H31A-0765

Modeling Crop Water Requirement at Regional Scales in the Context of Integrated Hydrology

Emin C. Dogrul, Tariq N. Kadir, Charles F. Brush and Francis I. Chung

California Department of Water Resources Bay-Delta Office Modeling Support Branch

1. Background

- In heavily cultivated and inhabited watersheds, agricultural and urban water requirements and management of water resouces dictate the hydrologic flow processes
- Groundwater and stream flows are used conjunctively to meet agricultural and urban water demands; resulting root zone and land surface flow processes affect groundwater and stream flow dynamics
- Integrated hydrologic models (**IHMs**) simulate land surface runoff processes, route moisture through root zone, and compute aquifer recharge and lateral flows into streams when agricultural and urban applied water is specified; BUT they do not dynamically compute agricultural and urban applied water as a function of climate, soil and land cover properties
- Irrigation scheduling models (**ISMs**) simulate agricultural water requirement, root zone and land surface flow processes under specified climate and farm management settings with given soil and crop properties; BUT they can not simulate conjunctive use of surface and subsurface water resources and they are developed for the simulation of a single crop at a single farm scale
- A new tool (named IWFM Demand Calculator or **IDC**) has been developed to integrate the ISM methods for the simulation of water requirements, root zone and land surface flow processes with the IHMs at regional scales

2. Computational Framework

- IDC requires a computational grid (finite-element or finite-difference) to be specified; the grid is used to represent the spatial distibution of climatic, soil, land-use and water management properties, and to facilitate the easy linking with IHMs
- IDC is IHM-independent; i.e. it can be linked to any finite-element or finite-difference IHM or it can be used as a stand-alone ISM at a regional scale
- 4 general land-use types are modeled: agricultural, urban, native vegetation and riparian vegetation; agricultural lands are further distributed among ponded (rice and managed wetlands) and user-specified number of non-ponded (e.g. corn, alfalfa, almonds, etc) crops
- Area of each land-use type is specified for each grid cell; land-use areas can be time-series and change during the simulation period
- Agricultural and urban water requirements, root zone and land-surface flow processes are computed at each grid cell; water requirements are not computed for native and riparian vegatation
- When IDC is linked to IHMs, applied water for agricultural and urban lands is the summation of the pumping and stream diversions simulated by the IHM and can be less than the computed water requirement depending on the aquifer storage and available stream flow
- When IDC is used as a stand-alone ISM, agricultural and urban applied water is assumed to be equal to the computed water requirement

3. Soil Moisture Routing and Water Requirement

- Conservation equation that is solved iteratively to route the moisture through root zone (Figure 1):

$$\theta^{t+1} = \theta^{t} + \Delta t\left(P^{t+1} - R_P^{t+1} + A_w^{t+1} - R_f^{t+1} - D_r^{t+1} - D^{t+1} - ET^{t+1}\right) + \Delta\theta_a^{t+1}$$

where θ = soil moisture, P = precipitation, R_P = direct runoff, A_w = applied water, R_f = net return flow, D_r = drainage of ponds, D = deep percolation, ET = evapotranspiration, $\Delta\theta_a$ = change in soil moisture due to change in land-use area, Δt = time step length, t = time step index

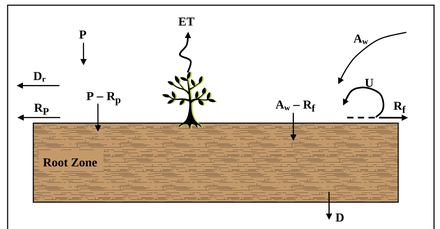

Figure 1

- Direct runoff is computed using SCS Curve Number method
- Deep percolation is computed using van Genuchten-Mualem equation
- ET is equal to potential ET if θ is above half of field capacity; otherwise it decreases linearly with respect to θ until wilting point where it is zero
- Water requirement is computed by re-writing conservation equation for A_w when θ^t falls below a user-specified threshold (i.e. management allowable depletion):

$$A_w^{t+1} = \frac{\theta_{trg}^{t+1} - \theta^{t} - \Delta\theta_a^{t+1}}{\Delta t} - P^{t+1} + R_p^{t+1} + R_f^{t+1} + D_r^{t+1} + D^{t+1} + ET^{t+1} \geq 0$$

- Agricultural water requirement is the amount of water to bring the soil moisture up to a target mositure: field capacity for non-ponded crops, and total porosity plus ponding depth for rice and managed wetlands

4. Test Case

- IDC was used as a stand-alone ISM to simulate the agricultural applied water at a 2805 km^2 basin in the Central Valley of California from October 1998 to September 2001 (Figure 2)
- A finite-element grid with 2622 cells was generated (Figure 2)
- Basin included rice fields, several managed wetlands, 20 non-ponded crop types, urban areas and areas with native vegetation

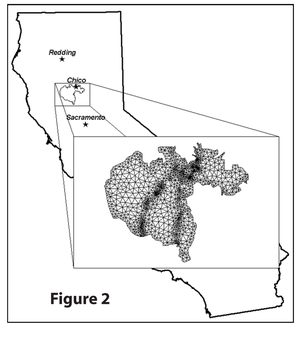

Figure 2

- Soil properties were assigned to each cell by intersecting the grid with the NRCS SSURGO soils database; precipitation was obtained from PRISM data; crop characteristics, potential ET and farm management data were asssigned to each cell using data from previous modeling studies

4. Test Case *(continued)*

- Sensitivity analysis:
  - Applied water for non-ponded crops is not very sensitive to soil saturated hydraulic conductivity, K_{sat} (Figure 3); it is more sensitive to pore size distribution index, λ (Figure 4)
  - Applied water for rice is very sensitive to soil saturated hydraulic conductivity, K_{sat} (Figure 5); one needs to be careful in choosing K_{sat} values since large K_{sat} values can lead to unrealisticly high magnitudes of applied water
  - Applied water for rice is not sensitive to pore size distribution index, λ, since rice fields are managed under saturated conditions

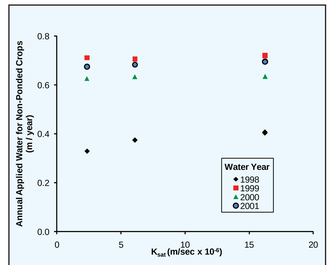

Figure 3

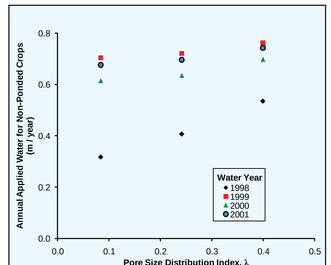

Figure 4

- IDC results were compared to the results from another model (named DSIWM Model) also developed by California Department of Water Resources at different locations of the basin (Figure 6):
  - The two models have different potential ET rates, precipitation data and land-use areas; differences in the input data are responsible for most of the differences among the results
  - Applied water for non-ponded crops match better compared to applied water for rice; for this test case all cells with rice were assigned a K_{sat} value of 0.01 μm/sec. A better match canbe achieved if K_{sat} values were calibrated
  - Overall, IDC produced reasonable values even with no calibration effort and with different key input data

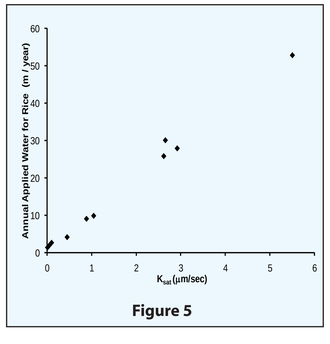

Figure 5

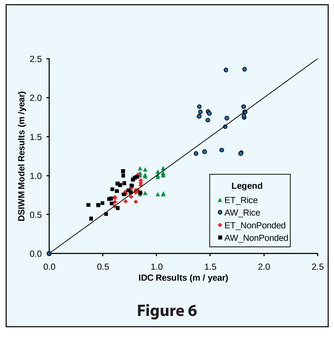

Figure 6

5. Additional Information

- Emin C. Dogrul, CA Department of Water Resources, **dogrul@water.ca.gov**
- IDC source code, executables and documentation can be downloaded from **http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/**