ETH zürich

Bushfire modelling

Lea Beusch and Christoph Horat – Monday 30^{th} May

Note: Version without pictures

Australia – a history of fire

Content

Content

– Motivation

Content

- Motivation
- Hazard model

Content

- Motivation
- Hazard model
- Future development

Content

- Motivation
- Hazard model
- Future development
- Adaptation

Content

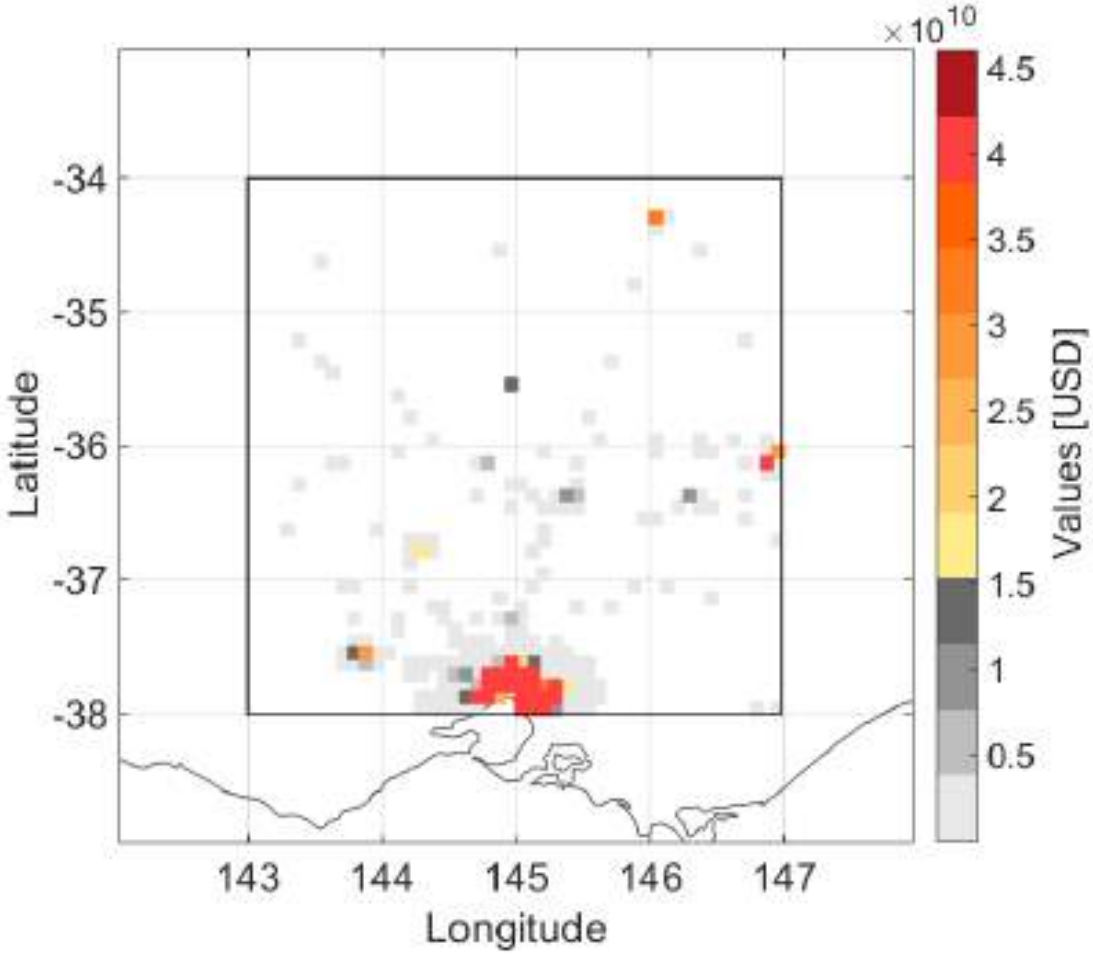
- Motivation
- Hazard model
- Future development
- Adaptation
- Limitations and outlook

Model domain

- Domain area: 165'107 km^2
- Model resolution: 1 cell $\equiv$ 0.1651 km^2

Model domain – asset map

– Asset (2016): $1293.7 billion



Hazard (toy!) model

0	**0**	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**
0	**0**	**1**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**

0: unburnt cell

1: fire

2: ember

at time t_0

Hazard (toy!) model

0	**0**	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**
0	**0**	**1**	**0**	**0**	**0**
0	**1**	**2**	**0**	**0**	**0**
0	**0**	**1**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**

0: unburnt cell

1: fire

2: ember

at time $t_0 + \triangle t$

Hazard (toy!) model

0	**0**	**0**	**0**	**0**	**0**
0	**0**	**1**	**0**	**0**	**0**
0	**0**	**2**	**1**	**0**	**0**
1	**2**	**2**	**0**	**0**	**0**
0	**1**	**2**	**1**	**0**	**0**
0	**0**	**0**	**0**	**0**	**0**

0: unburnt cell

1: fire

2: ember

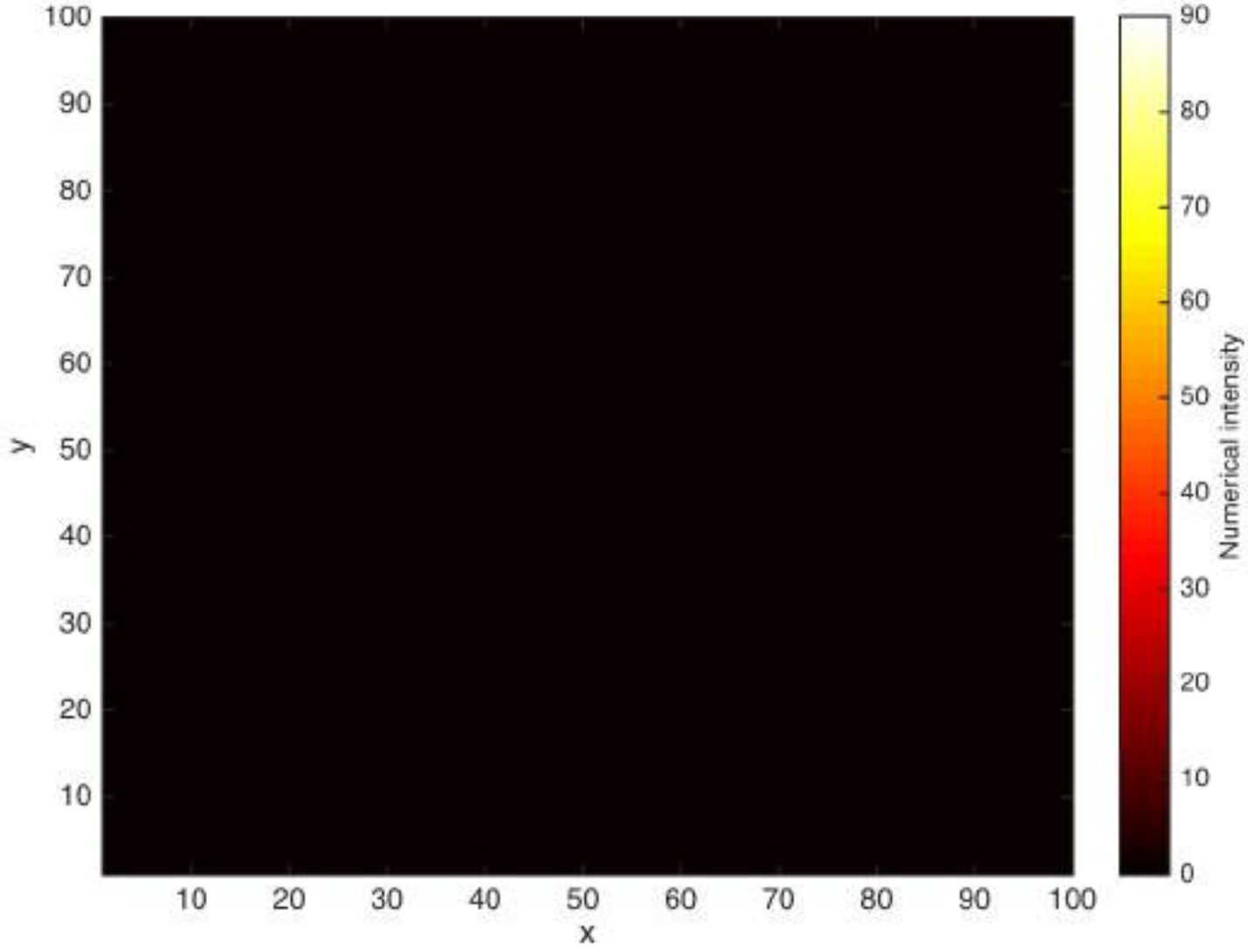
at time $t_0 + 2 \triangle t$

Hazard – numerical intensity

0	0	0	0	0	0
0	0	1	0	0	0
0	0	3	1	0	0
1	3	5	0	0	0
0	1	3	1	0	0
0	0	0	0	0	0

sum up fields over all time steps

Animation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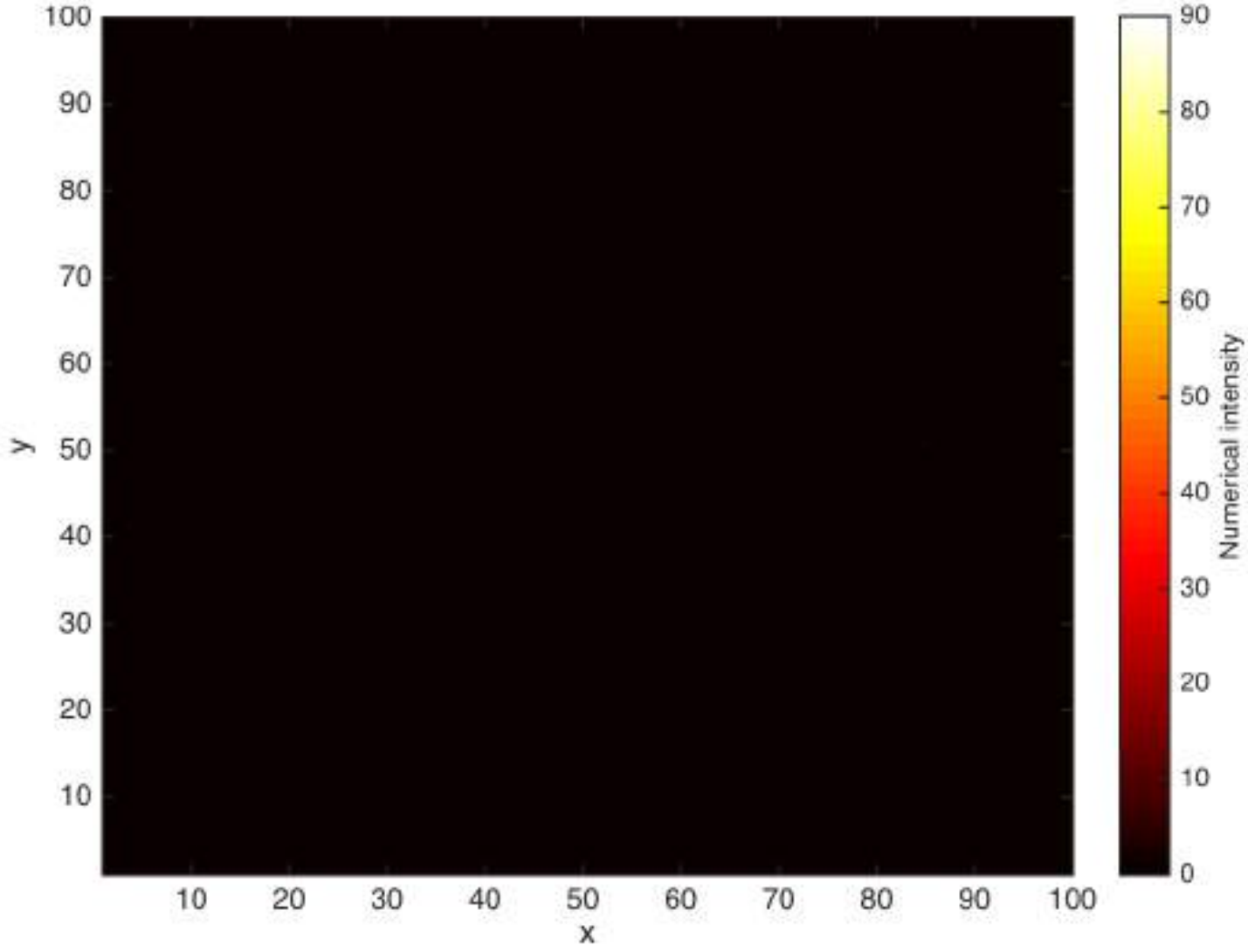
Numerical intensity

Animation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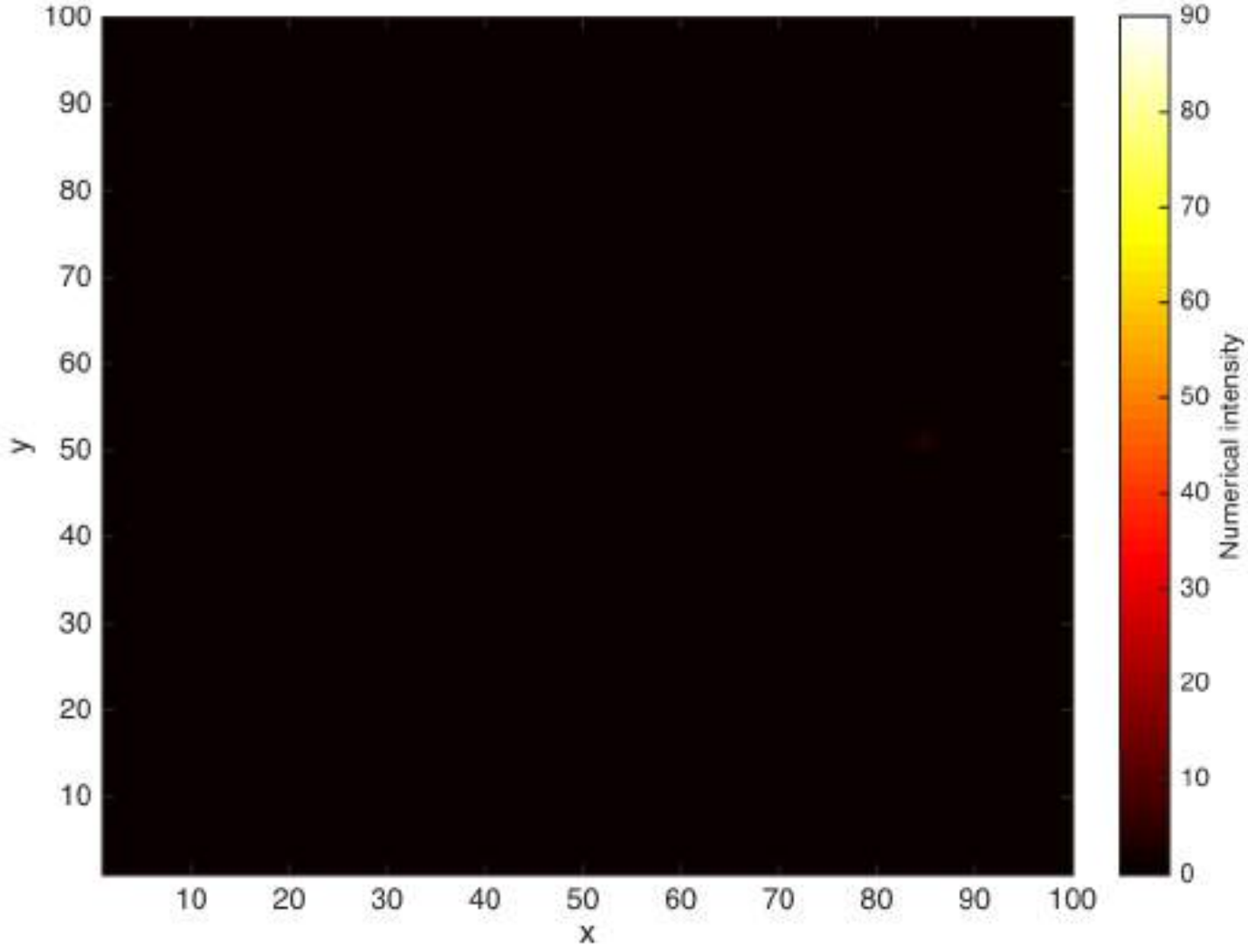
Numerical intensity

Animation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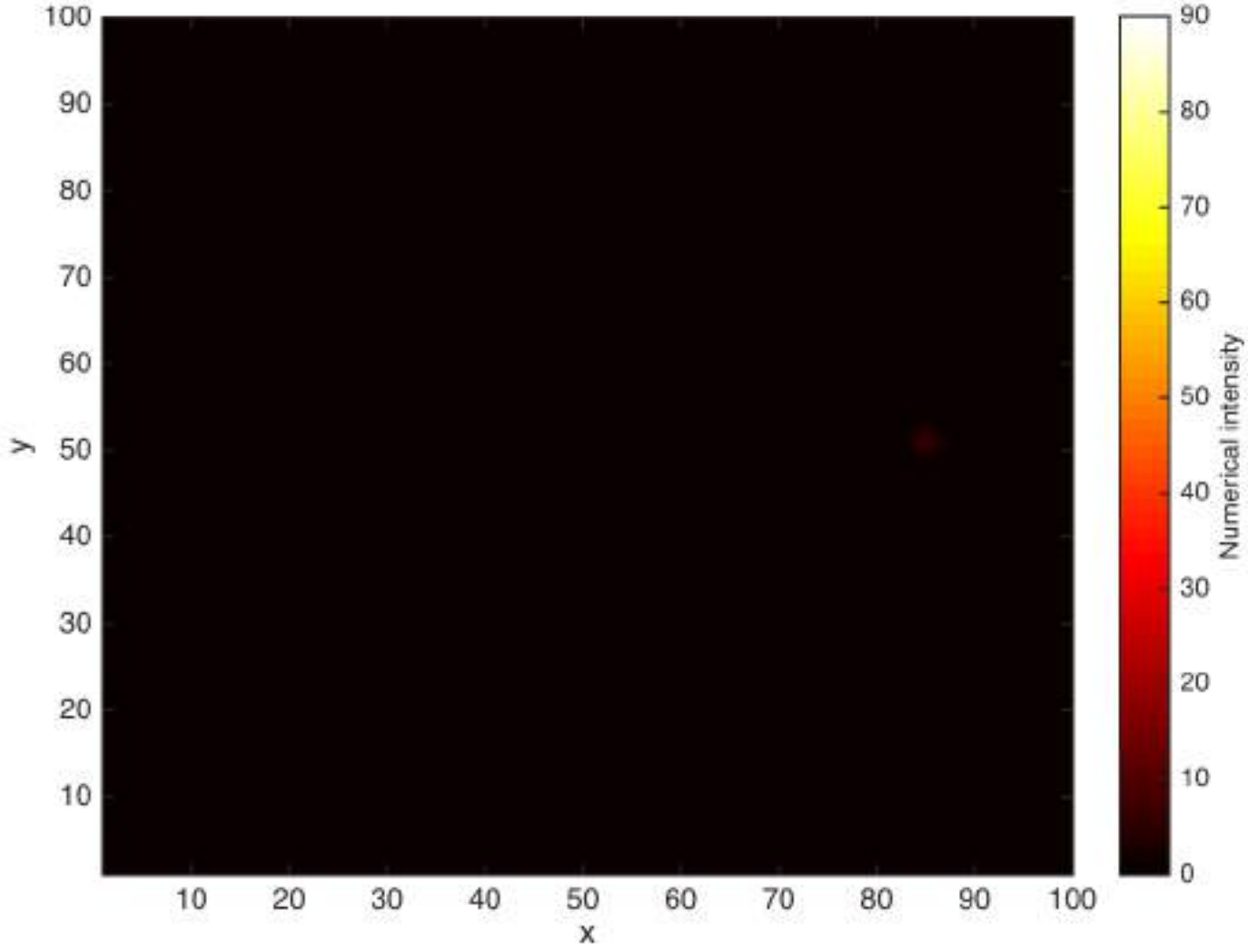
Numerical intensity

Animation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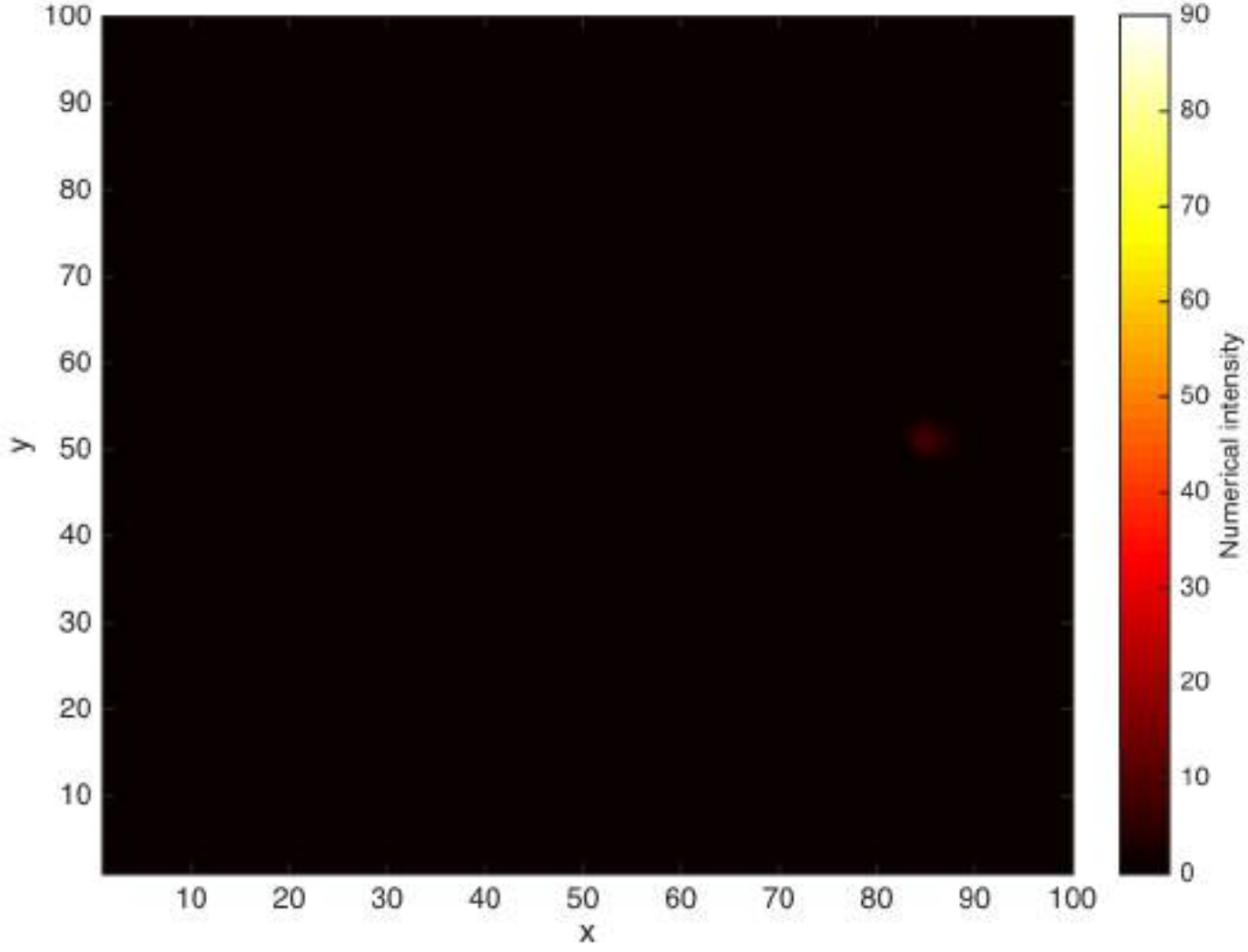
Numerical intensity

Animation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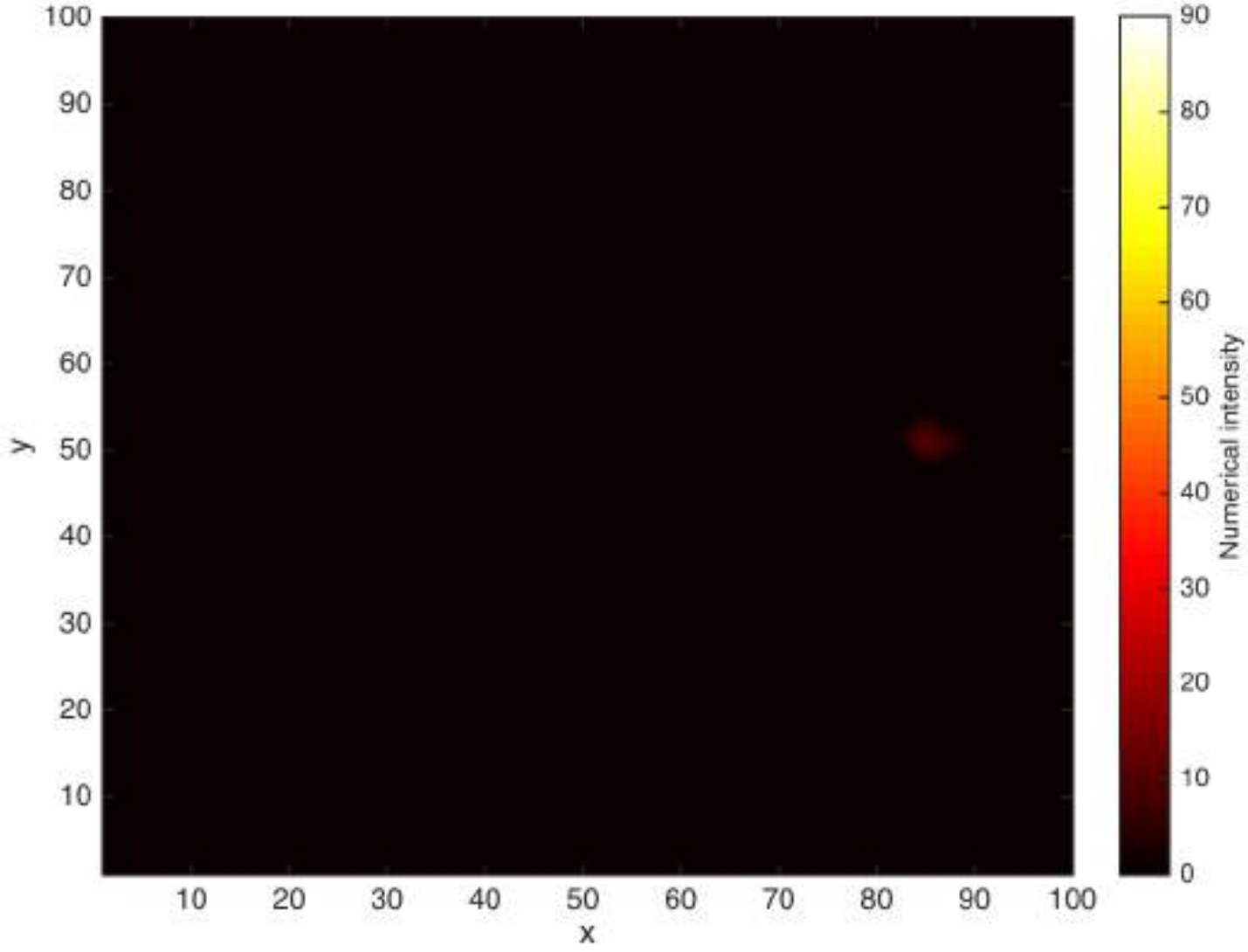
Numerical intensity

Animation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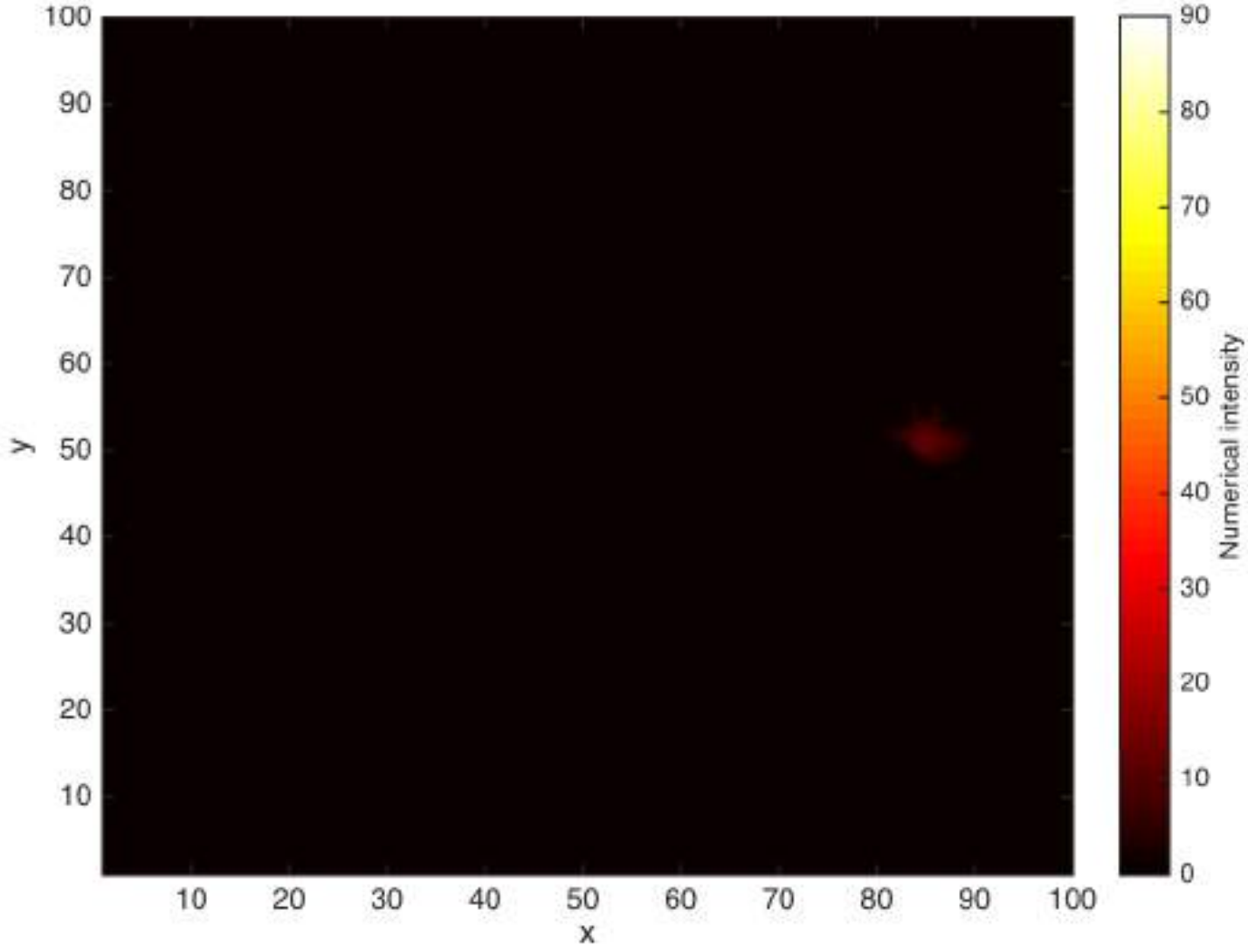
Numerical intensity

Animation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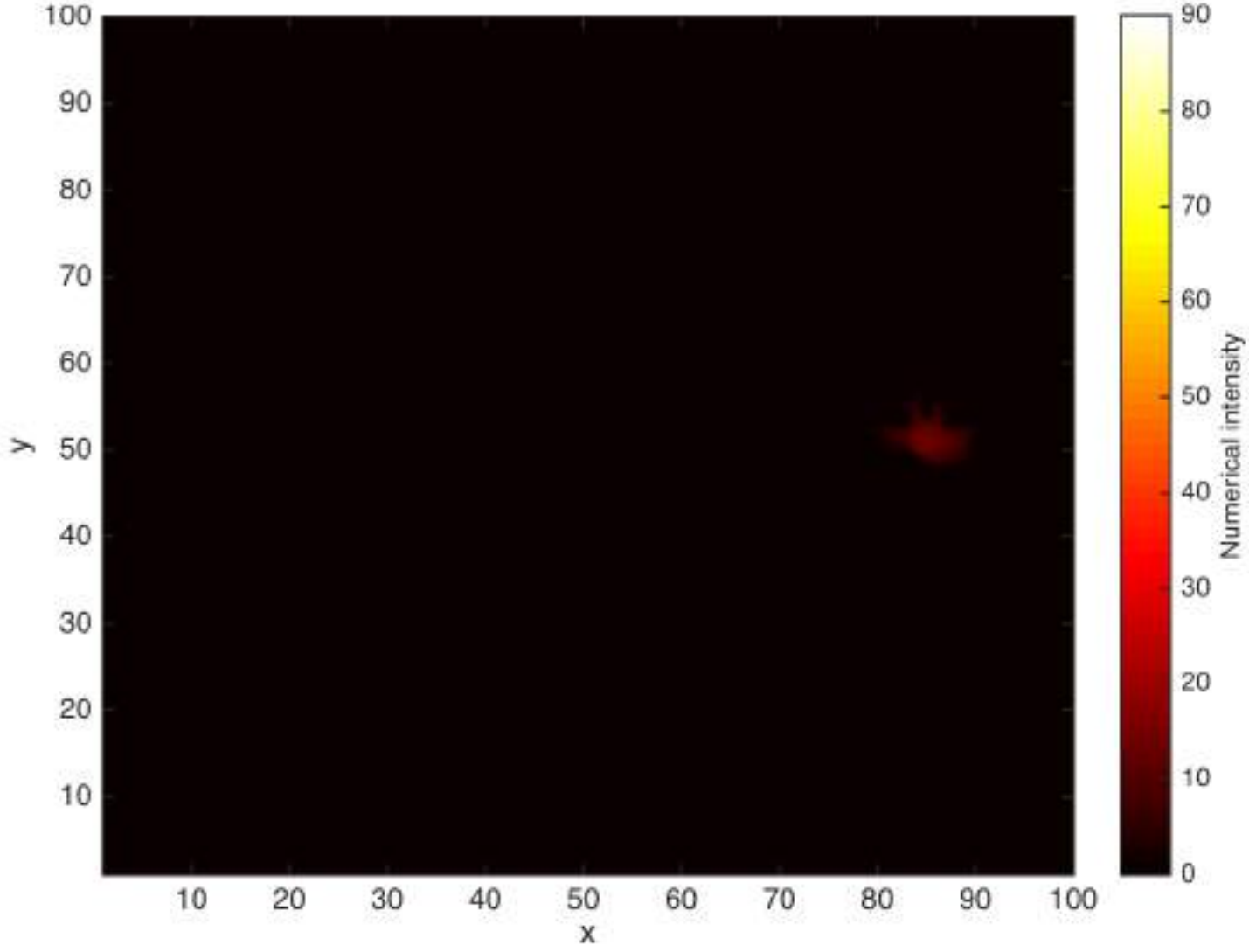
Numerical intensity

Animation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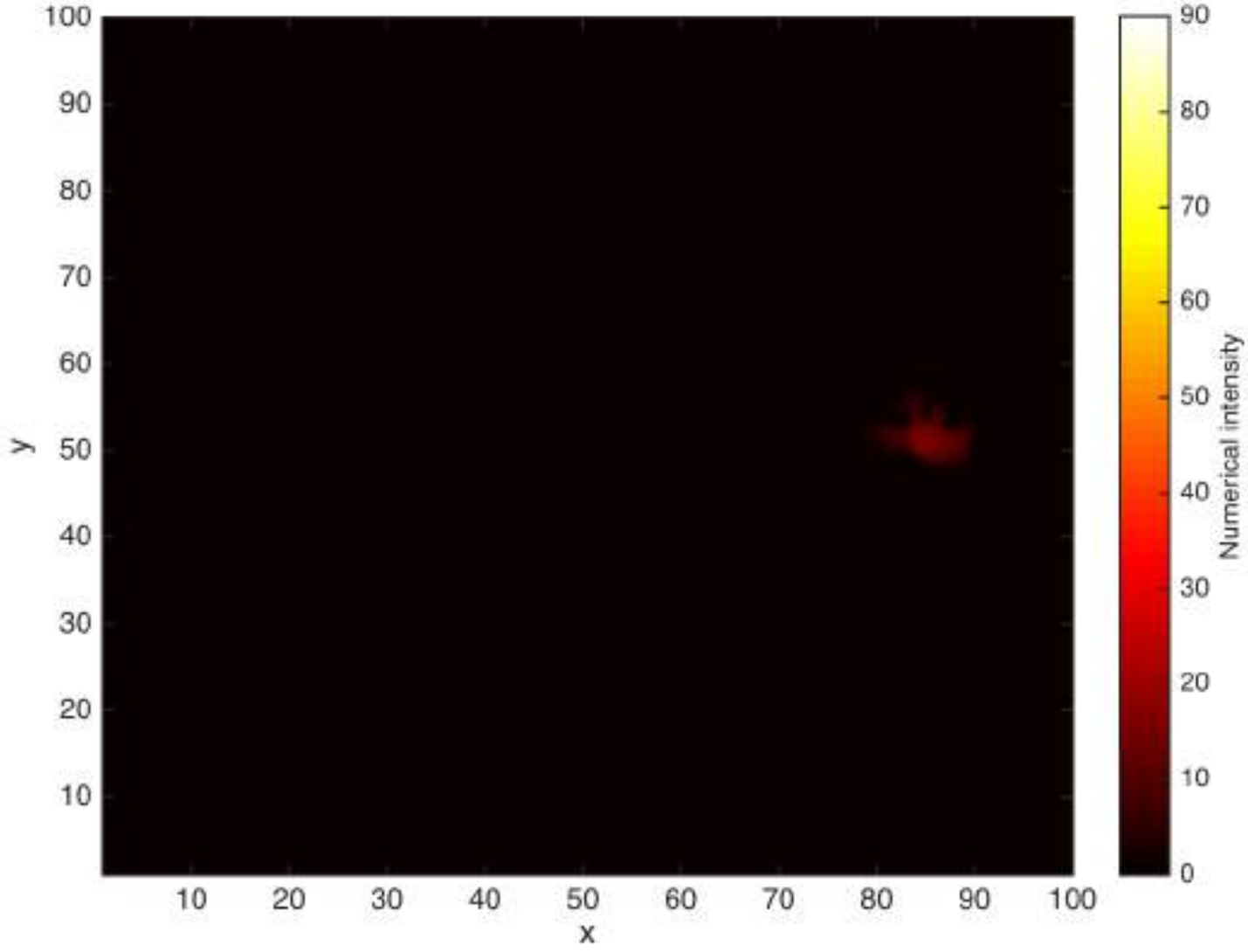
Numerical intensity

Animation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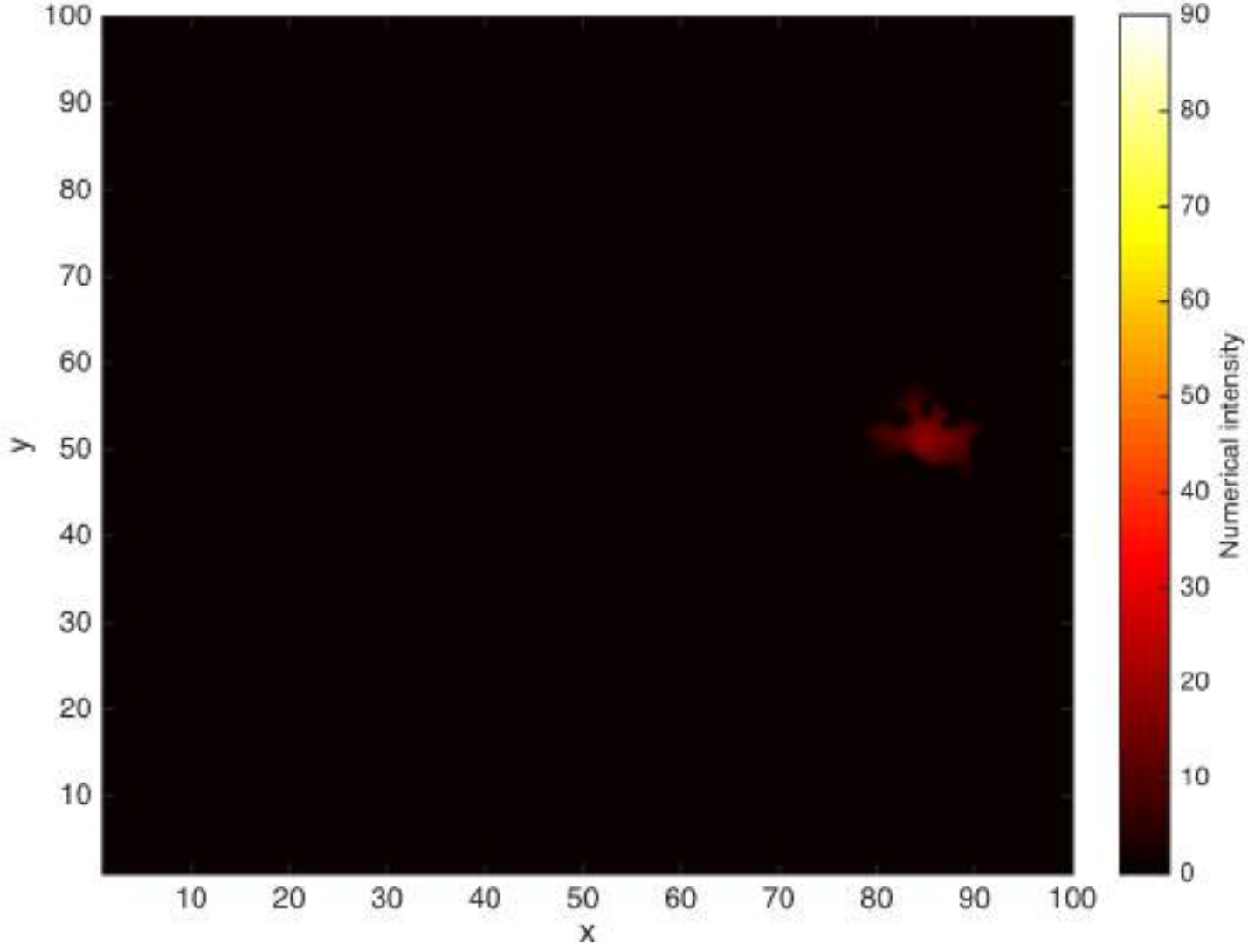
Numerical intensity

Animation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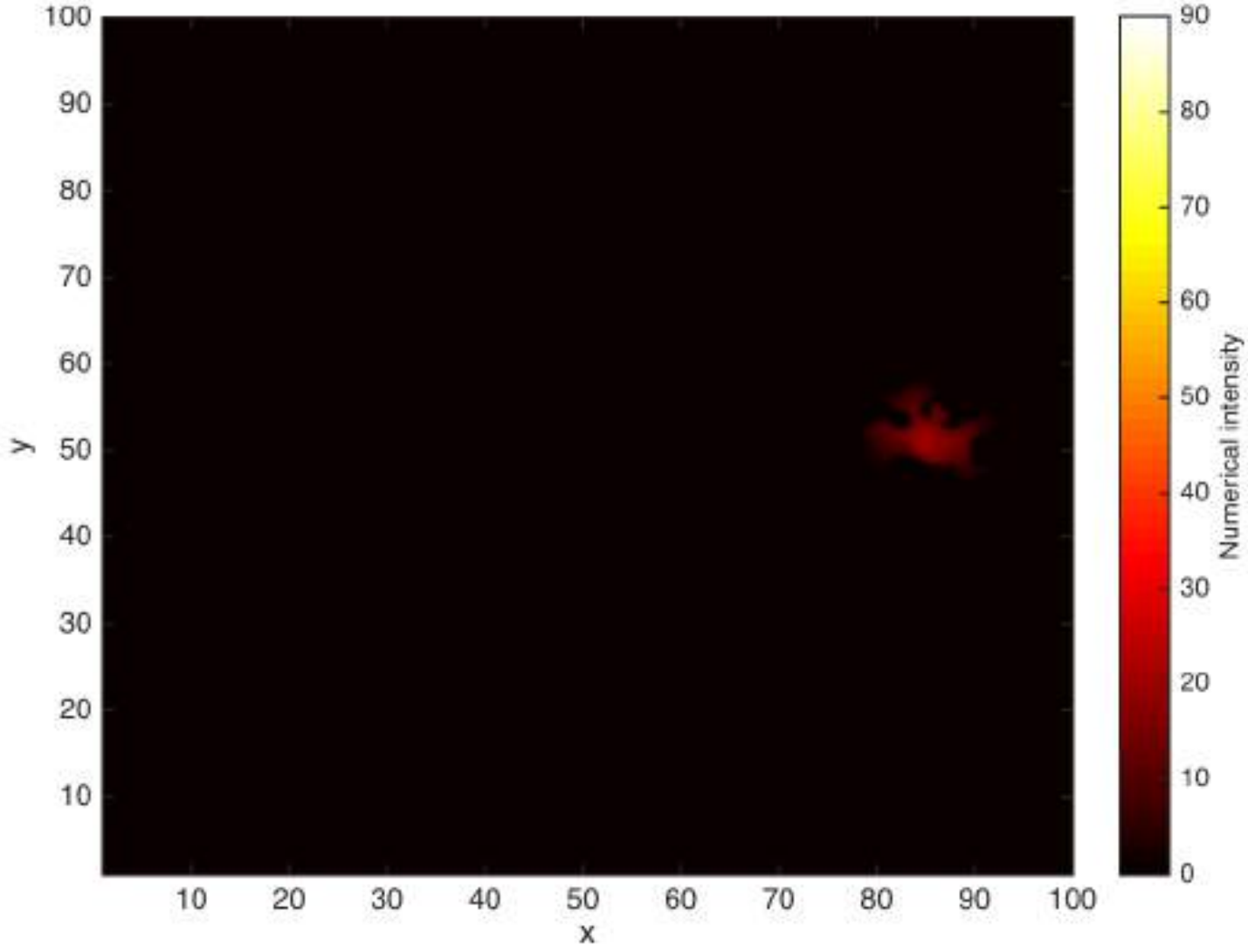
Numerical intensity

Animation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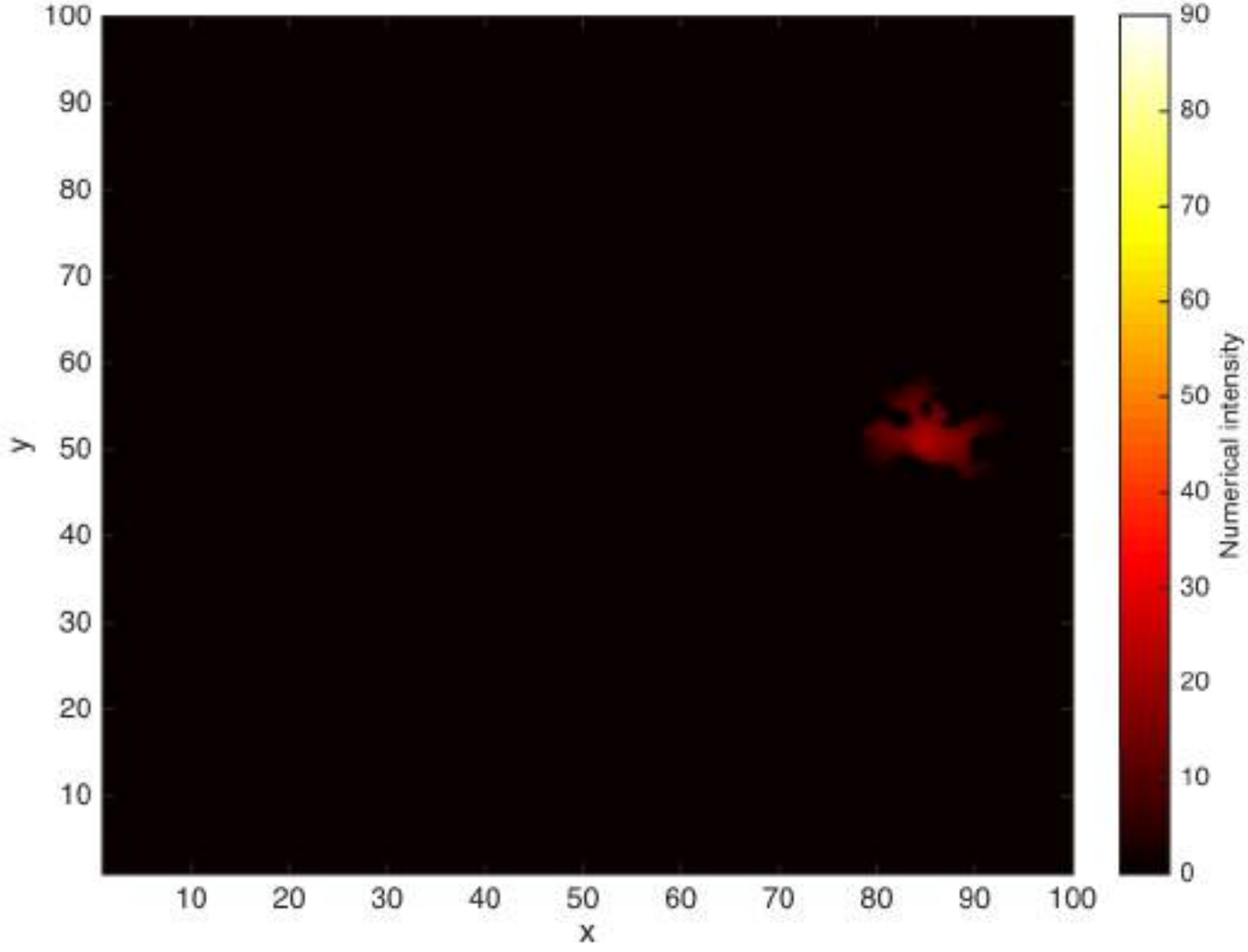
Numerical intensity

Animation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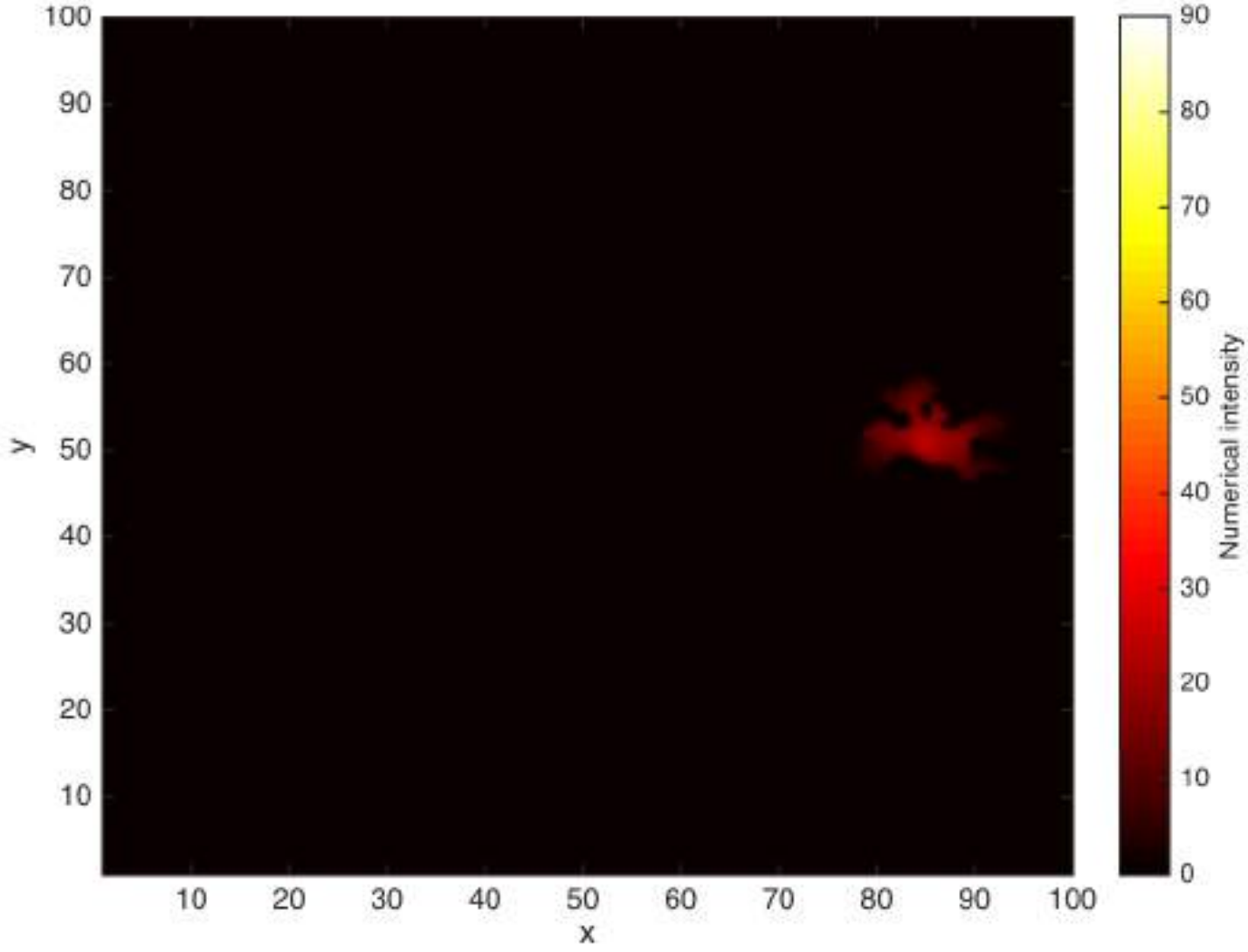
Numerical intensity

Animation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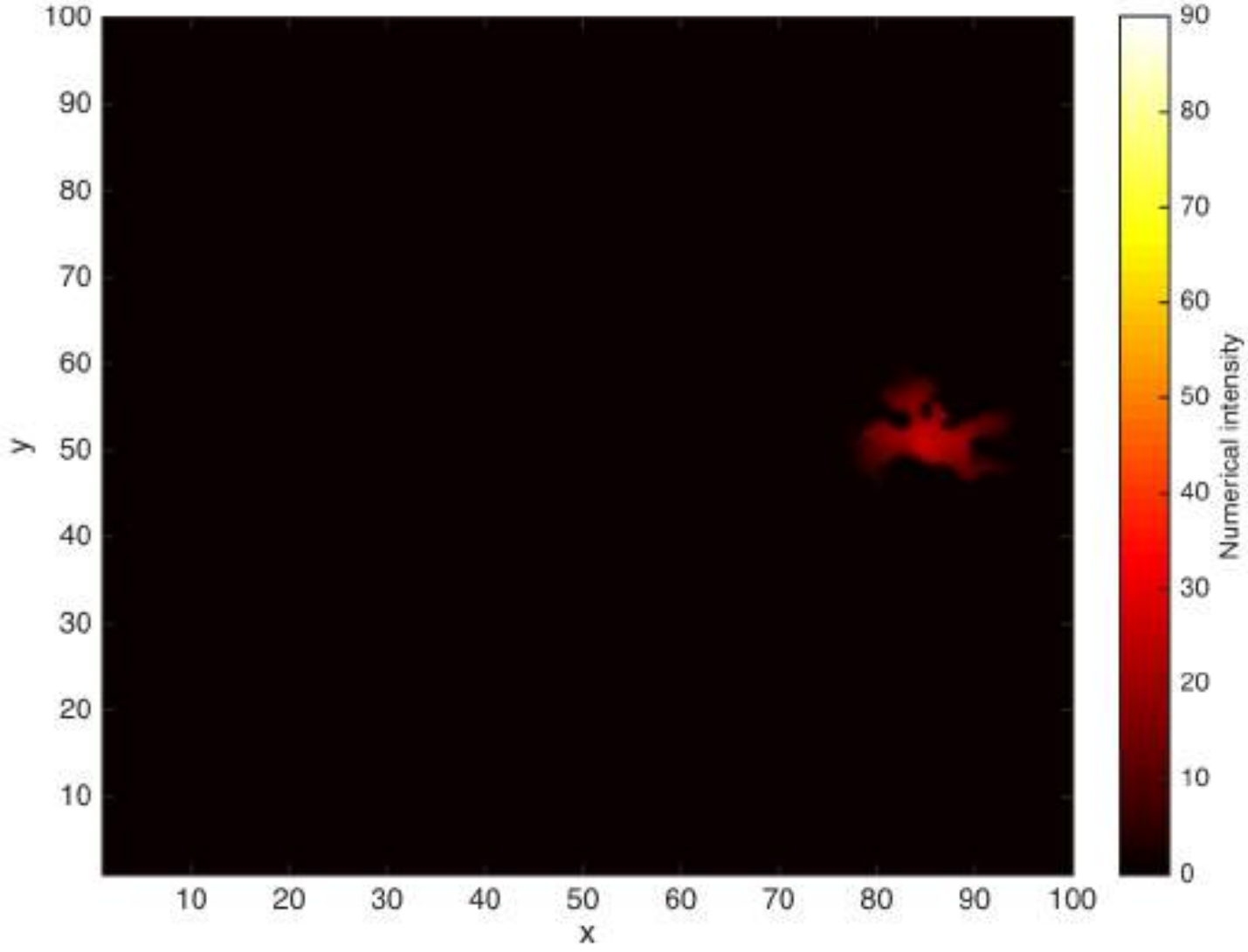
Numerical intensity

Animation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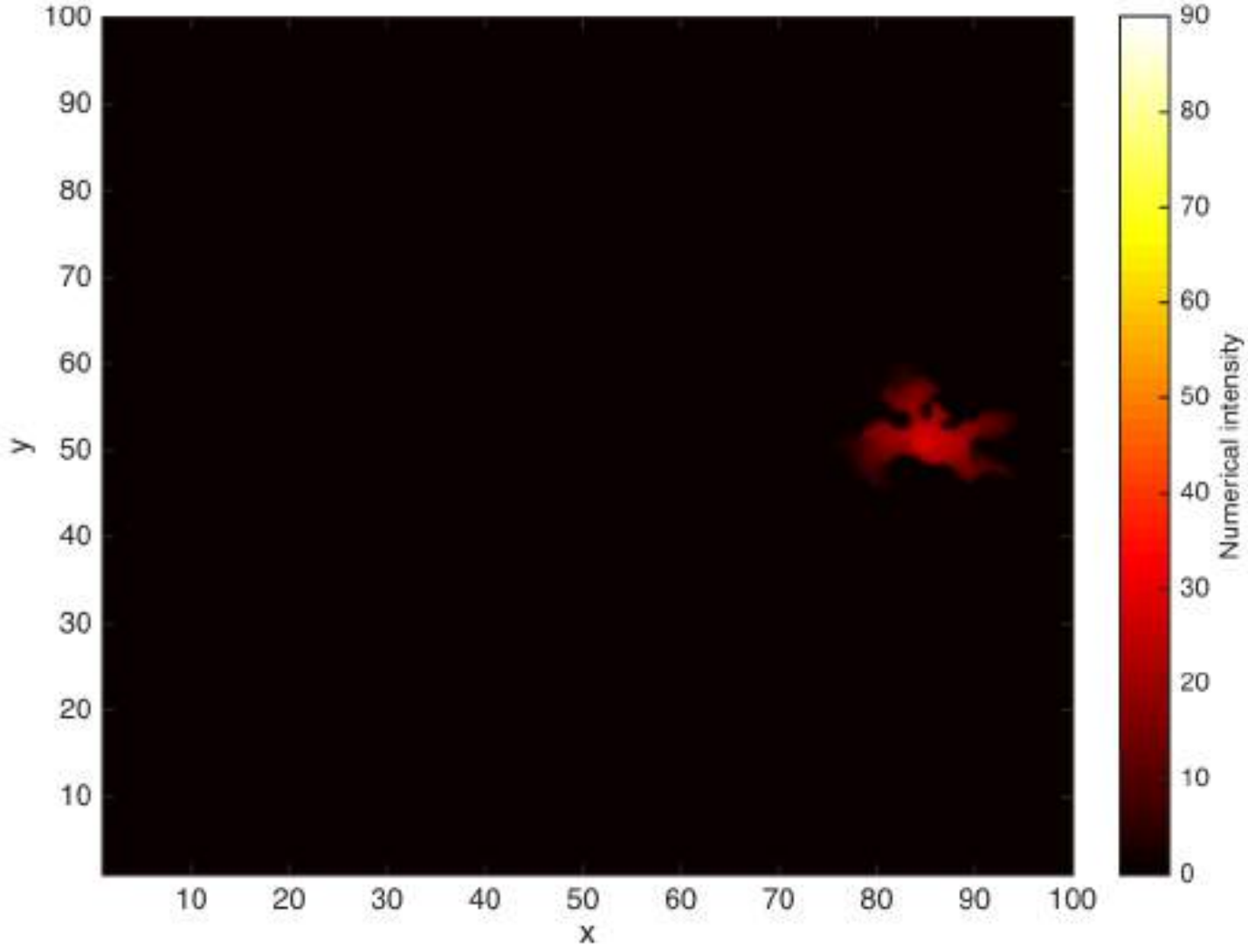
Numerical intensity

Animation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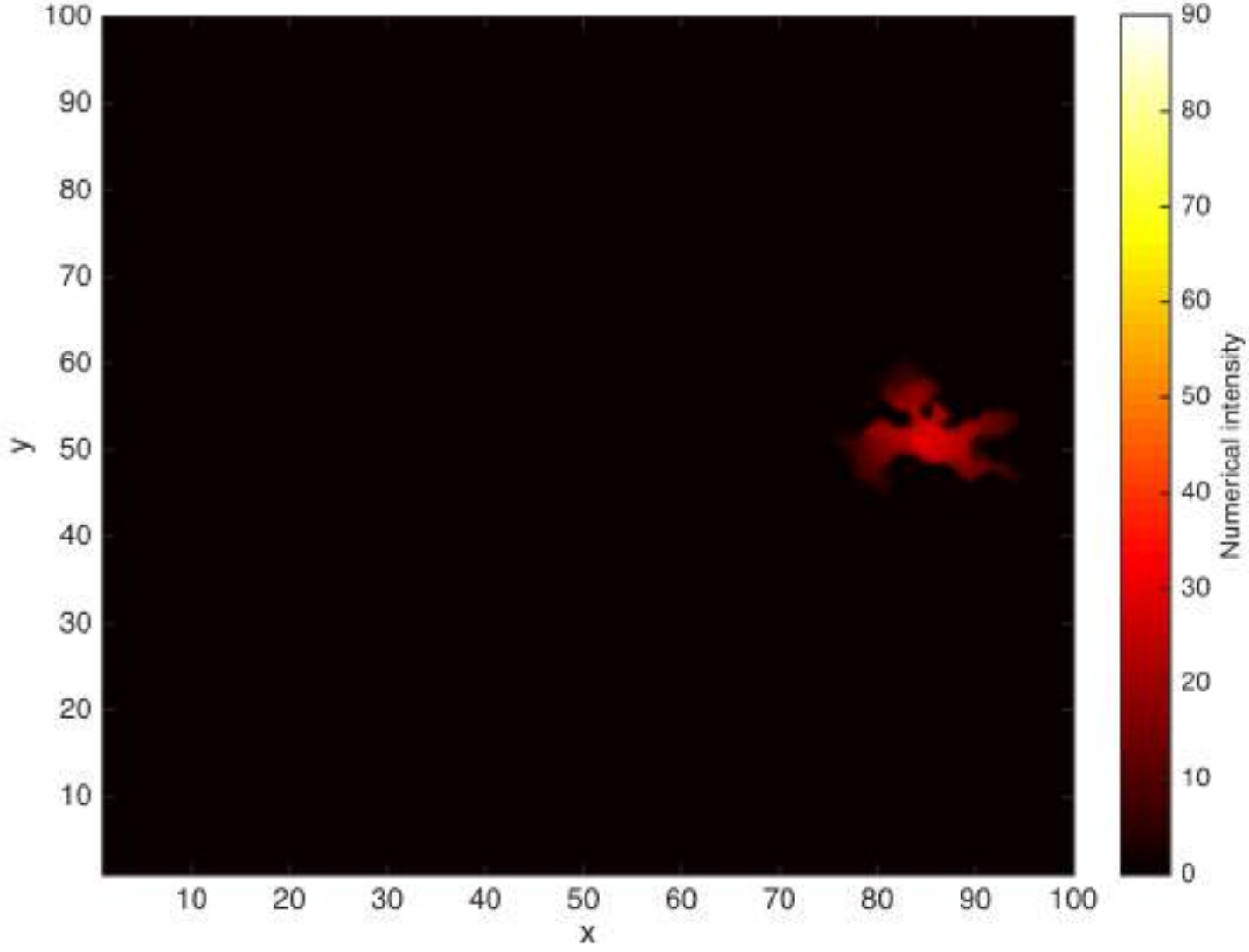
Numerical intensity

Animation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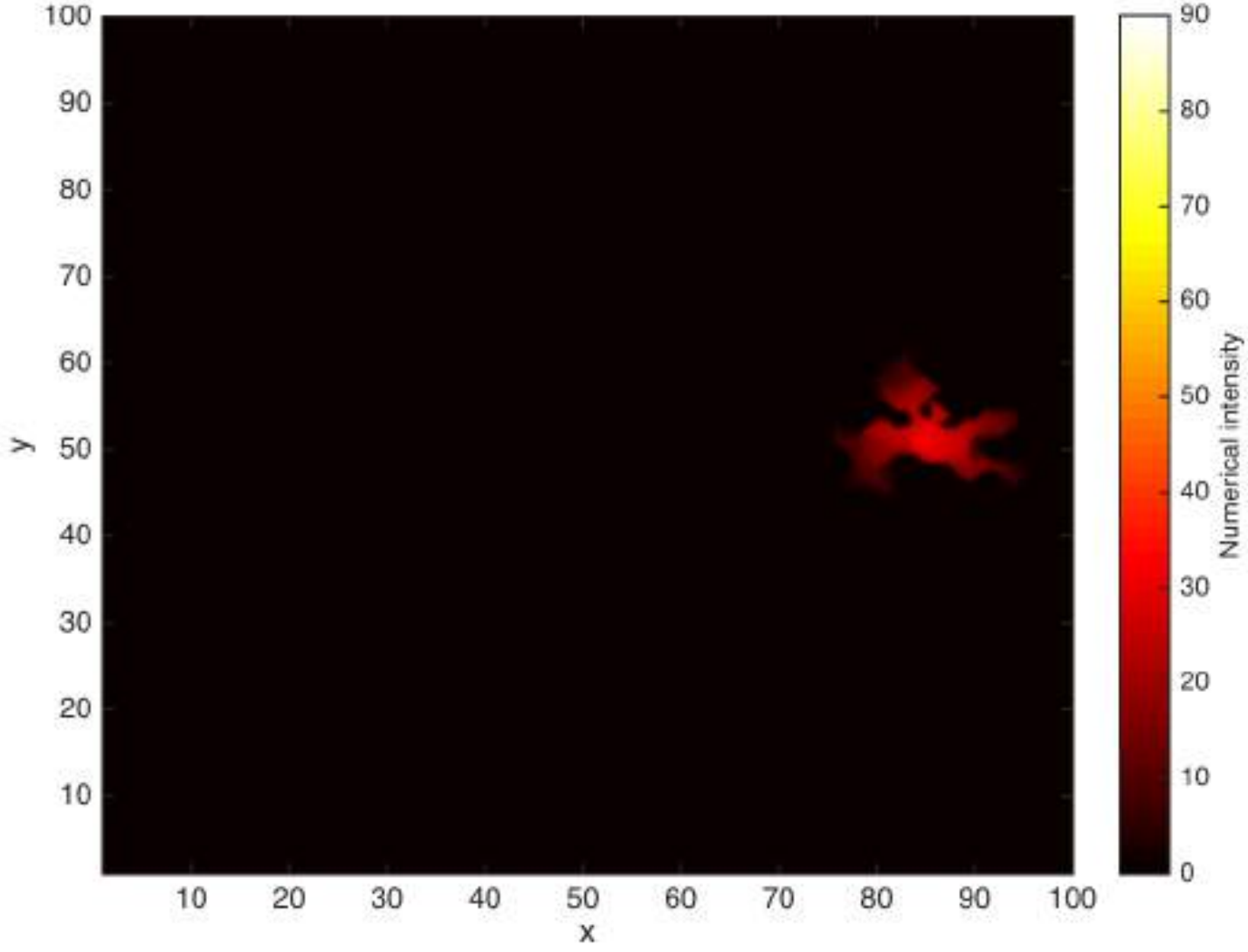
Numerical intensity

Animation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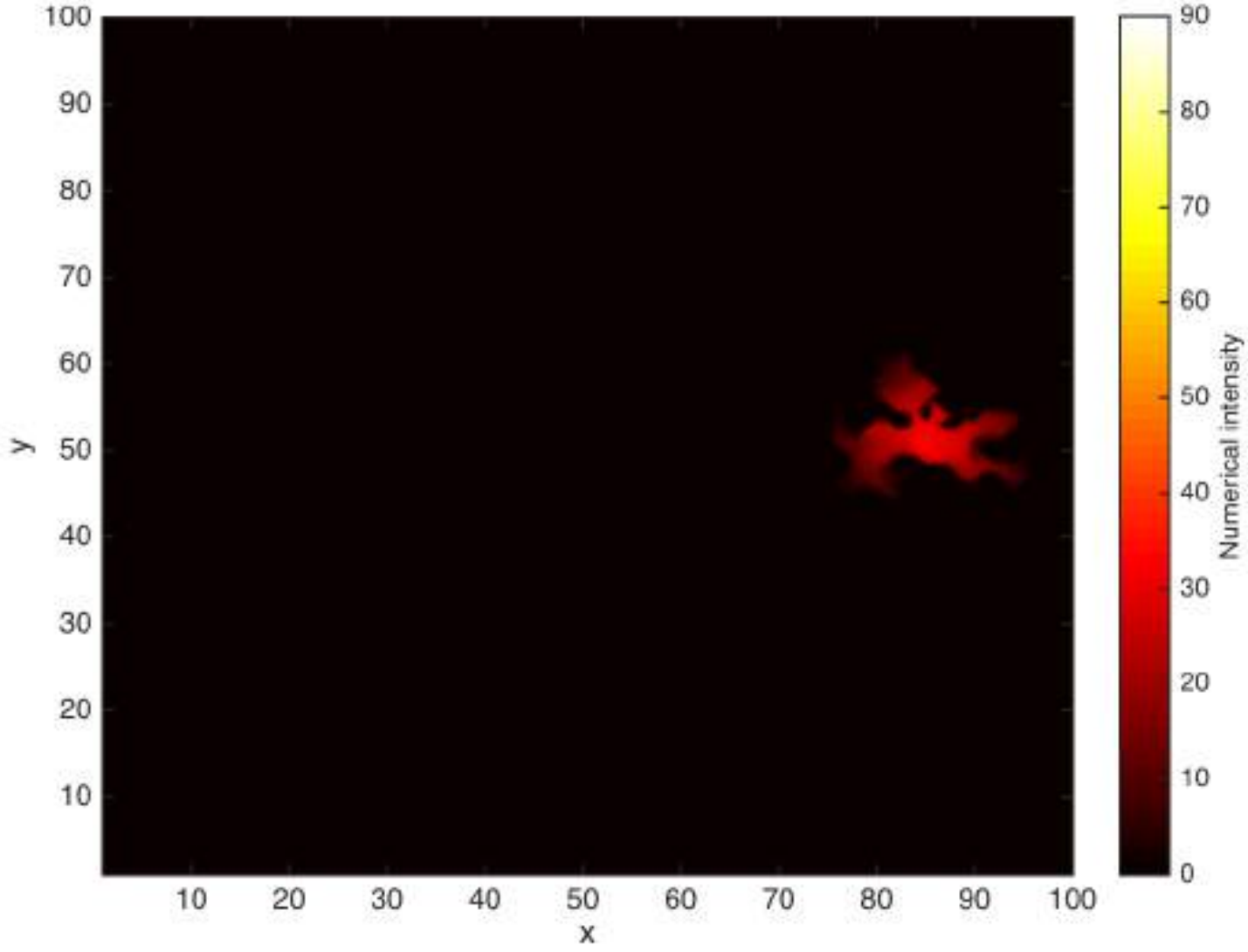
Numerical intensity

Animation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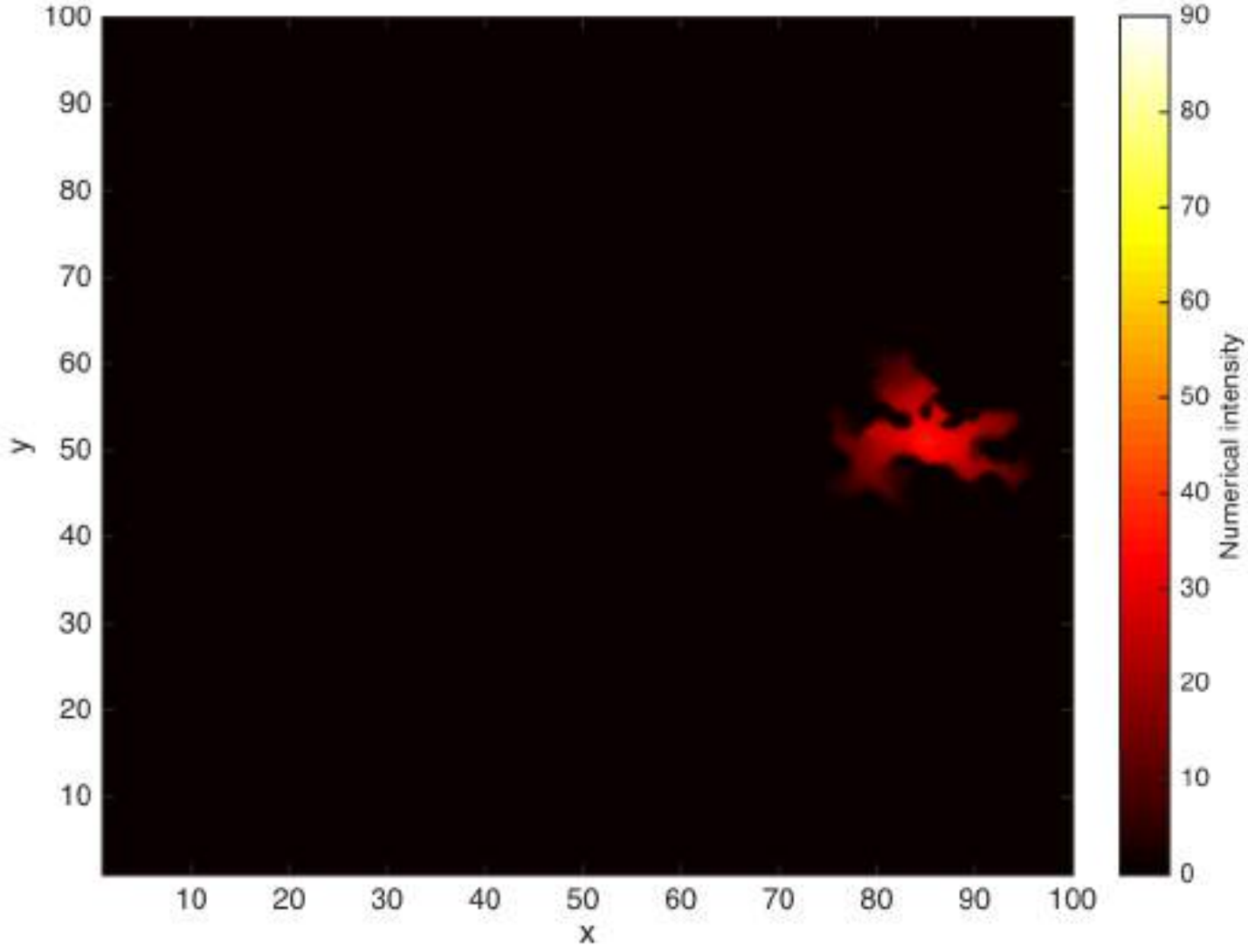
Numerical intensity

Animation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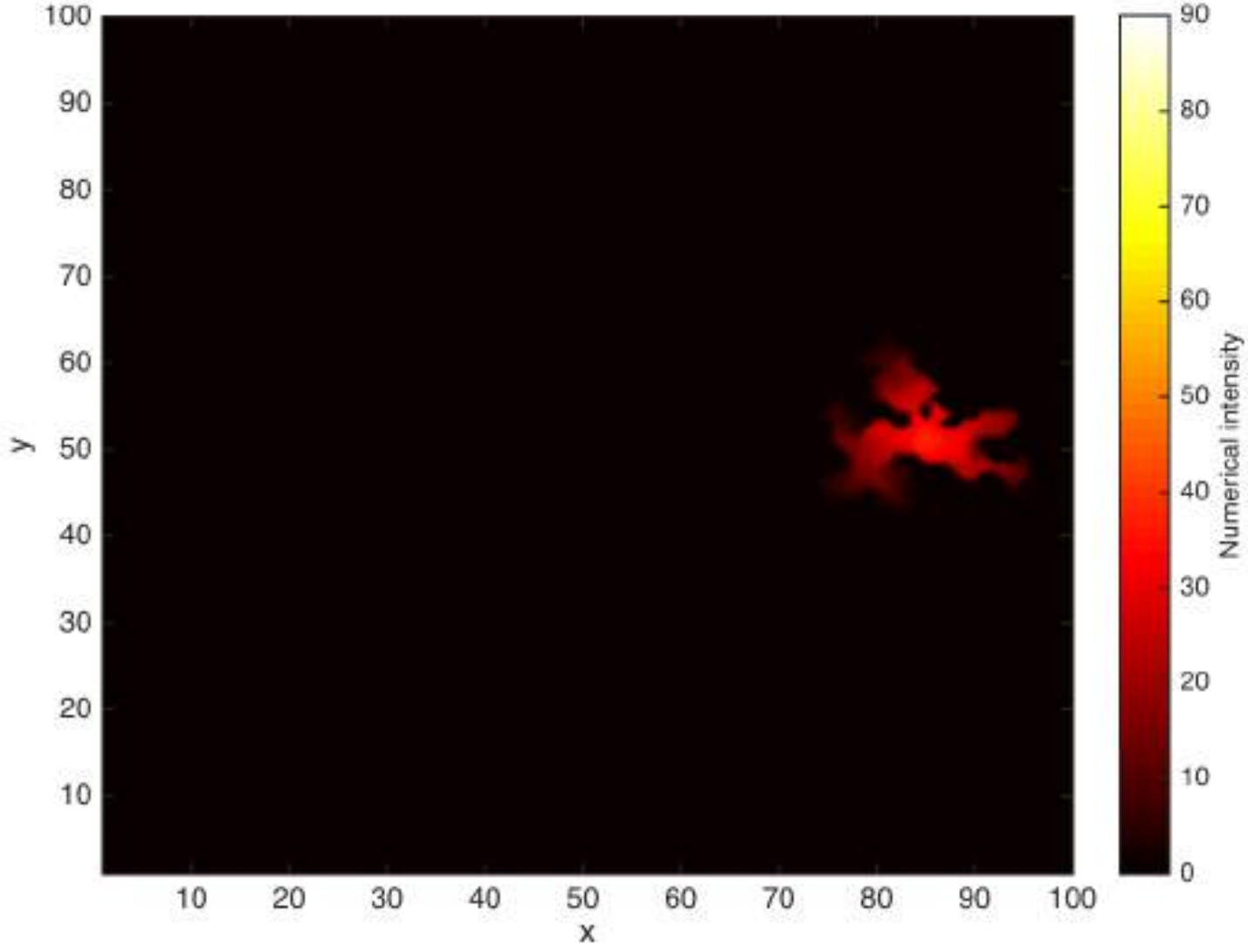
Numerical intensity

Animation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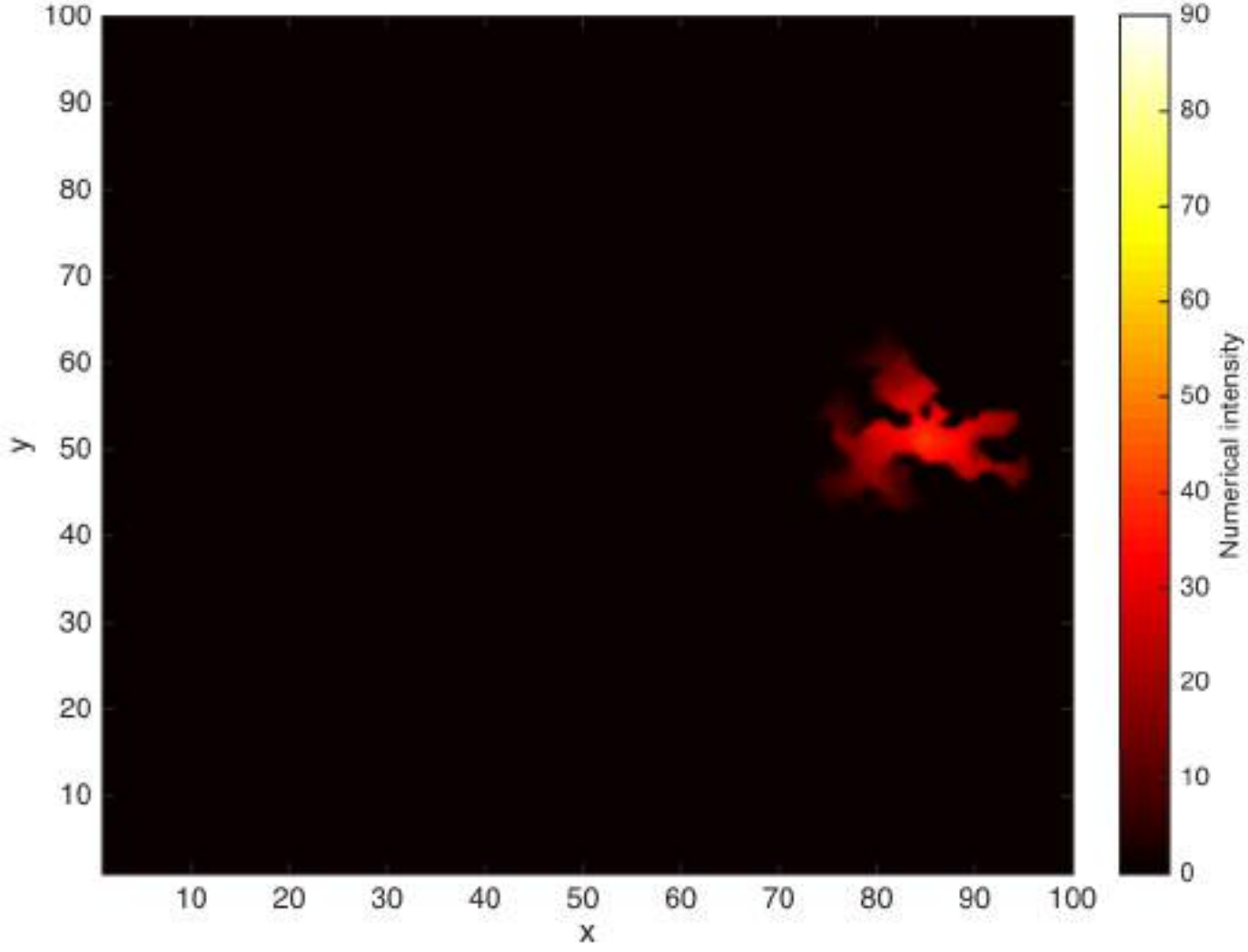
Numerical intensity

Animation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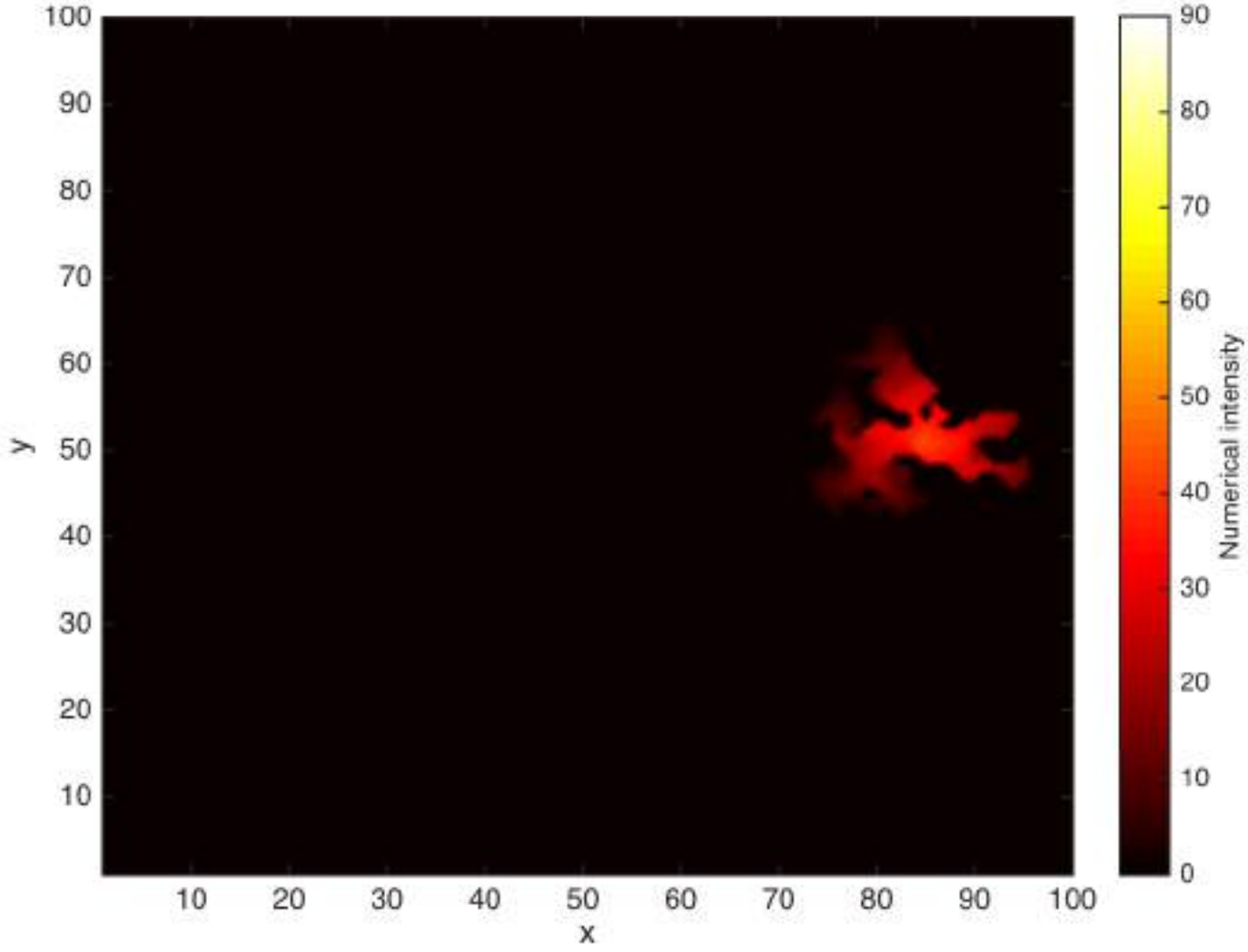
Numerical intensity

Animation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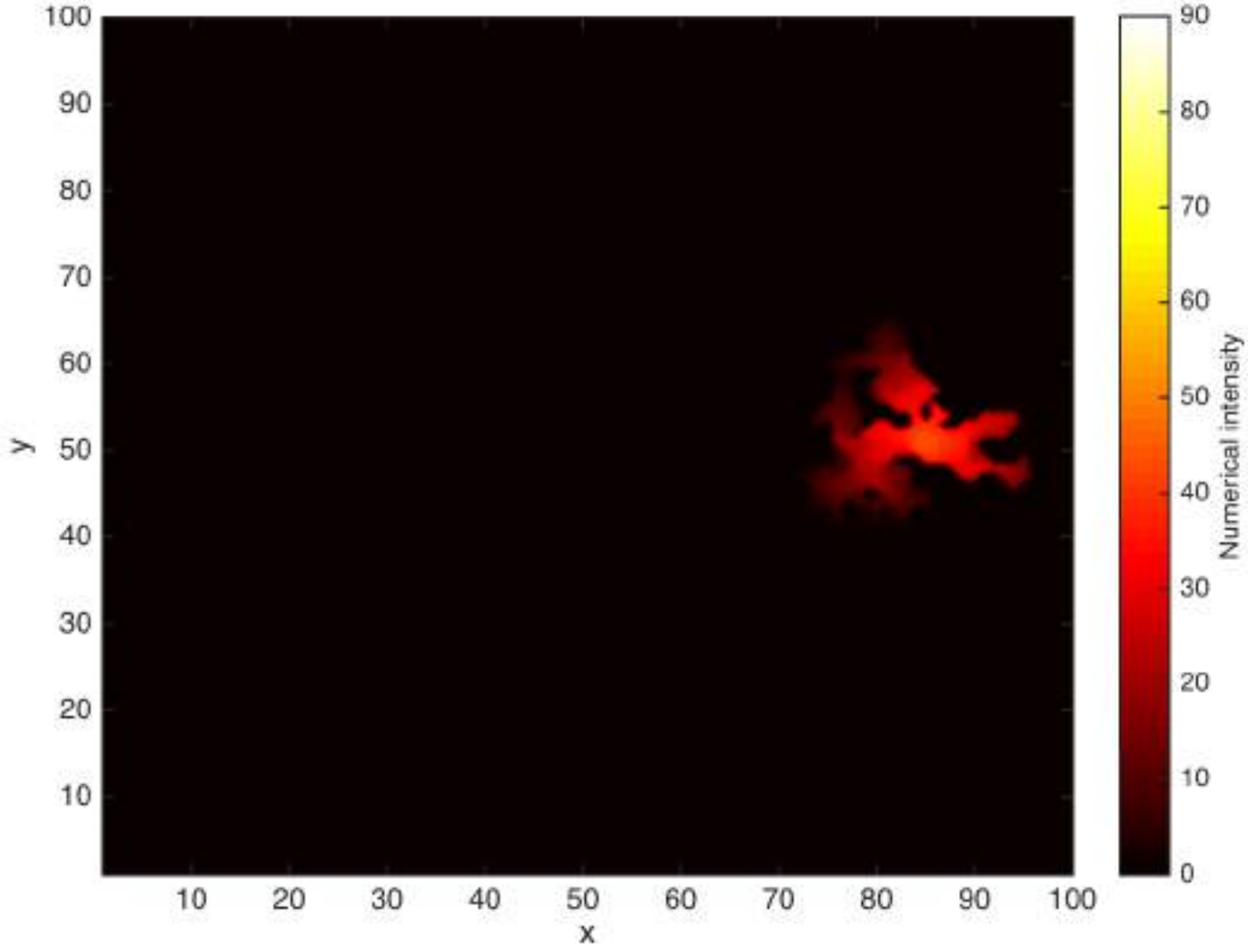
Numerical intensity

Animation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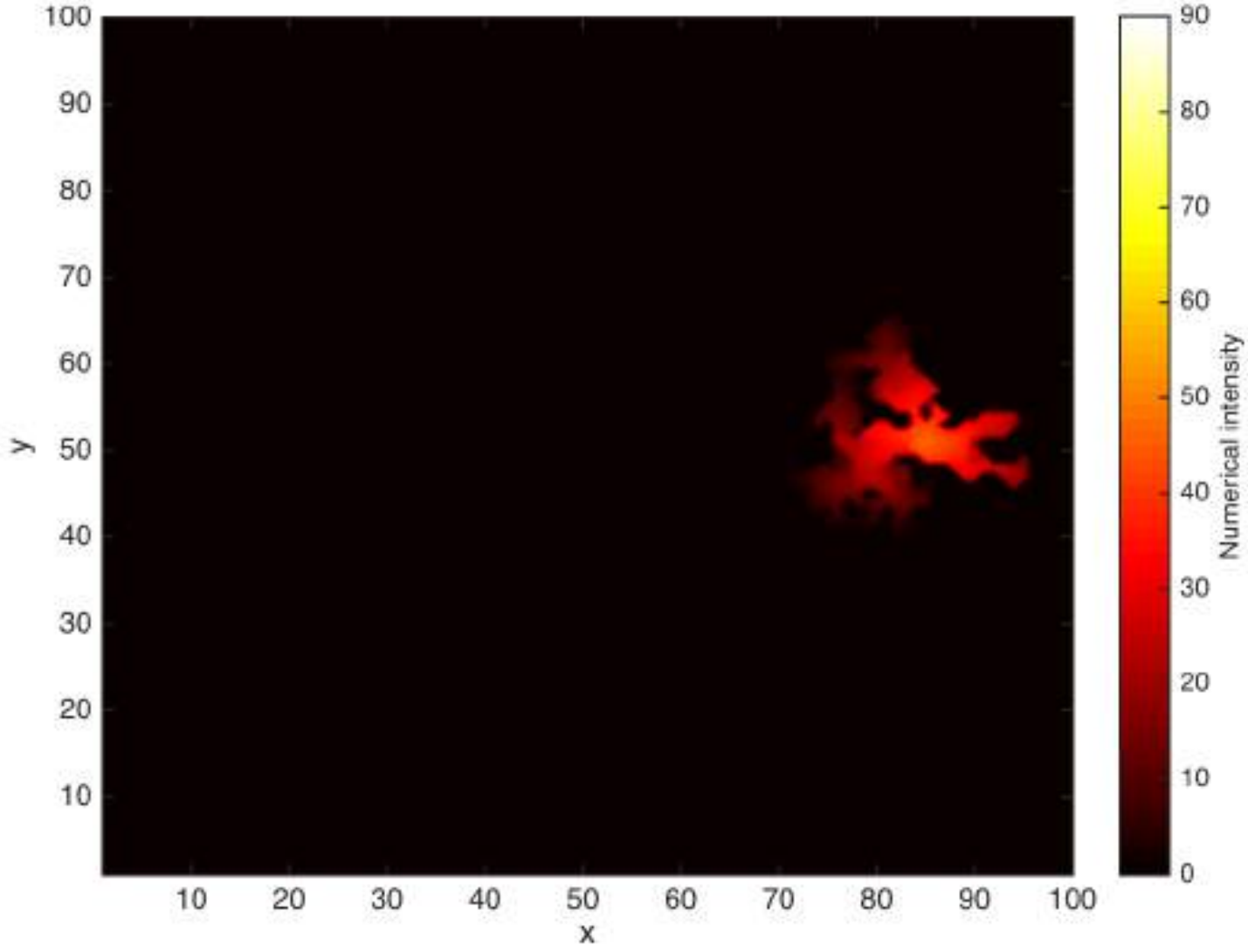
Animation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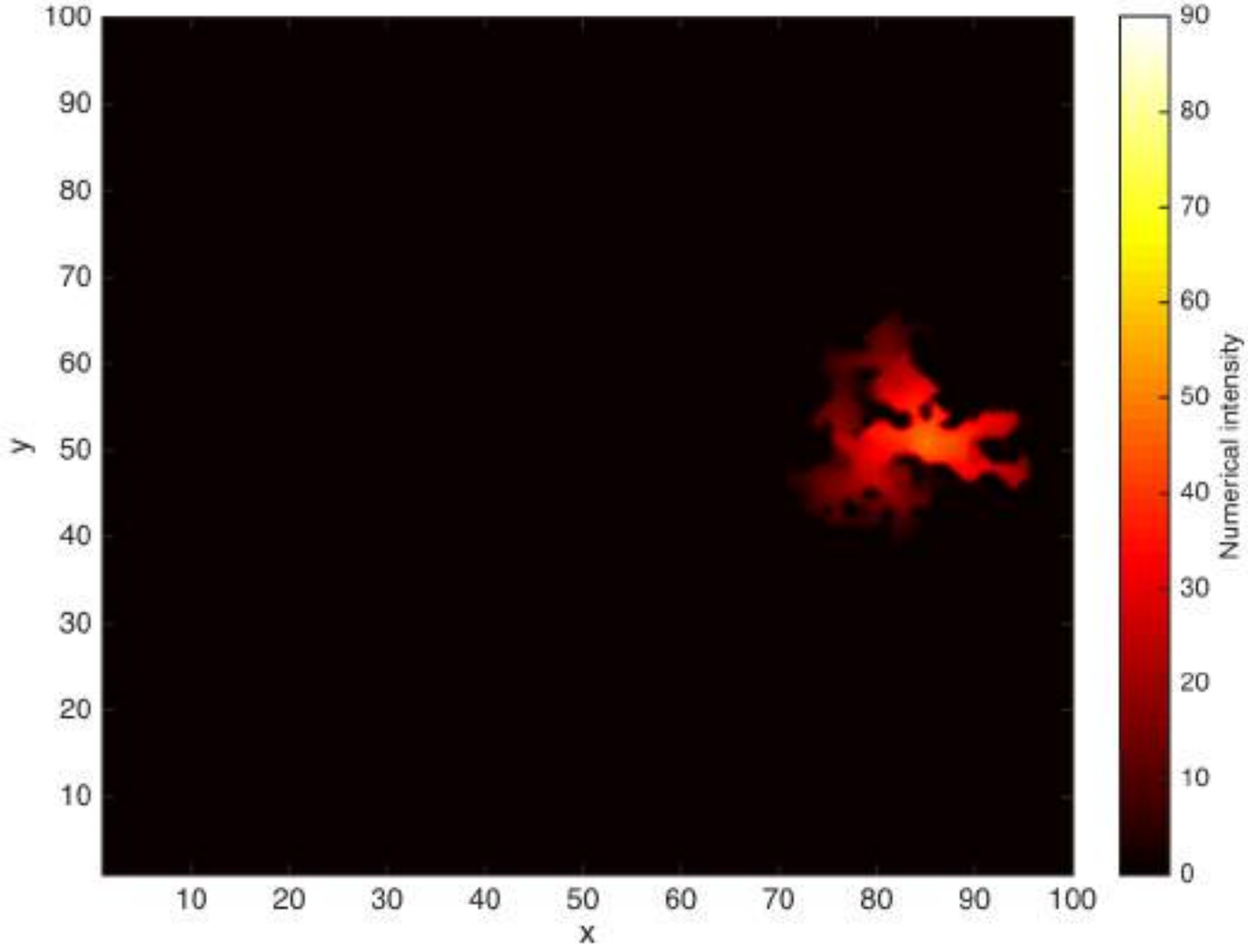
Animation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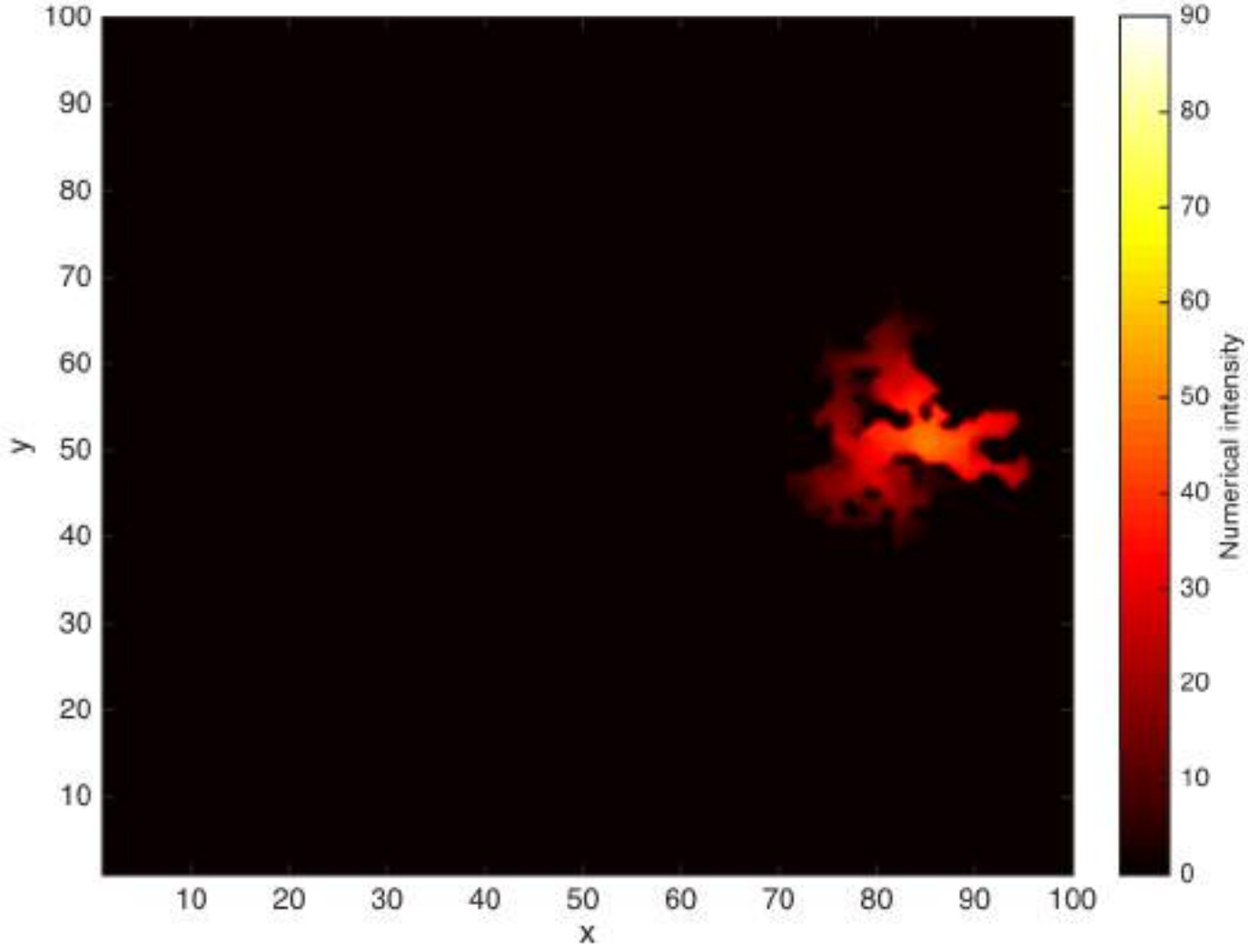
Animation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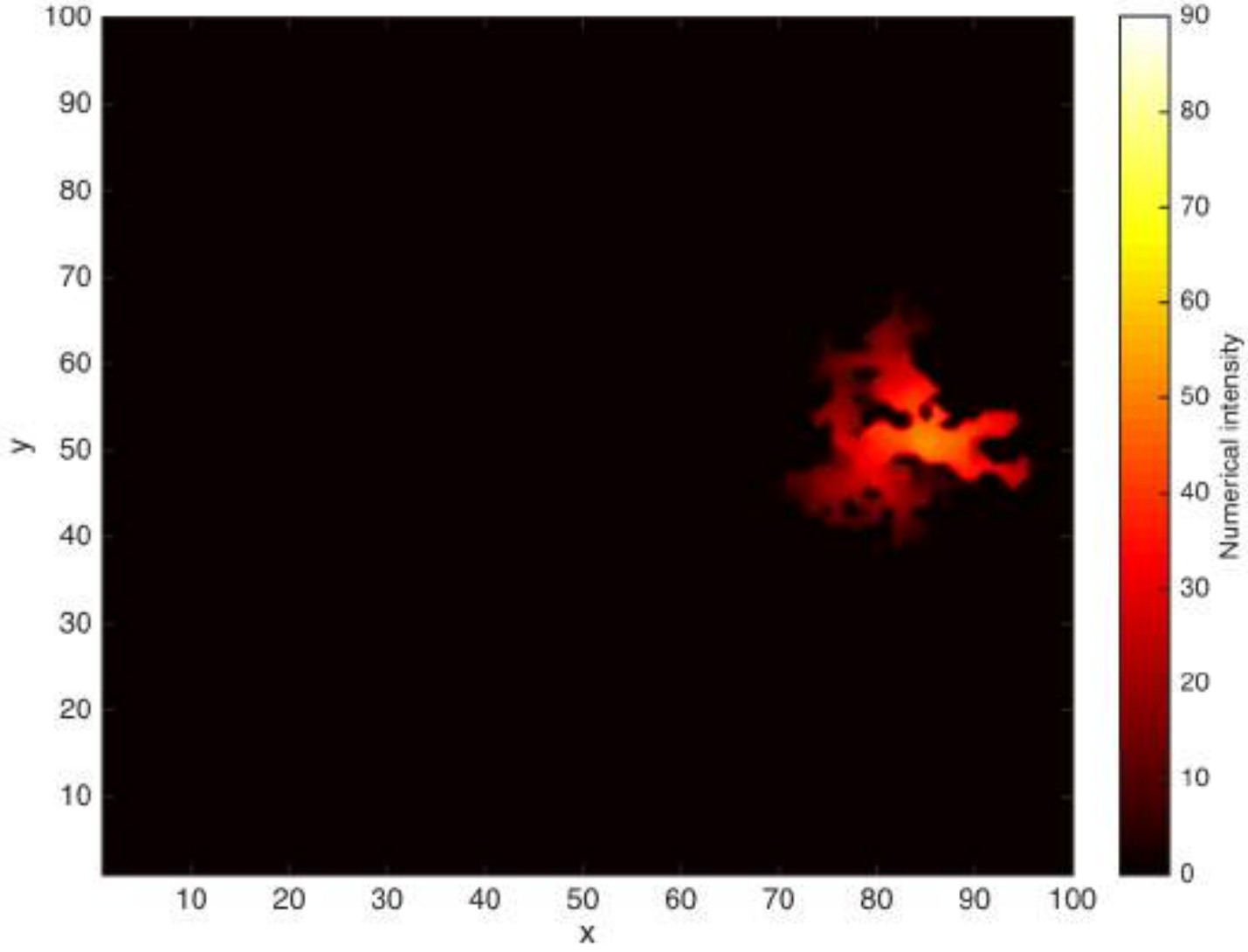
Animation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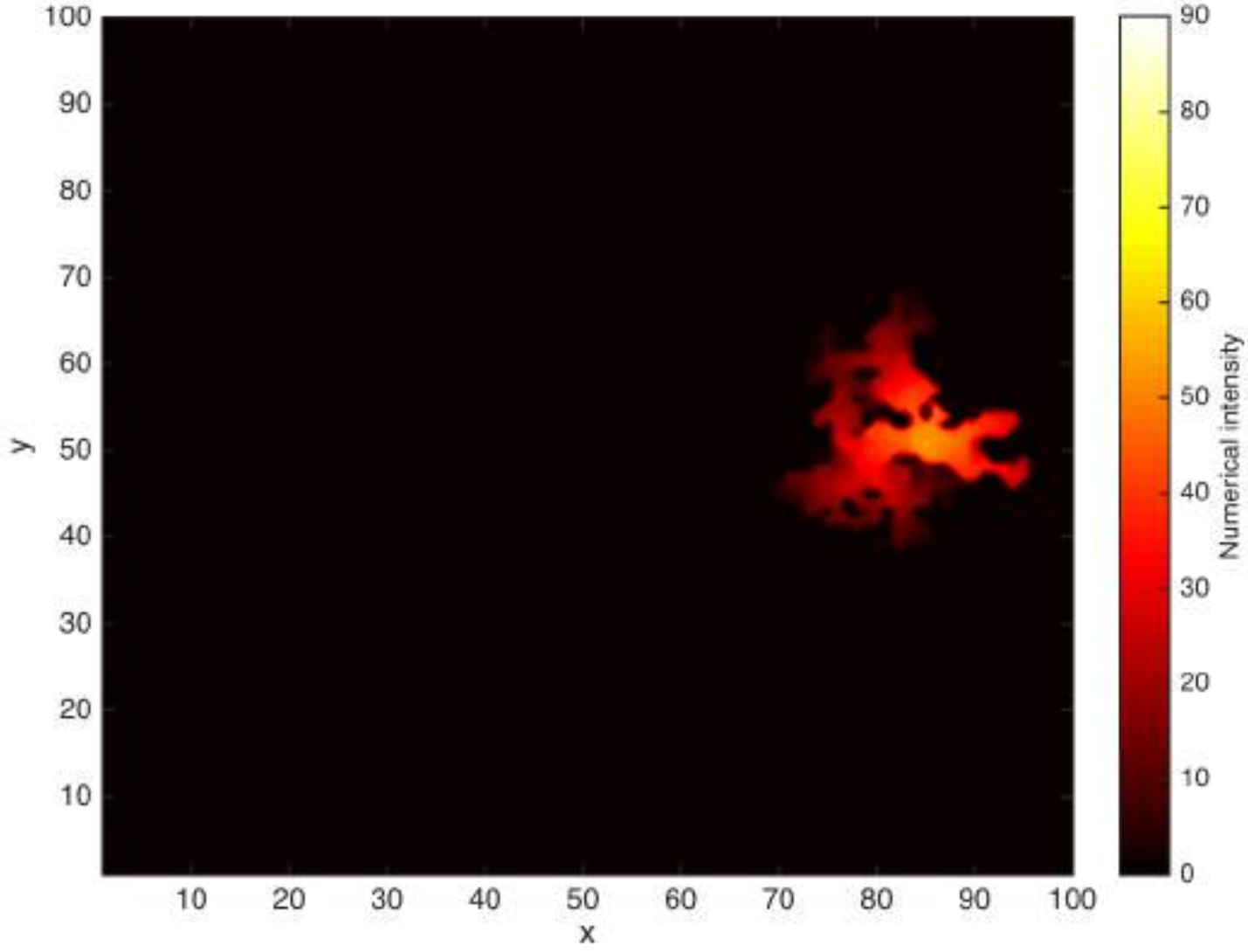
Animation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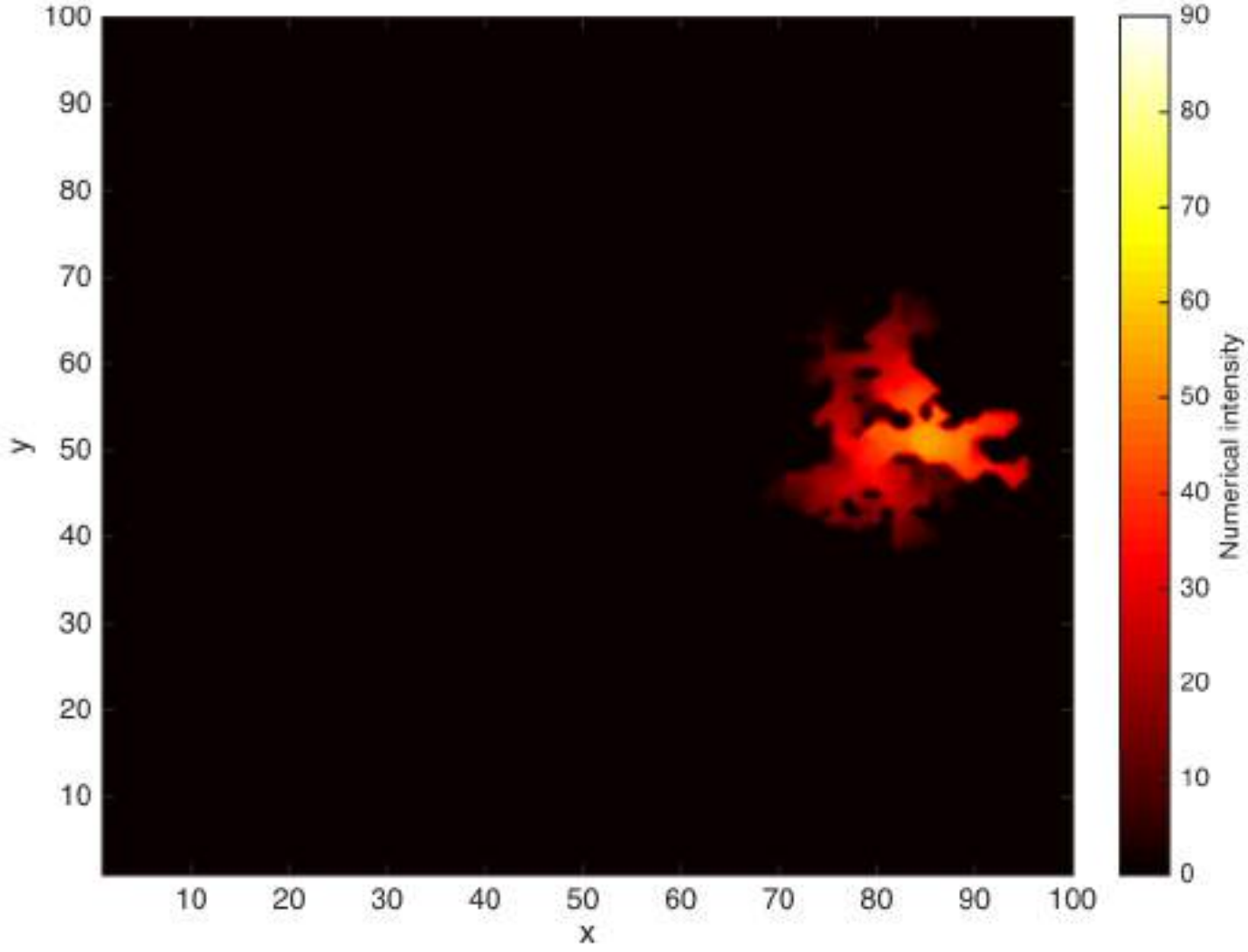
Numerical intensity

Animation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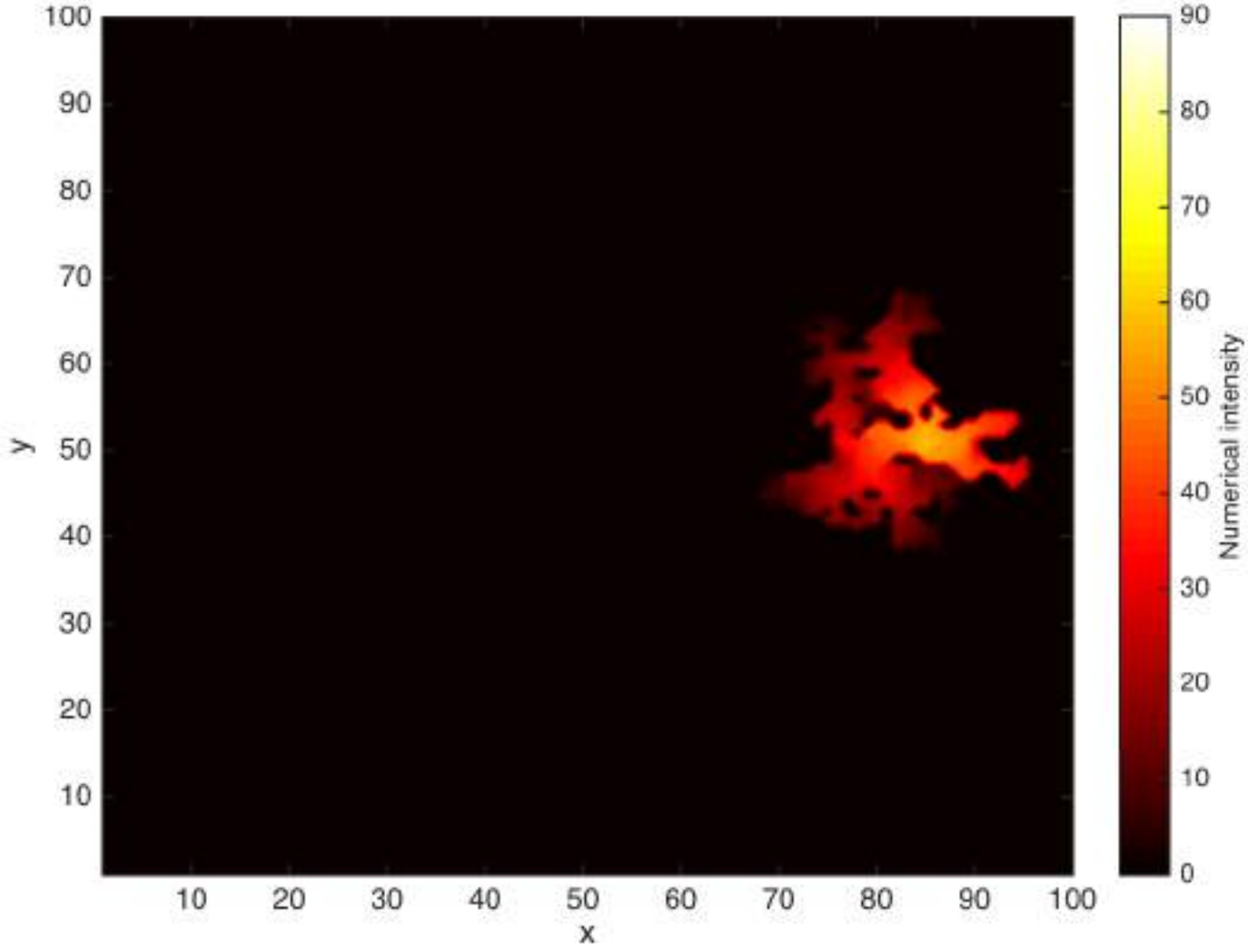
Numerical intensity

Animation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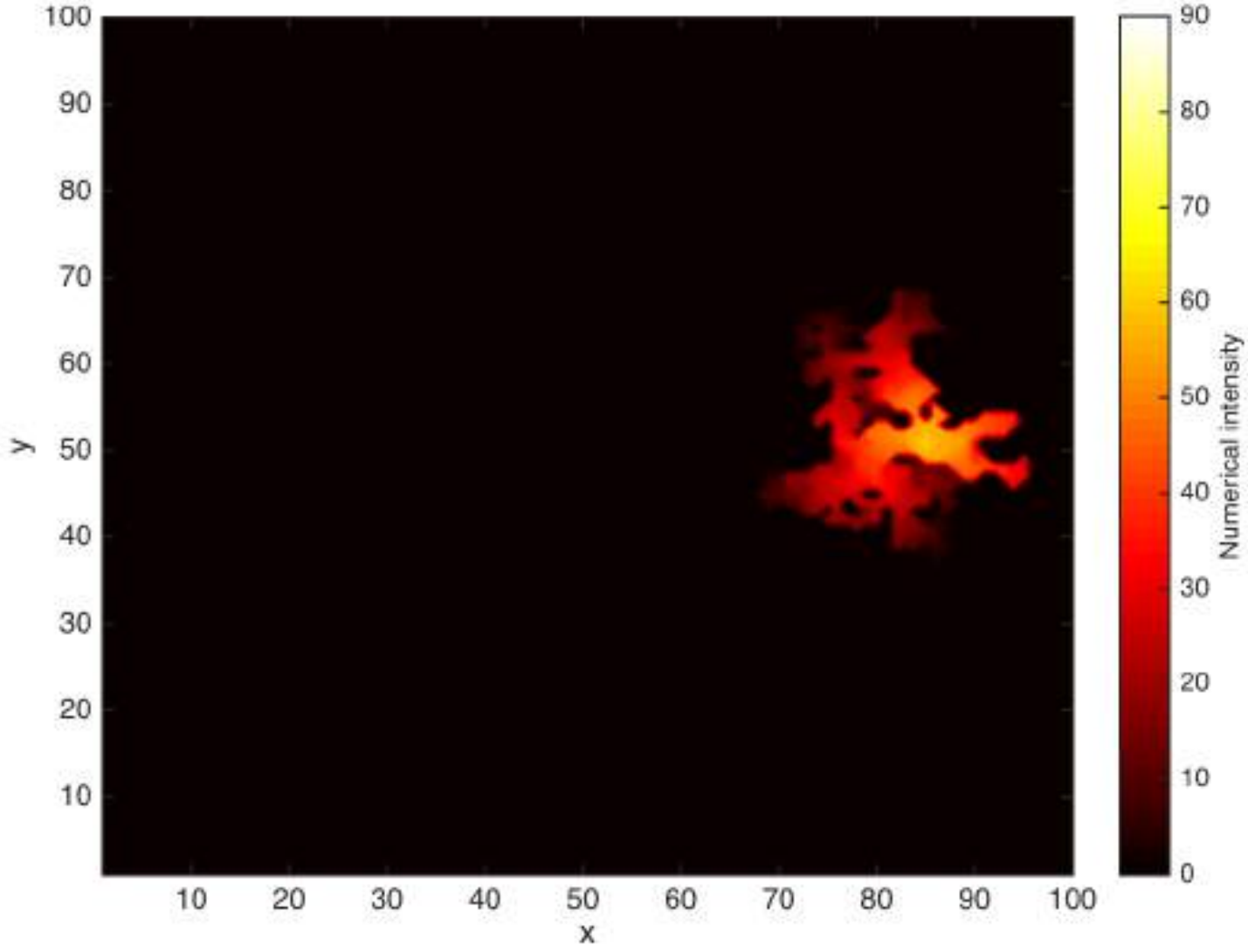
Numerical intensity

Animation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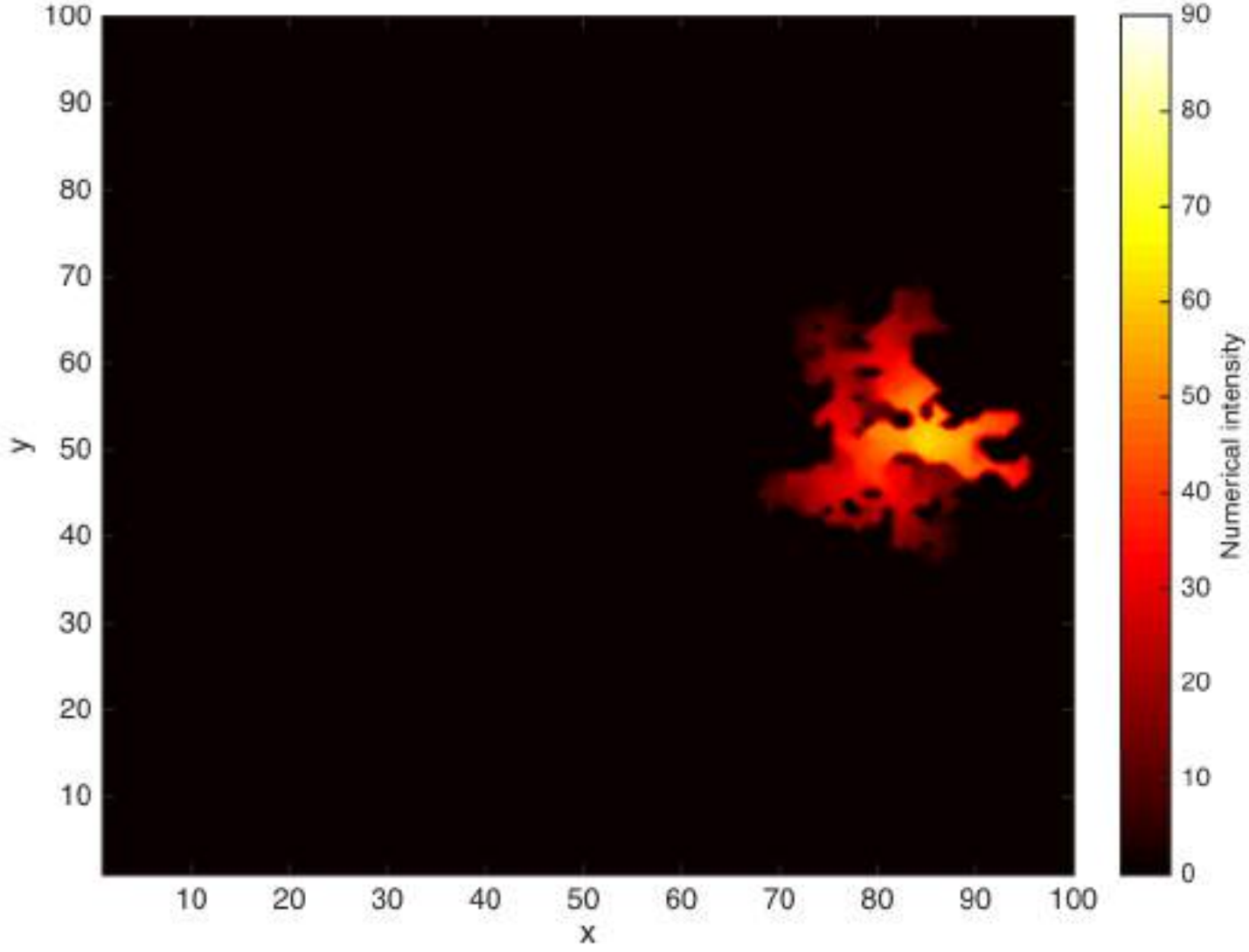
Numerical intensity

Animation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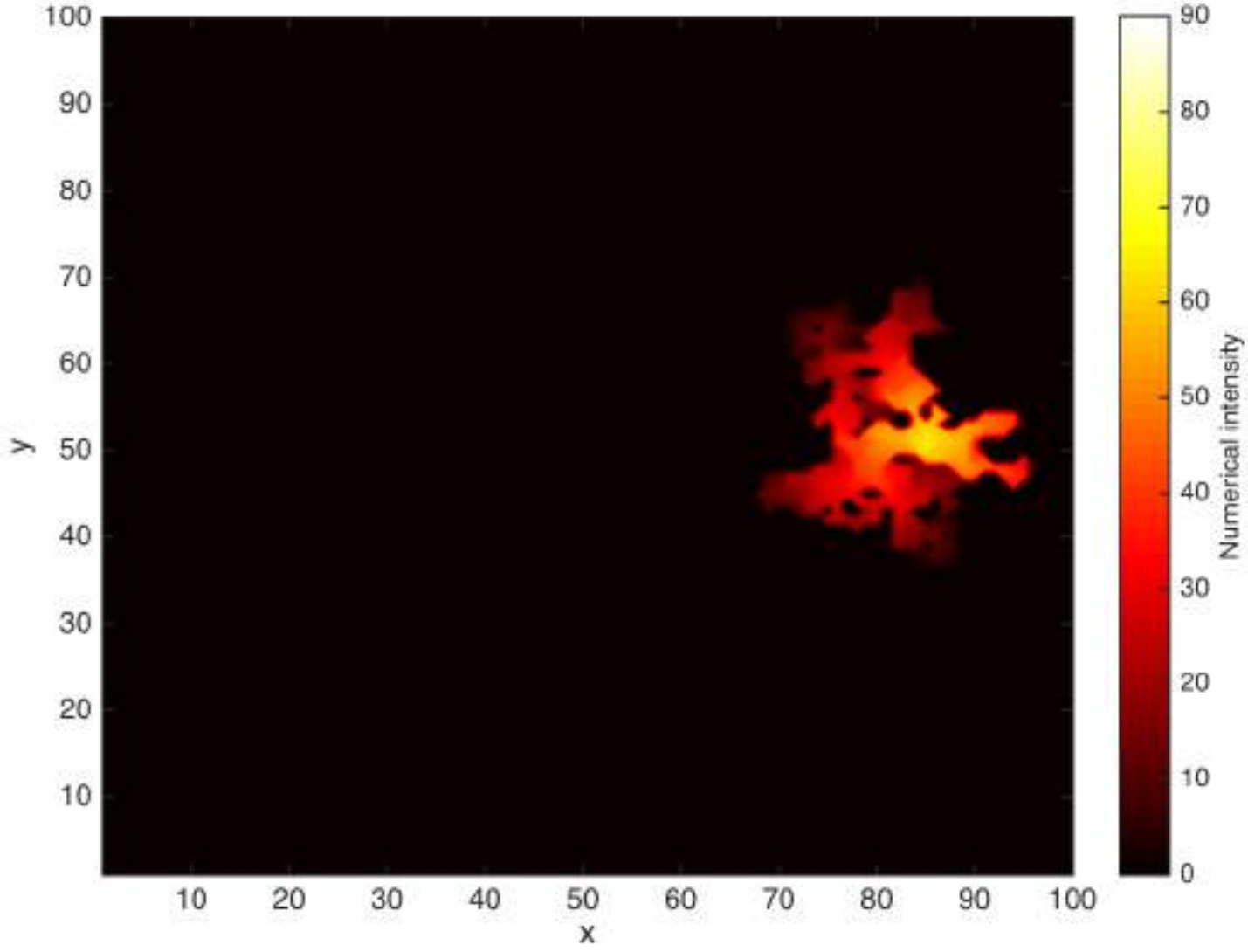
Numerical intensity

Animation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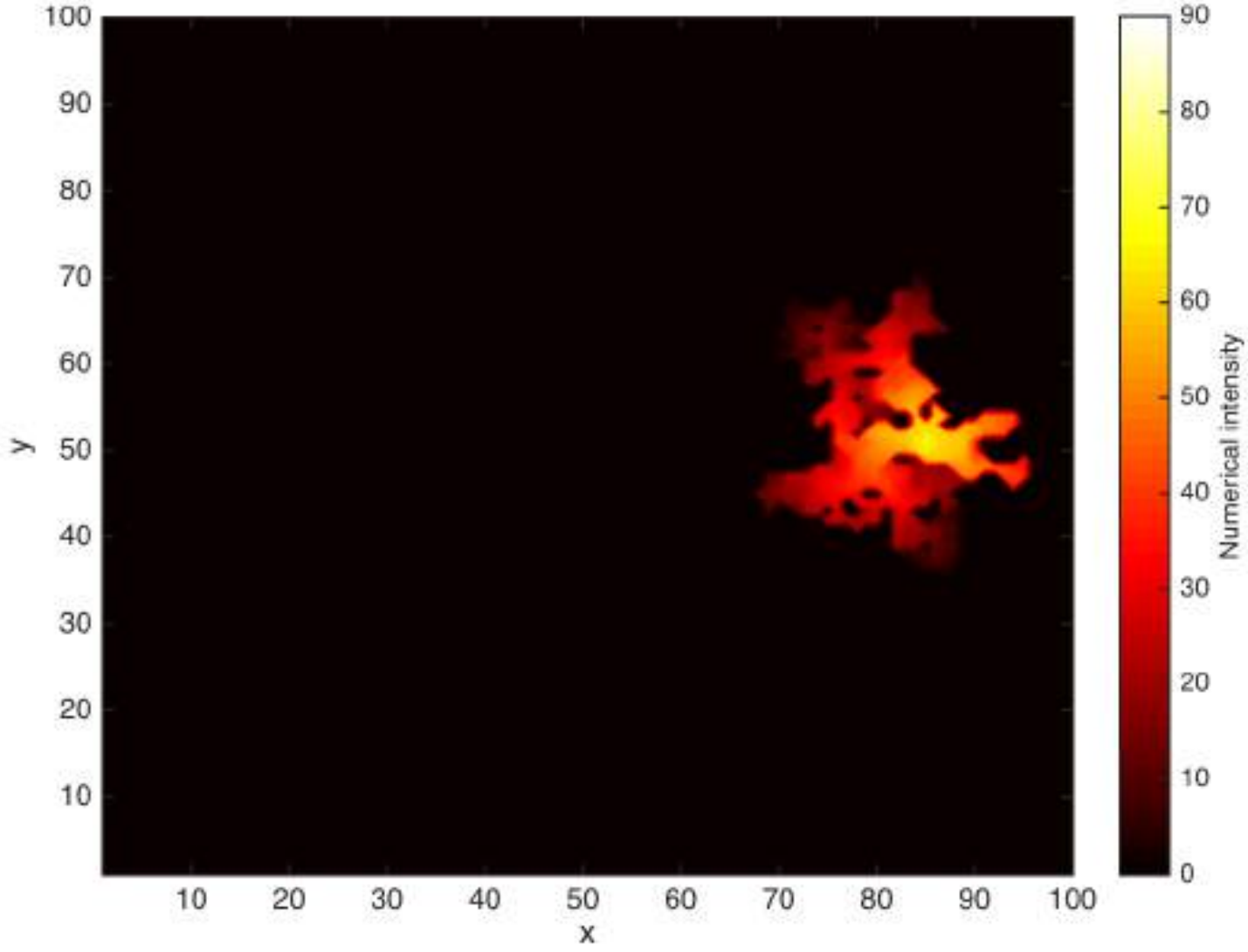
Numerical intensity

Animation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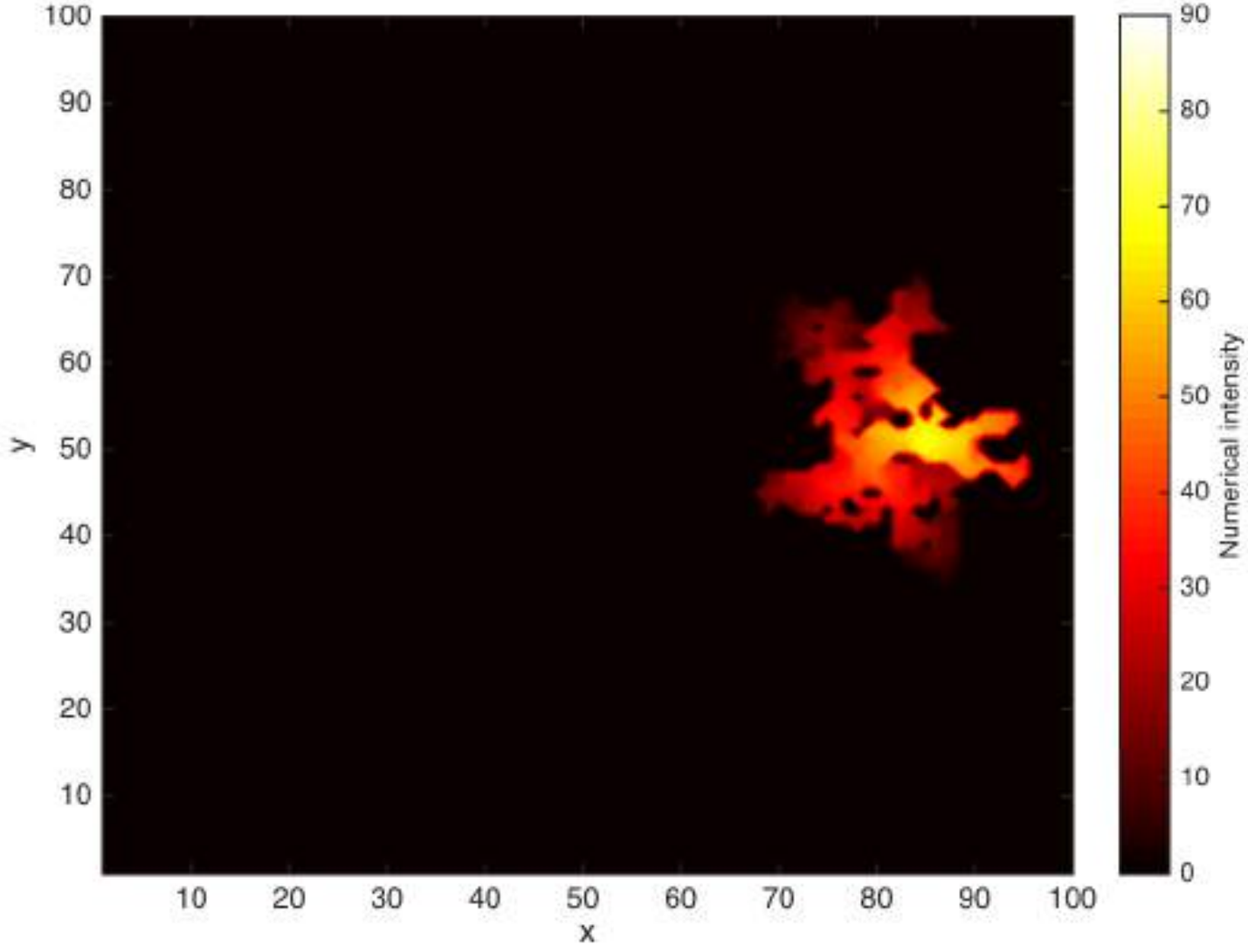
Numerical intensity

Animation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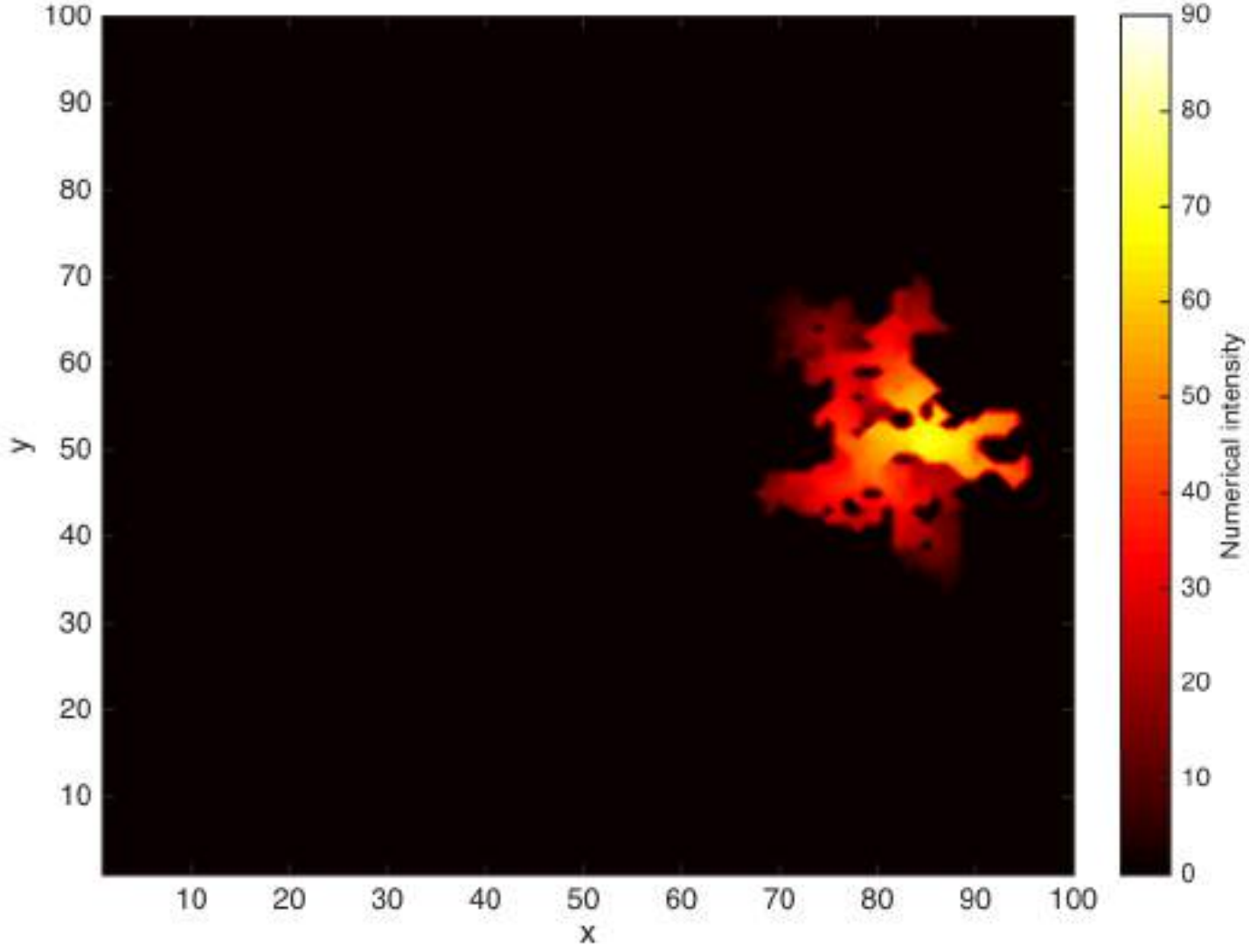
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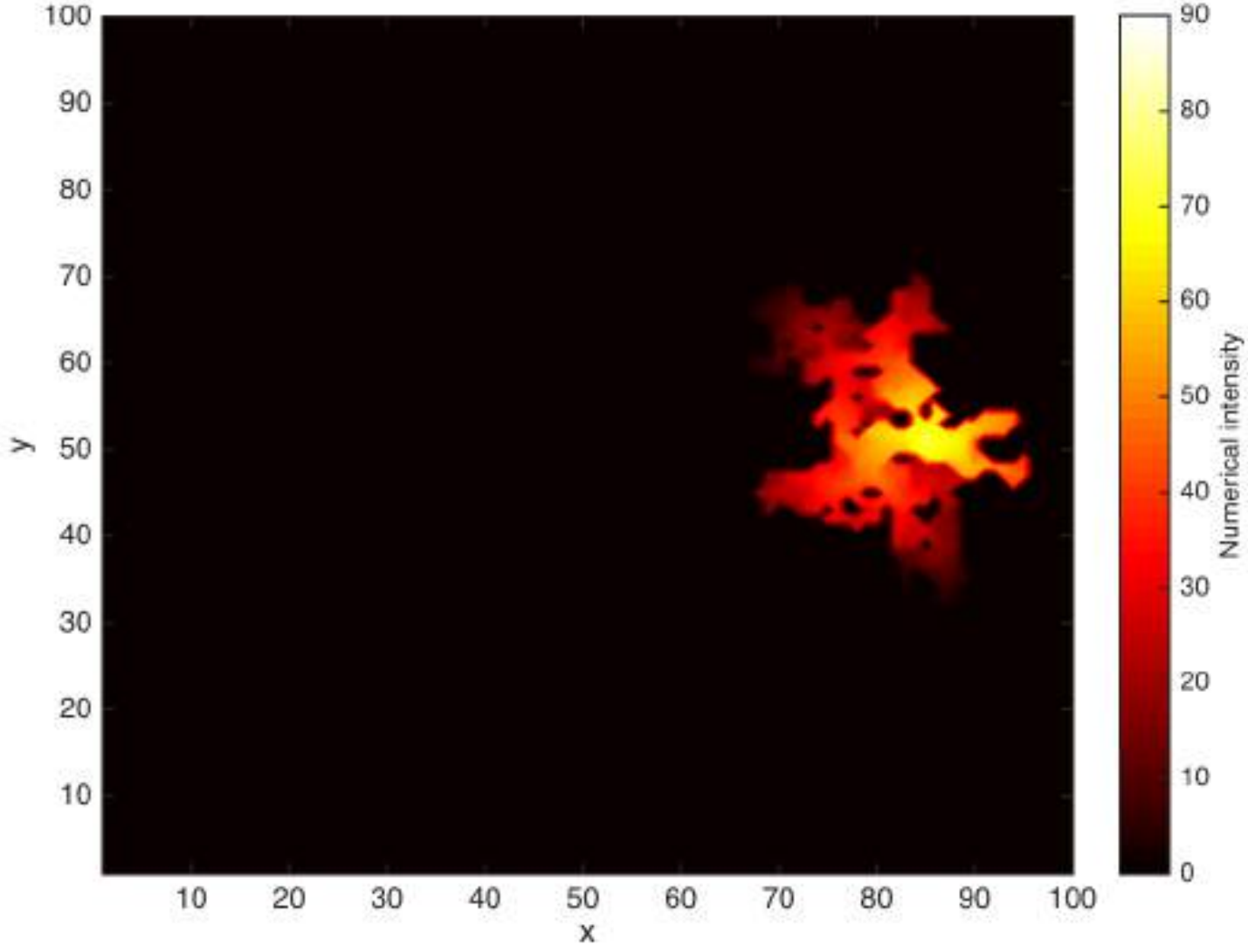
Animation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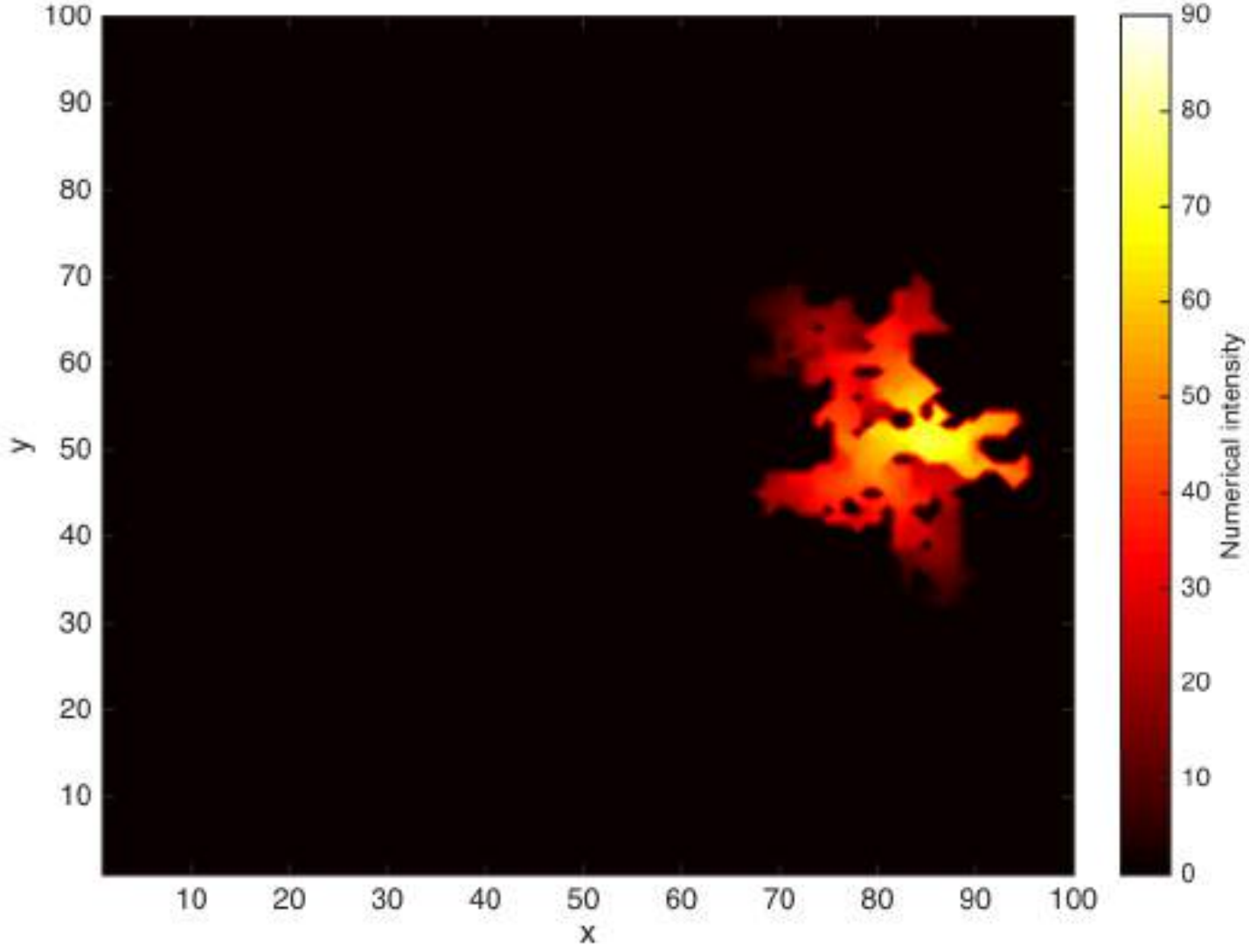
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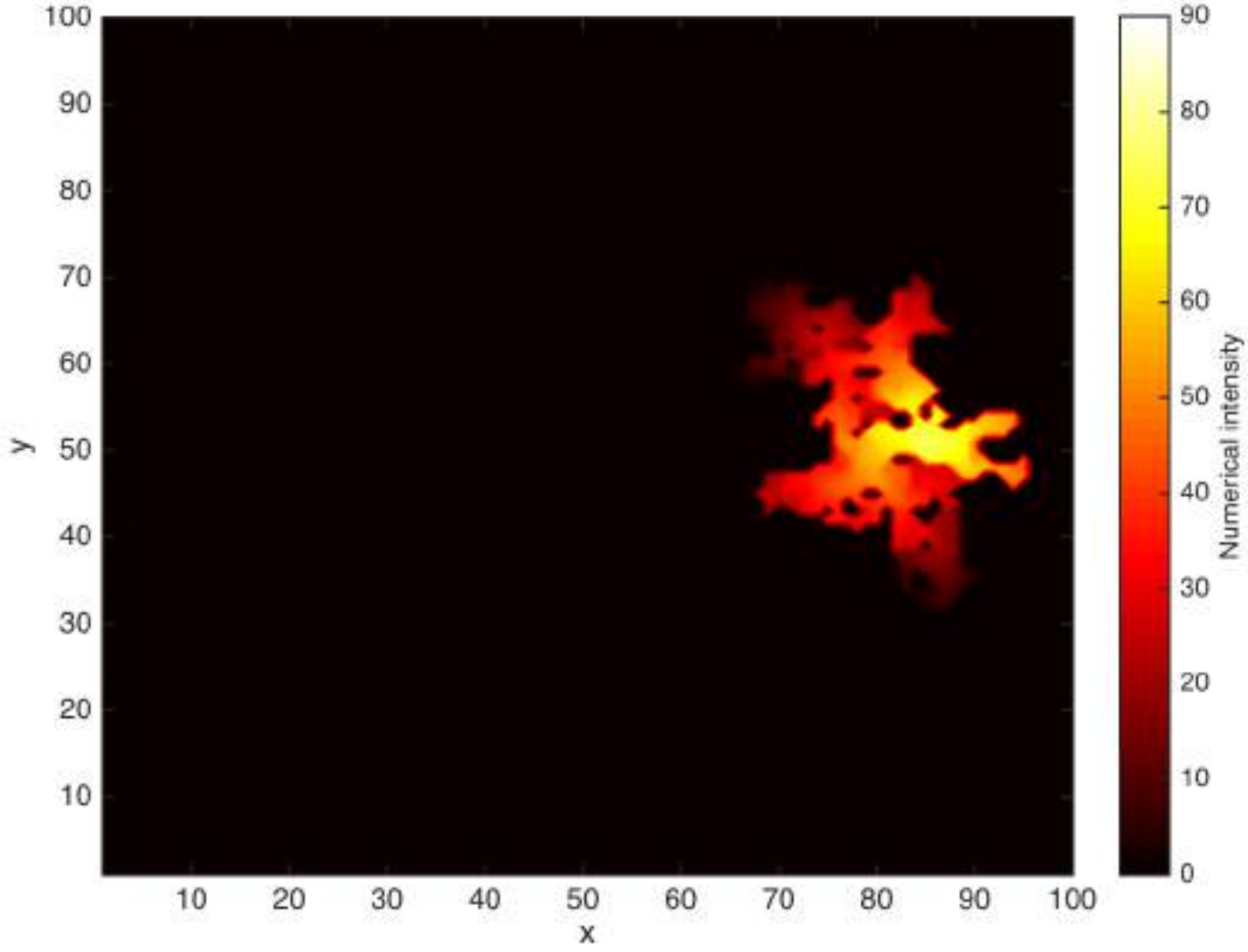
Animation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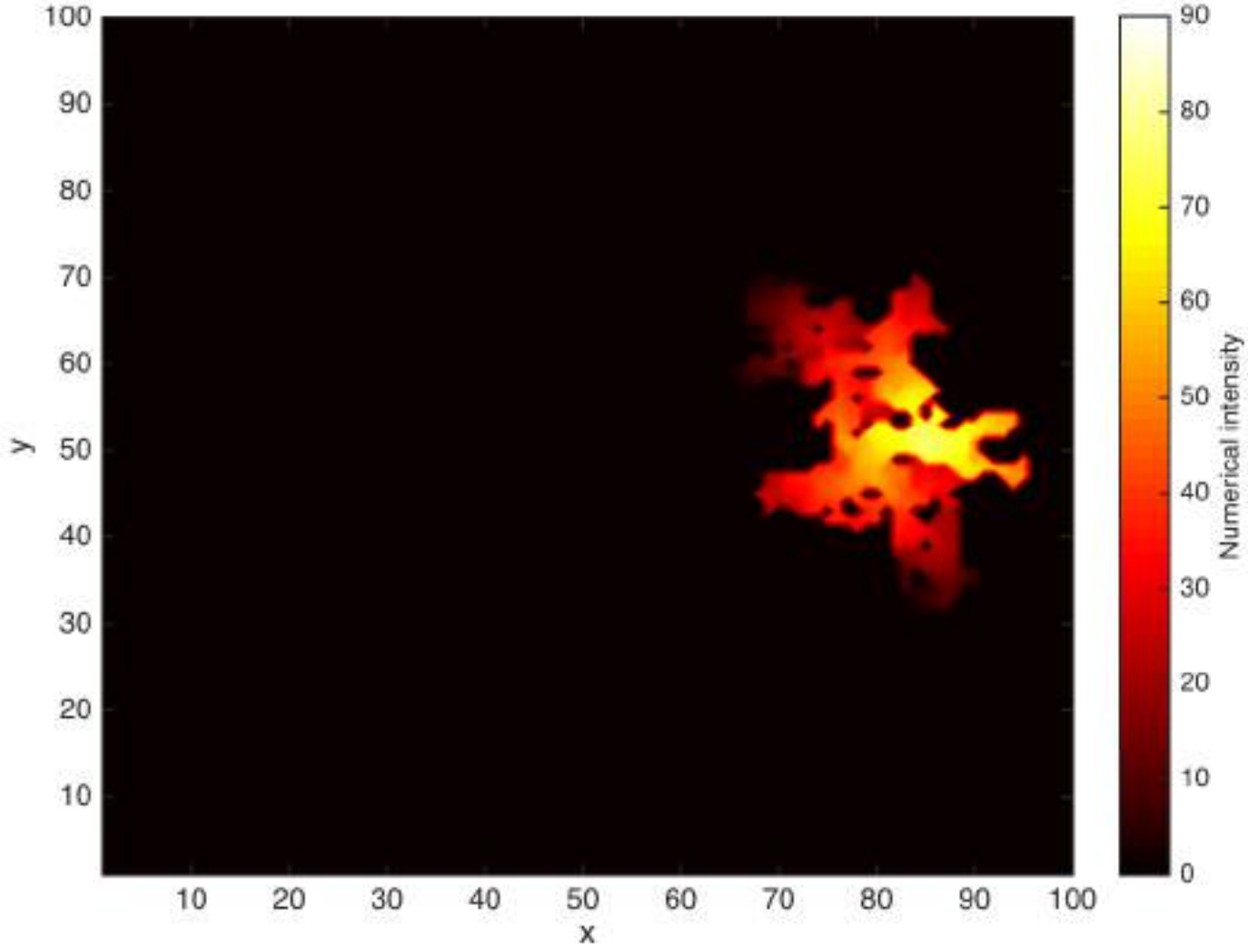
Numerical intensity

Animation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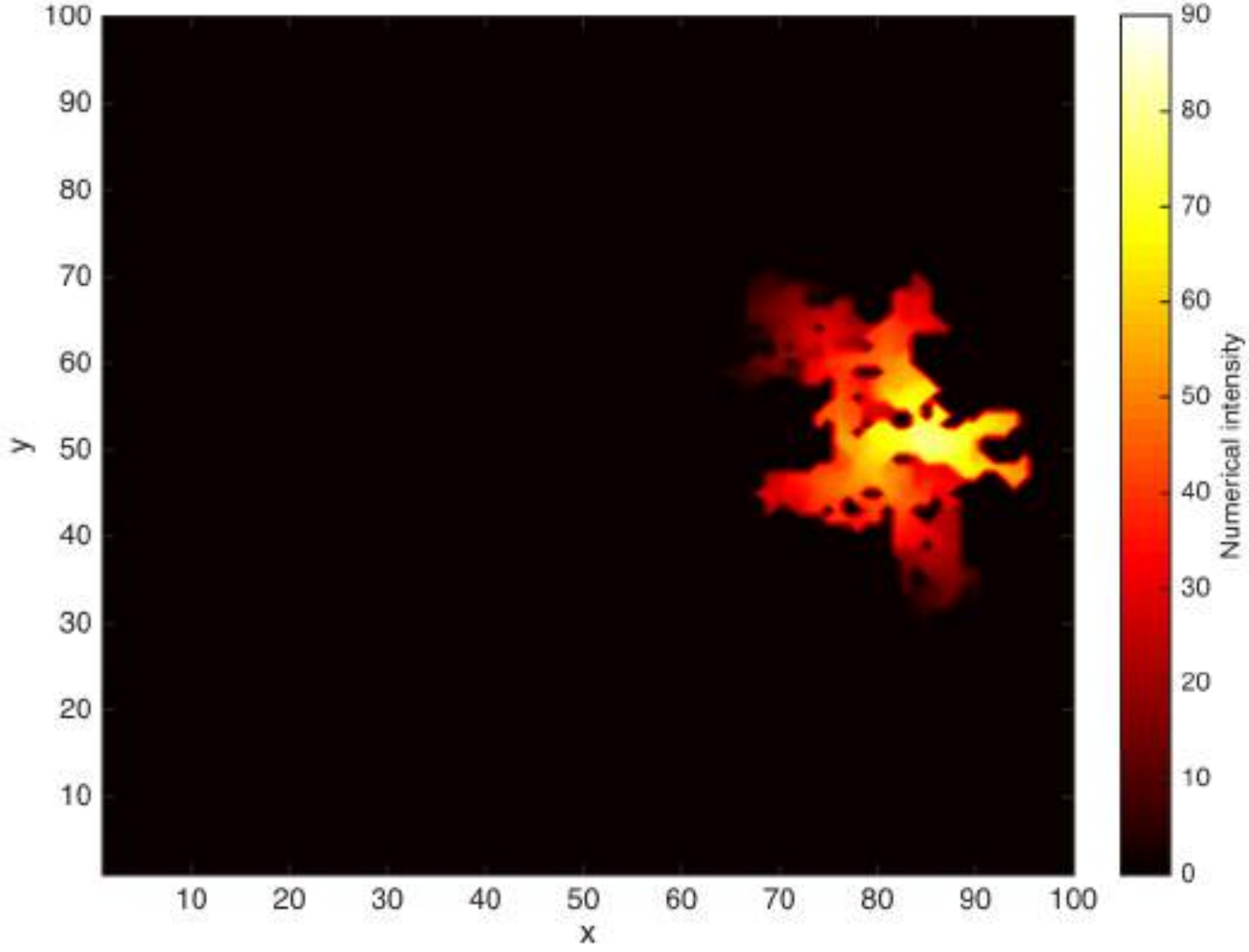
Animation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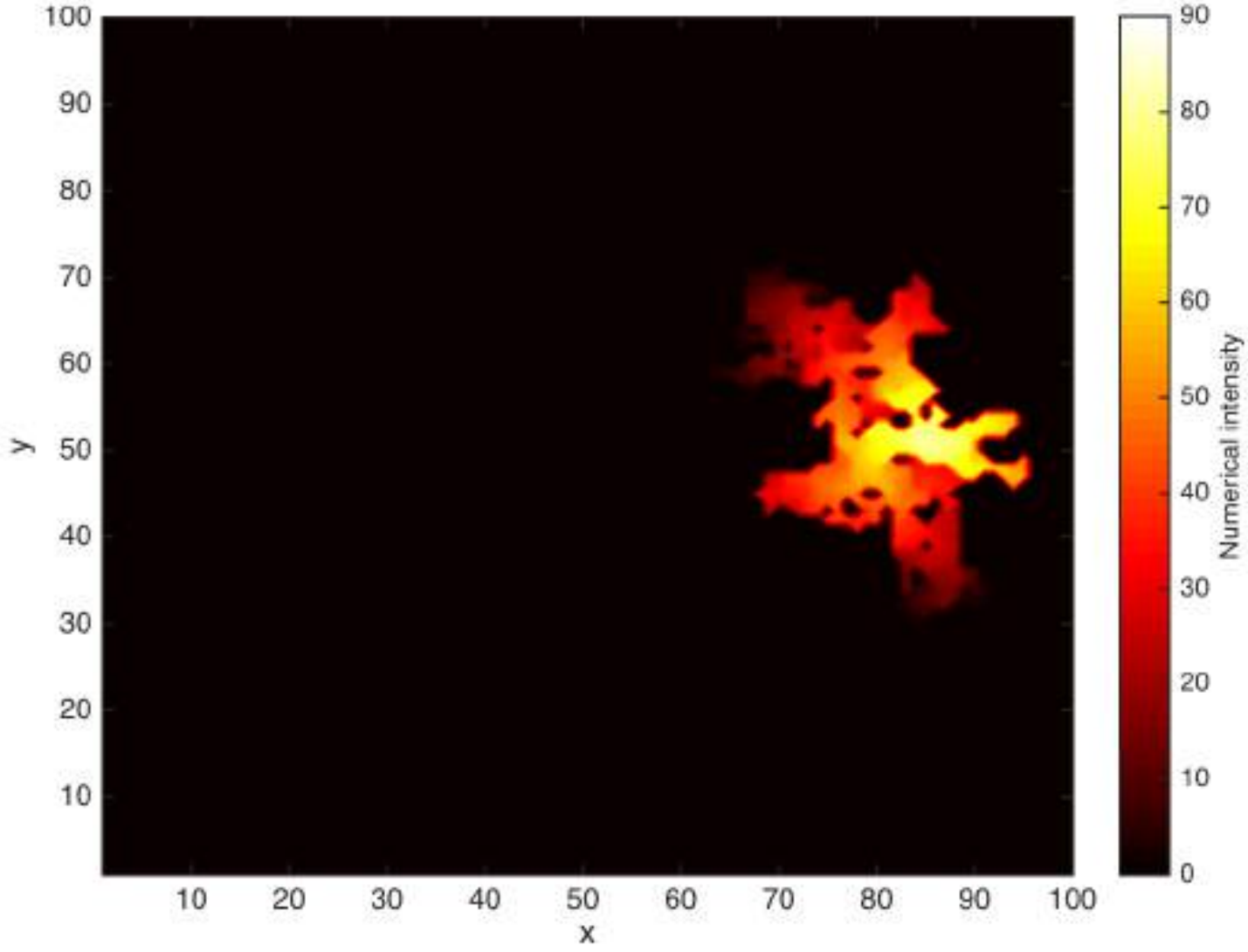
Animation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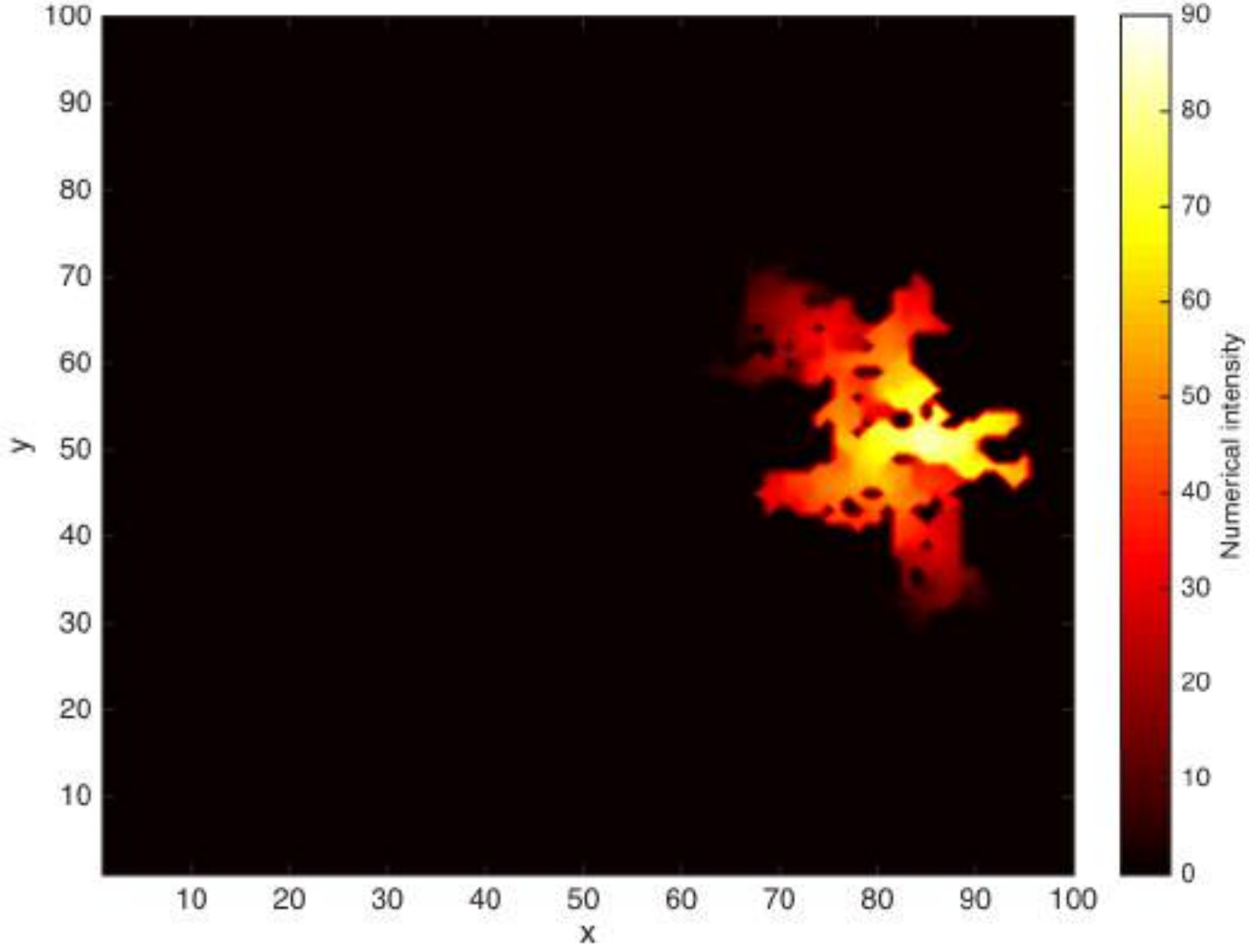
Animation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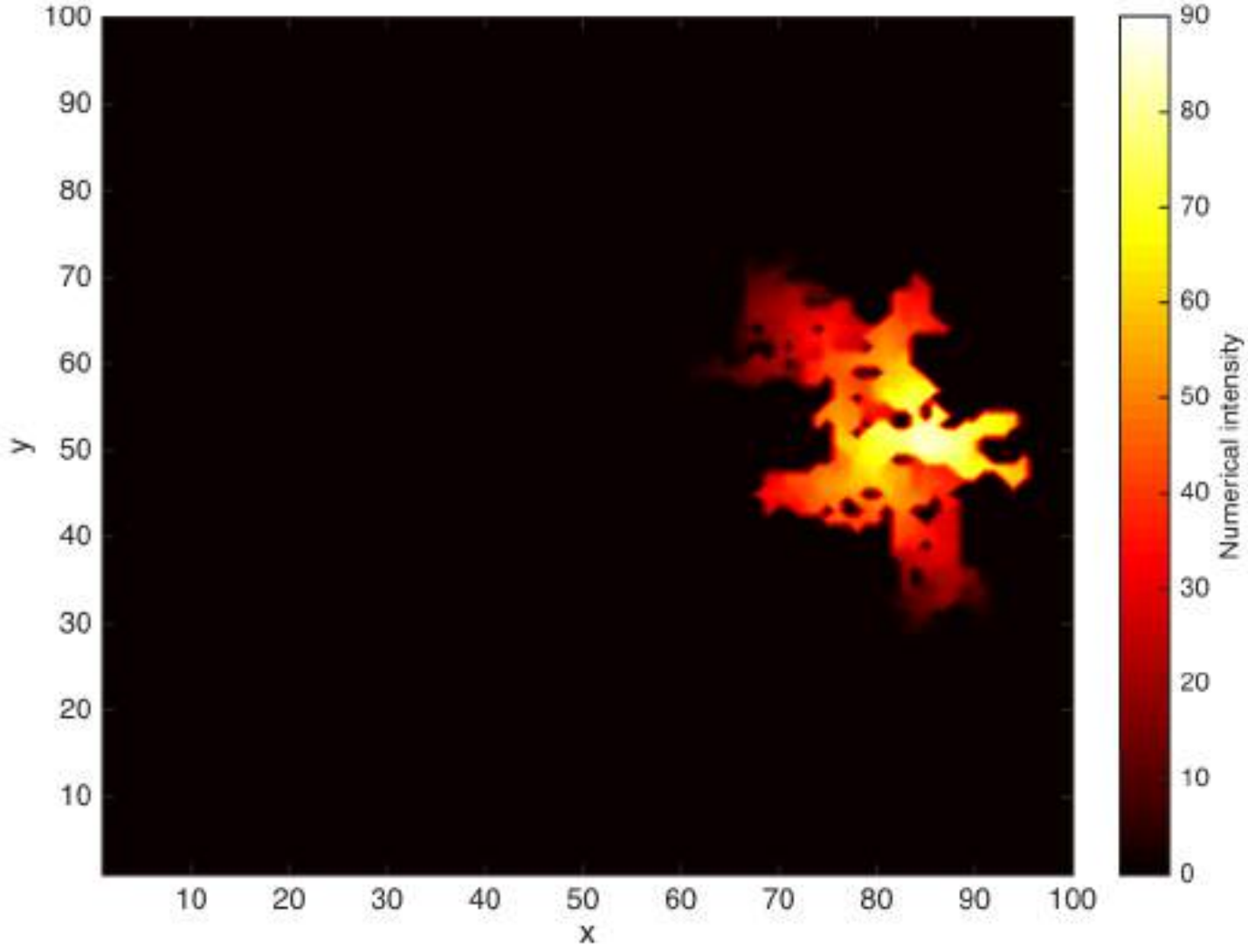
Animation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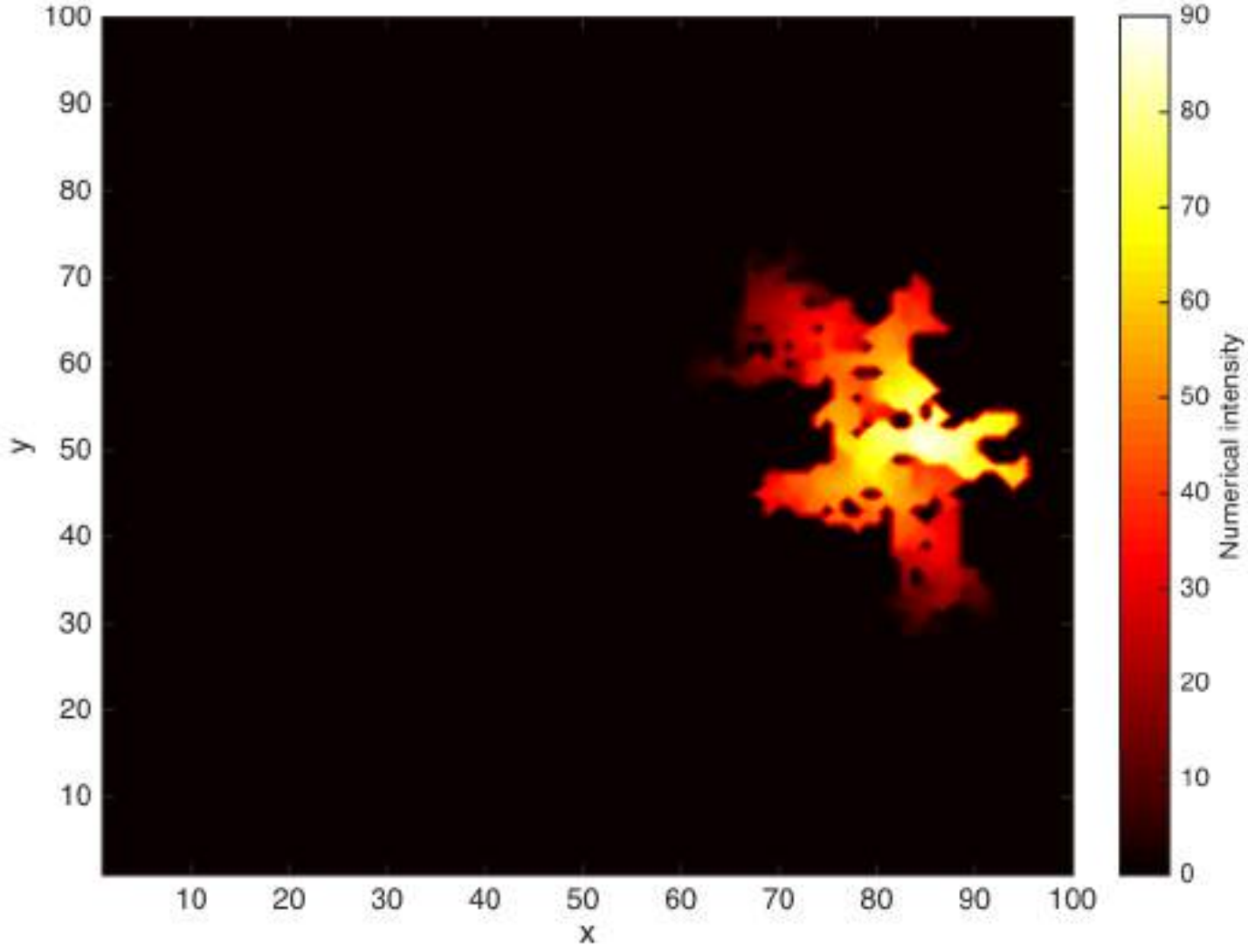
Animation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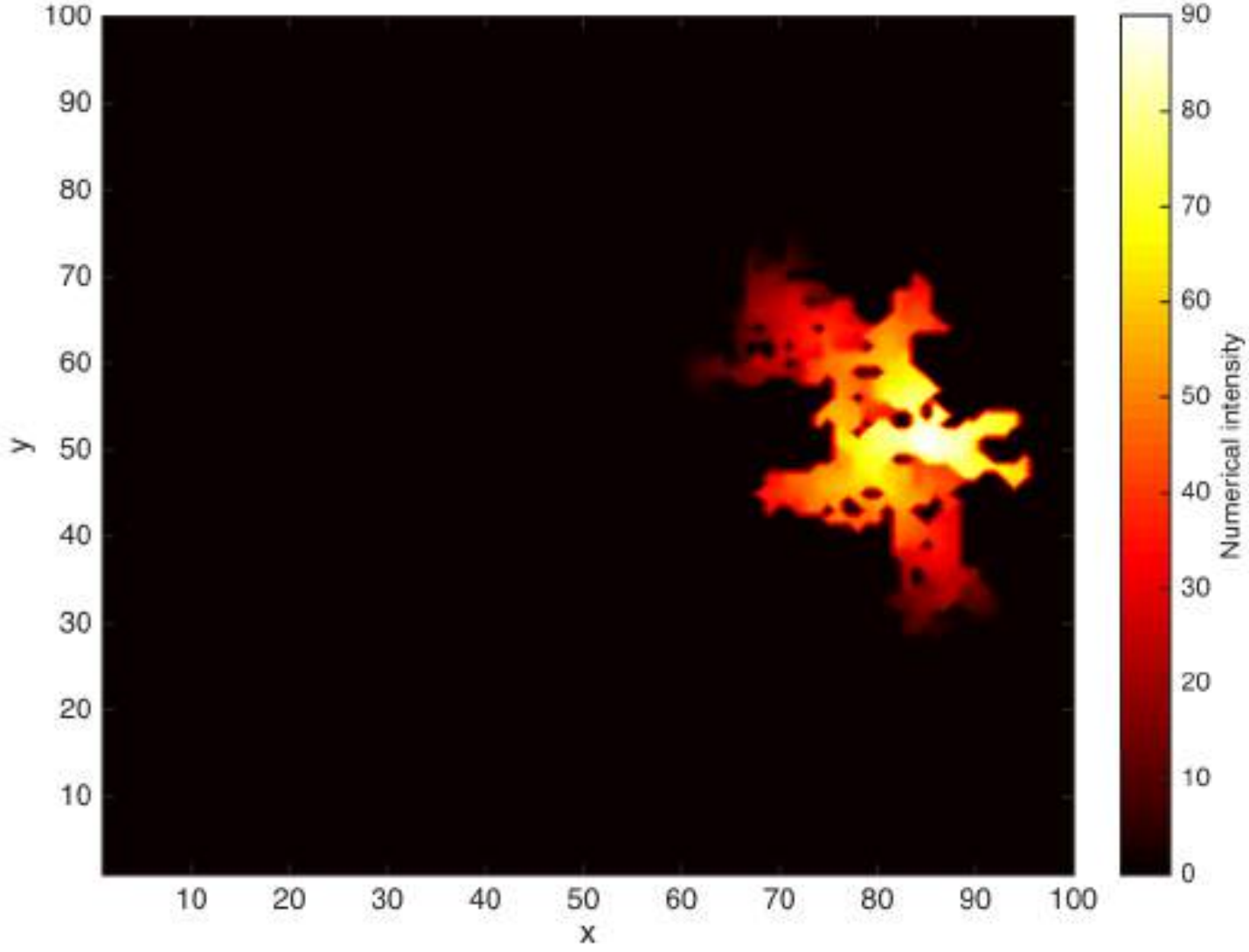
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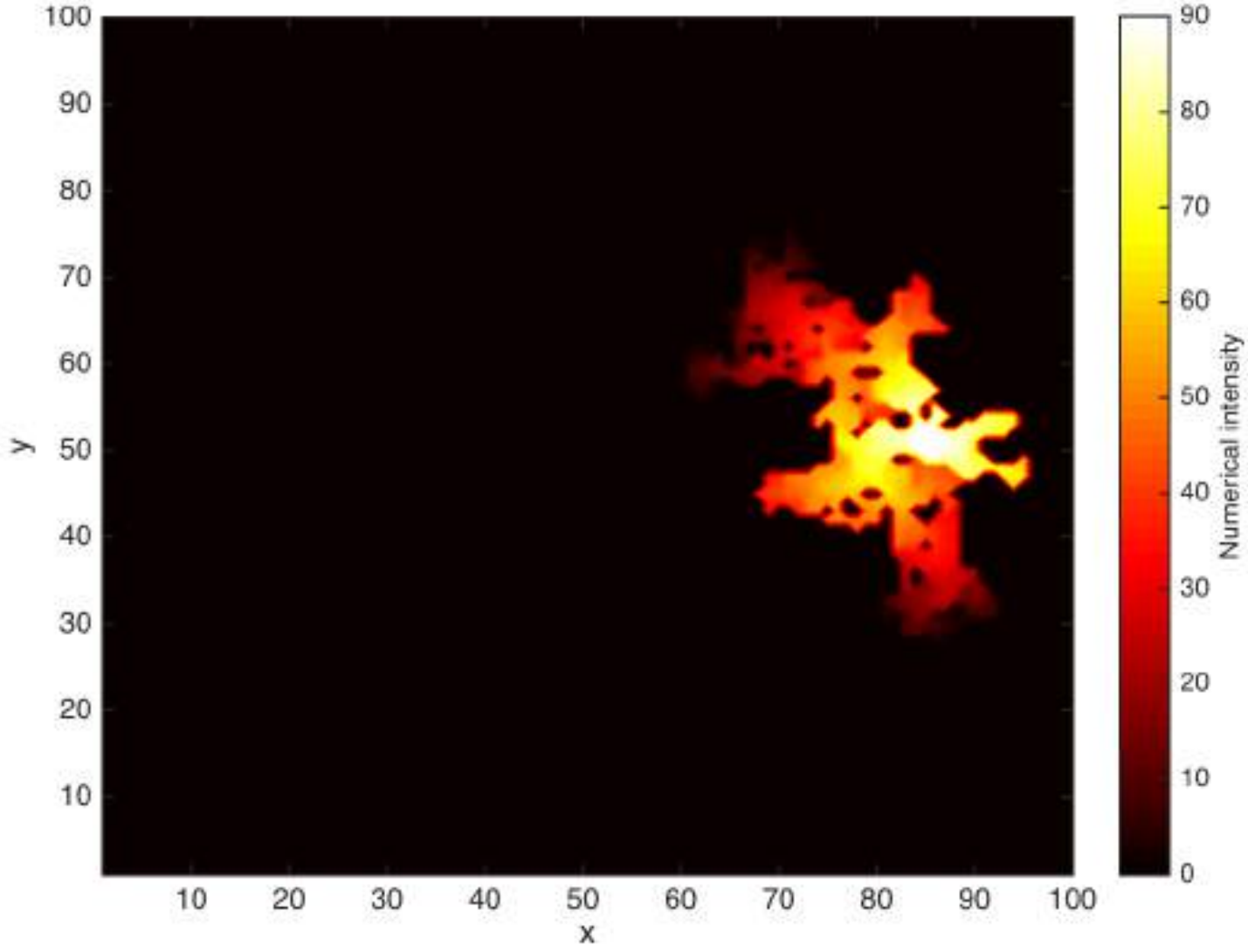
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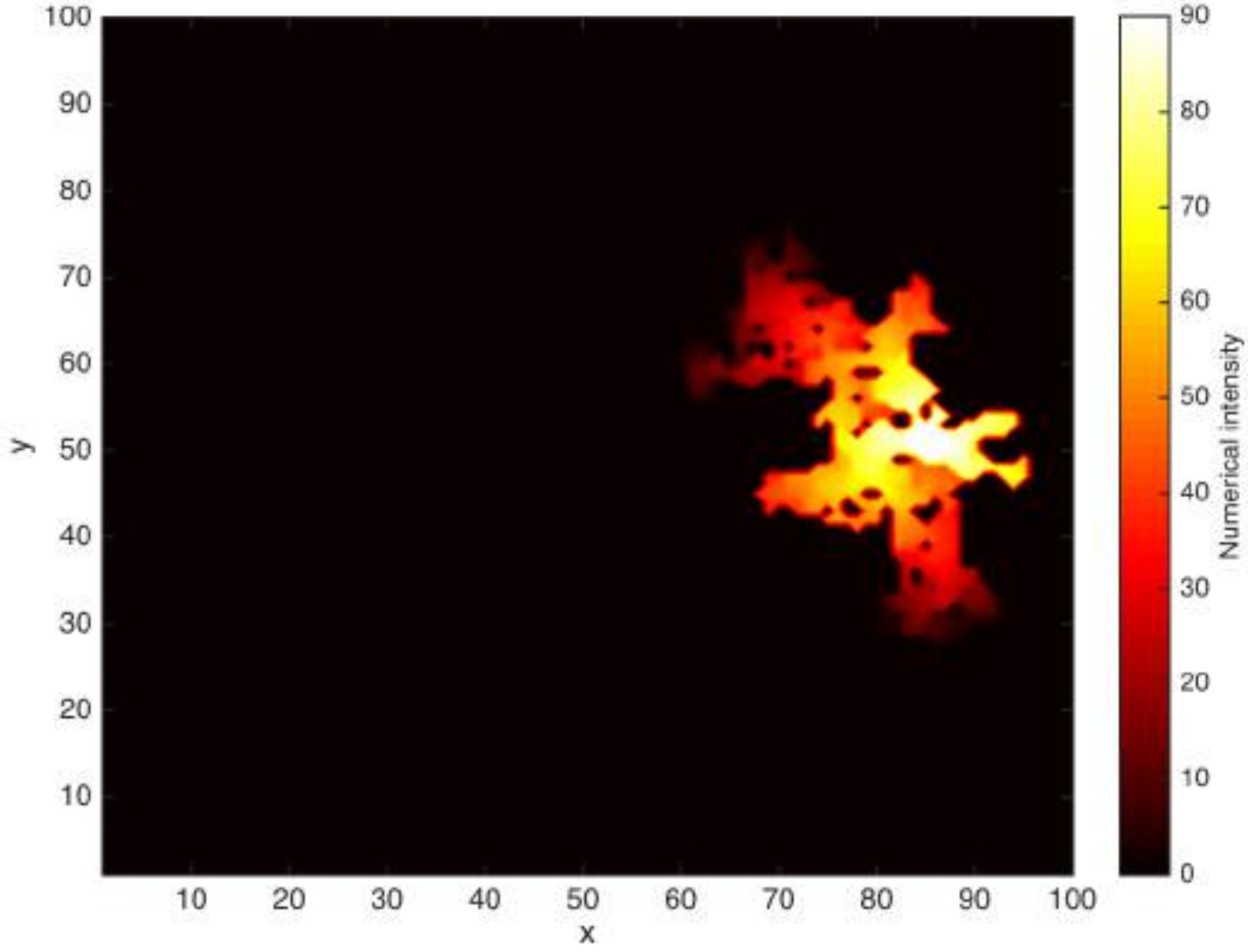
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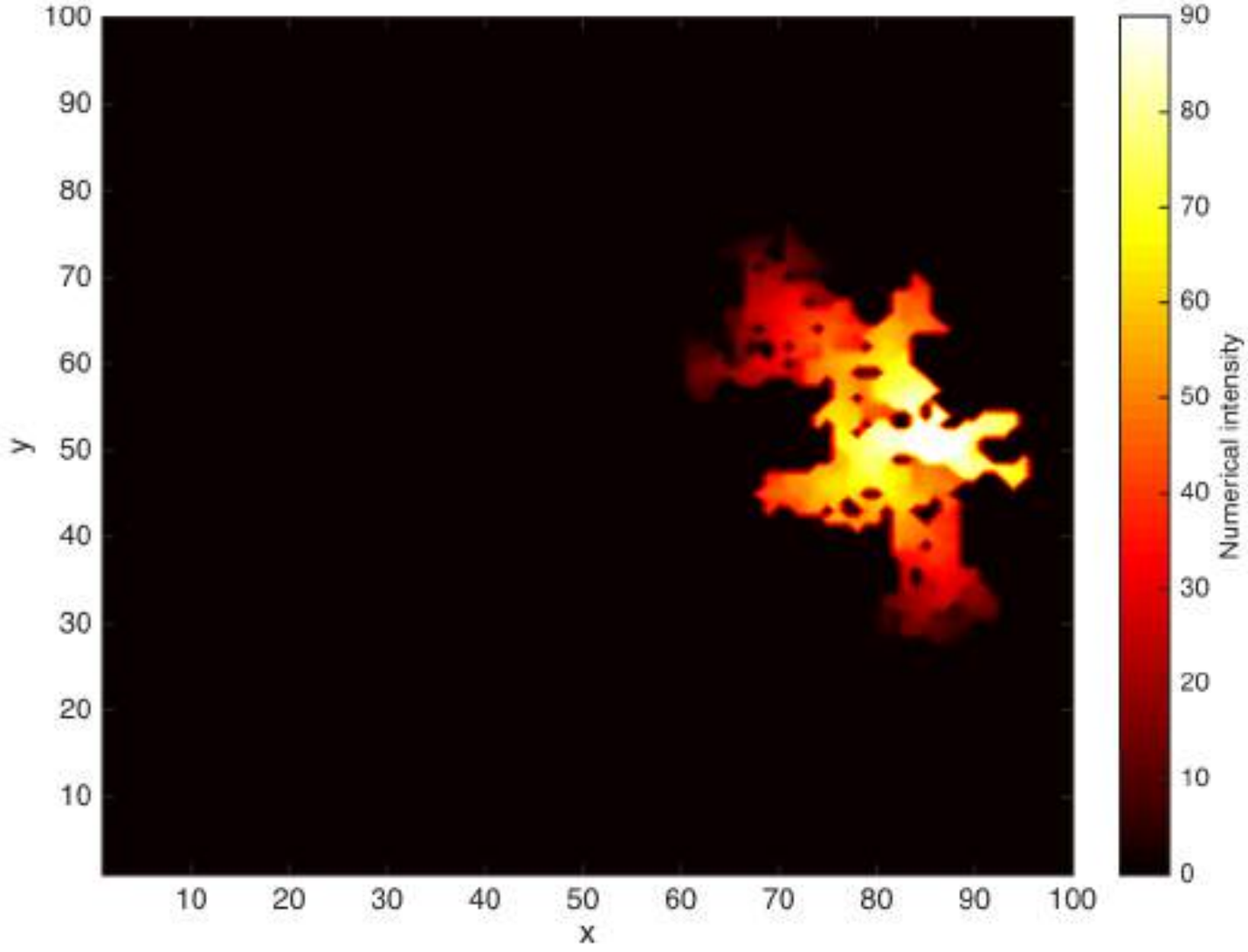
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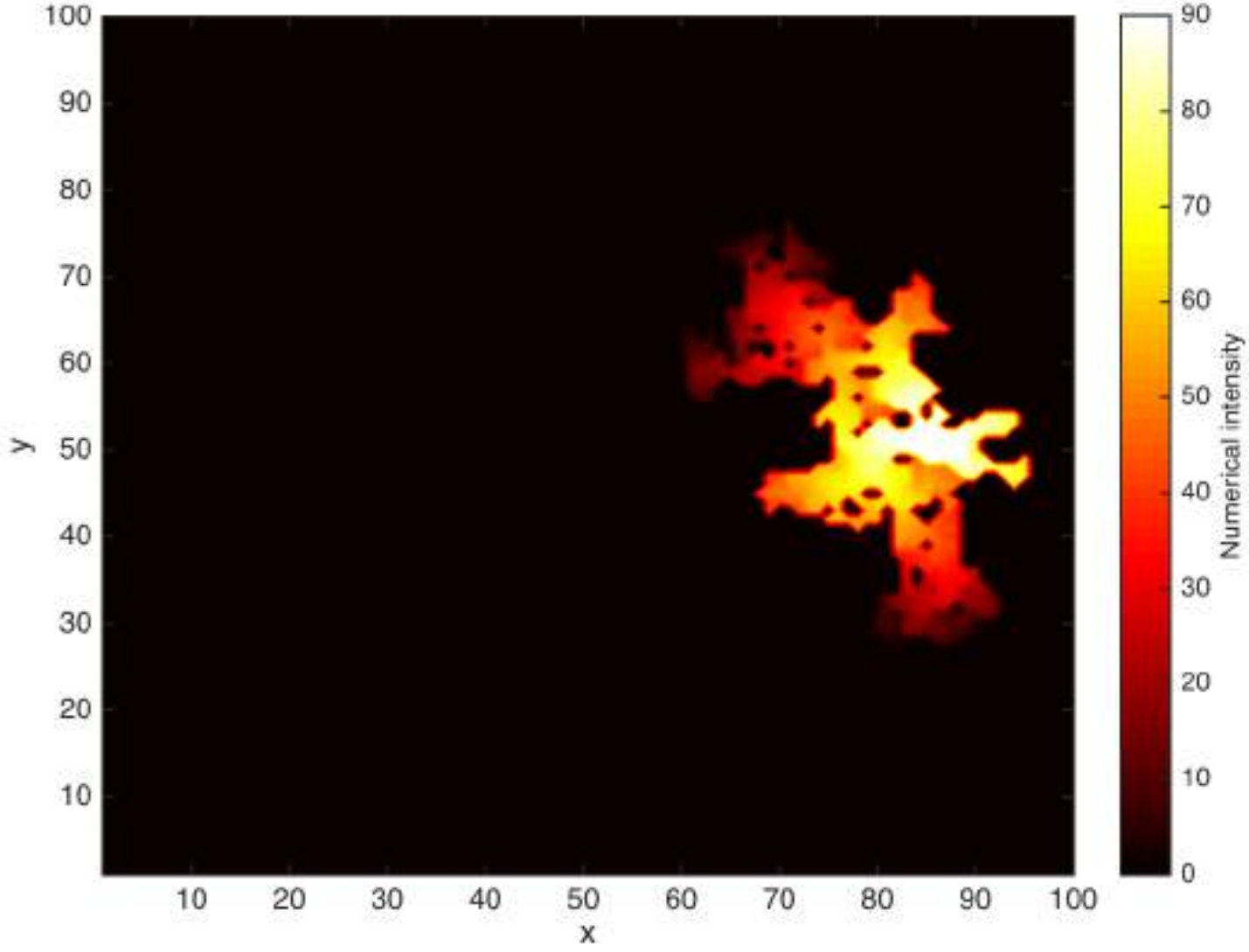
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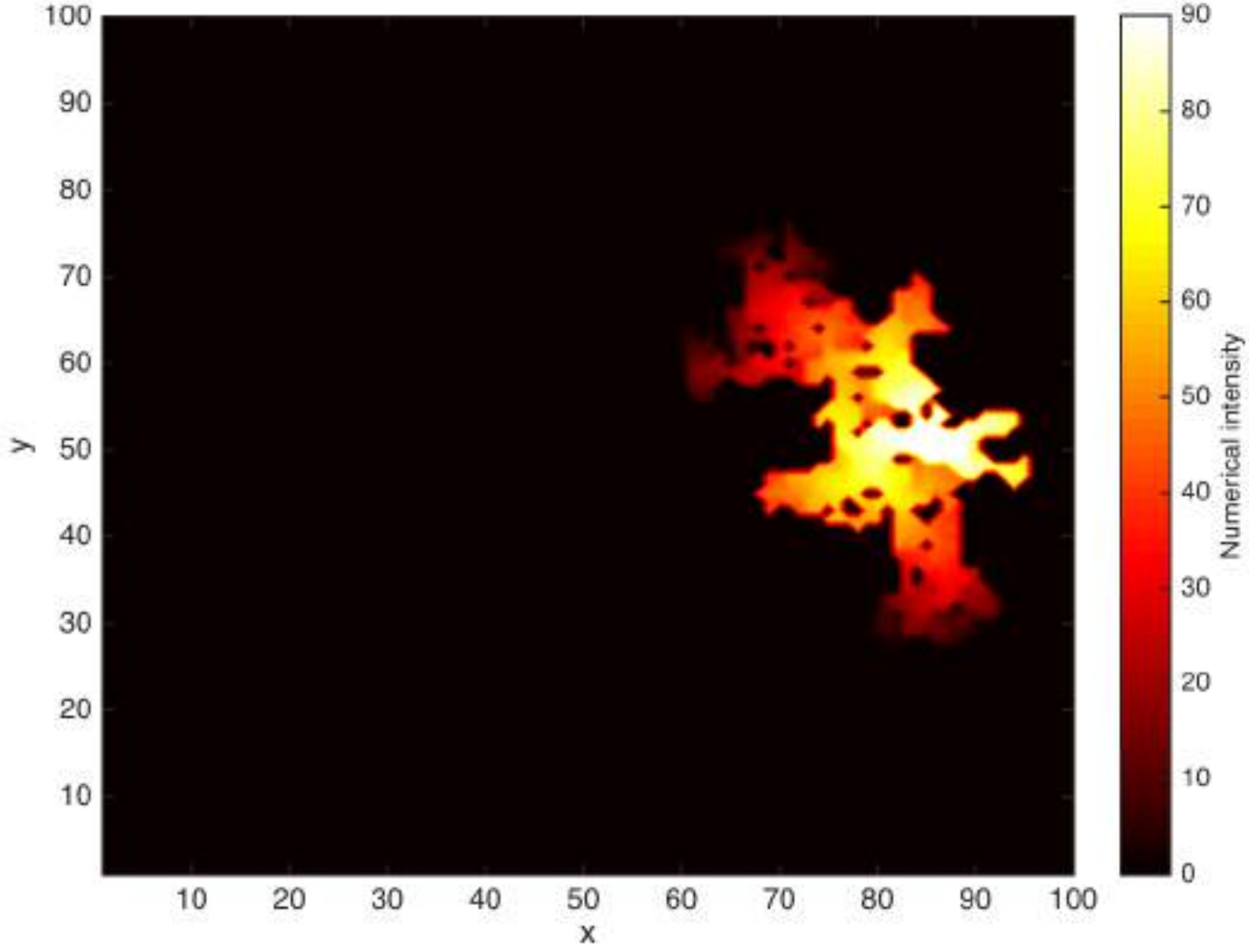
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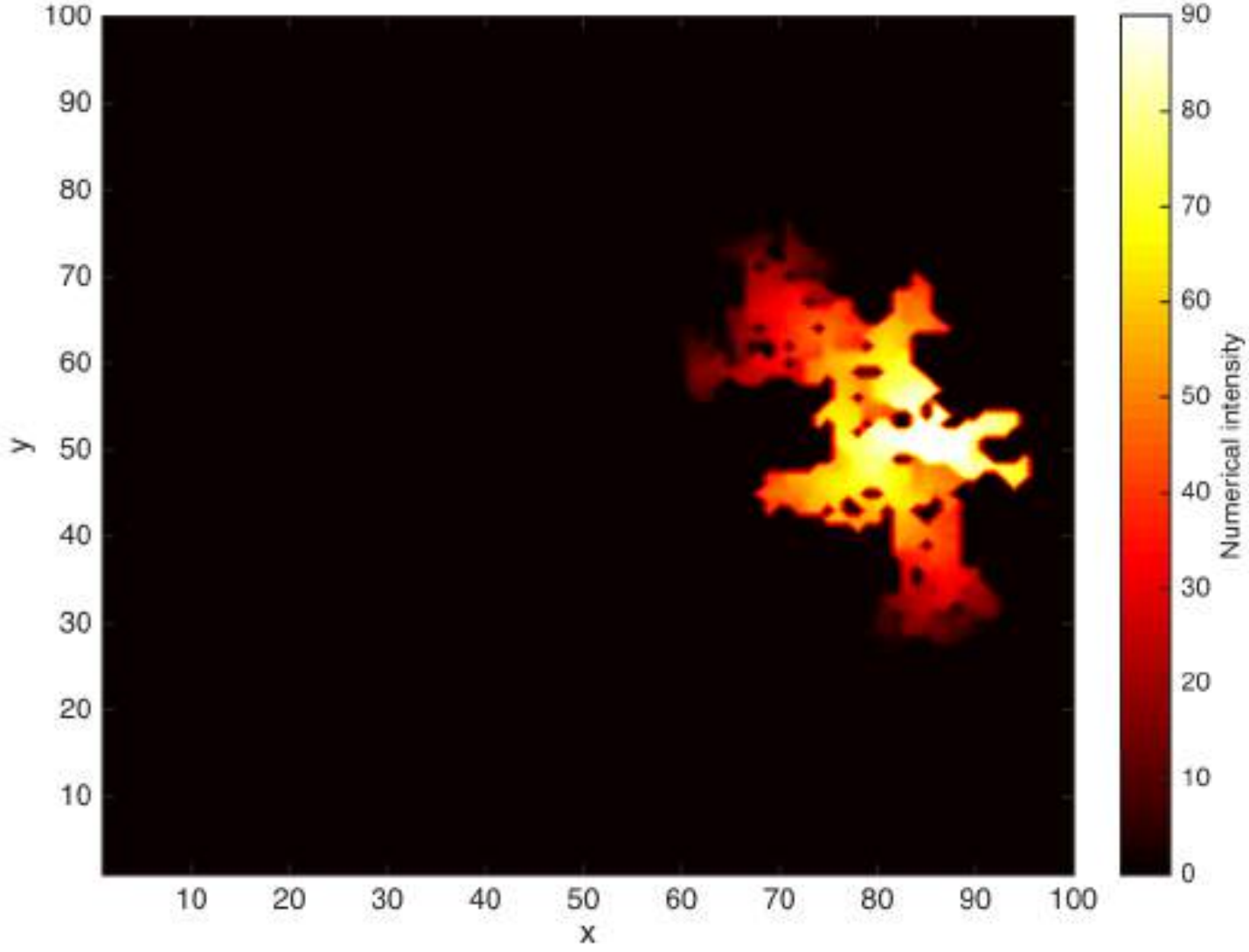
Animation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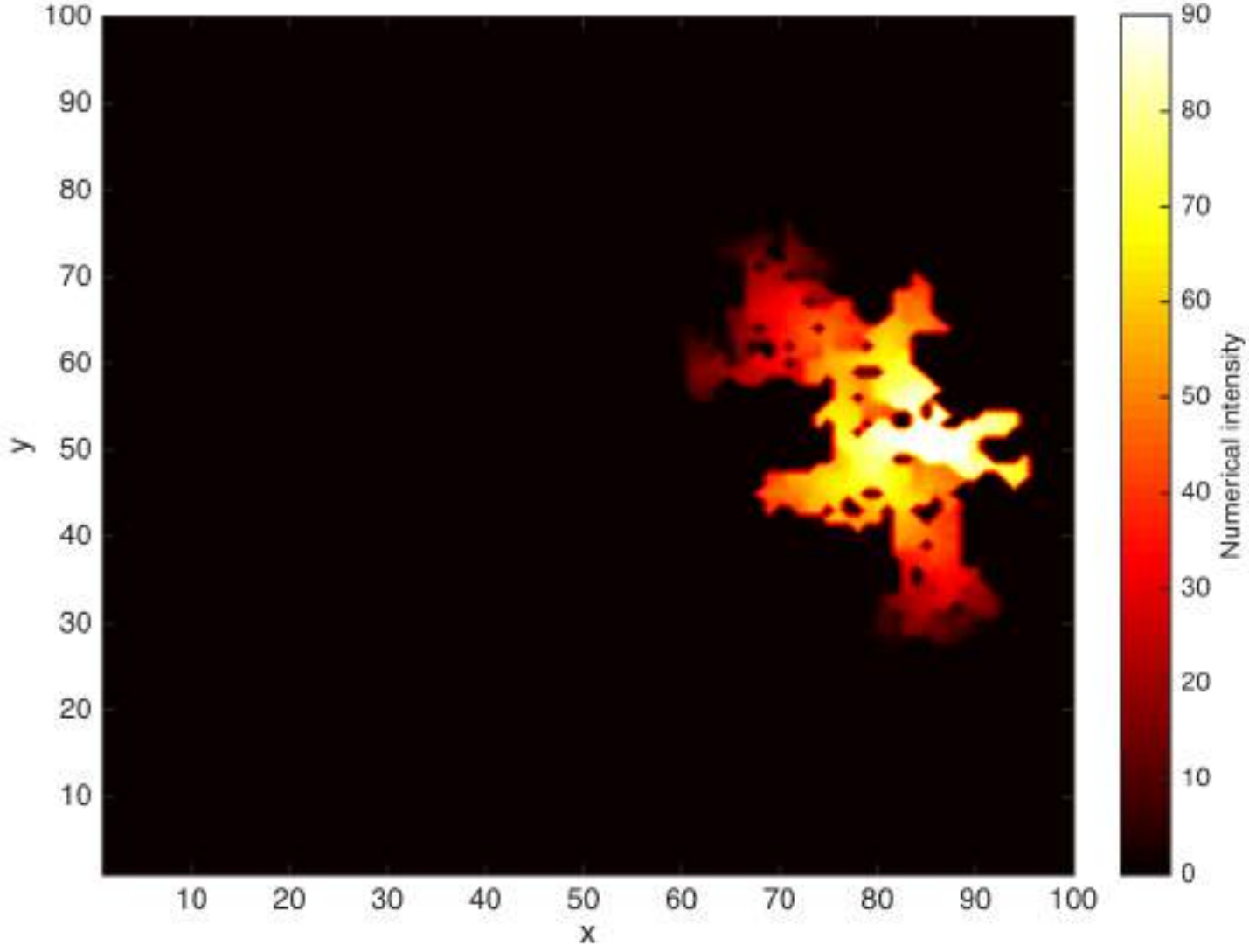
Animation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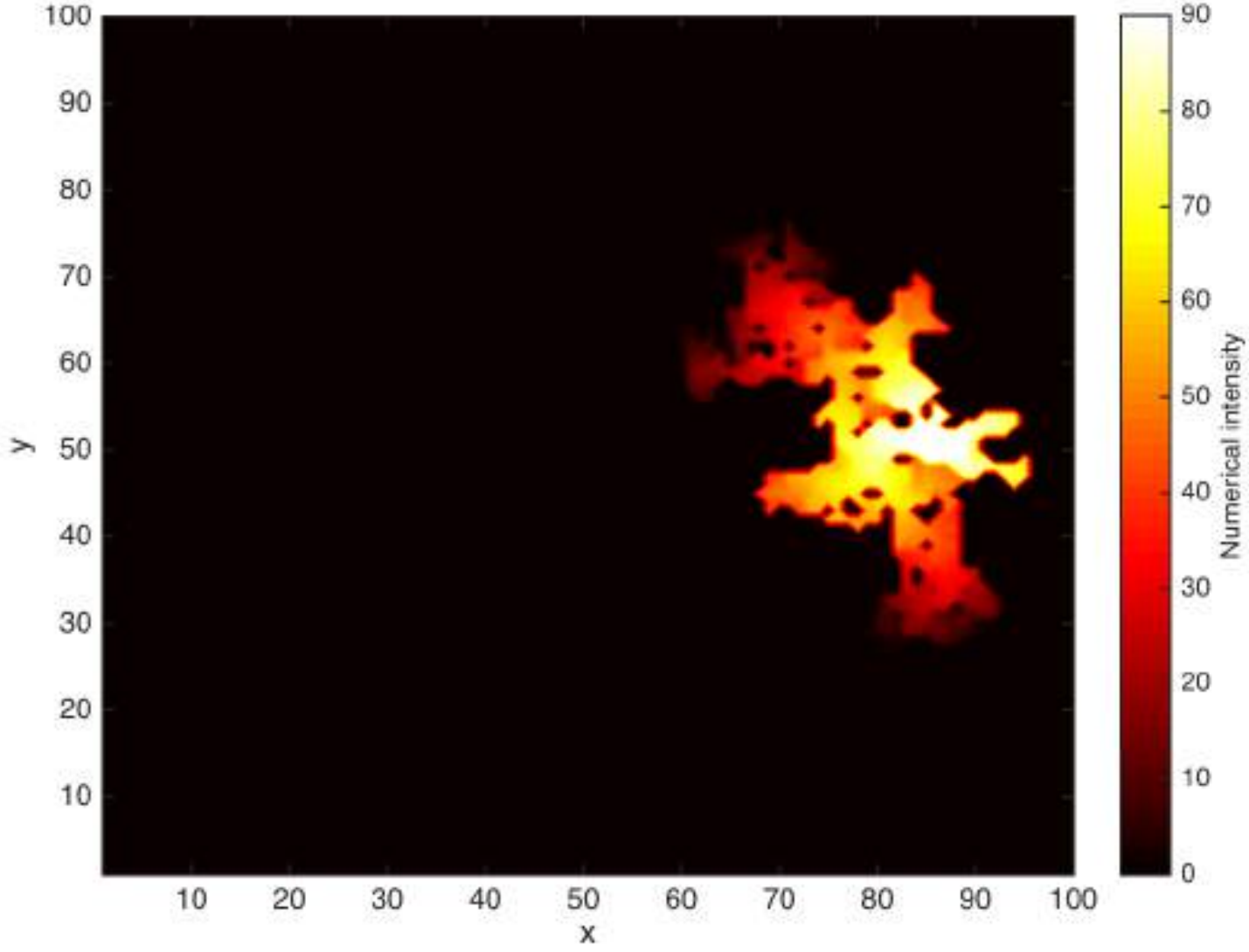
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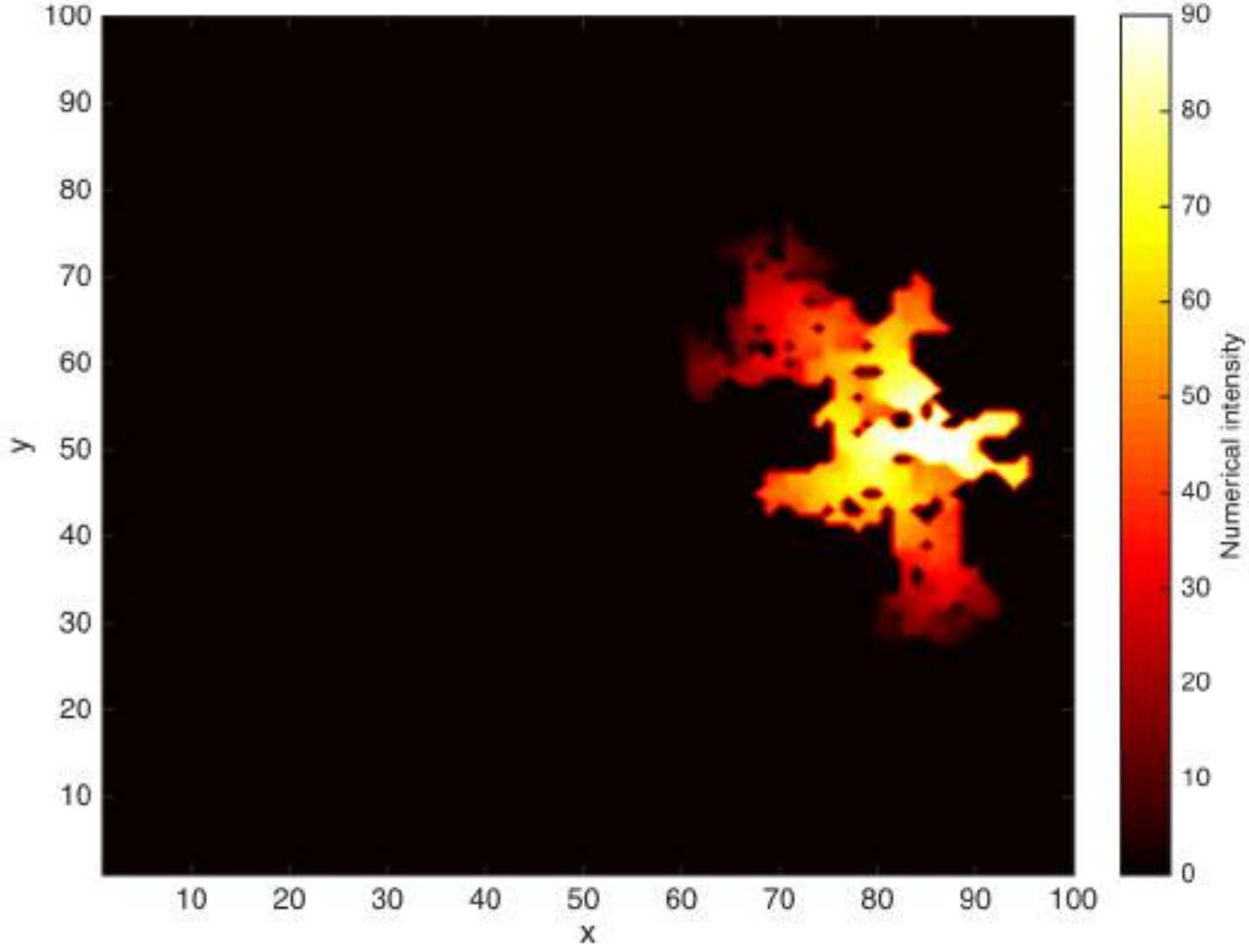
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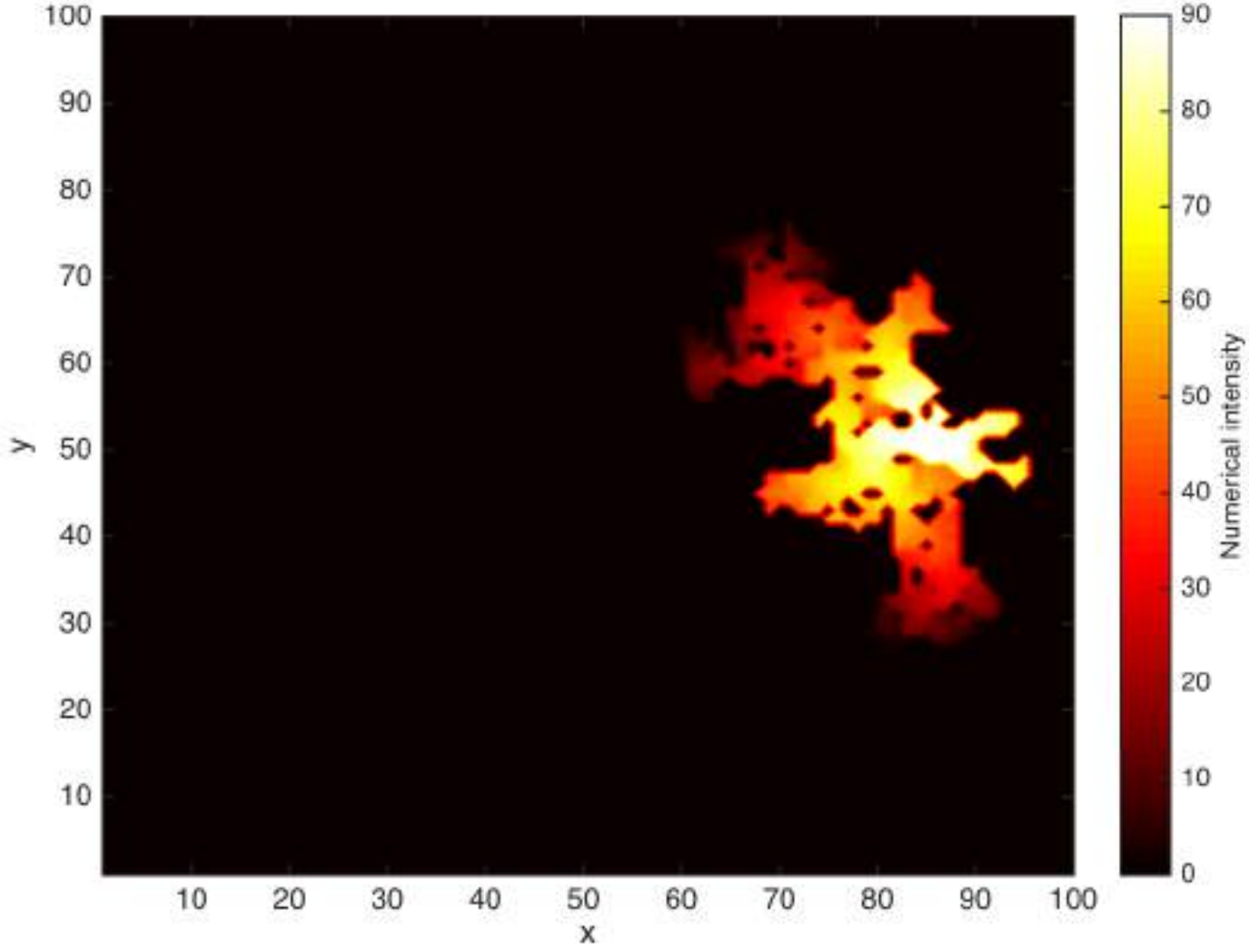
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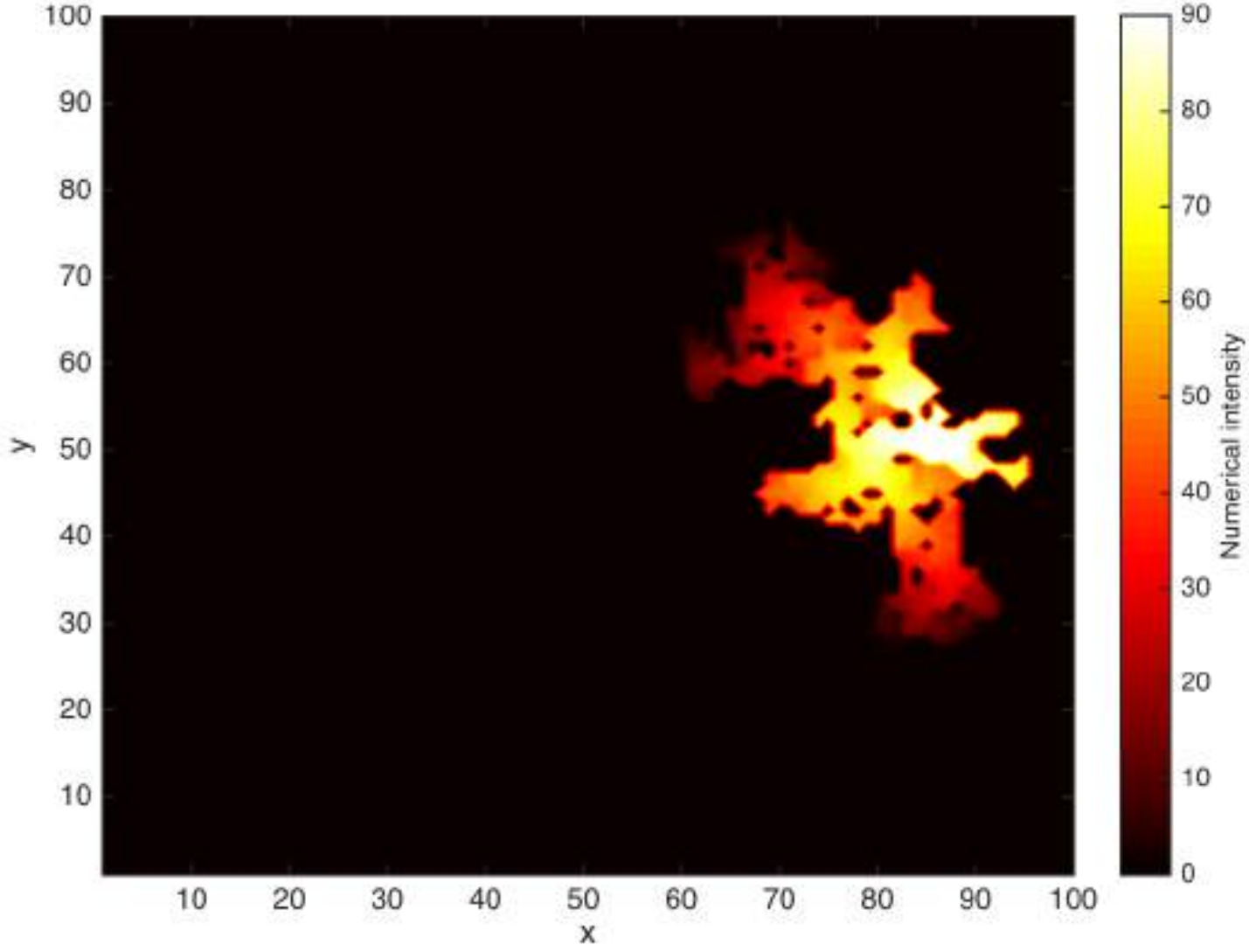
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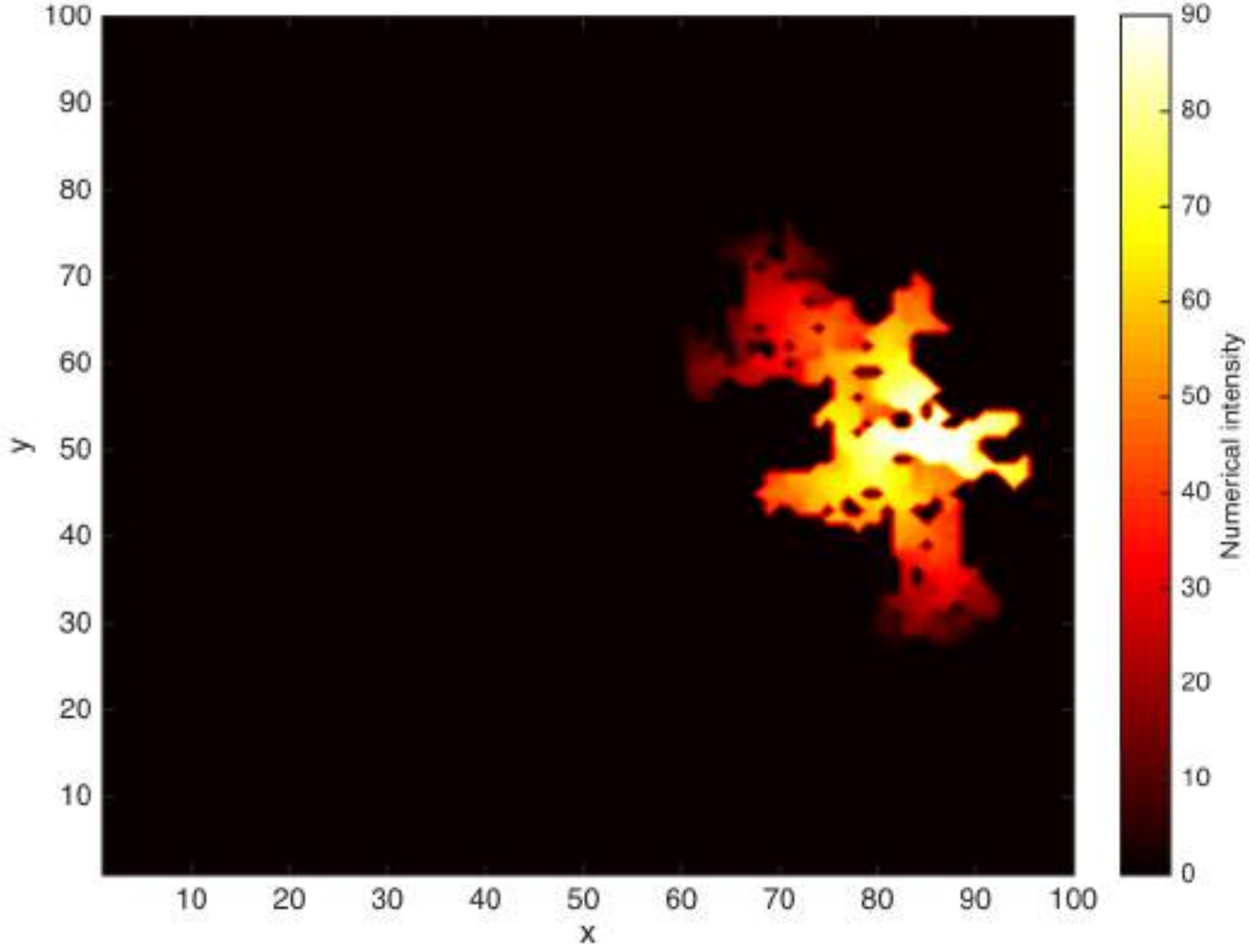
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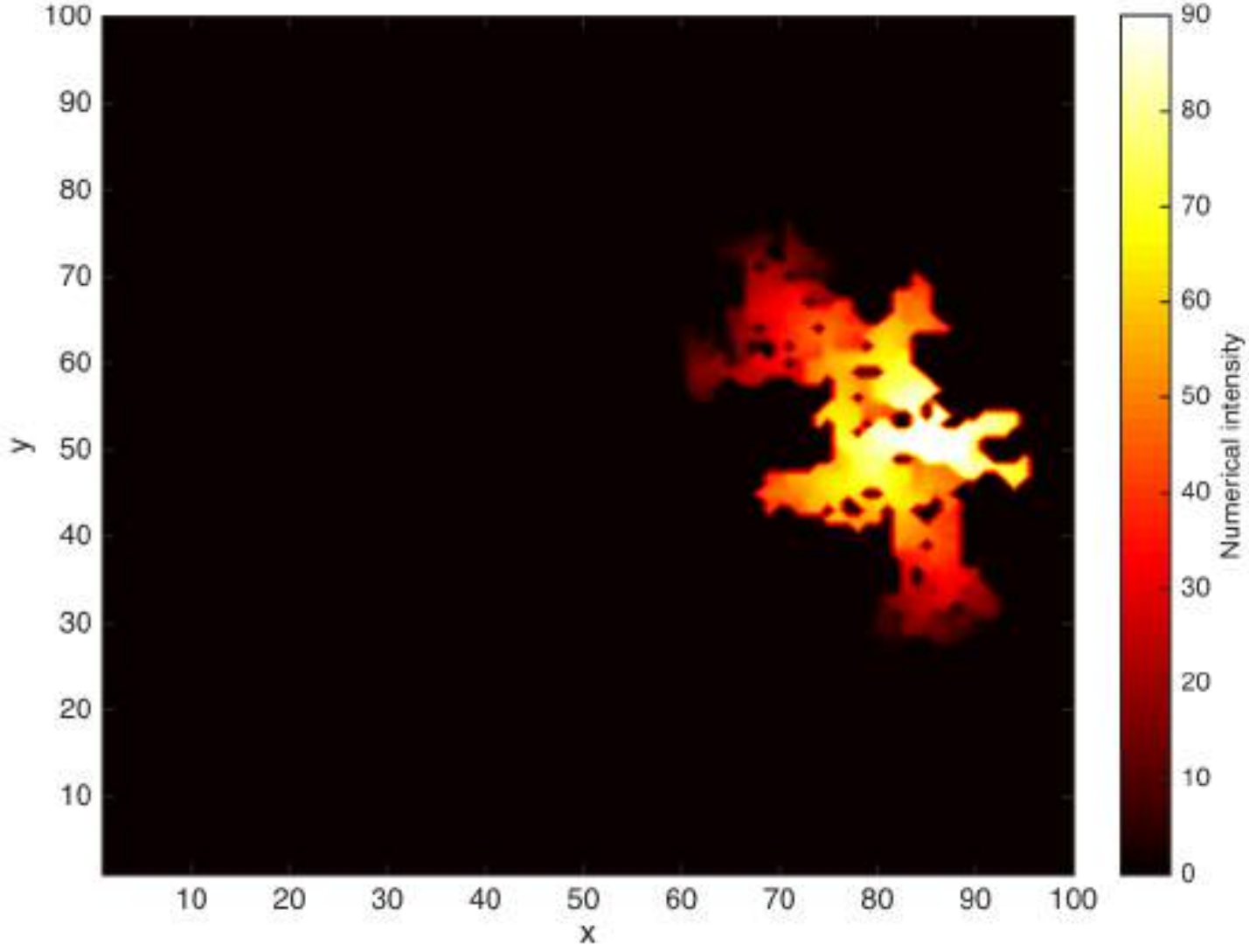
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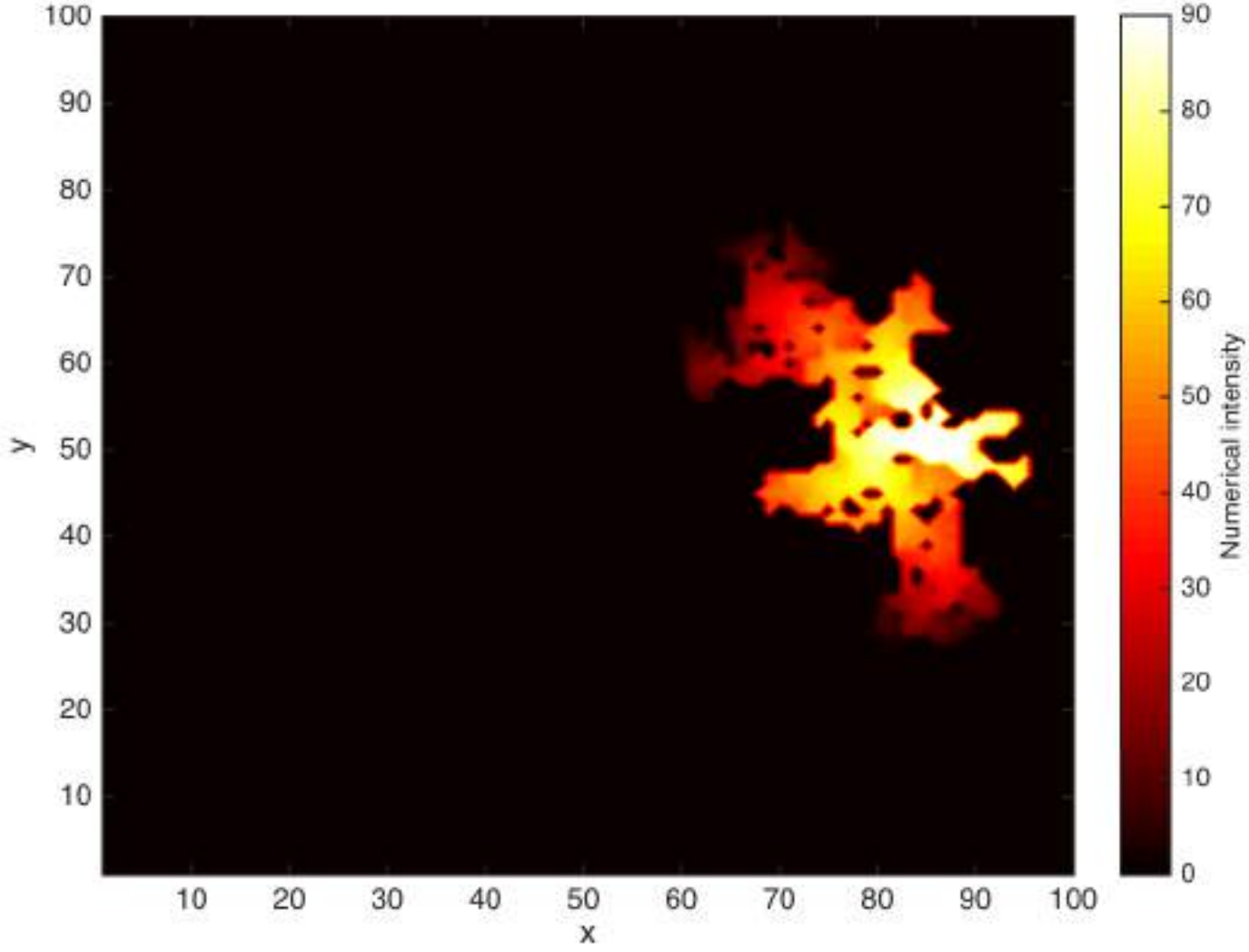
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Hazard model – scale it!

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Bushfire record – Australian Bureau of Statistics (ABS, 2004)

1976-77 to 1995-96, scaled to our domain

- Average no. of fires each year: 424
- Burnt area of average fire: 1.978 km^2 ($\equiv$ 12 cells)

Hazard model – scale it!

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Calibration

- Probability threshold parameter
- Time step parameter

Hazard model – scale it!

Bushfire record – Australian Bureau of Statistics (ABS, 2004)

1976-77 to 1995-96, scaled to our domain

- Average no. of fires each year: 424
- Burnt area of average fire: 1.978 km^2 ($\equiv$ 12 cells)

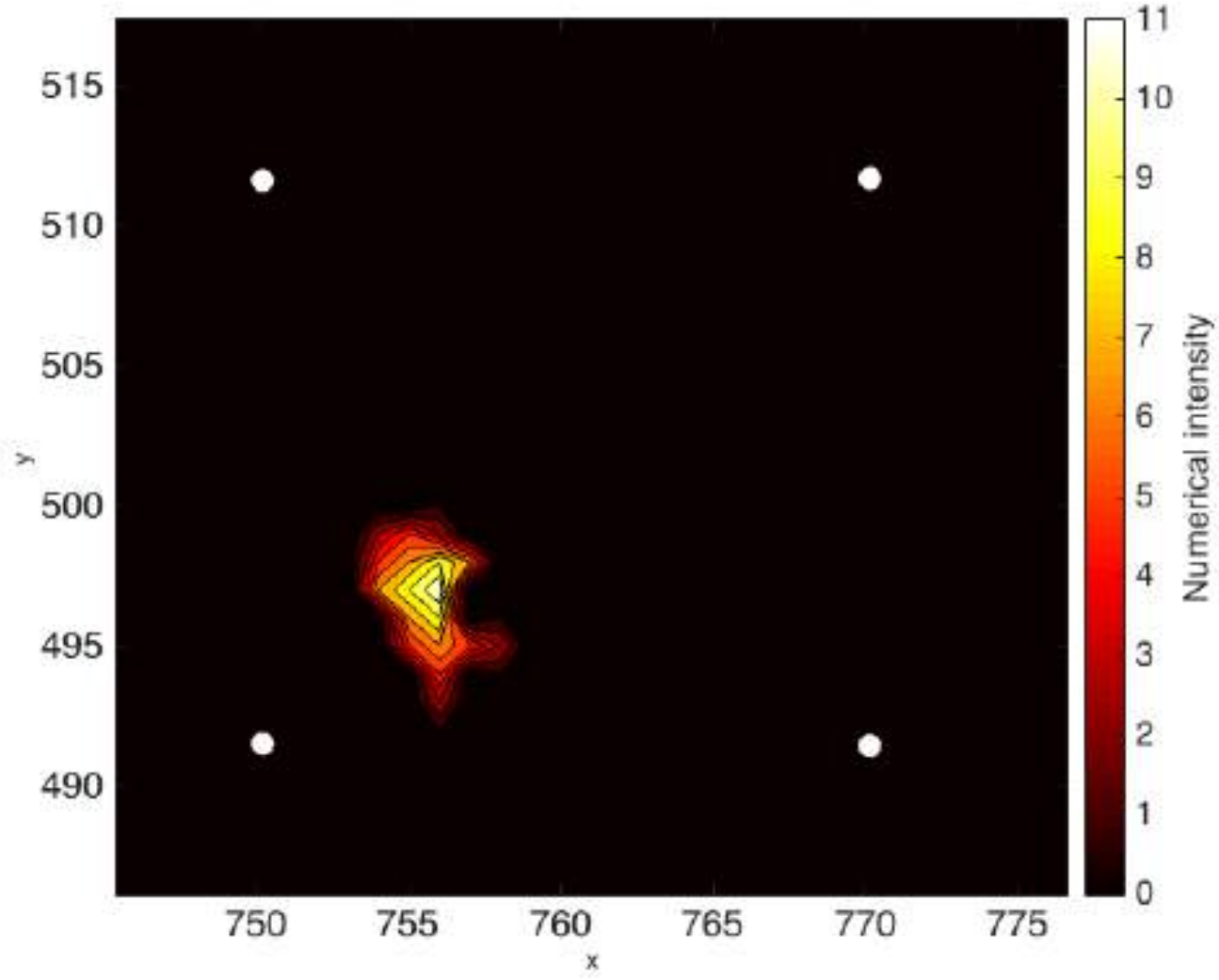
Calibration

- Probability threshold parameter
- Time step parameter
- Maximum area

Result hazard set – 100 years of simulation

	Observation	**Simulation**
Area burnt [km^2]	84'003	84'005
No. of fires	42'400	41'631

Attribute intensity to centroids



Damage functions

Damage functions

Economic impact – Australian Government, BushFIRE Bulletin (2009), scaled to our domain according to asset

- Insurable losses approximately $10 - 12 million each year

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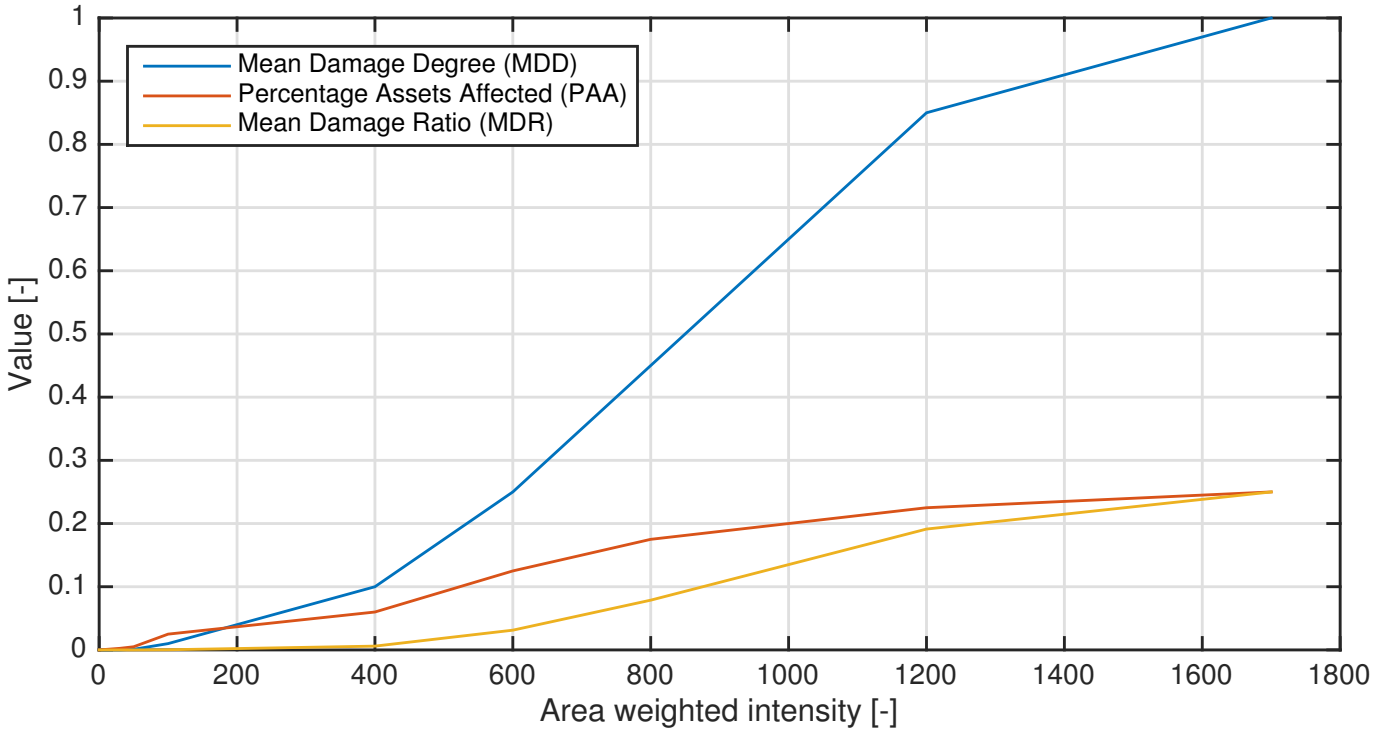

Future development: economic growth and more bushfires

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Economic development: Growth rate: 2 % per year

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Climate change: IPCCC WGIIAR5 (2014)

Future development: economic growth and more bushfires

Economic development: Growth rate: 2 % per year

Climate change: IPCCC WGIIAR5 (2014)

- Fire danger is weather constrained

Future development: economic growth and more bushfires

Economic development: Growth rate: 2 % per year

Climate change: IPCCC WGIIAR5 (2014)

- Fire danger is weather constrained
- Projected for 2030:
  - Hotter and drier conditions

Future development: economic growth and more bushfires

Economic development: Growth rate: 2 % per year

Climate change: IPCCC WGIIAR5 (2014)

- Fire danger is weather constrained
- Projected for 2030:
  - Hotter and drier conditions
  - Increase in days with very high and extreme fire danger index by 3 % (reduced emissions, scenario B1) to 65 % (business-as-usual emissions, scenario A2)

Future development: economic growth and more bushfires

Economic development: Growth rate: 2 % per year

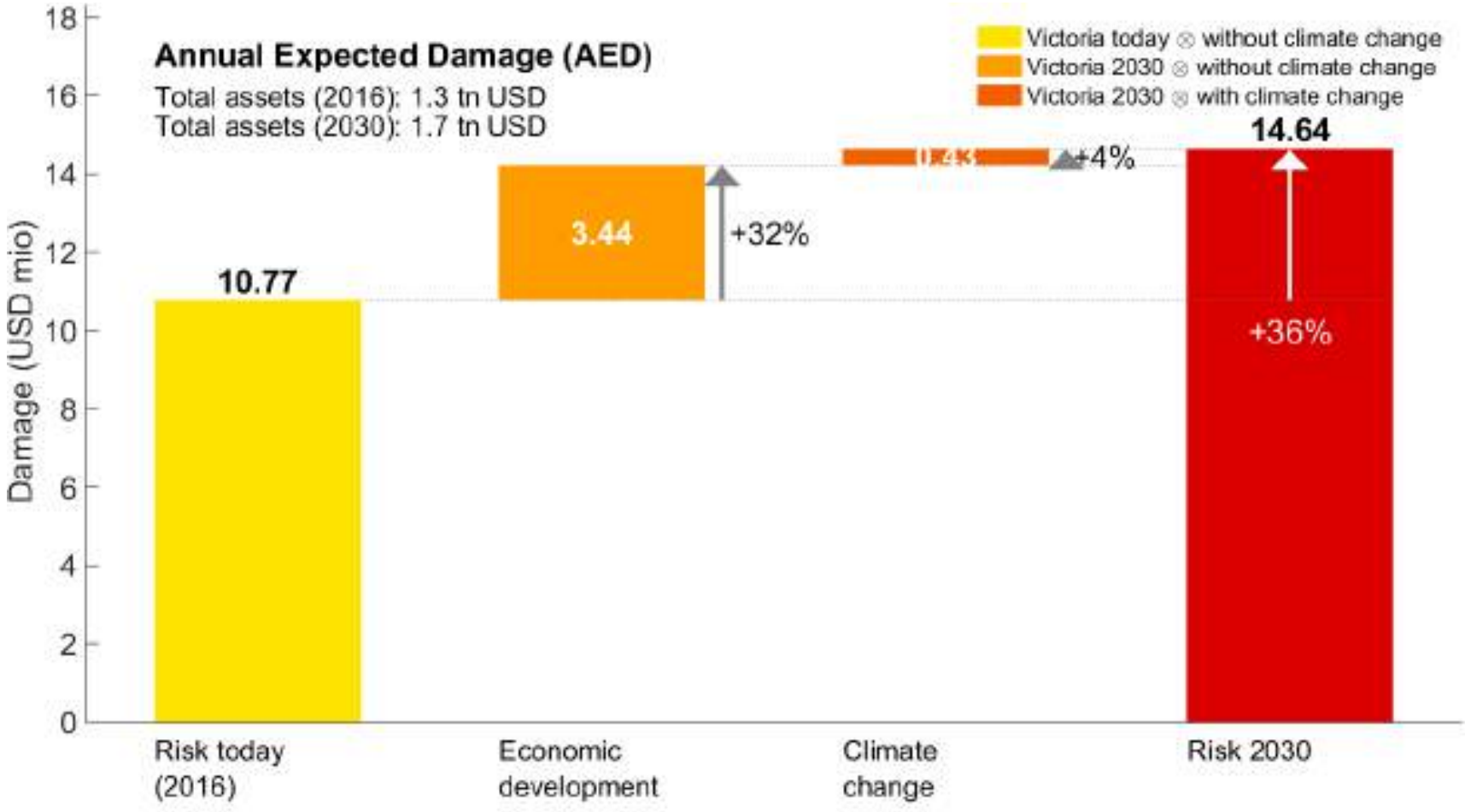
Climate change: IPCCC WGIIAR5 (2014)

- Fire danger is weather constrained
- Projected for 2030:
  - Hotter and drier conditions
  - Increase in days with very high and extreme fire danger index by 3 % (reduced emissions, scenario B1) to 65 % (business-as-usual emissions, scenario A2)

Assumption: Bushfire frequency increase by 3 % and 65 %

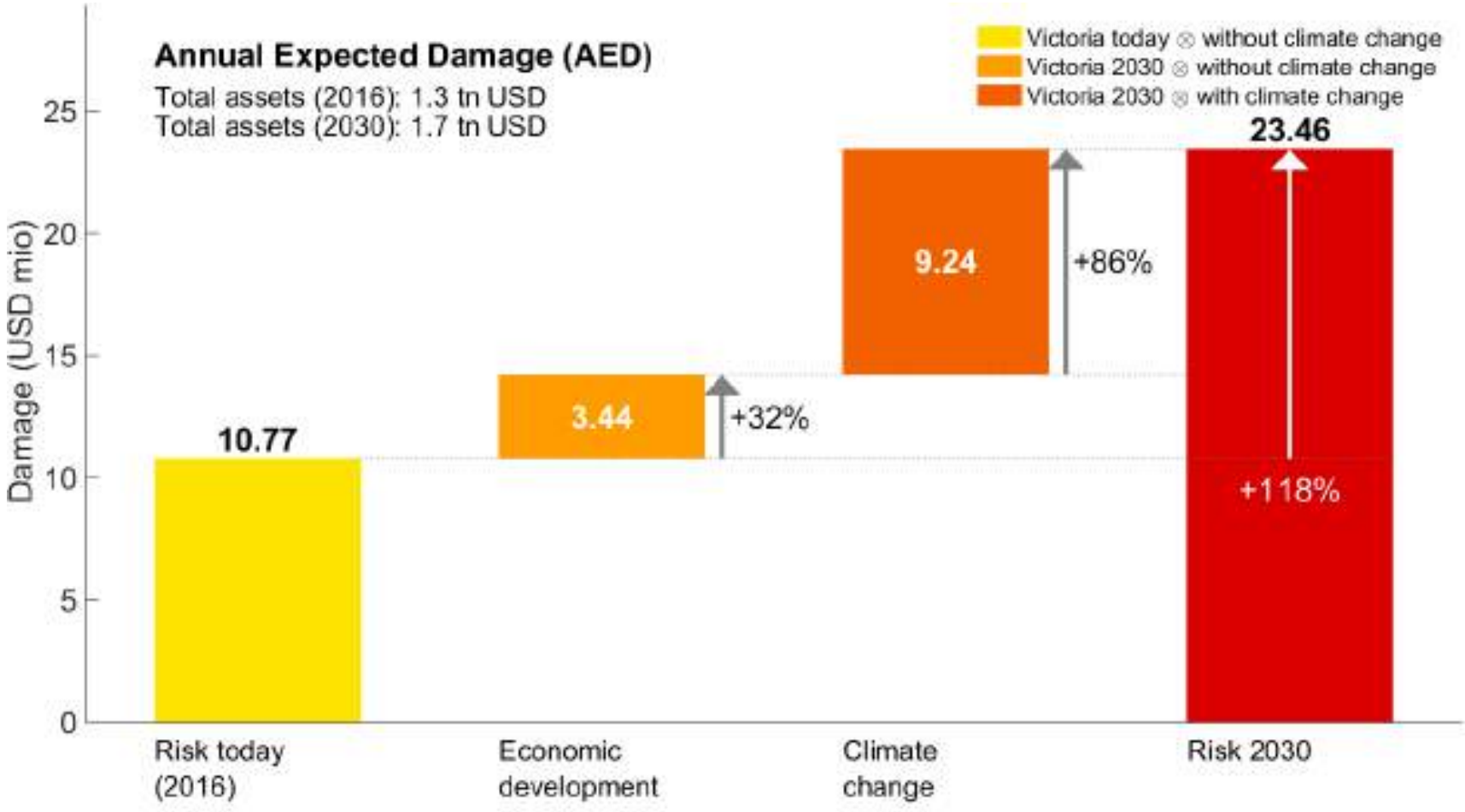
With reduced emissions, the risk is estimated to increase by 36 % by 2030

Scenario B1



With business-as-usual emissions, the risk is estimated to increase by 118 % by 2030

Scenario A2



Adaptation – 1) Education

Costs Net present value (NPV): **$3 mio**

(Australian Bureau of Statistics)

Adaptation – 2) Firefighter

Costs Net present value (NPV): **$34 mio**

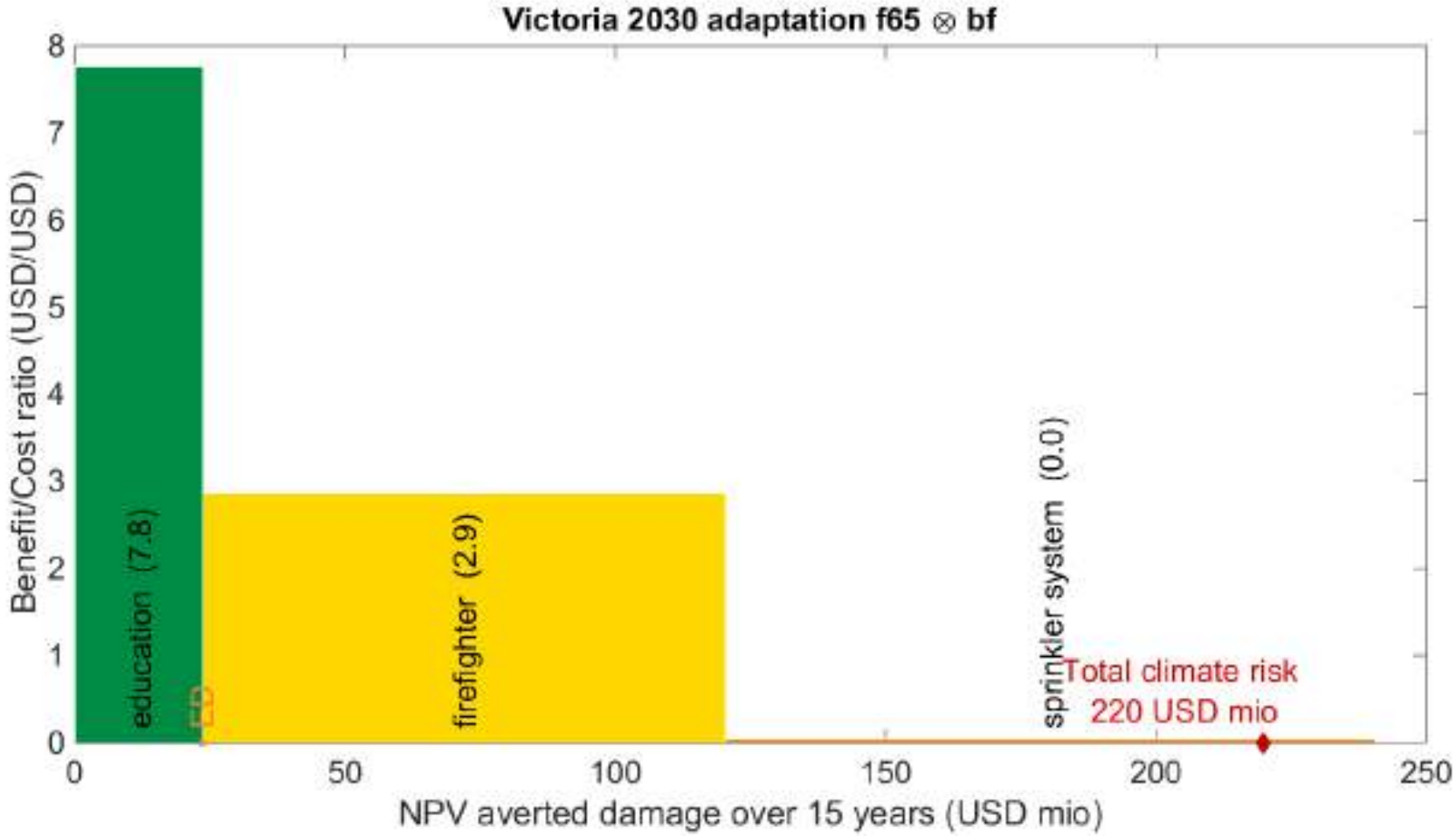
(State of Victoria Budget 2016/2017)

Adaptation – 3) Sprinkler system

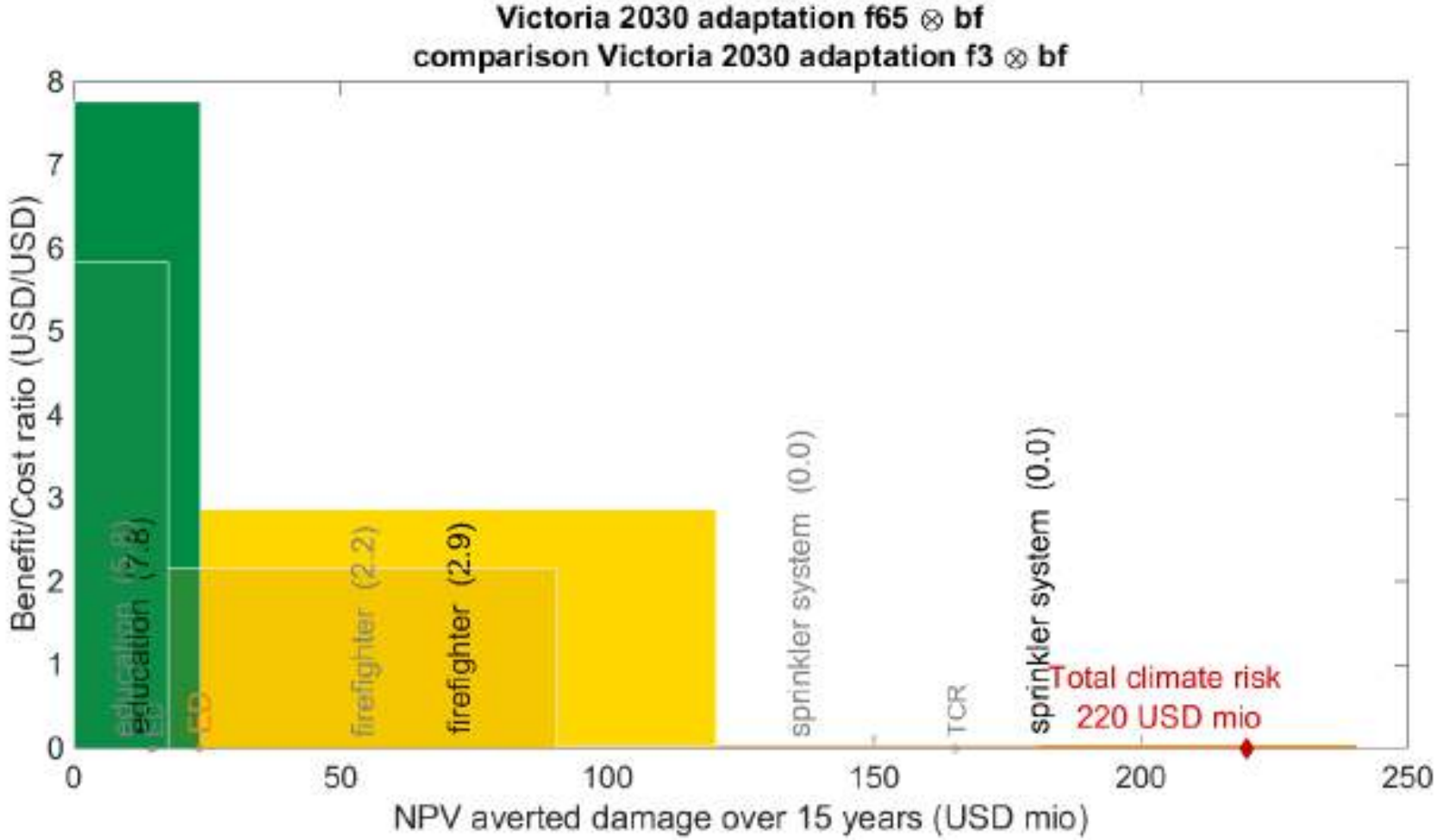
Costs Net present value (NPV): **$2.734 bn**

(Platypus sprinkler systems)

Education and firefighters are cost-effective measures in 2030 (business-as-usual emissions)



The more severe the climate change impact, the more cost-effective are education and firefighters



Limitations and outlook

Limitations and outlook

– Time!

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- Time!
- Large uncertainties with damage function and adaptation impact

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- Need for more data

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- Need for more data
- Simulate Megafires

Limitations and outlook

- Time!
- Large uncertainties with damage function and adaptation impact
- Need for more data
- Simulate Megafires
- Make hazard model more physical and include GIS data

Conclusion

– Interesting and challenging to deal with completely new topic

Conclusion

- Interesting and challenging to deal with completely new topic
- Reasonable results

Conclusion

- Interesting and challenging to deal with completely new topic
- Reasonable results
- Connection to real life possible although toy model

Questions?

References

- **Australian Bureau of Statistics** – accessed 21/5/2016
  http://www.abs.gov.au/ausstats/
- **Australian Institute of Criminology – BushFIRE Arson Bulletin** – accessed 21/5/2016
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- **Climate Council** – accessed 21/5/2016
  http://www.climatecouncil.org.au
- **IPCC WGIIAR5**
  Reisinger, A., R.L. Kitching, F. Chiew, L. Hughes, P.C.D. Newton, S.S. Schuster, A. Tait, and P. Whetton, 2014: Australasia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1371-1438.
- **State of Victoria Budget 2016/2017** – accessed 21/5/2016
  http://www.budgetfiles201617.budget.vic.gov.au/
- **Platypus sprinkler systems** – accessed 21/5/2016
  http://http://www.platypussprinkler.com

Appendix Black Saturday – 7/2/2009

Picture by Christoph Horat

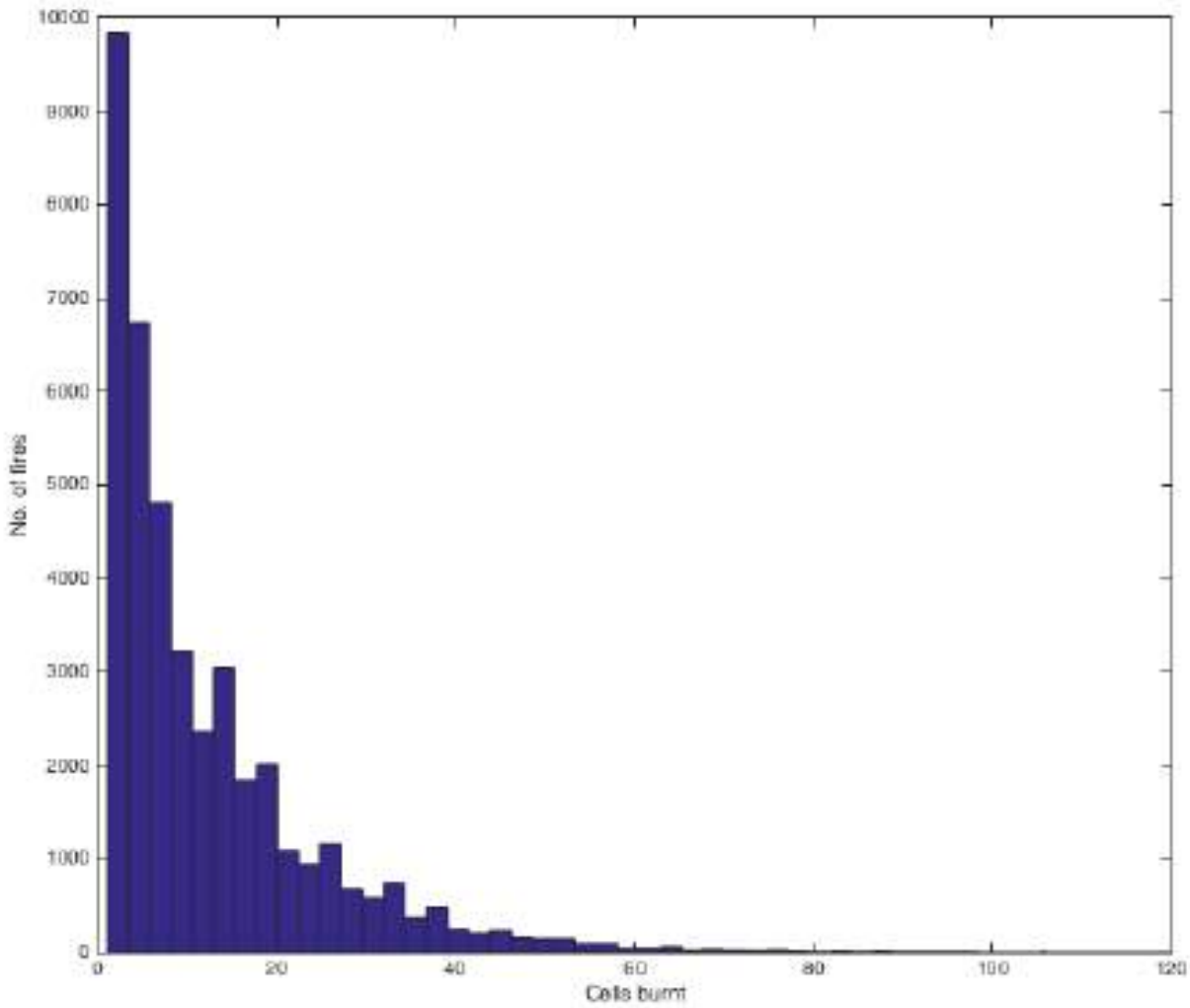
Appendix Hazard model – MATLAB code (1/2)

```
if A(i,j,t) == 1
        if A(i-1,j,t) == 0 && rand > p_threshold;
             A(i-1,j,t+1) = 1;
        end
        if A(i+1,j,t) == 0 && rand > p_threshold;
             A(i+1,j,t+1) = 1;
        end
        if A(i,j-1,t) == 0 && rand > p_threshold;
             A(i,j-1,t+1) = 1;
        end
        if A(i,j+1,t) == 0 && rand > p_threshold;
             A(i,j+1,t+1) = 1;
        end

        A(i,j,t+1) = 2;
end
```

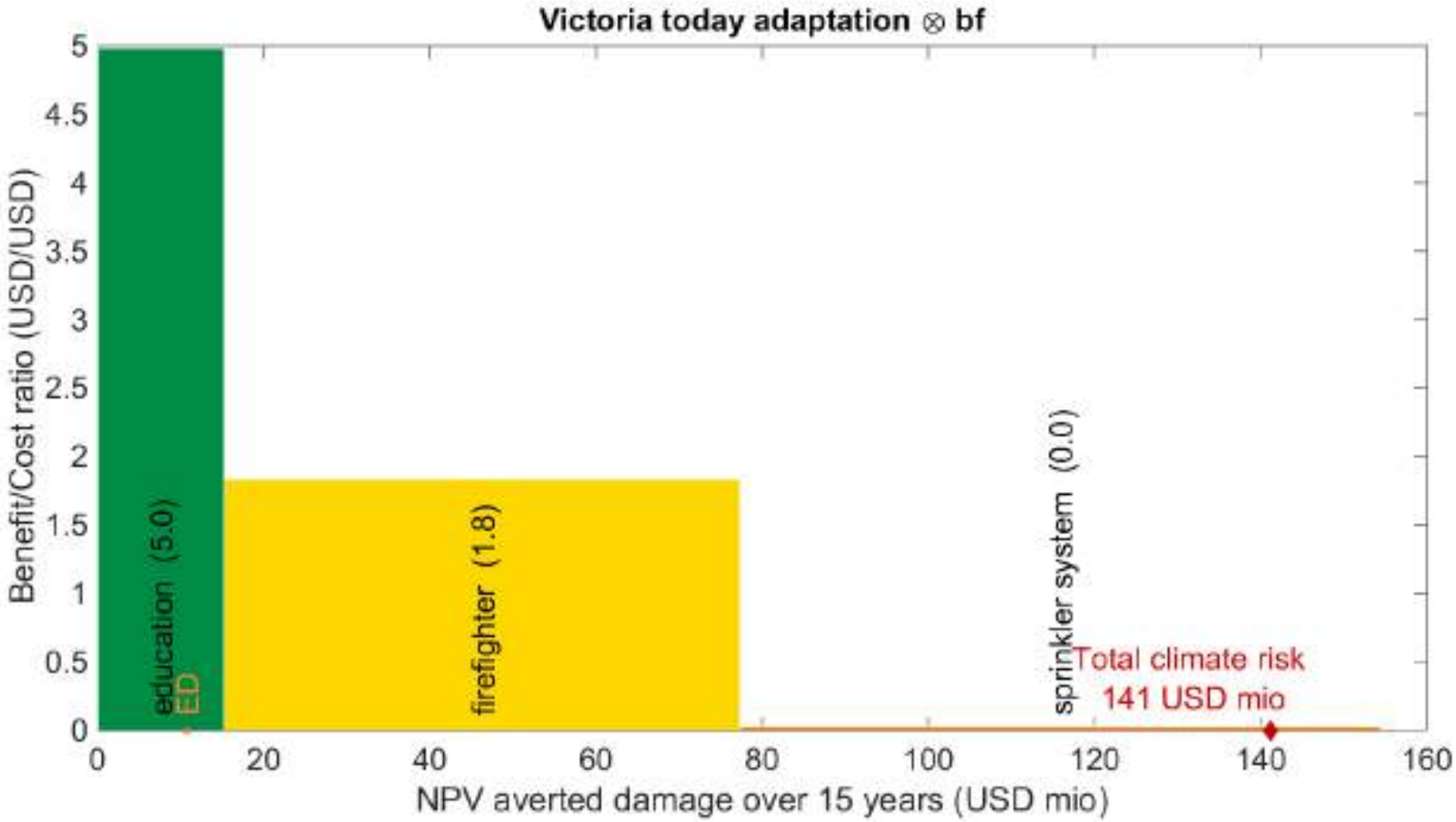
Appendix Hazard model – MATLAB code (2/2)

```
area_max = max(1,round(exprnd(12)));
count_cell = 0;

for t = 1:(time_steps-1)
    if count_cell >= area_max
        break;
    else
    ...
```

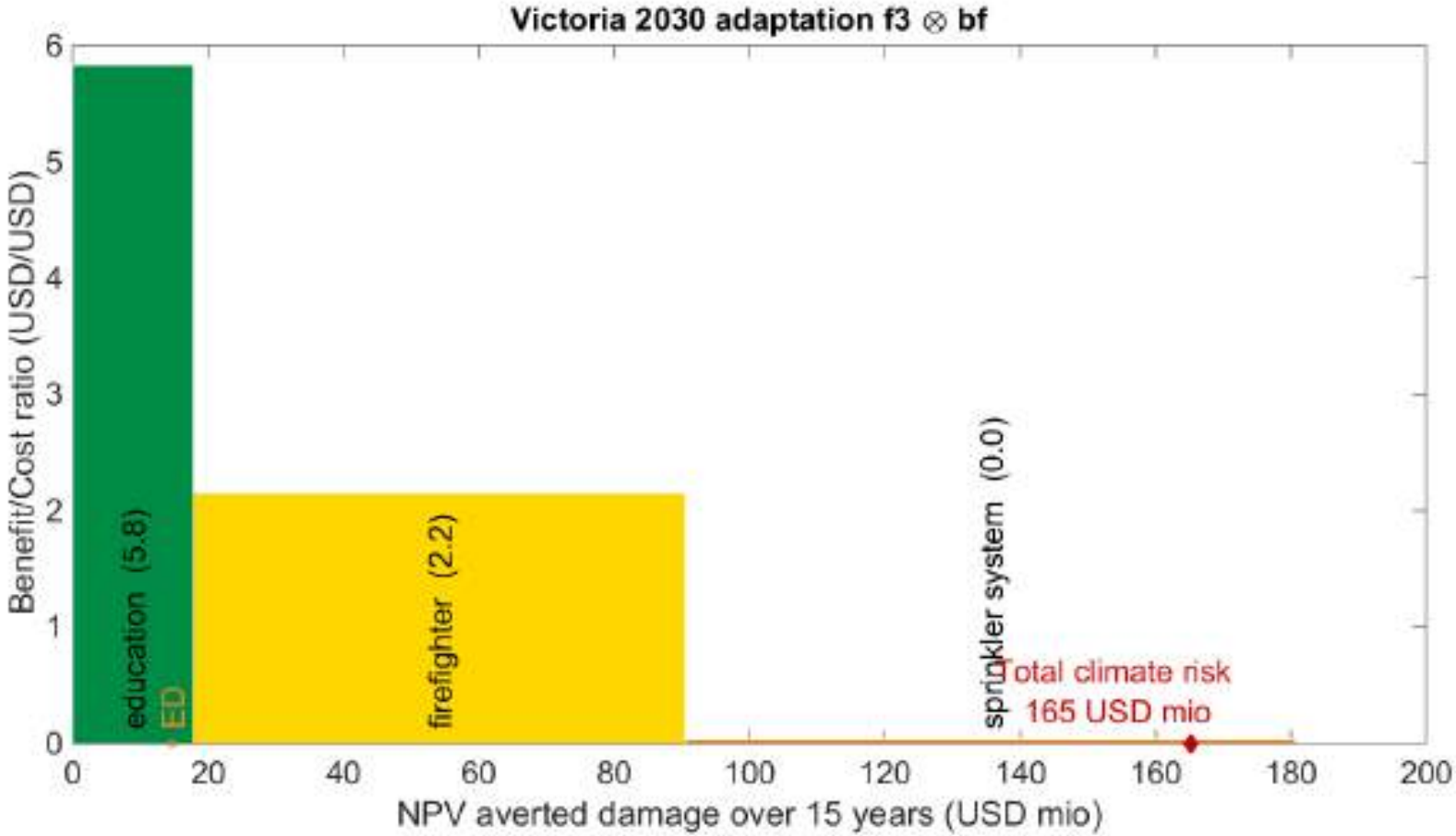
Appendix Distribution of fires



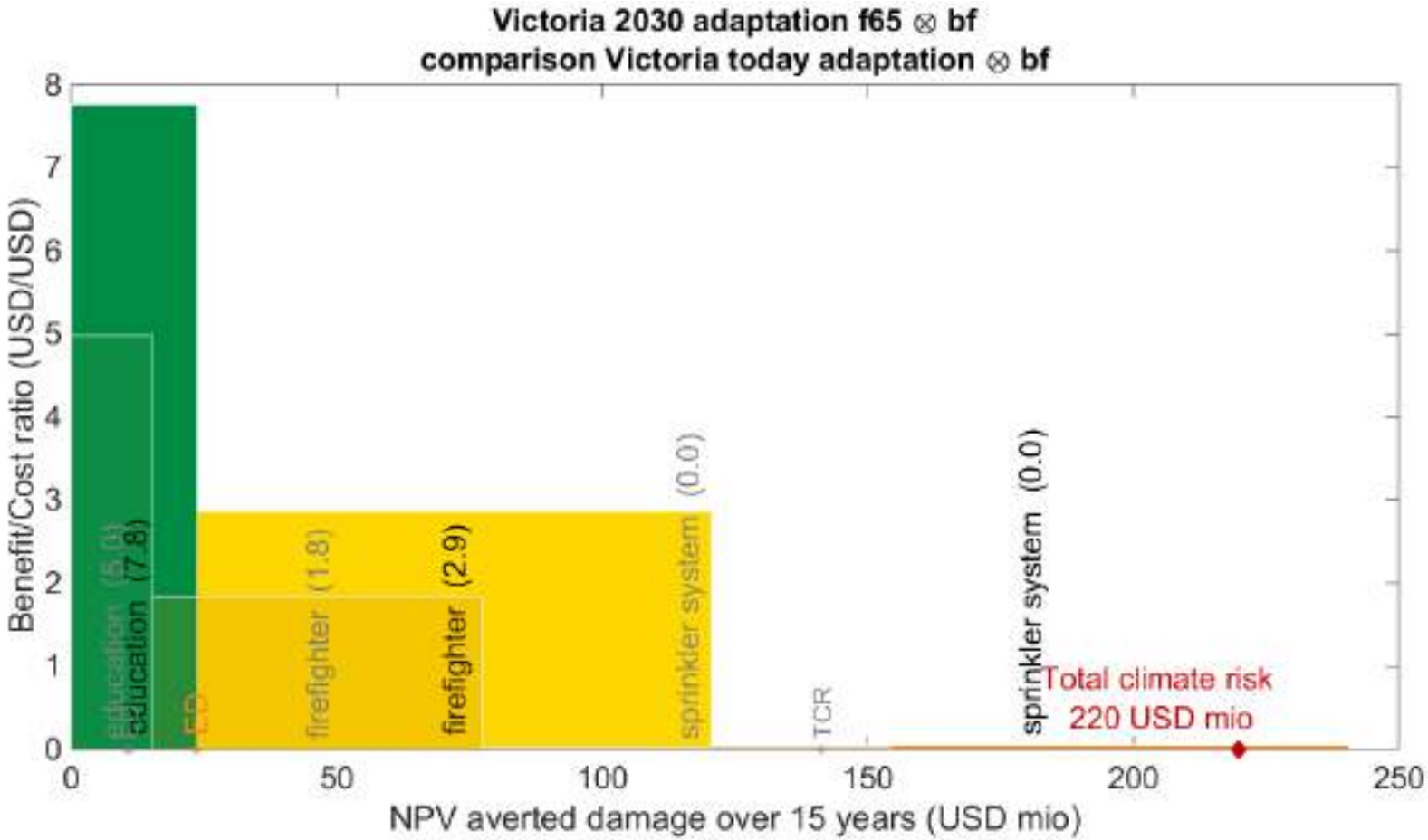
Appendix Education and firefighters are cost-effective measures for today's climate risk



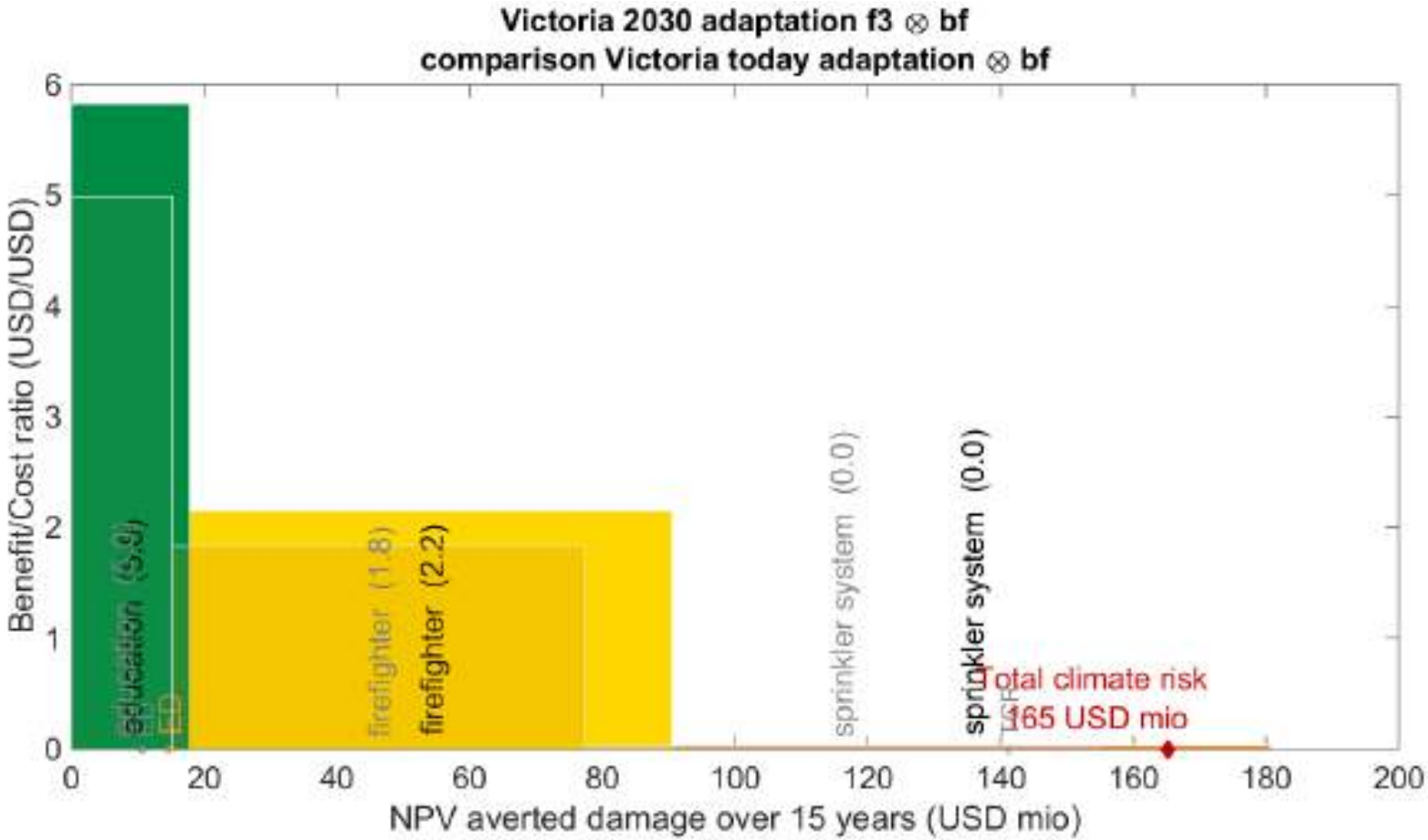
Appendix Education and firefighters are cost-effective adaptation measures in 2030 (under reduced emissions)



Appendix Comparison between adaptation cost curve for today and for business-as-usual scenario in 2030



Appendix Comparison between adaptation cost curve for today and for reduced emissions scenario in 2030



Appendix Adaptation – 1) Education

Costs	Net present value (NPV):	**$3 million**
Impact	Mean Damage Degree (MDD)	= 0.97
	Percentage Assets Affected (PAA)	= 0.92

Appendix Adaptation – 2) Firefighter

Costs	Net present value (NPV):	**$34 million**
Impact	Mean Damage Degree (MDD)	= 0.8
	Percentage Assets Affected (PAA)	= 0.7

Appendix Adaptation – 3) Sprinkler system

Costs	Net present value (NPV):	**$2.734 billion**
Impact	Mean Damage Degree (MDD)	= 0.72
	Percentage Assets Affected (PAA)	= 0.63