Arctic Dust Observation Network

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Introduction
Dust forms an important component of the earth-atmosphere system, yet is mainly associated with subtropical deserts. In contemporary climate conditions, dust is produced by a number of geophysical processes taking place in the high latitudes, including glacial and periglacial processes (Bullard, 2013). Arctic dust storms are frequent in Alaska (e.g. Crusius et al., 2011), Canada (e.g. Lewkowicz, 1998), Greenland (Bullard and Austin, 2011) and Iceland (e.g. Arnalds, 2010). Dust emissions from these events affect terrestrial, marine and atmospheric systems. Glacier albedo is decreasing owing to dust deposition, forging a positive feedback and enhancing glacier melt (Dumont et al., 2014). Transport of dust to the ocean provides a source of iron to the high latitude oceans (Prospero et al., 2012), which can potentially boost primary productivity and enhance CO_2 drawdown (Achterberg et al., 2013). Dust emissions can also lead to exceedences in air quality standards and health impacts in populated areas such as south central Alaska and south west Iceland (Department of Environmental Conservation, 2012; Thorsteinsson et al., 2011). Yet despite affecting both the environment and societies, the timing, frequency and magnitude of high latitude dust storm events remain poorly understood. Source areas for dust production may be on the rise, owing to the fast retreat of glaciers that are a producer of this sediment, leading to enhanced dust emissions. Or, surfaces could become armoured by the glacial sediment, decreasing future emissions. To address these unknowns, a coordinated monitoring effort is required in the high latitudes to improve understanding surrounding dust generation and emissions, and how these may change as cold climate environments start to warm.

Current effort & associated problems
At present, there is spatio-temporal scarcity of ground-based measurements to determine the magnitude of dust emissions as highlighted by an ongoing survey by the High Latitude and Cold Climate Dust Network (www.hlccd.org). There have been a handful of ground-based measurements in the Arctic, which use a variety of instruments to determine the volume of dust. These have been geographically sparse, and actively monitoring for only short time periods. Satellite images overcome spatial constraints, revealing the distances that dust storms travel (>500 km). However, cloud cover restricts the availability of suitable images, providing sporadic temporal coverage and is a particular limitation during spring and autumn which are the main dust storm seasons. An intense field campaign in Iceland during summer 2015 (Mockford et al., 2015) highlighted that ground-based measurements, spanning eight weeks, can reveal the timing, frequency and magnitude of storms. In addition, particle measurements indicate the source location of the dust. These

measurements can be used to providing a better understanding of the characteristics of dust being removed from source areas and entering the ocean or being deposited in terrestrial systems to affect soil formation and lake biogeochemistry. Such a study provides a basis to expand dust monitoring, and has readily highlighted that existing monitoring programmes are not adequate to properly resolve dust emissions in the Arctic.

Proposed solution

Dust monitoring is established in the tropics, where hot arid deserts are known active dust sources. Focus on the high latitudes and cold environments has only recently gained momentum, owing to the key linkages with the climate system and human health. Forming an integrated dust observation network across the Arctic together with existing automatic weather station infrastructure would provide valuable data to assist in quantifying dust storm events. Recent technological advances have led to automated instrumentation to quantify dust and the ability to download data from remote areas via satellite, which are helping to overcome previous temporal sampling and access issues. By selecting strategic locations based upon dust source characteristics, an in depth knowledge of dust activity in the Arctic would be obtained. Collaboration with an automatic weather station network would provide complimentary data, enabling the climate thresholds (wind, temperature, precipitation and humidity) for active dust transport to be established. The proposed dust monitoring network would use the same instrumentation at each location, ensuring data consistency. In addition, a community dust monitoring and reporting network would be valuable in known dust source areas, to enhance data capture and overcome logistical issues with instrumentation and satellite data. Such programmes have been effective in Australia, which has similar data scarcity issues (DustWatch, 2015; Leys et al., 2008). Forming such a synergy would allow for better predictions of future dust emissions, which is an important part of the global climate system.

Benefits of the Dust network

Monitoring dust emissions and associated air quality in the Arctic is challenging due to the size of the area of interest and the relatively small and dispersed population. A single pan-Arctic network of specified instruments collecting data using an agreed set of protocols will allow comparison of observations across the region. Data from such a network will be invaluable to stakeholders with interests at a variety of scales. It will enable users to determine the magnitude, frequency and impact of local dust events for understanding their contribution to air quality, local soil nutrient redistribution and hazards such as reduced visibility. This will be of particular value to those concerned with public health, transportation networks and land management. At a regional to global scale, quantification of the spatial and temporal variations in the relative importance of natural dust events across the Arctic region will be invaluable to scientists including marine biologists, biogeochemists, atmospheric scientists and sedimentologists. A better understanding of dust emissions and dust redistribution from the Arctic would also contribute to improved global climate modelling and forecasting.

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