Time-Scales for Sediment Focusing in Lake Michigan Based on Fallout $^{137}$Cs Data: A Thirty-Year Study

The Problem

Lake Michigan, the second largest lake in the world and central among the Laurentian Great Lakes, has a sedimentary history that stretches back 16,000 years. In terms of both natural and anthropogenic influences, Lake Michigan is a unique and important ecosystem. The lake's sedimentary record holds key information about its history and the changes that have occurred over time. However, the sediment column is not uniform; instead, it is characterized by layers of varying thickness and composition, which reflect different processes and conditions at the time they were deposited. Understanding these processes is crucial for interpreting the historical record and for assessing the impact of human activities on the lake.

Approach

To address the problem of sediment focusing in Lake Michigan, a comprehensive study was conducted to analyze the fallout of $^{137}$Cs, a radioactive isotope, in the lake. This isotopic fingerprint can be used to trace the movement and distribution of sediments over time, providing insights into the lake's sedimentary history. The study involved the analysis of cores collected from various sites in the lake, each representing a different time period. The cores were examined to determine the distribution of $^{137}$Cs and other radionuclides, and the results were used to infer the sedimentation rates and focusing factors at different depths.

Results

The study revealed that the focusing factor over "non-depositional" areas may be calculated as $FF_{nd} = (1-f_{dep})FF_{dep}/(1-f_{dep})$. FF$_{dep}$ represents the focusing factor over "depositional" areas, which can be estimated using the STA (Spreading-Time-Averaging) model. The STA model takes into account the time-averaged, decay-corrected atmospheric flux of $^{137}$Cs delivered to the lake and the time-resolution achievable in reconstructing historical records from core profiles at the site. The absolute inventory, $I_s(t)$, may then be determined by choosing the non-depositional time-scale, $\tau$, as a model parameter.

Evolution of $^{137}$Cs Focusing Maps

The focusing of $^{137}$Cs in the lake is a result of both natural processes and human activities. The decay-corrected difference profile in sample core LM22-210Pb (upper panel) shows that the inventory had increased toward the center of the lake, with the highest activity observed in the central part of the lake. The deficit is made up by temporary storage of $^{137}$Cs over non-depositional areas, with a second-order equation of the form: $F_{st}(t) = F_{st}(0) - \frac{F_{st}(0)}{\lambda + \tau} e^{-\lambda + \tau}$, where $F_{st}(t)$ is the accumulation rate at any time $t$, and $F_{st}(0)$ is the accumulation rate at time $t=0$.

Evolution of 210Pb Focusing Maps

The recent lake-wide inventory of $^{137}$Cs shows that the lake is characterized by focusing factors over "non-depositional" areas, with a second-order equation of the form: $F_{st}(t) = F_{st}(0) - \frac{F_{st}(0)}{\lambda + \tau} e^{-\lambda + \tau}$, where $F_{st}(t)$ is the accumulation rate at any time $t$, and $F_{st}(0)$ is the accumulation rate at time $t=0$. The deficit is made up by temporary storage of $^{137}$Cs over non-depositional areas, with a second-order equation of the form: $F_{st}(t) = F_{st}(0) - \frac{F_{st}(0)}{\lambda + \tau} e^{-\lambda + \tau}$, where $F_{st}(t)$ is the accumulation rate at any time $t$, and $F_{st}(0)$ is the accumulation rate at time $t=0$.

Conclusion

The study provides valuable insights into the sediment focusing processes in Lake Michigan. The results highlight the importance of understanding the historical record of the lake and the impact of human activities on its ecosystem. The findings can be used to inform conservation efforts and to develop strategies for mitigating future environmental impacts.

References


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