Development and Assessment of a Nudged Version of the UKCA Model

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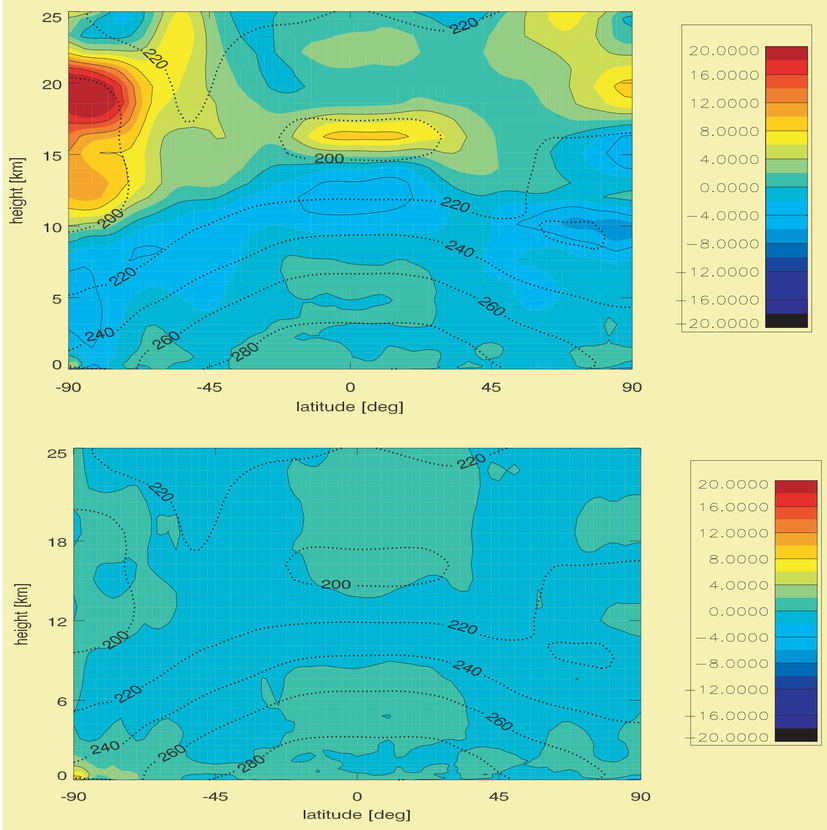
Introduction:

General Circulation Models provide a good/reasonable description of the climate over a timescale of months and longer, though there are possible biases. However the complexity of the climate system makes impossible the reproduction of the "weather" on shorter time scales.

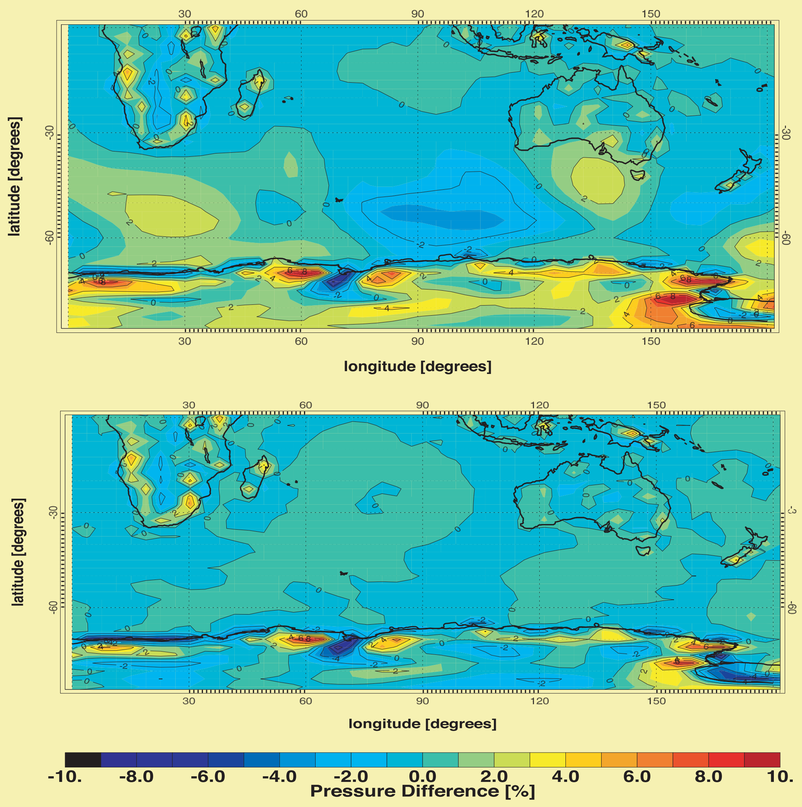
This makes it difficult to compare the models to data taken over short timescales, such as campaign data, and to study processes with short timescales.

The solution, proposed by Jeuken et al (1996), was to assimilate data from meteorological analyses and "nudge" the model towards this data. The technique has been successfully incorporated into several models, most notably the ECHAM model. However this is the first time this capability has been added to the UKCA chemistry climate model (Morgenstern et al, 2007).

We present here an overview of the model and demonstrate that it is able to both remove biases and give a more realistic description of synoptic scale systems. More details are given of the set-up of the model and methods used to assess its performance.



Removal of Biases: Difference in zonal mean potential temperature between our model and the ECMWF analyses averaged over October 1999. The dashed lines are isotherms.The plot above shows this with no nudging and the plot below with nudging added. The nudging removes the warm biases in the tropical tropopause and over the Poles.



Reproduction of Synoptic Systems: Difference in surface pressure between our model and the ECMWF analyses for 30th October 1999. The top plot shows this without nudging and the bottom plot with. the nudging. The large scale storm systems over the Southern Ocean are now in the same phase in the model and the analyses.

Model Setup:

The GCM used is the new dynamics UM (v6.1) with

- Horizontal grid of 3.75°×2.5°
- 60 vertical levels from surface to 84 km
- Dynamical time-step of 20 minutes

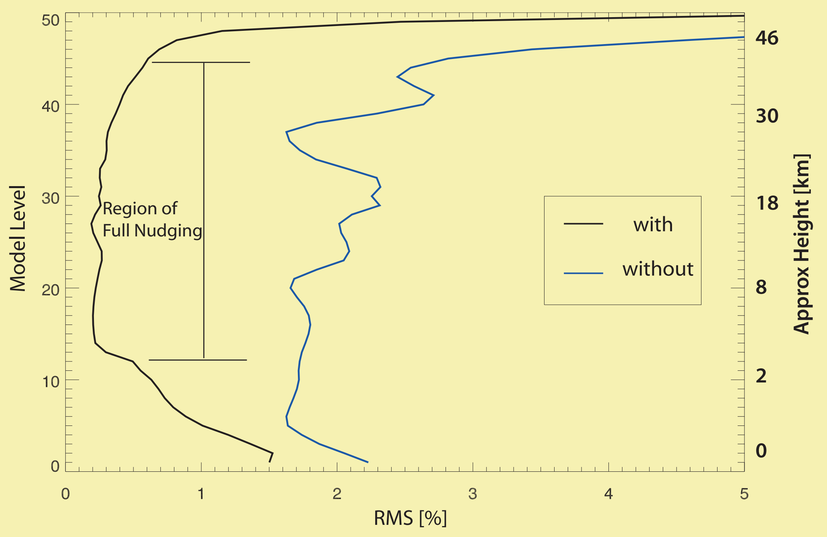
To this model is added a module that assimilates data from the ECMWF ERA-40 analyses. The variables assimilated into the model are

- Potential temperature (θ)
- Zonal wind (u)
- Meridional wind (v)

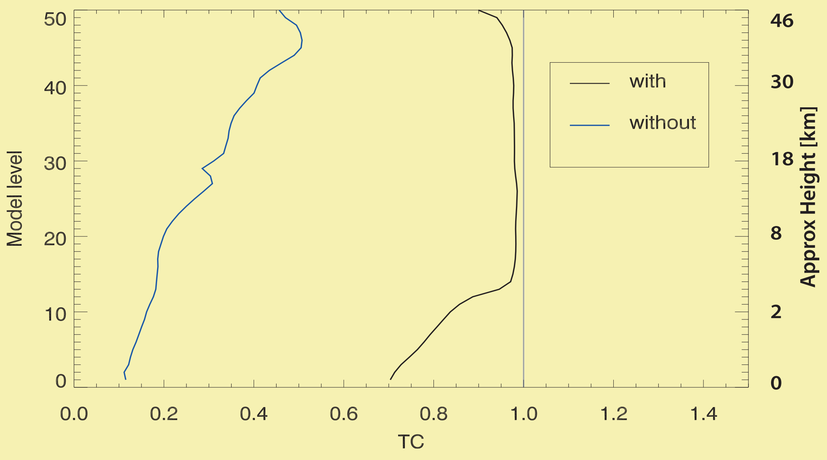
The data is assimilated by adding an additional forcing term. The change in a variable, ΔX, for each timestep (Δt) is a sum of the free model forcing, F(X) and a nudging term:

$$\Delta X = F(X) + G\Delta t(Y-X),$$

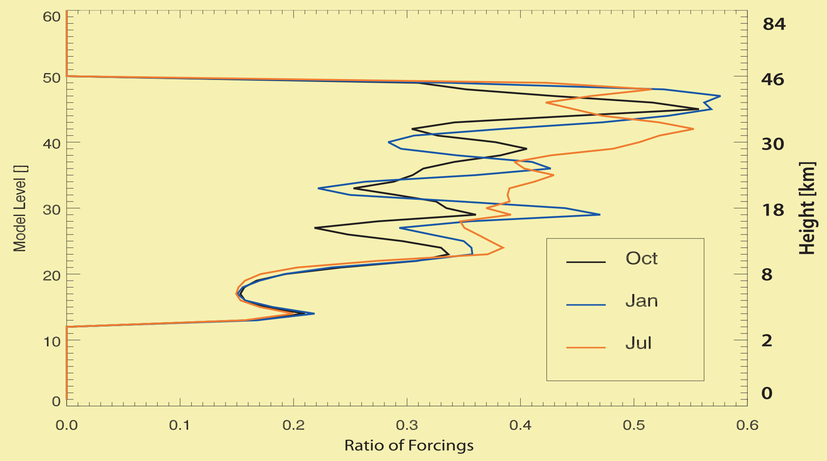
where X is the model value, Y is the value in the analyses and G is an (arbitrary) constant of proportionality.
We choose G to equal 1/(6 hr), the size of the time intervals in the ECMWF data. Nudging is used in the height range from about 3-45 km above the surface.



Magnitude of Errors: RMS difference in θ between the model and the ECMWF analyses, as a function of model level, in October 1999. The black line is with nudging added and the blue line without.



Representing variability of the analyses: Correlation in time of u between the model and the analyses, as a function of model level, in October 1999. The black line is with the nudging added and the blue line without. A grey line is added to show maximum correlation. The additon of nudging improves variabilty even in regions not directly adjusted.



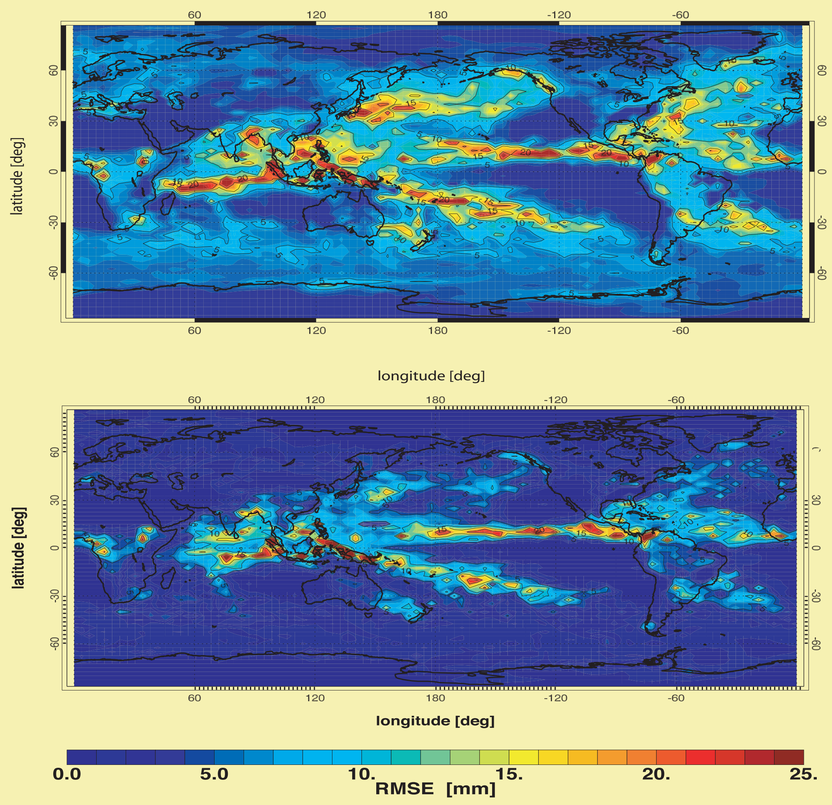
Tendencies: Ratio of tendencies for theta, of nudging to all others, as a function of model level for October 1999 and January and July 2000. This is always less than unity, indicating that the nudging never predominates over the model's own mechanisms. The increase with height reflects that the UM and ECMWF temperature structure diverges.

Performance Assessment:

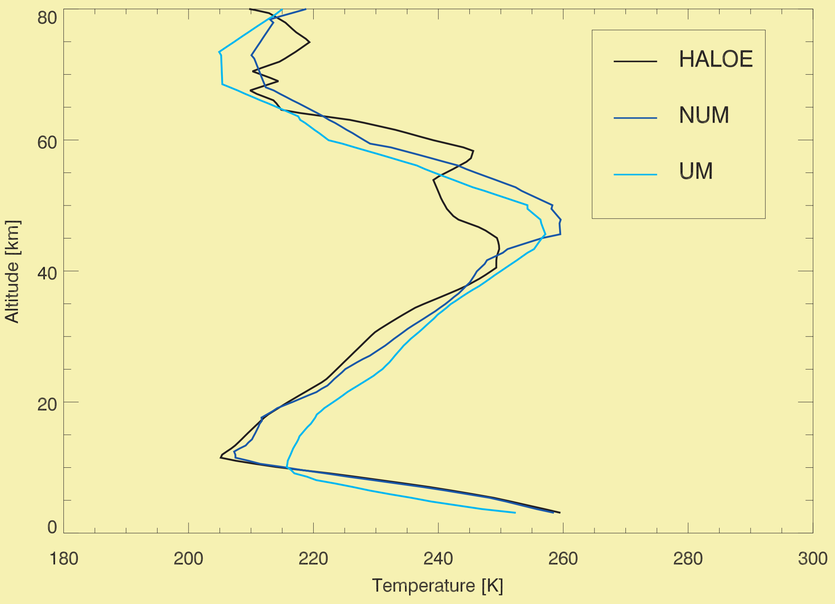
As well as making qualitative judgements about the model performance we use quantitative measures as well.

1. Bias of model vs analyses
2. Root Mean Squared difference (RMSE) between model and analyses
3. Correlation in time of the model and analyses
4. Correlation in space of the model and the analyses.

These are used to compare the nudged model with the free running



Derived Variables: RMS difference in precipitation between the model and the ECMWF analyses in October 1999. The top plot is without nudging and the bottom plot with. The different model physics produces some differences, but, especially in the extra-tropics the differences are much reduced as the large scale motions are synchronised by nudging.



Application of the Model: Comparison of a single temperature profile between the model, with and without nudging, and the HALOE satellite. The addition of nudging can produces a reasonable representation of the observed conditions, unlike the free running model. The model and the profile diverge above the region where the nudging is no longer applied (above 40 km).

Status:

- ► The capability to nudge has been added to the UKCA chemistry climate model (see Telford et al, 2007 for detailed description).
- ► Demonstrate that reduces biases and improves the description of the short term "weather"
- ► Show improvements in variables directly and indirectly adjusted
- ► Already applying to examining episodic data such as satellite profiles, aircraft and balloon data
- ►Start to use for studying chemistry

References:

1. A.B.M. Jeuken et al, On the Potential of assimilating meteorological analyses in a global climate model for the purpose of model validation, JGR 101 (1996)
2. O. Morgenstern et al, UKCA website http://www.ukca.ac.uk/
3. P. Telford et al, Description and Assessment of a Nudged Version of the New Dynamics Unified Model, ACPD 7 17,261-97 (2007)

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Summary: We summarise work done on developing a nudged version of the UKCA global aerosol chemistry climate model. We constrain a usually free running climate model using ERA-40 re-analysis data with the aim of reproducing the observed "weather" in the climate model over selected periods. This model allows more extensive use of data with short timescales, such as campaign data, to be used in model assessment, providing a more robust test of the chemistry model.