Convective and Orographically Induced Precipitation Study – COPS

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Analysis of the regional water balance for COPS IOPs using COSMO model simulations

R. Schnitter, Ch. Kottmeier, G. Schädler

Institute for Meteorology and Climate Research, University of Karlsruhe / Forschungszentrum Karlsruhe

Introduction

The atmospheric water vapour content is controlled by the processes precipitation, evapotranspiration and advection. These components, their relations and contributions to the regional water budget are insufficiently known. Routine observation networks are expensive to run, therefore observations are quite rare. Assumed that the distribution of the balance components in nature and in the model are similar, water balances can be estimated by combining observations and model simulations, especially based on potentials supplied by GPS measurements. Besides the quantification of the components the influence of specific regional characteristics (topography, land use) and time-dependent factors on a synoptical scale (weather situation, air mass features) to the regional water budget can be extracted.

Experiments like COPS provide an ideal opportunity to analyse the atmospheric water budget for different episodes. Furthermore balancing over longer time periods is needed to study the variability of the water budget components on a climatological scale. In the following model based atmospheric water balances for IOP 8b (July 15, 2007) are presented.

Methods

The presented water balances are related to the water vapour budget. A model of the atmospheric moisture fluxes is shown in figure 1. On this basis it can be established that the temporal change of the water vapour content in a volume is caused by advective and turbulent fluxes as well as phase transformations. Vertical turbulent fluxes on the land surface can be set equal to evapotranspiration.

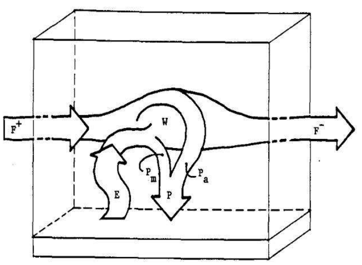

Fig. 1: Model of the atmospheric moisture fluxes; W = water vapour content, $F^{+/-}$ = moisture flux into/out of the volume, E = evapotranspiration, P = precipitation (Brubaker, 1993).

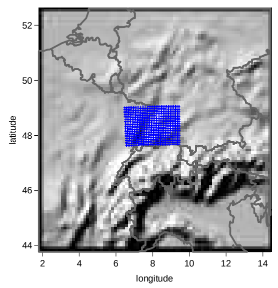

Fig. 2: Area of the model simulations. The water budget computations are related to the region marked in blue.

The atmospheric water balances are computed with the COSMO 4.2 model after the implementation of some modifications (Grams, 2008). This model based moisture budget implies that the temporal change of the specific humidity is set together by different physical and numerical processes which are listed in equation 1.

$$\frac{\partial q}{\partial t} = HADV + VADV + MTD + MMC + SQ + MCM + MLB + MRD$$

Eq. 1: Model based balance equation; q = specific moisture; Tendencies due to: HADV = horizontal advection, VADV = vertical advection, MTD = turbulent mixing, MMC = subgrid scale moist convection, SQ = cloud evaporation/condensation, MCM = computational mixing, MLB = lateral boundary relaxation, MRD = Rayleigh damping scheme (Doms and Schättler, 2002).

To establish the water budget balance of a region a control volume has to be set up. The location and the dimension of the control volume can be chosen arbitrarily within the simulation area. Figure 2 illustrates the simulation area. Marked in blue is the region of the water budget examinations. The height of the control volume is up to ca. 5 km. The features of the model set-up are presented in table 1.

Spatial resolution	7 km
Horizontal dimension of the simulation area	124 x 140 gridpoints
Number of model layers	40
Considered period	15.07.07 (0 UTC) to 17.07.07 (0 UTC)
Time scheme	Leapfrog

Tab. 1: Model set-up.

Results

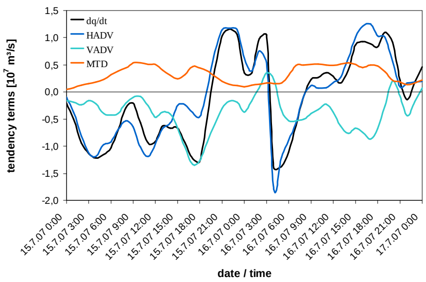

Fig. 3: Variation of the balance components dq/dt, HADV, VADV and MTD for the control volume from 15.07.07 to 17.07.07.

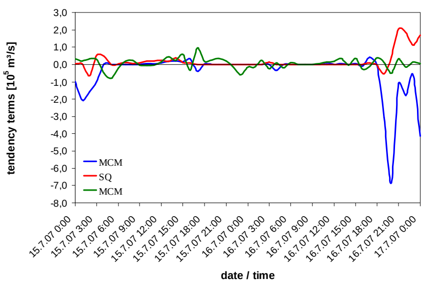

Fig. 4: Variation of the balance components MMC, SQ and MCM for the control volume from 15.07.07 to 17.07.07.

Balance calculations were done for IOP 8b to exclude contributions due to phase transformations and to find out which components are dominating in this case. The variations of the balance components can be seen in figure 3 and 4.

On July 15 an decrease and on July 16 an increase of water vapour can be noticed. Table 2 shows the mean contributions of all balance components to the temporal change of the specific humidity. The tendencies due to advection dominate the moisture change. A positive (negative) value indicates an inflow (outflow) of water vapour into (out of) the volume. The vertical turbulent mixing exhibits a typical diurnal variation because of the relation to the evapotranspiration. The lower contributions of moist convection and phase tranformations can be explained by the marginal development of convection and precipitation, especially on July 15.

The difference between the temporal moisture change and the sum of the other balance components, the so-called residuum, indicates to which extent the balance is closed. For model based balancing a residuum not equal to zero has to be expected. The contribution of the residuum for the simulated case averages -0,015% which signifies an almost closed balance.

Balance component	Contribution in %
Horizontal advection (HADV)	92,087
Vertical advection (VADV)	11,154
Vertical turbulent mixing (MTD)	-3,272
Subgrid scale moist convection (MMC)	0,074
Cloud evaporation and condensation (SQ)	0,065
Numerical diffusion (MCM)	0,022
Lateral boundary relaxation (MLB)	0,000
Rayleigh damping scheme (MRD)	0,000
Residuum	-0,015

Tab. 2: Listing of the balance components and their contributions to the moisture change in %.

Conclusions and Outlook

The model based balancing for an episode with a low number of convection cells and precipitation events reaches an almost closed balance for the atmospheric water vapour budget. The dominating contributions to the moisture change are advective and diffusive processes.

For further testing of this balancing method model simulations for episodes with phase transformations and computations for longer periods are necesseray. In a next step the model results are to be compared with measurements. In particular the comparison of the simulated water vapour content with GPS measurements is of significance.

References: Doms, G., Schättler, U. (2002): A Description of the Nonhydrostatic Regional Model LM, Part I: Dynamics and Numerics. COSMO model documentation. German Weather Service.
Grams, Ch. (2008): Der „Atlantik Inflow": Atmosphäre-Land-See-Wechselwirkung am südwestlichen Rand des Sahara-Hitzetiefs. Diploma thesis. University of Karlsruhe.

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Contact: romi.schnitter@imk.fzk.de