Turbulent Dynamics of Sandstorms

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Abstract

Sandstorms are a wide range of extreme catastrophic weather, effective prevention and control of sandstorms is one of the main objectives of sustainable development in China and even in the world. Meanwhile, sandstorms, as essentially high-Reynolds-number gas-solid two-phase wall turbulence occurring over erodible beds, are the most challenging problems in fluid dynamics. However, researches on sandstorms are currently focused on the fields of geoscience and atmospheric science, and the understanding of the turbulence dynamics involved is still absent. Therefore, our research on sandstorms from the perspective of turbulence dynamics can not only deepen the understanding of turbulent multiphase flow, which is the most challenging common scientific problem in fluid dynamics, but also contribute to the improvement of the accuracy of the prediction of sandstorms and the scientific prevention and control. Specifically speaking, we conducted the multi-physics and multi-point synchronous three-dimensional high-frequency field observations of 95 sandstorms, based on the processing and analysis of the observation data, the main innovative results achieved are as follows: 1) A universal method for statistical processing of nonstationary data is proposed; a key mechanism determining the tilting characteristics of turbulent structures is discovered, and the reconstruction and characterization of the three-dimensional topological morphology of the very-large-scale motions is successfully achieved; and its origin, evolution and mechanism in nonstationary flow processes are revealed; 2) It is observed that not only the flow field, but also the dust concentration field contain the characteristics of very-large-scale motions and wall-attached eddies; however, the dust structure is obviously different from the flow structure; therefore, wind tunnel experiments are designed to reveal the feedback effect of the non-equilibrium process of particle motions on the turbulence; 3) Bispectral analysis of the sandstorm process, multiscale analysis of turbulence modulation, and interphase modulation analysis of gas-solid two-phase wall turbulence are proposed, revealing the interaction patterns including stage characteristics, scale effects and interphase modulation; a prediction model of the real turbulent wind field of sandstorms is established; and a simulation of the dune field evolution considering turbulence effects is achieved to improve the accuracy of its simulation.

Keywords: Sandstorms, Nonstationary flow, Two-phase structures, Turbulent dynamics

Acknowledgments

We sincerely thank the Asian Fluid Mechanics Committee (AFMC) for their exceptional efforts in organizing the 18th Asian Congress of Fluid Mechanics (ACFM) scheduled to be held in Seoul, Korea, from September 10 to 13, 2025. Support from National Natural Science Foundation of China (Grants No. 12388101, No. 92052202, and No. 12372217) is gratefully acknowledged.

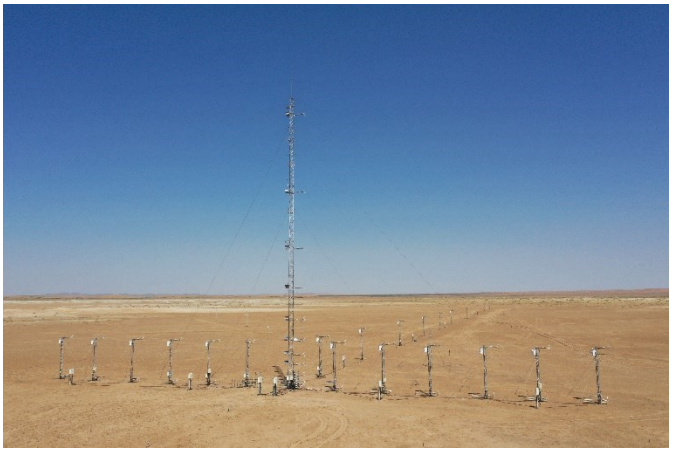

Figure 1. Multi-physics and multi-point synchronous three-dimensional high-frequency field observations system

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