THE ATLANTIC MULTIDECADAL OSCILLATION (AMO) AND THE FOREST FIRES IN FRANCE IN THE PERIOD 1980–2014

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Abstract: The study examines the connection between the Atlantic Multidecadal Oscillation (AMO) and the forest fires (the annual number of fires, the annual burned area and the average burned area per fire) in France in the period 1980–2014. In order to determine the strength of the correlation connection Pearson correlation coefficient (R) was used. Monthly, seasonal and annual values of AMO were used in calculations, and one year phase shift was performed (the values for the previous year were used). In burned area the highest values of R on the monthly level were recorded for April (-0.474) and January (-0.470), and on the seasonal level for winter (-0.459) and spring (-0.447). These values are statistically significant at the level of p≤0.01. By phase shifting the highest level of correlation was obtained for the autumn (-0.489). In the average burned area per fire on a monthly level the highest value of R was for January (-0.522), and on seasonal for winter (-0.506). By phase shifting the highest value of R was obtained for autumn (-0.522). In the number of fires the highest values were recorded by phase shifting for September (-0.382) and autumn (-0.337). All R values recorded during the study had a negative sign (the correlation is antiphase). In addition, downward trends were determined for all three examined indicators of forest fires in the researched period (1980–2014). Results of the research could be used as a basis for the long-term forecast of the risk of forest fires, and the approach used in the research could be applied for the other areas of the world. However, the more detailed research of the effects of other teleconnections are necessary.

Key words: AMO, forest fires, burned area, France

Introduction

The Atlantic Multidecadal Oscillation (AMO) is a pattern of natural variability of the Sea Surface Temperature (SST) in the northern part of the Atlantic Ocean. This teleconnection is characterized by positive (warm) and negative (cold) phases that last 20–40 years. The connection between AMO and forest fires was investigated mostly for North America. It was determined that the positive phase

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of AMO yields a higher frequency of fires in the western United States (Kitzberger, Brown, Heyerdahl, Swetnam, & Veblen, 2007), as well as in the western Colorado (Schoennagel, Veblen, Kulakowski, & Holz, 2007). The authors also state that forest fires are also influenced by El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO). During the positive phases of AMO the greatest part of the USA has less precipitation than usual (Enfield, Mestas-Nunez, & Trimble, 2001). The connection between AMO and the drought in the USA was also noticed by McCabe, Palecki, and Betancourt (2004), Nigam, Guan, and Ruiz-Barradas (2011) and Hu, Feng, and Oglesby (2011). However, Mo, Schemm, and Yoo (2009) find that AMO has small direct influence on the drought in the USA and that the main influence is via ENSO. Having in mind that Wyatt, Kravtsov, and Tsonis (2012) state that AMO signal extends over the northern hemisphere, the aim of the research was to determine the connection between AMO and the forest fires in some of the European countries. France was selected as a country that is among the most threatened by forest fires, and is exposed to the influence of the Atlantic Ocean.

Material and methods

The study used monthly, seasonal and annual values of AMO index. The data were taken from Earth System Research Laboratory, National Oceanic & Atmospheric Administration, US. Department of Commerce:

> http://www.esrl.noaa.gov/psd/data/correlation//amon.us.long.data
> http://www.esrl.noaa.gov/psd/data/correlation/amon.us.data

The data on the forest fires in France in the period 1980–2014 covered:
  – Total annual number of forest fires (N)
  – Total annual burned area (P)
  – The average burned area per fire (P/N)

The data were taken from the European Commission Report — Forest Fires in Europe, Middle East and North Africa 2014, Joint Report of JRC and Directorate — General Environment (2015):
  – http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

Pearson correlation coefficient (R) on the basis of linear trend was used for the calculation of correlation, and statistical significance was tested on $p \leq 0.05$ and $p \leq 0.01$. Monthly, seasonal and annual AMO values were used in the calculations, and one year phase shift was also performed (values from previous year were used). Calculation for the same year did not include data for the period September to December, since the main fire season in France ends in September.

Statistical significance of linear trend was determined for (n-2) and on the basis of the coefficient of determination (R^2, attached to the charts). For the testing of the significance of linear trend t test was used:

$$t = R\sqrt{\frac{n-2}{1-R^2}} \qquad (1)$$

wherein R^2 — the coefficient of determination; n — the length of the series.

Results and discussion

In France in the period 1980–2014 a trend of reduction of the annual number of forest fires was noted (Figure 1). On the basis of table values it was determined that the trend is statistically significant at p≤0.05.
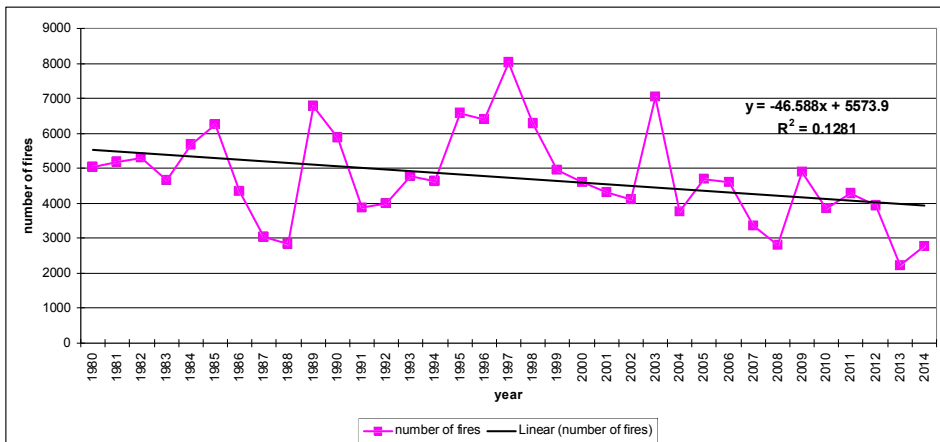

Figure 1. Annual number of forest fires in France (1980–2014) with the trend line

Source of data: http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

In the same period a downward trend of the total annual burned area was also noted (Figure 2). On the basis of Table values it was determined that the trend is statistically significant at p≤0.01.
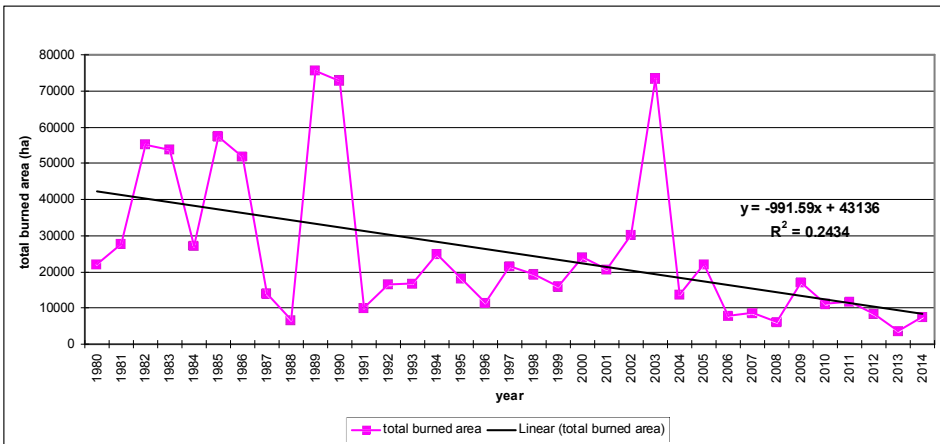
Figure 2. Annual burned area in France (1980–2014) with the trend line

Source of data: http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

In accordance with the previously shown data average burned area per fire has decreasing trend in the period 1980–2014 (Figure 3). On the basis of table values it was determined that the trend is statistically significant at $p \leq 0.01$.
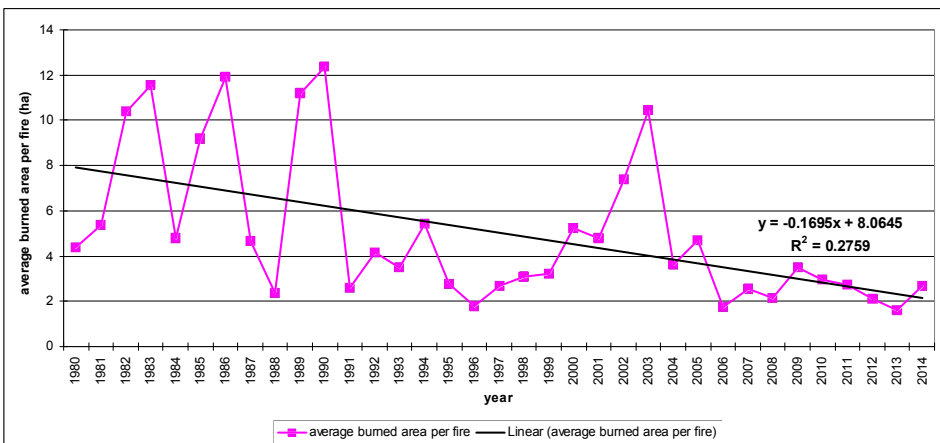

Figure 3. Average burned area per fire in France (1980–2014) with the trend line

Source of data: http://forest.jrc.ec.europa.eu/effis/reports/annual-fire-reports/

Table 1 shows the results of the research of the correlation between AMO and the forest fires in France (1980–2014).

Table 1. Pearson correlation coefficient (R): AMO — forest fires in France in the period 1980–2014 (N — the number of fires, P — the annual burned area, P/N — the average annual burned area per fire)

	AMO – monthly values											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
N	-0.198	-0.208	-0.230	-0.211	-0.119	-0.088	-0.108	-0.112	-	-	-	-
P	-0.470**	-0.424*	-0.394*	-0.474**	-0.417*	-0.321	-0.286	-0.284	-	-	-	-
P/N	-0.522**	-0.450**	-0.391*	-0.489**	-0.475**	-0.401*	-0.363*	-0.358*	-	-	-	-
	AMO – seasonal and annual values											
	Winter		Spring		Summer		Autumn		Annual			
N	-0.217		-0.193		-0.106		-		-0.148			
P	-0.459**		-0.447**		-0.303		-		-0.382*			
P/N	-0.506**		-0.473**		-0.382*		-		-0.447**			
	AMO – monthly values (phase shift – 1 year)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
N	-0.039	-0.099	-0.106	-0.132	-0.174	-0.261	-0.312	-0.298	-0.382*	-0.352*	-0.242	-0.220
P	-0.145	-0.235	-0.261	-0.397*	-0.405*	-0.368*	-0.391*	-0.386*	-0.481**	-0.495**	-0.449**	-0.432**
P/N	-0.233	-0.310	-0.333	-0.492**	-0.482**	-0.392*	-0.420*	-0.427*	-0.500**	-0.525**	-0.498**	-0.485**
	AMO – seasonal and annual values (phase shift – 1 year)											
	Winter		Spring		Summer		Autumn		Annual			
N	-0.062		-0.144		-0.298		-0.337*		-0.258			
P	-0.160		-0.371*		-0.391*		-0.489**		-0.424*			
P/N	-0.241		-0.456**		-0.423*		-0.522**		-0.481**			

* significant $p \leq 0.05$; ** significant $p \leq 0.01$

All R values are negative (the correlation is antiphase). At burned area and average burned area higher degrees of correlation with respect to the number of fires were recorded. In case of number of fires statistically significant R values were recorded only in phase shifting (AMO values from previous year); wherein, the highest value on a monthly level was recorded for September (-0.382), and on seasonal for autumn (-0.337).

With the burned area the highest R values on a monthly level were recorded for April (-0.474) and January (-0.470), and on seasonal for winter (-0.459) and spring (-0.447). These values are statistically significant at the level $p \leq 0.01$. When phase shifting for the period September to December values of R significant at $p \leq 0.01$ were also obtained. Accordingly, the highest R on the seasonal level is for autumn (-0.489) — Figure 4.
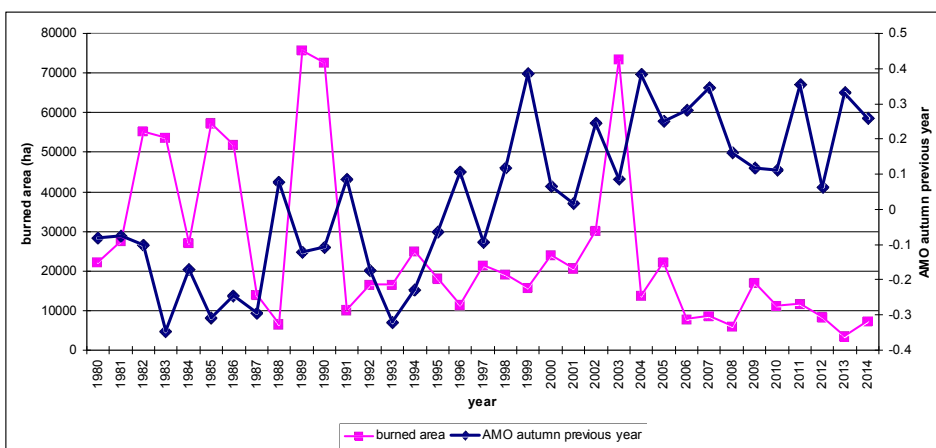
Figure 4. Annual burned area in France (1980–2014) and AMO values for the autumn of the previous year: R=−0.489 (significant p≤0.01)

At average burned area per fire higher R values were recorded in comparison to the annual burned area. At the monthly level the highest value is for January (-0.522), and at the seasonal one the highest is for winter (-0.506) — Figure 5. With phase shift the values of R for the period September–December are also significant at p≤0.01. At seasonal level the highest R value is for autumn (-0.522).
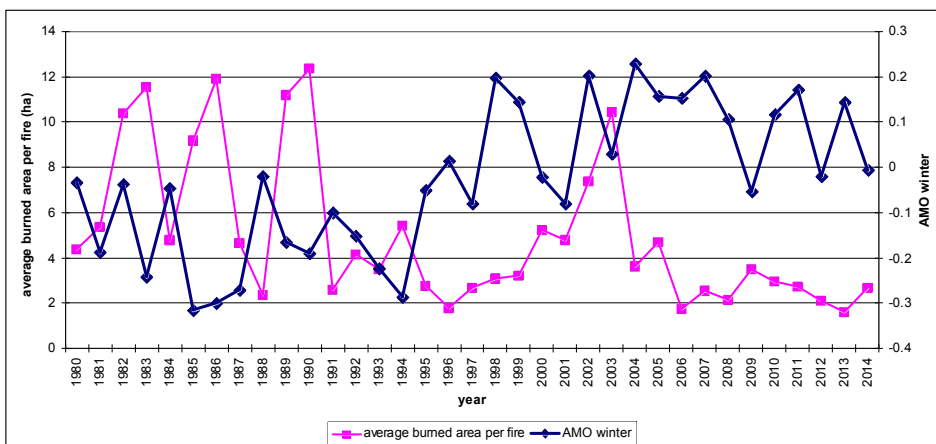

Figure 5. Average burned area per fire in France (1980–2014) and AMO values for winter: R=−0.506 (significant p≤0.01)

The obtained results confirm the antiphase connection between AMO and forest fires in France. In the case of the USA, Milenković and Barović (2015) determined synphase correlation between AMO and annual burned area. With phase shift (1 year) all recorded R values were significant at p≤0.01. However, in the analysis with AMO data for the same year, only the values for January and for winter were significant at p≤0.01. The results of this type of research could be used as a basis for the long-term forecast of the fire hazard. Thereby the total burned area is better indicator than the number of fires and the average burned area per fire. To this favor there is also a positive correlation between AMO and very large fires (over 10,000 ha of burned area) in Canada (Beverly, Flannigan, Stocks, & Bothwell, 2011).

For the longer term forecast of forest fires besides AMO it is necessary to analyze influences of other teleconnections, as well as their joint action. The studies should be carried out as a part of the climate research, whereby it should be kept in mind the opinion of Griffies and Bryan (1997) that the climate conditions of North Atlantic can be foreseen for periods longer than a decade.

When making conclusions about the influence of AMO on the fires the possibility should be considered that both phenomena are under the influence of the external forcing. Knudsen, Jacobsen, Seidenkrantz and Olsen (2014) point to the influence of solar and volcanic forcing at AMO. The influence of solar forcing to other teleconnections was also determined. Boberg and Lundstedt (2002) and Boberg and Lundstedt (2003) determined the influence of the solar wind on the North Atlantic Oscillation (NAO). On the other hand, the connection between the solar wind and the fires was confirmed (Radovanović et al., 2013; Radovanović et al., 2014; Radovanović, Vyklyk, Malinović-Milićević, Jakovljević, & Pecelj, 2014; Radovanović et al., 2015; Radovanović, Vyklyuk, Milenković, Vuković, & Matsiuk, 2015). Therefore, in future research more attention should be given to the influence of the solar wind (speed, temperature, density of the particles, the flow of protons and electrons), as well as to other teleconnections.

Conclusion

In France in the period 1980–2014 negative trends in the annual number of forest fires, total annual burned area and the average burned area per fire were recorded. The correlation between Atlantic Multidecadal Oscillation and listed indicators of forest fires for the studied period was negative (antiphase). With burned area and average burned area per fire higher values of Pearson's correlation coefficient (R) were recorded in relation to the number of fires. At

burned area R values statistically significant at p≤0.01 were recorded for January (-0.470) and April (-0.474), and with phase shift (previous year) for September (-0.481), October (-0.495), November (-0.449) and December (-0.432). At the seasonal level R for winter is -0.459, and for spring is -0.447, while with phase shift the highest value was recorded for the autumn (-0.489). For the average burned area per fire R values statistically significant at p≤0.01 were recorded for January (-0.522), February (-0.450), April (-0.489) and May (-0.475), and with phase shift for April (-0.492), May (-0.482), September (-0.500), October (-0.525), November (-0.498) and December (-0.485). For seasonal level R for winter is -0.506, and for spring is -0.473, while with the phase shift for spring it is -0.456, and for autumn is -0.522. With number of the fires the highest R values were recorded with phase shift — for September (-0.382) and for autumn (-0.337), whereby both values are statistically significant at p≤0.05. The results of this research may find use in a longer-term forecast of the risk of forest fires, but the more detailed research of influence of other teleconnections are necessary.

Acknowledgements

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