On the Multiple-Core Updraft Smoke Plume Problem: Is the Genie Out of the Bottle?

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The Problem

- Getting the following accurate information on prescribed burns to regional scale AQ models
  - emissions data – date, time (hourly), location
  - injection data – time, altitude

  for the simulation of the relative contribution of wildland burning to air quality.

The Solution

- The Bluesky modeling framework plus the plume model CalPuff (O'Neill et al. 2003)
- SHRMC 4S/CMAQ plus Daysmoke (Liu et al 2007)
- CMAQ plus a plume rise scheme for SMOKE Pouliot et al. (2005)

The Outcome

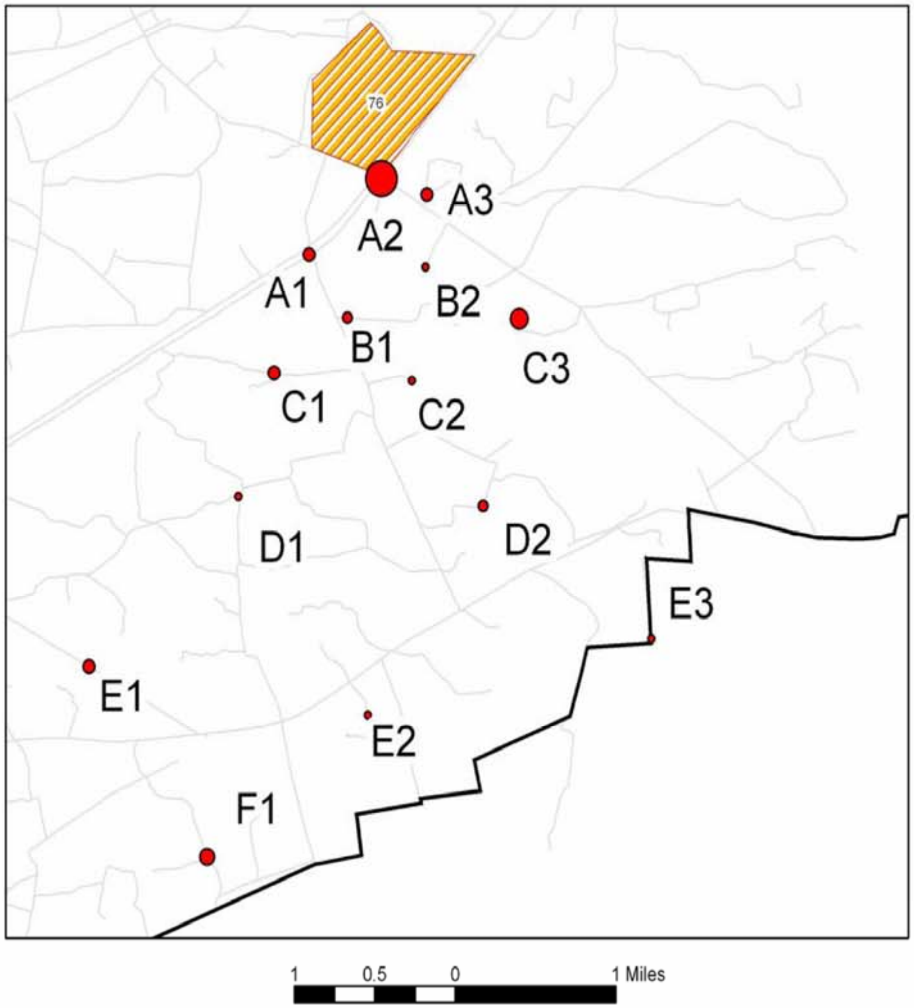
- Predicated smoke concentrations were not as accurate as desired (BSRW, 2006)
- Plume rise schemes and models did not take into consideration the human element – how the fire was done – and unrealistically distributed smoke in the atmosphere

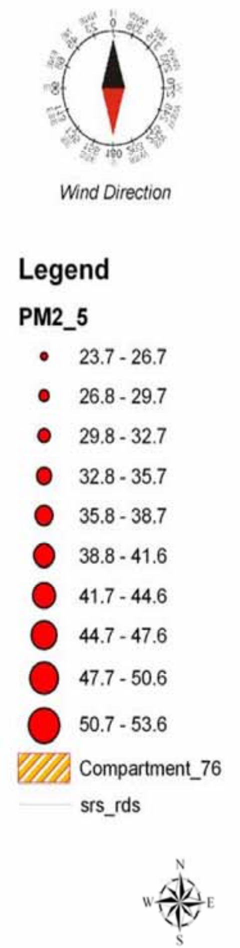
The Human Element – How Important Is It?

- The Savannah River Smoke Project: 2003-2007 set up to measure 24 hr PM2.5 smoke concentrations 0-5 miles downwind from prescribed burns.
- Dense networks of up to 22 gravimetric PM2.5 samplers.
- Up to 6 Dust Trac real time PM2.5 samplers.

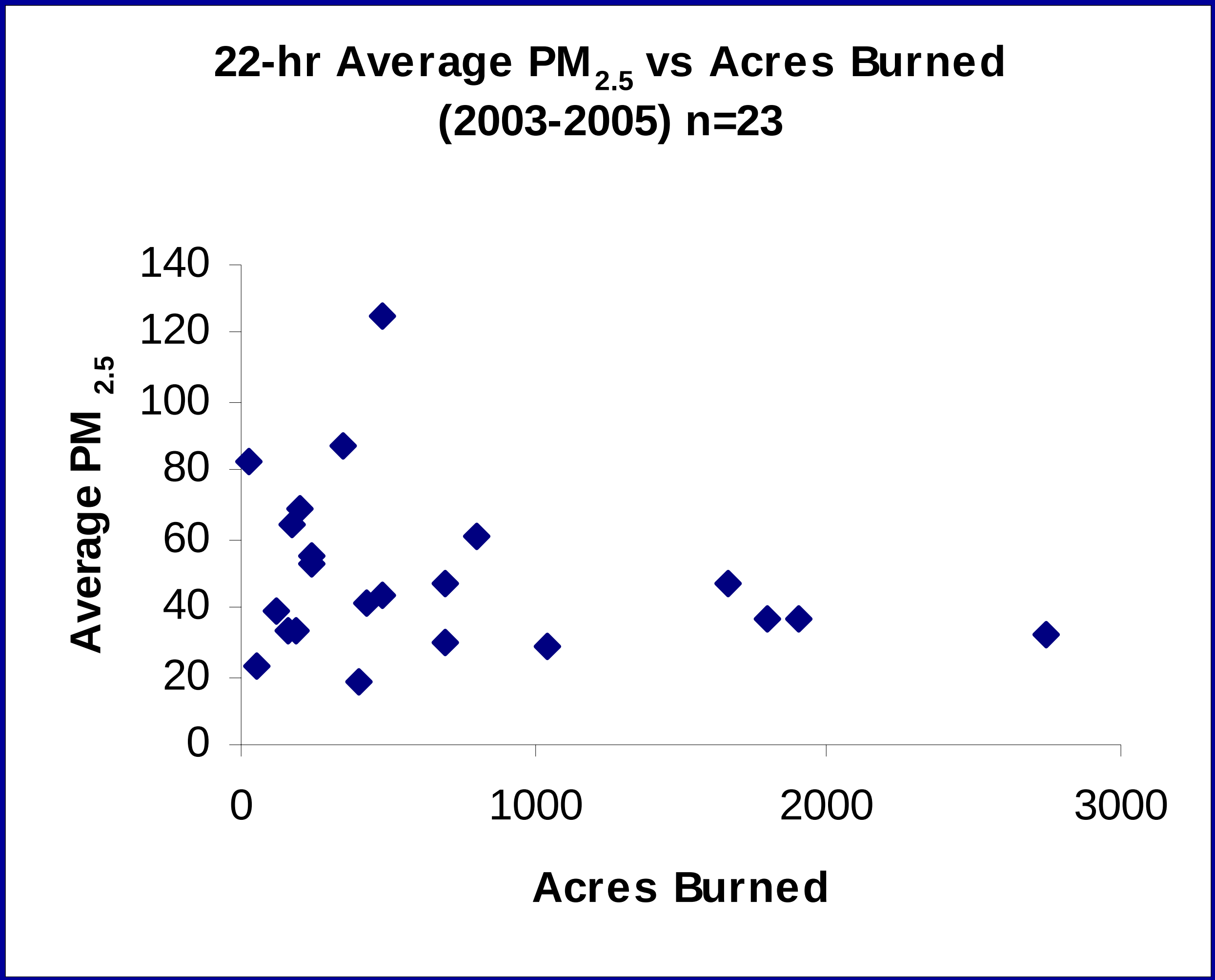
SRS Burn January 21th 2005

Burn Location: Compartment 76
Burn Size: 800 acres
Sample Duration: 10am-8am





Savannah River Smoke Project

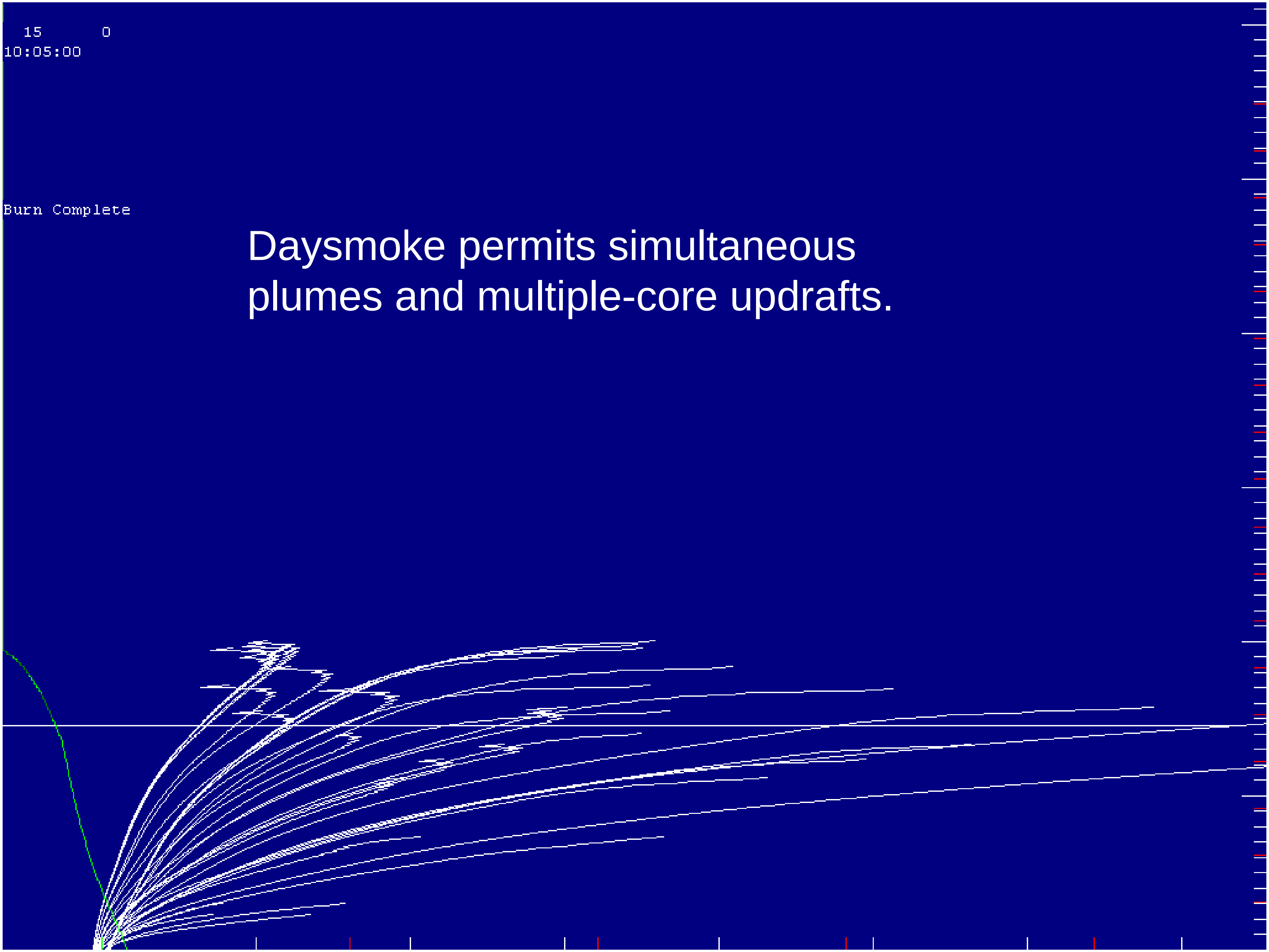


Preliminary Results

- No correlation between acres burned and PM2.5 concentrations.
- Cannot use acres burned as an estimate of PM2.5 concentrations.
- We know that larger fires produce larger emissions. But….
- Not all prescribed burns are the same

Daysmoke - Purpose

- Daysmoke designed to simulate daytime smoke plumes from prescribed burns
- Created to give the forestry community a “say” in how smoke from wildland burning is included in regional scale AQ models.
- Created to let the forestry community contribute to how smoke from planned burns is regulated.
- Helps the forestry community understand how burn design impacts the dynamics of plume behavior
- Assists the forestry community in pre-burn planning.

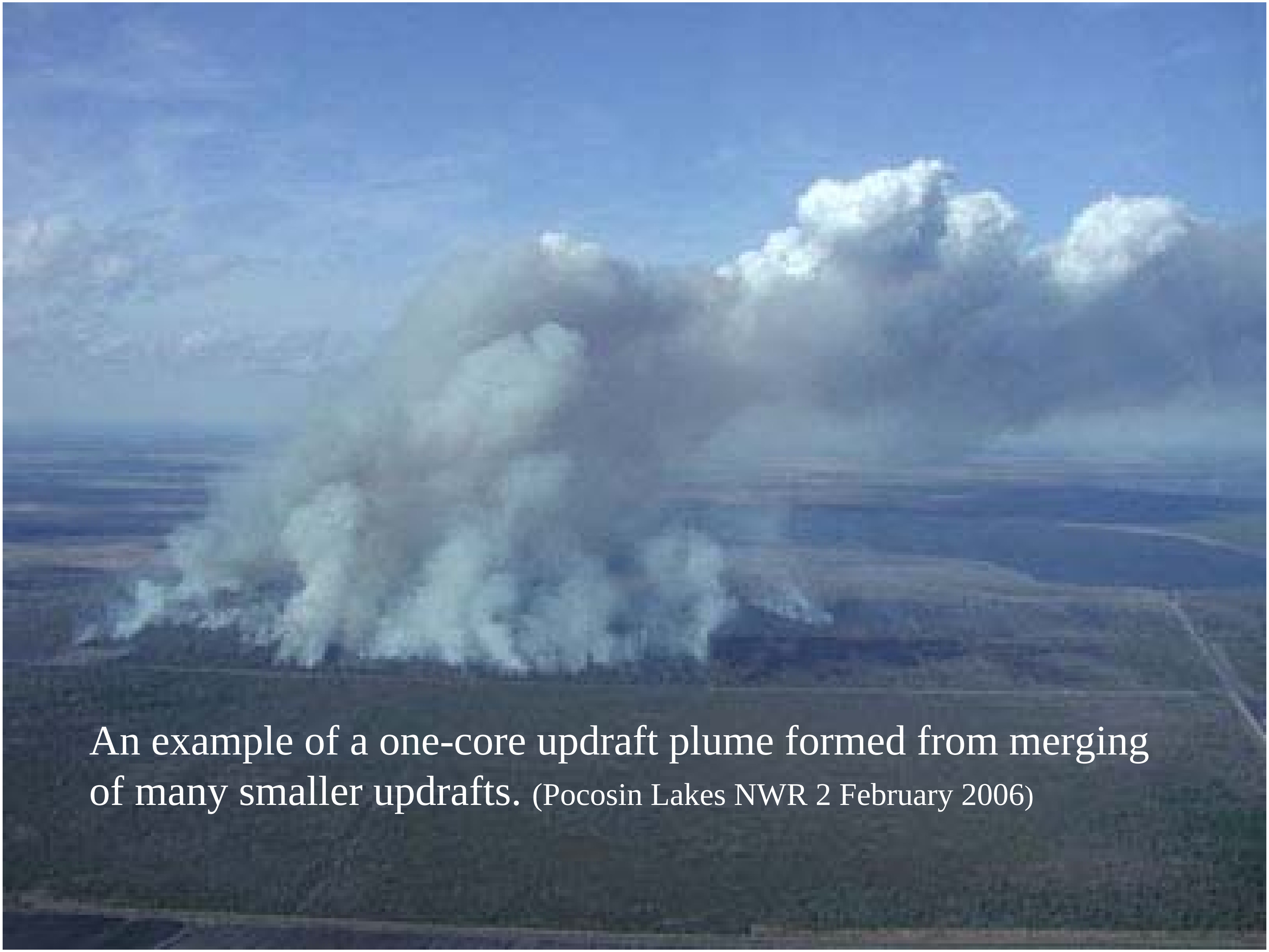


Daysmoke permits simultaneous plumes and multiple-core updrafts.

Prescribed Burn Engineering
and
Multiple-Core Updraft Plumes

- Not all plumes from prescribed fires appear similar in structure.
- Suspect plume dynamics differs
- Representing prescribed fire plumes by simple algorithms or single plume models problematic

Multiple-core updraft problem – one-core updraft Cedar Island burn 6 April 2005.



An example of a one-core updraft plume formed from merging of many smaller updrafts. (Pocosin Lakes NWR 2 February 2006)

An example of a two-core updraft plume

An example of a multiple-core updraft plume -
Magazine Mountain, AR 27 February 2004.


Atlanta Smoke-Out –
28 February 2007
28/02/2007 13:10

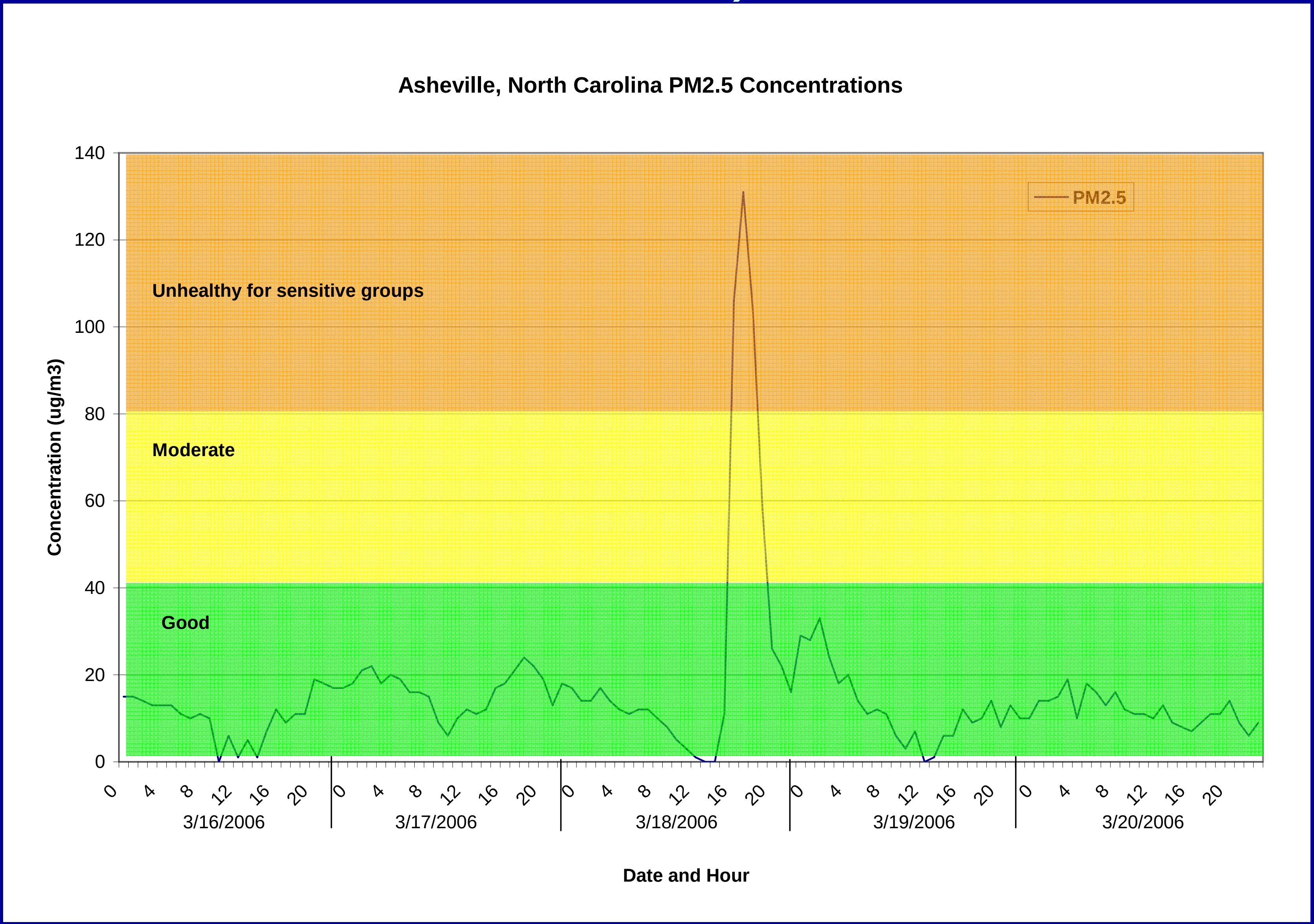

Atlanta Smoke-Out
28/02/2007 13:42

What Daysmoke Tells Us:

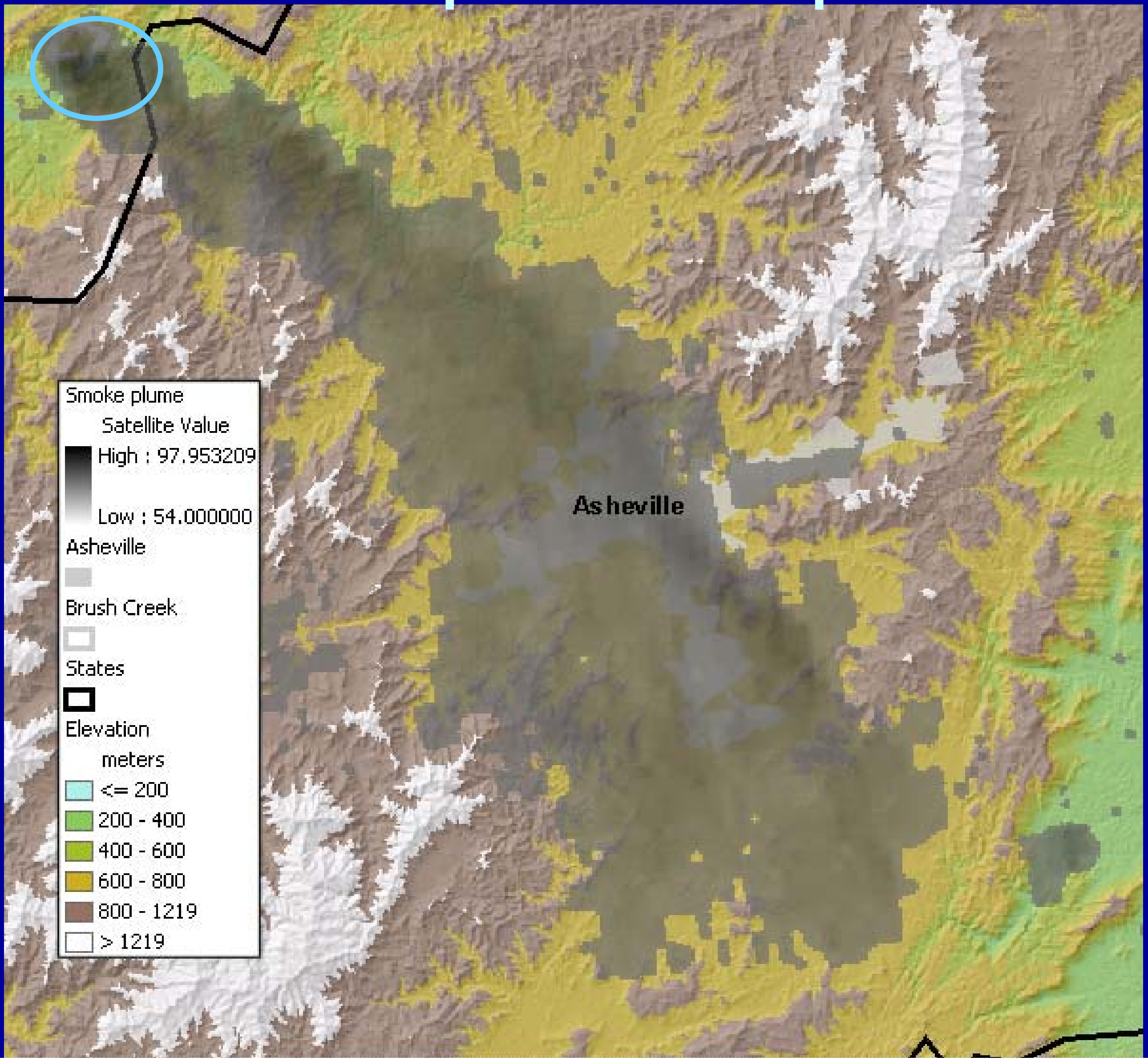
In comparison with single-core updrafts, multiple-core updrafts…

- Have weaker updraft velocities
- Are smaller in diameter
- Are more impacted by entrainment
- Are less efficient in the vertical transport of smoke.

Brush Creek Smoke Incident (18 March 2006)

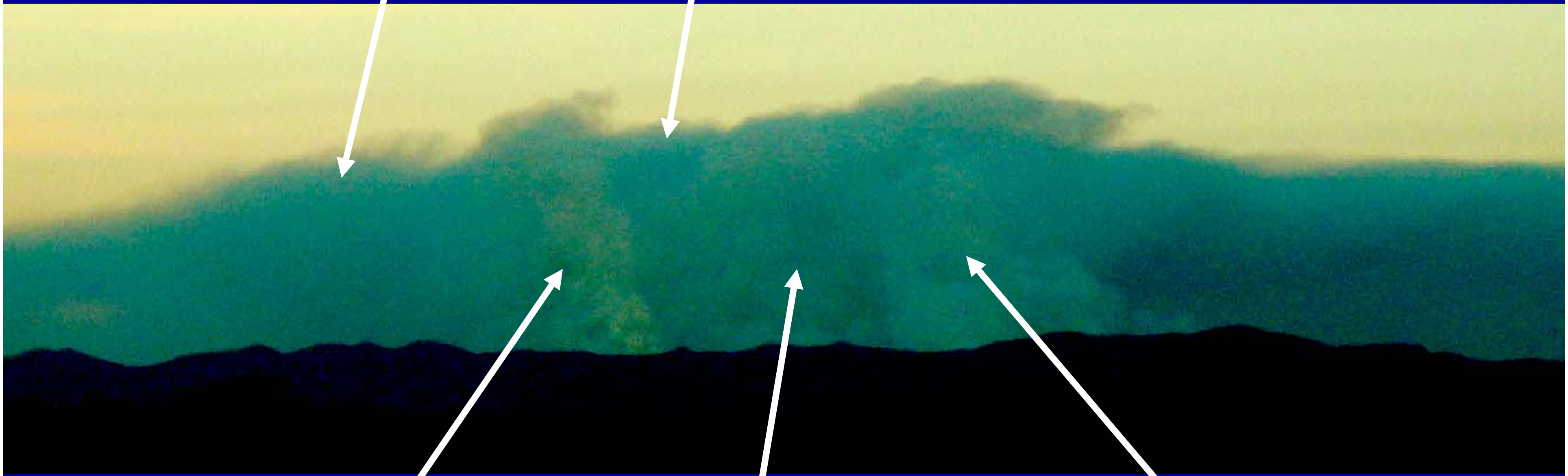


1840 Acre Brush Creek Burn - a multiple-core plume incident

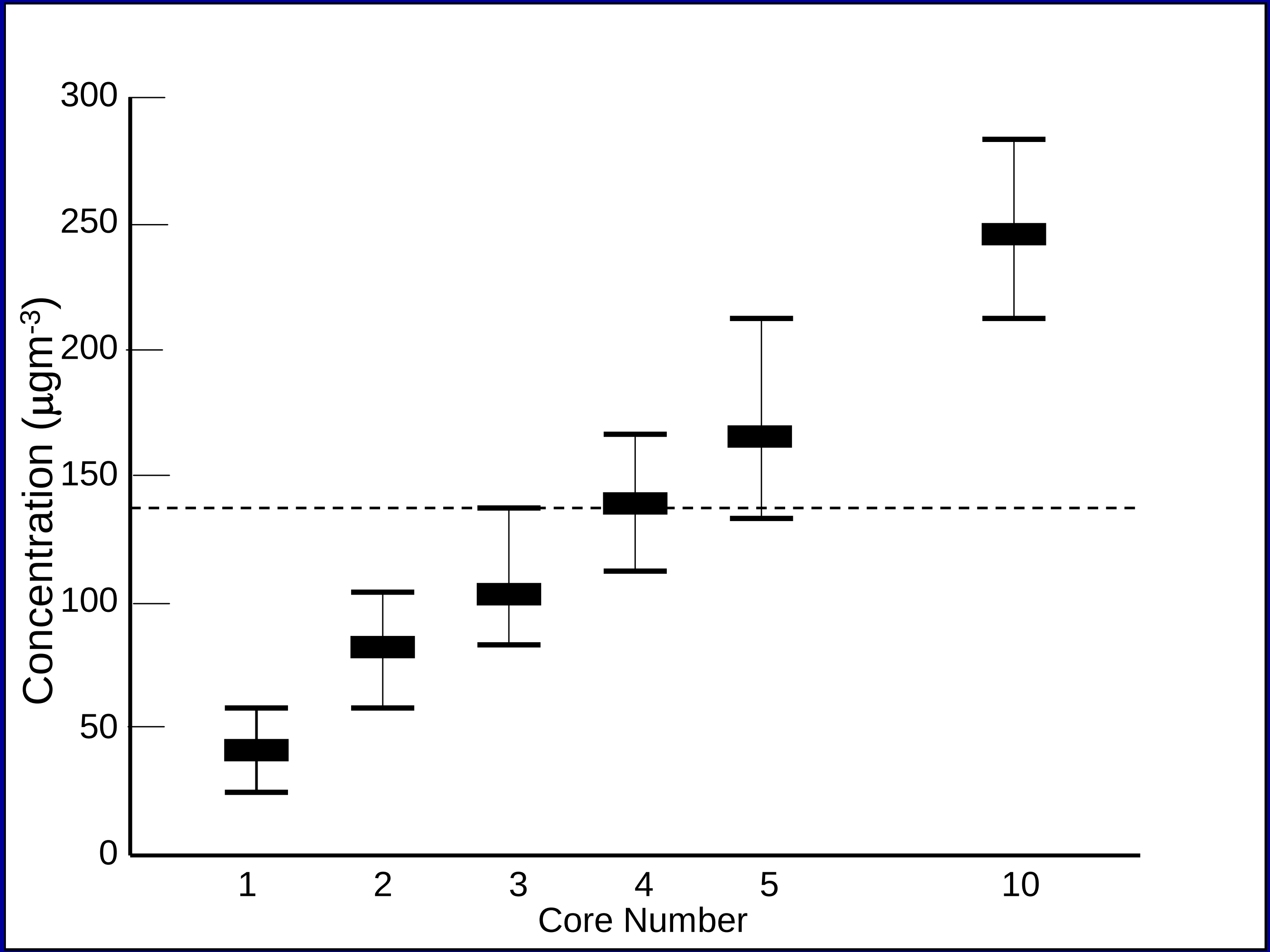


18 March 2006 Asheville plume collapse.

The burn plan for the Brush Creek burn led to the creation of a plume with multiple core updrafts.



Daysmoke multiple-core updraft solutions for PM at Asheville, NC



What Daysmoke is NOT Telling Us

- No information on how to supply Daysmoke with core number needed to run the model.

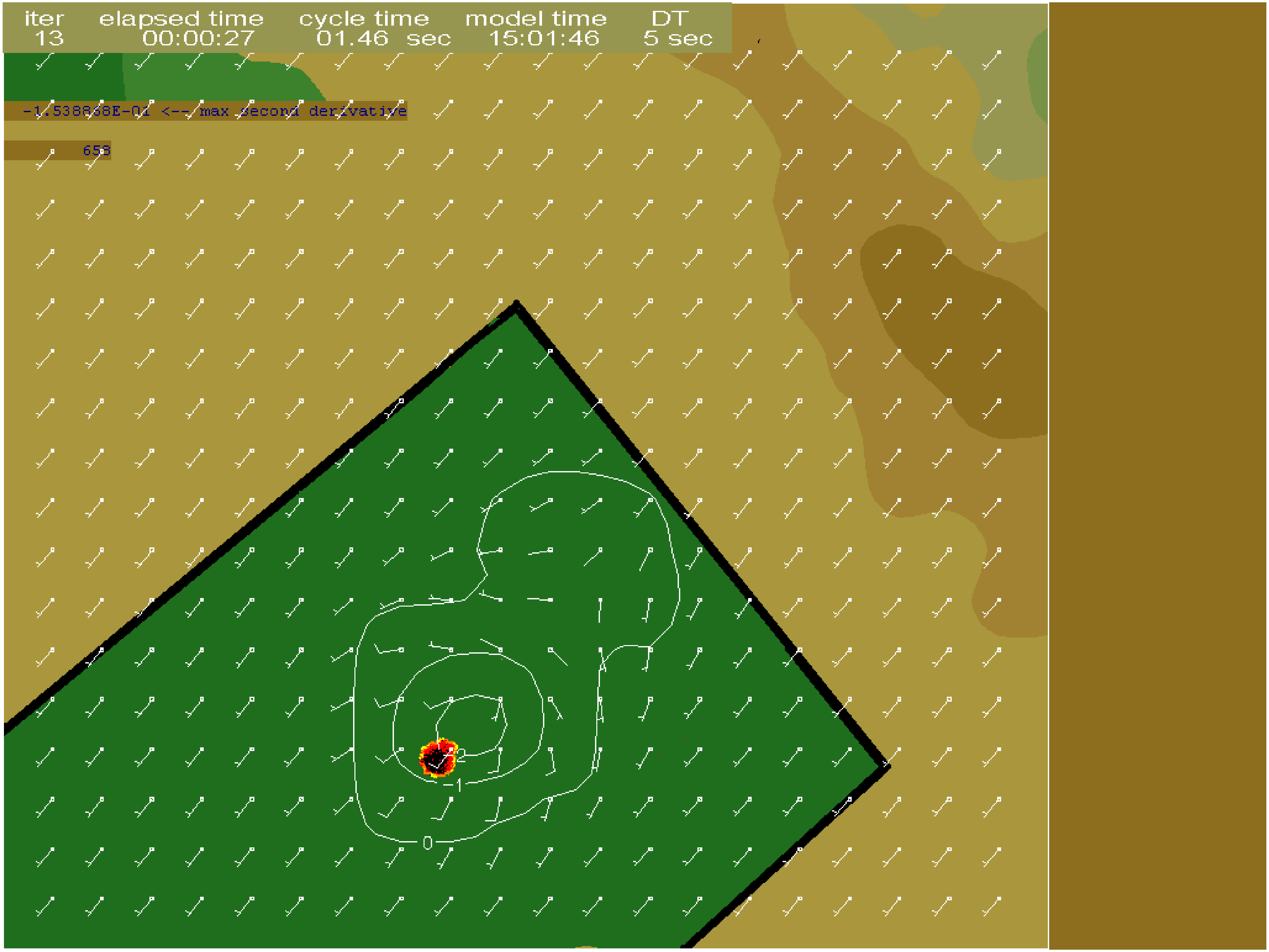
A Possible Answer: RABBIT RULES

- Rabbit Rules is a rule-based fire spread model
- RR based on the premise developed by Wolfram (2002) that complex partial differential equations can be replaced by simple rules that can be formulated as computer algorithms and solved recursively.
- A “rabbit” is an “autonomous agent” representing a “unit area of fire” defined internally in the model.
- The rabbit is subject to rules that govern production, elimination, and behavior over a landscape of heterogeneous fuels, complex terrain, and variable weather.
- Rabbit behavior is also impacted by the locations and behaviors of neighboring rabbits.
- The outcomes are complex distributions of fire, fire behavior, fire spread, and fire weather.

A Possible Answer: RABBIT RULES

- A coupled fire/weather rule requires Rabbit Rules to manage the distribution of temperature within the plumes of heated air discharged from burning areas.
- The location of warm plume air aloft can be detected in the surface pressure and wind fields.


iter
5
elapsed time
00:00:06
cycle time
01.46 sec
model time
15:00:52
DT
9 sec
<--- max second derivative
-1
0



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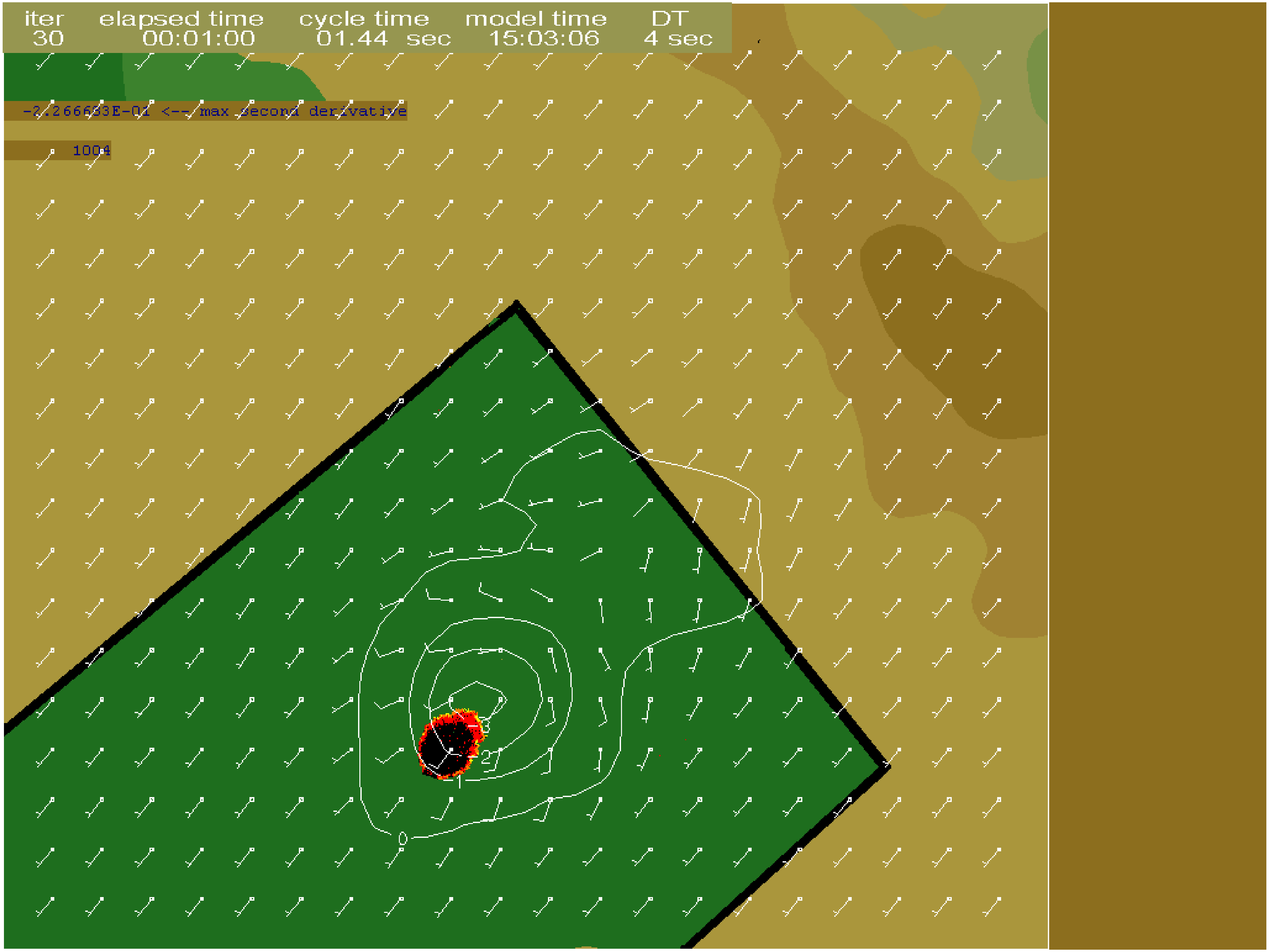

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1
2
3


iter
61
elapsed time
00:01:51
cycle time
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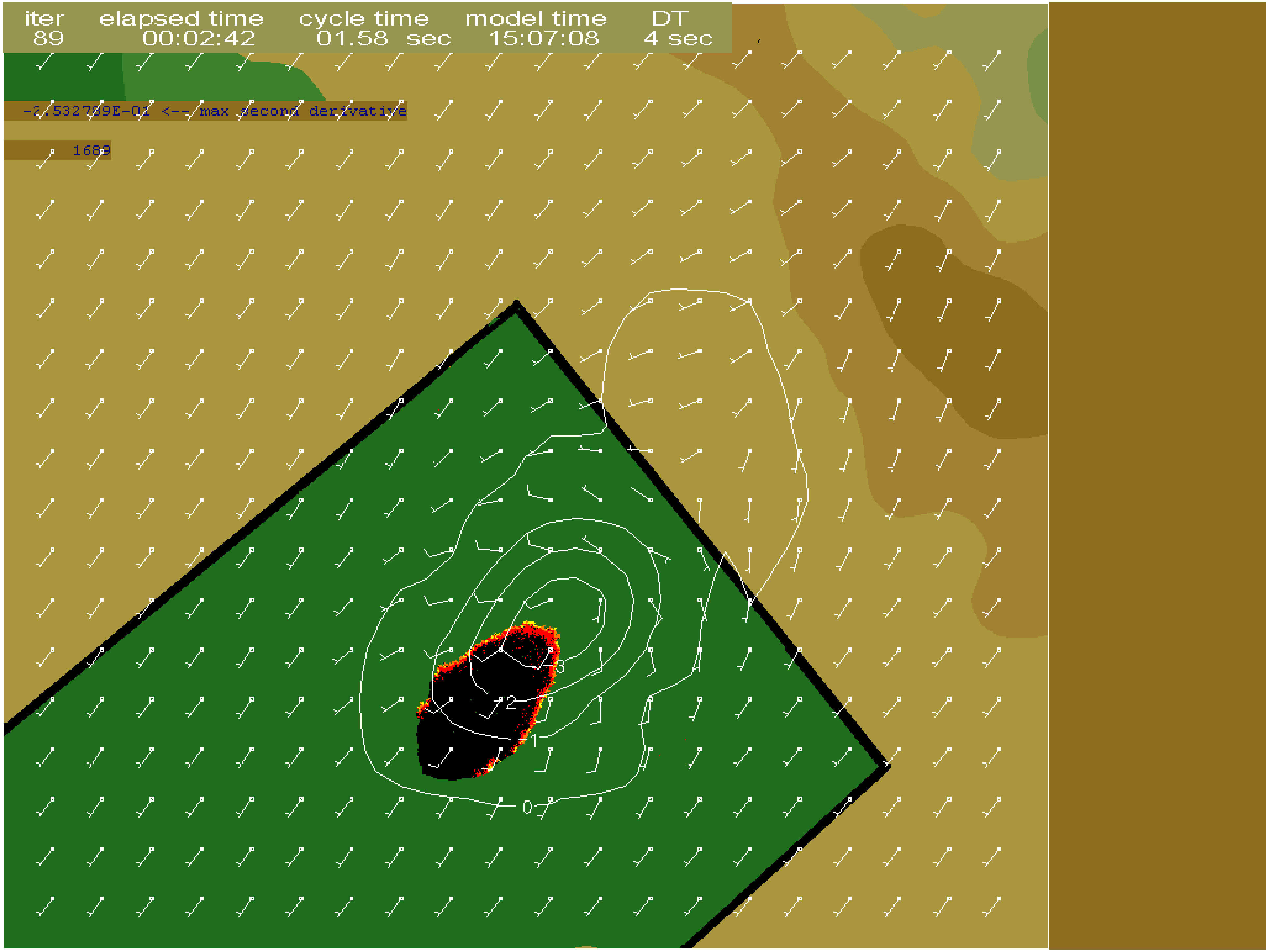

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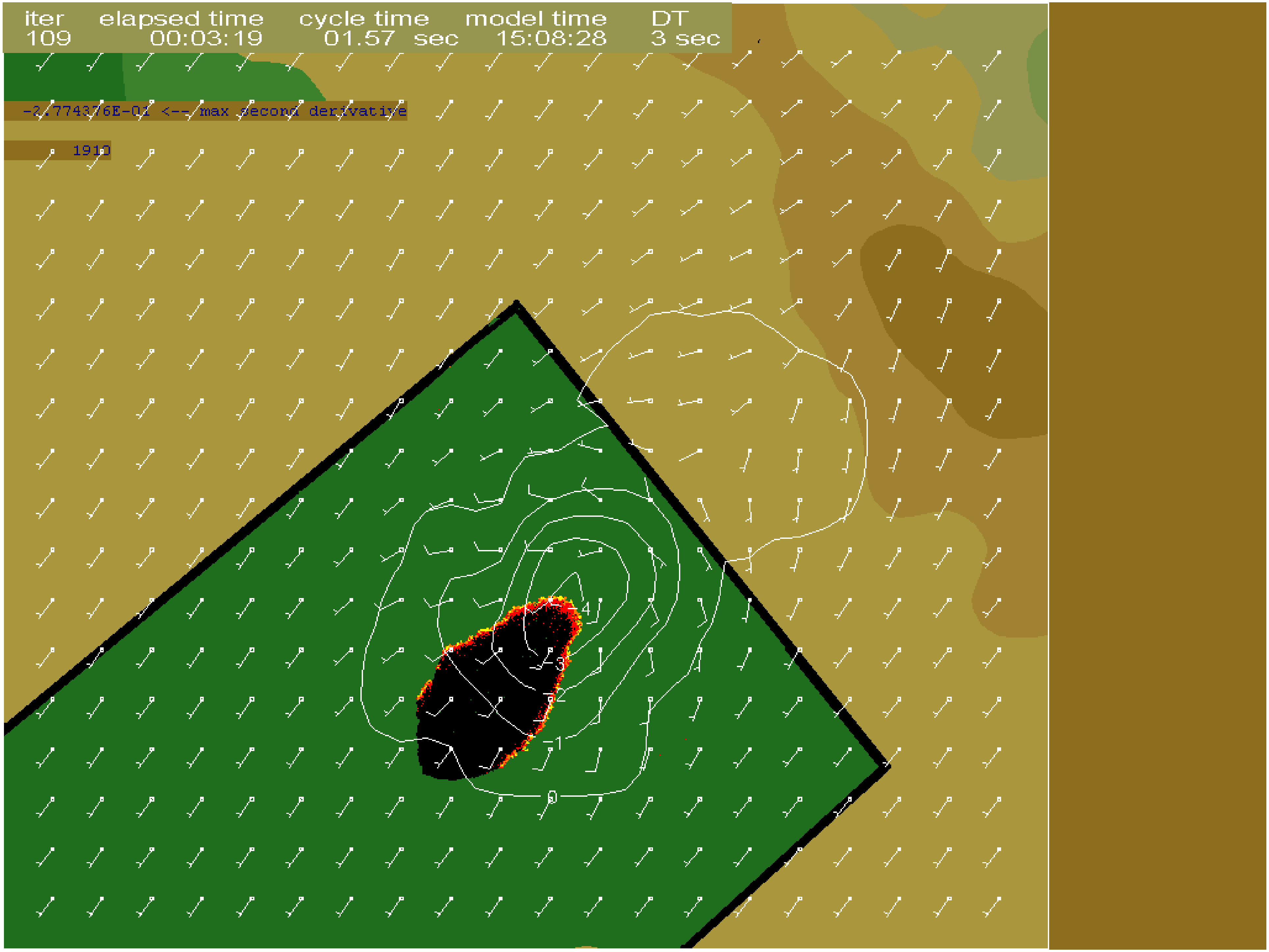
iter elapsed time cycle time model time DT
109 00:03:19 01.57 sec 15:08:28 3 sec
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3
2
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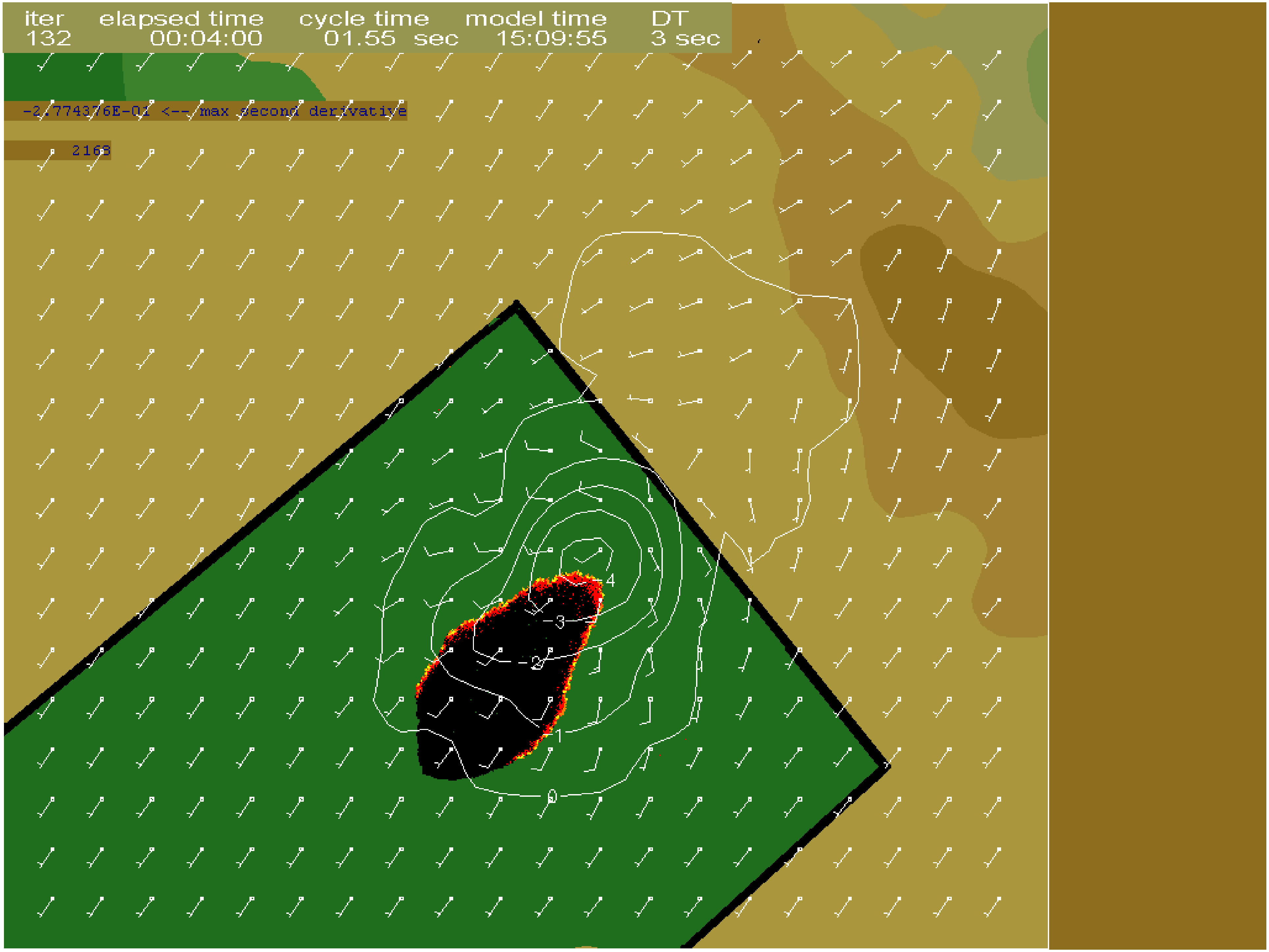

iter
132
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00:04:00
cycle time
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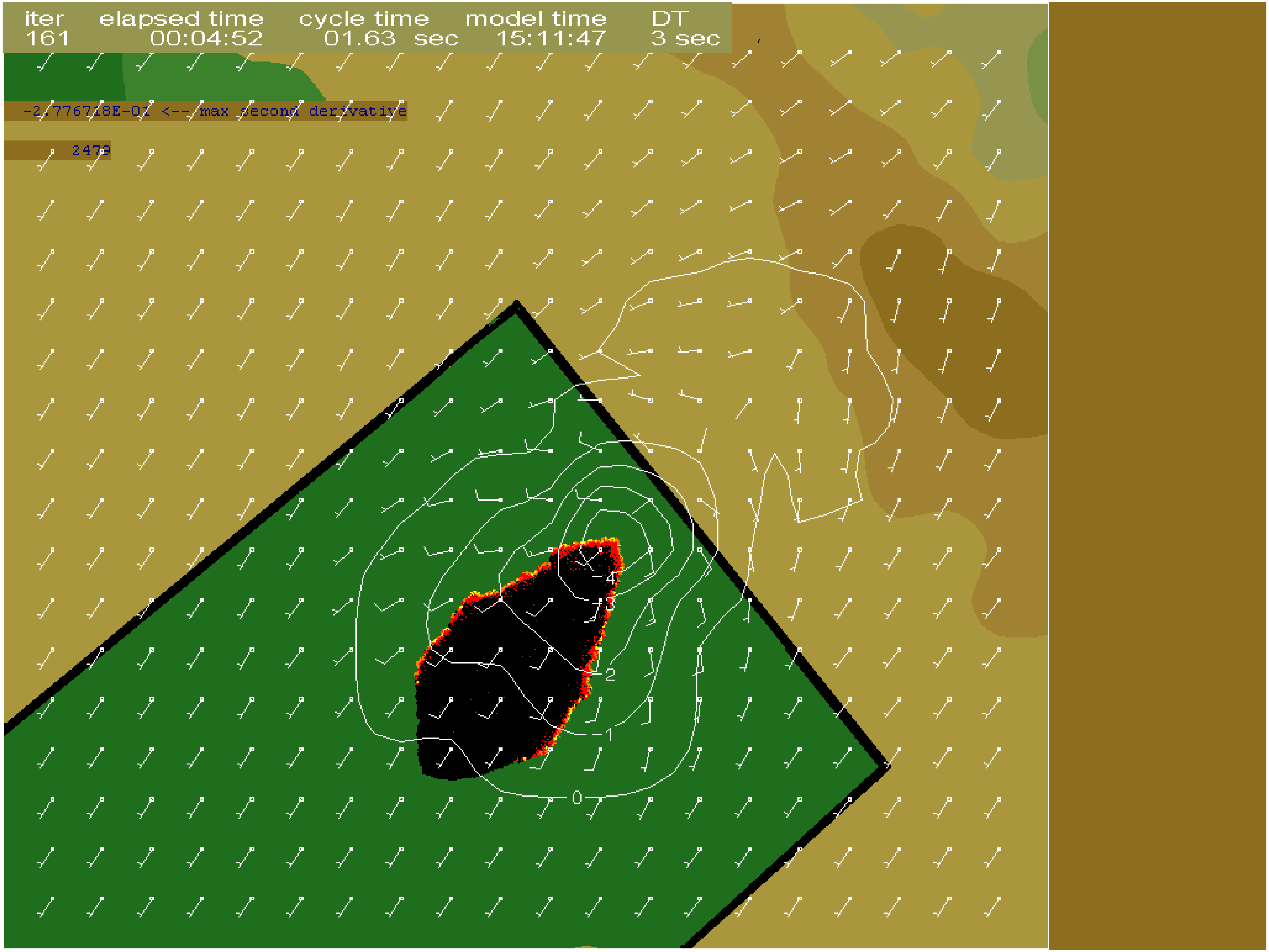
1
2
3
4



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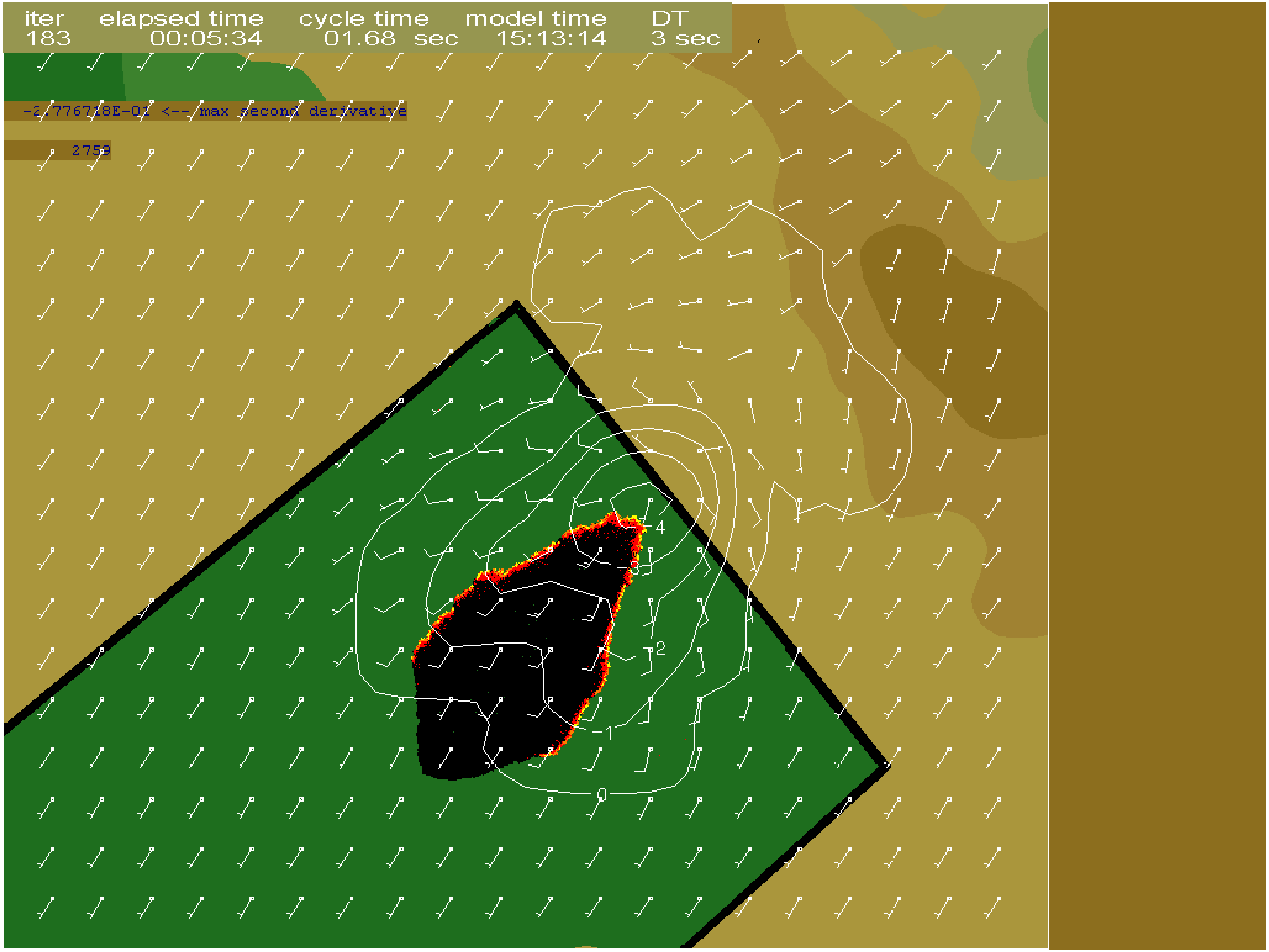
3
2
1
0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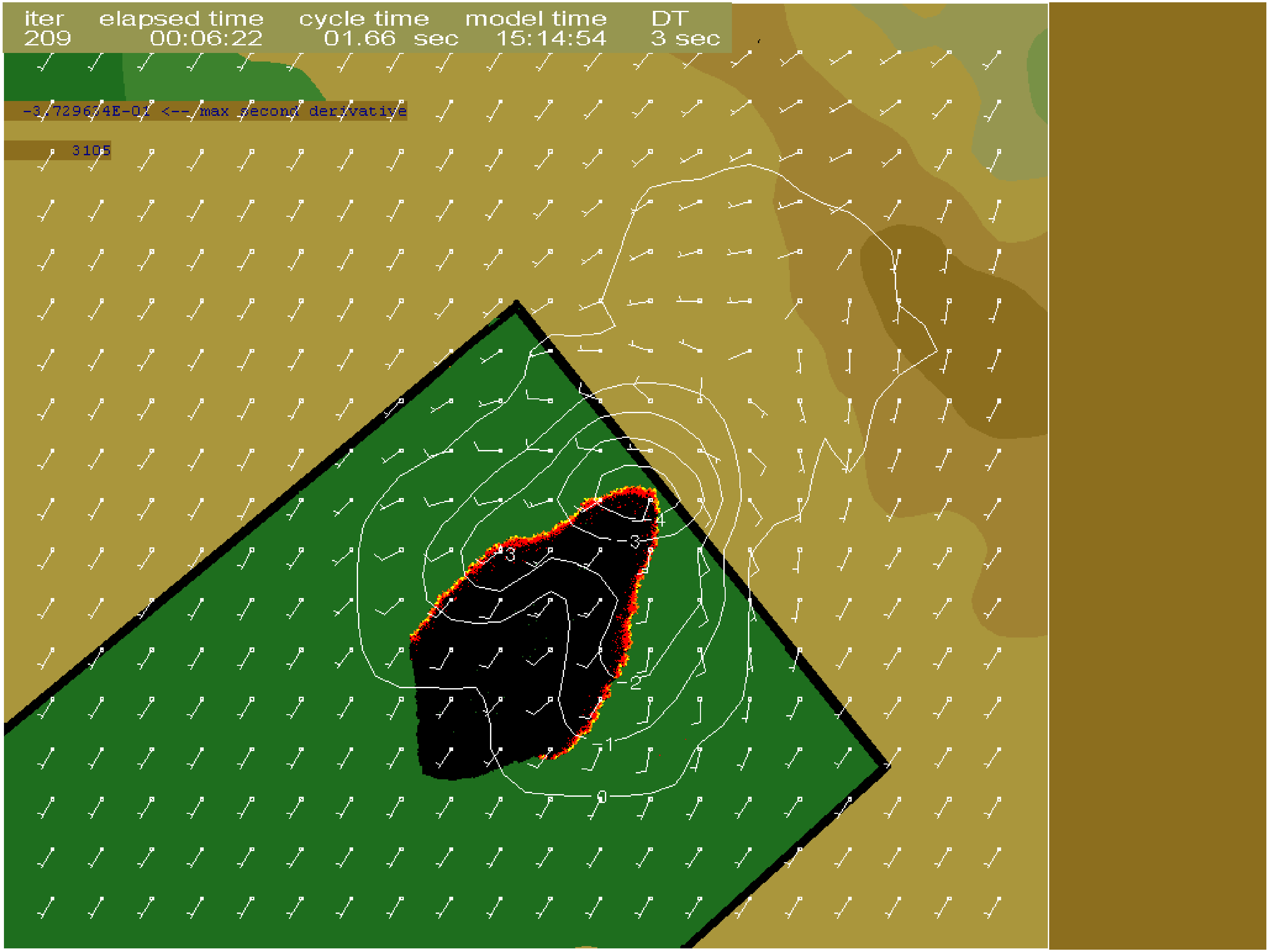
3
2
1
0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3
2
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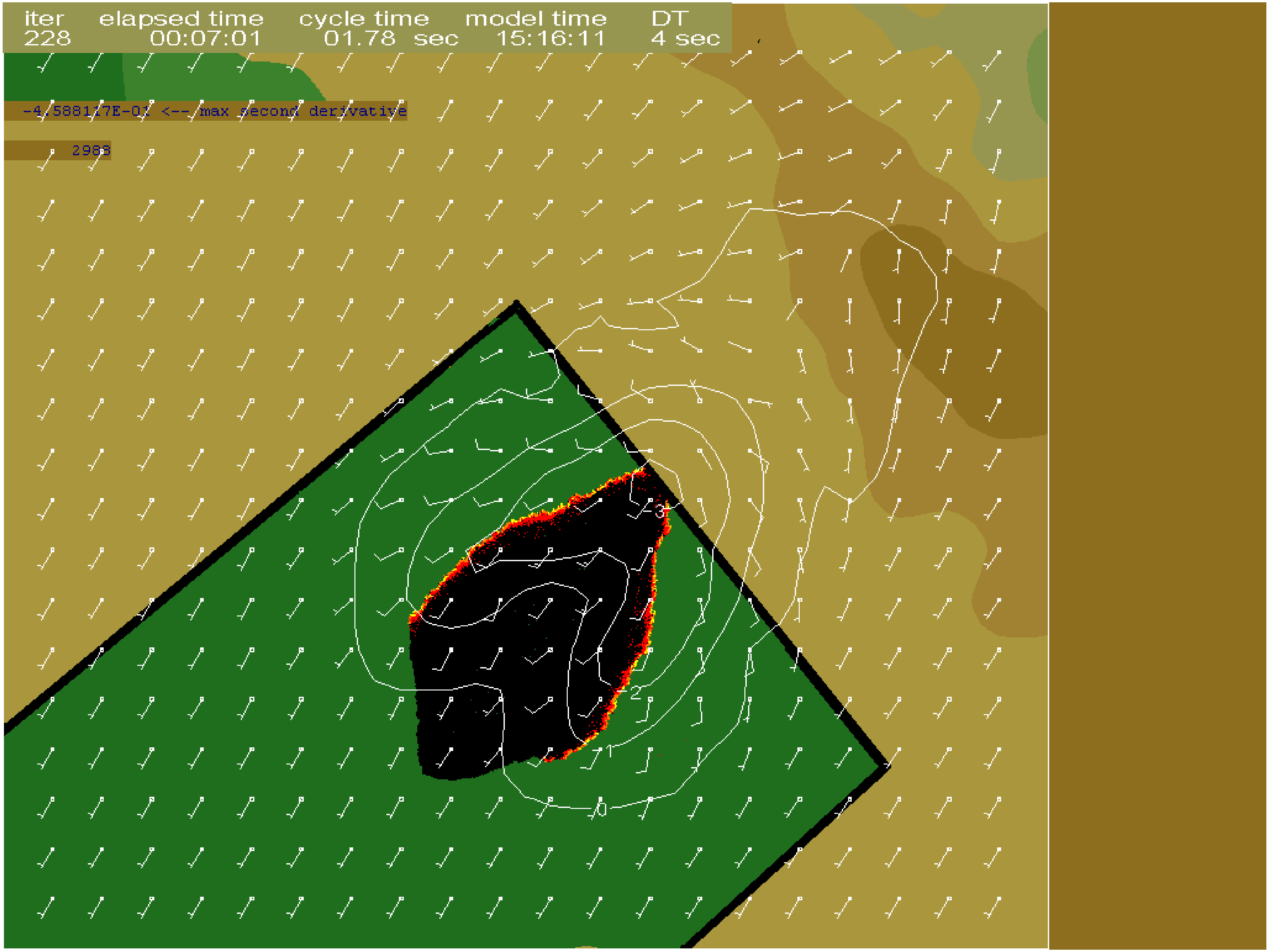

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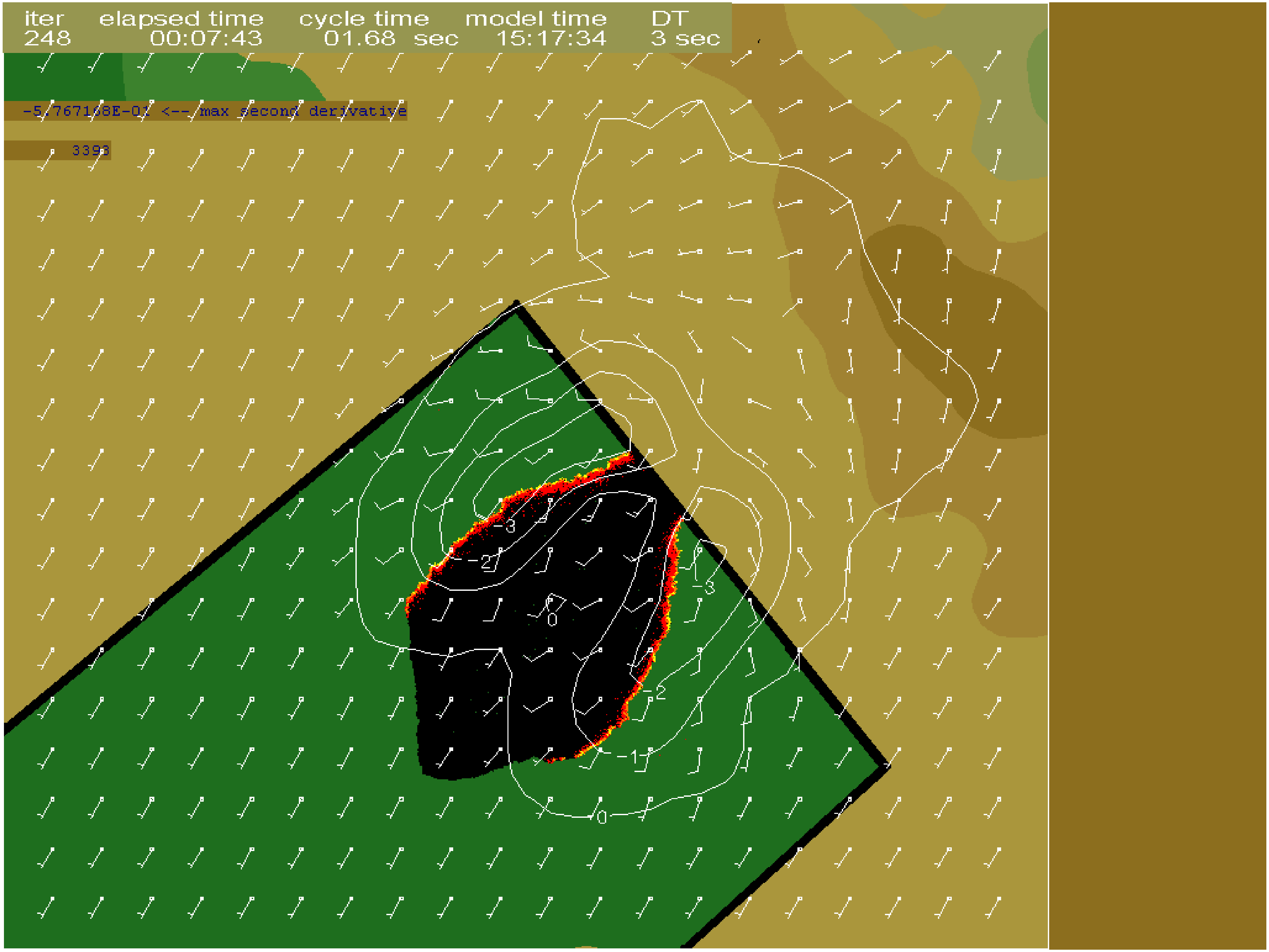
1
0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model time
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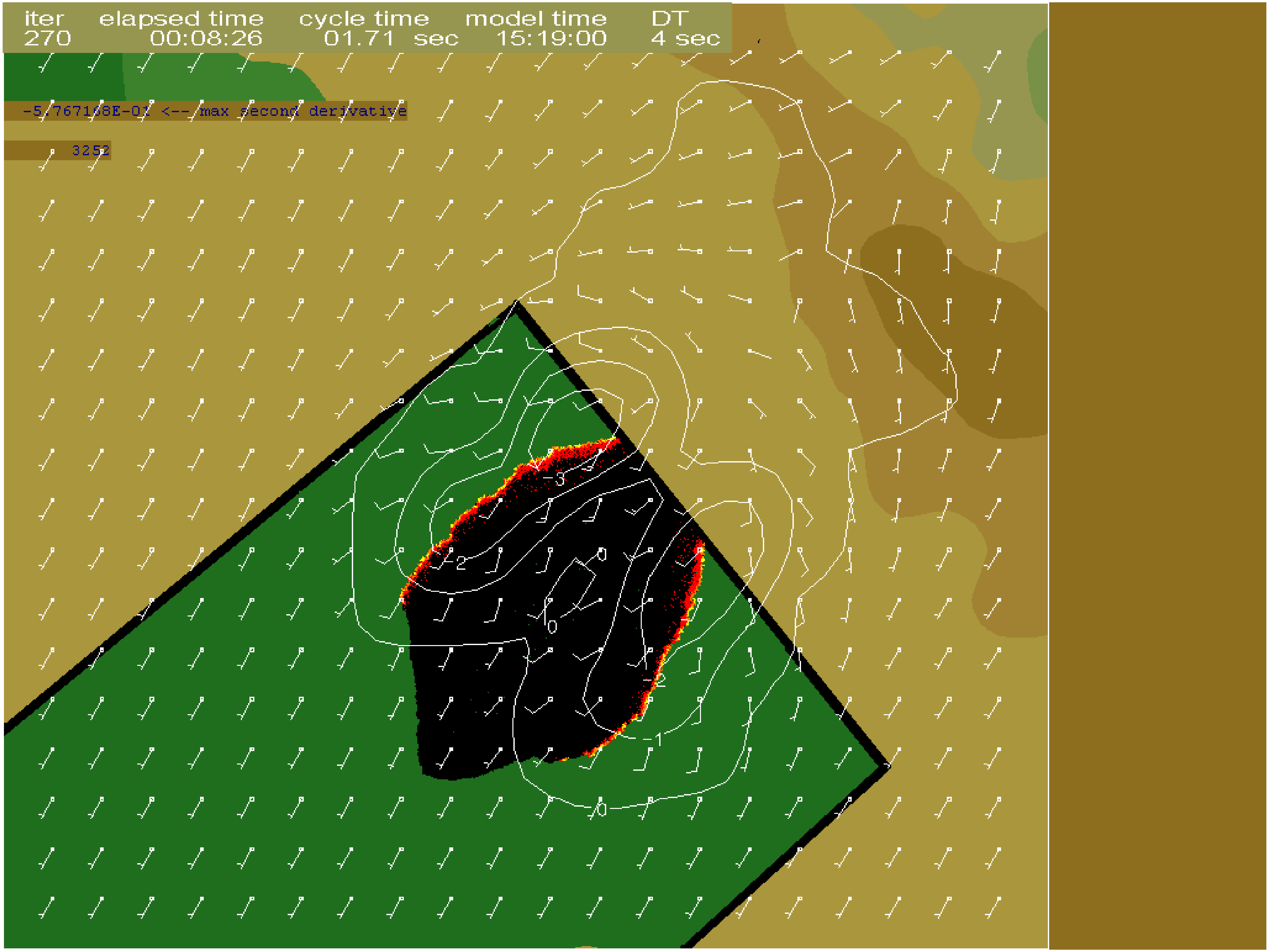
-2
0
-3
-2
-1
0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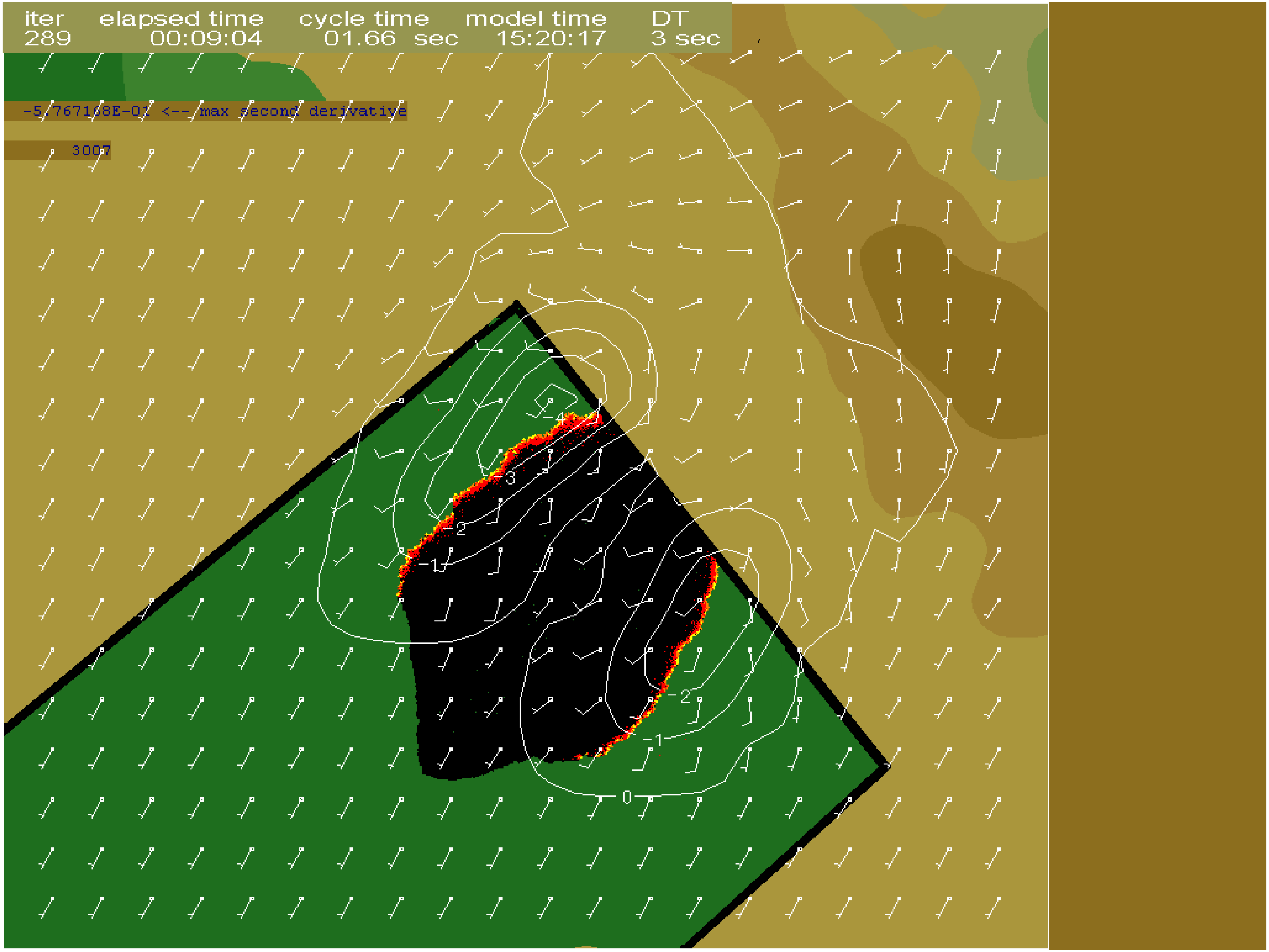
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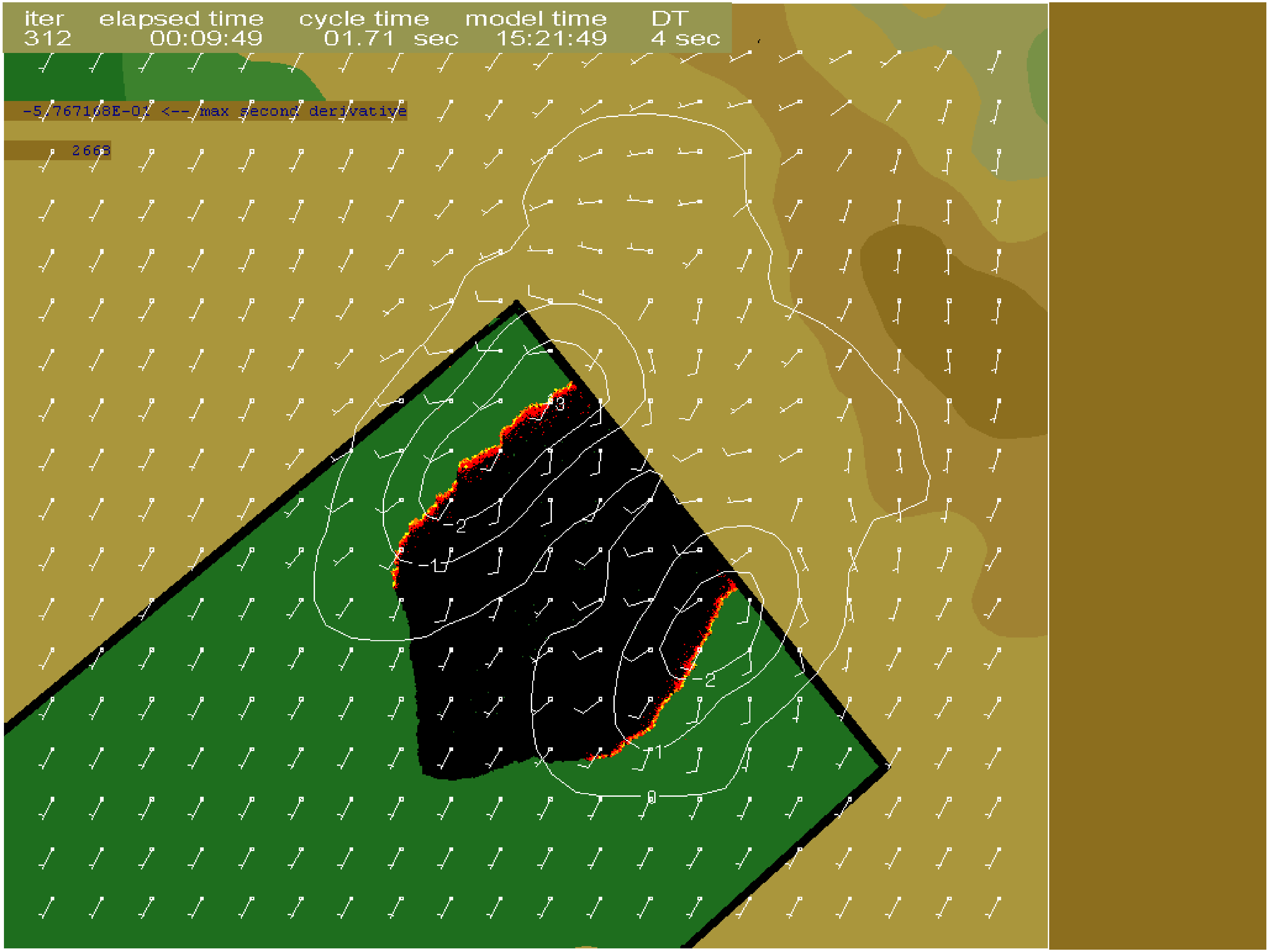
-1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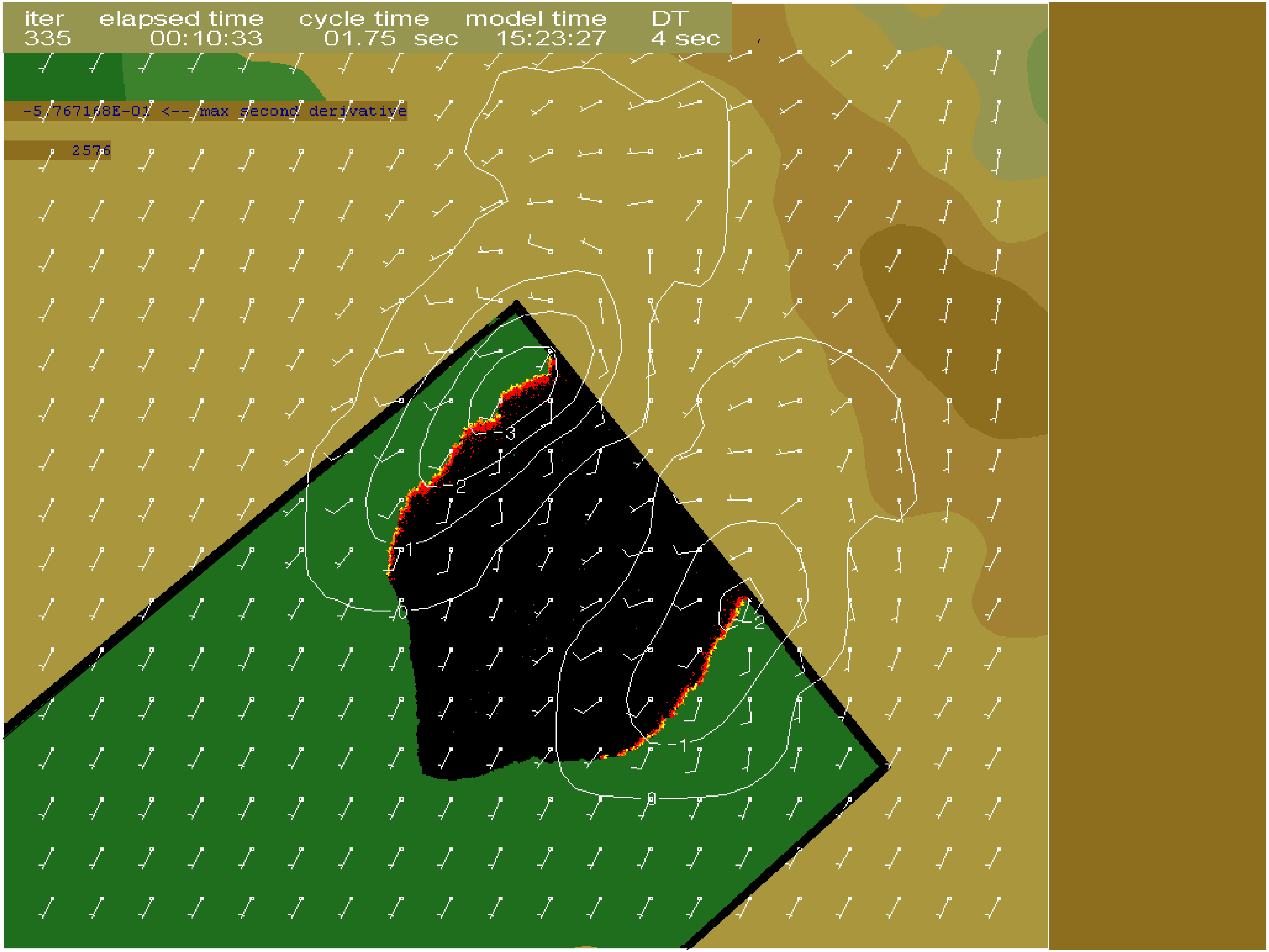
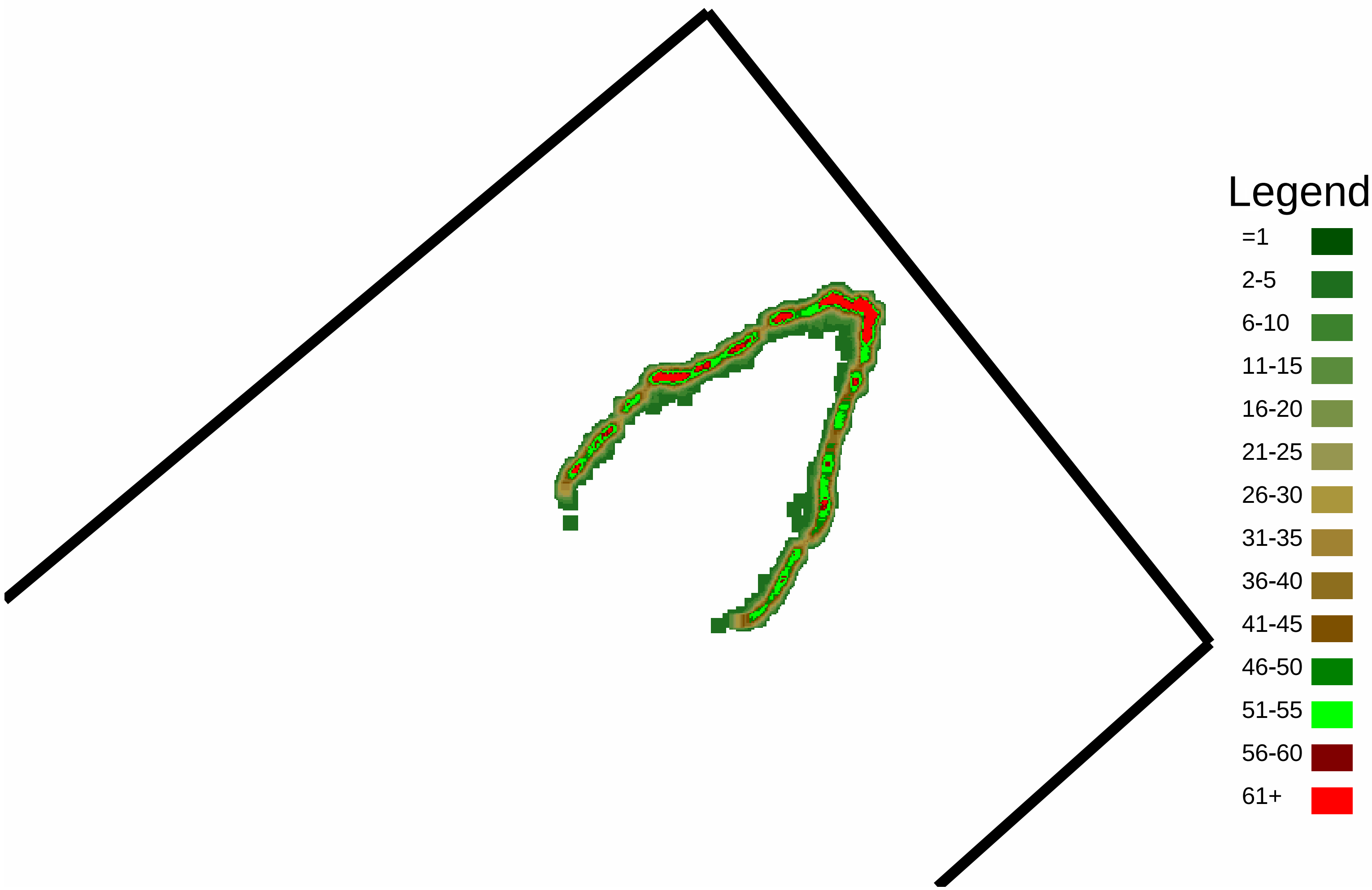
-1
0



iter 335
elapsed time 00:10:33
cycle time 01.75 sec
model time 15:23:27
DT 4 sec
-5.767168E-01 <-- max second derivative
2576

Number of Rabbits on
9x9 pixel squares at
1513 LST



Summary

- Daysmoke has identified a mechanism of smoke plume dynamics - multiple-core updraft plumes - within wildland fire
- Identifying multiple-core updraft plumes may be the singlemost limitation to the accuracy of modeling frameworks such as BlueSky and SHRMC-4S and to air quality models in general that include emissions inventories from prescribed burns.
- Daysmoke offers no assistance on solving the problem.
- Rabbit Rules offers a way to supply the needed information on plume core dynamics?

Summary

- From a land manager perspective, the conflict between managing for natural resources and managing for air quality has placed Southern land managers in the difficult position of "getting it right all of the time."
- The land manager can burn on a day selected from a set of days during a typical year that fit his burn prescription.
- He can determine how fire is distributed over his landscape
- He can determine how much fire to distribute.
- He can, at least in theory, determine the core number of his plume.

Questions

- What information does the land manager need to engineer his burn to minimize ground-level smoke?
- What scale of research program and what resources must be marshaled to get him the information he needs?