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GEOMORPHOLOGY OF DUST SOURCES AND DYNAMICS OF DUST EMISSION FROM DIFFERENT GEOMORPHIC UNITS

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ABSTRACTS

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DUST ON GLACIERS: QUANTIFICATION, SOURCES AND EFFECTS

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In this work we show the results of a pilot study we performed to detect and quantify fine debris coverage at the melting surface of an alpine debris-free glacier to evaluate its seasonal variability and its influence on ice albedo. Despite the abundant literature dealing with dust and black carbon deposition on glacier accumulation areas only a few studies on the distribution and properties of fine debris in the ablation areas are available. Furthermore, guidelines are needed to standardize field samplings and lab analyses thus permitting comparisons among different glaciers. We proposed a novel integrated method to describe fine debris occurring at the surface of a debris-free glacier and we found a linear relation between the surface covered by debris (mainly dust) and the natural logarithm of ice albedo. An innovative approach based on the semi automatic analysis of high-resolution digital images (describing sample areas with a size of 1m x 1m) was developed in order to quantify the surface area covered by debris. The procedure was tested on the Forni Glacier (Italian Alps), in the ablation period of the years 2011, 2012 and 2013. Debris analyses generally indicate a local origin of debris and dust with a locally high organic content. Nevertheless, the finding of some cenospheres also suggests an anthropic contribution. In addition, for a more exhaustive albedo analysis the effect of the water (originating from both ablation and liquid precipitation) was considered as well. In particular, we observed that the rainfall has a non-negligible effect on ice: in almost all events we analyzed the mean daily albedo is found increasing slightly higher than 20% after the rain occurrence. However, the incidence of the washing out effect and the consequent reflectivity increase is found to be short lasting (ranging from 1 to 4 days).

DUST ON GLACIERS: QUANTIFICATION, SOURCES AND EFFECTS

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Understanding the control that the land surface exerts on dust emission is an important goal for better understanding the initial phase of the global 'dust cycle'. The Preferential Dust Source (PDS) scheme is a land surface classification scheme that outlines the key concepts accounting for why dust emission is variable between different geomorphologies. PDS has also been developed to enable large scale mapping of geomorphology in terms of its importance for dust production. Recently, the PDS scheme (as a qualitative conceptual model of surface emissivity) has been assessed against a quantitative measurement of remotely sensed dust loading (MODIS Deep Blue Collection 6) for a major dust source region in North America - the Chihuahuan Desert. The predicted ranked importance of each geomorphic type for dust emissions is compared with the actual ranked importance as determined from the long term satellite dust loading. For the Chihuahuan Desert, the predicted variability and magnitude of dust emissions from most surface types coincides with PDS characteristics, which demonstrates the significance of geomorphological controls on emission. The exception is for areas of low magnitude but persistent emissions such as alluvial surfaces where PDS is found to over-predict emission. Overall, PDS emerges as a good predictor of dust emissions at a broad scale, and by inherently incorporating the dynamics of land surface types (e.g. susceptibility to flooding, frequency of sediment supply), PDS could be used to improve models of future dust emissions.

SOUTHERN AFRICAN DUST SOURCES

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Southern African dust sources have been identified using a variety of remotely sensed products including Photography, TOMS, SeaWifs, MODIS and MSG. Southern African sources include ephemeral recharge playas of the interior as well as coastal discharge sabkhas from Namibia in addition to dry river valleys with headwaters in the western escarpment and beyond. The Kalahari and Namib consistently produce plumes while dust in the Karoo region has remained undetected from space. The temporal plume detection record from remote sensing combined with reanalyses data suggests distinct synoptic drivers at play, which include west coast troughs intensified by continental high pressure systems at a regional scale and berg winds in coastal slope settings. Ground based observations have added important dimensions to our understanding of the processes. Applying the Gobabeb weather observations to the Kuiseb River plumes suggest persistent winds and topographic channelling of air flow may be an additional factor for many of the Namibian River valleys. Saltation as an agitator appears a lesser driver but cannot be discounted in the proximity of active dune fields. Intensive ground based observations as part of DO4 (Dust Observation For Models) have been underway since 2011. In general southern African sources are supply limited in nature and availability of material is controlled by flooding history for both river and lake systems, while playas feature the additional limitation of crust formation and fluff retention. Southern Africa may not be the dustiest place on earth but numerous discrete sources including Sua Pan and Namibian West Coast have enhanced our understanding of surface process geomorphology.

THE DUST EMISSION FROM THE CENTRAL ANDES, ITS ROLE AS SOURCE OF THE CHACO-PAMPEAN LOESS

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The Pampen loess belt in South America is the most extensive and voluminous paleo-dust archive in the Southern Hemisphere. This belt belongs to the Pampean Aeolian System mainly generated during the Last Glacial Maximum (LGM). Stratigraphic and sedimentological studies of loess units of the Pampa region have been applied to better understand the provenance of the fine materials. The grain-size trend in a SW-NE direction, the mineralogical association, the geochemical data, and the geomorphological indicators are evidences of multiple sources of the LGM loess. Some geomorphological units of the Central Andes are identified as the primary sources of loess units. Also, a direct contribution of fine pyroclastic material from Andean volcanic eruptions is widely accepted. Silt-producing mechanisms as frost weathering, glacial grinding and fluvial comminution mainly in the Andean upper basin of the Bermejo–Desaguadero–Salado fluvial system during the LGM, transported by meltwaters along the eastern Andean piedmont and spreading out in terminal sand flats and wide alluvial plains represent the Southern Central Andes/North Patagonian source (Western Argentina). The fine materials accumulated were subsequently deflated by southwesterly winds to the Pampa region. The Altiplano/Puna Plateau (Southwestern Bolivia, Northwestern Argentina and Northern Chile) is another primary source of LGM loess. The plateau comprises large playa, salt lakes, and outwash plains with extensive areas of fine sediment available for aeolian entrainment and the transport of fine materials in a NW-SE direction to the lowlands. Particularly the Southern Puna Plateau shows impressive Quaternary aeolian landforms as megaripples, gravel dunes and yardangs, and also being a present active area of dust. A first evaluation related to the volume and type of deflated sediment from the Purulla basin during the Holocene contributed to the analysis of the Southern Puna (25°-27°S; 68°30′-66°30′W) as a major dust exporting region.

HIGH RESOLUTION MAPPING OF DUST SOURCES IN NORTHERN AFRICA REVEALS DIVERSE GEOMORPHOLOGICAL SOURCES SOURCES

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The Sahara desert is considered to be the world's primary dust source. Previous studies suggested that most dust sources are located in topographic lows and composed of dry-lake deposits and playas. However, recent studies found that Saharan dust sources are more diverse and include other geomorphological units such as alluvial fans, sand dunes, rocky slopes. Despite these advancements, there are still knowledge gaps regarding the precise identification of geomorphological units that are major sources of dust, and the dynamics of dust emissions from those sources.The goal of the current study is to identify and characterize in high resolution the geomorphological units that are active dust sources in the Northern Africa during two years (1/2005-12/2006). The study site includes parts of Algeria, Tunisia, Libya and Egypt (80 W - 310 E to 220 N - 360 N). Dust sources were identified using a SEVIRI sensor installed on the MSG satellite imageries that enabled visual tracking dust plumes to their origins. The high spatial (3X3 km) and temporal resolutions (15 min) of the sensor allowed us to identify and delineate dust sources in 3-10 km. For each dust emission event we delineated polygon that circulate the area of the emission. Total of 2700 individual polygons were created for 2 years of data. Our preliminary results show that dust emissions are located in specific geomorphic units across the study area. Visual estimation of the geomorphic units that serve as dust sources reveal that most sources are Playas, floodplains, alluvial fans and anthropogenic areas. The next step of the study will include quantitative spatial analysis, of the data with relationship to geomorphic units, soil types, vegetation, and land use.

GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL CONTROLS ON ICELANDIC DUST EMISSIONS: OBSERVATIONS FROM MARKARFLJOT, SOUTH ICELAND

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There is increasing evidence for high magnitude dust storms in High Latitude Cold Climate (HLCC) regions. Yet, aeolian processes in these areas have been largely understudied and therefore our knowledge of these systems is limited. Understanding dust emission processes from HLCC regions is of increasing importance because future climate scenarios indicate a reduction in terrestrial ice masses and an expansion in glacial outwash plains which are the main dust sources in HLCC environments. Of these regions, Iceland is the most researched HLCC dust source region, however our understanding of processes which lead to dust events are still poorly understood. This paper focuses on a dust source in South Iceland. Markarfljot is a glacial river which is fed by the volcanic systems of Eyjafjallajökull and Mýrdalsjökull. The downstream outwash plains have been identified as contemporary dust sources from field observations and satellite imagery. Results from two spring field seasons (May/June 2014 and 2015) indicate that event emission rates are comparable to hot, arid desert regions (>7000µg/m3). Emission magnitudes are closely linked to the source's temporal state, particularly factors which affect surface sediment availability. Aeolian particle size varies dependent on surface characteristics, with some sources producing extremely fine particulates at source (Mode: <2µm). These sediments are of volcanic origin but are heavily affected by glacial, fluvial and aeolian processes. SSE wind directions transport particles towards Reykjavik (>80% of Iceland's total population) potentially creating a significant regional public health concern.

LONG-TERM AND SHORT-TERM DUST DEPOSITION IN CENTRAL ASIA – CLOSING THE KNOWLEDGE GAP CAUSED BY THE EMERGING ARALKUM

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Central Asia is part of the northern hemisphere desert belt, and is known as one of the main source areas of dust in the atmosphere. Over the last decades several dust studies have been carried out in this region, which have vastly expanded our knowledge of the spatial and temporal dust transport dynamics and the related processes. In consequence of the desiccation of the Aral Sea and the therefore expected intensification of the aeolian dust and sand transport, a demand for more detailed and up to date knowledge became obvious within the Aral Sea syndrome research community as this presented the rare opportunity to study an emerging desert. The main objectives of three different projects, aimed at closing this knowledge gap, were the retrospective analyses of the existing data about the Aral Sea syndrome, Central Asian desertification, regional dust sources, transport fluxes, and the dust depositions. As data about the deposition of aeolian sediments and their characteristics is still scarce, one important pillar of the research setup was the set up of a monitoring network for the long-term and short-term measurements of dust depositions in the Aral Sea basin. Literature analyses for the last decades and own dust deposition measurements between 2003 and 2012 showed an increase of the dust deposition rates on different temporal scales (from individual dust storm events up to the whole decade). Based on 23 meteorological stations, which also served as the sampling points for the dust deposition, regional dust sources like the Kyzylkum, Aralkum, Karakum or Khorezm were differentiated. The collected dust samples were characterized by the combination of meteorological and soil surface data, grain sizes as well as by their mineralogical and chemical composition.

EXPERIMENTAL STUDY OF AEOLIAN DUST EMISSION FROM SANDS UNDER SALTATION

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Dust emission is a major process in determining the global dust cycle. One of the key surface factors in dust emission is the particle composition of the topsoil. Surfaces composed of active sand grains (dunes, sand sheets) have been identified as dust sources in northern Africa, China, and elsewhere. This dust is apparently generated by different aeolian mechanisms that are related to settled dust particles and/or to the abrasion of the sand grains themselves under saltation. However, no empirical evidence of dust emission from active sands under saltation has yet been reported. The aim of this study is to explore aeolian dust emission from active sands by integration of wind tunnel simulations and laboratory analyses under different experimental conditions of shear velocities and particle compositions. First experiments were performed on sand from dunes of the Northern Negev Desert with modal diameter of 250 μm and initial content of dust-sized particles (< 63 μm) at 3-8 % by mass. Under low shear velocities, below the saltation fluid threshold, no emission of loose dust-sized particles was recorded. The amplification of the velocities, above the saltation fluid threshold (> 0.46 m s-1), caused an increase in PM10 emission, the magnitude of which depended on the specific shear velocity and the initial content of dust-sized particles in the sand bed. In addition, the dust emission under specific shear velocity and saltation flux declined over time until stabilizing at a constant low level of dust emission. Future experiments and field studies will enable a better understanding on the mechanisms of dust generation and emission from active sands.

SPATIO-TEMPORAL DISTRIBUTION OF NORTH AFRICAN DUST SOURCES AND THEIR VARIABILITY

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Mineral dust aerosol emitted from arid and semi-arid areas plays an important role to the Earth's weather and climate system. To estimate the effect of dust aerosol on e.g. radiation fluxes and nutrient cycles, detailed knowledge on the spatio-temporal distribution of active dust sources is necessary. The presentation will discuss the spatio-temporal distribution of active dust sources over North Africa as inferred from satellite observations and examined by numerical modelling. Furthermore, aspects of meteorological conditions fostering dust emission and determining dust transport pathways will be addressed.