Robust meteorological data analysis with CWM filters

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Kraków, 15-04-2010

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Part 1

CWM FILTERS - THEORY

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CWM filters in a nutshell

To compare or merge meteorological data from different observing and prediction system it is necessary to cope with differences in their characteristic time and space scales .

Current methods suffer because of sensitivity to outliers and dependence on assumption of error distribution.

The growing amount of operationally processed meteorological data needs unsupervised scale separation methods. Robustness becomes a key feature.

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CWM filters in a nutshell (2)

Newly proposed 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 CWM filter is superposition of 2 kinds of elementary bricks: A-brick and B-bricks. A-brick of level l is WM filter of size 2*l+1 and weights a(1,2,...2,1). B-brick of level l is WM filter of size 2*l+1 and weights (1,1,...1,1). 2-D CWM filter is two-stage 1-D filter applied to different directions. 1-D CWM filter seems to be idempotent – mathematical proof is under preparation.

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Part 2

EXAMPLE – ALADIN PRECIPITATION FIELD

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Let's apply CWM filters of various orders to ALADIN precipitation field (marked as Field1) and compare results with original pattern.

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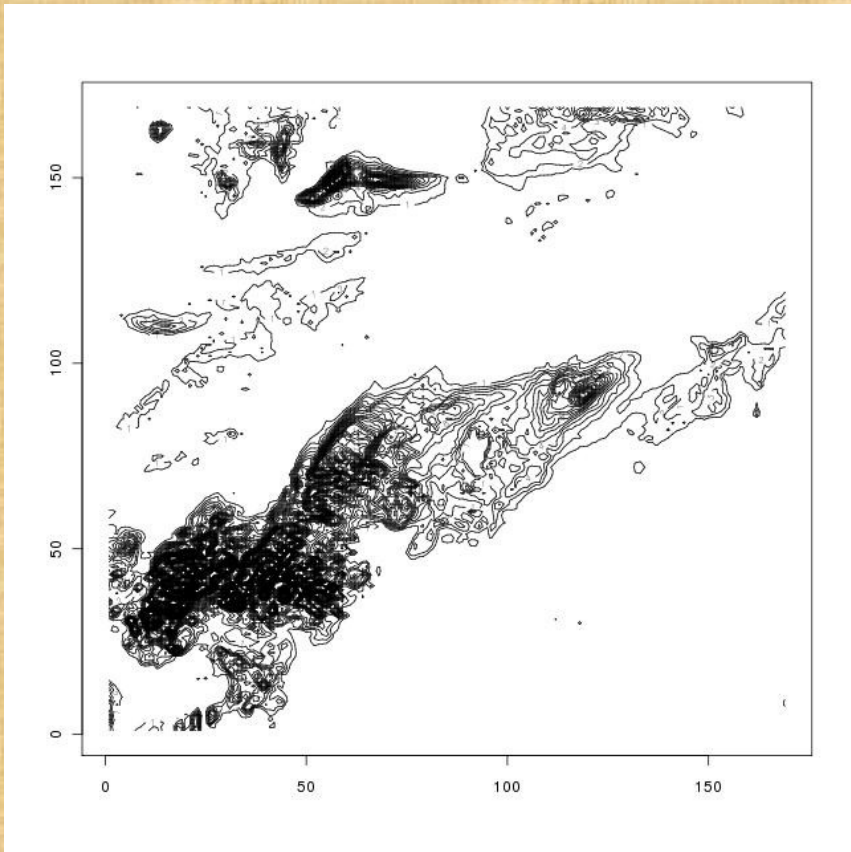
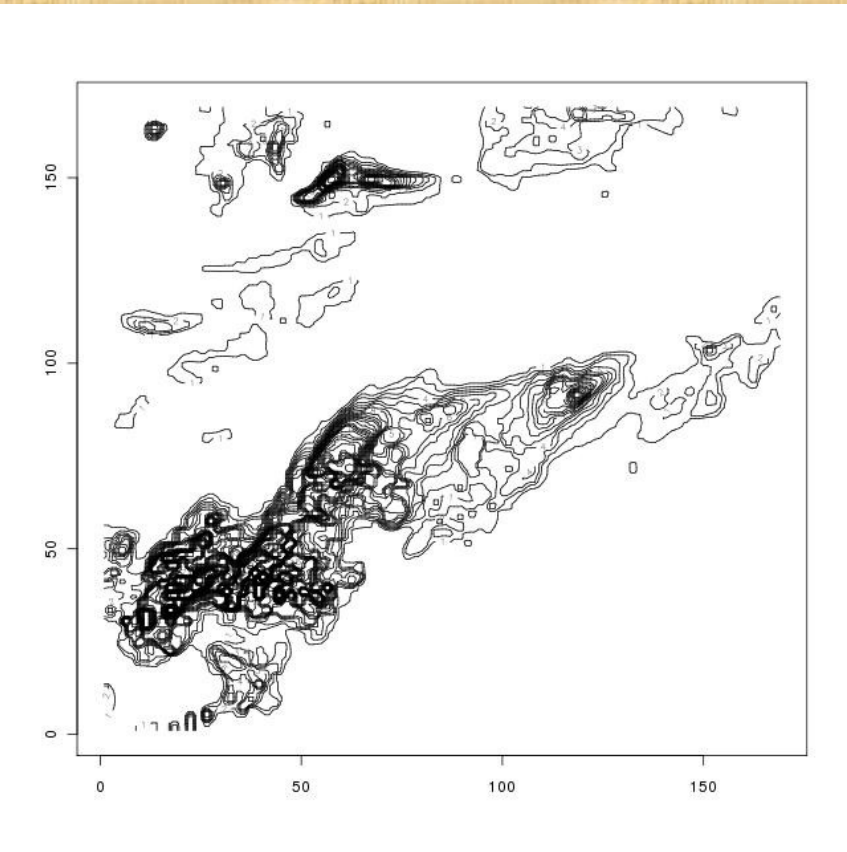
Field1 - original vs 01





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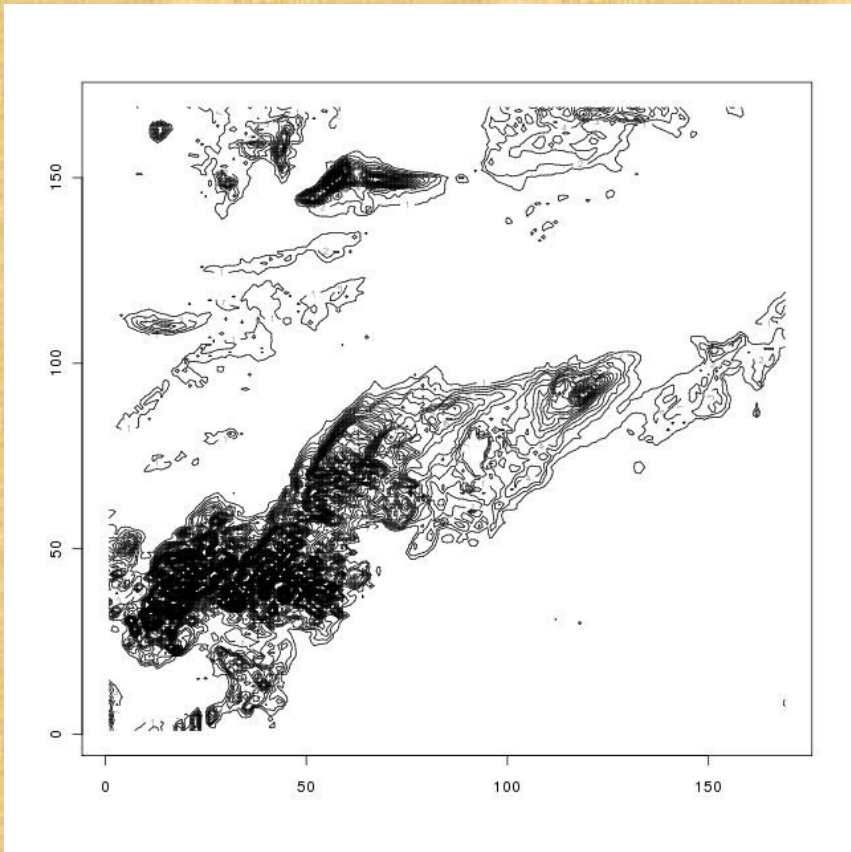
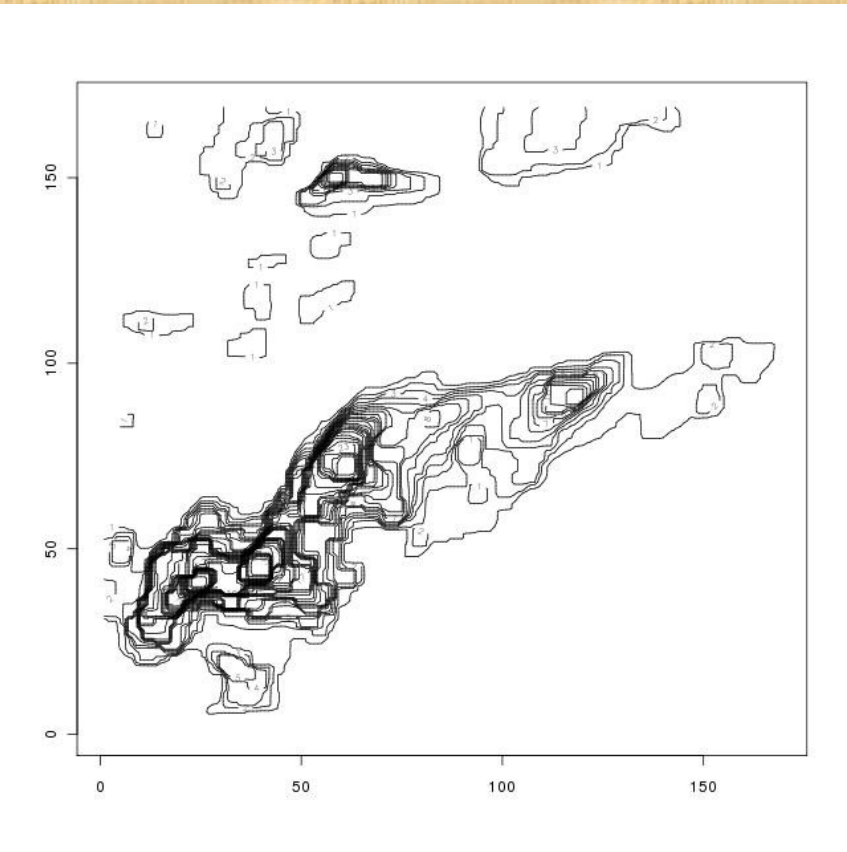
Field1 - original vs 03





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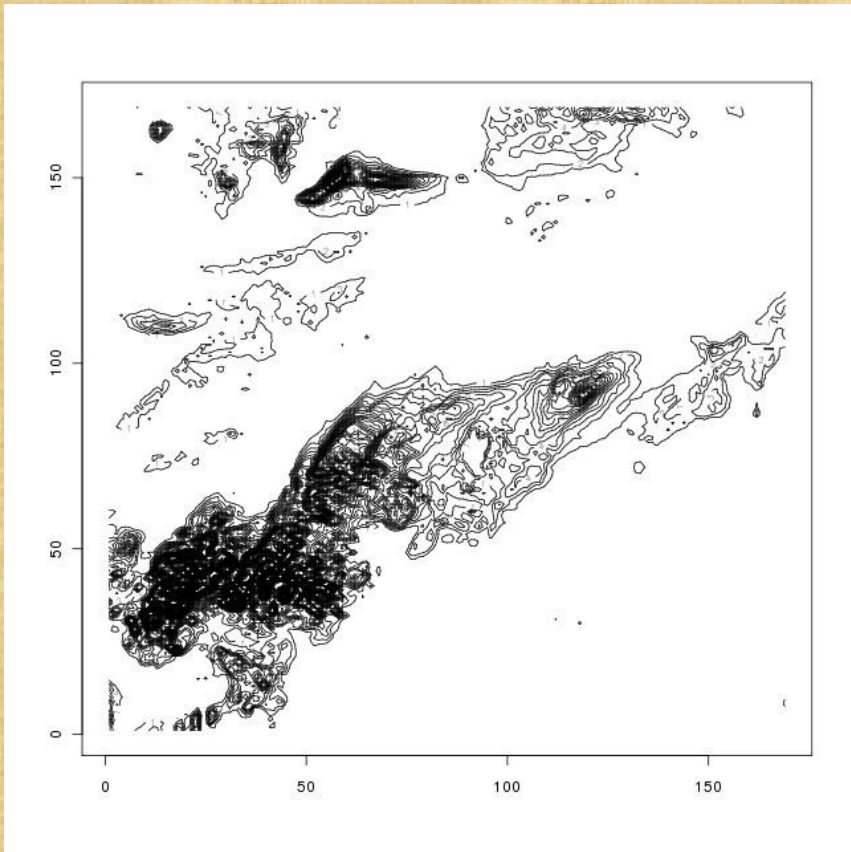
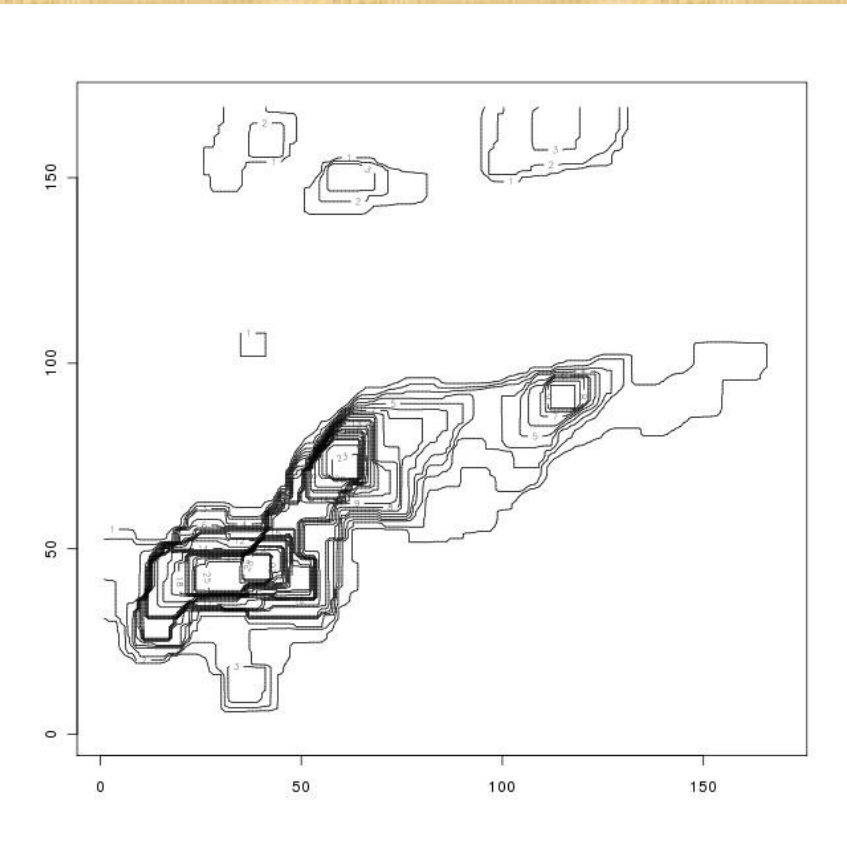
Field1 - original vs 06





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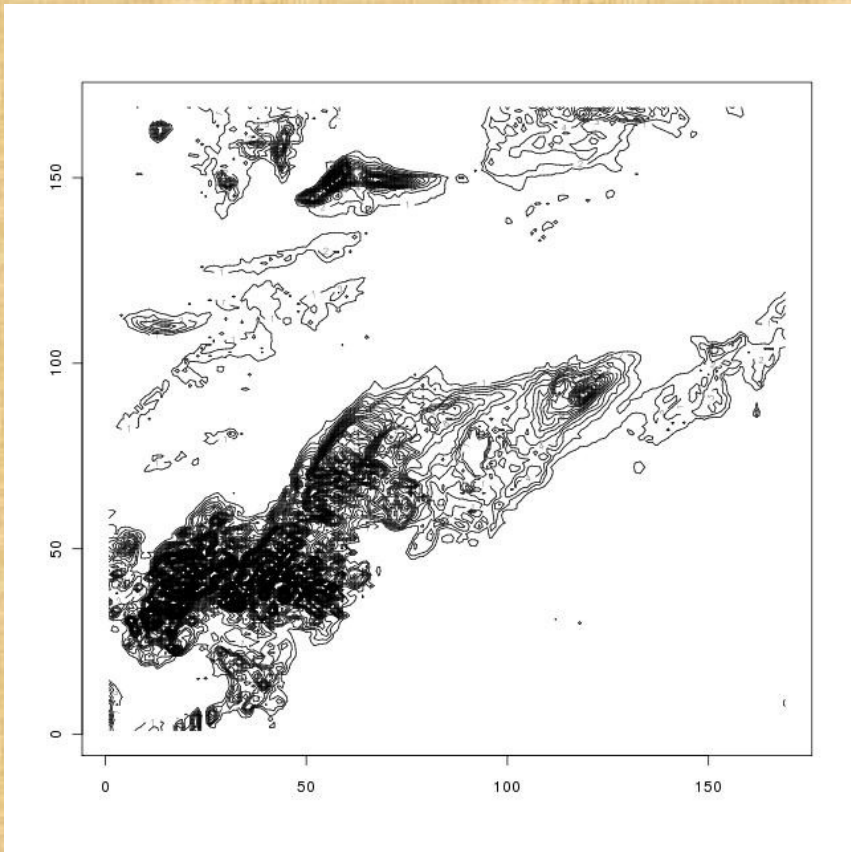
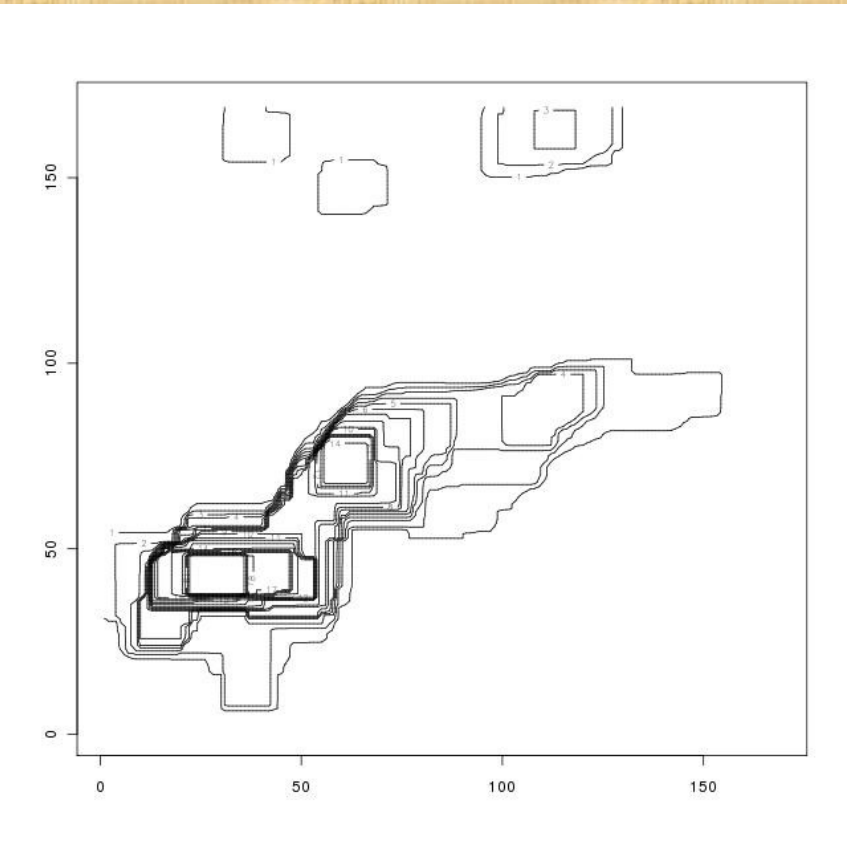
Field1 - original vs 10





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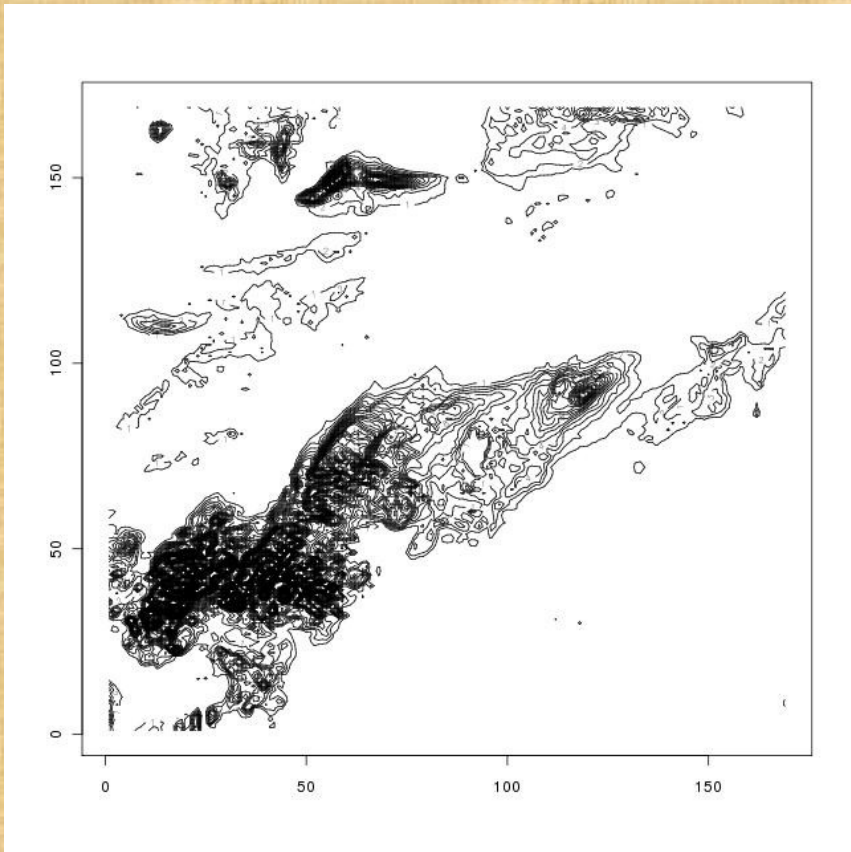
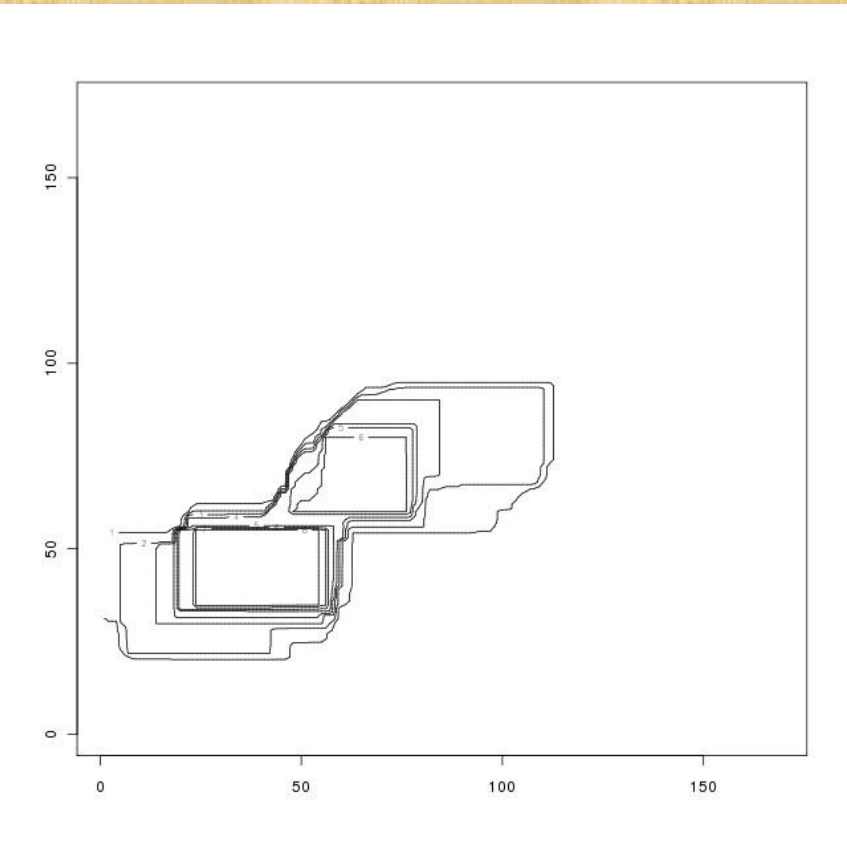
Field1 - original vs 20





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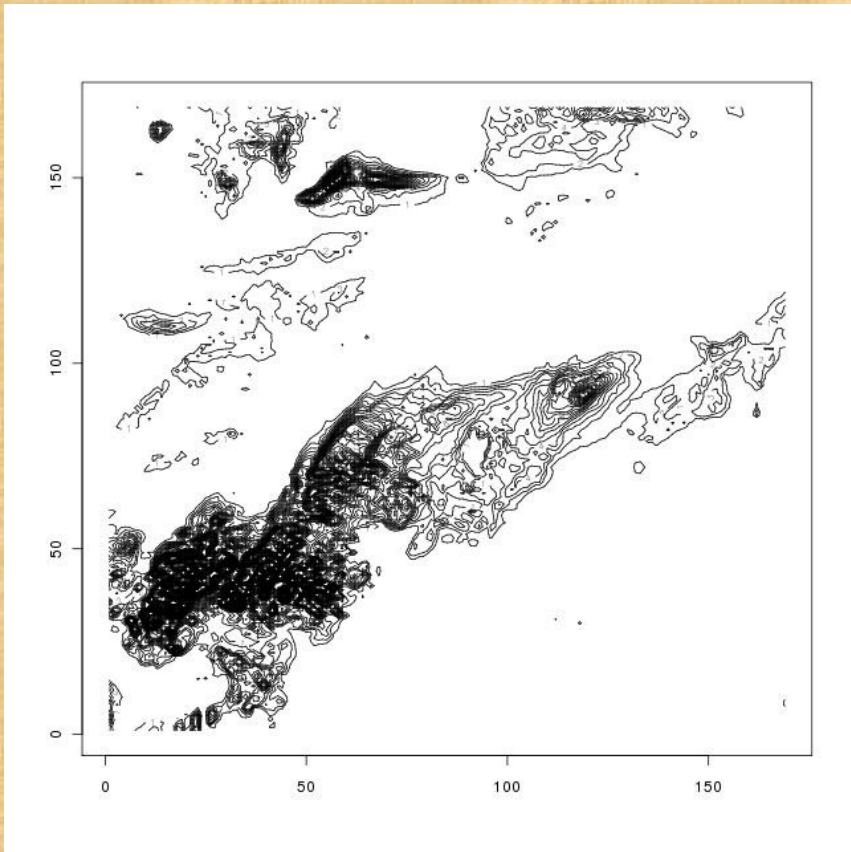
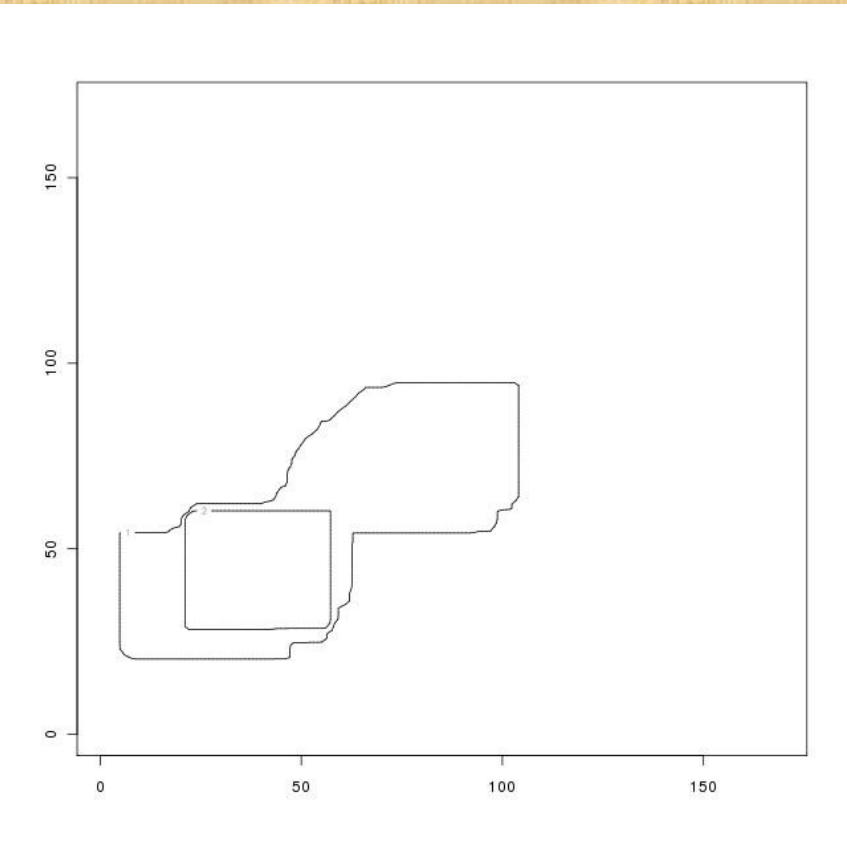
Field1 - original vs 30





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Now let's apply CWM filters of various orders to two ALADIN preciptiation forecasts (marked as Field1 and Field2) valid at the same time and compare the results.

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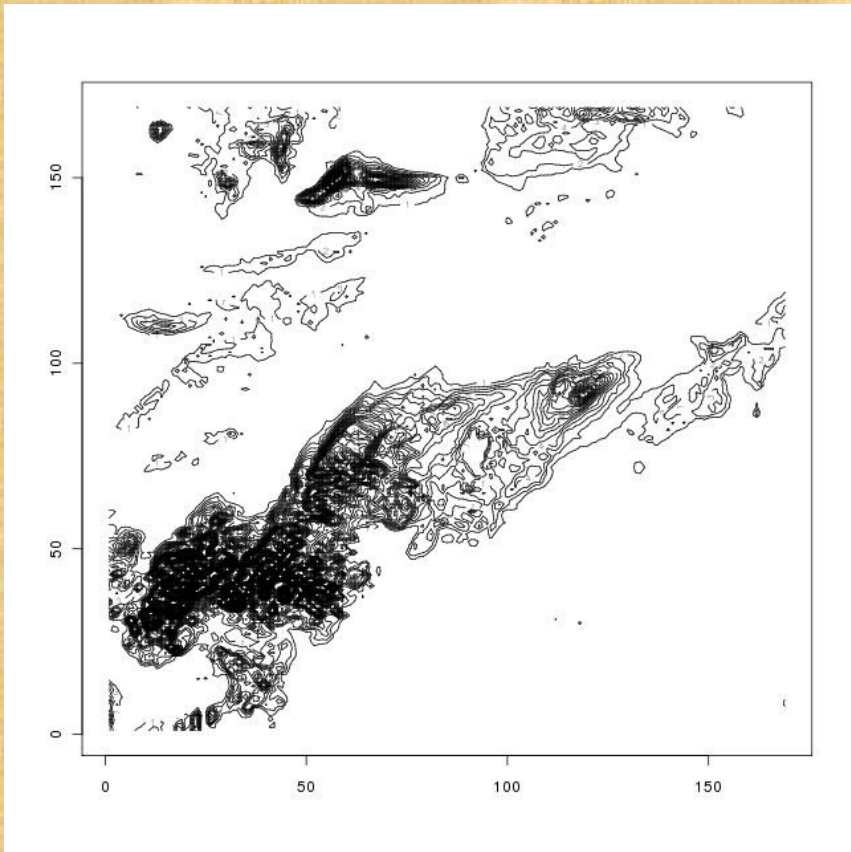
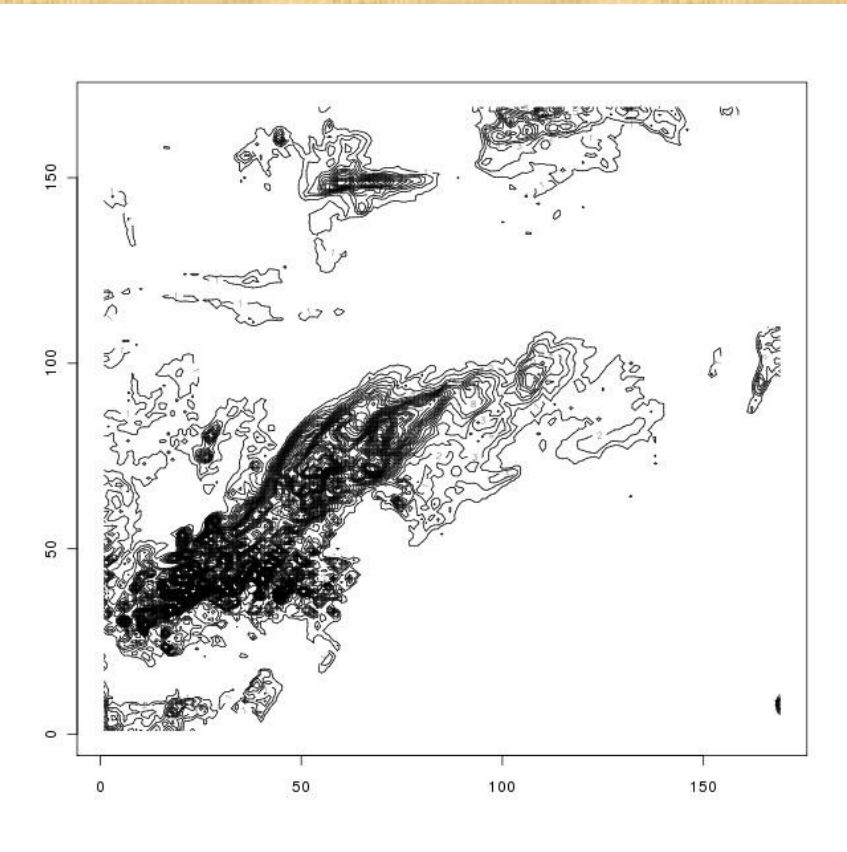
Field1 vs Field2 - originals





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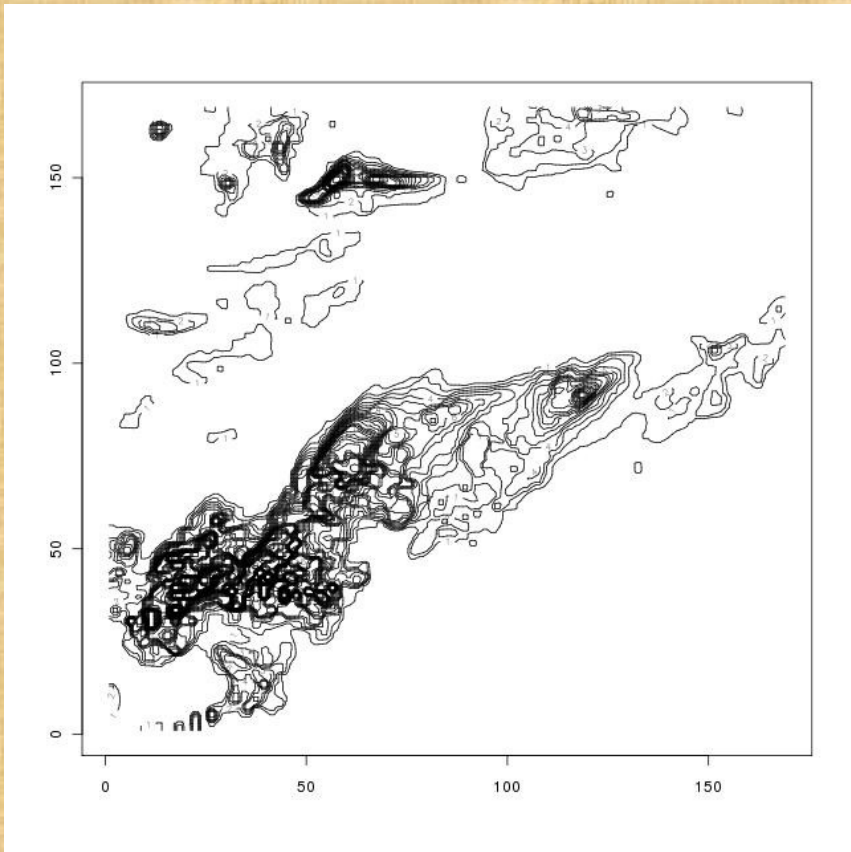
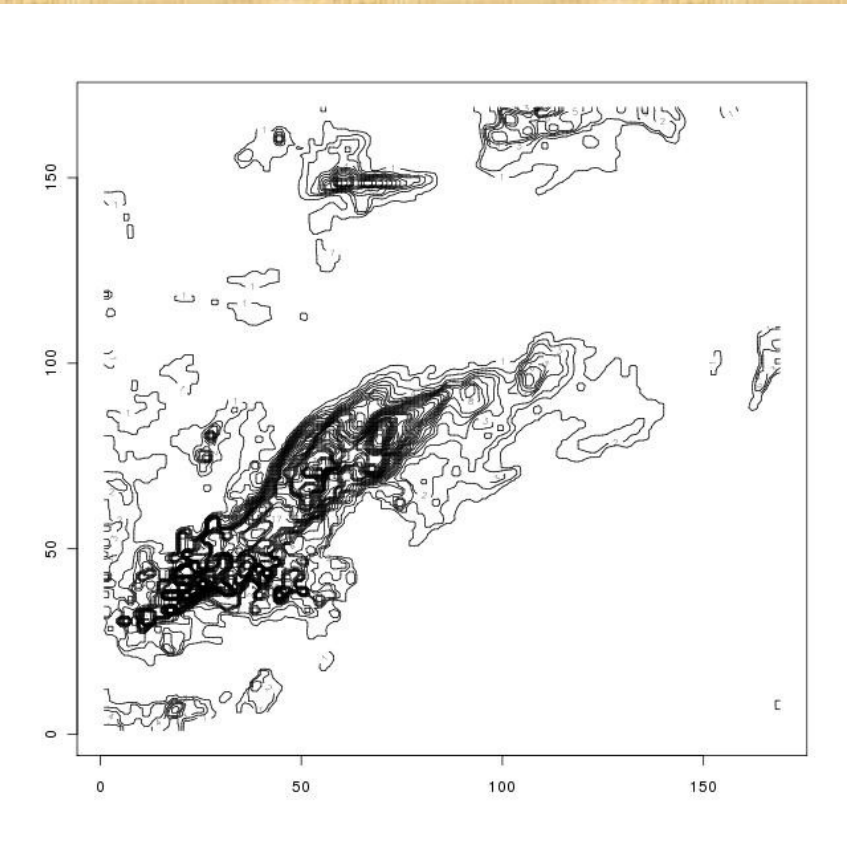
Field1 vs Field2 - 01





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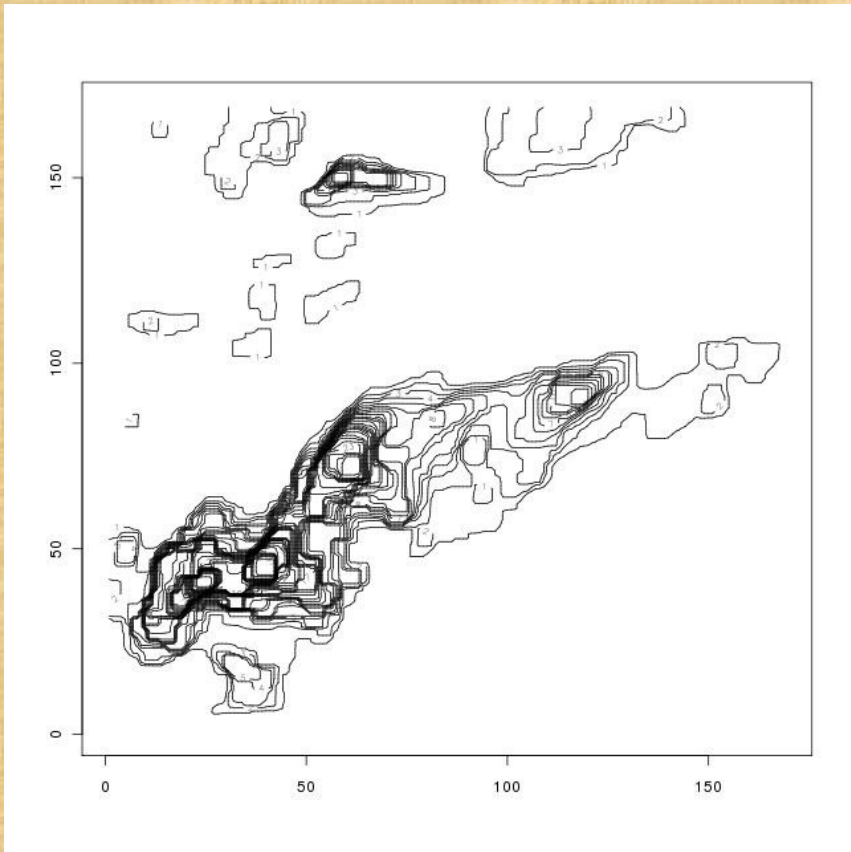
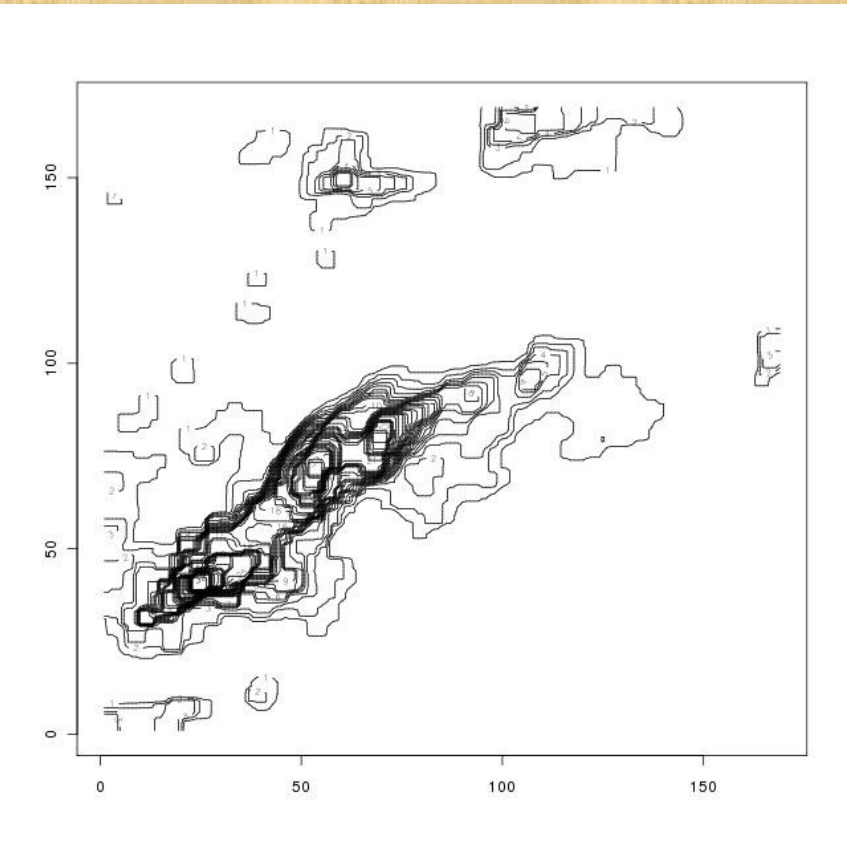
Field1 vs Field2 - 03





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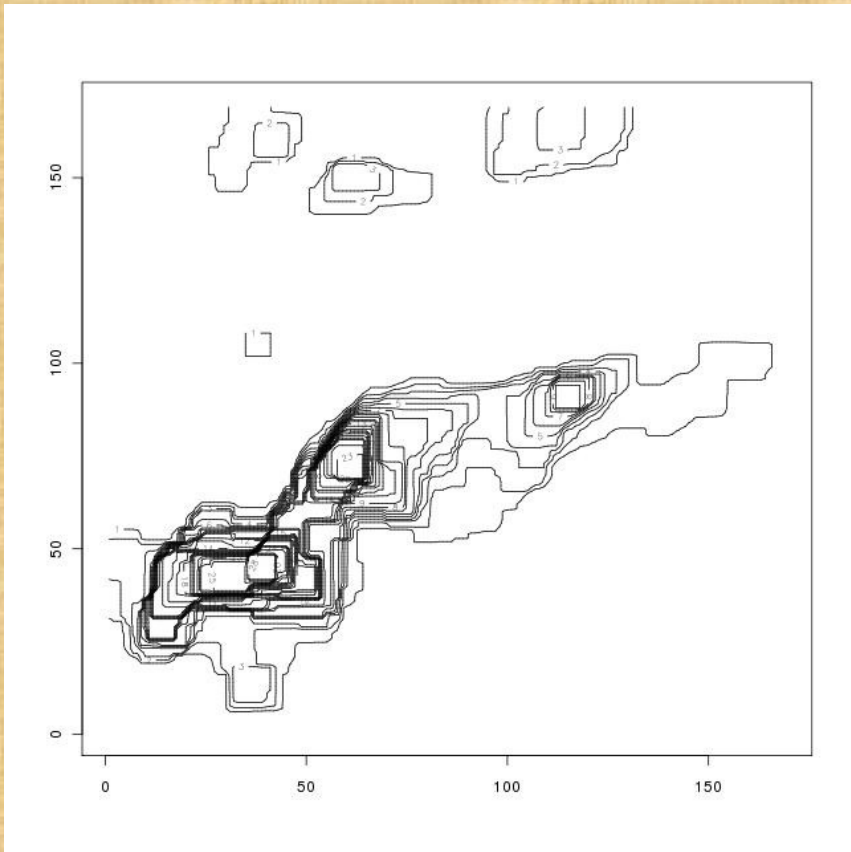
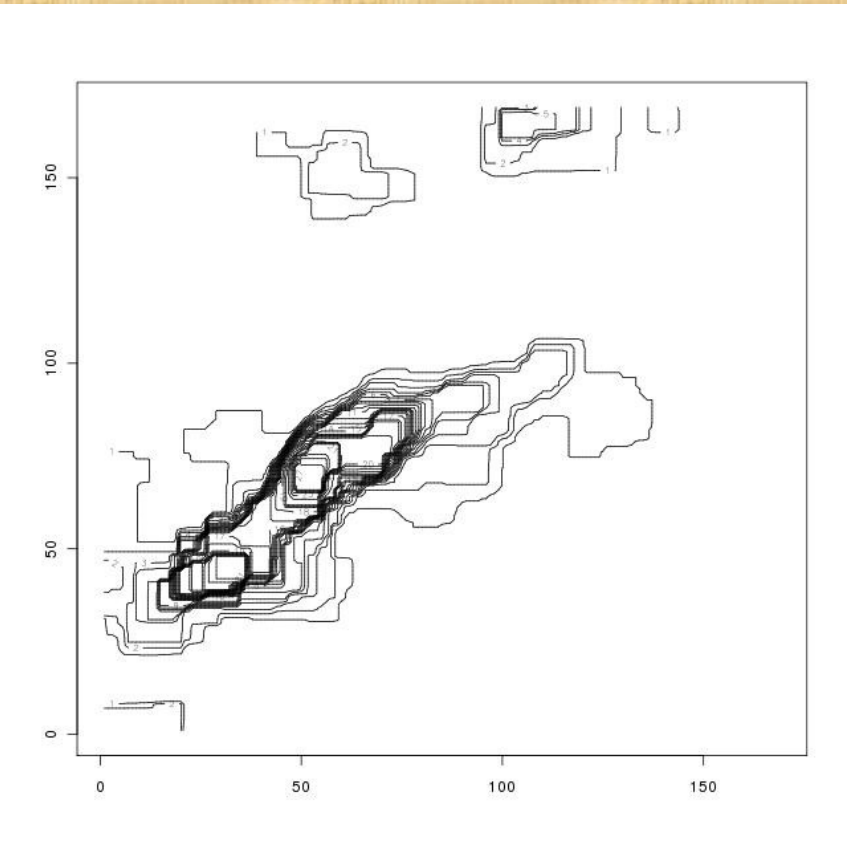
Field1 vs Field2 - 06





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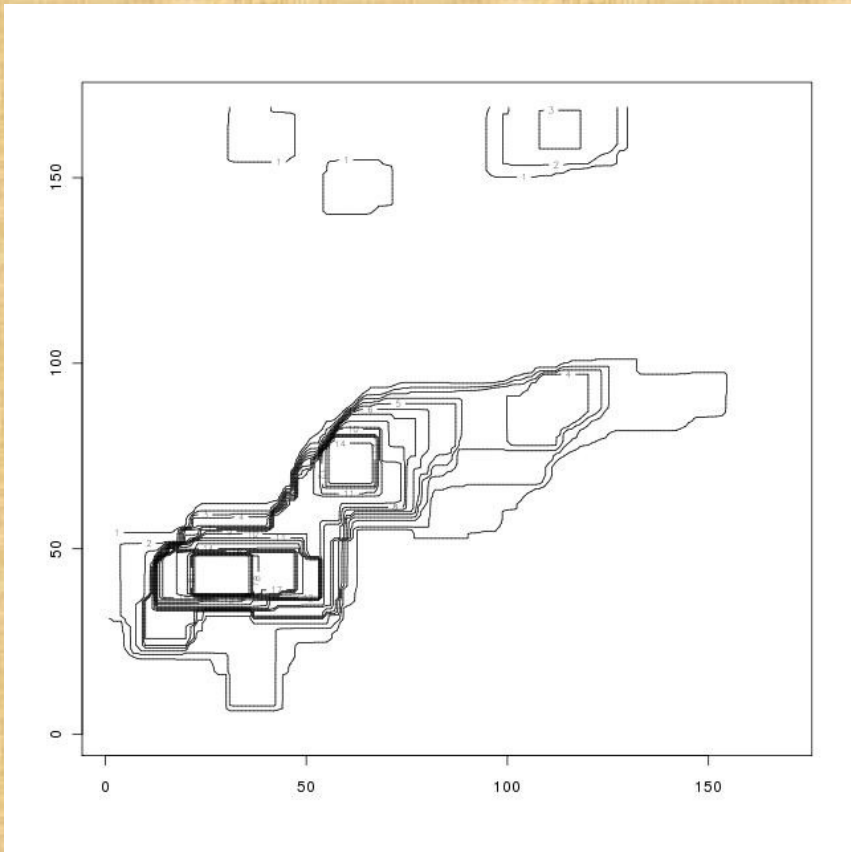
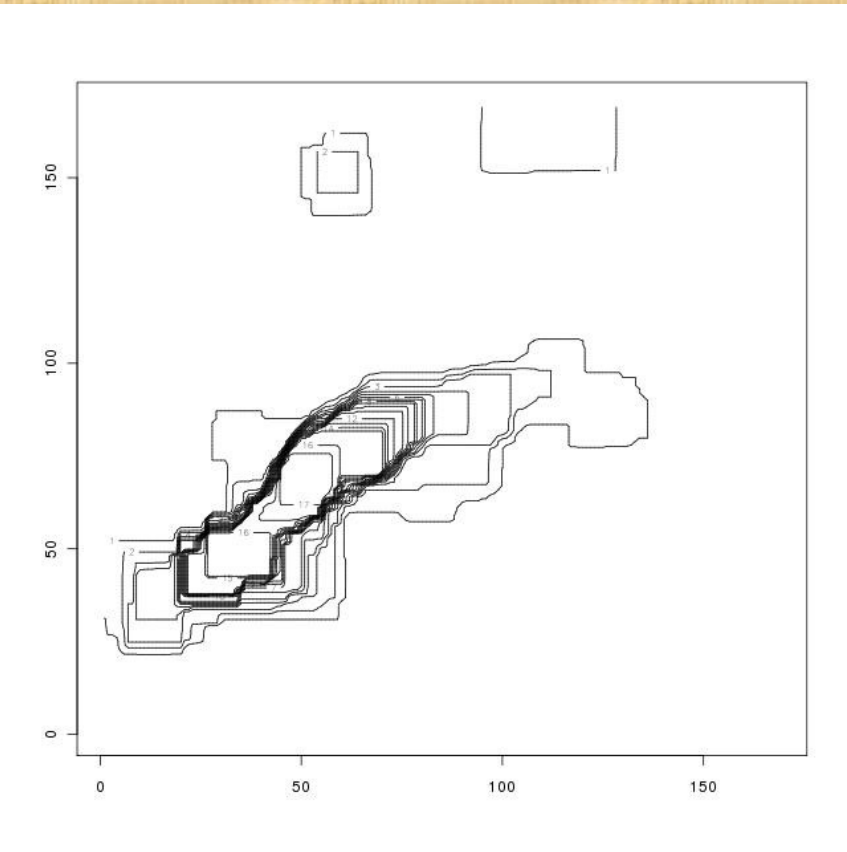
Field1 vs Field2 - 10





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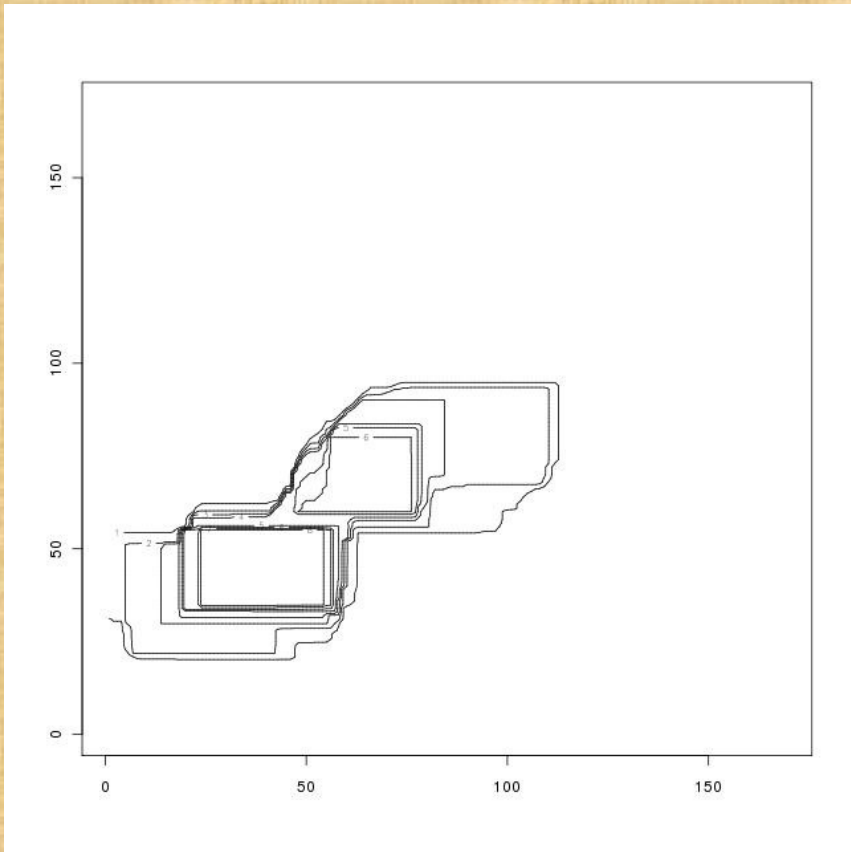
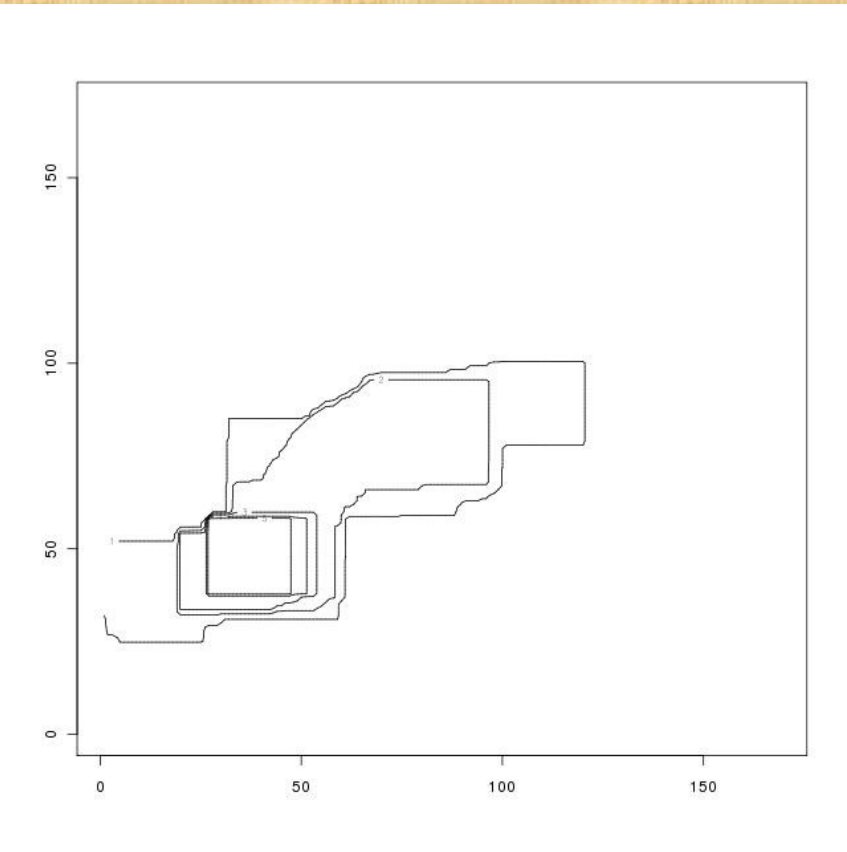
Field1 vs Field2 - 20





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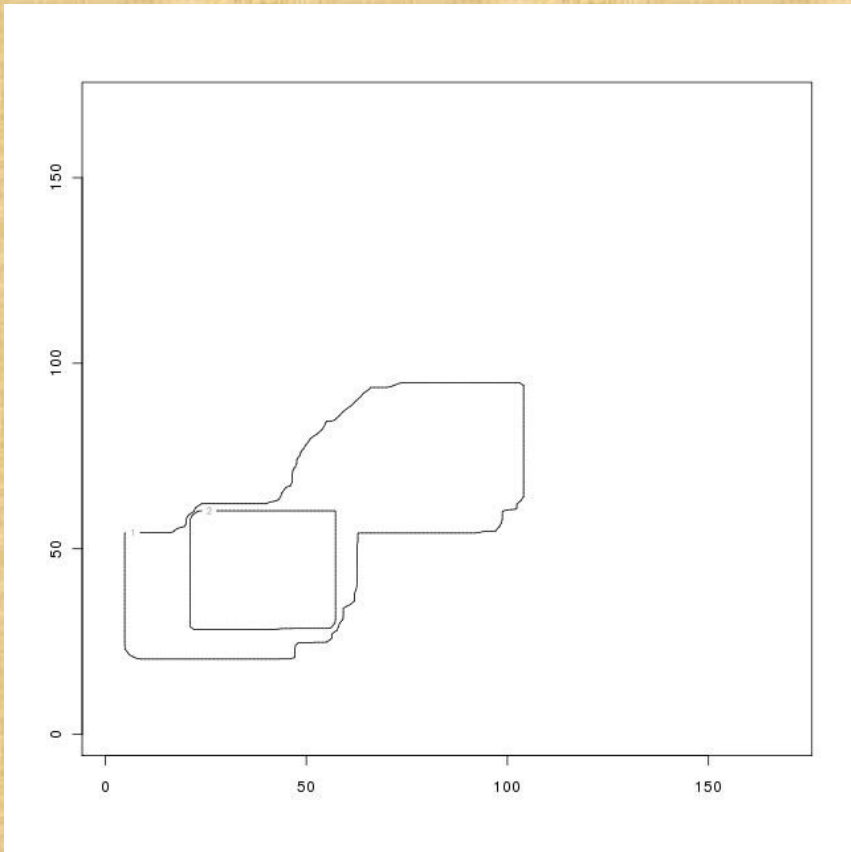
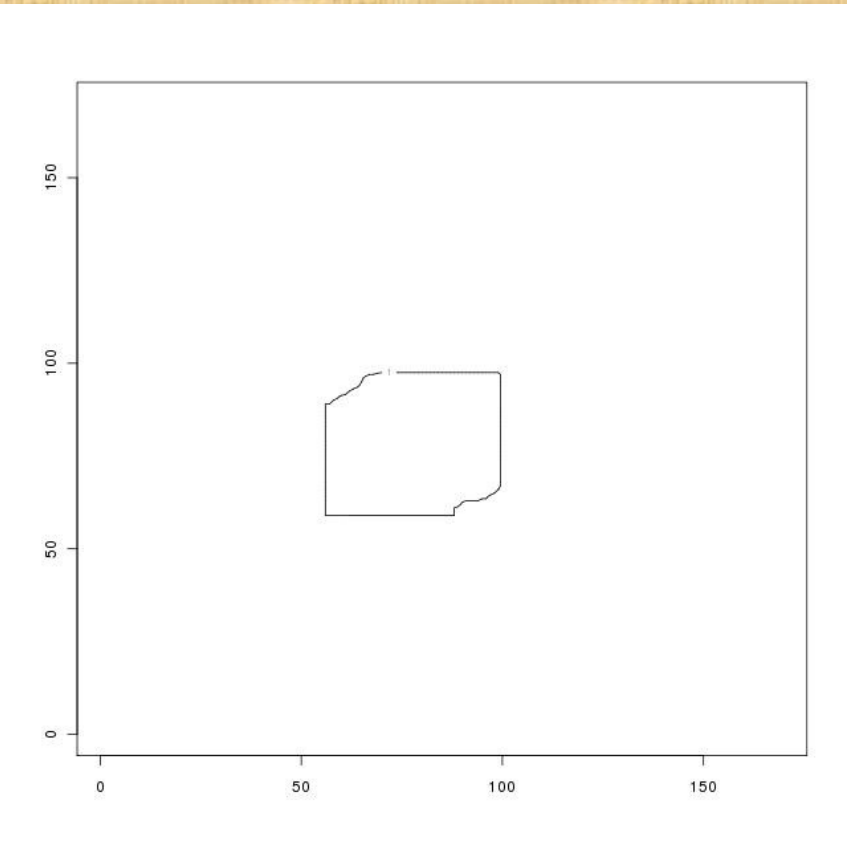
Field1 vs Field2 - 30





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Part 3

EXAMPLE - SATELLITE IMAGE I

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CWM filters can be applied also to images - Meteosat image (marked as Image1) with visible convection cloud pattern filtered and compared with original one.

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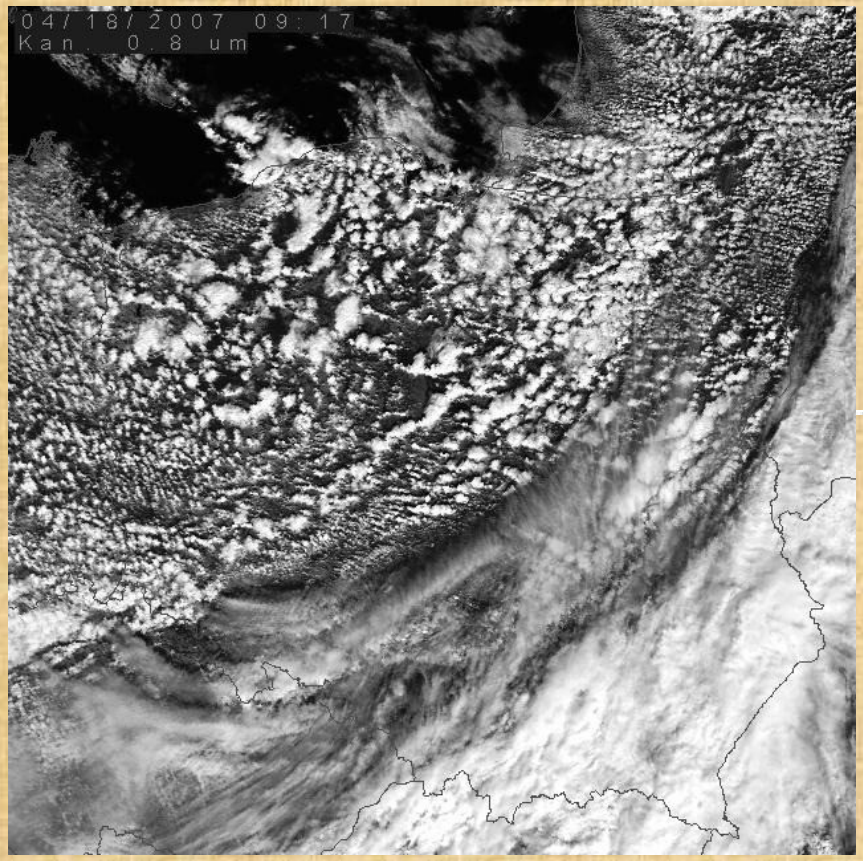
Image1 – original vs 01



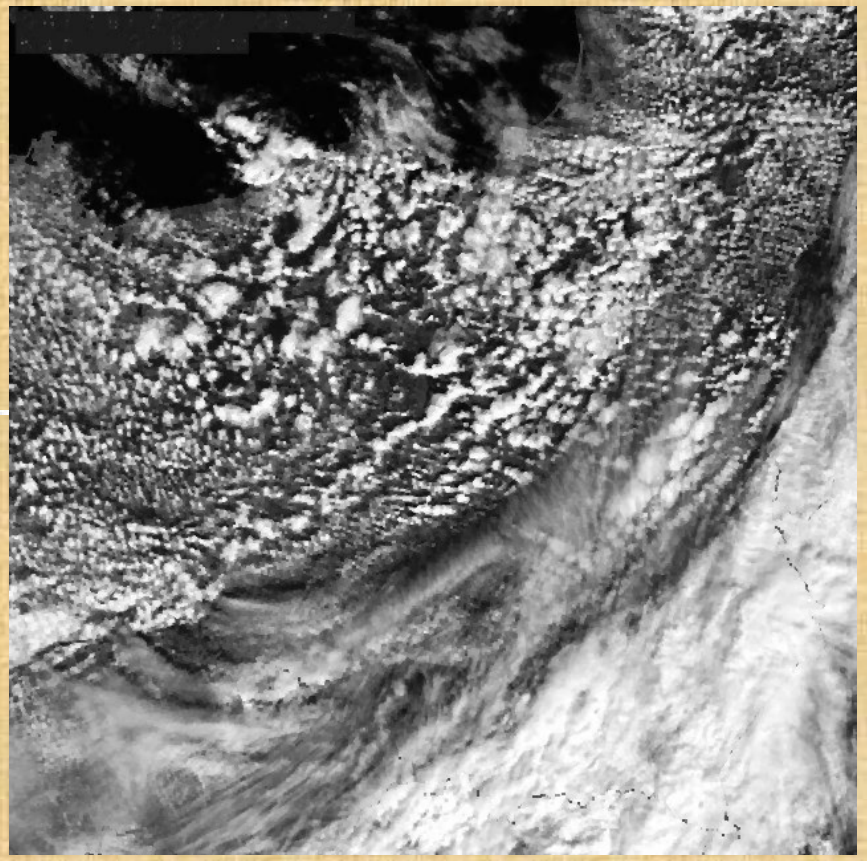


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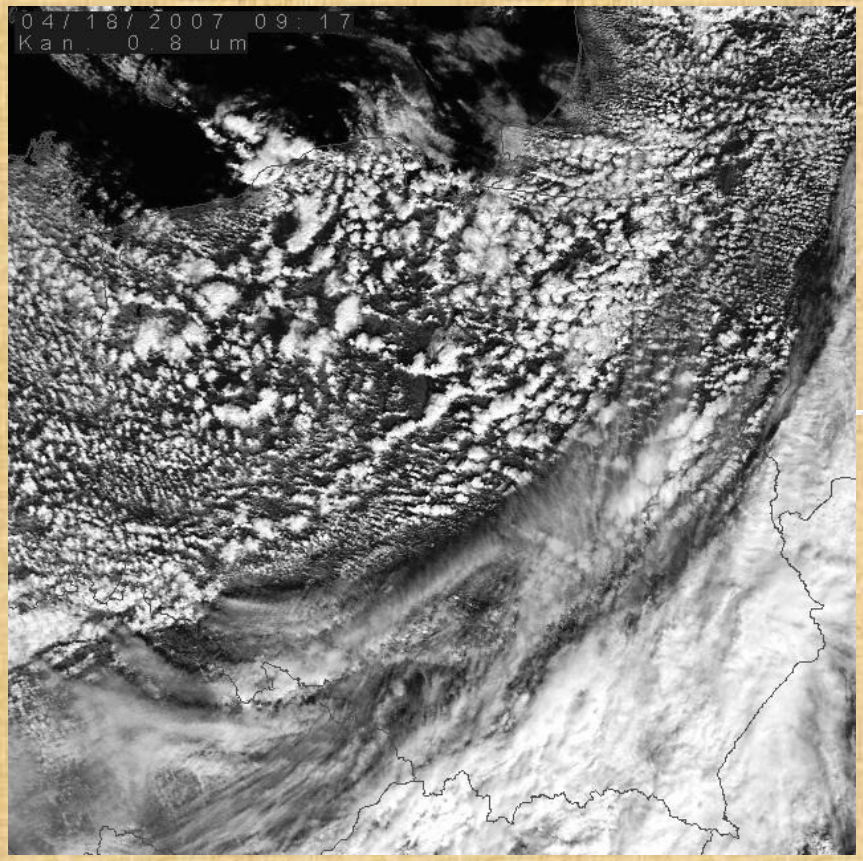
Image1 – original vs 02



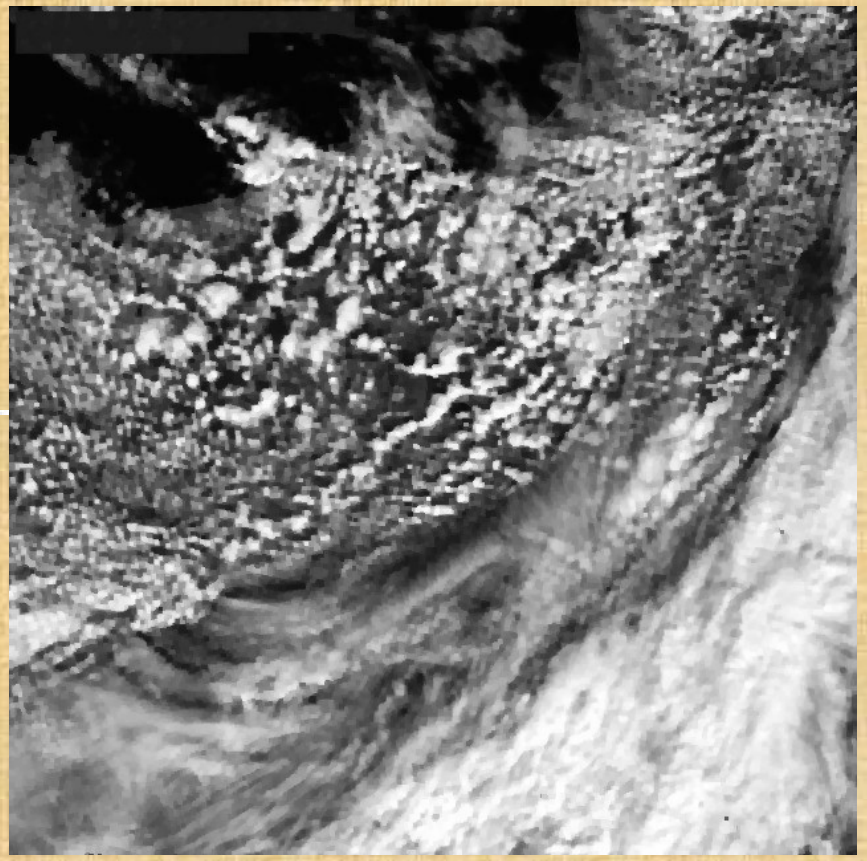


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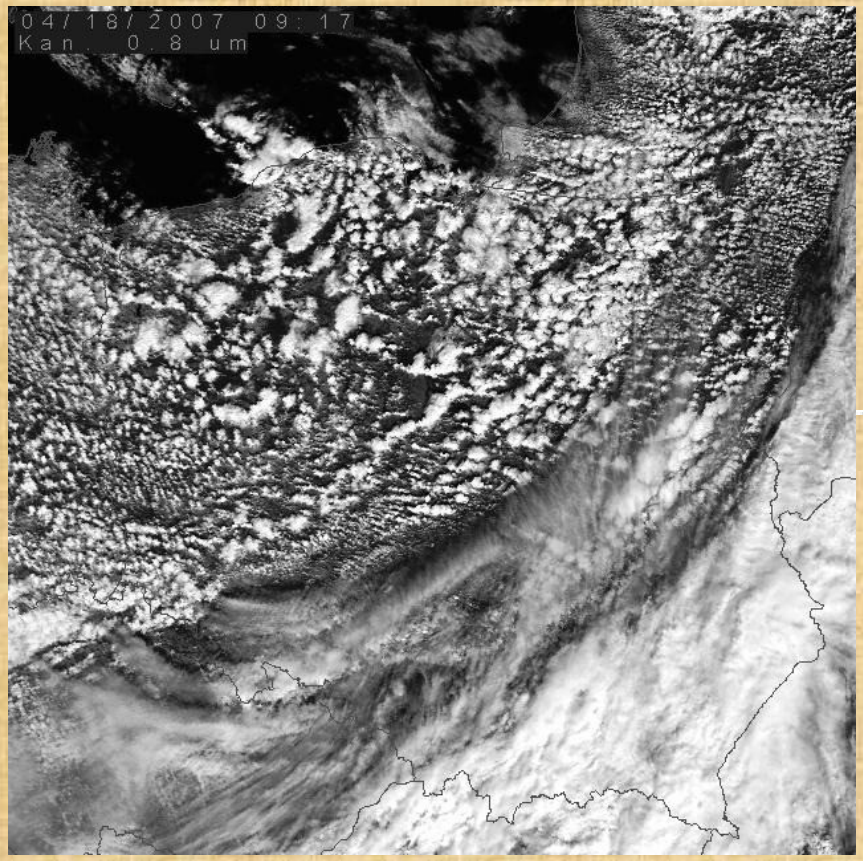
Image1 – original vs 04



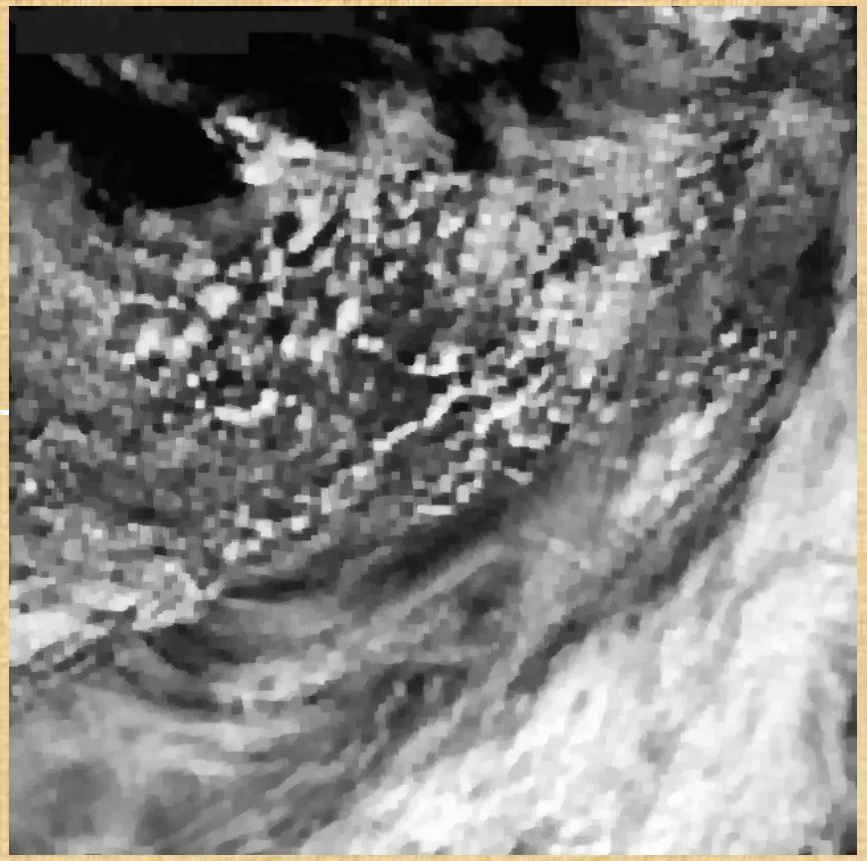


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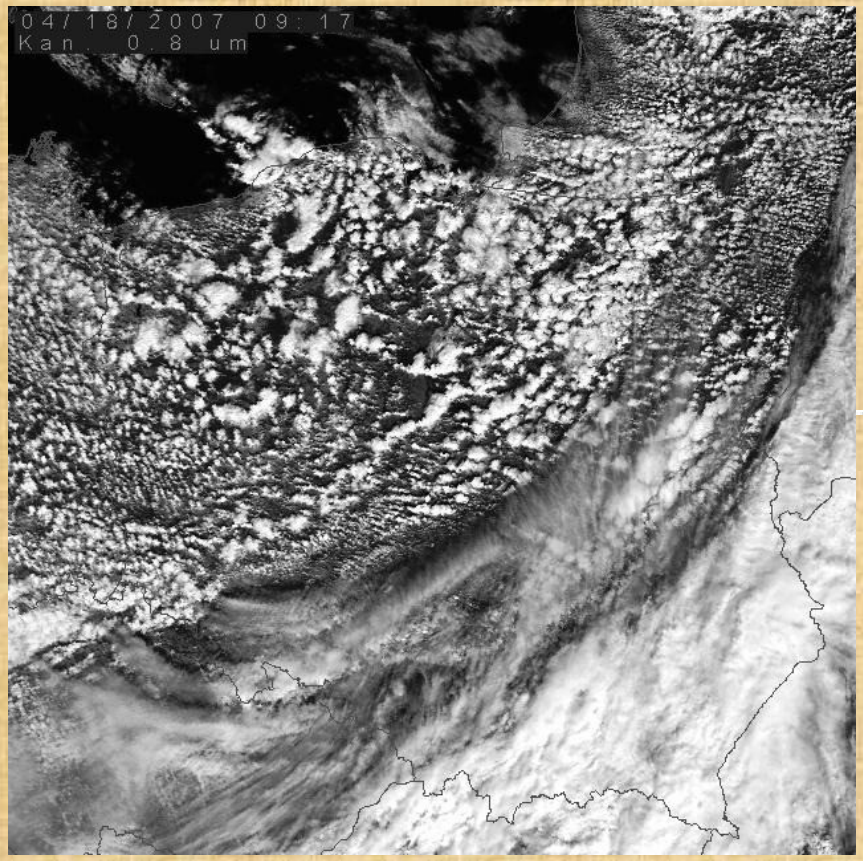
Image1 – original vs 08



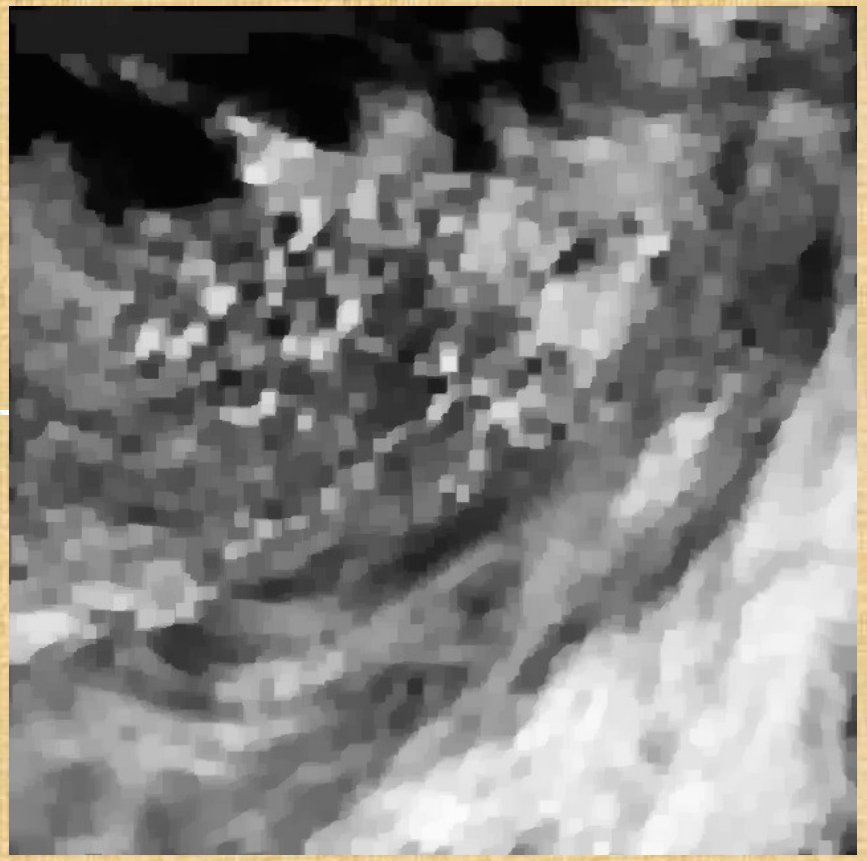


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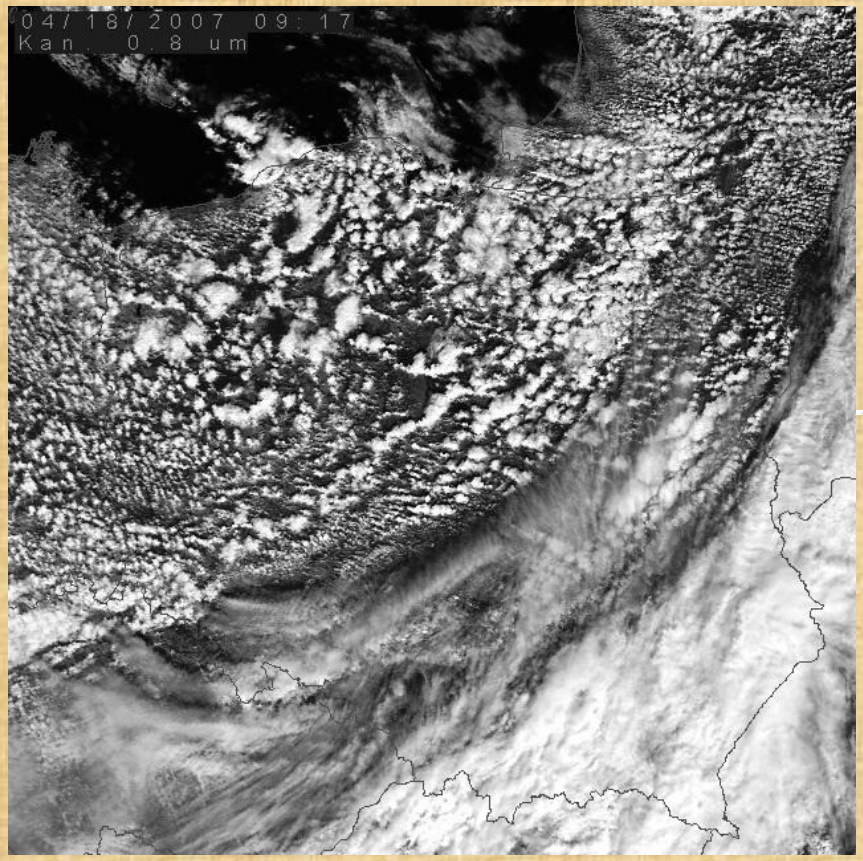
Image1 – original vs 16



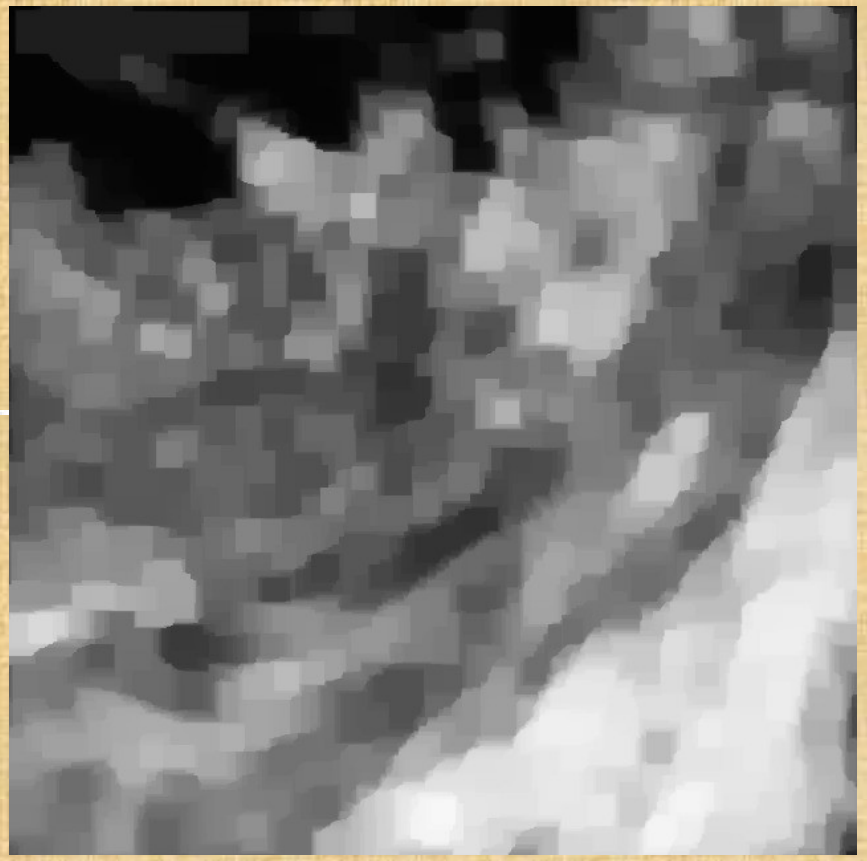


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Image1 – original vs 32

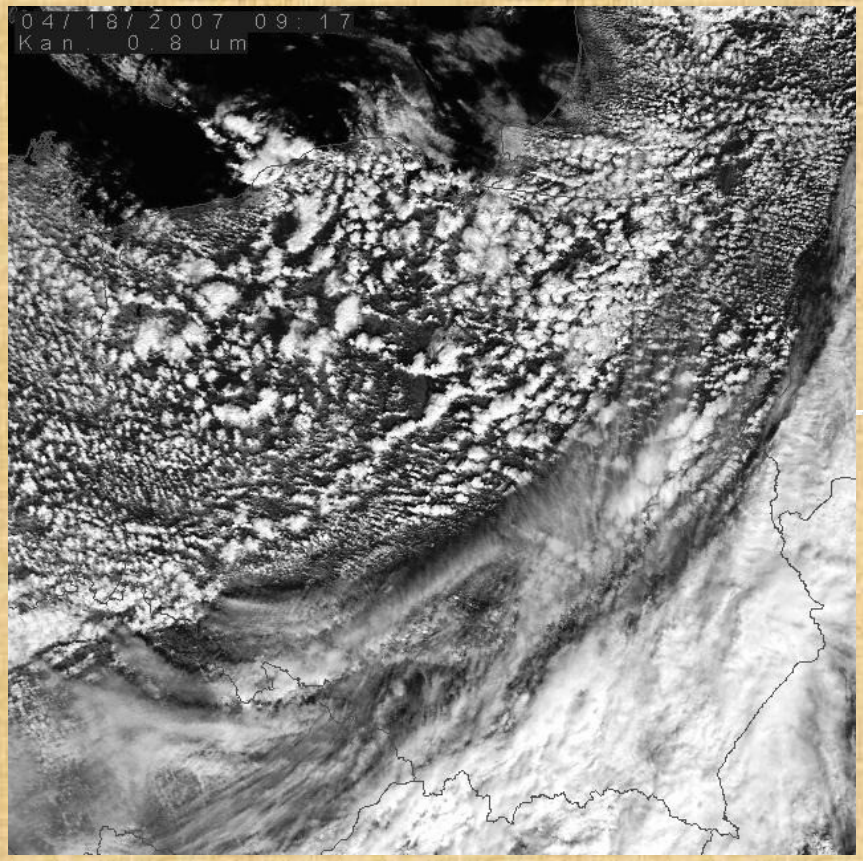

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Image1 – original vs 64

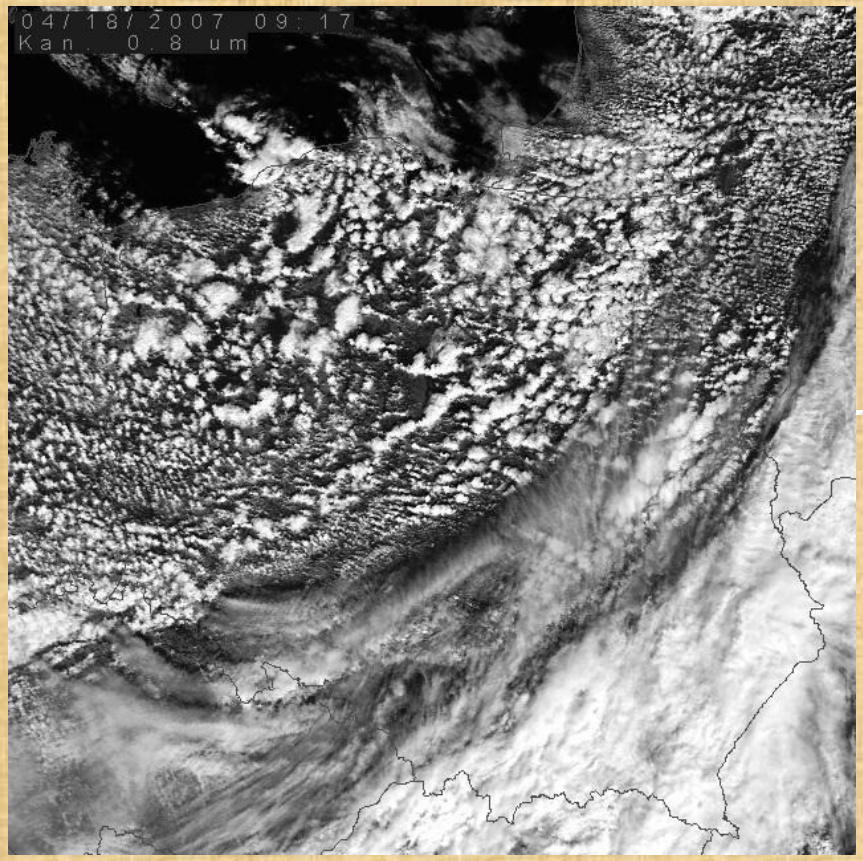

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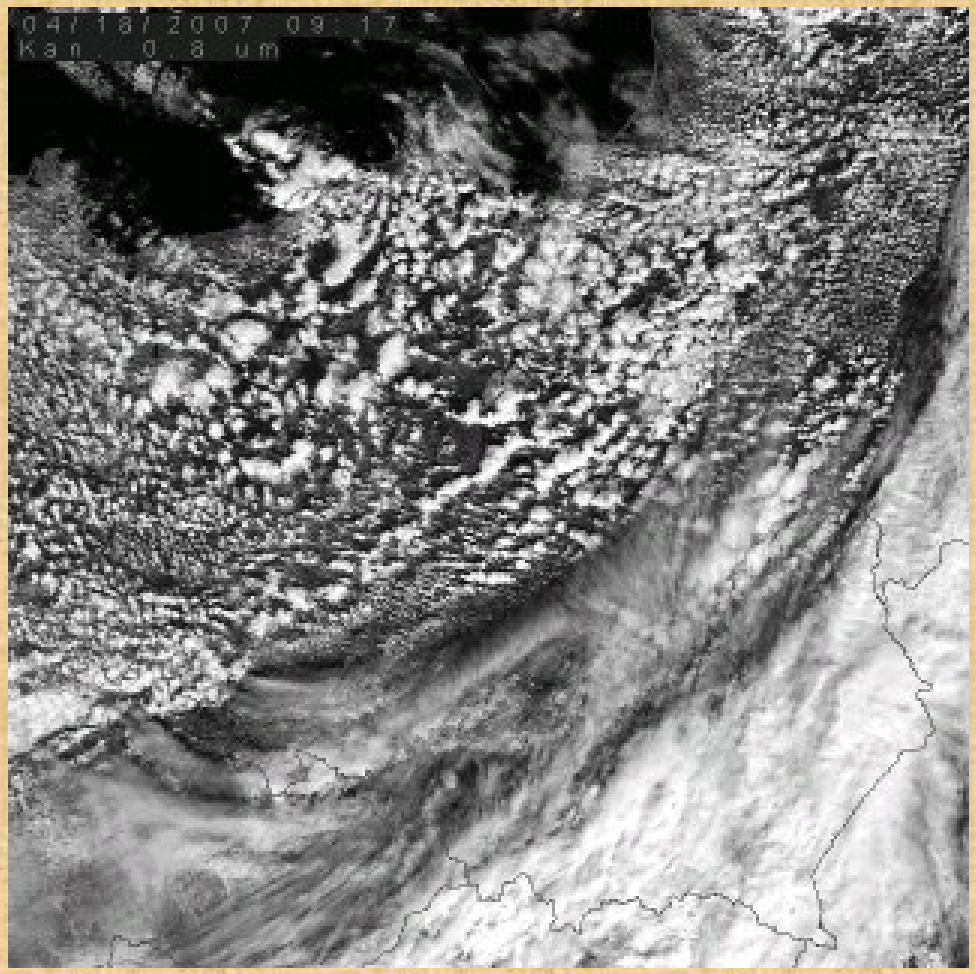
Image1 – filtering animation



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Part 4

EXAMPLE - SATELLITE IMAGES II

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CWM filters applied to another Meteosat image (marked as Image2) with frontal cloud patterns filtered and compared with original one.

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Image2 – original vs 01

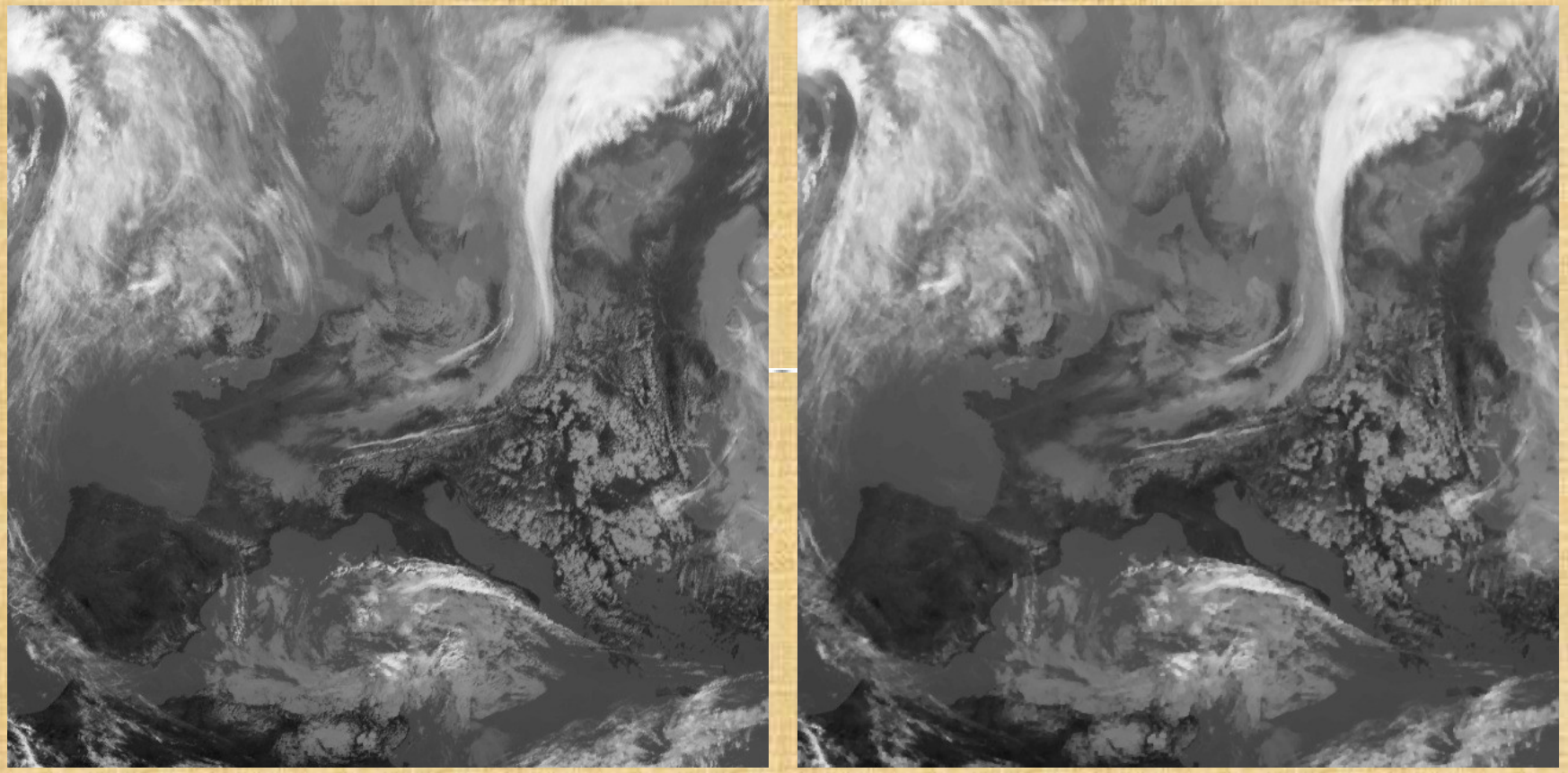

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Image2 – original vs 02

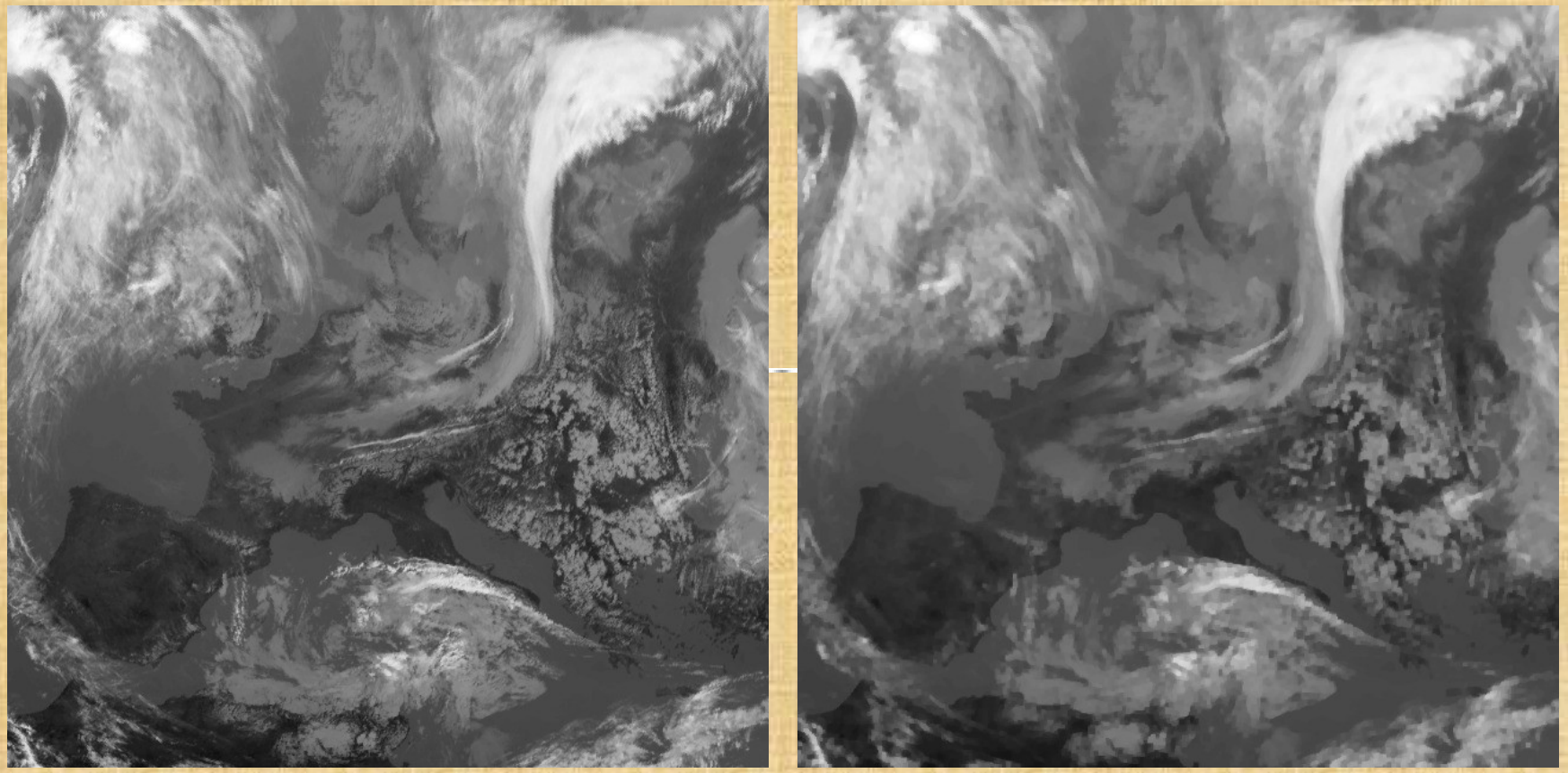

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Image2 – original vs 04

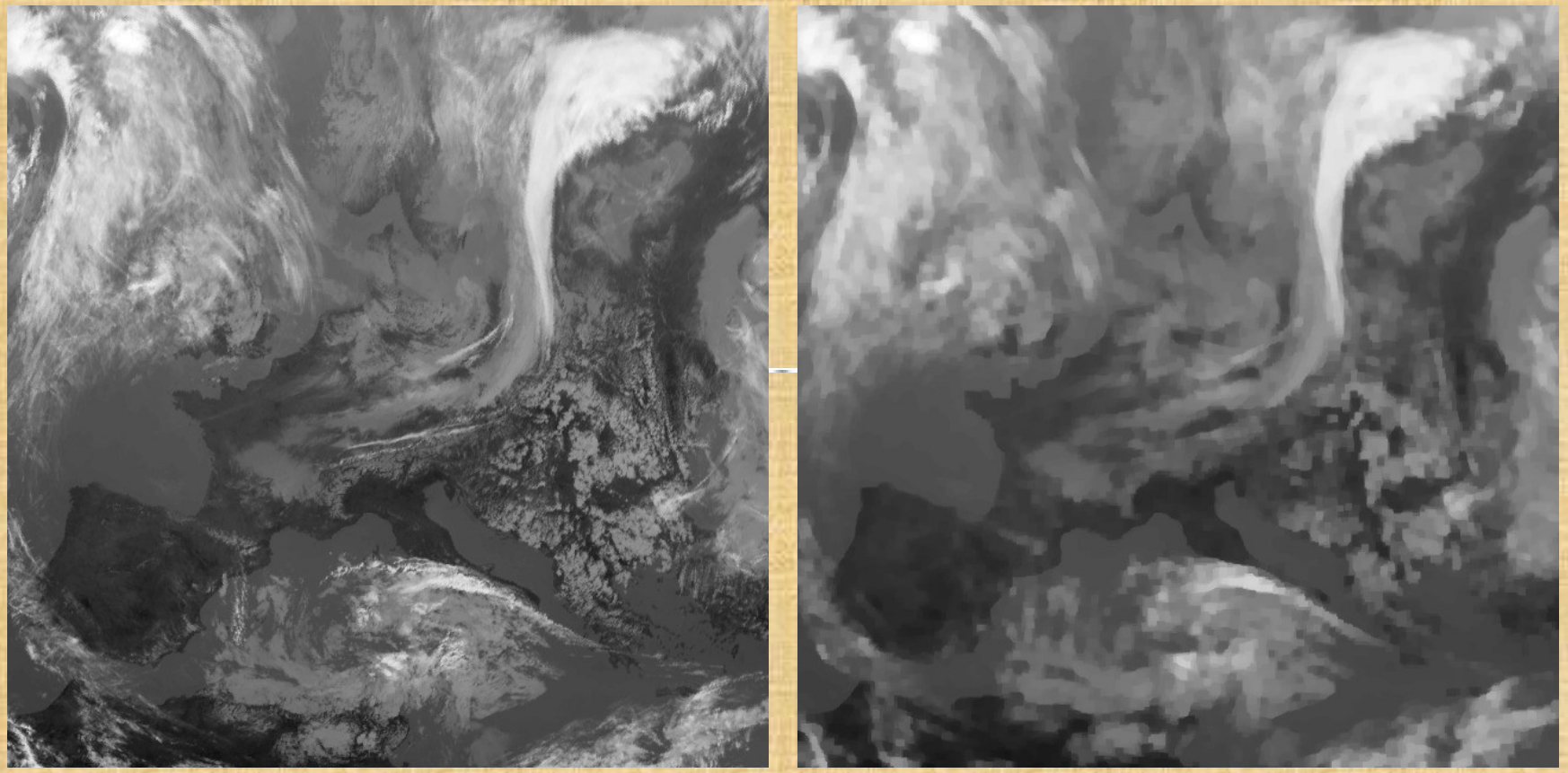

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Image2 – original vs 08

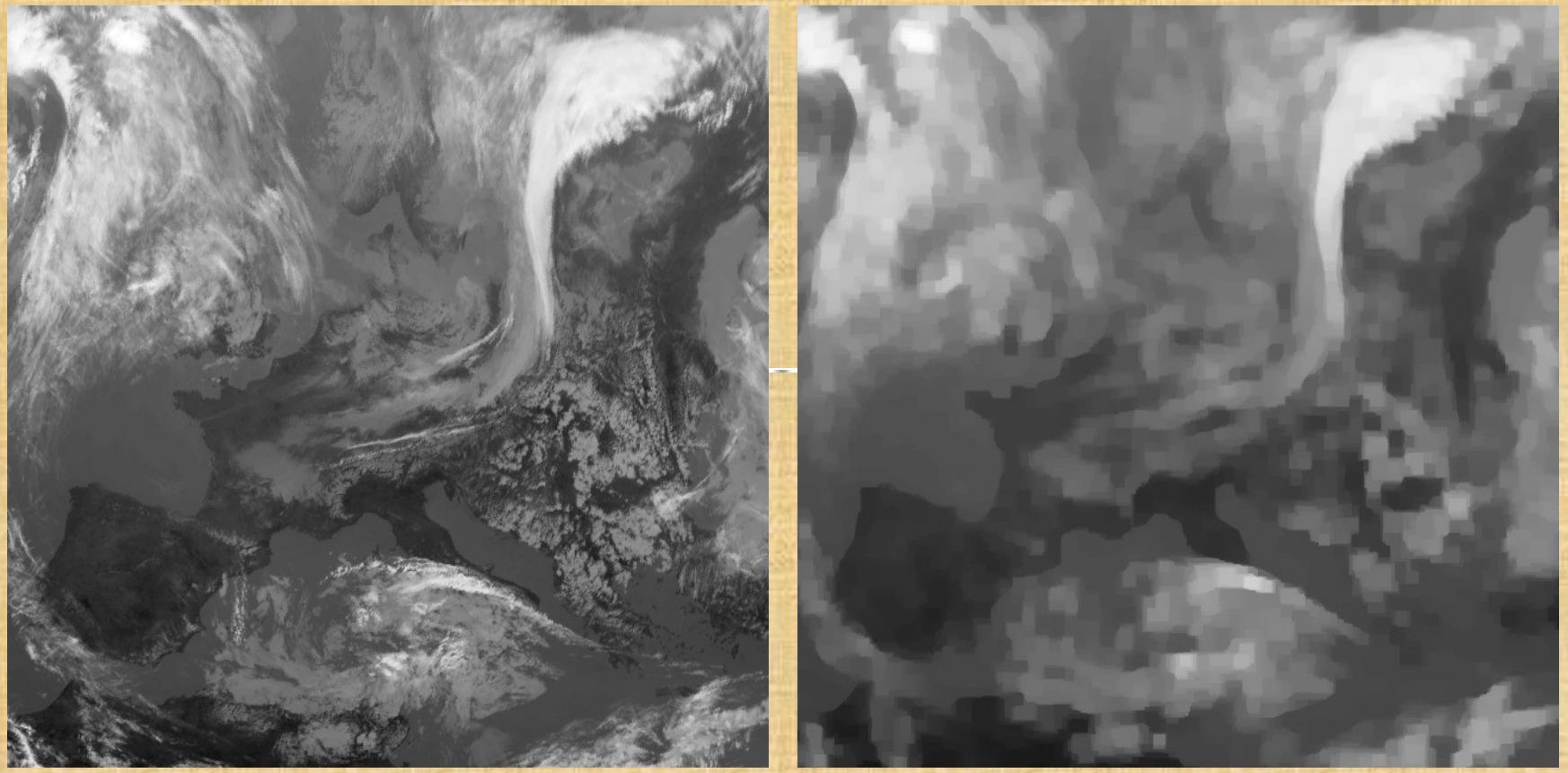

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Image2 – original vs 16

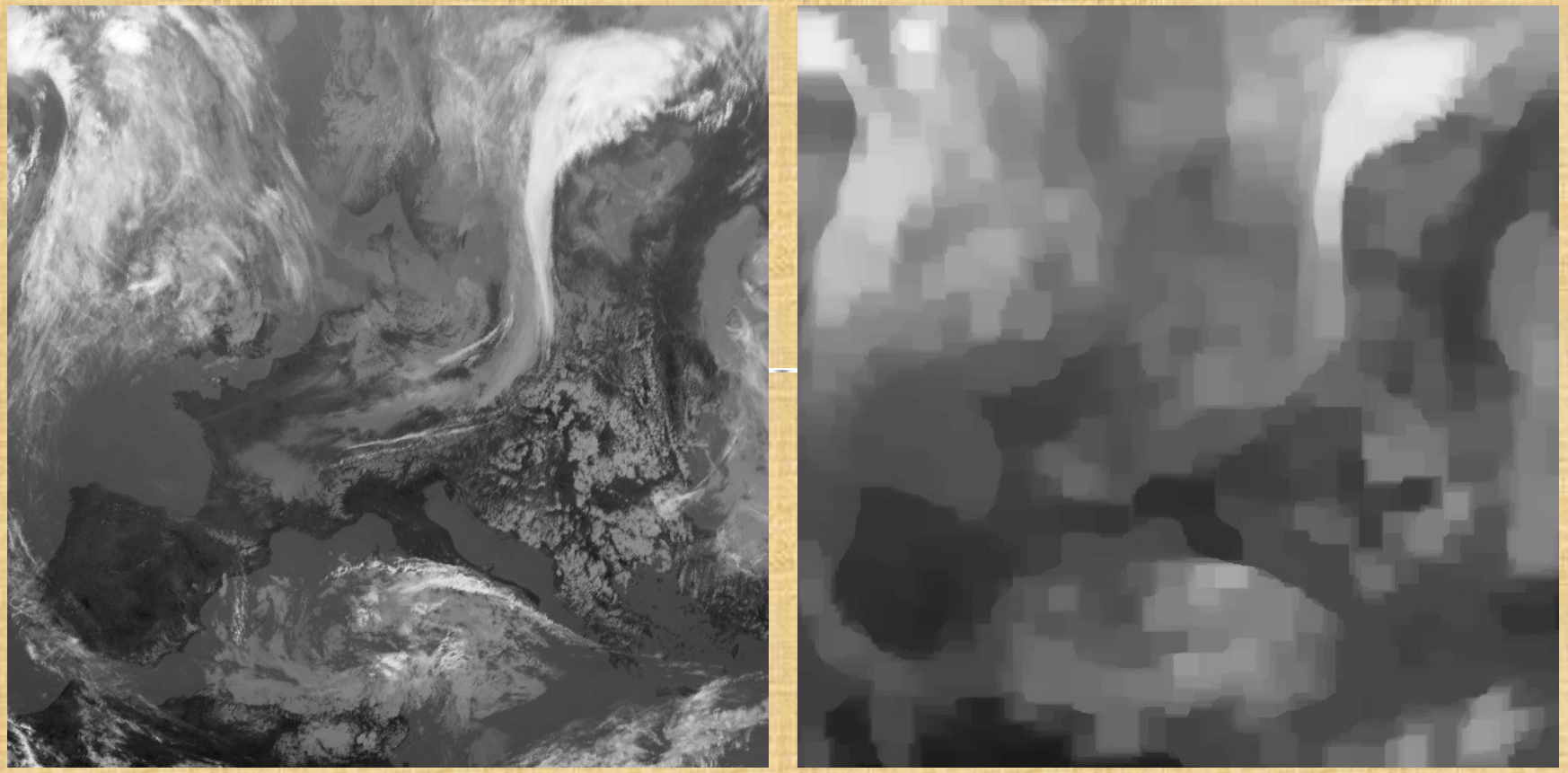

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Image2 – original vs 32

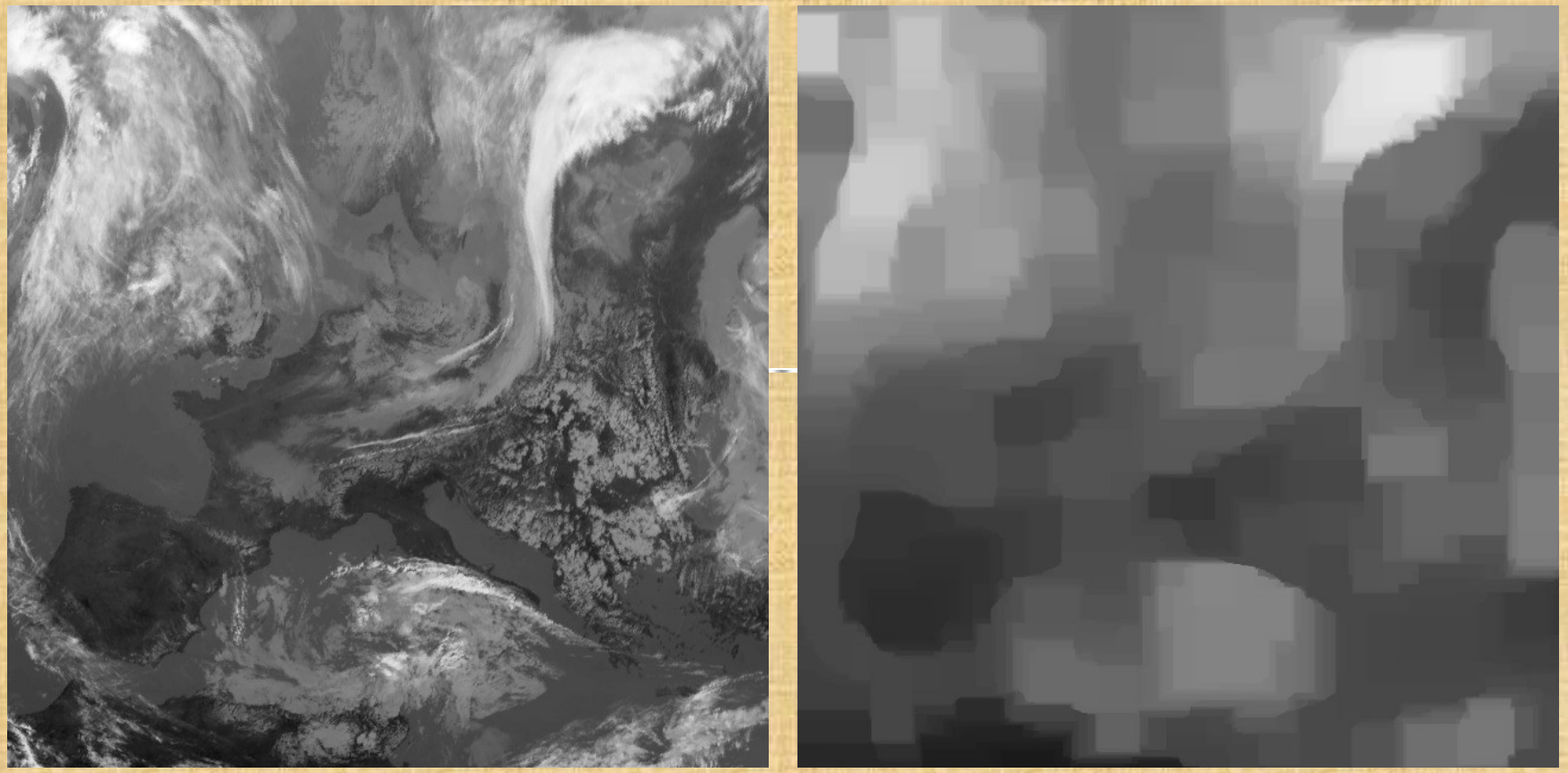

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Image2 – original vs 64

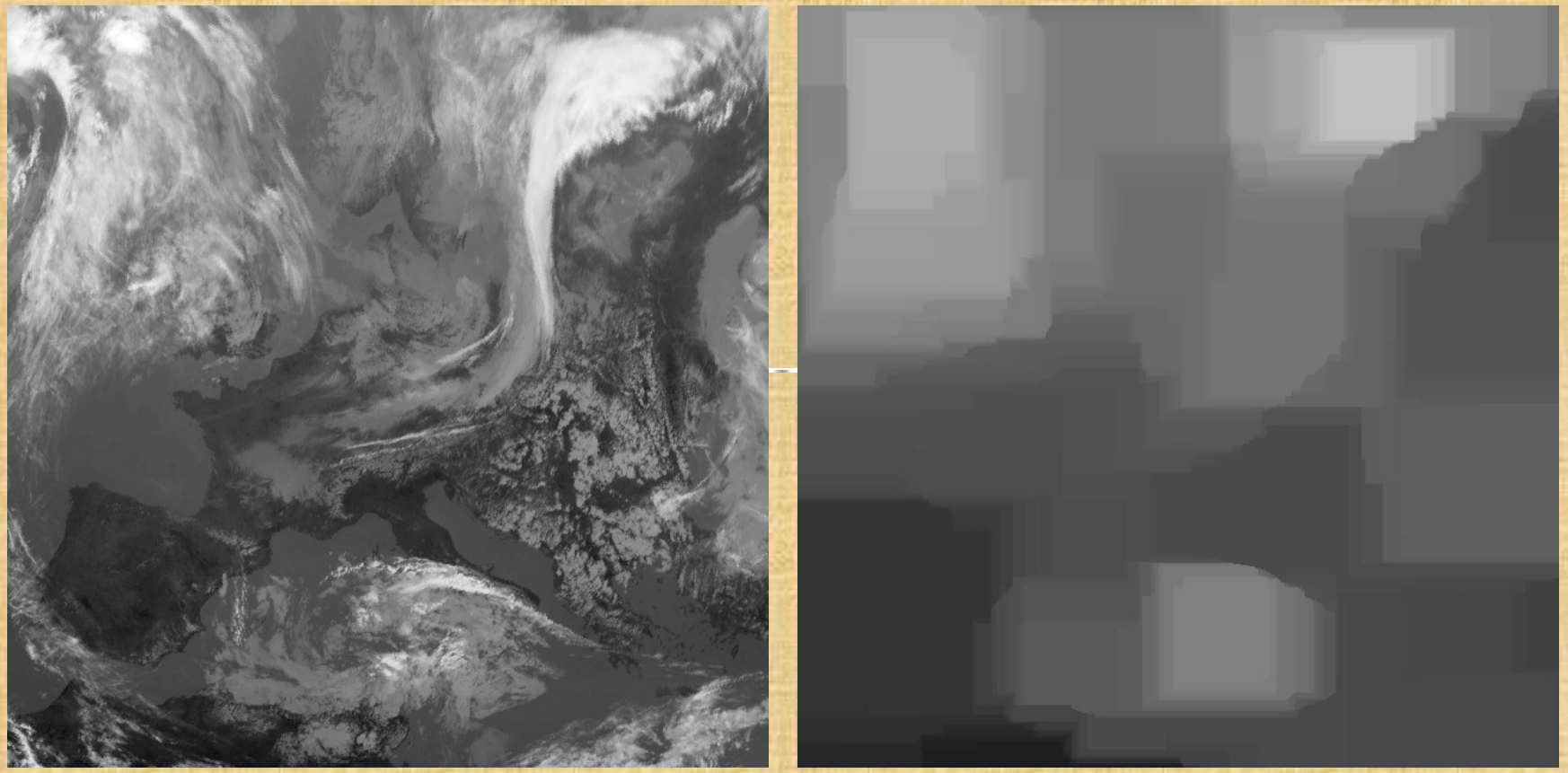

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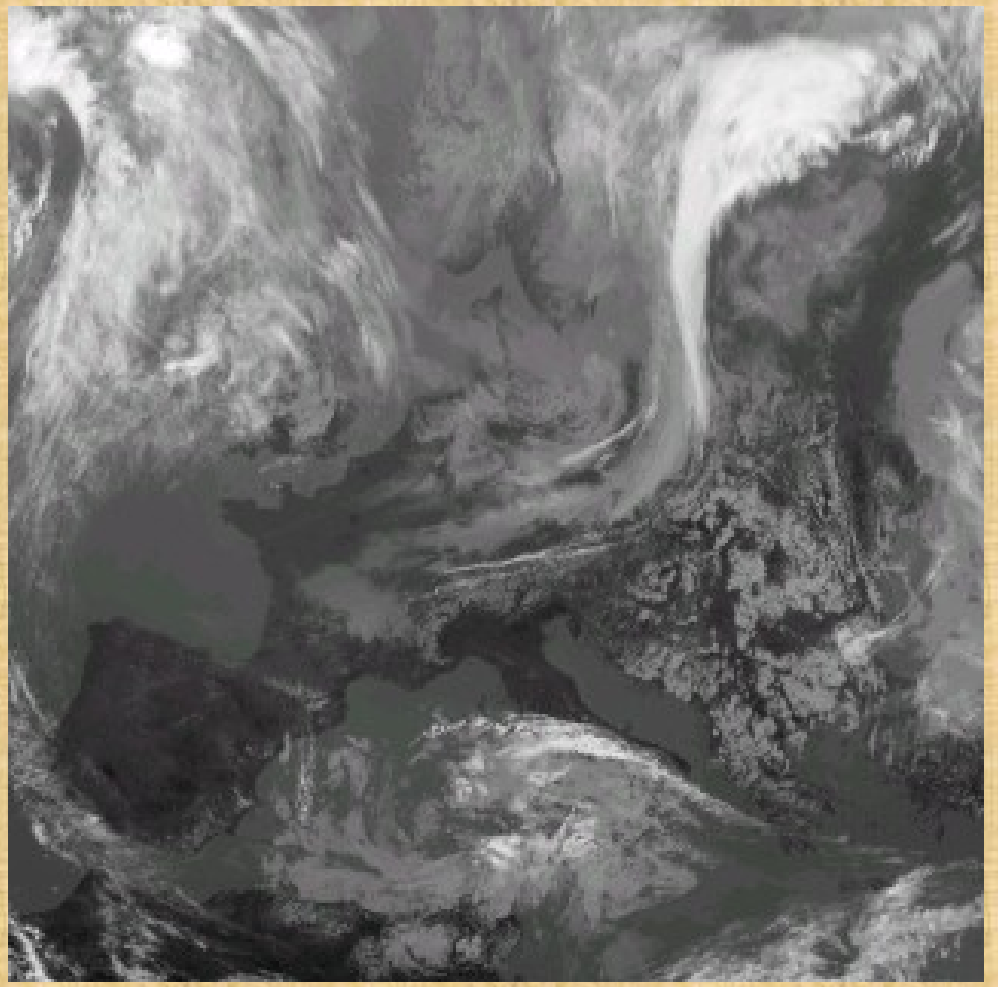
Image2 – filtering animation



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Below CWM filters are applied to two Meteosat images (marked as Image2 and Image3) and then results for first of them are compared with absolute difference of filtered images (marked as ADiff).

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Image2 vs Image3 - orig.

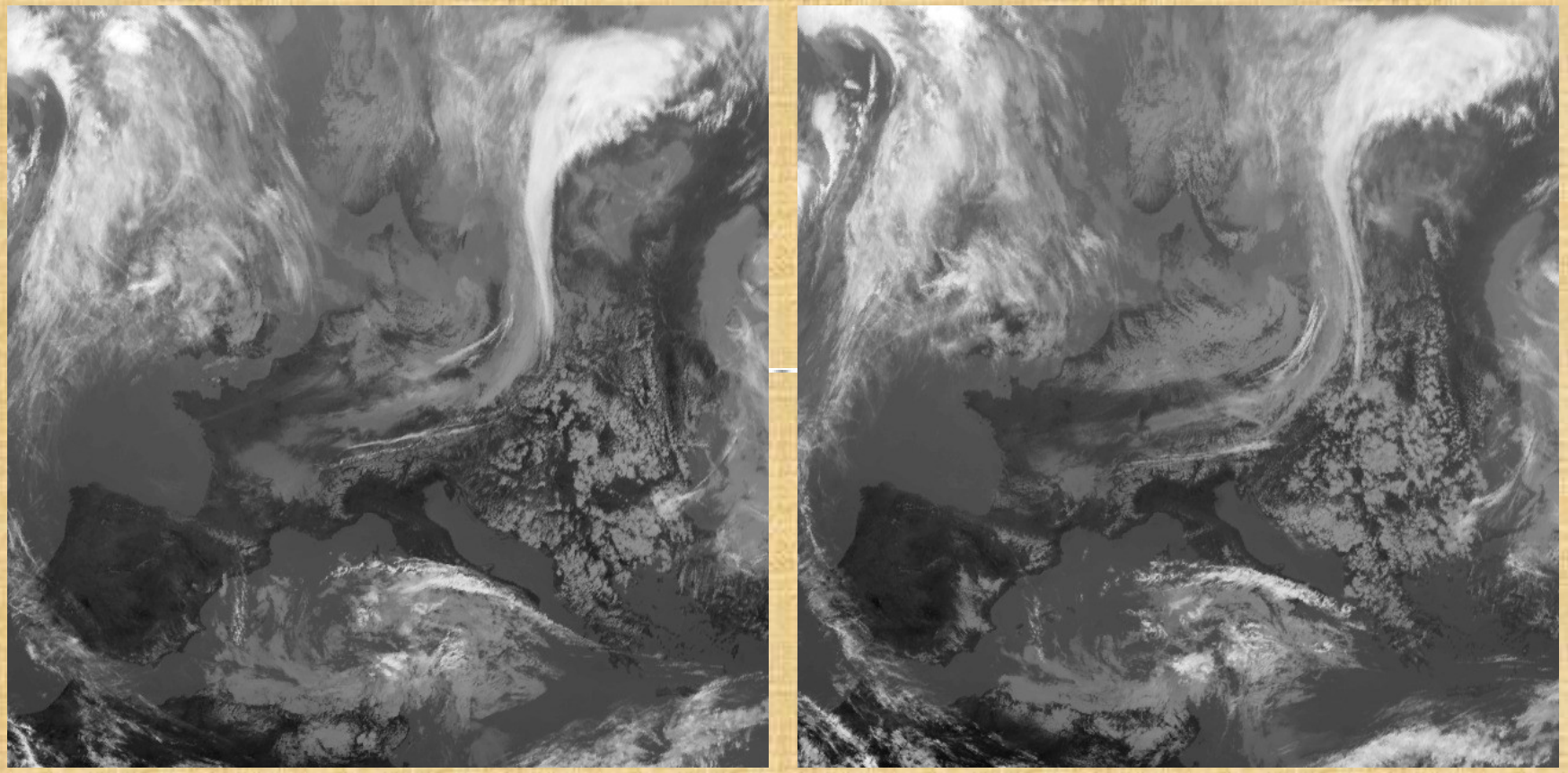

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Image2 vs ADiff - orig.

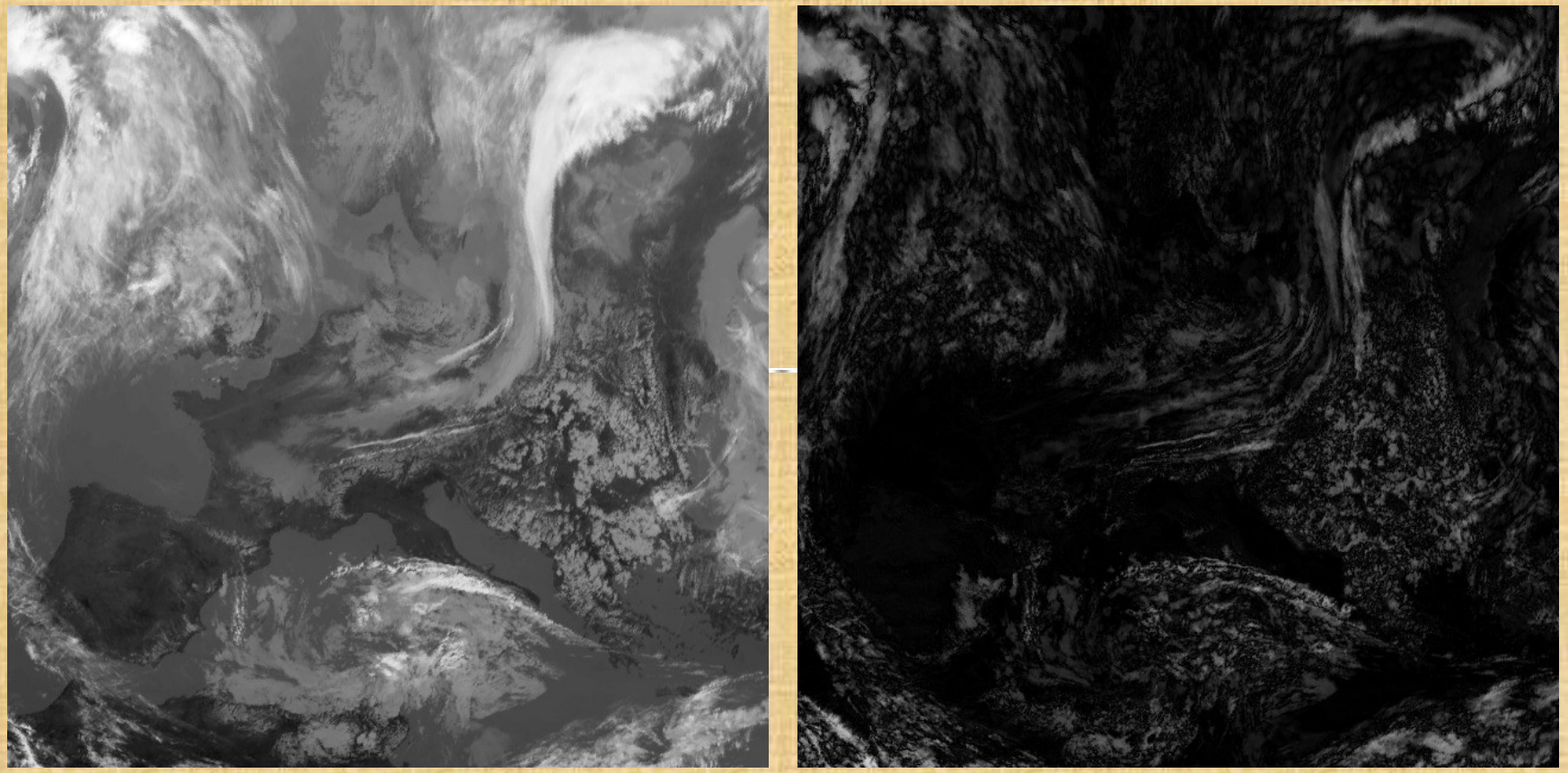

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Image2 vs ADiff - 01

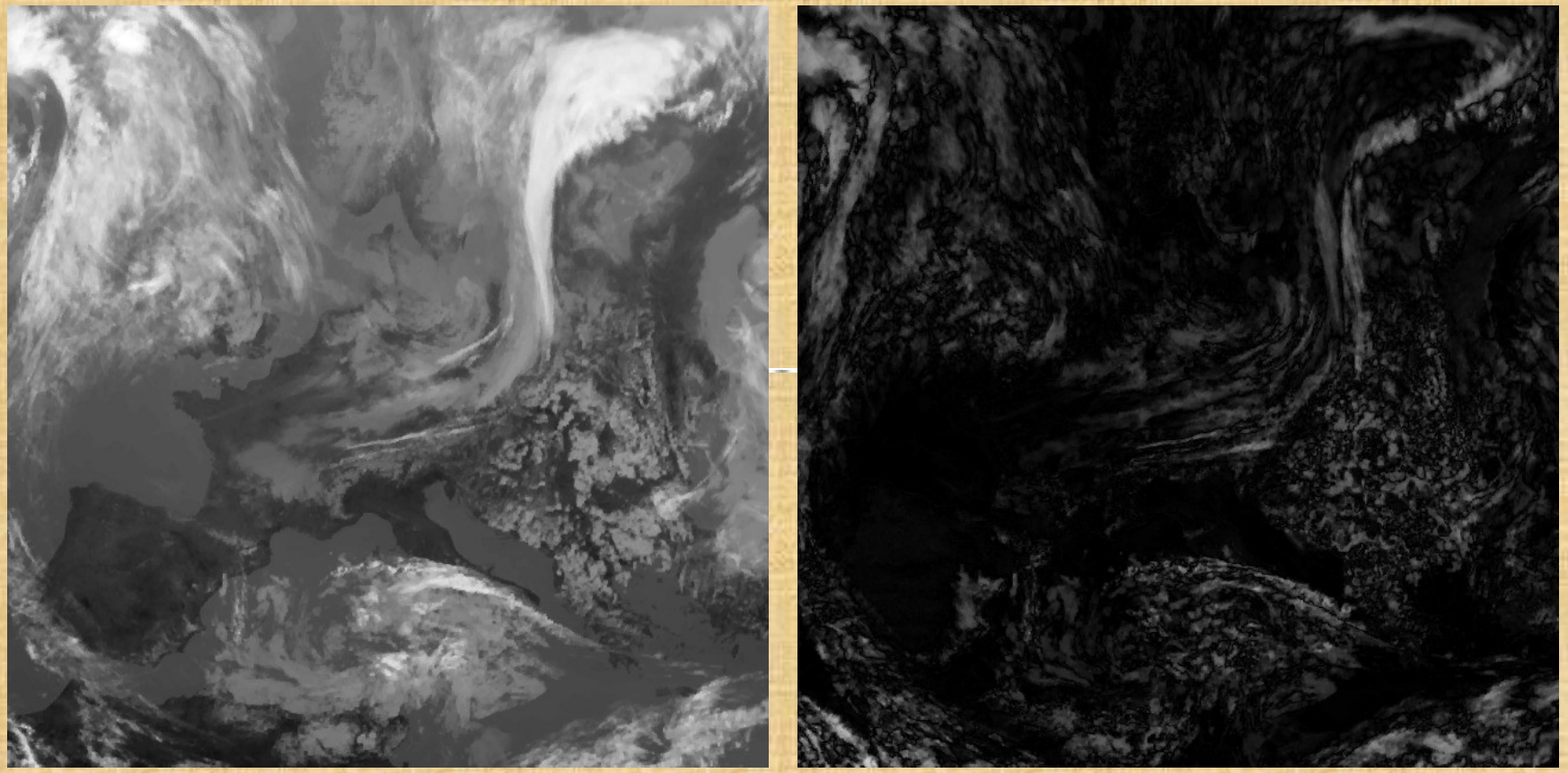

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Image2 vs ADiff - 02

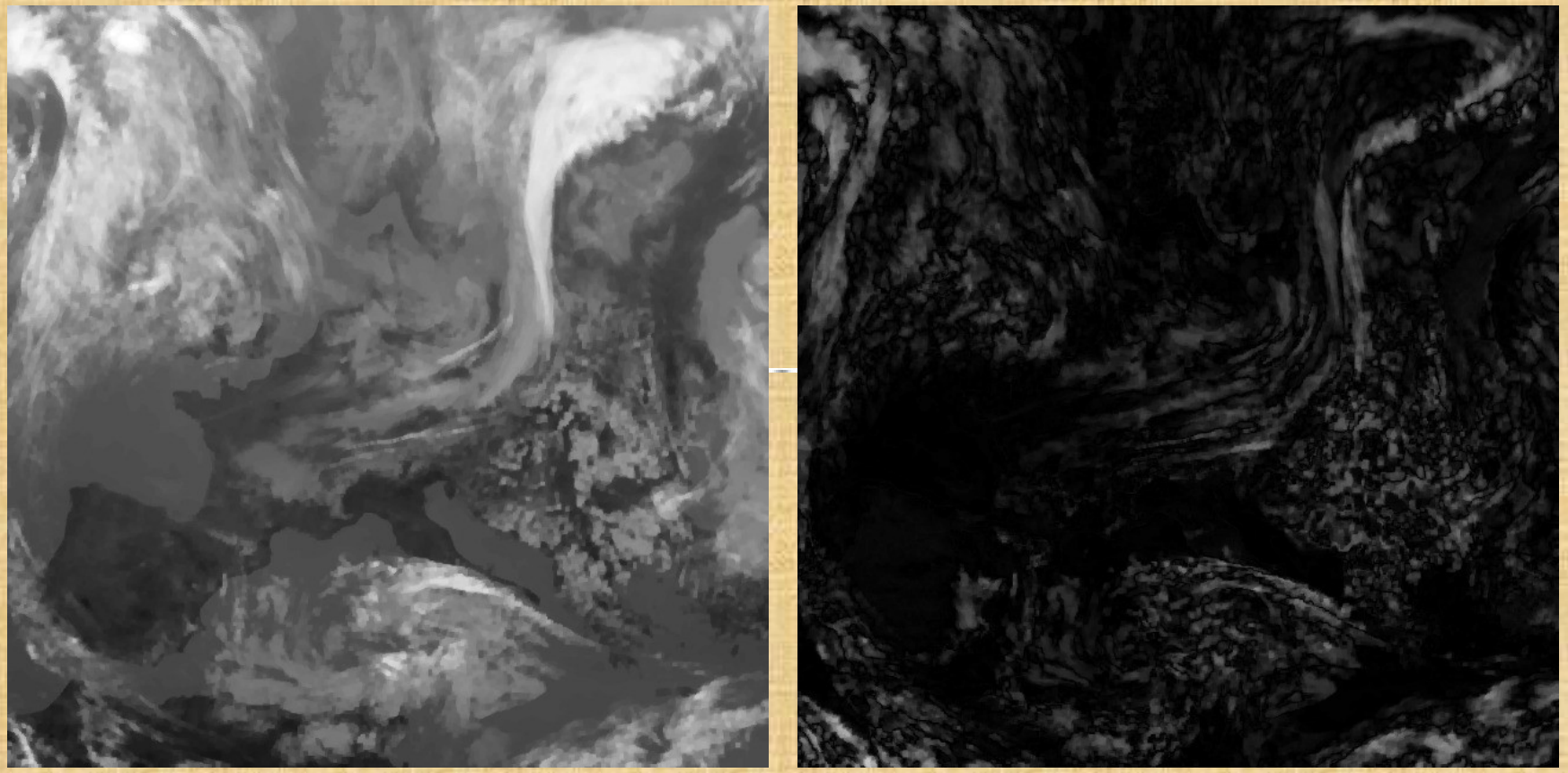

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Image2 vs ADiff - 04

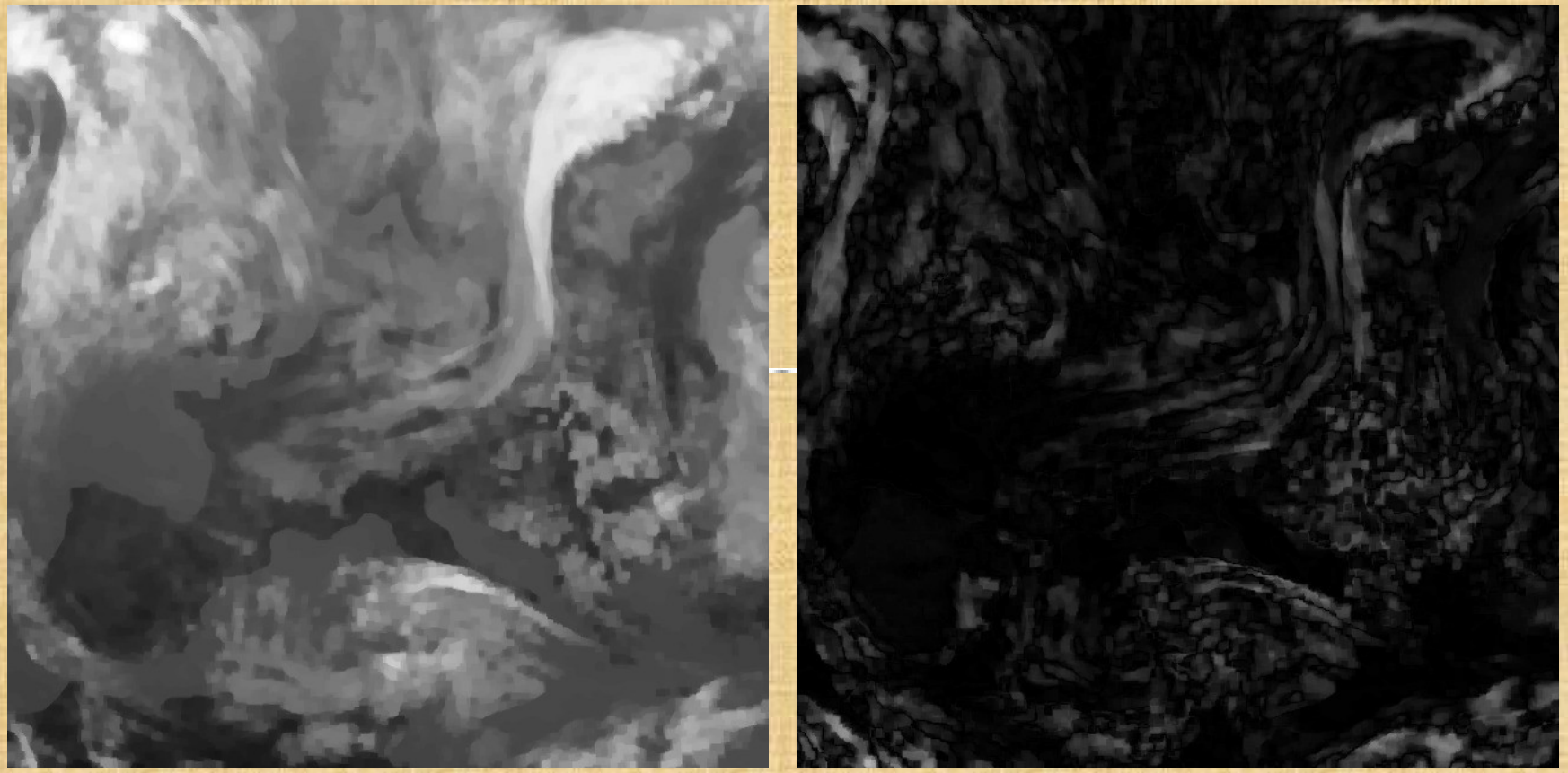

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Image2 vs ADiff - 08

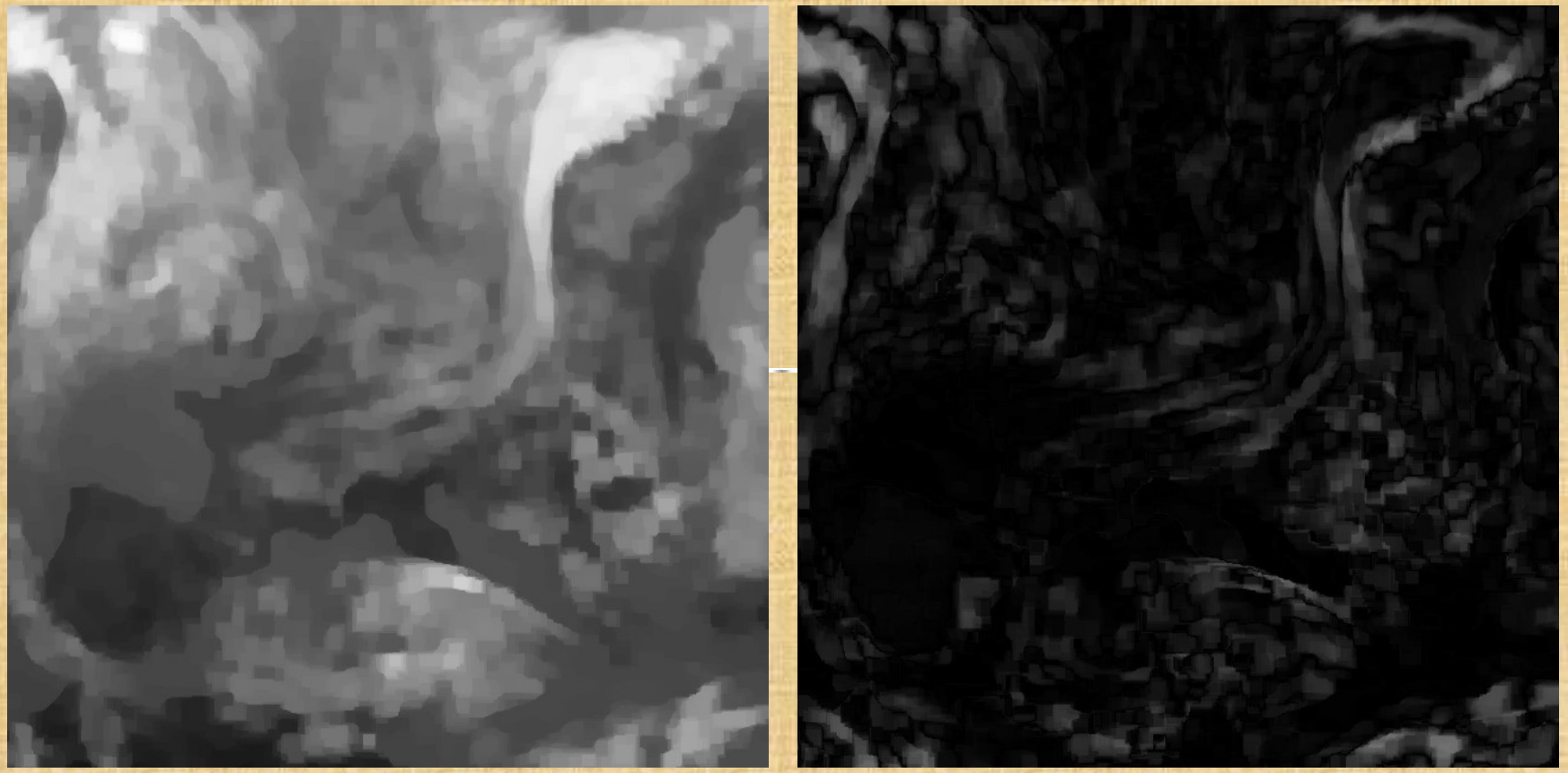

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Image2 vs ADiff - 16

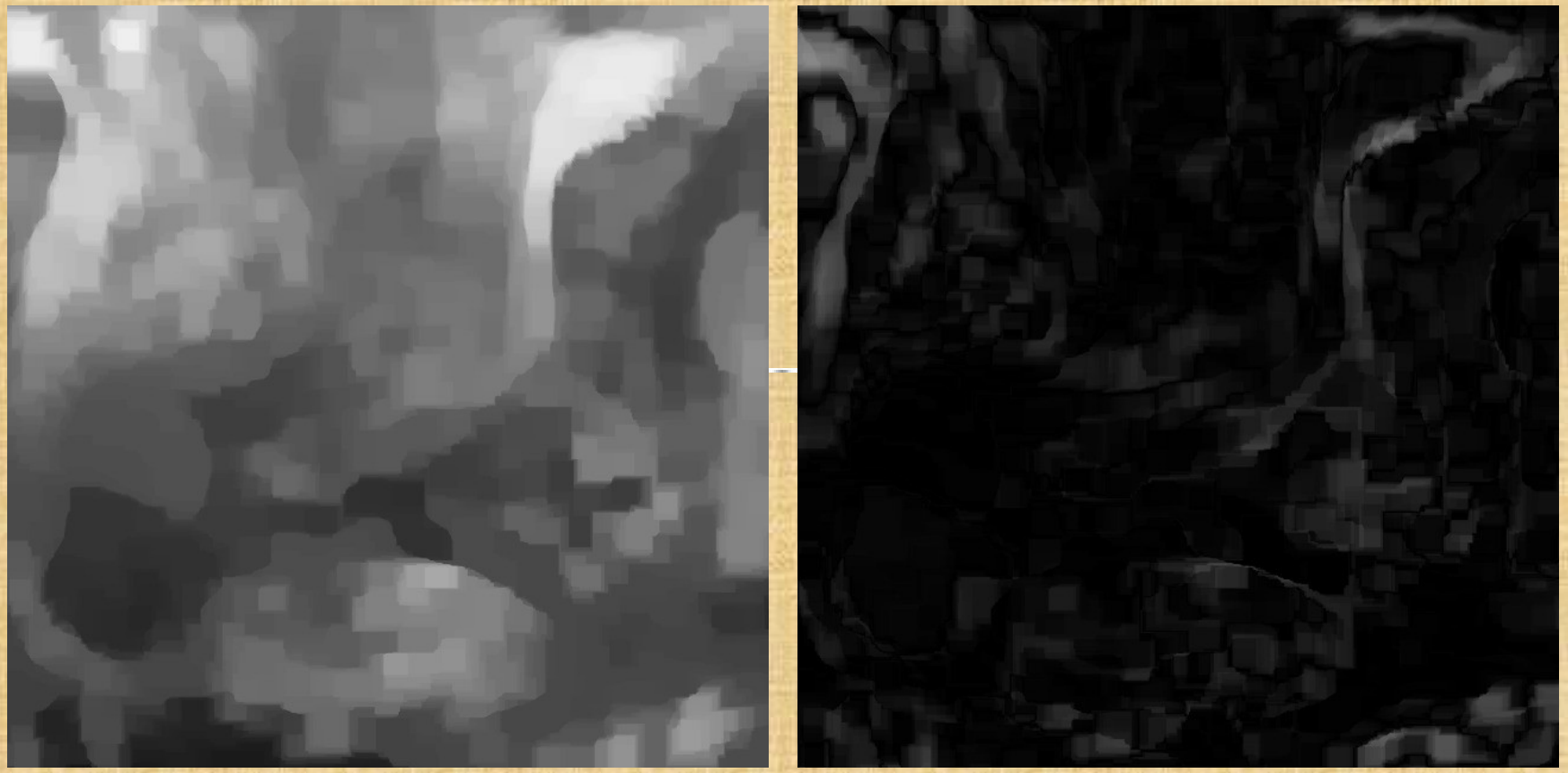

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Image2 vs ADiff - 32

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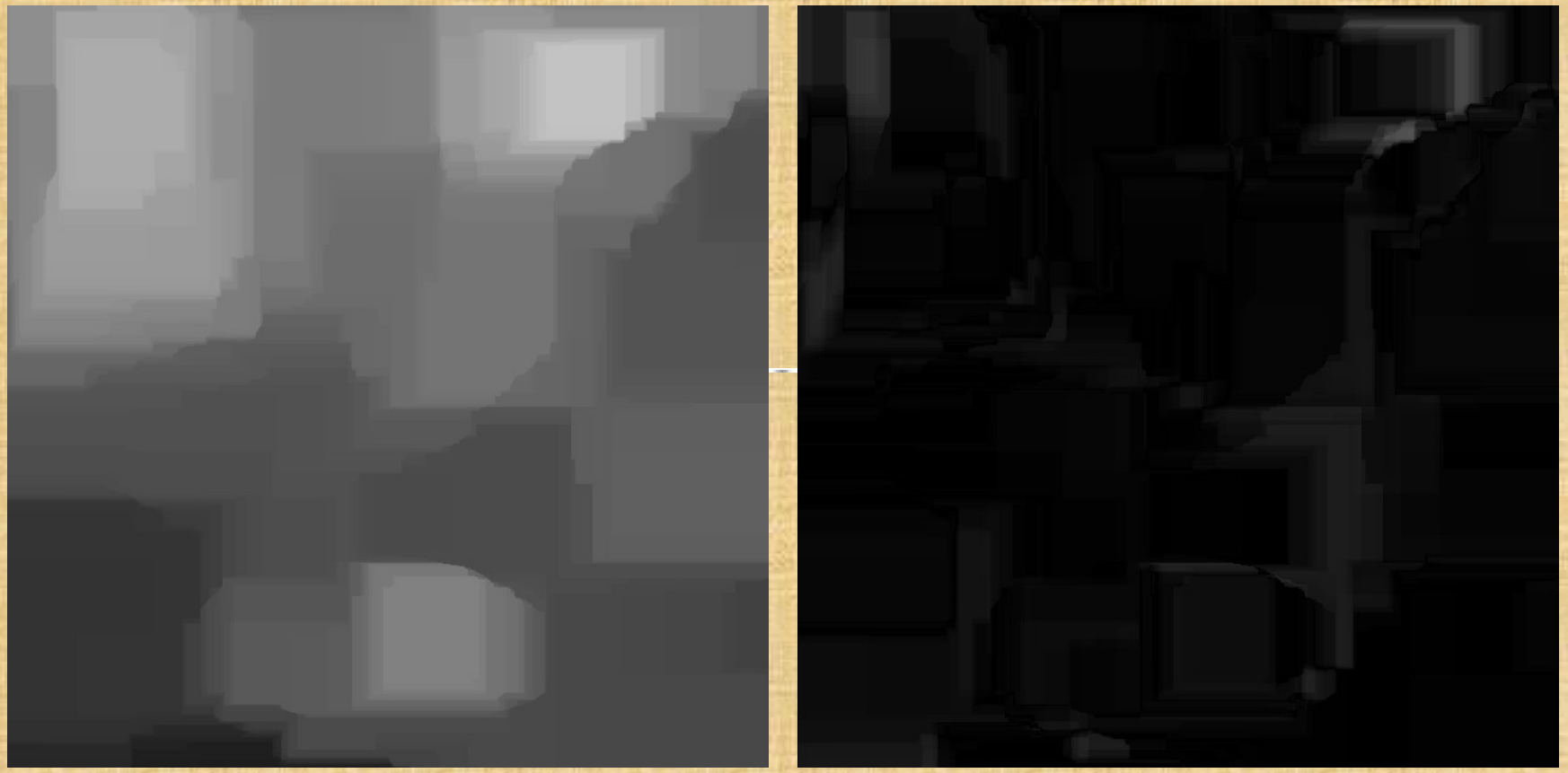
Image2 vs ADiff - 64



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Adiff - filtering animation

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The presented examples show that CWM filters seem to be powerful and flexible tool for non-smooth meteorological fields analysis and comparison. They gather in unique way many desired features:

- are robust
- are “almost” idempotent
- keep contrast as much as possible
- generally keep shapes and localization of characteristic features
- and more ...

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Thank you for your attention

The title of Project: “The impact of climate change on the environment, economy and society”. Work supported by The Programme Innovative Economy under National Strategic Reference Framework, which is co-financed from EU resources. The project is realized by the Institute of Meteorology and Water Management, Poland.

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