Enhancing the Unified Forecast System Capabilities through Integration of a Coupled Fire- Atmosphere Model

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Motivation and Objective

- Wildland fires have significant socio-economic impacts
- Climate trends indicate an increase in intensity and frequency
- Accurate predictions crucial for aiding decision-makers
- Weather and atmospheric forcing are significant factors in determining the spread rate and intensity of fires
- Fire behavior models that balance realism in physical processes with computational efficiency can produce real-time forecasts
- UFS model lacks a dedicated fire behavior model

Objective: Implement a fire behavior model in the UFS

The WRF-Fire fire behavior model

Level set method tracks & propagates fire perimeter

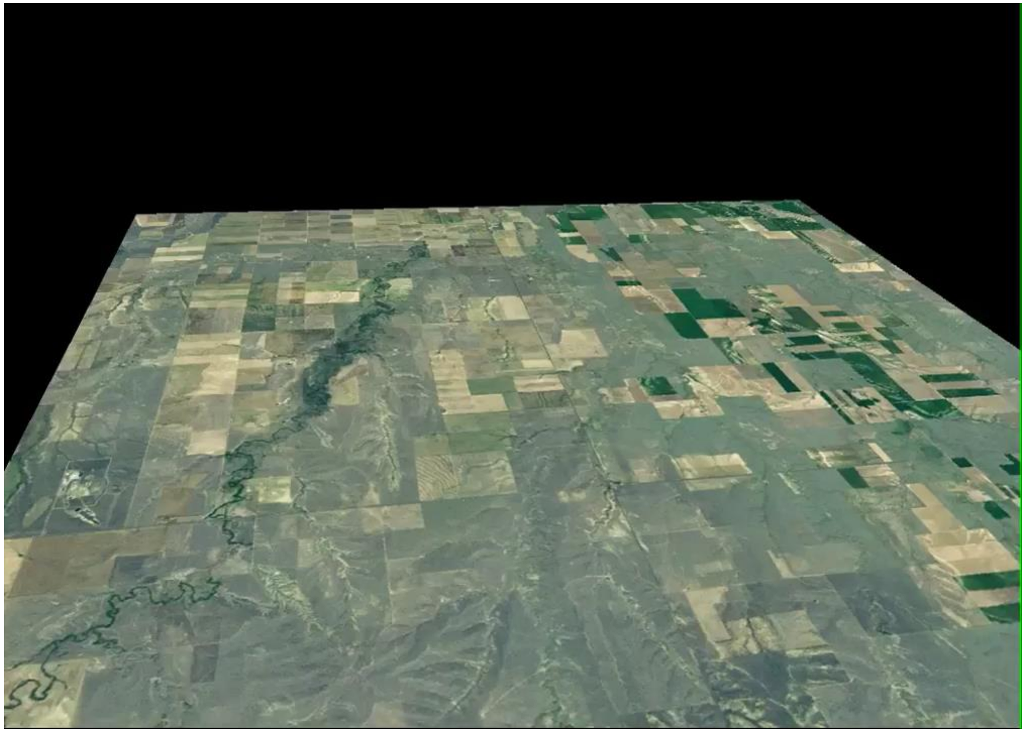
Rate of spread of flaming front is computed as function of fire-affected fuel, wind, and terrain slope using semi-empirical Rothermel's (1972) model

Fuel burn rate is based on laboratory experiments [Albini (1995)]

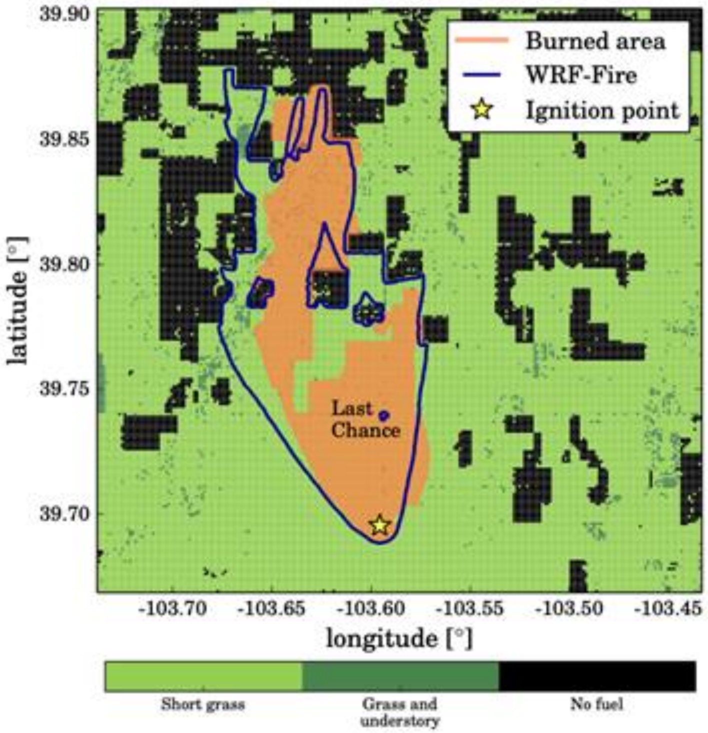
The flow in the atmosphere is influenced by fire through the release of **heat and water vapor fluxes** resulting from the burning of fuel (smoke currently a passive tracer)

WRF simulation of Last Chance Colorado, on June 25, 2012

- The animation shows both smoke concentration and burned areas
- More turbulence in the beginning due to daytime convection
- More confined smoke later in the day



- Modeled fire perimeter reveals good agreement with observation



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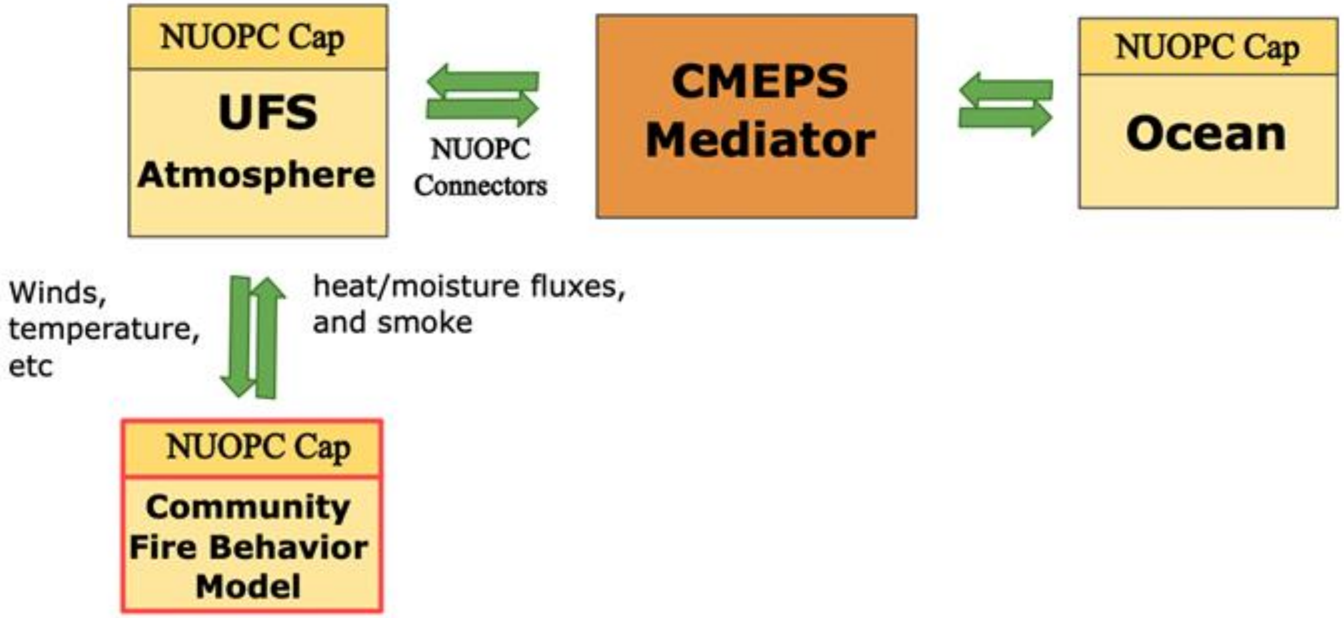
Simplified representation of the UFS to illustrate the coupling with the Community Fire Behavior Model NUOPC

- Earth System Modeling Framework (ESMF) libraries
- We added The Earth System Modeling eXecutable (ESMX) Layer
- A component of ESMF is NUOPC: National Unified Operational Prediction Capability



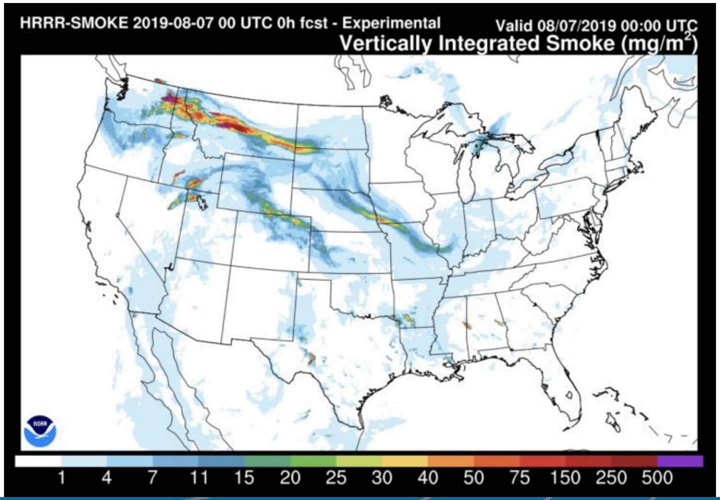
Project Tasks and Progress

- Eliminated WRF-Atmosphere dependencies in fire behavior code
- Developed one-way (atmosphere -> fire) stand alone fire-behavior model
- Implemented fire behavior NUOPC for both ESMF library and ESMX layer
- Continuous Integration (CI) workflows
- Independent fire domain

Coupling with the UFS

- Acquired knowledge of UFS fundamentals and how to run the workflow
- Integrated the fire behavior NUOPC with the UFS model. We are able to simulate the evolution of wildland fires with the UFS model (one way coupling)
- Two-way coupling with the FV3:
  - Heat and moisture
  - Smoke (tracer)

CCPP->RRFS_SD wrapper

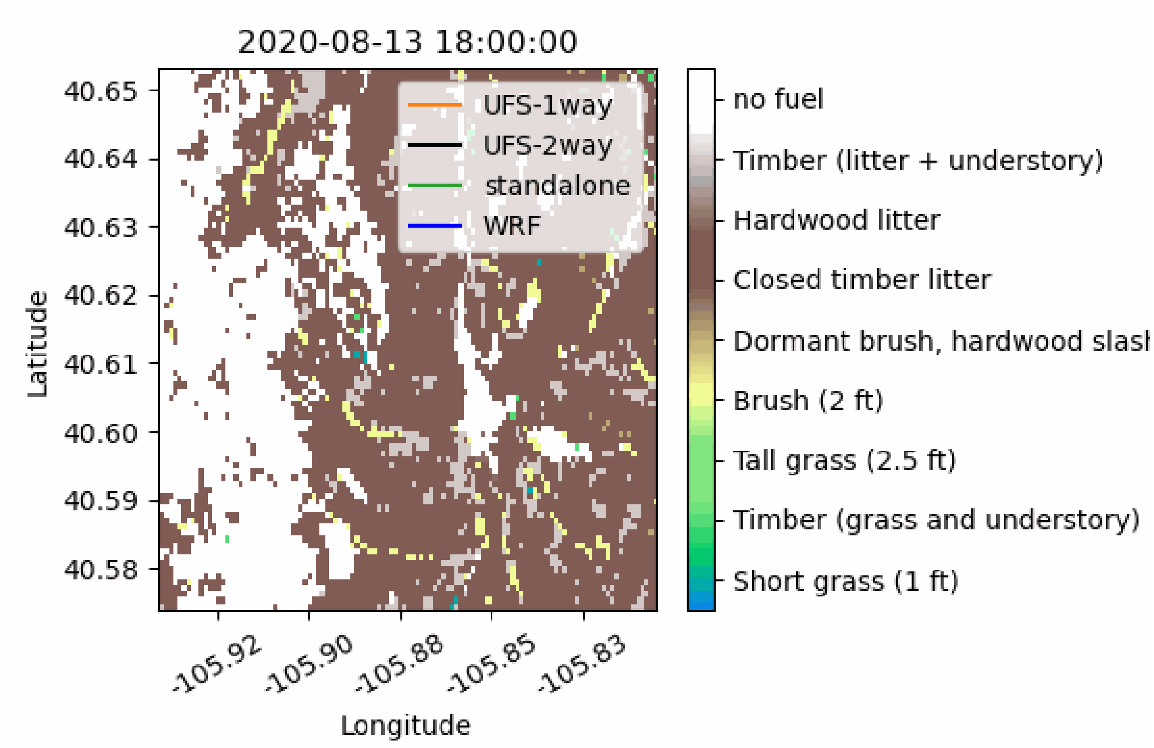


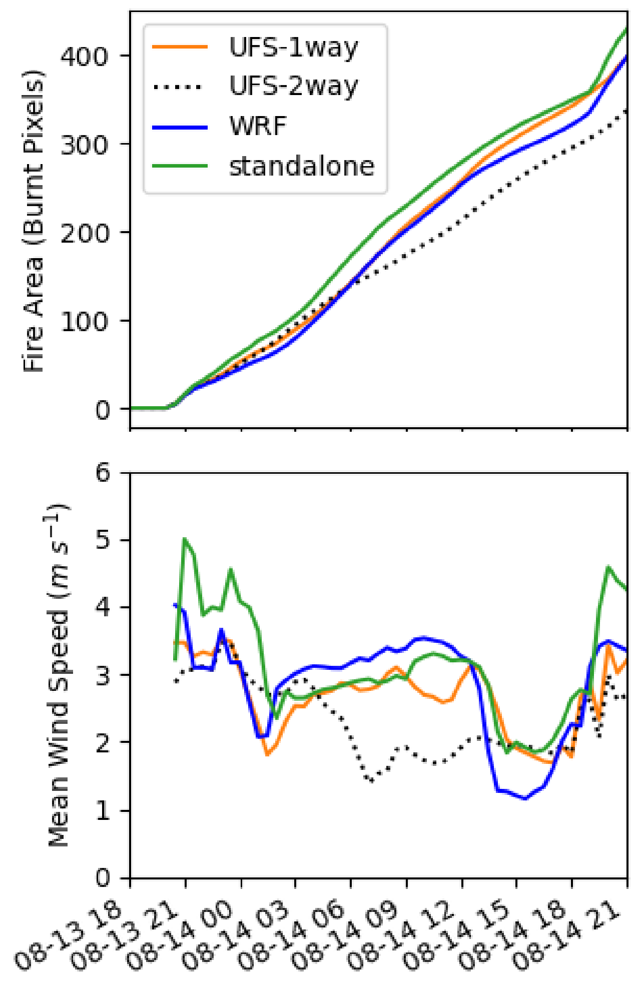
Case Studies and Workflow

- Configured UFS to simulate specific wildland fires ("Cameron Peak" and "Last Chance")
  - Cameron Peak: uses HRRR initial and boundary conditions
  - Last Chance: requires merging GFS and RAP
- Developed a user-friendly workflow for running the “Cameron Peak” case

Comparison of WRF-Fire, offline fire behavior model and UFS-FV3 driven model (1- and 2-way)

WRF-Fire and fire behavior model driven by WRF and UFS Cameron Peak Fire





Webpage for the Community Fire Behavior Model

The Community Fire Behavior Model

Simulating the Evolution of Wildland Fires

CONTENTS

- Overview
- Documentation
- UFS Implementation

https://ral.ucar.edu/model/community-fire-behavior-model

Summary and Future Steps

- Complete first prototype and the pull request to CCPP, FV3 and UFS weather model (In progress)
- Add refinements and testing to ensure proper implementation before the public release (In progress)
- Add initialization from fire perimeter (In progress)
- Currently the fire behavior is serial and we want to implement parallel processing capabilities

- See our website for updates:
https://ral.ucar.edu/model/community-fire-behavior-model

Questions? PI Email: jimenez@ucar.edu