Soilborne plant pathogen dispersal and assessment: Building a remote sensing-based global surveillance system for plant disease

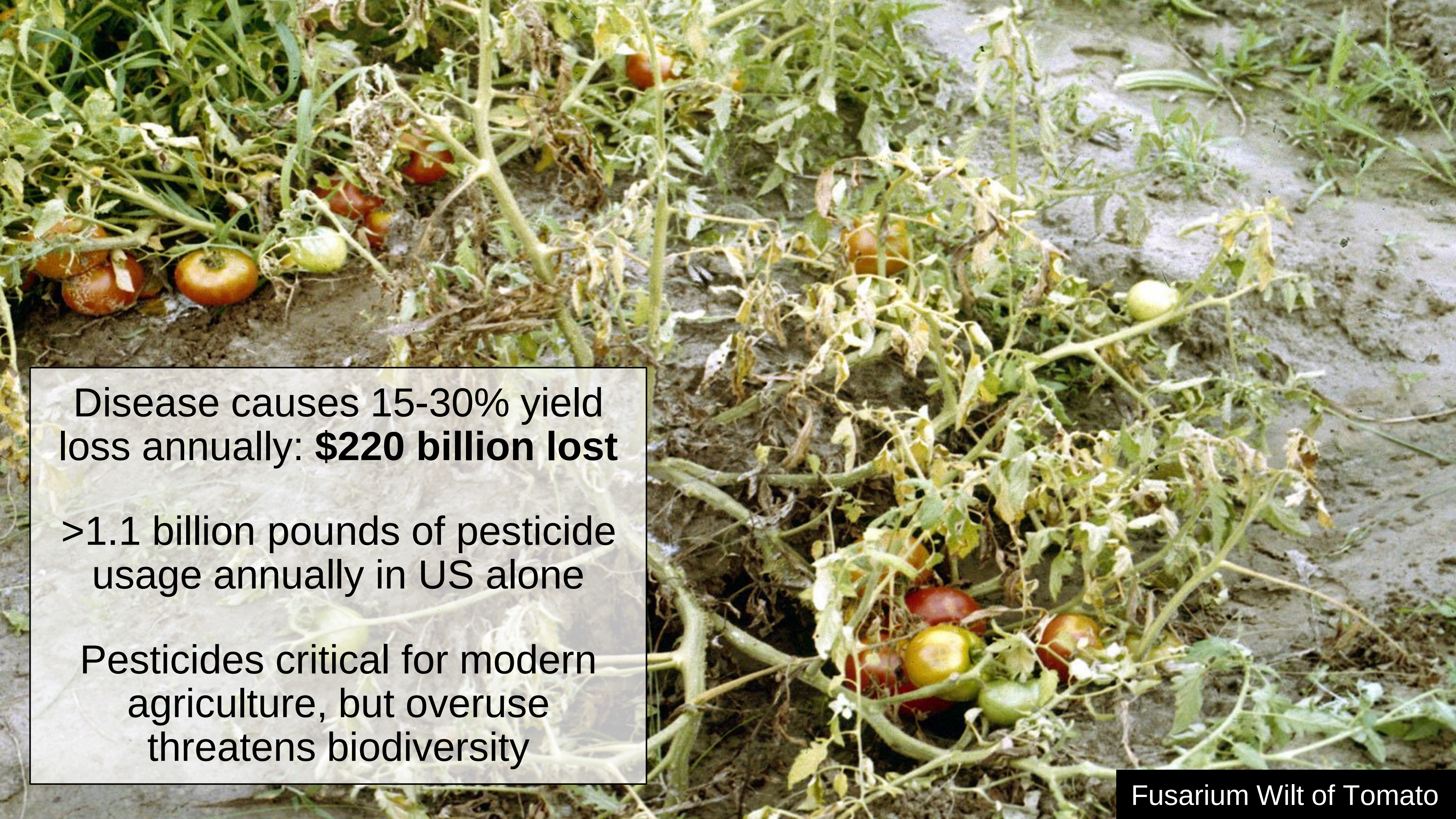
Katie Gold, Cornell University

Rocio Calderón, Hannah Brodsky, Jaclyn Eller (CSUN), Andrew Miles (PSU), Natalie Mahowald, Sharifa Crandall (PSU), and Ryan Pavlick (JPL)

NASA ROSES Interdisciplinary Sciences Grant #80NSSC20K1533

Global dust current

Fusarium oxysporum



Disease causes 15-30% yield loss annually: **$220 billion lost**

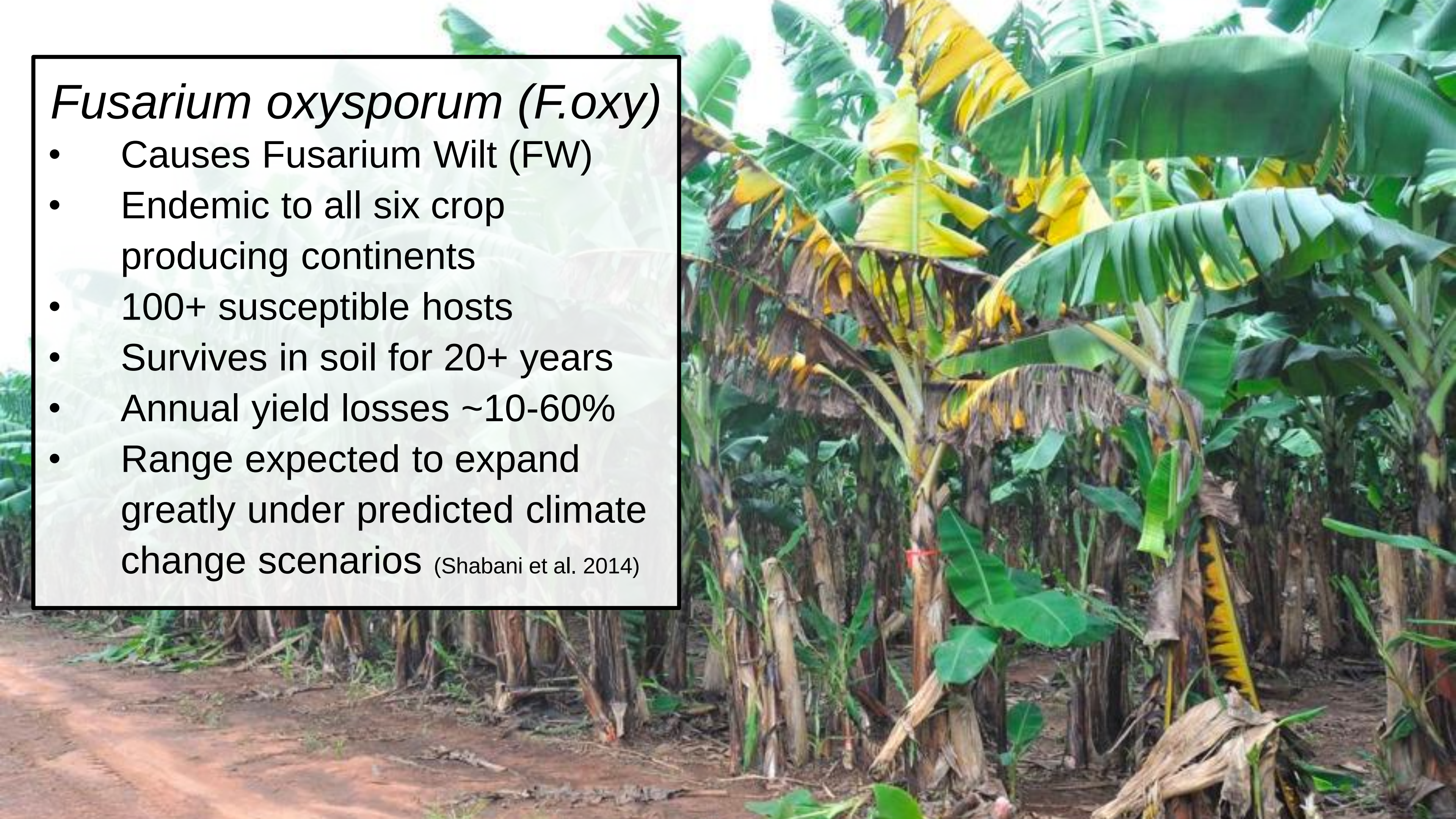
>1.1 billion pounds of pesticide usage annually in US alone

Pesticides critical for modern agriculture, but overuse threatens biodiversity

Fusarium Wilt of Tomato

Fusarium oxysporum (F.oxy)

- Causes Fusarium Wilt (FW)
- Endemic to all six crop producing continents
- 100+ susceptible hosts
- Survives in soil for 20+ years
- Annual yield losses ~10-60%
- Range expected to expand greatly under predicted climate change scenarios (Shabani et al. 2014)



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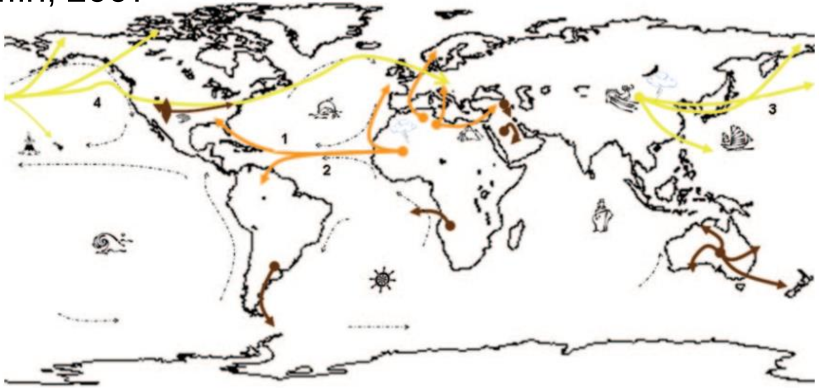
Preserving existing agroecosystems is critical to preserving natural ecosystems and global biodiversity

Griffin, 2007



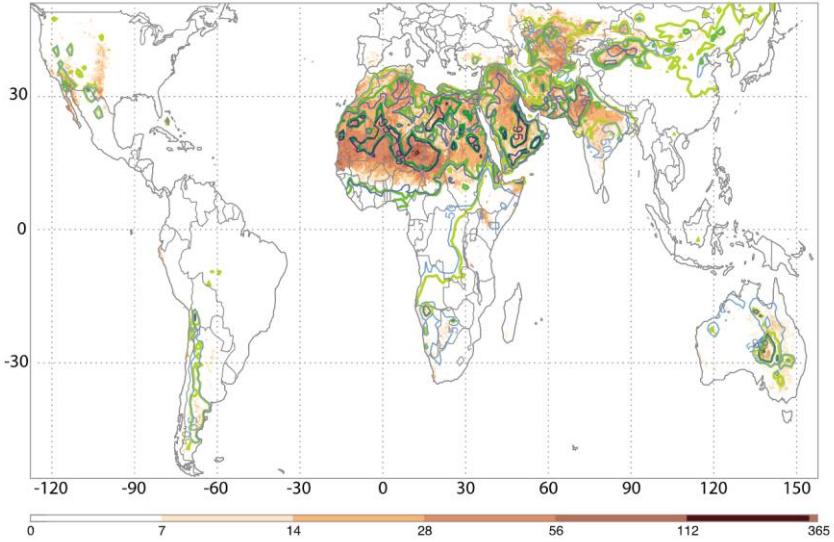
Soil dwelling fungi are capable of aerosolization and transport in global dust plumes.

Griffin 2001, Kellogg 2004, Barberan 2015

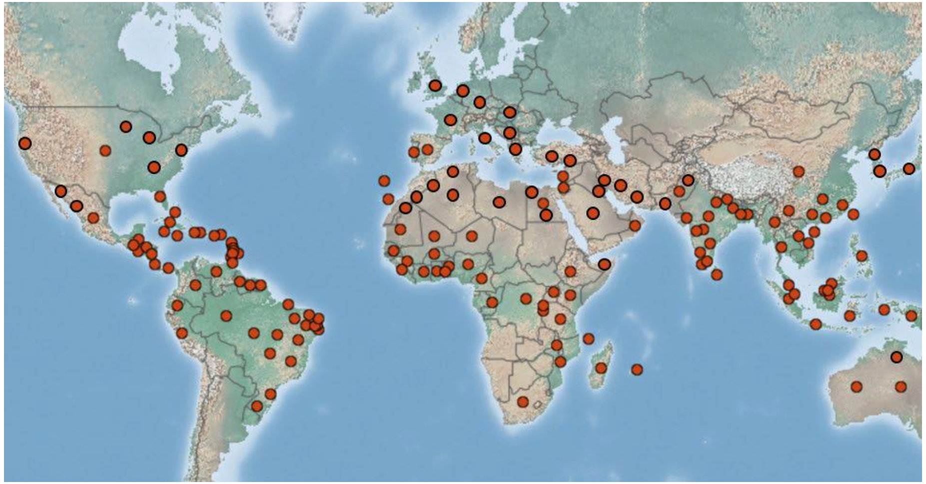
Infectious *F.oxy* spores and DNA have been isolated from North African and Asian dust samples.

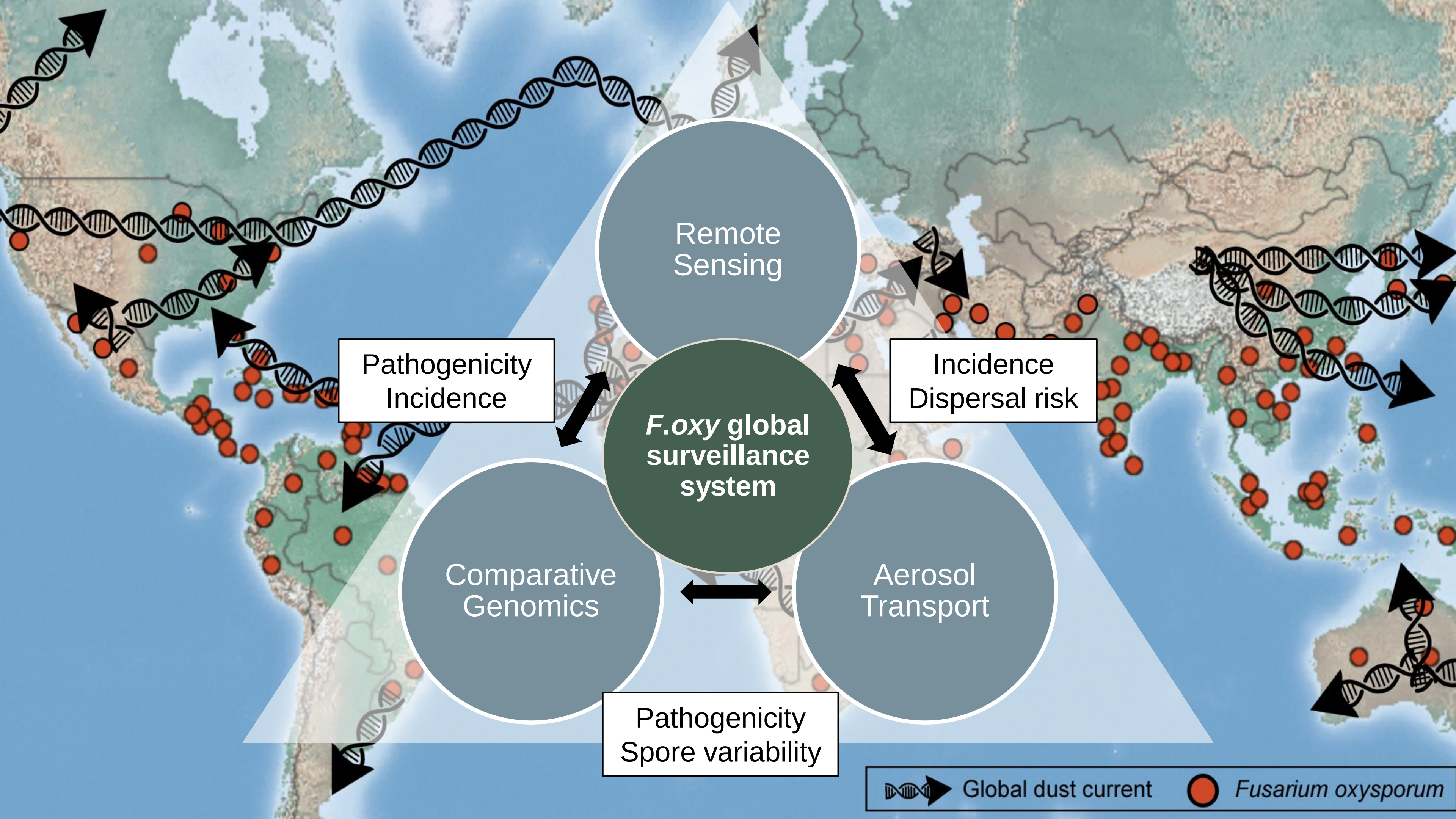
Yeo & Kim 2002, Palmero 2011, Giongo 2013, Gonzalez-Martin 2014

Ginoux et al. 2012



CABI, 2019




Remote Sensing
Pathogenicity Incidence
Incidence Dispersal risk
F.oxy global surveillance system
Comparative Genomics
Aerosol Transport
Pathogenicity Spore variability
Global dust current
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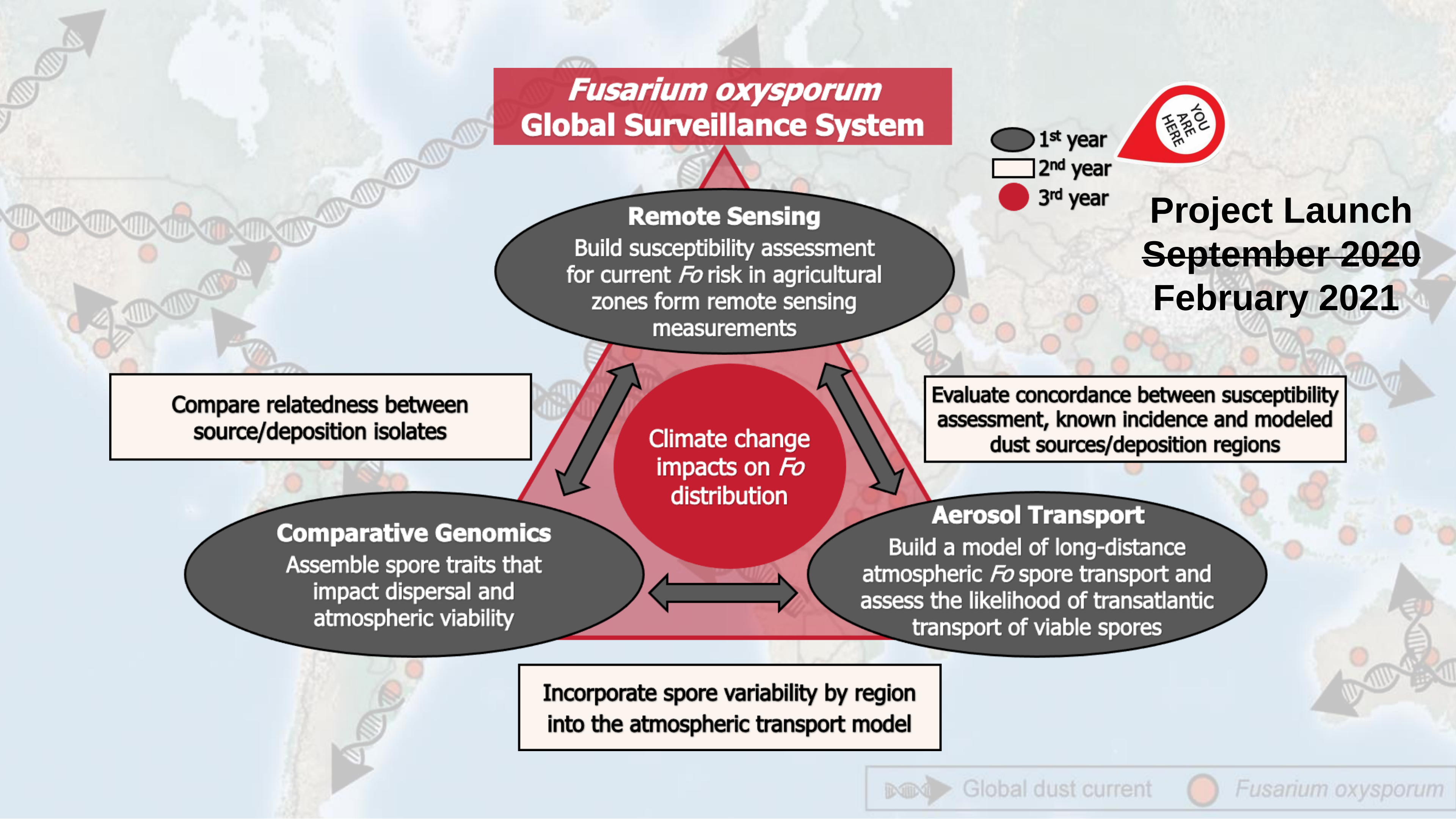
Fusarium oxysporum
Global Surveillance System
1st year
2nd year
3rd year
YOU ARE HERE
Project Launch
~~September 2020~~
February 2021
Remote Sensing
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Compare relatedness between source/deposition isolates
Climate change impacts on Fo distribution
Evaluate concordance between susceptibility assessment, known incidence and modeled dust sources/deposition regions
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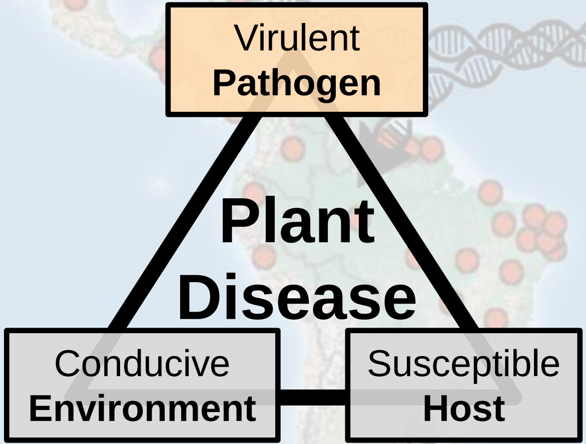
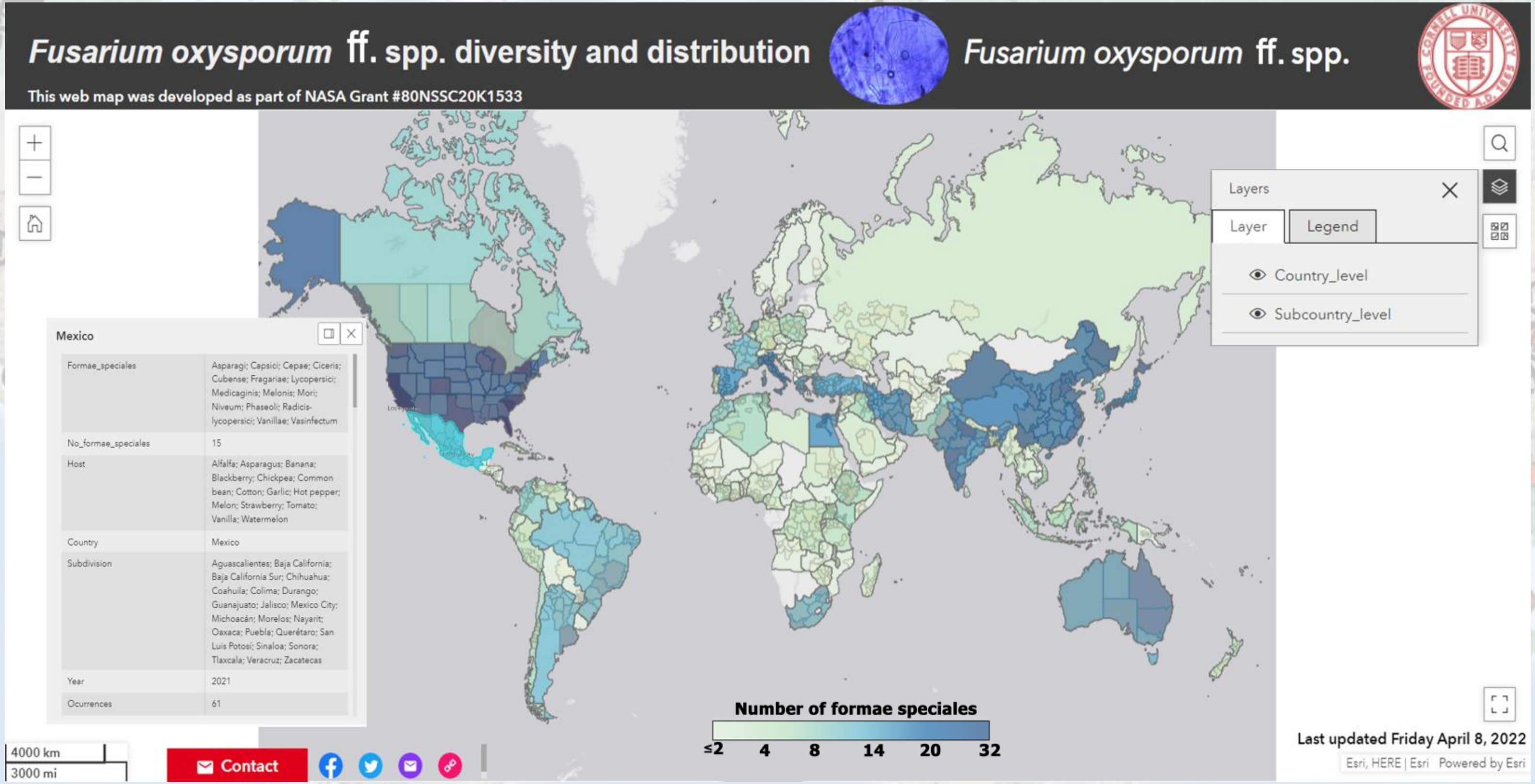


3980 *Fo* incidence reports at country and sub-country level derived from 1180 references

Global dust current
Fusarium oxysporum

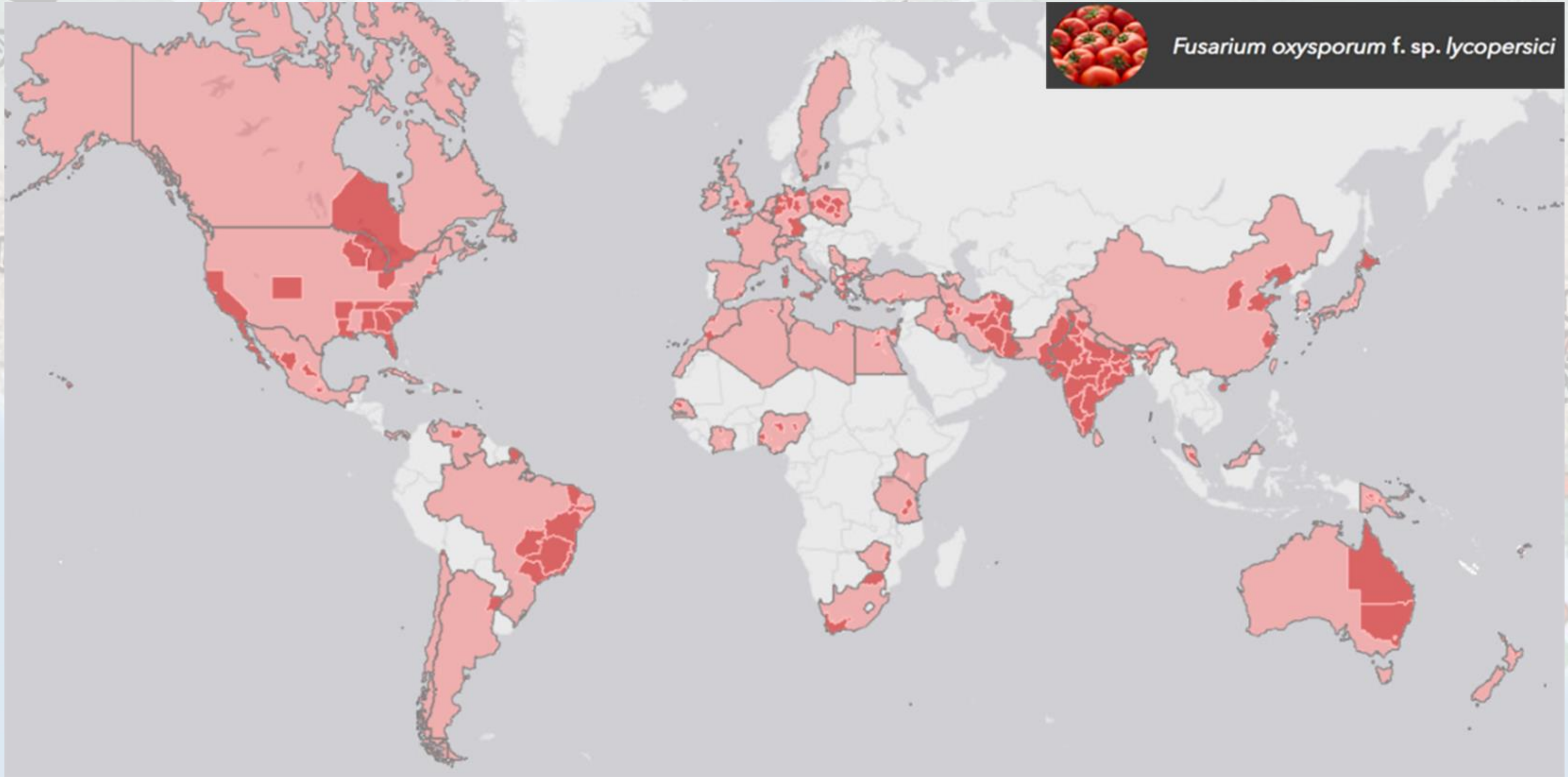


Remote Sensing

Build susceptibility assessment for current *Fo* risk in agricultural zones form remote sensing measurements

Calderón, R., Eller, J., Brodsky, H., Miles A., Crandall, S., Mahowald, N., Pavlick, R., and Gold, K. (in press). An interactive, online web map resource of global *Fusarium oxysporum* ff. spp. diversity and distribution. *Plant Disease.*

SCAN ME to visit the online web map



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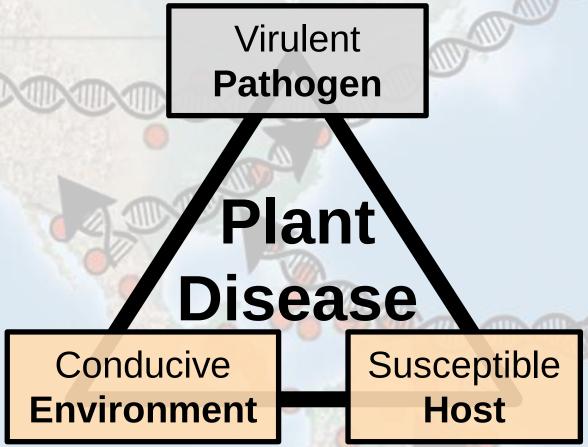
Calderon et al, *in prep*



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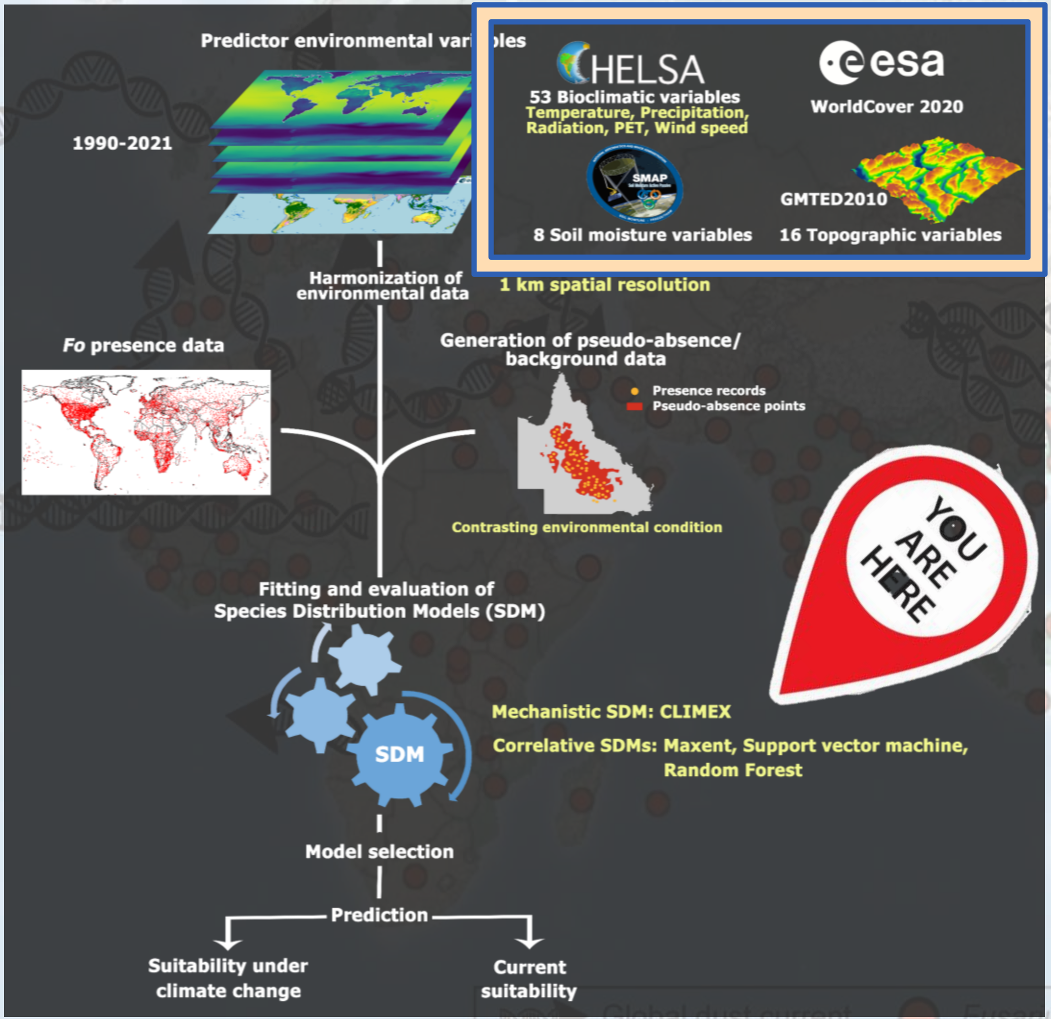
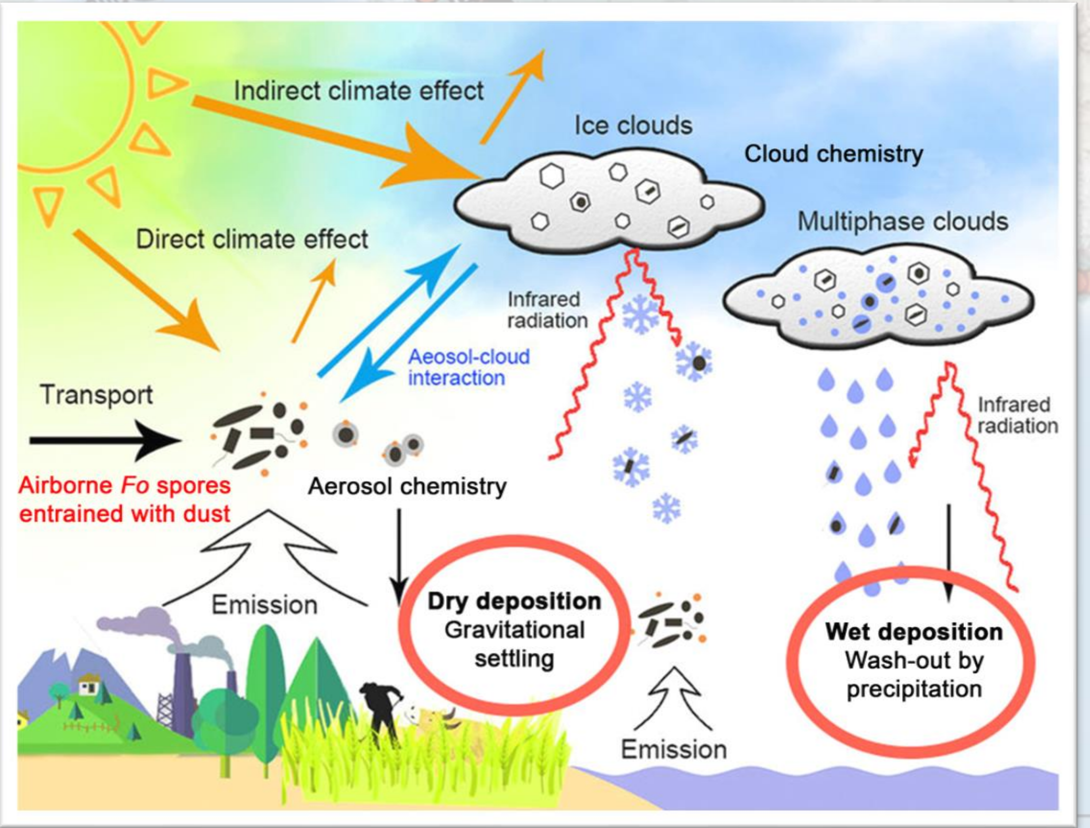


Aerosol Transport

Build a model of long-distance atmospheric *Fo* spore transport and assess the likelihood of transatlantic transport of viable spores

CESM-CAM6-MIMI



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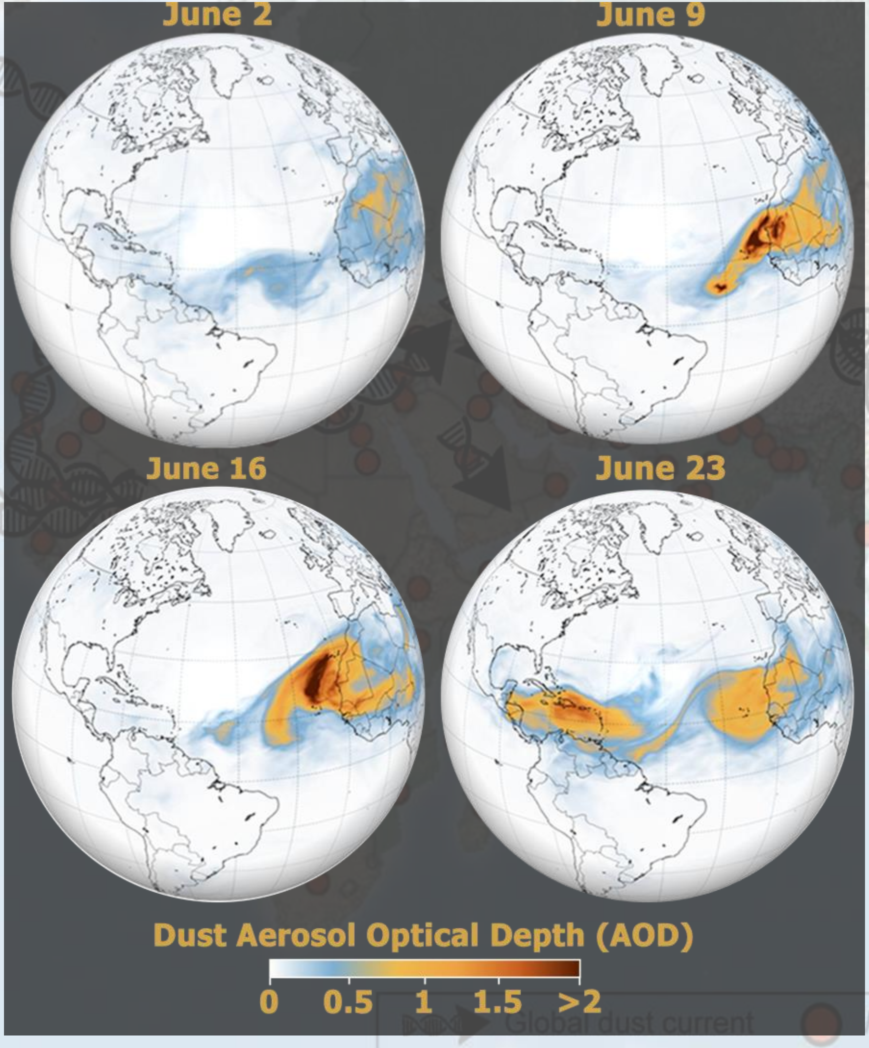
In order to ask "**Can viable Fo spores be transported across the Atlantic?**"

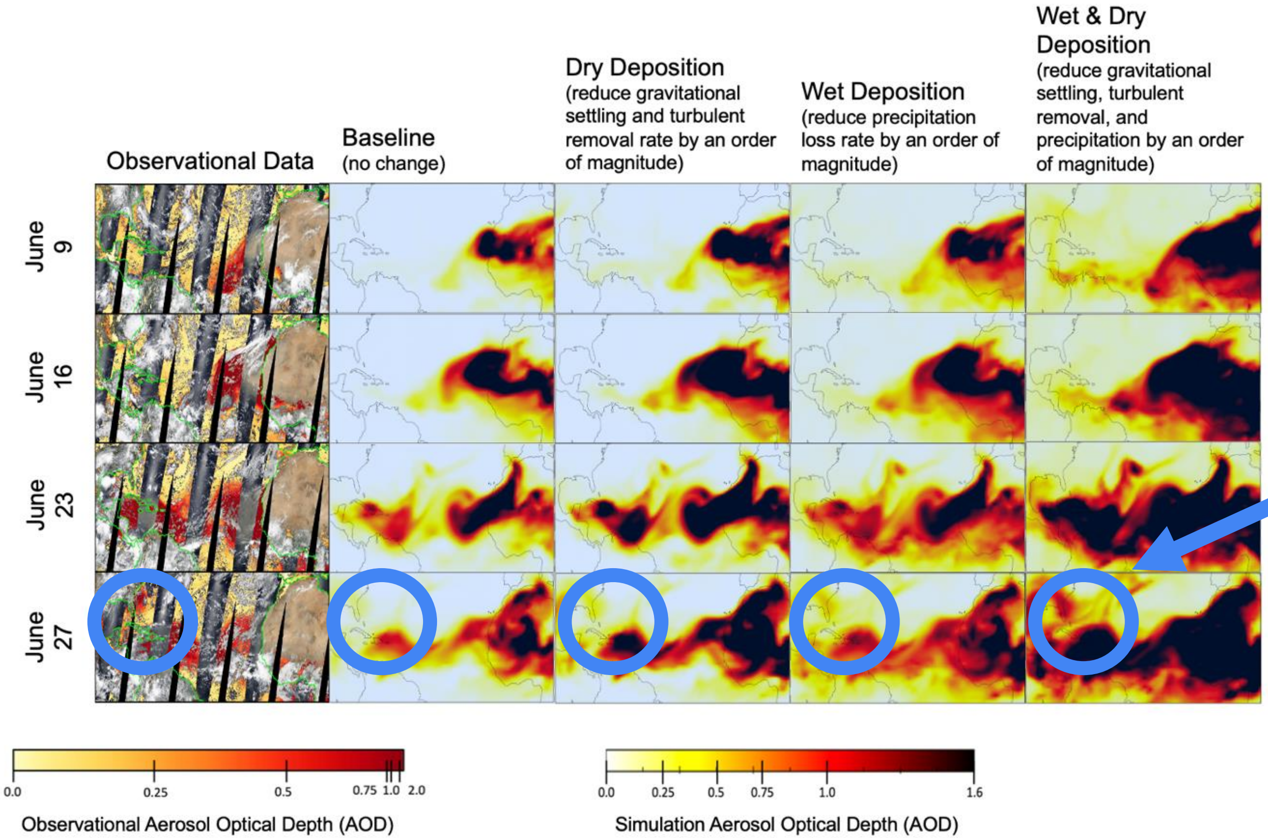
We first had to….

1) …accurately simulate the "Godzilla" dust event of Summer 2020
2) …adapt the CESM-CAM6-MIMI to include **agricultural dust**
3) …adapt the step 2 model to include **spore transport** with uniform concentration and fixed properties (e.g. size, weight) and an exponential decay function to kill off 99% of spores in 3 days



Brodsky et al. *in prep*

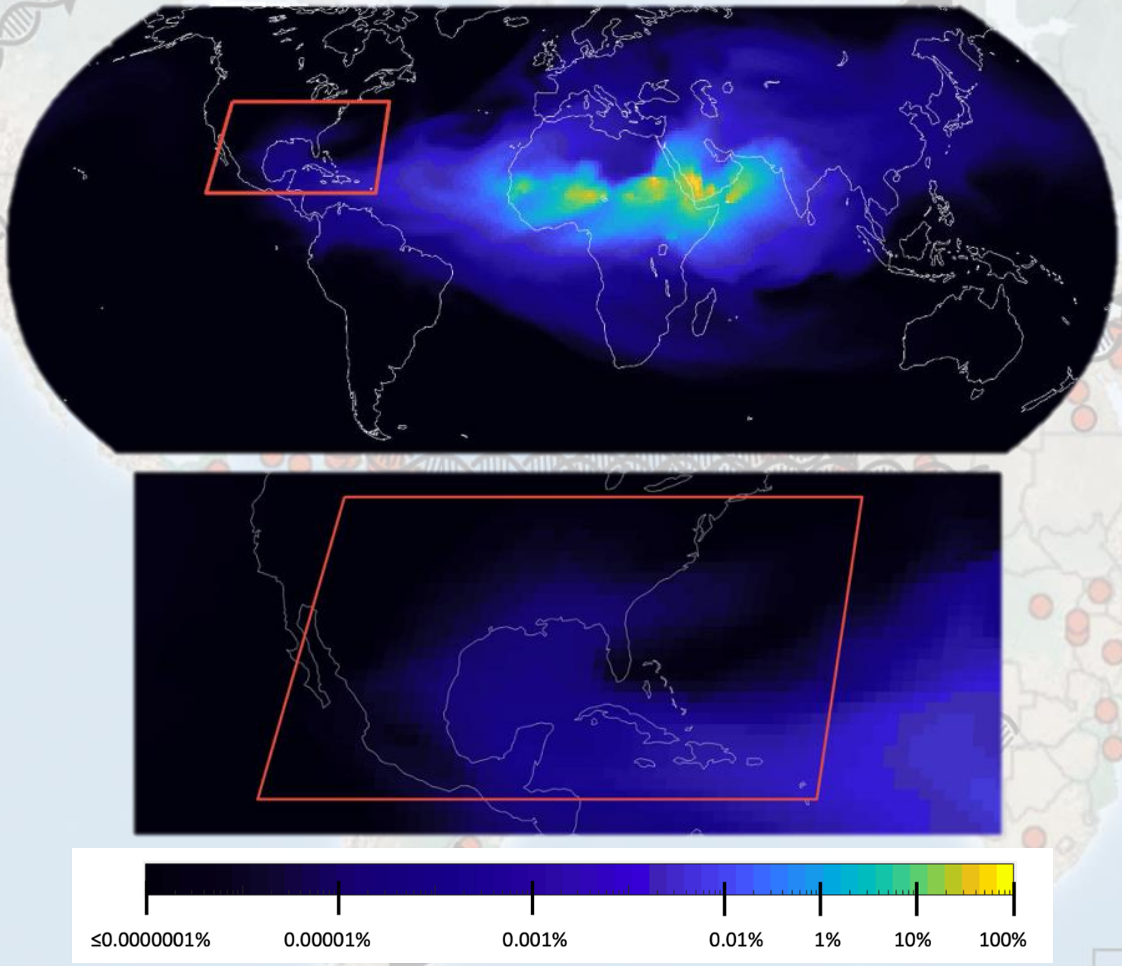
Accurate tuning of the wet & dry deposition parameters is important for ensuring an accurate amount of dust reaches the Americas.



Not enough dust reaches Americas without tuning deposition parameters. Among the four models tested, the model with **lower wet & dry** deposition rates was the most accurate.

Brodsky et al. *in prep*

Global dust current
Fusarium oxysporum



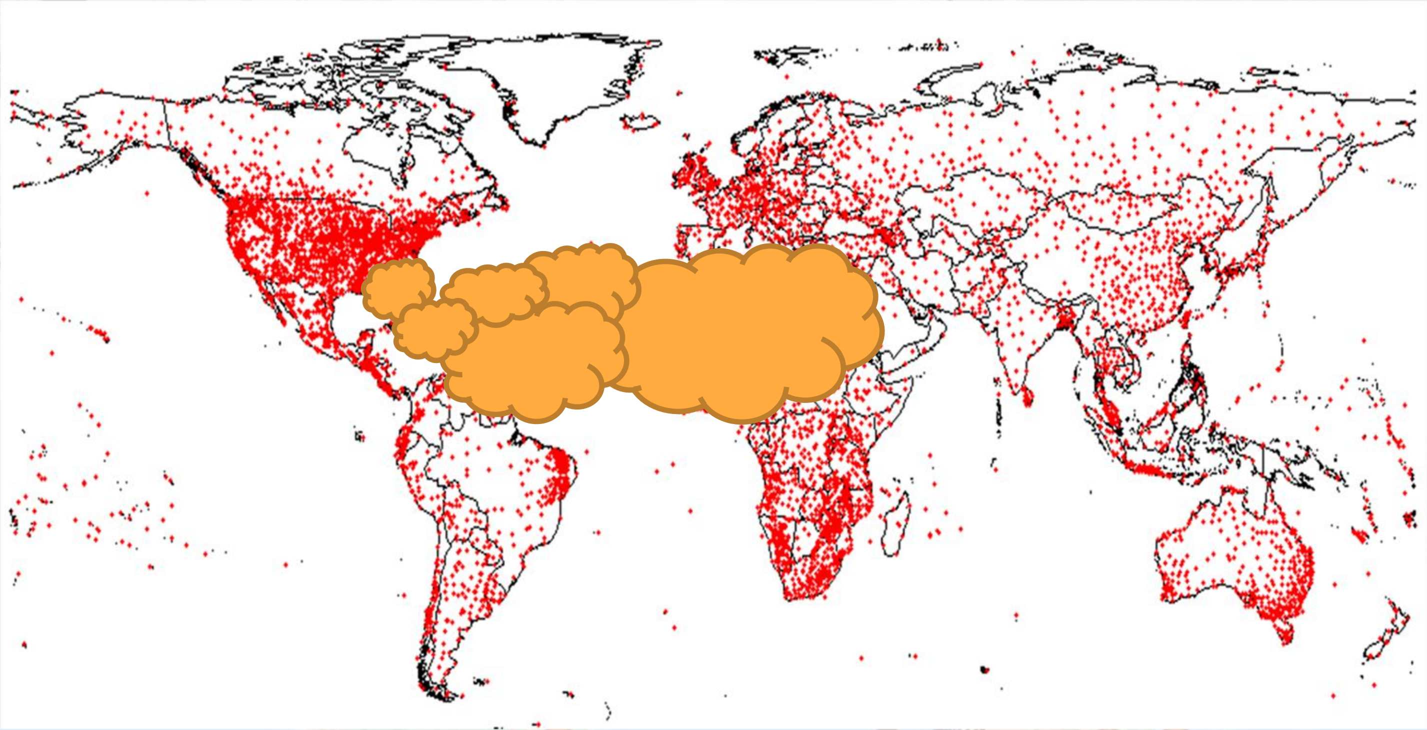
Percentage Live Spores

Almost all spores lose viability before reaching Americas….

<u>but not all!</u>

→ Our model indicates that **~4 million live spores** could have been deposited in North America in June 2020

→ Theoretically, if there is substantial fungal infestation in North Africa, a big dust event like Godzilla could carry millions of live spores to the Americas.



Evaluate concordance between susceptibility assessment, known incidence and modeled dust sources/deposition regions

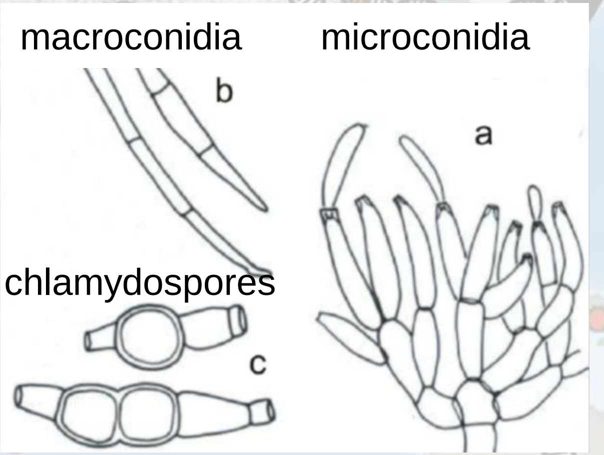
Calderon *in press* + Brodsky *in prep* = Calderon *in prep*

Global dust current   *Fusarium oxysporum*

Comparative Genomics

Assemble spore traits that impact dispersal and atmospheric viability

Spore Type	Spore Information	Reference
Ciceris	Chlamydospore diameter 4.8-8.1 µm; Microconidia size 5.1-12.8 x 2.5-5.0 µm; Macroconidia 16.5-37.9 x 4.0-5.9 µm	Arvayo-Ortiz et al., 2011; Dubey et al., 2010
General	average ascospore size: 21 um x 3.5 µm; 19–24 x 3–4 µm and macroconidia as 25–50 x 3–4 µm	Booth, 1971; Trail et al., 2002
General	long-distance ascospore dispersal will not be effective at relative humidity less than 50 %	Beyer et al., 2005
General	Gravitational settling of 1-2 mm per s-1 in still air	Keller et al., 2014



Global dust current *Fusarium oxysporum*

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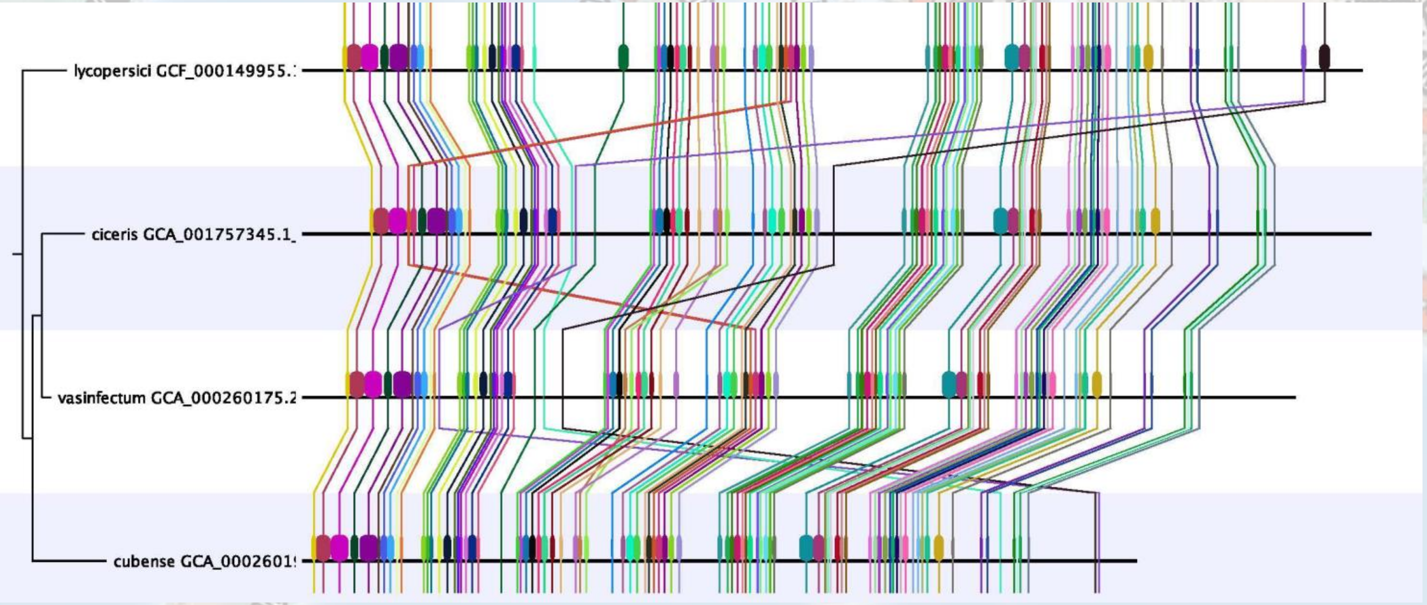
Incorporate spore variability by region into the atmospheric transport model



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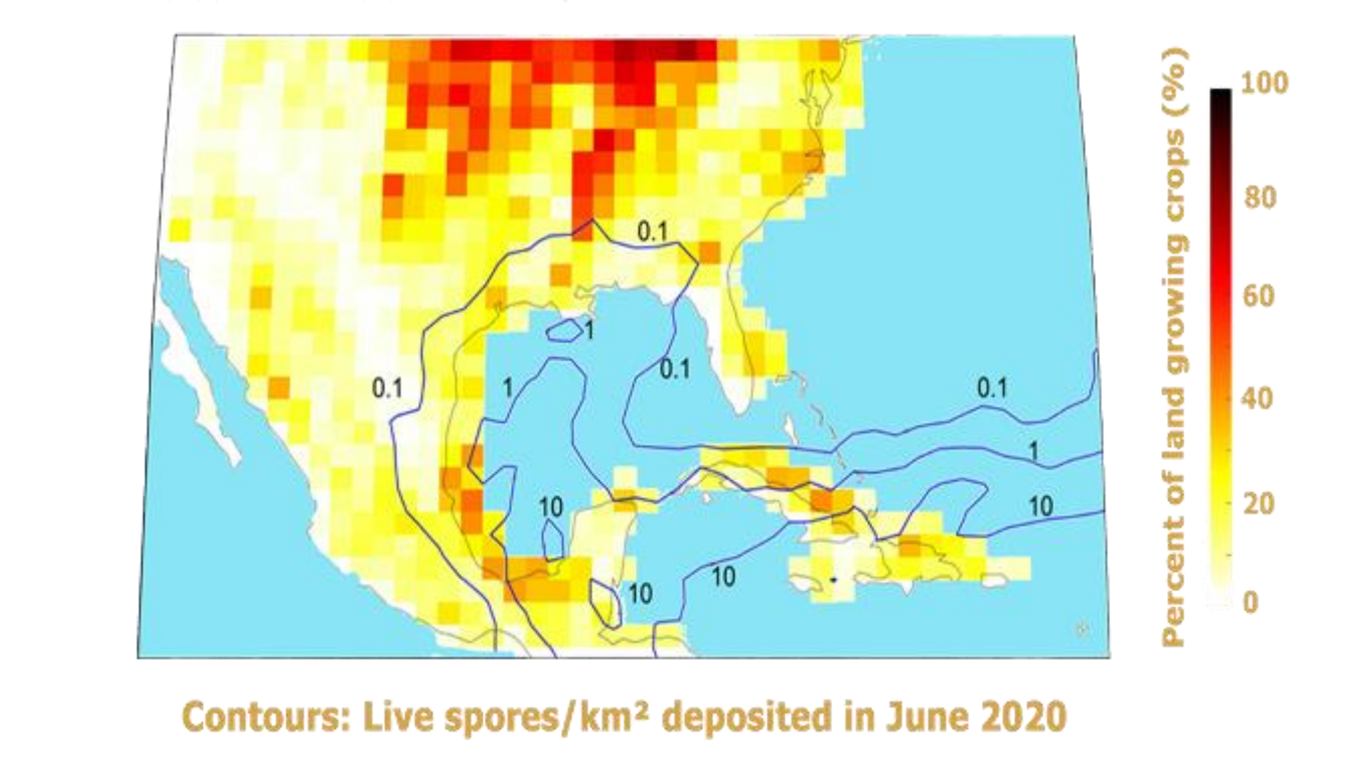

The Caribbean Islands and east Mexico are the most at risk, as they have the most agricultural land within the infectious spore deposition zone.

Extremely preliminary data from Calderon in prep – model yet to be properly parameterized

The story thus far…

- En route to building our Fo risk map, we developed an interactive webmap to improve global study of the disease (Calderon et al. *accepted)*
- We built adapted CESM-CAM6-MIMI to incorporate dust of agricultural origin and modifiable spore parameters (Brodsky et al. *in prep)*
- We've assembled and are investigating the commonality (and dissimilarity) between key Fo subspecies genomic regions that may impact transport, survival, and deposition (Crandall et al. *in prep)*
- **Long distance transport of viable Fo spores on transatlantic dust events to agricultural zones in North America appears possible (!!)**
    - HOWEVER, more investigation needed. Parameterization with Fo distribution will improve this understanding, as will continued exploration of between Fo genomes

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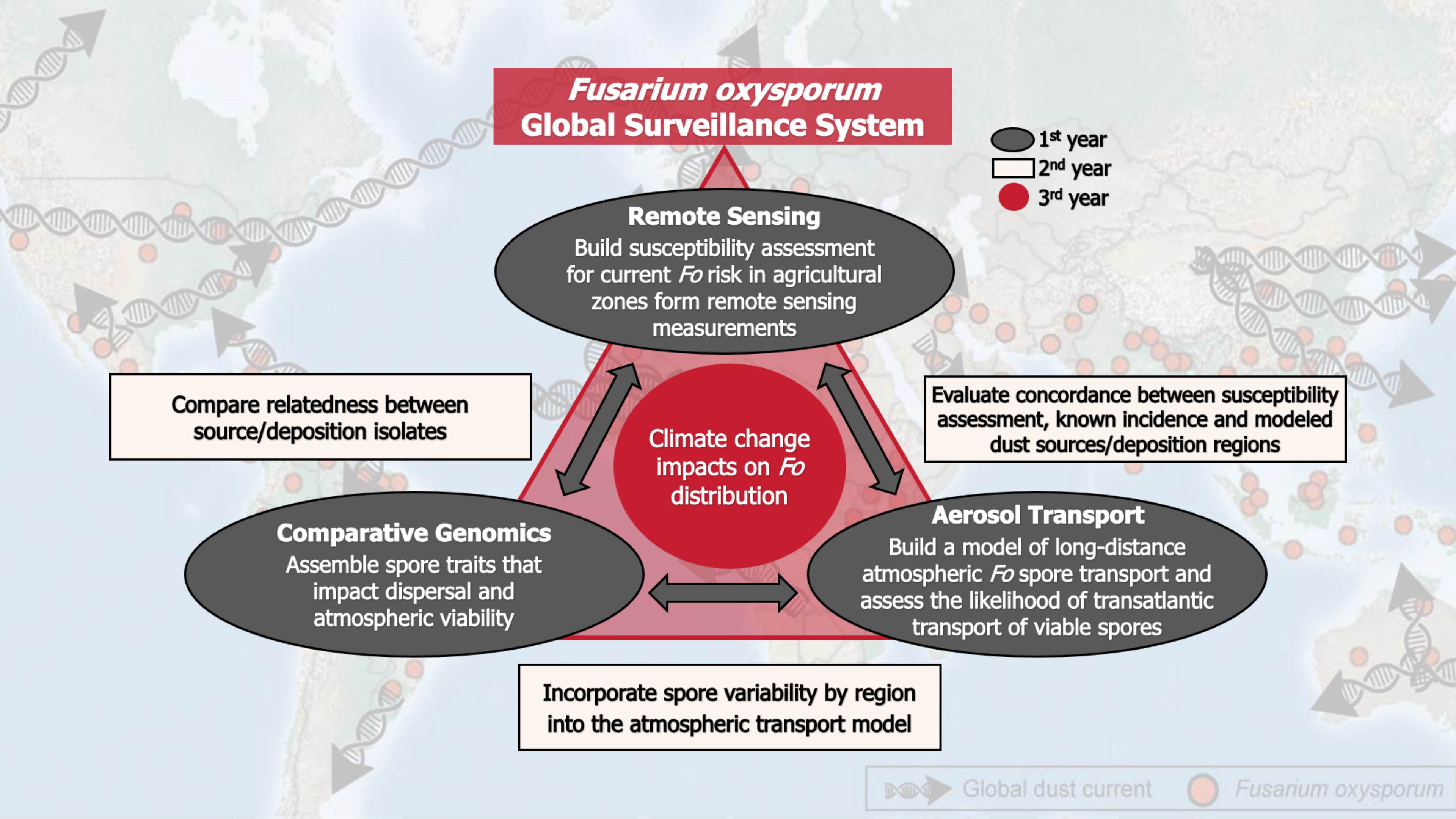

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Interested in more plant disease remote sensing?

Visit Fernando Romero Galvan’s NASA FINESST poster this afternoon!

SCAN ME to visit the online web map

Questions?

kg557@cornell.edu

Twitter @KaitlinMGold

blogs.cornell.edu/goldlab

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