

## **NEWA (Network for Environment and Weather Applications) 2010 - 2012:**

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**Abstract:** The Network for Environment & Weather Applications (NEWA) conducts onsite environmental monitoring and transmits weather data to NEWA's servers which automatically calculate and provide tabulated weather data summaries, degree days, and IPM forecast model results for 21 insects and diseases. The average grower of high-value fruits and vegetables can save \$19,500 per year in spray costs and prevent \$264,000 per year in crop loss by using NEWA information. Funding support from the NYS IPM Program was drastically reduced beginning in 2010. NEWA was maintained largely through grants and with fees supporting four new expansion networks in neighboring states. NEWA usage continues to increase and the network has doubled in size with 216 station locations. Rainwise MKIII instruments continued to be added to the NEWA system. A new Ethernet interface: the IP100 was deployed in 2010. The Northeast Regional Climate Center (NRCC) continued archiving data, running and refining the IPM forecast models, and providing the NEWA hourly data, daily weather summaries, and degree days. Several of the IPM forecast models have seen significant improvement, two new models have been implemented and three Decision Support Systems have been created.

### **Objectives:**

- 1) Operate and maintain the NEWA electronic weather network.
- 2) Track and promote NEWA usage.
- 3) Update the NEWA website and pest forecast models.
- 4) Collaborate with the Northeast Regional Climate Center (NRCC).

### **Procedures, Results, and Discussion:**

#### **1. OPERATE AND MAINTAIN THE NEWA ELECTRONIC WEATHER NETWORK.**

During 2010, NEWA was phased out of the NYS IPM Program budget. As a result phone lines for communicating with older loggers were discontinued or transferred to growers. The Canandaigua server was shut down and all operations were moved to Geneva where all modem communications are carried out. Most FTP data communications are now done through the NRCC. The Geneva server continues to be pared down and will eventually be phased out.

***Data transmission to NEWA.*** In 2010, with funding through the E-IPM grant, a device was introduced that allowed weather data to be transmitted without a computer. The device, the IP100, transmits data to Rainwise servers which then make the data available to the NRCC servers via RainwiseNet. Data is housed in two locations. The RainwiseNet website allows growers to access their data at a second location. New applications will be available from this site, including the ability to create graphs and set alarms for monitoring various weather conditions, such as frost. Figure 1 shows a RainwiseNet web page. Many of NEWA station owners have upgraded to this device, but some prefer to use the FTP system which logs data to their computer. New in 2012 is the ability of the IP100 to send data to other weather networks such as the Weather Underground, providing yet another way for growers to access their data in

real time. Figure 2 is a depiction of a web page from a station in the NEWA network on the Weather Underground. It should be noted that none of the models for crops are available on the other web sites. NEWA is the only outlet for pest forecast information.

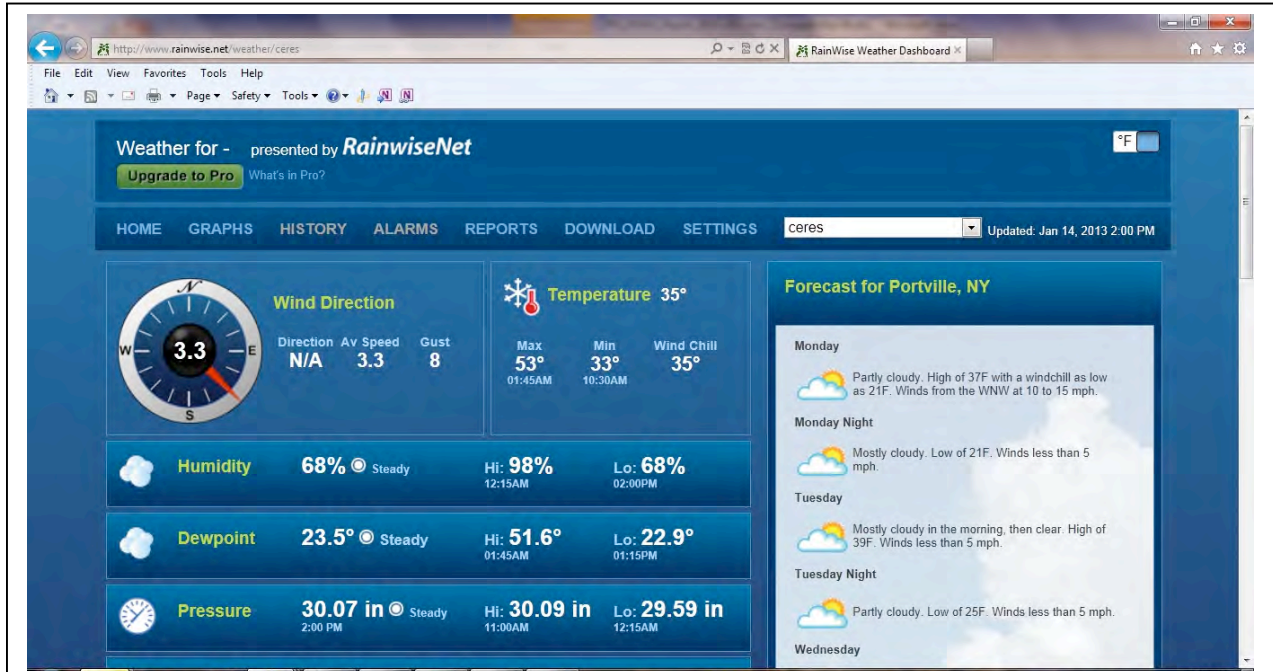


Figure 1. RainwiseNet web page view for NEWA-connected Rainwise instrument.

NEWA personnel have made fewer maintenance and trouble-call field visits due to funding cuts.

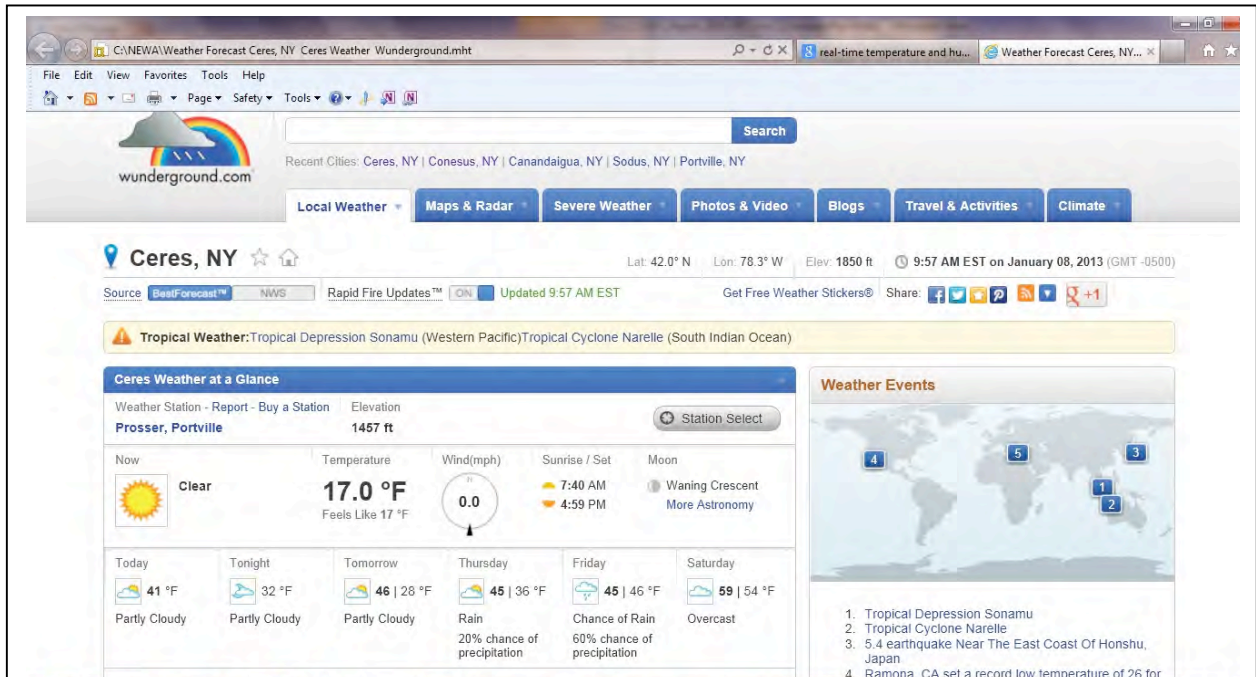


Figure 2. Weather Underground web page view of real time data for a NEWA-connected Rainwise instrument.

Most visits made to the field were to assist with station installations for specific grants. The IP

100 data transmission device has greatly improved trouble-free weather data transmission to NEWA servers. Assistance with weather stations is frequently accomplished via email.

**Weather station locations.** There are now 70 weather stations in the NY NEWA mesonet. Thus, in the past three years the mesonet size in NY has almost doubled. Data is also made available from National Weather Service airport locations in the state, so that at the end of 2009 the number of stations totaled 106. With NEWA expanding coverage into three neighboring states, as of the end of 2012, the total number of weather stations reporting to the NEWA system now totals 216, twice the number in 2009.

New weather stations have been added to the network routinely and some highlights are listed. A Rainwise MKIII instrument was added to the NEWA network in 2010 that was purchased by growers, at Arkport. Another was added in 2011 in Baldwinsville as part of a late blight grant. In 2011 and 2012, seven stations were added in the Lake Erie grape belt, with grant funding secured by Tim Weigle, at Silver Creek, Portland Escarpment, Versailles, Sheridan, Portland Rt 5, North East Lab and the North East Escarpment. Three weather stations were added by the Cornell University Experiment Station, located at field research facilities in Chazy, Aurora, and Willsboro. One site was added at Freeville at the Cornell Research Farm under a potato late blight grant with Dr. Bill Fry. Another site was added at the Long Island Horticultural Research and Extension Lab under the supervision of Dr. Meg McGrath. A station was added at the Bejo Seeds research facility in Geneva. The Seneca County Soil and Water Conservation District funded weather stations for vineyards in Seneca County at Fayette (3 Brothers), Lodi (Lamoreaux), Varick (Swedish Hill), Ovid (Hosmer Winery), Lodi (Shalestone) and Lodi (Standing Stone).

Three expansion networks were established in 2010, including Vermont-NEWA (12 weather stations, Univ of Vermont), Massachusetts-NEWA (40 weather stations, The Univ. of Mass.), and EcoOrchard-NEWA (eight weather stations, New England Advanced Apple IPM Group). Another expansion network was established in 2011, New Jersey-NEWA (46 weather stations, Rutgers-The State University). Data is also available from airport stations in those states.

In 2012, Rainwise has started testing a new version of the MKIII weather station. The station will be similar to the old stations but with new modifications and capabilities. One of the best features of the new station will be the ability to add more sensors. Growers will now be able to monitor conditions such as soil temperature and field moisture in addition to the other sensors. Improvements to how the station utilizes voltage have also been implemented.

## 2) TRACKING AND PROMOTING NEWA USAGE

Tracking NEWA usage has become a complicated task because several websites and servers contribute data and information through NEWA, including the ITX NEWA website, the NRCC NEWA servers, and the Late Blight DSS. The ITX website [newa.cornell.edu](http://newa.cornell.edu) has rudimentary capabilities to access usage which gives a partial picture. All the pest forecast model output web pages are served up by the NRCC NEWA server. The forecast program, Late Blight DSS, runs on a dedicated server, but uses NEWA weather data to create the late blight forecasts. Specific requests for web usage data have been received and we have provided this to our collaborators, as needed, but no longer track and chart these data routinely for the entire NEWA system.

**Table 1.** Presentations promoting NEWA given in the period January 2010 to December 2012.

Presenter	Date	Title	Location	Audience	# of people
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Carroll	1/19/2010	NEWA – weather app's for your fruit farm	Lake Ontario Fruit School, Albion, NY	Growers, extension educators, faculty and consultants.	100
Carroll	1/20/2010	NEWA – weather app's for your fruit farm	Lake Ontario Fruit School, Newark, NY	Growers, extension educators, faculty and consultants.	125
Petzoldt	2/16/2010	NEWA Information for potato growers	Liverpool, NY	Growers	75
Weigle	4/8/2010	NEWA Meeting	CLEREL, Portland, NY	Growers, Industry and Extension Staff	5
Weigle	5/6/2010	NEWA Training at LERGP Field Rep Meeting	CLEREL, Portland, NY	Industry Reps, research and extension staff	18
Carroll	5/13/2010	Status of fruit IPM Program and NEWA update	LOF Petal Fall Meeting, Newark, NY	Apple growers and consultants	45
Carroll	5/18/2010	Status of fruit IPM Program and NEWA update	Spring Grape IPM Meeting, Bluff Point, NY	Grape growers and chemical company rep's	125
Carroll	6/30/2010	Status of fruit IPM Program and NEWA update	Coffee Pot Meeting, Portland, NY	Grape growers, CCE, and processors	30
Carroll	7/14/2010	NEWA and TracGrape	Am Soc Enol & Viticulture, Eastern Brach, Geneva, NY	Research and extension scientists	55
Weigle	7/21/2010	Using the Improved NEWA website in Vineyard Pest Management Decision Making	LERGP Summer Growers' Conference, CLEREL, Portland, NY	Growers and Industry Reps	73
Carroll	7/28/2010	Weather stations for NEWA	Cornell Fruit Field Days, Geneva, NY	Fruit growers, industry rep's, educators and faculty	30
Carroll	8/6/2010	Current projects on the Network for Environment and Weather Awareness (NEWA)	MidWest Weather Working Group meeting, Charlotte, NC	Scientists – plant pathologists, entomologists, meteorologists	28
Carroll	9/15/2010	NEWA – weather app's for IPM	Webinar, Wide Area Pest Monitoring	Educators, scientists, others	90
Carroll	2/8/2011	NEWA – tools for IPM	VT Tree Fruit Growers Assoc Mtg., Middlebury, VT	Apple growers and extension personnel	80
Weigle	2/18/2011	2011 Update on NEWA and Trac Grape	Holiday Inn, Kingston, NY	Growers	32
Carroll	3/5/2011	Updates to NEWA and TracGrape	Finger Lakes Grape Growers Conference	Grape growers, research and extension	120
Weigle	3/8/2011	Using NEWA Resources in Your Vineyard IPM Strategy	LERGP Growers Conference, Portland, NY	Growers and Industry Reps	108
Gibbons	4/28/2011	On Farm AES Implementation Workshop	East Aurora, NY	Growers, educators	10
Seaman	6/27/2011	NEWA resources for tomato and sweet corn growers	Monroe Co. CCE Late blight DSS training	Growers and consultants	15
Weigle	8/24/2011	Using Disease and Insect Models found on NEWA	2nd Annual LERGP Summer Growers Conf, Portland, NY	Growers and Industry Reps	85
Carroll	11/30/2011	Improving and Sustaining the NEWA System	Apple Research & Development Program Board Reporting Session	ARDP Board members and researchers	15
Gibbons	3/21/2012	Late Blight DSS Meeting	Batavia, Geneva NY	Growers and researchers	6
Seaman	3/21/2012	Introduction to the Late Blight Disease Support System	Batavia, Genesee Co.	Growers	6
Gibbons	3/23/2012	Late Blight DSS Meeting	Geneva, Ontario Co.	Growers and researchers	15
Seaman	3/23/2012	Introduction to the Late Blight Disease Support System	Geneva, Ontario Co.	Growers	15
Weigle	3/27/2012	NEWA Resources for implementation of IPM in Lake Erie vineyards	7th International IPM Symposium Memphis TN	IPM professionals	400
Carroll	3/28/2012	Site specific applications via integration of existing weather networks and proven predictive models	7th International IPM Symposium, Memphis, TN	IPM professionals	400
Weigle	7/25/2012	Using NEWA Resources in Your Vineyard IPM Strategy	North East Lab, North East, PA	Growers and Industry Reps	100
Weigle	11/13/2012	Using GIS and Sensor Technology in Vineyards	National Grape Cooperative Annual Meeting, Erie, PA	Grape Growers and Staff of National Grape Cooperative	100
Weigle	11/14/2012	Using GIS and Sensor Technology in Vineyards	National Grape Cooperative Annual Mtg, Hamburg, NY	Grape Growers and Staff of National Grape Cooperative	100

NEWA weather and pest forecast information is also multiplied via extension newsletters and email alerts that reach many farms. At various meetings, talks were given describing NEWA and

the new RainWise weather instruments (Table 1). There continues to be interest in training sessions on the NEWA system as part of pest model implementation.

The climate information from the NEWA weather stations is increasingly being utilized for crop risk management, horticultural research, and crop forecasting. For instance, in the Lake Erie grape belt, NEWA stations have provided critical low temperature data during the frequent freeze events that occurred in 2012. In viticulture, weather data information is being used in the project A Whole-System Approach to Vineyard Management and the “9-Site Study” that examines the effects of weather and pruning levels in the three distinct vineyard growing areas (lakeshore, lake plain and escarpment) of the Lake Erie region by Dr. Terry Bates and the National Grape Cooperative. Dr. Terence Robinson and Dr. Alan Lakso, Horticultural Sciences, use NEWA data for a carbohydrate utilization model for apple to predict response to fruit thinning applications.

A daily email message alert, e-NEWA, including weather information, plum curculio and apple scab forecasts was beta-tested in 2012. The sixteen apple growers who receive the e-NEWA email alerts found them extremely useful. Conservative projections are that e-NEWA subscriptions could generate approximately \$16,000 per year to support NEWA. Delivering NEWA information in this manner to smart phone devices could significantly increase NEWA usage.

### **3) UPDATE THE NEWA WEBSITE AND PEST FORECAST MODELS.**

In late 2009, the completely revised and redesigned NEWA website was launched at the url addresses [newa.cornell.edu](http://newa.cornell.edu) and [www.newa.cornell.edu](http://www.newa.cornell.edu). In the subsequent three years, 2010-2012, the growth of NEWA, demonstrated by the doubling of weather station locations, the expansion into adjoining states, the widespread interest in development and implementation of crop-, pest-, and disease-phenology models, has underscored the impact of the new website design in facilitating and promoting NEWA use.

During 2010 to 2012, several of the IPM forecast models have seen significant improvement, two new models have been implemented and three Decision Support Systems have been created. This work has been made possible through collaborations with the Departments of Entomology, Plant Pathology and Plant-Microbe Biology, Horticulture, and Earth and Atmospheric Sciences, and with the Pesticide Management Education Program.

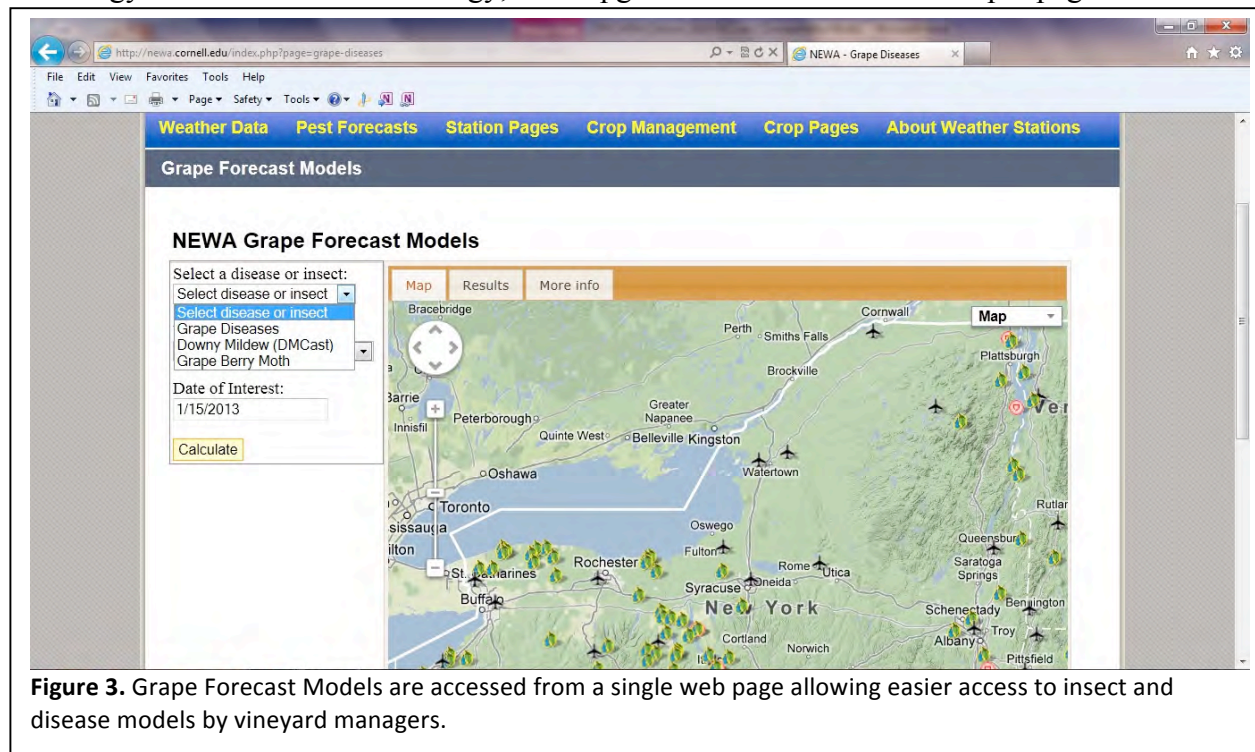
***Grape forecast models:*** grape berry moth degree day model, grape diseases (Phomopsis leaf and cane blight infection events, powdery mildew ascospore release, and black rot infection events), and DMCAst grapevine downy mildew. There were extensive improvements made to the grape forecast section on NEWA in the past two years. Improvements were made to the interface, shown in Figure 3, so that all the IPM forecast models for grapes are now available through a single NEWA portal to make it easier for grape growers to access them under Grape Forecast Models at [newa.cornell.edu/index.php?page=grape-diseases](http://newa.cornell.edu/index.php?page=grape-diseases).

**Grape berry moth degree day model** –This new IPM forecast model has been based on Dr. Michael Saunders’ research at Pennsylvania State University showing the life cycle of grape berry moth requires 810 degree days, base temperature 47.14 F. A biofix of wild grape bloom has been used to start the accumulation of degree-days. Dr. Greg Loeb, Department of Entomology, Tim Weigle, and Dr. Juliet Carroll implemented the degree-day model with accompanying pest management messages on the NEWA website to time management strategies



against grape berry moth. Results of the model have been provided to growers via The Crop Update, Lake Erie Regional Grape Program weekly e-newsletter. This model has been utilized by grape growers in the Finger Lakes, the Lake Erie region and Long Island — providing better management of GBM than the previous IPM risk management system, based on preliminary results in Lake Erie vineyard demonstration sites. This model was the first in NEWA to implement National Weather Service forecasts and provide a 5-day GBM forecast.

Grape diseases –Tim Weigle, Dr. Juliet Carroll, and Dr. Wayne Wilcox, Department of Plant Pathology and Plant-Microbe Biology, have upgraded the disease model output page for



Phomopsis leaf and cane blight infection events, powdery mildew ascospore release, and black rot infection events. The model results provide the disease status and pest management messages throughout the course of the season. Users can change the estimated grape phenology stage to adjust model results for their vineyard.

DMCast, grapevine downy mildew –This simulation model has been translated into a compatible programming language by NRCC and rescued from a server in Dr. Robert Seems' Lab, Department of Plant Pathology and Plant-Microbe Biology, that has been phased-out, in order to bring this model back online within NEWA.

**Apple crop production models:** apple fruit thinning model and apple evapotranspiration model. Dr. Terence Robinson and Dr. Alan Lakso, Department of Horticulture, have been utilizing NEWA weather data to implement and validate a carbohydrate utilization model for apples that has revolutionized the ability to predict fruit thinning response in apples. Though the model results are not automatically being generated in NEWA because it is still being demonstrated in field trials, apple growers find the results so beneficial, many have purchased weather stations to have access to farm-specific thinning recommendations.

Apple evapotranspiration model –Developed by Dr. Alan Lakso, Horticultural Sciences, the apple evapotranspiration model has been implemented at [newa.cornell.edu/index.php?page=apple-et](http://newa.cornell.edu/index.php?page=apple-et) and has been providing information for an apple irrigation model.

**Estimation algorithms:** leaf wetness hour estimator and soil temperature model. These two equations will provide significant improvement in coverage for disease forecast models that require data on hours of leaf wetness and weed phenology models that require data on soil temperature, because leaf wetness is not collected routinely by many weather station manufacturers or the National Weather Service and soil temperature sensors are not deployed in the weather stations in the network.

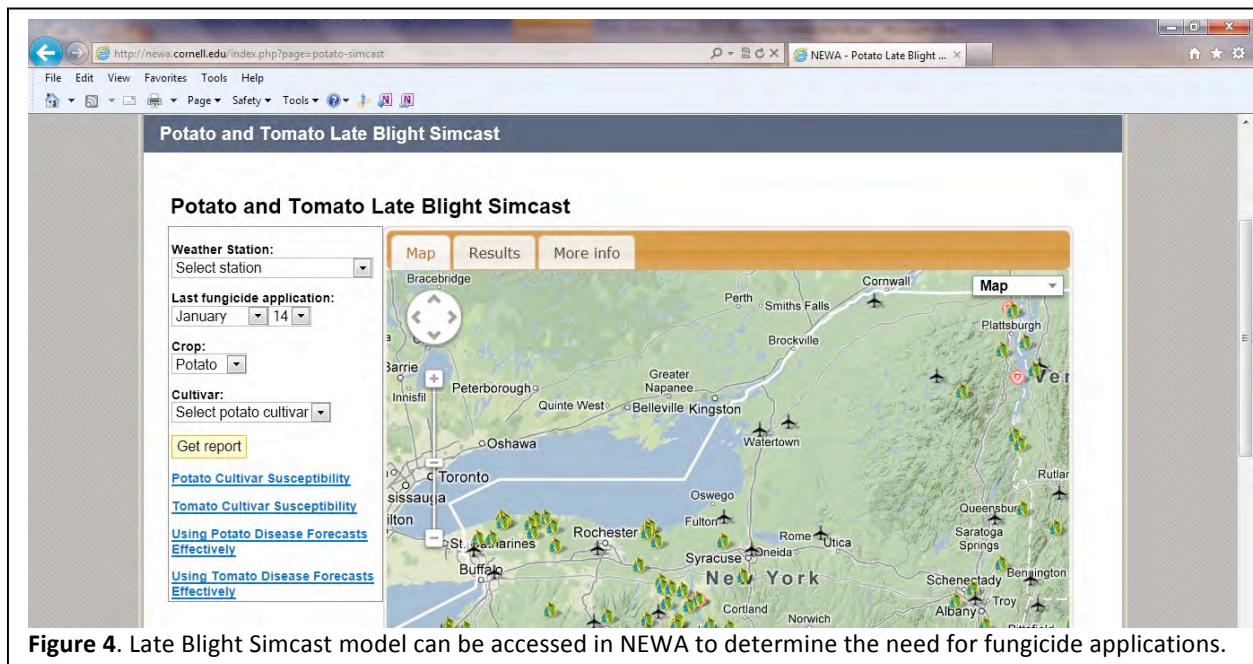
Leaf wetness –Developed by Dr. Juliet Carroll and the NRCC, this estimator of a leaf wetness hour has been programmed into the NEWA system to provide an alternate source of leaf wetness information which is critical to many of the disease forecast models. The estimate is based on relative humidity and precipitation events and returns either a “yes” or a “no” value for a wet hour or a dry hour, respectively. The estimated leaf wetness has been used in the disease models for those NEWA station locations where there is no leaf wetness sensor, significantly increasing coverage of the disease forecast models.

Soil temperature –Developed by Dr. Art DeGaetano, Department of Earth and Atmospheric Sciences, this model estimates 2-inch soil temperature equation from air temperature. The model can be applied to over 100 stations in New York and several hundred stations across the Northeast. The model has been able to simulate the observed 2-inch soil temperatures with an average error of approximately 0.5°C (0.9°F). In the future, it will be implemented in weed germination models for large crabgrass, giant foxtail, yellow foxtail, common lambsquarters, eastern black nightshade, smooth pigweed, common ragweed, and velvetleaf to improve weed management practices on agronomic and horticultural crops.

**Decision Support Systems:** Tree Fruit IPM DSS, Late Blight DSS and Vegetable IPM DSS. These Decision Support Systems are utilizing databases and web technology to generate support systems for farmers. The IPM DSS’s have been collaborations with the Pesticide Management Education Program and weave together the NEWA interactive web page design with a database of pesticides registered for specific crops to provide a pesticide decision system that can generate results for organic, IPM or conventional production systems or for multiple pests. The Late Blight DSS brings together knowledge of pesticide weathering, cultivar susceptibility, and *Phytophthora infestans* life history to improve late blight IPM decisions.

Tree Fruit IPM Decision Support System (DSS) –Developed by Dr. Harvey Reissig and Dr. Art Agnello, Department of Entomology, Dr. Kerik Cox, Department of Plant Pathology and Plant-Microbe Biology, and Dr. Juliet Carroll, the website at [treefruitipm.info/](http://treefruitipm.info/) features interactive pesticide tables from the Tree Fruit Guidelines which are updated yearly served by the Pesticide Management Education Program (PMEP) database and apple IPM forecast models served by NEWA.

Late Blight Decision Support System (DSS) –Developed by Dr. William Fry, Department of Plant Pathology and Plant-Microbe Biology, and NRCC, the interactive Late Blight DSS features a new late blight simulation model, Simcast, which kicks in once the Blitecast model has accrued 18 severity values. The Simcast model derives late blight favorable weather to calculate if it is necessary to apply fungicides. The model also has a component to calculate fungicide weathering based on weather data. The model uses data from the weather stations in the NEWA network and also uses National Weather Forecast data to provide future late blight conditions. In 2012, the system incorporated alerts to growers using smart phones and email. Late Blight DSS has become available through the NEWA website and has been a popular system for potato growers. Figure 4 shows the NEWA portal to Simcast.



**Figure 4.** Late Blight Simcast model can be accessed in NEWA to determine the need for fungicide applications.

Vegetable IPM Decision Support System –This DSS is under development by Dr. Curt Petzoldt, Dr. Harvey Reissig, PMP, and NRCC, who have completed nearly seven chapters of information organization. Parts of two chapters, crucifers and onions, are online in review mode. Information for pests and pesticides of peas, carrots, potatoes and beans are largely complete in template form and will soon be programmed into interactive websites. This DSS will provide calendar-based, interactive, crop-specific IPM messages linked to a pesticide decision system updated yearly as part of the Vegetable IPM Guidelines.

#### **4) COLLABORATE WITH THE NORTHEAST REGIONAL CLIMATE CENTER.**

The Northeast Regional Climate Center (NRCC) and NEWA have continued to collaborate in 2010 - 2012, recognizing the benefits of building a stronger collective for weather information at Cornell University. NRCC data is compiled from information provided by airport observations and the Cooperative Observer Network in the Northeastern USA and they now have access to additional sources of weather data from the NEWA mesonets in NY, MA, VT, and NJ.

NRCC continues to provide NEWA with links to the Stewart's wilt forecast maps, evapotranspiration (ET) maps, degree-day maps and NWS degree day forecasts. Programming for new models and the web pages serving the results of the models is done by NRCC staff.



Cornell University faculty members often work directly with the NRCC to develop new models and upgrade existing models. These models utilize NEWA data and are displayed within the framework of the NEWA website.

Data Quality Control (QC) measures have been recognized as paramount to good model results. Complementary projects at NRCC and NEWA, with the goal of implementing automated QC subroutines as data is ingested and utilized in model results, have been nearing completion. An automatic email would generate via NEWA to alert the weather station owner that there is a problem with the station being able to transmit data or with data that is coming from one of the sensors on the instrument. Data QC in NRCC would identify and adjust out-of-range data to prevent its being utilized in the models. Current data QC extrapolates for small gaps in data transmission to the NEWA servers of up to 3 hours and “patches” larger gaps in data, up to one month, with data from a nearby weather station, the designated “sister” station.

### **NEWA PUBLICATIONS**

- Oudemans, P., Clements, J., Cooley, D., Bradshaw, T., Robinson, D., Berkett, L., and Carroll, J. 2012. Site specific applications via integration of existing weather networks and proven predictive models. P049. 7th International IPM Symposium, Memphis, TN.  
[http://www.ipmcenters.org/ipmsymposium12/049\\_Clements.pdf](http://www.ipmcenters.org/ipmsymposium12/049_Clements.pdf)
- Weigle, T., Wilcox, W., Loeb, G., and Carroll, J. 2012. NEWA Resources for Implementation of IPM in Lake Erie Vineyards. P089. 7th International IPM Symposium, Memphis, TN.  
[http://www.ipmcenters.org/ipmsymposium12/089\\_Weigle.pdf](http://www.ipmcenters.org/ipmsymposium12/089_Weigle.pdf)
- Carroll, J., Weigle, T. and Petzoldt, C. 2011. The Network for Environment and Weather Applications (NEWA). NY Fruit Quarterly 19(1):4-9.
- Carroll, J. and Weigle, T. 2010. Weather-driven Grape IPM Forecast Models and Decision Aids from the Network for Environment and Weather Awareness. NYS IPM Program Project Report. <http://nysipm.cornell.edu/grantspgm/projects/proj09/fruit/carroll3.pdf>
- Gibbons, J., Carroll, J., TenEyck, C., Petzoldt, C., and Weigle, T. 2010. NEWA (Network for Environment and Weather Applications) 2009: A Year in Review. NYS IPM Program Project Report.  
[http://nysipm.cornell.edu/grantspgm/projects/proj09/pgm\\_wide/gibbons.pdf](http://nysipm.cornell.edu/grantspgm/projects/proj09/pgm_wide/gibbons.pdf)

### **GRANTS SUPPORTING NEWA ACTIVITIES**

- Judelson et al. 2011-2016. Reducing losses to potato and tomato late blight by monitoring pathogen populations, improved resistant plants, education, and extension. USDA NIFA – AFRI CAP program. (\$9,000,000, 26 Co-PI’s.)
- Carroll and DeGaetano. 2011. Improving and Sustaining the NEWA System. Apple Research and Development Program. \$12,401.
- DeGaetano. 2011. Modeling two-inch soil temperatures using daily air temperature observations. NYS IPM Program. \$5000.
- Weigle, Carroll, Peterson, and DeGaetano. 2011. Ensuring the Continued Delivery of Weather and Pest Management Information for Grapes through the Network for Environment and Weather Applications (NEWA). LERGREP, Inc., NY Wine and Grape Foundation and Vit Consortium-East. \$8501.
- Loeb, Isaacs, Saunders, Weigle. 2010-2013. Testing the Use of a Degree Day Model to Time Control of Grape Berry Moth. Viticulture Consortium-East/LEGREP, Inc. \$41,280

Saunders, Muza, Loeb and Weigle. 2010-2012. Improved timing of control for the grape berry moth, *Paralobesia viteana*, using a degree day model. USDA RIPM Northeast. \$166,904

Petzoldt and Reissig. 2009-2011. A web based decision support system for vegetable crop IPM. Cornell Federal Formula Funding. \$75,000.

Reissig, Agnello, Cox and Carroll. 2008-2011. Development of web-based New York tree fruit pest management guidelines. Smith-Lever. \$75,000.

Petzoldt and Grant. 2009-2010. New York State (Cornell) Integrated Pest Management Program –NEWA Collaboration. USDA-CSREES. \$8000 subcontract.

Seem, Gadoury, Carroll, Weigle, DeGaetano, and Loeb. 2009-2010. Grape Downy Mildew and Grape Berry Moth: Model reimplementation and redefinition for New York. NYS IPM Program. \$5000.

Carroll and Weigle. 2008-2010. Weather-driven grape IPM forecast models and decision aids from the Network for Environment and Weather Awareness. Smith-Lever \$20,000.

Fry. 2007-2010. Improved late blight forecasting – the roles of weather, inoculum, host resistance, and fungicide. Hatch. \$60,000.