A global surveillance system for Fusarium wilt in a changing climate by integrating remote sensing and aerosol transport modeling

Rocío Calderón[1]✉, Hannah Brodsky[2], Chad Vosburg[3], Jaclyn Eller[1], Andrew Miles[3], Natalie Mahowald[2], Sharifa Crandall[3], Ryan Pavlick[4], and Kaitlin Gold[1]

[1]Plant Pathology and Plant-Microbe Biology Section, Cornell AgriTech, Cornell University, Geneva NY, USA.
✉ mc2283@cornell.edu
[2]Department of Earth and Atmospheric Sciences, Cornell University, Ithaca NY, USA.
[3]Department of Plant Pathology and Environmental Microbiology, Pennsylvania State University, University Park PA, USA.
[4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA, USA.

Abstract

Fusarium oxysporum (*Fo*) is a ubiquitous soilborne fungus that causes Fusarium wilt (FW) in 100+ crops. Uncertainties in aspects of its epidemiology and a lack of global distribution data have historically challenged monitoring and containment efforts.

We address this need by integrating remote sensing, aerosol transport and comparative genomics to build a global disease surveillance system for FW incidence and *Fo* dispersal risk in aerosolized agricultural dust under various climate change scenarios. As foundation, we developed:

1. A global susceptibility assessment based on satellite data that integrates the three aspects of the disease triangle: host, pathogen, and environment. We identified agricultural production zones conducive to FW, noting subsets capable of serving as dust sources, by overlapping the MODIS Deep Blue algorithm with Landsat-based cropland product. We then restricted this assessment to only regions with reported *Fo* in the past 30 years so that we released an interactive, global web map documenting 4500+ FW incidences reported in peer-reviewed literature. Conducive disease environment was modeled using multiple satellite-derived products with species distribution models (SDM).
2. An adapted CAM6-MIMI climate model to simulate long-distance atmospheric *Fo* spore transport by incorporating spore traits that may influence dispersal and atmospheric survival. This model was parameterized using the 2020 Godzilla dust event. We found modeling evidence of transoceanic and intercontinental atmospheric transport of viable *Fo* spores and offered a danger index for *Fo* spore deposition on susceptible agricultural zones.

This integrated approach to disease surveillance provides key insights about FW epidemiology, drivers for current and future FW distribution and the *Fo* spread on global dust currents, while increasing our knowledge of the capacity of remote sensing and earth system modeling to detect, quantify and inform risk of biotic stress.

Acknowledgements

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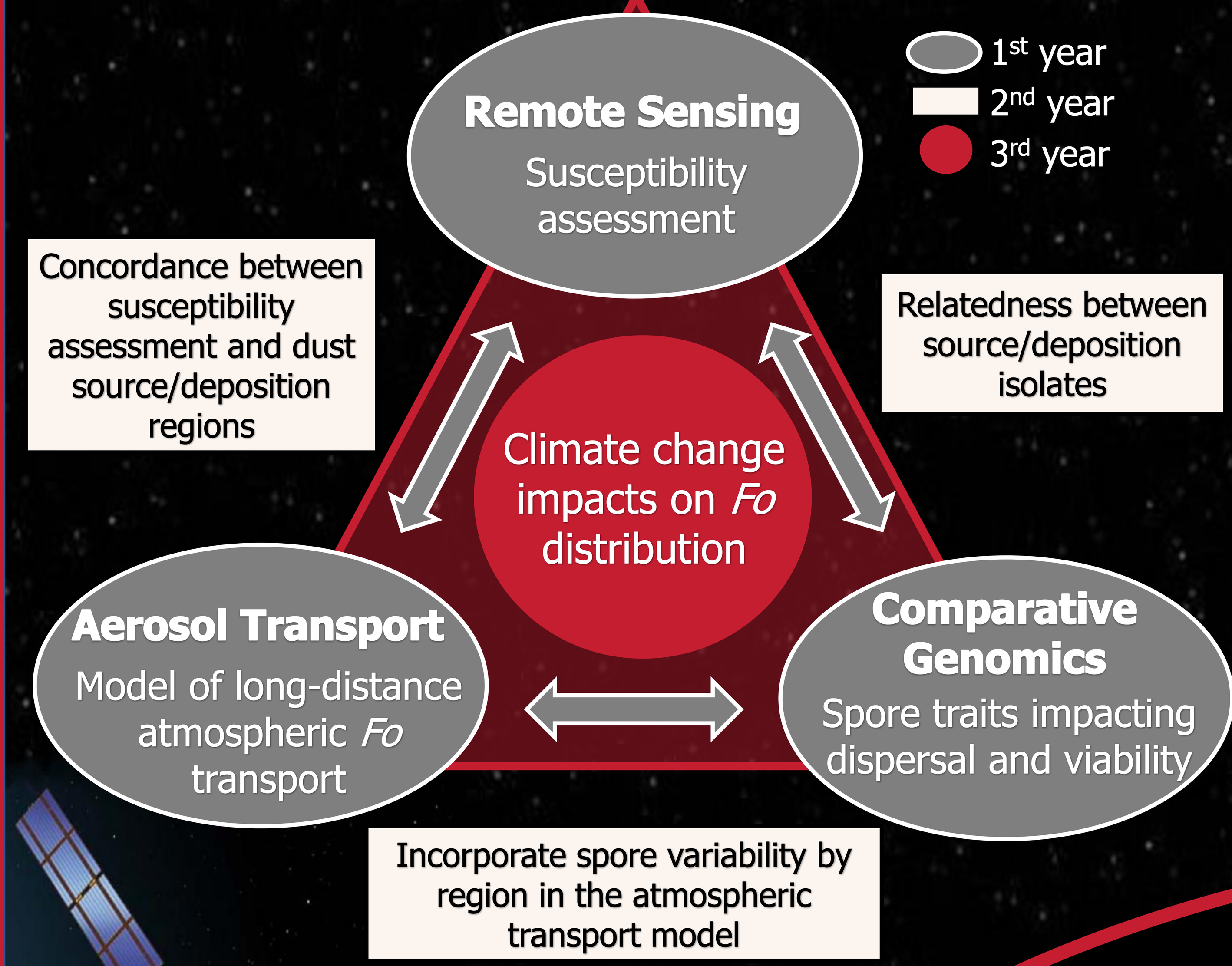
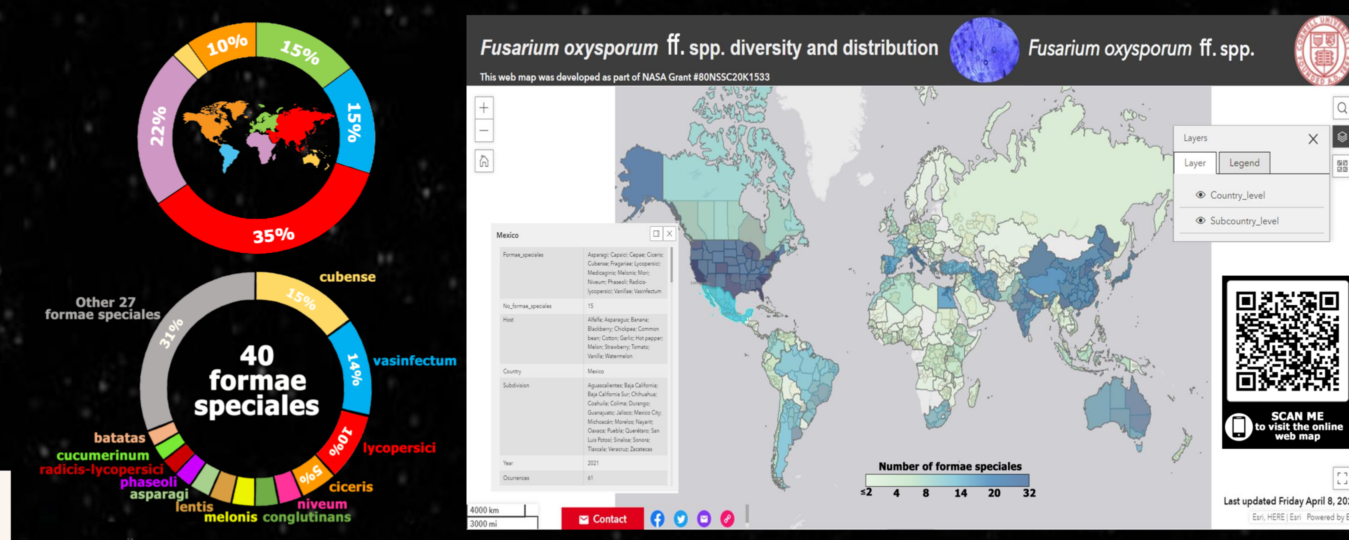
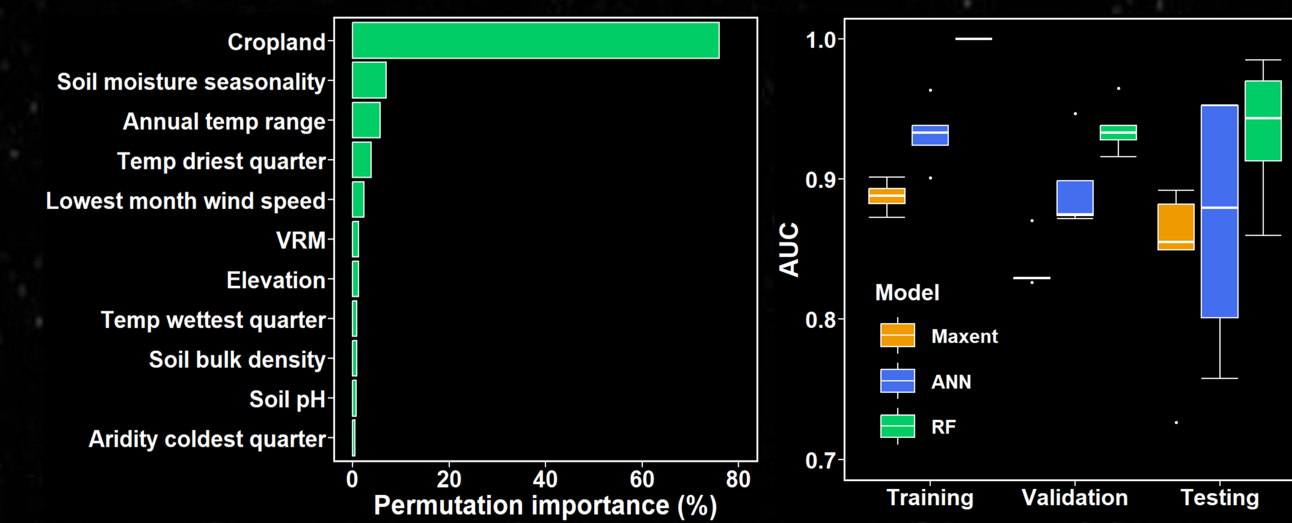
Fusarium oxysporum Global Surveillance System framework

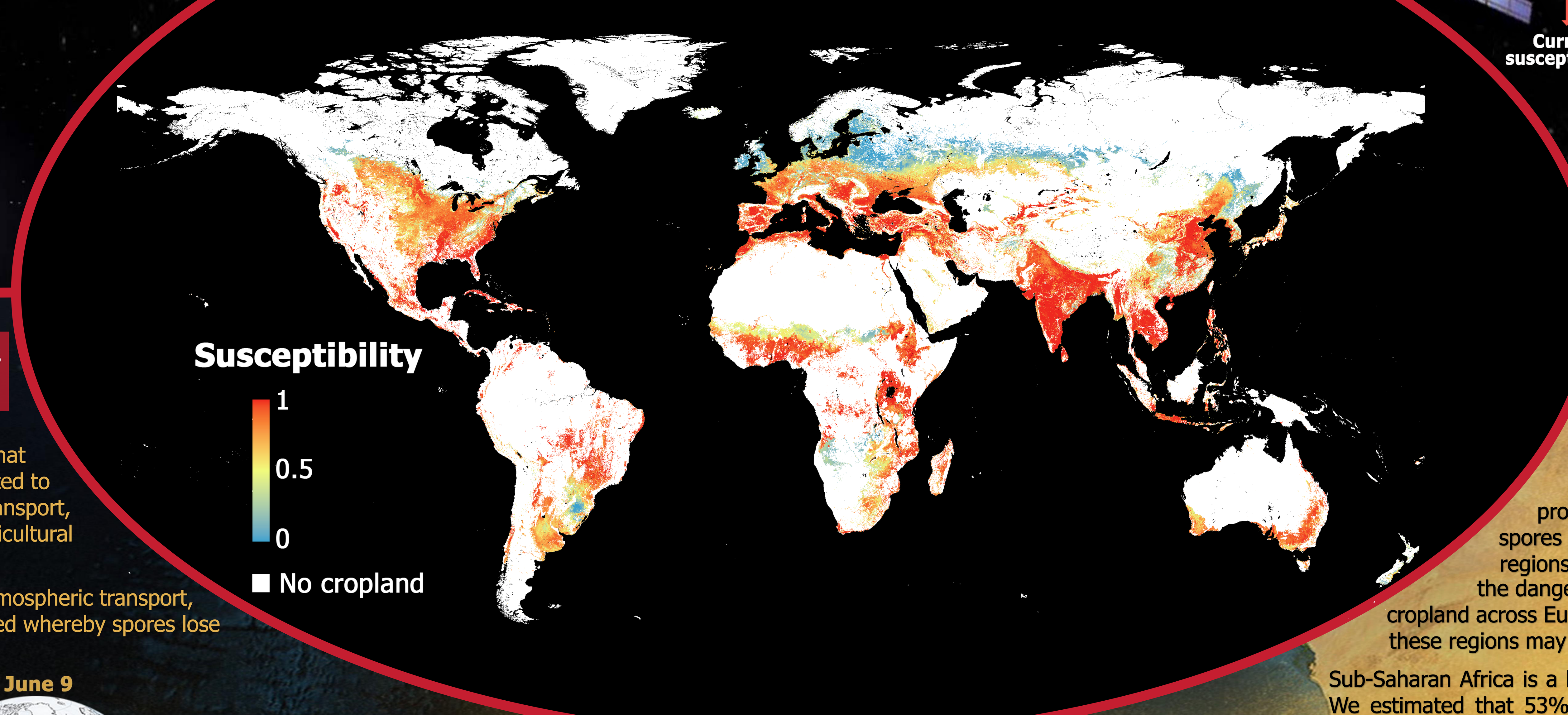






Susceptibility assessment workflow and results

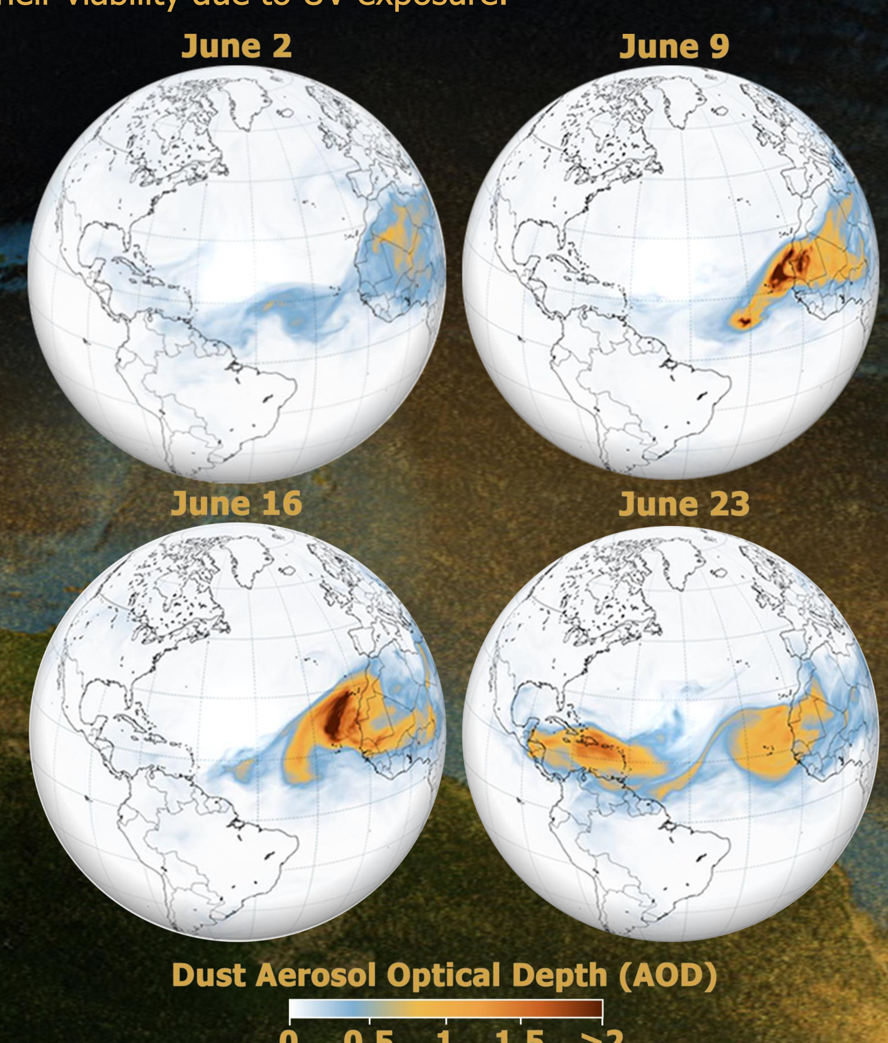
Global susceptibility assessment 1990 - 2022



CAM6-MIMI modifications and simulations

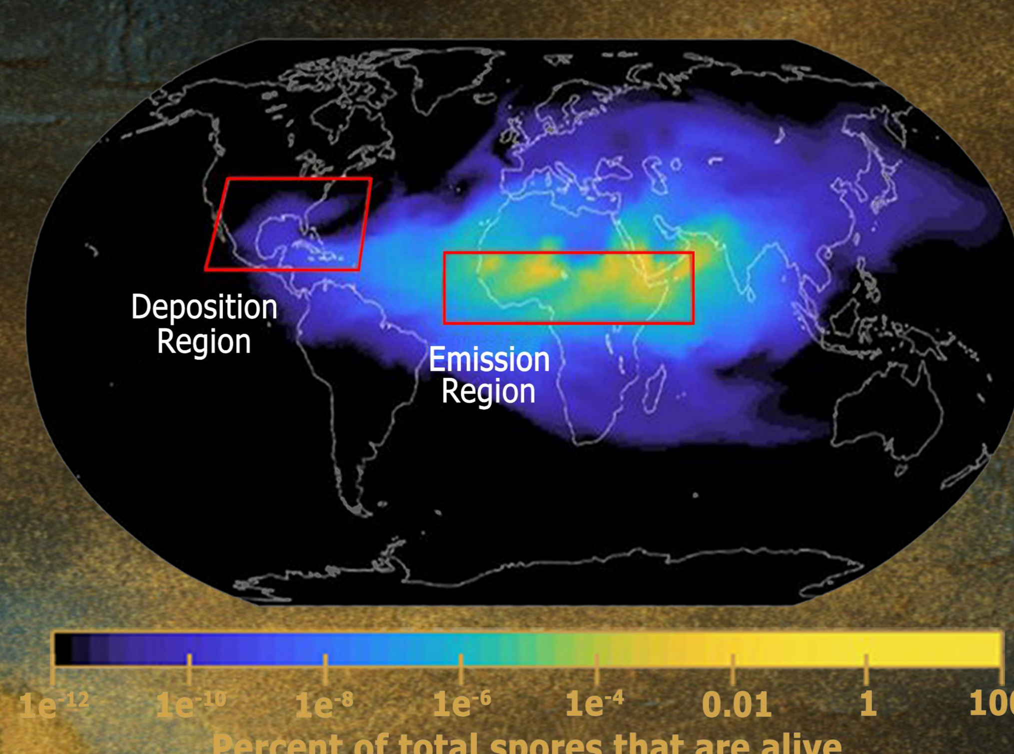
The Earth System Model (CAM6-MIMI) that simulates the aerosol lifecycle was adapted to include agricultural dust and *Fo* spore transport, estimating *Fo* spore concentration in agricultural soil from our web map.

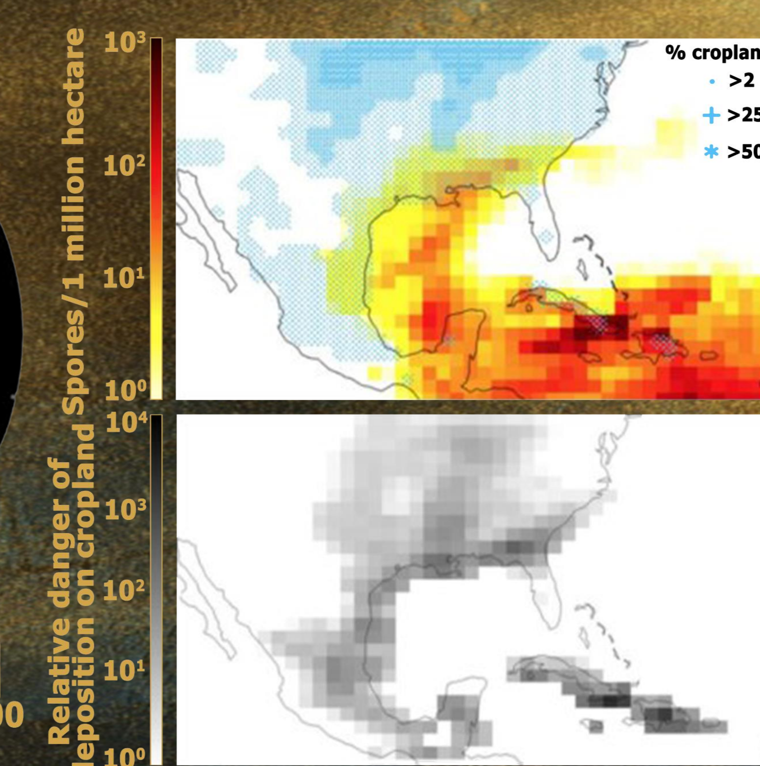
To simulate spore deactivation during atmospheric transport, an exponential decay function was applied whereby spores lose their viability due to UV exposure.



We simulated the transatlantic transport of *Fo* spores during a major dust storm (Godzilla event) in June 2020 from Northern Sub-Saharan Africa (Emission Region) to the Caribbean and southeastern US (Deposition Region).

Sensitivity analysis for Godzilla dust event in June 2020



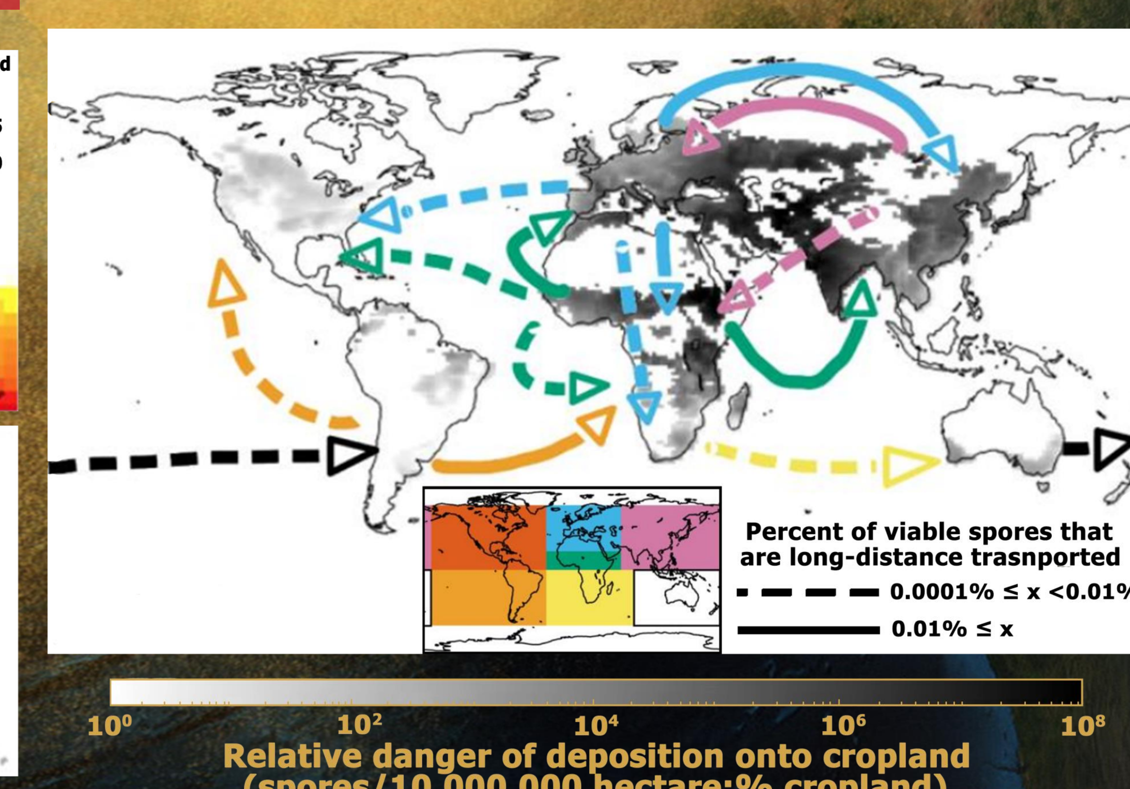


A maximum of $10e^{-7}$% of spores from the Emission Region that reached the Deposition Region were still viable. Although most spores from North Africa were deactivated long before they arrived in the Americas, this model study suggests that viable transatlantic spore transport is possible during extreme events. The danger index, defined as the number of viable spores deposited onto cropland, was higher in Mexico, Cuba, Haiti and the Dominican Republic than in the continental US.

Global implications

Global long-distance spore transport in 2020 was dominated by interactions between western Eurasia, North Africa, and Northern Sub-Saharan Africa due to their proximity; 96% of viable long-range transported spores either originated or ended up in one of these regions. This connectivity produced a high rating for the danger of long-distance viable spore deposition on cropland across Eurasia-Africa. The aerial interconnectedness of these regions may lead to shared genetic material across them.

Sub-Saharan Africa is a hub for long-distance viable spore transport. We estimated that 53% of all viable spore deposition and 14% of long-distance transported viable spore deposition originated in Sub-Saharan Africa. Thus, Sub-Saharan Africa could be important for plant disease spread.



Brodsky H., Calderón R., Hamilton D. S., et al. Assessing long-distance atmospheric transport of soilborne plant pathogens. In review, *Environmental Research Letters*.

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