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Aeolian erosion and sand transport over the Mejillones Pampa in the coastal Atacama Desert of northern Chile

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ABSTRACT

The Mejillones Peninsula in the coastal Atacama Desert of northern Chile is a region in which ocean–atmosphere–land interactions are particularly strong, resulting in enhanced alongshore winds that erode the surface and transport sand particles to the sea. Because the aeolian particles in the laminated sediments at the bottom of Mejillones Bay record long-term changes in the intensity of prevailing southerly winds, it is fundamental to understand aeolian processes such as wind erosion and sand transport to improve paleoceanographic reconstructions. The aim of the present study is to characterize the wind erosion process over the flat geomorphology of the northern portion of the Mejillones Peninsula, the Mejillones Pampa, including the influence of wind erosion on the initial particle size distribution and the associated fractionation processes of the mineralogical composition of moving particles, through field measurements. In addition, we test the ability of an existing saltation model (MB95) to reproduce the variability of the erosion process during the field experiment. Soil samples from 17 locations on this flat surface contain significant amounts of highly erodible particles with diameters in the 200–300 µm and 100–150 µm size ranges. Aeolian particles collected in BSNE sand traps located at different heights near the surface, exhibit a bimodal size distribution similar to that of the erodible fraction of the soils; the abundance of the fine class increasing with height. Small stones that have a spatially variable distribution can locally reduce the intensity of wind erosion. The mineralogical composition of moving particles is similar to that of the soils, with quartz, feldspar and calcite as the most important minerals, followed by clay minerals, gypsum and amphibole. A value of u_t^* is calculated for each soil particle size class. Subsequently, the elementary contribution of each size class to the horizontal flux is calculated using White (1979)'s equation and the total flux is finally obtained by integration. The saltation model successfully reproduces the variability of the wind erosion process during the field experiment, but over-estimates the vertically integrated mass fluxes measured *in situ* by two orders of magnitude.

1. Introduction

The nearshore waters along the eastern South Pacific Ocean constitute one of the most productive regions of the world's oceans, partly because of the upwelling of nutrient-rich water masses driven by the prevailing southerly winds. In the coastal Atacama Desert of northern Chile, these southerly winds respond to land–ocean–atmosphere interactions and regional climate features, resulting in the intensification of wind speed during the austral spring–summer (Rutllant et al., 1998).

The ocean-climate and geomorphological situation of Mejillones Bay (23°S) at the northern side of the Mejillones Peninsula (Fig. 1) provides a favourable setting for high-resolution paleoceanographic studies of laminated marine sediments (Ortlieb et al., 2000; Valdés et al., 2004; Vargas et al., 2004) aimed at reconstructing the variability of the southerly winds on timescales ranging from centuries up to thousands of years. The variability in mineral content and grain size of sand particles in these laminated sediments has been interpreted as resulting from variations in the wind intensity (Vargas et al., 2004) driving sand particles from the Mejillones Pampa — a flat surface of

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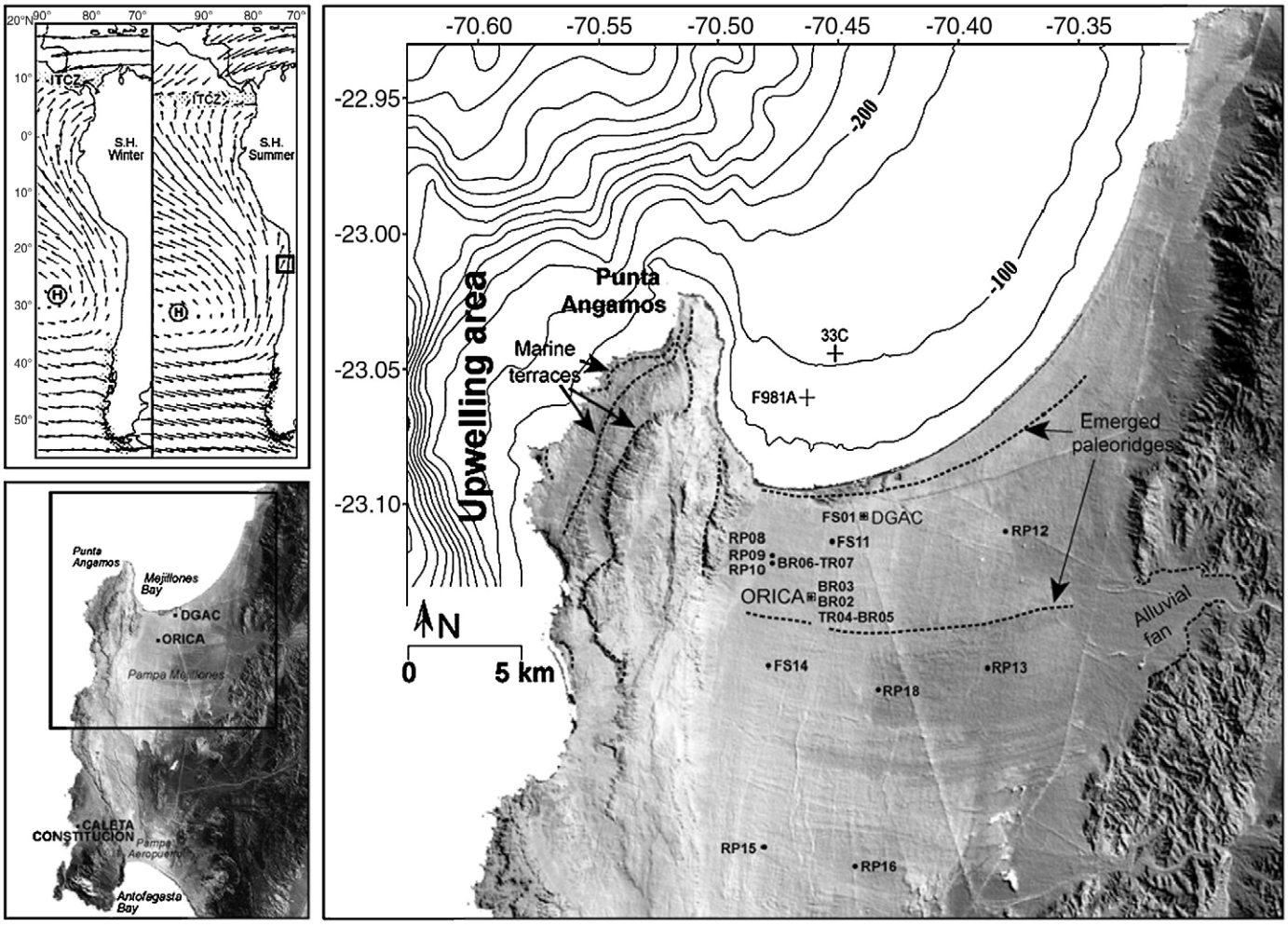

Fig. 1. Main features at the experimental site. Upper left panel: The subtropical anticyclone (H) and associated surface winds over the southeastern Pacific (after Strub et al., 1998); Lower left panel: The Mejillones Peninsula with location of measuring stations and geomorphological features; Right panel: Soil sampling sites (SM), sediment cores (+), bathymetry and local geomorphological features.

uplifted Pleistocene coastal plains — located just south of the Mejillones Bay. This interpretation is supported by the presence of generally E–W oriented ripples over the sandy surface of the pampa. These ripples are asymmetric towards the north, indicating that the strongest erosion events occur mostly in connection with southerly winds (Flores-Aqueveque et al., 2009). Recent paleoceanographic reconstructions based on mineralogical and textural analyses of these laminated sediments suggest decadal to centennial variations of coastal winds that induced changes in upwelling and primary productivity over the last ca. 250 years (Vargas et al., 2007).

The first aim of the present study is to characterize the wind erosion process over the Mejillones Pampa through the analysis of data from sediment traps collected in 2002 (EOLOS 2002) and from a field experiment performed in October–November 2006 (EOLOS 2006). To extend these results in time with standard wind observations from the Antofagasta (Cerro Moreno) airport and to simulate the subsequent transport and deposition processes of the eroded particles towards Mejillones Bay, a suitable erosion model will have to be considered.

Although many wind erosion models exist, very few are based on an explicit description of the physics of the aeolian processes involved in dust emission, and only one (Marticorena and Bergametti, 1995, hereinafter referred to as MB95) has been tested in a variety of arid and semiarid conditions (Gomes et al., 2003; Rajot et al., 2003; Alfaro et al., 2004). These studies showed that MB95 is able to predict the magnitude of particle transport over loose sandy soils, but that it must be adjusted in more complex cases, as for instance in fine, textured soils whose surface can easily become encrusted. The ability of the MB95 model to reproduce the variability of the erosion process during the field experiment is tested here.

In order to account for the diversity of the soil texture at the pampa surface and to enable simulation of the variability in the mineral content of the sediment cores beyond the experimental period, an explicit link must be found between the wind strength and the characteristics of the marine sediment laminae. Theoretically, this link can be provided by models describing the selective mobilisation of soil particles under the effect of surface wind stress, and their subsequent transport and deposition in the bay. Therefore, a second objective of the present study is to document the influence of wind erosion on the initial particle size distribution of the soil surface and the associated fractionation processes of the mineralogical composition of particles moving in the immediate vicinity of the source's surface, as deduced from analysis of the soil and aeolian particle samples collected during EOLOS 2002 and 2006.

2. Site description and experimental methods

2.1. Regional climate dynamics

The climate of the Mejillones Pampa, located north of Antofagasta (Fig. 1), is a good illustration of the way in which large scale atmospheric circulation is modified by the regional land–sea thermal contrast and the local geomorphology associated with bays and capes