Canadian fireball rates and meteorite falls – declining returns ?

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Are we better at recovering meteorite falls now than we were in the past? A leading question and one that we would hope to answer in the affirmative. An examination of the available data, however, reveals a less than comforting result. In a previous article (Beech, 2002) the global annual meteorite fall rate was examined, for the time interval January 1800 to December 1999, and it was found that we are no more successful at collecting meteorite falls now than our ancestors were 100 years ago. It was also found that in spite of otherwise reasonable expectation, the meteorite fall recovery record has not improved with increasing population since circa 1940, and that the onset of the space race circa 1960 did not result in more meteorite falls being recovered.

The reasons why so few meteorite falls are recovered per year worldwide are no-doubt many, complex and time variable. Rasmussen (1990) has discussed a number of the possible historical reasons why the meteorite recovery rate and the documentation of fireball observations have varied with time. A short list of possible factors includes, the non-uniform distribution of people; the required development of a scholarly community interested in investigating falls; major wars, diseases and natural disasters adversely affecting the population density; societal structure and habits; the development of a written language and the keeping of systematic records. The list is not quite endless, but it could certainly go on to include geographical conditions in the fall area and weather factors. A nice example illustrating some of the factors just described can be seen in figure 11 of Hughes (1981), where a very distinct ‘string’ of Asian meteorite falls and finds can be seen to delineate the route of the trans-Siberian railway (Sears, 1987, p. 41). Likewise, figure 21A of Buchwald (1975, p. 40) illustrates the point that in Southern Africa, “the number of recovered meteorites is proportional to the population density, the educational level and the intensity of farming.” With respect to camera surveys, Halliday (2001) further comments that one of the conclusions to be drawn from the operation of the Meteorite Observation and Recovery Project (MORP) was that finding meteorites on the ground was much more difficult than originally anticipated. And this was so even when the fall location was known to within a few square kilometers. To underscore this point, Halliday *et al*., (1989) list some 44 MORP camera observed suspected meteorite fall locations within the Canadian prairies. We further note that not one of these suspected meteorite falls has been recovered, and this in spite of a number of field searches being made (see e.g., Cloutis *et al.*, 2001).

If we take 0.1 kg as a reasonable ‘good chance of recovery’ limit for meteorite falls, then of order 5800 meteorites potentially fall per year on the total land mass of the Earth (Halliday *et al*., 1984). Of these potential falls typically only some 0.1% (that is some 5 to 6 falls per year) are actually collected. Even in 1933, the best ever year for meteorite fall recovery, only 0.3% (or 17 meteorites – see Beech, 2002) of the potential fall total were recorded. Using a slightly different chain of reasoning to the one just outlined, Buchwald (1975, p. 40) also suggests that something like 0.1 % of the potential meteorite falls per year are actually recovered. In Canada there have been a total of 14 meteorite falls in the time interval 1887 to 2002. The first fall in Canada was the De Crewsville (Ontario) meteorite; the last fall (to the date of writing) was the Tagish Lake (British Columbia) meteorite. The Canadian meteorite fall recovery rate, during the past 115 years, is 0.12 falls per year on average (or approximately one fall recovery per 8-year time interval, or equivalently, 0.01 falls per year per 10^6 km^2).

While there will always be an element of luck involved in meteorite fall recovery, one might expect that the reporting of the fireball phenomena associated with possible meteorite falls would be more complete. A nighttime fireball, after all, will be visible over a much larger geographical region than that in which the meteorite physically falls. And, again one might reasonably expect that the greater the viewing population, the greater the number of reported fireball observations. It has recently been possible to evaluate this latter possibility with respect to Canadian fireball reports through the use of the Millman Fireball Archive (MFA).

The MFA constitutes a total of 3876 report cards on 2129 fireball events observed from across Canada in the time interval from 1962 to 1989 (Beech, 2003; and see the webpage http://hyperion.cc.uregina.ca/~astro/MIAC/MFA/Intro.html). The archive was initially maintained by Dr. Peter Millman for the Associate Committee on Meteorites, the forerunner of the present day Meteorite Impacts Advisory Committee (MIAC) to the Canadian Space Agency, and was a specific attempt to systematically record fireball meteor observations from across Canada. The archive was actively expanded through the efforts of numerous volunteer ‘recorders’ in each Province and Territory and through the establishment of specific Government Agency reporting channels. The time variation of the annual fireball rate, expressed in five-year averages, is shown in the top panel of figure 1. The bottom panel of figure 1 further shows the time variation of the Canadian population density (number of people per square kilometer) as determined by Statistics Canada in the census years starting in 1961. A comparison of the upper and lower panels immediately gives us the result that as the Canadian population density has increased so the efficiency of reporting fireball meteor observations has decreased. It would appear that Canadian observers are some two to three times ‘worse’ at reporting observations now (circa 2000) than they were some forty years ago. Also, we note, the fireball reporting rate has remained remarkably constant at about 50 ± 10 fireballs per year since circa 1975.

The cumulative number of Canadian meteorite falls since 1960 is shown in the middle panel of figure 1 (solid line with ‘dotted’ data points). The time period of figure 1 covers the interval between the fall of the Bruderheim meteorite (March 4, 1960) and the Tagish Lake meteorite fall (January 18, 2000). In the 40-year time interval from 1961 to 2001 eight meteorite falls were recorded in Canada and the Canadian population density increased by some 50%. If we assume that the meteorite fall rate varies linearly with the time varying population density P(t), then the expected number of falls ΔN in the time interval Δt will be of order $\Delta N = K\, P(t)\, \Delta t$, where K is an assumed constant accounting for fall recovery efficiency. Using the population density variation described in the lower panel of figure 1, we determine the 'predicted' number of falls in Canada (see the middle panel of figure 1, dashed line with 'square' data points). Scaling the model results so that the observed fall rates for1961 and 1966 are correctly accommodated we find that some 22 meteorite falls might have reasonably been expected in the time interval of interest, provided the recovery constant K was actually a constant that is. It would appear, therefore, that the fall recovery rate has not kept pace with the increasing Canadian population, or that the recovery constant has decreased, or that both of these effects have occurred. An estimate of the efficiency of meteorite fall recovery in Canada can be gauged from Halliday *et al.*, (1984), whose survey results indicate that some 15,360 meteorites with a masses greater than 0.1 kg potential fell within Canada in the 40 year time interval being considered. With these numbers in place, we find the potential meteorite fall recovery efficiency in Canada to be something like 0.05%. The efficiency of fall recovery in Canada is probably better than the value just derived. Given, for example, that Canadians mostly reside in an area that accounts for some $1/3^{rd}$ that of the actual country, the recovery efficiency might easily be of order 0.2 %. For comparison, Dodd (1986, p.15) suggests that 10% of falls with masses greater than 1 kg are found, and that "almost every" observed fall with a mass greater than 100 kg is recovered.

At this stage it might be prudent to ask if the apparent decline in meteorite recovery will continue. Figure 2 shows a graphical 'history' of Canadian meteorite falls and finds. There is, from figure 2, an implied hope for the future, since the top panel in the figure indicates a decreasing interval between subsequent reported fall and/or find events. In the lower panel of figure 2, the greater the slope of the line, the greater the number of meteorite falls and finds being made per year. It is reasonably clear, therefore, that the most dramatic times for meteorite recovery in Canada stretched from 1960 to circa 1980, a time interval essentially spanning the period between the falls of the Bruderheim and Innisfree meteorites. Why was this time interval so productive with respect to meteorite finds and falls? Some of the answer to this question lies behind the establishment of the fireball reporting center (i.e., the MFA) and with the MORP becoming fully operational, both of which initiatives set out to deliberately promote public interest in meteorites and meteorite recovery (Beech, 2003; Halliday, 1971). The time interval also corresponds to the period when a strong meteorite recovery group operated from within Alberta. Indeed, the Alberta team of field researchers, headed by geologist R. E. Folinsbee, was directly involved in the recovery of the Bruderheim (1960), Peace River (1963), Revelstoke (1965), Vilna (1967) and Innisfree (1977) meteorites. With respect to the Bruderheim fall, Halliday *et al*, (1978) noted, "the collection of the fallen meteorites and their acquisition for scientific study had been handled efficiently because of the presence and interest of amateur astronomers within the Edmonton Center of the Royal Astronomical Society of Canada and geologists of the University of Alberta and the Research Council of Alberta. In many other parts of Canada the event might have gone unnoticed". To some extent, the foregoing statement proves a simple point: if there are researchers 'out in the field' exciting the lay publics interest in meteorites, and who actively investigate fall accounts, then more meteorites, both falls and finds, will be recovered. The observations by Halliday *et al.*, (1978) both reinforce and complement the observations made by Harvey Nininger. Writing in his book *Out of the Sky* Nininger (1952: p 3) argues, "meteoritical phenomena are sufficiently rare that if it were left to a small especially trained group to make observations and the reports for science, the records would be embarrassingly bare. Chance is the determining factor as to who shall see the important meteor or who shall plow up a long-buried meteorite. Instruction of the general public in the art of making the most useful observations on meteors and in the recognition of meteorites and appreciation of their worth will go far in determining how frequently such knowledge as is accidentally acquired reaches the scientist." To further reinforce Nininger's point, one might not unreasonably argue that it was his visit to Saskatchewan in 1931 (Nininger, 1972, p 53) that 'sparked' an increase of interest in meteorites in Canada; his visit ending a 15 year drought on meteorite finds. So, to perhaps state the obvious, it would seem that to recover more meteorites one needs both an educated and inspired public, as well as an active team of field researchers.

"If yea look, then yea shall find" is apparently the best and simplest motto for the would-be meteorite hunter. This sentiment being true for both the recovery of meteorite finds and falls. Indeed, the tremendous efforts and success of the Antarctic meteorite searches have admirably proved this point when it comes to finds. So, perhaps the question should switch to "what is more valuable to science, a meteorite fall or a multitude of meteorite finds?" The answer is presumably that both are equally important, but that is a topic for another time.

To summarize, based upon the Canadian data it appears that there has been a clear decline in the reporting rate of fireballs over the past forty years. Likewise, while meteorite falls since circa 1960 have been reported at an average rate of something like one fall per five year time interval the fall recovery rate has apparently not increased with increasing population density since 1961. The reasons for these declines are multifaceted and complex. History does tell us, however, that within Canada, when there has been a drive to promote public interest in meteorites and/or fireball reporting, then more events are recorded. In this respect the declining fireball reporting rate and the failure of the meteorite fall recovery rate to keep pace with the rising population does not necessarily reflect a waning of public interest, but rather it reflects a failure of Canadian scientists to promote their subject effectively in recent decades. One recent attempt to reverse this trend has been the initiation, in the summer of 2000, of the Prairie Meteorite Search. This program has built directly upon the ideas espoused by Harvey Nininger (Nininger, 1952: pp. 63-70), and with the aid of a field researcher, employed to literally tour the prairie provinces, aims at promoting an interest in meteorite recovery within rural communities (see http://www.geo.ucalgary.ca/PMSearch). The PMSearch has already had a significant effect with respect to meteorite find recovery in Canada, and to date four brand new meteorite finds have been reported from Saskatchewan and Manitoba and some 30 new meteorite fragments have been identified. Most of the newly identified fragments relate to continued finds from the Red Deer Hill meteorite, which was first identified in 1977. Indeed, in light of the PMSearch the Red Deer Hill region is now recognized as containing both the most numerous meteorite find in Canada and the most numerous meteorite strewn field in Saskatchewan. It may be hoped that the recent increased interest in meteorite finds within Canada will eventually translate into the improved reporting of fireball sightings and to the recovery of new meteorite falls.

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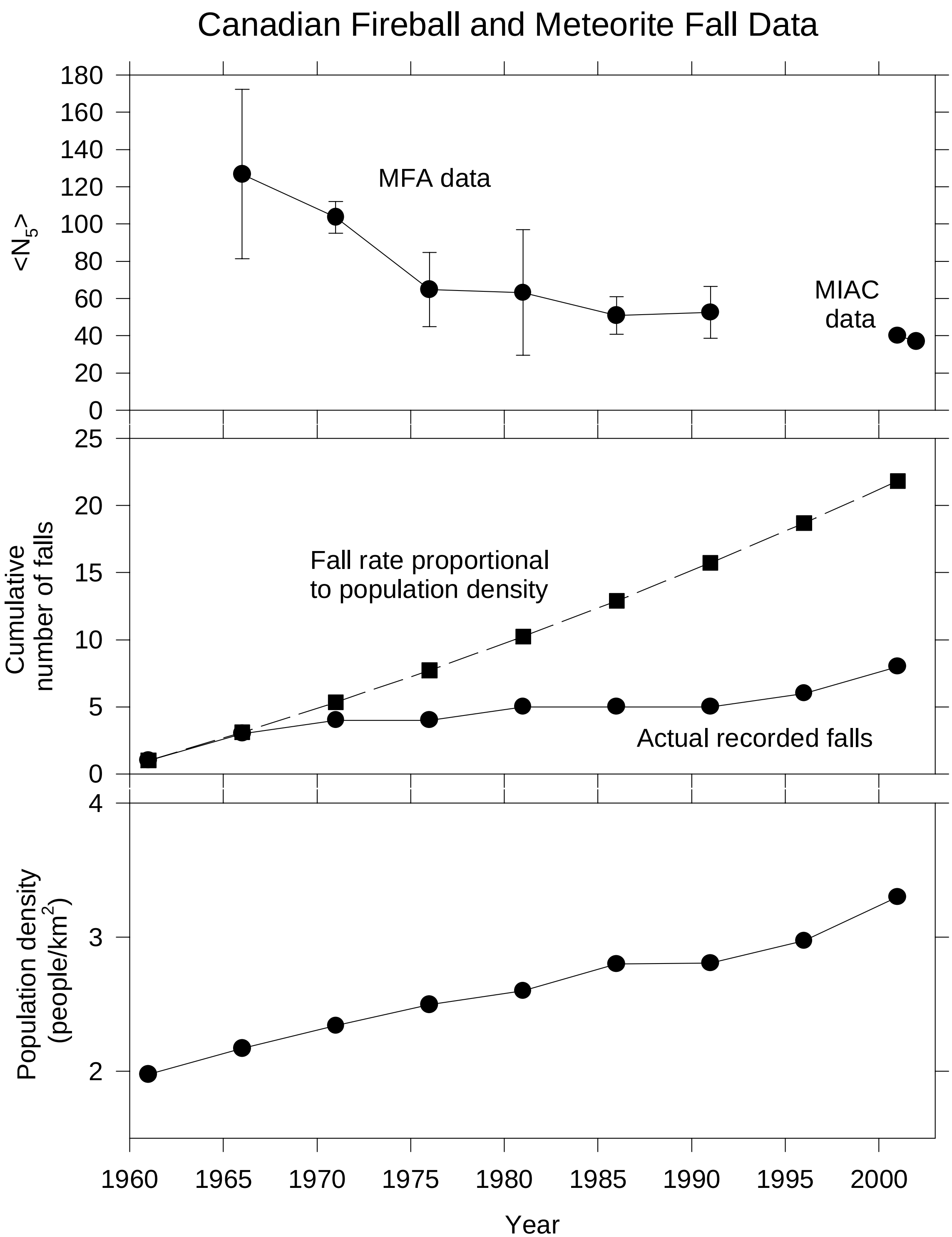
Figure 1: Canadian fireball sighting and meteorite fall data. The top panel shows five year averaged fireball rates as deduced from the MFA. The time intervals of the data points correspond to those of Canadian census years. Also shown are the annual totals of fireballs reported to the MIAC fireball webpage (http://hyperion.cc.uregina.ca/~astro/MIAC/index.html) for the years 2001 and 2002. The middle panel shows the cumulative number of meteorite falls recorded in Canada (dotted solid line) beginning with the fall of the Bruderheim meteorite in 1960. The dashed line (square data points) shows the expected number of falls if the fall recovery rate increased linearly with population density. The lower panel shows the Canadian population density (people per square kilometer) as determined by Statistics Canada in the census years from 1961 to 2001.



Canadian Fireball and Meteorite Fall Data
MFA data
MIAC data
<N5>
180
160
140
120
100
80
60
40
20
0
Cumulative number of falls
25
20
15
10
5
0
Fall rate proportional to population density
Actual recorded falls
Population density (people/km2)
4
3
2
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year

Figure 2: Canadian meteorite finds and falls. The upper panel shows the meteorite (finds and falls) recovery rate. The lower panel shows the cumulative number of finds and falls. The data has been taken from Grady (2000) and recent literature, and find dates have been displayed according to the year of their discovery rather than the year of their identification (the two dates can differ by many tens of years). The dates of several key meteorite falls are indicated in the lower panel, as well as the times during which various surveys operated. 'Nininger (1931)' corresponds to the time that Harvery Nininger visited his relatives in Saskatchewan and accordingly prompted the 'discovered' the Bruno iron and Springfield pallasite meteorites. The Meteorite Observation and Recovery Project (MORP) operated in the Canadian Prairies from 1971 to 1985 and accommodated the successful recovery of the Innisfree chondrite meteorite which fell on February 5th, 1977. The Millman Fireball Archive (MFA) was actively maintained from early 1962 to late 1989 and was initiated in response to the Bruderheim chondrite meteorite fall on March 4th, 1960. The Prairie Meteorite Search began in the summer of 2000, and has to date produced 4 new meteorite finds and overseen the recovery of some 30 meteorite fragments (most of the fragments being related to the Red Deer Hill meteorite). Note, the multiple Red Deer Hill meteorite finds and a second Saskatchewan Landing meteorite find have been included as 2 new finds for 2002. The most recent fall in Canada was the Tagish Lake carbonaceous chondrite meteorite which fell on January 18, 2000.