Comments on: Water Accounting Plus (WA+); A water accounting procedure for complex river basins based on satellite measurements, by P. Karimi et al.

General comments

The authors have written a good paper on an important topic. Water accounting is critical to planning and managing water resources. As the demand on water becomes greater, and the margins for error ever smaller, the need for sound water accounts grows. Good water accounts, as the authors state, is the basis for sound decisions, and a common framework for accounts and terminology is important. The authors present a good case, and a good system for presenting a simple summary of the accounts, based on four simple but useful account sheets: resource, consumption, productivity and withdrawal sheets.

However, I feel that the authors let themselves down in a couple of ways. Firstly, although they draw analogies with financial accounting, they do not approach the task with the rigour that we expect in financial accounting. They describe the confusion that surrounds terms such as water efficiency and water withdrawal; yet they introduce confusion over net and gross terms, symbols and so on, which I describe in greater detail below. Secondly, there are several inconsistencies or errors in equations and the explanation of terms, which again I describe in greater detail below.

Specific comments

1. Rigorous water accounting

The authors refer to the Australian Bureau of Statistics national water account (ABS 2004, 2006), but miss the rather different and far more comprehensive new Australian Water Accounting Standard (Water Accounting Standards Board, 2010). The draft standard was applied to eight regions in Australia in the web-based 2011 account, accessible on the web at http://www.bom.gov.au/water/nwa/2011/index.shtml: one of the regions was the Murray-Darling Basin. The objective of the National Water Account is to disclose information about the total water resource, the volume of water available for abstraction, the rights to abstract water, and the actual abstraction of water for economic, social, cultural and environmental benefit, for geographic regions of national significance. The Murray-Darling Basin account has detailed statements about Water assets and liabilities, changes in water assets and liabilities, and physical water flows (including urban and rural water diversions) (Bureau of Meteorology, 2011). The accounting standard and the accounts relate to the detailed nature of Australian water rights and the tradeable nature of both the rights to water and actual volumes of water. However, they differ greatly to the water account of the authors in that neither rain (except on water surfaces) nor land based ET are considered. The account statements in the Australian 2011 Water Account are a stocks and flows account, and do not extend to matters such as productivity which the authors consider in their productivity sheet.

My main point in drawing attention to this standard is the rigour behind it. The standard and the accounts represent a rigorous approach to water accounting, and include continuous water accounting. I feel that this level of rigour is lacking in the authors' presentation, with its confusion over terms and equations (more below).

2. Inconsistencies and errors in equations and explanation of terms

The paper is muddled in its presentation of water balances. Starting with Equation 1 and 2:

$$ET = ET_{prec} + ET_{Q} \quad (1)$$

$$ET_{prec} = P - R \quad (2)$$

where P is gross precipitation, R is the return flow (and described as surface runoff, lateral subsurface drainage and deep percolation) ET is the total ET, ET_{prec} is ET from natural processes, ET_Q is variously described as the incremental ET, net withdrawal, and the difference between gross withdrawals and return flow. Equation (2) is described as approximate. So, what is the actual equation?

The total (soil) surface water balance implied by Figure 1 is:

$$P + Q_W^{Sw} + Q_W^{Gw} - ET_{prec} - ET_Q - R_o - P_{deep} + \Delta S_S = 0 \qquad (22)$$

(I have labelled this equation as 22, to distinguish it from equations in the paper) where P is precipitation, Q_W^{Sw} and Q_W^{Gw} are surface and groundwater withdrawals, ET_{prec} and ET_Q are as above, R_o is runoff, P_{deep} is percolation to groundwater, and ΔS_S is the change in soil water storage. If we deal with averages, $\Delta S_S = 0$. Using equation (3) in the paper to equate the return flow, R, from (2) above with $R_o + P_{deep}$, we rearrange (22) to get:

$$ET_{prec} + ET_Q = P + Q_W^{Sw} + Q_W^{Gw} - R + \Delta S_S \qquad (23)$$

and hence eliminating terms using (2)

$$ET_Q = Q_W^{Sw} + Q_W^{Gw} + \Delta S_S \qquad (24)$$

which is not what the authors describe it as – incremental ET, net withdrawal, or the difference between gross withdrawals and return flow. If we accept equations (1) and (2) and Figure 1 in the paper, ET_Q is actually the gross withdrawal plus the change in soil water storage.

On the other hand, figure 5 of the paper implies that:

$$ET_Q = Q_W^{Sw} + Q_W^{Gw} - Q_R^{Sw} - Q_R^{Gw} - \Delta S_P \qquad (25)$$

where Q_R^{Sw} and Q_R^{Gw} are surface and groundwater return flows, and ΔS_P is a sink, which is not explained. This figure uses symbols for return flow that differs from that in equation (3) of the paper. Accepting figure 5, ET_Q is what the authors describe it as, a net withdrawal, but because of the sink term it is not strictly the difference between gross withdrawals and return flow. However, on this interpretation, Figure 1 is wrong and equation (2) is either wrong or R has not been defined properly (it could be defined to include only those flows to surface and groundwater which do not originate from a withdrawal – though that's a rather arbitrary and un-measurable distinction).

Following equation (3) in the paper, the authors write "The key point is that ET_Q can be determined from ET and ET_{prec}, without any flow measurement (not further demonstrated in this paper)". But equation (2) demands that R be known in order to evaluate ET_{prec}, which means that some estimate or measurement of a flow or flows is required. The statement in the paper appears to be wrong, and the claim should certainly be further demonstrated.

To further confuse the description of water balances, most of the quantities are described as flows of one sort or another. For example, on page 12886 (first paragraph of section 3.1), the authors write "outflows from a certain river basin are explicitly related to the inflow from rainfall"; in equation (2), R is described as the return flow. Yet on page 12892 (3rd paragraph of section 4.1) we are told that "The rate P – ET ($L\ T^{-1}$) from a discrete area (L^2) represents a flow ($L^3\ T^{-1}$)". So, rain and ET are no longer volumetric flows, and cannot be equated with R in equation (2).

Given the confusions above, I think it might be better if the authors were to start with a complete, rigorous water balance equation which contains all the terms they will use, and then relate all terms

in the resource, consumption, productivity and withdrawal sheets explicitly to terms in the water balance.

3. Other specific comments

Basin closure should be explained further. According to equation (7), the basin closure fraction is utilized flow / available flow, but available flow is only a fraction of the total flow. Thus a basin could have substantial discharge but a closure fraction of 1 – this arises when utilized flow = available flow < total flow. Depending on what one views as closure (actual closure, economic closure), one might not regard such a situation as a closure fraction of 1.

The reserved flow fraction should be explained further. According to equation (7), the reserved flow fraction is reserved flow / surface water outflow (Q_{out}^{SW}). However, figure 2 shows the outflows to be both surface and groundwater but makes no distinction between surface and groundwater in the reserved and utilizable flows that contribute to the outflows. Is the reserved flow intended to refer to surface water flows only? (There could be groundwater reserved flows to maintain groundwater dependent ecosystems.) If not, then equation (7) makes sense only in terms of the surface water part of the reserved flow.

On page 12901 (2nd paragraph of section 5), the authors write: "Except for the withdrawal sheet that is more related to the classical water accounting processes, the input data for the other WA+ sheets can be estimated through satellite measurements". Not all the input data can be so estimated: the resource datasheet has surface and groundwater inflows and outflows, which cannot be estimated from satellites, at least, not currently with any degree of precision.

In section 6, the authors write that all rivers and tributaries are regarded as being one single bulk river and all aquifers as one single bulk aquifer. It need not be so. As the Australian Bureau of Meteorology's Murray-Darling Basin 2011 account shows, an overall basin account can be an aggregation of sub-accounts for different elements, whether they be geographic elements such as catchments, or use or process elements such as irrigation or urban water use. Thus, each of the resource, consumption, productivity and withdrawal sheets described by the author could have sub-accounts at finer geographic or use resolution. Finer geographic resolution implies considerably greater measurement or modelling of flows than is contemplated by the authors. This approach was taken by Kirby et al (2010), who describe dynamic (monthly for many years) water accounts that deal with precipitation, dryland and irrigated ET from a range of land uses (including natural vegetation), runoff, river flow, withdrawals from both surface and groundwater for irrigation and other use, and return flows from irrigation. The approach is based primarily on modelling, and thus provides a complement to the more satellite based methods that the authors describe, and it does not distinguish beneficial uses except insofar as withdrawals are intended for beneficial use.

References:

Water Accounting Standards Board, 2010. Exposure Draft of Australian Water Accounting Standard 1: Preparation and Presentation of General Purpose Water Accounting Reports, Commonwealth of Australia. Available at: http://www.bom.gov.au/water/standards/documents/ed_awas1_v1.0.pdf (Accessed November 2012).

Bureau of Meteorology, 2011. To access the detailed accounts, go direct to http://www.bom.gov.au/water/nwa/2011/mdb/statement/waterassetsandwaterliabilities.shtml, http://www.bom.gov.au/water/nwa/2011/mdb/statement/changesinwaterassetsandwaterliabilities.shtml, and http://www.bom.gov.au/water/nwa/2011/mdb/statement/physicalwaterflows.shtml, from where detailed information can be accessed for most line items in the accounts.

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