Homework 2: Hydrologic Cycle: Evaporation/Transpiration GEOS 4430 - Fall 2011

Due: Sept. 20th

1 Evaporation

1. Problem 2, Chp. 2 (use $539\frac{\text{cal}}{\text{gm}}$ as heat of vaporization)

2. UTD has new reflecting pools and a "misting fountain that can create a cooling fog as high as 200 feet above the plaza". During times of drought the issue of water losses are likely to arise. Compute the average summer evaporation to be expected from the pools (with a 300 x 6 m surface area) area, assuming 17 cm/month pan evaporation for June-August, and given a water cost of $3./1000 gal, use the coefficients in textbook Table 2.2 to compute the monthly water loss and cost in dollars from the pool. Report the average monthly water loss and total cost for the summer. Note daily pan evaporation data available here (try station "Lavon", note values are in hundredths of an inch).

2 Evapotranspiration

1. Apply the *Thornthwaite Method* for the following example of a farm field in Canada (Table 1):

$$E_t = 1.6\left[\frac{10T_a{}^\circ\text{C}}{I}\right]^a \quad (1)$$

$$I = \sum_{i=1}^{12}\left(\frac{T_a}{5}\right)^{1.5} = \mathbf{31.48} \quad (2)$$

$$a = 0.492 + 1.79\text{x}10^{-2} \cdot I - 7.771\text{x}10^{-5} \cdot I^2 + 6.75\text{x}10^{-7} \cdot I^3 \quad (3)$$

   (a) Compute the monthly ET (fill in blank columns in Table 1) 10 pts

   (b) plot the monthly ET values vs month 10 pts

   (c) compute a total ET (i.e. the total water need of that field during that growing season May-Sept) 10 pts

2. Updated approaches for ET, see Texas ET Website[1]. International hydrologists, and now at least those in Texas have adopted the UN

[1] `http://texaset.tamu.edu`

Table 1: Problem 1 temperature and daylight correction factor for a field at 50° N latitude. Adjusted ET is ET from eqn. (1) times daylight factor.

Month	T_a°F	T_a°C	ET (cm)	Daylight Factor	Adjusted ET (in)
May	52.8			1.33	
June	67.4			1.36	
July	66.8			1.37	
August	70.3			1.25	
Sept.	47.7			1.06	

FAO Penman-Monteith equation to predict potential ET (maximum possible ET) in a globally-standardized fashion. We'll practice using this method.

(a) Plot potential evapotransportation (PET or ET_o) for the DFW area for the past 7 days vs. Tmax, Solar (insolation) and 4pm Wind using the data at `http://texaset.tamu.edu/dallas1.php` (normally we use AgriLife Center, but that may have closed; try exporting CSV data from the "Other Date Range" link on that page). A scatter plot is probably best...

(b) For this time period, which input variable was most influential (correlates best) with ET (e.g. you might try to fit a curve to each dataset and look at the R^2)? Can you use the FAO Penman-Monteith equation given in class to explain why? How does your observation compare with the studies cited summaried in the Bibliography *Brutsaert* (2006); *Roderick et al.* (2007); *Wild* (2009)?

(c) Compare the total ET for the 7 day period with the rainfall. How much irrigation would be required to supply the total water requirement for the last 7 days?

References

Brutsaert, W., 2006. Indications of increasing land surface evaporation during the second half of the 20th century. *Geophys. Res. Lett.*, 33:4. doi: 10.1029/2006GL027532.

Key: brutsaert-2006
Annotation: It is generally agreed that the evaporation from pans has been decreasing for the past half century over many regions of the Earth. However, the significance of this negative trend, as regards terrestrial evaporation, is still somewhat controversial, and its implications for the global hydrologic cycle remain unclear. The controversy stems from the alternative views that these evaporative changes resulted, either from global radiative dimming, or from the complementary relationship between

pan and terrestrial evaporation. Actually, these factors are not mutually exclusive but act concurrently. It is shown quantitatively that, if the presently available data records are taken at face value, despite global dimming, the observed decreases in pan evaporation are generally evidence of increased terrestrial evaporation in those regions. This is consistent with independent hydrologic budget calculations for several large river basins in the USA, and likely further evidence of an accelerating hydrologic cycle in many areas.

Roderick, M. L., L. D. Rotstayn, G. D. Farquhar, and M. T. Hobbins, 2007. On the attribution of changing pan evaporation. *Geophys. Res. Lett.*, 34(17):L17403. ISSN 0094-8276. doi:10.1029/2007GL031166.

Key: roderick-rotstayn-2007
Annotation: Evaporative demand, measured by pan evaporation, has declined in many regions over the last several decades. It is important to understand why. Here we use a generic physical model based on mass and energy balances to attribute pan evaporation changes to changes in radiation, temperature, humidity and wind speed. We tested the approach at 41 Australian sites for the period 1975–2004. Changes in temperature and humidity regimes were generally too small to impact pan evaporation rates. The observed decreases in pan evaporation were mostly due to decreasing wind speed with some regional contributions from decreasing solar irradiance. Decreasing wind speeds of similar magnitude has been reported in the United States, China, the Tibetan Plateau and elsewhere. The pan evaporation record is invaluable in unraveling the aerodynamic and radiative drivers of the hydrologic cycle, and the attribution approach described here can be used for that purpose.

Wild, M., 2009. Global dimming and brightening: A review. *J. Geophys. Res.*, 114. doi:10.1029/2008JD011470.

Key: wild-2009
Annotation: There is increasing evidence that the amount of solar radiation incident at the Earth's surface is not stable over the years but undergoes significant decadal variations. Here I review the evidence for these changes, their magnitude, their possible causes, their representation in climate models, and their potential implications for climate change. The various studies analyzing long-term records of surface radiation measurements suggest a widespread decrease in surface solar radiation between the 1950s and 1980s ("global dimming"), with a partial recovery more recently at many locations ("brightening"). There are also some indications for an "early brightening" in the first part

of the 20th century. These variations are in line with independent long-term observations of sunshine duration, diurnal temperature range, pan evaporation, and, more recently, satellite-derived estimates, which add credibility to the existence of these changes and their larger-scale significance. Current climate models, in general, tend to simulate these decadal variations to a much lesser degree. The origins of these variations are internal to the Earth's atmosphere and not externally forced by the Sun. Variations are not only found under cloudy but also under cloud-free atmospheres, indicative of an anthropogenic contribution through changes in aerosol emissions governed by economic developments and air pollution regulations. The relative importance of aerosols, clouds, and aerosol-cloud interactions may differ depending on region and pollution level. Highlighted are further potential implications of dimming and brightening for climate change, which may affect global warming, the components and intensity of the hydrological cycle, the carbon cycle, and the cryosphere among other climate elements.