Atmos. Chem. Phys. Discuss., 6, S3252–S3256, 2006
www.atmos-chem-phys-discuss.net/6/S3252/2006/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "CHEM2D-OPP: A new linearized gas-phase ozone photochemistry parameterization for high-altitude NWP and climate models" *by* J. P. McCormack et al.

J. P. McCormack et al.

Received and published: 20 September 2006

Reply to Referee #2 Comments

The referee raises a very good question about the direction forward for ozone photochemistry parameterizations in NWP/DA systems. In discussing the origins of this approach and presenting our results in the context of both operational NWP and extended climate simulations, we have tried to make the point that CHEM2D-OPP and similar parameterizations are useful first-order approximations for ozone photochemistry. The utility in this approach is that, in simplest terms, it acts as an accurate, physically-based constraint on 3D prognostic ozone fields in the stratosphere with very little computational cost. There are numerous applications both in NWP/DA and climate applications where realistic 3D stratospheric ozone fields are required, but the details of the ozone photochemistry are not as important. Ultimately, development of increasingly complicated schemes will probably be less of a priority for NWP/DA applications, but refinement of existing schemes for both stratospheric and possibly mesospheric applications will likely improve these systems' performance as they are extended upwards in altitude.

One advantage of newer neural-network approaches such as Taylor and Bourqui (2005) for fast ozone photochemistry is that they are not sensitive to the assumed background reference ozone and temperature distributions. A possible disadvantage, however, is that they are currently based on box models with simplified ozone photochemistry whereas the CHEM2D model includes full (gas-phase) ozone photochemistry with a self-consistent treatment of temperature and radiative effects. Direct comparisons of both approaches in an operational NWP/DA system would be a valuable future exercise.

The CHEM2D model does not contain a treatment of tropospheric ozone chemistry, so our method is not applicable to the troposphere.

We will address these issues in revision along the lines outlined above, keeping in mind Referee 1's recommendation to limit detailed discussion of future work.

Response to specific comments:

The term "cold-start" is used to make the distinction the way we initialize the NOGAPS-ALPHA hindcasts and the way operational NWP/DA are commonly initialized. In the latter case, the forecast model is restarted using output from a previous forecast run that has been passed through an analysis system to include the latest observations. The intrinsic vertical and horizontal (or spectral) model resolutions for all variables are preserved in this method. In the present study, our cold start procedure takes operational NOGAPS analyses archived on specified pressure levels (i.e., not hybrid model levels), and often at slightly degraded horizontal resolution, and combines these fields

ACPD

6, S3252–S3256, 2006

Interactive Comment

EGU

with zonally averaged climatologies at upper levels where no operational analyses are available. These combined initial fields are passed through a non-linear normal mode initialization routine to ensure that these fields are in dynamical balance.

In the 6-day hindcasts performed here, spin-up or spin-down of relevant fields is not an issue between 1000-0.4 hPa where operational analyses are available. Above this level there is some spin-up as model dynamics evolve from their 2D initial states, but the effect on the ozone profiles presented here is minimal. We have conducted initial studies on the sensitivity of prognostic ozone to the upper boundary of the meteorological analyses in NOGAPS-ALPHA using a prototype univariate data assimilation system interfacing with the model. Results show that the ozone transport is significantly affected by the upper boundary level of the meteorological in the mesosphere, but the impact on ozone at altitudes below the 1 hPa level is small. This work is to be submitted shortly to Atmospheric Physics and Chemistry.

The presentation of 135/138-hour results here represents a choice on our part to demonstrate CHEM2D-OPP performance near the limit of the 6-day operational NOGAPS forecast length. In response to Referee 1, we are including some quantitative examples of hindcast ozone performance as a function of the forecast time from 12-144 hours for the Feb 7 2005 case (see below).

CHEM2D-OPP is applied between 500-0.1 hPa. Outside of this range, prognostic ozone is relaxed to the corresponding 2D climatological values as a function of pressure, latitude, and month in a manner similar to that described in McCormack et al. (2004).

In response to Referee 1's comments, we have produced figures illustrating the performance of the CHEM2D-OPP, GSFC2, and CD86 V2.1 schemes over the Northern Hemisphere on February 7 as compared to the 12Z NASA GMAO ozone analysis at 5 hPa. We have computed the difference between the ozone analysis (A) at 12UT on 7 Feb 2005 and NOGAPS-ALPHA ozone forecasts (F) as

ACPD
6, S3252–S3256, 2006

a function of forecast length (24-144 hours) at 5 hPa. The zonal structure in the analysis and 135-hour forecast ozone fields using 3 different photochemistry schemes (CHEM2D-OPP, GSFC2, and CDV2.1) can be seen here: http://uap-www.nrl.navy.mil/dynamics/html/chem2dopp/fig_r1.html. Values of (A-F) for each photochemistry scheme as well as passive ozone (no photochemistry) can be seen here: http://uap-www.nrl.navy.mil/dynamics/html/chem2dopp/fig_r2.html. Hemispheric mean and rms values of (A-F) for the 12UT 7 Feb 2005 verification time at 5 hPa, as a function of forecast length, can be seen here: http://uap-www.nrl.navy.mil/dynamics/html/chem2dopp/fig_r3.html. We plan to incorporate these figures into our revision. A more comprehensive evaluation of CHEM2D-OPP performance relative to MLS and other observations, to include other regions and times, will be the subject of future work.

The low ozone values at high Southern latitudes in July, compared to the URAP climatology, are likely due to issues with the model dynamics. An examination of July zonal mean zonal winds from this 1-year run shows that the zonal jet in the upper stratosphere is too strong and lacks the characteristic poleward tilt with height. The lack of a middle atmosphere gravity wave drag parameterization is likely to contribute to the excessive westerly flow in the upper stratosphere and mesosphere, which can in turn reduce the upward propagation of planetary waves in the winter stratosphere. The results are excessive descent of ozone-poor air within the polar vortex between 10-1 hPa and a lack of horizontal mixing by planetary wave activity in the lower stratosphere near 100 hPa.

The higher model ozone values in October in the souther polar region is likely due to the lack of heterogeneous chemical effects in the parameterized photochemistry. Although the background ozone climatology does include an October "ozone hole" minimum at high southern latitudes, the photochemical relaxation coefficient is still relatively small there and so the scheme does not draw the model ozone strongly toward the background ozone distribution in this case. These features of the model ozone distribution in July and October are discussed in the revised manuscript.

Minor comments:

These have been corrected in the revised manuscript.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 6627, 2006.

ACPD

6, S3252–S3256, 2006

Interactive Comment