Identification of Model-Forecast Thunderstorm Outflows to Enhance Wildland Firefighting Safety

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The Problem for Wildfires

Outflows from thunderstorms— known as gust fronts— can present abrupt changes in surface winds that can dramatically impact wildfire direction, intensity, and spread rate. These changes in fire behavior can pose a significant danger to firefighters and have caused a number of fatalities. To assist fire weather forecasting and planning, we have developed a software tool to objectively identify thunderstorm outflow boundaries in high-resolution numerical weather forecasts. We have applied this capability with forecasting systems that employ the widely-used Weather Research and Forecasting (WRF) Model.

Gust Fronts: A Weather Phenomenon

A gust front is the leading edge of a thunderstorm's outflow near the ground. It is accompanied by a significant change in wind speed or direction, a temperature drop, a pressure rise, and usually an increase in relative humidity. Gust fronts can be generated by different types of thunderstorm (also known as convective) activity, from individual cells to aggregations called mesoscale convective systems (MCSs). Figure 1 shows a thunderstorm outflow kicking up dust.

Fig. 1: Thunderstorm outflow raising dust in Montana.

The Tool and its Information

The gust front detection tool processes weather model output and produces plots showing where the boundary of the outflow is predicted to be. The model forecasts the atmospheric conditions of temperature, pressure, humidity, and winds. The software then analyzes such inputs to determine the presence of a gust front. The algorithm considers three meteorological conditions in the forecast: (1) the elements of the processes forming gust front boundaries (e.g., local air flows); (2) radar reflectivity; and (3) the temperature variation over an area. The tool can be run either for a single model forecast or for a set of model forecasts known as an *ensemble*. The tool has been tested in cases across varying terrains, including wildfires in complex topography.

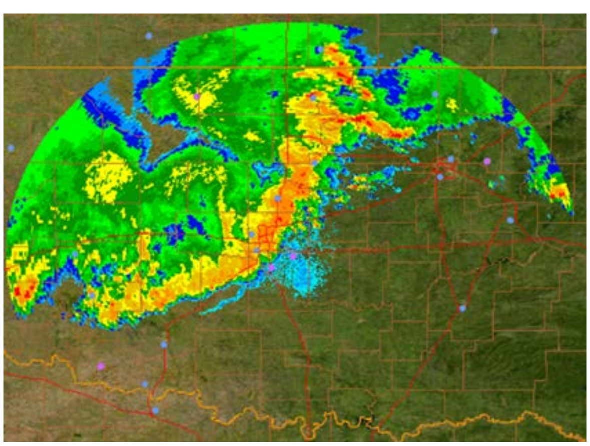


Fig. 2: Radar reflectivity from 02 UTC 4 July 2017 showing the convective line (red-orange-yellow area) responsible for the gust front in Fig. 3.

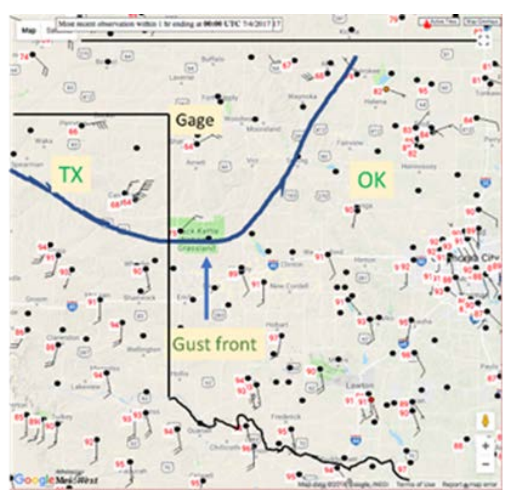
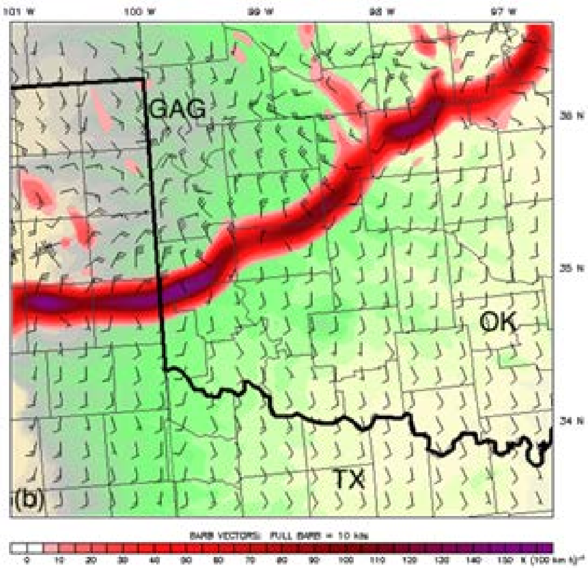


Fig. 3: Surface weather observations and analysis of gust front in NW Oklahoma, 00 UTC 4 July 2017.



Figures 2 and 3 show a case of tool application, a thunderstorm event over simple terrain. On July 3–4, 2017 a thunderstorm system (MCS) moved SE across northwest Oklahoma producing a strong gust front. Figure 2 shows its radar signature (red-orange-yellow shading). Figure 3 shows the position of the gust front (heavy line) at 00 UTC 4 July based on the weather observations. Figure 4 shows the tool output: the dark red band depicts the predicted gust front location, based on forecast output from the National Weather Service's High Resolution Rapid Refresh (HRRR) modeling system.

Fig. 4: Gust front tool plot of thunderstorm outflow boundary of 4 July 2017. Surface wind barbs (full barb= 10 kts) also plotted. Forecast produced from NOAA HRRR forecast system using 3-km WRF Model.

The tool has also been applied in mountainous terrain cases, and we present an example with the Highline Fire occurring in central Idaho in September 2017. Figure 5 shows the extensive fire activity as of 00 UTC 8 Sept. Figure 6 shows the tool's guidance from an ensemble of 10 WRF Model forecasts with 3-km grid spacing, valid 00 UTC 9 Sept. The forecast gust fronts for each member are presented as lines of different colors, and there are a number of forecasts predicting gust fronts in and around the Highline Fire. From an ensemble, the tool can also present the forecast probability of a gust front being near a fire. Figure 7 shows this in shaded probabilities (red=100%, green= 50%, and white= 0%) of such a boundary occurring within 25 mi/40 km of a given point at 00 UTC 9 Sept. Around the Highline Fire, the probability of a gust front is about 90%.

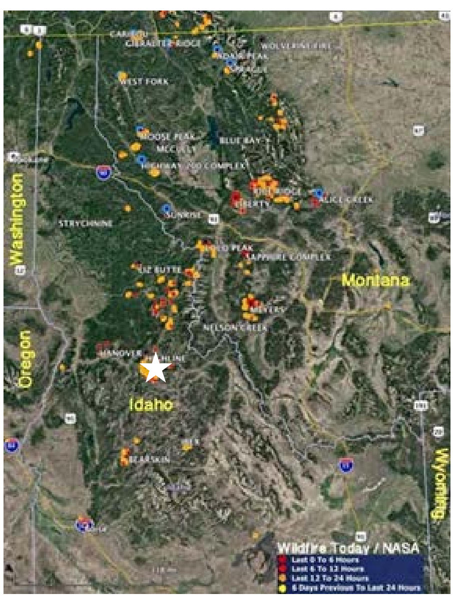


Fig. 5: Fires across Idaho and Montana as of 00 UTC 8 Sept 2017. Star marks Highline Fire location (Credit: *Wildfire Today*).

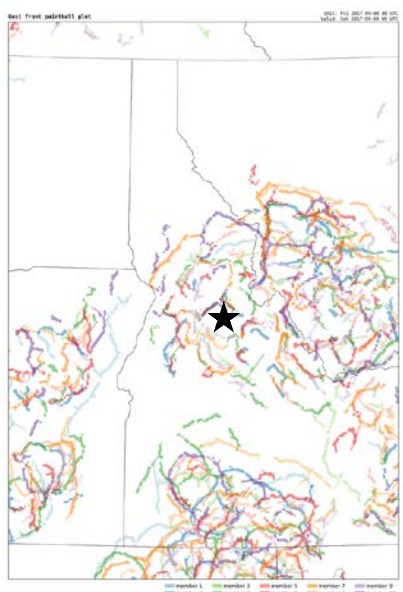


Fig. 6: Forecast of gust front positions from WRF ensemble, valid 00 UTC 9 Sept 2017. Star marks Highline Fire location.

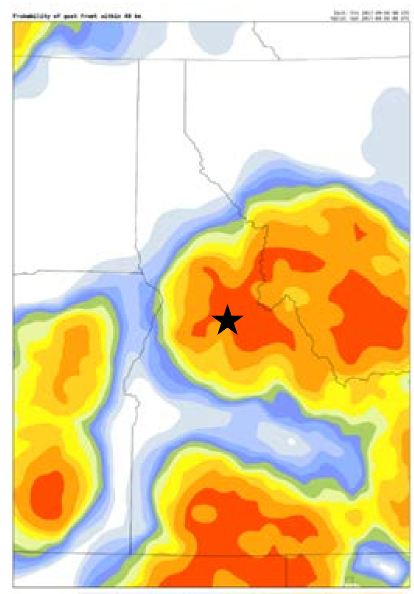


Fig. 7: Forecast probability of gust front within 25 mi/40km of underlying point at 00 UTC 9 Sept 2017, based on WRF ensemble.). Star marks Highline Fire location.

Summary

A software tool has been developed to identify wildfire-impacting gust fronts forecast by numerical weather prediction models. It takes advantage of existing, readily-available information from such models, including those in ensemble forecasting systems, to warn of potentially dangerous thunderstorm outflows in wildfire areas. The tool operates in Linux environments, employs C-shell and Python for its scripting and plotting, and is computationally quick. This software is being provided to the Joint Fire Science Program, and a web page providing examples of gust front tool outputs may be found at: http://www2.mmm.ucar.edu/prod/rt/pages/jfsp.html .

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