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Use of precipitation radar in hydrologic modelling in Norway

Perspectives for a new research project

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Sintef Energy Research

Outline

- New project
- Previous projects
- Analysis of Norwegian radar data
- Bayesian combination of radar and gauge data
- Gaussian random fields for conditional simulations

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New project:

- Operational use of weather radar, for EBL 2009-2011
- Cooperation with met.no, Cemagref and NTNU
- Continuing development of the radar-gauge assimilation, hopefully merging with the simulation approach
- Analysing reflectivity data from the radar for assimilation into fine scale meteorological models.
- Error models for radar data, and the value of gauges in improving radar data quality
  - Hourly data and temporal covariance structure
  - Special focus on mountainous areas
  - Effect on precipitation validation on reflectivity data quality

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Recent projects

- Developed and implemented conditional simulation method as an alternative to Inverse distance
- Development of a distributed model framework
- Improved simulation of snow processes
- Implemented a Kriging approach, focusing on station selection and variable uncertainty
- Started evaluating weather radar maps, and implementing Todini's (2001) routine for Bayesian assimilation of radar and gauge data
- Also focusing on the use of gridded meteorological forecasts

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Ongoing and planned projects

- ”The Hydrological Crystal Ball” for Statkraft 2008-2011
  - A full range project on uncertainty in operational forecasts
  - Target: Decision supporting information for power traders, includes estimating the econimic value of information
  - Error models for measured data:
    - Precipitation and temperature
    - Discharge and naturalised flow series.
  - Simulation using meteorological ensemble forecasts
  - Parameter uncertainty estimation
  - Error models for the HBV lumped model and a distributed model

  - One of several projects on implementing distributed models

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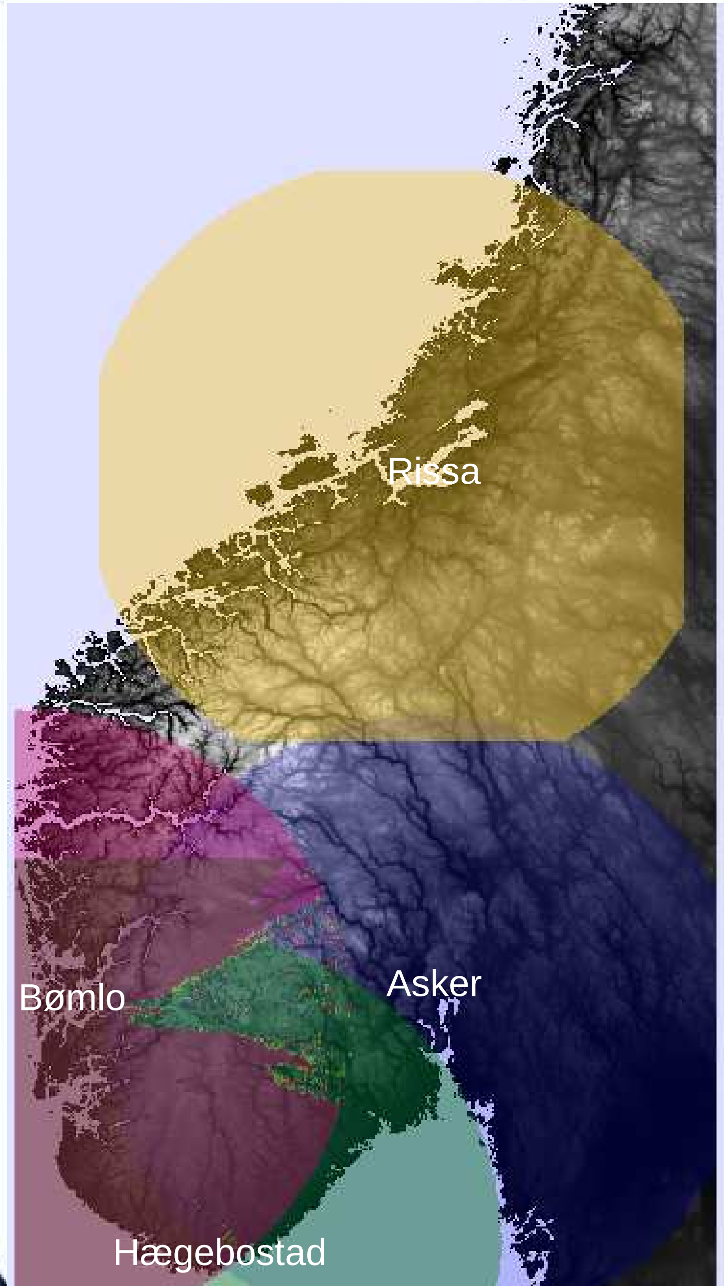
Precipitation data

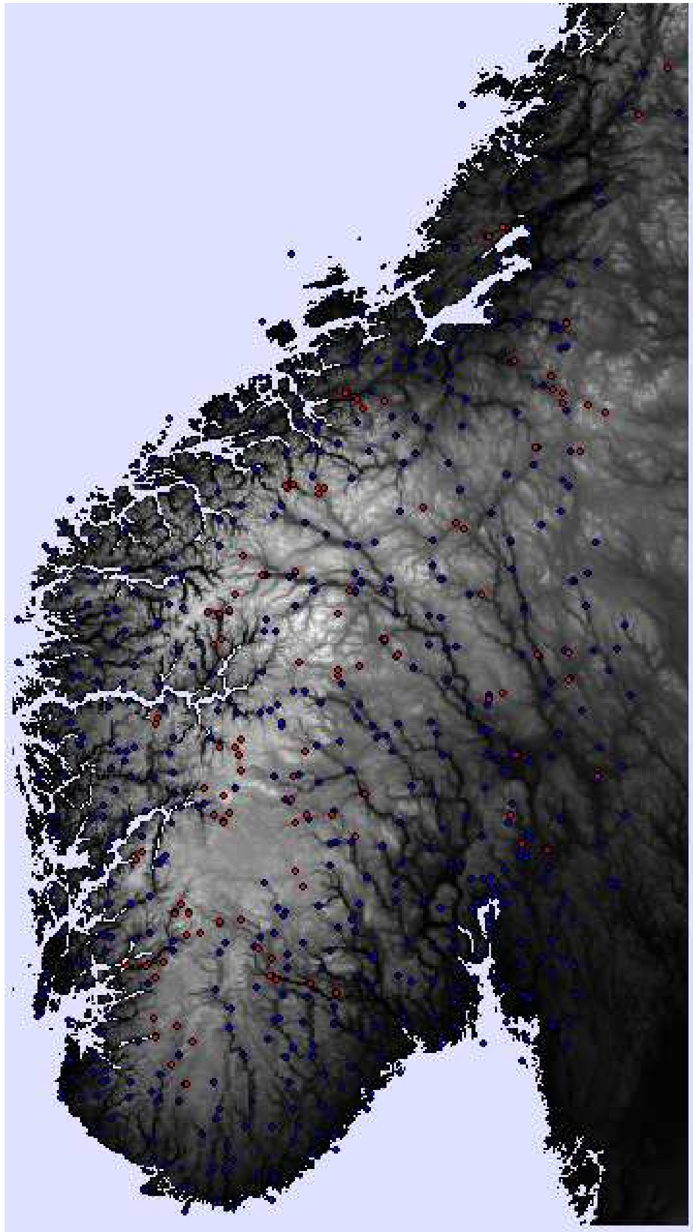
	Radar	Gauge
Spatial support	~1 km^2	~100 cm^2
Spatial resolution	~1 km	~10 km - ~100 km
Spatial coverage	Southern Norway	All Norway
Temporal support	~4x1 min?	~1 h; ~24h
Temporal resolution	~1h	~1 h; ~24h
Temporal coverage	2000 ->	1900 ->
Bias	Large ?	Wind dependent
Uncertainty	Large ?	Small



Radar data:

- Rissa (Jan 2006- April 2008)
- Bømlo (April 2007-April 2008)
- Asker (April 2007-April 2008)
- Hægebostad (April 2007-April 2008)

Daily data accumulated from hourly data



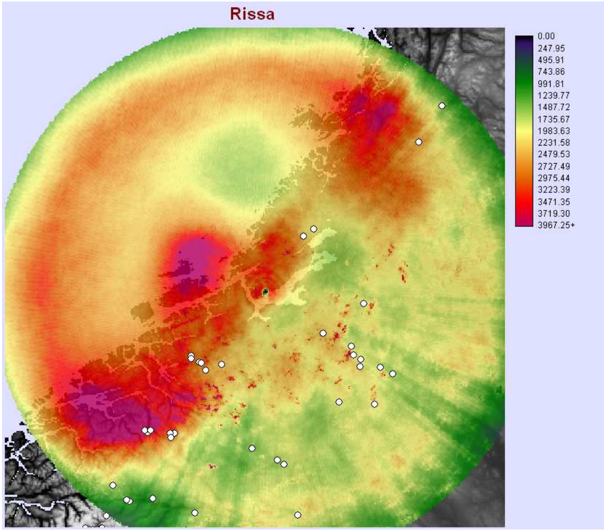
Precipitation gauge data for evaluation:

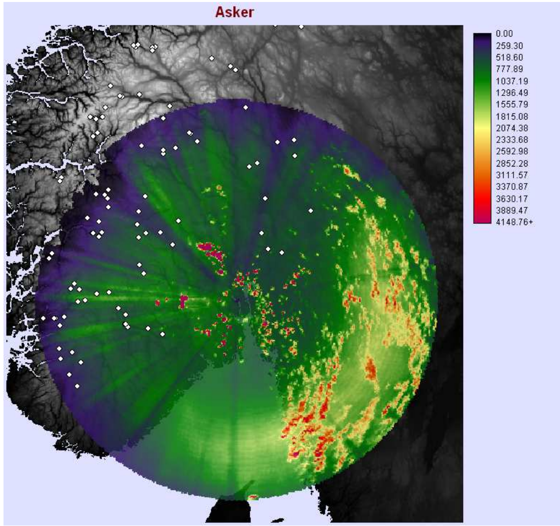
- dependent stations
  - Norwegian met. office
  - already used in adjusting the radar precipitation
- independent stations
  - hydro power companies

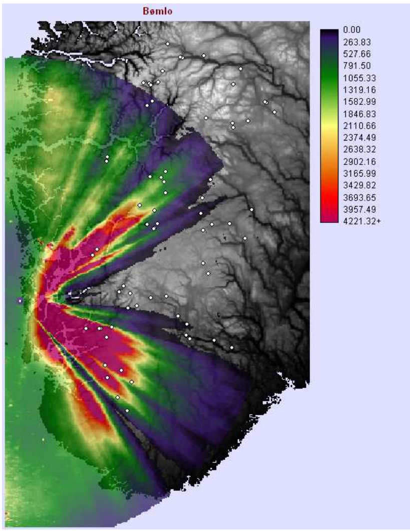
Evaluation against gauge stations

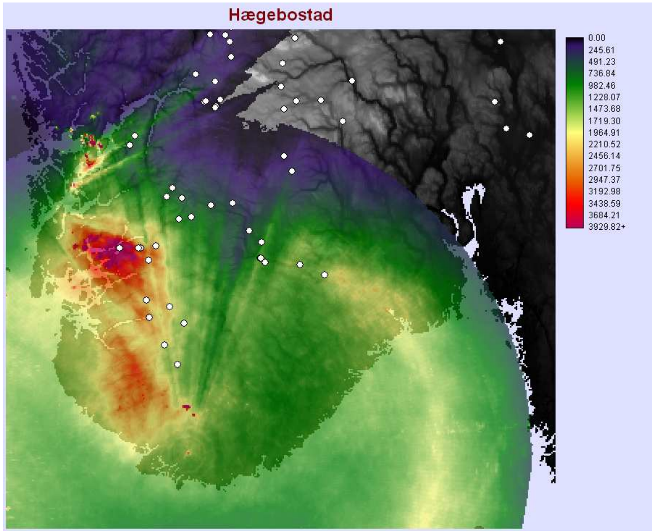
- correlation
- average values
- Nash-Sutcliffes efficiency criteria R^2

Sum radar precipitation

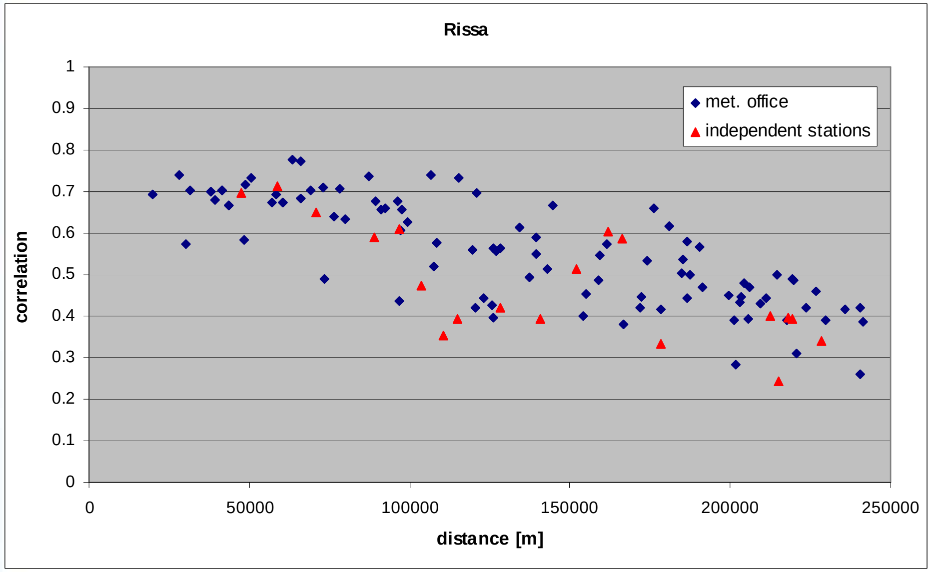


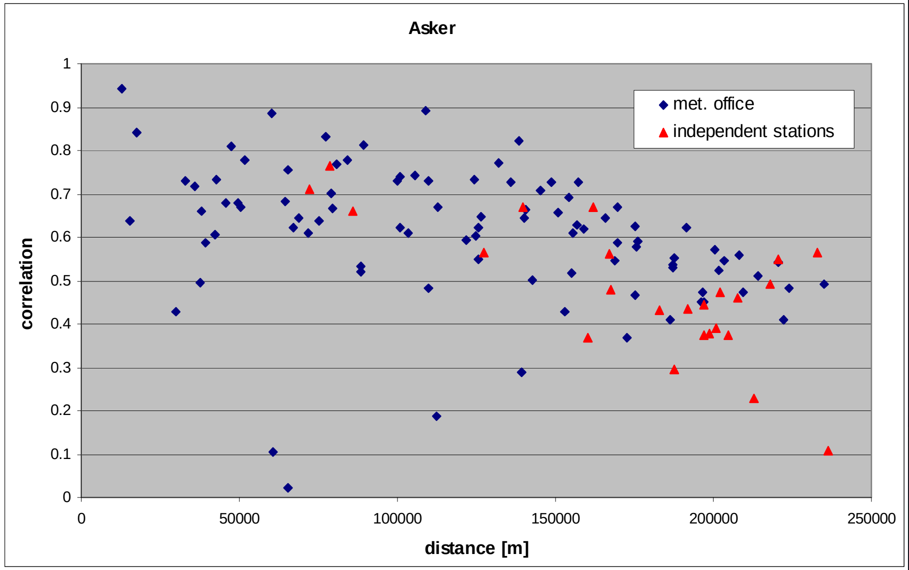


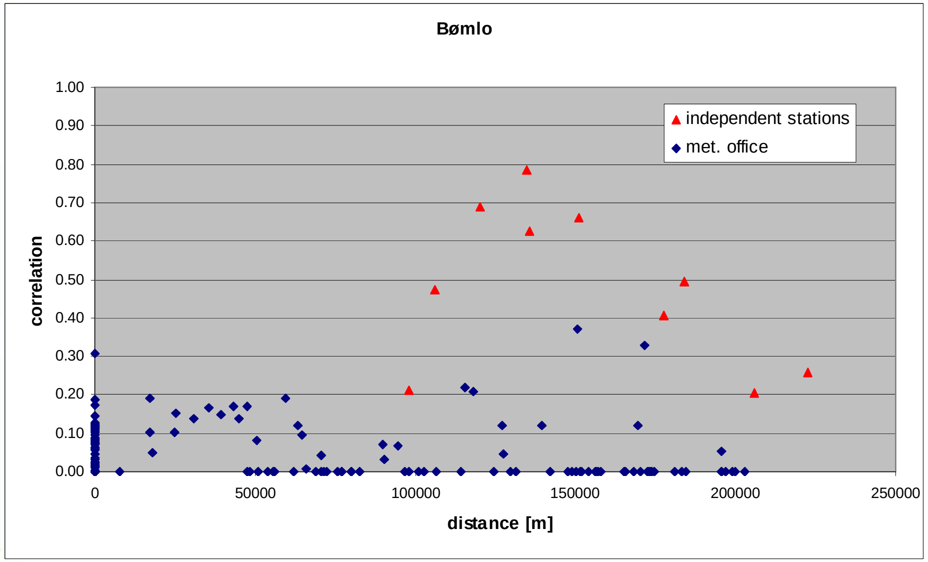


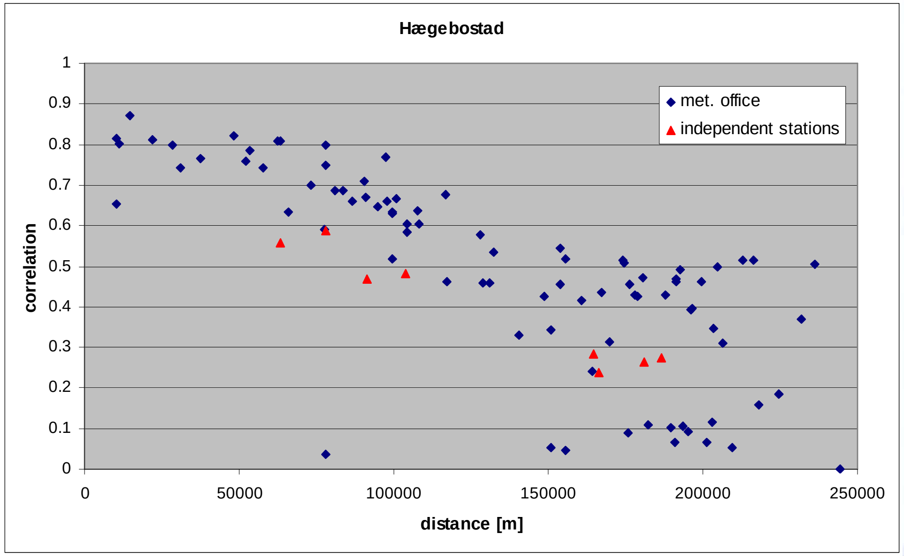


Correlation

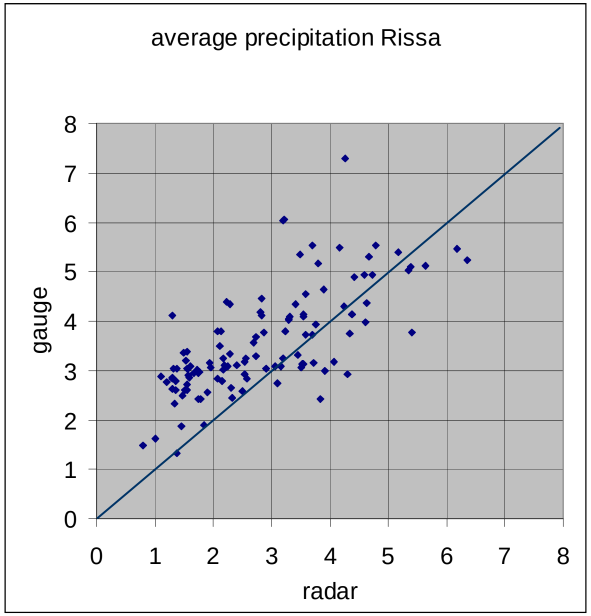


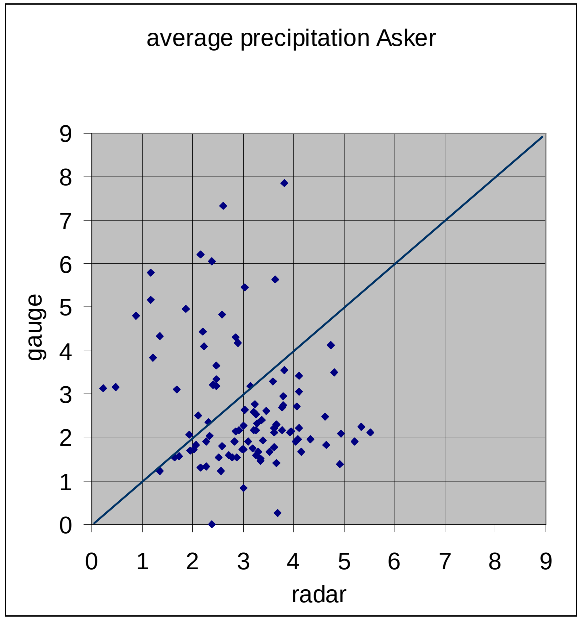


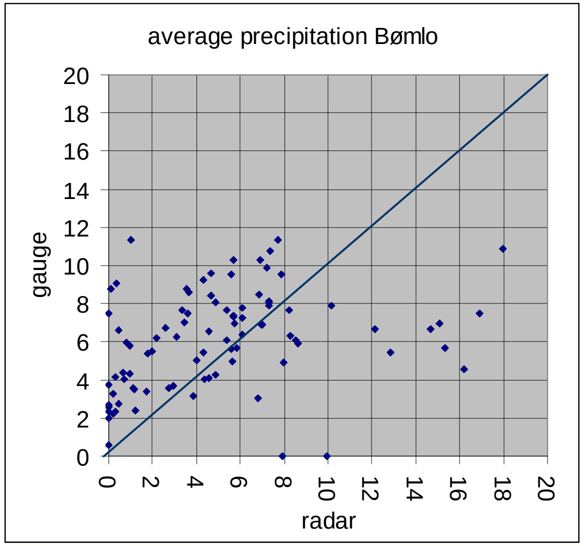


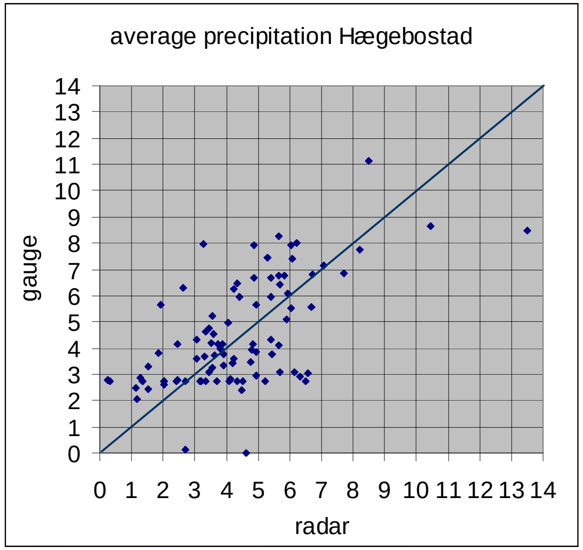


Average values

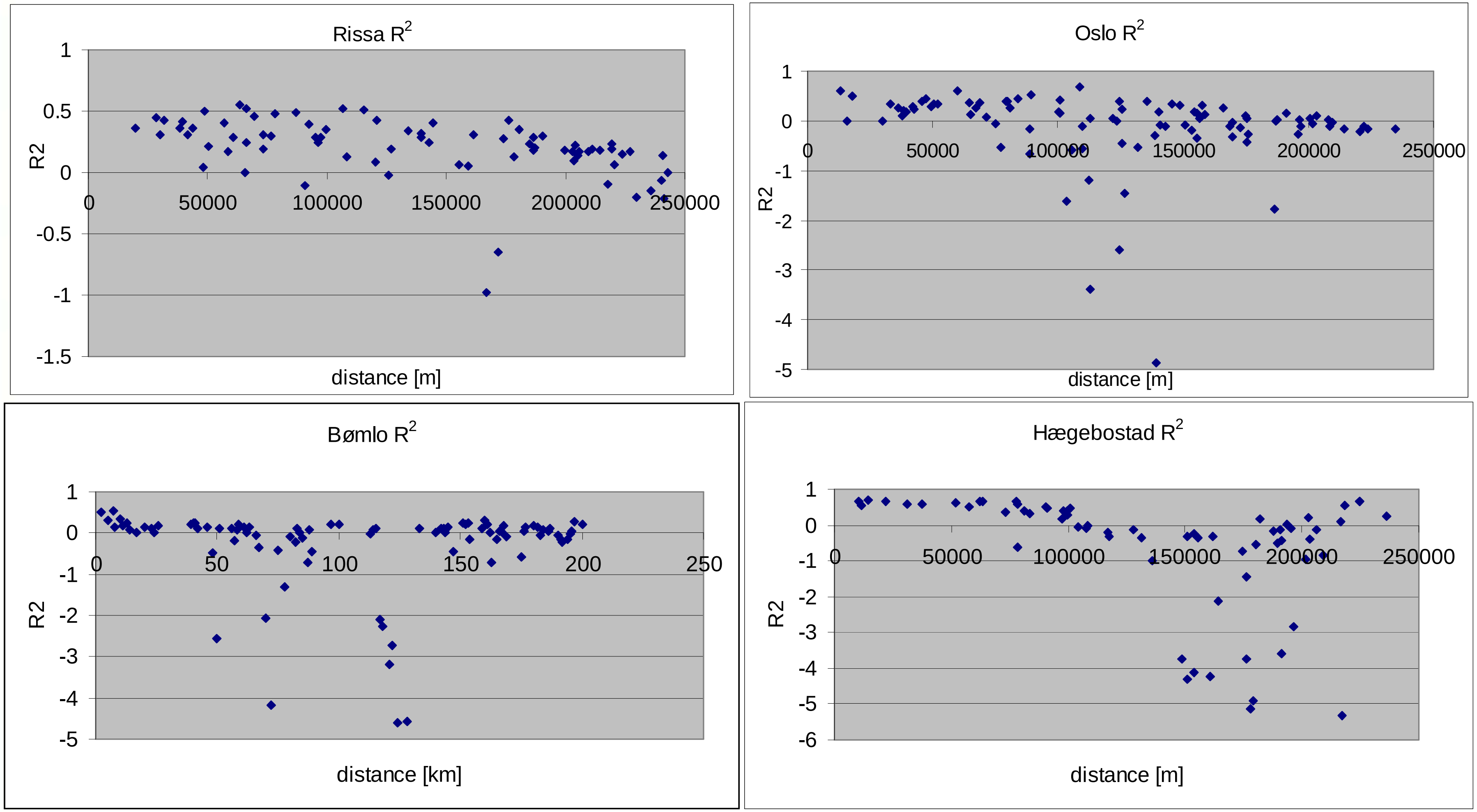








Nash-Sutcliffe R^2



Bayesian Combination method

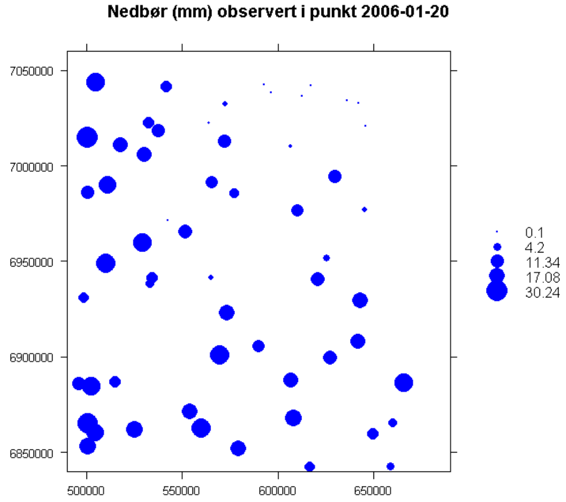
- Interpolation of point precipitation to grid-squares 1x1 km2
- Estimate the bias and variance of the radar precipitation
- Combine the interpolated grid and the radar based on Kalmar gain.

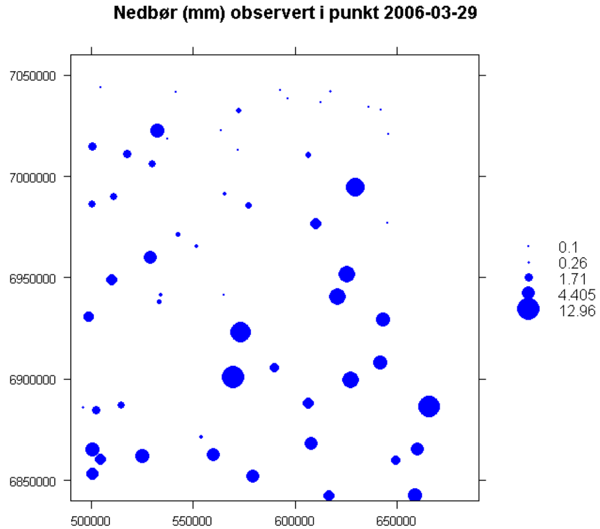
Interpolation to grid squares

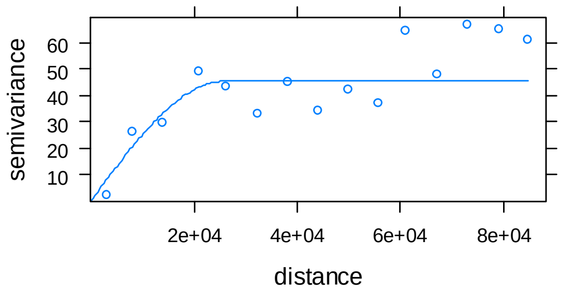
- Using block Kriging
- Estimate point semivariogram
- Estimate covariances between points and grid-squares
- Expectation and covariance

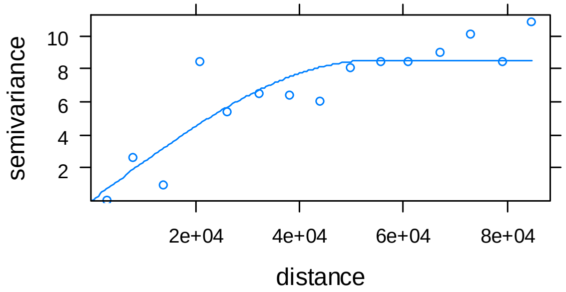
Interpolation to grid squares

20. January 2006 and 29. March 2006



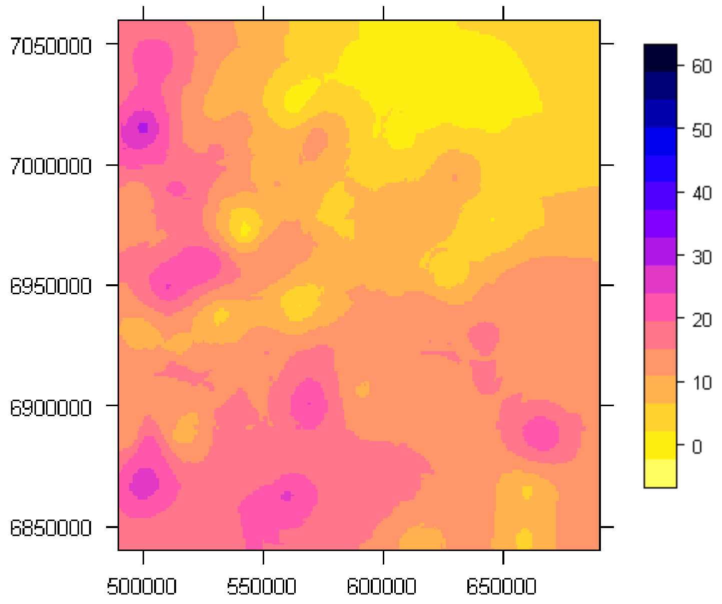


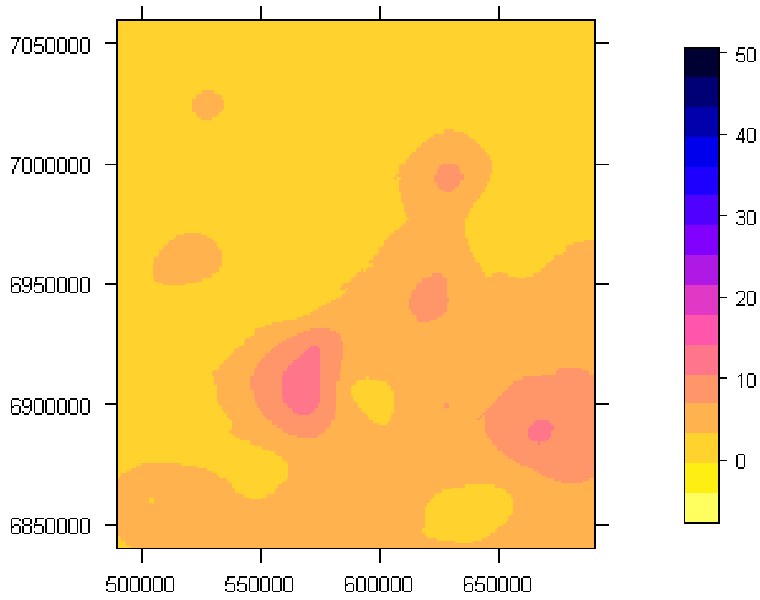




Interpolation to grid squares

20. January 2006 and 29. March 2006



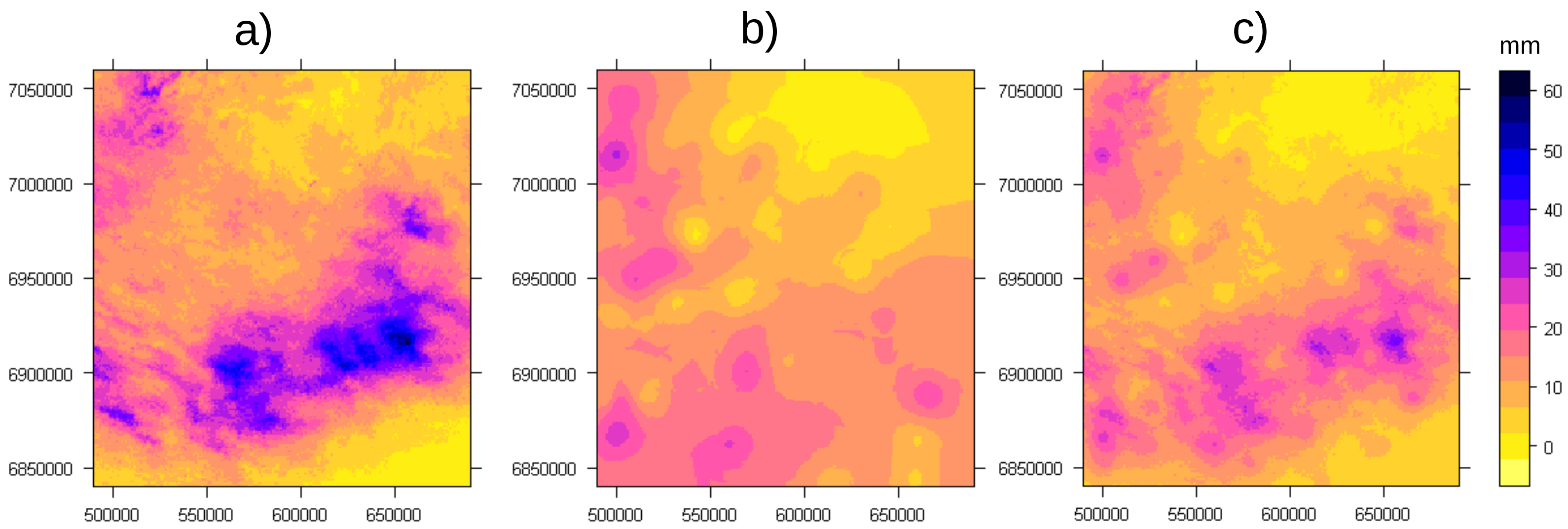


Kalman filter

- Assuming block-kriged values are un-biased and the kriging covariance is known.
- Bias of radar precipitation is average difference between interpolated and radar values
- Exponential semiovariogarm is fitted to the differences and the covariance matrix of radar precipitation is estimated from the fitted semiovariogram
- The to data sources are weighted according to their variance.
- I.e. decreasing differences between the radar and the interpolation, leads to increasing weight to the radar image

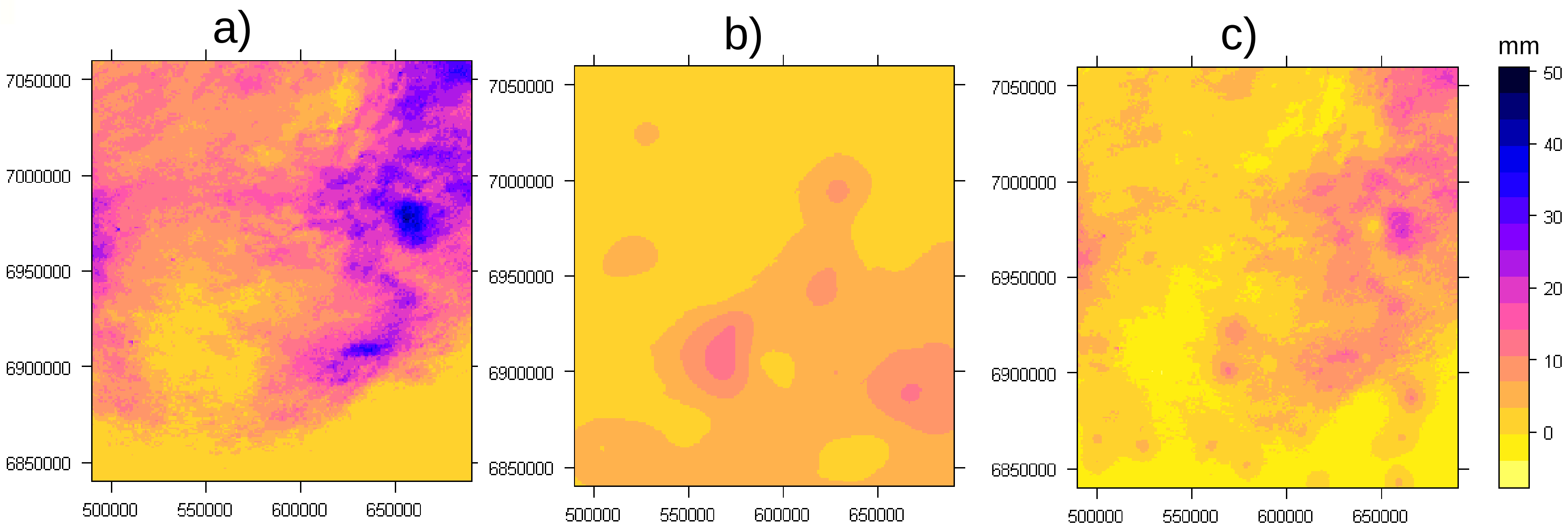
Results

- 20 january 2006



Results

- 29 mars 2006



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Summary

- Makes a reasonable combination
- Many challenges
  - Zero precipitation.
    - Interpolation
    - Radar
  - Interpolated precipitation will be smooth and not a realistic precipitation-field whereas radar images are more patchy
  - Independent estimates of bias and variance in radar precipitation.
  - Time dependence (advection).
  - Alternative approaches:
    - Use conditional simulations in stead of block-kriging
    - Use radar images in conditional simulations.

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Conditional simulation of precipitation

- Provides several possibile realisations of precipitation.
- Might obtain both expectation and uncertainty of both catchment precipitation and the distributed precipitation field in a consistent way.
- Accounts for zero precipitation.
- Observed values are reproduced.

Operational motivation

- The tradition: ~200 lumped HBV models, in each catchment calibrating or subjectively assessing
  - 2 catch deficit compensating parameters
  - 1 elevation gradient
  - 2-3 gauge weights
- In a distributed model needing gridded input data, a less calibration-dominated approach is required.
- Input uncertainty estimation is desirable both for operational runoff prediction and to reduce over-conditioning in calibration

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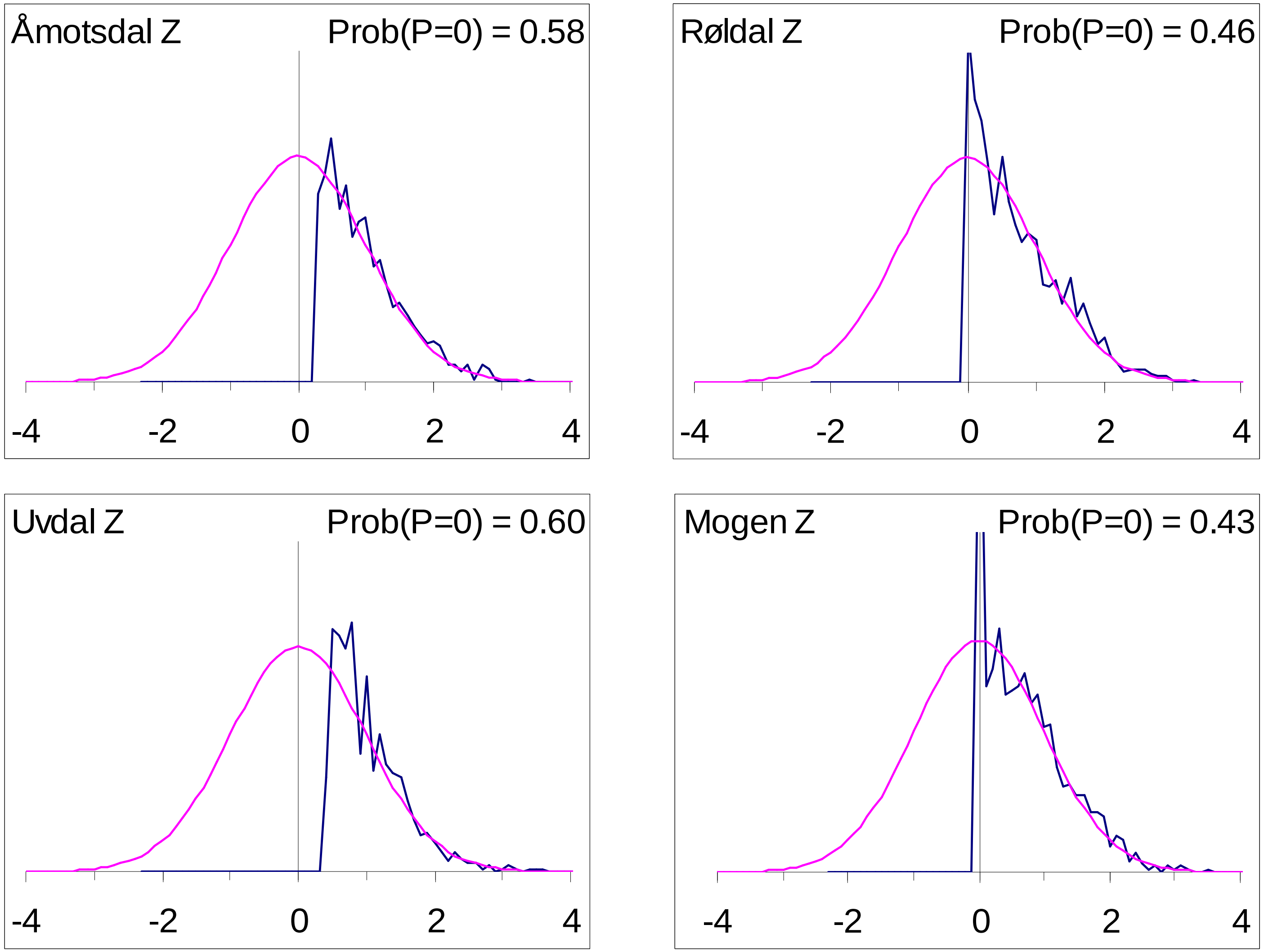
Simulation approach

- Preprocessing:
  - For each station positive precipitation is fitted to a gamma distribution and probability of no precipitation, then Interpolatete parameters.
- For each day
  - Transform all positive P observations to truncated normaly distributed values above the truncation level
  - Initiate $Z < Z_0$ at P=0 sites.
  - Conditionally simulate Z at stations observing P=0, drawing from a truncated Normal distribution ($Z < Z_0$), given neighbour Z values. This step employs a Markov sequence since also the other 0-observing stations are included in the conditioning set. Repeat n_1 times.
  - Simulate the complete field, conditionally on both the transformed Z values and the current simulated Z values. Repeat step 1 and 2 n_2 times.
  - Back-transform each of the n_2 realisations, using the maps of Z_0 and transformation parameters. Aggregate the desired statistics for the back-transformed P values, for instance E[P], HPD[P], Var[P], Prob(P>0),…..

Z standard normal with different truncation level



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Pragmatic decisions in current version

- Estimation of the covariance structure (semivariogram) is external to the model, and can be treated separately.
- A Matern semivariogram model, and a Gamma density model for positive precipitation is assumed
- So far no seasonal or situational conditioning of the assumptions, neither daily estimation of semivariogram (apart from variance scaling).

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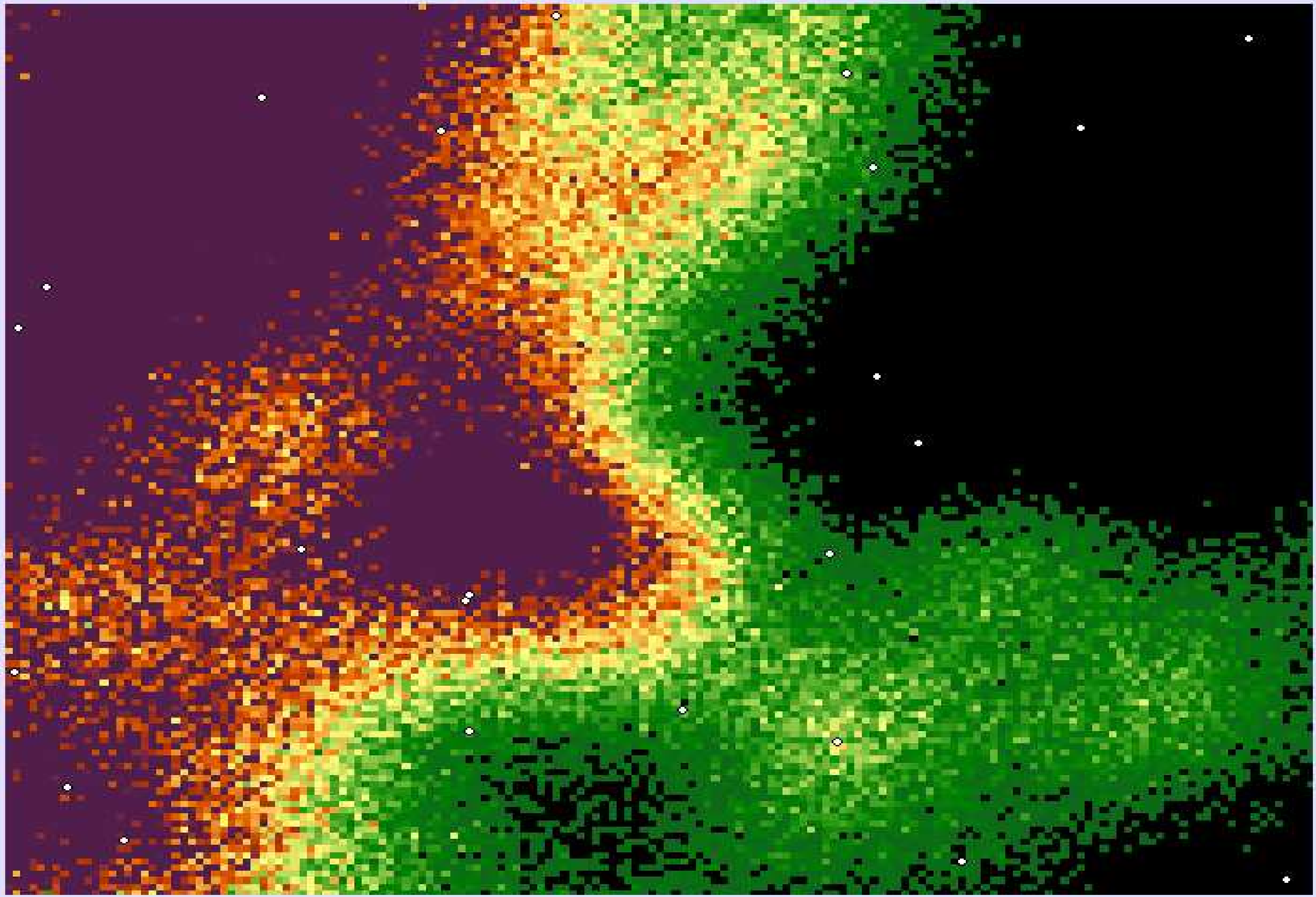

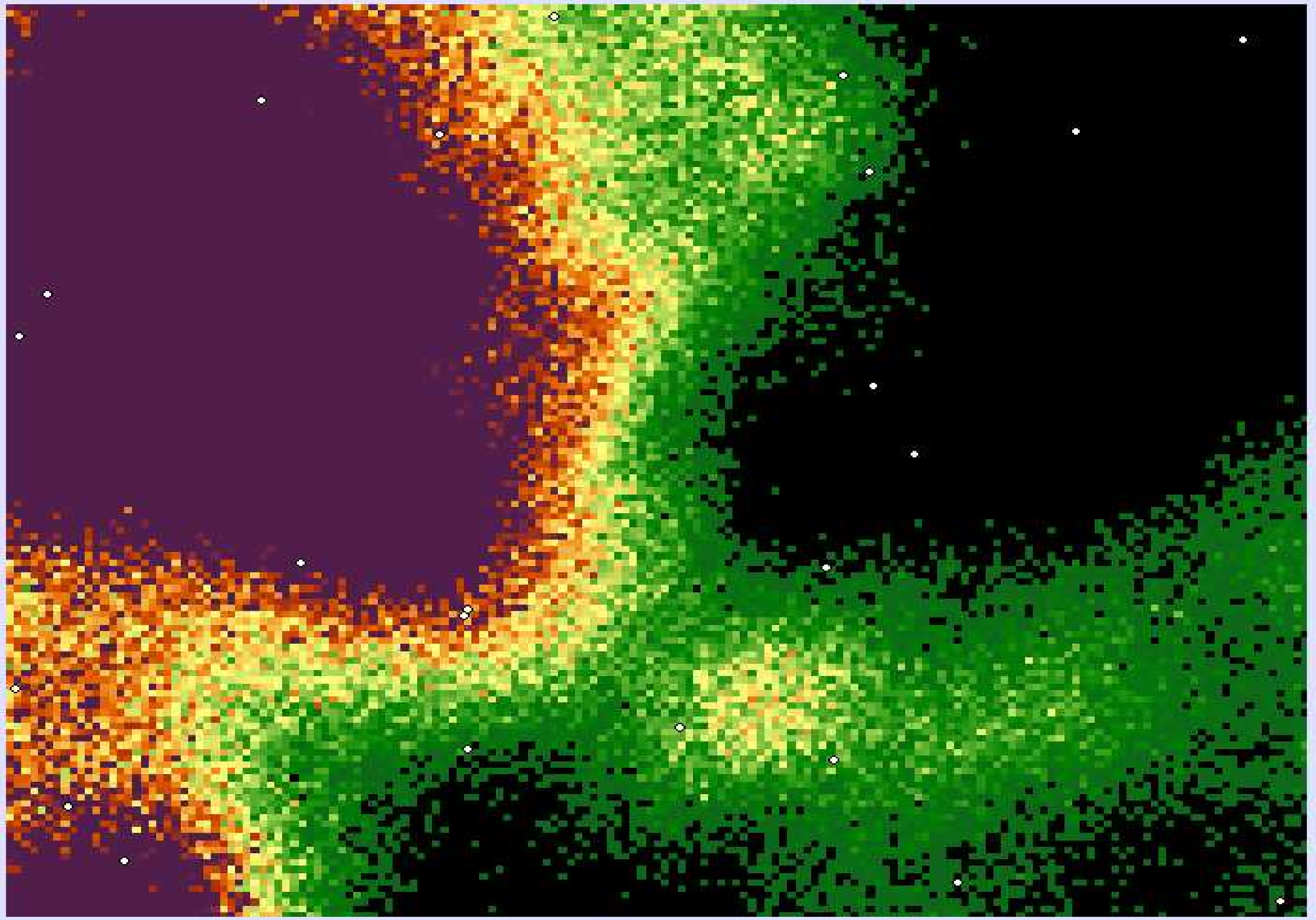

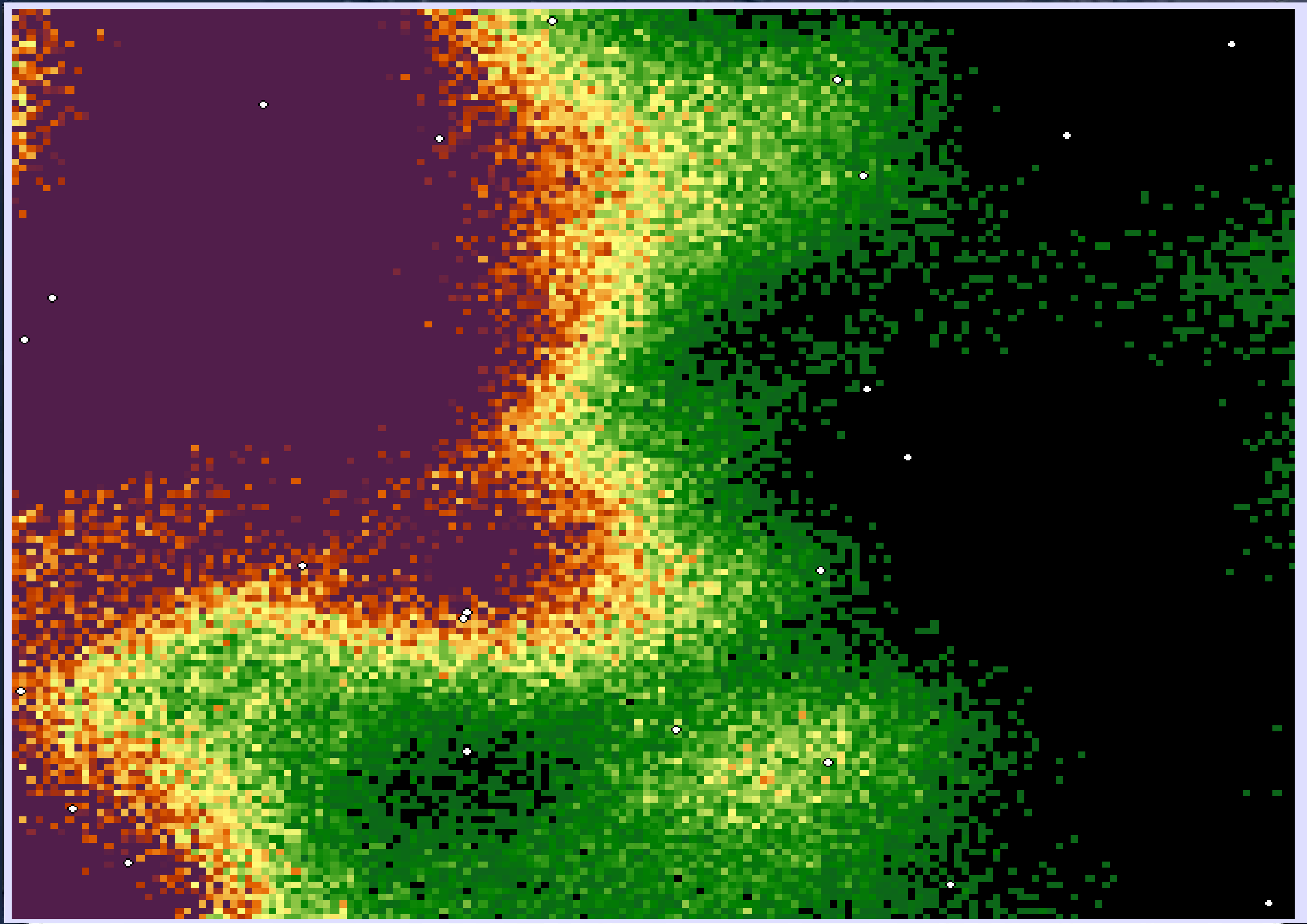

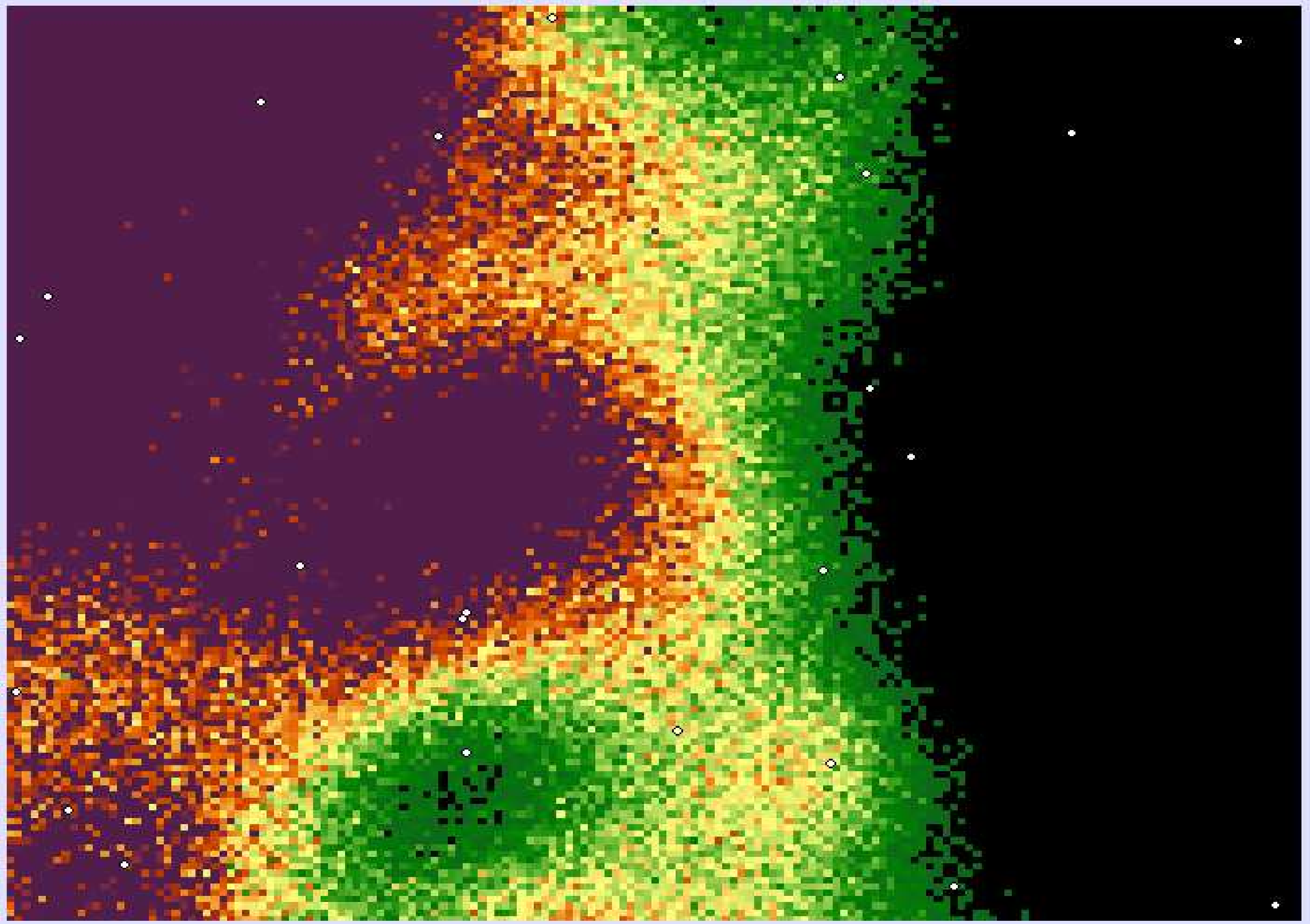

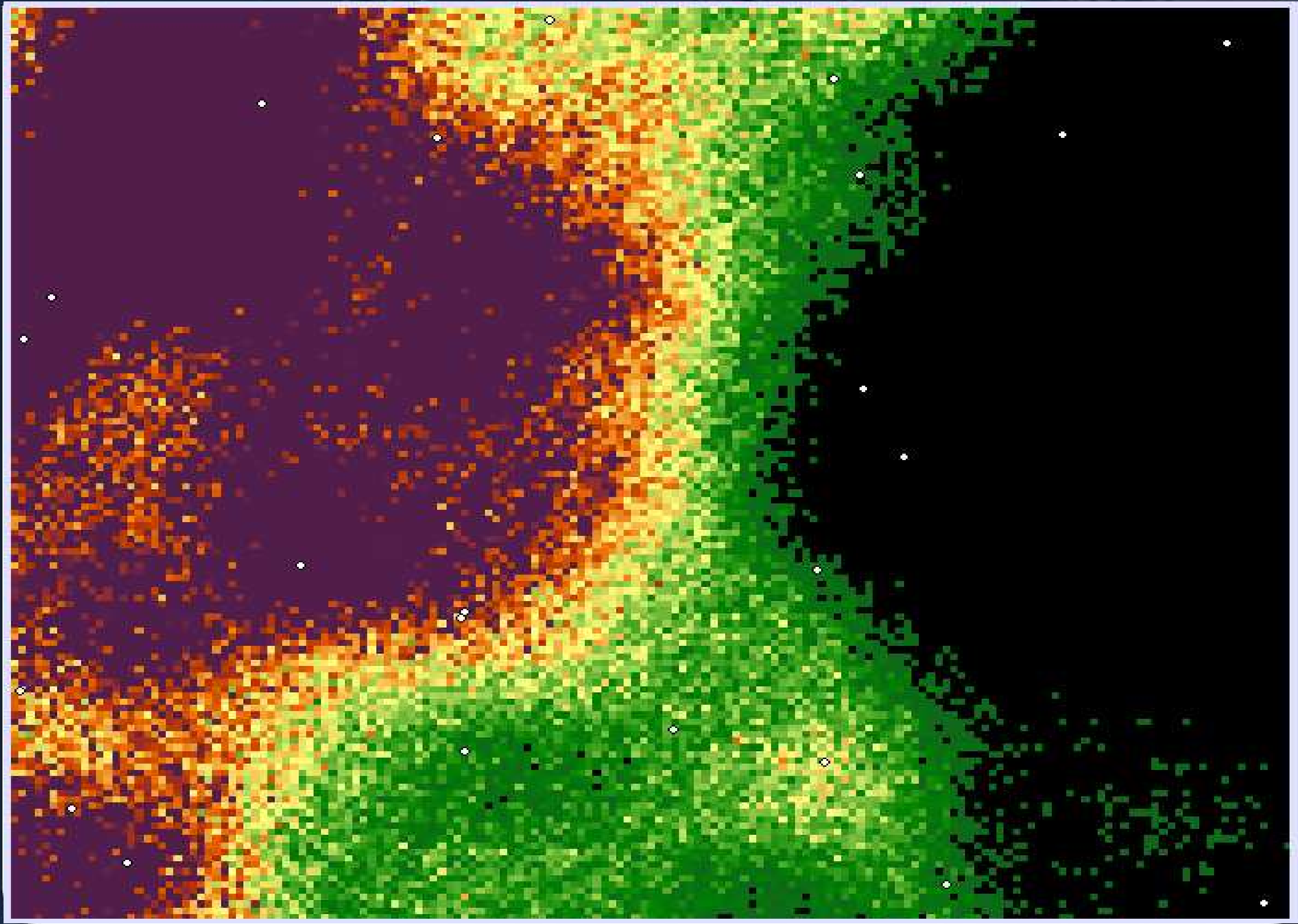

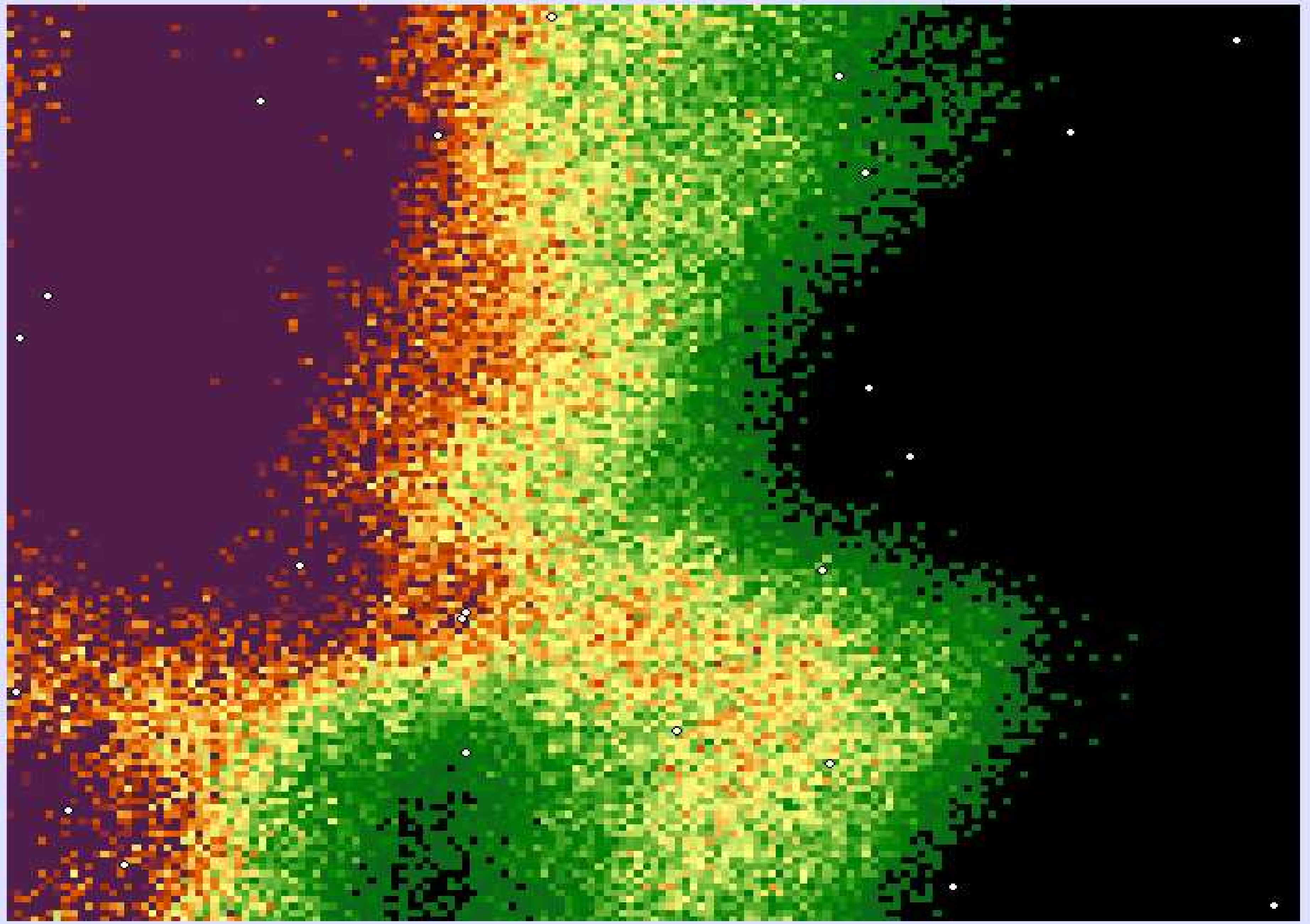

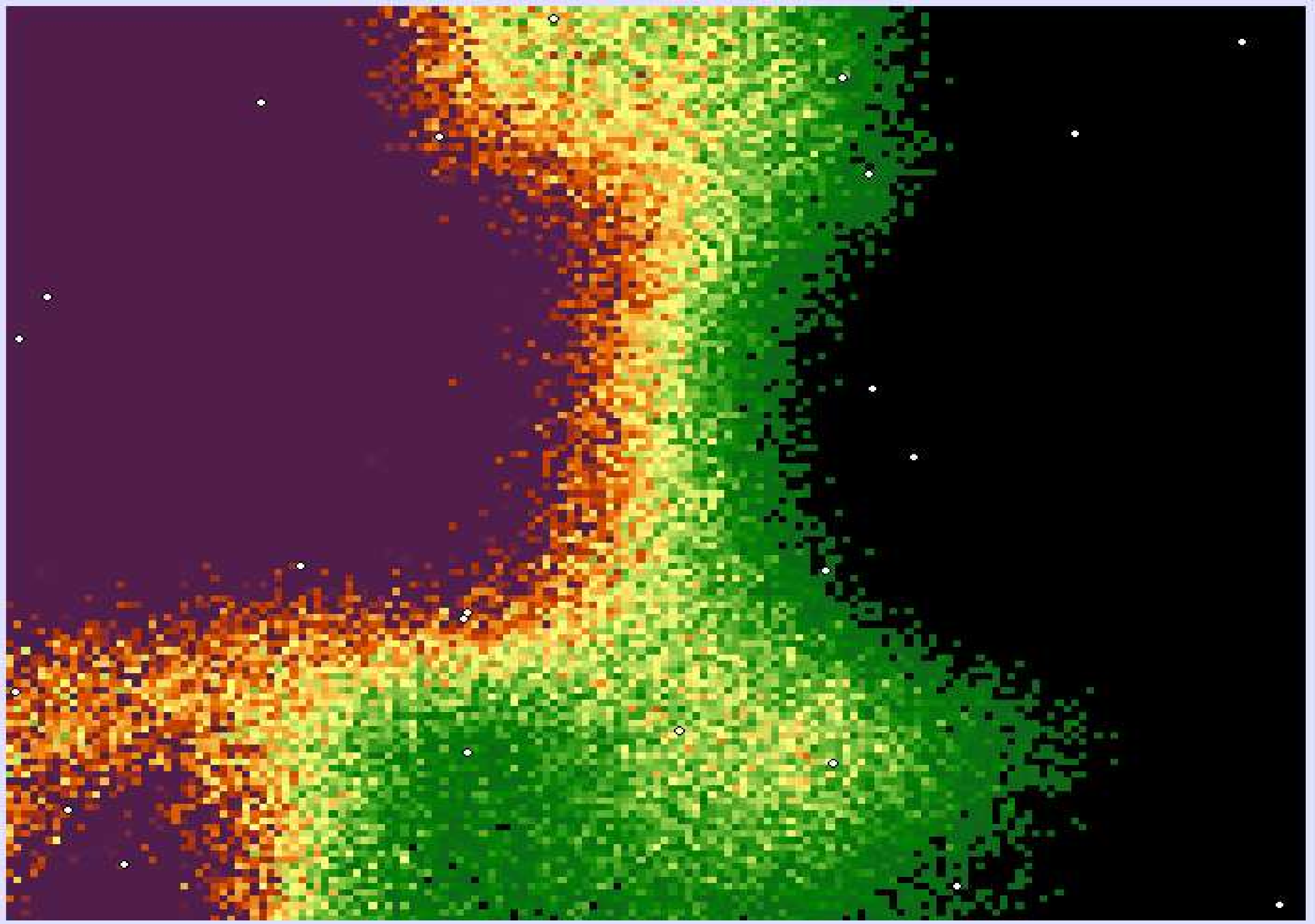

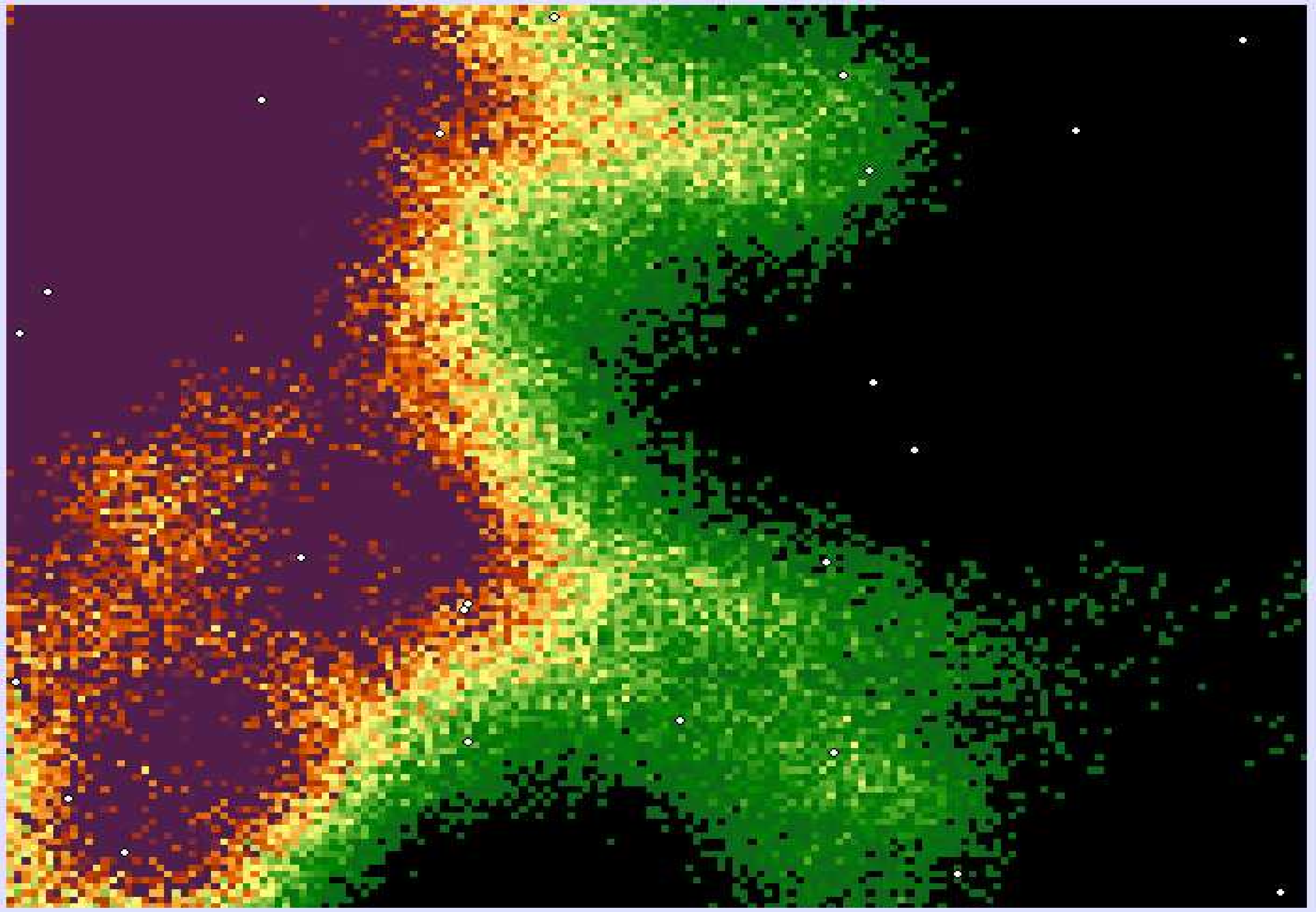

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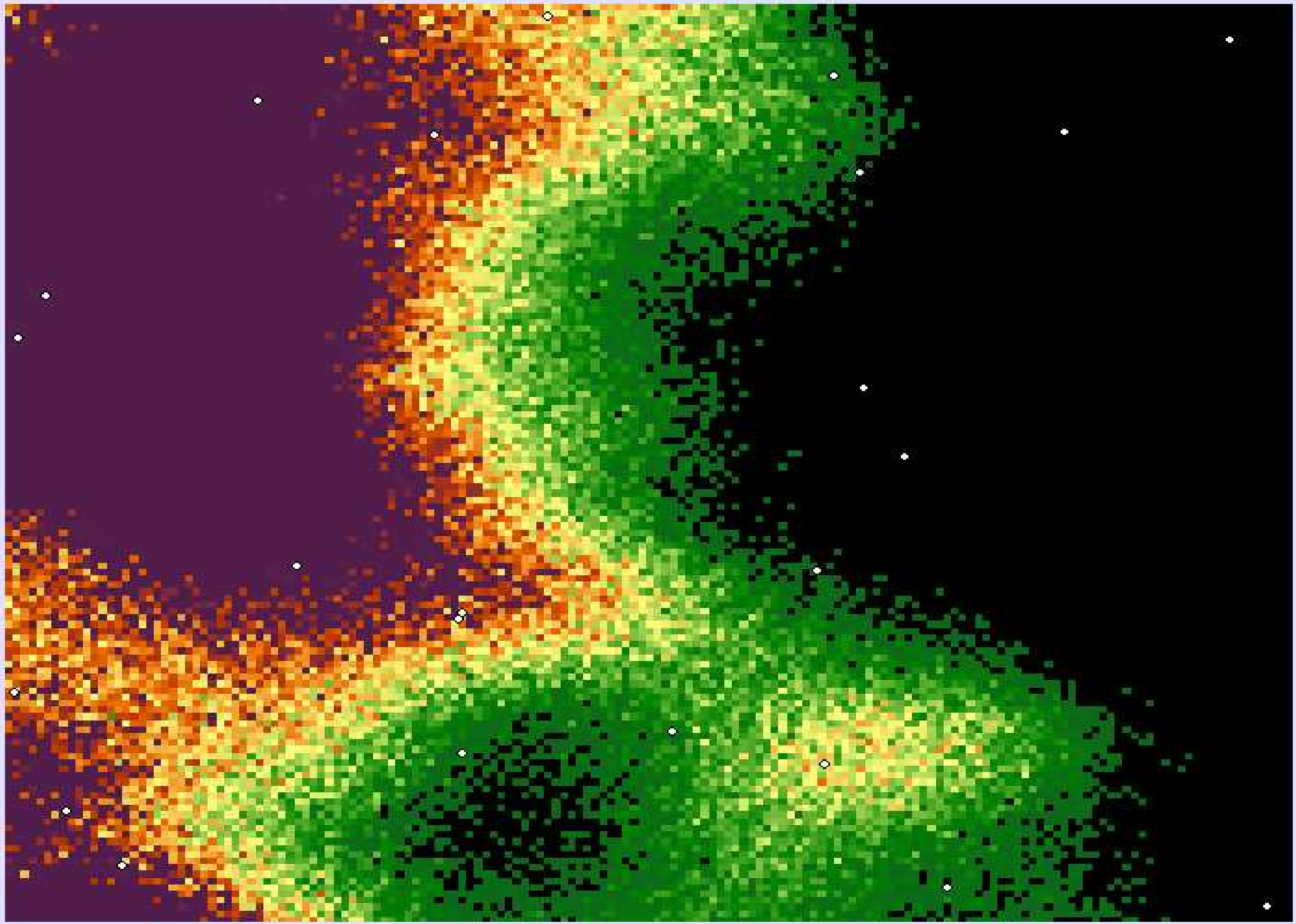

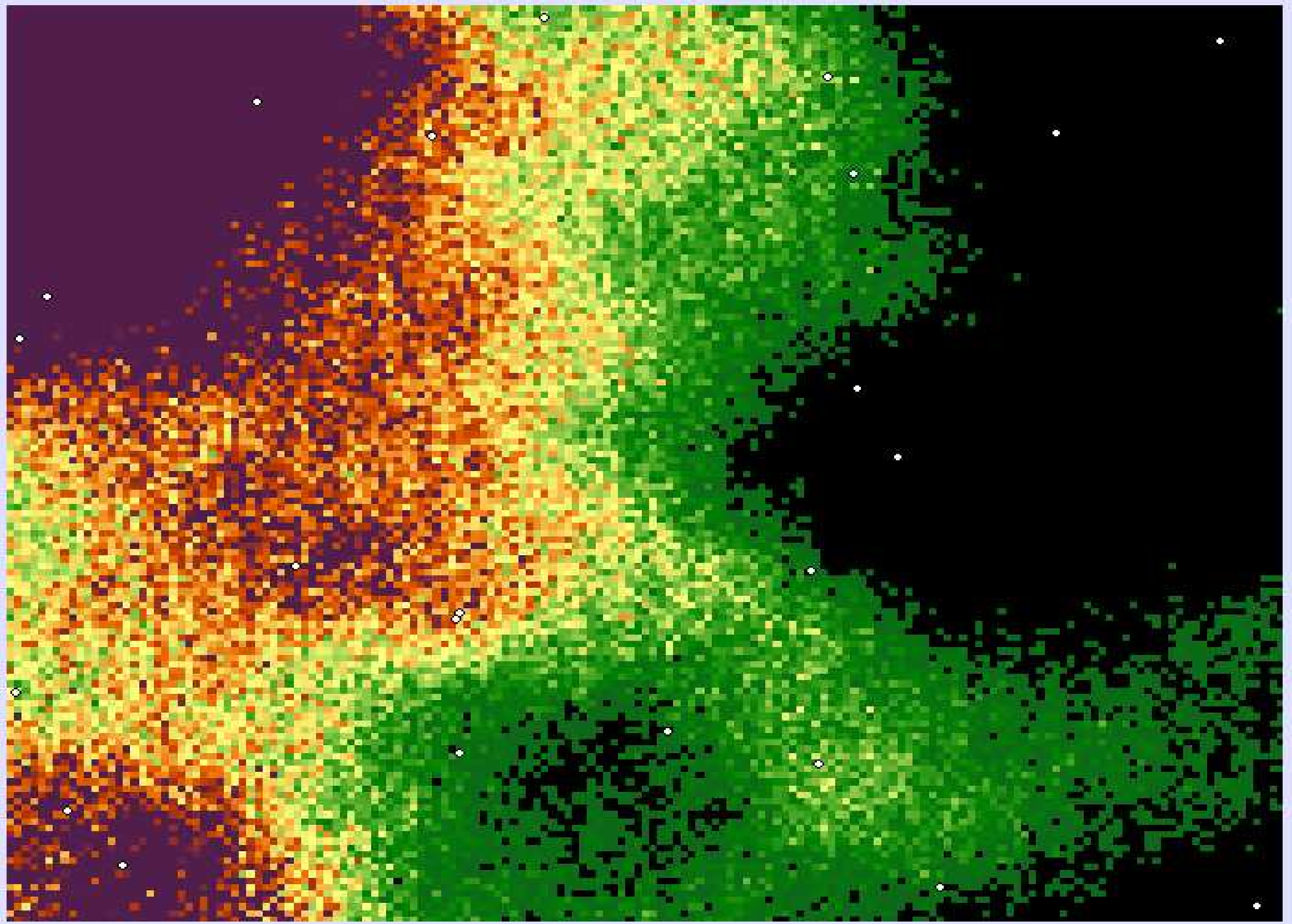

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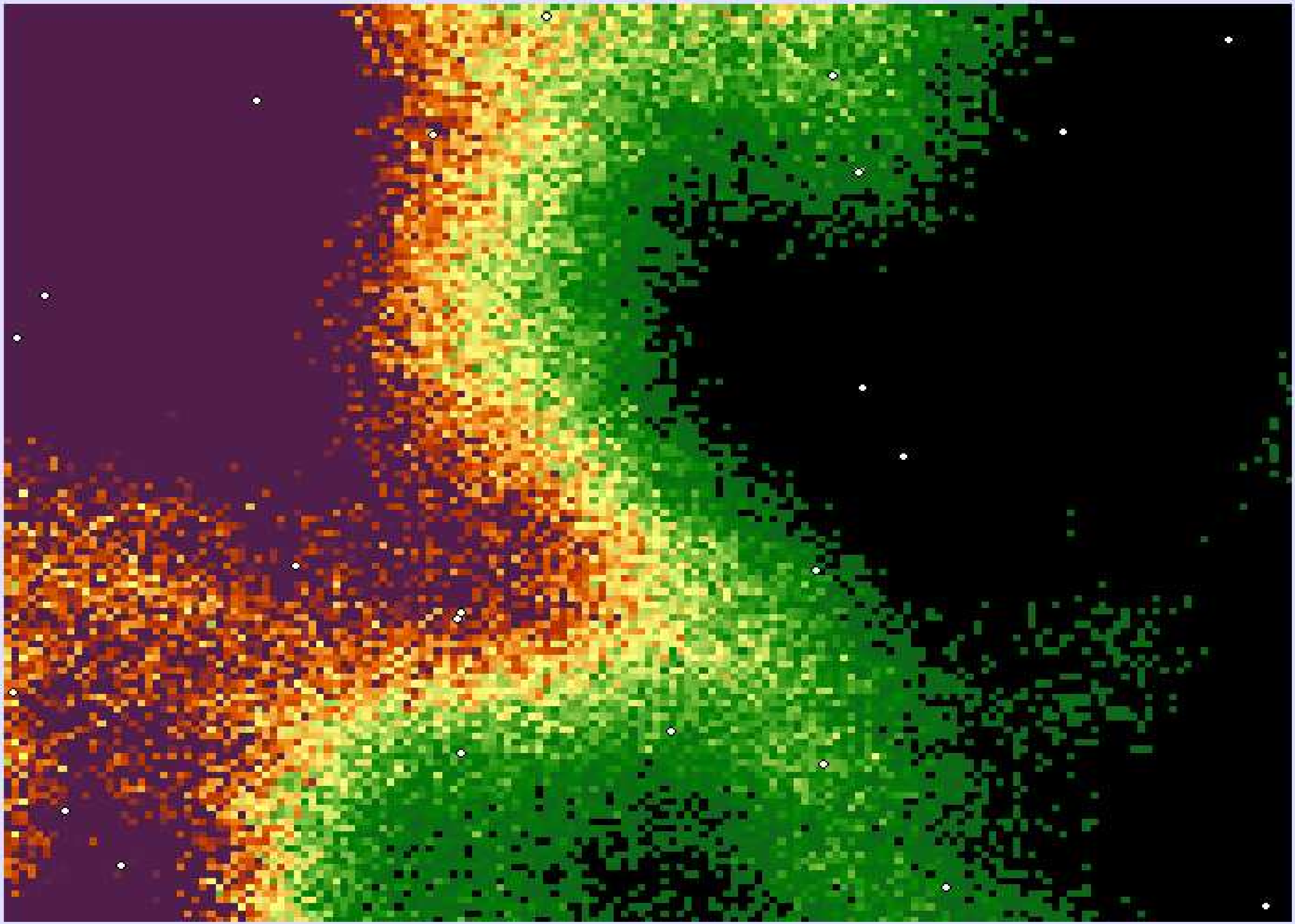

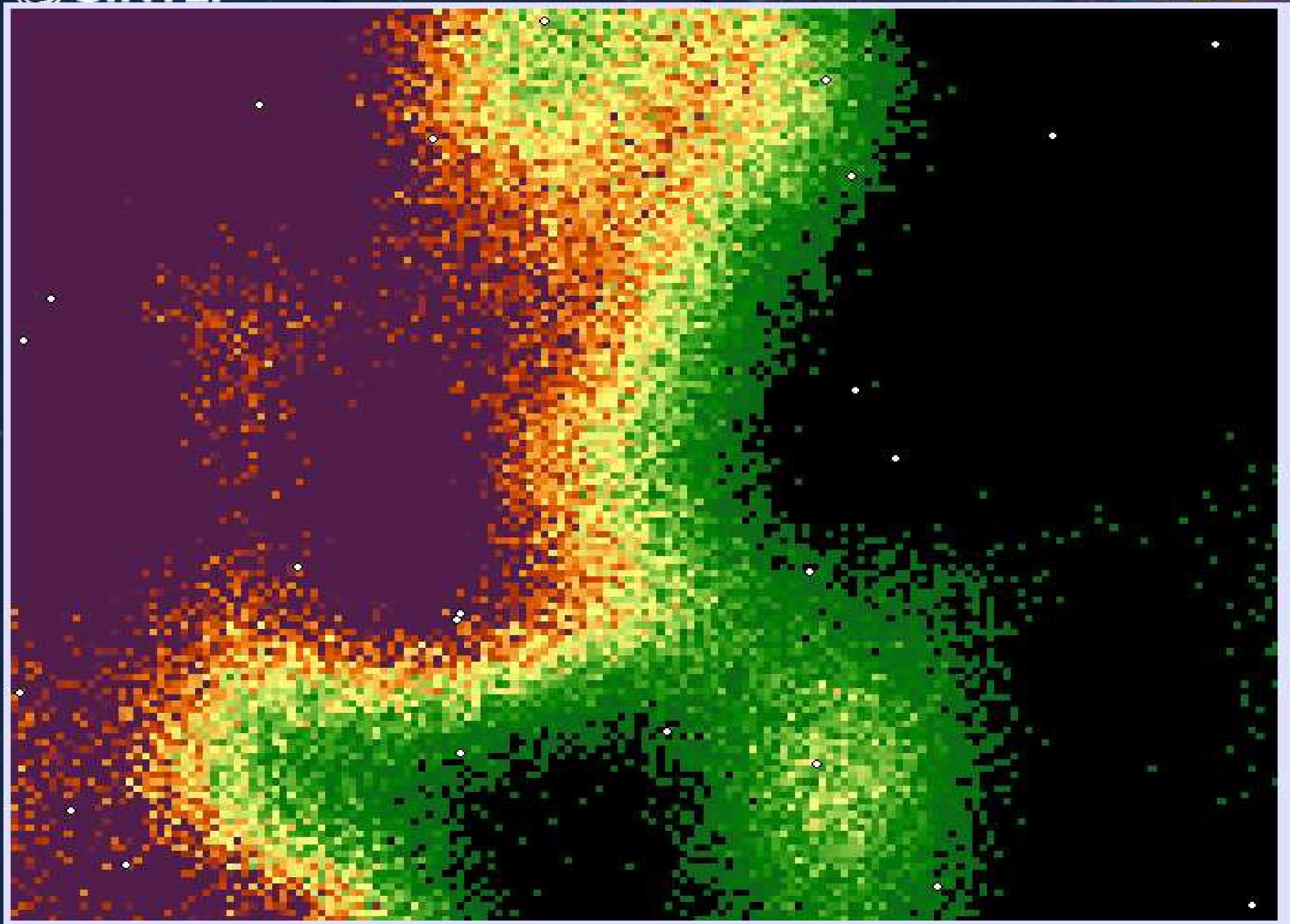

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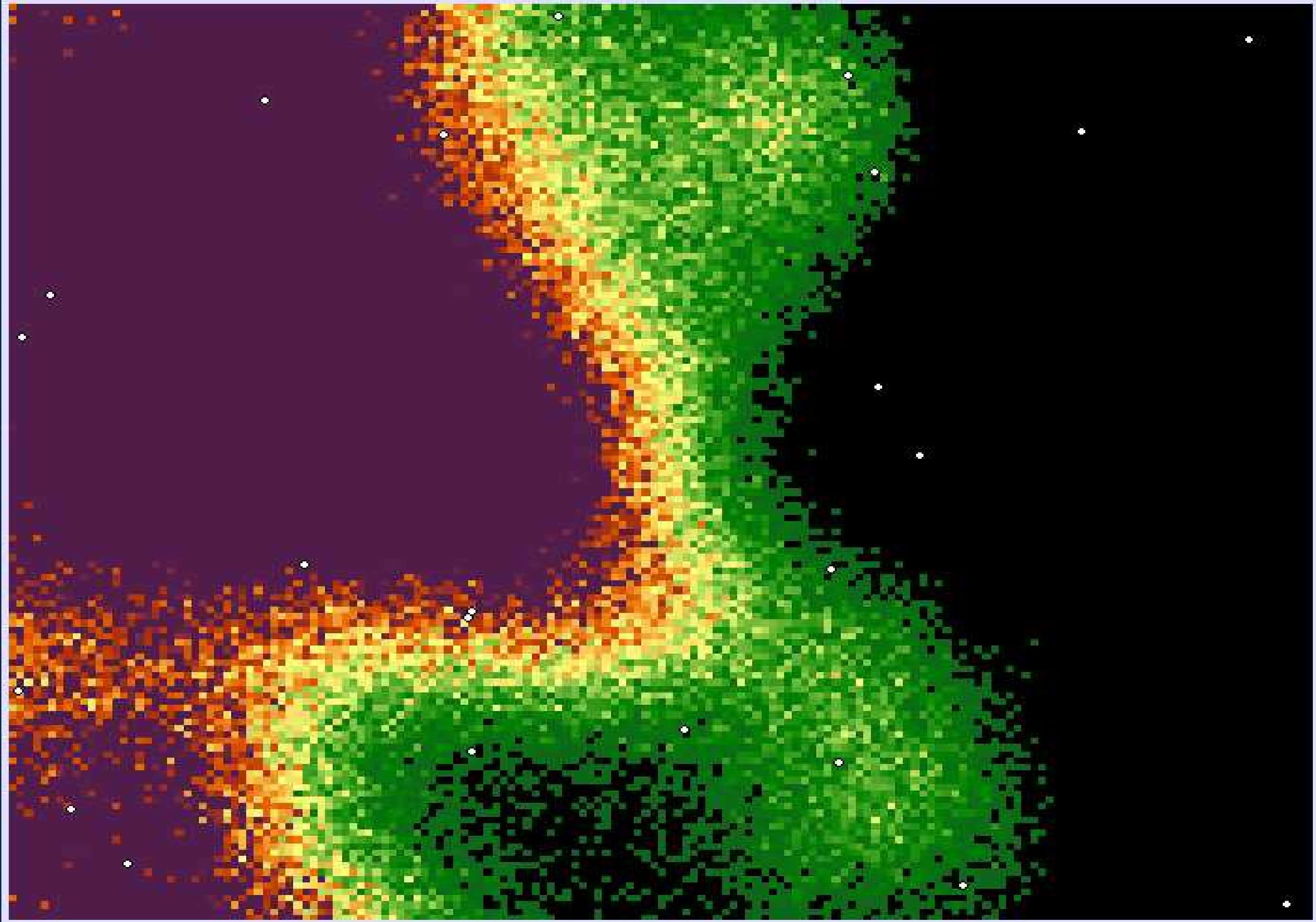

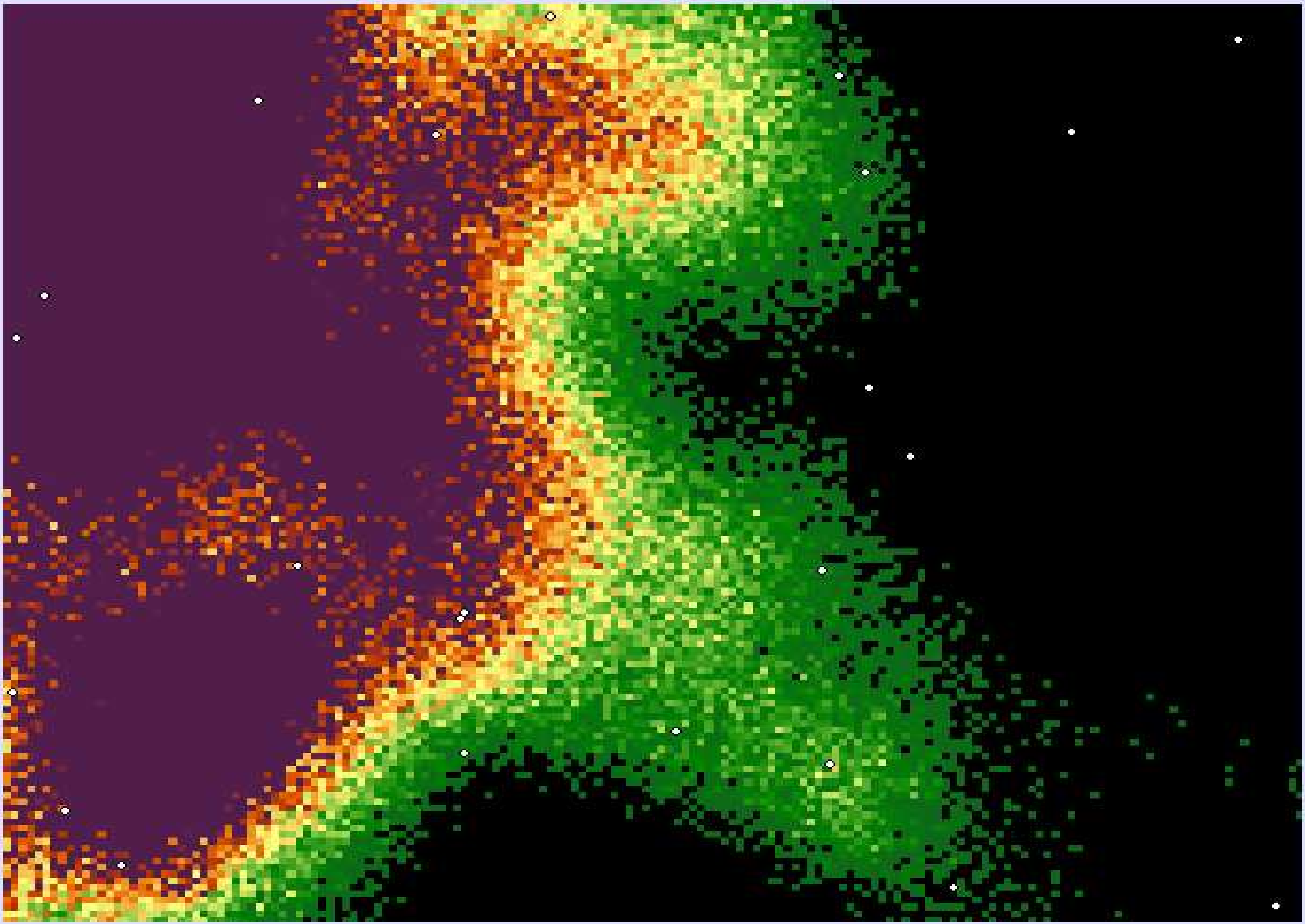

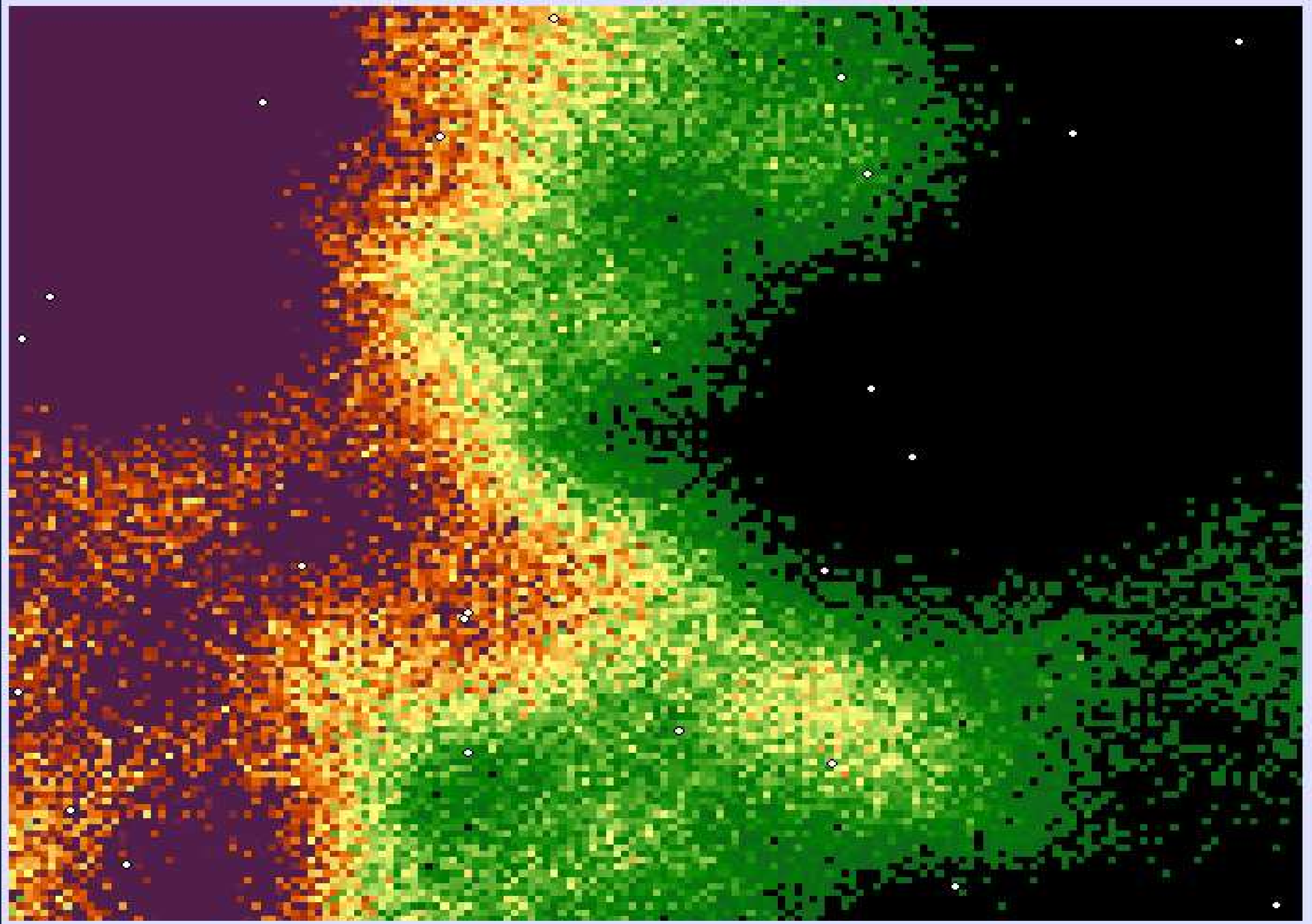

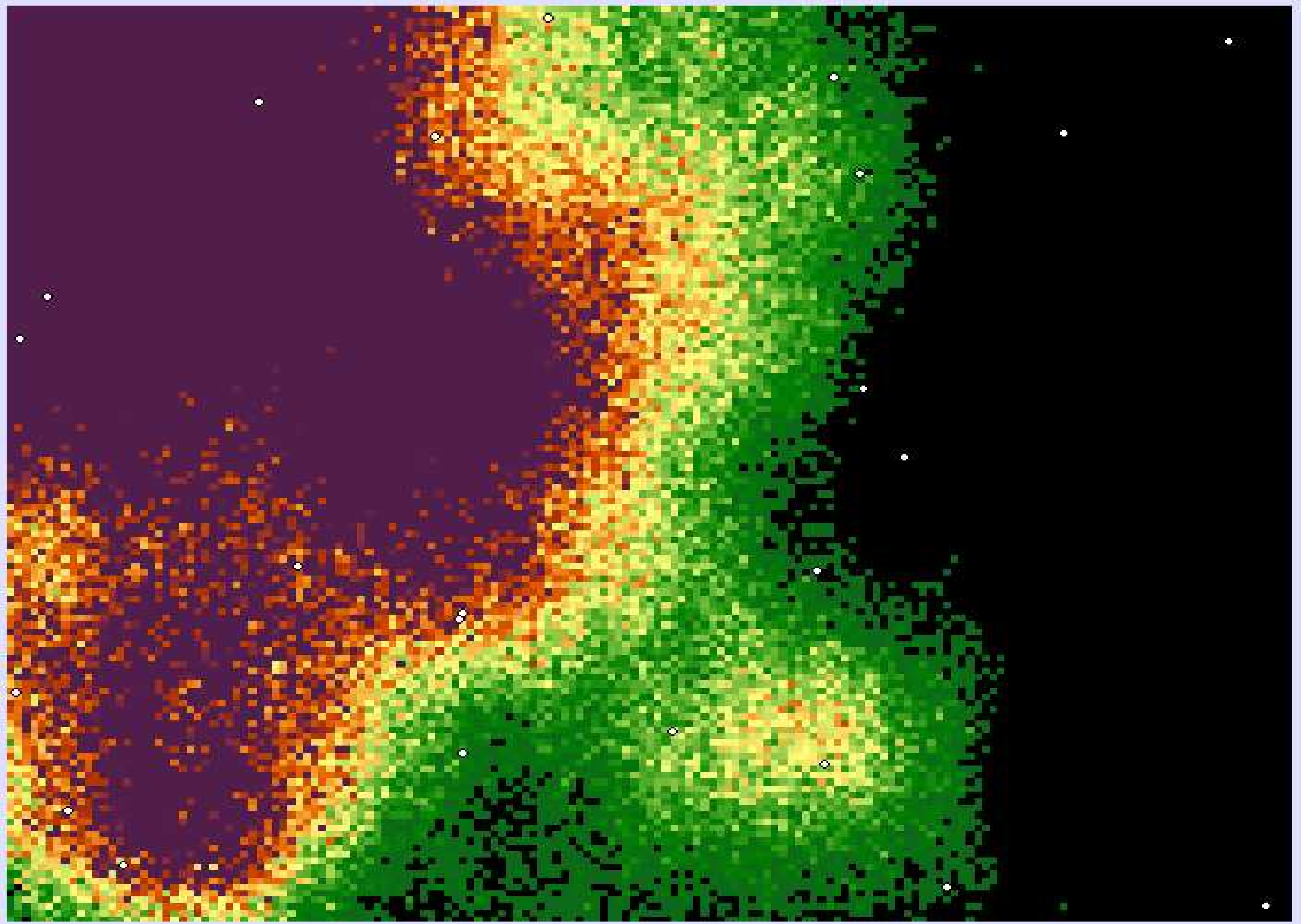

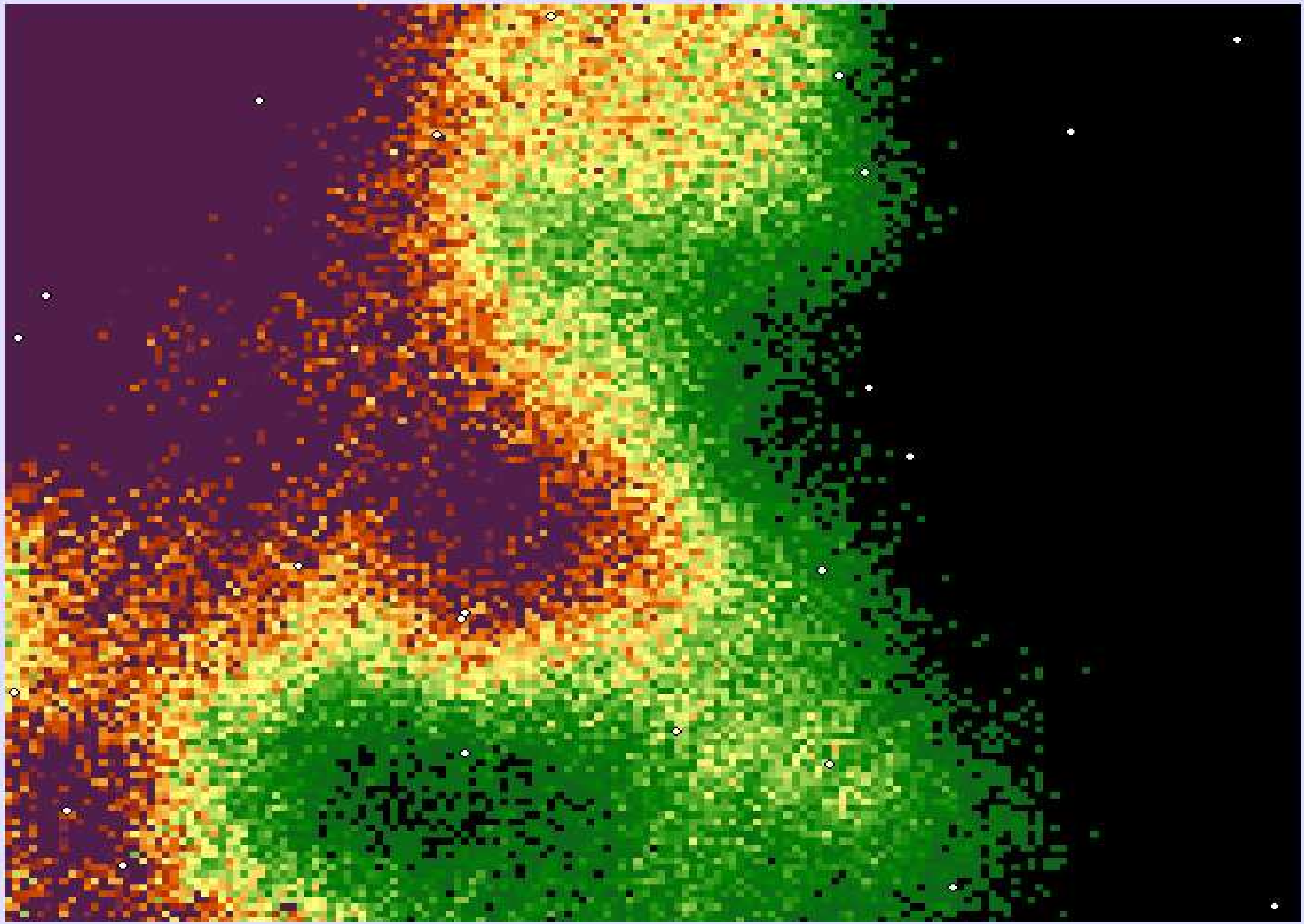

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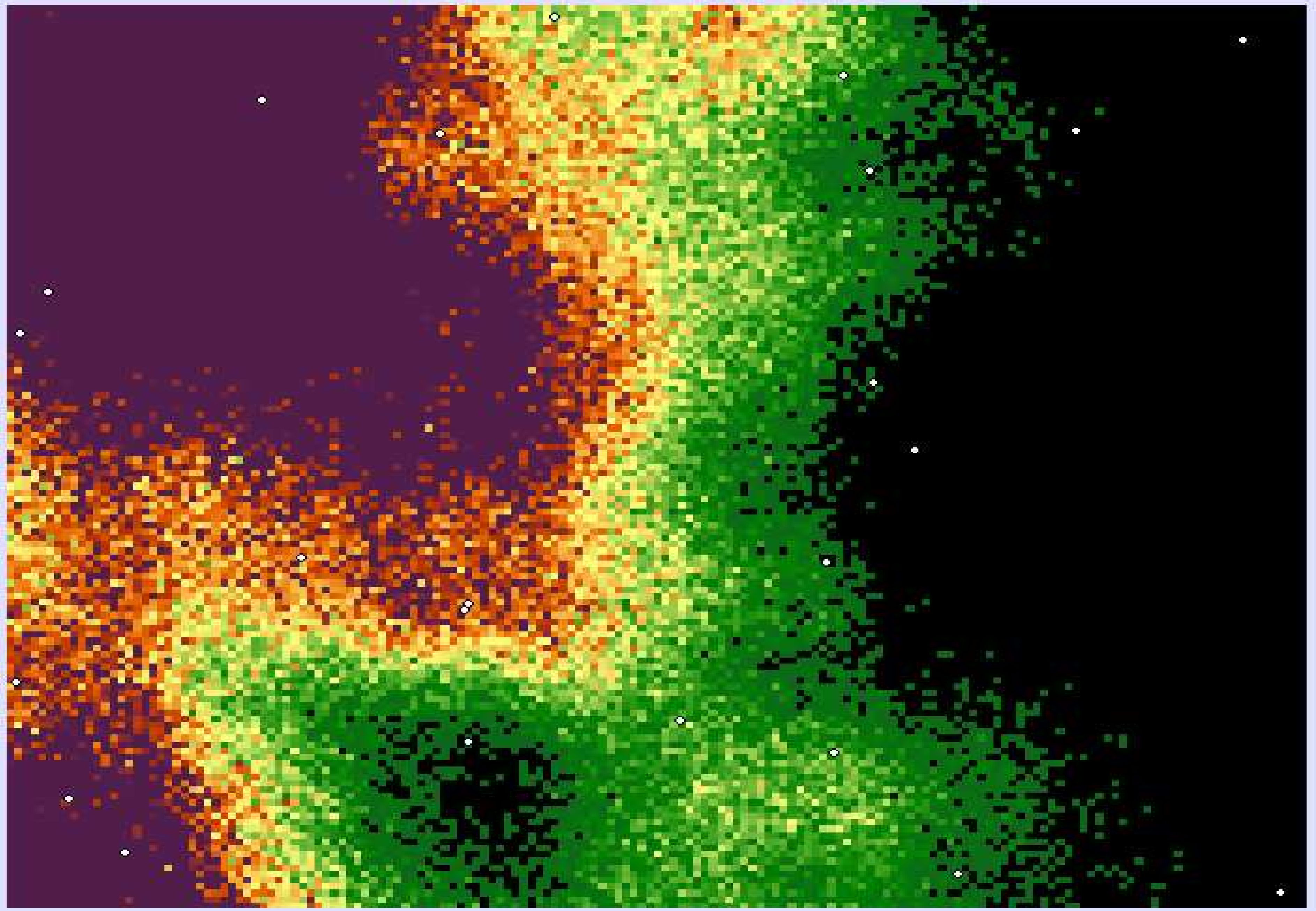
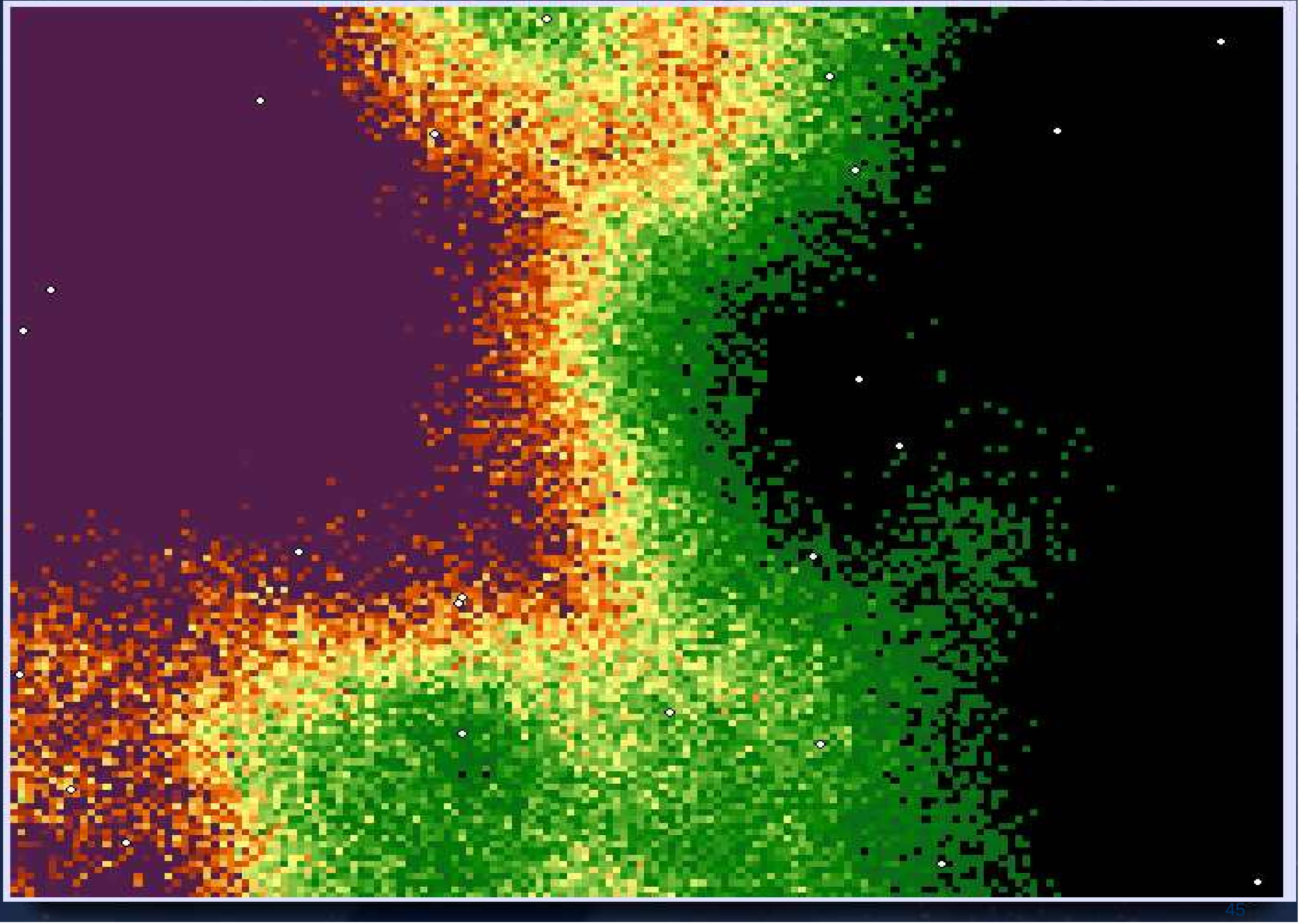
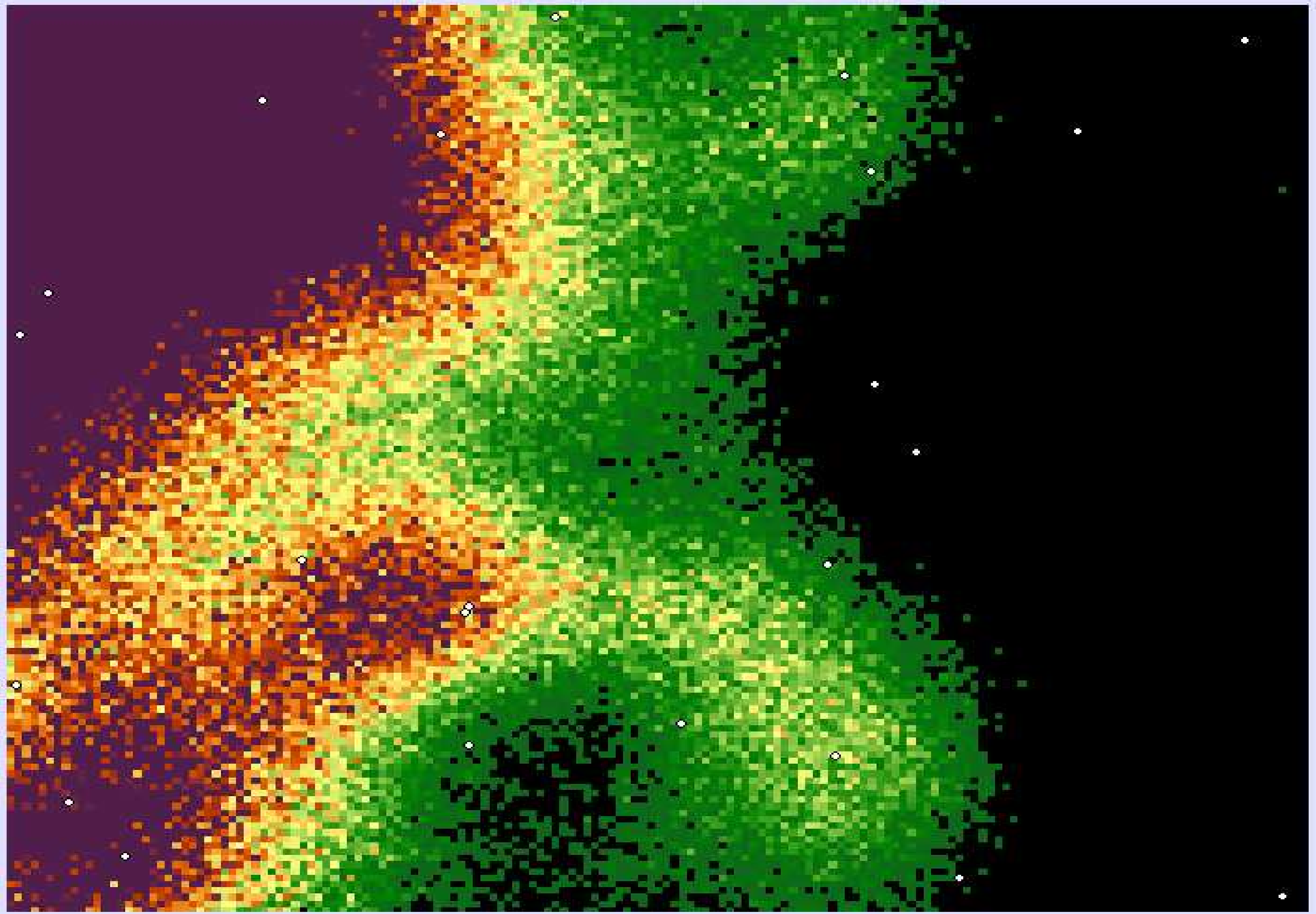
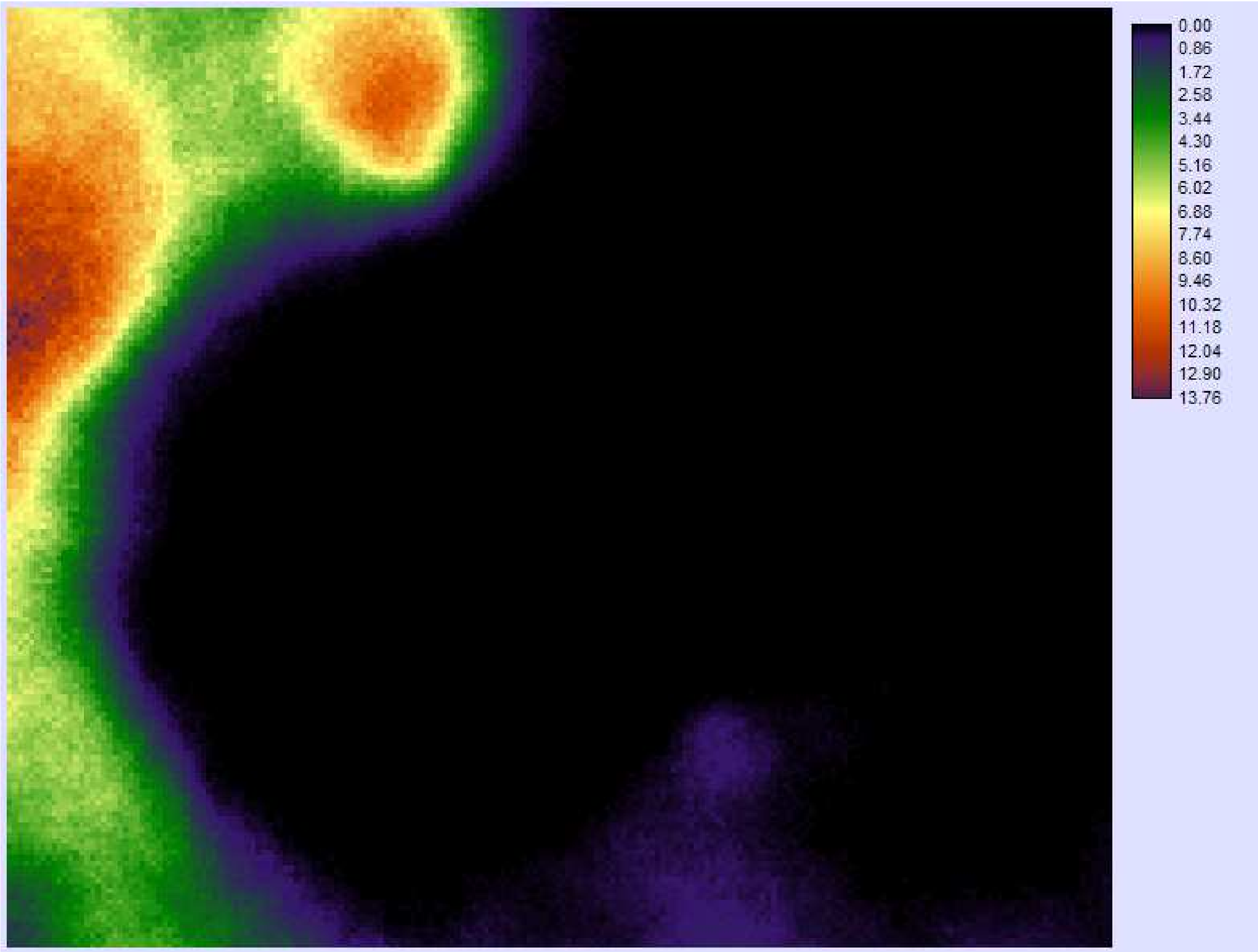


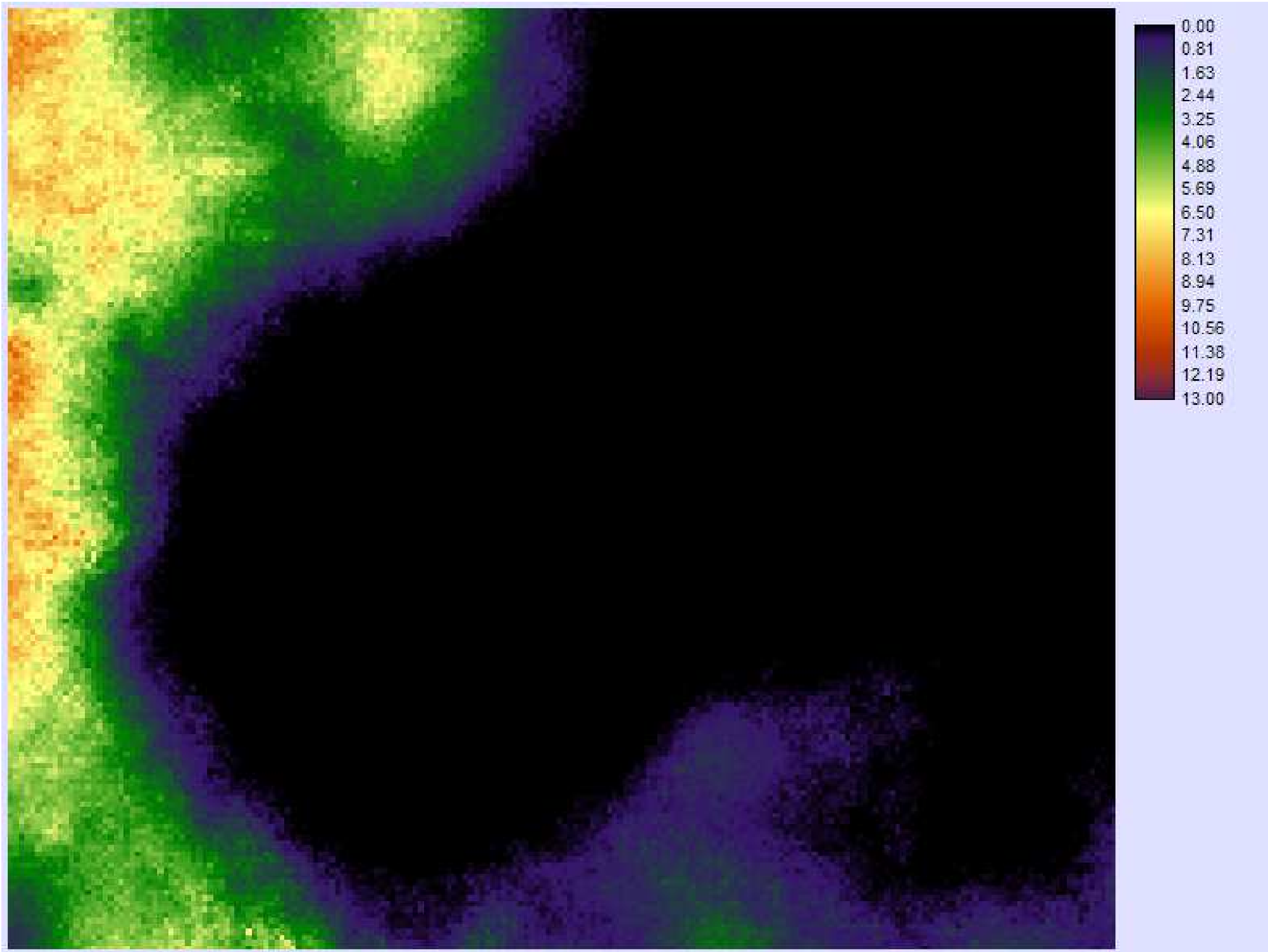




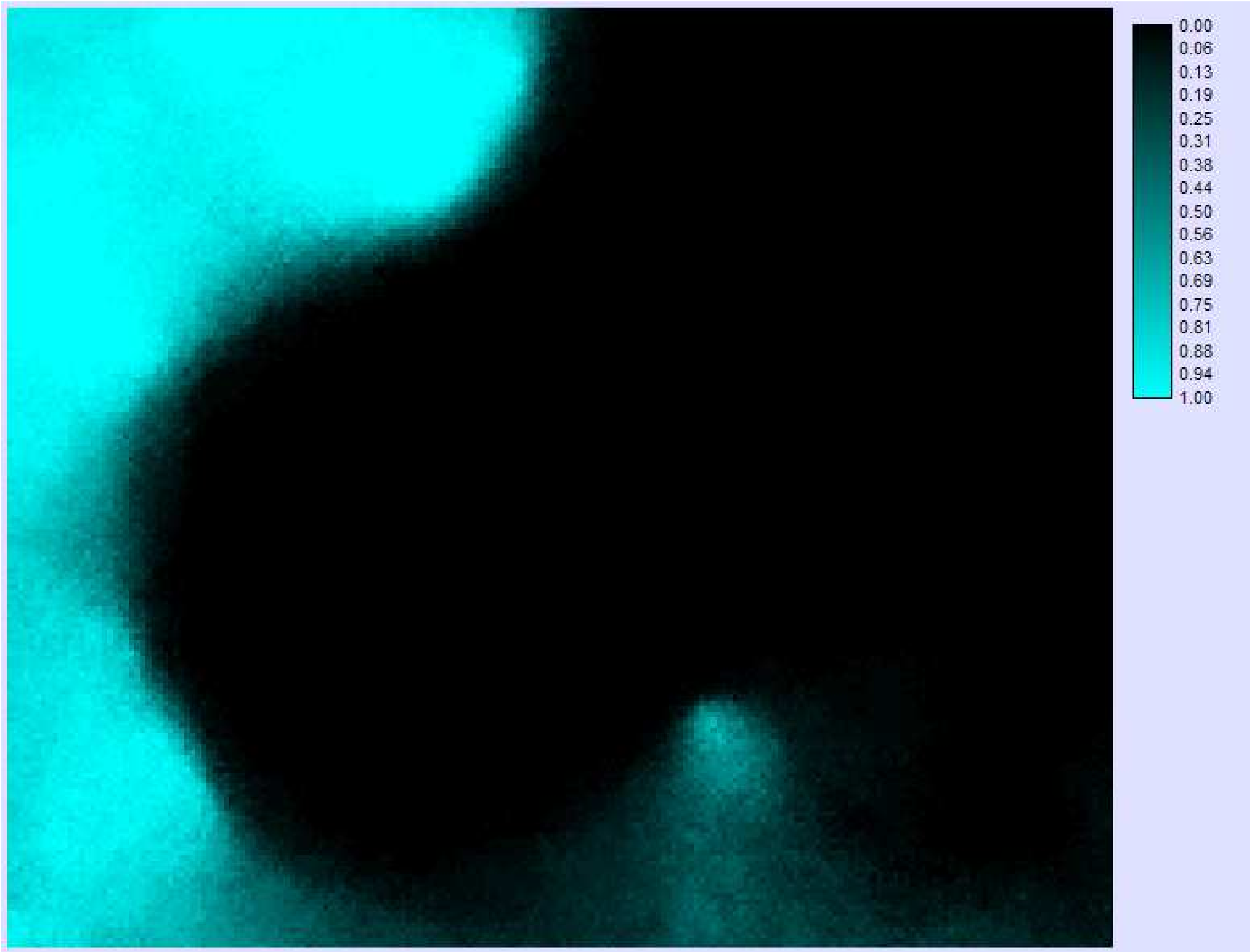
16. januar 2000 (0-12 mm nedbør), forventa nedbør:



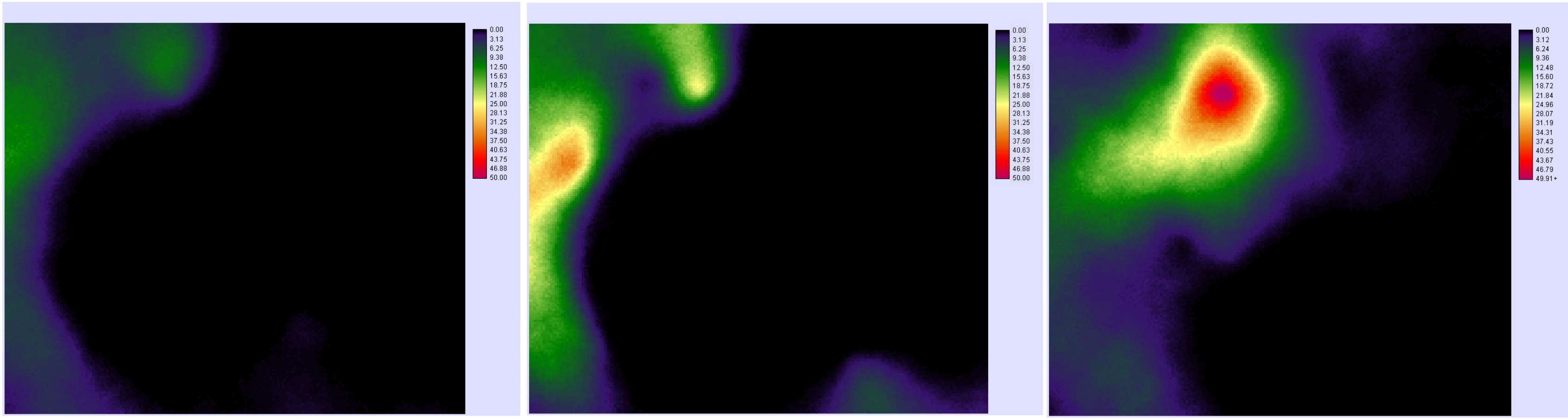
16. januar 2000, usikkerhet (SD):



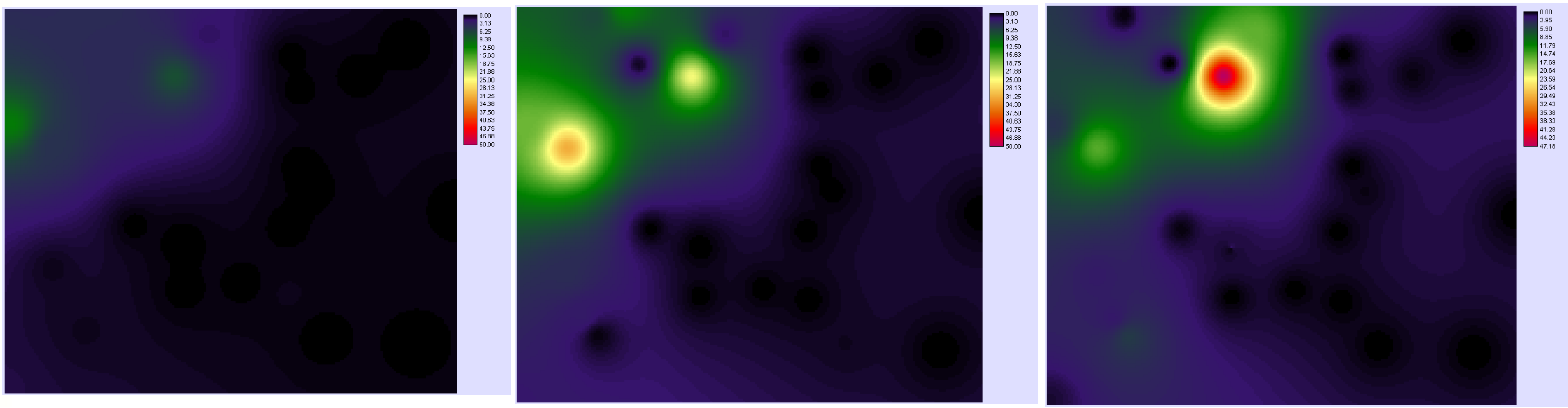
16. januar 2000, sannsynleghet for nedbør:



Simulation results (January 16 – 18 2000):



Inverse squared distance interpolation:



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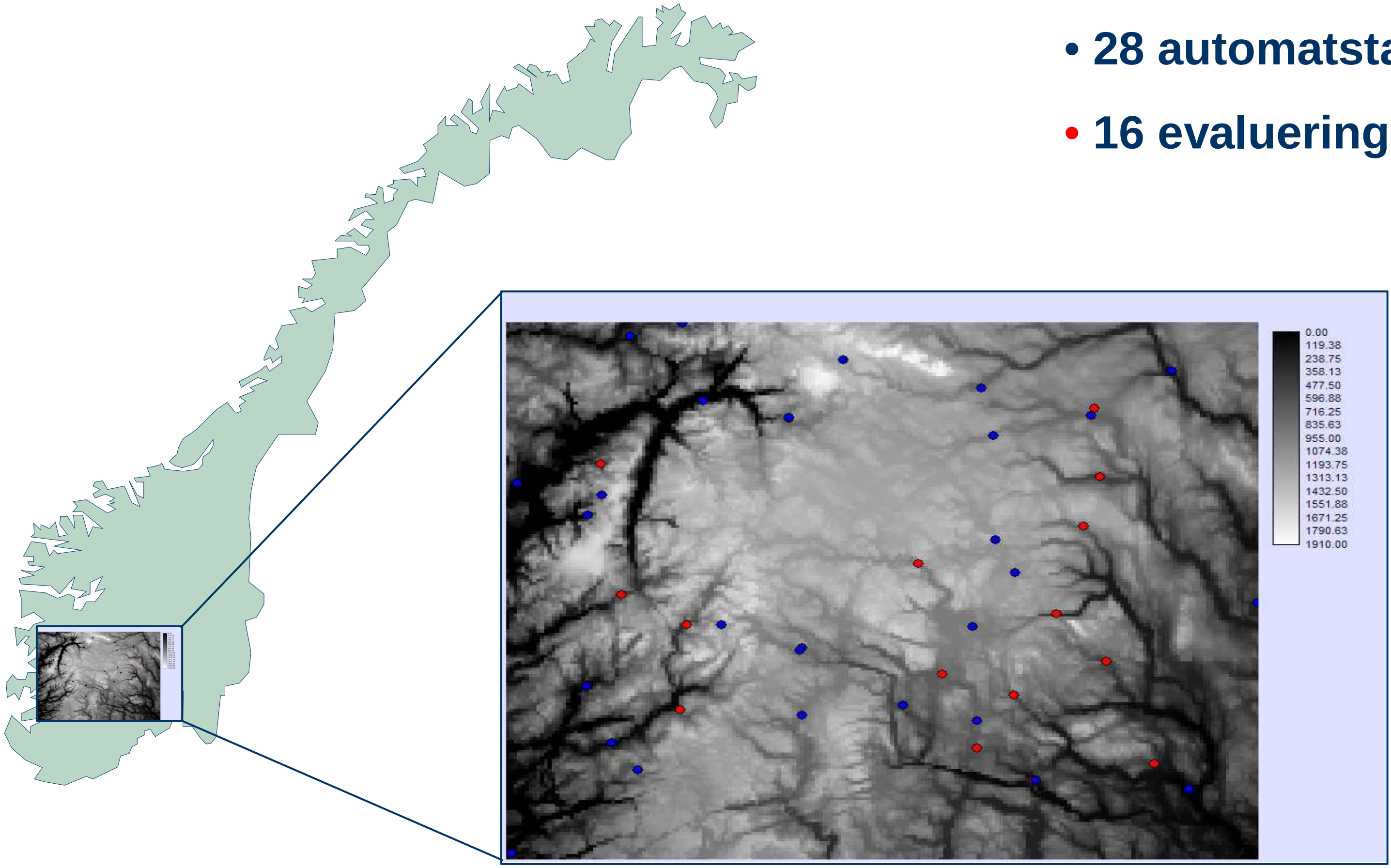
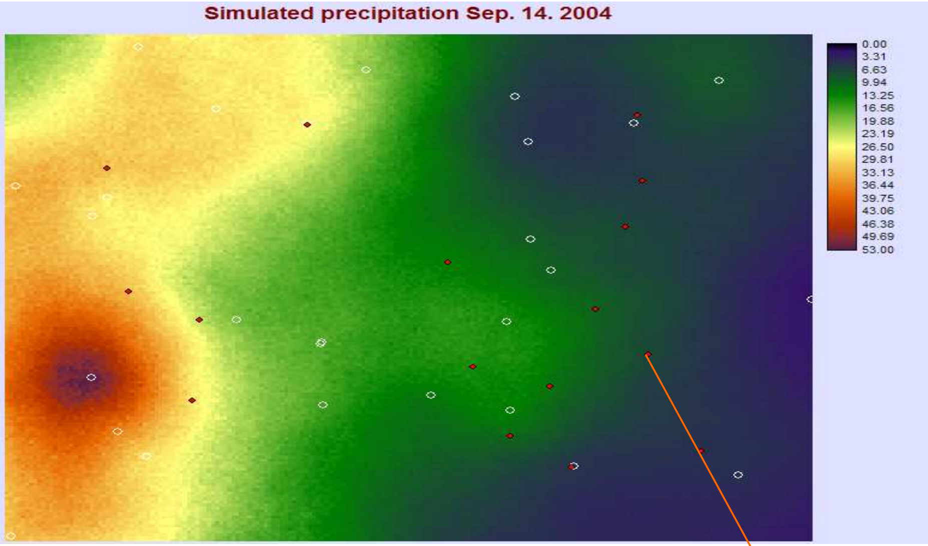
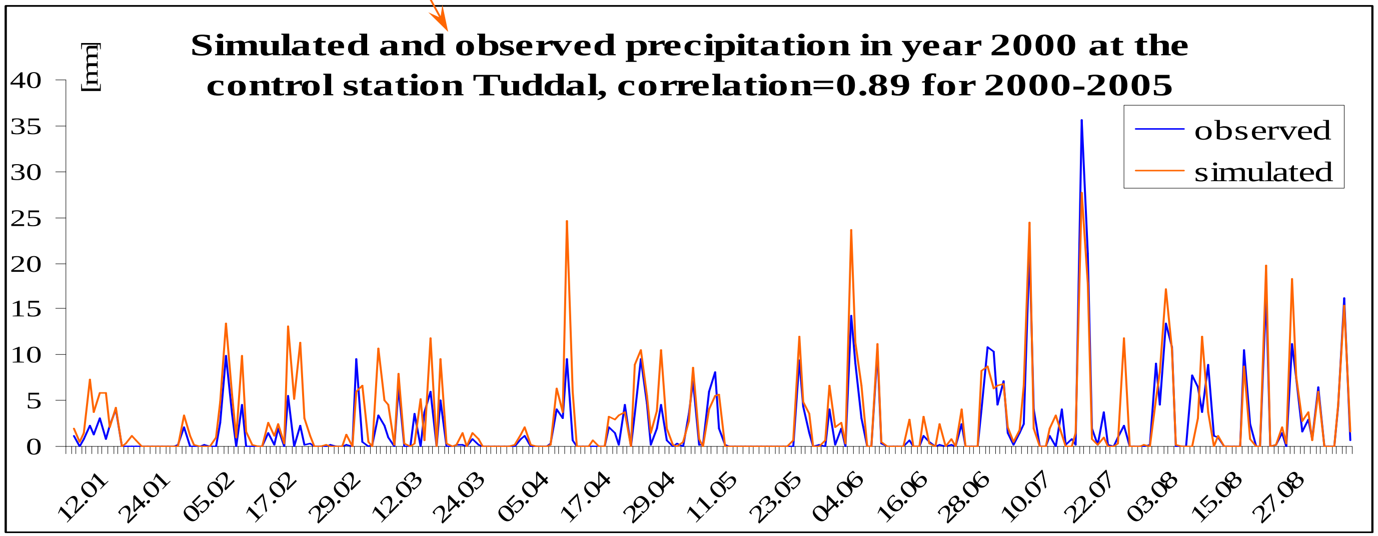
Eksempel: Hardangervidda



- 28 automatstasjonar
- 16 evalueringsstasjonar

Evaluering:


Simulated precipitation Sep. 14. 2004
0.00
3.31
6.63
9.94
13.25
16.56
19.88
23.19
26.50
29.81
33.13
36.44
39.75
43.06
46.38
49.69
53.00


Simulated and observed precipitation in year 2000 at the control station Tuddal, correlation=0.89 for 2000-2005
[mm]
40
35
30
25
20
15
10
5
0
observed
simulated
12.01
24.01
05.02
17.02
29.02
12.03
24.03
05.04
17.04
29.04
11.05
23.05
04.06
16.06
28.06
10.07
22.07
03.08
15.08
27.08

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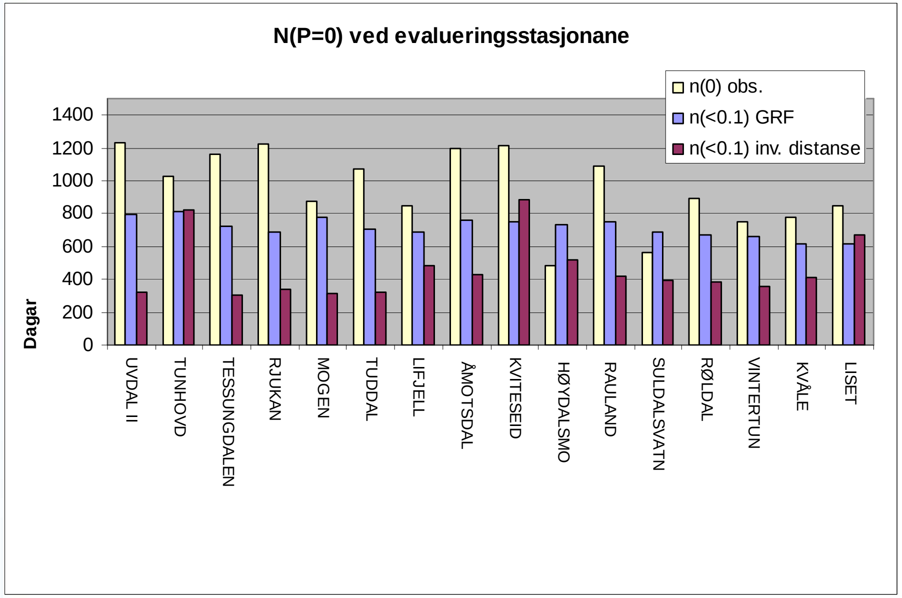
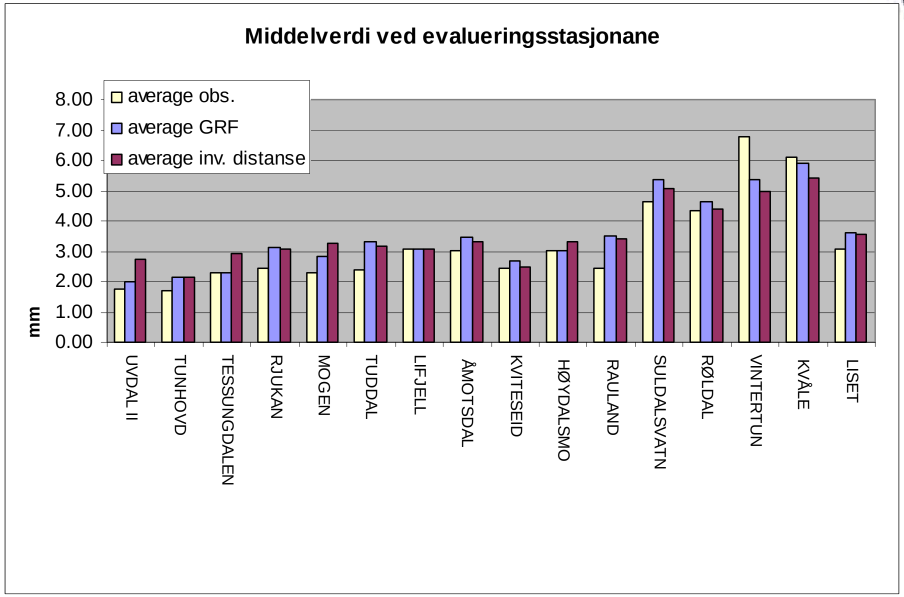
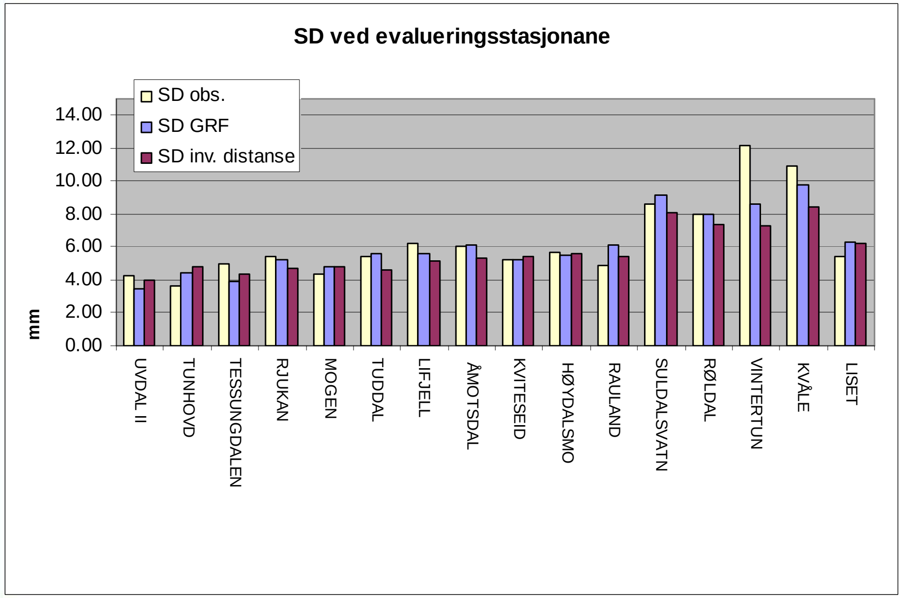


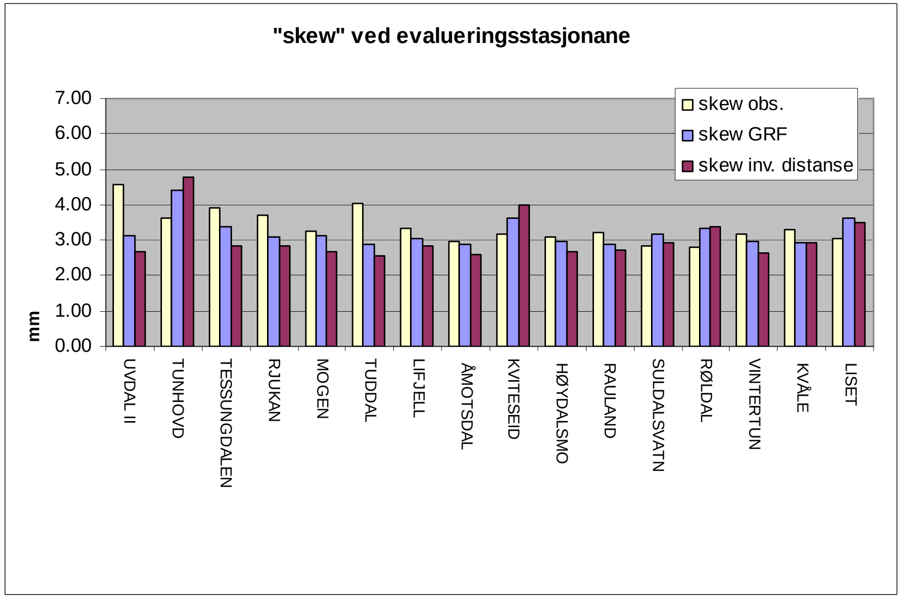
N(P=0) ved evalueringsstasjonane
n(0) obs.
n(<0.1) GRF
n(<0.1) inv. distanse
Dagar
1400
1200
1000
800
600
400
200
0
UVDAL II
TUNHOVD
TESSUNGDALEN
RJUKAN
MOGEN
TUDDAL
LIFJELL
ÅMOTSDAL
KVITESEID
HØYDALSMO
RAULAND
SULDALSVATN
RØLDAL
VINTERTUN
KVÅLE
LISET



Middelverdi ved evalueringsstasjonane
average obs.
average GRF
average inv. distanse
mm
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
UVDAL II
TUNHOVD
TESSUNGDALEN
RJUKAN
MOGEN
TUDDAL
LIFJELL
ÅMOTSDAL
KVITESEID
HØYDALSMO
RAULAND
SULDALSVATN
RØLDAL
VINTERTUN
KVÅLE
LISET



SD ved evalueringsstasjonane
SD obs.
SD GRF
SD inv. distanse
mm
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
UVDAL II
TUNHOVD
TESSUNGDALEN
RJUKAN
MOGEN
TUDDAL
LIFJELL
ÅMOTSDAL
KVITESEID
HØYDALSMO
RAULAND
SULDALSVATN
RØLDAL
VINTERTUN
KVÅLE
LISET



"skew" ved evalueringsstasjonane
skew obs.
skew GRF
skew inv. distanse
mm
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
UVDAL II
TUNHOVD
TESSUNGDALEN
RJUKAN
MOGEN
TUDDAL
LIFJELL
ÅMOTSDAL
KVITESEID
HØYDALSMO
RAULAND
SULDALSVATN
RØLDAL
VINTERTUN
KVÅLE
LISET