Geosci. Model Dev. Discuss., 7, C2474–C2479, 2014
www.geosci-model-dev-discuss.net/7/C2474/2014/

Geoscientific Model Development Discussions

Interactive comment on "The implementation of a MiXed Layer model (MXL, v1.0) for the dynamics of the atmospheric boundary layer in the Modular Earth Submodel System (MESSy)" *by* R. H. H. Janssen and A. Pozzer

R. H. H. Janssen and A. Pozzer

ruud.janssen@mpic.de

Received and published: 28 November 2014

Reply to Anonymous Referee 1

The manuscript 'The implementation of a MiXed Layer model (MXL, v1.0) for the dynamics of the atmospheric boundary layer in the Modular Earth Submodel System (MESSy)' by R. Janssen and A. Pozzer presents a detailed description of the new developed model and a short application to field measurements. So concerning the idea of GMD the paper falls complete in the strategy of the journal. It was a pleasure and

also a kind of lecture for me to go through all the equations showed in sufficient detail in the manuscript and besides some minor comments I would say the paper is ready for publication in GMD.

We thank the reviewer for this positive comments on our paper. Please find below our replies to the individual comments. The comments are printed in italics and our replies in normal font.

Minor comments for consideration: In chapter 3 you start to explain VERTICO and although I read this section a couple of times the complete sense of this module is still somehow mysterious for me and should be explained – specially in his use – more carefully. Maybe I just don't got the idea behind it and you can explain it specially to me.

In short, the VERTICO basemodel contains calls to modules for time and tracer management, the time loop which integrates the model equations and in the VERTICO basemodel, tracer concentrations are updated each timestep, combining the tracer tendencies from each active submodel.

Perhaps we should further explain the idea behind MESSy to make the raison d'être of VERTICO clear: MESSy is an interface for submodels that represent processes in the earth system, and not a model by itself. It combines a basemodel (which can be a box, 1D or 3D model) with submodels that calculate the individual processes relevant to atmospheric chemistry and dynamics (see also Fig. 3). Before the implementation of the generic 1D model VERTICO, MESSy was available as box model (CAABA/MECCA, Sander et al. 2011), regional model (COSMO/MESSy, Kerkweg et al., 2012) and a global model (ECHAM5/MESSy (also EMAC), Jöckel et al. 2010). We have included VERTICO as a column model to be able to perform types of studies that are not possible with a box or 3D model, and MXL is implemented as the first dynamics submodel in the basemodel VERTICO, focusing on interactions between BL dynamics and atmospheric chemistry (see the Introduction on p. 7198 lines 12-26 and p. 7199 lines 1-3).

In line with the naming convention in MESSy (i.e. the coupled model is called after the dynamical core, see the examples above) and to make the relation clear with previous implementations of MXL, we have called the coupled model MXL/MESSy.

We will change the introduction (p. 7198 line 16) 'Here we describe the implementation of a MiXed Layer model for the dynamics of the atmospheric boundary layer (ABL) and a generic 1D basemodel called VERTICO (VERTIcal COlumn) in the Modular Earth Submodel System (MESSy, Jöckel et al. 2010). The implementation of the latter is necessary because of the structure of the MESSy framework: in this framework, a basemodel determines the basic configuration of the coupled model, which can be a box, 1D or 3D model, and the individual processes are represented by basemodel independent process submodels that are coupled to the basemodel through an interface layer (Jöckel et al., 2010).'

And we will rewrite Sect. 3 (p. 7219, line 1-8) 'For the implementation of MXL, a generic 1D basemodel is created in MESSy, called VERTICO. VERTICO contains calls to modules for time and tracer management, the time loop which integrates the model equations and in VERTICO tracer concentrations are updated each timestep, combining the tracer tendencies from each active submodel. It is de facto a 3D basemodel in which the horizontal resolution has been reduced to a single grid box, to facilitate the submodel coupling within the MESSy framework. This also facilitates the possible development of a column model that includes more vertical levels in both boundary layer and free troposphere.'

Second in the beginning of your equation sections you use the subscript 's' for example to define the surface heat flux. Later on you use the same subscript for the subsidence velocity (ws). Although it is clear what you mean it should be avoided to use the same subscript for spatial complete different places.

Good point, to avoid confusion we will replace w_s with w_l (for large-scale vertical velocity) in the revised MS.

On page 7204 line 1 and later in table A1 you define the entrainment/surface heat flux ratio with 0.2 but without any explanation where you received this value. Is it based on measurements, from literature or just defined by you?

This value of the entrainment/surface heat flux (beta) is based on literature: Large Eddy Simulation results (e.g. Pino et al. 2003) yield this value under conditions for which convection as the main source of turbulence. In cases where turbulence is also generated by wind shear, this ratio could vary between 0.1 and 0.4. More sophisticated parametrizations have been developed to account for the effects of wind shear, but these tend to increase complexity and therefore the number of poorly constrained coefficients (Tennekes and Driedonks 1981). Therefore we have chosen the simple solution of fixing beta at 0.2, which is a commonly used value in the literature (Vila et al. 2009 and other references for the MXLCH model in the MS). We will add a reference to Pino et al (2003) here.

On page 7212 lines 6-13 you describe the calculation of the incoming long wave radiation, which I never saw before in this way – but why not. However, I would like to know how you get the value of 0.8 to calculate the atmospheric emissivity and also 10% of the boundary layer height as the surface layer top.

The emissivity of the atmosphere is a function of its temperature and of the concentration of water vapor and other greenhouse gases. Clear-sky values are 0.8 ± 0.2 (Staley and Jurica, 1972), so that is why we adopted this number.

The approximation that the height of the surface layer is at 10% of the boundary layer height is one that is commonly used in the literature (e.g. Jacobs and De Bruin 1992, Van Heerwaarden et al. 2010). We will add this reference to the MS.

Figures 6 and 7: Although this is a model development journal there is one result plotted which surprised me. In figure 6 you show that your model reproduce the ozone concentration very well compared to the measurements. And then in figure 7 you present that nearly until noon the downward flux of ozone is the dominating source *or production term of ozone in your model. This result presents for me a relatively high contribution to the measured ozone concentration at the ground from the free troposphere but I would not say it is not the truth. Can you discuss this!*

That the relative contribution of entrainment to the O3-budget seems too high can be because 1) entrainment is overestimated or 2) because chemical production is underestimated.

Ad 1) During the period of BL growth, the BL mixing ratio of O3 becomes more similar to the FT mixing ratio (initialized at 41 ppb, so there is a jump of 11 ppb between BL and FT, Table 2). We cannot be sure that this FT mixing ratio represents the real concentration of O3 above the ABL, since there are no observations to support this.

Ad 2) At only 100 ppt NO and 50 ppt isoprene, O3 production is low and this could be the reason that the relative contribution of entrainment seems too high. To demonstrate this effect we made a sensitivity analysis by increasing NO and isoprene emissions by a factor 10. Fig. 1 shows that for this 10x emission scenario we overestimate the NOx and isoprene concentrations compared to the measurements with NO peaking at 700 ppt and isoprene at 750 ppt. Under these conditions, the contribution of chemistry and entrainment to the O3-budget are much more equal (Fig. 2). Besides, other VOCs than isoprene (terpenes, aromatics) have been observed during DOMINO, which could contribute to O3 production, but were not included in the reaction mechanism. Mixing ratios of the individual compounds never exceeded 100 ppt, however, so we expect that the effect of including them would be smaller than that of the increased isoprene emissions by a factor 10.

Page 7219, line 9: figure 3 should be mentioned before figure 4 or just change the order Spelling error: Page 7201 line 24: 'in into' should be 'into' Table A1: second line 'as as' should be 'as'

We will change the figure order and correct the spelling errors in the revised MS.

References

Jacobs, C. M. J. and De Bruin, H. A. R. The Sensitivity of Regional Transpiration to Land-Surface Characteristics: Significance of Feedback Journal of Climate, 1992, 5, 683-698

Jöckel, P., Kerkweg, A., Pozzer, A., Sander, R., Tost, H., Riede, H., Baumgaertner, A., Gromov,S., and Kern, B.: Development cycle 2 of the Modular Earth Submodel System (MESSy2), Geosci. Model Dev., 3, 717–752, 2010.

Pino, D.; Vilà-Guerau de Arellano, J. and Duynkerke, P. G. The contribution of shear to the evolution of a convective boundary layer J. Atmos. Sci., 2003, 60, 1913–1926

Staley D.O. and G. M. Jurica, 1972: Effective Atmospheric Emissivity under Clear Skies. J. Appl. Meteor., 11, 349–356.

Tennekes, H. and Driedonks, A. Basic entrainment equations for the atmospheric boundary layer Boundary-Layer Meteorol., 1981, 20, 515-531

Van Heerwaarden, C. C.; Vilà-Guerau de Arellano, J.; Gounou, A.; Guichard, F. and Couvreux, F. Understanding the daily cycle of evapotranspiration: a method to quantify the influence of forcings and feedbacks J. Hydrometeor., 2010, 11, 1405-1422

Vilà-Guerau de Arellano, J.; van den Dries, K. and Pino, D. On inferring isoprene emission surface flux from atmospheric boundary layer concentration measurements Atmos. Chem. Phys., 2009, 9, 3629-3640