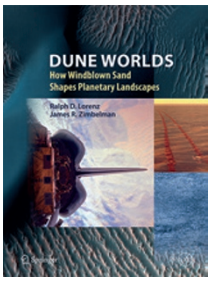
Wind-swept planets



Dune Worlds: How Windblown Sand Shapes Planetary Landscapes

by Ralph D. Lorenz and James R. Zimbelman

SPRINGER PRAXIS BOOKS, 2014. 308PP. £90

Dunes — shaped by dynamic interactions between granular material and boundary layer winds — have been observed on several planetary bodies, including Earth, Mars, Venus, and Titan. Dunes and (at a smaller scale) wind ripples that form on sand surfaces are some of the most aesthetically pleasing landforms known and are excellent examples of emergent behaviour in complex systems. *Dune Worlds* is a well-illustrated book that introduces the curious reader to the characteristics of dunes, and to the processes underlying their formation in different planetary environments.

Written by two planetary scientists who have studied dunes on Mars and Titan as well as terrestrial analogues, *Dune Worlds* brings a fresh perspective to dune science by comparing dunes and other aeolian bedforms across a diversity of planetary environments. The book is similar in its breadth to a predecessor, *Wind as a Geological Process on Earth, Mars, Venus and Titan* by Greeley and Iversen (Cambridge Univ. Press, 1985), but benefits from the explosion of observations of planetary surfaces by orbiters, landers and rovers over the past 30 years. The same time period has also seen a proliferation of dune studies on Earth, including detailed process-based field and laboratory studies, remote-sensing analyses, and development of numerical models of dune formation and evolution. Hence, there is a rich sandbox of scientific advances for *Dune Worlds* to draw on in its summary of dunes across the Solar System.

The book begins with the physical principles of dune formation and dune dynamics. Our understanding of the physics of sand and dunes owes much to the seminal studies of Ralph Bagnold in the 1930s and 1940s. Subsequent research has refined the fundamentals put forth by Bagnold. As Lorenz and Zimbelman explain, we now understand how sand entrainment and transport differ in cold and thin atmospheres, such as on Mars; cold and dense atmospheres (on Titan, for example); and hot and dense atmospheres, as is the case on Venus.

The reader is next taken on a tour of planetary dune systems. Despite different atmospheres and even different sand compositions, dune forms on different planetary bodies are remarkably similar. Images of Titan have revealed large linear dunes that have similar dimensions to terrestrial dunes found in the Arabian Peninsula and Namibia. This suggests that the fundamental processes of sand movement and dune formation are similar across the Solar System despite differing atmosphere and sand characteristics.

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The book provides a valuable summary of planetary dune characteristics, as well as the atmospheric and geologic boundary conditions relevant to dune formation. Lorenz and Zimbelman detail how the variable degree of dune formation on different planetary bodies reflects the supply of sand-sized sediment, atmospheric circulation patterns, and climatic or topographic conditions that promote sand deposition. Dunes cover 1–2% of Earth's land area, 0.62% of Mars, and as much as 12.5% of Titan's surface. Two small dune fields have also been imaged on Venus. In all cases, most dunes and windblown sand are concentrated in sand seas and dune fields. On Earth, these mostly lie in the major deserts. Dunes on Mars are concentrated in the vast sand seas that surround the north polar ice caps, with smaller dune fields located in impact craters in the southern hemisphere. Titan's dunes are mostly concentrated in extensive low latitude belts of linear dunes composed of sand-sized grains of organic compounds.

Dunes have been an active area of study since Bagnold pioneered desert exploration and sand research in the 1930s. The book summarizes the various methods employed in dune science, with an emphasis on modern techniques — for example, the use of GPS to measure dune movement, ground penetrating radar to image dune sedimentary structures, and experiments in wind tunnels. Methodologies for planetary dune study, such as thermal imaging of Martian surfaces and radar imaging of dunes on Earth and Titan, are covered with authority. Numerical modelling, which has advanced rapidly in recent years to include computational fluid dynamics simulations of airflow and cellular automaton models of dune development, is also shown to provide valuable insights into formative dune processes.

The final section provides an eclectic overview of the significance of dunes to science, civilisation and culture, with a lengthy and over-illustrated section about moving in manned and unmanned vehicles across sand. The mobility of military and recreational vehicles is referenced in the context of rovers on Mars.

The view of dunes presented by *Dune Worlds* reflects the authors' own research experience. As a result, there are some topics that receive only cursory attention. For example, more could be said about the significance of Earth's dunes as palaeoclimatic indicators and the dynamics of airflow and sediment transport across dunes. The authors write with much greater authority when discussing Mars and Titan and these chapters also feature the best illustrations.

Dune Worlds is not a textbook but appropriate literature is cited, although somewhat inconsistently. I would have preferred a list of further reading at the end of each section to guide the inspired or curious reader to delve into the scientific literature in greater depth. Some of the illustrations are also poorly reproduced or either too small or too large.

Formed by wind-blown sand in starkly different surface environments, dunes can help us to constrain the atmospheric and geologic properties of planetary surfaces. *Dune Worlds* concludes with an interesting chapter on fictional dune worlds, such as the science-fiction novel *Dune* and the Star Wars films. Even as the book ventures into fantasy, the reader remains grounded in the fundamental aspects of dune science, and will be inspired to explore further. ❐

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