Producing a “Nudged” version of the UKCA CCM

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Motivation

- GCM produces reasonable agreement over long timescales
- Doesn't reproduce day to day weather
- Still a few biases
- Complicates the study of chemistry
- Assimilate ERA-40 to reproduce observations
- Allow chemistry to be studied in 'isolation'
- Increases data sets available for validation

Introduction

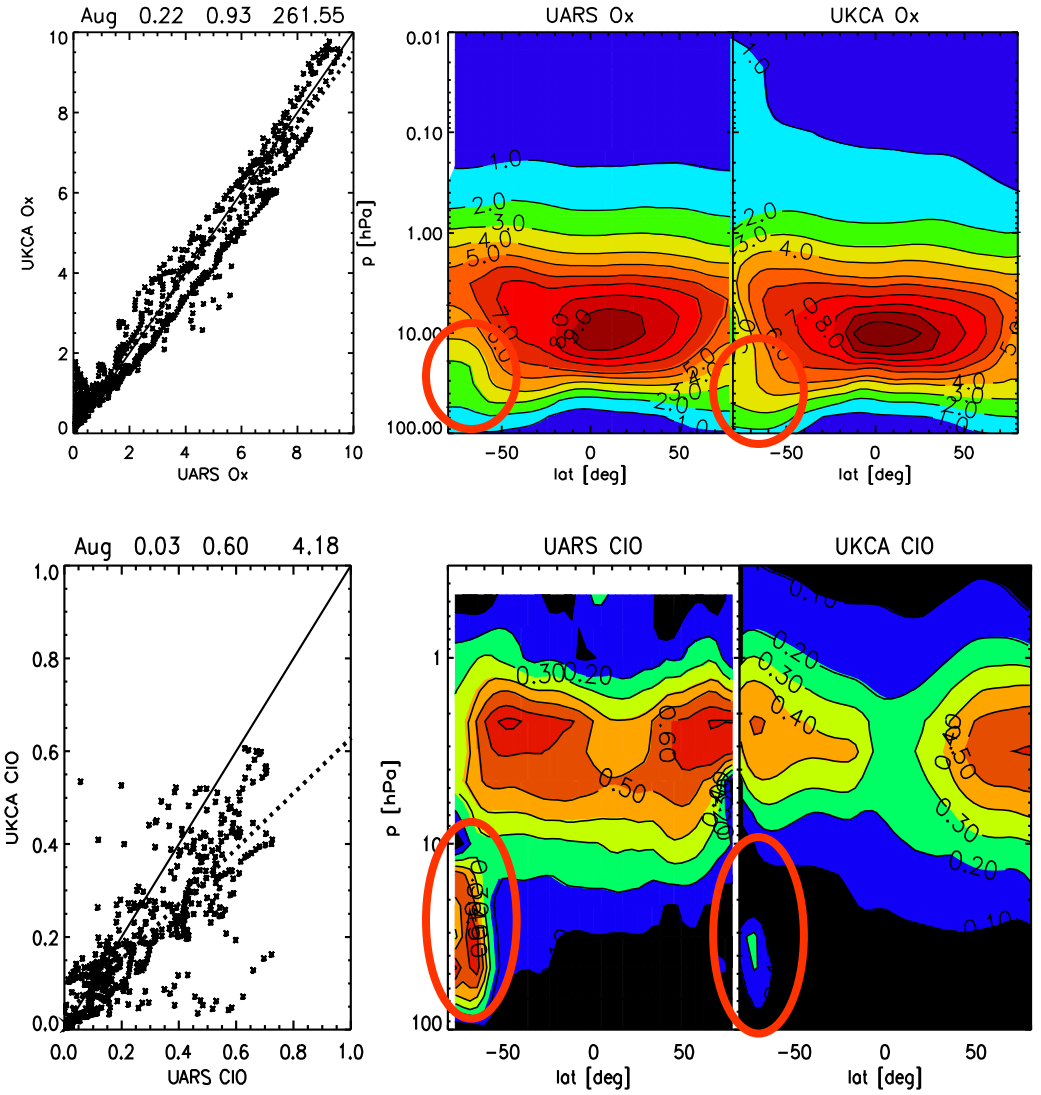
- Introduce model & nudging
- Demonstrate that nudging works
- Compare to some ‘real’ data
- Describe some applications for nudging
- Talk about prospects for the work

Model

- Model is Met Office GCM: 'Unified Model'
- Resolution 3.75 ° ×2.5° horizontally and 60 levels from 0 to 80 km vertically.
- UKCA new (aerosol)-chemistry climate model
- Collaboration between NCAS & Met Office
- Tropospheric & stratospheric flavours
- Concentrate on stratospheric model

Specimen UKCA Results

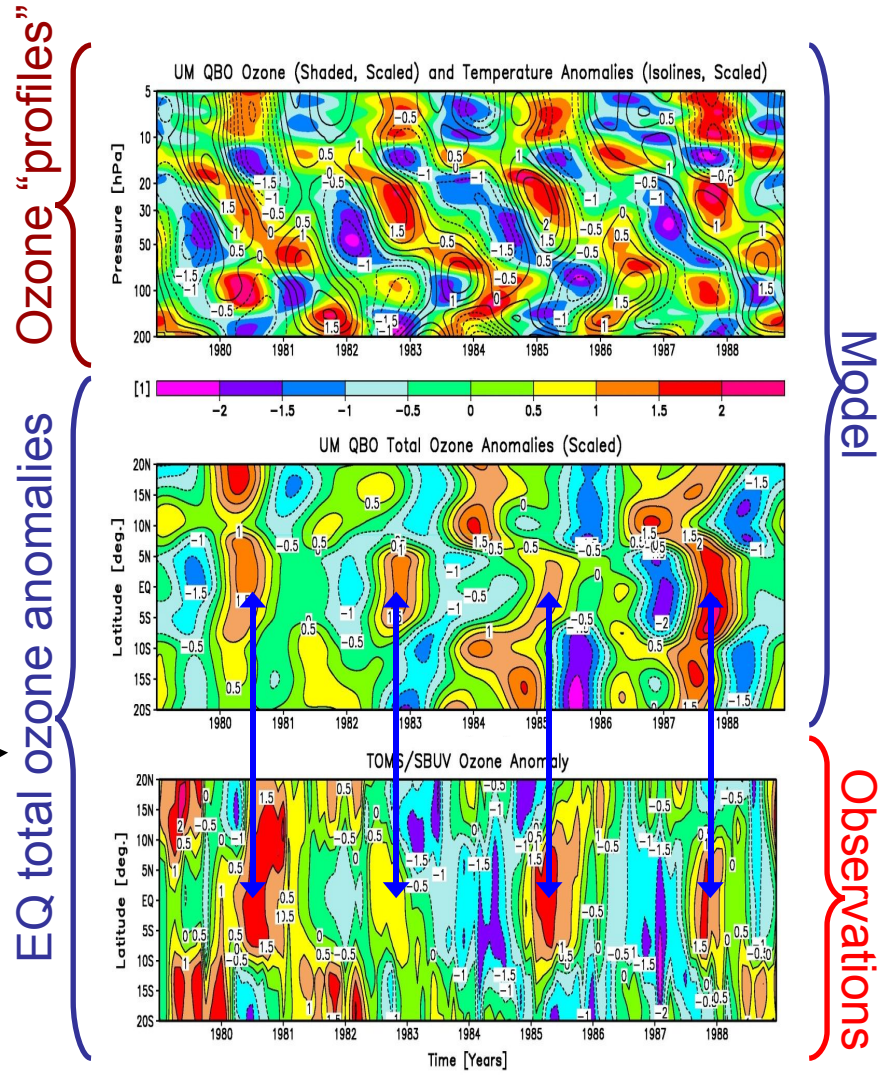
- Plot some UKCA results
- Plot O_3 zonal mean in model & UARS climatology
- In general agree, but too small hole
- Examine ClO
- In general good, but too little over Antarctica



(image courtesy of O. Morgenstern)

History of Nudging

- Nudging is weak form of data assimilation on global scales
- Constrain GCMs using meteorological analyses
- Developed by ECHAM to validate chemistry
- Used in Old UM to study clouds and QBO
- We introduce to new UM comprehensively



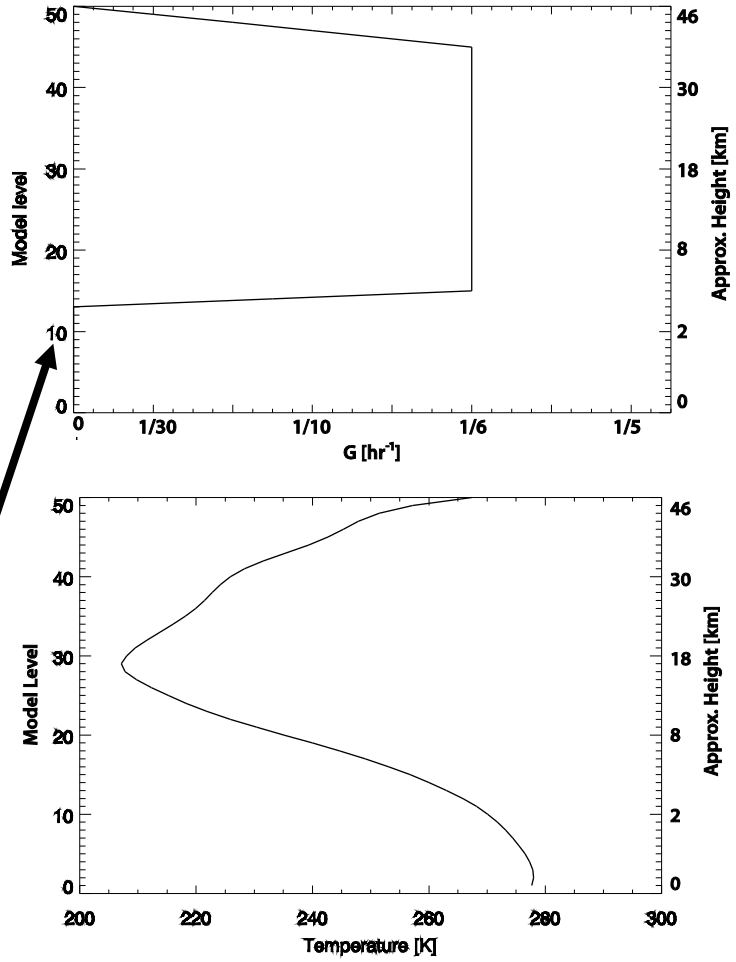
(image courtesy of P. Braesicke)

Set-up of Nudging

- Data from ERA-40
- Adjust u, v, T (θ)
- Interpolated onto model grid, levels, time
- Introduce as extra term

$$XXX_{MOD}\, Xa(X_{DAT}\, XX_{MOD})$$

- Small relaxation parameter (a=0.056)
- Limited height range

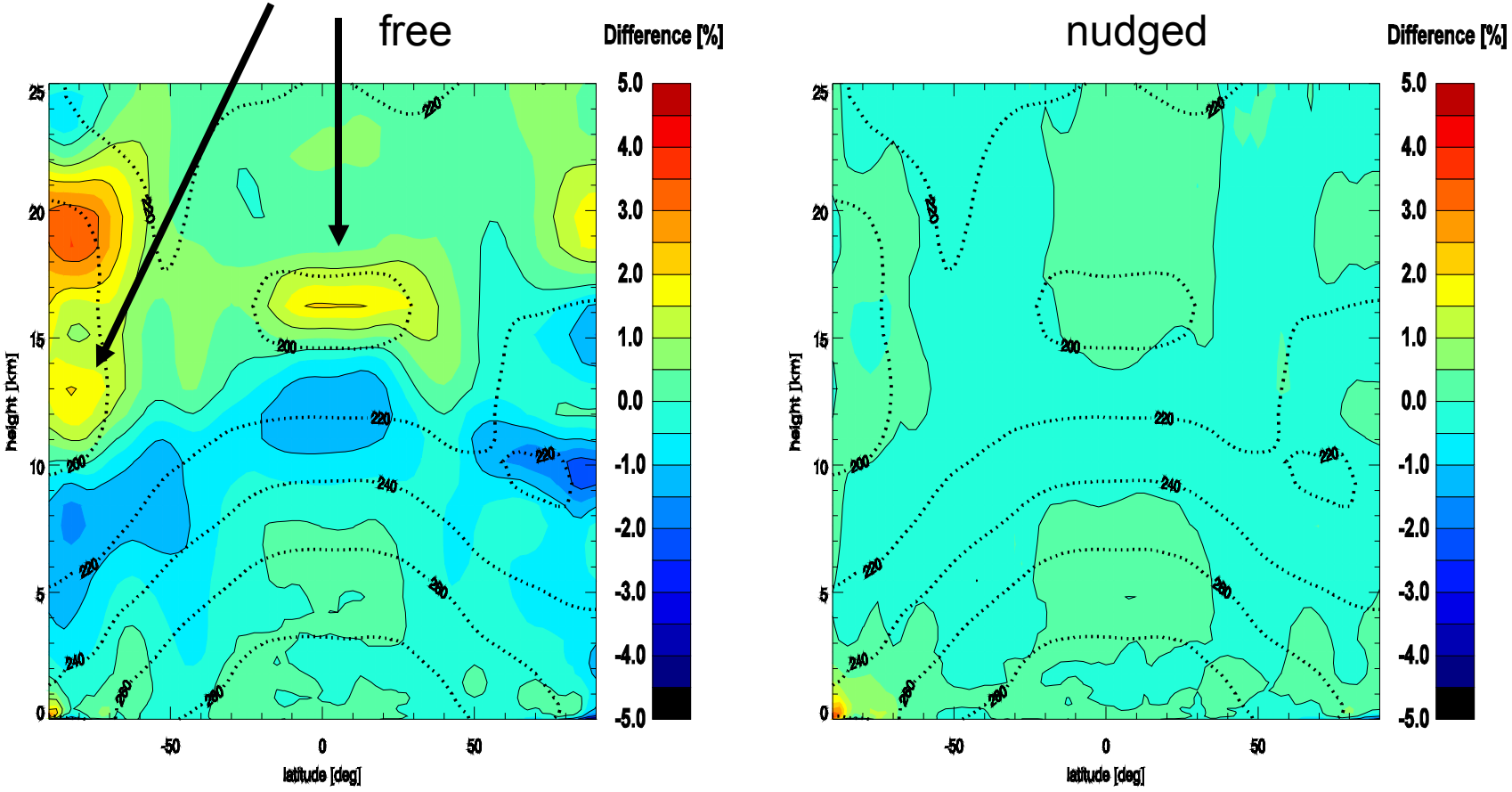


Validation of the Nudging

- Compare to ERA-40 data
- Use model w & w/o nudging
- Evaluate biases
- Calculate absolute differences & variability
- Study variables directly (θ,u) & indirectly (P_s, precip.) adjusted
- Sensitivity studies to chosen parameters
- Fuller description in ACPD

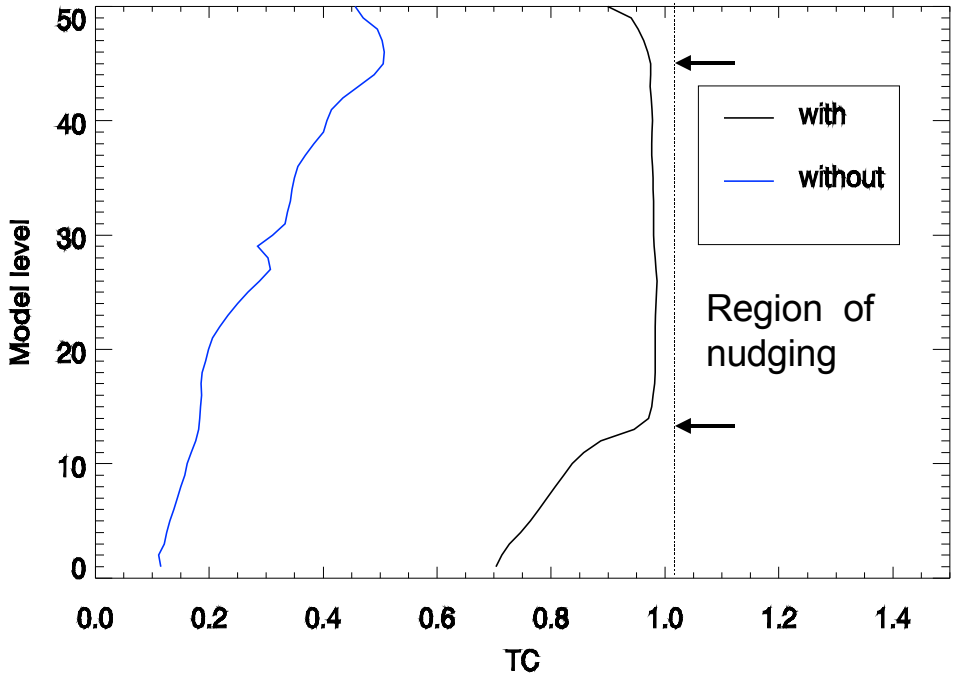
Potential Temperature (θ) Biases

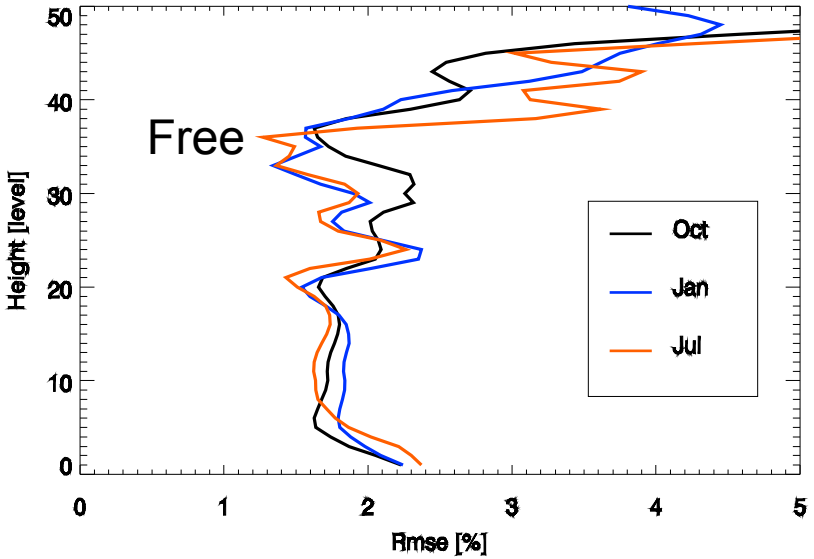
- Bias in model (free and nudged) wrt data
- Warm biases in model disappear

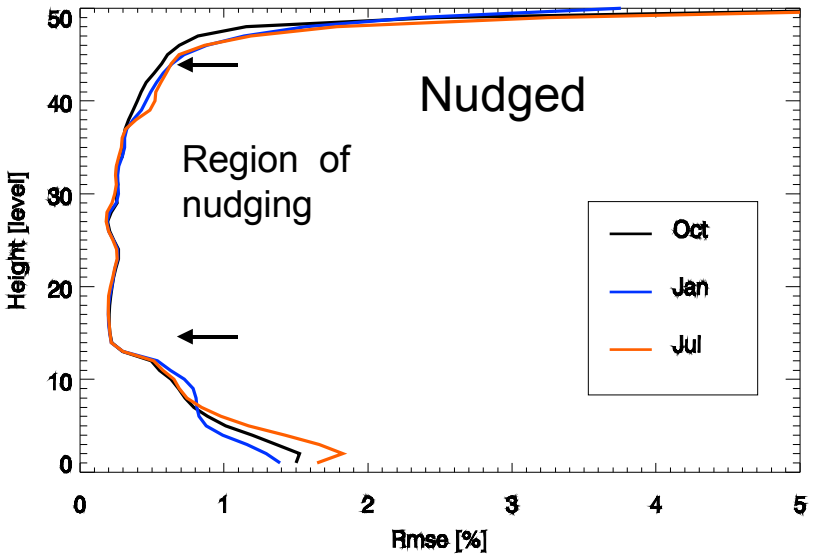


Differences & Variability

- Examine differences and correlations in time and space

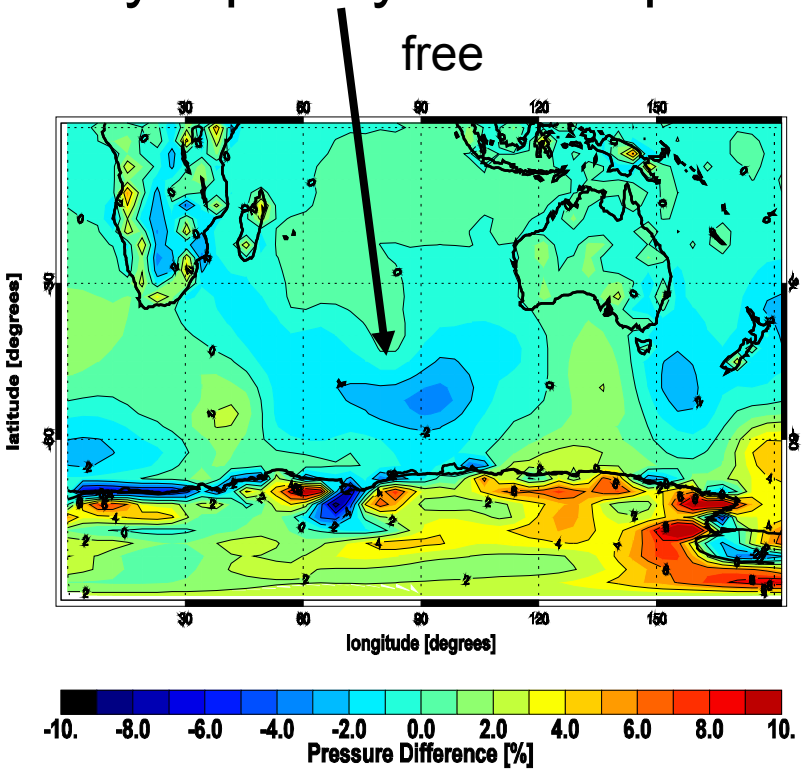


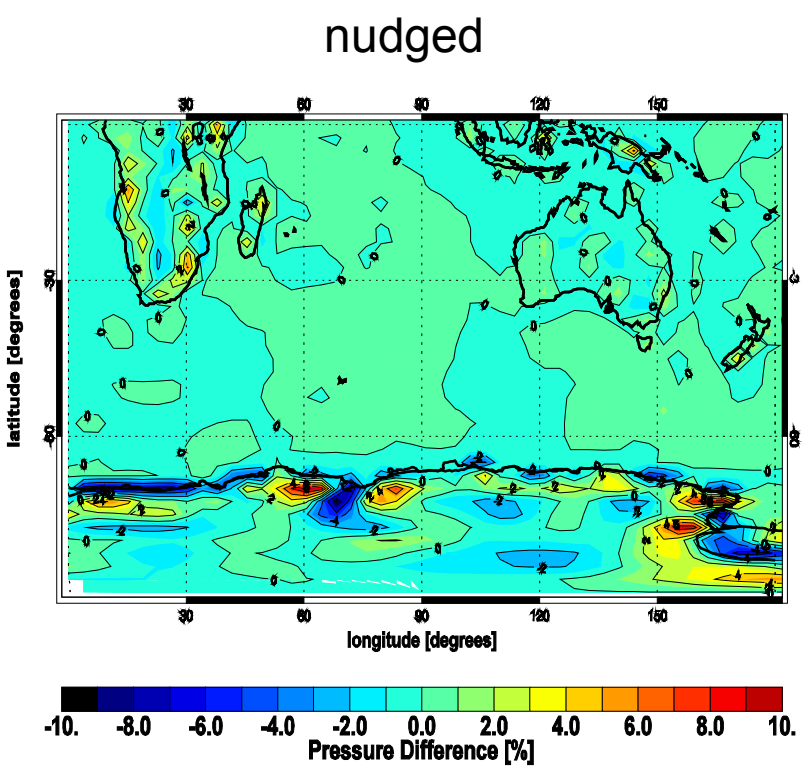




Surface Pressure

- Look at a variable that we don't adjust
- Make snapshot comparisons between models (with & w/o nudging) and data
- Synoptic systems reproduced in S Ocean

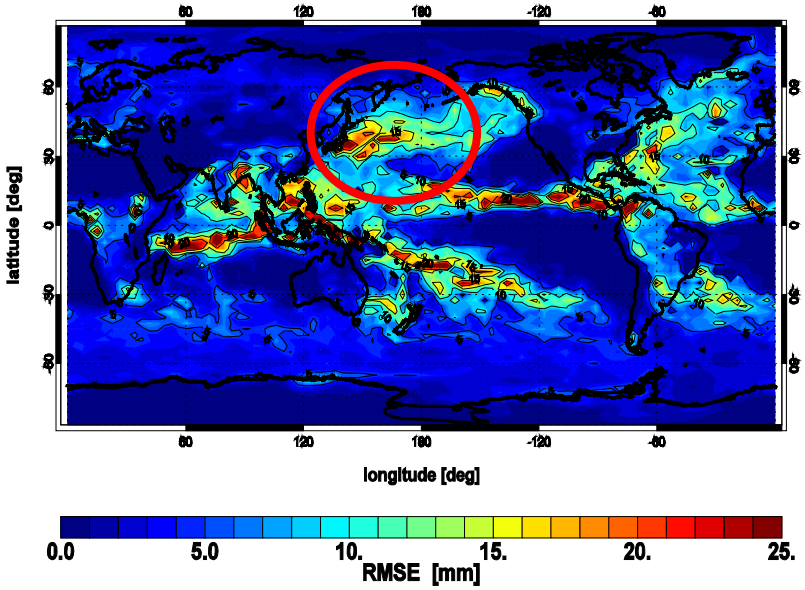




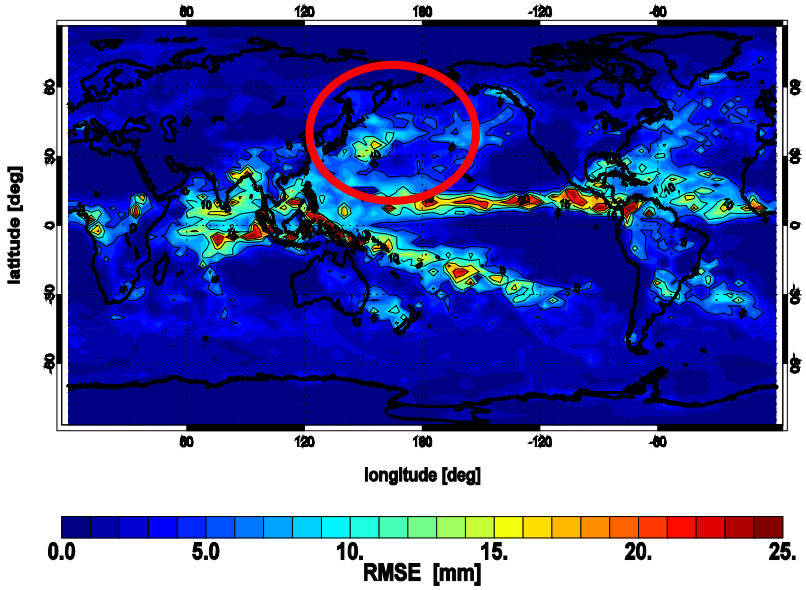
Precipitation

- More complicated variable to model
- Plot differences (RMSE) between model & ERA-40
- See large improvements in extra-tropics
- Reduced improvement in tropics

free

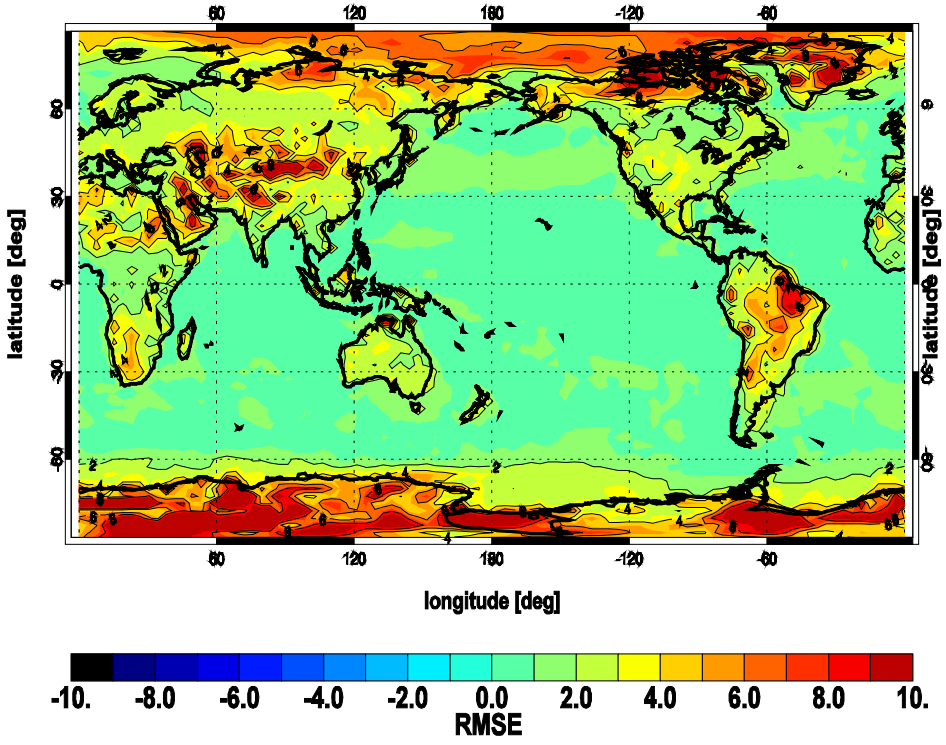


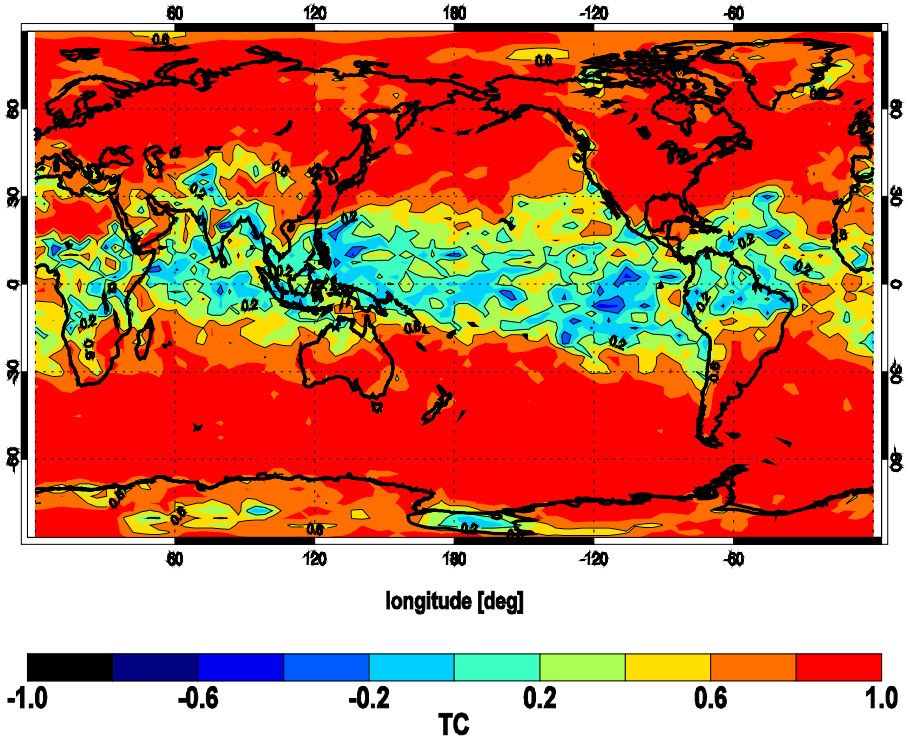
nudged



Spatial Variation

- Look at surface differences & correlation in θ
- Prescribing SSTs constrains surface
- Correlations best in extra-tropics
- Errors still small in tropics though correlation lower



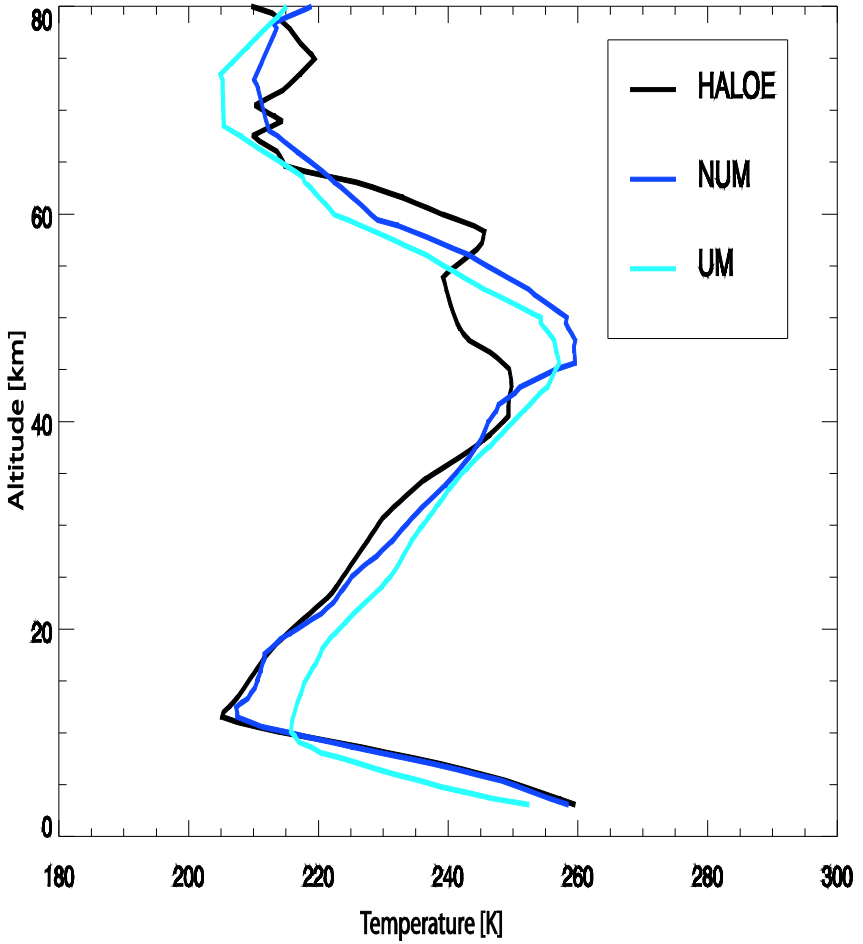


Nudging for Model Validation

- Improved correspondence to ERA-40 demonstrates that nudging works
- Allows us to represent instantaneous weather
- Can compare to episodic data (satellites, campaigns..)
- Provide examples to demonstrate this
- Start using to examine chemistry

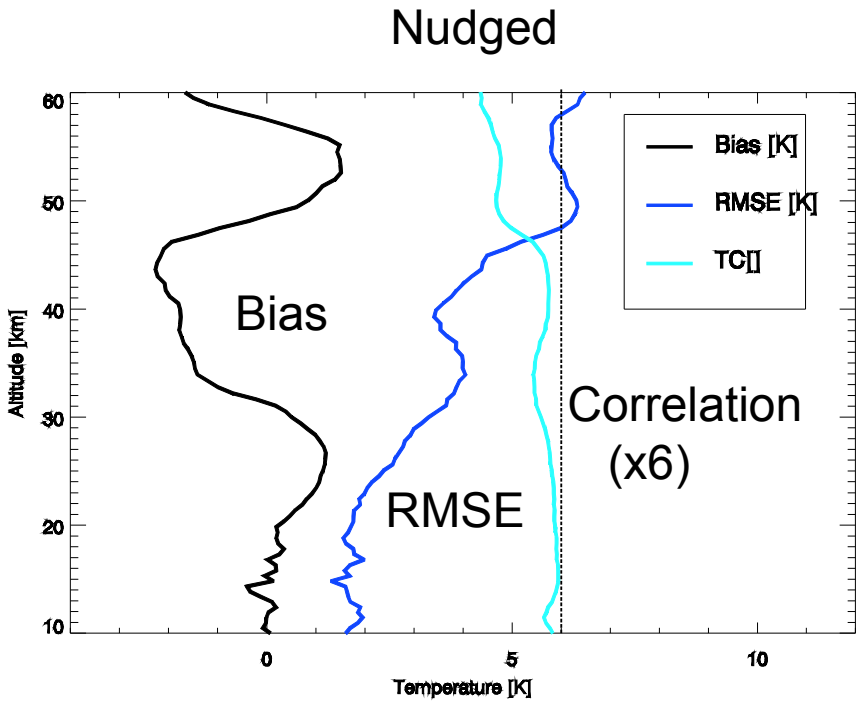
Comparing to Satellite Data

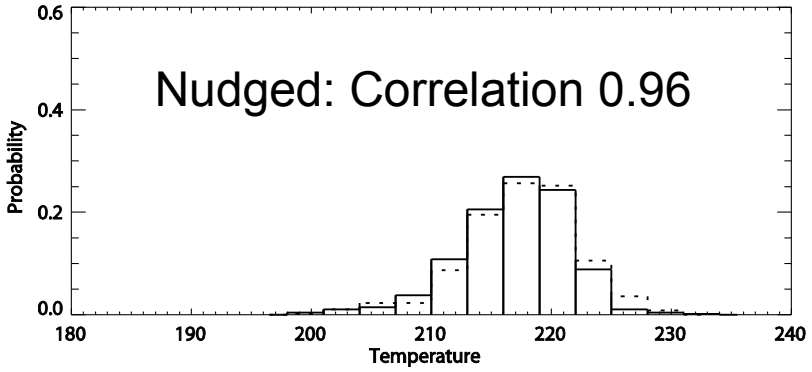
- Compare to HALOE Profiles (T, O_3, CH_4)
- Concentrate on T as simpler
- Show example from Sep 1999 at 50°S
- Without nudging large tropopause difference
- Differences still above nudging (40-50 km+)

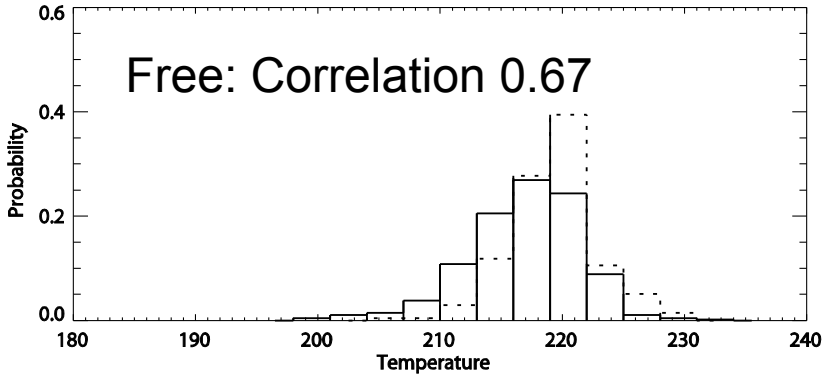


Quantitative Assessments

- Make quantitative comparisons with HALOE
- Use bias, RMSE and correlation
- Compare PDFs for T at 30 hPa (Sep-Dec '99) for greater than 30° N

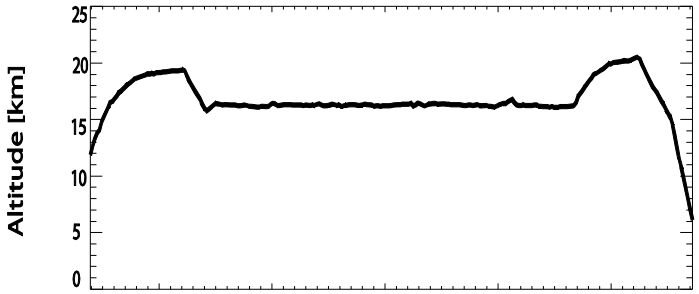


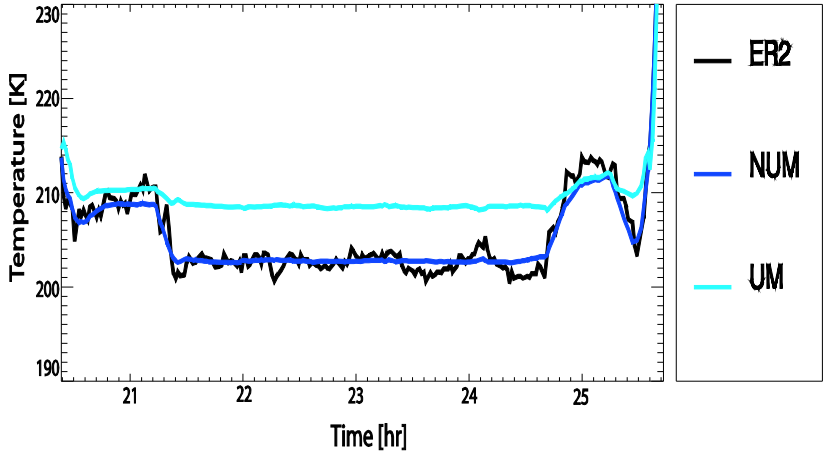




Comparing to Campaign Data

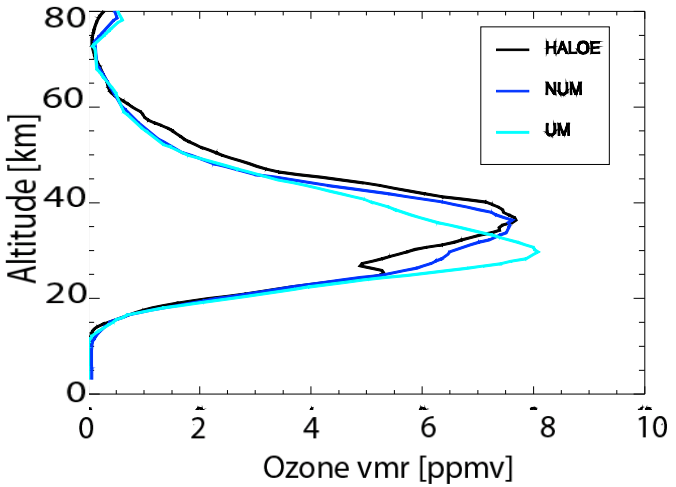
- Look at NASA ER-2 aircraft in campaign (THESEO/SOLVE)
- Compare flight data to nudged & free models
- Nudging captures large scale structure
- The chemistry is more complicated

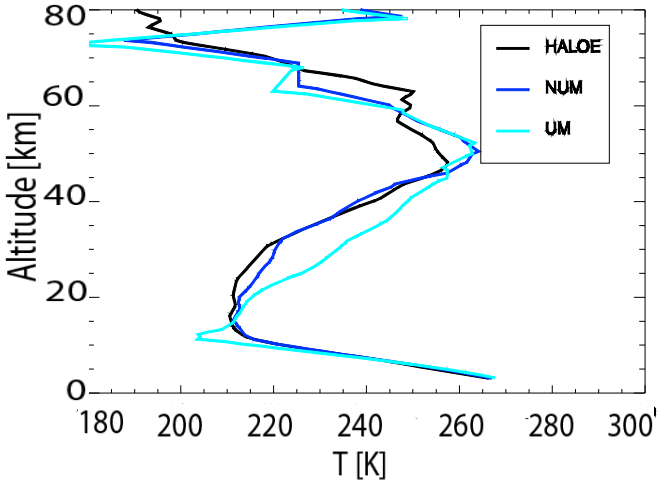




Chemistry Profiles

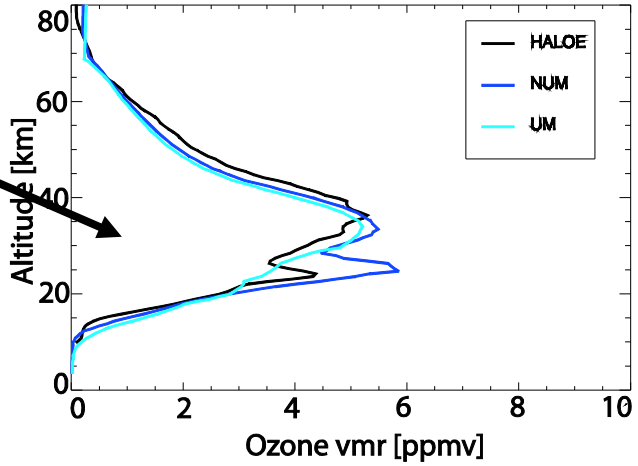
- Look at O_3 profile early Nov '99 65° N
- For reference include T profile
- Nudging produces better agreement
- Still some differences
- Other factors at play (eg NOx, initialisation)

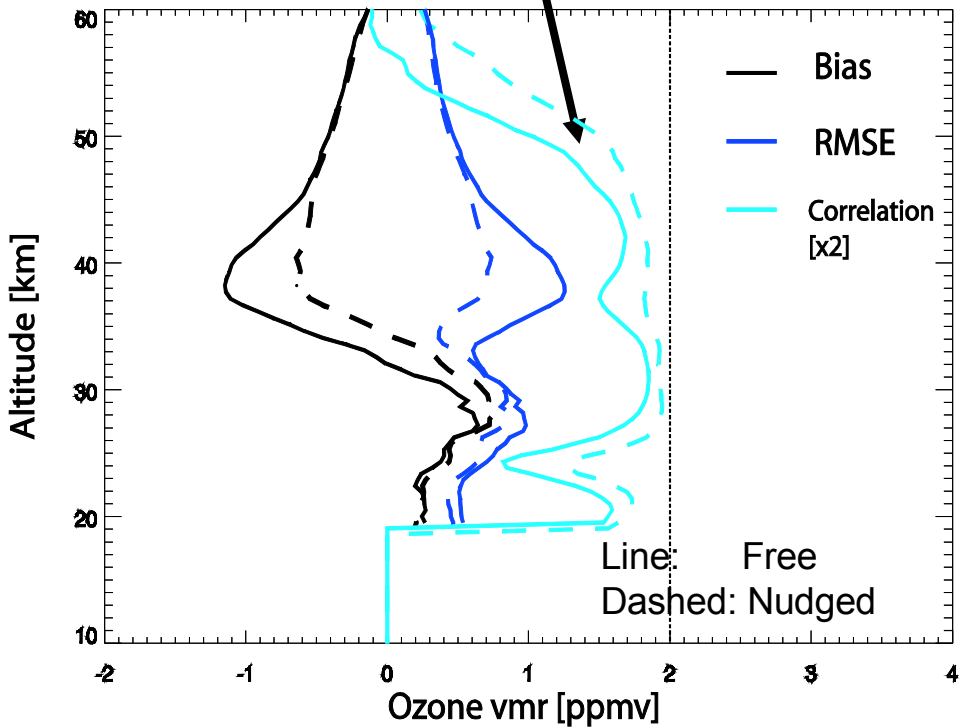


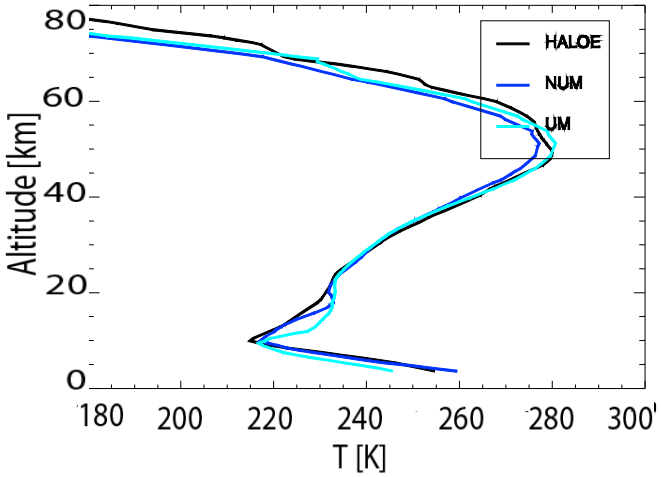


Chemistry Profiles

- Nudging doesn't always improve
- Look at quantitative assessment (Sep thru Dec 1999)







Modelling Episodic Data

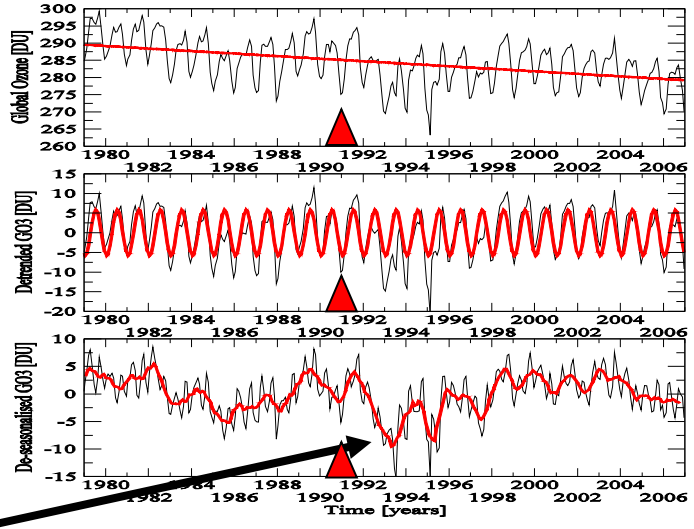
- Nudging allows GCM to be compared to episodic data
- Compare to campaign data (Theseo/SOLVE)
- Gives data greater statistical power
- Study specific events (eg Pinatubo, 2003 summer)

(image courtesy of NASA)

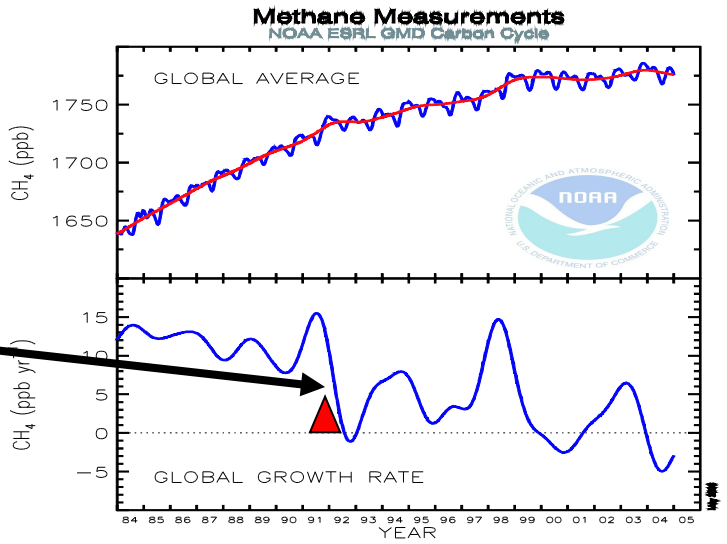
(image courtesy of the U.S. Geological Survey)

Pinatubo Eruption

- Erupted 15th June 1991
- Largest stratospheric aerosol loading in C20th (30Tg)
- Heated stratosphere
- Record lows of Ozone
- Cooled troposphere
- Change in rate of methane increase
- Changes in CO_2 increase as well



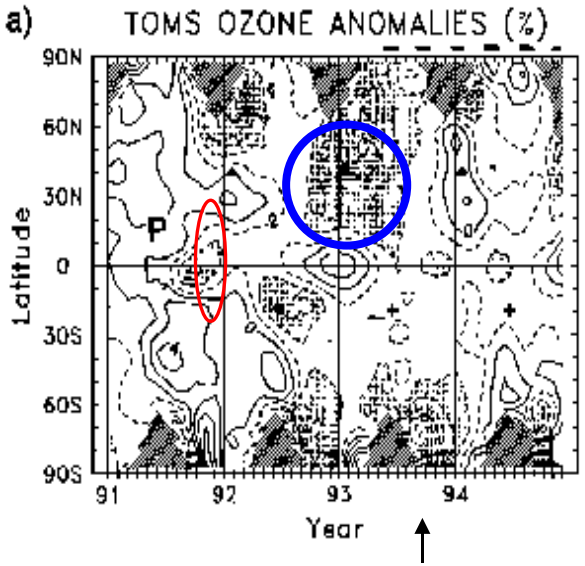
(image courtesy of P. Braesicke)



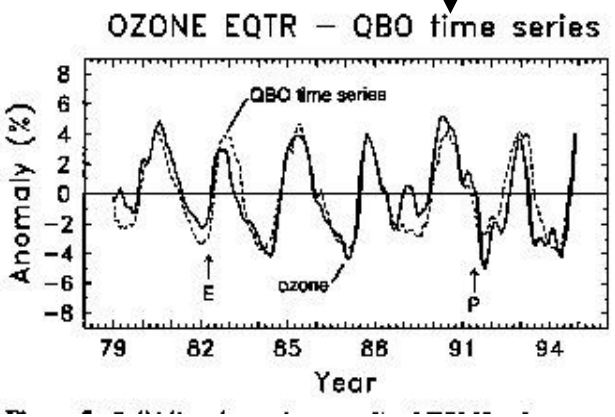
(image courtesy of NOAA)

Stratospheric Ozone

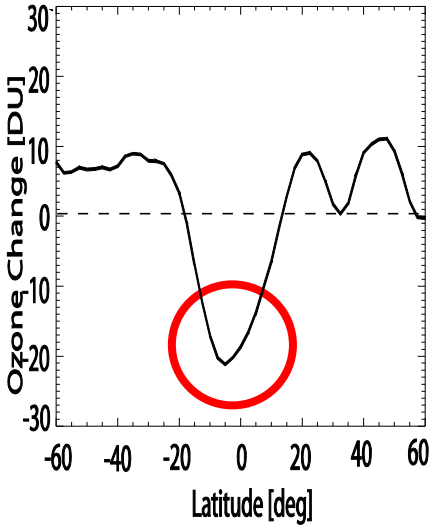
- Record lows in extra-polar region
- Preliminary results
- Caused by
- Higher Aerosol loading
- Hotter stratosphere
- More uplift
- Also QBO effects
- Investigate split
- Interesting test o UKCA chemistry

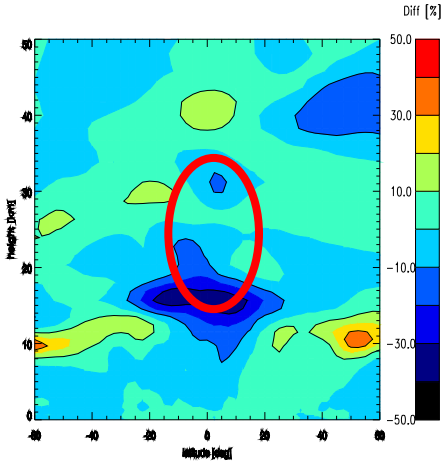


(from Randel et al 1995)



Nudged Nov '91-'90

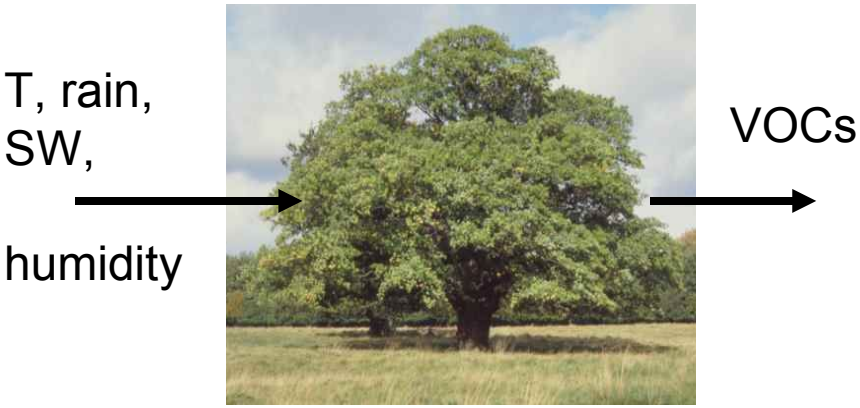




Earth System Modelling

- Earth system model QUEST
- Pinatubo interesting test
- Nudge to constrain atmospheric response
- Test effect on other parts of model
- Try with biosphere
- Consider feedbacks

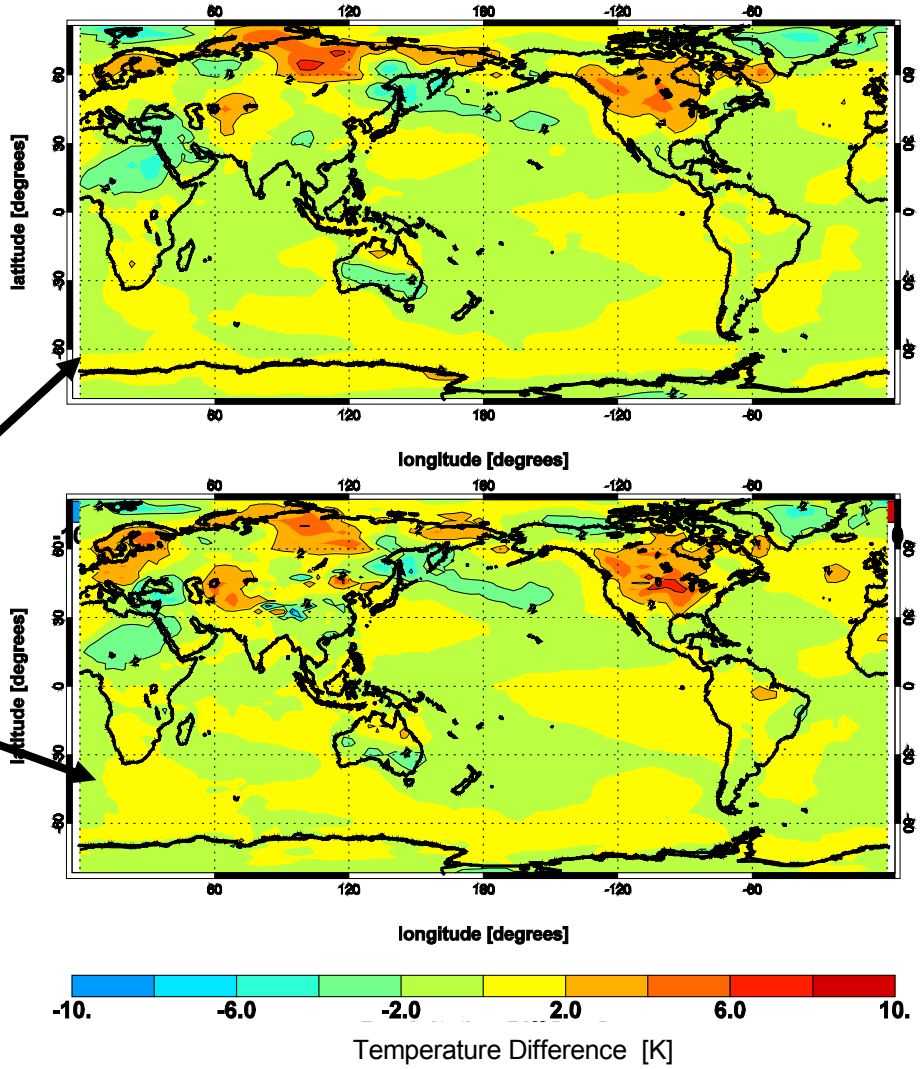
(image courtesy of U. Bristol)



(image courtesy of P. Young)

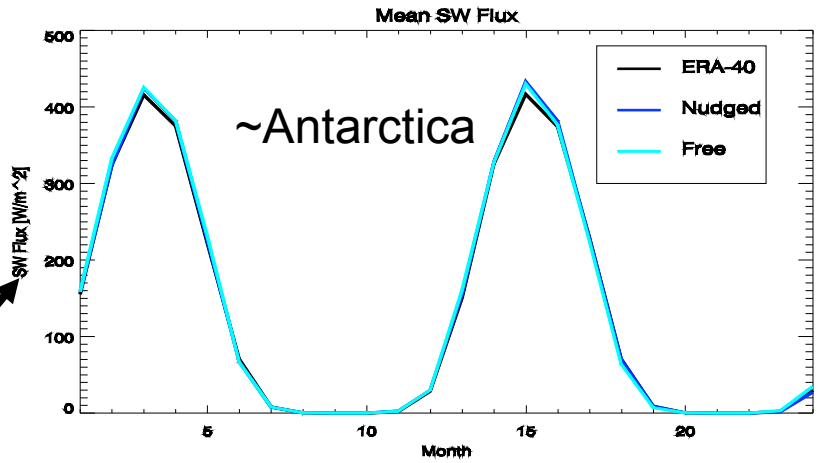
Surface Effects

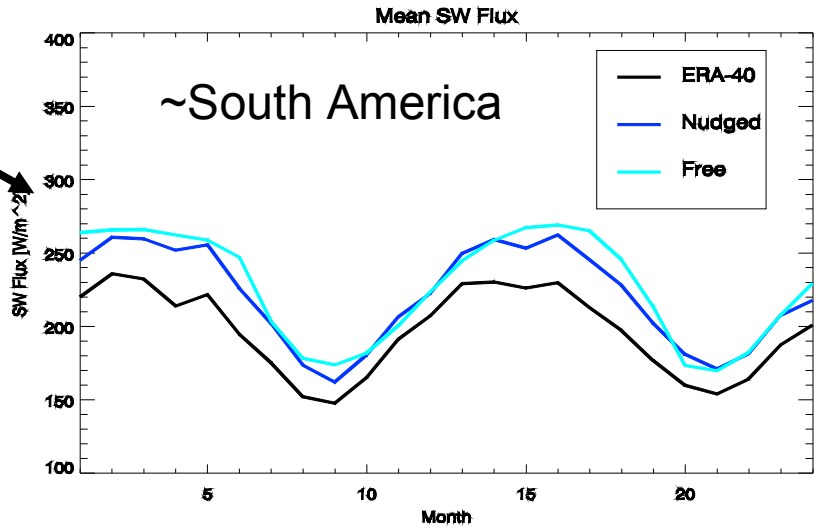
- Surface where atmosphere interacts with biosphere
- Radiative effects moderate surface T
- Compare ERA-40 with Nudging for DJF post Pinatubo
- Both show winter warming/ tropical cooling



Nudging vs Analyses

- Why use nudging rather than analyses?
- More comprehensive output
- Same set-up as ‘finished ’model
- Eg Look at SW Flux
- Can test feedbacks (biogenic emissions etc) in same model





Oct 1990

Sep 1992

Prospects

- Model works, beginning to apply
- Shown preliminary studies of some effects of Pinatubo, finish these studies
- Use model to help validate UKCA
- Allows us to make direct comparisons with other NGCMs/CTMs (ECHAM,TOMCAT..)
- And hopefully many other uses….

Summary

- Nudging has been added to UKCA model
- Improves agreement with ERA-40 analyses
- Full evaluation complete & published
- Allows study of chemistry in isolation
- Allows use of episodic datasets