Present and Future Weather-Based Modeling for Orchard Applications

Education Section IV: Innovation in Climate Change Strategies & Production

Joe Russo

56th Annual Conference Intensive Workshop
International Fruit Tree Association (IFTA)
Boston, Massachusetts
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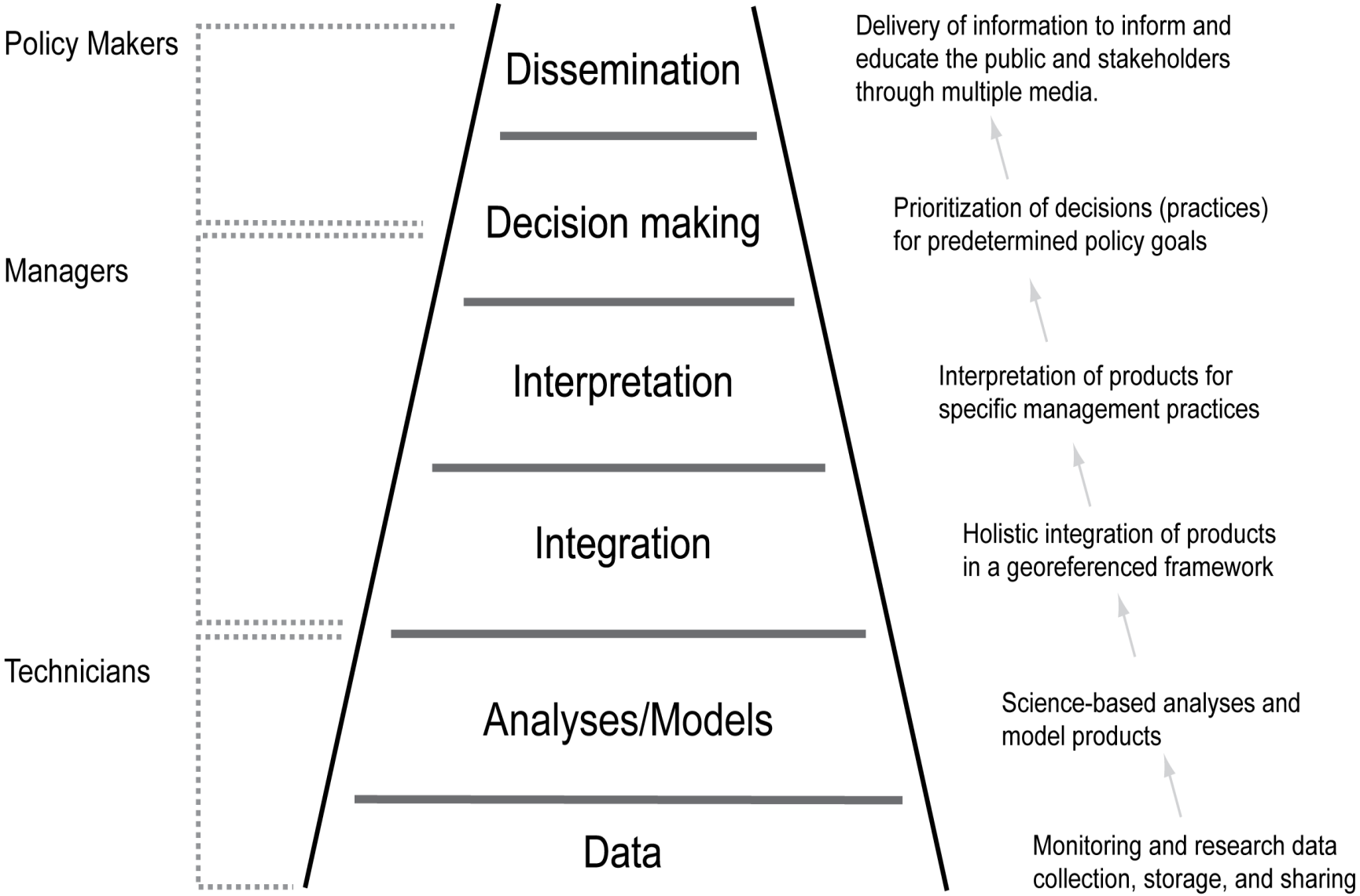
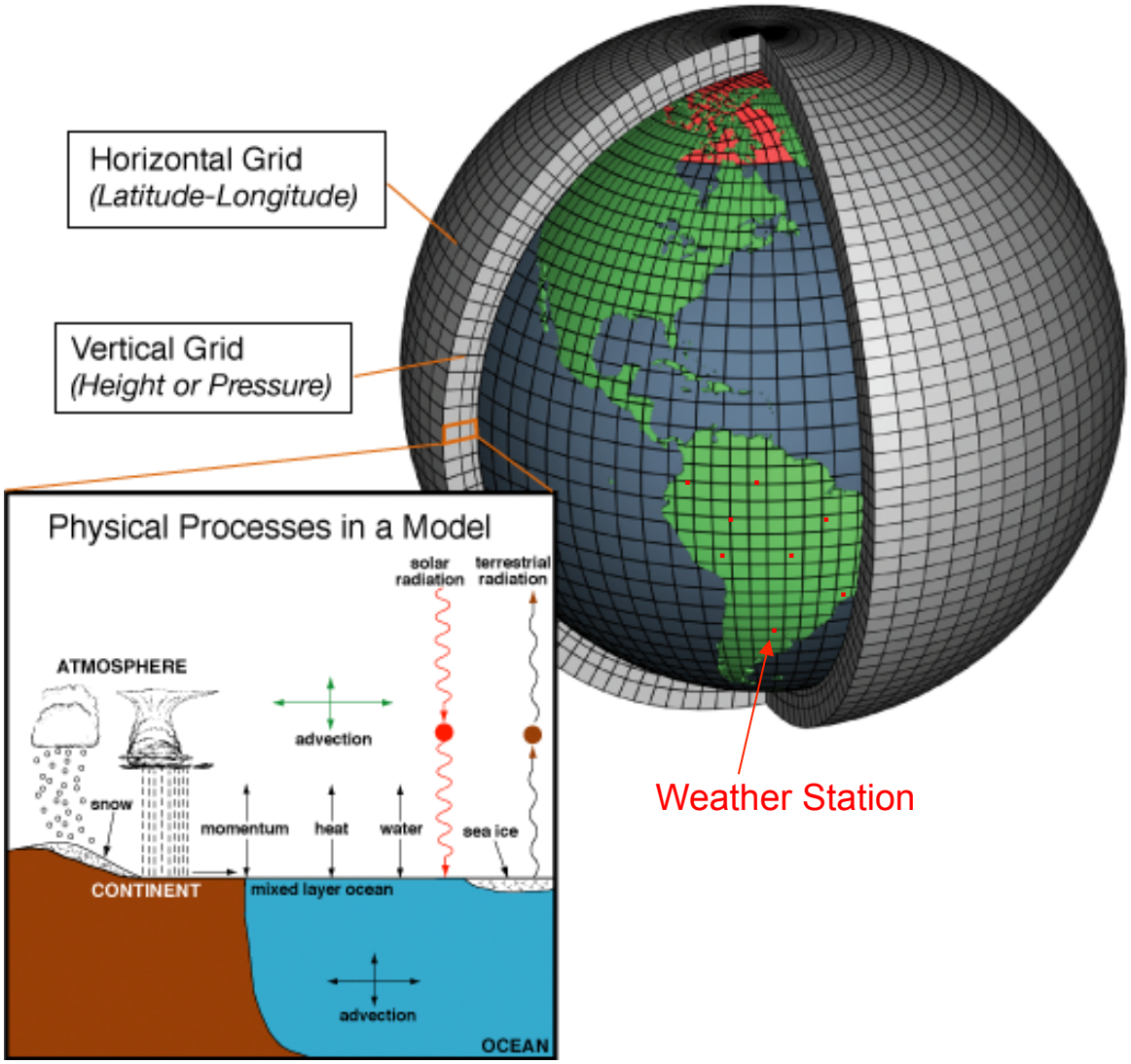
Information Technology (IT) Paradigm

Hierarchy of Information Flow

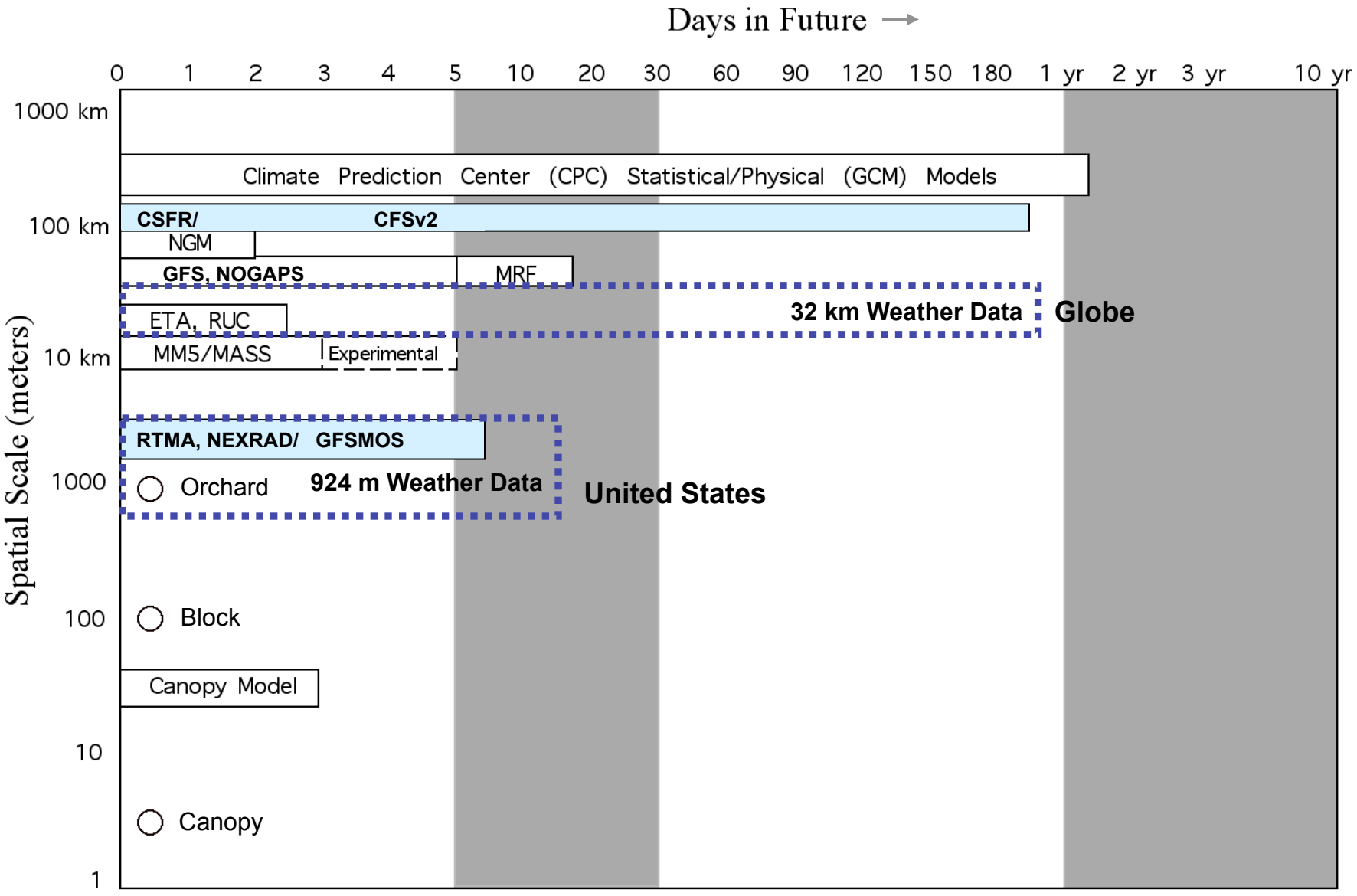


Grid Versus Station Weather Data



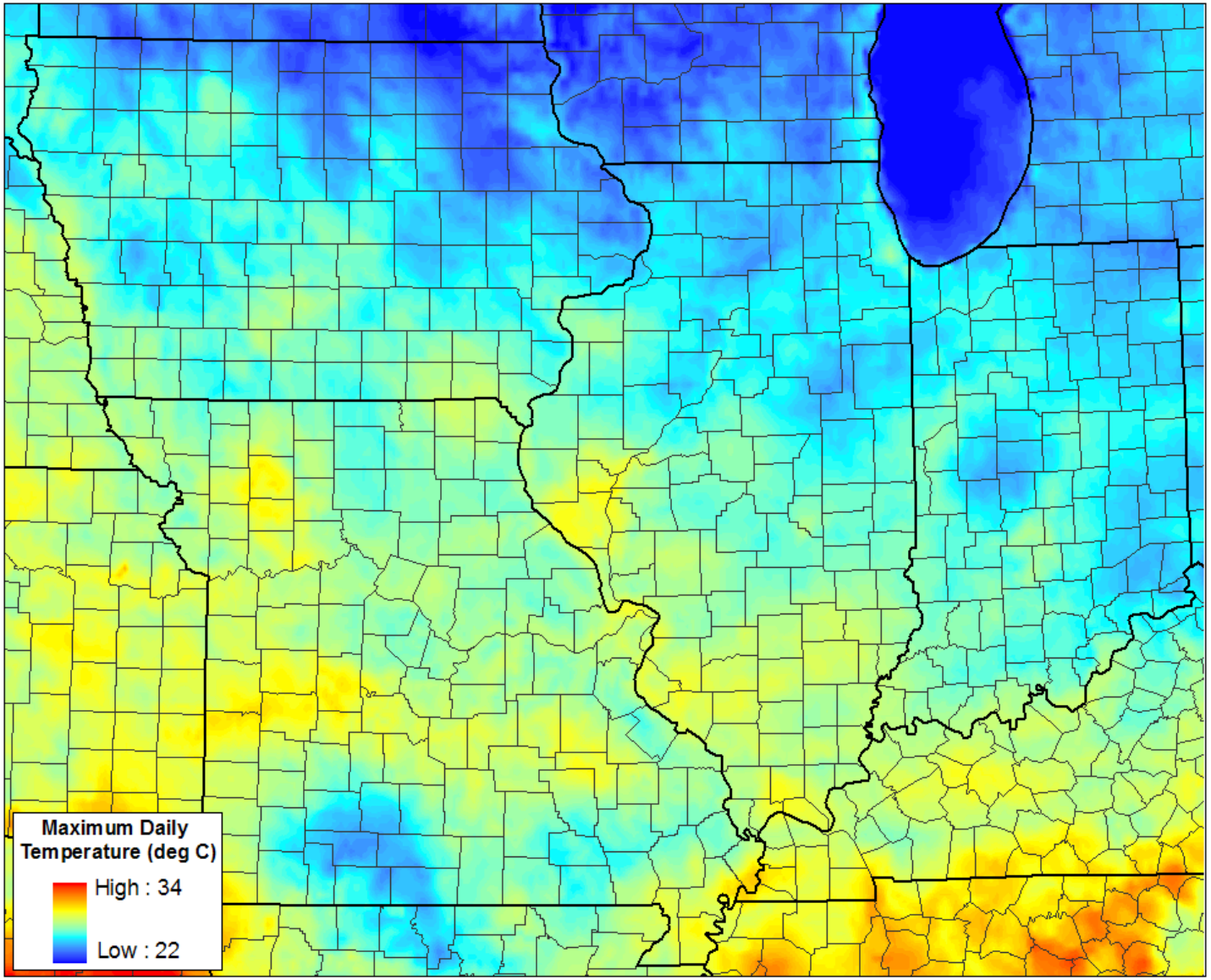
Source: http://www.research.noaa.gov/climate/images/modeling_grid.png

Scale of Weather Systems Relative to Orchard, Block, Canopy



U.S. Weather Data Input for Models

924 m Daily Maximum Temperature July 26, 2009



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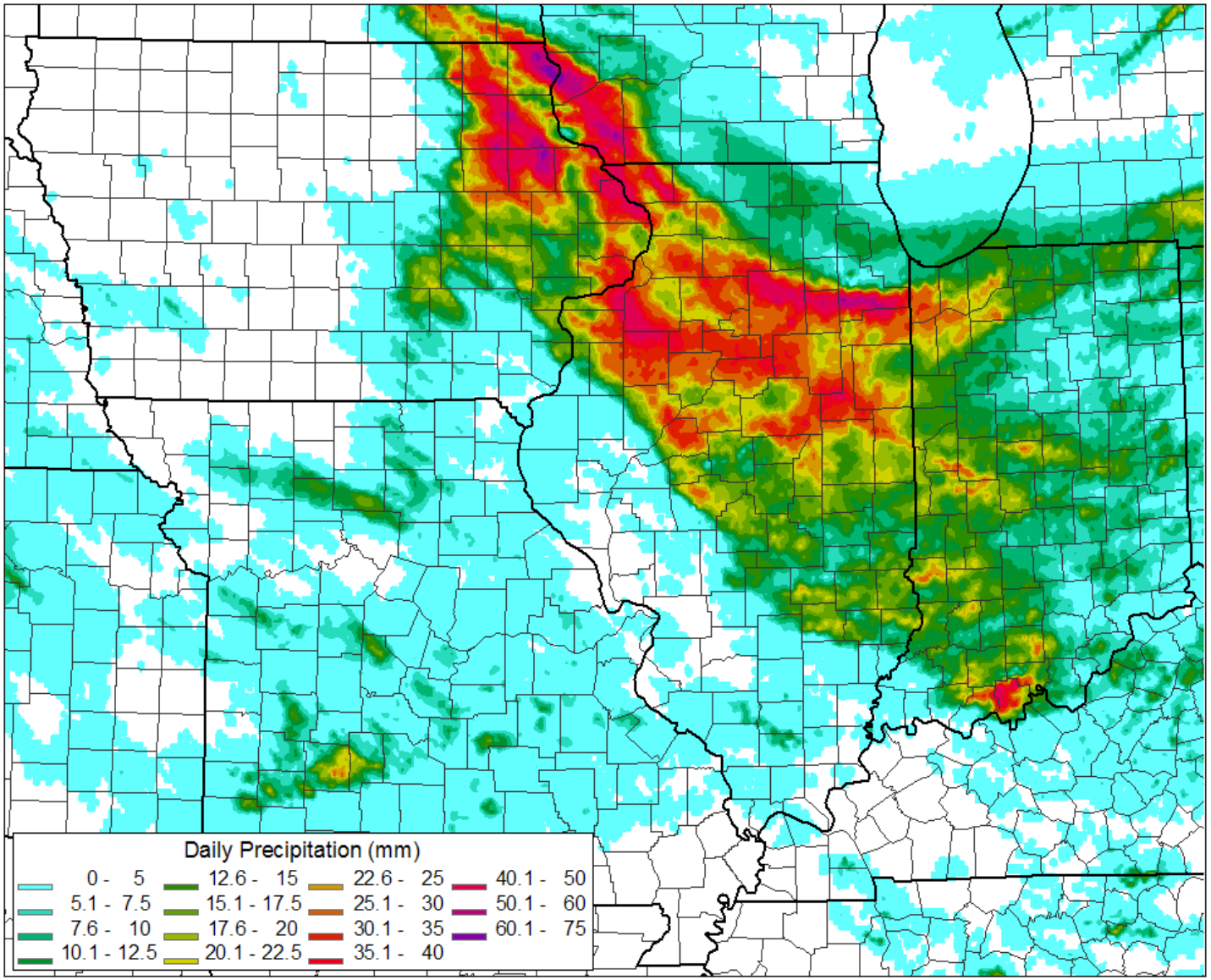
924 m Daily Precipitation Total July 26, 2009



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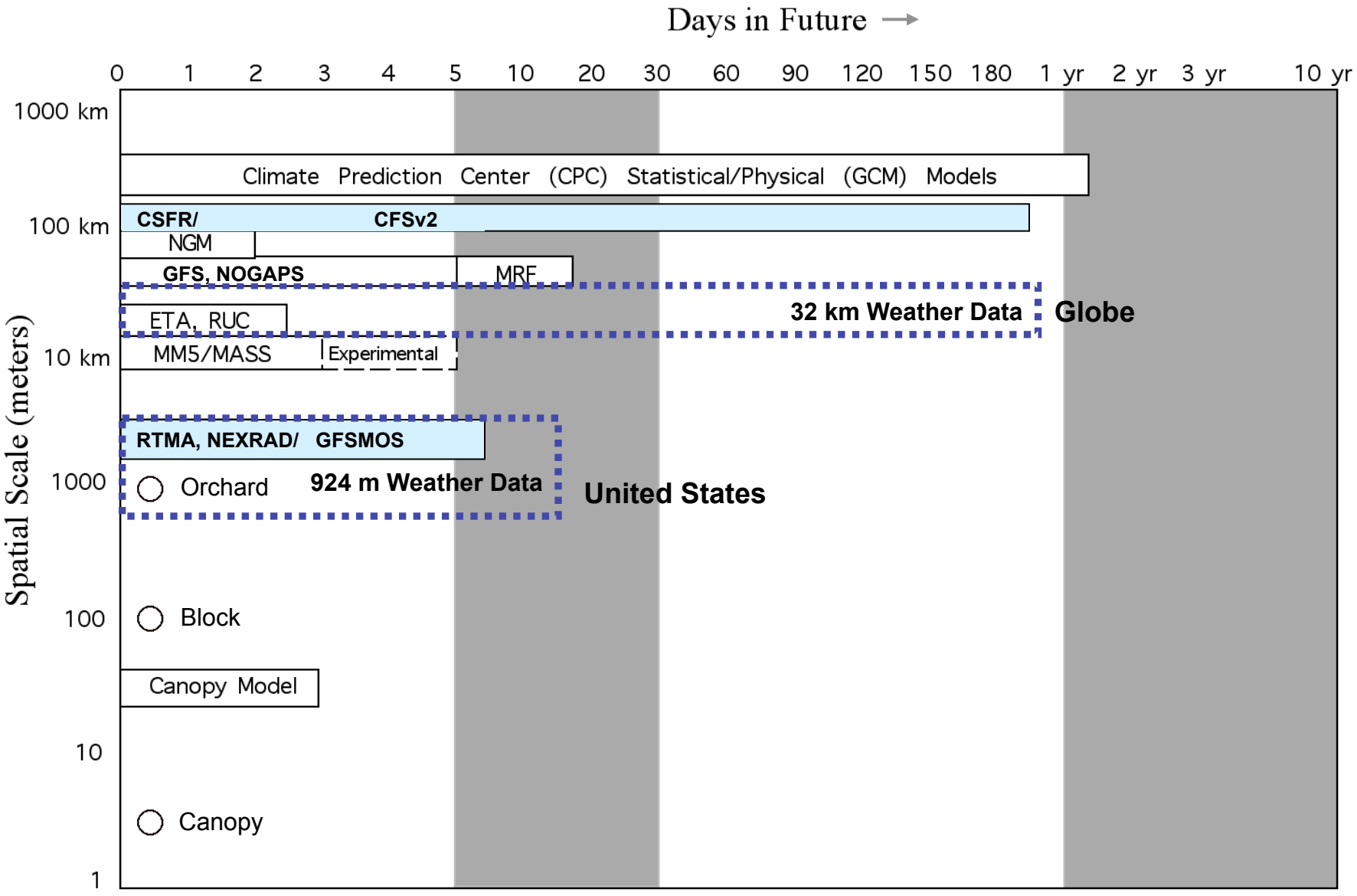
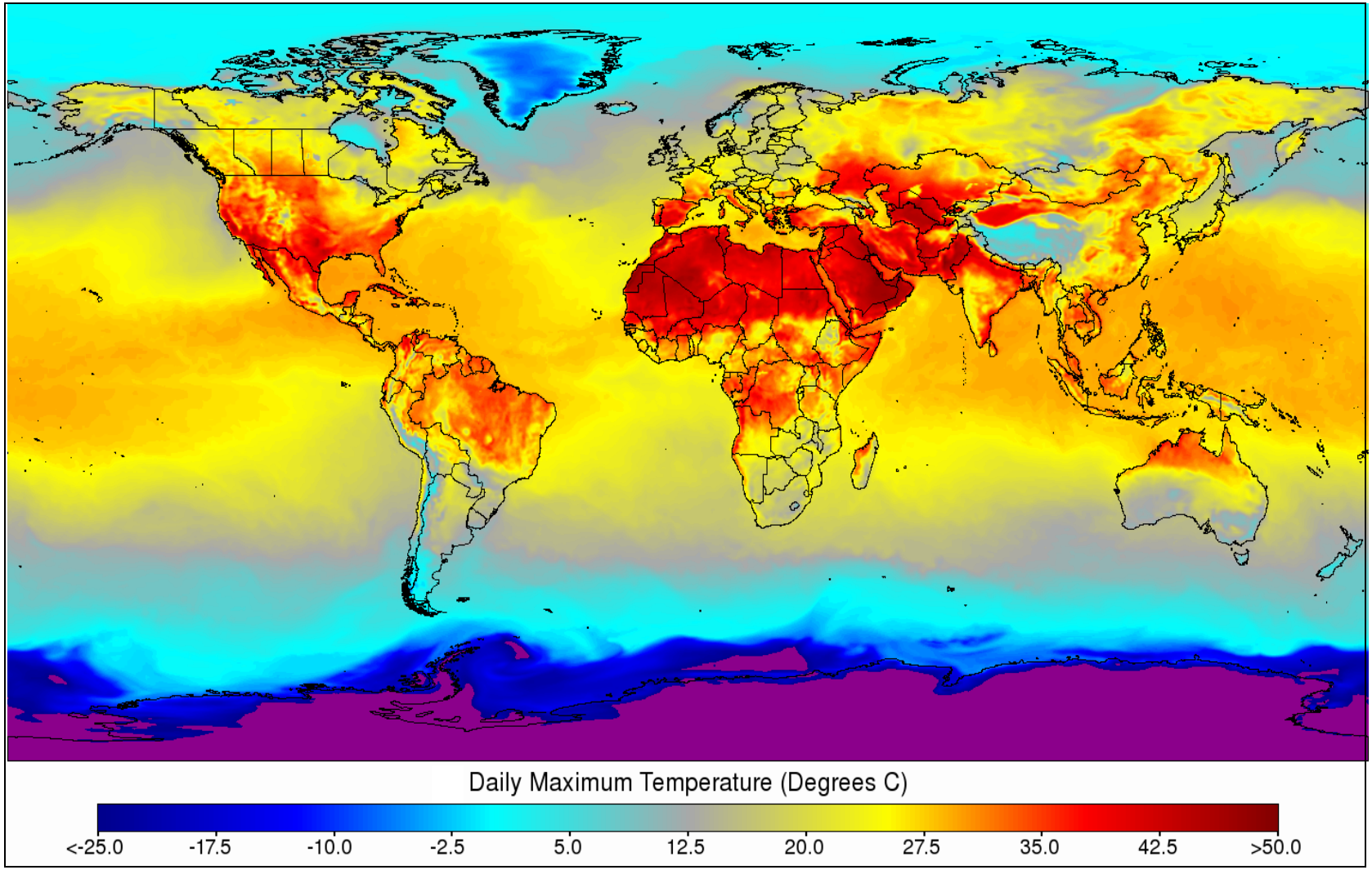


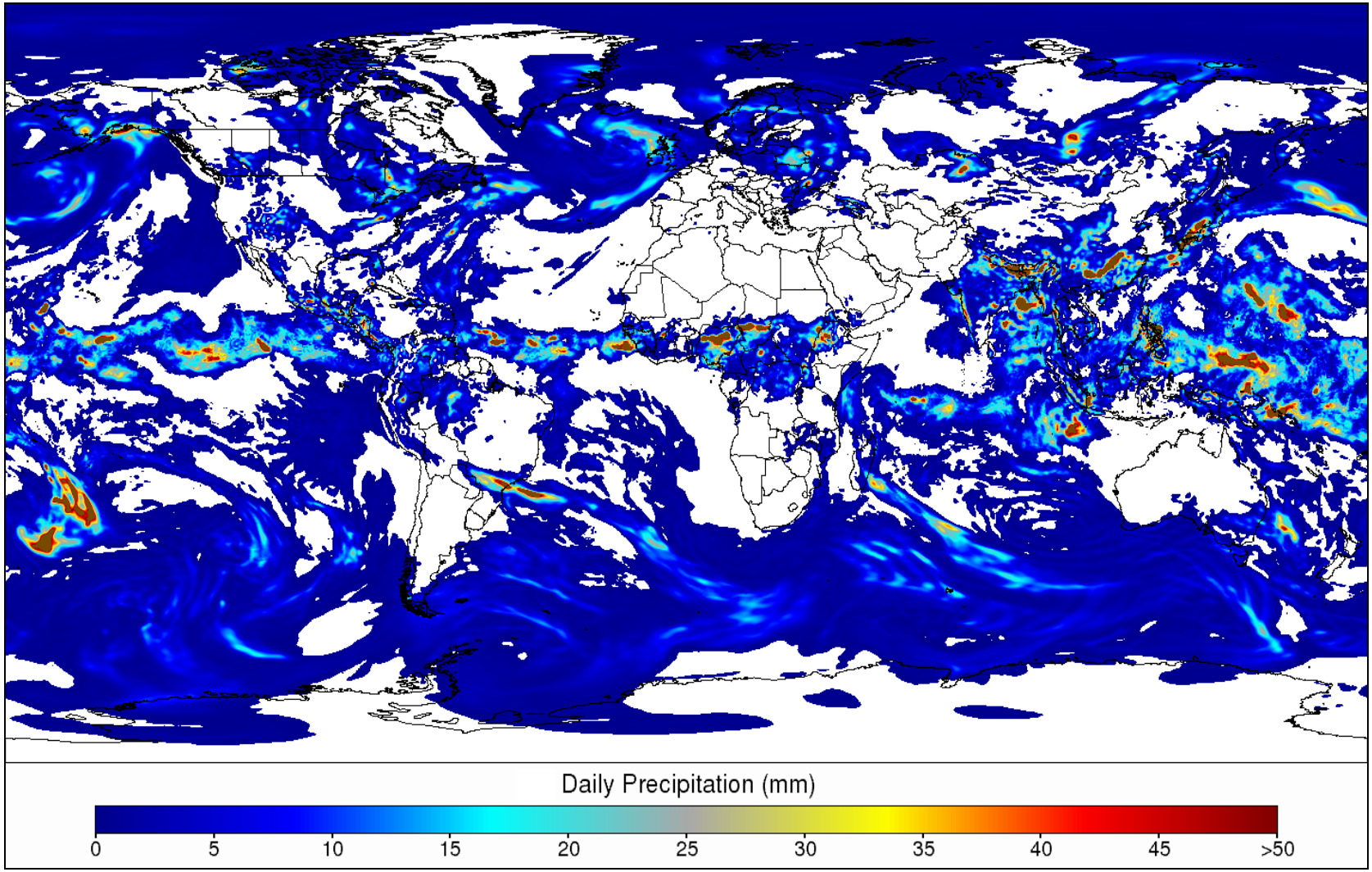
Global Weather Data Input for Models

32 km Daily Maximum Temperature July 26, 2009

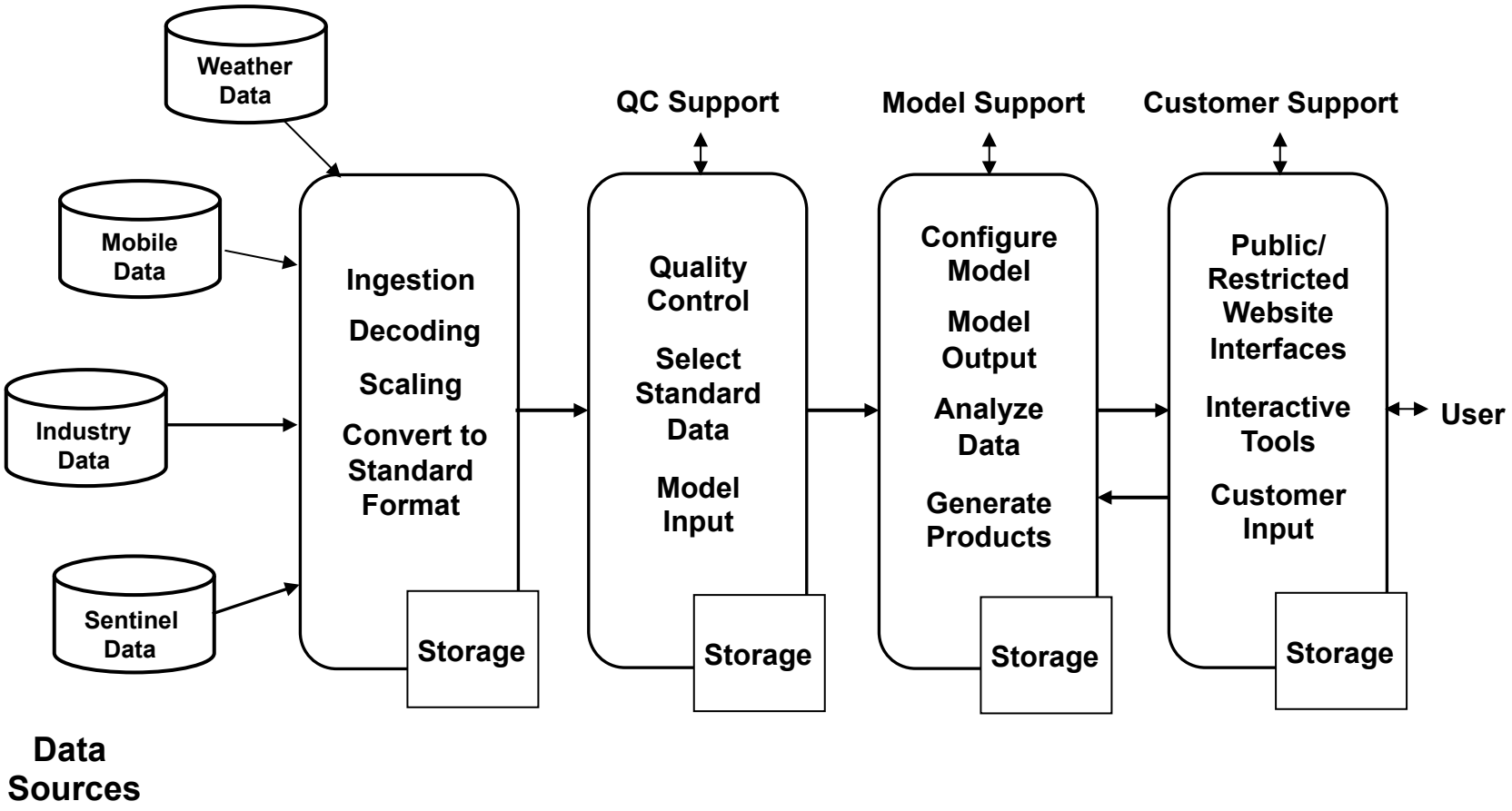


Global Weather Data Input for Models

32 km Daily Precipitation Total July 26, 2009



Data Processing From Source to User



Levels of Weather-Based Models

Computer, technological, and modeling advances can be organized into "levels," with each level representing a significant change in both the quality and quantity of grower input to generate information on pest activity and management options.

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SkyBit's E-Weather Service offers site-specific, model predictions of pest "windows" based on weather and grower-provided biofixes.

Level 2. Weather-based predictive models with grower input from field. (Present)

Grower input from the field allows for the "fine tuning" of predictions to the block scale by configuring models with local information on weather events, cultivar, growth stage, and cultivar susceptibility.

Level 3. Weather-based predictive models integrated with in-field sensor networks, aerial imagery, and other production data sources. (Future)

In-field sensor networks data automatically collect data in the field or data derived from imagery are used to calibrate the model for the block scale.

Level 1 Weather-Based Models

E-WEATHER — FORECAST AND SUMMARY
For: PA-BELLEFONTE-ZEDX — Date: WED JUL 11, 2007

<-------------- 0-48 HOUR FORECAST---------------->

DATE	Jul 11						Jul 12					
HOUR (EDT)	8a	11a	2p	5p	8p	11p	2a	5a	8a	11a	2p	5p	8p	11p
TEMP (F)	71	77	79	79	73	66	60	56	59	71	77	79	73	65
2"- SOIL TEMP (F)	65	70	76	79	77	72	67	58	60	66	72	76	74	68
REL HUM (%)	85	75	65	61	65	73	79	81	75	47	35	34	45	66
6HR PRECIP(in)	.00/		.05/		.09/		.00/		.00/		.00/		.00/	
6HR PRECIP PROB(%)	17/		42/		56/		17/		9/		9/		6/	
3HR EVAP (in)	.01	.04	.07	.09	.04	.01	.00	.00	.01	.07	.11	.10	.04	.00
3HR WETNESS (hrs)	0	2	3	3	3	3	3	3	3	0	0	0	0	0
WIND DIR (pt)	SW	SW	WSW	W	WNW	NW	NW	WNW	W	W	W	W	WSW	WSW
WIND SPEED (mph)	3	6	10	11	8	8	4	2	2	7	8	9	5	2
CLOUD COVER	OVC	OVC	BKN	BKN	BKN	CLR	CLR	CLR	CLR	CLR	SCT	SCT	SCT	BKN
3HR RADIATION (ly)	15	62	113	140	57	2	0	0	31	157	207	180	75	2
PCT RADIATION (%)	49	39	48	67	66	90	---	---	100	96	85	85	85	90
DRYING (key)	3	5	6	6	6	5	4	3	3	7	9	9	7	5
SPRAYING (key)	9	7	4	4	5	6	8	9	9	7	6	6	8	10

<---------- 1-7 DAY FORECAST ------------> <8-10 DAY OUTLOOK>

DATE	Jul 11	12	13	14	15	16	17	18	19	20
DAY	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU	FRI
MAX AIR TEMP (F)	82	80	74	77	84	88	87	88	85	82
MIN AIR TEMP (F)	60	54	57	56	56	61	64	64	63	61
PRECIP PROB (%)	84	24	62	41	31	35	33	35	34	33
AVG DAILY RH (%)	73	59	59	64	61	64	66	67	68	69
AVG WND SPD (mph)	6	6	5	7	7	6	5	5	5	5
DRYING (key)	5	6	6	6	6	6	5	6	6	5
SPRAYING (key)	6	7	8	6	6	7	7	7	7	7

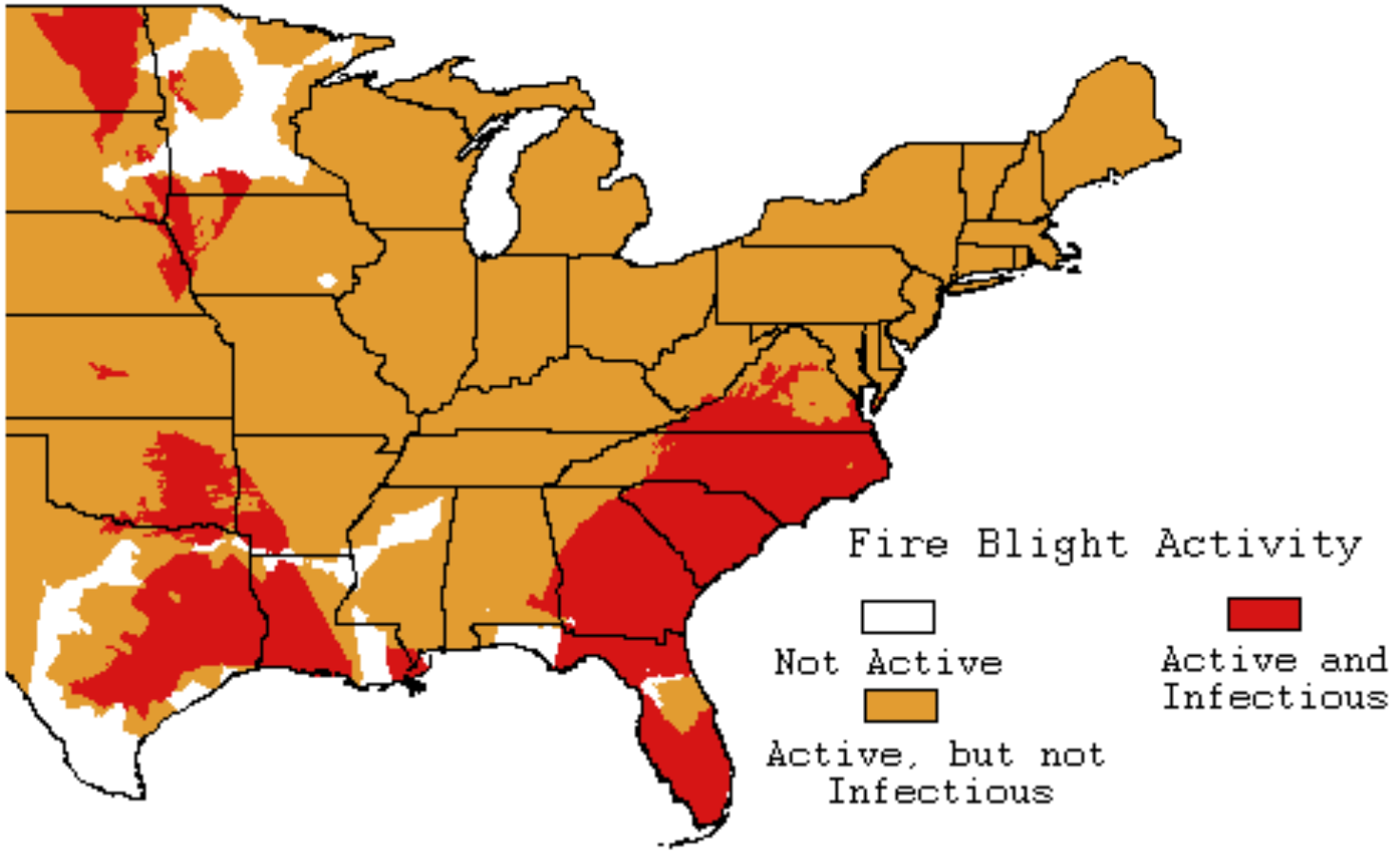
<---------- 1-7 DAY SUMMARY ---------->

DATE	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Jul 9	Jul 10
DAY	WED	THU	FRI	SAT	SUN	MON	TUE
MAX AIR TEMP (F)	73	79	82	84	90	93	90
MIN AIR TEMP (F)	63	64	63	55	59	66	66
MAX 2" SOIL TMP (F)	73	79	82	83	89	92	90
MIN 2" SOIL TMP (F)	65	64	66	63	67	71	72
AVG DAILY RH (%)	87	92	66	62	62	62	65
PRECIP (in)	0.25	0.55	0.00	0.00	0.00	0.00	0.00
EVAP (in)	0.21	0.20	0.27	0.25	0.30	0.29	0.28
WETNESS (hrs)	10	23	9	1	1	0	5
WIND SPEED (mph)	4	5	7	6	7	6	4
RADIATION (ly)	550	456	628	570	731	636	692
PCT RADIATION (%)	75	63	85	77	100	88	95
DRYING (key)	3	3	6	6	6	6	6
SPRAYING (key)	8	7	6	7	6	7	8

key: 0..1..2..3..4..5..6..7..8..9..10
LESS FAVORABLE MORE FAVORABLE

Note: Key for drying and spraying assumes no precipitation.
Local precipitation may result in unfavorable conditions.

Level 1 Weather-Based Models



Level 1 Weather-Based Models

E-WEATHER SERVICE — AGWEATHER IPM APPLE DISEASE PRODUCT
For: PA-BIGLERVILLE — Date: THU Jul 12, 2007

	WEATHER					APPLE SCAB 070331				FIRE BLIGHT 070423				SOOTY BLOTCH 070508	
Date	TMX F	TMN F	PREC in	ARH %	LW hr	ASM %	AW hr	TW F	PW	ADH 65F	AW hr	TW F	PW	ALW hr	PW
BASED ON OBSERVATIONS															
0701	77	55	0.00	50	0	100	0	-	+	225	0	-	-	228	+
0702	76	46	0.00	56	3	100	3	50	+	225	3	50	+	231	+
0703	77	53	0.00	61	0	100	0	-	+	225	0	-	-	231	+
0704	81	61	0.06	78	8	100	8	70	++	225	8	70	++	239	+
0705	83	68	0.44	78	20	100	11	74	++	225	11	74	++	259	+
0706	84	64	0.00	66	9	100	20	72	++	225	20	72	++	268	+
0707	85	62	0.00	61	0	100	0	-	+	225	0	-	-	268	+
0708	92	64	0.00	59	0	100	0	-	+	225	0	-	-	268	+
0709	96	66	0.00	57	0	100	0	-	+	225	0	-	-	268	+
0710	94	68	0.00	68	0	100	0	-	+	225	0	-	-	268	+
0711	83	68	0.25	74	11	100	11	76	++	225	11	76	++	279	+
BASED ON FORECASTS															
0712	81	62	0.00	58	1	100	12	75	++	225	12	75	++	280	+
0713	78	60	0.00	60	0	100	0	-	+	225	0	-	-	280	+
0714	83	59	----	62	0	100	0	-	+	225	0	-	-	280	+
0715	85	64	----	70	7	100	7	70	++	225	7	70	++	287	+
0716	87	65	----	70	4	100	4	68	+	225	4	68	++	291	+
0717	89	68	----	70	4	100	4	71	+	225	4	71	++	295	+
0718	87	69	----	73	14	100	8	82	+	225	8	82	++	309	+
0719	83	68	----	76	24	100	32	78	++	225	32	78	++	333	+
0720	83	67	----	77	24	100	56	77	++	225	56	77	++	357	++
0721	83	66	----	76	24	100	80	76	++	225	80	76	++	381	++

********* IMPORTANT: Check the dates at the top of each column. *********
Green Tip Date - is used for Apple Scab
Blossom Date - is used for Fire Blight
Petal Fall Date - is used for Sooty Blotch

ASM = Apple Scab Maturity Percentage
ADH = Accumulated degree-hours from blossom date up to a max of 225.
ALW = Accumulated leaf wetness hours from petal fall date.
AW = Accumulated wetness hours for the most severe event.
TW = Average temperature during the most severe event.
PW = Pest Wait/Watch/Warning: - = not active
+ = active but no infection
++ = possible infection & damage

****** ATTENTION: Please report your biofix dates (1-800-454-2266) ********
Please call 1-800-454-2266 to report your biofix dates for Green Tip, Blossum, and Petal Fall. Your product will NOT be correct unless these dates are reported accurately. Thank you.

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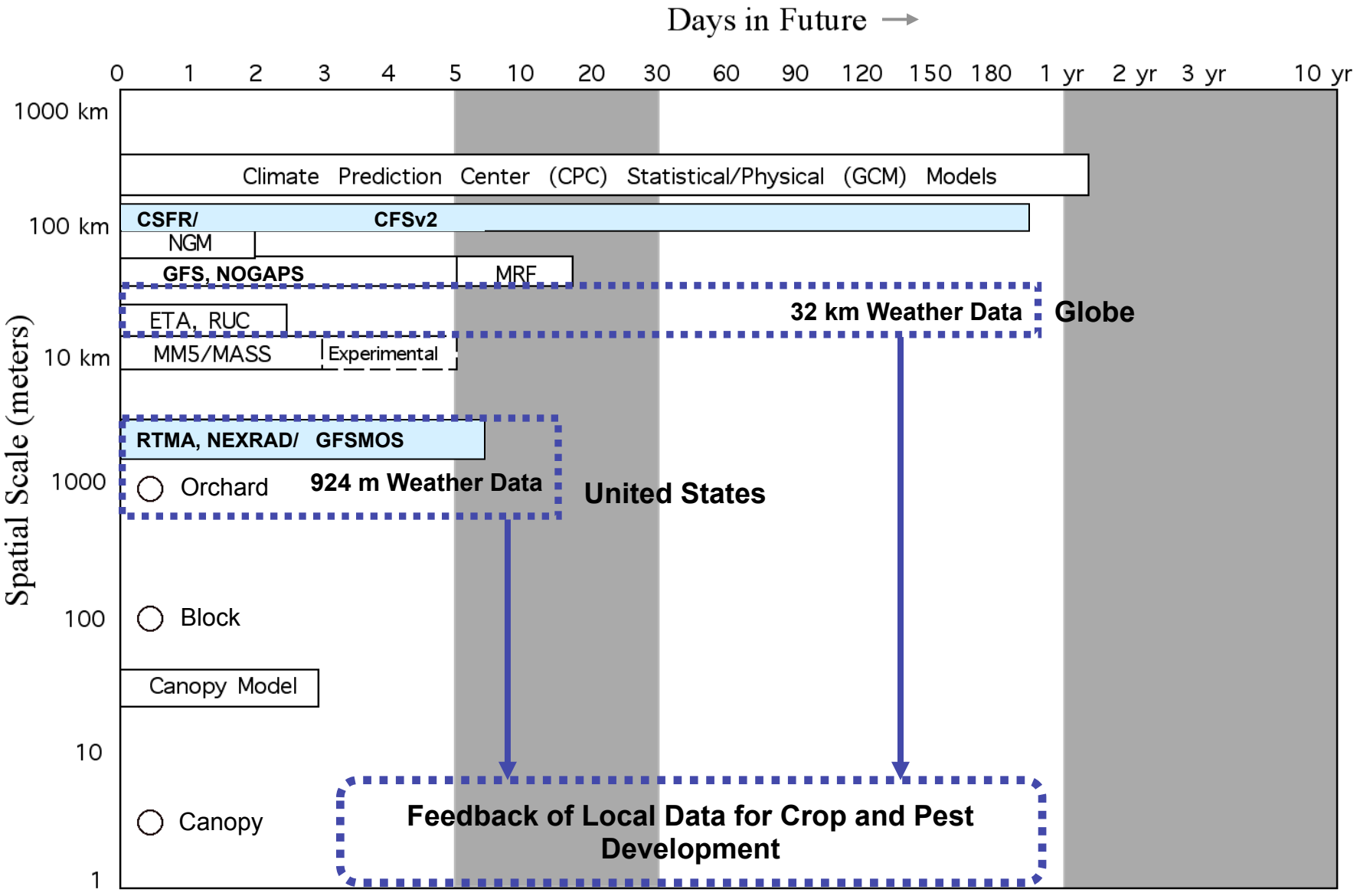
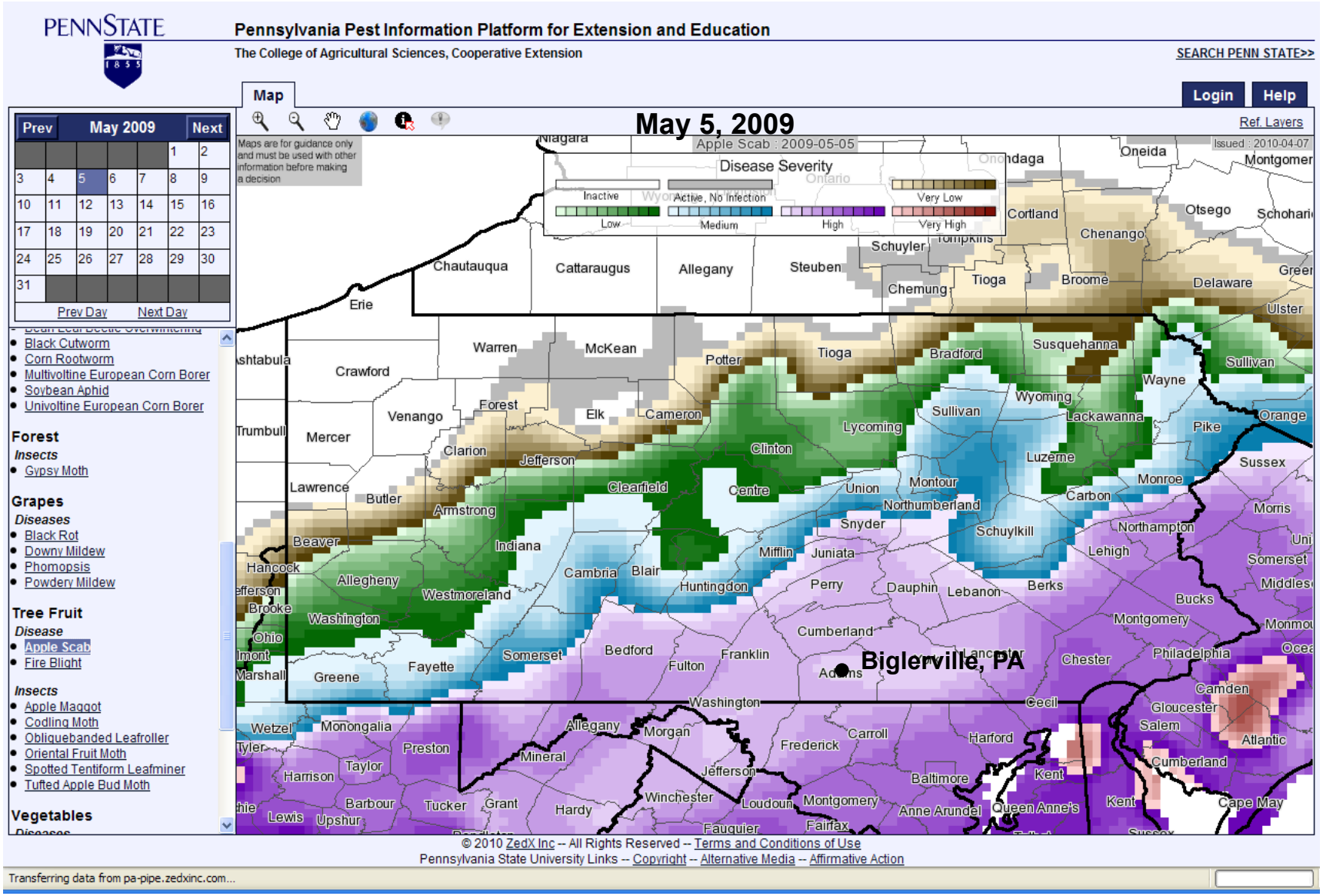


Level 2 Weather-Based Models

PA-PIPE 5 km Apple Scab Model Simulation

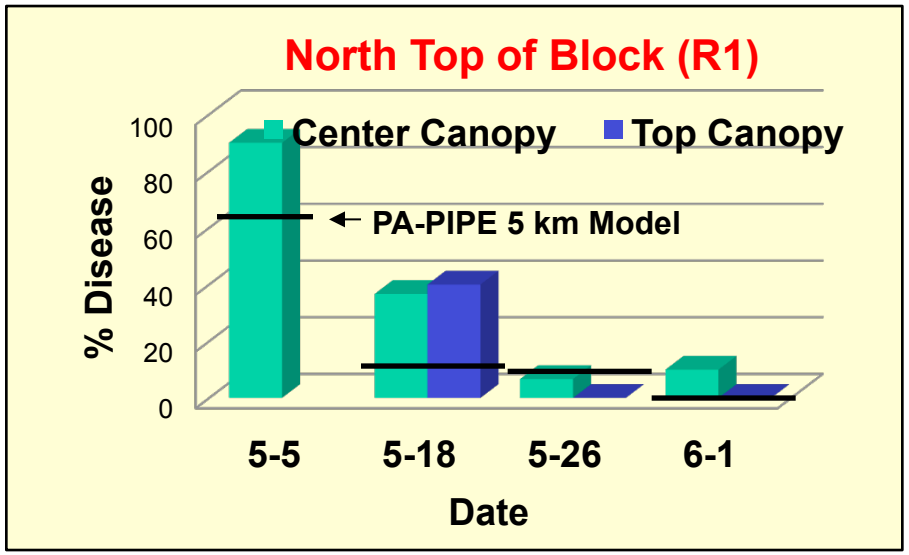


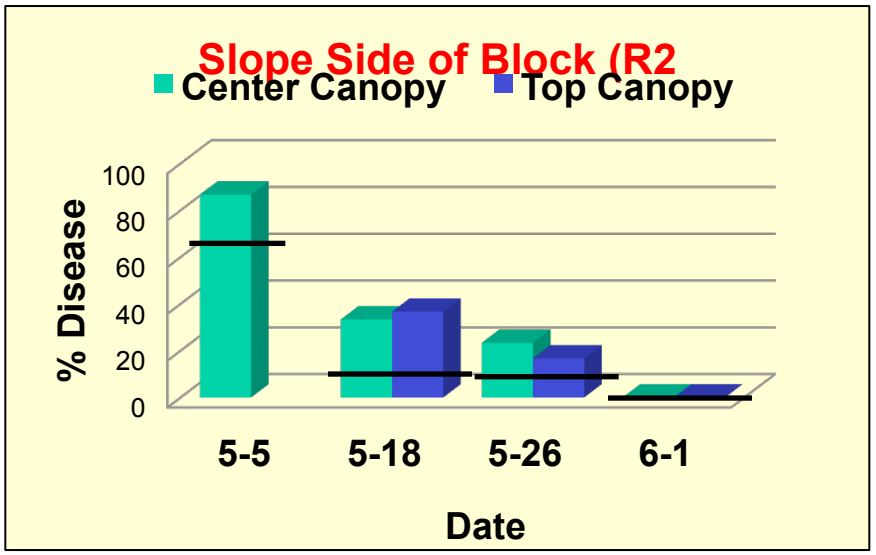
Source: pa-pipe.zedxinc.com

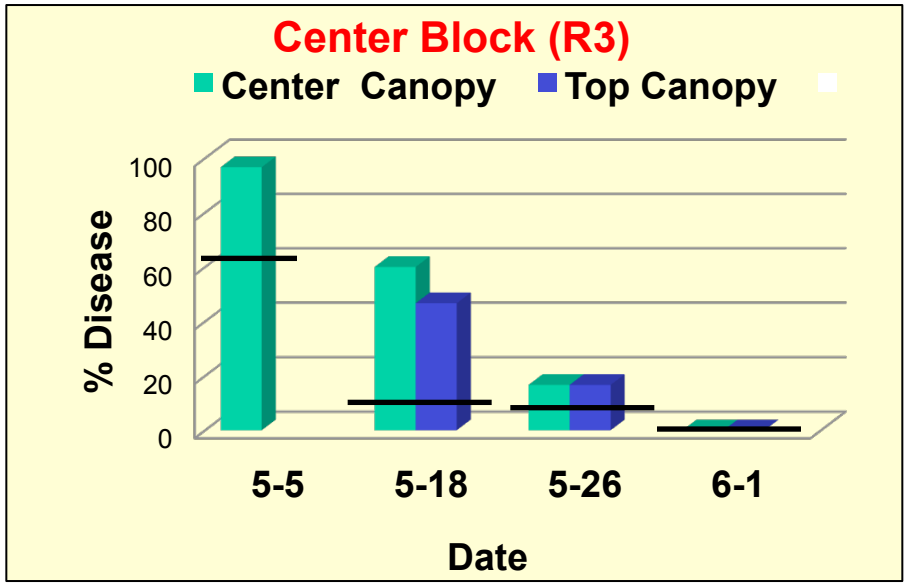
Level 2 Weather-Based Models

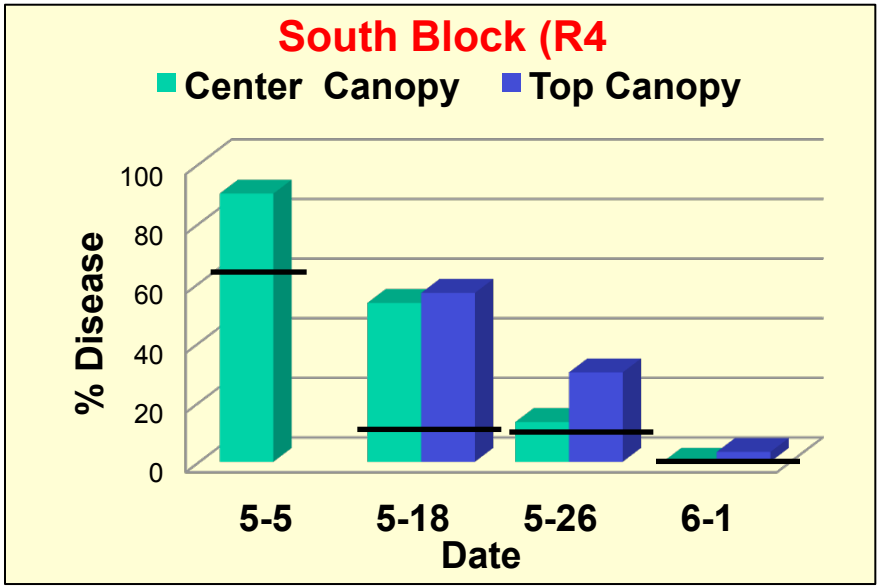
2009 Scab Incidence on Shoot Leaves, Red Delicious

University Drive Orchard, PSU-FREC, Biglerville, PA





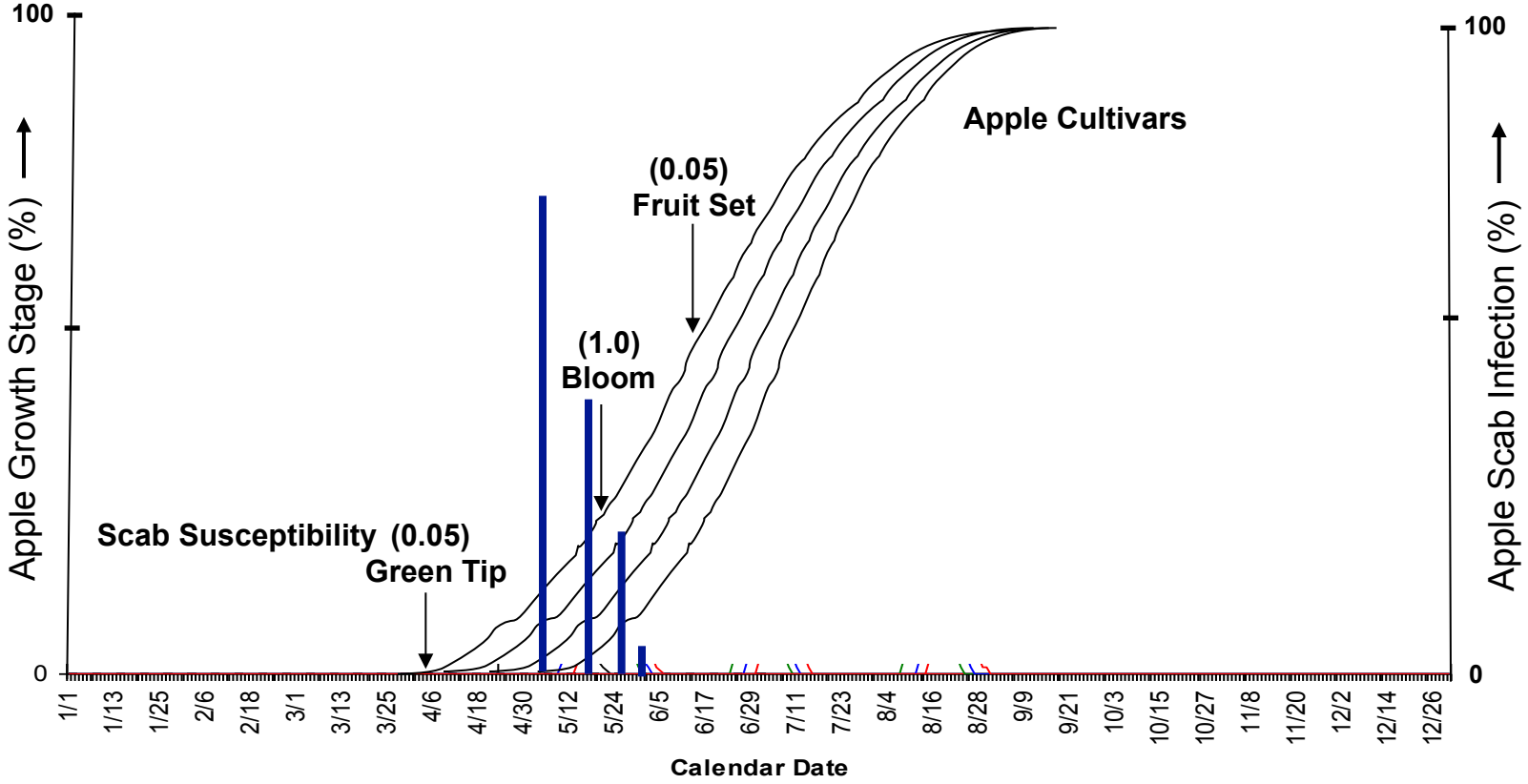




Credit: Jim Travis, Noemi Halbrendt, Penn State Fruit Research & Extension Station, Biglerville, PA

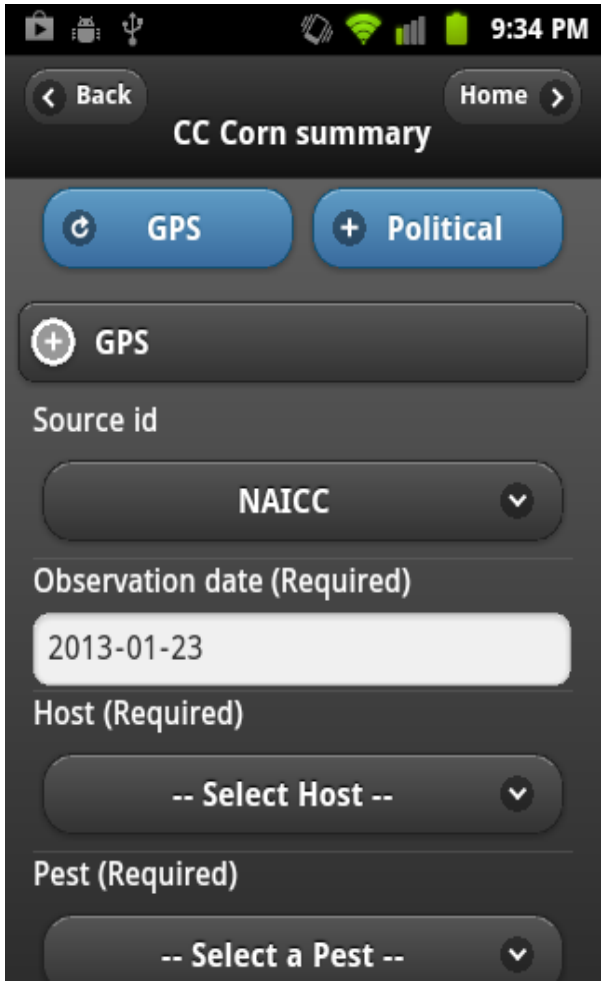
Level 2 Weather-Based Models

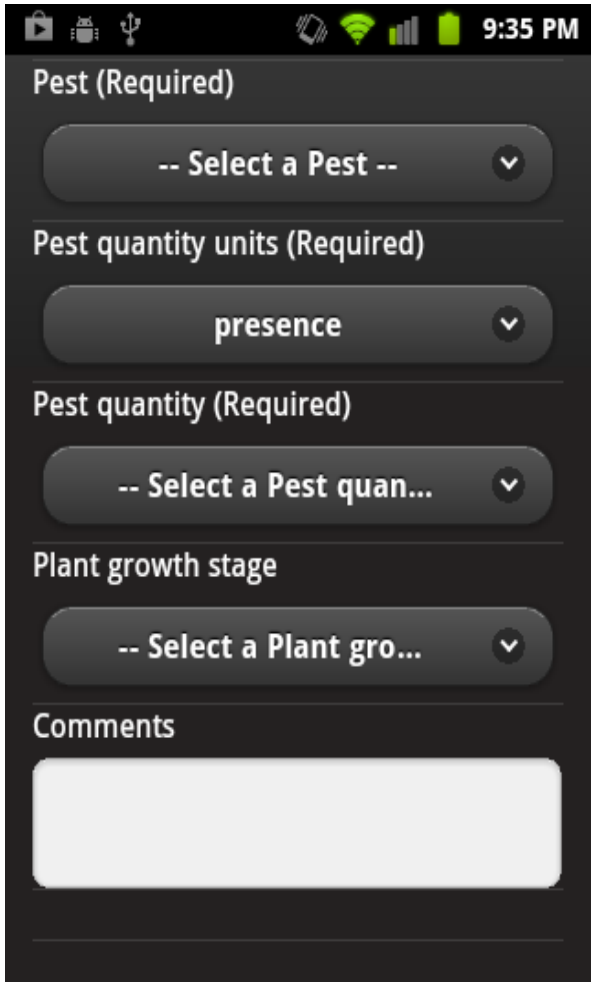
Comparison of Apple Tree Growth and Scab Infection



Level 3 Weather-Based Models

Mobile Device Applications for In-Field Data Entry





Source: IPIPE

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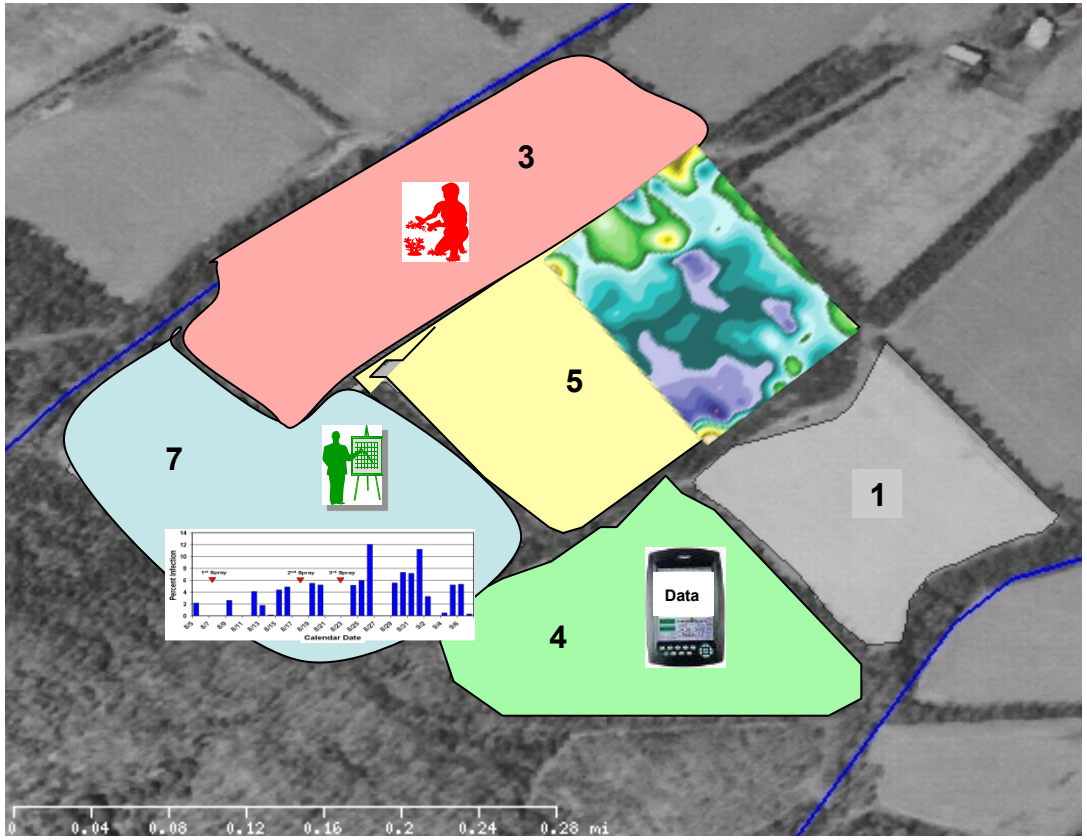
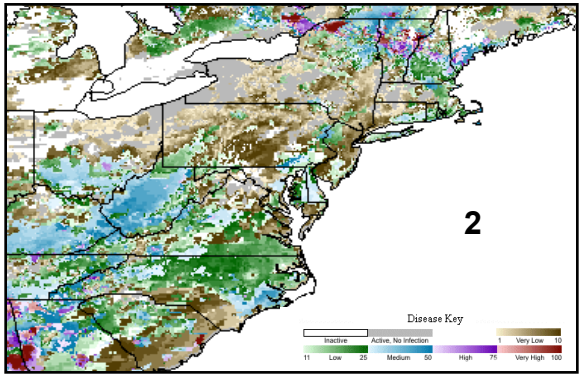
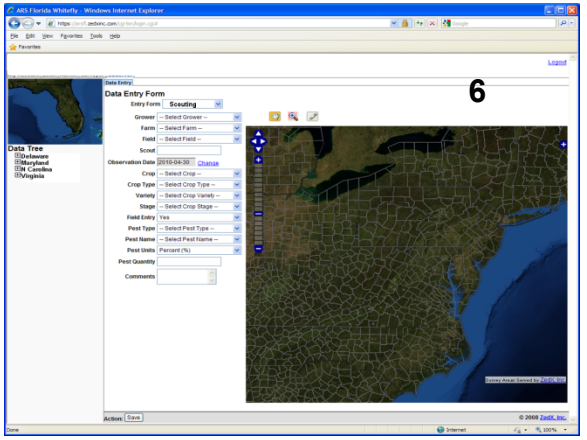
Level 2 Weather-Based Models

1. Preseason: Grower bounds fields & provides soil, hybrid, pest history.
2. In-season: Model predicts crop stage and disease infection at 924 m resolution.
3. In-season: Scout records field-level crop stage and disease development.
4. In-season: Smartphone transmits recorded crop & pest data via the Internet.
5. In-season: Model inputs recorded crop & pest data to calibrate output to block scale.
6. In-season: Interface allows grower/consultant to view crop and pest data geospatially and track pest control applications.
7. Post-season: Grower/consultant/specialist analyzes practices versus predictions on a field-by-field basis to improve management decision making.







Level 2 Weather-Based Models

Grower Work Sheet for Primary Apple Scab

Primary Apple Scab Relative Risk of Infection (PASRRI)
Grower Work Sheet

Robert C. Seem
Cornell University

Introduction

The Primary Apple Scab Relative Risk of Infection (PASRRI) work sheet is an experimental product and should be used with caution. The work sheet instructs a grower on how to interpret the site-specific Ascospore Maturity Release and Apple Scab Infection model results for local orchard management. In the absence of well-understood apple scab infection history, growers are urged to have a "potential ascospore dose" survey done in their orchard to establish the level of inoculum.
Grower Note 1: PASRRI is designed for modern apple trees with a predominance of spur leaves. Conventional trees with many vegetative shoots should be managed more conservatively since susceptible tissue will be available longer into the growing season.
Grower Note 2: If primary apple scab has not been controlled, additional management will be required to control the secondary phase of this disease beyond fruit set.

Grower Work Sheet

To calculate the PASRRI, enter the appropriate value under each column of the work sheet below according to the following instructions. Examples are on the first line.

- Enter the date of the entries onto the work sheet. Example: May 15, 2005 (5-15-05)
- Enter the name and/or number of the orchard block. Example: Home 1
- From Table 1 on second page, determine the phenologically-based risk by finding the apple growth stage of at least 50% of the trees in the block and enter under column (1) the corresponding growth stage susceptibility value. Example: Pink has a value of 1.0.
- Divide by 100 the percent (%) available ascospores according to the Ascospore Maturity Release model and enter result under column (2). Example: 90% / 100 = 0.90.

  Grower Note 3: If an orchard block is wet by an unreported local rain event, enter 0.5 under column (2) if the average daily temperature is less than 10 C (50 F), or enter 0.9 under column (2) if the average temperature is greater than 10 C (50 F).
- Divide by 100 the percent (%) likelihood of infection according to the Apple Scab Infection model and enter result under column (3). Example: 92% / 100 = 0.92.
- Multiply together the values under each of the three columns and enter the product under the Score column. Please note that the result must be less than or equal to 1.
- Use score in Table 2 on second page to determine management options.

Date	Orchard Block	(1)	x	(2)	x	(3)	=	Score
5-15-05	Home 1	1.00	x	0.90	x	0.92	=	0.83
_____	_____	____	x	____	x	____	=	____
_____	_____	____	x	____	x	____	=	____

Table 1. Apple growth stage susceptibility.

Stage	Value	Stage	Value	Stage	Value
Prior to Green Tip	0.01	Tight Cluster	0.40	Fruit Set	0.05
Green Tip	0.05	Pink	1.00	6 mm. Diameter Fruit	0.01
Centimeter Green (1/2 in. Green)	0.20	Bloom	1.00	(1/4 in. diameter)	
		Petal Fall	0.60	> 6 mm. Diameter Fruit	0.00

* Based on Fig. 6 in Gadoury and Seem, 1998. The values in this table factor in average ascospore maturity, tissue susceptibility, and tissue area.

Table 2. Apple scab management options.

Score Range	Management Option
0.00	No action is necessary
0.01 - 0.20	Depending on personal risk aversion, no action may be necessary, but conditions should be monitored closely. If scab has been a problem in the past year, follow a regular scab control program. Reduced rates may be used for less susceptible cultivars (see Table 3).
0.21 - 0.30	A regular scab control program should be followed. Reduced rates may be used for less susceptible cultivars (see Table 3).
0.31 - 1.00	Extra vigilance must exercised: do not exceed 7-day spray interval for fungicides (captan, mancozeb, etc.); for susceptible varieties, use maximum recommended rates; attempt to keep coverage of protectant fungicides, especially if an infection event is forecast.

Table 3. Apple cultivar susceptibility.

Most Susceptible	Less Susceptible**	Least Susceptible***
McIntosh	Empire	(All "scab resistant" cultivars)
Cortland	Golden Delicious	
Jersey Mac	Jonagold	
Ida Red	Rome Beauty	

** Less susceptible cultivars can receive a reduced amount of conventional fungicide (captan, mancozeb, etc), e.g., if 3 lbs. a.i./A of captan is normally applied to susceptible cultivars, then less susceptible cultivars might receive 1.5 lbs. a.i./A of captan. Do not apply less or more than the labeled rate. DO NOT extend intervals in place of reduced rates since fungicide degradation is less dependent on application rate.

*** No apple scab management program is necessary.

References and Resources

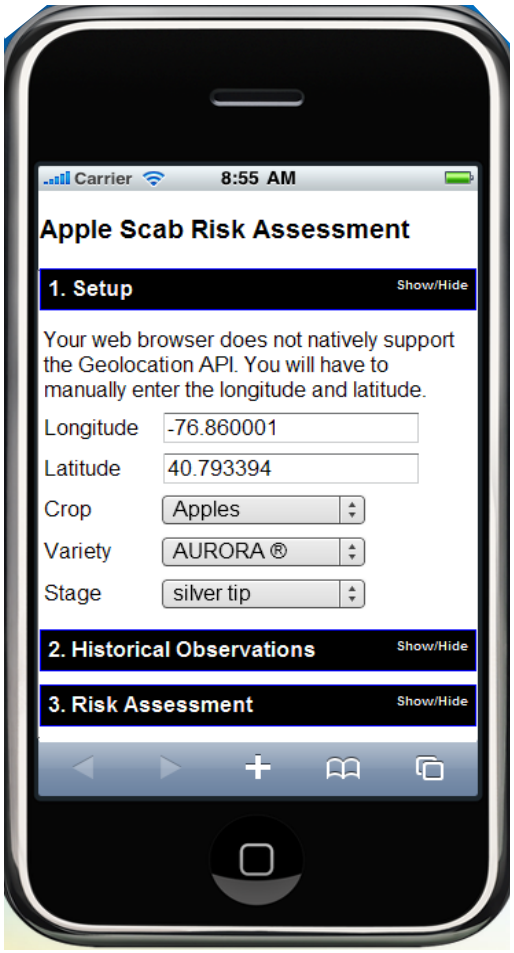
Gadoury, D. M. and Seem, R.C. 1998. A review or research on apple scab, with particular reference to the 1998 growing season in New York. NY Fruit Quarterly 6(3): 17-22.
Stensvand, A., Gadoury, D. M., Amundsen, T., Semb, L., and Seem, R. C., 1997. Ascospore release and infection of apple leaves by conidia and ascospores of Venturia inaequalis at low temperatures. Phytopathology 87:1046-1053.
Stensvand, A., Eikemo, H., Gadoury, D.M., and Seem, R.C. 2005. Use of rainfall frequency threshold to adjust a degree-day model of ascospore maturity of *Venturia inaequalis*. Plant Dis. 89:198-202.

Apple Scab Fact Sheet: http://www.nysaes.cornell.edu/pp/extension/tfabp/apscpm.shtml
Notes on Apple Scab: http://www.nysaes.cornell.edu/ent/treefruit/html/05dm/05dm_60.php
NYS IPM Resources for Fruits: http://www.nysipm.cornell.edu/fruits.html
Cornell Commercial Tree Fruit Production Guide: http://www.nysaes.cornell.edu/ent/treefruit/

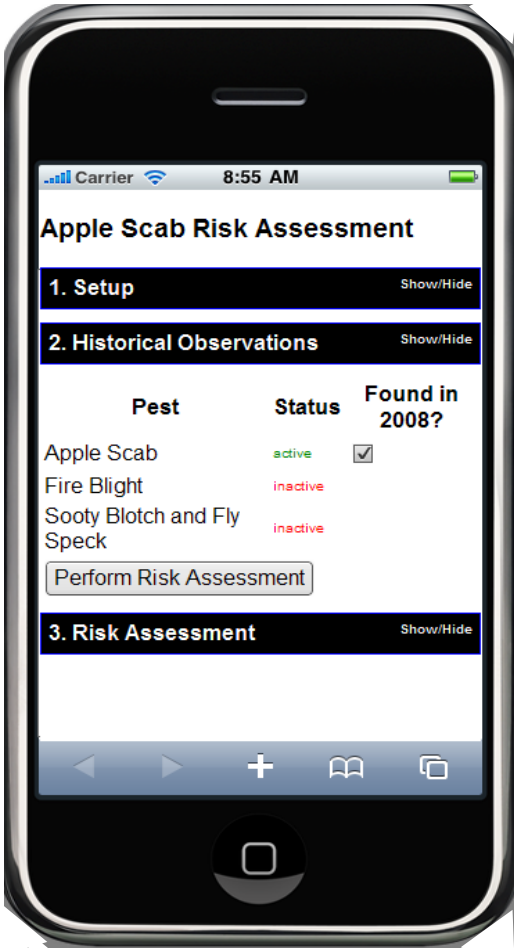
Level 2 Weather-Based Models

Smartphone Applications for Recording and Uploading Field Data

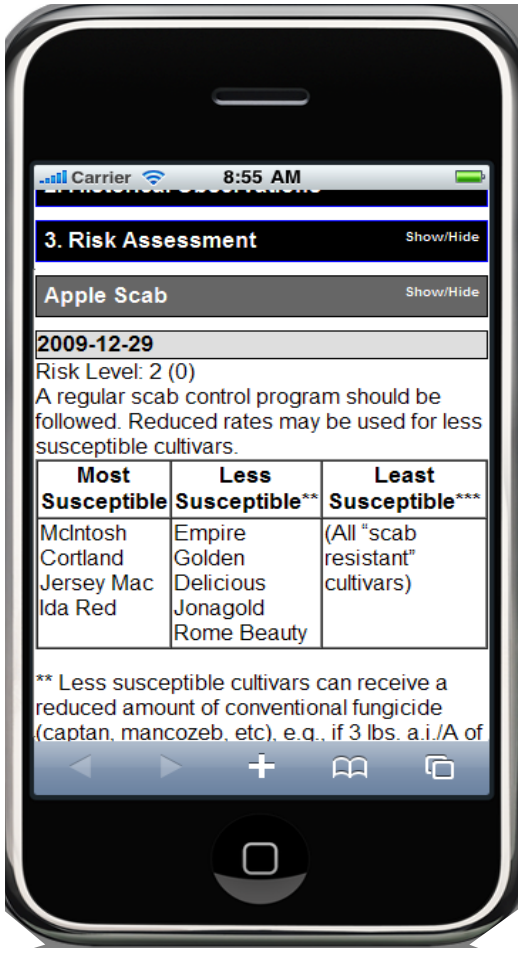
1. Setup



2. Historical/Real-time Forecast Obs.



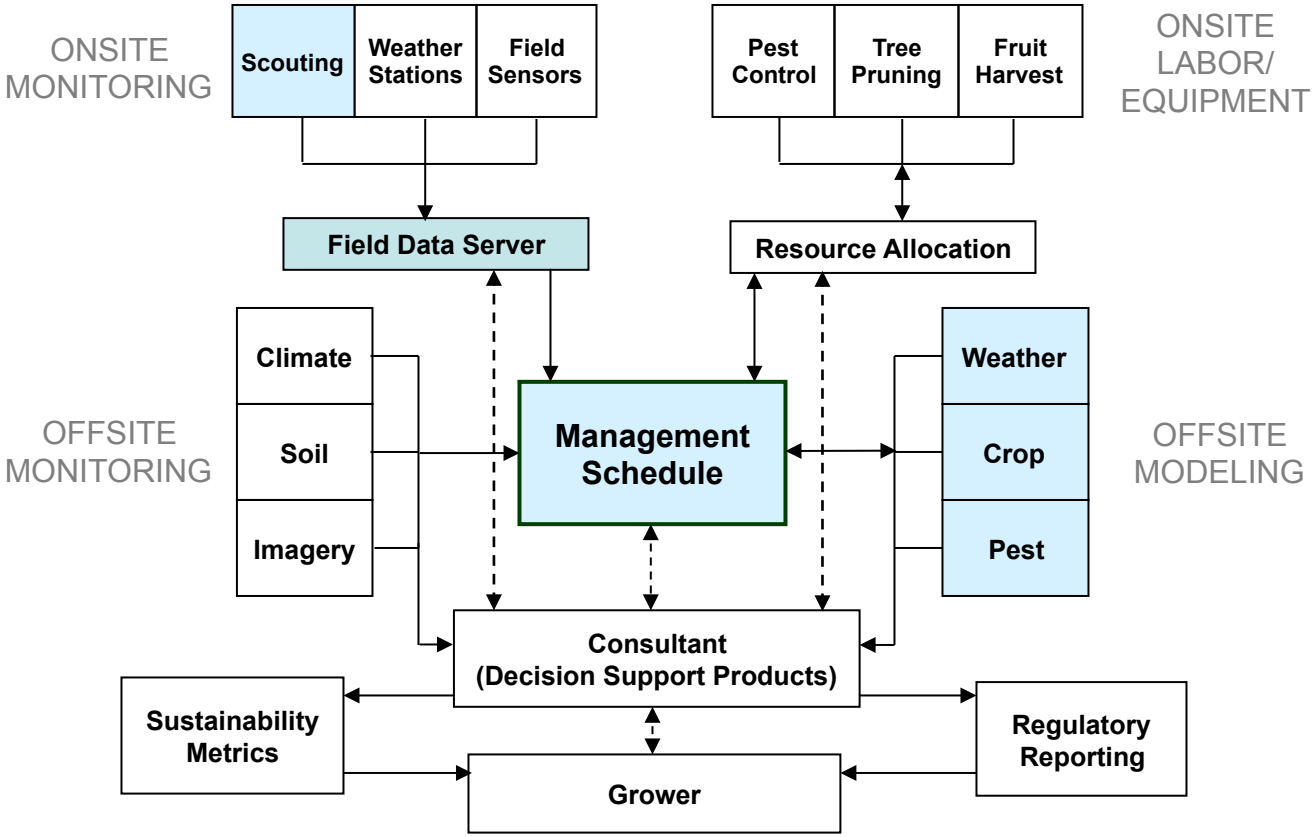
3. Risk Assessment & Management Options



Credit: iPhone Simulator by Testiphone.com (http://www.testiphone.com/) Copyright © 2007-2010 Web design

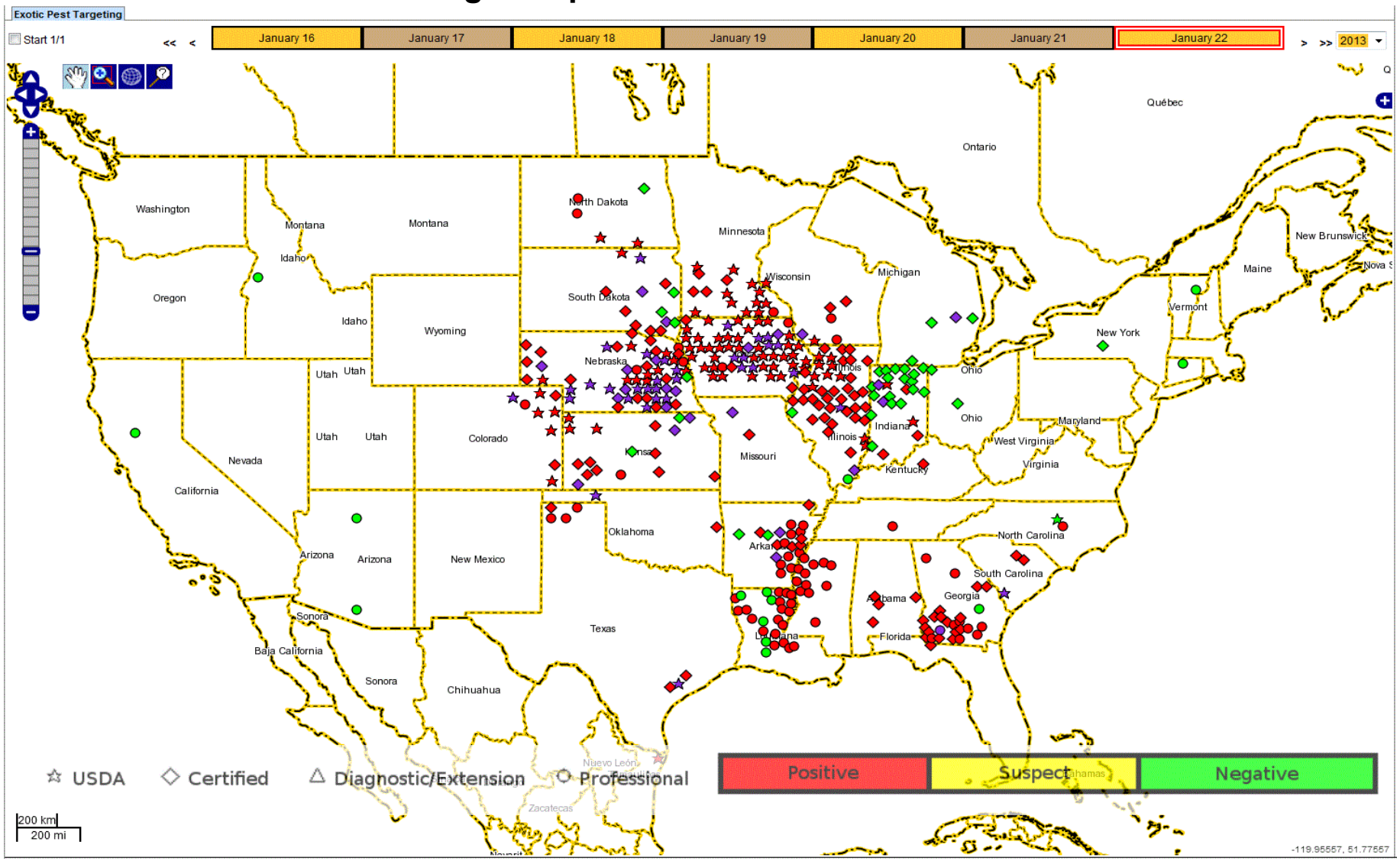
Level 3 Weather-Based Models

Flow of Information in a Orchard Management System



Level 3 Weather-Based Models

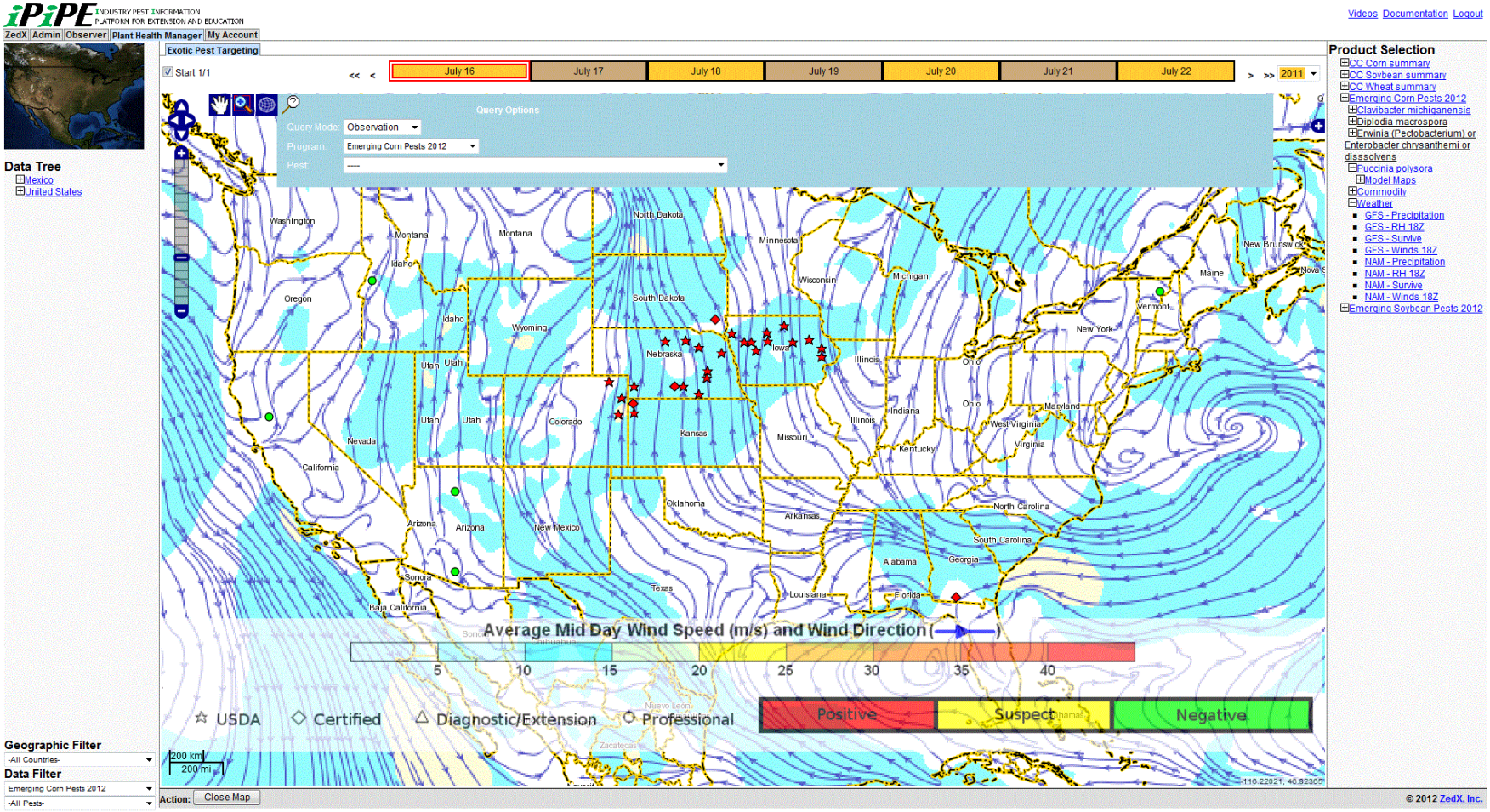
Combining Multiple Sources of Pest Observations



Source: IPIPE

Level 3 Weather-Based Models

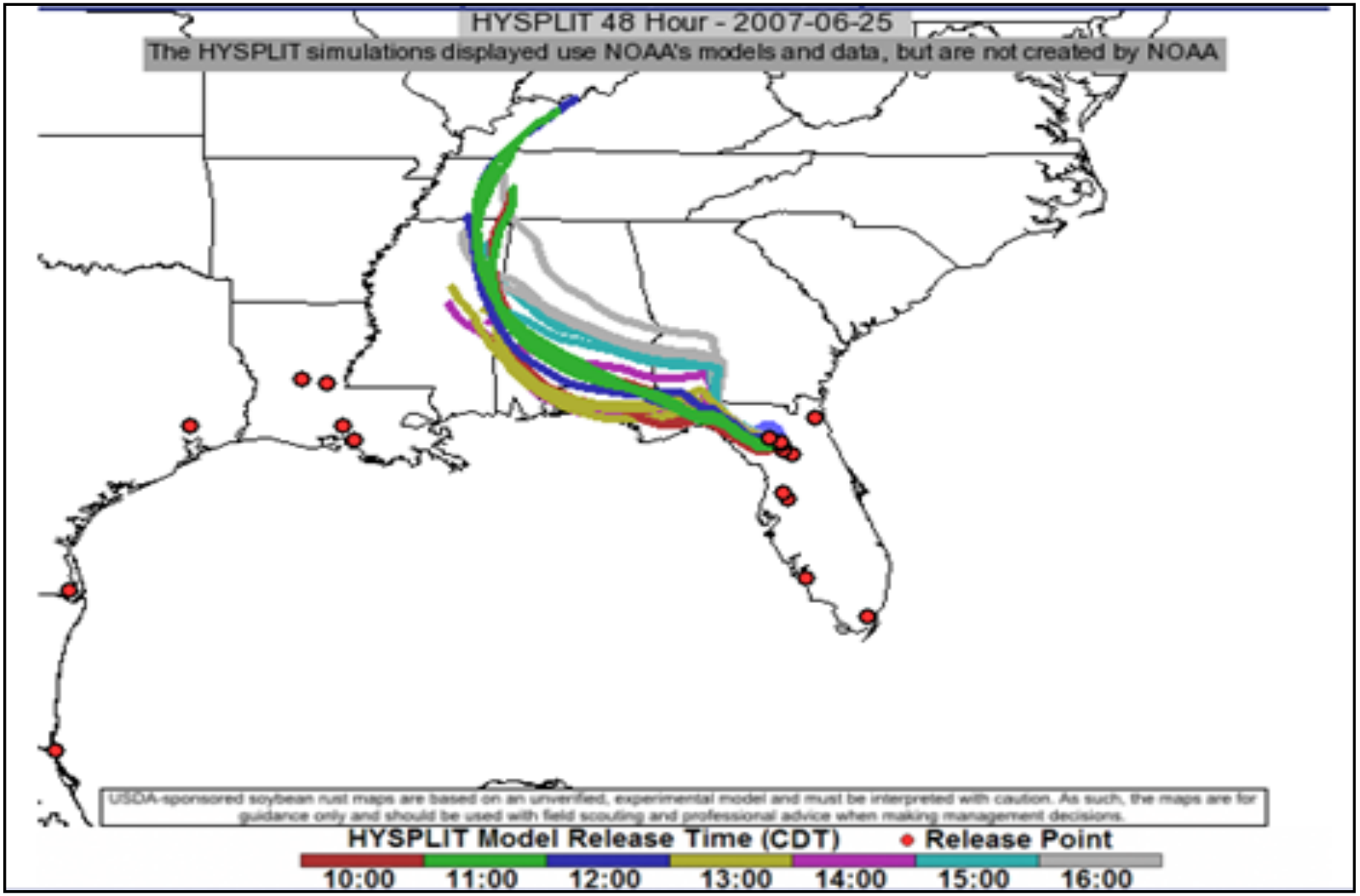
Combining Pest Observations with Weather Data: Wind Example



Source: IPIPE

Level 3 Weather-Based Models

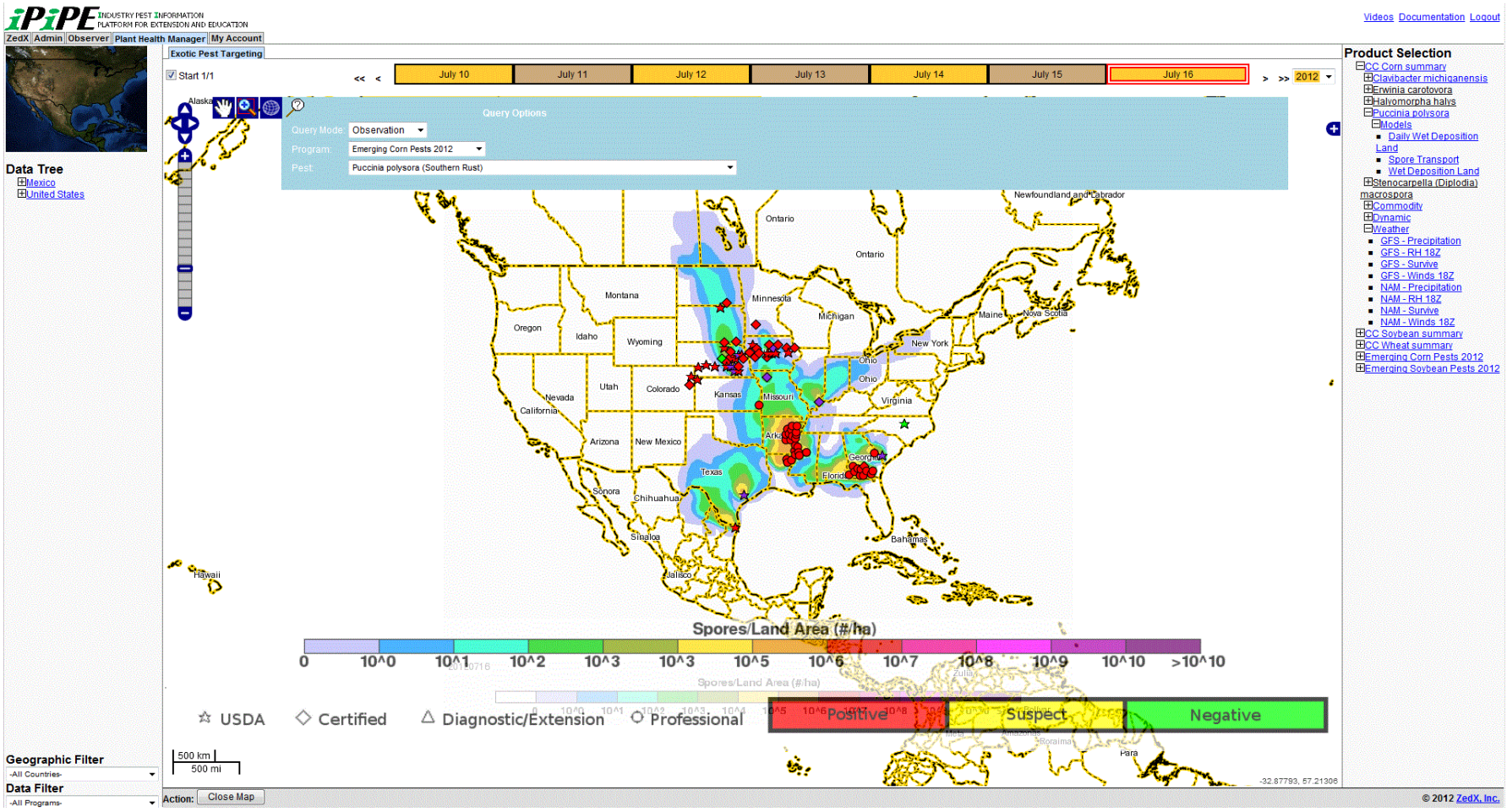
Pest Observations and NOAA HYSPLIT Model



Source: IPIPE

Level 3 Weather-Based Models

Pest Observations as Source for Aerobiological Models



Source: IPIPE

Thank you!

Questions?