Using SMOS satellite data as an input to hydrological models in the northern areas

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Abstract

Soil moisture is the most important storage in hydrological forecasting at summer due to the strong effect of soil moisture deficit on runoff. It is also difficult to observe and update in hydrological model in catchments scale. The Finnish Environment Institute (SYKE) is in a joint project SMOS-Nora with other research institutes. The project is connected to ESA. The project objectives are to assimilate SMOS soil moisture data to the operational hydrological forecasting model and validate the SMOS soil moisture data with in-situ observations in the northern areas.

The ground truth measurements are made within different depths to get a profile of the sub-surface soil moisture as well. The measurement is based on the difference of dielectric properties between free water and soil. The data is collected all year round and transferred automatically in real time to SYKE's database and forecasting system WSFS (www.environment.fi/waterforecast).

The aim is to use the soil moisture satellite data as an input to the hydrological forecasting model covering all Finland. Three different approaches concerning soil moisture modeling are developed. These include conceptual one storage, multi-layer models and also a more physical model based on the Community Land Model (CLM), which is a part of US Department of Energy Earth System Grid model.

1. Introduction

Observation of soil moisture on daily basis has long time been both time consuming and difficult. With relatively new sensor types and the technology becoming cheaper this has become possible. However, as the soil types differ considerably and therefore the value of water in the soil, spaceborne measurements are valuable.

The Finnish Environment Institute (SYKE) is in a joint project SMOS-Nora with Helsinki University of Technology, Finnish Meteorological Institute and Finnish Marine Research Institute. The goal of the project is to use the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) satellite data to estimate the amount of water in the soil and use this data as an input to hydrological models. The scheduled launch of SMOS satellite is in 2009.

In SMOS-Nora project SYKE is responsible for the ground truth measurements and incorporating the coming SMOS data to the Watershep Simulation and Forecasting System (WSFS) (Vehviläinen et al., 2005) developed in the Hydrological Services Division. The WSFS system covers the whole Finland and is used for flood forecasting and hydrological research. Soil moisture and ground water are components in the model.

2. Soil Moisture Observations

The observation system for the ground truth of soil moisture is constructed with sensors from Campbell Scientific Inc. The measuring technique is based on the difference of dielectric constants of soil and free water.

The four sensor are measuring 80cm (with 20cm interval) in vertical direction starting from the surface. Four sensors are preferred as using more would require a datalogger, which costs more than double the one used. It seems that the variation already at 60-100cm depth is small. This suggests that it is possible to catch almost all the changes in the water column with the current setup. The values are stored in the datalogger memory and transferred daily via GSM network to the databases in SYKE. See the Figure 1 for a description of the system. Eight stations are currently deployed around Finland and added into the WSFS model.

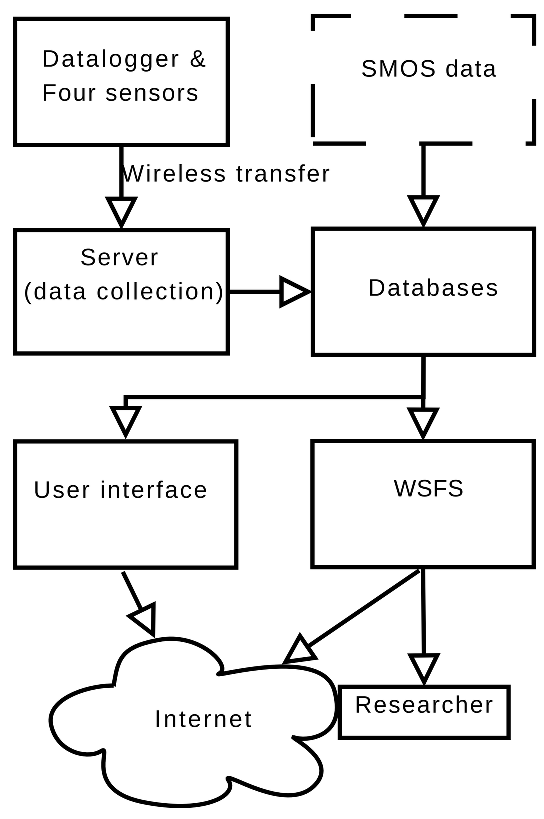

Figure 1: *The flow chart of the data in the system.*

Observations from Lammi, Finland are shown in Figure 2. They show high variation in the first layer and more constant values when going deeper apart from the fourth layer. It has the second highest values, which demonstrates the challenges of simulating the soil moisture as the soil types also in vertical direction are heterogeneous.

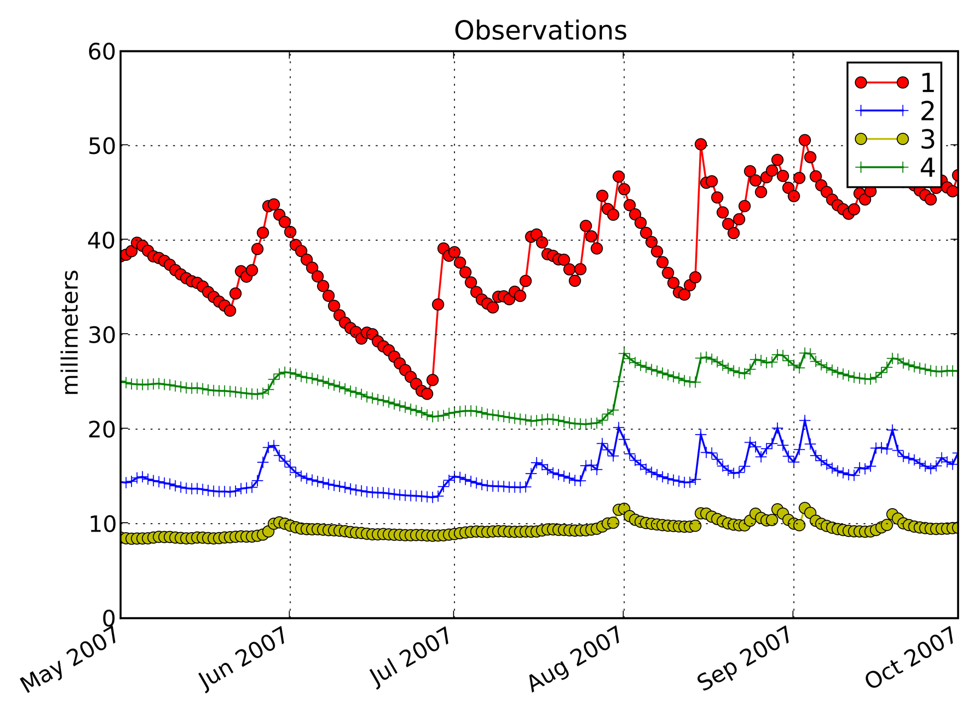

Figure 2: *Soil moisture observation from Lammi, Finland. The values represent amount of water in millimeters in* 200*mm (vertical) soil column.*

The SMOS satellite data will deal with the uppermost part of the soil column. The satellite will have a passive microwave 2D-interferometer in L-band ($\lambda = 21$cm) with spatial resolution of 35km for detection of water in the soil. One of the observational challenges, especially in Finland, is the vegetation cover i.e. forests. In SMOS-Nora project the feasibility of remote sensing soil moisture data will be tested trough ground truth measurements and simulations.

3. Soil Moisture Model

The Watershed Simulation and Forecasting System (WSFS) is used to model the soil moisture in catchment scale. A part of SMOS-Nora program is to develop this component and try to search new model types for soil moisture, which ultimately will be incorporated into operational version of WSFS. Three different approaches are developed.

The first one, which is already in the operational version, is effectively a one-layer model calibrated against the observations. In Figure 3 the one-layer model is shown in solid blue line with the observations marked with black ticks. The one-layer model is based on conceptual catchment scale model and seems to work fairly good.

The second approach (Fig. 4) is based on the ideas of the conceptual one-layer model. The number of layers has been increased to four and lateral runoff (Q) and vertical infiltration (inf) mechanisms have been modified extensively. Number of calibrated parameters has increased, which increases the complexity of the model.

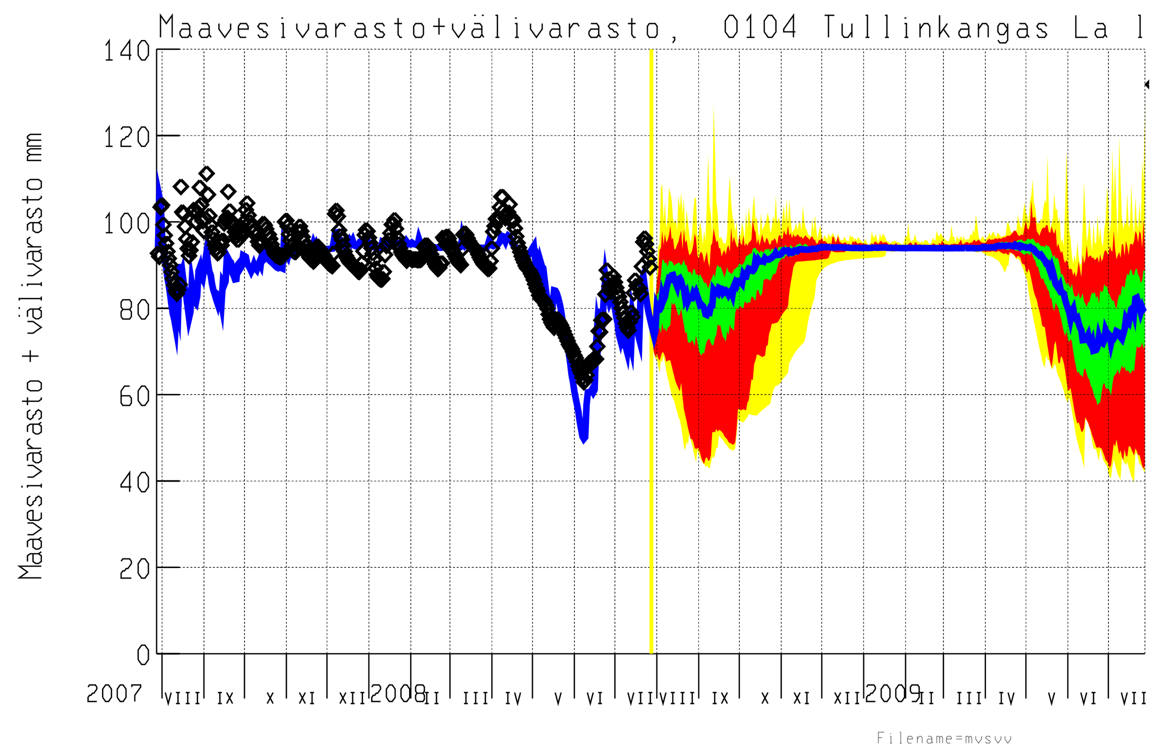

Figure 3: *The one-layer model of the soil moisture used in the operational WSFS in Lammi (Southern Finland). The black ticks represent the observations of the soil moisture in mm and the solid blue line is the median value from the model. The forecast begins after the vertical yellow line.*

In Figure 4 a sketch of the model structure is shown. The arrows represent the direction the water moves in the soil or the evapotranspiration (E). Two components outside the soil moisture model are also shown. These are yield, which represents the input from precipitation and melting of snow. On the bottom is the ground water model of WSFS. Cap represents capillary rise from ground water. At this point the model needs more development.

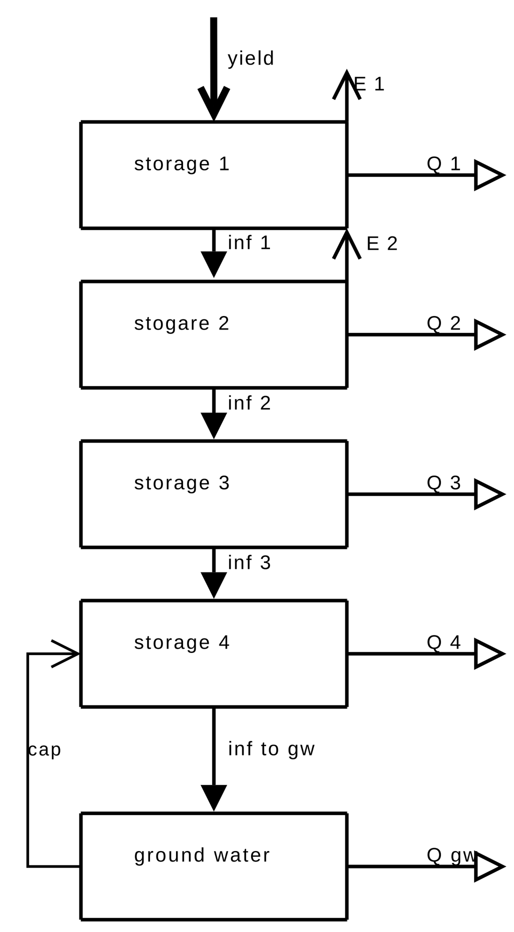

Figure 4: *Structure of the current multi-layer soil moisture model in the WSFS.*

The third possible approach for the soil moisture model would be a more physical one. This type of model pose a great problem as more information of the soil types and textures are needed than is available in catchment scale. Development of this model is just in beginning and the whole structure is not clear at this point. A good description of a physical model is written by Oleson et al. (2004).

References

Campbell Scientific Inc.: *CS616 & CS625 Water Content Reflectometers*, 2004, Manual

Oleson, K.W. et al.:*Technical Description of the Community Land Model (CLM)*, 2004, National Center for Atmospheric Research Technical Note, Boulder, CO

Vehviläinen, B., Huttunen, M. and Huttunen, I.: *Hydrological forecasting and real time monitoring in Finland: The watershed simulation and forecasting system (WSFS)*, 2005, Innovation, Advances and Implementation of Flood Forecasting Technology, Conference Proceedings, Tromsø

http://www.environment.fi/waterforecast