Forecasting the spread of soybean rust using a nested climate model

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Outlines

- Prediction model system
  - Prediction experiments
  - Validation
- Analyses of disease spread pattern
  - West Kentucky hot spot
  - Mississippi route
- 2006 climate conditions for rust dispersion and looking ahead
  - “Wind hole”
  - Rainfall/humidity
  - Future model improvements

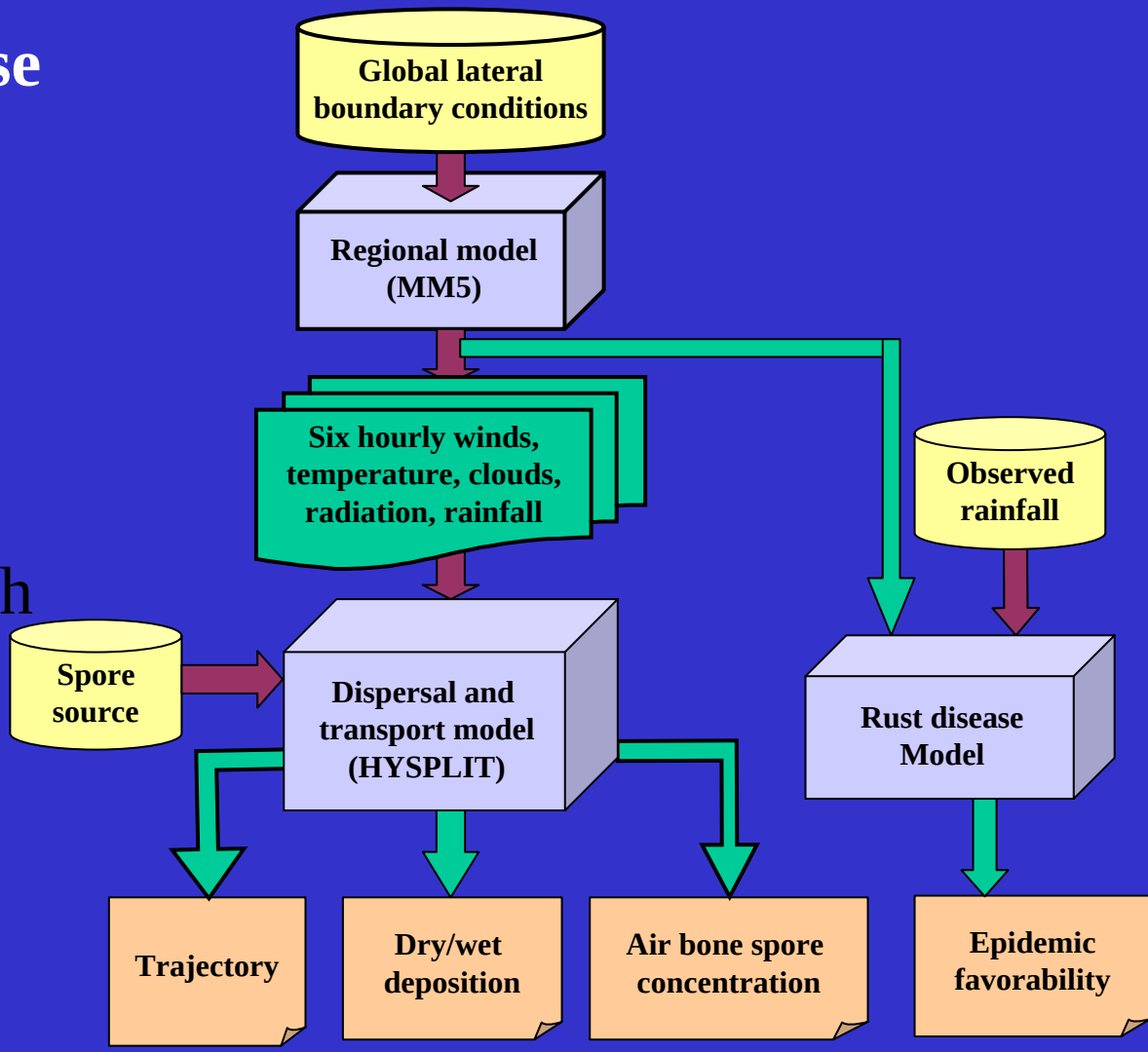
SLU/ISU Rust prediction model – An climate-dispersal-disease integrated system

Global model – Scripps Institution of Oceanography

MM5 – National Center for Atmospheric Research

HYSPLIT – NOAA Air Resource Lab

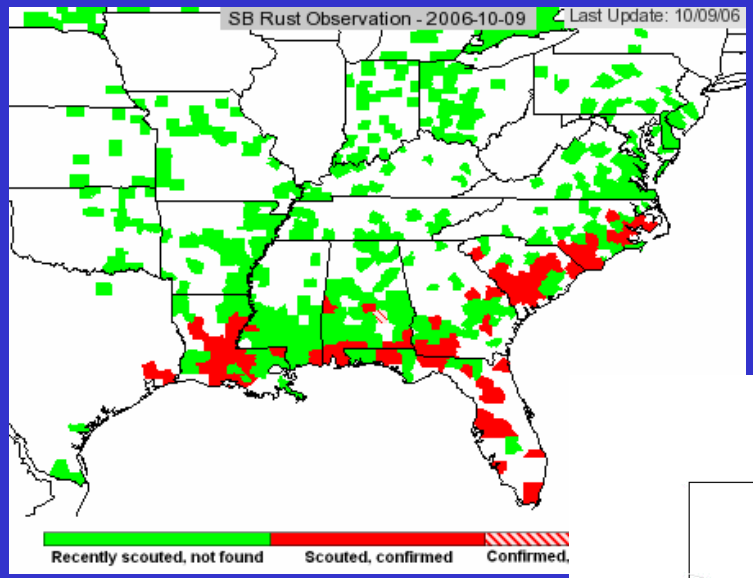
Disease model – Iowa State University



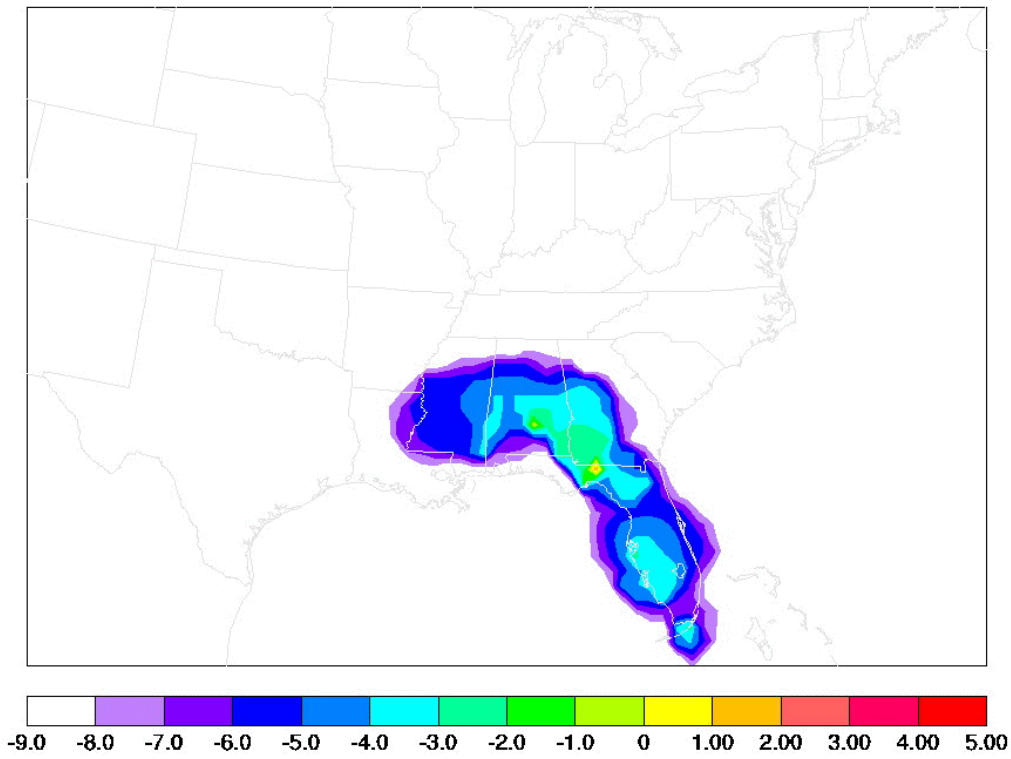
The Coupled Dispersal Model

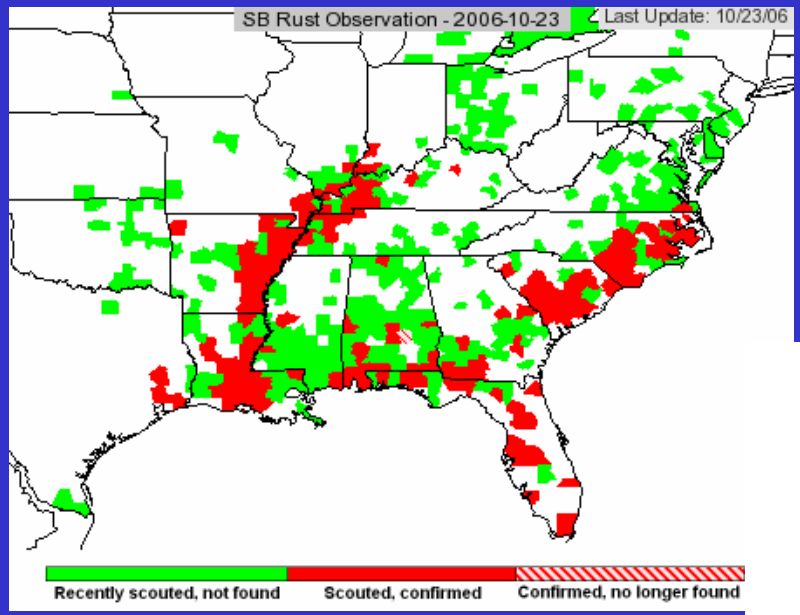
- ✓ **Runs in trajectory or concentration mode**
  - o trajectory – forward/backward tracking
  - o concentration – airborne and at surface
- ✓ **Treats spores as particles of plumes**
  - o spores passively move in with atmosphere once lifted
  - o spore plumes dilute, split, merge according to advection and diffusion physics
- ✓ **Considers dry and wet deposition**
  - o gravitational settling
  - o rainfall washout
- ✓ **Incorporates simple aerobiological viability criteria**

  UV radiation, temperature

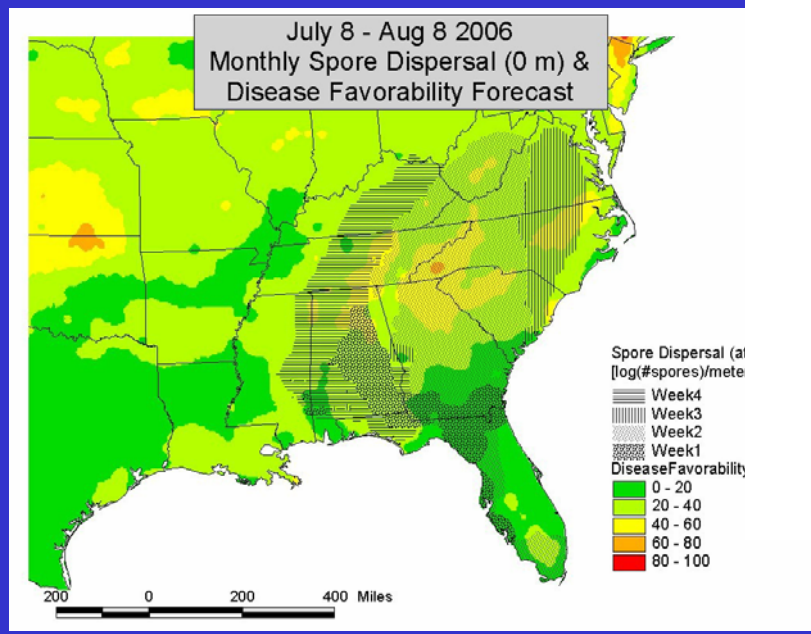


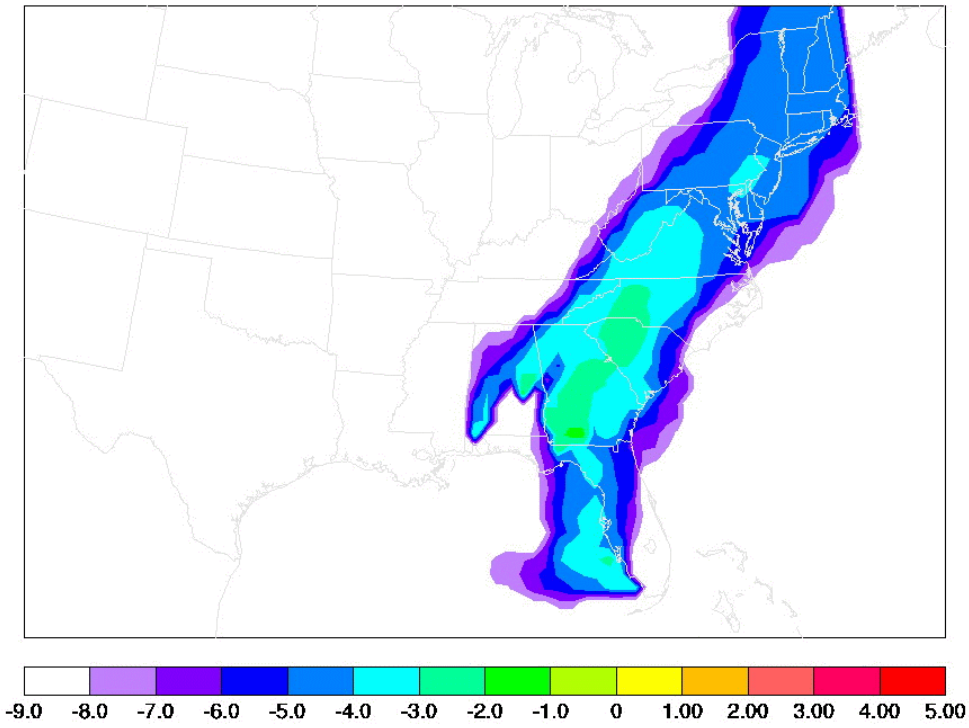
Weekly forecast airborne spore concentration during 6/24-7/29

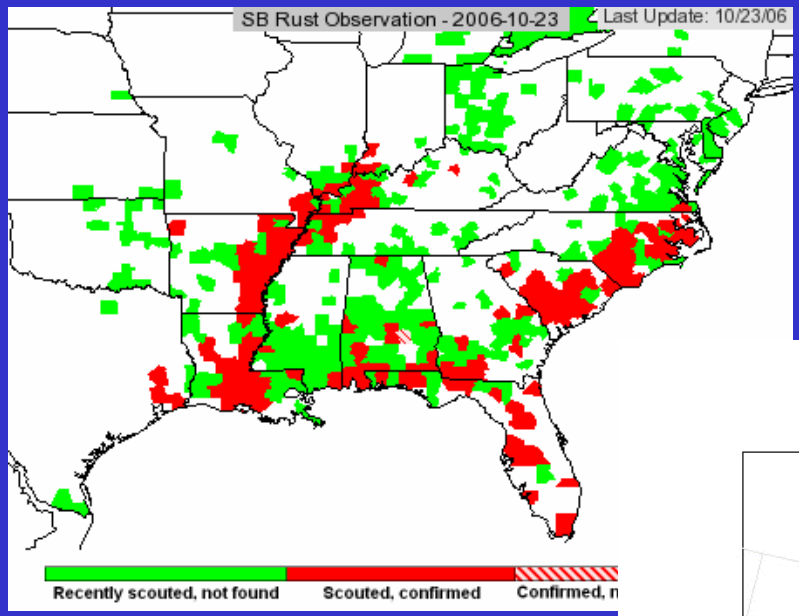




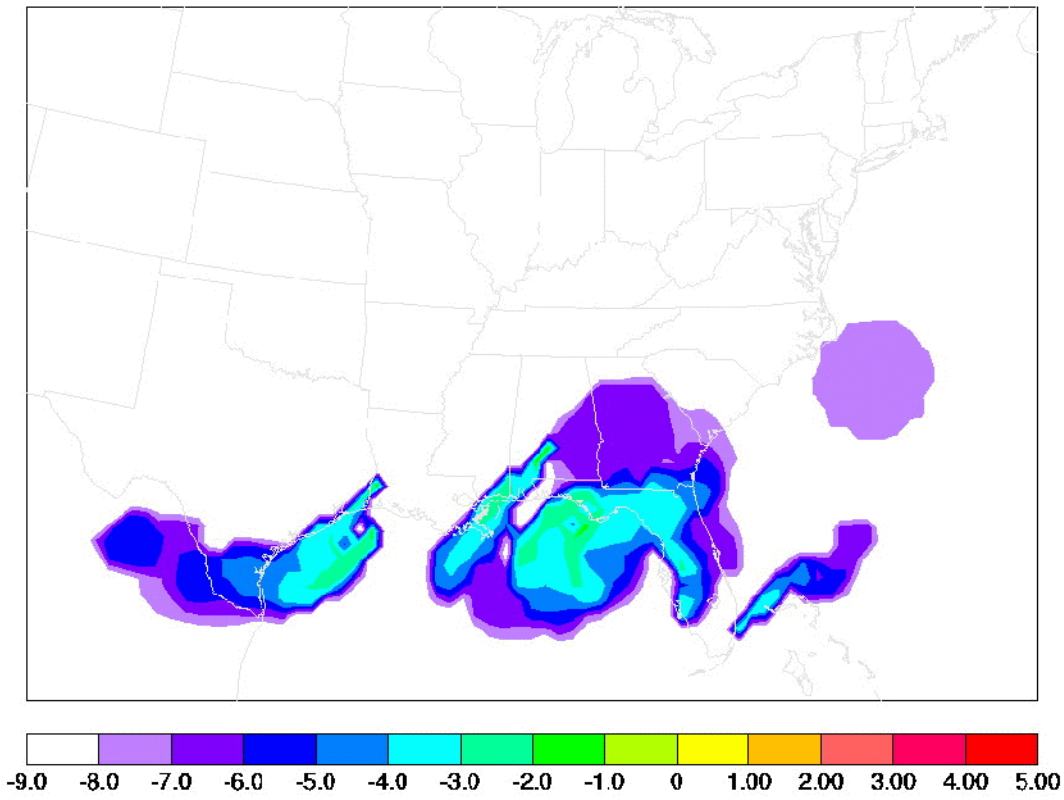
Weekly forecast ground spore concentration during 7/1-8/11

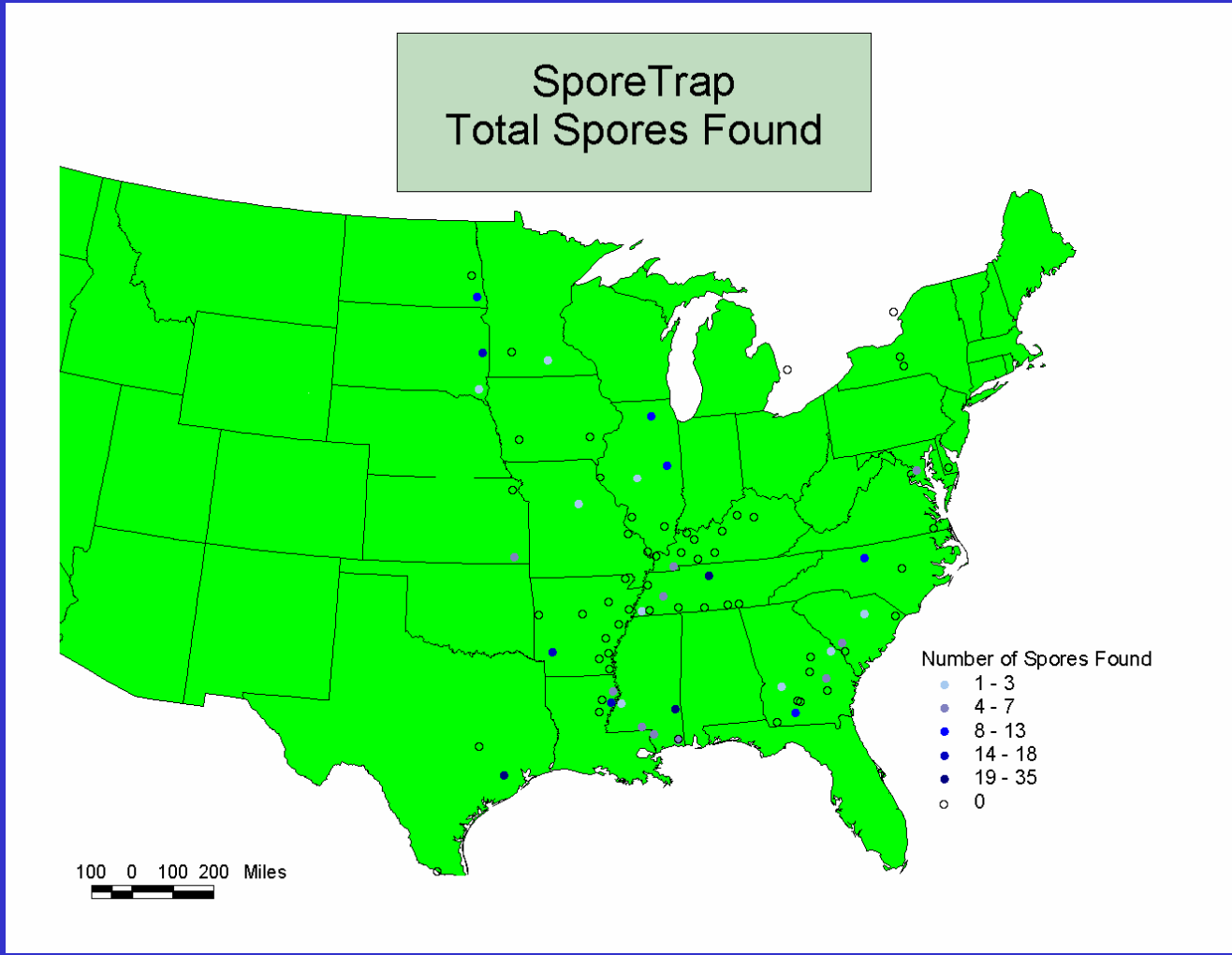






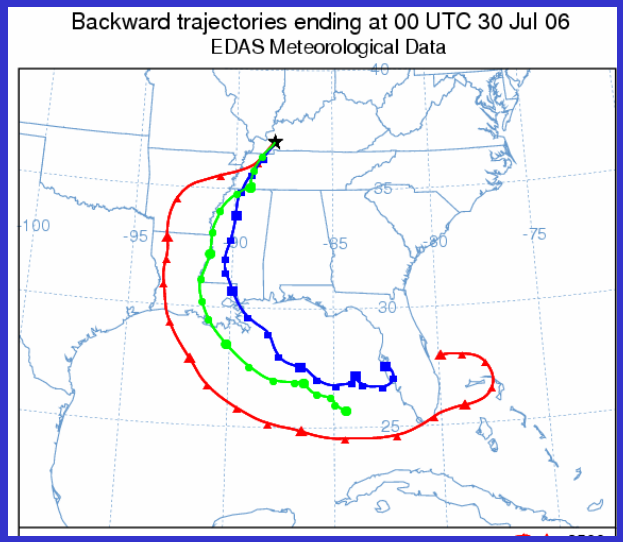
Weekly forecast of ground spore concentration during 8/12-9/22

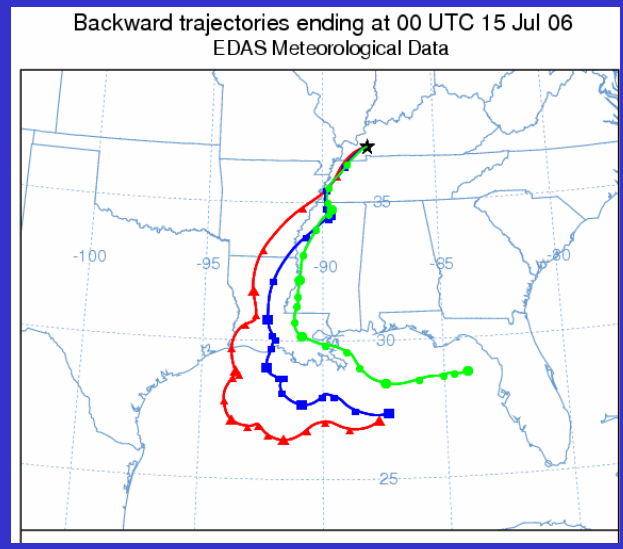


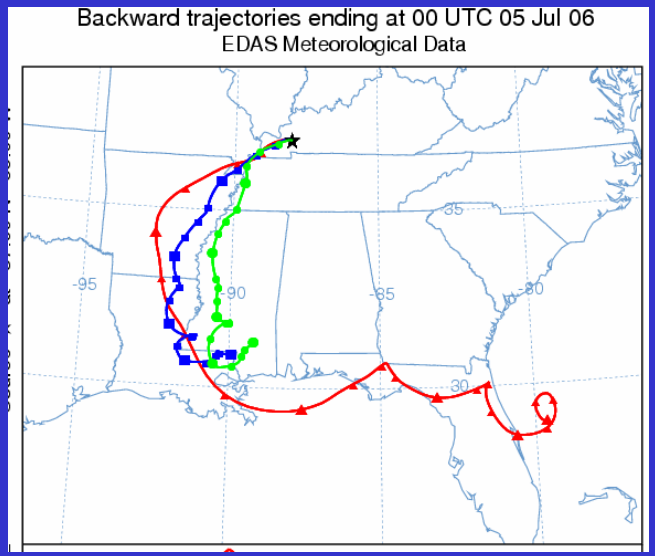


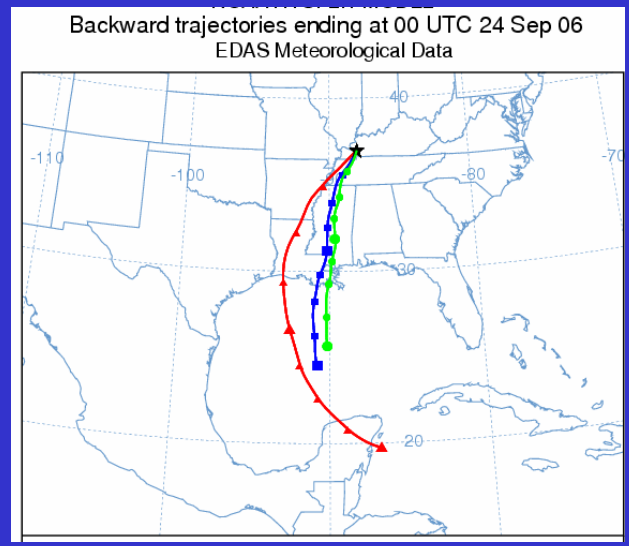
Courtesy of Marshall Beatty, Syngenta
(Spore counts are based on morphology only)

Samples of model simulated spore tracks ending at western Kentucky - hindcast

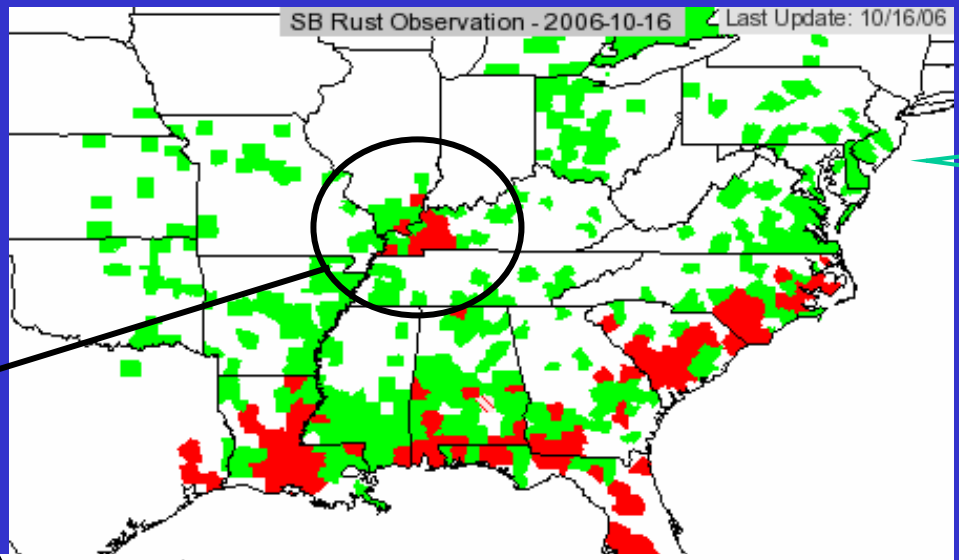




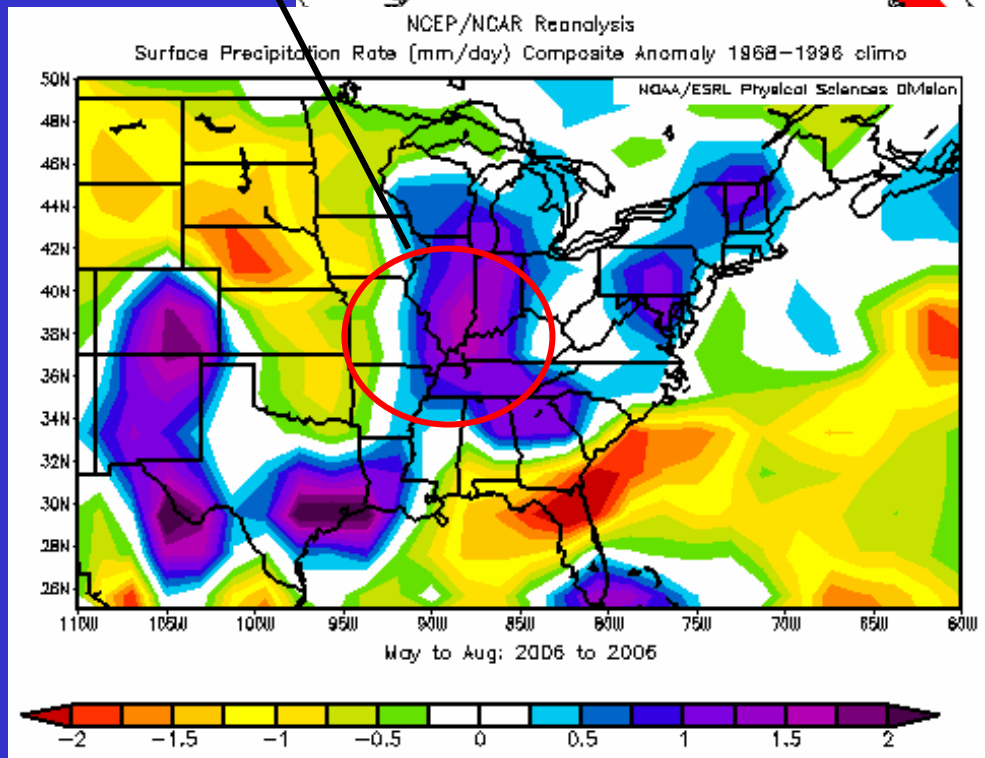




Comparison of disease detection with rainfall anomaly



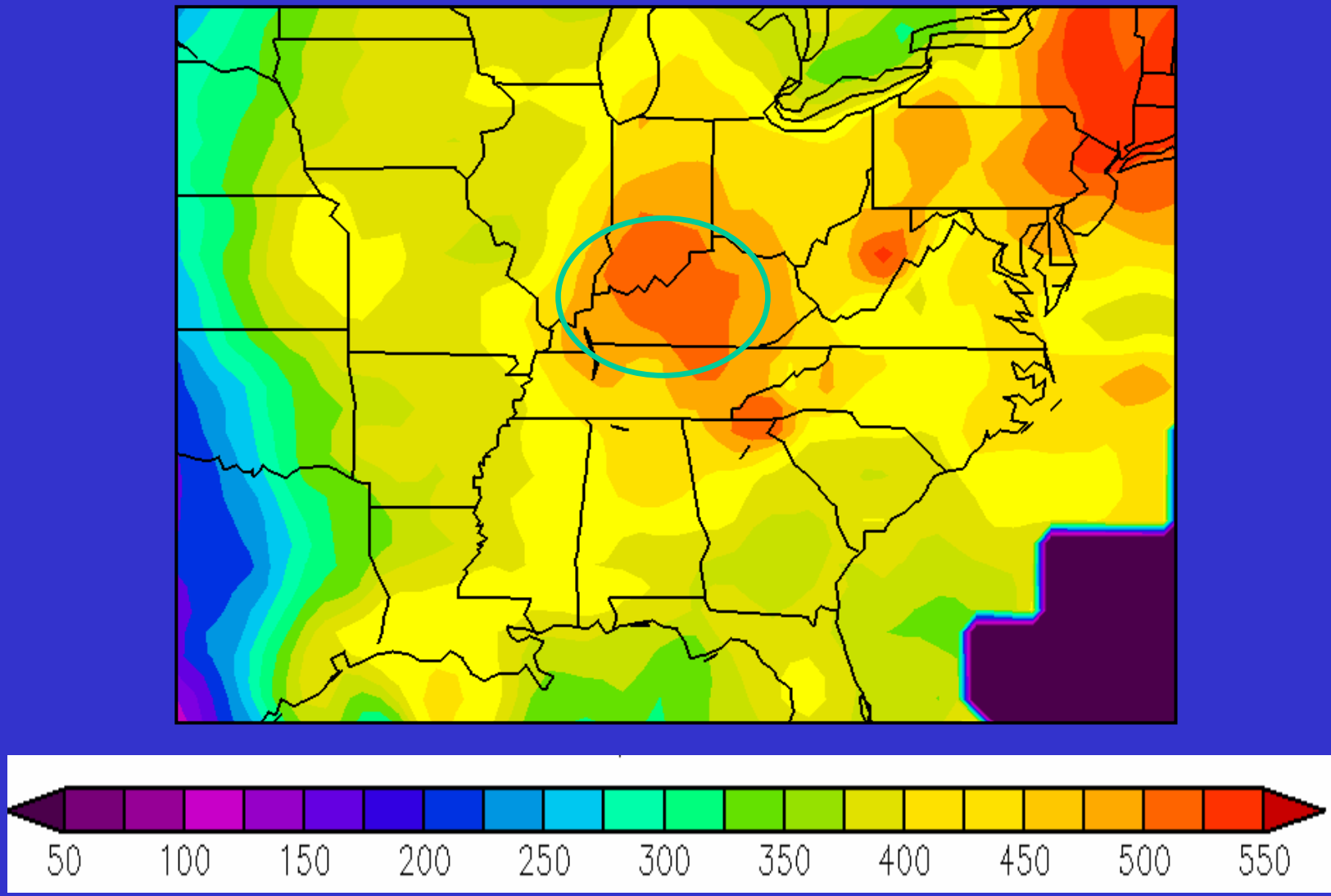
SBR infection as of 10/16/2006



ed, no longer found

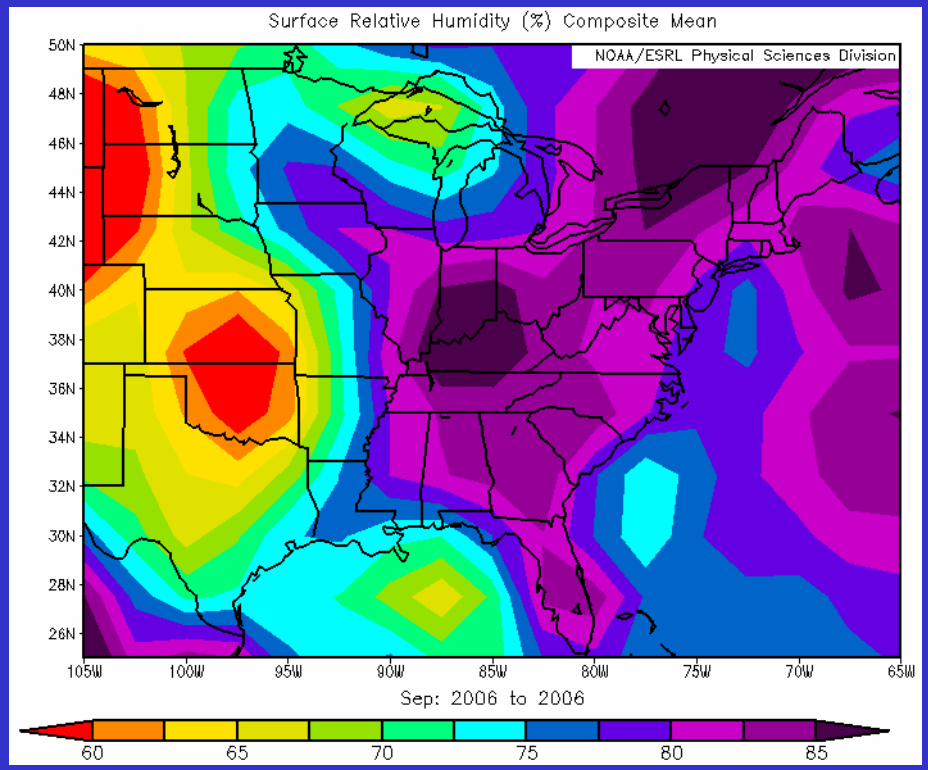
May-Sept rainfall, 2006

Soil Moisture(in mm) within top 2 m, May-October, 2006

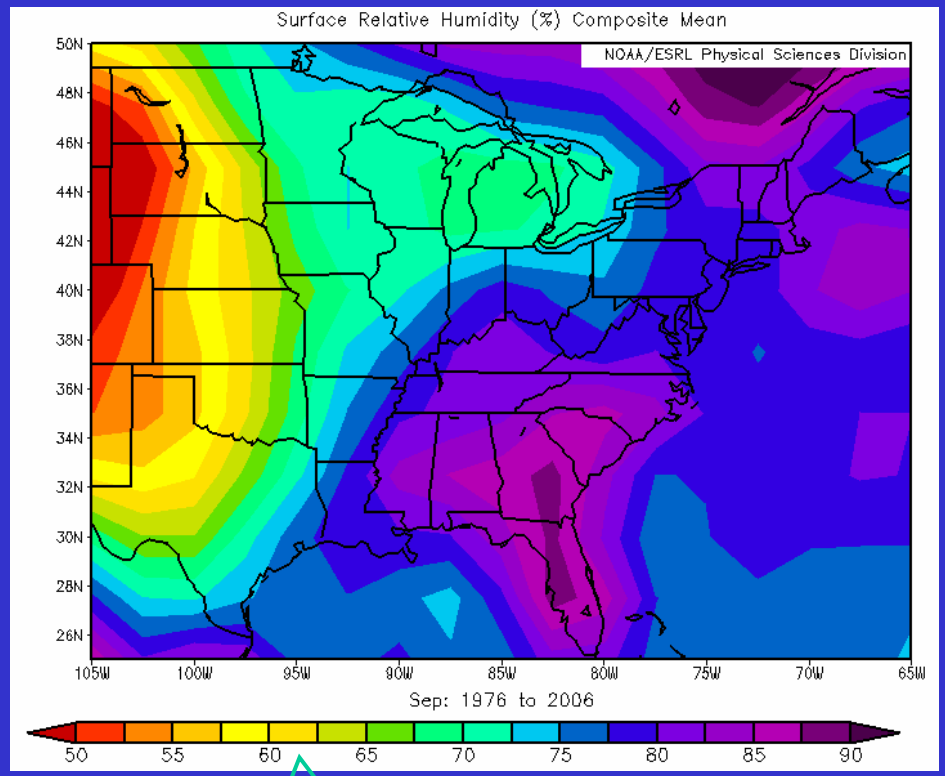


Source: NCEP/NOAA

Surface relative humidity (%): 2006 vs. long-term mean

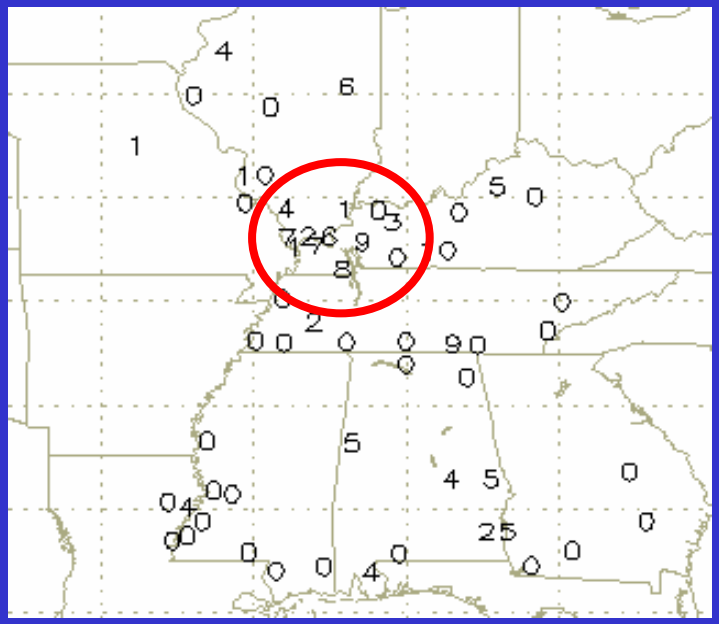


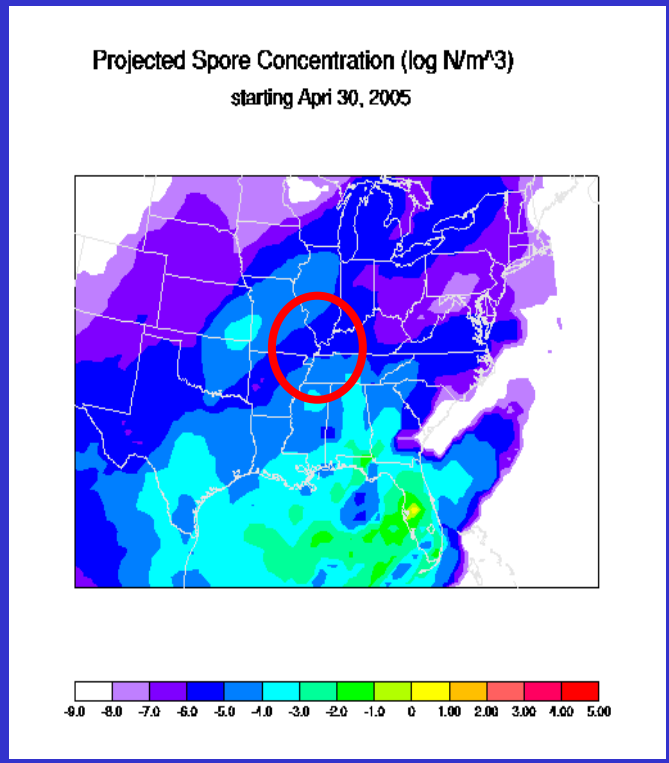
Sept, 2006



Sept, climatology

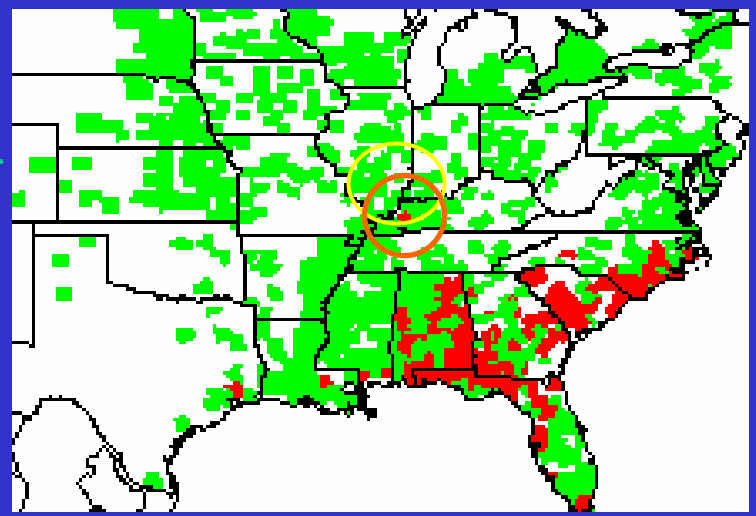
Source: NCEP/NOAA



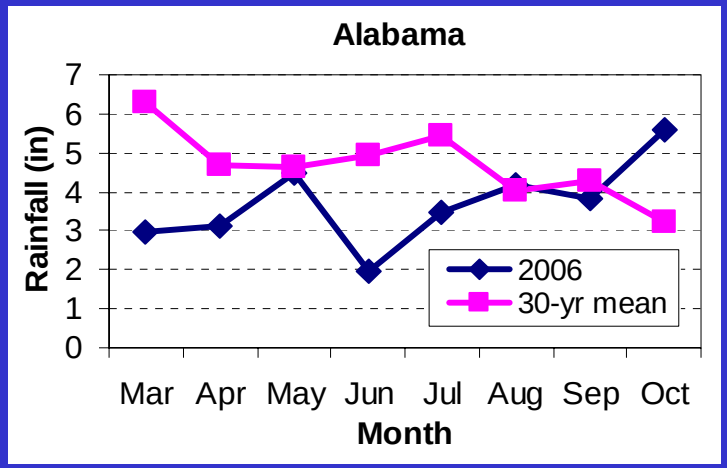


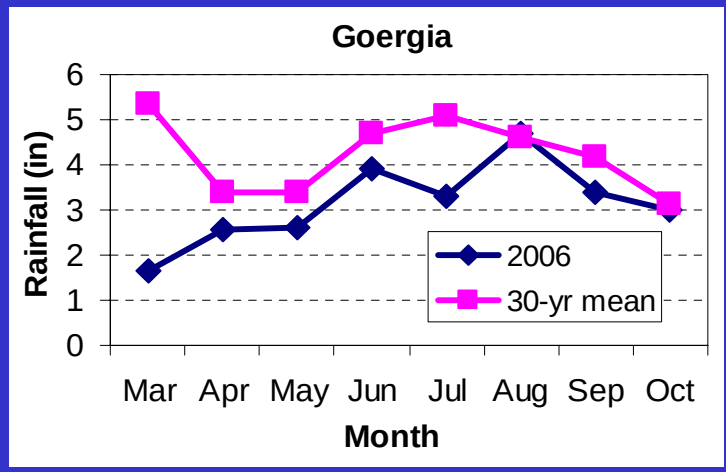
Spore counts: which are visually inspected, but not PCR checked. Courtesy of Syngenta

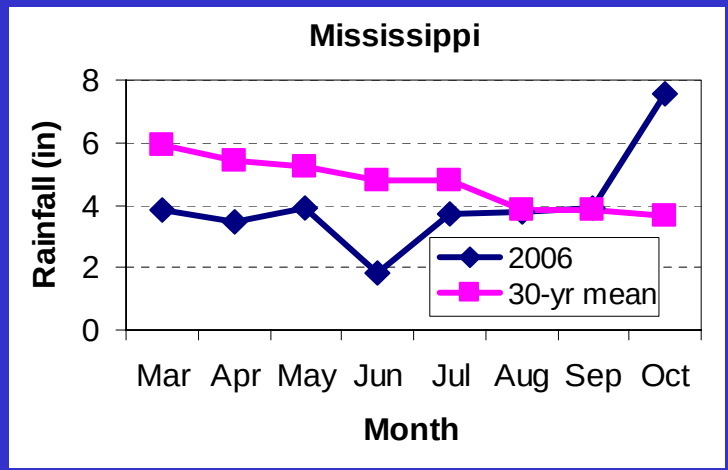
As of 11/18/2005



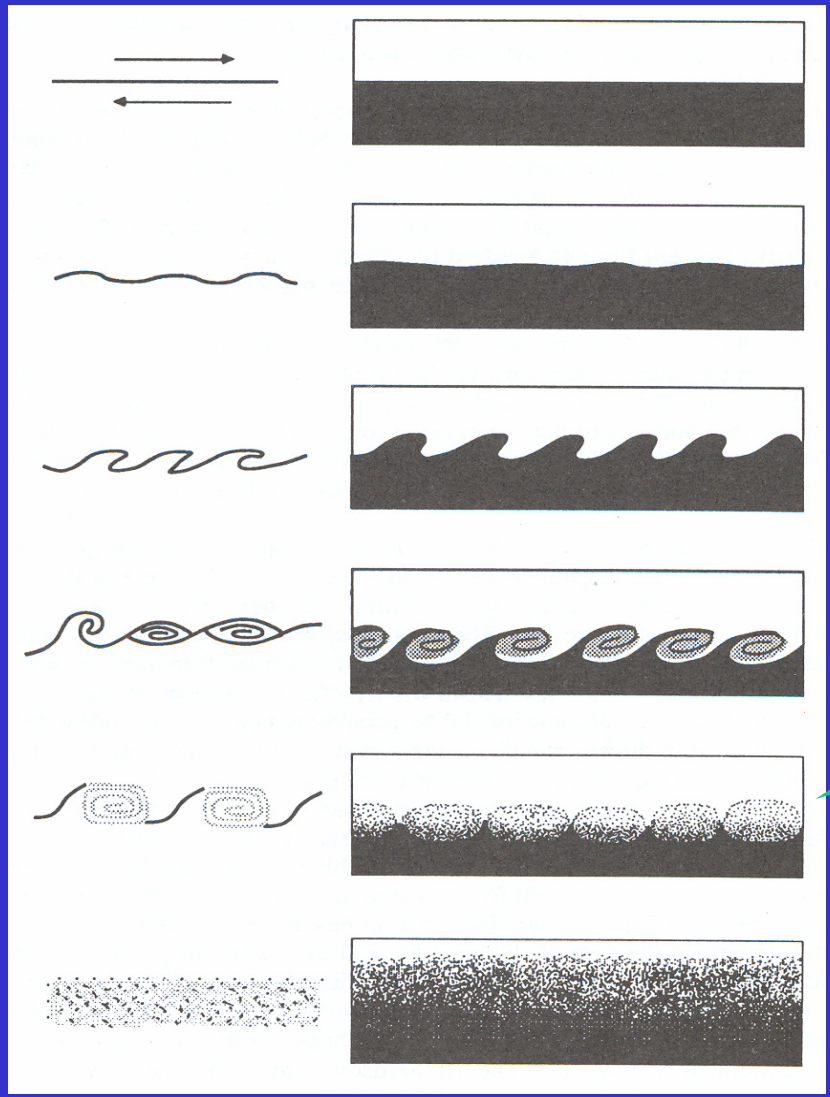
Monthly rainfall amounts anomaly in 2006







Schematics showing wind shear generating turbulence



Time sequence of shear-generated turbulence development

(adapted from Stull 1998)

z=1 km

U=2 m/s

5 m/s

$$\frac{\partial(Ek)}{\partial t} = -\frac{g}{\theta} K_h \frac{\partial \theta}{\partial z} + K_m \left(\frac{\partial U}{\partial z}\right)^2 + Tr - D$$

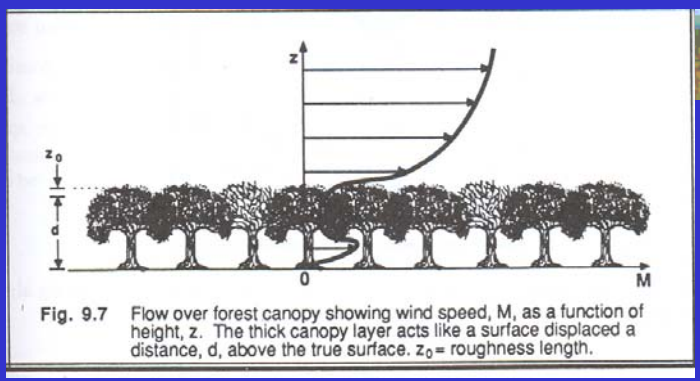
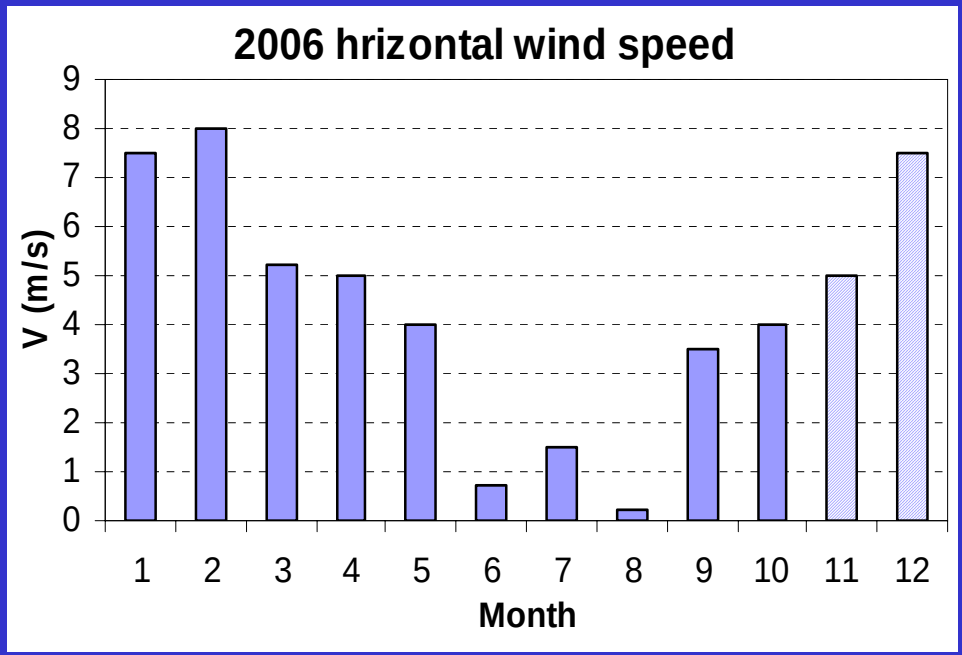


Fig. 9.7 Flow over forest canopy showing wind speed, M, as a function of height, z. The thick canopy layer acts like a surface displaced a distance, d, above the true surface. z_0 = roughness length.

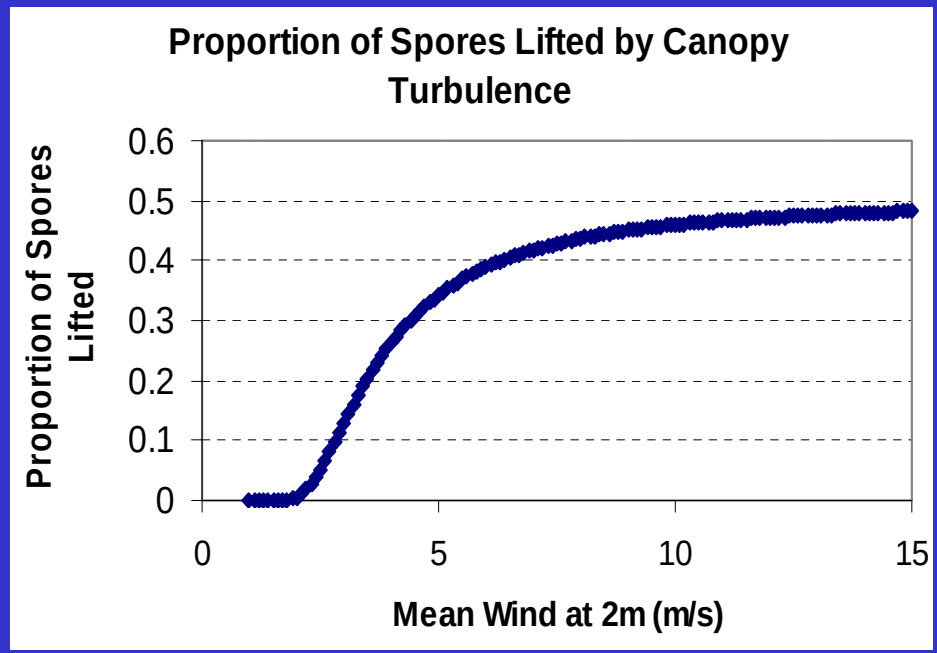
Schematics illustrating wind speed effects on turbulent mixing

Wind effects on spore escape rate through turbulence

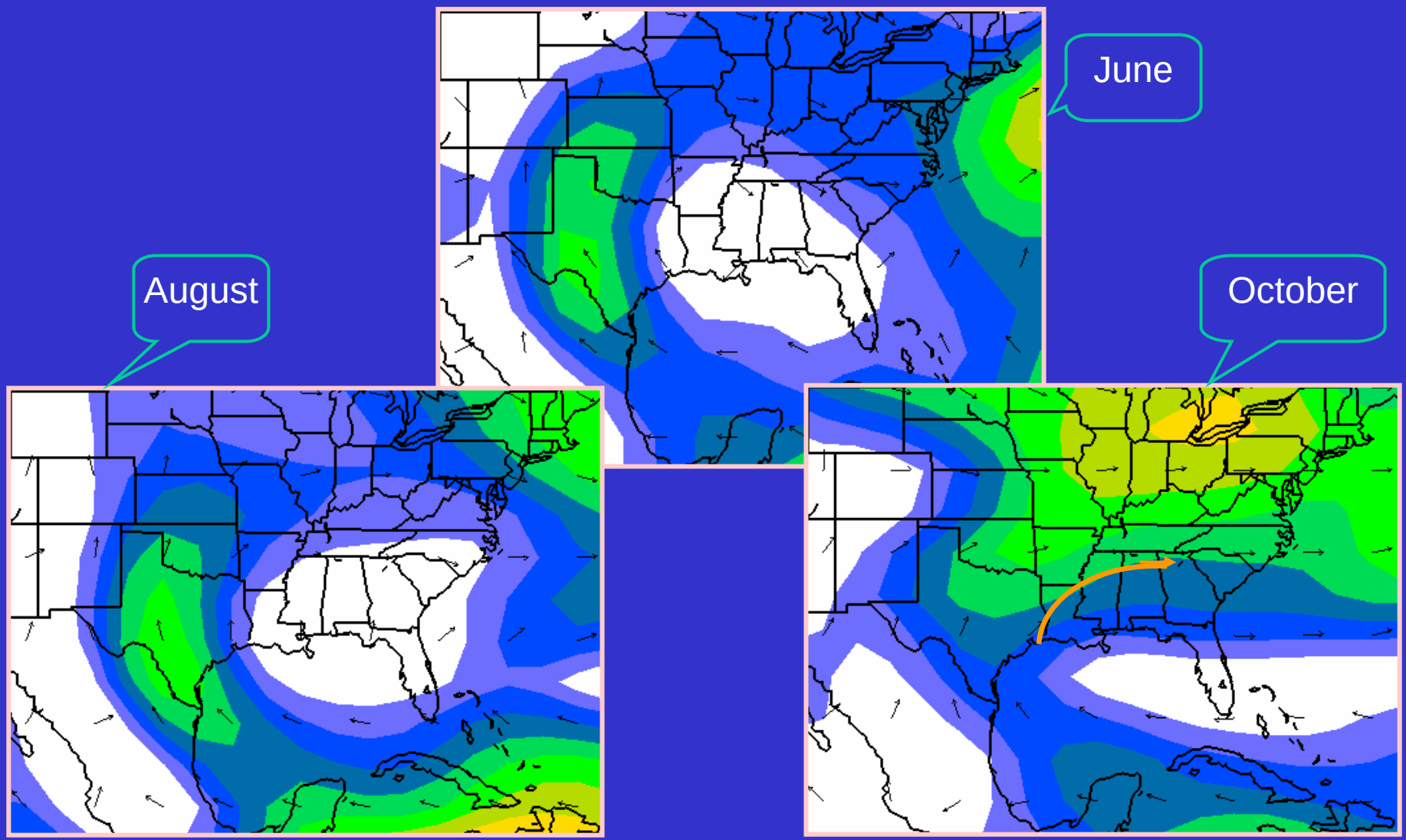
Monthly surface mean wind velocity near LA-MS border



Dependence of spore escape on wind speeds (theoretical)



Monthly wind velocity at 850mb (~1500m), showing “wind hole” in early season



Summary and Discussion

- The climate-dispersal coupled model was used to forecast spore movement and disease development up to 2-4 weeks in advance.
- The 2006 growing season forecasts suggest that the model can capture general patterns of spore dispersal, including the routes along the East Coast and lower Mississippi Basin.

Summary and Discussion - continued

- A “wind hole” was evident in early season, but diminished later, which possibly allowed the rust to spread northward near the end of the season.
- Western Kentucky was found to be conducive to the rust infection, likely due to the high humidity resulting from more precipitation and soil moisture.
- The South Costal states were drier in early season 2006, partly explaining the lateness of the disease spread.

Future Work

- Further quantify spore releasing rate using canopy turbulence model.
- Use EPA's CMAQ and WRF chemistry models with different dispersal parameterizations, in addition to HYSPLIT.