**P1.7** PLANNING FORECASTS FOR THE COASTAL AND OFFSHORE AIR QUALITY MEASUREMENT ACTIVITIES FOR THE ICARTT SUMMER 2004 CAMPAIGN

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## 1. INTRODUCTION

During the summer of 2004, the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) coordinated a major field campaign to study air pollution transport and its chemical transformation, to evaluate air quality forecast models, and to investigate direct and indirect cloud radiative effects. The consortium consisted of a large number of research participants from government, academia, and other organizations. Many more details on the program can be found on the NOAA Aeronomy Laboratory's ICARTT web page (http://www.al.noaa.gov/icartt/) that provides the background information and links to the sites of the participating organizations.

One of the major geographical focus areas for this project was the New England coastal zone and the Gulf of Maine. The NOAA Research Vessel (R/V) Ronald H. Brown was one of the primary mobile measurement platforms stationed in this region and frequently operated in tandem with several NOAA and NASA research aircraft that provided airborne measurements. A team of three faculty and six students from Plymouth State University (PSU) provided detailed planning forecasts and products used throughout the campaign for optimizing platform placements in this region.

Some of the aspects of ICARTT were follow-ons and expansions of the activities that were conducted during the New England Air Quality Study (NEAQS) that was sponsored largely by the National Oceanic and Atmospheric Administration (NOAA) (Koermer et. al.,2003b). This was also 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.

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## 2. FORECAST NEEDS

Perhaps, the two most important weather inputs for planning ICARTT air quality activities were air trajectory and temperature forecasts. Obviously, trajectories are needed to determine where pollution plumes from industrial and urban source regions may be heading and certain temperature thresholds are important for chemical transformations. For the direct/indirect radiation measurements, cloud and/or no cloud forecasts were also extremely important.

Angevine et al. (2004) reported on some of the important results of the 2002 NEAQS in the New England coastal region. An important observation was that elevated ozone pollution episodes in New England tended to be more acute when associated with trajectories that first carried emissions offshore and then back onshore, rather than trajectories that brought source emissions over land into the region. Koermer et. al. (2003a) presented evidence that S through SW 12-24-hour trajectories sources (i.e. over water) were typically found for most of the pollution episodes of the summer of 2002. In addition, they noted that these episodes usually occurred in conjunction with maximum surface temperatures that were typically at or above 24$^{o}$C. One of the objectives of ICARTT was to confirm these previous observations.

The NOAA Research Vessel Ronald H. Brown (Figure 1) was the focal point for much of the PSU weather support during the campaign, as it was during 2002 NEAQS. Augmented by a suite of ground-based and airborne measurements, the ship also carried a large number of air quality and meteorological sensors as well as a large group of supporting scientists.

One major difference for the R/V Brown between NEAQS in 2002 and ICARTT in 2004 was the geographical area of operations. Outside of transit activities during NEAQS, the ship tended to stay fairly close to shore and confined its activities to the New England coastal region from Cape Cod up to Bar Harbor. During ICARTT, ship operations extended from Cape Cod to western Nova Scotia and included the entire Gulf of Maine and adjacent coastal waters.

Figure 1. NOAA Research Vessel Ronald H. Brown in the Portsmouth (NH) harbor on July 25, 2004.

Another difference was the desired weather conditions by the research team. During NEAQS, participants wanted dry (no fog) conditions and were not overly concerned about cloud cover. Since the ICARTT had additional radiation experiments in mind, this time they wanted some fog conditions and were also more interested in the other clouds.

For air quality studies, there were different track scenarios planned for different synoptic situations as follows:

- For NW flow, the ship would attempt to measure biogenic emissions from the Maine forests.
- For SW flow, the ship would attempt to measure the anthropogenic emissions from either power plants or urban areas and their transport and transformation. Sea breeze conditions might dictate a track closer to shore.
- In cleaner flow situations, the ship would often try to measure pollution from other ships in the region.
- Sea breezes might dictate coastal tracks.

The radiative direct/indirect studies usually involved rendezvous with NOAA or NASA aircraft taking airborne measurements. Usually these experiments were also scheduled when there were over-flights of the MODIS satellite sensors aboard the TERRA and AQUA satellites. For these operations, some experiments wanted clouds and others wanted clear air.

The ship arrived in Portsmouth, NH, around 1 July 2004. Specialized instrumentation for the campaign was loaded and set up during the next few days and the ship departed the harbor to start its ICARTT measurements on 5 July 2004. The ship remained at sea until 12 August 2004 except for a short mid-cruise hiatus from 23-25 July, when it returned to Portsmouth harbor for a mid-campaign science meeting and open house.

## 3. PLYMOUTH STATE FORECAST SUPPORT

During the months leading up to the start of the ICARTT campaign, participants in the northeast regional portion of the study were queried and consulted in order to develop a custom forecast package to be used during the campaign. Because of some important cost considerations, the R/V Brown usually only allocates an hour in the morning and an hour in the late afternoon for higher bandwidth satellite communications—a major consideration in the type and content of the information to be provided to the ship. On the other hand, real-time updates could always be provided to land-based users.

From previous NEAQS user experience, a detailed narrative discussion and text forecast became the highest priority requirement for the support package. These text products would again be provided in 12-hour blocks out to 48 hours, which roughly coincide with typical decision points and track changes. Compared to NEAQS, additional emphasis was placed on fog and cloud forecasts. More general outlooks were also provided for periods beyond 48 hours and primarily concentrated on whether and when changes were or were not expected.

Based on feedback received from prior NEAQS participants, the fairly large number of computer-generated products (based exclusively on the ETA model) provided by Plymouth State were not very interpretable by the participants, most of whom were non-meteorologists. As an alternative, they requested that most of these products be replaced with multi-panel “cartoon” summary maps that would more simply depict the forecast situation. This new approach allowed the PSU team to incorporate information from other models and/or ensembles. This capability turned out to be very important during the summer of 2004.

The primary cartoons consisted of maps with four multi-panel 12-hour block forecasts of high and/or low temperature depending on the forecast period; a nephanalysis forecast for the end of each 12-hour period indicating cloud coverage and general bases/tops; and a corresponding map with frontal systems, pressure centers, surface wind vectors, precipitation areas, and areas of fog. After the campaign started, another four-panel chart containing the frontal/pressure, wind, precipitation and fog forecasts for the intermediate 6-hour intervals was added.

Besides these products, the PSU team also generated a significant number of trajectory maps from the NOAA Air Resource Laboratory READY site (https://www.arl.noaa.gov/ready/hysplit4.html). These included forecast HYSPLIT trajectories out to 48-hours at 6-hour intervals starting from Pittsburgh, New York City, Boston, and Central Maine and forecast HYSPLIT backward trajectories for the Isle of Shoals, just off the NH seacoast. Later, forecast backward trajectory maps from the latest know ship location were added to the package. All forecast trajectories were based on the ETA model.

During the campaign, the research team requested additional maps of chemical forecast model output from the NOAA Forecast Systems Laboratory (FSL) WRF-chem model and from the University of Iowa STEM model. The appropriate products were downloaded from their respective web sites and included as part of the package. The main problem encountered with these non-operational models was that updated data was occasionally not available for inclusion because of problems at the generating sites.

The only other products included in the Plymouth State package were the latest computer-generated surface data plots for the Gulf of Maine region, visible and infrared satellite images, and a NEXRAD composite summary for the region. During the campaign, the infrared images and radar were dropped to reduce the product size in order to add the chem model maps and the forecast backward trajectories for the ship's location. The trajectories and other observational products were updated continuously when new data arrived and retained for land-based users. The participants also had access to a customized PSU links page that provided access to other participants' data, as well as many more detailed meteorological products from Plymouth State.

Text forecasts, cartoons, trajectories, and other products were prepared and had to be up on the web by 1000 UTC and again at 2000 UTC daily. During the next hour, there was telephone coordination between Plymouth State forecasters and NOAA Aeronomy Laboratory (AL) representatives at the ICARTT Operations Center in Portsmouth, NH. This coordination was extremely important, especially on aircraft over-flight days, where short term cloud forecasts in marginal situations were of primary interest.

After this coordination, all of the latest text and graphics and the supporting HTML file were combined into a single compressed file and were sent via ftp to a NOAA AL computer. Personnel aboard the ship would then download the file and uncompress it to get the ship version of the weather support page.

The following URLs can still be accessed to view the last set of products prepared for the 2004 ICARTT campaign:

Ship Page:
http://pscwx.plymouth.edu/ICARTT/index_ship.html
Main Page:
http://pscwx.plymouth.edu/ICARTT/index.html
Links Page:
http://pscwx.plymouth.edu/ICARTT/links.html

The ship and main pages are somewhat abbreviated, since they were issued near the very end of the campaign and longer term outlooks were not needed.

## 4. WEATHER DURING ICARTT VS. NEAQS

The weather conditions in the northeast during ICARTT 2004 were considerably different than during NEAQS 2002. The NEAQS weather can be summarized as being generally warmer and drier than normal. Nearly all surface reporting sites along the coast and the data buoys had temperatures above and precipitation amounts below the mean for the period (Koermer et al., 2003a). During the ship's stay in the western Gulf of Maine, the ship only reported low visibilities on one occasion and these were only down to two statute miles. Precipitation was also an extremely rare occurrence for the ship during its mid-July to mid-August time on station in 2002. Hot and often prevailing southwesterly flow situations led to frequent episodes of elevated pollution in New England (Angevine et al., 2004). During this period, forecast models (ETA and AVN) were quite accurate and very consistent with each other.

In contrast, the summer of 2004 can be categorized as having below normal temperatures, greater precipitation frequency, more and denser fog conditions, and little southwesterly flow. This combination led to considerably fewer pollution episodes that were neither as widespread nor as elevated as they were in 2004. In particular, the frequency of fog in the eastern Gulf of Maine was very high and coverage was quite extensive.

During much of this period, numerical model performance was poor. The ETA and GFS models rarely agreed. The ETA was often too slow and kept transitory weather features too far north. On the other hand, the GFS was generally too fast and kept the transitory systems too far south, when compared to the situations that actually evolved. The UKMET model, which often was more closely in synch with ensemble forecasts, seemed to have the best handle on the situation for most days for this region. On one day, the 24-hour forecast positions from various models (including ECMWF) had a weak low center varying from southwest Ohio, the central North and South Carolina border, to off the coast of New Jersey. The verification analysis had it near the border area of central New York and Pennsylvania.

## 5. COASTAL AND OCEAN FORECAST ISSUES

For short term forecasts of fog and clouds, the team depended on GINI satellite imagery. During the day, 1-KM Visible images proved most useful. Figures 2 and Figure 3 show two of the prevalent fog situations that existed during ICARTT, which were widespread fog in the Gulf of Maine and widespread coastal fog, respectively.

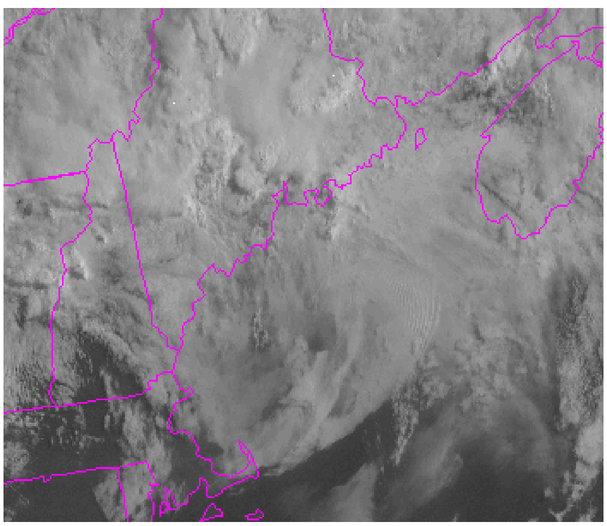

Figure 2. GOES 1-KM visible imagery on 9 July 2004 at 1245 UTC showing widespread fog.

At night, 3.9um infrared imagery in conjunction with color-enhanced 10.8um imagery provided some insight. However, important surface observations from the GoMoos buoys in the Gulf of Maine were also a tremendous help in assessing fog because of their added visibility reports. These systems cannot report visibilities better than 2.0 statute miles, but they were able to confirm dense fog situations.

The synoptic situation associated with nearly all widespread Gulf of Maine fog events was good low-level south-southeasterly to southerly flow that was advecting warm, moist air over a Gulf of Maine with sea surface temperatures that were near 10$^{O}$C in the eastern Gulf and in the mid- to upper-teens further west. As a result, fog was more prevalent and frequent in the eastern Gulf.

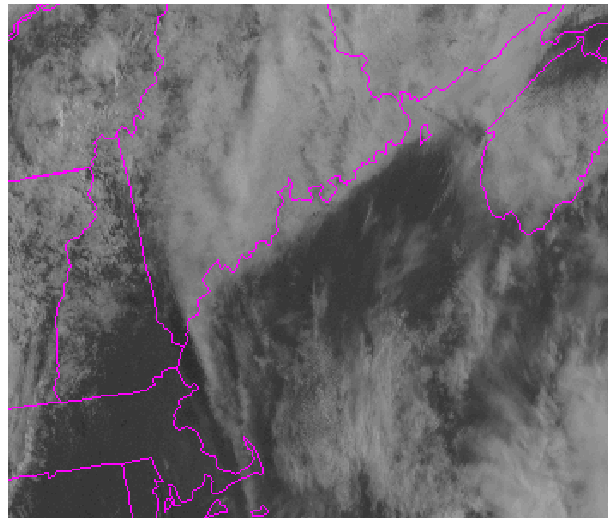

Figure 3. GOES 1-KM visible imagery on 16 July 2004 at 1225 UTC showing coastal fog.

Coastal fog situations were most often associated with moist onshore flow in association with radiational cooling over land. In both fog situations, low level wind forecasts from models were essential to the fog potential. Fortunately, in the Gulf of Maine, the models were reasonably on target.

Because of these kinds of forecasts and others, the Plymouth State forecast team depended on a number of visualization tools including the NOAA Forecast Systems Laboratory (FSL) FX-Net (Madine and Wang, 1999) and their own interactive or specially prepared web products. The group also used a variety of other web sources. These were very important for comparing various MM5 forecast and other model runs and other data not directly available at Plymouth State over their FX-Net, NOAAPORT or the Unidata Internet Data Distribution (IDD) systems.

However, most models had difficulty with clouds and precipitation in the Gulf of Maine. During ICARTT, there were frequent fronts or troughs that moved across New England into the Gulf of Maine. These systems were quite active in producing clouds and precipitation over land, but most quickly fizzled upon encountering the cooler waters of the Gulf of Maine. Model forecasts usually just carried the clouds and precipitation into the Gulf—something that was modified in most of the team's text and cartoon forecasts.

The last forecast issue for coastal regions was predicting whether or not sea breezes would occur. Sometimes the ETA would correctly predict these events and help the PSU forecasters, but there were several sea breeze events that developed when forecast gradients that would indicate stronger offshore flow weakened and allowed the sea breeze to develop. There were actually a few instances where inland flow seemed reasonably strong to prevent sea breezes, but the coastal differential heating was sufficient for them to form.

## 6. SUMMARY

During the summer 2004 ICARTT campaign, a team of nine faculty/students from Plymouth State University provided detailed planning forecasts for the NOAA Research Vessel Ronald H. Brown and other ICARTT participants. The products were used to select ship tracks and to assist in planning aircraft rendezvous with the ship and satellite overpasses.

Weather conditions during ICARTT were not very ideal for producing poor air quality events. Temperatures were cooler than normal, precipitation was above normal, and southwesterly winds were infrequent. These were just the opposite of the conditions encountered during NEAQS campaign in this same region during the summer 2002.

The PSU forecast team provided custom forecasts for the NOAA R/V Ronald H. Brown and other northeast participants. Coastal and offshore weather that impacted ICARTT and NOAA R/V Brown included frequent coastal and sea fog in the Gulf of Maine. On the other hand, troughs and fronts exiting the continent tended to dissipate rapidly. Most sea breeze situations were forecast correctly. However, some sea breezes developed despite some strong offshore flow just inland.

A climatological summary for the ICARTT summer 2004 campaign is currently being prepared.

## 7. ACKNOWLEGEMENTS

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