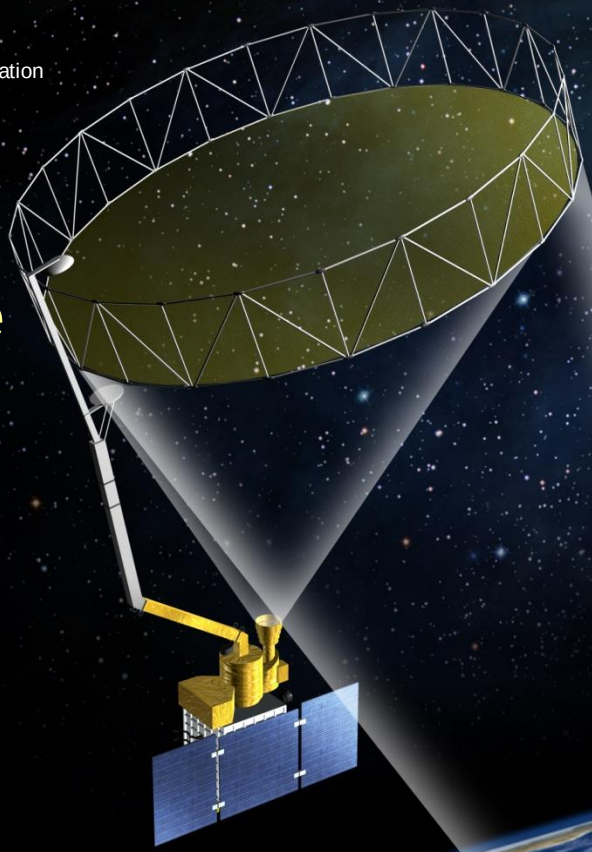
National Aeronautics and Space Administration



Soil Moisture Active Passive Mission

SMAP

Sentinel: Median-Filtering Application

Julian Chaubell, Simon Yueh, Scott Dunbar, Narendra Das, Kim Seungbum (Jet Propulsion Laboratory, California Institute of Technology).

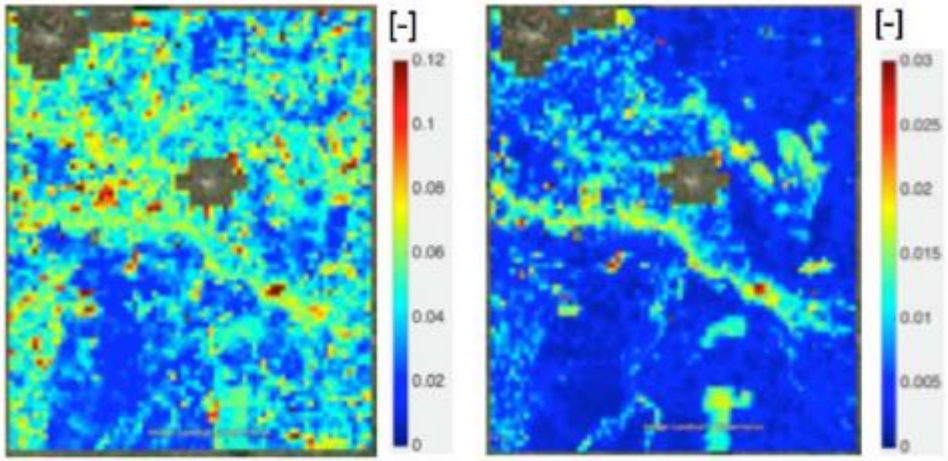
April 17-19, 2018
JPL, Pasadena

Outline

- Review the effort to eliminate unwanted outliers in the Sentinel backscatter
- Overview of methods:
  - Median Filter
  - Global and Local Std threshold
  - Hybrid method
- Show results
- Conclusion

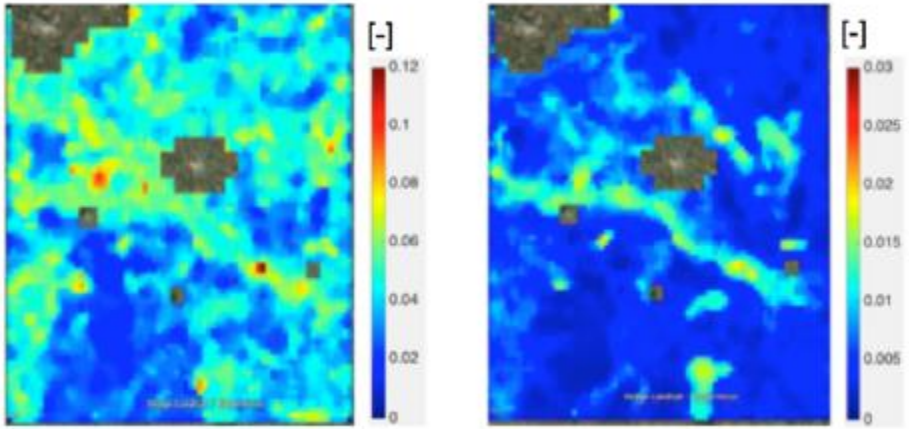
Median-Filter applied after 1km aggregation

May 5th, 2015



b) Sentinel σ_{vv} c) Sentinel σ_{vh}

May 5th, 2015



a) Median Filtered b) Median Filtered

Reference: Soil Moisture Active Passive (SMAP) Project Assessment Report for the L2SMSP Beta-Release Data Products

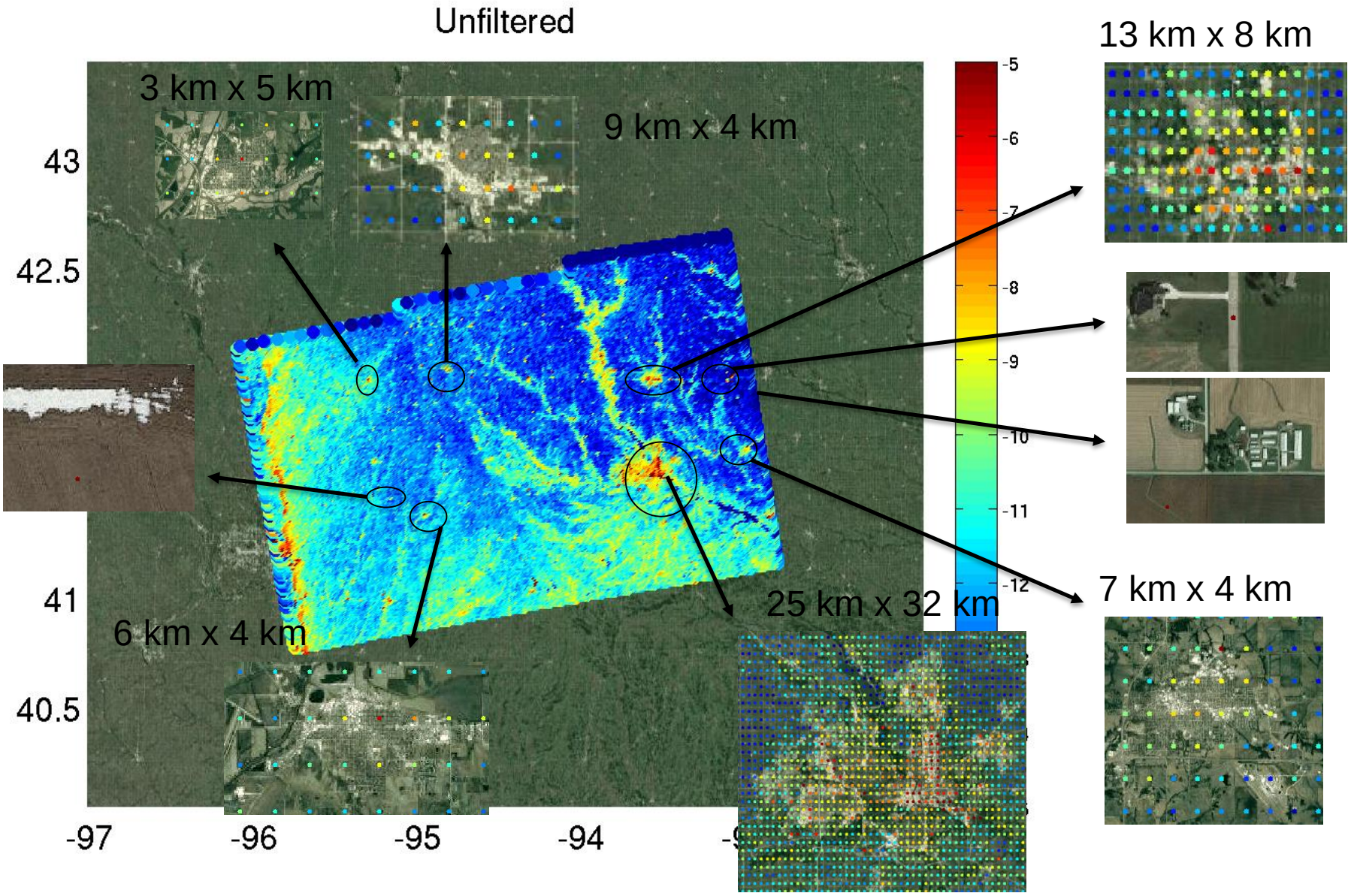
Even after applying the Mfil on the Sentinel observations, some residual impact of urban areas is still visible because there are locations where the urban areas are greater than the [3X3] window at 1 km EASE grid resolution. The Mfil data are now used in the Science Algorithm Software (SAS) to produce the L2SMSP product.

Sab and Narendra

Limitation for Analysis

- Only 11 images to work with
- No control over the aggregator input file
- Inability to process (disaggregated TBs or soil moisture) the aggregator output reduces the possibility of a deeper analysis of the impact of filtering on the disaggregated images
- Evaluation is done visually
- No quantitative analysis
- No metrics for evaluation

Sample Case: Various outliers with different sizes and shapes



Median-Filter applied before aggregation to 1km

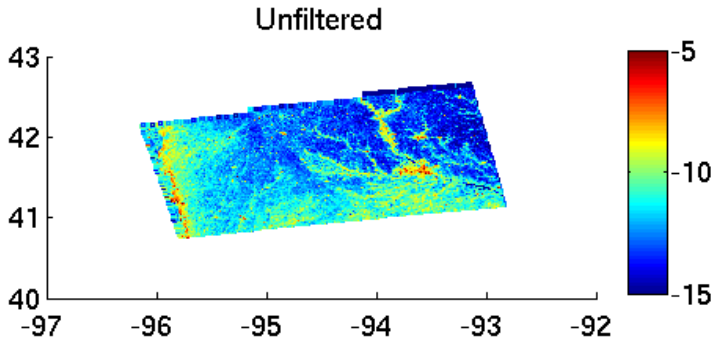
- We apply a median-filter to images (11) before aggregation is done
  - We explore results for different size of windows: 3x3 samples (60 meters^2), 5x5 samples (100 meters^2), 7x7 samples (140 meters^2), 9x9 samples (180 meters ^2), 21x21 (420 meters^2)
- Latency is an important limitation

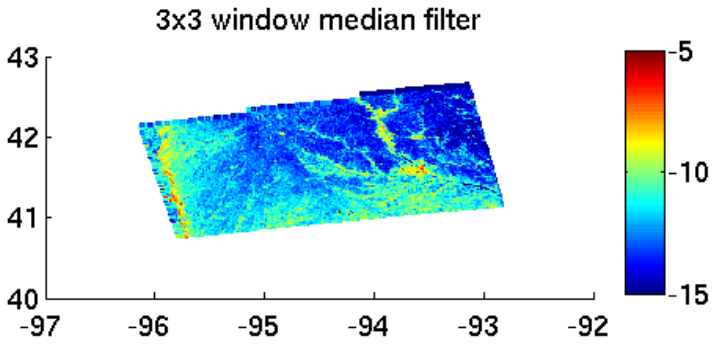
Windows size	~Time
Unfiltered	3 minutes
3x3 samples	3 minutes
5x5 samples	4.5 minutes
7x7 samples	6 minutes
9x9 samples	7 minutes
15x15 samples	23 minutes
21x21 samples	68 minutes

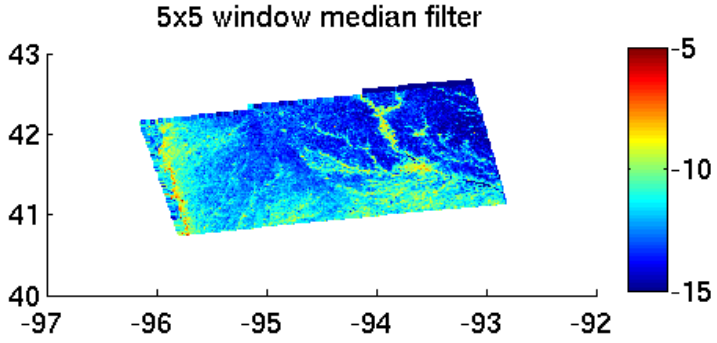
"Keep in mind that the entire L2_S0_S1 sigma processor usually runs in an average of 5-10 minutes per scene, so even 6 minutes -- while acceptable -- is still a significant contribution to the run time. 62 minutes/scene over 400K scenes would take a much bigger SDS (they can't handle the load now, as it is)."

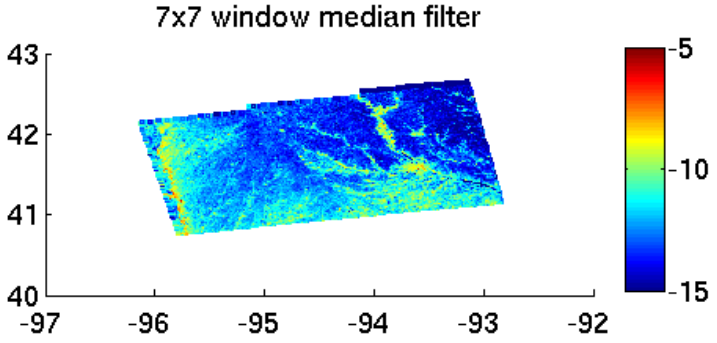
Scott Dunbar

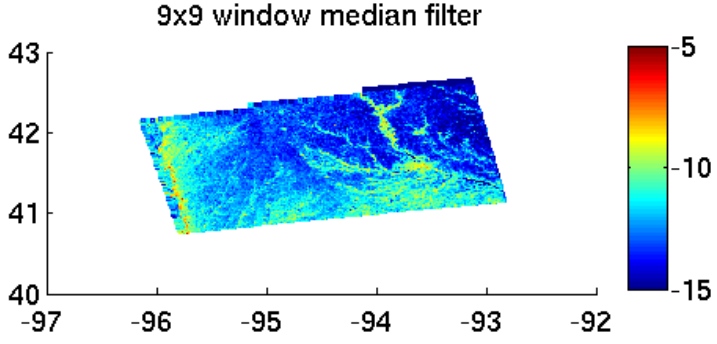
Results

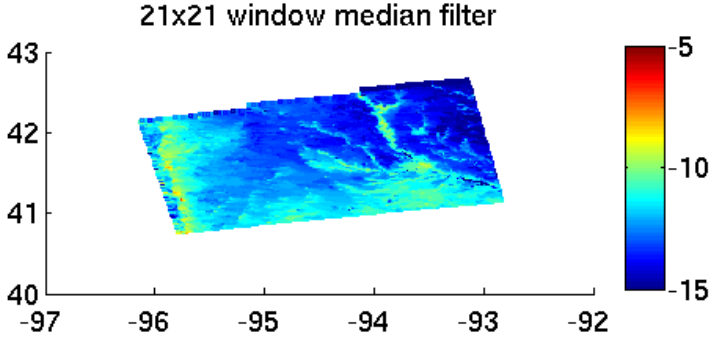

Unfiltered
43
42
41
40
-97
-96
-95
-94
-93
-92
-5
-10
-15


3x3 window median filter
43
42
41
40
-97
-96
-95
-94
-93
-92
-5
-10
-15

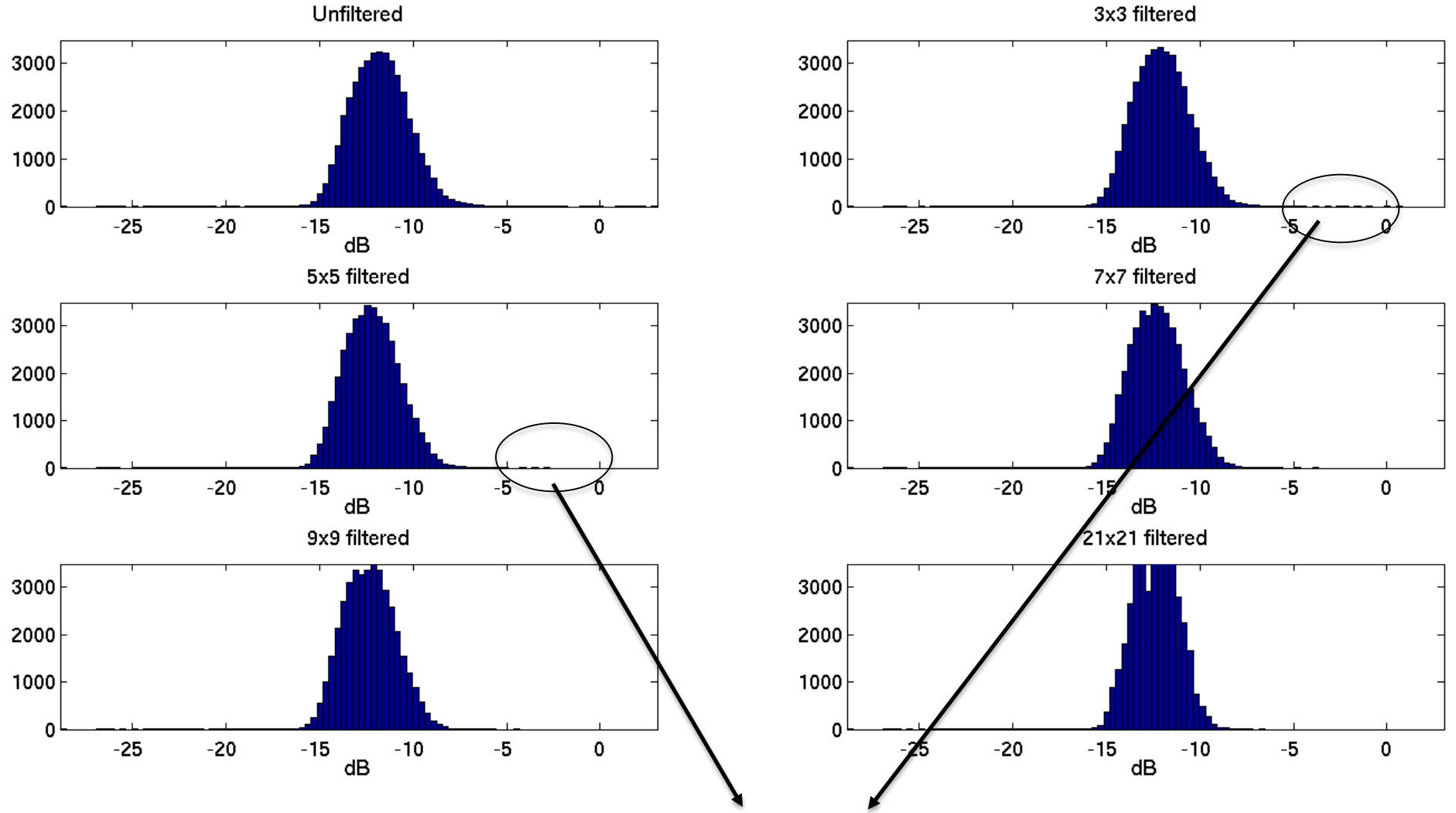

5x5 window median filter
43
42
41
40
-97
-96
-95
-94
-93
-92
-5
-10
-15


7x7 window median filter
43
42
41
40
-97
-96
-95
-94
-93
-92
-5
-10
-15


9x9 window median filter
43
42
41
40
-97
-96
-95
-94
-93
-92
-5
-10
-15

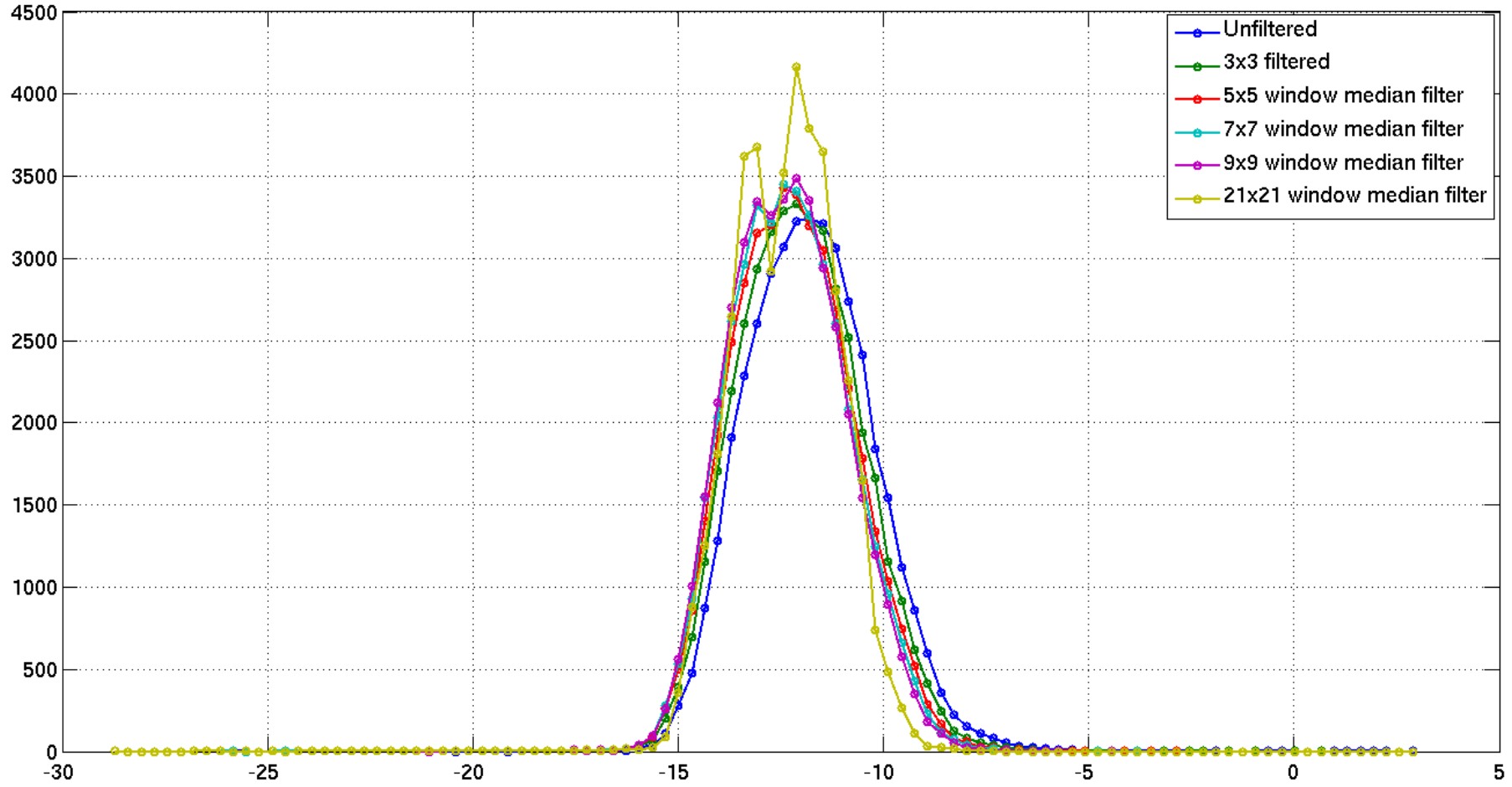

21x21 window median filter
43
42
41
40
-97
-96
-95
-94
-93
-92
-5
-10
-15

Histograms



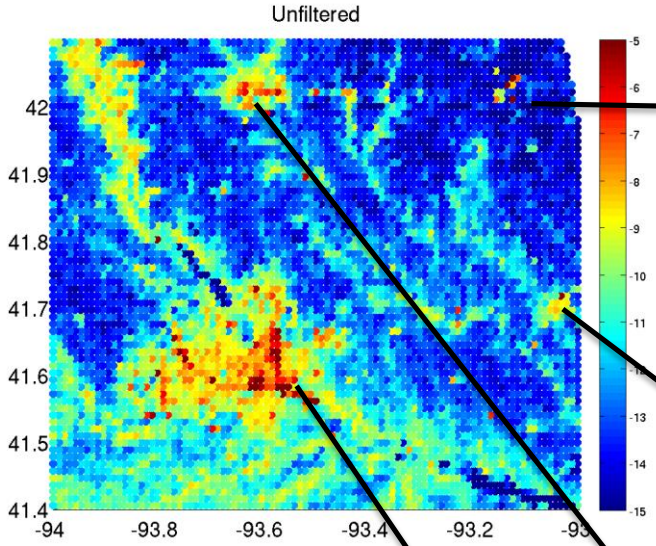
Still some high values for C band σ_0

Combine Histograms

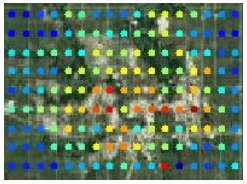


- We observe a shift in the mean to the left caused by the elimination of outliers but also by a smooth effect due to the median filter.

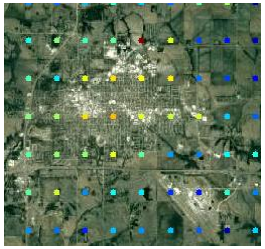
Zooming



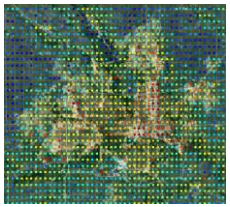
13 km x 8 km

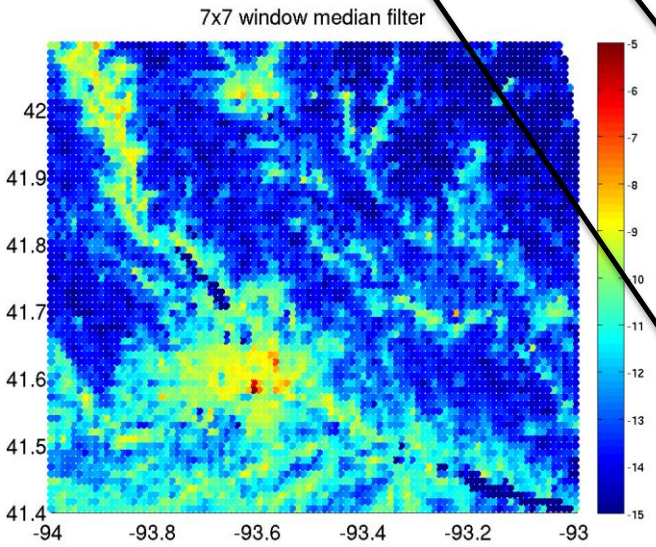


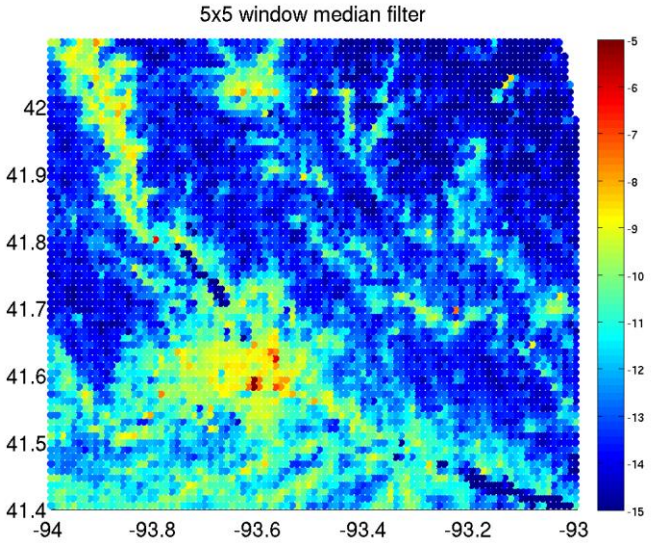
7 km x 4 km

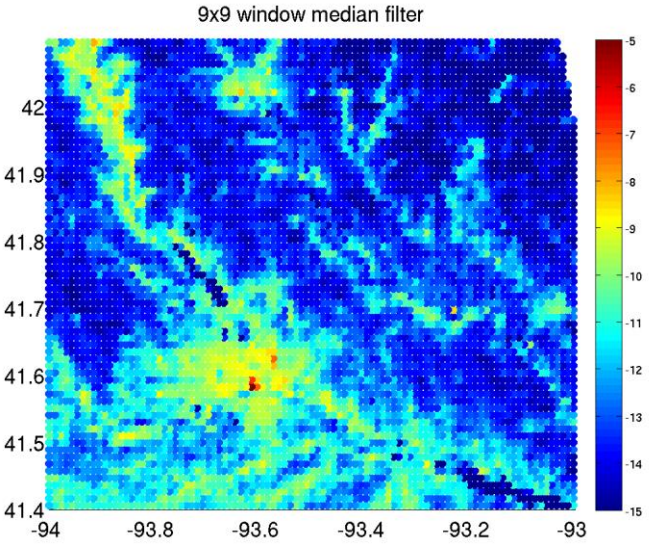


25 km x 32 km



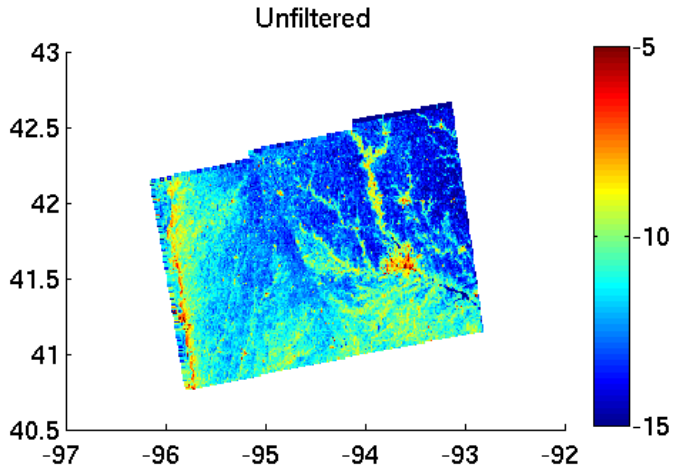


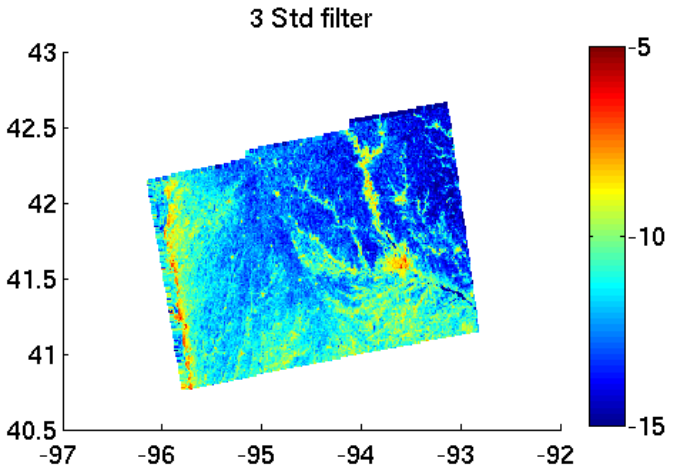


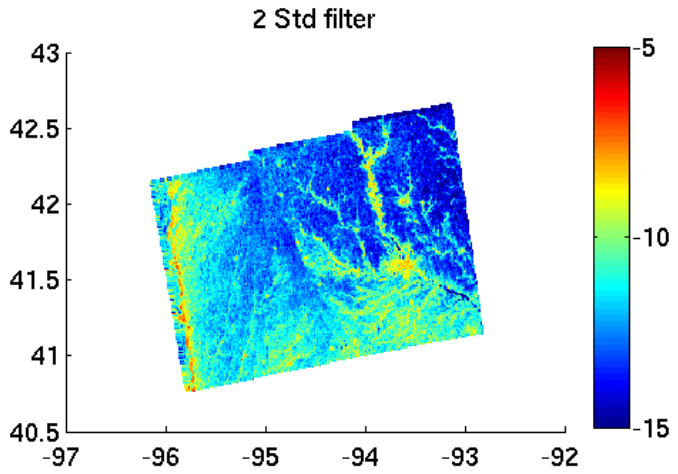


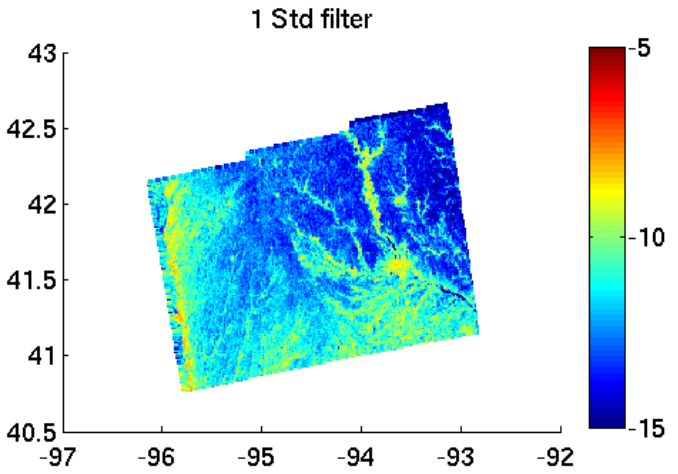
Global Standard Deviation (Std) Threshold

- Global mean (m) and Std (s) is computed and then 20 meter samples outside the range [m-s:m+s] are eliminated before aggregation to 1 km.

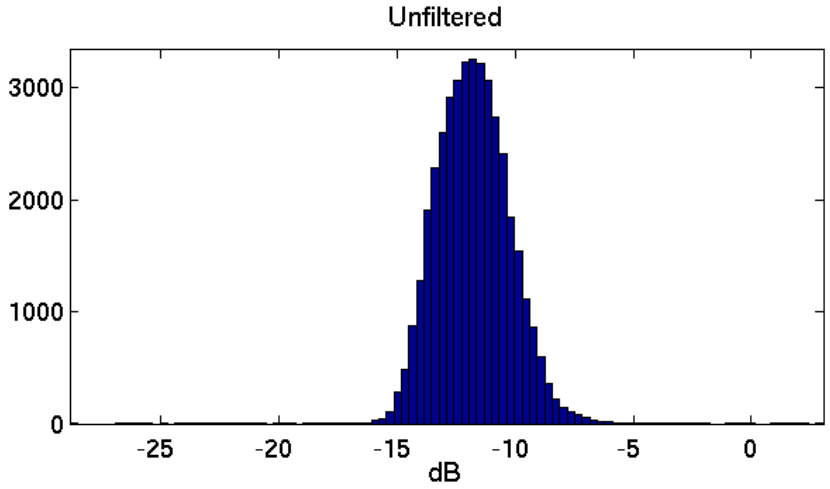


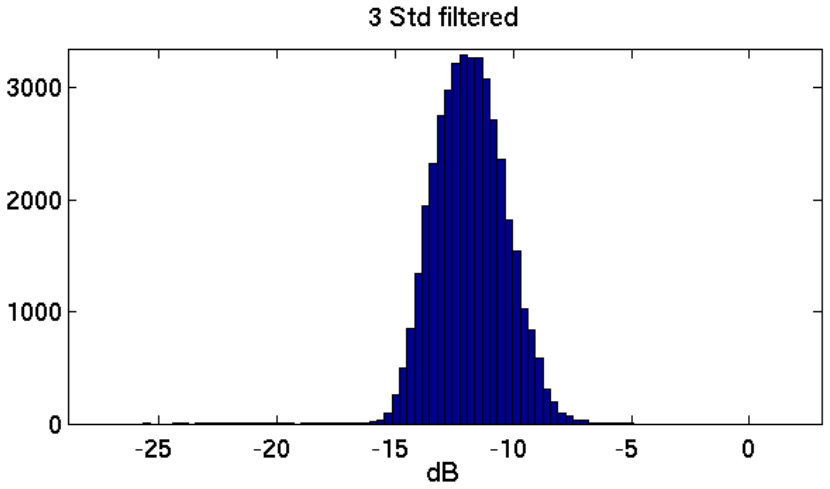


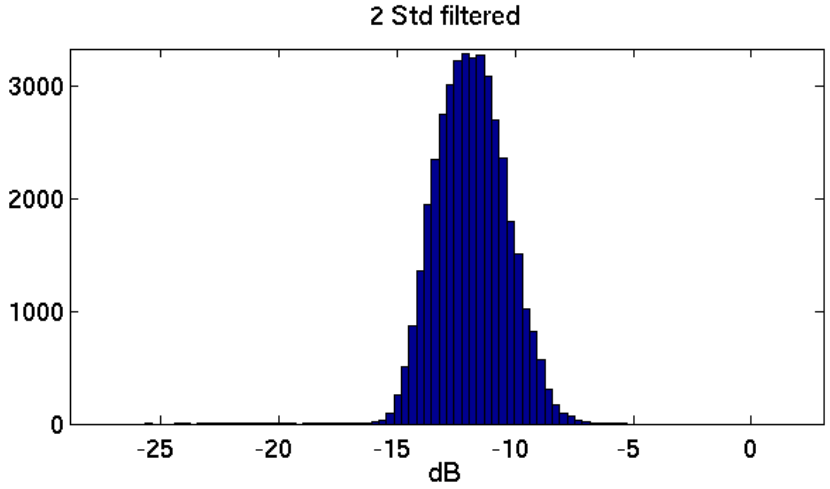


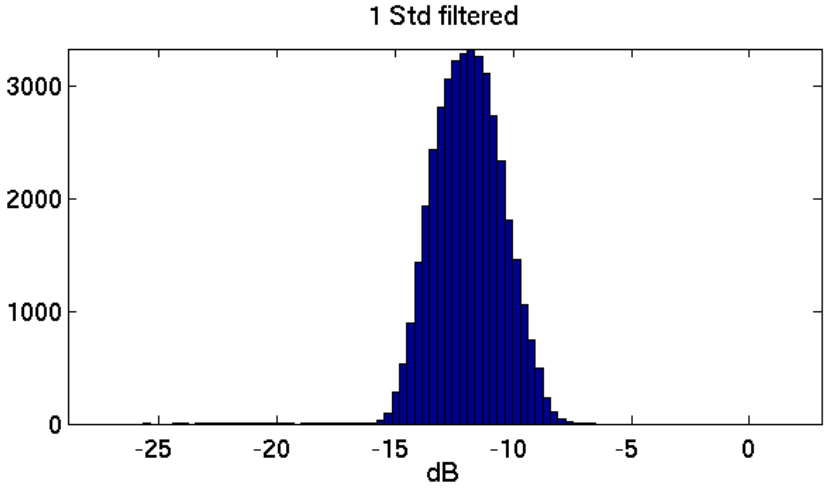


Histograms



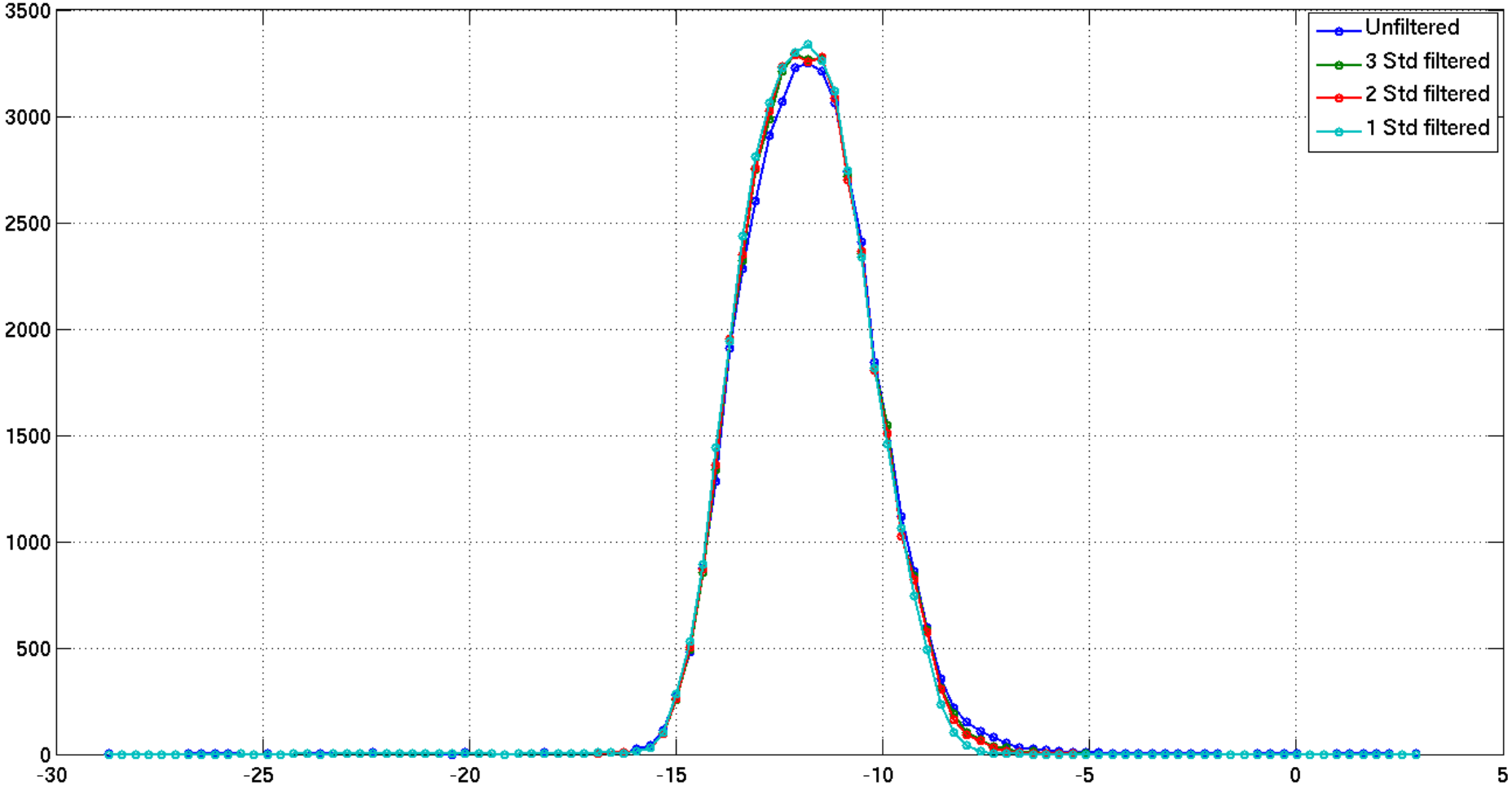






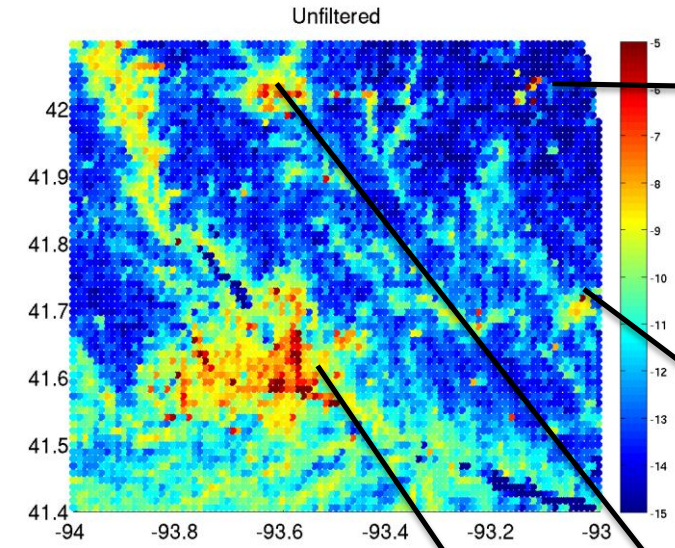
- Global Std threshold does a good job eliminating values >-5 dBs. High for C band

Combine Histograms

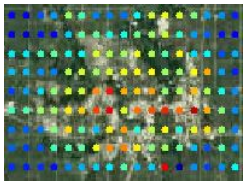


- No shift in the mean value is observed. I believe a small one exists, due to elimination of outliers, but it is not visible to my eyes. There is no smoothing effect here.

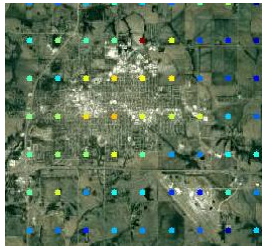
Zooming



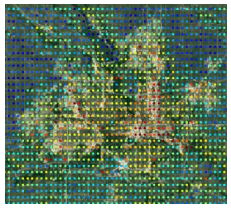
13 km x 8 km

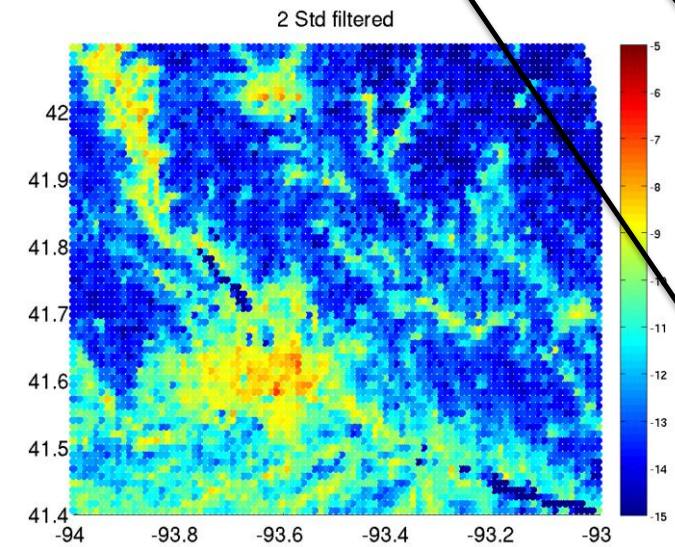


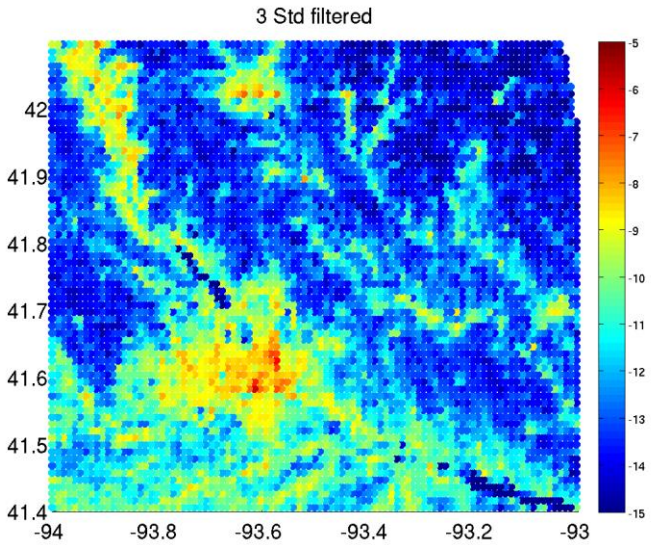
7 km x 4 km

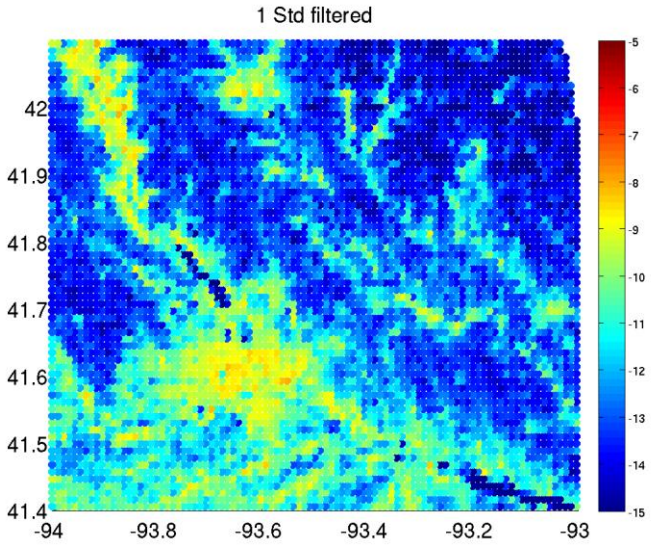


25 km x 32 km



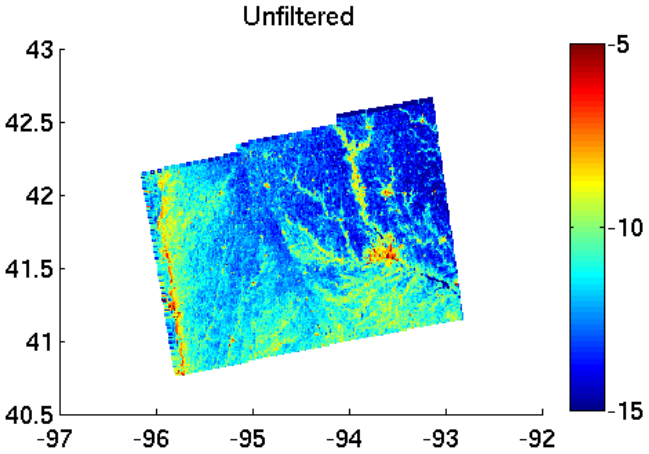


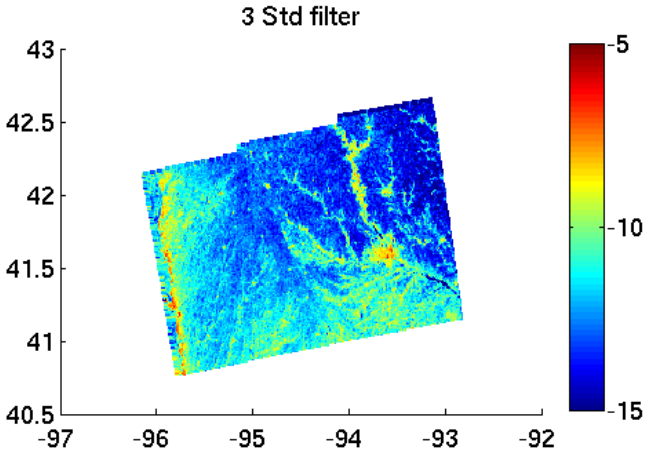


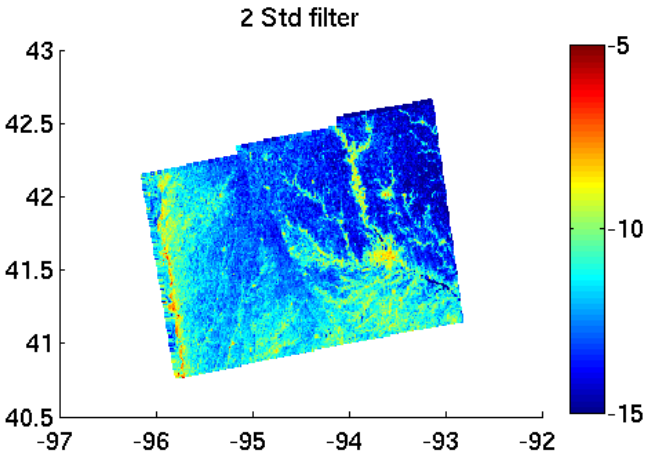


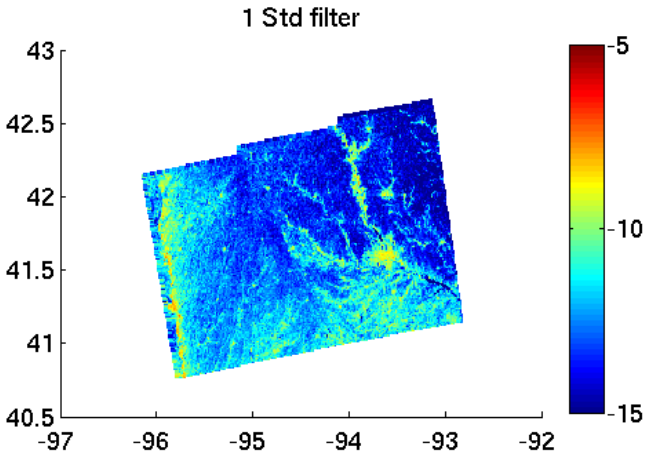
Local Standard Deviation (Std) Threshold

- Local mean (m) and Std (s) are computed at each 1 km cell and then 20 meter samples outside the range [m-s:m+s] in each cell are eliminated before aggregation to 1 km.

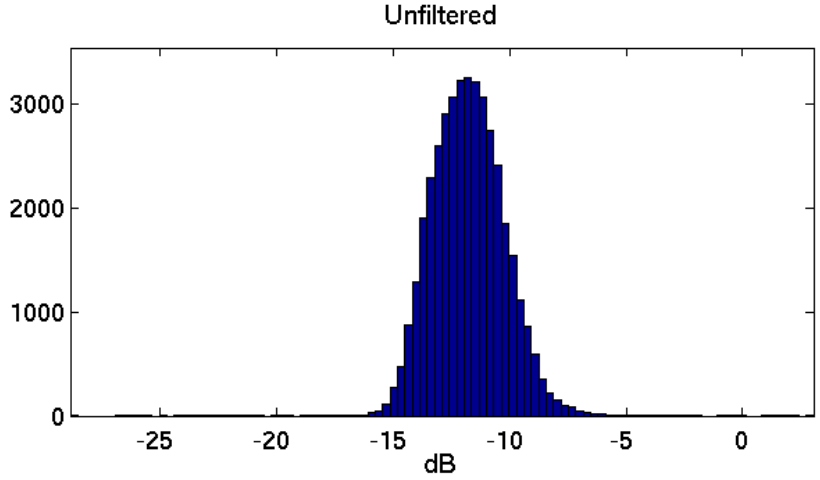


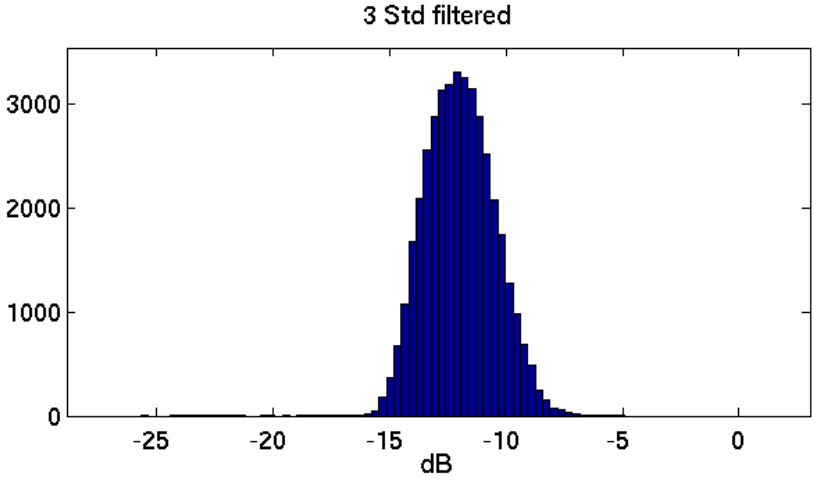


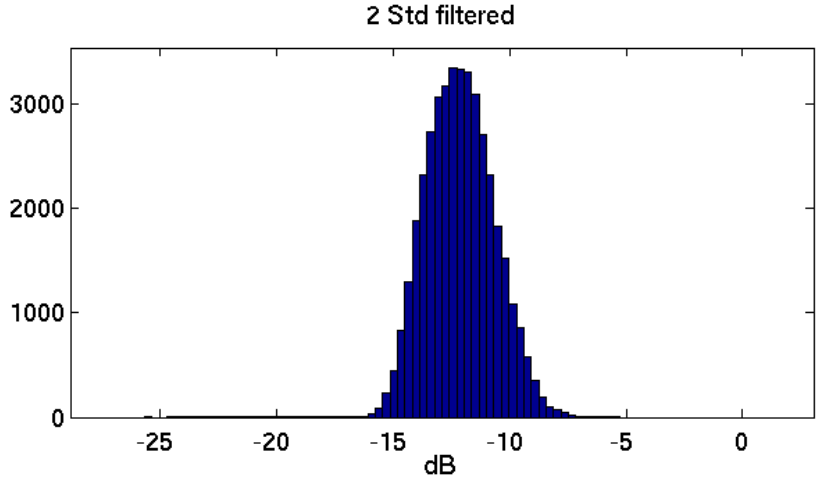


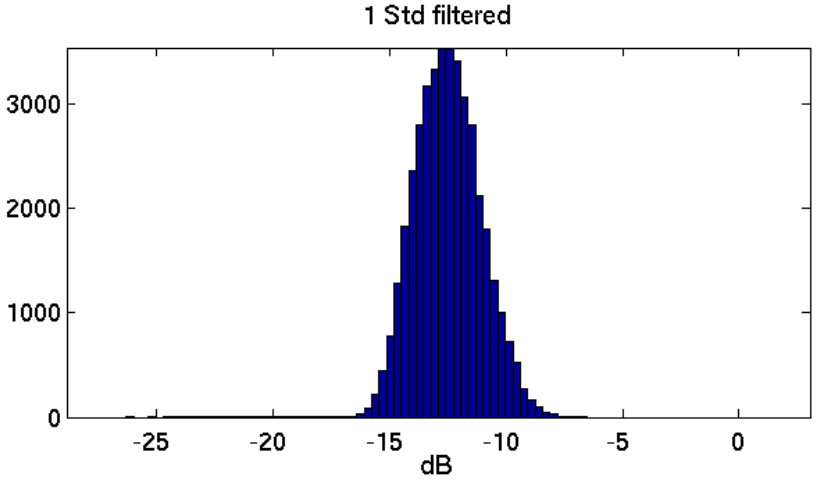


Histograms



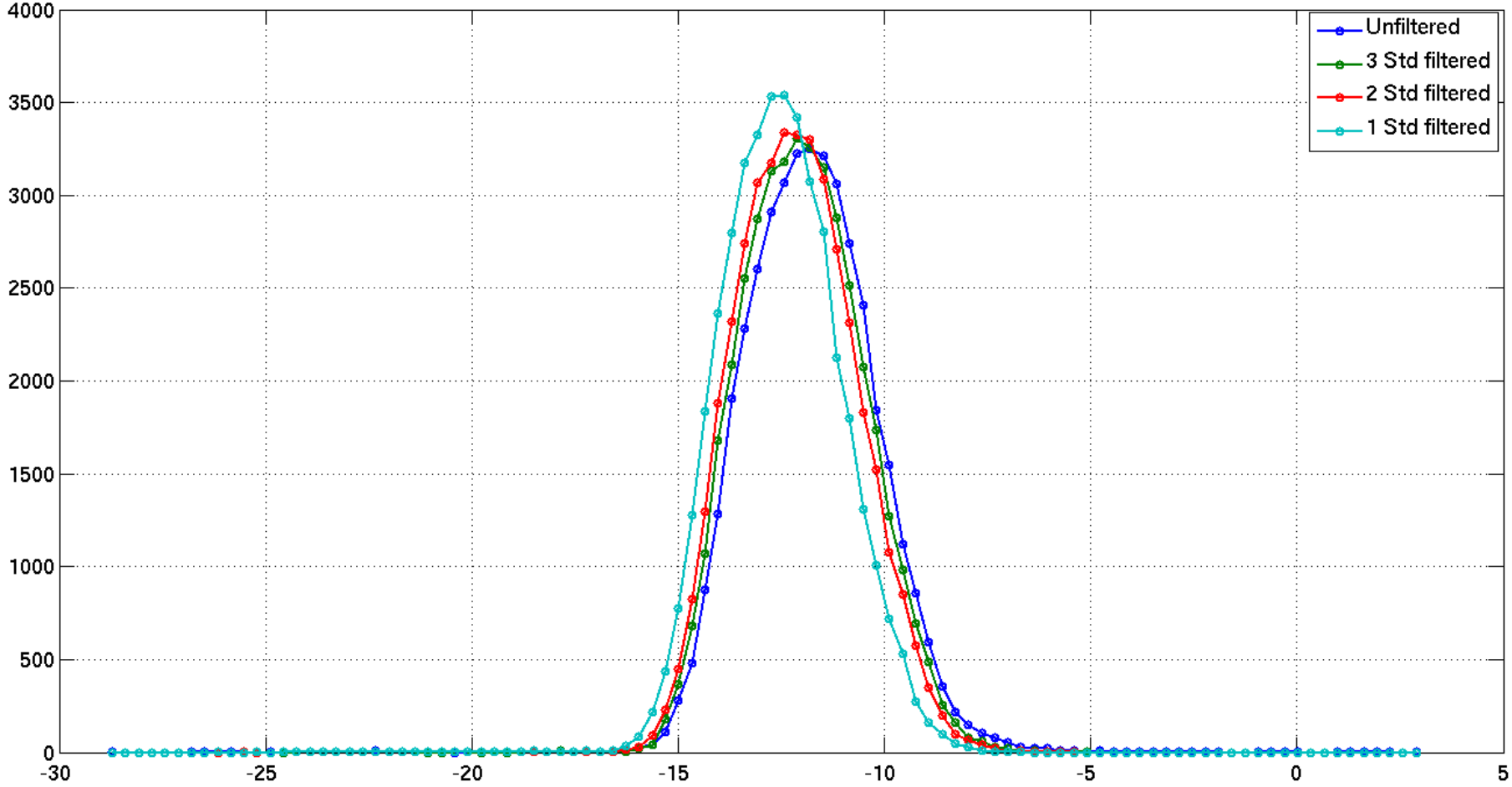






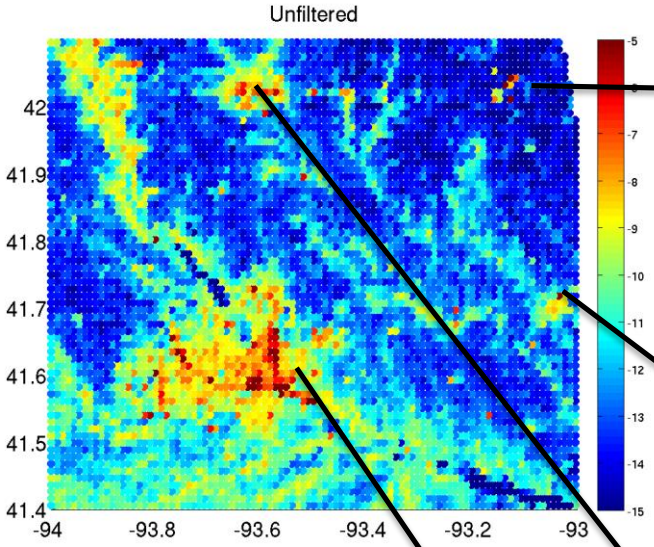
- Local Std threshold does a good job eliminating values >-5 dBs. High for C band

Combine Histograms

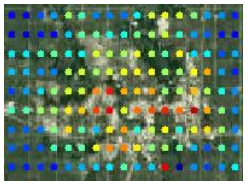


- We observe a shift in the mean to the left caused by the elimination of outliers but also by a smooth effect due to Std filter at local level, especially at the most aggressive 1 Std filter.

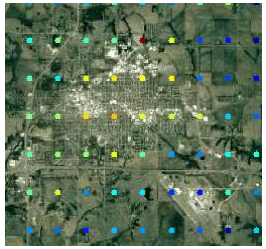
Zooming



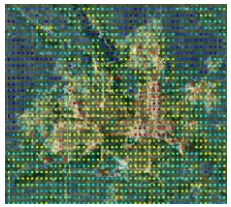
13 km x 8 km

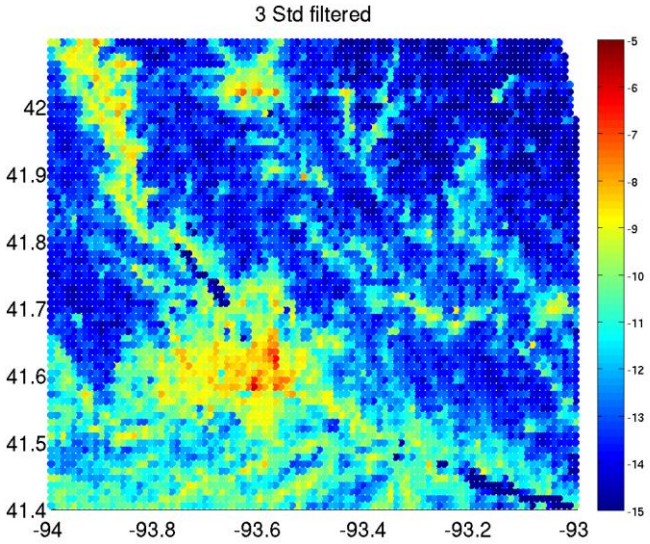


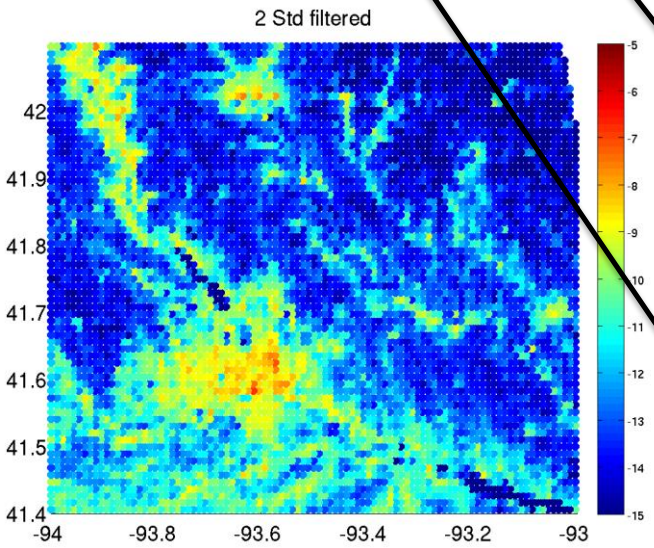
7 km x 4 km

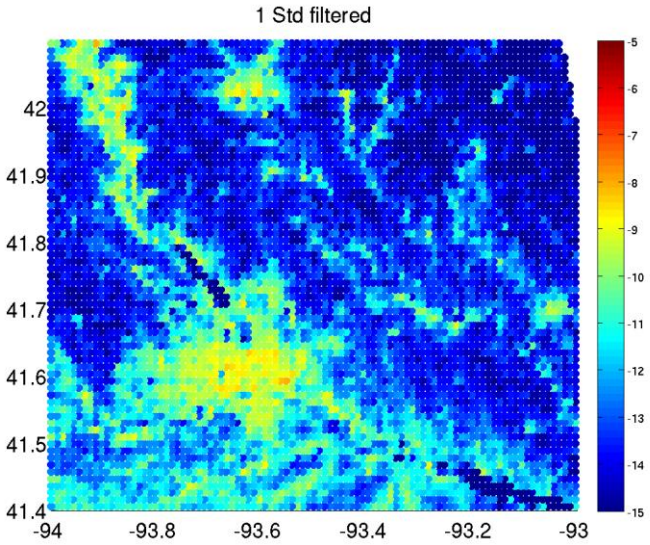


25 km x 32 km









Hybrid Method

- Hybrid method tries to address the filtering using a combination of median-filter and Std threshold.

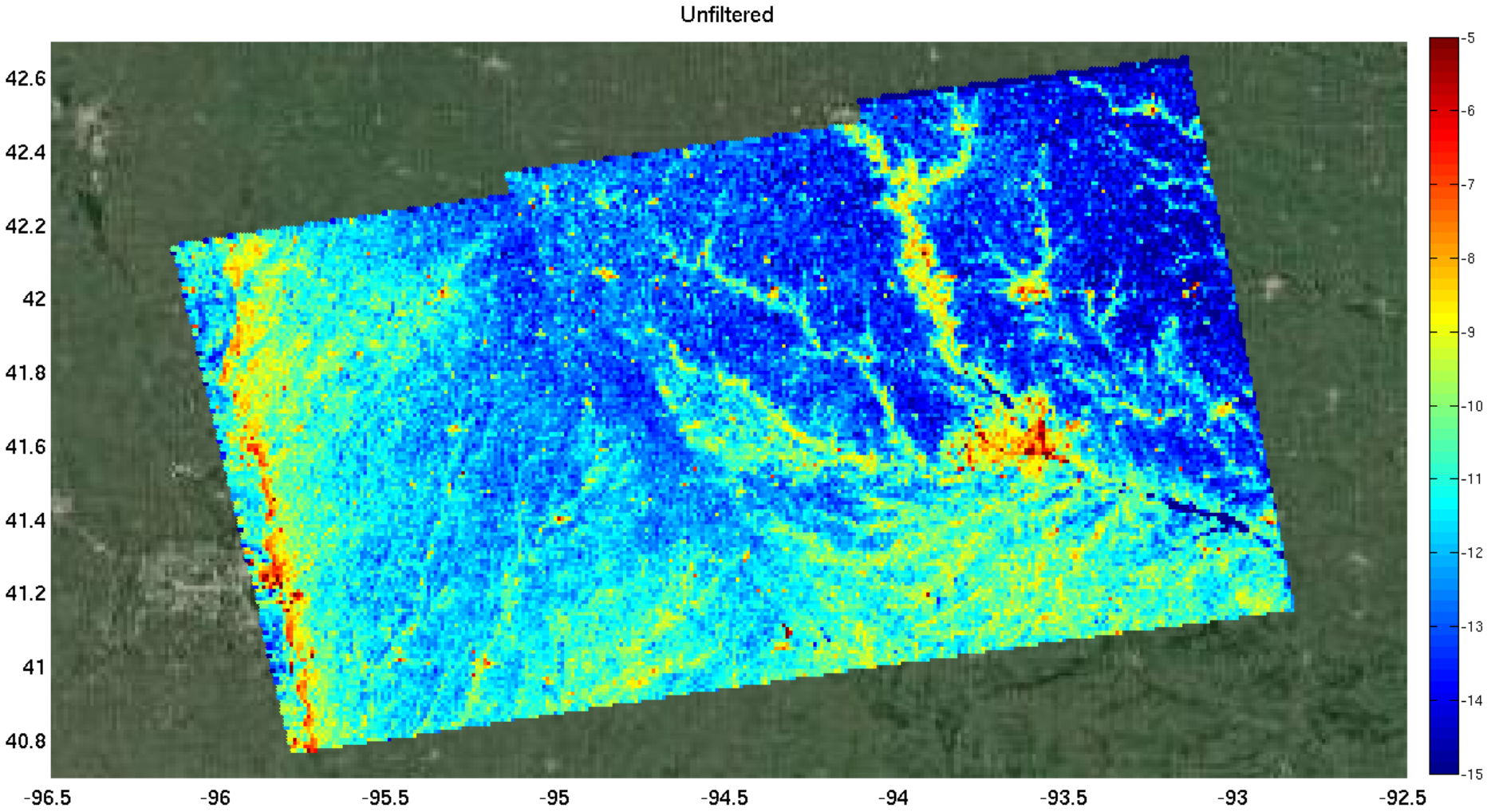
- Local Std (s) and local mean (m) values are computed for every 1 km cell.

- A Std threshold (T) is computed by averaging all the Std's in the image.

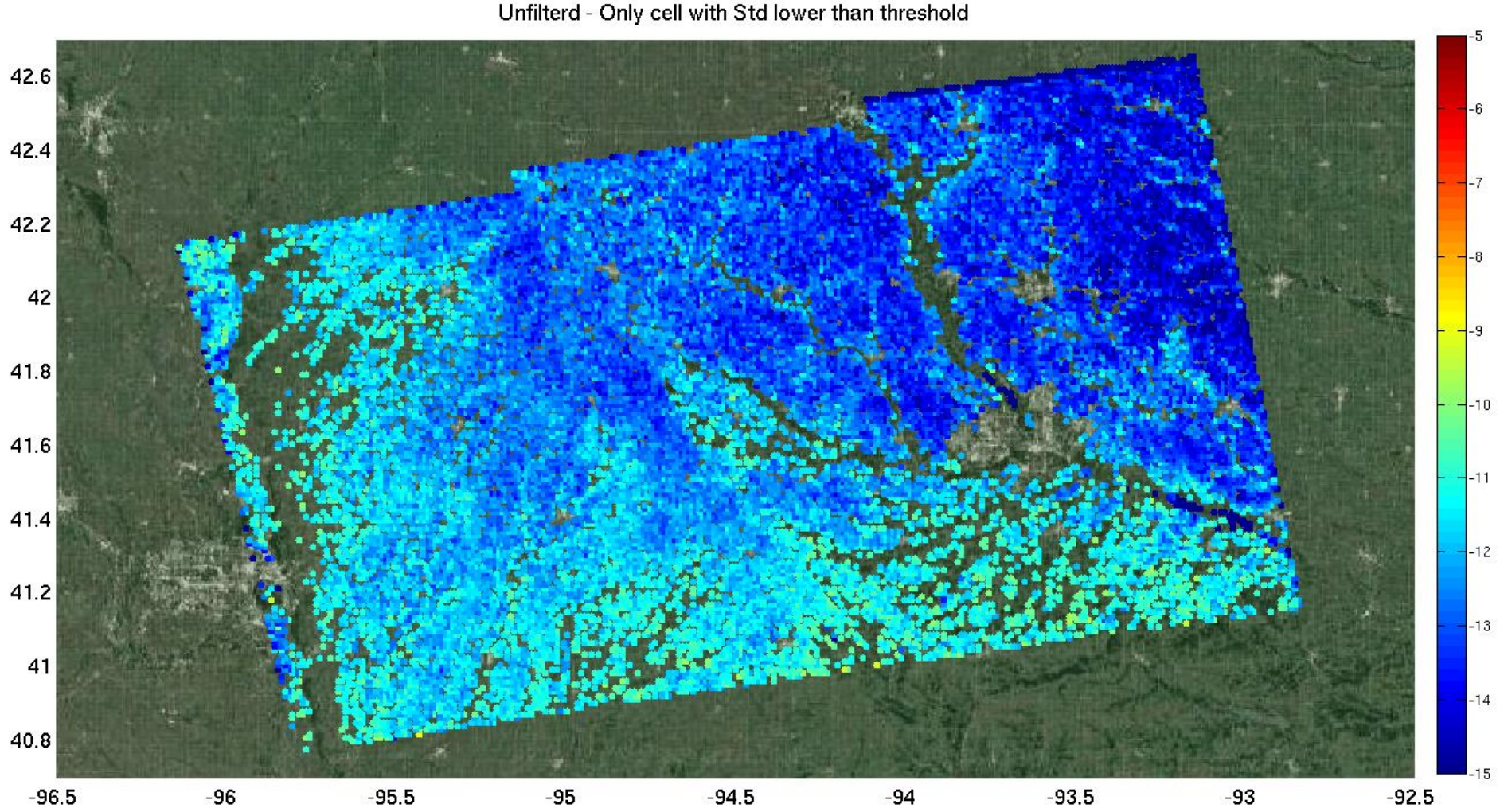
- For all 1 km cells with Std exceeding the threshold, a median filter is applied

- For all 1 km cells with lower Std, we eliminate all the 20 meters samples outside the range [m-T:m+T] (Note that the threshold T is used to avoid affecting areas with flat distribution).

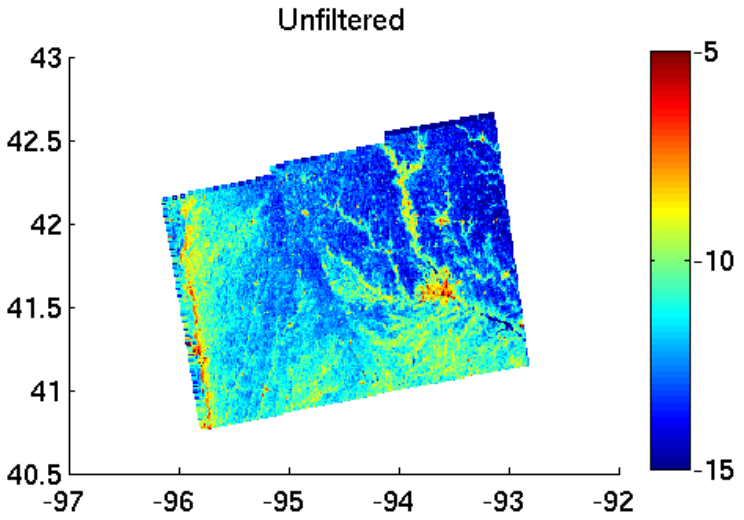
Unfiltered Image

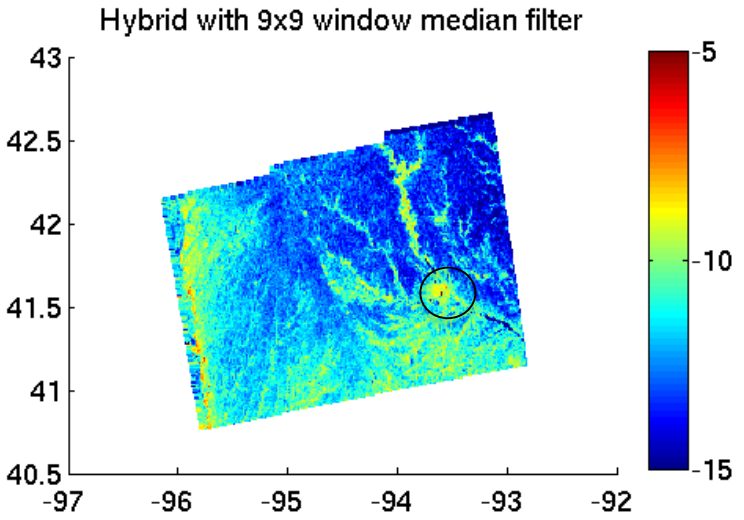


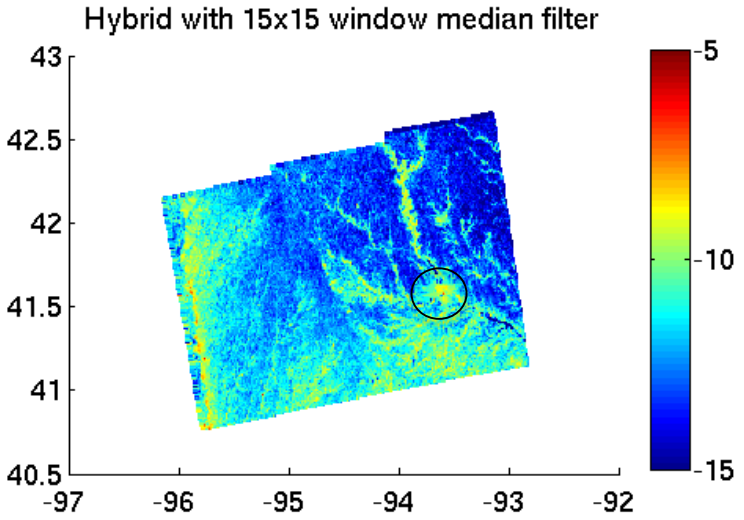
Unfiltered Image eliminating cell exceeding threshold

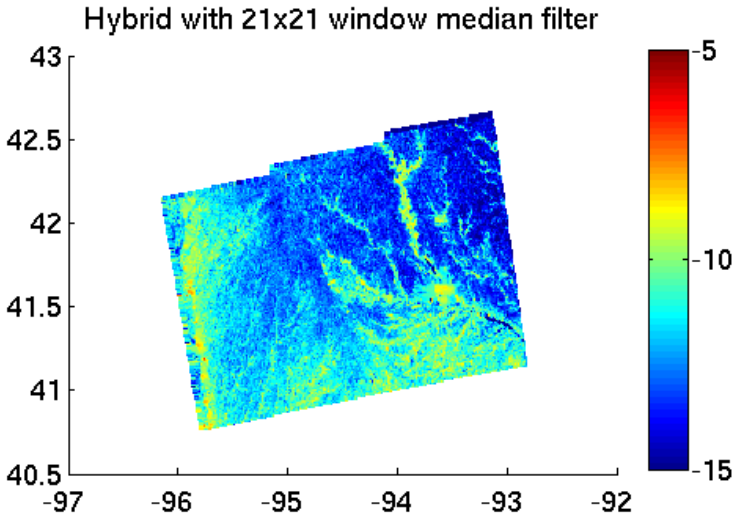


Hybrid Method



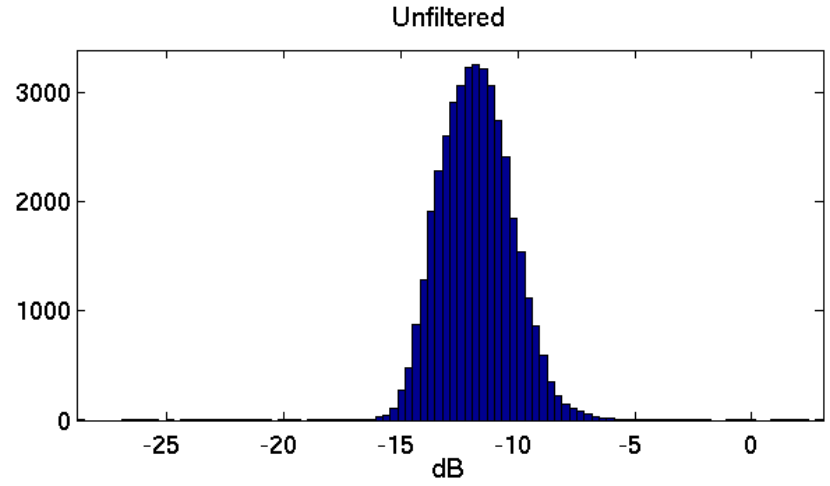


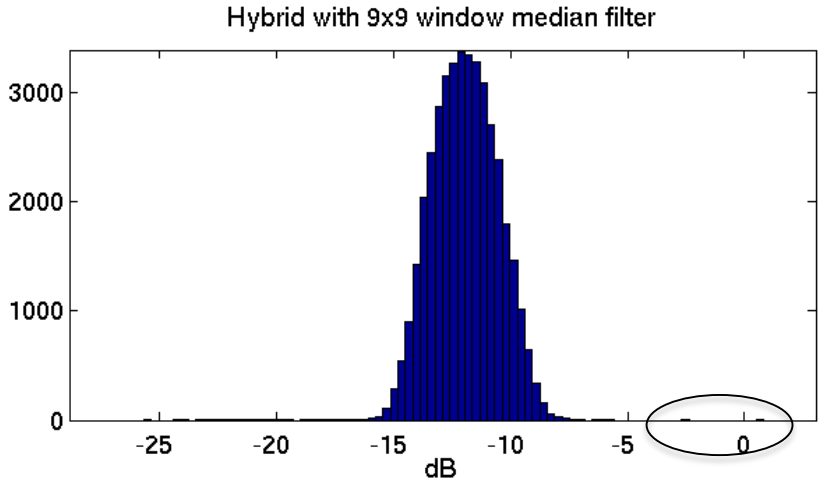


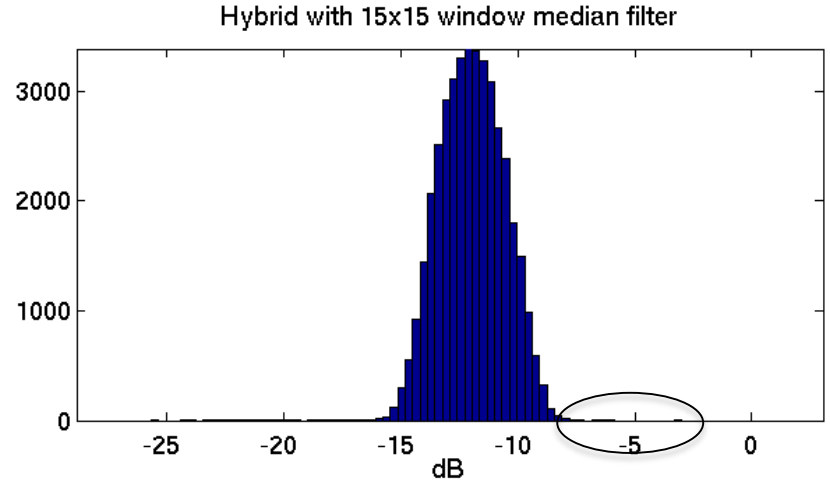


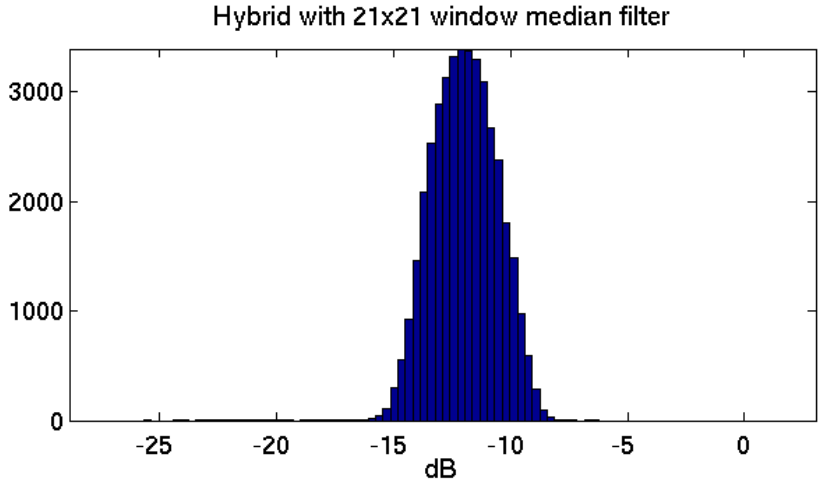
- Still some residual outliers.

Histograms



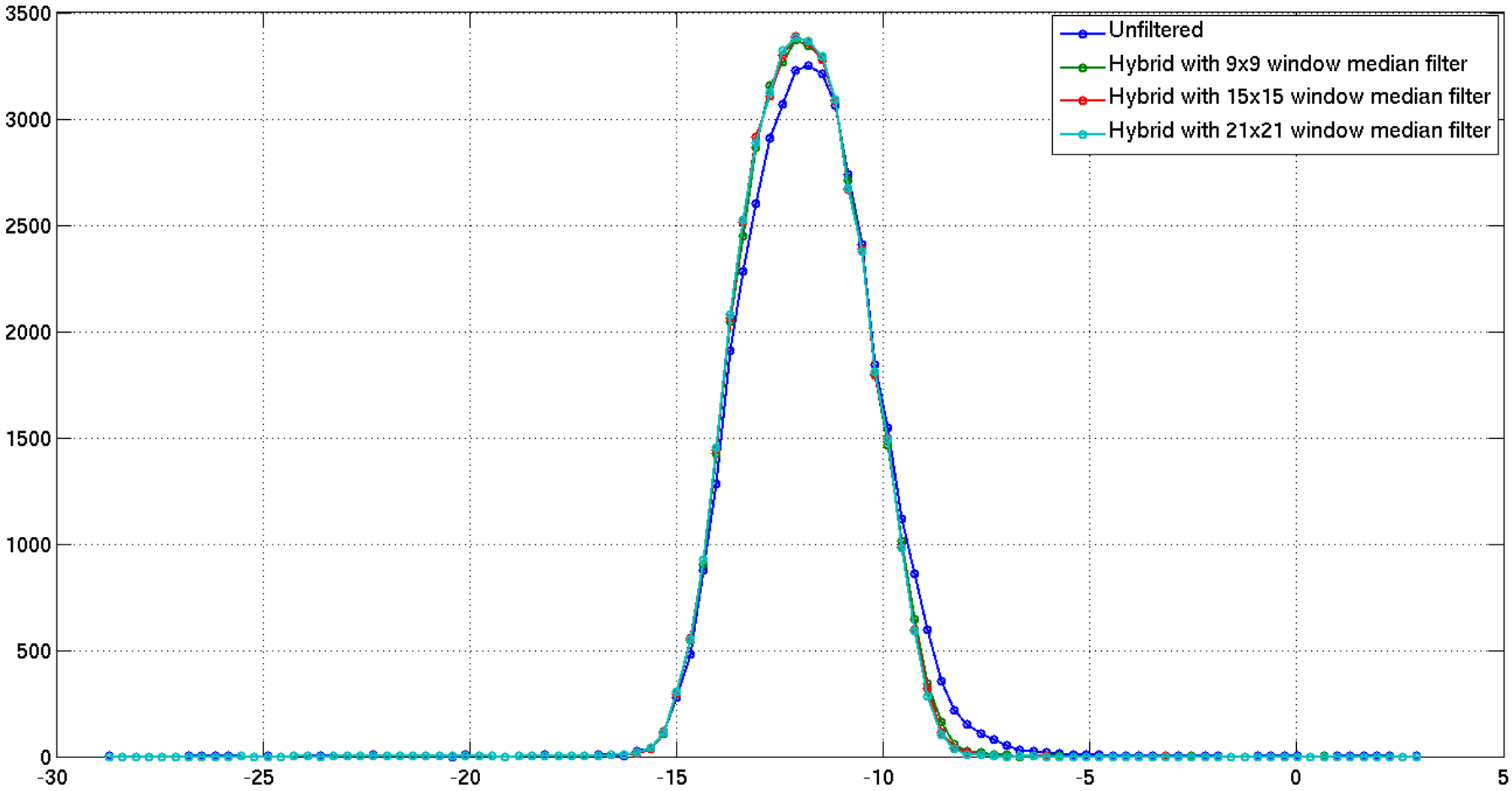






- Still some residual outliers

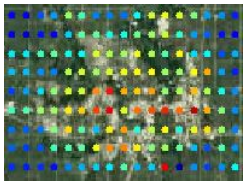
Combine Histograms



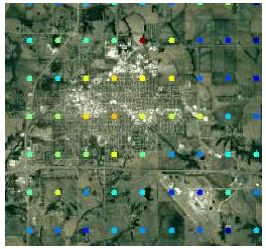
- We observe a small shift in the mean to the left caused by the elimination of outliers but also by a smooth effect due to the median filter.

Zooming

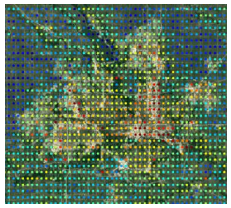
13 km x 8 km

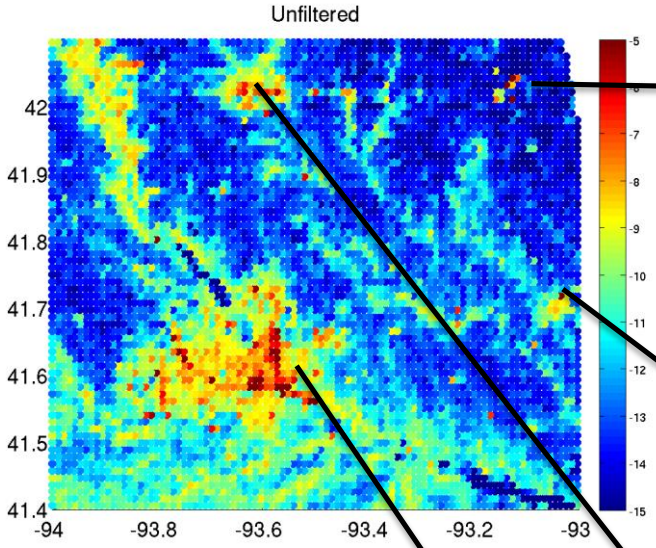


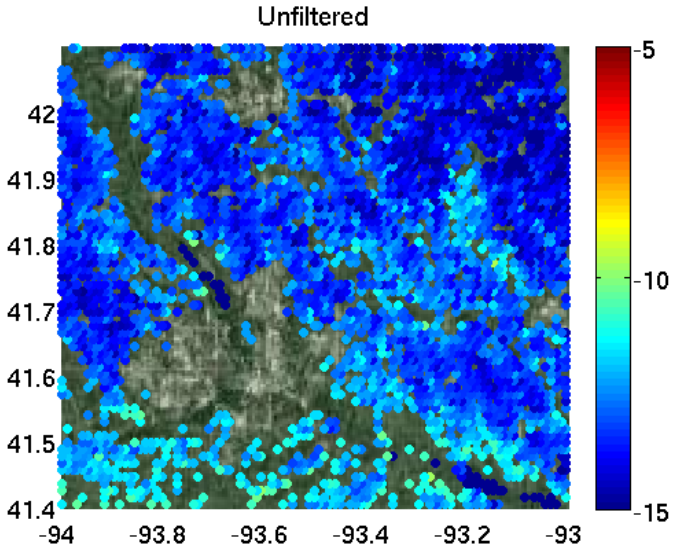
7 km x 4 km

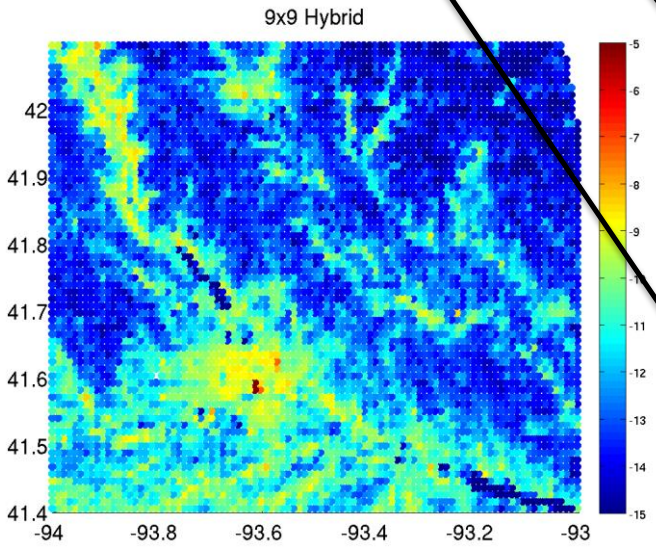


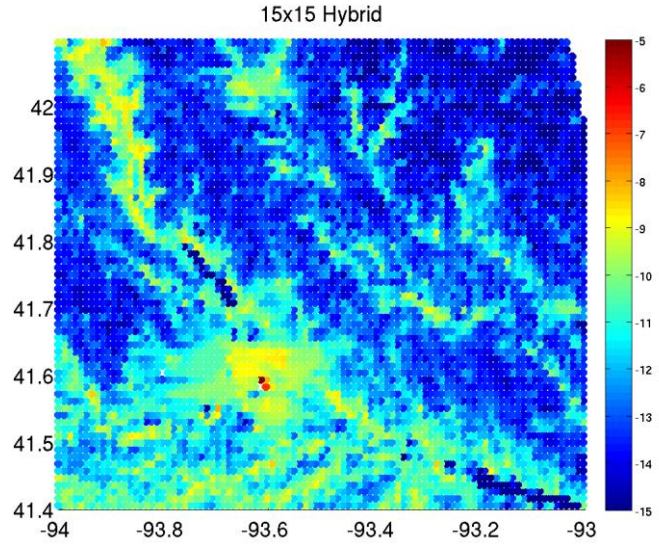
25 km x 32 km











Hybrid method timing

Windows size	~Time
Unfiltered	3 minutes
9x9 samples	4.5 minutes
15x15 samples	6 minutes
21x21 samples	12 minutes

Conclusions

- We analyzed several methods to filter to outliers from the images

- No filter is perfect

- Median filter does a good job but introduces a bias. It is not known how this bias will affect the disaggregated TBs. Was the original image biased by the existence of outliers? Latency requirements do not allow us to use windows bigger than 9x9

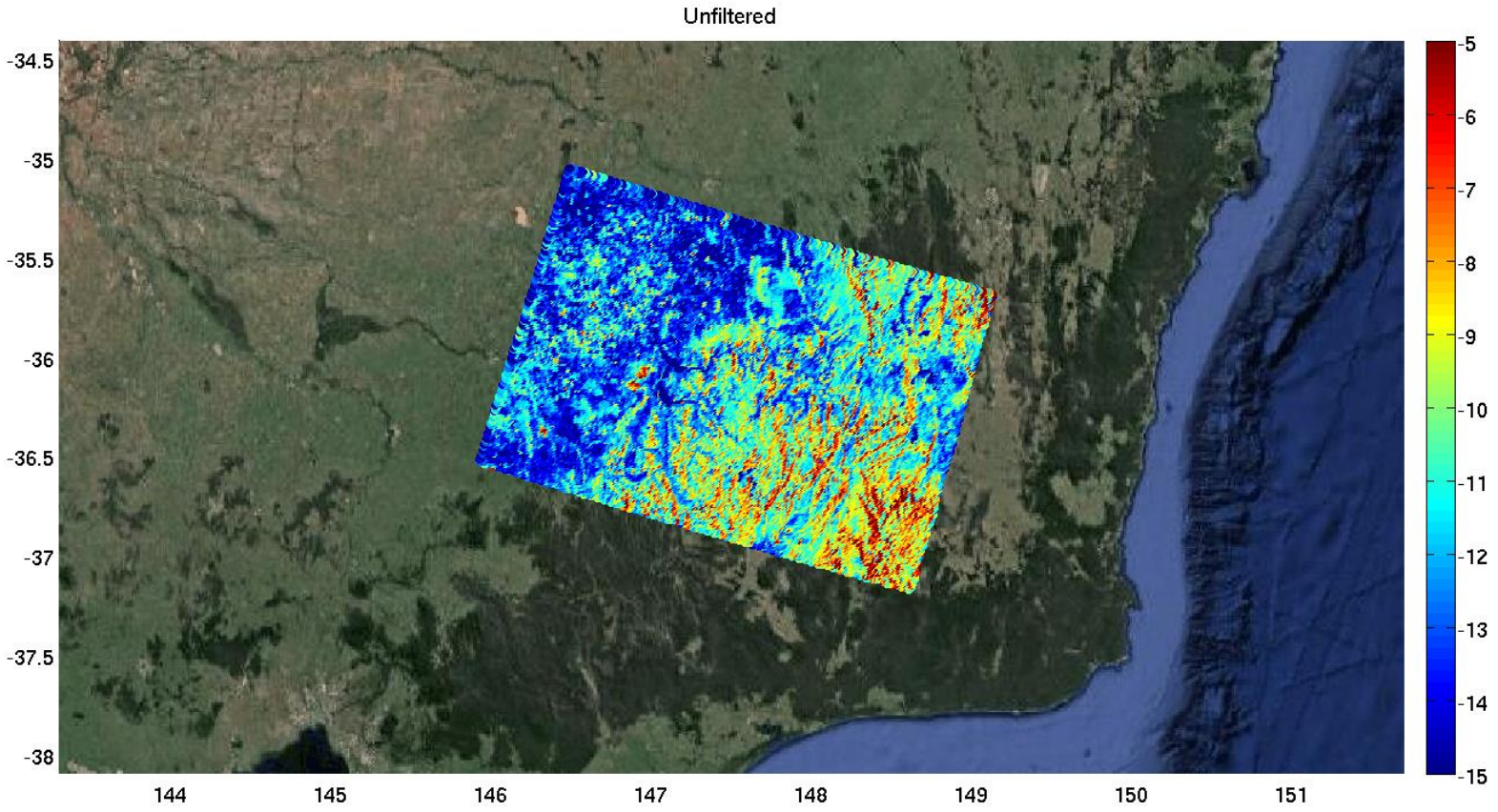
- Local and Global Std approach show good results. They eliminate the outlier and also preserve the mean value of the image. The caveat of using Std is that if the image or 1 km cells have narrow distribution, then we may be eliminating samples carrying significant information. This method does not add significant latency.

- Latency is an important factor. To reduce it, we explore a hybrid method that combines the two previous methods.

- Hybrid method performs well and reduces latency.

- I recommend implementing the hybrid method with a 9x9 window size and deploying the code to OASIS to facilitate further analysis at disaggregated TBs level and Soil moisture level.

Backup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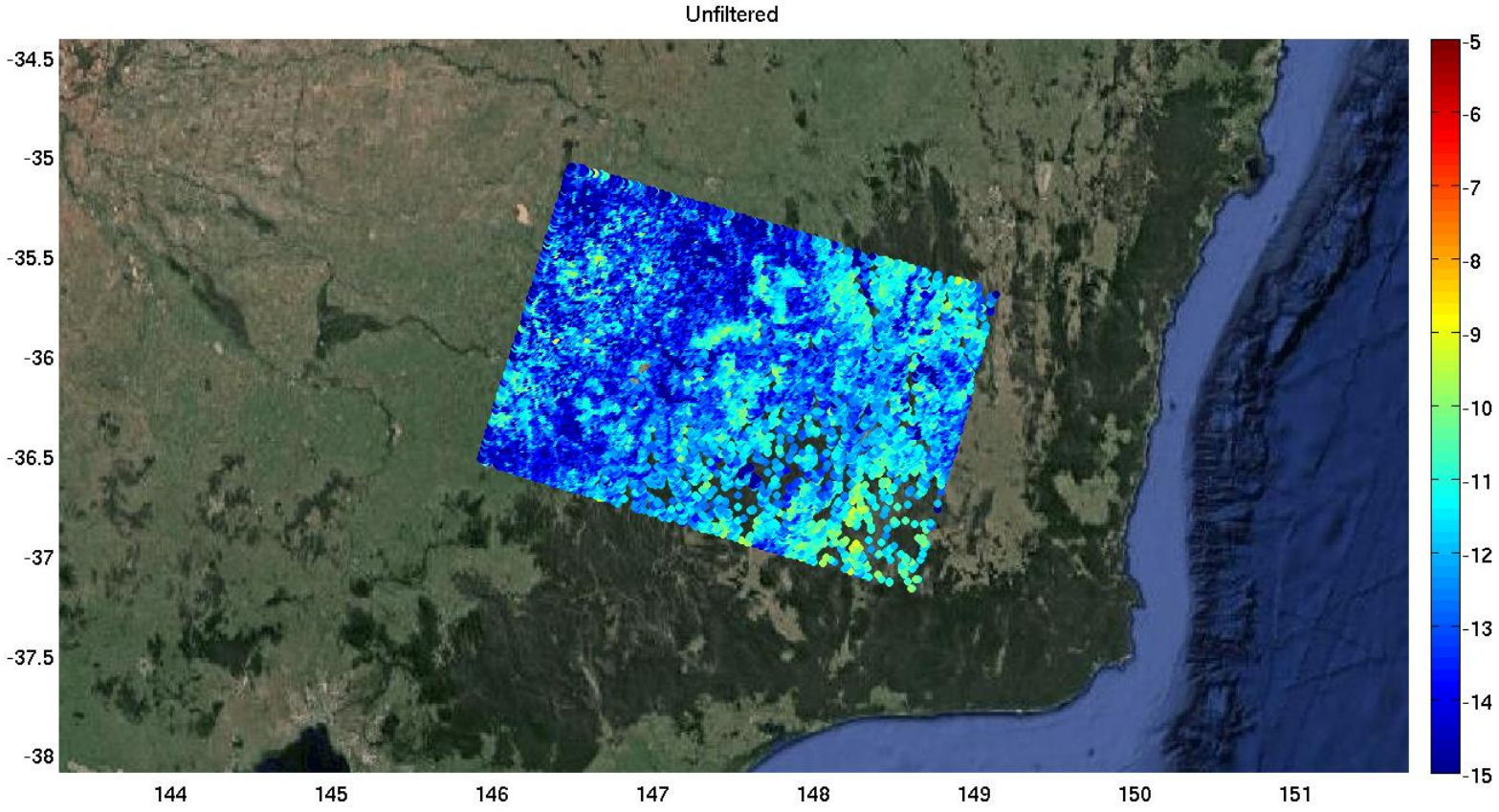
Backup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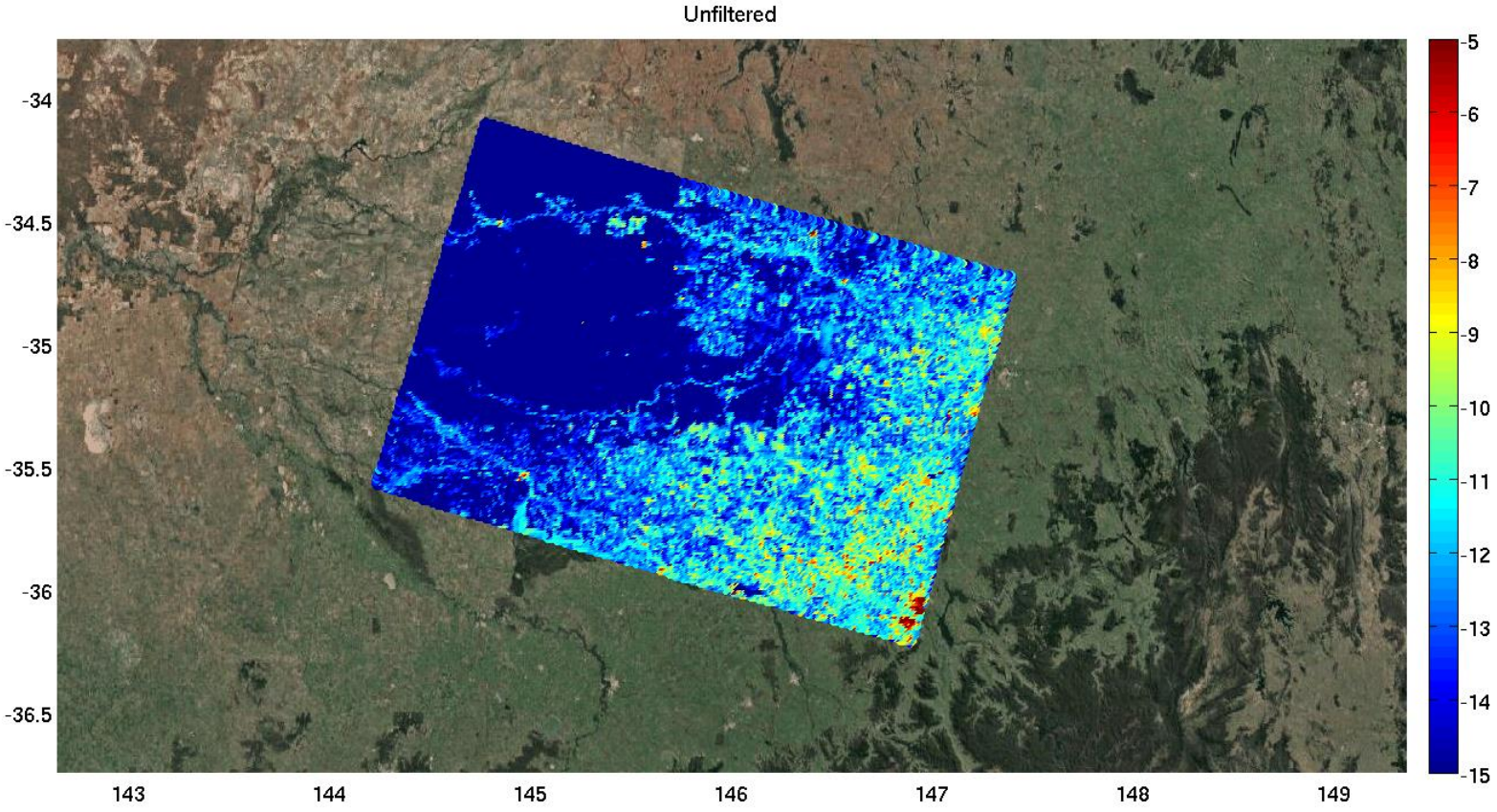
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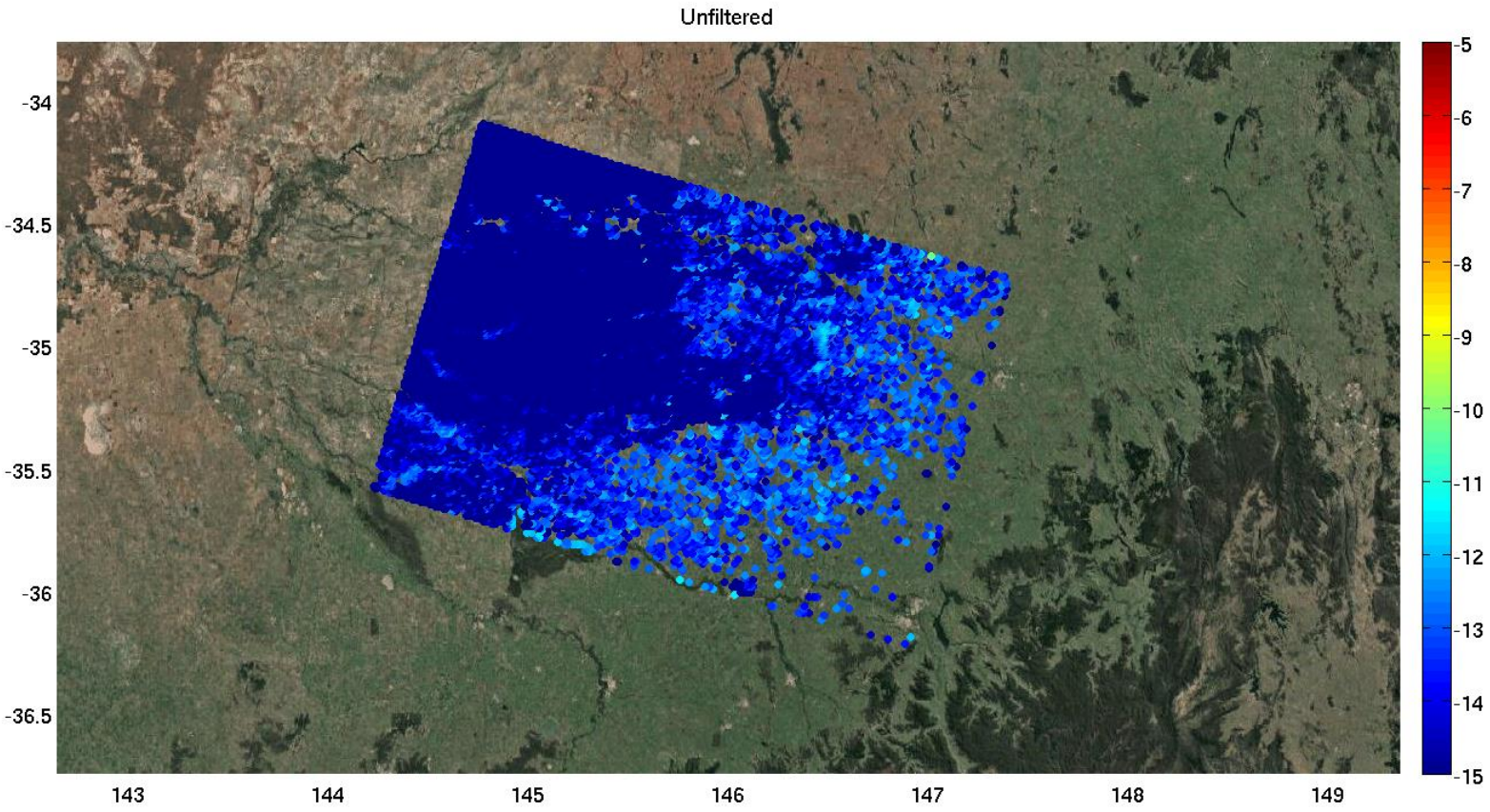
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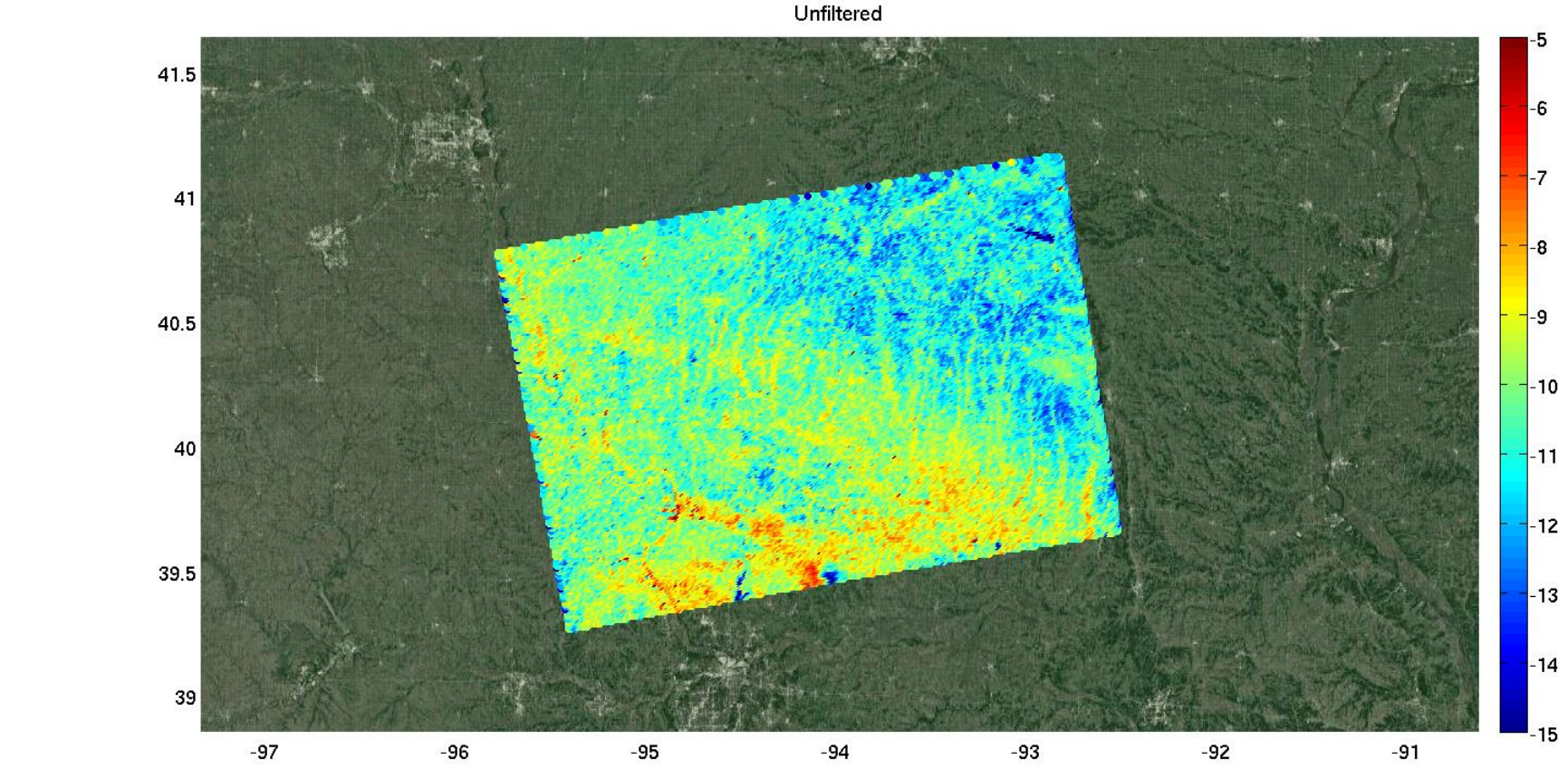
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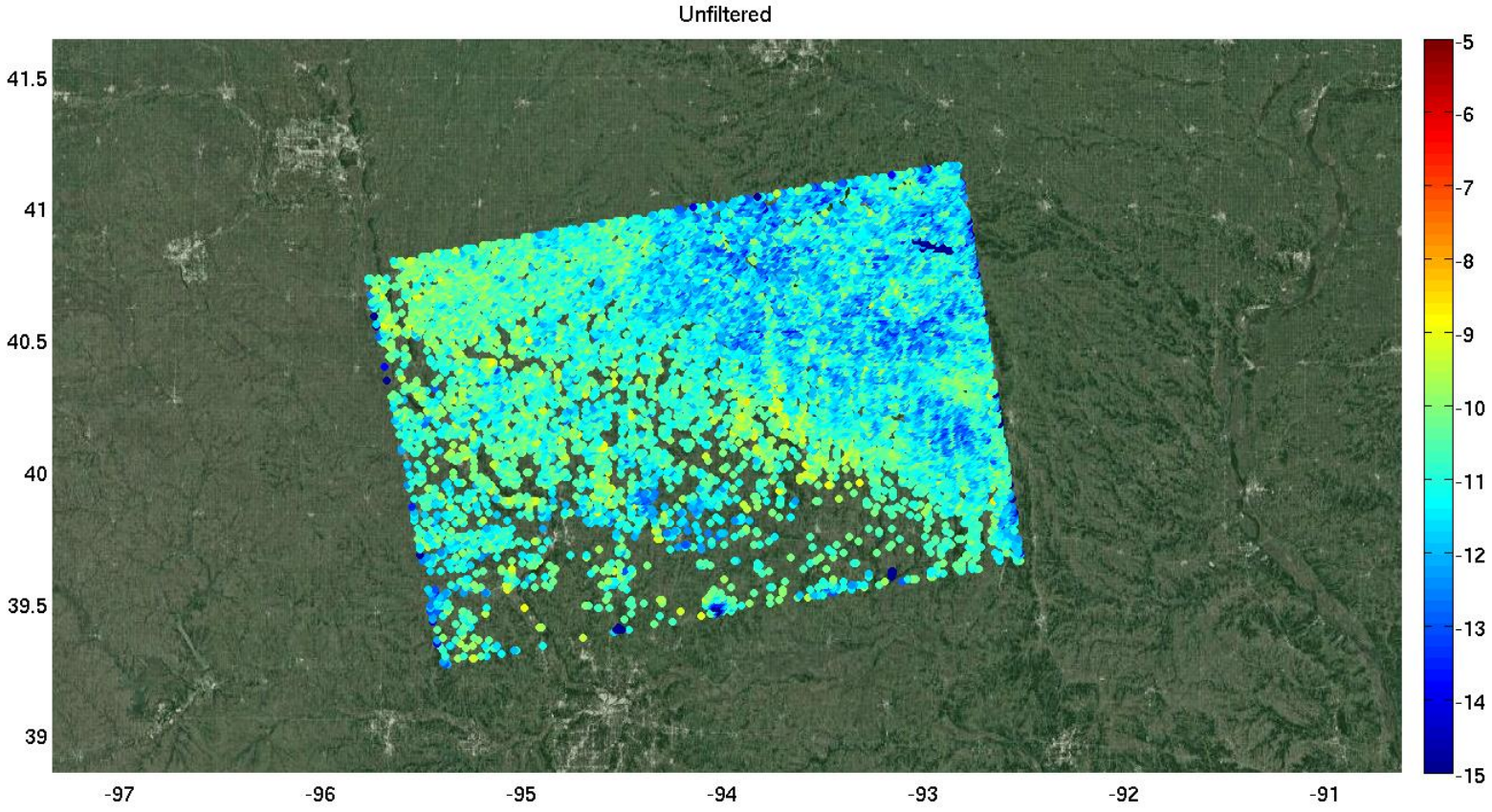
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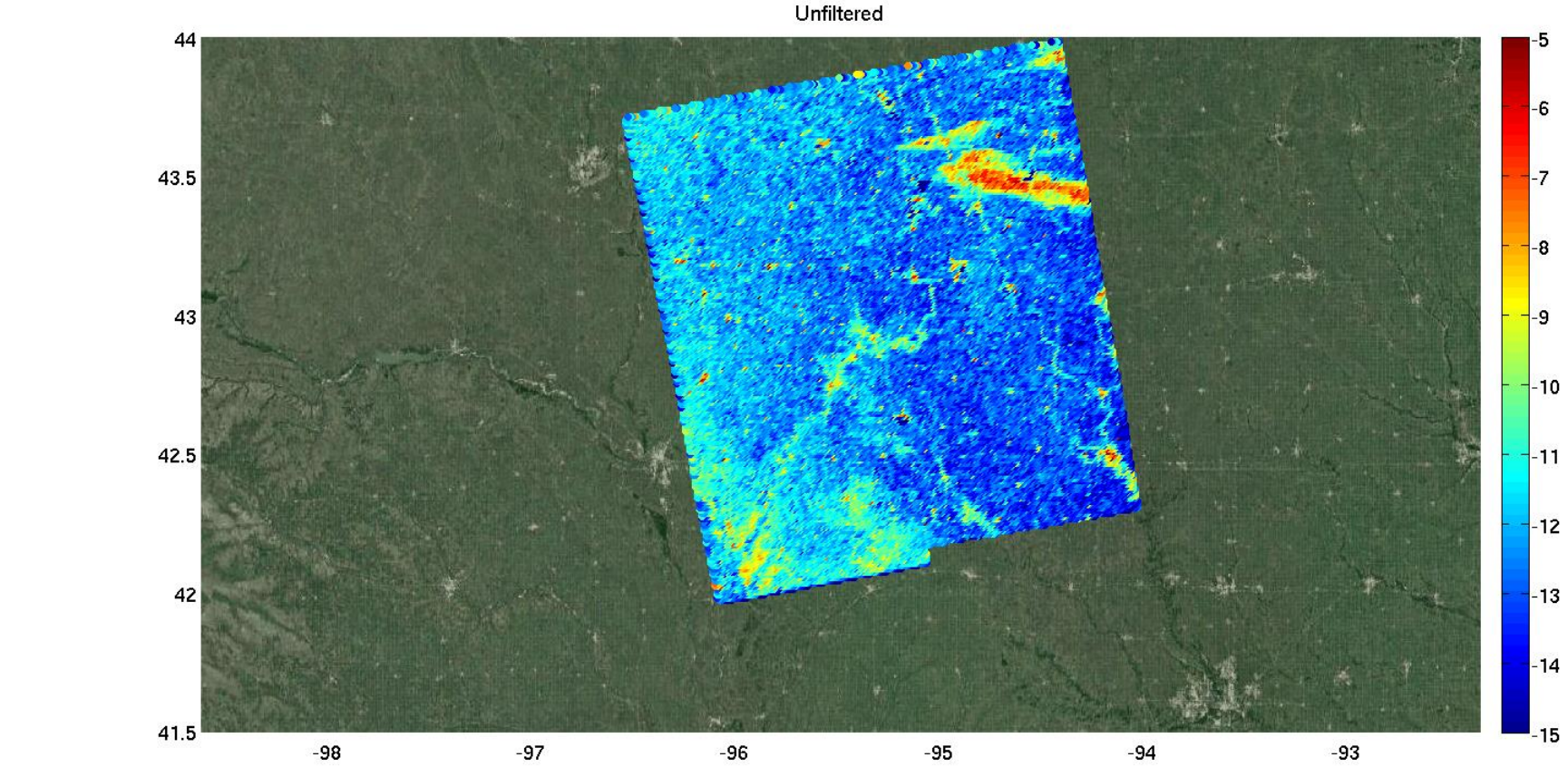
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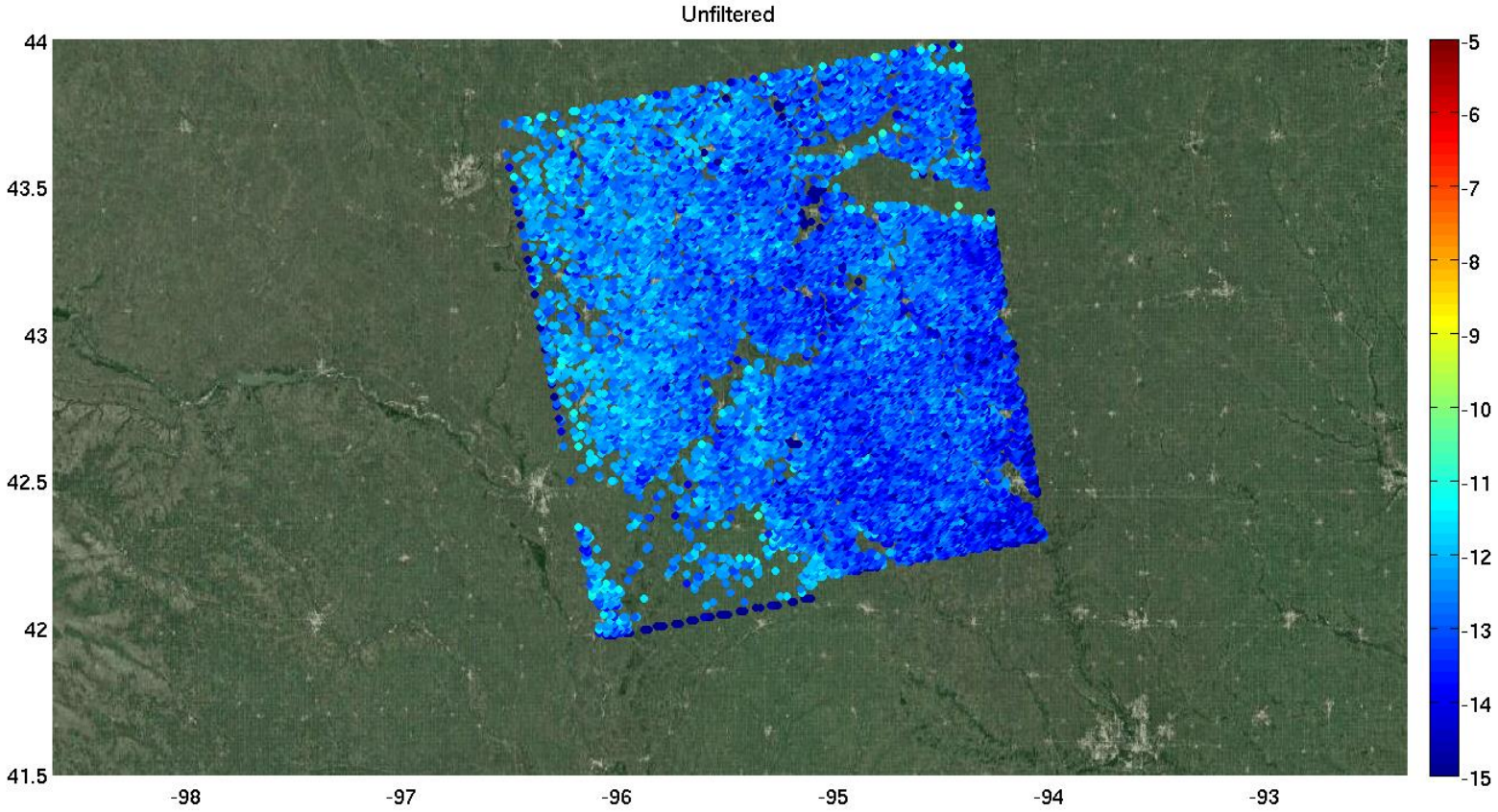
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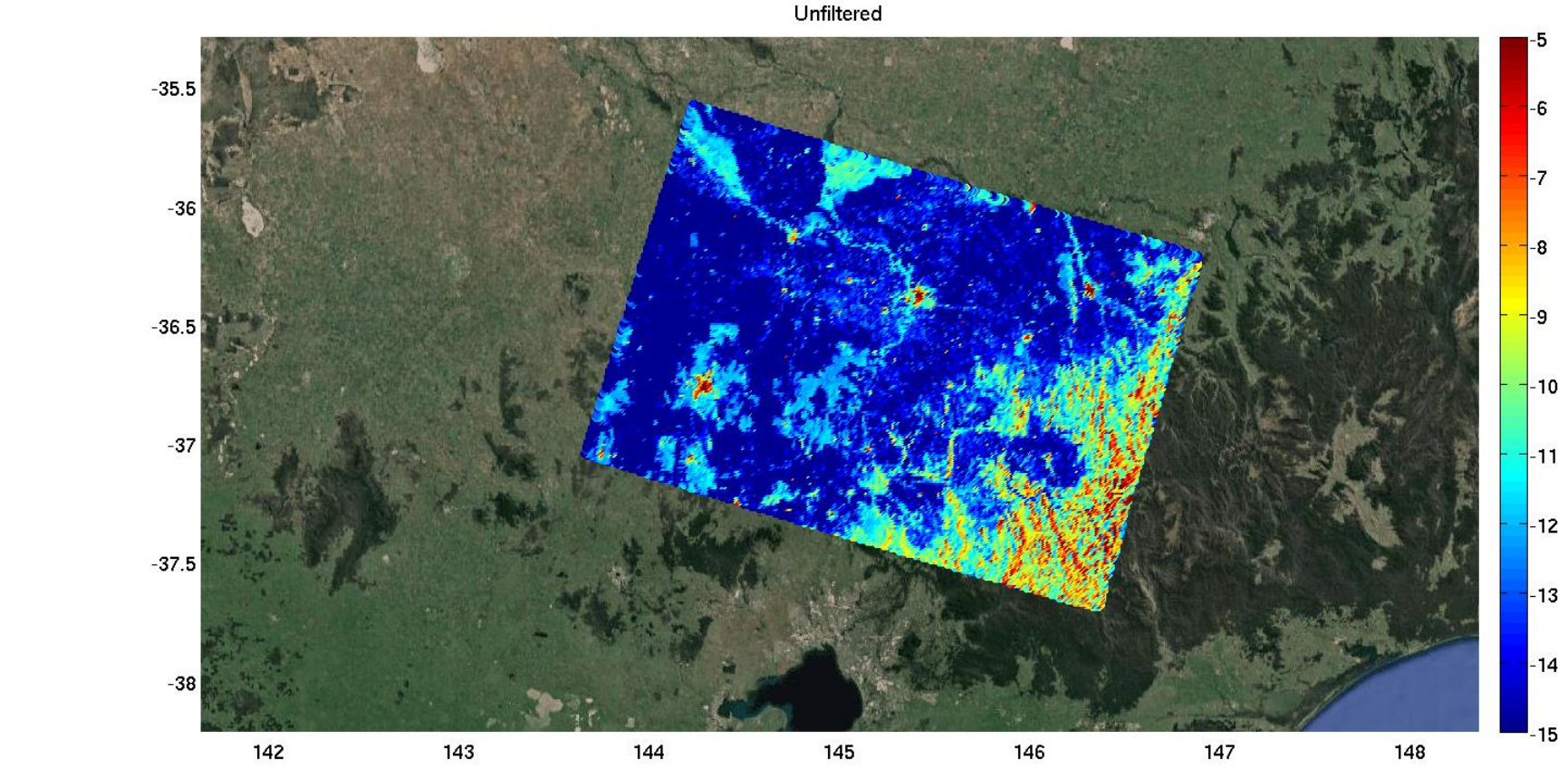
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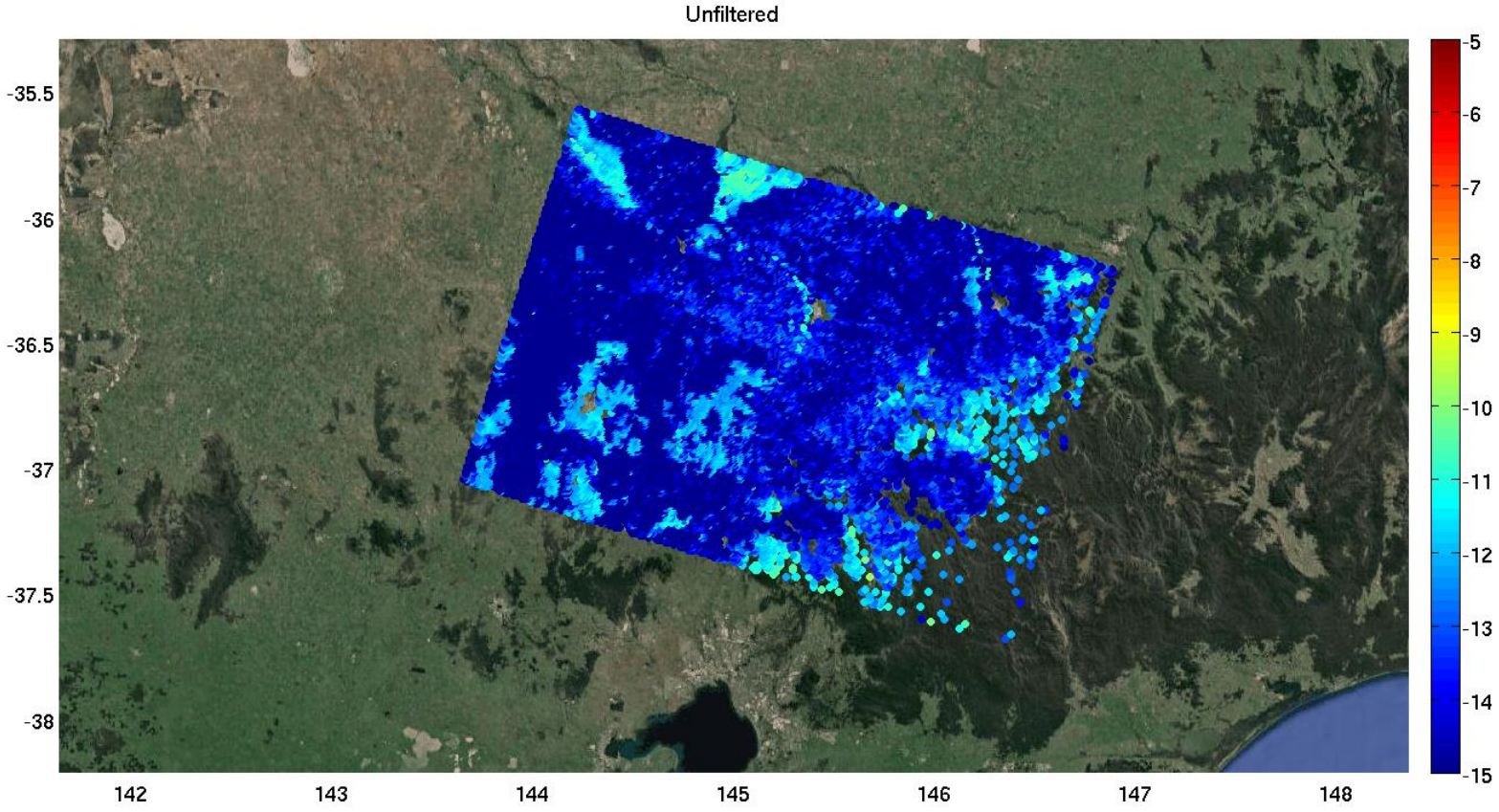
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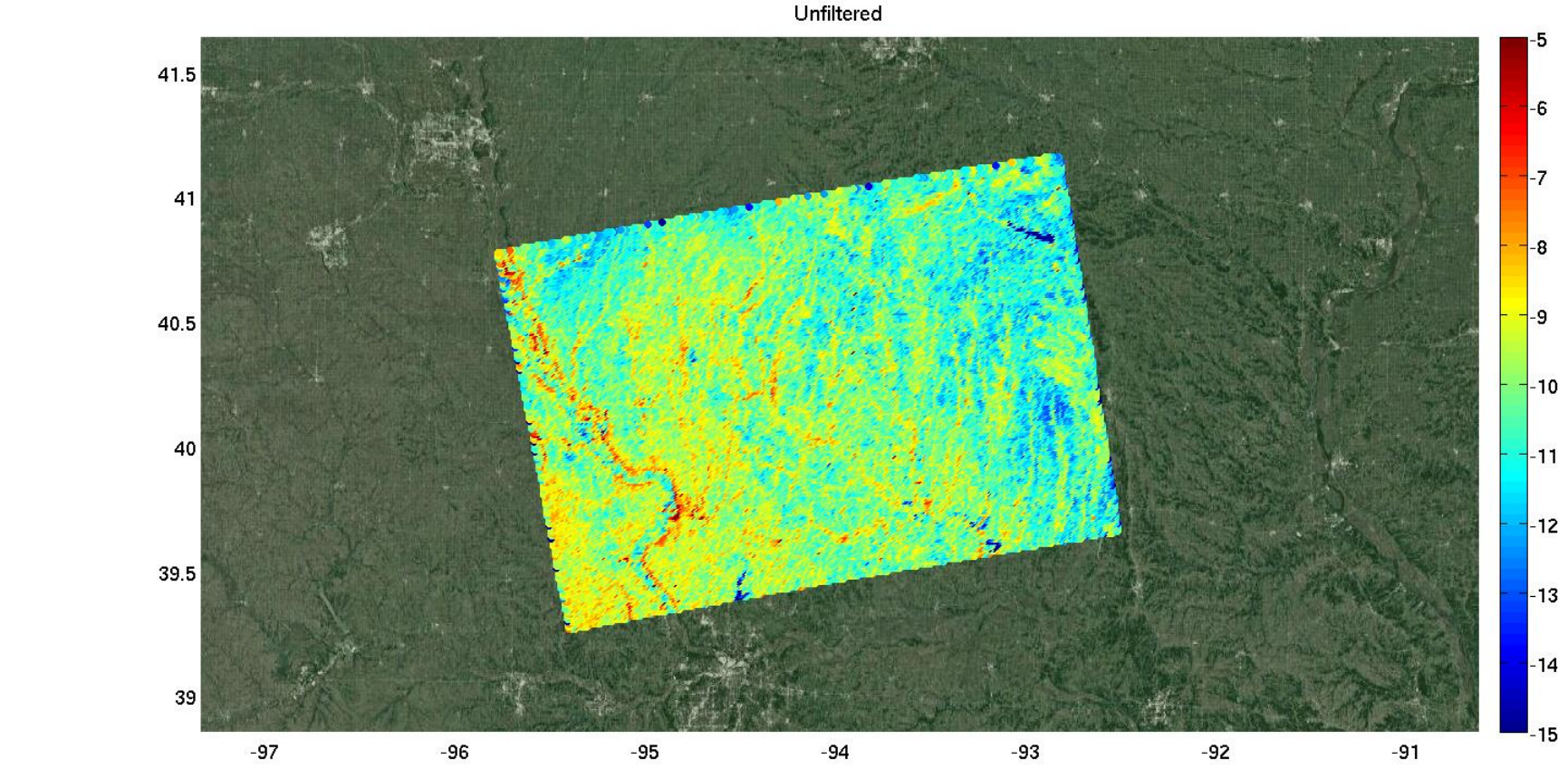
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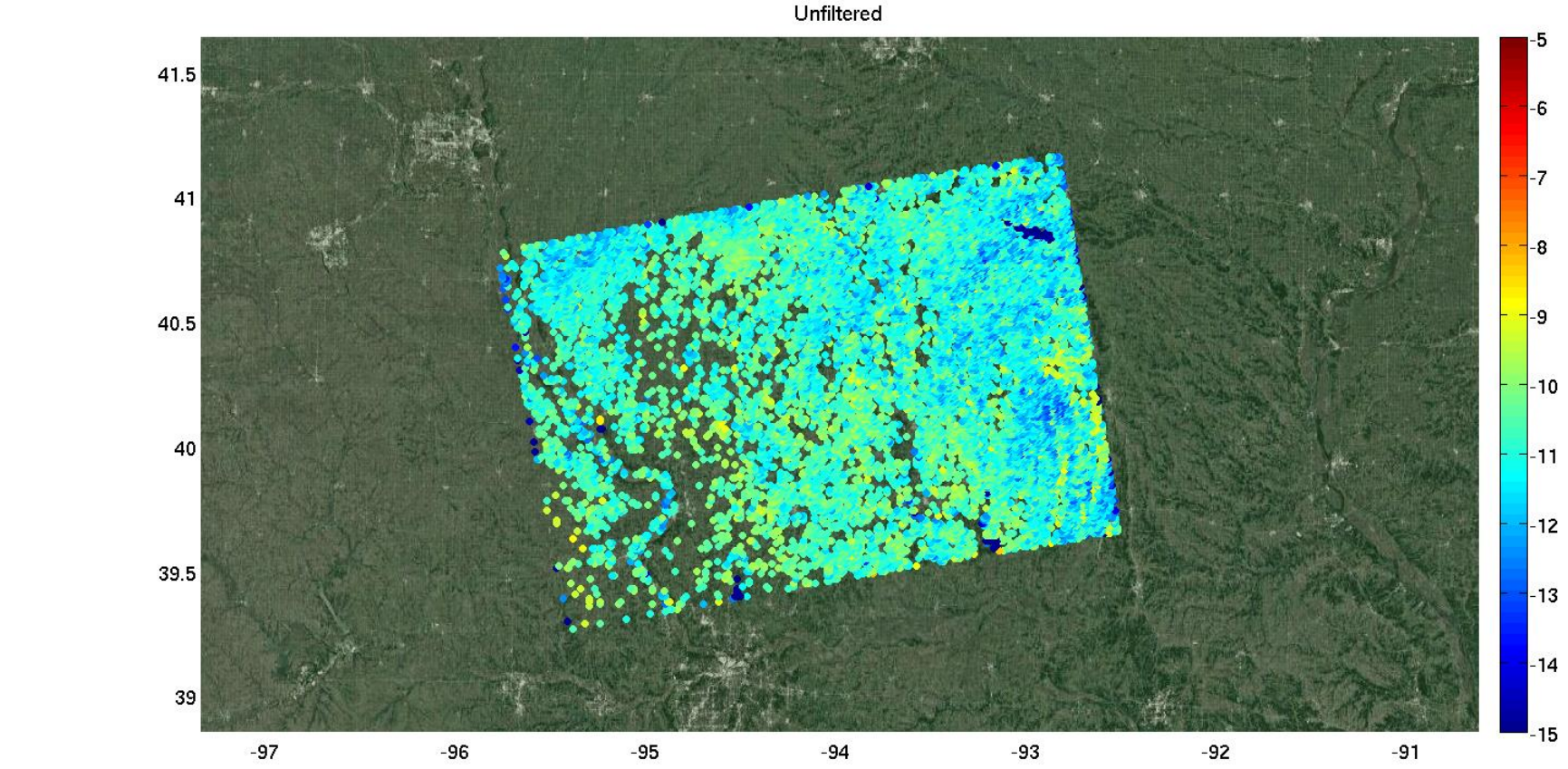
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