Forest/bush fire risk products in Croatia

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Outlines

- Operational fire danger rating in Croatia and wildfires under climate change
- Weather situations during large wildfires using numerical model and satellite products

(Photo: Marko Vucetic)
Köppen climatic zone (1961-1990)

Desert
Dry climate
Mild winter*
Dry summer
All wet seasons

Steppe
Cold winter*
Dry summer
All wet seasons

Polar climate
Tundra
Eternal ice

Climate change scenario in 2080

Source: Kristi Jylhä
Potential risk of forest fires in Europe from March to October

(Camia et al., 2008)
### Forest Fire Warning in Europe (RA VI)

<table>
<thead>
<tr>
<th>Country</th>
<th>days</th>
<th>Country</th>
<th>days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
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<td>Lebanon</td>
<td>26</td>
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<tr>
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<tr>
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<td>31</td>
<td>Montenegro</td>
<td>2</td>
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<tr>
<td>Bosnia and Herzegovina</td>
<td>2</td>
<td>Netherlands (the)</td>
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<td>33</td>
<td>Norway</td>
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<tr>
<td>Czech Republic</td>
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<td>Republic of Moldova</td>
<td>2</td>
</tr>
<tr>
<td>Denmark</td>
<td>37</td>
<td>Romania</td>
<td>0</td>
</tr>
<tr>
<td>Estonia</td>
<td>38</td>
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<td>3</td>
</tr>
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<td>Georgia</td>
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<td>Slovenia</td>
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<td>Switzerland</td>
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<td>Syrian Arab Republic</td>
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<td>46</td>
<td>FYRM of Macedonia</td>
<td>0</td>
</tr>
<tr>
<td>Israel</td>
<td>47</td>
<td>Turkey</td>
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</tr>
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<td>Jordan</td>
<td>49</td>
<td>United Kingdom</td>
<td>2</td>
</tr>
<tr>
<td>Latvia</td>
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</tbody>
</table>

- 34 European countries produce different warnings of extreme weather events every day for today and tomorrow in the frame of the MeteoAlarm but warning on forest fires is represented only in fifteen countries.

- Some of them have additional warnings as Italy, Serbia, Slovenia and Sweeden.

- There are also examples of five day warnings like Austria and Slovenia.
The climate in Croatia is influenced by the Alps in the north-west, the Pannonian lowlands in the north, the Bosnian mountains in the east and the Adriatic Sea in the south.

- The mountain barrier stretches along the Adriatic coast and separates the continental from the Mediterranean climate.
- The coastline is narrow and steep and there are more than 1200 islands.
Köppen climatic zone in Croatia

(Penzar and Penzar, 1985)

As maize accommodates very well to the continental climate conditions in the Pannonian lowlands, this climate type is known as maize climate, mountainous climate is known as common beach climate and the Mediterranean climate in the Adriatic coast as olive climate.

There are 19 variants of climate in Croatia.

Risk of summer droughts in the mid-Adriatic account for high vulnerability in agriculture and wildfires.
The greatest damage (38%) to Croatian economy and agriculture is caused by droughts, particularly Eastern Croatia and mid-Adriatic coast and islands during summer season.
Operational fire danger rating in Croatia and wildfires under climate change
Extremely years

HVAR 1859-2016

- Extremely dry: 1944, 1945, 1983
- Extremely cold: 1970, 1875, 1940
Heat stress

10 consecutive days with $t_{\text{max}} \geq 30^\circ\text{C}$

(Vucetic and Feist, 2013)
### Statistical review of forest fires > 10 ha

<table>
<thead>
<tr>
<th>Years</th>
<th>Number of wildfires</th>
<th>Burned area (ha)</th>
<th>Burned area/Number of wildfires</th>
</tr>
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<tbody>
<tr>
<td>2008</td>
<td>695</td>
<td>8541</td>
<td>12.3</td>
</tr>
<tr>
<td>2007</td>
<td>576</td>
<td>19121</td>
<td>33.3</td>
</tr>
<tr>
<td>2006</td>
<td>250</td>
<td>1694</td>
<td>6.8</td>
</tr>
<tr>
<td>2005</td>
<td>185</td>
<td>1044</td>
<td>5.6</td>
</tr>
<tr>
<td>2004</td>
<td>198</td>
<td>1466</td>
<td>7.4</td>
</tr>
<tr>
<td>2003</td>
<td>560</td>
<td>14155</td>
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</tr>
<tr>
<td>2002</td>
<td>329</td>
<td>5997</td>
<td>18.2</td>
</tr>
<tr>
<td>2001</td>
<td>358</td>
<td>1818</td>
<td>5.1</td>
</tr>
<tr>
<td>2000</td>
<td>730</td>
<td>27407</td>
<td>37.5</td>
</tr>
<tr>
<td>1999</td>
<td>386</td>
<td>1659</td>
<td>10.1</td>
</tr>
<tr>
<td>1998</td>
<td>711</td>
<td>17691</td>
<td>24.9</td>
</tr>
<tr>
<td>1997</td>
<td>682</td>
<td>6819</td>
<td>10.0</td>
</tr>
<tr>
<td>Mean</td>
<td>472</td>
<td>8951</td>
<td>16.4</td>
</tr>
</tbody>
</table>

Source: Vatrogasni vjesnik / Fire News

- The largest number of fires and burned vegetation area occur in an extremely warm and dry summers when dry periods last longer than a month.
Since 1981 the Canadian method Fire Weather Index has been applied to the fire weather indices once a day, from April to October.

The indices for a particular date are based on real-time data for 40 meteorological stations.

The predicted indices for the following two days are based on the products of the ALADIN/HR limited area numerical weather prediction model.

The actual fire weather indices are available on the web site of the Meteorological and Hydrological Service [http://meteo.hr](http://meteo.hr).
Fire Weather Index in Croatia

http//:meteo.hr
Seasonal Severity Rating (1960-2016)
Potential wildfire risk from June to September

Source: DHMZ
Mean Seasonal Severity Rating

Mean SSR (1961-1990)  
Mean SSR (1981-2010)

(Baresic and Vucetic, 2012)

Spreading of high wildfire risk from the mid-Adriatic to the northern Adriatic but also to inland and the eastern part of Croatia
SSR $> 7$ has appeared in 17 fire seasons in the last 30 years compared to 11 seasons in the previous 50 years.
Linear trend of monthly severity rating

Osijek (1951-2010)
MSR July

trend = 5.86/100 yrs

Gospić (1951-2010)
MSR July

trend = 4.56/100 yrs

(Baresic and Vucetic, 2012)
Climate scenarios

Difference SSR 2041-2070 and normal 1958-2006

Croatia until 2070

(Camia et al., 2008)
Sensitivity experiments using MUKLI\[3\]MO_3 model with resolution of 100 m

Foresation

Difference in mean annual summer days if agricultural areas are modified into forest

(Figure showing the difference in mean annual summer days)

Forest fire

Difference in mean annual summer days if all forest areas are turned into bare rocks

(Figure showing the difference in mean annual summer days)

(Zuvela-Aloise et al., 2013)
Conclusion 1

- Since 1981 the Canadian *Fire Weather Index* has been used to determine the potential risk of wildfire in the Meteorological and Hydrological Service of Croatia

- The impact of climate change on wildfire risk is reflected:
  
a) in the tendency of the fire season to start earlier (in May), as well as the possibility for the fire season to extend until October, particularly along the Adriatic.

b) spreading of high wildfire risk from the mid-Adriatic to the northern Adriatic but also to inland and the eastern part of Croatia

- The fire regime in Croatia fits into the bigger picture, which indicates that areas running a higher potential wildfire risk in the Mediterranean and eastern Europe in the summer months are expanding in size.
Weather situation during large wildfires using numerical model and satellite products
Main goal

to improve the warning of the wildfire risk predicting the additional indicators for "initial trigger" to start a large fire using numerical model products.

Deficit of rain amount + High air temperature + Low relative humidity → Dry period

Large wildfires ← Specific weather situation??? + Very dry fuel material
Mid-Adriatic fires

- Vertical wind profiles using ALADIN/LACE model (M. Vucetic and V. Vucetic 1999)
- Detailed fire weather analysis using ALADIN/HR and MM5 models (V. Vucetic et al., 2007; M. Vucetic and V. Vucetic, 2012)
- Analysis of vertical wind profiles during the 8 large wildfires using ALADIN/HR model (Tomasevic, 2012)
- Analysis of the largest wildfire in Croatia using ALADIN/HR model and satellite products (Mifka and V. Vucetic, 2012; Vodaric, 2015)
- Fire weather analysis using ALADIN/HR and WRF models (Omazic et al., 2017)

Northern Adriatic fires

- Fire weather analysis using Heines index (Kozaric and Mokoric, 2012; 2014)

Continental fire

- Detailed fire weather analysis of the largest continental fire using ALADIN/HR model (Kurazi and V. Vucetic, 2015)
Preliminary results using ALADIN/LACE model (M. Vučetić and V. Vučetić, 1999)
Significant maximum wind speed up to 1500 m

There are three criteria for definition of LLJ

<table>
<thead>
<tr>
<th>Low level jet</th>
<th>Maximum wind speed</th>
</tr>
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<tbody>
<tr>
<td><strong>Criterion 1</strong></td>
<td>≥ 12 m/s</td>
</tr>
<tr>
<td></td>
<td>≥ 43 km/h</td>
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<tr>
<td><strong>Criterion 2</strong></td>
<td>≥ 16 m/s</td>
</tr>
<tr>
<td></td>
<td>≥ 58 km/h</td>
</tr>
<tr>
<td><strong>Criterion 3</strong></td>
<td>≥ 20 m/s</td>
</tr>
<tr>
<td></td>
<td>≥ 72 km/h</td>
</tr>
</tbody>
</table>

(Bonner, 1968)
Adriatic wildfires
Large wildfires (2001-2011)

- Nine large wildfires with burned area greater than 500 ha happened on the mid-Adriatic during the period 2001-2011.
- Fire on the island of Brac was the largest fire and burned area was 5600 ha.
- Strong NE *bura* wind blew in all fire situations except in Brac fire when SE *jugo* wind prevailed.

Source: Vatrogasni vjesnik / Fire News
Surface synoptic situation under Europe
11 August 2001 at 00 UTC
(Source: DWD)
Vertical profile of wind speed using ALADIN/HR model

Split, 11 August 2001

<table>
<thead>
<tr>
<th>UTC</th>
<th>Altitude (m)</th>
<th>$v_{\text{max}}$ (m/s)</th>
<th>$v_{\text{max}}$ (km/h)</th>
<th>$d_{\text{max}}$ (°)</th>
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<tbody>
<tr>
<td>0</td>
<td>490</td>
<td>5</td>
<td>18</td>
<td>NNE</td>
</tr>
<tr>
<td>3</td>
<td>490</td>
<td>11</td>
<td>40</td>
<td>NE</td>
</tr>
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<td>6</td>
<td>380-490</td>
<td>11</td>
<td>40</td>
<td>ENE</td>
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<td>9</td>
<td>380-490</td>
<td>9</td>
<td>32</td>
<td>ENE</td>
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<td>12</td>
<td>490-640</td>
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<td>NE</td>
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<td>640</td>
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<td>NE</td>
</tr>
<tr>
<td>21</td>
<td>640</td>
<td>25</td>
<td>90</td>
<td>NE</td>
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Split, 11 August 2001

- criterion 1
- criterion 2
- criterion 3
Low Level Jet using ALADIN/HR model

11-12 August 2001

BRZINA (m/s)
NISKE MLAZNE STRUJE
BASE 00z12aug2001
VALID 09z12aug2001

HRDA BRZINA NISKE MLAZNE STRUJE u 12AUG2001 09UTC 09h forecast
Brac, mid-Adriatic, 14 July 2011

5600 ha
25000 olive trees

Source: Vuko, 2011
Wind vertical profiles of the Zadar sounding

Brac, 14-17 July 2011

(Mifka and Vucetic, 2012)
Satellite products for the Brac fire

True Image (RGB mixing channel 1 (0.62 – 0.67 μm), 4 (0.545 – 0.565 μm), 3 (0.459 – 0.479 μm)) for 15 July 2011 from 10:05 do 10:10 UTC. The smoke is visible as a result of a fire on the island of Brac.

(Vodaric, 2014)
MODIS product MOD14A1 with resolution of 1 km

14 July 2011 at 13:30 h

15 July 2011 at 12:45 h

Vodaric, 2014
7-day composite of the MODIS product MOD09A1 with resolution of 250 m

4–11 July 2011

12–19 July 2011

Earth's surface reflectivity in the wavelength range from 841 μm to 874 μm.

(Vodaric, 2014)
Using satellite data to locate forest fires

Fire season 2009

- Small fires: 29.1%
- Unknown: 3.2%
- Detected fires: 7.3%
- Clouds: 49.4%
- Night: 11.0%

• The key in hot-spot detection is the 3.9 μm temperature, whereas an additional criterion is provided by the temperature difference of channels 3.9 and 10.8 μm.
• The analysis of all recorded fires larger than 1 ha, during fire season 2009, was performed. The results show that only 7% of fires were evident in satellite data. For all other fires detection was not possible. The most frequent reason were clouds above the fires, but in many cases fires were too small to be recognized and a large number of fires during dawn, dusk or even night was also not visible.
• This result indicates that the early warning system could not be based only on satellite data from geostationary satellites, since the probability of fire detection is too low, especially for small fires up to 15 ha.

(Mahovic Strelec, 2011)
Peljesac wildfires, July 2015

PLOCE 18-25 July 2015

wind speed (m/s)

(smokvica, trstenik, ponikve)

v10 vmax

(photos: marko vucetic)

(omazic and vucetic, 2017)
### Peljesac wildfire, July 2015
#### Crown fire

**Burned area**
- **4000 ha**

**STON**

<table>
<thead>
<tr>
<th>DATE</th>
<th>t (°C)</th>
<th>RH (%)</th>
<th>v (m/s)</th>
<th>P (mm)</th>
<th>ISI</th>
<th>FWI</th>
<th>DSR</th>
<th>RISK</th>
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<tr>
<td>20.7</td>
<td>37.4</td>
<td>30</td>
<td>4</td>
<td>0</td>
<td>25.4</td>
<td>68.5</td>
<td>48.29</td>
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<tr>
<td>21.7</td>
<td>37.2</td>
<td>34</td>
<td>4</td>
<td>0</td>
<td>25.6</td>
<td>69.1</td>
<td>49.06</td>
<td>very high</td>
</tr>
<tr>
<td>22.7</td>
<td>35.1</td>
<td>39</td>
<td>4</td>
<td>0</td>
<td>23.6</td>
<td>66.0</td>
<td>45.21</td>
<td>very high</td>
</tr>
<tr>
<td>23.7</td>
<td>31.8</td>
<td>44</td>
<td>4</td>
<td>5.2</td>
<td>7.0</td>
<td>27.3</td>
<td>9.46</td>
<td>high</td>
</tr>
</tbody>
</table>

*(Omazic and Vucetic, 2017)*

*(Photo: Grgo Jelavic)*
Field of air temperature using ALADIN/HR model

20 July 2015 at 15 UTC

21 July 2015 at 3 UTC

(Omazic i Vucetic, 2017)
Continental wildfire
Continental wildfire, March 2012

Krapina, 22-26 March 2012 at 14 h

<table>
<thead>
<tr>
<th>Date</th>
<th>$t_{\text{air}}$ ($^\circ$C)</th>
<th>$t_{\text{soil2}}$ cm ($^\circ$C)</th>
<th>mean $t_{\text{soil2}}$ cm ($^\circ$C)</th>
<th>RH (%)</th>
<th>$v$ (m/s)</th>
<th>FWI</th>
<th>Risk</th>
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<tbody>
<tr>
<td>22.3.2012.</td>
<td>20.0</td>
<td>22.8</td>
<td>12.9</td>
<td>35</td>
<td>2</td>
<td>14.2</td>
<td>low</td>
</tr>
<tr>
<td>23.3.2012.</td>
<td>22.6</td>
<td>23.1</td>
<td>13.6</td>
<td>28</td>
<td>2</td>
<td>17.8</td>
<td>moderate</td>
</tr>
<tr>
<td>24.3.2012.</td>
<td>22.3</td>
<td>23.9</td>
<td>14.0</td>
<td>32</td>
<td>2</td>
<td>18.5</td>
<td>moderate</td>
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<tr>
<td>25.3.2012.</td>
<td>20.3</td>
<td>22.8</td>
<td>14.6</td>
<td>39</td>
<td>2</td>
<td>17.9</td>
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<td>26.3.2012.</td>
<td>17.9</td>
<td>22.2</td>
<td>14.1</td>
<td>27</td>
<td>4</td>
<td>31.5</td>
<td>high</td>
</tr>
</tbody>
</table>

(Kurazi and Vucetic, 2015)
Ccontinental wildfire, March 2012

Low level jet 26 March 2012 at 00 UTC

(Kurazi and Vucetic, 2015)
Conclusion 2

High Fire Weather Index

Cold front + Low level jet

Large wildfires
Common characteristics of Peljesac and Krapina wildfires are:

a) a long-lasting dry and warm period before the wildfires

b) Although the wind was weak, very dry dead fuel, strong convection of warm air and a very steep terrain helped in fire rapid spreading.

Polar and geostationary satellites have their advantages and disadvantages in recognition and monitoring of forest fire:

a) The advantage of polar satellites is that they can record with very large spatial resolution, but time interval is too long.

b) Geostationary satellites give data every 15 minutes but have smaller spatial resolution.

Thus, the early warning system in Croatia could not be based only on satellite data, since the probability of fire detection is too low, especially for small fires up to 15 ha.
Animated film “The fire is no joke”
Croatian Agrometeorological Society

- One of measures of forest protection against fire is a good education of the youngest.

- As the animated film is the most popular medium in children's lives, HAgMD produced the film with motto: “Do not play with flame and smoke, fire is no joke!”
Thank you for your attention