DEPARTMENT OF METEOROLOGY
UNIVERSITY OF UTAH

Air pollution forecasting by coupled atmosphere-fire model WRF and SFIRE with WRF-Chem

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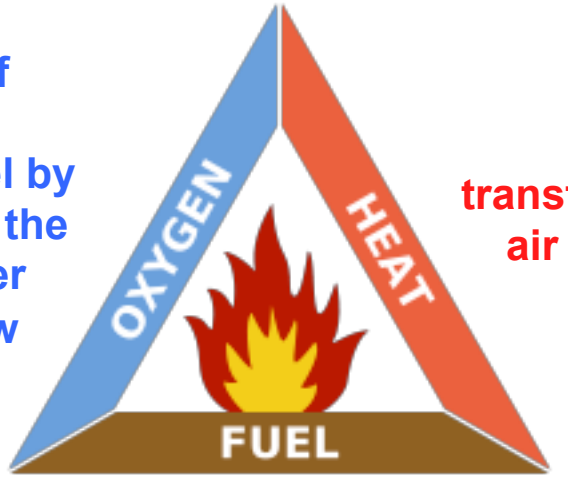
Motivations

- Forecasting of emissions from prescribed and wildland fires
- Investigation of the impact of fire emissions on air quality
- Forecasting of transport and dispersion of fire smoke
- Forecasting of air quality impact of secondary pollutants generated from fire emissions
- Investigation of the interaction between the fire and the atmosphere

Fire-Atmosphere interactions

- Strong convective updrafts generated by heat released by fires modifies the surface flow which in turns drives the fire propagation.
- Atmospheric conditions controls fuel moisture content that affects flammability, fire spread and fire intensity
- Atmospheric flow:

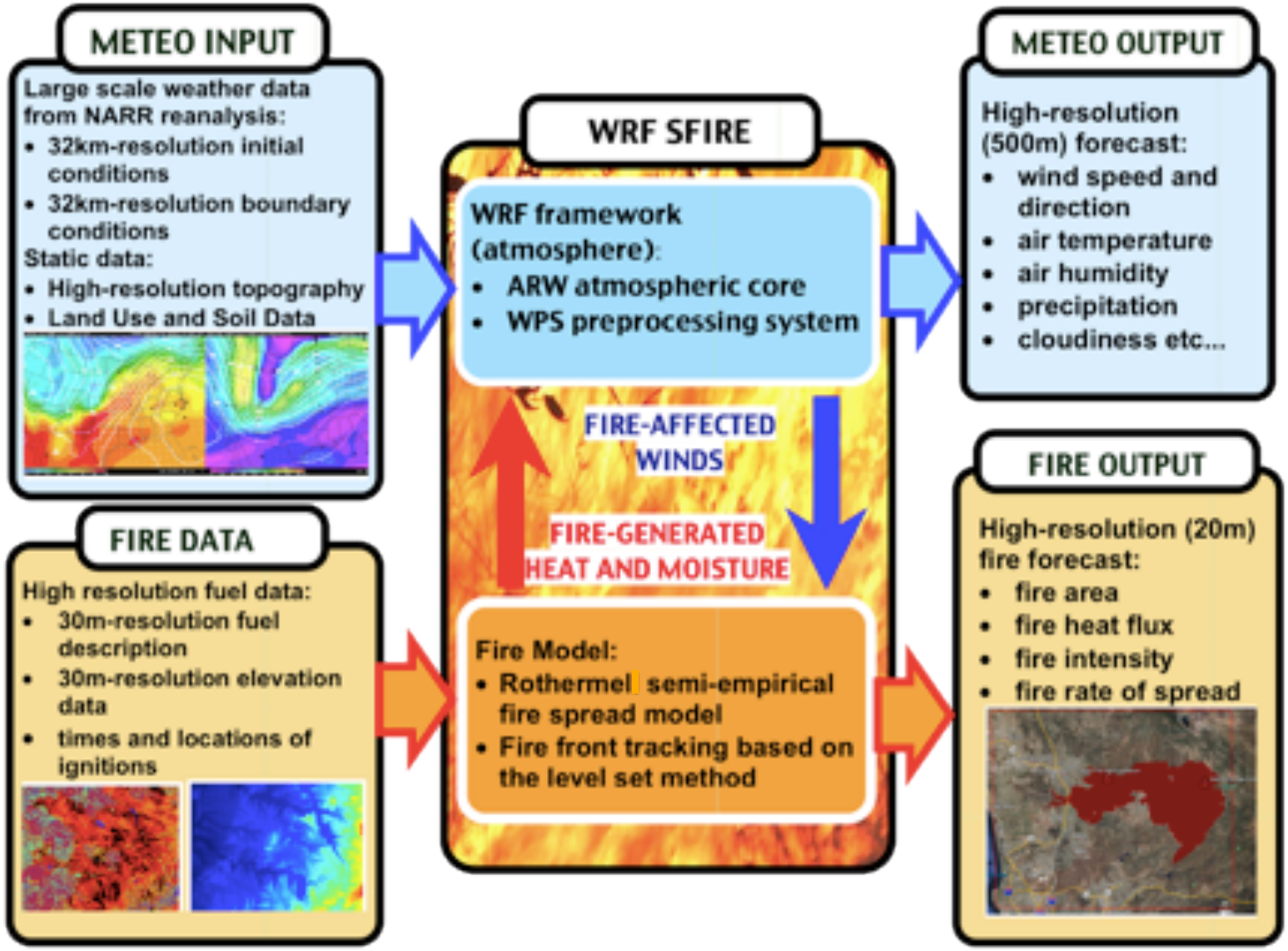
Enhances transport of oxygen from the atmosphere to the fuel by reducing the depth of the laminar boundary layer formed during the flow around fuel elements



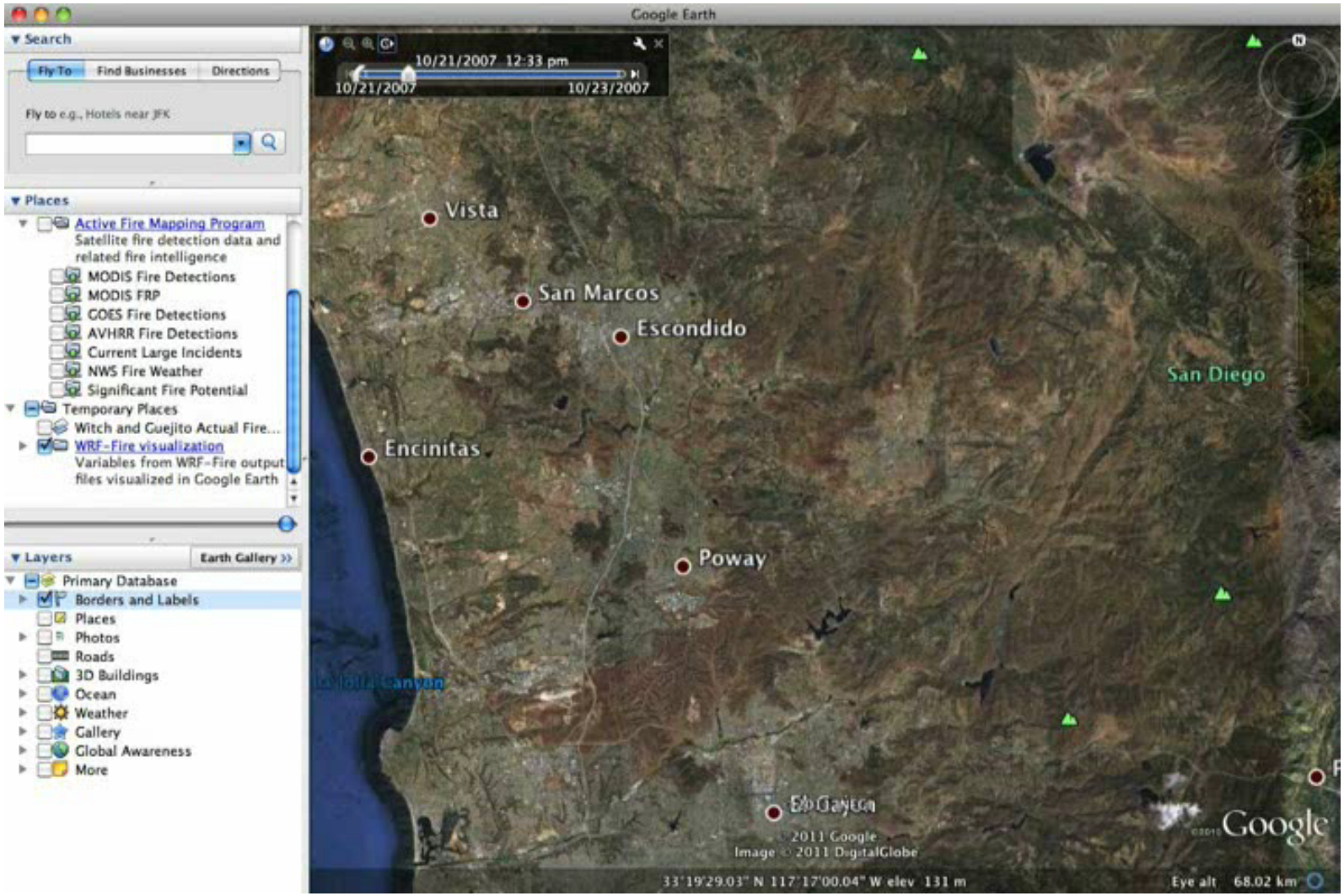
Intensifies heat transfer from the hot air to the fuel (pre-heating)

Increases rate of mass (moisture) transfer from fuel to the atmosphere (drying out of fuels)

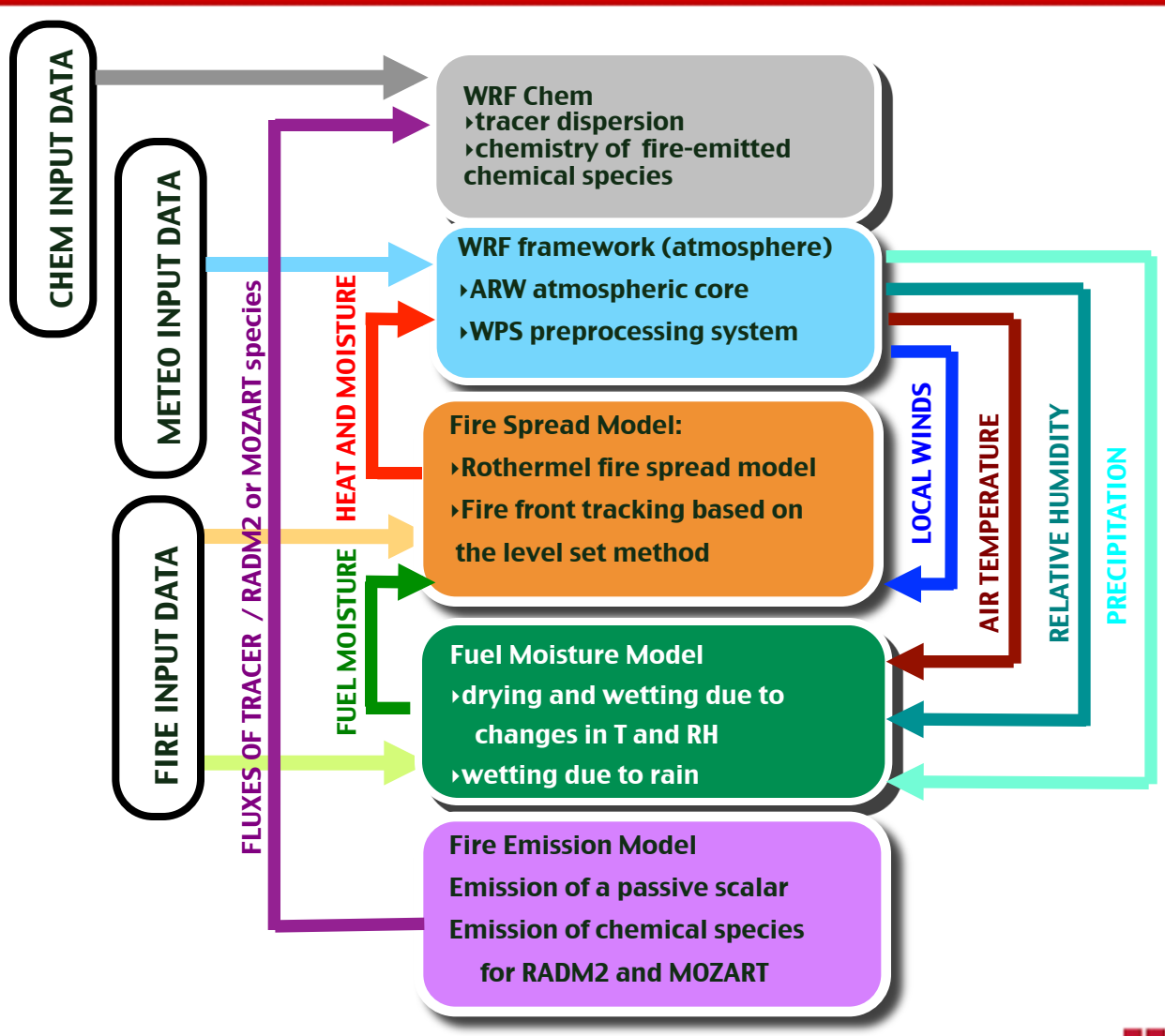
Modeling of Fire-Atmosphere interactions WRF-Sfire



Numerical fire spread modeling using WRF-Sfire



Modeling of Fire-Atmosphere interactions WRF-Sfire + Moisture + WRF-Chem



METEO OUTPUT

Standard weather forecast
- ›wind speed and direction
- ›air temperature
- ›air humidity
- ›precipitation
- ›cloudiness etc...

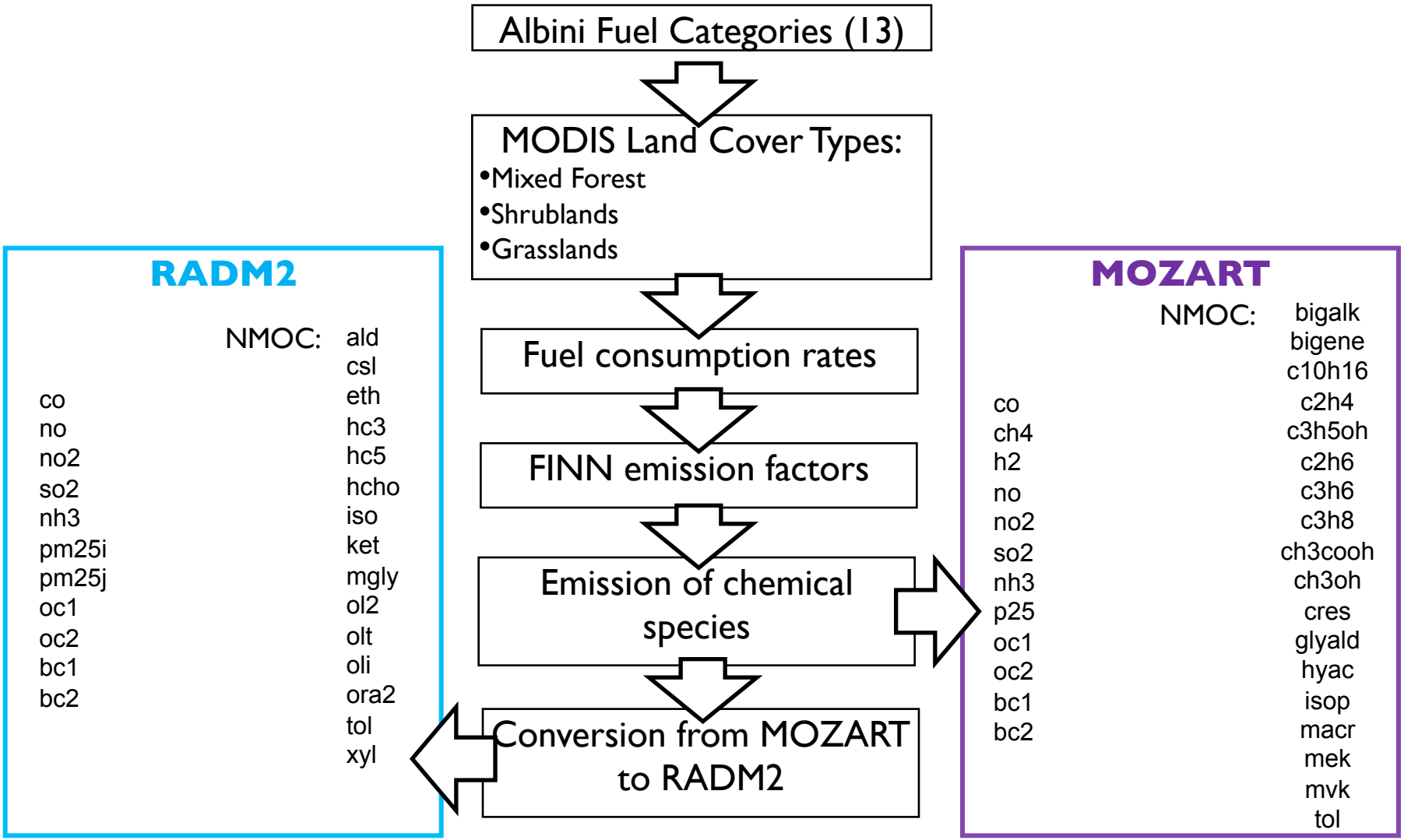
CHEM OUTPUT

Wildland fire emissions and air quality forecast:
- ›smoke (tracer concentration)
- ›concentration of: RADM2/ MOZART species
- ›concentration of secondary pollutants (O_3 etc)

FIRE OUTPUT

High-resolution fire forecast:
- ›fire area
- ›fire heat flux
- ›fire intensity
- ›fire rate of spread
- ›fuel moisture

Estimation of fire emissions



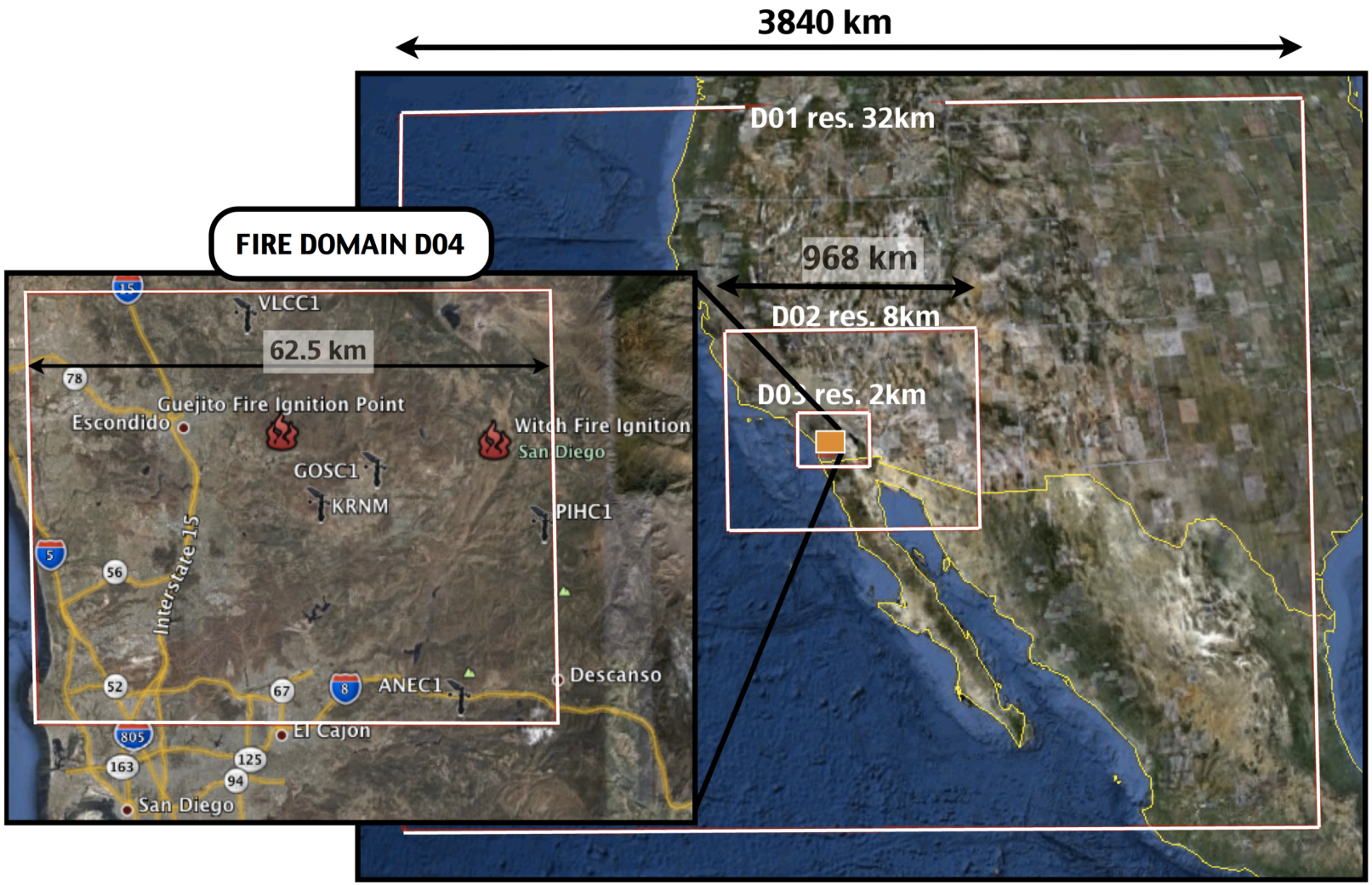
Real setup for Santa Ana fire simulation

Model Setup:

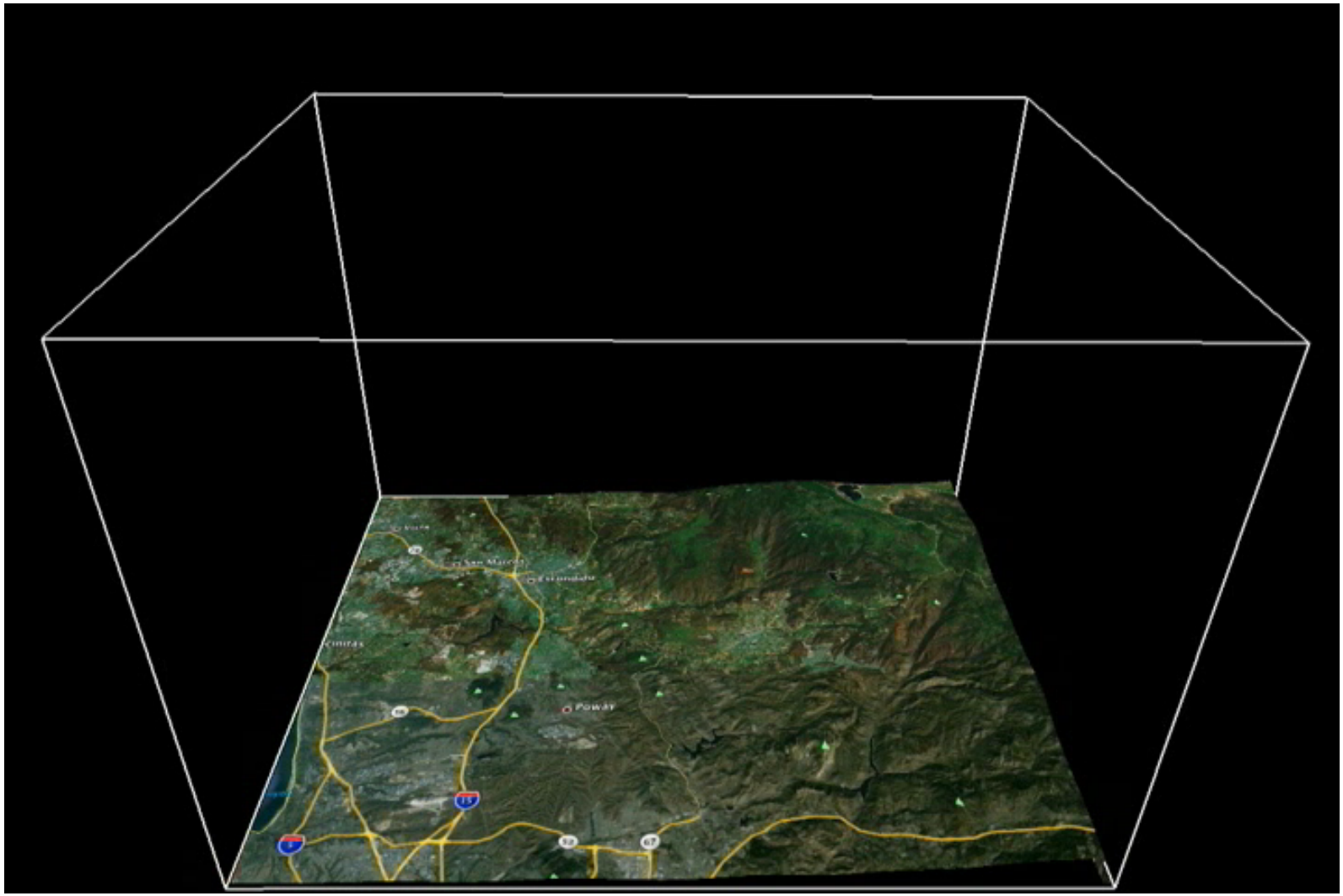
- Santa Ana event is a multiscale problem. We have to cover an area large enough to capture the large-scale synoptic pattern driving this event (High over Northern Nevada), but ultimately we need to resolve small-scale local flow near the fire.

- In order to accomplish that we use the nested setup with 4 domains:
  - D01 120x96 32km resolution
  - D02 121x97 8km resolution
  - D03 137x105 2km resolution
  - D04 185x165 500m resolution

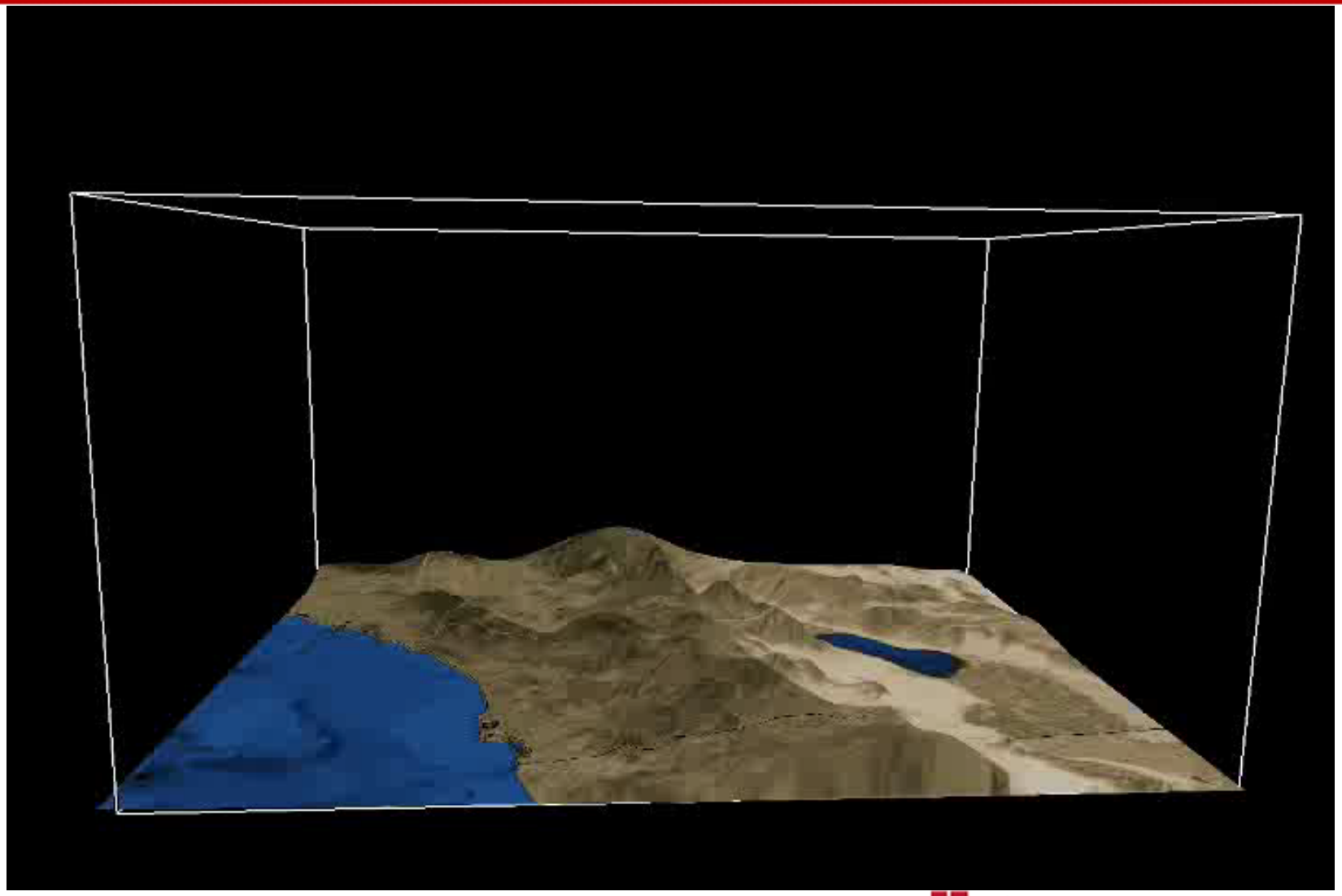
Multi-scale setup for Santa Ana fire simulation



Simulation of smoke emissions from 2007 Santa Ana fires (Witch and Guejito) 444m



Simulation of smoke emissions from 2007 Santa Ana fires (Witch and Guejito) 1.33km

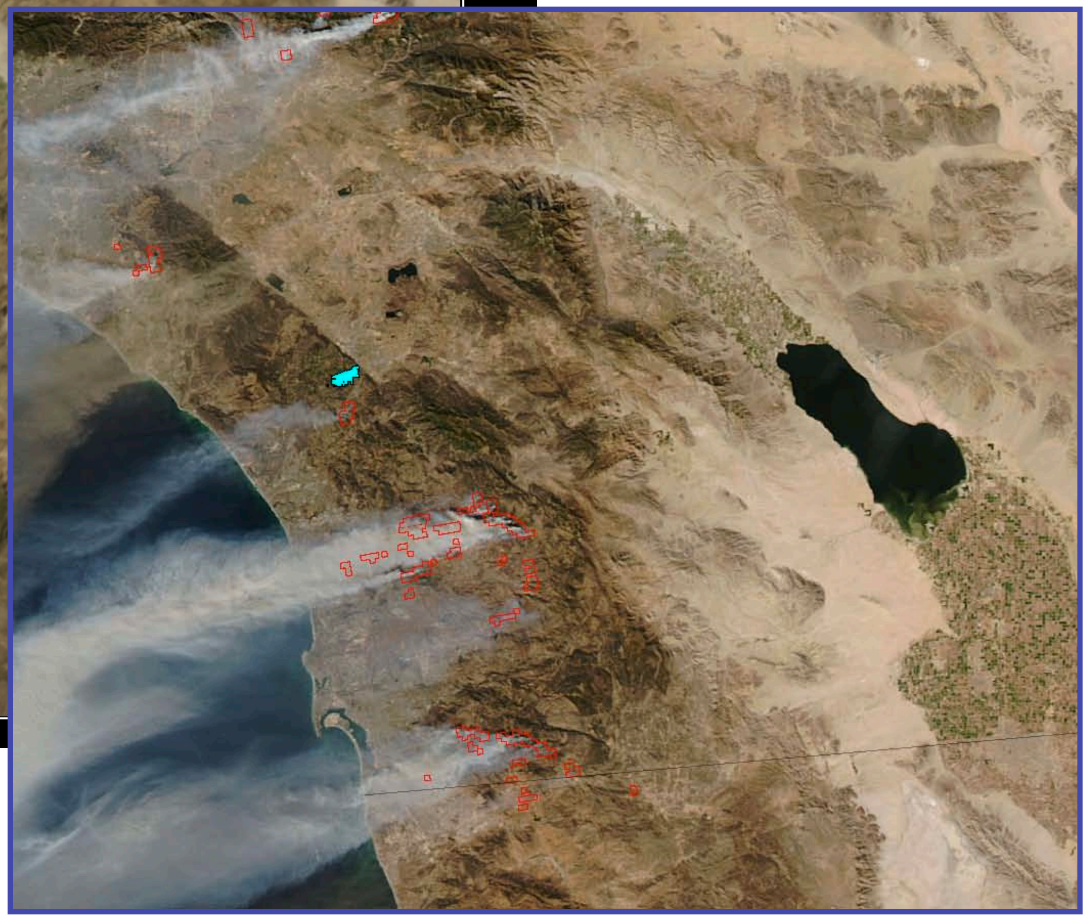


Simulation of smoke emissions from 2007 Santa Ana fires (Witch and Guejito) 1.33km

Simulated smoke emission from 2007 Santa Ana fires – WRF-Sfire vs. MODIS

WRF-Sfire 1.33km

MODIS



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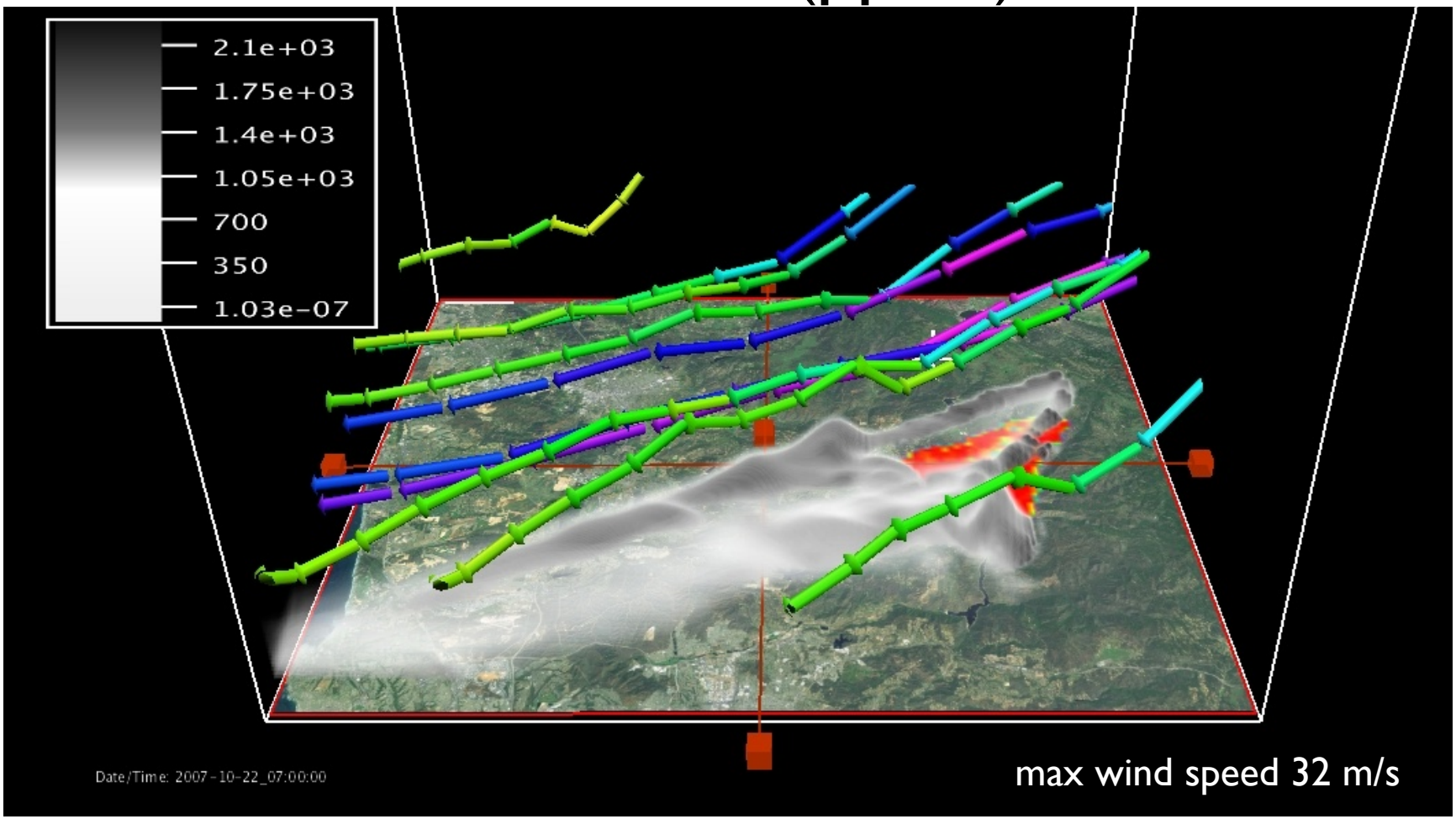
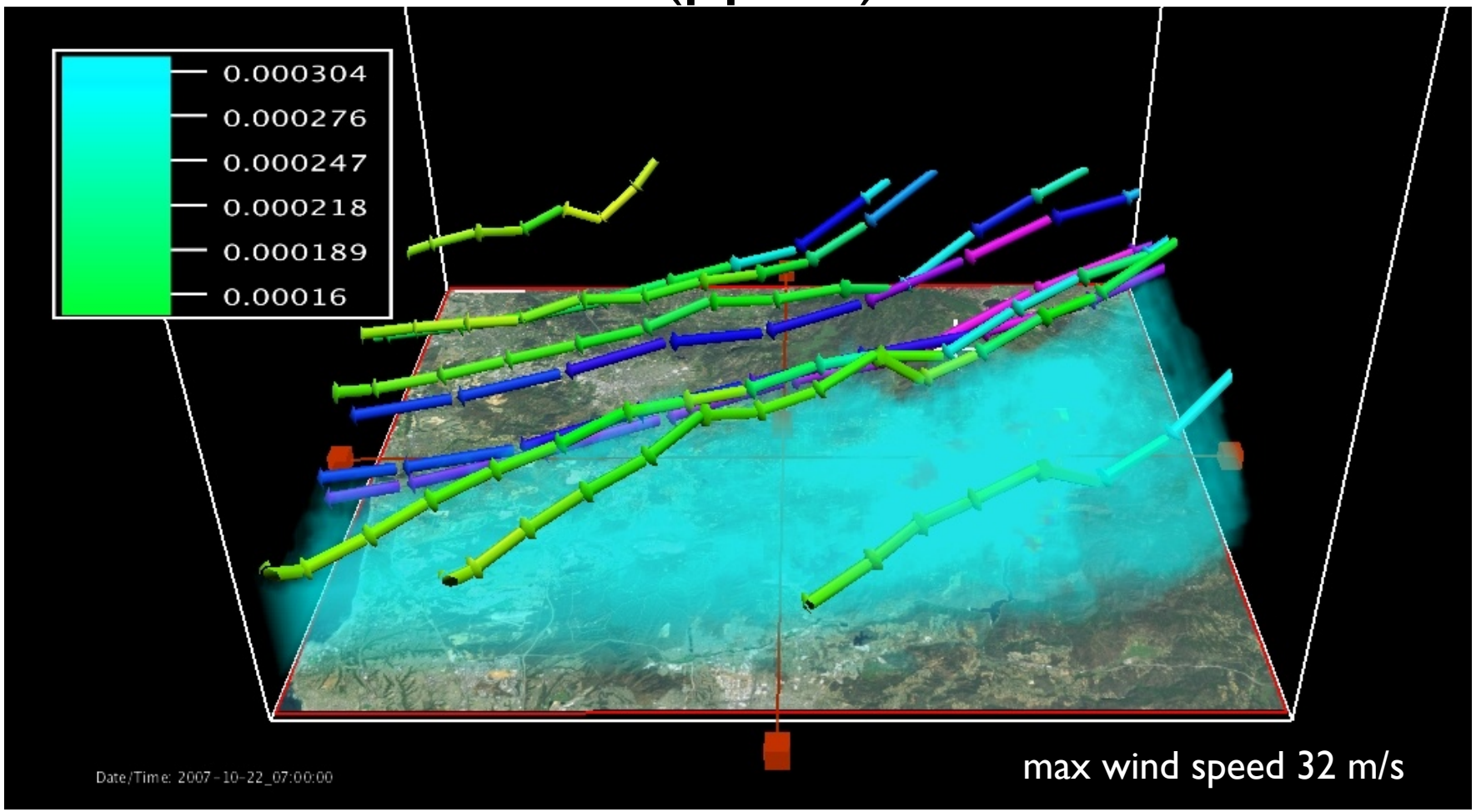
Simulated CO emission from Witch fire (one of 2007 Santa Ana fires)

Fire CO concentration (ppmv)



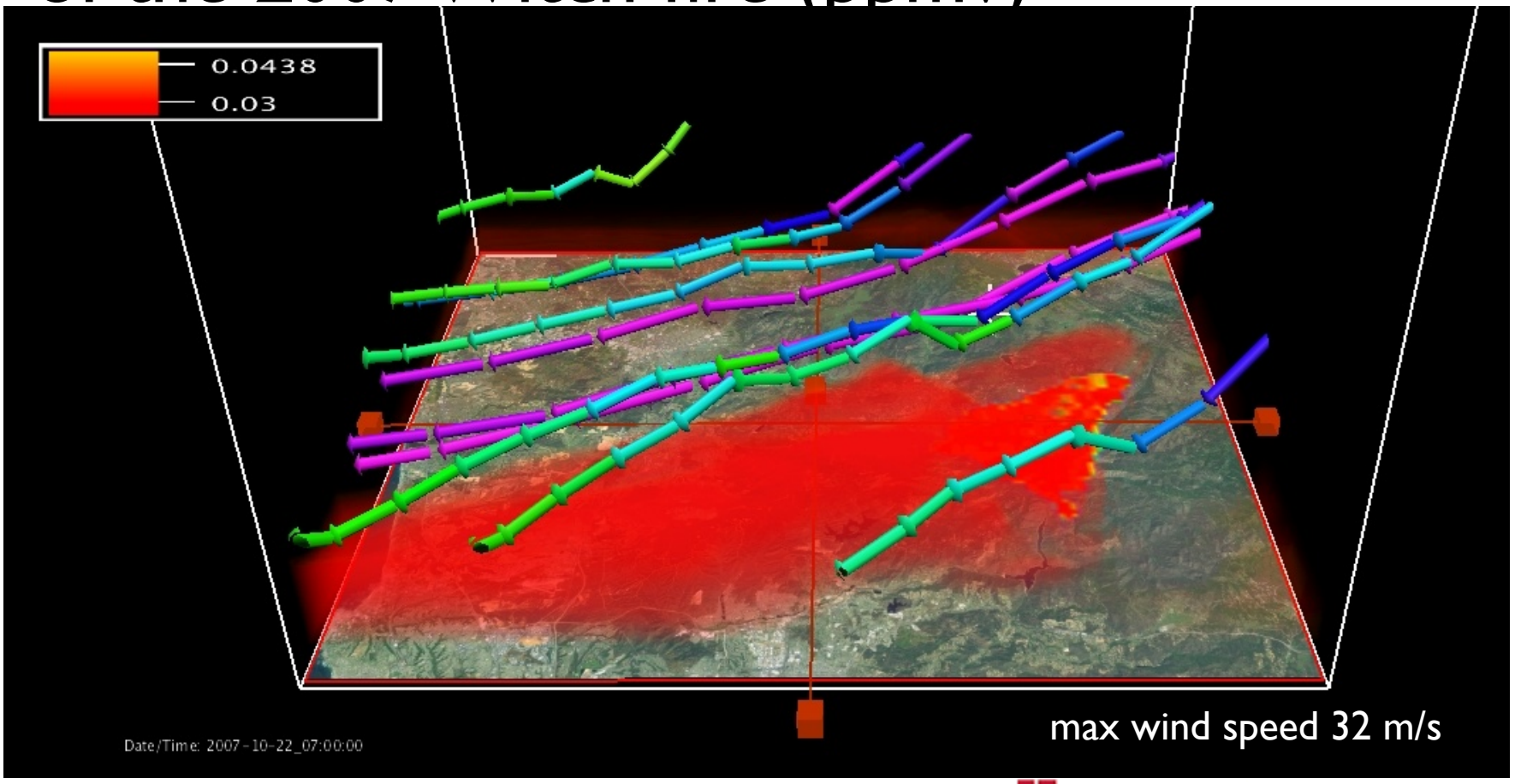
Simulated NO_2 emission from Witch fire (one of 2007 Santa Ana fires)

Fire NO_2 emission (ppmv)



Simulated increase in O_3 concentration associated with Witch Fire

Elevated ozone concentrations in the wake of the 2007 Witch fire (ppmv)



Summary

- New capabilities have been added to WRF-Sfire, but not validated yet:
  - fire smoke emission and dispersion - tracer
  - more detailed emission and dispersion of aerosols and chemical species
- The current way of defining emissions though the FINN global emission factors is very crude
- The conversion between the fire behavior classes and land use classes may introduce additional errors
- More detailed emission factors, with fuel characteristics are needed for a realistic estimation of actual fire emissions, if anyone has estimated emission factors and would be interested in collaboration please let me know at adam.kochanski@utah.edu
- Since the model aims to capture, fire intensity, fire-induced winds, fire heat release, injection height and the emissions. The perfect validation dataset would contain in-situ simultaneous measurements of the fire and plume properties, as well as the chemical fluxes.

Thank You

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