Development of Coupled Hydrodynamic-Water Quality Models for the Northern Gulf of Mexico Hypoxic Zone

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- NOAA (Multistress)
- NOAA (NGOMEX)
- NGI
- BP/GOMRI (Coastal Waters Consortium)
- BP (LSU)

Outline

Overview of hypoxia models

1. Gulf Hypoxia
2. "Dual-Budget"
3. Barataria 2-D
4. FVCOM LaTex
5. FVCOM Barataria Bay

Selected results

Future model developments

Gulf Hypoxia Model

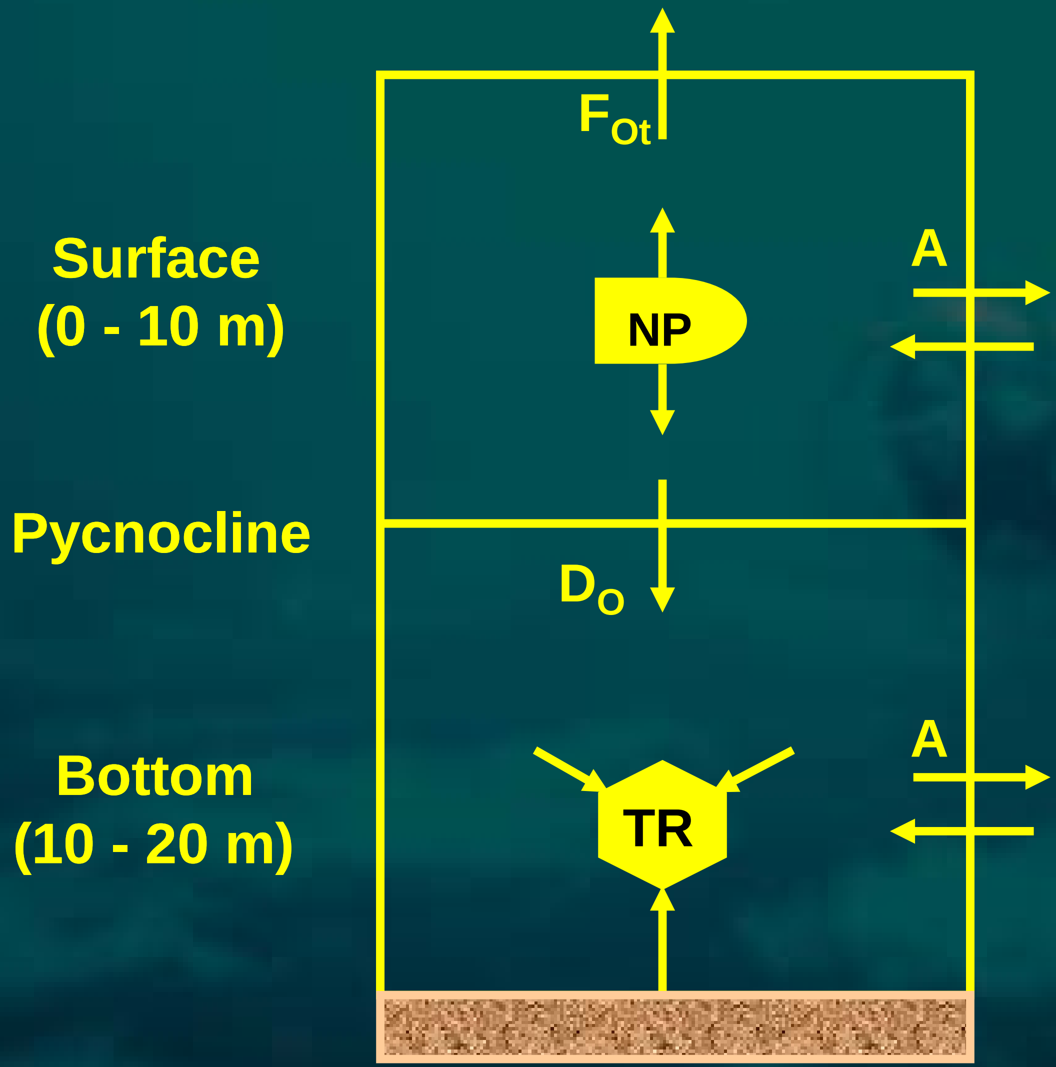
Years developed: 1996 – 2002

Publications: Justic et al. (1996, 1997, 2002, 2003, 2005)

Objectives/Research questions:

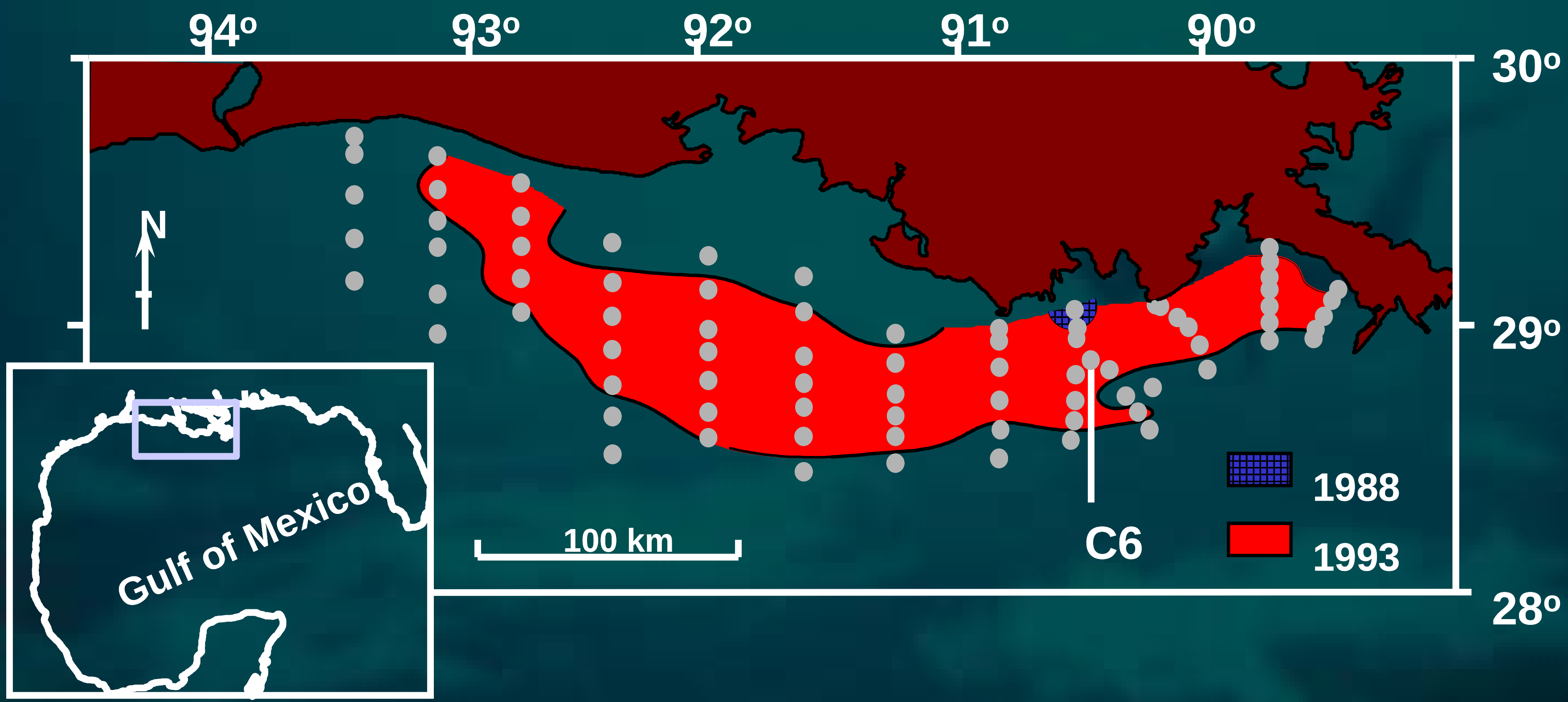
- Interannual variability in hypoxia
- Historical development 1955 – 2000
- Impacts of various climatic/anthropogenic scenarios

Gulf Hypoxia Model



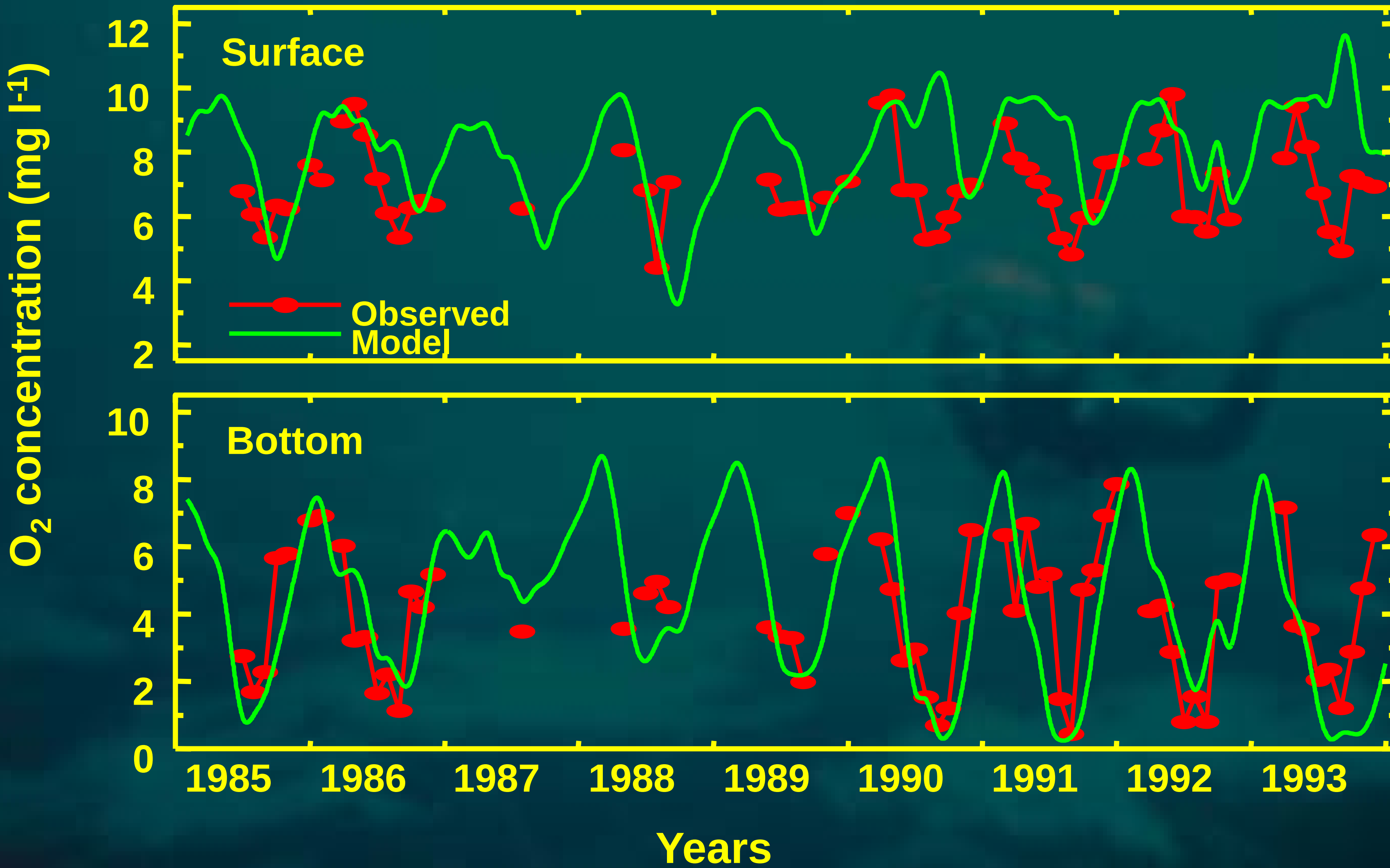
Justic et al. (1996)

Station C6 – Core of Hypoxic Zone



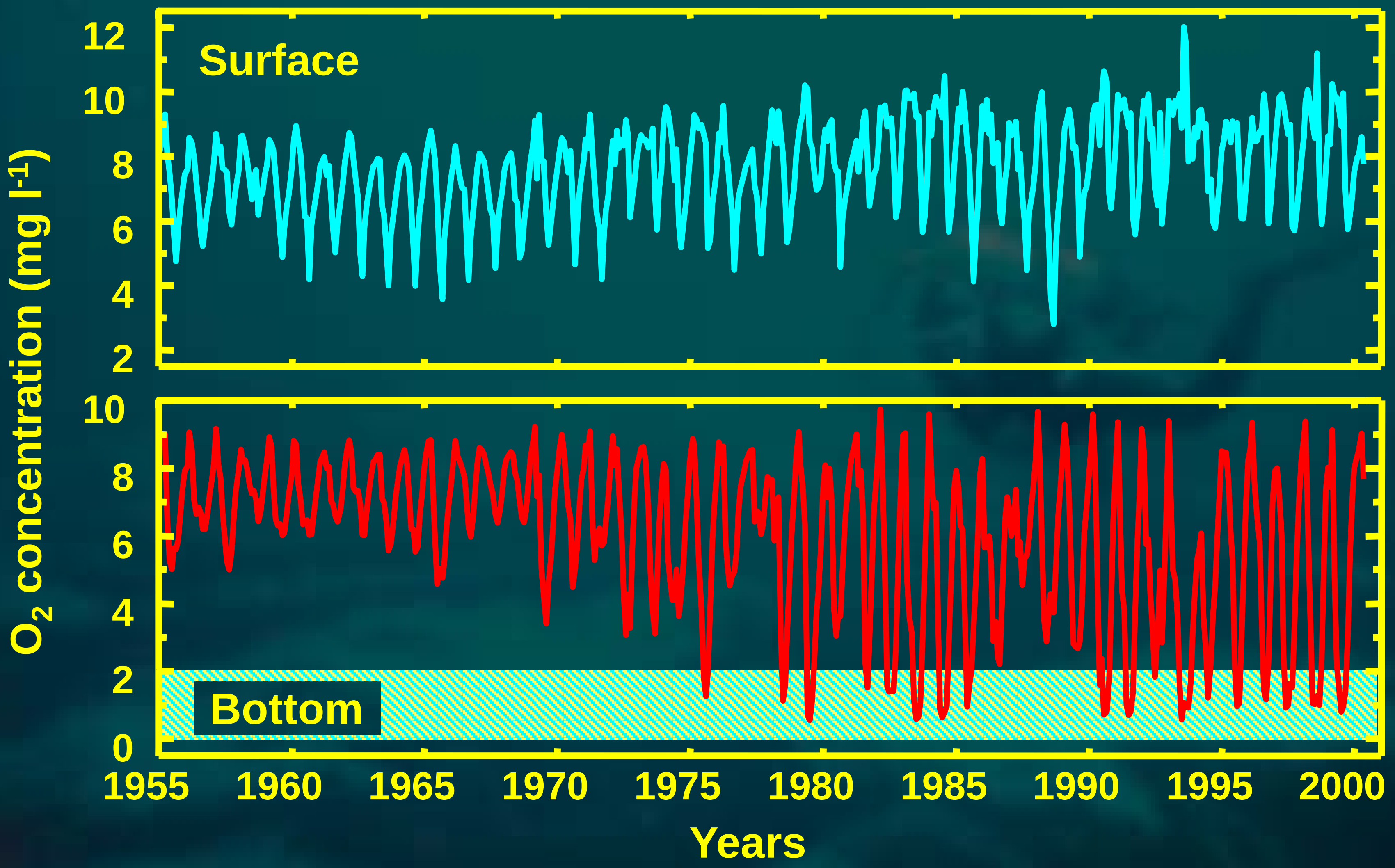
Justic et al. (2002)

Model Calibration



Justic et al. (2002)

Simulation 1955 - 2000



Justic et al. (2002)

Model Scenarios

- 30% reduction in MR runoff (Wolock and McCabe, 1999)
- MR nitrate concentration unchanged with respect to 1954 –1967
- 20% increase in MR runoff (Miller and Russell, 1992)
- 4 ^{o}C increase in NGM temperature (IPCC, 2001)
- 20% increase in MR runoff + 4 ^{o}C increase in NGM temperature (likely GCC scenario; IPCC, 2001)
- 30% reduction in MR nitrate flux (proposed management action; Rabalais et al., 2002)

Justic et al. (2003)

Model Results

Scenario	YWMH (< 2 mg/l)	YWSH (< 1 mg/l)	% Change
1. Nominal model	19	16	-
2. -30% MR runoff	8	4	-58
3. MR nitrate 1954-1967	0	0	∞
4. +20% MR runoff	26	20	+37
5. +4 ^{o}C	25	19	+32
6. +20% MR runoff +4 ^{o}C	31	26	+63
7. -30% MR nitrate flux	12	7	-37

The total number of years = 45

Justic et al. (2003)

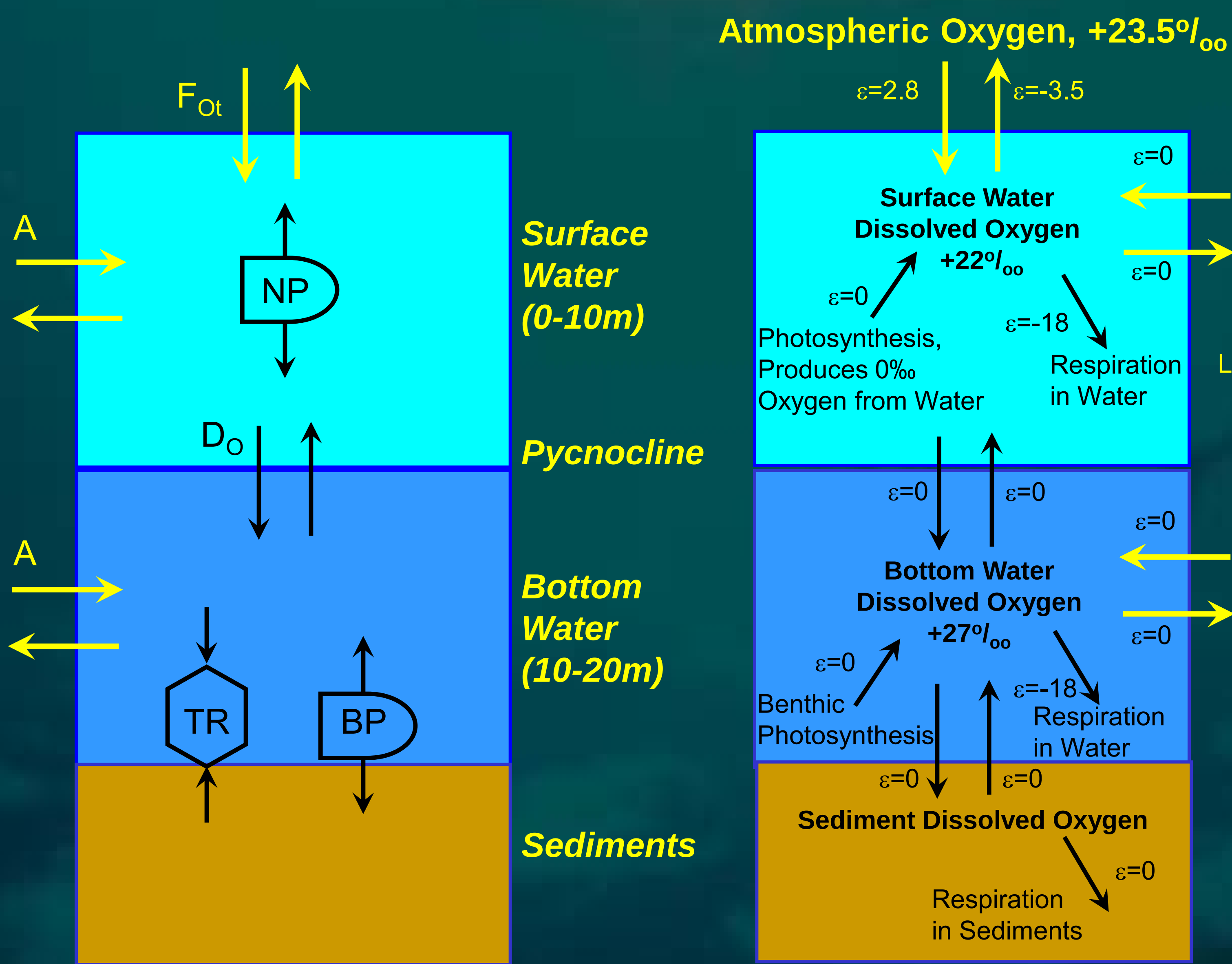
“Dual-Budget” Model

Years developed: 2007 - 2010

Publications: Quiñones-Rivera et al. (2007, 2009, 2010)

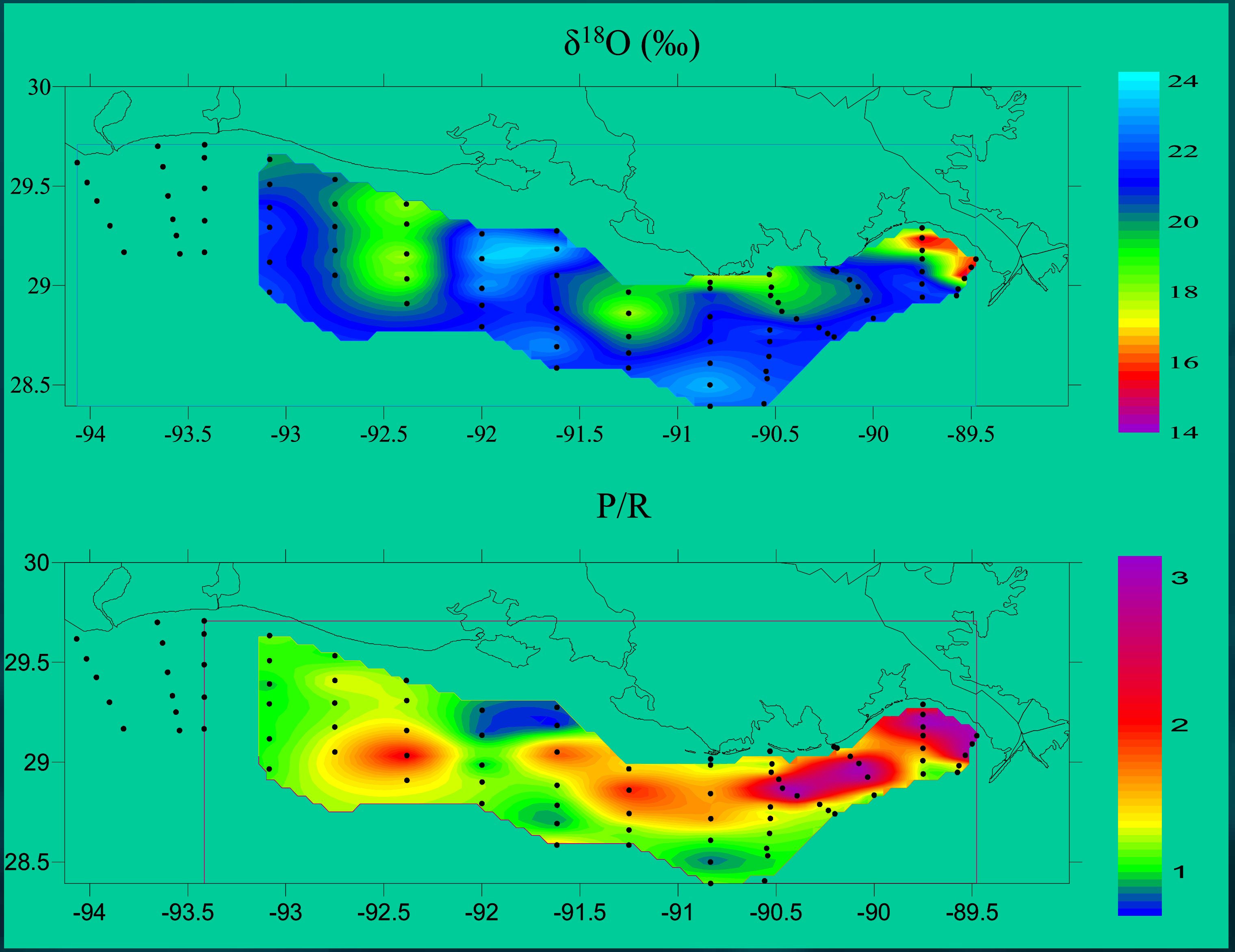
Objectives/Research questions:

- Sources of OM (P/R ratios)
- Relative importance of benthic and water column respiration



Quiñones-Rivera et al. (2007, 2009, 2010)

P/R Ratios (July 2001)



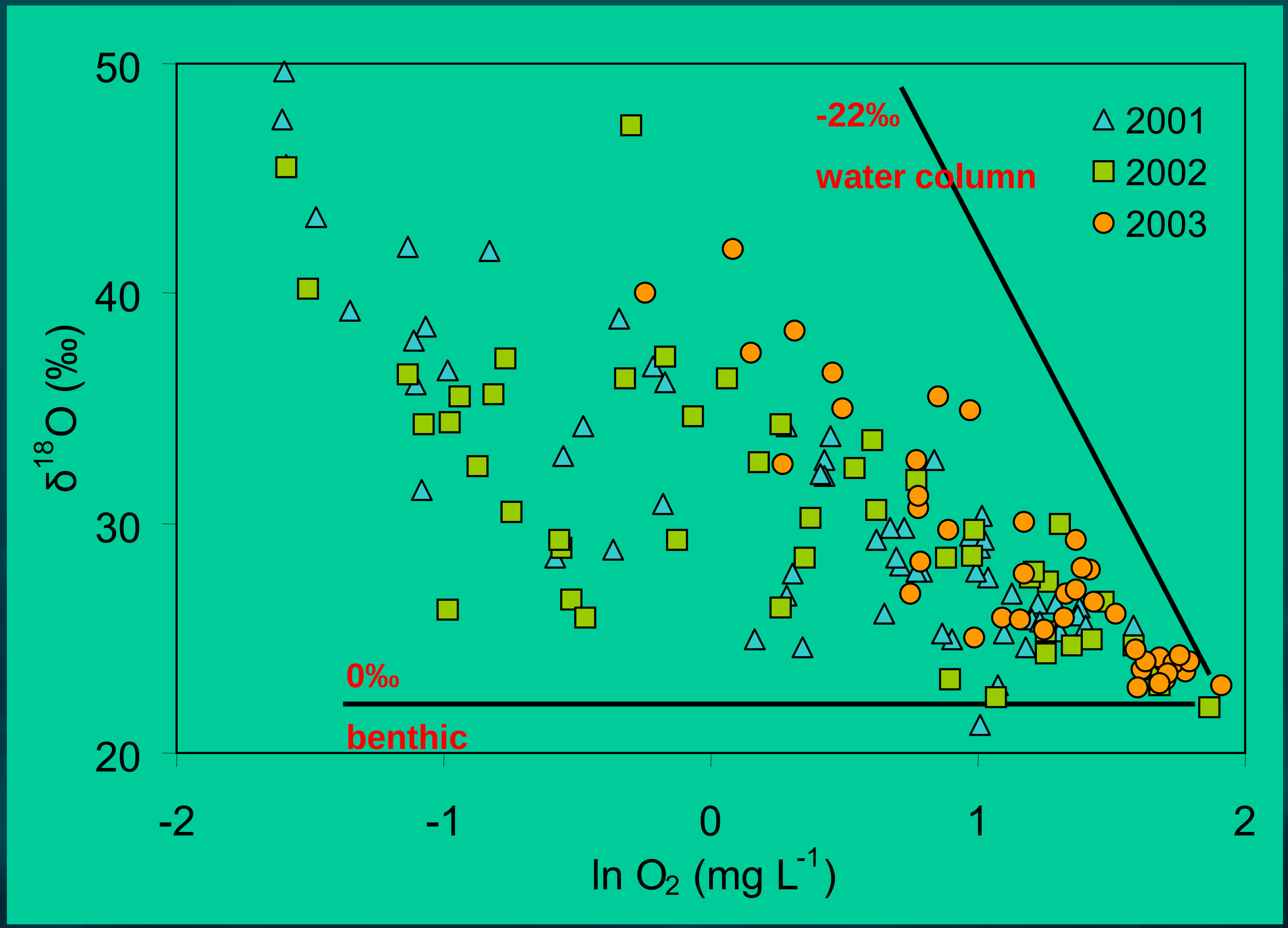
Quiñones-Rivera et al. (2007)

% Benthic Respiration

73%
(July 2001)

81%
(July 2002)

60% (July
2003)



Quiñones-Rivera et al. (2007, 2009, 2010)

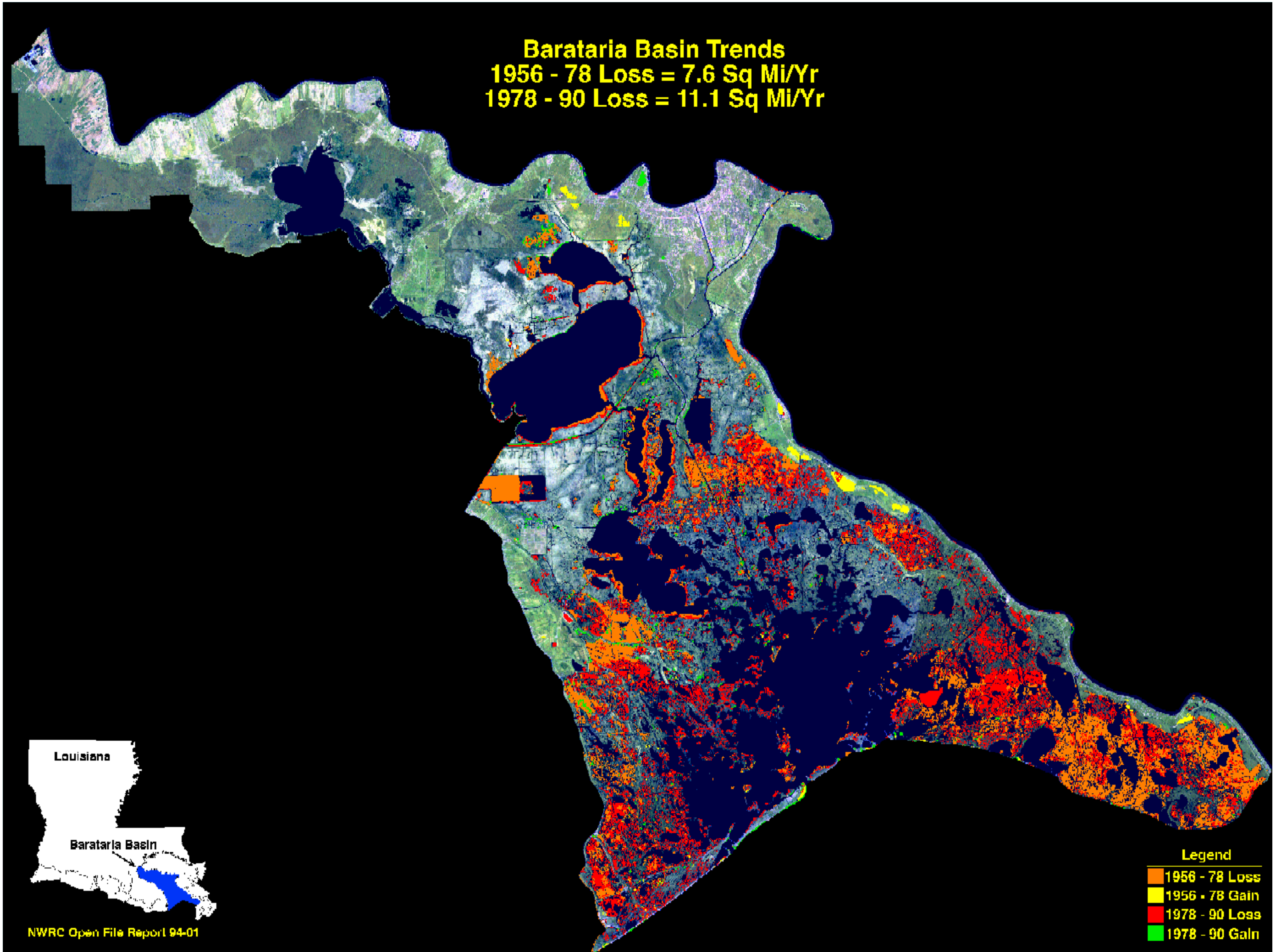
Barataria 2-D Model

Years developed: 2008 – 2012

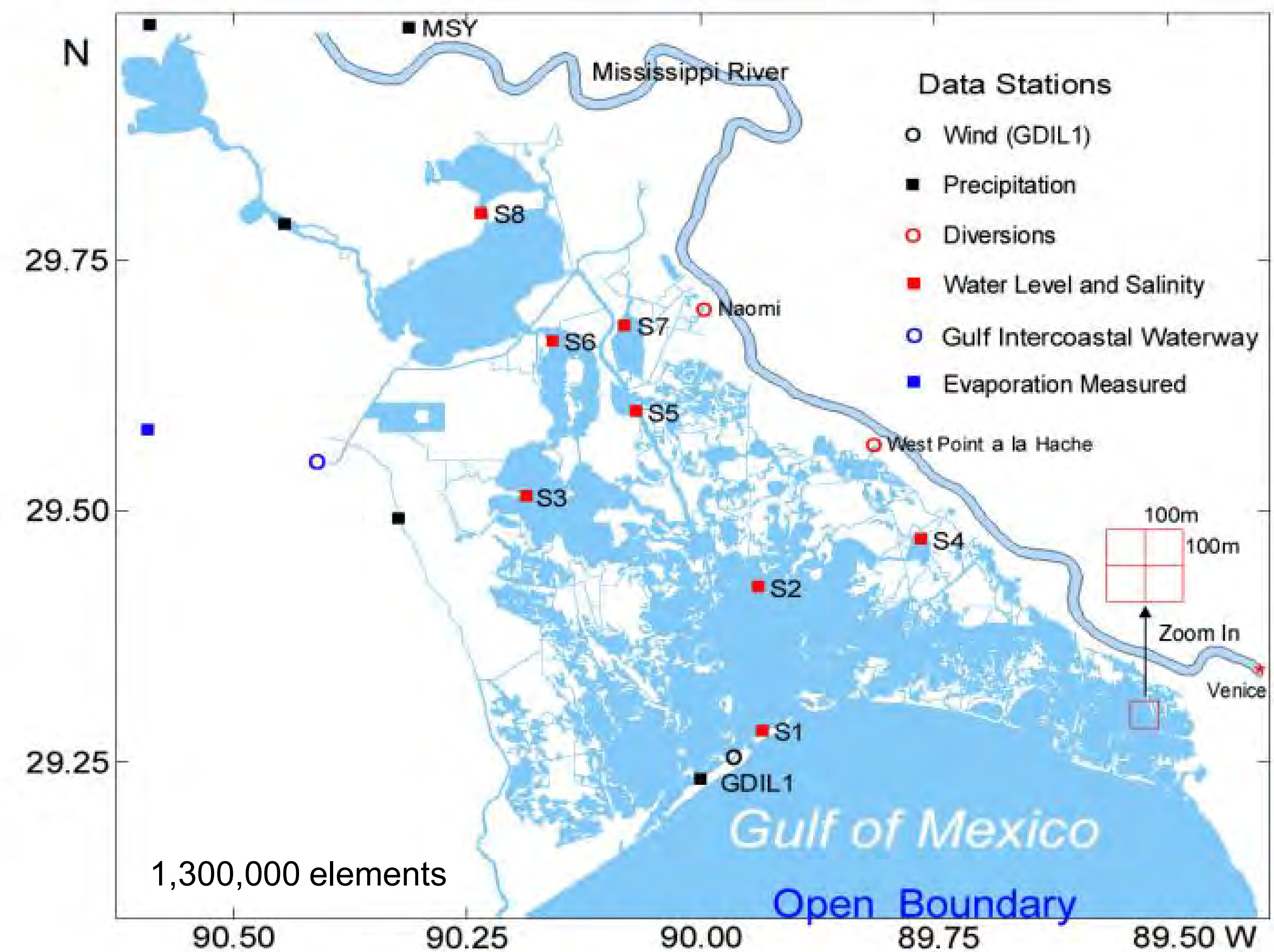
Publications: Inoue et al. (2008), Das et al. (2011, 2012)

Objectives/Research questions:

- Importance of estuarine-shelf exchanges for hypoxia development (i.e., “outwelling” hypothesis, “wetland” hypothesis, “missing carbon”)
- Implications of large scale coastal restoration efforts (i.e., river diversions)


Barataria Basin Trends
1956 - 78 Loss = 7.6 Sq Mi/Yr
1978 - 90 Loss = 11.1 Sq Mi/Yr
Louisiana
Barataria Basin
NWRC Open File Report 94-01
Legend
1956 - 78 Loss
1956 - 78 Gain
1978 - 90 Loss
1978 - 90 Gain

Barataria 2-D Model



Inoue et al. (2008)

Freshwater Sources

- 64 known streams
- 522 unknown streams
- Davis Pond diversion
- Naomi and Point a la Hache siphons
- Gulf Intracoastal Waterway

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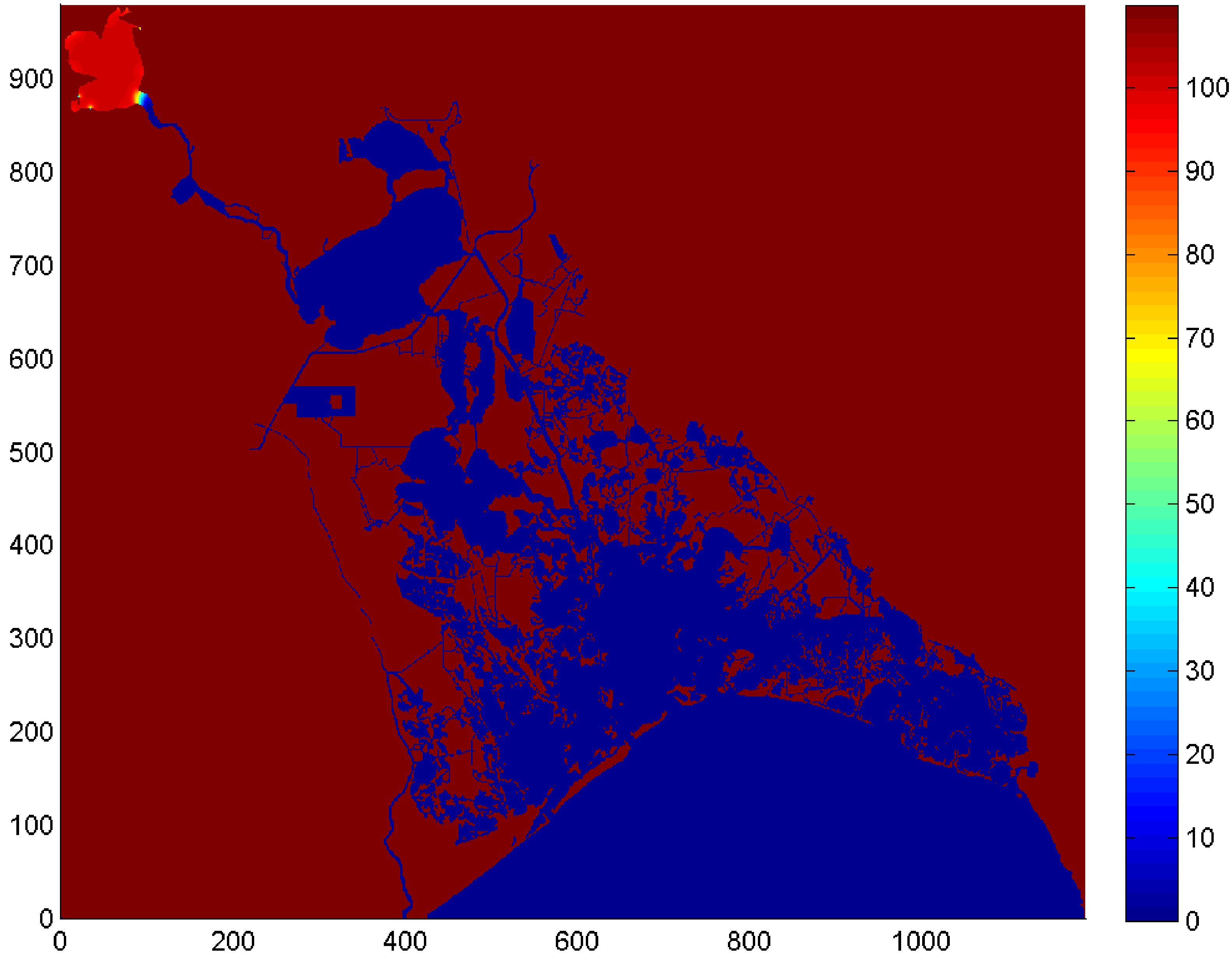

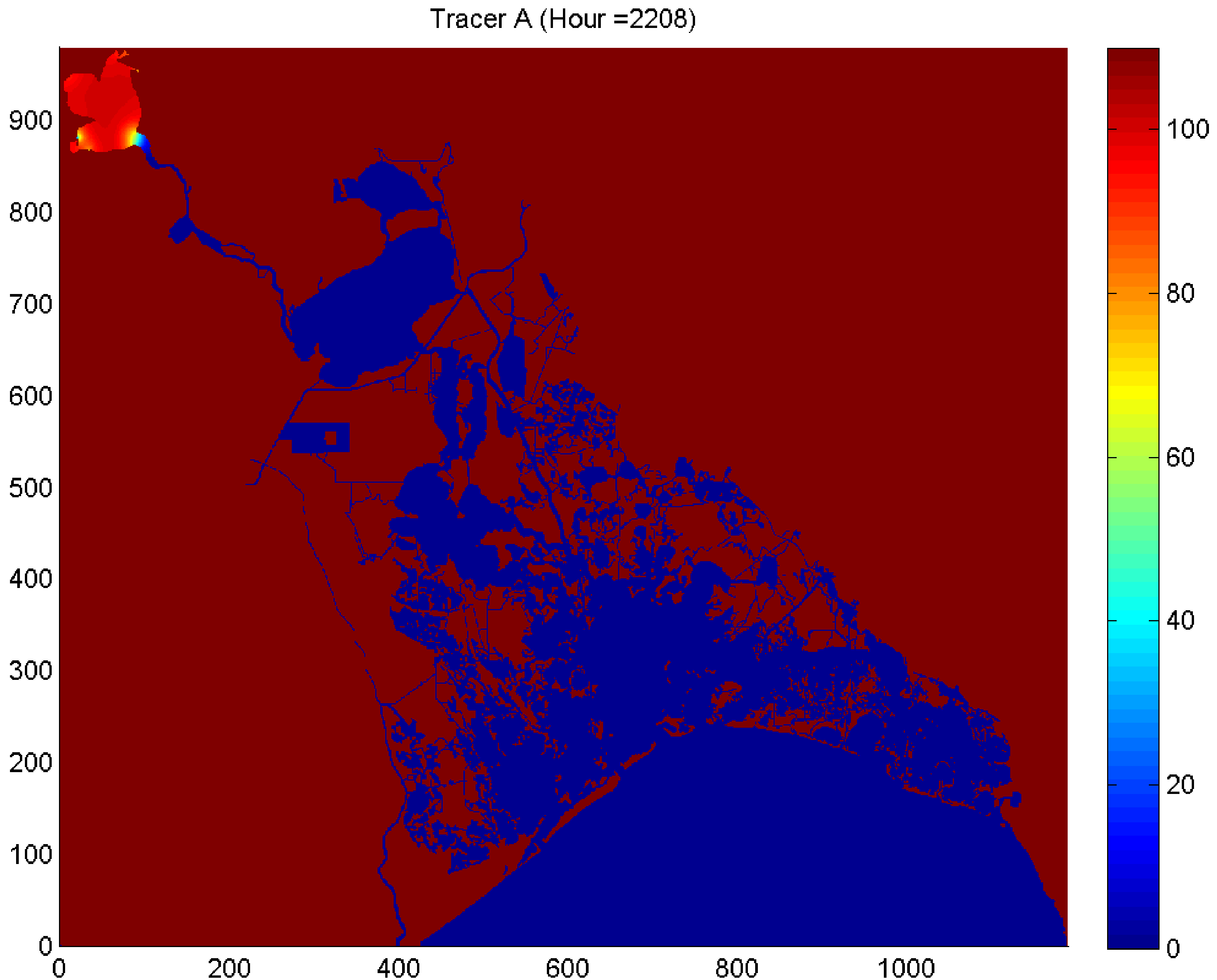

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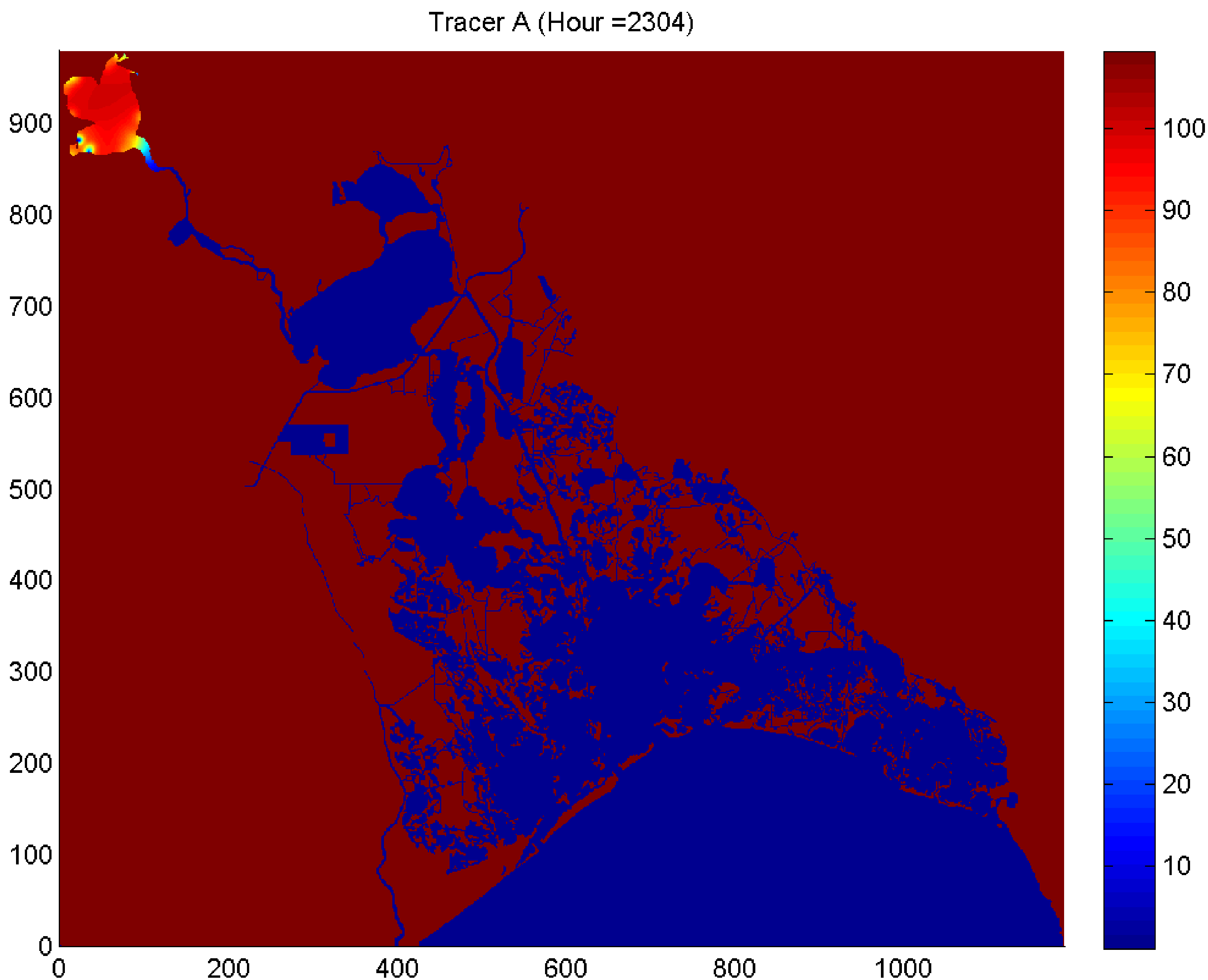

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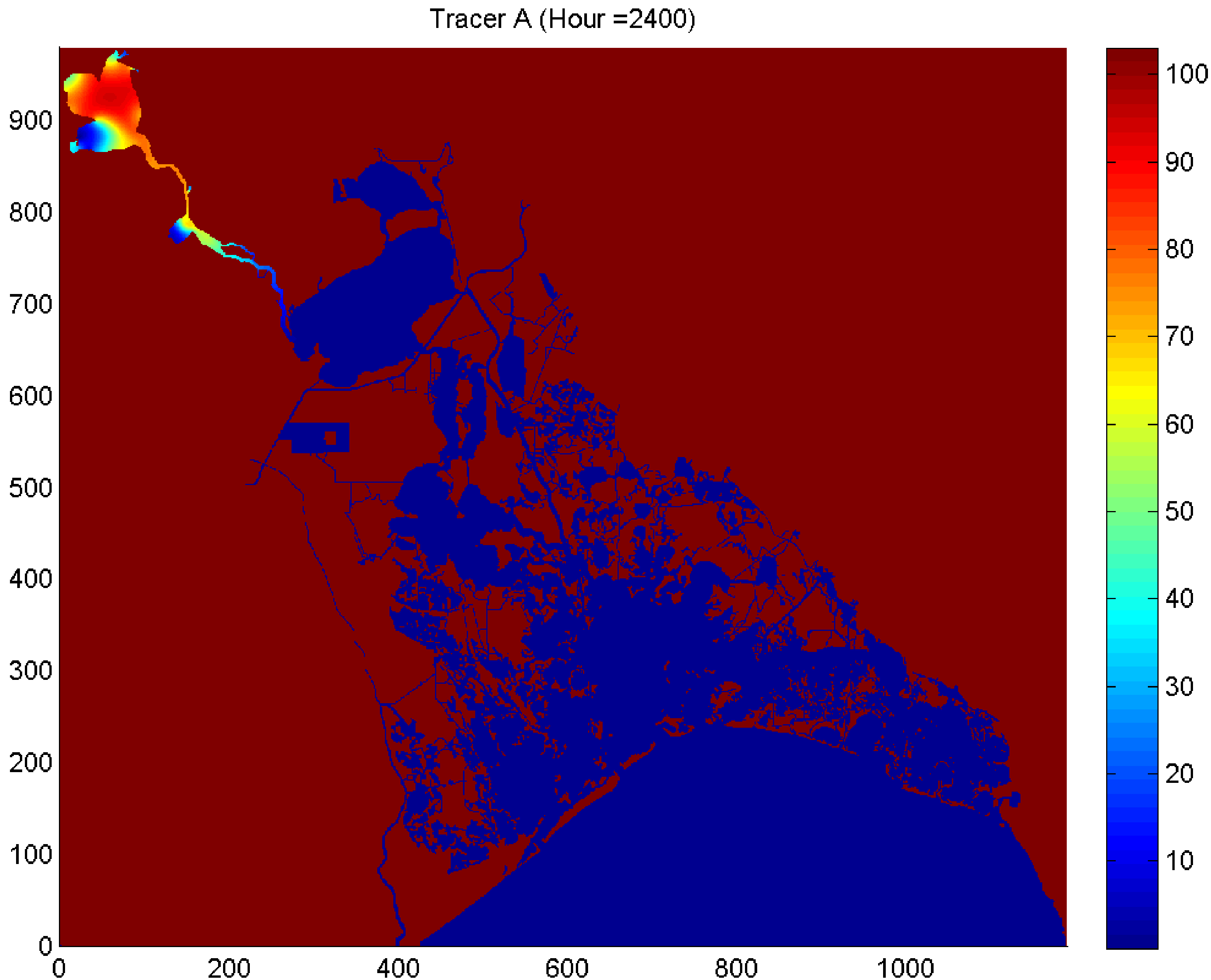

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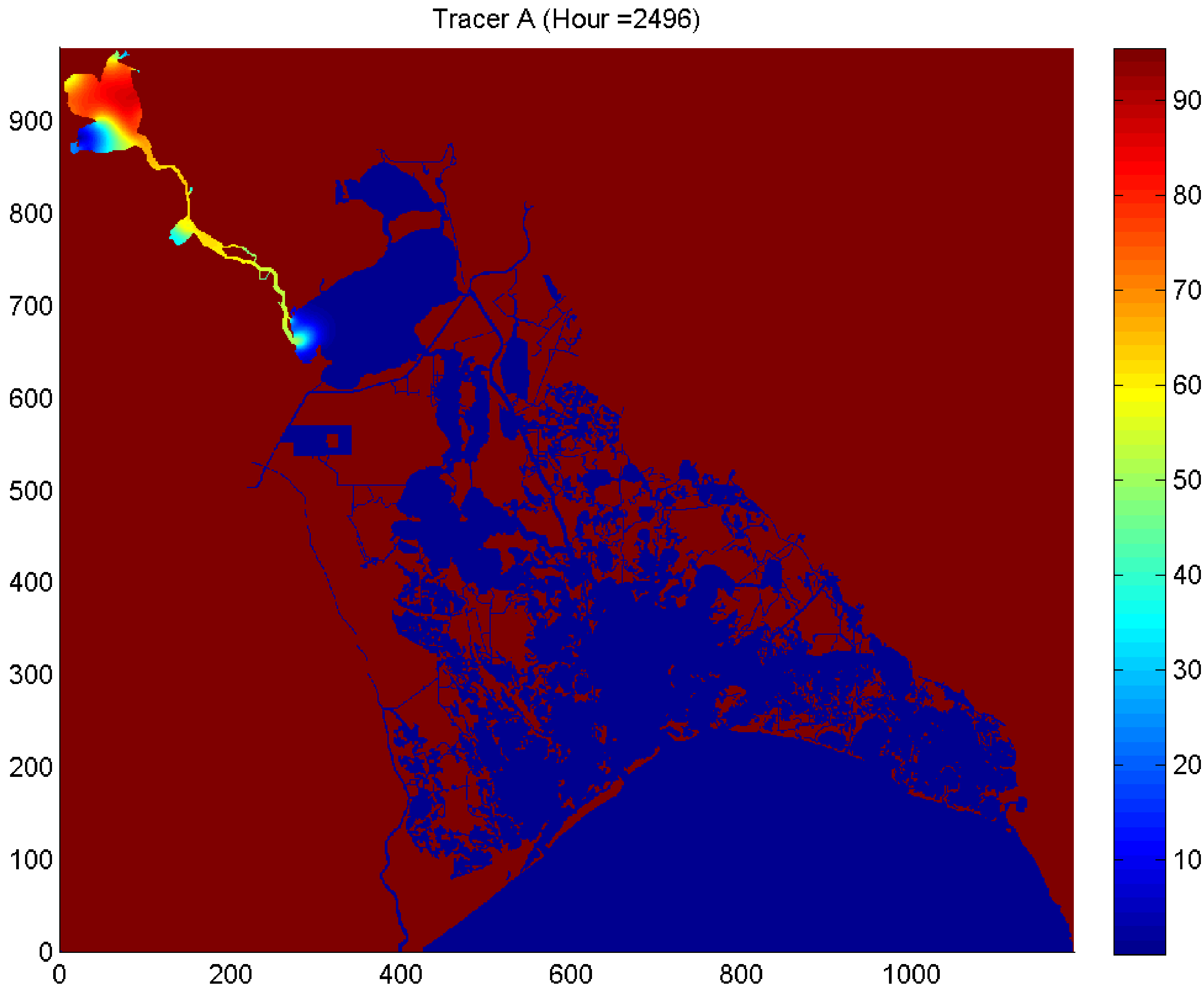

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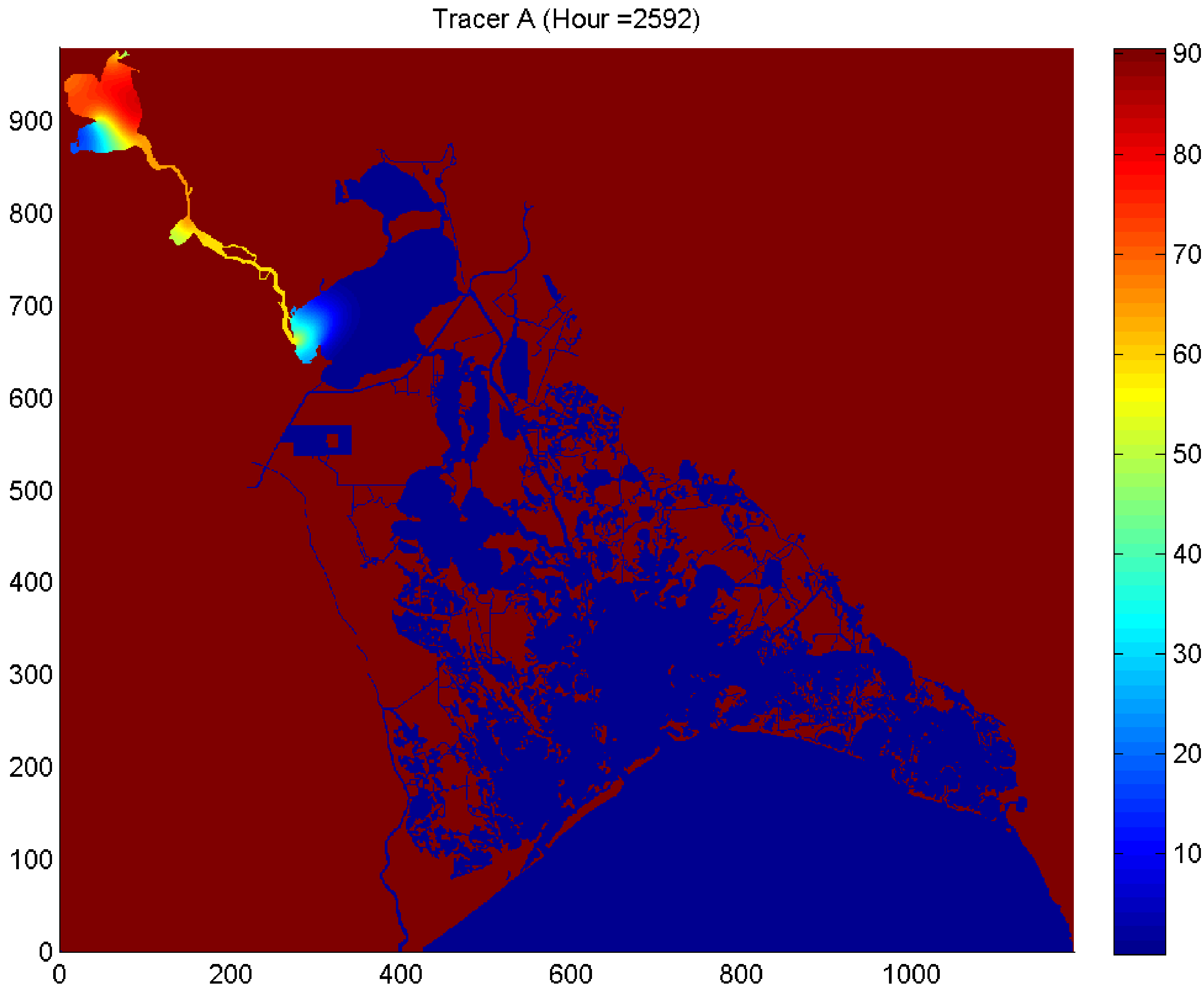

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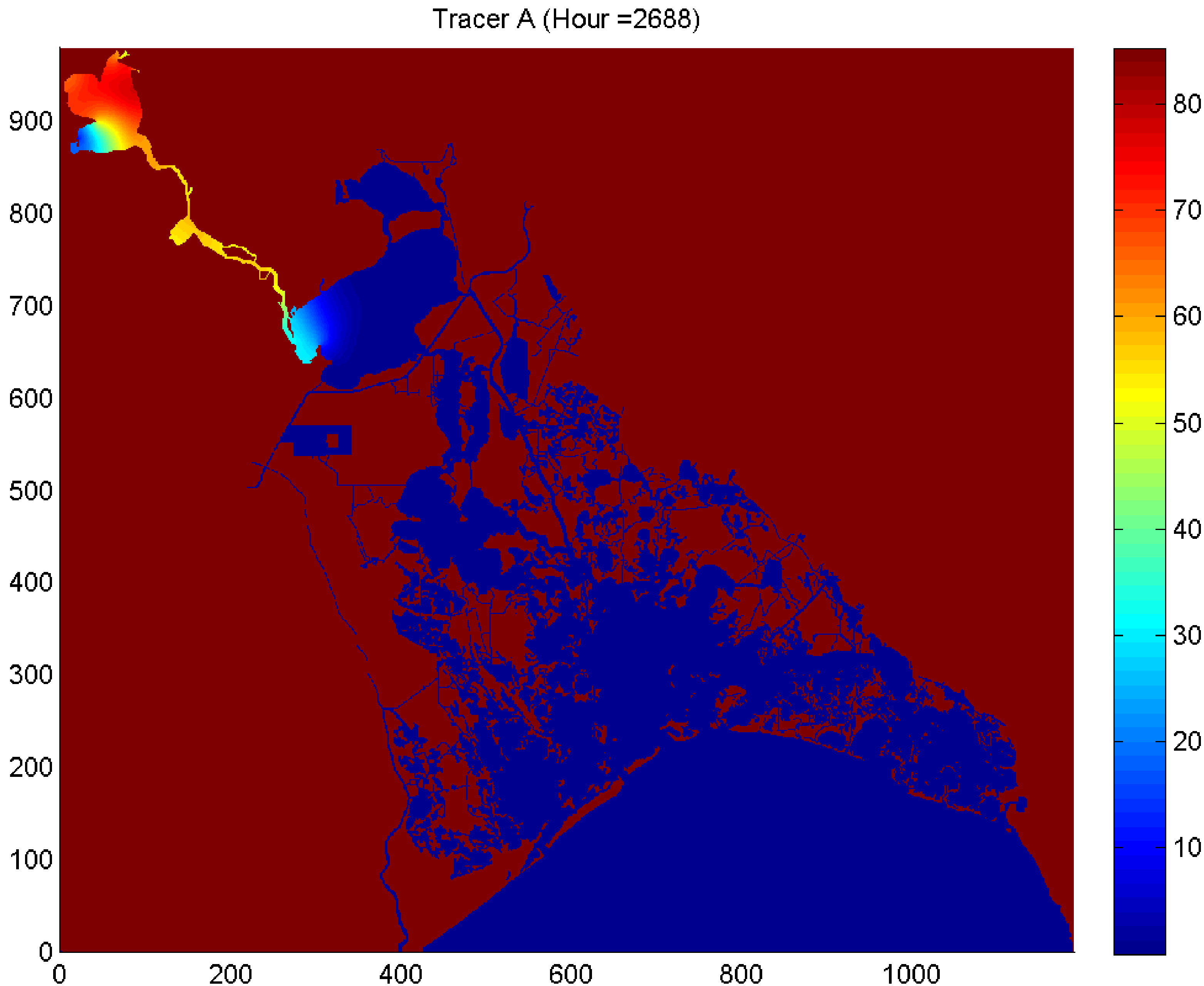
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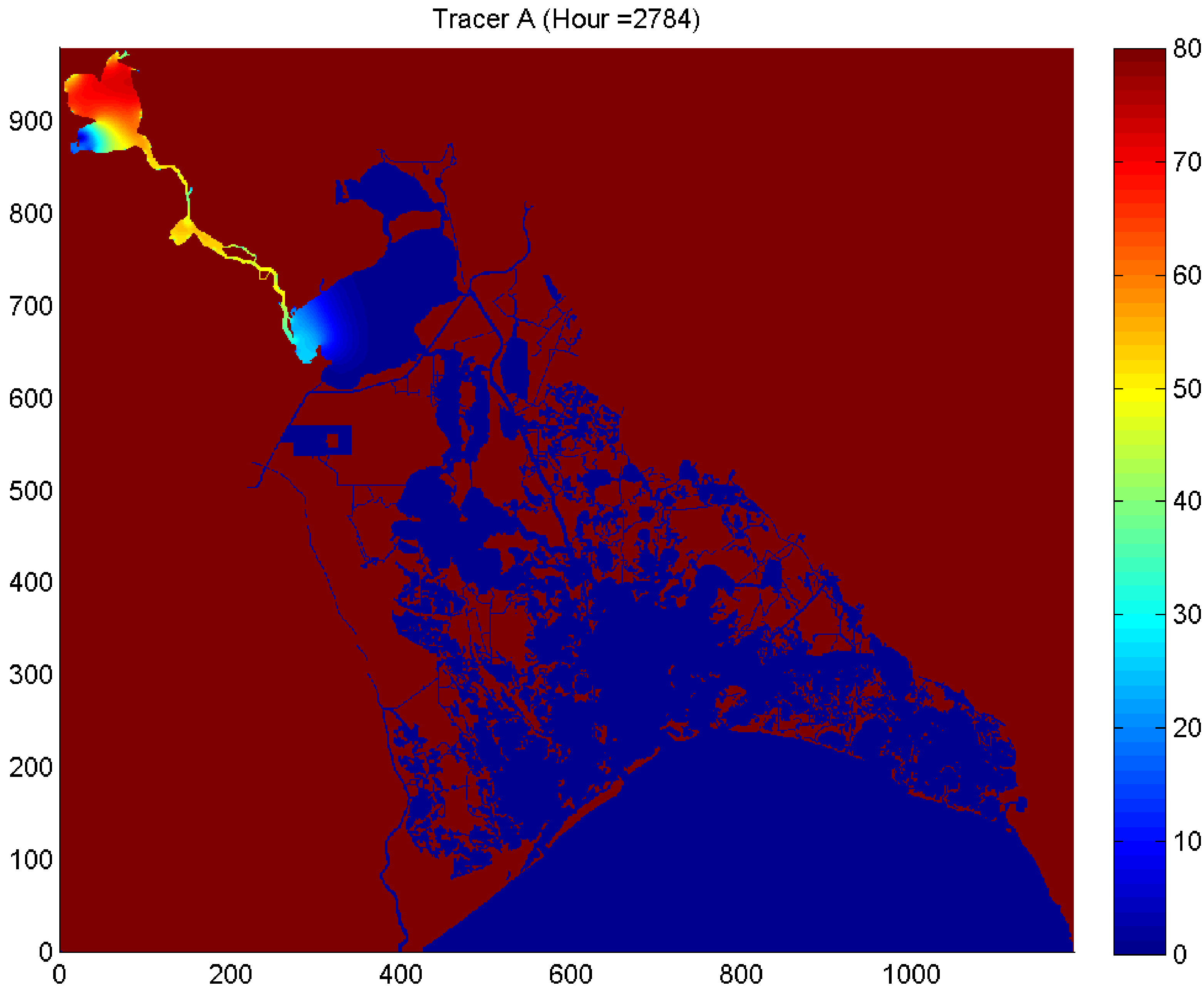

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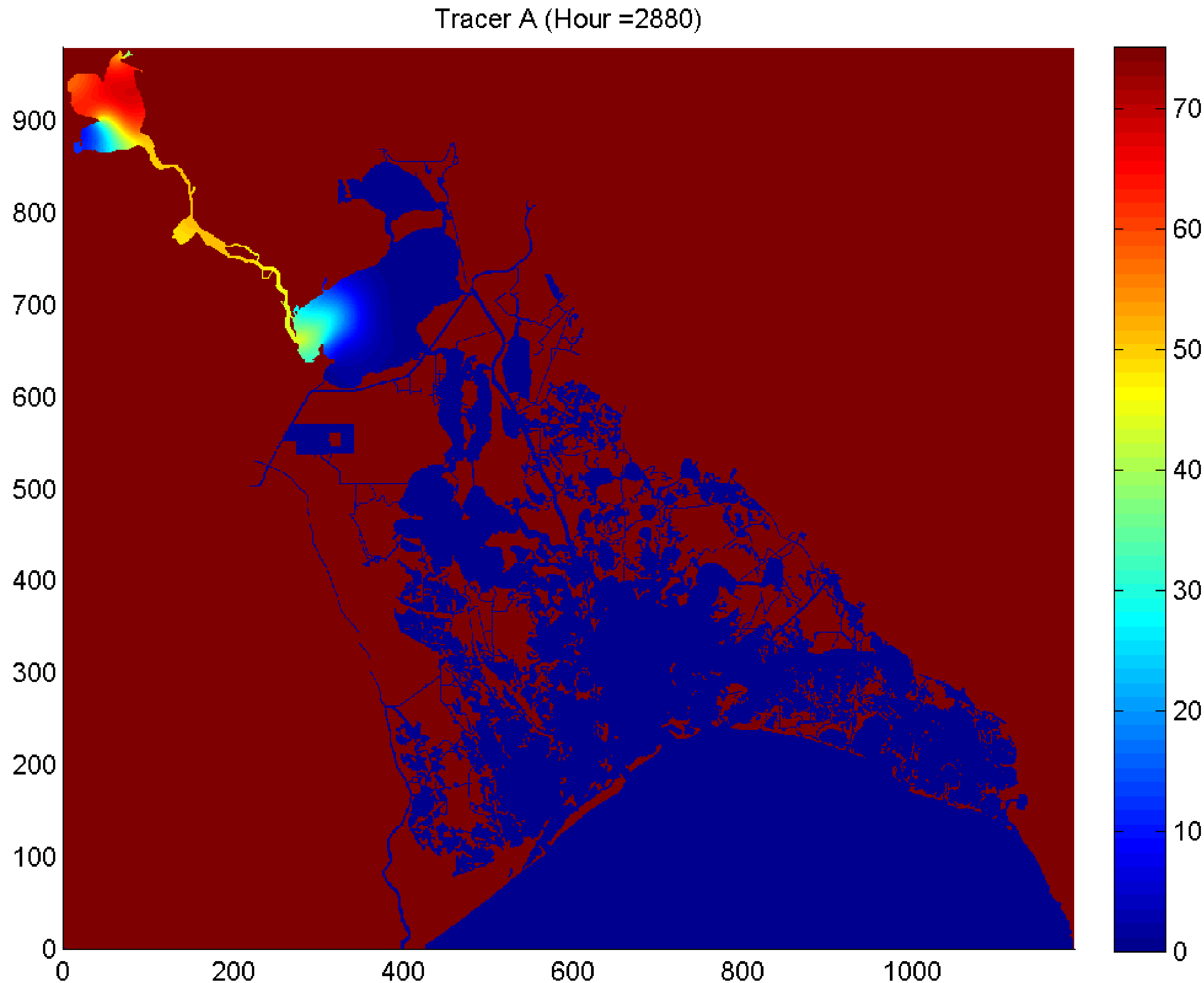

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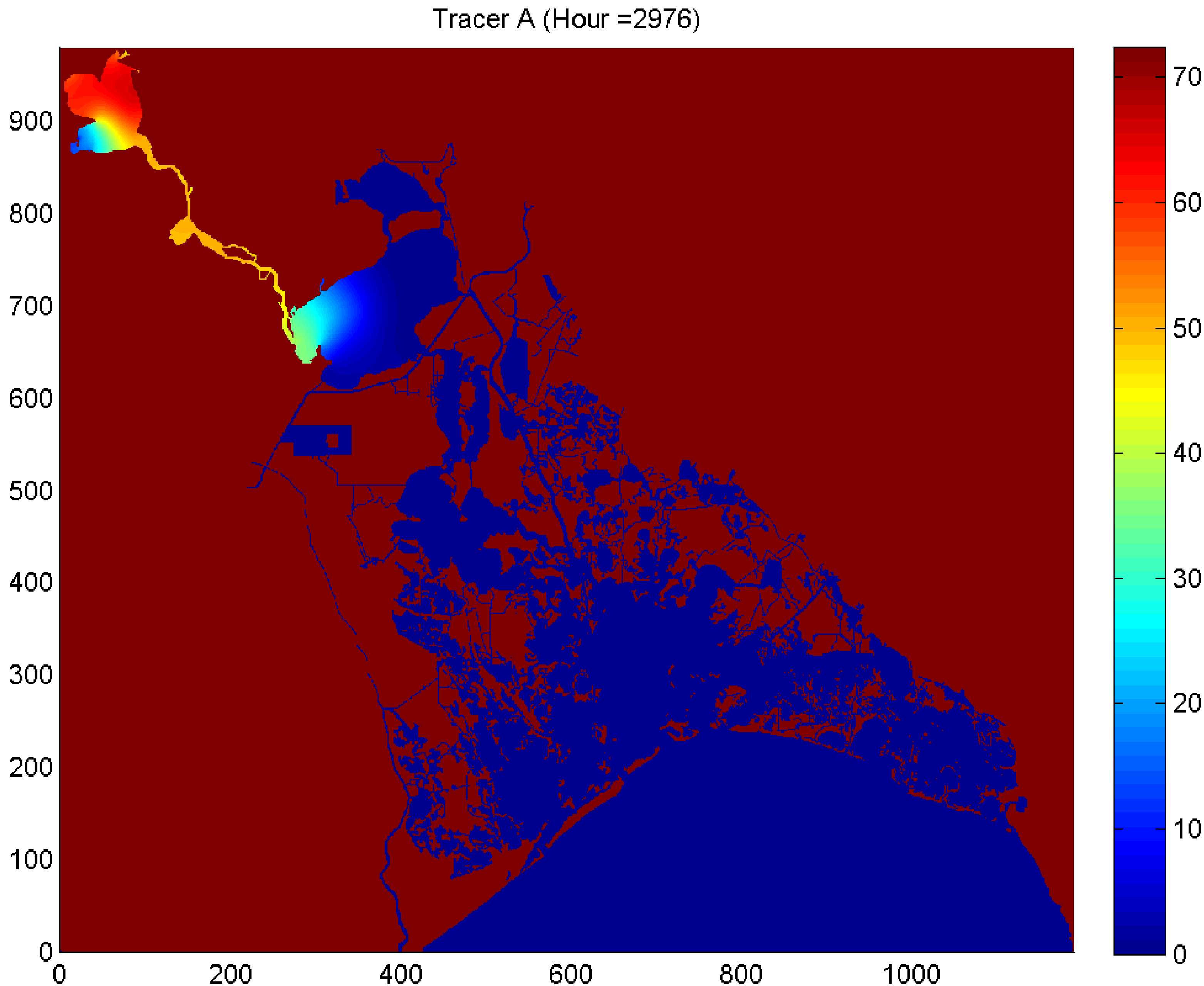

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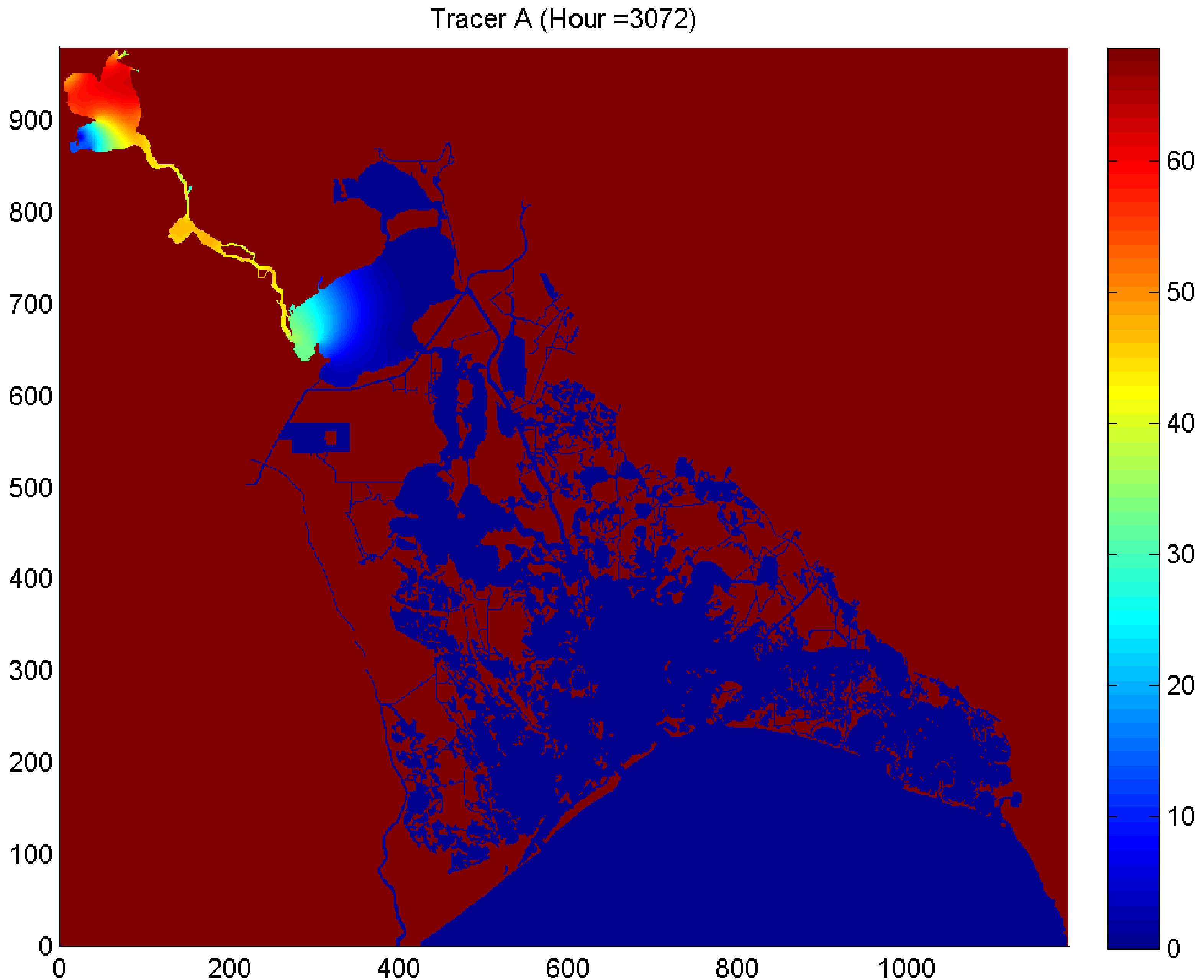
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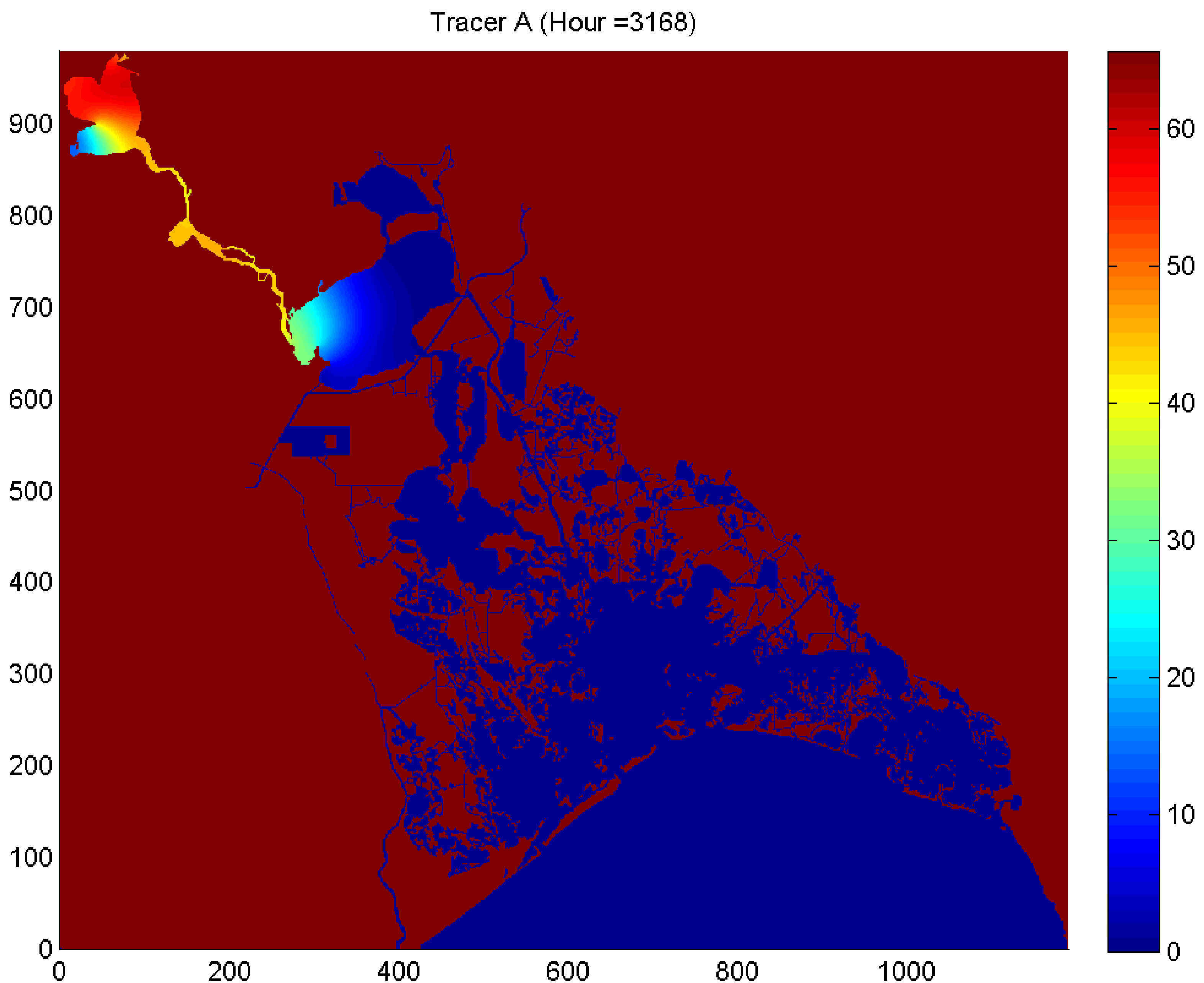
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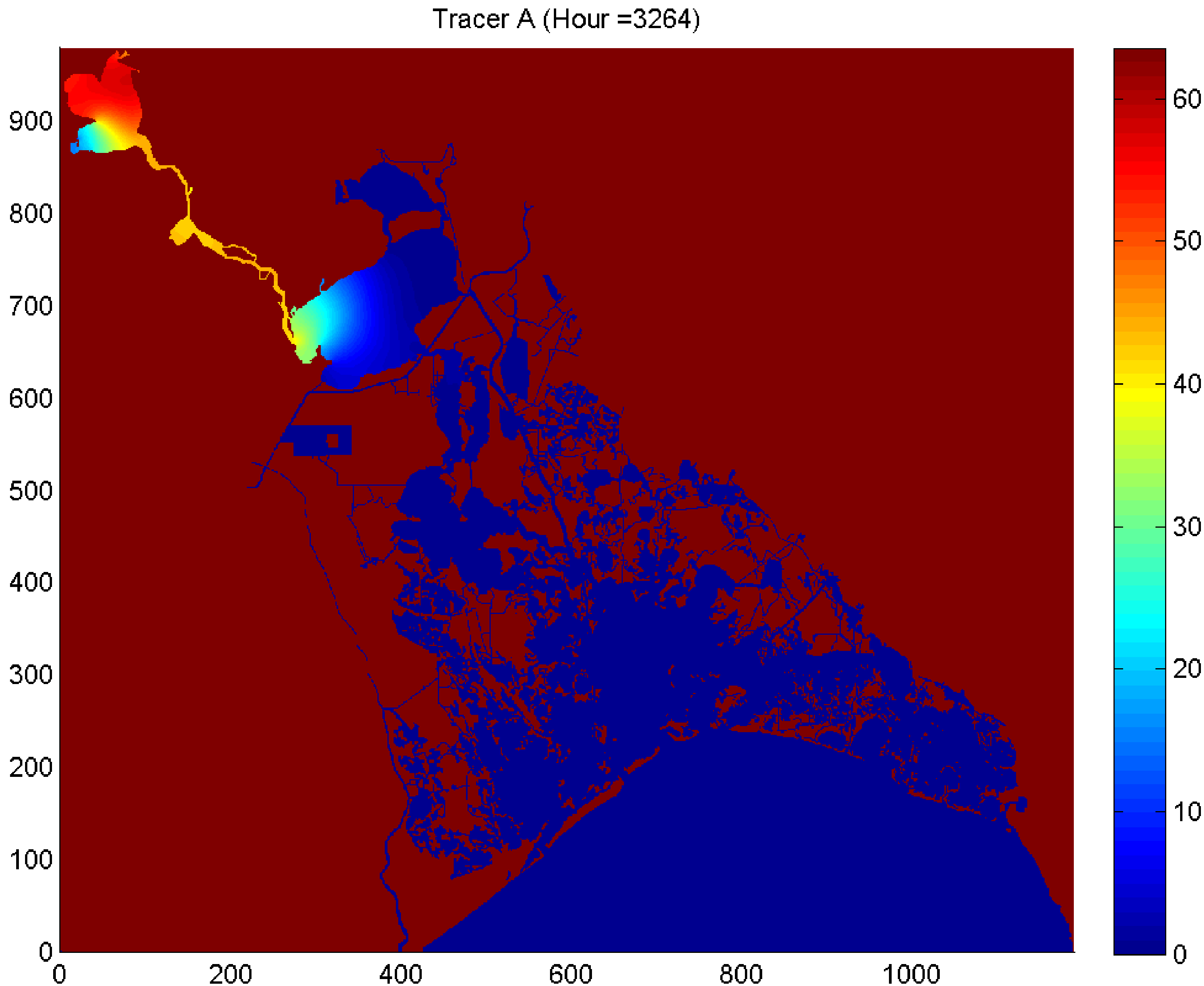

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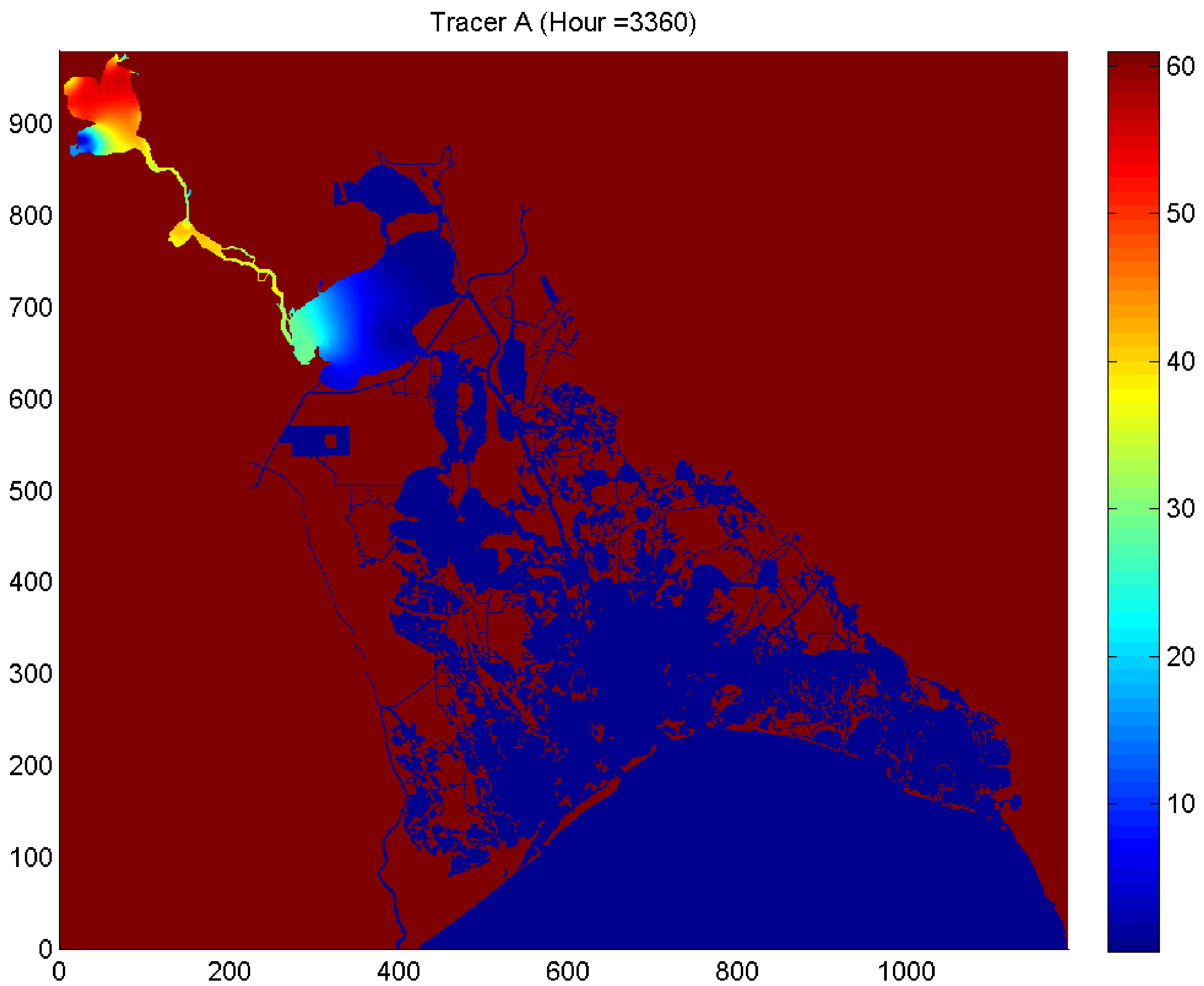
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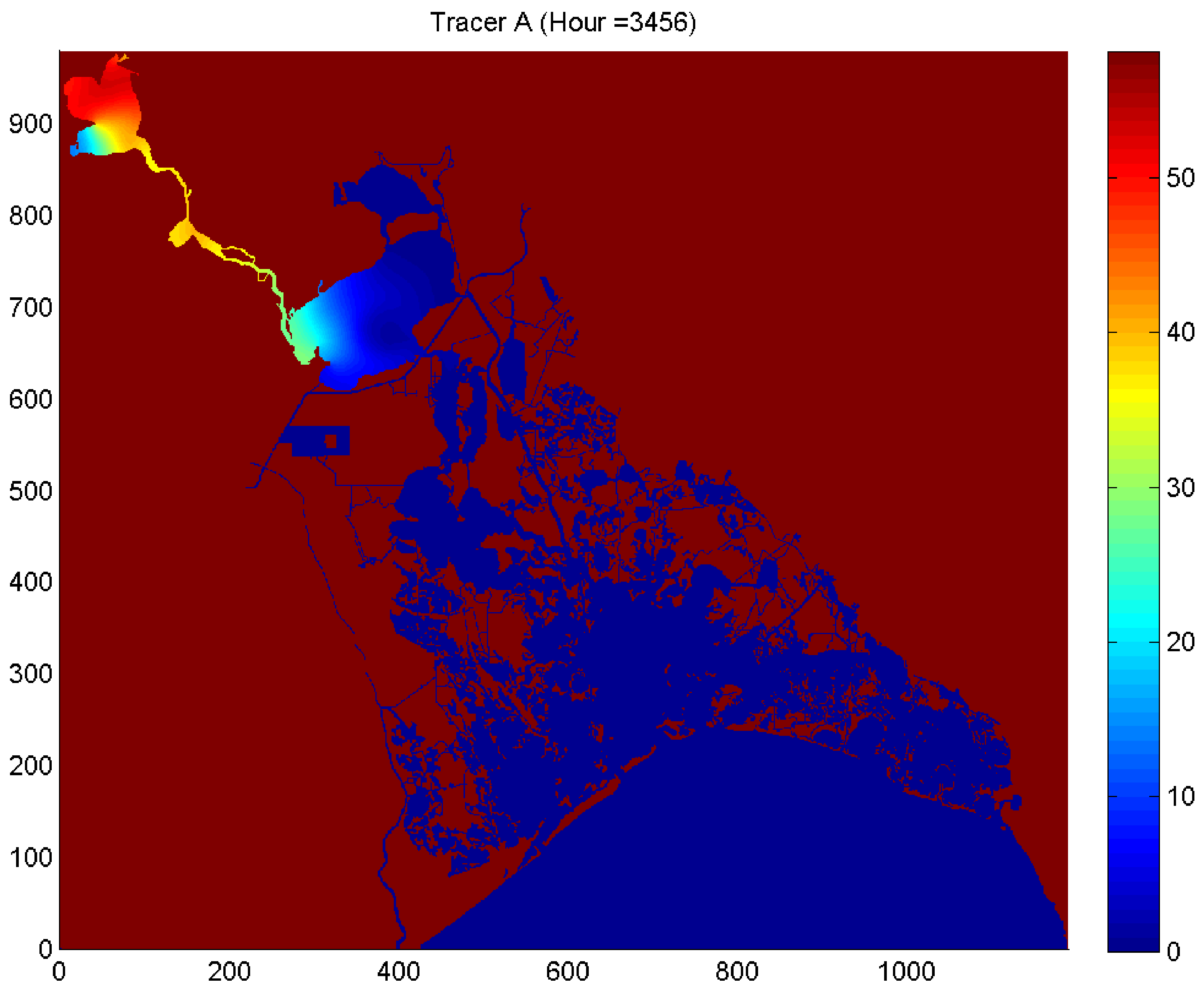

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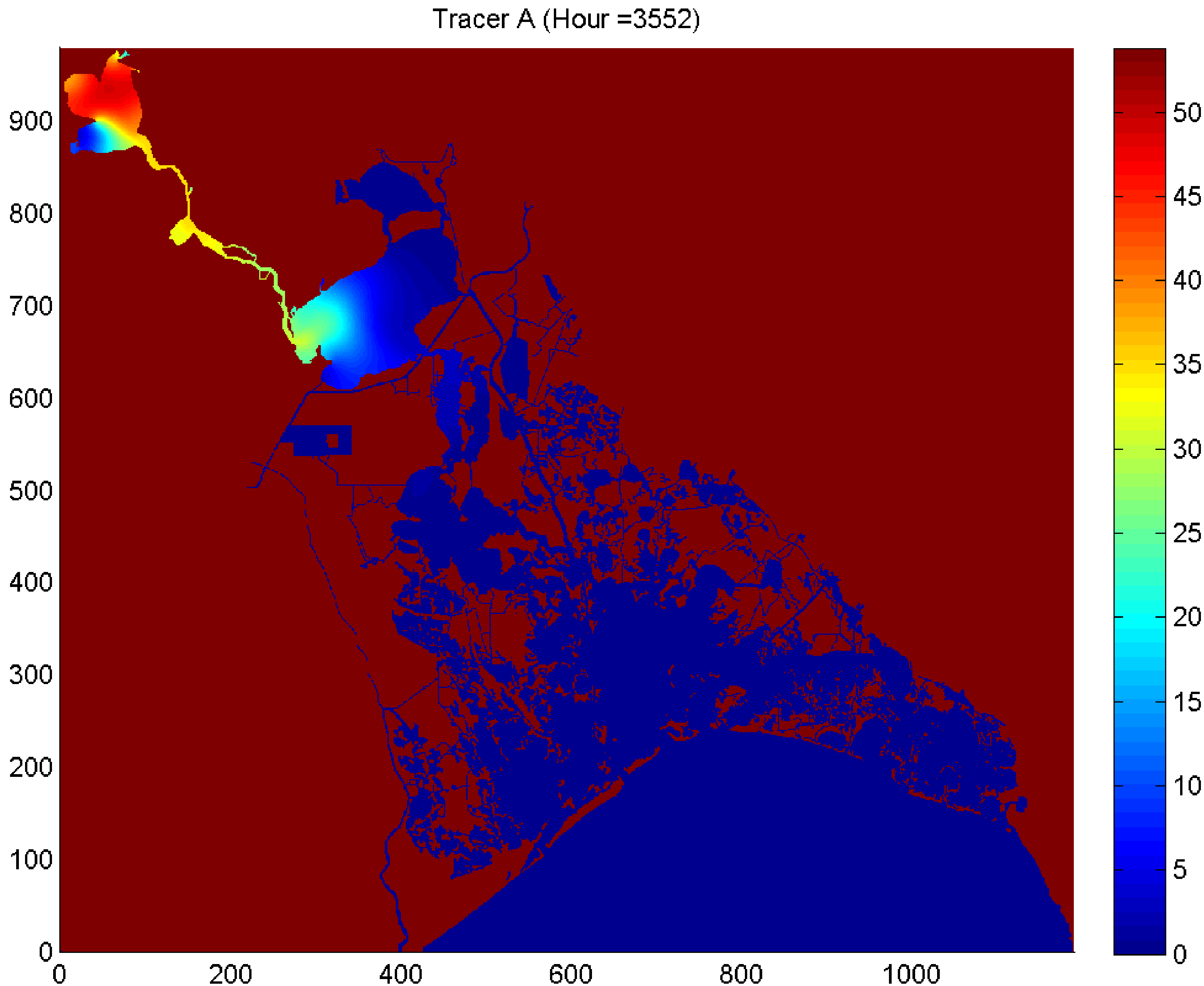

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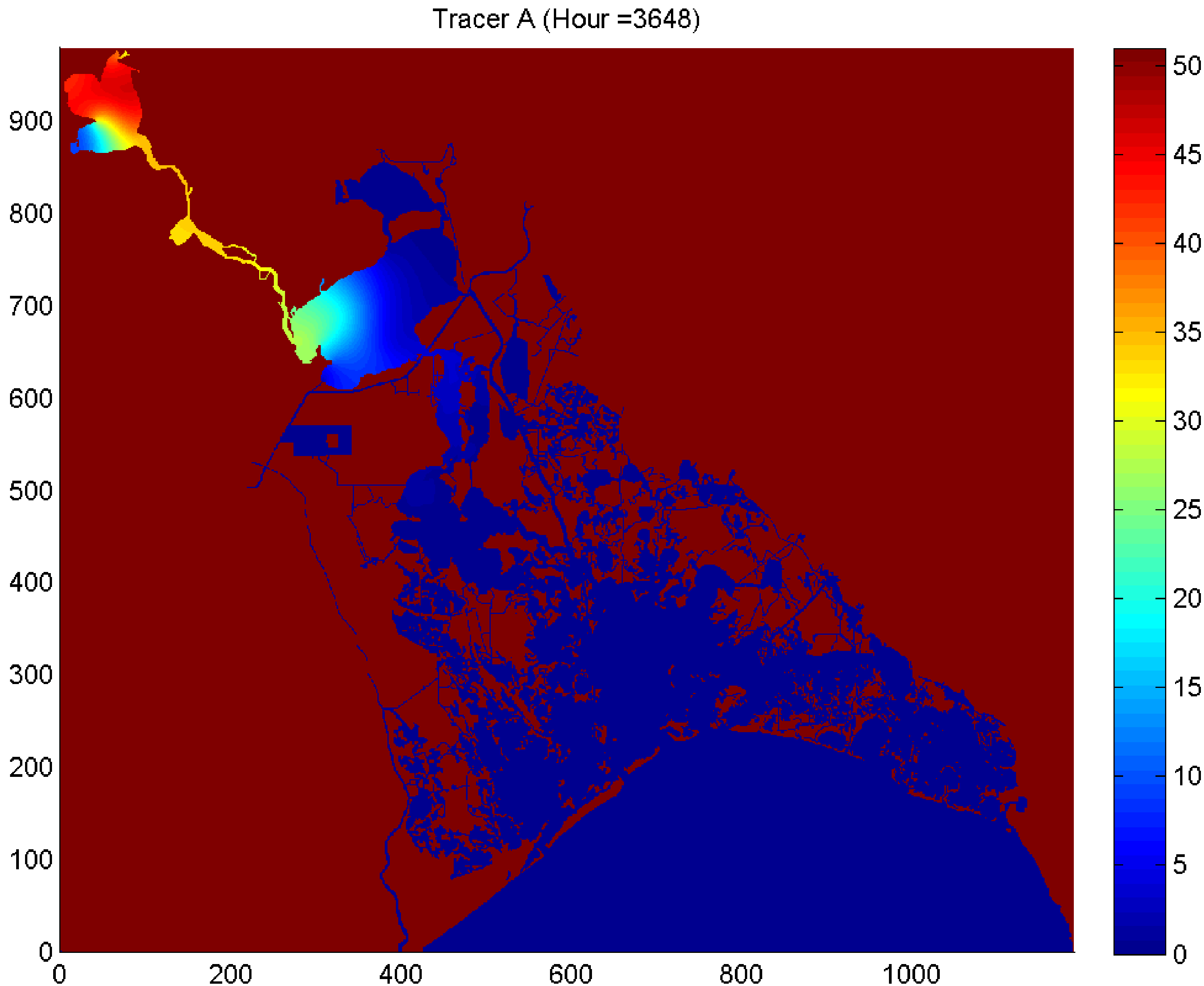

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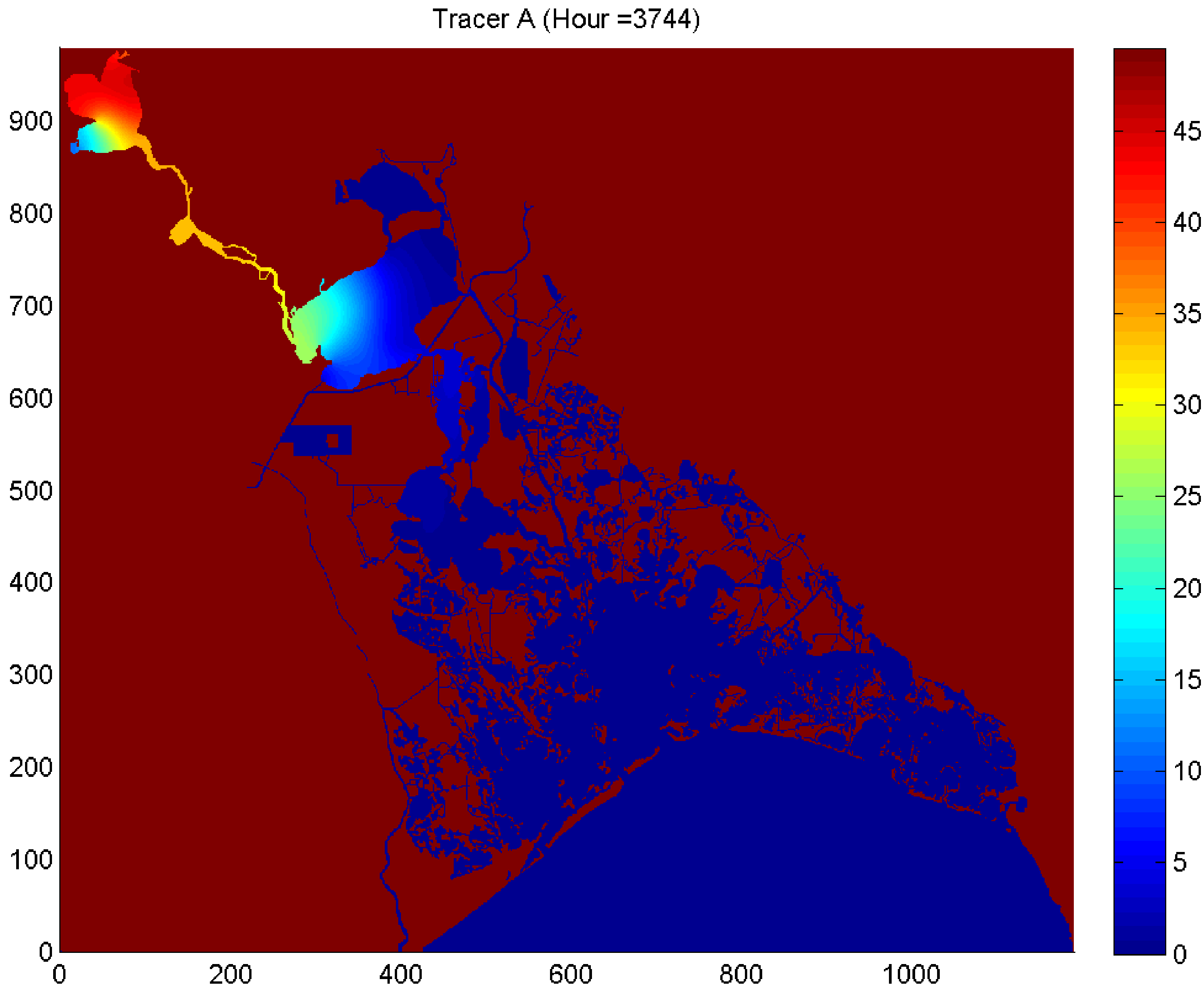
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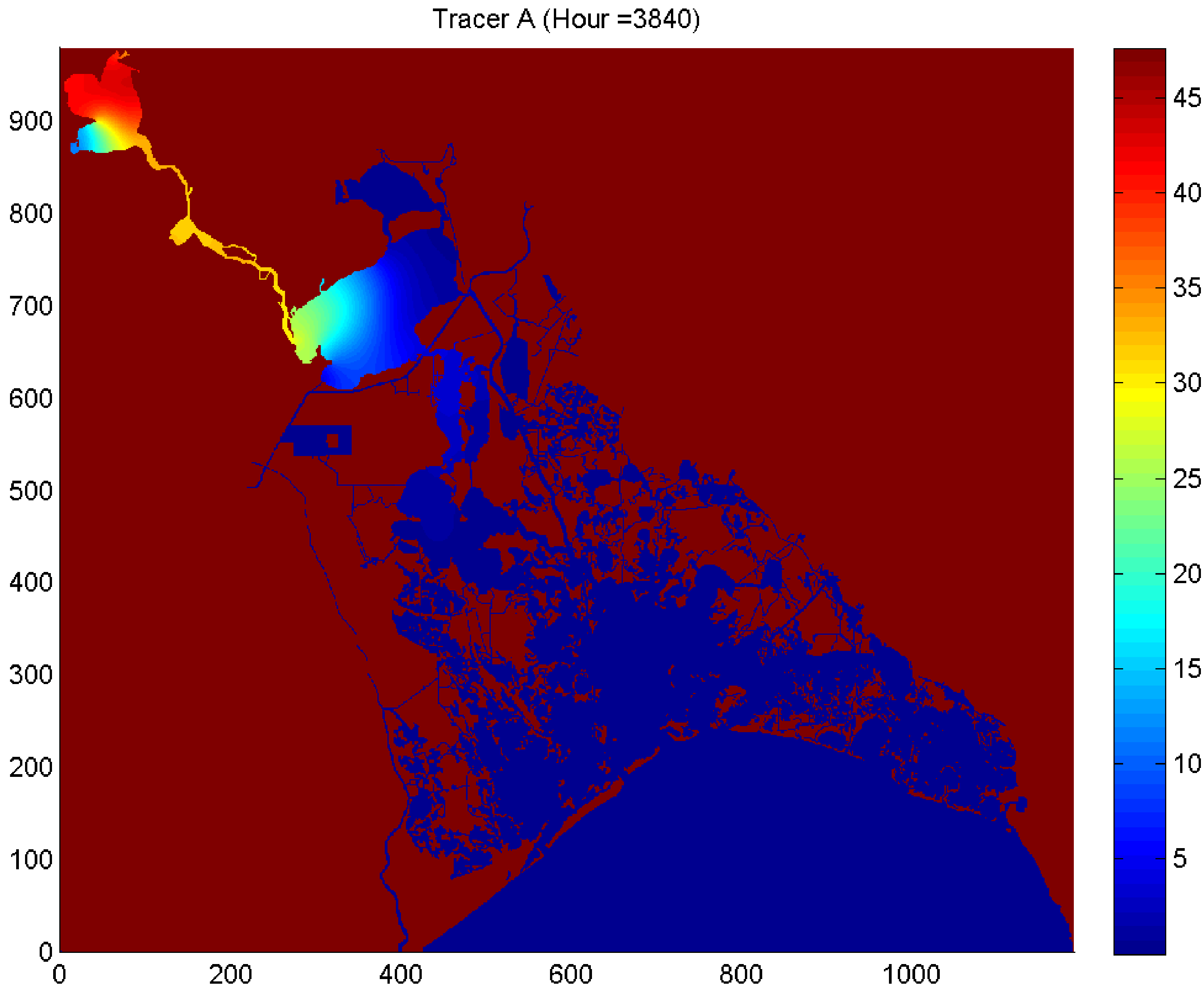
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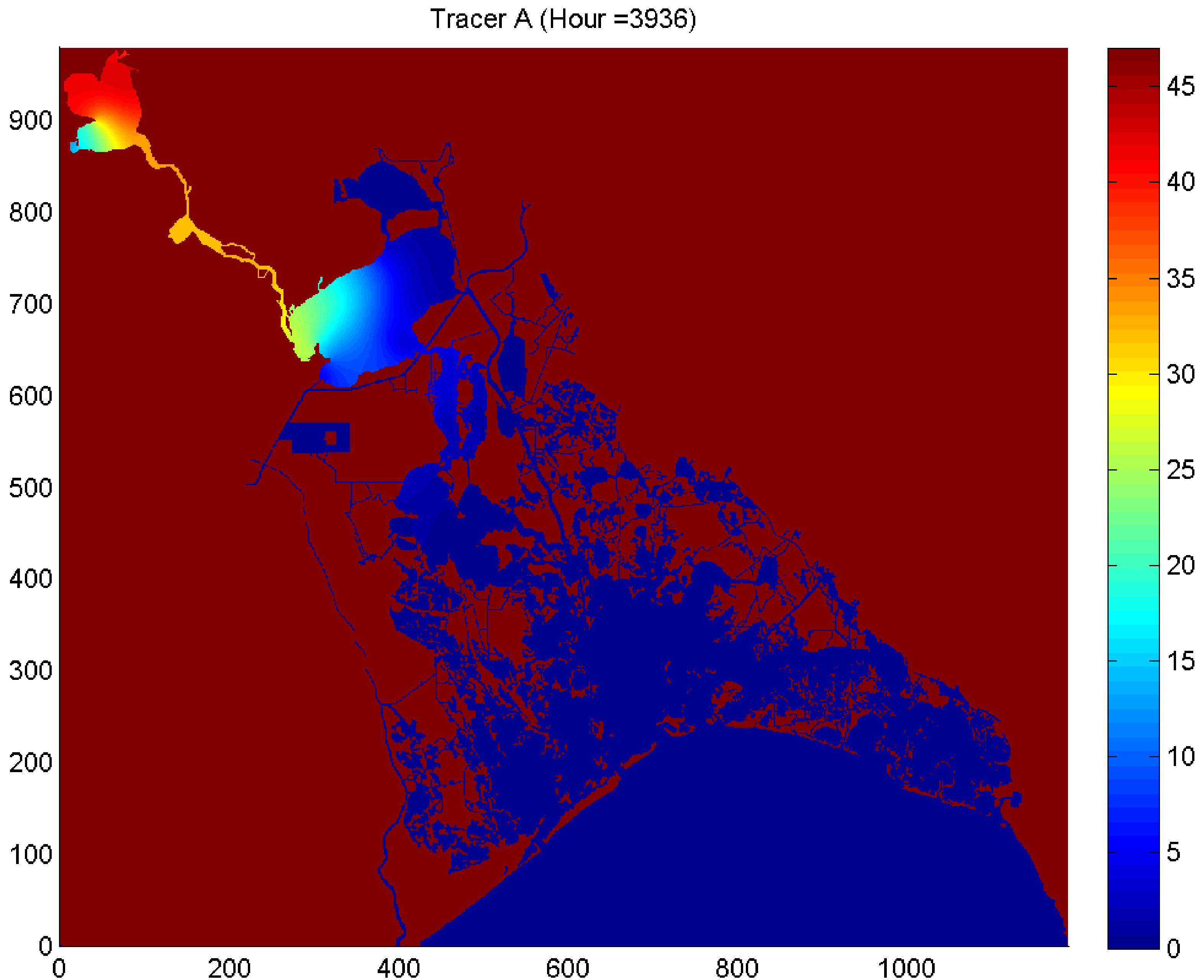

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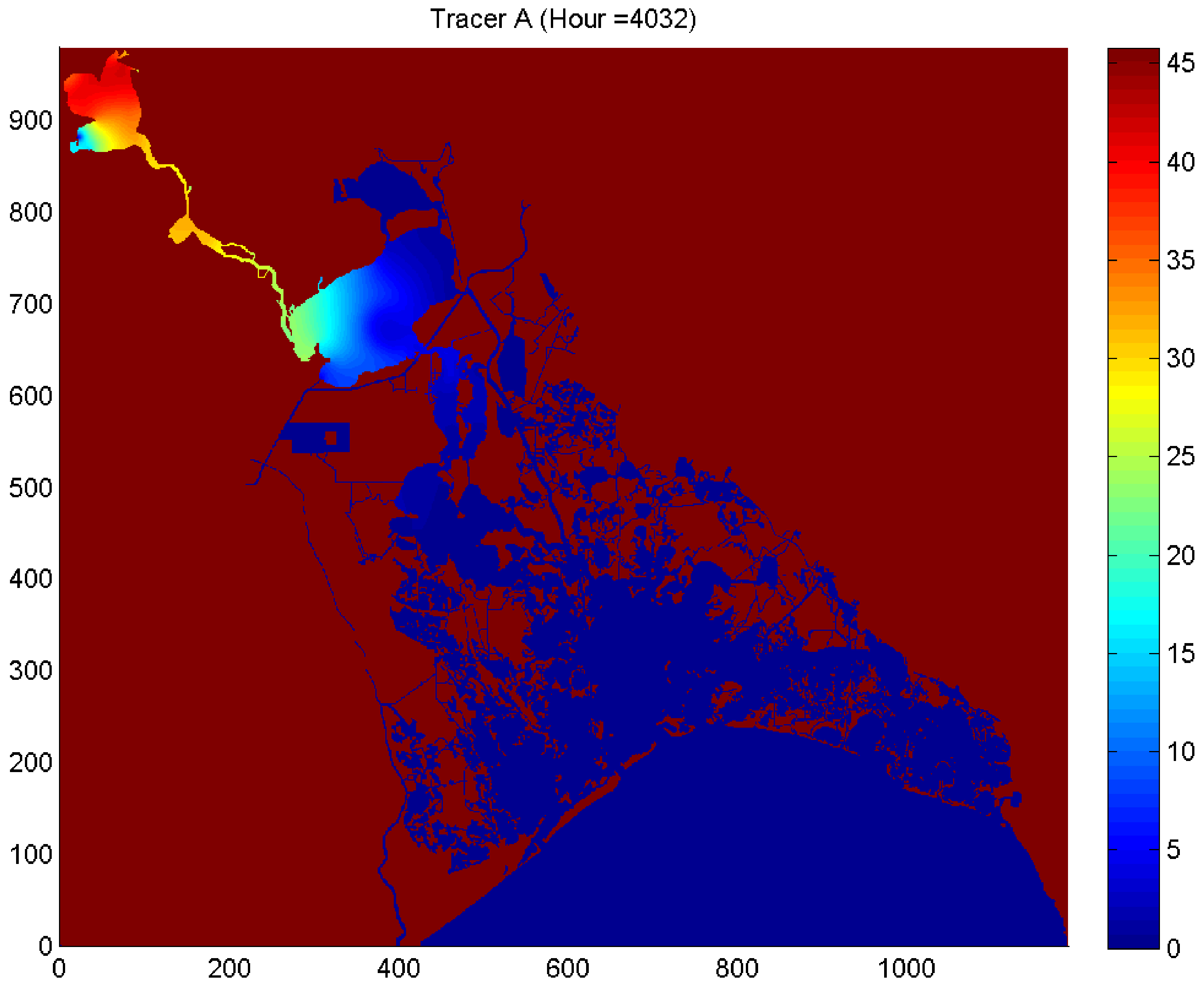

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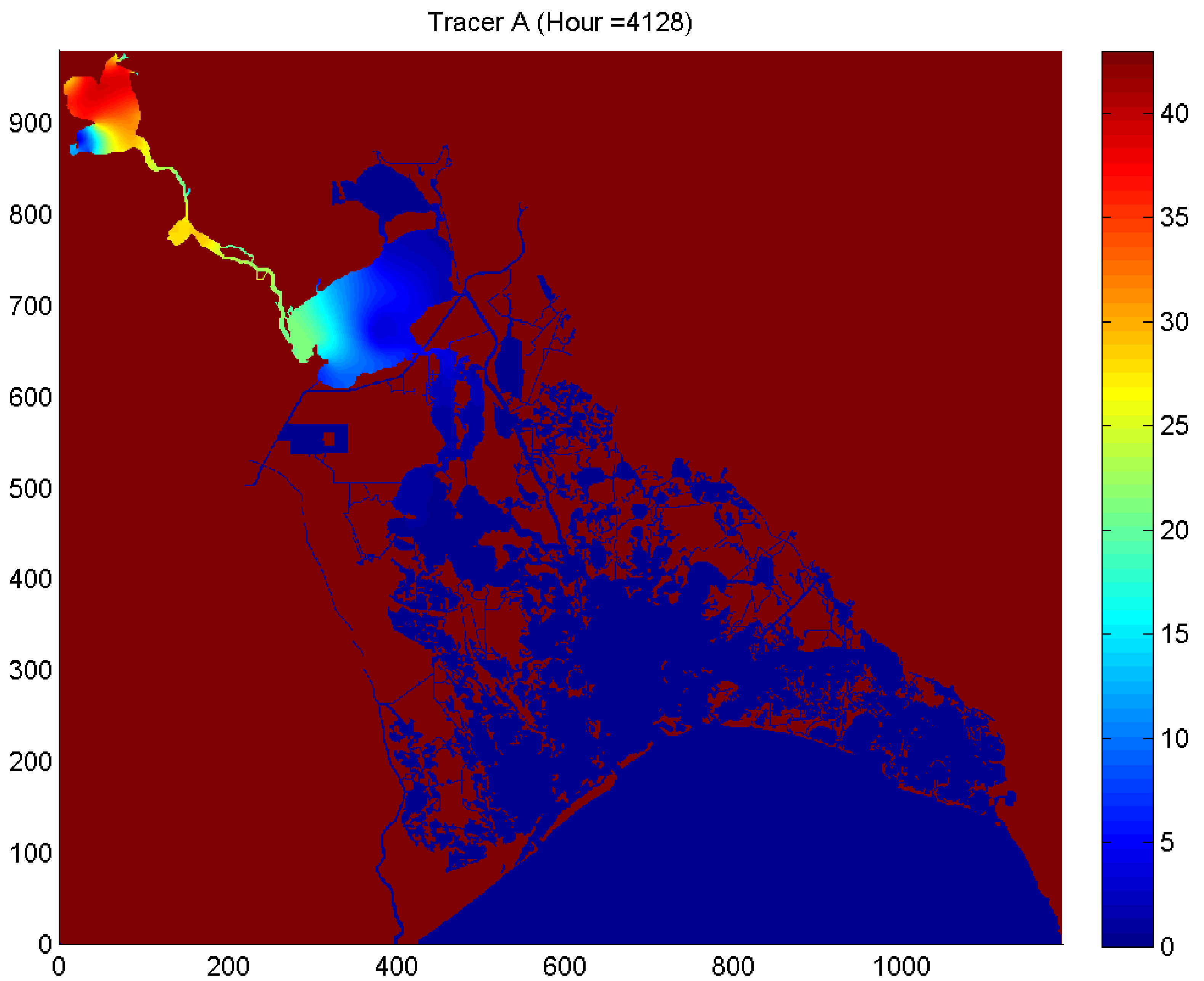
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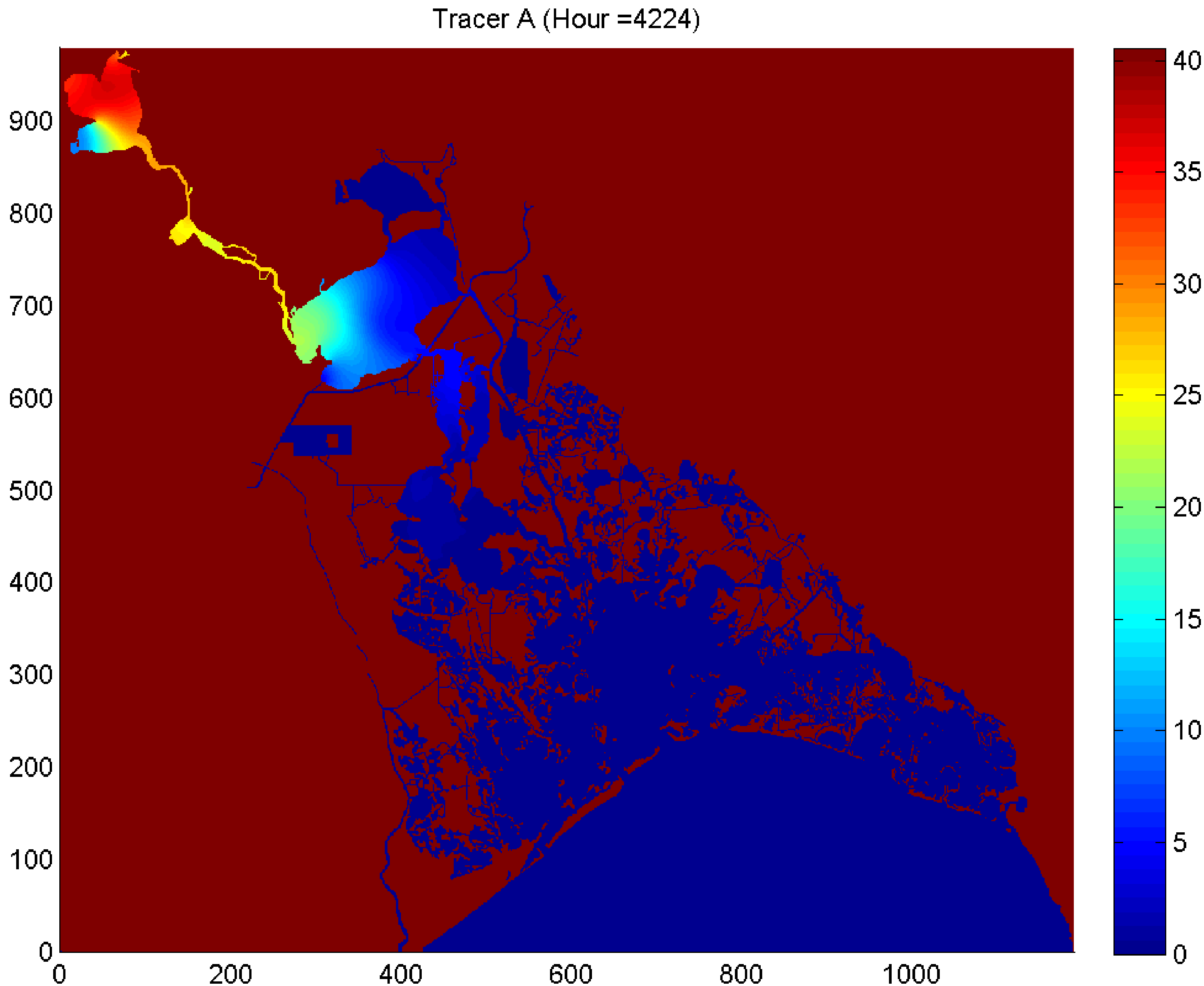

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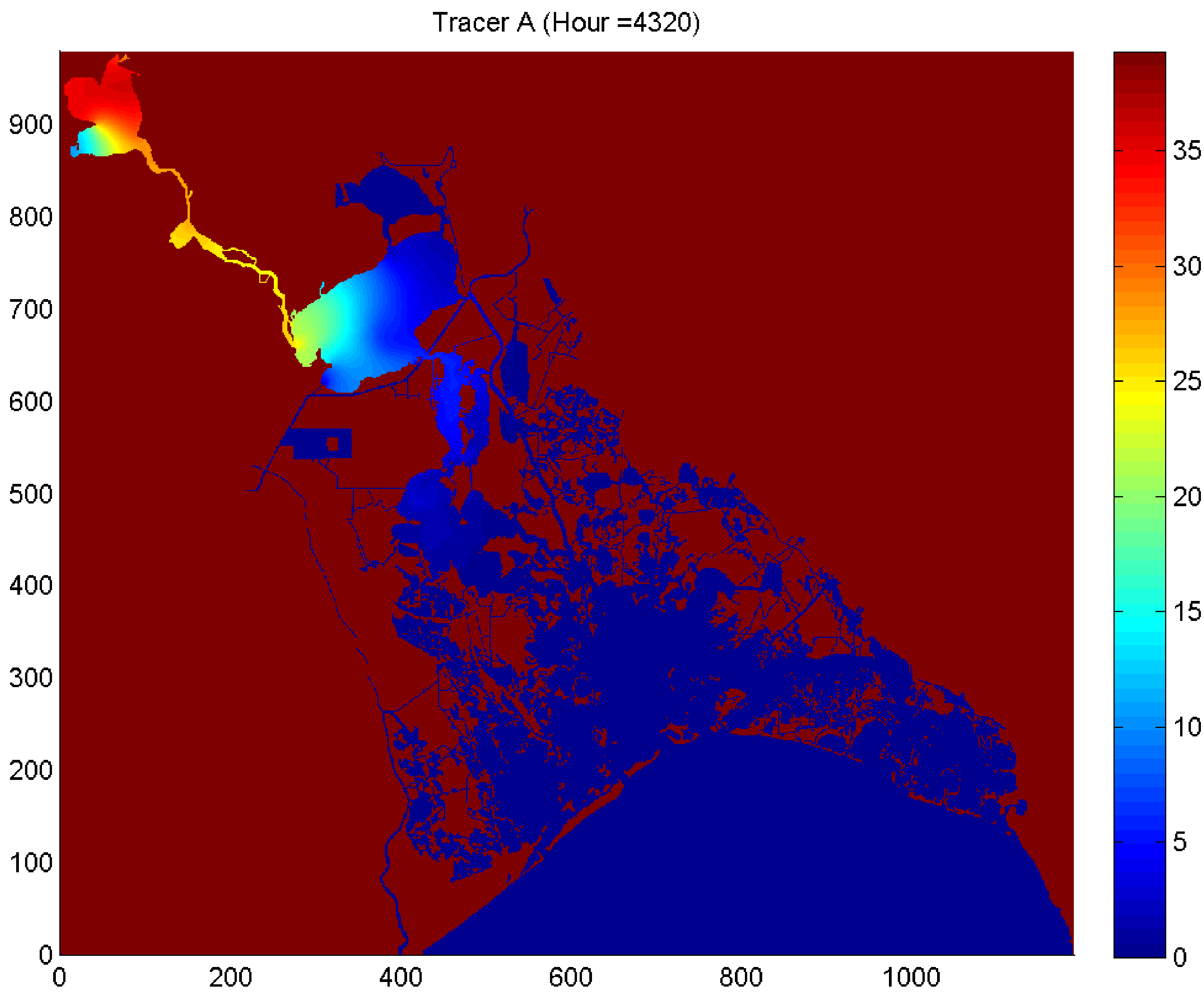

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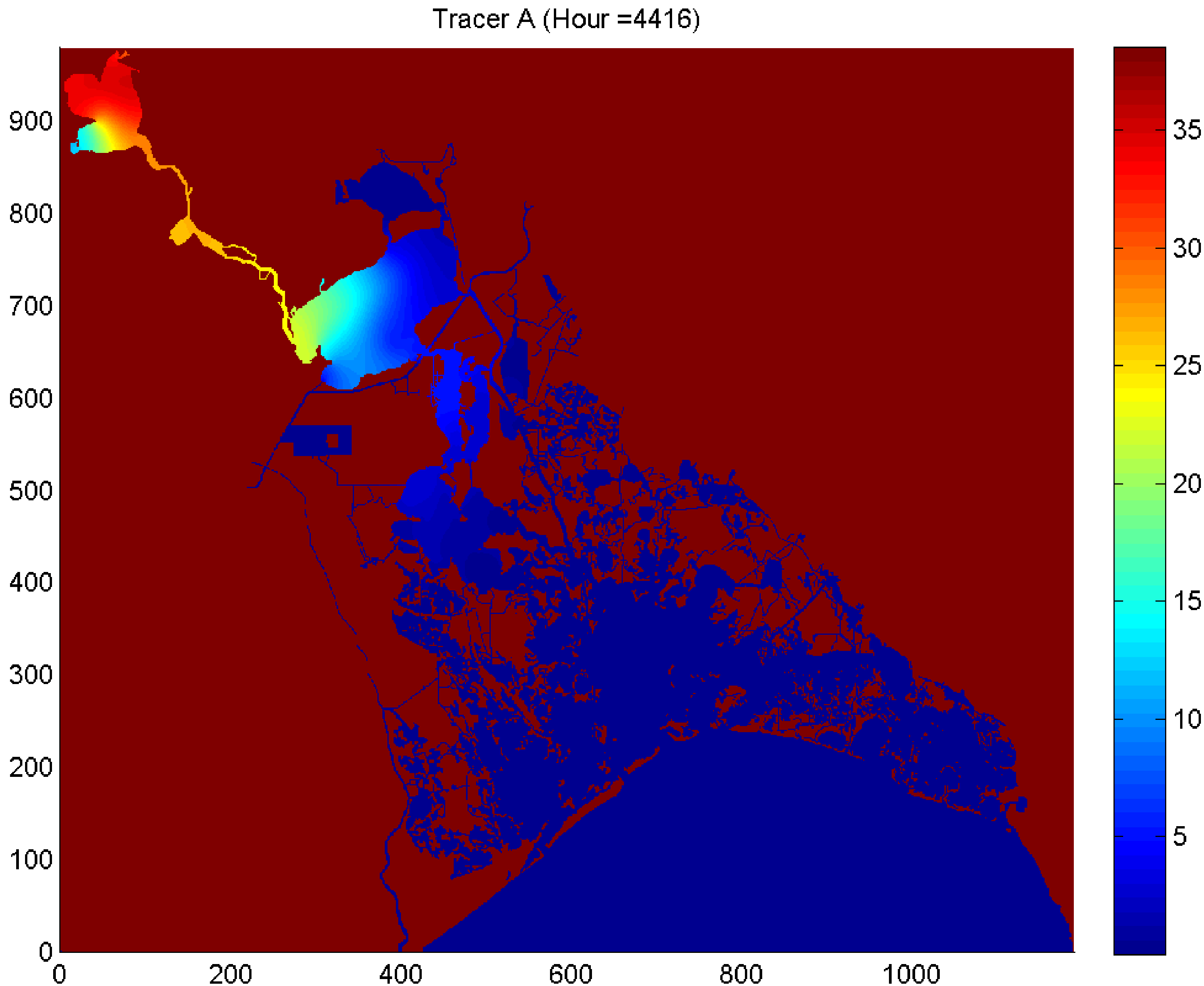

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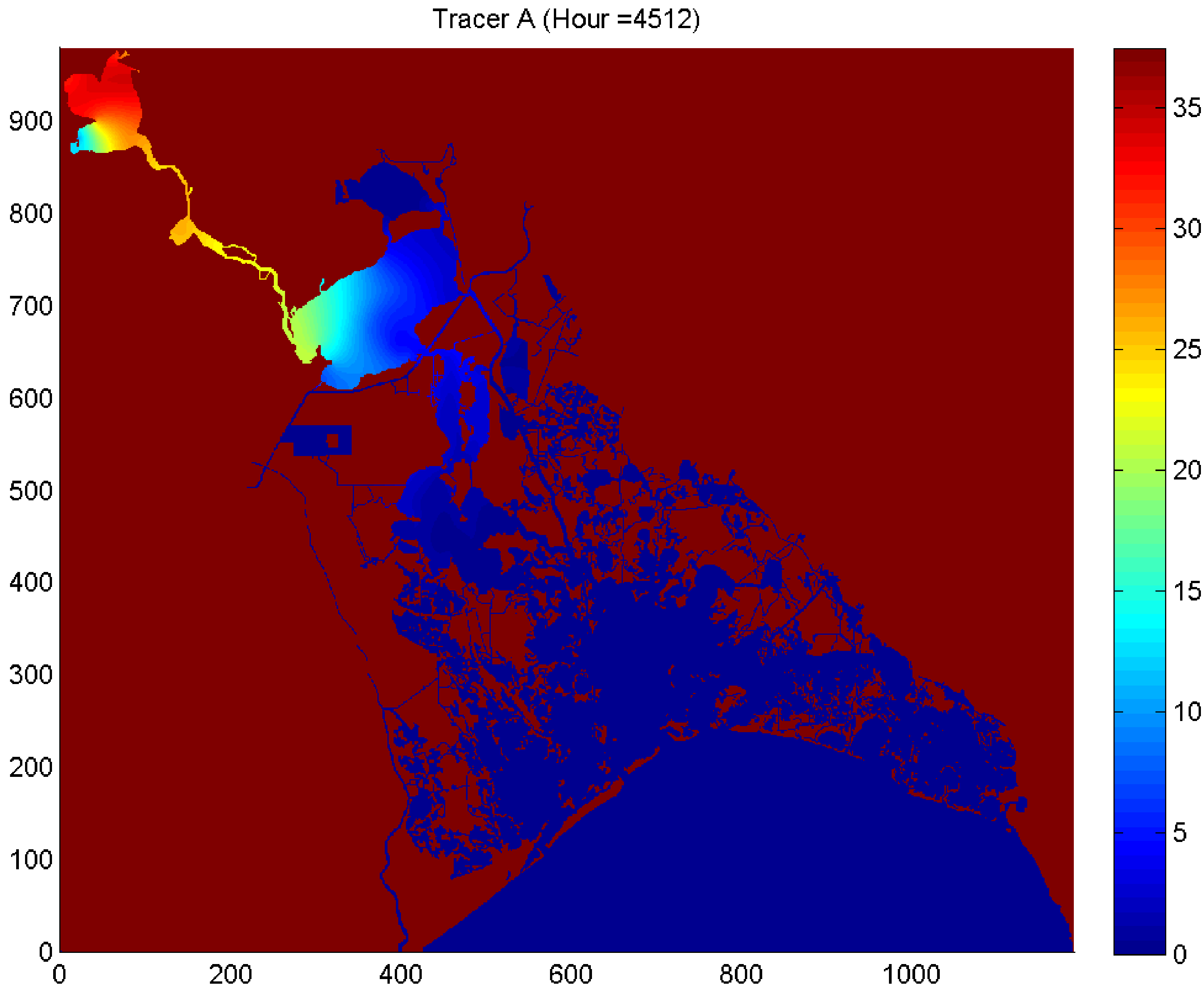

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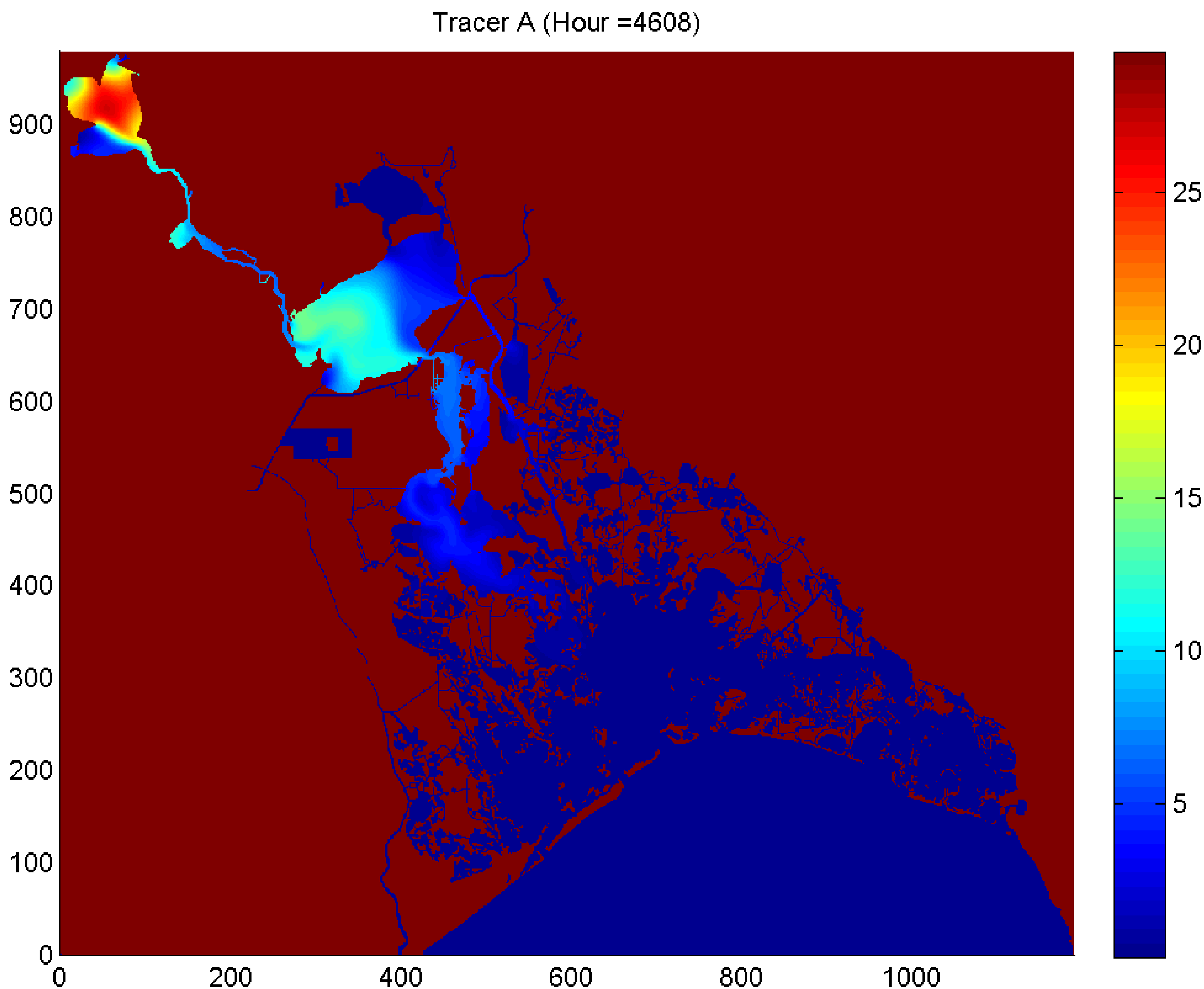

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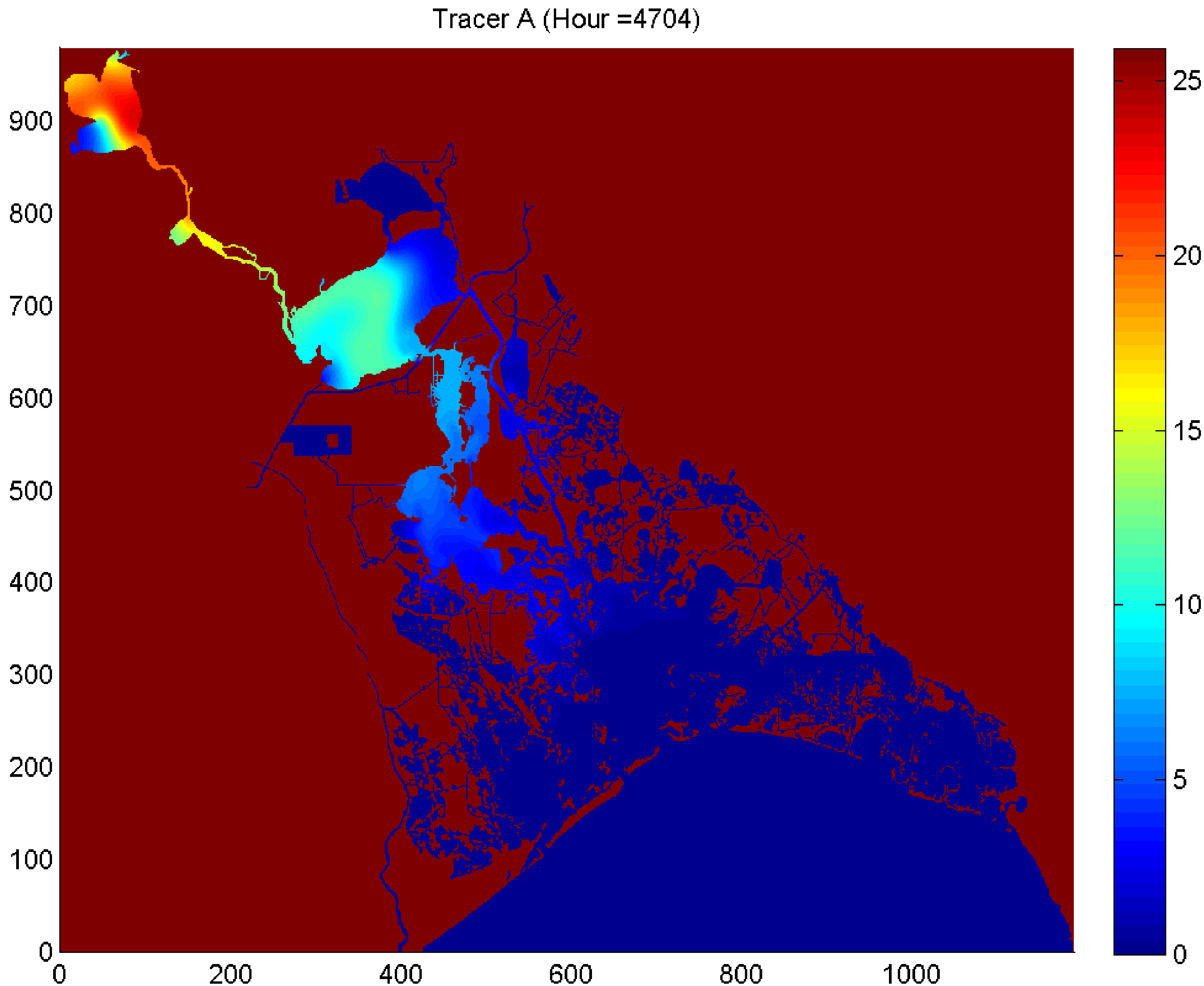

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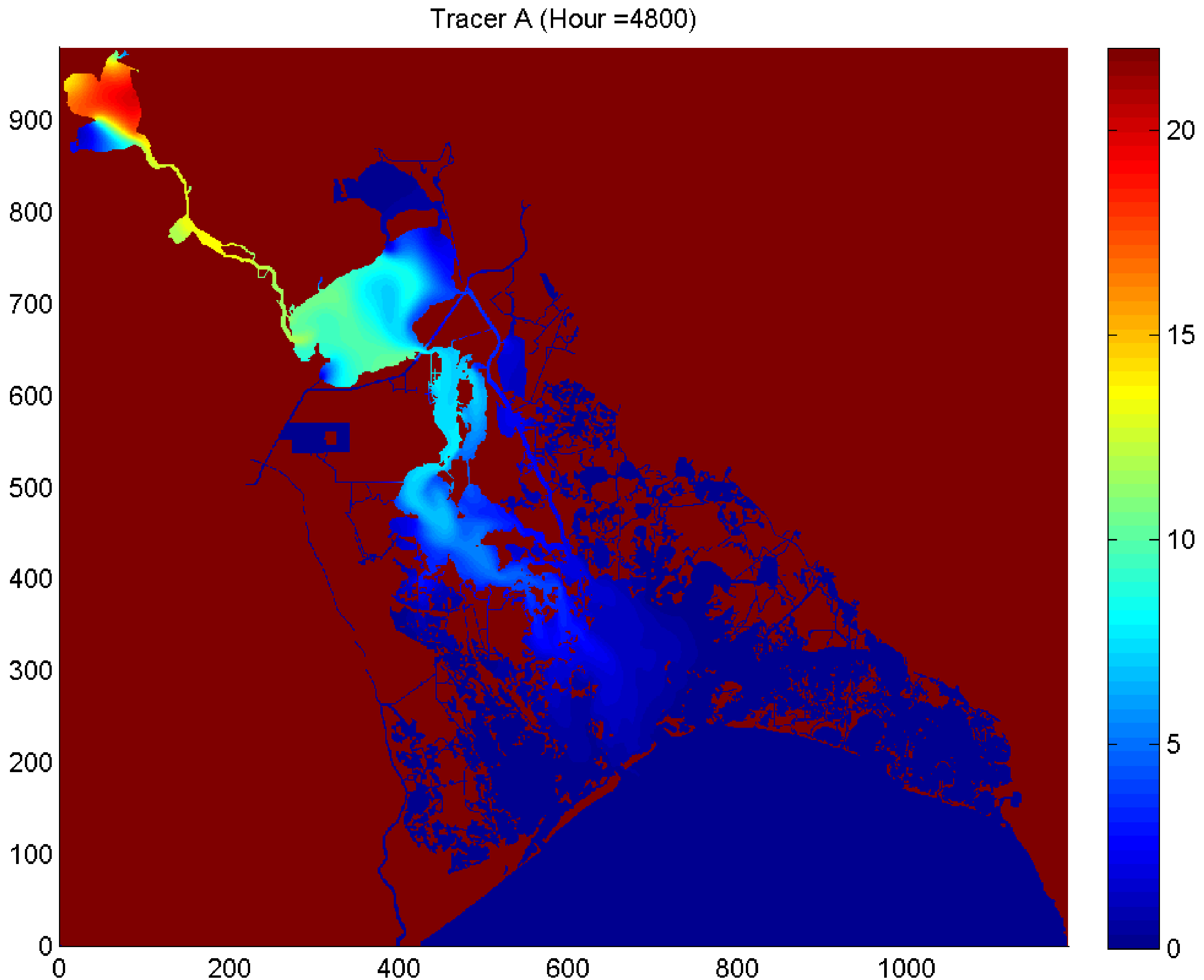

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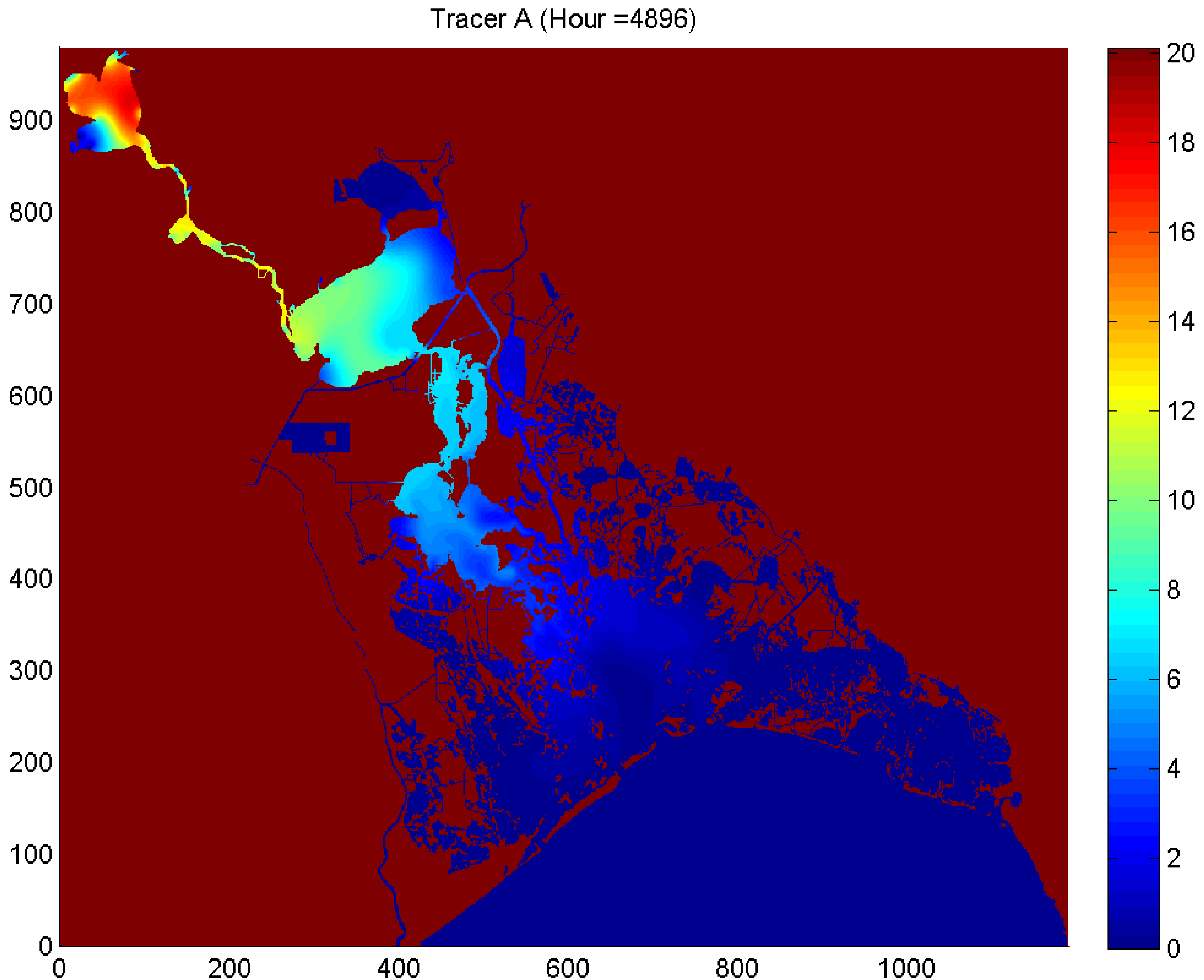

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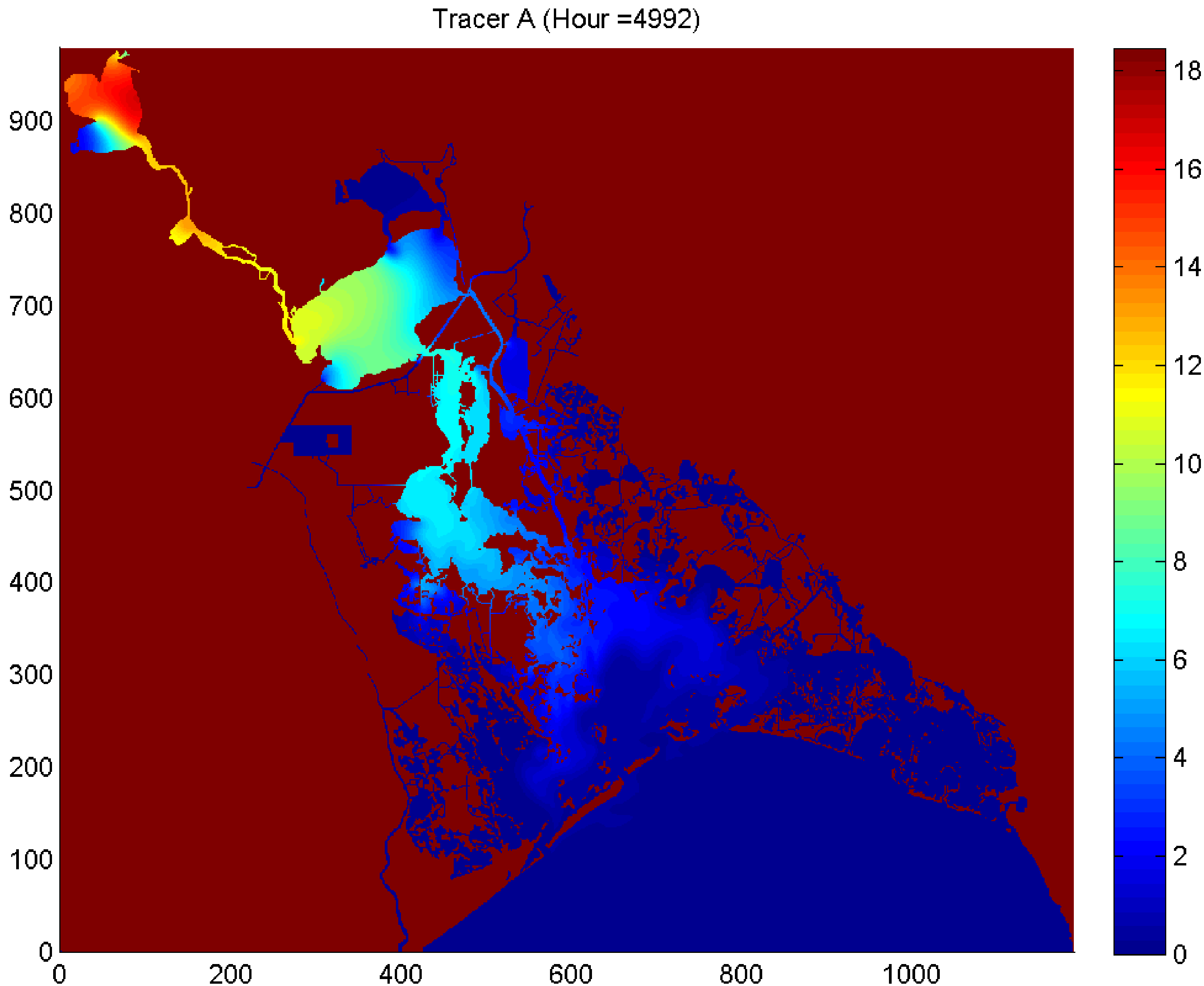
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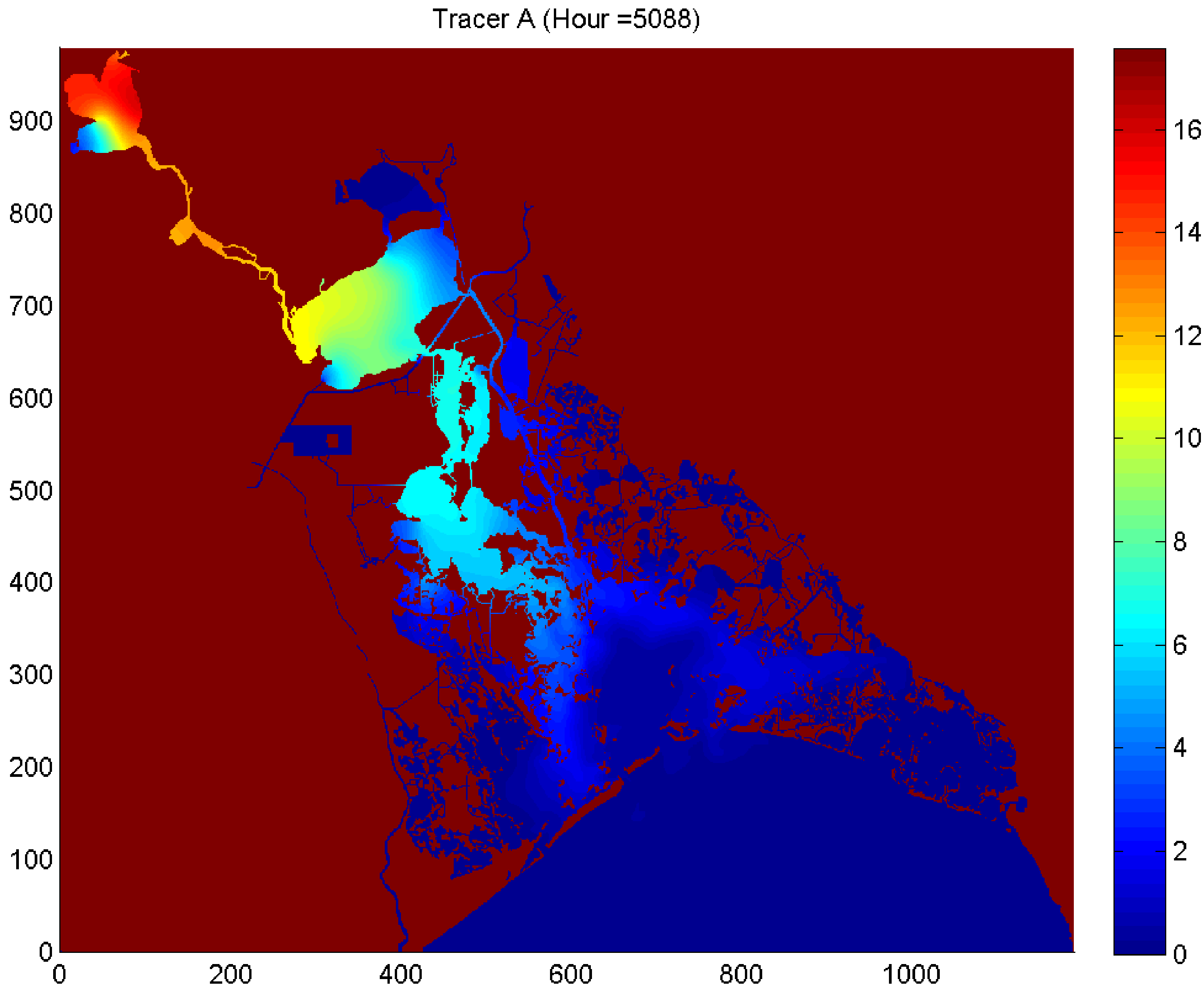
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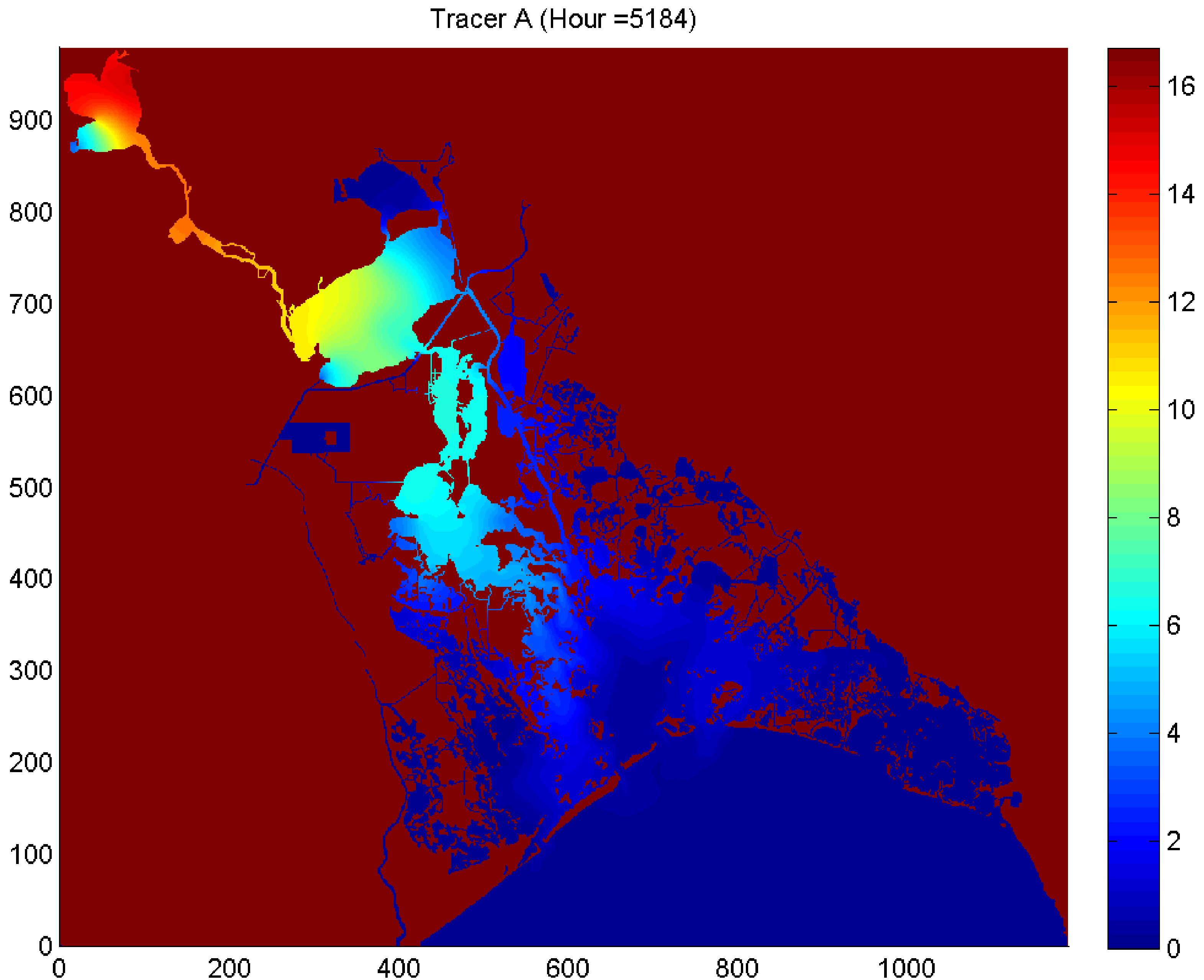

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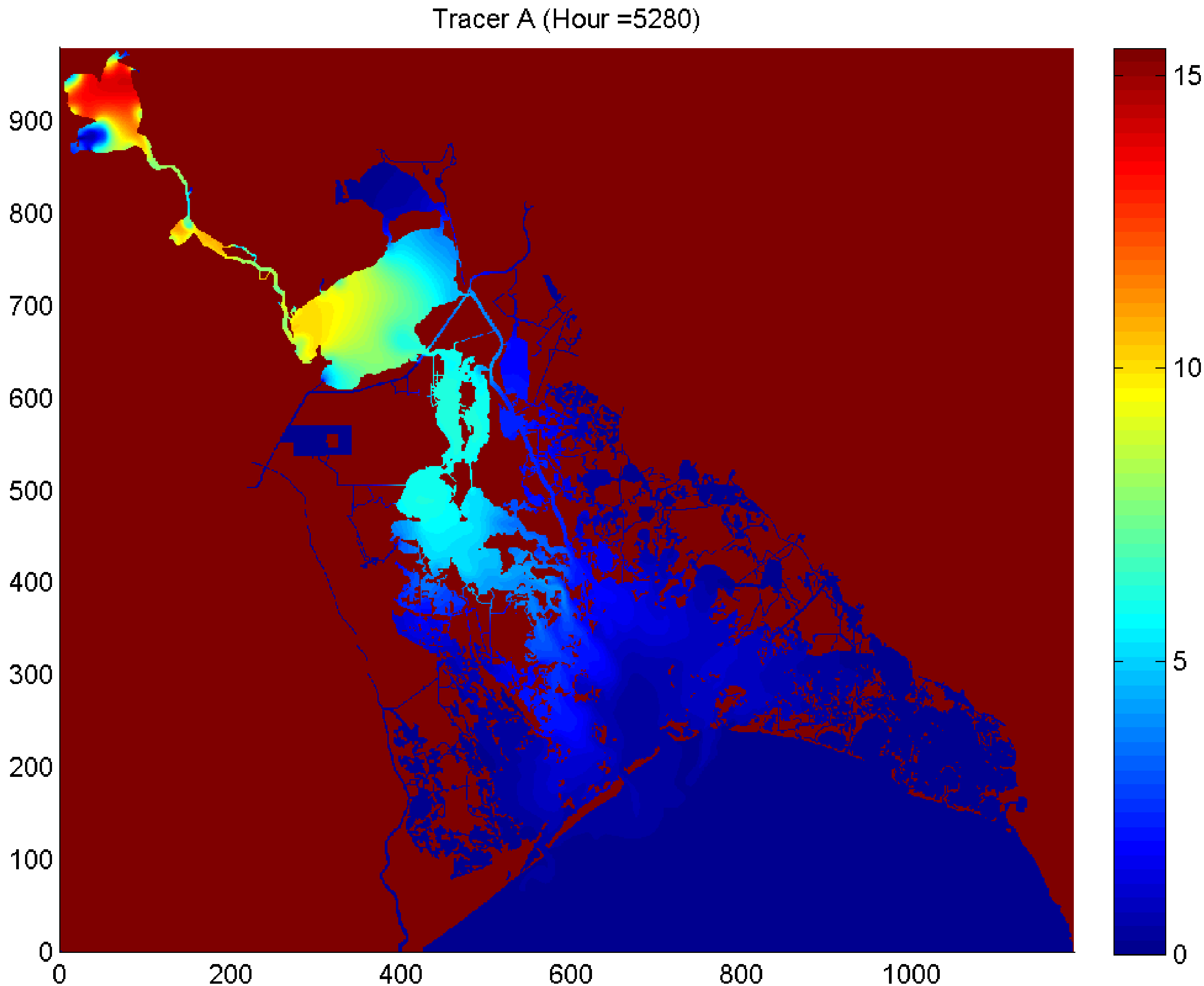
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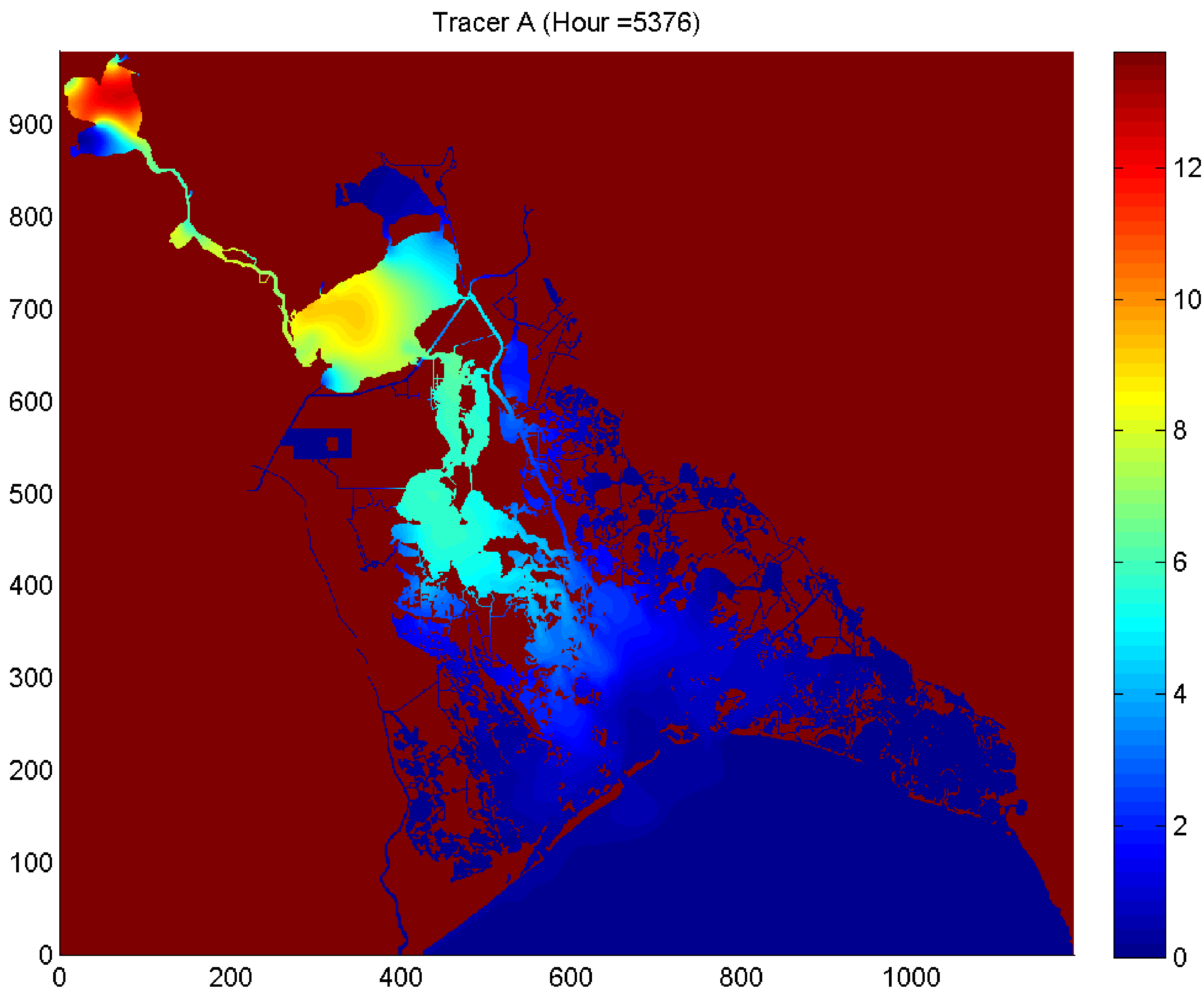
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10
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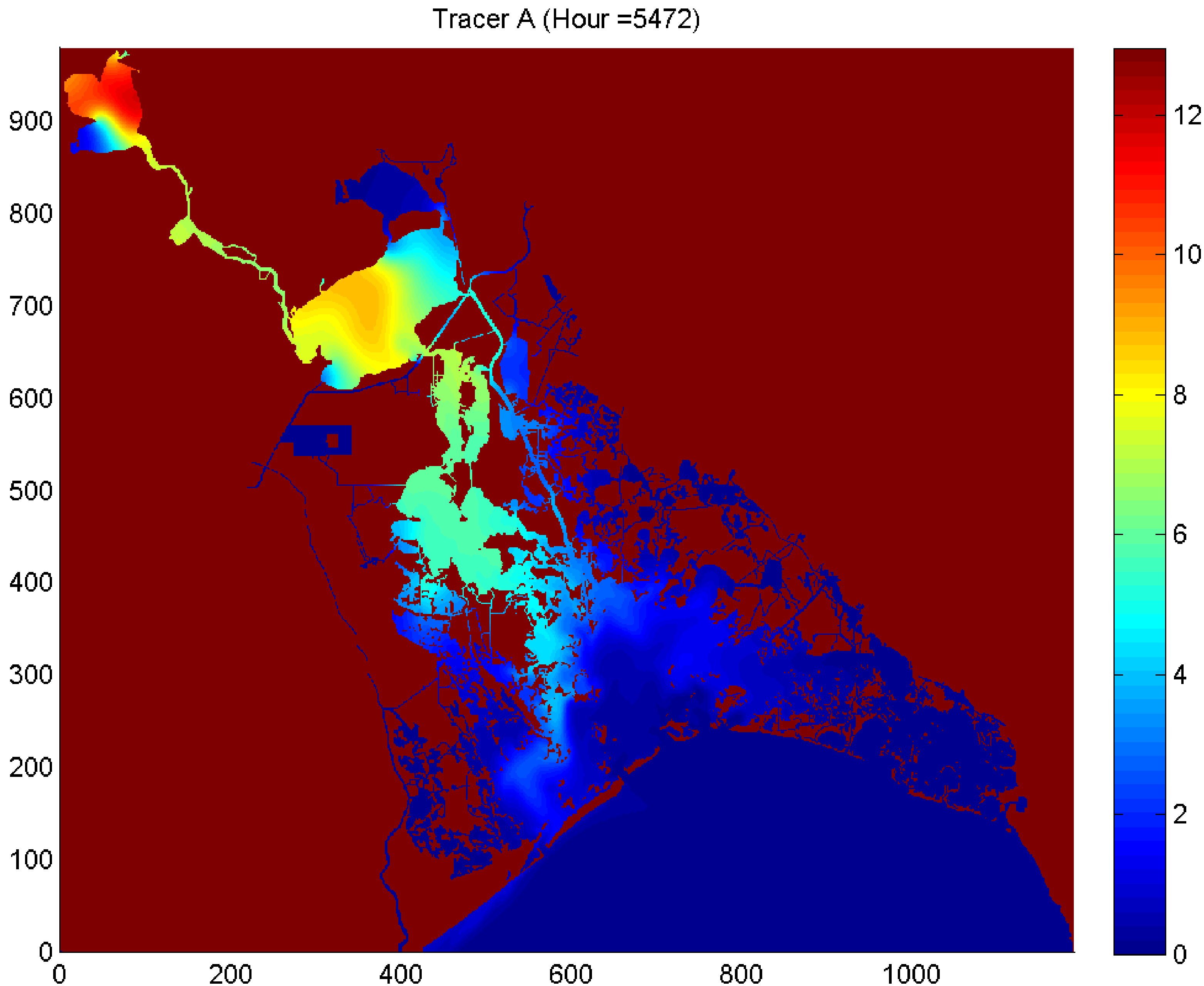

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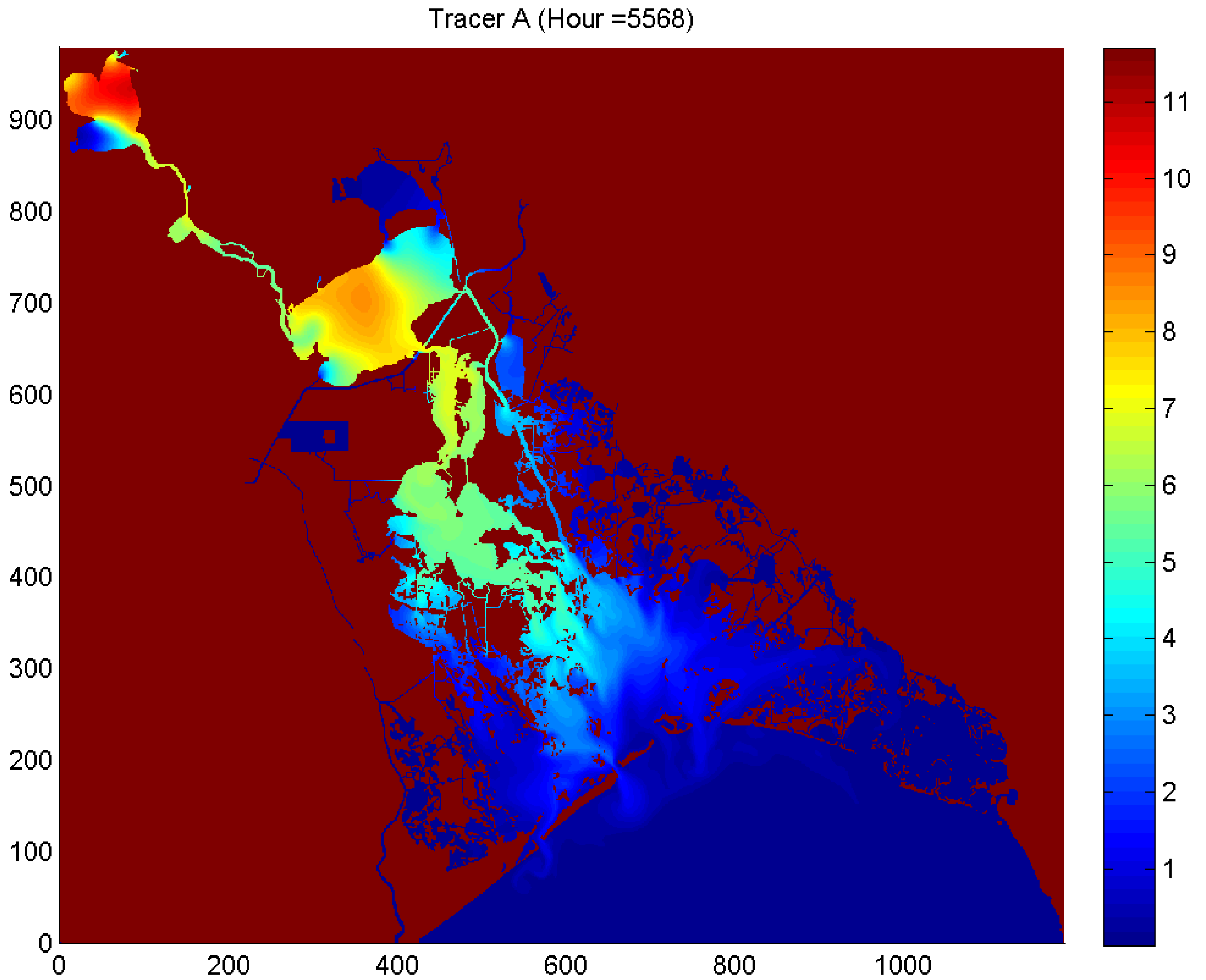

Tracer A (Hour =5568)
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2
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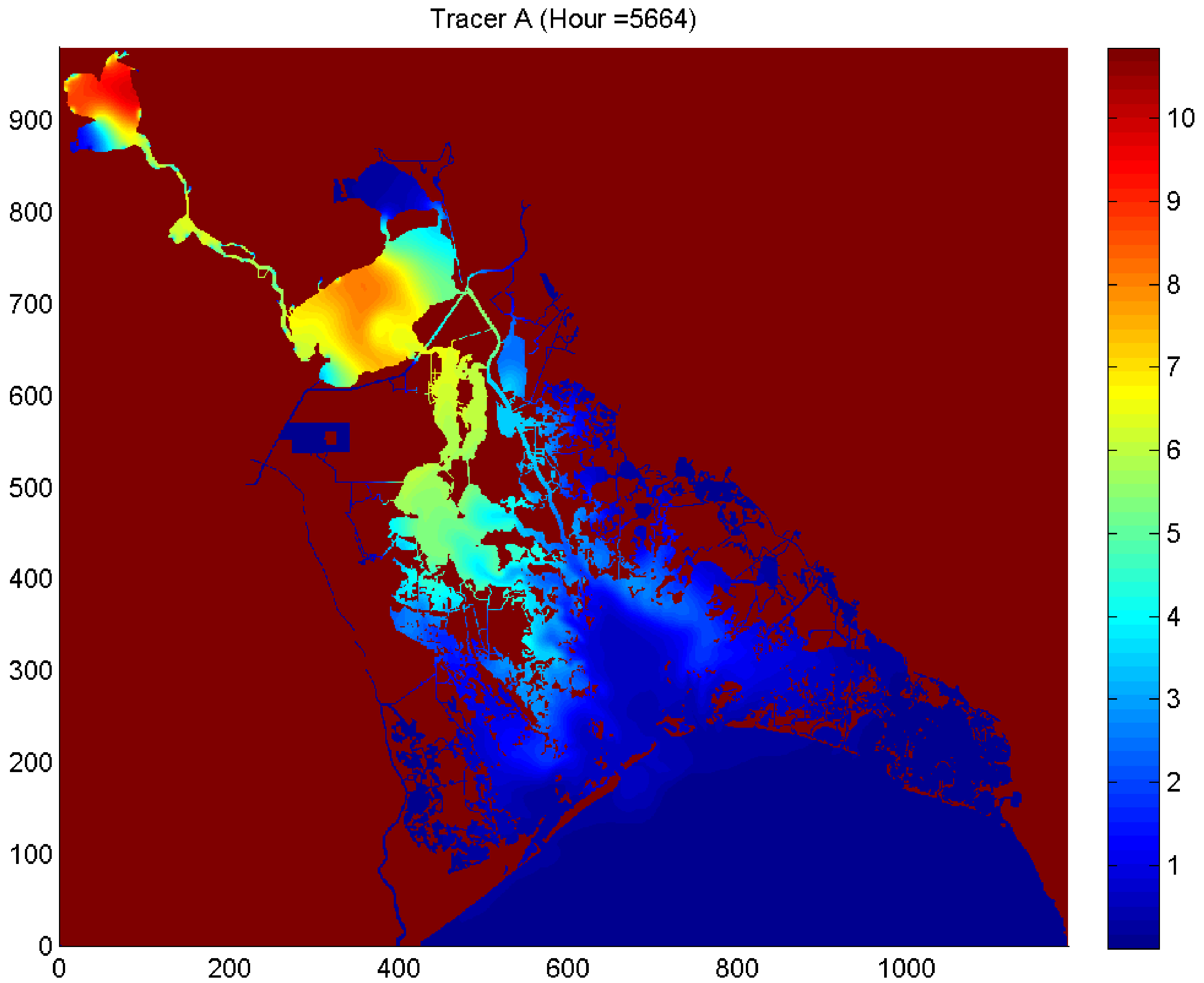

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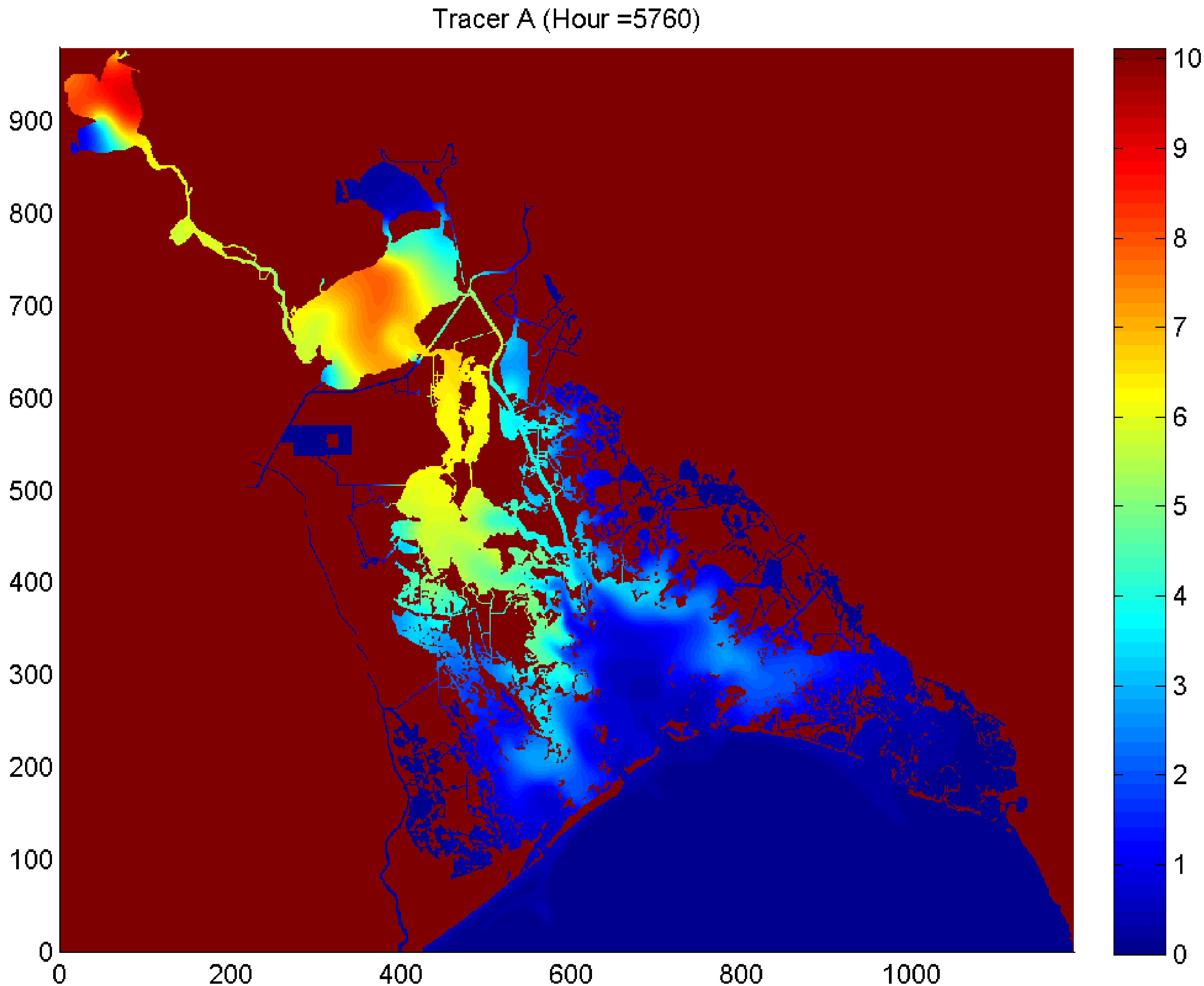

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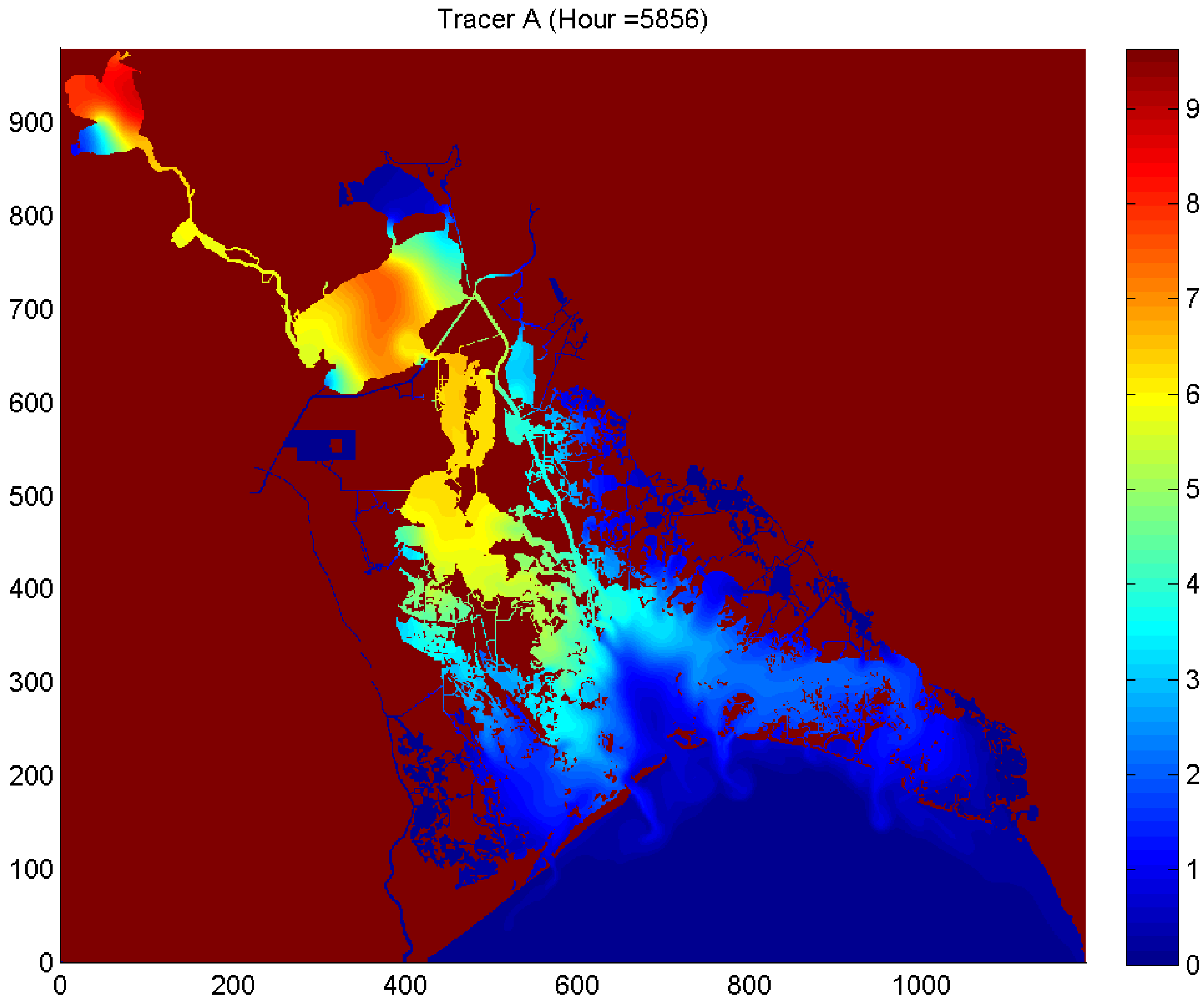

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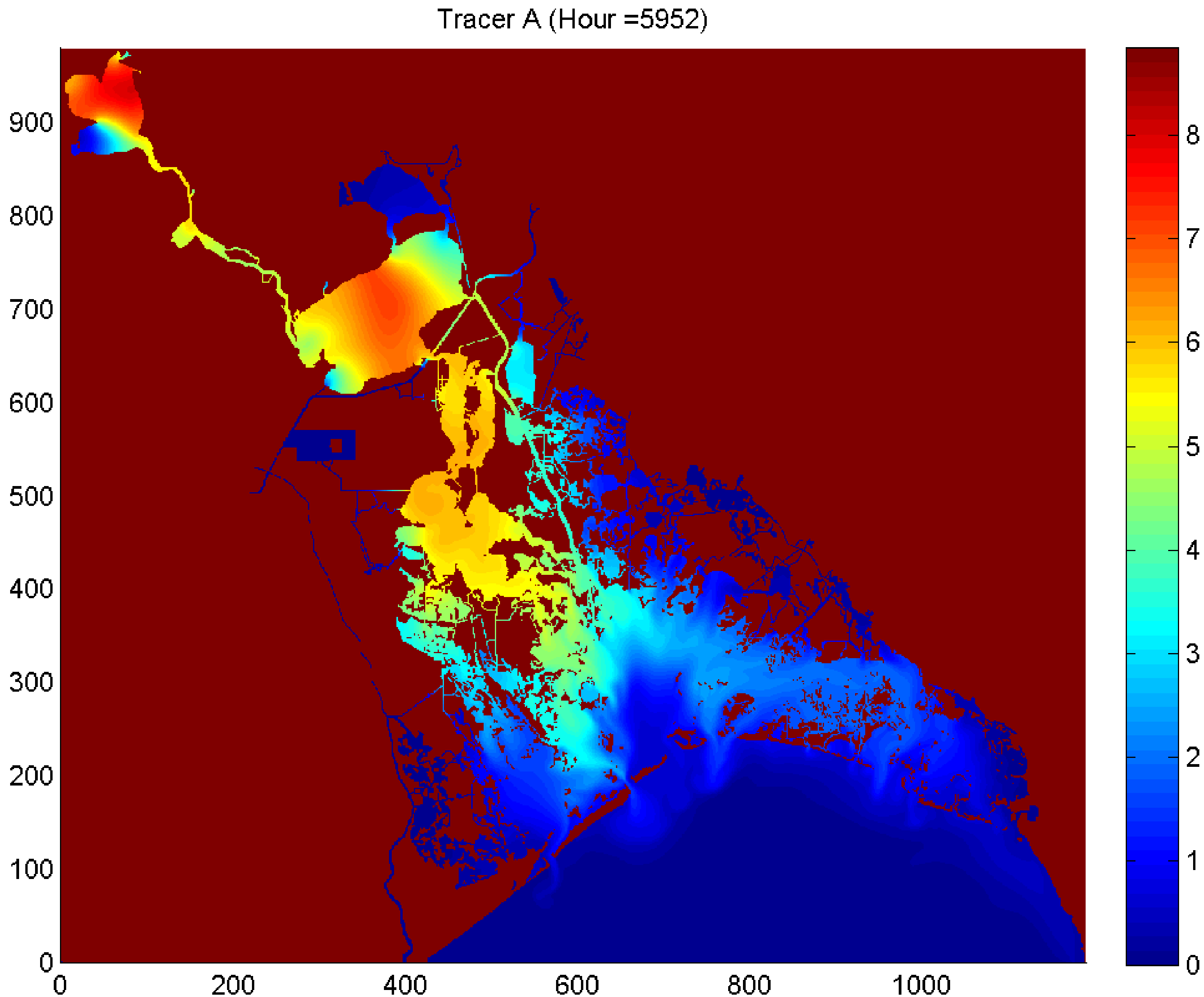
1
0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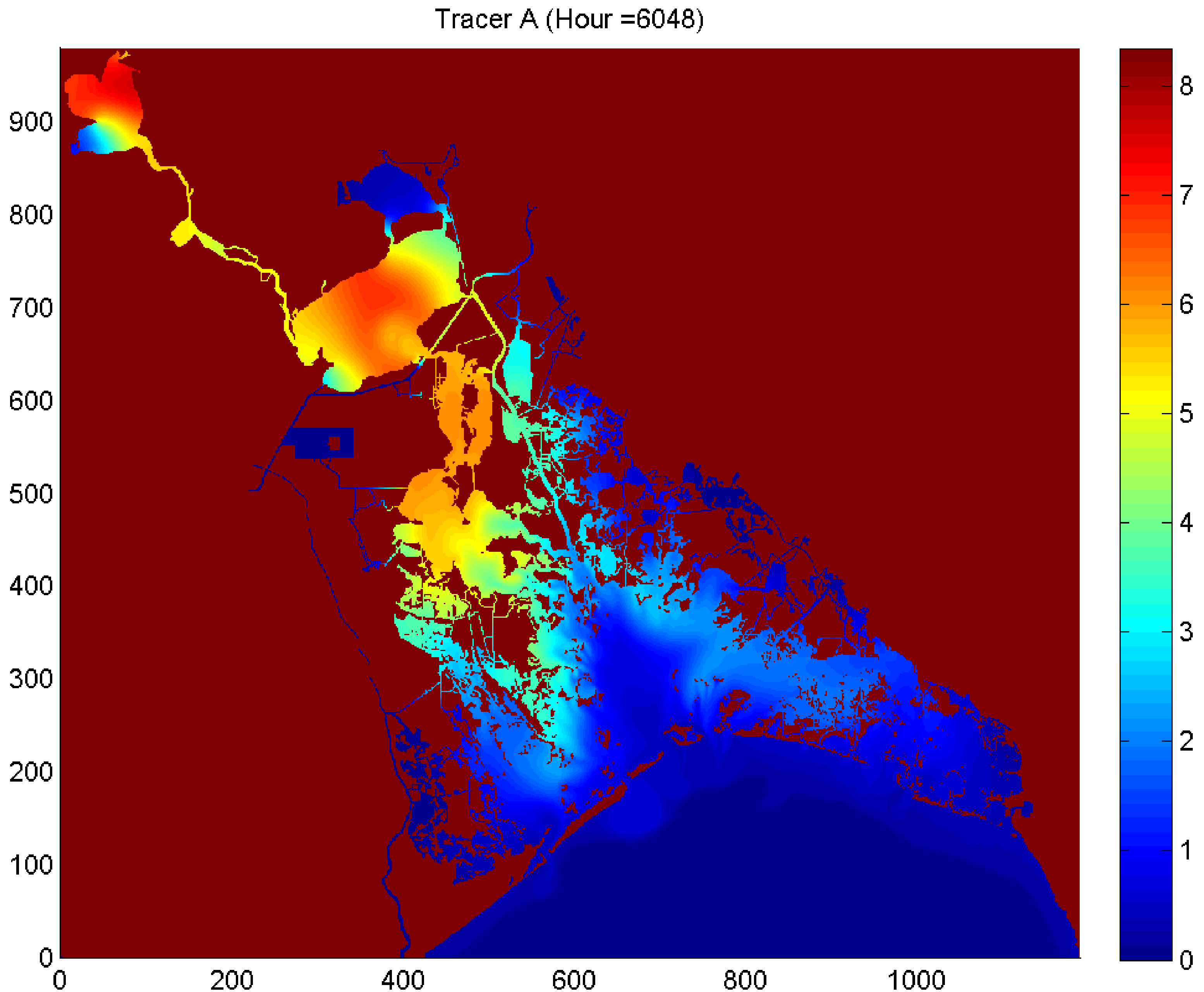
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7
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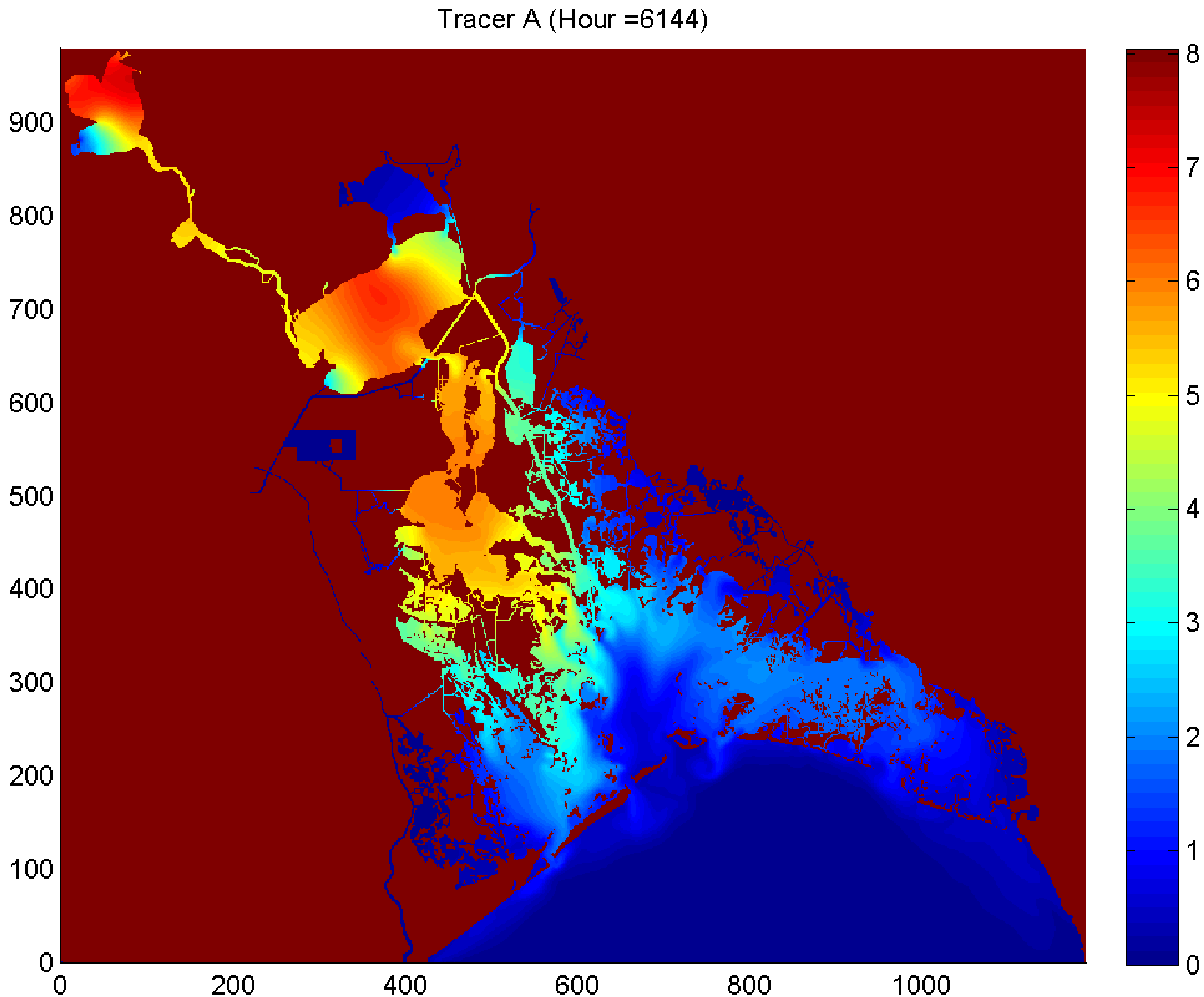

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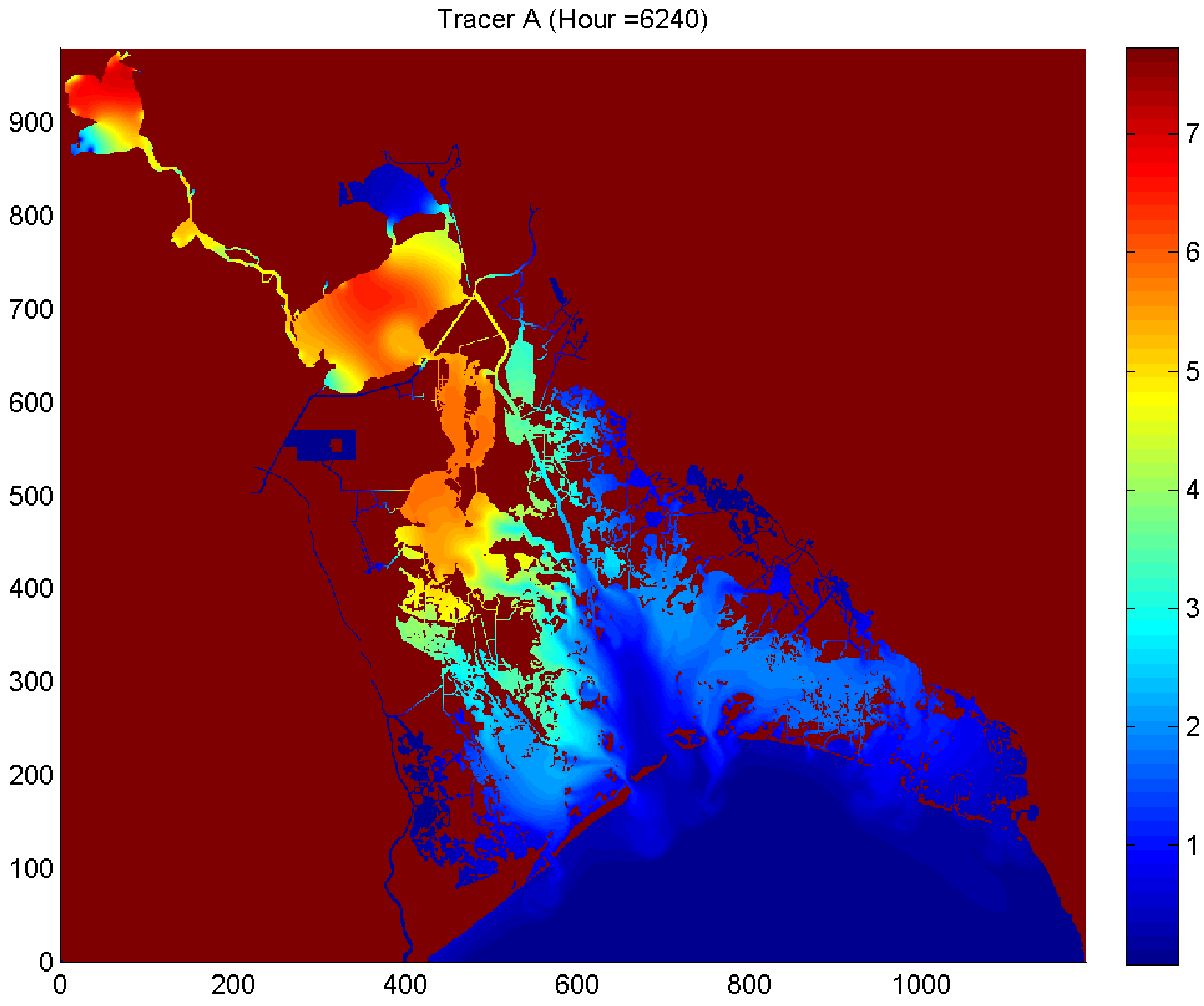

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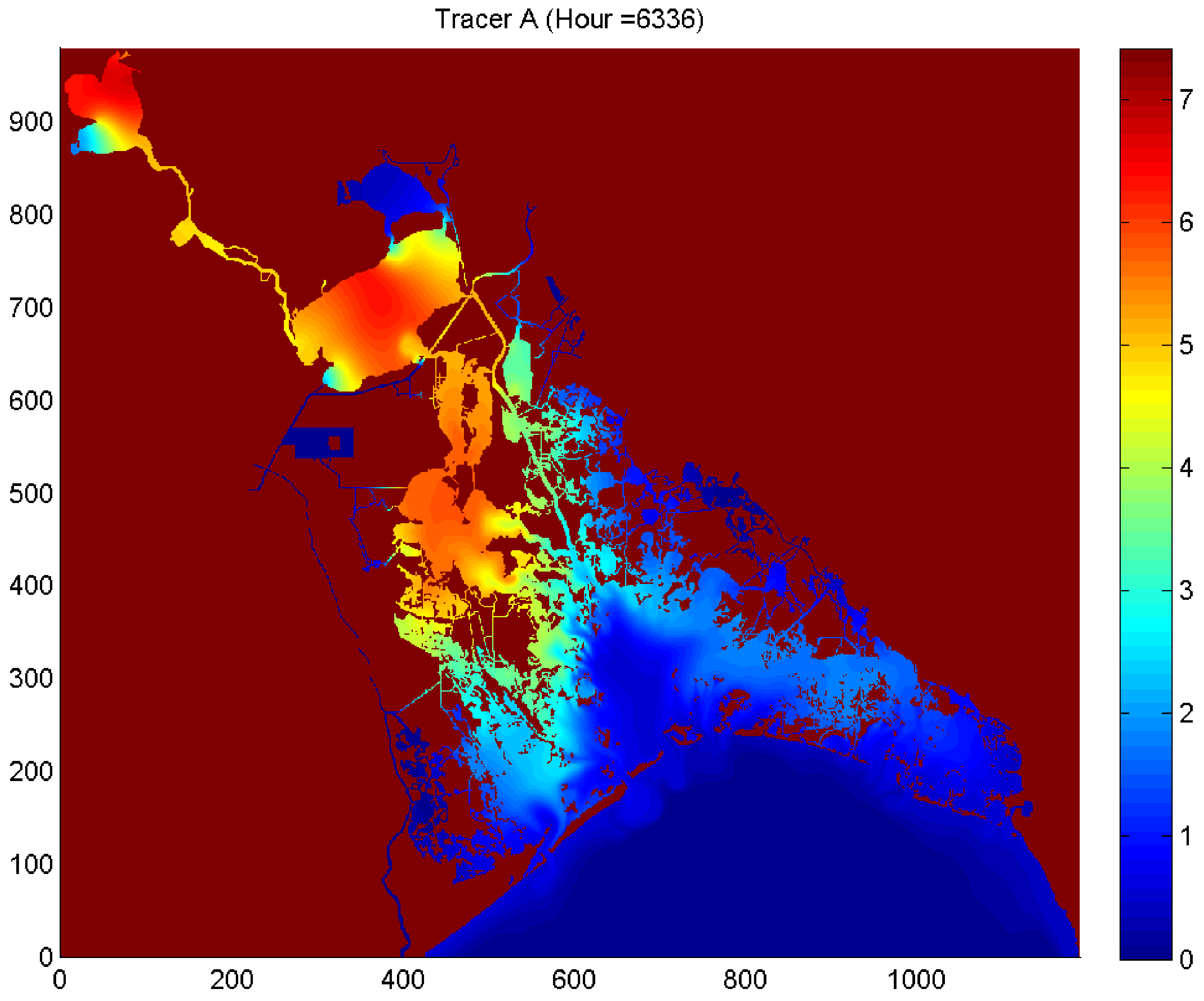
4
5
6
7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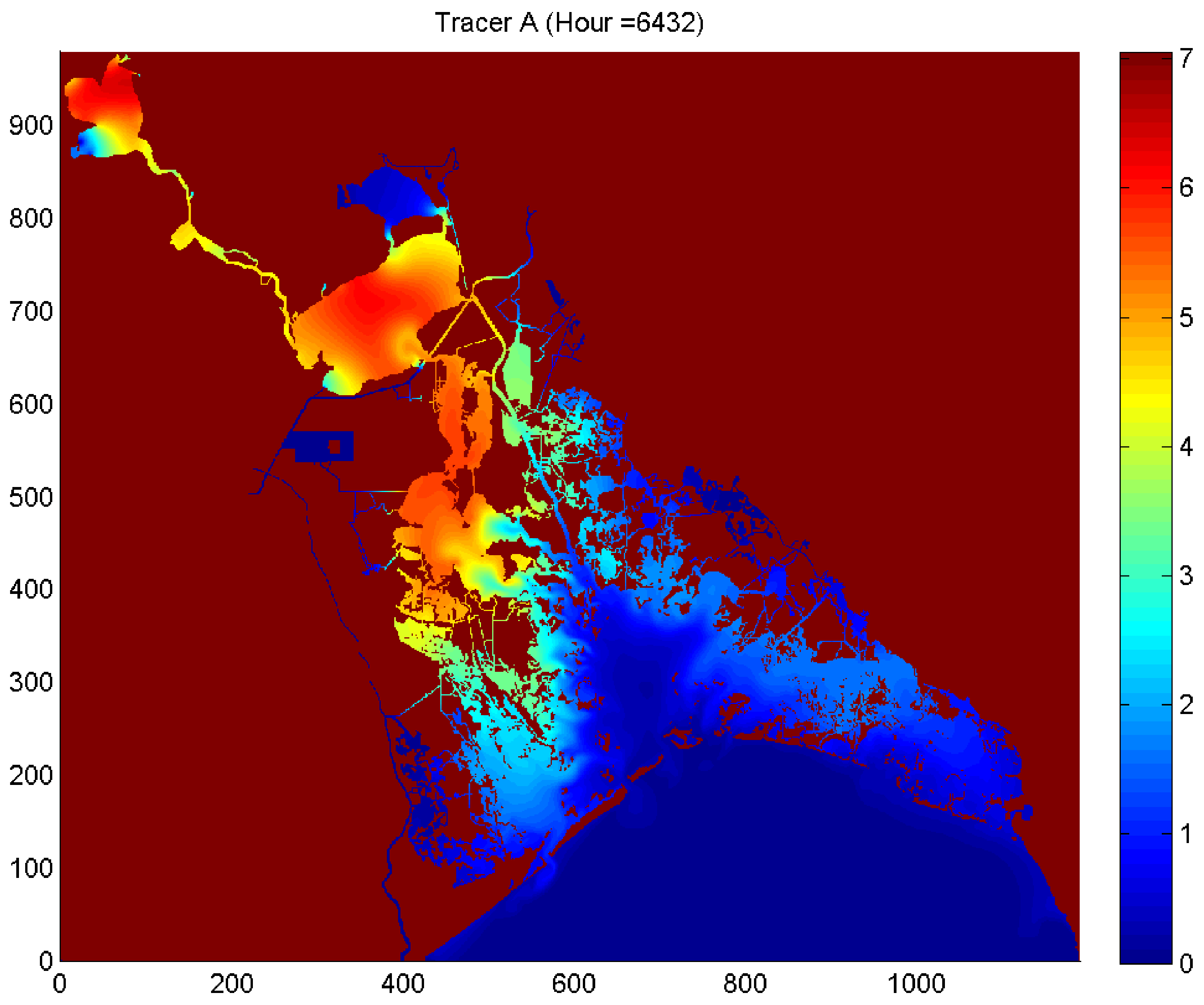

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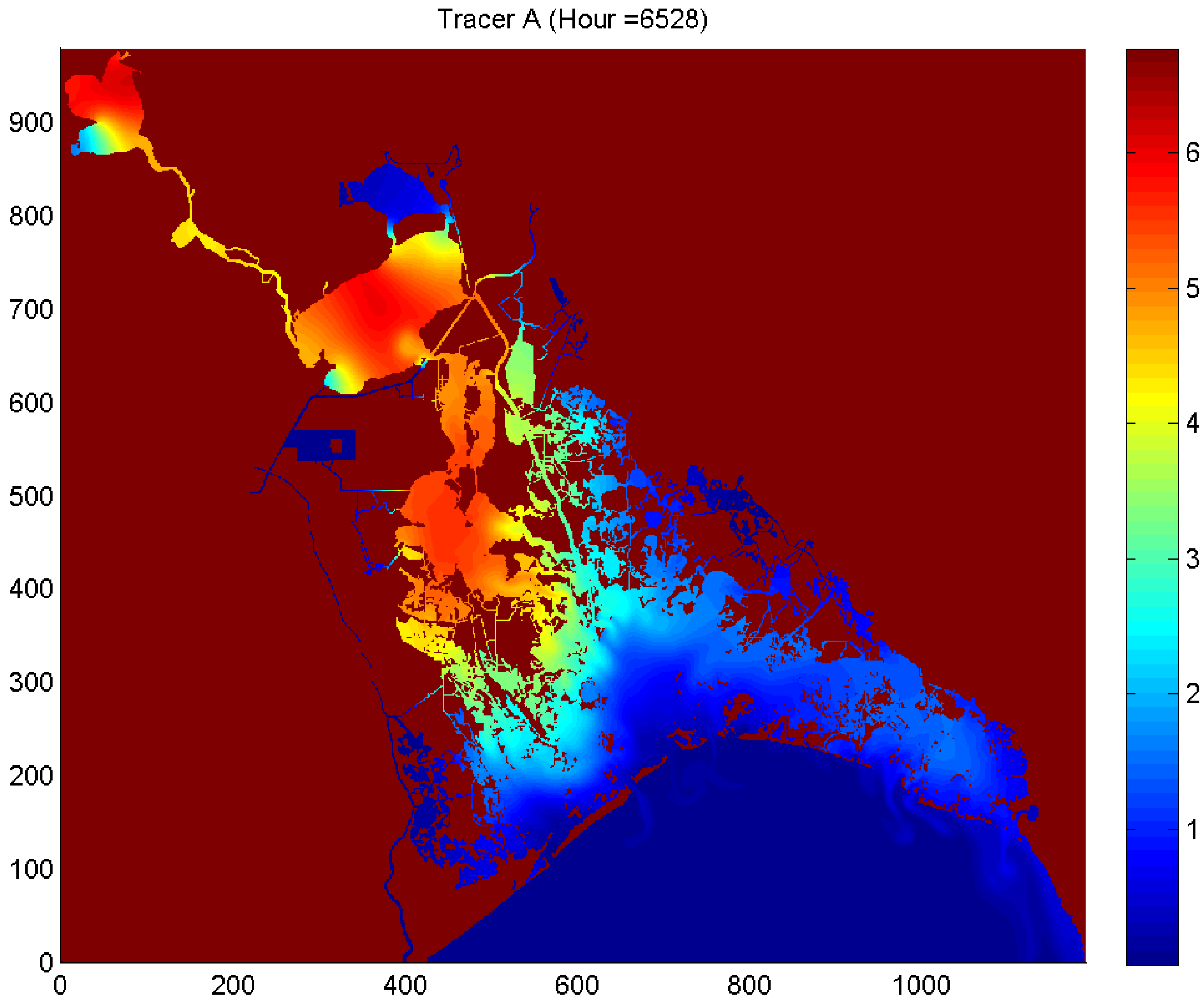
5
6
7



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4
3
2
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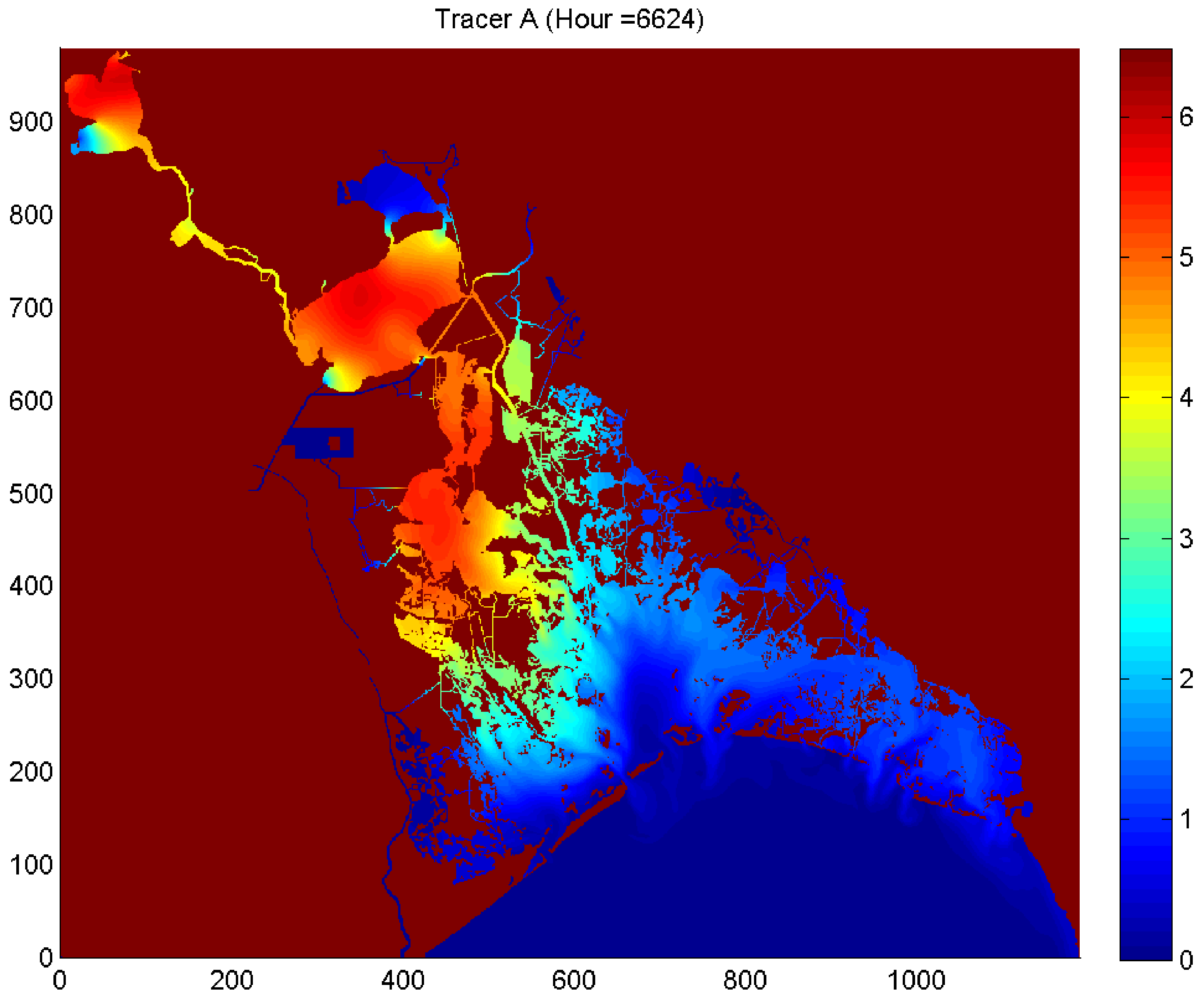

Tracer A (Hour =6624)
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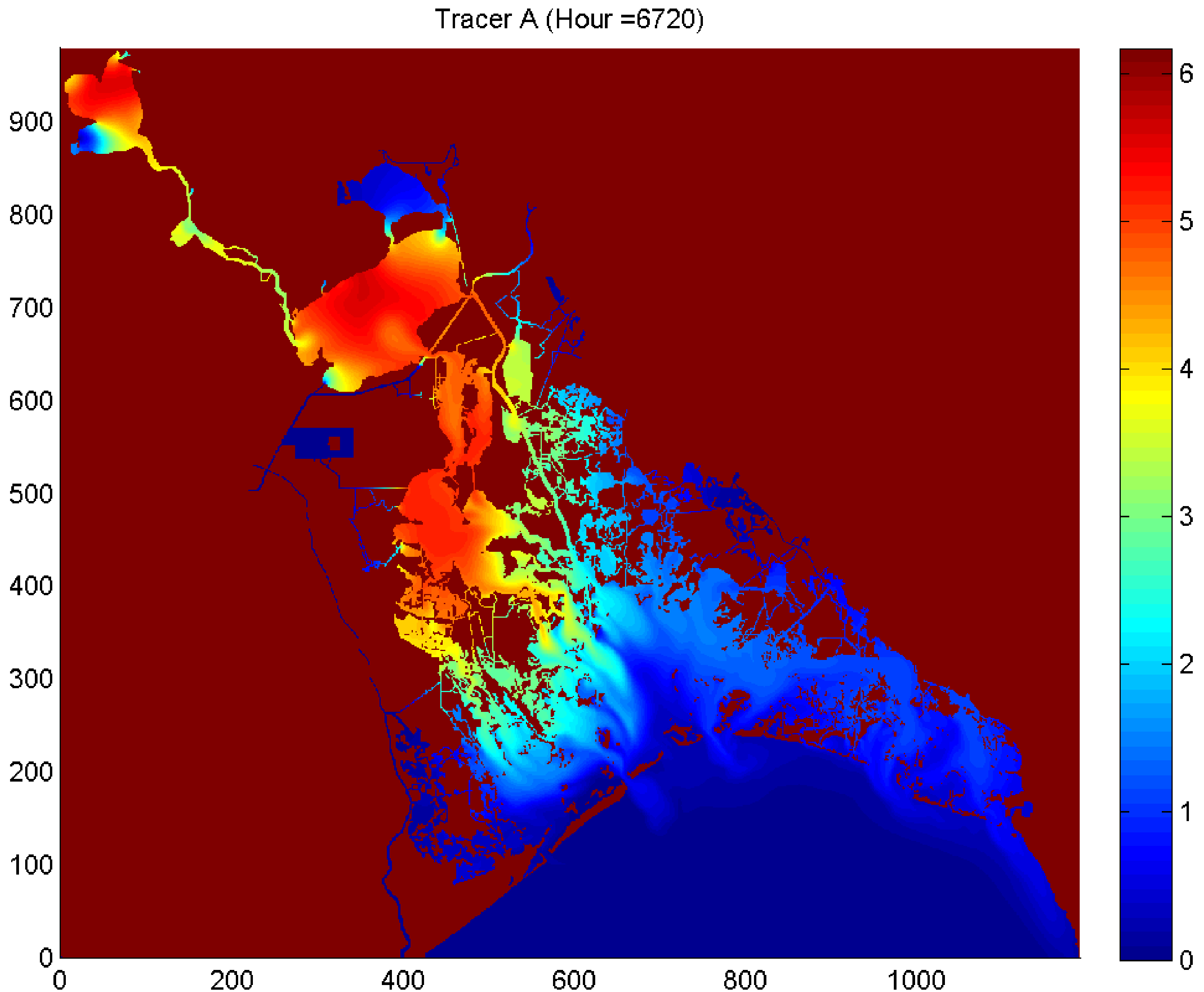
Tracer A (Hour =6720)
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3
4
5
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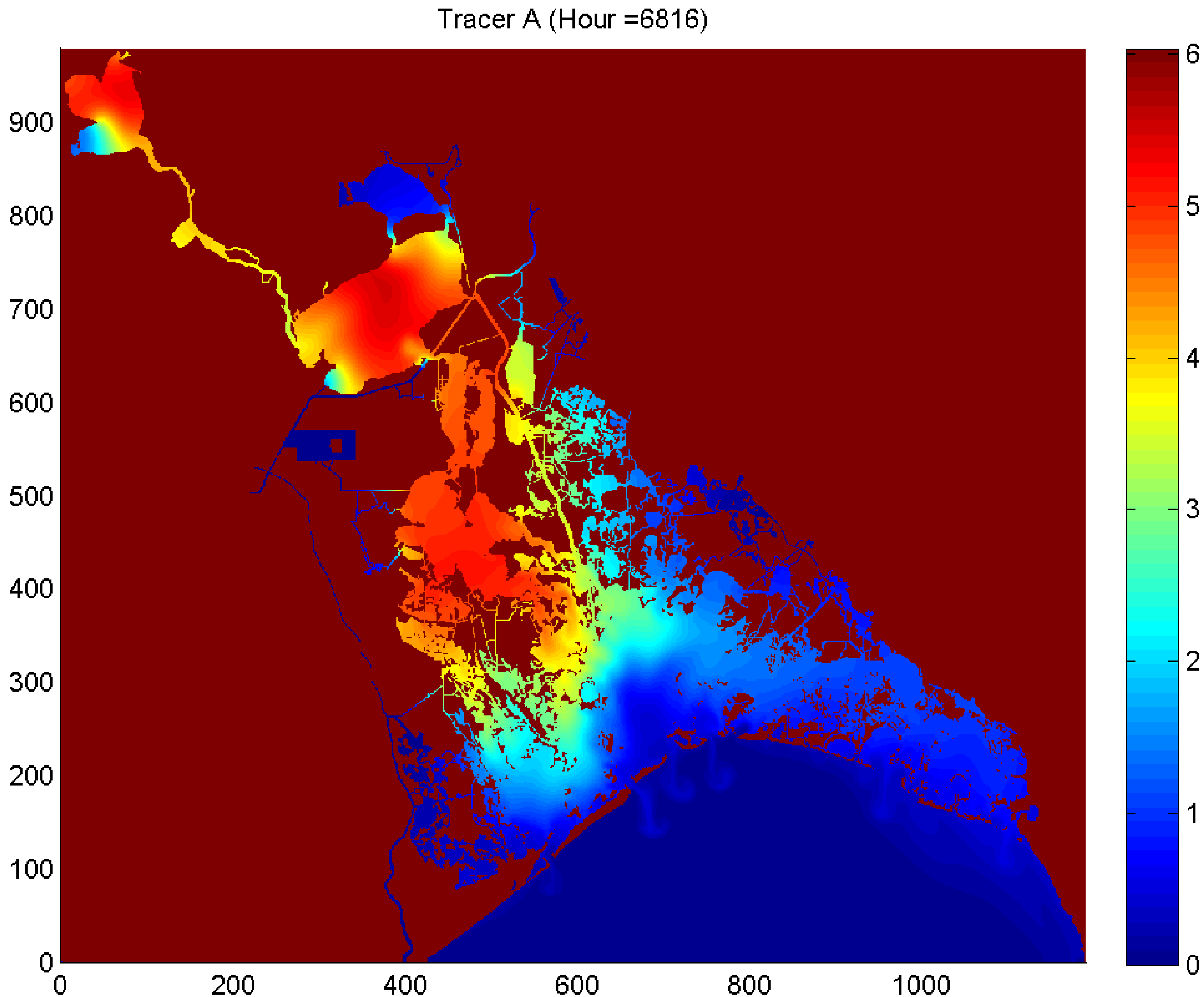
Tracer A (Hour =6816)
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3
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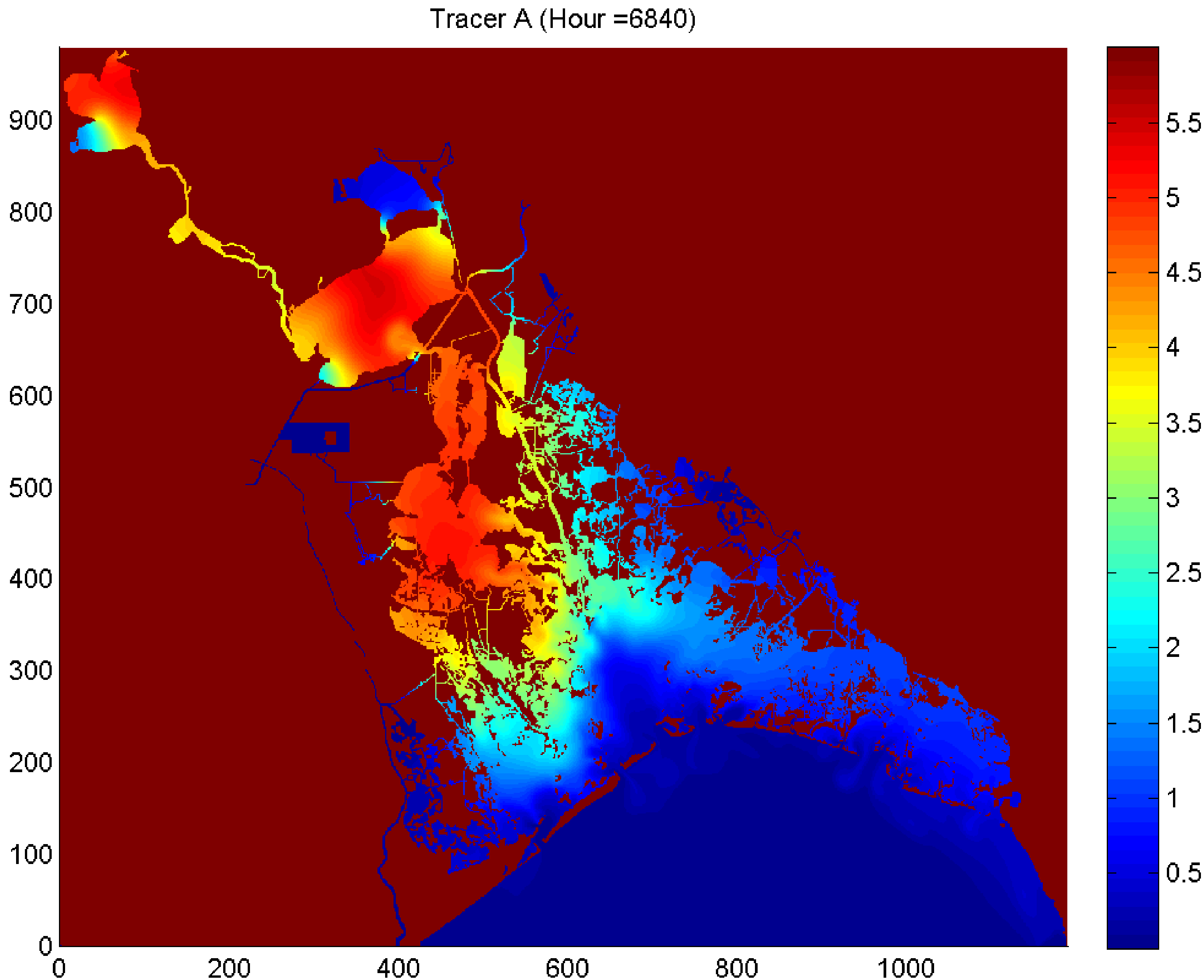
1
0



Tracer A (Hour =6840)
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200
100
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200
400
600
800
1000
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5

Comparison of Lower Mississippi River and Barataria Bay Fluxes

Constituent	Lower Mississippi River Discharge (MRD)	Barataria Bay Fluxes (BBF)	BBF:MRD (%)
Water (m^3 s^{-1})	15,874[a]	6,951[e]	43.7
NO_3+NO_2 (MT $year^{-1}$)	723,600[a]	7000[e]	1.0
Total Organic Carbon (MT $year^{-1}$)	4,000,000[b]	- 109,300[e]	2.7
Particulate Organic Carbon (MT $year^{-1}$)	480,000[c]	- 7,500[e]	1.4
Dissolved Organic Carbon (MT $year^{-1}$)	3,520,000[c]	- 94,000[e]	2.7
Chlorophyll *a* (MT $year^{-1}$)	2,000[d]	- 300[e]	18.4

a – Turner et al., 2007
b - Bianchi *et al*., 2007
c – Turner et al., unpublished data
d - Turner et al., unpublished data
e - this study

+ = import
- = export

FVCOM LaTeX Model

Years developed: 2009 - present

Publications: Wang et al. (2009), Justic et al. (2009, in preparation)

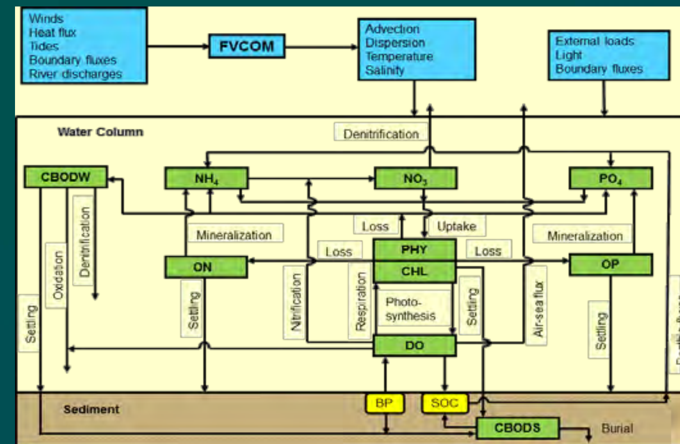
Objectives/Research questions:

- Physical/biological controls of hypoxia
- Hourly to decadal variability
- Nutrient management outcomes
- Climate variability/change
- Impacts of hypoxia on living resources

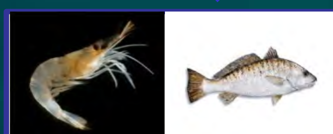
FVCOM LaTex Model

FVCOM

WASP



IBM

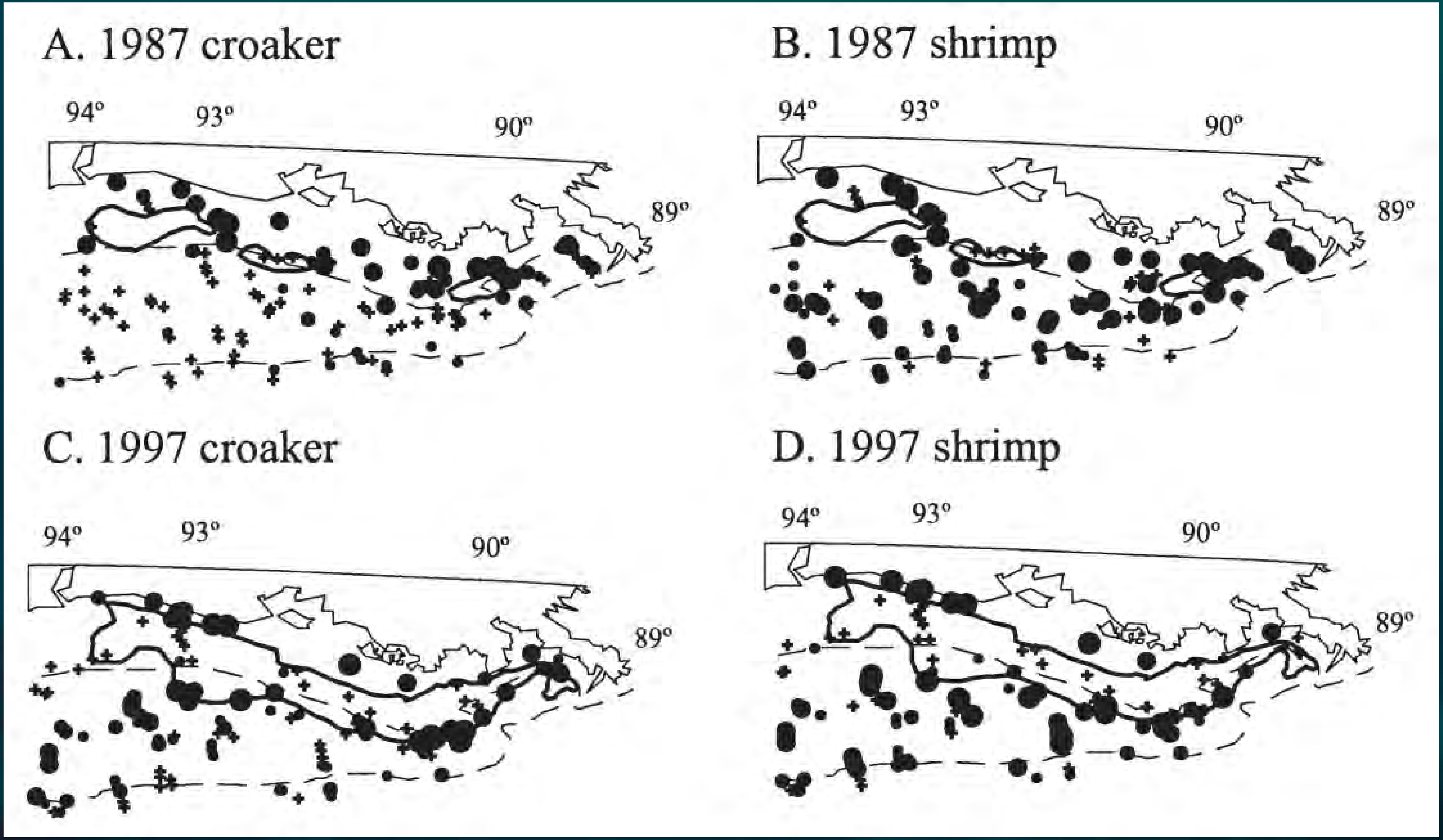


Individual Processes
- Movement
- Growth
- Mortality
- Spawning

Conditions
- Dissolved O_2
- Temperature
- Salinity
- Food density
- Predator Density
- Individual Size

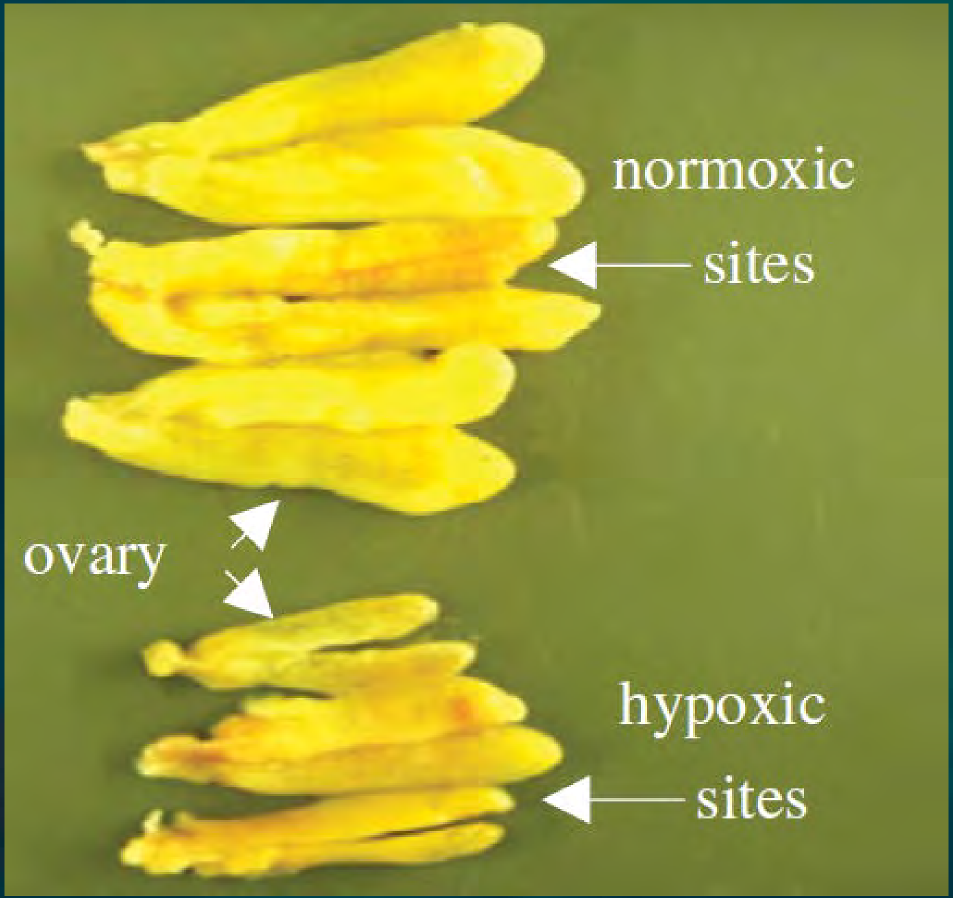
Justic and Wang (2009, in preparation); Wang and Justic (2009); Rose et al. (in preparation)

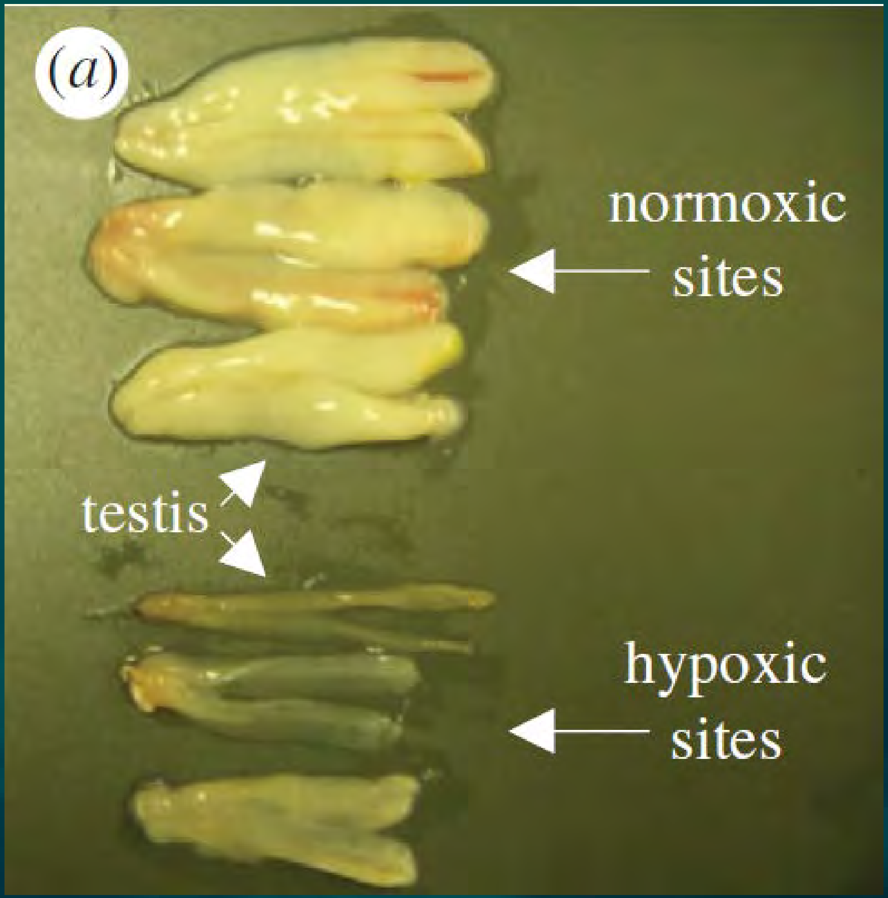
Population Displacements



(Craig and Crowder, 2005)

Reproductive Impairment (Atlantic Croaker)



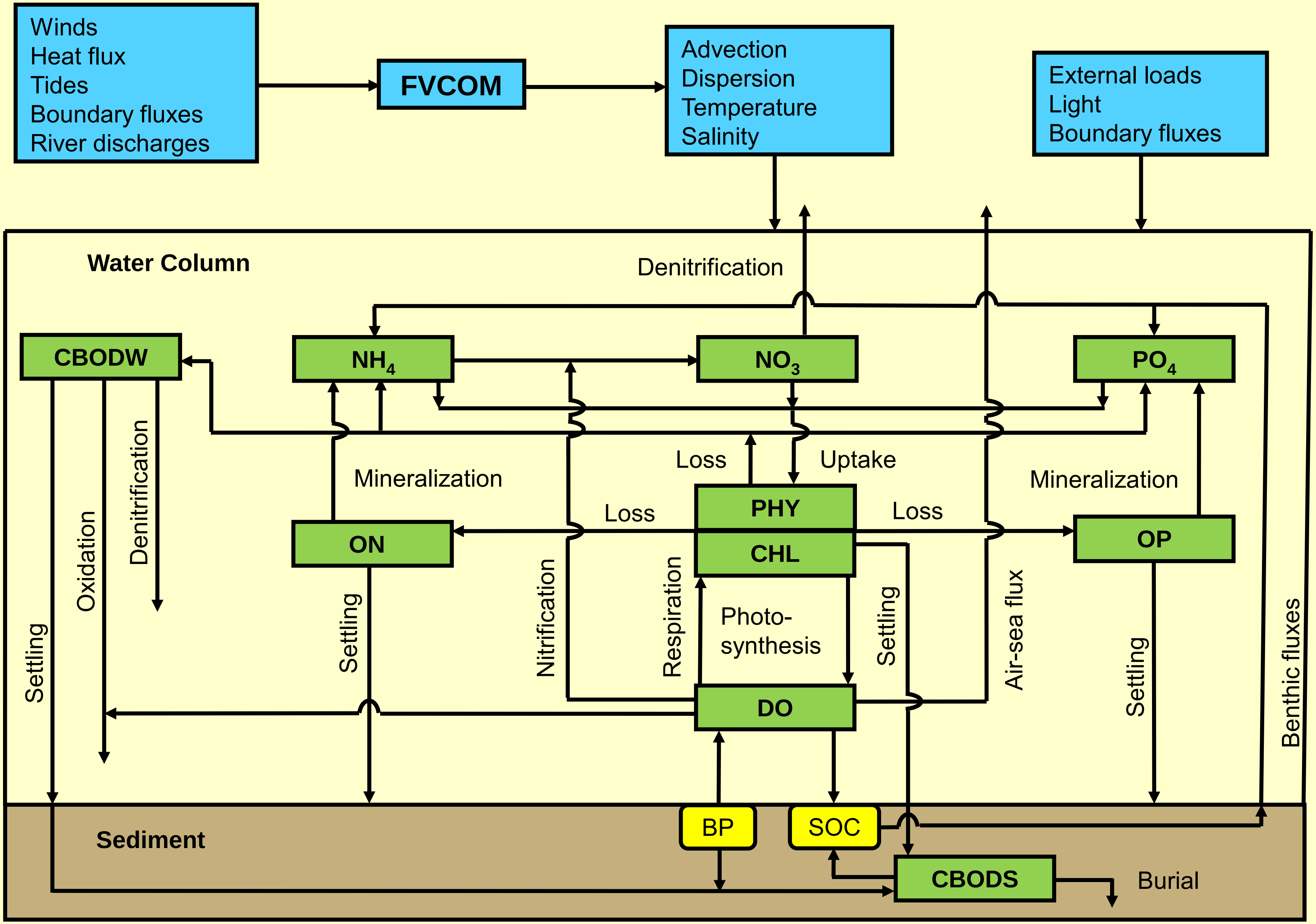


Thomas and Rahman (2012)

FVCOM-LaTex Model
Computational Domain and Grid

Wang and Justic (2009), Justic and Wang (2009)

FVCOM LaTex Water Quality Model

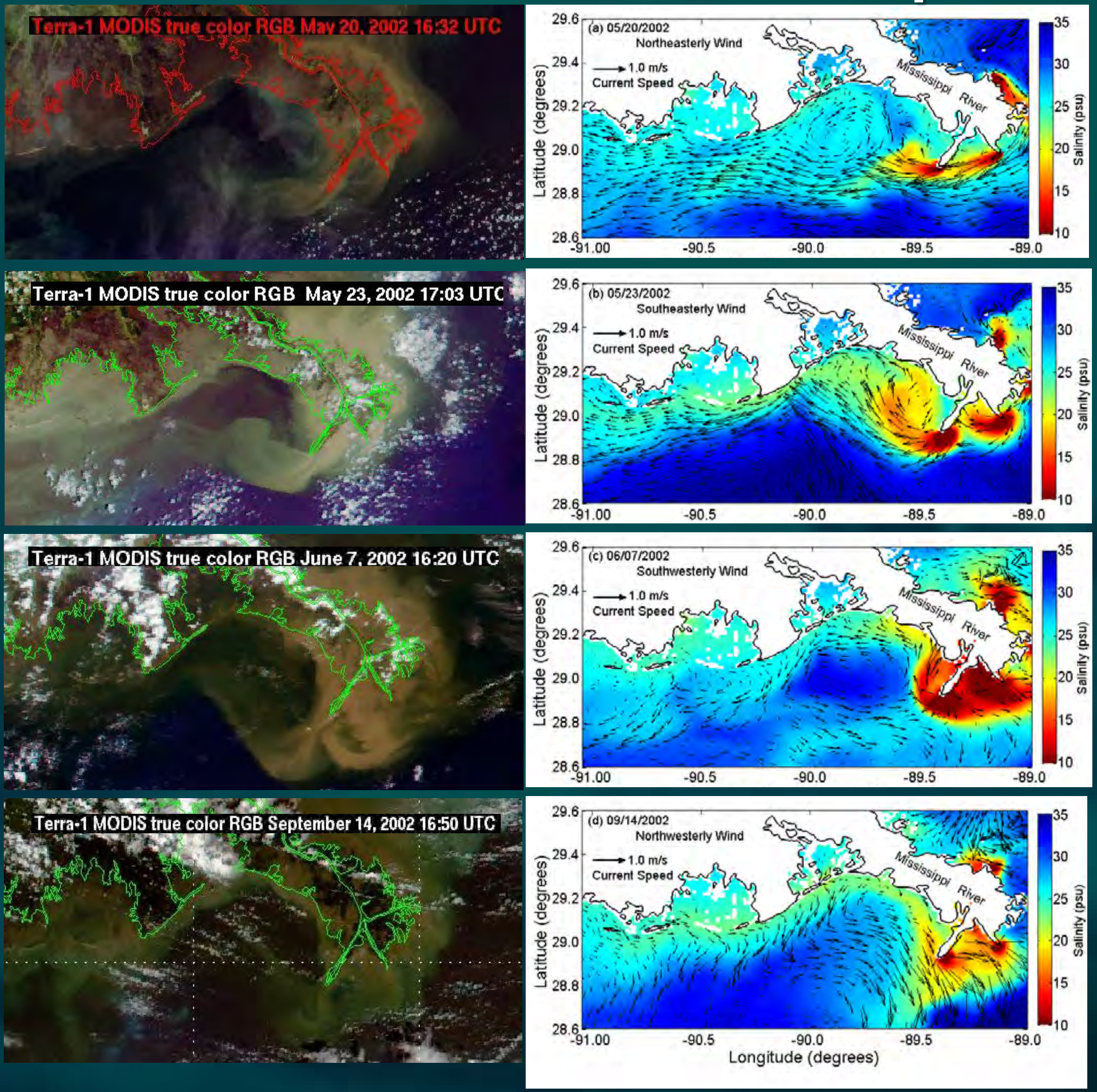


Justic and Wang (in preparation)

Model Calibration and Validation

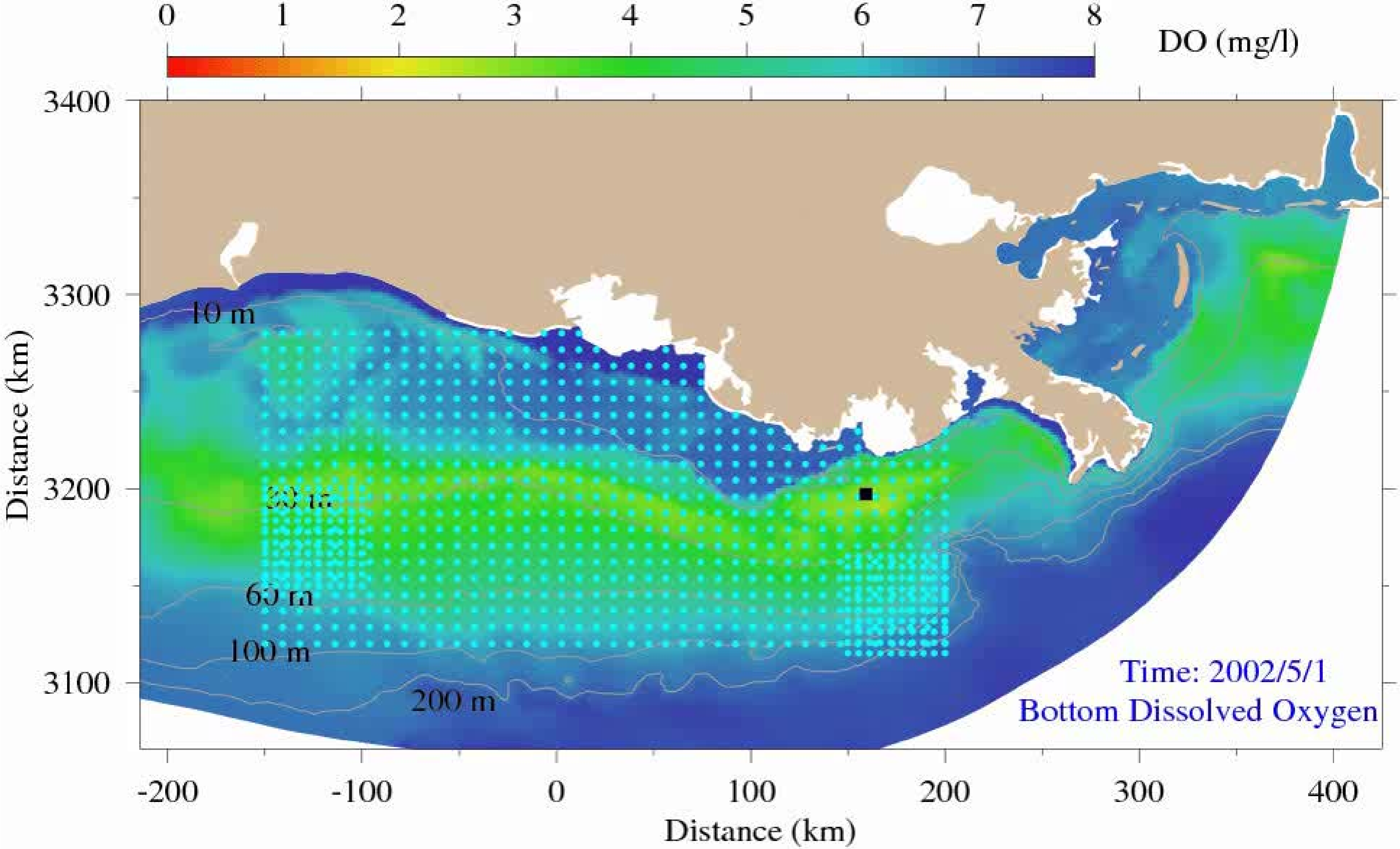
- Year 2002 – the largest hypoxic zone on record (22,000 km^2)
- Simulation period: January 1 to October 4, 2002; Integration step ~ 5 s
- Initial conditions inferred shipboard measurements and C6 and CSI03 moorings
- Model performance – evaluated using tidal gauges, ADCPs, shipboard measurements, C6 mooring, and satellite imagery

FVCOM LaTex Model-Data Comparison



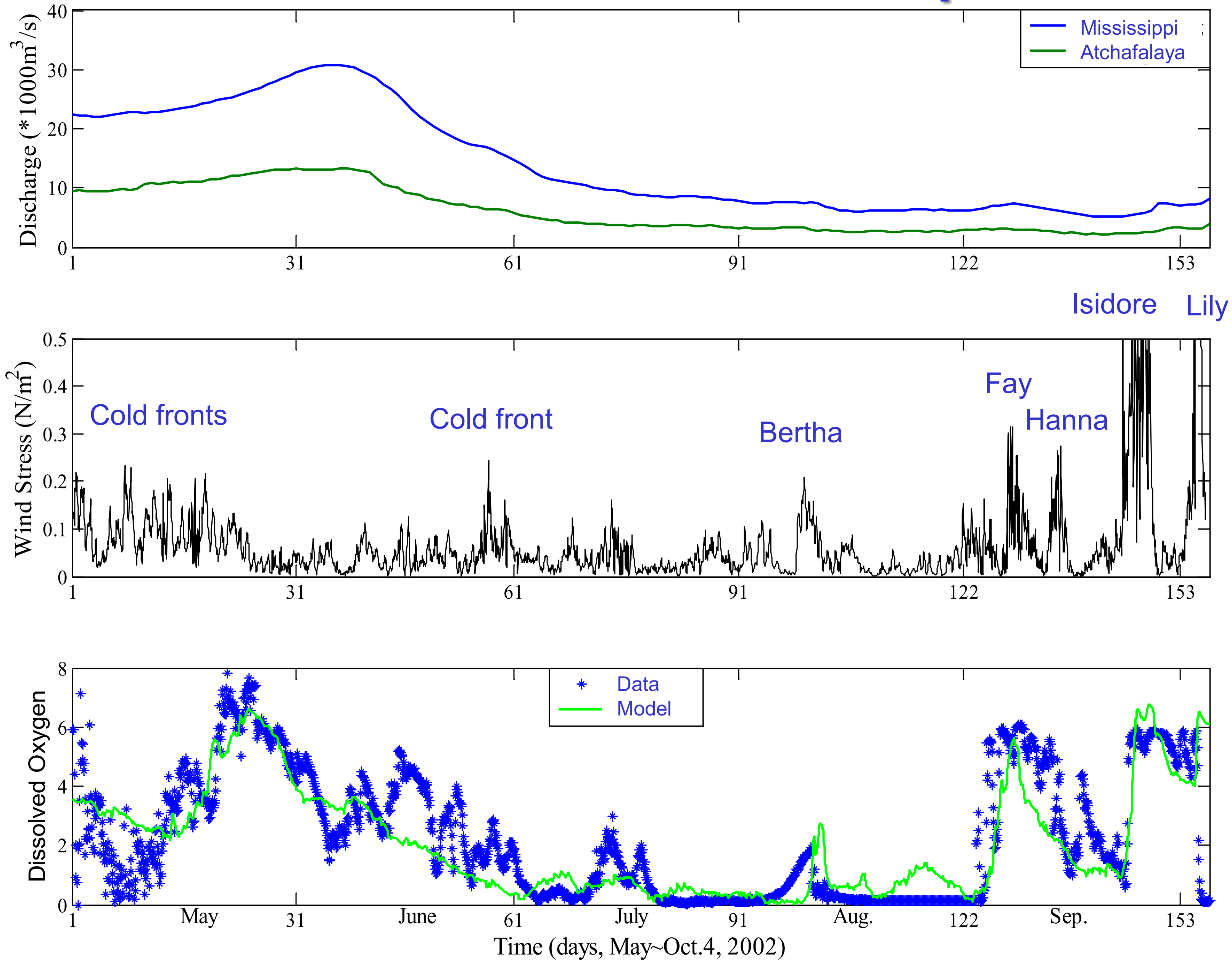
Wang and Justic (2009)

FVCOM LaTex Bottom DO + Fish
(May 1- October 1, 2012)



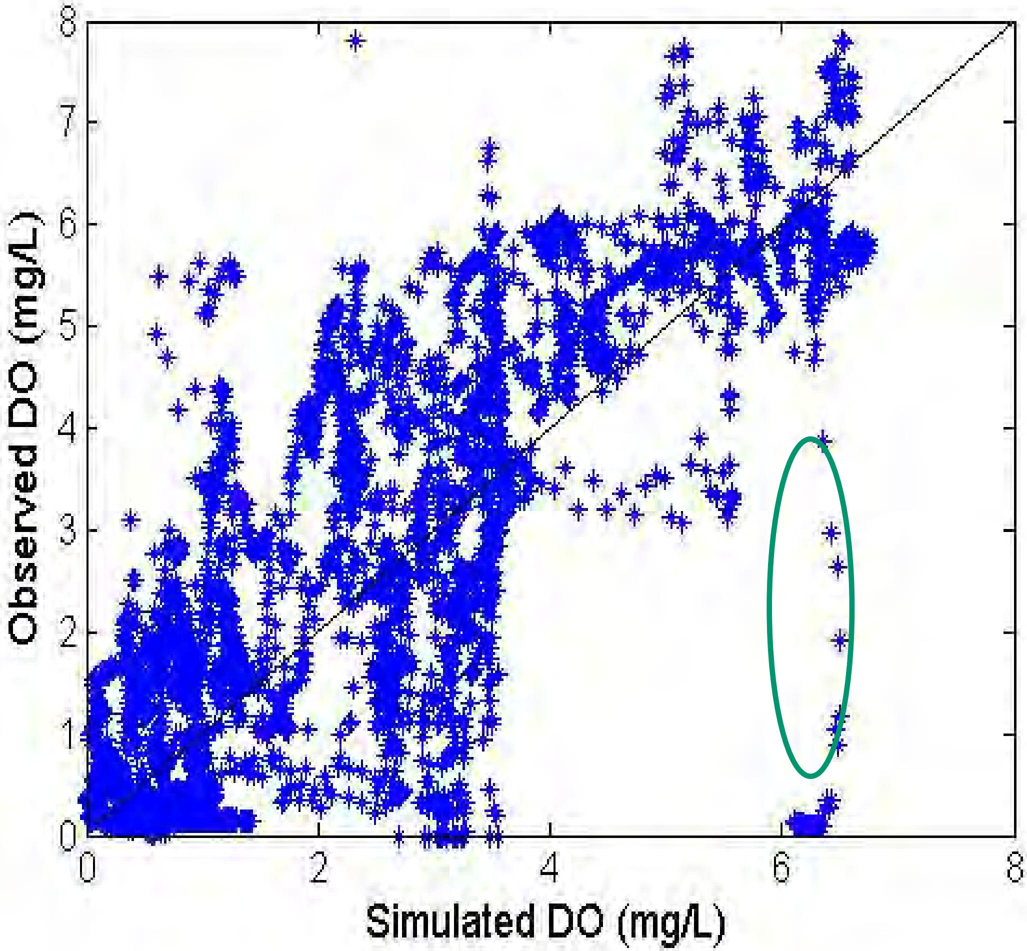
Justic et al. (in preparation)

FVCOM LaTex Model-Data Comparison



Justic and Wang (in preparation)

FVCOM LaTex Model Skill



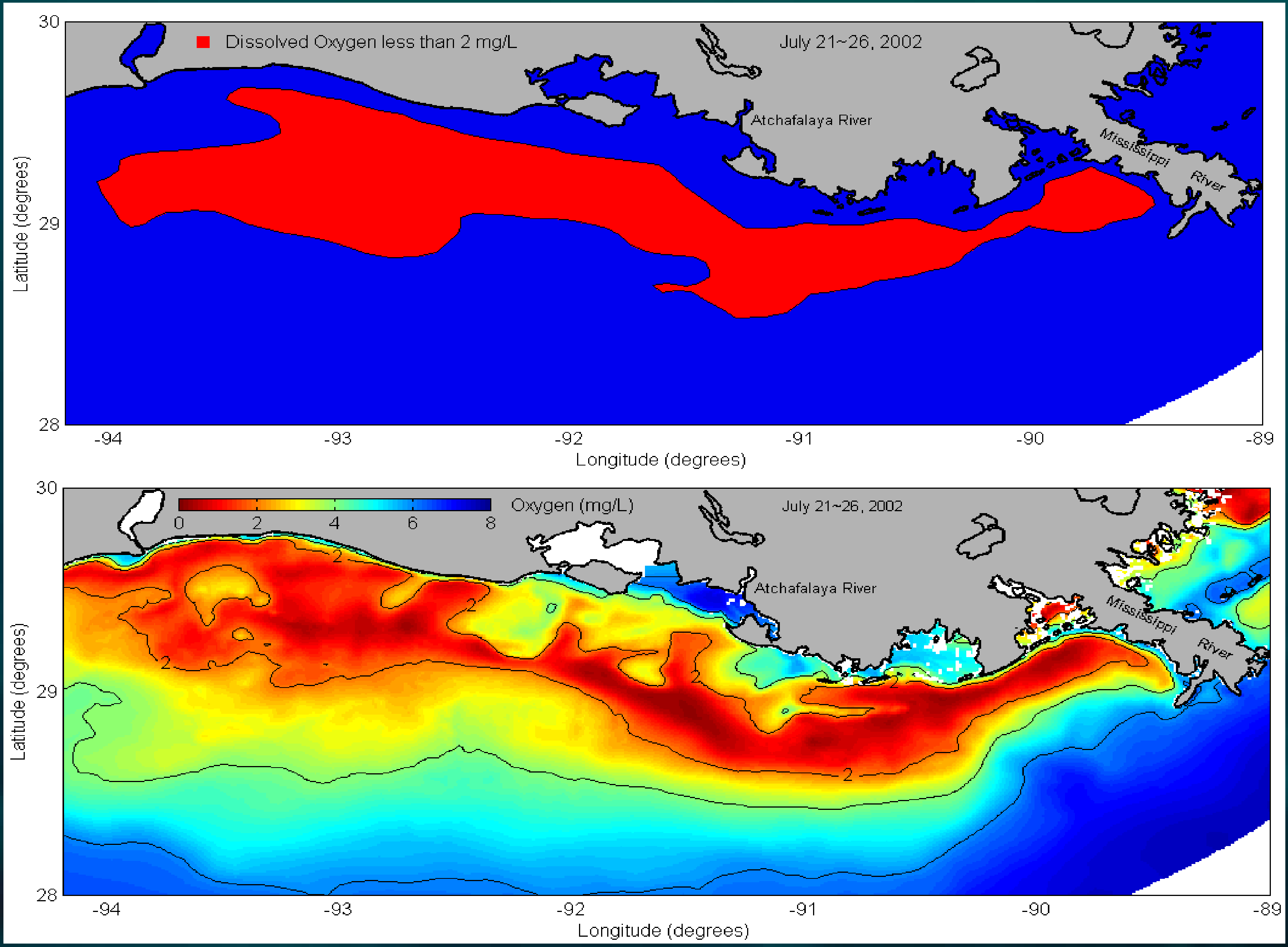
Willmott's index
d = 0.91

R^2 = 0.64

R^2 = 0.71

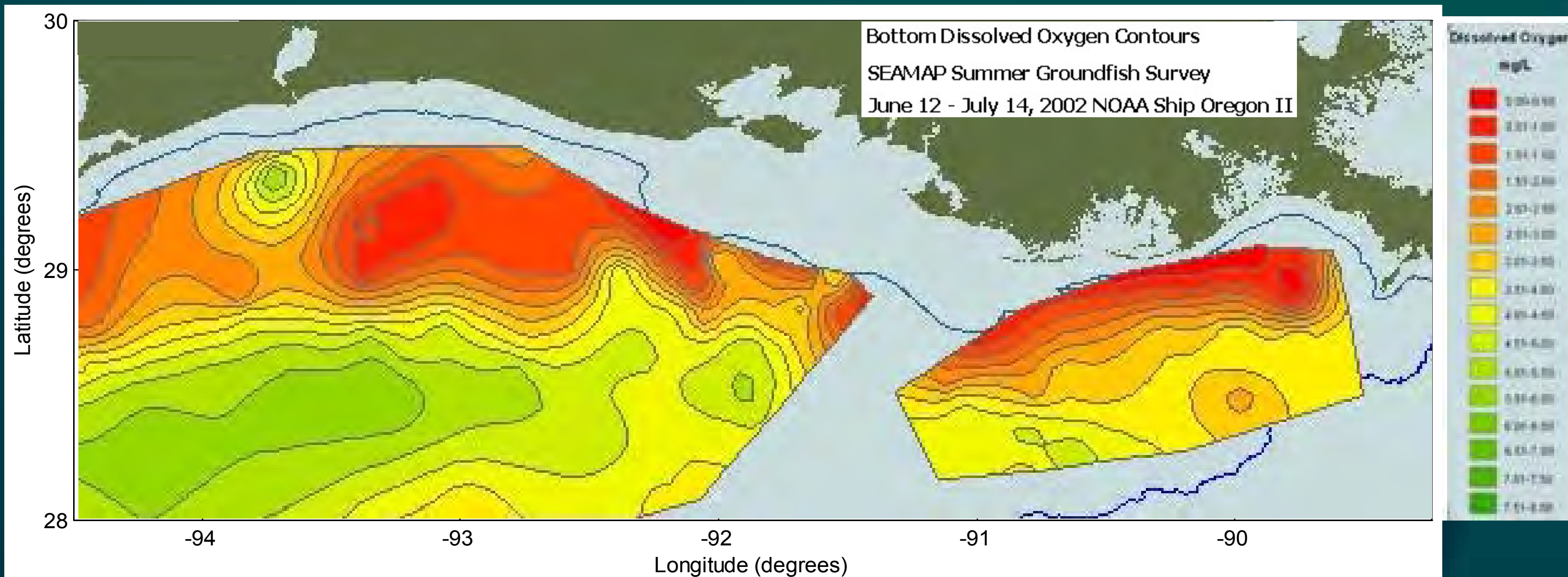
Justic and Wang (in preparation)

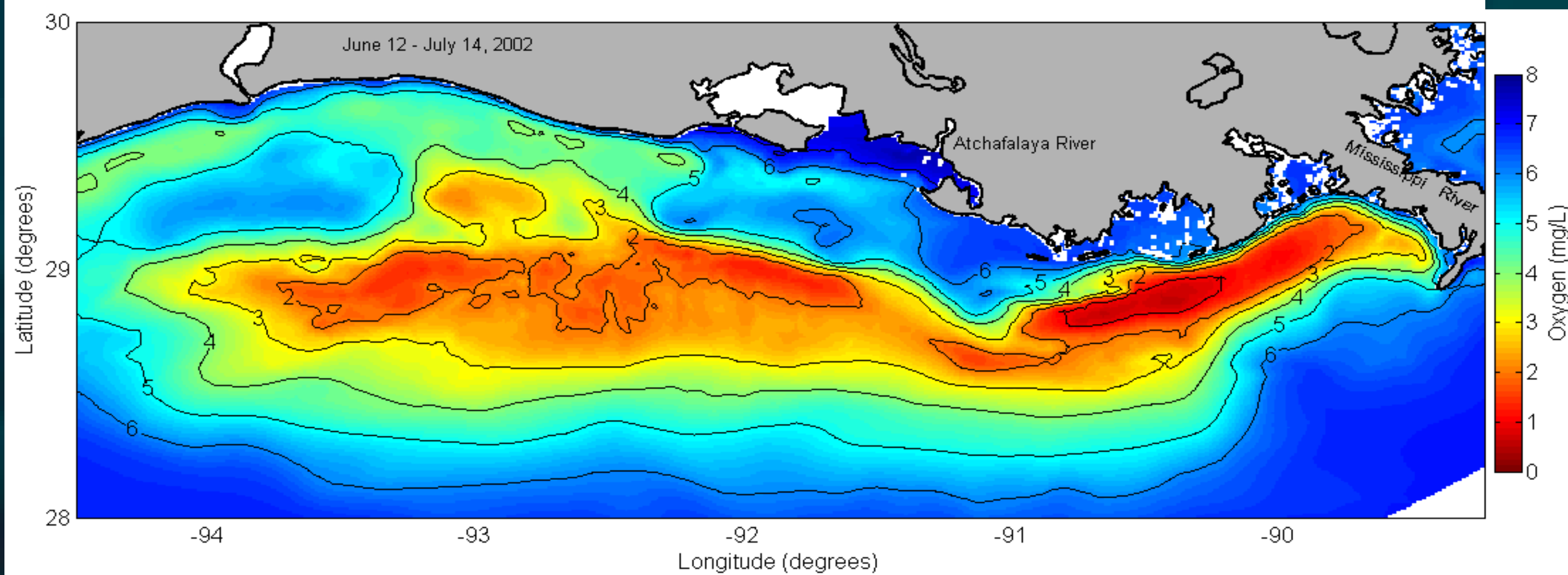
FVCOM LaTex Model-Data Comparison



Justic and Wang (in preparation)

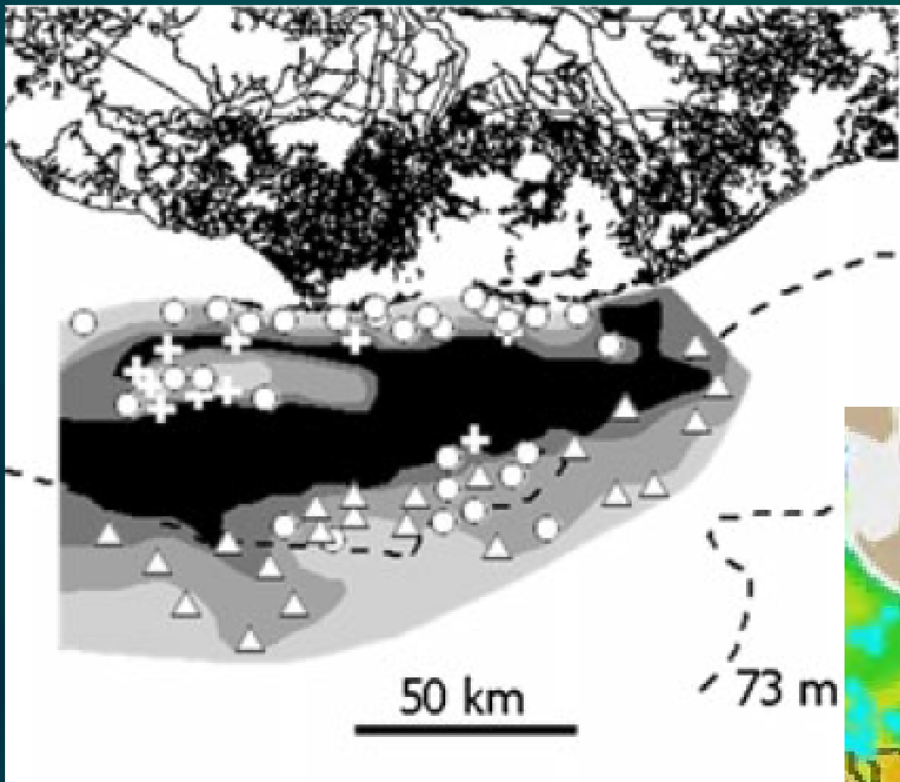
FVCOM LATEX Model-Data Comparison



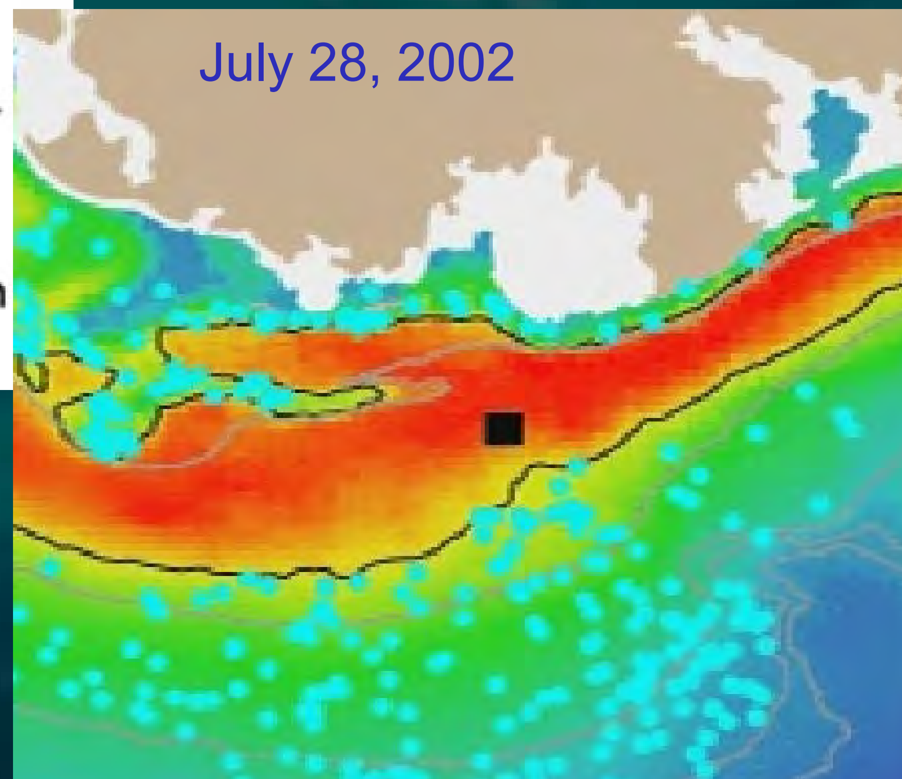


Justic and Wang (in preparation)

FVCOM LATEX Model-Data Comparison



July 20-28, 2002
Craig and Bosman (2012)



Justic et al. (in preparation)

FVCOM Barataria Bay Model

Years developed: 2013

Publications: Justic et al. (in preparation)

Objectives/Research questions:

- Replaces Barataria 2-D
- Importance of estuarine-shelf exchanges for hypoxia development (i.e., “outwelling” hypothesis, “wetland” hypothesis, “missing carbon”)
- Implications of large scale coastal restoration efforts (i.e., river diversions)
- TMDL and oil spill modeling

River Diversions

Existing

- Davis Pond (300 m^3/s)
- Naomi siphon (60 m^3/s)
- Point a la Hache siphon (60 m^3/s)

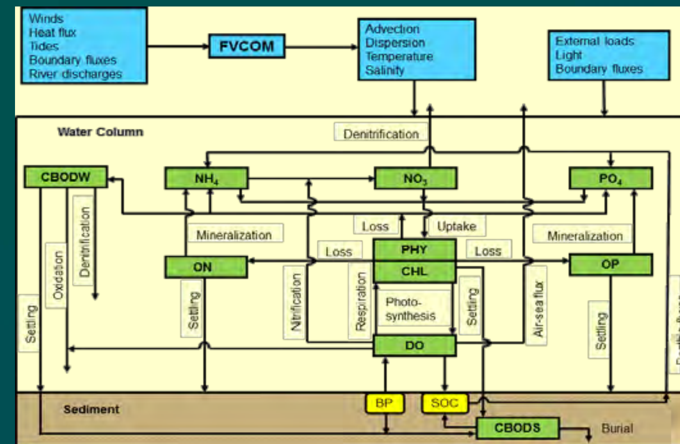
Proposed (2012 Louisiana's Comprehensive Master Plan for a Sustainable Coast)

- LCA diversion at Myrtle Grove (2,140 m^3/s)
- Mid-Barataria diversion (7,150 m^3/s)
- Lower Barataria diversion (1,430 m^3/s)

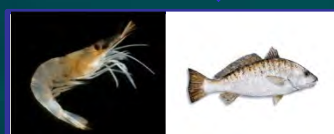
FVCOM Barataria Bay Model

FVCOM

WASP



IBM



Individual Processes

- Movement
- Growth
- Mortality
- Spawning

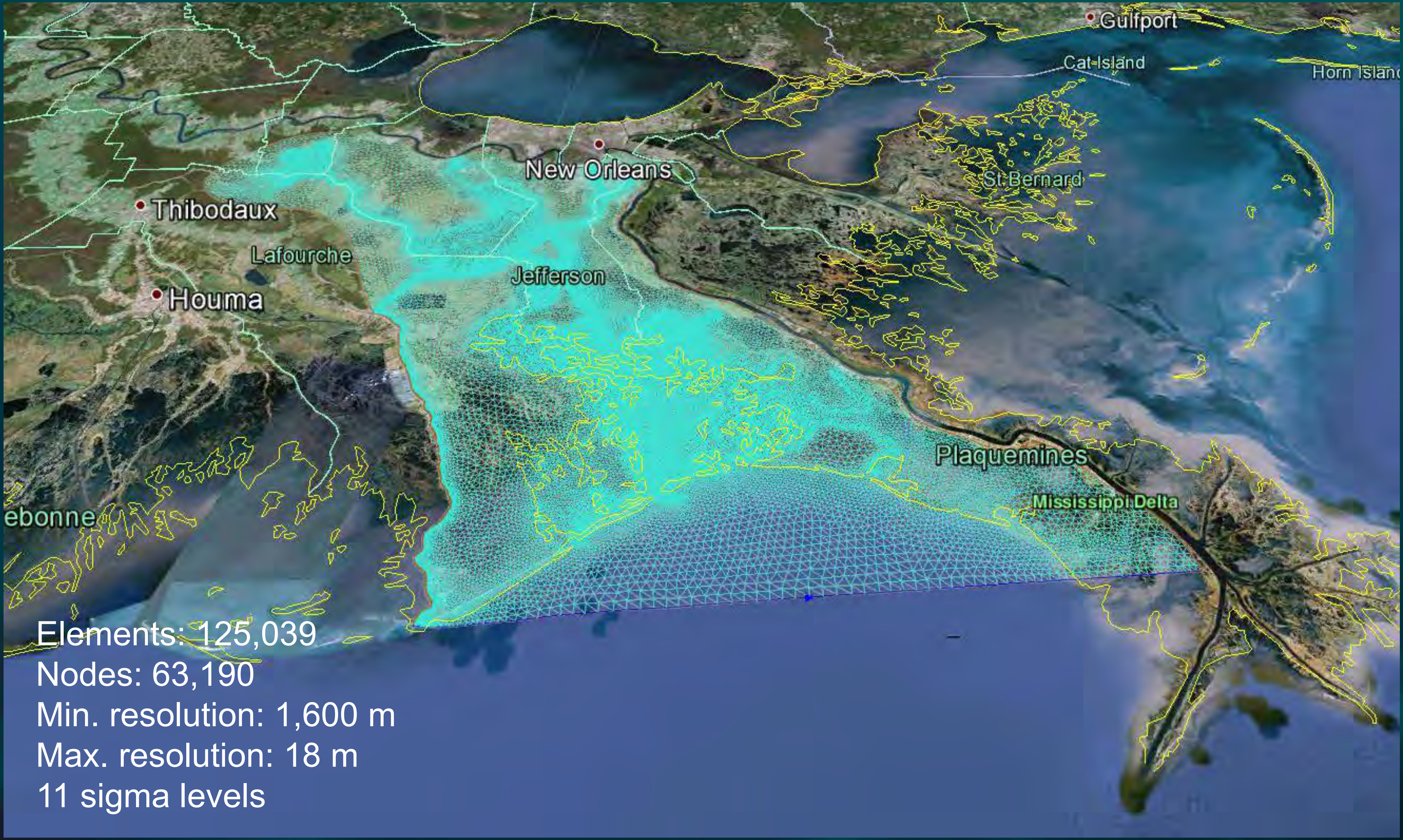
Conditions

- Dissolved O_2
- Temperature
- Salinity
- Food density
- Predator Density
- Individual Size

Justic and Wang (2009, in preparation); Wang and Justic (2009); Rose et al. (in preparation)

FVCOM Barataria Bay Model

Computational Domain and Grid

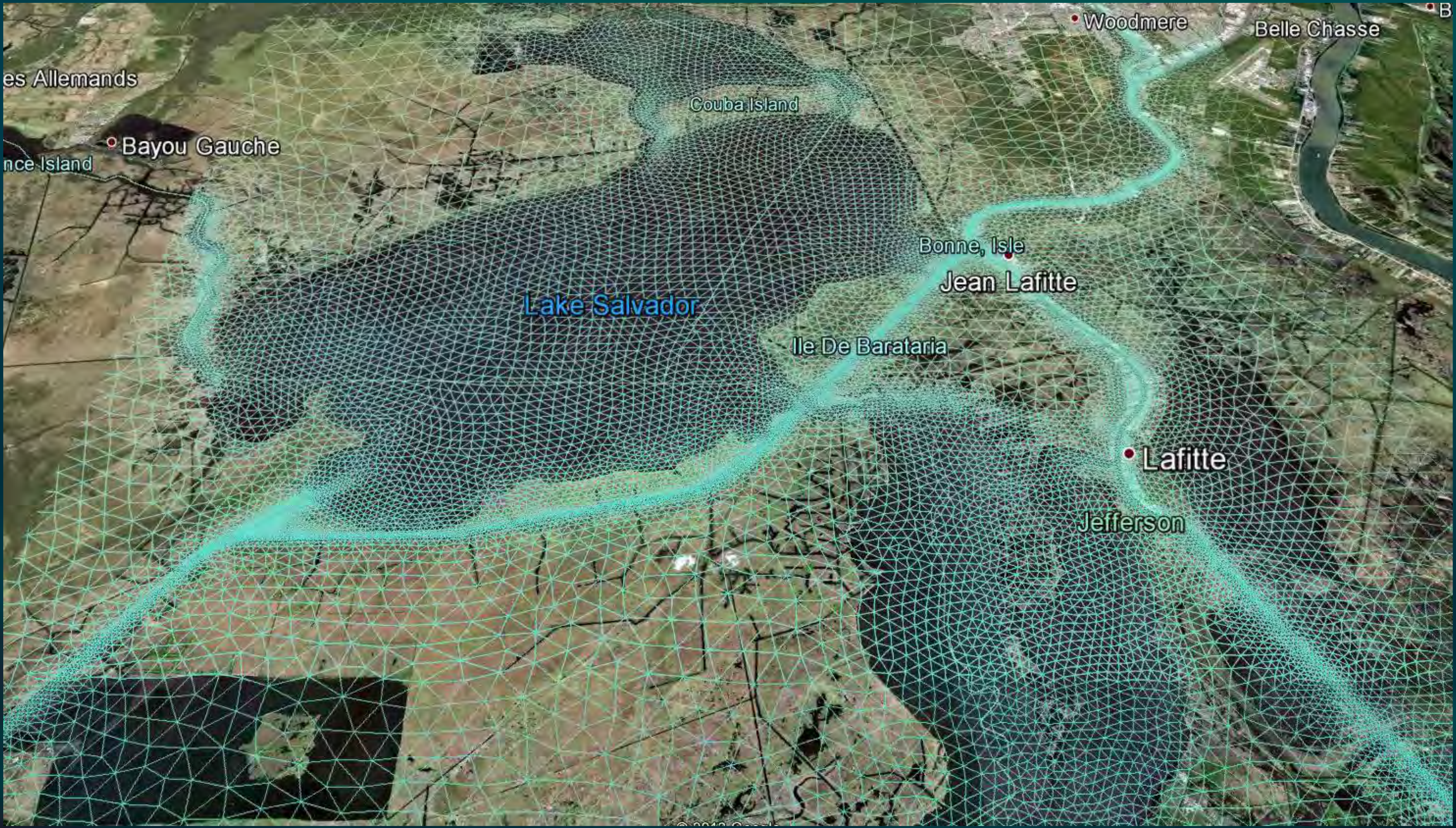


Elements: 125,039
Nodes: 63,190
Min. resolution: 1,600 m
Max. resolution: 18 m
11 sigma levels

Justic and Wang (in preparation)

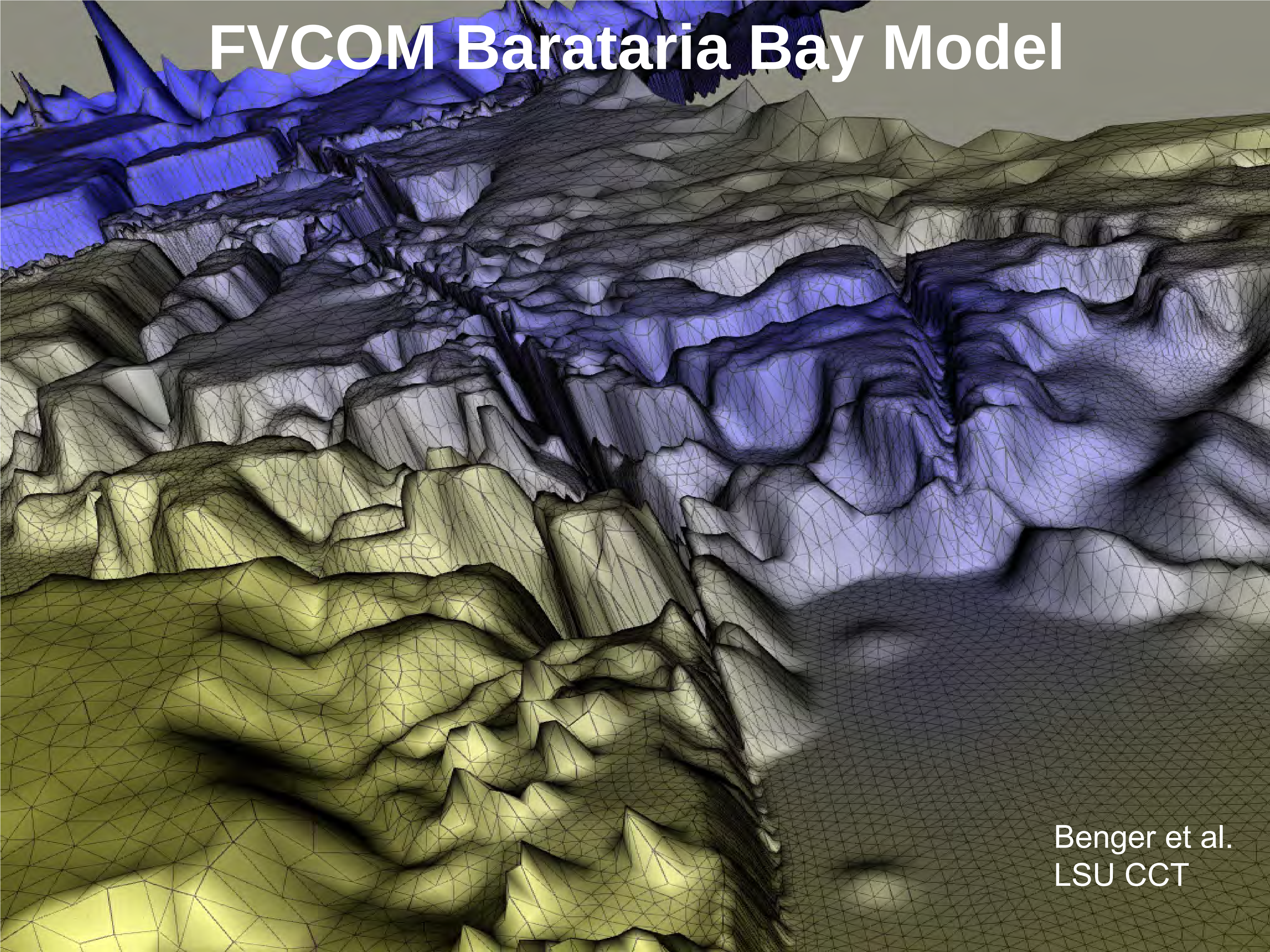
FVCOM Barataria Bay Model

Numerical Grid - Detail



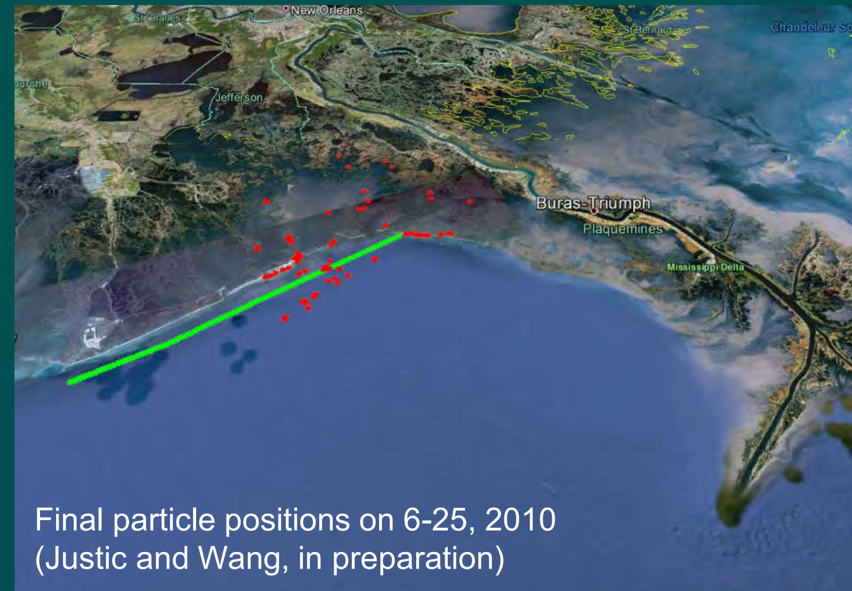
Justic and Wang (in preparation)

FVCOM Barataria Bay Model

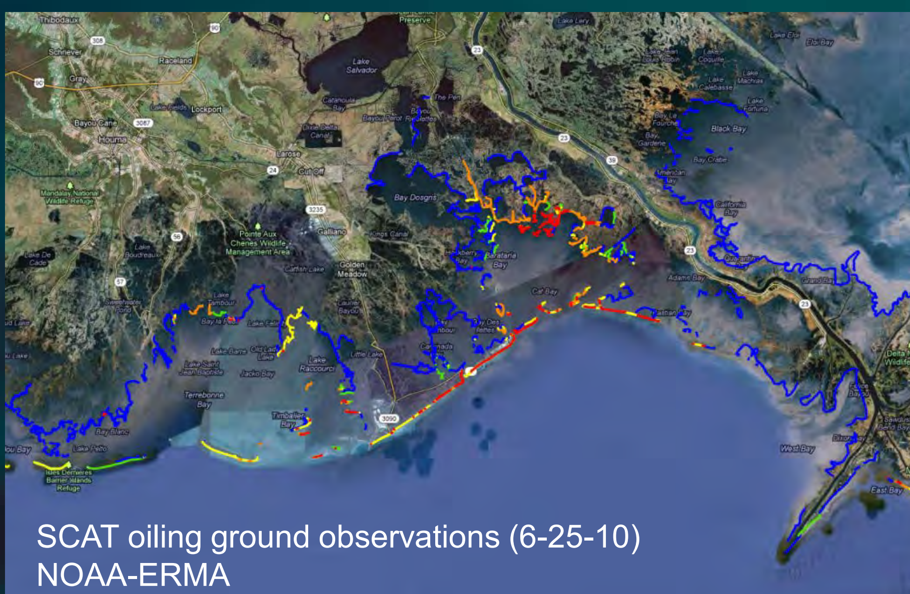


FVCOM Barataria Bay Model

Surface particle trajectories 5-29 to 6-25, 2010
(Justic and Wang, in preparation)



Final particle positions on 6-25, 2010
(Justic and Wang, in preparation)



SCAT oiling ground observations (6-25-10)
NOAA-ERMA

Oiled marsh sites September 2010 – February 2011
(Turner et al. in preparation)