PERIODIC PATTERNS IN SNOW STABILITY:UPDATE (1)

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Abstract.--"Periodic Patterns in Snow Stability Update" evaluates the original data, upon which the tidal effect theory was based, adds events to the original data base, and then relates a new simplified statistical analysis of the data to clarify the significance of the theory.

INTRODUCTION

In the early seventies at Alta, Utah, Snow Rangers Sandahl and Lev had the idea that snow avalanches which occurred when it was not snowing were unique. A study began to analyze the conditions which brought on these unique avalanche events. It was discovered that the events in question had certain specific parameters (Lev 1980). Once these parameters were outlined, the large data base of recorded snow avalanches could be studied and correlations could be made between certain pertinent characteristics and the unique avalanche events. From the study of the available data base (4) a theory of the earth's tide being a contributory factor in a specific type of avalanche was proposed. The theory, through a statistical study, was developed into a field usable system to aid the snow safety worker, (Lev 1980). Because of the number limitations of avalanche events and the nature of the presentation in regards to the original study, a review of the criteria, an increase in the original data base, and a simplified statistical analysis were warranted. This paper fulfilled these goals.

CRITERIA REVIEW

The general criteria for sorting the avalanche events are: A) They must come from a global base, spanning as many years as possible (26 years in this sample), and B) That the sample include as many events as possible.

(1) Paper presented at the International Snow Science Workshop, Aspen, Colorado, October 24-27, 1984

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These general criteria are necessary in order to develop a truly representative and reliable data base. Next, avalanche events are culled from the data sources (4) according to the following specific criteria:

1) No precipitation can occur at the time and location of the avalanche. The reason is to eliminate the primary contributory factor in avalanche release, which is generally accepted to be direct precipitation overload, and focus on avalanches which occur from a few hours to several days after the cessation of precipitation.

2) Only dry snow slab avalanches are considered, because loose snow and wet snow avalanches exhibit characteristics significantly different from dry snow slabs.

3) Only avalanches which run a track distance of 50 meters or more are considered, because avalanches which run less than 50 meters are small and are more likely to be the result of microclimatic effects.

4) Only avalanches which are natural releases (27% of the sample data are natural avalanches), or are triggered by unsuspecting skiers, climbers, and others are included. Unsuspecting is a key word; from the culled sample of 220 avalanches, 170 people died, as well as two dogs. The event of a skier going skiing is considered random in relation to the 26 year span of the data sample, because the event of a skier arriving at any given terrain can happen on any day within the sample (or during any hour of any given day). A purpose of the original 1980 paper was to present the data in usable form, therefore, specific risk times during the day and night were determined, (Lev 1980).

(4) Appendix A

The result of screening of avalanche events produced 220 individual events for analysis. Due primarily to the greater base of avalanche events available in the current study, 39 more events can be added to the 181 events of the 1980 study. At this point it should be interjected that discussions of the possibility of a temperature gradient sliding layer as an additional criterium will be considered later in the analysis. The next section describes how we analyze the data in terms of a simple experiment.

RANDOM STATISTIC

In the 1980 study, as well as here, avalanche occurrence is looked at in relationship to the lunar (tide) month, and that the new moon and the full moon periods are considered identical, producing a 15 day sample space. The only realistic way of evaluating this data is to compare it with a completely random statistic which matches the actual data's statistic if there were no day of the month effect. A generator of this completely random statistic is produced by the following experiment: Using a fair 15 sided die, the die is thrown 220 times and a tally is taken on the number of times each side shows up. Each side represents a day in the folded lunar month and the 220 throws of the die represent the 220 avalanches of the actual data. In order to find out how rare a particular count of avalanche events in a day is, the random probability of particular counts must be generated. The probability of a particular number of tallys for each die side in 220 throws is given by the following equation (Papoulis 1965):

$$P_{(220)}(k1,k2, . . ,k15)=$$

$$220! \; / \; (k1!k2! \; . \; . \; . \; k15!) \; (\; 15^{220})$$

Where k1 represents the tally obtained on day one of the month, k2 is the second day,etc. The closed form solution of this equation for a number of events happening on any day with the attendant permutations, combinations and values is extremely cumbersome.

To come up with a statistic which is functional and easier to generate, we have gone to a computer Monte Carlo analysis. With this technique it is very easy to repeat our random experiment many times and check to see how many times a specific number of events shows up. The ratio of the number of times a tally of events shows up for a particular day to the total number of experiments is the probability of this happening on that day if there were no day of the month effect in the data.

After 100,000 simulated experiments (2,200,000 throws) a smooth probability density function is generated with reasonable accuracy. It is observed that the resulting density function is non-Gaussian; though, we now have a probability density function of a completely random case (fig. 1). This may now be used to evaluate the actual culled data.

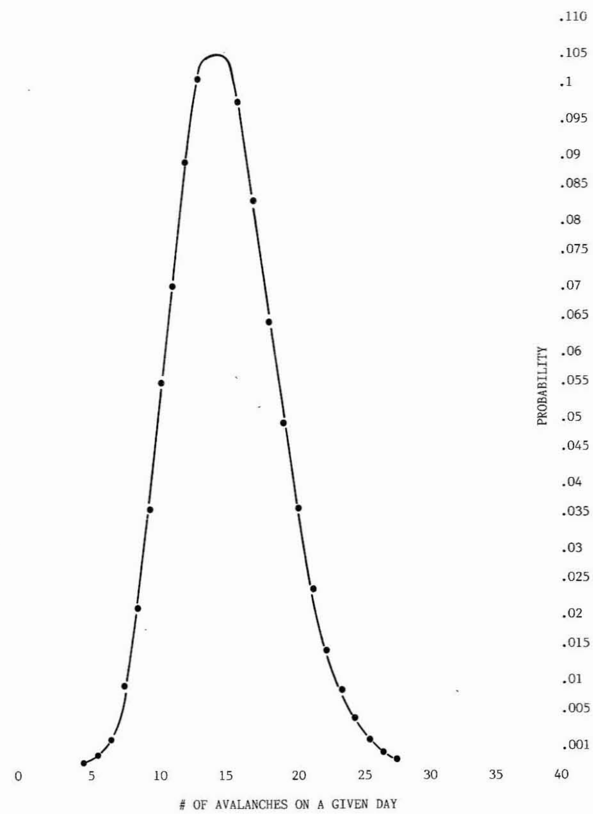

Figure 1.--Probability (Y-Axis) of a Number (X-Axis) of random avalanches occurring on a certain day for 220 total events.

DATA REDUCTION (Actual Events)

The actual data(5) culled from the sources(4) is plotted in respect to the lunar (tide) month. The grouping of all years and months into a half lunar month follows the assumption that the new and full moon effects are equivalent (Lev 1980) (fig 2).

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(4) Appendix A.

(5) Avalanche Data List (unpublished), Alpine Data, Box 2300, Aspen, Colorado,81612

Looking at figure 2, how the actual events are distributed, note is taken of the column of 29 events on one day in the sample of 220 events. The Monte Carlo analysis for 220 events has generated the probability of numbers of events happening on a given day. Since there is no bias in the random model as to which day a number of events will fall, the probability of a number of events falling on any day of the month is given by the sum of the probabilities of that number falling on any certain day. Therefore, we must multiply the resultant probability from the probability density function by the 15 days of the month. It is found that the probability of 29 or more random events occurring on a certain day is less than 0.0004, roughly one in 2,500, and the probability of 29 or more random events occurring on any day is less than 0.0004 x 15 or 0.006, roughly one in 100. This means the probability of the actual data being totally random and coming up with a number as large as 29 or greater anywhere in the month is roughly one in 100 exercises of the random experiment. This low probability of 29 or more random events occurring on any day with respect to the lunar month proves that there is only a one percent chance this could have occurred as a random set of lucky rolls of our experiment. Significance is found even if the events are not further cross referenced according to the time of day as in the 1980 study, (Lev 1980). Now, consider a data reduction of events screened according to the additional criterium of a temperature gradient sliding layer.

AVALANCHE EVENTS

									219					
									216					
									209					
									202					
									192					
									189					
									183					
									182					
									176					
									169					
					220	217			151					
					213	201	218		145					
					198	200	214		141					
					160	194	205	215	126		210	212		
					143	193	204	196	119		207	208		
		211			137	174	203	195	107		206	197		
	171	199			135	168	191	177	98		178	190		
144	170	186		185	109	167	152	172	96		158	184		
134	156	173		138	105	166	150	136	84		157	180		
133	155	142		115	103	165	132	121	83		154	175	179	
128	112	124	129	104	95	164	127	111	77	188	148	162	130	
123	110	101	125	94	79	163	106	89	64	187	147	161	122	159
116	60	100	91	93	62	149	86	67	46	181	117	108	120	153
92	58	97	73	80	61	140	65	63	39	146	99	82	113	139
76	57	87	52	78	53	102	43	37	31	118	70	81	90	131
55	56	85	49	75	29	71	35	28	25	114	50	40	51	88
48	47	72	42	74	14	69	34	22	23	66	44	30	36	54
27	20	59	41	21	11	68	12	13	18	24	9	26	10	33
15	7	38	2	16	8	45	4	3	6	19	1	17	5	32
-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7

LUNAR PHASES MONTHLY TREND (days)
"O" IS FULL OR NEW MOON

Figure 2.-- Histogram (220 avalanche events)

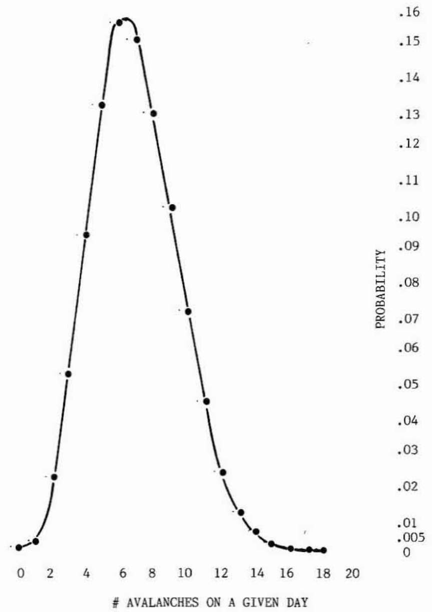

Figure 3.--Probability (Y-Axis) of a Number (X-Axis) of random avalanches occurring on a certain day for 104 total events.

TEMPERATURE GRADIENT

Finally one additional criterium is a sliding layer of temperature gradient snow playing a role in the tidal effect theory. The 220 events of this study are further culled to include in a sample only avalanches which had a known temperature gradient sliding layer. Only 104 events were available from the 220. It should be noted here that even a carefully culled group of 104 events is a very small sample from which to draw firm conclusions. A similar Monte Carlo analysis to the one that produces the probability density for the 220 events is used to generate a probability density function for the number of random avalanche events expected on a certain one of the 15 days in a sample of 104 events (fig. 3).

Plotting actual events in respect to the lunar month (fig. 4), a column of 20 events on one day in a sample of 104 events is noticed. Comparing this column with the random statistic in the same manner as the 220 event sample, it is found that the probability of 20 or more random events occurring on a certain day is less than 0.000018, or one in 56,000, and the probability of 20 or more random events occurring on any day is 0.000018 x 15 or 0.00027, roughly one in 3,700. Again it is noted this very low probability of 20 or more random events occurring on any day proves that there is less than a 0.03 percent chance that this could have occurred as a random set of lucky rolls of our experiment. The temperature gradient factor appears to be the key which makes the 220 event sample more significant.

AVALANCHE EVENTS

									219					
									216					
									209					
									202					
									192					
									189					
						217			183					
						201			182					
						194			176					
						193			169					
						174			96					
					220	168	218		84					
					213	167	214	215	83			212		
					198	166	204	196	77			208		
			91	94	160	165	203	195	46		207	175		
	171		73	93	95	164	191	172	39		206	162		
	170	186	52	80	61	163	150	89	31	188	178	161		
	47	173	49	78	53	71	43	37	22	187	70	82		
116	20	97	42	75	11	68	34	13	18	66	44	81	212	
76	7	87	41	16	8	45	4	3	6	19	1	40	5	88
-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7

LUNAR PHASES MONTHLY TREND (DAYS)
"O" IS FULL OR NEW MOON

Figure 4.-- Histogram
Avalanches with known sliding layer of temperature gradient snow (104 events).

CONCLUSION

By completing the above simplified analysis of the avalanche data, chosen according to the criteria set down in the tidal effect theory (Lev 1980), one can see that there are some very improbable groupings of avalanche events around the new moon full moon days of the lunar month. These improbable groupings in relation to the random sample occur regardless of the time of day correlation set down in the field usable system of the 1980 study (Lev 1980). Finally, if you still consider that the tidal effect is just like a set of lucky rolls in our random experiment, would you in the field want to bet 100 to one against yourself that the tidal effect has no significance?

LITERATURE CITED

Lev, P. and Mohwinkel, C.,"Periodic Patterns in Snow Stability", Vancouver Avalanche Forecasting Seminar, Nov 1980, Published Proceedings, NRCC, Ottawa, Canada.

Papoulis, A., Probability, Random Variables, and Stochastic Processes, McGraw-Hill, Inc, 1965.

APPENDIX A

Periodic Patterns In Snow Stability
Avalanche Event Data Sources

Snowy Torrents - Avalanche accidents in the United States 1910-1966, and 1967-1971; USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO 80521

Avalanche Accident File "AVACC", Colorado Avalanche Information Center, 10230 Smith Road, Denver, CO 80239

Avalanche Accidents in Canada I and II National Research Council Canada, Ottawa DBR papers 834 and 926

UNESCO Annual Summary of Information on Natural Disasters; UNIPUB, 345 Park Ave. S., New York, NY 10010

Mt. Alyeska List, Steve Hackett, Snow Safety, Mt. Alyeska, AK

UIAGM, International Union of Mountain Guides Association, Sion, Switzerland, Walter Strolz, Director Technical Committee, St. Anton, Austria

Mt. Cook National Park, New Zealand, Lisle Irwin Alpine Specialist, Mt. Cook Park, New Zealand

Snow Safety List:

B. Sandahl, Head Snow Ranger, Alta, UT
O. Wieringa, Head Snow Safety, Alta, UT
L. Fitzgerald, Head Snow Safety, Snowbird, UT
R. Newcomb, American Avalanche Institute, Wilson, WY
R. Mandahl, Snowbird Ski Patrol, Snowbird, UT
B. Redmayne, Colorado First Tracks, Crested Butte, CO
H. Hartman, Head Snow Safety, Snowmass, CO
P. Schaerer, National Research Council Canada
M. Wiegele, Wiegele Heli-Skiing, Blue River, BC, Canada
J. Stratton, Snow Safety, Snowbird, UT
P. Hutter, Alpine Data, Aspen, CO
P. Avenali, mountaineer, Seattle,WA
J. Freer, Avalanche Specialist, BC Dept. of Highways, BC, Canada
T. Howe, Aspen Ski Patrol, Aspen, CO
E. LaChapelle, Avalanche Consultant, Seattle, WA
G. Mace, Ashcroft Ski Touring, Aspen, CO
GTNP - Grand Teton National Park Records
M. Friedman, Telluride Helitrax, Telluride, CO
B. Arndt, Aspen Ski Patrol, Aspen, CO