The Firebrand Spotting Parameterization in WRF-Fire

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NCAR
UCAR

The Role of firebrands in fire spread

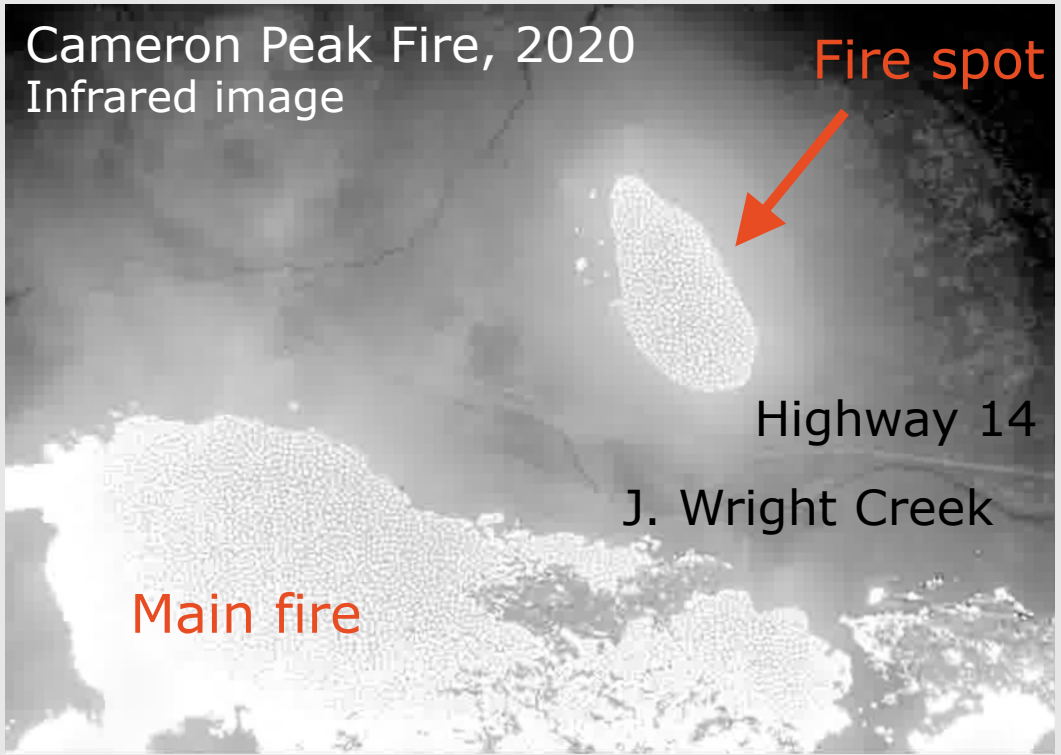
This diagram illustrates fire behavior on large wildfires.

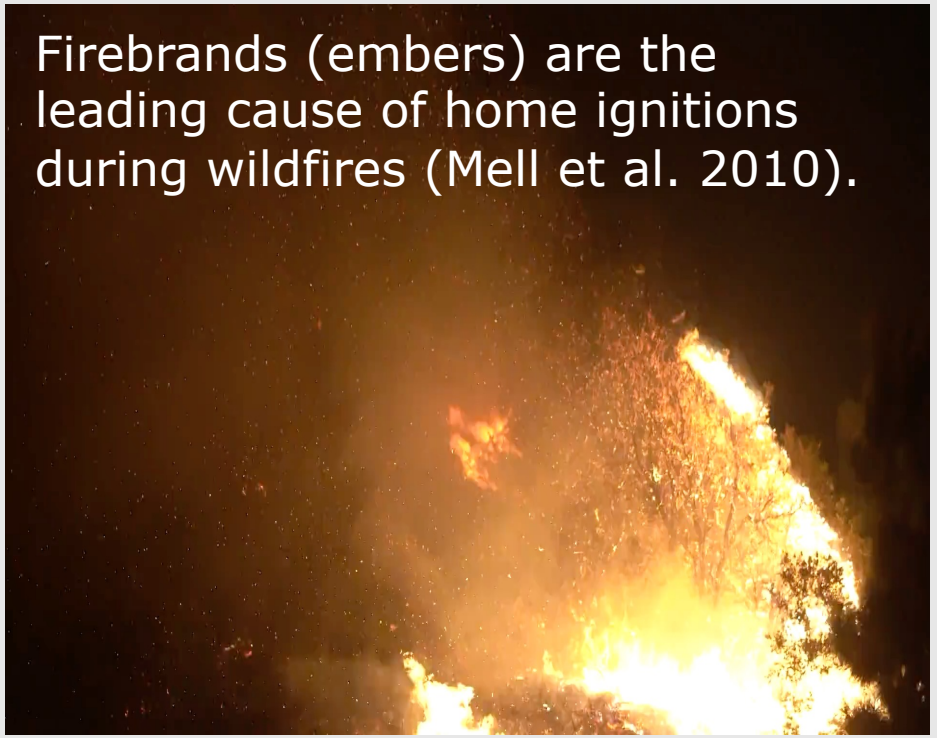
US Forest Service (1996)

Spotting

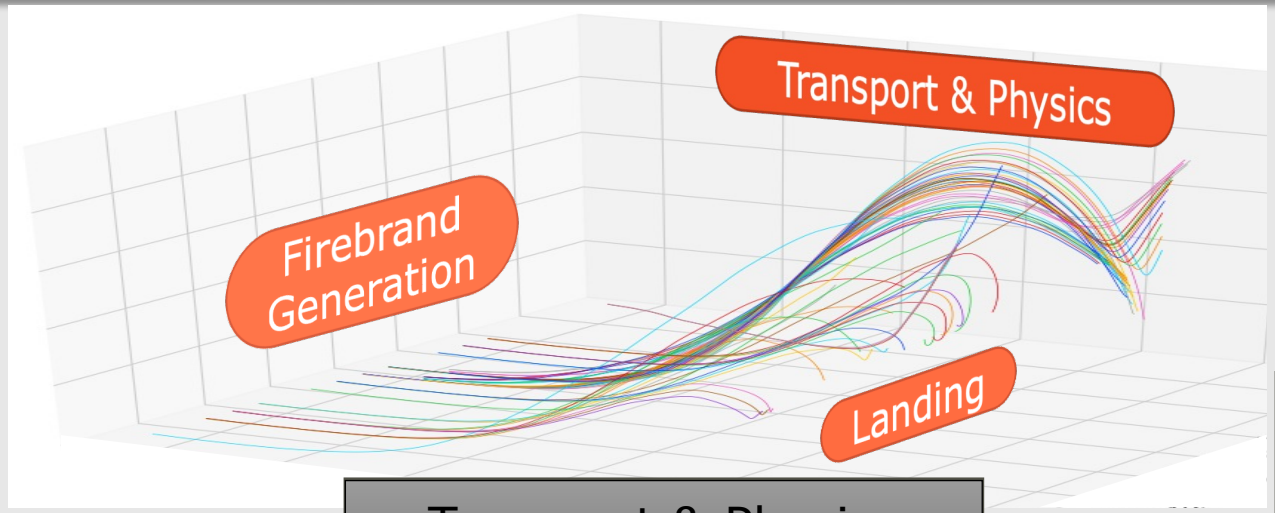
Winds and convection cause the lofting of embers and burning material ahead of the main fire. These firebrands start new fires.

US Forest Service





Parameterization Components



Firebrand Generation

1-Rate-of-spread

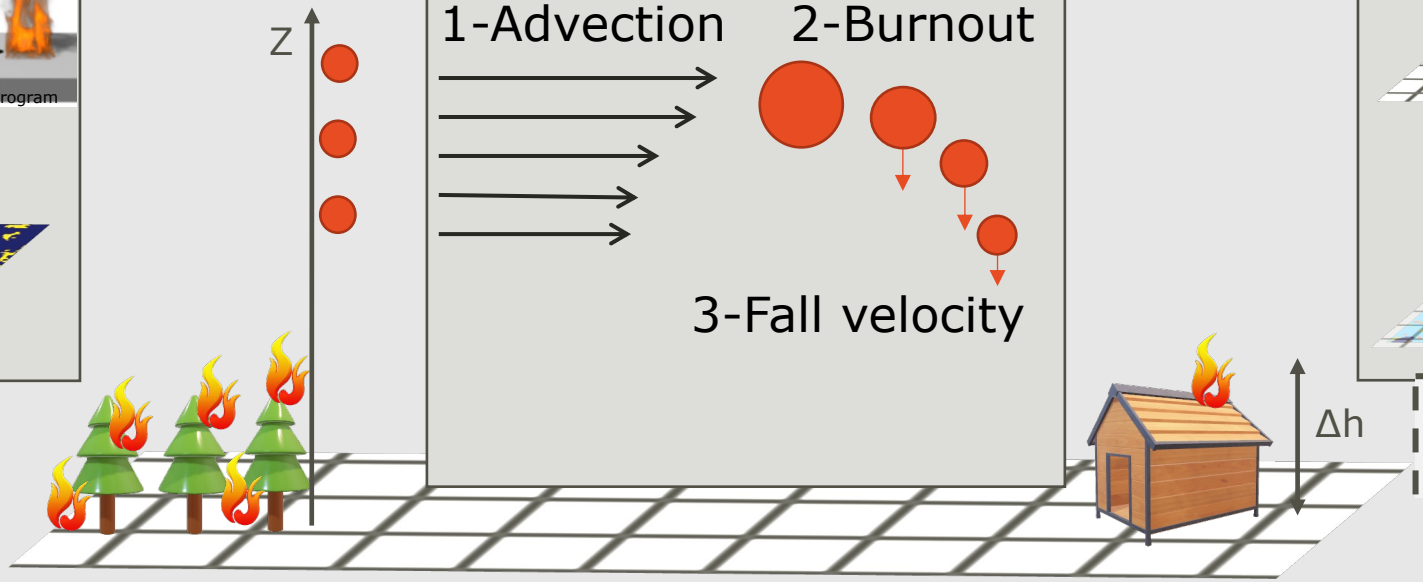
2-Fuel load [kg/m²]

Transport & Physics

1-Advection

2-Burnout

3-Fall velocity



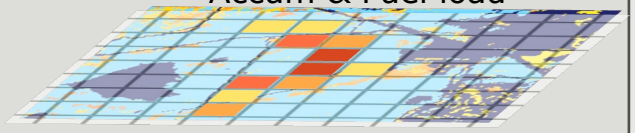
Landing

1-Accumulation

count or fraction per gridpoint

2-Spotting likelihood

Accum & Fuel load



3-Spot ignition

TBD funding dependent

Marshall Fire

Marshall fire: The Most Destructive in State History, 1084 homes destroyed and 149 damaged

" a perfect storm of fast winds and drought conditions as the combination of historically warm temperatures and low precipitation along the Front Range of the Rocky Mountains left the grasses in a state of extreme dryness"

R. Fovell et al. DOI:10.3390/atmos13050765

A pattern of unconsumed vegetation surrounding home destruction is typical of WU fire disasters

Jack Cohen and Dave Strohmaier, Wildfiretoday 2020

https://coloradosun.com/2022/01/06/marshall-fire-boulder-county-timeline/

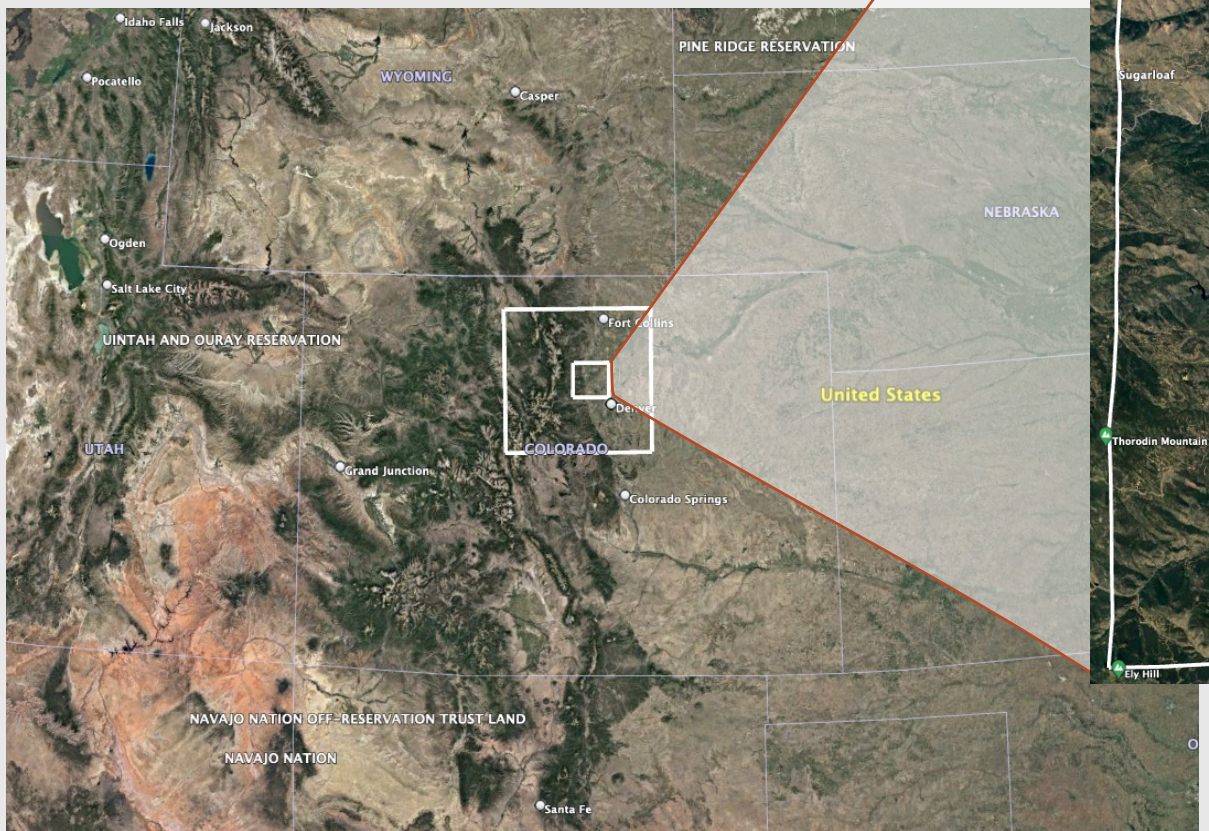
As structures are consumed, radiant and convective heat may ignite adjacent houses

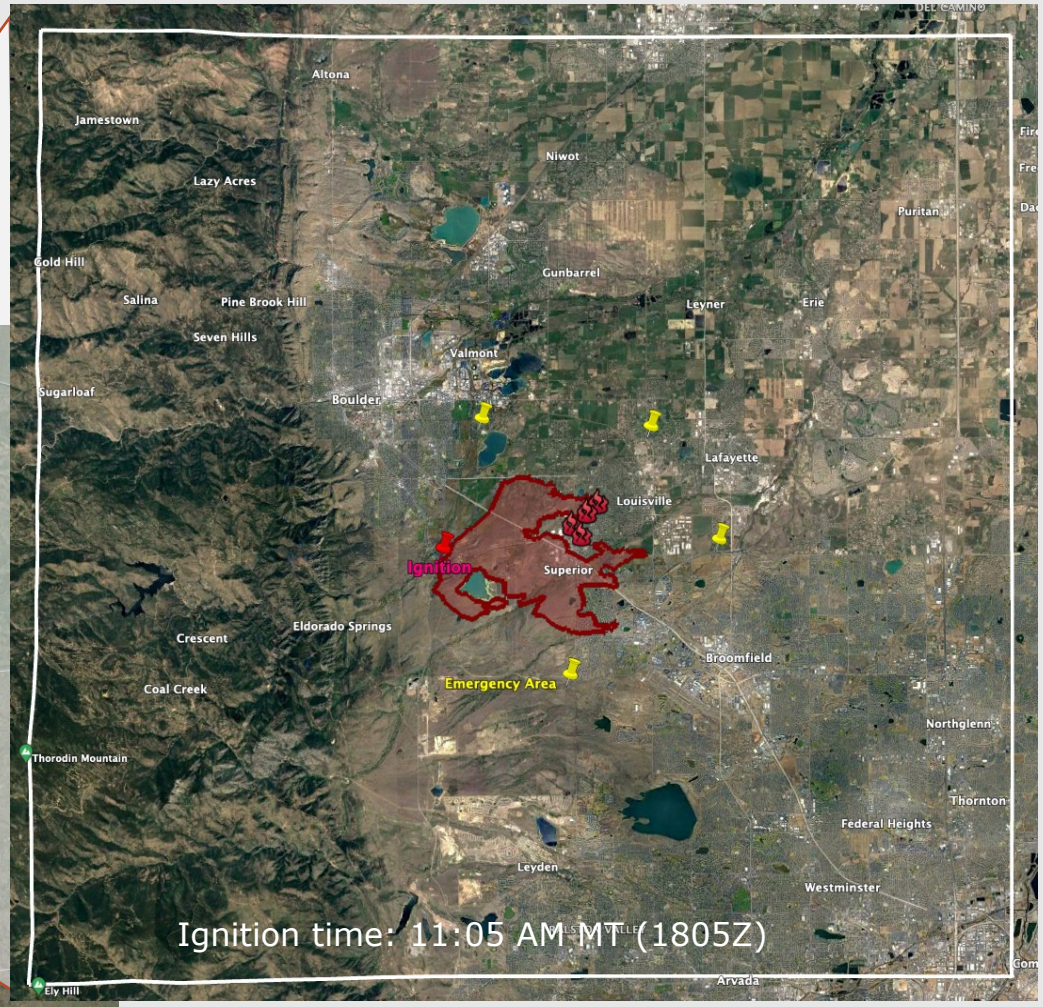
Whereas burning embers blown by the wind,
ignite spot fires near and far ahead when landing on flammable structures, leaf-filled gutters, vents, dry lawns, and mulch beds

Marshall Fire: Domains and Fire perimeter

WRF-Fire & firebrand spotting parameterization (WRF-ARW v4.4)

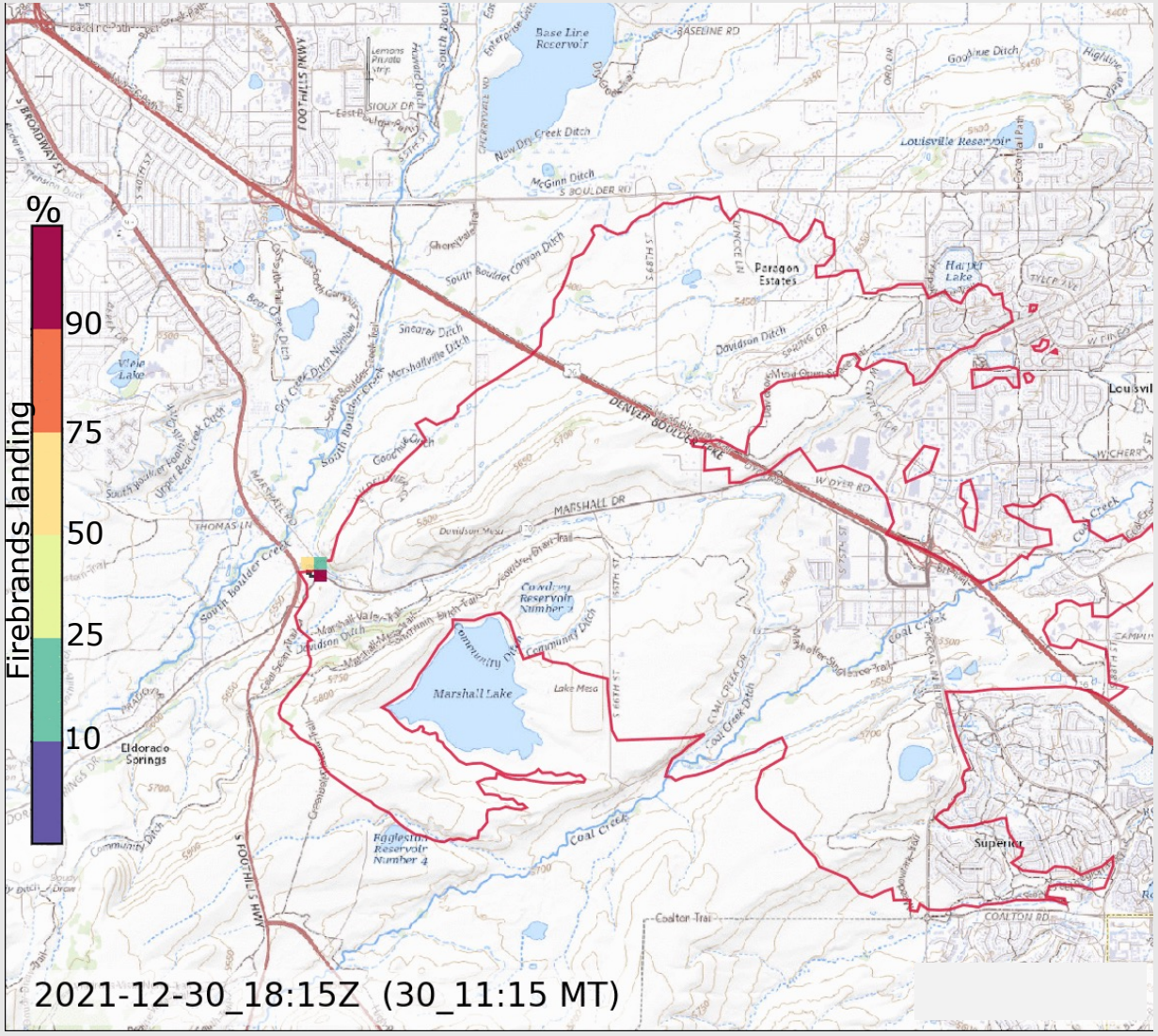
Meso-LES domain configuration:
D01: 1km + YSU PBL
D02: 111m + LES
Fire grid refinement = 4





Marshall Fire: Simulations

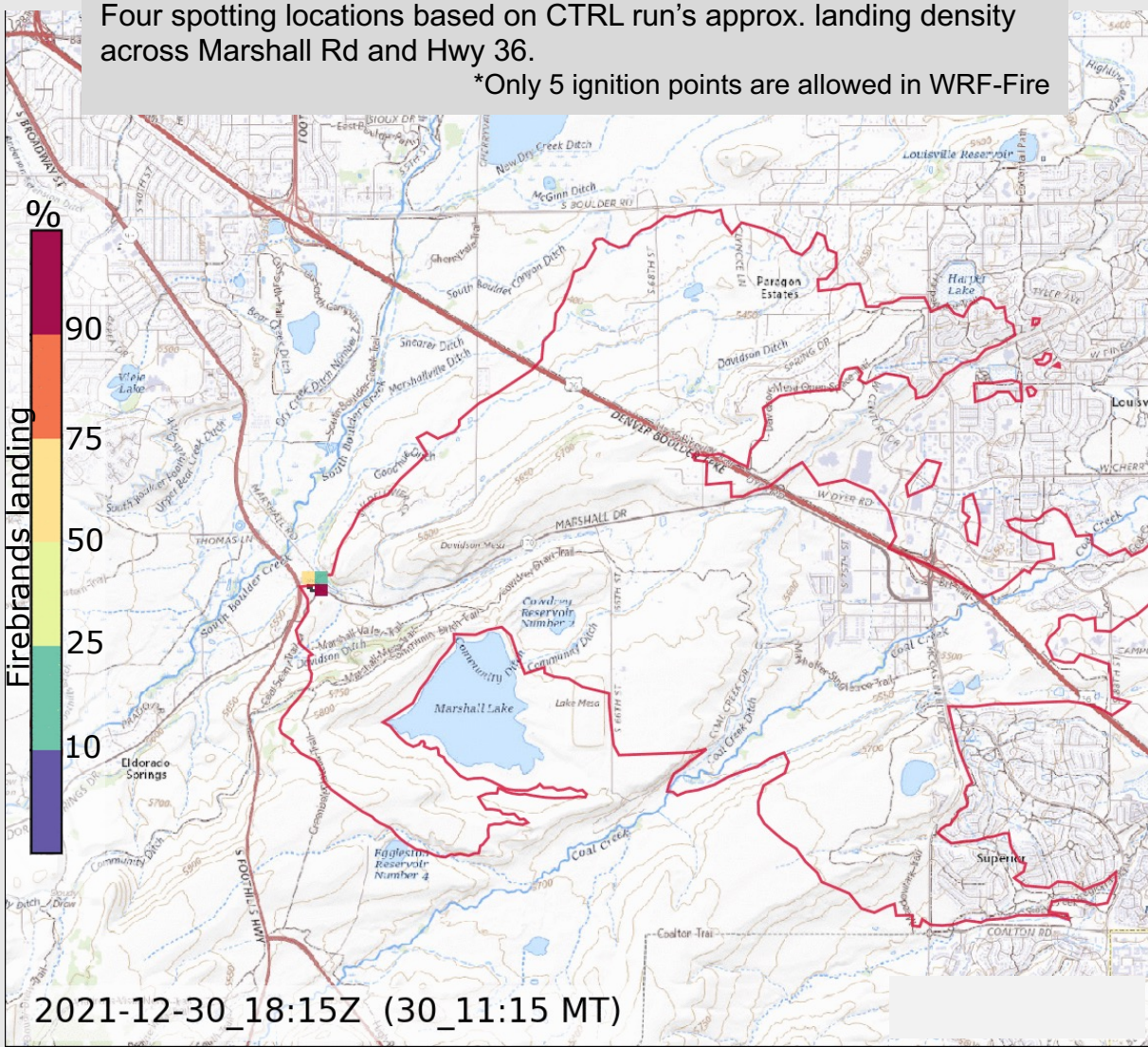
CTRL: No spotting



Manually ignited fire spots

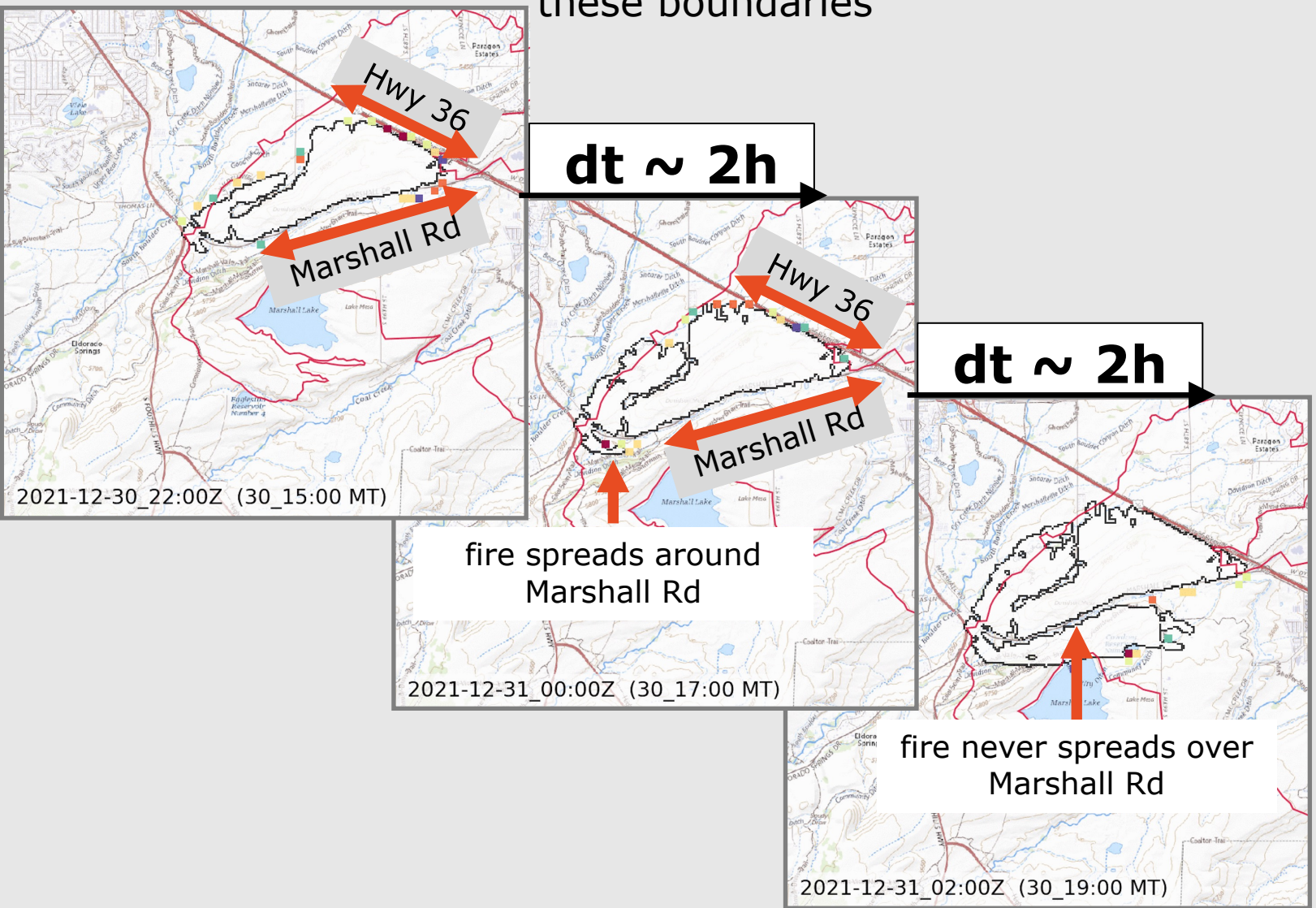
Four spotting locations based on CTRL run's approx. landing density across Marshall Rd and Hwy 36.

*Only 5 ignition points are allowed in WRF-Fire

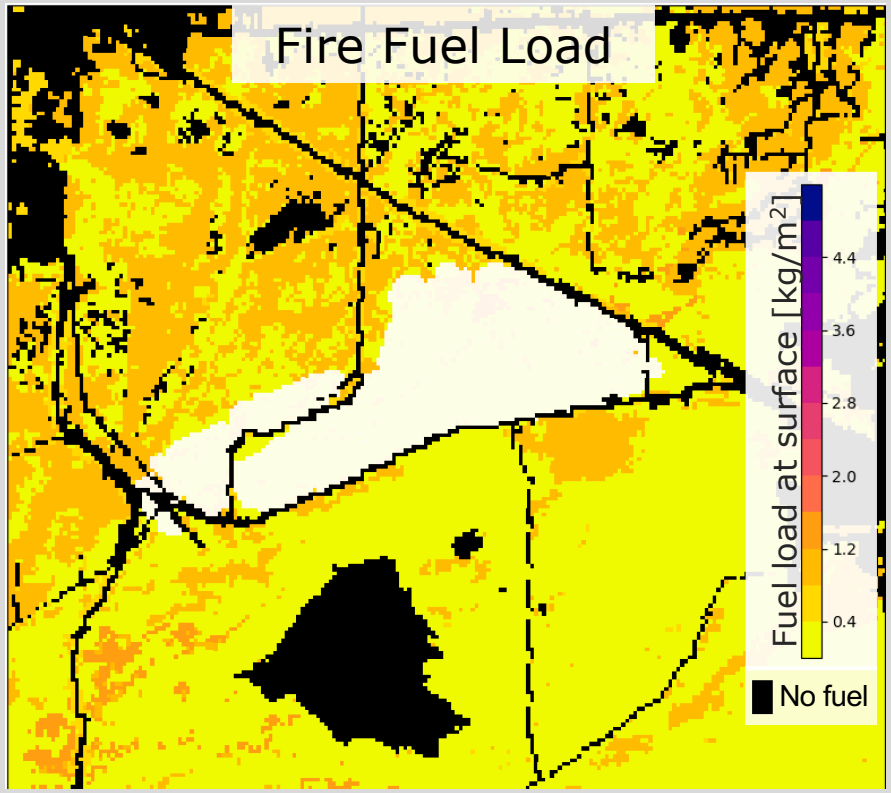


Spotting is critical for fire simulations

Fire reaches Marshall Rd and Hwy 36 and stays contained within these boundaries

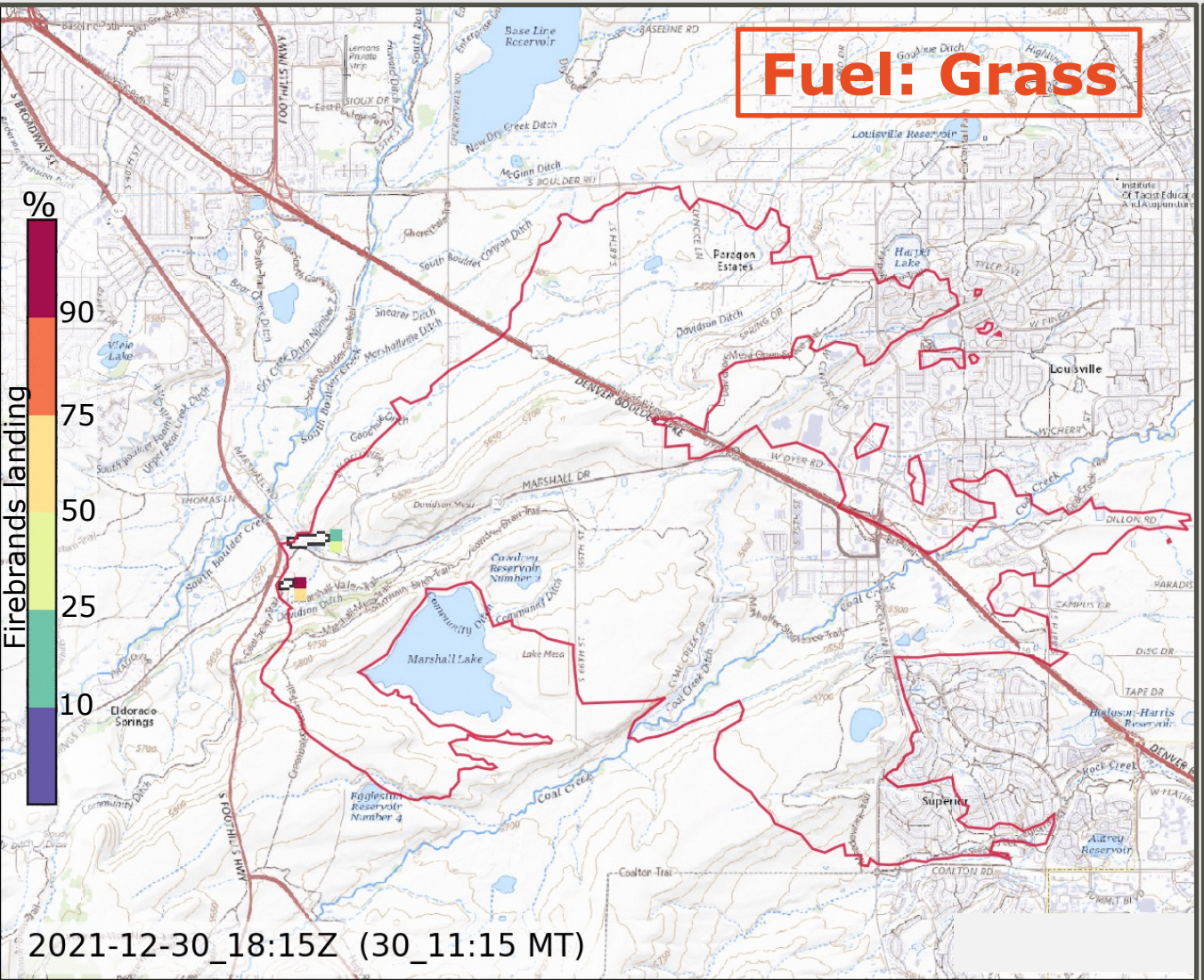


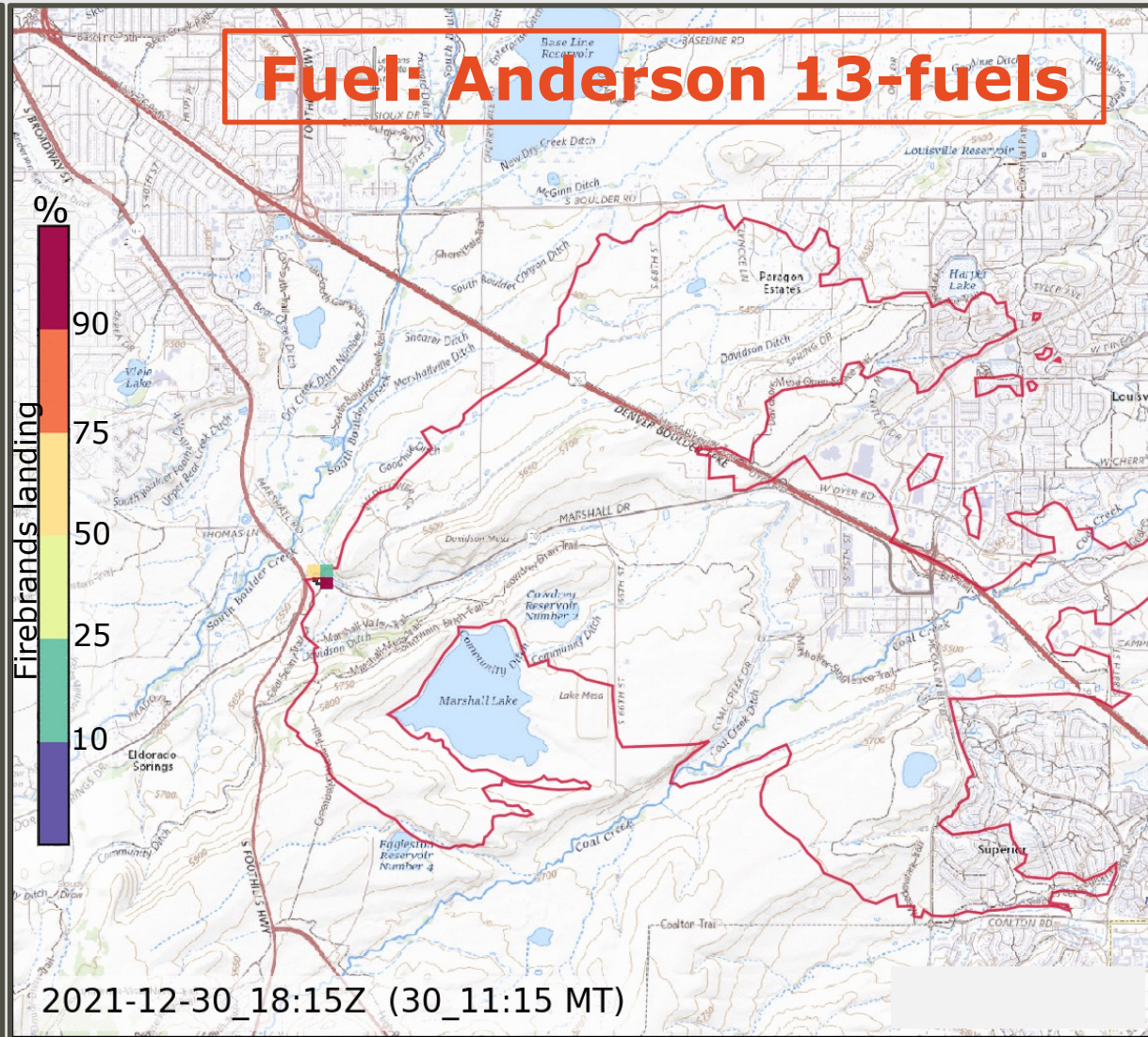
Certain surfaces (water, roads) do not provide fire fuel



Uniform fuels are not realistic

The temporary containment from roads and streams is a significant factor for fire behavior

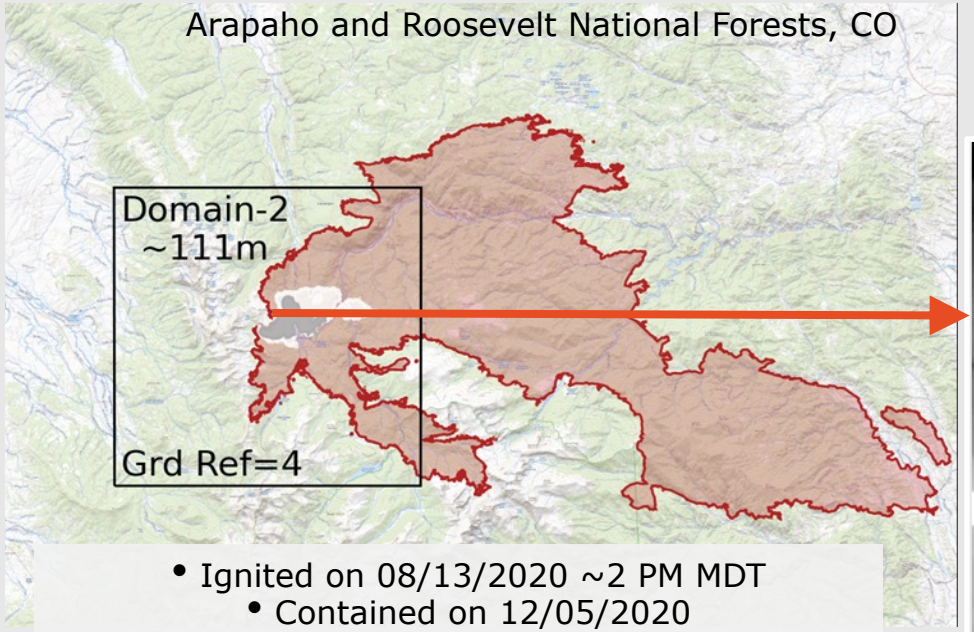




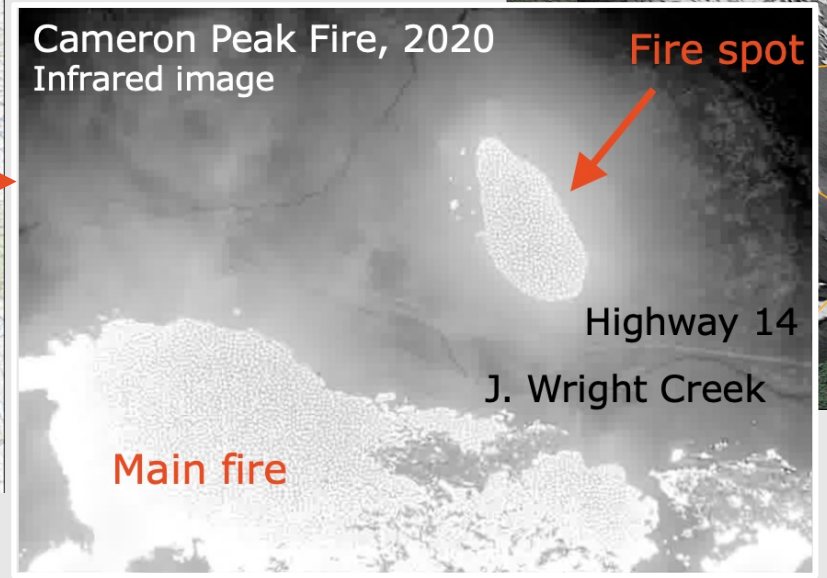
The Role of Fire Spotting in Wildfire Simulations

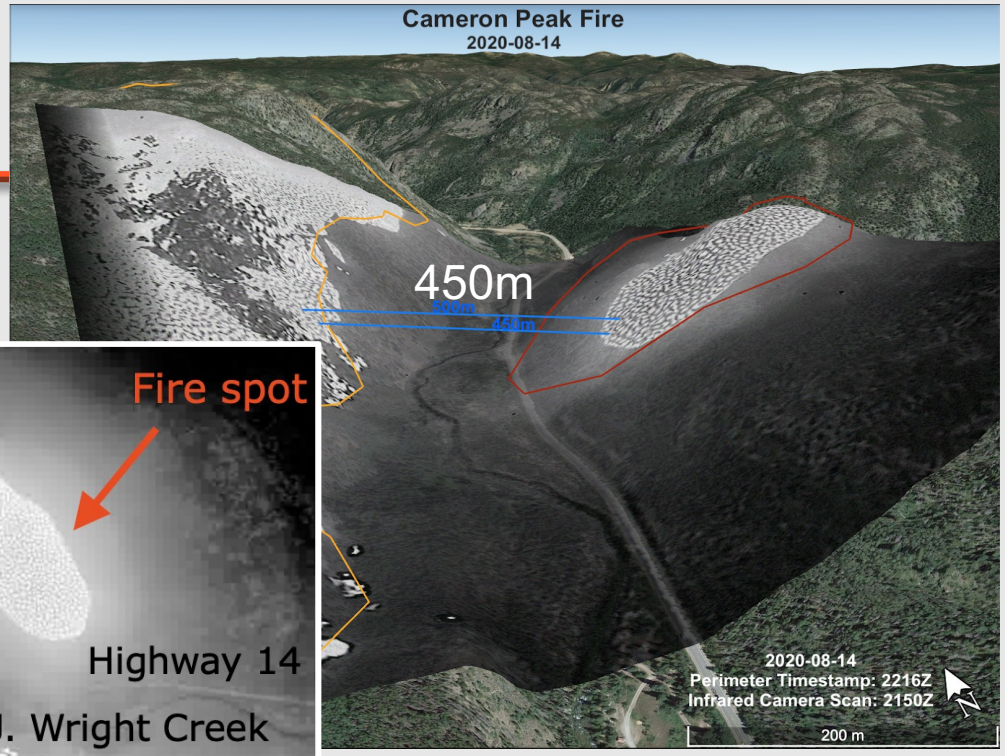
Typical wildland fires are different than the Marshall fire.
Yet, in high wind conditions, firebrands still contribute to increased rate of spread and fire spotting across containment barriers

Cameron Peak Fire



- Ignited on 08/13/2020 ~2 PM MDT
- Contained on 12/05/2020
- Estimated area of ~209K Acres

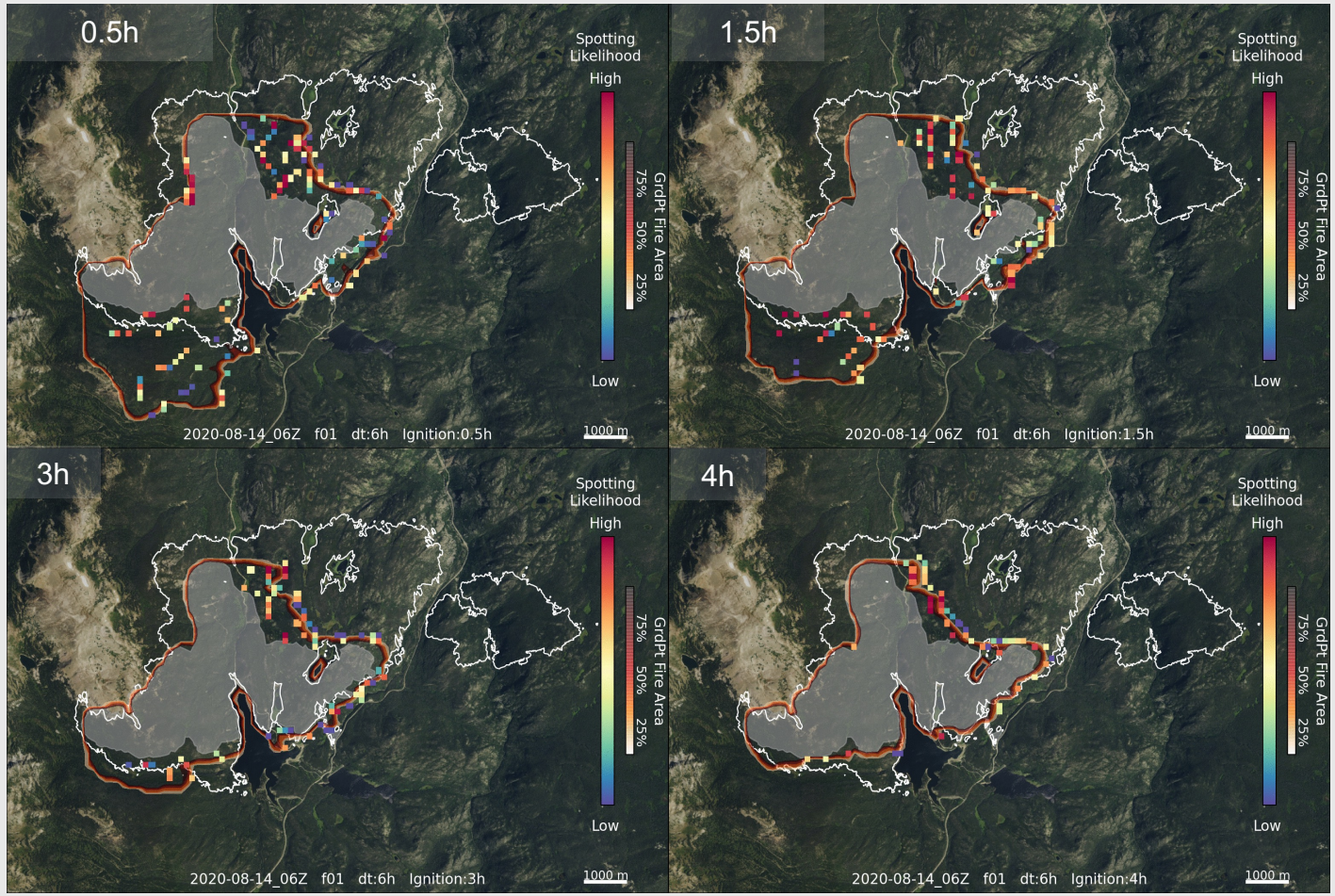


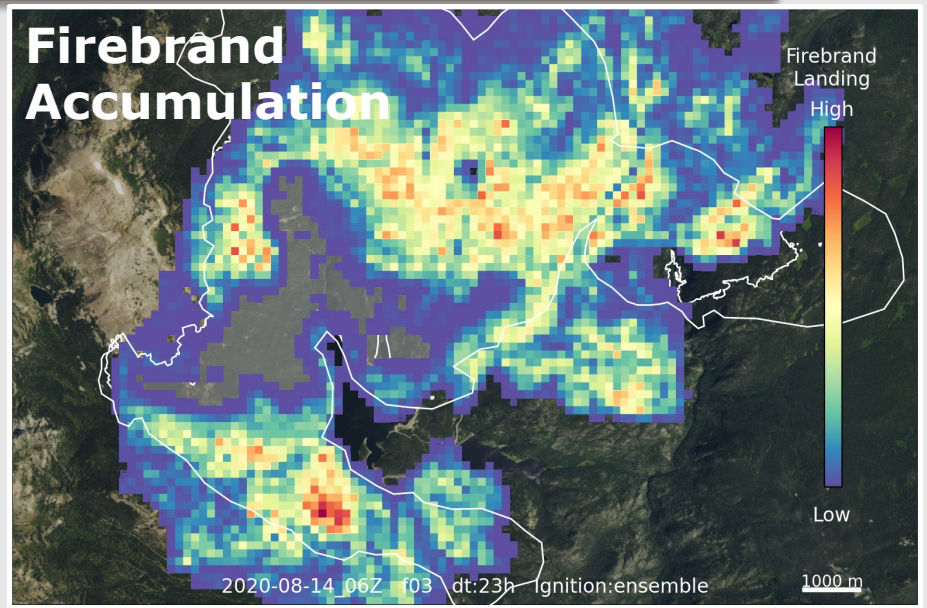


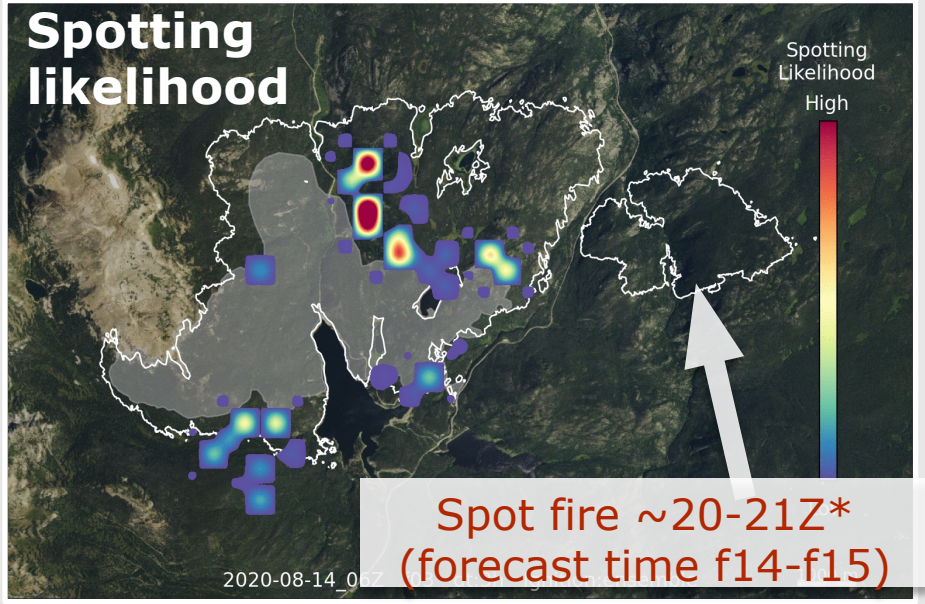
A spot fire was detected by satellites on 2020/08/14 at ~20Z (2 PM MDT), and recorded by the Multi-Mission Aircraft's Electro-Optical/Infrared camera system during a scan at 2150Z, indicating a spotting distance of at least 450m

Firebrand Accumulation & Spotting Likelihood ensemble

Spotting likelihood ensemble members



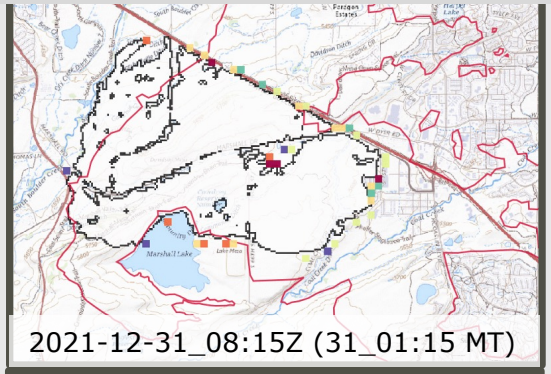


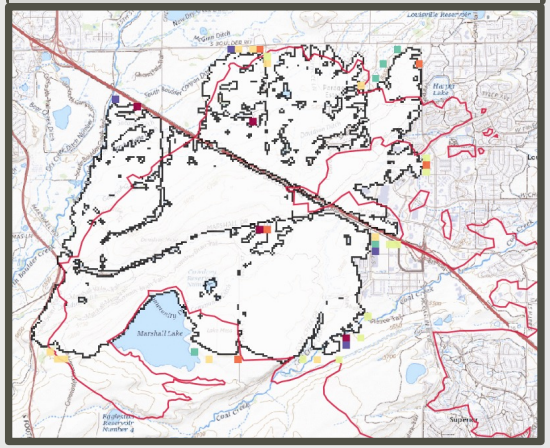


The Role of Fire Spotting in Wildfire Simulations

These fires illustrate the importance of modeling embers in fire simulations because it reveals **a critical model limitation**

No spot fire Ignitions!





- It is not feasible to run ensembles for urban fires and wildfires that may advance into urban zones
- It limits research advancement, for example:
  1. The Marshall fire is a strong case to investigate model errors and sources of uncertainty because there was no active fire suppression, which cannot yet be accounted for in the model
  2. It hinders efforts to develop urban fuels (representing residential areas), in that research using coupled simulations and ensembles would still encounter the no-fuel obstacle
  3. Ultimately, a significant component is missing: burning embers blown by the wind, ignite spot fires near and far ahead when landing on flammable structures and surfaces

Challenges

Model development challenges are mostly due to firebrand unknowns:

- Emission properties (size, mass, temperature)
- Burnout physics

Model verification challenges include:

- Uncertainties:
    - Atmospheric component (e.g. wind speed and direction)
    - Fire behavior processes
- Data scarcity and inconsistencies:
    - Fire spotting observations
    - Frequency and resolution of perimeters with reliable timestamps