The "Five W's" (and one H) of Geospatial Wildfire Simulation

I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who.

Rudyard Kipling , "Just So Stories" (1902)

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SDSU Geography Dp 9/2/2011

Outline

- Presentation
- Geotechnologies and Wildfires
- Geospatial WFS
  - **Why** so many efforts?
  - **What** is geospatial fire simulation?
  - **Who**'s who in GWFS
  - **When** is fire modeling useful?
  - **Where** can it be of any help?
  - **How** GWFS is helping fire modelling nowdays?
- GWFS in action¡ *Demoing Wildfire Analyst*

Geotechnologies and Emergencies

- Universal GIS: powerful and easy to use
- SDI's on the go
- OGC data transfer protocols ready
- New HR imagery
- GPS & Sensors on any device
- Communications even when you don't want ;-)
- Mobile tools cheap and affordable

…ok, maybe we need some help on the field ¡¡¡

do you have this trees in US?

Geotechnologies &Wildfires

- WF management need multiple scenarios and points of view

- Geoinformation is key in any decission process

Geotechnologies & Wildfires

1. **Why** so much efforts?

Cedar Fire, going through Sycamore Creek Neighborhood in Poway Ca., October 2003
http://youtu.be/-IG9Jhx4xIA

Why so much efforts?

Station fIre, LA, Sept 2009

http://www.boston.com/bigpicture/2009/09/wildfires_in_southern_californ.html

Why so much efforts?

Jacques Descloitres, MODIS Rapid Response System at NASA/GSFC http://youtu.be/eET7jwJOOqA

http://www.nifc.gov/fireInfo/fireInfo_statistics.html

Lower number of fires but bigger
- The better we are fighting fires, the bigger those we cannot win

acres burnt

fires

12000000
10000000
8000000
6000000
4000000
2000000
0

300000
250000
200000
150000
100000
50000
0

Fires
Acres

1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010

Where do we come from

Global spatial patterns burned area 1981-2000 (NOOA-NASA Pathfinder based)

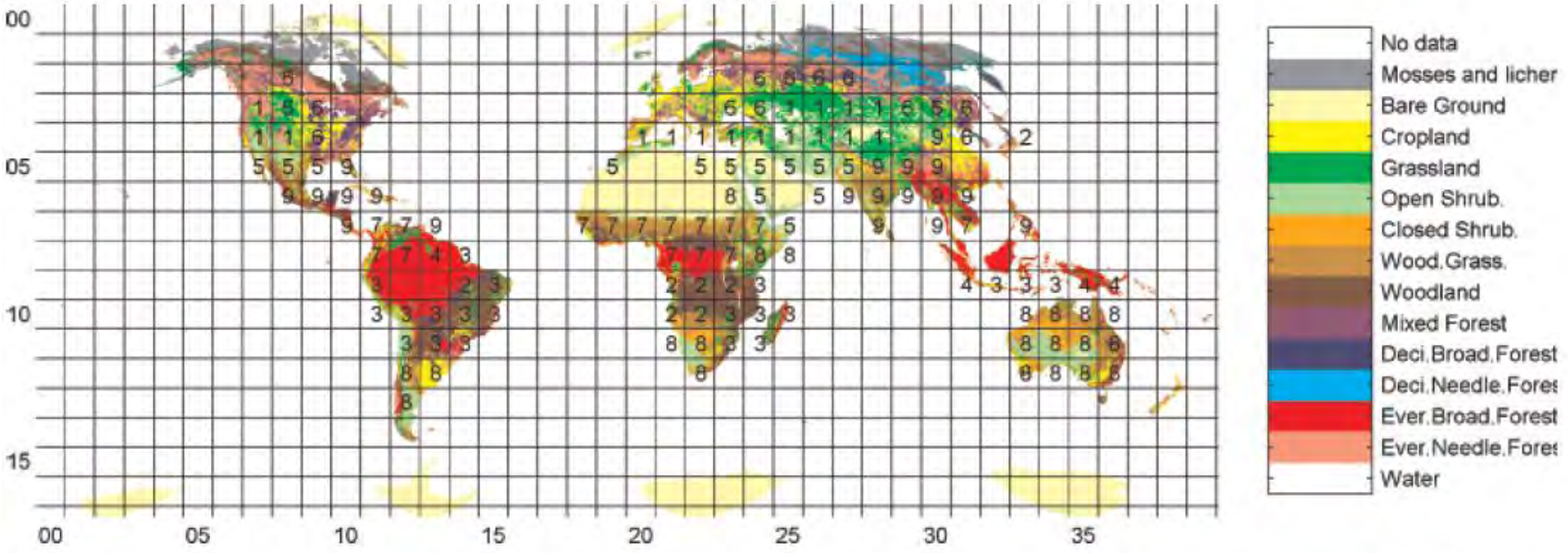


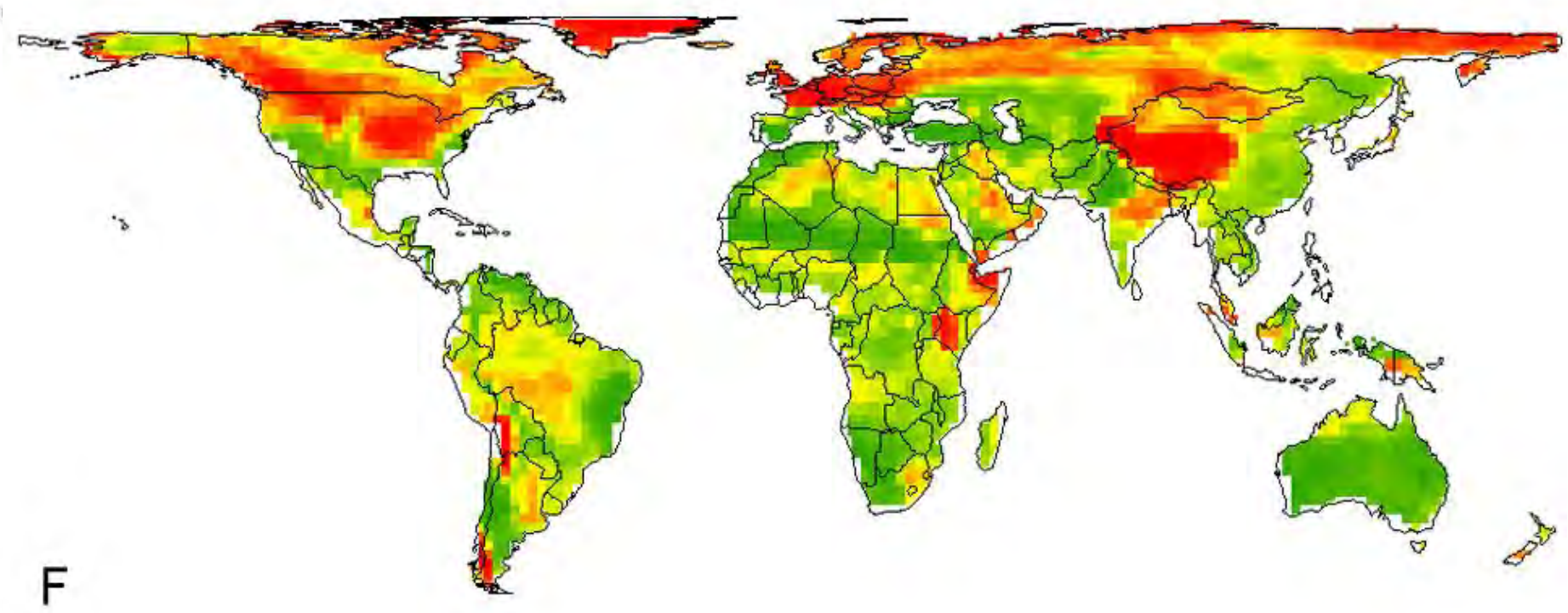
Fig. 3 Global land cover map showing the cluster number for each land cover tile. Map is presented in the interrupted Goode projection divided into 40 × 18 tiles of 125 × 125 pixels each.

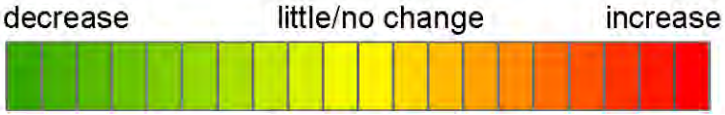
CL 1 and 5 showed an upward burned area trend annually and for particular months. (Jn-Jl)

Riaño, D., J.A. Moreno Ruiz, D. Isidoro, and S.L. Ustin. 2007. **Global spatial patterns and temporal trends of burned area between 1981 and 2000 using NOAA-NASA Pathfinder**. *Global Change Biology*, **13**, 40–50.

Where do we go

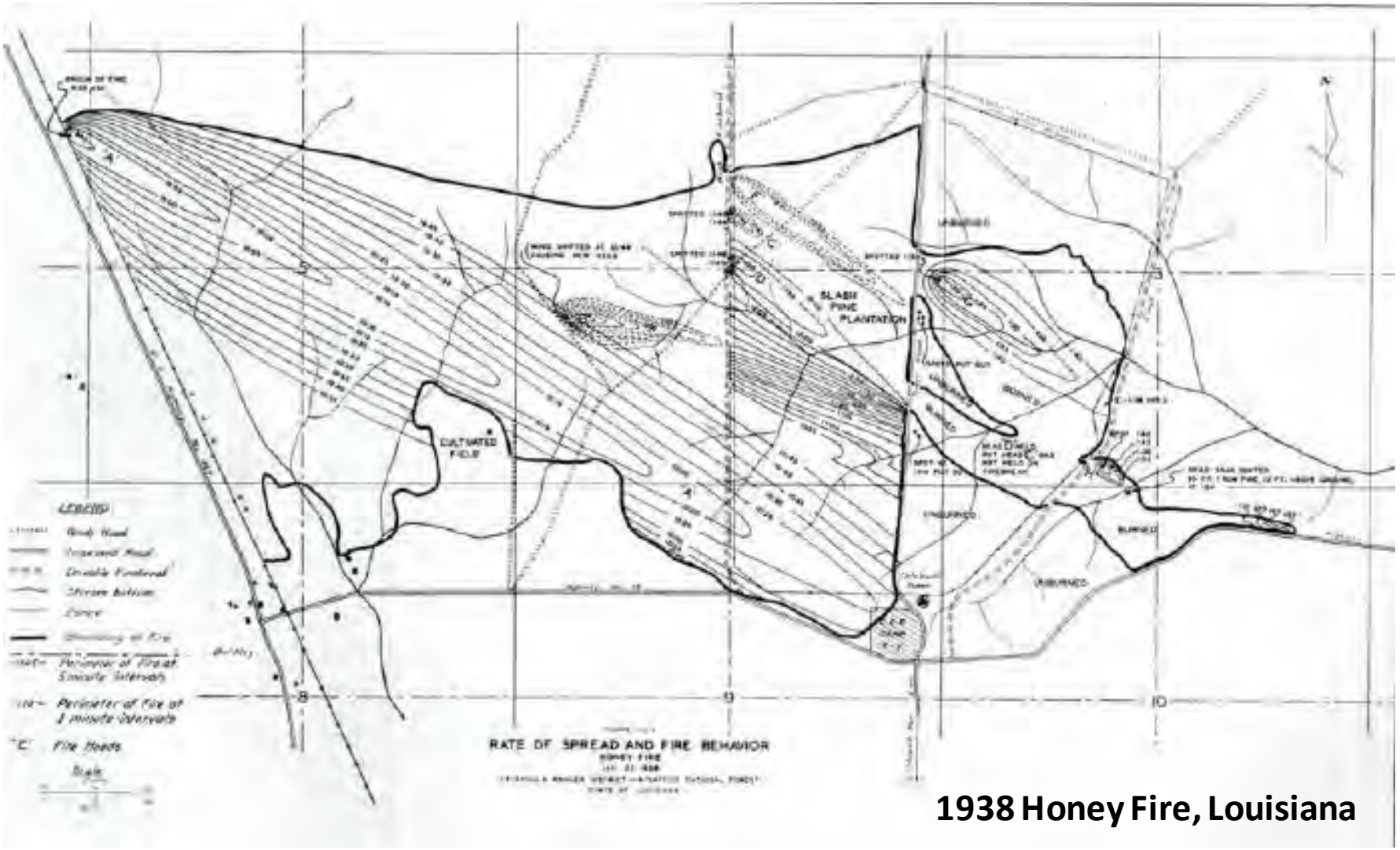
Fire scenarios from 2010 to 2070 (ATSR Fire Atlas based)





Krawchuk MA, Moritz MA, Parisien M-A, Van Dorn J, Hayhoe K, 2009. **Global Pyrogeography: the Current and Future Distribution of Wildfire**. *PLoS ONE* 4(4): e5102. doi:10.1371/journal.pone.0005102

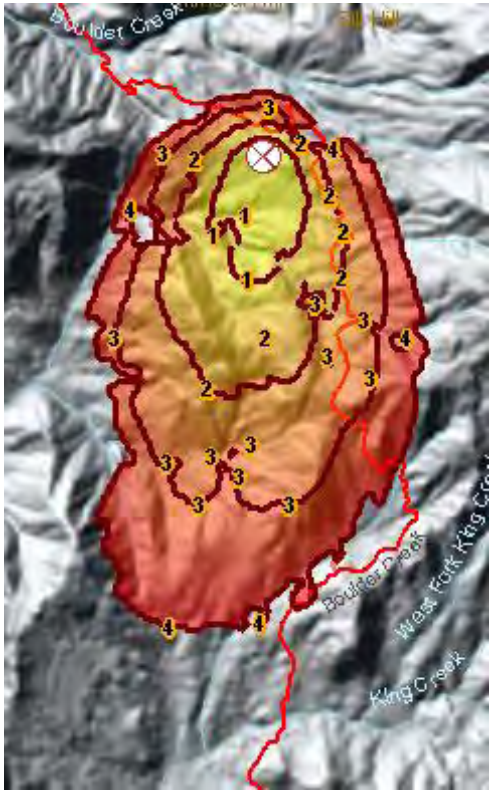
2. What is geospatial fire simulation?



1938 Honey Fire, Louisiana

The science and art of GWS

- **Where** the fire is going to be in the next …?
- How is it burning process?
- When can we expect to stop it?
- What is the potential of the fire?
- Why is the fire jumping?



All this question have an spatial answer

for this problem… we need models¡

- Models help us to better understand complex systems
- Helps us to quantify the problems
- Fire behavior involves (in a short approach)
  - Weather
  - Fuel
  - Terrain
  - Human factors
- Spatial and Temporal combined analysis is needed

Modeling fire behaviour

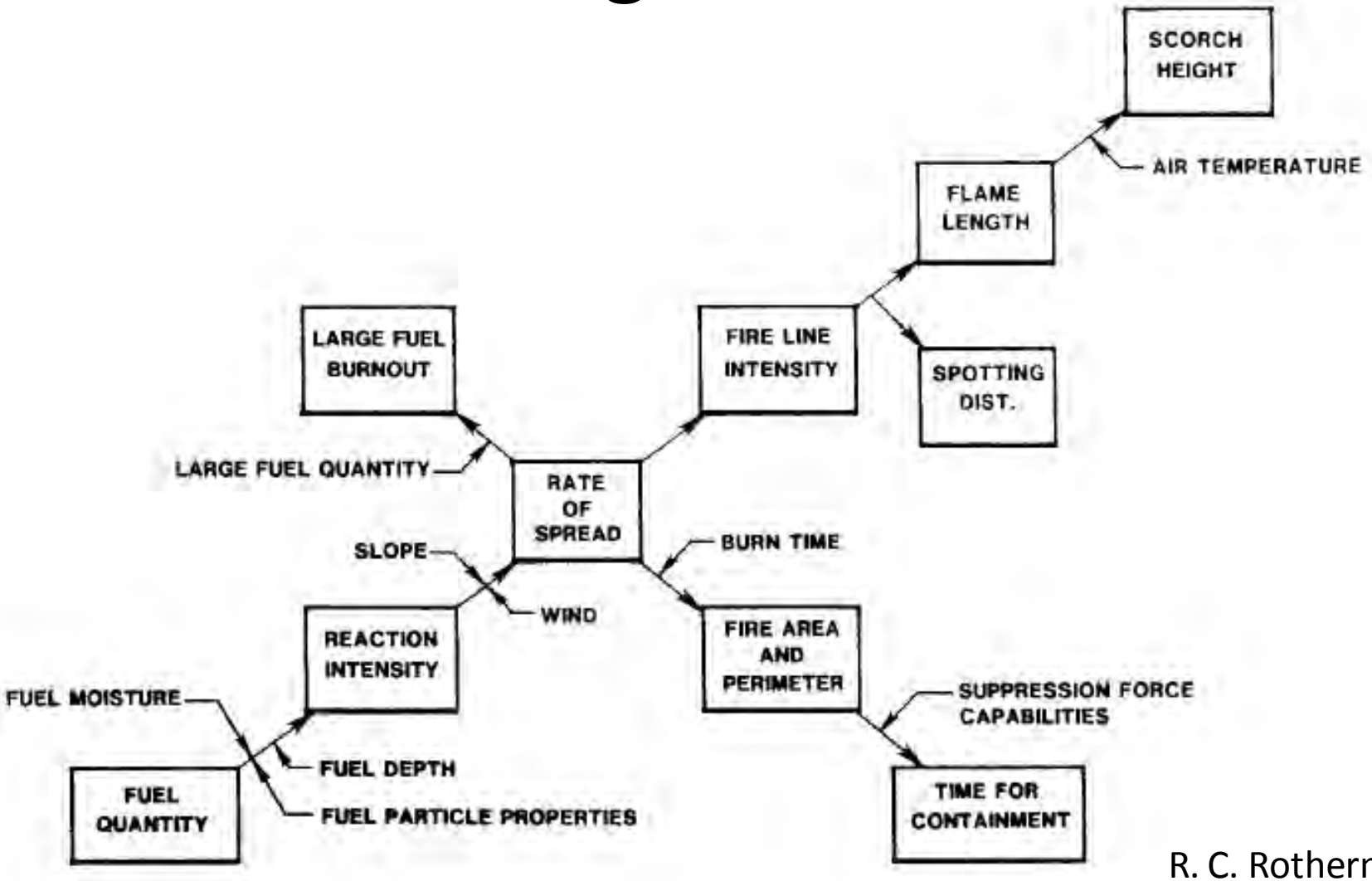


Figure 2--A series of fire models can be linked to meet a specific management problem.

R. C. Rothermel, 1987

Managing Research for Success

Gen. Tech. Rep. PSW-101 Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987

Models are out there

Models completed in period 1990-2007

12 Physical

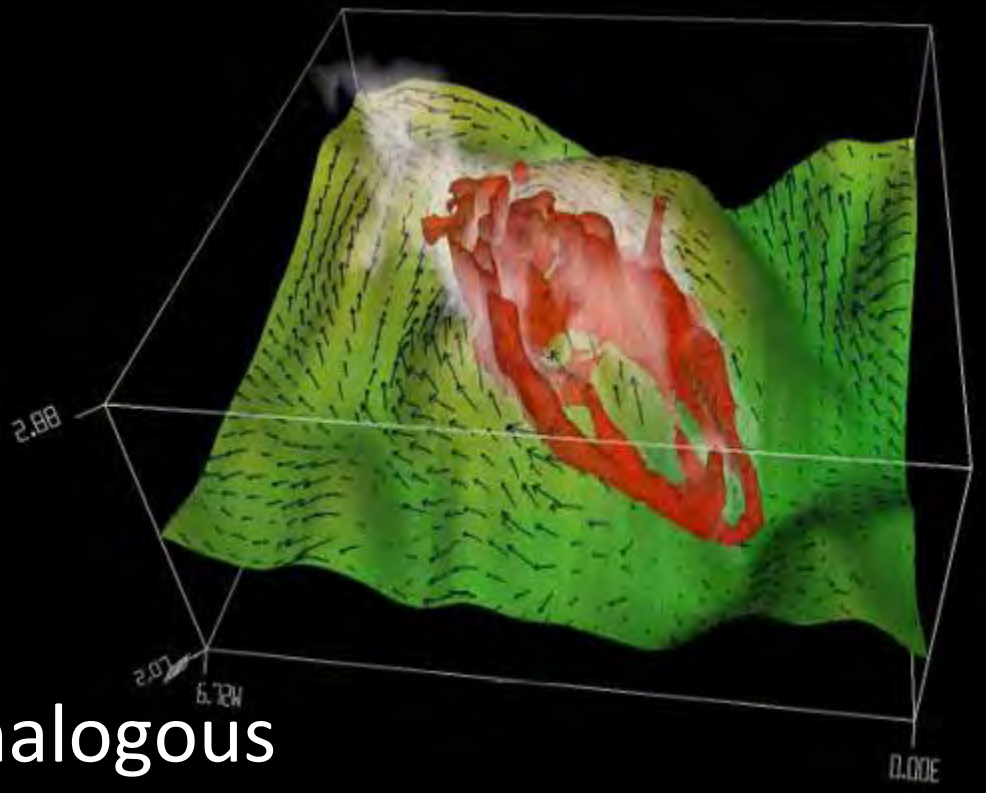
7 quasi-physical

15 empirical

5 quasi-empirical

11 simulation

22 mathematical analogous



Andrew L. Sullivan

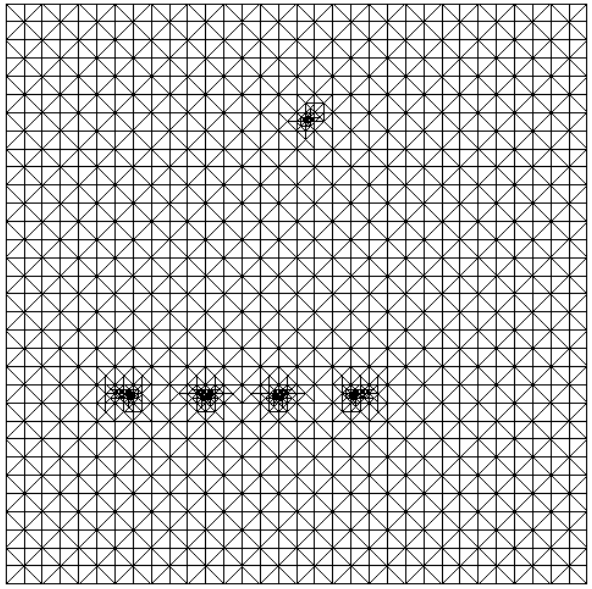
Wildland surface fire spread modelling, 1990–2007

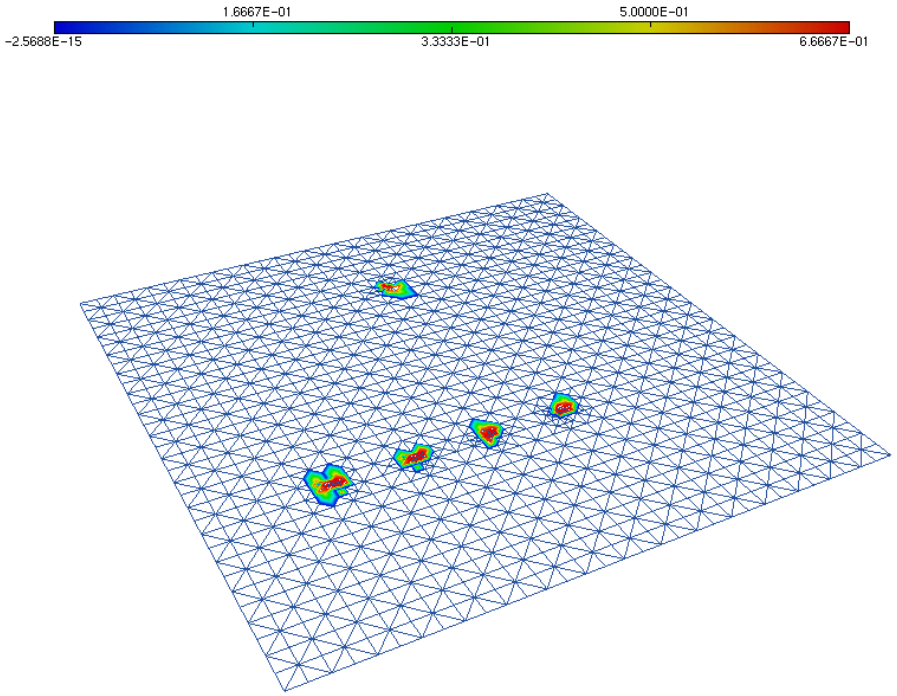
International Journal of Wildland Fire

Volume 18 Number 4 2009

Physical models

•FEM example with 4 ignition points





•Mesh

•Solution

•The resolution is done by the Finite Element Method with mesh adaptativity, we use the library Neptuno++ developed by Prof. Ferragut.

Physical models

	PROS	CONS
LOCAL	•Diffusion included: more complex •Convection included in ff equation	•Diffusion included: slower •Empirical model: hard to validate •Not valid for complex surface
Non LOCAL	•Valid for complex surfaces •External independent model •Validation independent of fire equations	•Wind effects only on radiation

Empirical models

PROS

- Widely known used and tested
- Based on experimental data
  - NFFL fuel types
  - European fuel types
- Very quick resolution
- FREE!
- Surface fire, crown fire, spotting, Fire acceleration

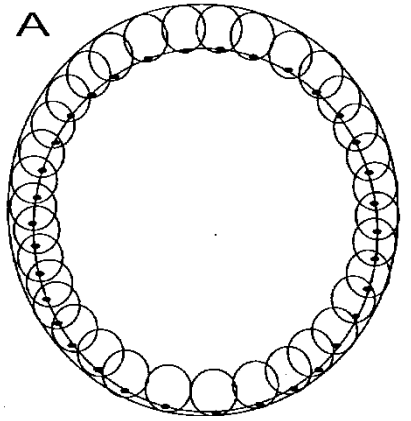
CONS

- Very technical
  Only user with training may use it.
- Based experimental data
  - Bad exportability
  - No new effects are expected
- No FFDSS embeded GIS:
  - Data conversion
  - No operational layers
  - Tedious file configurations
  - No enhanced GIS capabilities

GIS techniques
spatio-temporal calculations

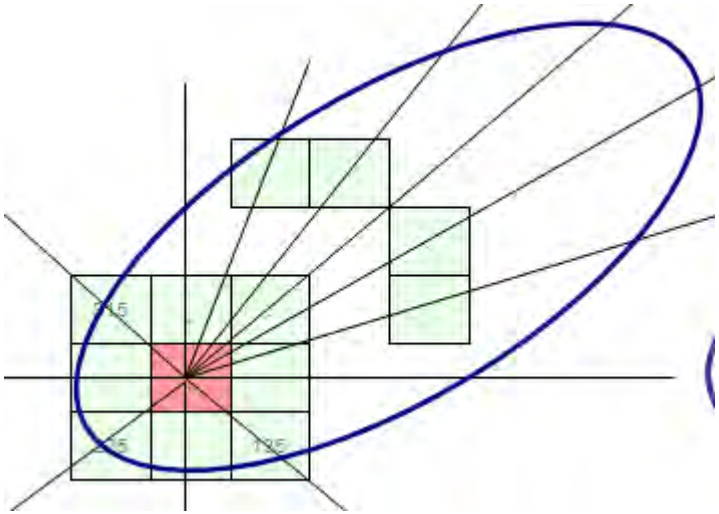
Huygens Principle

- **Temporal discretization**
- Less distortion on the front
- Only traditional Time of Arrival Calculations
- i.e. Farsite

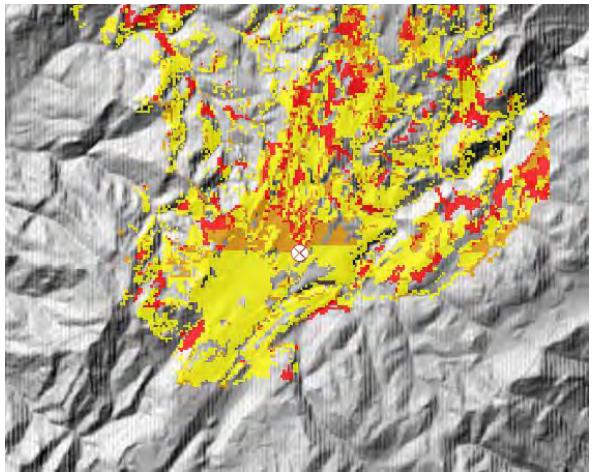


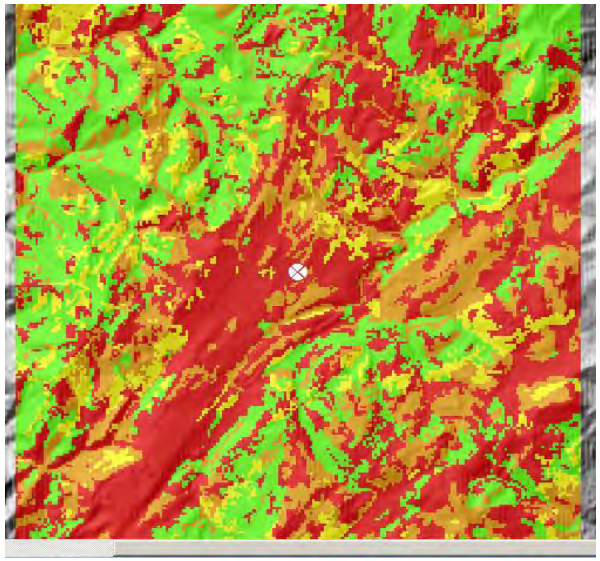
Mínimum Travel Time

- **Spatial discretization**
- Allows new simulation modes
- Firebreaks width effect incorporated
- Paralelizable
- i.e. Flammap & WFA

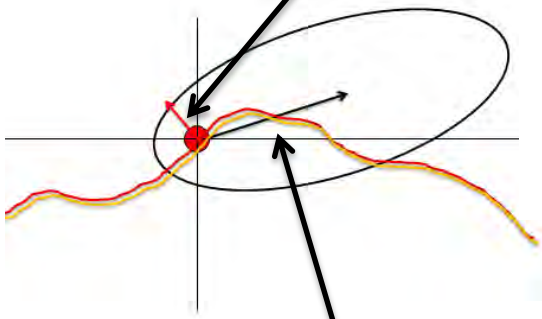


Static and dynamic simulations





- **Dynamic**
  - Only covers the simulation
  - Real found values



- ROS
- Flame length
- Flame intensity
- Suppression capacity

- **Static:**
  - Covers the whole scenario
  - Is not linked to any ignition

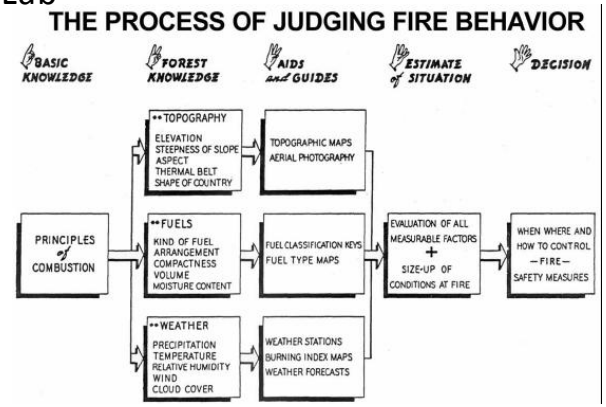
3. **Who**'s who in **GWS**

Harry T. Gisborne

First true specialist in forest fire research in the Nation

Jack S. Barrow

Director of the Missoula fire Lab

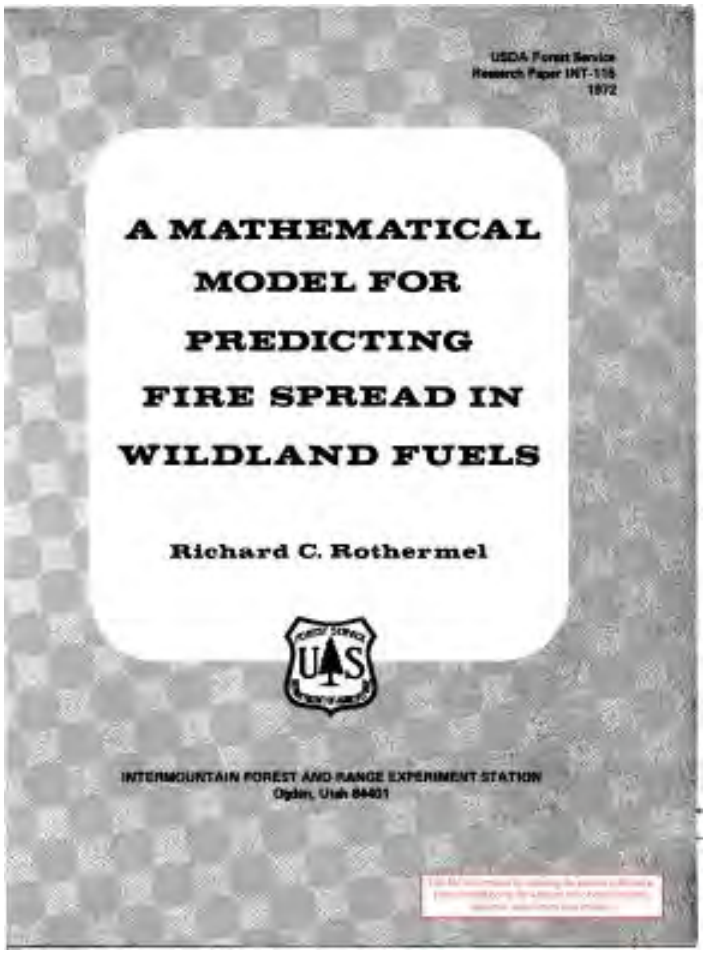


The Mann Gulch Fire (1949)

Who's who in **GWS**

Richard C Rothermel

"The beauty of Rothermel's model … is that it's simple— it can be run quickly with a low-capability Computer" B. Butler



Rothermel based GWS

Potential fire risk analysis

Table, graph, and diagram output

Rothermel

2-dimensional fire growth model

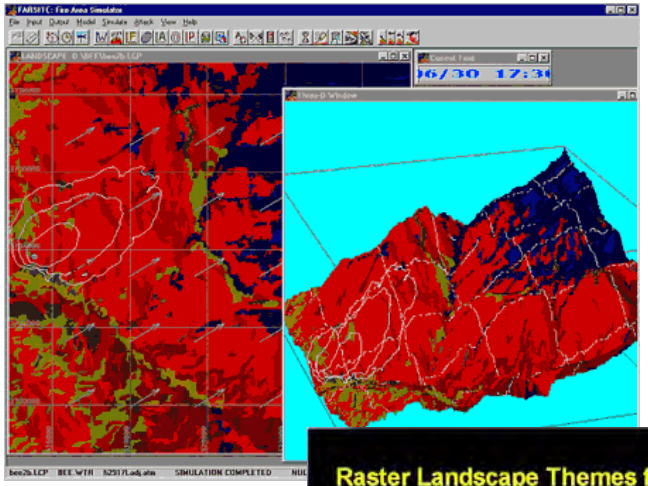
f(
- Fuel type
- Wind
- Terrain
- Moisture

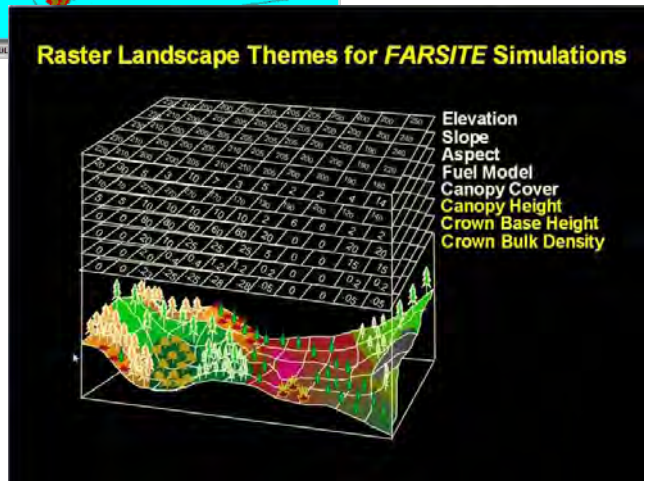
)

- ROS (Rate Of Spread)
- Fire line intensity
- Flame length

http://www.firemodels.org/

Farsite: Mark Finney's First complete GWS (1991-1998)



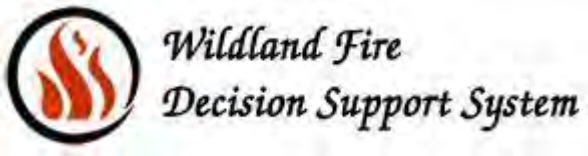


FBAN's: the guys that put the models in the right place ¡

4. **When** is fire modeling useful?

actual uses of GWS

Prevention	Operations	Postfire
• Fuel medication plans • Forest management	• Support on large scale incidents (WFDSS) • Impact analysis (RAVAR)	• AAR • Fire reconstructions



new uses of operational simulations

Prevention

- Observed Fire Behavior database
  - Fuel management
  - Analyze firebreaks efficiency
  - Resources location optimization

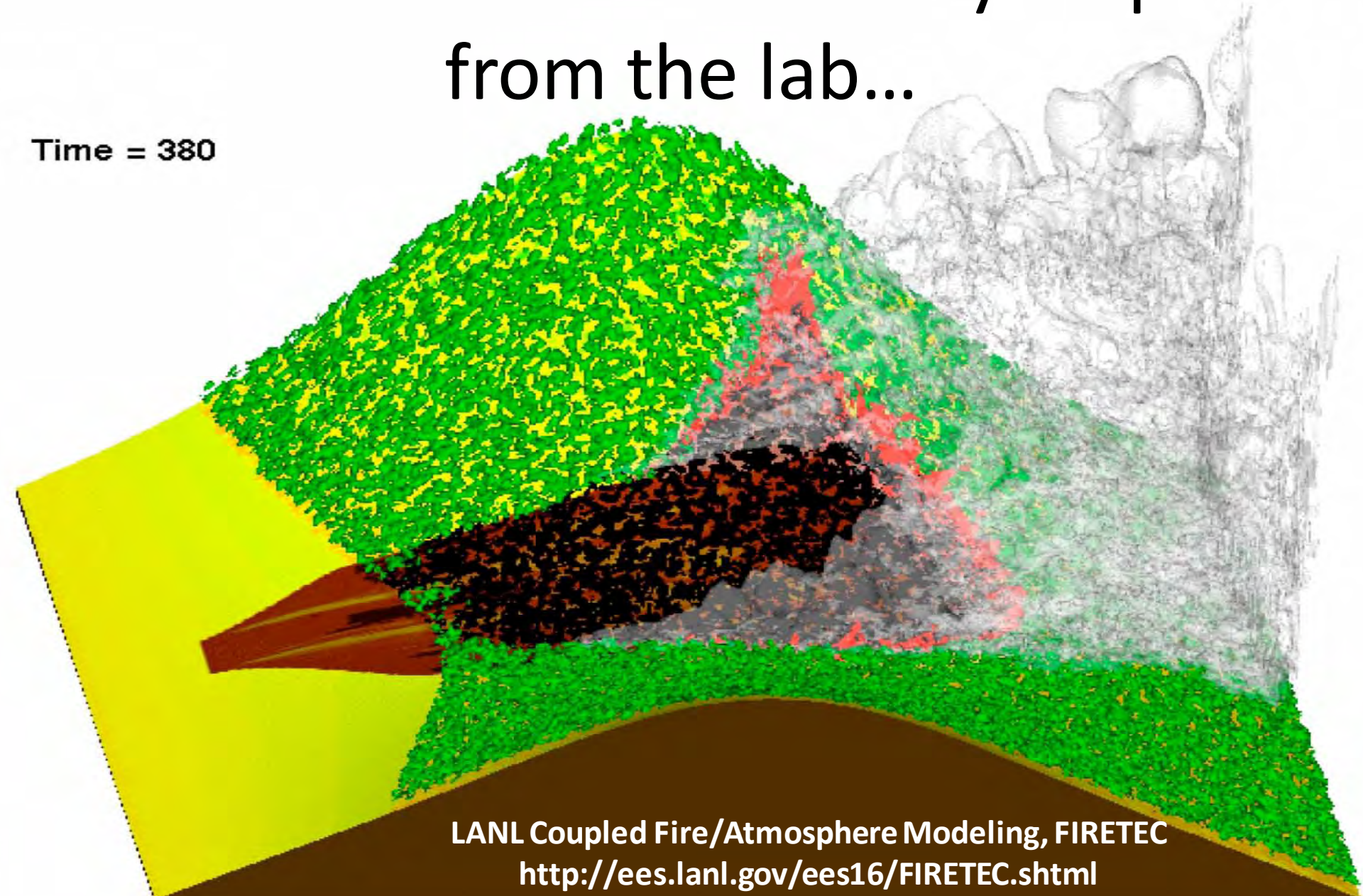
Operations

- Every Alarm Evaluation
- Multiple incidents
- IAP support
- Integration in DSS

Post fire

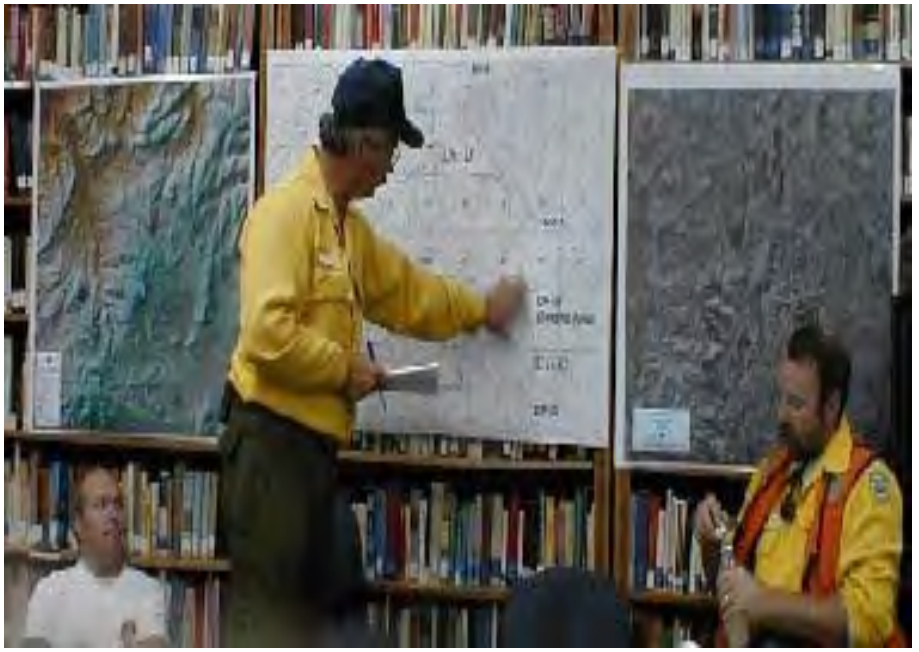
- Fire Scenarios
- Impact assesment
- What if?
- Historical analysis
- New local models

5. Where can it be of any help? from the lab…

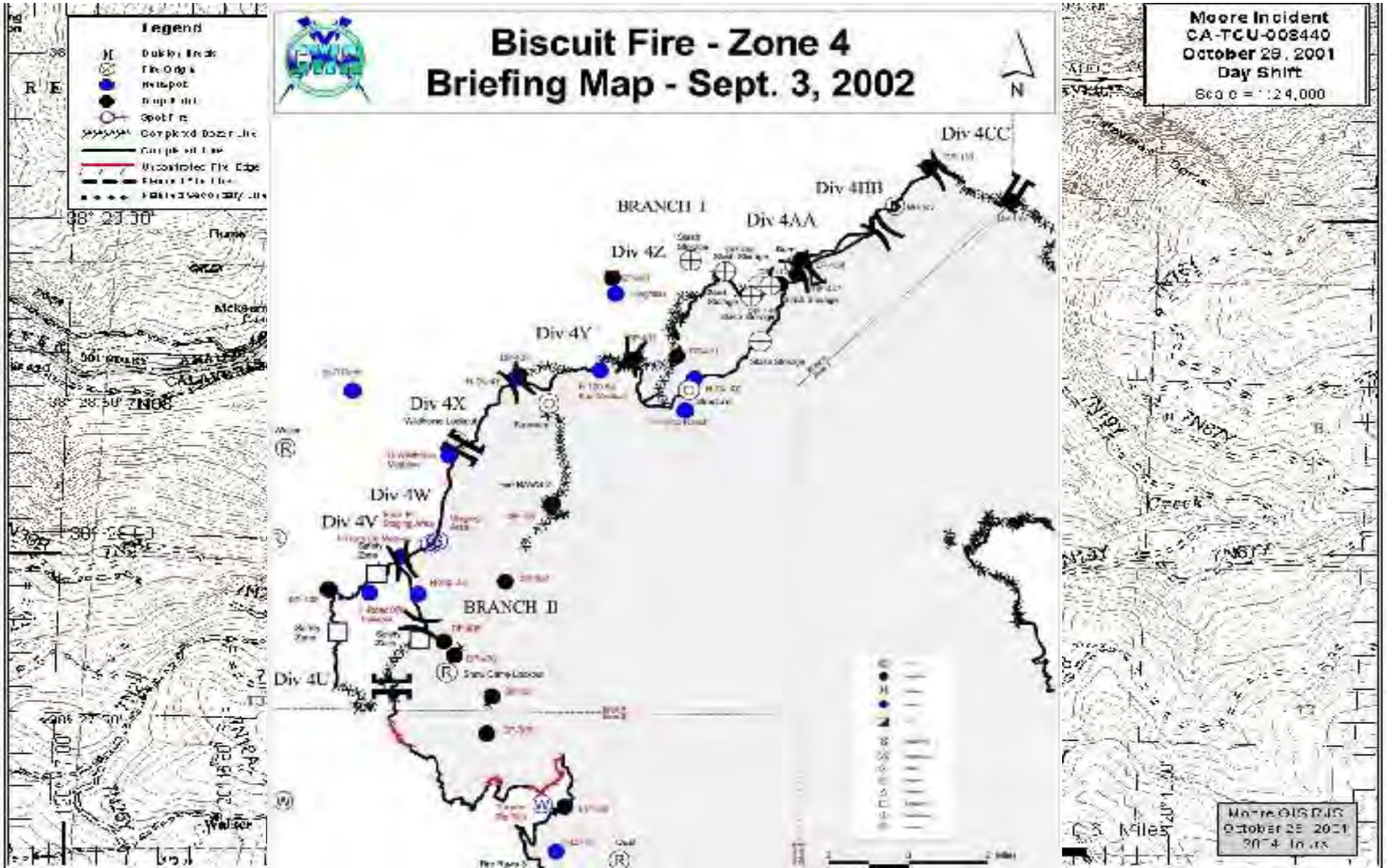


LANL Coupled Fire/Atmosphere Modeling, FIRETEC
http://ees.lanl.gov/ees16/FIRETEC.shtml

to the Incident Command Post ¡

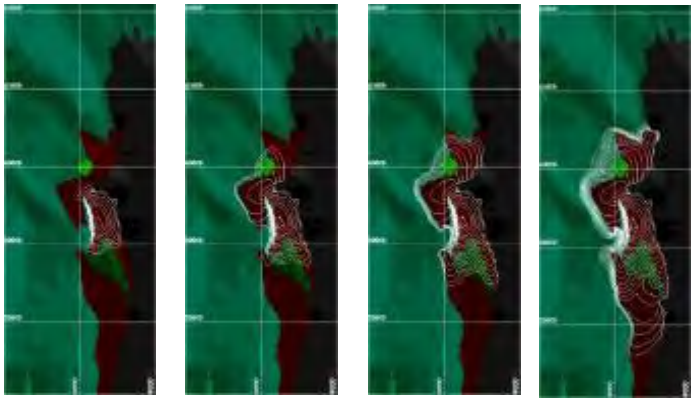


supporting operations is the basis for better modelling capabilities



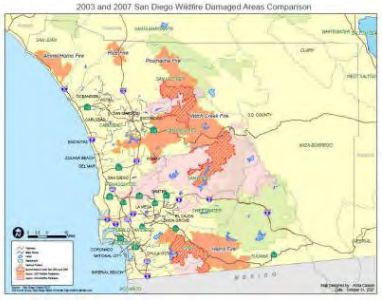
6. **How** GWS is helping fire modelling nowdays?

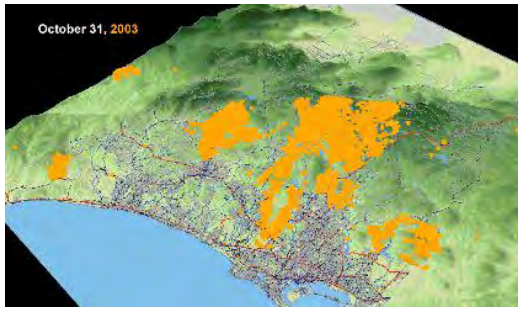
- Low use in European FF services of this kind of tools, unless in prevention phase, and in a few cases only (EUFIRELAB, 2005)[1]
  - Fires in euromediterranean countries are very fast, and a lot at the same time
  - Actual tools are difficult to feed, and use data not fitted to the needs of the users
  - Results needs of high skill users to get the best of them, and are difficult to evaluate
- Use of propagator in PREVENTION and mainly USA – big fires
- Bad perception of their utility, (lot of solutions, main approach of years of GIS developments in FF)
- Input data hard to process and not appropiate scales
- Results oriented more to laboratory than to real fire fighting



6. How GWS is helping fire modelling nowdays?

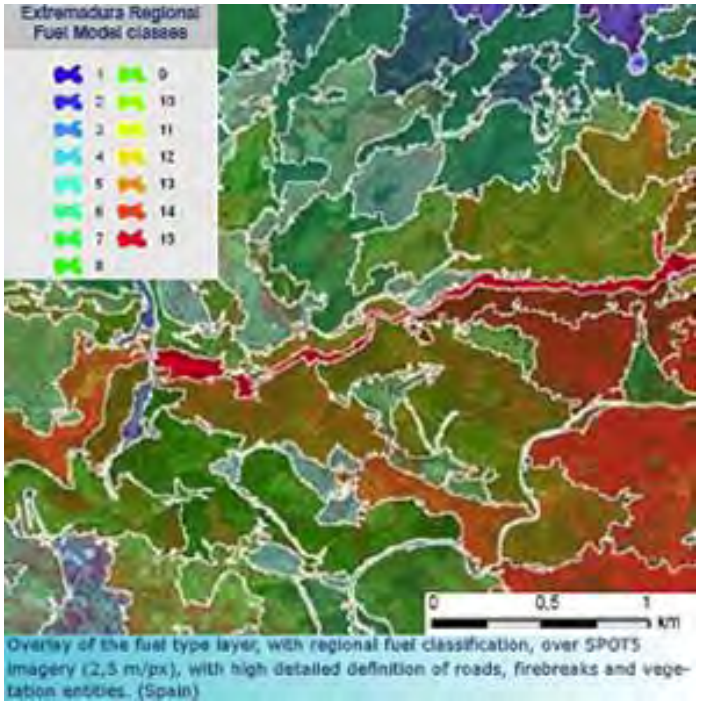
creating situational awareness



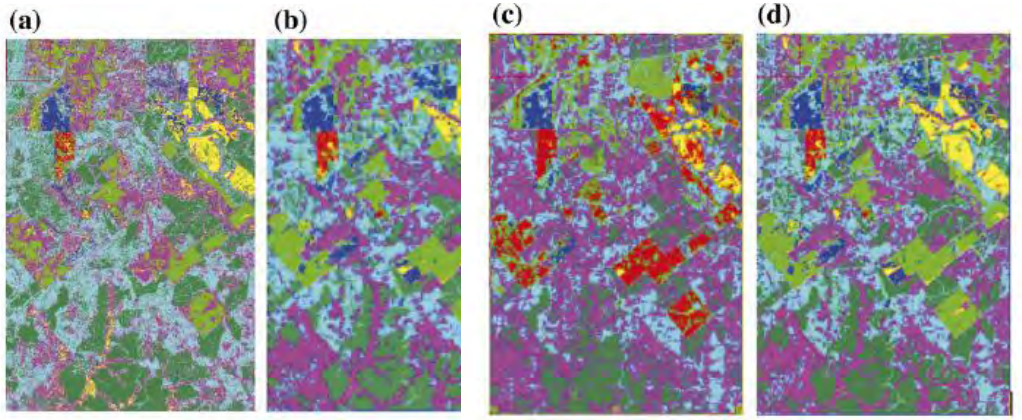


enhancing inputs

High resolution fuel models



Overlay of the fuel type layer, with regional fuel classification, over SPOT5 imagery (2,5 m/px), with high detailed definition of roads, firebreaks and vegetation entities. (Spain)



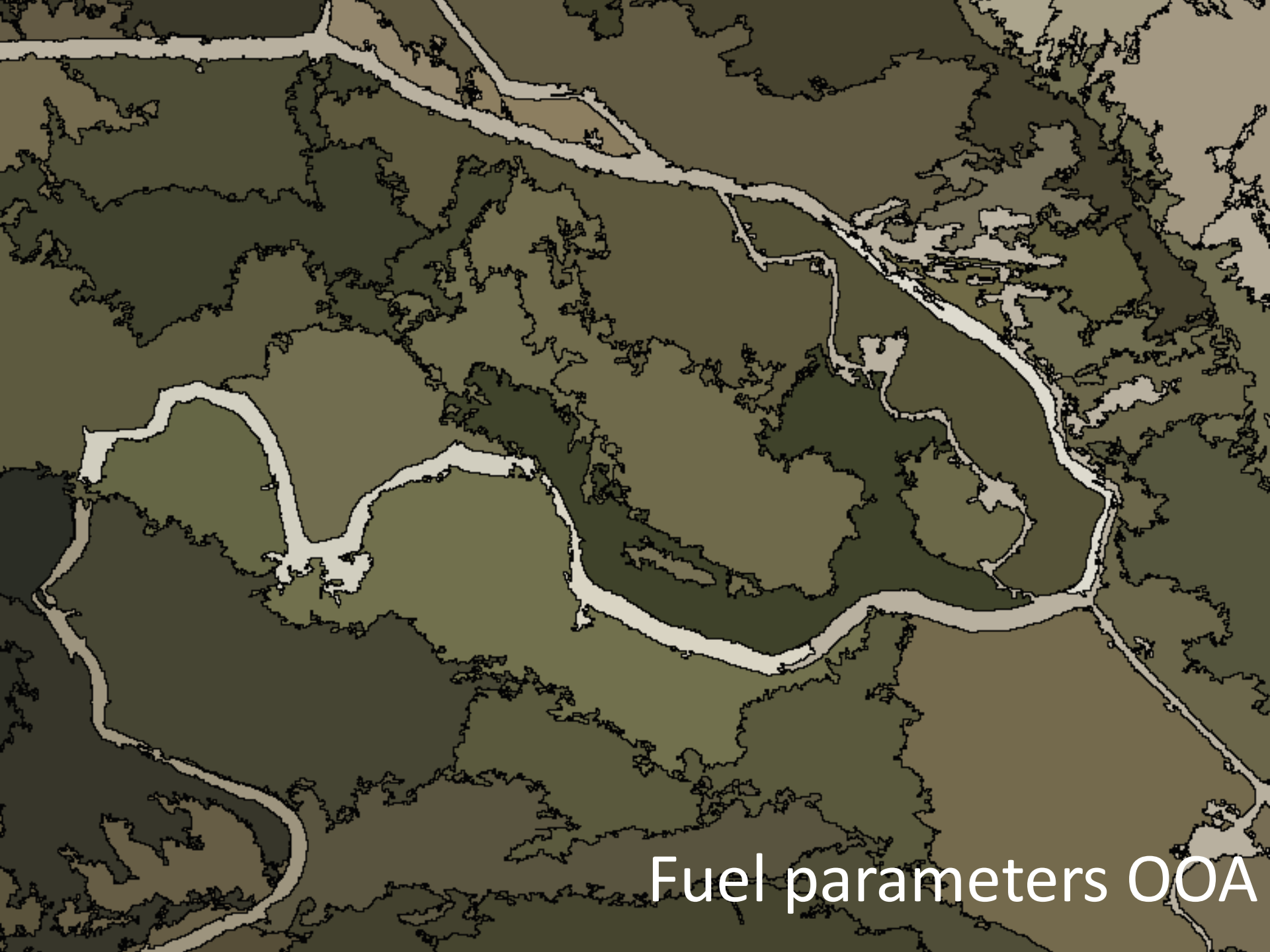
The classification result of multispectral QuickBird image, (b) the classification result of data fusion stack of lidar and multispectral imagery, and (c) The classification result of PC stack image, (d) The classification result of MNF stack image

F-M # 1	Grass
F-M # 2	Grass
F-M # 4	Brush
F-M # 5	Brush
F-M # 7	Brush
F-M # 8	Timber
F-M # 9	Timber

Legend for all classifications

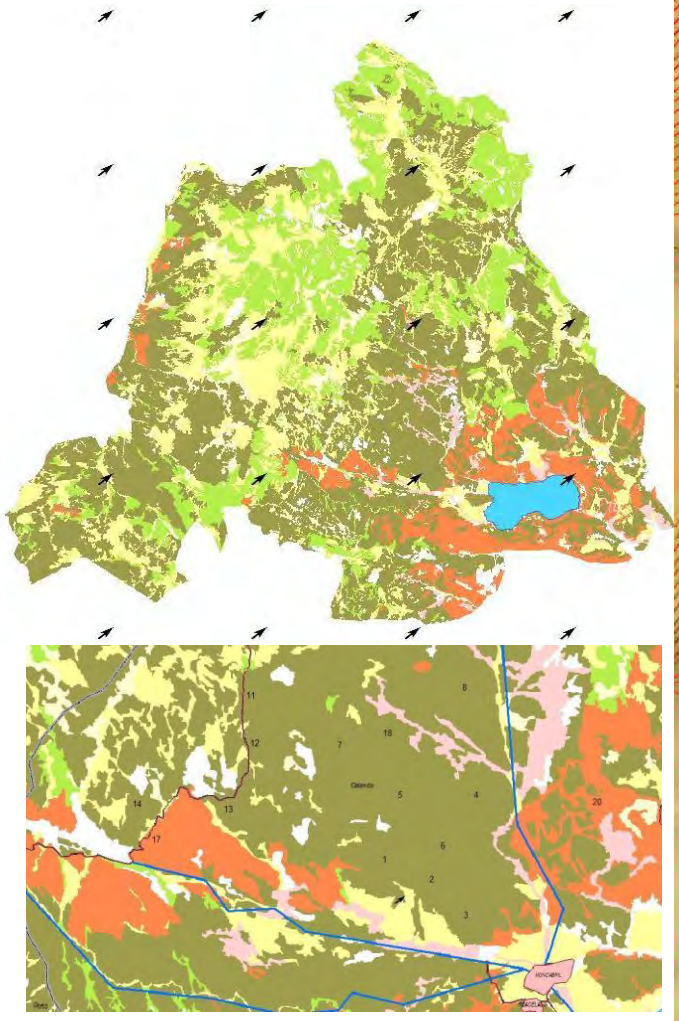
Ramirez, J. & Galera, J (2007)**. HR Fuel Parameters based on OOA & Cluster analysis**. Preview-Risk 6th FP project
http://www.preview-risk.com/site/FO/scripts/myFO_contenu.php?noeu_id=34&page_id=4&lang=EN

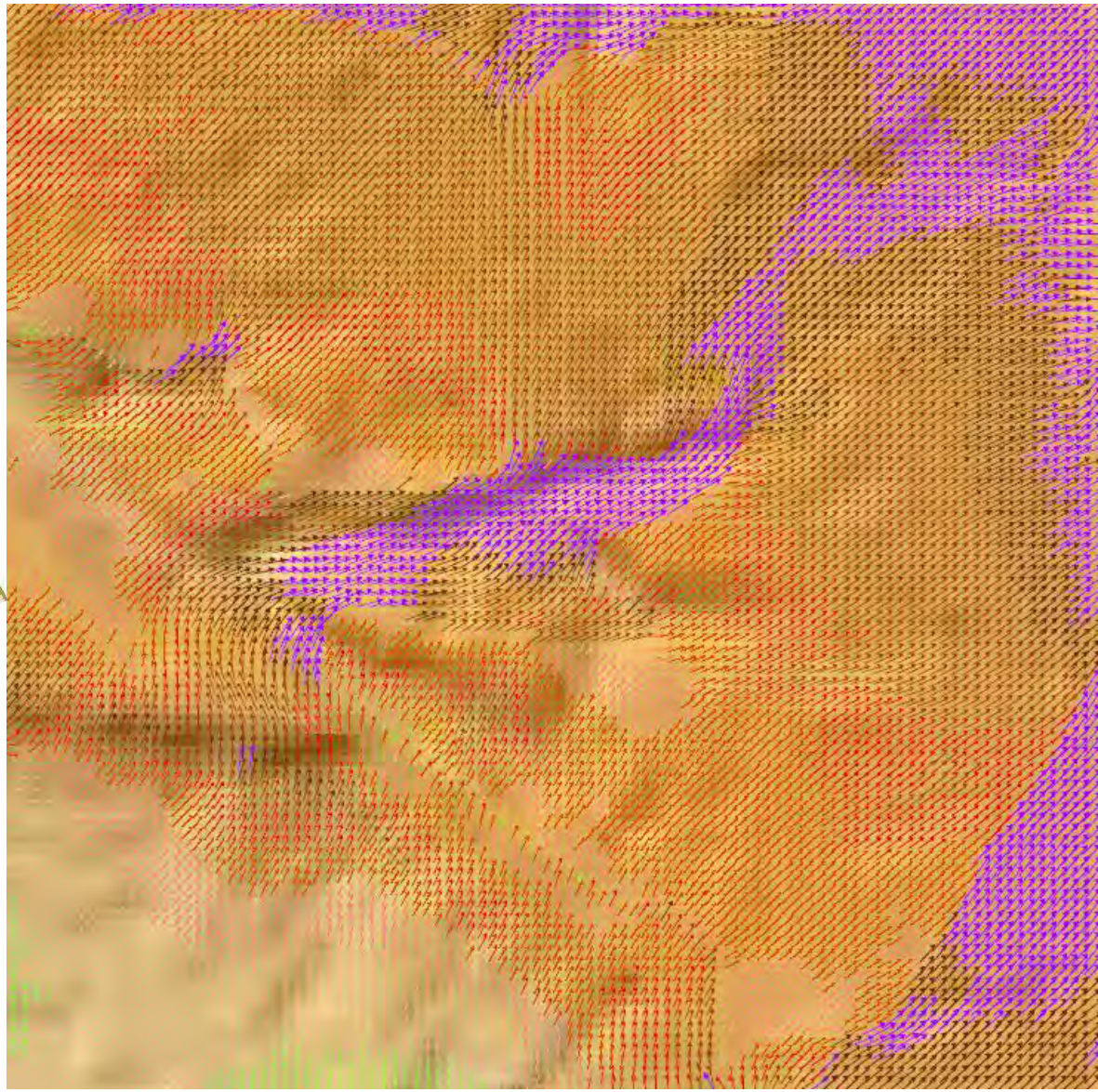
Muge Mutlu , Sorin C. Popescu, Curt Stripling, Tom Spencer
Mapping surface fuel models using lidar and multispectral data fusion for fire behavior
Remote Sensing of Environment 112 (2008)


Fuel parameters OOA

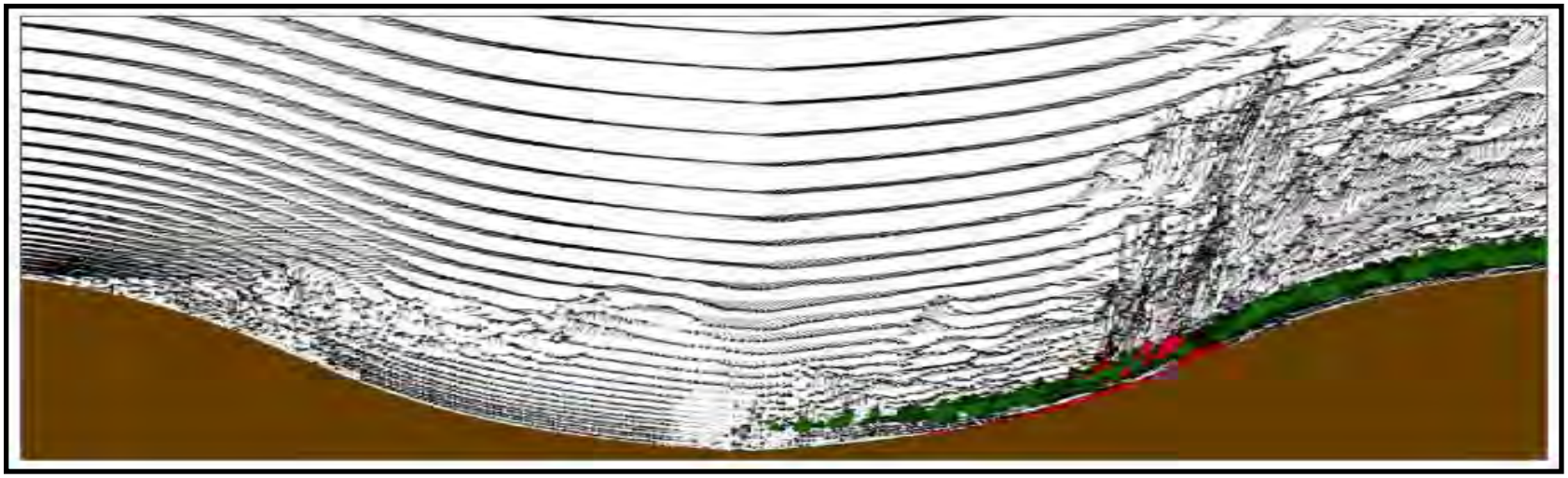
enhancing inputs: HR wind

- High Definition Wind Field:
from Hirlam =13 km data to 25 m data



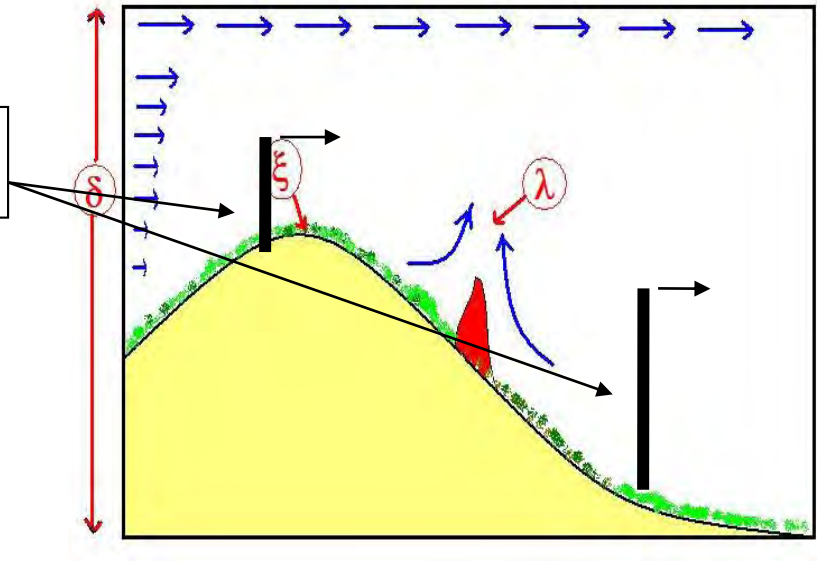


3D High Definition Wind



FireTEC. L. Winterkamp, R. R. Linn, Jonah J. Colman, William S. Smith

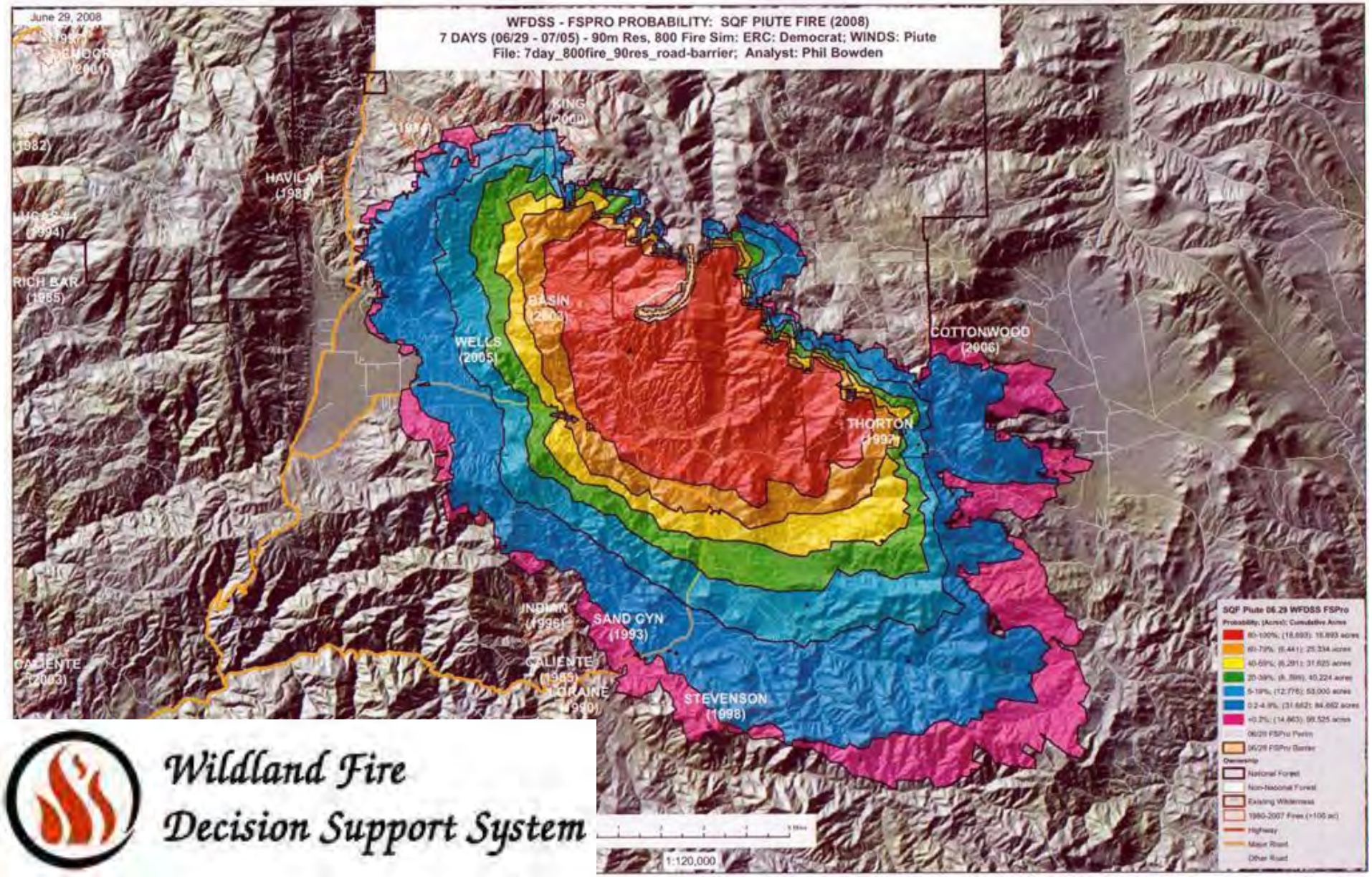
Enhaced with punctual
Wind value assimilation



M.I Asensio, L. Ferragut, J. Simon, (2005).
"A convective model for fire spread simulation."
Applied Mathematical Letters 18, pp. 673-677, 2005

FSPro&FPA: Strategical Probabilistic GWS

http://wfdss.usgs.gov (2007)



Operational needs: design principles

- Simulations must be able to run within 1-2 min
- Seamless data integration = minimal training
- Focus on generating products that users can walk away with (maps, reports, charts)
- Ability to accept field observations and adjust simulations interactively
  - Mobile devices
  - User input on-the-fly

TOOLS SHOULD BE LEARNED IN ONE HOUR, USED IN ONE MINUTE (R. KEANE)

What is Wildfire Analyst?

Wildfire ANALYST

understanding the risk

Objetives: provide simulation capabilities in operations scenarios, provide the foundations for a fire behavior database

Developed under the European Preview, Programme VI (R&D) framework, for the development of operational emergency tools (www.preview-risk.com)

In production in 2010 in Military Emergency Unit, Junta de Extremadura, 2011 Andalucía, Aragón y Murcia, partnership with GRAF (CAT)

Preparing Pilot in SD County, Alabama FS and Texas FS & Chile (V Region)

Integrating Rothermel´s (inc. Windninja & Farsite dll) , Kitral al McArthur models

Bombers GRAF (Gen. Catalunya)

Wildfire ANALYST

Simulating in new ways

PROPAGATION MODES

'cause protecting is even more important than extinguishing …..

(evacuation mode)

For when simulations just don't fit the real data….

(Adjustment mode)

Simulating backwards in time …

(Reverse time mode)

'cause sometimes we just can't relay on our inputs…

(Probabilistic mode)

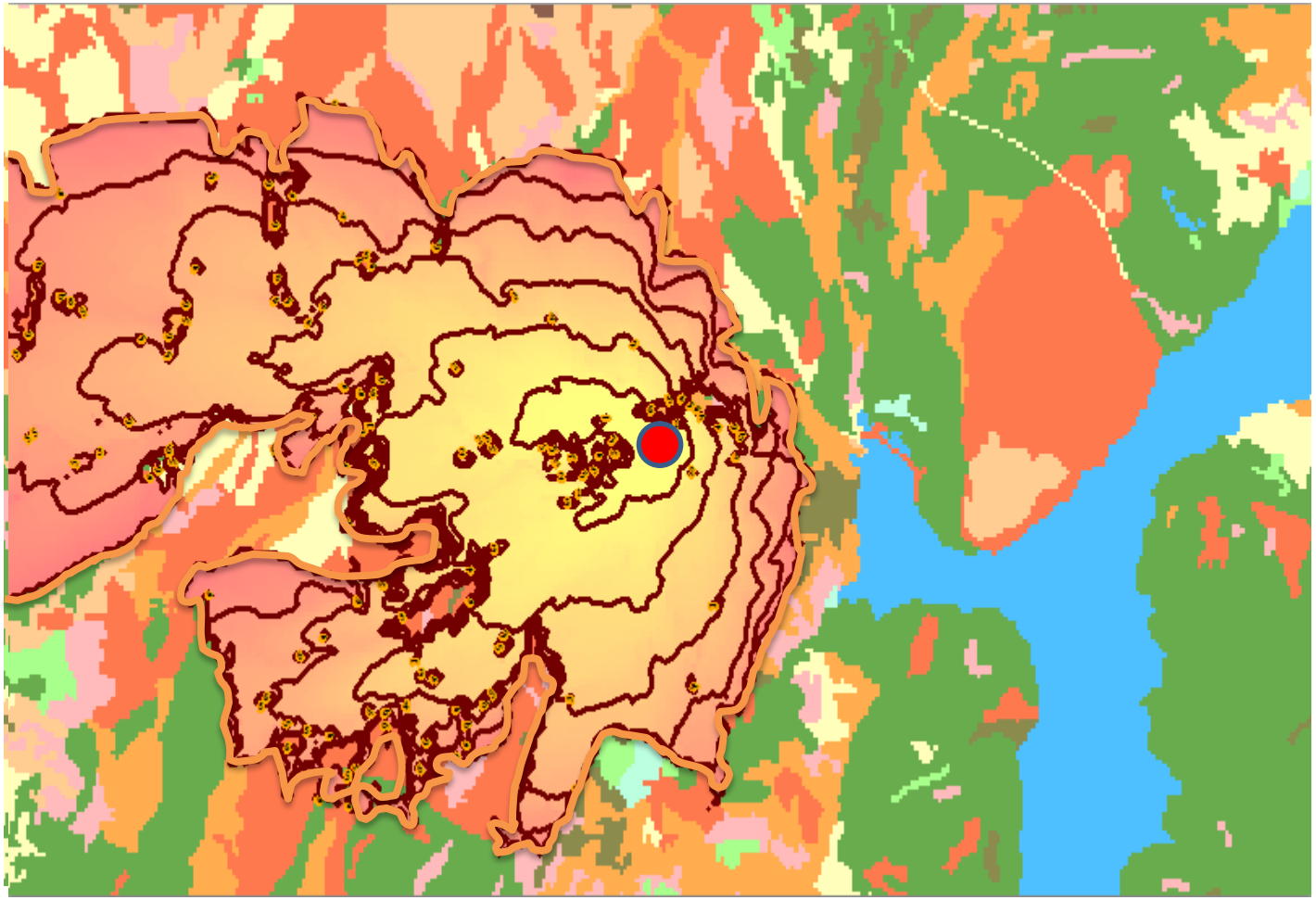
For when simulations just don't fit

Real data

A fire is reported and simulated….

Wildfire ANALYST

ADJUSTMENT MODE



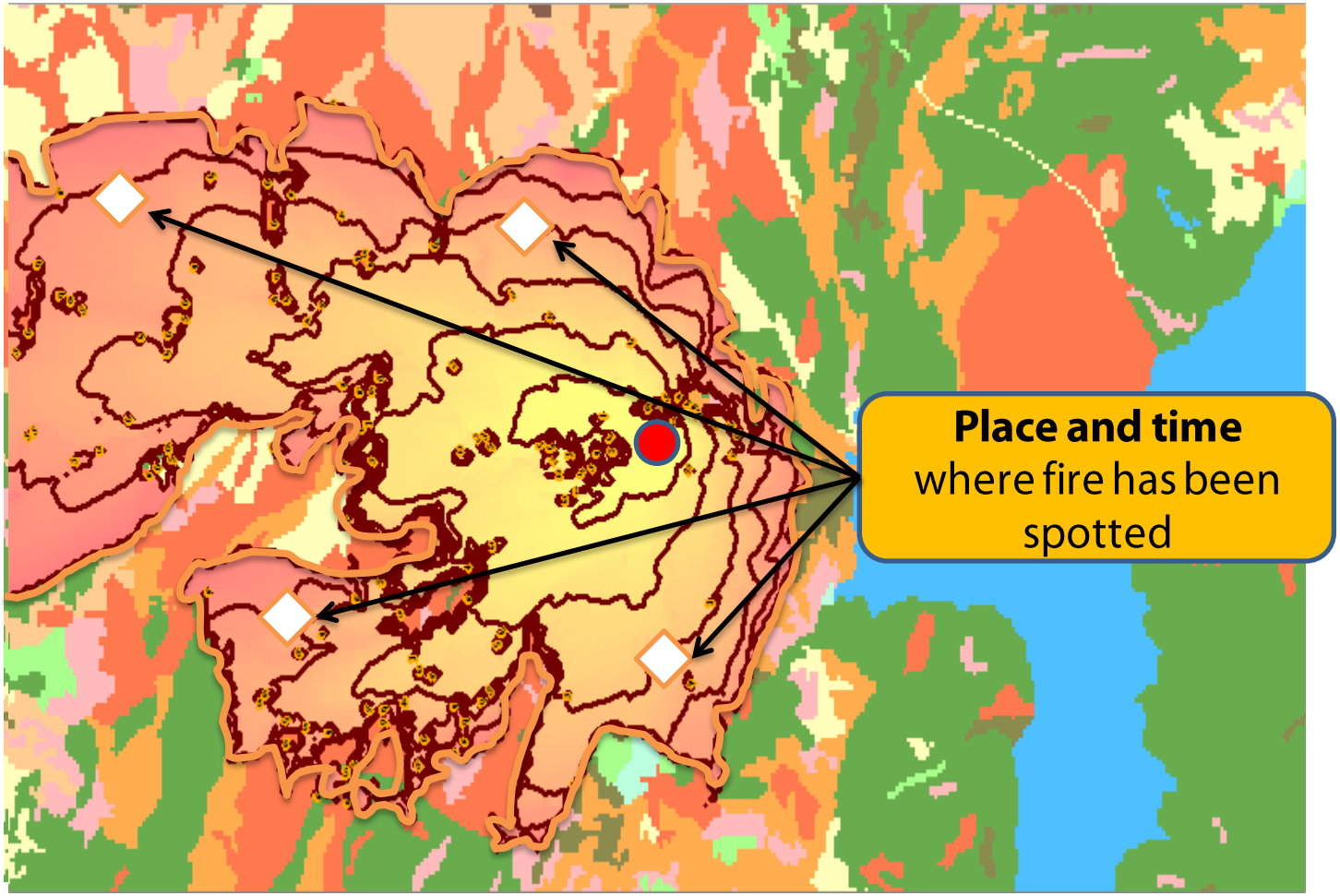
A fire is reported and simulated….

BUT

Real data shows that ROS is overstimated

Wildfire ANALYST

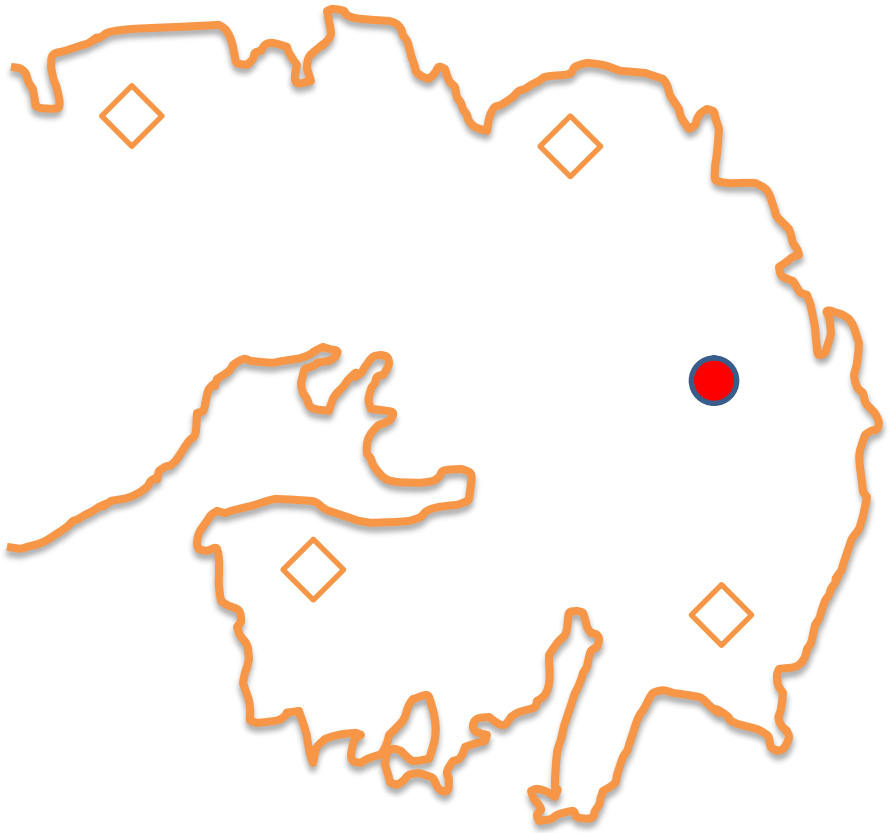
ADJUSTMENT MODE



Error cause is unknown…
But going on with the simulation will just cause increasing inaccuracy

Wildfire ANALYST

ADJUSTMENT MODE



Standard approach:

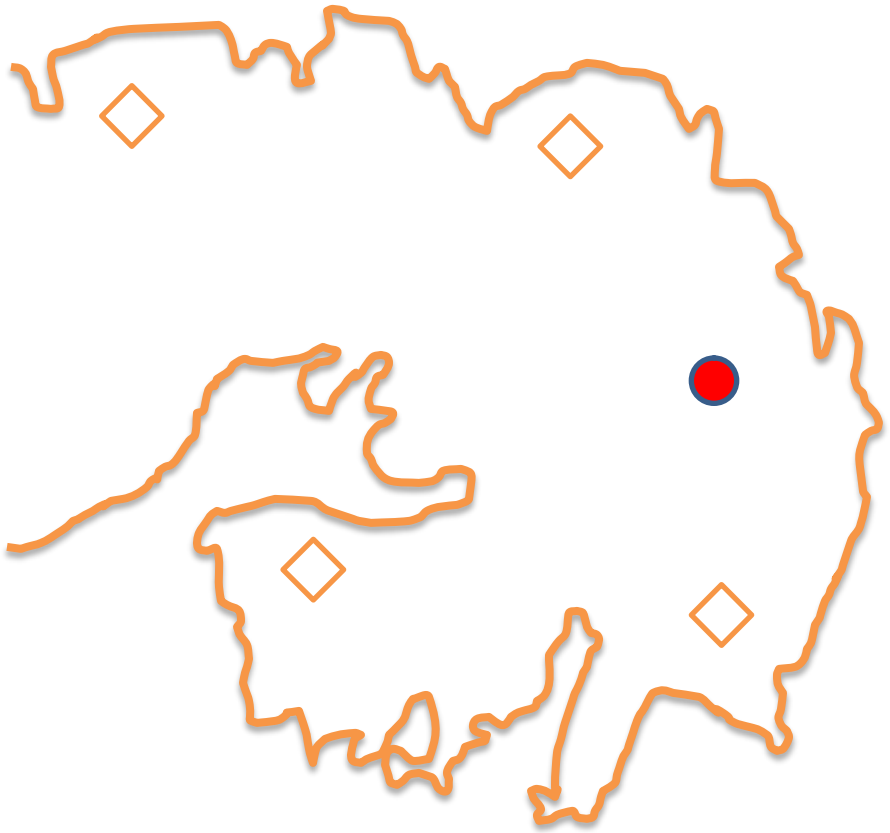
Find ROS factors to fit the simulation…

That is…

Find a ROS correction value for every fuel type such that final fire shape fits real data

Wildfire ANALYST

ADJUSTMENT MODE



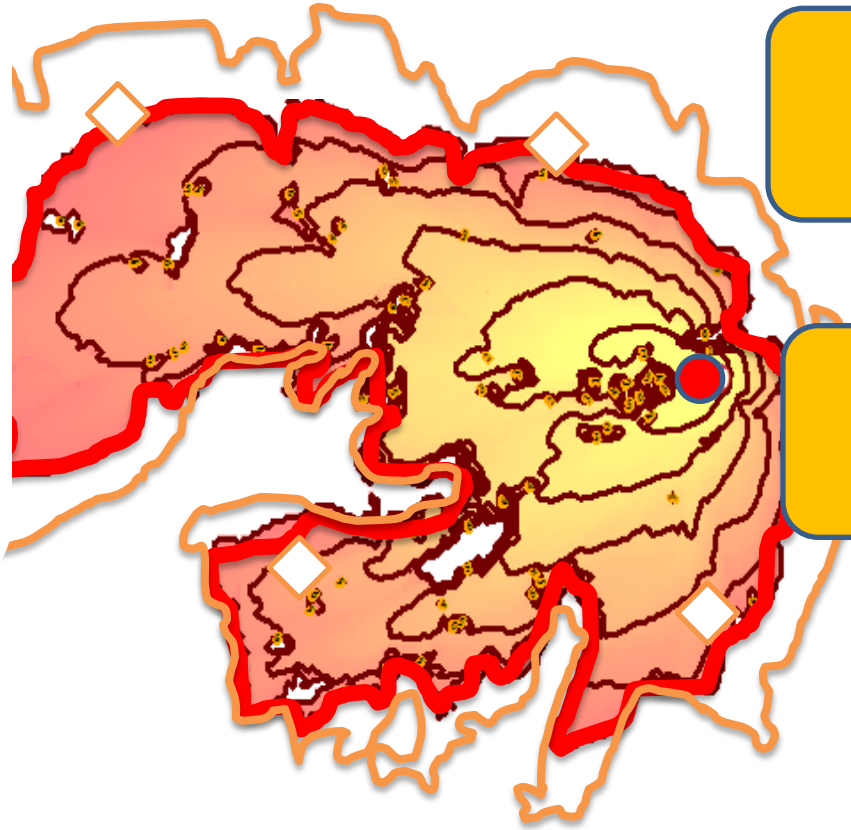
This usually takes **HOURS...**

BUT

WFA may just do it in **SECONDS...**

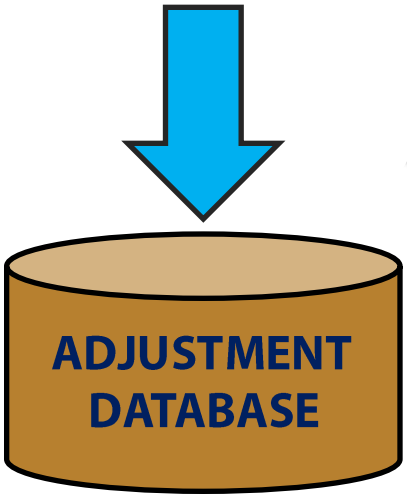
Wildfire ANALYST

ADJUSTMENT MODE



Based on those factors
A BEST FIT simulation
simulation is done

And found factors
are stored in a DATASET



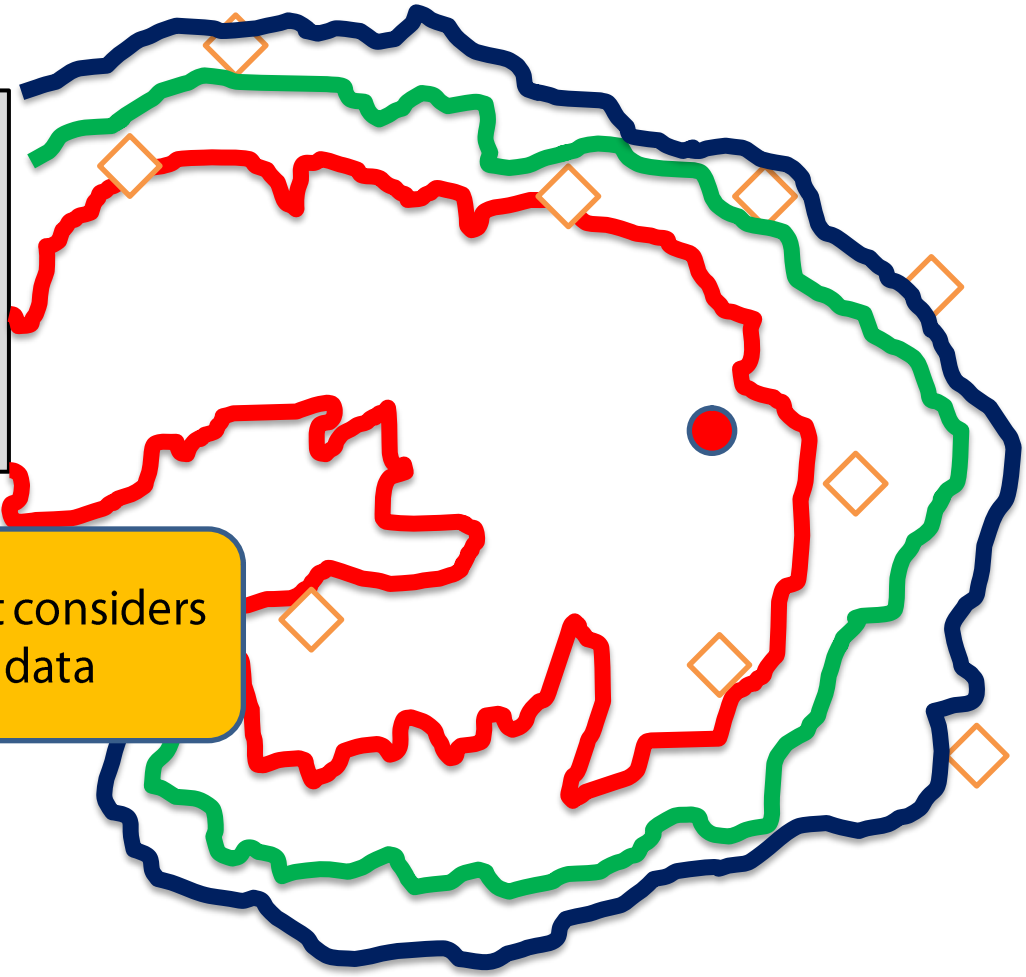
Used for **DATA ASIMILATION**
simply by continuously
updating new fire data..

Wildfire ANALYST

ADJUSTMENT MODE

ROS FACTORS

Fuel 2	..... 0.79
Fuel 3	..... 0.21
Fuel 4	..... 1.30
Fuel 5	..... 0.73
Fuel 9	..... 1.13



Every adjustment considers
ALL real fire data

For when the aim is not only to Extinguish

Wildfire ANALYST

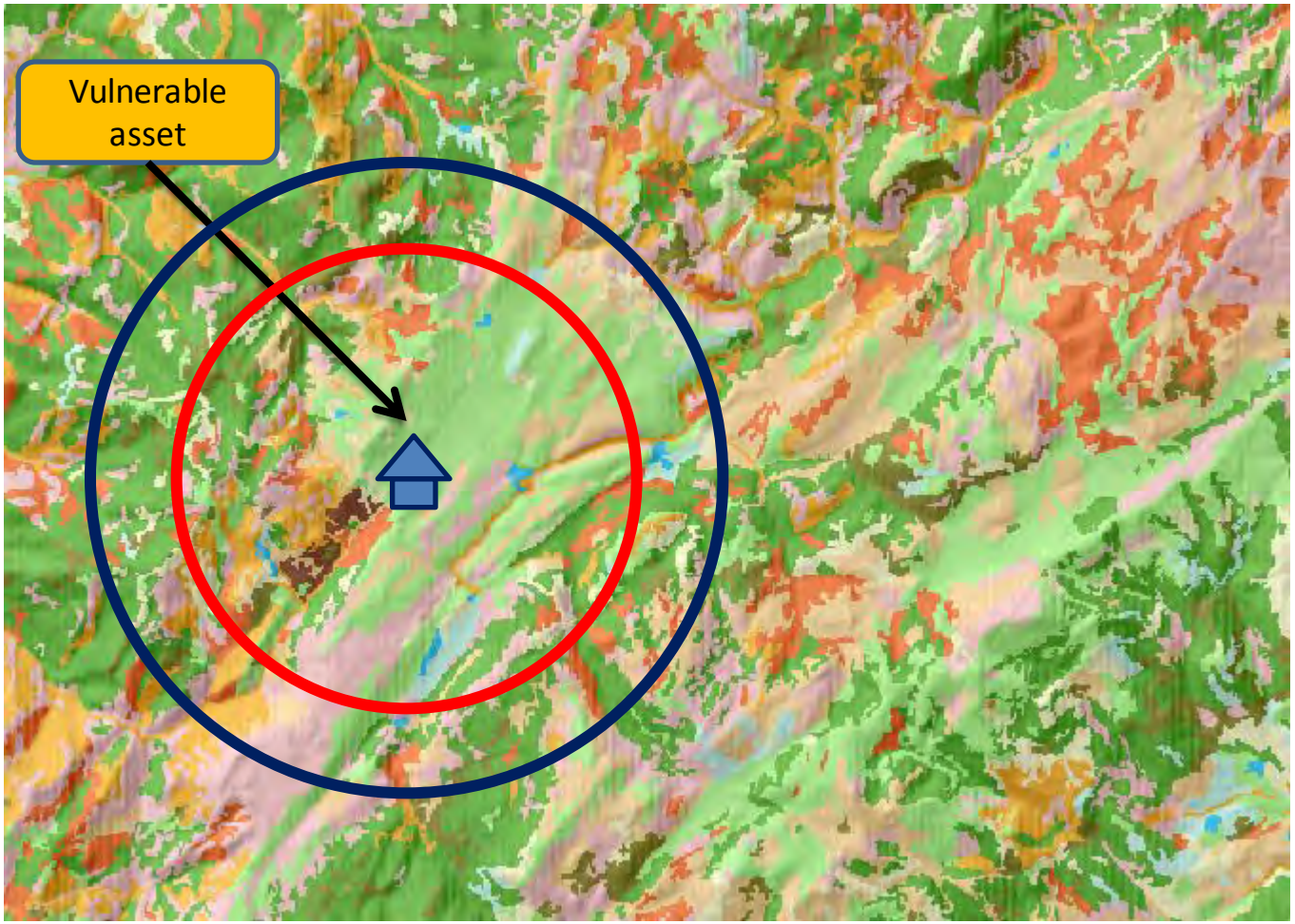
EVACUATION MODE

But to PROTECT

If fire gets inside evacuation regions an evacuation plan is required…

Wildfire ANALYST

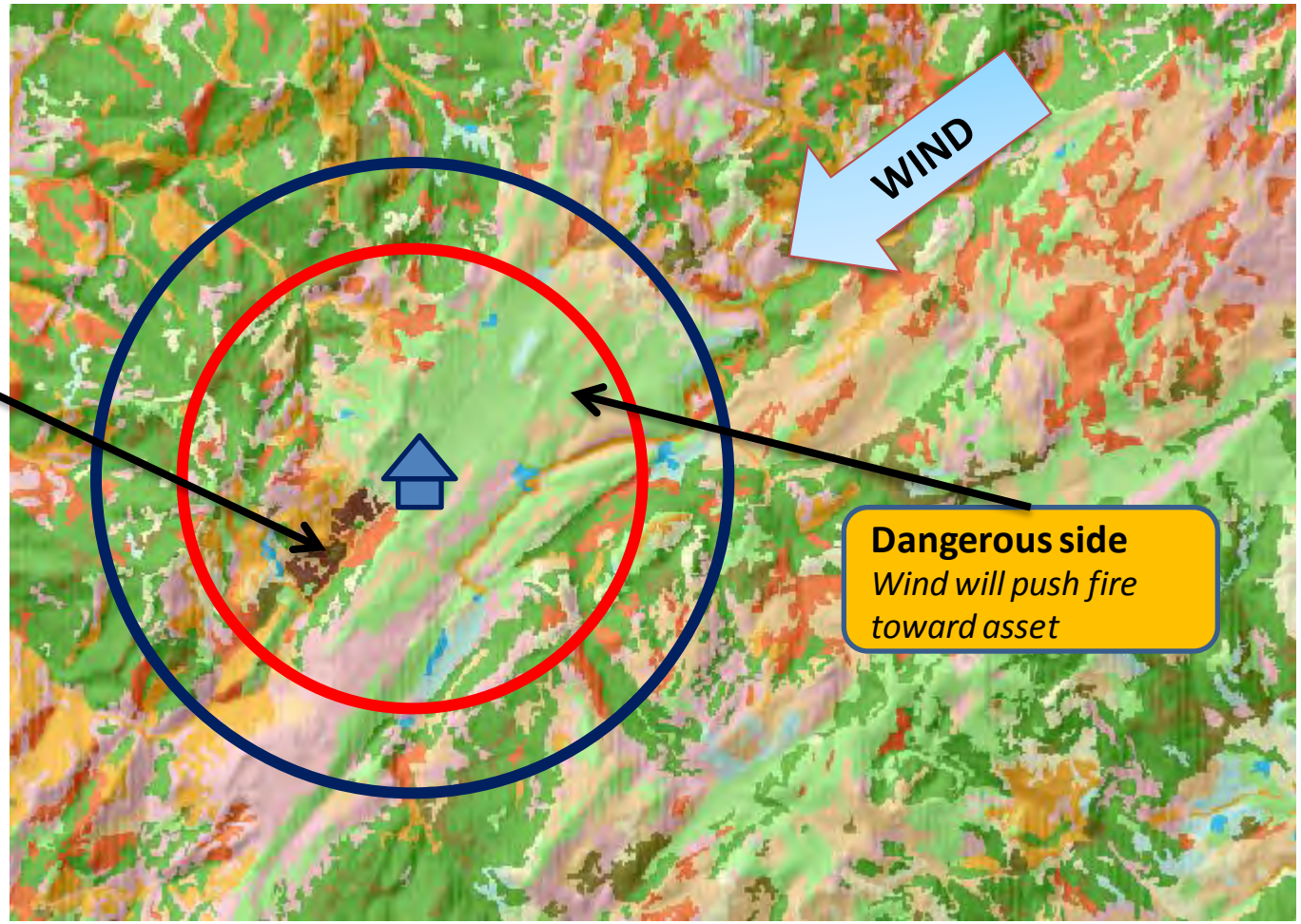
EVACUATION MODE



If **WIND** is present danger **WILL NOT** be homogeneous!!!

Wildfire ANALYST

EVACUATION MODE

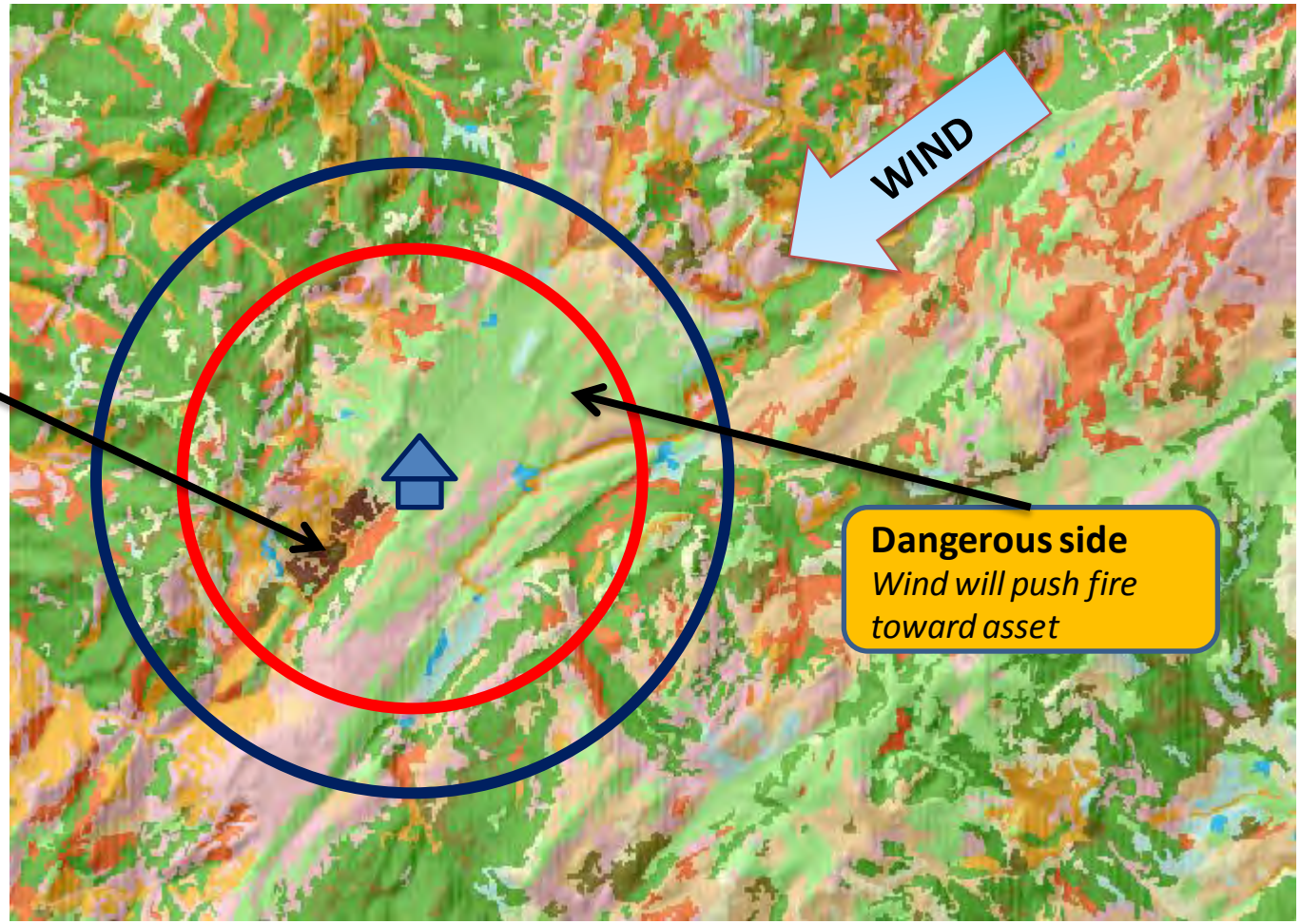


If **WIND** is present danger **WILL NOT** be homogeneous!!!
A better representation would be :

(Since the dangerous side requires a bigger safety region)

Wildfire ANALYST

EVACUATION MODE



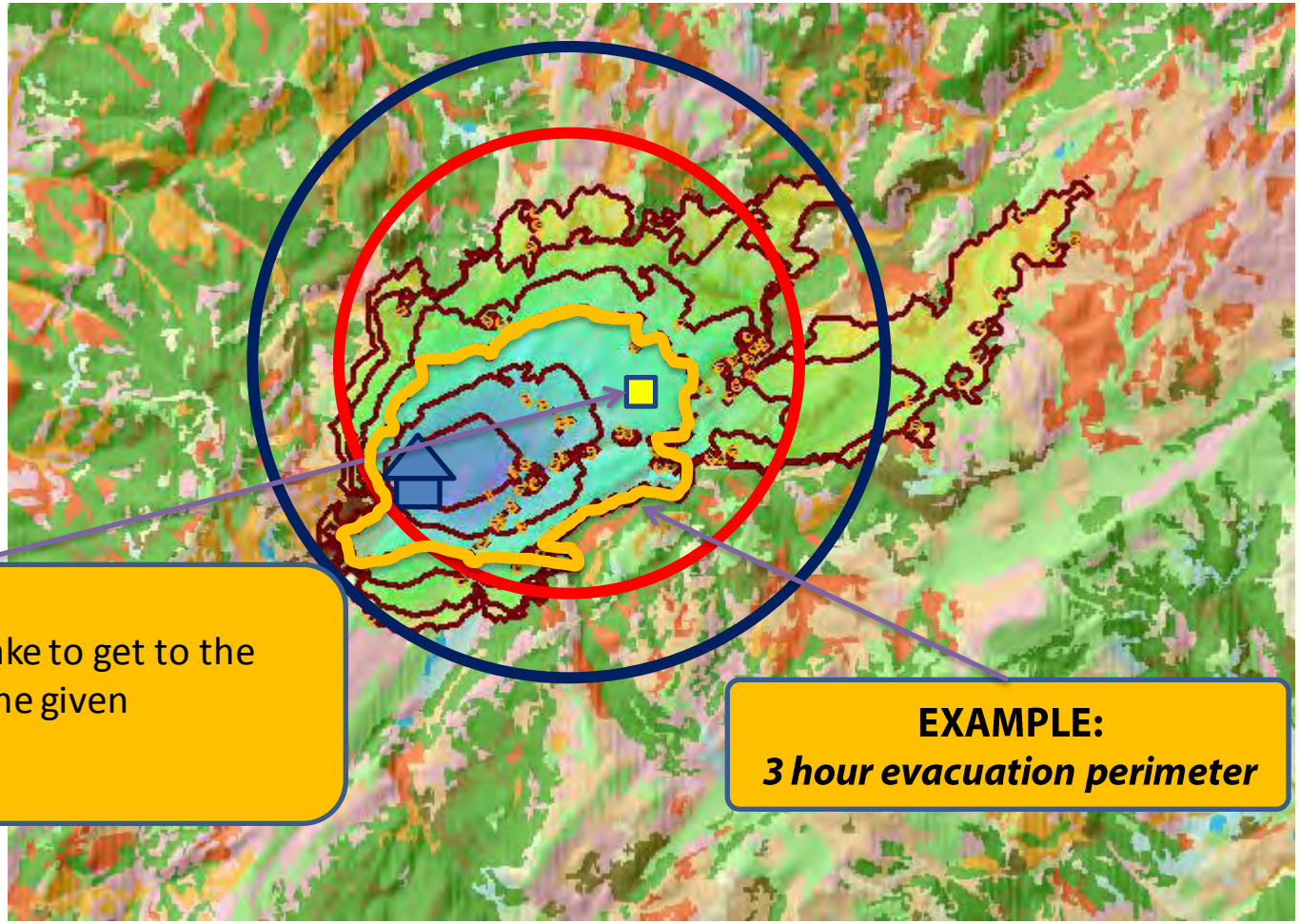
Wildfire Analyst does not only take wind into account but also :

Wildfire ANALYST

EVACUATION MODE

And the output looks like this:

WIND
FUEL
HEIGHT
MOISTURE
FIREBREAKS



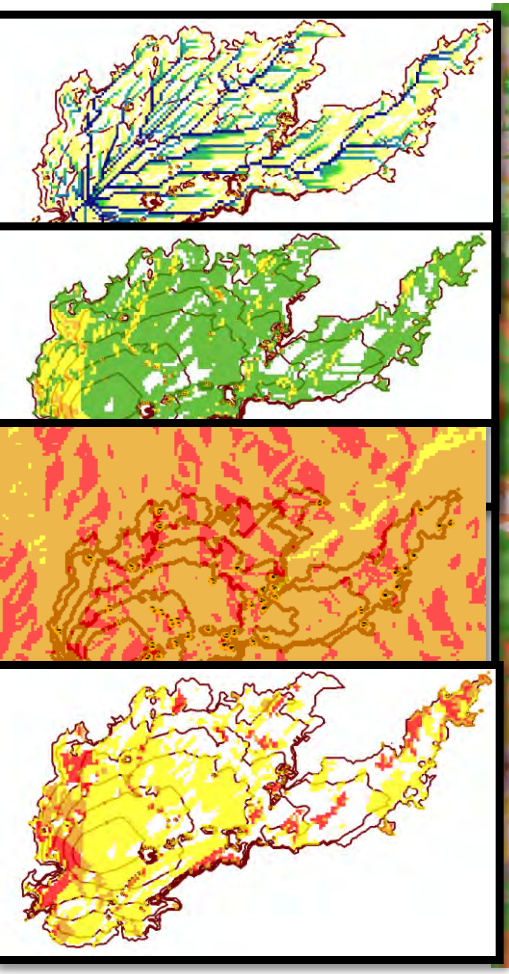
Each cell represents:
the **TIME** a fire would take to get to the evacuation point with the given conditions…

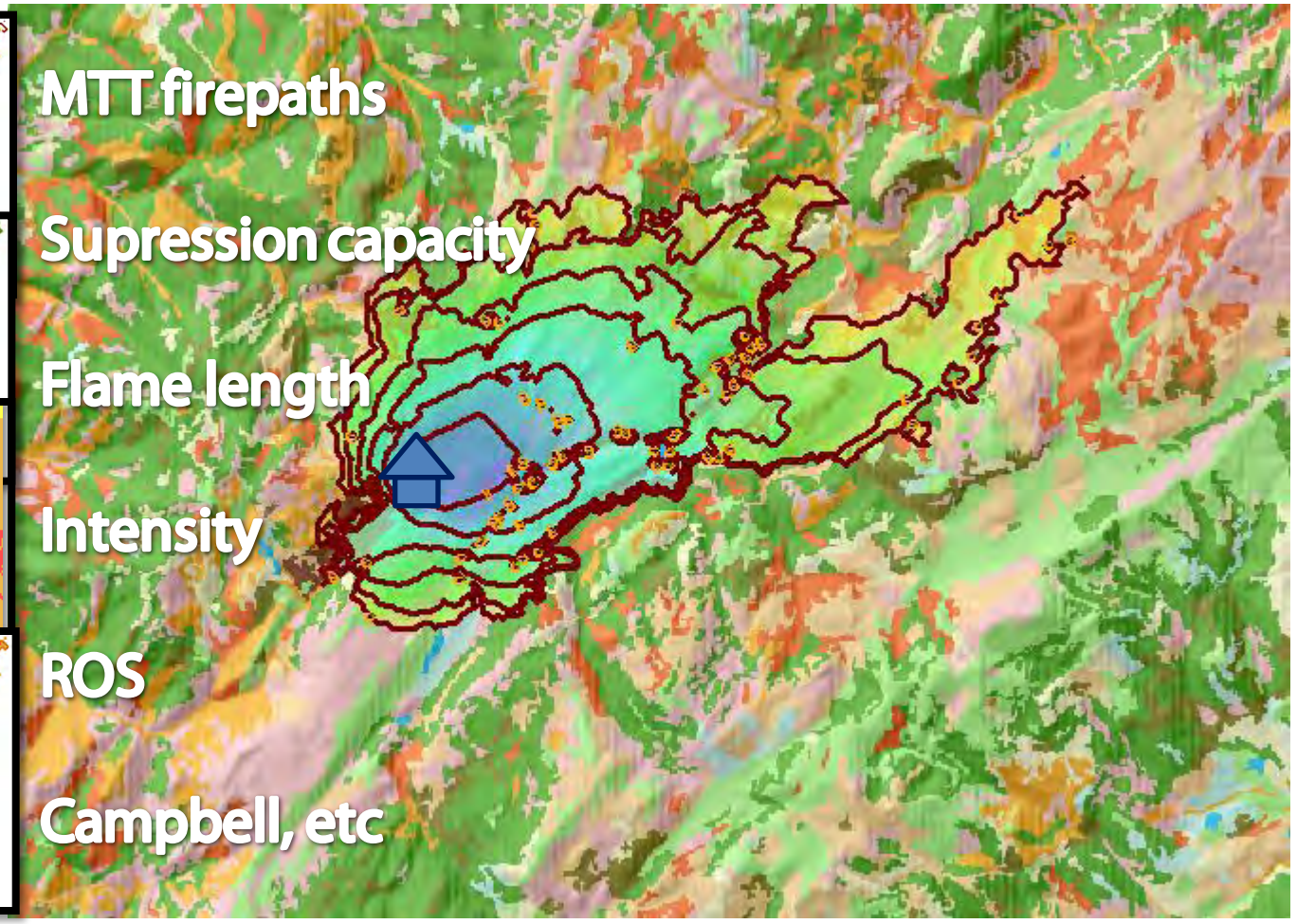
EXAMPLE:
3 hour evacuation perimeter

Add all standard outputs
an you get the
Perfect Framework
for Defense campaigns

Wildfire ANALYST

EVACUATION MODE





Wildfire ANALYST

REVERSE TIME MODE

Simulating fire_____

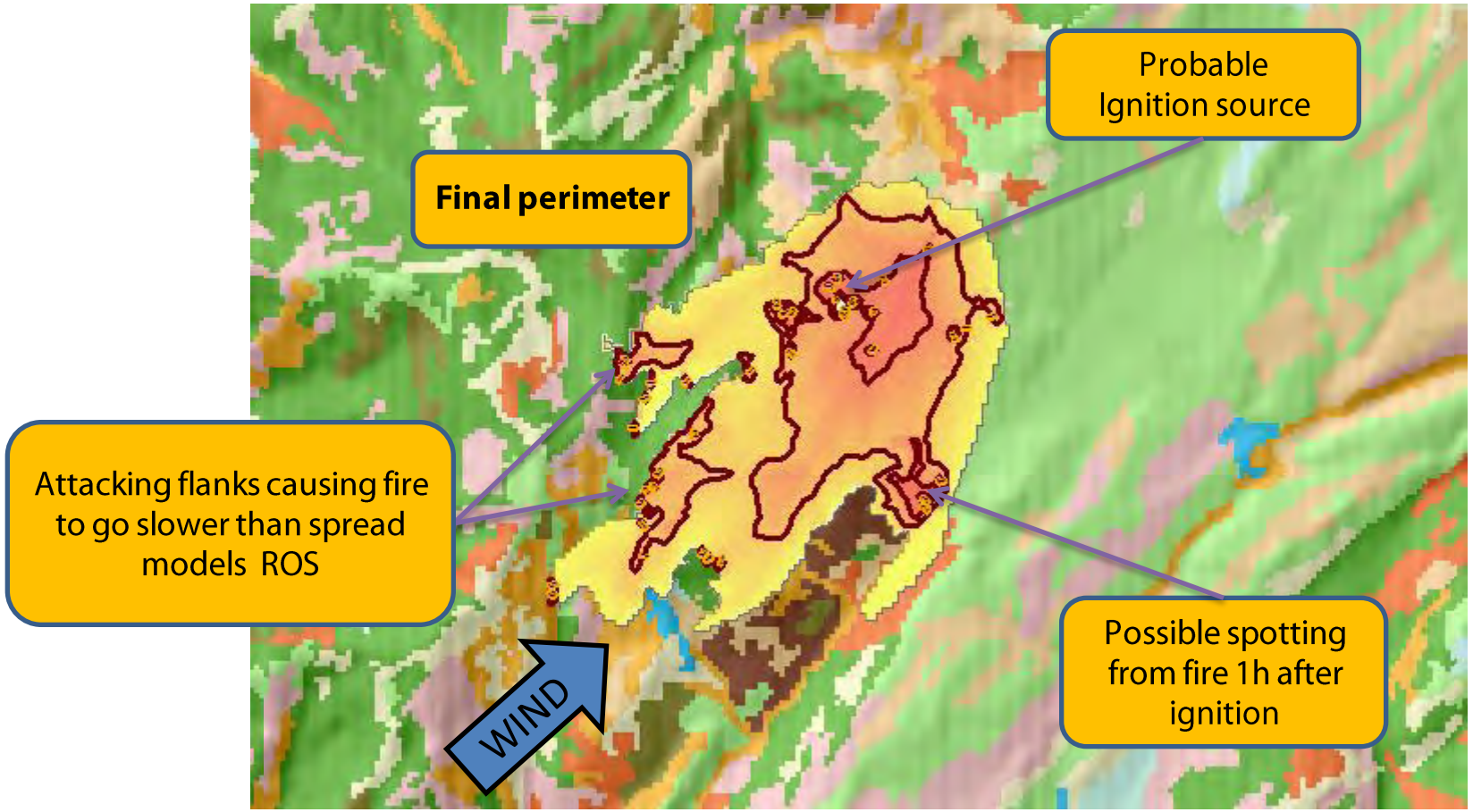
backwards in time

Consider a given final perimeter and some weather conditions…

We can to simulate past fire behavior…

Wildfire ANALYST

REVERSE TIME MODE



Consider a given final perimeter and some weather conditions…

we can try to simulate past fire behavior…

Wildfire ANALYST

REVERSE TIME MODE

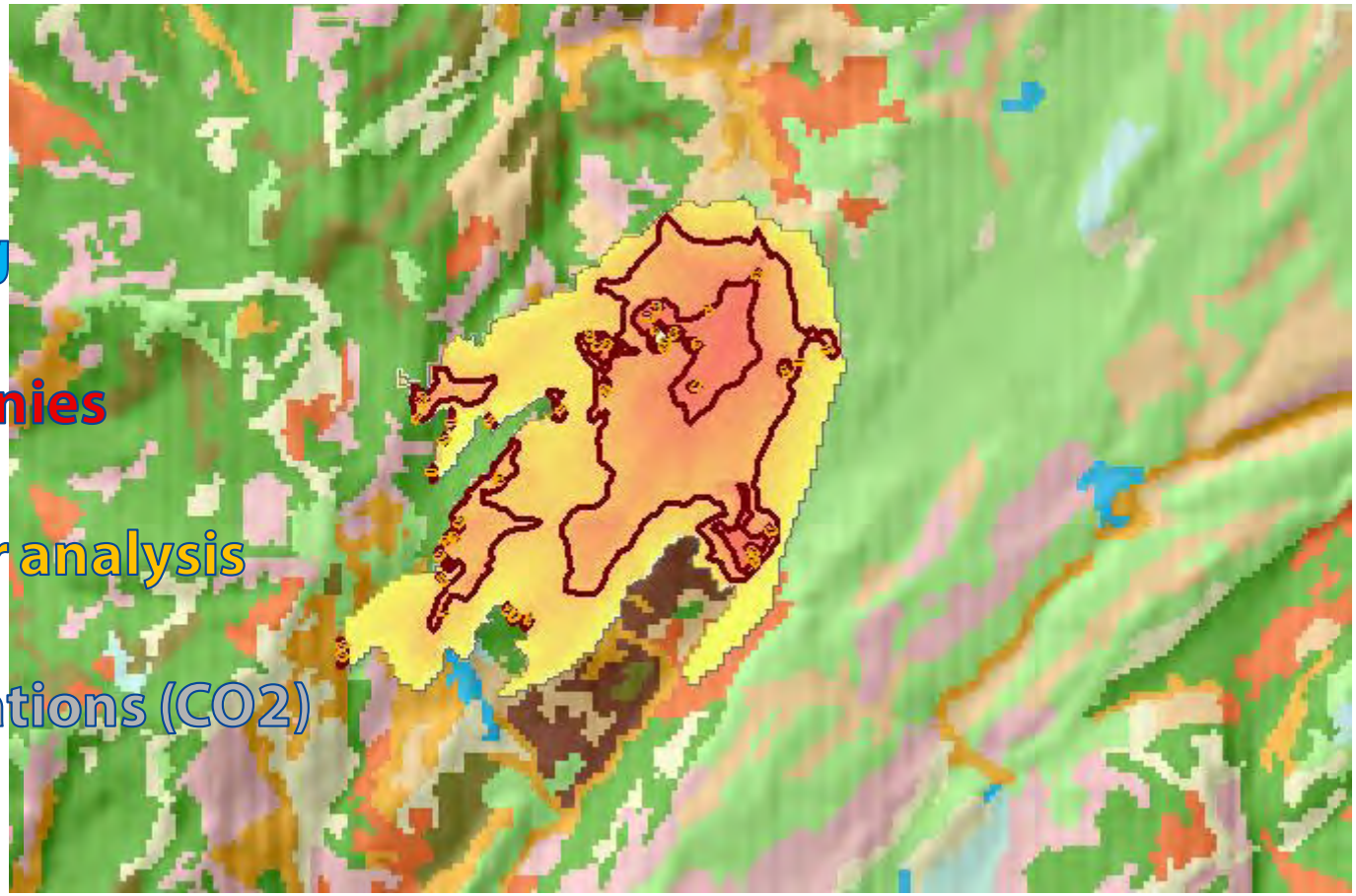
May be used for:

Prescribe burning

Insurance companies

Post fire behavior analysis

Wildfire investigations (CO2)



Wildfire ANALYST

PROBABILISTIC MODE

Because

sometimes we just

can't relay_____

on our inputs

A Monte Carlo approach is taken: Weather conditions are modified based on a Gaussian Distribution to obtain a Fire presence probabilistic analysis

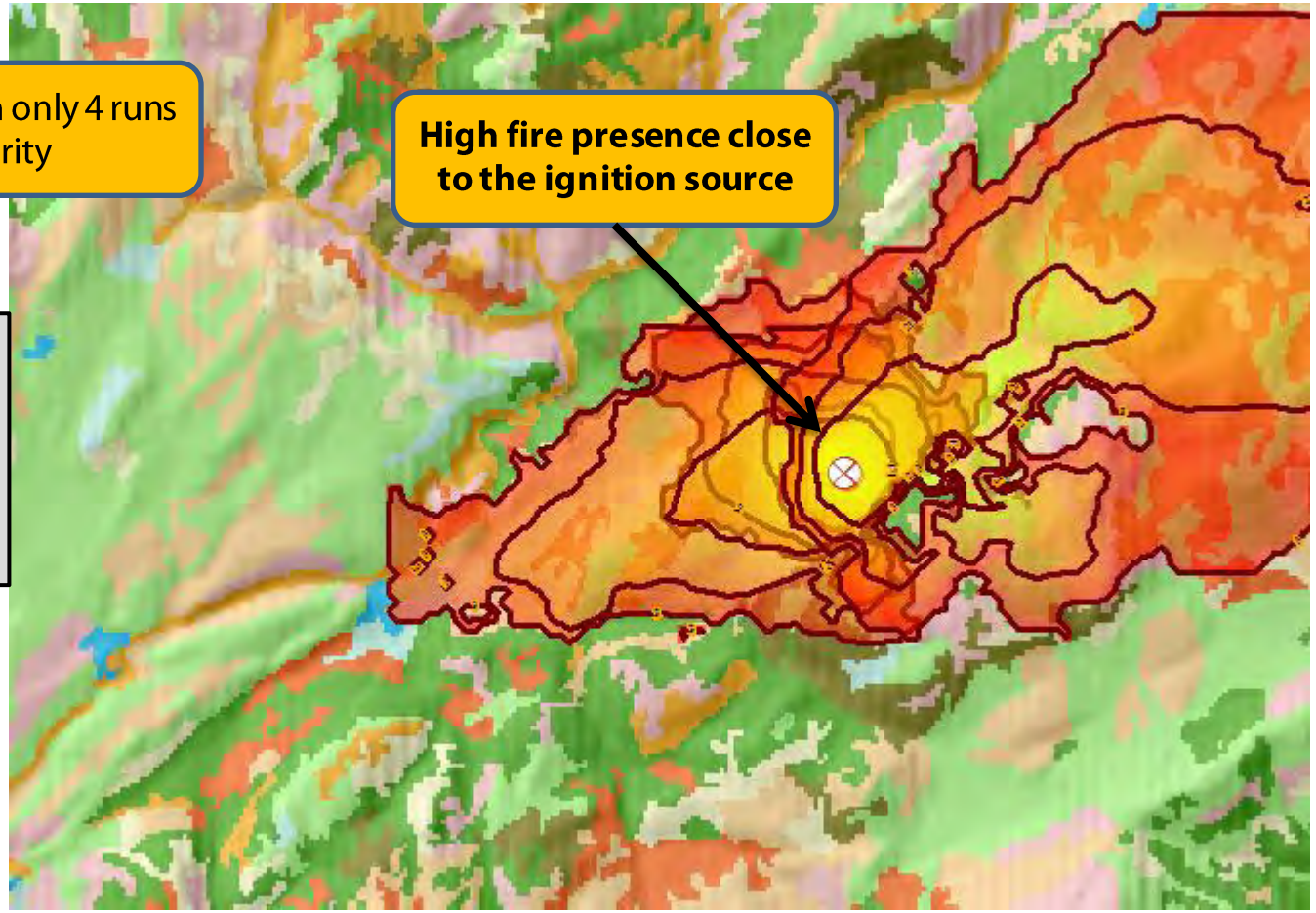
Wildfire ANALYST

PROBABILISTIC MODE

Example with only 4 runs for clarity

RUNS

Widn mod	 8
Wind direc	 180
moisture	 110

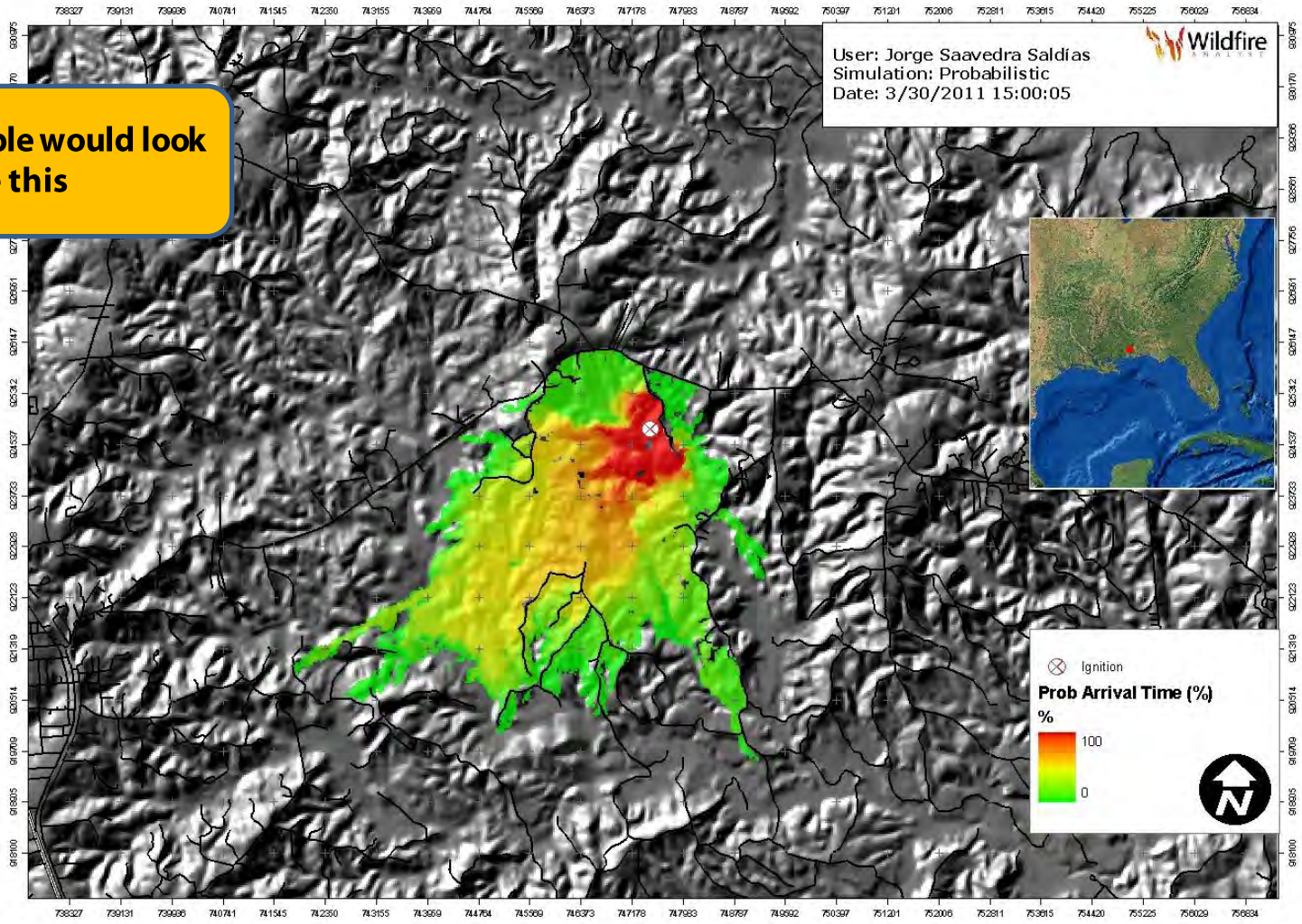


A Monte Carlo approach is taken: Weather conditions are modified based on a Normal Distribution to obtain a Fire presence probabilistic analysis

Wildfire ANALYST

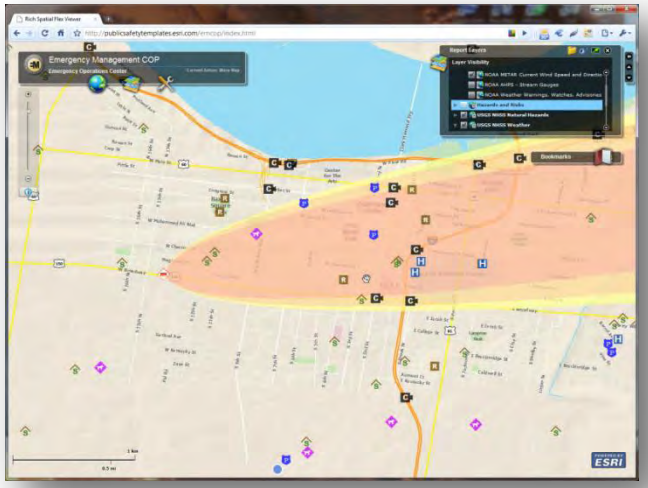
PROBABILISTIC MODE

A real example would look like this

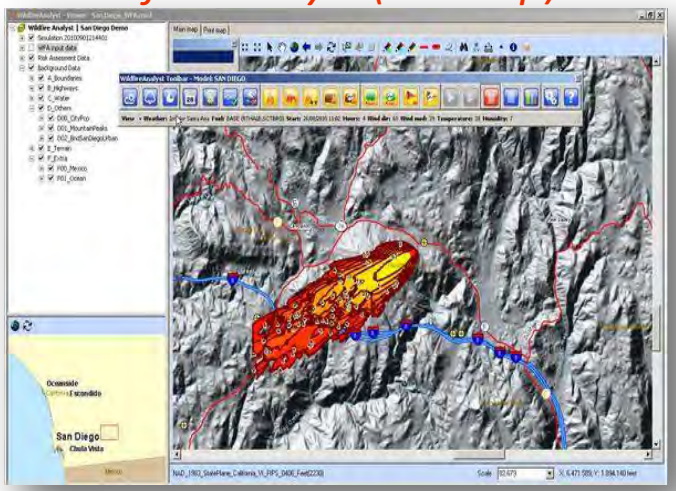


Going to operations: integration on DSS

Wildfire COP (web)



Wildfire Analyst (desktop)



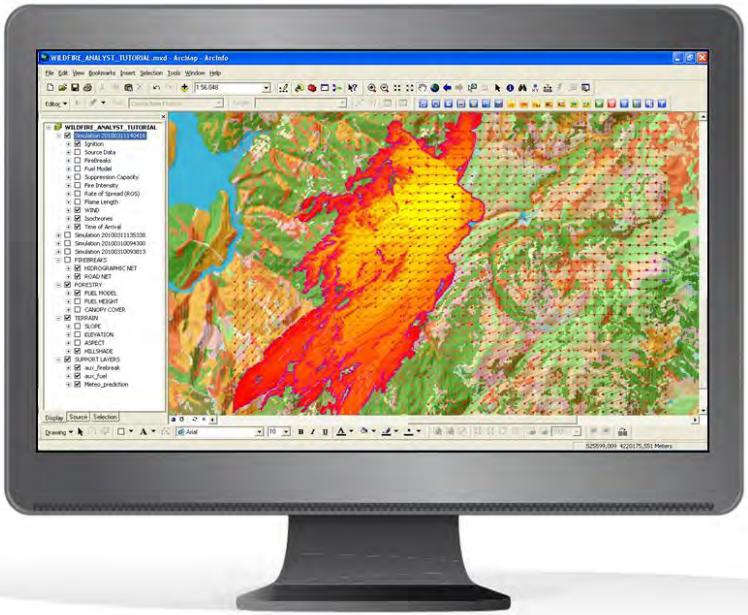
FiResponse (enterprise)

eyes on the field: mobile integration for data input

- Tablet (i.e. iPad etc)
- Smartphone
  - iPhone
  - Android

and now … a demo

Wildfire ANALYST



fiRESPONSE

conclusions

- Geospatial Wildfire Simulation is helping to better understand the biggest natural risk world wide
- Actual systems are ready to help real people
- There is a huge field for young geoscientists to help to solve real problems,

and you are at the right place to learn how ¡¡¡

Go Aztecs ¡

To know more:

Martin E. Alexander. **Some Random Thoughts on Fire Behavior Research and Operational Fire Behavior Considerations.** Keynote Address 2: Fire Paradox 4th Plenary Meeting, 9-13 June 2008, Chania, Crete, Greece
http://wildfirelessons.net/documents/M_E_Alexander_Keynote_Address_4th_Plenary_Meeting.pdf

fire is a good servant but a bad master

1977-2009

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Thank you for your attention

anyone joins the lady?

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jramirez@dtswildfire.com