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MEAN-SHIFT AND HIERARCHICAL CLUSTERING FOR TEXTURED POLARIMETRIC SAR IMAGE SEGMENTATION/CLASSIFICATION

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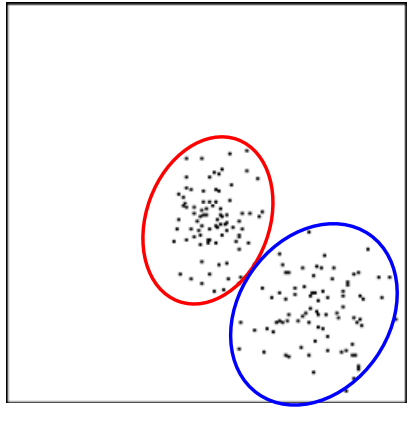
Exploration in Segmentation - Clustering

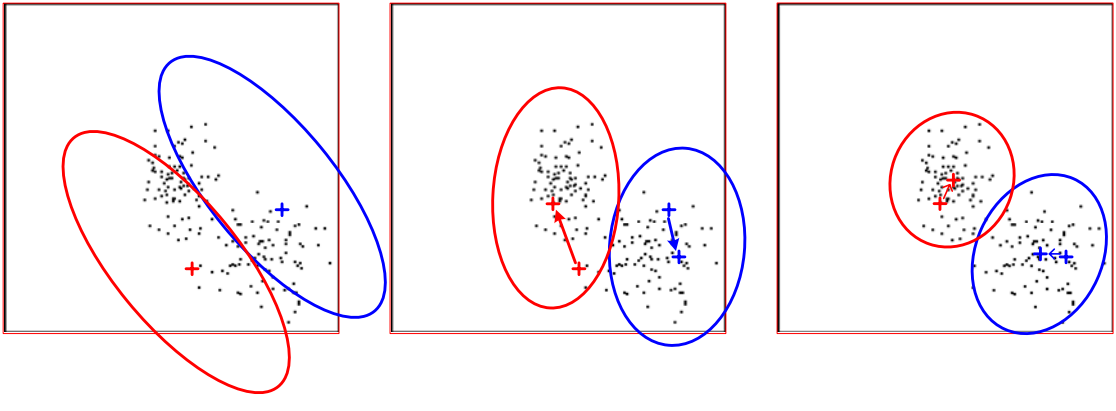
Utilization of texture information

- Clustering - attributes - segmentation
- The segment clustering approach
- Mean-shift clustering
- Distance measures for PolSAR images
- Results with the K distribution

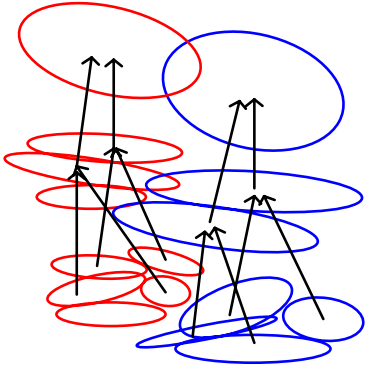
- **Clustering is the partition of data points into groups or clusters (unsupervised classification)**
- **Iterative and hierarchical techniques**

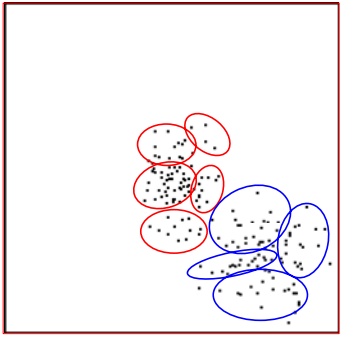


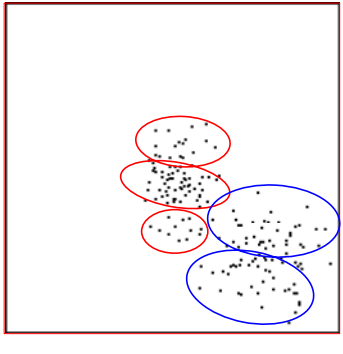
- **Iterative clustering**
- **Move group centers (K-means algorithm)**
- **The number of groups is fix**

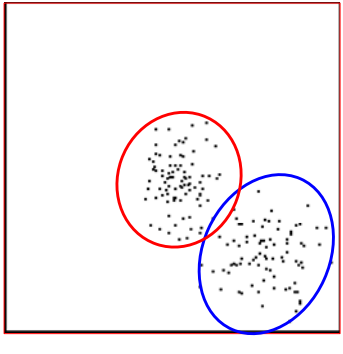


- **Hierarhical clustering**
- **Sequential merging of clusters**
- **Merge the best pair**
- **Represented by a tree**









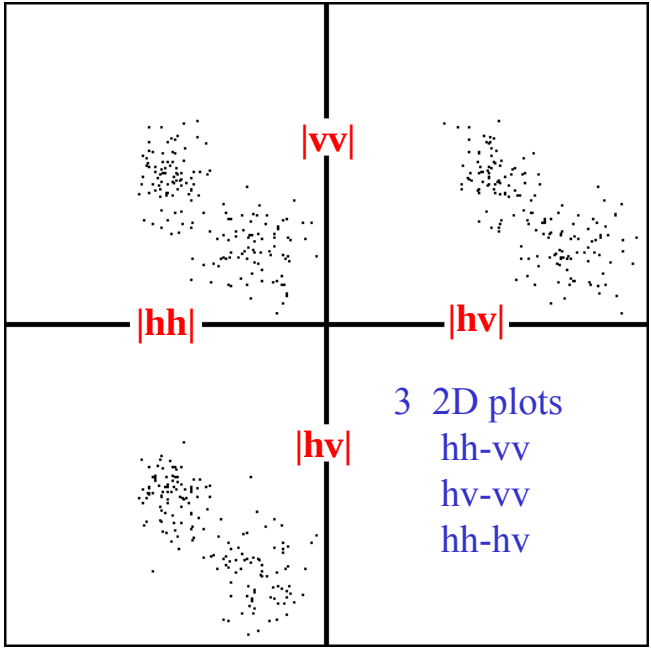
- **Attributes or feature space (many dimensions)**
- **Radiometric information (or color/spectral)**

Radar 1-look

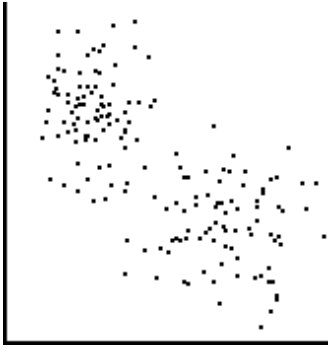
$$x = \begin{bmatrix} hh \\ hv \\ vv \end{bmatrix}$$

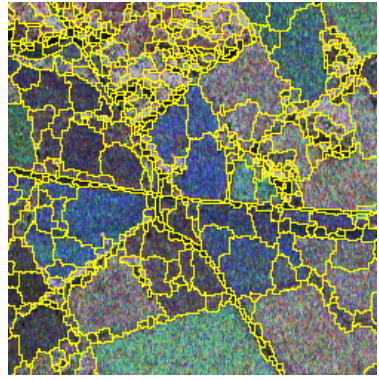
Radar multi-look

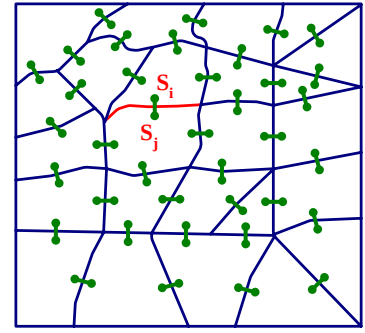
$$Z = \begin{bmatrix} \overline{hh\ hh^*} & \overline{hh\ hv^*} & \overline{hh\ vv^*} \\ \overline{hv\ hh^*} & \overline{hv\ hv^*} & \overline{hv\ vv^*} \\ \overline{vv\ hh^*} & \overline{vv\ hv^*} & \overline{vv\ vv^*} \end{bmatrix}$$



- **Spatial information - position in the image**
- **Clustering -- distance between points D(Gi,Gj)**
- **Segmentation -- only adjacent regions**

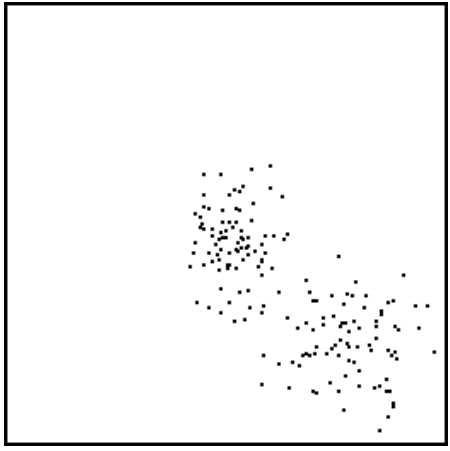




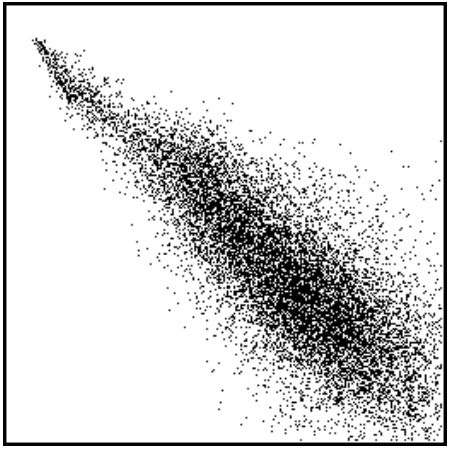


- **Exploring the space between**
  clustering --- and --- segmentation
  ← spatial information→

Subpart of image



Whole image



- **Exploring the space between**
  clustering --- and --- segmentation
  ← spatial information→

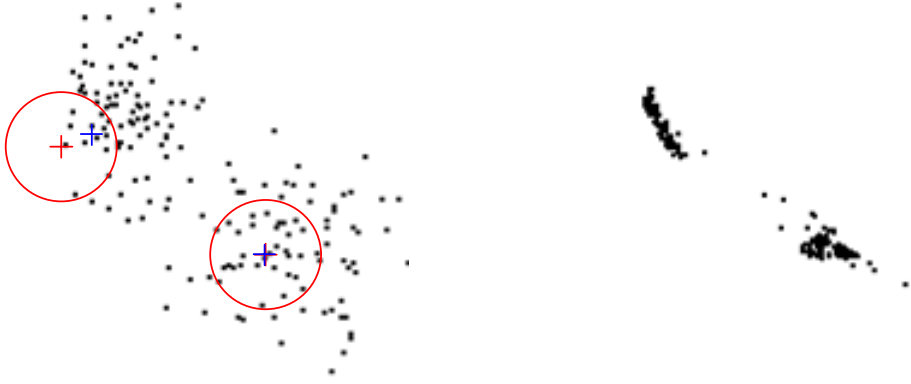
- **Hierarchical segmentation of the image**
- **Clustering of regions-segments**
  →region groups or aggregates

- **Use only large regions-segments**
- **Mean-shift clustering (iterative)**
- **Followed by hierarchical clustering**
- **Assign a small segment to the most similar group**

- **Combining → hierarchical / iterative**
  → segmentation / clustering
- **Different ways to explore the partition space**

- **Hierarchical segmentation** **- spatial information**
- **Iterative Mean-Shift clustering** **- spatial information**
- **Hierarchical clustering**

- **Mean-Shift clustering move every data points toward higher probability density zones (modes)**
- **Density → point count over a window (histogram)**
- **Direction toward higher density**
  → position of weighted mean (window)



MEAN-SHIFT

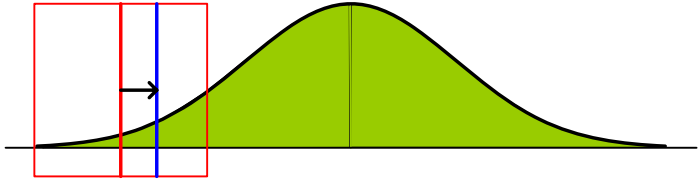
Dspectral = D(Gi,Gj) / Fspectral

Dspatial = Distance between centers / Fspatial

Weight = EXP [- ($Dspectral^2$ +$Dspatial^2$)]

Mean = weighted point mean

Fhift = α value + (1-α) Mean



- **Distance measure D(Gi,Gj) for PolSar images**
- **Maximum Log Likelihood criterion (MLL)**

$$P = \{G_i\} \quad \rightarrow \quad \theta_i = \Sigma_i, \alpha_i \quad \rightarrow \quad p(Z_k \mid \theta_{G(k)})$$

$$MLL(P) = \sum_{Z_k \in I} \ln p(Z_k \mid \theta_{G(k)}) = \sum_{G_i \in P} MLL(G_i)$$

$$D(G_i, G_j) = MLL(G_i) + MLL(G_j) - MLL(G_i \cup G_j)$$

- **Non textured PolSAR image**
- **Z_k follows a complex Wishart distribution**

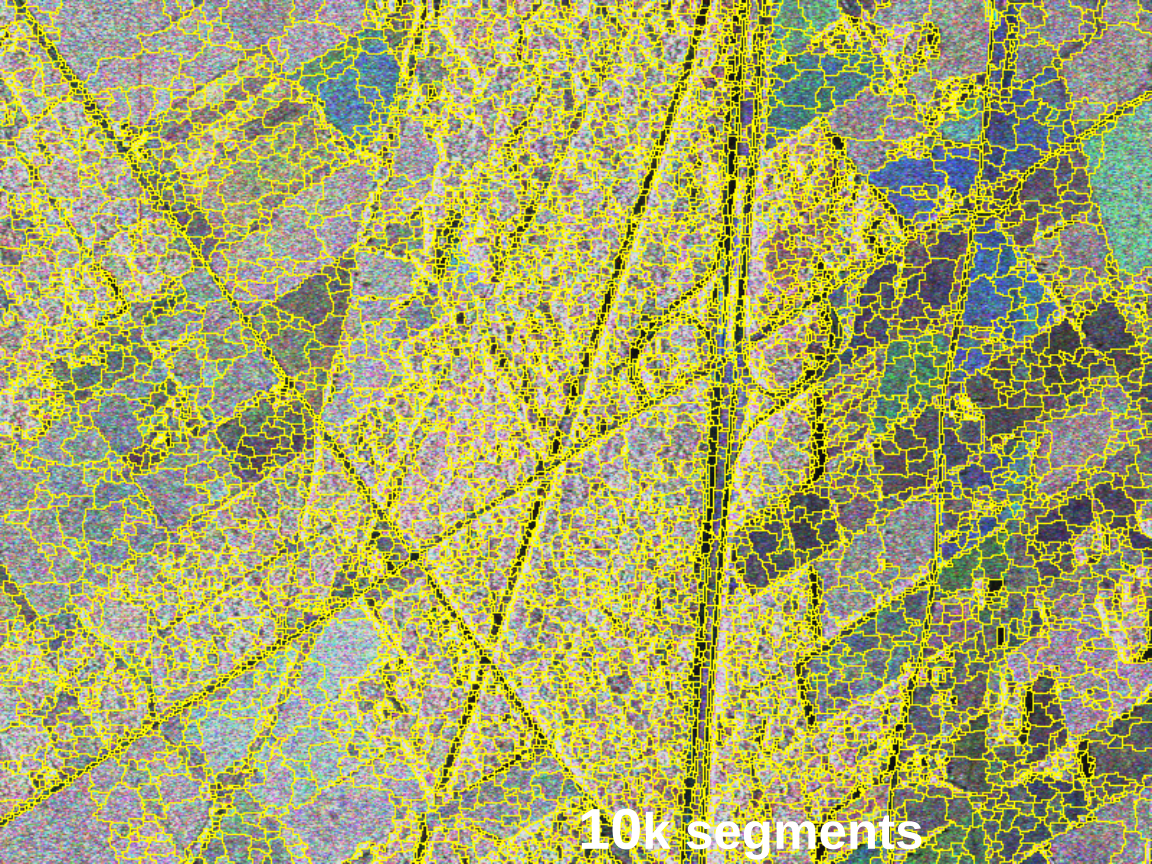
$$p(Z_k \mid \Sigma) = \frac{L^{3L} \left|Z_k\right|^{L-3} \quad \exp\left\{-L\, tr\left(\Sigma^{-1} Z_k\right)\right\}}{\pi^3\, \Gamma(L)\Gamma(L-1)\Gamma(L-2) \left|\Sigma\right|^{L}}$$

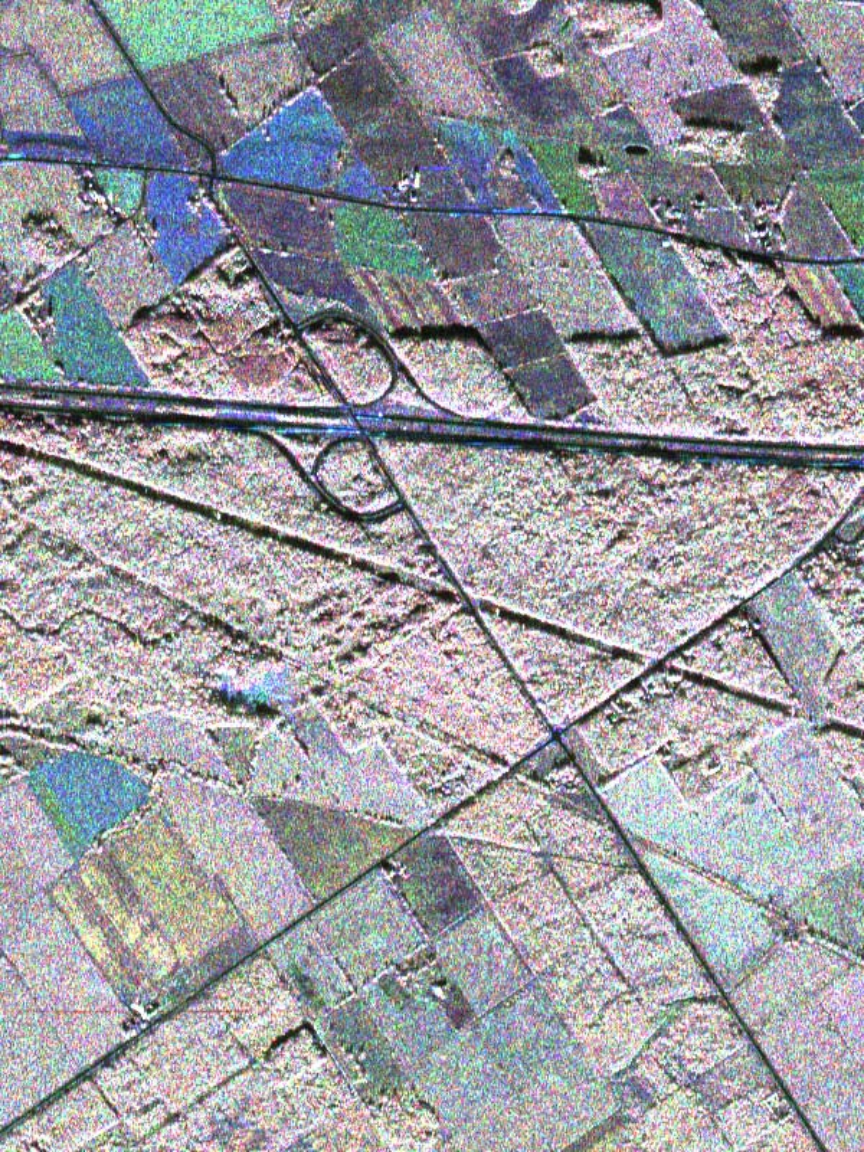
$$D(G_i, G_j) = (n_i + n_j) \ln\left|\hat{\Sigma}_{Gi \cup Gj}\right| - n_i \ln\left|\hat{\Sigma}_{Gi}\right| - n_j \ln\left|\hat{\Sigma}_{Gj}\right|$$

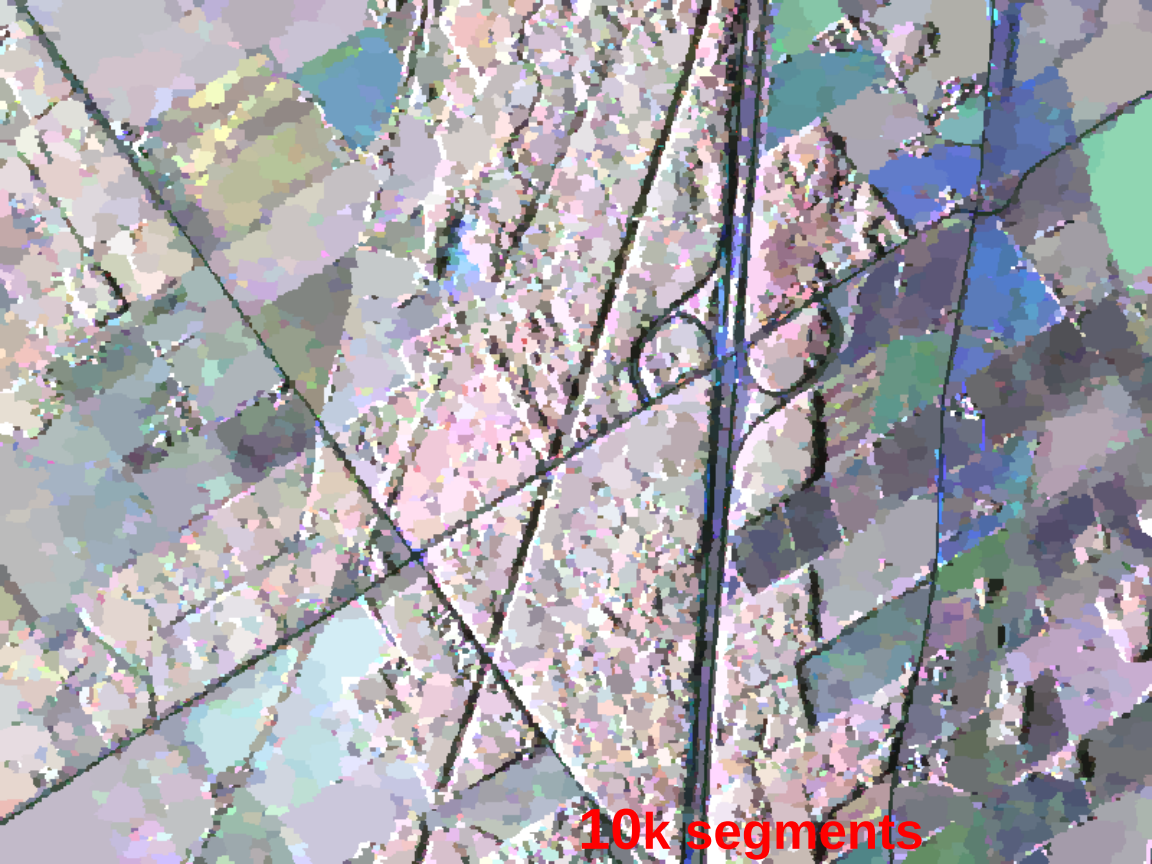
- **Textured PolSAR image** ($Z_k = \mu_k Z_{k\text{-homogeneous}}$)
- Z_k **follows a complex K distribution**

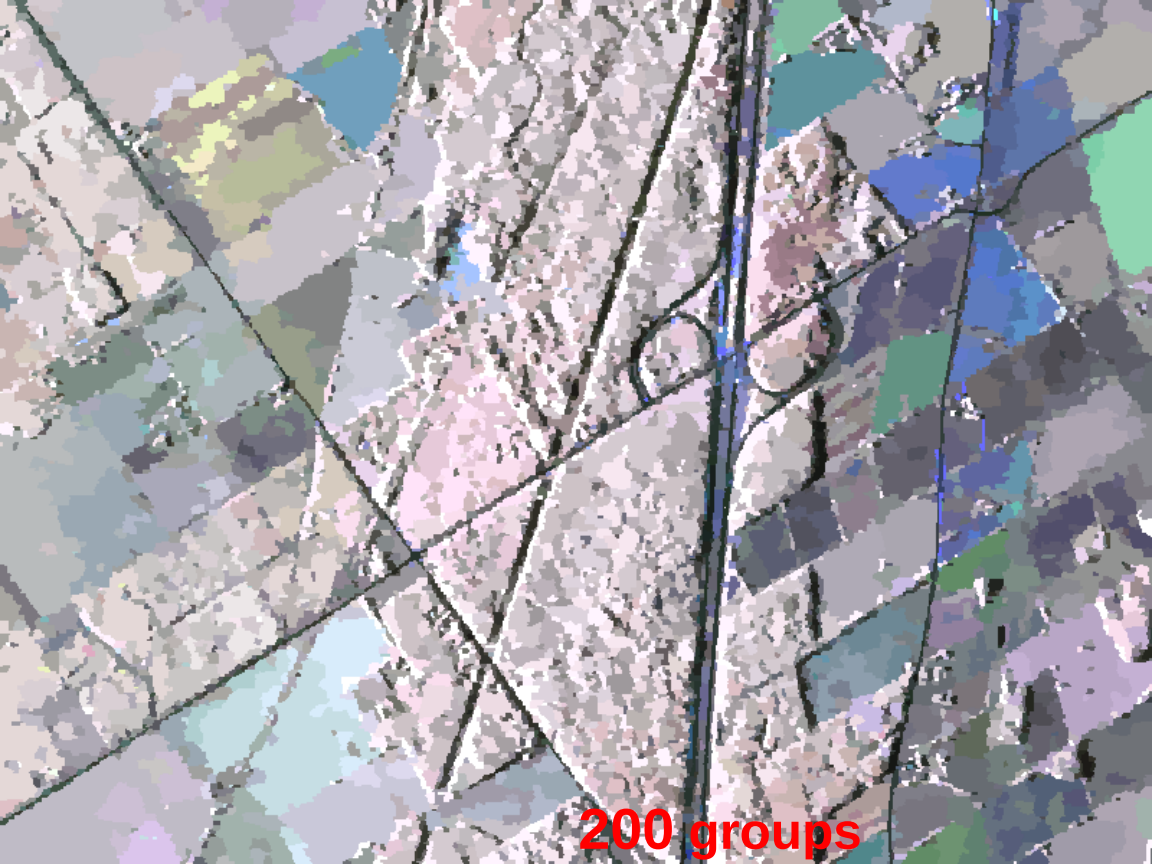
$$p(Z_k \mid \alpha, \Sigma) = \frac{(\alpha L)^{(3L+\alpha)/2}\, 2|Z_k|^{L-3} \left(tr\left(\Sigma^{-1} Z_k\right)\right)^{(\alpha-3L)/2}}{\pi^3\, \Gamma(L)\Gamma(L-1)\Gamma(L-2)\, \Gamma(\alpha)\, |\Sigma|^L} K_{3L-\alpha}\left\{2\sqrt{\alpha L\, tr\left(\Sigma^{-1} Z_k\right)}\right\}$$

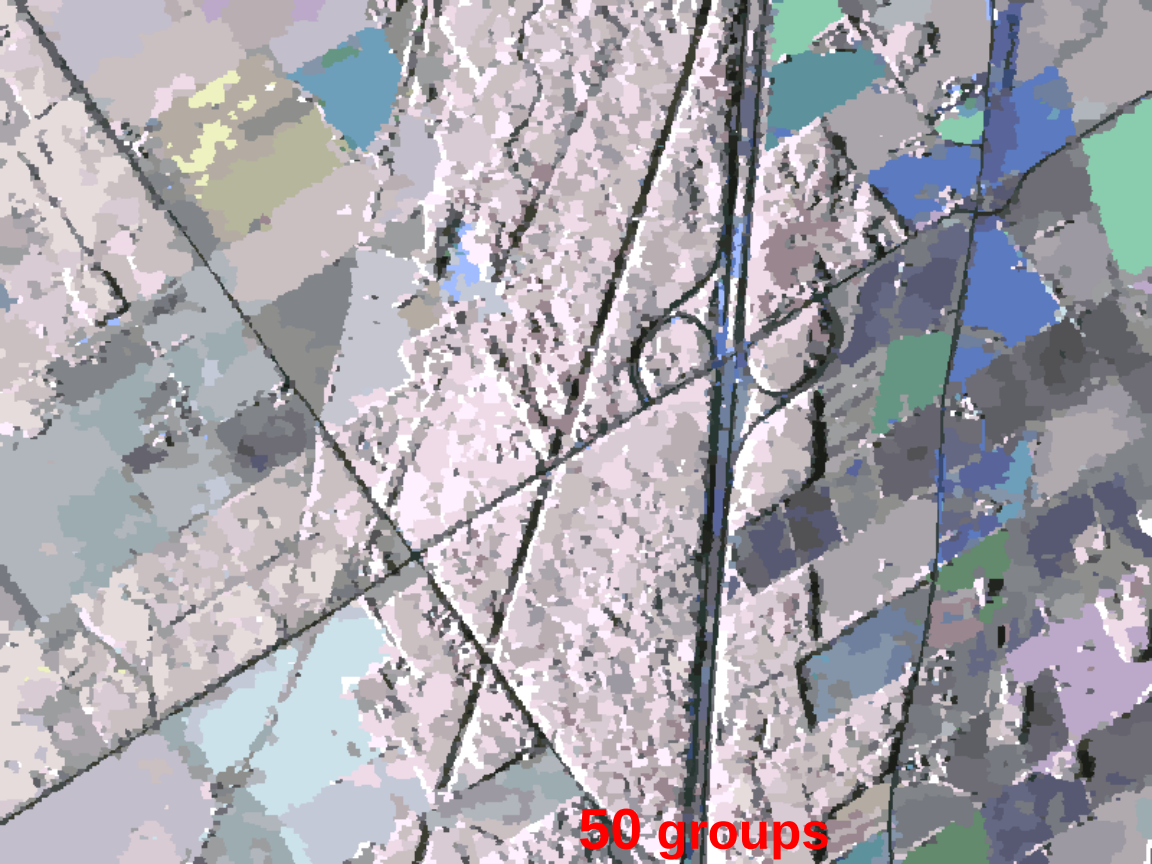
$$MLL(G) \propto n \tfrac{3L+\alpha}{2} \ln(\alpha L) - n \ln(\Gamma(\alpha)) - nL \ln\left(\left|\hat{\Sigma}\right|\right) + \tfrac{\alpha-3L}{2} \sum_{k \in G} \ln\left(tr\left(\hat{\Sigma}^{-1} Z_k\right)\right) + \sum_{k \in G} K_{3L-\alpha}\left\{2\sqrt{\alpha L\, tr\left(\hat{\Sigma}^{-1} Z_k\right)}\right\}$$

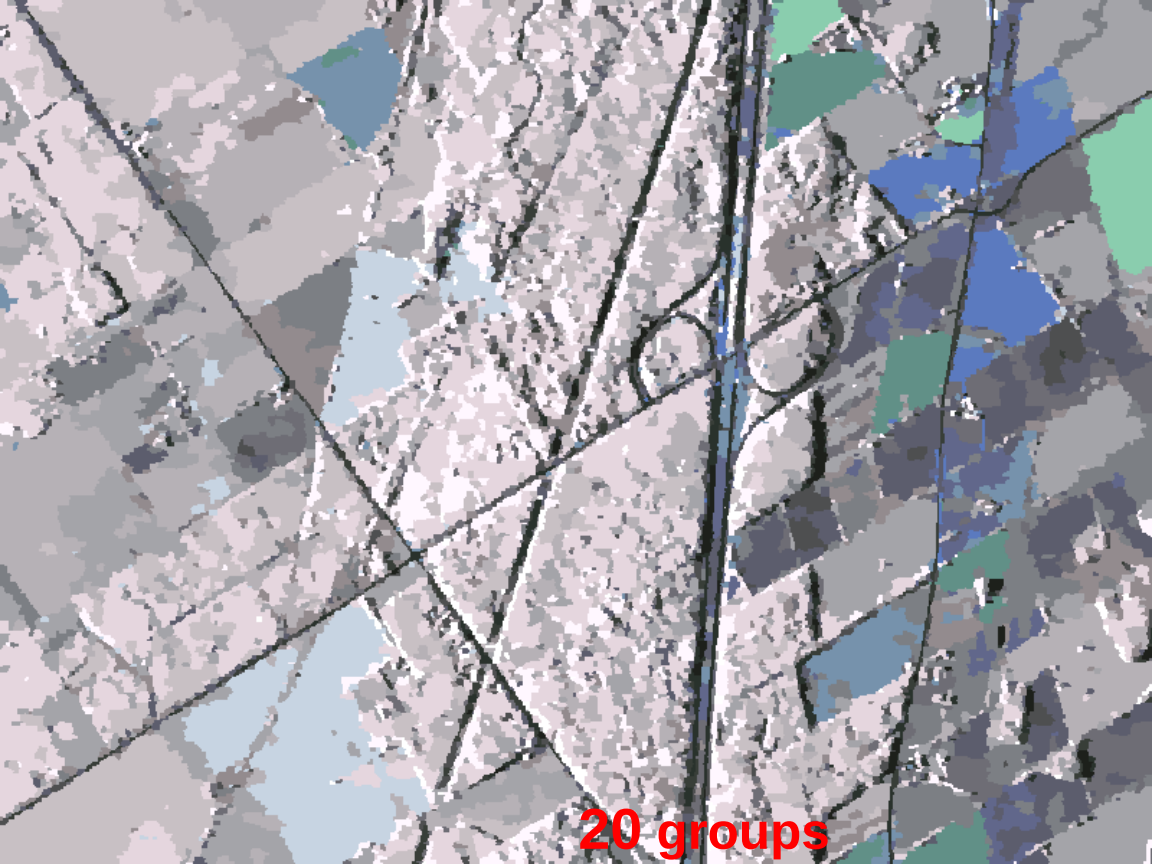

10k segments




10k segments


200 groups

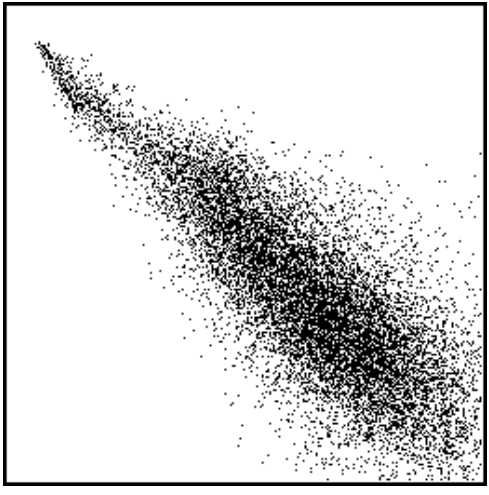

50 groups

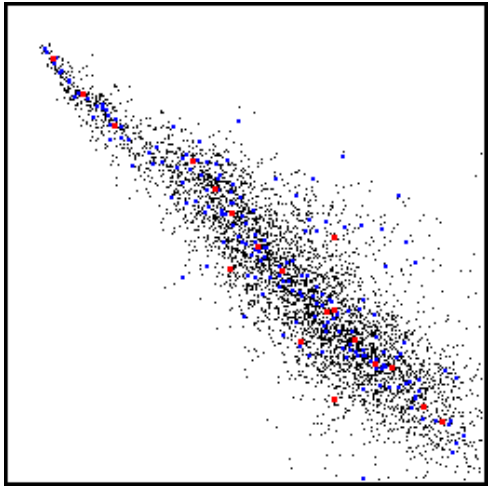

20 groups

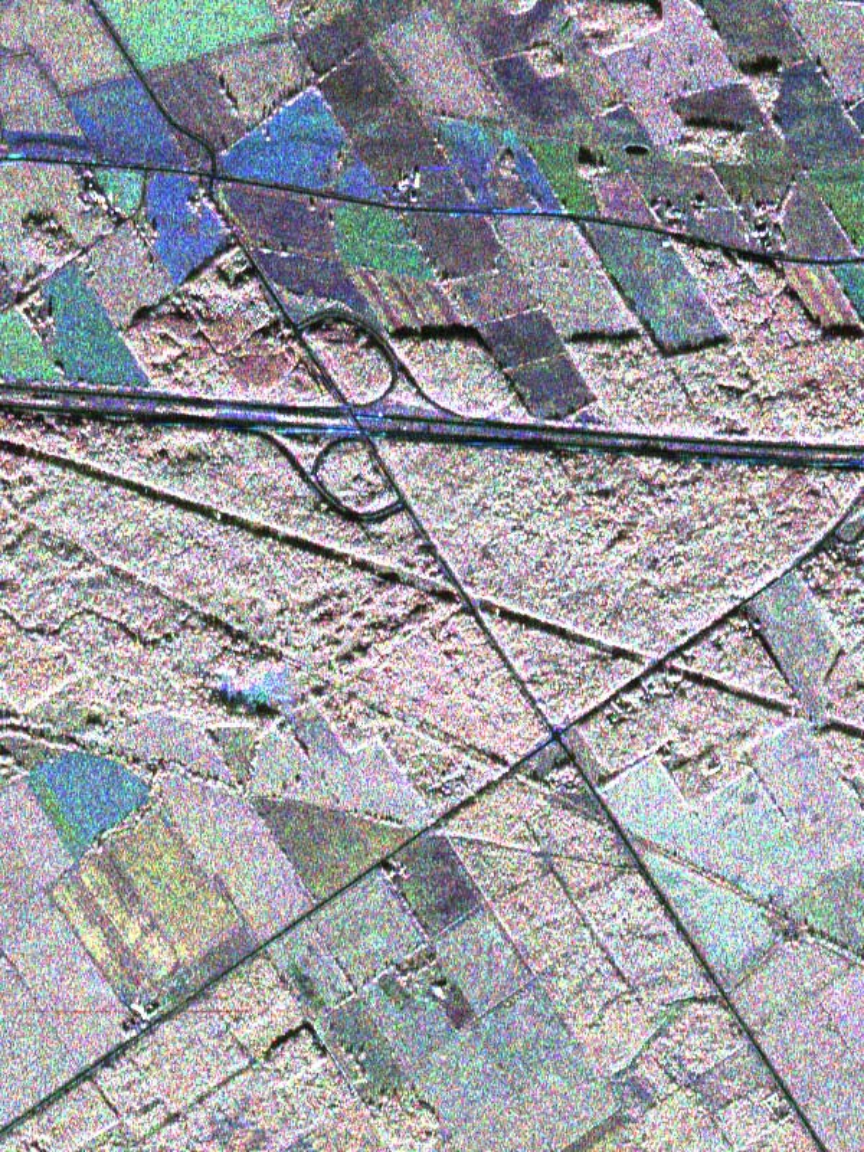
- **Group center positions**

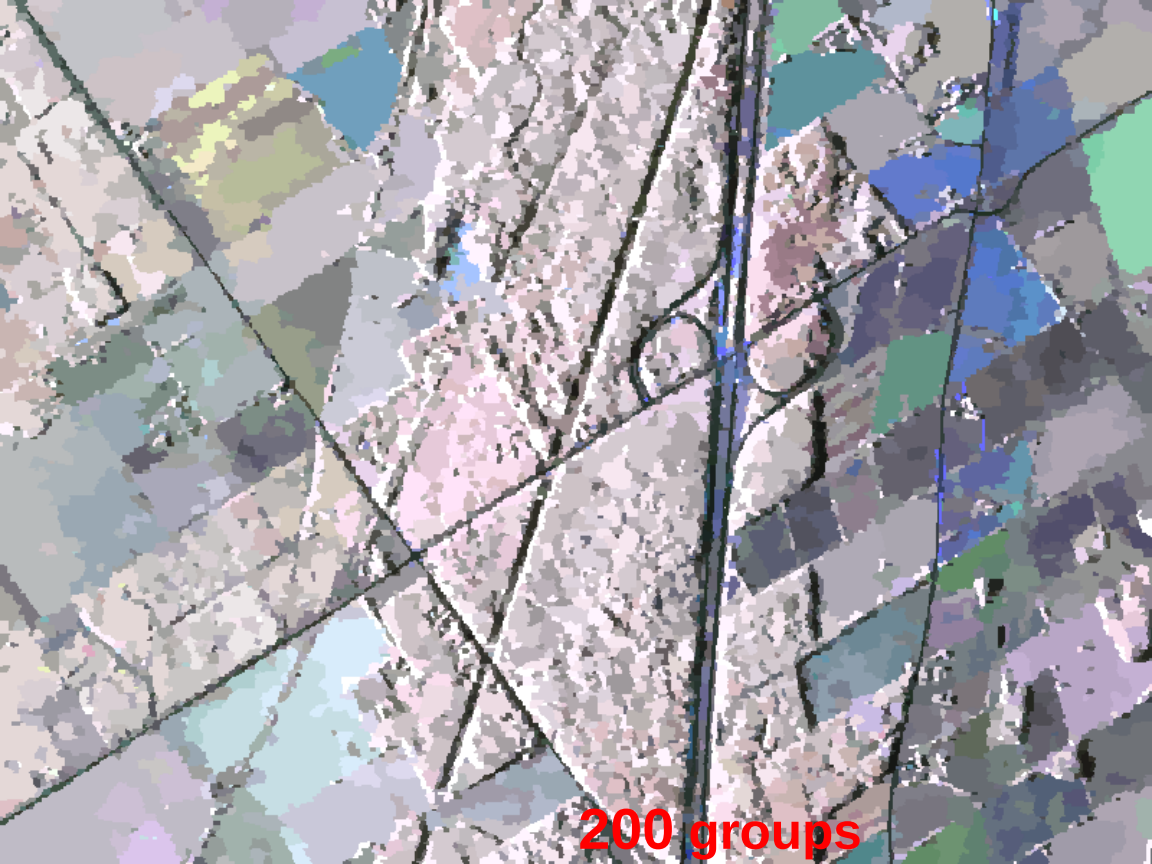
Initial 14804 large regions

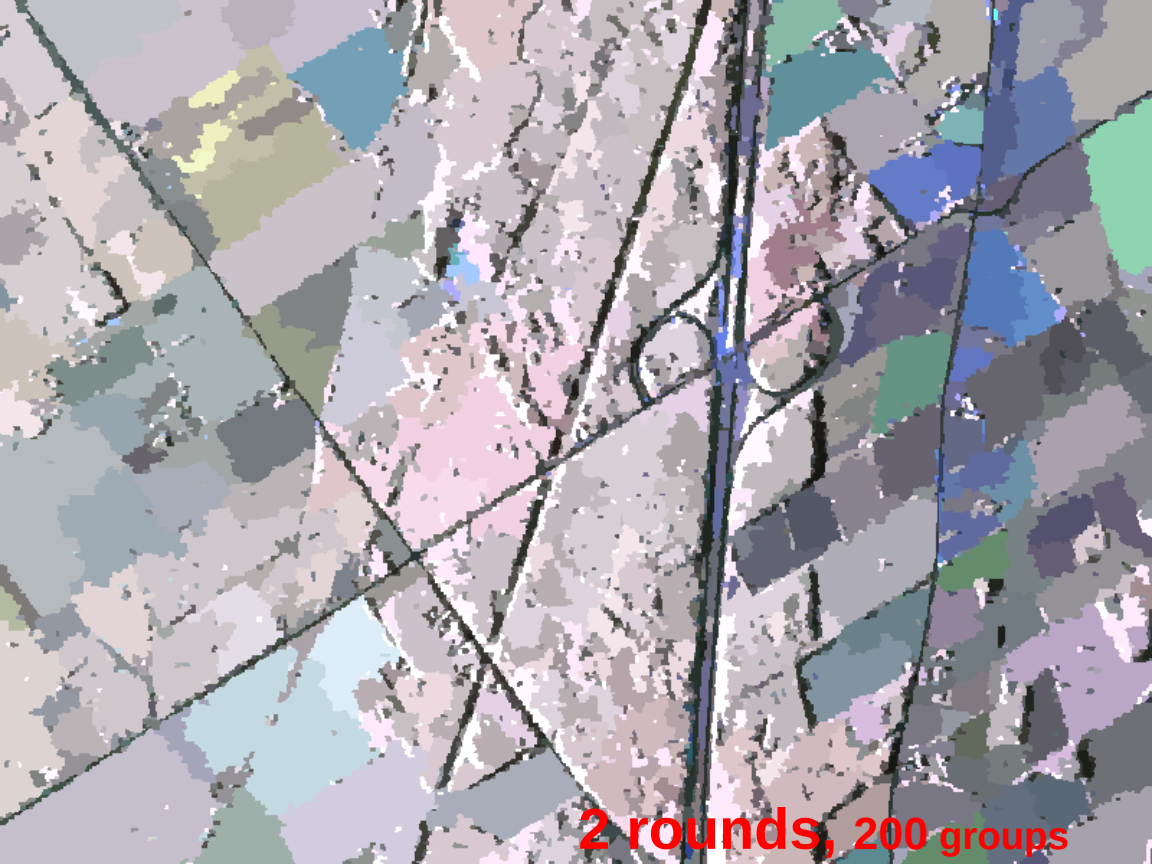
20 groups
200 groups
5000 groups

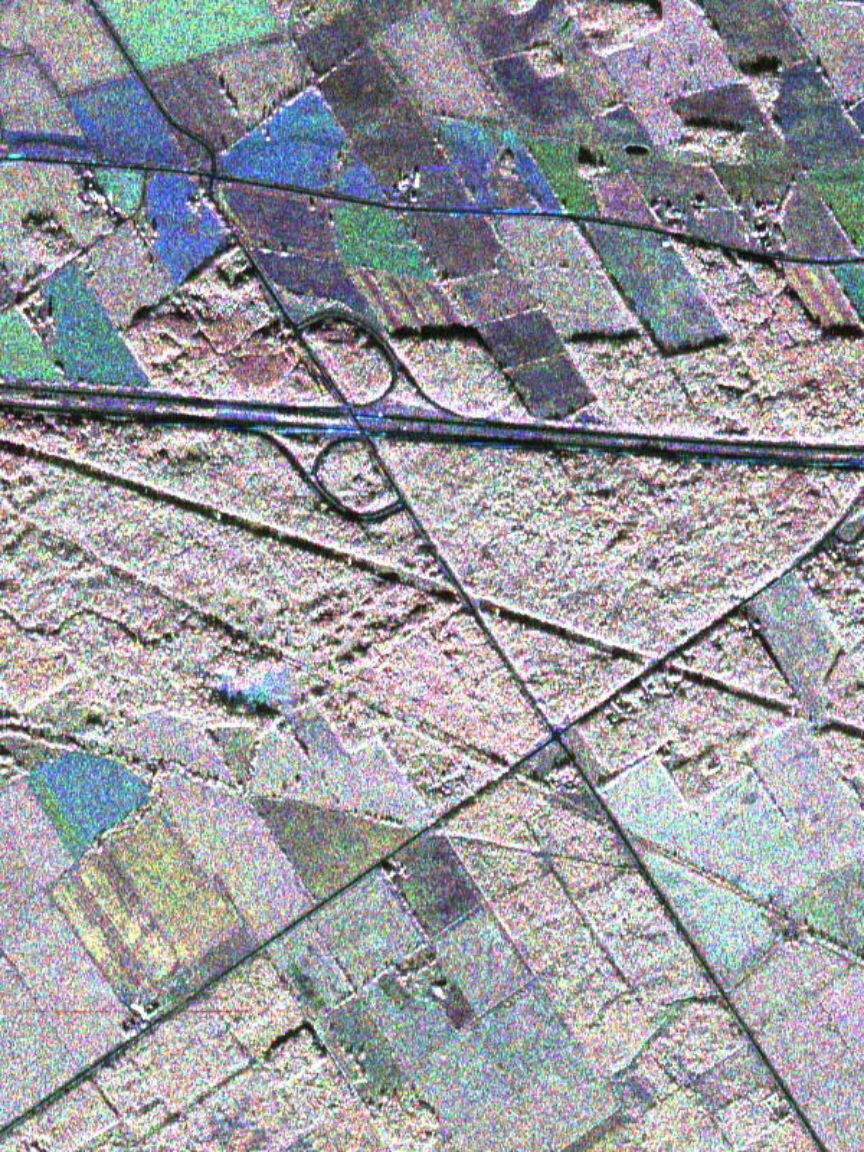


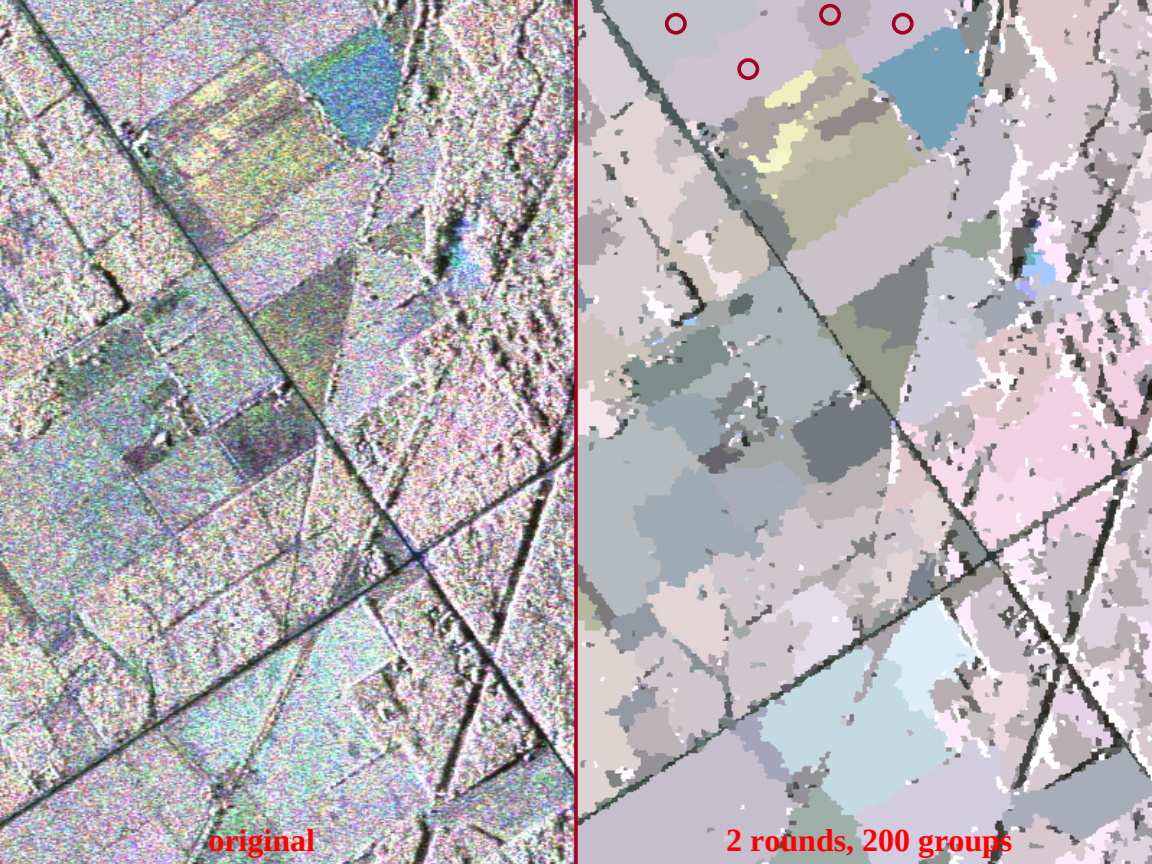


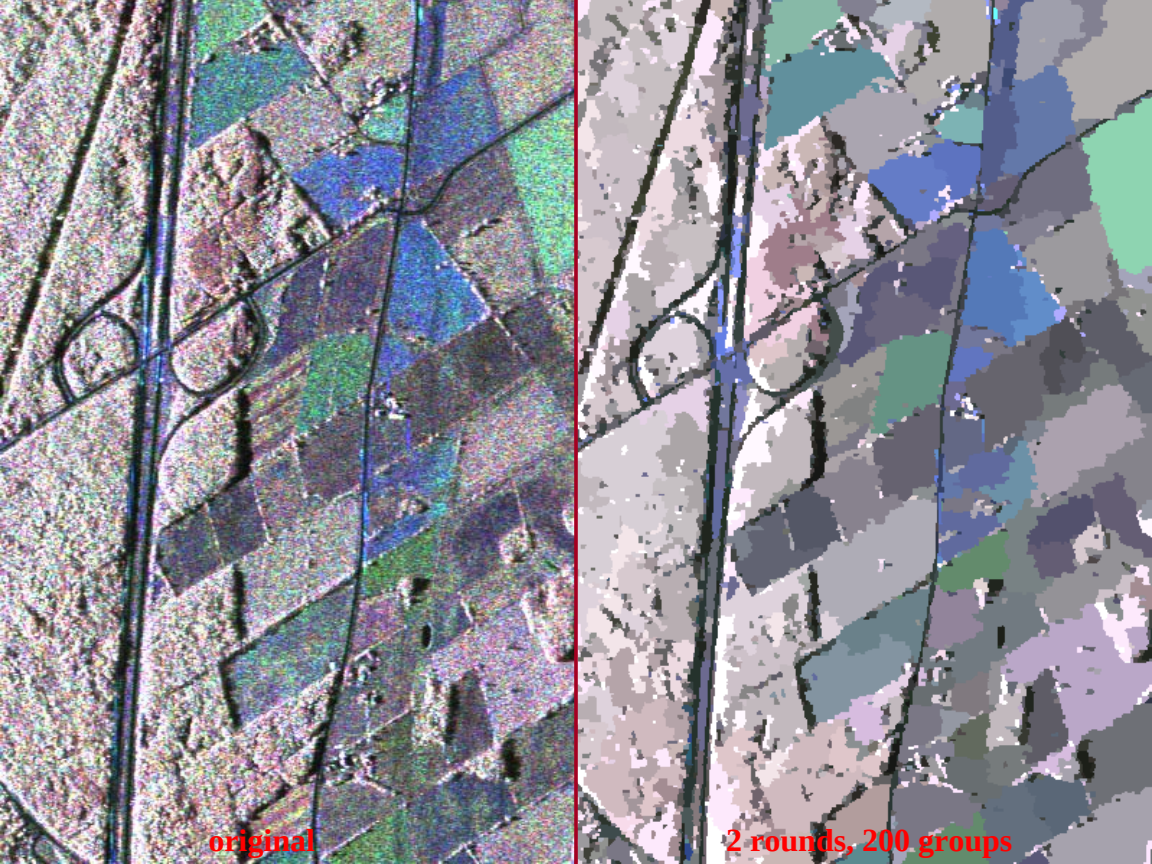


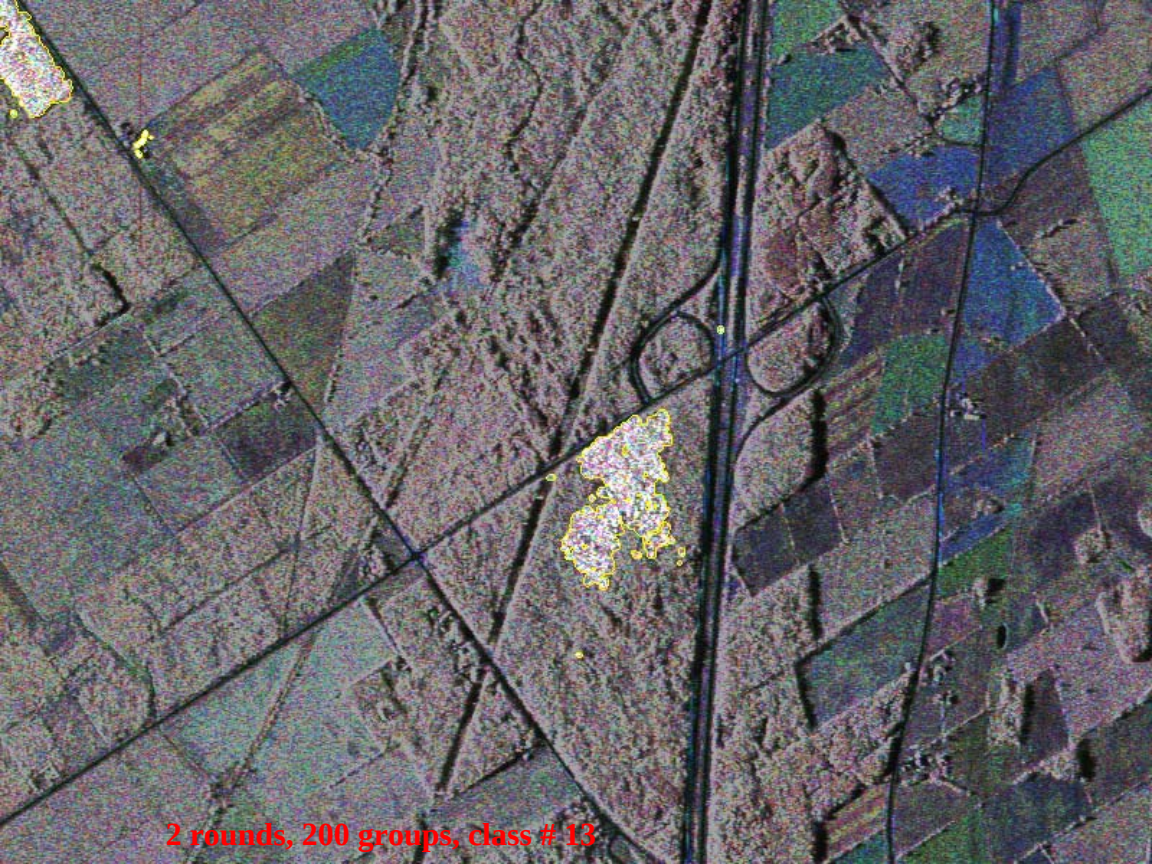

200 groups

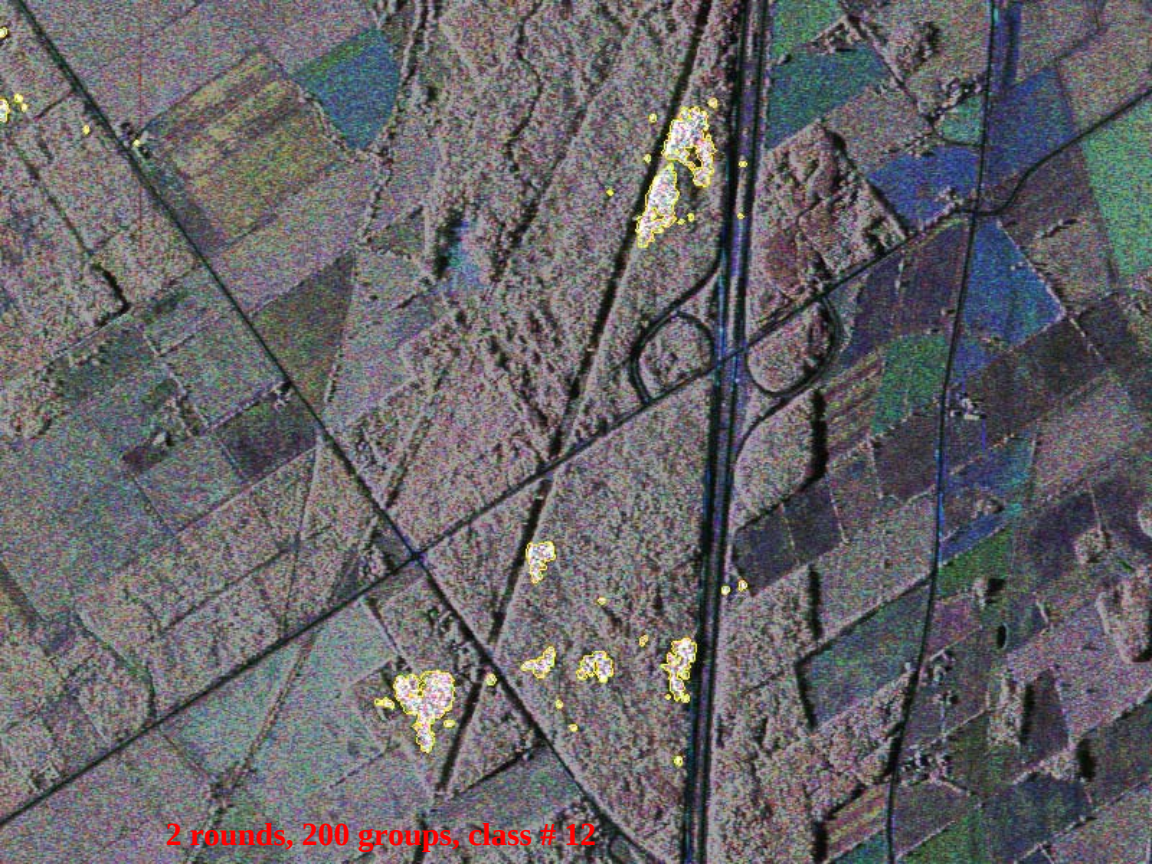

2 rounds, 200 groups

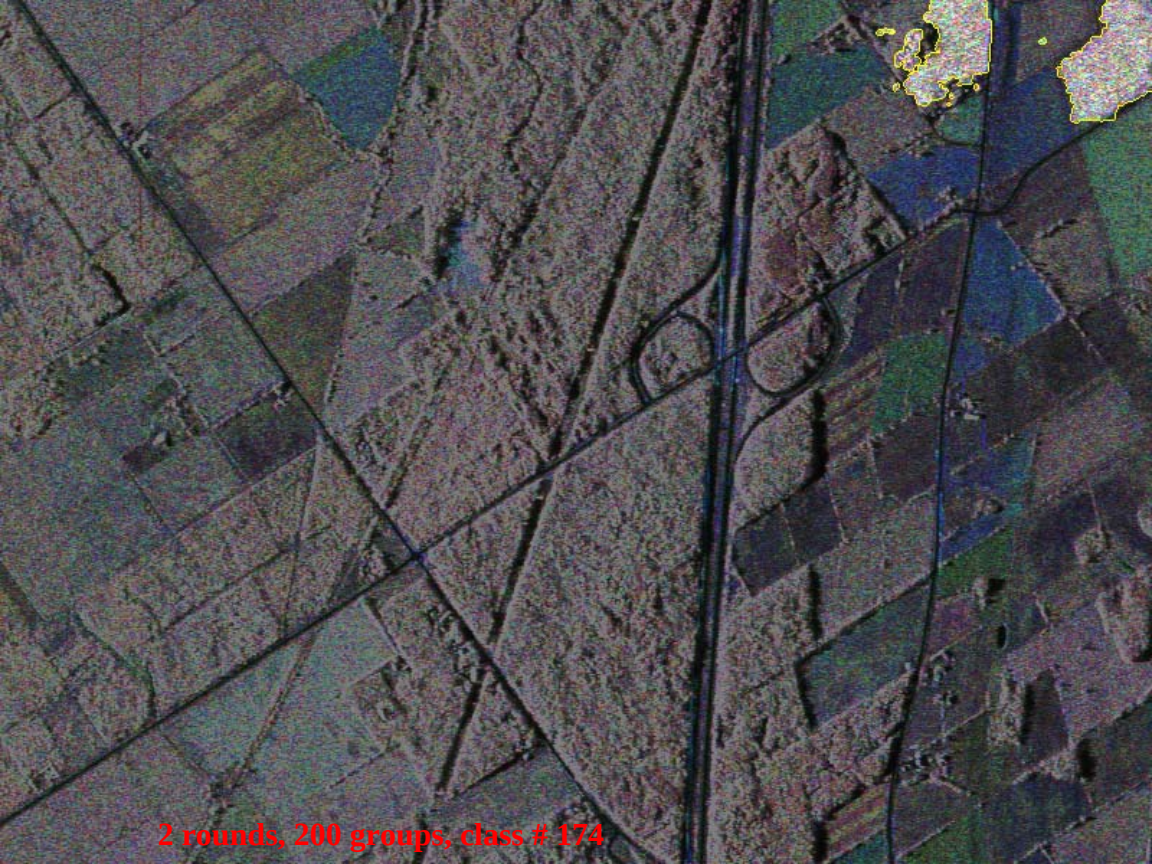


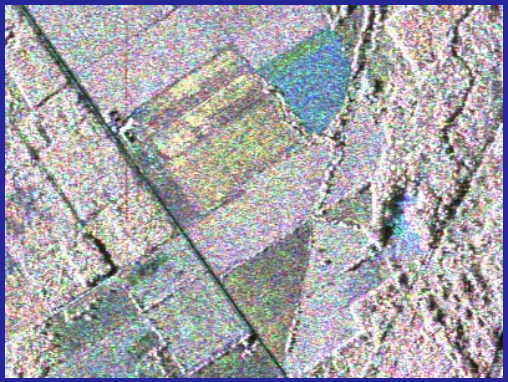

original
2 rounds, 200 groups


original
2 rounds, 200 groups


2 rounds, 200 groups, class # 13


2 rounds, 200 groups, class # 12


2 rounds, 200 groups, class # 174



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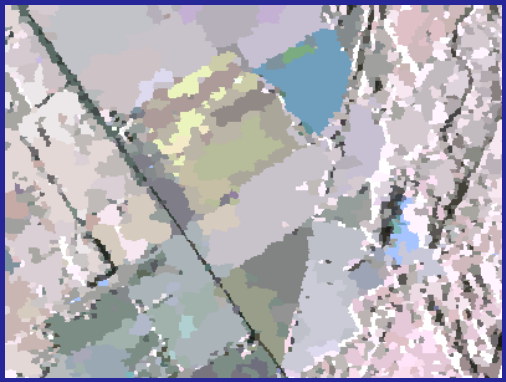
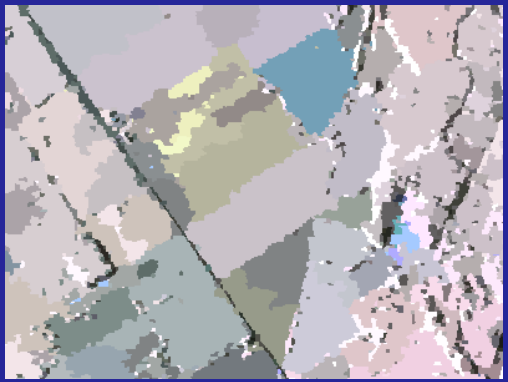
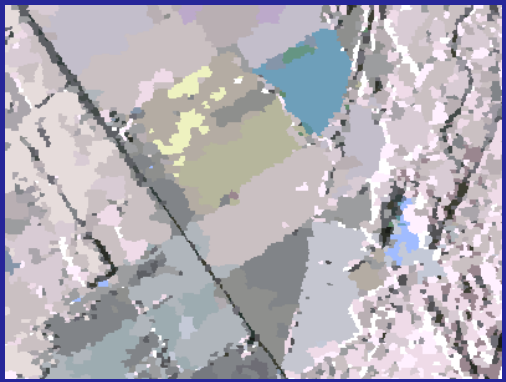


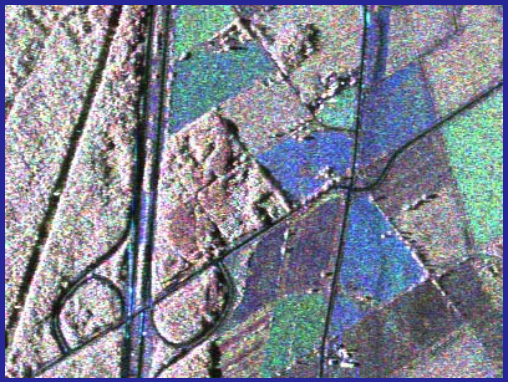
200 groups



2 rounds, 200 groups



50 groups



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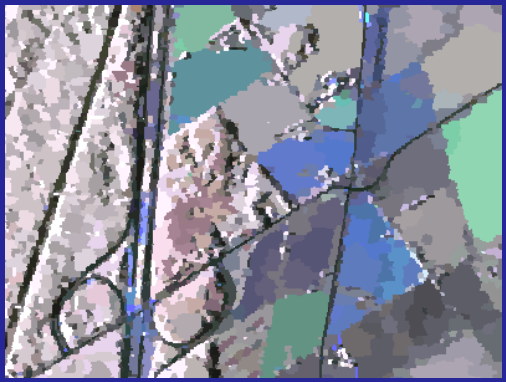
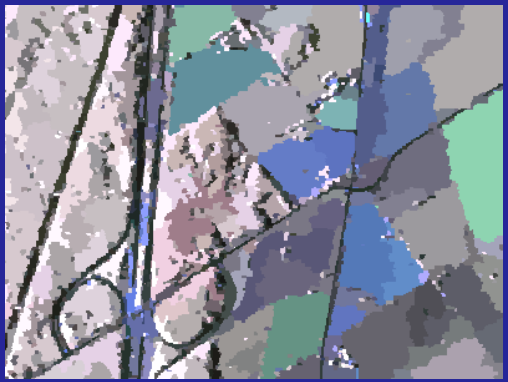
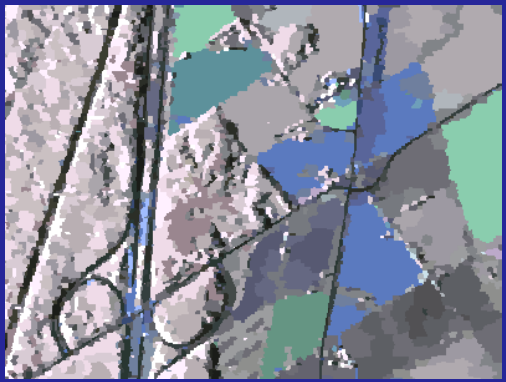


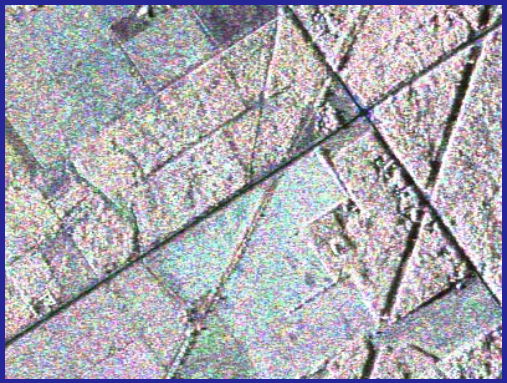
200 groups



2 rounds, 200 groups



50 groups



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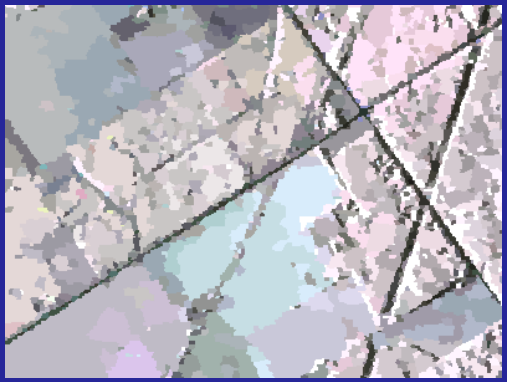
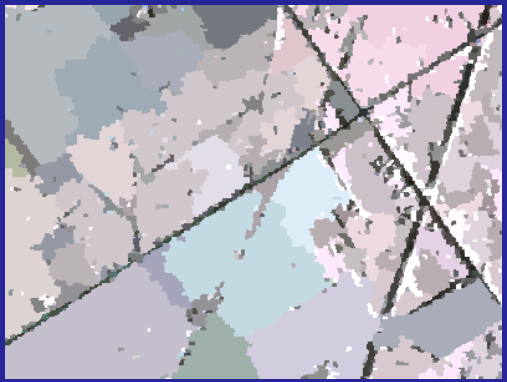
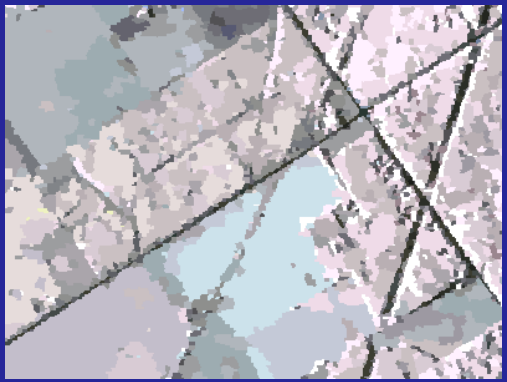


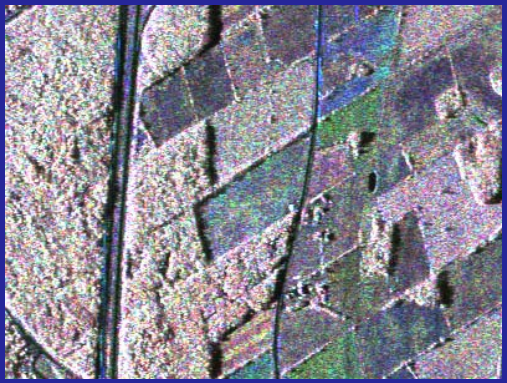
200 groups



2 rounds, 200 groups



50 groups



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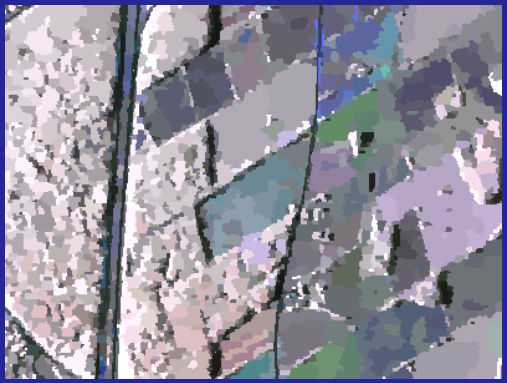
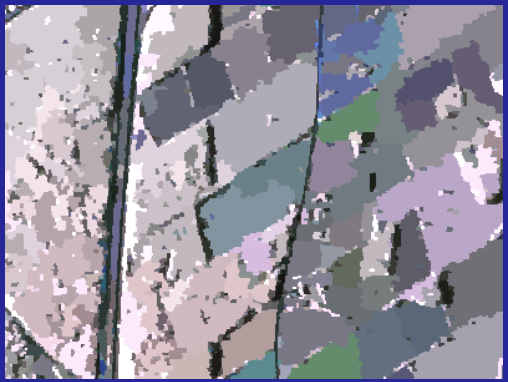
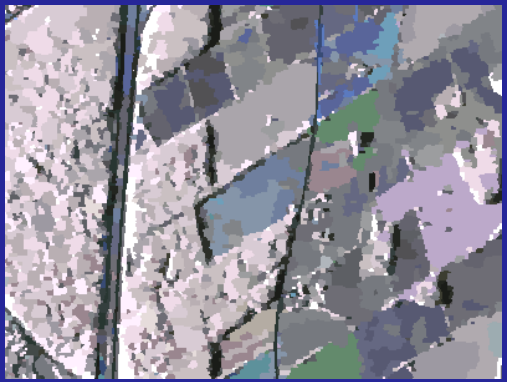


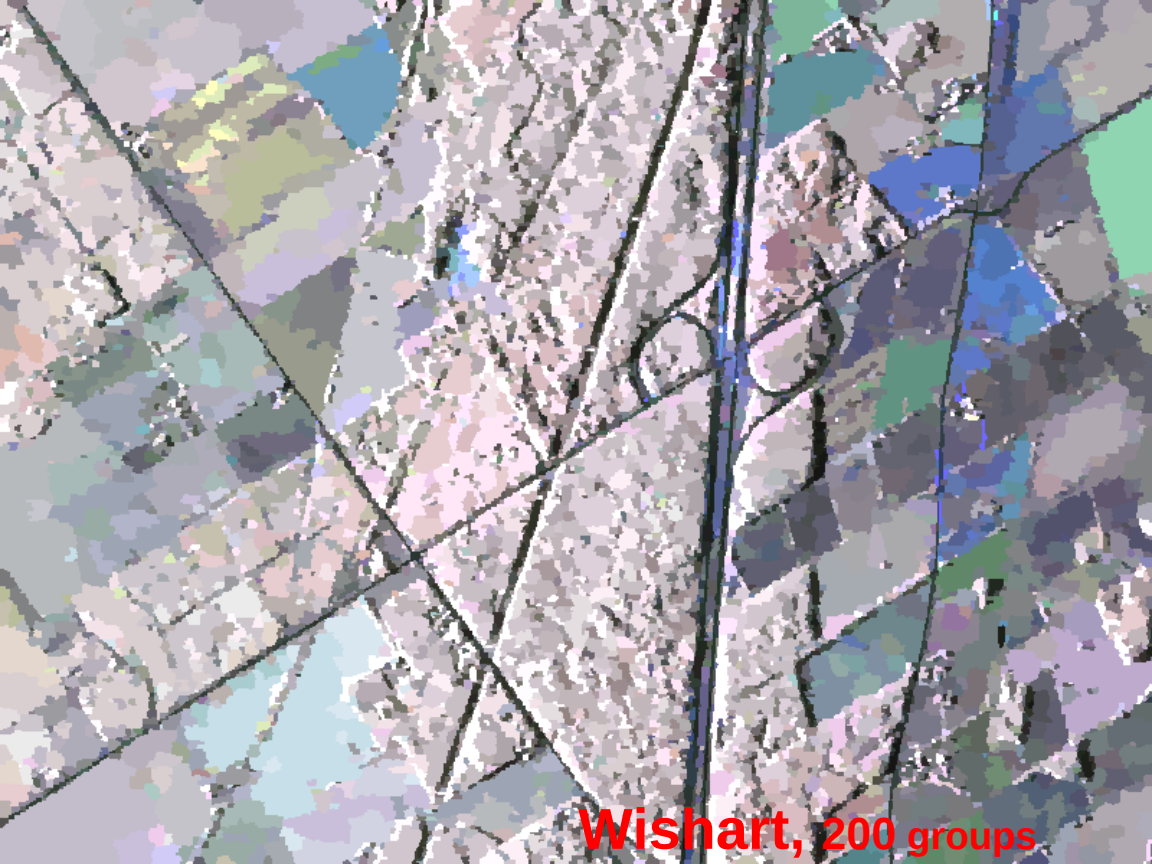
200 groups

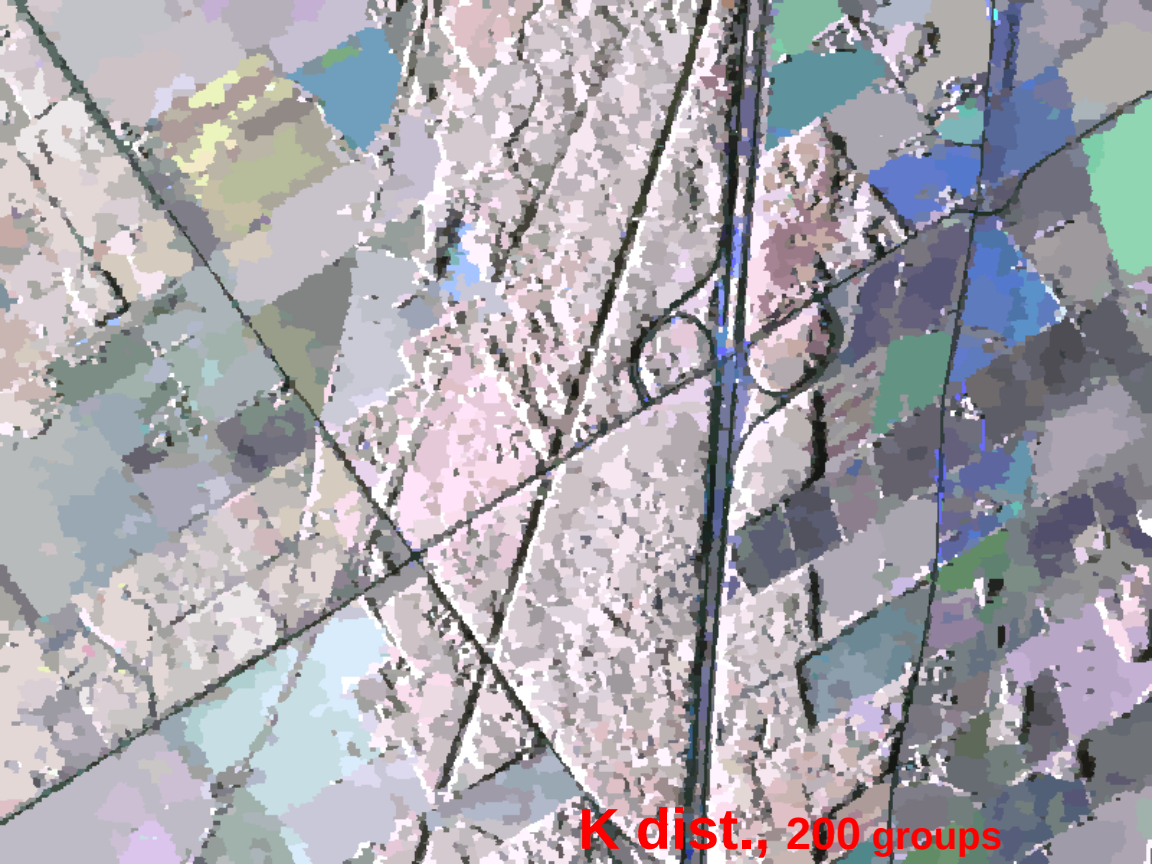


2 rounds, 200 groups



50 groups


Wishart, 200 groups


K dist., 200 groups

CONCLUSION

- Combination of segmentation and clustering
- Combination of iterative (Mean-Shift) and hierarchical techniques
- K distribution for segmentation and clustering