High-precision numerical simulation of dust devils

Investigating the influence of land-surface models on the formation of dust devils in Large-eddy simulations

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In Short

- Does an LSM influence boundary-layer statistics as opposed to a homogeneous forcing?
- Is dust devil formation influenced by using an LSM?
- Quantify the differences in terms of dust transport to give valuable information to climate research.

This project seeks to improve our understanding of how the use of a land-surface model (LSM) in a large-eddy simulation (LES) influence the formation and behavior of dust devils. Dust devils occur when strong surface heating causes hot air near the ground to rise and spin due to small disturbances in wind patterns. Though they are typically small and short-lived, dust devils can carry dust and other particles into the atmosphere, making them important for studying weather and climate processes, especially in arid regions.

LES allow us to model atmospheric turbulence, such as the swirling air patterns that give rise to dust devils, with high accuracy. However, to accurately simulate how dust devils form, we need to properly represent the interaction between the land surface and the atmosphere, which can be done in two ways. The simplest way is to prescribe surface conditions like heat and moisture, based on measurements or assumptions. While this method is straightforward, it assumes that the surface is uniform across the simulation area, which might not accurately reflect real-world conditions.

The more advanced approach is to use an LSM, which uses surface and soil characteristics as input such as soil type, vegetation cover, and surface roughness. An LSM calculates how heat and moisture are exchanged between the ground and the atmosphere, solving energy-budget equation for the surface temperature. This method allows for more realistic simulations. This approach is often applied in realistic simulations where detailed measurements of surface fluxes are missing and the landscape is highly varied, such as in cities or areas with different types of vegetation.

In this project, we will directly compare these two approaches—prescribed surface conditions versus detailed LSMs—to see how they affect the formation, size, intensity, and behavior of dust devils.

The project is built on our previous work, where we found that while LSMs improve the accuracy of how surface temperature is represented in LES, they do not drastically change the overall behavior of larger atmospheric turbulence. However, it remains unknown whether LSMs have a stronger influence on the formation of dust devils. By addressing this, our research will push the boundaries of what is currently understood about dust devils and the role of turbulent structures on the land surface in their formation. The insights gained from this project could have broader applications, such as improving climate models and environmental forecasts, particularly for regions prone to dust storms.

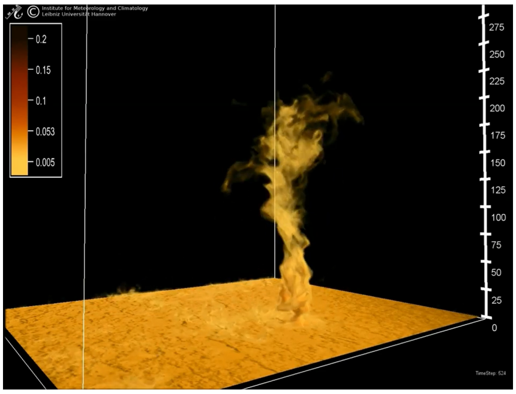

***Figure 1:** Screenshot of a dust devil animation created by B. Maronga, F. Hoffmann, T. Riechelmann and S. Raasch, copyright 2013 Institut für Meteorologie und Klimatologie, Leibniz Universität Hannover,* http://dx.doi.org/10.5446/9352

WWW

https://www.meteo.uni-hannover.de/de/forschung/grenzschichtmeteorologie

More Information

[1] Download PALMs source code at https://gitlab.palm-model.org

Project Partners

none

Funding

none

DFG Subject Area

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