

## Appendix 2: Hydrometeorology and Hydroclimatology of Baseflow

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A time series of end of month soil moisture data was developed for each climate division in the United States from 1931 to present using a nonlinear water balance (Huang, van den Dool and Georgarakos 1996). This data is available from the National Centers for Environmental Prediction (NCEP).

The components in this balance were precipitation, evaporation, runoff, and groundwater loss.

$$\frac{dW(t)}{dt} = P(t) - E(t) - R(t) - G(t)$$

Where:  
 $W(t)$  is the soil water content at time  $t$   
 $P(t)$  is the mean areal precipitation over area A  
 And so on...

Runoff, or net streamflow divergence, is composed of two components, surface runoff and baseflow.

$$S(t) = P(t) \left[ \frac{W(t)}{W_{\max}} \right]^m$$

$$B(t) = \frac{\alpha}{1 + \mu} W(t)$$

Where:

- $W_{\max}$  is the soil's water holding capacity in mm
- $m$  is a parameter with a value  $>1$  (typically in the range of 2-4)
- $\alpha$  is the inverse of the response time of baseflow
- $\mu$  is the portion of subsurface flow that becomes baseflow

Groundwater loss is also a function of these parameters, and evapotranspiration is estimated from the temperature, an estimate of radiation, and the  $W_{\max}$

Huang et al. calibrated this water balance to match observed runoff values by applying search optimization algorithms to the parameters until the model's estimates of hydrologic processes (runoff, baseflow, etc) showed the smallest deviation from real world, long term, and large scale data of these processes.

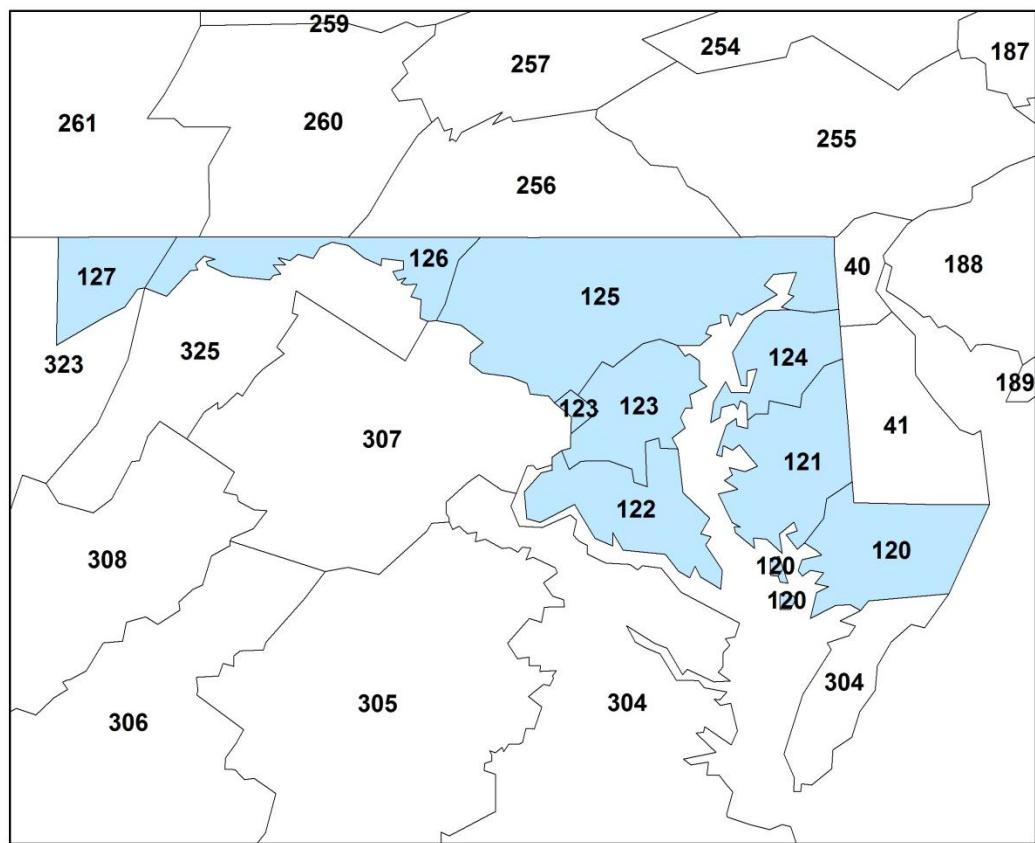
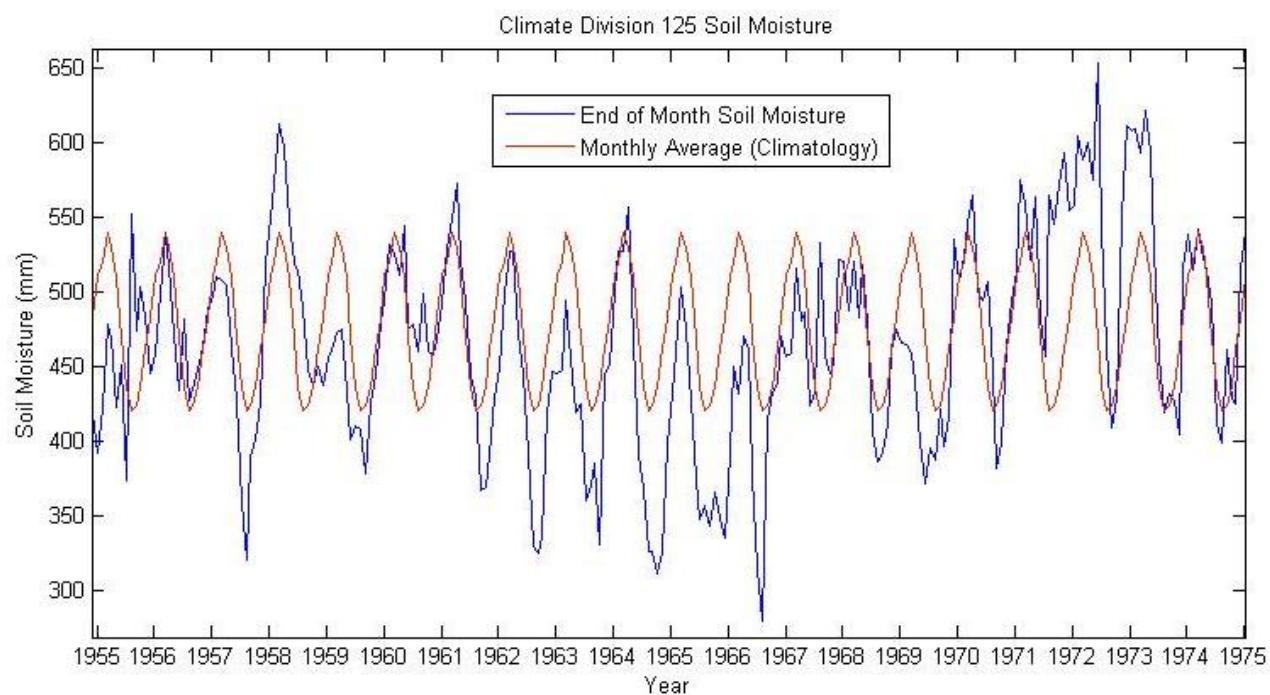


Figure 1 - Map of Climate Divisions with Maryland highlighted



This soil moisture data set was used to control for hydroclimatological variability when analyzing trends in streamflow.

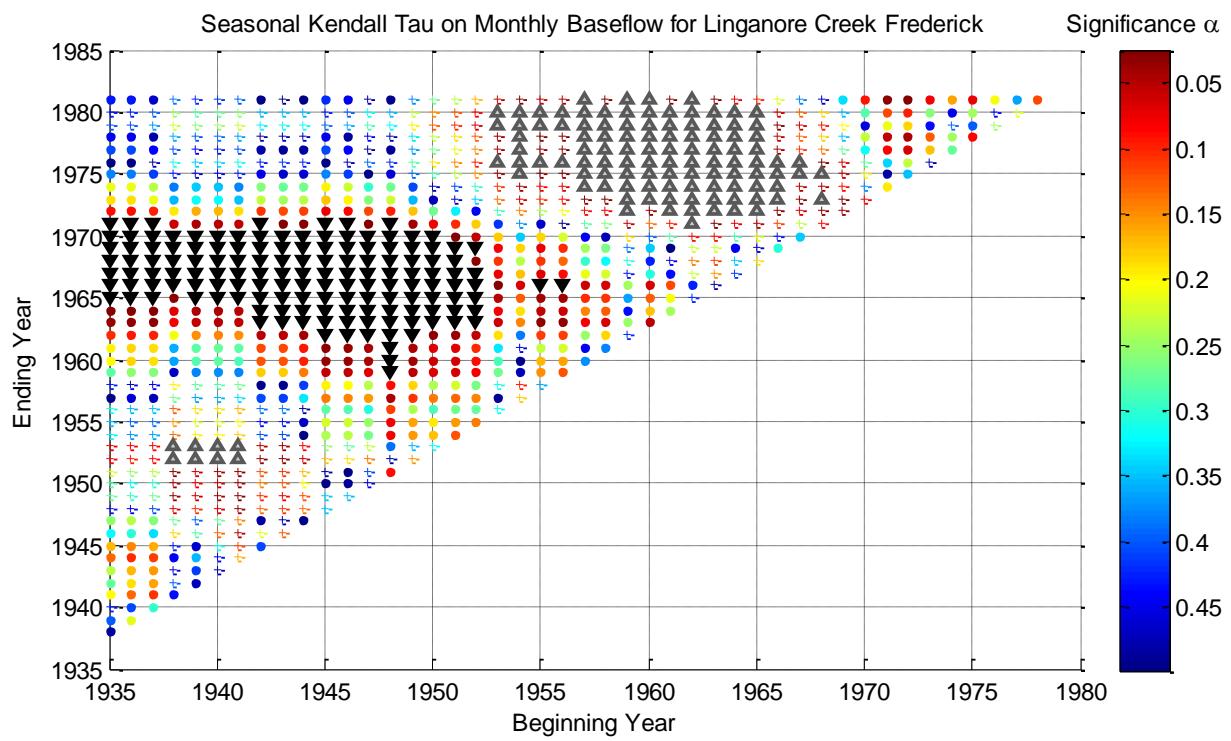
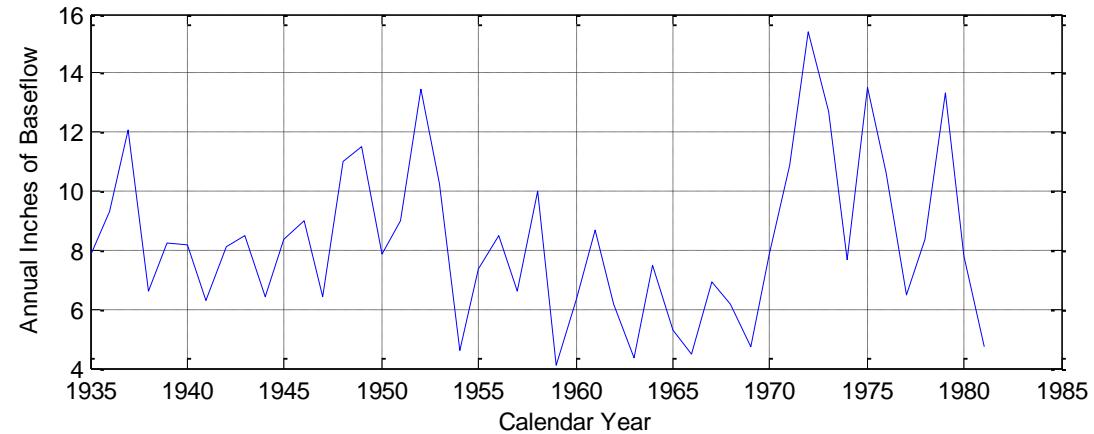


Figure 2 - Baseflow Timeseries and Seasonal Kendall Tau Plot for Linganore Creek at Frederick, MD

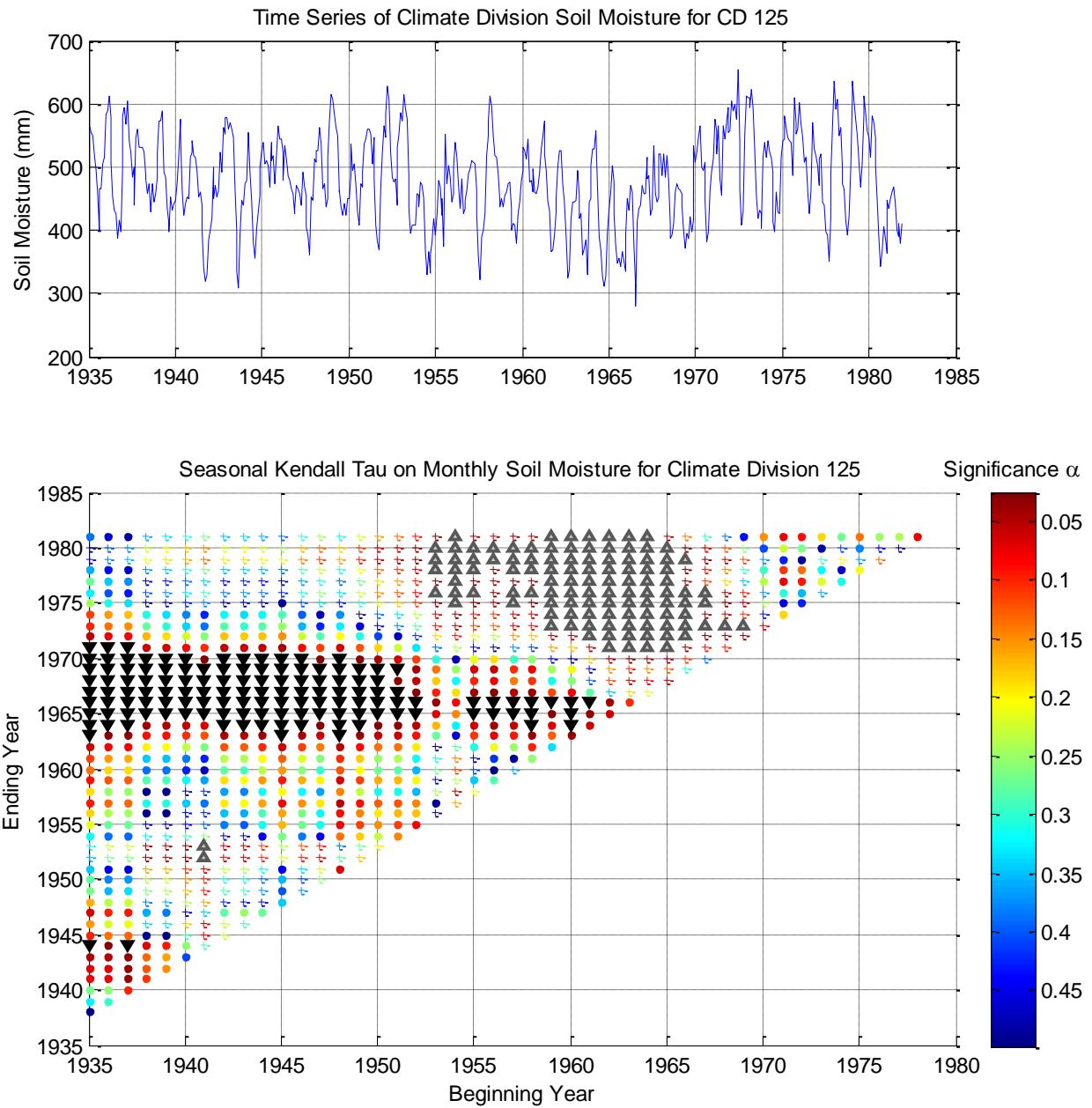


Figure 3 - Timeseries and Seasonal Kendall Tau for end of month soil moisture for Climate Division 125

A comparison of the Kendall Tau plots for monthly baseflow and end of month soil moisture values suggests that the trends seen in baseflow for Linganore Creek are explained almost entirely by climatological variation for Climate Division 125.

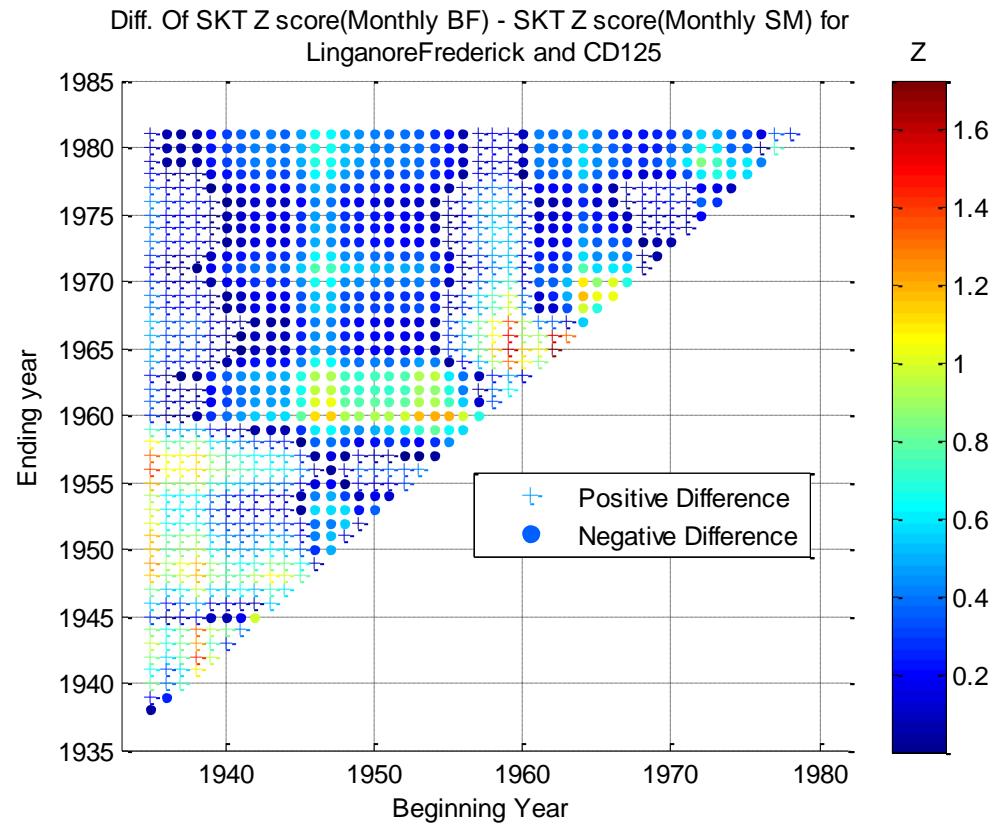


Figure 4 - "Difference Surface" comparing the difference in Z scores (computed from the probability of trend for each sub-period) between Linganore Creek's Monthly Baseflow and Climate Division 125's end of month soil moisture

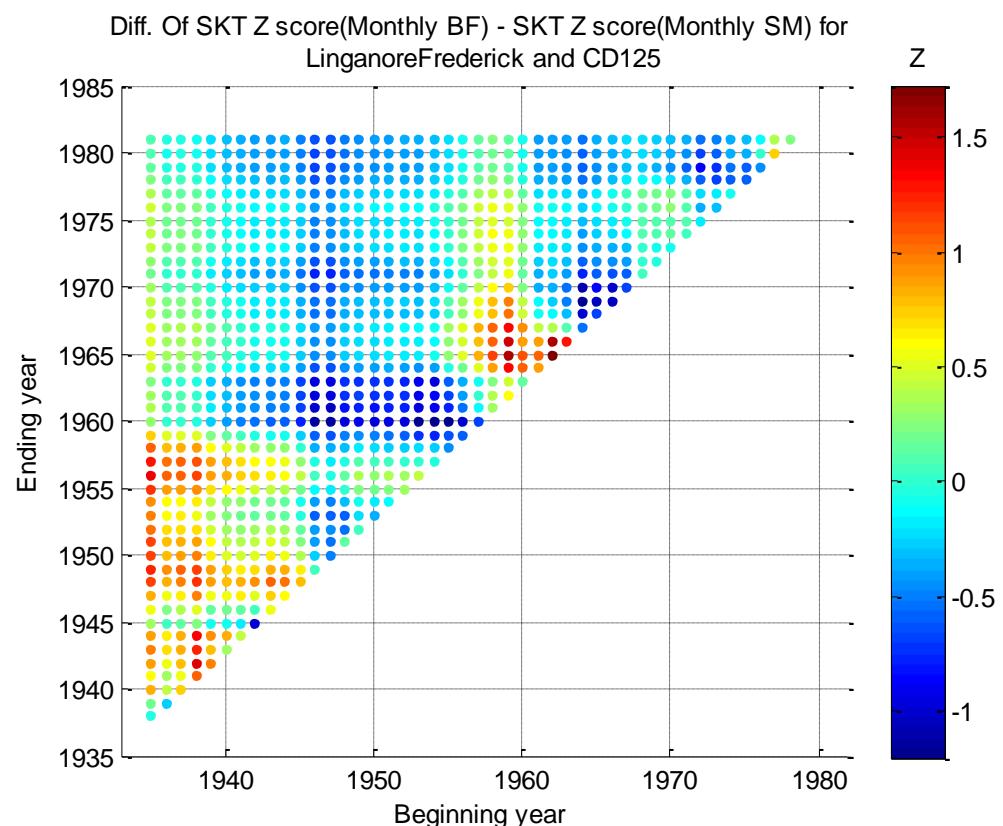
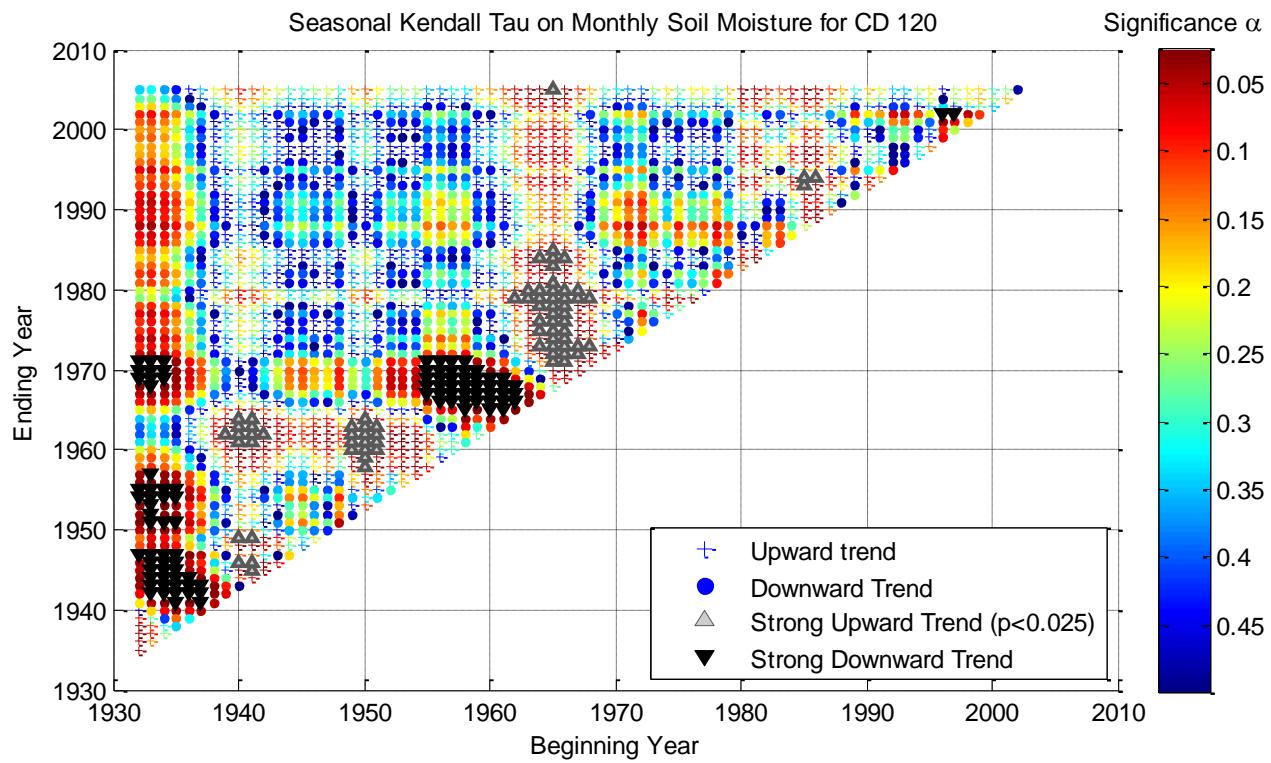
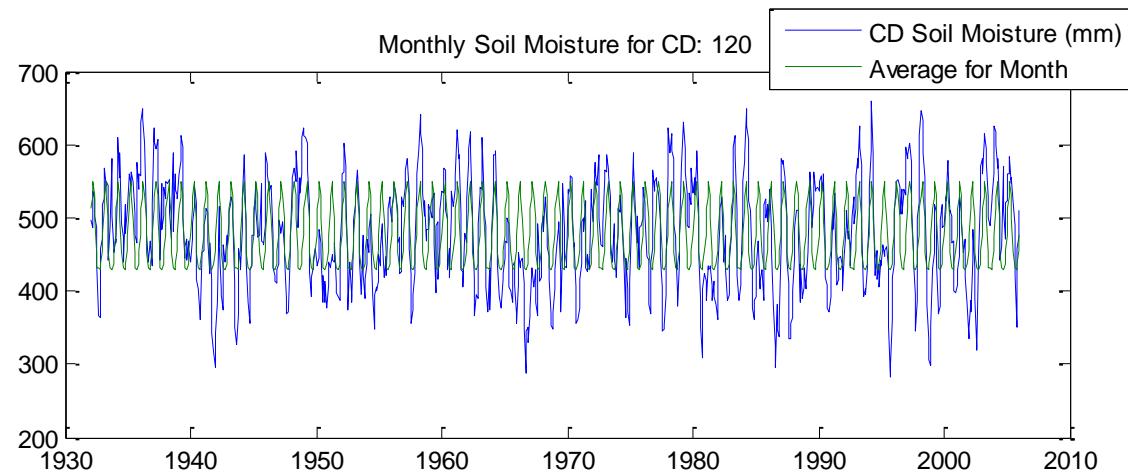
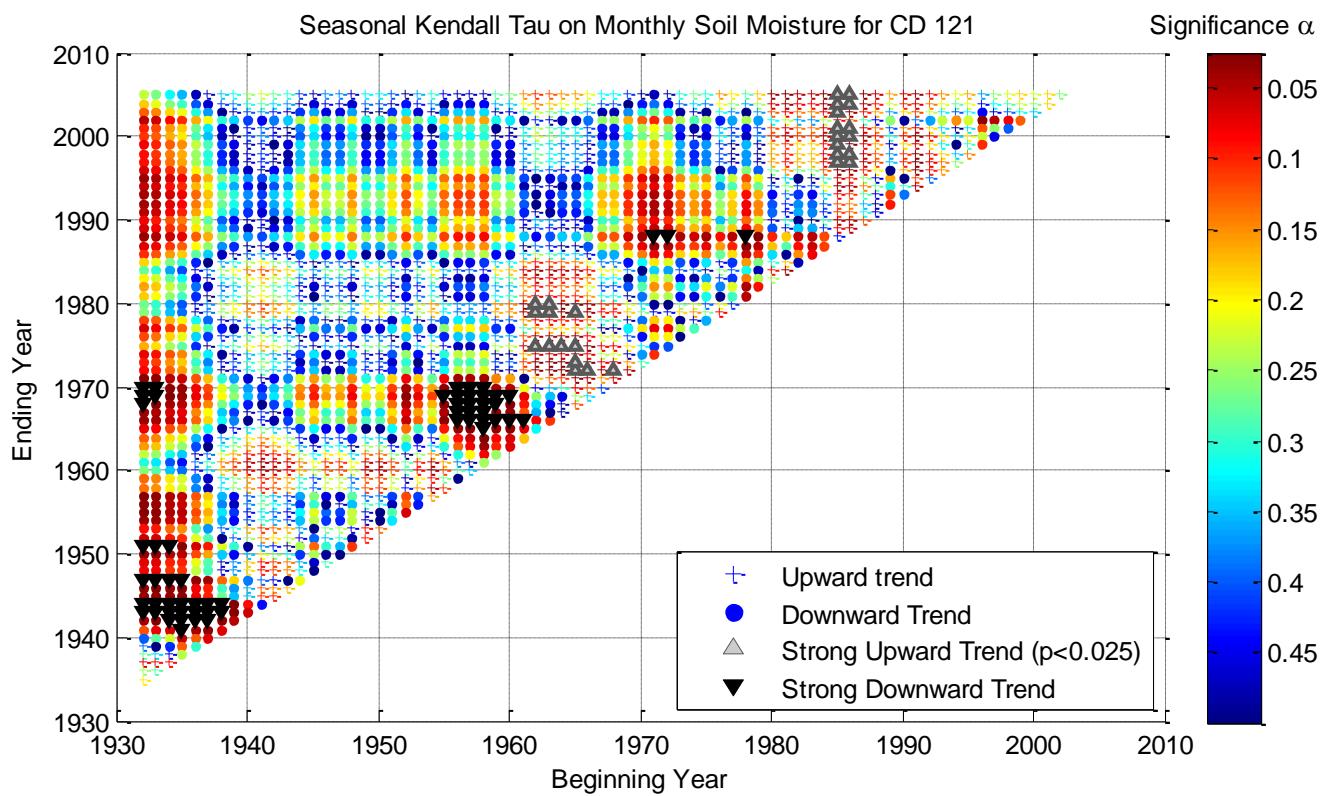
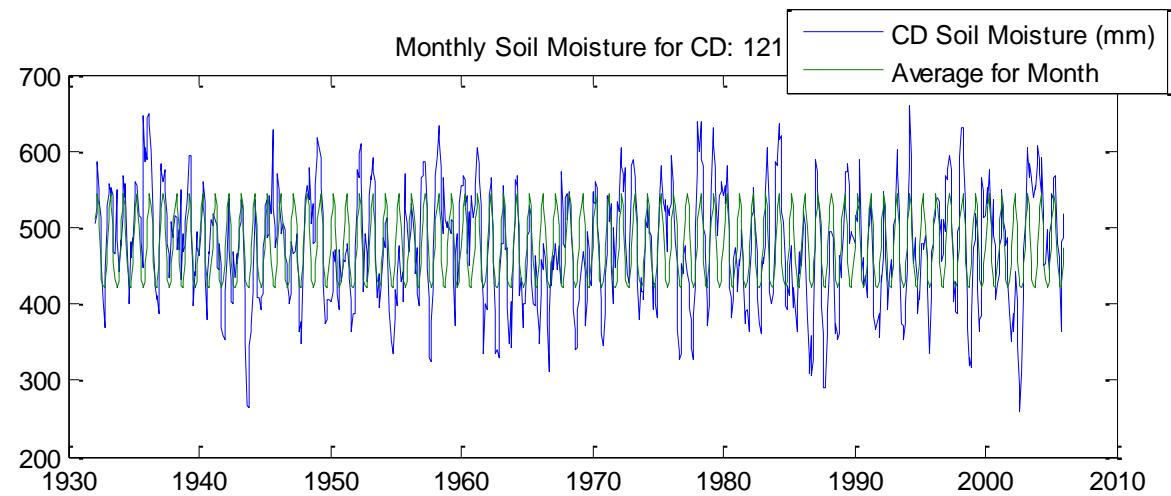
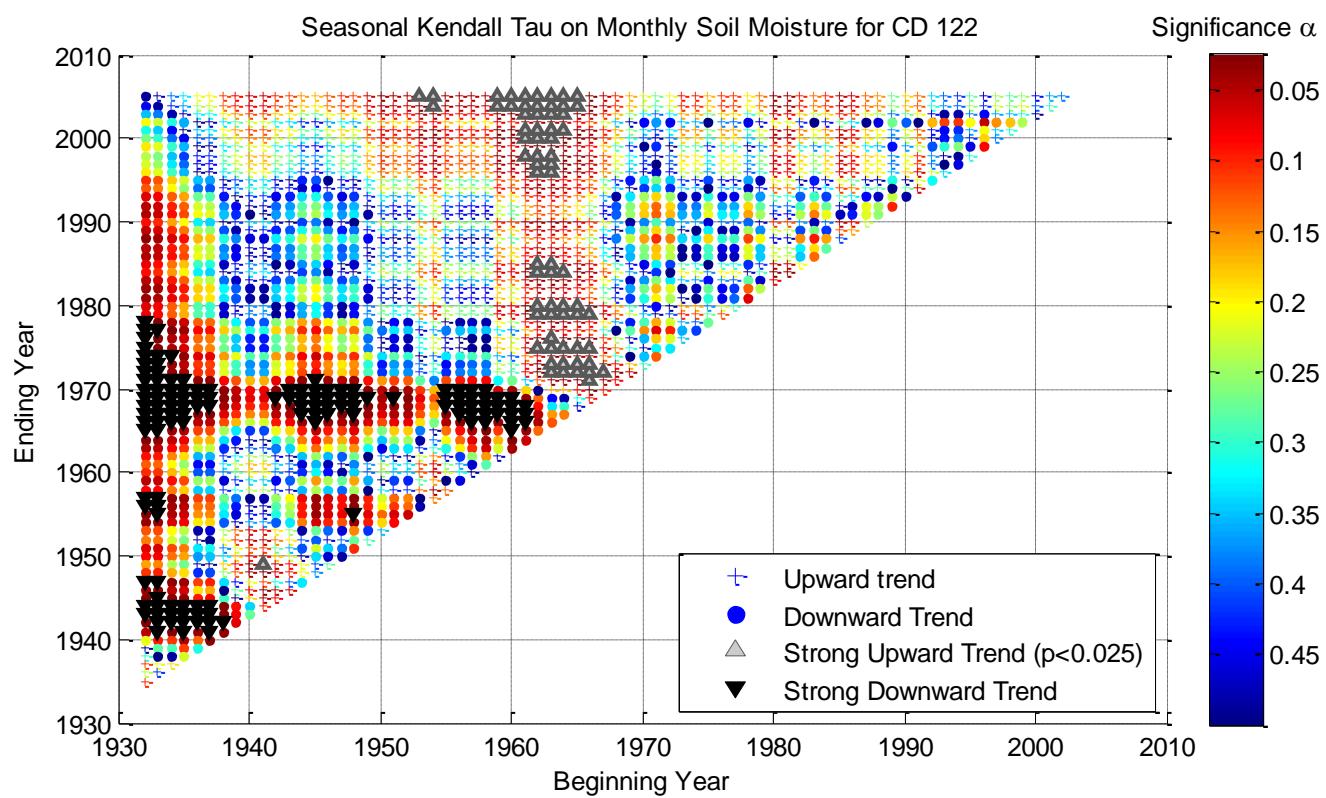
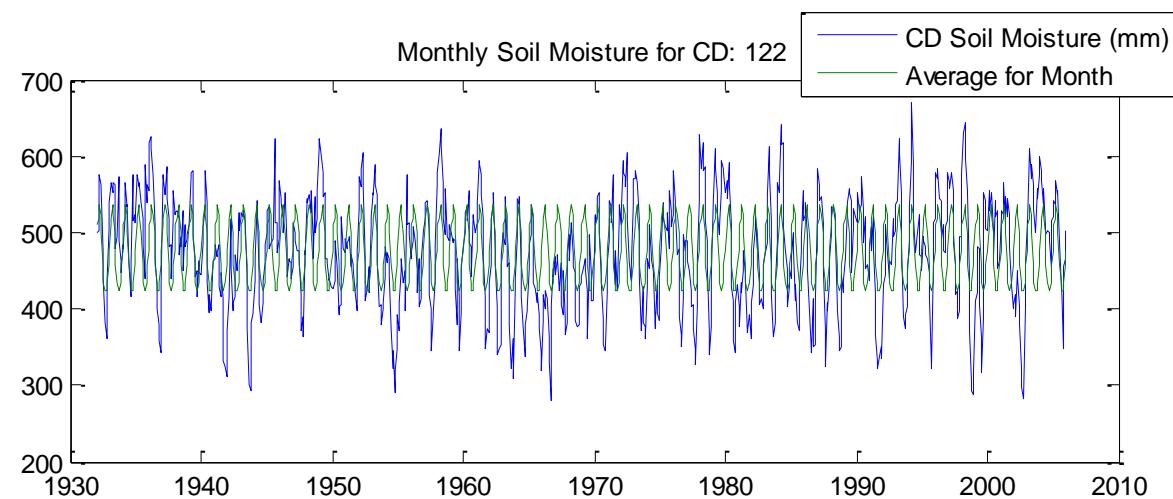


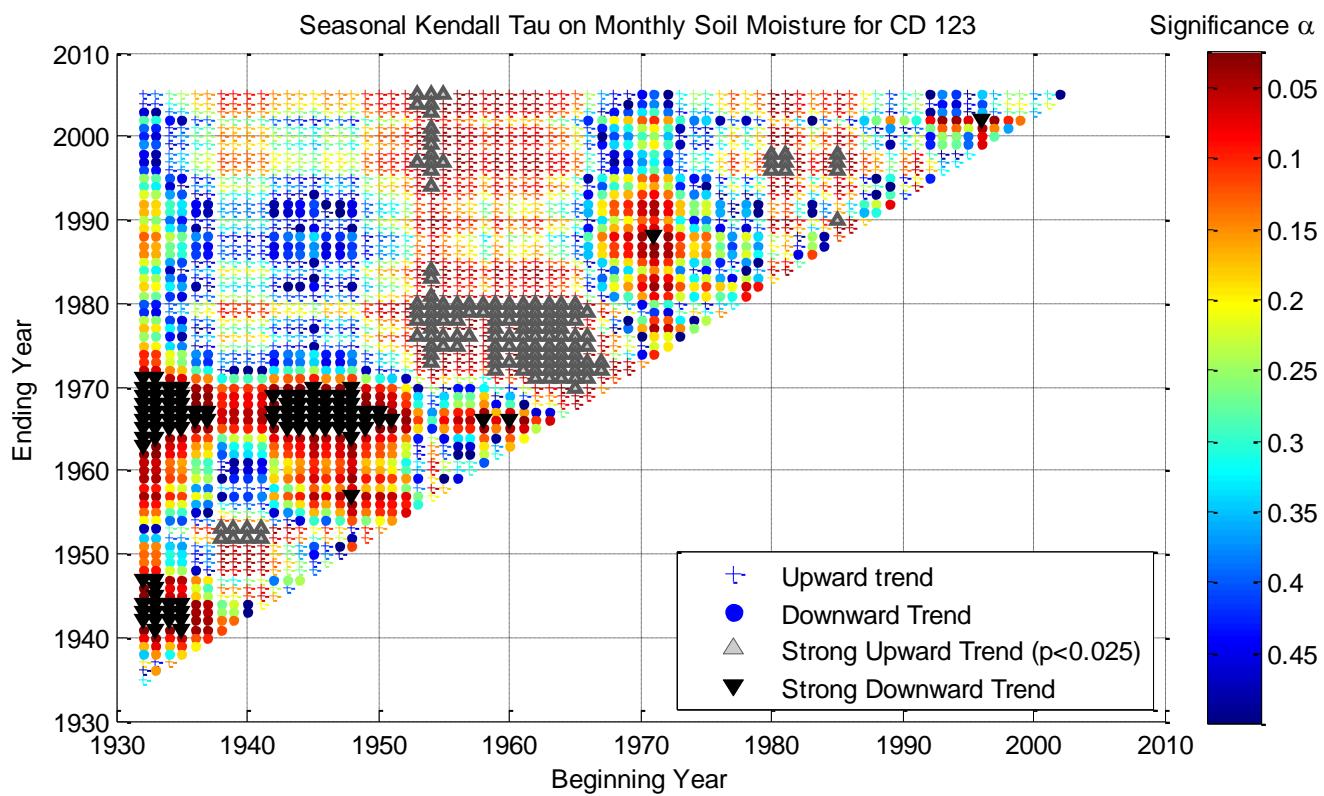
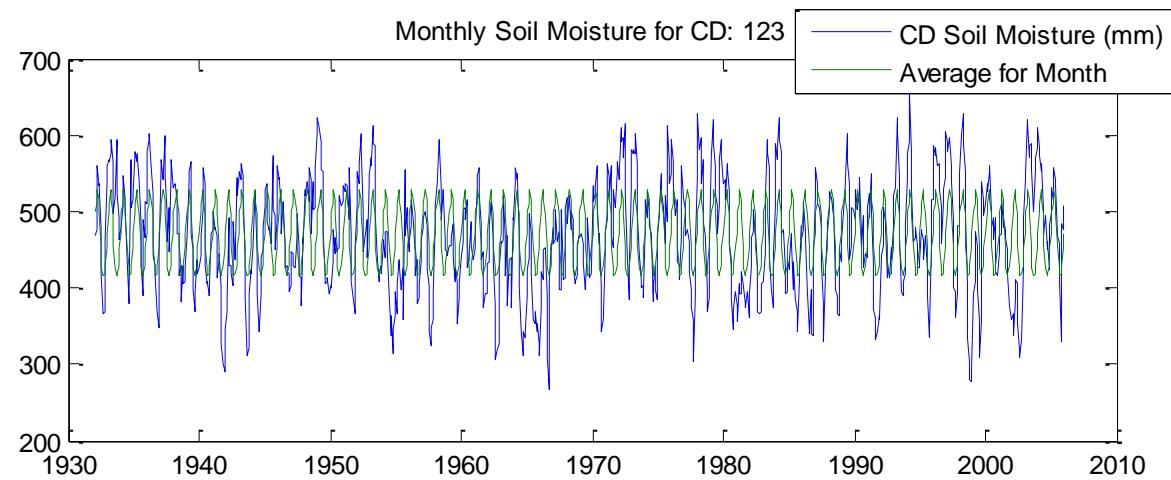
Figure 5 – Shows the same “Difference Surface” as Figure 4, but with the same symbol and Z scores being represented by the color gradient

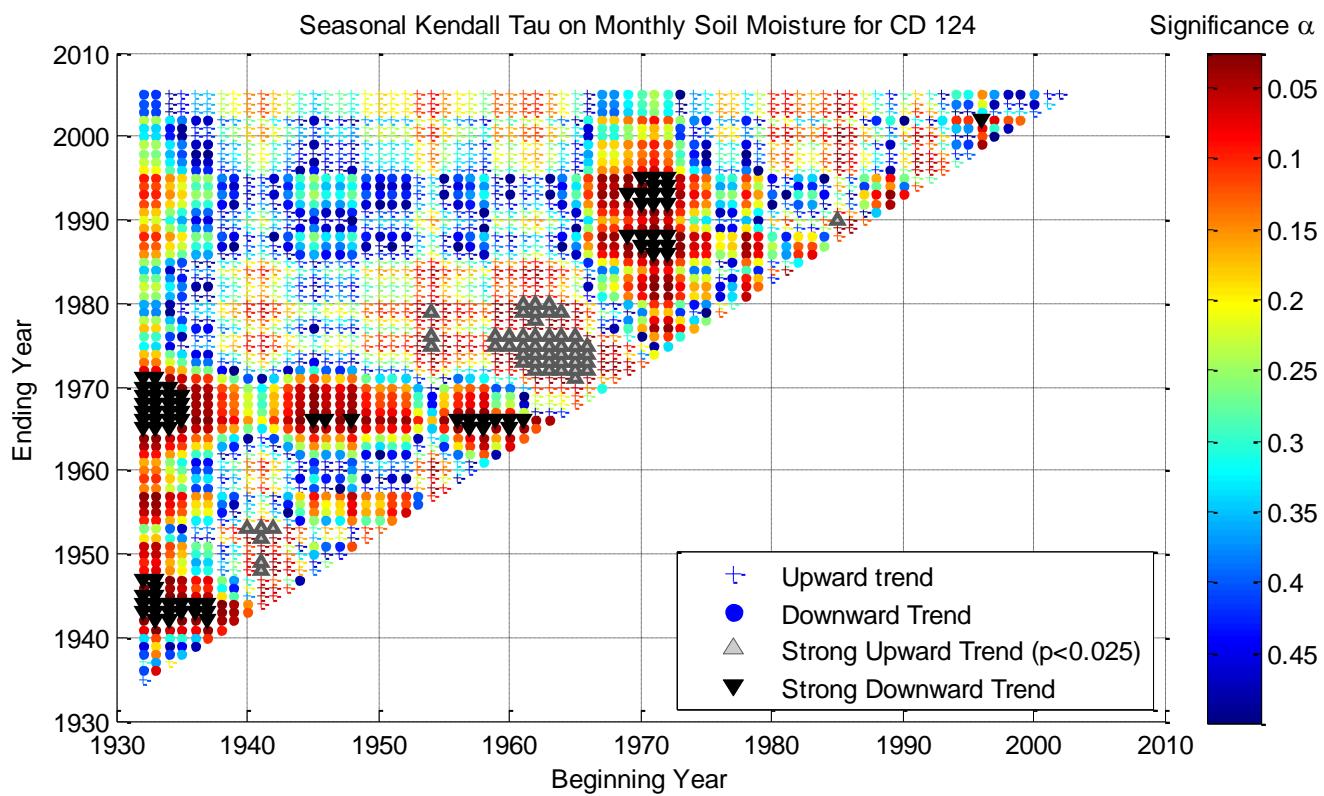
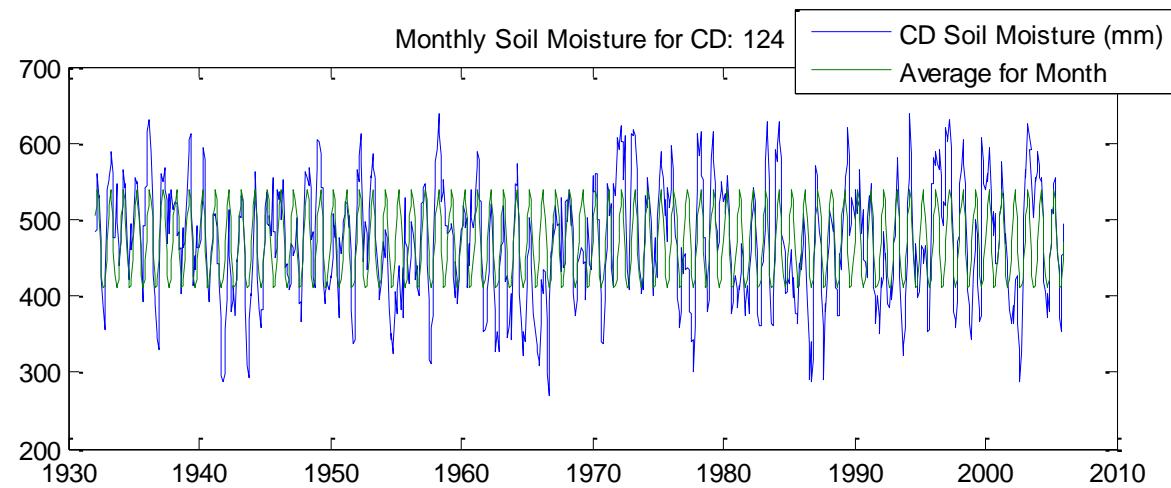
Additional Figures below for the Soil Moisture and associated trends of the other climate divisions used in this research:

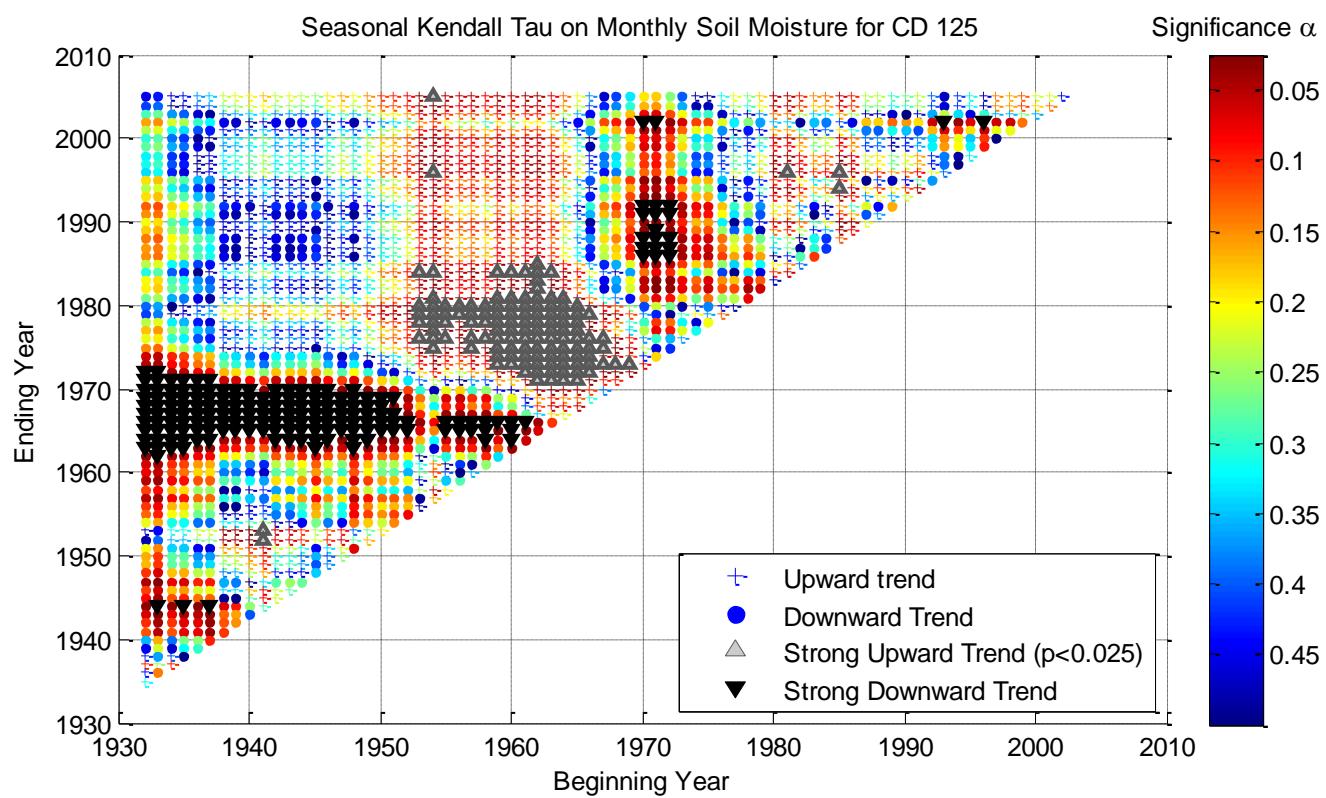
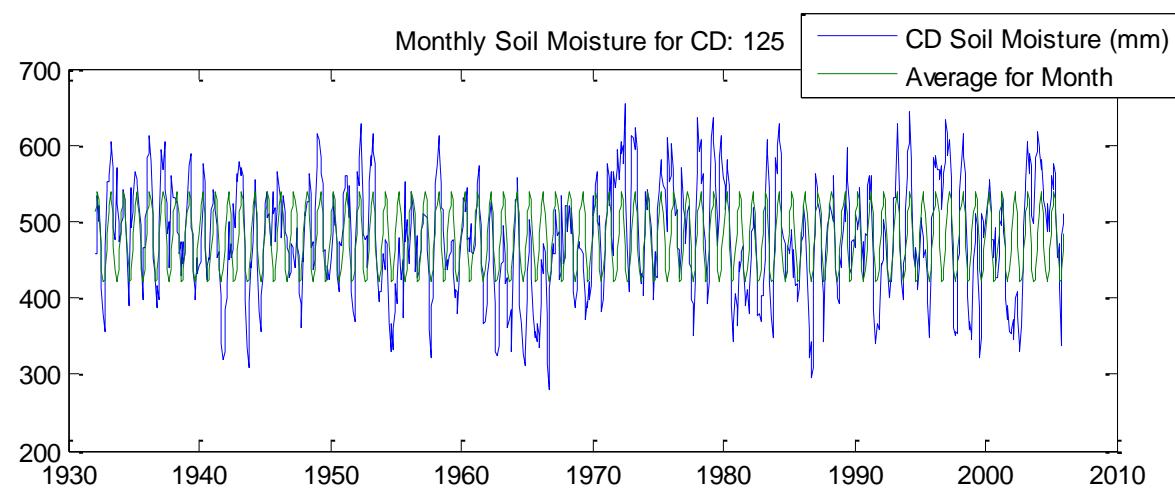


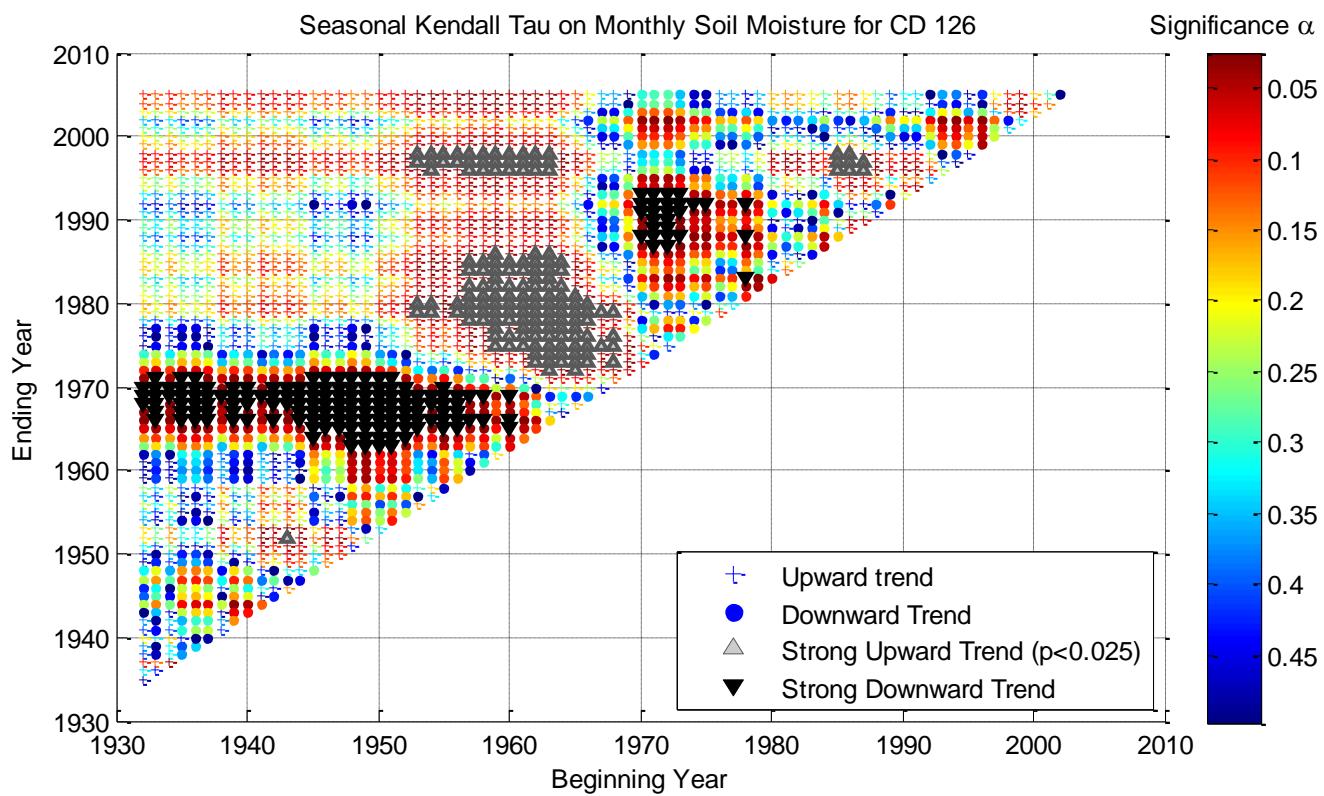
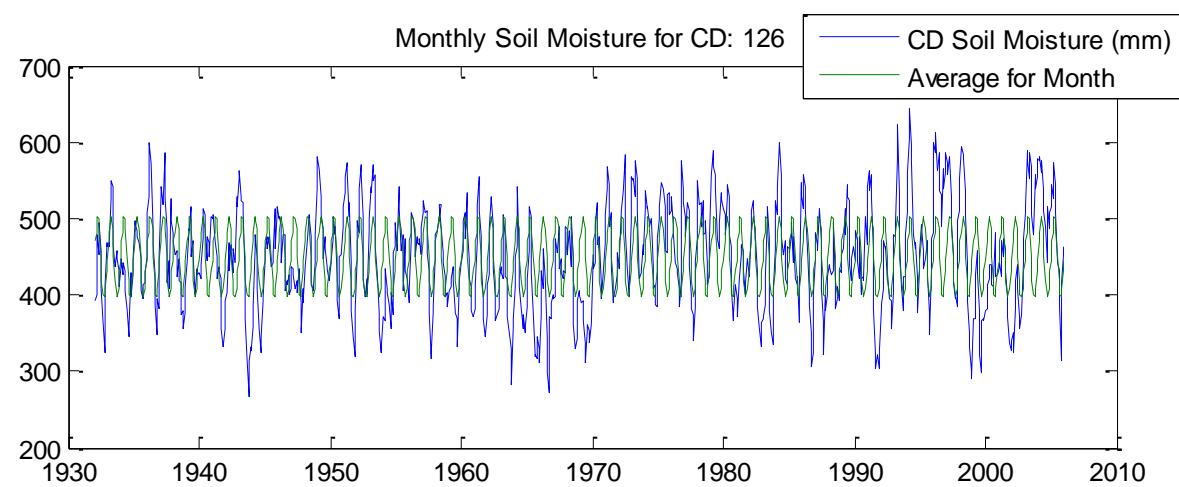


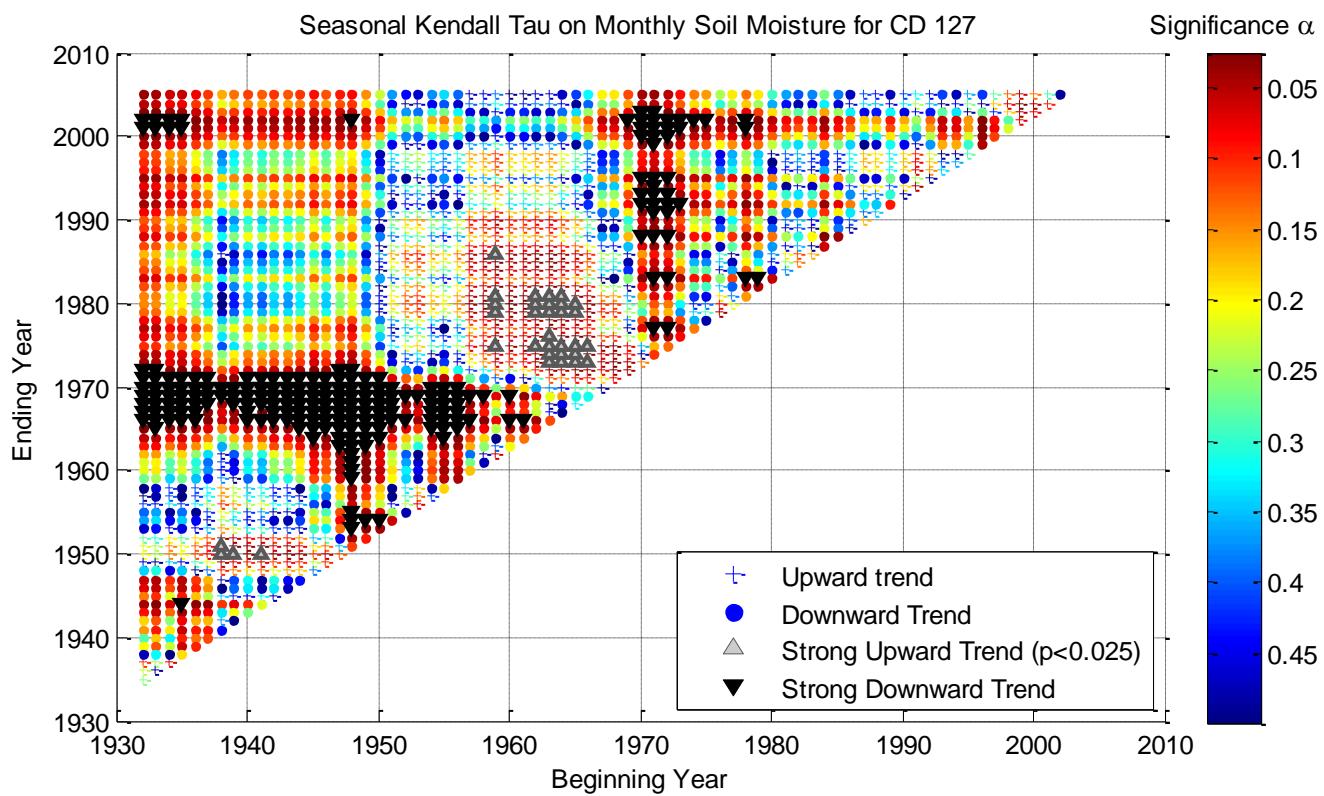
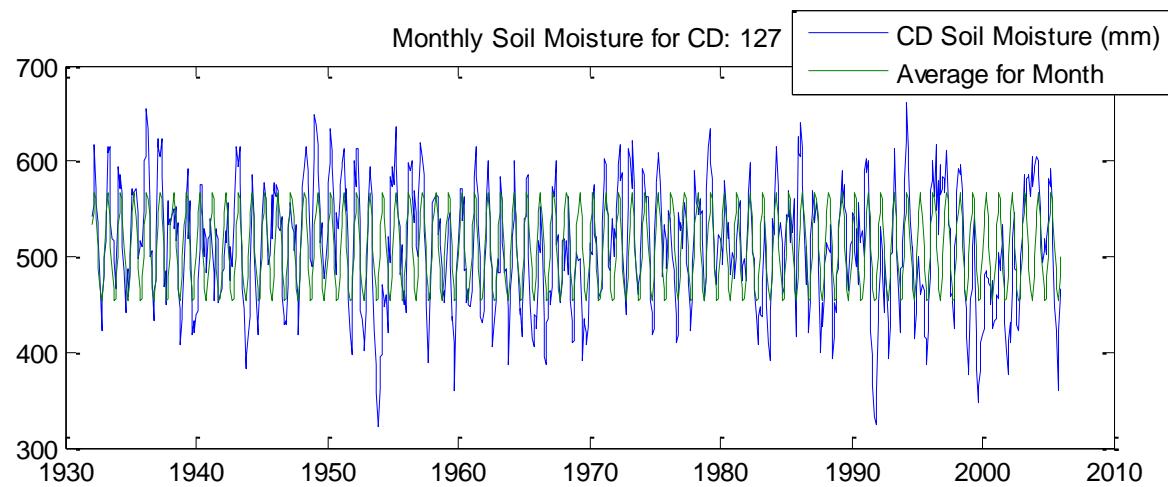


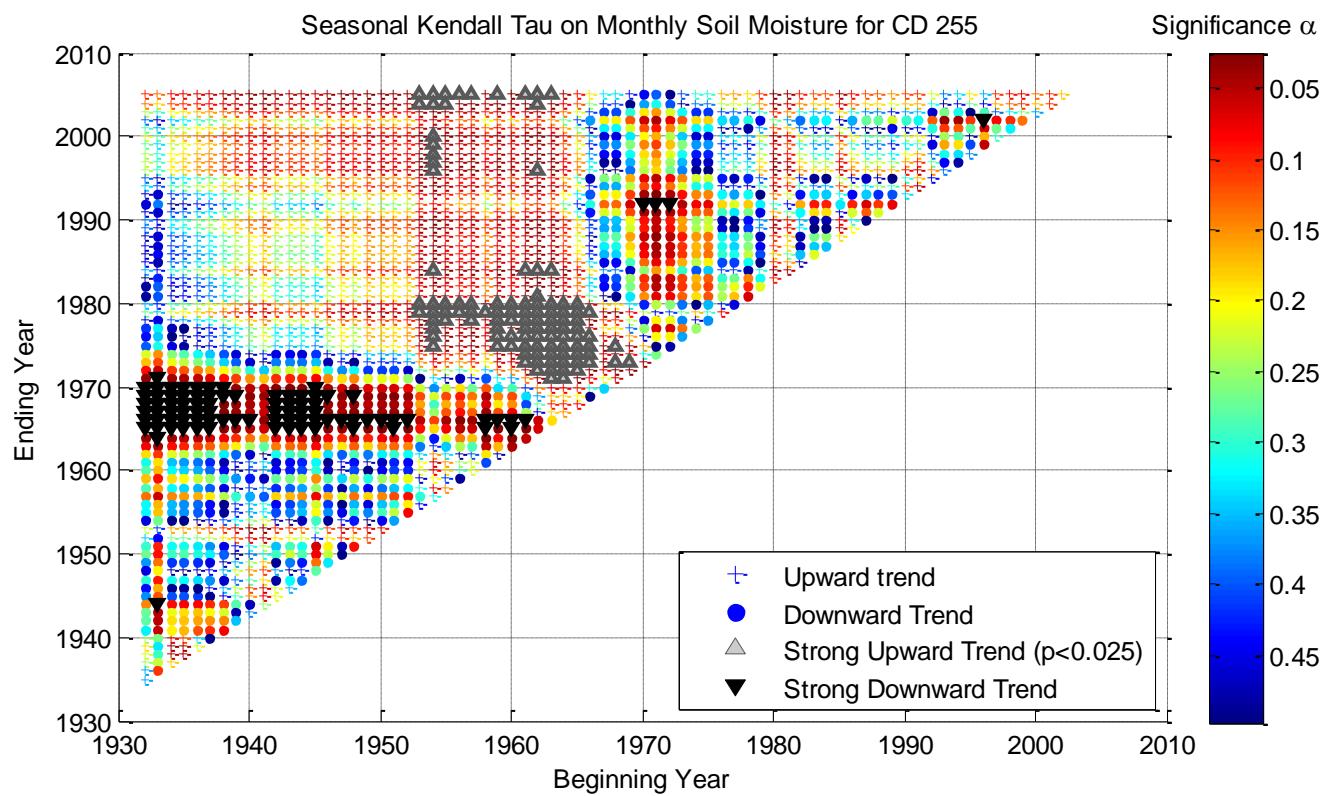
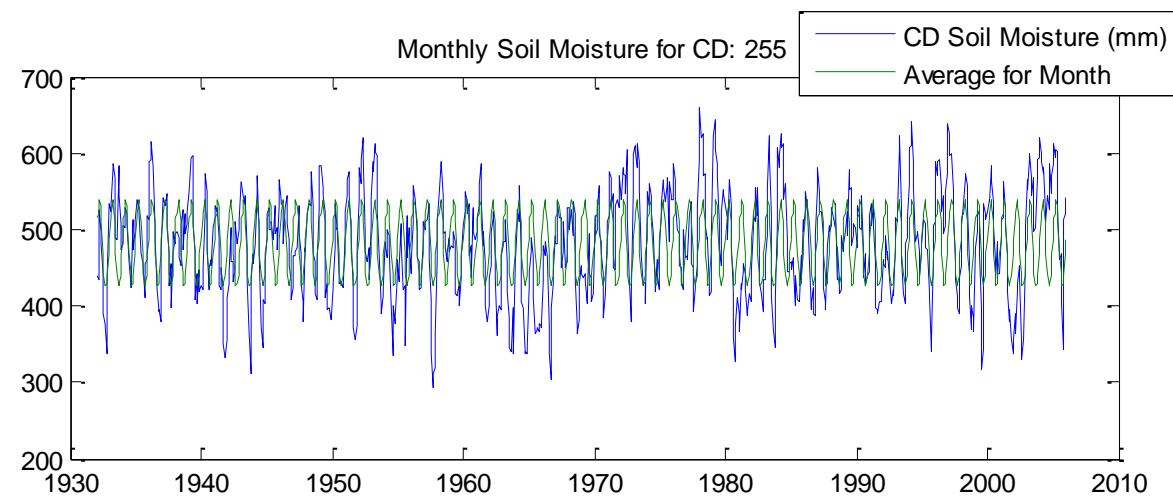


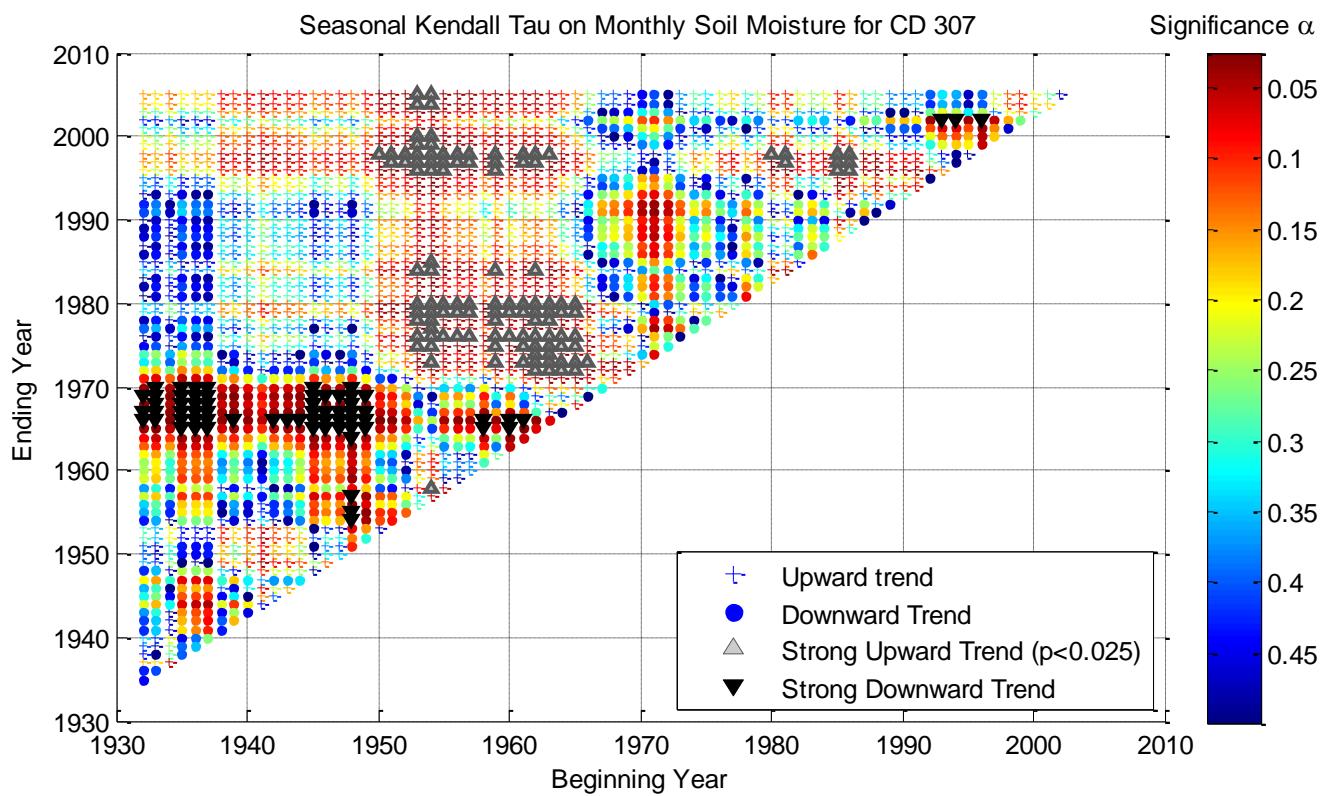
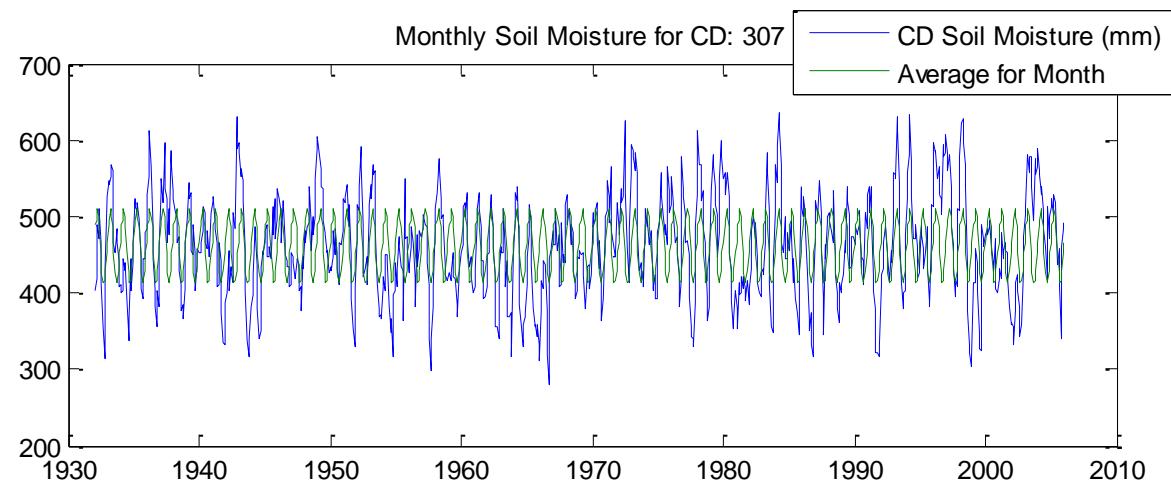












Huang, J., H. M. van den Dool & K. P. Georgarakos (1996) Analysis of Model-Calculated Soil Moisture over the United States (1931-1993) and Applications to Long-Range Temperature Forecasts. *Journal of Climate*, 9, 1350-1362.