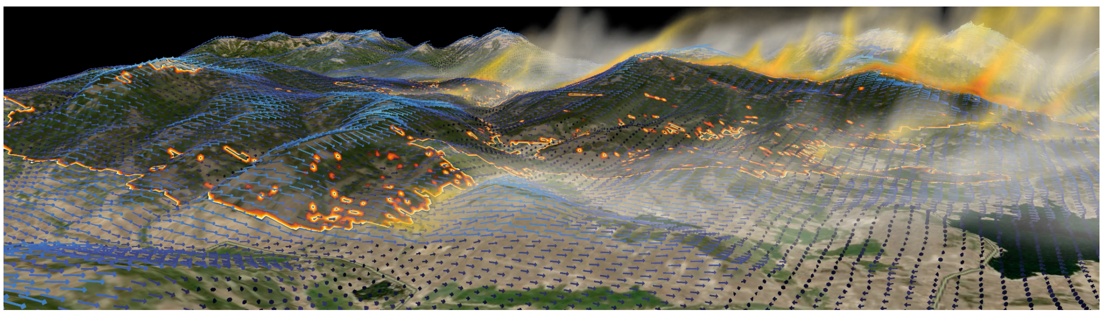
Visualizing Megafires: How AI can be used to drive wildfire simulations with better predictive skill

Scott Pearse Amy DeCastro Timothy Juliano
National Center for Atmospheric Research, Boulder, CO 80307, USA

May 15, 2023



Abstract

The East Troublesome Wildfire was the fourth largest wildfire to date in Colorado history, igniting on October 14, 2020. Driven by low humidity and high winds, the wildfire spread to over 200,000 acres in nine days, with 87,000 of those acres being burnt in a single 24 hour period. Wildfire simulations and forecasts help decision-makers issue evacuation orders and inform response teams, but these simulations depend on accurate variable inputs to produce trustworthy results. These wildfire visualizations demonstrate new AI tools developed at the National Center for Atmospheric Research (NCAR), which are producing superior wildfire simulation outputs than have been available in the past.

1 The WRF-Fire driven by AI inputs

WRF-Fire is a physics module within WRF ARW that allows for modelling fire growth according to factors such as terrain slope, fuel characteristics, atmospheric conditions, and dynamic feedbacks within the atmosphere. The conventional fuel data used as an input in WRF-Fire is published at a rate outpaced by environmental disturbance events. The East Troublesome Fire occurred in 2020, after significant Lodgepole Pine Beetle infestations and wind storms. At the time, the most recent fuel data had been published in 2016 and did not account for these disturbances, showing an underestimation of the dead and downed trees in the fire domain, and resulting in an underforecast of the East Troublesome fire size by 38%. NCAR scientists have developed remotely sensed geospatial wildfire fuel datasets to address the issue of outdated fuel inputs [1]. These visualizations compare WRF-Fire simulations using the conventional fuel data, and fuel parameters that come from an AI model based off of the ESA's Sentinel-1 and Sentinel-2 satellite imagery.

2 Simulation execution environment

These WRF-Fire simulations were executed on the Cheyenne supercomputer [6], a 5.34 petaflops system built for the National Center for Atmospheric Research in Boulder, Colorado. Cheyenne is comprised of 145,152 Intel Xeon processor cores in 4,034 dual-socket nodes, and contains 313 TB of total memory. The horizontal grid spacing for the simulations was set to 111 meters, and the total data footprint for both simulations is approximately 500 Gigabytes. This required approximately 9,000 CPU hours to execute.

Simulation Mesh	Discretization (XYZ)	Gridpoint Count
Fire	2452 x 1876 x 1	4,599,952
Meteorology	612 x 468 x 45	12,888,720

Table 1: Coupled WRF-Fire and WRF-MET grid discretization. Each grid cell on the meteorological mesh is subdivided into 4x4 (XY) grid cells to better resolve the surface fire spread.

3 Visualization toolset

The visualization was rendered using VAPOR [3], an open source desktop application developed at NCAR. VAPOR specializes in accessible 3D analysis of Earth System Sciences (ESS) data. The application is comprised of eleven OpenGL algorithms called Renderers, which depict scientific data in different ways according to user defined parameters. This visualization uses VAPOR's Direct Volume Renderer (DVR) to depict smoke emitting from a height-mapped 2D surface of the wildfire perimeter represented by VAPOR's TwoDData Renderer. The Barb Renderer shows vectors that are directed, colored, and lengthened by wind speed. The wind speed is not a native output from the WRF-Fire simulation code, and was derived from WRF-Fire's native U, V, and W variables using VAPOR's internal Python calculation engine that allows for deriving new variables with a script. The DVR and TwoDData Renderers used the BlackBody colormaps from matplotlib's cmocean module [7], and the wind vectors used the Ice colormap. Satellite imagery was acquired from NASA's EOSDIS Worldview server [4].

The simulation was rendered from four different perspectives: 1) from above, 2) looking west from Grand Lake, Colorado, 3) looking north from Granby, Colorado, and 4) looking west from Estes Park, Colorado at high elevation. These visualizations are currently been used in socio-ecological studies to better understand the perception of wildfire modelling by first responders as well as the public that are affected by this kind of wildfire [2].

Visualizations were executed on NCAR's Casper data analysis and visualization cluster [5]. Casper is a heterogeneous system comprised of 100 nodes that feature either Skylake or Cascade Lake processors. For this visualization, VAPOR utilized nodes that feature NVIDIA Quadro GP100 GPUs.

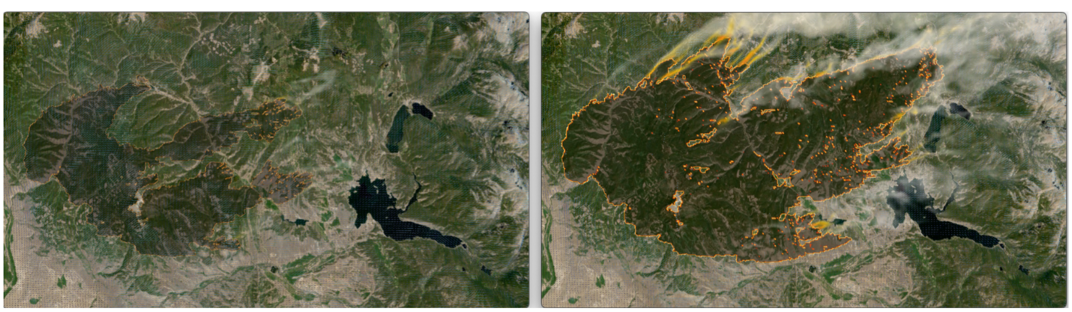


Figure 1: Imagrey of the WRF-Fire simulation with unmodified fuel inputs (left) and AI modified fuel inputs (right).

4 Acknowledgements

We acknowledge the use of the Cheyenne and Casper supercomputers at the NCAR-Wyoming Supercomputing Center (NWSC), which is supported by the National Science Foundation (NSF). We thank the staff at NCAR and NWSC for their assistance and support.

We also acknowledge the use of imagery from NASA's Earth Observing System Data and Information System (EOSDIS) Worldview platform.

References

[1] Amy L DeCastro, Timothy W Juliano, Branko Kosović, Hamed Ebrahimian, and Jennifer K Balch. A computationally efficient method for updating fuel inputs for wildfire behavior models using sentinel imagery and random forest classification. *Remote Sensing*, 14(6):1447, 2022.

[2] Edgeley C.M. Wolfle Hazard C. Sarna-Wojcicki D. Cannon W. Cameron O. Lombardozi D. Hillman L. Pearse S. Emard, K. and K. McCovey. In review: Participatory methods and climate science models: Pathways for incorporating local ecological knowledge. *Submitted to Ecology and Society*.

[3] Shaomeng Li, Stanislaw Jaroszynski, Scott Pearse, Leigh Orf, and John Clyne. Vapor: A visualization package tailored to analyze simulation data in earth system science. *Atmosphere*, 10(9):488, 2019.

[4] NASA Earth Observing System Data and Information System (EOSDIS). EOSDIS Worldview. https://worldview.earthdata.nasa.gov, Accessed 12-May-2023.

[5] National Center for Atmospheric Research (NCAR). Casper supercomputer at the ncar-wyoming supercomputing center (nwsc). accessed 2023-05-12. Boulder, CO: UCAR/NCAR/CISL.

[6] National Center for Atmospheric Research (NCAR). Cheyenne supercomputer at the ncar-wyoming supercomputing center (nwsc). accessed 2023-05-12. Boulder, CO: UCAR/NCAR/CISL.

[7] Kristen M Thyng, Chad A Greene, Robert D Hetland, Heather M Zimmerle, and Steven F DiMarco. True colors of oceanography: Guidelines for effective and accurate colormap selection. *Oceanography*, 29(3):9–13, 2016.