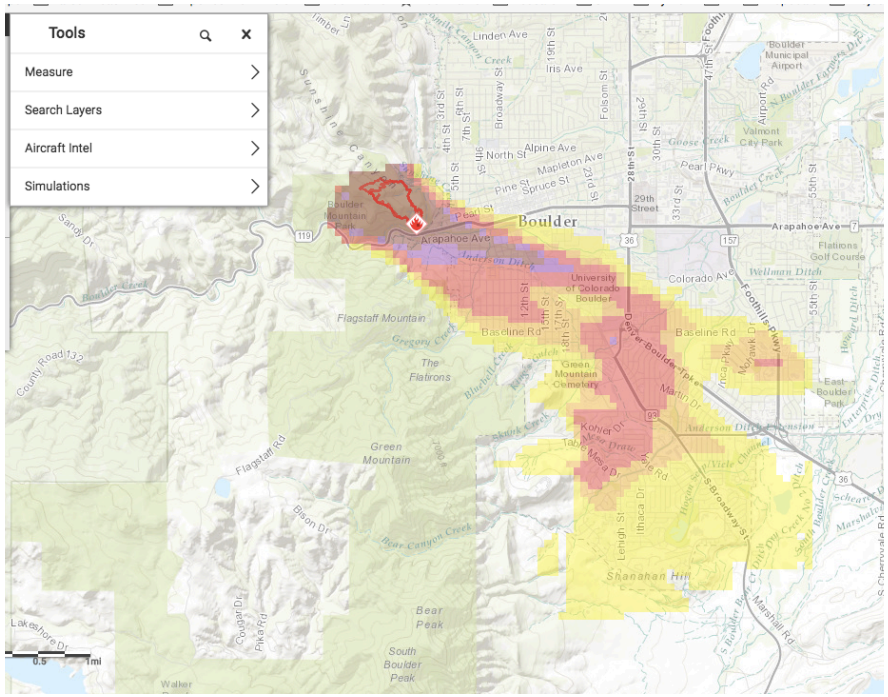
The Colorado Fire Prediction System: system description and evaluation



Pedro A. Jimenez, Branko Kosović, Domingo Muñoz-Esparza, Amanda Anderson, Bill Petzke, Jennifer Boehnert, Jim Cowie, Kevin Sampson, Barb Brown and Bill Mahoney

WRF User's Workshop. June 15, 2017

Colorado Fire Prediction System (CO-FPS)

Rep Tracy Kraft-Tharp | Dr. Jim Hurrell NCAR Director | Bill Mahoney NCAR/RAL | Gov. Hickenlooper | Dr.Janice Coen NCAR/MMM

Signed May 20, 2015

An Act

HOUSE BILL 15-1129

BY REPRESENTATIVE(S) Kraft-Tharp, Duran, Garnett, Ginal, Hamner, Kagan, Mitsch Bush, Pettersen, Rosenthal, Ryden, Salazar, Singer, Vigil, Williams, Winter, Hullinghorst, Lontine, Pabon;
also SENATOR(S) Roberts, Grantham, Heath, Aguilar, Carroll, Donovan, Hodge, Jones, Kefalas, Kerr, Merrifield, Newell, Todd.

CONCERNING DISASTER PREDICTION AND DECISION SUPPORT SYSTEMS BY THE DEPARTMENT OF PUBLIC SAFETY, AND, IN CONNECTION THEREWITH, MAKING AN APPROPRIATION.

Be it enacted by the General Assembly of the State of Colorado:

SECTION 1. Legislative declaration. (1) The general assembly hereby finds and declares that:

(a) Wildland fires are exceedingly complex phenomena. Despite rigorous training, abundant resources, and weather forecasts, even seasoned responders may be tragically unprepared for complex, unpredictable, and dramatic fire behavior. Human intelligence cannot integrate all the interacting factors to anticipate when weather and other factors will combine with topography to dramatically amplify fire behavior.

Colorado The Official State Web Portal

COLORADO

Division of Fire Prevention and Control

Center of Excellence for Advanced Technology Aerial Firefighting (CoE)

Our Mission

To protect the citizens, land, and resources in Colorado, the Center of Excellence will research, test, and evaluate existing and new technologies that support sustainable, effective, and efficient aerial firefighting techniques.

Our Vision

The Center of Excellence is the worldwide leader in collaboratively researching and developing innovative technologies and capabilities supporting or related to aerial firefighting.

Why Do We Need A High-Resolution Coupled Atmosphere Wildland Fire Prediction System?

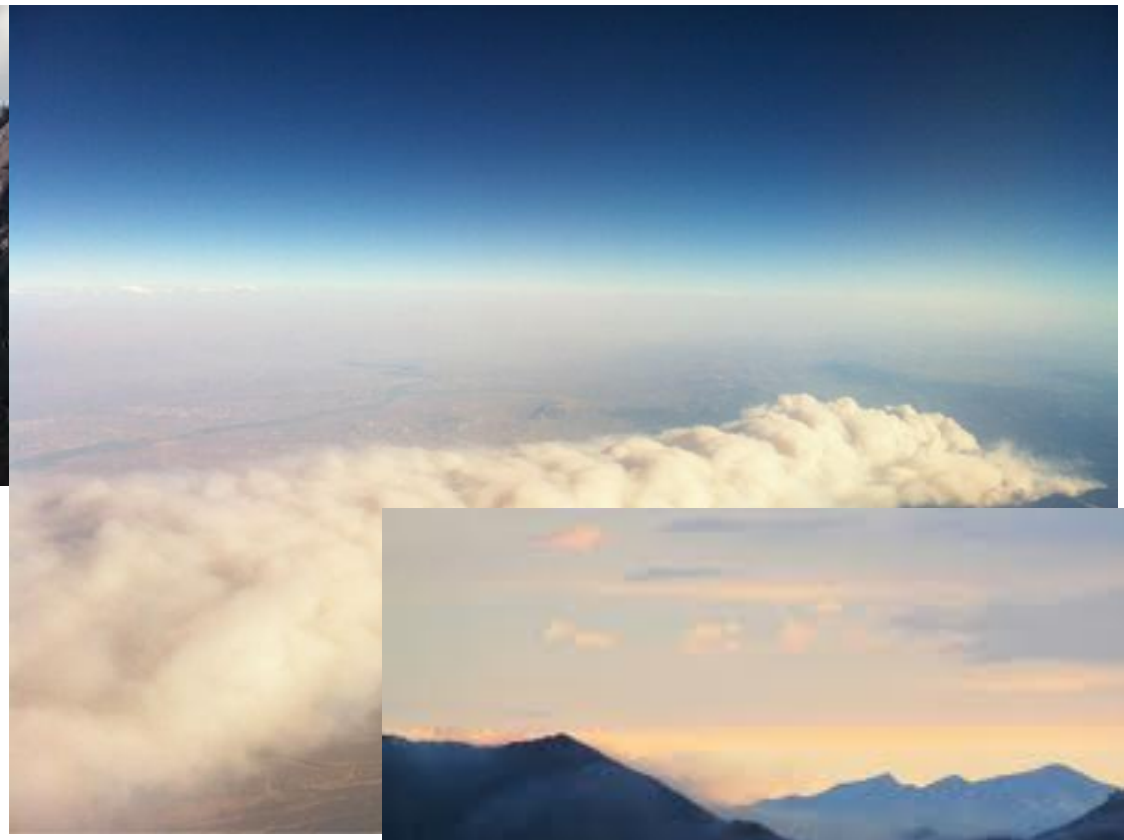
Flagstaff Fire June 2012

Weather Has Significant Effect on Rate of Fire Spread and Dispersion of Smoke

Flagstaff Fire June 2012

Wind Speed, Humidity, Atmospheric Stability Affect Fire Spread

Flagstaff Fire June 2012



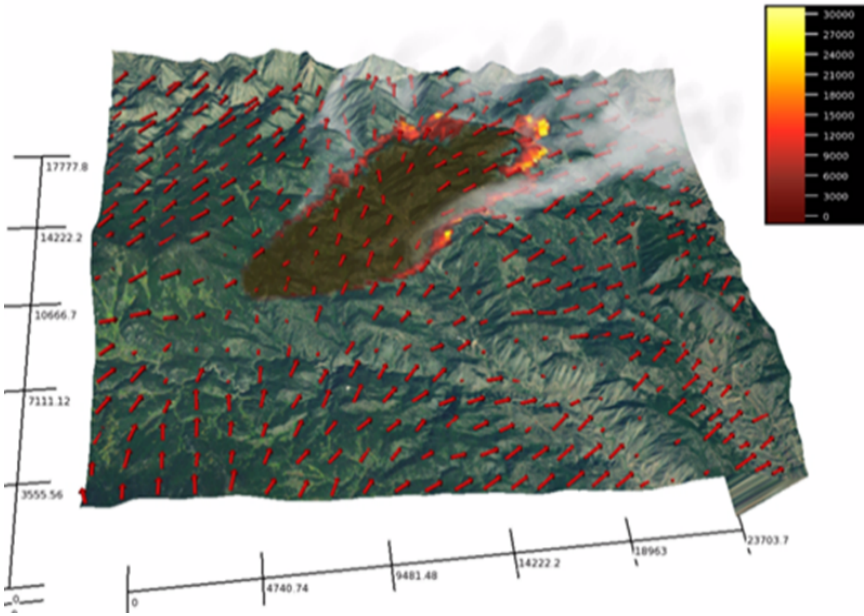
Coupled model enables simulation of fire weather phenomena

The wind (i.e. atmosphere) affects the rate of spread and direction of fire as well as fuel moisture (which determines weather and how intensely a fire burns).

Burning fuel and releases heat and water vapor into the atmosphere, causing updrafts and changing the winds

CO-FPS Project is Fulfilling NCAR's Mission to Forster Transfer of Technology

- Development of CO-FPS builds on more than two decades of fundamental research on wildland fire prediction at NCAR initiated and carried out by Terry Clark and Janice Coen
- CO-FPS builds on Coupled Atmosphere Wildland Fire Environment (CAWFE) model (Clark et al. 1996a and 1996b, Clark, Coen, and Latham 2004,)
- For operational purposes we have developed CO-FPS using WRF-Fire (Coen et al. 2013)



NWP Model Is Coupled With Fire Behavior Model

Level set method tracks fire perimeter

Fire Behavior Module Is Coupled With NWP Model

Level set method tracks fire perimeter

Rate of spread of flaming front is computed as function of fire-affected fuel, wind, and slope using a semiempirical Rothermel (1972) model.

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NWP Model Is Coupled With Fire Behavior Model

Level set method tracks fire perimeter

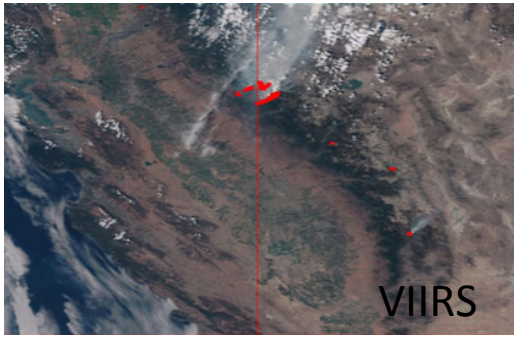
Rate of spread of flaming front is computed as function of fire-affected fuel, wind, and slope using a semiempirical Rothermel (1972) model.

Surface fire heats and dries the canopy.
If the surface fire heat flux exceed the empirical threshold fire transitions into the canopy.

Flow in atmosphere is affected by fire through heat, water vapor, and smoke released by burning of the fuel.

Colorado - Fire Prediction System Attributes

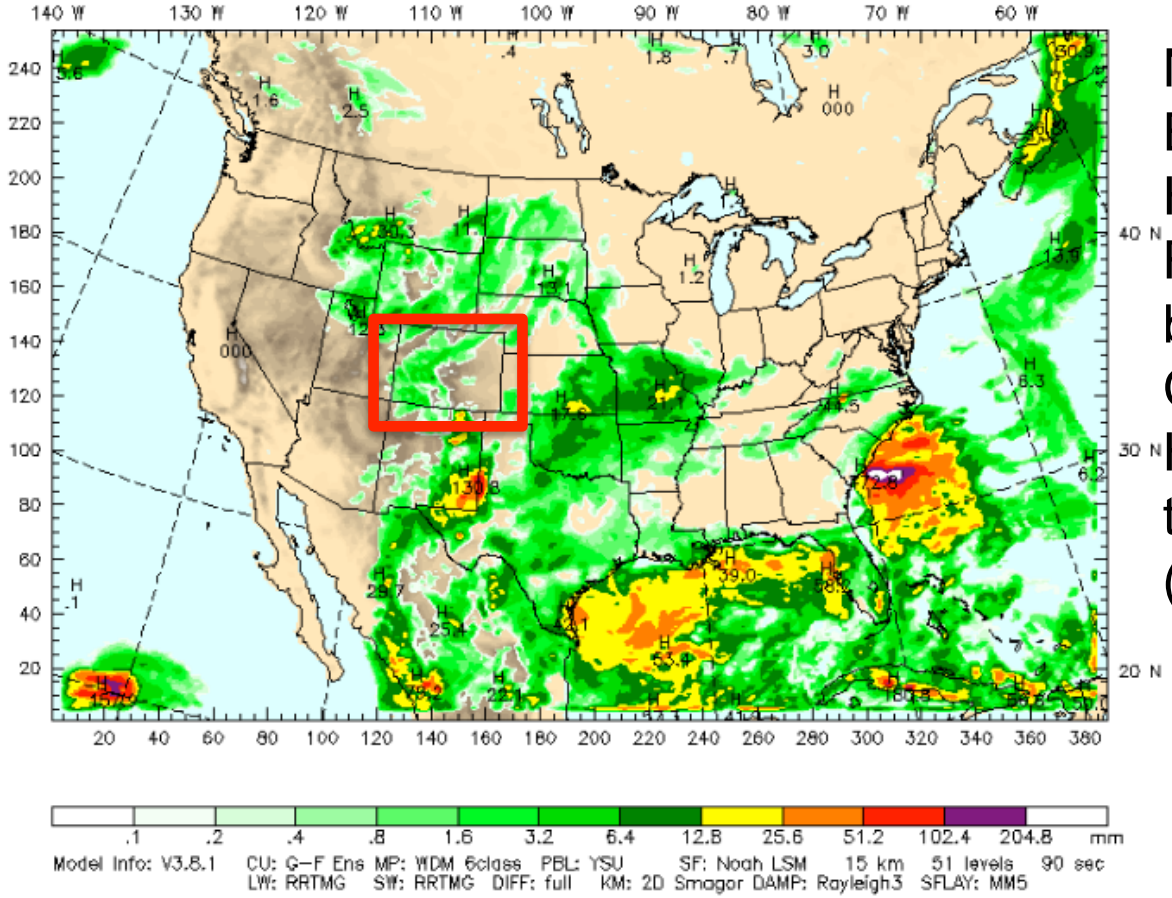
- Real-time utilization of weather, fuel, and active fire detection data from the MMA and other sources, where applicable
- Multiple fire model cycles (runs) per day (utilizing updated weather and fire mapping data)
- User ability to select fire prediction location and size via Colorado Wildfire Information Management System (CO-WIMS)
- User ability to input ignition information (via CO-WIMS)
- Output customized and formatted to be displayed on CO-WIMS



Rim fire in Central-East California. VIIRS active fire detection.

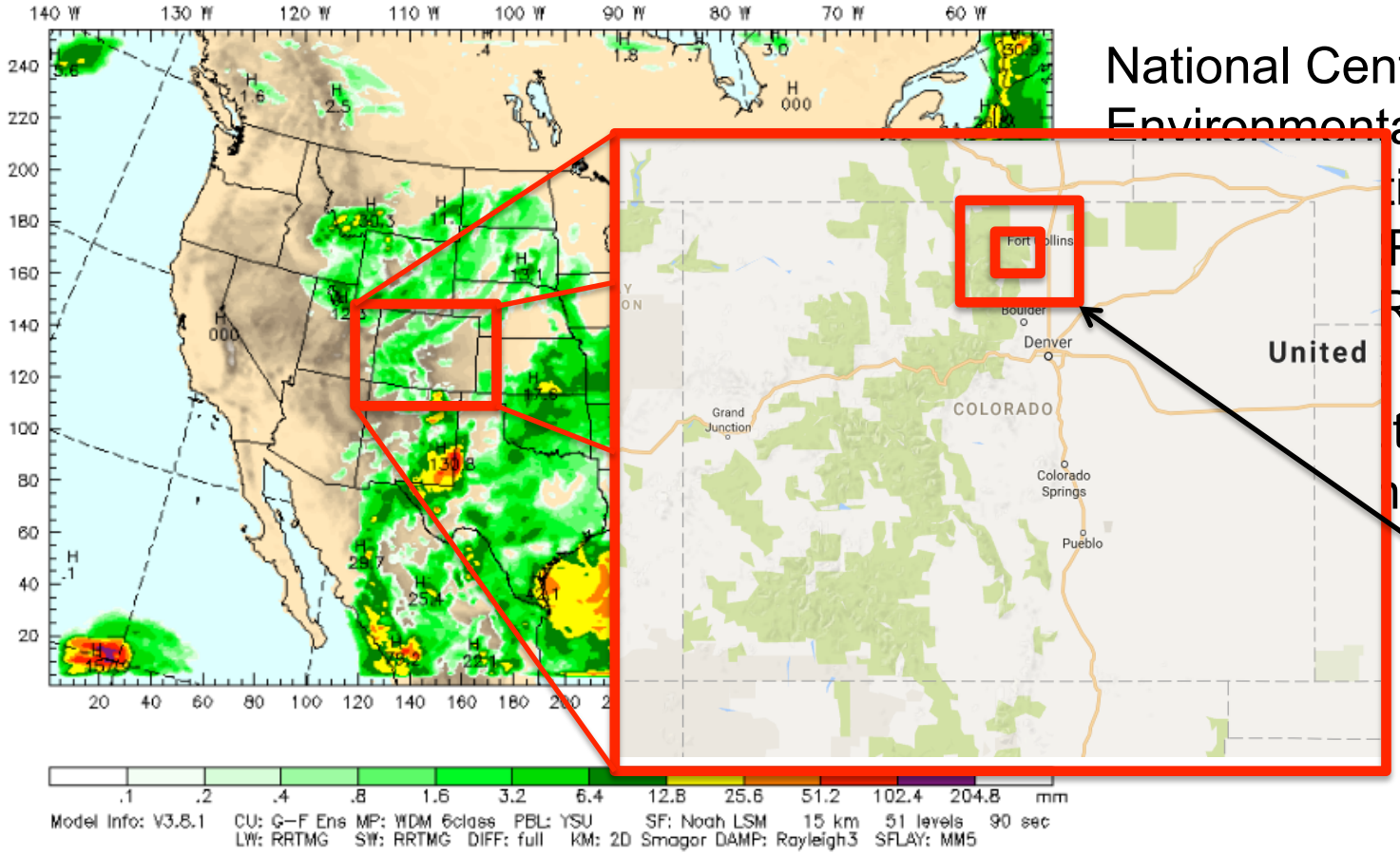
NASA, University of Maryland

We are downscaling HRRR forecasting system output



National Center for Environmental Prediction's High Resolution Rapid Refresh (HRRR) model is based on WRF and covers CONUS. We downscale from HRRR output and focus on the area of interest (Colorado).

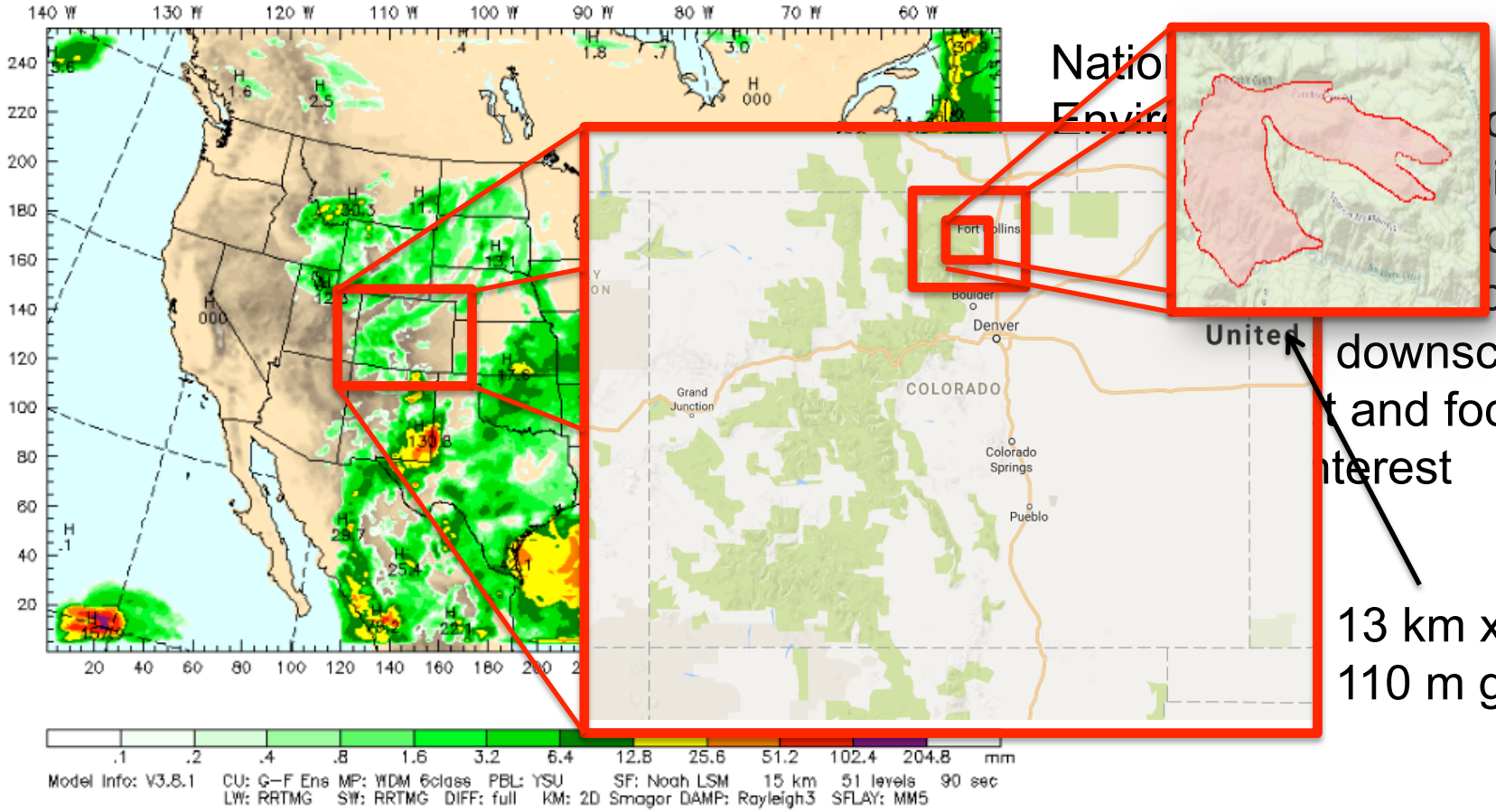
We are downscaling HRRR forecasting system output



National Center for Environmental Prediction's tion Rapid RR) model is RF and covers downscale from t and focus on terest

117 km x 117 km
1 km grid cell

We are downscaling HRRR forecasting system output



Natio
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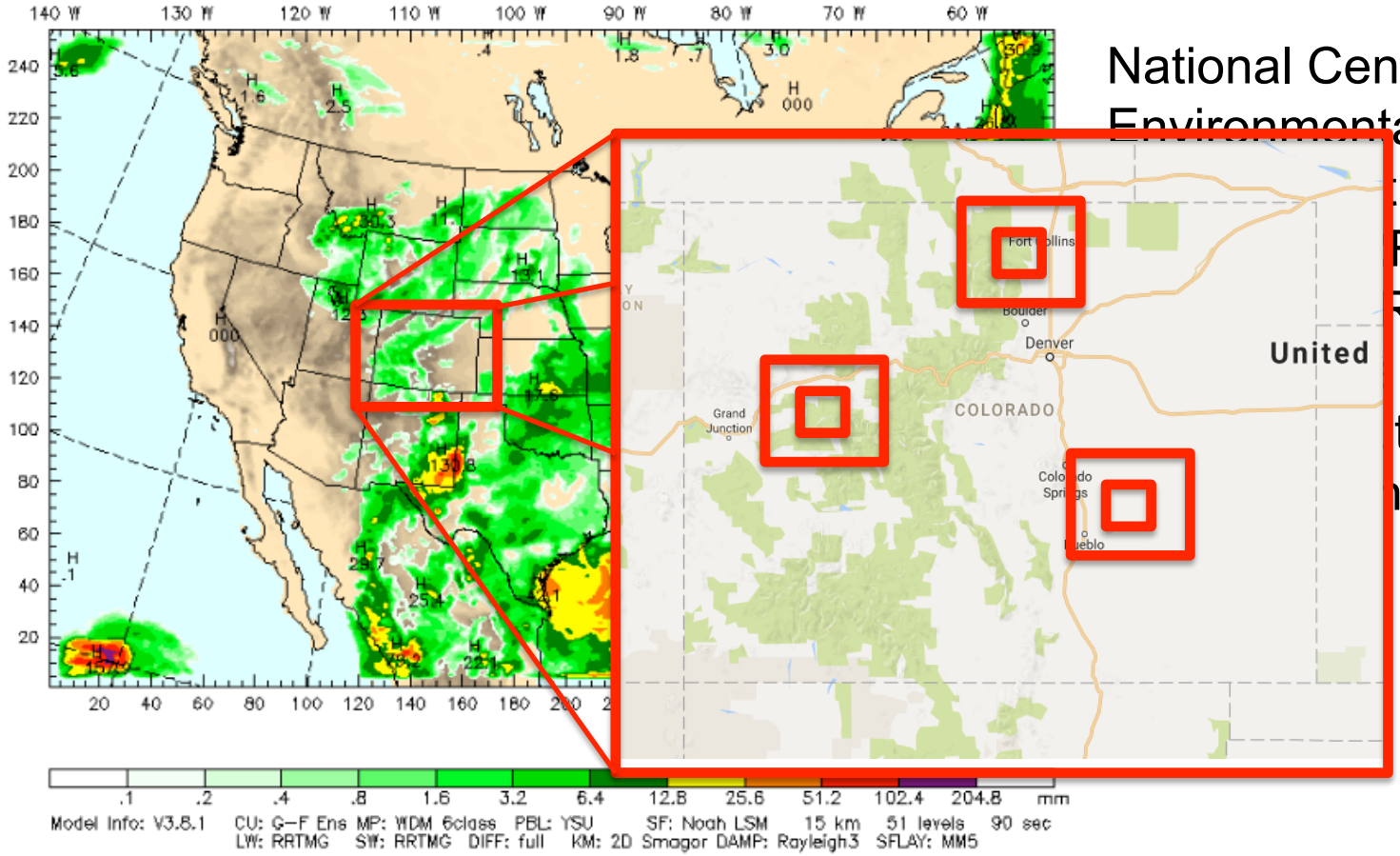
13 km x 13 km
110 m grid cell

The Fire Prediction System Needs to Simulate Three Fires Simultaneously



National Center for
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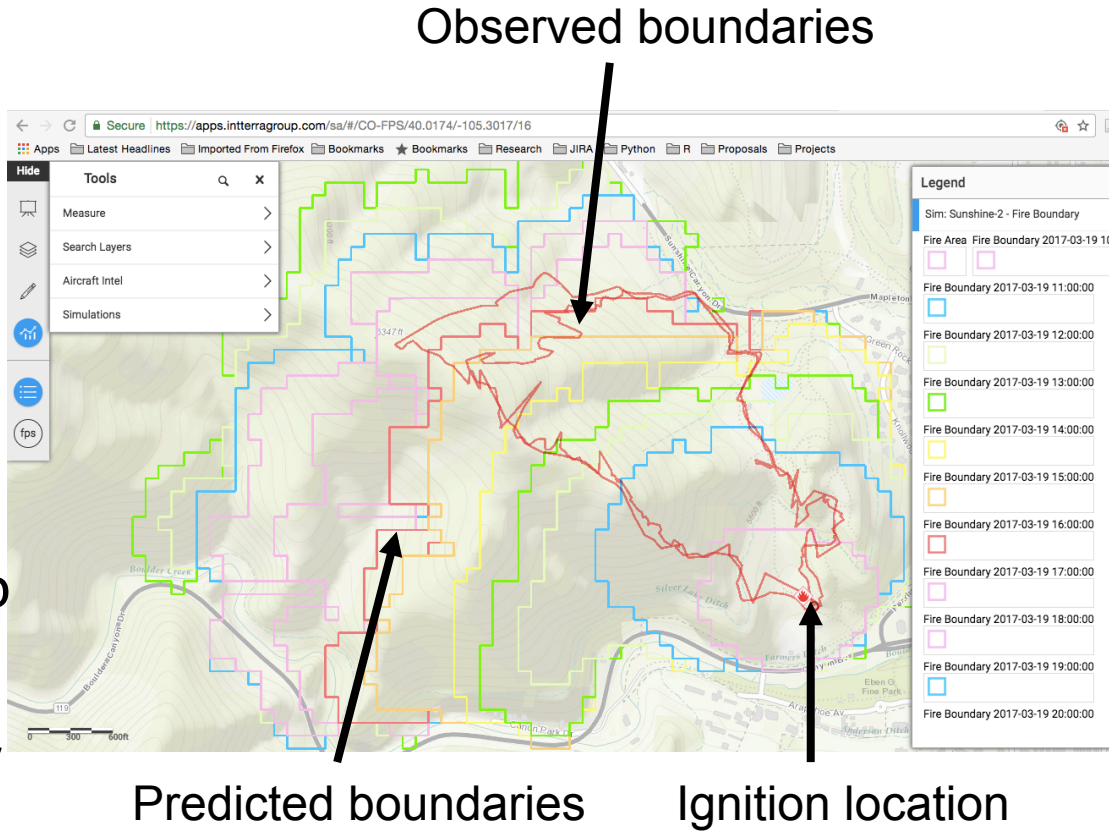
Fire Behavior Products

Fire Boundary

- Initial human-entered fire boundary provided
- Hourly prediction output increments provided out to 18 hours
- Color-coded boundaries by hour
- Fire grid resolution ~30 m (0.22 acres)

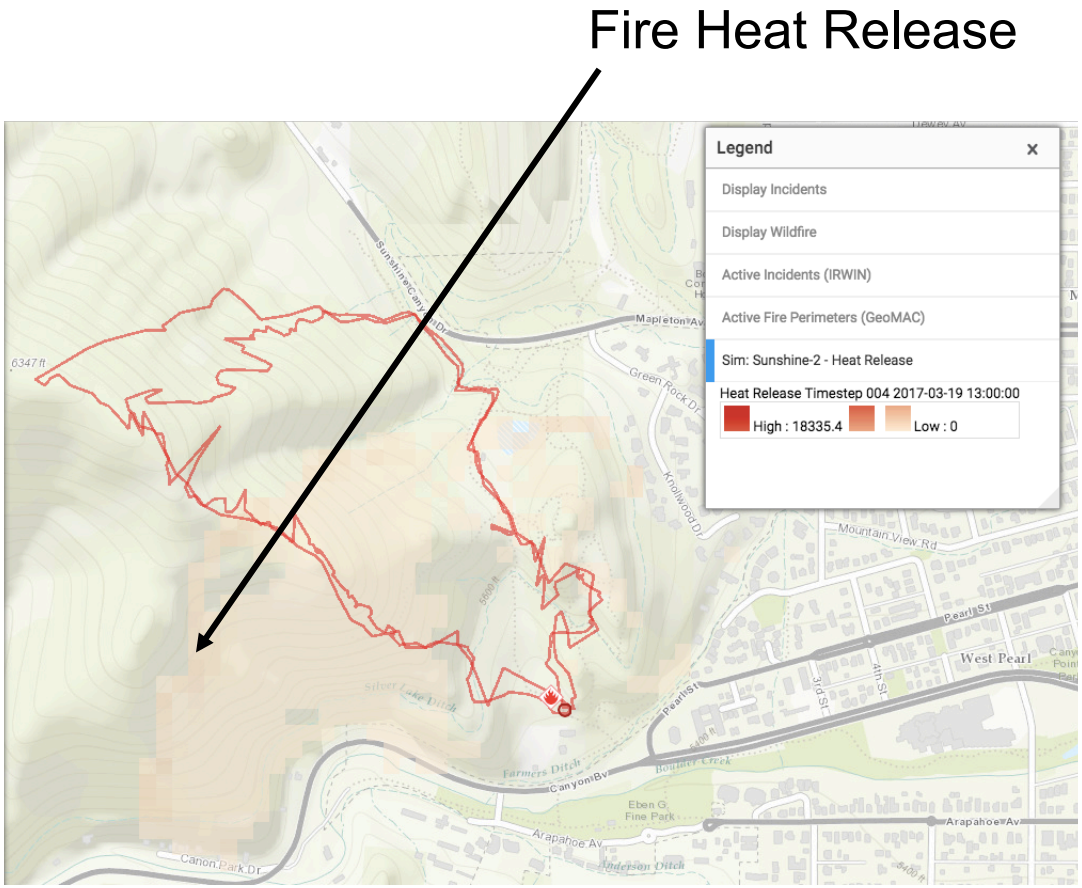


CO-FPS Fire Boundary Product
18 hour forecast summary with hourly increments

Fire Behavior Products

Fire Heat Release

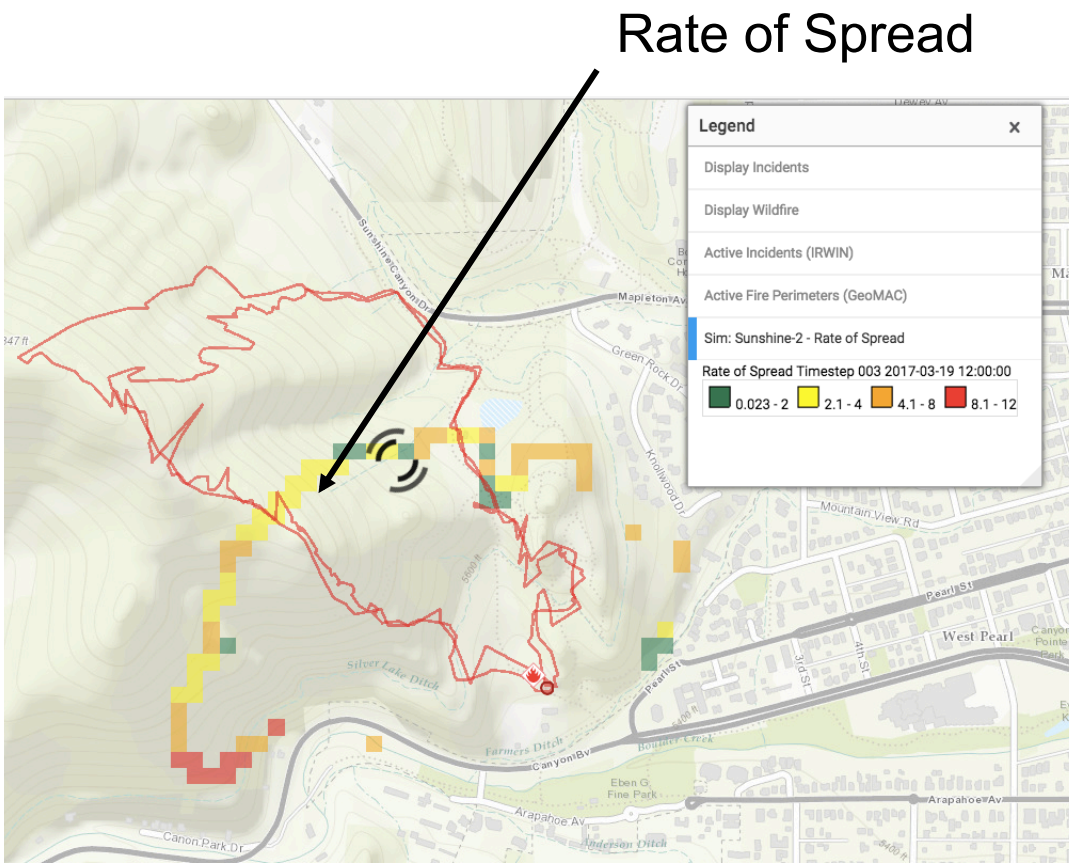
- Hourly output increments out to 18 hours
- Units: watts/m^2
- Fire grid resolution ~30 m (0.22 acres)



Fire Behavior Products

Rate of Spread

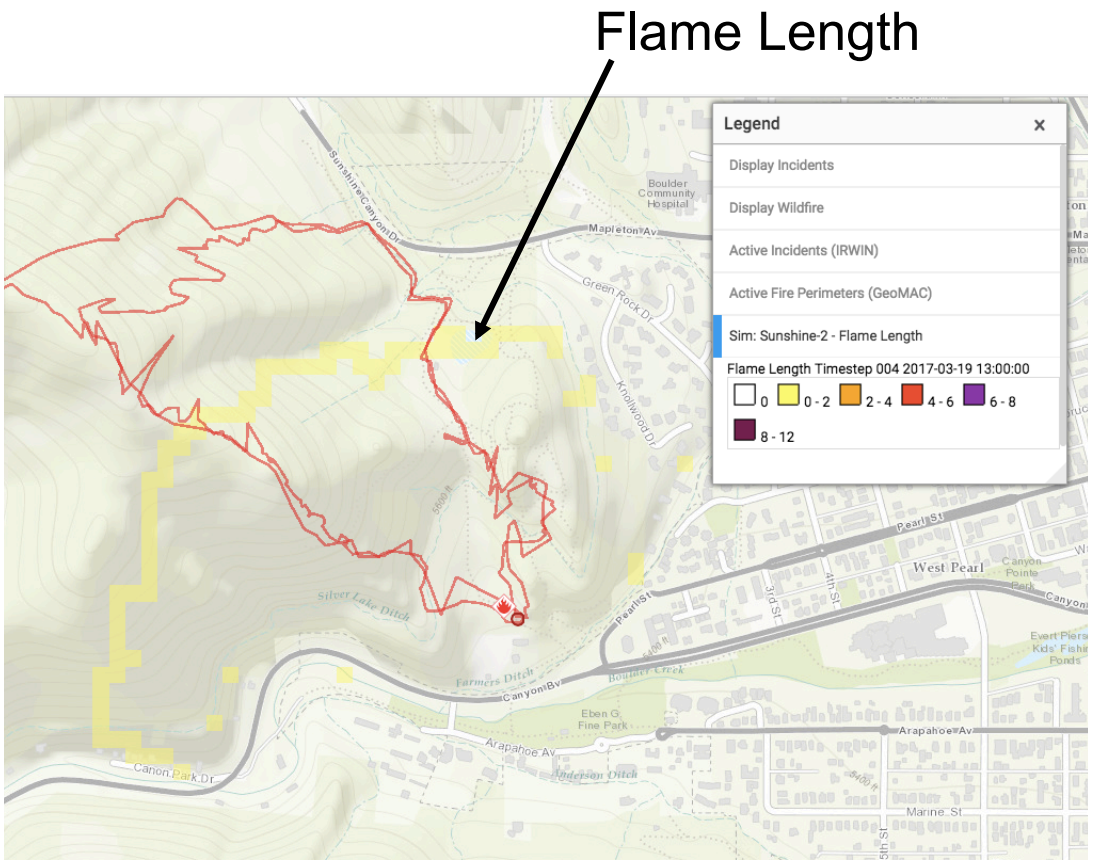
- Hourly output increments out to 18 hours
- Units: feet/min
- Fire grid resolution ~30 m (0.22 acres)



Fire Behavior Products

Flame Length

- Hourly output increments out to 18 hours
- Units: feet
- Fire grid resolution ~30 m (0.22 acres)



Fire Behavior Products

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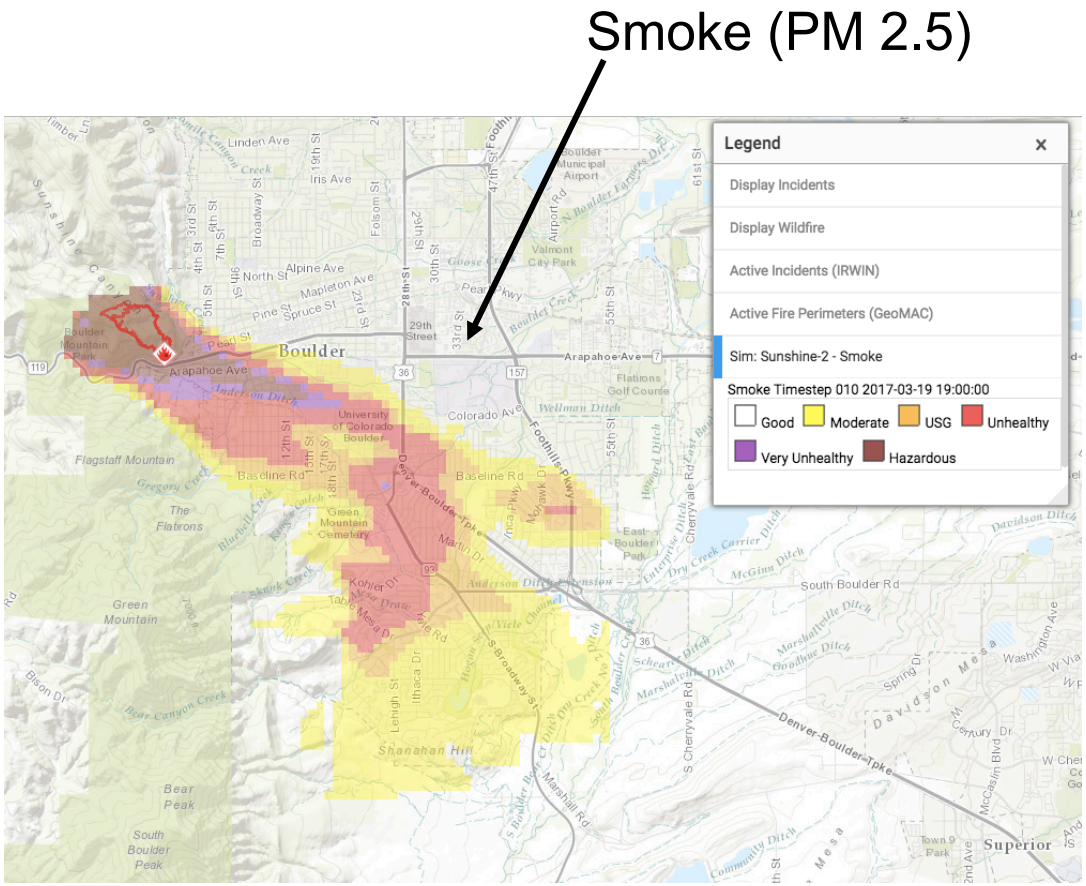


CO-FPS Products – End of Year 1

18 hour predictions of:

- Fire extent ✓
- Rate of spread ✓
- Heat release ✓
- Smoke concentration ✓
- Significant fire phenomena ✓

Fire behavior product group

- Turbulence intensity ✓
- Downdraft and updraft regions ✓
- Wind shear regions ✓

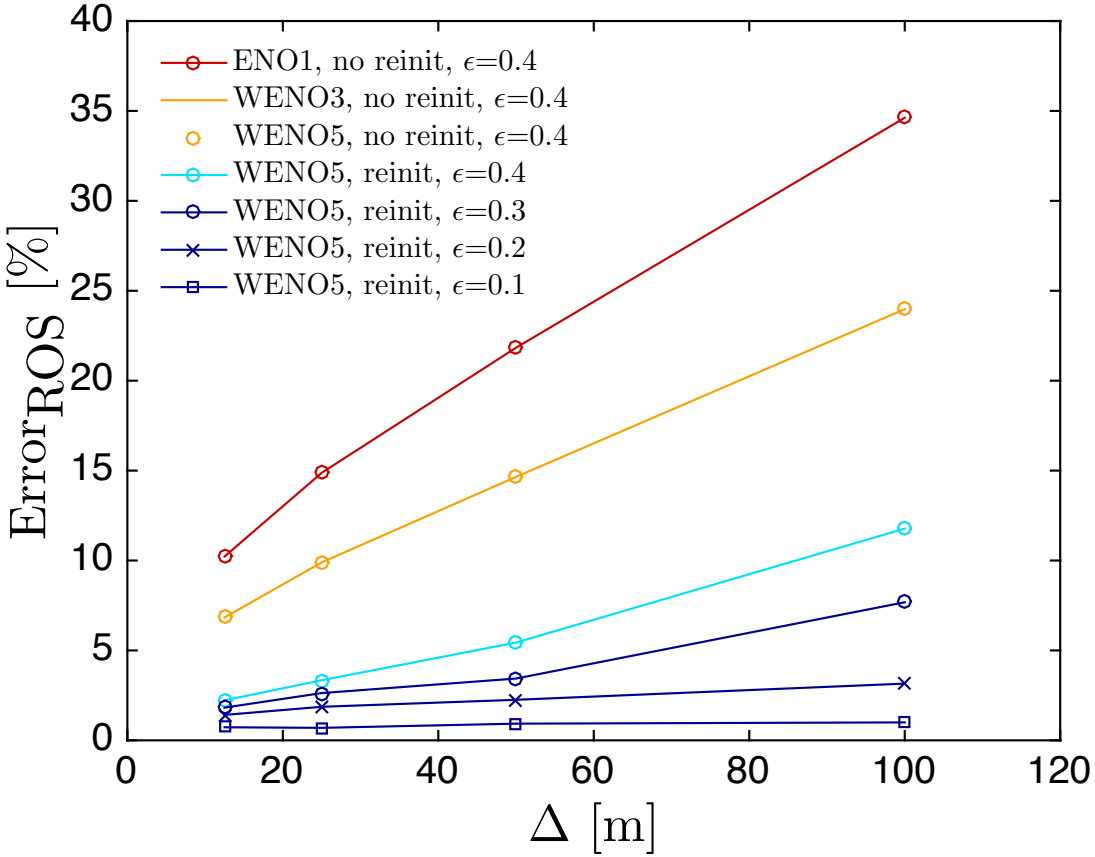
Aviation hazard product group

- Wind speed, direction, gustiness ✓
- Surface air temperature ✓
- Surface relative humidity ✓

Fire weather product group

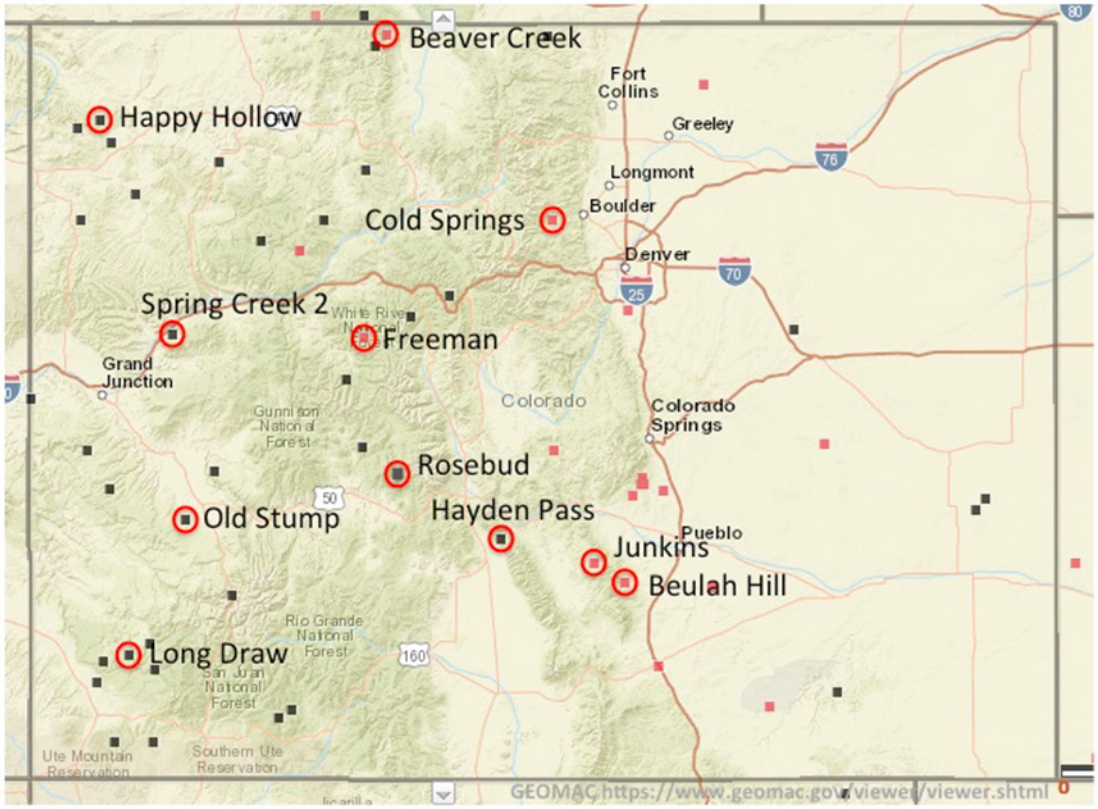
Higher Order Advection Scheme and Level Set Reinitialization Significantly Reduces Error

We replaced 1st order ENO scheme with 5th order WENO and introduced reinitialization of the level set function



Evaluation of the CO-FPS system

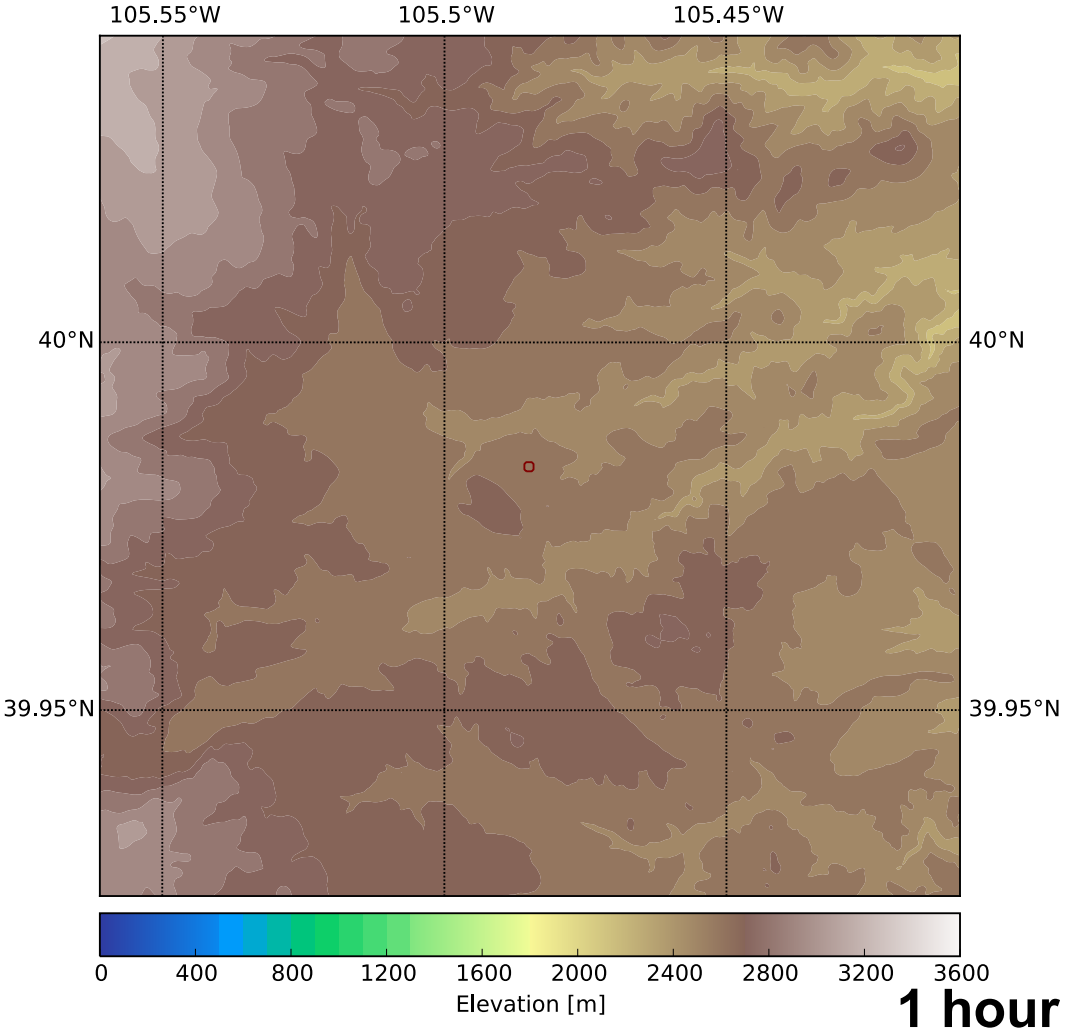
Validation over eleven fires during the CO 2016 season



Cold Springs Fire Near Nederland Was Simulated Using WRF-Fire

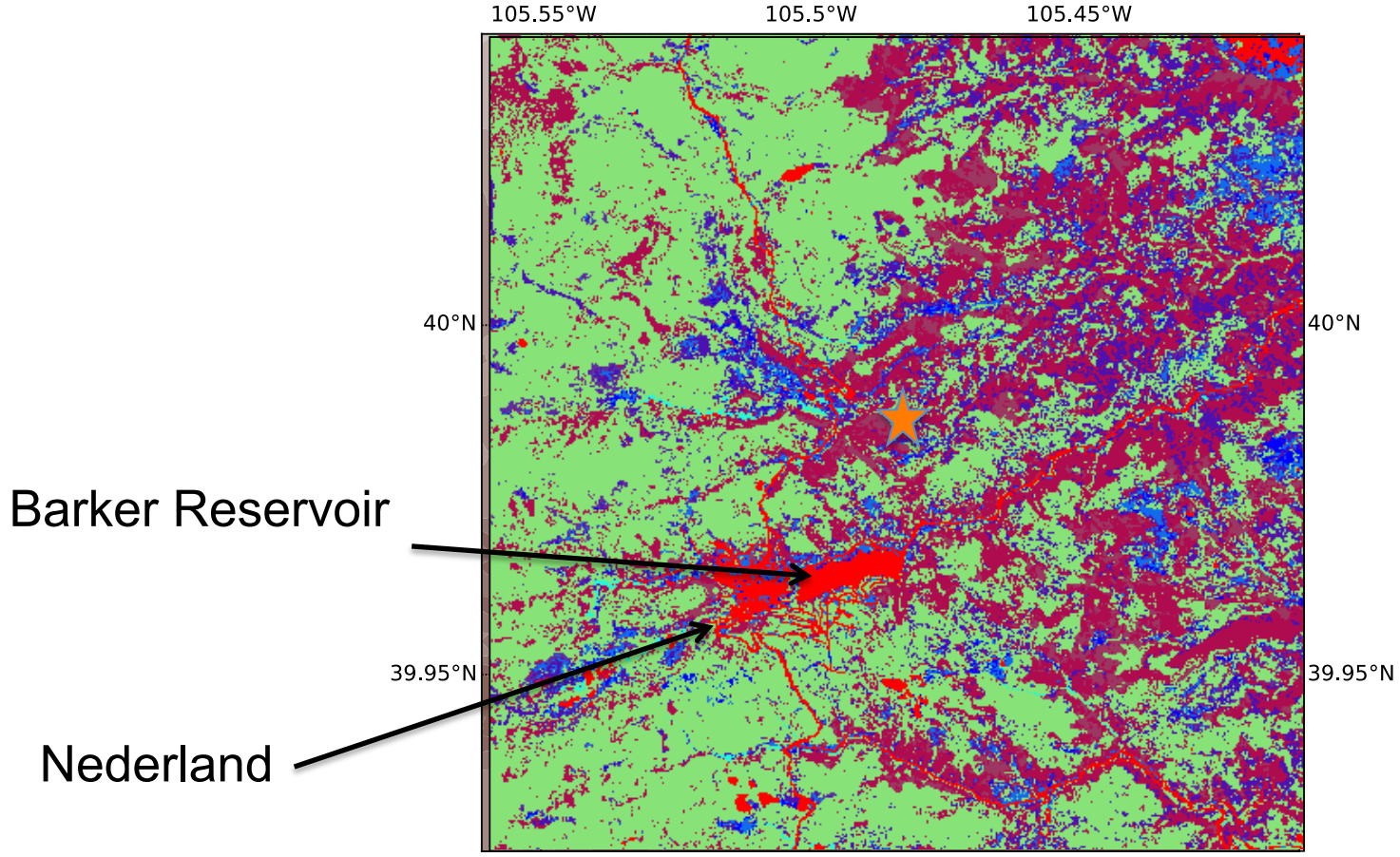
- Human caused fire ignited on Saturday July 9, 2016 at approx. 01:45 PM local time
- 528 acres burned
- 8 homes burned

Cold Springs Fire Near Nederland Was Simulated Using WRF-Fire



1 hour after ignition

Fuel Included Lodgepole Pine, Pondersosa Pine, and Douglas Fur



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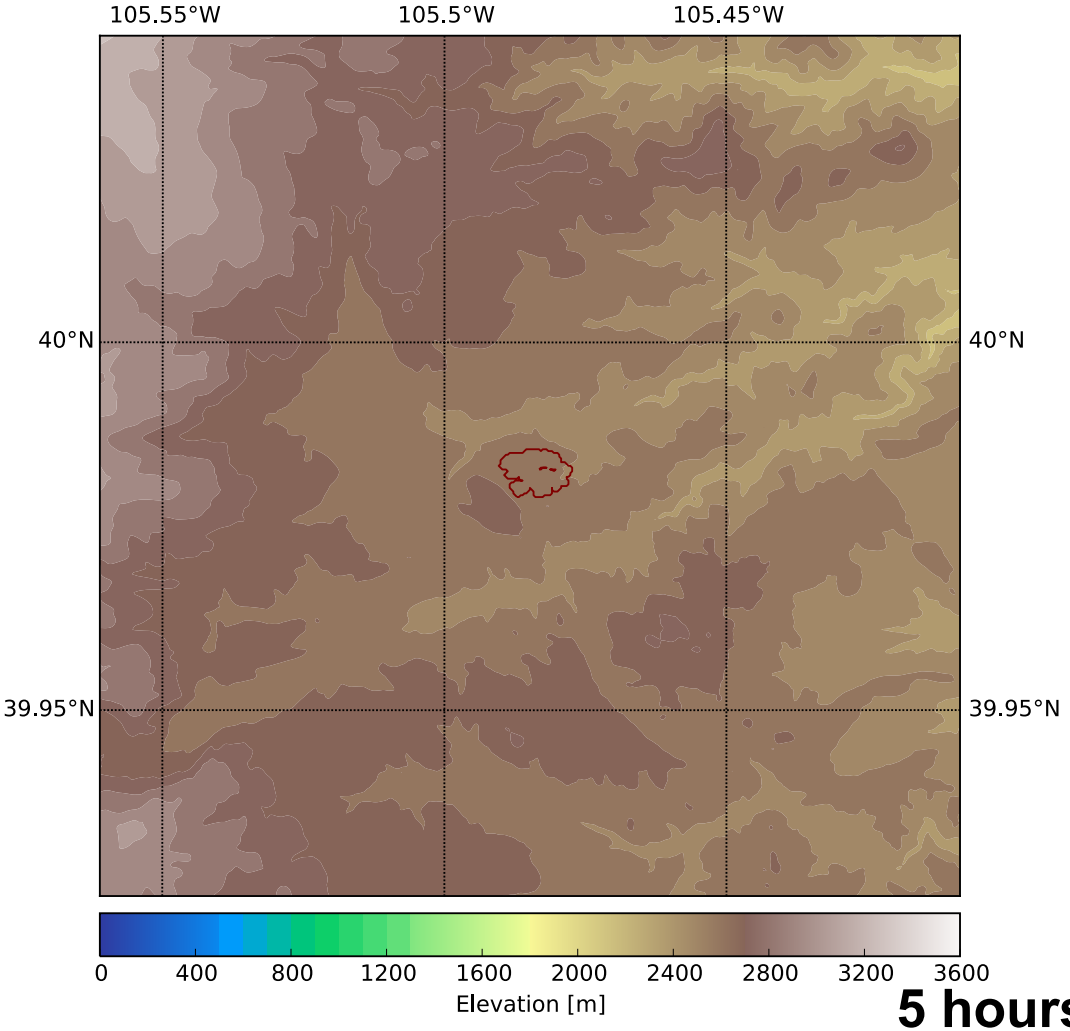
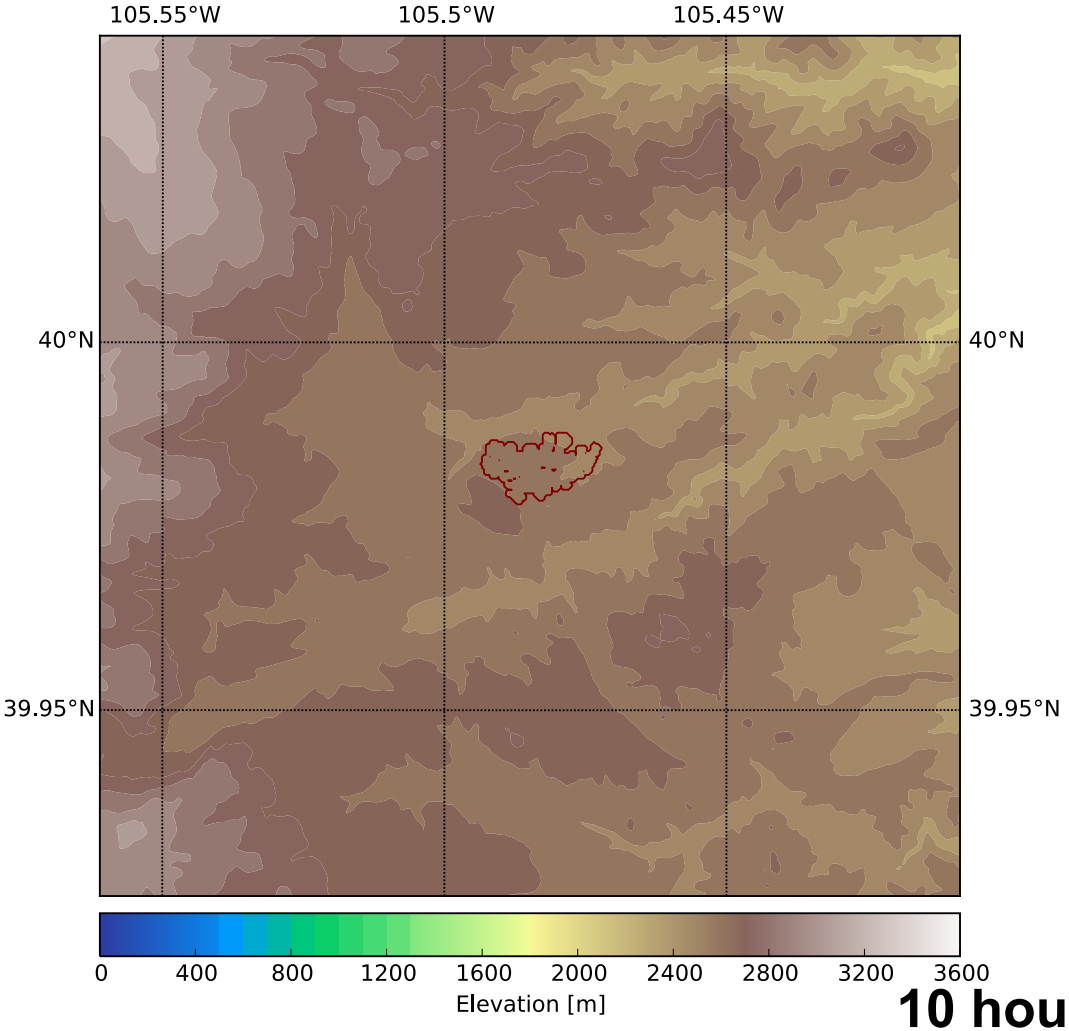


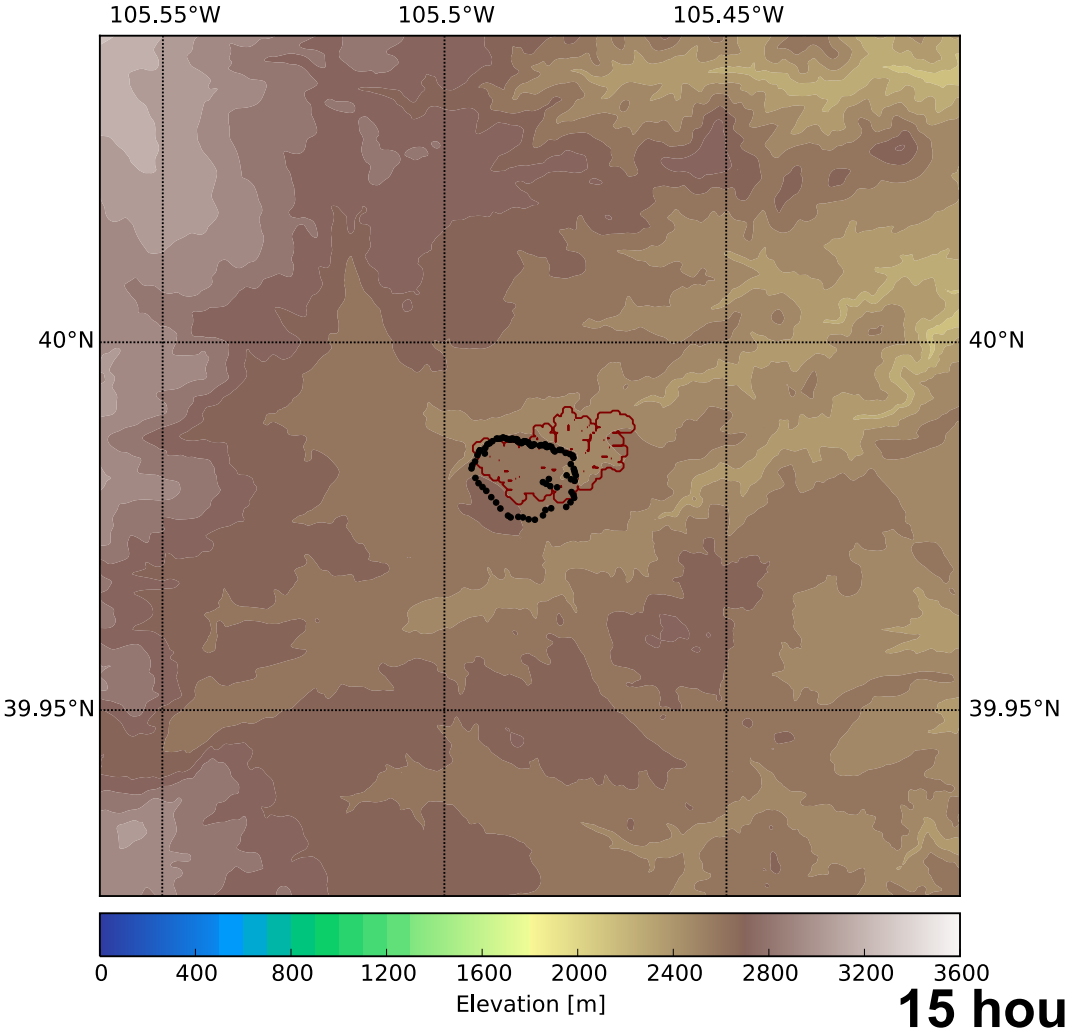
5 hours after ignition

Cold Springs Fire Near Nederland Was Simulated Using WRF-Fire



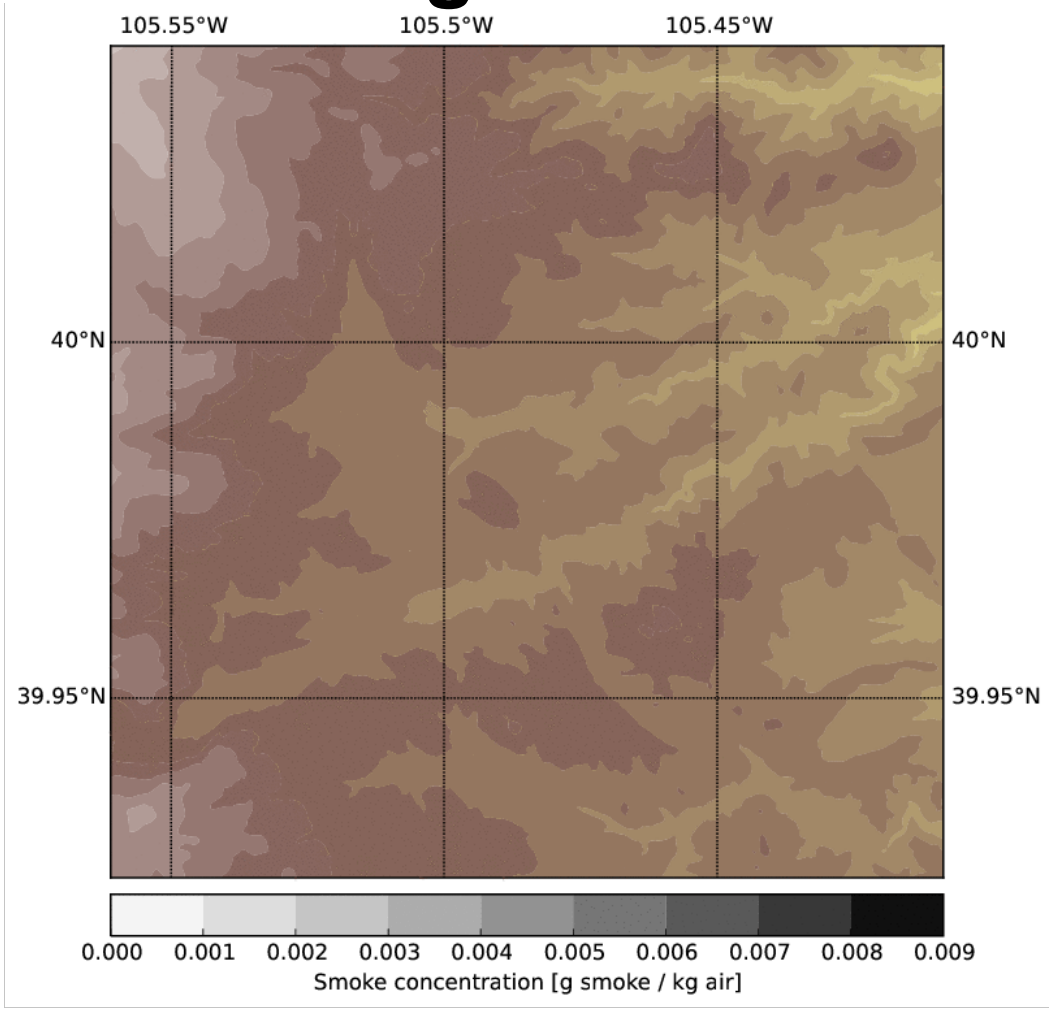
10 hours after ignition

Cold Springs Fire Near Nederland Was Simulated Using WRF-Fire

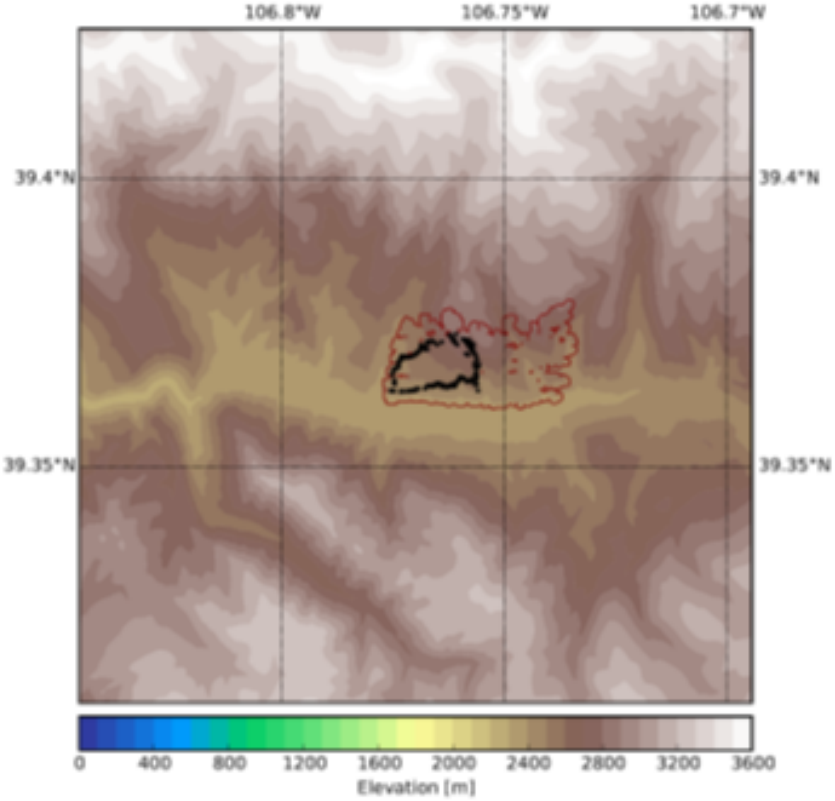


15 hours after ignition

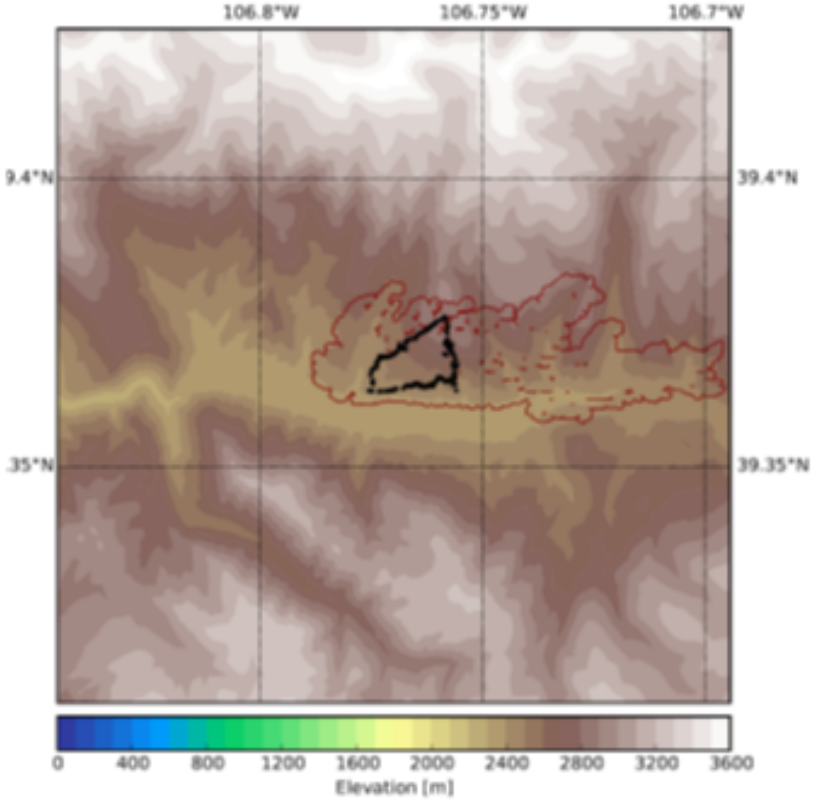
Smoke Transport Demonstrate Significant Changes In Wind Direction



Freeman fire

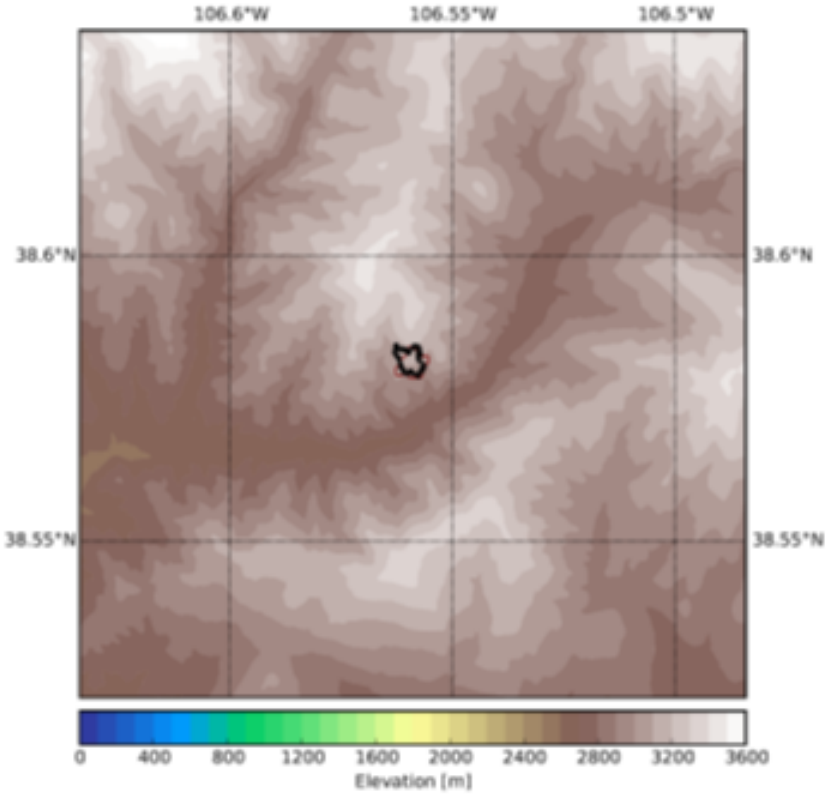


Freeman, Phase 1

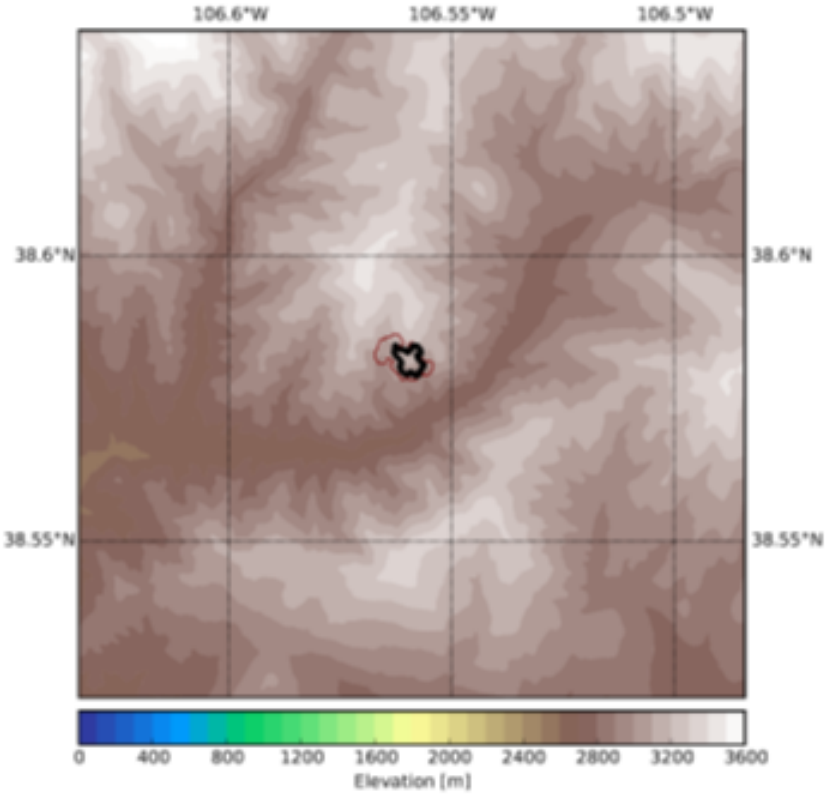


Freeman, Phase 2

Rosebud fire

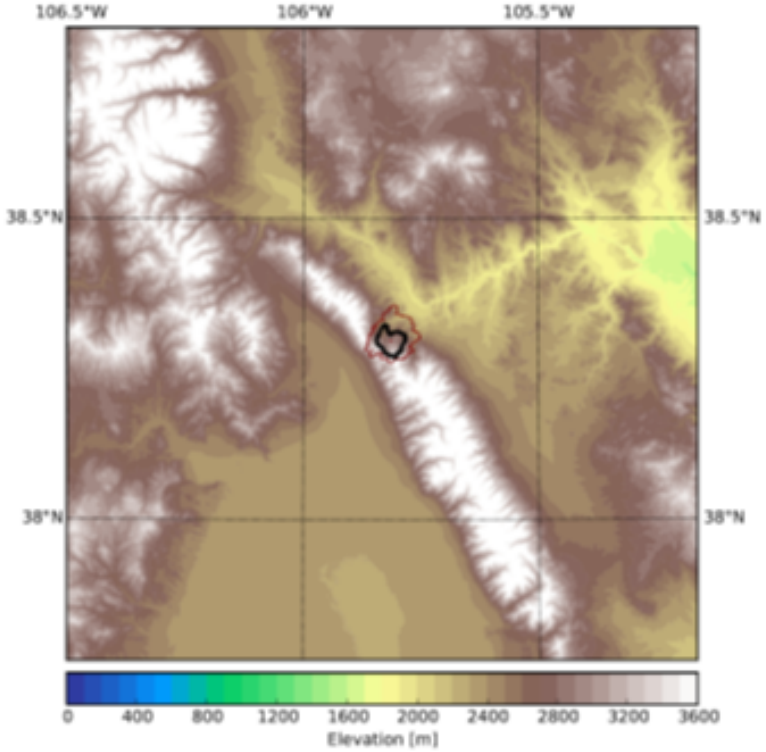


Rosebud, Phase 1

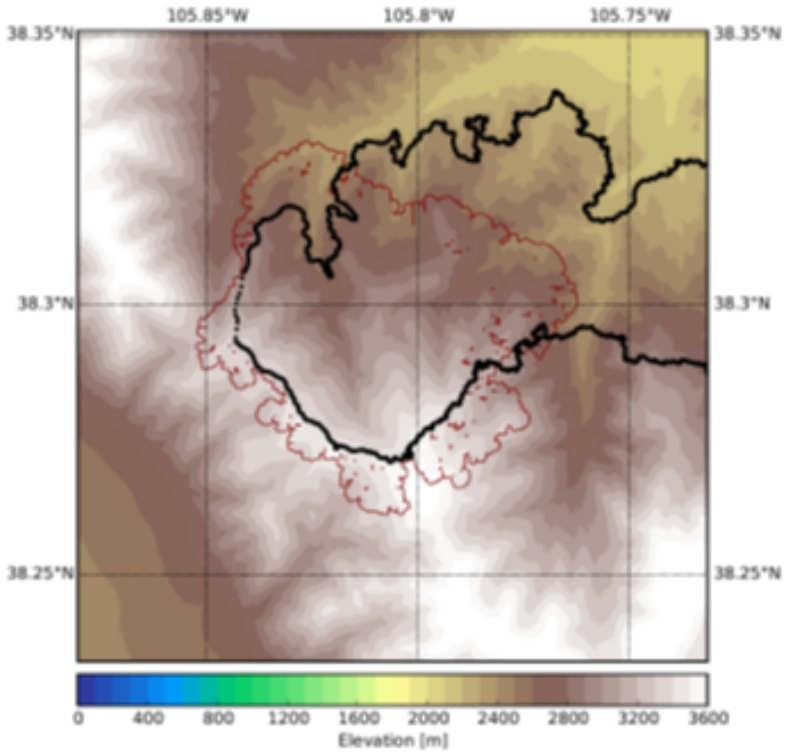


Rosebud, Phase 2

Hayden Pass fire



Hayden Pass, Phase 1



Hayden Pass, Phase 2

We Are Developing An Operational Coupled Atmosphere Wildland Fire Prediction System

- Assimilate as much real-time, quality controlled data as available (meteorological variables, fuel types, fuel moisture content, etc.).
- Use as high-resolution simulations as possible to resolve flow, terrain, and fuel characteristics (at present large-eddy simulation at 110 m over 13 km x 13 km domain).
- Develop a nowcasting capability (3 h forecast in less than 10 min on 24 cores) using coarser simulations at 1 km over 117 km x 117 km domain.
- Implement the system in on a cloud computing platform.
- Balance the speed and fidelity to produce useful, actionable information (18 h forecast in ~4 hours on 24 cores).
- Assess the system performance on recent historical fires for which we have good data.
- Improve model parameterizations and performance based on the assessment.

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