

# SWNM

February 18, 2021

## 0.1 Geothermal machine learning analysis: Southwest New Mexico

This notebook is a part of the GTcloud.jl: GeoThermal Cloud for Machine Learning.



More information how the ML results are interpreted to provide geothermal insights is discussed in our research paper.

## 0.2 Import required libraries for this work

If **NMFk** is not installed, first execute in the Julia REPL `import Pkg; Pkg.add("NMFk"); Pkg.add("DelimitedFiles"); Pkg.add("JLD"); Pkg.add("Gadfly"); Pkg.add("Cairo"); Pkg.add("Fontconfig"); Pkg.add("Mads")`.

```
[1]: import NMFk
      import DelimitedFiles
      import JLD
      import Gadfly
      import Cairo
      import Fontconfig
      import Mads
```

## 0.3 Load and pre-process the data

### 0.3.1 Setup the working directory containing the SWNM data

```
[2]: cd("/Users/vvv/Julia/GTcloud-SmartTensors.jl/SWNM");
```

### 0.3.2 Load the data file

```
[3]: d, h = DelimitedFiles.readdlm("data/Pepin_PCA_Input_Data_LANL.csv", ',', ;  
    ↴header=true);
```

### 0.3.3 Define names of the data attributes (matrix columns)

```
[4]: attributes_short = ["Boron"; "Gravity"; "Magnetic"; "Dikes"; "Drainage";  
    ↴"FaultInter"; "QuatFaults"; "Seismicity"; "NMFaults"; "Springs"; "Vents";  
    ↴"Lithium"; "Precip"; "Air_Temp"; "Silica"; "Subcrop"; "WT_Gradient";  
    ↴"WT_Elev"; "Heatflow"; "GS_Elev"; "DTW"; "Crst_Thick"; "Bsmt_Depth"]  
attributes_long = uppercasefirst.(lowercase.([ "Boron Concentration"; "Gravity"  
    ↴"Anomaly"; "Magnetic Intensity"; "Volcanic Dike Density"; "Drainage Density";  
    ↴"Fault Intersection Density"; "Quaternary Fault Density"; "Seismicity";  
    ↴"State Map Fault Density"; "Spring Density"; "Volcanic Vent Density";  
    ↴"Lithium Concentration"; "Precipitation"; "Air Temperature"; "Silica"  
    ↴"Geothermometer"; "Subcrop Permeability"; "Hydraulic Gradient"; "Watertable"  
    ↴"Elevation"; "Heat flow"; "Groundsurface Elevation"; "Watertable Depth";  
    ↴"Crustal Thickness"; "Depth to Basement"]))  
attributes_long_new = uppercasefirst.(lowercase.([ "Boron"; "Gravity anomaly";  
    ↴"Magnetic intensity"; "Volcanic dike density"; "Drainage density"; "Fault"  
    ↴intersection density"; "Quaternary fault density"; "Seismicity"; "State map"  
    ↴fault density"; "Spring density"; "Volcanic vent density"; "Lithium";  
    ↴"Precipitation"; "Air temperature"; "Silica geothermometer"; "Subcrop"  
    ↴permeability"; "Hydraulic gradient"; "Watertable elevation"; "Heat flow";  
    ↴"Groundsurface elevation"; "Watertable depth"; "Crustal thickness"; "Depth"  
    ↴to basement"]))  
attributes_ordered = ["Boron concentration", "Lithium concentration", "Drainage"  
    ↴density", "Spring density", "Hydraulic gradient", "Precipitation", "Gravity"  
    ↴anomaly", "Magnetic intensity", "Seismicity", "Silica geothermometer", "Heat"  
    ↴flow", "Crustal thickness", "Depth to basement", "Fault intersection"  
    ↴density", "Quaternary fault density", "State map fault density", "Volcanic"  
    ↴dike density", "Volcanic vent density"];
```

Short attribute names are used for coding.

Long attribute names are used for plotting and visualization.

### 0.3.4 Define attributes to remove from analysis

```
[5]: attributes_remove = uppercasefirst.(lowercase.([ "Air Temperature"; "Subcrop"  
    ↴Permeability"; "Watertable Elevation"; "Groundsurface Elevation";  
    ↴"Watertable Depth"]));
```

### 0.3.5 Define attributes for analysis

```
[6]: index_remove = indexin(attributes_remove, attributes_long)
attributes_cols = trues(length(attributes_long))
attributes_cols[index_remove] .= false
cols = vec(4:26)[attributes_cols]
attributes = attributes_long[cols .- 3];
```

### 0.3.6 Define names of the data locations

```
[7]: locations_short = ["Alamos spr";
"Allen spr";
"Apache well";
"Aragon spr";
"Ash spr";
"B.Iorio well";
"Cliff spr";
"Dent well";
"Derry spr";
"Faywood spr";
"Fed H1 well";
"Freiborn spr";
"Garton well";
"Gila spr 1";
"Gila spr 2";
"Goat spr";
"Jerry well";
"Kennecott well";
"Laguna Pbl";
"Lightning Dock";
"Los Alturas";
"Mangas spr";
"Mimbres spr";
"Ojitos spr";
"Ojo Caliente";
"Ojo Canas";
"Pueblo well";
"Radium spr";
"Rainbow spr";
"Riverside well";
"Sacred spr";
"Socorro Can";
"Spring";
"Spring Can";
"T or C spr";
"Turkey spr";
"Victoria well";
"Warm spr";
```

```
"Well 1";
"Well 2";
"Well 3";
"Well 4";
"Well 5";
"Carne well"]
```

```
locations_long = ["Alamos Spring";
"Allen Springs";
"Apache Tejo Warm Springs well";
"Aragon Springs";
"Ash Spring";
"B. Iorio 1 well";
"Cliff Warm Spring";
"Dent windmill well";
"Derry Warm Springs";
"Faywood Hot Springs";
"Federal H 1 well";
"Freiborn Canyon Spring";
"Garton well";
"Gila Hot Springs 1";
"Gila Hot Springs 2";
"Goat Camp Spring";
"Jerry well";
"Kennecott Warm Springs well";
"Laguna Pueblo";
"Lightning Dock";
"Los Alturas Estates";
"Mangas Springs";
"Mimbres Hot Springs";
"Ojitos Springs";
"Ojo Caliente";
"Ojo De las Canas";
"Pueblo windmill well";
"Radium Hot Springs";
"Rainbow Spring";
"Riverside Store well";
"Sacred Spring";
"Socorro Canyon";
"Spring";
"Spring Canyon Warm Spring";
"Truth or Consequences spring";
"Turkey Creek Spring";
"Victoria Land and Cattle Co. well";
"Warm Springs";
"Well 1";
"Well 2";
```

```
"Well 3";
"Well 4";
"Well 5";
"Well south of Carne"];
```

Short location names are used for coding.

Long location names are used for plotting and visualization.

### 0.3.7 Define location coordinates

```
[8]: dindex = d[:,end] .== 1
rows = convert.(Int32, d[dindex,end-1])
locations = locations_short[rows]
lat = d[dindex, 2]
lon = d[dindex, 3];
```

### 0.3.8 Set up directories tp store results and figures

```
[9]: figuredir = "figures-case01"
resultdir = "results-case01";
```

### 0.3.9 Define a range for number of signatures to be explored

```
[10]: nkrange = 2:10;
```

### 0.3.10 Define and normalize the data matrix

```
[11]: X = permutedims(d[dindex, cols])
Xu, nmin, nmax = NMFk.normalizematrix_row!(X);
```

## 0.4 Perform ML analyses

The **NMFk** algorithm factorizes the normalized data matrix  $X_u$  into  $W$  and  $H$  matrices. For more information, check out the [NMFk website](#)

```
[12]: W, H, fitquality, robustness, aic = NMFk.execute(Xu, nkrange, 1000;
    ↳ resultdir=resultdir, casefilename="nmfk", load=true)
W, H, fitquality, robustness, aic = NMFk.load(nkrange, 1000;
    ↳ resultdir=resultdir, casefilename="nmfk");
```

|          |        |                      |                  |           |
|----------|--------|----------------------|------------------|-----------|
| Signals: | 2 Fit: | 32.70151 Silhouette: | 1 AIC:           | -2276.215 |
| Signals: | 3 Fit: | 24.6022 Silhouette:  | 0.9999996 AIC:   | -2377.607 |
| Signals: | 4 Fit: | 18.46274 Silhouette: | 0.9999994 AIC:   | -2480.975 |
| Signals: | 5 Fit: | 14.74592 Silhouette: | 0.764538 AIC:    | -2535.007 |
| Signals: | 6 Fit: | 12.3538 Silhouette:  | -0.1423047 AIC:  | -2551.193 |
| Signals: | 7 Fit: | 10.29325 Silhouette: | -0.0733191 AIC:  | -2571.714 |
| Signals: | 8 Fit: | 8.237522 Silhouette: | 0.2518114 AIC:   | -2624.163 |
| Signals: | 9 Fit: | 7.607165 Silhouette: | -0.07981342 AIC: | -2563.213 |

```

Signals: 10 Fit:      6.023938 Silhouette:  0.02130362 AIC:   -2624.026
Signals:  2 Fit:      32.70151  Silhouette:    1 AIC:   -2276.215
Signals:  3 Fit:      24.6022   Silhouette:  0.9999996 AIC:   -2377.607
Signals:  4 Fit:      18.46274  Silhouette:  0.9999994 AIC:   -2480.975
Signals:  5 Fit:      14.74592  Silhouette:  0.764538 AIC:   -2535.007
Signals:  6 Fit:      12.3538   Silhouette: -0.1423047 AIC:   -2551.193
Signals:  7 Fit:      10.29325  Silhouette: -0.0733191 AIC:   -2571.714
Signals:  8 Fit:      8.237522  Silhouette:  0.2518114 AIC:   -2624.163
Signals:  9 Fit:      7.607165  Silhouette: -0.07981342 AIC:   -2563.213
Signals: 10 Fit:      6.023938  Silhouette:  0.02130362 AIC:   -2624.026

Info: Results
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkExecute.jl:15
Info: Optimal solution: 8 signals
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkExecute.jl:20
Signals:  2 Fit:      32.70151  Silhouette:    1 AIC:   -2276.215
Signals:  3 Fit:      24.6022   Silhouette:  0.9999996 AIC:   -2377.607
Signals:  4 Fit:      18.46274  Silhouette:  0.9999994 AIC:   -2480.975
Signals:  5 Fit:      14.74592  Silhouette:  0.764538 AIC:   -2535.007
Signals:  6 Fit:      12.3538   Silhouette: -0.1423047 AIC:   -2551.193
Signals:  7 Fit:      10.29325  Silhouette: -0.0733191 AIC:   -2571.714
Signals:  8 Fit:      8.237522  Silhouette:  0.2518114 AIC:   -2624.163
Signals:  9 Fit:      7.607165  Silhouette: -0.07981342 AIC:   -2563.213
Signals: 10 Fit:      6.023938  Silhouette:  0.02130362 AIC:   -2624.026

Info: Optimal solution: 8 signals
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkIO.jl:30

```

Here, the **NMFk** results are loaded from a prior ML runs.

As seen from the output above, the NMFk analyses identified that the optimal number of geothermal signatures in the dataset **8**.

Solutions with a number of signatures less than **8** are underfitting.

Solutions with a number of signatures greater than **8** are overfitting and unacceptable.

The set of acceptable solutions are defined as follows:

```
[13]: NMFk.getks(nkrange, robustness[nkrange])
```

```
[13]: 5-element Array{Int64,1}:
```

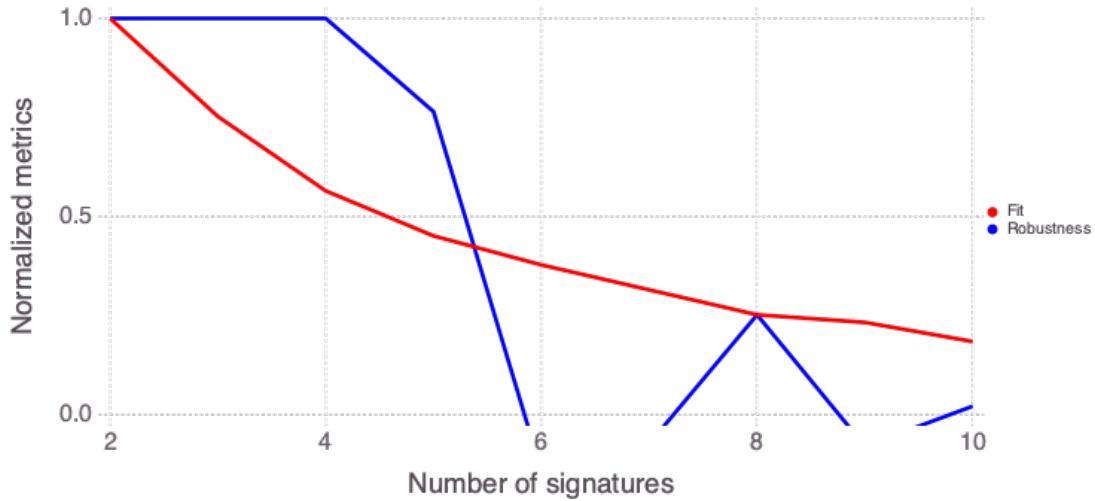
```
2
3
4
5
8
```

The acceptable solutions contain 2, 3, 4, 5 and 8 signatures.

#### 0.4.1 Post-process NMFK results

**Number of signatures** Plot representing solution quality (fit) and silhouette width (robustness) for different number of signatures k:

```
[14]: NMFK.plot_signal_selection(nkrange, fitquality, robustness; figuredir=figuredir,
                                xtitle="Number of signatures")
```



The plot above also demonstrates that the acceptable solutions contain 2, 3, 4, 5 and 8 signatures.

**Analysis of all the acceptable solutions** The ML solutions containing an acceptable number of signatures are further analyzed as follows:

```
[15]: NMFK.clusterresults(NMFK.getks(nkrange, robustness[nkrange]), W, H, attributes,
                        locations; lat=lat, lon=lon, resultdir=resultdir, figuredir=figuredir,
                        Hcasefilename="locations", Wcasefilename="attributes");
```

```
Signal importance (high->low): [1, 2]
Info: Number of signals: 2
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKPostprocess.jl:144
Info: Locations (signals=2)
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKPostprocess.jl:148
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
29×2 Array{Any,2}:
"Allen spr"      1.0
```

|                  |          |
|------------------|----------|
| "Turkey spr"     | 0.884139 |
| "Aragon spr"     | 0.849368 |
| "Gila spr 1"     | 0.845807 |
| "Ash spr"        | 0.839107 |
| "Gila spr 2"     | 0.829838 |
| "Garton well"    | 0.788626 |
| "Mimbres spr"    | 0.7852   |
| "Ojitos spr"     | 0.76979  |
| "Socorro Can"    | 0.761215 |
| "Freiborn spr"   | 0.745613 |
| "Well 1"         | 0.743076 |
| "Spring Can"     | 0.741828 |
| <br>             |          |
| "Warm spr"       | 0.676919 |
| "Cliff spr"      | 0.676442 |
| "Ojo Caliente"   | 0.670285 |
| "Spring"         | 0.669871 |
| "Alamos spr"     | 0.64752  |
| "Pueblo well"    | 0.63547  |
| "Rainbow spr"    | 0.635234 |
| "Jerry well"     | 0.622338 |
| "Laguna Pbl"     | 0.601675 |
| "Sacred spr"     | 0.597838 |
| "Apache well"    | 0.563514 |
| "Kennecott well" | 0.510178 |

15×2 Array{Any,2}:

|                  |          |
|------------------|----------|
| "Fed H1 well"    | 1.0      |
| "Well 4"         | 0.840281 |
| "Well 2"         | 0.78384  |
| "Well 5"         | 0.719246 |
| "Los Alturas"    | 0.692025 |
| "Radium spr"     | 0.687742 |
| "Lightning Dock" | 0.677317 |
| "T or C spr"     | 0.60486  |
| "Carne well"     | 0.592351 |
| "Well 3"         | 0.56113  |
| "B.Iorio well"   | 0.480433 |
| "Victoria well"  | 0.462937 |
| "Derry spr"      | 0.400573 |
| "Faywood spr"    | 0.391769 |
| "Goat spr"       | 0.354929 |



```

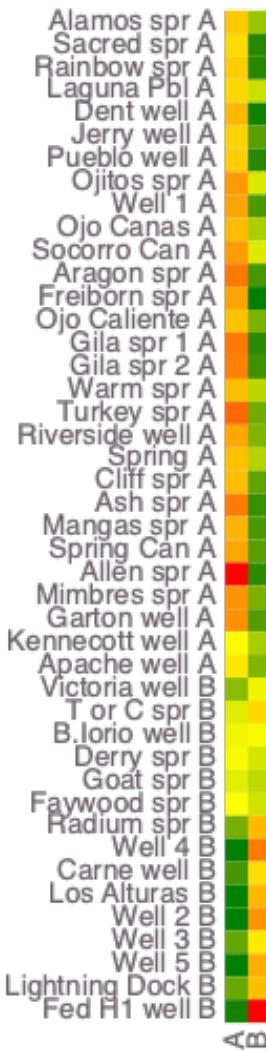
Info: Robust k-means analysis results are loaded from file results-
case01/Hmatrix-2-2_44-1000.jld!
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
Info: Robust k-means analysis results are loaded from file results-
case01/Wmatrix-2-2_18-1000.jld!

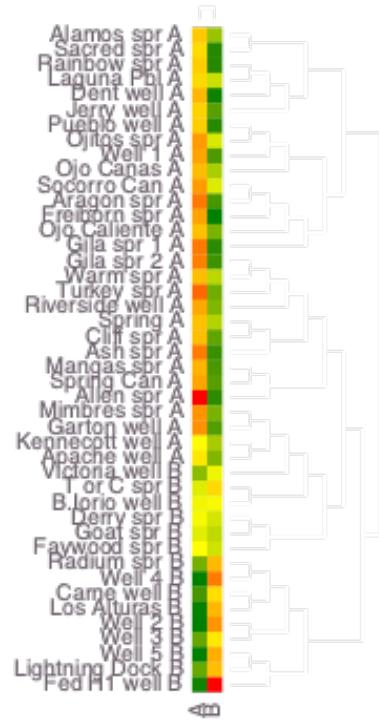
```

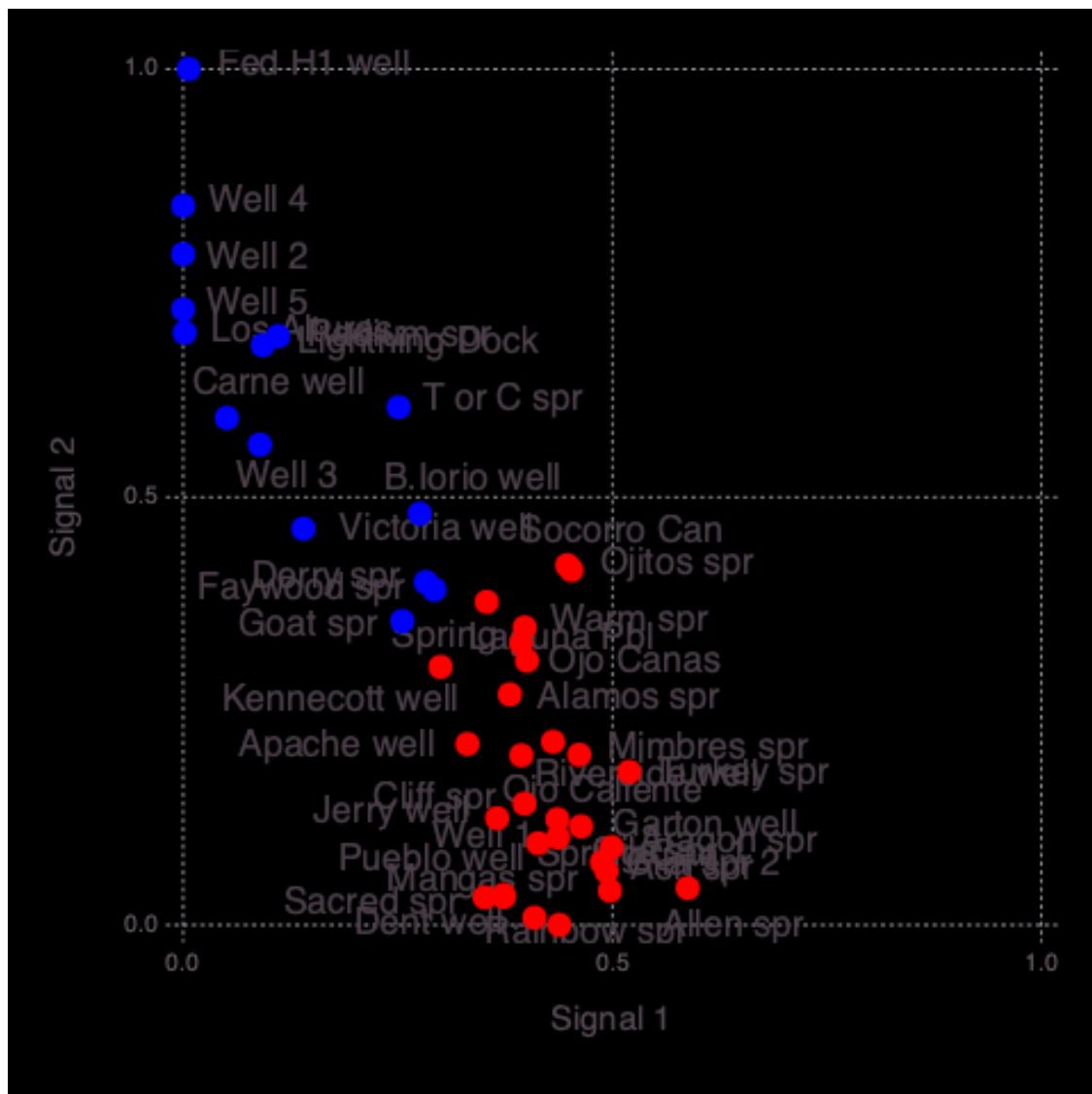
```

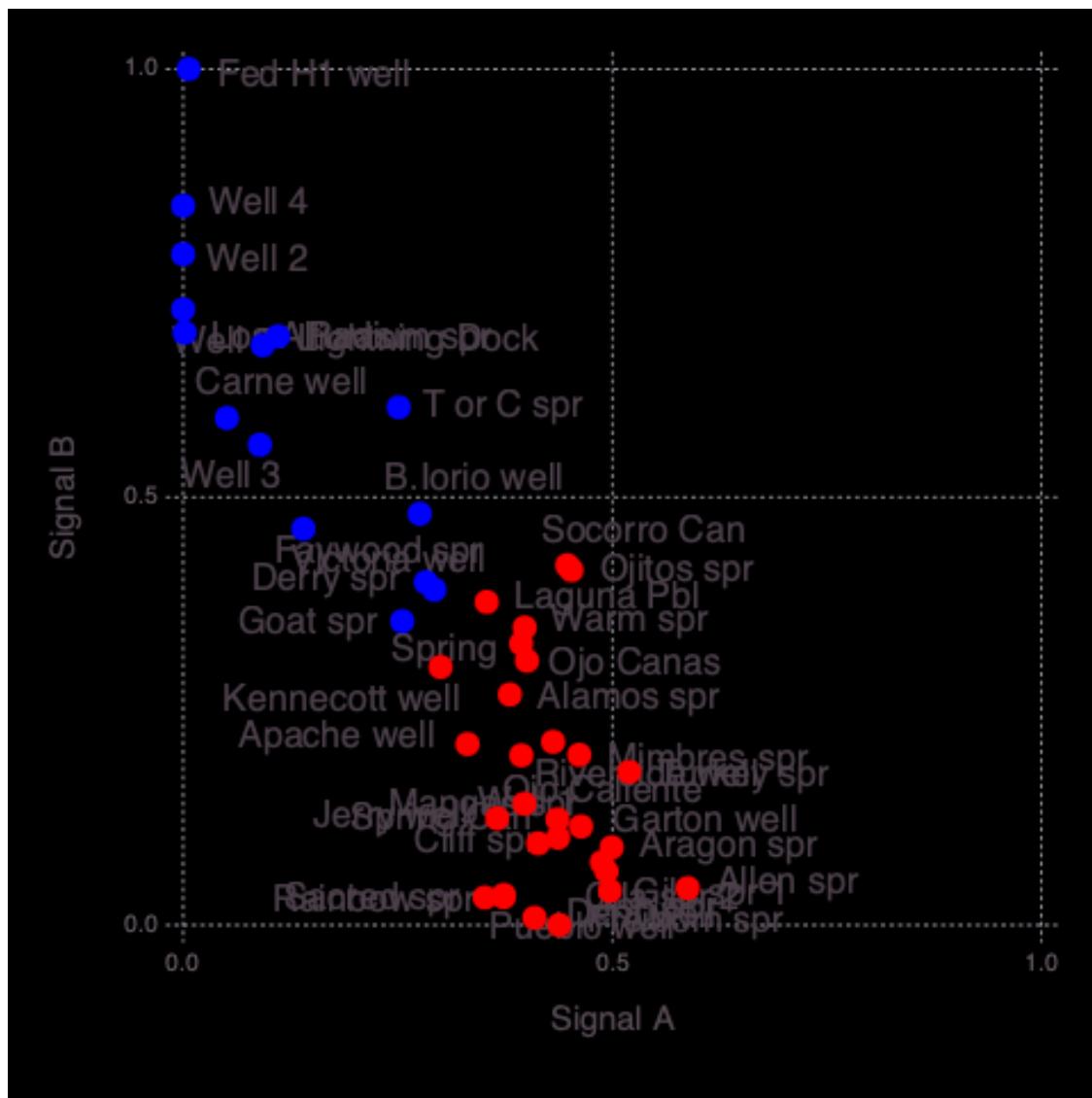
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
Info: Signal A -> A Count: 29
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal B -> B Count: 15
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal A (S1) (k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal B (S2) (k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272

```





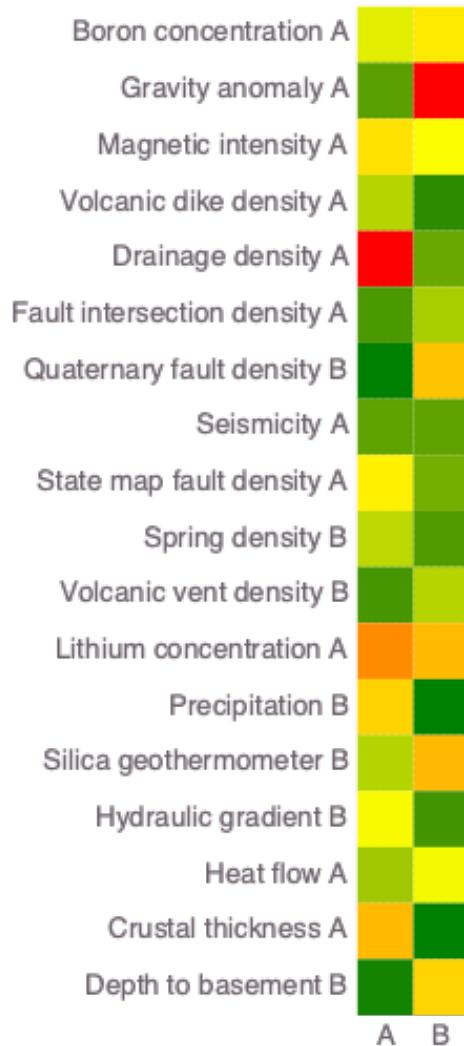




```
11×2 Array{Any,2}:
"Drainage density"           1.0
"Lithium concentration"      0.801888
"Crustal thickness"          0.684456
"Magnetic intensity"         0.581662
"State map fault density"    0.539332
"Boron concentration"        0.431691
"Volcanic dike density"      0.334325
"Heat flow"                  0.283606
"Seismicity"                 0.13724
"Gravity anomaly"            0.126086
"Fault intersection density"  0.097643
```

7×2 Array{Any,2}:

|                            |           |
|----------------------------|-----------|
| "Silica geothermometer"    | 0.690981  |
| "Quaternary fault density" | 0.664186  |
| "Depth to basement"        | 0.61722   |
| "Volcanic vent density"    | 0.334398  |
| "Spring density"           | 0.108699  |
| "Hydraulic gradient"       | 0.0811159 |
| "Precipitation"            | 0.0       |



Info: Attributes (signals=2)

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322

Info: Signal A (S1) Count: 11

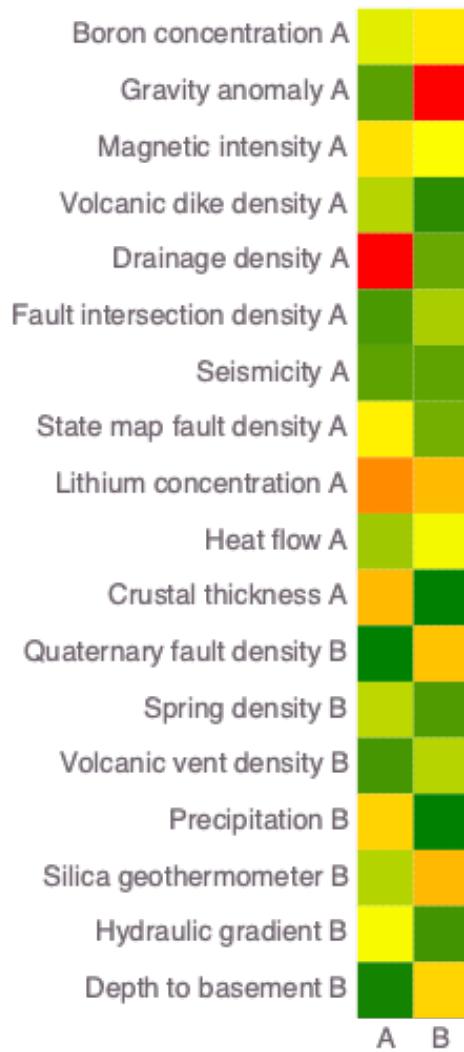
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335

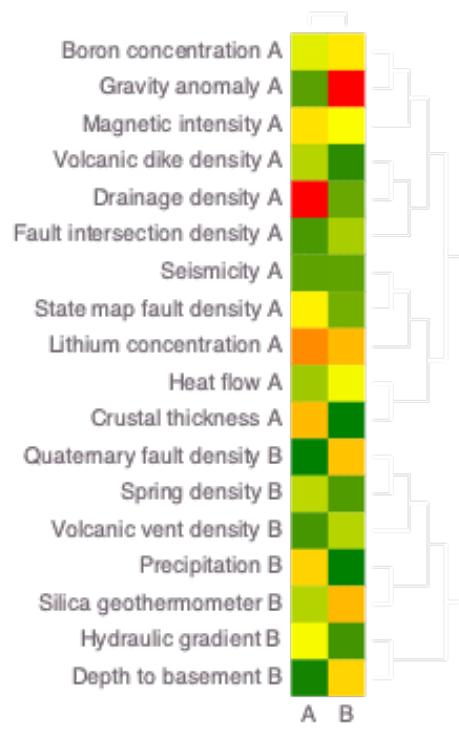
Info: Signal B (S2) Count: 7

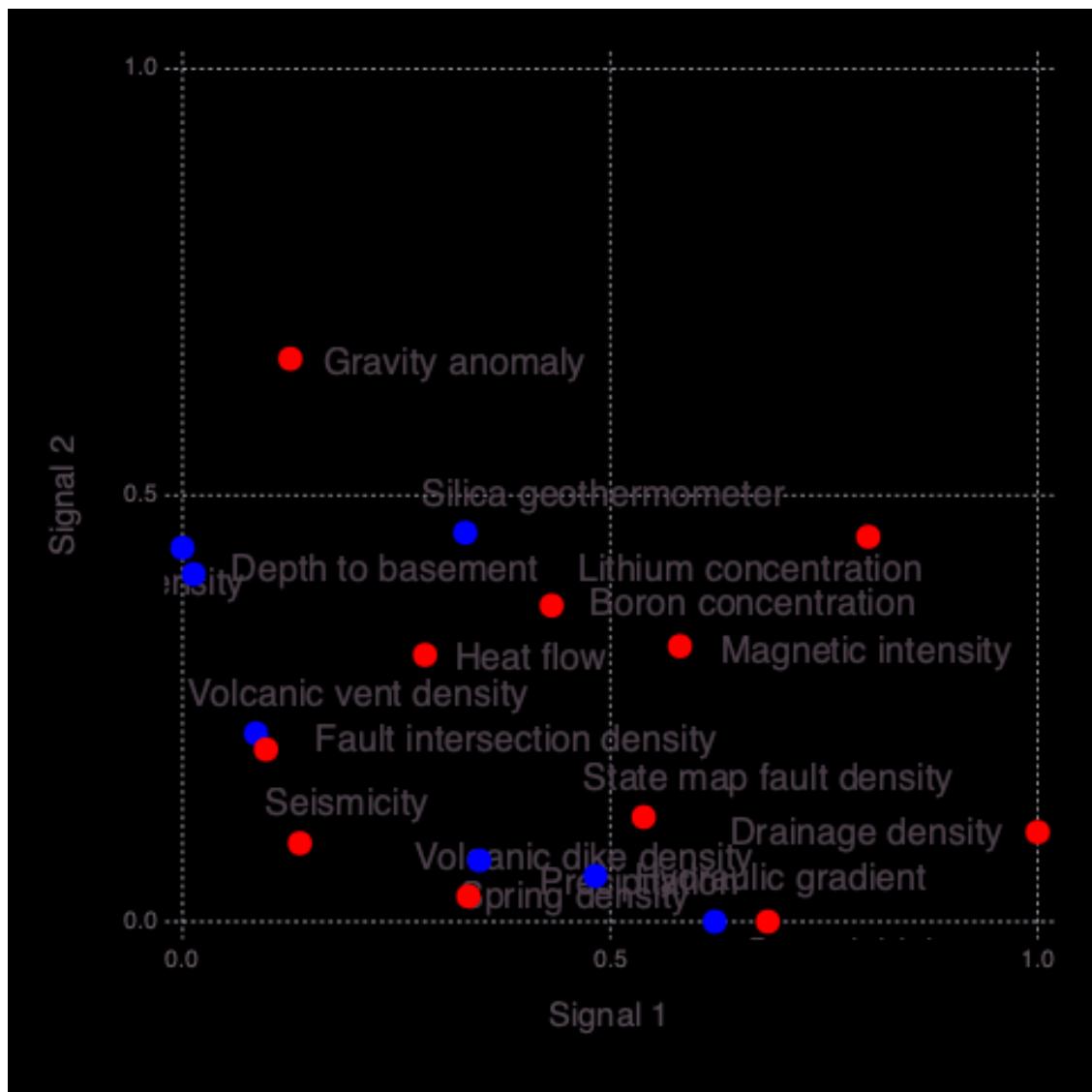
```

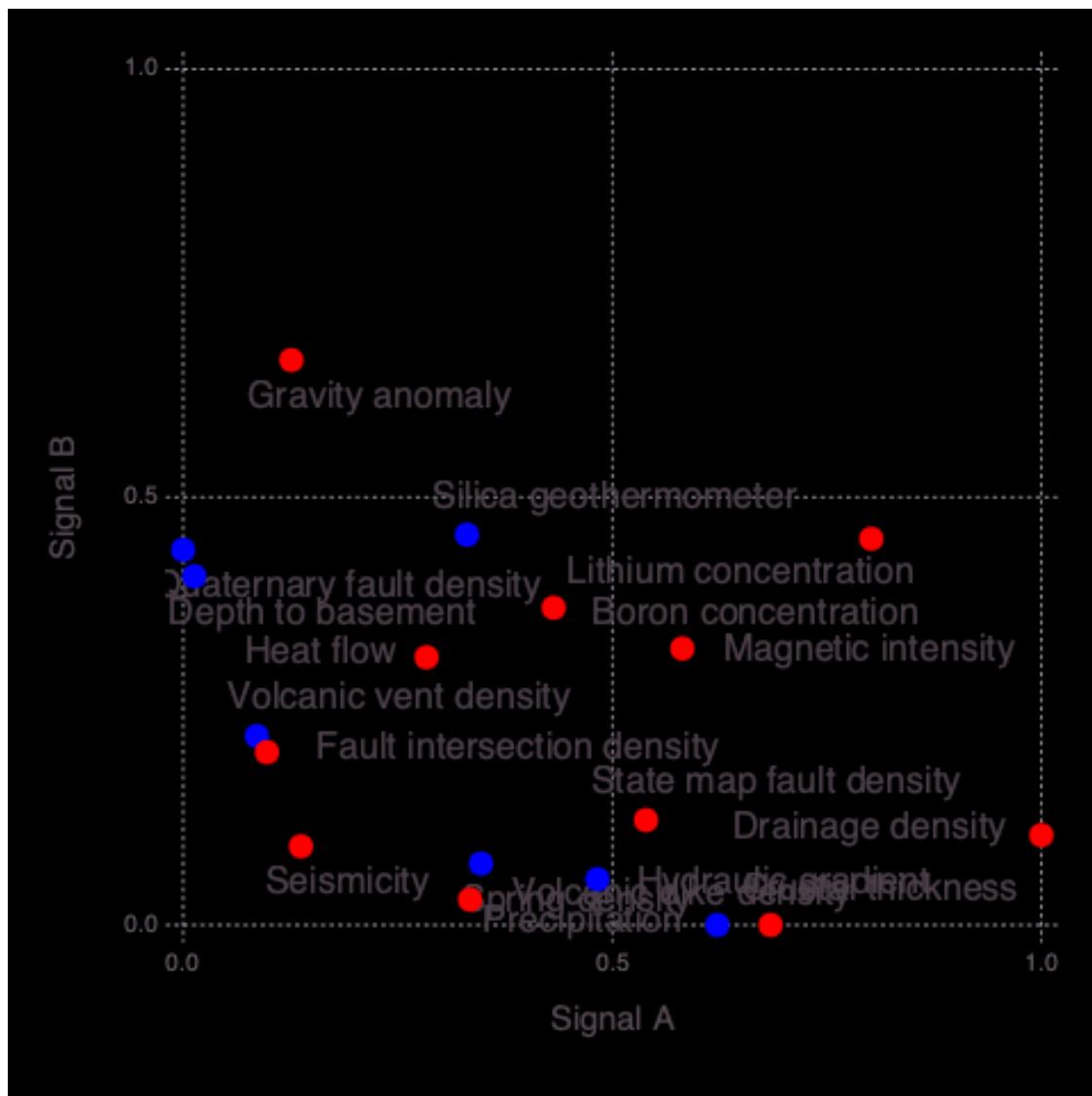
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal A -> A Count: 11
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal B -> B Count: 7
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A (remapped k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal B (remapped k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360

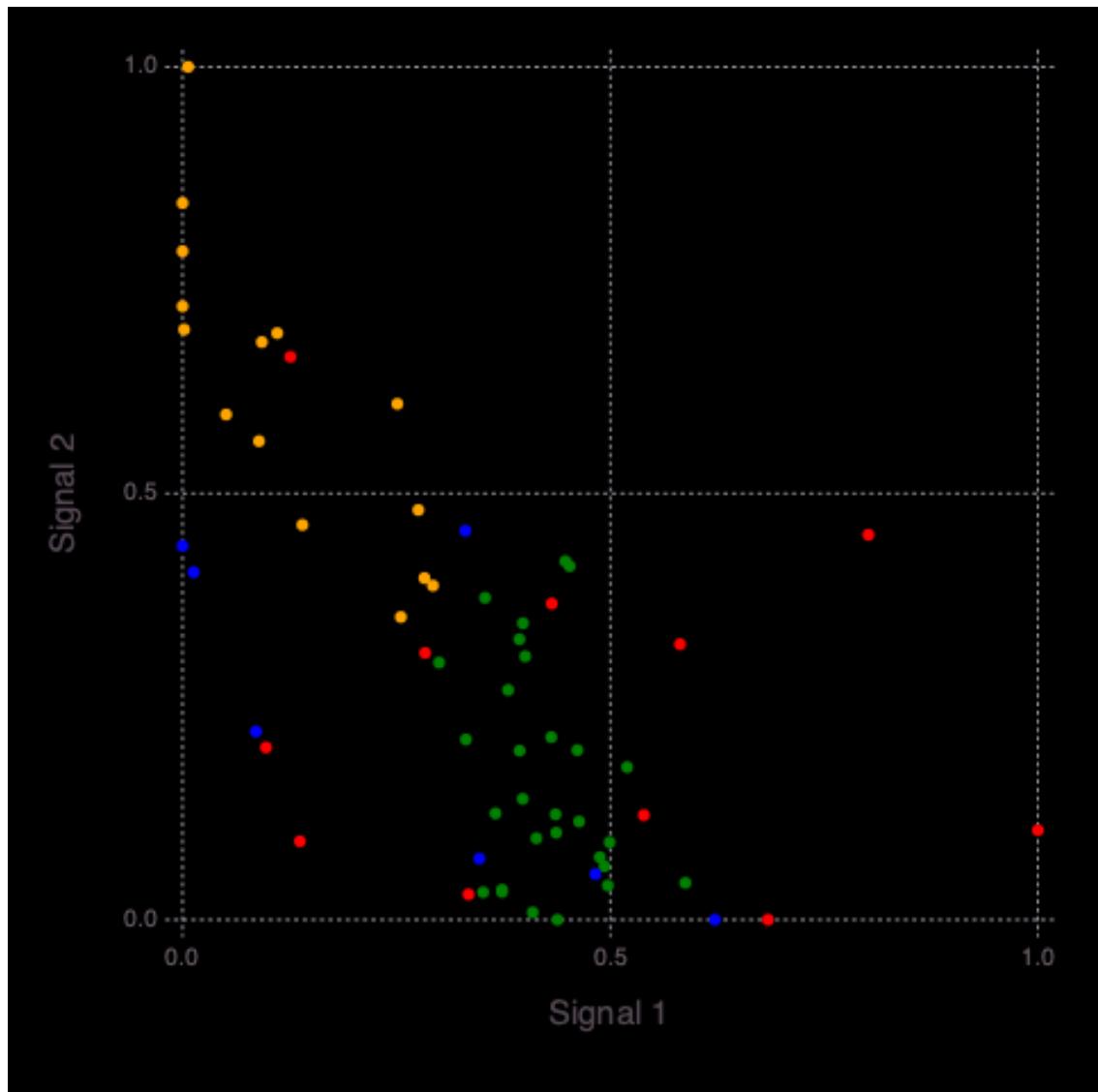
```

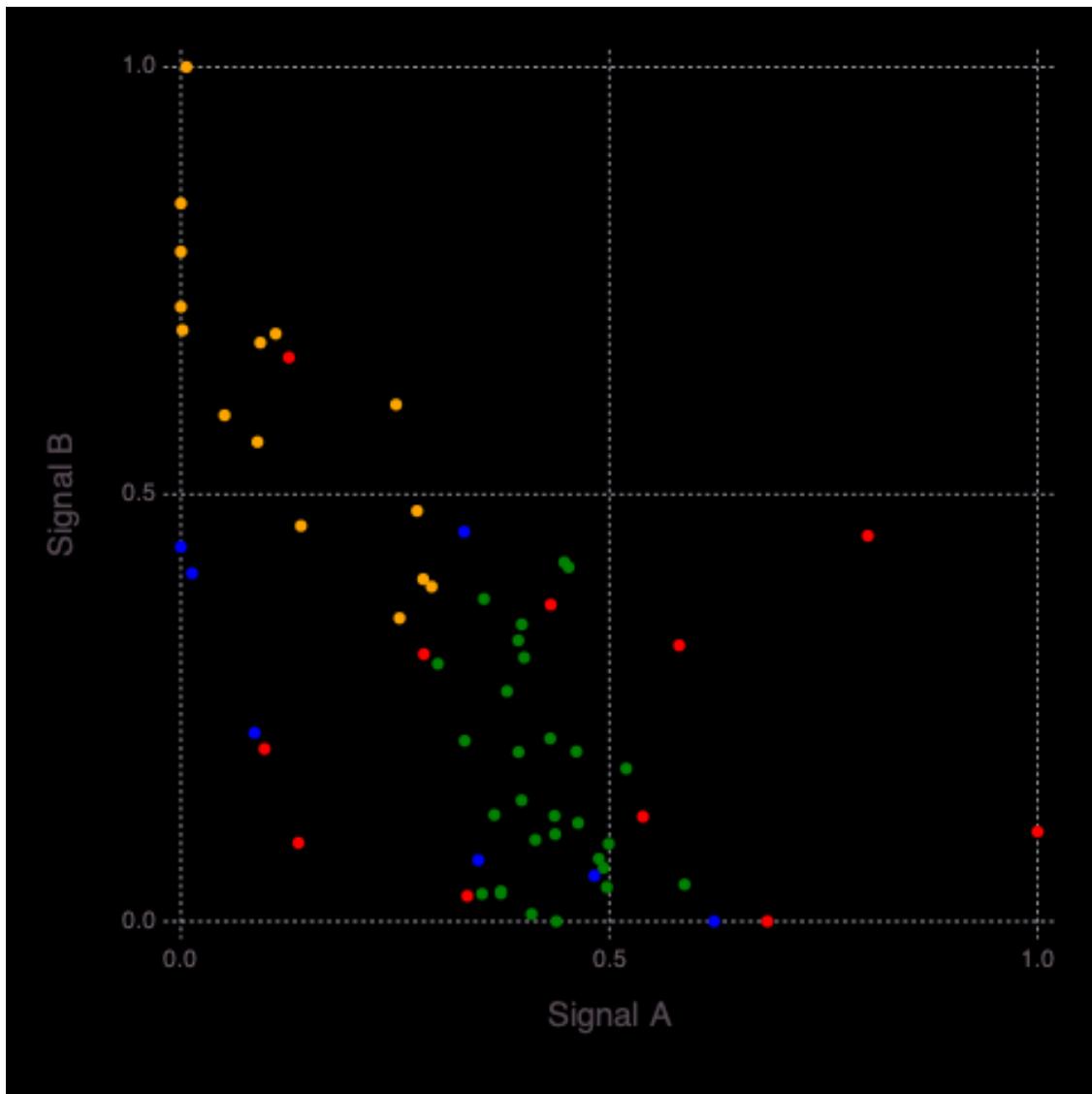












```
Signal importance (high->low): [1, 2, 3]
Info: Number of signals: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
Info: Locations (signals=3)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697

23×2 Array{Any,2}:
"Allen spr"      1.0
"Turkey spr"    0.916375
"Ash spr"        0.86
```

|                  |          |
|------------------|----------|
| "Gila spr 2"     | 0.81917  |
| "Garton well"    | 0.814428 |
| "Mimbres spr"    | 0.810983 |
| "Gila spr 1"     | 0.804735 |
| "Aragon spr"     | 0.760672 |
| "Spring Can"     | 0.74146  |
| "Riverside well" | 0.729138 |
| "Freiborn spr"   | 0.726089 |
| "Well 1"         | 0.721013 |
| "Mangas spr"     | 0.710025 |
| "Spring"         | 0.702419 |
| "Cliff spr"      | 0.681147 |
| "Dent well"      | 0.67989  |
| "Ojo Caliente"   | 0.678069 |
| "Pueblo well"    | 0.624881 |
| "Rainbow spr"    | 0.623511 |
| "Jerry well"     | 0.59157  |
| "Apache well"    | 0.58789  |
| "Sacred spr"     | 0.586264 |
| "Kennecott well" | 0.545995 |

13×2 Array{Any,2}:

|                  |          |
|------------------|----------|
| "Fed H1 well"    | 1.0      |
| "Well 4"         | 0.821925 |
| "Well 5"         | 0.773654 |
| "Los Alturas"    | 0.773565 |
| "Well 2"         | 0.752558 |
| "Lightning Dock" | 0.71038  |
| "Radium spr"     | 0.671286 |
| "Carne well"     | 0.644475 |
| "Well 3"         | 0.610426 |
| "Victoria well"  | 0.492095 |
| "Faywood spr"    | 0.385637 |
| "Goat spr"       | 0.341865 |
| "Derry spr"      | 0.336225 |

8×2 Array{Any,2}:

|                |          |
|----------------|----------|
| "Socorro Can"  | 1.0      |
| "Ojitos spr"   | 0.902801 |
| "Ojo Canas"    | 0.734799 |
| "T or C spr"   | 0.443392 |
| "B.Iorio well" | 0.437021 |
| "Laguna Pbl"   | 0.288994 |
| "Warm spr"     | 0.177227 |
| "Alamos spr"   | 0.139853 |

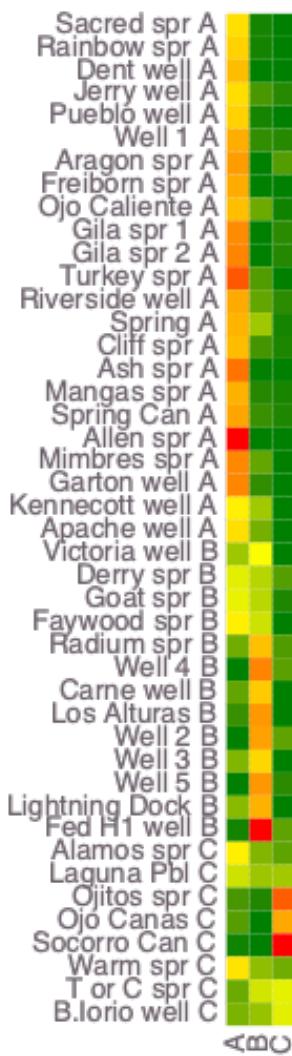


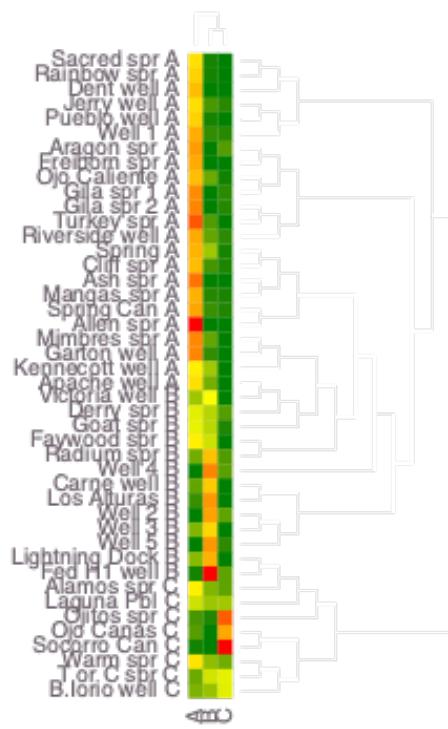
```

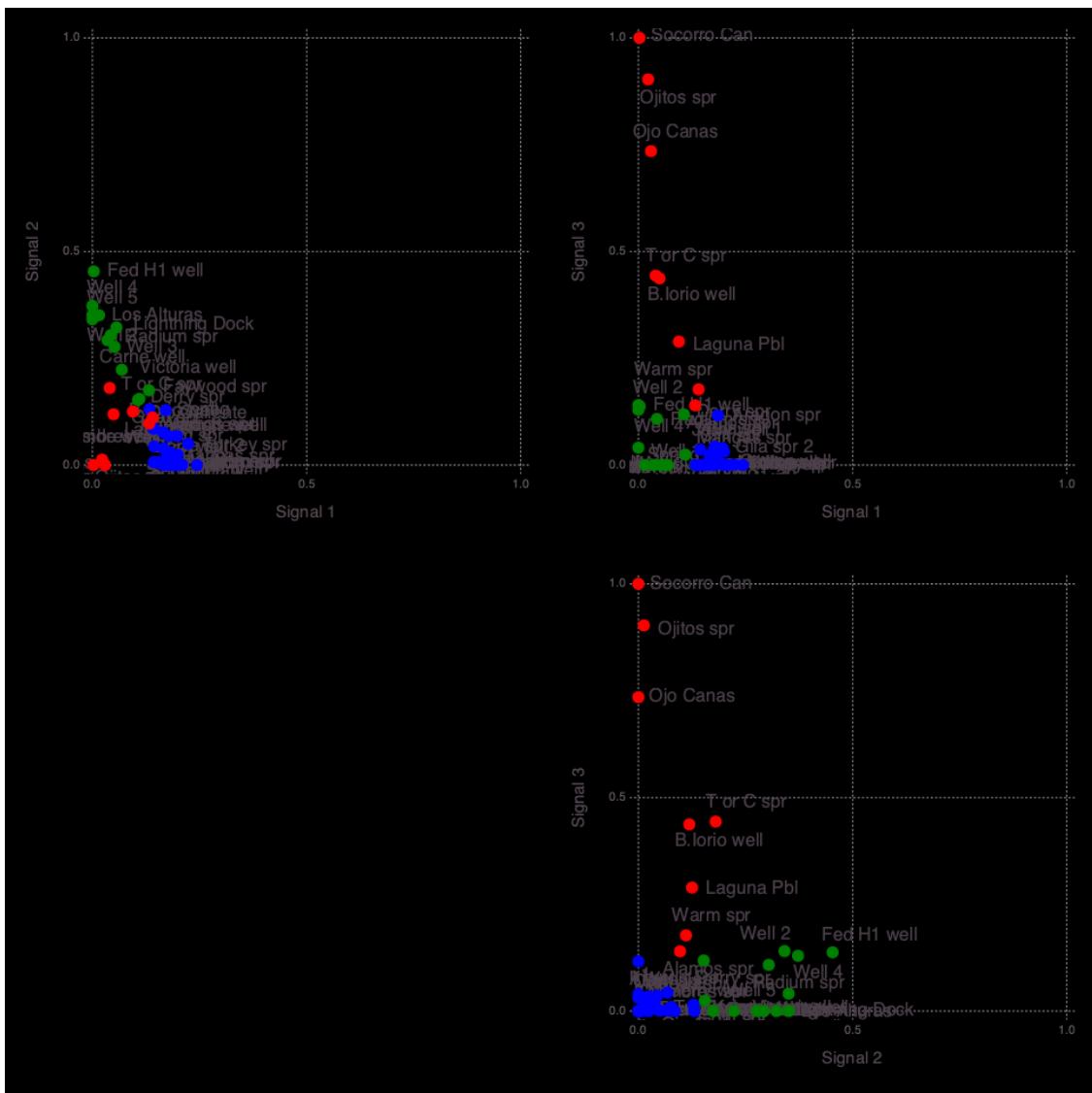
Info: Robust k-means analysis results are loaded from file results-
case01/Hmatrix-3-3_44-1000.jld!
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFkCluster.jl:67
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFkCluster.jl:158
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697

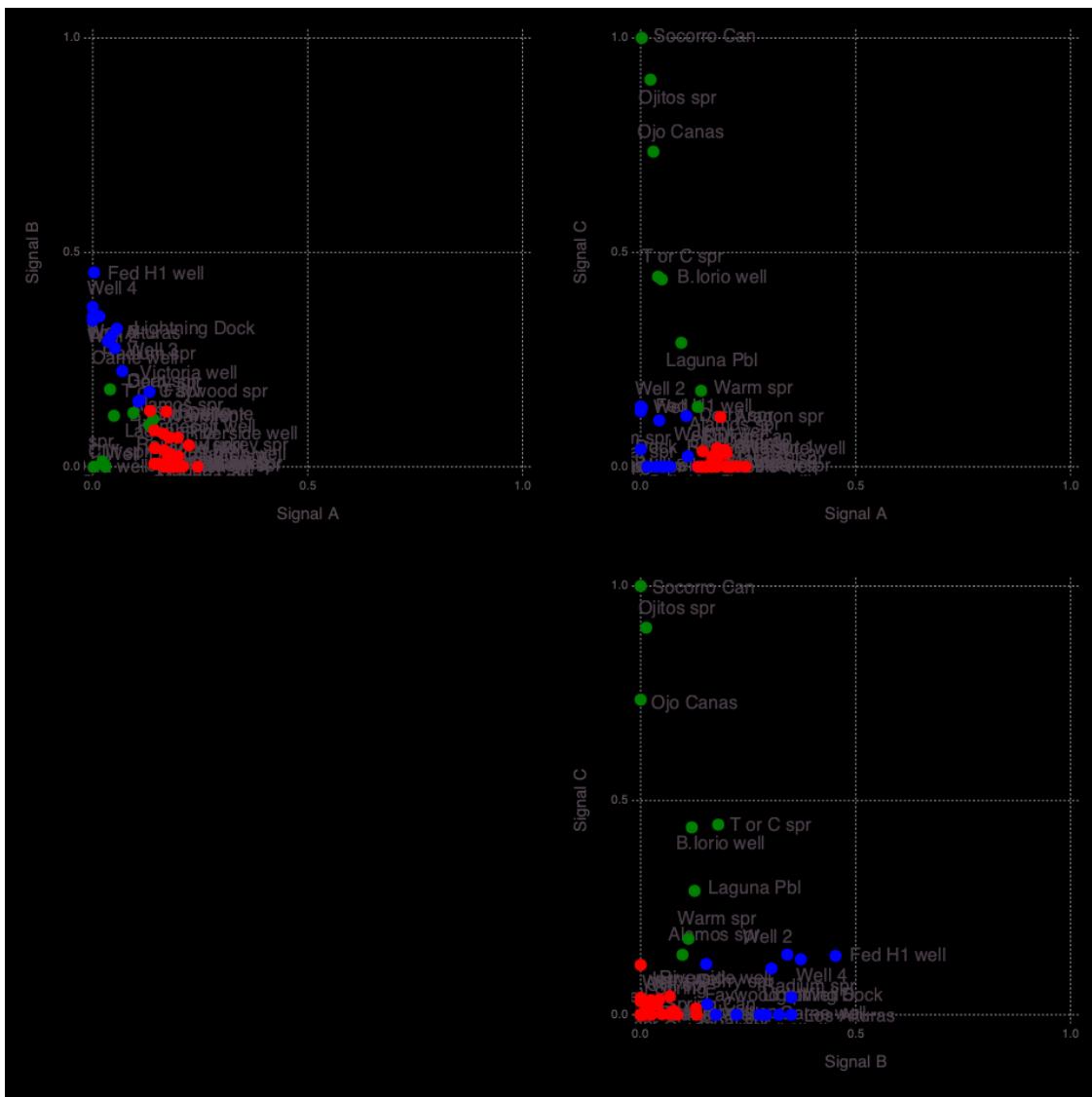
```

```
Info: Robust k-means analysis results are loaded from file results-
case01/Wmatrix-3-3_18-1000.jld!
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Info: Signal A -> A Count: 23
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal B -> B Count: 13
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal C -> C Count: 8
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal A (S1) (k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal B (S2) (k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal C (S3) (k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
```









3x2 Array{Any,2}:

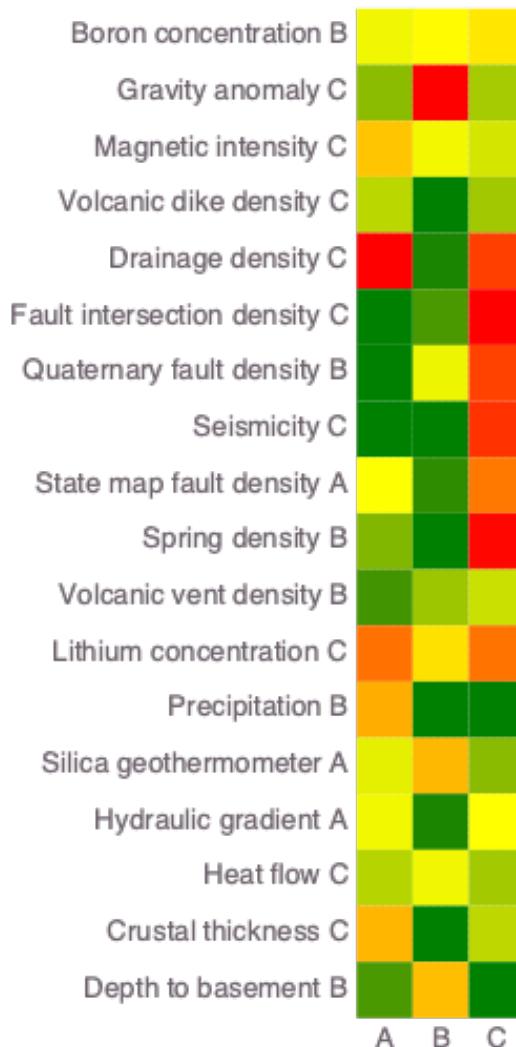
|                           |          |
|---------------------------|----------|
| "State map fault density" | 0.496198 |
| "Hydraulic gradient"      | 0.469537 |
| "Silica geothermometer"   | 0.439841 |

6x2 Array{Any,2}:

|                            |          |
|----------------------------|----------|
| "Depth to basement"        | 0.676939 |
| "Boron concentration"      | 0.511079 |
| "Quaternary fault density" | 0.460437 |
| "Volcanic vent density"    | 0.27834  |
| "Spring density"           | 0.0      |
| "Precipitation"            | 0.0      |

9x2 Array{Any,2}:

|                              |          |
|------------------------------|----------|
| "Fault intersection density" | 1.0      |
| "Seismicity"                 | 0.967935 |
| "Drainage density"           | 0.952827 |
| "Lithium concentration"      | 0.858236 |
| "Magnetic intensity"         | 0.403114 |
| "Crustal thickness"          | 0.346896 |
| "Gravity anomaly"            | 0.297228 |
| "Heat flow"                  | 0.290886 |
| "Volcanic dike density"      | 0.28542  |

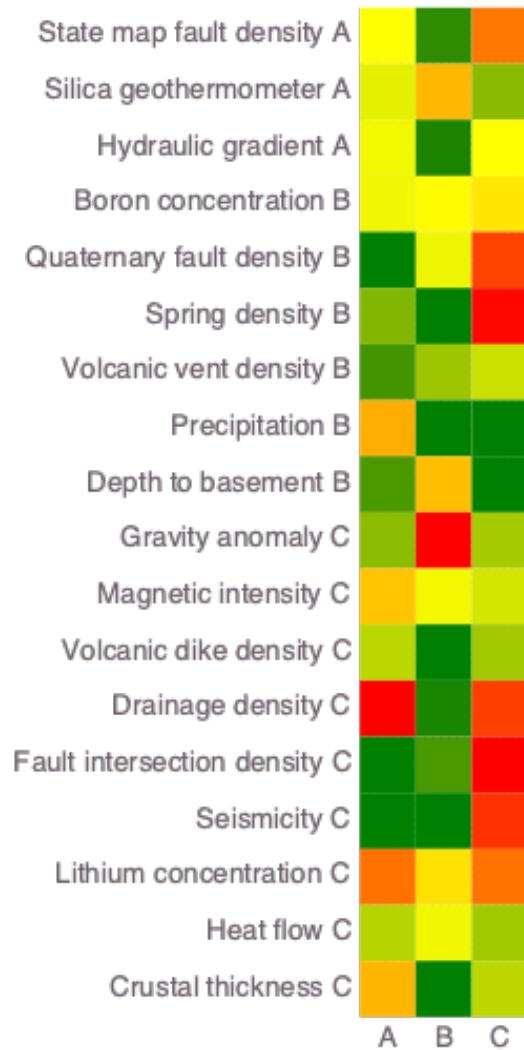


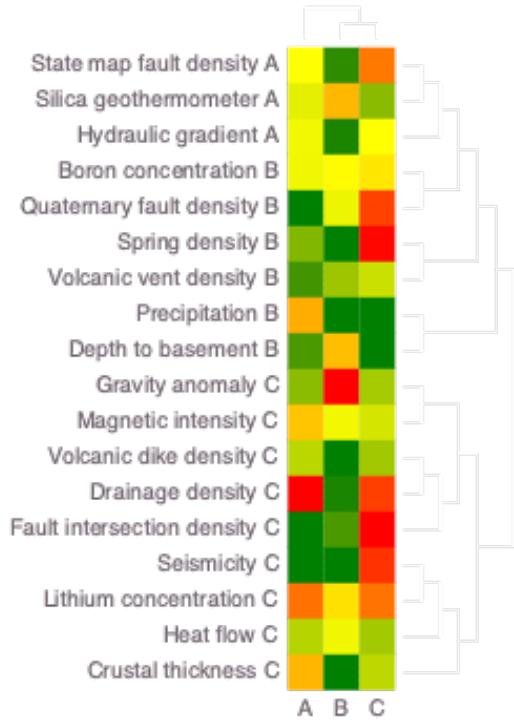
Info: Attributes (signals=3)

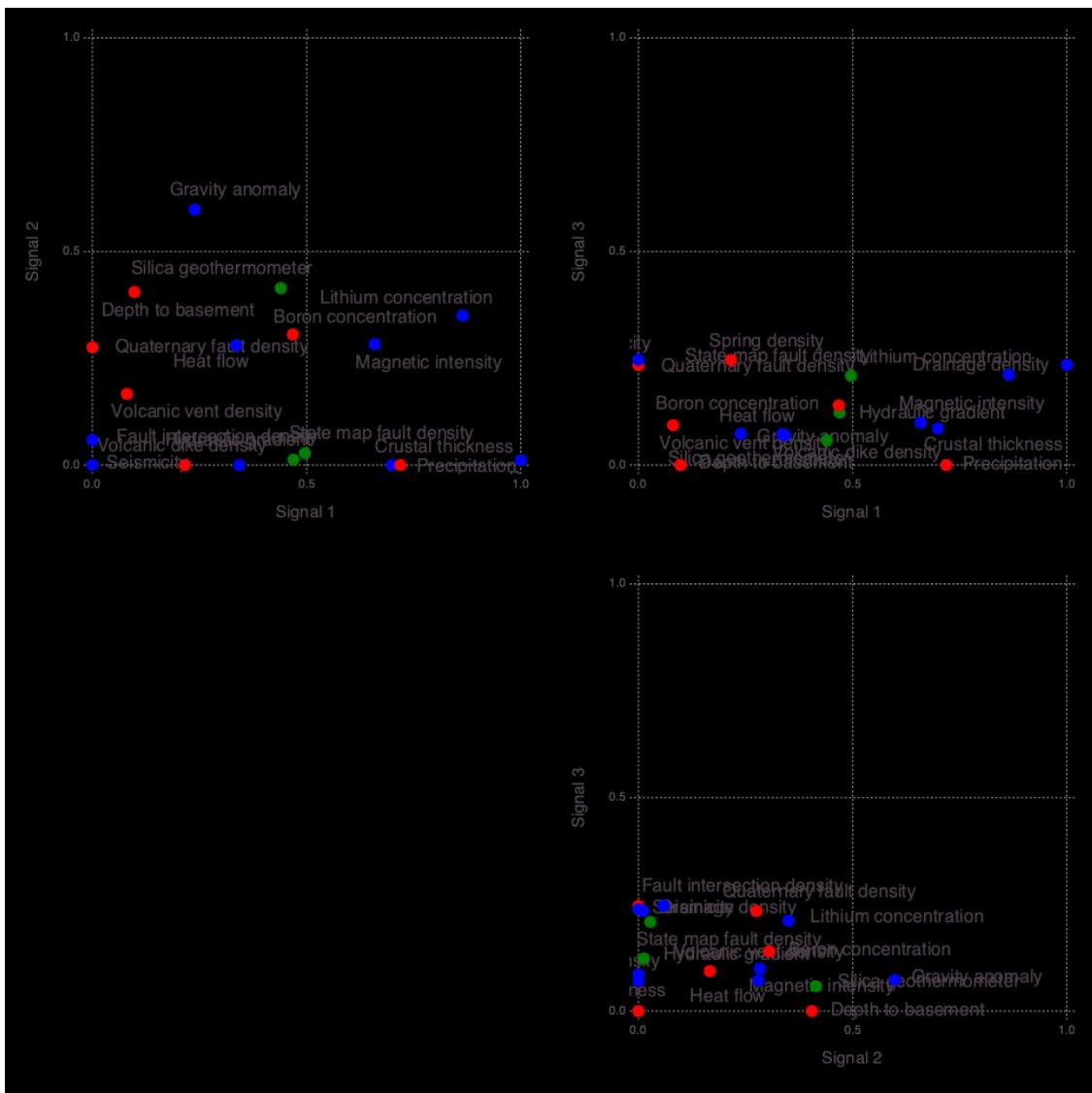
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322

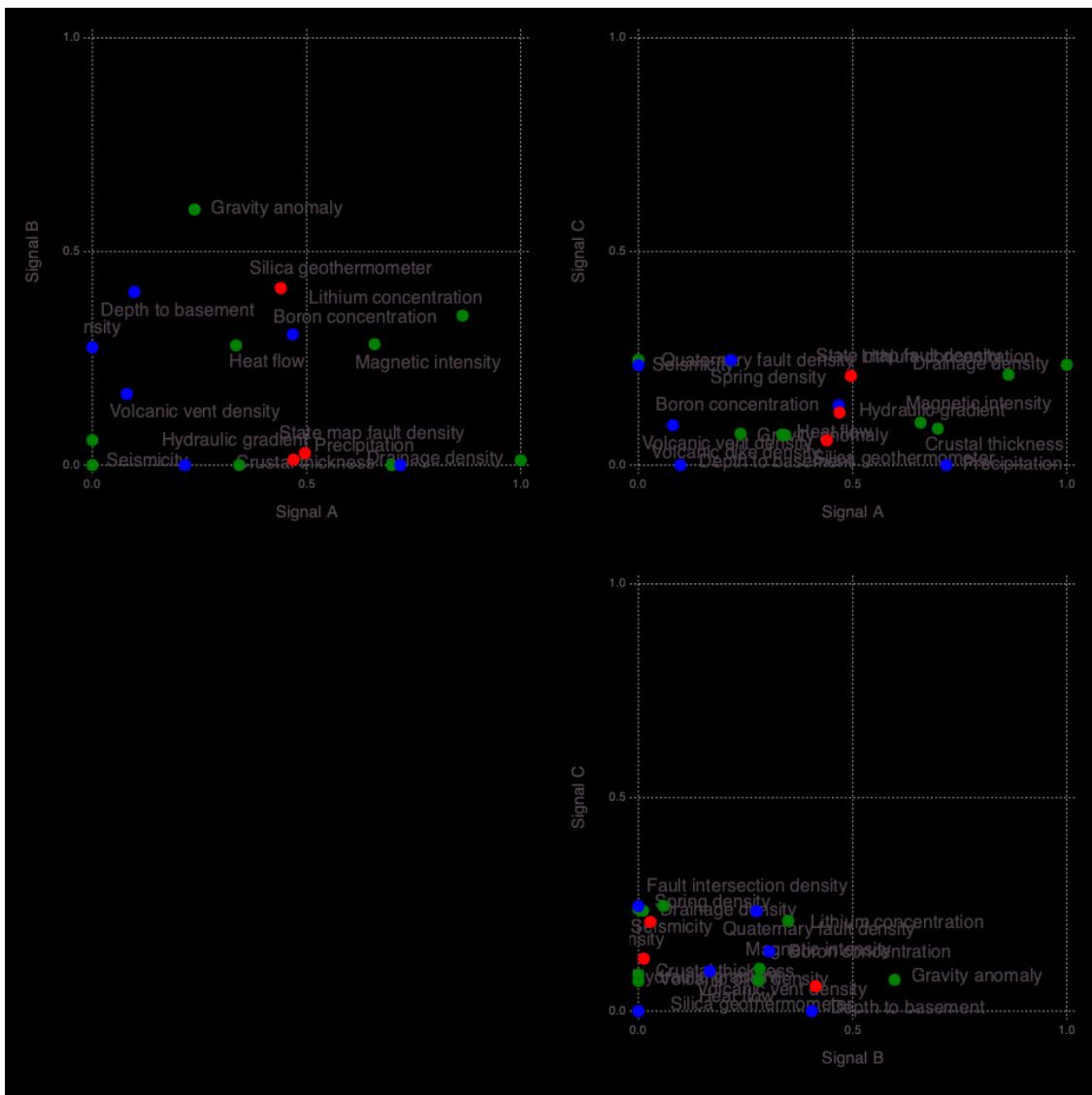
Info: Signal A (S3) Count: 9

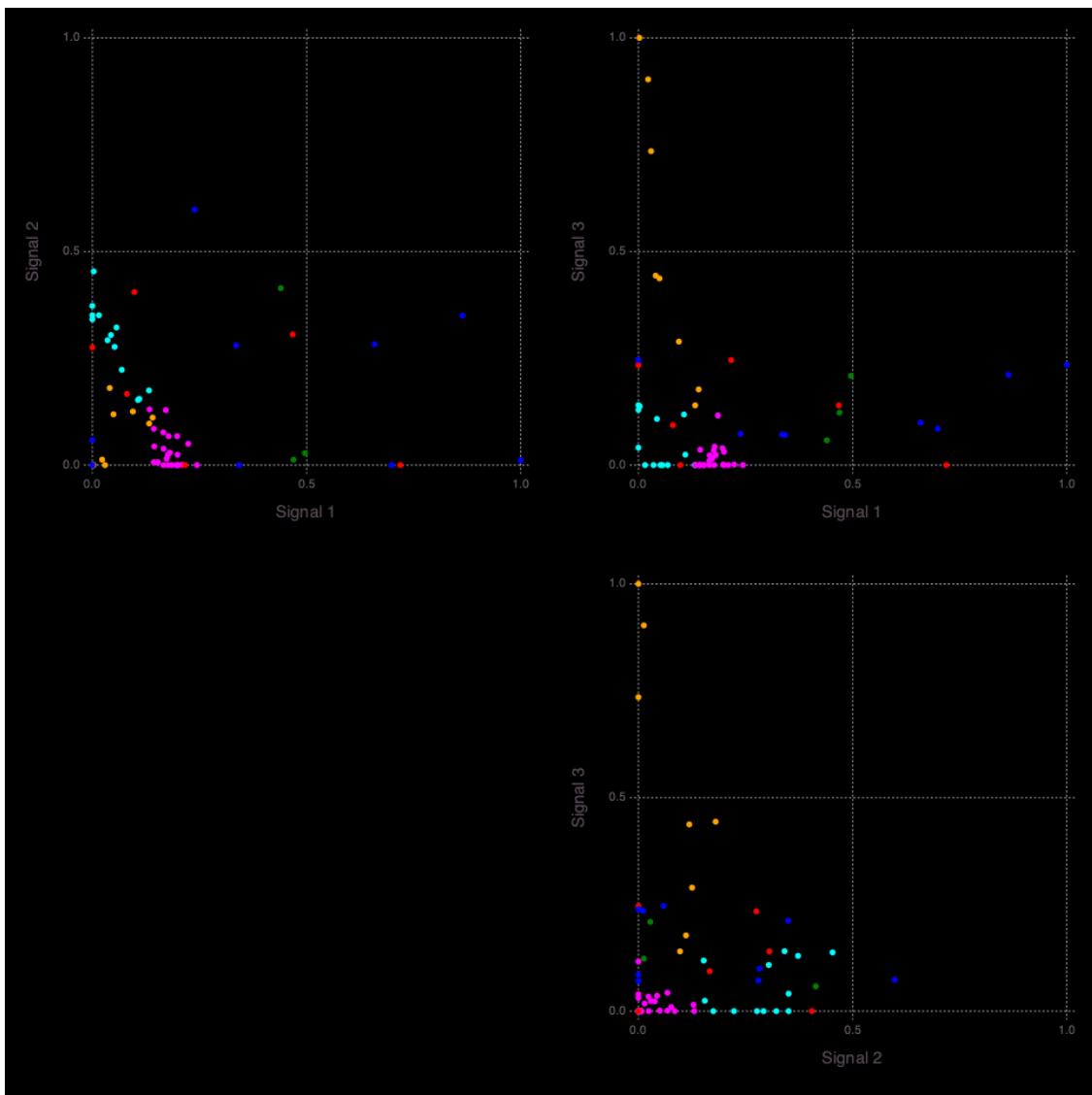
```
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal B (S2) Count: 6
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal C (S1) Count: 3
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal C -> A Count: 3
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal B -> B Count: 6
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A -> C Count: 9
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal B (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal C (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

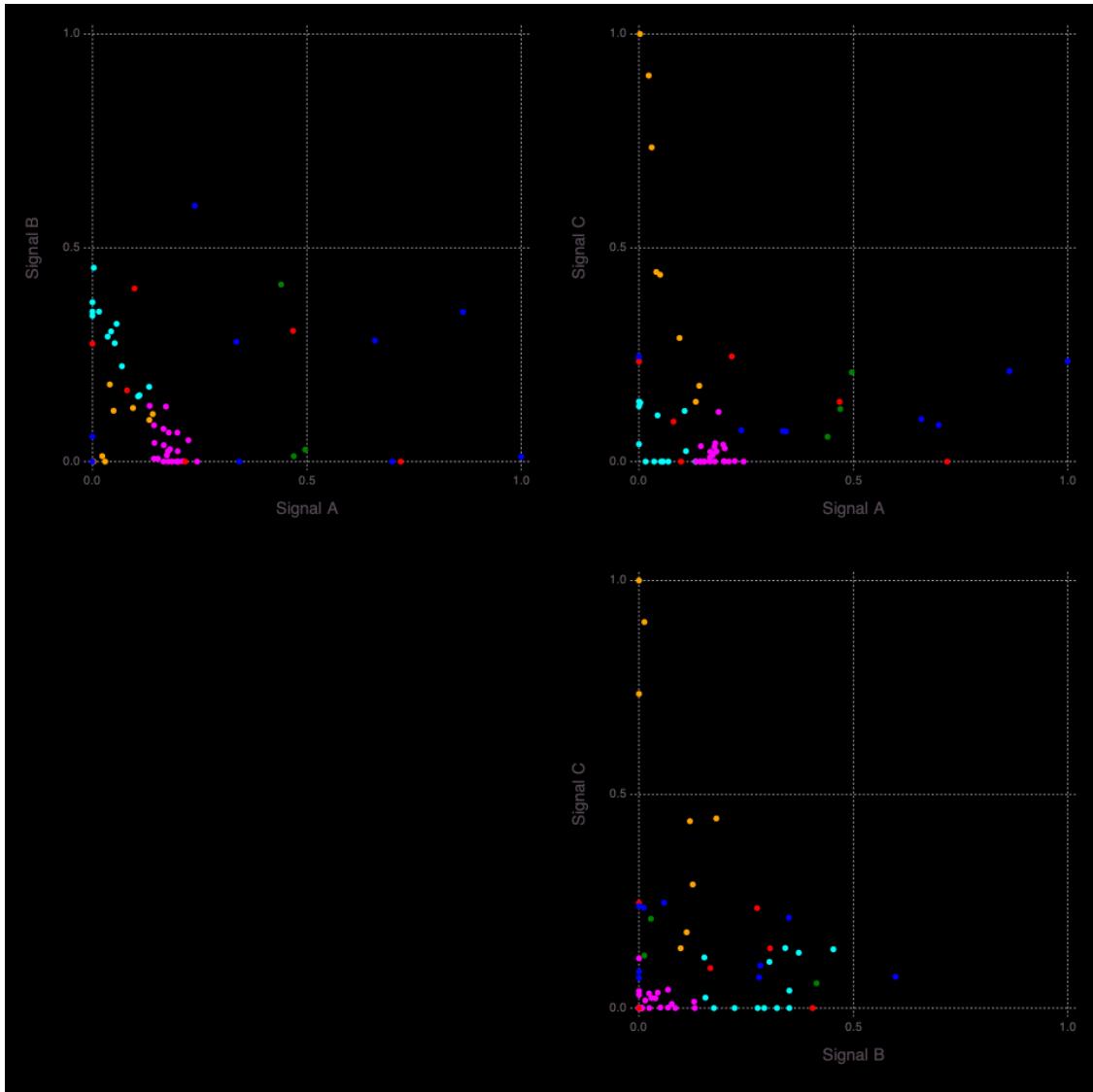












```

Signal importance (high->low): [2, 1, 4, 3]
Info: Number of signals: 4
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
Info: Locations (signals=4)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697

15×2 Array{Any,2}:
"Allen spr"      1.0
"Turkey spr"    0.890671
"Ash spr"       0.860399

```

```

"Garton well"      0.837981
"Mimbres spr"     0.756788
"Spring"          0.727799
"Mangas spr"      0.697281
"Gila spr 1"      0.667903
"Spring Can"      0.647347
"Gila spr 2"      0.646943
"Riverside well"  0.602983
"Cliff spr"       0.592572
"Freiborn spr"    0.579998
"Apache well"     0.569518
"Kennecott well"  0.546961

```

13×2 Array{Any,2}:

```

"Fed H1 well"      1.0
"Well 4"           0.820447
"Los Alturas"      0.774358
"Well 5"           0.771269
"Well 2"           0.755708
"Lightning Dock"   0.70557
"Radium spr"       0.666575
"Carne well"       0.631706
"Well 3"           0.596359
"Victoria well"   0.477645
"Faywood spr"      0.378783
"Goat spr"         0.330589
"Derry spr"        0.324788

```

10×2 Array{Any,2}:

```

"Jerry well"        1.0
"Pueblo well"      0.978656
"Rainbow spr"       0.926226
"Sacred spr"        0.920803
"Dent well"         0.911277
"Alamos spr"        0.869018
"Laguna Pbl"        0.779479
"Well 1"            0.701792
"Aragon spr"        0.678922
"Ojo Caliente"      0.473437

```

Info: Robust k-means analysis results are loaded from file results-case01/Hmatrix-4-4\_44-1000.jld!

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67

Warning: Procedure to find unique signals could not identify a solution ...

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158

Warning: Procedure to find unique signals could not identify a solution ...

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158

Warning: Procedure to find unique signals could not identify a solution ...

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158

```

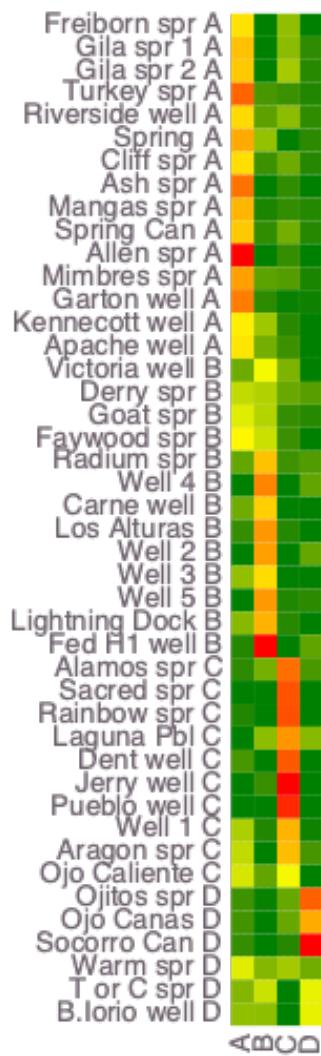
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
Info: Robust k-means analysis results are loaded from file results-
case01/Wmatrix-4-4_18-1000.jld!
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
Info: Signal A -> A Count: 15
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal B -> B Count: 13
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal C -> C Count: 10
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal D -> D Count: 6
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal A (S2) (k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal B (S1) (k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal C (S4) (k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272

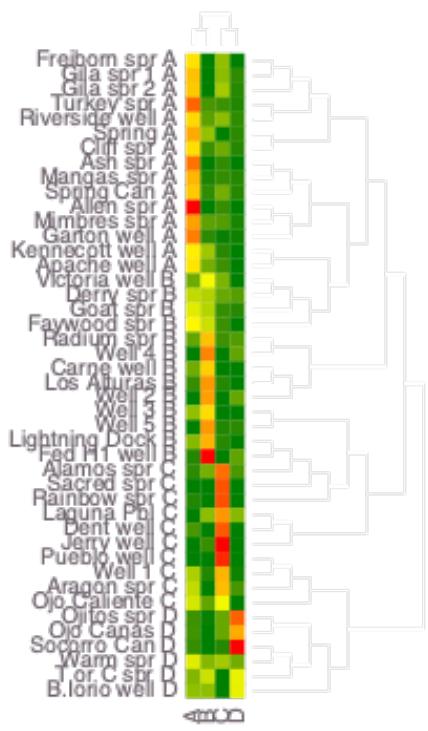
6x2 Array{Any,2}:
"_socorro Can"    1.0
"0jitos spr"     0.897681
"0jo Canas"      0.725719
"T or C spr"      0.449617
"B.Iorio well"   0.445734
"Warm spr"        0.177576

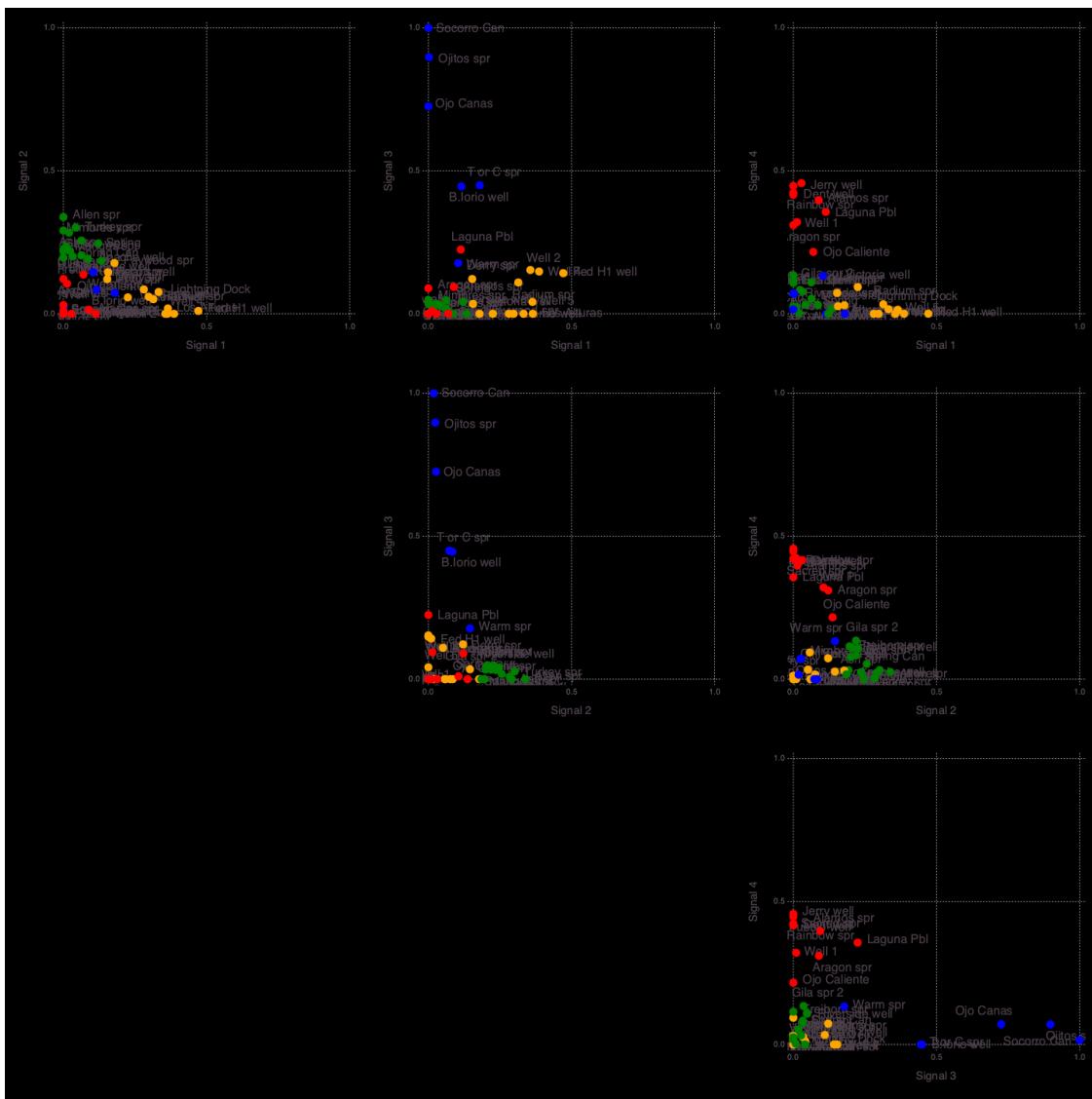
```



Info: Signal D (S3) (k-means clustering)  
 © NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272









3×2 Array{Any,2}:

|                           |          |
|---------------------------|----------|
| "Silica geothermometer"   | 0.565319 |
| "State map fault density" | 0.516354 |
| "Volcanic dike density"   | 0.46948  |

4×2 Array{Any,2}:

|                            |            |
|----------------------------|------------|
| "Depth to basement"        | 0.698015   |
| "Quaternary fault density" | 0.473285   |
| "Hydraulic gradient"       | 0.00393436 |
| "Precipitation"            | 0.0        |

5×2 Array{Any,2}:

|                     |     |
|---------------------|-----|
| "Crustal thickness" | 1.0 |
|---------------------|-----|

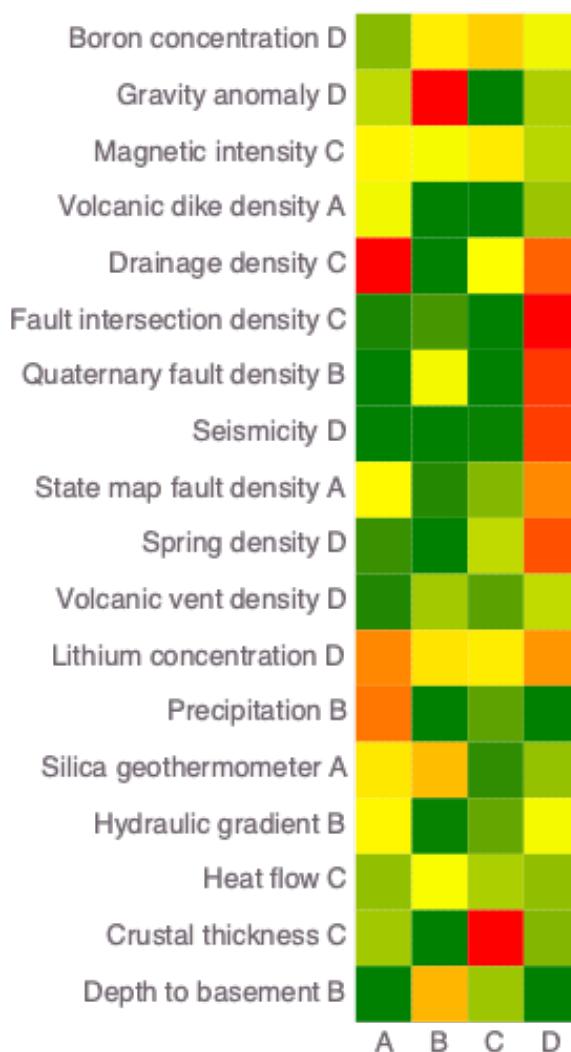
```

"Magnetic intensity"      0.556994
"Drainage density"       0.495465
"Heat flow"              0.311164
"Fault intersection density" 0.0

```

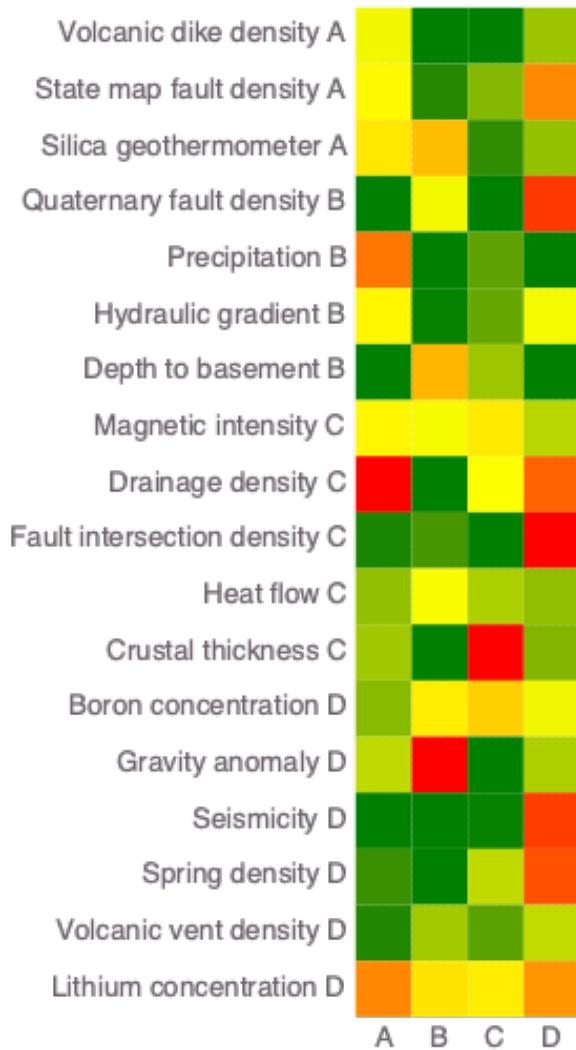
6×2 Array{Any,2}:

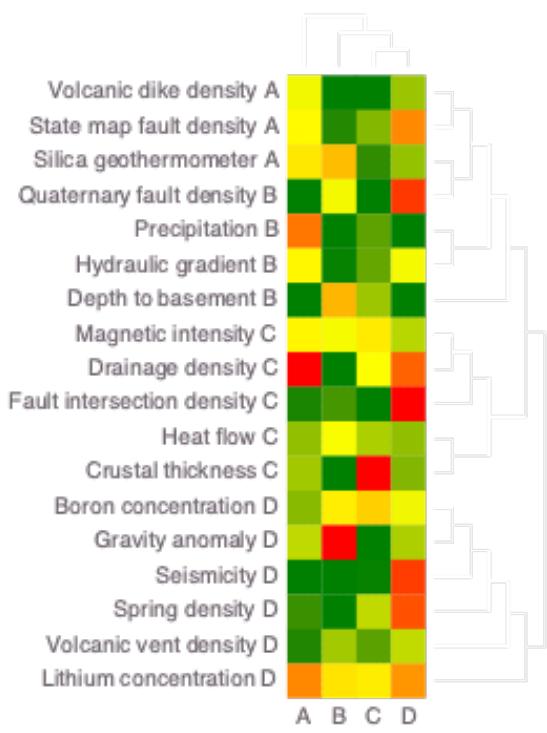
|                         |          |
|-------------------------|----------|
| "Seismicity"            | 0.95485  |
| "Spring density"        | 0.924999 |
| "Lithium concentration" | 0.779688 |
| "Boron concentration"   | 0.465497 |
| "Volcanic vent density" | 0.359763 |
| "Gravity anomaly"       | 0.313199 |

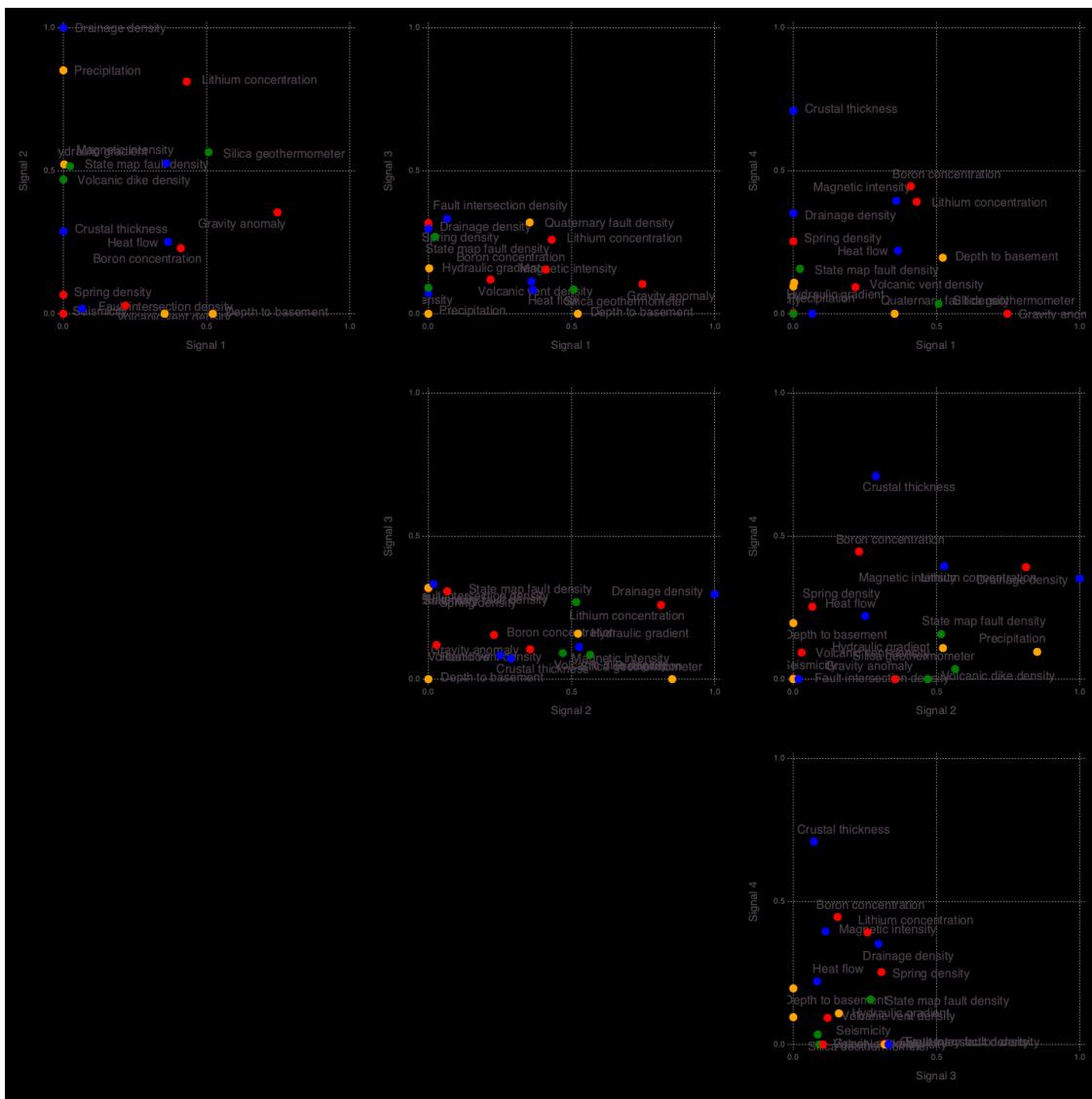


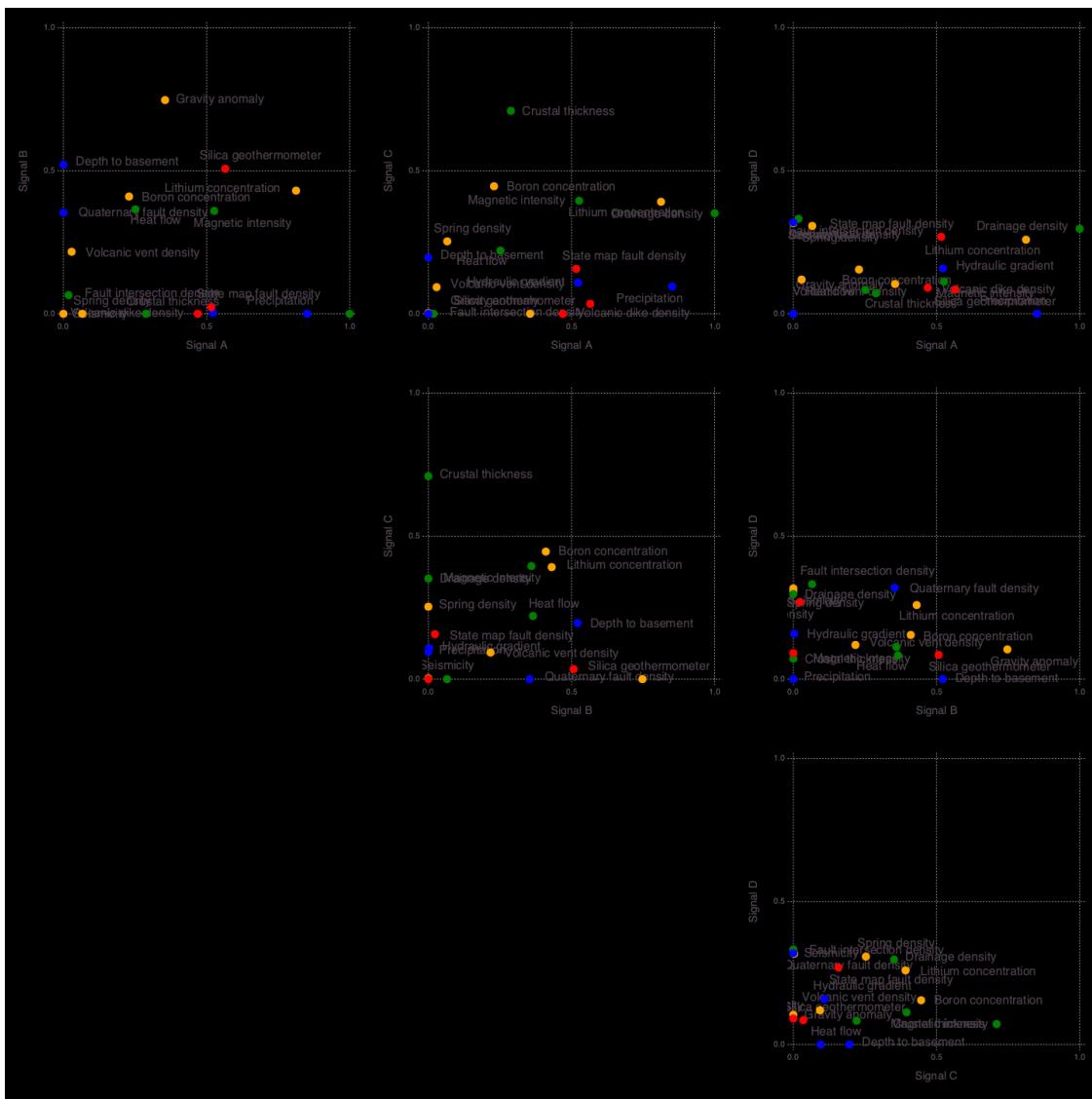
Info: Attributes (signals=4)

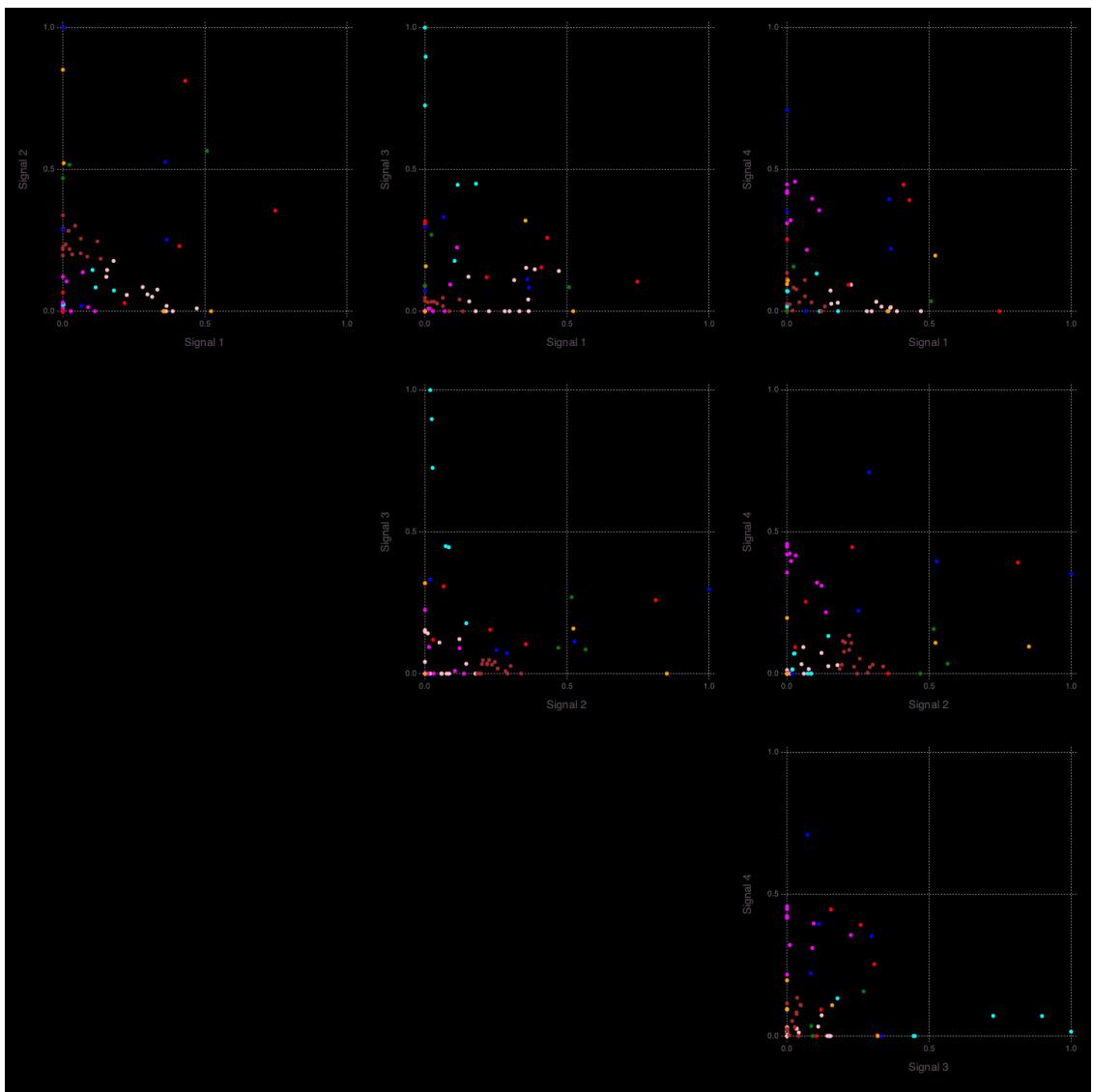
```
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
Info: Signal A (S3) Count: 6
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal B (S4) Count: 5
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal C (S1) Count: 4
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal D (S2) Count: 3
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal D -> A Count: 3
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal C -> B Count: 4
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal B -> C Count: 5
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A -> D Count: 6
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal B (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal C (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal D (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

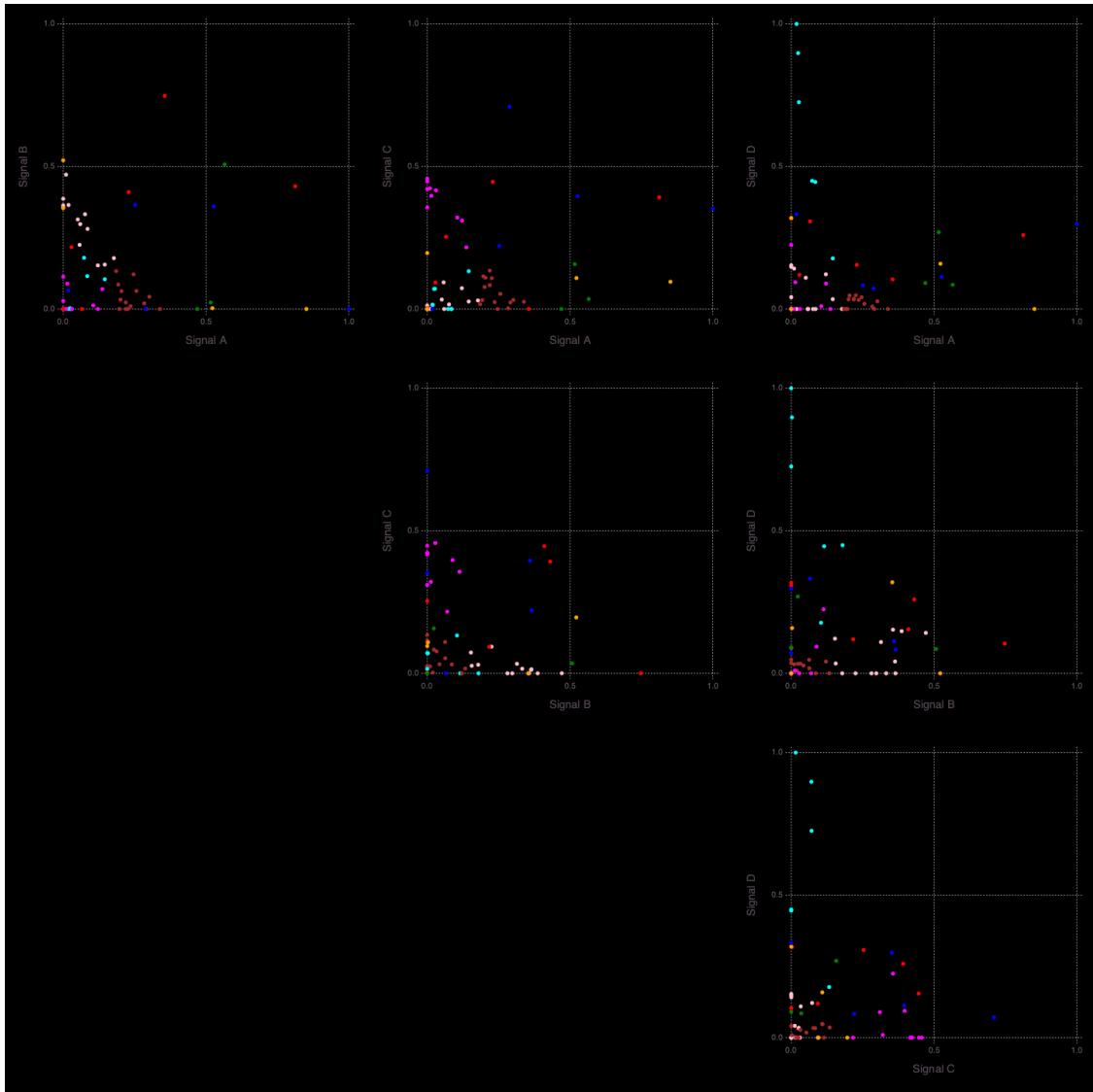












```

Signal importance (high->low): [1, 4, 2, 3, 5]
Info: Number of signals: 5
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144
Info: Locations (signals=5)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
Info: Robust k-means analysis results are loaded from file results-
case01/Hmatrix-5-5_44-1000.jld!
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
Warning: Procedure to find unique signals could not identify a solution ...

```

```

@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
@ JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
Info: Robust k-means analysis results are loaded from file results-
case01/Wmatrix-5-5_18-1000.jld!
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67

16×2 Array{Any,2}:
"Ash spr"      1.0
"Allen spr"    0.932476
"Mangas spr"   0.883364
"Riverside well" 0.834285
"Apache well"   0.782126
"Spring Can"    0.691235
"Turkey spr"    0.677725
"Spring"         0.676908
"Cliff spr"     0.650192
"Warm spr"       0.649358
"Garton well"   0.617193
"Faywood spr"   0.60702
"Kennecott well" 0.598779
"Derry spr"      0.578414
"Miribres spr"   0.564978
"Goat spr"       0.36953

10×2 Array{Any,2}:
"Fed H1 well"   1.0
"Well 4"         0.848078
"Los Alturas"    0.815345
"Well 2"          0.788889
"Well 5"          0.777949
"Lightning Dock" 0.687945
"Carne well"      0.627357
"Radium spr"      0.625606
"Well 3"          0.59283
"Victoria well"   0.379997

8×2 Array{Any,2}:
"Jerry well"     1.0

```

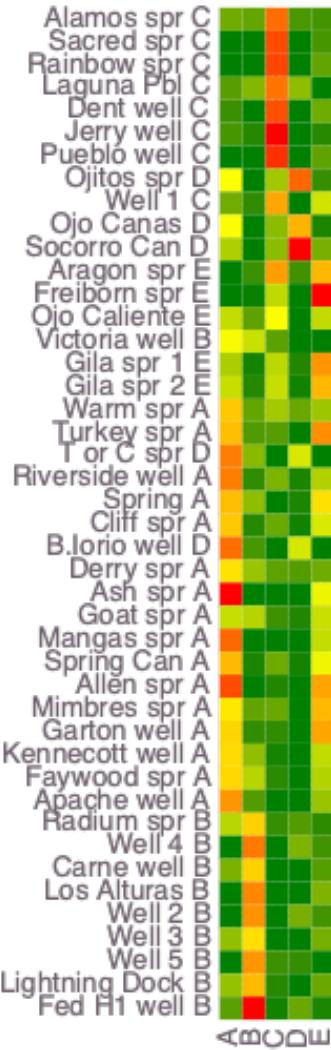
```
"Pueblo well"  0.971051
"Rainbow spr"  0.942867
"Sacred spr"   0.935706
"Dent well"    0.927135
"Alamos spr"   0.872535
"Laguna Pbl"   0.85495
"Well 1"        0.738413
```

5×2 Array{Any,2}:

```
"Socorro Can"  1.0
"Ojitos spr"   0.885484
"Ojo Canas"    0.707981
"T or C spr"   0.411346
"B.Iorio well" 0.409252
```

5×2 Array{Any,2}:

```
"Freiborn spr" 1.0
"Gila spr 1"   0.779561
"Gila spr 2"   0.695982
"Aragon spr"   0.695158
"Ojo Caliente" 0.359767
```



```

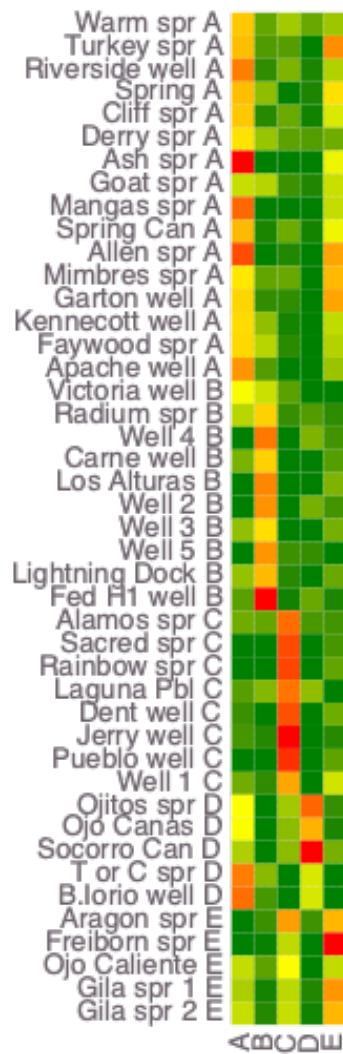
Warning: Procedure to find unique signals could not identify a solution ...
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKCluster.jl:158
Info: Signal A -> A Count: 16
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKPostprocess.jl:255
Info: Signal B -> B Count: 10
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKPostprocess.jl:255
Info: Signal C -> C Count: 8
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKPostprocess.jl:255
Info: Signal D -> D Count: 5
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKPostprocess.jl:255
Info: Signal E -> E Count: 5
@ NMFK /Users/vvv/.julia/dev/NMFK/src/NMFKPostprocess.jl:255
Info: Signal A (S1) (k-means clustering)

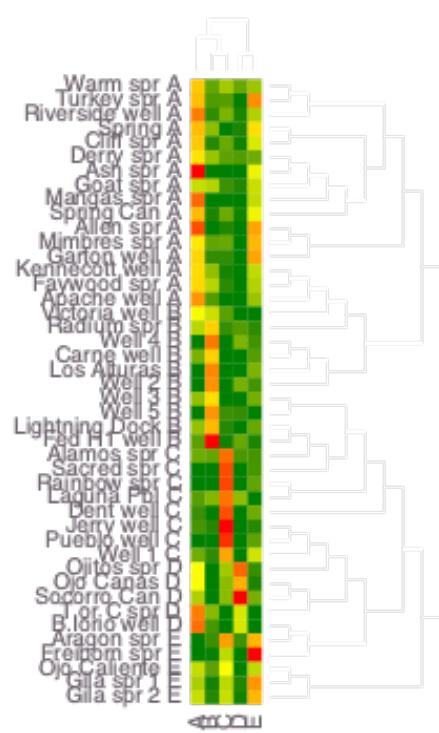
```

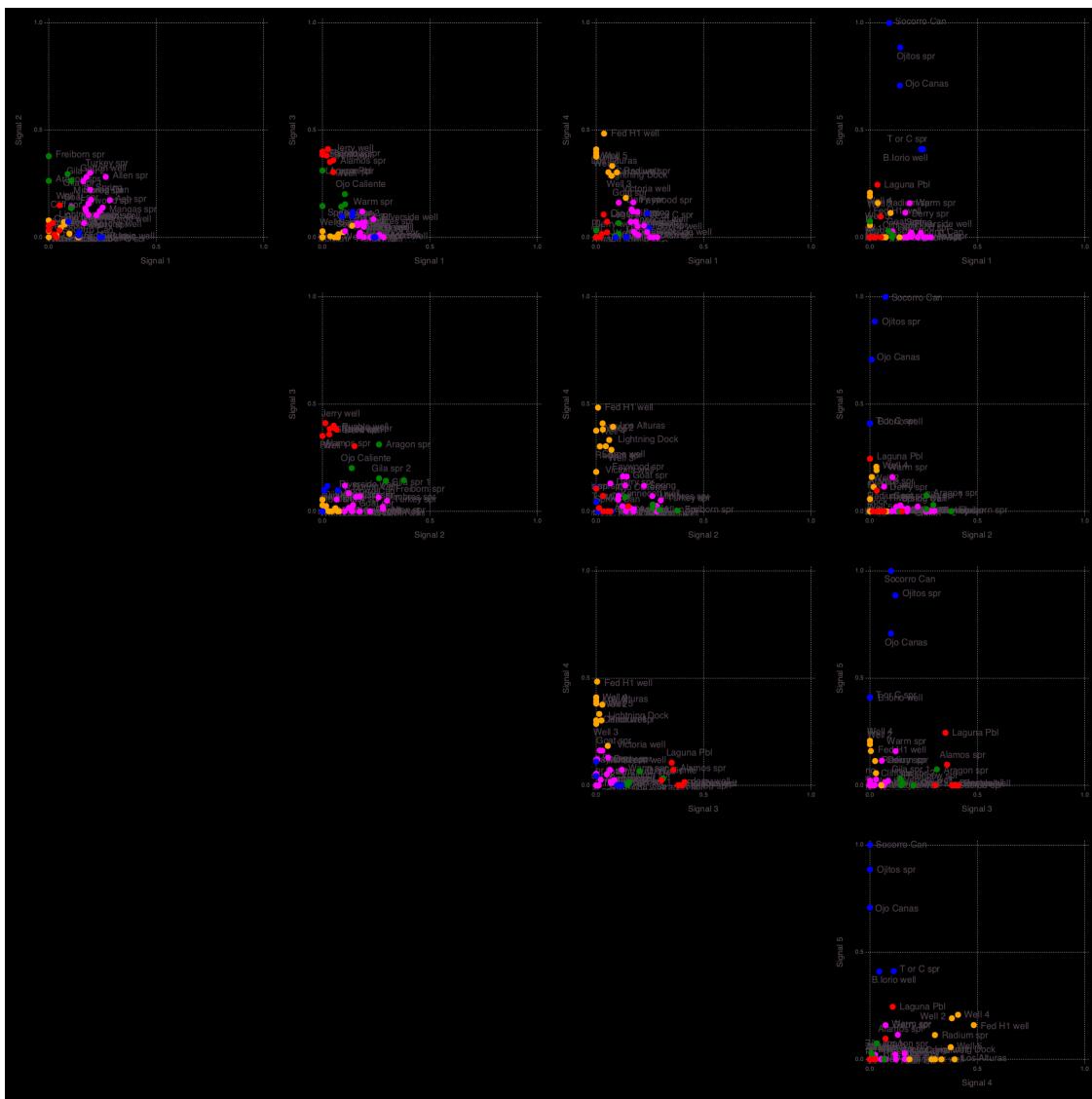
```

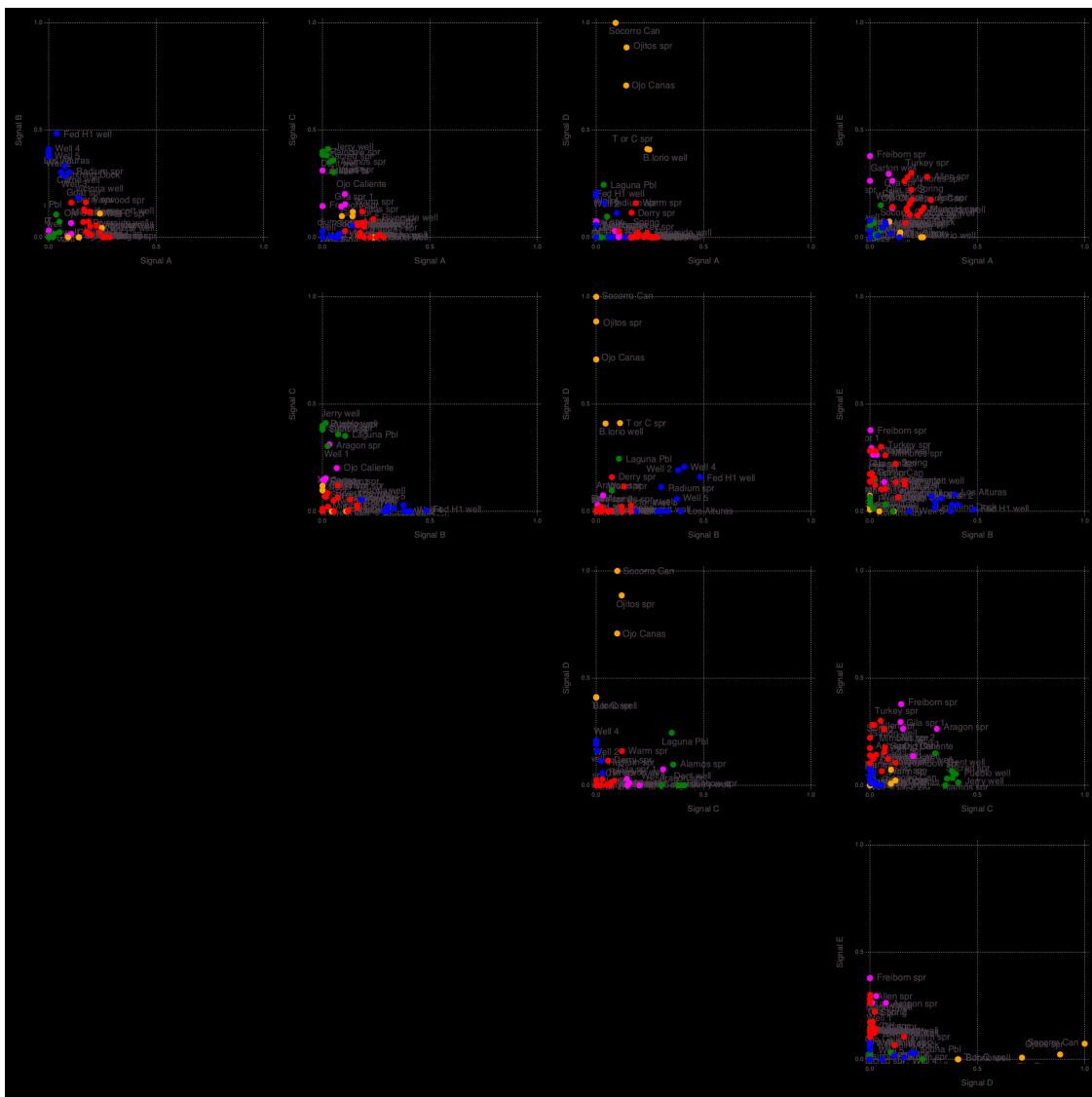
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal B (S4) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal C (S3) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal D (S5) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal E (S2) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272

```









2x2 Array{Any,2}:

|                         |         |
|-------------------------|---------|
| "Lithium concentration" | 1.0     |
| "Volcanic dike density" | 0.56854 |

6x2 Array{Any,2}:

|                            |          |
|----------------------------|----------|
| "Depth to basement"        | 0.760709 |
| "Boron concentration"      | 0.565134 |
| "Quaternary fault density" | 0.481084 |
| "Volcanic vent density"    | 0.303895 |
| "Spring density"           | 0.0      |
| "Precipitation"            | 0.0      |

4x2 Array{Any,2}:

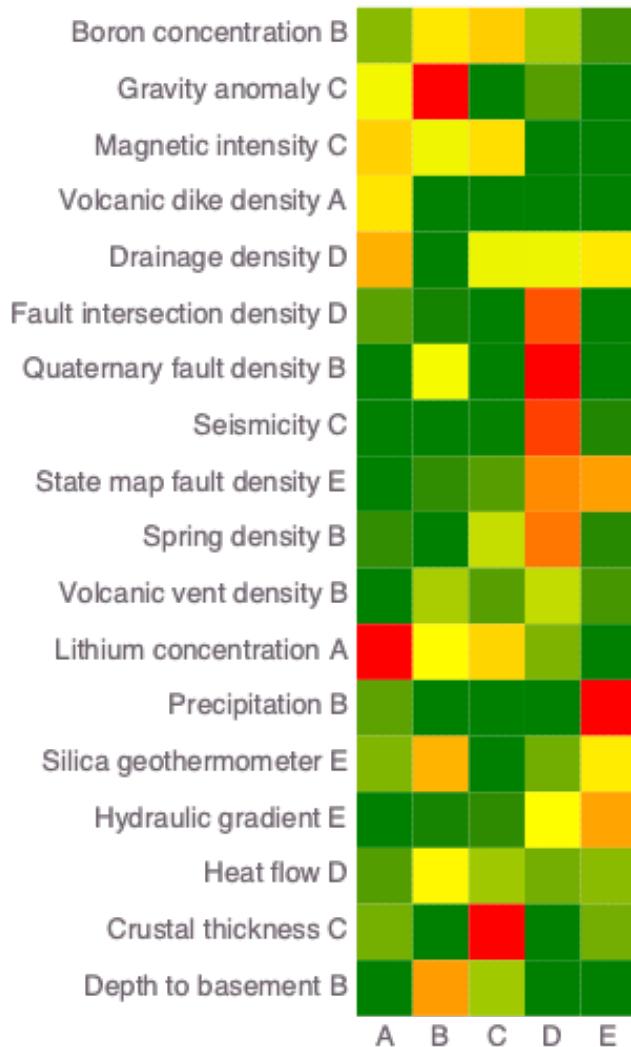
```

"Crustal thickness"    1.0
"Magnetic intensity"   0.590051
"Seismicity"          0.0030882
"Gravity anomaly"     0.0

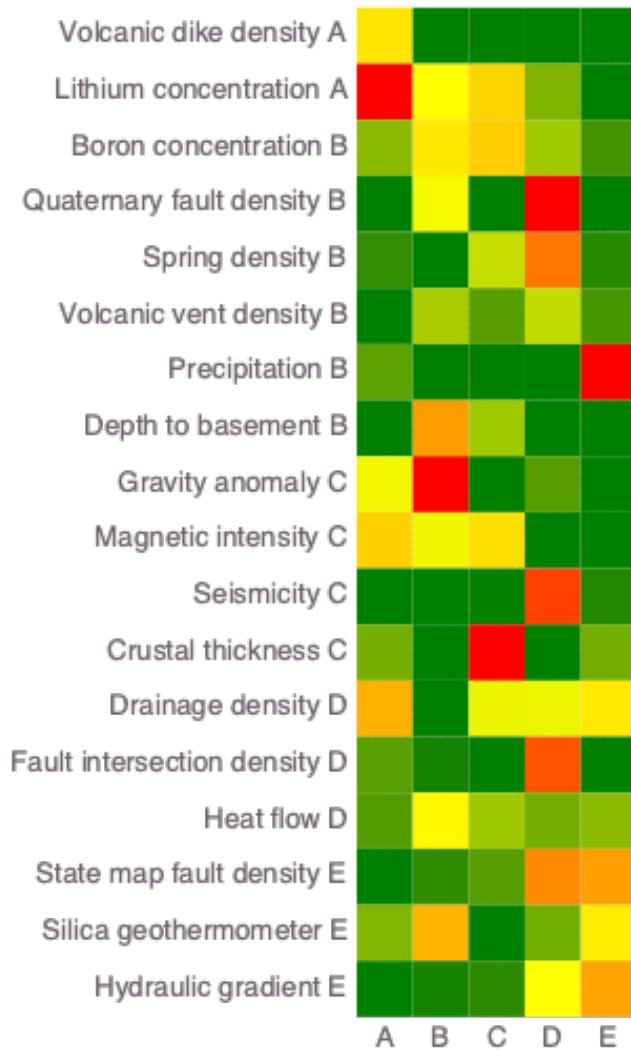
3x2 Array{Any,2}:
"Fault intersection density"  0.921753
"Drainage density"           0.458627
"Heat flow"                  0.183895

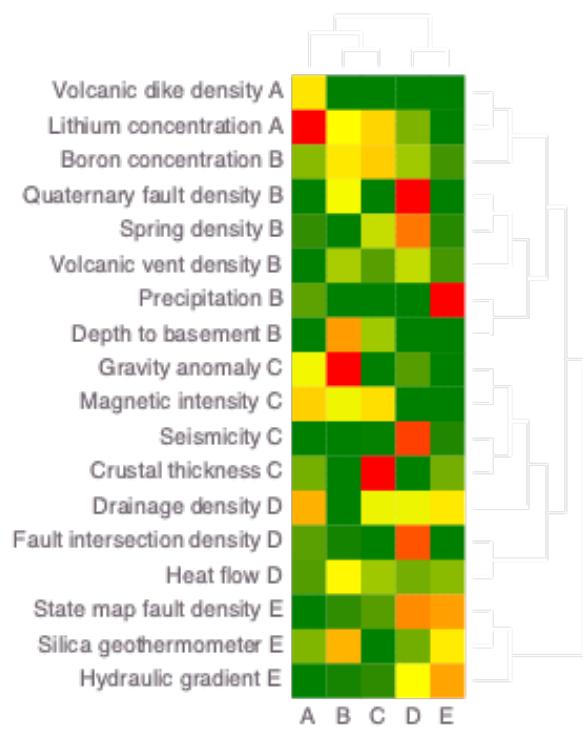
3x2 Array{Any,2}:
"State map fault density"   0.755023
"Hydraulic gradient"        0.743237
"Silica geothermometer"     0.553526

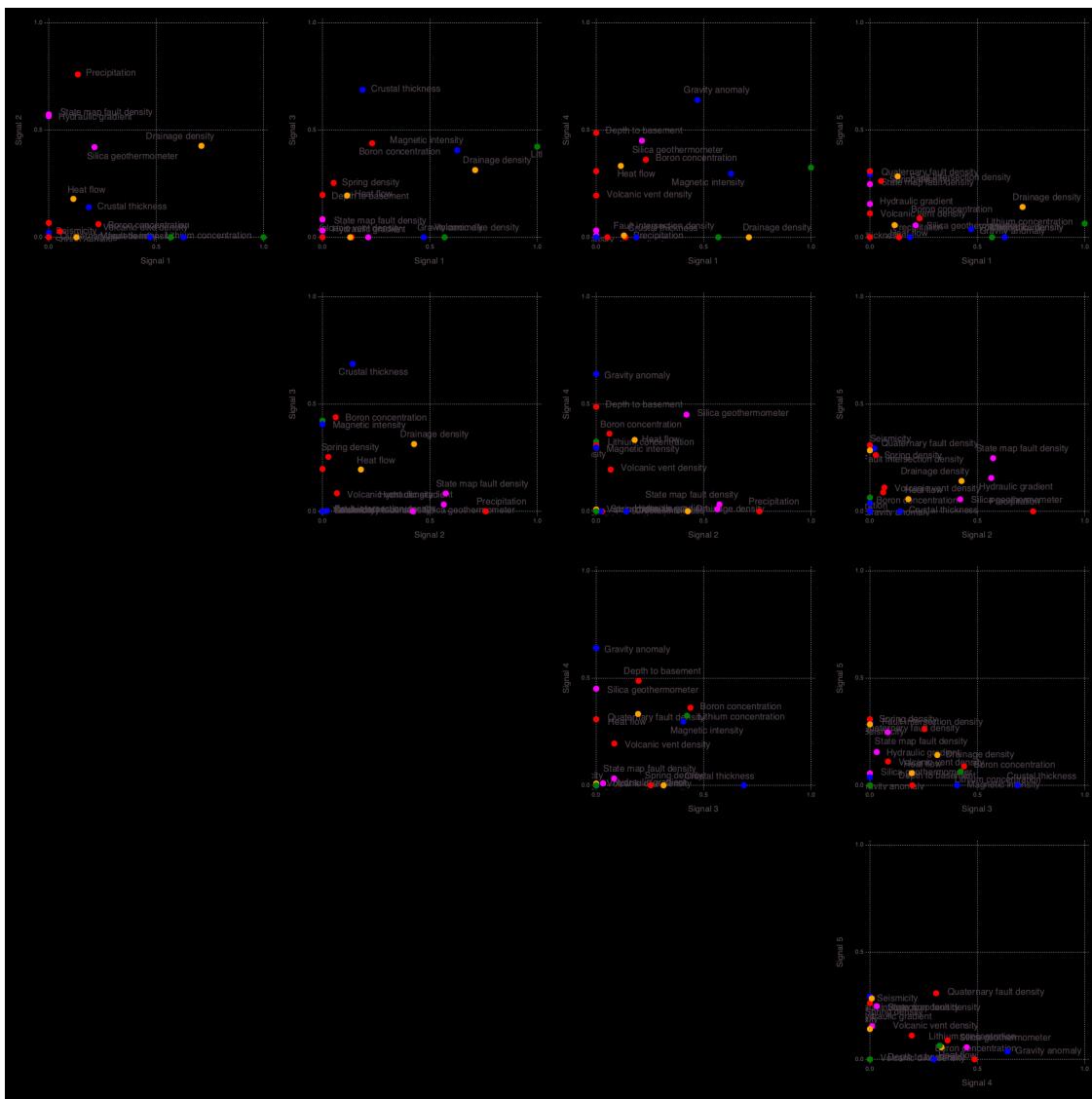
```

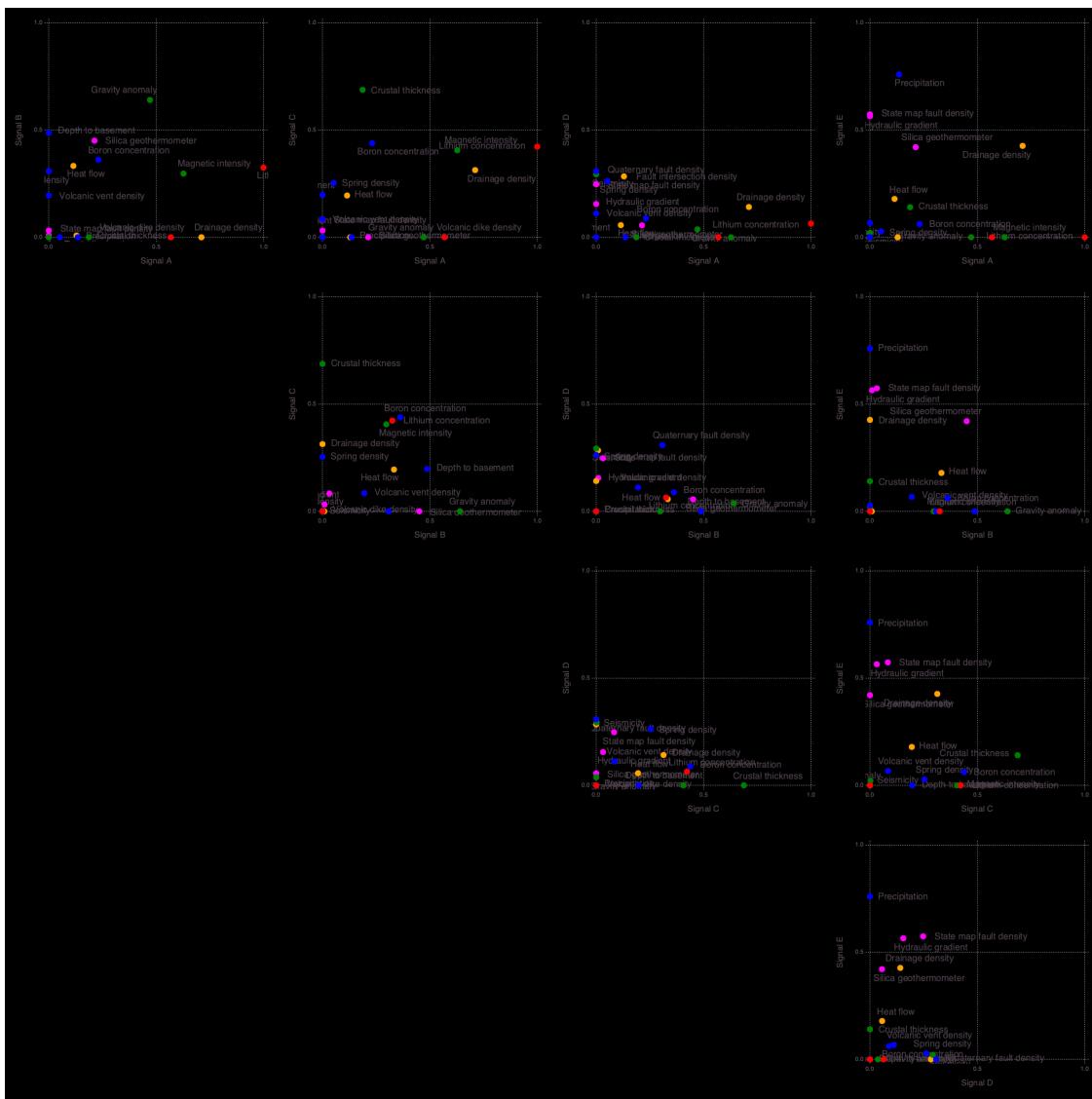


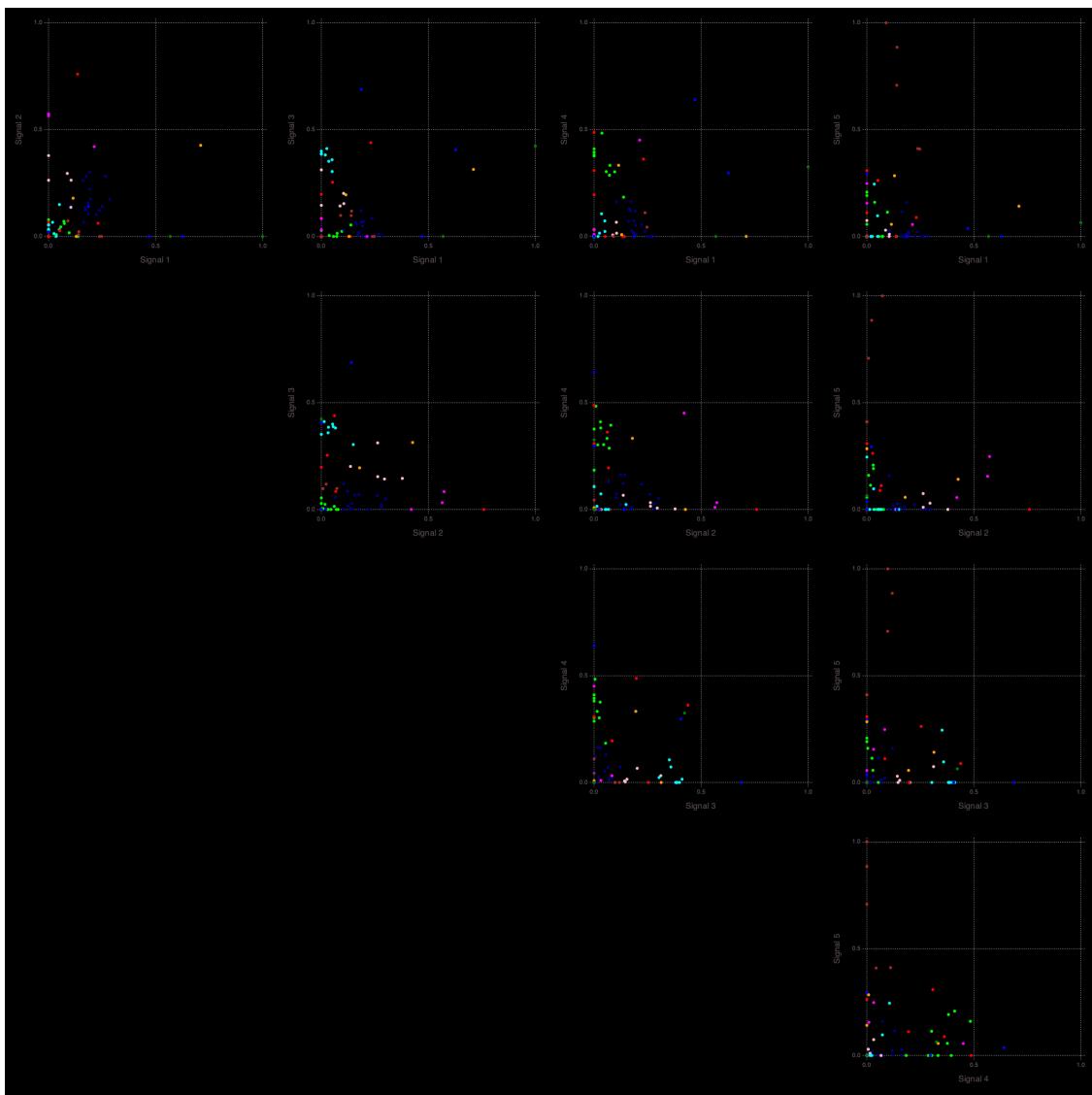
```
Info: Attributes (signals=5)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
Info: Signal A (S4) Count: 6
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal B (S3) Count: 4
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal C (S5) Count: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal D (S2) Count: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal E (S1) Count: 2
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal E -> A Count: 2
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A -> B Count: 6
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal B -> C Count: 4
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal C -> D Count: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal D -> E Count: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A (remapped k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal B (remapped k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal C (remapped k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal D (remapped k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal E (remapped k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

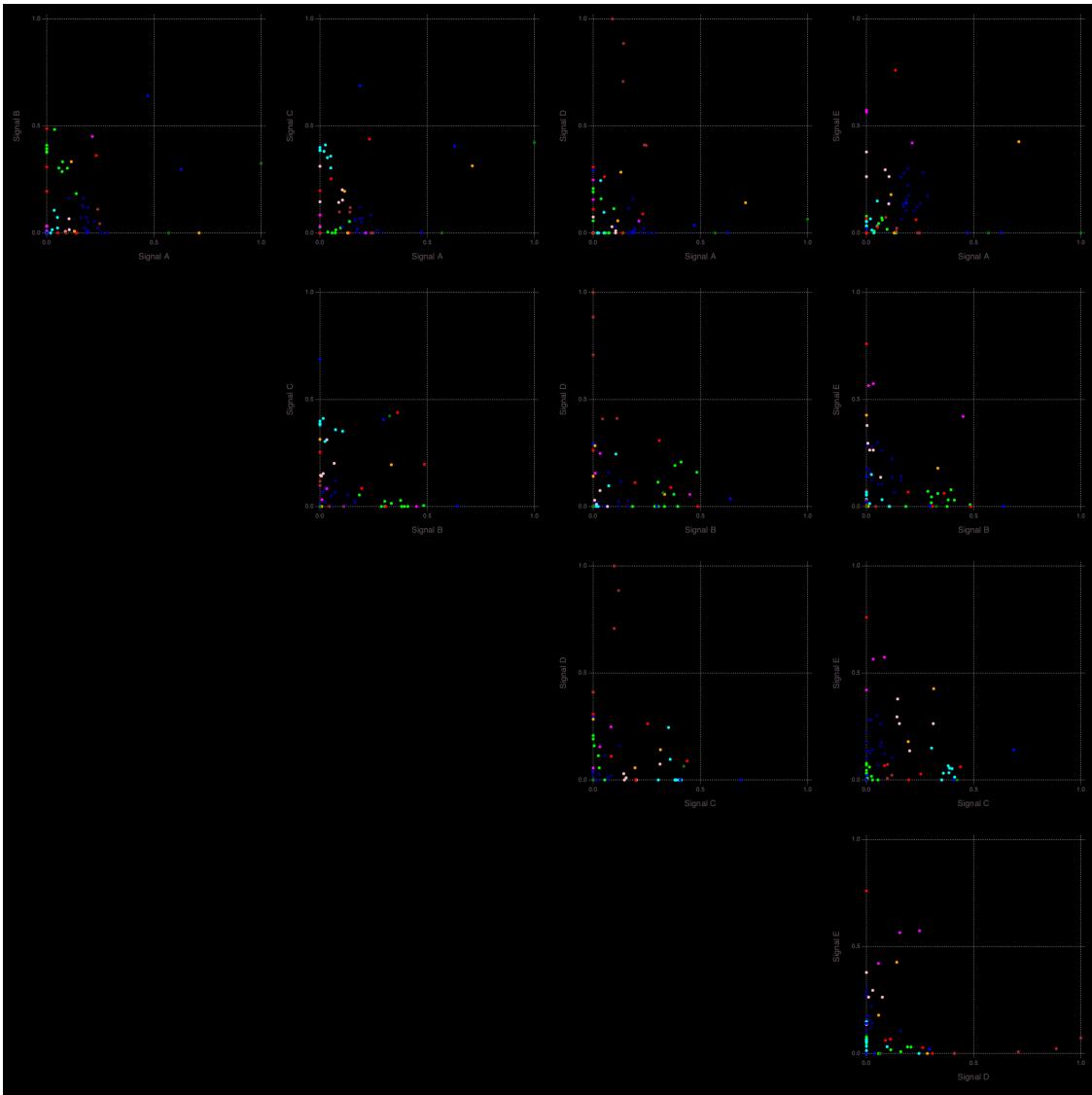












Signal importance (high->low): [2, 4, 8, 5, 1, 3, 7, 6]

Info: Number of signals: 8

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:144

Info: Locations (signals=8)

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:148

Warning: type

Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not present in workspace; reconstructing

© JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld\_types.jl:697

10×2 Array{Any,2}:

|               |          |
|---------------|----------|
| "Ash spr"     | 1.0      |
| "Apache well" | 0.950743 |
| "Spring Can"  | 0.798039 |

```

    "Mangas spr"      0.70694
    "Derry spr"       0.663338
    "Spring"          0.587286
    "Kennecott well" 0.550769
    "Faywood spr"    0.453699
    "Warm spr"        0.414987
    "Goat spr"        0.31845

7×2 Array{Any,2}:
    "Pueblo well"   1.0
    "Jerry well"     0.982349
    "Dent well"      0.884569
    "Rainbow spr"    0.884056
    "Sacred spr"     0.877946
    "Alamos spr"     0.733233
    "Laguna Pbl"     0.692272

7×2 Array{Any,2}:
    "Gila spr 2"     1.0
    "Aragon spr"      0.997091
    "Gila spr 1"      0.945916
    "Ojo Caliente"    0.578686
    "Well 1"           0.550929
    "Riverside well" 0.549312
    "Cliff spr"       0.5445

6×2 Array{Any,2}:
    "Victoria well"  0.949464
    "Lightning Dock" 0.823669
    "Radium spr"      0.601781
    "Carne well"       0.596224
    "Well 3"            0.531882
    "Los Alturas"      0.0

5×2 Array{Any,2}:
    "Allen spr"        1.0
    "Freiborn spr"     0.780095
    "Mimbres spr"      0.514682
    "Turkey spr"        0.427395
    "Garton well"      0.358771

4×2 Array{Any,2}:
    "Fed H1 well"     0.915735
    "Well 4"            0.772875
    "Well 2"            0.732798
    "Well 5"            0.720996

Info: Robust k-means analysis results are loaded from file results-
case01/Hmatrix-8-8_44-1000.jld!
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
Warning: Procedure to find unique signals could not identify a solution ...

```

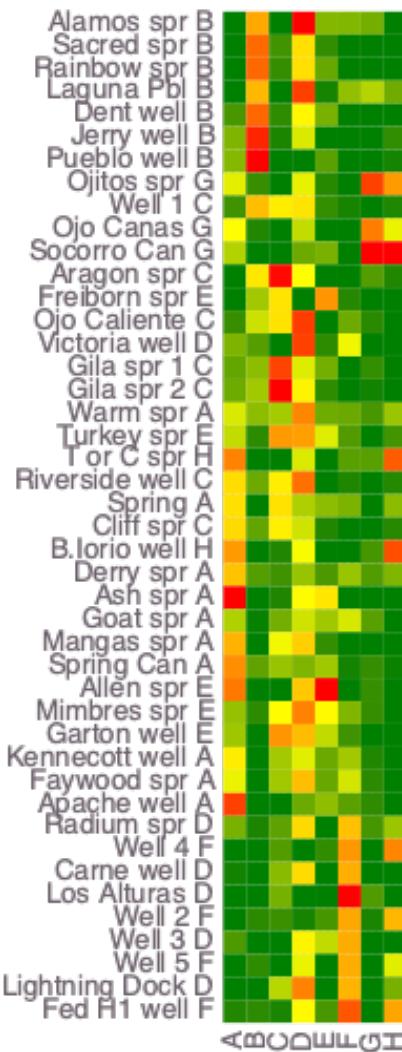
```

© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: type
Clustering.KmeansResult{Core.Array{Core.Float64,2},Core.Float64,Core.Int64} not
present in workspace; reconstructing
© JLD /Users/vvv/.julia/packages/JLD/nQ9iW/src/jld_types.jl:697
Info: Robust k-means analysis results are loaded from file results-
case01/Wmatrix-8-8_18-1000.jld!
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:67
Warning: Procedure to find unique signals could not identify a solution ...
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Warning: Procedure to find unique signals could not identify a solution ...
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkCluster.jl:158
Info: Signal A -> A Count: 10
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal B -> B Count: 7
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal C -> C Count: 7
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal D -> D Count: 6
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal E -> E Count: 5
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal F -> F Count: 4
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal G -> G Count: 3
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal H -> H Count: 2
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:255
Info: Signal A (S2) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal B (S5) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal C (S8) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal D (S3) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal E (S7) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal F (S4) (k-means clustering)
© NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272

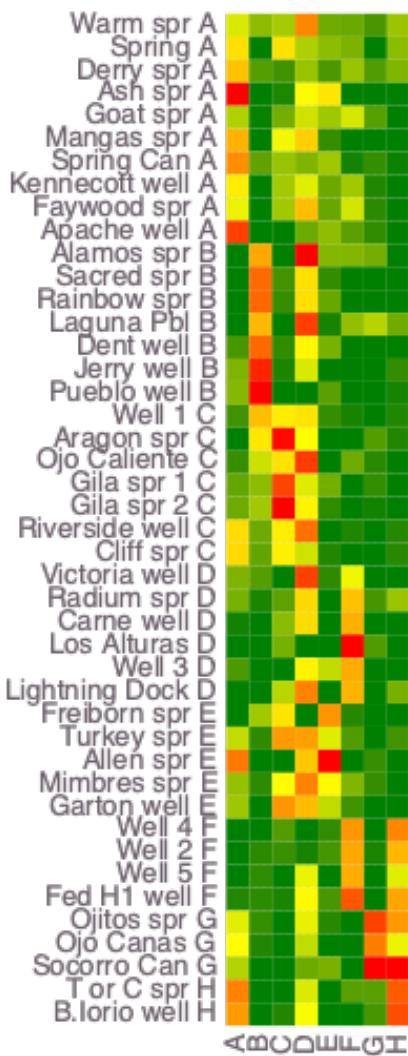
```

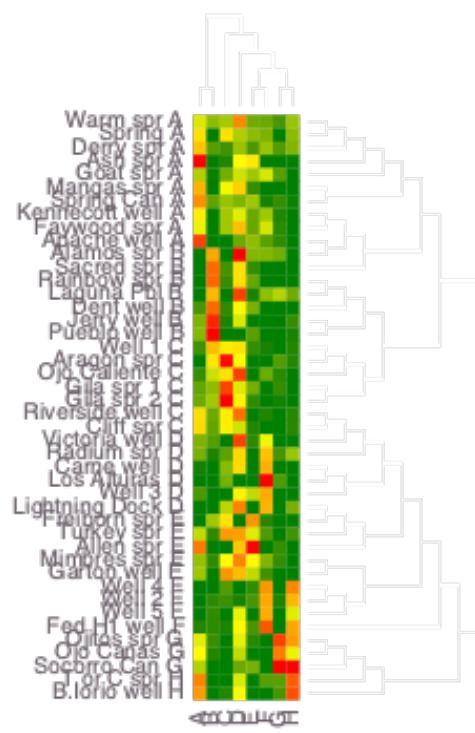
```
3x2 Array{Any,2}:
"Socorro Can" 1.0
"Ojitos spr" 0.948793
"Ojo Canas" 0.834717
```

```
2x2 Array{Any,2}:
"B.Iorio well" 0.929309
"T or C spr" 0.905042
```



```
Info: Signal G (S6) (k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
Info: Signal H (S1) (k-means clustering)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:272
```









**2×2 Array{Any,2}:**

|                              |          |
|------------------------------|----------|
| "Drainage density"           | 1.0      |
| "Fault intersection density" | 0.139857 |

**2×2 Array{Any,2}:**

|                      |          |
|----------------------|----------|
| "Crustal thickness"  | 1.0      |
| "Magnetic intensity" | 0.593375 |

**2×2 Array{Any,2}:**

|                           |          |
|---------------------------|----------|
| "State map fault density" | 0.889845 |
| "Volcanic dike density"   | 0.0      |

**3×2 Array{Any,2}:**

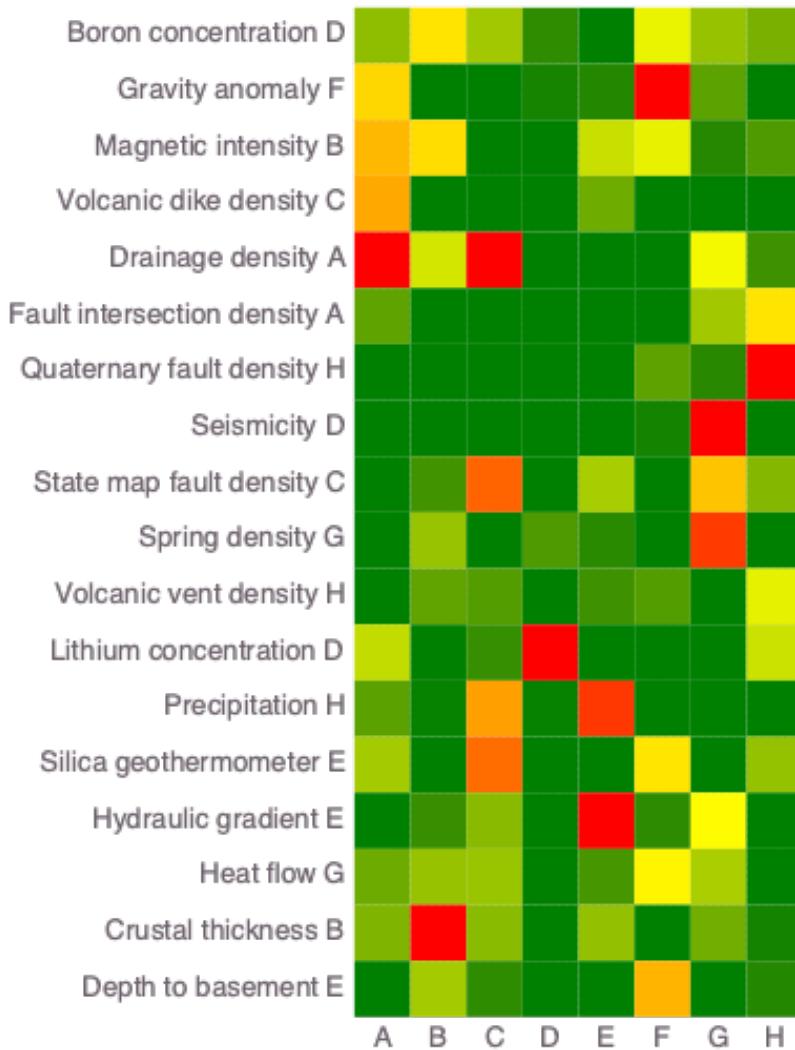
```
"Lithium concentration" 1.0
"Boron concentration"    0.0468254
"Seismicity"            0.0

3x2 Array{Any,2}:
"Hydraulic gradient"   1.0
"Silica geothermometer" 0.0
"Depth to basement"     0.0

1x2 Array{Any,2}:
"Gravity anomaly"      1.0

2x2 Array{Any,2}:
"Spring density"        0.957
"Heat flow"              0.308393

3x2 Array{Any,2}:
"Quaternary fault density" 1.0
"Volcanic vent density"    0.442817
"Precipitation"           0.0
```

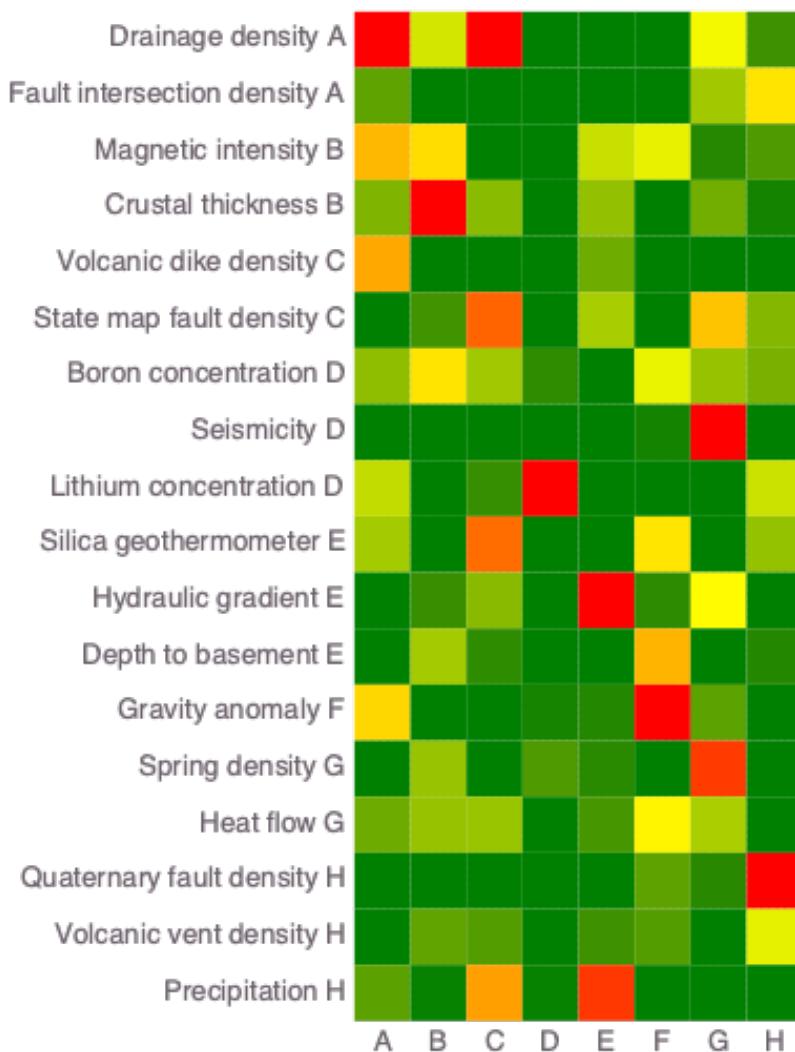


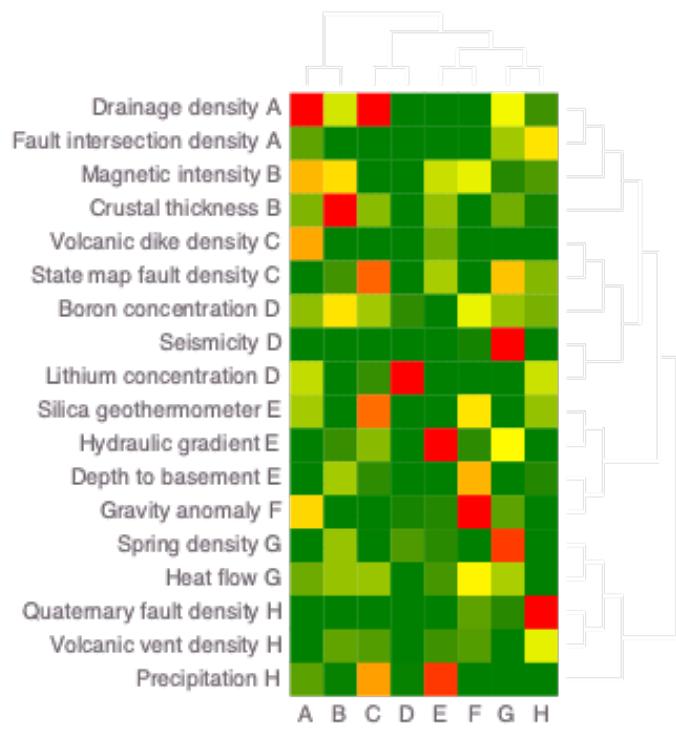
```

Info: Attributes (signals=8)
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:322
Info: Signal A (S3) Count: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal B (S1) Count: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal C (S7) Count: 3
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal D (S5) Count: 2
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal E (S8) Count: 2
@ NMFk /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal F (S2) Count: 2

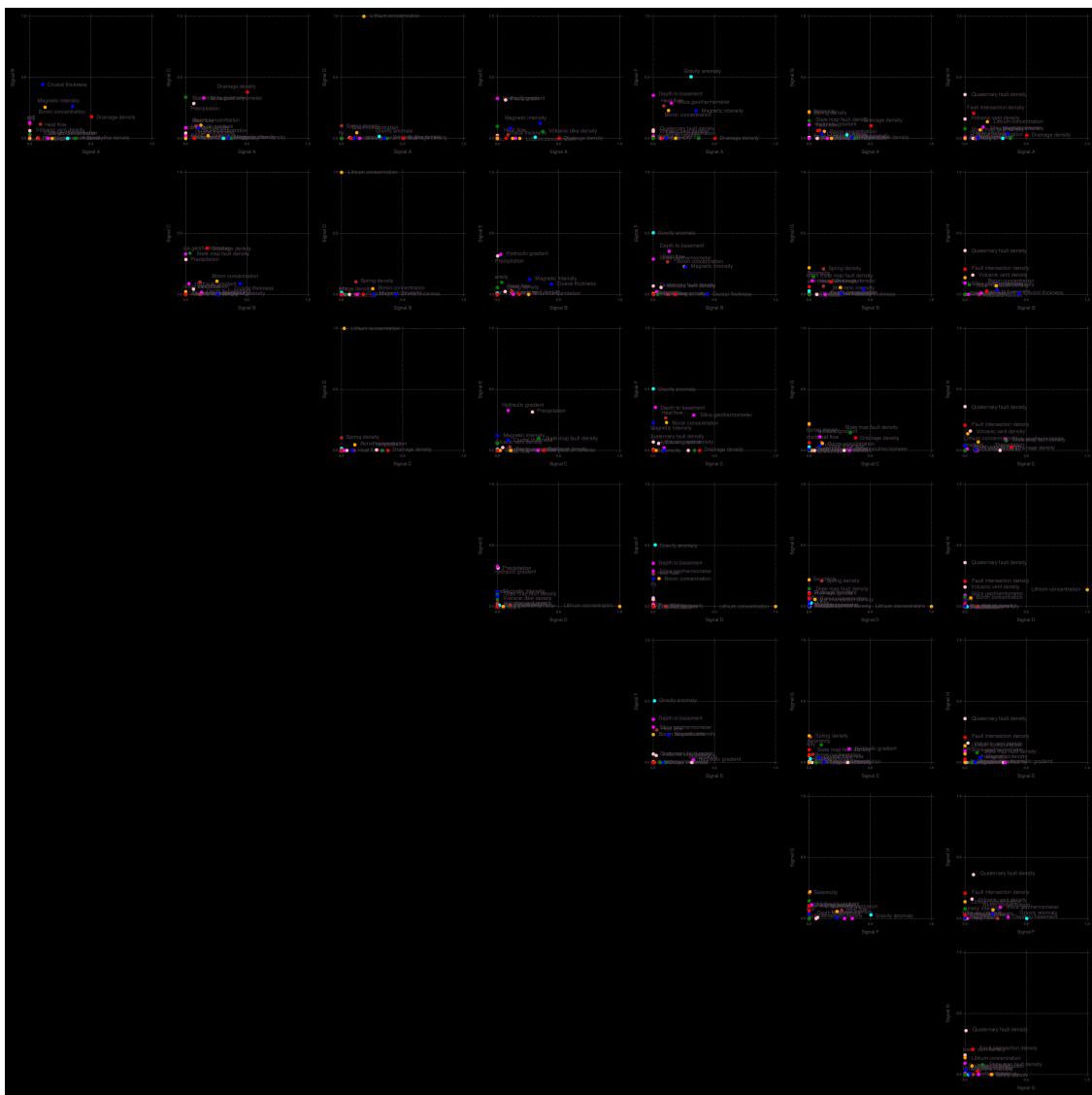
```

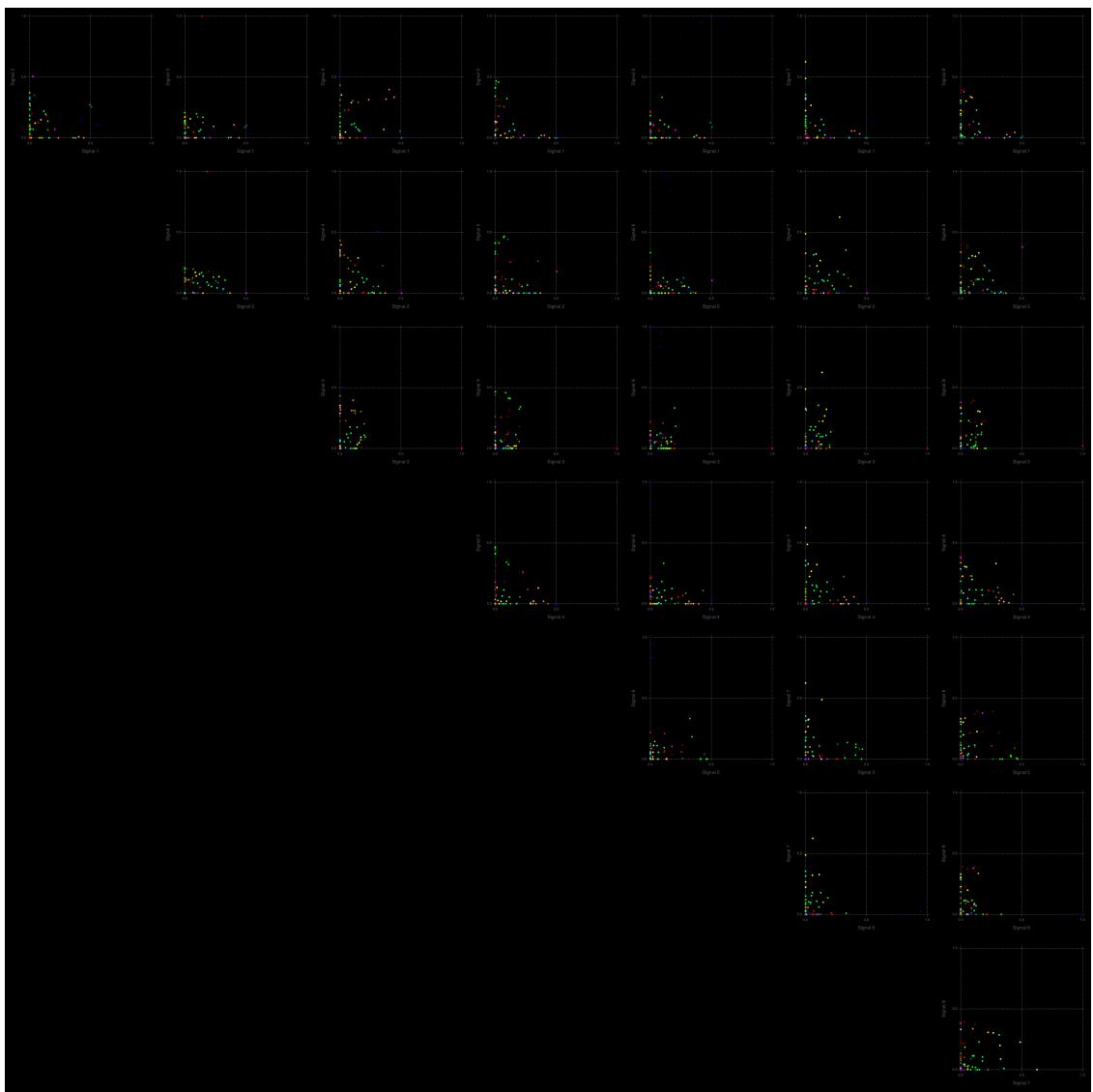
```
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal G (S6) Count: 2
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal H (S4) Count: 1
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:335
Info: Signal F -> A Count: 2
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal D -> B Count: 2
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal E -> C Count: 2
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A -> D Count: 3
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal C -> E Count: 3
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal H -> F Count: 1
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal G -> G Count: 2
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal B -> H Count: 3
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:345
Info: Signal A (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal B (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal C (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal D (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal E (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal F (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal G (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
Info: Signal H (remapped k-means clustering)
@ NMFK /Users/vvv/.julia/dev/NMFk/src/NMFkPostprocess.jl:360
```

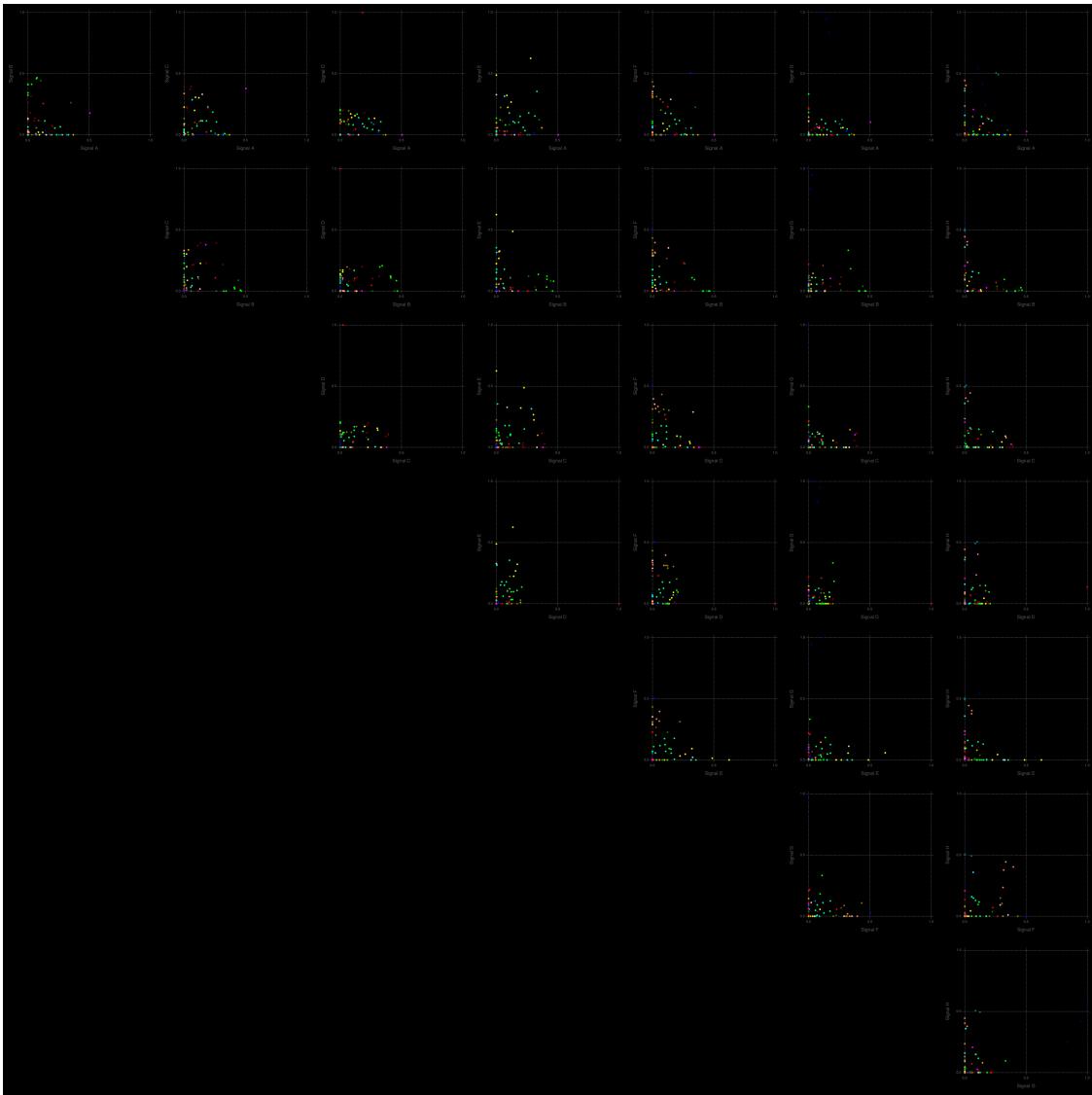










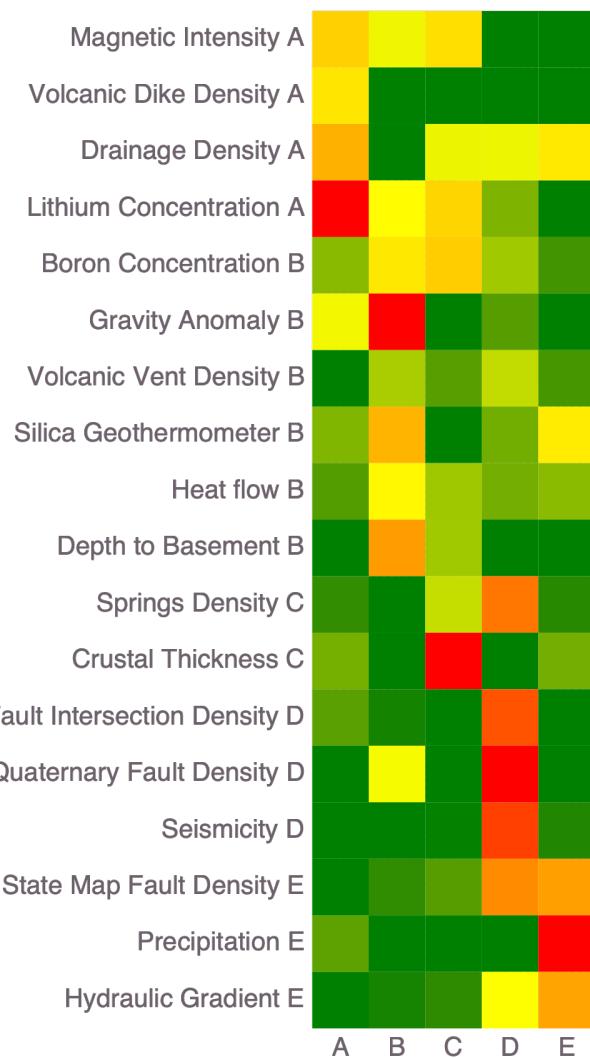


**Analysis of the 5-signature solution** The results for a solution with **5** signatures presented above will be further discussed here.

The geothermal attributes are clustered into **5** groups:

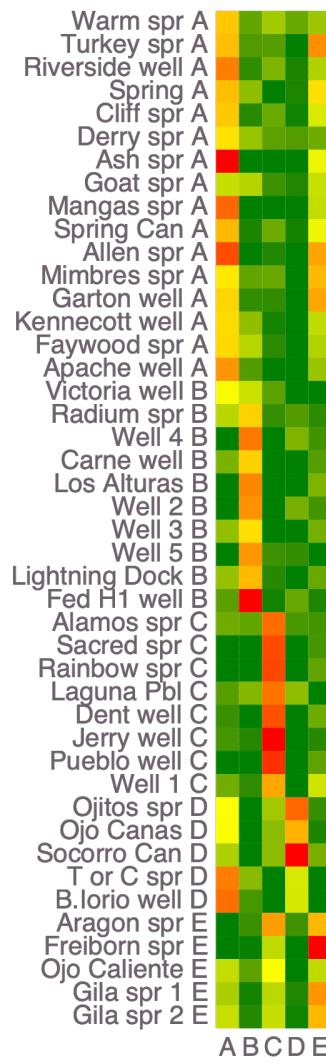
```
<iframe src="../results-case01/attributes-5-groups.txt" frameborder="0" height="400" width="95%"></iframe>
```

This grouping is based on analyses of the attribute matrix  $W$ :



The well locations are also clustered into **5** groups:

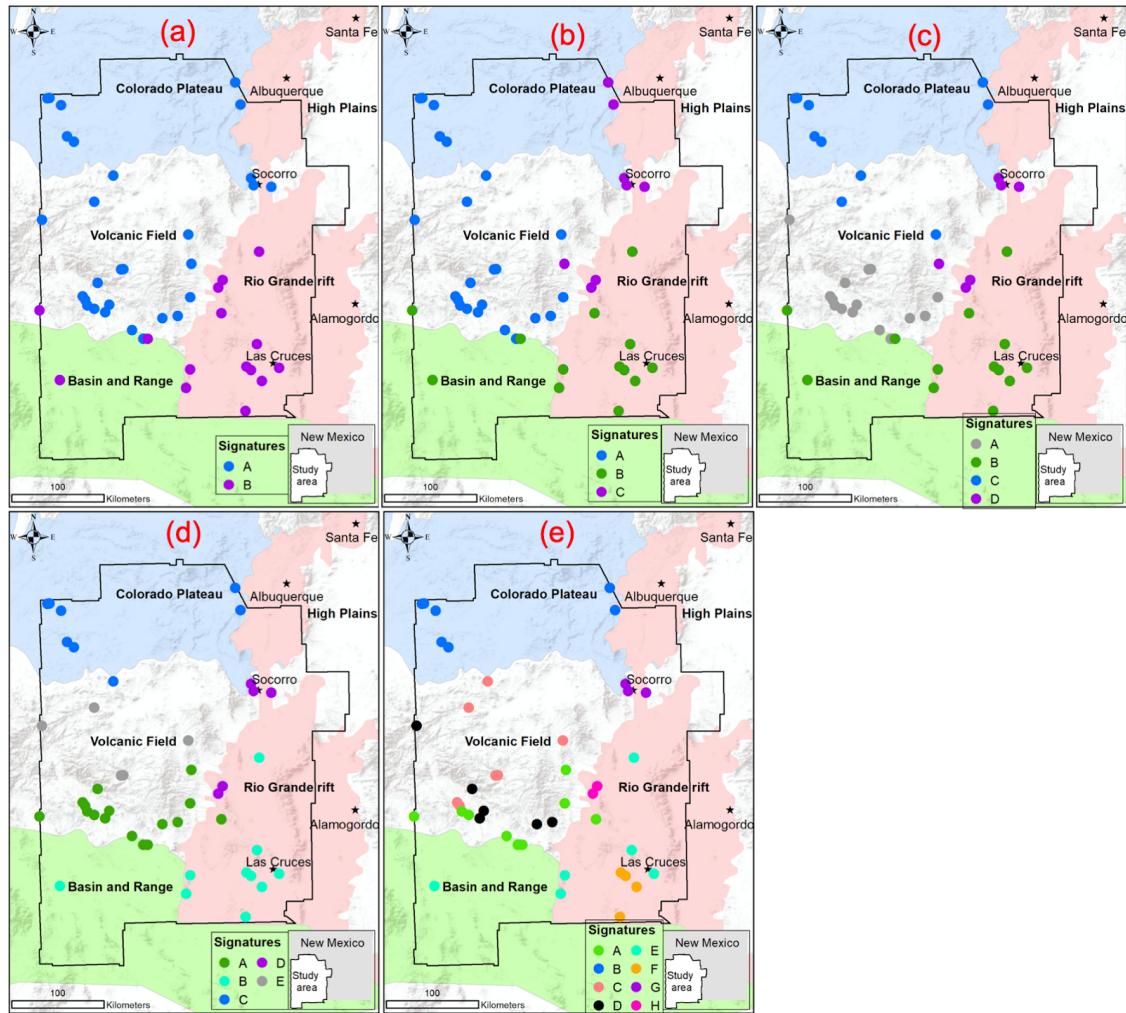
This grouping is based on analyses of the location matrix  $H$ :



The map [.../figures-case01/locations-5-map.html](#) provides interactive visualization of the extracted location groups (the html file can be also opened with any browser).

```
<iframe src=".../figures-case01/locations-5-map.html" frameborder="0" height="400" width="50%">>
```

**Comparison of the ML solutions against the SWNM physiographic provinces** Spatial association of the extracted signatures with the four physiographic provinces in SWNM is summarized here:



Clearly, the ML algorithm was able to blindly indentify the physiographic provinces associated with analyzed hydrogeothermal systems without providing any information about their location (coordinates).