Supplementary material for: "Exploring hydrological similarity during soil moisture recession periods using time dependent variograms" by

Mälicke et al.

July 23, 2018

1 Introduction

The publication "Exploring hydrological similarity during soil moisture recession periods using time dependent variograms" by Mälicke et al. presents a novel approach of coupling time dependent variograms with density based clustering. The presented method has been tested on more periods and an additional study site.

2 STU plot

The STU plot was introduced and described in detail in the main work. This supplements section collects the main result figures for the 2015 and 2016 drying period.

2.1 Summer 2015

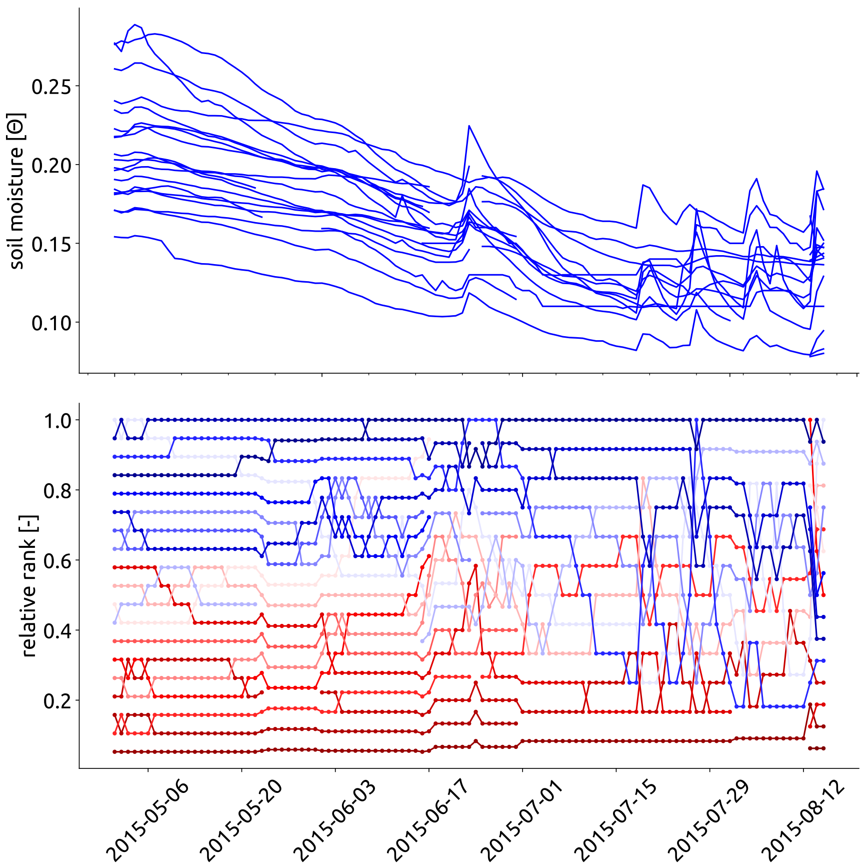

Figure 1: *Top:* Daily soil moisture observations from the 30 cm sensors used from **2015** at the **STU plot**. *Bottom:* The same data as in the top panel transformed to relative ranks. The $y = 1.0$ line marks the highest observation for each day, while the smallest observation is plotted to the $y = 0.0$ line. The color of each line indicates the mean rank over the whole period, with the most saturated blue line holding the highest mean and the most saturated red line holding the smallest mean rank.

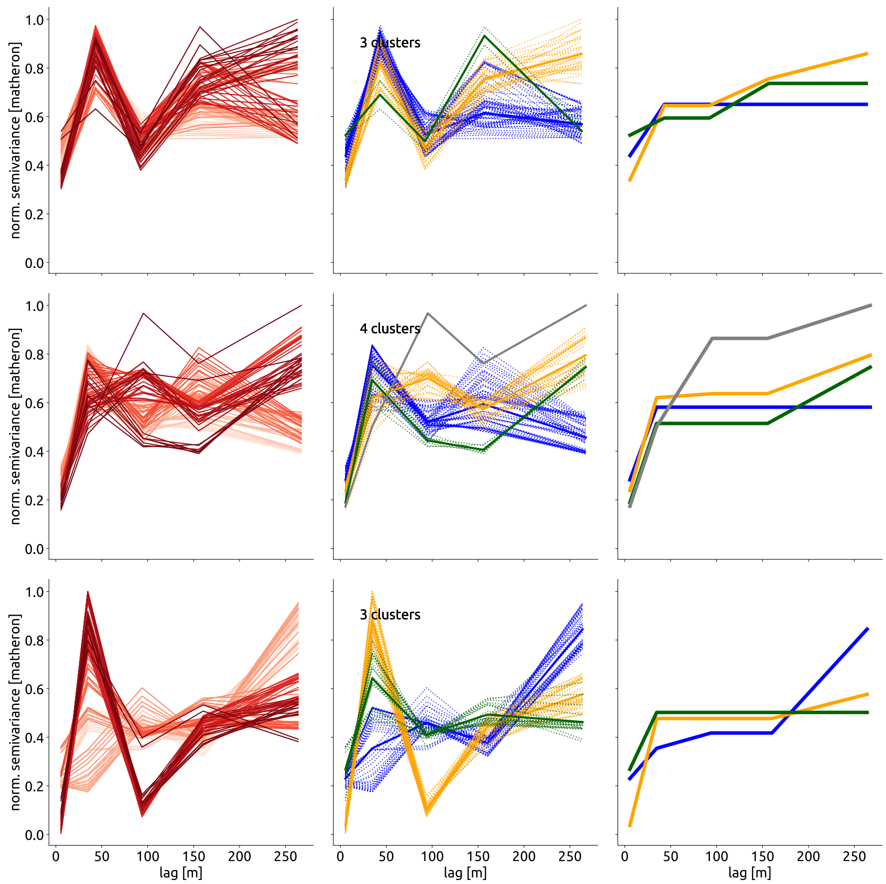

Figure 2: *Rows:* The rows represent the depth of the respective sensors with the first line being installed at 10 cm, the middle row at 30 cm and the bottom row at 50 cm depth. *Left:* The left panel shows all experimental variograms resulting from a moving window over the drying period in **2015** at the **STU plot**. The color indicates the window shift of that variogram with darker variograms occurring later in the period. The semivariance values on the y-axis have been normalized to the maximum value within each ensemble (row). *Middle:* The middle panel shows the same variograms from the left panel as dashed lines. Here, the color indicates the clusters yielded by the Mean Shift algorithm. Solid lines represent the cluster centroid variograms. *Right:* The same cluster centroids already presented in the middle are shown in the right panel. These cluster centroids have been monotonized and are thus monotonously ascending.

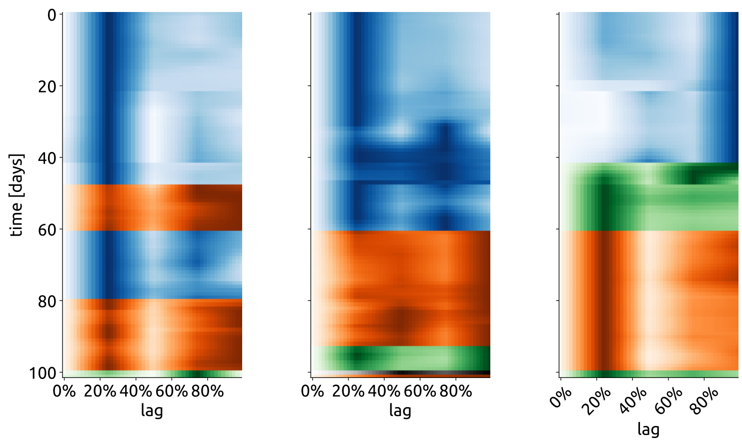

Figure 3: The columns represent the **2015** results from 10 cm (left), 30 cm (middle) and 50 cm (right) at the **STU plot**. The moving window variograms are shown with the separating distance lags normalized to the maximum search distance of 240 m on the x-axis. The y-axis indicates the window position and therefore the temporal dimension. The saturation of each pixel represents the semivariance at the given lag normalized to the maximum semivariance of the same variogram. The pixel color indicates the cluster the variogram has been grouped into. Pixels between the calculated lag classes have been interpolated by linear interpolation between the two neighboring lag classes, for visual reasons.

2.2 Summer 2016

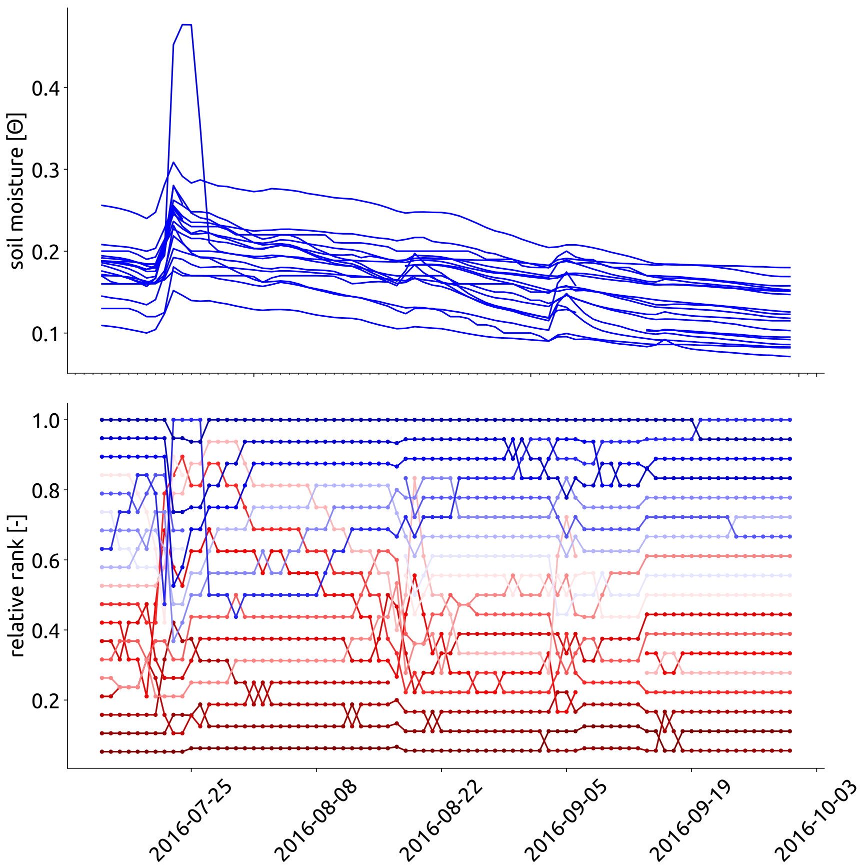

Figure 4: *Top:* Daily soil moisture observations from the 30 cm sensors used from **2016** at the **STU plot**. *Bottom:* The same data as in the top panel transformed to relative ranks. The $y = 1.0$ line marks the highest observation for each day, while the smallest observation is plotted to the $y = 0.0$ line. The color of each line indicates the mean rank over the whole period, with the most saturated blue line holding the highest mean and the most saturated red line holding the smallest mean rank.

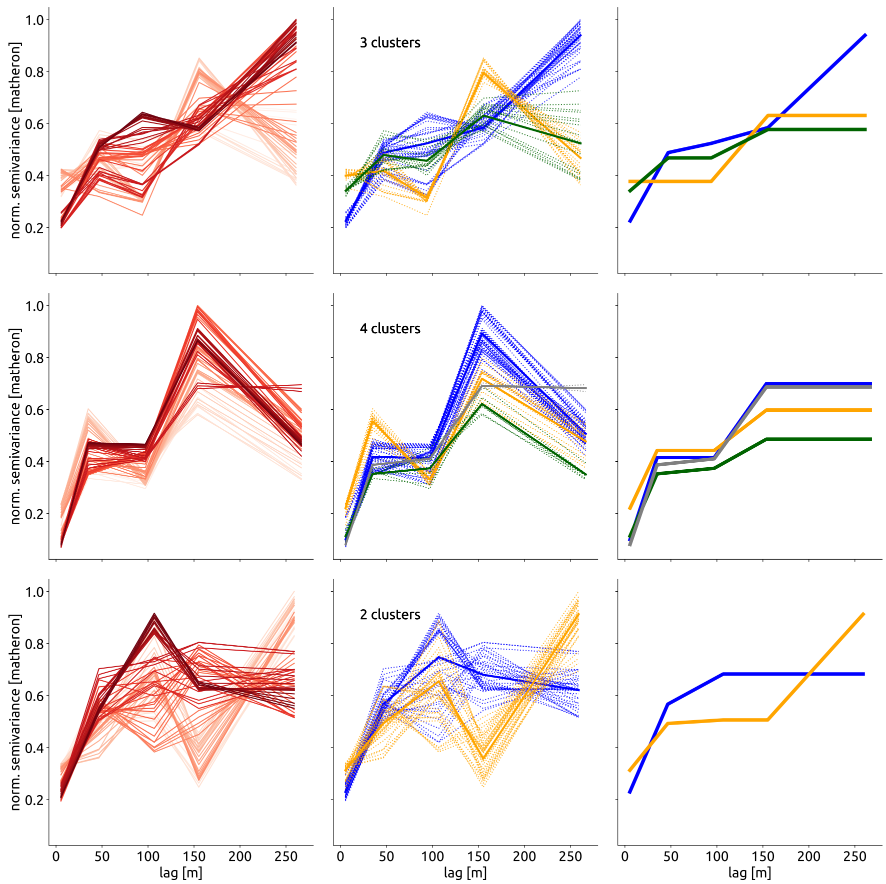

Figure 5: *Rows:* The rows represent the depth of the respective sensors with the first line being installed at 10 cm, the middle row at 30 cm and the bottom row at 50 cm depth. *Left:* The left panel shows all experimental variograms resulting from a moving window over the drying period in **2016** at the **STU plot**. The color indicates the window shift of that variogram with darker variograms occurring later in the period. The semivariance values on the y-axis have been normalized to the maximum value within each ensemble (row). *Middle:* The middle panel shows the same variograms from the left panel as dashed lines. Here, the color indicates the clusters yielded by the Mean Shift algorithm. Solid lines represent the cluster centroid variograms. *Right:* The same cluster centroids already presented in the middle are shown in the right panel. These cluster centroids have been monotonized and are thus monotonously ascending.

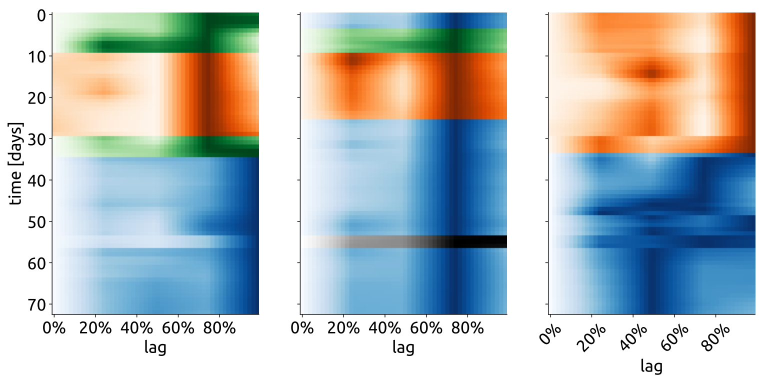

Figure 6: The columns represent the **2016** results from 10 cm (left), 30 cm (middle) and 50 cm (right) at the **STU plot**. The moving window variograms are shown with the separating distance lags normalized to the maximum search distance of 240 m on the x-axis. The y-axis indicates the window position and therefore the temporal dimension. The saturation of each pixel represents the semivariance at the given lag normalized to the maximum semivariance of the same variogram. The pixel color indicates the cluster the variogram has been grouped into. Pixels between the calculated lag classes have been interpolated by linear interpolation between the two neighboring lag classes, for visual reasons.

3 ABC plot

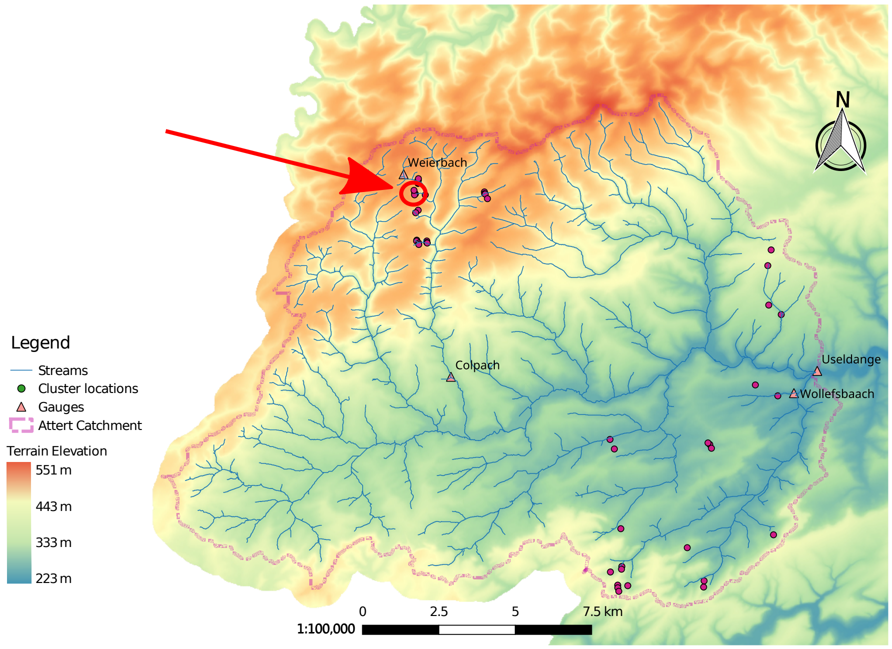

Figure 7: The Attert catchment in Western Luxembourg and partly Belgium. The purple points indicate the locations of the 45 sampling clusters. The underlying image is the terrain height. The red circle identifies the alternatice subsample **ABC plot**, used for this section.

The ABC plot is an alternative subsample of the CAOS data set introduced in the main work. It suffers more sensor failures and, especially for the deeper layers, had not enough sensors working in the 2016 period to produce stressable results. The red circle in on the map in figure7 identifies the ABC plot. This supplements section collects the main result figures for the 2013, 2015 and 2016 drying period.

3.1 Summer 2013

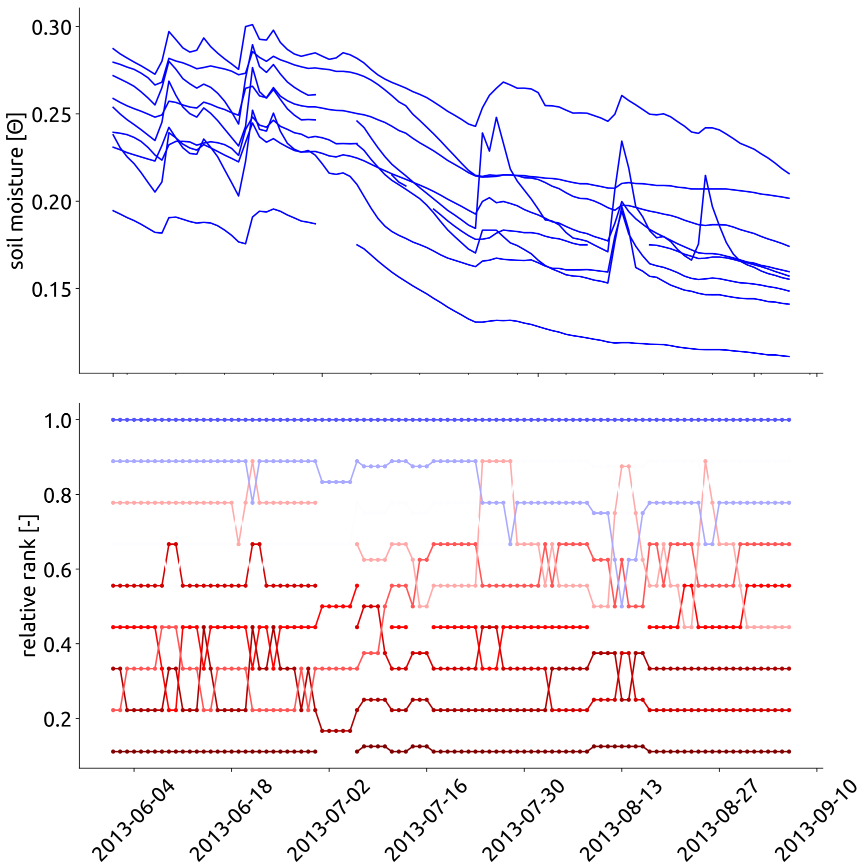

Figure 8: *Top:* Daily soil moisture observations from the 30 cm sensors used from **2013** at the **ABC plot**. *Bottom:* The same data as in the top panel transformed to relative ranks. The $y = 1.0$ line marks the highest observation for each day, while the smallest observation is plotted to the $y = 0.0$ line. The color of each line indicates the mean rank over the whole period, with the most saturated blue line holding the highest mean and the most saturated red line holding the smallest mean rank.

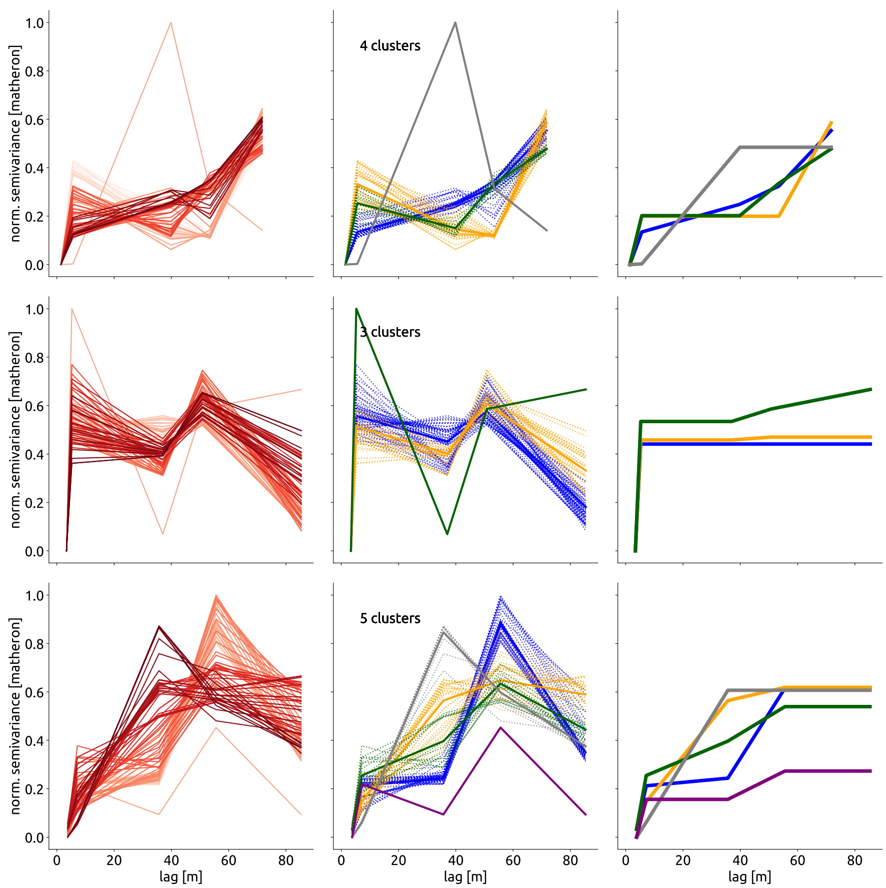

Figure 9: *Rows:* The rows represent the depth of the respective sensors with the first line being installed at 10 cm, the middle row at 30 cm and the bottom row at 50 cm depth. *Left:* The left panel shows all experimental variograms resulting from a moving window over the drying period in **2013** at the **ABC plot**. The color indicates the window shift of that variogram with darker variograms occurring later in the period. The semivariance values on the y-axis have been normalized to the maximum value within each ensemble (row). *Middle:* The middle panel shows the same variograms from the left panel as dashed lines. Here, the color indicates the clusters yielded by the Mean Shift algorithm. Solid lines represent the cluster centroid variograms. *Right:* The same cluster centroids already presented in the middle are shown in the right panel. These cluster centroids have been monotonized and are thus monotonously ascending.

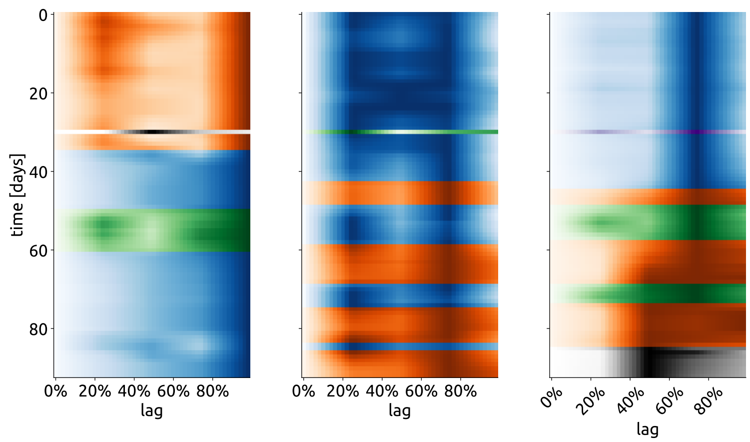

Figure 10: The columns represent the **2013** results from 10 cm (left), 30 cm (middle) and 50 cm (right) at the **ABC plot**. The moving window variograms are shown with the separating distance lags normalized to the maximum search distance of 240 m on the x-axis. The y-axis indicates the window position and therefore the temporal dimension. The saturation of each pixel represents the semivariance at the given lag normalized to the maximum semivariance of the same variogram. The pixel color indicates the cluster the variogram has been grouped into. Pixels between the calculated lag classes have been interpolated by linear interpolation between the two neighboring lag classes, for visual reasons.

3.2 Summer 2015

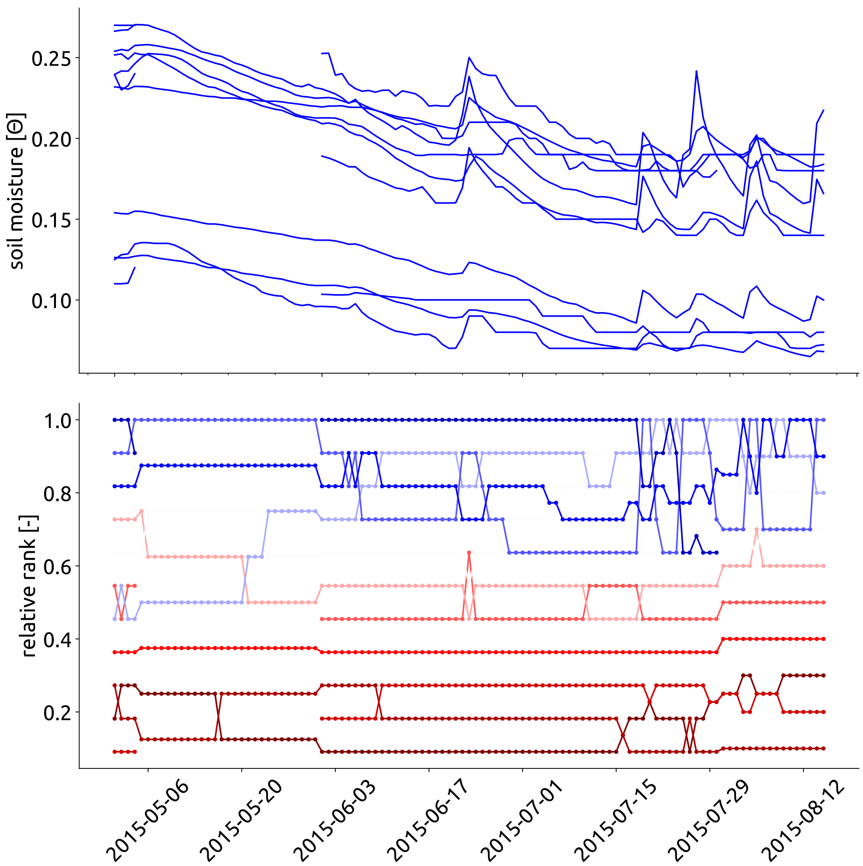

Figure 11: *Top:* Daily soil moisture observations from the 30 cm sensors used from **2015** at the **ABC plot**. *Bottom:* The same data as in the top panel transformed to relative ranks. The $y = 1.0$ line marks the highest observation for each day, while the smallest observation is plotted to the $y = 0.0$ line. The color of each line indicates the mean rank over the whole period, with the most saturated blue line holding the highest mean and the most saturated red line holding the smallest mean rank.

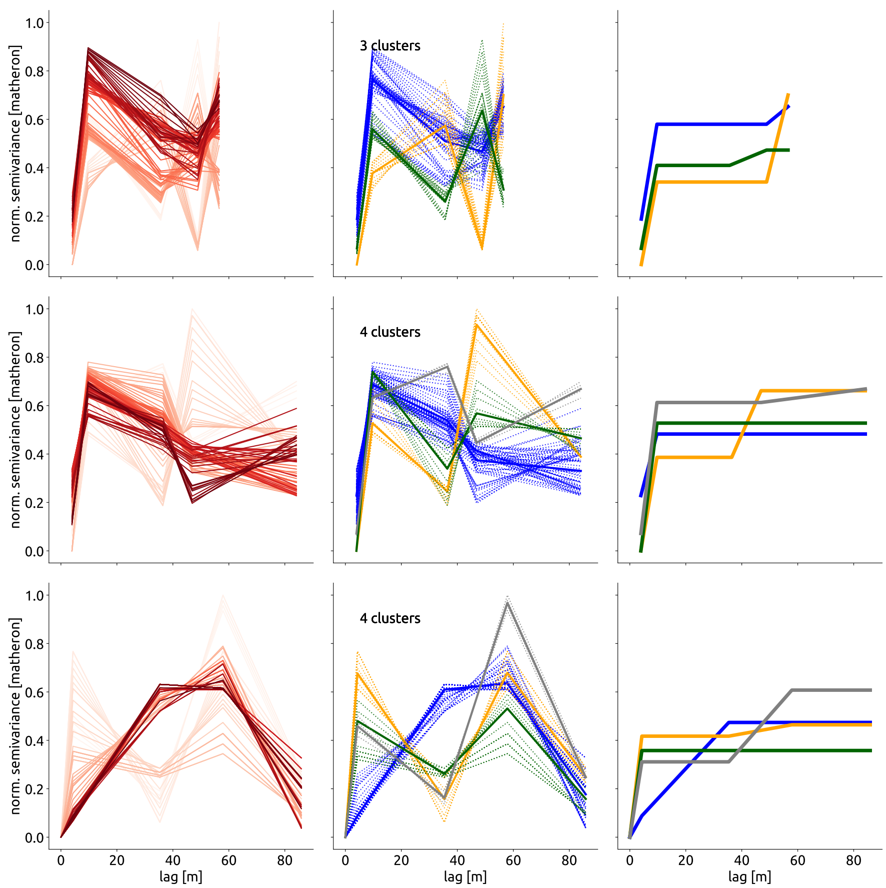

Figure 12: *Rows:* The rows represent the depth of the respective sensors with the first line being installed at 10 cm, the middle row at 30 cm and the bottom row at 50 cm depth. *Left:* The left panel shows all experimental variograms resulting from a moving window over the drying period in **2015** at the **ABC plot**. The color indicates the window shift of that variogram with darker variograms occurring later in the period. The semivariance values on the y-axis have been normalized to the maximum value within each ensemble (row). *Middle:* The middle panel shows the same variograms from the left panel as dashed lines. Here, the color indicates the clusters yielded by the Mean Shift algorithm. Solid lines represent the cluster centroid variograms. *Right:* The same cluster centroids already presented in the middle are shown in the right panel. These cluster centroids have been monotonized and are thus monotonously ascending.

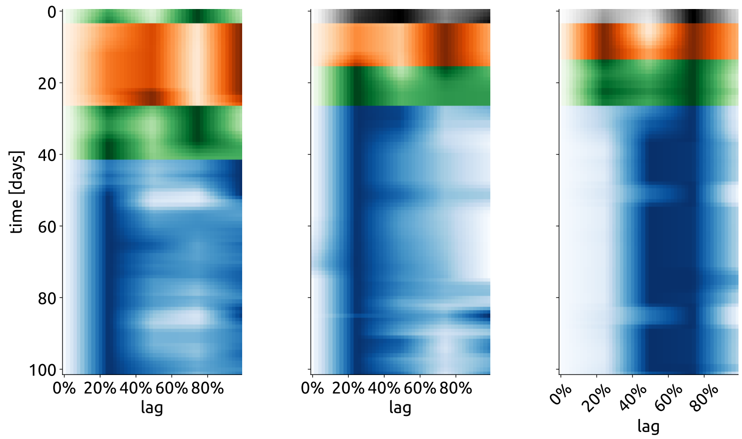

Figure 13: The columns represent the **2015** results from 10 cm (left), 30 cm (middle) and 50 cm (right) at the **ABC plot**. The moving window variograms are shown with the separating distance lags normalized to the maximum search distance of 240 m on the x-axis. The y-axis indicates the window position and therefore the temporal dimension. The saturation of each pixel represents the semivariance at the given lag normalized to the maximum semivariance of the same variogram. The pixel color indicates the cluster the variogram has been grouped into. Pixels between the calculated lag classes have been interpolated by linear interpolation between the two neighboring lag classes, for visual reasons.

3.3 Summer 2016

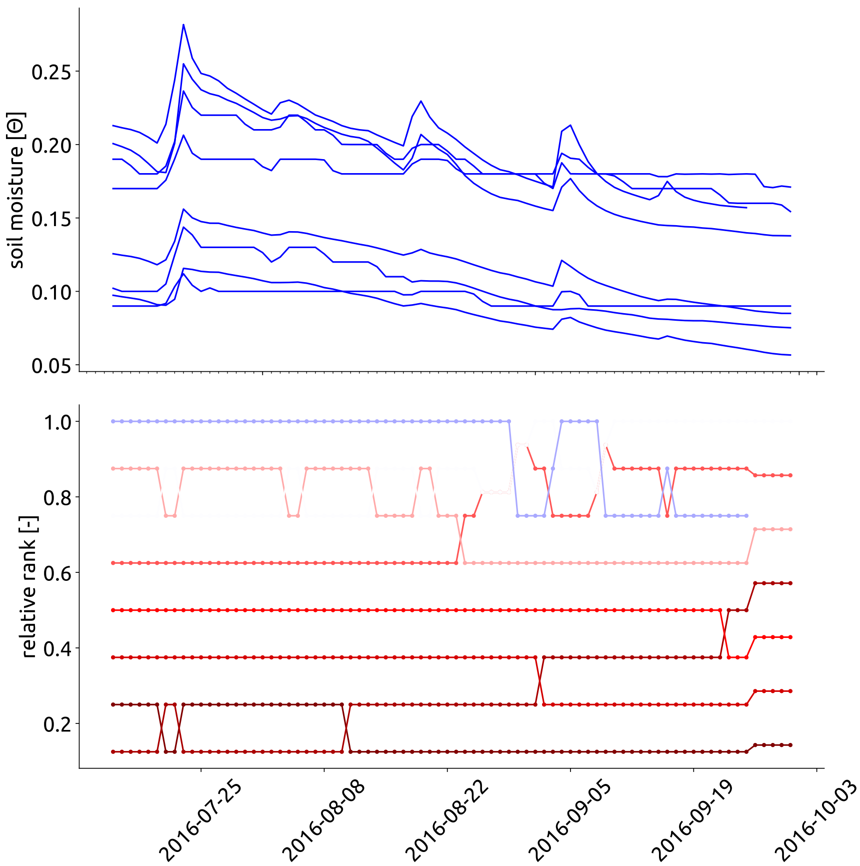

Figure 14: *Top:* Daily soil moisture observations from the 30 cm sensors used from **2016** at the **ABC plot**. *Bottom:* The same data as in the top panel transformed to relative ranks. The $y = 1.0$ line marks the highest observation for each day, while the smallest observation is plotted to the $y = 0.0$ line. The color of each line indicates the mean rank over the whole period, with the most saturated blue line holding the highest mean and the most saturated red line holding the smallest mean rank.

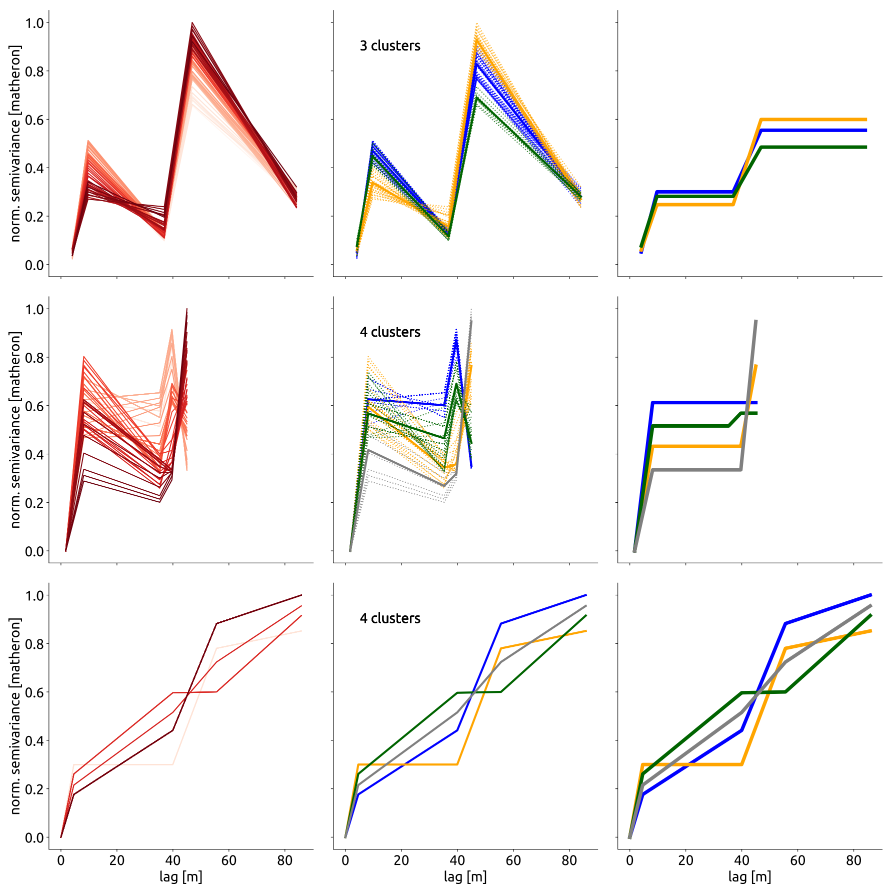

Figure 15: *Rows:* The rows represent the depth of the respective sensors with the first line being installed at 10 cm, the middle row at 30 cm and the bottom row at 50 cm depth. *Left:* The left panel shows all experimental variograms resulting from a moving window over the drying period in **2016** at the **ABC plot**. The color indicates the window shift of that variogram with darker variograms occurring later in the period. The semivariance values on the y-axis have been normalized to the maximum value within each ensemble (row). *Middle:* The middle panel shows the same variograms from the left panel as dashed lines. Here, the color indicates the clusters yielded by the Mean Shift algorithm. Solid lines represent the cluster centroid variograms. *Right:* The same cluster centroids already presented in the middle are shown in the right panel. These cluster centroids have been monotonized and are thus monotonously ascending.

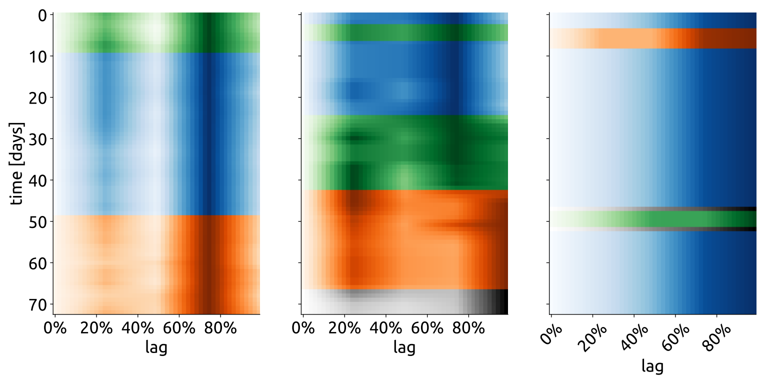

Figure 16: The columns represent the **2016** results from 10 cm (left), 30 cm (middle) and 50 cm (right) at the **ABC plot**. The moving window variograms are shown with the separating distance lags normalized to the maximum search distance of 240 m on the x-axis. The y-axis indicates the window position and therefore the temporal dimension. The saturation of each pixel represents the semivariance at the given lag normalized to the maximum semivariance of the same variogram. The pixel color indicates the cluster the variogram has been grouped into. Pixels between the calculated lag classes have been interpolated by linear interpolation between the two neighboring lag classes, for visual reasons.