



Interactive comment on “Coupled atmosphere-wildland fire modeling with WRF-Fire version 3.3” by J. Mandel et al.

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Response to Referee 1

We would like to thank the anonymous referee for useful suggestions that will undoubtedly improve the paper.

1. 498-9 Massively parallel execution is needed in order to run faster than real time, and we expect to add a reference with some relevant results in the revised version. Interfacing with the parallel infrastructure, described in Section 7.1, and WRF programming conventions impact the selection of the level set method algorithms. In particular, the need to make a pass through the code every time a halo exchange between the patches is needed makes high-order methods much less attractive (more expensive

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computationally and more complicated). Also, the available width of the halo strips is limited by the WRF programming environment.

2. 498-22 We'll change to: "while simulations of wildfires spreading across areas of tens of kilometers performed using FIRETEC and WFDS run slower than real time even if executed on a parallel supercomputer."

4. 499-8 We'll replace "correct" by more specific expressions, such as that the scheme is capable of reproducing certain qualitative fire behaviors.

5. 499-14 We'll replace "prediction" by "forecast" everywhere.

6. 499-19 We'll expand this sentence to something like "Although the Clark-Hall model has many good properties, it is a legacy serial code, not supported, and difficult to modify or use for real cases requiring real meteorological data, topography and fuel description, while WRF is a parallel supported community code routinely used for real runs."

7. 499-28 We'll note that tracers are also known as particles and represent a Lagrangian approach while the level set method is an Eulerian approach. However, the "global" remark later on (525-23) was meant to emphasize the nonlocal properties of the level set method; not all Eulerian methods are necessarily like that.

10. 502-10 Clark et al. (2004) note that from observations, the spread rate for chaparral depends primarily on the wind, which is why they introduced the special fuel model for it, even if there already is one in Anderson's categories (category 4). This is corroborated by recent research as well; e.g., other factors than wind account for less than 15% of the fire area (Clark et al., 2008). We are not aware of a physical explanation.

11. 503-14 W/m^2 is the unit of heat flux density, e.g., according to <http://physics.nist.gov/cuu/Units/units.html>

12. 504 We'll note that the approximations are not very accurate and here are many

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factors that influence the spread rate which are not accounted for, and refer to section 11.3 for more details.

13. 504-12 "Subgrid" is used consistently in the source code of the WRF infrastructure, perhaps in analogy with LES, and it would be good to be compatible. We could have said "refined grid" but the WRF "domains" are also what would be often called "refined grids", e.g., in numerical PDEs. We'll explain the refinement once and then just use "fire mesh" throughout.

15. 505-17: See 13.

16. 507 Yes, we did need more viscosity when running the basic experiments early in the development. We attribute this to the fact that we use a fairly simple low-order method (the options in the code include Godunov and first order ENO) due to parallel programming considerations (see remark 1). E.g. high order ENO would put quite a strain on the communication between the patches. It is likely that with better schemes (such as CHARM and Superbee mentioned by the reviewer) additional viscosity would not be needed, and we plan to look into that in future. The time step is not a problem, so far the stability constraints of WRF have been far more stringent than the CFL condition in the level set method. We will rerun some experiments and a convergence study and report in the discussions or add a section in the paper.

The time advancement scheme is second order in time (Runge-Kutta method of second order) because in our experiments, first order scheme was not good enough (too much systematic error in one direction caused the fire to disappear quickly). We need that even if the numerical scheme for the level set method is first order in space. The ignition front calculation needs to be gradual to avoid large jumps between time steps in the heat released. This is achieved by a method that is (almost) exact for level set functions that are linear in space. This is in fact first order, not second, and we'll correct that. We can add some explanations along the above lines to the paper, but we did not want to burden the paper with too much description and documentation of what did not

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work, which would be of peripheral interest.

17. Section 7.1 is important because of the effect on the choice of numerical methods, see remarks 1 and 16. We can delete 7.2. The explanations in sections 8 are important for running the model properly, i.e., for reproducibility. Because WRF has many possible settings, the activated schemes need to be clearly identified. Real data input and the extensions of WRF data preprocessing to fire data in Section 9 are important distinguishing features of this model and also important for reproducibility. We can shorten both sections and make the style more like a paper and less like a users' guide, e.g., omit references to specific variable names in namelist.input and instead refer to actual input files in examples that we can put in supplementary materials, and refer to our wiki pages or supplemental material for specific instructions on how to acquire and process data.

18. 523 Section 11.1 Here we can add something like:

Adding smoke from the fire to WRF is also under consideration. There are two possible approaches to implementation of the smoke dispersion in WRF Fire. The basic one would be to treat the smoke as a passive tracer advected by the wind, while the more advanced (taking into account its chemical reactivity during its transport), would require coupling between the WRF-Fire and WRF-Chem.

We look forward to supporting WRF-IBM when it becomes available in future. For now, we have to use WRF as is. Indeed WRF-IBM should provide as an extension of WRF capabilities leading to a better representation of the flow in complex terrain. Coupling the 2D fire model with WRF-IBM should not present any fundamental difficulties.

19. 524

We don't plan to account for radiation effects in the current version based on the Rothmel model. However, we consider using more physics-based fire models that would handle (in an approximate way) the effect of radiation on the fire spread.

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The fire model itself can easily handle the spot fire ignitions; however, the problem is the computation of the locations and the frequency at which they occur. A possible approach might involve tracing the wind away from the fire to provide the probability density of spot ignitions based on various characteristics of the fire.

20. 527-Section 12. Validation is a future research. We can add few paragraphs along the following lines.

Validation of a coupled atmosphere-fire model used for simulation of wild fires is very challenging. The biggest problem arises from the fact that the amount of measurement data that can be used for model validation is very limited. The laboratory-scale fire experiments performed in wind tunnels cannot be used directly as a benchmark for a model simulating wildland fires, since in the laboratory-scale fires tend to behave differently than in the open atmosphere (Beer 1991, Mell et al. 2007). Therefore, for the validation of the WRF-Fire we rather plan to use data collected during field experiments, and start from relatively simple cases, where there are not as many conflicting influences. We also foresee that the validation process will uncover the need to add further parametrizations of certain fire behaviors which are not currently captured.

The basic evaluation of the the model capability to simulate realistically the fire front shape and its propagation through a uniform fuel could be performed based on the data collected during the Australian Grass Fire Experiment. However, we realize that limitations of this data set would not allow for full investigation of the model capabilities and deficiencies. During this experiment the wind measurements were taken only upwind from the actual fire and only at two levels. Therefore, they do not provide a full description of the vertical wind profile which through the atmosphere-fire coupling may affect the fire rate of spread (Jenkins et al., 2010), and they lack the information about the actual wind at the fire line. Since the coupled fire-atmosphere model computes the fire rate of spread based on the local wind, it is absolutely crucial for its validation to know not only the fire spread rate but also the local wind speed. Therefore, for the first model validation, we plan to use the data collected during the FireFlux experiment.

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Preliminary results (Kochanski et al., 2010) show that WRF-Fire is capable of realistic rendering of the rate of the fire spread, as well as temperature, upward velocities, and horizontal wind speed associated with a steady fire front passage (not affected directly by the ignition). Unfortunately, the lack of full infrared documentation of the fire front evolution does not allow for an evaluation of the model in terms of a realistic representation of the fire front shape. We also consider using data collected during the Meteotron experiment (Benech 1976) to validate explicitly the plume dynamics simulated by WRF-Fire. However, it seems that the FireFlux is more appropriate since it provides data collected during the passage of the real fire, while Meteotron experiment focused on the dynamics of a stationary plume generated by a set of burners. Finally, we plan to perform the overall evaluation of the model in real fire cases. We are currently working on the WRF-Fire validation based on the observed fire perimeters during Harmanli fire (Bulgaria), Meadow Creek Fire (Colorado), Big Elk fire (Colorado) and Witch fire (California). Unfortunately, in most real fire cases, no meteorological data directly at the fire are available, so the only available information that may be used for model evaluation is the final fire perimeter.

References:

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