**Stationary Probe Data Calculations**

**Updated: 18 October 2018**

**Goal:** The goal of this assignment is to familiarize you with the cosmic-ray neutron correction factors and calibration function for converting corrected neutrons into volumetric water content. At the end of this assignment you should be able to perform all necessary computations for stationary probe data. Please see Zreda 2012 HESS, Franz 2012 VZJ, Desilets 2010 WRR, Bogena 2013 WRR, Franz 2015 GRL, and the COSMOS website for additional information.

**Tasks:**

1. The file Central City Data.xlsx is an excel spreadsheet of the basic data provided from the sensor via the iridium satellite uplink. Gary Womack of Quaesta Instruments provided me with the raw file for processing. At some point Gary will provide us with a GUI to download the data ourselves remotely. The excel file contains all transmission information from the sensor including diagnostic data. First, separate the file by including all data with a size of 18 bytes only (the larger bytes are diagnostic data streams). Note that because of bad transmission, power fluctuations, etc. that some hour periods will be missing. Dealing with missing data is a critical aspect of using real field data. Please keep the parsed data in chronological order.

2. Using the excel spreadsheet reported latitude and longitude (Col. 5 & 6) estimate the study site elevation in units of meters (I use Google earth to do this). Next calculate the site’s reference pressure value *P0* (mb) and fast neutron scaling factor (CS) by plugging in latitude, longitude, and elevation into the online calculator at <http://cosmos.hwr.arizona.edu/Util/calculator.php>.

3. Compute the *CP* factors using the *P0* value found in step 2 for all rows in the data series found in step 1. Please use the P4 sensor readings as the ambient air pressure (*Pi*) as it is the most accurate (Col. 12).

4. Compute the *CWV* factors for all data rows by using the ambient air pressure (Col. 12), air temperature (Col. 23) and air relative humidity (Col. 24). For reference air temperature use 25oC and for reference relative humidity use 0% (note reference absolute humidity should be 0!).

5. Compute the *CI* factors for all data rows by using the COSMOS website. You will have to match the timestamps in each data row with the reported values from the COSMOS website (Note: I do this in Matlab by subtracting the two time series, finding the closest value and reporting it for that line. Not sure how you would do this efficiently in Excel. **If you are using the hunt and find method by hand you are wasting a lot of time!!!!)**. The *CI* values can be found in the COSMOS level 2 data under the INTEN column. I typically use the Neb3 COSMOS site at it is a fairly continuous record. A link to the text file is at <http://cosmos.hwr.arizona.edu/Probes/StationDat/029/corcounts.txt>, and a download of the file in excel or matlab is at <http://cosmos.hwr.arizona.edu/Probes/StationDat/029/index.php> under the various links. This will probably be the toughest part of this assignment for Excel users. If you are wasting too much time find a matlab user and use their values and learn how they coded this.

6. With all of the correction factors by each line, compute the corrected neutron count rates using steps 2-5 and the raw counts from the excel file (N1, Col. 19).

7. Using the Central City calibration dataset (Central\_City\_Calibration\_20140529.xls) estimate the site’s average soil bulk density in the top 30 cm, (g/cm3) (this is in cell 16:22 and colored red) and average pore water content (g/g) (this is in cell 10:10 and colored red. Note the unites are Wt. % so you will have to divide the value by 100 to get to units of g/g).

8. Using the Chemistry Results Spreadsheet (Chemistry\_Results\_20140801.xlsx) estimate the Central City site’s lattice water (g/g) and soil organic carbon water equivalent  (g/g). Note: Central City is denoted as CC in the site list, lattice water is referred to as H2O+ (Col. BG and is in units of Wt. % so you need to divide by 100), total carbon is listed as C-Total (Col. BC in units of Wt. %) and soil *CO2* is listed as *CO2* (Col. BE in units of Wt. %).

9. Using your estimates from steps 7-9 rearrange the calibration function and solve for *N0*. For the value of *N* use the average corrected neutron count rate between 5/29/2014 19:10 and 5/30/2014 0:10. This is approximately when William and I were sampling the soils. Note that all COSMOS data is in time units of UTC. Greenwich, UK is 6 hours ahead of Central Standard Time but will get messed up with daylight savings so watch out. This is why UTC is a handy reference time.

10. With your value of *N0* from step 9 and your corrected neutron counts from step 6, compute the volumetric pore water content for the site (cm3/cm3). Note this will be  so don’t get confused with gravimetric water content (g/g)!

11. Compare your *N0* values with the rest of the group and plot the time series of volumetric water content found in step 10.

**Neutron correction factors**:

 (1)

Where *N* is the corrected neutron counts per hour (cph), *N’* is the raw moderated neutron counts (cph), *CP* is the pressure correction factor, *CWV* is the water vapor correction factor, *CI* is the high-energy intensity correction factor, and *CS* is the scaling factor for geomagnetic latitude. In *CS*, *x*, *y*, *z*, is location and elevation, and *t* is time.

 In *CP*, *Pi* is the current ambient pressure (mb), *P0* is the reference pressure (mb), and 130 is the attenuation length of neutrons (g/cm2) in Nebraska. In *CI*,  is the current high-energy neutron intensity,  is the reference level high-energy neutron intensity (1 May 2011 is the reference date for the COSMOS website). In *CWV*,  is the absolute humidity of the air (g/m3),  is the reference absolute humidity of the air (g/m3), *T* is air temperature in (oC), *P* is pressure (mb), and *RH* is relative humidity (%).

**Absolute Water Vapor Calculations:**



Where *es0* is the saturated vapor pressure at surface (Pa), *T* is air temperature (oC). Note: 1 mb = 1 hPa =100 Pa, and T(K)=T(oC)+273.15.



Where e0 is actual vapor pressure at surface (Pa) and *RH* is the relative humidity (%).



Where  is the absolute humidity of air (g/m3),  is the gas constant for water vapor (J/K/kg), *R* is universal gas constant ( = 8.31432 J/mol/K), *Mvap* is the molar mass of water vapor ( = 18.01528 g/mol = 0.01801528 kg/mol ), and *T* is air temperature (oC).

**Calibration Function:**



Where is pore water content (g/g),  (cm3/cm3) = $θ\_{p}\*\frac{ρ\_{b}}{ρ\_{w}}$,  is lattice water content (g/g),  is soil organic carbon water content (g/g),  is dry soil bulk density (g/cm3), $ρ\_{w}$ is the density of water = 1 (g/cm3), is the corrected neutron counts per hour (cph), and is an instrument specific calibrated parameter that represents the count rate over dry silica soils (cph). The 3 coefficients were determined by Desilets 2010 WRR from a semi-analytical solution of a neutron diffusion equation.

$$θ\_{SOC\_{eq}}=\left(TC-\frac{12}{44}CO\_{2}\right)0.494$$

Where *TC* is the soil total carbon (g/g), *CO2* is the soil *CO2* (g/g), 12/44 is the stoichiometric ratio of carbon to *CO2*, and 0.494 is the stoichiometric ratio of H2O to organic carbon (assuming organic carbon is cellulose C6H10O5).

**Biomass Correction Factor**

We correct for variations between instruments and for changes in *BWE* by scaling the fixed probe observations against the rover:



Where  is the fixed probe estimate of  with no standing biomass,  is the rover estimate of  with no standing biomass, and  is the slope of the relationship between  and *BWE* from the rover surveys and calibration datasets. The *BWE* was found from the calibration sampling as:



Where  is the standing wet biomass per unit area (kg/m2 ~ mm of water/m2) and *SDB* is the standing dry biomass per unit area (kg/m2 ~ mm of water/m2) found by oven drying samples at 70oC for 5 days. Note *fwe* is = 0.494 like above. From the available calibration datasets we found the rover had a statistically significant linear relationship yielding the coefficients of cpm and  with an R2 = 0.515 and p value = 0.03.