Surface energy and water balance of the Seyhan River Basin – present status and impacts of climate change –

Kenji TANAKA[1] **and Toshiharu KOJIRI**[2]
[1,2] *Water Resources Research Center, DPRI, Kyoto University*
WRRC, DPRI, Kyoto University, Gokasho, Uji, 611-0011, Japan
e-mail: [1] *tanaka@wrcs.dpri.kyoto-u.ac.jp,* [2] *tkojiri@wrcs.dpri.kyoto-u.ac.jp*

1. Basin characteristics

1.1 Basin boundary and topography

The start point of the surface hydrology group for FY2004-2005 was to define a physical boundary of the Seyhan River Basin. Once the basin boundary is defined, other basin characteristics can be extracted from the global data resources and local information. Three kinds of digital elevation model (DEM) were collected.

1. Turkish DEM (250m mesh)
2. Gtopo30 (30sec mesh)
3. SRTM (3sec mesh)

Among them, the first one was judged to have difficulty in describing the lowland area (lower Seyhan delta). The latter two datasets coincide with each other. Since planned target resolution of the hydrological model is 1km, **Gtopo30** is selected as basic topographic data. HYDRO1k (http://edcdaac.usgs.gov/gtopo30/hydro/) is also utilized to characterize the location of the boundary and river channel. By analyzing the topographic data together with HYDRO1k, physical boundary of the Seyhan River Basin is defined as **Fig. 1(a)** (catchment area is about 24625km^2). Created basin boundary information mostly coincides with that was produced by Turkish hydrology group. As for the small inconsistency, we need to discuss more and reproduce a common dataset.

1.2 Landuse/landcover

Several kinds of landuse/landcover datasets are available from global satelite products (GLC2000, ECOCLIMAP, GLCC, etc.). Considering currently available landscape information (photo images), **GLCC-v2** (http://edcdaac.usgs.gov/glcc/), the Global Land Cover Chacteristics version 2.0, is selected as basic landcover data. According to this information (**Fig. 1(b)**), five major landcover conditions of the Seyhan River Basin are grassland (40.45%), crop/natural mixture (31.08%), dry cropland (11.97%), savanna (7.49%), and irrigated cropland (4.42%). So far, this landcover information is utilized to run the land surface model. Landcover information will be updated by the product of **Vegetation sub-group**.

1.3 Soil Type

Detailed soil type information has been provided from Turkish team. By the way, this database (ARC GIS shape file) includes the legend in Turkish language, and it has not been utilized by Japanese team so far. Then, a global digital soil map (from FAO), which has 5 minutes resolution, is utilized to run the land surface model. According to this information (**Fig. 1(c)**), three major soil categories of the Seyhan River Basin are clay loam (53.55%), light clay (42.32%), and heavy clay (4.00%).

2. Analysis of meteorological data

2.1 Data density

All the available DMI meteorological data from 1971 to 2002 have been checked and analyzed. **Table 1** is a summary of available data within and near the Seyhan River Basin.

Table 1 : List of available DMI stations

meteorological element	number
Precipitation (daily)	44
Air temperature (hourly)	18
T_{max}, T_{min} (daily)	31
RH_{max}, RH_{min} (daily)	20
Wind, $SW_{down}, P_{surf}\cdots$ (daily)	20

domain: E34.0-E37.0, N36.5-N39.5

Fig. 2(a) shows a distribution of daily precipitation station. Based on these information, it is possible to create gridded meteorological dataset to some extent. **Fig. 2(b)** and **Fig. 2(c)** are examples of produced gridded dataset of average annual precipitation (climatology) and 1999 precipitation. By the way, as can be seen from **Fig. 2(a)**, only ten stations are located within the basin. It is not enough to capture the realistic distribution of precipitation in such a large (more than 20000km^2) and highly mountainous (altitude range is more than 3000m) area. Thus, there is a need for collecting more precipitation data even though they are stored as printed (not digitized) data. If additional dataset will be provided (from DSI or EIE?), it is possible to improve the accuracy of gridded data.

2.2 Reproduction of diurnal cycle

As for air temperature, diurnal cycle can be produced from 18 hourly stations. Typical diurnal cycles are prepared for every month at 18 stations (216 patterns). Daily mean, maximum, and minimum temperatures are utilized to select one diurnal cycle that fits most. Then, hourly values of each daily stations are reproduced by applying this pattern. As for other elements, it is rather difficult to produce diurnal cycle from stations' data alone. The product of RCM (Regional Climate Model) and possibly satelite (METEOSAT) will be utilized to obtain reasonable and consistent diurnal cycles (this work will be done in FY2005). Using hourly observed and hourly reproduced data at all surface stations, mesh dataset is produced using spatial interpolation. As for pressure and temperature, they have much dependency on altitude. So, they must be corrected (adjusted) to sea level value before the spatial interpolation process. After that these data are converted to the value for the altitude of ground surface.

3. SiBUC and irrigation scheme

SiBUC (Simple Biosphere including Urban Canopy) land surface scheme is designed to treat the landuse condition (natural vegetation, cropland, urban area, water body) in detail. Especially irrigation scheme for the various kinds of cropland is implemented. Basic concept of the irrigation scheme is to maintain the soil moisture within appropriate ranges which are defined for each growing stage of each crop type. The irrigation rules for cropland are based on at least four parameters; seeding date, harvesting date, the periods of each growing stage, and lower limit of soil wetness in each growing stage. As a default parameter, **Table 2** is prepared from agricultural manual in China. It represents the water requirement for four crops; spring wheat, winter wheat, maize, and soybean. Basically, growing stage is divided into five stages, and the period of each stage is represented by percentage of total growing period. This kind of table will be updated by the information from **Irrigation** and **Crop sub-group**.

Table 2 : Period of each growing stage and lower limit of soil wetness (unit: %)

crop	stage	1	2	3	4	5
spring	period	23	14	14	14	35
wheat	wetness	70	60	80	80	55
winter	period	26	20	22	13	19
wheat	wetness	70	70	80	80	55
maize	period	8	48	6	14	24
	wetness	75	65	70	75	65
soy	period	4	25	16	28	27
bean	wetness	75	65	65	70	65

4. Off-line simulation forced by RCM 8.3km product

4.1 Experimental design

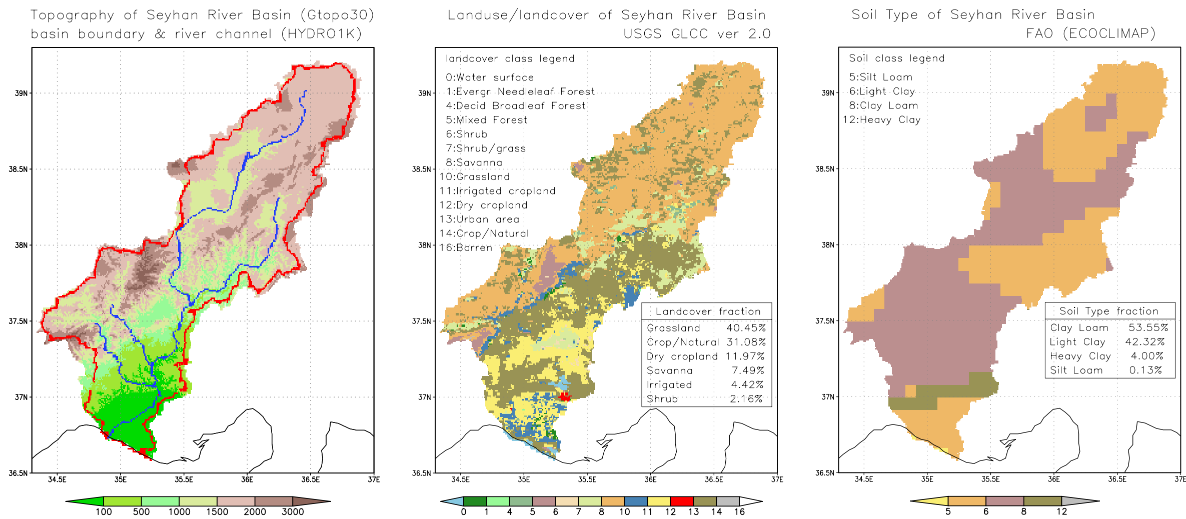
The first product of RCM (8.3km product) was provided from **Climate sub-group**. Preliminary simulation forced by this dataset was executed to start the discussion about the application of projected climate change information. Unfortunately, this first product does not cover the whole Seyhan Basin. Then, 2 degree × 2 degree area (E34.5-36.5, N36-N38) is selected as simulation domain. This area is divided by each 5 min (10km) grid boxes (24 × 24 grids). SiBUC uses mosaic approach to incorporate all kind of landuse. **Fig. 3** shows the fraction of major three landcover conditions in this region. In this study, irrigated cropland in the Seyhan delta is about 30 to 50 %. In order to estimate energy and water balance as accurately as possible, and to evaluate the impacts of climate change on water resources in this semi-arid region realistically, SiBUC is run with irrigation scheme activated. Since detailed distribution of each cultivated crops has not been obtained so far, all the irrigated croplands are assumed to be maize (irrigation period is from May 23rd to August 6th). The simulation period is from 1999 January to 1999 December for the present climate condition. Also, future climate condition (called as 'pseud warm-up' run) have been provided for one year. Here, spin-up period is 2 years and 9 months, and the results from third October to fourth September are used for analysis.

4.2 Results and discussions

Annual average (total) of surface energy and water balance components and state variables are shown in **Fig. 4**. Total evaporation is about 400mm in the Seyhan delta, and about 200mm of irrigation water is estimated to keep the soil wetness in the model. Comparing from the observation (**Fig. 2(c)**), RCM precipitation is much smaller in the Seyhan delta area and much larger in the mountainous area. Then, we do not look in detail about the quantity of water balance components so far. The second product of RCM that covers the whole Seyhan Basin will be provided in next June. This new product is expected to improve the accuracy of precipitation through the better treatment of soil moisture and landcover condition.

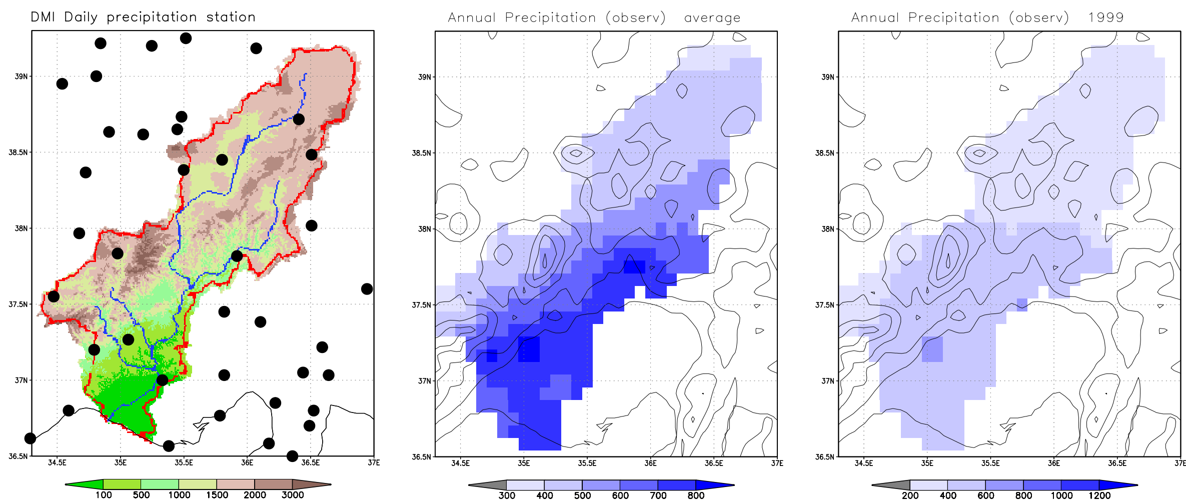
The difference of annual average surface energy and water balance components and state variables between present and warm-up runs are shown in **Fig. 5**. In the warm-up run, annual precipitation is projected to decrease, and evaporation decreases accordingly. Although the potential evaporation (evaporation demand) will increase by the temperature rise, actual evaporation will be limited by the dryness of soil wetness (**Fig. 5(h)**). Since the vegetation parameters (such as LAI) and farming calendar (such as irrigation period) are the same in both two simulations, irrigation water is projected to increase by the higher evaporation demand in the growing season. This result infers that it is rather difficult to keep the same cropping pattern under the future climate condition (reduced precipitation and increased evaporation demand).

To see the typical energy and water balance components and their impacts from climate change for each landcover, model outputs are aggregated according to the dominant landcover condition (dominant landcover is larger than 0.8). **Fig. 6(a)-(e)** shows the time series of energy and water balance components for irrigated crop, dry cropland, and grassland. As for energy balance, only the irrigated crop has large latent heat during summer season. In the dry cropland, sensible heat dominates from May to October. Comparing from winter time precipitation (main source of natural water balance), we can see that how large the summer time irrigation makes up in the water balance. As for soil wetness, irrigated crop has two peaks in seasonal cycle. First one is caused by winter time precipitation, and second one is by summer time irrigation. Looking at the accumulated water balance of irrigated crop, evaporation in May reduces in the warm-up simulation, but evaporation during irrigation period increases. On the other hand, evaporation reduces continuously from February through June in the dry cropland. To see the impacts of climate change on snow, model outputs are aggregated according to altitude band. **Fig. 6(f)** shows the time series of snow water equivalent (SWE) for middle (1000-2000m) and higher (over 2000m) elevation. For the middle elevation grids, maximum SWE will decrease and melt quickly. For the higher elevation grids, maximum SWE will increase due to the increase in winter precipitation, while it melt very quickly in April. Looking into detail, there is a snowfall event (increase of SWE) in April in the present simulation, while no snowfalls are seen in the warm-up simulation.



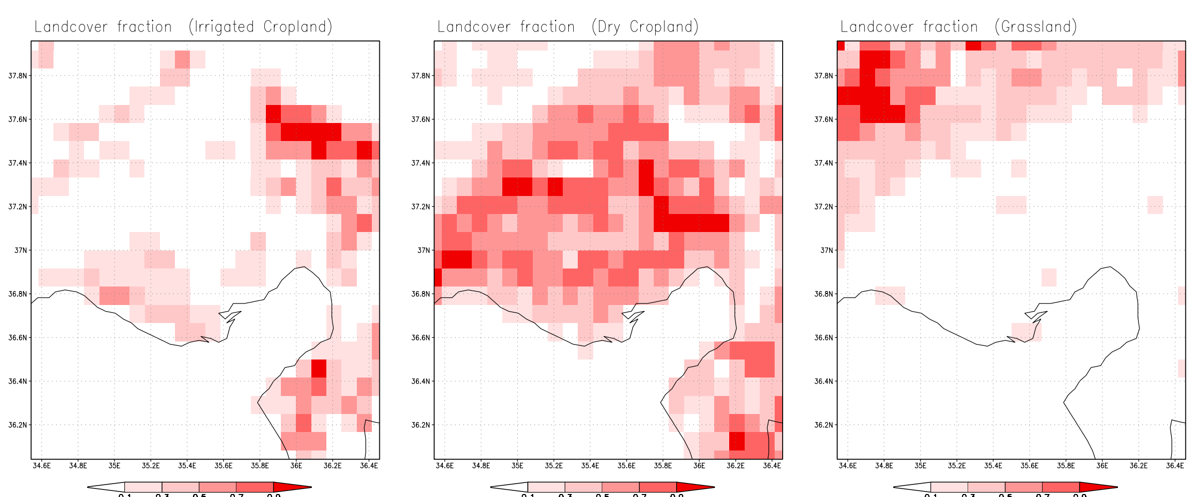
(a) Topography and river (b) Landuse/landcover (c) Soil Type

Fig. 1 : Land surface parameters of the Seyhan River Basin



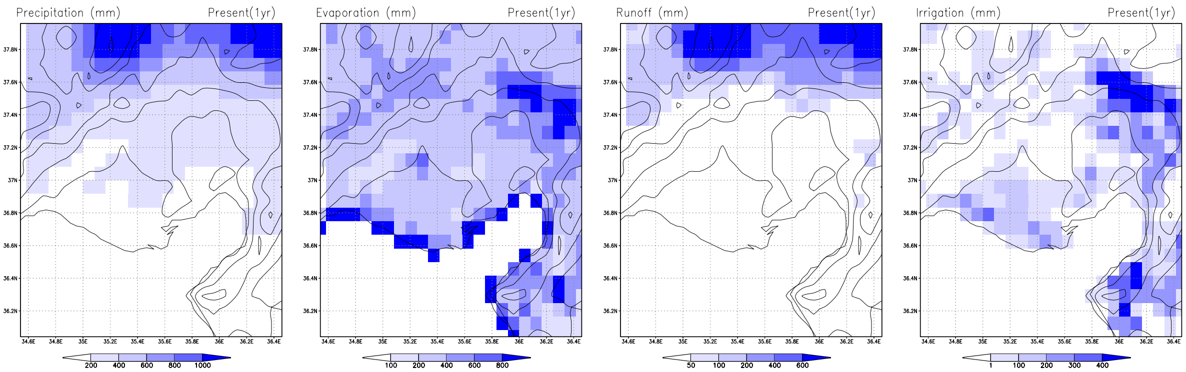
(a) DMI Station (precip) (b) Annual Precip (average) (c) Annual Precip (1999)

Fig. 2 : Surface meteorological station and gridded precipitation data

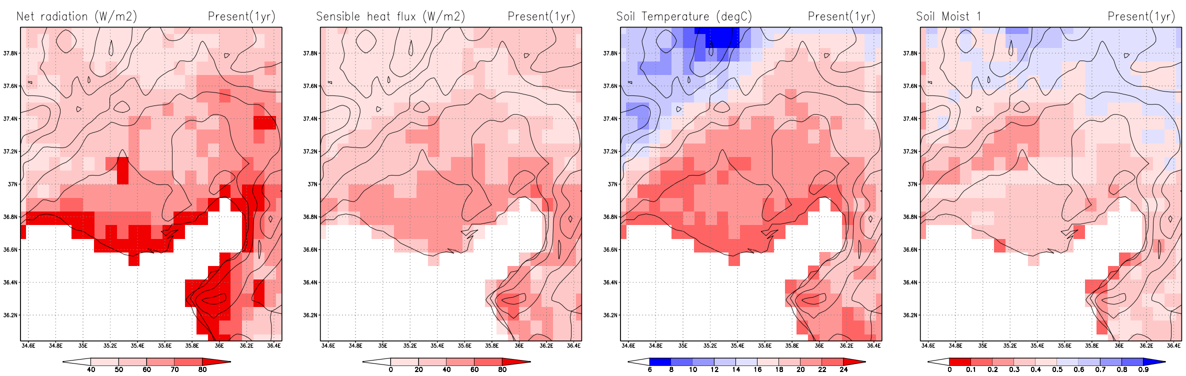


(a) Irrigated cropland (b) Dry cropland (c) Grassland

Fig. 3 : Landcover fraction of each grid (5 min resolution)

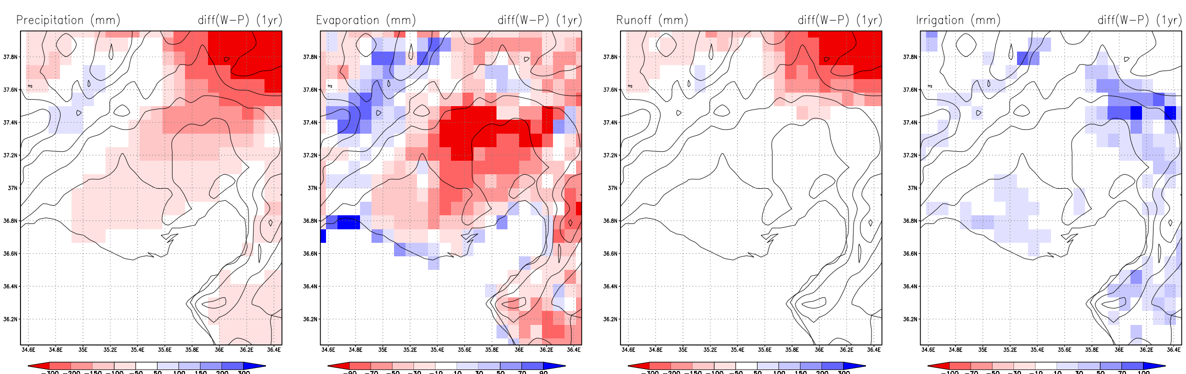


(a)Precipitation **(b)Evaporation** **(c)Runoff** **(d)Irrigation**

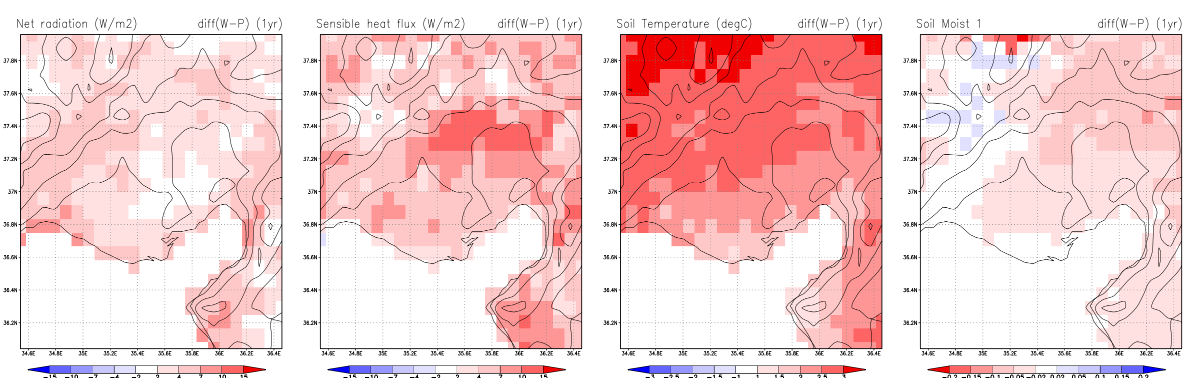


(e)Net radiation **(f)Sensible heat** **(g)Soil temperature** **(h)Soil wetness**

Fig. 4 : Annual energy and water balance components of the present run

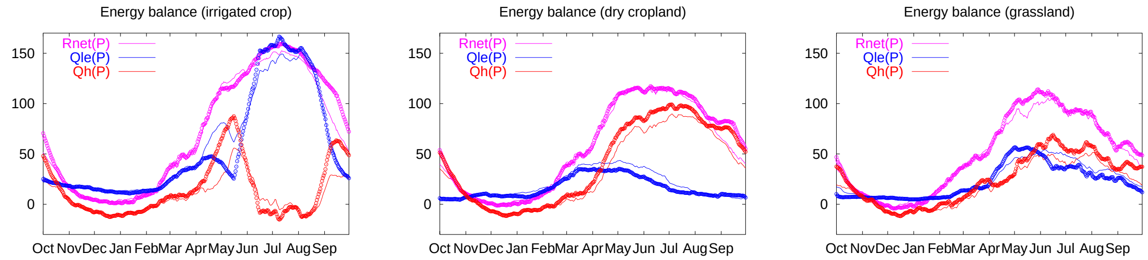


(a)Precipitation **(b)Evaporation** **(c)Runoff** **(d)Irrigation**

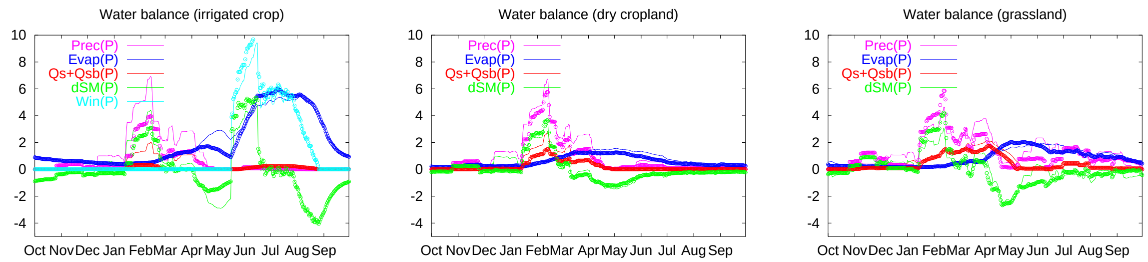


(e)Net radiation **(f)Sensible heat** **(g)Soil temperature** **(h)Soil wetness**

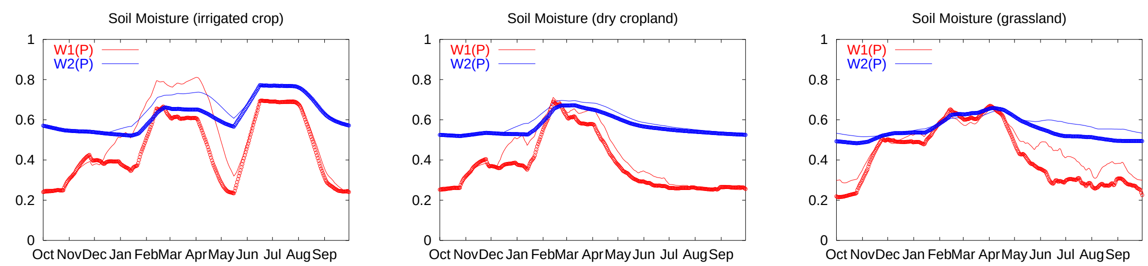
Fig. 5 : Difference (W-P) of annual energy and water balance components



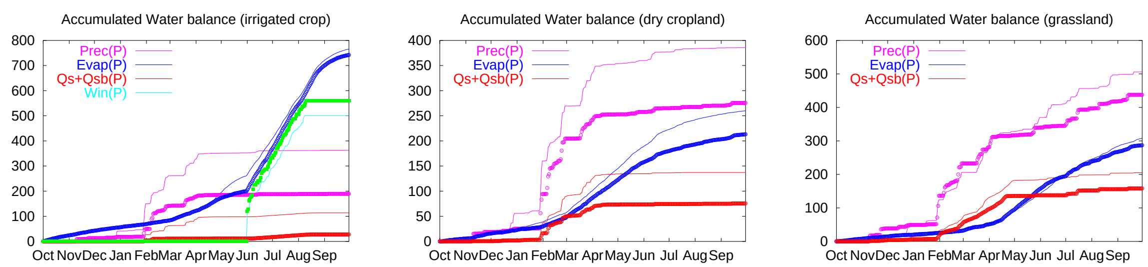
(a) Surface energy balance components (15days running mean)



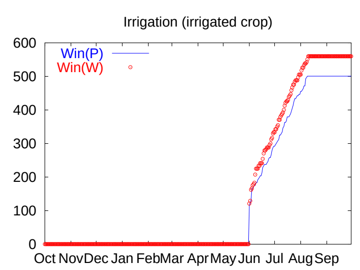
(b) Surface water balance components (15days running mean)



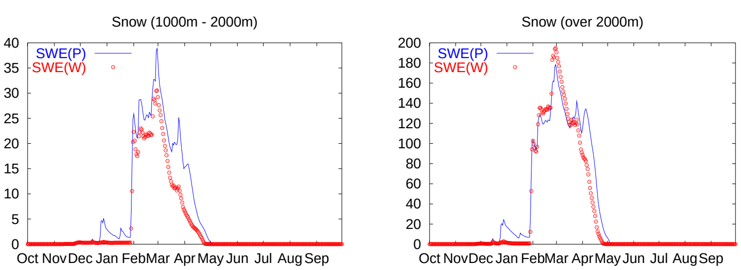
(c) Surface and root-zone soil wetness (15days running mean)



(d) Accumulated water balance components (daily)



(e) Irrigated water (daily)



(f) Snow water equivalent (daily)

Fig. 6 : Comparison of the present run and warm-up run at different landcover (lines: present run, dots: warm-up run)