Effect of the currently neglected diabatic terms in the p- and T- equations of the COSMO-Model

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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

INTRODUCTION

➔ In the COSMO-Model, continuity equation is replaced by equivalent Eq. (1) for pressure p, so p is prognostic variable instead of total density ρ. Individual pressure tendency from (1) is equal to „reversible“ term in Eq. (2) for temperature T.

➔ In (1) there are explicit source- and sink terms Q_h and Q_m related to diabatic processes (phase changes, molecular/ turbulent/ convective transports, divergence of radiation fluxes), which are necessary to close the mass balance.

➔ However, these diabatic terms are so far neglected in the COSMO-model (Eq. 4 and 5), which is a violation of mass conservation. Some (small?) systematic and/or daytime depended biases in pressure, geopotential and precipitation are to be expected.

➔ Investigation of this fact by implementing all diabatic terms into a COSMO test version (Eq. 1 and 3) and comparing with results from the official model version (Eq. 4 and 5).

Unapproximated p- and T-equations:

$$(1) \quad \frac{dp}{dt} = -\frac{c_p}{c_v} p \nabla \cdot \boldsymbol{v} + \left(\frac{c_p}{c_v} - 1\right) Q_h + \frac{c_p}{c_v} Q_m$$

$$(2) \quad \rho c_p \frac{dT}{dt} = \frac{dp}{dt} + Q_h \quad .$$

Inserting (1) into (2) $\Rightarrow$ equivalent T-equation

$$(3) \quad \rho c_v \frac{dT}{dt} = p \nabla \cdot \boldsymbol{v} + Q_h + Q_m$$

with the diabatic contributions Q_h and Q_m

$$Q_h = L_V I^l + L_S I^f + \nabla \cdot (\boldsymbol{J}_s + \boldsymbol{R}) + \epsilon - \sum_x c_{px} \boldsymbol{J}^x \cdot \nabla T$$

$$Q_m = -R_v T (I^l + I^f) - T \left(R_v \nabla \cdot \boldsymbol{J}^v + R_d \nabla \cdot \boldsymbol{J}^d\right) \quad .$$

Current COSMO-approximation:

$$(4) \quad \frac{dp}{dt} = -\frac{c_p}{c_v} p \nabla \cdot \boldsymbol{v}$$

$$(5) \quad \rho c_p \frac{dT}{dt} = \frac{dp}{dt} + Q_h \quad .$$

$I^{l,f}$: Phase fluxes
$\boldsymbol{J}_s$: Turb. heat flux
$\boldsymbol{R}$: Net radiative flux
$\boldsymbol{J}^v$: Turb. flux of vapor
$\boldsymbol{J}^d$: Turb. flux of dry air

SOME VERIFICATION RESULTS

Exp-IDs	EU	DE
Control	8901	8902
Experiment	9093	9094

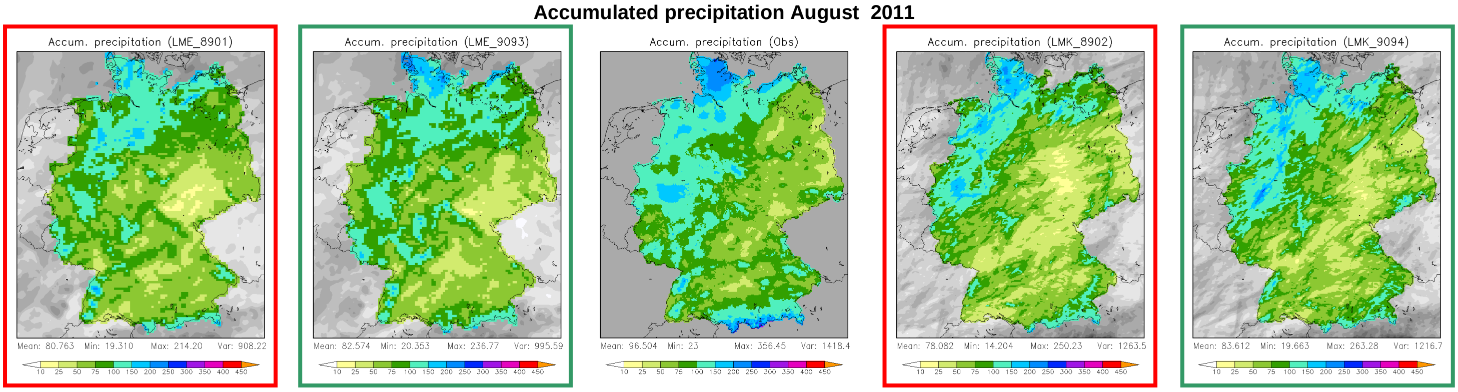
➔ Full model chain COSMO-EU ➔ COSMO-DE with nudging data assimilation

➔ Time period: August 2011

➔ Control run using Eq. (4) and (5) + Experiment using Eq. (1) and (3) with the additional diabatic terms (and new „isochoric“ formulation of the saturation adjustment process)

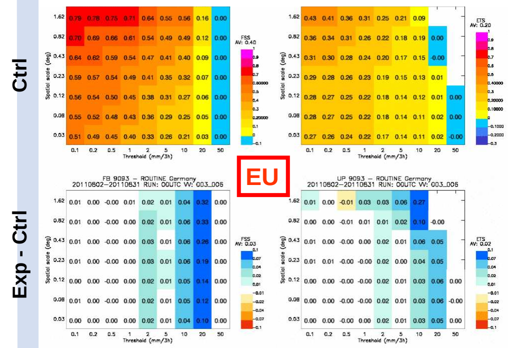
➔ Influence of the diabatic terms is generally not so large. Below we show only the most positively influenced model parameters. Others behave neutral or slightly negative.

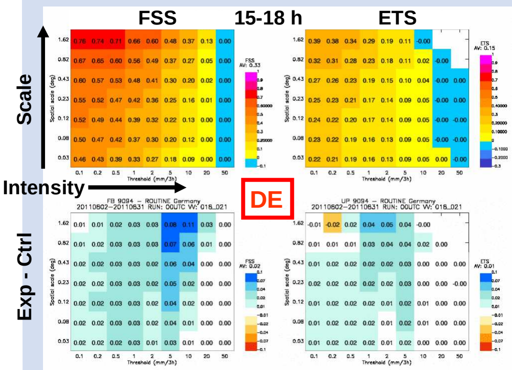
Accumulated precipitation August 2011



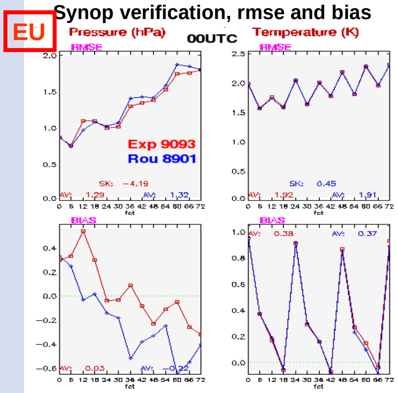
COSMO-EU Control | COSMO-EU + diabatic terms | Observations (REGNIE) | COSMO-DE Control | COSMO-DE + diabatic terms

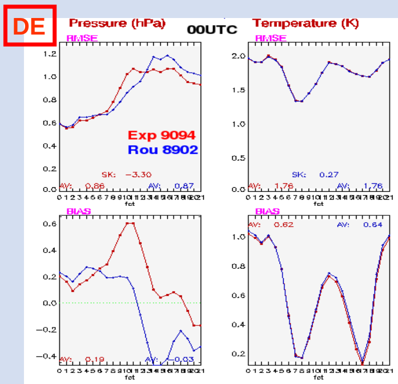
„Fuzzy“ precipitation verification



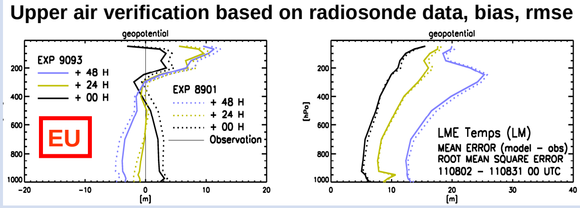


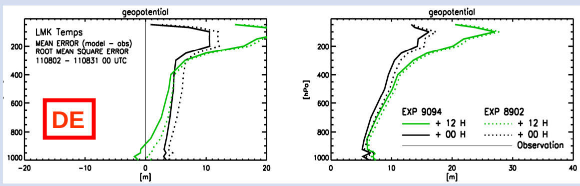
Synop verification, rmse and bias





Upper air verification based on radiosonde data, bias, rmse





Summary and Conclusions

➔ The diabatic terms in the p-equation mainly influence geopotential φ and surface pressure p_s. Less influence on T and other parameters.

➔ Precipitation amount is slightly increased in the experiment, and „fuzzy“ precipitation scores are neutral to positive, depending on model start time and forecast time.

➔ Only the „best“ verification results are shown to the left. Other model parameters behave neutral, some even slighty negative at times.

➔ Not shown: comparable verification experiment for winter period December/January 2011/2012 revealed influence on φ, p_s and surface precipitation, too, but influence on verification scores was more mixed. Will have to look deeper into that.