5.4 Assessing Dune Activeness by a Wind Direction Analysis?

It is of some interest to see whether the dark dunes on Mars are currently active or whether a proportion of them are inactive paleo-dunes. By answering this question, useful information about the relative age of the dunes or environmental influences might be discovered. A wind direction analysis involves a comparison of the orientation of the dune slip faces with recent modelled wind fields (GCMs) computed for all crater localities (Sect. 4.7). This should reveal which dunes are currently influenced by wind action and which are not.

Several authors have compared aeolian features with general circulation models (GCMs) on Mars [e.g. *Greeley et al.*, 1993; *Anderson et al.*, 1999; *Fenton and Richardson*, 2001]. A study of sand drift and dune orientation in correlation with GCMs on Earth was performed by *Blumberg and Greeley* (1996). The primary aim of these studies is to investigate the distribution and orientation of aeolian bed forms and wind streaks by GCM predictions. The analysis presented in this section aims to answer the question whether a comparison of slip face-deduced wind directions with modelled MCD data could reveal the activity or otherwise of the dunes.

An active dune is influenced by current-day winds. A slip face is created by a combination of grain flow and grain fall driven by grains lifted by saltation and/or suspension [*Fenton*, 2005b]. Furthermore, the wind transports sand grains down-wind across the brink of the dune so that they drop down the leeward side. Consequently, the orientation of the dune slip face correlates with the direction of the dune-forming wind. Because the wind direction determines the dune type and shape, slip face orientation is a reliable indicator of the direction of the dune-building winds.

The presumption for this analysis is the following: if a dune field shows coinciding morphology-deduced and modelled wind directions, this will indicate that the dunes are influenced by currently blowing winds and are thus active. Conversely, if the current wind direction does not correlate with the dune-forming wind direction, the dunes are supposed to have formed in earlier times when wind conditions were different. Thus, these dunes are supposed to be inactive because their slip face orientation does not match the direction of the prevailing wind. The vectors for the main dune-forming wind (see Sect. 4.7.2) and the modelled yearly maximum wind were included in the GIS and compared with each other. Fig. 52 shows examples of concurrent and divergent wind directions (see image caption for further explanations). This comparison of modelled and morphology-deduced wind directions was done for every locality. The question was whether the distribution of dunes showing concurrent and divergent wind directions follows a specific global pattern. Fig. 53 displays the global distribution of concurrent, partially concurrent, and divergent wind directions at the investigated dune fields.

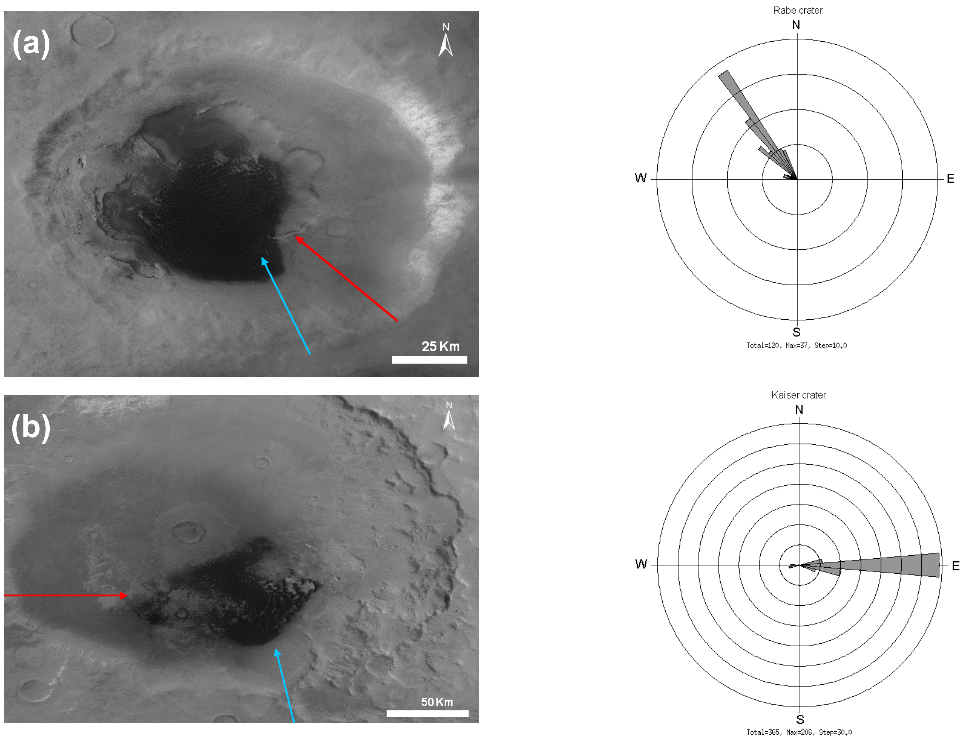

Figure 52: Wind direction comparison based on main dune-forming winds (morphology-deduced, red arrows) and modelled current wind data (MCD data, blue arrows) with corresponding rose diagrams showing the morphology-deduced wind direction.
(a) Concurrent wind directions at Rabe Crater (43.9°S, 34.8°E). The rose diagram indicates that the main dune-forming wind direction is northeast. The correlation of both wind directions leads to the assumption that the dune field has recently been influenced by current day winds. **(b)** Divergent wind directions at Kaiser Crater (46.5°S, 18.8°E). Main dune-forming winds come from the west as indicated by the rose diagram. The miscorrelation of the two wind directions points to different dune-forming wind conditions and the dunes are assumed to be inactive.

The global view shows clearly that there is no recognizable regional trend in the geographical position of dunes with correlating or divergent wind directions. In some cases, concurrent and divergent wind fields are close together. But does this examination really provide indications for active and non-active dunes? According to the physics of particle motion (Sect. 3.1), the friction threshold velocity needed to move sand-sized particles on Mars is 2.2 m/s [e.g. *Greeley et al.*, 1980; *Edgett and Christensen*, 1991] corresponding to an effective wind speed of more that 45 m/s [*Sullivan et al.*, 2005]. However, the modelled wind speeds, which were consulted for this analysis, reach a maximum of <20 m/s (see Table 6: the maximum wind speed predicted for Barnard Crater is 19.75 m/s). An additional problem involved in using modelled wind fields of the given spatial resolution is that the model does not account for local topography and thus ignores the local fall winds that may be caused by the crater morphology. These wind gusts can reach much higher velocities than those predicted by the regional wind models. It cannot be ruled out that the dunes are influenced by these faster local winds, too.

Consequently, modelled wind speeds alone cannot be regarded as forming the dunes on Mars because moving the dune sands requires higher wind velocities. Nevertheless, this analysis leads to the conclusion that the dunes studied are most likely to have been shifted by dust storm events when winds reach higher speeds. Dust storms events occur sporadically on Mars, and their extent varies from local to global. However, no dust storm was observed in the last 30 years which shifted a dune to a significant extent (e.g. in 1971, 1977, 1979, 2001, 2005, 2007, [e.g. *Leovy et al.*, 1972; *Ryan and Sharman*, 1981; *Zurek*, 1982; *Moore*, 1985; *Cantor et al.*, 2001; *Bowles et al.*, 2007; *Gawrych*, 2007; *Montabone et al.*, 2007]; cf. Sect. 3.1 and 3.2). The conclusion is that the dunes observed are at least older than the observation time range. In the following sections, it will be deduced that a much greater age may be assumed for these dunes.

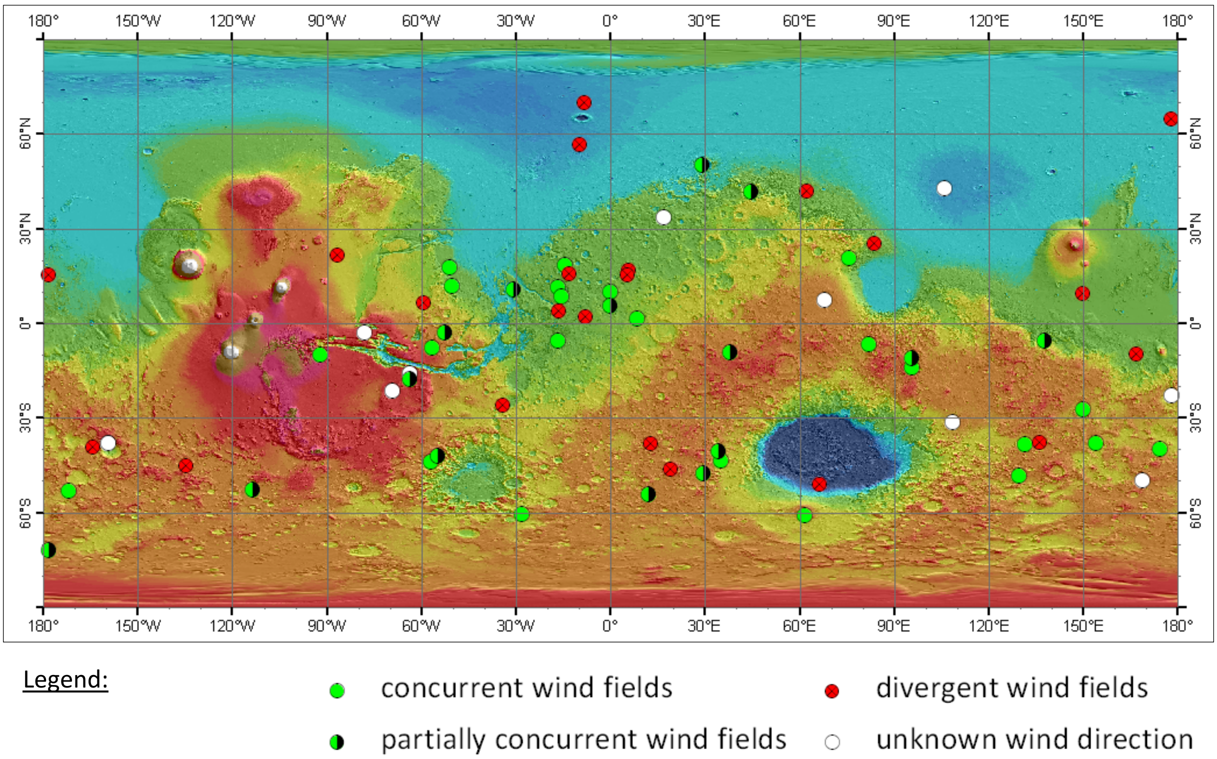

Figure 53: Results of the wind direction analysis showing the global distribution of dune fields with concurrent, partially concurrent, or divergent wind directions (background: MOLA topography map).

Correlation with modelled wind speed data is a difficult analysis whose results must be interpreted with care. Several authors have come to similar conclusions. Thus, for example, *Hayward et al.* (2007a) found a fair correlation between slip face orientation and GCMs in many places. However, they also found a number of dunes whose orientation differed from the predicted GCMs. In addition to the possibility that the dunes might not currently be influenced by wind, the reason for the miscorrelation might also be that local topography has a stronger influence on slip face orientation than regionally prevailing winds [*Hayward et al.*, 2007a]. Furthermore, meso-scale GCMs such as those used in this study cannot resolve all prevailing local near-surface winds that might influence a dune field. The uncertainty of model results has always to be considered when interpreting a comparison of GCM data with real conditions.

Greeley et al. (1993) correlated GCMs with dark streaks. The majority of dark streaks are composed of the same material as the dunes because they are formed by the down-wind deflation of dune material (for type-II dark deflational streaks see *Thomas et al.* (1981) and footnote on page 28) but might have a different particle size from the dunes. *Greeley et al.* (1993) revealed that the formation of dark streaks is not equally well reproduced by GCMs for all seasons. They found the dark streak formation to correlate with the decay phase of global dust storms. Furthermore, they found it to be very sensitive to high surface stress and low dust opacity. Because these factors are mutually exclusive in general, the right conditions for the formation of dark streaks and thus for the transport of dark material occur very seldom. This is consistent with the conclusion of this analysis that dark material transport is rare today, and might at best occur during dust storm events.