Analysis of the Atmospheric Water Cycle Components for Southern Germany during the COPS Experiment

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Motivation

Research demands on the **regional** scale:

- Quantification
- Analysis of influences
The Atmospheric Water Budget

Combination of
1. Regional model simulations (COSMO)
2. Observations (COPS, GPS)

Model of the atmospheric moisture fluxes (Brubaker 1993):

- $W = \text{Water vapour content}$
- $F^{+/-} = \text{Advection into/out of the control volume}$
- $E = \text{Evapotranspiration}$
- $P = \text{Precipitation}$
The Water Budget in COSMO

Budget Equations for the gaseous ($v$), liquid ($l$) and solid ($f$) phases of water

(I) \[ \frac{\partial q_v}{\partial t} = -\vec{v} \cdot \nabla q_v + S_v + M_{q_v} \]

(II) \[ \frac{\partial q_l}{\partial t} = -\vec{v} \cdot \nabla q_l - \frac{1}{\rho} \frac{\partial P_l}{\partial z} + S_l + M_{q_l} \]

(III) \[ \frac{\partial q_f}{\partial t} = -\vec{v} \cdot \nabla q_f - \frac{1}{\rho} \frac{\partial P_f}{\partial z} + S_f + M_{q_f} \]

\[ M_{q_x} = M_{q_x}^{TD} + M_{q_x}^{MC} + M_{q_x}^{CM} + M_{q_x}^{LB} + M_{q_x}^{RD} \]

Cloud water (c)
Rain water (r)
The Total Water Balance

\[
\frac{\partial q_v}{\partial t} + \frac{\partial q_l}{\partial t} = -\bar{v} \cdot \nabla q_v - \bar{v} \cdot \nabla q_l + M^{TD}_{q_v} + M^{TD}_{q_c} + M^{MC}_{q_v} - \frac{1}{\rho} \frac{\partial P}{\partial z} + S_v + S_l + M^{CM}_{q_v} + M^{CM}_{q_c}
\]

Neglecting the turbulent flux of \( q_r \)

Convective & gridscale precipitation

If \( S_f = 0 \) \( \rightarrow \) \( S_v + S_l = 0 \)

Neglecting the tendencies due to lateral boundary relaxation and Rayleigh damping
Modifications in COSMO:

Tendency terms for
- $q_v$-Budget
- $q_c$-Budget
- $q_r$-Budget

Output for each gridpoint

"Post-Processing":
Calculation of the tendencies for a control volume
## The Model Setup

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model version</strong></td>
<td>COSMO 4.2</td>
</tr>
<tr>
<td><strong>Spatial resolution</strong></td>
<td>7 km</td>
</tr>
<tr>
<td><strong>Size of the simulation area</strong></td>
<td>124 x 140 gridpoints</td>
</tr>
<tr>
<td><strong>Number of vertical layers</strong></td>
<td>40</td>
</tr>
<tr>
<td><strong>Time integration scheme</strong></td>
<td>Leapfrog</td>
</tr>
<tr>
<td><strong>Time step</strong></td>
<td>40 s</td>
</tr>
<tr>
<td><strong>Convection scheme</strong></td>
<td>Tiedtke</td>
</tr>
<tr>
<td><strong>Scheme for grid-scale precipitation</strong></td>
<td>Two-Category Ice Scheme</td>
</tr>
</tbody>
</table>
Investigation Area and Episodes (COPS)

Episodes:

• without precipitation
  15 July 2007

• with precipitation
  19-20 July 2007

Topography of the simulation area, position and size of the control volume
The Contributions to the Water Content for Different Episodes

Calculation of the contributions (in %):
\[
\frac{x}{dW/dt} \times 100\%
\]

Episode 1 (without precipitation)

Episode 2 (with precipitation)
Classification of the Topography

\[0m \text{ to } 300m \quad 300m \text{ to } 600m \quad 600m \text{ to } 1200m\]

Area 1  Area 2
The Contributions to the Water Content for Different Topography

Calculation of the contributions (in %):
\[
\left\{ \frac{x}{dW/dt} \right\} \times 100\%
\]

Control volume 1 (low)
- \(2\) Res
- \(11\) \(F^h_v\)
- \(18\) \(E\)
- \(2\) \(E\)
- \(F^v_v\)
- \(P\)

Control volume 2 (mountainous)
- \(5\) Res
- \(58\) \(F^h_v\)
- \(0\) \(P\)
- \(13\) \(E\)
- \(F^v_v\)
- \(P\)

\(F^h_v\) = hor. Advection \((q_v)\)
\(F^v_v\) = ver. Advection \((q_v)\)
E = Evapotranspiration
P = Precipitation
Res = Residuum
Summary

- Budget calculation for gaseous and liquid water with COSMO
- Good budget closure
- Main contribution due to advection of water vapour
- Contribution of evapotranspiration around 10 to 20%, except for the case of the Rhine Valley
Outlook

- Tendency terms for solid water
- Calculation of the Recycling Ratio to measure the contribution of advection and evapotranspiration to the precipitation
- Comparison of simulated water vapour content with GPS measurements
- Analyses of longer episodes
Thank you for your attention!