Policy Brief

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Glacial Flour and Downstream Ecosystems in a Warming World

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Introduction

Glacial meltwater transports fine sediments, known as glacial flour, which can contain both nutrients and heavy metals. When released to downstream ecosystems, the flour can enhance biological productivity through nutrient input but may also cause negative effects such as reduced light availability in the water column. The full extent of the impact of the flour to the downstream environment and global carbon balance is not yet understood.
The aim of this policy brief is to summarise the effects of glacial flour in Arctic marine environments and its climate impacts. We highlight key research findings and conclude with three recommendations on which research priorities should be considered when funding glacial flour research projects.

Summary

Glaciers are powerful abrading agents producing fine sediments called glacial rock flour which contains both nutrients and heavy metals. It is expected that the continuous melting of glaciers will lead to an increase in the production and export of glacial rock flour to recipients like lakes, rivers and fjords. As glacial flour is rich in nutrients, increased fertilization of downstream ecosystems is possible which could enhance algal growth. For example, bioavailable silicon can be utilized by diatoms. The formation and sedimentation of diatoms in turn accounts for 40% of the marine C-sequestration[1]. Hence, glacier-exported silicon can indirectly impact atmospheric CO_2 concentrations. However, high sediment loads can also reduce light penetration, limiting algal photosynthesis and suppressing carbon uptake—potentially reducing marine carbon sequestration. Since algae are the foundation of the marine food web, impacts to algal production affect coastal ecosystems. Moreover, the potential for glacial flour to contain and release heavy metals to the ecosystem is under-investigated. Arctic glacial discharge provides essential metals, like iron, for primary producers, but may also release toxic heavy metals like mercury, which bioaccumulates in the food web - through algae to fish - causing harm to the ecosystem and eventually may impact the health of coastal communities.

Key research findings and knowledge gaps

- Glacial flour fertilizes downstream ecosystems
  → Does the fertilizing effect reach offshore waters and how does it differ between flour exported from below marine- vs land-terminating glaciers?

- Glacial flour transports both nutrients and heavy metals
  → Can the increased nutrient input trigger microbial shifts toward harmful algal bloom-associated species, and are heavy metals present at concentrations that pose ecological risks? How does this impact marine CO_2 sequestration?

- High sediment load limits light penetration into the water column and particles can have harmful effects on plankton and marine animals
  → Do these negative impacts outweigh the potential positive effect of meltwater-induced freshening, which may extend the phytoplankton growing season?

Recommendation 1: Long term fine-spatial monitoring

Given seasonal changes in glacial runoff, monitoring over time and space is essential to capture fluctuations that could help describe and quantify the positive and negative effects of glacial flour in the ecosystem and for atmospheric CO_2 concentrations.

Recommendation 2: Incorporate findings into climate models

Incorporating the quantified effects of glacial flour export on algal blooms and the subsequent drawdown of atmospheric CO_2 into climate models would refine predictive capabilities. Accounting for changing glacial flour inputs to fjords as a result of glacial recession and the shift from marine- to land-terminating glaciers in climate models will help characterise future climate effects.

Recommendation 3: Cooperation between fields

Interdisciplinary research initiatives which combine geochemical studies on glacier flour, microbial research on glacial and marine communities, physical oceanography on fjord mixing dynamics, and climate modelling are crucial to better understand the current and future impacts of glacial rock flour.

"We advocate for intensified research targeting glacial rock flour, as the complex and ambiguous effects of the export to downstream ecosystems and the climate are not fully described yet. We recommend increased research on a broad variety of glaciers, catchments, and fjords. Given seasonal changes in glacial runoff, monitoring over time and space is essential to capture fluctuations."

References
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