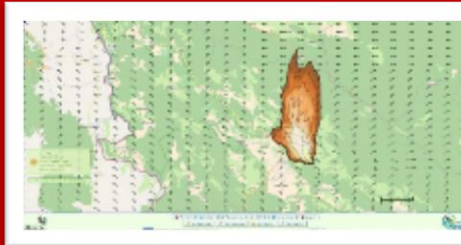
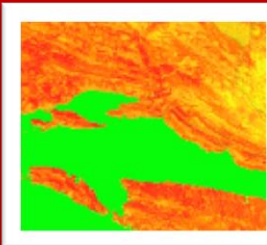


Projekt razvoja sustava za simulaciju širenja šumskog požara

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Katedra za modeliranje i inteligentne računalne sustave & Centar za istraživanje požara otvorenog prostora
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SVEUČILIŠTE U SPLITU, Hrvatska



Požari otvorenog prostora

- **Požari otvorenog prostora** predstavljaju stalnu opasnost – ljudima, infrastrukturi, cijelom ekosustavu
- Požari u Hrvatskoj
 - Požari otvorenog prostora
 - Požari raslinja
 - Šumski požari
- Milijunske štete
- Ljudske žrtve
 - Utjecaj na zdravlje



Klima i požari otvorenog prostora

- **Utjecaj promjene klime** na požare otvorenog prostora
 - Rezultati modeliranja klimatskih parametara
 - Dulja sušna razdoblja
 - Produljenje požarne sezone



- Povećanje broja požara
- Povećanje štete uzrokovane šumskih požarima

Gašenje požara otvorenog prostora

Postulati za uspješno gašenje požara:

- Rana detekcija požara otvorenog prostora
- Pravovremena reakcija koja zahtijeva što više informacija o samom požaru



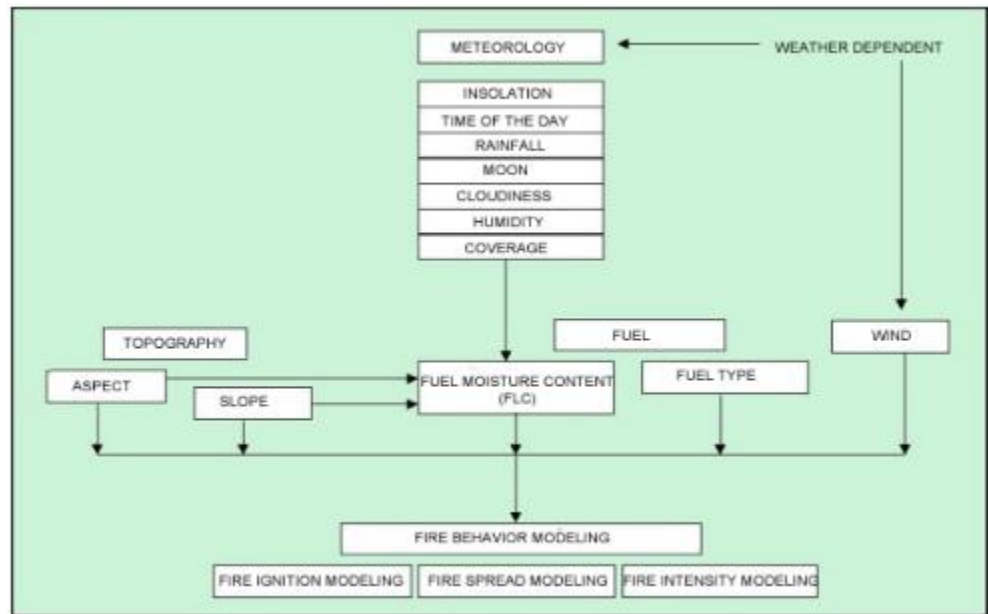
Sustav za upravljanje rizicima od požara otvorenog prostora

- Detekcija vatre i dima u vidljivom dijelu spektra
- Indeks opasnosti od požara
- **Simulacija širenja šumskih požara**



Simulacija širenja požara

- **Modeli širenja (propagacije) požara** većinom se osnivaju na:
 - Meteorološkim uvjetima (vjetar, vlaga, temperatura)
 - Vegetacija
 - Izvor požara
 - Vlaga goriva
 - Topografija



Simulacija širenja požara

- Fizikalni i semi-fizikalni modeli
 - modeli temeljeni na fizikalnim i kemijskim svojstvima propagacije požara
- Empirijski i semi-empirijski modeli
 - Empirijski modeli se baziraju samo na statistici temeljenoj na ekperimentima ili stvarnim požarima u povijesti.
 - Semi-empirijski modeli kombiniraju analitičku formulaciju fizikalnih pojava sa statističkim informacijama
- Modeli temeljeni na matematičkim analogijama
 - Umjesto fizikalnih, koriste se matematički modeli

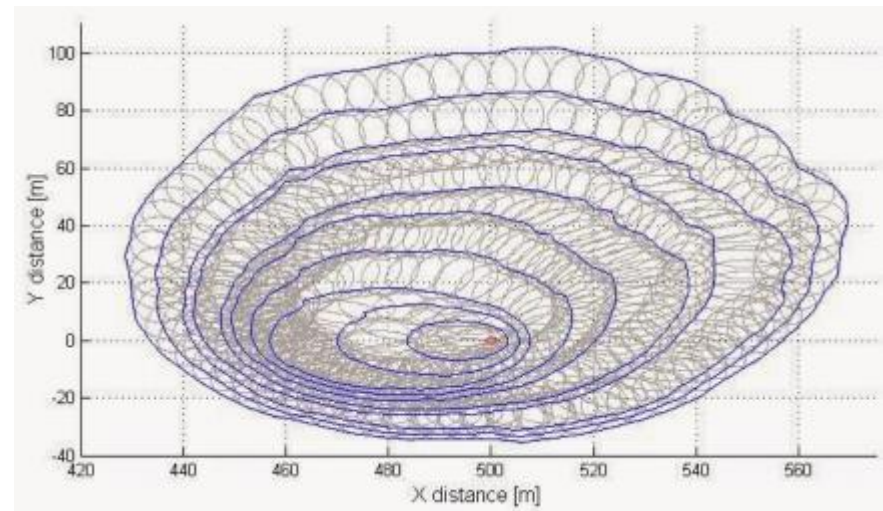
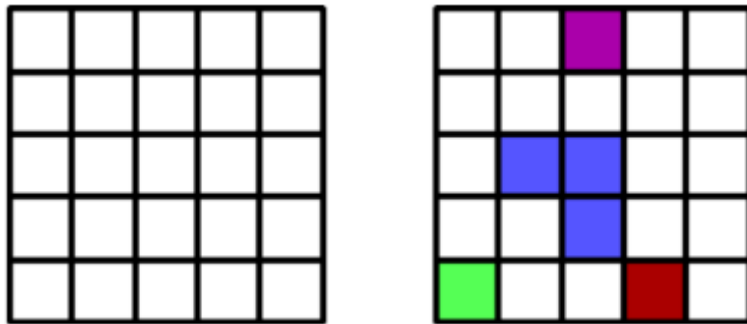
Simulacija širenja požara

■ Rothermelov model

$$\text{ROS} = \frac{
 \begin{array}{c}
 \begin{array}{c}
 \text{SA/Vol} \quad \text{Packing Ratio} \\
 \text{Moisture Effect} \quad \text{Load} \\
 \text{Mineral Effect} \quad \text{Heat} \\
 \downarrow \quad \downarrow \\
 I_R \quad \xi_o
 \end{array} \\
 \left(\text{Reaction Intensity} \right) \left(\text{Propagating Flux} \right) \left(1 + \begin{array}{c} \text{Wind Multiplier} + \text{Slope Multiplier} \end{array} \right)
 \end{array}
 }{
 \begin{array}{c}
 \begin{array}{c}
 \left(\text{Bulk Density} \right) \left(\text{Effective Heating Number} \right) \left(\text{Heat of Preignition} \right) \\
 \uparrow \quad \uparrow \quad \uparrow \\
 \begin{array}{c} \text{Load} \quad \text{Depth} \end{array} \quad \text{SA/Vol} \quad \begin{array}{c} \text{Moisture Content} \end{array}
 \end{array}
 \end{array}$$

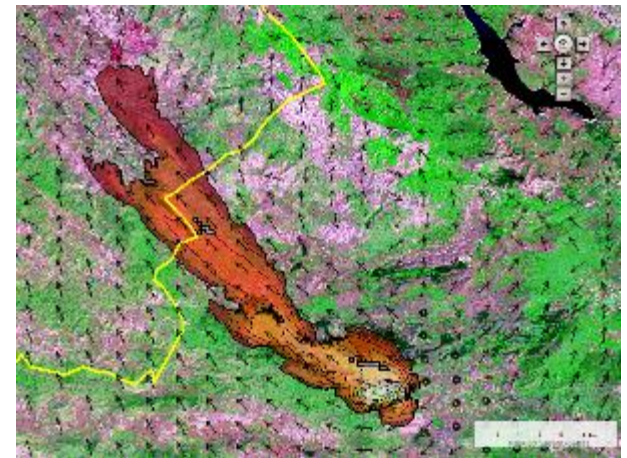
Simulacija širenja požara

- Različiti pristupi
 - Celularni automati
 - Huygensov princip širenja valova

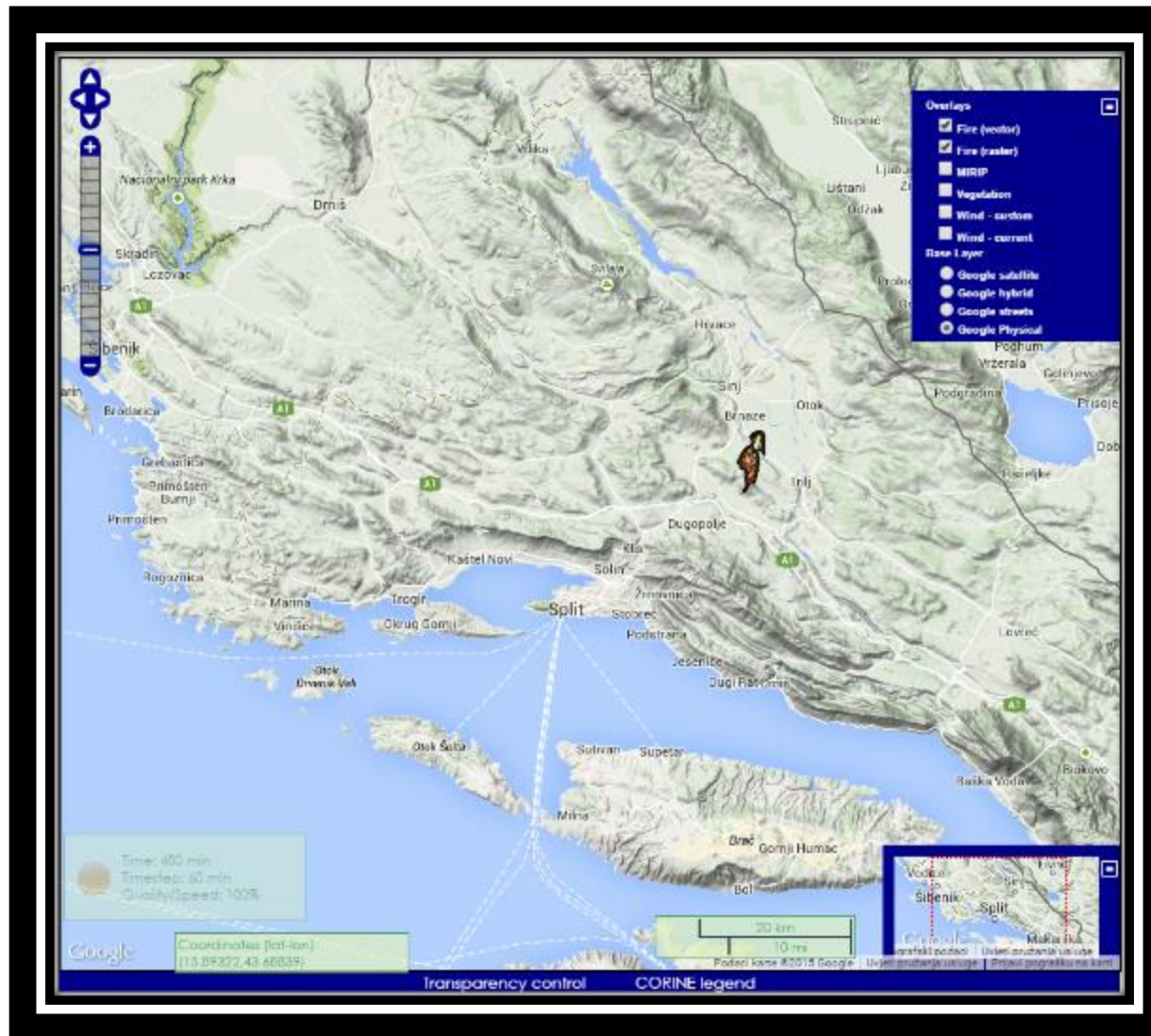


Simulacija širenja požara

- **Korištenje simulatora širenja požara:**
 - Aktivnosti prije požara
 - Educiranje i priprema vatrogasnog osoblja
 - Simulacija različitih scenarija koji se mogu dogoditi
 - Aktivnosti za vrijeme požara
 - Predviđanje kretanja vatre na temelju trenutnih vremenskih uvjeta
 - Dodatne informacija koja pomaže bitnim odlukama
 - Aktivnosti poslije požara
 - Istraga povijesnih požara



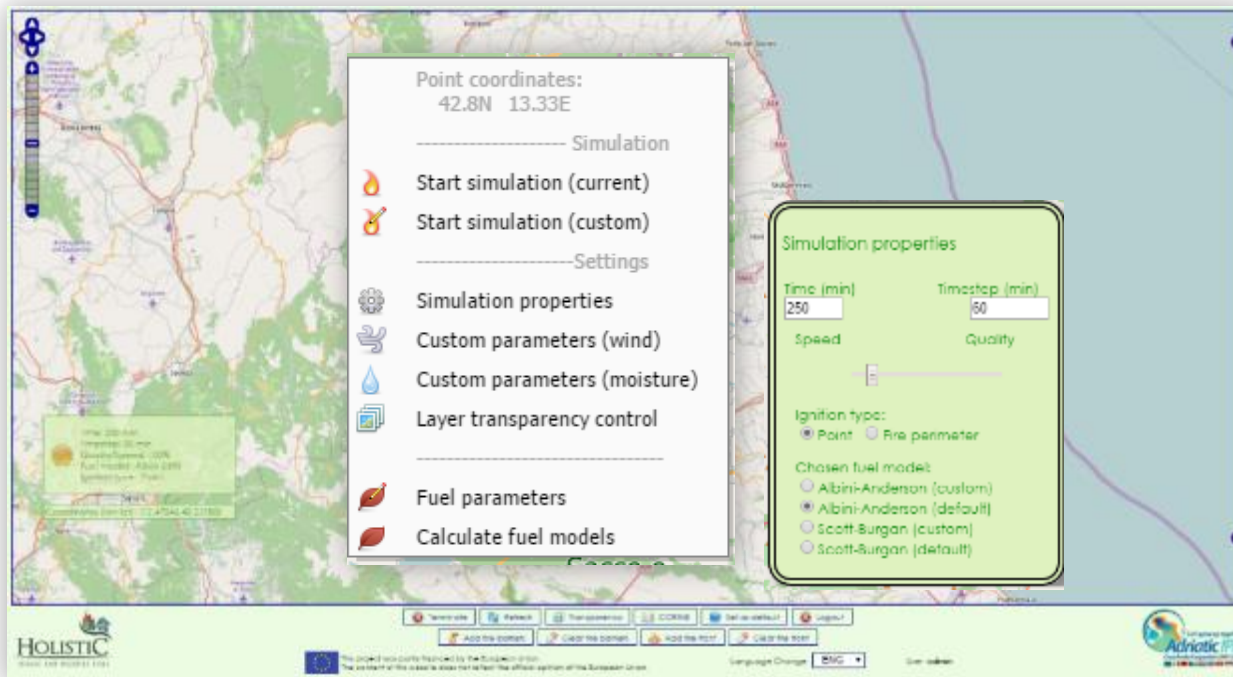
Simulacija širenja požara – razvijeni sustav



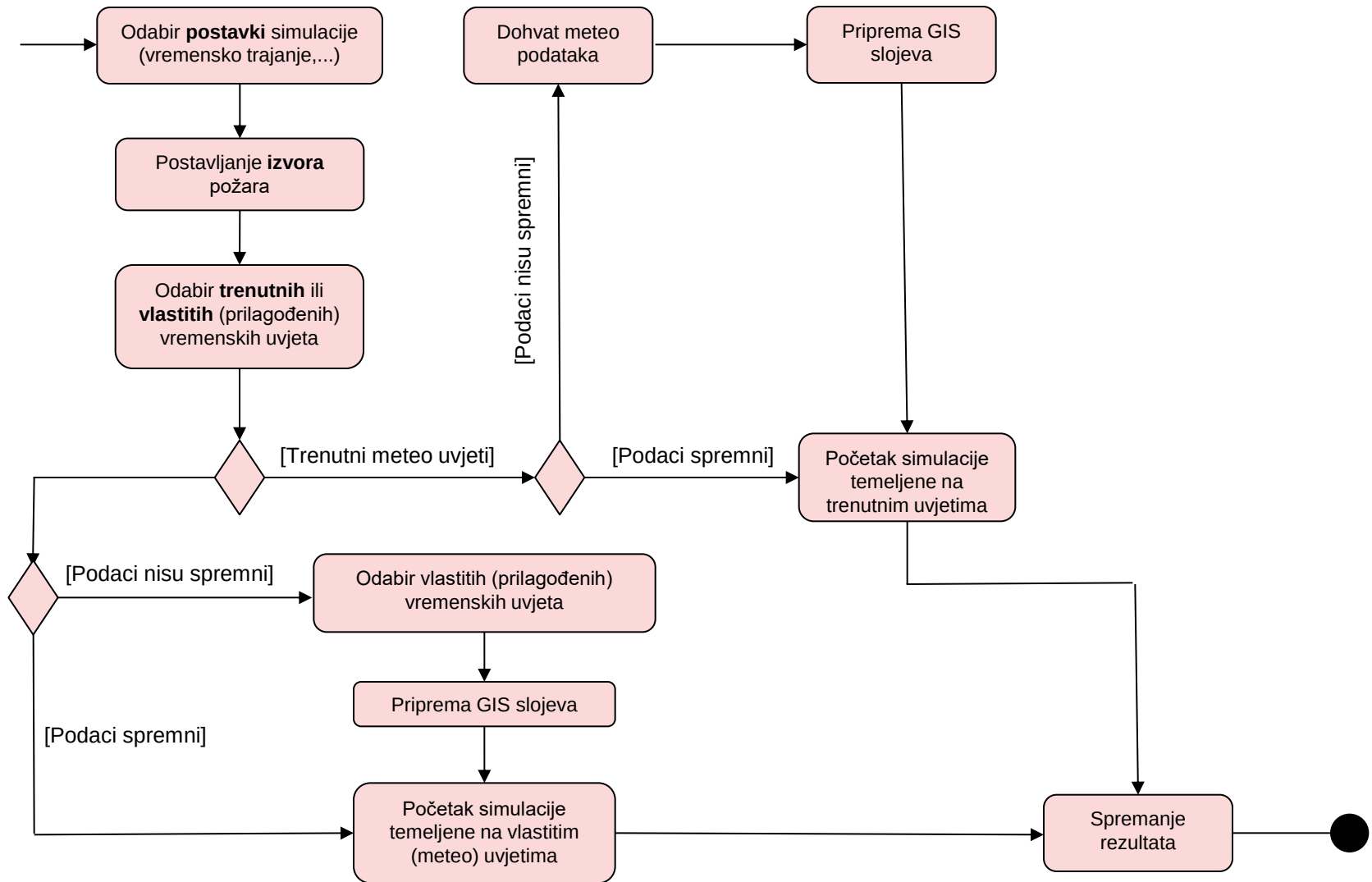
Simulacija širenja požara



Postavke simulacije

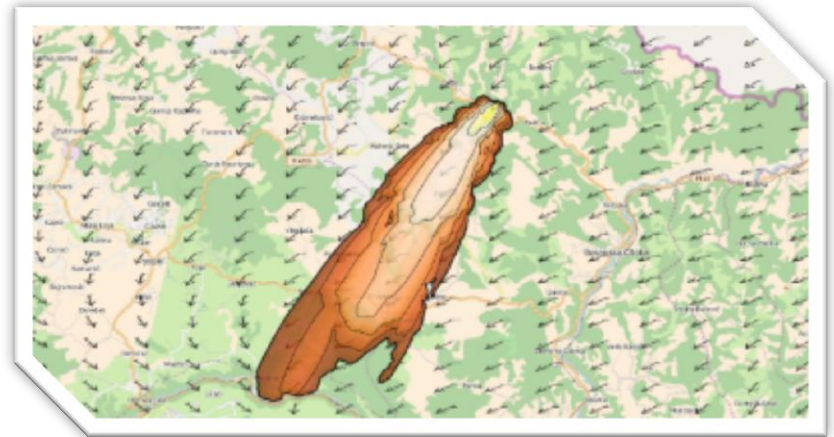


Simulacija širenja požara



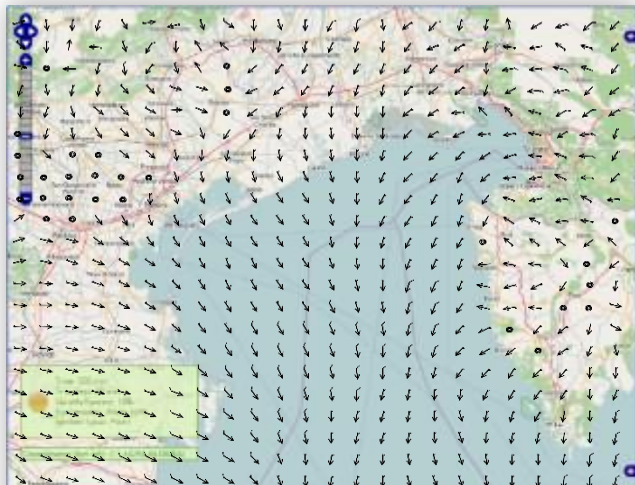
Simulacija širenja požara

- **Ulazni podaci potrebni za simulaciju**
 - Model goriva
 - Vlaga mrtvog goriva
 - Vlaga živog goriva
 - Brzina vjetra
 - Smjer vjetra
 - Nagib terena
 - Orijentacija terena

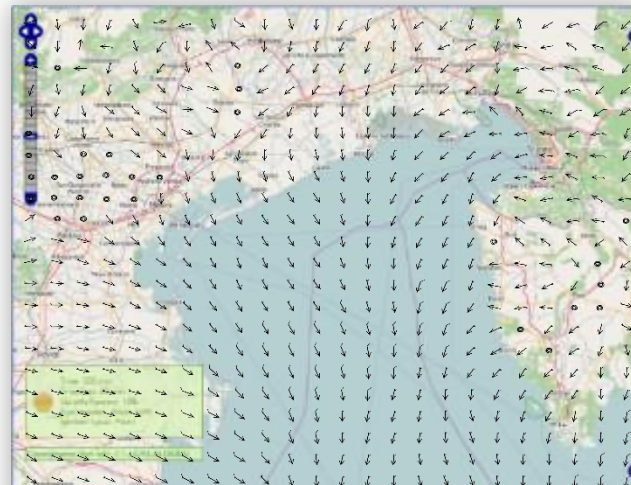


Simulacija širenja požara

Korisnik 1



Korisnik 2

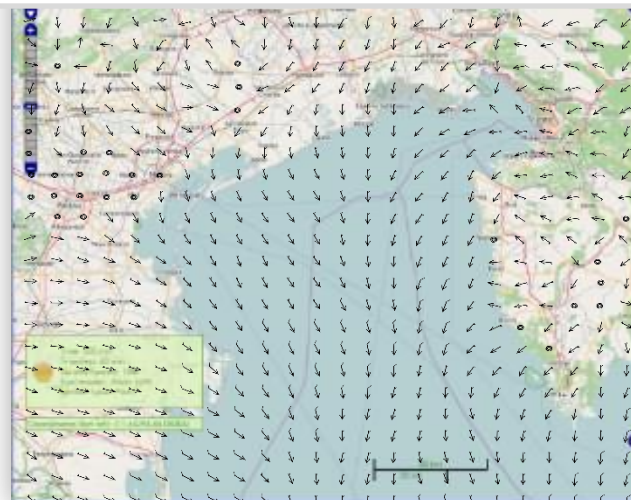


Trenutni vremenski uvjeti ne mogu se modificirati. Sustav ih automatski obnavlja.

Korisnik 3

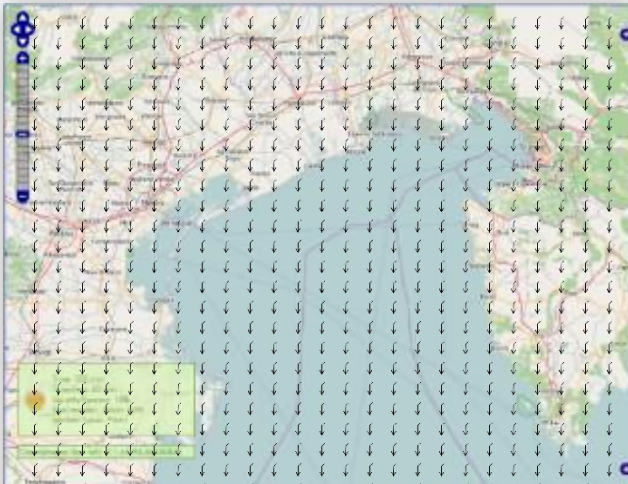


Korisnik 4

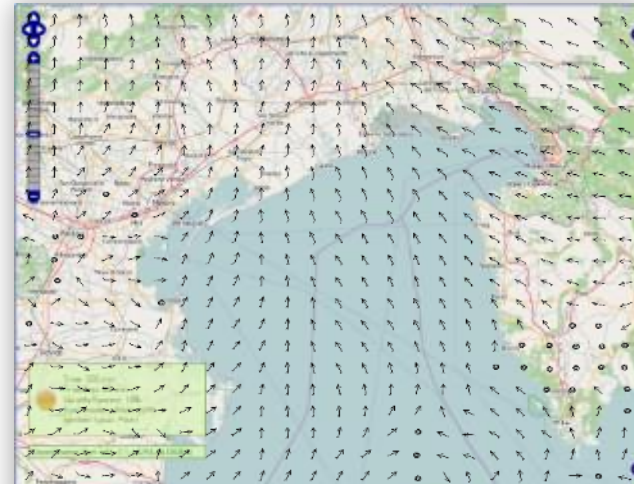


Simulacija širenja požara

Korisnik 1

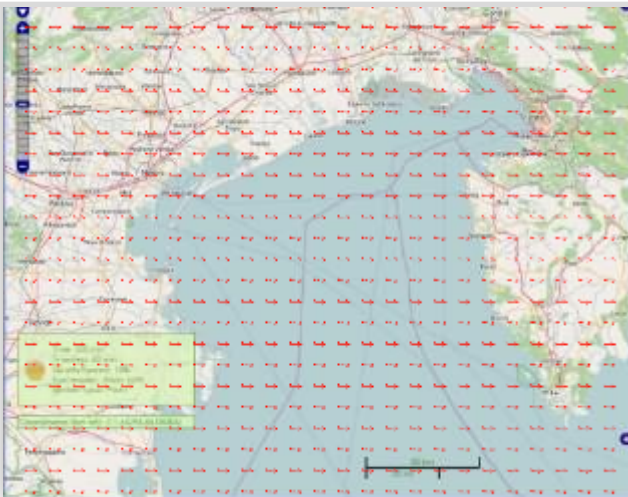


Korisnik 2

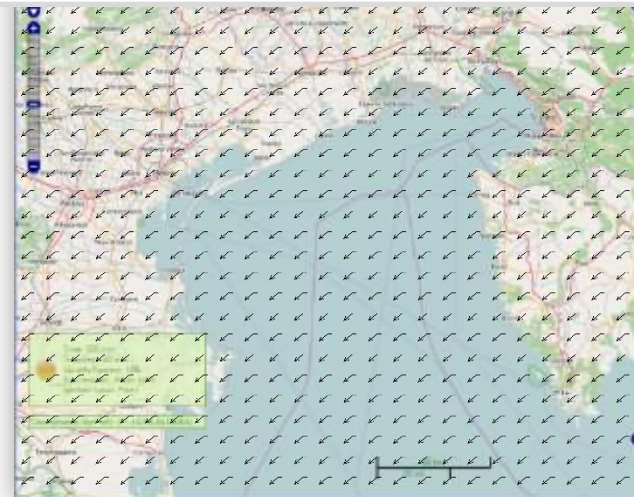


Svaki korisnik može mijenjati vlastite (prilagođene) vremenske uvjete za simulaciju.

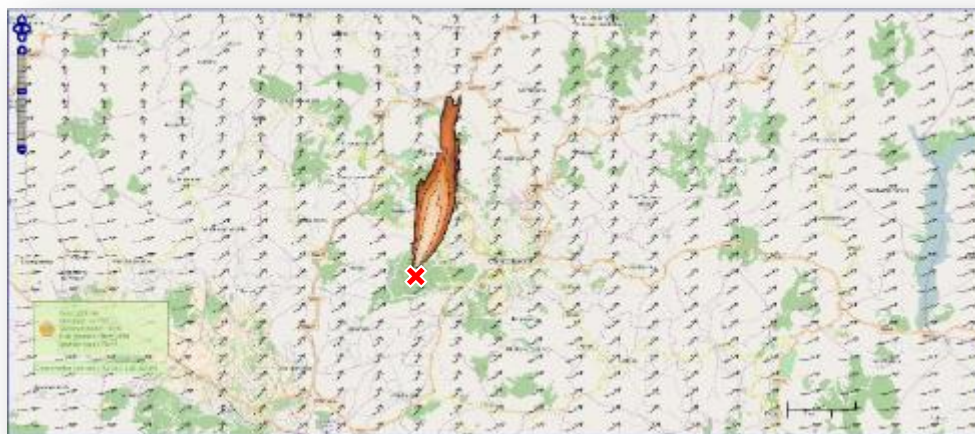
Korisnik 3



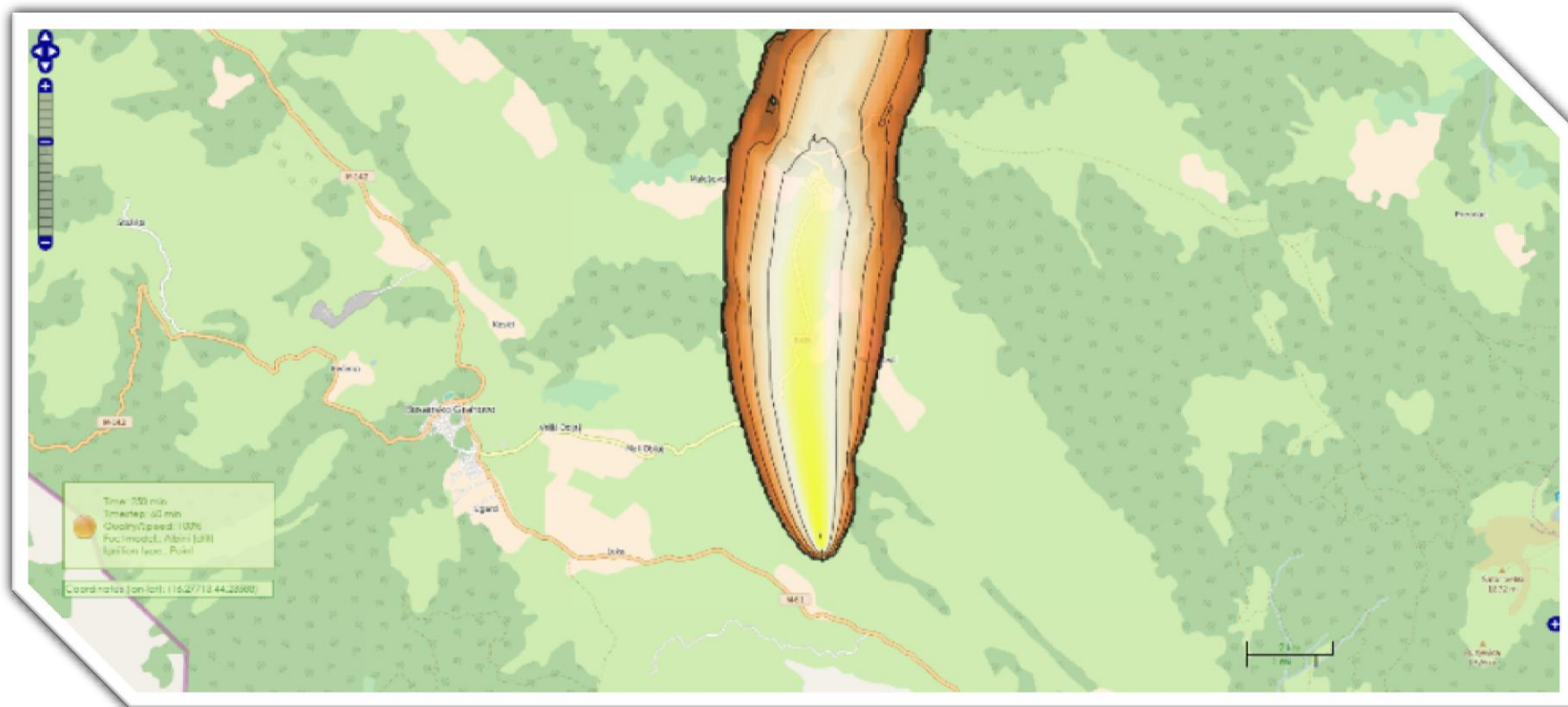
Korisnik 4



Točkasti izvor / požarna fronta



Požarne barijere



Parametri vjetra i vlage

MOISTURE PROPERTIES

☒ On-line
Get on-line moisture parameters

☐ Asc

☐ Value

Update moisture settings

WIND PROPERTIES

☐ On-line

☐ Meteo

☒ ASC

Direction: No file chosen

Speed: No file chosen

☐ Value

Update wind settings

Parametri goriva

FUEL MODEL PARAMETERS

Filter: **Albini** **Scott** Sort: **Asc** **Desc** Save: **Save (all)** Reset: **Reset Albini** **Reset Scott**
 Import: **Choose File** No file chosen **Import Albini** **Import Scott** Export: **Export Albini** **Export Scott**

1. Short, sparse dry climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	0.1000	ton/ha
10-h Fuel Load	0.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	0.3000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	2200	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	2200	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	0.4000	feet
Dead Fuel Moisture at Extinction	15	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

2. Low load, dry climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	0.1000	ton/ha
10-h Fuel Load	0.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	1.0000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	2000	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1000	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	1.0000	feet
Dead Fuel Moisture at Extinction	15	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

3. Low load, very coarse, humid climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	0.1000	ton/ha
10-h Fuel Load	0.4000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	1.5000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	1500	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1300	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	0.9000	feet
Dead Fuel Moisture at Extinction	20	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

4. Moderate load, dry climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	0.1000	ton/ha
10-h Fuel Load	0.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	1.0000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	2200	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1000	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	0.9000	feet
Dead Fuel Moisture at Extinction	15	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

5. Low load, humid climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	0.1000	ton/ha
10-h Fuel Load	0.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	0.5000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	1800	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1800	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	1.0000	feet
Dead Fuel Moisture at Extinction	40	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

6. Moderate load, humid climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	0.1000	ton/ha
10-h Fuel Load	0.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	3.4000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	2200	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	2200	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	1.0000	feet
Dead Fuel Moisture at Extinction	40	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

7. High load dry climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	1.0000	ton/ha
10-h Fuel Load	0.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	5.4000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	2000	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1500	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	0.9000	feet
Dead Fuel Moisture at Extinction	15	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

8. High load, very coarse, humid climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	0.5000	ton/ha
10-h Fuel Load	1.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	7.0000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	1500	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1300	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	4.0000	feet
Dead Fuel Moisture at Extinction	20	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

9. Very high load humid climate grass

Fuel Model Type	Dynamic	
1-h Fuel Load	1.0000	ton/ha
10-h Fuel Load	1.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	9.0000	ton/ha
Live Woody Fuel Load	0.0000	ton/ha
1-h Surface Area/Vol Ratio	1500	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1300	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	5.0000	feet
Dead Fuel Moisture at Extinction	40	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

10. Low load, dry climate grass-shrub

Fuel Model Type	Dynamic	
1-h Fuel Load	0.2000	ton/ha
10-h Fuel Load	0.0000	ton/ha
100-h Fuel Load	0.0000	ton/ha
Live Herbaceous Fuel Load	0.5000	ton/ha
Live Woody Fuel Load	0.6500	ton/ha
1-h Surface Area/Vol Ratio	2000	m ² /m ³
Live Herbaceous Surface Area/Vol Ratio	1500	m ² /m ³
Live Woody Surface Area/Vol Ratio	1500	m ² /m ³
Fuel Bed Depth	0.9000	feet
Dead Fuel Moisture at Extinction	15	percent
Dead Fuel Heat Content	8000	Btu/lb
Live Fuel Heat Content	8000	Btu/lb

Simulacija širenja požara

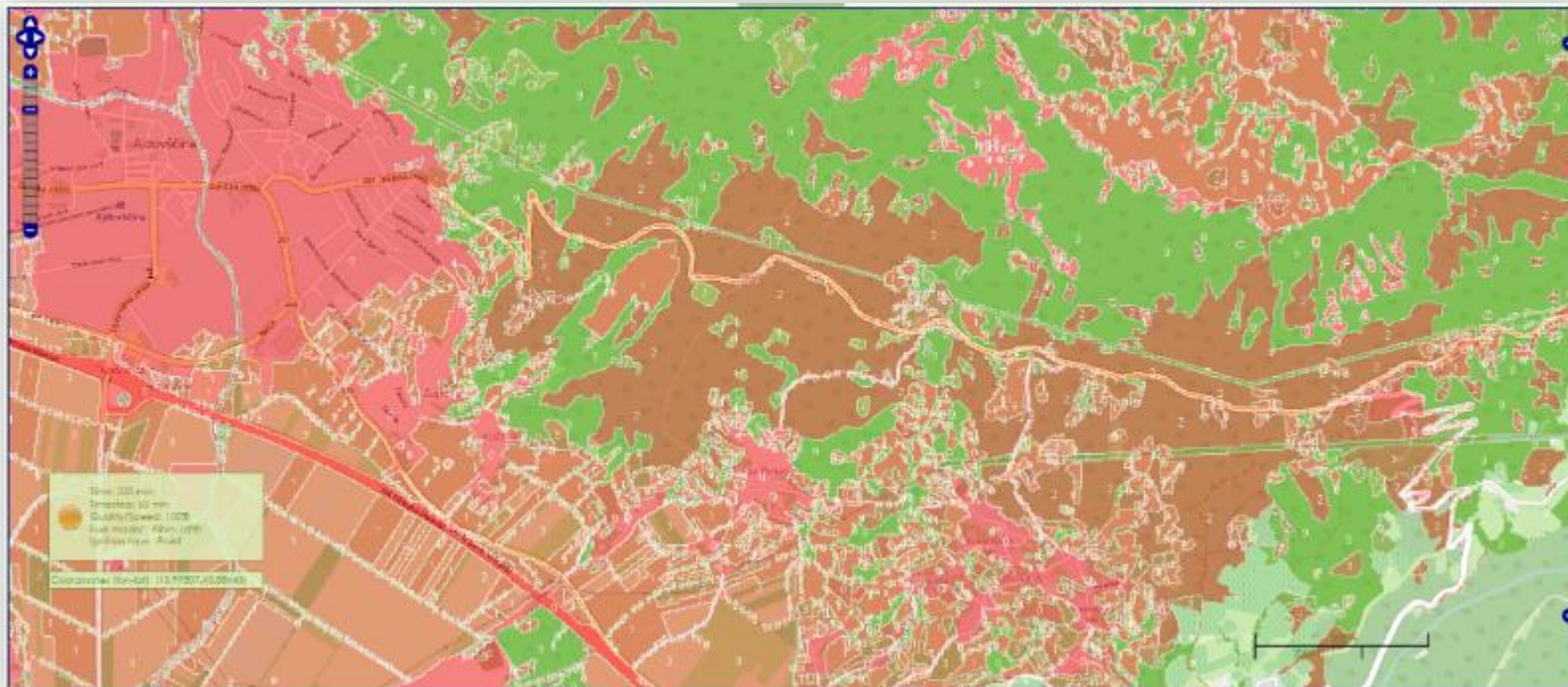
■ Parametri goriva

- 1-h Fuel Load
- 10-h Fuel Load
- 100-h Fuel Load
- Live Herbaceous Fuel Load
- Live Woody Fuel Load
- 1-h Surface Area/Vol Ratio
- Live Herbaceous Surface Area/Vol Ratio
- Live Woody Surface Area/Vol Ratio
- Fuel Bed Depth
- Dead Fuel Moisture of Extinction
- Dead Fuel Heat Content
- Live Fuel Heat Content

Simulacija širenja požara

- **Modeli goriva:**
 - Albini Anderson
 - 13 kategorija
 - Scott-Burgan
 - 40 kategorija
- **Mape goriva:**
 - Geografska područja

Mapa goriva



Validacija?



Ideje za daljnji rad

- Korištenje preciznijih meteoroloških podataka
 - Prilagodba modela i mapa goriva našem području
 - Unaprjeđivanje modela simulacije širenja požara
 - Uključivanje rezultata klimatskih modela
-
- Širenje dima
 - Planiranje evakuacije korištenjem GIS-a
 - Opasnost od poplava

ZAHVALJUJEM NA PAŽNJI

?