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XXIV International Conference Ecological Truth

Editors
Radoje V. Pantovic
Zoran S. Marković

EcoIst '16

12 – 15 June 2016
Hotel "BREZA" Vrnjacka Banja,
SERBIA

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THE CONNECTION BETWEEN ARCTIC OSCILLATION (AO) AND THE FOREST FIRES IN MANITOBA PROVINCE (CANADA)

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ABSTRACT

A downward trend of the annual number of forest fires and upward trends of the annual burned area and the average burned area per fire were recorded in Manitoba in the period 1970-2014. Pearson's correlation coefficient (R) was used in the research of the connection between Arctic oscillation (AO) and forest fires. The values of R significant at $p \leq 0.01$ were recorded for the annual burned area and summer AO (0.425) and July AO (0.402), as well as for the average burned area per fire and summer AO (0.445).

Key words: forest fires, Arctic Oscillation, Manitoba, Canada.

INTRODUCTION

The Manitoba Province is situated in the longitudinal center of Canada. It covers an area of 649,950 km^2, and at 2011 census had the population of 1,208,268 (density 2.2/km^2) [1]. More than half of the province population lives in the capital city of Winnipeg. Forests cover about 48% of the province territory. The forest types are: Boreal forest, Broadleaf/mixed forests and Small broadleaf forest stands. The most common conifers are jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea glauca* (Moench) Voss) and white spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenb.), and the most common deciduous tree species are poplars and aspens (*Populus* spp.), white birch (*Betula papyrifera* Marshall) and swamp birch (*Betula pumila* L.) [2]. Great share of conifers significantly contributes to the forest fire danger. The main fire season is April to October, and the annual number of fires and the annual burned area vary significantly. Extreme fire season was in 1989, when the weather conditions were exceptionally suitable for the spread of fire: high air temperature, prolonged drought and strong winds. During the season 24,500 people were evacuated (about 2.2% of the province population), and the burned area was over 3,280,000 ha (more than the territory of the Kingdom of Belgium) [3]. Besides weather conditions, the link between teleconnections and forest fires have also been researched. Teleconnections are defined as impacts of distant climate phenomena on the climate of a region, and the distances are measured in thousands of kilometers. Great part of research in this scientific field refers to certain parts of the USA [4-7]. As regards Canada, the connection between the fires in British Columbia and Niño3.4, Pacific Decadal Oscillation (PDO) and Arctic Oscillation (AO) with 1-2 year phase shift was determined [8]. The research of this type could be used as the basis for long-term forest fire forecasting. The main goal of our research was to determine the impact of the AO on forest fires in the central part of Canada.

MATERIAL AND METHODS

Monthly, seasonal and annual values of AO index were used in the research. AO index is calculated on the basis of the differences in air pressure between 45°N (high) and over Arctic (low). AO has a positive phase and a negative phase. The positive phase in North America is a warm phase. The AO data were downloaded from Climate Prediction Center, National Weather Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce [9].
The data on forest fires in Manitoba were downloaded from National Forestry Database, Canadian Forest Service [10] and refers to the period 1970-2014. The following data were used:

- Total annual number of fires (N)
- Total annual burned area (P)
- Average burned area per fire (P/N)

Pearson correlation coefficient (R) based on the linear trend was used for the calculation of correlation, and statistical significance was tested at $p \le 0.05$ and $p \le 0.01$. Monthly, seasonal and annual AO values were used in the calculations. One year phase shift was also performed, e.g. AO values from previous year were used. Data for the period September to December for the same year weren't used in the calculation, since the main fire season in Manitoba 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:

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

where R^2 - the coefficient of determination; n – the length of the series.

RESULTS

A decreasing trend in the annual number of forest fires was recorded in Manitoba in the period 1970-2014 (Figure 1). On the basis of table values it was determined that the trend is not statistically significant at $p \le 0.05$.

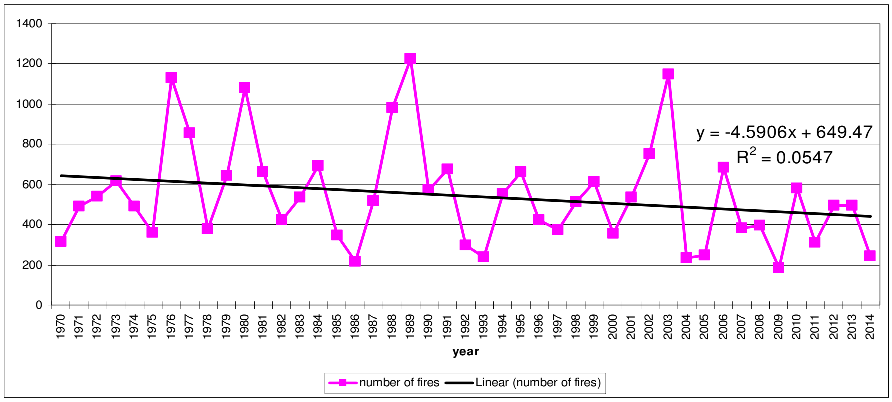

Figure 1. The annual number of forest fires in Manitoba (1970-2014) [10] with the trend line

In the same period an increasing trend in the total annual burned area was also noted (Figure 2). On the basis of table values it was determined that the trend is not statistically significant at p≤0.05.

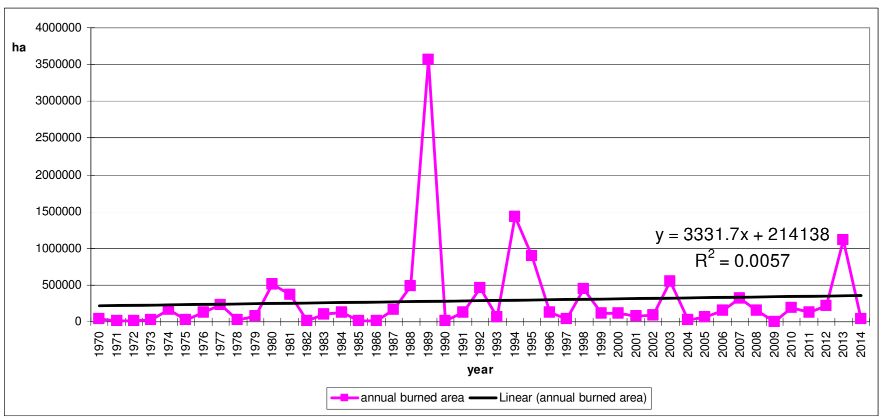

Figure 2. The annual burned area in Manitoba (1970-2014) [10] with the trend line

The average burned area per fire also had an increasing trend in the period 1970-2014 (Figure 3). On the basis of table values it was determined that the trend is not statistically significant at p≤0.05.

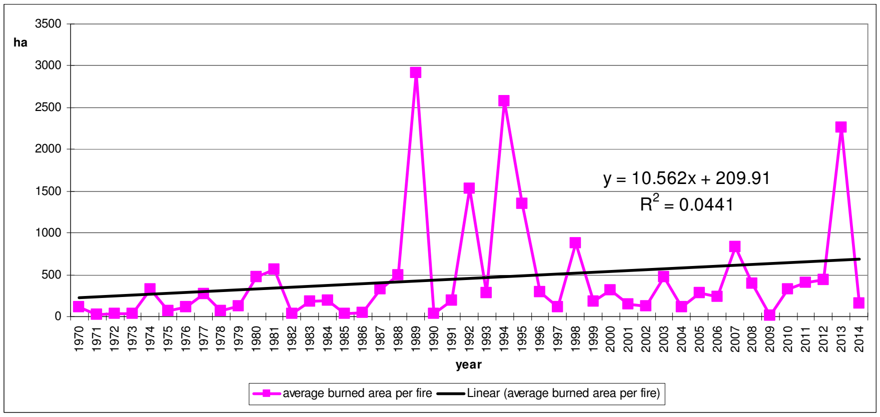

Figure 3. The average burned area per fire in Manitoba (1970-2014) [10] with the trend line

Table 1 shows the results of the research of the correlation between AO and the forest fires in Manitoba (1970-2014).

Table 1. Pearson correlation coefficient (R): AMO – forest fires in Manitoba in the period 1970-2014 (N – the number of fires, P – annual burned area, P/N – average annual burned area per fire)

	AO – monthly values											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	0.021	0.224	-0.054	-0.112	0.032	0.325*	0.273	0.157	-	-	-	-
P	0.254	0.299*	0.132	-0.133	0.149	0.229	0.402**	0.277	-	-	-	-
P/N	0.191	0.210	0.086	-0.132	0.157	0.245	0.366*	0.326*	-	-	-	-

	AO – seasonal and annual values				
	Winter	Spring	Summer	Autumn	Annual
N	0.105	-0.071	0.371*	-	0.079
P	0.304*	0.087	0.425**	-	0.366*
P/N	0.234	0.059	0.445**	-	0.339*

	AO – monthly values (phase shift – 1 year)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	0.173	0.107	0.071	0.020	-0.103	0.122	-0.034	0.069	0.239	-0.132	-0.102	-0.003
P	0.167	-0.029	0.115	-0.142	-0.312*	0.027	-0.050	0.060	0.276	-0.195	0.017	0.155
P/N	0.235	-0.013	0.180	-0.115	-0.317*	-0.025	-0.065	0.076	0.232	-0.300*	0.086	0.145

	AO – seasonal and annual values (phase shift – 1 year)				
	Winter	Spring	Summer	Autumn	Annual
N	0.126	0.019	0.093	-0.039	0.104
P	0.091	-0.091	0.027	0.017	0.065
P/N	0.170	-0.038	-0.001	-0.018	0.092

* significant p≤0.05; ** significant p≤0.01

All statistically significant R values for the same year (no phase shift) have a positive sign. For burned area, R values significant at p≤0.01 were recorded for summer AO (0.425) (Figure 4) and AO for July (0.402). The highest R value (0.445) was recorded in the case of average annual burned area per fire and summer AO (Figure 5). For the number of fires, R values significant at p≤0.05 were recorded only for summer

(0.371) and July (0.325). With one year phase shift statistically significant R values ($p \leq 0.05$) were recorded only for May (P, P/N) and October (P/N All statistically significant R values recorded in the calculations with phase shift have a negative sign.

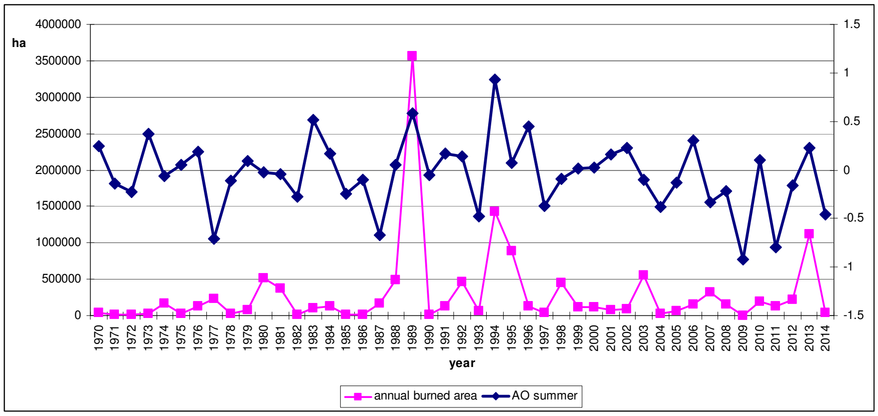

Figure 4. The annual burned area in Manitoba (1970–2014) [10] and AO values for summer [9]: R=0.425 (significant $p \leq 0.01$)

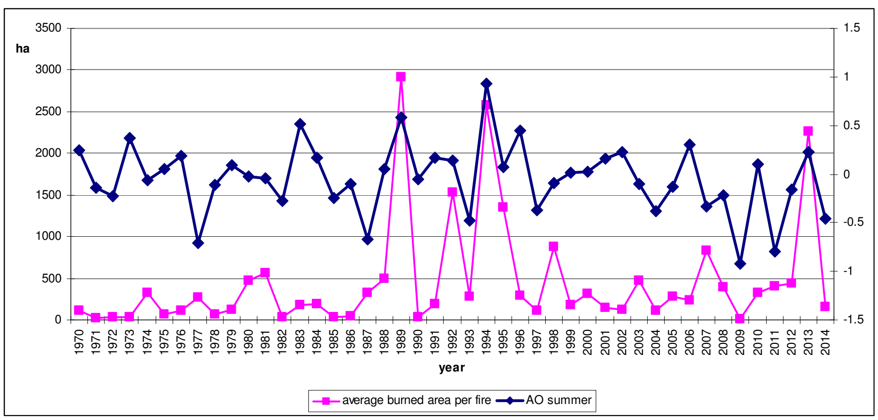

Figure 5. The average burned area per fire in Manitoba (1970–2014) [10] and AO values for summer [9]: R=0.445 (significant $p \leq 0.01$)

DISCUSSION

The results of the research point to the existence of the connection between AO and forest fires in Manitoba, primarily annual burned area and average annual burned area per fire. The highest R values were recorded for the summer, which is the main fire season in Manitoba. The results of the research are expected, since the burned areas are larger during the positive (warm) phase of AO. However, the connection is less strong compared to the connections recorded for fires in the USA and (Atlantic Multidecadal Oscillation) [11] and fires in France and AMO [12]. It is important to emphasize that high values of R were recorded with one year phase shift.

The results also lead to the conclusion that, besides AO, there are some other climate indices which affect forest fires in Manitoba. Thus, detailed climate research studies are necessary for the improvement of the long-term forecast of forest fires. Besides, it should be kept in mind that some teleconnections are under influence of solar wind, e.g. North Atlantic Oscillation (NAO) [13]. It is also confirmed that particles of solar wind cause wildfires in the USA [14-16]. For the previous, the research of climate indices and solar wind parameters are important in the fire forecast.

CONCLUSION

In the Manitoba Province (Canada), a downward trend of the annual number of forest fires was recorded in the period 1970-2014. Increasing trends were recorded in the case of the annual burned area and the average annual burned area per fire. In the research of the connection between Arctic Oscillation (AO) and the annual burned area, the values of Pearson's correlation coefficient (R) significant at $p \leq 0.01$ were recorded for summer AO (0.425) and AO for July (0.402). However, a higher value of R (0.445) was recorded for the average annual burned area per fire and summer AO. For the number of fires the highest values of R (significant at $p \leq 0.05$) were recorded for summer (0.371) and July (0.325). All these R values are positive. With one year phase shift the values of R are lower, and they are negatively significant at $p \leq 0.05$. The results of the research could be used in the fire forecast in Manitoba only after detailed investigations of other climate indices and solar wind parameters.

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