Weighted median filters for meteorological data analysis

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Introduction – need of adequate scale separation

- *Meteorological systems work in various characteristic time and space scales*
- *To compare or merge data of various origin we always meet question of scales*
- *It is matter of prime importance to have adequate scale separation methods*

Introduction – from current methods to CWM filters I

- *Current methods suffer because of sensitivity to outliers, depend on assumption of error distribution, depend on lack of data*
- *To process effectively huge amount of data of different origin meteorological systems need unsupervised scale separation methods*
- *Robustness become a key feature*
- *Proper analysis of non-smooth meteorological fields – e.g. precipitation – is a challenge especially in high resolution NWP*

Introduction – from current methods to CWM filters II

- *Simple median filters are widely applied in image processing for noise removal*
- *Median filter is effective and robust tool*
- *Median filter keeps contrast untouched*
- *Mentioned above features suggest that median filter is good basis for search for new scale separation method applicable to non-smooth meteorological fields e.g. precipitation, cloudiness*

Introduction – from current methods to CWM filters III

- *Proposed new tool for scale separation is a set of Composite Weighted Median Filters i.e. complex filters which are superposition of weighted median filters with different sizes and weights*
- *1-D and 2-D CWM filters for gridded data are proposed in the presentation*

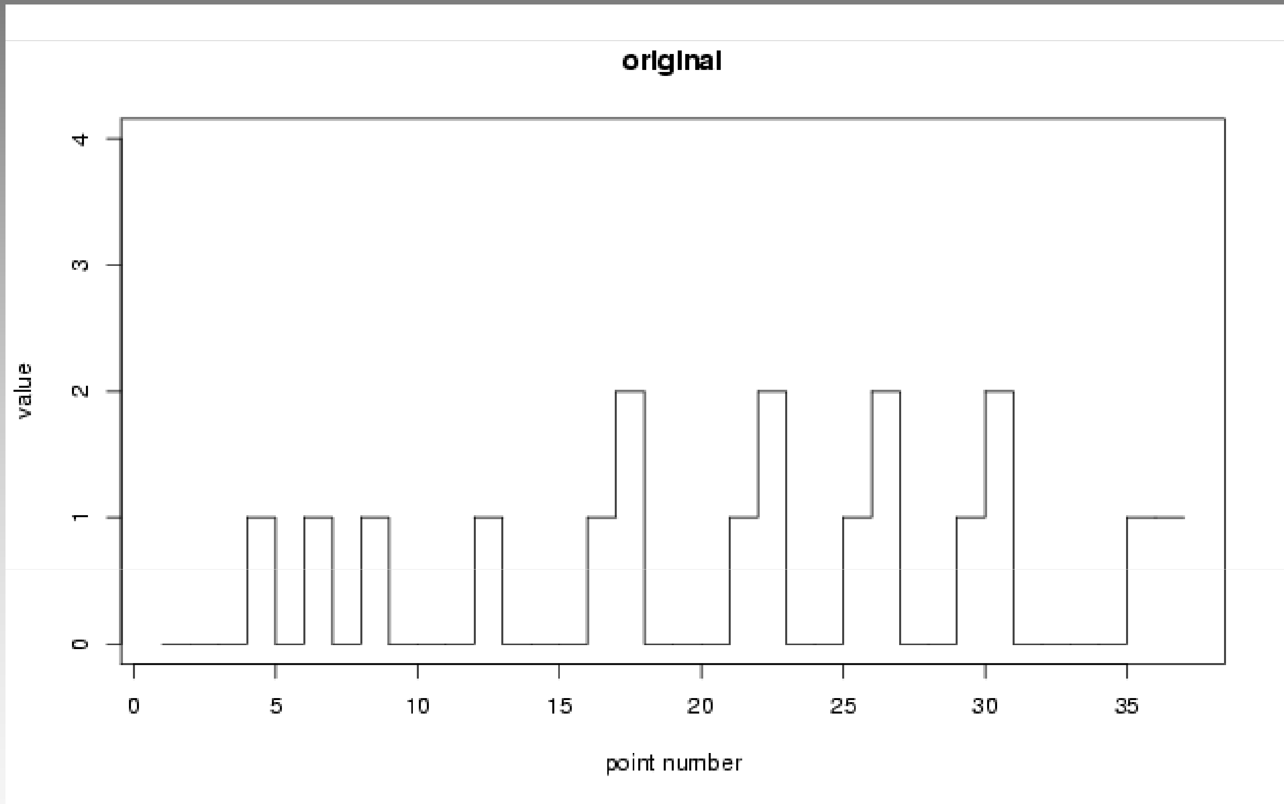
1-D and 2-D CWM Filters – recipes

- *1-D CWM filter is superposition of 2 kinds of elementary bricks: A-brick and B-brick*
- *A-brick of level l is WM filter of size 2*l+1 and weights (1,2,...2,1)*
- *B-brick of level l is WM filter of size 2*l+1 and weights (1,1,...1,1)*
- *CWM filter F of level l is defined as follows:*
  $F(l) = B(l)A(l)B(l-1)A(l-1)\ldots B(1)A(1)$
- *2-D CWM filter is built similarly but elementary brick in not just weighted median filter but weighted median of weighted medians filter*

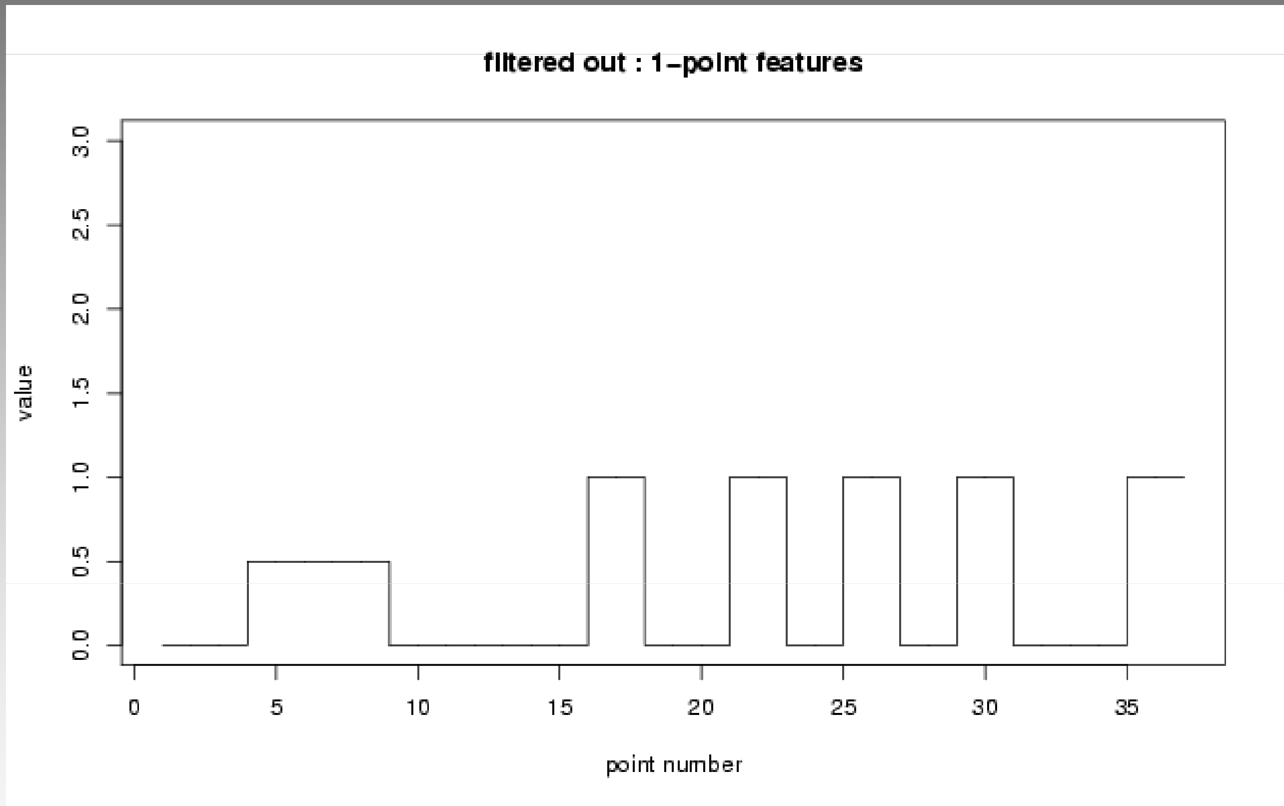
1-D and 2-D CWM Filters – how they work

- *Shortly speaking: 1-D CWM filter of level l leaves peaks of size l+1 points or grater and averages 2l-point waves*
- *Shortly speaking: 2-D CWM filter of level l leaves features of size (l+1)x(l+1) or greater and averages 2l-point waves*
- *Let's take a look for examples !*

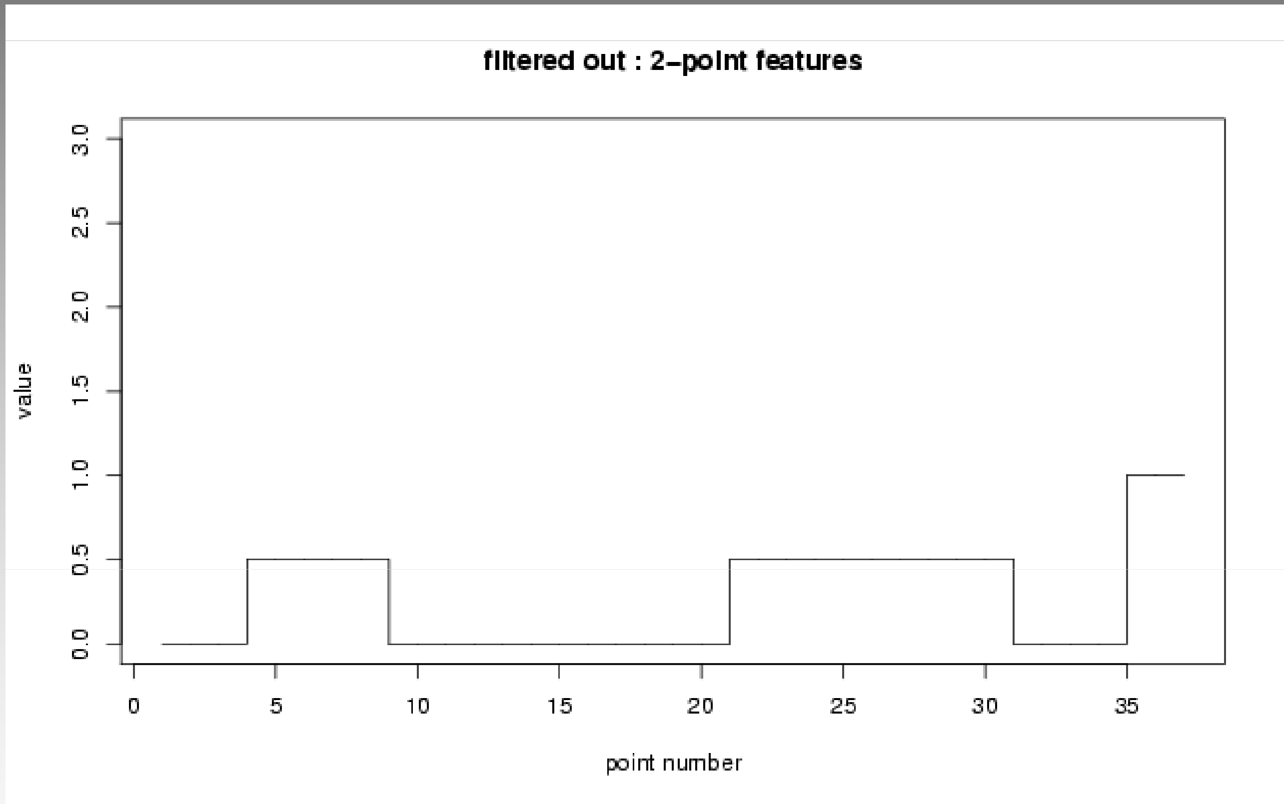
1-D filtering example – original



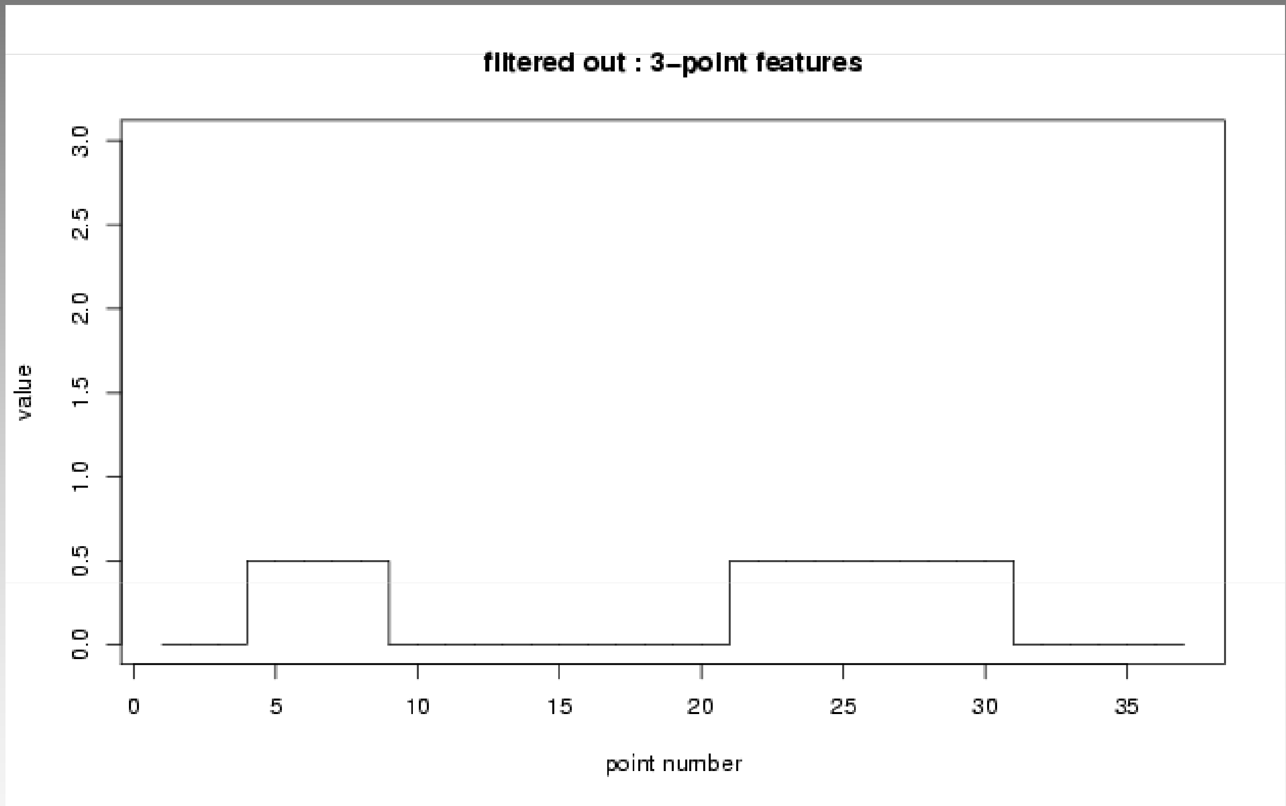
1-D filtering example – 1-point features filtered out



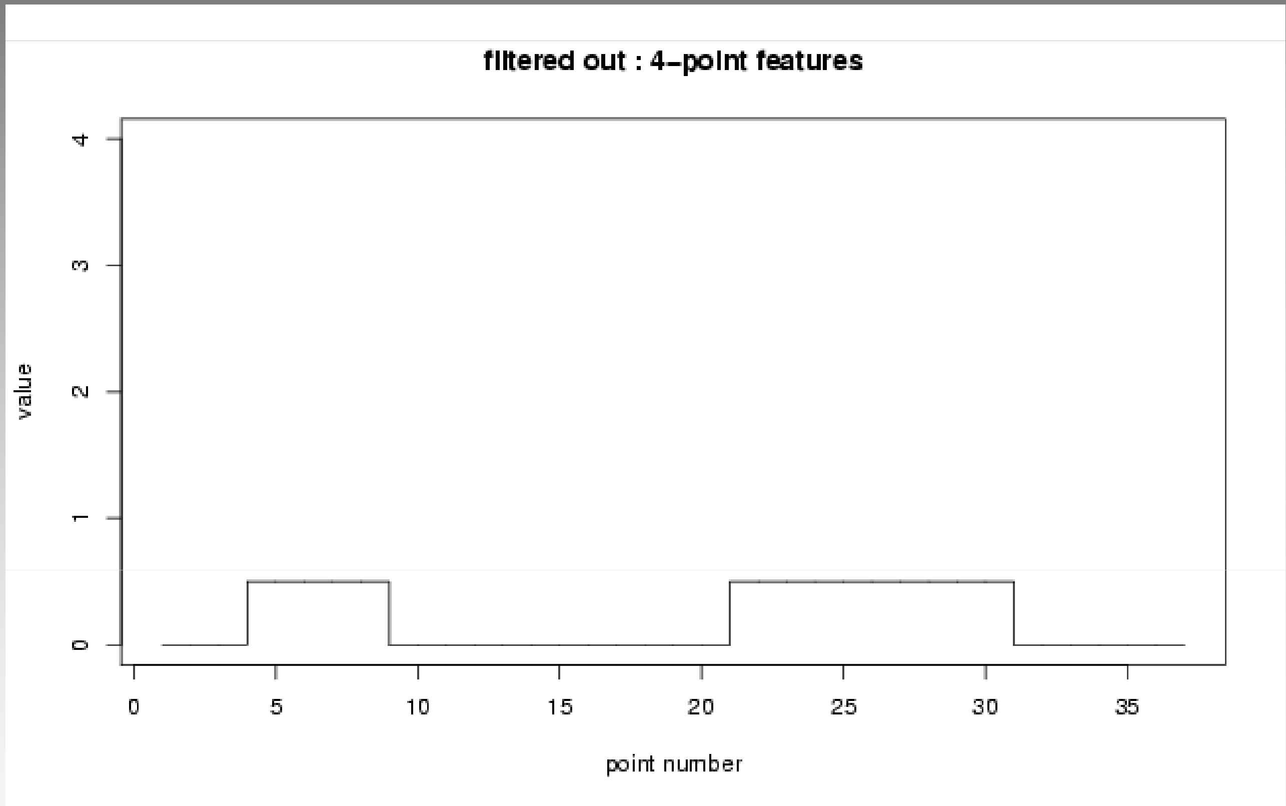
1-D filtering example – 2-point features filtered out



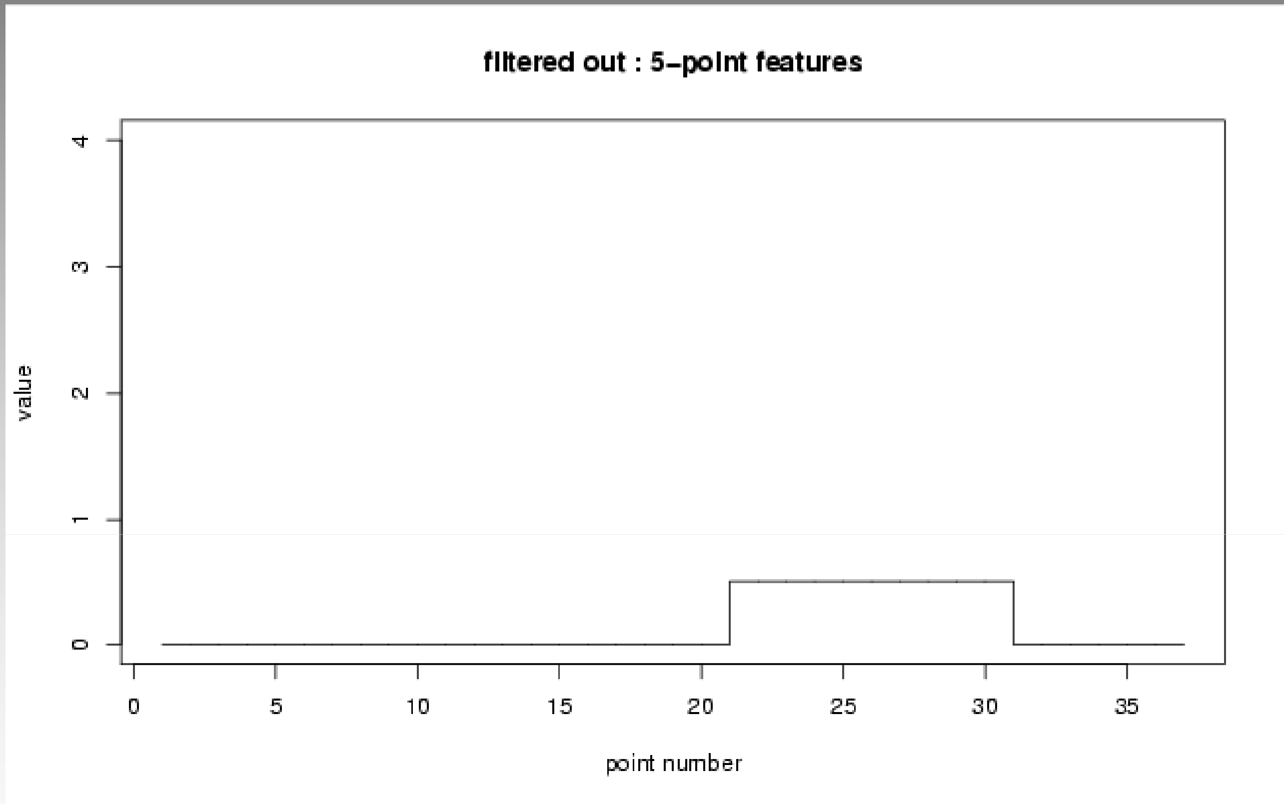
1-D filtering example – 3-point features filtered out



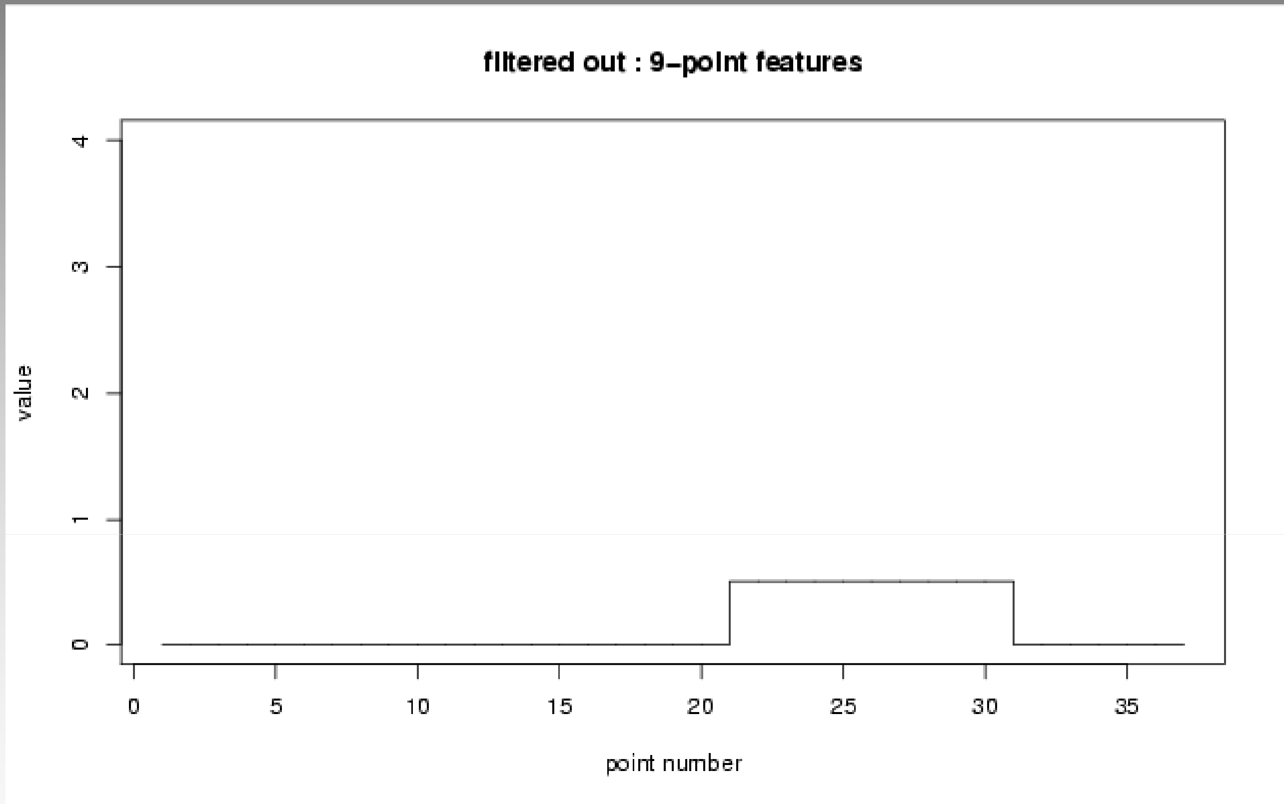
1-D filtering example – 4-point features filtered out



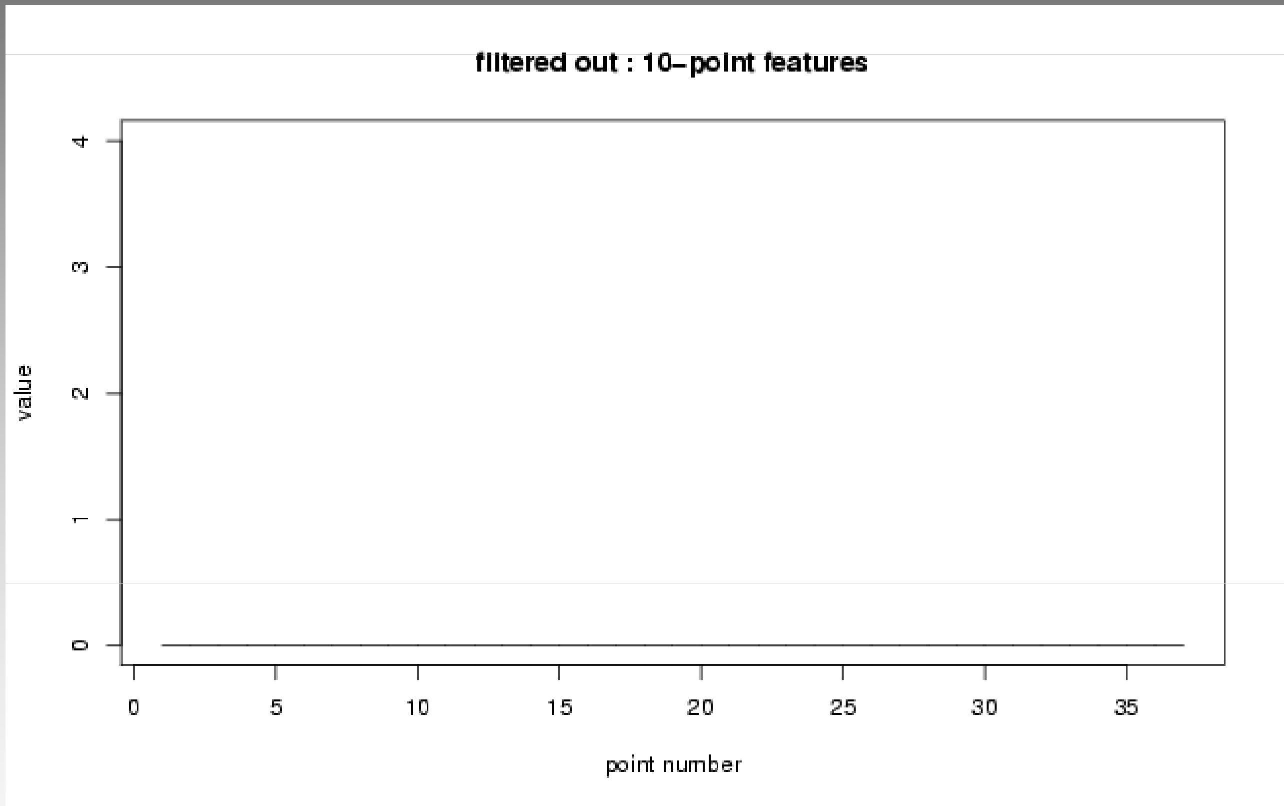
1-D filtering example – 5-point features filtered out



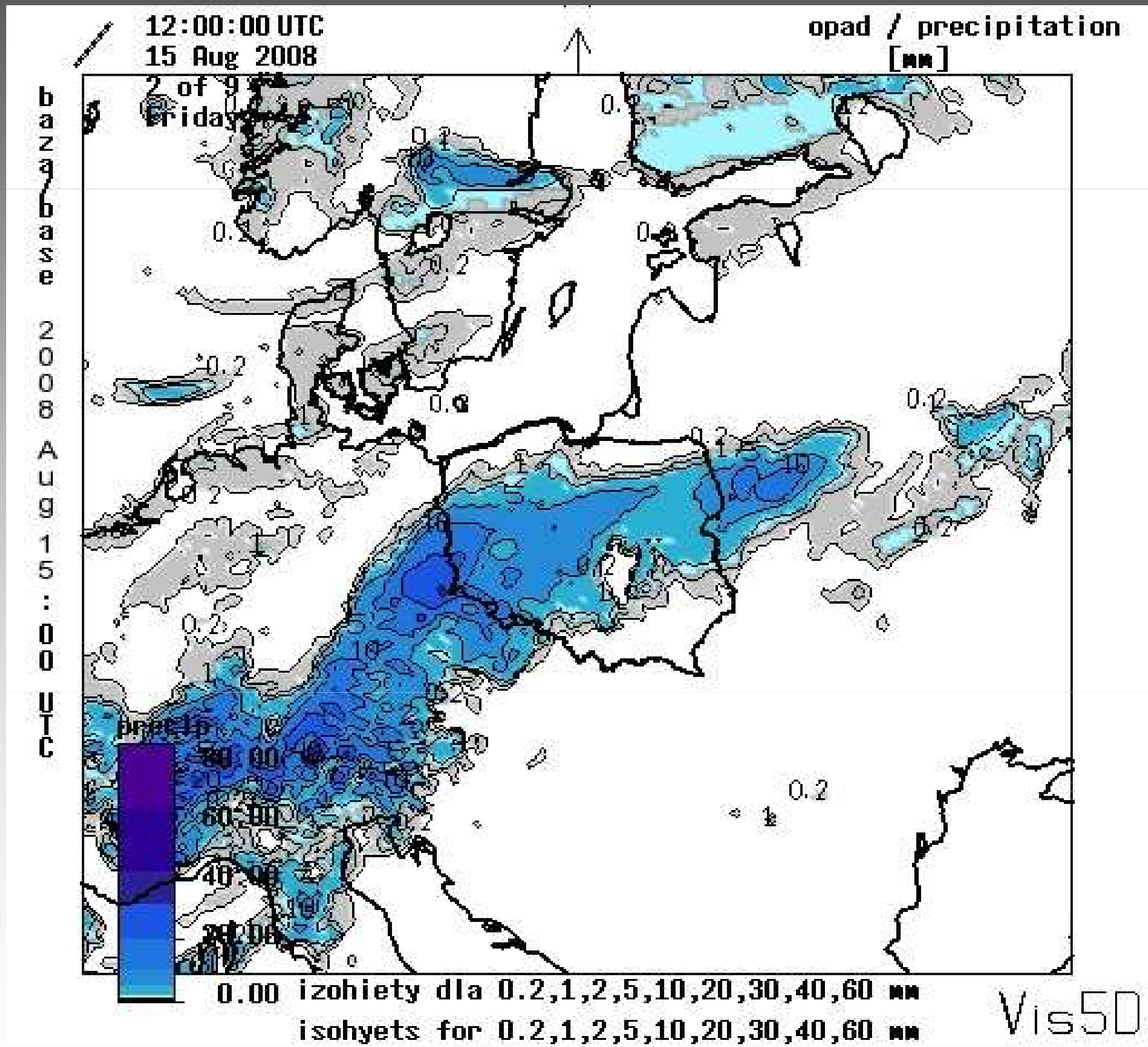
1-D filtering example – 9-point features filtered out



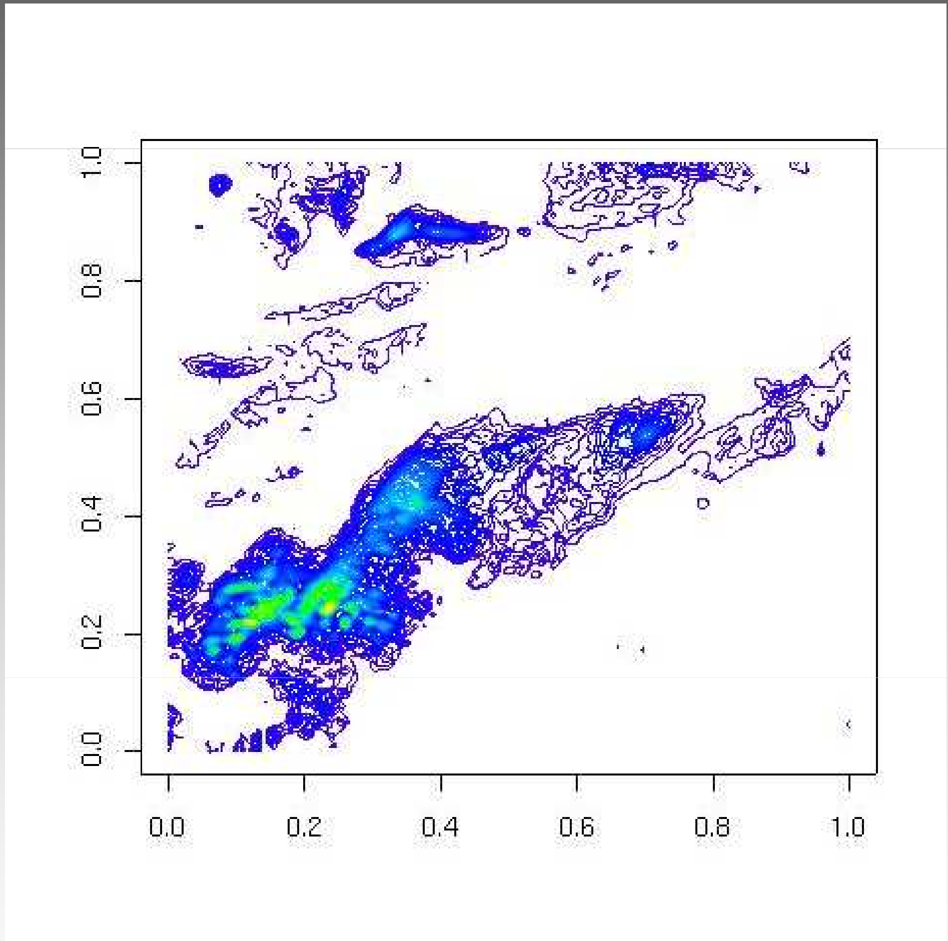
1-D filtering example – 10-point features filtered out

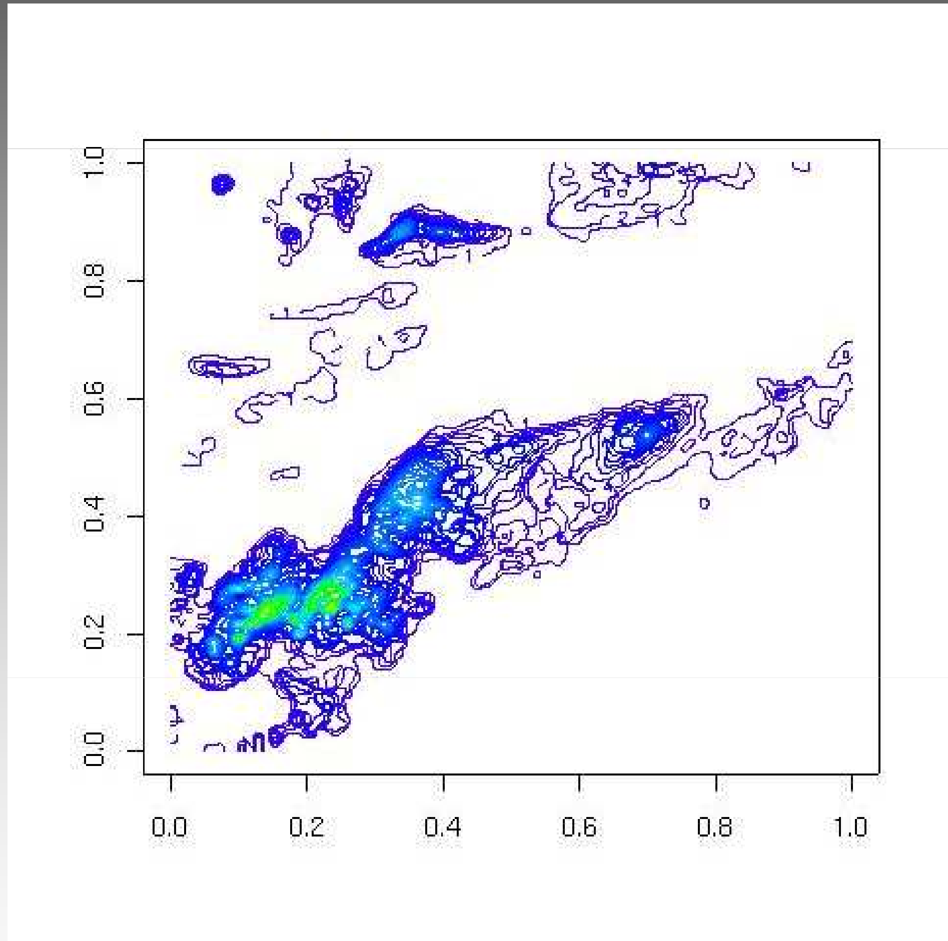


2-D filtering example - 12-hour cumulated precipitation field

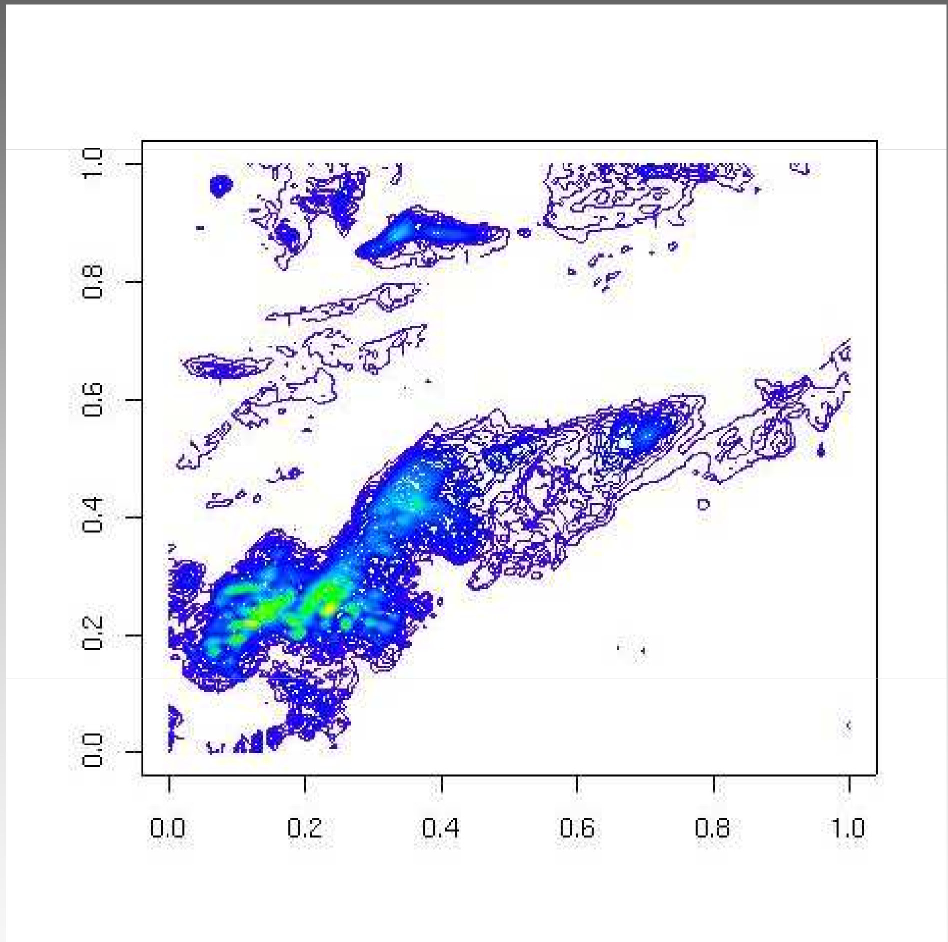


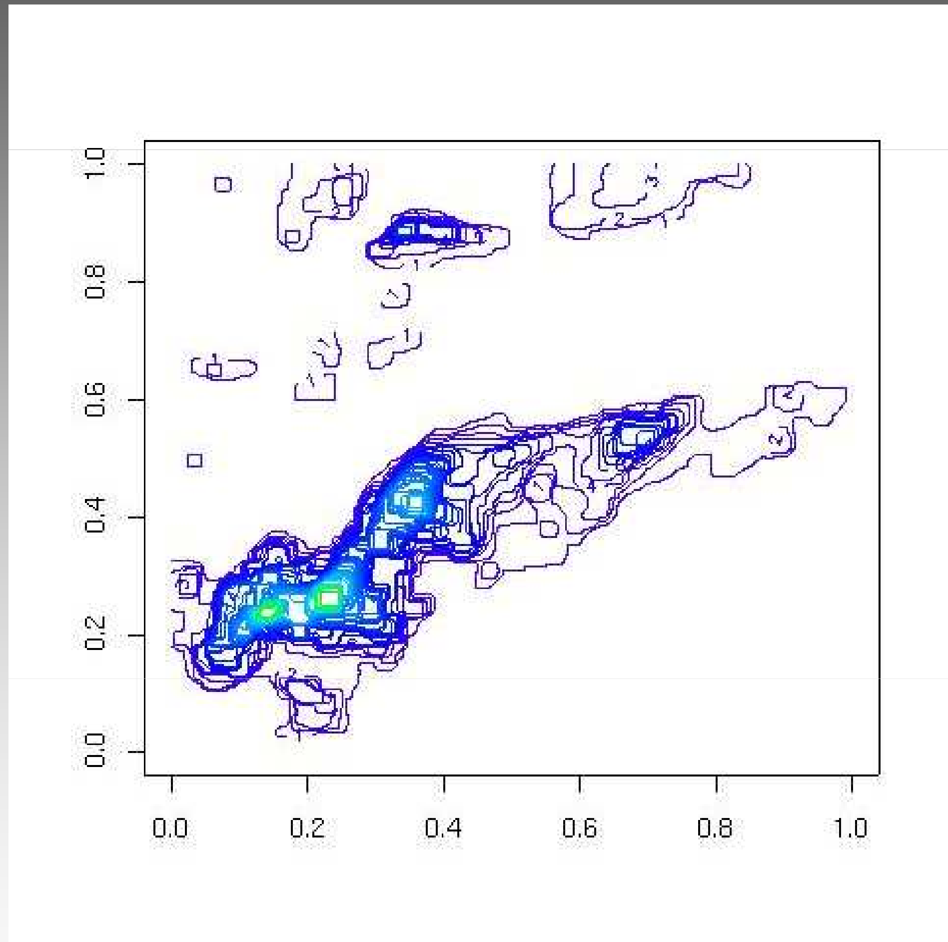
2-D filtering example – original vs 1-point features filtered out



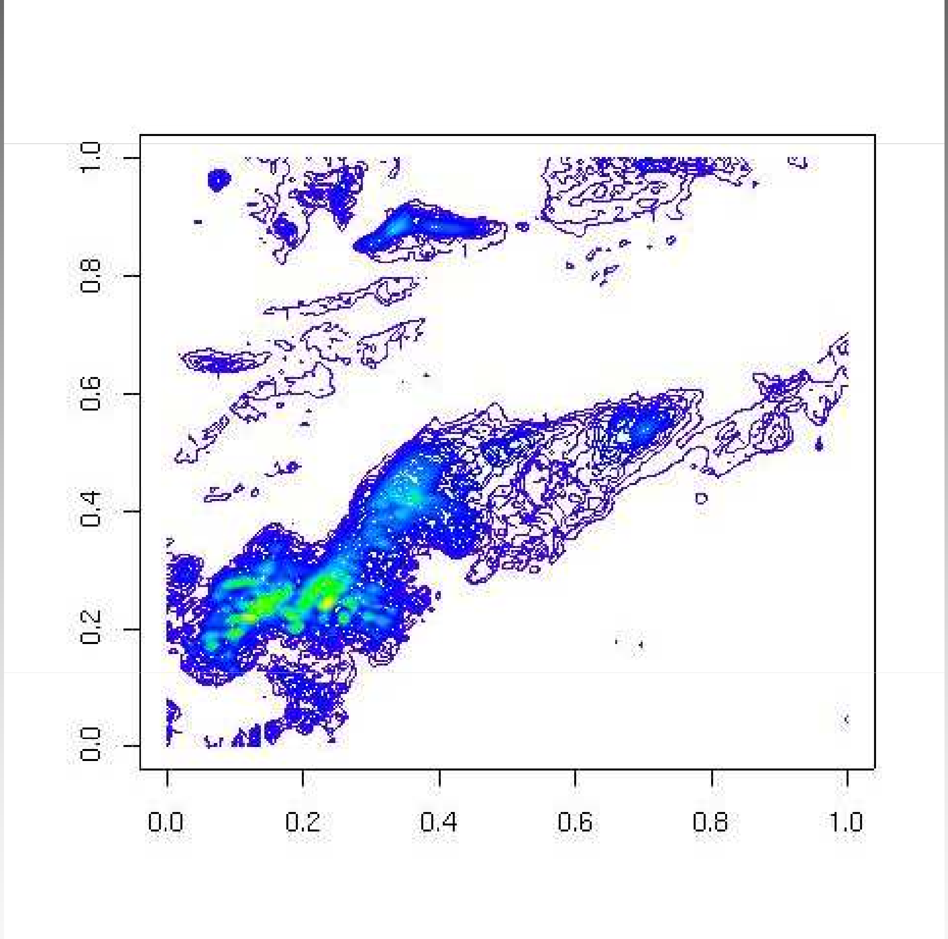


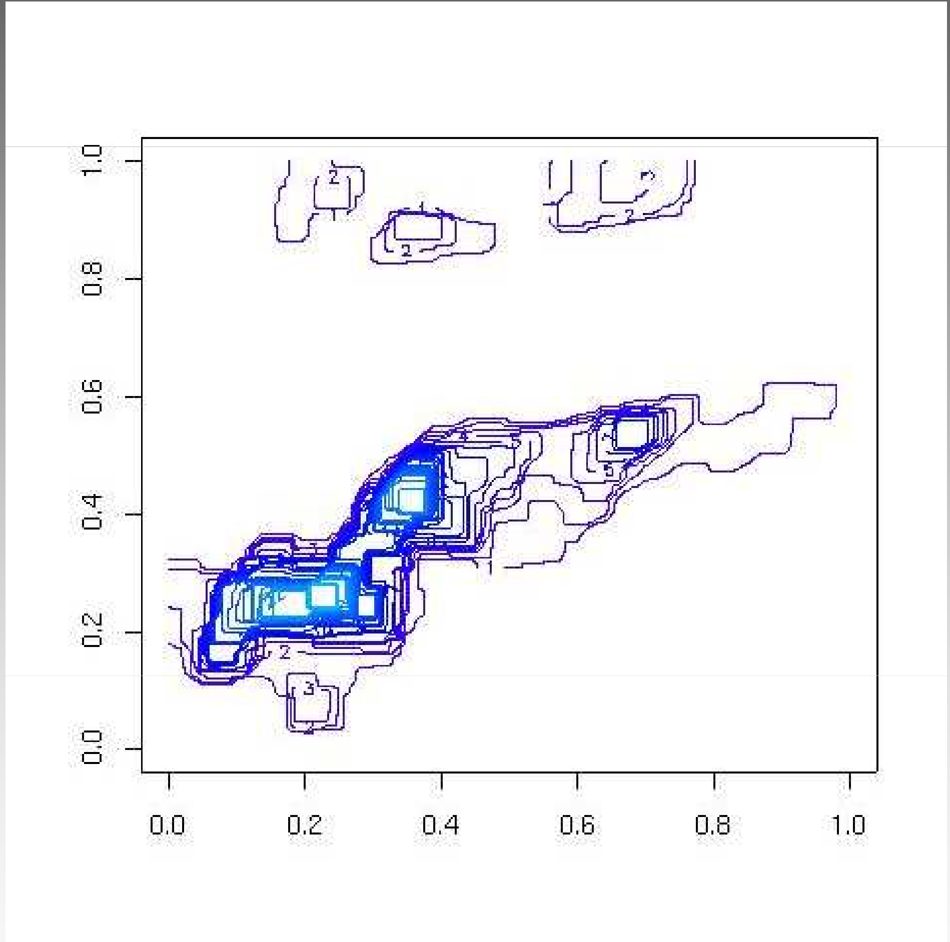
2-D filtering example – original vs 3-point features filtered out



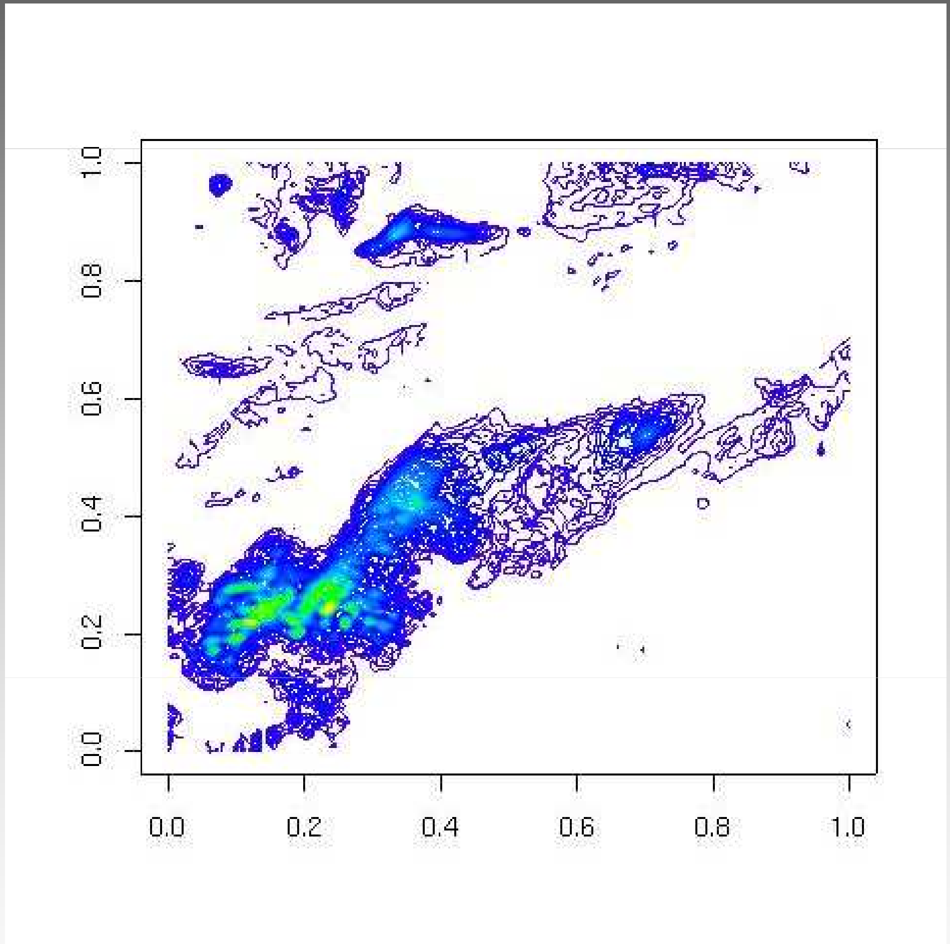


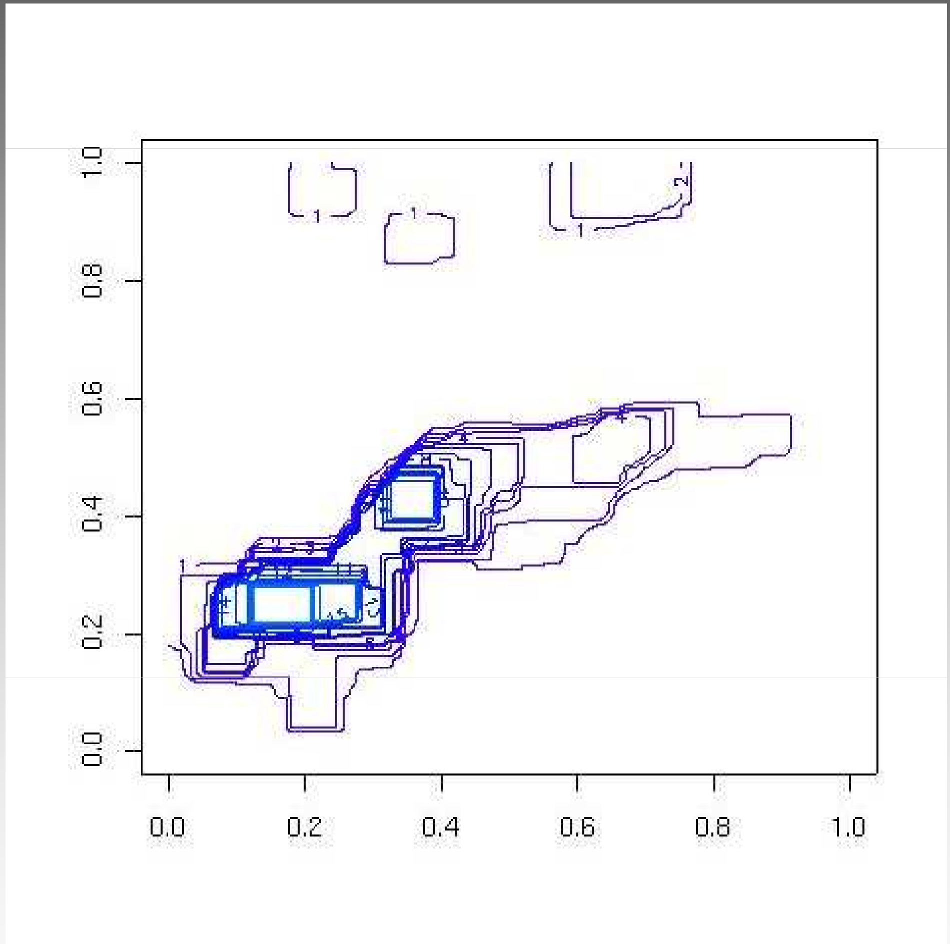
2-D filtering example – original vs 6-point features filtered out



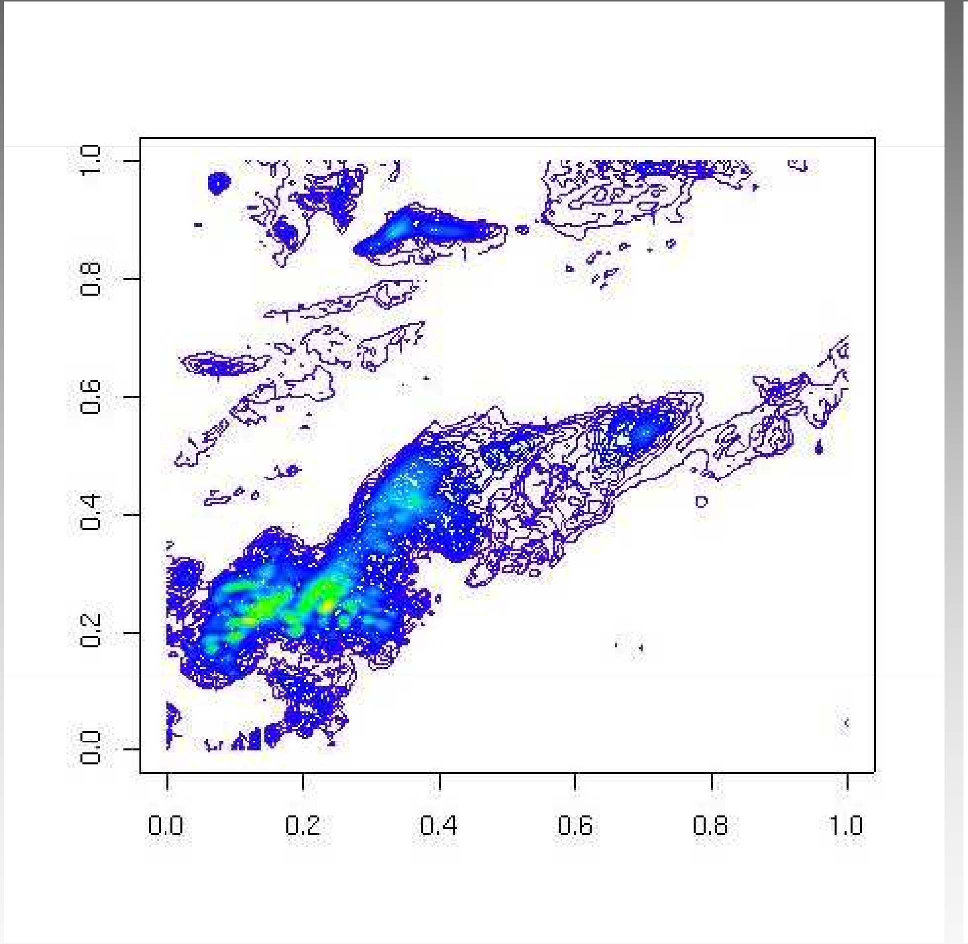


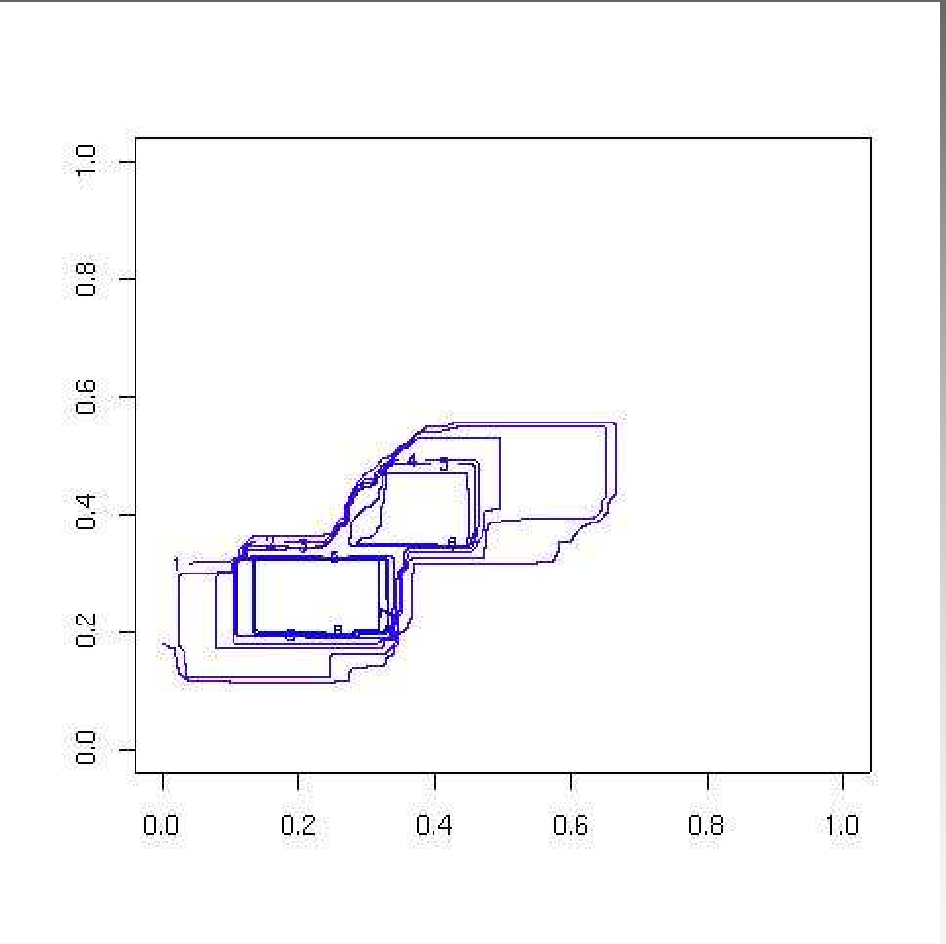
2-D filtering example – original vs 10-point features filtered out





2-D filtering example – original vs 20-point features filtered out





CWM Filters – open questions I

- *Is CWM filter an idempotent operator ?*
  - ✓ *idempotence is desired property for filters*
  - ✓ *this question needs detailed mathematical investigation yet*
  - ✓ *CWM filter applied to set of primitive shapes shows such property*

CWM Filters – open questions II

- *Is directional dependence of 2-D CWM filter procedure a deficiency ?*
  - *directional dependence of the procedure can be overcome be taking minimum or average of two filter passes: x axis - oriented and y axis – oriented ones*
  - *even one-pass CWM filter applied to some primitive shapes shows no directional dependence of results - both passes give the same*

CWM Filters – deficiencies I

- *For efficient filtering mean derivative of analysed field averaged over domain should be close to zero:*
  - *for large domains, bigger then analysed patterns, it isn't serious problem at all*
  - *for small domains boundary conditions should be posed properly*

CWM Filters – deficiencies II

- *High computational cost of large scale features removing*
  - *forget about “cheap” statistics - modern statistical methods need more and more computational power*
  - *it is tool rather for research purposes*
  - *small scale patterns removal is not expensive*

CWM Filters – future research

- *Methods of data analysis which can fully exploit potential of CWM filters and specificity of their results*
  - *CWM filters rather eliminate finer features then average them*
- *3-D filtering*

CWM Filters – end of tour

Thank you for your attention