Índice

1 Introducción

Se testea la función de balance adoptada

2 Función de recarga con datos diarios y cálculos horarios

```
def ugw_drainage(whcmax, whcr, whc0, kuz, exp, p, et):
    """
    args
    whxmax: max water holding content mm
    whcr: residual whc mm
    whc0: initial whc mm
    kuz: satured permeability mm/h
    exp: empirically deduced exponent
    p: water input mm/h
    et: evapotranspiration mm/h
    output
    whc3: whc at the end mm
    wd: water drained mm/h
    runoff: runoff mm/h
    etr: real et mm/h
    """
    tiny = 0.00001
    whce = whcmax - whcr
    if whcmax < tiny:
        return 0., 0., p, 0.
    whc1 = whc0 + p
    whc2 = min(whcmax, whc1)
    runoff1 = whc1 - whc2
    x1 = whc2 - whcr
    wd1 = kuz * (x1 / whce)**exp
    if p > 0:
        etr1 = 0.
    else:
        etr1 = min(x1, et * x1 / whce)
    out1 = wd1 + etr1
    out2 = min(x1, out1)
    if out1 > out2:
        wd1 = wd1 * wd1 / out1
        etr1 = etr1 * etr1 / out1
    whc3 = whc2 - wd1 - etr1
    balan = p - wd1 - runoff1 - etr1 + whc0 - whc3
    a = f'p {p:0.1f} - wd1 {wd1:0.1f} - runoff {runoff1:0.1f} -' +\
    f' etr {etr1:0.1f} - whc0 {whc0:0.1f} - whcf {whc3:0.1f} = {balan:0.5f}'
    print(a)
    if abs(balan) > tiny:
        raise ValueError(f'Error de balance {balan:0.5f}')
    return whc3, wd1, runoff1, etr1
```

3 Elemplos

A continuación, se presentan los resultados de algunos periodos de 1 día

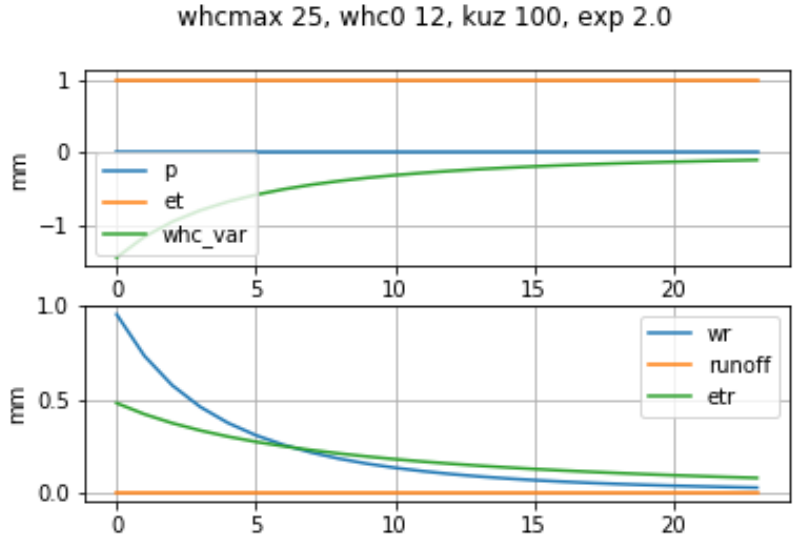
La fila final en las tablas de resultados se obtiene a partir de las 24 filas precedentes y suele contener pequeños errores de balance por problema de redondeo en la presentación de los resultados de las filas precedentes.

En los gráficos se presente p, et, whc_var (variación del almacenamiento en el suelo), wr (drenaje subterráneo), escorrentía (runoff), y et real.

3.1 Sin Lluvia

Los efectos del drenaje diferido y la etr resultan en una disminución del almacenamiento

3.1.1 Exponente 2

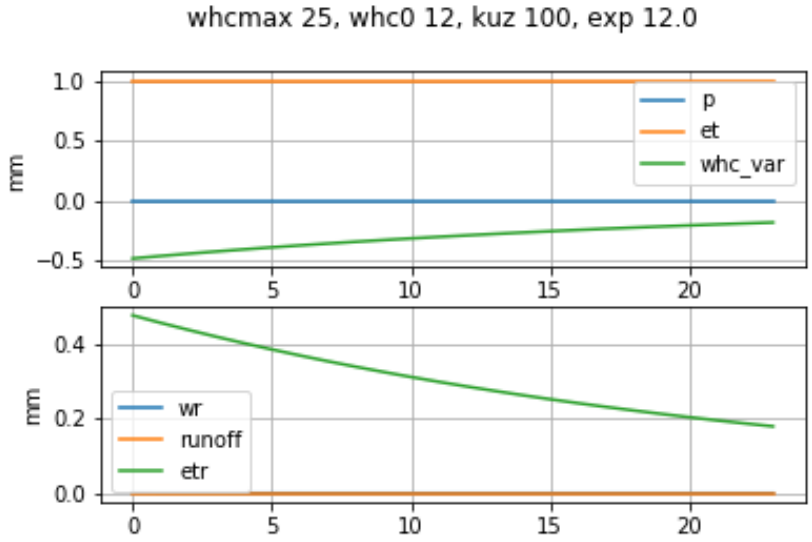


p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	1	0	0.5	12.5	11.1	0
0	0.7	0	0.4	11.1	9.9	0
0	0.6	0	0.4	9.9	9	0
0	0.5	0	0.3	9	8.2	0
0	0.4	0	0.3	8.2	7.5	0
0	0.3	0	0.3	7.5	6.9	0
0	0.3	0	0.2	6.9	6.4	0
0	0.2	0	0.2	6.4	6	0
0	0.2	0	0.2	6	5.6	0
0	0.2	0	0.2	5.6	5.3	0
0	0.1	0	0.2	5.3	4.9	0
0	0.1	0	0.2	4.9	4.7	0
0	0.1	0	0.2	4.7	4.4	0
0	0.1	0	0.1	4.4	4.2	0
0	0.1	0	0.1	4.2	4	0
0	0.1	0	0.1	4	3.8	0
0	0.1	0	0.1	3.8	3.6	0
0	0	0	0.1	3.6	3.5	0
0	0	0	0.1	3.5	3.3	0
0	0	0	0.1	3.3	3.2	0
0	0	0	0.1	3.2	3.1	0
0	0	0	0.1	3.1	2.9	0
0	0	0	0.1	2.9	2.8	0
0	0	0	0.1	2.8	2.7	0
0	5.1	0	4.7	*12.5*	*2.7*	*0*

3.1.2 Exponente 5

p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	0.1	0	0.5	12.5	11.9	0
0	0.1	0	0.5	11.9	11.4	0
0	0.1	0	0.4	11.4	10.9	0
0	0	0	0.4	10.9	10.4	0
0	0	0	0.4	10.4	10	0
0	0	0	0.4	10	9.6	0
0	0	0	0.4	9.6	9.2	0
0	0	0	0.3	9.2	8.8	0
0	0	0	0.3	8.8	8.5	0
0	0	0	0.3	8.5	8.2	0
0	0	0	0.3	8.2	7.9	0
0	0	0	0.3	7.9	7.6	0
0	0	0	0.3	7.6	7.3	0
0	0	0	0.3	7.3	7	0
0	0	0	0.3	7	6.8	0
0	0	0	0.2	6.8	6.5	0
0	0	0	0.2	6.5	6.3	0
0	0	0	0.2	6.3	6.1	0
0	0	0	0.2	6.1	5.9	0
0	0	0	0.2	5.9	5.7	0
0	0	0	0.2	5.7	5.5	0
0	0	0	0.2	5.5	5.3	0
0	0	0	0.2	5.3	5.1	0
0	0	0	0.2	5.1	4.9	0
0	0.3	0	7.2	*12.5*	*4.9*	*0.1*

3.1.3 Exponente 12

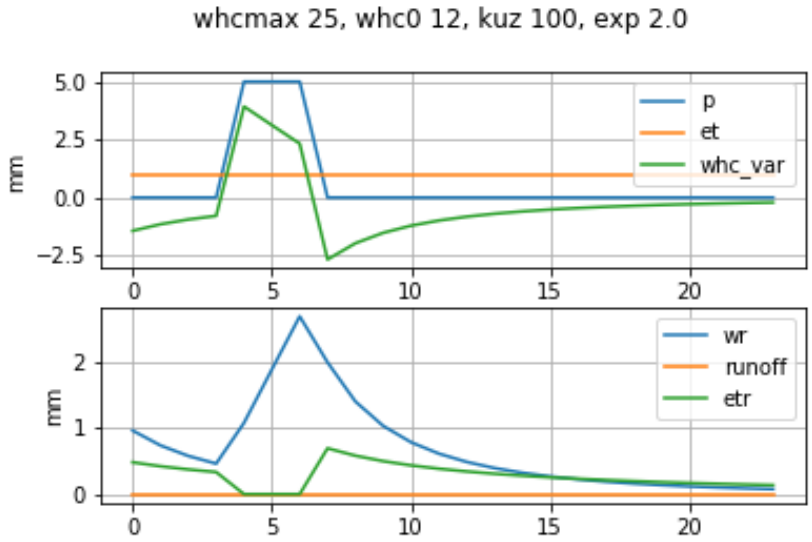


p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	0	0	0.5	12.5	12	0
0	0	0	0.5	12	11.6	0
0	0	0	0.4	11.6	11.1	0
0	0	0	0.4	11.1	10.7	0
0	0	0	0.4	10.7	10.3	0
0	0	0	0.4	10.3	9.9	0
0	0	0	0.4	9.9	9.5	0
0	0	0	0.4	9.5	9.2	0
0	0	0	0.3	9.2	8.8	0
0	0	0	0.3	8.8	8.5	0
0	0	0	0.3	8.5	8.2	0
0	0	0	0.3	8.2	7.9	0
0	0	0	0.3	7.9	7.6	0
0	0	0	0.3	7.6	7.3	0
0	0	0	0.3	7.3	7.1	0
0	0	0	0.3	7.1	6.8	0
0	0	0	0.2	6.8	6.6	0
0	0	0	0.2	6.6	6.3	0
0	0	0	0.2	6.3	6.1	0
0	0	0	0.2	6.1	5.9	0
0	0	0	0.2	5.9	5.7	0
0	0	0	0.2	5.7	5.5	0
0	0	0	0.2	5.5	5.3	0
0	0	0	0.2	5.3	5.1	0
0	0	0	7.4	*12.5*	*5.1*	*0*

3.2 Con lluvia

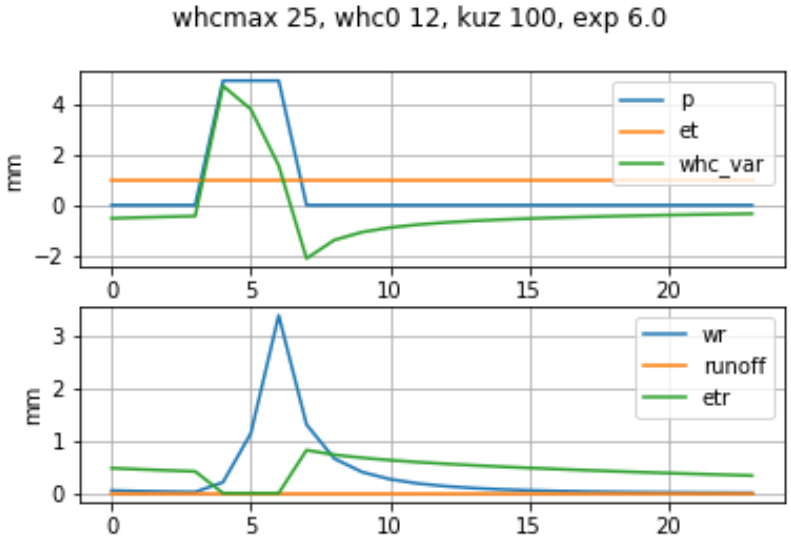
Aumento del drenaje y el almacenamiento del suelo a consecuencia del pulso de lluvia; en algunos casos se puede producir escorrentía superficial.

3.2.1 15 mm de Lluvia en 3 horas y exponente 2



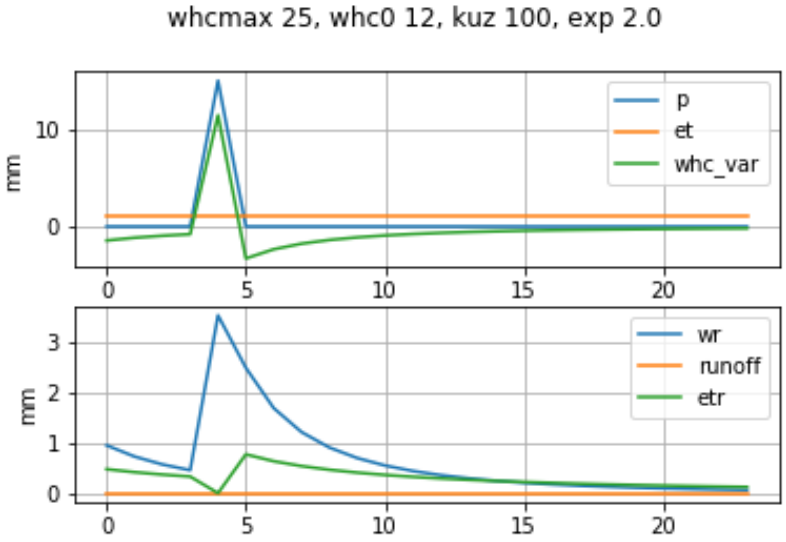
p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	1	0	0.5	12.5	11.1	0
0	0.7	0	0.4	11.1	9.9	0
0	0.6	0	0.4	9.9	9	0
0	0.5	0	0.3	9	8.2	0
5	1.1	0	0	8.2	12.1	0
5	1.9	0	0	12.1	15.2	0
5	2.7	0	0	15.2	17.6	0
0	2	0	0.7	17.6	14.9	0
0	1.4	0	0.6	14.9	12.9	0
0	1	0	0.5	12.9	11.4	0
0	0.8	0	0.4	11.4	10.2	0
0	0.6	0	0.4	10.2	9.2	0
0	0.5	0	0.3	9.2	8.4	0
0	0.4	0	0.3	8.4	7.7	0
0	0.3	0	0.3	7.7	7.1	0
0	0.3	0	0.3	7.1	6.5	0
0	0.2	0	0.2	6.5	6.1	0
0	0.2	0	0.2	6.1	5.7	0
0	0.2	0	0.2	5.7	5.3	0
0	0.1	0	0.2	5.3	5	0
0	0.1	0	0.2	5	4.7	0
0	0.1	0	0.2	4.7	4.5	0
0	0.1	0	0.1	4.5	4.2	0
0	0.1	0	0.1	4.2	4	0
15	16.9	0	6.8	*12.5*	*4*	*-0.2*

3.2.2 15 mm de Lluvia en 3 horas y exponente 6



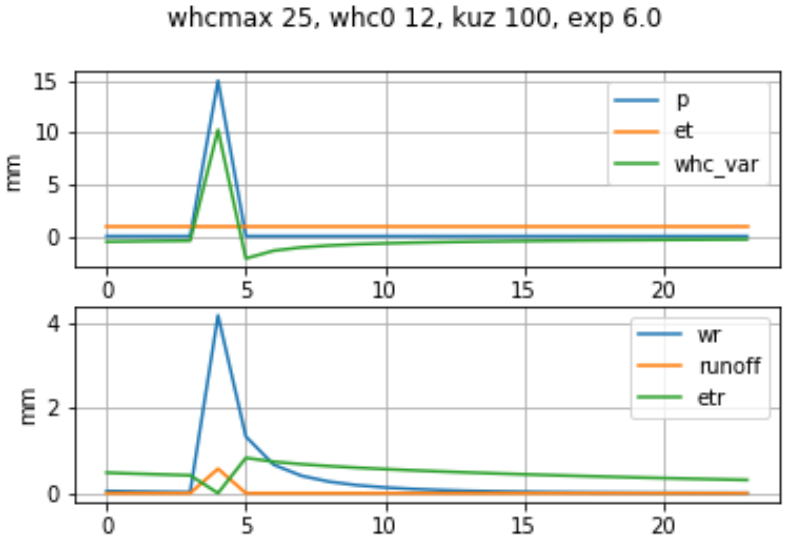
p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	0.1	0	0.5	12.5	12	0
0	0	0	0.5	12	11.5	0
0	0	0	0.4	11.5	11	0
0	0	0	0.4	11	10.6	0
5	0.2	0	0	10.6	15.4	0
5	1.1	0	0	15.4	19.2	0
5	3.4	0	0	19.2	20.8	0
0	1.3	0	0.8	20.8	18.7	0
0	0.7	0	0.7	18.7	17.3	0
0	0.4	0	0.7	17.3	16.2	0
0	0.3	0	0.6	16.2	15.3	0
0	0.2	0	0.6	15.3	14.5	0
0	0.1	0	0.6	14.5	13.8	0
0	0.1	0	0.5	13.8	13.2	0
0	0.1	0	0.5	13.2	12.6	0
0	0.1	0	0.5	12.6	12.1	0
0	0	0	0.5	12.1	11.6	0
0	0	0	0.4	11.6	11.1	0
0	0	0	0.4	11.1	10.6	0
0	0	0	0.4	10.6	10.2	0
0	0	0	0.4	10.2	9.8	0
0	0	0	0.4	9.8	9.5	0
0	0	0	0.4	9.5	9.1	0
0	0	0	0.3	9.1	8.7	0
15	8.1	0	10.5	*12.5*	*8.7*	*0.2*

3.2.3 15 mm de Lluvia en 1 hora y exponente 2



p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	1	0	0.5	12.5	11.1	0
0	0.7	0	0.4	11.1	9.9	0
0	0.6	0	0.4	9.9	9	0
0	0.5	0	0.3	9	8.2	0
15	3.6	0	0	8.2	19.6	0
0	2.5	0	0.8	19.6	16.3	0
0	1.7	0	0.6	16.3	14	0
0	1.2	0	0.5	14	12.2	0
0	0.9	0	0.5	12.2	10.9	0
0	0.7	0	0.4	10.9	9.7	0
0	0.6	0	0.4	9.7	8.8	0
0	0.4	0	0.3	8.8	8.1	0
0	0.4	0	0.3	8.1	7.4	0
0	0.3	0	0.3	7.4	6.8	0
0	0.2	0	0.2	6.8	6.3	0
0	0.2	0	0.2	6.3	5.9	0
0	0.2	0	0.2	5.9	5.5	0
0	0.1	0	0.2	5.5	5.2	0
0	0.1	0	0.2	5.2	4.9	0
0	0.1	0	0.2	4.9	4.6	0
0	0.1	0	0.2	4.6	4.4	0
0	0.1	0	0.1	4.4	4.2	0
0	0.1	0	0.1	4.2	4	0
0	0.1	0	0.1	4	3.8	0
15	16.4	0	7.4	*12.5*	*3.8*	*-0.1*

3.2.4 15 mm de Lluvia en 1 hora y exponente 6

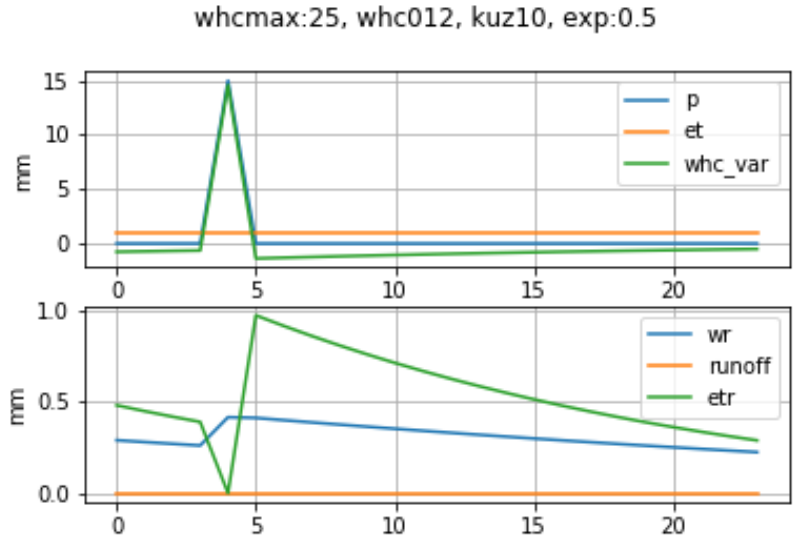


p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	0.1	0	0.5	12.5	12	0
0	0	0	0.5	12	11.5	0
0	0	0	0.4	11.5	11	0
0	0	0	0.4	11	10.6	0
15	4.2	0.6	0	10.6	20.8	0
0	1.3	0	0.8	20.8	18.7	0
0	0.7	0	0.7	18.7	17.3	0
0	0.4	0	0.7	17.3	16.2	0
0	0.3	0	0.6	16.2	15.3	0
0	0.2	0	0.6	15.3	14.5	0
0	0.1	0	0.6	14.5	13.8	0
0	0.1	0	0.5	13.8	13.2	0
0	0.1	0	0.5	13.2	12.6	0
0	0.1	0	0.5	12.6	12.1	0
0	0	0	0.5	12.1	11.6	0
0	0	0	0.4	11.6	11.1	0
0	0	0	0.4	11.1	10.7	0
0	0	0	0.4	10.7	10.2	0
0	0	0	0.4	10.2	9.8	0
0	0	0	0.4	9.8	9.5	0
0	0	0	0.4	9.5	9.1	0
0	0	0	0.3	9.1	8.8	0
0	0	0	0.3	8.8	8.4	0
0	0	0	0.3	8.4	8.1	0
15	7.6	0.6	11.1	*12.5*	*8.1*	*0.1*

3.2.5 15 mm de Lluvia en 1 hora, exponente 2 y kuz 10

p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	0.1	0	0.5	12.5	11.9	0
0	0.1	0	0.5	11.9	11.4	0
0	0.1	0	0.4	11.4	10.9	0
0	0.1	0	0.4	10.9	10.4	0
15	0.4	0.4	0	10.4	24.6	0
0	0.4	0	1	24.6	23.2	0
0	0.4	0	0.9	23.2	21.9	0
0	0.3	0	0.9	21.9	20.7	0
0	0.3	0	0.8	20.7	19.6	0
0	0.3	0	0.8	19.6	18.6	0
0	0.2	0	0.7	18.6	17.6	0
0	0.2	0	0.7	17.6	16.7	0
0	0.2	0	0.7	16.7	15.9	0
0	0.2	0	0.6	15.9	15.1	0
0	0.1	0	0.6	15.1	14.4	0
0	0.1	0	0.6	14.4	13.7	0
0	0.1	0	0.5	13.7	13.1	0
0	0.1	0	0.5	13.1	12.5	0
0	0.1	0	0.5	12.5	11.9	0
0	0.1	0	0.5	11.9	11.3	0
0	0.1	0	0.4	11.3	10.8	0
0	0.1	0	0.4	10.8	10.4	0
0	0.1	0	0.4	10.4	9.9	0
0	0.1	0	0.4	9.9	9.5	0
15	4.3	0.4	13.7	*12.5*	*9.5*	*-0.4*

3.2.6 15 mm de Lluvia en 1 hora, exponente 0.5 y kuz 10



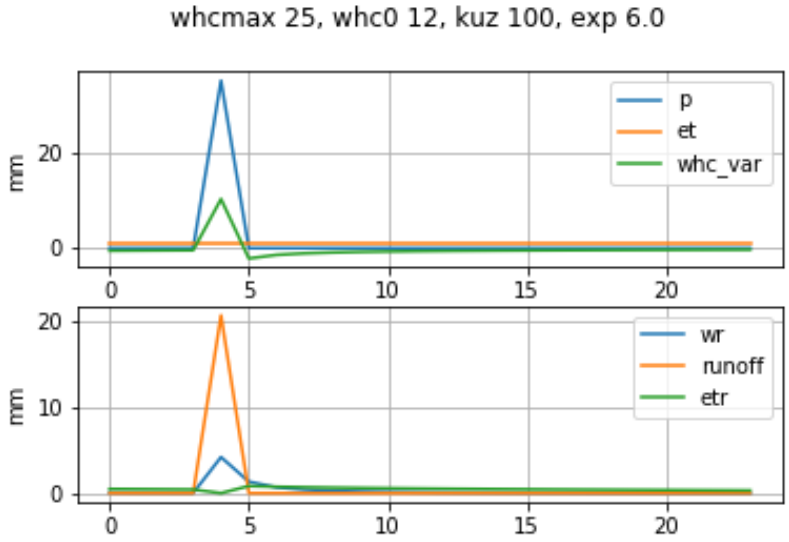
p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	0.3	0	0.5	12.5	11.7	0
0	0.3	0	0.4	11.7	11	0
0	0.3	0	0.4	11	10.3	0
0	0.3	0	0.4	10.3	9.7	0
15	0.4	0	0	9.7	24.3	0
0	0.4	0	1	24.3	22.9	0
0	0.4	0	0.9	22.9	21.6	0
0	0.4	0	0.9	21.6	20.3	0
0	0.4	0	0.8	20.3	19.1	0
0	0.4	0	0.8	19.1	18	0
0	0.4	0	0.7	18	17	0
0	0.3	0	0.7	17	16	0
0	0.3	0	0.6	16	15	0
0	0.3	0	0.6	15	14.1	0
0	0.3	0	0.5	14.1	13.3	0
0	0.3	0	0.5	13.3	12.4	0
0	0.3	0	0.5	12.4	11.7	0
0	0.3	0	0.4	11.7	11	0
0	0.3	0	0.4	11	10.3	0
0	0.3	0	0.4	10.3	9.6	0
0	0.2	0	0.4	9.6	9	0
0	0.2	0	0.3	9	8.4	0
0	0.2	0	0.3	8.4	7.9	0
0	0.2	0	0.3	7.9	7.4	0
15	7.5	0	12.7	*12.5*	*7.4*	*-0.1*

3.3 Eventos lluviosos con escorrentía

3.3.1 35 mm de Lluvia en 1 hora, exponente 2

p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	1	0	0.5	12.5	11.1	0
0	0.7	0	0.4	11.1	9.9	0
0	0.6	0	0.4	9.9	9	0
0	0.5	0	0.3	9	8.2	0
35	4.2	18.2	0	8.2	20.8	0
0	2.8	0	0.8	20.8	17.2	0
0	1.9	0	0.7	17.2	14.6	0
0	1.3	0	0.6	14.6	12.7	0
0	1	0	0.5	12.7	11.2	0
0	0.8	0	0.4	11.2	10	0
0	0.6	0	0.4	10	9.1	0
0	0.5	0	0.3	9.1	8.3	0
0	0.4	0	0.3	8.3	7.6	0
0	0.3	0	0.3	7.6	7	0
0	0.3	0	0.2	7	6.5	0
0	0.2	0	0.2	6.5	6	0
0	0.2	0	0.2	6	5.6	0
0	0.2	0	0.2	5.6	5.3	0
0	0.1	0	0.2	5.3	5	0
0	0.1	0	0.2	5	4.7	0
0	0.1	0	0.2	4.7	4.4	0
0	0.1	0	0.1	4.4	4.2	0
0	0.1	0	0.1	4.2	4	0
0	0.1	0	0.1	4	3.8	0
35	18.1	18.2	7.6	*12.5*	*3.8*	*-0.2*

3.3.2 35 mm de Lluvia en 1 hora, exponente 6



p	gw drainage	runoff	etr	whc0	whcfinal	balance
0	0.1	0	0.5	12.5	12	0
0	0	0	0.5	12	11.5	0
0	0	0	0.4	11.5	11	0
0	0	0	0.4	11	10.6	0
35	4.2	20.6	0	10.6	20.8	0
0	1.3	0	0.8	20.8	18.7	0
0	0.7	0	0.7	18.7	17.3	0
0	0.4	0	0.7	17.3	16.2	0
0	0.3	0	0.6	16.2	15.3	0
0	0.2	0	0.6	15.3	14.5	0
0	0.1	0	0.6	14.5	13.8	0
0	0.1	0	0.5	13.8	13.2	0
0	0.1	0	0.5	13.2	12.6	0
0	0.1	0	0.5	12.6	12.1	0
0	0	0	0.5	12.1	11.6	0
0	0	0	0.4	11.6	11.1	0
0	0	0	0.4	11.1	10.7	0
0	0	0	0.4	10.7	10.2	0
0	0	0	0.4	10.2	9.8	0
0	0	0	0.4	9.8	9.5	0
0	0	0	0.4	9.5	9.1	0
0	0	0	0.3	9.1	8.8	0
0	0	0	0.3	8.8	8.4	0
0	0	0	0.3	8.4	8.1	0
35	7.6	20.6	11.1	*12.5*	*8.1*	*0.1*