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

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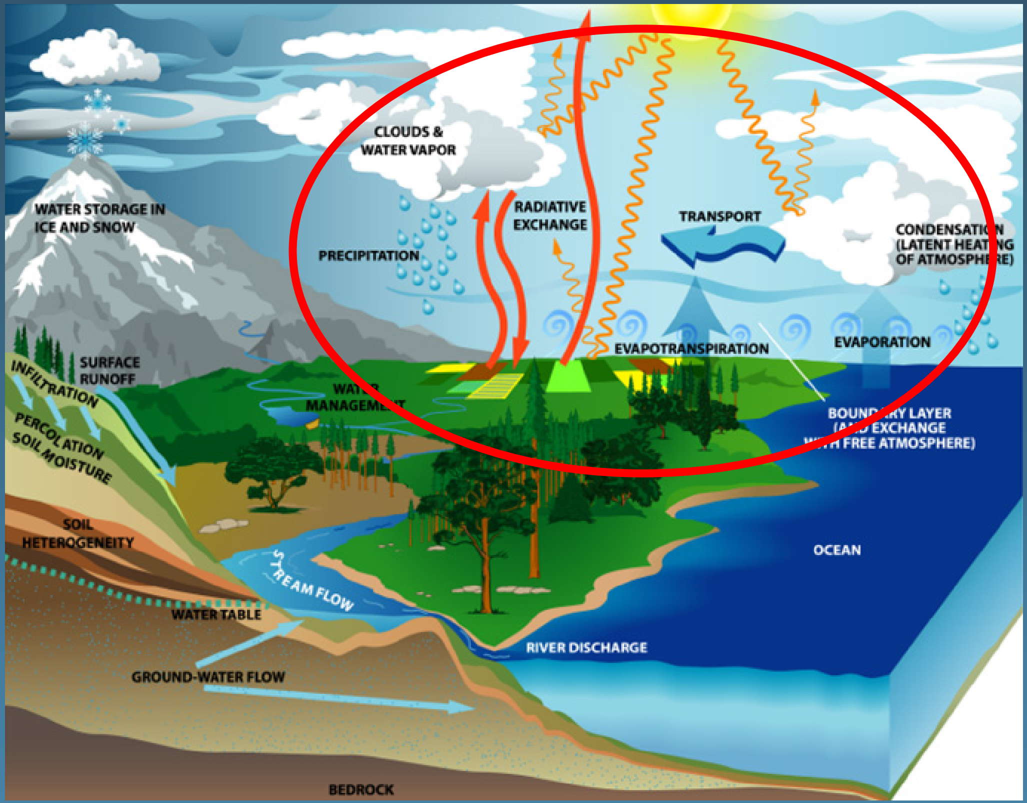
# Motivation




**Hydrological Cycle**
**(http://www.usgcrp.gov/usgcrp/images/ocp2003/ocpfy2003-fig5-1.htm)**

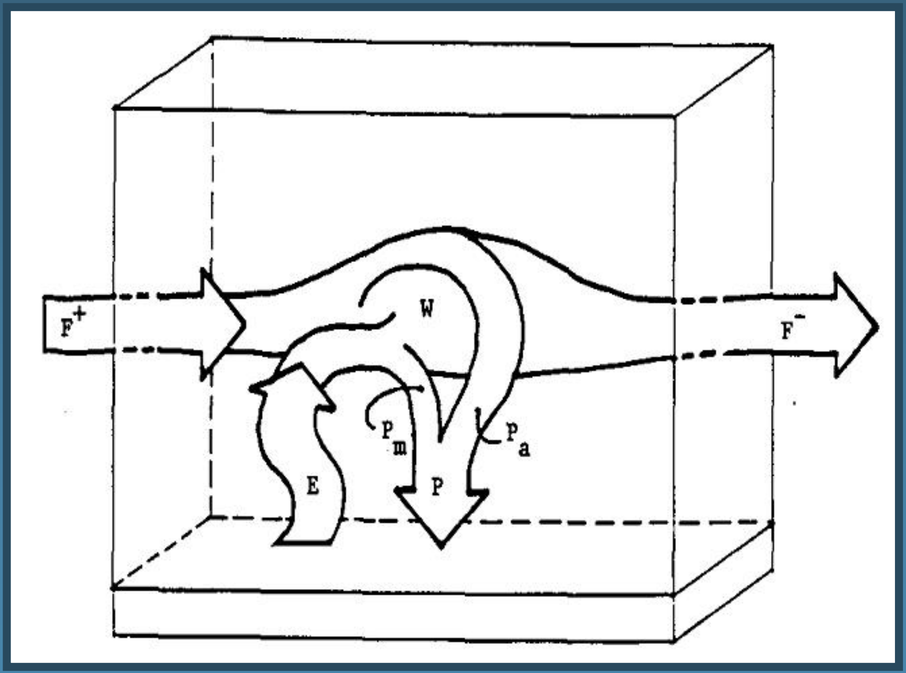
**Research demands on the regional scale:**

- **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 = Water vapour content

$F^{+/-}$ = Advection into/out of the control volume

E = Evapotranspiration

P = 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

$$\underbrace{\frac{\partial q_v}{\partial t}+\frac{\partial q_l}{\partial t}}_{dW/dt} = \underbrace{-\vec{v}\cdot\nabla q_v - \vec{v}\cdot\nabla q_l}_{F} + \underbrace{\underbrace{M_{q_v}^{TD}}_{E} + M_{q_c}^{TD}}_{TD} + \underbrace{M_{q_v}^{MC} - \frac{1}{\rho}\frac{\partial P_r}{\partial z}}_{-P} + \underbrace{S_v + S_l}_{S} + \underbrace{M_{q_v}^{CM}+M_{q_c}^{CM}}_{CM}$$

TD → Neglecting the turbulent flux of $q_r$

−P → Convective & gridscale precipitation

S → If $S_f = 0 \rightarrow S_v + S_l = 0$

CM → Neglecting the tendencies due to lateral boundary relaxation and Rayleigh damping

# Application of the COSMO Model

**Modifications in COSMO:**

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

→

Output for
each gridpoint

J. Schwendike & Ch. Grams

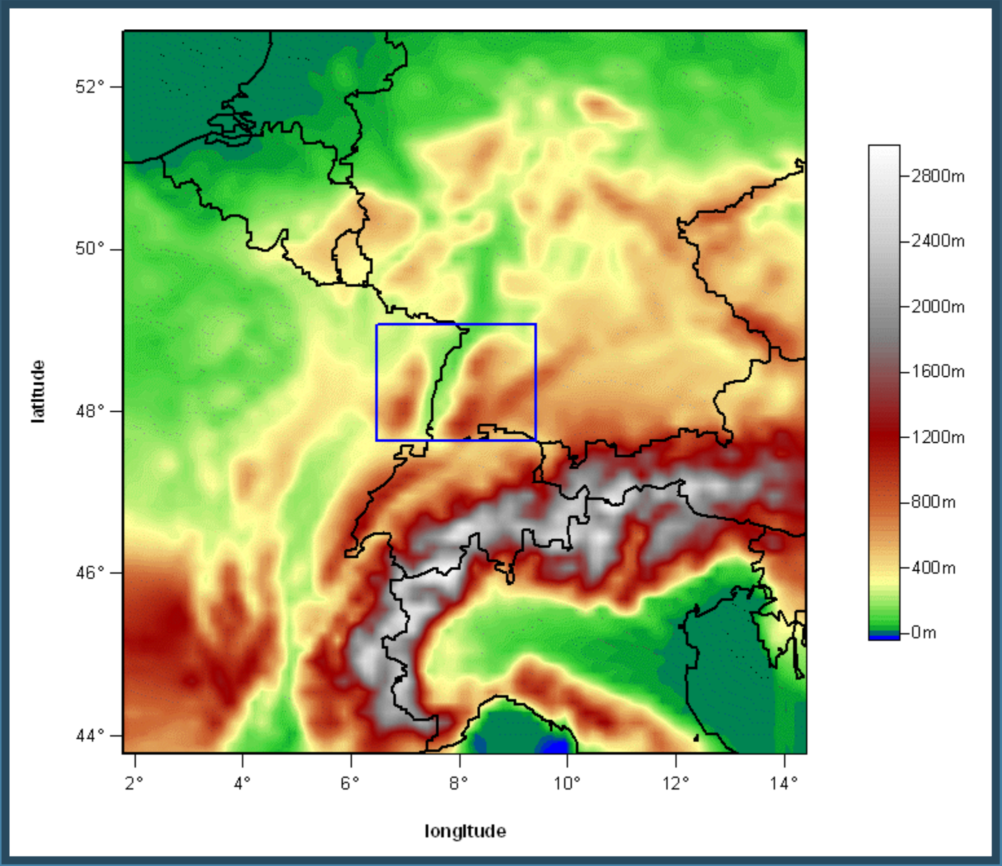
**„Post-Processing":**

Calculation of the tendencies
for a control volume

# The Model Setup

| Model version | COSMO 4.2 |
|---|---|
| Spatial resolution | 7 km |
| Size of the simulation area | 124 x 140 gridpoints |
| Number of vertical layers | 40 |
| Time integration scheme | Leapfrog |
| Time step | 40 s |
| Convection scheme | Tiedtke |
| Scheme for grid-scale precipitation | Two-Category Ice Scheme |

# Investigation Area and Episodes (COPS)




Topography of the simulation area, position and size of the control volume

**Episodes:**

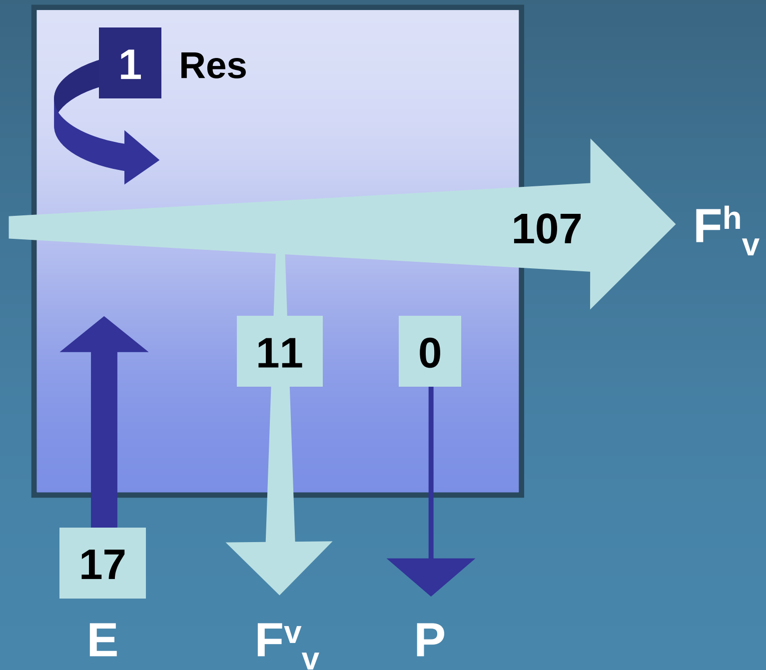
- **without precipitation 15 July 2007**
- **with precipitation 19-20 July 2007**

# The Contributions to the Water Content for Different Episodes

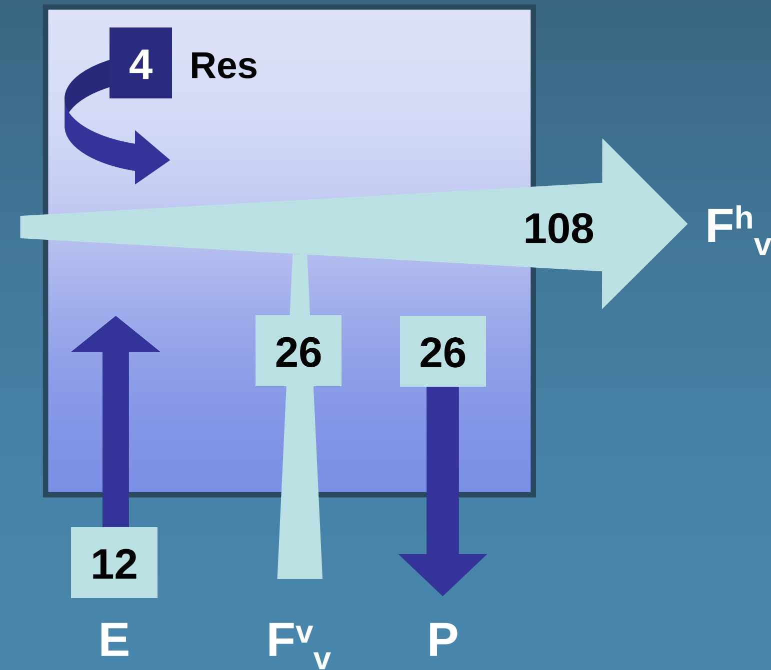
Calculation of the contributions (in %): $\left| \dfrac{x}{dW/dt} \times 100\% \right|$

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

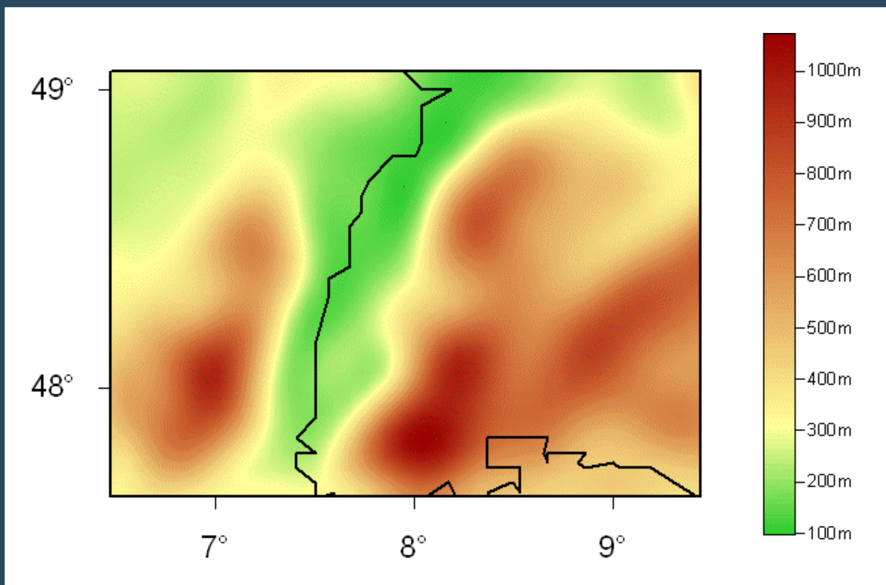
## Episode 1 (without precipitation)

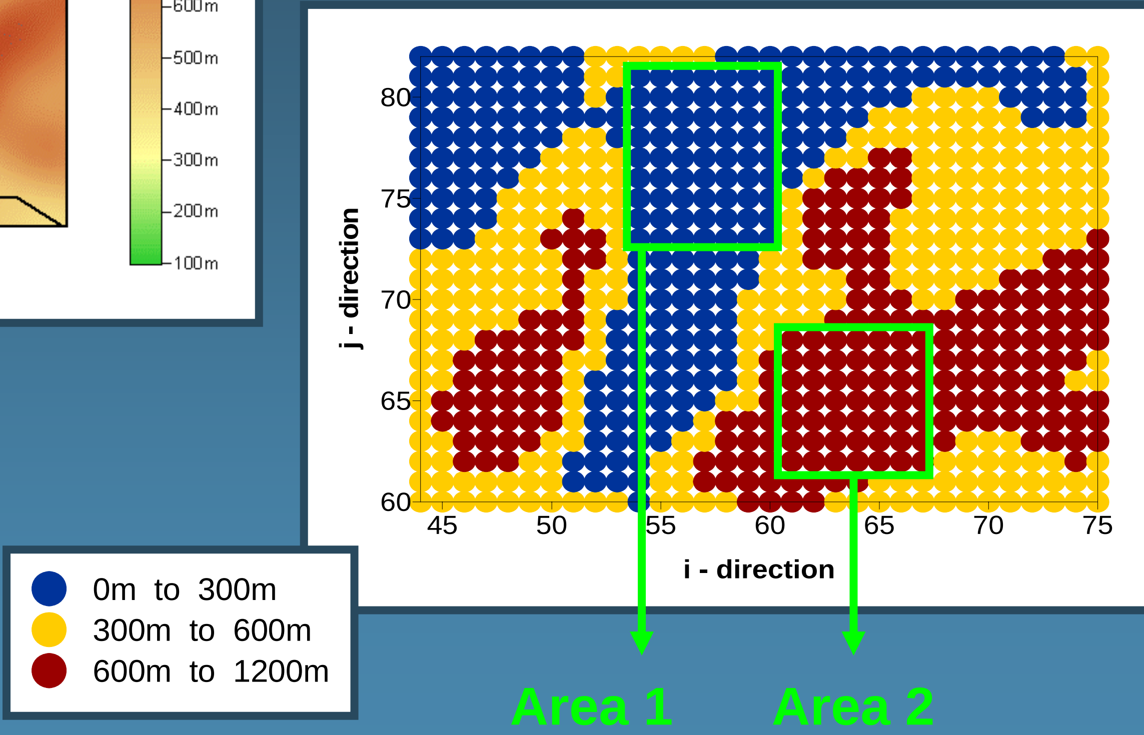



## Episode 2 (with precipitation)



# Classification of the Topography



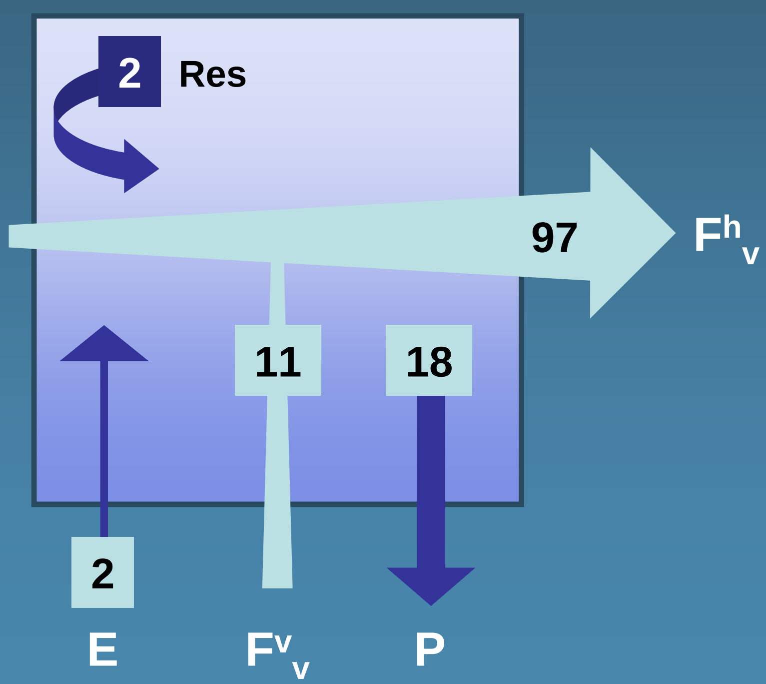



# The Contributions to the Water Content for Different Topography

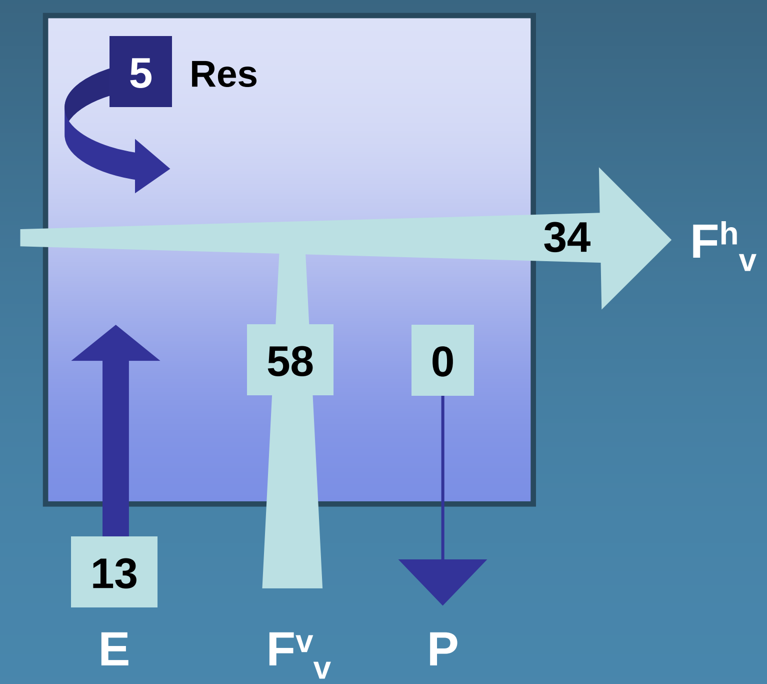
Calculation of the contributions (in %): $$\left|\frac{x}{dW/dt}\times 100\%\right|$$

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

## Control volume 1 (low)




## Control volume 2 (mountainous)



# 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!