Decision Support for Freeze Protection Using Artificial Neural Networks

R.W. McClendon, G. Hoogenboom
A. Jain, R. Ramyaa, B.A. Smith

Biological & Agricultural Engineering,
University of Georgia,
Athens and Griffin Campuses

Artificial Intelligence Center

Agricultural Outlook Forum 2005

Discussion

1) Frost/Freeze Problem

2) Recommendations

3) Weather Monitoring Systems

1) Frost / Freeze Problem

Goal

- Goal of Frost/Freeze Protection is to prevent plant parts (particularly flower and fruit) from being damaged by temperatures that drop below a critical level.

- Critical temperature is a function of crop, variety and growth stage.

Factors in degree of injury due to low temperature

1) Type of plant
2) Stage of development of the crop
3) Amount of leaf cover over the blossoms and fruit
4) Severity and duration of freeze
5) Wind speed

Problem associated with irrigation

If humidity is low and wind speed is high during freeze, insufficient irrigation may cause evaporative cooling which may damage crops more than non-irrigated fields.

2) Recommendations

Recommendations

- **If RH > 90%, little likelihood of worsening freeze damage with irrigation**

- **Open blueberry flowers cannot survive T < 28 ºF. After petal fall, the developing berry can be damaged by T < 30 ºF.**

- **Overhead irrigation can be very effective in preventing damage to blueberries if there is little wind when temp drops below freezing.**

Recommendations

- If humidity is low, start irrigation at 37 ºF.

- If temp. drops to low 20's or below *or* if wind is higher than 5 mph, sprinkling can cause increased damage.

Recommendations

- If wind rises to 5 mph, an application rate of 0.5 in. / hr. will be needed to give some protection.

- At wind speeds above 5 mph, more damage may be done by irrigating than not irrigating

Dew point temperature (T_{DP})

- Producers need estimates of temperature, wind speed, relative humidity (or T_{DP}) during critical times of the freeze.
- T_{DP} is useful for estimating moisture content of air during freezes.
- With little wind, the T_{DP} changes little between noon and the following sunrise.

3) Weather Monitoring Systems

AEMN

The University of Georgia's

Automated

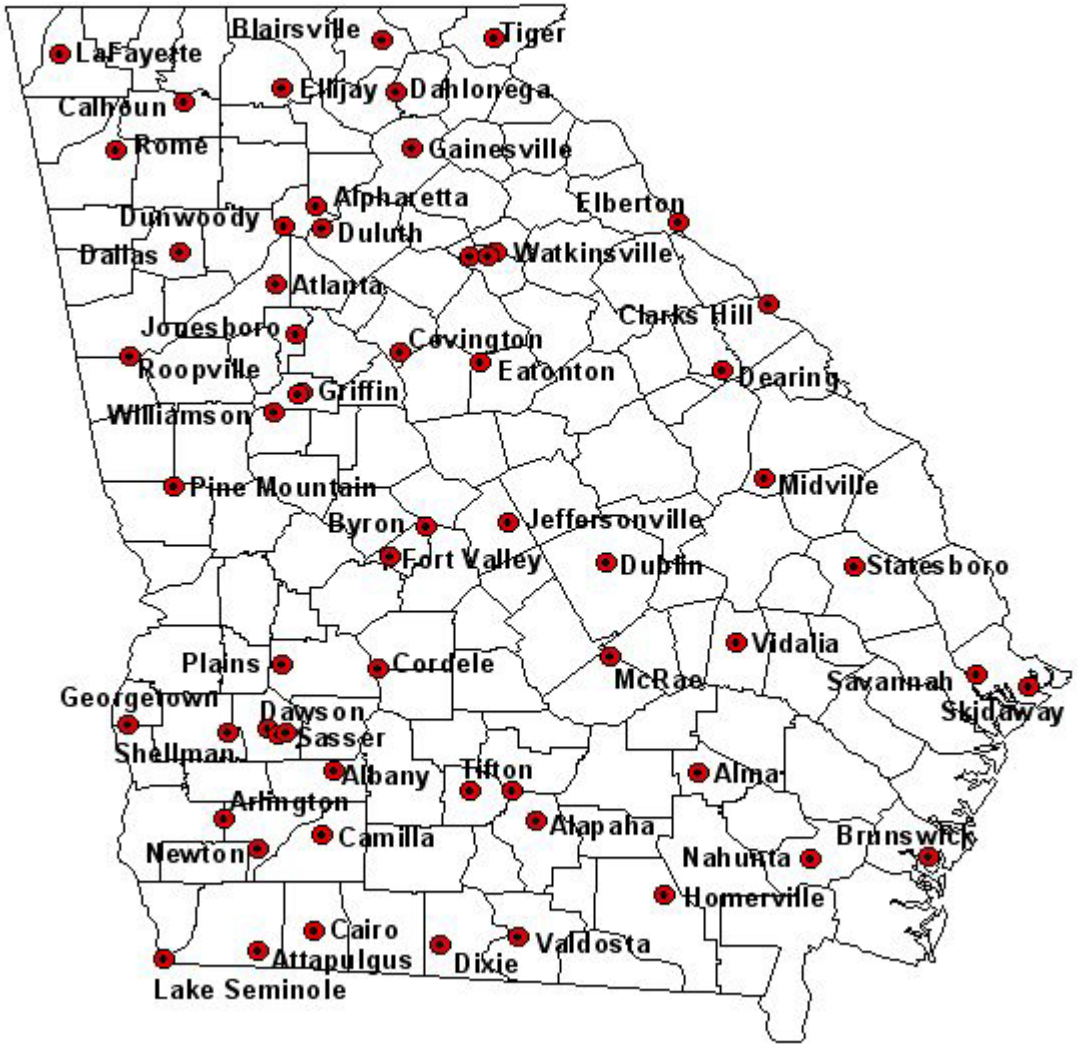
Environmental

Monitoring

Network

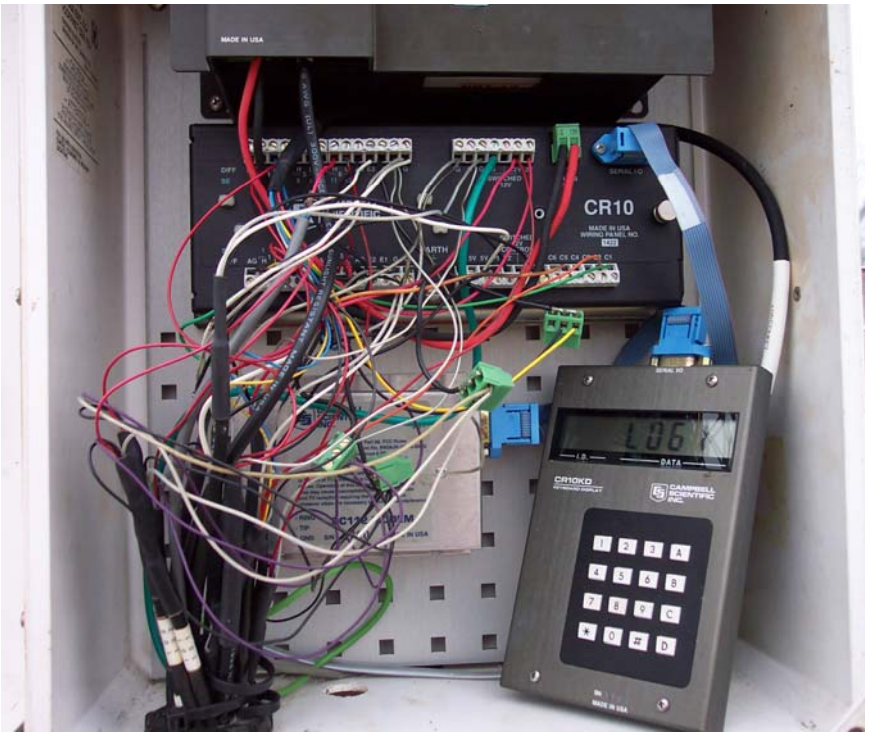
- Dr. Gerrit Hoogenboom
- 58 automated weather stations in rural areas of Georgia
- http://www.griffin.peachnet.edu/bae/

AEMN Stations

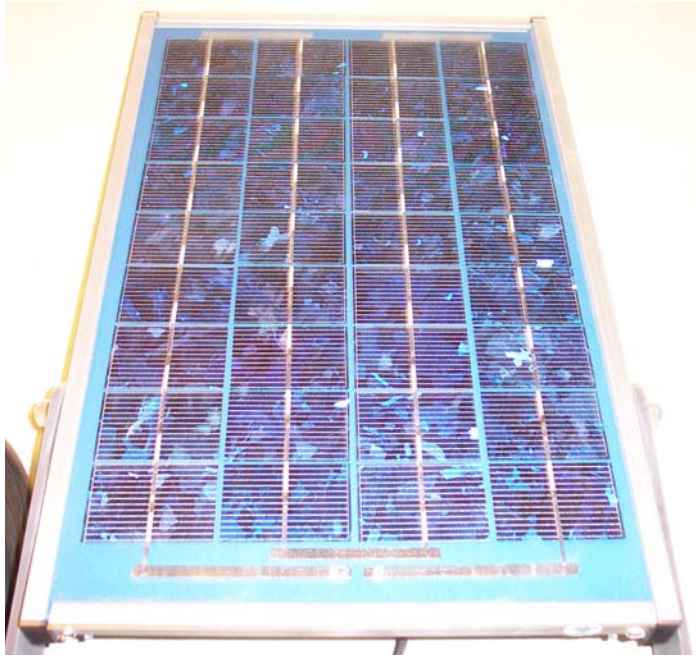


Equipment

- Campbell Scientific
  - CR10/CR10X Measurement and Control Module



Air Temperature & Relative Humidity



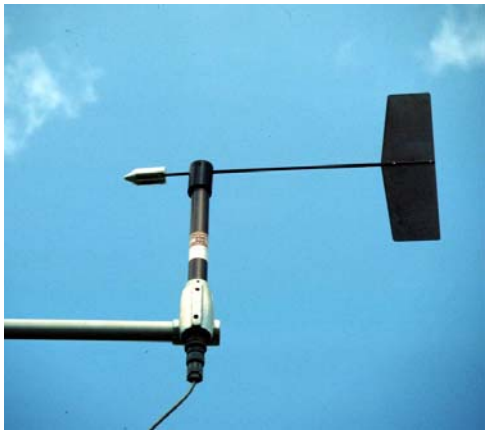
Rainfall

CR10 Power Supply

Solar Radiation

Wind Speed

Wind Direction

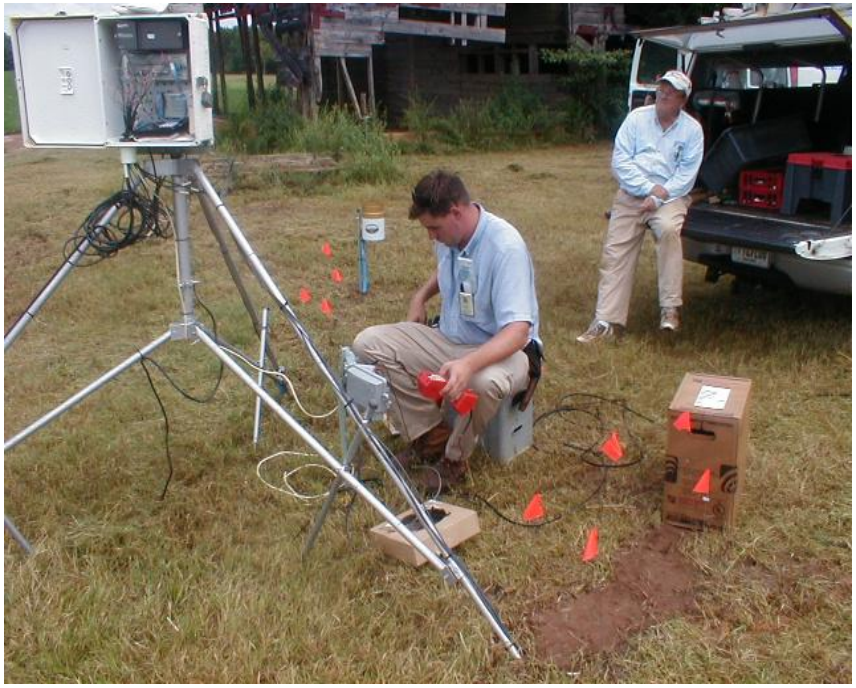


Soil Temperature

Communications

- **Telephone**
- Modem
- Voice modem

- Dedicated land lines
- Cellular phone/modem combination



Data Recording

- Collect data every second on:
  - Air temperature
  - Relative humidity
  - Soil temperature (4 depths)
  - Wind speed
  - Wind direction
  - Solar radiation
  - Vapor pressure deficit
  - Soil moisture

Data Recording

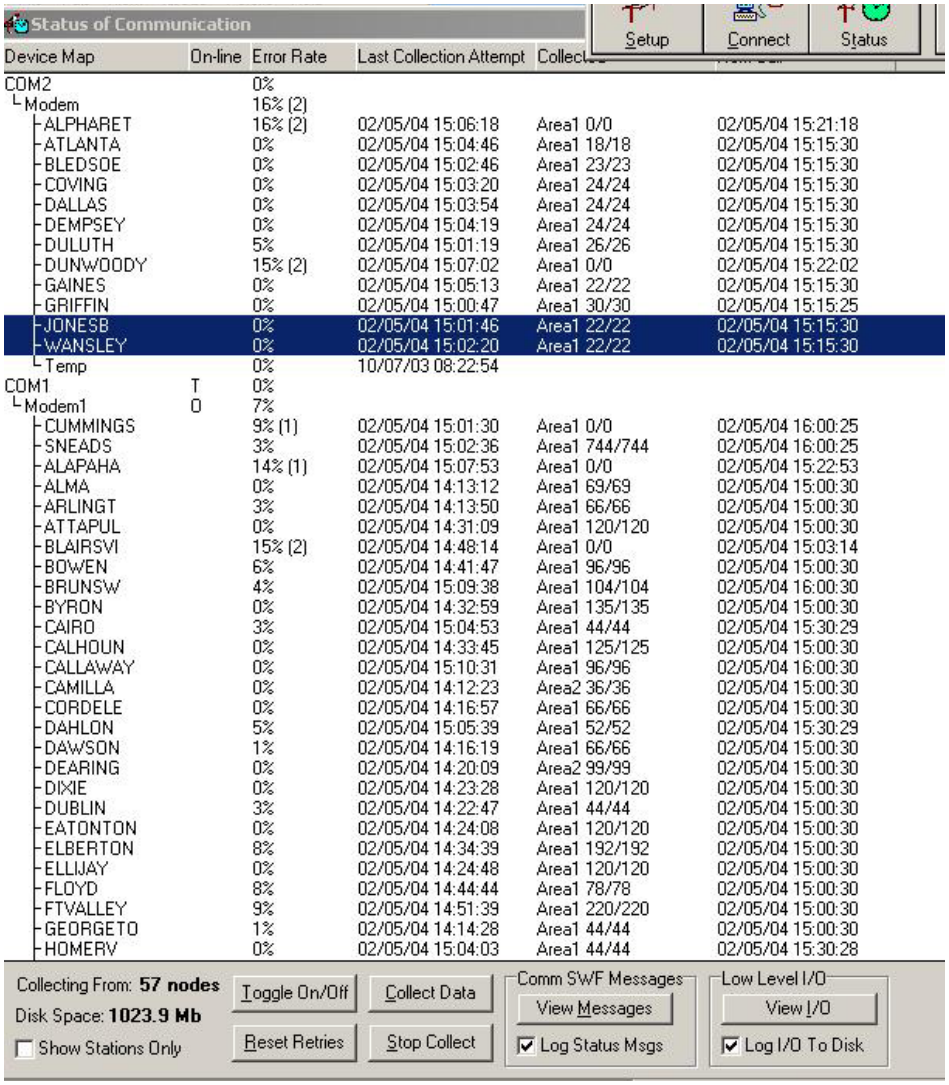
- Sensors are scanned at a *one-second* frequency
- Data are stored at 15-minute intervals
  - 15-Minute Average
  - 15-Minute Total
  - Maximum wind speed
  - Time of maximum wind speed
  - First rainfall occurrence

Automated Processing

Communications

- Call ***all*** stations,

  at least, every hour
- Call local stations at 15 minute intervals
- Loggernet (Campbell Scientific) software for data downloading



Device Map	On-line	Error Rate	Last Collection Attempt	Collect	
COM2		0%			
└Modem		16% (2)			
├ALPHARET		16% (2)	02/05/04 15:06:18	Area1 0/0	02/05/04 15:21:18
├ATLANTA		0%	02/05/04 15:04:46	Area1 18/18	02/05/04 15:15:30
├BLEDSOE		0%	02/05/04 15:02:46	Area1 23/23	02/05/04 15:15:30
├COVING		0%	02/05/04 15:03:20	Area1 24/24	02/05/04 15:15:30
├DALLAS		0%	02/05/04 15:03:54	Area1 24/24	02/05/04 15:15:30
├DEMPSEY		0%	02/05/04 15:04:19	Area1 24/24	02/05/04 15:15:30
├DULUTH		5%	02/05/04 15:01:19	Area1 26/26	02/05/04 15:15:30
├DUNWOODY		15% (2)	02/05/04 15:07:02	Area1 0/0	02/05/04 15:22:02
├GAINES		0%	02/05/04 15:05:13	Area1 22/22	02/05/04 15:15:30
├GRIFFIN		0%	02/05/04 15:00:47	Area1 30/30	02/05/04 15:15:25
├JONESB		0%	02/05/04 15:01:46	Area1 22/22	02/05/04 15:15:30
├WANSLEY		0%	02/05/04 15:02:20	Area1 22/22	02/05/04 15:15:30
└Temp		0%	10/07/03 08:22:54		
COM1	T	0%			
└Modem1	O	7%			
├CUMMINGS		9% (1)	02/05/04 15:01:30	Area1 0/0	02/05/04 16:00:25
├SNEADS		3%	02/05/04 15:02:36	Area1 744/744	02/05/04 16:00:25
├ALAPAHA		14% (1)	02/05/04 15:07:53	Area1 0/0	02/05/04 15:22:53
├ALMA		0%	02/05/04 14:13:12	Area1 69/69	02/05/04 15:00:30
├ARLINGT		3%	02/05/04 14:13:50	Area1 66/66	02/05/04 15:00:30
├ATTAPUL		0%	02/05/04 14:31:09	Area1 120/120	02/05/04 15:00:30
├BLAIRSVI		15% (2)	02/05/04 14:48:14	Area1 0/0	02/05/04 15:03:14
├BOWEN		6%	02/05/04 14:41:47	Area1 96/96	02/05/04 15:00:30
├BRUNSW		4%	02/05/04 15:09:38	Area1 104/104	02/05/04 16:00:30
├BYRON		0%	02/05/04 14:32:59	Area1 135/135	02/05/04 15:00:30
├CAIRO		3%	02/05/04 15:04:53	Area1 44/44	02/05/04 15:30:29
├CALHOUN		0%	02/05/04 14:33:45	Area1 125/125	02/05/04 15:00:30
├CALLAWAY		0%	02/05/04 15:10:31	Area1 96/96	02/05/04 16:00:30
├CAMILLA		0%	02/05/04 14:12:23	Area2 36/36	02/05/04 15:00:30
├CORDELE		0%	02/05/04 14:16:57	Area1 66/66	02/05/04 15:00:30
├DAHLON		5%	02/05/04 15:05:39	Area1 52/52	02/05/04 15:30:29
├DAWSON		1%	02/05/04 14:16:19	Area1 66/66	02/05/04 15:00:30
├DEARING		0%	02/05/04 14:20:09	Area2 99/99	02/05/04 15:00:30
├DIXIE		0%	02/05/04 14:23:28	Area1 120/120	02/05/04 15:00:30
├DUBLIN		3%	02/05/04 14:22:47	Area1 44/44	02/05/04 15:00:30
├EATONTON		0%	02/05/04 14:24:08	Area1 120/120	02/05/04 15:00:30
├ELBERTON		8%	02/05/04 14:34:39	Area1 192/192	02/05/04 15:00:30
├ELLIJAY		0%	02/05/04 14:24:48	Area1 120/120	02/05/04 15:00:30
├FLOYD		8%	02/05/04 14:44:44	Area1 78/78	02/05/04 15:00:30
├FTVALLEY		9%	02/05/04 14:51:39	Area1 220/220	02/05/04 15:00:30
├GEORGETO		1%	02/05/04 14:14:28	Area1 44/44	02/05/04 15:00:30
├HOMERV		0%	02/05/04 15:04:03	Area1 44/44	02/05/04 15:30:28

Georgia Automated Environmental Monitoring Network

www.GeorgiaWeather.net

The Georgia Automated Environmental Monitoring Network was established in 1991 by the College of Agricultural and Environmental Sciences of the University of Georgia. The objective of the AEMN is to collect reliable weather information for agricultural and environmental applications. Each station monitors air temperature, relative humidity, rainfall, solar radiation, wind speed, wind direction, soil temperature at 2, 4, and 8 inch depths, atmospheric pressure, and soil moisture every 1 second. Data are summarized at 15 minute intervals and at midnight a daily summary is calculated. A microcomputer at the Georgia Experiment Station initiates telephone calls to each station periodically and downloads the recorded data. The data are processed immediately and disseminated via the world wide web (www.Georgiaweather.net). Click on a site below to obtain local weather and related information.

Warning! Please note that the web address http://www.griffin.peachnet.edu/bae will be discontinued. Please check your bookmark and change to www.Georgiaweather.net or www.griffin.uga.edu/aemn if needed.

24-hour graphical display for current conditions. See example for Covington, Georgia UPDATE!!

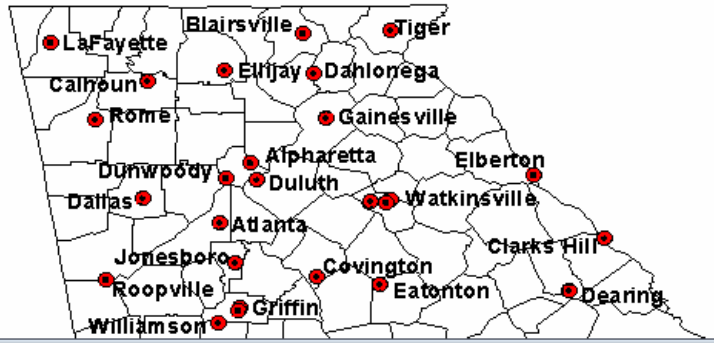
Frances spawned highest winds and Jeanne, the most rain new

Hurricane highlights documented new ...more news

Position: Agrometeorologist/Agroclimatologist, Hydroclimatologist/Hydrologist, Crop Modeler

Recent new stations: Tiger, Sasser, Clarks Hill. new

Select a Site on the Map



Simple Applications & Calculators

- Heat Index/Wind Chill (humans & livestock)
- *WBGT – Wet Bulb Globe Temperature = Heat stress index* (humans & livestock)
- Degree Days
- Chilling Hours
- Water Balance Calculator
- Heating Degree Days
- Cooling Degree Days
- Rainfall Calculator
- Average Temperature Calculator
- Soil Temperature Calculator

Georgia Weather

AEMN Home

Stations

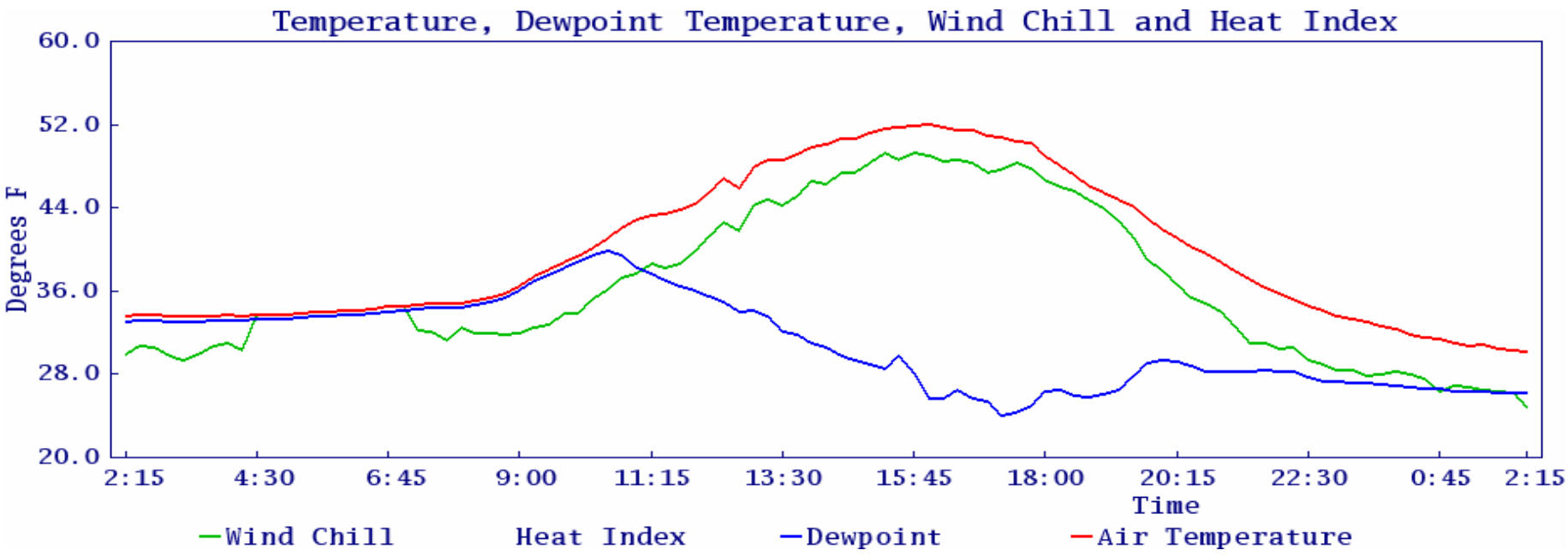
Alapaha
Albany
Alma
Alpharetta
Arlington
Atlanta
Attapulgus
Blairsville
Brunswick
Byron
Cairo
Calhoun
Camilla
Clarks Hill new
Cordele
Covington
Dahlonega
Dallas
Dawson
Dawson-HHERC
Dearing
Dixie

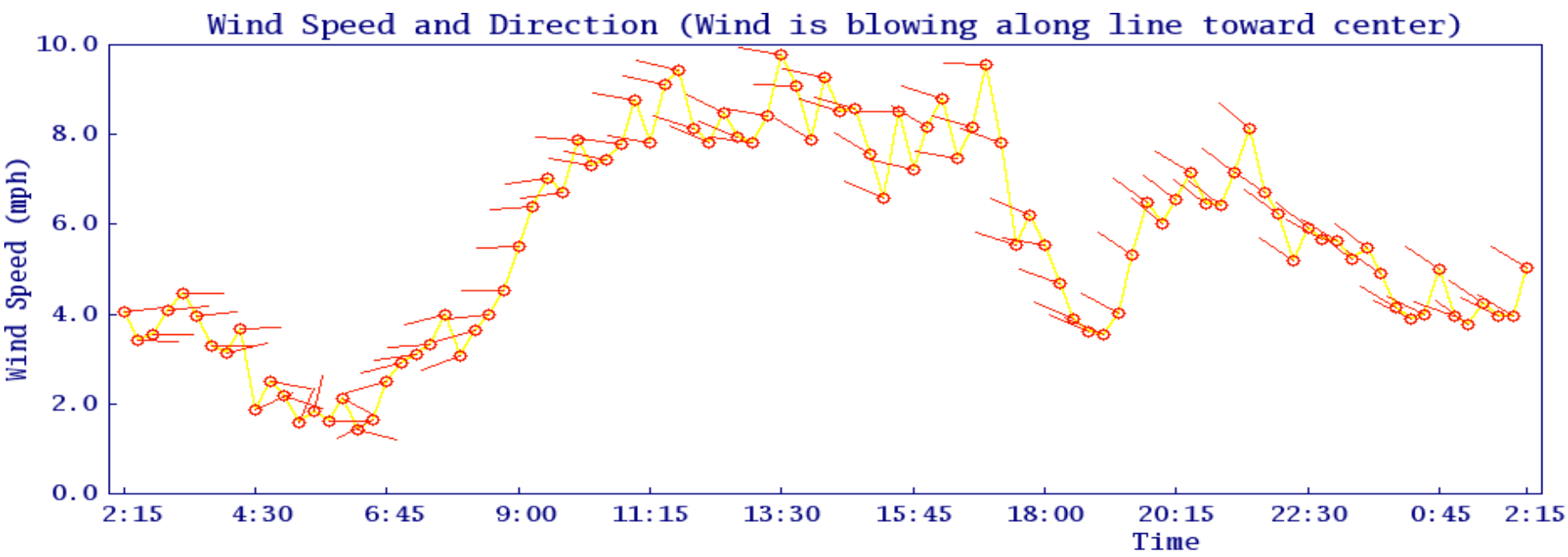
Georgia Experiment Station
The University of Georgia
Griffin, Spalding County, GA

Warning: Please note that the web address www.griffin.peachnet.edu/bae will be discontinued. Please check your bookmark and change to www.Georgiaweather.net or www.griffin.uga.edu/aemn if needed.

- Current Conditions UPDATE!
- Graph Current Conditions UPDATE!
- Yesterday's Conditions
- 31-Day Summary
- Historical Data
- Climate Data
- Today's local forecast
- Temperature Prediction
- Minimum Temperature Estimator
- Sunrise and Sunset Times and Moon Phases
- Background Information new
- Rainfall Calculator
- Average Temperature Calculator
- Soil Temperature Calculator
- Degree Day Calculator
- Chilling Hours Calculator
- Water Balance Calculator
- Heating Degree Day Calculator
- Cooling Degree Day Calculator
- Simulation Model Application

All units will be in US system. Click the button to use Metric units


Temperature, Dewpoint Temperature, Wind Chill and Heat Index
Degrees F
60.0
52.0
44.0
36.0
28.0
20.0
2:15
4:30
6:45
9:00
11:15
13:30
15:45
18:00
20:15
22:30
0:45
2:15
Time
Wind Chill
Heat Index
Dewpoint
Air Temperature


Wind Speed and Direction (Wind is blowing along line toward center)
Wind Speed (mph)
10.0
8.0
6.0
4.0
2.0
0.0
2:15
4:30
6:45
9:00
11:15
13:30
15:45
18:00
20:15
22:30
0:45
2:15
Time

FAWN

FAWN Homepage - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://fawn.ifas.ufl.edu/ Go Links

FAWN Florida Automated Weather Network

DATABASE : CLIMATE : TOOLS : FOCUS : NEWS : TOUR

UNIVERSITY OF FLORIDA IFAS EXTENSION

FAWN THANKS FOR THEIR SUPPORT

FAWN Focus
Our Sponsors

Latest Observations

Graph Weather Data

Archived Weather Data

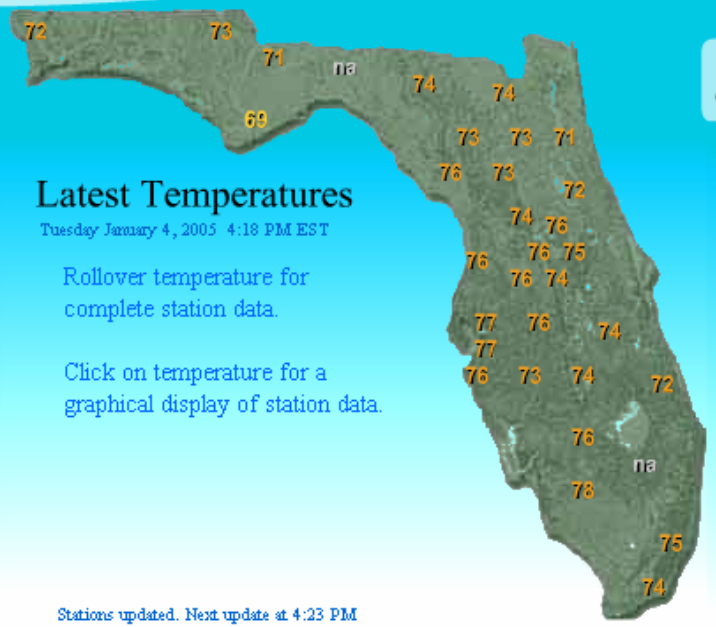
Management Tools

Latest Temperatures

Tuesday January 4, 2005 4:18 PM EST

Rollover temperature for complete station data.

Click on temperature for a graphical display of station data.



Stations updated. Next update at 4:23 PM

******* BELLE GLADE station will be offline for repairs until mid-January *******

Click for location Info...
Toll-free in-state telephone access (866)754-5732

We site suggestions, questions? Email FAWN's staff!
Read the Terms of use under which this service is provided to you.
Copyright© 2004 UF/IFAS Last Modified: 01/04/2005 16:18:30

Internet

start | Resource - Patt... | FTVALLEY - Wor... | weather | 20050108 ANN ... | FAWN Homepag... | Windows Print S... | 4:21 PM

Florida Automated Weather Network: Latest Observations - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://fawn.ifas.ufl.edu/scripts/flash_latest.asp Go Links

UNIVERSITY OF FLORIDA
IFAS EXTENSION

FAWN Florida Automated Weather Network

FAWN THANKS

AgriLogic, Inc.

FOR THEIR SUPPORT

DATABASE | CLIMATE | TOOLS | FOCUS | NEWS | TOUR

Latest Observations

Select Stations

Location	Datetime (Eastern Standard Time)	Temperature (F) Air 2ft	Air 6ft	Air 30ft	Dew* 30ft	Soil 4in	RH (pct)	Rain (in)	Wind Dir. (deg)	Wind Speed (mph)	Solar Rad. (Wm2)
ALACHUA	TUE 1/4/2005 4:15 PM	75.5	74	74.2	55.8	63.1	53	0	171	4.27	233
APOPKA	TUE 1/4/2005 4:15 PM	76.4	75.2	75.3	56.9	69.9	53	0	75	5.82	117
AVALON	TUE 1/4/2005 4:15 PM	74.4	74.3	74.2	57.2	72.9	55	0	72	4.56	79
BALM	TUE 1/4/2005 4:15 PM	79	77.8	76.8	59.6	80.5	54	0	82	7.78	241
BELLE GLADE2	WED 11/17/2004 7:45 AM	63.1	62.4	62.3	62.1	68.9	99	0	0	0	0
BRADENTON	TUE 1/4/2005 4:15 PM	76.6	76.8	76.2	58.8	66.7	54	0	134	4.58	133
BRONSON	TUE 1/4/2005 4:15 PM	79.4	76.1	74.8	57	68.3	52	0	92	6.17	230
BROOKSVILLE	TUE 1/4/2005 4:15 PM	76.8	76	75.3	56	62.2	50	0	76	5.46	195
CARRABELLE	TUE 1/4/2005 4:15 PM	73.2	69.6	69.6	59.3	61.4	70	0	116	1.96	141
CITRA	TUE 1/4/2005 4:15 PM	73.4	73.6	72.9	59	69.8	60	0	21	3.04	66
DOVER	TUE 1/4/2005 4:15 PM	79	77.2	76.9	59.3	62.7	54	0	102	3.29	272
FORT LAUDERDALE	TUE 1/4/2005 4:15 PM	74.7	75	74.3	62.1	72	64	0	95	11.65	144
FT PIERCE	TUE 1/4/2005 4:15 PM	72.7	72.5	72.6	64.5	68.8	76	0	105	8.15	98
HASTINGS	TUE 1/4/2005 4:00 PM	71.7	71.1	71.1	61.2	65	71	0	84	6.76	131
HOMESTEAD	TUE 1/4/2005 4:15 PM	74.9	74.8	73.6	62.4	75.4	65	0	105	10.98	166

Items with an asterisk(*) are calculated values. They are not measured directly by FAWN.

Internet

start | Resource - Patt... | FTVALLEY - Wor... | weather | 20050108 ANN ... | Florida Automat... | Windows Print S... | 4:22 PM

Florida Automated Weather Network: Graphing Applet - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://fawn.ifas.ufl.edu/graph/

DATABASE | CLIMATE | TOOLS | FOCUS | NEWS | TOUR

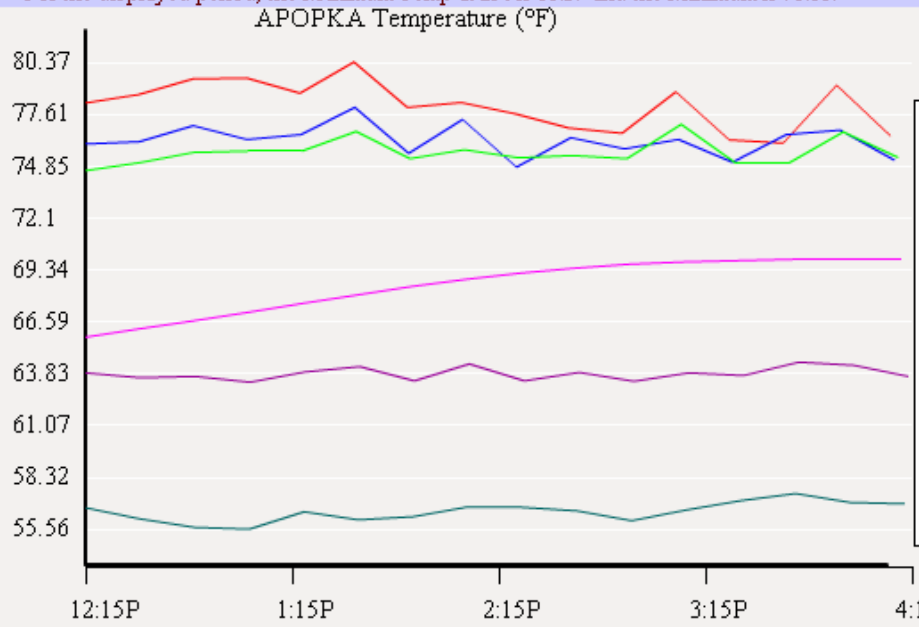
Station: APOPKA | Parameter: Temperature | Range: Last 4 Hours | Units: English

☑ Temp at 2 Ft ☑ Temp at 6 Ft ☑ Temp at 30 Ft ☑ Soil Temp ☑ Dew Point ☑ Wet Bulb Temp

Latest Readings

Temp at 2Ft: 76.44 Temp at 6Ft: 75.18 Temp at 30Ft: 75.31 Soil Temp: 69.93 Dew Point: 56.91

For the displayed period, the Maximum Temp at 2Ft is 80.37 and the Minimum is 76.08.



Temp at 2Ft

Time	Readings
Jan 4 12:30 PM	78.21
Jan 4 12:45 PM	78.66
Jan 4 1:00 PM	79.48
Jan 4 1:15 PM	79.52
Jan 4 1:30 PM	78.73
Jan 4 1:45 PM	80.37
Jan 4 2:00 PM	77.97
Jan 4 2:15 PM	78.22
Jan 4 2:30 PM	77.63
Jan 4 2:45 PM	76.87
Jan 4 3:00 PM	76.59
Jan 4 3:15 PM	78.78
Jan 4 3:30 PM	76.23
Jan 4 3:45 PM	76.08
Jan 4 4:00 PM	79.14
Jan 4 4:15 PM	76.44

Copyright © 2003 UF/IFAS
Read the Terms of use under which this service is provided to you.
Web site suggestions, questions? Email FAWN's staff!
Last Modified: *01/04/2005 16:23:20*

Click for Location Info...

Toll-free in-state telephone access
(866) 754-5732

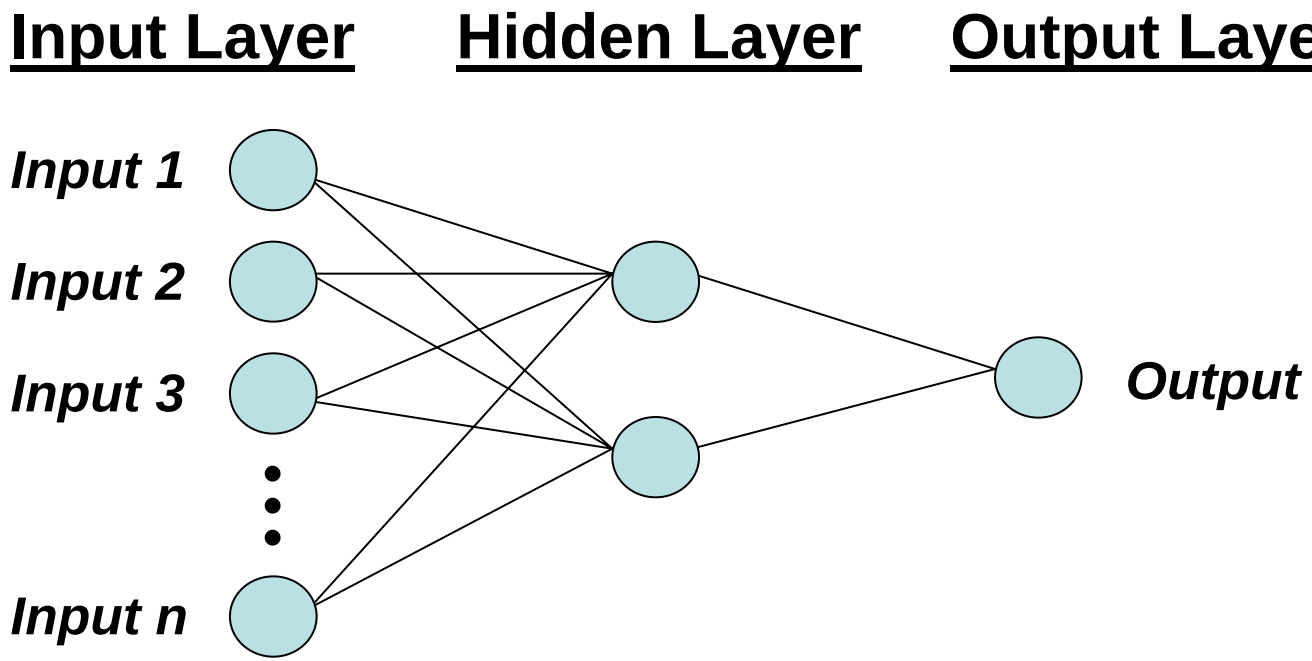
Done | Internet

start | Resource - Patt... | FTVALLEY - Wor... | weather | 20050108 ANN ... | Florida Automat... | Windows Print S... | 4:24 PM

Approach

- Develop web-based, frost-warning Decision Support System (DSS) which utilizes current and prior weather data
- Use Artificial Neural Networks (ANNs) to develop the algorithms used in the DSS

Standard Three-Layer Back-Propagation Artificial Neural Network

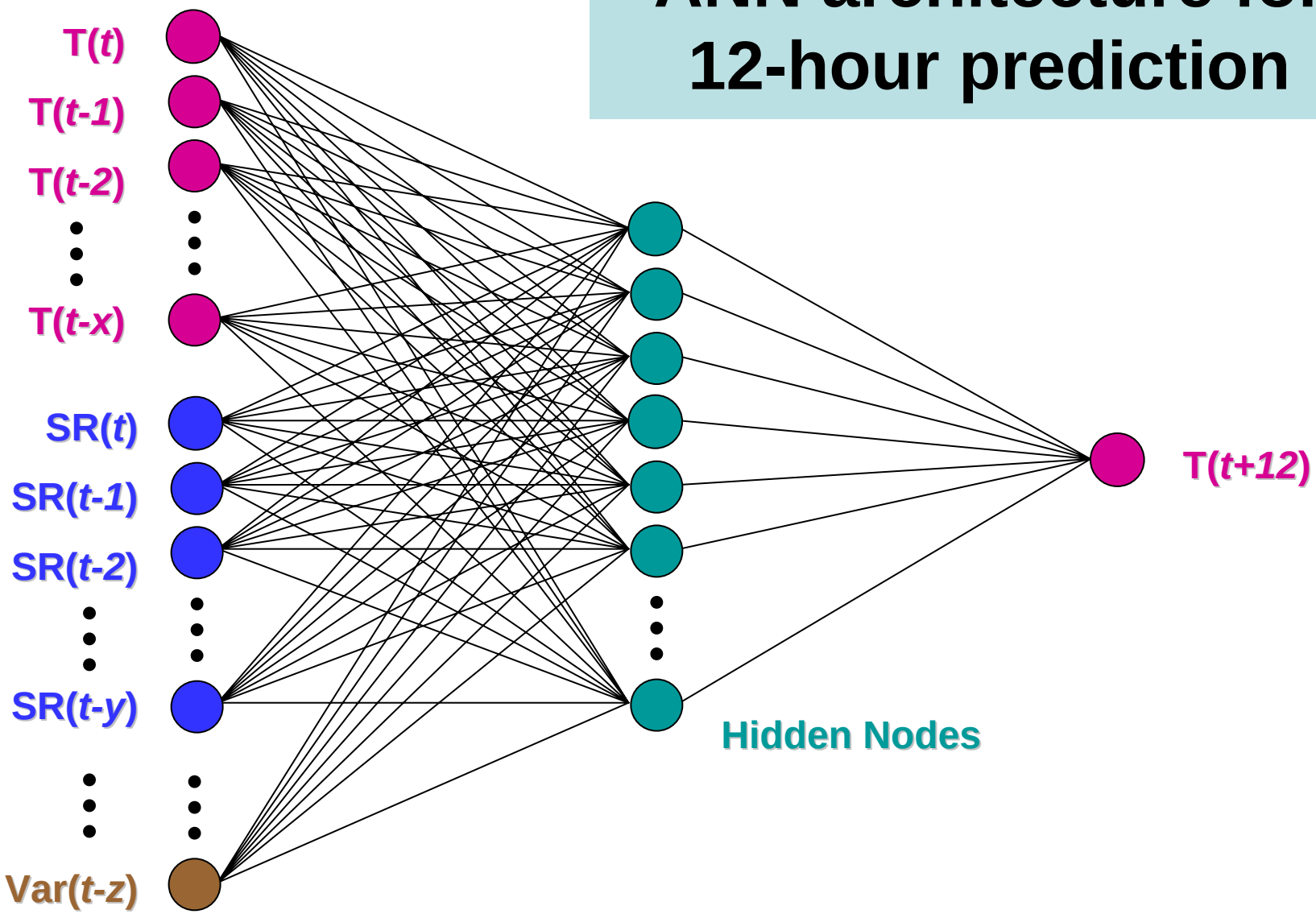


Pattern	Input 1	Input 2	Input 3	…	Input n	Output
1	-	-	-	…	-	-
2	-	-	-	…	-	-
⋮						

Temperature	Rel. Humidity	Wind	Solar Radiation	Rainfall	MAE °C *
X					1.41
X	X				1.19
X		X			1.34
X			X		1.35
X				X	1.44
X	X	X			1.15
X	X		X		1.17
X	X			X	1.21
X	X	X	X		1.12
X	X	X		X	1.16
X	X	X	X	X	1.14

*** Ft. Valley evaluation data set, Four-hour temperature prediction**

ANN architecture for 12-hour prediction



Two General Categories of ANNs

1) Estimation of a numerical value

2) Classification

We have pursued both types of ANNs in our research project.

A. Jain, M.S. Artificial Intelligence, UGA

- Developed estimation ANNs to predict air temperature in hourly increments from one to twelve hours in the future based on current and prior weather data.

R. Ramyaa, M.S. Artificial Intelligence, UGA

- Developed classification ANNs to predict if frost occurs in a subsequent four, eight, or twelve-hour period.

B.A. Smith, M.S. Artificial Intelligence, UGA (expected 2005)

- Developed software to allow the automatic training of large numbers of temperature-predicting ANNs using larger data sets.

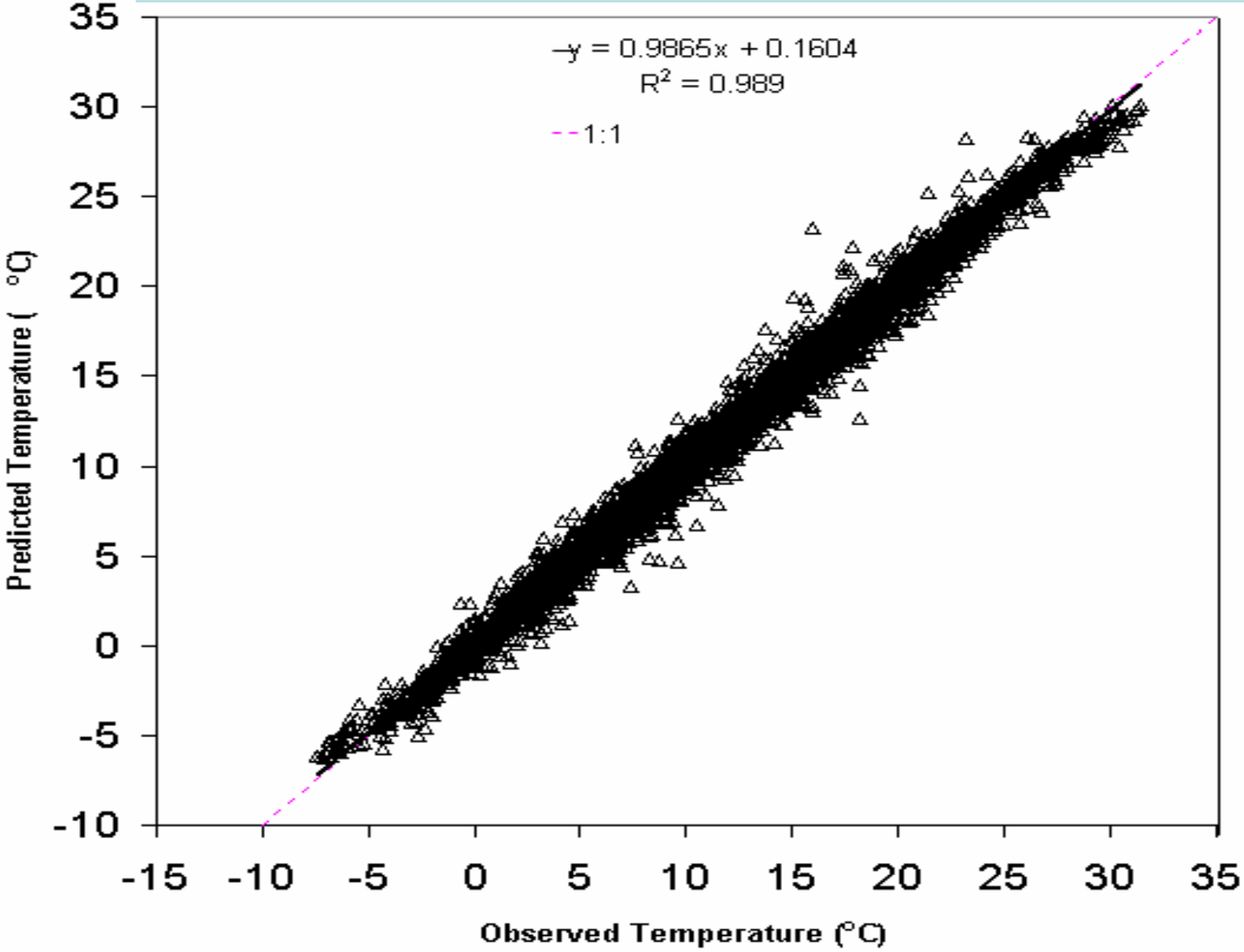
Initial Study Locations

- Blairsville – North Georgia Mountains
- Fort Valley – Central Georgia
- Alma – South Georgia

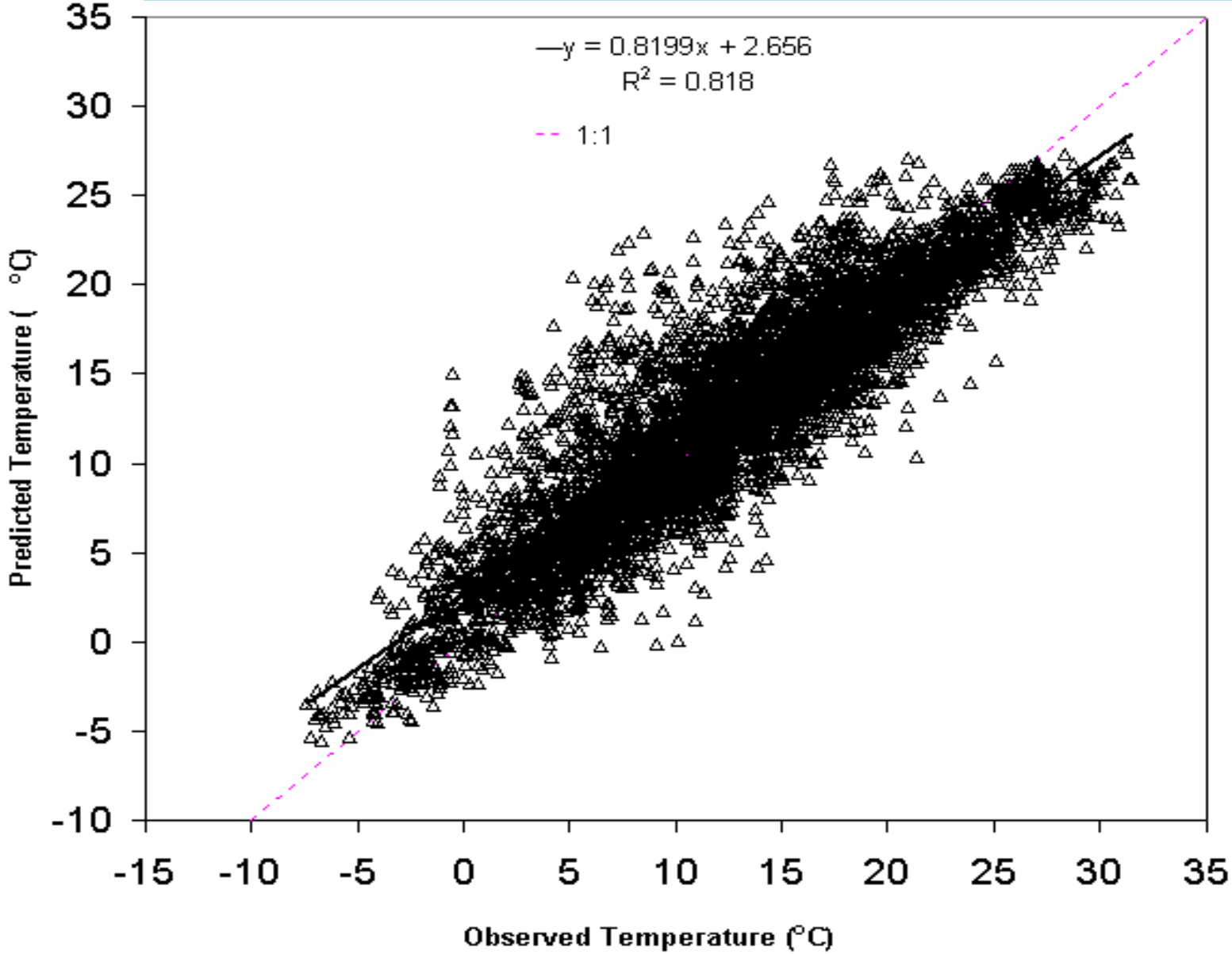
Weather Data

- Model Development: 1993-2000
- Model Evaluation: 2001-2003

Predicted and observed one-hour temperature predictions for Fort Valley, 2001 and 2002 data.



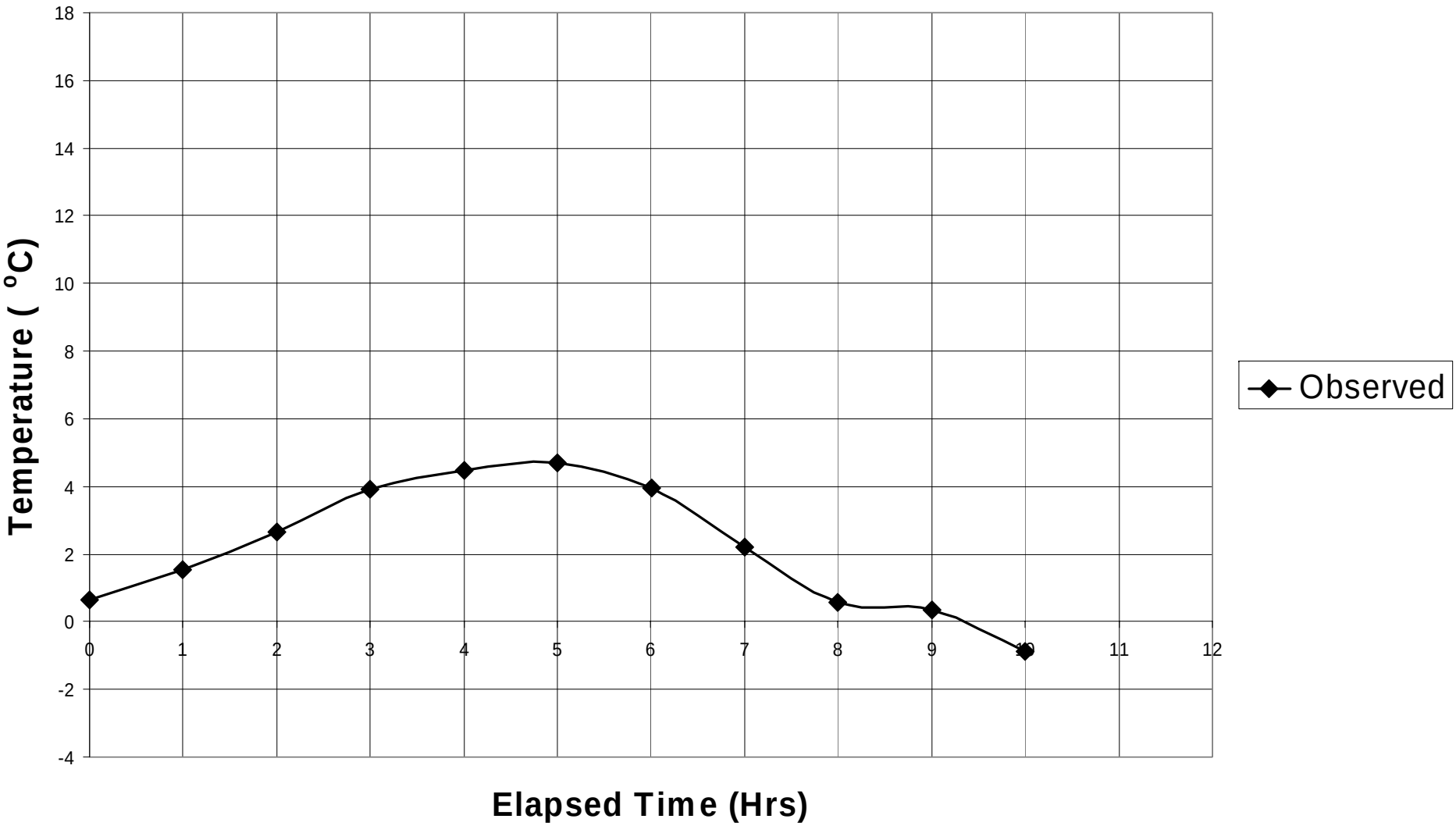
Predicted and observed twelve-hour temperature predictions for Fort Valley, 2001 and 2002 data.



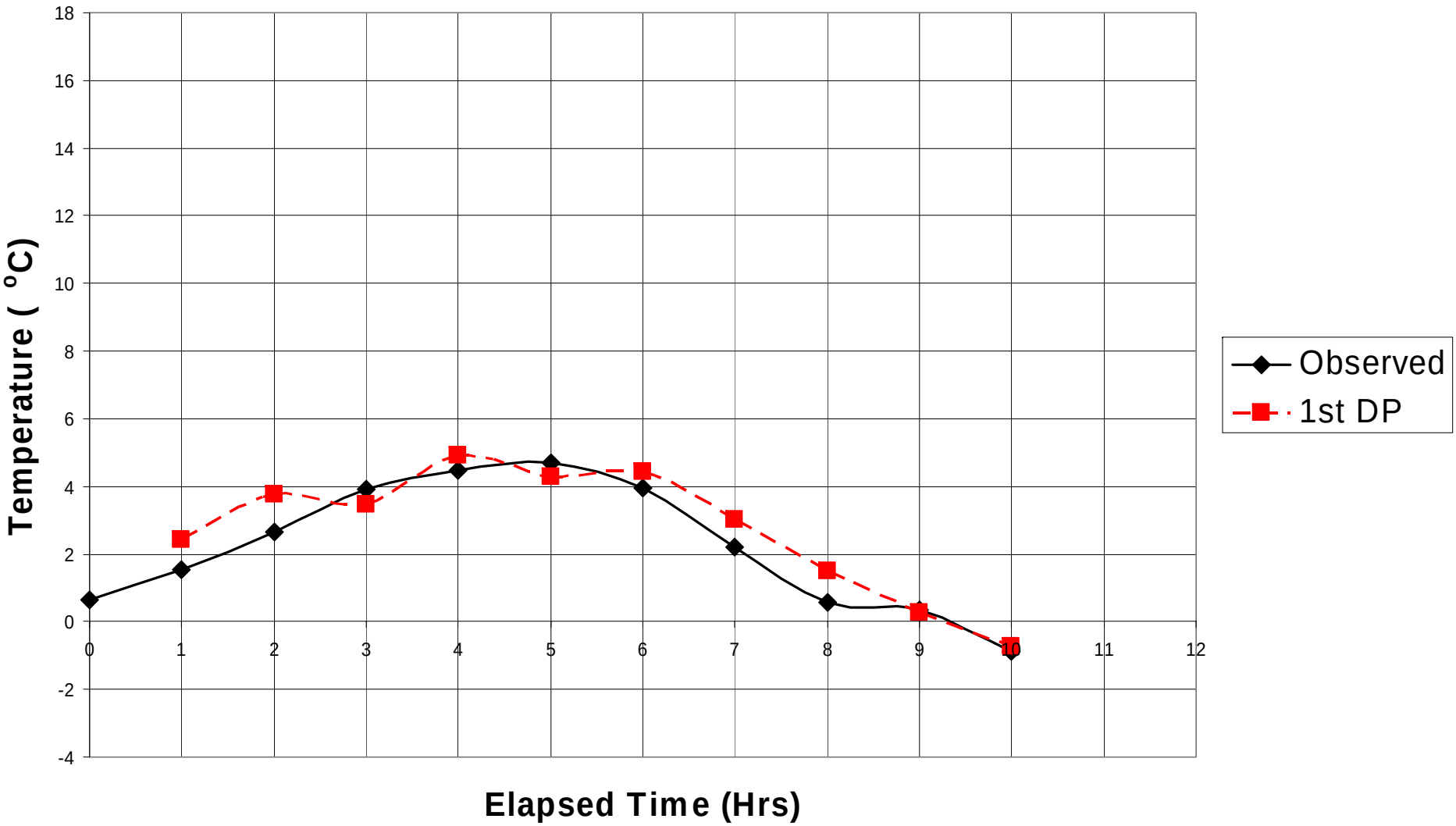
A Predicted Freeze Event

March 4, 2002

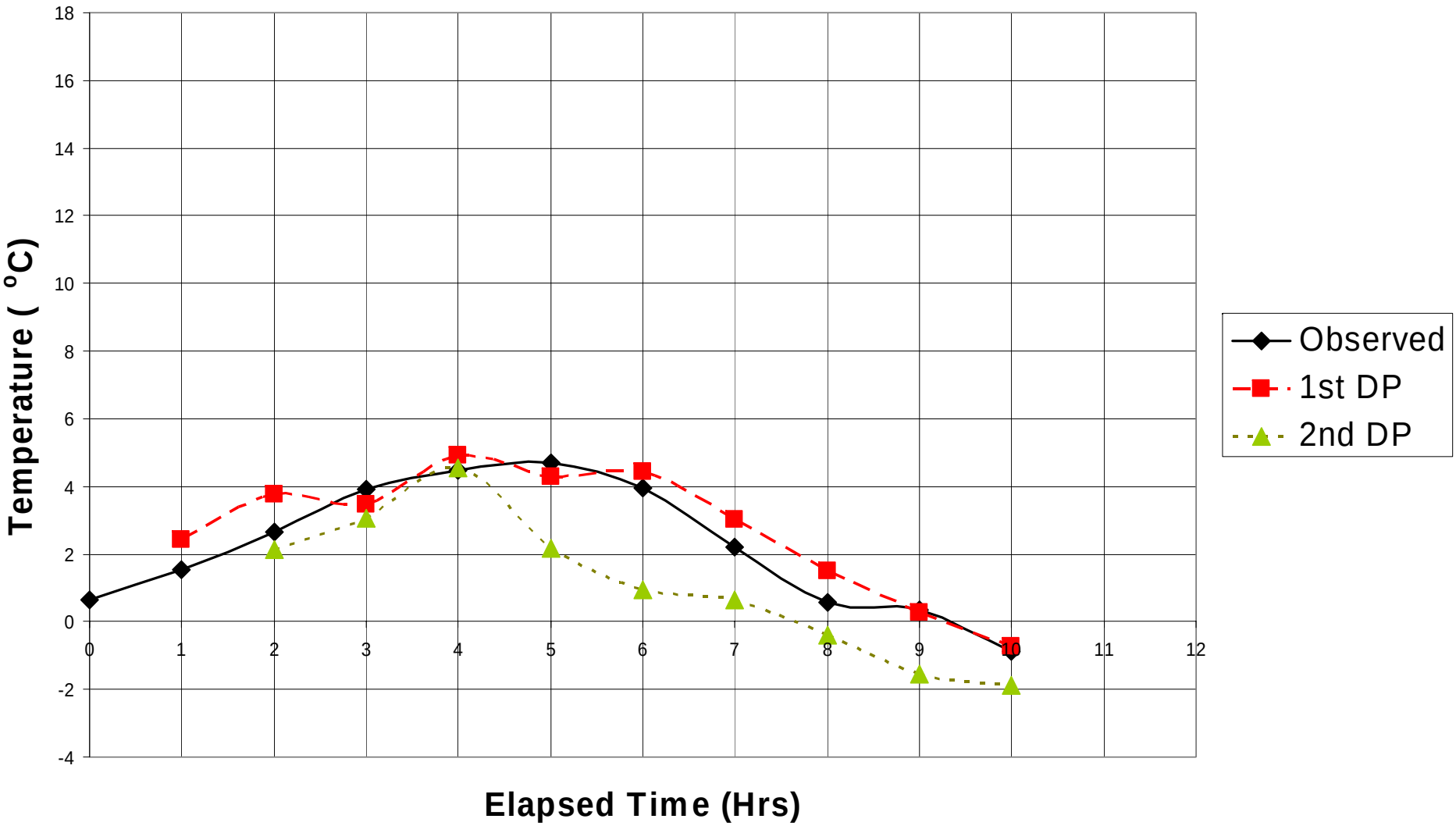
1200 hrs to 2200hrs



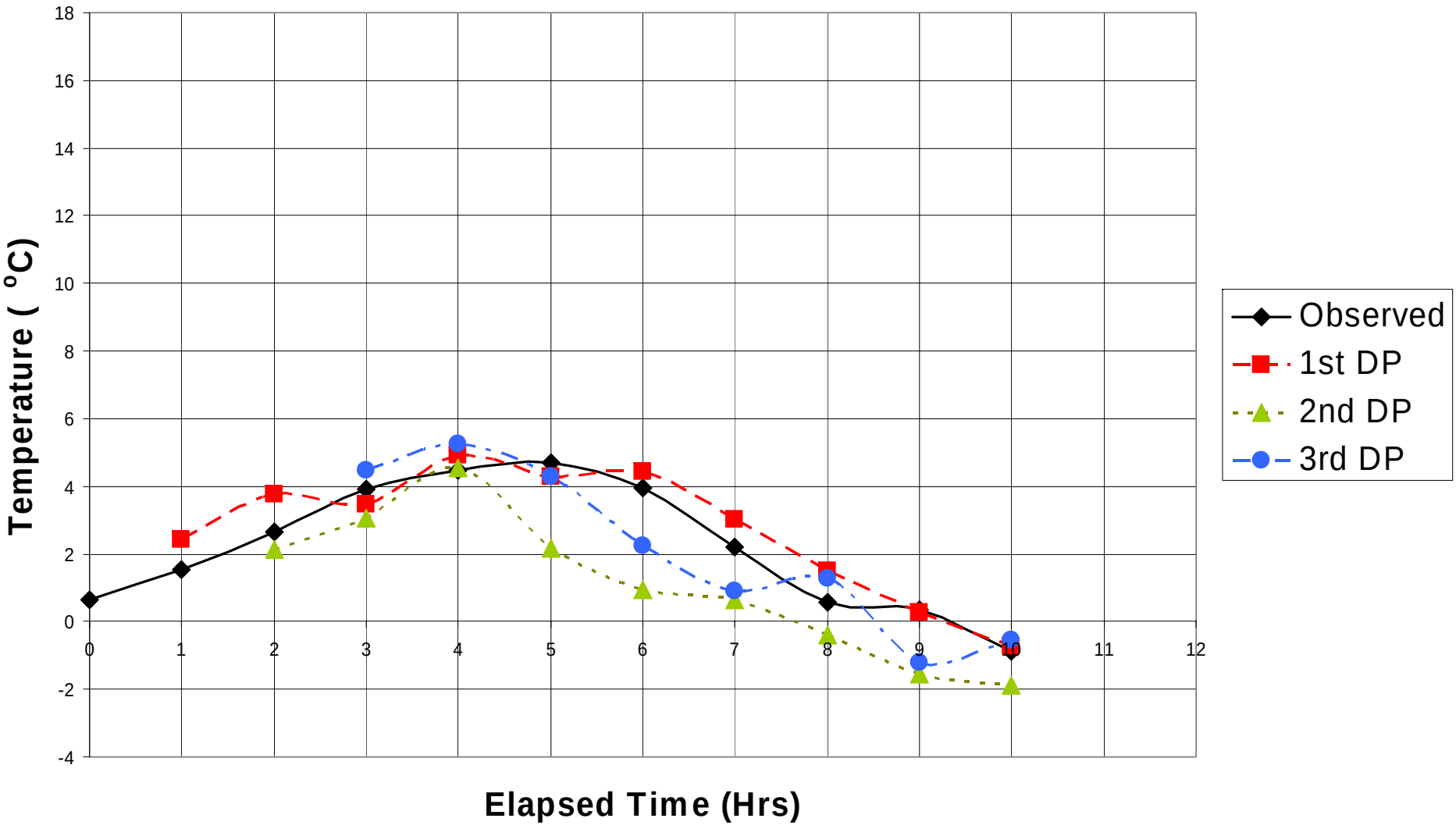
Observed temperatures on
March 4, 2002, 1200hrs to 2200hrs



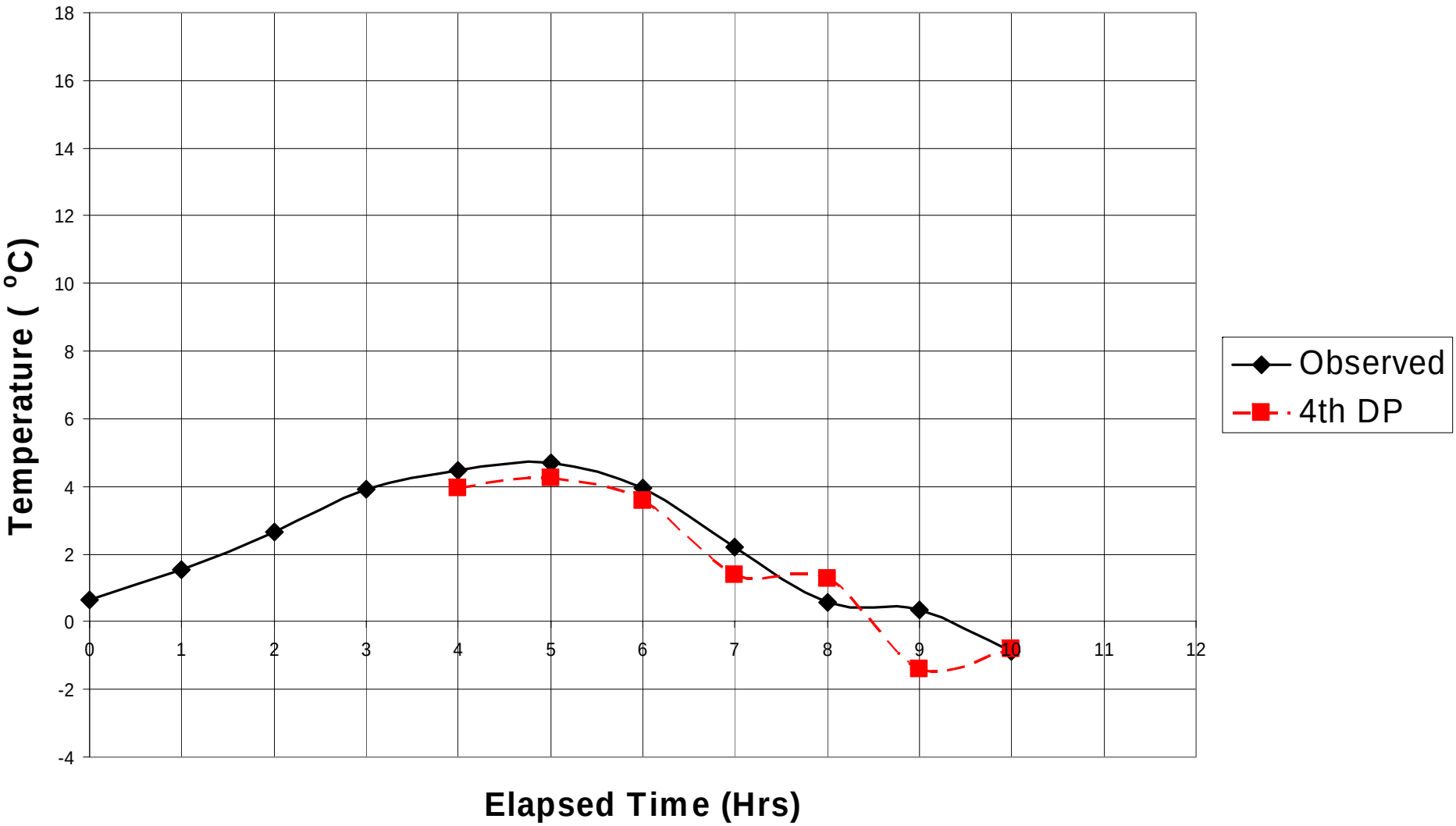
Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



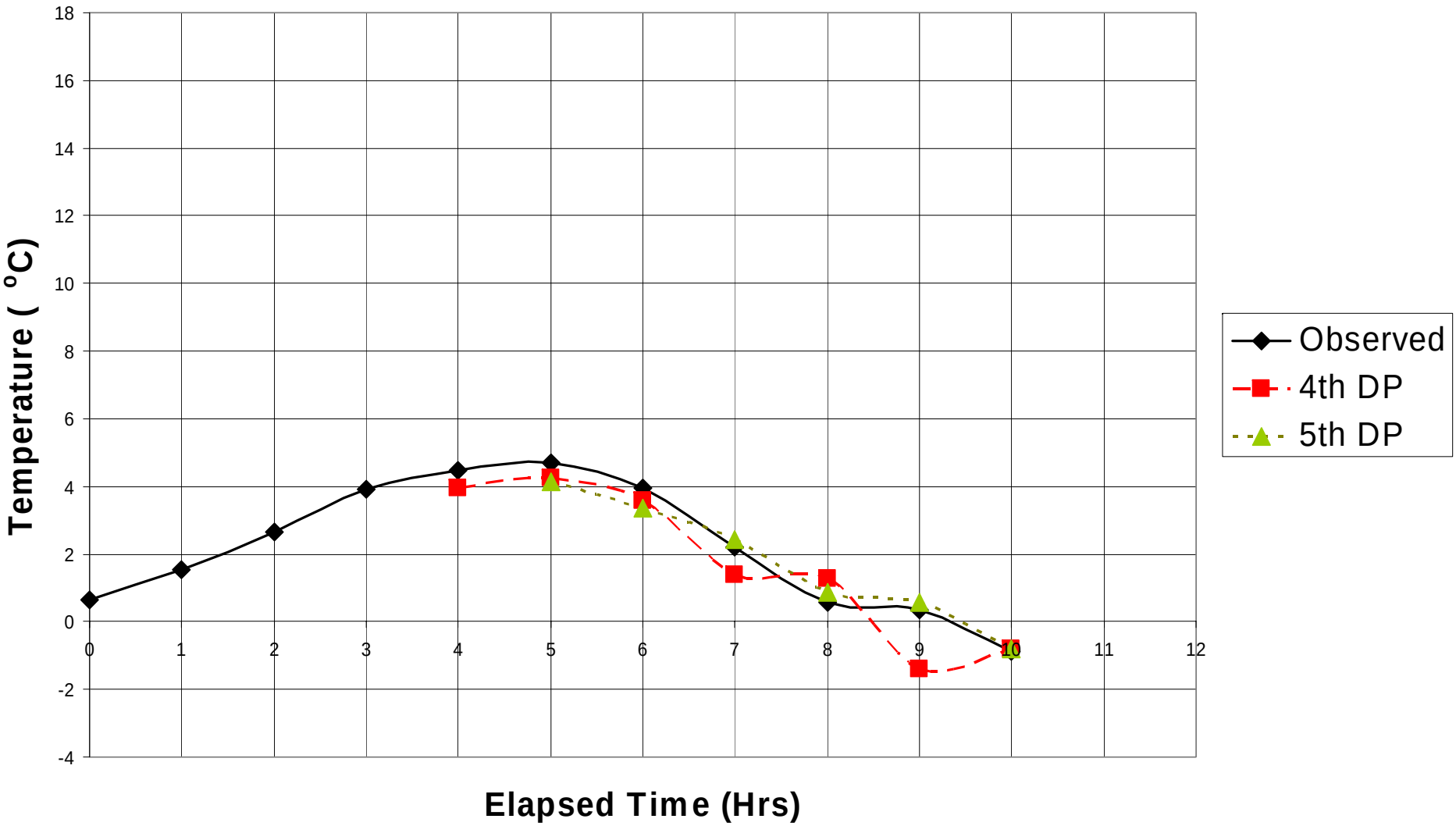
Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



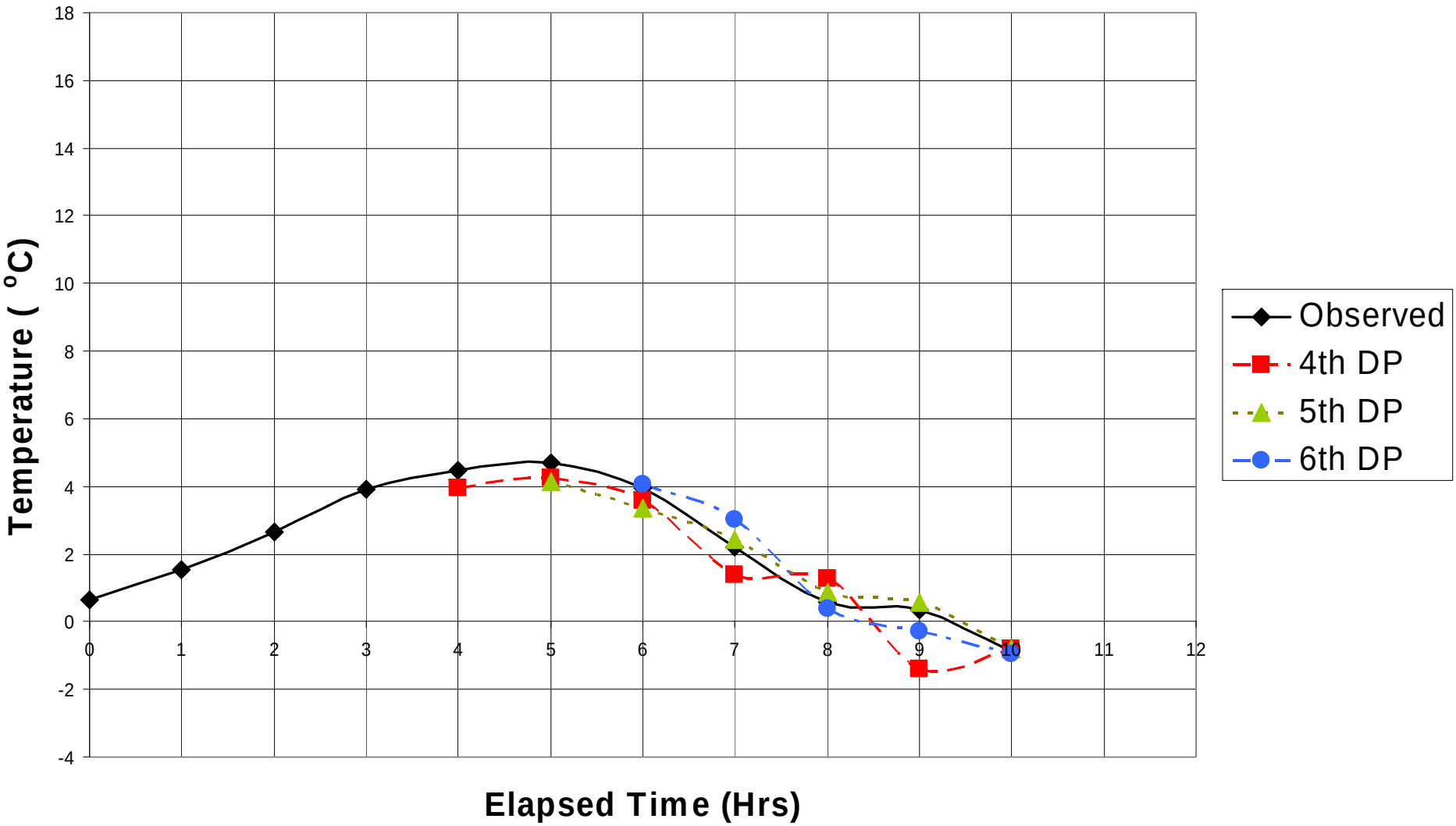
Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



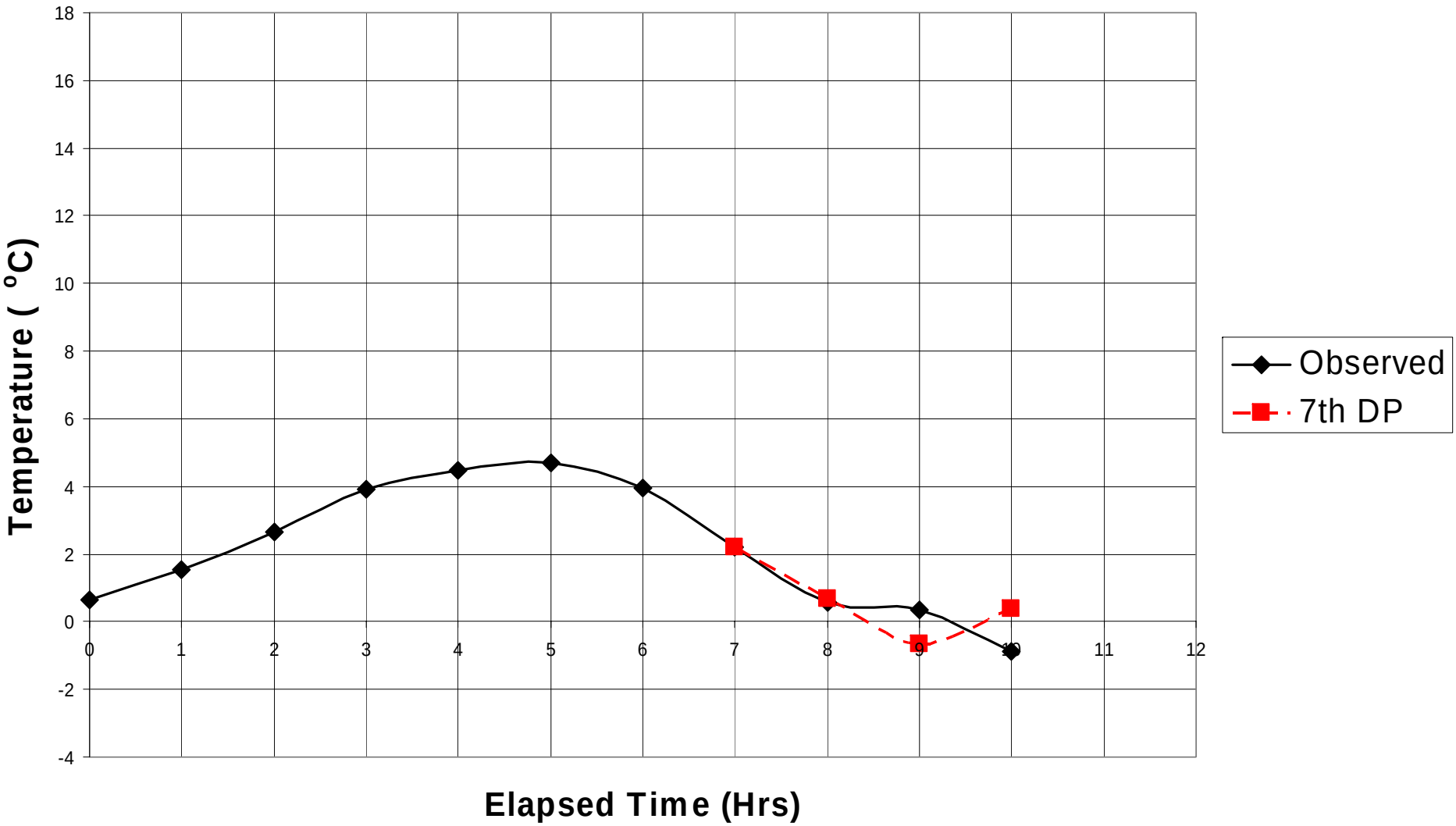
Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



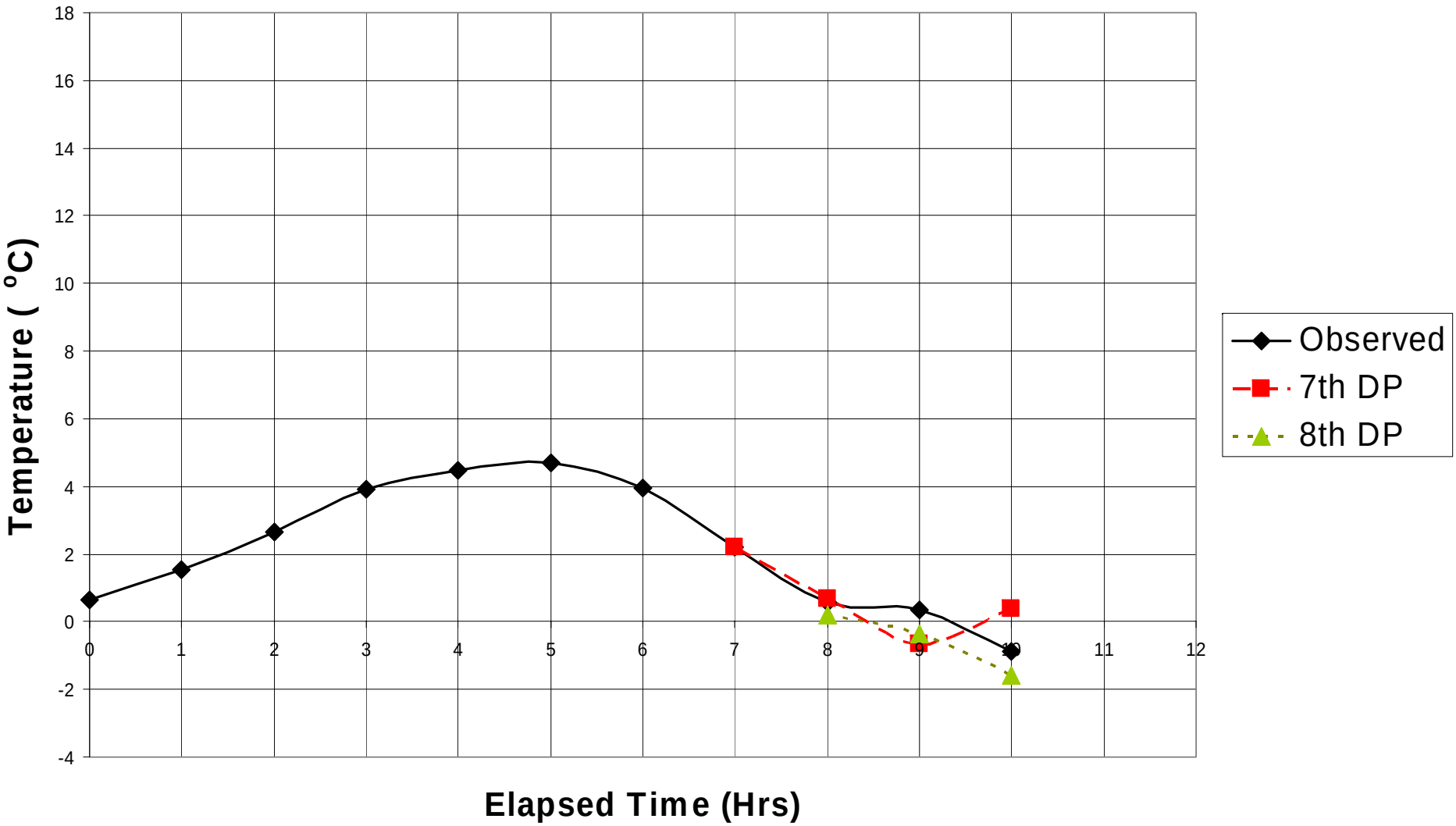
Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



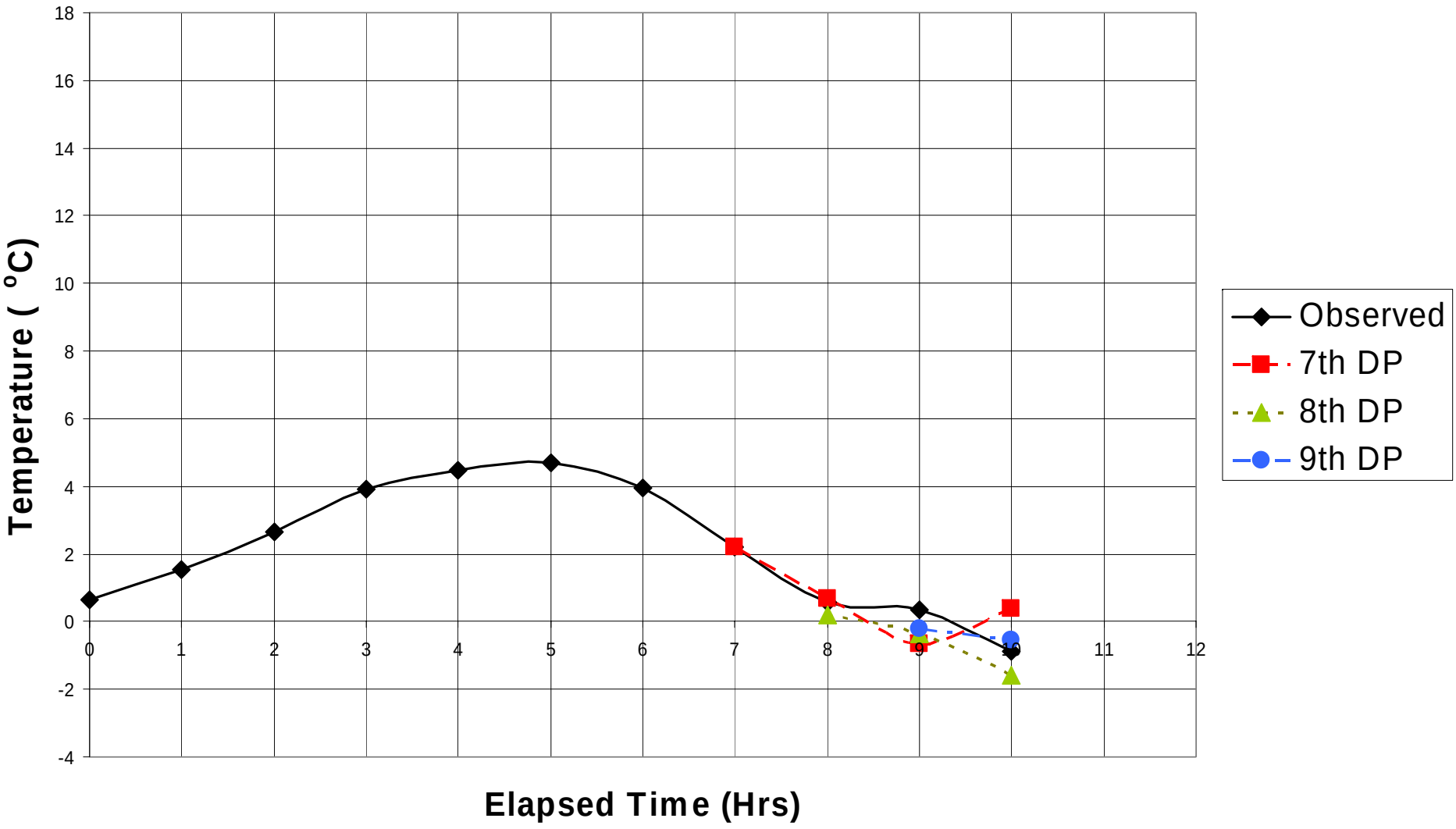
Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



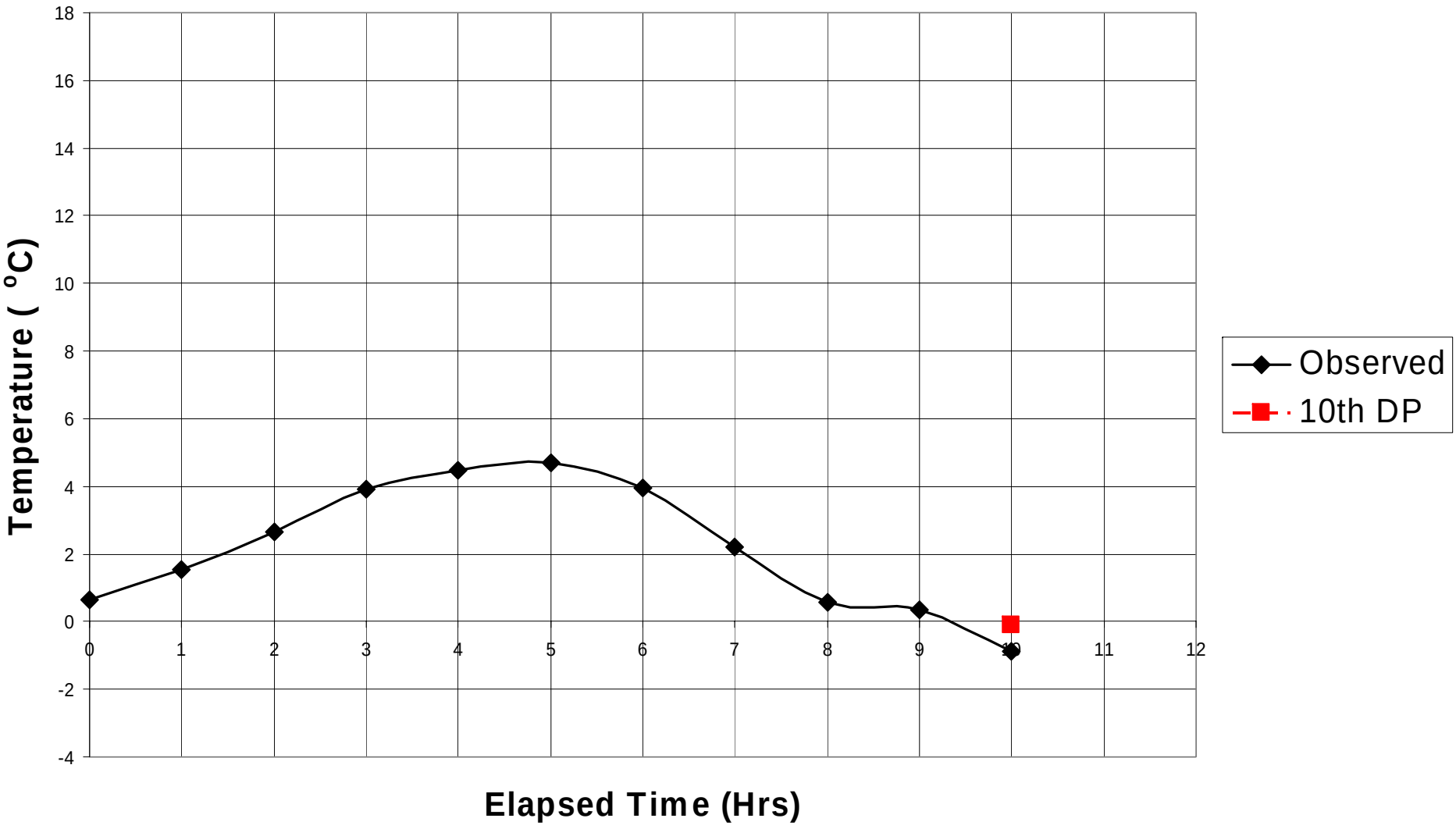
Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs



Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs

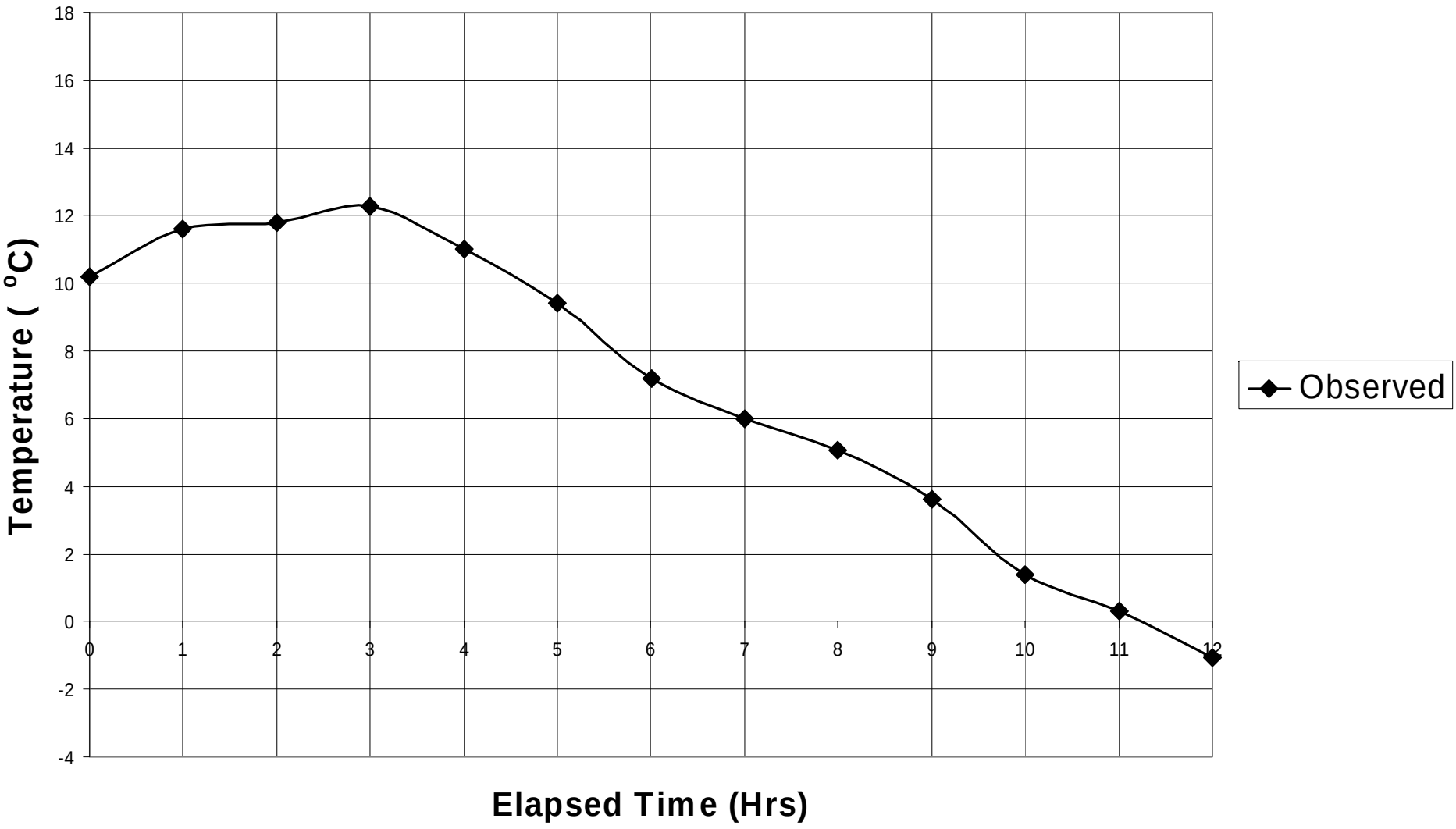


Predictions made from the Decision Points (DP),
March 4, 2002, 1200hrs to 2200hrs

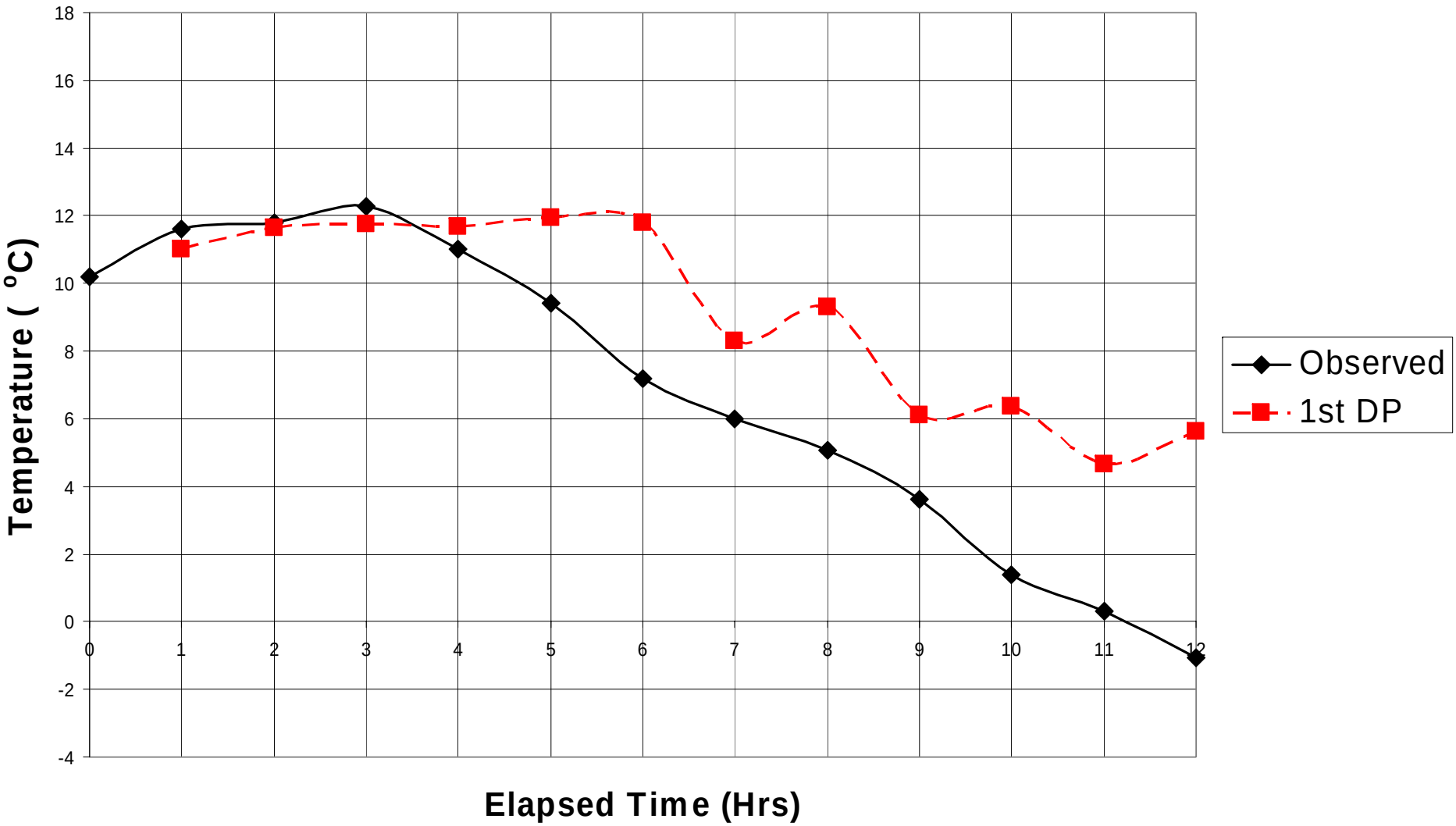
A Predicted Freeze Event

January 8, 2001

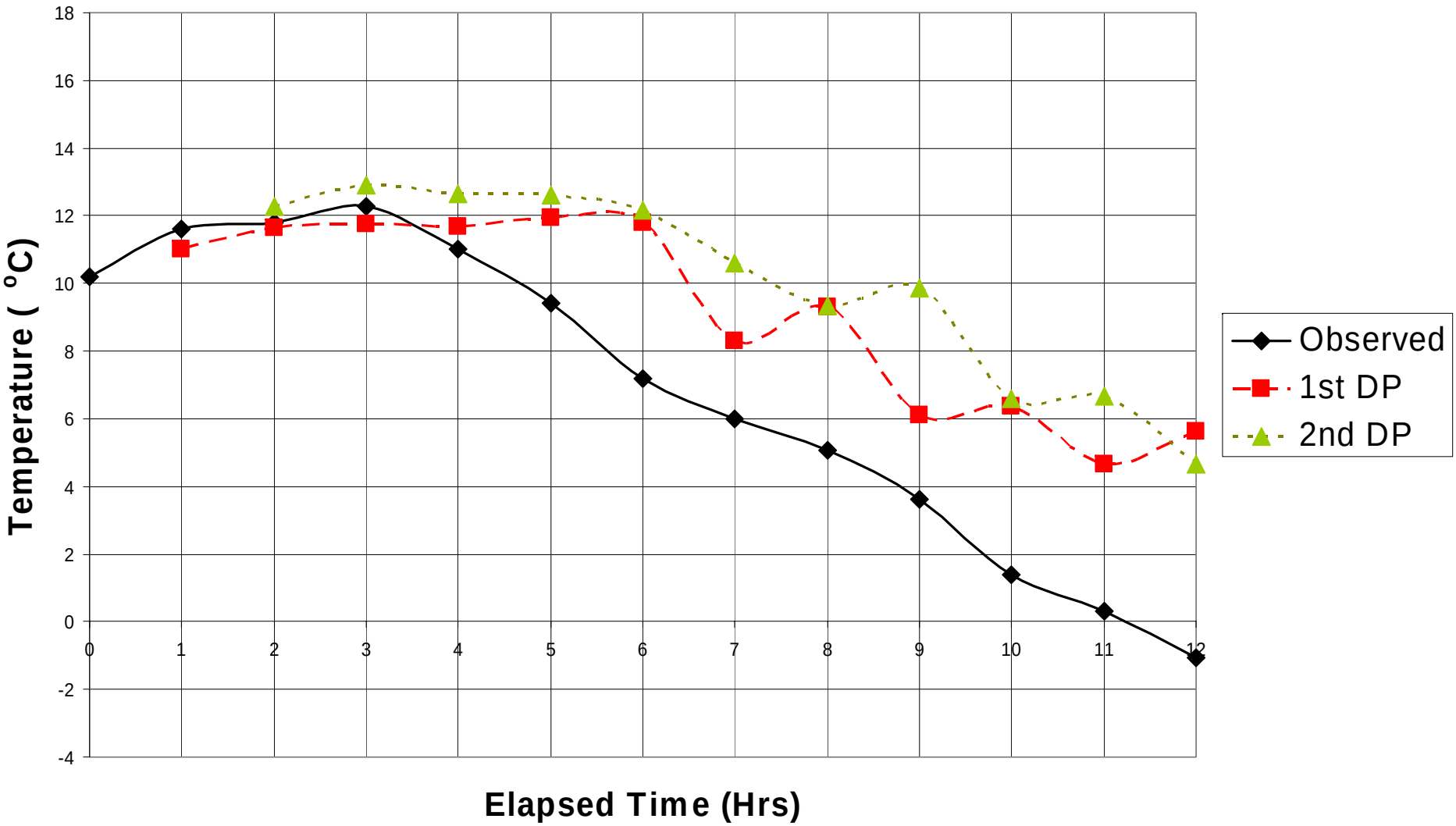
1200 hrs to 2400hrs



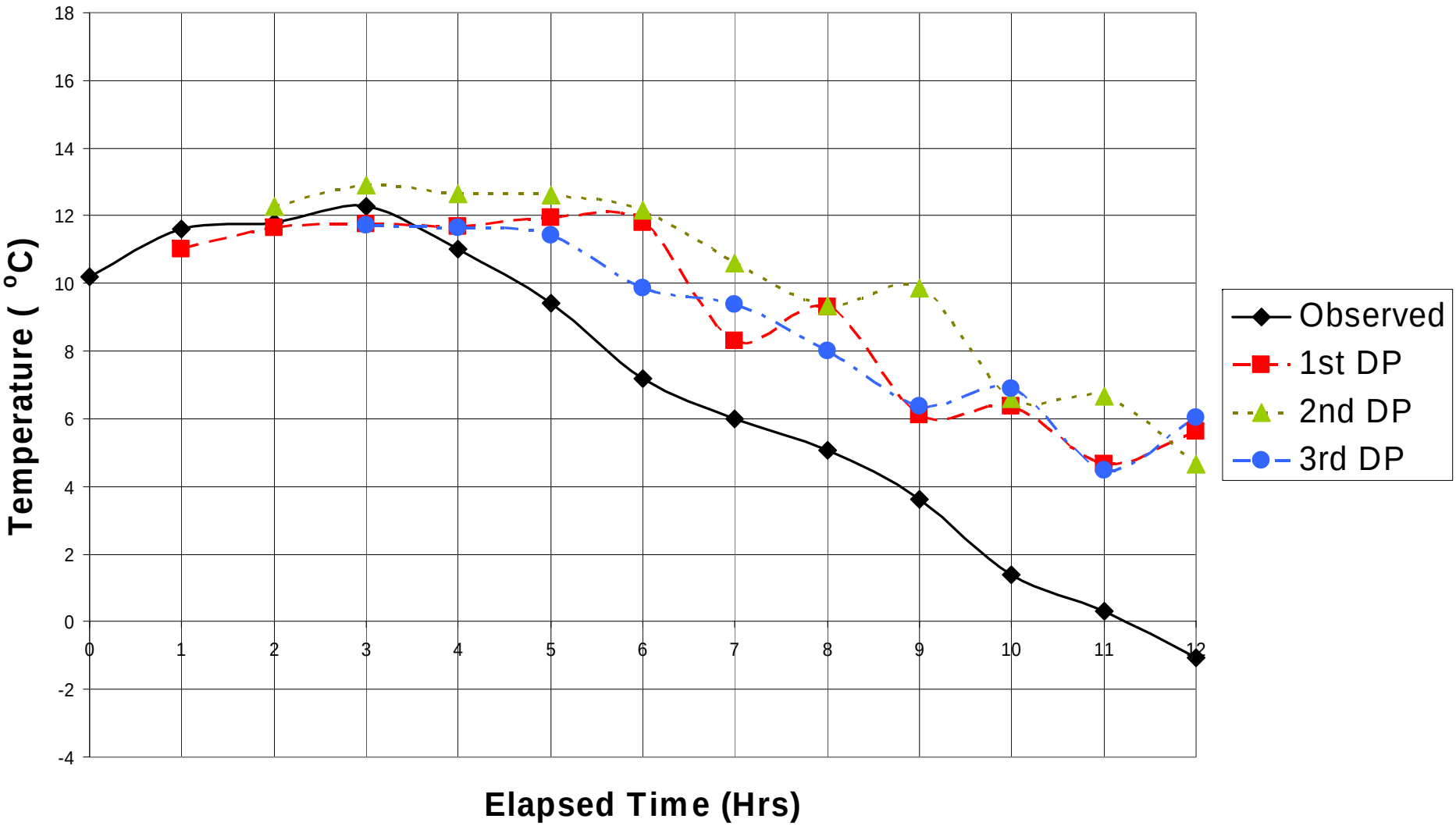
Observed temperatures on,
January 8, 2001, 1200hrs to 2400hrs



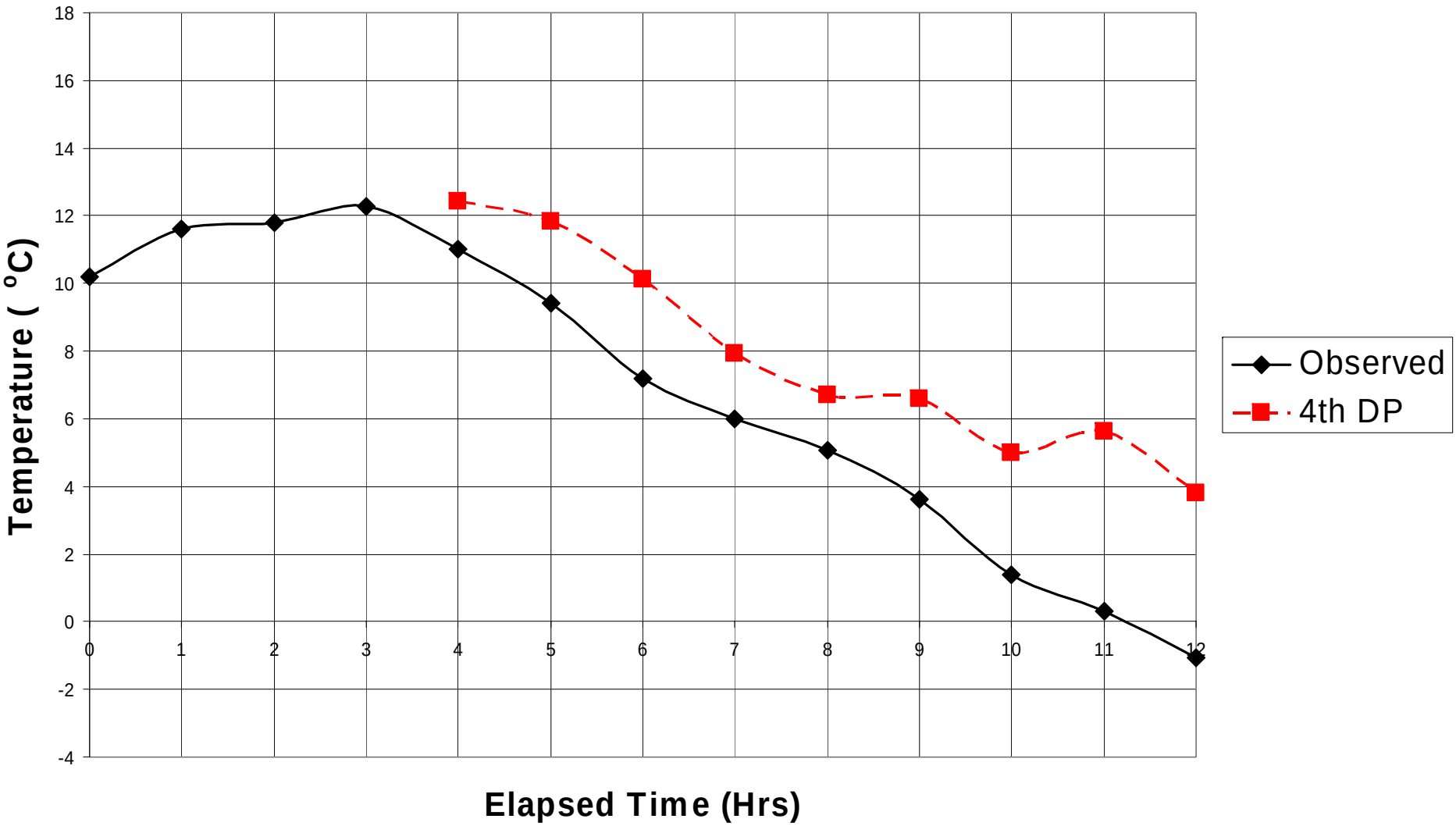
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



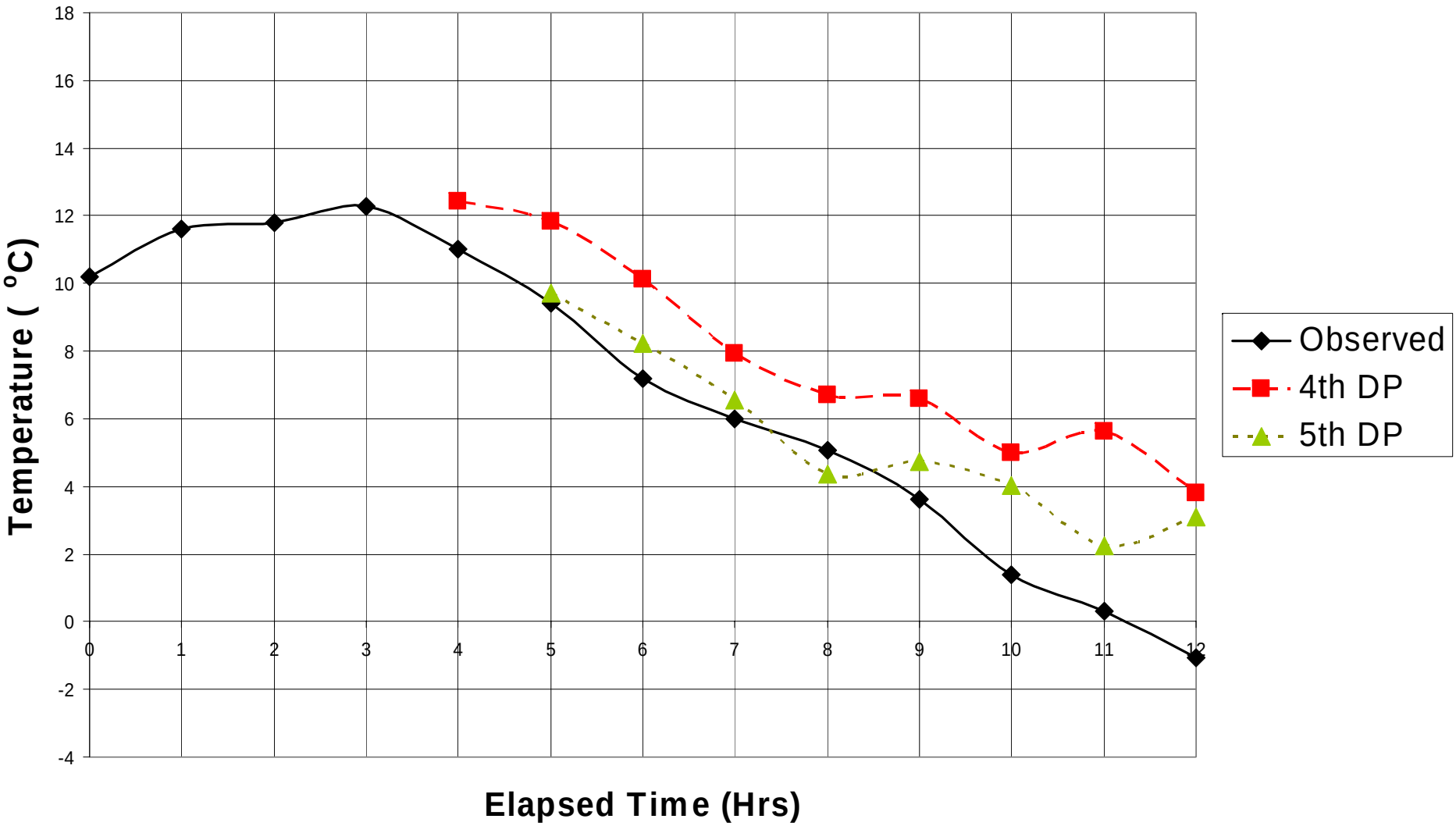
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



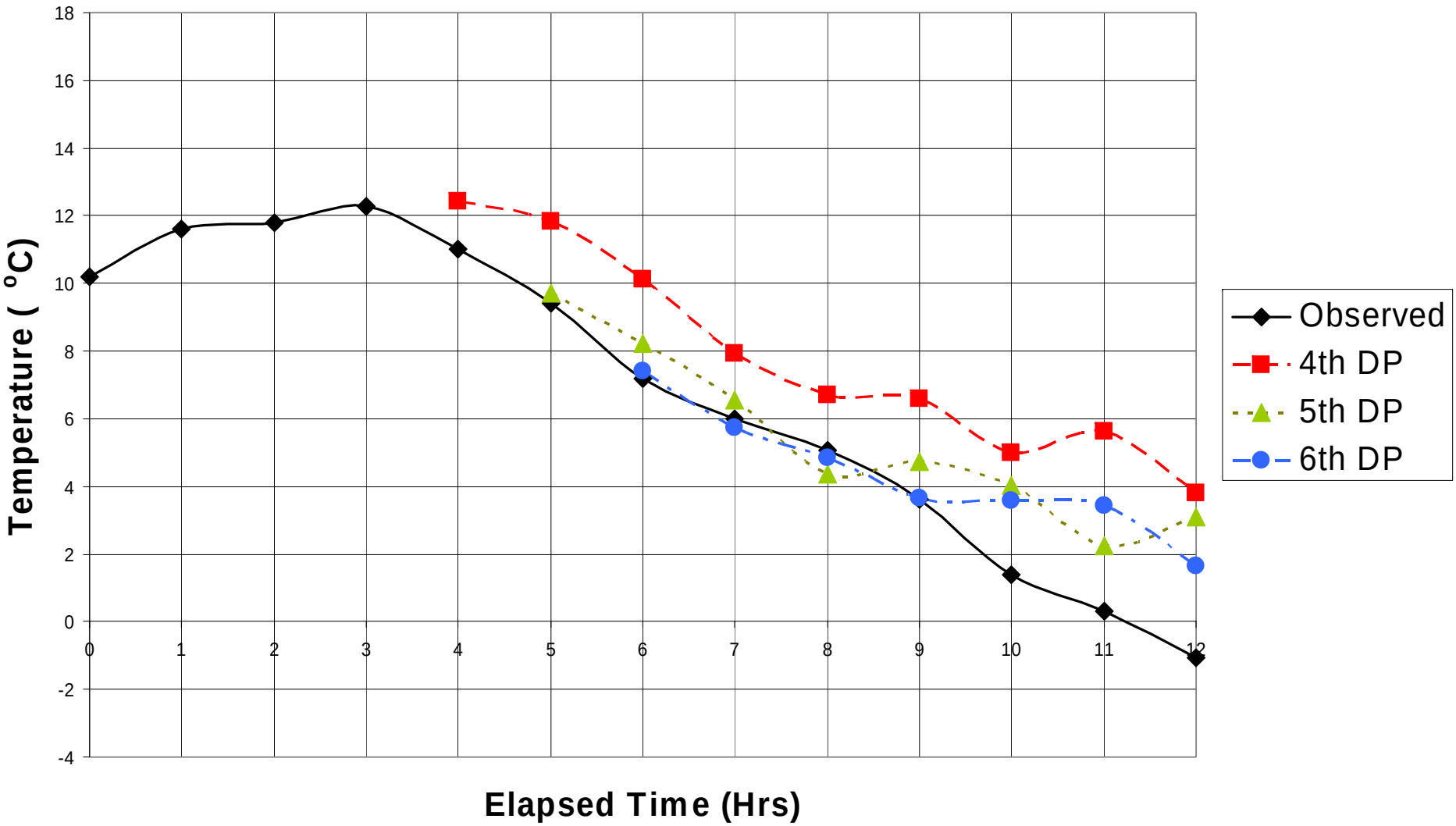
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



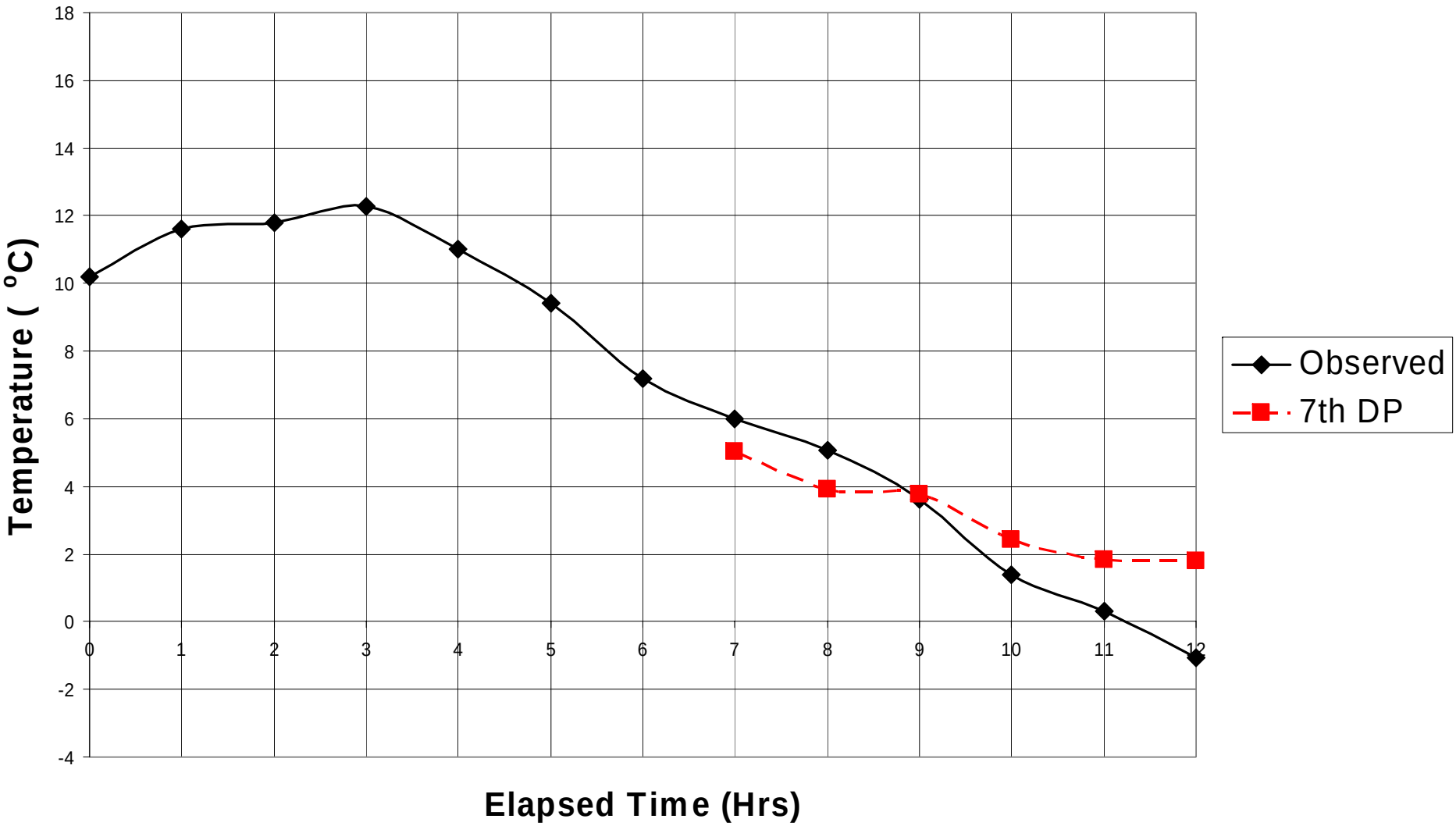
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



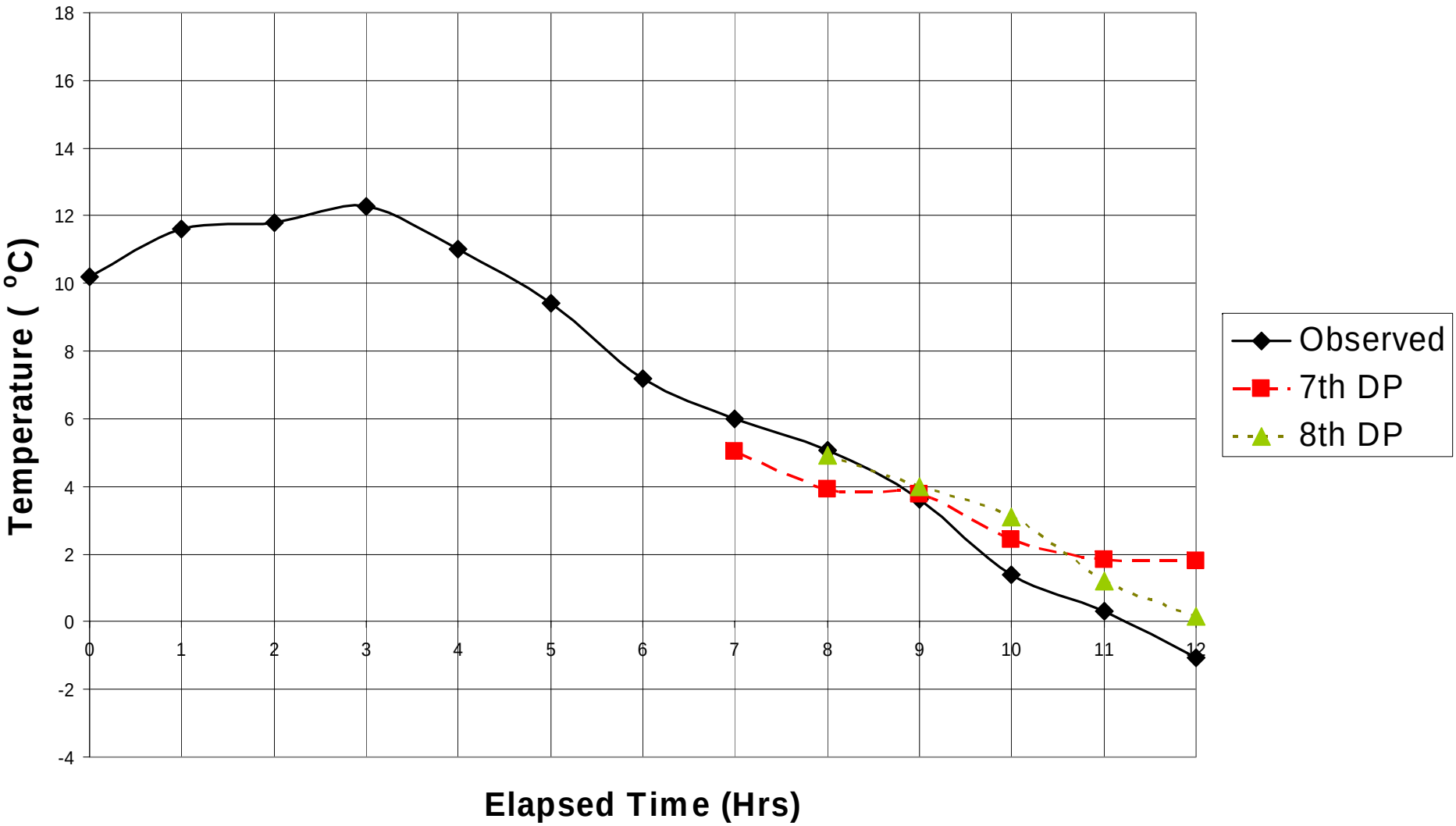
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



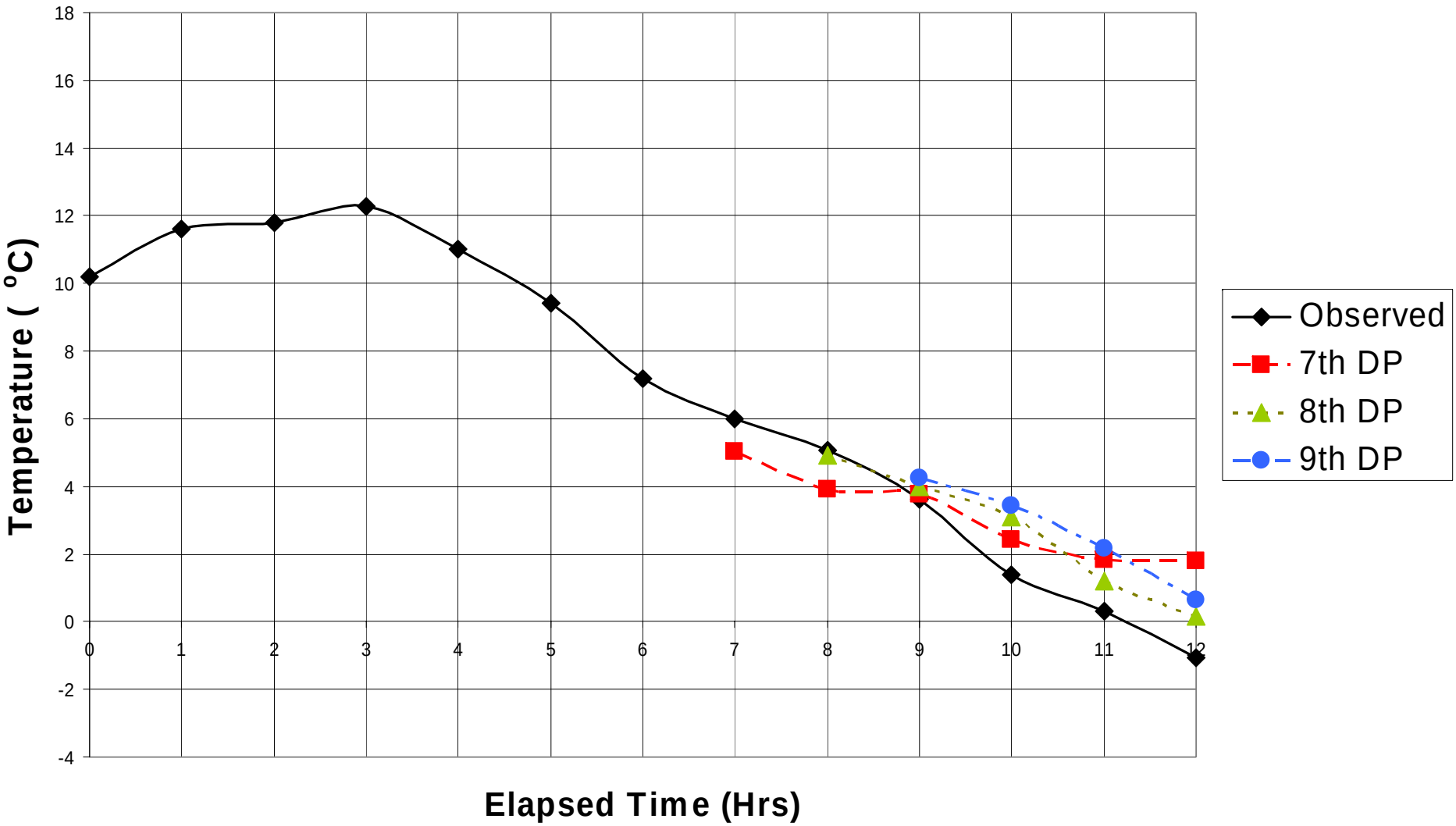
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



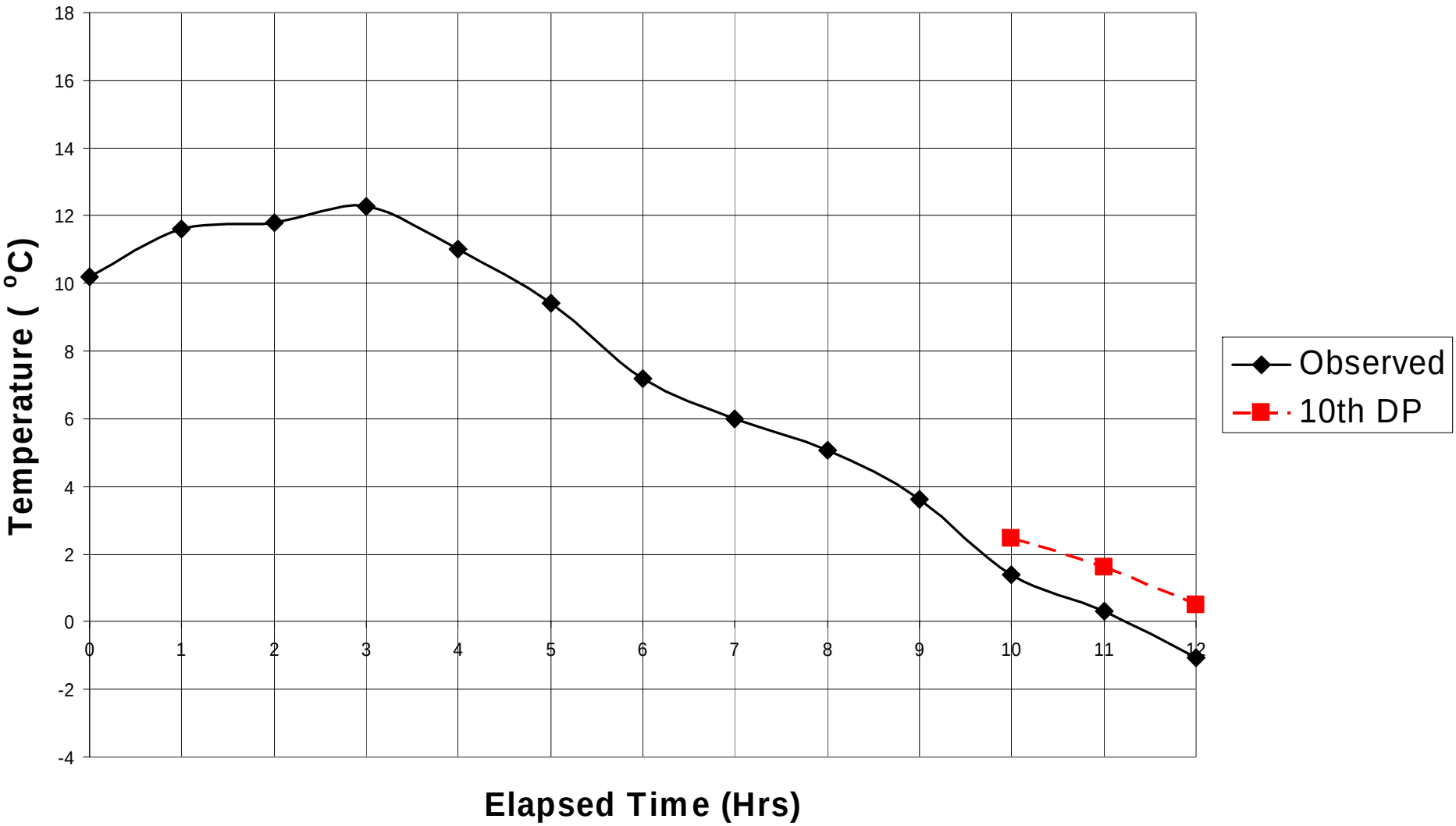
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



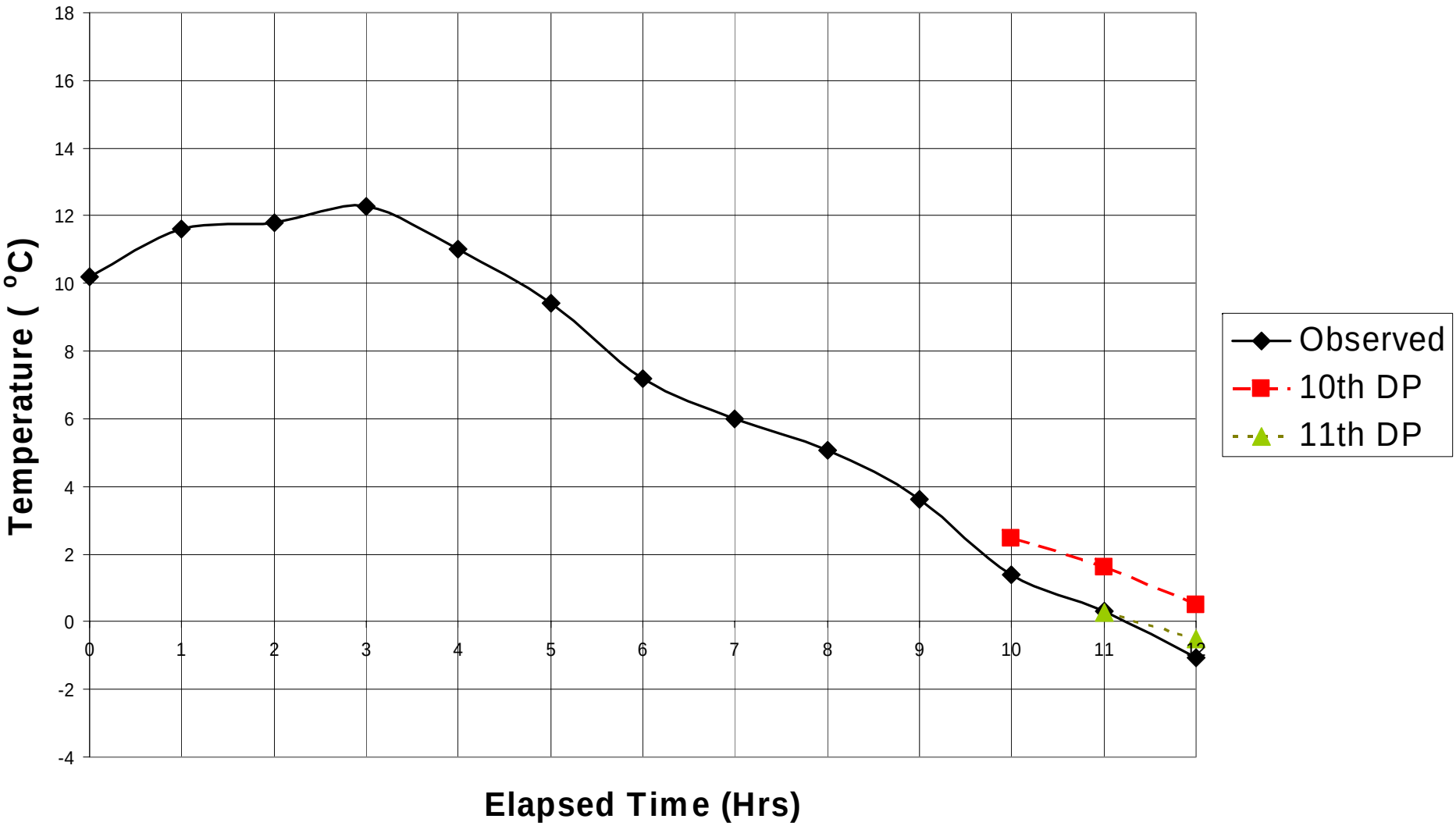
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



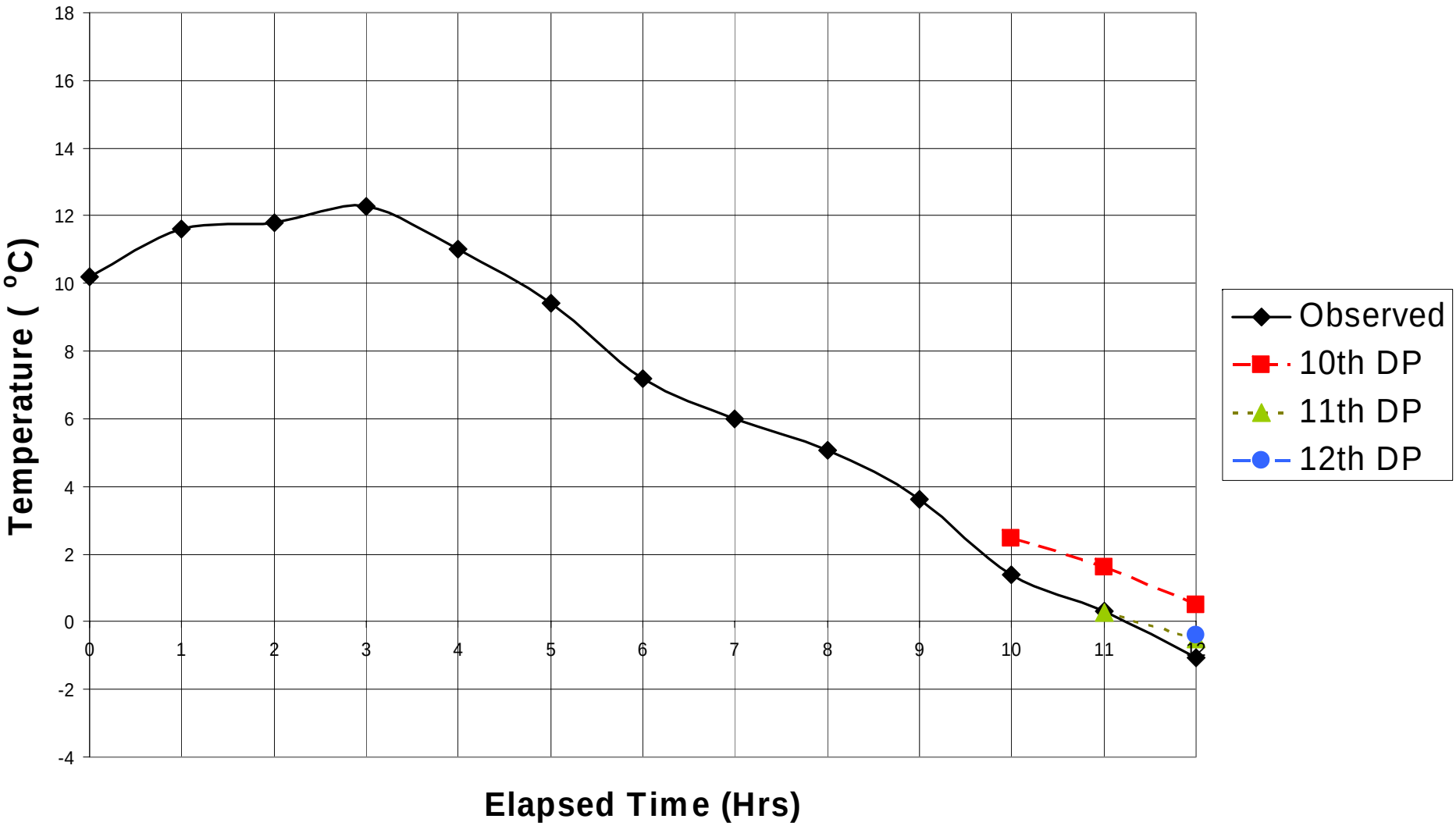
Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs



Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs

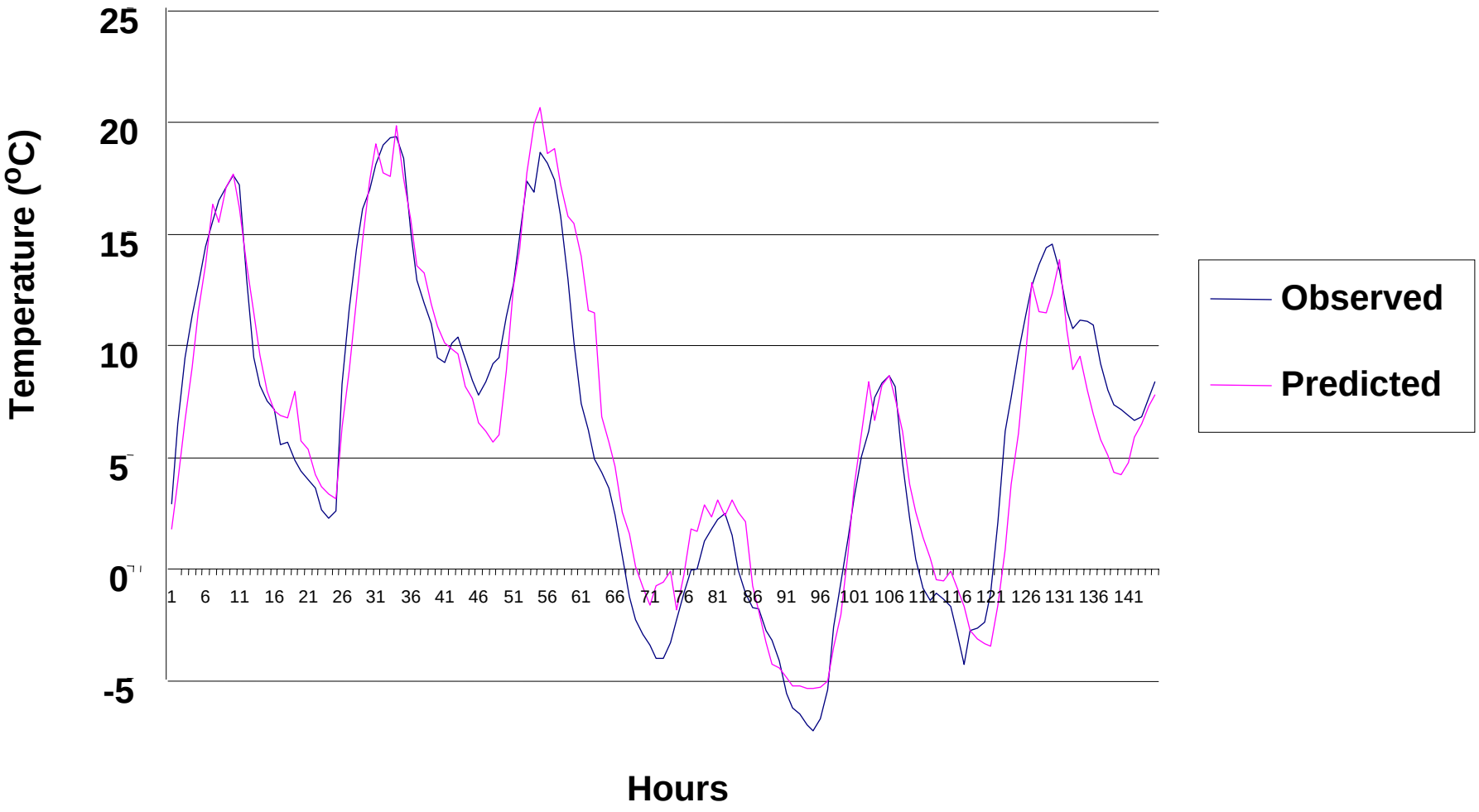


Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs

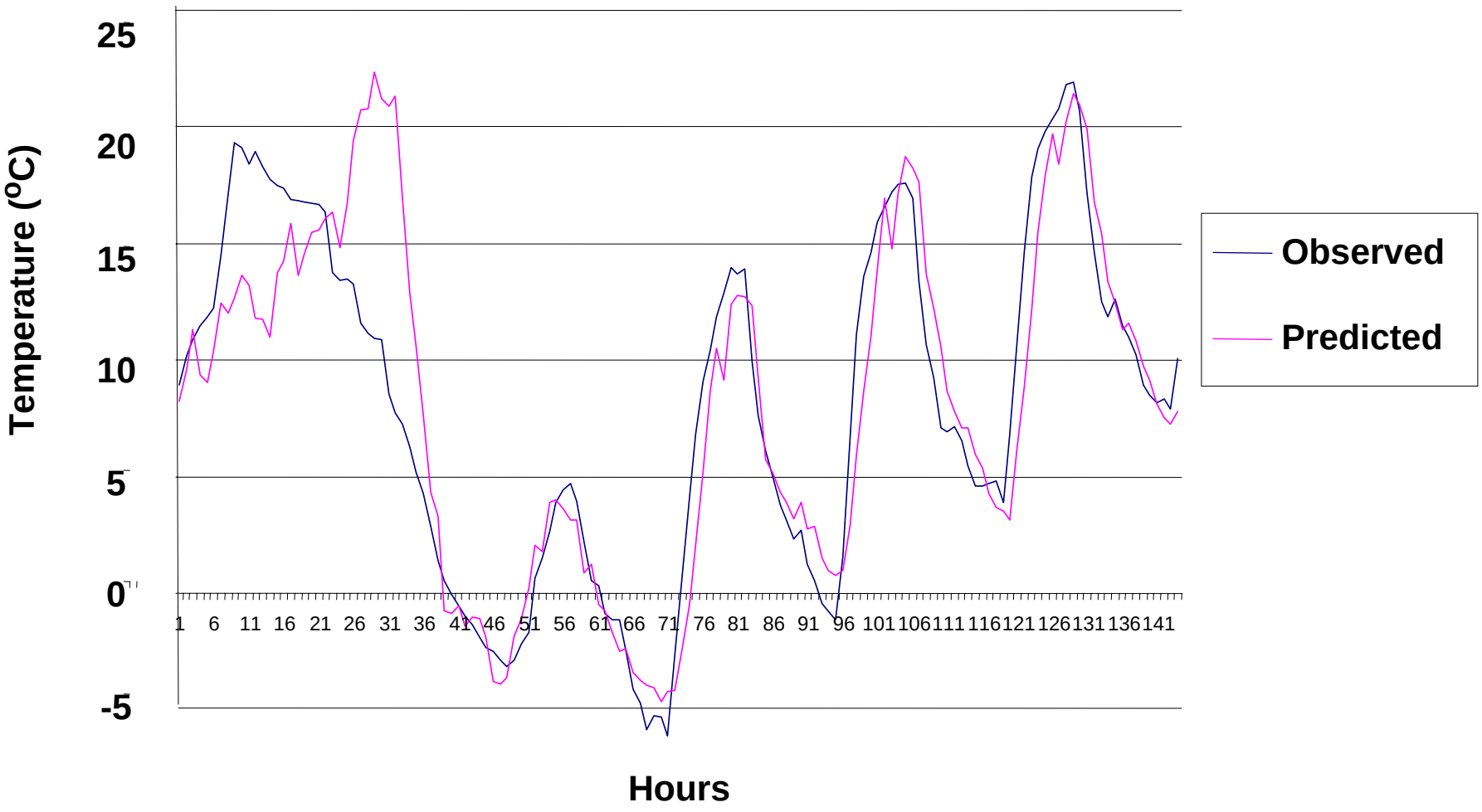


Predictions made from the Decision Points (DP),
January 8, 2001, 1200hrs to 2400hrs

Fort Valley-8 hour prediction
February 24-March 1, 2002



Fort Valley-8 hour prediction
March 2-7, 2002



Implementation

During Spring 2004, the temperature prediction ANN was implemented on the website.

File Edit View Go Bookmarks Tools Window Help

Georgia Automated Environmental Monitoring Network

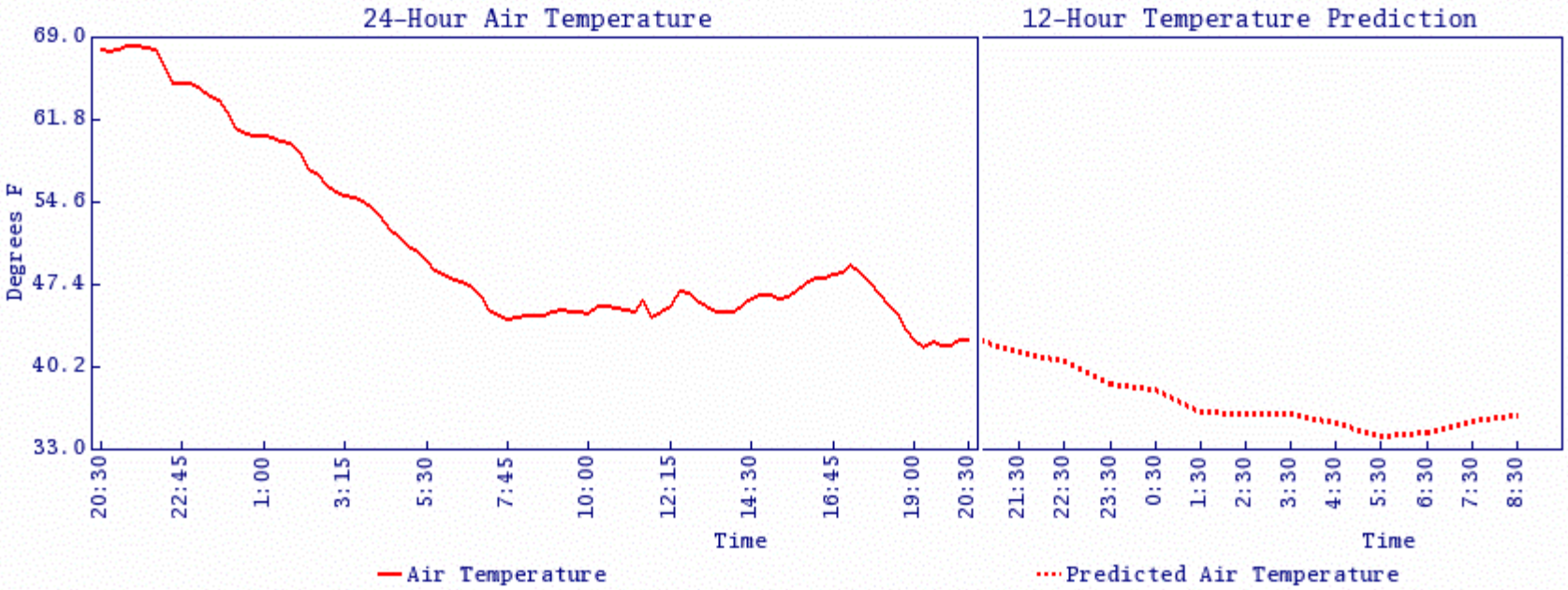
www.GeorgiaWeather.net

Alma - Bacon County Airport

Alma, Bacon County, GA

Temperature Prediction

Current Air Temperature: 8:30 PM, January 5 through 8:30 PM, January 6
Predicted Temperature: 8:30 PM, January 6 through 8:30 AM, January 7



RMA

The development of this program was partially supported by USDA-RMA

Robert T. Boland Jr., Brantley County Agent

"Brantley County Southern Highbush Blueberry growers have an early market window during which they can receive higher prices, around $10 per pound. However, with early maturing varieties they face the risk of late freezes. Losses from the Feb. 28, 2002 freeze were a whopping 80%, an estimated $115,000 loss to the Brantley County Blueberry crop's early maturing varieties. The Georgia [AEMN] is, and will continue to be, a management tool which Brantley County Southern Highbush Blueberry growers are using to monitor weather conditions... [It] will allow growers to use current and local weather data to guide them on when to start freeze protection for their blueberries."

Acknowledgement

Risk Management Agency of the USDA
Federal Crop Insurance Corporation

Decision Support for Freeze Protection Using Artificial Neural Networks

Questions and Comments