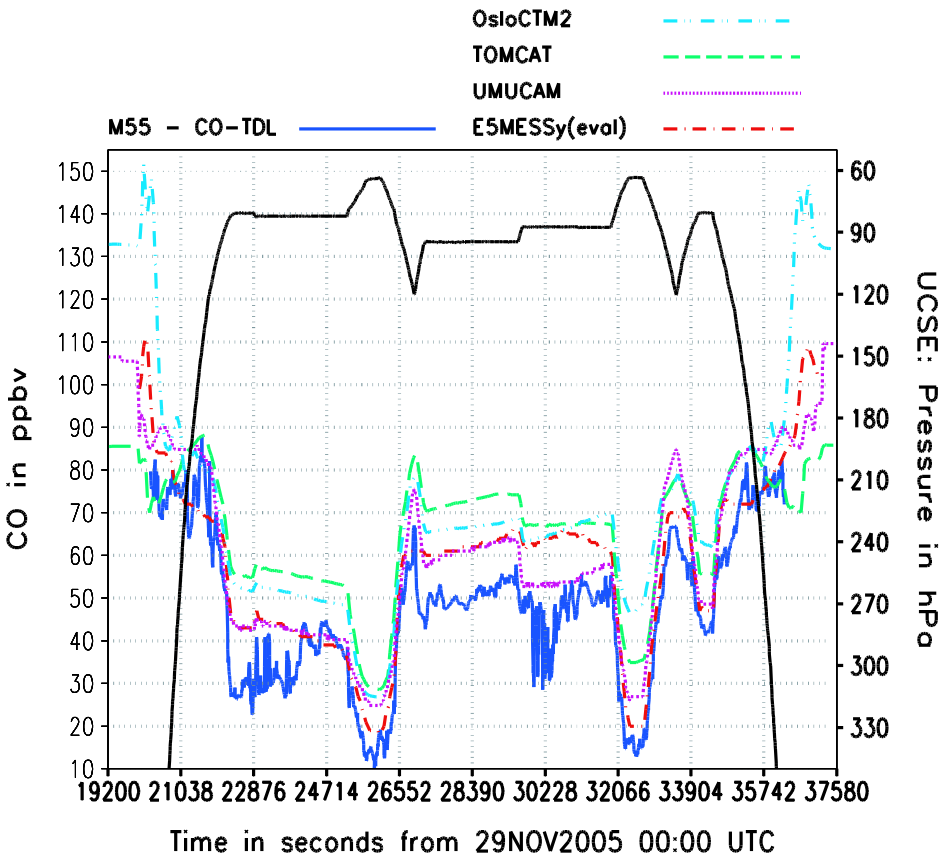
Stiller et al, ACP 2008



P. Braesicke

Comparisons to Campaign Data

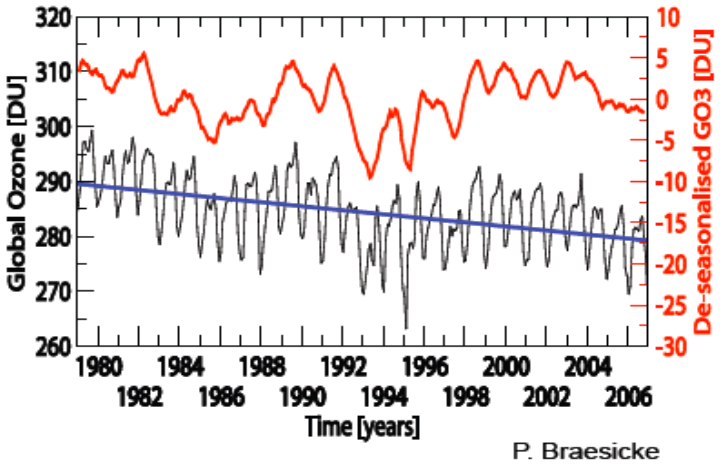
- Nudged model allows us to compare with episodic data from campaigns
- Example flight from the SCOUT-O3 campaign in Darwen
- Model reproduces features of CO well
- Campaign data confirms overestimation of O3
- Confirms results of other studies



M. Kunze, F Berlin

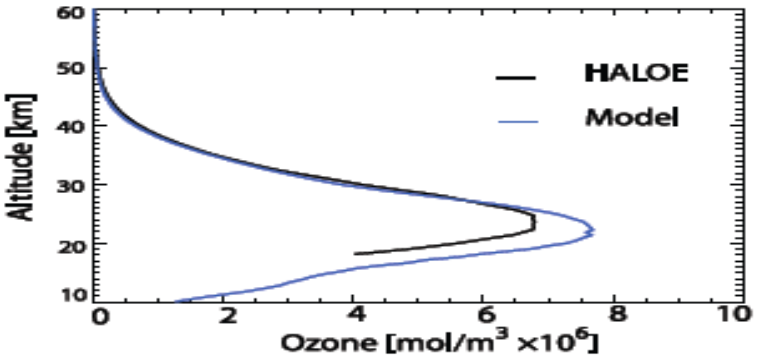
Application of Nudging: Pinatubo

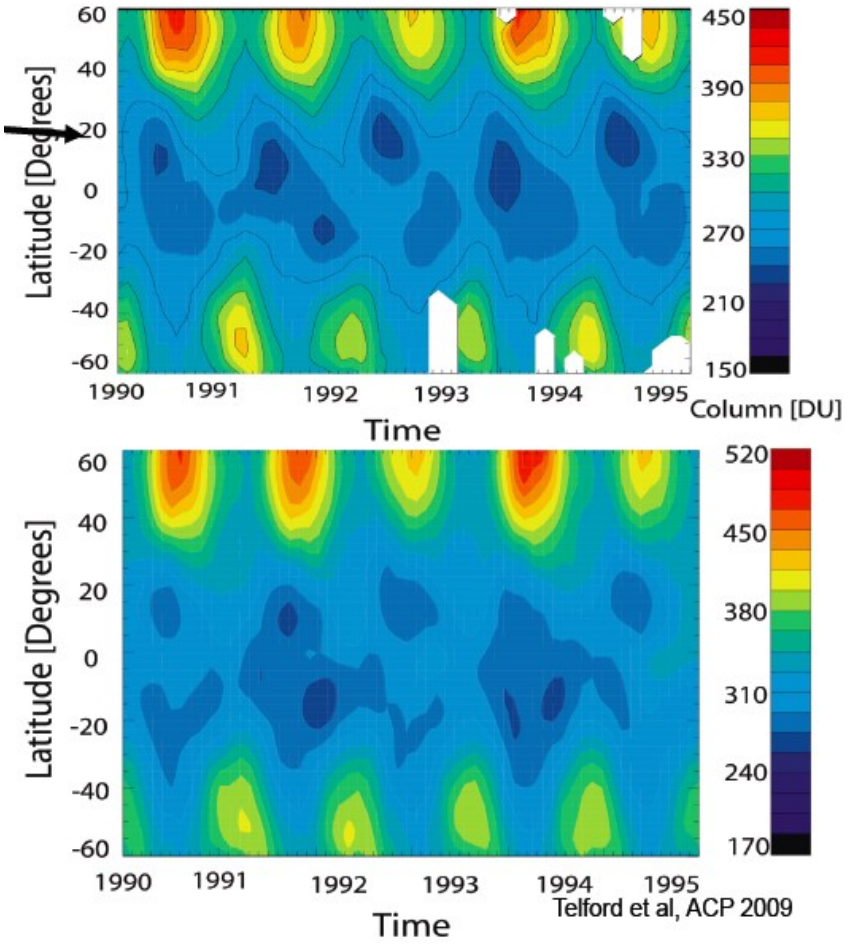
- Pinatubo was the largest eruption in the twentieth century
- The large blanket of sulfate aerosol heated the stratosphere and cooled the troposphere
- Caused record low values of stratospheric ozone
- Combine nudged model and satellite data to attribute causes of low ozone
- Use to investigate biosphere atmosphere couplings



Nudged Model Ozone Column

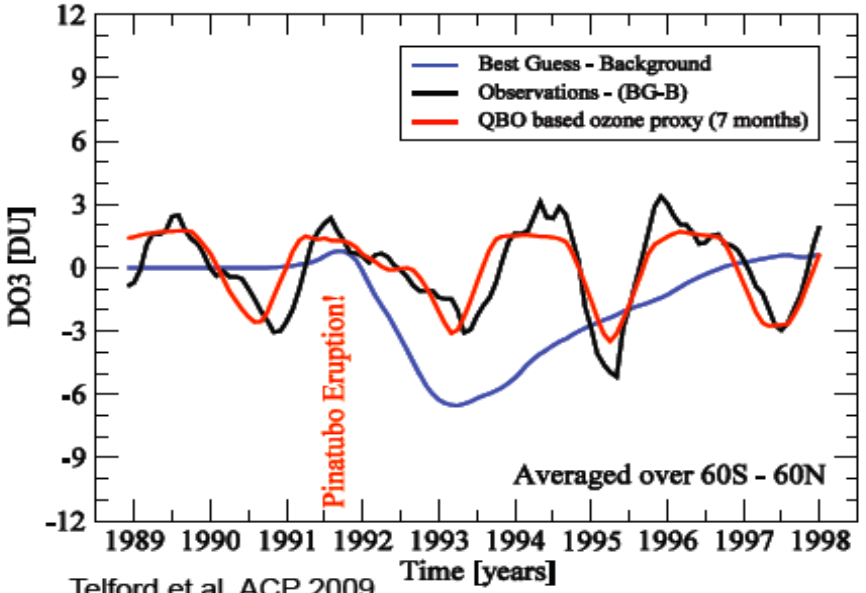
- Compare nudged model (bottom) to TOMS/SBUV data (top)
- Agreement good, pick up low values in NH spring after eruption
- Slight high bias everywhere
- HALOE indicates too much below vmr peak





Attribution of Global Ozone Changes

- Run nudged model with and without increased aerosol in chemistry
- Differences between runs attributed to chemical effects
- Dominant effect globally
- Remainder of variability attribute to dynamics
- Correlates well with QBO proxy

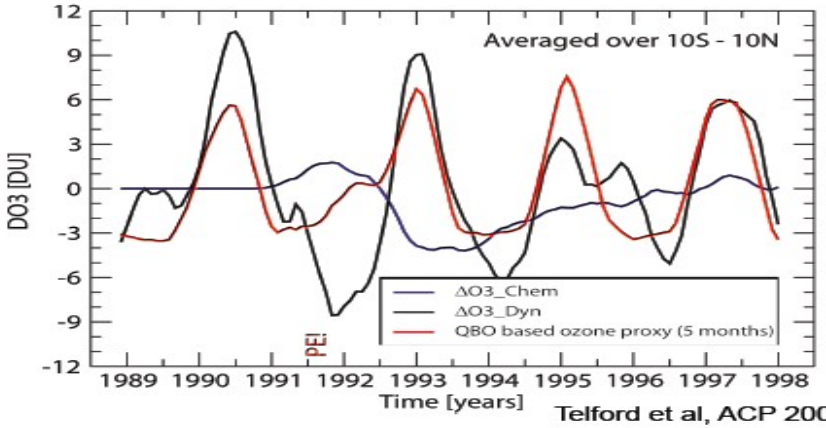


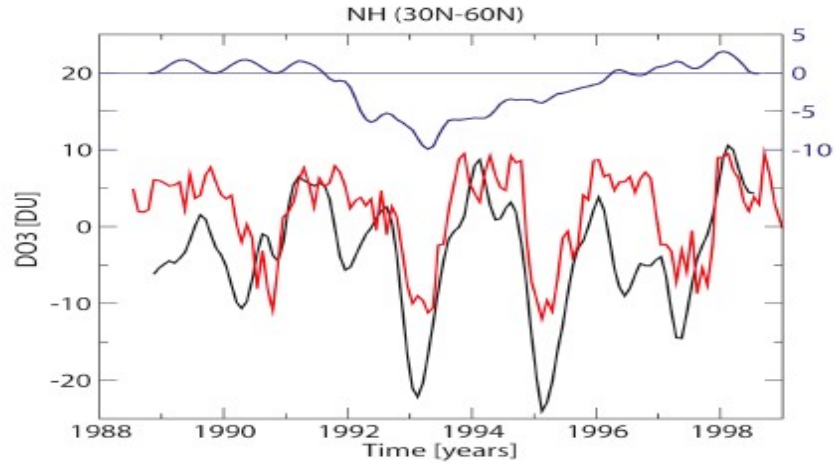
Telford et al, ACP 2009

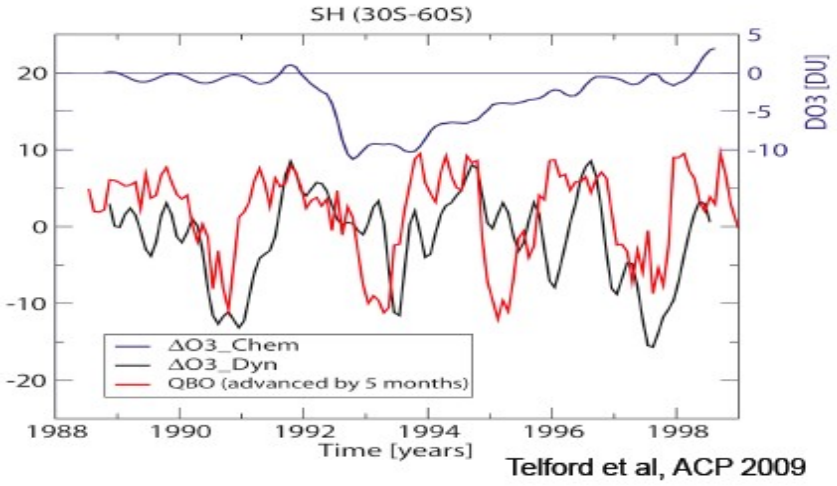
- Blue line is changes in ozone column caused by chemical effects
- Subtract from observed column
- Black line is residual which we attribute to dynamic variability
- Correlated with QBO proxy (red)

Local Ozone Changes

- Examine impacts of dynamics & chemistry in tropics & mid-latitudes
- Contribution of ENSO in tropics
- Large dynamical effects in NH

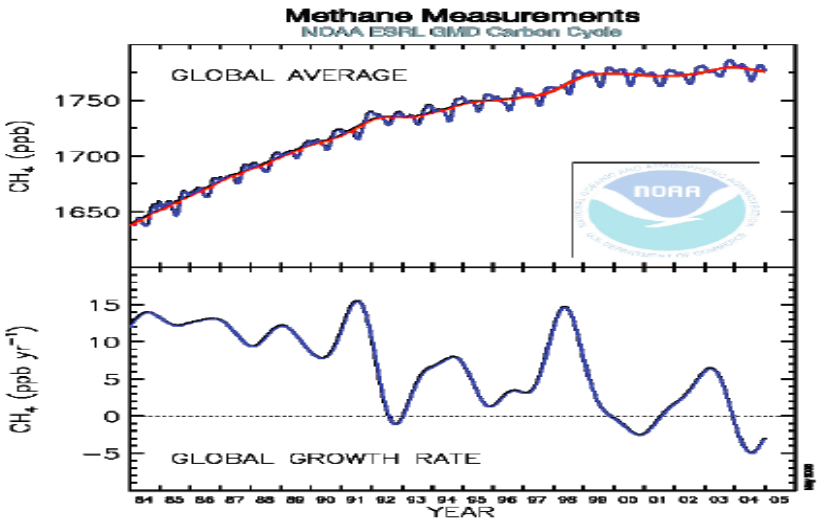


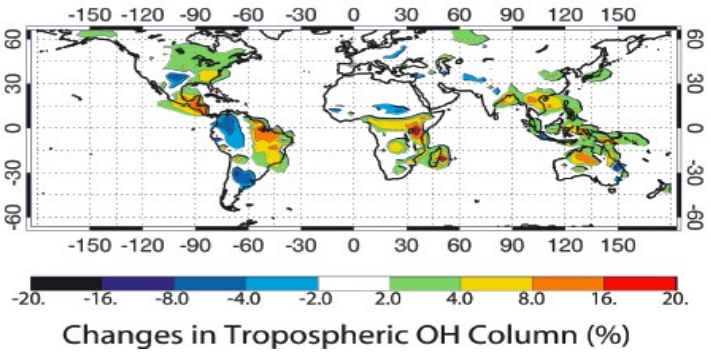




Pinatubo & Biosphere

- Pinatubo also linked to changes in troposphere due to cooler drier conditions produced
- This changes biosphere (drought, dieback) which changes emissions
- Investigate impacts of changes in isoprene emissions on oxidising capacity
- Sizeable effect, contributes to changes in methane growth rates





Telford et al, ACPD 2010

Conclusions

- Described a nudged version of the Met Offices UM
- Confirmed that nudging produces a more faithful representation of past conditions
- Demonstrated applications of the model for hindcast simulations (eg Pinatubo)
- Expands the range of data that can be used to validate the model and allows us to ignore large scale circulation issues
- Prospects for investigating how correcting errors in one area of the model improve remote predictions