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Regional Cooperation for Limited Area Modelling in Central Europe

RC LACE Stay Report

Topic: Debugging and testing 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 [1].

2 Work

This stay continued the work of the previous stay [2], 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 stay, the code was logically reorganized and cleaned, with negligible numeric effect to the results. This version of code was backphased to cycle 40t1bf6.

In the TOUCANS documentation [1], on page 34, there is a list of known bugs in the `ACDIFV3` routine, along with suggestions on how to correct them and comments on stability of corrections.

First, the code was rechecked from the beginning to see if the proposed corrections are correct, and in the process, one more bug was found. It was found out that all correction proposals are correct, except for the bug in the `ZZZ` variable (point 1. in the list of bugs in [1]).

All bugs mentioned in [1] were corrected as proposed (without taking into account the stability considerations), and a new way of correcting the ZZZ bug was proposed, and also the new bug found was corrected (see sections 3 and 4).

This work continued for the next two months from home, because we found out that the new way of correcting the ZZZ bug is not consistent with the equations.

The bug in ZZZ influences the calculation (solving) of the diffusion-like equation to calculate TOMs corrections to heat and moisture fluxes. The relevant section in [1] is section 7.1, in which a form of the equations, suited for solving, is derived (equations (249) and (253)). This derivation was redone (for heat flux equation only, as the derivation for the moisture flux is identical), in order to check if the final equation is correct. Some errors in documentation were found, and a correct solver equation was rederived. In the code, this correct version of the equation is already implemented, so these errors are just typos, and not relevant to the results.

Next, the whole code of the ACDIFV3 routine was converted to mathematical expressions, in order to be able to keep track of the potentially wrong expression for the ZZZ variable (again, only for the code describing the heat flux, as the code for the moisture flux is directly analogous). The algorithm, which implements all terms and then uses the Thomas algorithm to solve the equation was then rewritten in mathematical terms and compared to the code in the ACDIFV3 routine, in order to find discrepancies from the ZZZ variable.

During this procedure, additional three bugs were found in the code.

After this work, the way to correct the ZZZ bug was derived. The three new bugs were also corrected (see sections 3 and 4).

3 Documentation and bug Corrections

All line numbers refer to the cleaned version of the ACDIFV3 routine, phased into cycle 40t1bf6.

Typos in the Toucans documentation:

- In equation (239), the second term on the LHS should be a derivative of z, not t.

- In equations (245), (250) and (254), there should be a hat operator on $\frac{1}{e_k}$ in the $K^{(A_3)}$ term.
- In equations (244), (248), (249) and (253), change $\widehat{K_{cr}^{sq}}\, e_k$ and $\widehat{K_{cr}^{qs}}\, e_k$ to $\widehat{K_{cr}^{sq} e_k}$ and $\widehat{K_{cr}^{qs} e_k}$ in last terms on the RHS.
- In second paragraph on page 26, the s_{sL}^* variable is not defined anywhere.
- In equations (248), (249) and (253) the first four terms on RHS should not be multiplied by $\frac{1}{1+\frac{A_t}{\delta t}}$.

Corrections for bugs mentioned in the Toucans documentation and checked previously:

- Divide `ZPT_INS0_3II(j)` by `PF_EPS(j)` on *line 372*,
- Delete one multiplication by `ZTKE_CEPS2` from the calculation of variable `ZT_INSS2(j)` on *line 382*,
- Delete one multiplication by `RG` from the calculation of variables `ZT_INSS(j)` and `ZT_INSSQ(j)` on *lines 407 and 412*,

New bugs found:

- Variable `ZKTROV2Q(j)` is not initialized at the top level. Add the line
  `ZKTROV2Q(JLON,KTDIA-1)=0.0_JPRB`
  in the loop on `JLON` at *line 573*,
- *Lines 503-506* should be outside of the solver iteration loop as they represent the values of variables `ZDIFSO`, `ZDIFSI`, `ZDIFQO` and `ZDIFQI` before the start of iterations. Move them to right after *line 492*,
- *Lines 785 and 786* (with the 'cheat?' comment) are not correct, and should be deleted.
- `ZN1` and `ZN2` variables in *lines 754, 755, 762 and 763* should be multiplied by `TSPHY`.

4 Bug in the ZZZ variable

The ZZZ variable is defined as:

```
ZZZ(JLON,JLEV)  =  0.5_JPRB*ZKTROV(JLON,JLEV)  *
                   (PAPHIF(JLON,JLEV)-PAPHIF(JLON,JLEV+1))  /
                   RG*PTH_FUN(JLON,JLEV)/TSPHY
```
(1)

or, with mathematical expression:

$$\texttt{ZZZ} = 0.5 K'_H T''_H \frac{\Delta\Phi}{g} \frac{1}{\Delta t} \tag{2}$$

The 'bug' here is, that it is not known exactly if ZZZ should be divided by TSPHY or not. ZZZ is an auxiliary variable that enters in both equations (249) and (253) that describe the heat and moisture flux diffusion iterated by the TOMs solver. Since it enters in almost all the terms, it was necessary to derive expressions for all temporary variables, used in the solver iteration loop. For the ZSCG0 variable, which represents the RHS for the solver algorithm, it was found out that the expression (1) is correct. The extra TSPHY is not correct, however, in the expressions of the Thomas algorithm, which solves the tridiagonal matrix system of equations. The corrections that should be made, are:

- terms with PRDELP(j) should be divided by TSPHY for variables ZELIM (*lines 732, 746*), ZELIMQ (*lines 736, 749*), ZMUL (*lines 722, 734, 747*), ZMULQ (*lines 724, 738, 751*), ZSUB1 (*lines 723, 735*) and ZSUB1Q (*lines 725, 739*).

5 Verification

This verification was done for the way of correcting the ZZZ bug devised while at stay. It should be redone, as the derived correction is now different.

Verification was done by comparing the spectral and grid-point norms written out in the NODE file of the forecast for each time step. Two convective cases were chose, one in july 2009 with a forecast of 54 hours, and one in March 2016 with a forecast of 12 hours, both starting at 00 UTC.

We compared forecasts using three different versions of the `ACDIFV3` routine:

- the cleaned version from the previous stay,
- version where only the 1. (`ZZZ` variable) bug is corrected,
- version where all the bugs are corrected.

All forecasts were stable with no errors, while the norms differed slightly.

6 To be done

As said, the verification of the bug corrections should be redone, as there were new bugs found after the stay, and the way of correcting the `ZZZ` bug is now different.

Also, since in [1] there are comments that warn about the stability of some of the bug corrections, we should also prepare more convective cases to check, and verify the impact of each correction individually. This work will continue.

References

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

[2] Peter Smerkol, *RC-LACE Stay report*, Prague, 6th March - 19th March 2016.