Statistical Analysis of the Effects of Winter Aircraft Artificial Snow Enhancement Operations in Karamay City (Postprint)

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Abstract

Utilizing annual December precipitation observation data from 1957 to 2016 at the Karamay District Meteorological Station, and applying statistical methods including serial test, unpaired rank-sum test, and t-test, a systematic difference analysis was conducted on December precipitation as a statistical variable for the 31-year historical period prior to the initiation of winter aircraft-based artificial snow enhancement operations and the 29-year operational period. The results indicate that following the implementation of winter aircraft-based artificial snow enhancement operations, December precipitation in Karamay City increased significantly, with the mean precipitation increasing by 2 mm. The significance level of the non-parametric unpaired rank-sum test reached 0.025, while that of the parametric t-test also approached 0.025. Selecting a confidence interval at a statistical significance level of 0.1, it was calculated that after the implementation of winter aircraft-based artificial snow enhancement operations, the absolute increase in mean annual December precipitation in Karamay City was 1.15 mm, corresponding to a relative increase rate of 24.5%. Consequently, it is concluded that winter precipitation in Karamay City has exhibited a significant increase following the implementation of winter aircraft-based artificial snow enhancement operations.

Full Text

3. Statistical Analysis

3.1 Sequence Test

The sequence test method is employed to analyze the statistical significance of differences between the 31-year historical period and the 29-year operational period of aircraft artificial snowfall enhancement. The test results indicate that

after the implementation of artificial snowfall enhancement, the maximum, minimum, and average precipitation values in December at Karamay Weather Station all showed significant increases. Specifically, the maximum precipitation increased from 4.70 mm to 6.72 mm, while the minimum precipitation increased by a factor of 12. The absolute increase in average precipitation is calculated as ΔR = x - x = 2.02 mm, with a relative enhancement rate of E = (x - x)/x × 100% 42.98%. Consequently, the statistical analysis reveals that the artificial snowfall enhancement resulted in an absolute precipitation increase of 2.02 mm and a relative increase of 42.98%.

3.2 Unpaired Rank Sum Test

The unpaired rank sum test (Mann-Whitney U test) is a non-parametric statistical method. The test statistic is calculated as:

$$u = \frac{T - \frac{n_1(n_1+n_2+1)}{2}}{\sqrt{\frac{n_1 n_2(n_1+n_2+1)}{12}}}$$

where T represents the rank sum, and n_1 and n_2 are the sample sizes. For a two-tailed test at significance level $\alpha = 0.05$, the critical value range is $(-1.96, +1.96)$. If the calculated u statistic falls within this range, the null hypothesis is accepted, indicating no significant difference; if it falls outside this range, the null hypothesis is rejected, indicating a statistically significant difference with $p < 0.05$. For a one-tailed test at $\alpha = 0.10$, the critical value is $u \geq 1.64$ (or $u \leq -1.64$), with the same interpretation of significance [**?**].

In this analysis, with $n_1 = 29$, $n_2 = 31$, and $T = 1016$, the calculated test statistic is $u \approx 1.95$. Since $u > 1.64$, the results indicate a significant systematic difference in December precipitation before and after the implementation of artificial snowfall enhancement. The inspection significance level for the non-parametric unpaired rank sum test is 0.025, and the parametric t-test yields a similar significance level of approximately 0.025.

3.3 t-Test

The t-test is a parametric statistical method used to compare means between two groups. When sample sizes are small ($n < 30$), the t-test is based on small-sample theory and is appropriate for testing differences between two independent samples [**?**]. Given that the precipitation data from Karamay Weather Station for the two periods represent independent samples with $n < 30$, the t-test is applicable for analyzing the significance of differences between them. The test results demonstrate statistically significant differences between the precipitation amounts in the pre- and post-enhancement periods.

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Statistical Analysis of Effect of Aircraft Artificial Snowfall Enhancement in Winter at Karamay

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Abstract: In order to objectively evaluate the effect of the aircraft artificial snowfall enhancement in winter in Karamay, Xinjiang, China, it is necessary to analyze the systematic significance of snowfall enhancement. Utilizing the sequence test, unpaired rank sum test, and t-test of statistical methods, the systematic differences of annual precipitation in December of the former historical period 31a and the latter period 29a of carrying out the aircraft artificial snowfall enhancement are analyzed in Karamay, with annual precipitation data of Karamay Weather Station in December from 1957–2016, as a beginning to

carry out the aircraft artificial snowfall enhancement in 1988. The results show that the precipitation in December in Karamay was significantly increased after the operation of the aircraft artificial snowfall enhancement, regardless of the maximum, minimum, and average value. It added 2.3 mm, 1.1 mm, and 2.02 mm respectively. In particular, the minimum rainfall period is 12 times that of the historical period. This would play a positive role in alleviating the shortage of water resources. The inspection significance level of non-parameter unpaired rank sum test is 0.025, and the inspection significance level of parametric t-test is also close to 0.025. According to the calculation, the absolute increase of the precipitation in Karamay in December is 1.15 mm, and the relative enhancive rate is 24.5% after carrying out the aircraft artificial snowfall enhancement in winter in Karamay when the statistical significant level =0.1 is chosen. Therefore, through carrying out the aircraft artificial snowfall enhancement in winter, it is significant for the precipitation enhancement in Karamay, it has a certain effect on the local tense production and domestic water consumption in arid areas. Remarkable social and economic benefits. This paper makes a reasonable utility of statistical methods to analyze the effects of aircraft artificial snowfall enhancement in the winter in Karamay, and concludes the qualitative conclusions and the quantitative results. It is of some guiding significance to design and evaluate the application of aircraft artificial precipitation enhancement in science.

Keywords: aircraft artificial snowfall enhancement; effect; statistical analysis

Note: Figure translations are in progress. See original paper for figures.