Regional Cooperation for Limited Area Modelling in Central Europe

RC LACE Stay Report

Topic: Debugging and testing TOMs subroutine in TOUCANS module for ALARO-1

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1 Introduction

TOUCANS (Third Order moments Unified Condesation Accounting and N-dependent Solver for turbulence and diffusion) is a compact turbulence parameterization, used in the ALARO-1 physical package. TOUCANS integrates several ideas in turbulence parameterization: no existence of critical Richardson number, anisotropy of turbulence, prognostic treatment of mixing length, third order moments parameterization, parameterization of moisture influence and the possibility of 3D parameterization [3].

2 Previous work

This stay continued the work of the previous stays [6], [5], [4], which focused on the `ACDIFV3` routine in the TOUCANS parameterization. This routine calculates the TOMs (third order moments) contributions to the turbulent heat and moisture fluxes. In the previous stays, the code was first logically reorganized and cleaned, with negligible numeric effect to the results. This version of code was backphased to cycle 40t1bf6.

Next, the list of known bugs in the routine from the TOUCANS documentation [3] was checked by checking all the code from the `ACDIFV3` routine from the beginning. In the process, four more bugs were found. All bugs except one (the so-called `ZZZ` bug in [3]) were corrected and checked, and the result was numerically stable and had little effect on the numerical values of the spectral norms.

The `ZZZ` bug, when corrected, causes the code to become numerically unstable. The correction influences the calculation (solver) procedure of the diffusion-like calculations, so to understand the influence, the equations were rederived, using [3] as a guideline. Next, the code of the `ACDIFV3` routine was converted to mathematical expressions and compared to the derived equations. No discrepancies were found, and the `ZZZ` bug was confirmed to be a bug which should be corrected.

Because of this, the conclusion was that the problem lies in the algorithm which protects some variables in the code from a non-linear instability, since the `ZZZ` variable enters the expressions inside it.

3 Current work

First, the code was ported to cycle 43t2plus_op1 and checked that the results were not changed by the change of cycle by comparing the spectral norms, which remained the same.

Our plan (with R.Brožkova and J.Mašek) was to try and understand and derive the protection from instability part of the code, in order to fix the problems caused by the `ZZZ` bug.

To do that, the entire code was rechecked to be absolutely sure that the right mathematical expressions are coded, to truly isolate the problem to the protection from instability part of the code. In this process, we found that one of the variables (the `ZTSTAR` variable) has an additional minus which was previously overlooked, which significantly changes the expressions coded for the RHS part of the equations, the instability protection algorithm and solver equations.

Because of cycle change, all bugs except the `ZZZ` all bugs were then corrected again and the setup was tested individually for each bug, and for all bugs at once. For all cases, the results were numerically stable and had little effect on th spectral norms. The code was cleaned some more and variables were renamed to have more understandable names, and this version is now prepared to be phased into the next cycle.

Next, we (with J. Mašek) tried to derive the algorithm for protection of instability used in the routine. This algortihm was coded by J.F.Geleyn and is not completely understood as there is no documentation that describes it. J. Mašek found papers [1] and [2], which contain descriptions of similar procedures, that could help us. Unfortunately, the algorithm coded in the `ACDIFV3` routine is significantly different, so we weren't able to understand it fully even with the help from the cited papers.

R.Brožkova then found a note that J.F.Geleyn has written, explaining an (old) version of the protection from instability algorithm for TOMs. As we weren't able to understand the newest version of the algorithm, we decided to implement the old version, as the note explained it well.

4 Future work

As the stay was over, it was agreed that I will implement the alternative protection from instability back in Slovenia. The question of the additional minus in the `ZTSTAR` variable will also have to be addressed and finally a detailed document that will replace the TOMs chapter in TOUCANS documentation [3] will be written.

References

[1] B.Catry *et al.*, *A new sub-grid scale lift formulation in a mountain drag parameterisation scheme*, Met. Zeit. Vol**17**, 193-208, April 2008.

[2] J.F.Geleyn, C.Girard, J.F.Louis, *A simple parameterization of moist convection for large-scale atmospheric models*, Beitr.Phys.Atmosph. Vol**55**, No. 4, November 1982.

[3] Ivan Bašták-Ďurán, *TOUCANS documentation*, 15. July 2015.

[4] Peter Smerkol, *RC-LACE Stay report*, Prague, 16th March - 30th March 2018.

[5] Peter Smerkol, *RC-LACE Stay report*, Prague, 6th March - 19th March 2017.

[6] Peter Smerkol, *RC-LACE Stay report*, Prague, 26th February - 11th March 2016.