5.9 FORECASTING SUPPORT FOR THE SUMMER 2002 NEW ENGLAND AIR QUALITY STUDY (NEAQS) CAMPAIGN BY AN UNDERGRADUATE PROGRAM

James P. Koermer*, Joseph Zabransky, Jr., and Eric G. Hoffman
Plymouth State College
Plymouth, New Hampshire

Wayne Angevine
NOAA Aeronomy Laboratory
Boulder, Colorado

1. INTRODUCTION

During the summer of 2002, many organizations participated in the New England Air Quality Study (NEAQS) that was sponsored by the National Oceanic and Atmospheric Administration (NOAA). This was a multi-institutional research project with the overall goal of improving the understanding of atmospheric processes that control the production and distribution of air pollutants in the New England region. The primary focus for the 2002 study was on onshore and offshore areas along the New England coast from Cape Cod up to Bar Harbor Maine

The four major components of this program include (a) ground-based measurements, (b) ship and aircraft measurements; (c) air quality forecasting, and (d) modeling analysis. Many of the details on the program can be found on the NOAA Aeronomy Laboratory's NEAQS web page (http://www.al.noaa.gov/neaqs/) that provides the background information and detailed links to the pertinent sites of the participating organizations.

One of the major participants was the AIRMAP consortium that consists of scientists from the University of New Hampshire (UNH), Plymouth State College (PSC), the Mount Washington Observatory (MWO), and the New Hampshire Department of Environmental Services (NHDES).

The purpose of this paper is to describe the important role played by the PSC Meteorology Program (an undergraduate program) faculty and students in supporting this major air quality campaign. During the month long intensive study period, PSC provided detailed weather products and support that were used in planning measurement activities.

*Corresponding author address: James P. Koermer, MSC#48, Natural Science Dept., Plymouth State College, Plymouth, NH 03264; e-mail: koermer@mail.plymouth.edu.

2. NEED FOR WEATHER SUPPORT

The NOAA Research Vessel Ronald H. Brown (Figure 1) was the focal point of the campaign. Supported by ground-based and airborne measurements, the ship carried a suite of air quality and meteorological sensors as well as a group of 30 scientists.

Figure 1. NOAA Research Vessel Ronald H. Brown in the Portsmouth (NH) harbor with J. Koermer in the foreground. Much of the deployed instrumentation was located on the deck above the NOAA seal.

The ship left Charleston, South Carolina on 12 July 2002 for the trip northward to the campaign area. Measurements were taken throughout the transit. It reached the New York City coastal area on 14 July and because of good offshore flow from the city, stayed near the mouth of the harbor for about 24-hours taking measurements. It resumed its trip northward and arrived in the waters offshore of Portsmouth, NH early on July 16th. The ship remained in the general vicinity of this New England coastal region until August 7th, when it started to sail back to Charleston, arriving there on August 11th. Many detailed measurements were taken during this voyage.

Some of the greatest weather concerns for the ship operations were sea fog and precipitation, since many of the air quality sensors were configured for sampling dry air. Other devices could be used for wet conditions, but dry conditions were preferred. The other issue was avoiding tail winds that could carry the ship plume forward over the sensors located towards the bow of the ship. It was also important to have a sufficient head wind component to insure sufficient air flow for some of the measuring devices. Another interest area for planning possible ship tracks was the interaction of airborne constituents with sea breeze events.

Besides the standard complement of ground-based air quality and meteorological observations, additional coastal area observations were taken to supplement them. These included air quality sensors and a radar wind profile by the NOAA Environmental Technology Laboratory (ETL) at the Isle of Shoals, several miles offshore and east of Portsmouth; another wind profiler was setup at the Pease Tradeport in Newington several miles west of Portsmouth by the NOAA Aeronomy Laboratory (AL); and ETL also ran an ozone lidar at a coastal site near of Portsmouth.

The Department of Energy (DOE) Brookhaven National Laboratory and the Pacific Northwest National Laboratory also participated by taking airborne measurements throughout the campaign using the DOE Gulfstream G-1 aircraft.

3. PSC NEAQS SUPPORT

Weather was a major concern for the participants and PSC responded by providing detailed climatological information about the campaign region during a fall 2001 planning meeting. During an early spring 2002 meeting, initial concepts for PSC's operational weather support to NEAQS were developed. The rest of the period leading up to the campaign was spent developing products and fleshing out details and logistics by coordinating with AL and ETL participants. The AL would act as the coordinating agency and make recommendations for planning activities and ETL would be responsible for downloading the PSC products aboard the ship.

The plan was that two detailed discussions/forecasts would be issued daily (see the Appendix for an actual sample). The discussions would provide the background and reasoning for the forecasts and would include comments of how things may have differed from the previous forecasts. The actual forecast sections would concentrate on those parameters most likely to affect measurement operations. The discussions and forecasts were formatted in 12-hour blocks, roughly corresponding to the period planned for a single ship track operation. There was also a tabular summary of the forecasts. The forecasts would go out to 48-hours with longer outlooks included (where needed) to allow mission planners to look ahead.

Besides the text forecasts, the product would also include a host of graphical products generated by PSC and designed specifically for the campaign region. Some of the products were based on observational data, such as, the latest CONUS maps (fronts/pressures, RCM radar summary, IR satellite, and temperature contours, and a satellite radar animation), zoomed visible and infrared satellite imagery, latest sounding plots for KGYX and LCHH, latest NEXRAD reflectivity and VAD wind profile plots for GYX and BOX, and the latest surface observations on a station plot map. The infrared satellite data included 3.9 micron imagery to help in identifying possible sea fog. The surface plot map was augmented with special experimental buoy data from the University of Maine. The buoys were important, since they reported visibility information that was useful in forecasting fog.

The forecast suite of graphics was quite extensive and based mainly on the ETA model data from NOAAPORT. Forecast charts/maps included were as follows (most overlays):

- Precipitation, sea-level pressure, 10m above ground (AG) wind vectors
- 10m AG wind isotachs and wind vectors
- 925 hPA wind isotachs and wind vectors
- 2m AG and 925 hPA temperatures
- 2m AG and 925 hPA dewpoint temperatures
- 2m AG and 925 hPA relative humidity
- 950-1000 hPA Bulk Richardson Number (gridded values on map)
- Forecast skew-T log-p soundings for IOSN3 and KBOS
- HYSPLIT backward trajectories for IOSN3
- HYSPLIT forward trajectories for KBOS

All of the above products were produced for each 11 time periods starting at the ETA analysis time and for every 6 hours out to 60 hours. Automatically scheduled scripts, using WXP

software, were used to produce all of the data except for the trajectory maps. PSC personnel used the Air Resources Laboratory (ARL) HYSPLIT web site to produce the corresponding trajectory maps.

The text discussion/forecast product and all of the graphics were brought together in a web page (http://pscwx.plymouth.edu/NEAQS/). For the ship, the entire web page was packaged in a single compressed file for automatic uploading to a NOAA computer for later downloading to the ship by ETL personnel. Another file containing all the hourly surface maps was also packaged for similar uploading and downloading.

During transit operations, PSC prepared an additional forecast/discussion and map package similar to the regular product except it concentrated on the transit area and anticipated ship movements. This support was provided for both transit legs and started several days in advance for planning transit activities.

4. 24-HOUR WEATHER CENTER

The morning discussion/forecast text product had to be completed by 1000 UTC and the afternoon product had to be ready by 2000 UTC. This schedule allowed time for PSC to call and discuss the forecast with AL personnel working at UNH who were planning and coordinating campaign activities. Downloads at the ship were generally scheduled about an hour after the above completion times.

In order to provide this support, PSC established a 24-hour weather center. Operations started on July 8th and continued through August 10$^{th.}$ The only exception was a brief 2-day interlude in the middle of the campaign when the ship came into port and where most of the NEAQS participants met in Portsmouth for a science meeting and a semi-private open house tour of the ship.

Three PSC meteorology faculty members and six PSC meteorology students manned the facility. Students worked three rotating shifts (midnights, days, and swings) and faculty covered the midnight and day shifts. The midnight and day shift teams put together the detailed text products. All shifts generated both forecast trajectory maps for the web page product and other trajectory maps based on reported data for post analysis and archival purposes. The swing shift was important for keeping up a meteorological watch and for preserving continuity between shifts. It was also important for having an on-site person for other contingencies, such as, the time the facility lost electrical power. The student on duty notified faculty who were then able to help recover affected systems.

Assembling the forecasts was truly a team effort. During transit operations, the faculty member usually worked on the transit product and the student worked on the regular forecast page. During this period, they would have synoptic discussions on the overall situation, so that both would be on the same page. About an hour before the deadline both would get together, review their forecasts, and resolve any differences. The faculty forecaster would then provide a final review before dissemination to insure consistency. The text products were often several pages long and took quite a long time to produce because of the detail needed and numerous forecast aids to review.

When the ship wasn't in transit, the faculty forecaster would cover the 24-hour and beyond periods and the student forecaster would work on the shorter term forecasts. They would also be coordinating their reasoning and forecasts during the preparation period. Again, the faculty member would combine the forecasts and conduct a final review.

5. SUPPORTING DATA AND RESOURCES

The PSC forecasters used PSC standard web pages (Koermer, 2003) and some custom PSC pages, created for NEAQS. These included the main campaign and transit pages and another page with direct links to either pertinent external sites or internal links to produce outputs of the latest data in real-time. Buoy, profiler, and NCEP model data proved extremely useful and were easily accessible.

PSC also used a variety of other web sources. These were very important for comparing various MM5 forecast model runs and other data not available at PSC over NOAAPORT or the Unidata Internet Data Distribution (IDD) system. For example, the NOAA Forecast Systems Laboratory (FSL) and MCNC ran customized MM5 models for the campaign and PSC was able to access those results via the web. PSC also used SUNY Brockport's web site to view another set of MM5 results.

The FSL FX-NET software (Madine and Wang, 1999) on PSC workstations was also used extensively to visualize current and forecast data. The overlay, looping, and stepping capabilities proved essential in comparing model forecasts. The FX-NET displays also made it much easier to make forecasts for very specific parameters.

6. THE PSC NEAQS EXPERIENCE

The NEAQS project provided a fantastic educational experience for the participating students—all had just completed their junior year at PSC as meteorology majors. They definitely got the feel for a real-time forecast operation with associated deadlines and shift work. They quickly learned when products become available. They also learned to recognize many of the products' strengths and weaknesses, since so many were referenced in developing forecasts.

Since the forecasts covered a wide range of parameters from sea-surface temperatures (SSTs) to sea breezes to sea fog along with the more normal suite of parameters, such as, temperatures, wind, and precipitation forecasts, students gained valuable insight and experience. They now have a much greater appreciation of what it is like to be a forecaster. They also learned about the importance of teamwork and collaboration.

Faculty also benefited by getting an operational view of meteorology that sometimes differs from the more idyllic academic and research mindset. They were able to work closely with students on a professional level. In some instances, they tuned up some rusty skills.

The entire NEAQS campaign also reaped the benefits of the PSC forecasting. In particular, the R/V Ronald H. Brown was able to achieve all of its goals and more. The ship encountered a complete range of conditions, from clean to highly polluted air and also sampled in classic sea-breeze events. The participants were able to take advantage of opportunities because of the accurate forecast information provided by the PSC. One of the lead NOAA scientists for the NEAQS campaign commended PSC and stated, "Your team provided us with the data and insights that we needed to maximize the capabilities of the ship and your forecasts were almost always right on target."

7. ACKNOWLEGEMENTS

The NOAA-funded AIRMAP program, the NASA Space Grant program, and Plymouth State College provided support for the PSC Meteorology Program's NEAQS participation.

8. REFERENCES

Koermer, J.P., 2003: The PSC Weather Center web portal. Preprints, *19th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology*, Amer. Meteor. Soc., Long Beach, 8 pp., submitted

Madine, S. and N. Wang, 1999: Delivery of meteorological products to an internet client workstation. Preprints, *Fifteenth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, Amer. Meteor. Soc., Dallas, 356-359.

APPENDIX – Actual PSC NEAQS campaign-area text discussion/forecast product.

Issued: 6 Aug 2002 at 10Z(Last Forecast-see Transit Page for future updates)

SYNOPTIC DISCUSSION: The cold front has passed with NW winds dominating the region for the forecast period. High pressure will build in from the west and will cause a strong pressure gradient in association with the departing low. This will cause strong winds to develop for the earlier part of the forecast. As the low pressure continues to move out expect the pressure gradient to slacken and winds to become less intense. Once the High pressure moves in, it will stall out over the Great Lakes region during almost the entire forecast. The ETA is calling for some wrap around precip with the departure of the surface low. At upper levels the trough in the east will continue to deepen as the ridge in the central U.S. will continue to build. It appears that in the extended forecast that the ridge in the central U.S. will topple over bringing warm temperatures back to the Northeast.

0-12HR FORECAST (06/12Z-07/00Z):

DISCUSSION: NW flow behind the cold front will be gusty at times. The surface front moves north of Nova Scotia and high pressure builds in north of the Great Lakes. The upper level trough moves eastward over Nova Scotia bringing positive vorticity advection over the forecast area early in the period with a maximum around 12Z and then some negative vorticity advection will allow for some clearing after noon. Daytime temperatures will not depart much from overnight lows due to cold advection from the NW.

PRECIPITATION: PoP 20% associated with the vorticity max passage and from possible wrap-around precipitation in the north.

FOG: None.

LOW LEVEL WINDS: NW 15-20kts diminishing to 10-15kts by the end of the period.

SOURCE REGIONS: Low, Mid and High: 49N, 74W.

2M TEMPS:

	North (IOS)	South (IOS)	Cape Cod Bay
Onshore:	63-66F(17-19C)	66-70F(19-21C)	68-72F(20-22C)
Coastal:	63-66F(17-19C)	68-72F(20-22C)	67-70F(19-21C)
Offshore:	63-66F(17-19C)	66-70F(19-21C)	

SST: 18-20C from Portland harbor south to Boston Harbor; 21-25C from Boston Harbor to Cape Cod Bay; decreasing to 15C near Bar Harbor.

12-24HR FORECAST (07/00Z-07/12Z):

DISCUSSION: The surface low stalls north of Nova Scotia and the high pressure system builds over the Great Lakes area. The forecast region will be locked into NW flow.

PRECIPITATION: PoP near 0%.

FOG: Not likely.

LOW LEVEL WINDS: NW 10-15kts.

SOURCE REGIONS: Low: western Quebec; Mid and High: northern Quebec.

2M TEMPS:

	North (IOS)	South (IOS)	Cape Cod Bay
Onshore:	53-56F(12-13C)	55-60F(13-16C)	64-66F(18-19C)

Coastal:	58-60F(14-16C)	58-62F(14-17C)	65-66F(18-19C)
Offshore:	60-64F(16-18C)	62-66F(17-19C)	

SST: 18-20C from Portland harbor south to Boston Harbor; 21-25C from Boston Harbor to Cape Cod Bay; decreasing to 15C near Bar Harbor.

24-36HR FORECAST (07/12Z-08/00Z):

DISCUSSION: NW flow will shift to W as the high moves further southward over the Great Lakes area. A vorticity maximum drops down from northern New England to the Chesapeake Bay Virginia area by the end of this period.

PRECIPITATION: PoP 0%

FOG: not likely.

LOW LEVEL WINDS: NW 10-15kts shifting to W 7-12kts

SOURCE REGIONS: Low: James Bay; Mid and High: northern Quebec

2M TEMPS:

	North (IOS)	South (IOS)	Cape Cod Bay
Onshore:	62-65F(17-18C)	62-65F(17-18C)	65-68F(18-20C)
Coastal:	63-66F(17-19C)	65-68F(18-20C)	64-66F(18-19C)
Offshore:	64-67F(18-19C)	65-68F(18-20C)	

SST: 18-20C from Portland harbor south to Boston Harbor; 21-25C from Boston Harbor to Cape Cod Bay; decreasing to 15C near Bar Harbor.

36-48HR FORECAST (08/00Z-08/12Z):

DISCUSSION: W flow will switch back to NW flow by 06Z and then turn to N flow by the end of the period. The piece of vorticity over us in the previous period will continue its southward progression to south of Long Island. At upper levels the upper level trough and ridge are continuing to be strongly amplified. The surface High Pressure slowly moves south and is centered over Michigan by the end of the period

PRECIPITATION: PoP 0%

FOG: not likely.

LOW LEVEL WINDS: W->NW->N 5-10kts

SOURCE REGIONS: Low and Mid: James Bay; High: Northeastern Quebec

2M TEMPS:

	North (IOS)	South (IOS)	Cape Cod Bay
Onshore:	70-75F(20-24C)	75-80F(23-26C)	70-75F(20-24C)
Coastal:	65-70F(18-21C)	68-72F(19-22C)	65-70F(18-21C)
Offshore:	64-67F(18-19C)	65-68F(18-20C)	

SST: 18-20C from Portland harbor south to Boston Harbor; 21-25C from Boston Harbor to Cape Cod Bay; decreasing to 15C near Bar Harbor.

EXTENDED OUTLOOK (Beyond 08/12Z): See Transit Forecast Page.

SUMMARY:	PRECIP	FOG	WIND DIR	TEMPS(onshore/coastal)

06/12Z-07/00Z	20% early	none	NW 15-20	66F(19C)/66F(19C)
07/00Z-07/12Z	0%	none	NW 10-15 ->W 7-12	55F(13C)/60F(16C)
07/12Z-08/00Z	0%	none	NW 10-15	67F(19C)/62F(17C)
08/00Z-08/12Z	0%	none	W->NW->N 5-10	80F(26C)/66F(19C)