Integrating the biological and physical components of maize pollen dispersal

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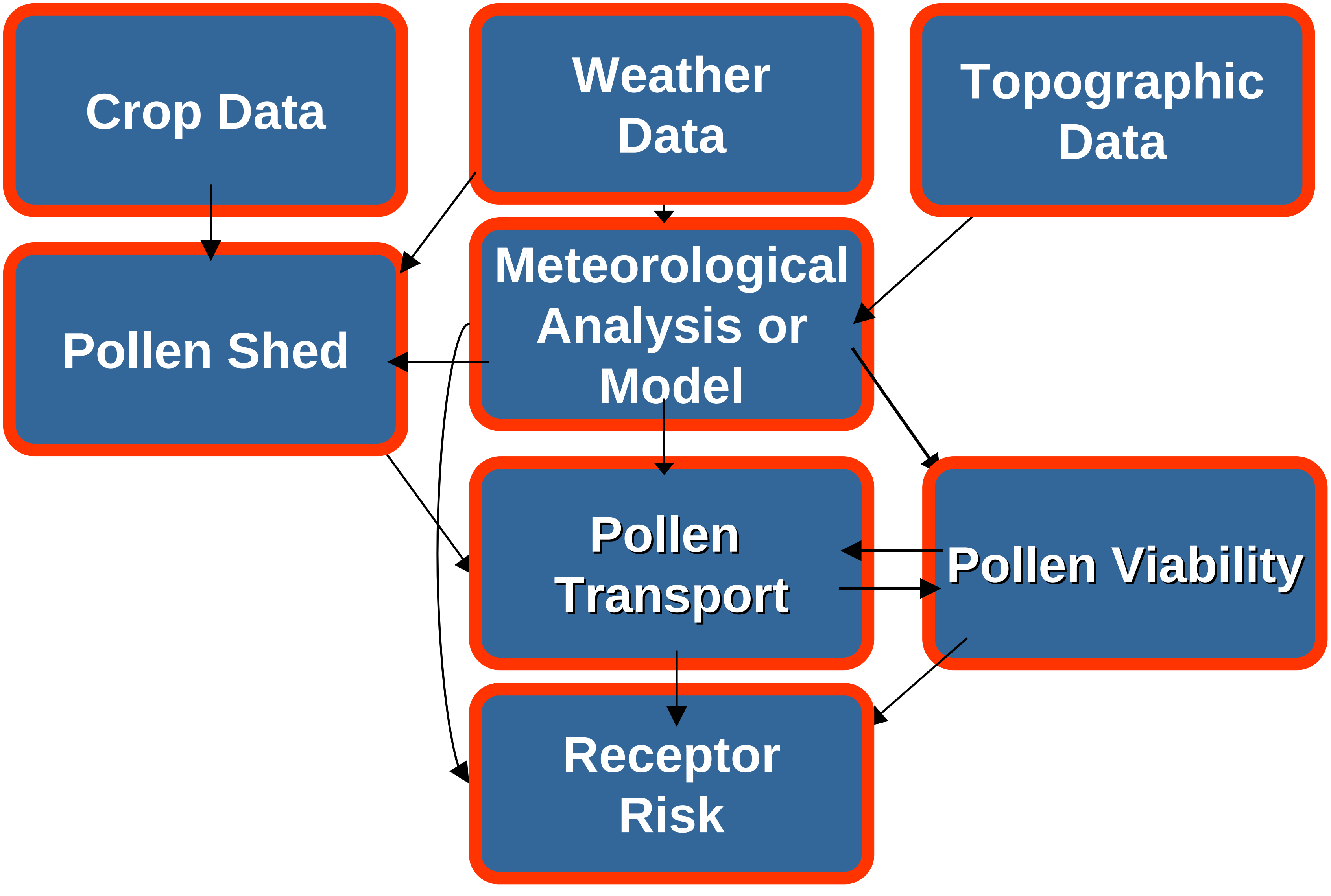
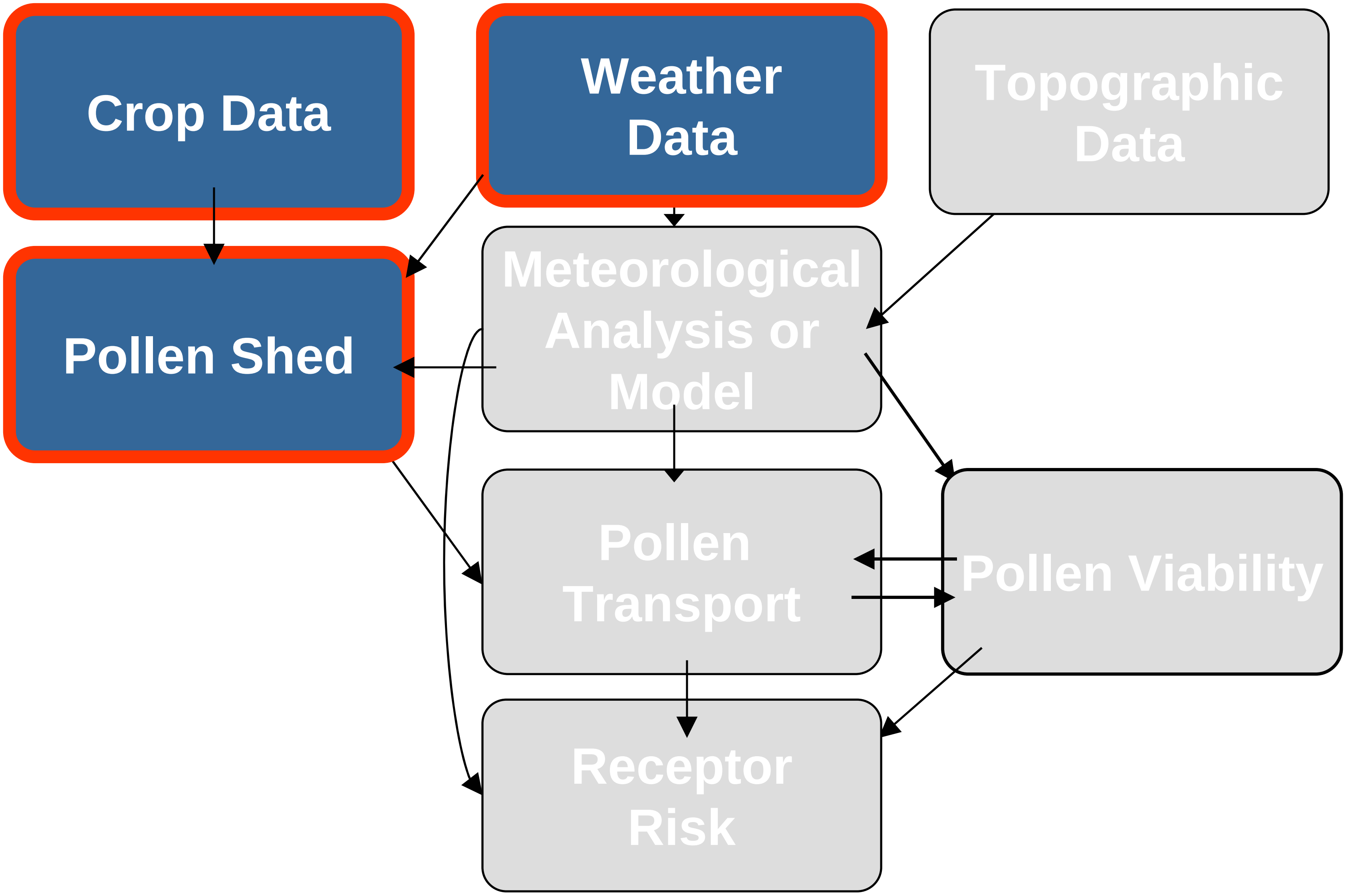
Biological and Physical Components of Out-crossing

- Biological (source)
  - Pollen shed characteristics
    - Timing, intensity, viability
- Physical (delivery system)
  - Topography
    - Distance, elevation, wind breaks, border rows
  - Atmospheric conditions
    - Wind speed, wind direction, stability index, mixing height, air temperature, relative humidity
- Biological (receiver field)
  - Pollen shed characteristics
  - Synchrony with female and adventitious pollen source
  - Specific combining ability

Structure of pollen production, dispersal, and out-crossing model



Pollen production



- Pollen shed characteristics
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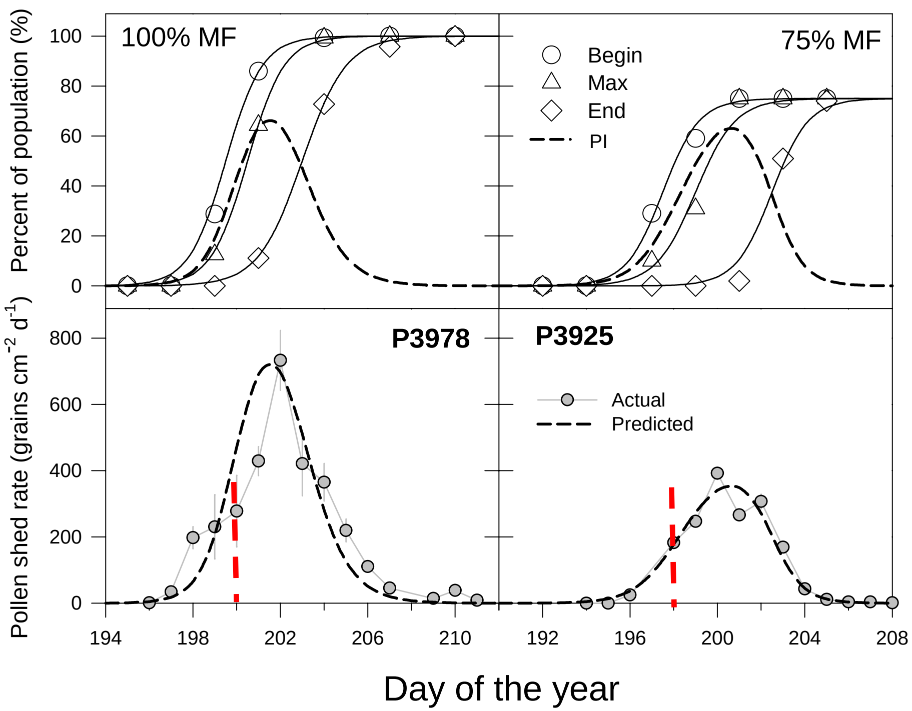
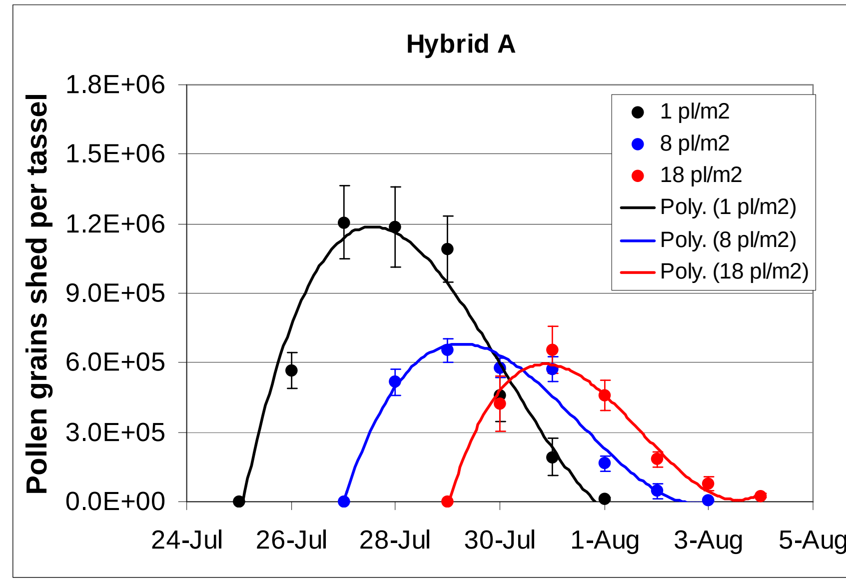


Timing of pollen shed can be simulated from tassel development and population dynamics

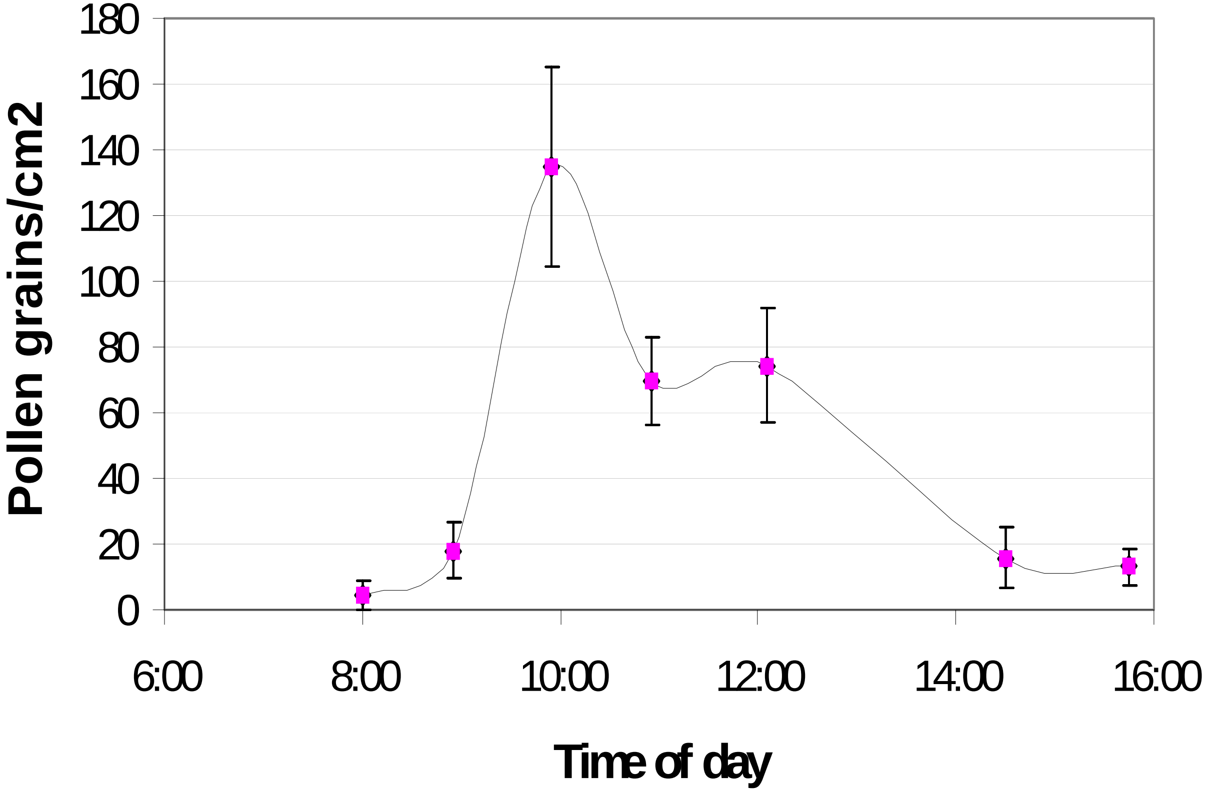


Pollen shed intensity typically peaks 2 days after first anthers appear

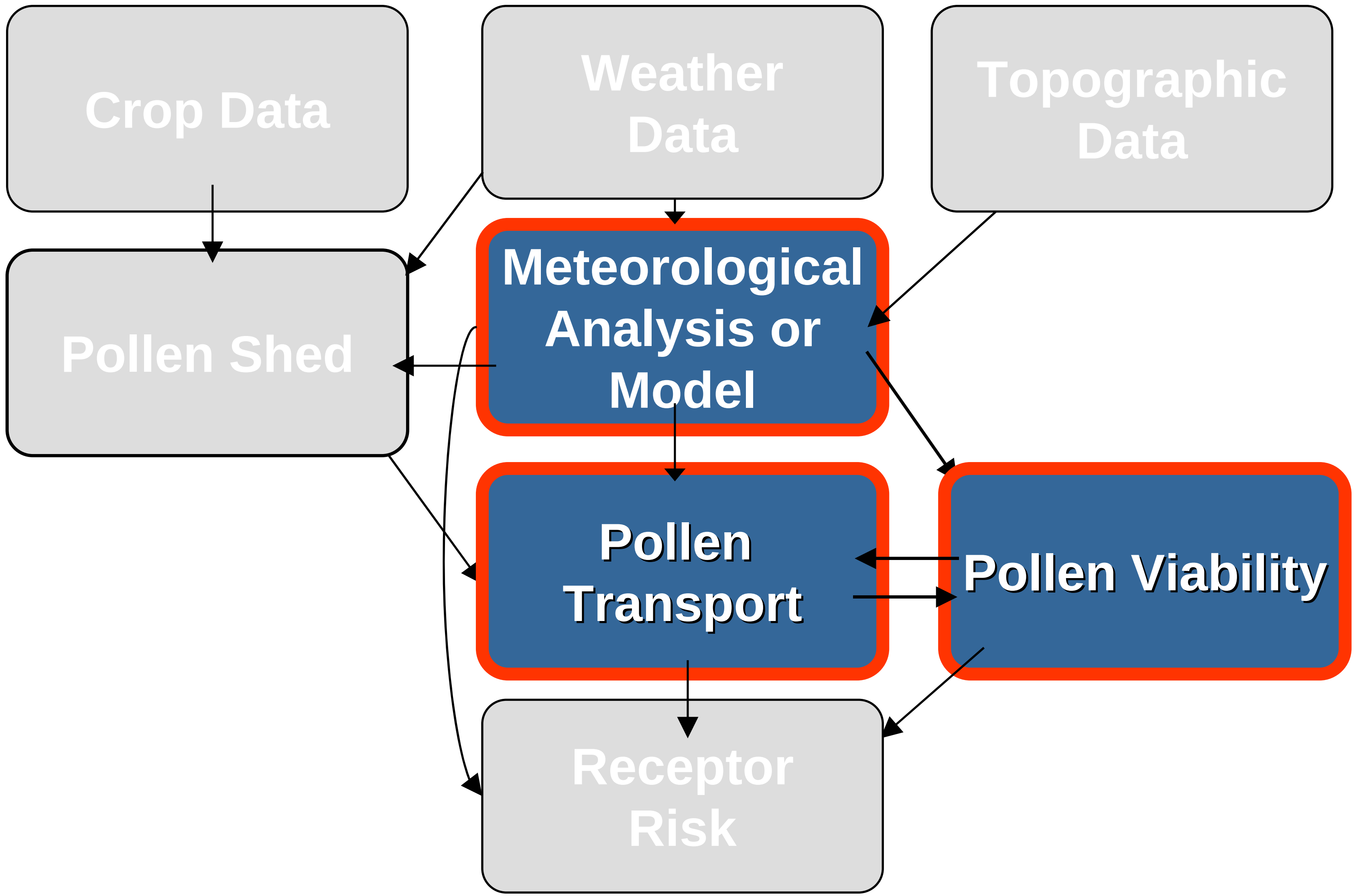
Diurnal patterns of pollen shed vary

Temp, RH, and wind speed affect the initiation and intensity of pollen shed

Shed typically begins at RH < 90%



Pollen dispersal



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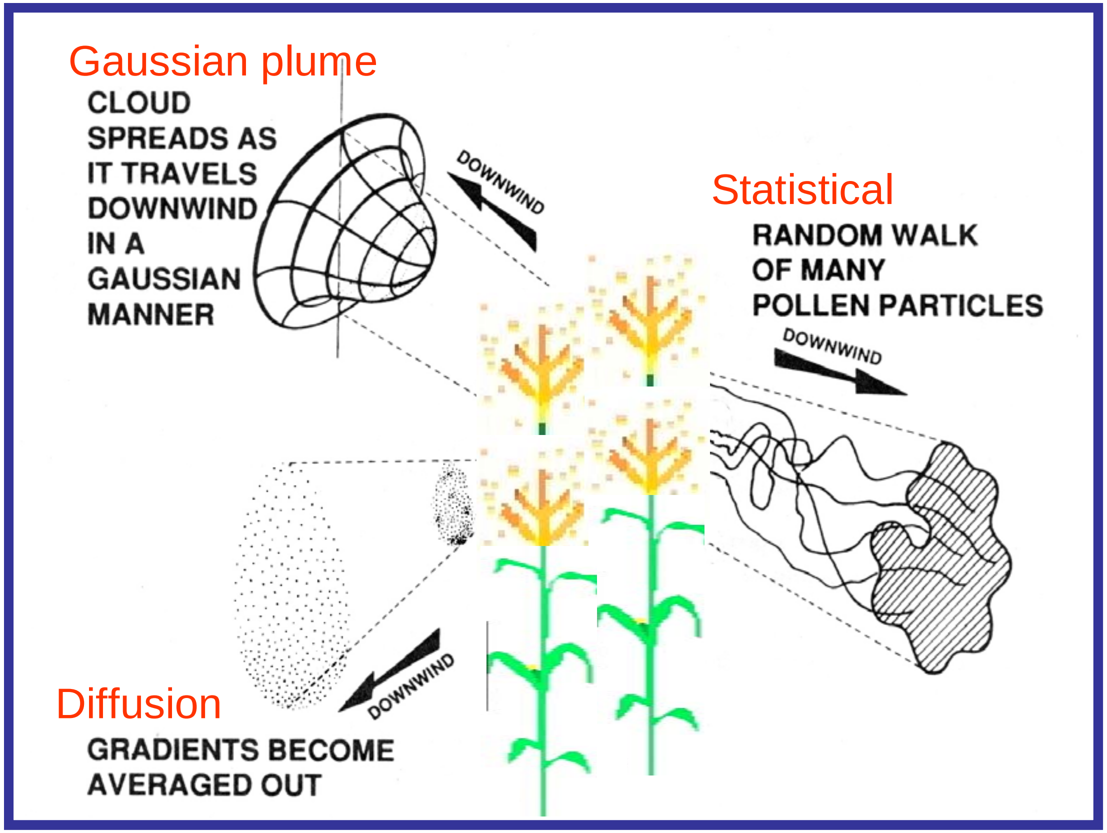


Adapted from Di-Giovanni and Kevan, 1991

Pollen transport models

- Lagrangian random-walk approach
  - the pollen cloud is represented as a population of virtual “particles”
  - each virtual particle can be traced according to its source, path, or other property of interest
- Gaussian plume approach
  - the pollen cloud is ‘constrained’ to a normal distribution that is modified hourly by local atmospheric conditions

Physical parameters for modeling maize pollen dispersal are fairly well established

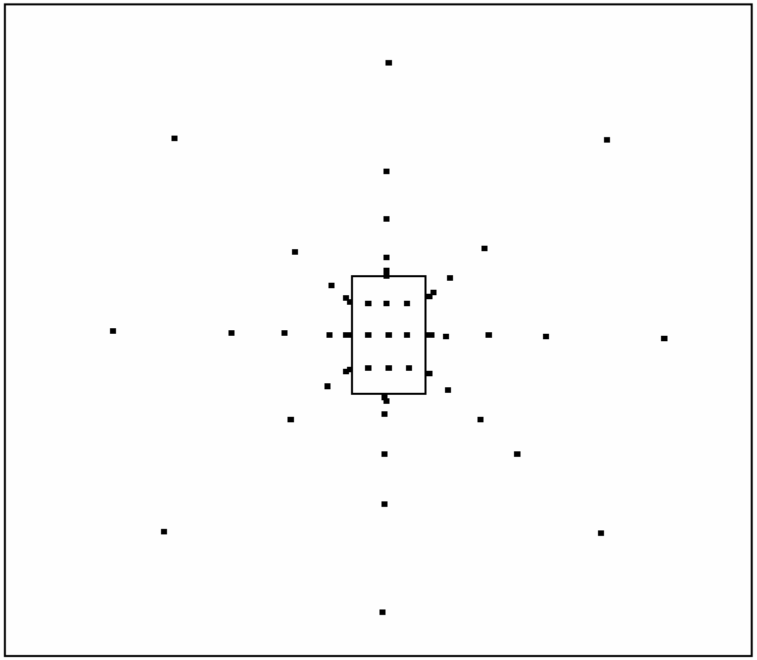
-- weight/grain: 250 to 350 ng
-- diameter: 50 to 90 µM
-- density: 1.25 to 1.45 g cm^{-3}
-- settling velocity: 20 – 32 cm s^{-1}
-- number per plant: 0.5 to 6 x 10^6
-- duration of shed: 4 to 6 days

Field evaluation of the pollen transport models:

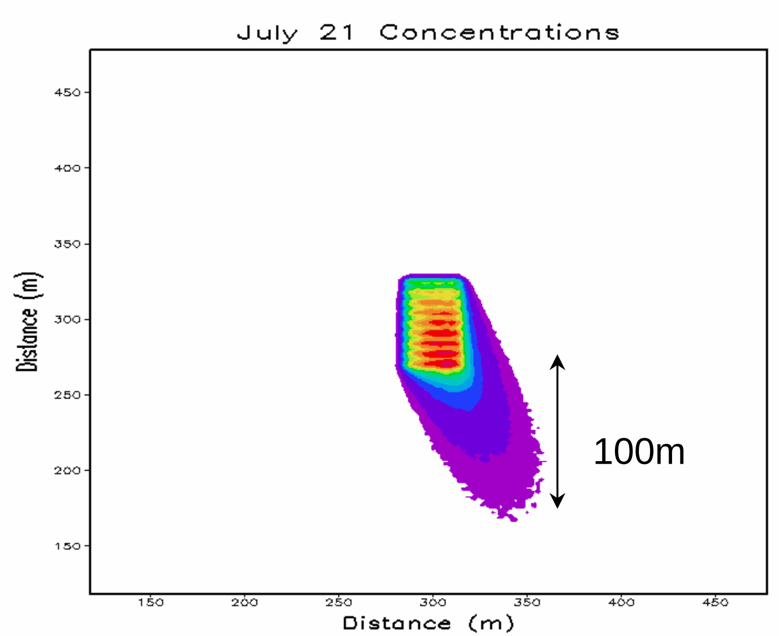
- 9 monitoring locations within the source field

- Receptors (sticky traps) placed at 5, 10, 30, 90, 165, 330, and 660 feet from the edge of the source field in the 8 major directional axes

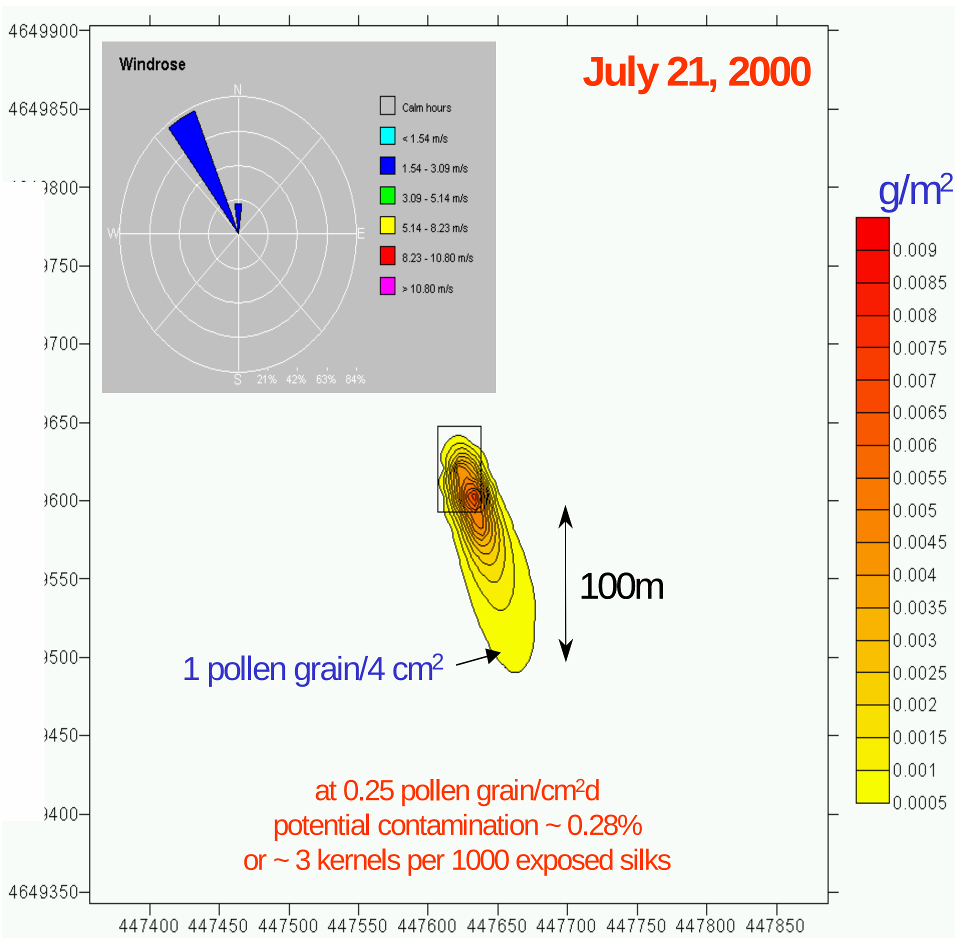
- Pollen dispersal monitored from 0730 to 1700 hours.



Daily and seasonal patterns of pollen dispersal from a source field can be simulated fairly accurately



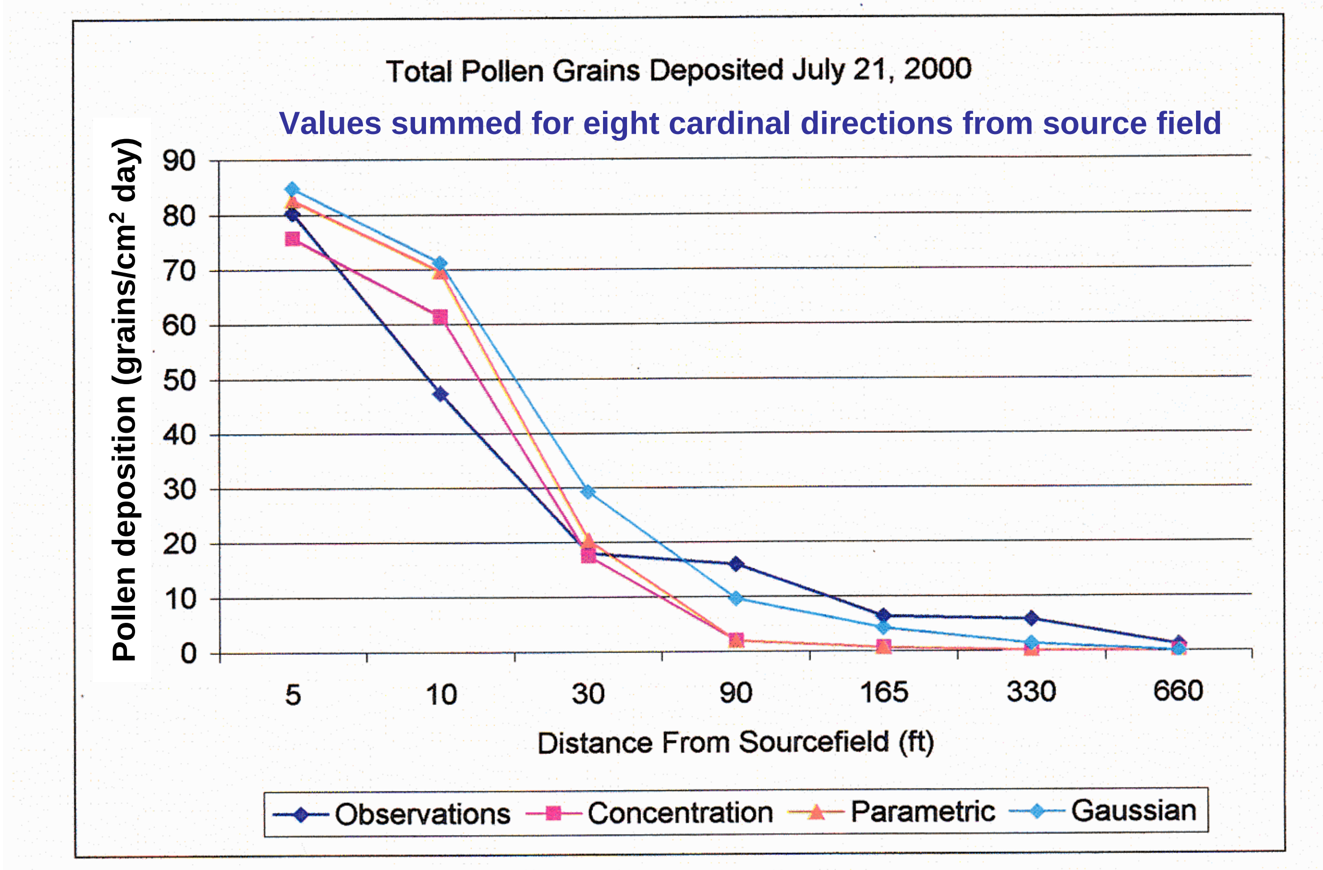
Lagrangian numerical simulation
-- Arritt et al. ISU



Gaussian plume
– ISCST3/AERMOD EPA models

…but both models tend to overestimate deposition near the source field, and underestimate deposition at greater distances

from Riese, 2004

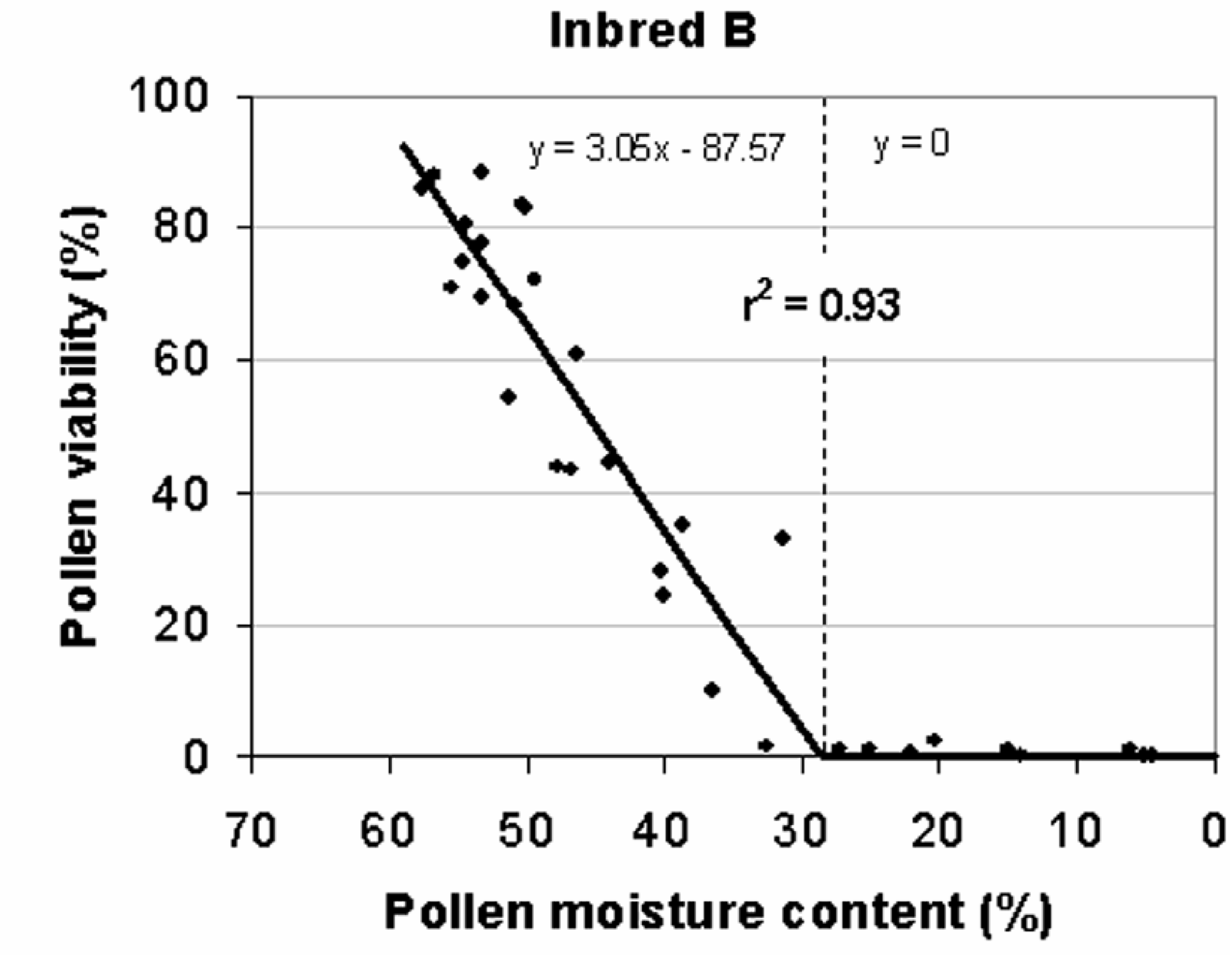


Lagrangian model **ISCST3**

Need to account for modification of the 3D flow field by the crop (windbreak) and atmospheric turbulence on a larger scale (large eddy simulation).

Pollen viability decreases linearly with moisture content.

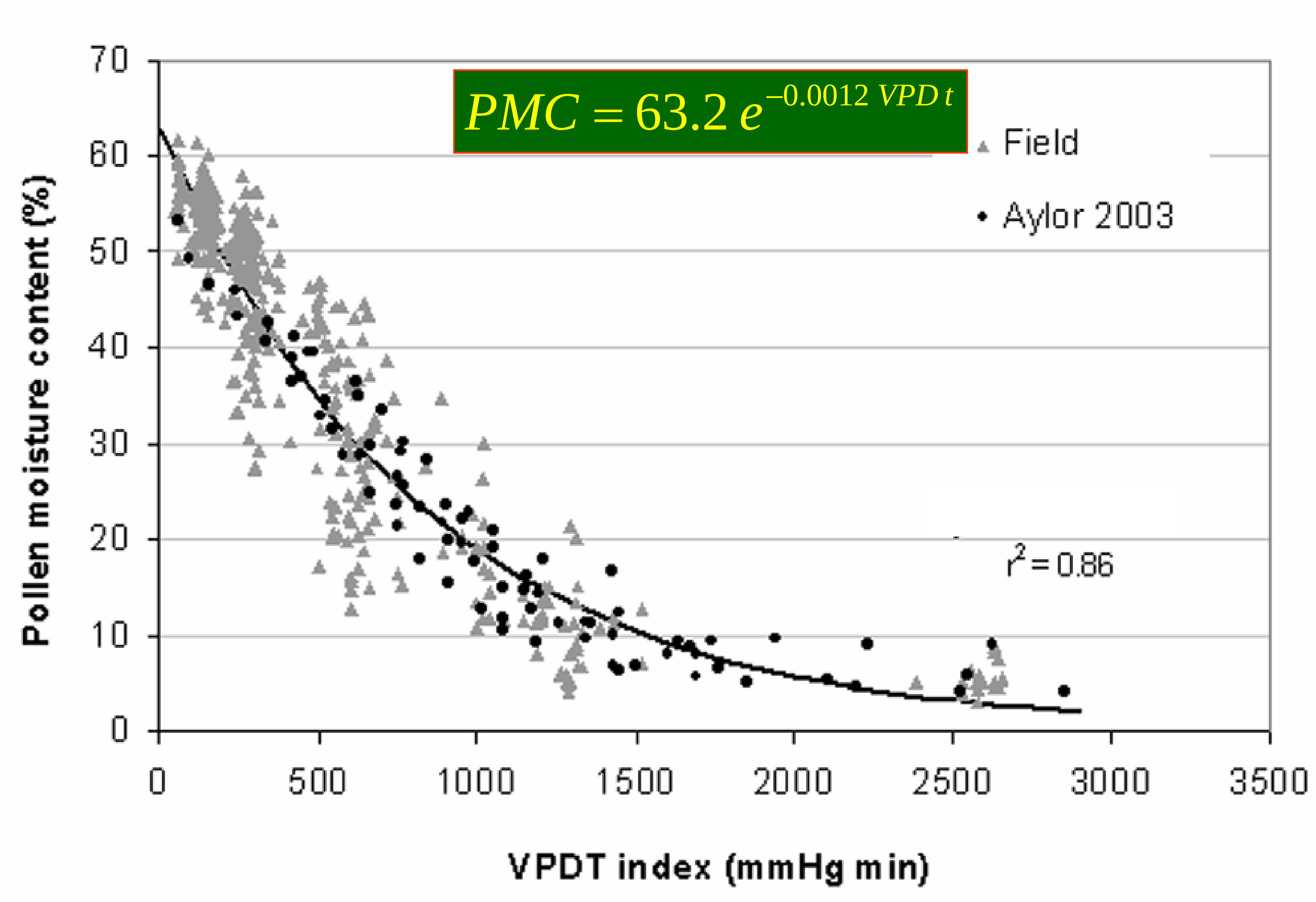
Pollen of the 'average' maize genotype loses viability completely at about 30% moisture



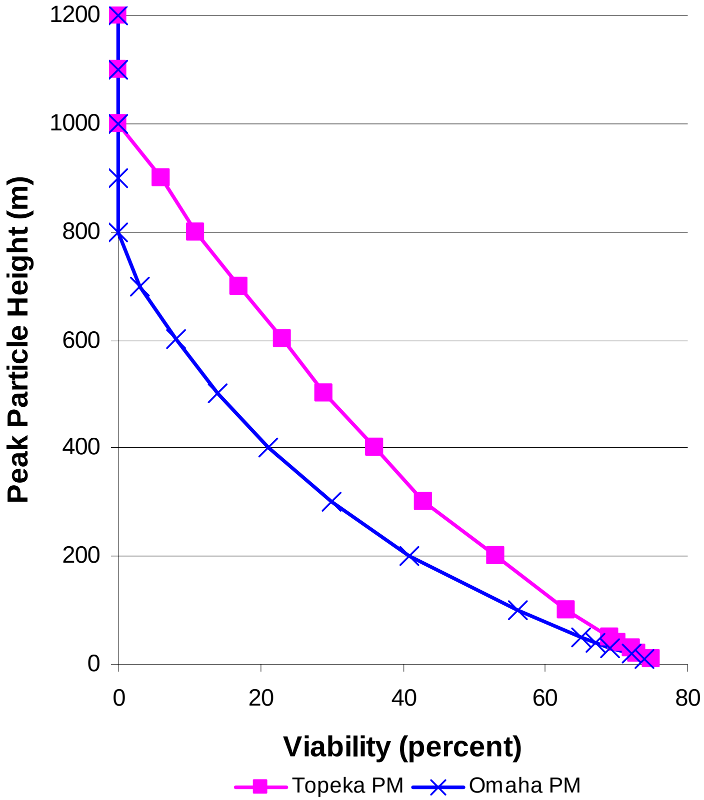
Average values for 11 genotypes

Initial viability	80%
PMC at 0%	30%
Pollen/tassel	$3.1E^6$

Loss of pollen moisture is an exponential function of VPD and time



“Terminal viability” of lofted maize pollen



- **Pollen lofted through two representative atmospheric soundings (updraft at 3 m/s, fall at 20 cm/s)**
- **Viability adjusted accounting for VPD through the profile until the pollen grain returned to the ground.**

Brunet et al., 2004

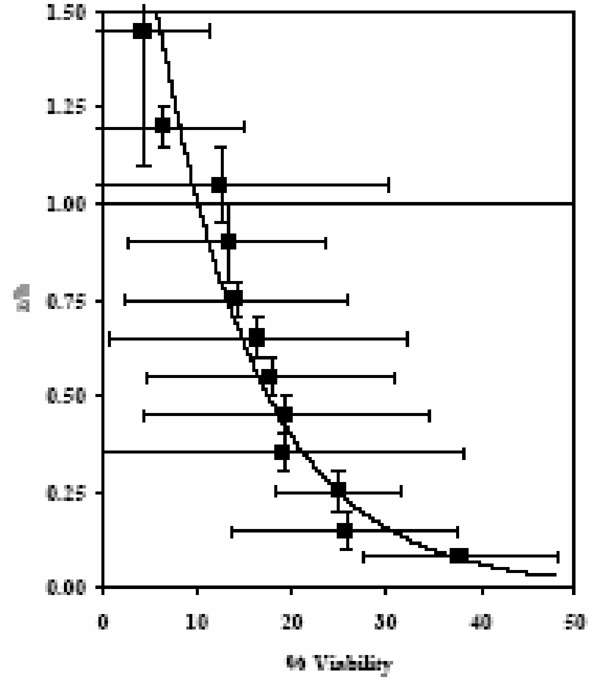
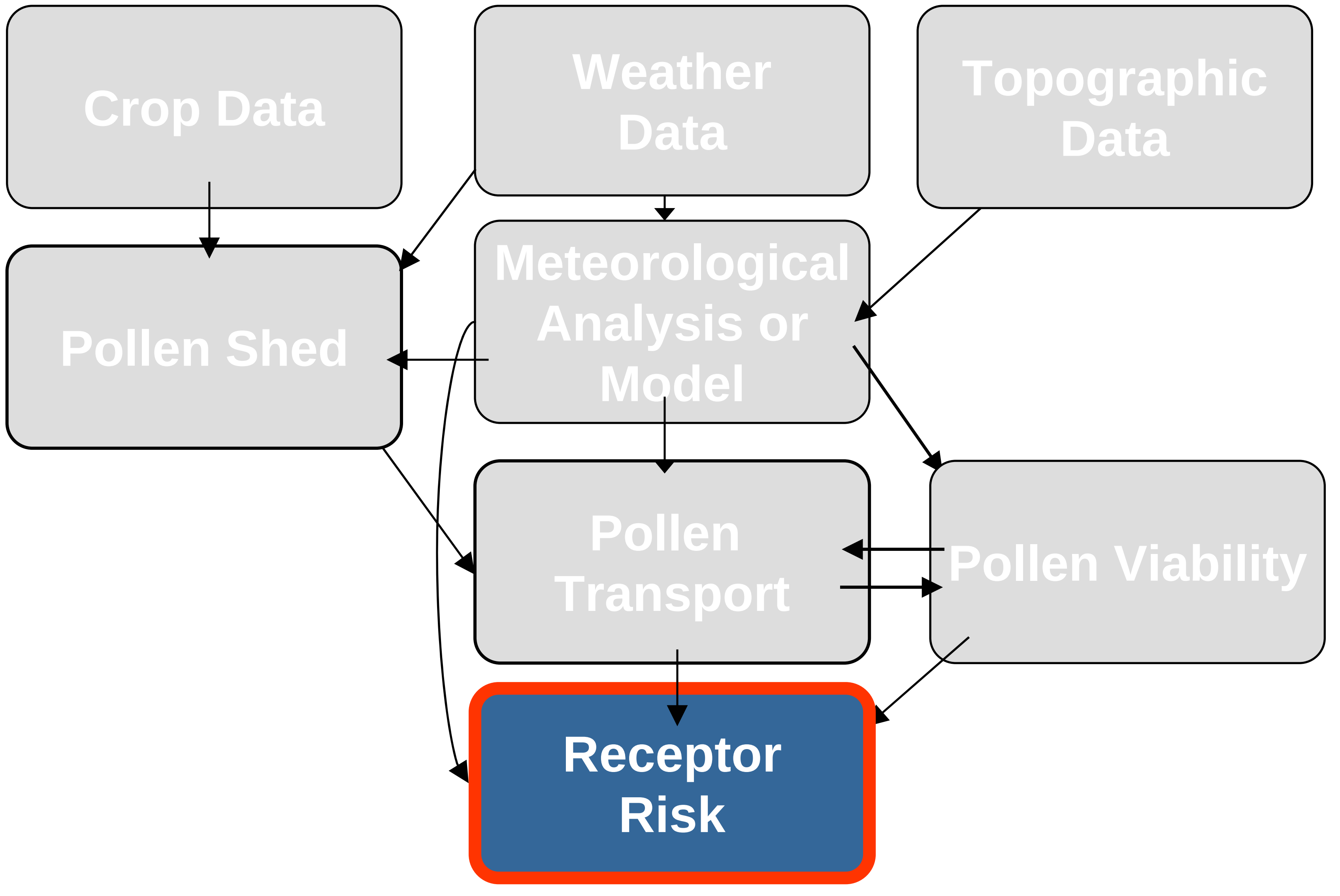


Figure 3. Vertical variation in viability: mean values and standard deviations over all complete flights. The curve is an exponential adjustment through the experimental points.

Y-axis normalized to daily convective boundary layer, 800-2000m

Out-crossing



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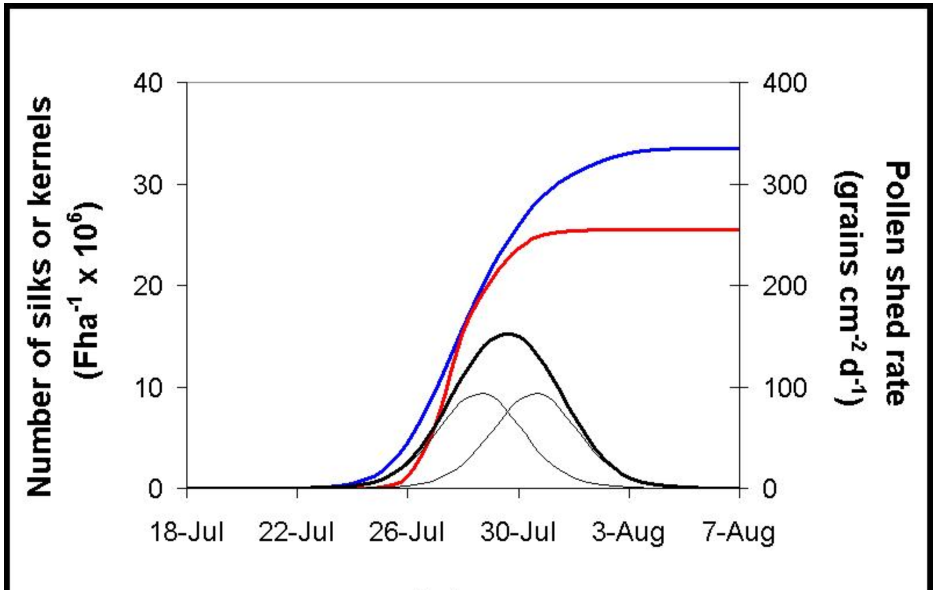
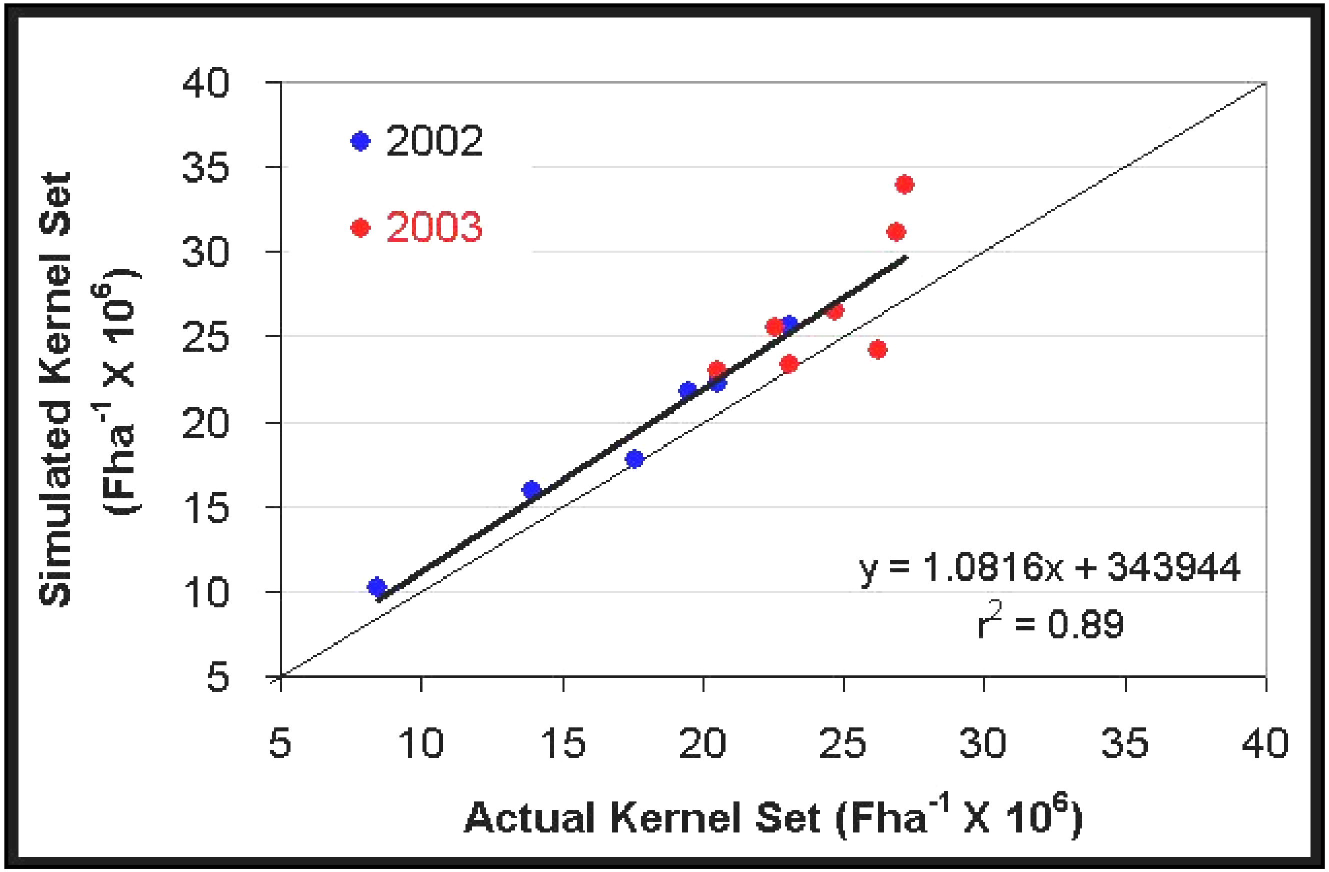
"Nick Manager" converts daily estimates of pollen shed and silk emergence to simulate kernel set for any given field condition



Lizaso et al. 2003

Temporal profile of silk exsertion (blue), temporal profile of pollen shed (black), and simulated daily values of kernel set (red).

Simulated kernel set in 13 seed production fields



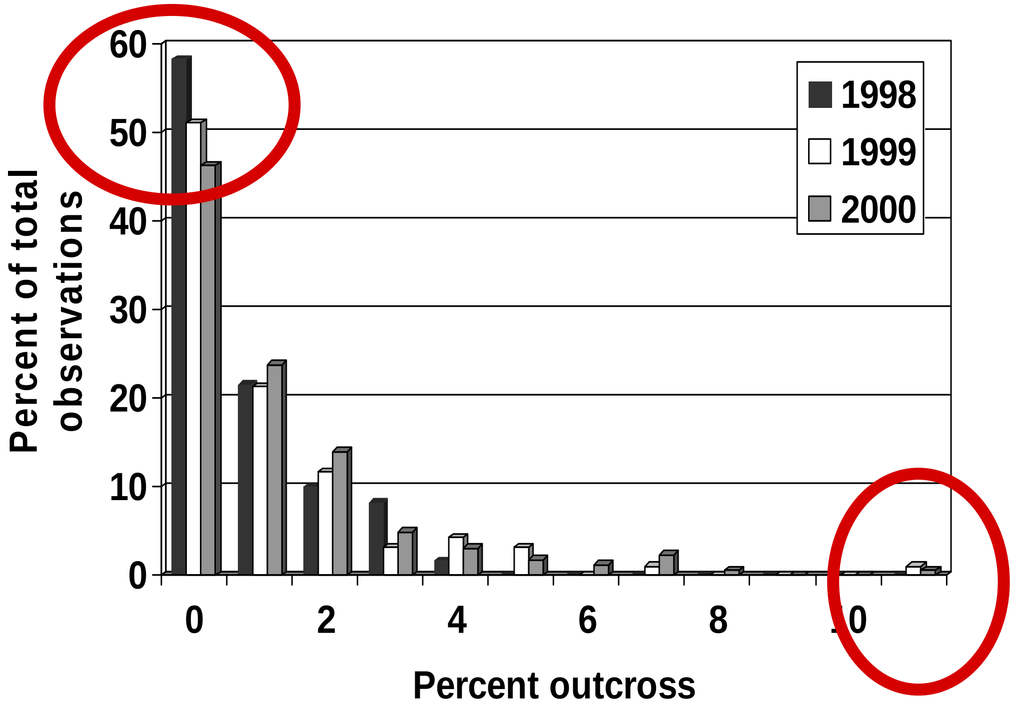
Fonseca et al. (unpublished)

Loss of pollen viability and pollen trapping by leaves not taken into account

3-year seed industry study

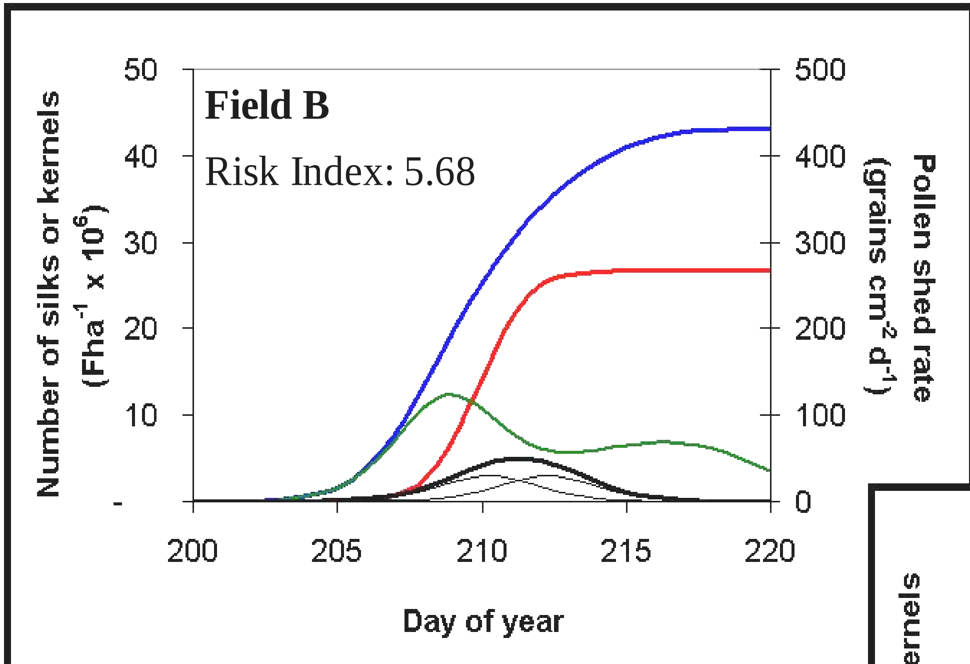
About 50% of the mid-field samples were free of out-crosses

A few mid-field samples had > 10% out-crosses

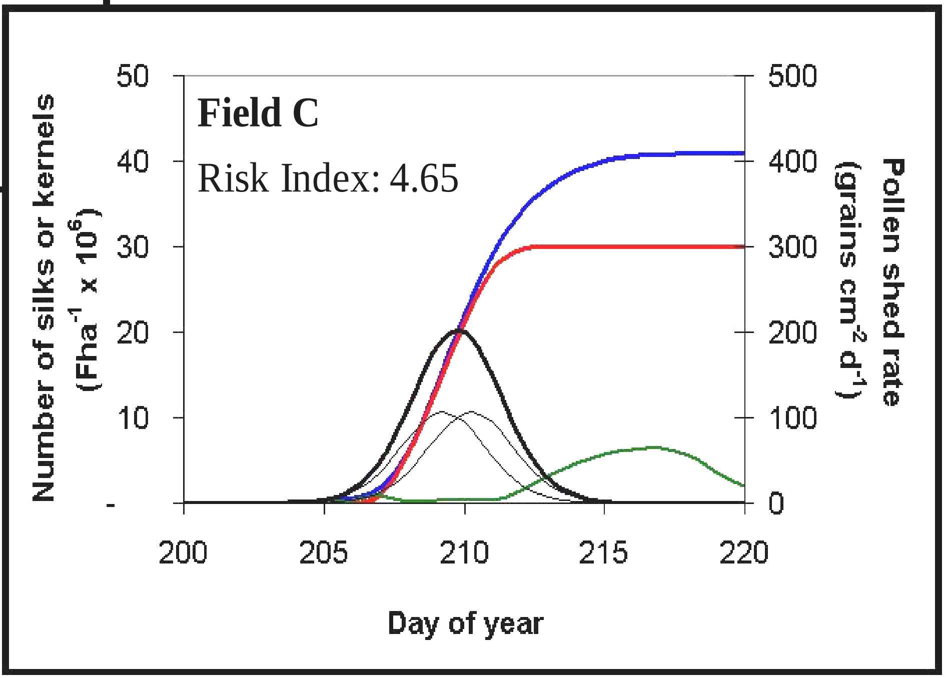


Ireland et al 2004

Risk of Out-crossing

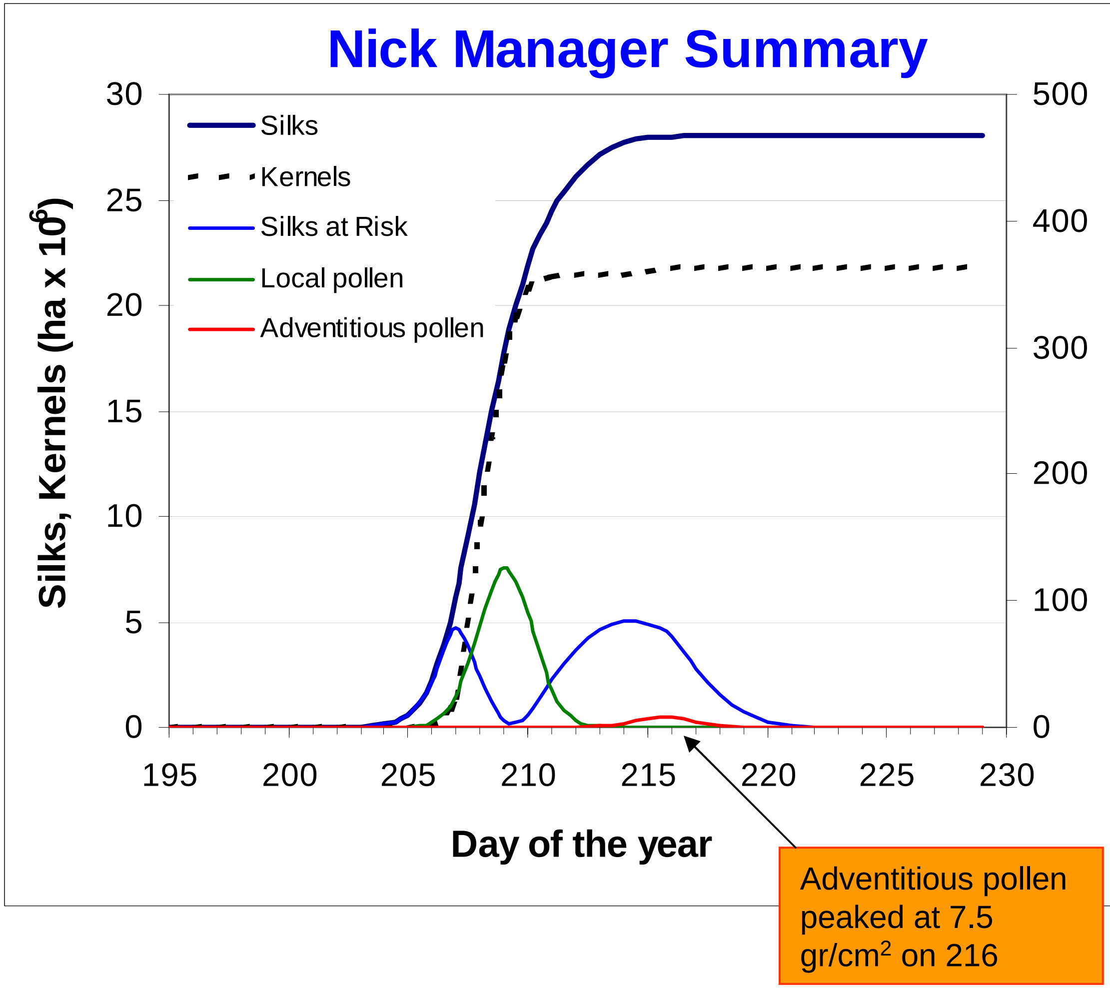


Early and late appearing silks at risk



Late appearing silks at risk

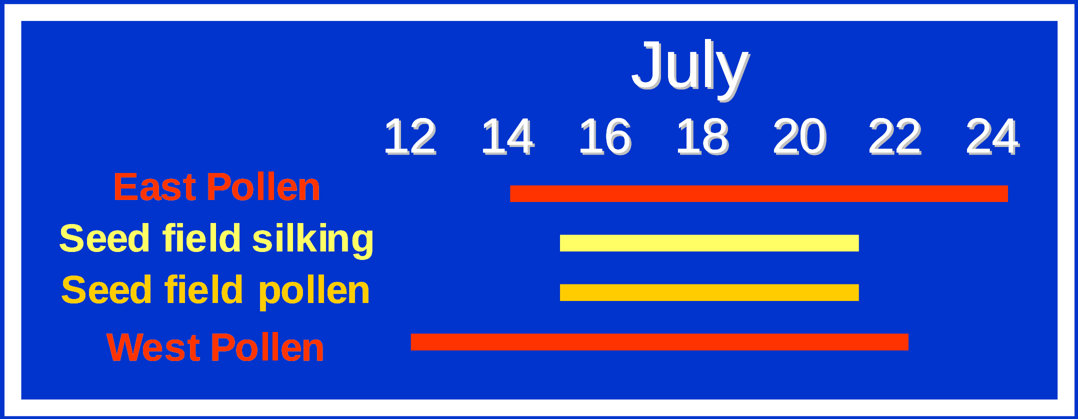
An example of simulated out-crossing resulting from "adventitous presence" late in flowering



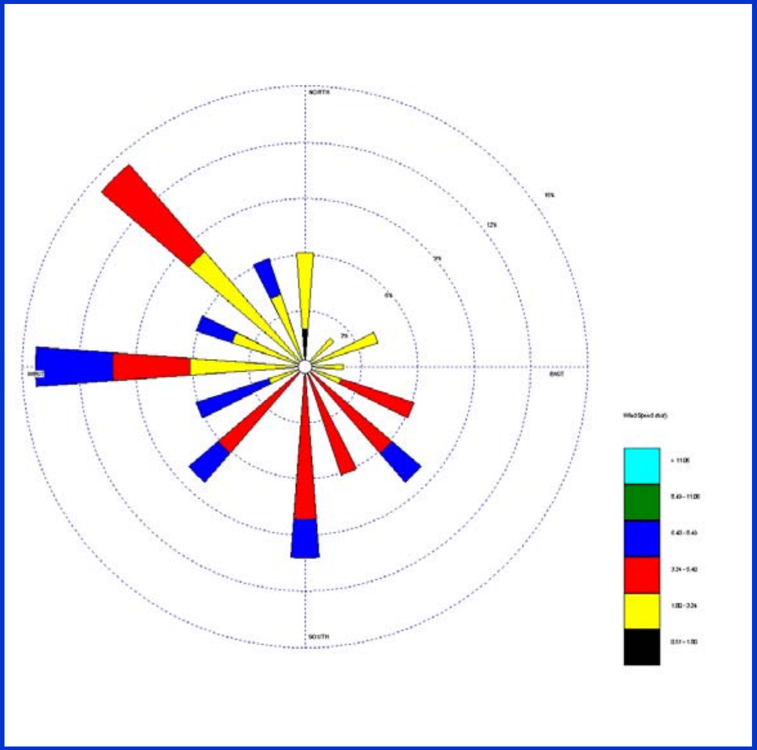
Total kernel production
21.8 mil kernels/ha

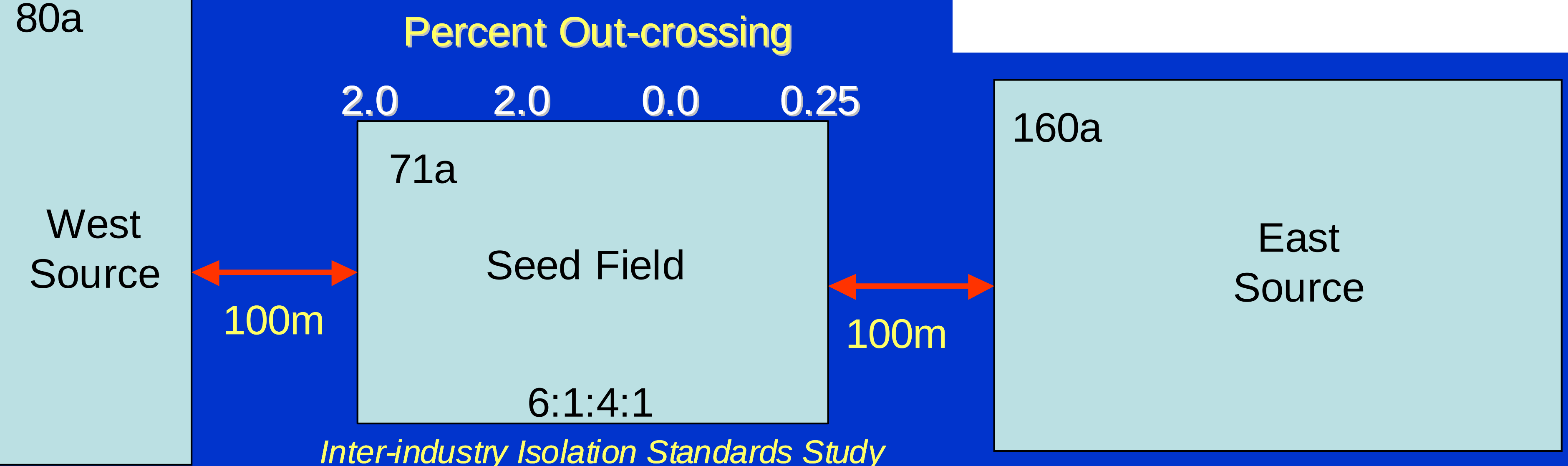
76.5% silks were pollinated
98.4% genetically pure seed
1.6% out-crossed seed

Durant, IA :1998



WindRose for Durant, IA
15-21 July 1998: 0800 – 1400 h





Inter-industry Isolation Standards Study