Regional Cooperation for Limited Area Modelling in Central Europe

RC LACE Stay Report

Topic: TOUCANS brainstorming 2022

Prague 5th June - 17th June 2022

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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 [1]. It is a two-energy turbulence scheme [2] and it also integrates several ideas into the 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].

TOUCANS scheme was developed by the RC-LACE community and is used operationally, however, some of the features were additionally developed and bug-fixed since the last operational version - turbulence length scale formulation [4], TOMs parameterization [7], [8], coupling to the surface scheme [6] and numerical stability [5]. Some of these developments are still ongoing.

There are also parts of TOUCANS scheme, such as full prognostic turbulence length scale and 3D turbulence mixing, that need further development.

Further developments in the two-energy turbulence scheme have been made at the Goethe University in Frankfurt, regarding coupling to the APDF method, reformulation of the stability parameter, inclusion of the entropy potential temperature [9], and formulation of the turbulence length scale [10], which were implemented into the ICON modeling framework.

TOUCANS brainstorming was organized to review developments done so far and exchange information about them, and identify and discuss problems that arose during development. A plan was made to correct and finish current developments, and merge the separate developments into an improved TOUCANS scheme. Additionally, technical aspects of TOUCANS development such as code cleaning and organization and optimal evaluation tools usage were discussed.

2 TOUCANS/ICON CURRENT STATE OF DEVELOPMENTS

First part of brainstorming was the presentation of current state of development. Thre are several parts of TOUCANS that are being developed:

- Length scale formulation (developed by M.Hrastinski and J.Mašek) - TOUCANS still uses the Geleyn-Cedilnik length scale, an algebraic formulation dependent of PBL height. A new length scale dependent on TKE and buoyancy/shear is being implemented, based on Bougeault-Lacarrere mixing length. Proper scaling has to be determined.
- TOMs parameterization (developed by P.Smerkol) - optimization, debugging and code celaning of the ACDIFV3 routine was done. The problem with numerical stability of the TOMs solver remains unsolved.
- 3D turbulence (developed by M.Hrastinski) - development started.
- TKE/TTE oscillations treatment (developed by J.Mašek and R.Brožkova) - There are numerical oscillations visible in turbulent fluxes, TKE and TTE fields, in stable stratification cases. Oscillations are related to computation of flux Richardson number from TKE and TTE, and are caused by inaccurate explicit estimate of equilibrium TKE and TTE in TKE/TTE solver equations. Solution is to add 1 iteration in the solver where updated equilibrium TKE/TTE ideas computed. The paper was already published, howvere, treatment introduces near surface cold bias.
- 2TE + APDF (developed by I.Bašták-Ďurán) - development done in ICON framework and the paper is published.

3 TOUCANS DEVELOPMENT PLAN

In the next part, existing problems in development were discussed and a plan for solving problems and further work was devised. Plan consists of various topics:

- Length scale (M. Hrastinski) - work is nearly done, the Bougeault-Lacarrere mixing length needs to be implemented, some PBL height diagnostics needs to be done, and the paper is being written.
- TOMs implementation (P. Smerkol) - The numerical instability occurs in the joint solver for static energy and moisture. This solves the moist case, with non-neutral stratification. Also, there is an additional temporal term in the solver equations, and virtual potential temperature is used in the computation of fluxes.

  All this represents the most complex case, so the plan to resolve numerical instability is to first try to solve and stabilize the simplest case, which is the dry neutral case without temporalterms and then gradually increase complexity until we come back to full TOMs representation.

  The theory also needs to be revised, since there are some questonable assumptions in the derivation of TOMs equations. The virtual potential temperature should also be replaced with entropy potential temperature, which is a conservative quantity in all stratification types.

  Results should then be evaluated via diagnostic tools in 3D model and MUSC, and also compared to LES results.
- 3D turbulence (M.Hrastinski) - a horizontal length scale, which will probably be linked to the vertical length scale, should be implemented. A contribution of horizontal shear to TKE/TTE prognostic equations should be determined, and SHLD solver should be implemented for horizontal transport.
- TKE/TTE oscillations (J. Mašek) - The cold bias introduced by oscillation treatment should be mitigated.
- 2TE + APDF (I.Bašták-Ďurán) - the extension should be implemented and tested in TOUCANS. stability parameters, length scale and connection to TOMS should then be investigated in the TOUCANS framework.
- Code modifications (I.Bašták-Ďurán, P.Smerkol) - unused options in TOUCANS (such as different closure models, cloud fraction calculation, etc.) should be removed from

the code. Code should be generally cleaned and reorganized to improve readability and make further developments easier to integrate.

- Documentation (I.Bašták-Ďurán, P.Smerkol) - documentation should be checked and updated with new developments regularly, and not implemented parts should be removed. The future plans should also be included.

4 Preparation for work at home

The rest of the stay was used to prepare the environment on ČHMU for working from home. This includes selection of an appropriate case for testing, preparing the source code from cycle 46 on which the testing will be done, preparing the boundary condition files and scripts for running, reviewing the literature for TOMs theory and reviewing the Epygram tool for diagnostics. For this part, I thank J. Mašek and A. Trojakova for their much needed help.

References

[1] I.Bašták-Ďurán, J.-F.Geleyn, F.Vaña, *A compact model for the stability dependency of TKE production-destruction-conversion terms valid for the whole range of Richardson numbers.*, JAS, 71(8), 3004-3026 (2014).

[2] I.Bašták-Ďurán, J.-F.Geleyn, F.Vaña, J.Schmidli, R.Brožkova, *A turbulence scheme with two prognostic energies.*, JAS, 75(10), 3381-3402 (2018).

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

[4] M.Hrastinski, *Improvement of TKE-based mixing length formulation in TOUCANS*, RC-LACE stay report, 2020.

[5] J.Mašek, I.Bašták-Ďurán, R.Brožkova, *Stable numerical implementation of a Turbulence Scheme with Two Prognostic Turbulence Energies.*, MWR, 2022.

[6] M.Dian, *Investigating SURFEX in ALARO-1.*, RC-LACE stay report, 2019.

[7] P.Smerkol, *Debugging TOMs routine in TOUCANS.*, RC-LACE stay reports, 2016-2019.

[8] P.Smerkol, *Derivation of TOMs solver.*, RC-LACE addendum to stay report, 2018.

[9] I.Bašták-Ďurán, M.Sakradzija, J.Schmidli, *The two-energies turbulence scheme coupled to the assumed PDF method.*, JAMES, 14, e2021MS002922, 2022.

[10] I.Bašták-Ďurán, J.Schmidli, R.Bhattacharya, *A budget-based turbulence length scale diagnostic.*, Atmosphere, 11(4), 2020.