LINKING HYDROLOGY AND METEOROLOGY: MEAUSRING WATER BALANCE TERMS IN CABAUW, THE NETHERLANDS

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Keywords: water balance, discharge measurements, soil moisture measurements, polder area

1. INTRODUCTION

In many meteorological models the interface between atmosphere and soil compartment is implemented as a lower boundary, but from a hydrological viewpoint this interface is the upper boundary. Complex exchange processes occur at the surface and uncertainty in water and energy fluxes across the model boundaries is a source of model errors. Understanding and quantifying these flux processes through observation can help to improve both meteorological and hydrological models.

At the Cabauw Experimental Site for Atmospheric Research (CESAR) in the Netherlands all meteorological quantities are measured as part of the surface radiation and energy balances. In addition, the Hydrology and Quantitative Water Management Group of Wageningen University installed equipment to complete the terrestrial observation program by quantifying the water balance terms.

Water balances are often used to determine the size of water fluxes across catchment boundaries. In this research project a water balance is set up for the water system in Cabauw.

Parts of this study have already been presented at the International Symposium on Tropospheric Profiling [1].

2. FIELD SITE

The "catchment" of approximately 0.5 km^2 can be divided in two nested catchments of 0.3 and 0.2 km^2. It is part of a polder area, and drained by small, man-made channels (Fig. 1). The soil consists of heavy clay on peat and is mainly covered with grass or cultivated for maize. The area is flat and at an elevation of approximately one meter below mean sea level. It is possible that there is seepage from the nearby river Lek, of which the water level is variable and on average approximately 2 m higher than the water levels in the catchment.

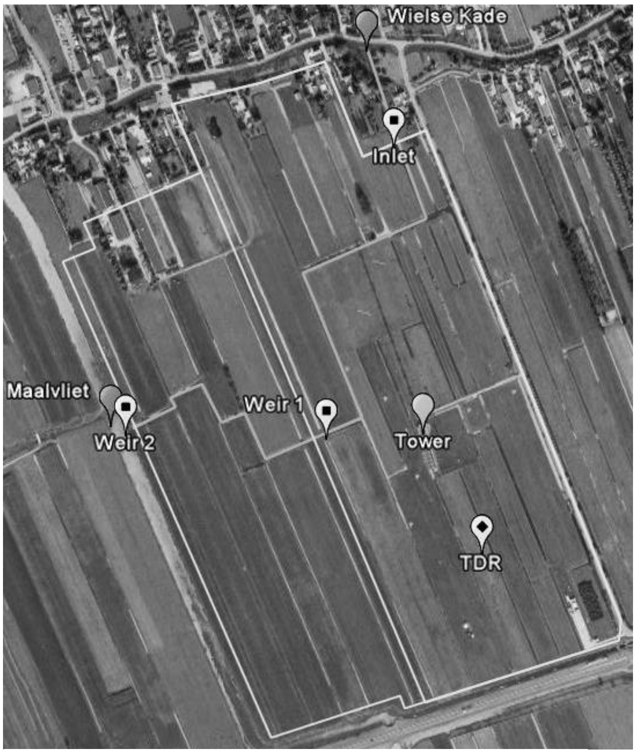

Figure 1. Overview of the catchment.

Water is supplied upstream into the catchment from the more elevated Wielse Kade by the water authority. Then it follows the main water course via the outlet of the first catchment (weir 1) and via the outlet of the second catchment (weir 2) and flows out into the Maalvliet. The water levels of surface water inside and outside the catchment are regulated. Different levels are maintained in summer and winter.

2. WATER BALANCE

The water balance for the Cabauw catchment is given by

$$P - ET_{act} + Q_{in} - Q_{out} = \Delta S$$

where P = precipitation [mm/d], ET_{act} = actual evapotranspiration [mm/d], Q_{in} = inflowing discharge [mm/d], Q_{out} = outflowing discharge [mm/d] and ΔS = change in soil storage [mm/d]. The water balance can be set up for the two sub-catchments and for the whole catchment. The rest term is the imbalance between the left-hand side and the right-hand side of the equation.

In theory the water balance should close, but in practice it never closes completely. This can mainly be attributed to (1) measurement errors or (2) water balance terms that have been omitted, such as upward seepage from the river Lek.

3. MEASUREMENTS

Discharge

Downstream of the inlet a V-notch weir has been installed. At the outlets of the first and second sub-catchment Rossby-weirs have been installed. Upstream of the weirs Keller water level sensors have been placed. Discharge is derived from the recorded water levels and a stage-discharge relationship obtained in the laboratory. In April 2009 a magneto-strictive sensor has been installed upstream of the V-notch weir to measure water levels directly. For the water balance in mm/d volumetric discharges can be converted using catchment sizes. Accurate discharge data are available since May 2007.

Soil moisture

In 2003 a TDR-system has been installed in the field. This system consists of 6 vertical arrays (3.5 m apart) of 6 sensors at 5, 15, 30, 45, 60 and 72.5 cm depth. It measures 36 volumetric water content (θ) values on a daily base. Soil moisture data are available since November 2003, but few data are available for June and July 2007 and for July and August 2008 due to system collapses.

It should be stressed that these soil moisture sensors represent one location in the catchment and that moisture content can be highly variable in space. Additional errors arise when clayey soil becomes dry and contact between sensors and soil becomes sub-optimal due to fracturing.

Precipitation and evapotranspiration

Daily precipitation sums (P) have been collected by a rain gauge network and by the Royal Netherlands Meteorological Instute, KNMI, at the automatic weather station in the catchment. These last data have been used here.

Actual evapotranspiration rates (ET_{act}) have been estimated by the KNMI. With an eddy covariance set-up first estimates of latent and sensible heat fluxes are made and subsequently their Bowen ratio is computed. Finally this ratio is used to divide the available energy (net radiation minus soil heat flux) between latent and sensible heat flux.

4. RESULTS

Presented results in the next section are illustrative for the 0.5 km^2 catchment. Since data analysis is work in progress, probably not all (minor) errors have yet been corrected.

Water balance terms vary during the year. We selected 2-month winter and summer periods for which daily sums of water balance terms are shown in detail (Figure 2 and Table 1).

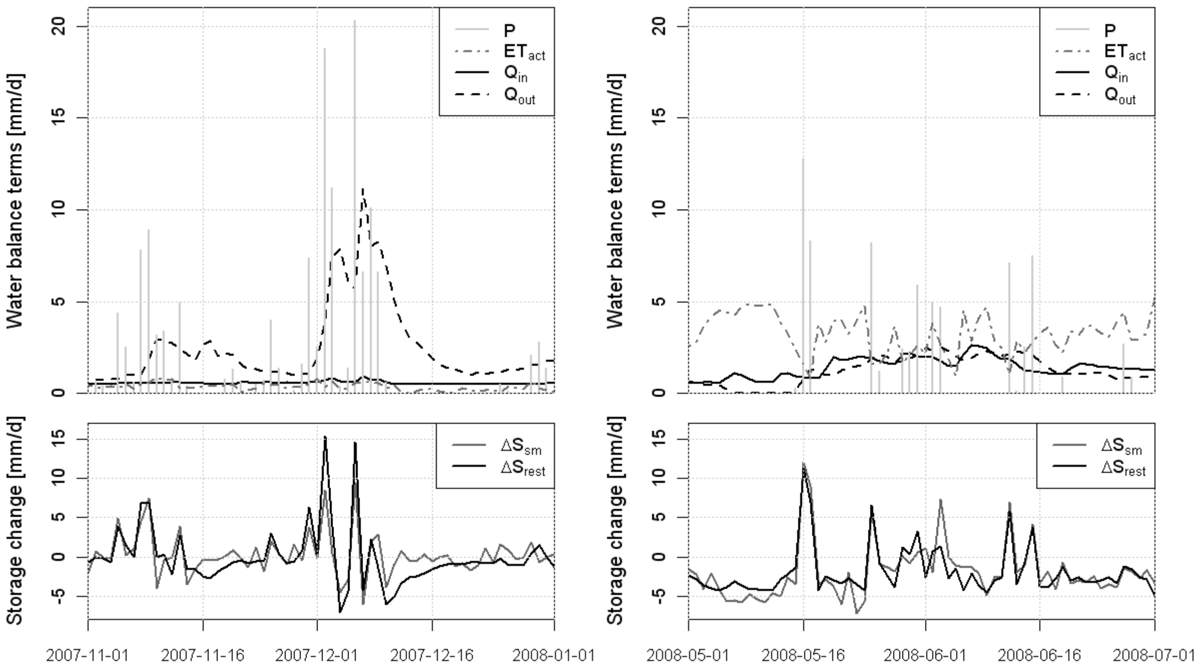

Figure 2. Water balance terms in two two-month periods.

From November 1st 2007 to January 1st 2008 all terms are smaller than 1 mm/d except P and Q_{out} (Fig. 2). ET_{act} is small because temperature and radiation intensities are low in this period. Q_{in} is nearly zero because natural drainage maintains acceptable water quality in the polder area. Because ET_{act} is also small in winter, Q_{out} is strongly linked to P.

From May 1st 2008 to July 1st 2008 ET_{act} is the largest term in the water balance. No longer a strong link exists between P and Q_{out}. During this period Q_{in} is larger than Q_{out}, which means that water is episodically infiltrating out of the channels to replenish the soil moisture deficit.

The lower graphs in Fig. 2 show the daily fluctuation in storage change. The storage change is estimated from soil moisture data (ΔS_{sm}) and as a rest term from the total balance: $\Delta S_{rest} = P - ET_{act} + Q_{in} - Q_{out}$. When the water balance closes, ΔS_{sm} should be equal to ΔS_{rest}. In winter ΔS_{sm} and ΔS_{rest} are fluctuating around zero, but in summer they are nearly always smaller than zero, which means that soil moisture content decreases. Although individual fluctuations of ΔS_{sm} and ΔS_{rest} are different, the sums over the period are quite close together (see Table 1).

Water balances have also been set up for two years: from June 1st 2007 to June 1st 2008 and from June 1st 2008 to June 1st 2009 (see Table 1). In contrast to the two two-month periods, the water balance does not close well for these years. The rest terms are large and negative, which means that the outflow terms and storage change are larger than the inflow terms.

An explanation for the imbalance could be that there is indeed seepage from the river Lek. If this is the case, an input term is not taken into account, leading to negative rest terms.

Table 1. Water balance terms for two two-month periods and two years (from June 1st to June 1st).

	Nov + Dec 2008	May + June 2008	2007 - 2008	2008 - 2009
P	141	73	966	683
ET_{act}	22	195	618	601
Q_{in}	34	87	224	645
Q_{out}	153	76	759	997
ΔS	18	-114	-60	23
Rest	-17	1	-127	-293

5. CONCLUSIONS

Climate models need information about radiation, energy and water fluxes at the soil surface. In Cabauw these fluxes and the corresponding balances are measured. Water balances have been set up for a summer and a winter period to check the correctness of these fluxes.

In Cabauw the most important water balance terms are precipitation, evapotranspiration, inflowing and outflowing discharge and change in storage. Two two-month periods have been analysed in detail. In winter precipitation is the largest input term and outflowing discharge the largest output term. In summer inflowing discharge is the largest input term and evapotranspiration the largest output term.

The water balance closes quite well for these periods. The water balance set up over two years closes less well. It is possible that there is upward seepage from the river Lek which has to be taken into account.

Our intention is to continue this hydrological field study over a period of several years for modelling purposes.

6. ACKNOWLEDGEMENTS

We thank Jantine Bokhorst and Fred Bosveld of the KNMI for cooperation and for delivering precipitation and actual evapotranspiration data.

REFERENCES

[1] C.C. Brauer, J.M.N. Stricker and R. Uijlenhoet (2009), “Linking meteorology and hydrology: measuring water balance terms in Cabauw, the Netherlands”, Proceedings of the 8th International Symposium on Tropospheric Profiling, 19–23 October, Delft, The Netherlands, Edited by A. Apituley, H.W.J. Russchenberg, W.A.A. Monna, ISBN 978-90-6960-233-2