# Coupling fire information with climate: General methodology

Valentina Bacciu, IAFES Sassari valentina.bacciu@cmcc.it 3<sup>rd</sup> Workshop on "Fire Spread and Behavior Modeling in a context of Climate Change"

July 25-29, 2016 Sassari - Italy





# Fire Weather Fuel moisture Wind COSMO-CLM RCP scenarios UVE Fuel moisture = DC UVE Fuel moisture = FFMC FWI FWI

# **Fire Weather Index structure**



#### **Fire Weather Index structure**

Low numbers mean wet; high numbers mean dry.

#### Fine Fuel Moisture Code (FFMC) Range: 0 - 101

The dryness of the smallest forest fuels (surface litter, leaves, needles, small twigs, etc). Derived from yesterday's FFMC and the local noon dry bulb temperature, relative humidity, wind speed, and 24-hour precipitation.

#### Duff Moisture Code (DMC) Range: 0 - Unlimited

The dryness of the medium-sized surface fuels and upland duff layers (approximately 2 to 10 cm). Derived from yesterday's DMC and the local noon dry bulb temperature, relative humidity and 24-hour precipitation.

#### Drought Code (DC)

Range: 0 - Unlimited

The dryness of the largest surface fuels and deep duff layers (approximately 10+ cm). Derived from yesterday's DC and the local noon dry bulb temperature and 24-hour precipitation.

#### **Fire Weather Index structure**

#### Initial Spread Index (ISI)

#### Range: 0 - Unlimited

A relative measure of how quickly a fire can be expected to spread. Derived from the FFMC and wind speed.

#### Build Up Index (BUI)

#### Range: 0 - Unlimited

A relative measure of the amount of fuel available for combustion. Derived from the DC and DMC.

#### Fire Weather Index (FWI)

#### Range: 0 - Unlimited

A relative measure of potential fire intensity—or energy available to be released. The FWI is a good indicator of overall fire danger. Derived from the BUI and ISI.

#### Methodology

1981-2005, 2021-2050, Three 30-years period 2051-2080

1) Calculate of 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup>, 90<sup>th</sup>, 95<sup>th</sup> and 97<sup>th</sup> percentile of FFMC and DC daily values for each pixel, and then summarized in the 4 30-years periods.

2) Label FFMC and DC values above the Sardinian 75th percentile as "moderate", "dry", "very dry" or "extreme".

3) Associate the abovementioned labels to specific moisture conditions for the vegetation

4) Calculate the percentage of days corresponding to each moisture class for the 30-years periods and each macro-area.

#### How to...

How to calculate FWI using current and future climate data? **R facilities → cffdrs/fireDanger** 

How to set-up wind and fuel moisture conditions from current and future climate data?

How to visualize the data? PANOPLY

How to present the data? R facilities

# Application of R tools and methods to calculate fire danger

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# An introduction to R

 ${\bf R}$  is an integrated suite of software facilities for data manipulation, calculation and graphical display. It has

- · an effective data handling and storage facility,
- a suite of operators for calculations on arrays, in particular matrices, a large, coherent, integrated collection of intermediate tools for data analysis,
- · graphical facilities for data analysis and display,
- a well developed, simple and effective programming language (called 'S') which includes conditionals, loops, user defined recursive functions and input and output facilities.

#### R is a free software!

# How to download R

#### http://cran.mirror.garr.it/mirrors/CRAN/

← → C 🐔 🗋 cran.mirror.garr.it/mirror	s/CRAN/
R	The Comprehensive R Archive Network
	Dewnload and Install R Precompiled binary distributions of the base system and contributed packages, Windows and Mac users most likely want one of these versions of R:
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Abour R E-Homenans The R-Journal Software R-Sources R-Bunites Packages Other Documentation Manuals EAQs Contributed	<ul> <li>Source Code for all Platforms</li> <li>Windows and Mac users most likely want to download the precompiled binaries listed in the upper box, not the source code. The sources have to be compiled before you can use them. If you do not know what this means, you probably do not want to do all</li> <li>The latest release (2015-03-09, Smooth Sidewalk) <u>R-3.1.3 tor gr</u>, read <u>what's new</u> in the latest version.</li> <li>Sources of <u>R alpha and beta releases</u> (daily snapshots, created only in time periods before a planned release).</li> <li>Daily snapshots of current patched and development versions are <u>available here</u>. Please read about <u>new features and bug fires</u> before filing corresponding feature requests or bug reports.</li> <li>Source code of older versions of R is <u>available here</u>.</li> <li>Contributed extension <u>packages</u></li> </ul>
	Questions About R <ul> <li>If you have questions about R like how to download and install the software, or what the license terms are, please read our answers to frequently, asked questions before you send an email.</li> </ul>
	What are R and CRAN?



https://www.rstudio.com/products/rstudio/download2/

# **R** packages

Once you have downloaded the R executable, you only have to run it and follow instruction. Some R functions are available in additional packages, so you need to install them.

You can download them from http://www.cran.rproject.org/web/packages/available\_packages\_by\_name.html

In order to carry out the exercises of hands-on session you need some packages to work with excel files:

cffdrs

#### Canadian Forest Fire Danger Rating System (CFFDRS)

http://rpackages.ianhowson.com/rforge/cffdrs/man/cffdrs-package.html

Package: cffdrs Type: Package Version: 1.7.4 Date: 2016-04-26 License: GPL-2

This package includes 10 functions:

FWI System calculation  $\rightarrow$  fwi, fwiRaster, hffmc, hffmcRaster, sdmc, gfmc, and wDC FBP System calculation  $\rightarrow$  fbp and fbpRaster

fireSeason has been added to determine fire season start and end dates based on weather.

# Canadian Forest Fire Danger Rating System (CFFDRS)

The fwi, fwiRaster, and sdmc functions calculate the outputs based on daily noon local standard time (LST) weather observations of temperature, relative humidity, wind speed, and 24-hour rainfall, as well as the previous day's moisture content.

The hffmc, gfmc, and hffmcRaster functions calculate the outputs based on hourly weather observations of temperature, relative humidity, wind speed, and hourly rainfall, as well as the previous hour's weather conditions.

The fbp and fbpRaster functions calculate the outputs of the FBP System based on given set of information about fire weather conditions (weather observations and their associated FWI System components), fuel type, and slope (optional).

#### cffdrs package - fwi

**Function FWI** 

fwi(input,init=data.frame(ffmc=85,dmc=6,dc=15,lat=55), batch=TRUE, out= "all", lat.adjust=TRUE,uppercase=TRUE)

INPUT: A dataframe containing input variables of daily weather observations taken at noon LST. Variable names have to be the same as in the following list, but they are case insensitive. The order in which the input variables are entered is not important.

id	(optional)	Unique identifier of a weather station or spatial point (n restriction on data type); required when batch=TRUE	0
lat	(recommended)	Latitude (decimal degree, default=55)	
long	(optional)	Longitude (decimal degree)	
yr	(optional)	Year of observation; required when batch=TRUE	
mon	(recommended)	Month of the year (integer 1-12, default=7)	
day	(optional)	Day of the month (integer); required when batch=TRUE	
temp	(required)	Temperature (centigrade)	
rh	(required)	Relative humidity (%)	
WS	(required)	10-m height wind speed (km/h)	
prec	(required)	24-hour rainfall (mm)	
			0

#### cffdrs package - fwi

Function FWI

fwi(input,init=data.frame(ffmc=85,dmc=6,dc=15,lat=55), batch=TRUE, out= "all", lat.adjust=TRUE,uppercase=TRUE)

INIT: A data.frame or vector contains either the initial values for FFMC, DMC, and DC or the same variables that were calculated for the previous day and will be used for the current day's calculation. The function also accepts a vector if the initial or previous day FWI values is for only one weather station (a warning message comes up if a single set of initial values is used for multiple weather stations). Defaults are the standard initial values for FFMC, DMC, and DC defined as the following:

ffmc	Fine Fuel Moisture Code (FFMC; unitless) of the previous day. Default value is 85.
dmc	Duff Moisture Code (DMC; unitless) of the previous day. Default value is 6.
dc	Drought Code (DC; unitless) of the previous day. Default value is 15.
lat	Latitude of the weather station (optional, default=55). Latitude values are used
	to make day length adjustments in the function.

#### cffdrs package - fwi

**Function FWI** 

fwi(input,init=data.frame(ffmc=85,dmc=6,dc=15,lat=55), batch=TRUE, out= "all", lat.adjust=TRUE,uppercase=TRUE)

BATCH: Whether the computation is iterative or single step, default is TRUE. When batch=TRUE, the function will calculate daily FWI System outputs for one weather station over a period of time chronologically with the initial conditions given (init) applied only to the first day of calculation.

If multiple weather stations are processed, an additional "id" column is required in the input to label different stations, and the data needs to be sorted by date/time and "id".

If batch=FALSE, the function calculates only one time step (1 day) base on either the initial start values or the previous day's FWI System variables, which should also be assigned to init argument.

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# cffdrs package - fwi

**Function FWI** 

fwi(input,init=data.frame(ffmc=85,dmc=6,dc=15,lat=55), batch=TRUE, out= "all", lat.adjust=TRUE, uppercase=TRUE)

#### out

The function offers two output options, out="all" will produce a data frame that includes both the input and the FWI System outputs; out="fwi" will generate a data frame with only the FWI system components.

#### lat.adjust

The function offers options for whether day length adjustments should be applied to the calculations. The default value is "TRUE".

#### uppercase

Output in upper cases or lower cases would be decided by this argument. Default is TRUE.

# cffdrs package intallation with RStudio

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# cffdrs package installation with R

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# cffdrs package

```
workdir <- "C:/CLIMASOUTH/HANDS-ON_R/"
setwd(workdir)
library(cffdrs)</pre>
```

```
nsard <- read.table("C:/CLIMASOUTH/HANDS-ON_R/nsard2.txt",
header=T)
summary(nsard)
```

long Min. :8.000 1st Qu.:8.000 Median :8.000	Median :40 Med	Qu.:1998 ian :2002	mon Min. : 1.000 1st Qu.: 4.000 Median : 7.000	day Min. : 1.00 1st Qu.: 8.00 Median :16.00	temp Min. : 3.80 1st Qu.:15.40 Median :20.40	rh Min. :26.00 1st Qu.:67.00 Median :76.00
Mean :8.333 3rd Qu.:9.000	Mean :40 Mea 3rd Qu.:40 3rd	n :2002 Qu.:2006	Mean : 6.523	Mean :15.73 3rd Qu.:23.00	Mean :21.17 3rd Qu.:26.40	Mean :74.11 3rd Qu.:83.00
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мin. : 0.00	Min. : 0.000					
1st Qu.: 8.10	1st Qu.: 0.000				<b>V</b>	
Median :11.70	Median : 0.000					
Mean :13.87	Mean : 1.155			Can nre	vent the analy	rcic
3rd Qu.:17.40	3rd Qu.: 0.000			can pre	vent the analy	515
Max. :77.80	Max. :157.990					
NA's :280	NA'S :899					

nsard2 <- na.exclude(nsard)</pre>

# cffdrs package

```
# (1) FWI System variables for a single weather station:
# Using the default initial values and batch argument,
# the function calculate FWI variables chronically:
```

fwi.alghero<-fwi(alghero)</pre>

Dafault value of lat is 55, while Alghero is 40

#### cffdrs package

Dafault value of lat is 55, while Alghero is 40

```
# Using a different set of initial values:
fwi.alghero2<-fwi(alghero,init=data.frame(ffmc=80,
dmc=10,dc=16, lat=40))
# This could also be done as the following:
fwi.alghero2 <-fwi(alghero,init=data.frame(80,10,6,40))
# Or:
fwi.alghero2 <-fwi(alghero,init=c(80,10,6,40))</pre>
```

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# cffdrs package

#### Summary(fwi.alghero2)

LONG	LAT	YR	MON	DAY	TEMP	RH	WS
Min. :8	Min. :4	0 Min. :1995	ы мin. : 1.000	Min. : 1.00	Min. : 3.8	Min. :30.00	Min. : 0.00
1st Qu.:8	1st Qu.:4	0 1st Qu.:1998	3 1st Qu.: 3.000	1st Qu.: 8.00	1st Qu.:16.0	1st Qu.:68.00	1st Qu.: 7.40
Median :8	Median :4	0 Median :2002	Median : 6.000	Median :16.00	Median :21.2	Median :76.00	Median :10.00
Mean :8	Mean :4	0 Mean :2002	Mean : 6.416	Mean :15.64	Mean :21.9	Mean :74.35	Mean :11.39
3rd Qu.:8	3rd Qu.:4	0 3rd Qu.:2006	5 3rd Qu.: 9.000	3rd Qu.:23.00	3rd Qu.:27.4	3rd Qu.:82.00	3rd Qu.:14.10
Max. :8	Max. :4	0 Max. :2009	Max. :12.000	Max. :31.00	Max. :40.4	Max. :98.00	Max. :54.30
PREC		DATE	FFMC	DMC	DC	ISI	
Min. :	0.000 Min	. :1995-01-01	Min. : 7.88	Min. : 0.1115	Min. : 1.	108 Min. :	0.000001
1st Qu.:	0.000 1st	Qu.:1998-03-26	1st Qu.:74.89	1st Qu.: 6.1984	1st Qu.: 209.	998 1st Qu.:	1.311108
Median :	0.000 Med	ian :2002-03-17	Median :82.01	Median : 18.1217	Median : 396.	780 Median :	2.533475
Mean :	1.292 Mea	n :2002-03-13	Mean :76.48	Mean : 47.6799	Mean : 467.	634 Mean :	2.837236
3rd Qu.:	0.000 3rd	Qu.:2006-01-31	3rd Qu.:85.33	3rd Qu.: 65.2808	3rd Qu.: 685.	304 3rd Qu.:	3.919576
Max. :15	7.990 Max	. :2009-12-31	Max. :94.53	Max. :430.7015	Max. :1587.	844 Max. :2	22.166060
BUI		FWI	DSR				
Min. :	0.1982 Mi	n. : 0.0000	Min. : 0.00000				
1st Qu.: 1	1.0035 1s	t Qu.: 0.8872	1st Qu.: 0.02201				
Median : 3	1.5235 Me	dian : 5.2314	Median : 0.50877				
Mean : 6	9.0551 Me	an : 8.8873	Mean : 2.24366				
3rd Qu.:10	2.2818 3r	d Qu.:15.4623	3rd Qu.: 3.46405				
Max. :50	2.3488 Ma	x. :53.6454	Max. :31.32146				
>							

plot(fwi.alghero2\$DATE,fwi.alghero2\$FWI, ty="1")

cffdrs package

plot(fwi.alghero2\$DATE,fwi.alghero2\$FWI, ty="1")





# cffdrs package

quantile(fwi.alghero2\$FWI, probs=.9) -> fwi90
abline(h=fwi90)

points(fwi.alghero2\$DATE[which(fwi.alghero2\$FWI>fwi90)],fwi.alghero2\$FWI[which(fwi.alghero2\$FWI>fwi90)], pch=21, col='red',bg='yellow')



cffdrs package

The following are the FWI values used by EFFIS as thresholds of the fire danger classes

Fire Danger Classes	FWI ranges (upper bound excluded)			
Very low	< 5.2			
Low	5.2 - 11.2			
Moderate	11.2 - 21.3			
High	21.3 - 38.0			
Very high	38.0 - 50.0			
Extreme	>= 50.0			

#### cffdrs package

```
par(mfrow=c(3,1))
plot(fwi.alghero2$DATE,fwi.alghero2$FWI, ty="l")
plot(fwi.alghero2$DATE,fwi.alghero2$FFMC, ty="l")
plot(fwi.alghero2$DATE,fwi.alghero2$DC, ty="l")
```

```
write.table(fwi.alghero2, "C:/CLIMASOUTH/HANDS-
ON_R/fwi.alghero.txt", sep="\t")
```

#### fireDanger Package

Provides functions for the calculation of several popular indices for fire risk assessment based on meteorological data.

Author(s)

Joaquin Bedia, with contributions of Sixto Herrera and Maialen Iturbide Santander Meteorology Group (http://www.meteo.unican.es) Maintainer: Joaquin Bedia <bediaj@unican.es>

This R package contains implementations of several popular fire danger indices widely applied in many areas of the world:

- \* The Canadian Fire Weather Index System (including all its components)
- \* The Angstron Index
- \* The Fuel Moisture Index
- \* The Nesterov Index (including the more recent modified version)
- \* The Keetch-Byram Drought Index
- \* The McArthur's drought factor, and the Forest Fire Danger Index (FFDI)

#### fireDanger Package

fwi(date, Tm, H, r, W, return.all = FALSE)

Arguments

- date A vector of dates.
- Tm A numeric vector of temperature records (in degree C)
- H A numeric vector of relative humidity records (in %)
- r A numeric vector of precipitation records (in mm)
- W A numeric vector of wind speed records (in km/h)
- **return.all** Logical. Should all FWI system components be returned?. If TRUE, a complete dataframe is returned with all FWI components. Default to FALSE, and in this case only FWI is returned.

#### fireDanger Package

# Prepare the data.frame for Tm, H, r, W, in R with the package ncdf4

```
ncname <- "rh_2000_boxrnnALG"
ncfname <- paste(ncname, ".nc", sep = "")
dname <- "rh"
ncin <- nc_open(ncfname)
lon <- ncvar_get(ncin, "lon")
nlon <- dim(lon)
lat <- ncvar_get(ncin, "lat", verbose = F)
nlat <- dim(lat)
print(c(nlon, nlat))
t <- ncvar_get(ncin, "time")
tunits <- ncatt_get(ncin, "time", "units")
nt <- dim(t)</pre>
```

#### fireDanger Package

```
rh.array <- ncvar_get(ncin, dname)
dlname <- ncatt_get(ncin, dname, "long_name")
dunits <- ncatt_get(ncin, dname, "units")
dim(rh.array)
rh.vec.long <- as.vector(rh.array)
length(rh.vec.long)
rh.mat <- matrix(rh.vec.long, nrow = nt, ncol = nlon * nlat)
rh.df <- data.frame(rh.mat)
rh.df2[is.na(rh.df)] <- 0</pre>
```

```
read.table('.../date.txt',h=TRUE) -> date2000
date2000p <- as.Date(as.POSIXlt(paste(date2000$YEAR, "-",
date2000$MONTH, "-", date2000$DAY, sep="")))</pre>
```

fireDanger Package



```
[ ,i], W=ws.df[ ,i], ret=FALSE) -> fwi.alg[ ,i]
```

}

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#### fireDanger Package

```
apply(fwi.alg, FUN=mean, MARGIN=2) -> fwi.alg.map
cbind.data.frame(coords, fwi.alg.map) -> fwi.alg.map
coordinates(fwi.alg.map) <- c(1,2)
gridded(fwi.alg.map) <- TRUE
spplot(fwi.alg.map, col.regions=rev(heat.colors(21)))
```



