**Homework 3 Solution CE374K Hydrology Spring 2013**

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**Question 1.** Table 1 below shows the hourly heat balance in Austin as of 24 January 2013 from the National Land Data Assimilation System. Radiation and heat fluxes are positive upwards and negative downwards. Net Radiation = - (Shortwave + Longwave) is the radiant energy absorbed by the land surface. Balance = Net Radiation – Sensible – Latent + Ground is the energy remaining at the land surface after exchanges of sensible and latent heat fluxes with the overlying air, and ground heat flux with the underlying soil. The radiation and heat balance has an overall average of almost zero (-0.6 W/m2), as it should do.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Radiation Fluxes (W/m2)** | **Net Radiation** | **Heat Fluxes (W/m2)** | **Balance** |
|  | **Shortwave** | **Longwave** | **(W/m2)** | **Sensible** | **Latent** | **Ground** | **(W/m2)** |
| 12:00 AM | 0 | 50 | -50 | -4 | -5 | 40 | -1 |
| 1:00 AM | 0 | 50 | -50 | -4 | -6 | 39 | -1 |
| 2:00 AM | 0 | 50 | -50 | -4 | -6 | 37 | -3 |
| 3:00 AM | 0 | 48 | -48 | -4 | -6 | 36 | -2 |
| 4:00 AM | 0 | 48 | -48 | -4 | -6 | 35 | -3 |
| 5:00 AM | 0 | 47 | -47 | -4 | -6 | 34 | -3 |
| 6:00 AM | 0 | 46 | -46 | -4 | -6 | 33 | -3 |
| 7:00 AM | 0 | 44 | -44 | -4 | -6 | 30 | -4 |
| 8:00 AM | 0 | 42 | -42 | -5 | -6 | 17 | -14 |
| 9:00 AM | -17 | 46 | -29 | -2 | 2 | -59 | -88 |
| 10:00 AM | -121 | 63 | 58 | 17 | 24 | -110 | -93 |
| 11:00 AM | -235 | 83 | 152 | 66 | 63 | -115 | -92 |
| 12:00 PM | -340 | 96 | 244 | 112 | 85 | -127 | -80 |
| 1:00 PM | -416 | 93 | 323 | 134 | 102 | -125 | -38 |
| 2:00 PM | -452 | 91 | 361 | 122 | 113 | -114 | 12 |
| 3:00 PM | -445 | 96 | 349 | 72 | 116 | -102 | 59 |
| 4:00 PM | -391 | 102 | 289 | 23 | 98 | -76 | 92 |
| 5:00 PM | -296 | 99 | 197 | -16 | 57 | -46 | 110 |
| 6:00 PM | -173 | 87 | 86 | -8 | -5 | 17 | 116 |
| 7:00 PM | -42 | 72 | -30 | -5 | -3 | 51 | 29 |
| 8:00 PM | 0 | 60 | -60 | -5 | -4 | 47 | -4 |
| 9:00 PM | 0 | 56 | -56 | -5 | -5 | 47 | 1 |
| 10:00 PM | 0 | 58 | -58 | -5 | -6 | 46 | -1 |
| 11:00 PM | 0 | 57 | -57 | -5 | -6 | 42 | -4 |
| 12:00 AM | 0 | 54 | -54 | -5 | -7 | 42 | 0 |
| **Average** | **-117.12** | **65.52** | **51.6** | **18.12** | **22.84** | **-11.24** | **-0.6** |

Prepare two charts, one of the radiation fluxes (short-wave, long-wave, net) and one of the heat fluxes (sensible, latent, ground). What percentages of the net radiation become sensible heat flux, latent heat flux, and ground heat flux? Why are the average sensible and latent heat fluxes positive and the ground heat flux negative?

Percentage of Net Radiation:

* Sensible
* Latent
* Ground

The sensible and latent heat average percentages are positive because the direction is upward (absorbed by the atmosphere). The average ground flux is negative because it absorbers (gains) energy; the energy absorbed during the sunlight is greater than the energy released at night.

**Question 2.** The evaporation example presented in class is for average conditions over 24 hours on 24 January 2013, as shown at: <http://www.caee.utexas.edu/prof/maidment/CE374KSpr13/Evaporation/EvaporationExample.pdf> Go through the same computations for the conditions at 2PM on that day when the net radiation is 361 W/m2, the climate conditions recorded at Bergstrom airport are air temperature 23°C, relative humidity 64%, and wind speed 1.5 m/s. Prepare a summary table comparing the values of the potential evaporation at 2PM computed by the energy balance method (Er), the aerodynamic method (Ea) and the combination method (Eo) with those computed in the class example for daily average conditions.

* + Energy method
	+ Aerodynamic method

Wind run:

* + Combination method

 (Table)

|  |  |  |
| --- | --- | --- |
| **Method** | **Average Conditions** | **Bergstrom airport** |
| Energy | 1.80 | 12.74 |
| Aerodynamic | 1.58 | 6.27 |
| Combination | 1.73 | 10.91 |

**Question 3.** The potential evaporation on 24 January 2013 for daily average conditions is Eo = 1.73 mm/day. The daily average of the values of the latent heat flux is 22.84 W/m2. Determine the corresponding value of the actual evaporation (mm/day) and find what percentage of the potential evaporation actually occurrs on this day. Comment on this percentage in light of the drought conditions currently prevailing.

The actual evapotranspiration is less than the half of the potential. This might be due the lack of available water because of the drought conditions.

**Question 4.** The particle size distribution of a soil sample is 25% sand, 65% silt and 10% clay. What soil texture does this sample represent?



The soil texture of the sample is **silt loam**.

**Question 5.** Compute the infiltration rate (cm/hr) and the cumulative infiltration (cm) at hourly intervals from 0-5 hours for three soil textures: sand, silt loam and clay. Plot a graph showing the three infiltration rate (f) curves and the three cumulative infiltration (F) curves. In each case, assume that the initial effective saturation is 20% and that water is instantaneously ponded on the soil.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Soil Class | η | θe | ψ [cm] | K [cm/hr] |
| Sand | 0.437 | 0.417 | 4.95 | 11.89 |
| Silt loam | 0.501 | 0.486 | 16.68 | 0.65 |
| Clay | 0.475 | 0.385 | 31.63 | 0.03 |

|  |  |  |  |
| --- | --- | --- | --- |
| Sand |  |  |  |
| Δθ= | 0.334 |  |  |
| ψΔθ= | 1.651 |  |  |
|  |  |  |  |
| Time [hr] | F(t) [cm] | f [cm/hr] | Depth of infiltration [cm] |
| 0 | 0.00 | - | 0.00 |
| 1 | 15.78 | 13.13 | 47.31 |
| 2 | 28.58 | 12.58 | 85.67 |
| 3 | 41.04 | 12.37 | 123.02 |
| 4 | 53.35 | 12.26 | 159.92 |
| 5 | 65.57 | 12.19 | 196.55 |

|  |  |  |  |
| --- | --- | --- | --- |
| Silt loam |  |  |  |
| Δθ= | 0.389 |  |  |
| ψΔθ= | 6.485 |  |  |
|  |  |  |  |
| Time [hr] | F(t) [cm] | f [cm/hr] | Depth of infiltration [cm] |
| 0 | 0.00 | - | 0.00 |
| 1 | 3.35 | 1.91 | 8.62 |
| 2 | 5.01 | 1.49 | 12.90 |
| 3 | 6.40 | 1.31 | 16.47 |
| 4 | 7.66 | 1.20 | 19.69 |
| 5 | 8.82 | 1.13 | 22.68 |

|  |  |  |  |
| --- | --- | --- | --- |
| Clay |  |  |  |
| Δθ= | 0.308 |  |  |
| ψΔθ= | 9.742 |  |  |
|  |  |  |  |
| Time [hr] | F(t) [cm] | f [cm/hr] | Depth of infiltration [cm] |
| 0 | 0.00 | - | 0.00 |
| 1 | 0.78 | 0.40 | 2.55 |
| 2 | 1.12 | 0.29 | 3.64 |
| 3 | 1.38 | 0.24 | 4.50 |
| 4 | 1.61 | 0.21 | 5.23 |
| 5 | 1.81 | 0.19 | 5.88 |

**Question 6.** Determine the ponding time for the same three soils if infiltration occurs under rainfall intensities of 1 cm/hr and 10 cm/hr. Prepare a table showing the resulting ponding times (including “No Ponding” if necessary). How quickly will surface runoff happen on these soils?

Ponding Time Equation:

Ponding time [hours (minutes)]

|  |  |
| --- | --- |
| Soil Class | Infiltration Rate |
| i=1cm/hr | i=10cm/hr |
| Sand | No Ponding | No Ponding |
| Silt loam | 12.05 (723) | 0.05 (2.71) |
| Clay | 0.30 (18) | 0.00 (0.18) |

How quickly will surface runoff happen on these soils?

There will be no surface runoff for the sand soil class. In contrast for the clay soil class, the surface runoff will appear almost instantaneously. For a silt loam soil the ponding time relies greatly in the rainfall intensity; the surface runoff will appear after a couple of minutes for a heavy rain (i=10cm/hr) but it will take more than 12 hrs for a light rain (i=1cm/hr)