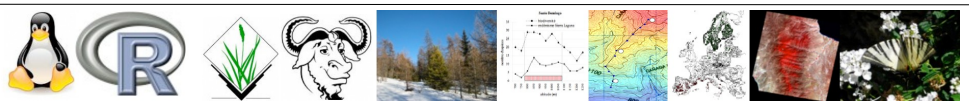
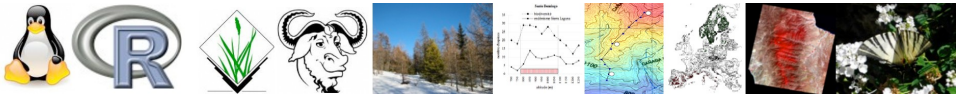
Modelling forest fire under climate change scenarios.

Giuseppe Amatulli

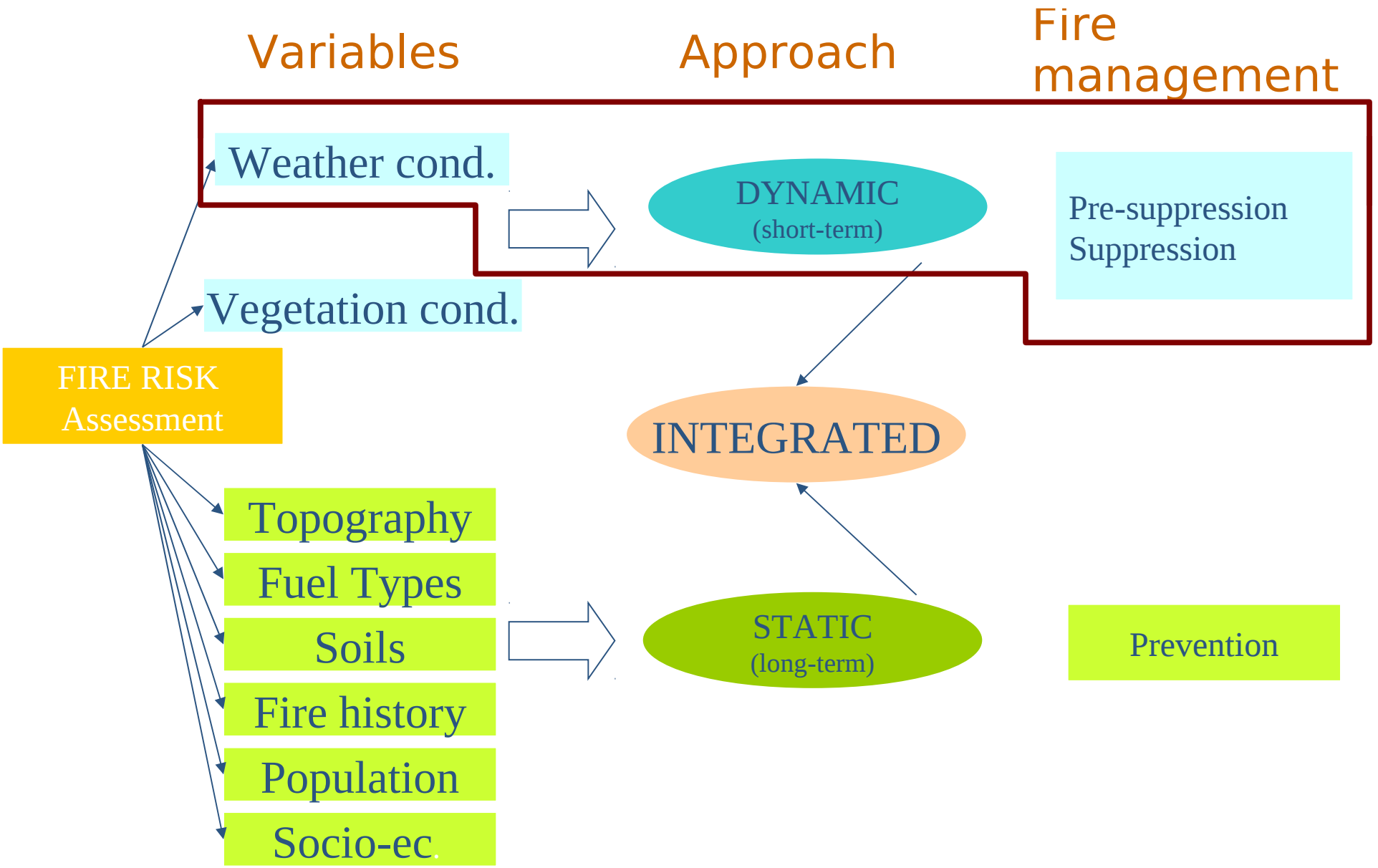


Overview

- Introduction to the forest fire issues
  - Objectives of the research
  - Dataset
    - EU fire database (Burnt Area) (response variable)
    - Weather data (ECMWF-ERA40 / PRUDENCE-DMI) (predictor variables)
  - Methodology
    - Data integration
    - Model fitting and prediction
  - Results
    - Model performance and visualization
  - Conclusions
  - Technical details

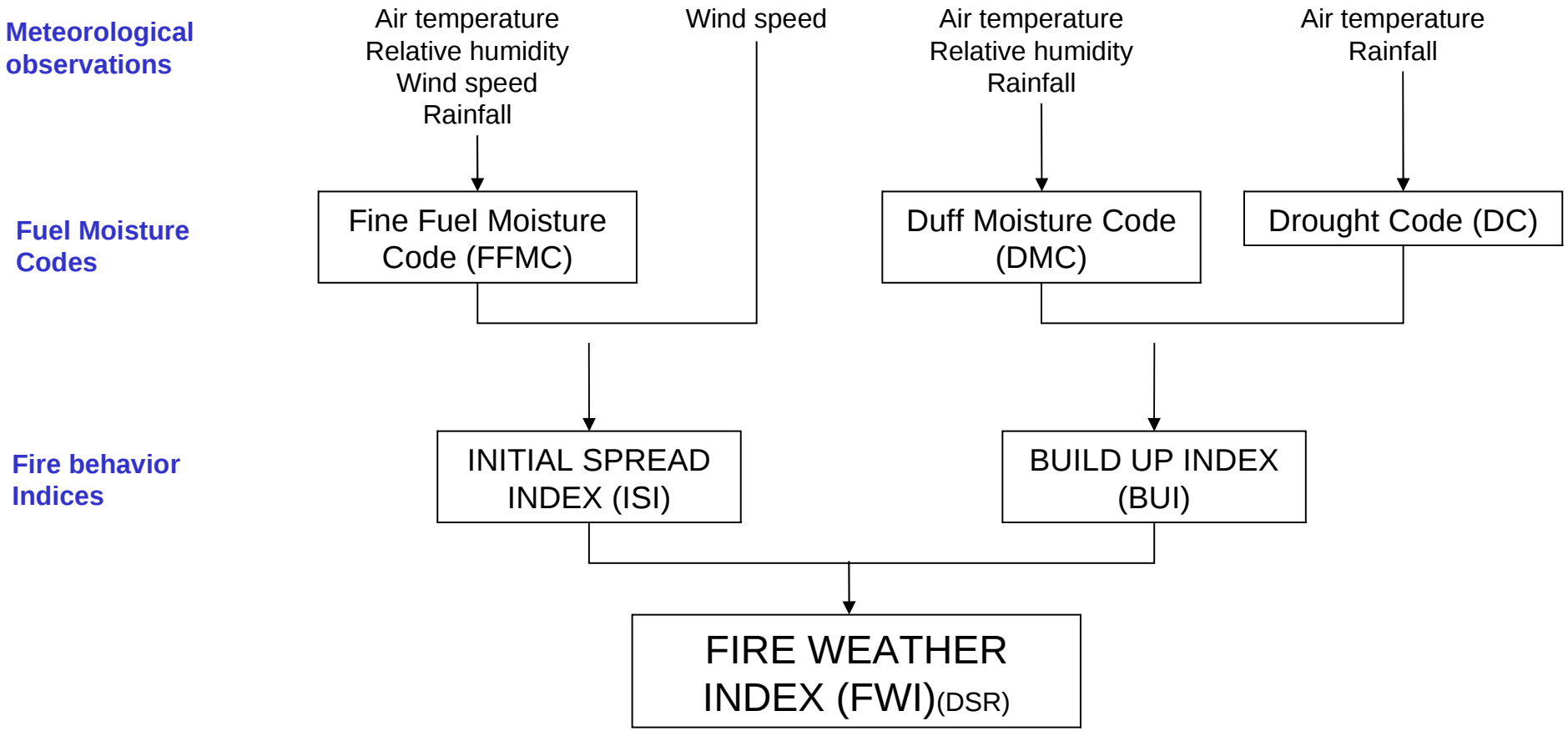


Introduction to the forest fire issues

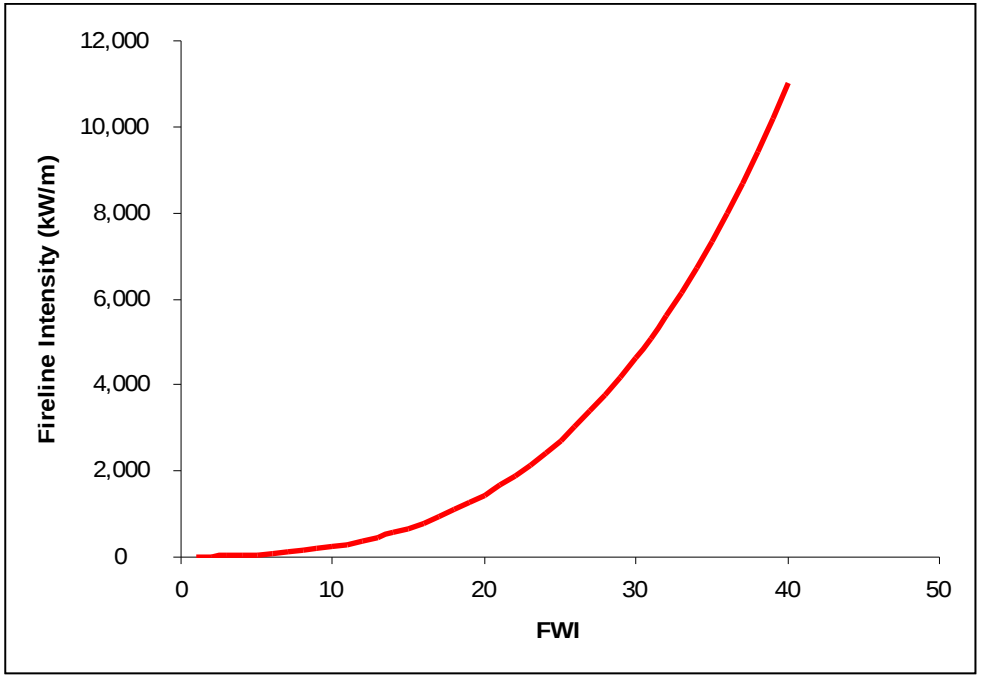


Introduction to the forest fire issues
Fire Weather Index (FWI)

Mature Pine Forest (jack pine and lodgepole pine) - Level terrain



Each individual component is a fire danger index, reveling different aspects of fire danger which are finally difficult to synthesize with one single number (Alexander 2008)


12,000
10,000
8,000
6,000
4,000
2,000
0
Fireline Intensity (kW/m)
0
10
20
30
40
50
FWI


FWI 9


FWI 34

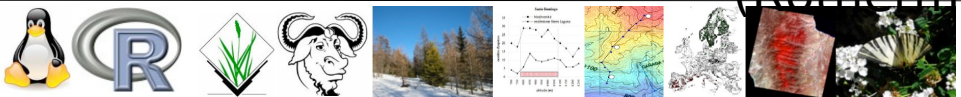

FWI 24


FWI 17

Interpretation of Fireline intensity

Fireline Intensity (kW/m)	Flame Length (m)	Interpretation
Under 350	Under 1.2	Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire.
350-1750	1.2-2.4	Fires are too intense for direct attack on the head by persons using hand tools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, pumpers, and retardant aircraft can be effective.
1750-3500	2.4-3.4	Fires may present serious control problems - torching out, crowning, and spotting. Control efforts at the fire head will probably be ineffective.
Over 3500	Over 3.4	Crowning, spotting, and major fire runs are probable. Control efforts at head of fire are ineffective.

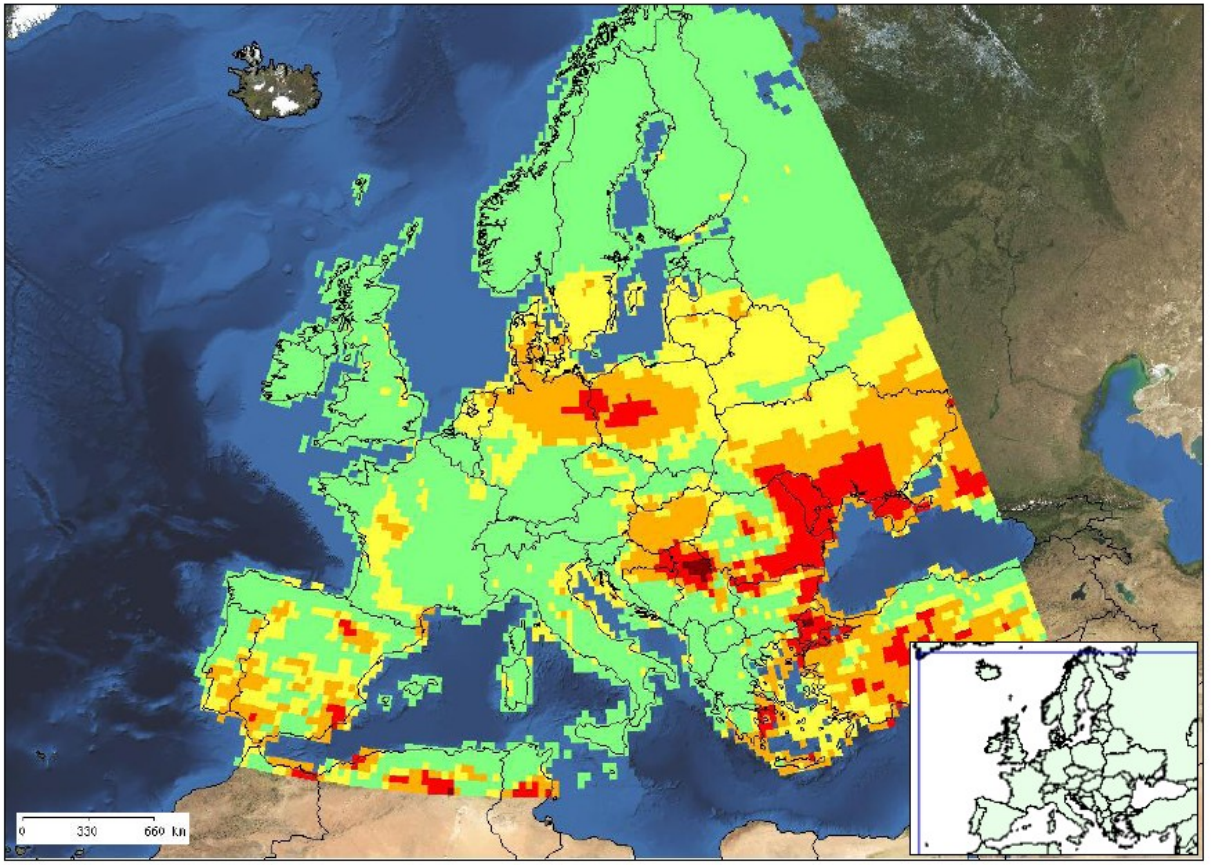
(Rothermel 1983)



European Commission
Joint Research Centre
Institute for Environment and Sustainability

EFFIS Current Situation

Thursday 16th of April 2009



Fire Danger Forecast Levels
16/04/09 + 4 day(s)

- Very Low Risk
- Low Risk
- Moderate Risk
- High Risk
- Very High Risk

Countries

- Boundaries

The European Forest Fire Information System (EFFIS) supports the services in charge of the protection of forests against fires in the EU member states.
EFFIS has been developed jointly by the Directorate General for the Environment and the Joint Research Centre.
It provides the European Commission services and the European Parliament with updated and reliable information on wildland fires in Europe.

ies
Institute for Environment and Sustainability

The European Forest Fire Information System (EFFIS)

email: effis@jrc.it web: http://effis.jrc.ec.europa.eu

Meteorological Data from Deutscher Wetterdienst
(c)EuroGeographics for the Administrative Boundaries
Processing by JRC/IES/LMNH - Forest Action

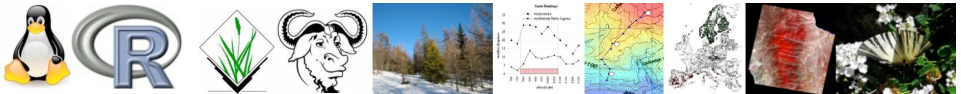
Objectives

- To build up a statistical model based on historical data (1985-2004) at EU-Mediterranean and Country level:

  Monthly burnt areas -> Monthly weather data (Fire Weather Index)

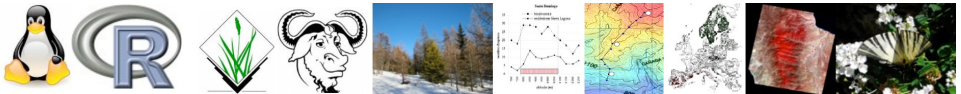
- To analyze potential trends under present and future climate condition

- To consider possible applications for monthly forecasting using ECMWF products



The EU Fire Database is a collection of fire events recorded by the EU member states and compiled at EU level at JRC.

- NUTS3 level (province), reporting date, burnt area, etc.
- Available period for EU-Med 1985 - 2004 (20 years)



Dataset: ECMWF-ERA40

http://www.ecmwf.int/products/data/archive/descriptions/e4/index.html

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ECMWF 40 Year Re-analysis (ERA-40) Data Archive

Archive

- Operational
- ERA-15
- ERA-40
- ERA Interim

On-line

- A good place to begin
- How to find data
- Main steps
- General information
- Top 5 questions

The re-analysis project ERA-40 will cover the period from mid-1957 to mid-2002, overlapping the earlier ECMWF re-analysis, ERA-15, 1979 to 1993.

The whole period from September 1957 to August 2002 is now available.

The Level III-B archive is subdivided into four classes of data sets:

- Basic 2.5° atmospheric
- Full Resolution atmospheric
- Wave
- Atmospheric Monthly Means

The data sets are based on quantities analysed or computed within the ERA-40 data assimilation scheme or from forecasts based on these analyses.

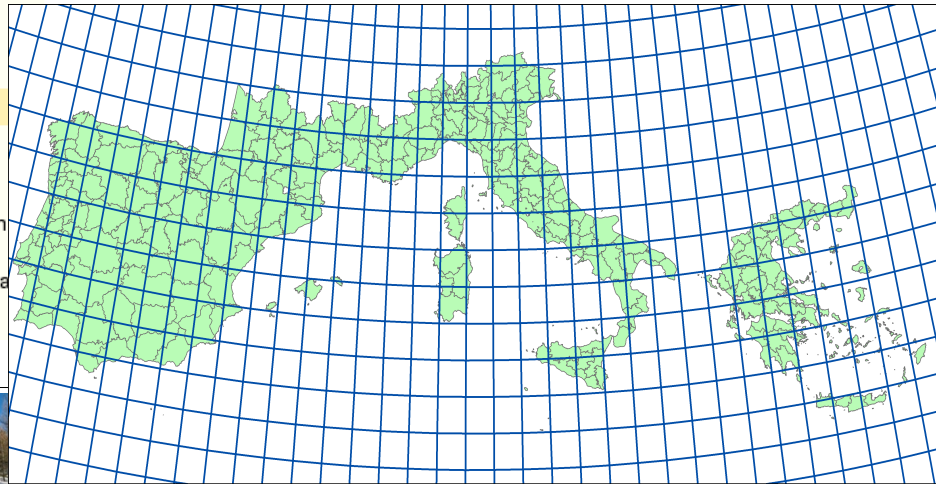
Basic 2.5° atmospheric

- These Data Sets contain values in a compact form at a resolution of 2.5° x 2.5°.
- They are particularly suitable for users with limited data processing resources.
- Much of this data is available from the ECMWF Data Server at no charge for research usage.
- All the ERA-40 data from the Data Server can be supplied by ECMWF Data Services a described.

ERA40 1958-2002
MARS 2003-2007
Resolution 1.125°

ERA40 1961-1990
ERA40 1985-2004

Parameters:
Temperature
Precipitation
Wind
Humidity



Dataset: PRUDENCE-DMI

http://prudence.dmi.dk/

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Front page

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- Participants
- Project summary
- Description of work (.PDF)
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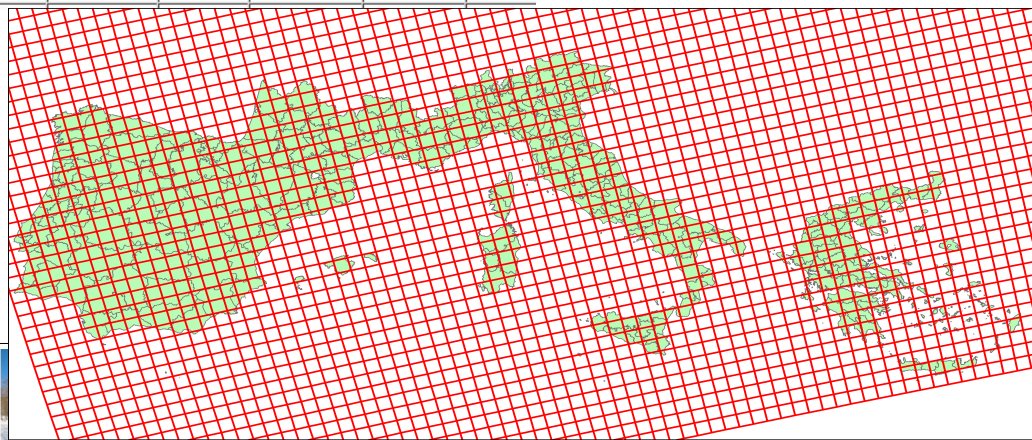
Data distribution front page

- Direct download
- DODS

Participants-only data:

Institute/ Contact	Model	Driving data	Ens.	Experiment	Acronym	Seasonal data	Monthly data	Daily data
DMI Jens H. Christensen	HIRHAM	HadAM3H A2	1	Control	HC1	Online	Online	Online
			1	Scenario	HS1	Online	Online	Online
			2	Control	HC2	Online	Online	Online
			2	Scenario	HS2	Online	Online	Online
			3	Control	HC3	Online	Online	Online
			3	Scenario	HS3	Online	Online	Online
		HadAM3H A2 (SMHI Baltic SSTs)	1	Scenario	HS4	Online	Online	Online
		HadAM3H B2		Scenario	HB1	Online	Online	Online
		ECHAM4/OPYC (OAGCM SSTs)		Control	ecctrl	Online	Online	Online
		ECHAM4/OPYC A2 *Not the same expt. as the SMHI MPIA2!*		Scenario	ecscA2	Online	Online	Online
		ECHAM4/OPYC B2		Scenario	ecscB2	Online	Online	Online
		ECHAM5 A2		Control	ECC	Online	Online	Online
				Scenario	ECS	Online	Online	Online
	HIRHAM High res.	HadAM3H A2	1	Control	F25	Online	Online	Online
			1	Scenario	S25	Online	Online	Online
	HIRHAM Extra High res.	HadAM3H A2	1	Control	F12	Online	Online	Online

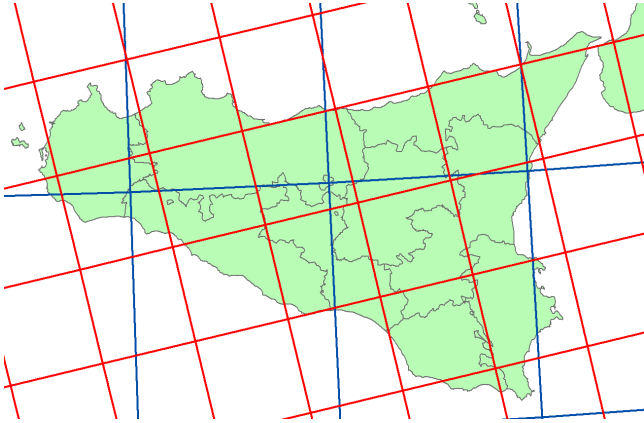
PRUDENCE
DMI
(RCM) HIRHAM
Resolution 50 km
Control 1961-1990
A2 2071-2100
A2 2071-2100
Parameters:
Temperature
Precipitation
Wind
Humidity



The Control under-estimate the parameters

Not easy to re-project the data

Methodology



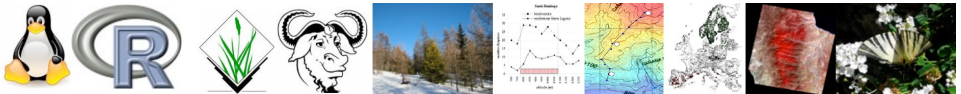
- Daily calculation of FWI and sub-indexes
  - Era40 -> 1958-2007
  - Prudence DMI -> Control and A2 B2 scenarios
  - Monthly average for each sub-indexes
- Finally weighted average for each NUTS3 based on the area
- NUTS3 weighted aggregation at EU-Med. and Country level

- Multiple regression with step-wise selection

  Sum of Burnt Area -> Indexes Monthly Average (240 observations)

$$\text{Burnt Area}_{sum} = a\,\text{FFMC}_{avg} + b\,\text{DMC}_{avg} + c\,\text{DC}_{avg} + d\,\text{ISI}_{avg} + f\,\text{BUI}_{avg} + g\,\text{DSR}_{avg} + h + \varepsilon$$

- 2 Models: Summer-Autumn (May to November) (140 observation)
  Winter-Spring (December to April) (100 observation)
- Future climate condition = ERA40 1961-1990 + (Scenario PrudenceDMI – Control PrudenceDMI)



Model Results

$$BurntArea = \exp\hat{}(a\ X_1 + b\ X_2 + \ldots\ldots + c\ )$$

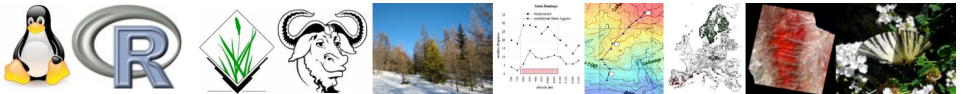
Summer-Autumn (May to November)

Country	Intercept	Std.Err	P-value	Signif	AV_DC	Std.Err	P-value	Signif	AV_ISI	Std.Err	P-value	Signif	Res.Std.Err	R-sq	Adg.R-sq	p-value
EUmed	4.8504	0.1733	0.0000	***	0.0036	0.0003	0.0000	***	0.6462	0.0293	0.0000	***	0.6058	0.875	0.8739	.0000
PT	1.0777	0.3257	0.0000	***	0.0048	0.0005	0.0000	***	0.8372	0.0540	0.0000	***	1.2880	0.788	0.7855	.0000
ES	4.0657	0.2509	0.0000	***	0.0030	0.0003	0.0000	***	0.4862	0.0335	0.0000	***	0.8978	0.749	0.7460	.0000
FRmed	1.3545	0.2813	0.0000	***	0.0049	0.0006	0.0000	***	0.8919	0.0760	0.0000	***	1.1430	0.707	0.7030	.0000
IT	2.8087	0.2195	0.0000	***	0.0039	0.0004	0.0000	***	0.9184	0.0562	0.0000	***	0.7673	0.816	0.8136	.0000
GR	1.8402	0.3019	0.0000	***	0.0033	0.0003	0.0000	***	0.5514	0.0418	0.0000	***	1.1070	0.725	0.7215	.0000

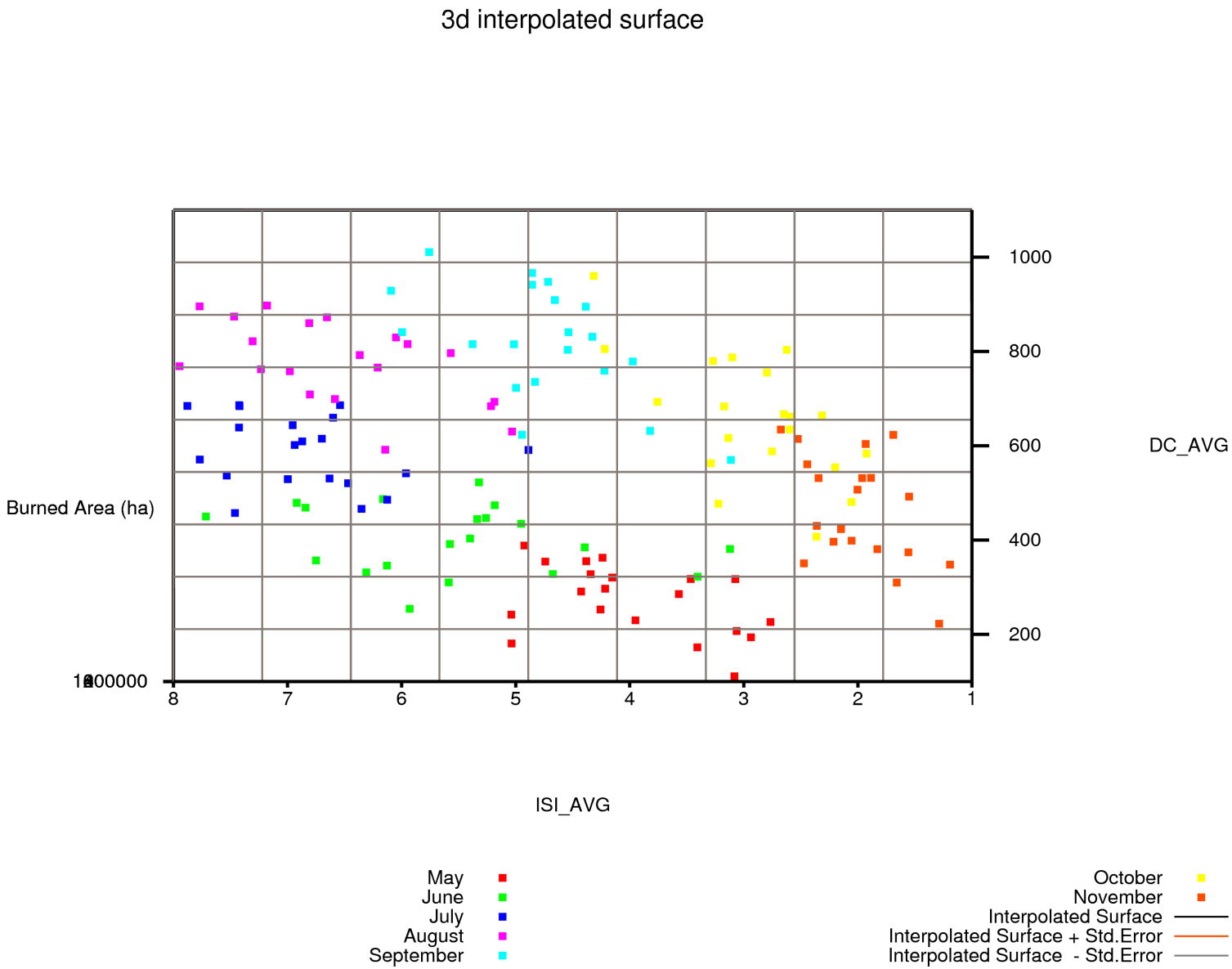
Winter-Spring (December to April)

Country	Intercept	Std.Err	P-value	Signif	AV_FFMC	Std.Err	P-value	Signif	AV_DC	Std.Err	P-value	Signif	AV_ISI	Std.Err	P-value	Signif	Res.Std.Erro	R-sq	Adg.R-sq	p-value
EUmed	-1.8339	0.7241	0.0129	*	0.1447	0.0104	0.0000	***	0.0018	0.0007	0.0150	*					0.76	0.691	0.6854	0.0000
PT	1.1440	0.4329	0.0097	**									1.3905	0.1615	0.0000	***	0.7569	0.457	0.4511	0.0000
ES	1.4753	0.4300	0.6680		0.0820	0.0270	0.0031	**	0.0017	0.0009	0.0650	.	0.3241	0.1757	0.0681	*	1.5000	0.503	0.5031	0.0000
FRmed	1.2196	1.6297	0.4561		0.0487	0.0317	0.1277						0.6987	0.2824	0.0151	*	0.3703	0.357	0.3573	0.0000
IT	-0.6097	1.2776	0.6343		0.0770	0.0254	0.0032	**	0.0033	0.0008	0.0001	***	0.8480	0.2425	0.0007	***	0.8796	0.703	0.6937	0.0000
GR	-4.5568	1.8016	0.0131	*	0.0940	0.0328	0.0051	**					0.7161	0.2476	0.0047	**	1.9450	0.594	0.5860	0.0000

Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1



Results: Model fitting



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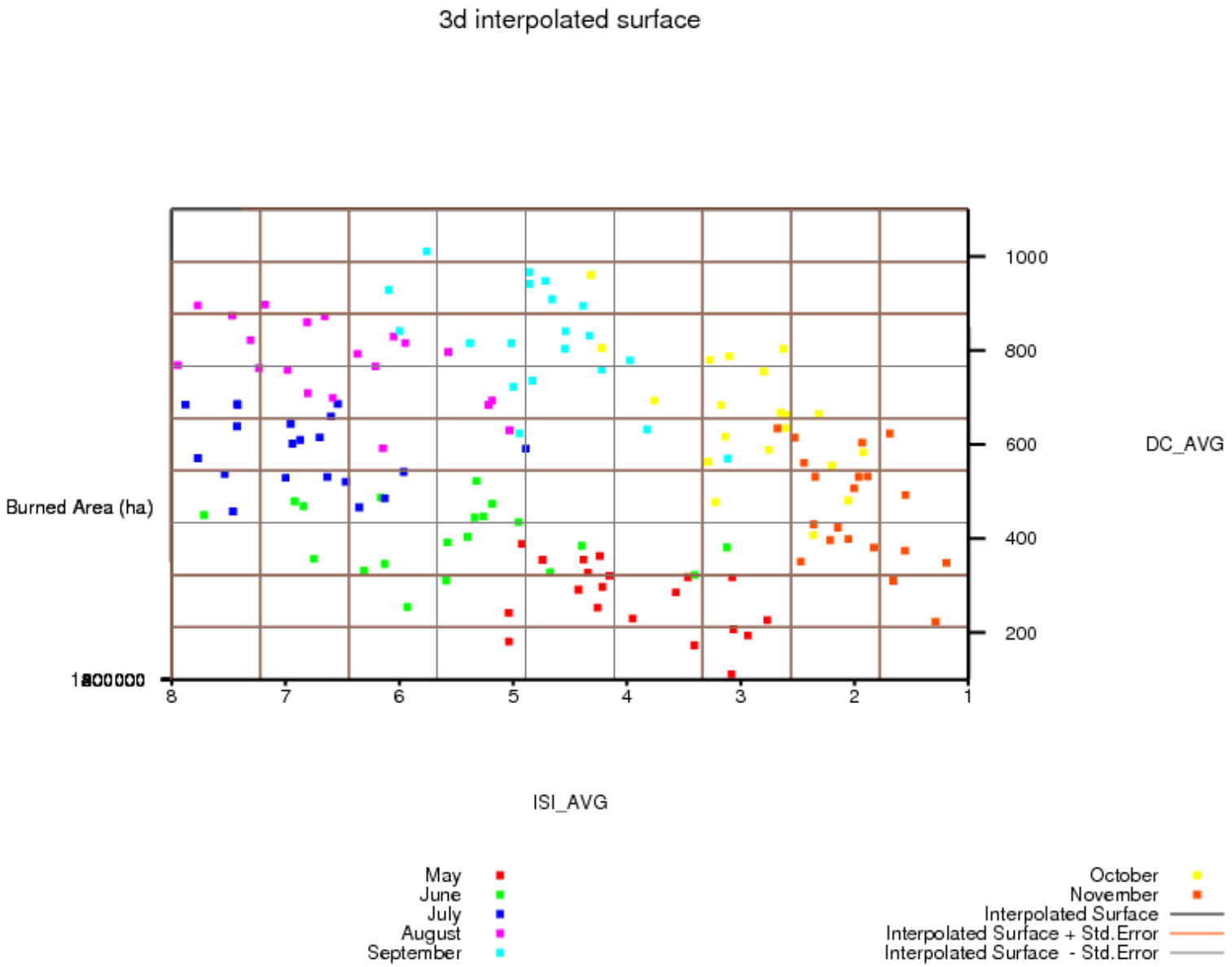

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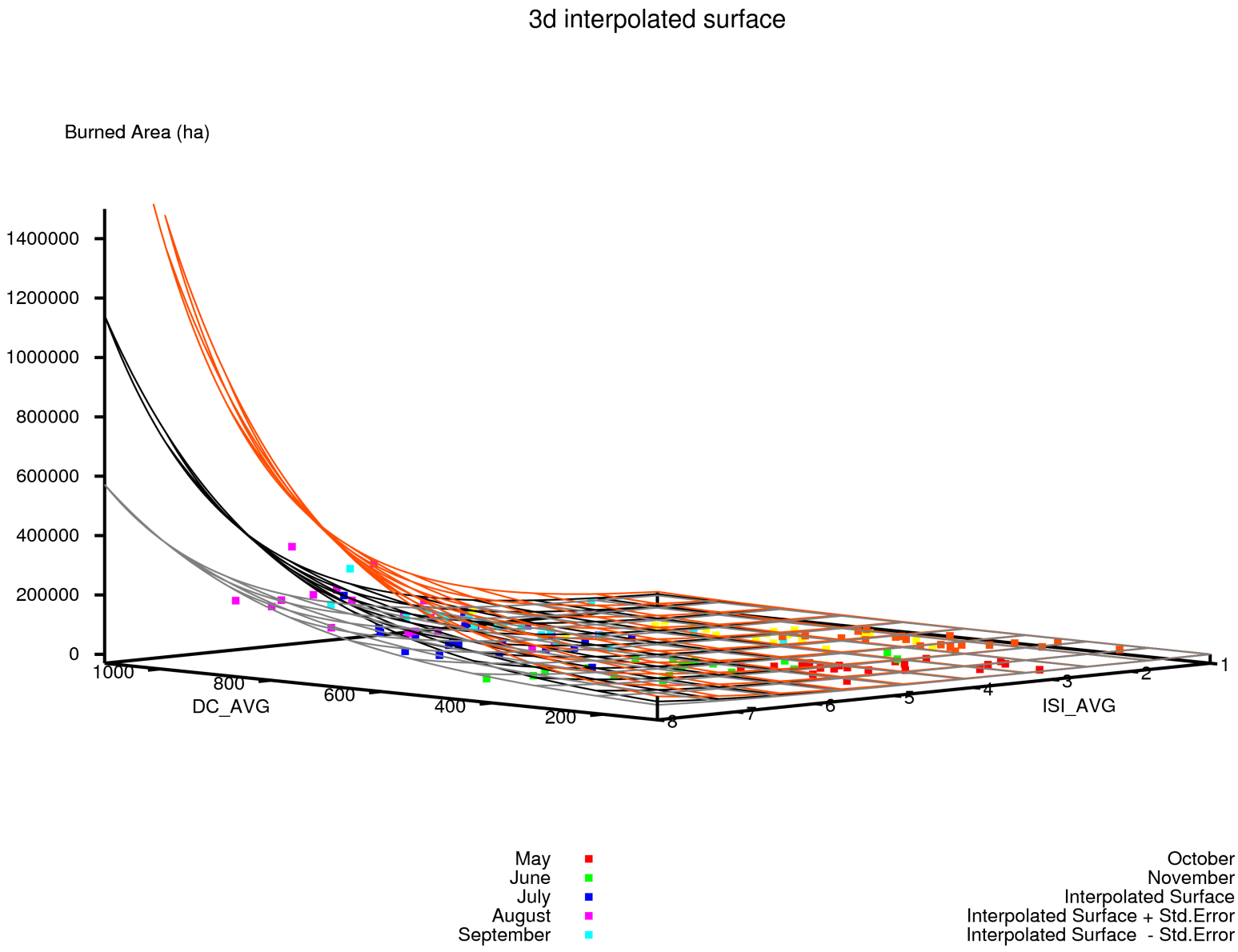
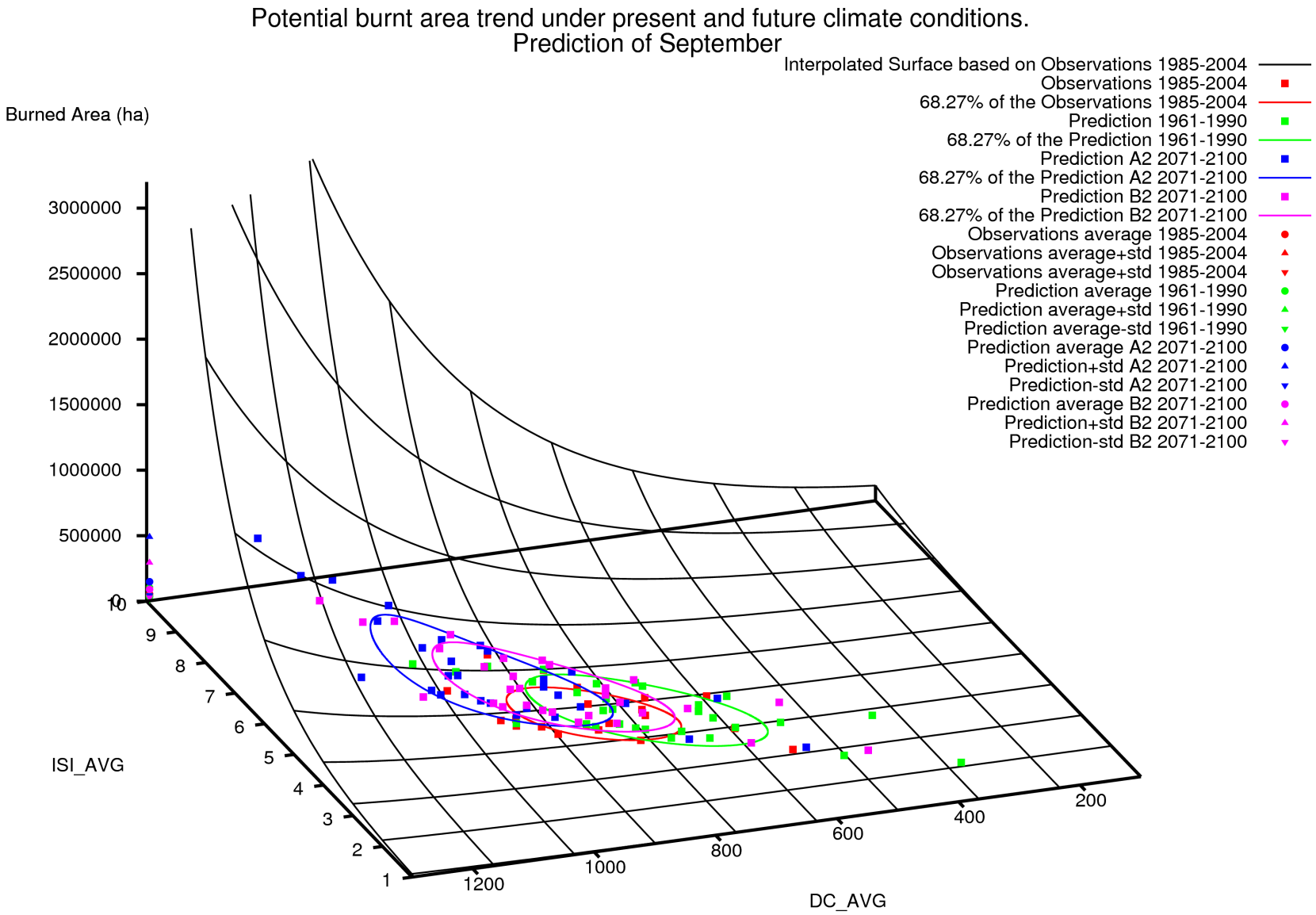
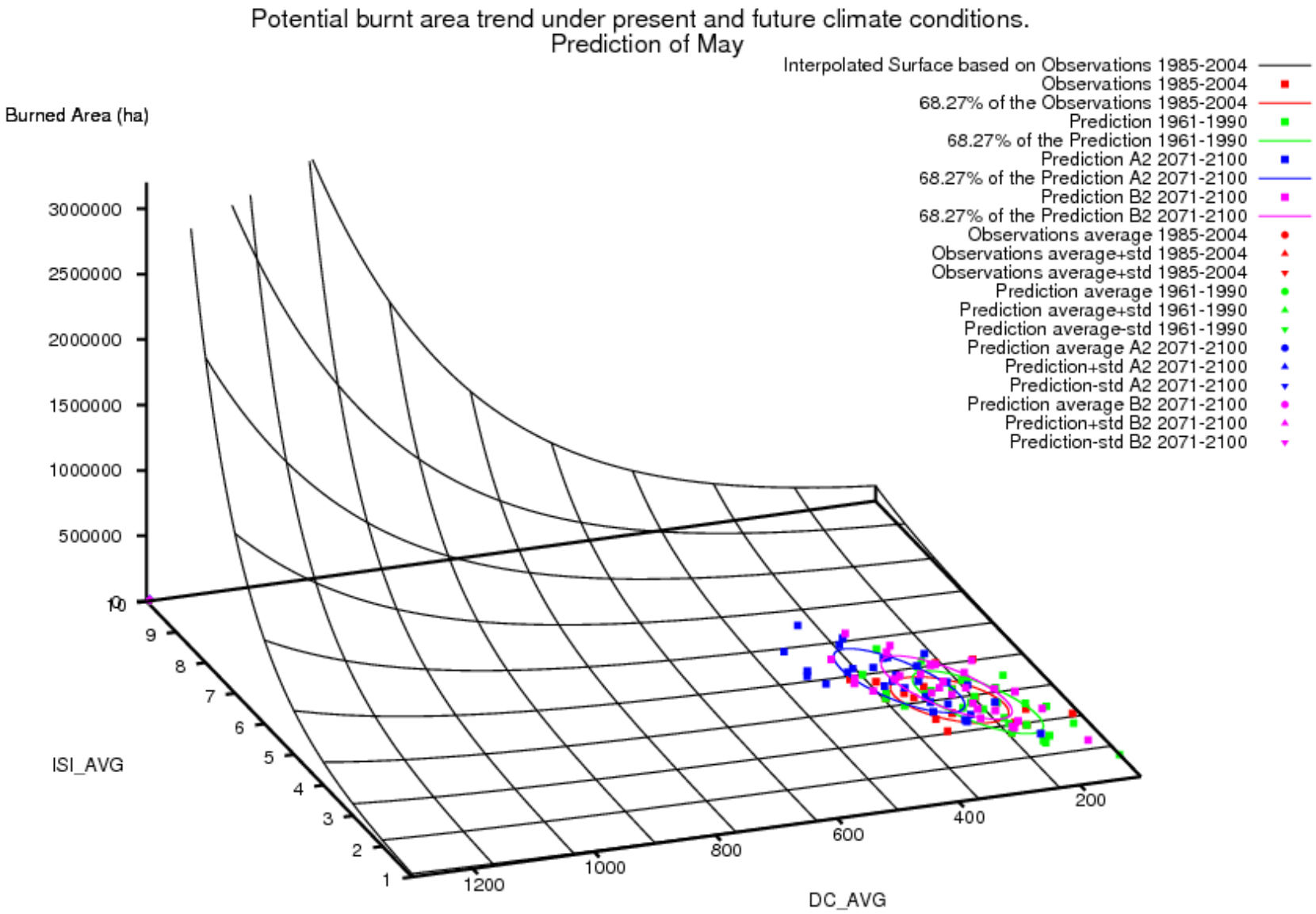


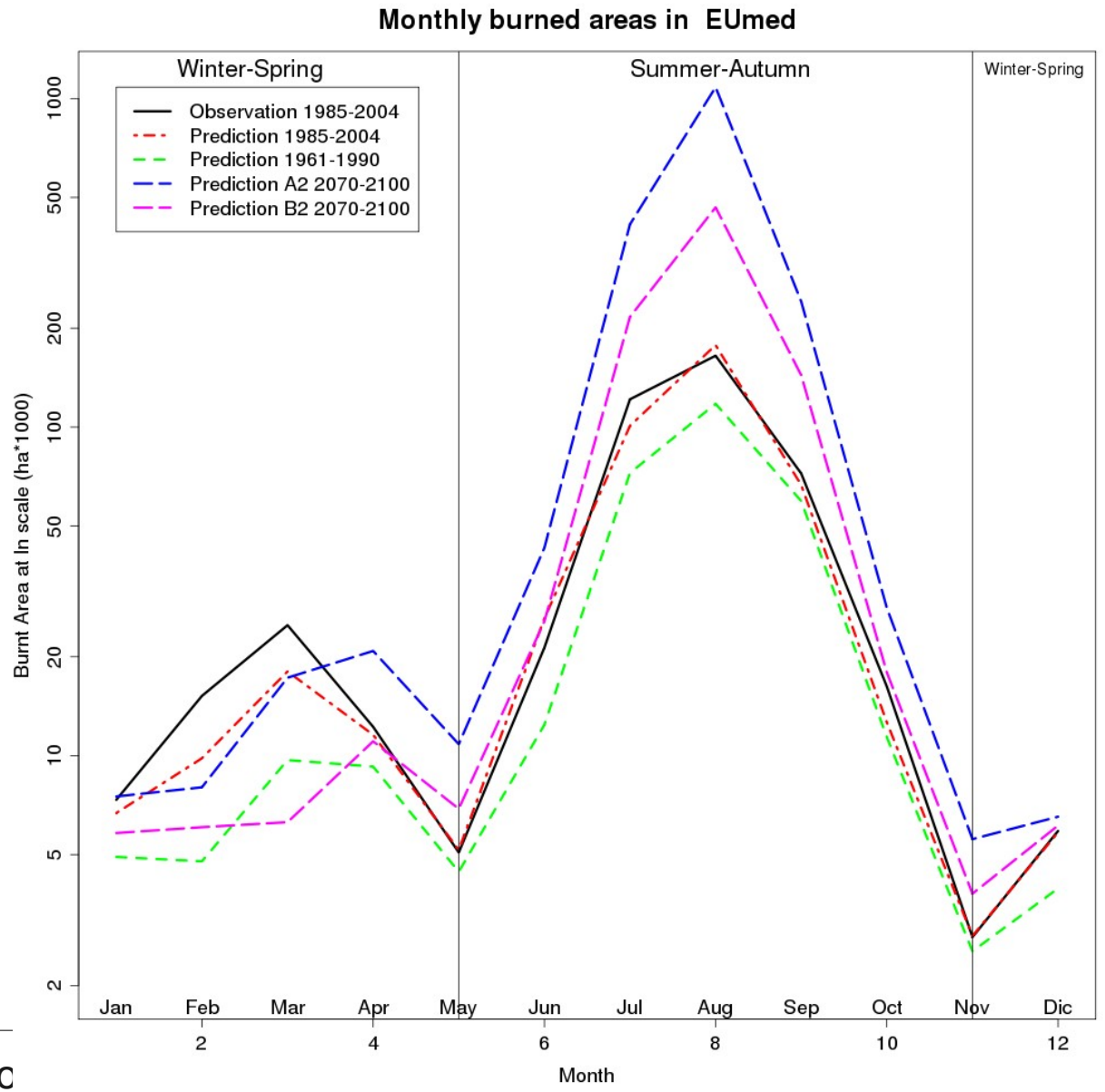
Results: Present and future trends



Results: Present and future trends



Results: Inter-annual variability



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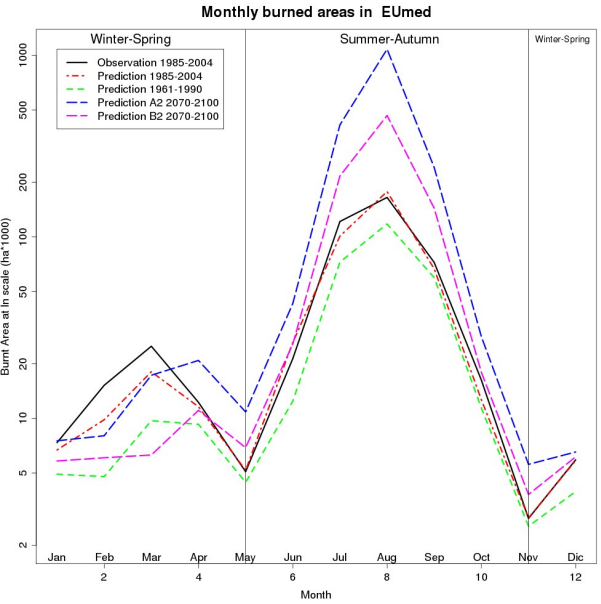
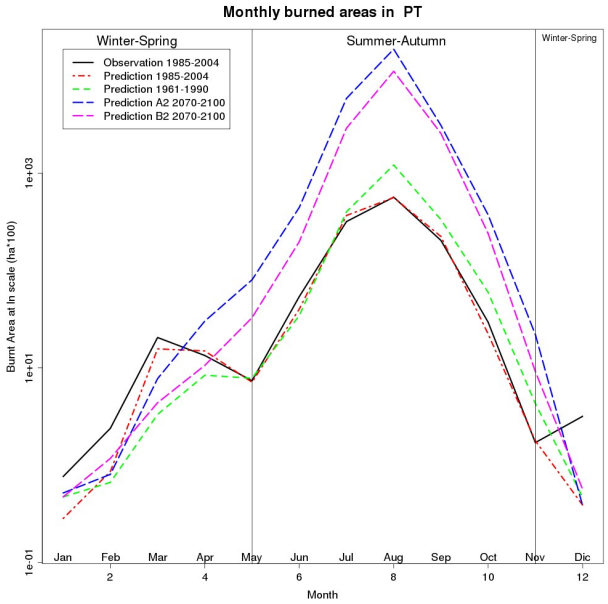
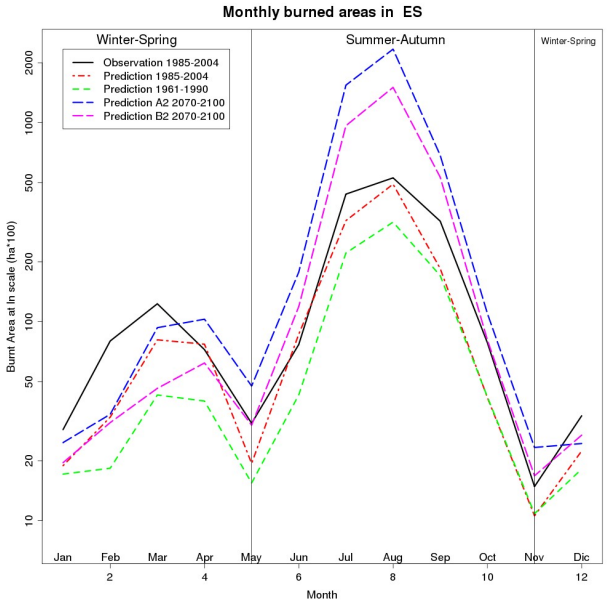
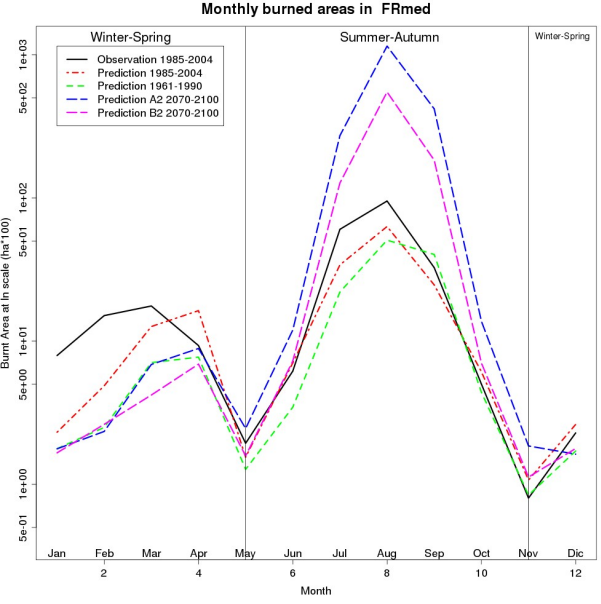
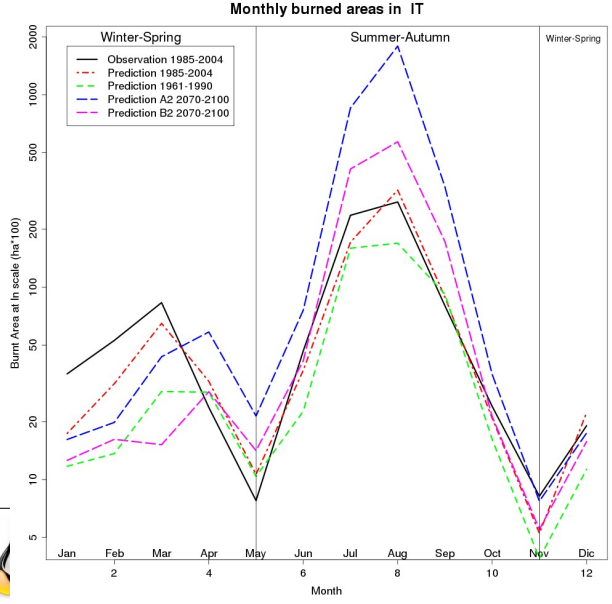
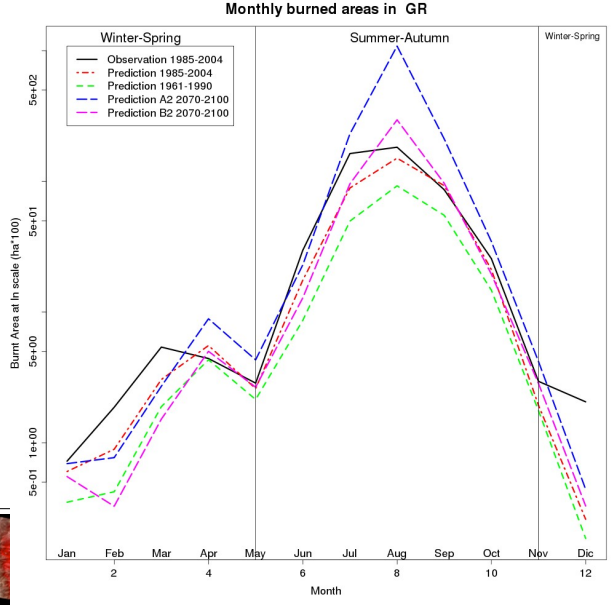


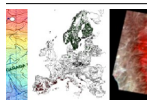




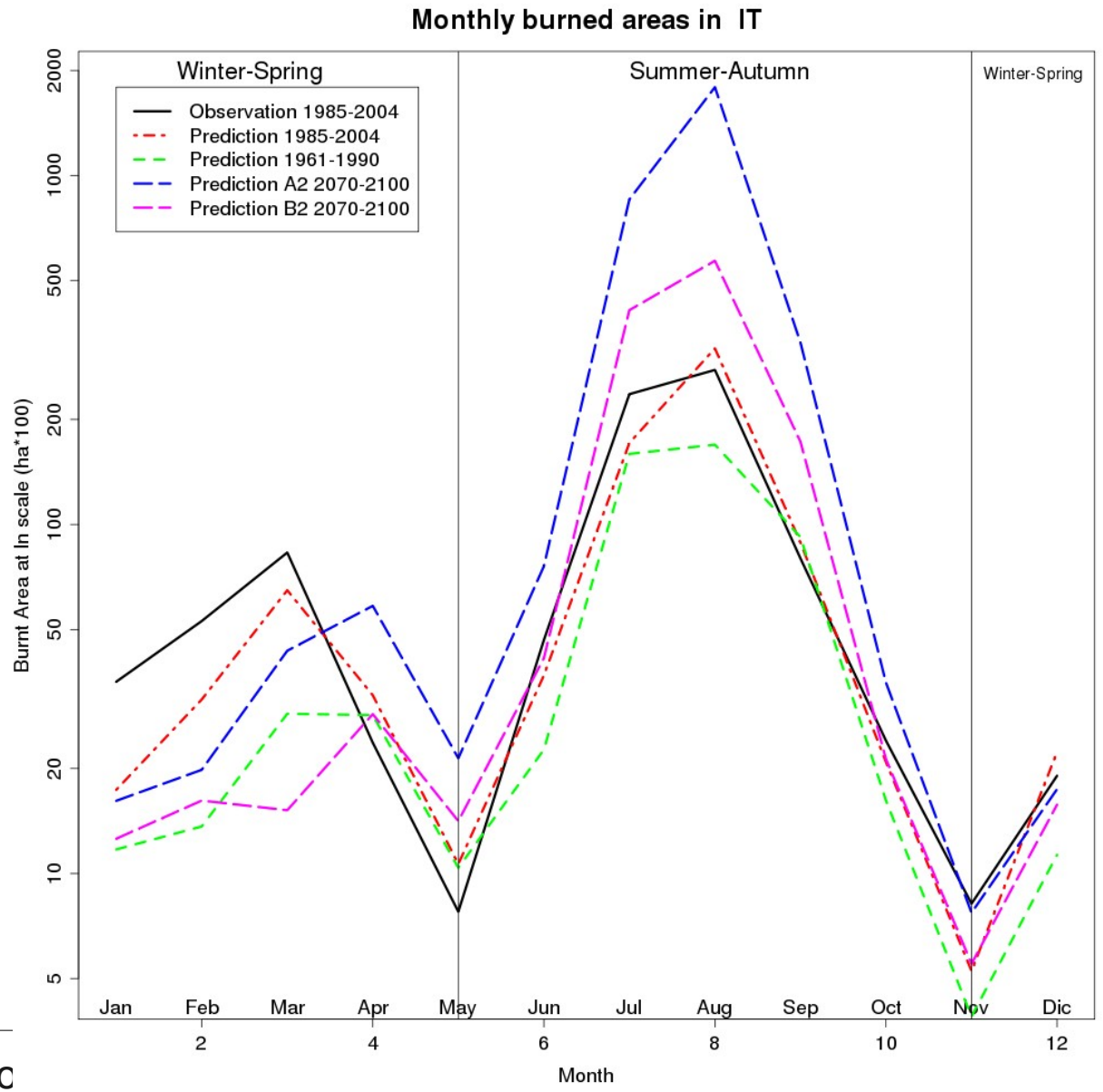




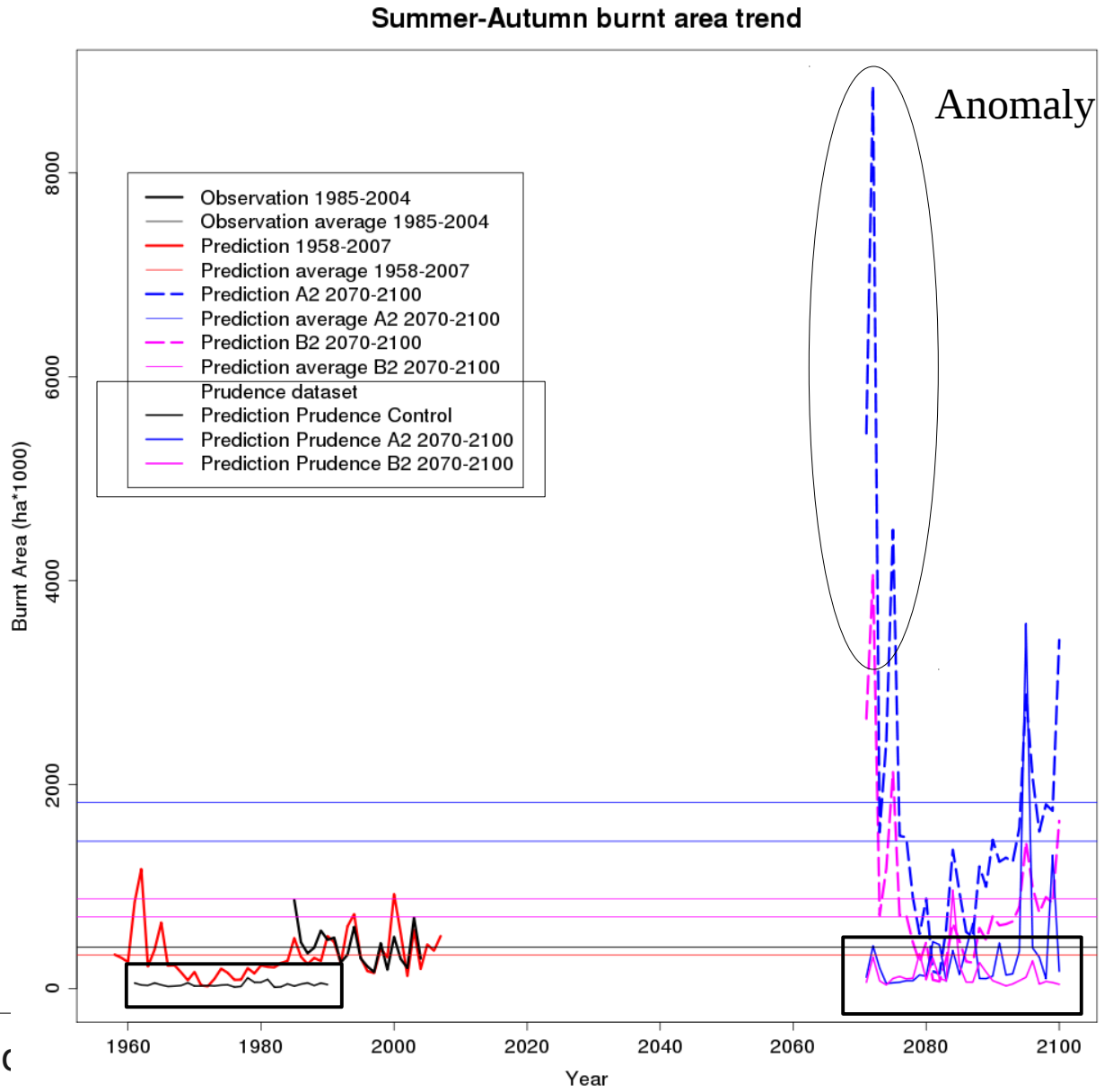




Results: Inter-annual variability



Results: Annual variability

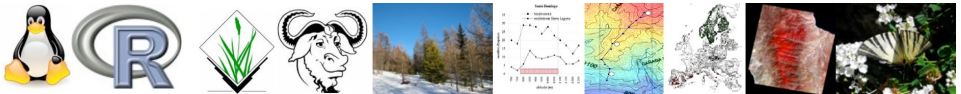


Conclusions

- Ability of FWI/sub-index to predict Monthly burnt area
  - Good correlation for the Summer-Autumn fire season (by DC-ISI)
  - Discrete correlation for the Winter-Spring fire season (by FFMC DC ISI)
- Potential prediction under future climate change (drastically increment of burnt area)
- Foreseen in the use of obtained models to predict monthly forecasting

Improvements

- Use several future climatic change models (ensemble prediction)
- Building up model at regional scale



Hardware:

- Server-cluster of twelve 32bit bi-processor machines running Linux operating system (running bash scripts in processing chains)

Software: (under the GNU General Public License)

- Weather data manipulation (NetCDF-GRIB)-> CDO - Climate Data Operators
- Geoprojection change -> GDAL library
- FWI/sub-indexes calculation and average -> AWK language
- Model fitting and prediction -> R
- 3d visualization -> GNUPLOT
- 2d graphs -> R

Thanks

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