Forest fires prevention in Catalonia: from daily to seasonal forecasting

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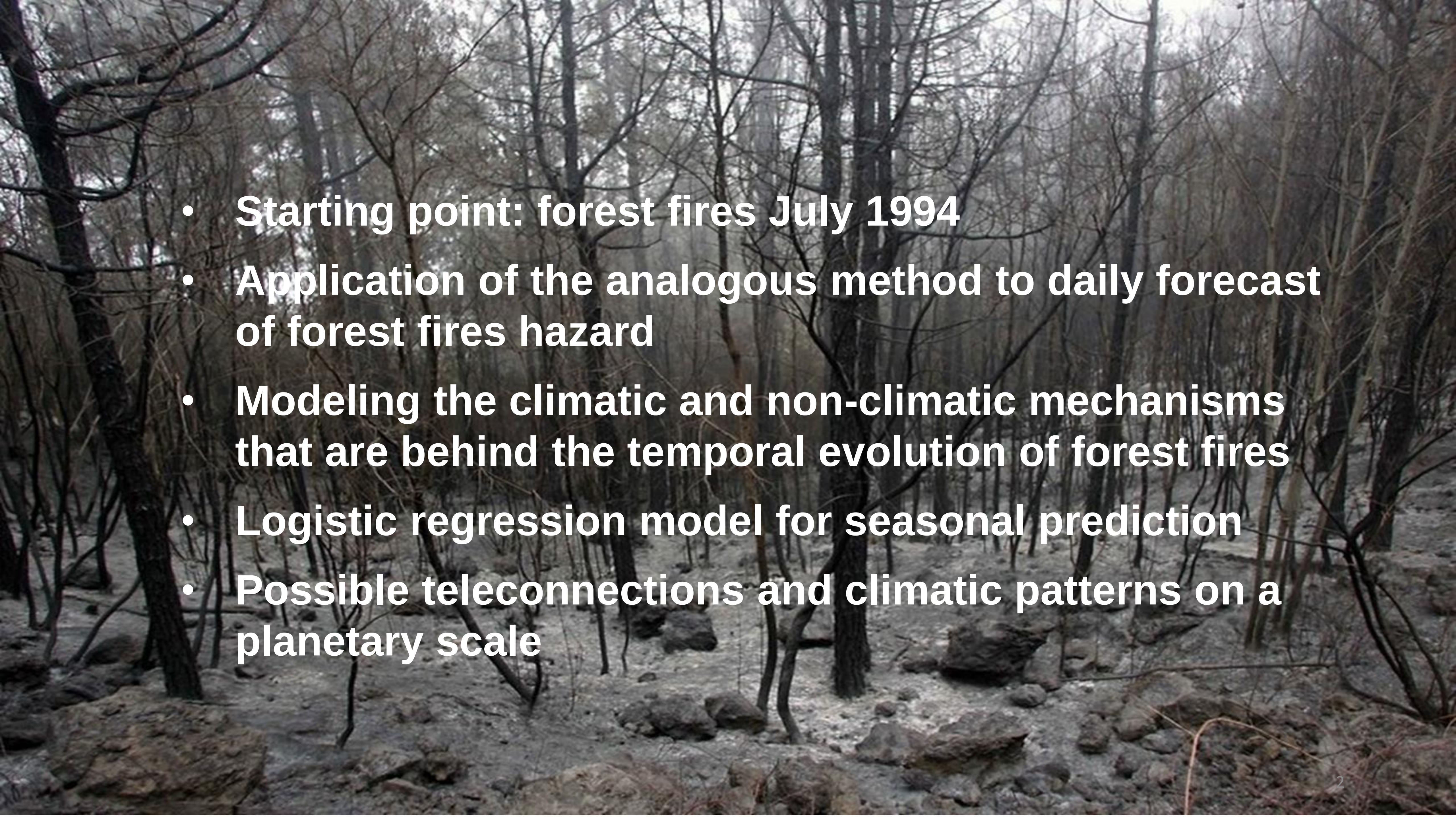
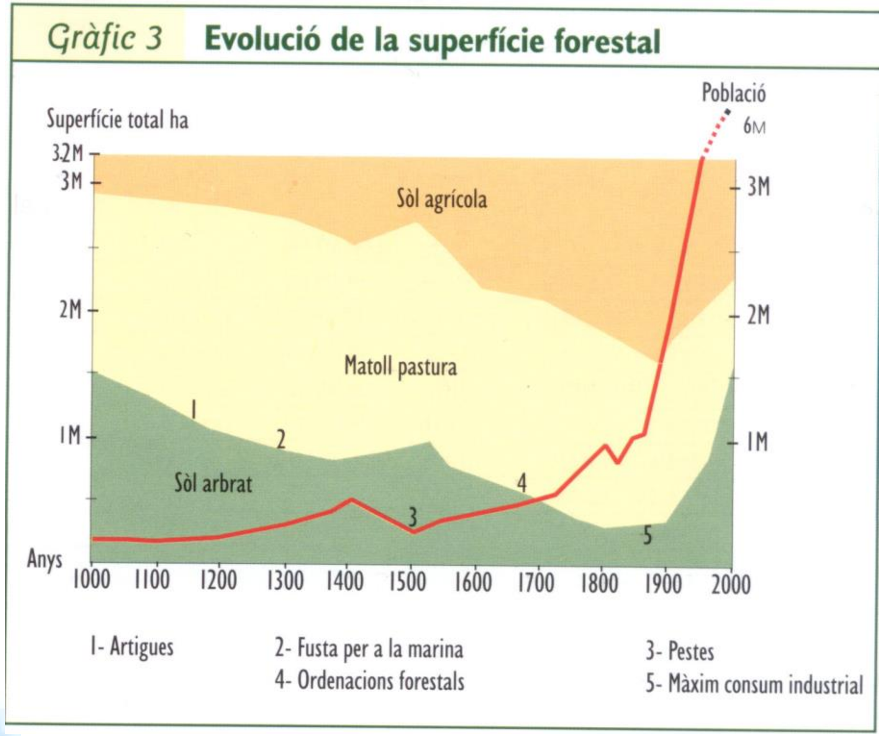
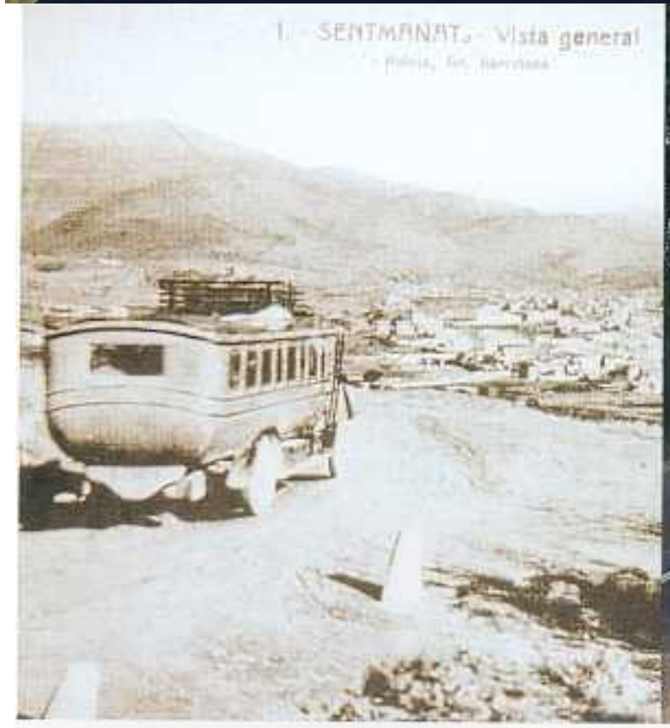
Weather and Climate Extremes and their Predictability, CAFE Final Conference, 27 to 29 September 2022 (Barcelona, Spain)



- Starting point: forest fires July 1994
- Application of the analogous method to daily forecast of forest fires hazard
- Modeling the climatic and non-climatic mechanisms that are behind the temporal evolution of forest fires
- Logistic regression model for seasonal prediction
- Possible teleconnections and climatic patterns on a planetary scale

WHERE WE ARE?

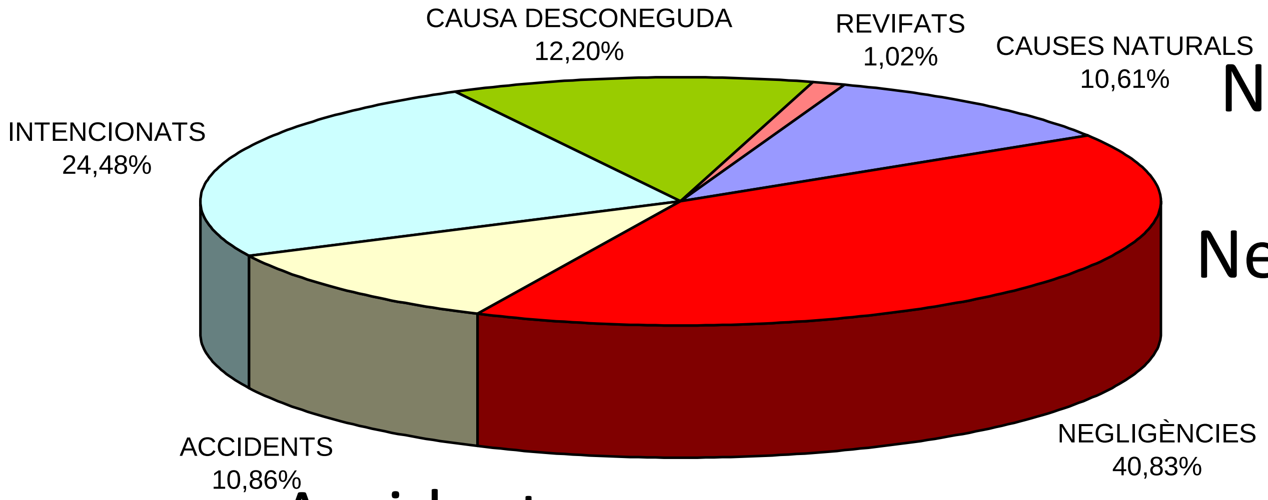




Catalonia
32.108 km²: 64% is forest area (2,06 M ha)
(Europe: 45% average)

Distribució dels incendis forestals per causa

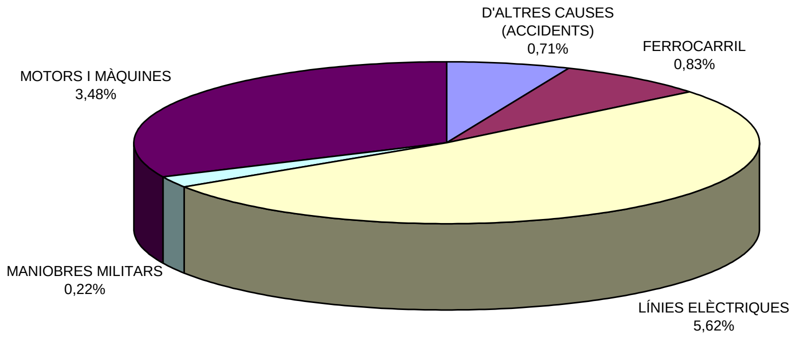
FOREST FIRES, AN ANTHROPOGENIC HAZARD OR A NATURAL HAZARD?



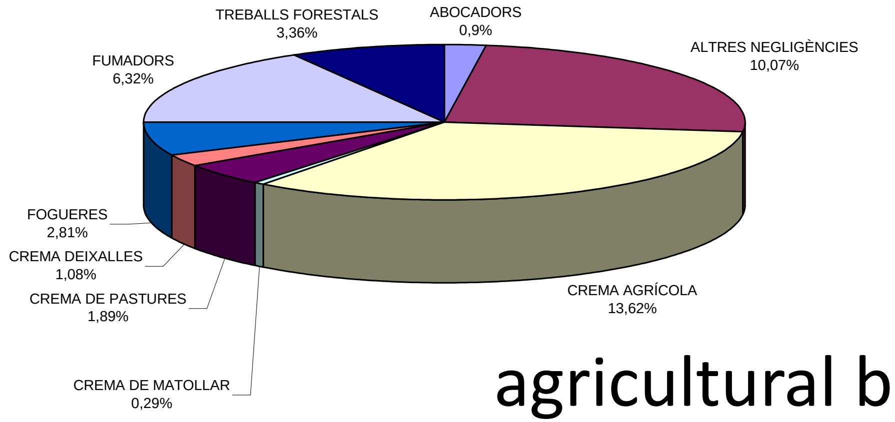
Natural causes

Neglicences

Accidents



Power lines



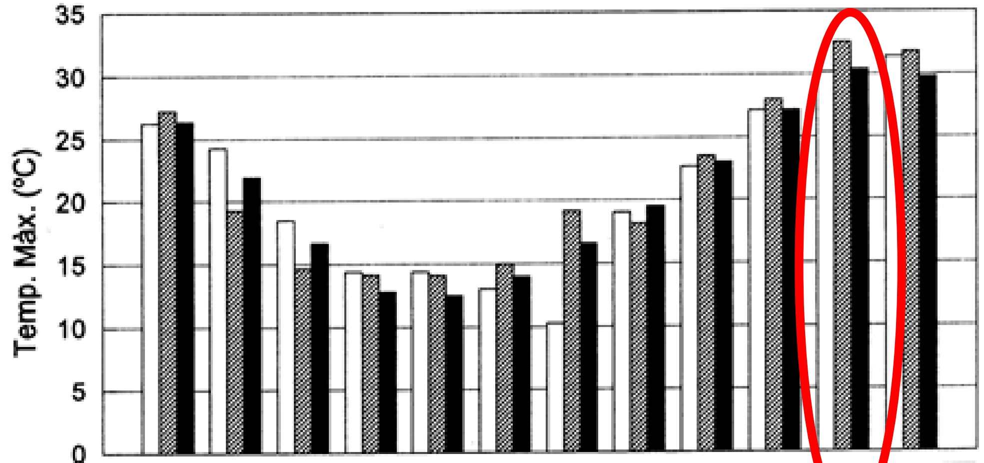
agricultural burning

Període: 1994-2011

PRECEDENT

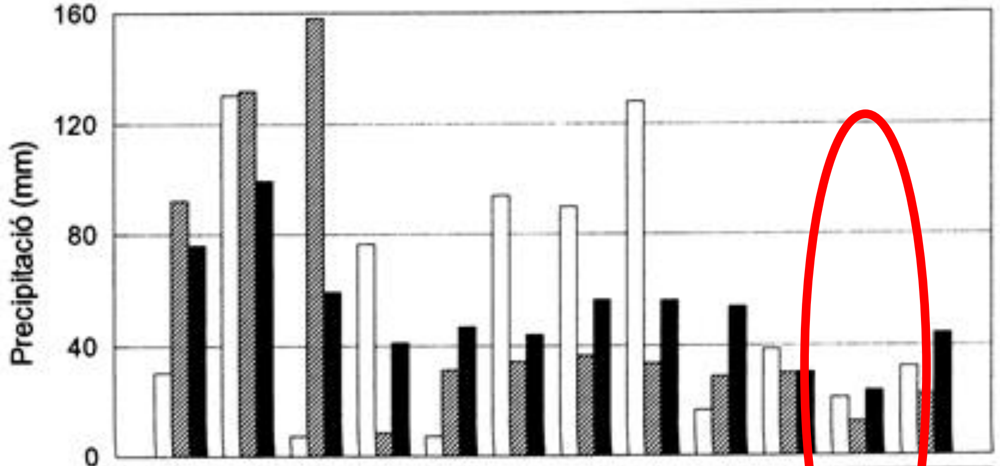
The “horribilis” year of 1994

Spain: 437.635 ha, 20.000 forest fires, 33 deaths. In one week: 45.000 ha in two Catalan counties (Bergadà, Bages)



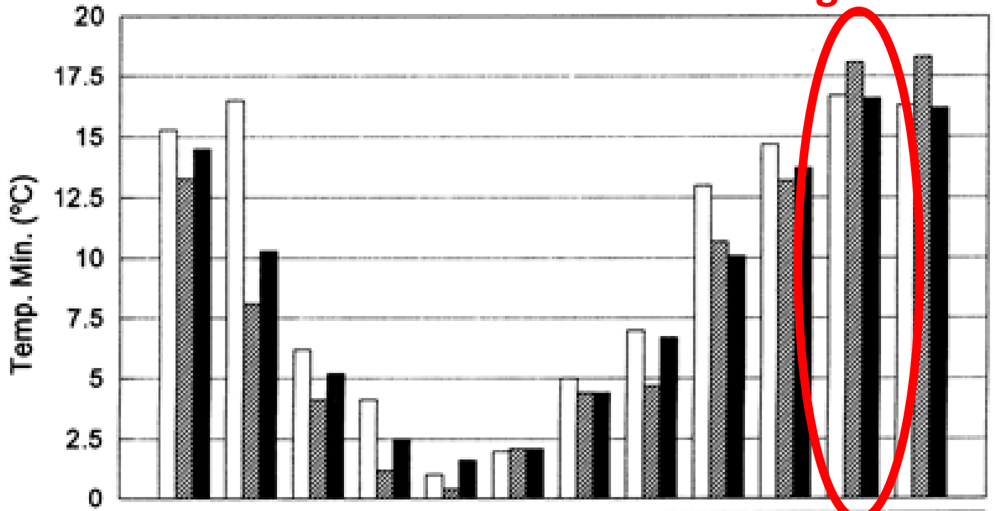
	Set.	Oct.	Nov.	Des.	Gen.	Feb.	Març	Abr.	Maig	Juny	Jul.	Ago.
□ 92-93	26.3	24.3	18.5	14.4	14.4	13	10.3	19.1	22.7	27.2	[illegible]	31.4
▨ 93-94	27.3	19.3	14.7	14.2	14.1	15	19.2	18.2	23.5	28	32.6	31.8

4-10 July 1994



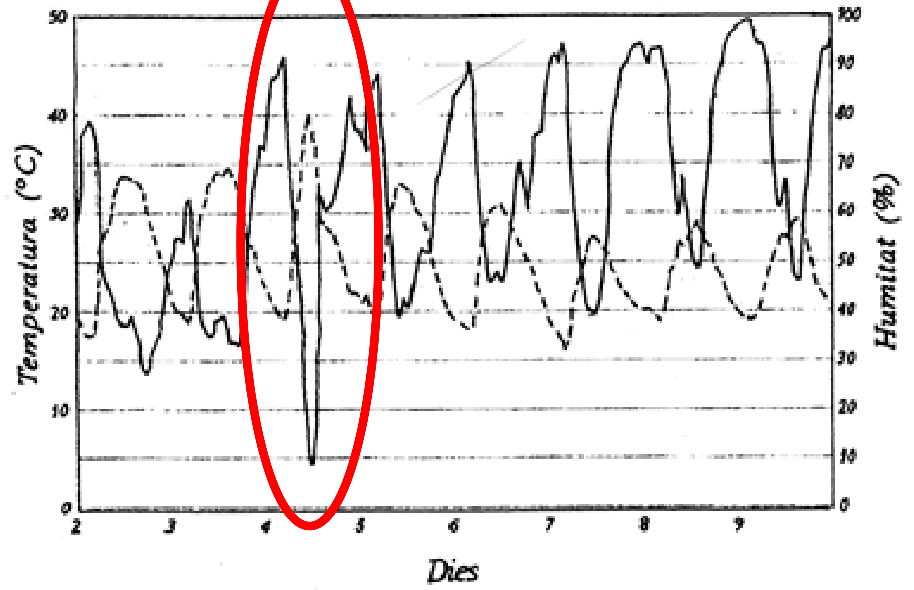
	Set.	Oct.	Nov.	Des.	Gen.	Feb.	Març	Abr.	Maig	Juny	Jul.	Ago.
□ 92-93	30.3	130.3	7.2	76.5	7.2	94	90.1	128.1	16.2	38.8	21	32.4
▨ 93-94	92.3	132	158.4	8.5	31.4	34.4	36.5	33.7	28.8	30	12.3	22.1
■ V.Climàtic	76	99.4	59.6	41.2	46.7	44	56.4	56.2	54	30.2	23.5	44.2

Antecedent and ignition conditions



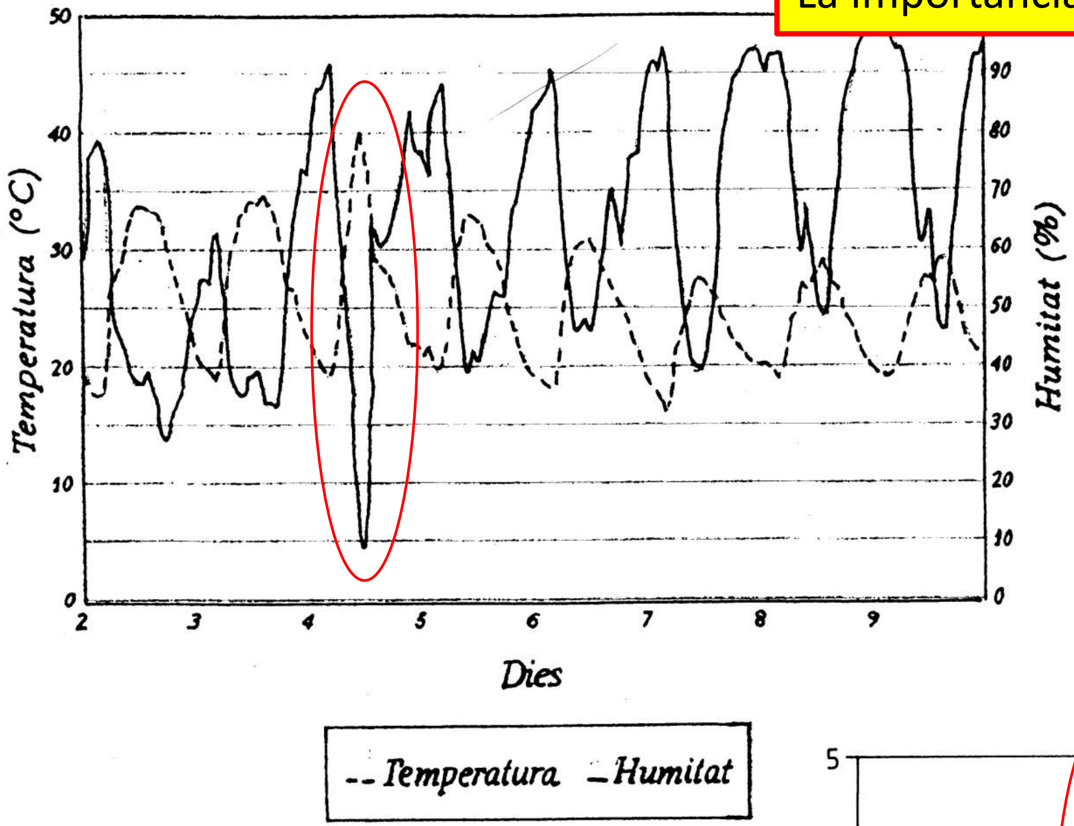
	Set.	Oct.	Nov.	Des.	Gen.	Feb.	Març	Abr.	Maig	Juny	Jul.	Ago.
□ 92-93	15.3	16.5	6.2	4.1	1	2	5	7	13	14.7	16.7	16.3
▨ 93-94	13.3	8.1	4.1	1.2	0.4	2.1	4.4	4.7	10.7	13.2	18.1	18.3
■ V.Climàtic	14.5	10.3	5.2	2.5	1.6	2.1	4.4	6.7	10.1	13.7	16.6	16.2

Evolució mensual de la temperatura màxima/ mínim mitjana i de la precipitació pel període setembre 1992-agost 1994 a l'estació de Caldes de Montbui (XAC)

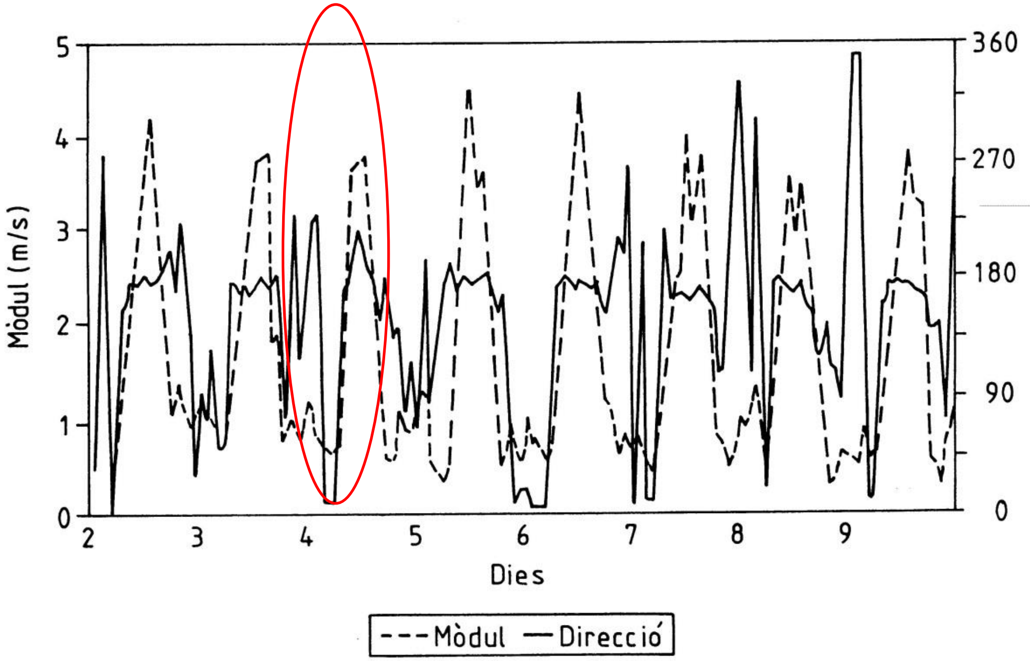


Evolució de la temperatura i humitat relativa entre els dies 2 i 10 de juliol de 1994 a l'estació de Caldes de Montbui (XAC). Les mesures es varen fer cada 10 minuts.

La importància de les condicions per l'ignició

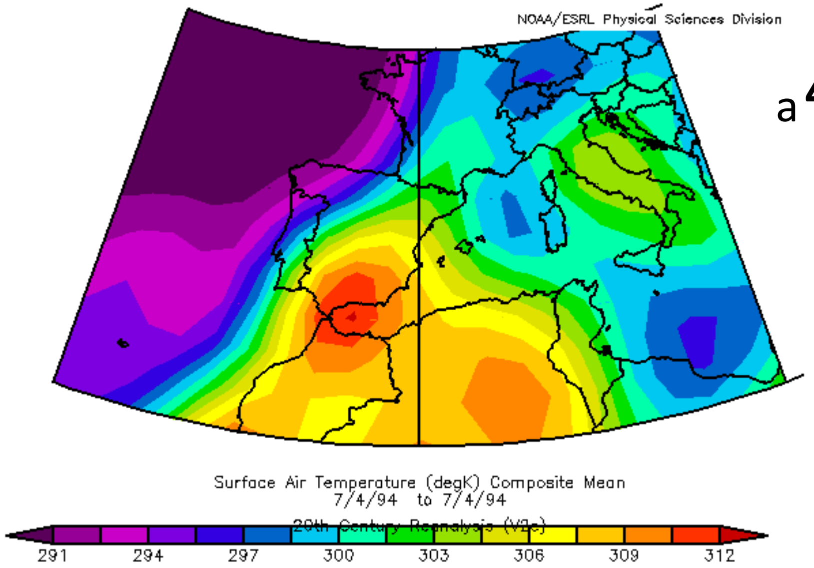


Evolució de la temperatura i humitat relativa 2-10 juliol 1994 (Caldes de Montbui-XAC). Mitjanes 10-minutals.

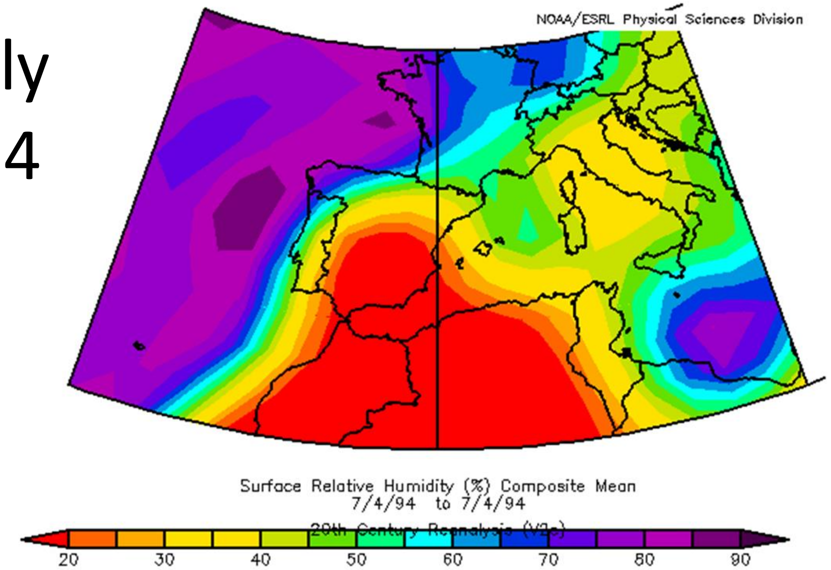


Evolució de la direcció i velocitat del vent 2-10 juliol 1994 (Caldes de Montbui-XAC). Mitjanes 20-segons.

a 4 July 1994



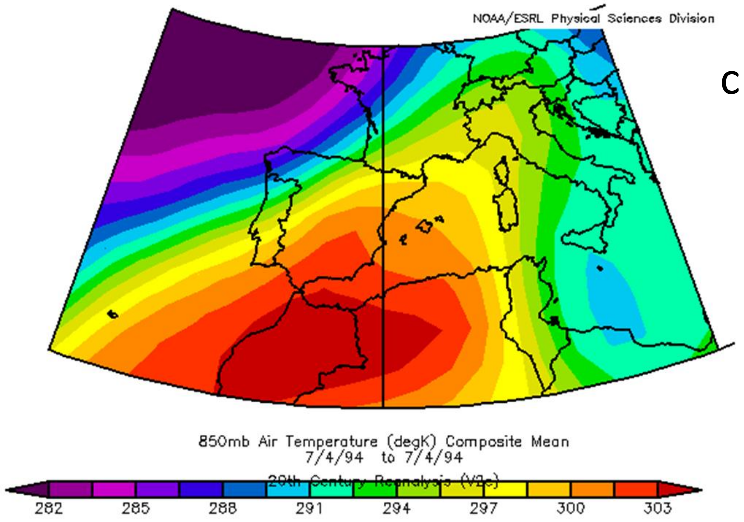
b



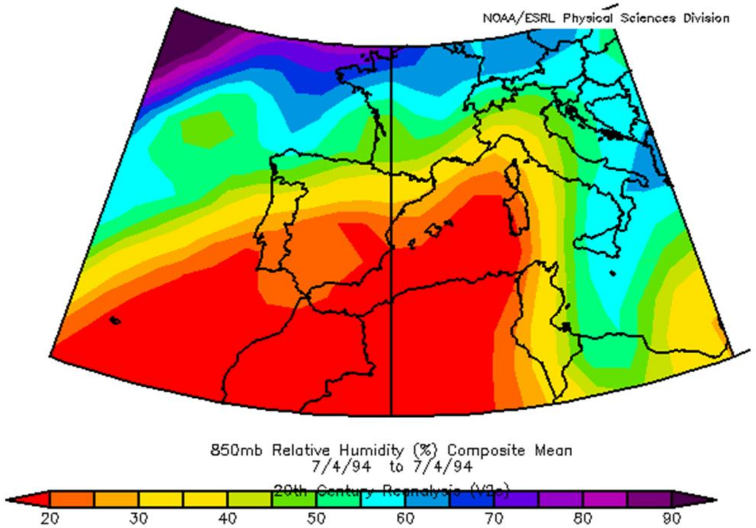
Surface

Synoptic conditions: very dry and warm Flow from the south. Dry Westerly winds. Strong antyciclone in N Africa

c

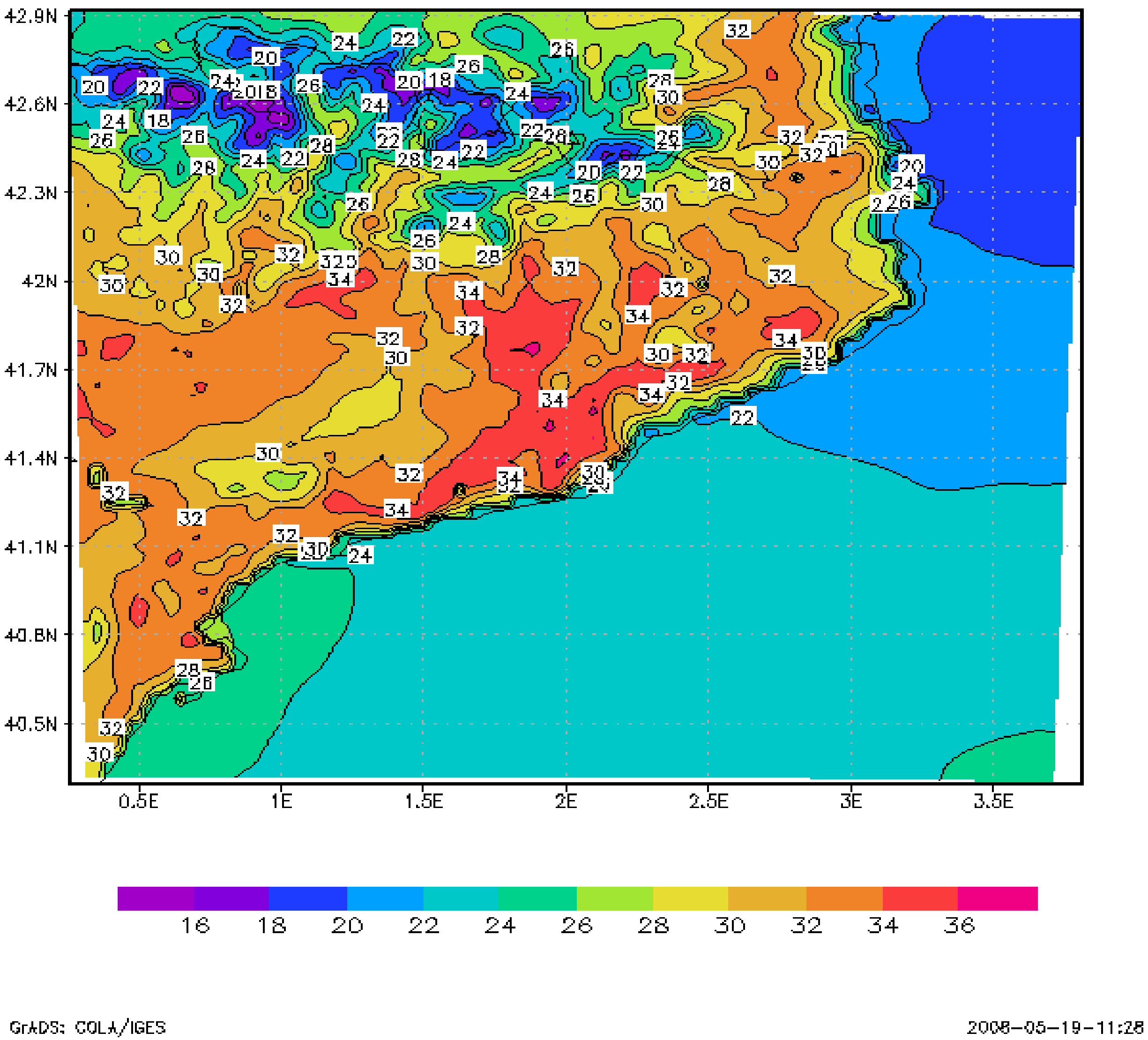


d



850 hPa

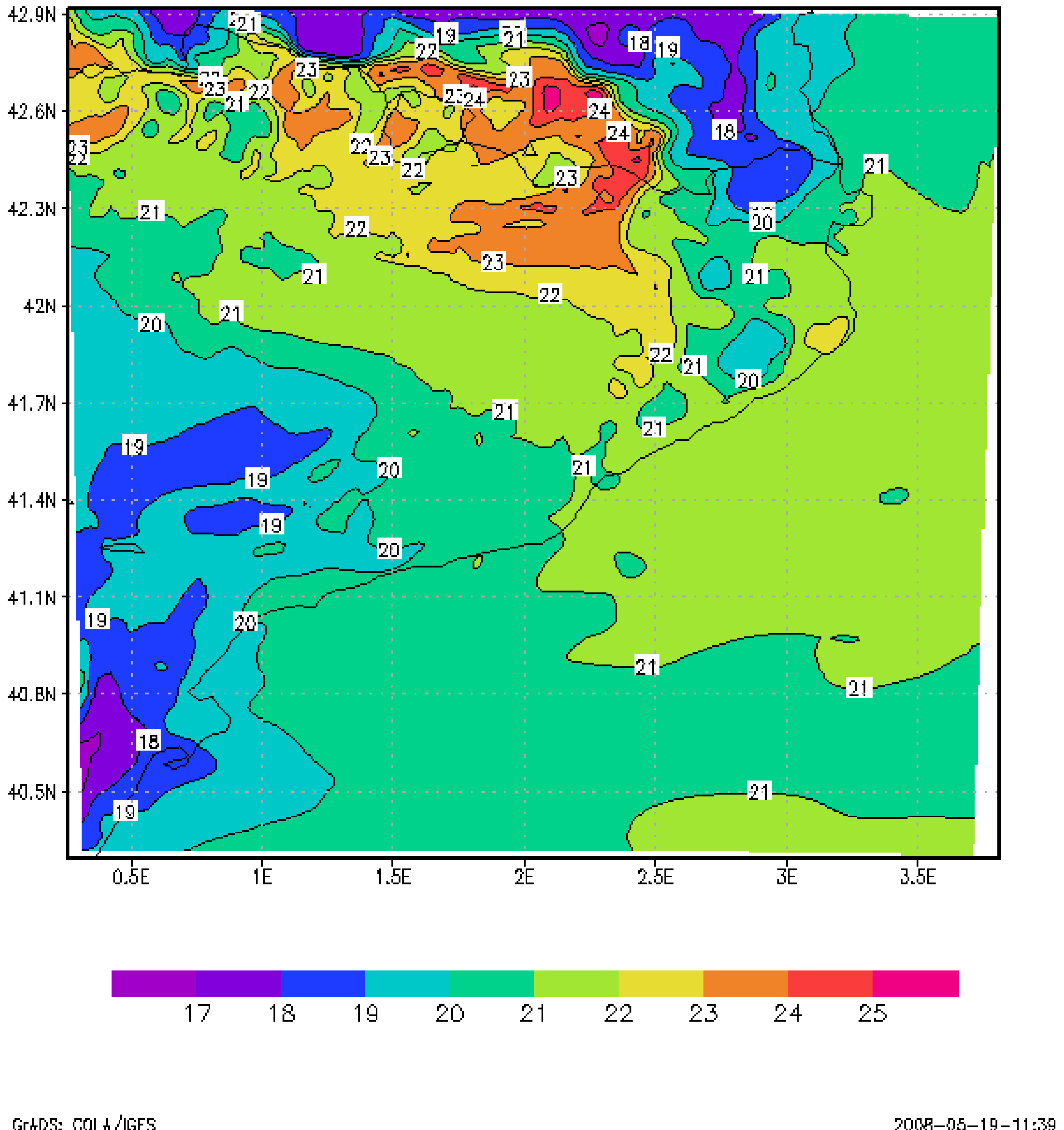
Source: 20th Century Reanalysis)



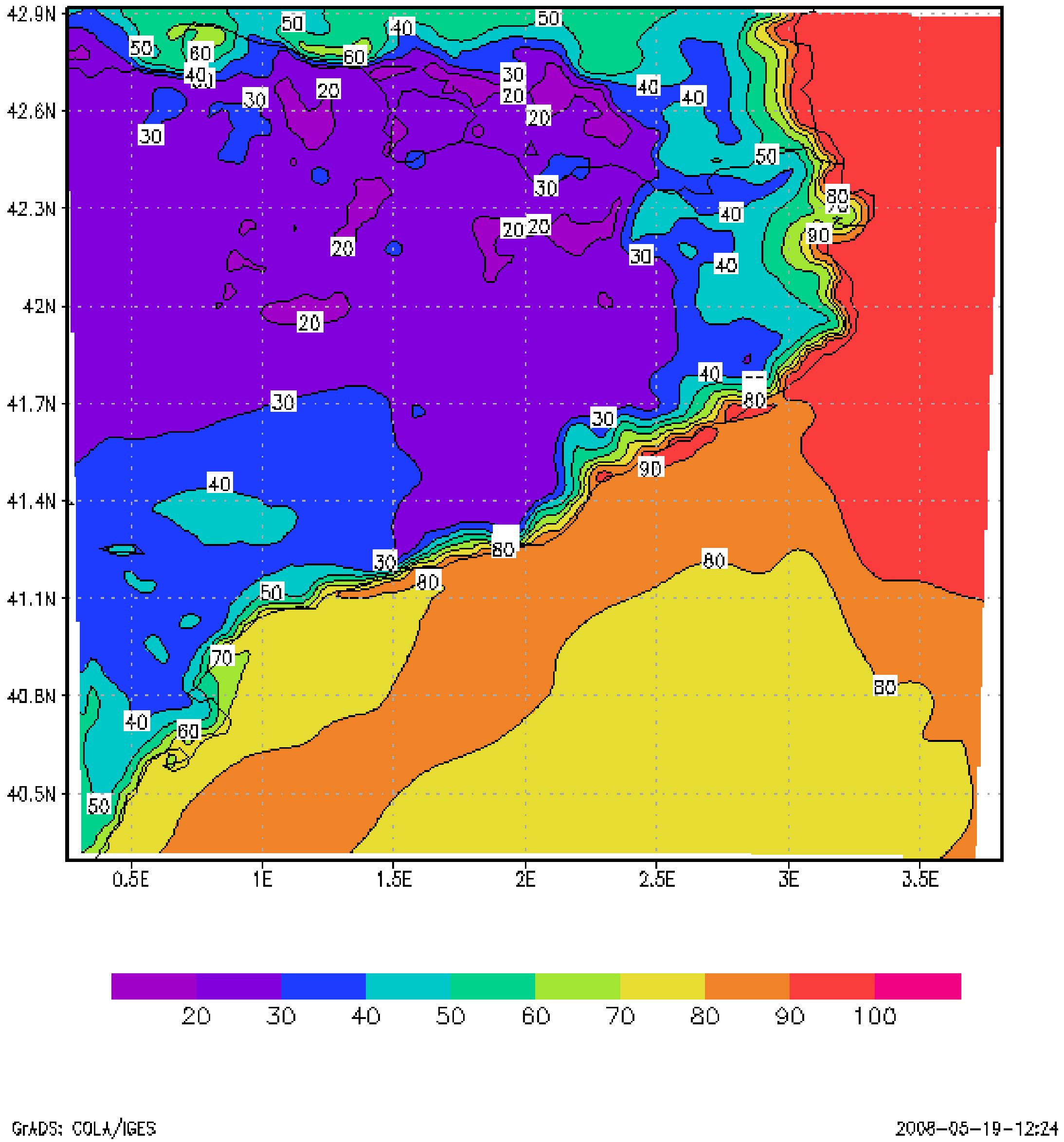
Surface temperatures above 35ºC

Mapa de temperatura en superficie del día 4 de juliol de 1994 a las 12 UTC (model MM5)

Mapa de temperatura a 850 hPa del día 4 de juliol de 1994 a las 12 UTC (model MM5)



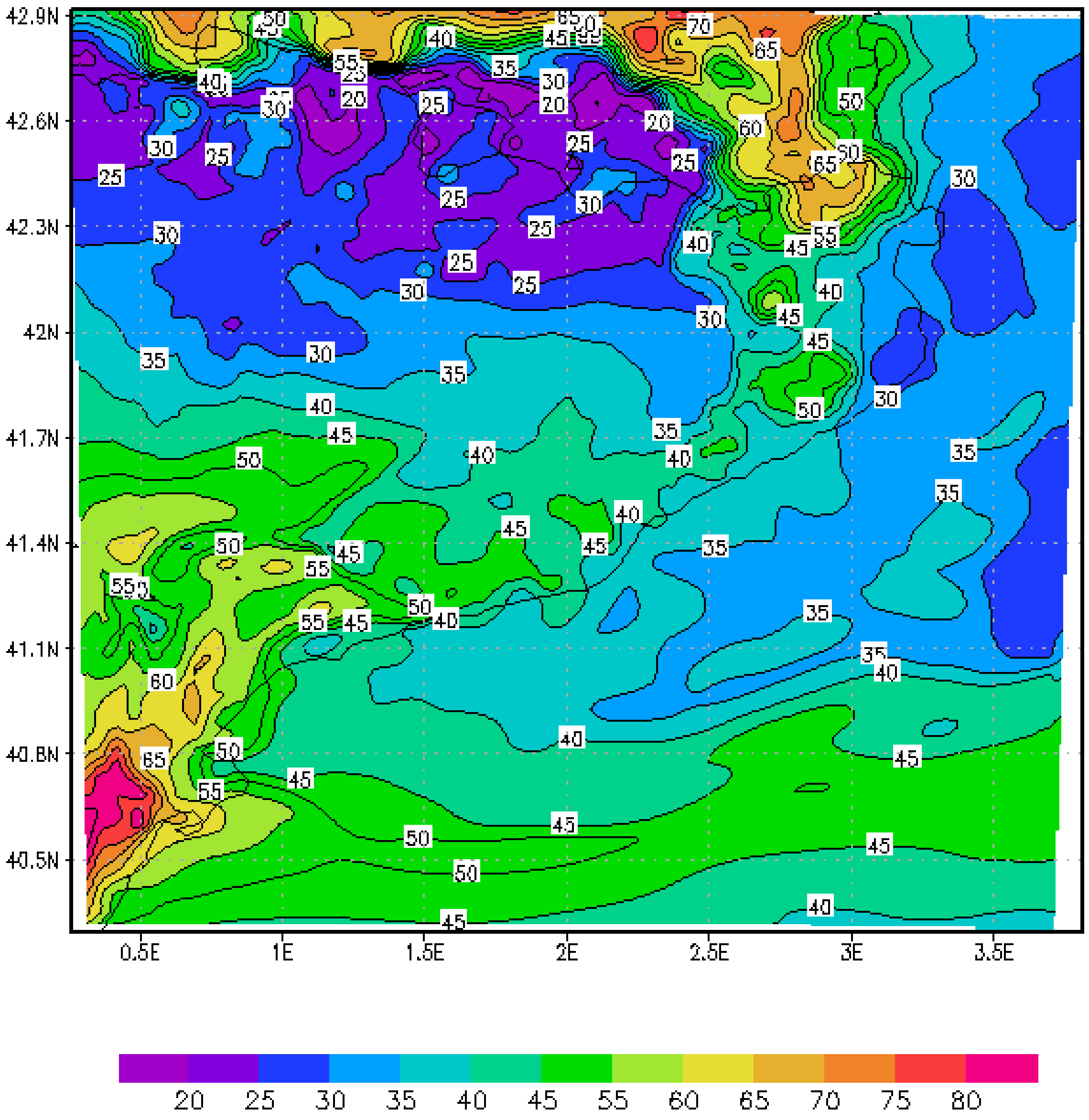
850 hPa (aprox 1500 m) temperatures above 22ºC



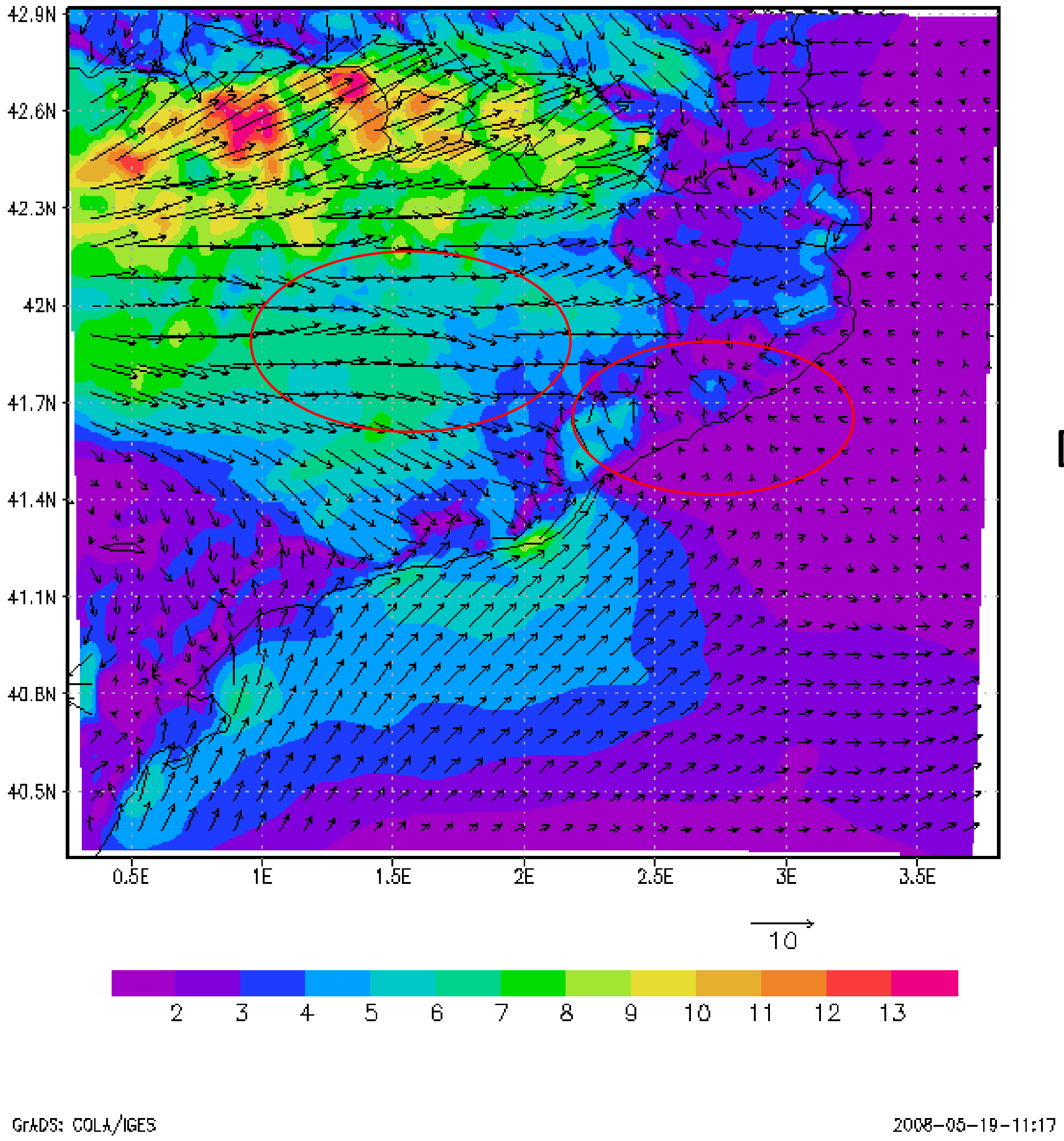
Relative humidity in surface under 25%

Mapa de humitat relativa en superficie del día 4 de juliol a las 12 UTC (model MM5)

Mapa de humitat relativa a 850hPa del día 4 de julio a las 12 UTC (model MM5)



Relative humidity at 850 hPa under 40%



Dry westerly winds

Mapa del vent del día 4 de juliol a las 12 UTC (model MM5)

METEOROLOGICAL CONDITIONS are responsible for the appropriate scenario for the production of large forest fires, both IN THE IGNITION AND in the PROPAGATION, both antecedent “climatic” conditions and “weather” conditions

HUMAN ACTIVITIES “only” ACT AS A TRIGGER FACTOR

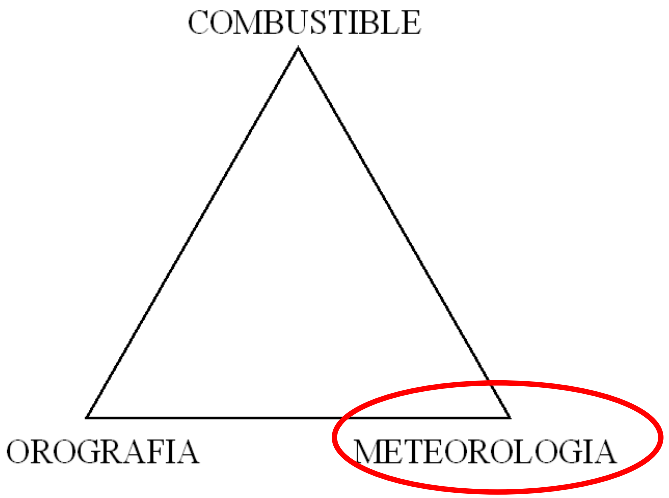
AN AFFIRMATION:

A LARGE FOREST FIRE IS AN UNPROBABLY EVENT THAT HAPPENS, NECESSARILY, UNDER UNPROBABLY CONDITIONS

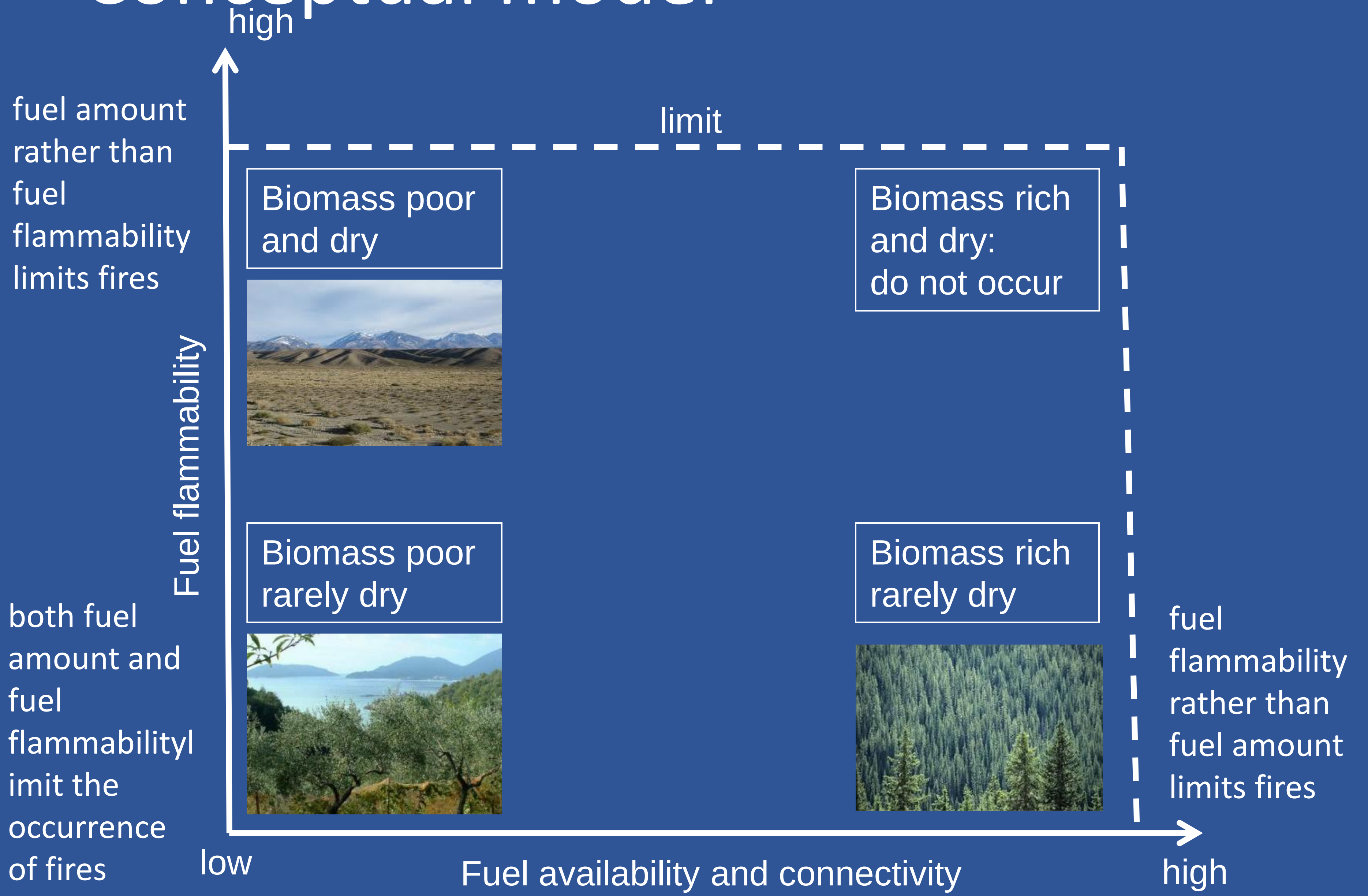
UNISDR include them between the **hydrometeorological hazards**

CONDITIONS:

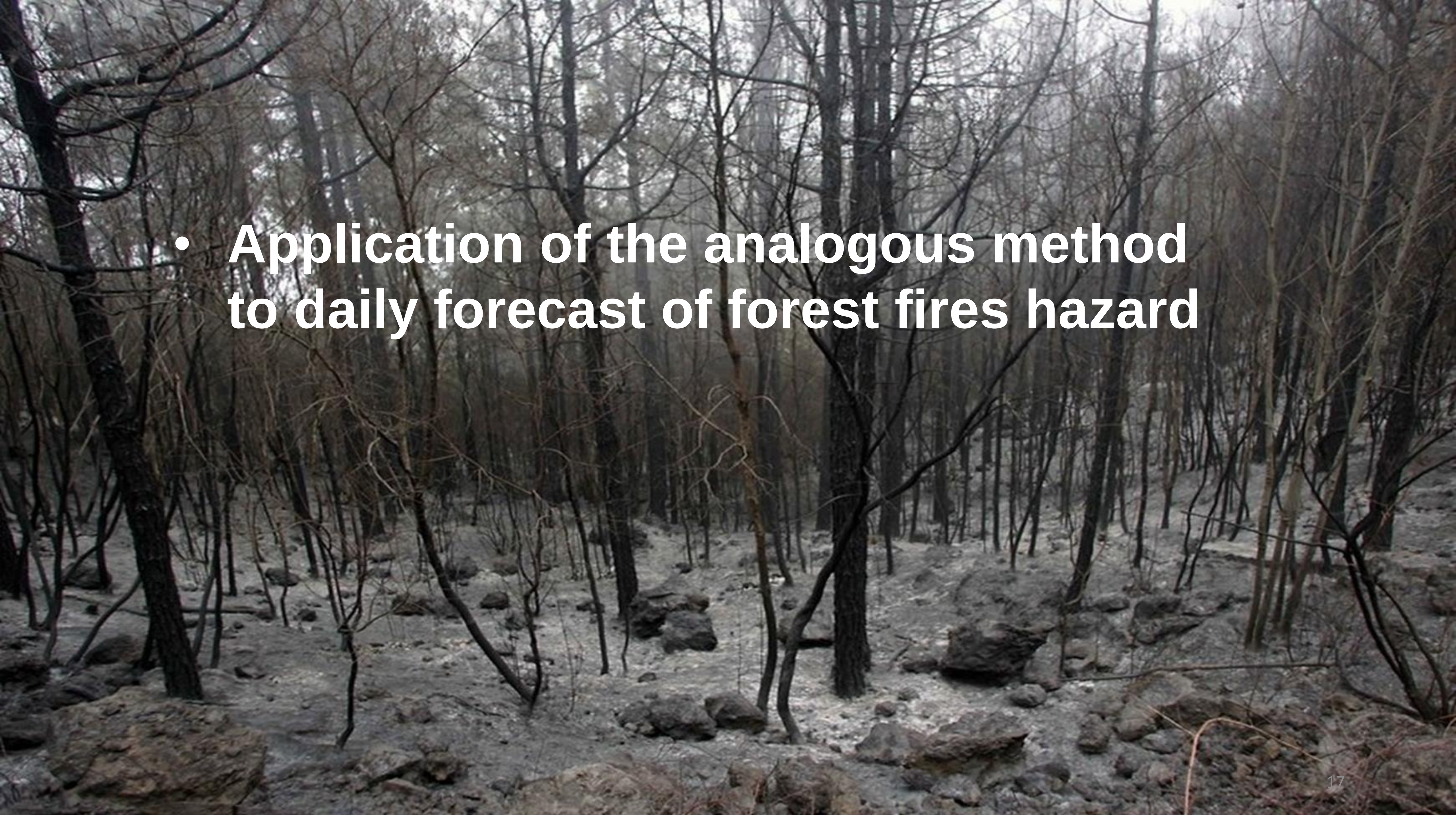
- Ignition
- Vegetation
- Meteorological
- Prevention and extinction



Conceptual model



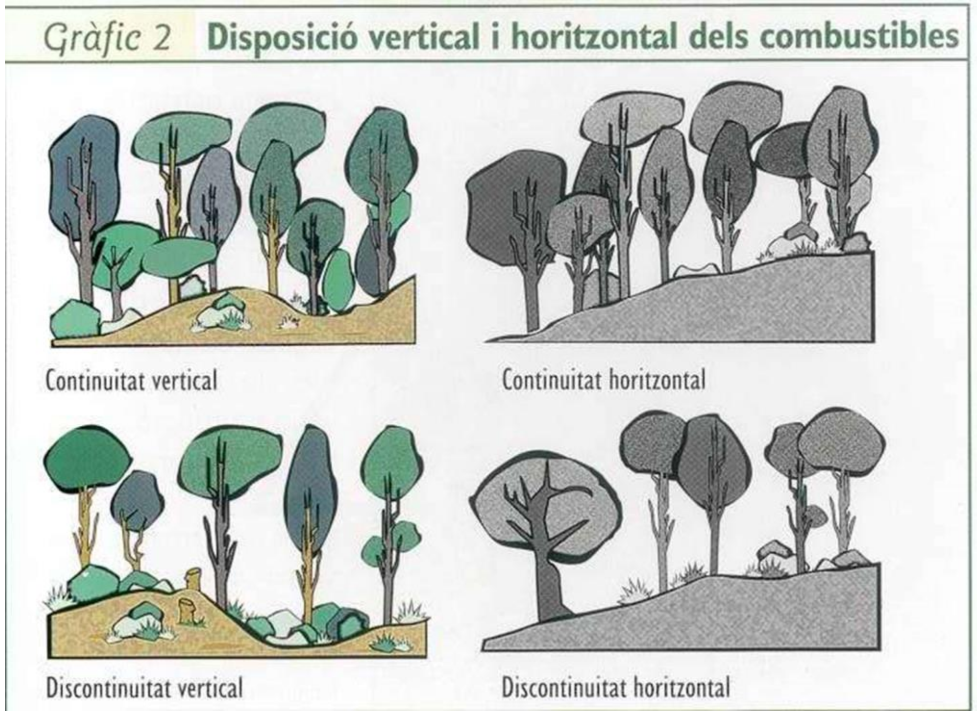
Meyn, a., P. S. White, C. Buhk, and a. Jentsch (2007), Environmental drivers of large, infrequent wildfires: the emerging conceptual model, Progress in Physical Geography, 31(3), 287–312



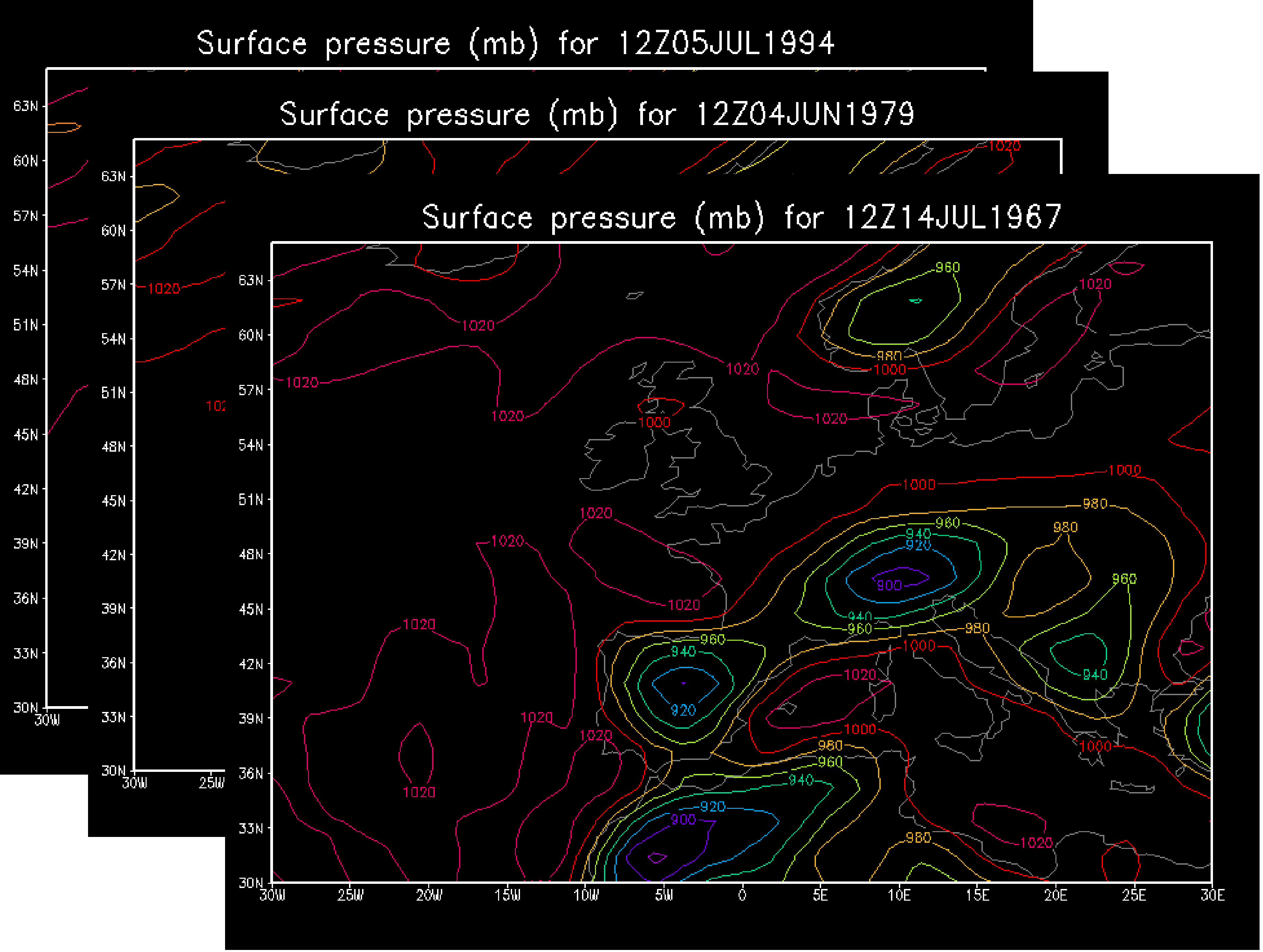
- **Application of the analogous method to daily forecast of forest fires hazard**

Every day a team of the Service of Forest Fire Prevention (SPIF) analyses:

- A man-made SYNOPTIC model (initially developed in the context of a PhD) that considers 850 hPa data (geopotential, temperature, relative humidity, wind and antecedent data from the previous months).
- A MESOSCALE model that considers drought conditions, phenology, relative humidity and wind.
- A COMBINATION of information layers:
  - Vegetation samples,
  - satellite data,
  - orography,
  - types of vegetation,
  - other drought indexes
- Outputs from different meteorological models, rainfall and drought indexes



dead fine material in the undergrowth



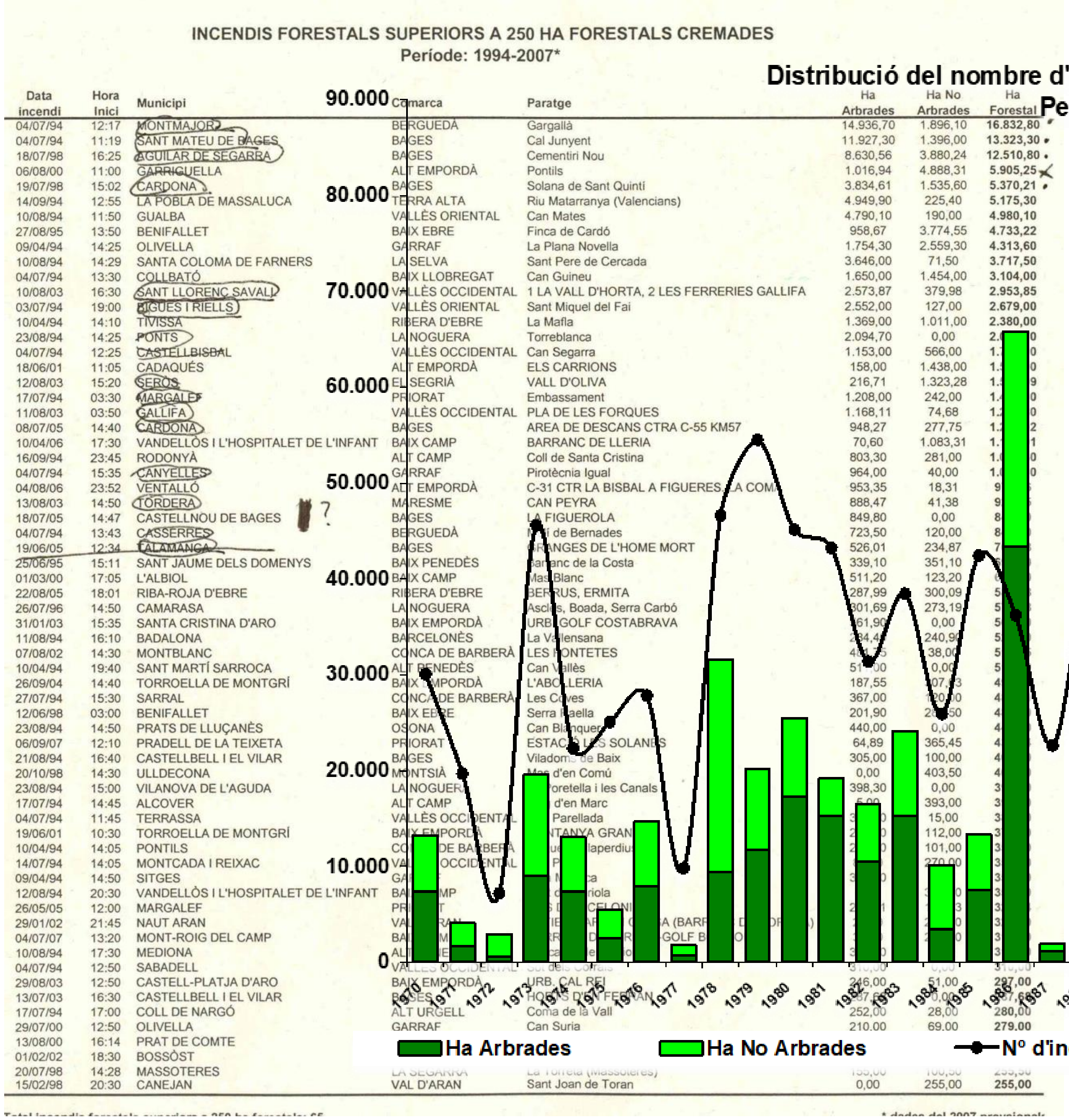
ANALOGOUS METHOD

NCEP/NCAR reanalysis. 1958-2003. Geopotential fields 1000 and 850 hPa at 00, 12 UTC, 2,5º resolution (window 30W-30E, 30N-65N)
GFS/NCEP Forecasts, 1º, each 6h, 12 days

- PREVIOUS ANALOGOUS SITUATIONS
- WILDFIRES ASSOCIATED
- EVOLUTION OF THE PREVIOUS SITUATIONS

This application was also developped in a PhD

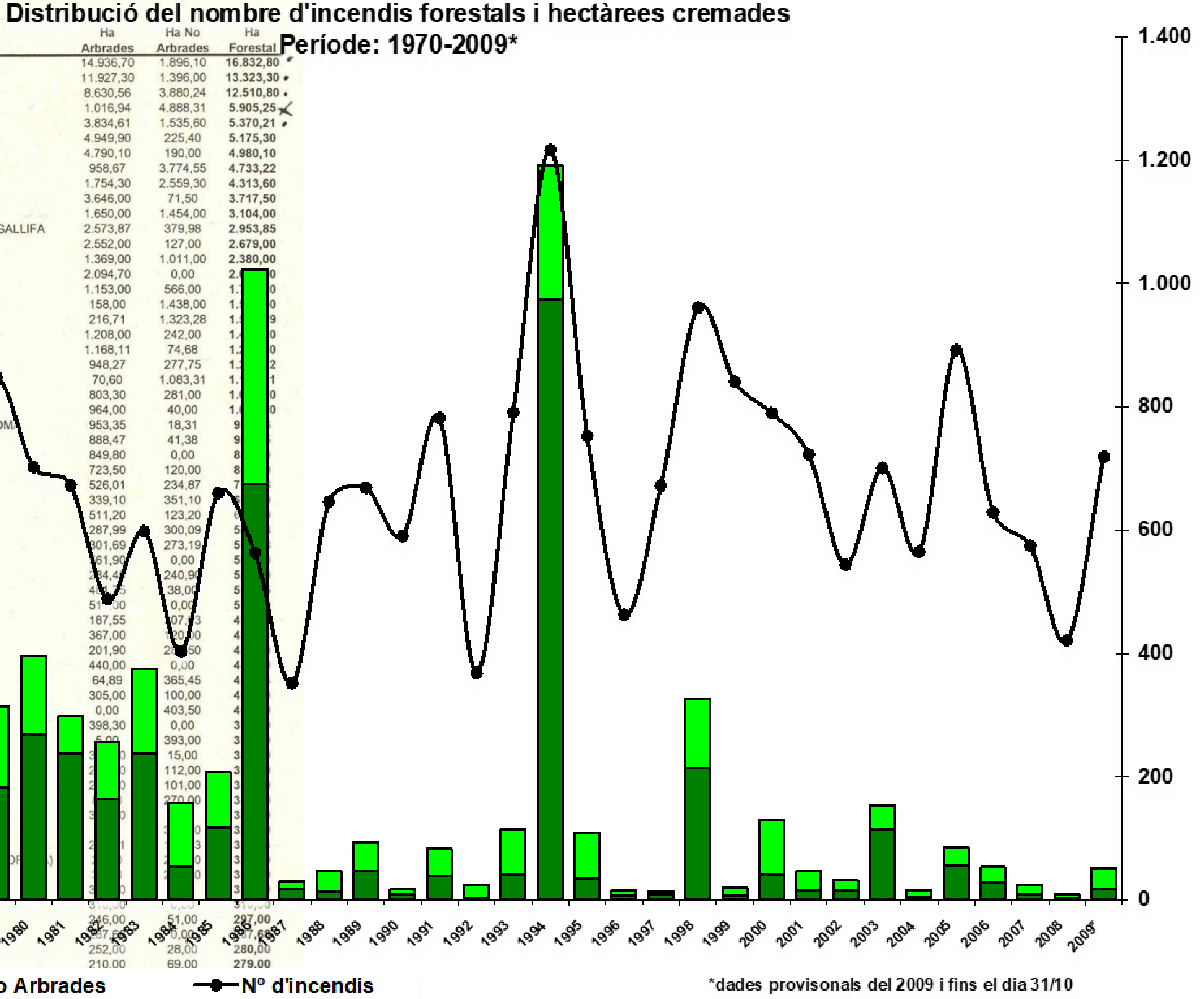
- **Modeling the climatic and non-climatic mechanisms that are behind the temporal evolution of forest fires**



INCENDIS FORESTALS SUPERIORS A 250 HA FORESTALS CREMADES
Període: 1994-2007*

Data incendi	Hora Inici	Municipi	Comarca	Paratge	Ha Arbrades	Ha No Arbrades	Ha Forestal
04/07/94	12:17	MONTMAJOR	BERGUEDÀ	Gargallà	14.936,70	1.896,10	16.832,80
04/07/94	11:19	SANT MATEU DE BAGES	BAGES	Cal Junyent	11.927,30	1.396,00	13.323,30
18/07/98	16:25	AGUILAR DE SEGARRA	BAGES	Cementiri Nou	8.630,56	3.880,24	12.510,80
06/08/00	11:00	GARRIGUELLA	ALT EMPORDÀ	Pontils	1.016,94	4.888,31	5.905,25
19/07/98	15:02	CARDONA	BAGES	Solana de Sant Quintí	3.834,61	1.535,60	5.370,21
14/09/94	12:55	LA POBLA DE MASSALUCA	TERRA ALTA	Riu Matarranya (Valencians)	4.949,90	225,40	5.175,30
10/08/94	11:50	GUALBA	VALLÈS ORIENTAL	Can Mates	4.790,10	190,00	4.980,10
27/08/95	13:50	BENIFALLET	BAIX EBRE	Finca de Cardó	958,67	3.774,55	4.733,22
09/04/94	14:25	OLIVELLA	GARRAF	La Plana Novella	1.754,30	2.559,30	4.313,60
10/08/94	14:29	SANTA COLOMA DE FARNERS	LA SELVA	Sant Pere de Cercada	3.646,00	71,50	3.717,50
04/07/94	13:30	COLLBATÓ	BAIX LLOBREGAT	Can Guineu	1.650,00	1.454,00	3.104,00
10/08/03	16:30	SANT LLORENÇ SAVALL	VALLÈS OCCIDENTAL	1 LA VALL D'HORTA, 2 LES FERRERIES GALLIFA	2.573,87	379,98	2.953,85
03/07/94	19:00	BIGUES I RIELLS	VALLÈS ORIENTAL	Sant Miquel del Fai	2.552,00	127,00	2.679,00
10/04/94	14:10	TIVISSA	RIBERA D'EBRE	La Mafla	1.369,00	1.011,00	2.380,00
23/08/94	14:25	PONTS	LA NOGUERA	Torreblanca	2.094,70	0,00	[illegible]
04/07/94	12:25	CASTELLBISBAL	VALLÈS OCCIDENTAL	Can Segarra	1.153,00	566,00	[illegible]
18/06/01	11:05	CADAQUÉS	ALT EMPORDÀ	ELS CARRIONS	158,00	1.438,00	[illegible]
12/08/03	15:20	SEROS	EL SEGRIÀ	VALL D'OLIVA	216,71	1.323,28	[illegible]
17/07/94	03:30	MARGALEF	PRIORAT	Embassament	1.208,00	242,00	[illegible]
11/08/03	03:50	GALLIFA	VALLÈS OCCIDENTAL	PLA DE LES FORQUES	1.168,11	74,68	[illegible]
08/07/05	14:40	CARDONA	BAGES	AREA DE DESCANS CTRA C-55 KM57	948,27	277,75	[illegible]
10/04/06	17:30	VANDELLÒS I L'HOSPITALET DE L'INFANT	BAIX CAMP	BARRANC DE LLERIA	70,60	1.083,31	[illegible]
16/09/94	23:45	RODONYÀ	ALT CAMP	Coll de Santa Cristina	803,30	281,00	[illegible]
04/07/94	15:35	CANYELLES	GARRAF	Pirotècnia Igual	964,00	40,00	[illegible]
04/08/06	23:52	VENTALLÓ	ALT EMPORDÀ	C-31 CTR LA BISBAL A FIGUERES, LA COM[illegible]	953,35	18,31	[illegible]
13/08/03	14:50	TORDERA	MARESME	CAN PEYRA	888,47	41,38	[illegible]
18/07/05	14:47	CASTELLNOU DE BAGES	BAGES	LA FIGUEROLA	849,80	0,00	[illegible]
04/07/94	13:43	CASSERRES	BERGUEDÀ	[illegible] de Bernades	723,50	120,00	[illegible]
19/06/05	12:34	CALAMANÇA	BAGES	[illegible]RANGES DE L'HOME MORT	526,01	234,87	[illegible]
25/06/95	15:11	SANT JAUME DELS DOMENYS	BAIX PENEDÈS	[illegible] de la Costa	339,10	351,10	[illegible]
01/03/00	17:05	L'ALBIOL	BAIX CAMP	Mas Blanc	511,20	123,20	[illegible]
22/08/05	18:01	RIBA-ROJA D'EBRE	RIBERA D'EBRE	BERRUS, ERMITA	287,99	300,09	[illegible]
26/07/96	14:50	CAMARASA	LA NOGUERA	[illegible], Boada, Serra Carbó	[illegible]	273,19	[illegible]
31/01/03	15:35	SANTA CRISTINA D'ARO	BAIX EMPORDÀ	URB GOLF COSTABRAVA	[illegible]	0,00	[illegible]
11/08/94	16:10	BADALONA	BARCELONÈS	[illegible]	[illegible]	[illegible]	[illegible]
07/08/02	14:30	MONTBLANC	CONCA DE BARBERÀ	LES [illegible]ONTETES	[illegible]	[illegible]	[illegible]
10/04/94	19:40	SANT MARTÍ SARROCA	ALT PENEDÈS	Can [illegible]	[illegible]	[illegible]	[illegible]
26/09/94	14:40	TORROELLA DE MONTGRÍ	BAIX EMPORDÀ	L'ABO[illegible]LLERIA	187,55	[illegible]	[illegible]
27/07/94	15:30	SARRAL	CONCA DE BARBERÀ	Les C[illegible]	367,00	[illegible]	[illegible]
12/06/98	03:00	BENIFALLET	BAIX EBRE	Serra [illegible]	201,90	[illegible]	[illegible]
23/08/94	14:50	PRATS DE LLUÇANÈS	OSONA	Can Bl[illegible]	440,00	0,00	[illegible]
06/09/07	12:10	PRADELL DE LA TEIXETA	PRIORAT	[illegible] SOLANES	64,89	365,45	[illegible]
21/08/94	16:40	CASTELLBELL I EL VILAR	BAGES	[illegible] de Baix	305,00	100,00	[illegible]
20/10/98	14:30	ULLDECONA	MONTSIÀ	[illegible] d'en Comú	0,00	403,50	[illegible]
23/08/94	15:00	VILANOVA DE L'AGUDA	LA NOGUERA	[illegible]oretella i les Canals	398,30	0,00	[illegible]
17/07/94	14:45	ALCOVER	ALT CAMP	[illegible] d'en Marc	[illegible]	393,00	[illegible]
04/07/94	11:45	TERRASSA	VALLÈS OCCIDENTAL	[illegible] Parellada	[illegible]	15,00	[illegible]
19/06/01	10:30	TORROELLA DE MONTGRÍ	BAIX EMPORDÀ	[illegible]	[illegible]	112,00	[illegible]
10/04/94	14:05	PONTILS	[illegible]	[illegible]	[illegible]	101,00	[illegible]
14/07/94	14:05	MONTCADA I REIXAC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
09/04/94	14:50	SITGES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12/08/94	20:30	VANDELLÒS I L'HOSPITALET DE L'INFANT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26/05/95	12:00	MARGALEF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29/01/02	21:45	NAUT ARAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
04/07/07	13:20	MONT-ROIG DEL CAMP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10/08/94	17:30	MEDIONA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
04/07/94	12:50	SABADELL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29/08/03	12:50	CASTELL-PLATJA D'ARO	BAIX EMPORDÀ	URB. CAL RE[illegible]	[illegible]	51,00	[illegible]
13/07/03	16:30	CASTELLBELL I EL VILAR	BAGES	[illegible]	[illegible]	[illegible]	[illegible]
17/07/94	17:00	COLL DE NARGÓ	ALT URGELL	Coma de la Vall	252,00	28,00	280,00
29/07/00	12:50	OLIVELLA	GARRAF	Can Suria	210,00	69,00	279,00
13/08/00	16:14	PRAT DE COMTE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
01/02/02	18:30	BOSSÒST	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20/07/98	14:28	MASSOTERES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15/02/98	20:30	CANEJAN	VAL D'ARAN	Sant Joan de Toran	0,00	255,00	255,00

* dades del 2007 provisionals



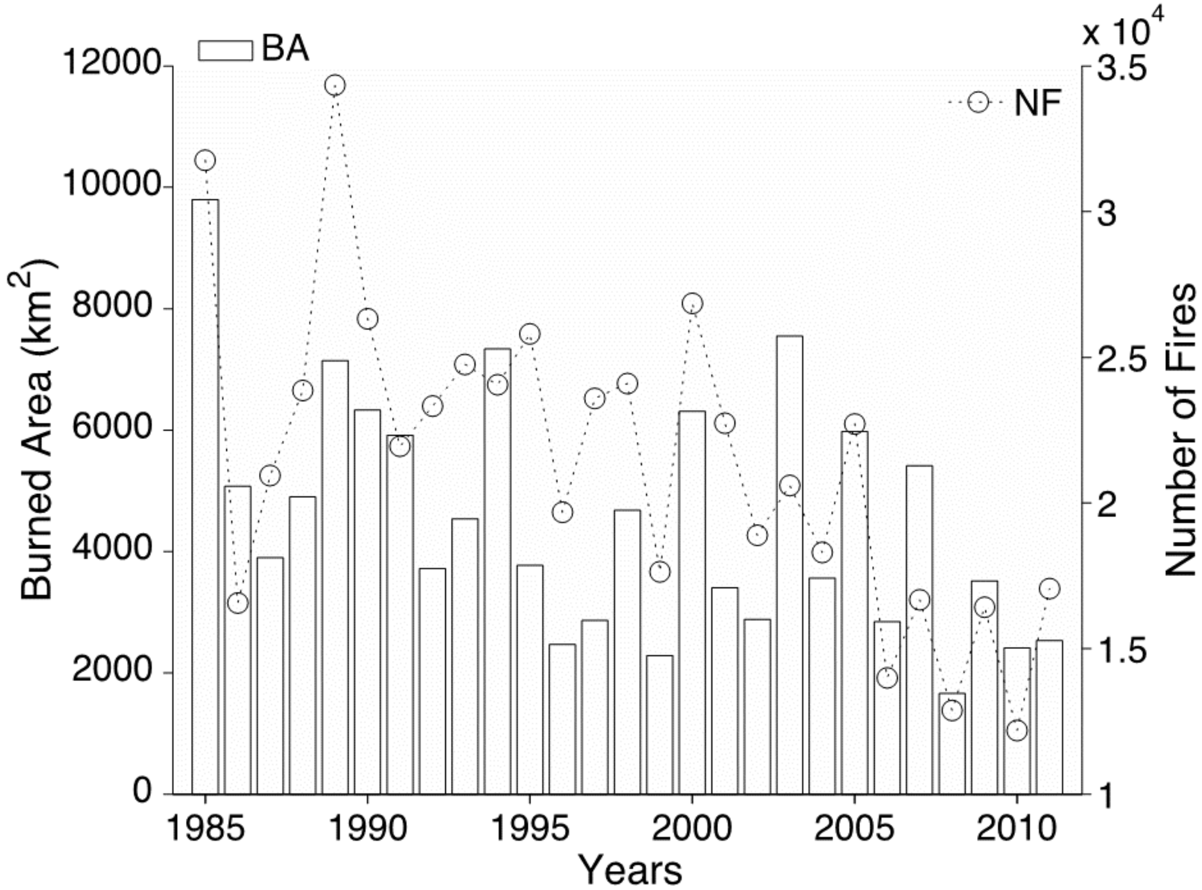
1970–2010 Eastern Catalonia: 9284 FF, BA 417000 ha.
1983–2010 whole Catalonia: 6385 FF, BA 286000 ha.
Around 70% of the burned area is associated with fires with a burned area above 500 ha.
The trend significance is estimated with the Monte-Carlo test implemented by Turco and Llasat (2011)
BA>0,5 ha

East Catalonia	**−3.0 *Kha/decade,**	**−79 **FF/decade**	**+44* FF/decade (non homogeneous series)**
Whole Catalonia	**−7.3 * Kha/decade**	**−108 ** FF/decade**	
*** P > 95 %, ** P > 99%**			

After the large fires of 1986 and 1994, the increased effort in fire prevention and suppression could explain part of the decreasing trend. The increasing number of fires reported for the Mediterranean region in recent decades could indeed mix an actual trend with a growing fire detection ability.

Turco, M., M. C. Llasat, A. Tudela, X. Castro, and A. Provenzale, 2013. Nat. Hazards Earth Syst. Sci., 13, 649–652, 2013. www.nat-hazards-earth-syst-sci.net/13/649/2013/ doi:10.5194/nhess-13-649-2013

Are fires increasing in the S of Europe?



BA decreased by about 3020 km2 over the 27-year-long study period (i.e. about **-66%** of the mean historical value).

Similar overall results were found for the annual number of fires (NF), which globally decreased by about 12600 in the study period (about **-59%**).

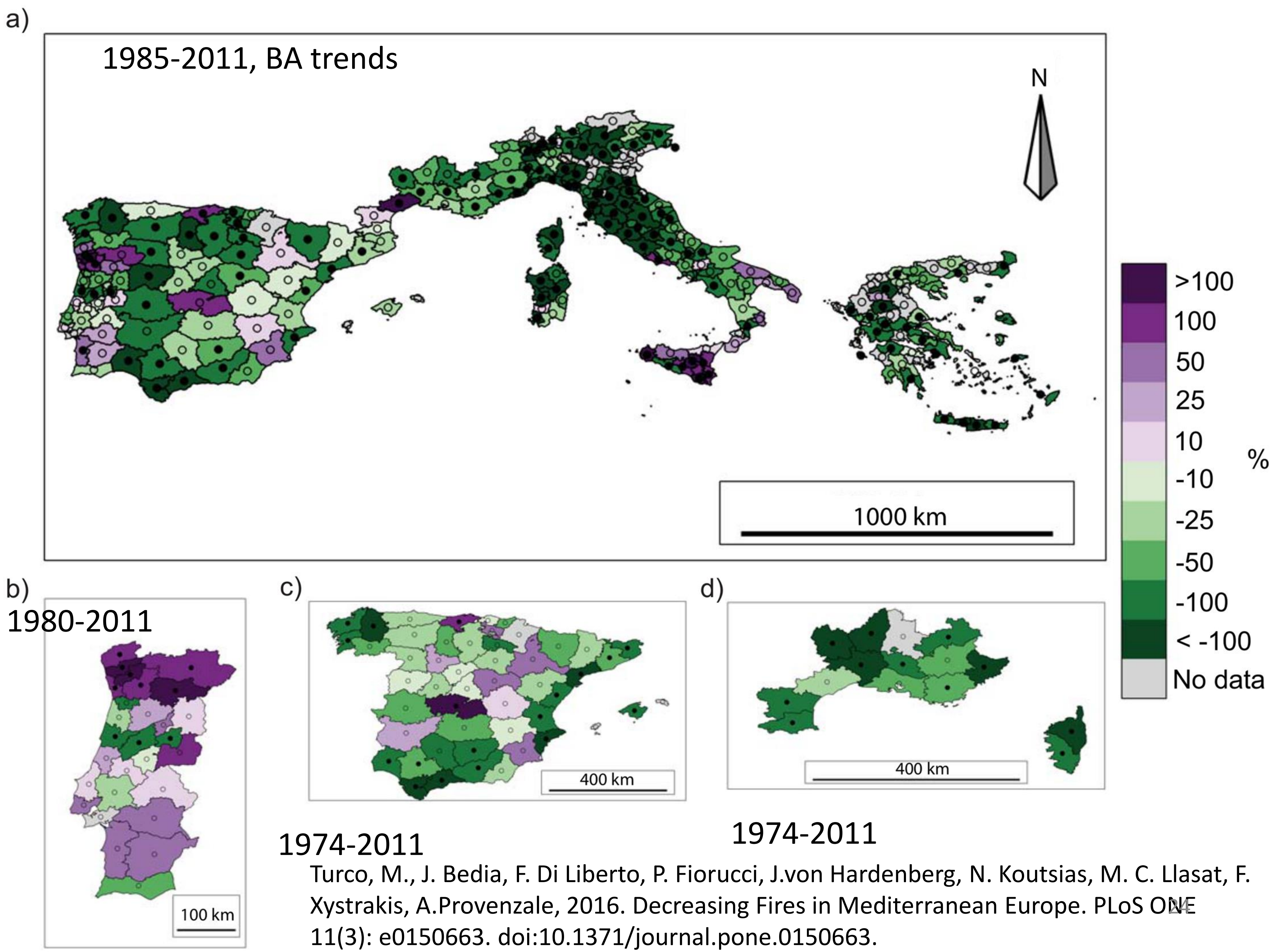
Study of recent fire trends **1985-2011 in Portugal (1980-2011), Spain, southern France, Italy (1985-2011) and Greece (1983-2011),** building on a homogenized fire database integrating official fire statistics provided by the European Forest Fire Information System (EFFIS) and several national agencies at NUTS3 level (Nomenclature of Units for Territorial Statistics, which corresponds to aggregations of municipalities or provinces).

Annual Burned Area trends

Spanish series show a positive trend until the late 1980's — early 1990's, followed by a negative trend till 2011. Greece: almost steady signal when considering the regional database (GRC), and a negative trend when considering the EFFIS series. The NF series display an overall negative trend in France and Italy.

Great dependence of Data base

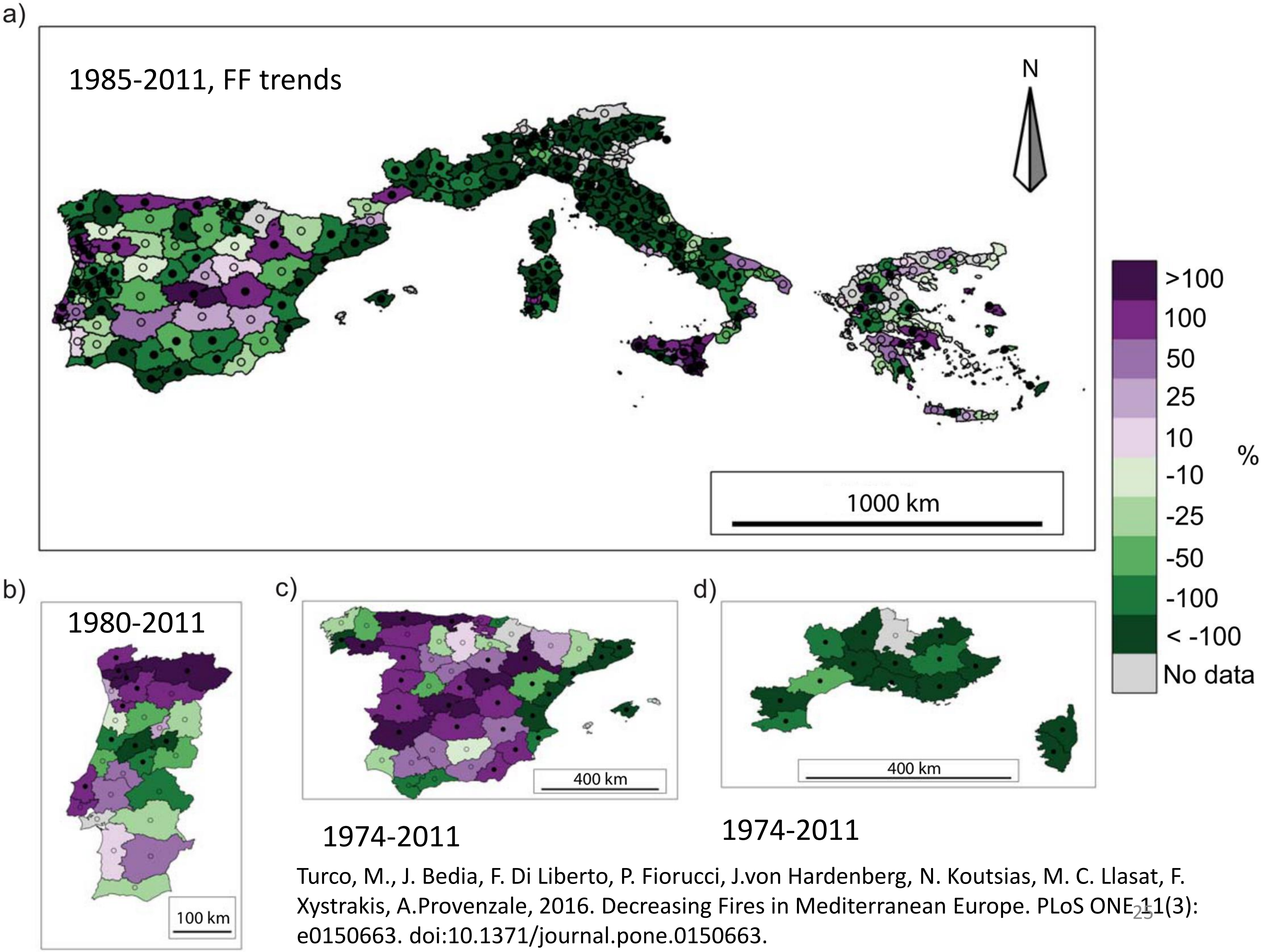
Significant trends ($p < 0.05$) are indicated by the filled black circles. Trends are shown as the percentages of the total trend for the available period (e.g. ha per 27 years) divided by the historical mean calculated over the same period



Turco, M., J. Bedia, F. Di Liberto, P. Fiorucci, J.von Hardenberg, N. Koutsias, M. C. Llasat, F. Xystrakis, A.Provenzale, 2016. Decreasing Fires in Mediterranean Europe. PLoS ONE 11(3): e0150663. doi:10.1371/journal.pone.0150663.

In Portugal, BA and NF increased in winter and spring. The summer and autumn Spanish series indicated statistically significant negative trends. The BA and NF series in France and Italy displayed negative trends in all seasons.
Finally, statistically significant and negative trends for Greece were found for the BA series in spring, summer and autumn, while the NF series showed a statistically significant downward trend only in autumn.

Great dependence of the series lenght



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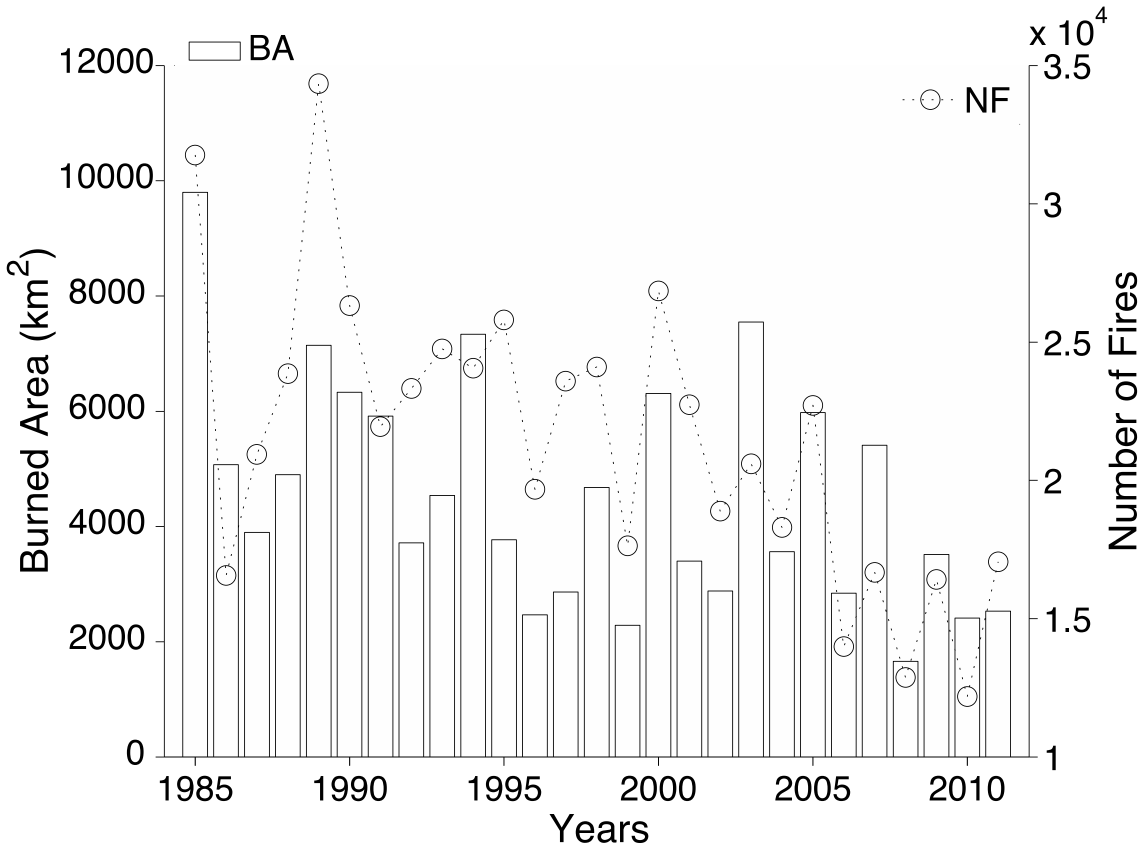
Which is the link between climate and fires?



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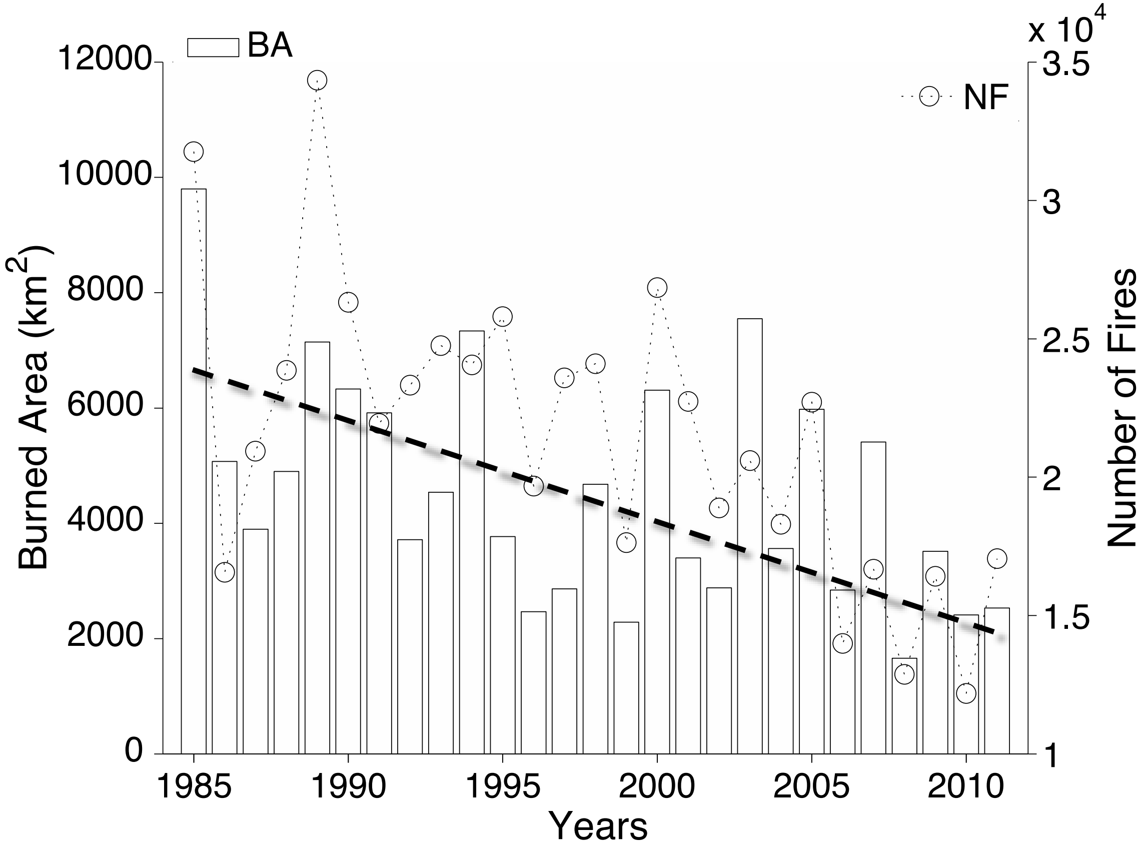
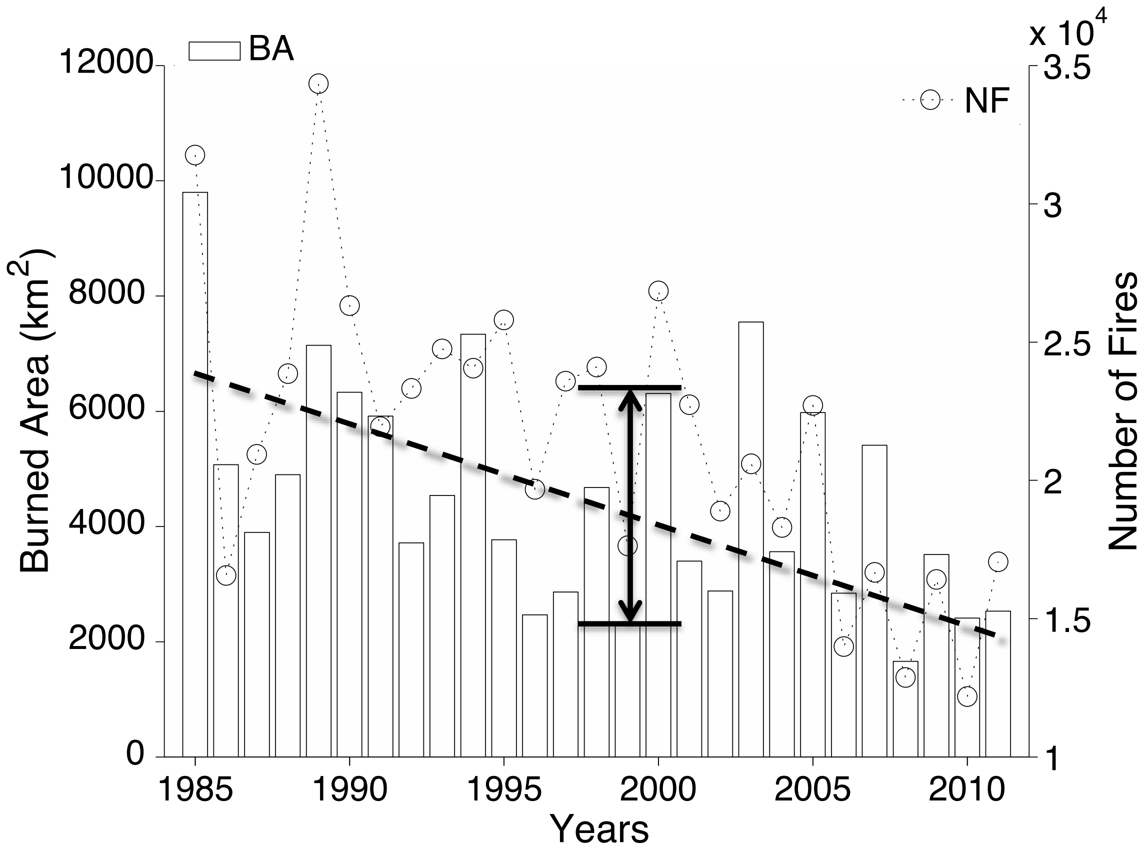


Two main working hypotheses :

1. Anthropogenic effects and climate trends are "slowly changing factors". They drive variations on the scales of decades

Turco M., Llasat M. C., von Hardenberg J., Provenzale A. Impact of climate variability on summer fires in a Mediterranean environment (northeastern Iberian Peninsula). Climatic Change, 2013

Which is the link between climate and fires?



Two main working hypotheses :

1. **Anthropogenic effects** and **climate trends** are “**slowly changing factors**”. They drive variations on the scales of decades

2. Although most fires are ignited by people, the **year-to-year changes** in the ease of ignition and in the burned areas, are mainly related to the **interannual climate variability**

Turco M., Llasat M. C., von Hardenberg J., Provenzale A. Impact of climate variability on summer fires in a Mediterranean environment (northeastern Iberian Peninsula). Climatic Change, 2013

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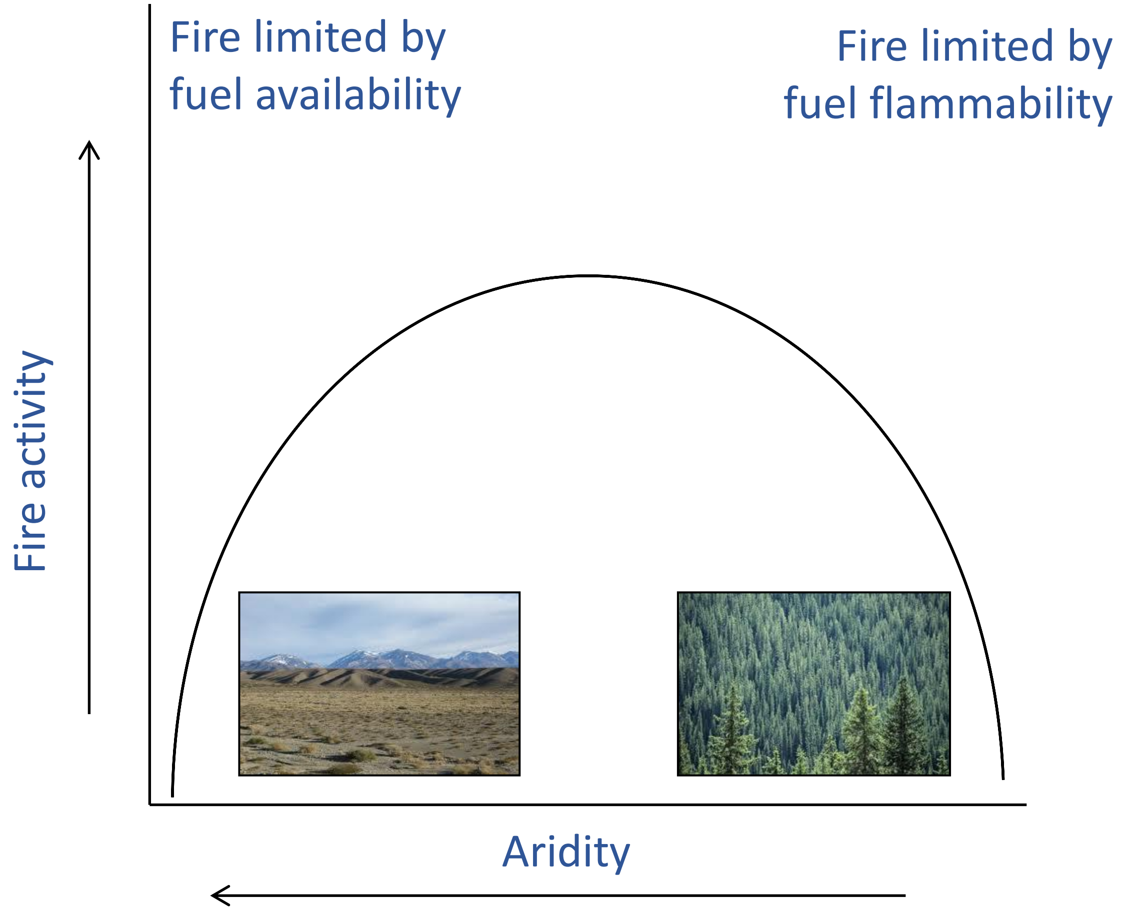

Adapted from Pausas J.G. & Bradstock R.A. 2007. Fire persistence traits of plants along a productivity and disturbance gradient in Mediterranean shrublands of SE Australia. Global Ecology & Biogeography 16: 330-340.

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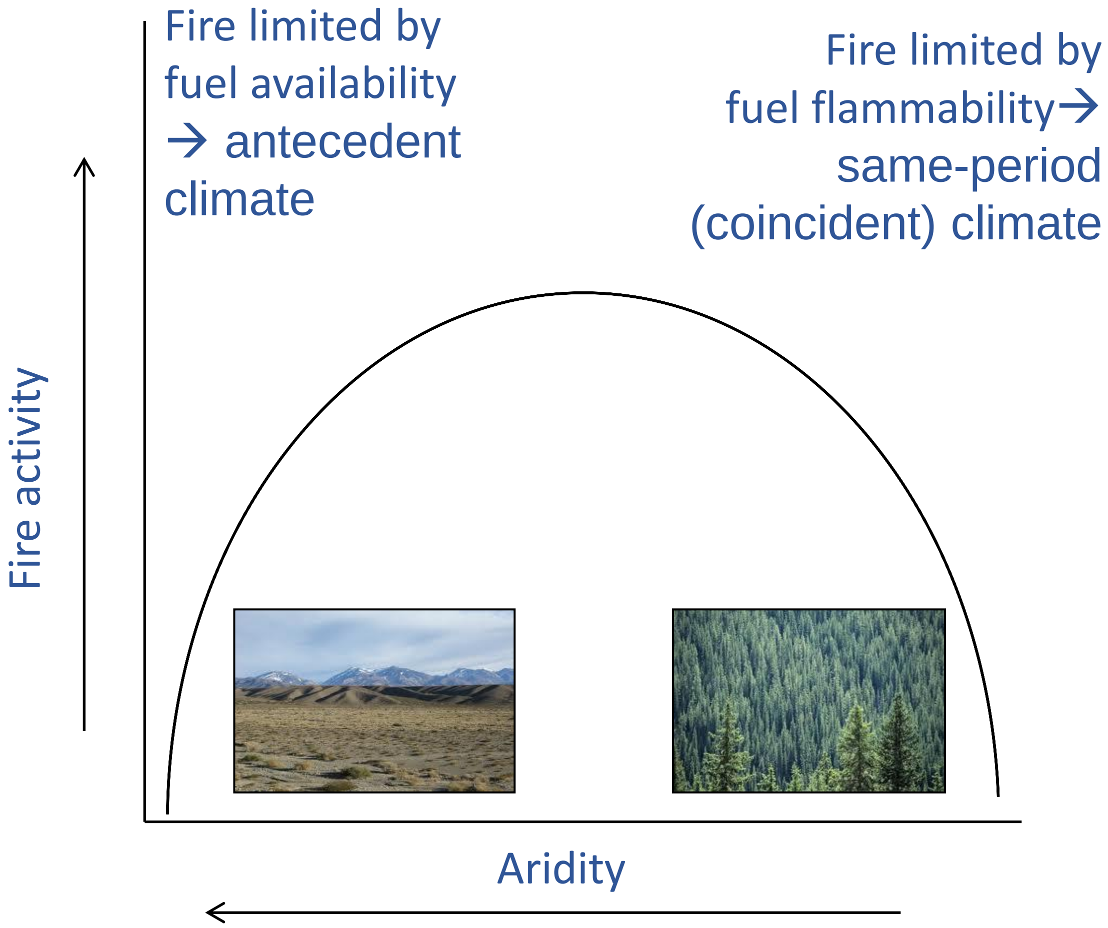

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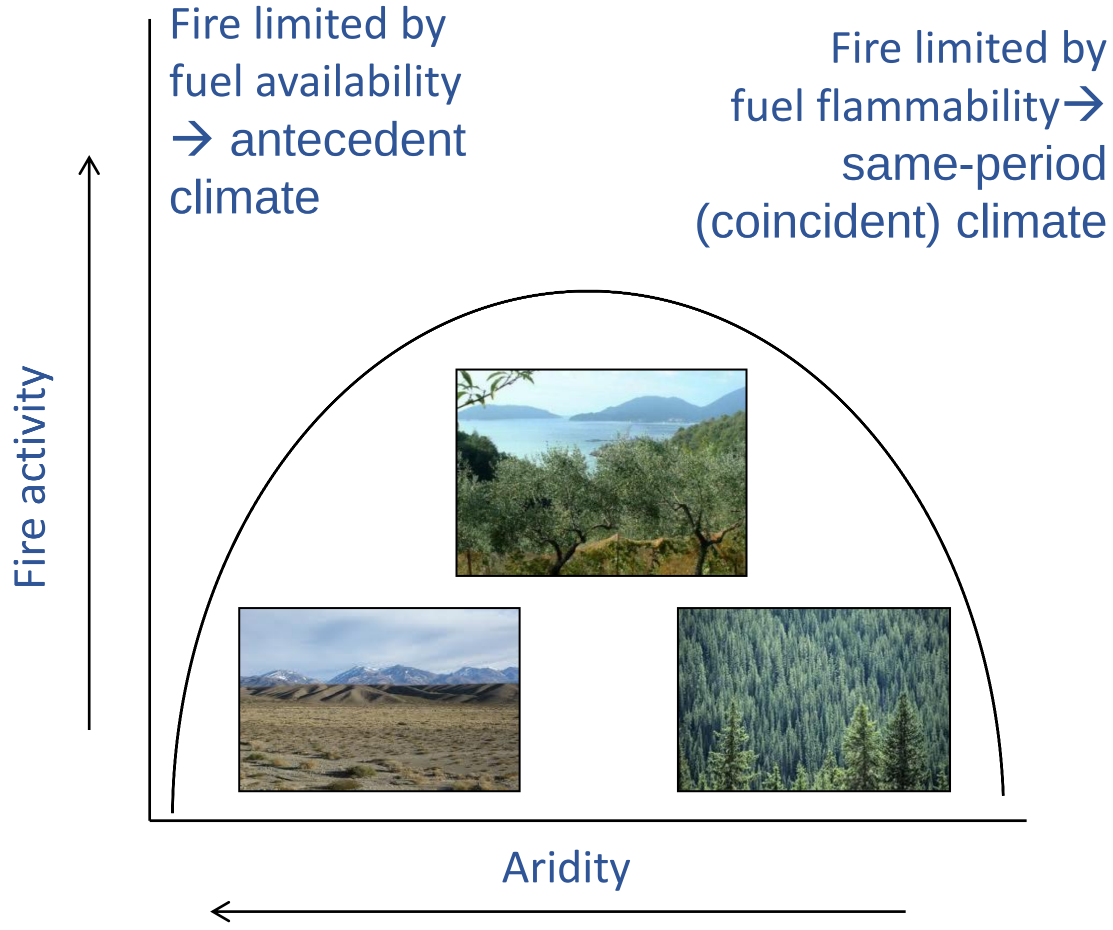

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25 summer’s (JJAS): 1983-2007: 16753 fire events (NF), total burned area (BA)> 240000 ha (around 7.5% of Catalonia).
Threshold: 0.5 ha BA. Summer: 60% of the annual FF, 86% of the annual BA
Data: Spain02 gridded dataset (20 × 20 km); mean regional standardized series of P,T; detrended series (climate and fires).

Testing for the importance of all possible combinations of the potential predictors, and sorting the resulting models based on their Akaike Information Criterion score (trade-off between its accuracy and its complexity). Interannual variability of summer fires significantly correlated with:

- *summer precipitation -*
- *summer maximum temperature +*
- *lagged precipitation (-2 y) +*
- *lagged temperatures (-2 y) +*
- *minimum temperature in spring –*

A simple regression model that explains up to 76% of the variance of the BA and up to 91% of NF.

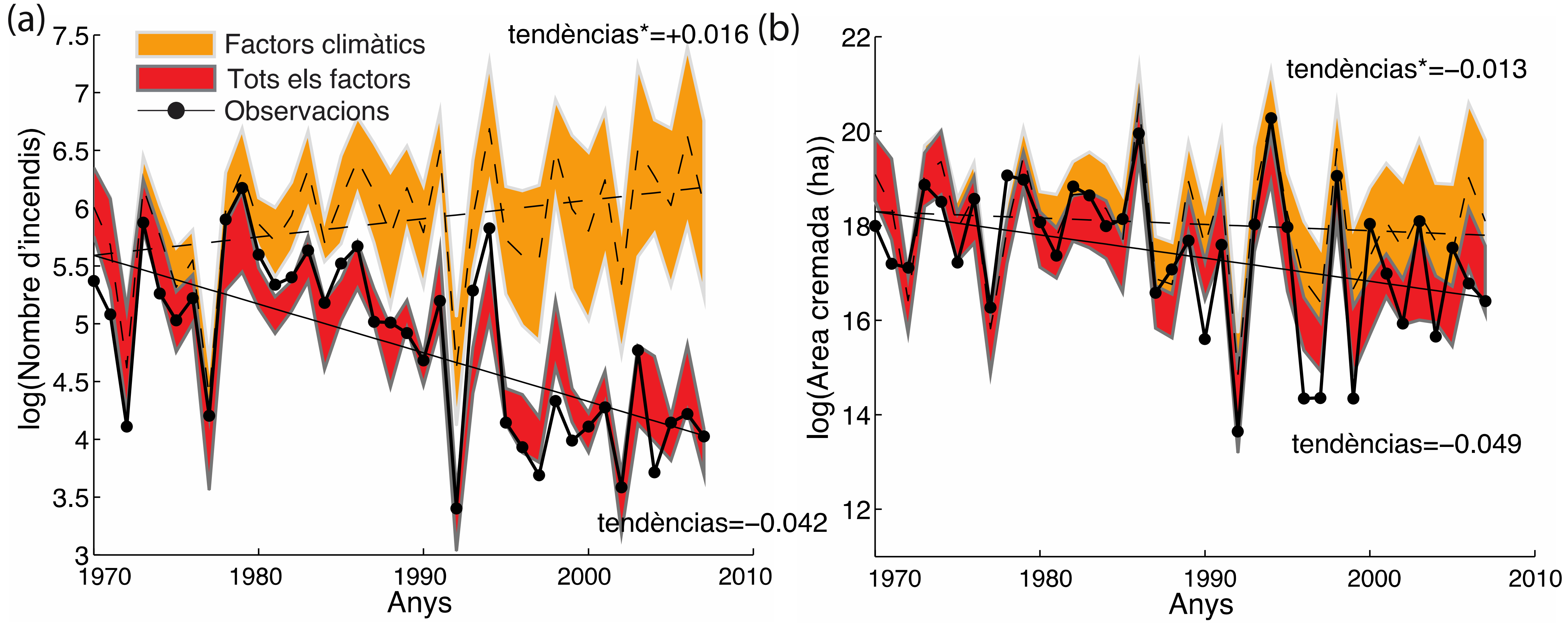
$$\mathbf{BA = exp(17.22 - 0.75P(12\text{–}8) + 0.95Tx(6\text{–}6) - 0.69Tn(3\text{–}4) - 0.58Tx(3\text{–}4)(2) + \varepsilon)}$$

$$\mathbf{NF=exp(139-0.07t-0.24P(6\text{–}8)+0.33Tx(6\text{–}8)-0.28Tn(1\text{–}5) - 0.22Tn(2\text{–}6)(2) + \varepsilon)}$$

The interaction between antecedent climate conditions and fire variability highlights the importance of climate not only in regulating fuel flammability, but also fuel structure.

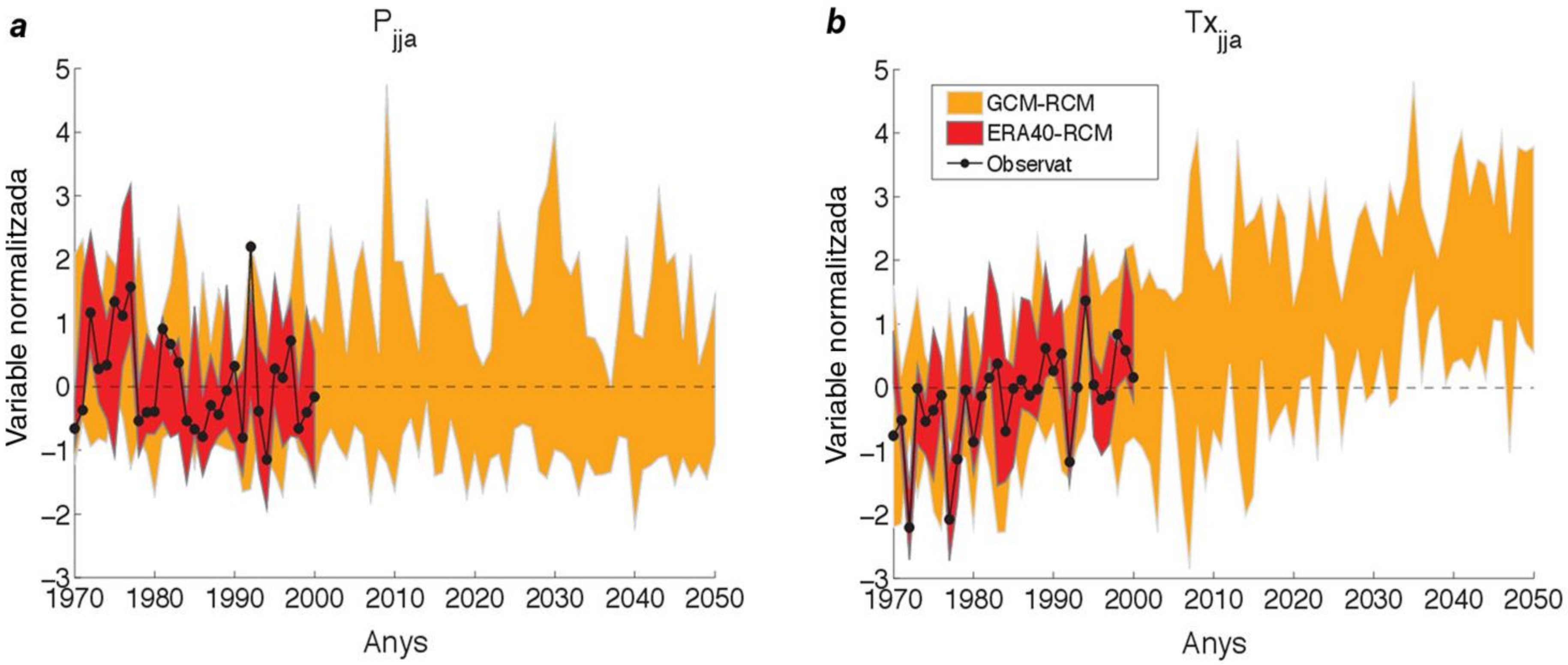
Application: to estimate fire response to different climate change scenarios, assuming that climate-vegetation-humans-fire interactions will not change significantly.

Turco, M., M.C. Llasat, J. von Hardenberg, A. Provenzale, 2013. Climatic Change, vol. 16, 3, 665-678. DOI 10.1007/s19584-012-0505-6



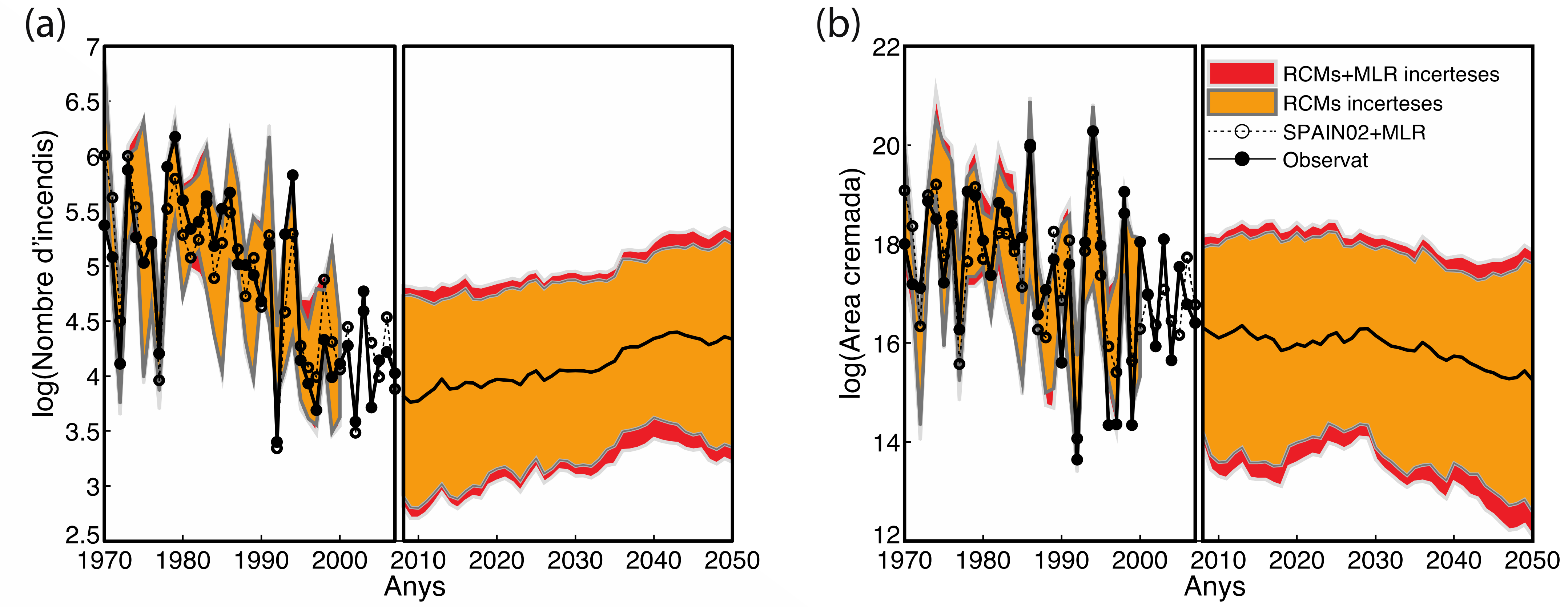
Evolució del nombre d'incendis forestals (a) i de l'àrea cremada (b) considerant solament la influència dels factors climàtics (banda taronja) i de tots els factors (banda vermella). L'amplitud de la banda dona idea del grau d'incertesa i inclou el 90% de l'inteval de confiança de les simulacions fetes a partir dels diferents RCMs. Les tendències tenen una significança del 95% i estan donades en escala logarítmica (logaritmes naturals). Figura modificada a partir de Turco et al, (2014).

Tendències i projeccions precipitació i temperatura estiu



Evolució de la precipitació i la temperatura màxima estival (JJA) de Catalunya, normalitzades respecte al període 1970-2000. La línia negra representa les dades observades en aquest període; la banda vermella mostra els valors obtinguts a partir dels RCM alimentats amb les observacions de l'ERA-40. En el cas de la banda taronja, els models regionals s'han alimentat amb els escenaris generats pels GCM. L'amplitud de les bandes donen una idea del grau d'incertesa. Font: Figura modificada a partir de Turco et al. (2014).

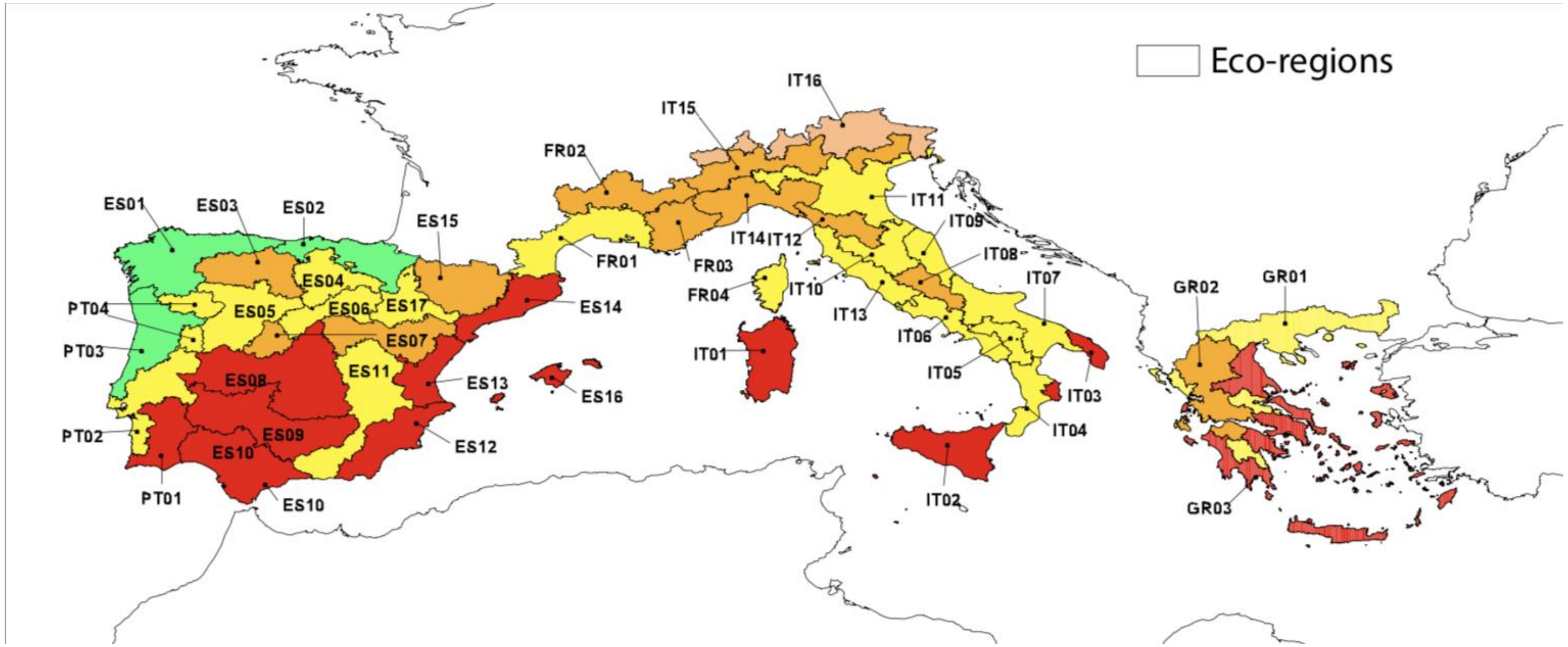
Tendències i projeccions incendis forestals



Evolució present i futura del (a) nombre d'incendis i (b) àrea cremada a Catalunya. La línia negre amb cercles negres correspon a les observacions; la de cercles buits, a la modelització a partir de les dades de SPAIN02; la banda taronja mostra el conjunt de sortides del downscaling sobre els RCMs amb un 90% d'interval de confiança; la banda vermella mostra les sortides després d'aplicar 1000 simulacions a cada RCMs; la línia negra continua es la mitjana mòbil per una finestra de 10 anys de la mitjana de tots els models. Figura modificada a partir de Turco et al, (2014).

Data-driven climate-fire model

We aim to model BA(*i*,*t*): the Burned Area in the ith eco-region and summer *t* (total BA June-September)



Turco, M. et al. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Sci. Rep. 7, 81 (2017)
Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Data-driven climate-fire model

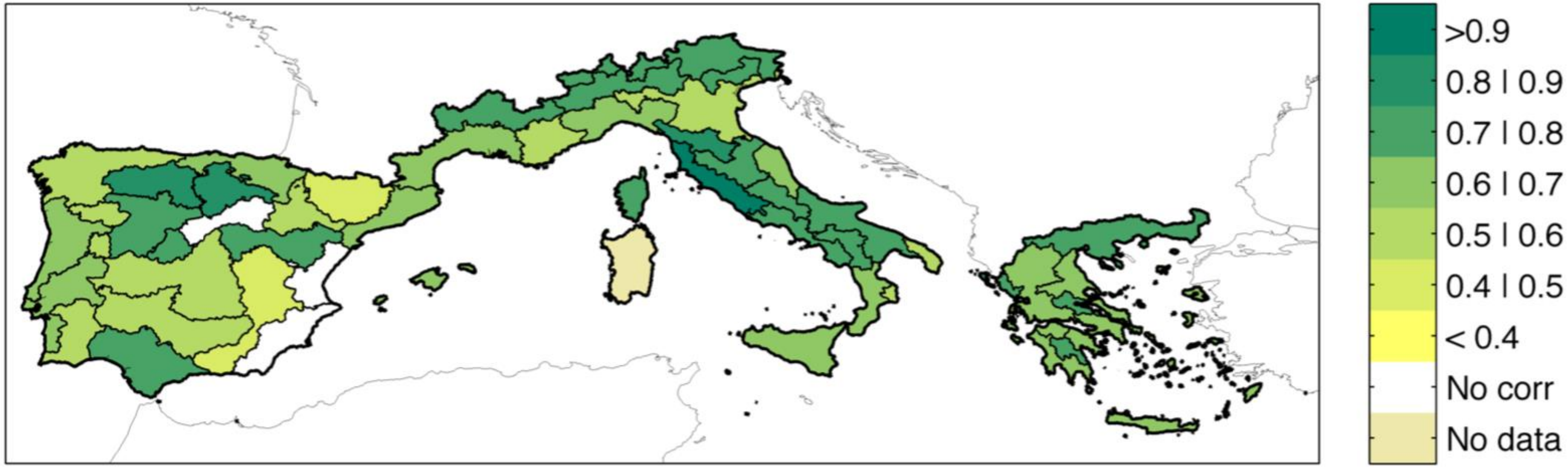
$$\log[BA(i,t)] = \beta_1(i) + \beta_2(i)\, SPEI_{sc,m}(i,t) + \beta_3(i)\, T(t) + \varepsilon(i,t)$$

$\beta 1$ is the intercept
$\beta 2$ represents the sensitivity of BA in each region to the SPEI
$\beta 3$ is the coefficient of the time term T (in years) that characterizes the temporal trends of BA, thus taking into account the possible influence of slowly changing factors over the study period
ε is a stochastic noise term

$SPEI_{sc,m}$: m is the month for which the SPEI is computed (which we allow to vary from previous spring to coincident summer months) and sc is the time scale (number of months) used to compute the SPEI (we consider periods of 3, 6, and 12 months)

Turco, M. et al. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Sci. Rep. 7, 81 (2017).

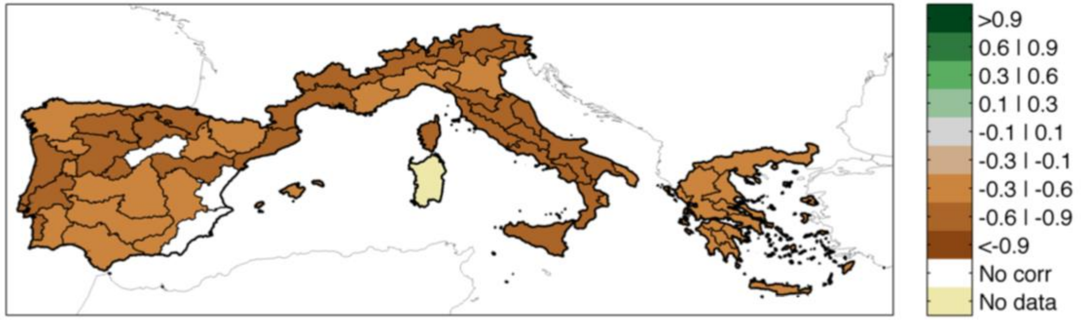
Correlation between modelled and observed log(BA) for each eco-region



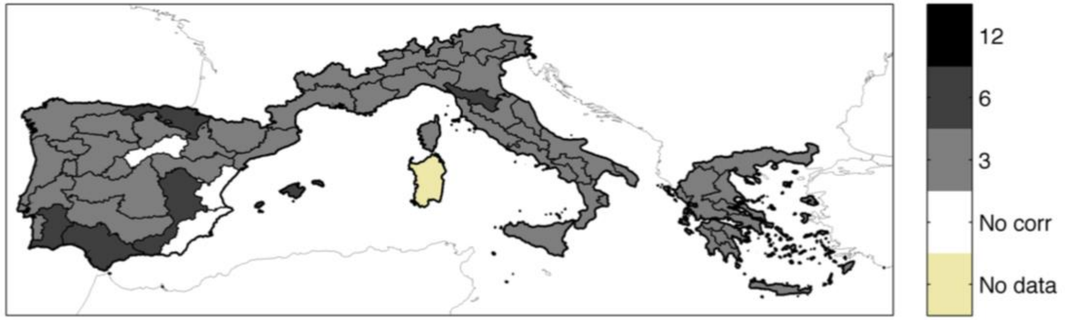
Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Current drought impacts on forest fire risk

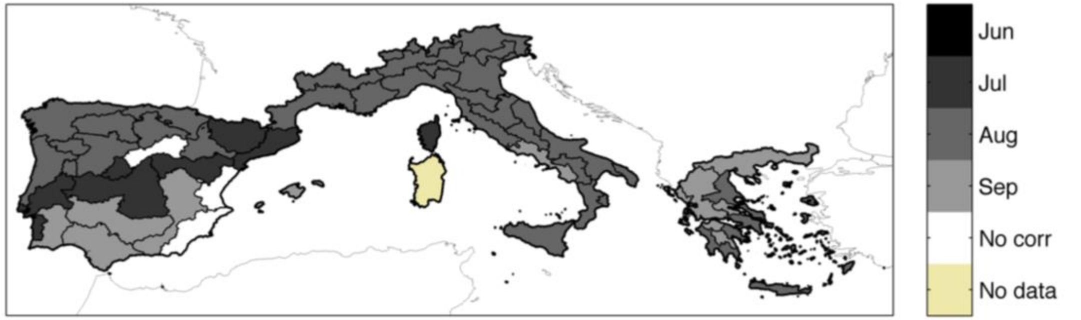
Correlation between detrended[log(BA)] and detrended($SPEI_{sc,m}$)



sc: time scale of the SPEI index (3, 6 or 12 months)



m: final month of accumulation of the SPEI



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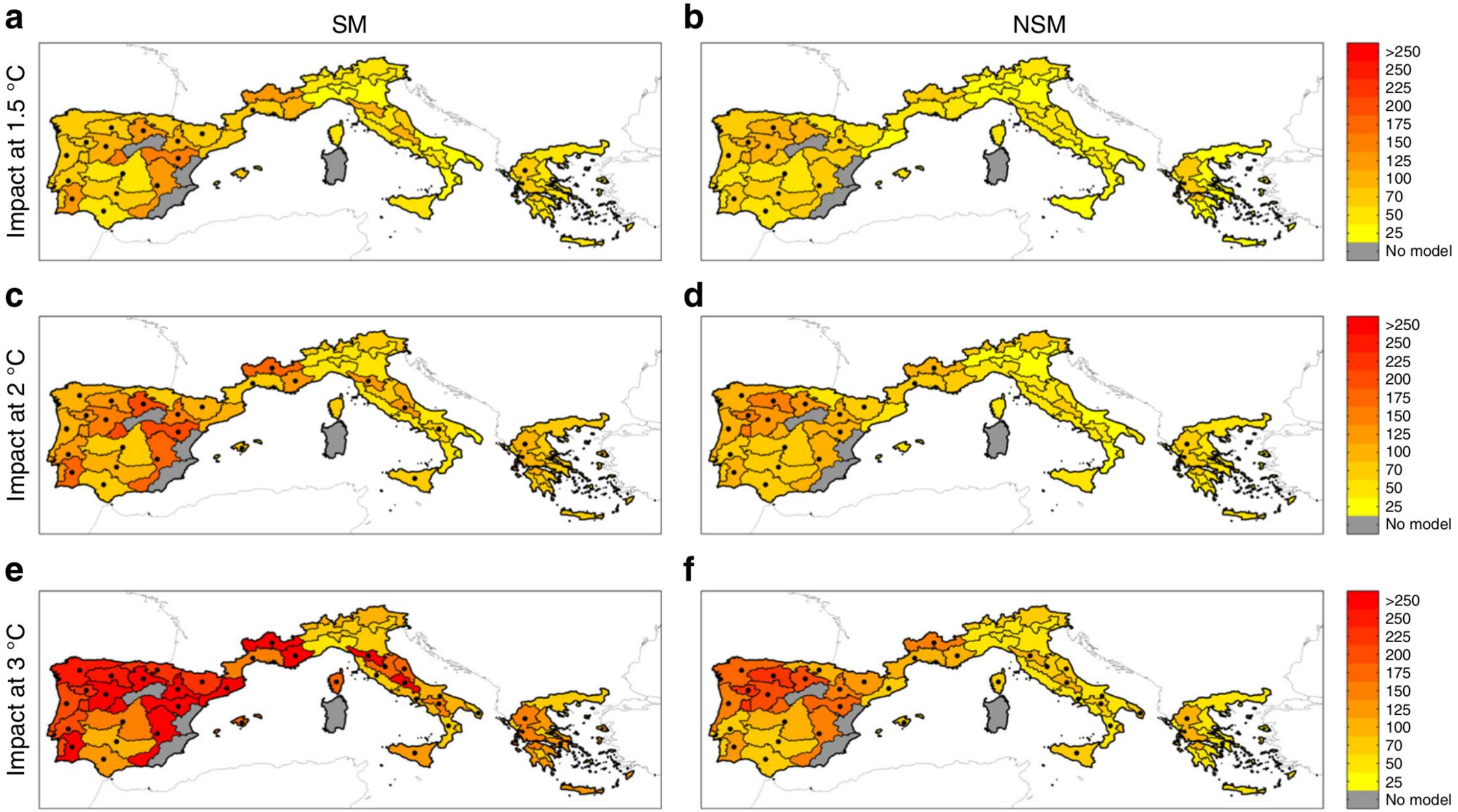
Future drought impacts on forest fire risk



Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

- **Logistic regression model for seasonal prediction**

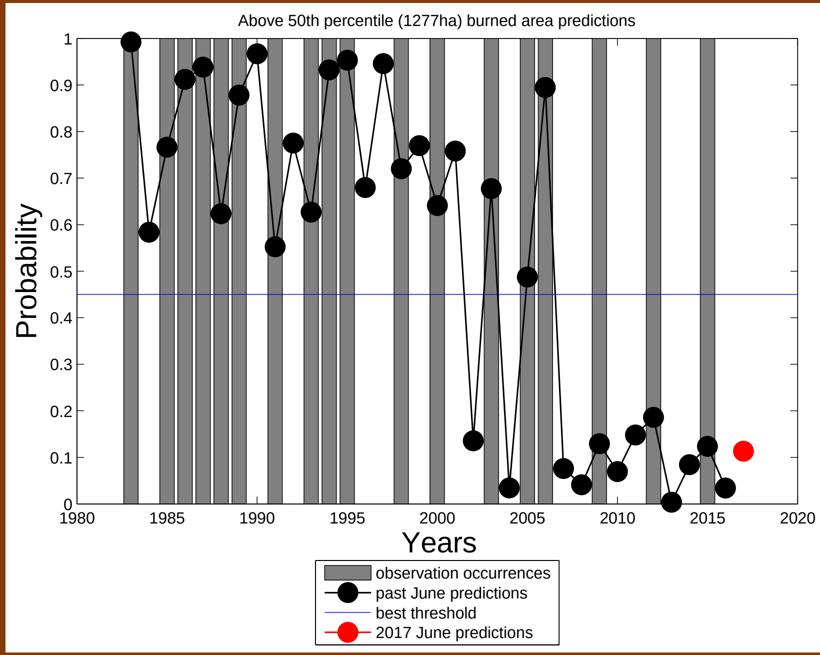
DATA

- **Fire data**: Forest Fire Prevention Office of the 'Generalitat de Catalunya' dataset
- **Temperature**
- **Precipitation**

CLIMATE-FIRE MODEL

- Precipitation, Temperature → SPEI
- SPEI forecast: antecedent observed conditions + climatology
- Logistic regression SPEI-FIRE model

FIRE-RISK SEASONAL PREDICTION



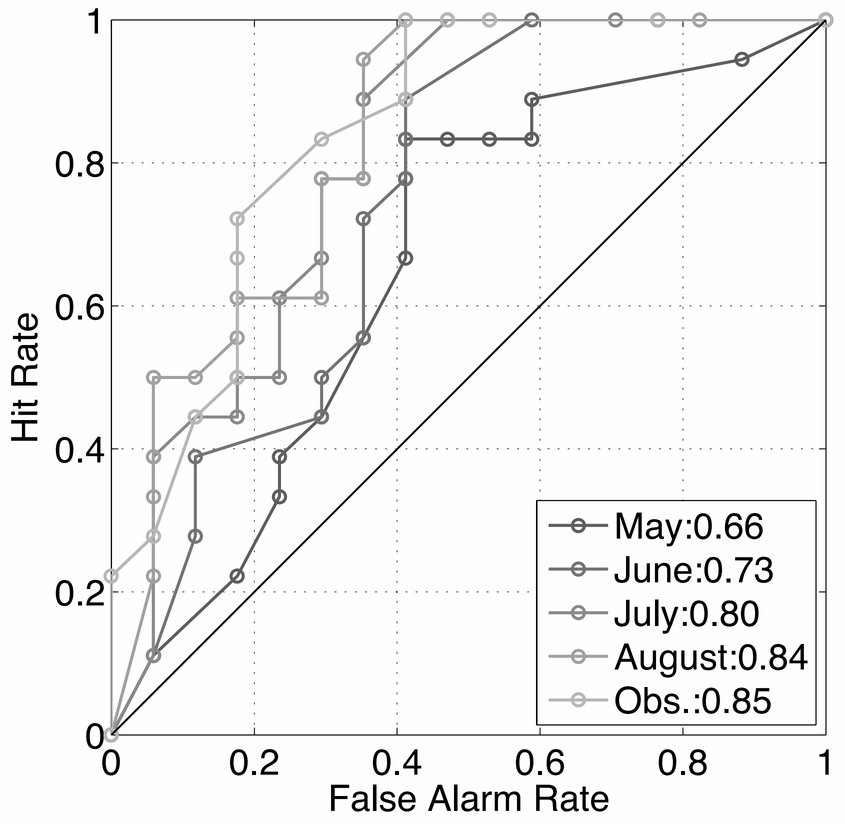
Climate-fire model

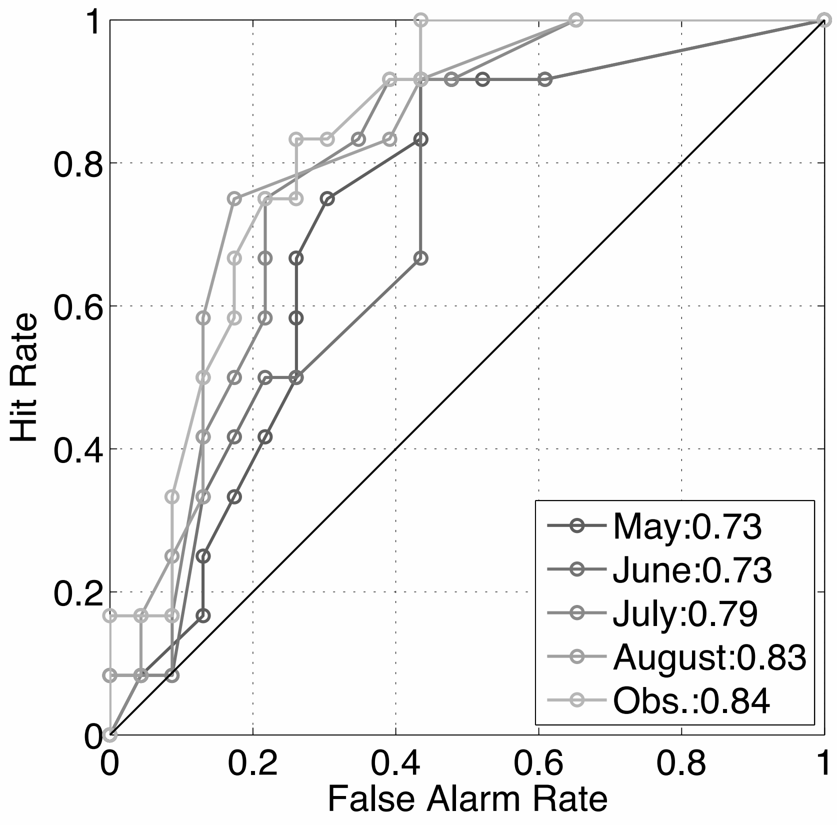
$$\log(p/(1-p)) = \beta 0 + \beta 1 \cdot \mathrm{SPEIsc},(8-m) + \beta 2 \cdot T + \varepsilon$$

Where:

- p is the response variable (i.e. the probability of burned area above a certain percentile),
- β0 is the intercept
- β1 represents the sensitivity of BA in each region to dry conditions as indicated by the SPEI
- β2 is the coefficient of the time term T (in years) that characterises the temporal trends of the fire variable
- and thus takes into account the possible influence of slowly changing factors over this period of time;
- ε is a stochastic noise term that captures all other (neglected) processes that influence BA, apart from SPEI and T.

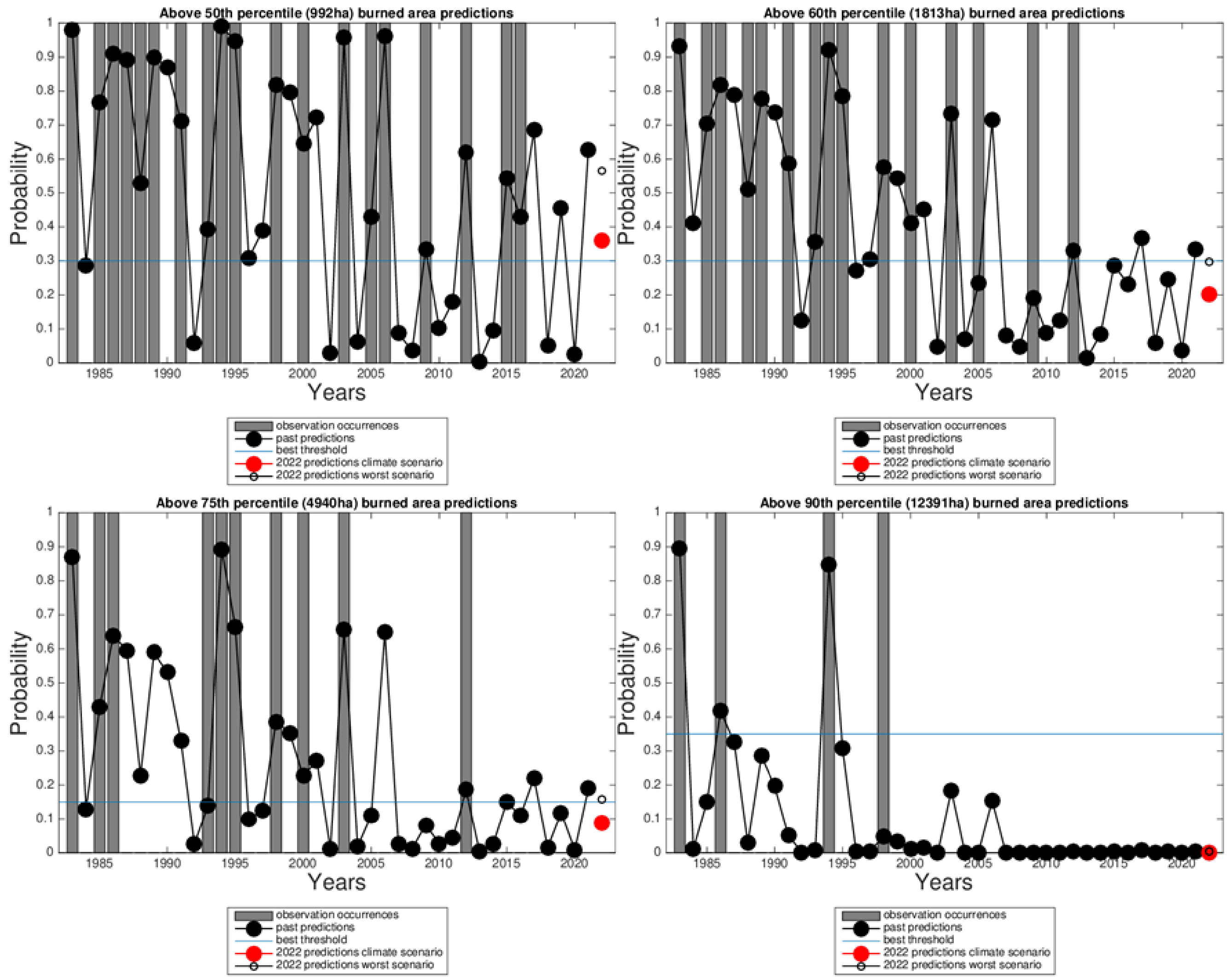
The values of the β coefficients are determined using generalised linear models (GLMs).
Drought conditions are measured by the SPEI indices aggregated in multi-month values, SPEIsc,(8-m), where 8-m is the calendar month for which the SPEI is computed (e.g., in August when m = 0) and sc is the time scale (number of months) used to compute the SPEI.

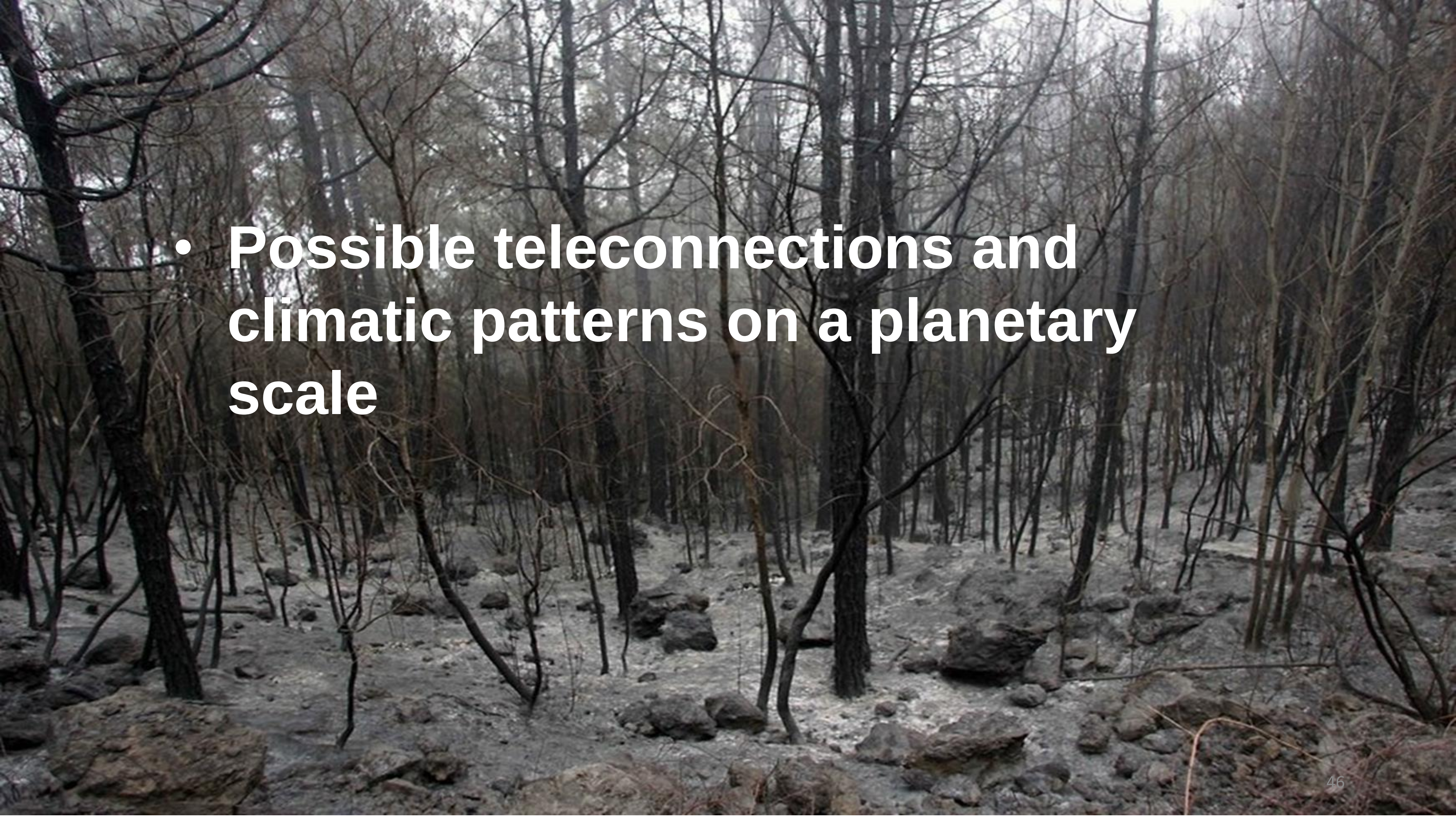




Relative operation characteristics diagram (ROC) for predictions of BA50 (left panel) and BA66 (right panel). These are out-of-sample predictions initialized in May, June, July and August. The skill of the out-of-sample predictions with the observed SPEI is also shown for reference. The numbers in the legend indicate the Roc Area of the different forecasts.

Nivell perill a 1/7 JA22	ha (50%)	ha (60%)	ha (75%)	ha (90%)
Catalunya	992	1813	4940	12391
Regió 1	2	4	10	60
Regió 2	38	55	77	1245
Regió 3	237	393	808	7436
Regió 4	51	89	287	2857
Regió 5	466	557	882	3463

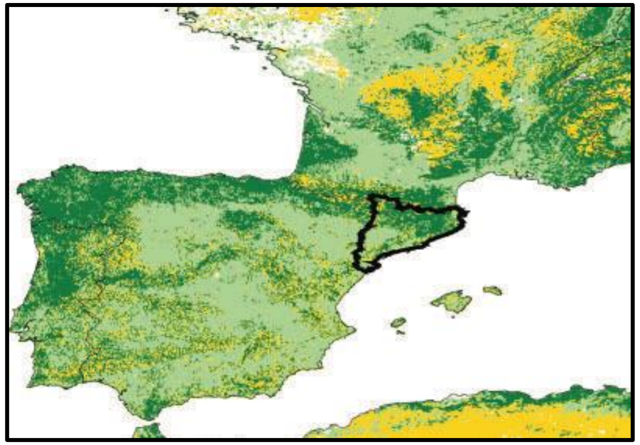


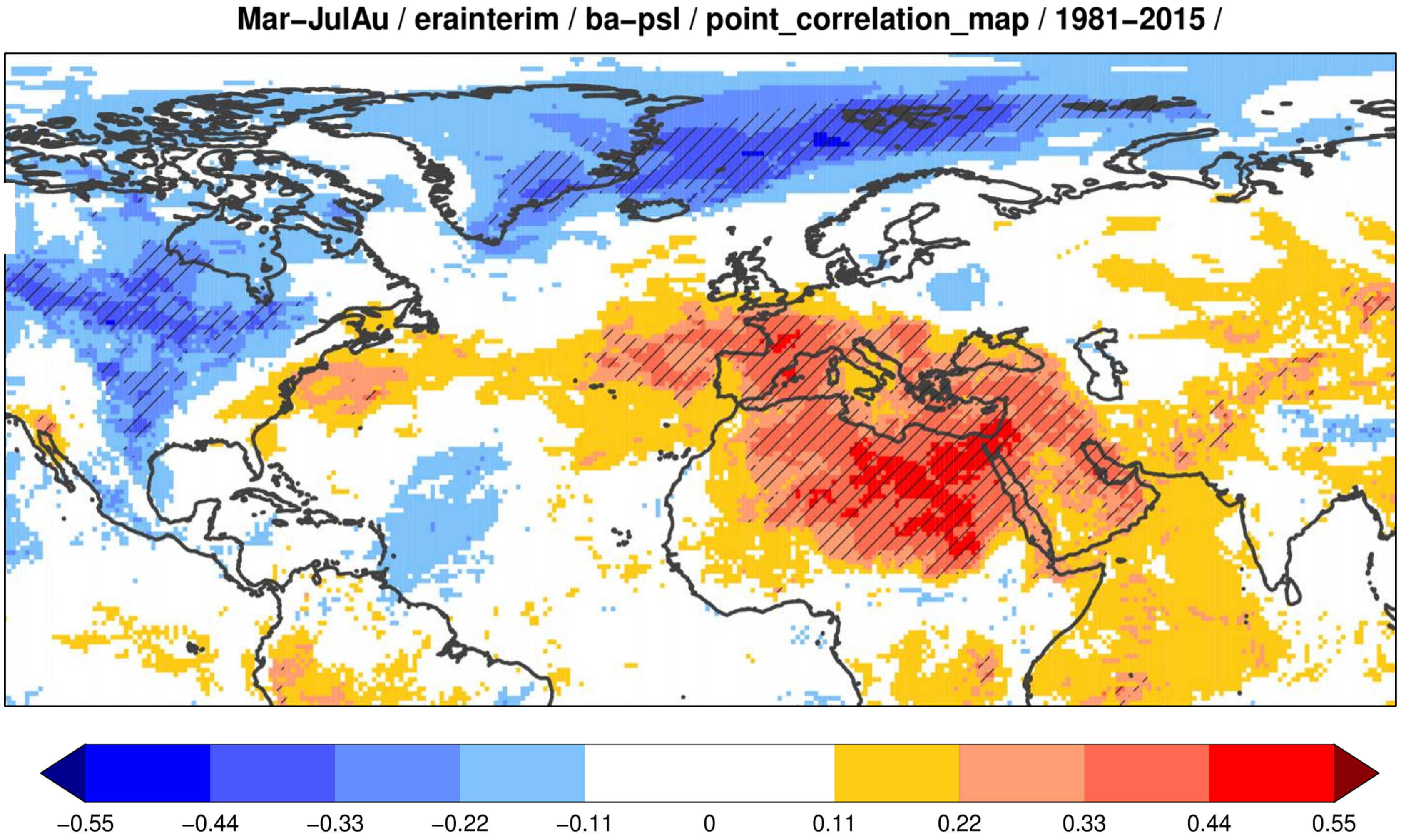


- **Possible teleconnections and climatic patterns on a planetary scale**

Burnt area and teleconnection patterns in Catalonia

The Catalonia **summer burnt area** anomalies are correlated with the anomalies of **past** variables to identify potential **teleconnection patterns** that can be used to **forecast** BA for the **following** summer.





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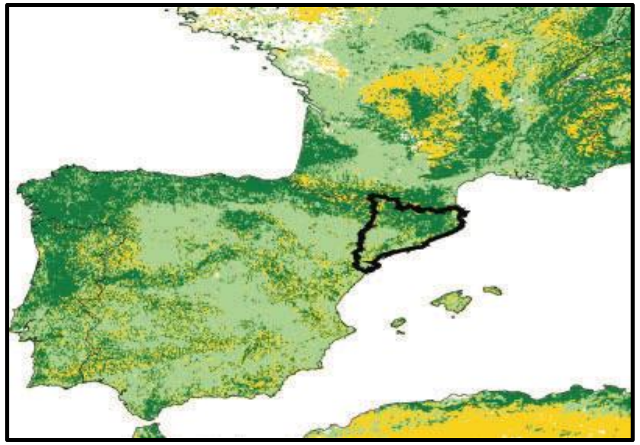

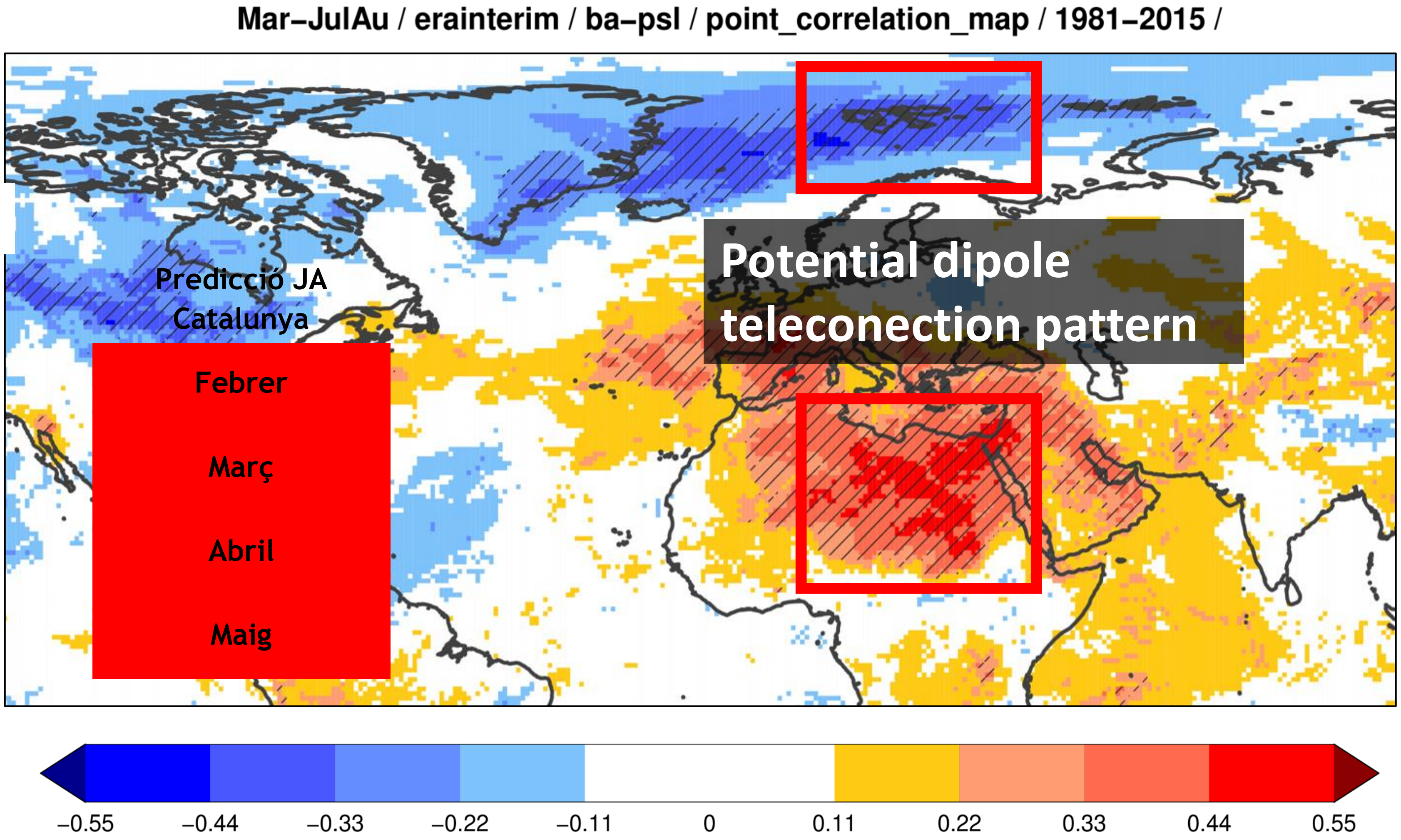

Conclusions

- Forest fires should be treated as a complex system
- Fires are not increasing in Mediterranean Europe --> the negative trends can be explained, at least in part, by an increased effort in fire management and prevention
- There is a strong evidence that the same-summer-drought is related to fires
- Overall, we found that the projected increase in drought conditions leads to larger burned area values and that limiting global warming to 1.5°C can strongly reduce the increase of burned area
- These results, in combination with the increase in societal exposure to large wildfires in recent years, call for a rethinking of current management strategies
- Substantial BA predictability exists based on antecedent and forecasted climate conditions that can be exploited for fire risk management months ahead

REFERENCES

Turco, M., M.C. Llasat, J. von Hardenberg, A. Provenzale, 2013. Climatic Change, vol. 16, 3, 665-678. DOI 10.1007/s19584-012-0505-6

Turco, M., M.C. Llasat, J. von Hardenberg, A. Provenzale, 2014. Climate change impacts on wildfires in a Mediterranean environment. Climatic Change. Published on-line 02 July 2014. Climatic Change (2014) 125:369–380. DOI 10.1007/s10584-014-1183-3

Marcos, R., M. Turco, J. Bedía, M.C. Llasat i A. Provenzale, 2015. Seasonal predictability of summer fires in a Mediterranean environment. International Journal of Wildland Fire http://dx.doi.org/10.1071/WF15079.

Turco, M., J. Bedia, F. Di Liberto, P. Fiorucci, J.von Hardenberg, N. Koutsias, M. C. Llasat, F. Xystrakis, A.Provenzale, 2016. Decreasing Fires in Mediterranean Europe. PLoS ONE 11(3): e0150663. doi:10.1371/journal.pone.0150663.

Turco, M., J. von Hardenberg, A. AghaKouchak, M.C. Llasat, A.Provenzale, and R.M. Trigo, 2017. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Scientific Reports-Nature. Scientific RepoRts |7:81,| DOI:10.1038/s41598-017-00116-9. 2015 / 2016

Turco, M., S. Jerez, F.J. Doblas-Reyes, A. Aghakouchak, M.C. Llasat and A. Provenzale, 2018. Skilful forecasting of global fire activity using seasonal climate predictions. Nature Communications. NCOMMS-17-30118B. 9:2718 |DOI: 10.1038/s41467-018-05250-0. Quartile:

Turco, M., J. J.Rosa-Cánovas, J. Bedia, S. Jerez, J. P. Montávez, M. C. Llasat and A. Provenzale, 2018. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with nonstationary climate-fire models. NATURE COMMUNICATIONS | (2018) 9:3821 | DOI: 10.1038/s41467-018-06358-z |

Turco, M., R. Marcos-Matamoros, X. Castro, E. Canyameras, M.C. Llasat, 2019. Seasonal prediction of climate-driven fire risk for decision-making and operational applications in a Mediterranean region. Science of The Total Environment, vol. 676, 1 August 2019, pp. 577-583. https://doi.org/10.1016/j.scitotenv.2019.04.296.

THANK YOU VERY MUCH FOR YOUR ATTENTION

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