Wind flow and microclimate in vineyards and their impact on spore and pest dispersion and vineyard epidemiology

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Disease Development

Microclimate

Aerial Dispersion

Plant Growth and Infection

Pathogen Development

Overwintering
Disease Development

- Aerial Dispersion
- Microclimate
- Overwintering
- Plant Growth and Infection
- Pathogen Development
Can we develop useful models for this system that are biophysically based (e.g., not purely empirical)?

If we can, what can we do with them?

1\textsuperscript{st} Step, we need to study the system to understand:

- What biological and physical process are the most important?
- At what length and time scales should these processes be represented?
Vineyard Dispersion

Adapted from: Mahaffee and Stoll, Phytopathology 2016
Airborne Dissemination

Two main modes:

- **Short distance** -
  - Transport distances of about the canopy height and smaller
  - Impacted by source characteristics
  - Highly dependent on local topography and architecture
Airborne Dissemination

Long distance -
- Transport distances 100s m – 10s Km
- Presumably well behaved on average
- Impacted by topography and weather

Figure from Tallapragada et al., 2011
Simulated Particle flow

With increased row spacing stronger structures will form.
- Particles will be retained in the lower 75% of the canopy
- Particles will be ejected from the upper 25% of the canopy
Short Distance Transport

• Measured Winds (turbulence) and performed particle release experiments in two vineyards over four different years in Oregon.
  - 2011, 2013, 2016: “flat” VSP vineyard
  - 2014: “hilly” VSP vineyard
Short Distance Transport

In a vineyard -
- Winds are strongly channeled parallel to the rows
Observed Dispersion

Wind 21° from parallel

Wind 45° from parallel

Wind 89° from parallel
Modeling Airborne Transport

- **QUIC** Dispersion Modeling System (Pardyjak and Brown 2001; Williams et al. 2004)
- Validation and enhancements for vineyards ongoing (e.g., Ulmer et al., 2016).
QUIC System

- Joint development and support: LANL, UofU
- “Easy” to use Graphical User Interface (GUI)
QUIC Dispersion
QUIC Dispersion

- Comparison to field data
Leaf Energy Balance

\[ R_s + R_L - \varepsilon \sigma T_L^4 = c_p g_H (T_L - T_a) + \lambda g_M \frac{(e_s(T_L) - e_a)}{\rho_{atm}} \]

**Radiation** = **Convection** + **Latent**
Vineyard Microclimate

- Leaf temperature (Thermal image and DTS)
  - 1 to 20°C higher for sun-exposed
  - On a sunny day at 27°C leaf temperature can be 28 - 40°C

Ambient Temperature - 23°C

△T>15°C

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Microclimate Modeling Framework

Most models currently in use aggregate microclimate

*Assumes homogeneity in horizontal or vertical directions*
Model Discretization

- 3-D radiation model, complex 3-D models for conductances
- Ray Tracing for Radiation
- Aggregate volumes of leaves
  - Statistical representation of leaves
    - Leaf area density
    - Leaf angle
    - Leaf azimuth
- Ground surface energy budget (close the radiation exchange budget)
- GPU computing for fast execution

[Bailey et. al. 2014]
115,591 trees

Leaf Temperature
Evaporative Flux
Leaf Temperature Validation
Example Validation: Temperature

Dispersion + Growth + Microclimate + Infection

- Deposited Spore
- Infection
Powdery Mildew Example
Using a biophysical approach enables:

- predict yields
- predict disease/pests
- assess disease risk
- assess water use
Can we predict disease origin and spread?
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Long-Range Vision: Cyber-Physical Systems

remote sensing

low-cost wireless sensors

drone scouts

heads-up display
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- Tim Price

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- Tara Neill

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Instantaneous wind flow from Particle Imaging Velocimetry (PIV) between two model vineyard rows taken in the University of Utah wind tunnel.