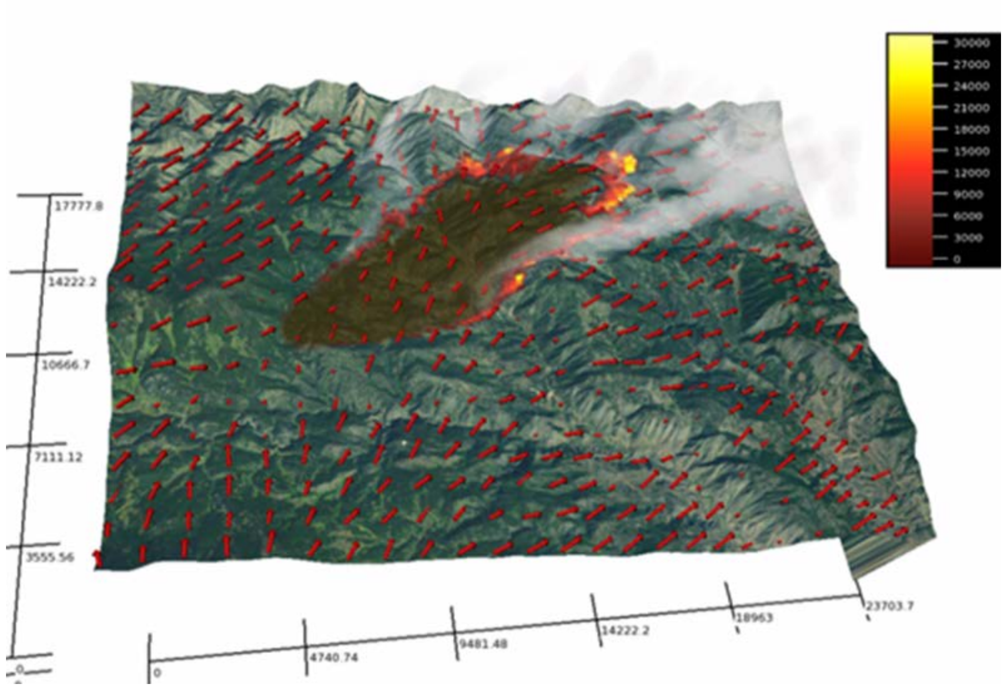
Colorado Decision Support System for Prediction of Wildland Fire Weather, Fire Behavior, and Aircraft Hazards



Stakeholder Meeting #2
26 January 2016
CoE, Rifle, CO

Introduction of research comparing CAWFE® accuracy to current decision support systems

Dr. Janice Coen, Project Scientist

Presented by:

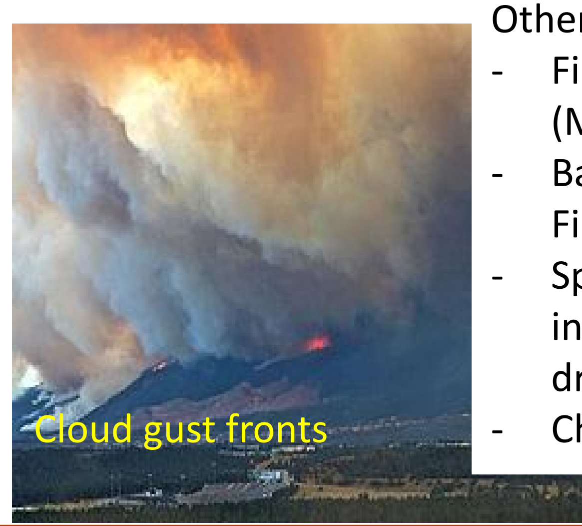
Bill Mahoney, Deputy Director, Research Applications Laboratory

Status of operational fire behavior models

- Weather is the wildcard in a wildland fire event.
- Current models (FARSITE, NTFB, FSPro) similarly:
  - Estimate how fast the leading edge of the fire will spread, based on effects of wind speed, terrain, & fuel properties or fire spread probability
  - Use station measurements, simple approximations, or coarse weather forecast grids (e.g., 5-km NDFD grids)
  - Frequently require calibrating inputs to capture observed fire behavior
  - **Do not include how the fire creates its own weather**
  - **Current tools are weak in these (and other) events below**:

Plume-driven fires (fire-induced winds)

Mountain airflows



Cloud gust fronts

Others:
- Fire whirls (Missionary Ridge)
- Backfires (Spade Fire)
- Splitting/fire-induced + wind-driven heads
- Chimney effect

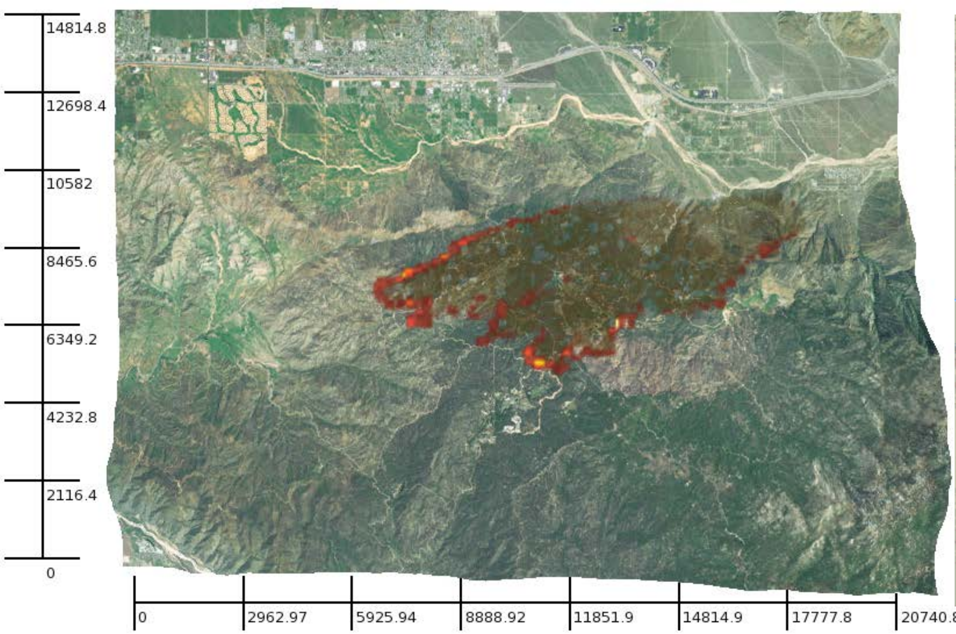
CAWFE® Testing and Verification Cases

Simulated large wildfires in many fuel & weather conditions:

- Little Bear Fire, NM
- High Park Fire, CO
- Esperanza Fire, CA
- Real-time simulation of CO fires during 2004
- Simi Fire, CA
- Troy Fire, CA
- Spade Fire, MT
- Big Elk Fire, CO
- Hayman Fire, CO
- Yarnell Hill Fire, AZ
- King Fire, CA

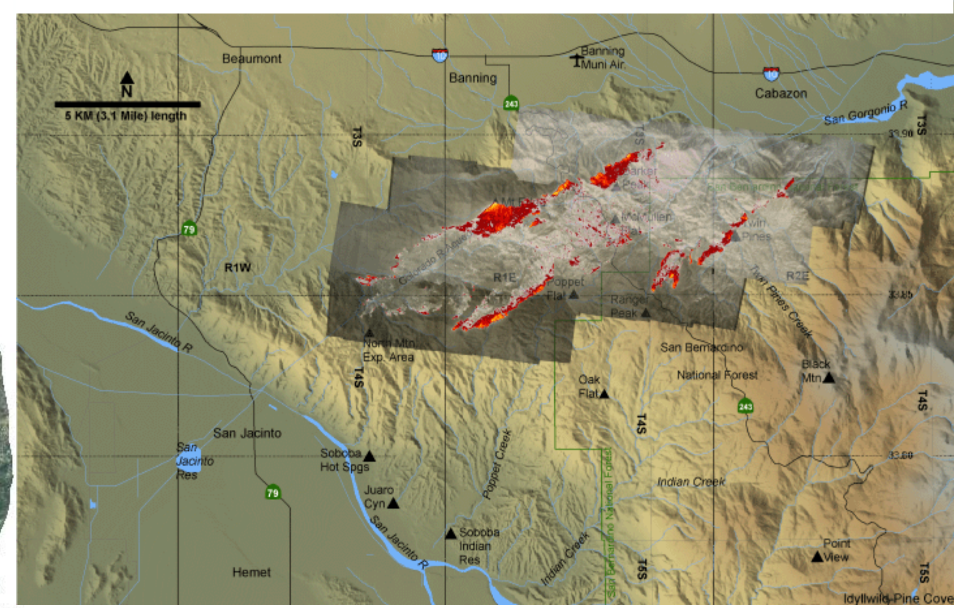
ESPERANZA WILDFIRE

CAWFE SIMULATION



INFRARED DATA

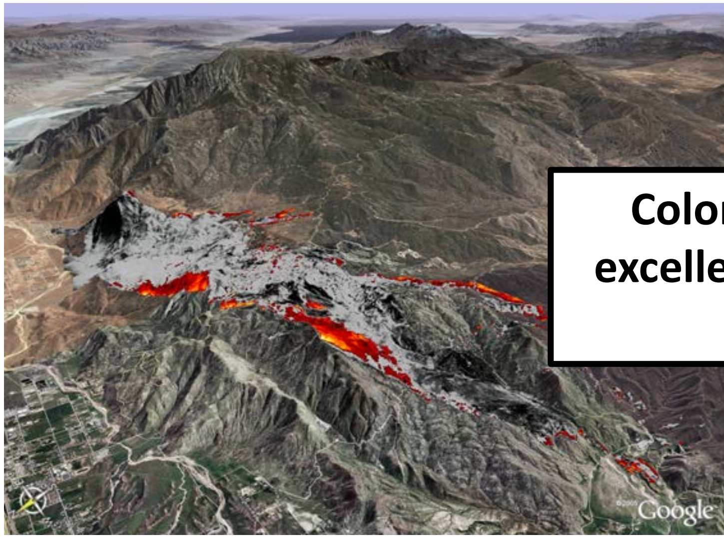
FireMapper, USDA Forest Service



Modeled weather, fire extent, shape, intensity, and land surface effects can be validated.
Airborne or space borne infrared data reveal fire properties through smoke.

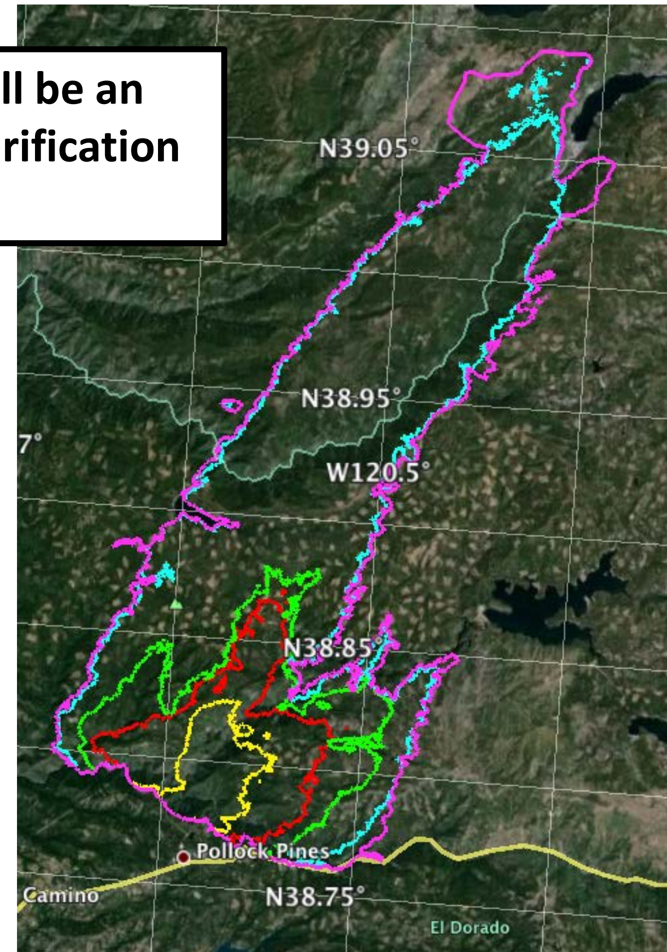
Data sources for verifying simulated fire growth

Infrared data from USDA Forest Service research aircraft (not routine)

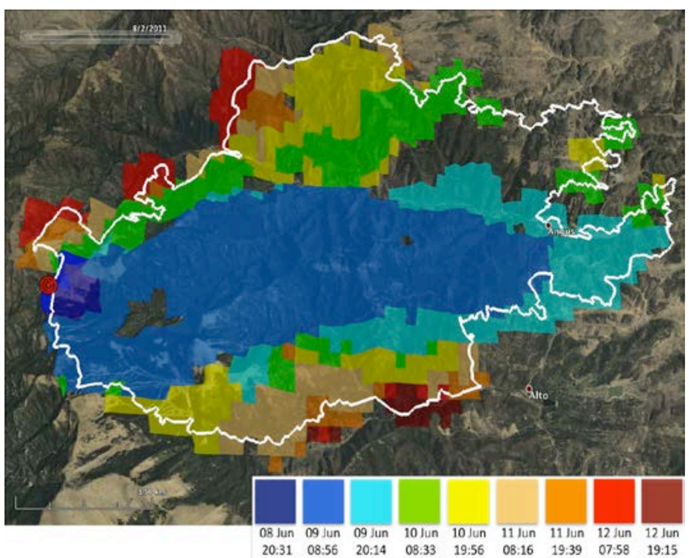


USDA Forest Service National Infrared Operations (NIROPs) airborne mapping of high priority fires (once per night)

Colorado's MMA will be an excellent source of verification data!



Since 2012: Visible Infrared Imaging Radiometer Suite (VIIRS) Satellite Active Fire Detection infrared data (at least two times daily at 375 m resolution)



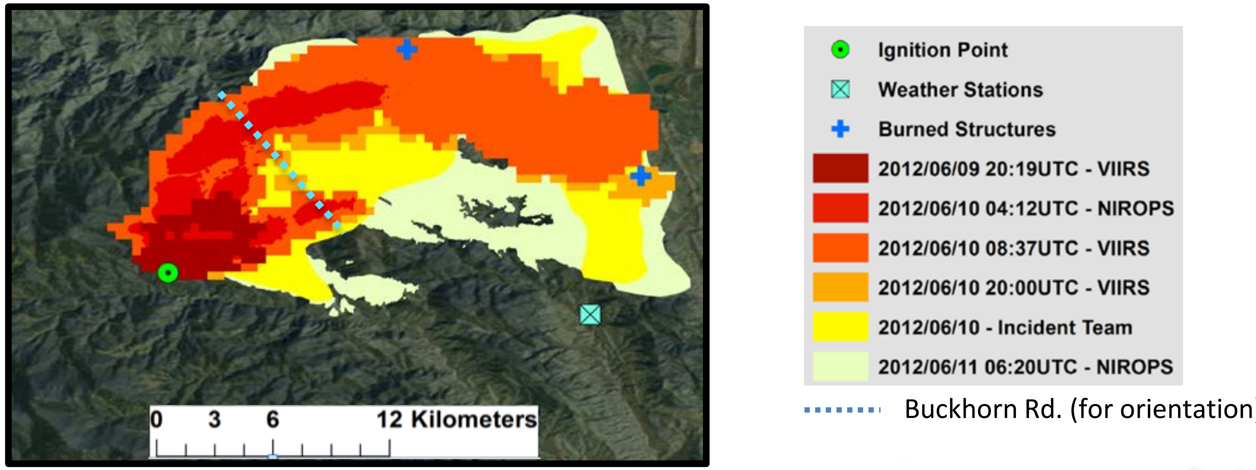
The High Park Fire
Northern Colorado, June 2013

Windstorm Event

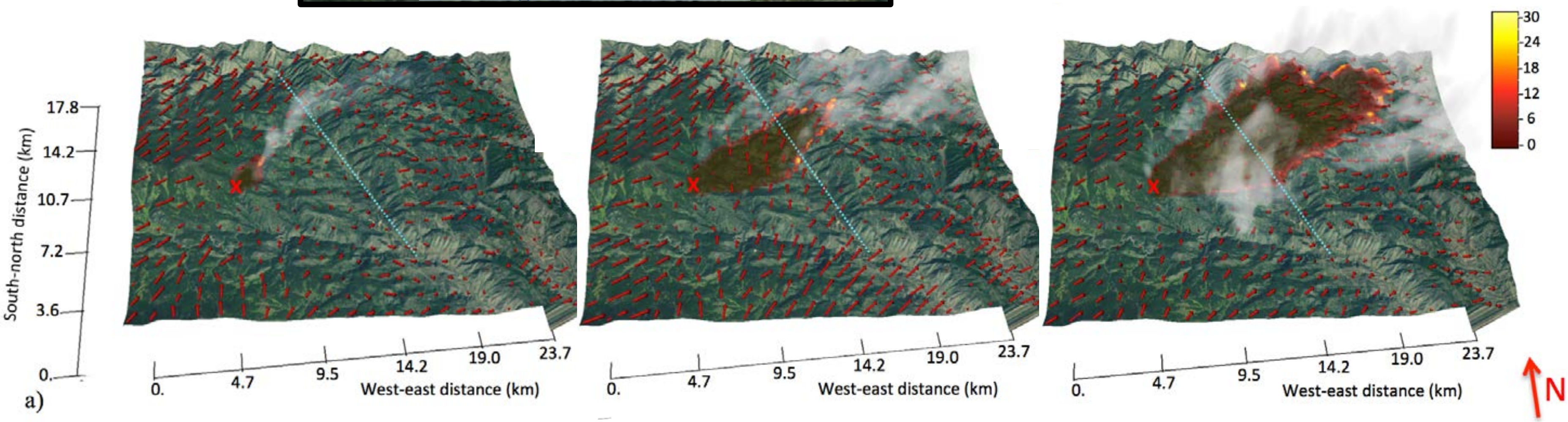
Many of the most destructive fires in recent history have been associated with June windstorms. The airflow patterns in the mountains of Colorado vary significantly in time and space and sparse weather station data are often not representative of the local conditions.

High Park Fire growth on June 9-10, 2012

FIRE MAP DATA



CAWFE MODEL



2019 UTC **9 June** (2:19 P.M.), the time of the 1st VIIRS data (**brick red**, in figure above). (X is the ignition point.)

Comparison: Simulated fire & mapped fire are both 4 km long wedges.

0412 UTC **10 June** (10:12 P.M. 9 June), the time of the NIROPS map (**red**, in figure above) and near the time of the incident team map (**yellow**)

Comparison: Simulation underestimated the leading edge by 2 km but showed the wide (5 km in simulation, 7 km in map) north-south burning area mapped by the incident team.

0837 UTC **10 June** (2:37 A.M.), the time of the 2nd VIIRS data (**dark orange**, in figure above)

Comparison: The fire grew north to Poudre Canyon and east in the next 4.5 h. This was captured by the simulation, although it lagged the observations by 2–3 km.

Yarnell Hill Fire
Yarnell, AZ June 2013

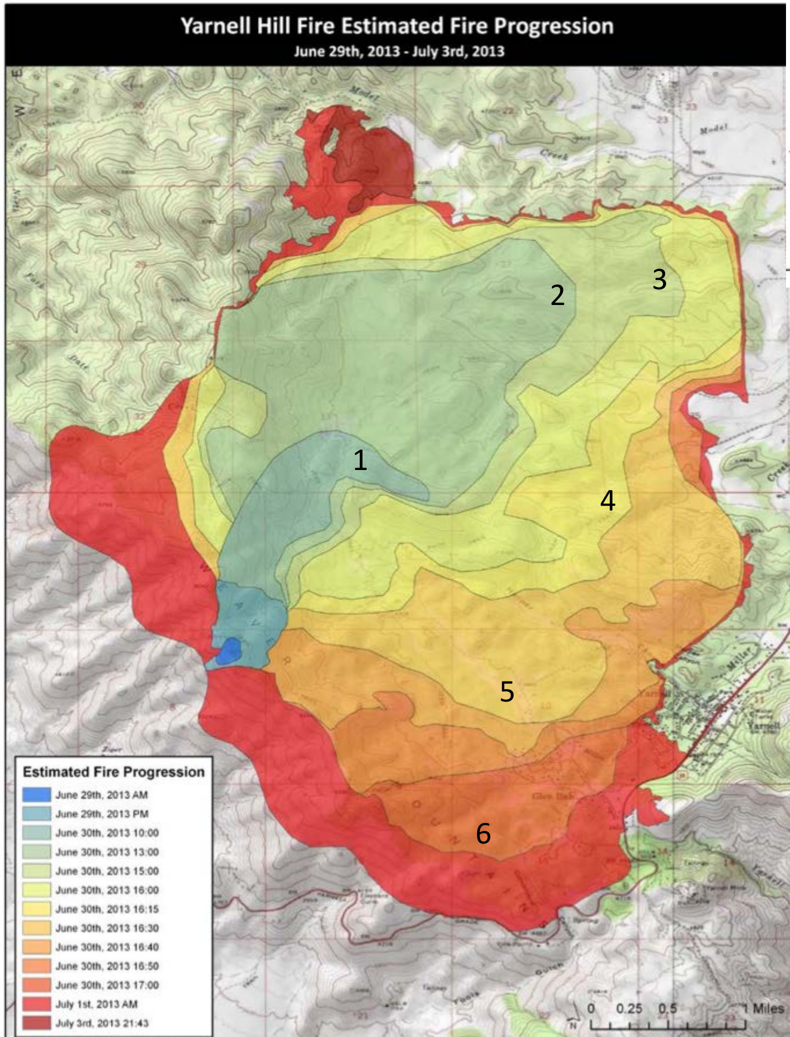
Gust Front Event

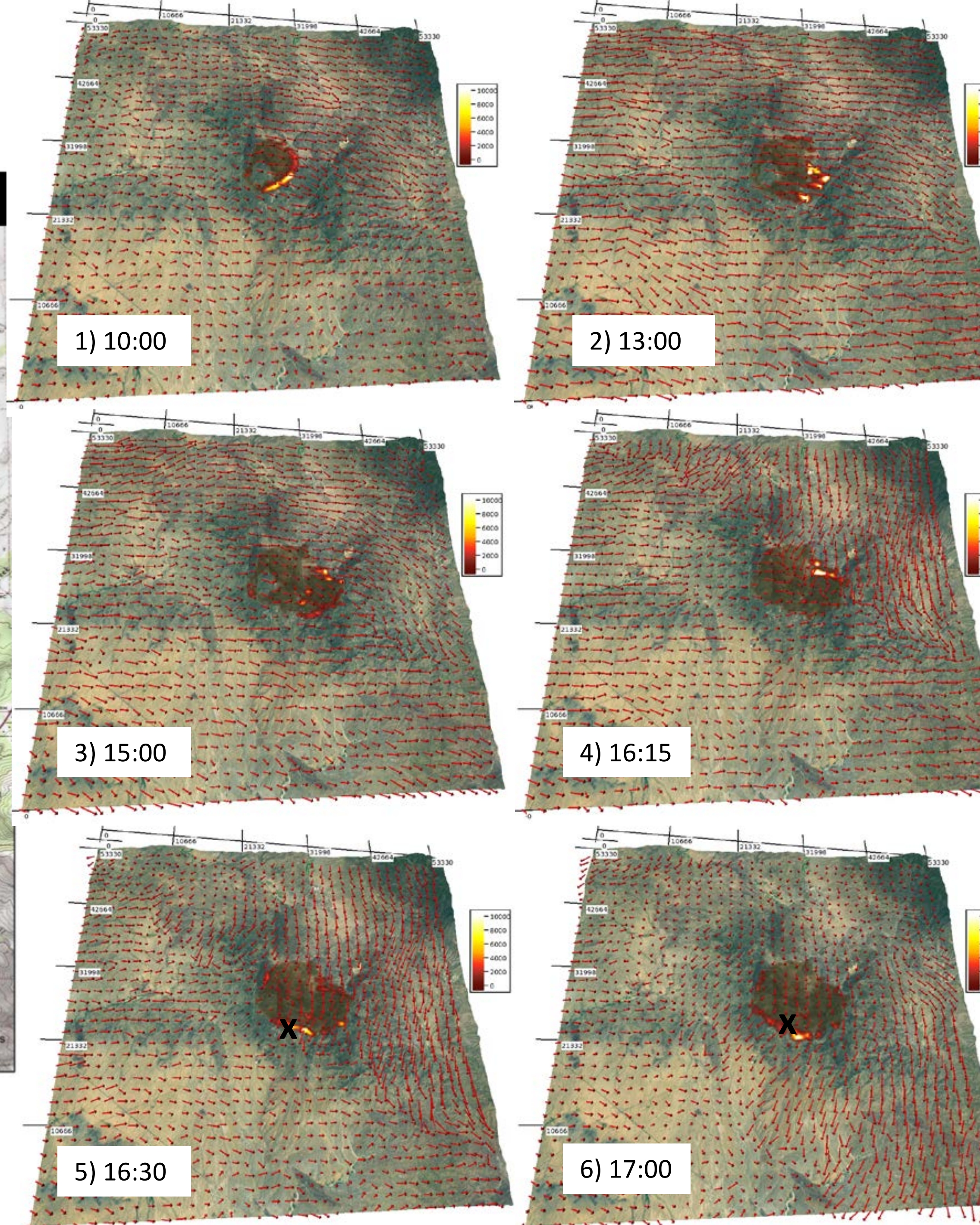
Sudden changes in wind direction (for example, thunderstorm-produced gust fronts) are firefighter safety hazards and can result in a fire spreading rapidly (as occurred in Waldo Canyon).

Current tools are challenged by erratic wind conditions.

The fatalities occurred between 4:30 P.M. and 5:00 P.M.

Yarnell Hill fire progression from the *Serious Accident Investigation Report (below) and CAWFE simulation (at right)*





★ Gust front hits southern edge of the fire at 16:30 (in report and CAWFE model simulation) driving fire to the south.

King Fire
Near Pollock Pines, CA September 2014

Plume Driven Fire

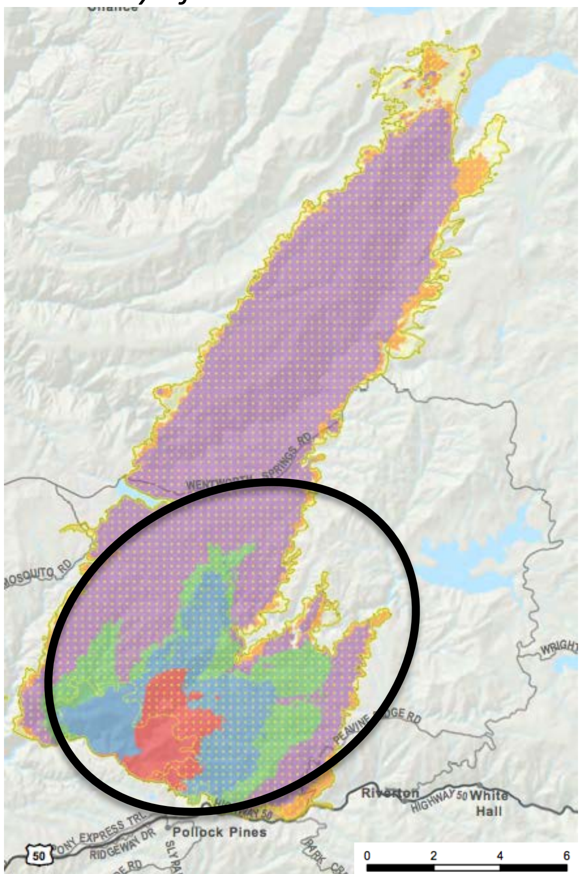
The King Fire grew over 40,000 acres in one day. Fires such as this (e.g., the Missionary Ridge Fire, near Durango CO) are called “plume-driven” fires and are driven by fire-induced winds, which the current tools are not designed to handle.

The prediction made during the event by fire managers (shown in next slide) uses the Near Term Fire Behavior tool within WFDSS.

King Fire growth Sep 14 at 22:17 to Sep 18 at 22:02 LT

a) NIROPS Infrared fire map

Courtesy of USDA FS and CAL FIRE



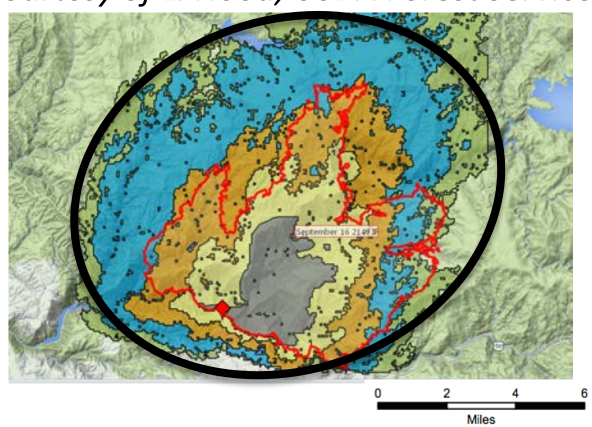
Progression Up to 9-18-2014

- 9/14 10:17 P.M.
- 9/16 2:00 A.M.
- 9/16 9:49 P.M.
- 9/18 12:16 A.M.
- 9/18 10:02 P.M.

b) Growth prediction from Wildland Fire Decision Support System (WFDSS) Near-Term Fire Behavior (NTFB) tool, the current Federal operational tool, during the event

The operational tool missed the 10-mile run to the northeast during the afternoon of 9/17/14.

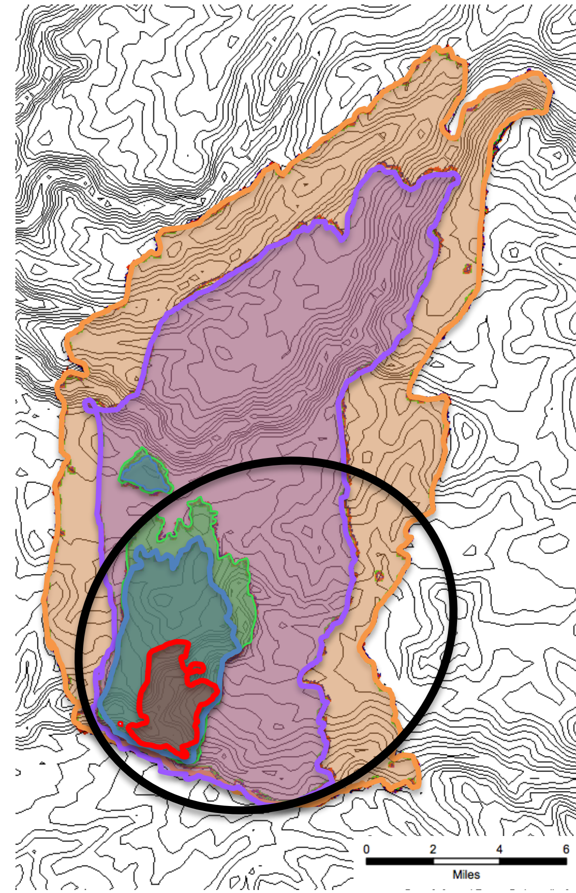
Courtesy of L. Hood, USDA Forest Service



Progression Up to 9-18-2014

- 9/14 10:17 P.M.
- Late 9/15
- Late 9/16
- Late 9/17
- Late 9/18

c) CAWFE simulation



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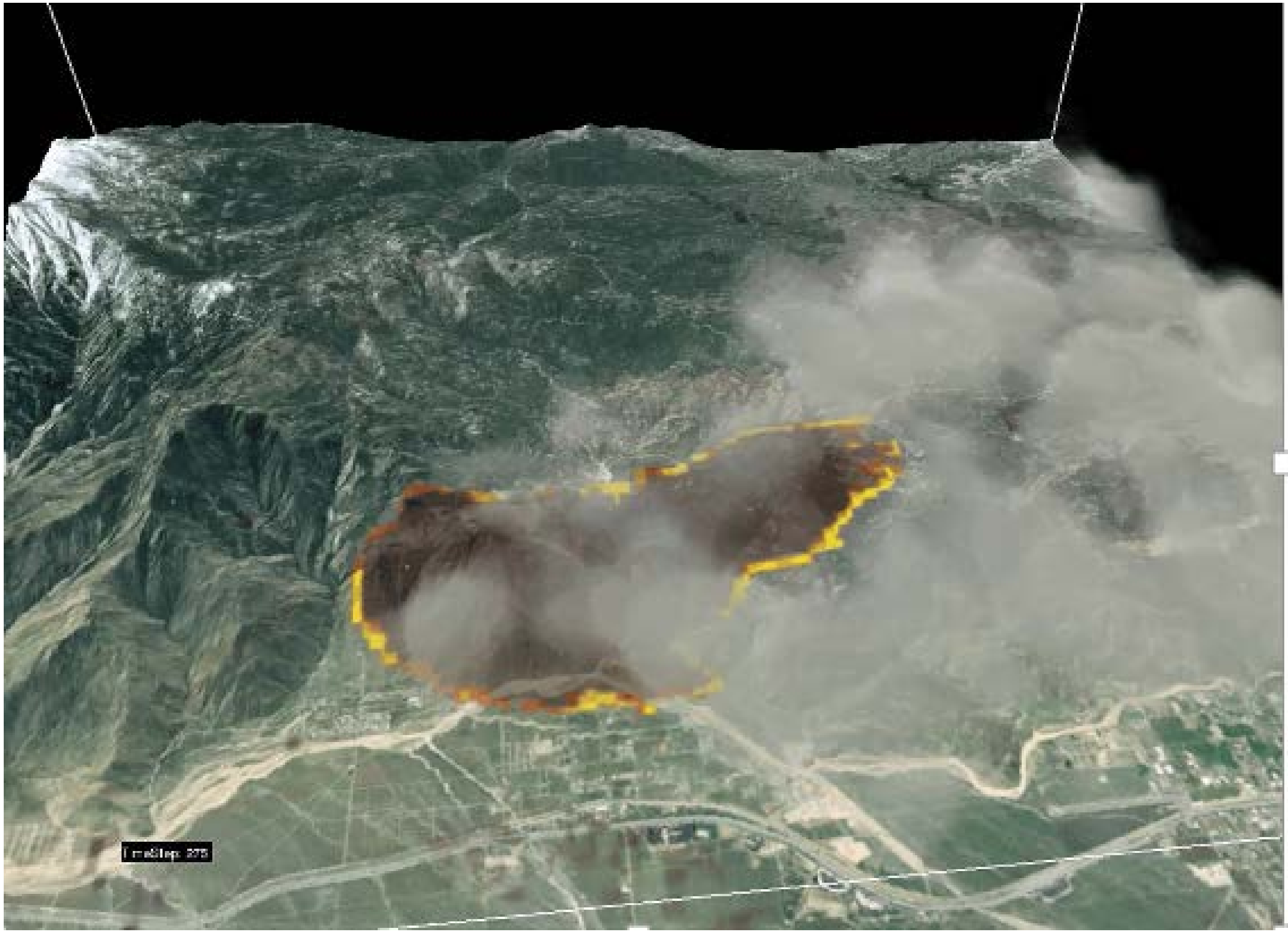
Esperanza Fire
Riverside County, CA   Oct. 2006

Comparison of CAWFE® to the FARSITE fire behavior model (using a variety of weather inputs)



The 5-fatality Esperanza Fire

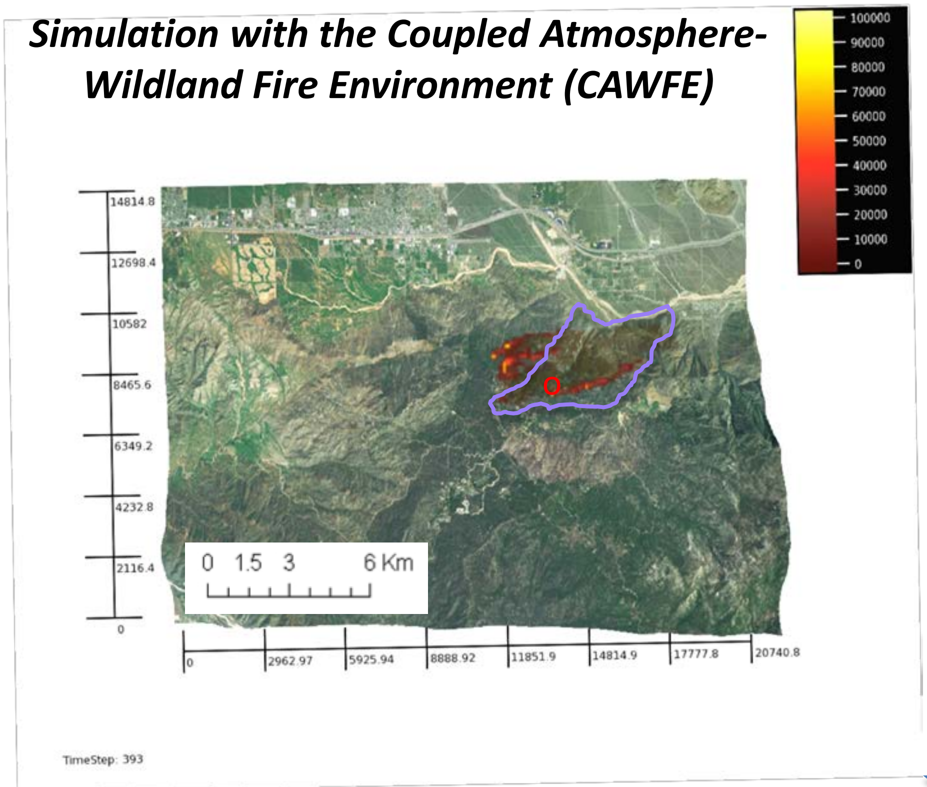
Riverside County, CA. Oct. 2006

15-30 min. after the fatalities (location shown by o)

6.8 h after ignition – arson (location shown by x)

Incident team assessment of fire extent:

Simulation with the Coupled Atmosphere-Wildland Fire Environment (CAWFE)

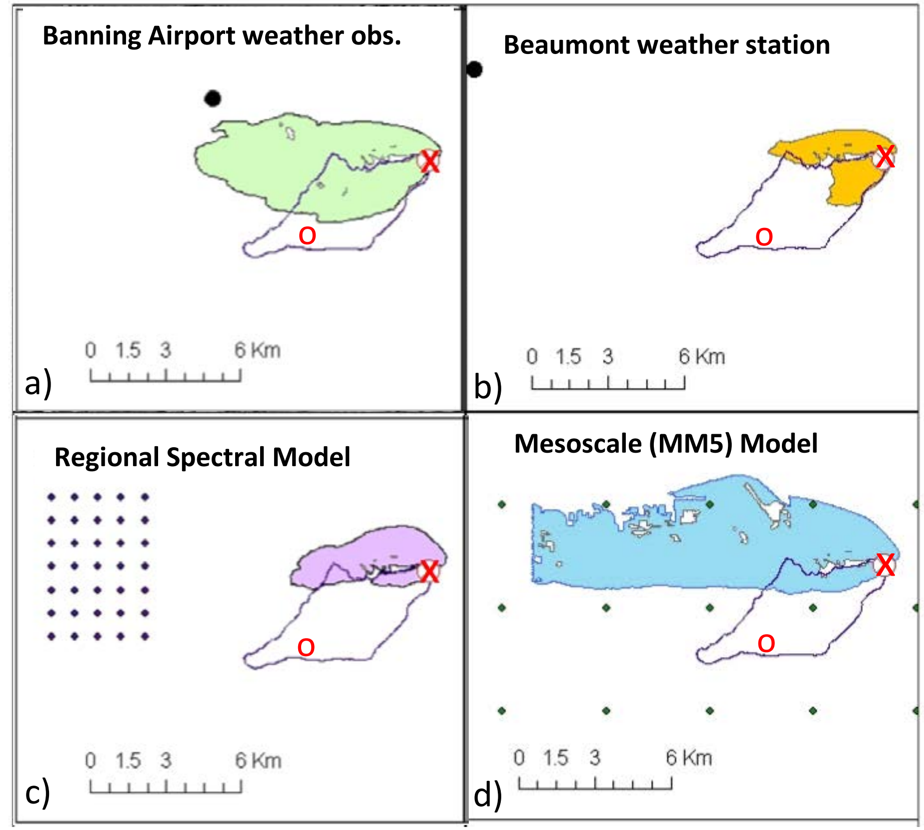


CAWFE modeled the airflow with very high resolution (grid points 123 m apart) and included the feedback of the fire's heat upon the weather.

Heat intensity is colored according to the color bar at right, with more intensely burning regions in yellow, and less intensely burning regions in dark red.

Simulation using current methods:

4 different weather sources used as input into the FARSITE fire behavior model (another current tool)



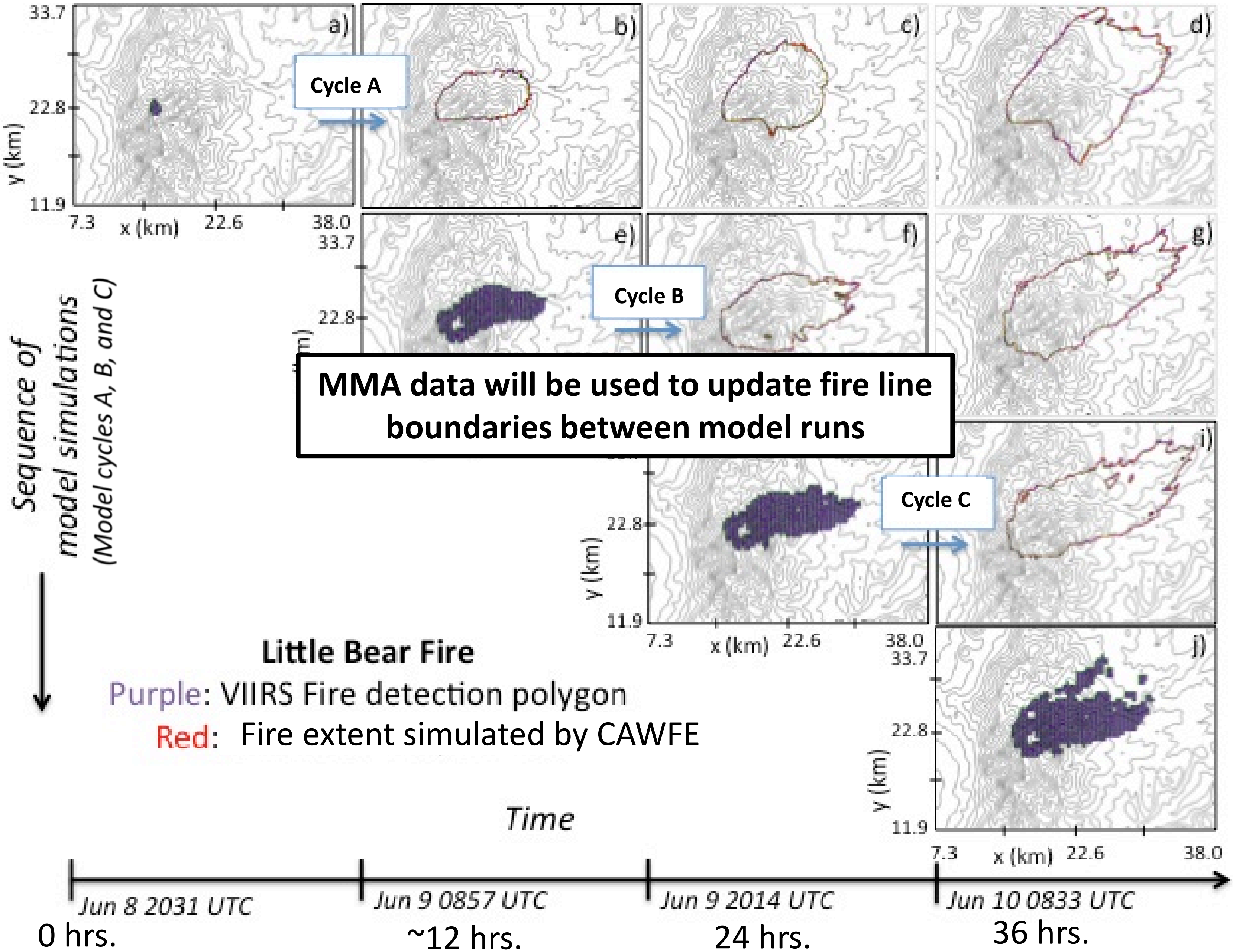
Reproduced from Weise et al. (2007) 7th Symp. Fire & Forest Meteor.
Dots indicate location of or spacing between weather data points.

The methods that use nearby weather station data, (a) and (b), or those that use weather model data, (c) and (d), as input into current modeling tools (without considering the fire's impact on the weather) did not predict that the fire would be anywhere near the fatality site.

The next slide shows how CAWFE® will be applied as a forecasting tool with regular updates (model cycles)

Little Bear Fire

Near Ruidoso, NM   June 2013



CO-FPS Benefits Summary

- **CAWFE® improves upon current tools as illustrated here**
- **CAWFE® predicts how weather varies in time and space at very high resolution, including the complex airflows that occur in Colorado's mountains**
- **CAWFE® includes the feedbacks that fire has on winds, i.e., how the fire creates its own weather, and thus captures fire growth in "plume-dominated" fires.**
- **CAWFE® has captured critical fire behavior changes in fire behavior**
- **CAWFE® complements existing fire management tools by addressing situations where they are weakest.**

Discussion of current fire behavior analysis practices

Discussion of Current Practices

- How do various decision makers use current fire behavior analysis products?
- Where do you get the tools/information (sources)?
- What are the pros and deficiencies in current tools?
- What are the pros and deficiencies in current practices?

Break

Review of CO-FPS fire behavior prediction products

But first, a brief review of the weather prediction (modeling) process

The forecasting process

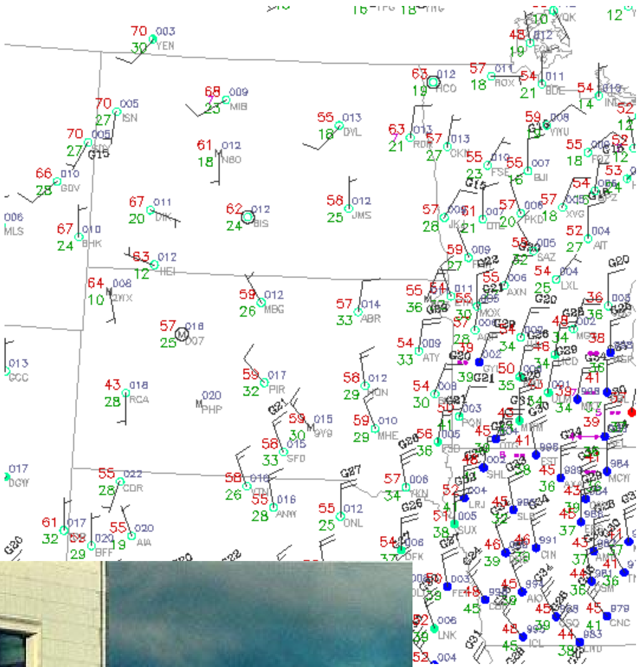
1) Collect worldwide weather, ocean, lakes, and land surface observations (including vegetation state)
2) Perform quality control on all data
3) Assimilate worldwide observations into weather models – balance the physics
4) Create global weather analysis
5) Ingest analysis data into numerical weather prediction model(s)
6) Run the forecast modeling system
7) Statistically correct forecast results (using history)
8) Disseminate forecast (human-in-loop or otherwise)

Weather Observations

Upper Air
- Balloons
- Aircraft

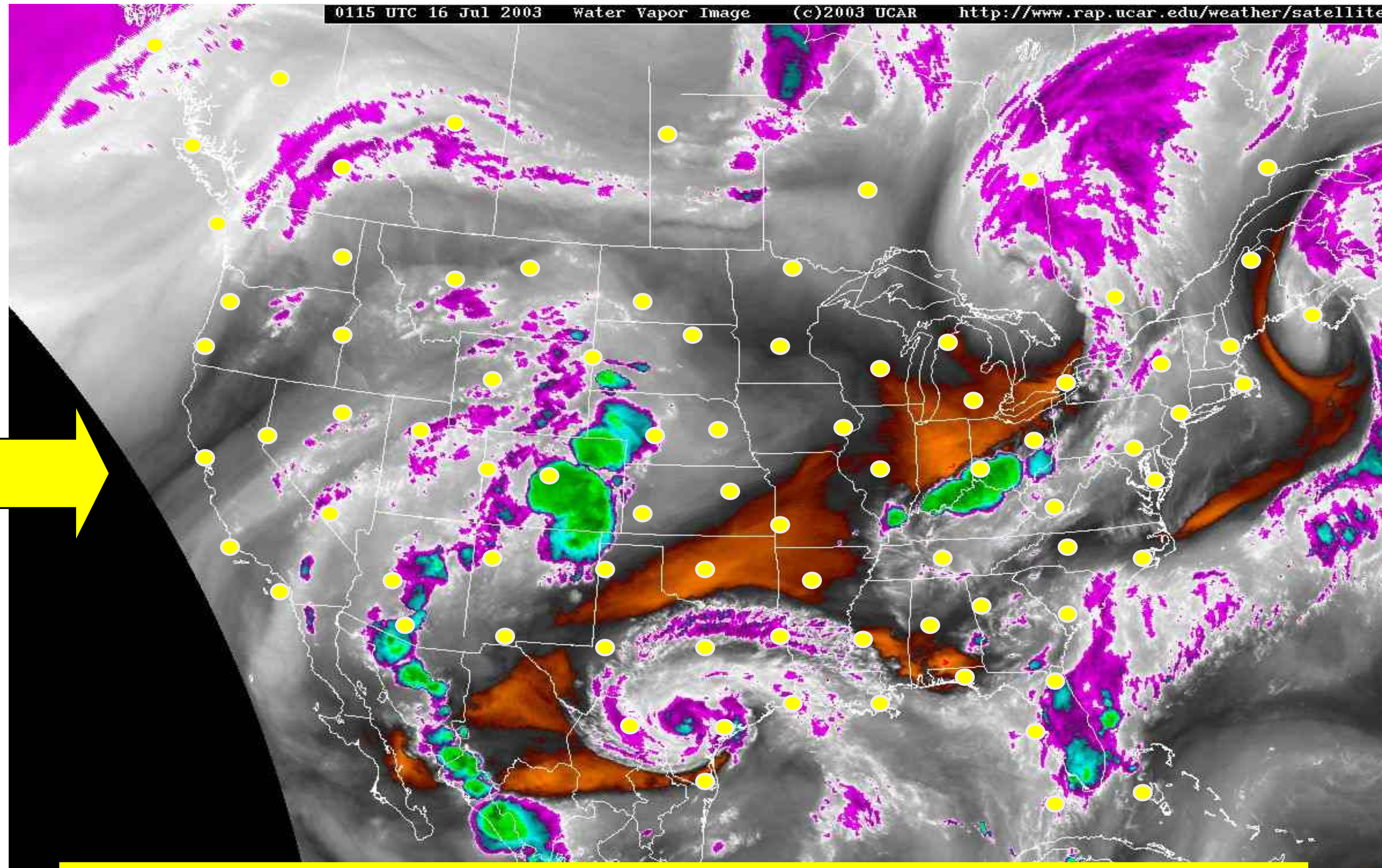
Surface
- Airport Observations
- Road weather sensors
- Local networks
- Volunteer observers
- Agriculture sensors
- Ships and Buoys

Remote Sensors
- Satellites
- Radar
- Lidar



USA Upper Air Observation Sites

USA Upper Air Observation Sites



A lot of details are missed between observations!

Data Void Areas - Impacts

Lack of data over the Pacific Ocean results in poorer mid-range forecasts for U.S.

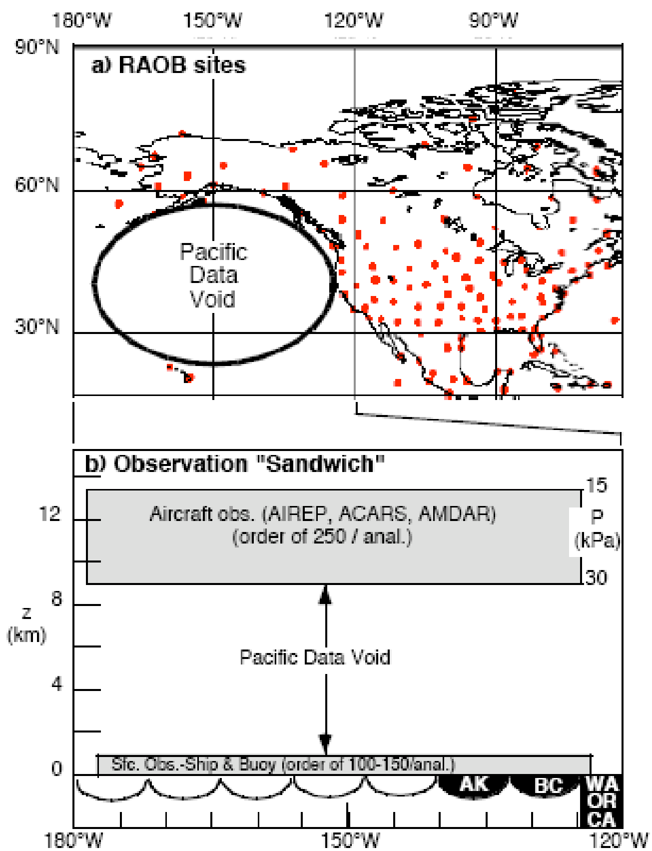
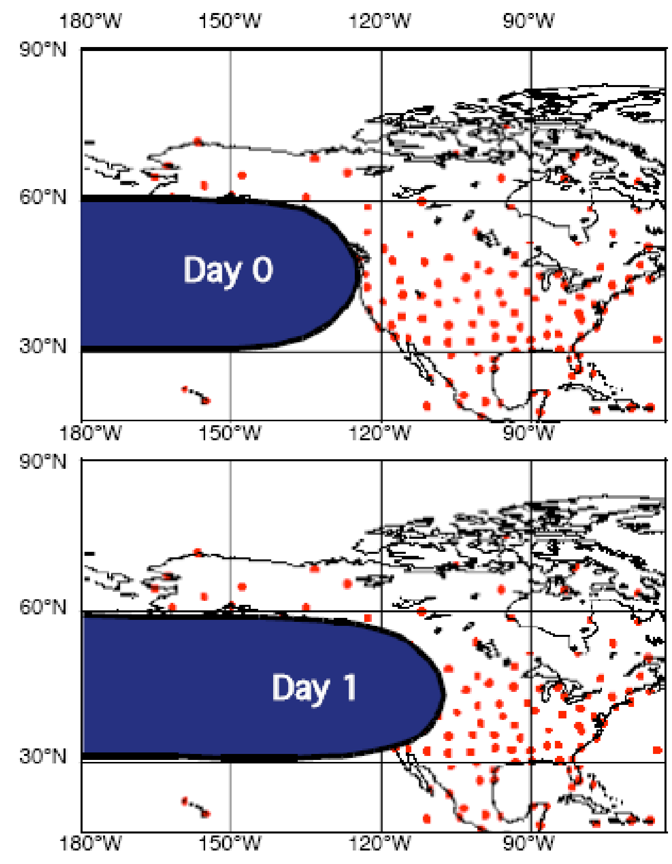


Figure 1. The Pacific Data Void.

4. SHADOW OF THE PACIFIC DATA VOID

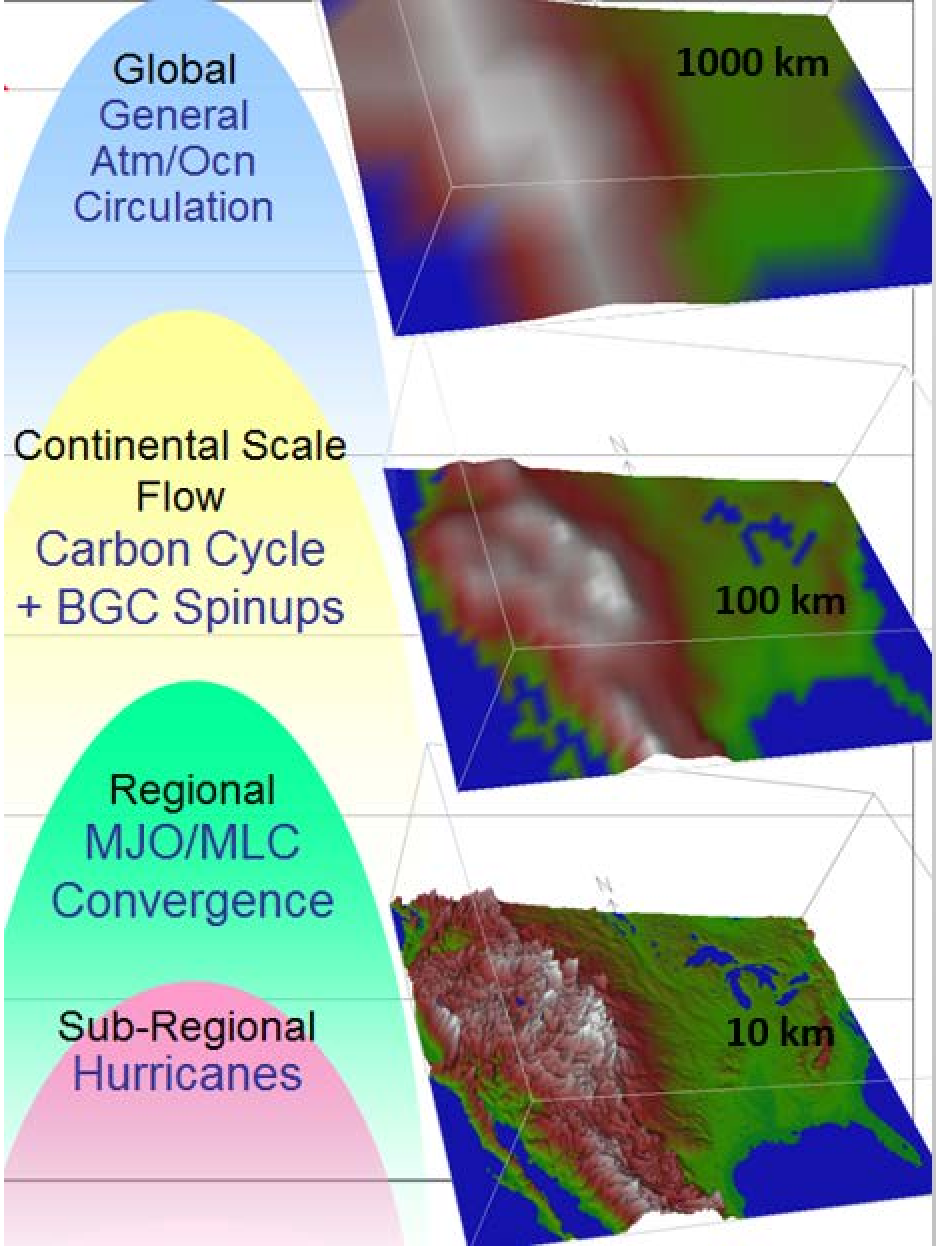


Model Resolution - Impacts

Resolution makes a large difference.

Climate models are run with coarse resolution (~1000 km) predicting 10s to 100s years.

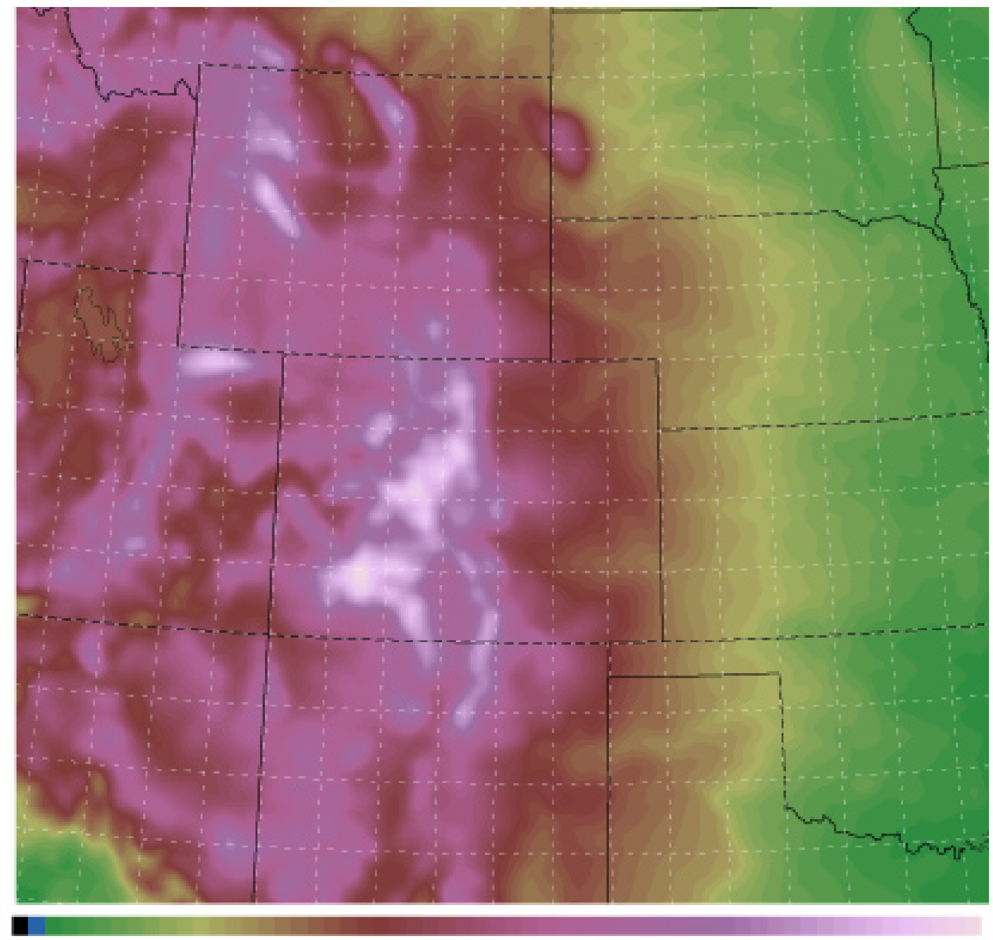
A NWS weather model is now run hourly at 3 km across CONUS out to 18-hours



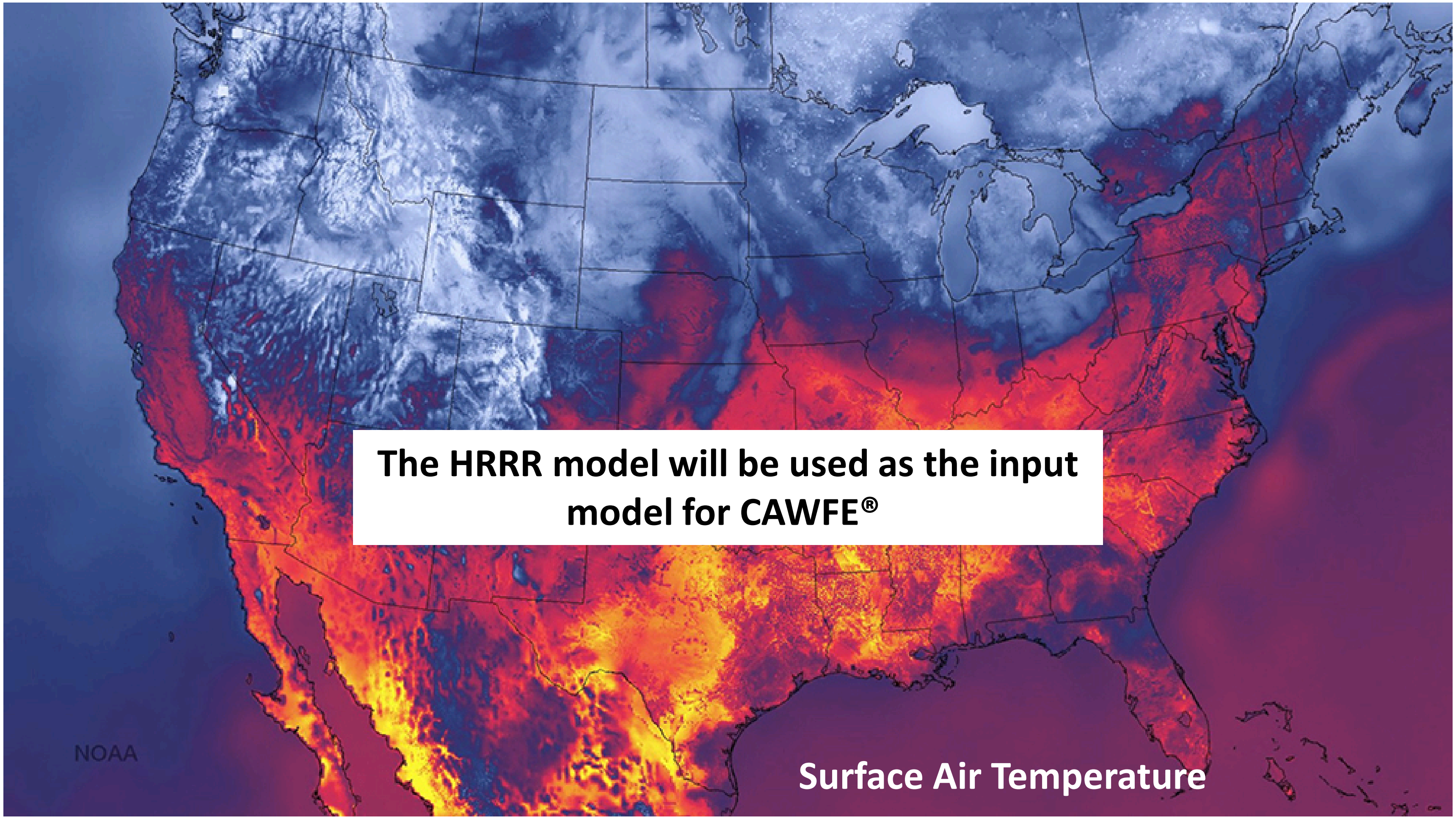
Model Resolution - Impacts

NWS global model (GFS) now running at 12-km grid spacing (as of 2015)!

Mountains resolved better than before, but still smoothed.



NWS HRRR Model Resolution – 3 km



The HRRR model will be used as the input model for CAWFE®

HRRR Weather Model Inputs

Data input examples, not exhaustive

Data Type	Number Per Day (USA)
Weather balloons	150 twice per day
Wind Profilers - RASS	60
Radar winds	120 - 140
Commercial aircraft	3500 - 10000
Regional aircraft	200 - 3000
Buoy/ship	200 - 400
Satellite winds	4000 - 8000
GPS precipitable water	300 - 12000
Surface Observations	8000 - 10000
Satellite radiances	Tens of thousands
Radar reflectivity (intensity)	Every 1 km

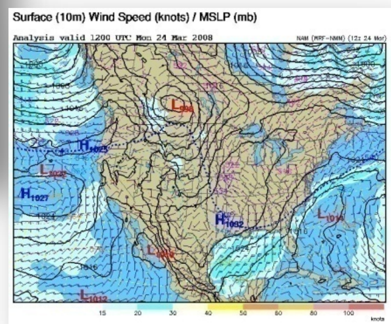
Weather Model Nesting

Scale Interactions are Critical

40,000 km

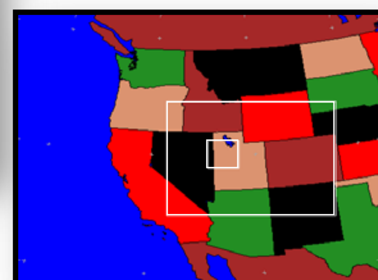
Global Scales

5,000 km



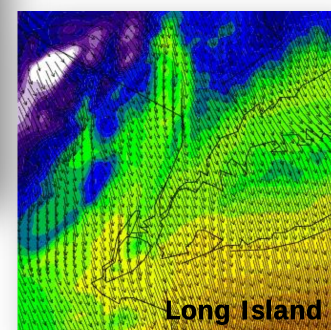
Continental Scales

1,000 km



Regional Scales

100 km



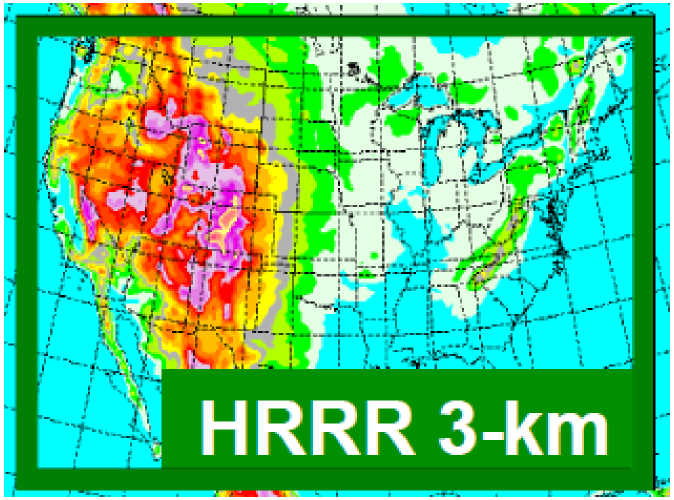
Local Scales

1-10 km

Urban Scales

CO-FPS Model Nesting

Source - NWS

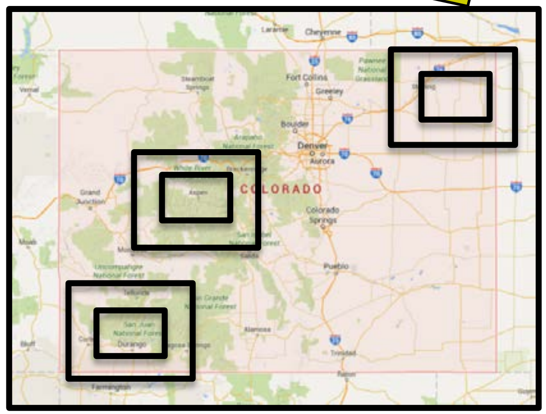


CONUS Scale

High-Resolution Rapid Refresh model

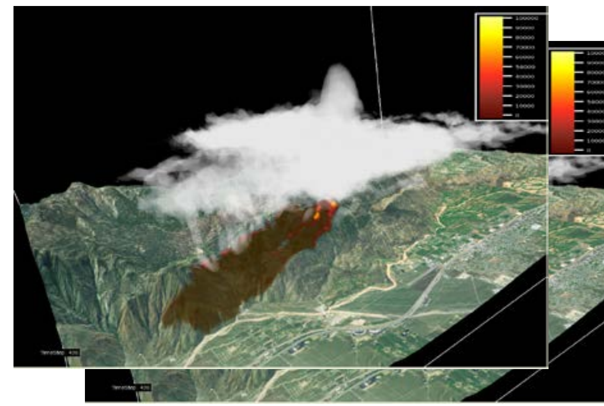
- Hourly updates
- 24 hour forecasts

CAWFE®



3 km (1.8 mi) over Colorado
Hourly updates
1 km outer subdomain

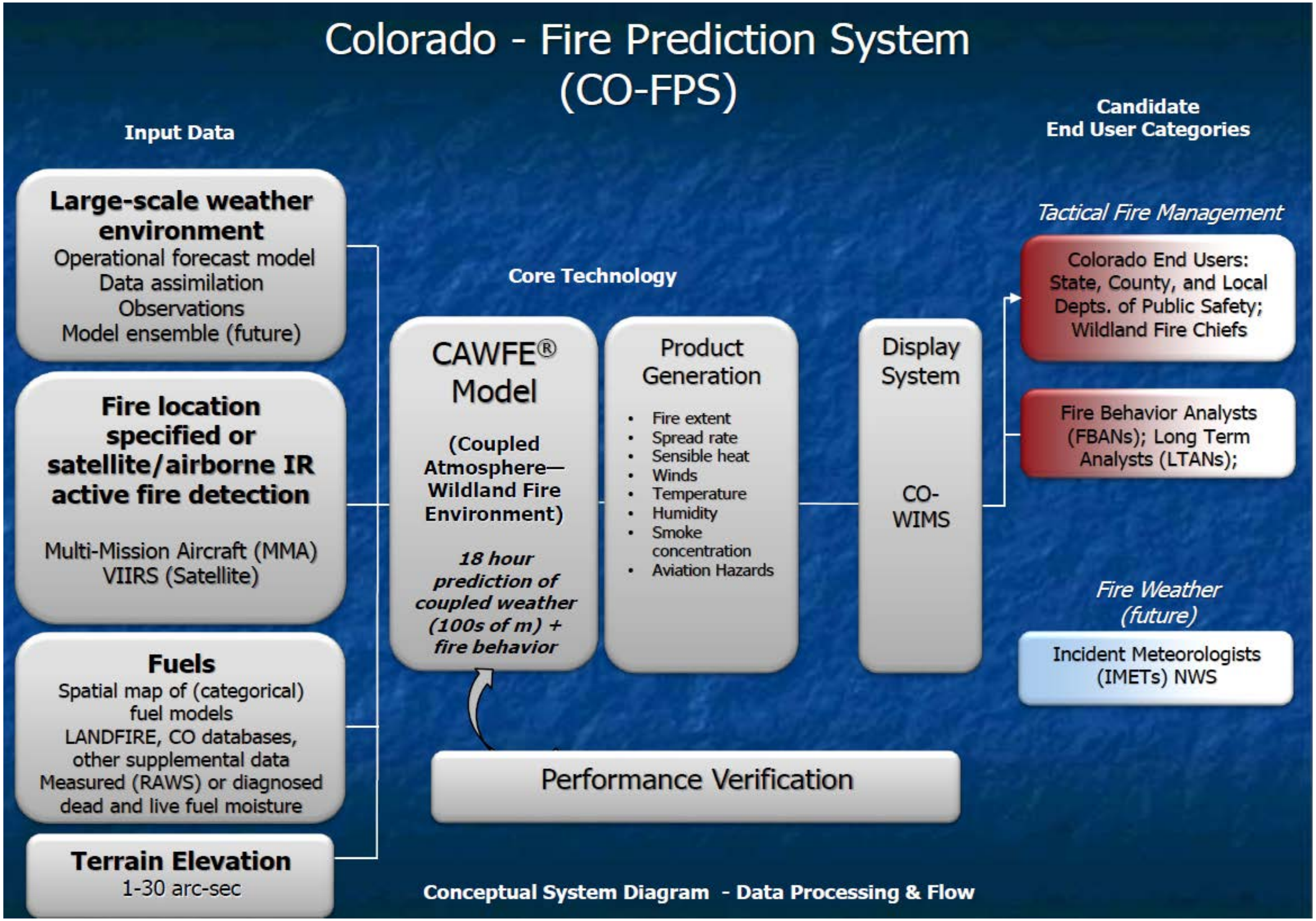
CAWFE®



100 meter (finest grid)

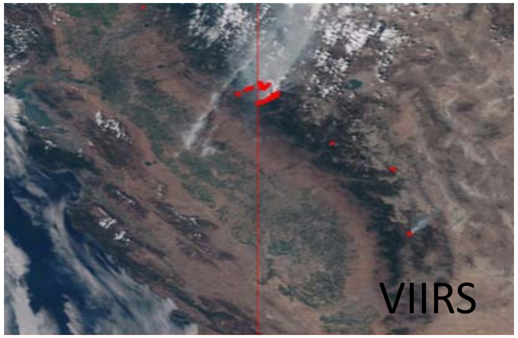
Wildland Fire Scales

System Concept Diagram



Planned System Attributes

- Real-time data ingest of weather, fuel, and active fire detection data from the MMA and Visible Infrared Imaging Radiometer Suite (VIIRS)
- Multiple fire model cycles (runs) per day (utilizing updated weather and fire mapping data)
- User ability to select fire prediction location and size (via 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

Initial Operating Capability CO-FPS Products

18 hour predictions (at user defined increments) of:

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

Fire behavior product group

Will be calculated on 100 m fire scale grids when triggered

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

Aviation hazard product group

Could be calculated on 3 km (state scale), 1 km, and fire scale grids (100 m)

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

Fire weather product group

Could be calculated on 3 km (state scale), 1 km, and fire scale grids (100 m)

Discussion on priorities for CO-FPS fire behavior prediction products and critical functionality

Discussion on User Needs for CO-FPS

- What are the priorities for the fire behavior products?
- What types of significant fire behavior are most critical?
- Are “alerts and advisories” or similar notices needed for certain combination of predicted hazards? If so, how should they be delivered?
  - Significant wind shifts and/or gust fronts
  - Fire line rate of spread above a threshold
  - Prediction of pyro-cumulus
  - Heat release above a threshold
  - Etc.

Discussion on User Needs for CO-FPS

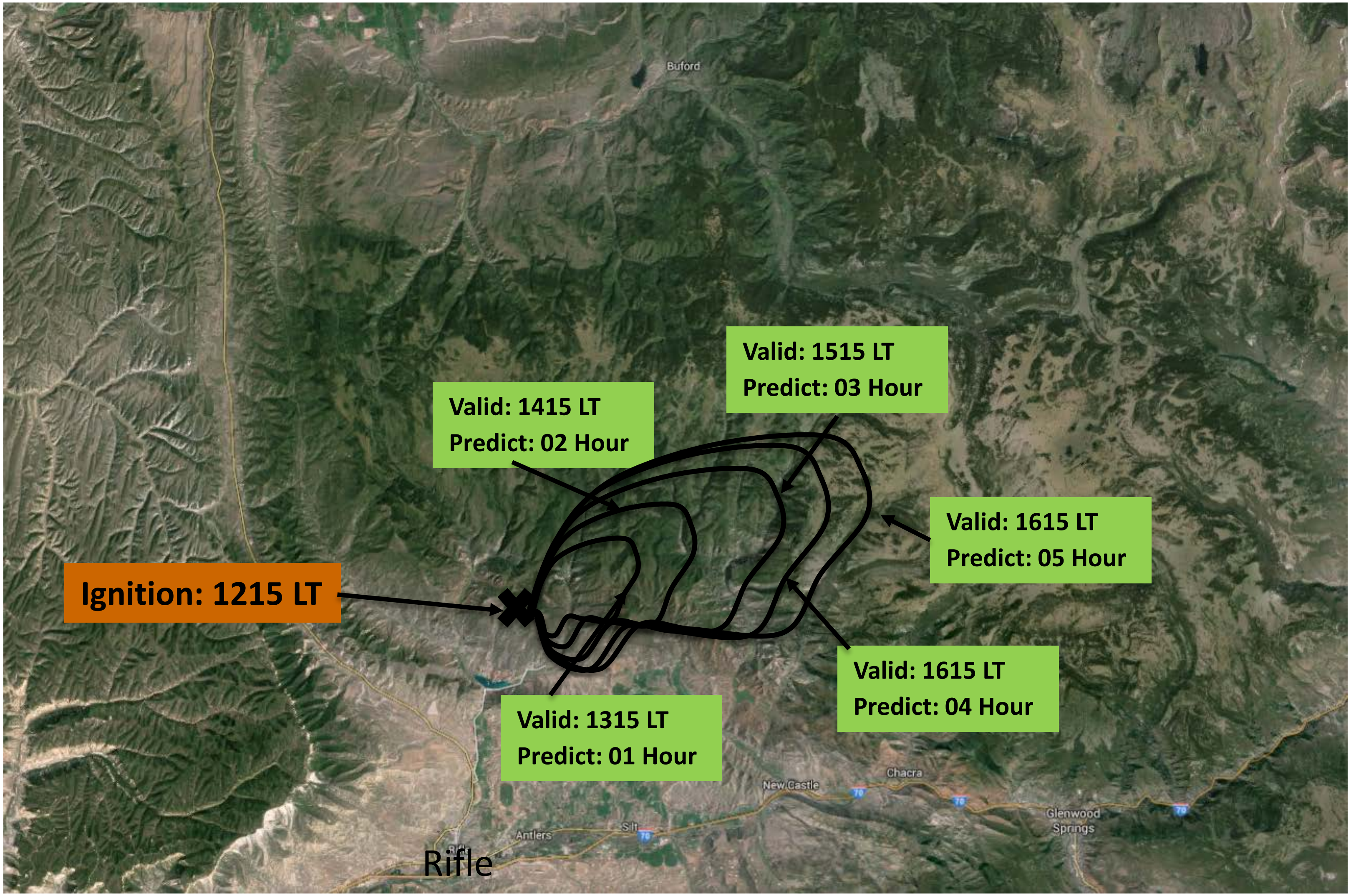
- How long are you willing to wait for the system to generate its 18 hour forecast (ignition to output time)?
- The output forecast length is 18 hours in the first year? Would a longer than 18 hour forecast period be more useful? How long?
- Output forecast interval (hourly, 3-hourly, etc.?)
- How often do you want fire weather predictions to be updated? Every hour, 3 hours, other? How much is too much information?
- How often do you want fire behavior predictions to be updated? Every hour, 3 hours, other?

Discussion on User Needs for CO-FPS

- Do you want to have access to the fire weather products at all grid resolutions (~3 km, 1 km, 100m) or only selected grids? How much is too much information?

- How do you want to view the fire behavior products on CO-WIMS? Presentation of output options.
    - Polygons (shapes)
    - Filled polygons
    - Animations
    - Other

Fire Rate of Spread Storyboard

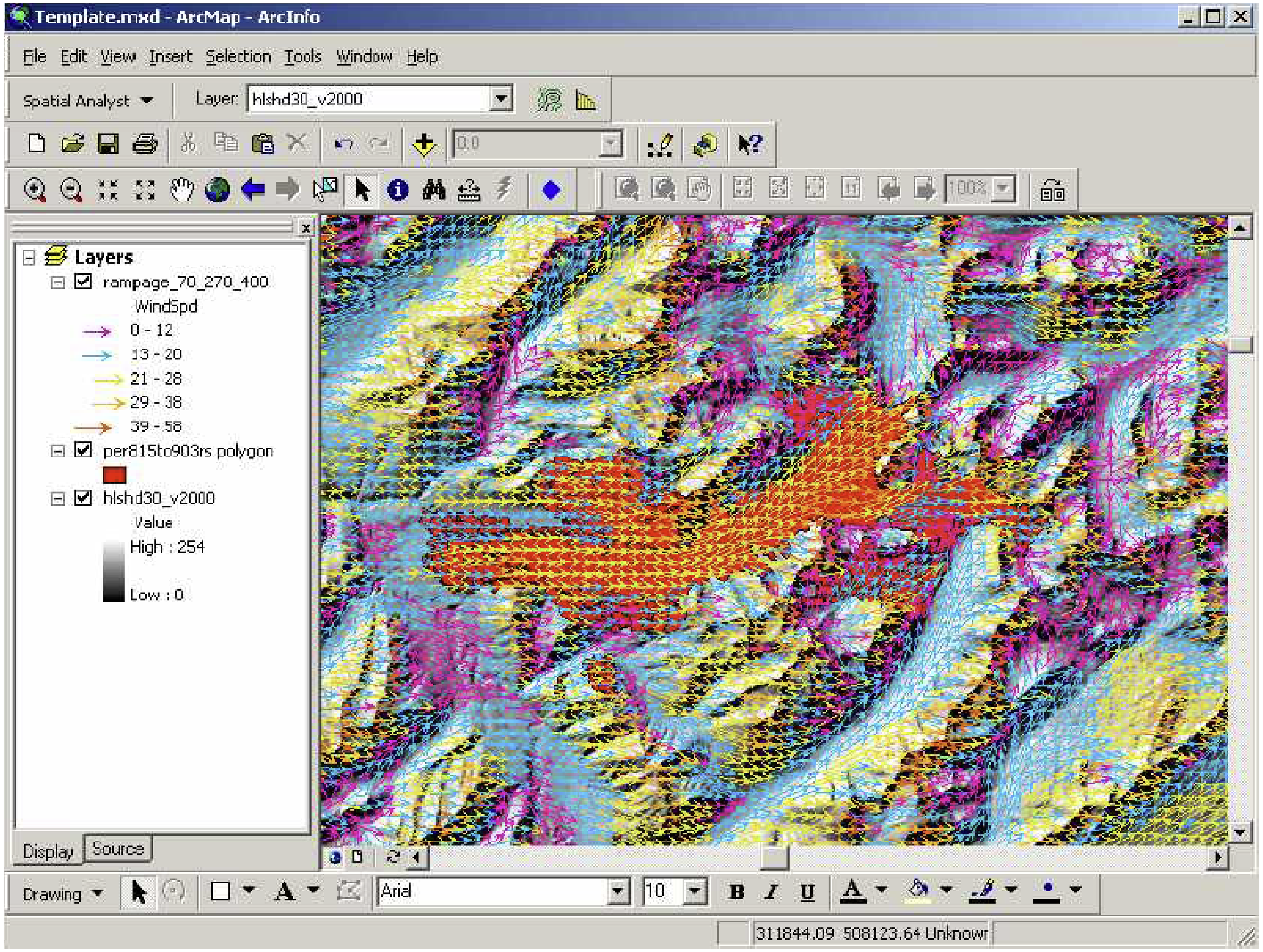


Wind Vector Storyboard

How much information is too much information w.r.t. gridded data?

Do you need to see the fire weather data on the 100 m grid, 1 km, and/or 3 km?

Note: the fire behavior output will be created on the 100 m grid



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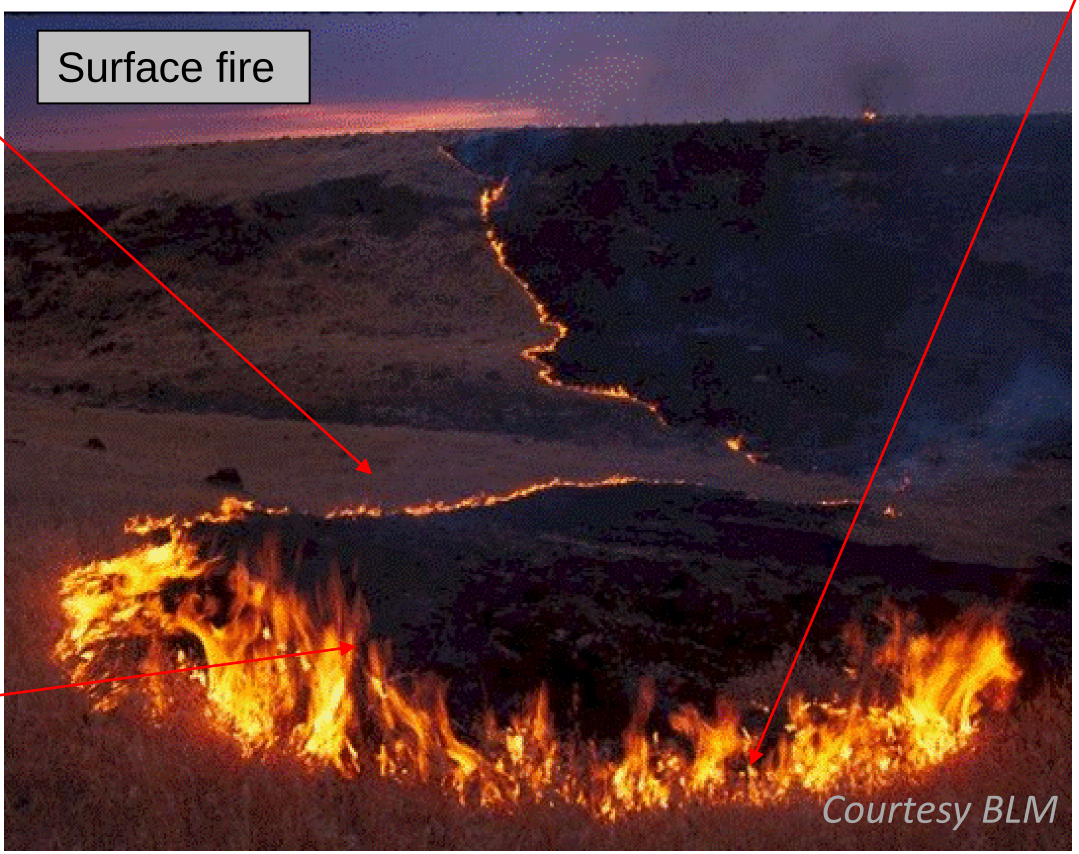
Reference Slides

Fire Behavior Module

Overview of Components

1. Represent & track the (subgrid-scale) **interface** between burning and nonburning regions (the ‘flaming front’)



2. Rate of spread (ROS) of flaming front calculated as function of **fire-affected** wind, fuel, and slope using Rothermel (1972) semi-empirical equations

3. Post-frontal heat & water vapor release. Once ignited, the fuel remaining decays exponentially, acc. to lab experiments.

4. Heat, water vapor, and smoke released by surface fire into lowest layers of atmospheric model

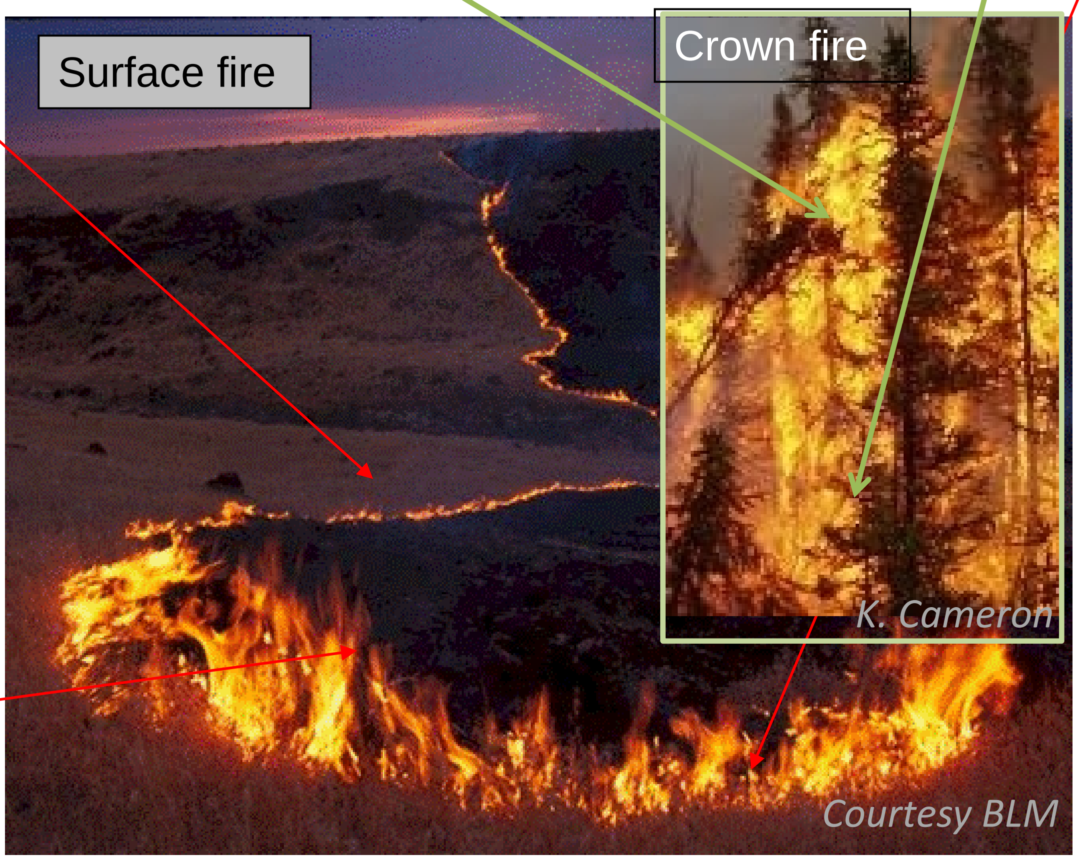
Fire Behavior Module

Overview of Components

6. Calculate the rate of spread of the crown fire using empirical relationships to surface fire ROS

5. Surface fire heats and dries canopy. Does the surface fire heat flux exceed the (empirical) threshold to transition into the tree canopy (if present)?

1. Represent & track the (subgrid-scale) **interface** between burning and nonburning regions (the ‘flaming front’)



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7. Heat, water vapor, and smoke released by crown fire into atmospheric model