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# Ignition from a Fire Perimeter in a WRF Wildland Fire Model

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Based on joint work with Jan Mandel, Jonathan Beezley and Adam Kochanski

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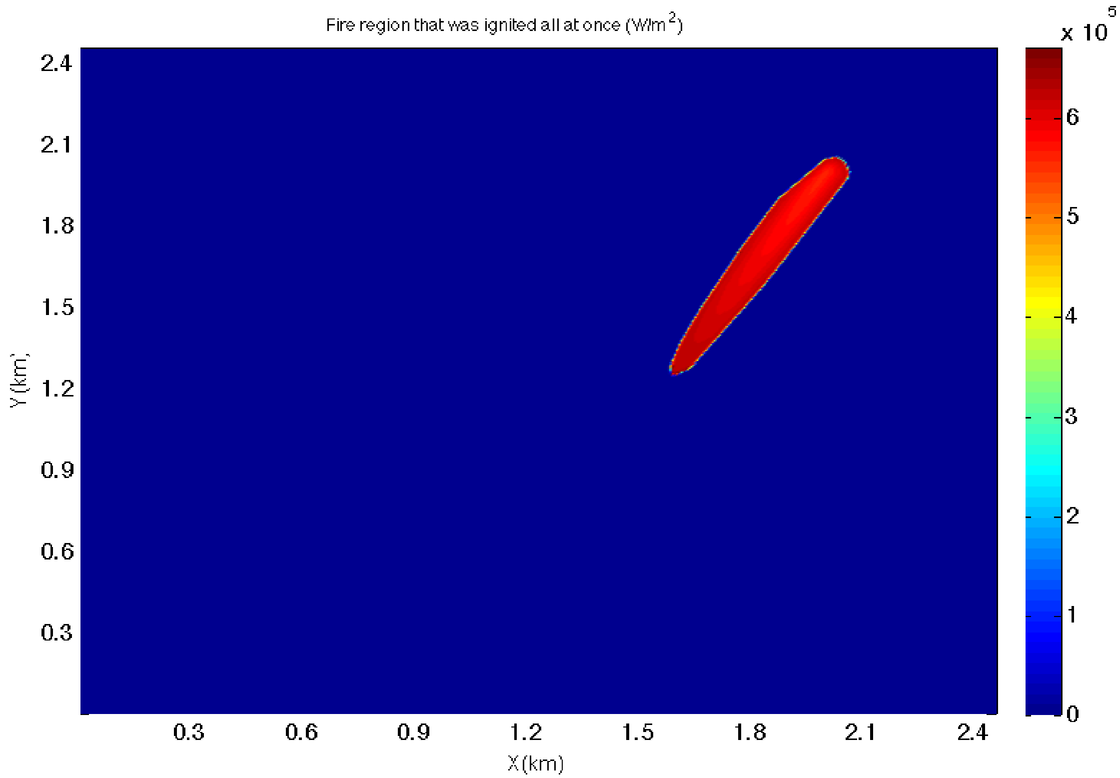
# Region of fire all ignited in one time



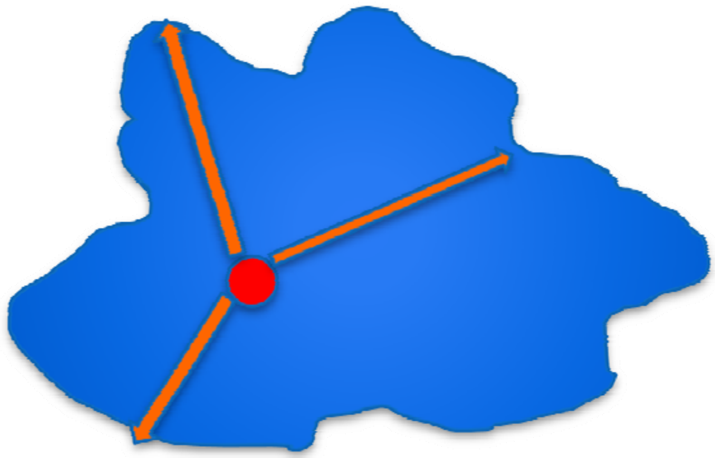

-First data about the fire perimeter arrives after the fire was running for some time (T_perimeter);
-All area is set on fire at once and as result atmosphere state is incorrect and CFL conditions are violated

# Problem

- Want to get reasonable atmosphere state
- Need to avoid violating vertical CFL condition, that occurs in case of igniting everything at once
- Traditional solution: the fire model needs to start from a very small area, but we are not guaranteed that the fire will reach the same fire perimeter at time T_perimeter
- New solution: Create an artificial history from the known fire perimeter, filling in the missing data history

# Problem description

- Create an approximate artificial history of the fire based on
  - Ignition point
  - fire perimeter
  - time the perimeter is from



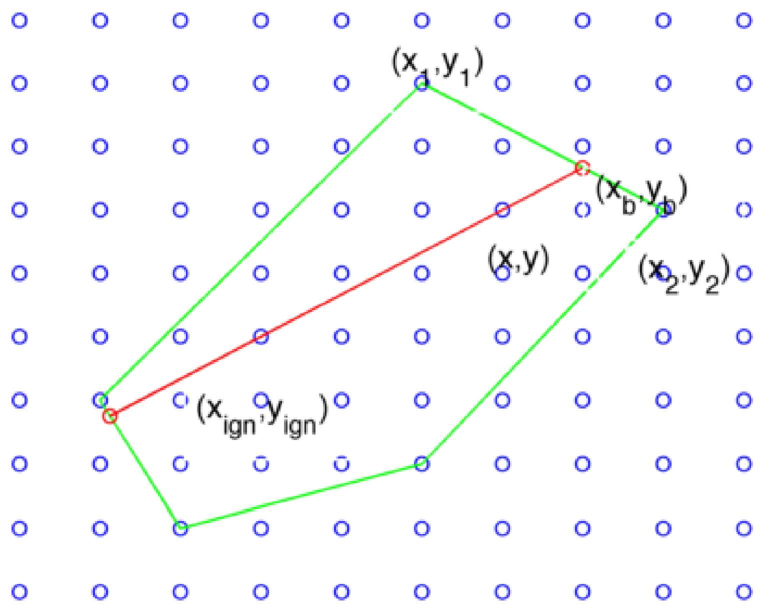
# Solution of the problem with the convex fire perimeter(1)

Algorithm:

For each mesh point on the surface:

1) Build a line through mesh point and ignition point

2) Find the intersection of the line with fire perimeter and what are the points, that form a corresponding line of the perimeter



# Solution of the problem with the convex fire perimeter(2)

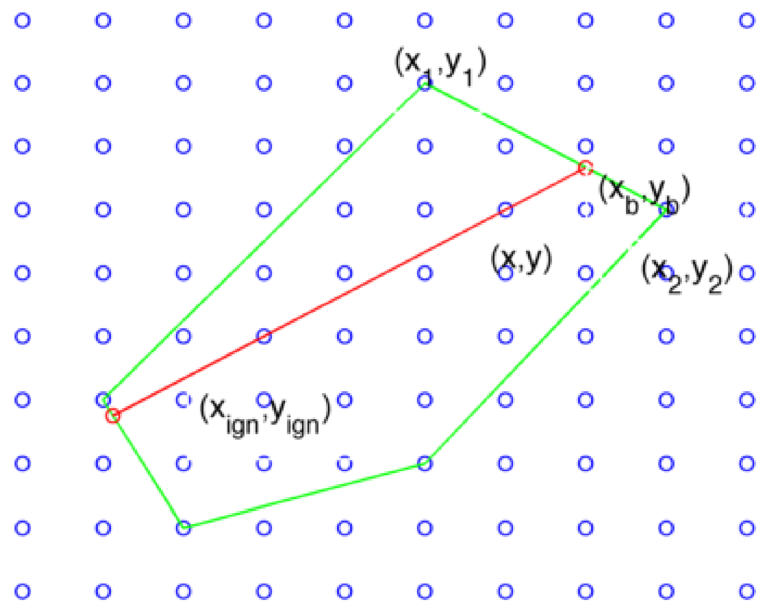
3) If right, calculate the ignition time, in proportion of the distances from the points to the perimeter.

$$T_i(x,y) = T_{ign} + \frac{\left\|(x,y)-(x_{ign},y_{ign})\right\|}{\left\|(x_b,y_b)-(x_{ign},y_{ign})\right\|} * (T_{per} - T_{ign});$$

$(x_{ign},y_{ign})$ – ignition point;

$(x,y)$ – point which ignition time is unknown;

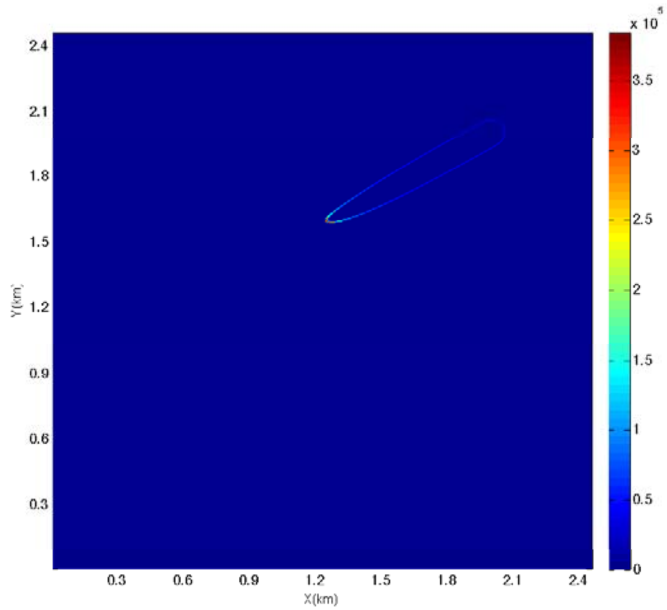
The result represents time of the fire ignition in point $(x,y)$

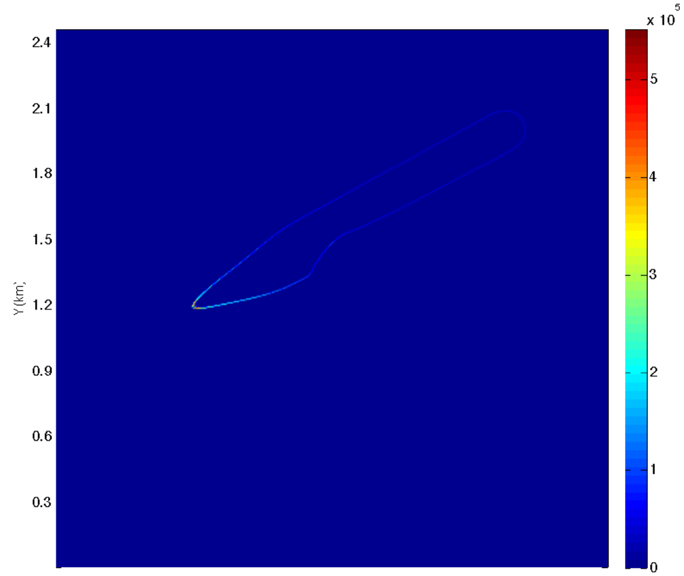


# How the model works

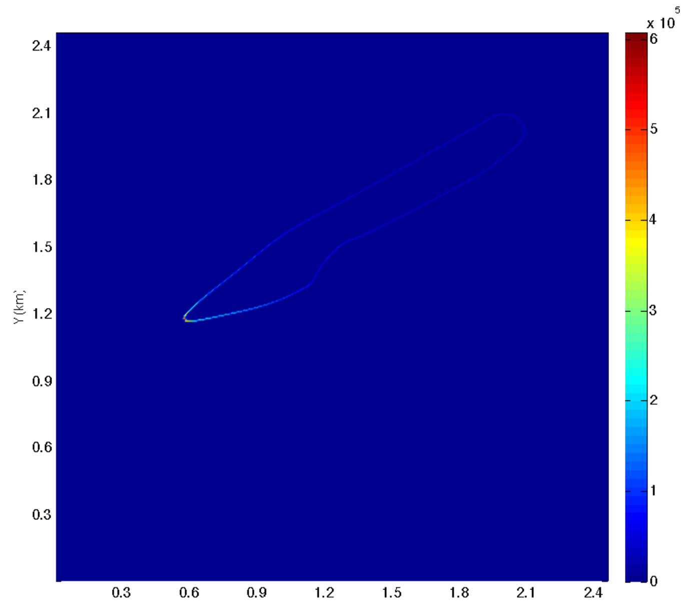
- If the first data about the fire perimeter arrives after the fire was running for some time:
  - The ignition times (artificial history) of the area are computed.
  - The model runs from the ignition point and until the given fire perimeter, using artificial history
    - To get the evolution of the fire from the ignition time and up to the time when the fire perimeter was given;
    - To spin up the atmosphere and so get correct atmosphere state eventually
  - After model reaches the fire perimeter it runs further in a usual way

# Heat flux

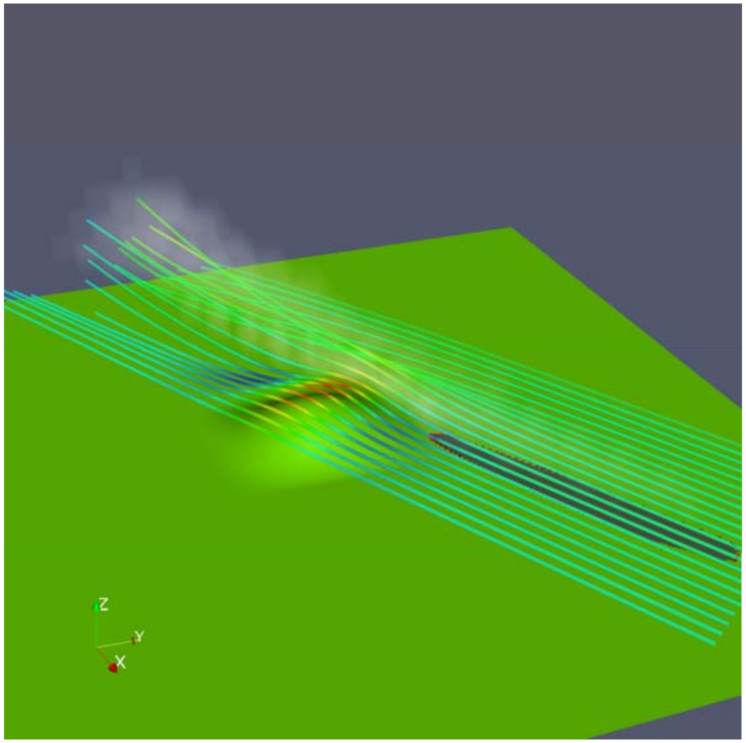


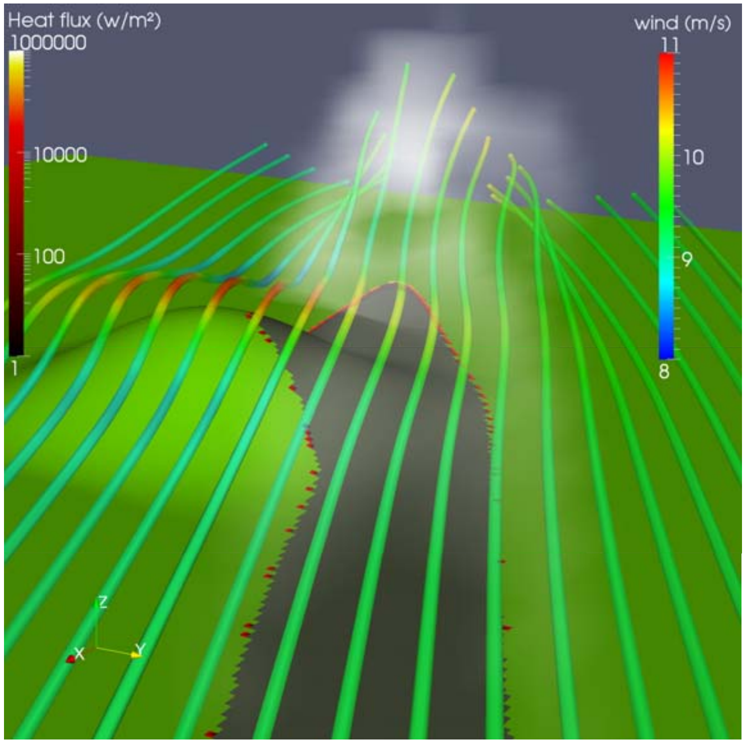

Top-left: Propagation of the fire at time 40 min from which fire perimeter for artificial data was taken;
Top-right: Heat flux at time 68min, model runs from the ignition point;
Bottom-right: Heat flux at time 68 min, model runs from the artificial history.
Conclusion: The thickness of the region with high heat flux seems the same, so the speed of propagation is about the same



# Fire simulation



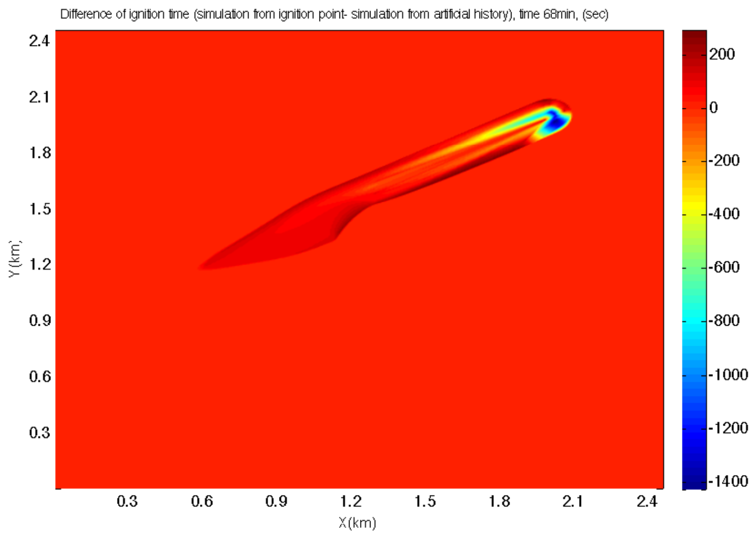

(a) The artificial fire simulation at 40 minutes.

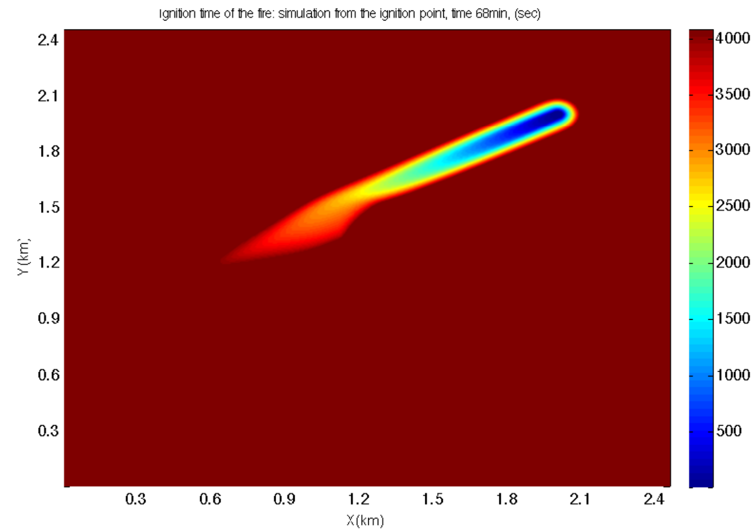


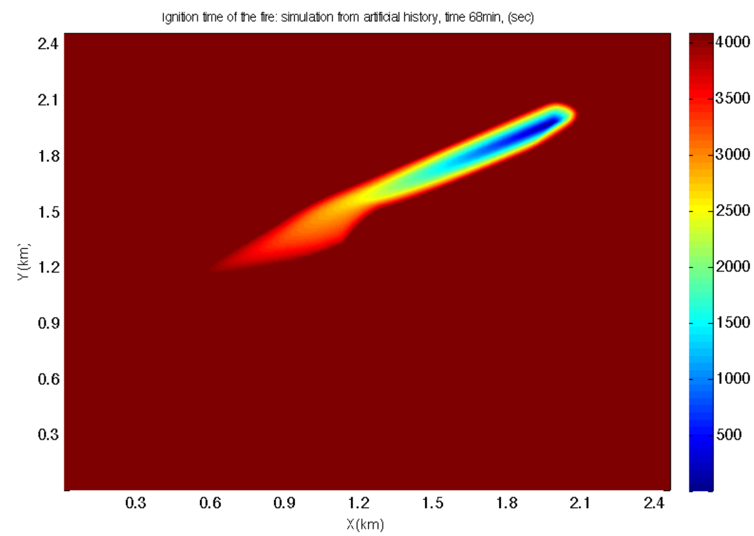

(b) The direct fire simulation at 68 minutes.

Conclusion: in the simulation from the artificial history data, the flow lines are lifted by the fire also

# Ignition time

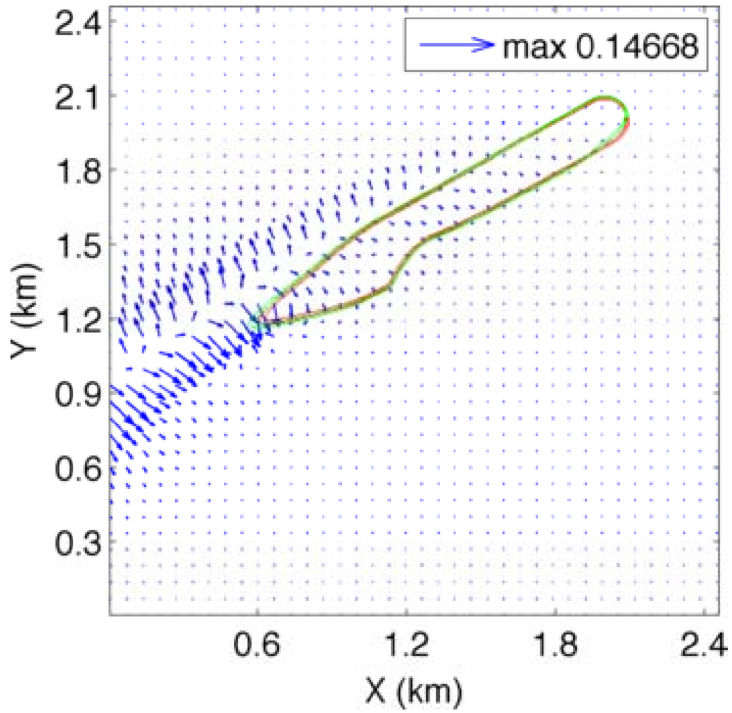


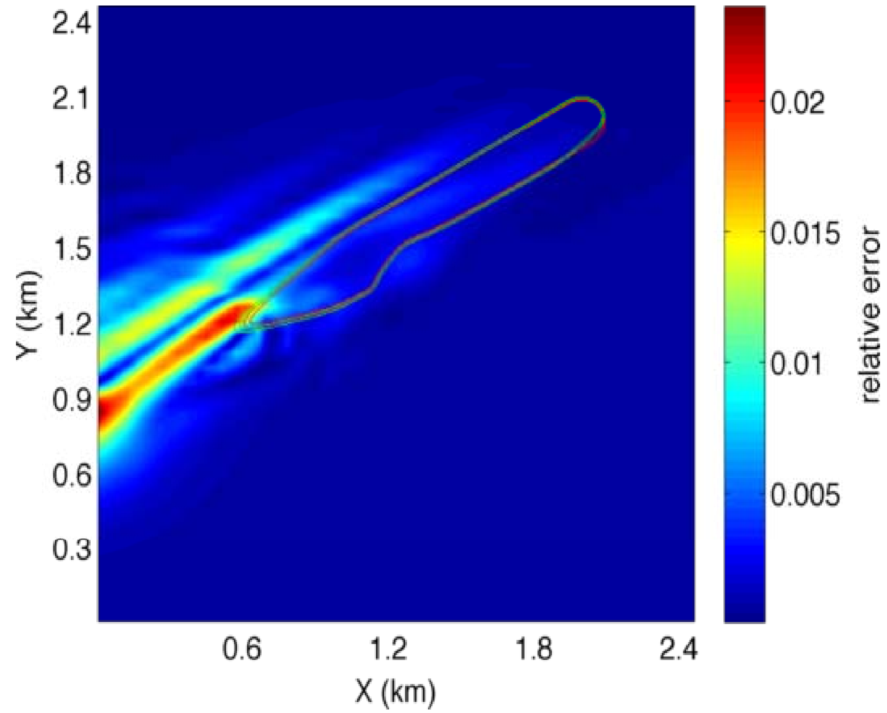




Top-right: Time of ignition at time 68min, model runs from the ignition point;
Bottom-right: Time of ignition at time 68 min, model runs from the artificial history;
Top-left: Difference of the time of ignition between the real simulation and the simulation from the artificial history, time 68 min.

# Wind difference




(a) The difference in the winds of the direct simulation minus the artificial propagation at 68 minutes.




(b) The relative error in the speed of the wind at 68 minutes. The maximum relative error is 2.3%

# Conclusions

- Artificial history of the fire was created
- Replaying the fire history establishes a reasonable fuel balance and atmospheric state
- This provides appropriate starting conditions for the computation to continue with the full coupled fire-atmosphere simulation
- Simulation results for the ideal example show, that the fire can continue to proceed in a natural way if the model runs from the artificial history
- The algorithm allows you to initialize a fire from a perimeter, rather than a point

# Future plans

- Test the model on the real case
- Realize more sophisticated calculation of the ignition times (including variables as wind, type of fuel, etc.)
- Make fire model run backwards (defining ignition point and time of ignition of the mesh points inside the perimeter, given fire perimeter, its time of ignition, atmospheric state, etc)

# References


- Mandel, J., J. D. Beezley, J. L. Coen, and M. Kim, 2009: Data assimilation for wildland fires: Ensemble Kalman filters in coupled atmosphere-surface mod- els. IEEE Control Systems Magazine, 29, 47–65, doi:10.1109/MCS.2009.932224.
- Mandel, J., J. D. Beezley, and A. K. Kochanski, 2011: Coupled atmosphere-wildland fire modeling with WRF-Fire version 3.3. Geoscientific Model Devel- opment Discussions, 4, 497–545, doi:10.5194/gmdd- 4-497-2011.
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