Lightning-induced fires in the Alpine region: An increasing problem

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Abstract: Fires ignited by lightning are not considered a serious problem in Europe and, in particular, the Mediterranean region where lightning is only a minor cause of forest fires. In the Central Alps and especially on the southern slope of the Alps, however, lightning fires are common in summer time, have increased in frequency, and resulted in increasing costs for their control. Based on historical records dating back over several decades, we analysed frequency, distribution pattern, differences in features as compared with man-induced fires, and relationships with meteorological conditions for representative regions of the Central Alps (cantons of Valais and the Grisons in Switzerland) and the southern slope of the Alps (Valle d'Aosta in Italy and canton of Ticino in southern Switzerland).
In the Alps, lightning-induced fires occur from May to October with a peak in July-August (78% of the events!). These fires differ from fires of anthropogenic origin in geographic distribution and duration. For example, lightning-induced fires occur at higher elevations on steeper relief and are usually harder to extinguish because of underground fires. In hot and dry summers, such as the drought-period in summer 2003, lightning-fires have become particularly frequent with significant higher burned area and fighting costs. This is an important point that has to be taken in consideration in view of the postulated climate change toward an increase in severity and frequency of prolonged summer drought-periods.

Keywords: natural forest fires, Alps, fire control, lightning-induced fire

1. Introduction

In most forest ecosystems lightning is the only natural source of ignition in natural fire regimes (Pyne *et al.*, 1996). The study of lightning-induced fires is therefore of

particular relevance for ecological reasons, lightning fires being a primary agent of forest renewal and succession (Podur *et al.*, 2003; Larjavaara *et al.* 2005a). From a management point of view, lightning-induced fires occur mostly in more remote locations and therefore detection and arrival of fire fighters for suppression activities are usually delayed. In case of intense lightning activity following a drought period, this causes an aggregation in time and space of lightning-ignited fires, which may put a strain on the initial attack by the fire brigades and thus lead to longer and more difficult fire fighting campaigns (Podur *et al.* 2003; Wotton & Martell 2005).

In the boreal and subalpine forests of Canada, lightnings cause around 60% of the forest fires and over 80% of the area burned (Nash & Johnson 1996). In the boreal forest of Fennoscandia there is a high density of lightning-ignited fires, especially in the southern part (0.1 to 0.2 fires/years 100 ha), whereas the humid part in the north has a very low density of lightning fires (0.01 to 0.03 fires/years 100 ha) (Granström 1993; Larjavaara *et al.* 2005b). As a consequence, research on lightning behaviour related to forest fire has a long tradition in the boreal regions (Podur *et al.* 2003). In the Mediterranean countries, lightning ignited fires have long been ignored by wildfire research as the events were regarded as statistically insignificant (1-2 % of the events according to Susmel 1973) in most regions. Recently however, the existence of a significant lightning fire regime has been reported for a Mediterranean area such as the NE coast of the Iberian Peninsula (Vasquez & Moreno 1998; Galan *et al.* 2002).

Frequency and distribution of lightning-caused forest fires depend on weather (drought or lack of precipitation, frequency and type of the thunderstorms and of the associated lightning discharges, ventilation), fuel (type, moisture, density and depth) and topography conditions (Flannigan & Wotton 1991; Anderson 2002; Cesti *et al.* 2005; Larjavaara *et al.* 2005a). Some authors suggest in this context that changes in summer weather conditions and land use may lead to an altered lightning-ignited fire regime in the future (Street 1982; Flannigan & van Wagner 1991; Balling et al. 1992; Weber & Stocks 1998).

In this paper we present and discuss data on the occurrence and characteristics of lightning-ignited fires in the Western and Central Alps.

2. Methods

Wildfire data for the Alpine region are scarce and heterogeneous. In Switzerland, systematic forest fire data have been collected for the canton of Ticino (100 years coverage) and the canton of the Grisons (25 years), whereas in the canton of Valais a historical survey of forest fire events is currently ongoing. In Valle d'Aosta (Italy) data have been collected since 1961. All existing data are collected in the forest fire data-base of WSL (Pezzatti *et al.* 2005). When complete, the information entered in the forest fire data-base includes date, ignition time and duration of the fire event, estimated cause, location (ignition point and burned perimeter), and total area burned.

For the Canton Ticino, we performed the analysis of the meteorological conditions related to lightning-ignited fires. To this purpose, we calculated the Canadian Forest Fire Weather Index (FWI) and the related subindexes (FFMC, DMC, DC) (van Wagner 1987, Lawson *et al.* 1996), for the meteorological station of Meteoswiss located in Locarno-Monti (Fig. 1).

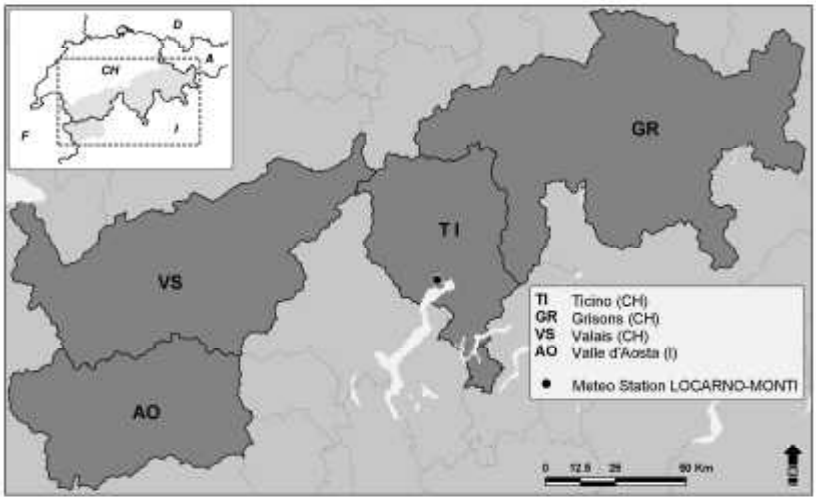

Fig. 1. Study area.

In the same meteorological station for the period 1982-2004 the daily number of lightning discharges in a radius within 3 and 300 km was registered by means of electric field antennas. We consider this information as a rough estimation of the discharge activity since the incoming electromagnetic signal was not verified during registration (possible other sources, number of return strokes, etc.) and a lightning location system was missing.

Due to the inconsistency of the data available, results are presented using different data sets according to the availability and reliability of the information.

3. Results and discussion

The relative importance of lightning-caused fires increased in the last decades in the Alps. For the study area covering the Swiss Alps and Valle d'Aosta, lightning was the cause of 4.3% of the total number of fires in the 1980ies. This percentage rose to 8.1% for the period 1991-2004. The highest proportion of lightning-ignited fires with respect to the total number of forest fires was registered in the canton of the Grisons (26.8% in the period 1991-2004). For the period 1991-2004, the highest concentration of lightning-ignited forest fires took place in the canton Ticino where 0.25 events per year and 100 km^2 were registered. This means that 33.8% of all forest fires events happened between May and October in canton Ticino in the last 15 years were ignited by lightning.

There is a great annual variability among and within each single region (Fig. 2). Not even the extremely dry and hot summer 2003 was a lightning-fire year throughout the study area: significant high frequency of lightning-ignited fires is reported for the Grisons and valle d'Aosta, whereas in the Canton of Valais, very few lightning-fire events occurred, probably because of the different (low) thunderstorm and strike frequency in the area.

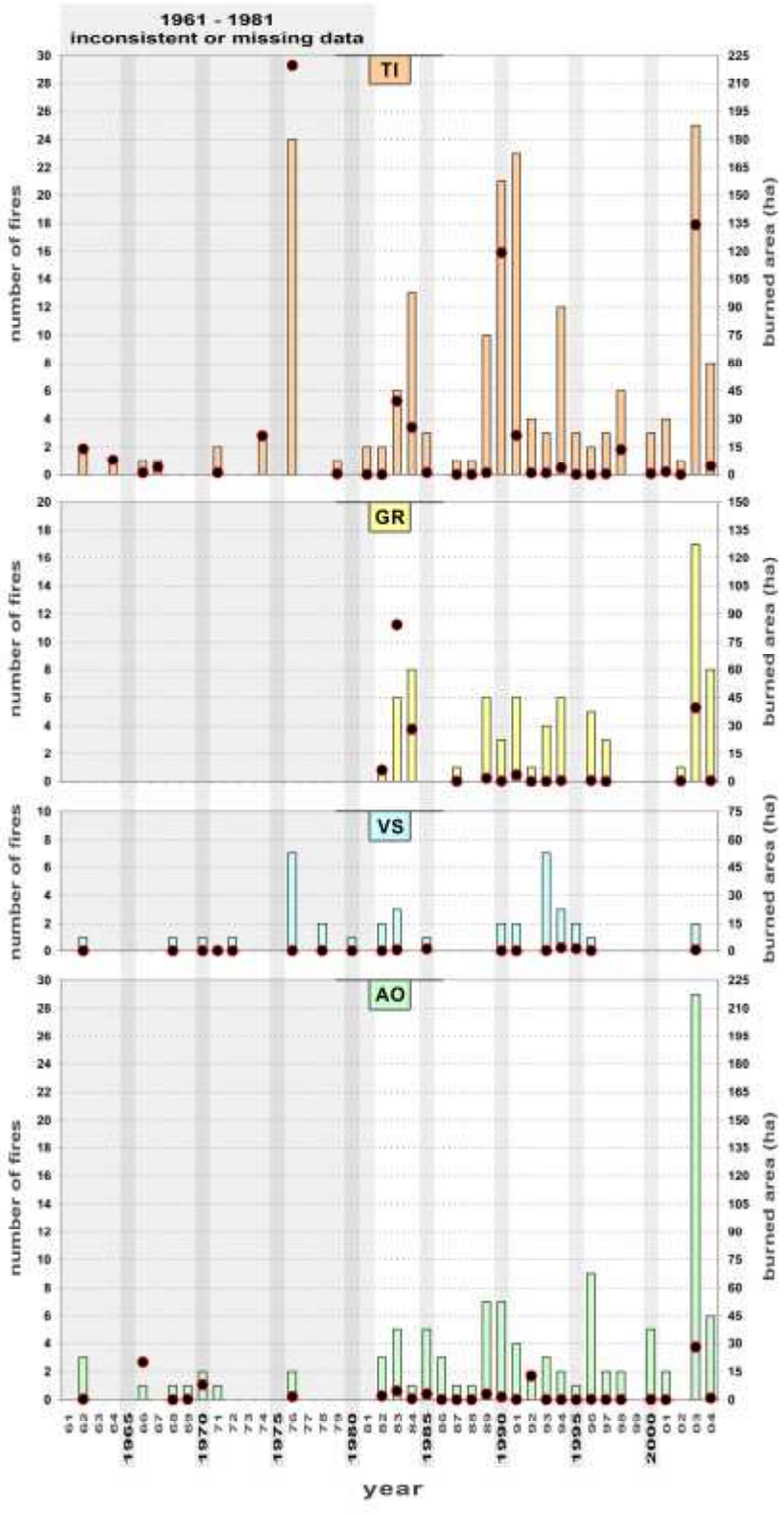

Fig. 2. Annual frequency (bars) and area burned (dots) by lightning-ignited fires in the study area for the period 1961-2004 (TI = Ticino; GR = Grisons; VS = Valais; AO = Valle d'Aosta).

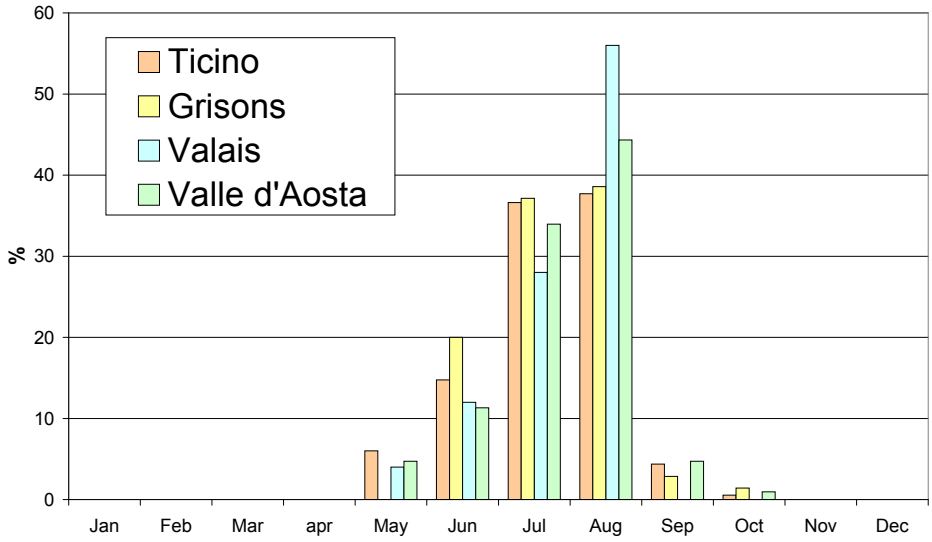

Fig. 3. Monthly distribution of lightning-ignited fires in the study area in the period 1991-2004

In the Alps, lightning-caused forest fires usually occur between May and October (Fig. 3). Similar to what other authors reported for the boreal area (Granström 1993; Wotton & Martell 2005), the bulk of the events (90.9%) takes place during the warm summer months of June to August, with some differences within the regions because of the different elevation, expositions and start of the warm season.

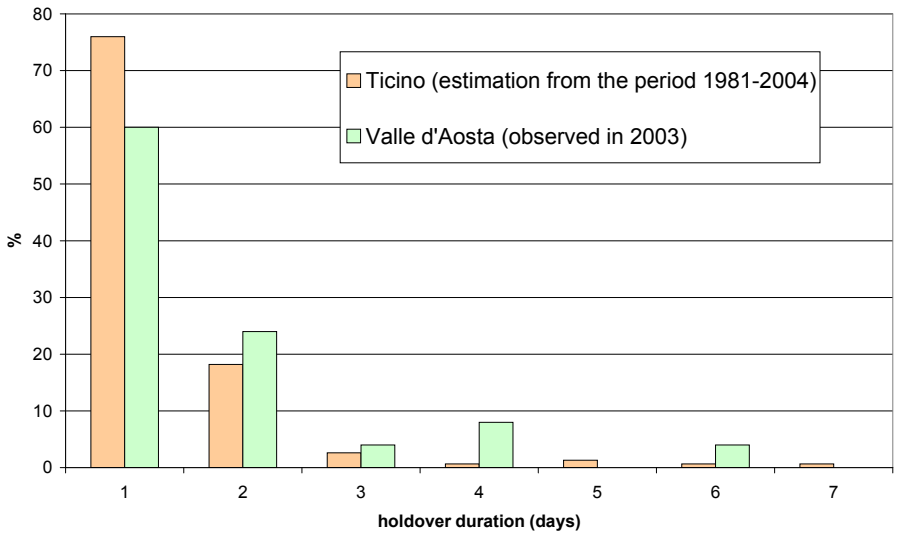

Fig. 4. Time elapsing between lightning-strike and fire detection in the Alps.

In the Alps, very few observations exist about the process and the time usually elapsing between ignition through a lightning strike and the detection of the fire (holdover duration). Similar to what is reported for the Boreal and subalpine forests of Canada (Nash & Johnson 1996; Wotton & Martell 2005), there is a time lag (holdover duration) between

the lightning strike and the detection of the fire (Fig. 4). For the canton of Ticino we estimated the holdover duration searching backwards for the first days with discharges from the time of the notification of a lightning-ignited fire. This may cause an underestimation of the holdover duration since we do not have precise information about the location of the discharges. Generally speaking, the shorter holdover duration in the Alps (96-98% of the events are detected within 3 days) compared to Canada (only 76-78% of the events are detected within 3 days, Nash & Johnson 1996; Wotton & Martell 2005) may be due to the greater chance of a starting fire to be detected in the Alps (higher population density and favourable detecting conditions on the steep slopes).

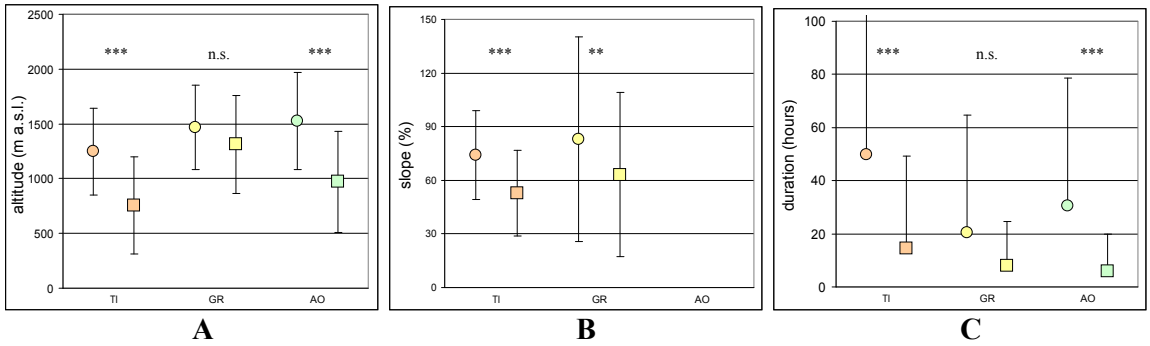

Fig. 5. Different characteristics of lightning-ignited (dots) and anthropogenic (squares) fires in the vegetation period (May to October). A = altitude of the ignition point; B= mean slope of the burned area; C = duration of the fire event; period 1981-2004 (TI = Ticino; GR = Grisons; AO = Valle d'Aosta).

In contrast to the situation in the boreal forests of Canada (Weber & Stocks 1998), fires caused by lightning were only responsible for 4.1% of the total burned area in the Alps (period 1991-2004). Similar to what Vasquez & Moreno (1998) report for peninsular Spain, lightning-caused fires as a rule produce small-size fires. In fact, lightning usually causes fires in the coniferous forests at high elevation in the Alps. Such fires are often started by a underground ignition that may keep smouldering locally for days and weeks. Lightning-ignited fires thus tend to be clustered toward higher elevation, steeper slopes and to last longer before being extinguished than the anthropogenic fires that occur in the same period (Fig. 5). The differences are high significant (non parametric Mann-Whitney U-test) for all the analysed characteristics in the canton of Ticino and Valle d'Aosta. This is not the case in the canton of the Grisons, where the general high elevation of the territory reduces the difference between naturally induced and anthropogenic fires. In fact, human caused fires usually occur in areas with high population density or improved access (Weber & Stocks 1998).

In extreme drought-summers or under particular fuel and topographic conditions, lightning-fires are more likely to turn into surface or crown fires causing a significant increase in the fire frequency and/or burned area. This was the case in 1976, 1983-84, 1990-91 and 2003 in Ticino; 1983-84 and 2003 in the Grisons; 2003 in Valle d'Aosta (Fig. 2).

Figure 6 shows the relationship between the mean value of the Canadian Forest Fire Weather Index (FWI) and of the Drought Code (DC) for the summer months and number and characteristics of the corresponding lightning-ignited fires.

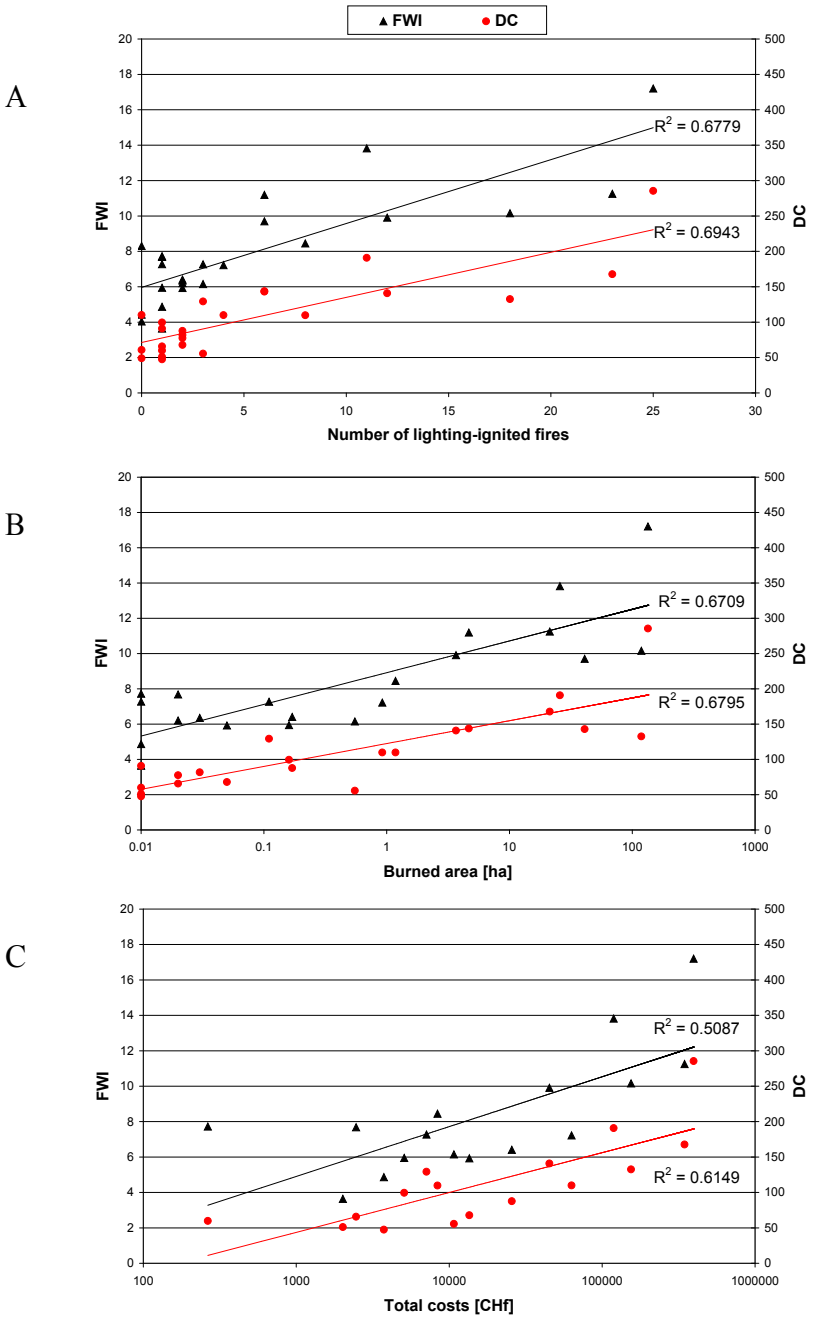

Fig. 6. Mean values of FWI and DC for the summer months June to August in Locarno-Monti with respect to the number of fires (A), total burned area (B) and total fighting costs (C) in the canton Ticino (period 1982-2004).

Fire frequency (Fig. 6A), total area burned (Fig. 6B) and total fighting costs (Fig. 6C) tend to increase with increasing values of FWI and DC. Both indexes correlate well with the analysed response variable and the correlations are throughout high significant ($p < 0.001$) with the only exception of the fighting costs with respect to the FWI ($p < 0.01$). This is probably due to the fact that mean values over the summer very well describe the dryness of the season, which is not the case for the daily values, especially the FWI. Daily observations of the FWI in Valle d'Aosta where the Canadian Forest Fire Weather Index has been used since the early 1990ies (Cesti & Cerise 1992) show the limited correlation between the FWI values of the day (or of the days before the event) and the lightning-ignited fires (data not shown).

4. Conclusions

The statistical data on lightning-ignited fires confirmed the existence of a natural fire regime in the Alps as already demonstrated by Tinner *et al.* (2005) for the past. Frequency and severity of lightning-ignited fires seem to be strongly dependent on seasonal weather conditions. In the light of a possible climate change towards an increased frequency of hot and dry summers (Schär et al. 2004), our results suggest that in the future, lightning-induced fires may assume a significant ecological role and have a higher economical impact in the Alps, as already suggested by Schumacher (2004) who used a modelling approach.

Acknowledgements

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