

Interactive comment on “A new version of the CNRM Chemistry-Climate Model, CNRM-CCM: description and improvements from the CCMVal-2 simulations” by M. Michou et al.

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1 Response to Anonymous Referee #2

Thank you for your detailed review of our article. Please find below our responses to your remarks and suggestions that appear below in italics. The amendments to the text of the paper that we propose appear in bold.

1. *A weakness of the paper, as commented on by reviewer 1, is that it only documents performance and does attempt to explain the differences in performance.*

C582

The authors indicate that differences in the coupling method and changes to the radiation scheme may have caused the performance improvement. It is possible that investigating these causes would require a substantial effort. I suggest that more is made of the linkages between the different performance changes.

We include below the response we made to a similar comment of referee #1.

In response to your remark, we propose to amend our “Synthesis of the CNRM-CCM model performance and outlook p1154” paragraph as follows:

In the previous section we showed that the new version of the CNRM Chemistry-Climate Model, so called CNRM-CCM, had a better performance than the previous version. We did not conduct a step-by-step analysis of what caused the differences between these two models, **as that would be to a certain extent specific to our models**, but changes in the radiation scheme led to a better mean meteorological stratosphere.

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Stratospheric temperature biases in spring and winter at high latitudes are smaller or comparable to those of the CCMVal-2 models, with the exception of the upper stratosphere between 5 and 1 hPa where the model is too warm (5 to 9 K). This warm bias extends to all latitudes, is permanent throughout the year, **and simulations performed with no retroaction with the chemistry onto the radiative scheme reveal that it is intrinsic to the GCM itself. It is related undoubtedly to the radiative scheme (Morcrette et al., 2001) that is in itself also perturbed by the 3-D distribution of the greenhouse gases. Bechtold et al. (2009) report on the reduction of this warm bias in the region of the stratopause due to a new greenhouse climatology. In the end, a number of biases appear in the chemistry of the upper stratosphere.** The model produces not enough O_3 , but too much NO_2 and N_2O_5 at 1 hPa and is then at the high end of the CCMVal-2 models.

C583

In link with this stratospheric distribution of temperatures, the other dynamical features analysed, transition to easterlies at 60 S, strength and position of the stratospheric jets, and pressure of the tropopause compare favorably to the ERA-40 and ERA-Interim reanalyses.

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Further developments of the model will also include the non-orographic aspects of the gravity waves, as well as the short-lived source gases containing bromine (WMO/UNEP, 2010). The latter will require a description of the tropospheric processes (e.g., emissions, convection, scavenging) that drive the evolution of these short-lived species. **CNRM-CCM is planned for use in a variety of projects linked with the interactions between chemistry and climate, in particular in seasonal and decadal predictions, where it could possibly be coupled to an interactive ocean.**

2. *Also, a few sentences about the future applications of the model may be of interest, as well as possible future lines of model development.*

We propose to amend our concluding remarks as follows:

Further developments of the model will also include the non-orographic aspects of the gravity waves, as well as the short-lived source gases containing bromine (WMO/UNEP, 2010). The latter will require a description of the tropospheric processes (e.g., emissions, convection, scavenging) that drive the evolution of these short-lived species. **CNRM-CCM is planned for use in a variety of projects linked with the interactions between chemistry and climate, in particular in seasonal and decadal predictions, where it could possibly be coupled to an interactive ocean.**

3. *Section 2.1.1: How do you deal with sea-surface forcing? Which off-line SSTs are used? Can you use an interactive ocean with chemistry?*

C584

The sea-surface forcings of both CNRM-ACM and CNRM-CCM are identical and comply with the CCMVal-2 REF-B1 requirements; they correspond to the HAdISST1 (Rayner et al., 2003) dataset. We could indeed run the chemistry-climate model coupled with an interactive ocean (see our response to your previous comment), provided we have the necessary computing and time resources. Such a climate model (with interactive chemistry and ocean) is currently used in our group in the framework of the French ITAAC project that documents the past and future impact of aviation upon climate.

4. *P1134, I6: So you do not couple other GHGs, such as CH₄, N₂O, and the CFCs?*

In our CCMVal-2 CCM, so called CNRM-ACM, the chemistry module provided only the 3D O₃ field to the radiative code of the GCM. The distribution of the other radiatively active gases, like the ones you cite, consisted of yearly mixing ratios, constant throughout the atmosphere (see also response to reviewer #1).

5. *P1136, I11: Is this inconsistent with P1134, I6?*

There is no inconsistency as such between the description that appears p1134 I6 which concerns the CNRM-ACM model and the one p1136 I6 for the CNRM-CCM model. One major difference between the two models is their radiative code, Morcrette (1991) for CNRM-ACM and Morcrette et al. (2001) for CNRM-CCM. A second difference of importance is that in CNRM-ACM the chemistry module provided the 3D O₃ field only to the radiative code, while in CNRM-CCM it provides the 3D distribution of all seven gases considered by the radiative code. To clarify this issue, we propose to amend the text of our paper as follows:

Seven gases are considered as absorbers, H₂O, CO₂, O₃, CH₄, N₂O, CFC11, and CFC12 whose 3-D distributions are provided by the chemistry module of CNRM-CCM (see below).

6. *P1136, I24ff: It is correct that most CCMVal-2 models do not include a detailed tropospheric chemistry, but many use a background chemistry based around*

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CH₄ oxidation, which is relatively adequate in remote regions of the planet. This might have been an alternative approach to take.

Actually, only three out of the eighteen CCMVal-2 models included a detailed tropospheric chemistry. They could handle the related computing cost thanks to reduced costs because of a low horizontal resolution or a low model top. The rest of the CCMs handled the evolution of the chemical compounds in the troposphere in different ways, five of them for instance described a background tropospheric chemistry/methane chemistry as you indicate (Morgenstern et al., 2010a). In our case, the chemistry scheme is the same throughout the atmosphere down to a level in the free troposphere that has been fixed to the model level close to 580 hPa and consists of the Lefèvre et al. (1994) scheme. However, the link between the stratosphere and the troposphere is more and more recognised. The next CCMVal workshop that will be held in May 2012, in contrast to previous CCMVal workshops which have focused exclusively on stratospheric chemistry and its impacts on climate, will also include an emphasis on connections with tropospheric chemistry, including the effect of stratospheric changes on tropospheric climate, the chemical connections between the troposphere and stratosphere, and building upon the findings from the ACC-MIP initiative (Atmospheric Chemistry and Climate Model Intercomparison Project, see <http://www.giss.nasa.gov/projects/accmip/>) that relate to connections with the stratosphere. In our case, we will continue to build upon the MOCAGE model that is the Chemistry Transport Model of Meteo-France. We will test the implementation in CNRM-CCM of the stratospheric/tropospheric scheme so-called RELACS that has been described and evaluated in Teyssède et al. (2007).

7. *P1138, I12: What are the consequences of not having a QBO in your model? Erroneous wave amplification of planetary waves? Biases in polar ozone? Please expand.*

We propose to add the following sentences in our paper p1137 I12:

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A lot of research activity has been devoted to this major mode of variability of the equatorial stratosphere. Baldwin et al. (2001) review in a detailed and didactic way the knowledge acquired since its discovery in 1960, and their summary indicates that its effects range from modulating the stratospheric flow from pole to pole, to affecting the variability of the mesosphere up to 85 km and the strength of Atlantic hurricanes. Changes in atmospheric dynamics in turn affect the distribution of chemical compounds, including O_3 , H_2O , and CH_4 . The QBO also has an effect on the breakdown of the wintertime stratospheric polar vortices and the severity of high-latitude ozone depletion. Indirectly, through impacting polar vortices it then has an effect on the surface meteorology. Dynamical processes also influence temperatures which in turn impact on the chemistry of ozone because of the temperature dependence of the reaction rates. The natural variability of O_3 has been analysed in a specific chapter of the SPARC (2010) report. For instance, amplitude of the global (60°S-60°N) column ozone variations in link with the QBO has been estimated to amount to 4DU, to be compared with an annual cycle where the natural variability has an amplitude of 12 DU. However, analysis of the CCMVal-2 model results suggest a range of sensitivity of the ozone to the QBO. The simulation of the QBO still remains a challenge for CCMs as it requires a high enough vertical resolution, an accurate parametrisation of the gravity waves that has been adjusted specifically to the model to interact in a realistic way with its synoptic-scale waves, and a realistic stratospheric Brewer-Dobson circulation in particular its tropical upwelling.

8. *P1145, section 3.2.4: Errors in transport were often reflected in unrealistic Cly , e.g., in CCMVal-1 Cly used to be larger in the stratosphere than the maximum of imposed chlorine at the surface, or unrealistically smaller. How does your model behave in this regard? I suggest to include a plot of total organic + inorganic*

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chlorine, as a function of time, such as in WMO (2007), figure 1-10.

The analysis of Cl_y in chapter 5 of SPARC (2010) concluded for CNRM-ACM in very realistic Cl_y quantities, for all the diagnostics examined. We have plotted in the supplementary document the evolution of Cl_y in the lower southern polar stratosphere (50 hPa, October) for CNRM-ACM and CNRM-CCM (see Figure 8). Both models produce very similar evolutions. In addition, total chlorine has been analysed in chapter 6 of SPARC (2010) (see for example Figure 6.21) and the conclusion for CNRM-ACM was that “The model shows a slight lack of conservation of total chlorine and total bromine in the mid- to upper stratosphere.” We could not perform the same total chlorine analysis for CNRM-CCM as we did not archive the necessary fields during the course of the simulations. However, comparisons between the chlorine compounds available both for CNRM-ACM and CNRM-CCM did not reveal any major difference between the two models. We plotted as you suggested the evolution of the total organic+inorganic chlorine for CNRM-ACM at stratospheric mid-latitudes, and our figure resembled very much that of figure 1-10 in WMO (2007). However, we did not include that in our supplementary document as we could not produce it with the outputs of the CNRM-CCM simulations.

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