Overview of plant protection models

Lučka Kajfež-Bogataj

University of Ljubljana, Biotehnical faculty

- **Introduction**
- **Principles of pest, disease modelling**
- **Problems with leaf wetness estimation**
- **Linking pest damage models with crop models**
- **Concluding remarks**

Why do we need models to predict pest, disease outbreaks?

or

What are the uses of plant protection forecasts ?

In practise:

- **For making strategic decisions**
- **For making tactical decisions**

In science

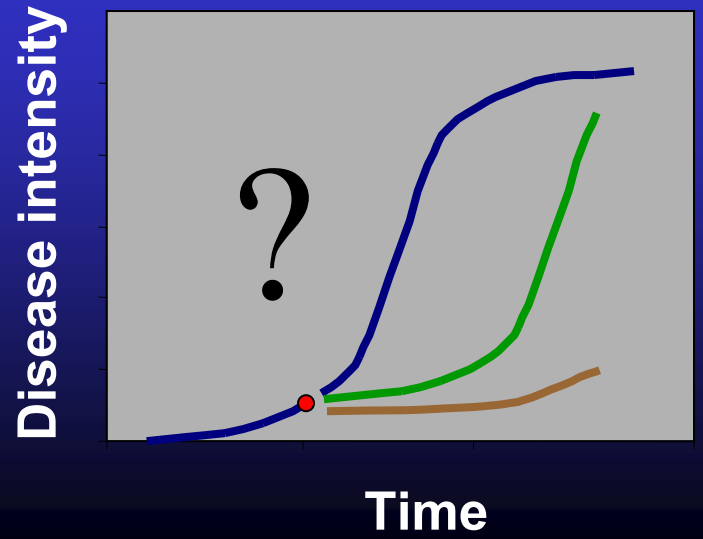
- **For better understanding of crop&pest&weather processes**

Making strategic decisions

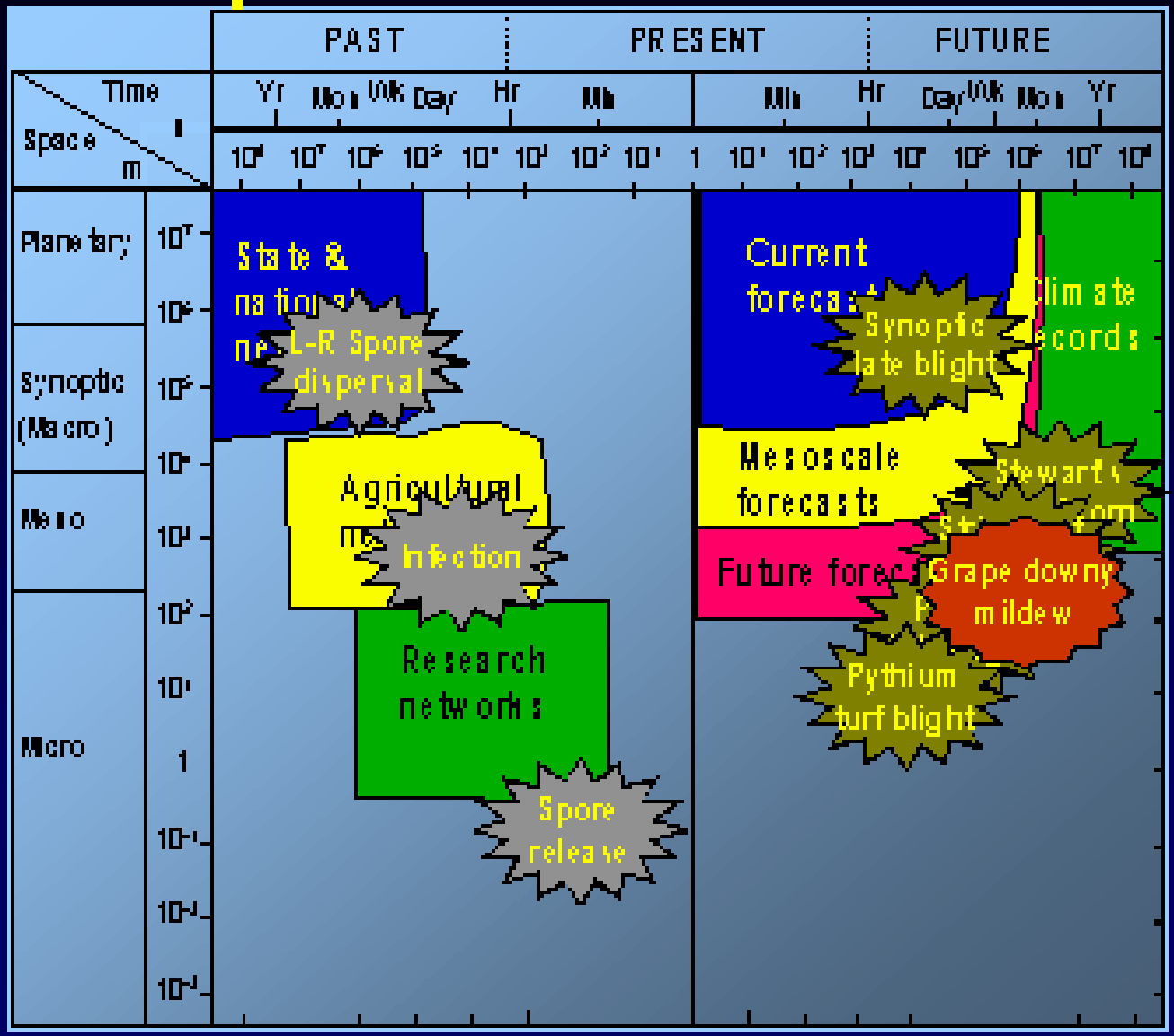
- Prediction of the risks involved in planting a certain crop
- Deciding about the need to apply strategic control measures (soil treatment, planting a resistant cultivar, etc.)
- Assesment of climate change effects and adaptation

Making tactical decisions

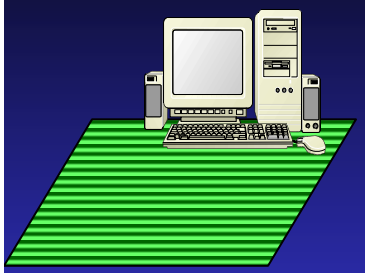
- Deciding about the need to implement disease management measure



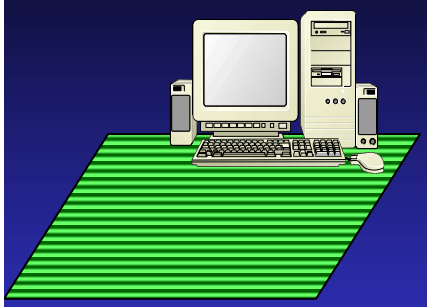
Temporal and spatial dimensions of weather and plant disease information



Steps in development and implementation of a model for operative use



Step	Time (years)
Biological research	5-10
System development	<0.5
Validation and improvements	2-4
Technology transfer	1-2
Maintenance	forever



Can plant protection models (or decision support systems) be exported?

From country to country?

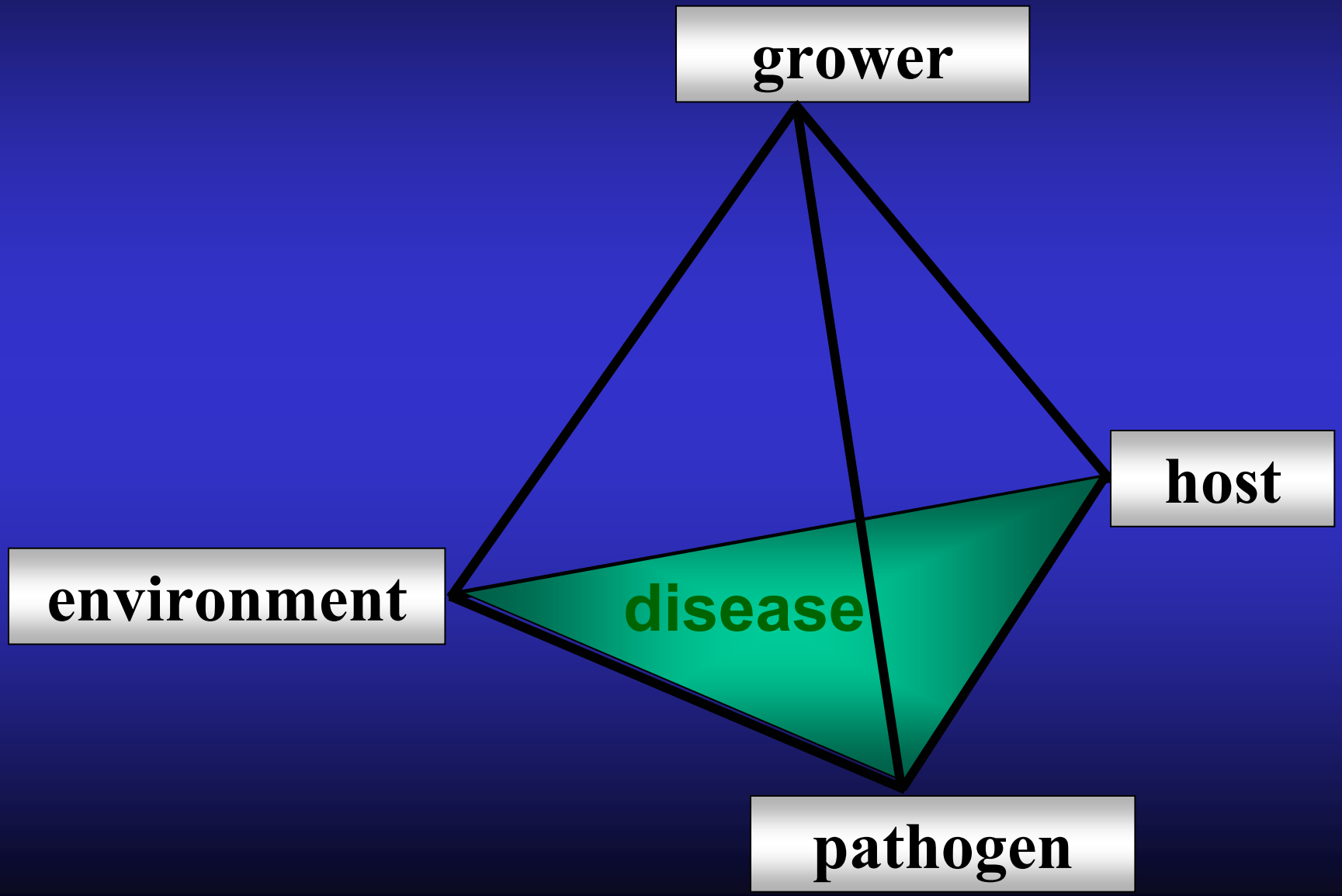
From region to region?

From crop to crop?

In most cases, the answer is NO !

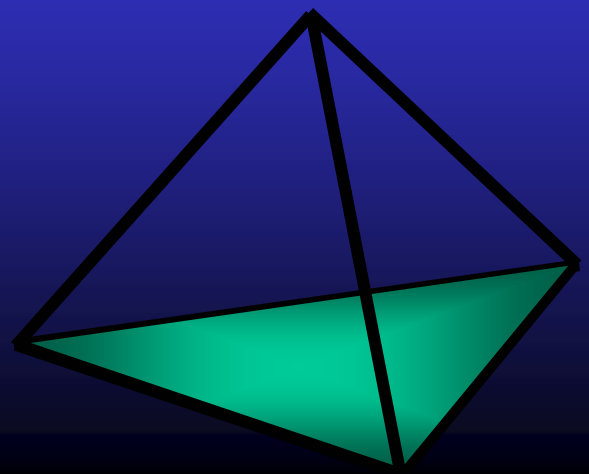
The rules, reflect in most cases, local relationships.

The disease pyramid



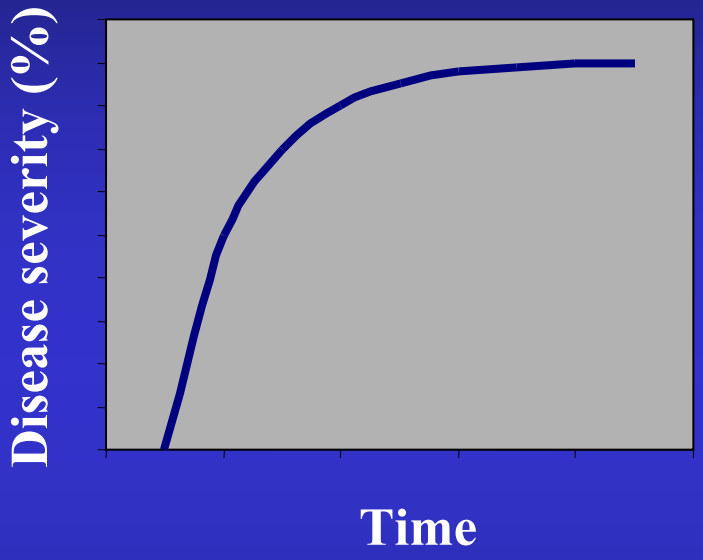
Disease (pest) modelling is based on:

- The nature of the **pathogen** (monocyclic or polycyclic)
- Effects of the **environment** on stages of pathogen and host development
- The response of the **host** to infection (example: age-related resistance)
- Activities of the **growers** that affect the pathogen or the host



Complete only one disease cycle in a growing season

Monocyclic pathogens



Q = amount of initial inoculum

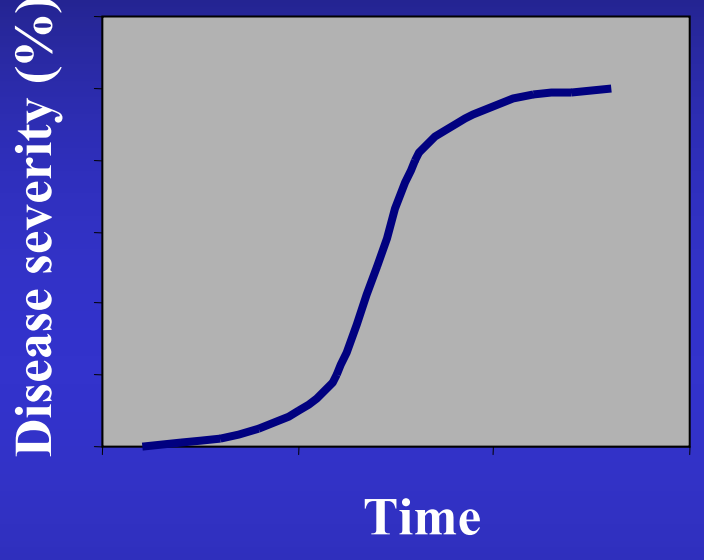
R = infection efficacy of the inoculum

y = disease intensity

$$\frac{dy}{dt} = QR\ (100 - y)$$

Complete several disease cycles in a growing season

Polycyclic pathogens



r = apparent infection rate

y = disease intensity

$$\frac{dy}{dt} = r\ y\ (100 - y)$$

Prediction of a monocyclic pathogen that complete only one disease cycle in a growing season - <u>indirect prediction</u>

Wilt disease in maize induced by *Erwinia stewartii*

Severe infections occur after moderate winters.

Mild infections occur after cold winters.

-1.1°C > **Average Temp. in December, January and February** > **0.7°C**

Low probability for severe epidemic

High probability for severe epidemic

Consequences from predicting the severity of *Erwinia stewartii* in maize on grower's action

Low probability for severe epidemic

Sow maize as planned

High probability for severe epidemic

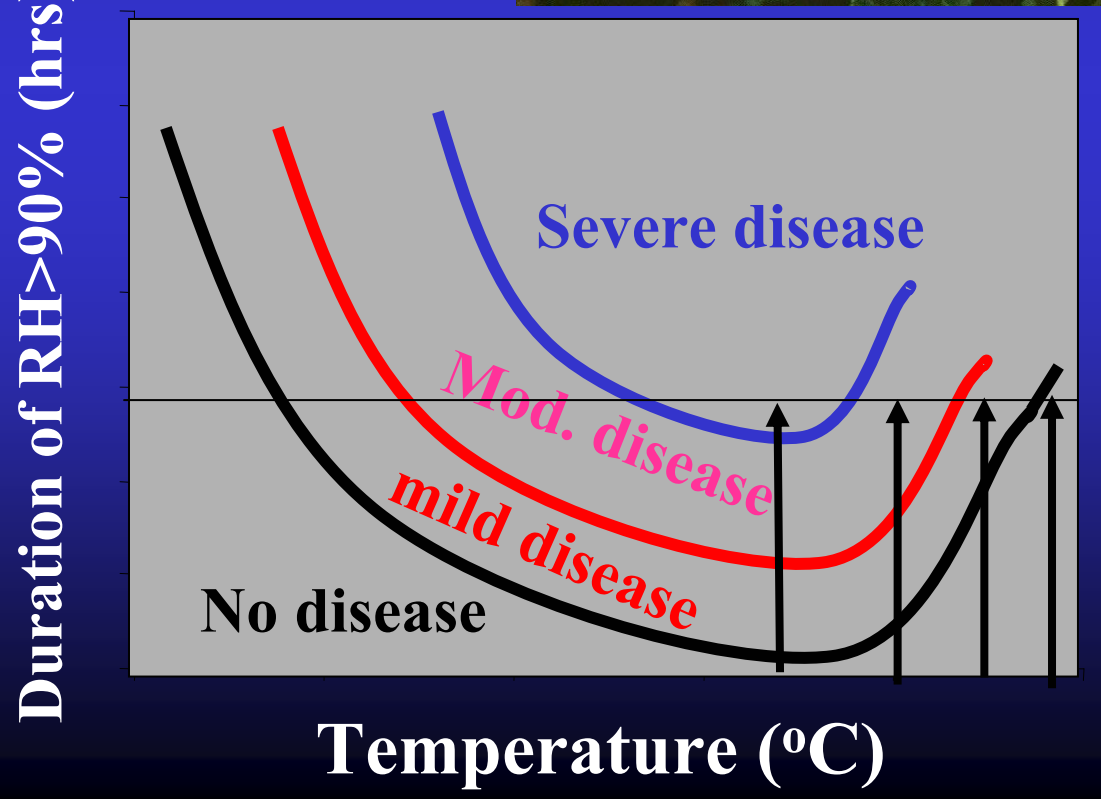
Do not sow maize at all

Sow only resistant cultivars

Prediction of a polycyclic pathogen that complete very few disease cycles in a growing season

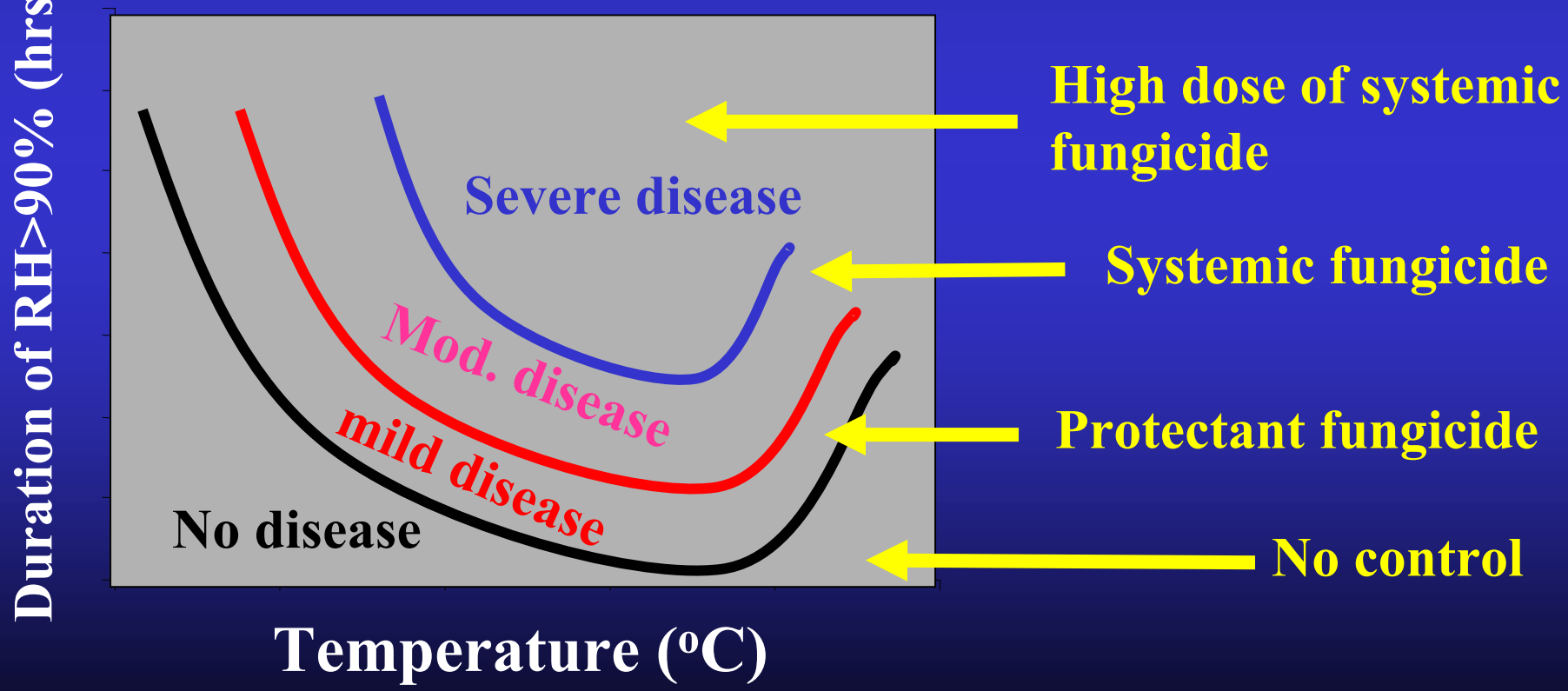
Apple scab induced by *Venturia inaequalis*

1. Amount of initial inoculum is high (ascospores)
2. Only young leaves are susceptible
3. Film of water on the leaves and proper temperatures are needed for infection



Consequences from predicting the occurrence of infections of apples by *V. inaequalis* on grower's actions

Decision concerning the need for fungicide spraying is made daily during the beginning of the season



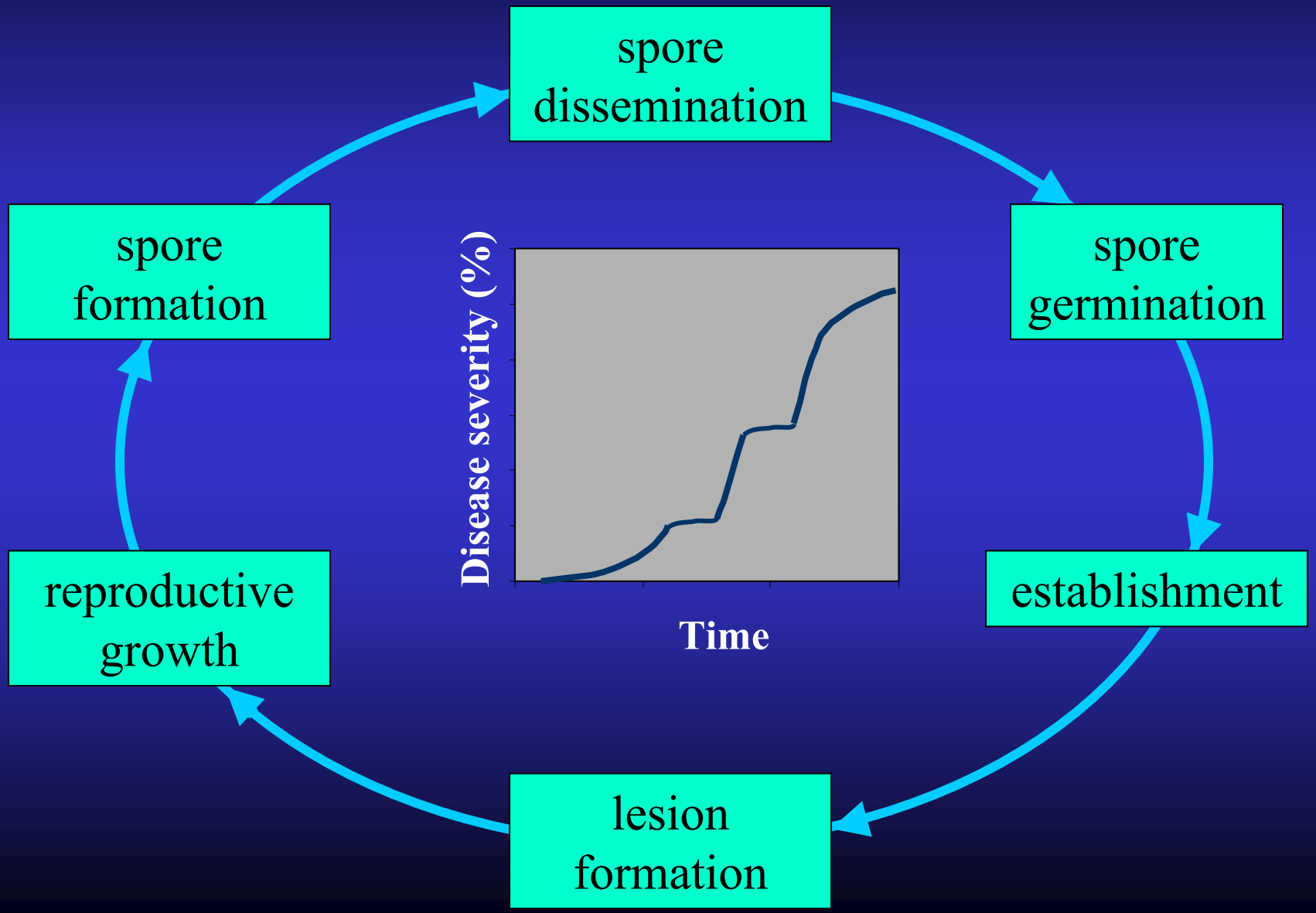
The most important models for apple scab

- **RIMpro by Marc Trapman (Holland)**
- **Schorfprognose by Herbert Welte (Germany)**
- **Adem by Xiangming Xu (East-Malling, England)**
- **Clean Arbo by CTIFL (France)**
- **Aschorf by K.P. Wittich (German weather Service)**

respective websites:

http://www.biofruitadvies.nl (RIMpro)
http://www.farmsoft.de/index.html (Schorfprognose)
http://www.hri.ac.uk/site2/research/fres.htm (Adem)
http://www.ctifl.fr (Clean Arbo)
http://agromet-cost.istea.bo.cnr.it/aschorf.pdf (Aschorf)

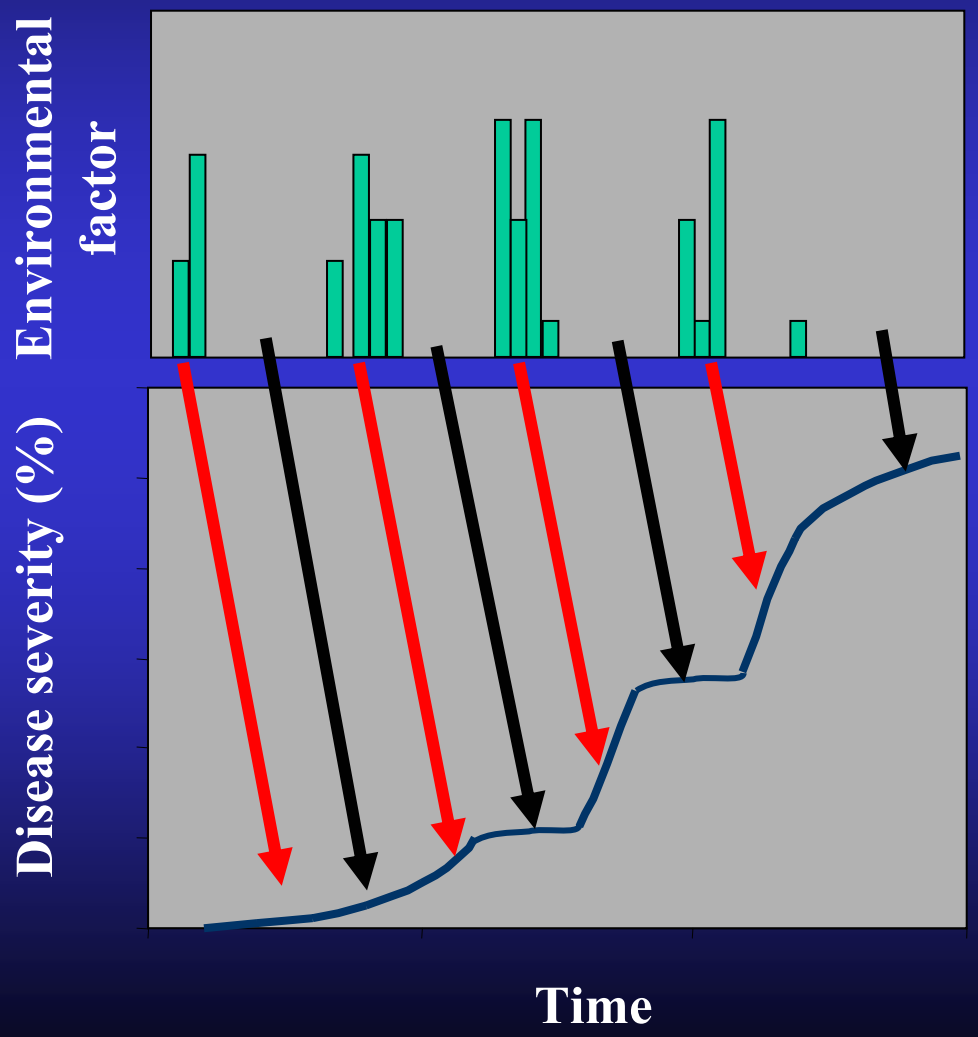
Effects of the environment on pathogens



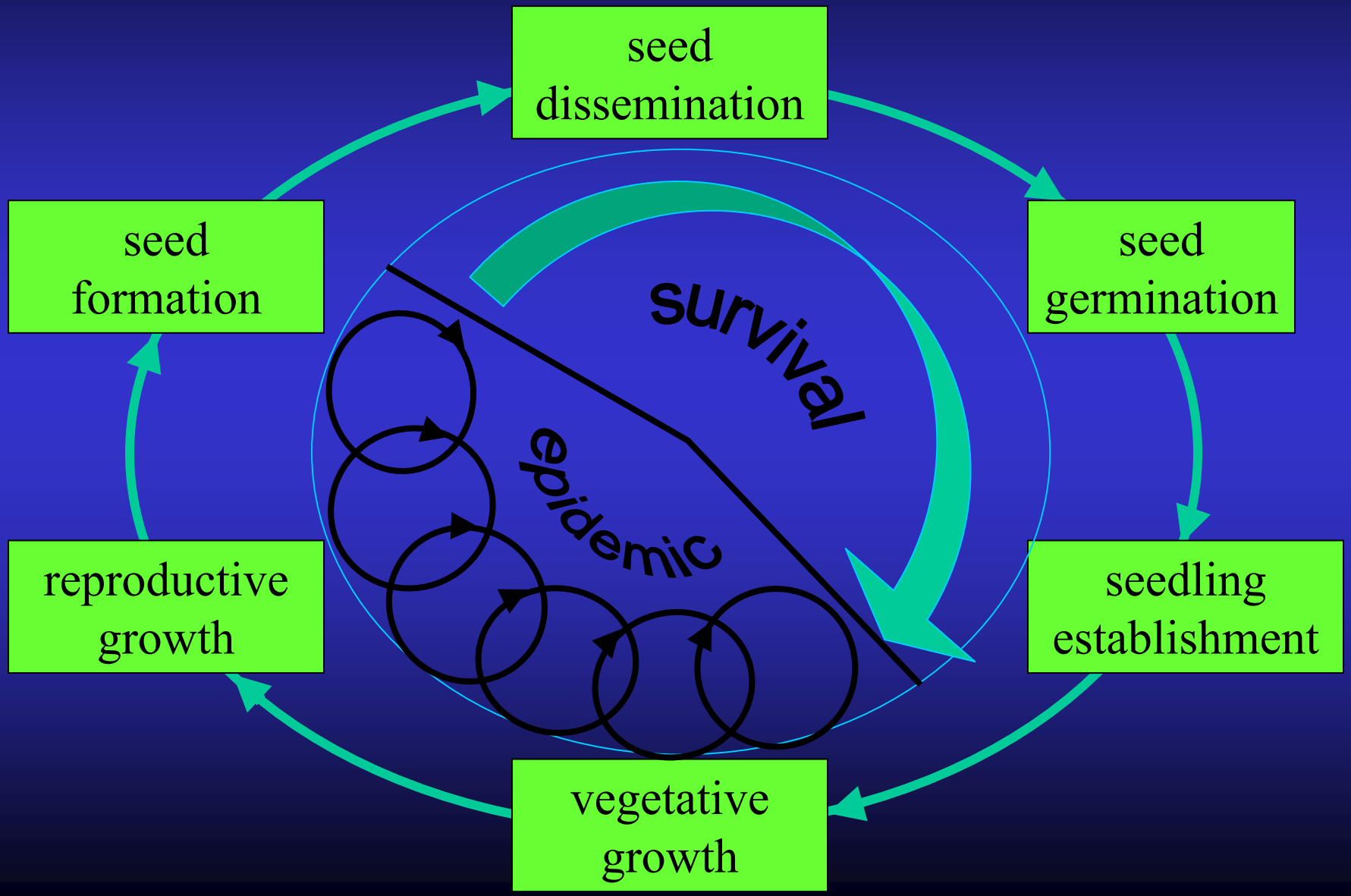
Effects of the weather on pathogens

Environmental factors

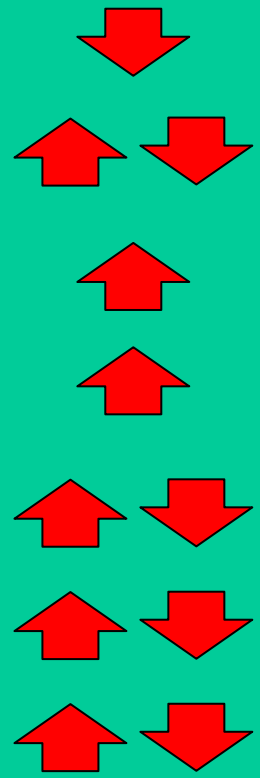
- Rain
- Periods of high relative humidity
- High or low temperatures
- Hail



Plant and pathogen life cycles



Model input: measurement of weather parameters

Parameter	Precision of measurement	Variability over distances
Temperature		
Rain		
Relative humidity		
Leaf wetness		
Radiation intensity		
Cloudiness		
Wind		

Low precision
High precision

Low variability
High variability

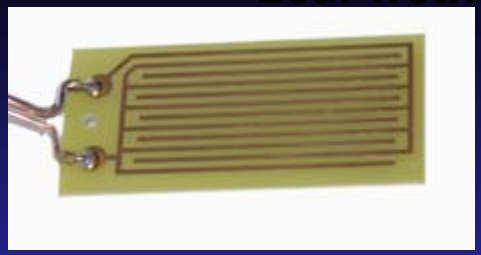
Leaf wetness duration (LWD)

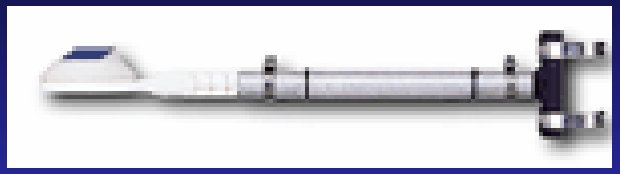
- a key factor in plant disease occurrence in many phytopathosystems
- an important variable in disease warning systems.

Measurement of LWD is often problematic

- the lack of a standard sensor
- the lack of a standard exposure protocol

Leaf wetness sensors

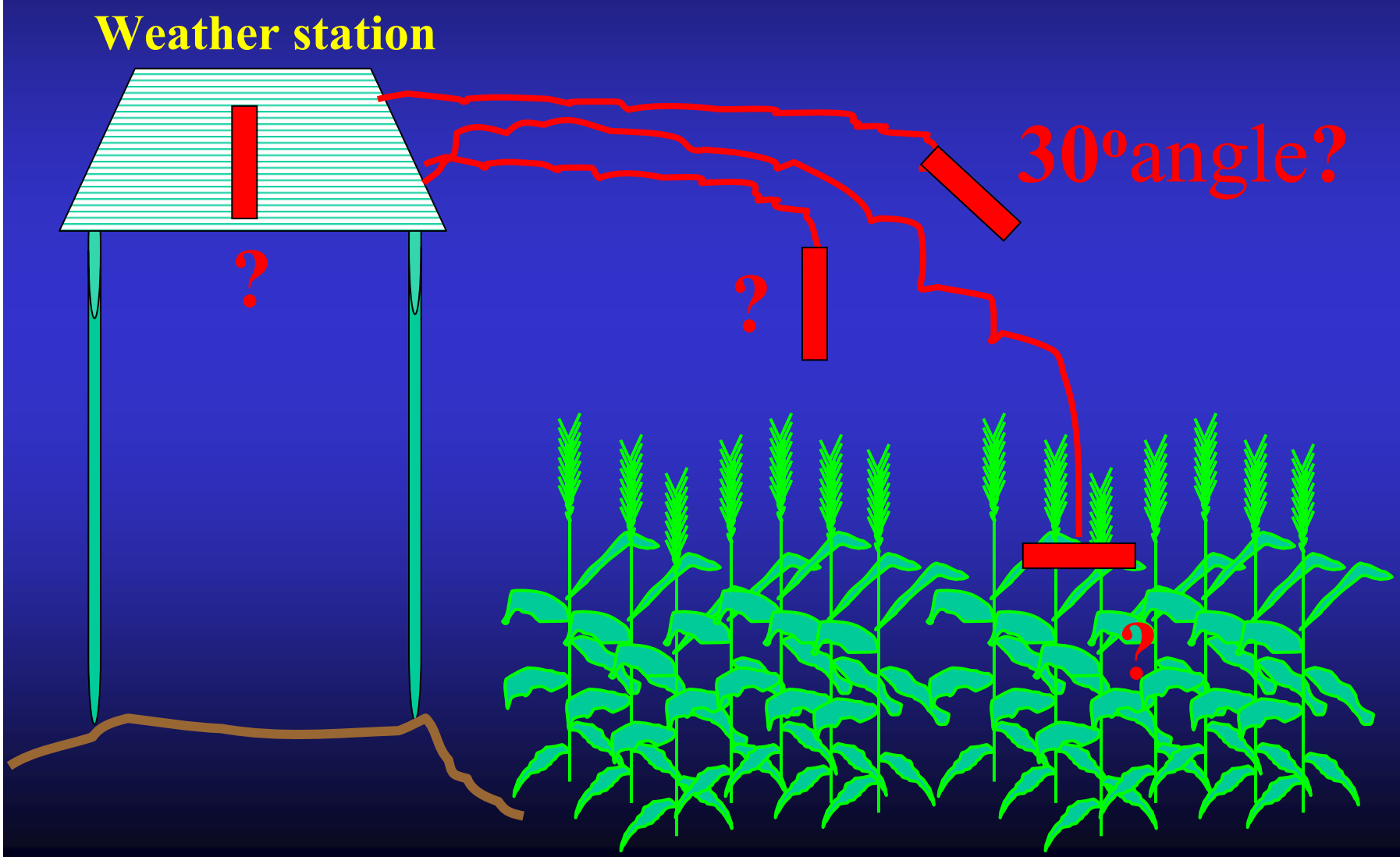




3 types of LWD sensors :

- **static leaf wetness instruments**
  (only give an indication of wet or dry conditions)
- **mechanical leaf wetness instruments**
  (record changes in sensor length, size or weight caused by wetness)
- **electronic leaf wetness instruments**
  (promote a change in sensor impedance)

Where to put the weather sensors?



Prediction (modelling) of weather parameters

Parameter	Precision of prediction	Variability over distances
Temperature	very low	
Rain		
Relative humidity		
Leaf wetness		
Radiation intensity		
Cloudiness		
Wind		

Low precision
High precision

Low variability
High variability

Simulation of surface wetness duration

models at 3 scales: drop, leaf and canopy scales

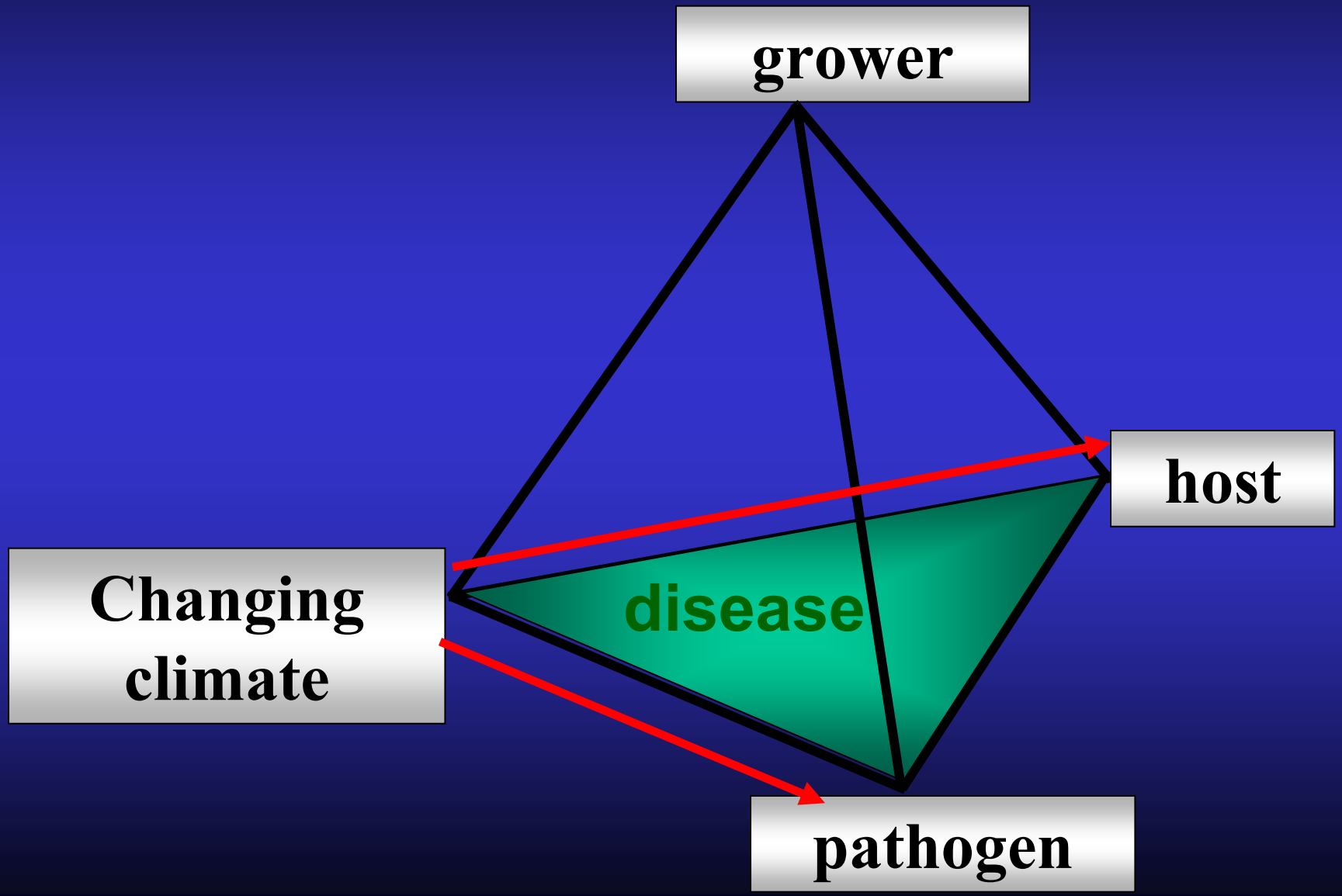
- Physically based simulation models

  SWEB model (canopy water budget model)

  http://www.nysaes.cornell.edu/pp/faculty/seem/magarey/leafwet/simulation.html
- Parameterisations that predict dew amount and dew duration (Pedro and Gillespie dew model)
- RIVM constant threshold value for the relative humidity model
- empirical SWD simulation models
- SWD models based on neural networks

Making long term strategic decisions

Assesment of climate change effects and adaptation



Climate change - Mechanisms of impact

- More rapid pathogen development
- More rapid vector development
- Increased overwintering of pathogen/vector
- Increased pathogen transmission
- Increased host susceptibility

Climate change effects

- Weeds are expected to benefit from higher CO_2 concentrations.
- Increasing precipitation and temperature will be linked to increasing air humidity and possibly leaf wetness duration. All factors are favorable to early (fall, spring) disease outbursts for annual and perennial crops
- the same holds for early pest attacks

- The risk of crop damage from pests and diseases increases in all regions under a warming of climate (northward shifts in the distribution of certain pests)
- Additional generations of multivariate species also can be expected.

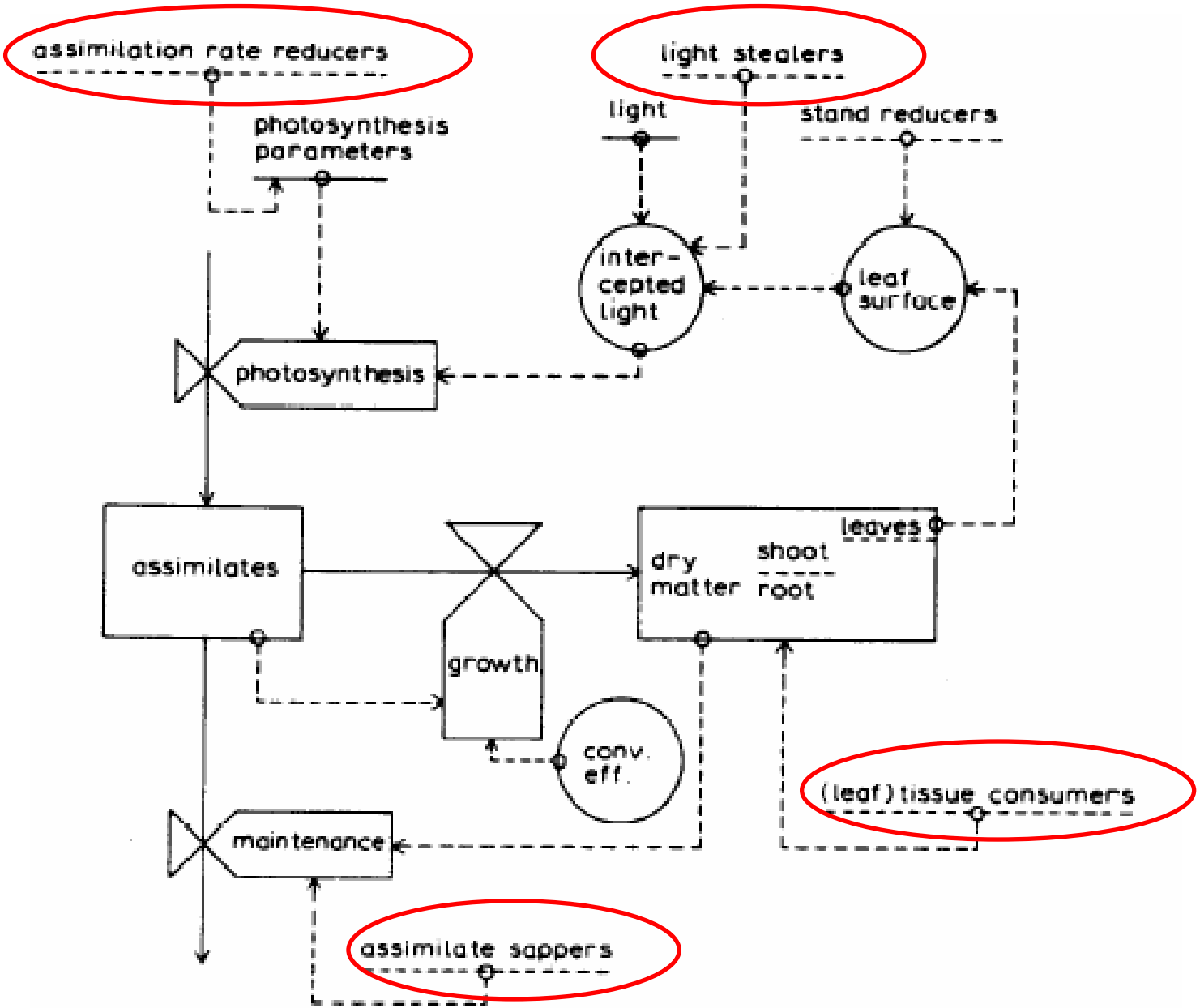
CONCLUSION: **an increased requirement for pest and disease control, with associated consequences for the environment**

Linking generic pest damage models
with crop models
is important for strategic decisions

(example: climate change impact on
crop yield)

Damage Mechanisms of Pests on Crops (Modified from Rabbinge & Bastiaans, 1989)

Categories of pests	*Growth-determining aspects*	*Examples*
Resource stealers	— covering leaf area — capture of light, water or nutrients	— fungi that cover leaves — weeds
Stand reducers	— reduction plant density — compensation mechanisms	— fungi — insects (e.g. stemborer in rice)
Assimilation-rate reducers	— effect on photosynthetic reactions — position of affected leaves in canopy	— powdery mildew — beet yellow virus — leaf blast (rice)
Assimilate sappers	— carbohydrate consumption excretion harmful products	
Tissue consumers	— tissue consumption rate	— mites — aphids — insects



Relational diagram of the model SUCROS indicating the generic linking points for pests (Rabbinge *et al.*, 1989).

Conclusions

- Models are tools that can assist to conduct a rational decision making procedure and reach a sound decision.
- The most time consuming step in development of a model is the accumulation of biological knowledge and relevant weather input parameters
- Models seem to be local tools. In most cases it is not possible to import and use a model from another place.
- Important challenges remain in developing meaningful models of disease intensity and crop losses under climate change