Recovering fire arrival time from satellite data by machine learning

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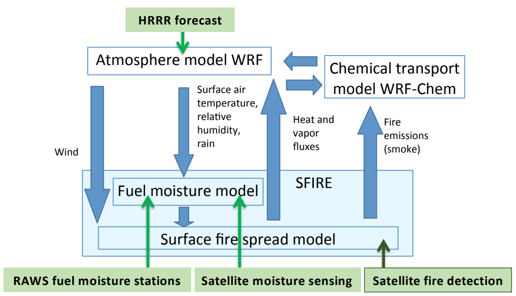
1. INTRODUCTION

WRF-SFIRE is a coupled **atmosphere-fire model** which can be assimilated using different data sources. [1]



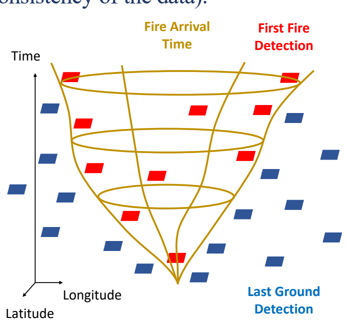
Satellite data can **start fire simulations** from an ignition point or from an assumed fire perimeter. By estimating the **fire arrival time** (time that the fire arrives at each location), one can **spin up the weather model**, and proceed with the **assimilated** coupled simulation in a **consistent fire-atmosphere state.**

2. OBJECTIVES

Estimation of fire arrival time as a function on a 2D domain on Earth surface going through some constraints or bounds.

- **Upper bounds:** information that a certain location at a certain time space is burning.
- **Lower bounds:** information that a location is not burning.

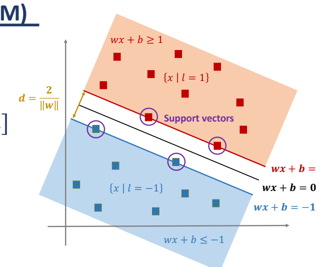
Find the best **separation** between **soft bounds** (errors and inconsistency of the data).



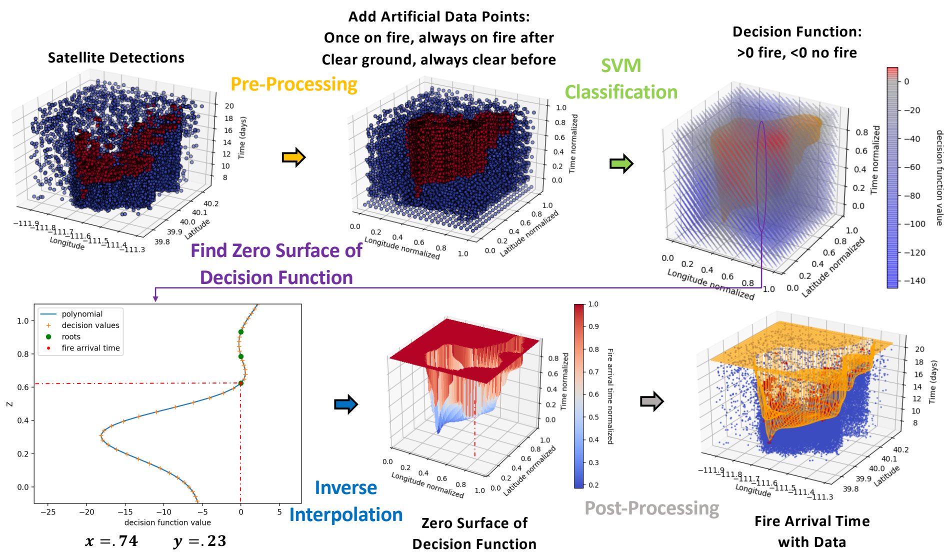
3. SUPPORT VECTOR MACHINE (SVM)

SVM is a **machine learning** technique which finds the best separation between two groups of data **maximizing the margin** between both representatives of each group or **support vectors**. [2]

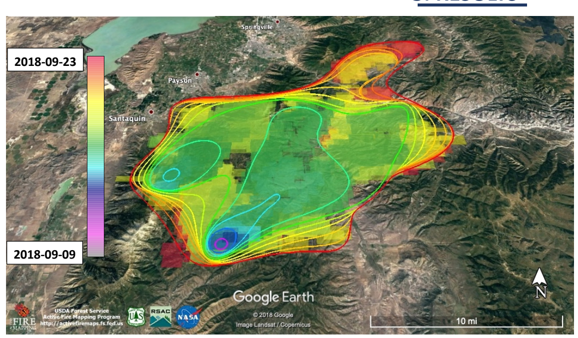
Allow bends by using a separating surface defined by a Gaussian radial basis kernel decision function, and use **soft bounds** by including a penalization term.



4. METHOD



5. RESULTS



Pole Creek Fire, Utah, 2018

Visualization in Google Earth of **satellite fire detections** compared with the **evolution of the perimeters** of the fire arrival times.

6. CONCLUSIONS

The SVM approach **offers improvements** over other methods, which tend to be harder numerically or develop artifacts. These methods include:

- Penalize the difference of the posterior fire arrival time surface from the prior assuring that point constraints are visible (using Sobolev norms $H^{1+\varepsilon}$, $\varepsilon > 0$ or $W^{1,p}$, $p > 1$). [3]
- Penalize by a norm of the residual of the eikonal equation $\|\nabla u\| = \frac{1}{R}$, where the rate of spread $R = R(x, y, u)$ depends on the fuel in the first approximation, and really on the history of the fire through the fire winds. [4]
- Use the prior assumption that in the absence of other information, the fire propagation does not change: $\nabla u =$ constant. Thus, minimize $\|\nabla^2 u\|_{L^p}$ subject to the upper and lower bounds, with penalizations for soft bounds. [5]

Next step would be to assimilate other data inputs:

- **Infrared fire perimeters** can be interpreted as mesh points inside the perimeter on fire, providing upper bounds, and points outside of the perimeter not on fire, providing lower bounds.
- **Forecast fire arrival time** (Bayesian prior) becomes both an upper bound and a lower bound at every mesh point. The softer the bound, the less weight the data assimilation puts on the prior.

ACKNOWLEDGMENTS

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