Streamflow data assimilation for root zone soil moisture analysis

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Objectives of STREAMDATA

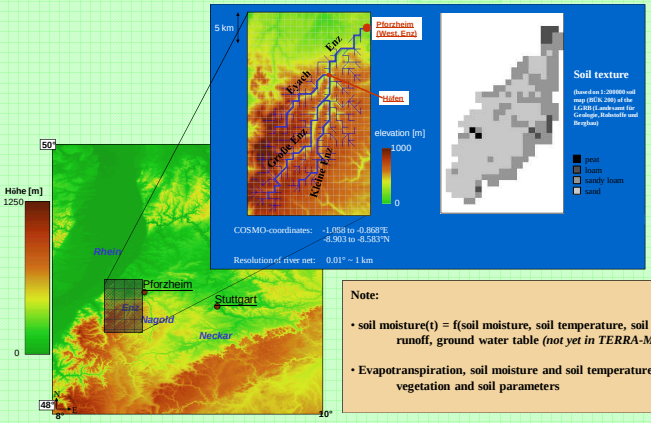
- Streamflow data assimilation for NWP
- Root zone soil moisture analysis
- Error statistics of root zone soil moisture

Models

(Description in Warrach et al., 2008, Met. Zeitschr. 17)

- TERRA-ML (vertical land surface model of COSMO; e.g. Doms et al., 2005; Heise et al., 2006)
- TERRA-ML set up in COSMO-framework (Ament and Simmer; 2006) forced with measured meteorological data
- Lumped River Routing Scheme (Lohmann et al., 1998; Lohmann et al. 2004) based on Unit Hydrograph concept and St. Venant equation

The Enz River



Soil texture	Sand	Sandy loam	Loam	Peat
η_s [M/M]	0.364	0.445	0.463	0.863
ψ_s [m]	-0.121	-0.218	-0.478	-0.356
K_s [m/s]	1.76E-4	3.47E-5	6.95E-6	2.E-5
η_{res} [M/M]	0.012	0.03	0.035	0.098
K_0 [m/s]	479E-7	943E-8	531E-8	58E-9
K_1 [-]	-19.27	-20.86	-19.6	-16.48
D_1 [M^2/S]	184E-7	34E-8	357E-8	10E-9
D [-]	-8.45	-9.47	-7.44	-5.97

Note: FAO soil map shows only loam

Vertical soil water equation:

$$\frac{\partial \eta}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\partial \eta}{\partial z}\right) - \frac{\partial K}{\partial z} - S_{root}$$

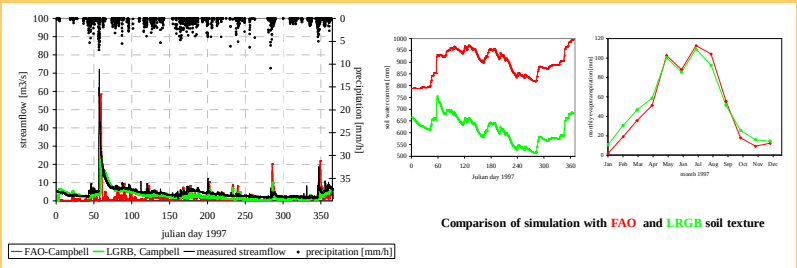
$$K = K_s \cdot (\eta/\eta_s)^{2b+3}$$

$$D = -b \cdot K_s \cdot \psi_s / \eta_s \cdot (\eta/\eta_s)^{b+3}$$

Note:

- soil moisture(t) = f(soil moisture, soil temperature, soil texture, vegetation properties, weather, runoff, ground water table *(not yet in TERRA-ML)*, snowpack)
- Evapotranspiration, soil moisture and soil temperature depend non-linearily on vegetation and soil parameters

Coupled simulations with TERRA-ML and Lumped River Routing Scheme (*Warrach et al., 2008, Met.Zeitschrift 17*)



Comparison of simulation with FAO and LRGB soil texture

Implementation of the Square Root Analysis Scheme for the EnKF*

Variables and Constants

$n \in [1,N]$ = ensemble member
$m \in [1,M]$ = number of measurement
a = analysis, f = forecast, tr = truth
x,y,z = space variables, t = time
i = index for period of streamflow assimilation, e.g. 15 hours
W = soil water content, T = soil temperature
H = TERRA-ML+ROUTING = model operator
$\Psi^{tr}(x,y,z,t_i) = (T^{tr}(x,y,z,t_i), W^{tr}(x,y,z,t_i))$ = True state variable
$\Psi^{a}(x,y,z,t_i,n) = (T^{a}(x,y,z,t_i,n), W^{a}(x,y,z,t_i,n))$ = Analysis ensemble
$\Psi^{f}(x,y,z,t_i,n) = (T^{f}(x,y,z,t_i,n), W^{f}(x,y,z,t_i,n))$ = Forecast ensemble
$S(t_i,m)$ = streamflow observation at gauging station
$D^{f}(t_i,n) = H\,\Psi^{f}(x,y,z,t_i,n)$ =forecast streamflow ensemble
$\varepsilon(t,m,n)$ = perturbated observation ensemble

Application of COPS/D-PHASE data in STREAMDATA

The ensembles need to be chosen carefully, since outliers and too wide spreads may lead to wrong results or instabilities with EnKF. Consistent ensembles for the meteorological forcing are the results of the weather forecast models applied during COPS/D-PHASE. Since TERRA-ML is part of COSMO, the COSMO-simulations will be preferably applied. Possible ensembles are the COSMO-LEPS and a lagged ensemble of the COSMO-EU simulations. The former is only available as 3 hourly data, which might cause problems since the radiation and temperature are only saved as averages. Therefore the peak values are unknown and a too low evapotranspiration might be simulated with TERRA-ML.

FLOW CHART FOR STREAMFLOW DATA ASSIMILATION

1. CONTROL RUN: TERRA-ML+ROUTING
(Forcing: measured meteorological data 1997)

$S(t,m), \Psi^{tr}(x,y,z,t_i)$

2. SET UP INITIAL FIELD ENSEMBLE
(e.g. gaussian noise for precipitation (+/- 50%) applying Evensen (2004)'s sampling

$\Psi^{a}(x,y,z,t_0,n)$

3. ENSEMBLE RUN (TERRA-ML+ROUTING)
(e.g. applying gaussian noise for precipitation (+/- 50%) applying Evensen (2004)'s sampling and with changed soil and plant parameters)

$\Psi^{f}(x,y,z,t_i,n), D^{f}(t_i,n)$

4. SET UP PERTURBED OBSERVATION ENSEMBLE

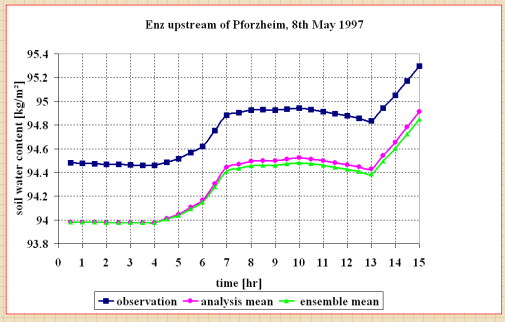
$\varepsilon(t,m,n)$

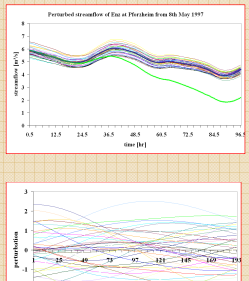
5. Apply EnKF (with Square Root Analysis)

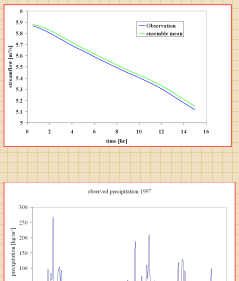
$\Psi^{a}(x,y,z,t_i,n)$

CONTROL: TERRA-ML + ROUTING for 1997 measured forcing
=> delivers „truth" and „observed streamflow"

EXPERIMENT 1 (preliminary results):
- Ensemble $\Psi^{a}(x,y,z,t_0,n)$: perturbed precipitation * * from 27th April to 7th May 1997, N=40, M=30, state variables=257*6*2=3084
- Ensemble Forecast: perturbed saturated hydraulic conductivity, perturbed precipitation* *, ensemble of initial condition, assimilation of 30 hours starting 8th May, 0:00h







*Ensemble Kalman Filter (Evensen, 1994 and 2004, and http://enkf.nersc.no)

(* * precipitation=1.5*precipitation*perturbation/3.)