How Wildfires Spread and Why: Visual Multi-field Analysis of Vorticity-driven Lateral Spread Ensembles

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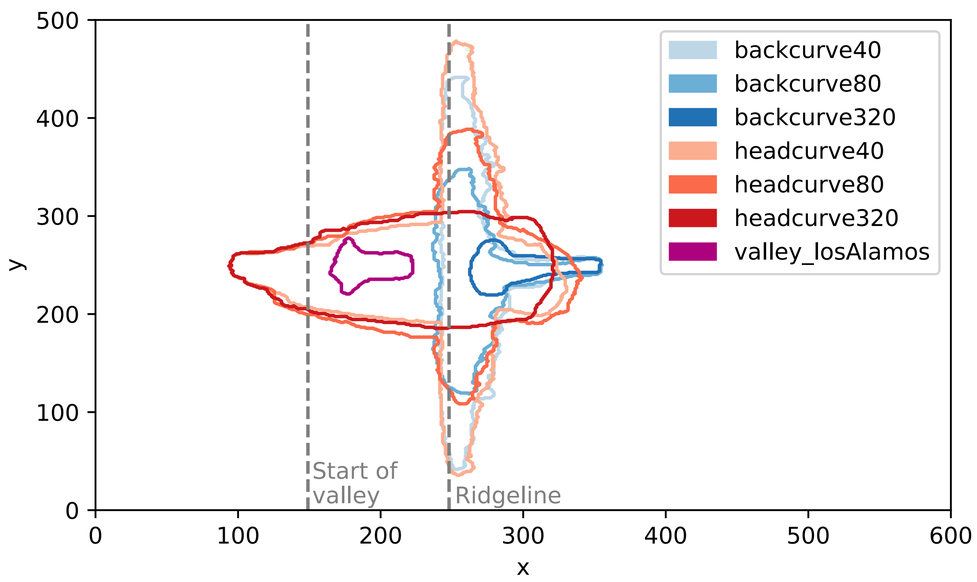
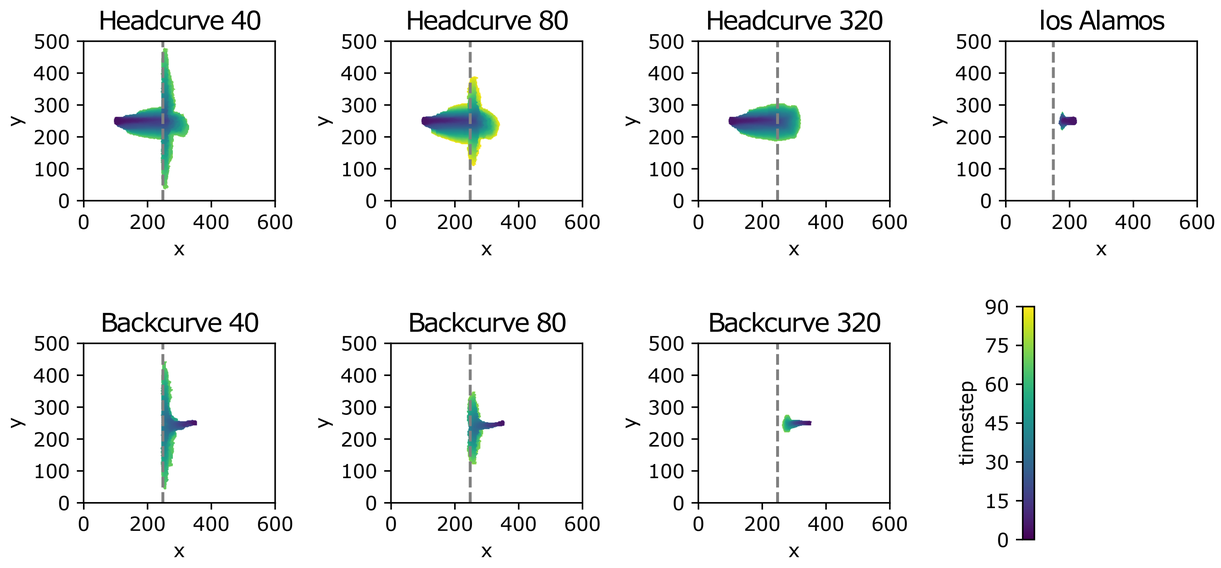
Abstract

We present an interactive visual analysis tool for the spread of wild-fires and what influences their evolution. Multiple spatio-temporal scalar and vector fields are investigated and related to each other to identify causes of atypical fire spread. Our tool allows for the comparative analysis of multiple runs of a simulation ensemble as provided in the IEEE SciVis Contest 2022.

Fire Spread

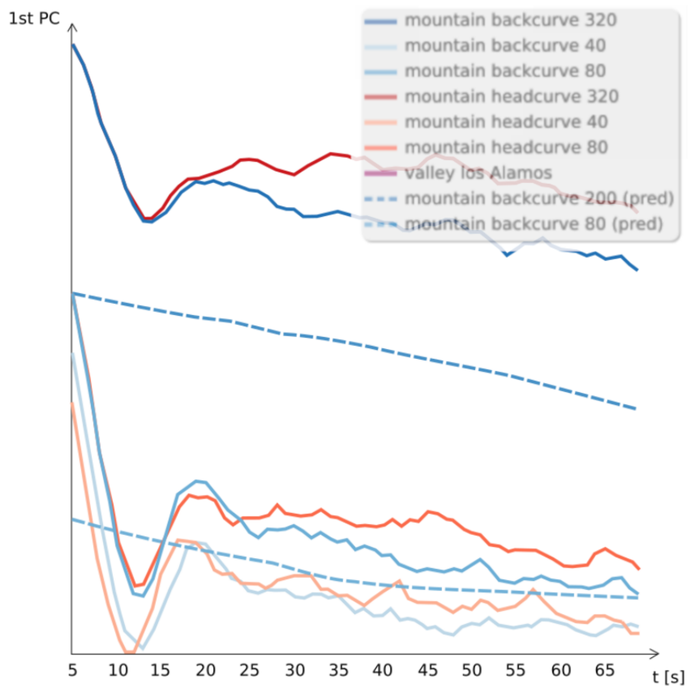


The temporal evolution of the rhof_1 field at ground level shows an overview of the overall spread of the fire and when it first starts to spread.



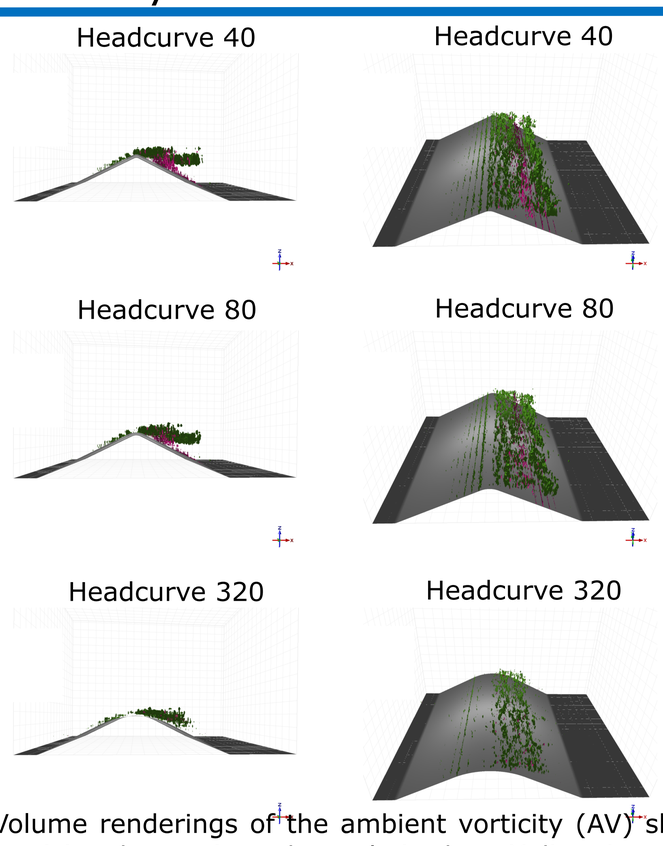
Encoding the timestep with color shows the start of the lateral spread. We note that the lateral spread is greater for steeper terrain.

Comparison of Simulation Runs



Similarity plots for the rhof_1, rhowatervapor and theta fields show two groups with a similar evolution: headcurve and backcurve. For this plot of the wind velocity magnitude, the runs form three groups w.r.t ridge smoothness.

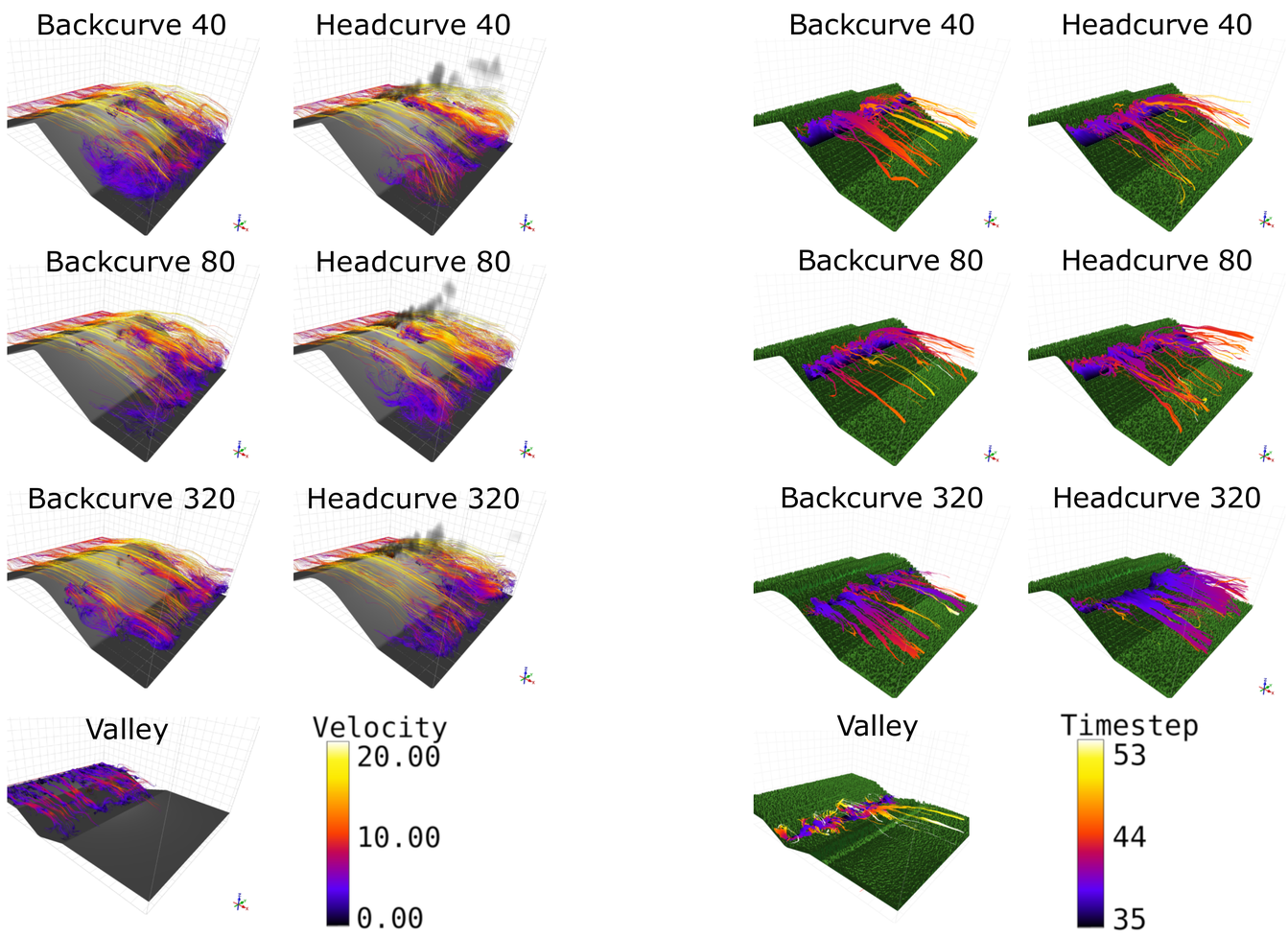
Vorticity



Volume renderings of the ambient vorticity (AV) show a vorticity sheet oriented mostly in the $+Y$ direction on the lee side. Its height and density above the mountain ridge increase with decreasing mountain curvature.

For the pyrogenic vorticity (PV), we observe two distinct regions of high vorticity on the two opposing flanks of the fire. The interaction of this PV with the AV sheet creates the possibility for lateral spread near the ridge.

Flow Analysis



Streamlines show winds develop into updrafts in the opposite direction on the leeward side of the mountain, pushing the fire towards the mountain ridge. We observe similar vorticity and updraft in the Los Alamos valley run. In this regard, it behaves more like a backcurve run.

Path surfaces help in gaining an intuition for different kinds of turbulence. Ambient turbulence occurs independent of the fire (i.e. caused by the terrain). Pyrogenic turbulence is a direct result of the fire interacting with the wind through heat transfer or pressure changes.

Conclusion

Overview plots showing, e.g., the expansion of fire over time allow immediate comparison between simulation runs. Stream and pathlines (as well as their surface variants) can be used to visualize wind flow in a single or multiple timesteps. Combined with visualizations of vorticity and divergence, these tools provide an intuitive understanding of the VLS phenomenon and the influence that the fire and surrounding terrain have on it.

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