Coupling fire information with climate: General methodology

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3rd Workshop on "Fire Spread and Behavior Modeling in a context of Climate Change"

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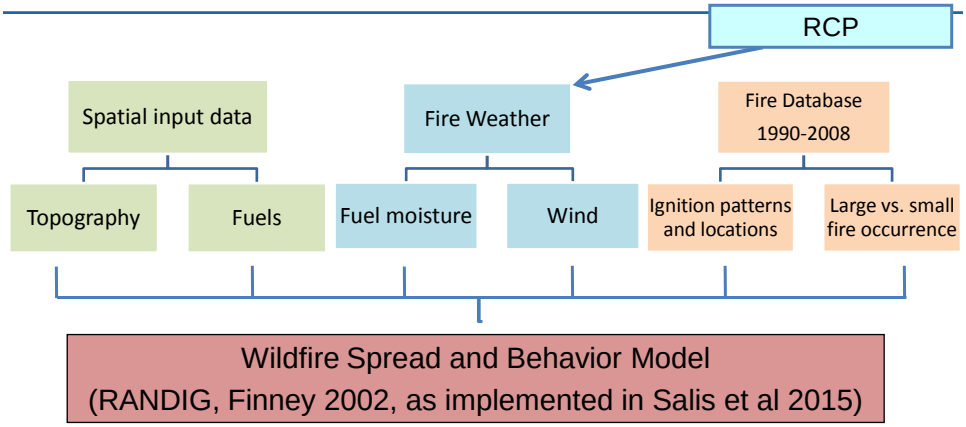
cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici

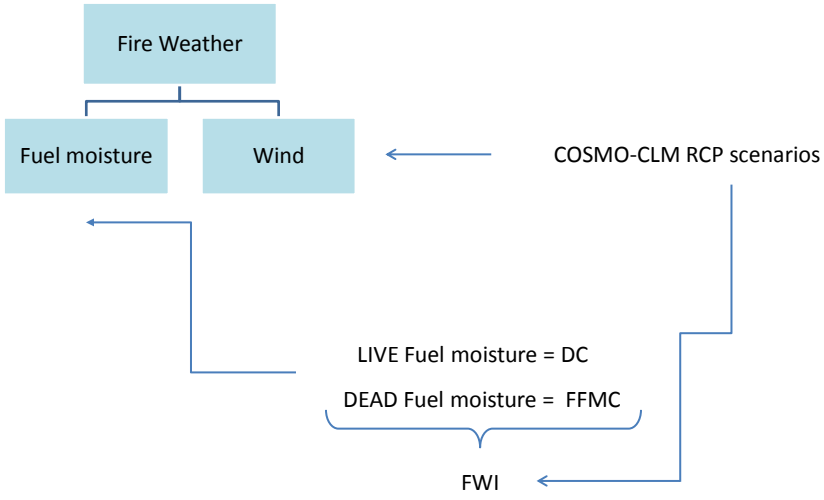
Methodologies development to assess fire exposure



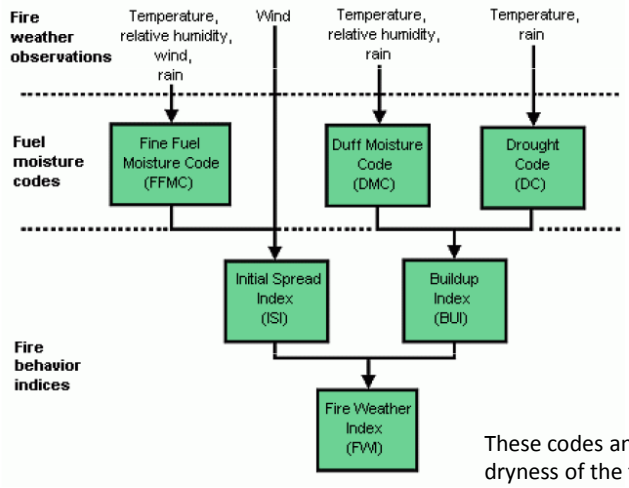
Burn probability (BP), Conditional flame length (CFL), Average fire size (FS), Fire potential index (FPI), etc.

Salis et al., 2013

Data collection



Fire Weather Index structure



These codes and indices are indicators of the dryness of the forest fuels and give relative measure of the burning conditions that can be **expected** for a "standard" fuel type.

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

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

1) Calculate of 25th, 50th, 75th, 90th, 95th and 97th 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?

CDO

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

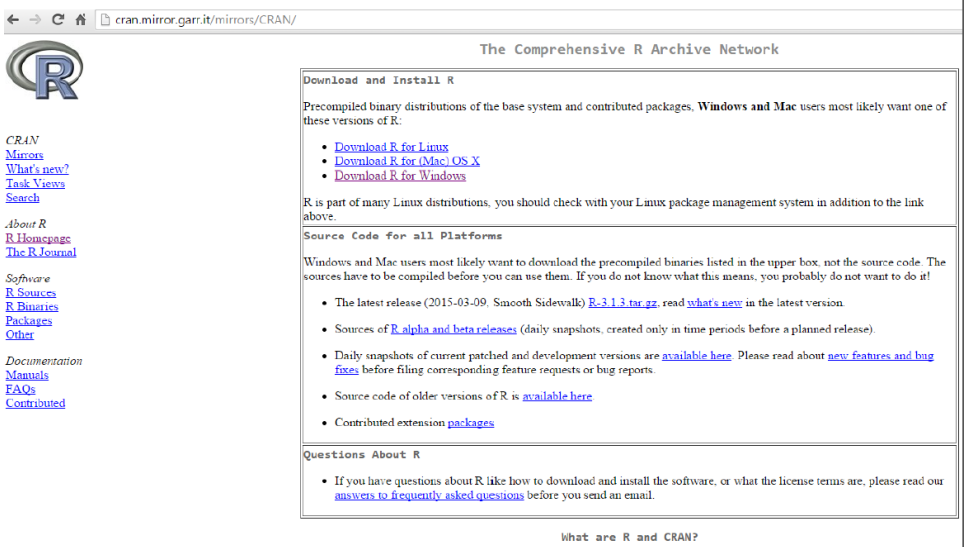
R is an integrated suite of software facilities for data manipulation, calculation and graphical display. It has

- 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.

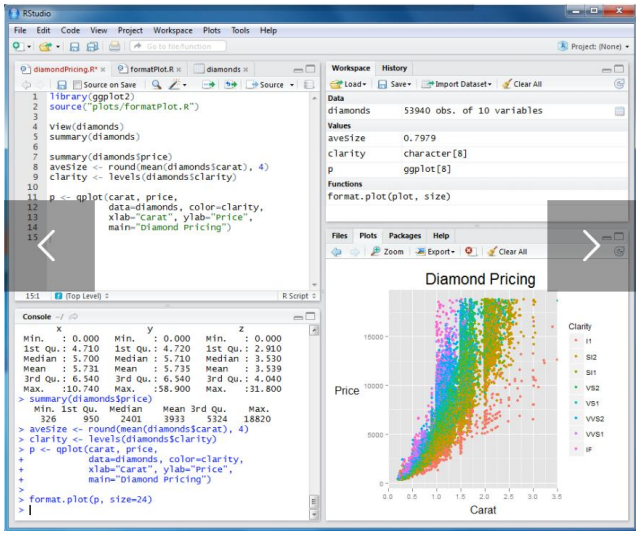
R is a free software!

How to download R

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



RStudio is accessed over the web



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.r-project.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 → fwi, fwiRaster, hffmc, hffmcRaster, sdmc, gfmc, and wDC
FBP System calculation → 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 (no restriction on data type); required when batch=TRUE
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)

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.

cffdrs package - fwi

Function FWI

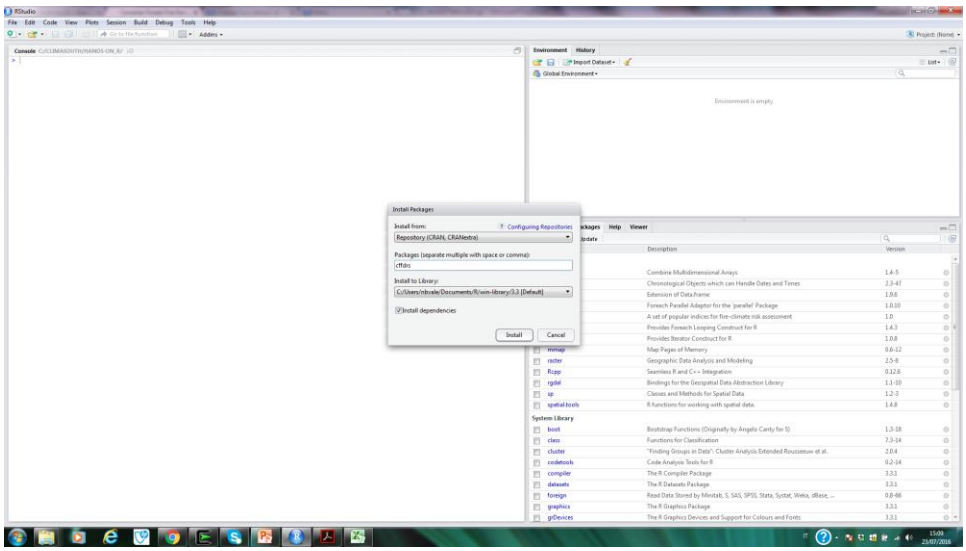
```
fwi(input,init=data.frame(ffmc=85,dmc=6,dc=15,lat=55), batch=TRUE,
out= "all", lat.adjust=TRUE, uppercase=TRUE)
```

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.

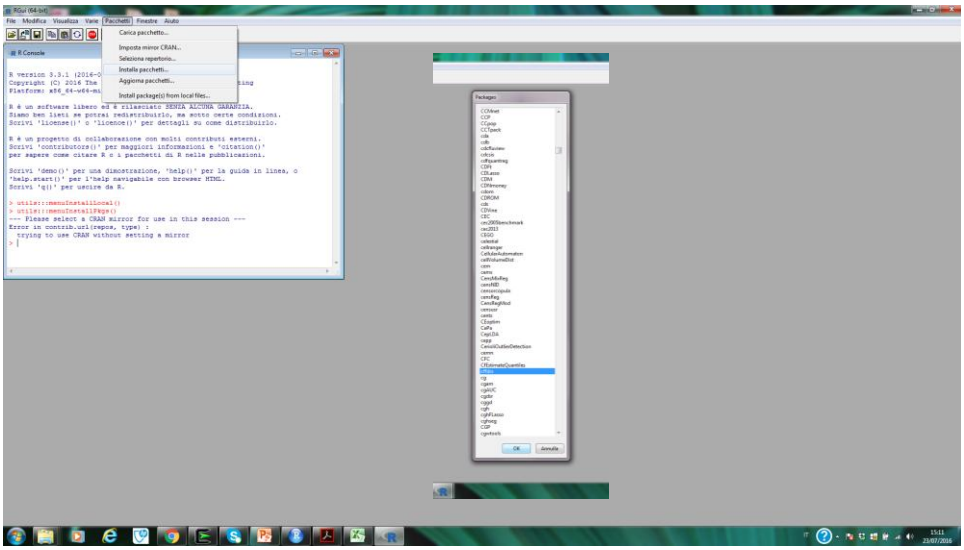
lat.adjust
The function offers options for whether day length adjustments should be applied to the calculations. The default value is "TRUE".

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

cffdrs package intallation with RStudio



cffdrs package installation with R



cffdrs package

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

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

```
      long             lat              yr             mon              day             temp             rh        
 Min.   :8.000   Min.   :40   Min.   :1995   Min.   : 1.000   Min.   : 1.00   Min.   : 3.80   Min.   :26.00  
 1st Qu.:8.000   1st Qu.:40   1st Qu.:1998   1st Qu.: 4.000   1st Qu.: 8.00   1st Qu.:15.40   1st Qu.:67.00  
 Median :8.000   Median :40   Median :2002   Median : 7.000   Median :16.00   Median :20.40   Median :76.00  
 Mean   :8.333   Mean   :40   Mean   :2002   Mean   : 6.523   Mean   :15.73   Mean   :21.17   Mean   :74.11  
 3rd Qu.:9.000   3rd Qu.:40   3rd Qu.:2006   3rd Qu.:10.000   3rd Qu.:23.00   3rd Qu.:26.40   3rd Qu.:83.00  
 Max.   :9.000   Max.   :40   Max.   :2009   Max.   :12.000   Max.   :31.00   Max.   :41.60   Max.   :99.00  
                                                                             NA's   :227     NA's   :245    

       ws              prec        
 Min.   : 0.00   Min.   :  0.000  
 1st Qu.: 8.10   1st Qu.:  0.000  
 Median :11.70   Median :  0.000  
 Mean   :13.87   Mean   :  1.155  
 3rd Qu.:17.40   3rd Qu.:  0.000  
 Max.   :77.80   Max.   :157.990  
 NA's   :280     NA's   :899      
```

Can prevent the analysis

```
nsard2 <- na.exclude(nsard)
```

cffdrs package

```
nsard2[1:5259,] -> alghero
alghero$date <- as.Date(as.POSIXlt(paste(alghero$yr, "-",
   alghero$mon, "-", alghero$day,sep="")))
```

```
# (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)
```

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))
```

cffdrs package

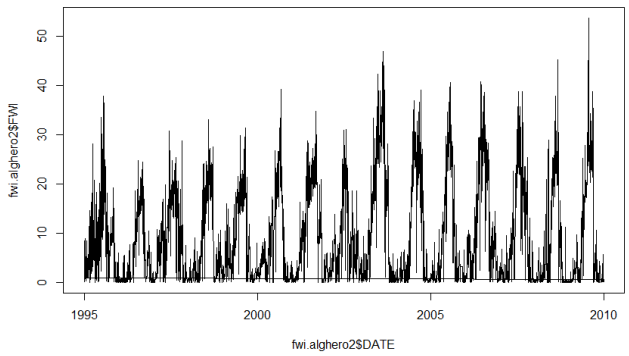
```
Summary(fwi.alghero2)
```

```
      LONG          LAT            YR            MON             DAY             TEMP            RH              WS        
Min.   :8   Min.   :40   Min.   :1995   Min.   : 1.000   Min.   : 1.00   Min.   : 3.8   Min.   :30.00   Min.   : 0.00  
1st Qu.:8   1st Qu.:40   1st Qu.:1998   1st Qu.: 3.000   1st Qu.: 8.00   1st Qu.:16.0   1st Qu.:68.00   1st Qu.: 7.40  
Median :8   Median :40   Median :2002   Median : 6.000   Median :16.00   Median :21.2   Median :76.00   Median :10.00  
Mean   :8   Mean   :40   Mean   :2002   Mean   : 6.416   Mean   :15.64   Mean   :21.9   Mean   :74.35   Mean   :11.39  
3rd Qu.:8   3rd Qu.:40   3rd Qu.:2006   3rd Qu.: 9.000   3rd Qu.:23.00   3rd Qu.:27.4   3rd Qu.:82.00   3rd Qu.:14.10  
Max.   :8   Max.   :40   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   Median :2002-03-17   Median :82.01   Median : 18.1217   Median : 396.780   Median : 2.533475  
Mean   :  1.292   Mean   :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.   :157.990   Max.   :2009-12-31   Max.   :94.53   Max.   :430.7015   Max.   :1587.844   Max.   :22.166060  
      BUI               FWI              DSR        
Min.   :  0.1982   Min.   :  0.0000   Min.   : 0.00000  
1st Qu.: 11.0035   1st Qu.:  0.8872   1st Qu.: 0.02201  
Median : 31.5235   Median :  5.2314   Median : 0.50877  
Mean   : 69.0551   Mean   :  8.8873   Mean   : 2.24366  
3rd Qu.:102.2818   3rd Qu.: 15.4623   3rd Qu.: 3.46405  
Max.   :502.3488   Max.   : 53.6454   Max.   :31.32146  
> 
```

```
plot(fwi.alghero2$DATE,fwi.alghero2$FWI, ty="l")
```

cffdrs package

```
plot(fwi.alghero2$DATE,fwi.alghero2$FWI, ty="l")
```

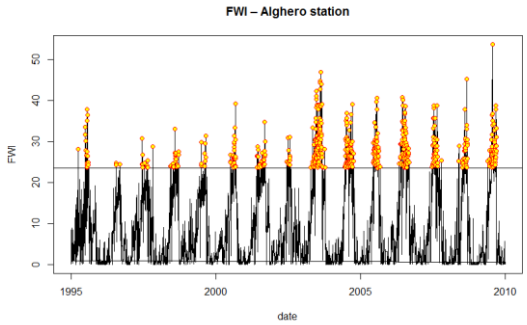



```
plot(fwi.alghero2$DATE,fwi.alghero2$FWI, ty="l", main="FWI –
   Alghero station", xlab="date", ylab="FWI")
```

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)
```

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
```

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

fireDanger Package


```
matrix(rep(NA, 366*2255), ncol=2255) -> fwi.alg
for (i in 1:2255) {
print(paste('calculating point',i))
fwi(date=date2000p, Tm=temp.df[ ,i], H=rh.df[ ,i], r=prec.df
[ ,i], W=ws.df[ ,i], ret=FALSE) -> fwi.alg[ ,i]
}
```

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)))
```

Thanks

cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici