

Testing and optimizing of the integrated C-IFS

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Deliverable

G-RG WP 4.7

Abstract

A first version of an inline chemistry model in ECMWF's integrated forecast system (IFS) based on the TM5 chemistry package has been implemented as part of the MACC project. The details of the chemistry, the emissions package and the deposition parameterisation can be found in deliverables GRG_4.4-GRG_4.6. C-IFS-TM5 comprises of 52 chemical species and 95 reactions describing tropospheric chemistry and applies a linearisation of the stratospheric ozone chemistry. Simple routines for wet deposition and lightning NO emissions have been implemented, which make use of the IFS cloud and convection fields. Here we describe a first two year simulation of this model which is compared to a TM5 standalone simulation and a selection of observational data. The results are encouraging: Concentration fields of the main tracers in C-IFS deviate less than 10-20% from the TM5 standalone model and C-IFS shows reasonable agreement against measurements of ozone and carbon monoxide. However, the current C-IFS-TM5 version exhibits an exaggerated oxidative capacity, which is related to an overestimation of tropospheric NO₂ compared to SCIAMACHY observations. This points to the fact that several of the current C-IFS parameterizations are overly simplified at present and require further development. With the C-IFS-TM5 model it is now possible to proceed with such developments and to provide robust assessments of their impact on the model performance.

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1. Introduction

A major new development in the MACC G-RG subproject concerns the development of inline chemistry within IFS, which is referred to as C-IFS. The C-IFS system could resolve limitations of the current coupled CTM-IFS system, for instance tracer concentration dislocation issues between the CTM and IFS, and improve the computational efficiency.

Building blocks of the C-IFS system are the transport (deliverable 4.2) chemistry and photolysis module (deliverable 4.4), as well as modules for emission, dry and wet deposition (deliverables 4.5 and 4.6). It was already found that the chemistry budgets in C-IFS deviate in some cases substantially from the TM5 offline model (see deliverable 4.4). Specifically, the CH₄ lifetime is only 7.7 year in C-IFS, compared to 8.5 year in TM5. This illustrates that the oxidative capacity in C-IFS is too high. In this report, we provide a summary of initial evaluation efforts and present a basic model comparison against observations that illustrate the implications of the chemistry budgets.

2. C-IFS model setup

The chemical mechanism in C-IFS is based on an updated version of the modified Carbon Bond Mechanism 4 (CBM4) scheme as described in Huijnen et al. (2010), which was recently extended to include explicit chemistry for CH₃OH, C₂H₆, C₃H₈, C₃H₆ (deliverable G-RG 4.4). The photolysis rates calculation is based on a lookup table approach as described by Krol and van Weele (1997) to account for the variations in actinic fluxes below, in and above clouds, variations caused by snow and ice surfaces with high albedo, and variations in the (largely stratospheric) overhead O₃ column. The stratospheric ozone concentrations are described either by assimilated ozone fields or by a linear ozone scheme (Cariolle and Teysedre, 2007). Concerning the surface fluxes, monthly mean deposition velocity fields are based on 3-hourly TM5 model output for the year 2006 (deliverable G-RG 4.5). Emissions are implemented according to the prescribed inventory as used for the POLMIP model intercomparison study (deliverable G-RG 4.6). Although the various model parameterizations behave reasonably on a global scale, it must be stressed that they all need a more detailed assessment and improvement. Different aspects were identified in the earlier deliverables.

With this model configuration a two-year model run has been conducted and compared to a simulation performed with TM5, and to actual observations. In this way one can discriminate between biases that are specific for C-IFS and those that are common for TM5 and C-IFS. The latter type should be explained by the common chemical mechanism.

3. Results

Zonal monthly mean C-IFS concentrations of CO are compared to the offline TM5 model, Figure 1. It illustrates that C-IFS shows very similar features to TM5, concerning its gradients and the seasonal variation between summer and winter. The C-IFS fields are lower by ~10% compared to TM5, consistently on both hemispheres, and also both in summer and winter.

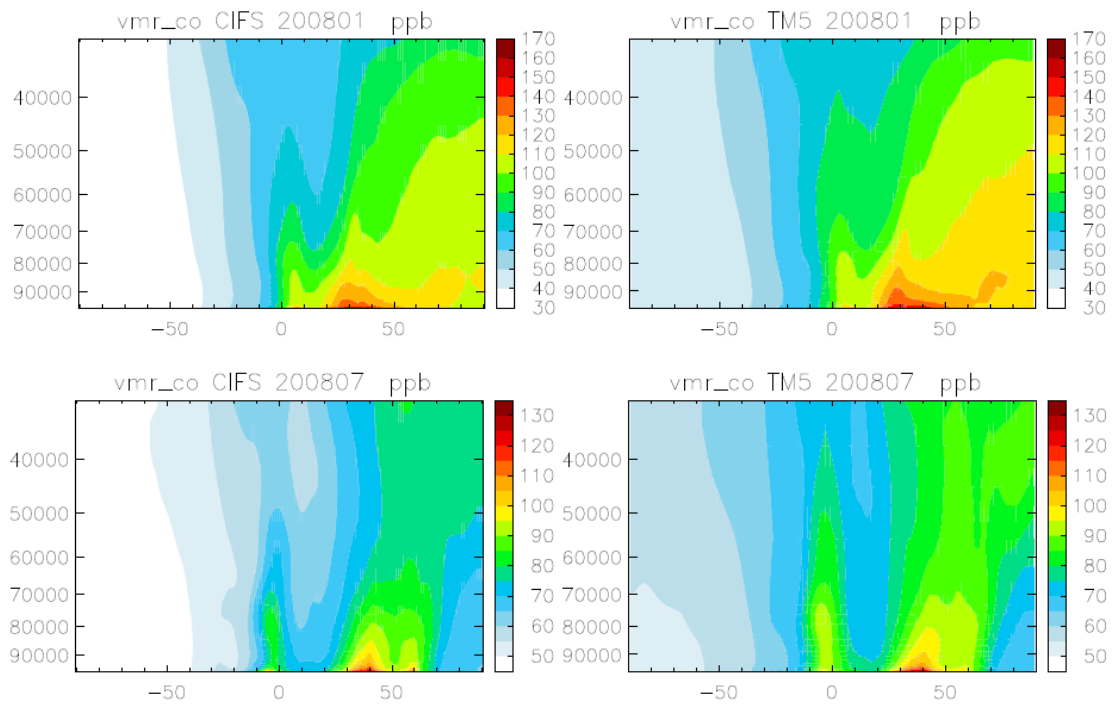


Figure 1. Zonal monthly mean CO concentrations in January (top) and July (bottom) 2008 for C-IFS (left) and TM5 (right)

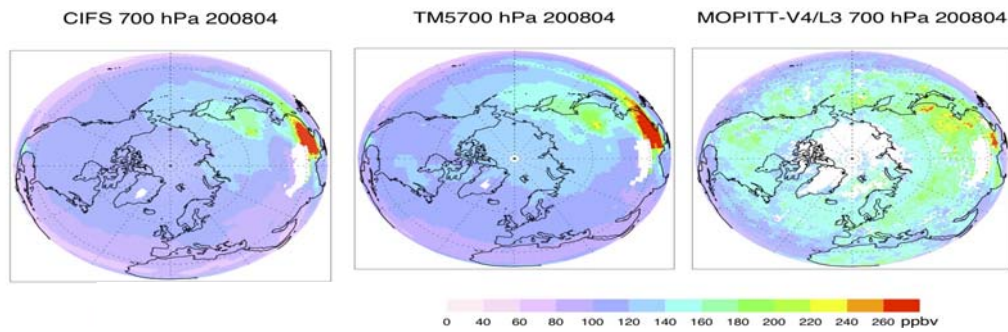


Figure 2. C-IFS and TM5 monthly mean CO concentrations at 700hPa against MOPITT V4.

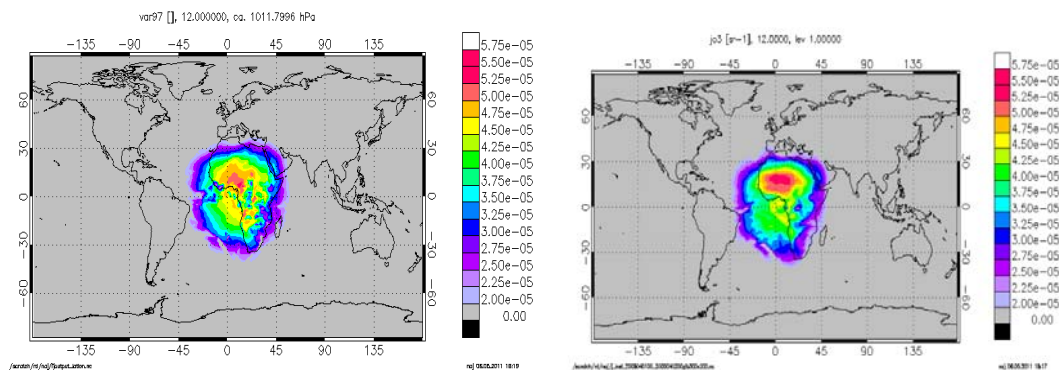


Figure 3. Instantaneous O_3 photolysis rates at the surface level for C-IFS (left) and TM5 (right) for 1 April 2008.

As emissions are identical between these two runs, this indicates a different CO loss rate. In a comparison against MOPITT observations of CO (Deeter et al., 2009), Figure 2, we find a negative bias which is larger for C-IFS. A potential explanation for these differences could be the simulation of photolysis rates in C-IFS and TM5. As explained in Deliverable G-RG 4.4, there is an excess of OH primary production by ozone photolysis and recycling by NO_x.

Ozone photolysis rates at the surface are shown in Figure 3. The photolysis rate in C-IFS is equal in magnitude to TM5 (or even slightly lower) but shows different patterns. Detailed differences in photolysis rates can be explained by different methods to calculate the cloud fraction and optical depth, the surface albedo, and the overhead ozone column.

The tropospheric ozone in C-IFS again show the same spatial patterns as TM5, but concentrations are ~10% larger, Figure 4. This implies a too large ozone production. In an evaluation against EMEP surface observations both TM5 and C-IFS show in general a positive bias, which is larger in C-IFS than TM5, Figure 5. Therefore differences in the ozone photolysis budget are also caused by the larger ozone concentrations.

Also zonal mean NO₂ concentrations are higher in C-IFS than TM5, Figure 6, which in turn contributes to the higher ozone production and OH recycling. This bias in NO₂ appears to be strongest in July.

In an evaluation of tropospheric NO₂ columns against SCIAMACHY, Figure 7, a strong positive bias in C-IFS was confirmed, which was larger than found for TM5. Reasons for an overestimation of tropospheric NO₂ are not yet understood. Sensitivity studies have been performed where the HNO₃ wet deposition has been scaled up maximally did not lead to significant improvements.

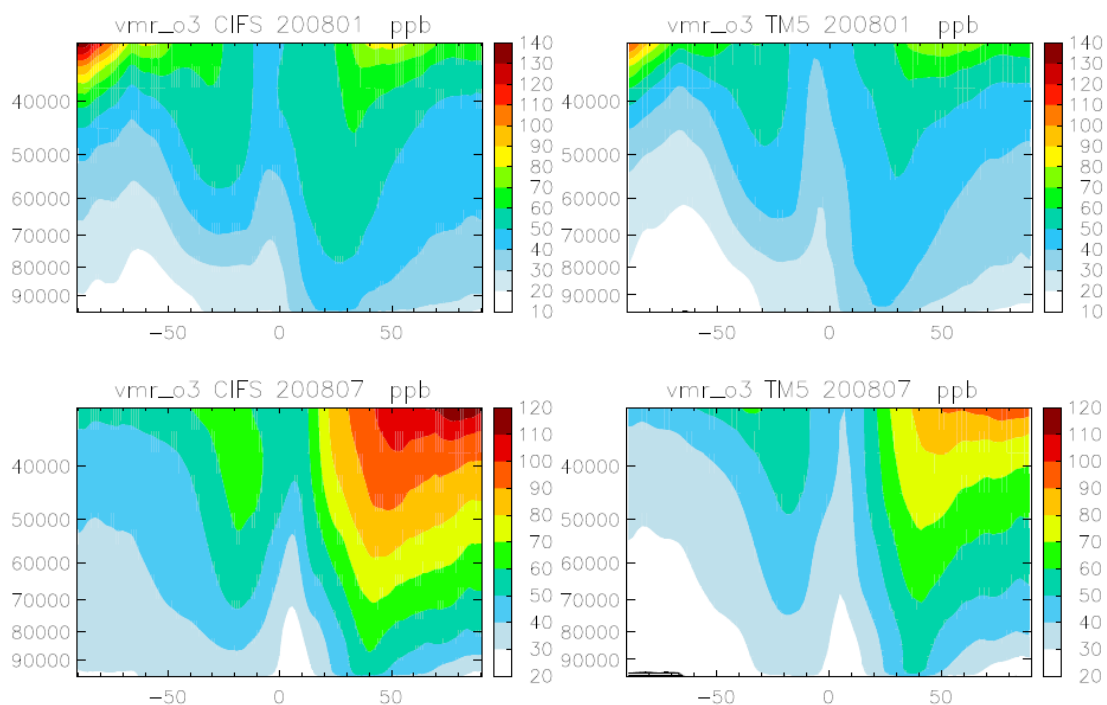


Figure 4. Zonal monthly mean O₃ concentrations in January (top) and July (bottom) 2008 for C-IFS (left) and TM5 (right)

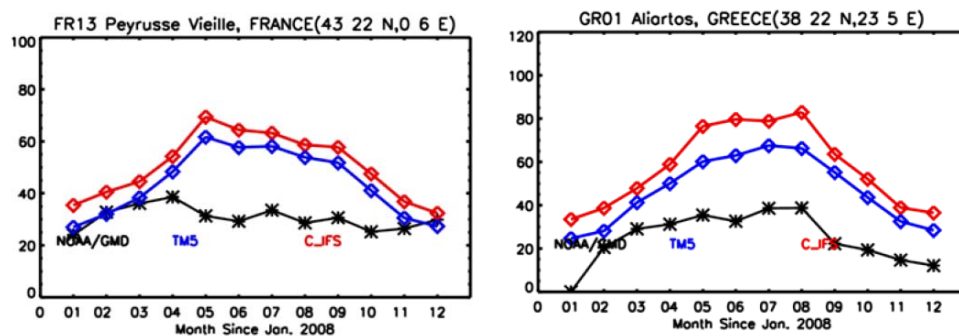


Figure 5. Evaluation of model surface ozone concentrations (units in ppbv) against EMEP observations. Red: C-IFS, Blue: TM5.

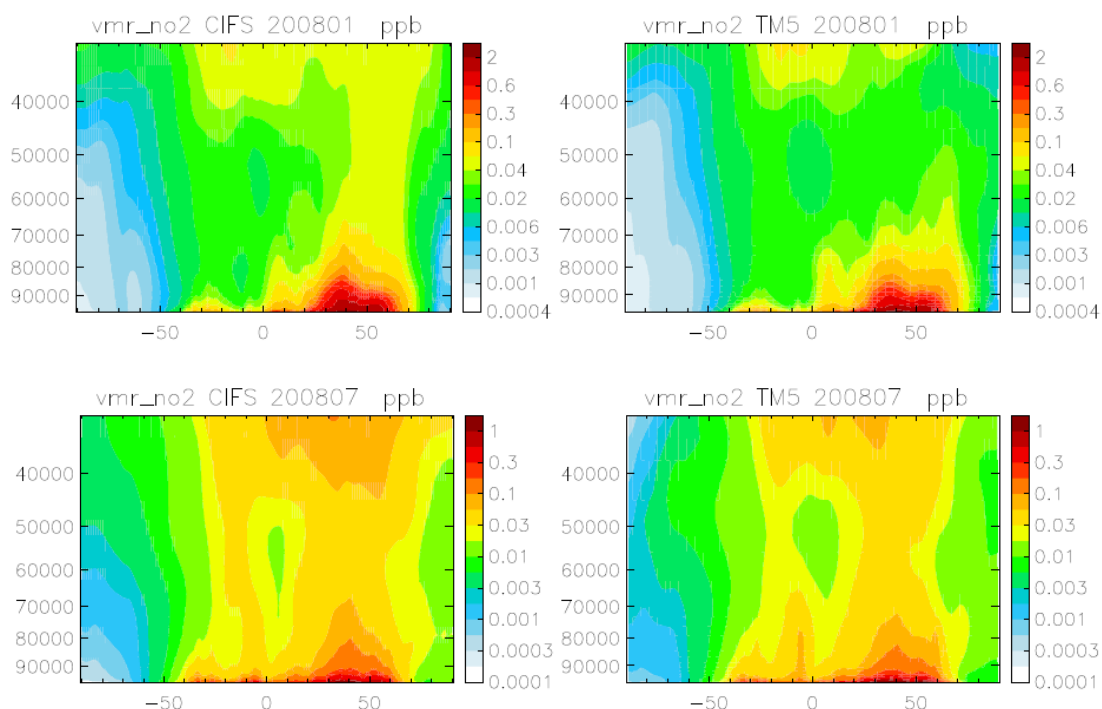


Figure 6. Zonal mean NO₂ concentrations in January 2008 for C-IFS (left) and TM5 (right)

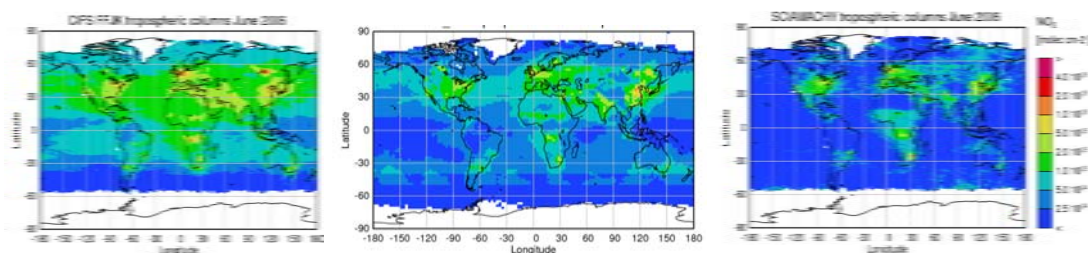


Figure 7. Evaluation of tropospheric NO₂ columns in C-IFS (left), TM5 (middle) against SCIAMACHY (right)

Also the introduction of a family approach for NO and NO₂, thereby reducing the spatial gradients and possible errors in the advective transport scheme, did not lead to significantly better results. Further sensitivity studies are needed to resolve the positive bias in NO₂.

Conclusions

We have presented a first evaluation of the C-IFS system against the TM5 offline model and against observations. C-IFS is able to produce realistic concentrations with very similar patterns as TM5 of the key trace gases. Absolute differences of C-IFS to TM5 concentration fields are generally in the order of 10-20 %. An overestimation of the oxidative capacity of C-IFS is illustrated by a low bias in CO against MOPITT observations. This is consistent with the high bias in tropospheric NO₂, which results in too much radical recycling by NO_x as well as an overestimation of ozone production. Reasons for the NO₂ bias are not yet understood and need further investigation. Such analysis requires a careful evaluation of all chemical and physical processes affecting OH and the NO_x cycle.

References

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