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SEA BREEZE REGIMES IN THE NEW YORK CITY REGION - MODELING AND RADAR OBSERVATIONS

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I. INTRODUCTION

During spring and summer, the well known sea breeze circulations (e.g., Simpson 1994, Atkinson 1981) can strongly influence airport operations, air-quality, energy utilization, marine activities and infrastructure. The geographic configuration of the New York City region presents a special challenge to atmospheric prediction and analysis. The New Jersey and Long Island coasts are at approximate right angles to each other; additionally Long Island is separated from the mainland of Connecticut by Long Island Sound. The various bodies of water in the region (Atlantic Ocean, Long Island Sound, New York Harbor, Jamaica Bay, etc.) have different surface temperatures. In addition the urbanization of the New York areas can modify atmospheric flows. Various studies have indeed focused upon this region, e.g., Frizzola and Fisher (1963), Bornstein 1987, Bornstein et al 1994.

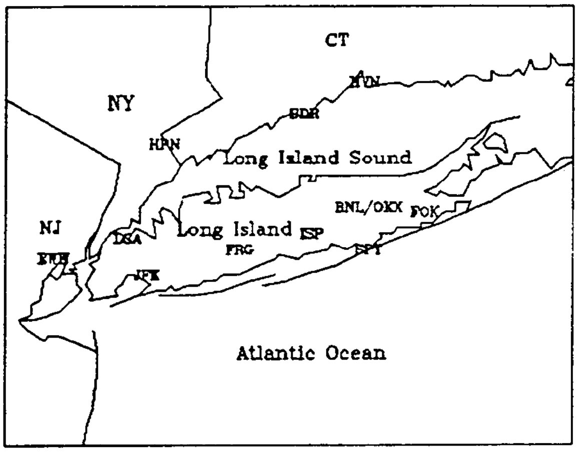

Figure 1. New York City Region. Three letter codes indicate surface stations; SPT (Smith Point Beach) and BNL (Brookhaven National Laboratory) are research stations operated by BNL, the rest are standard reporting stations. OKX indicates the New York City Forecast Office, which is located on the BNL site.

If the gradient winds are light, a few hours after sunrise the circulations are dominated by scales of the order of 10 km or less. These include locations such as La Guardia airport, or the north shore of Long Island, where the morning flow is often from the Long Island Sound; i.e., from the north or northeast; later in the day local circulations are replaced by what appears to be a single mesoscale regime - a sea breeze circulation that encompasses all of Long Island and penetrates deeply into Connecticut.

The evolution of the sea breeze front in the region where New York and New Jersey meet can be different from that in adjacent regions. Bornstein (1994) and Reiss et al. (1996) have reported observations that show the sea breeze front advancing more slowly in this region than over Long Island and central New Jersey. While in the southern section of New Jersey a single, "classical" sea breeze development occurs.

This paper will present results from model simulations, surface observations and remote sensing using the Weather Surveillance Radar-1988 Doppler (WSR-88D).

The modeling was done using the Regional Atmospheric Modeling System (RAMS) Version 2c described by Pielke et al.(1992) and Walko (1991). The surface observational data is from standard reporting stations and two research stations operated by Brookhaven National Laboratory. (Locations are shown in Figure 1.) The radar data used is from the National Weather Services operational WSR-88D at Upton, NY (OKX).

The deployment of the WSR-88D (Crum and Alberty, 1993b) provides a means of observing the evolution of the sea breeze fronts with significantly greater spatial and temporal coherence than obtainable from routine surface instrumentations. The primary purpose of the WSR-88D is the observation and analysis of precipitating systems. However, its high power and alternate operating modes (NOAA 1991, Klazura and Imy 1993) also provide usable returns in clear air situations. A number of investigators (Bellue and Tongue, 1994, Bellinger 1996, Gould et al. 1996, Tongue et al. 1996, Michael et al. 1996, and Reiss et al. 1996, Wilson et al. 1994) have noted that under sea breeze conditions, the reflectivity data fields from the WSR-88D (and other radars) have narrow regions of

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increased reflectivity, with echoes that are often as large as 20 dBZ. These zones evolve in time tracking the location of the sea breeze front.

The physical source of the clear air echoes is not immediately obvious. The returns are often attributed to a number of phenomena: refractive index inhomogeneities, atmospheric ducting, suspended debris (dust, leaves, etc.), birds, aerosols, and insects (Sauvageot and Despaux, 1996). Wilson et al. (1994), from studies done in Florida and Colorado, make a strong case for insects being the primary source of returns.

Instead of the usual constant elevation angle displays it is useful and concise to use a display mode that approximates the returns at a specified single altitude (Constant Altitude Plan Position Indicator — CAPPI); 500 meters being most convenient for the studies reported here. The CAPPI displays used in this paper were produced using the Interactive Radar and Analysis Software (IRAS) (Priegnitz, 1995).

2. ZERO GRADIENT FLOW-MODELING RESULTS

Figure 2 shows winds 30 m above the surface at local noon (1700 UTC) from a three dimensional, time dependent, simulation that used conditions representative of June: sunrise at the center of the grid at 0720 UTC, sunset at 0025 UTC, typical sea surface temperatures, initial sounding, etc. Calm conditions were assumed prior to sunrise. The overall region was covered by a 4 km grid that extended from Cape May to beyond Montauk Point on Long Island and well into Connecticut. Nested grids (at ¼ of the primary grid spacing) were used so as to allow a reasonable representation of the geographical details in the New York City and on central Long Island. One can see that at 1700 UTC (local noon) sea breezes have developed in New Jersey, the New York City region and in Connecticut. On Long Island a sea breeze has developed along the south shore and a "sound" breeze along the north shore.

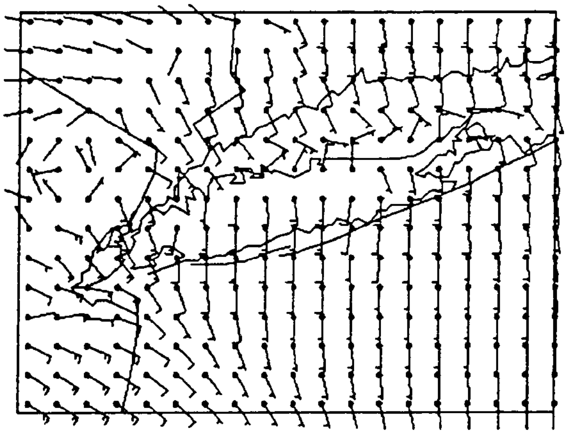

Figure 2. Winds at 1700 UTC (local noon) from a RAMS simulation initialized with "typical" June conditions and zero gradient wind. Full barb represents wind of 5 m sec^{-1}.

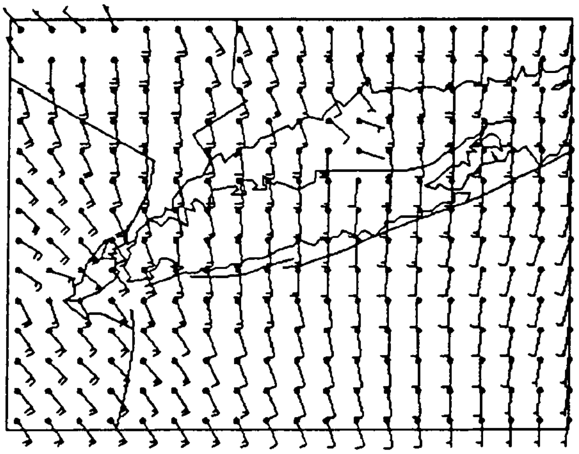

Figure 3. Same as Figure 2 except that simulated time is 2100 UCT (1600 LST).

Four hours later (2100 UTC), Figure 3, the sound breeze on the north shore of Long Island has been overtaken by the sea breeze from the south. Except for an area over Long Island Sound, where it is the widest, one large scale system is operating over all of the Long Island and Connecticut region.

3. OFFSHORE GRADIENT FLOW - MODELING AND OBSERVATIONS

A sea breeze event on 19 August 1996 was characteristic of many summer sea breeze events. The synoptic situation was dominated by a slow moving high pressure cell, initial conditions were such that the sea breeze development along the south shores of Long Island and Connecticut had to overcome an initial offshore geostrophic flow of 5 to 8 m sec^{-1}. The conditions indicated minimal cloud formation and substantial solar heating. Figure 4 shows the winds, temperature and dew point at surface stations at 1150 UTC. (Sunrise was at 1002 UTC, sunset at 2341

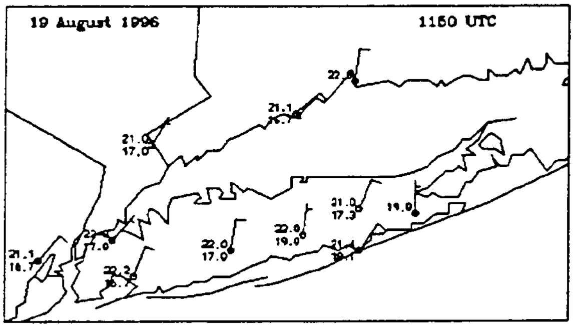

Figure 4. Surface observations of winds (full barb is 5 m sec^{-1}), temperature and dew point (°C)at 1150 UTC (about 2 hours after sunrise) on 19 August 1996.

UTC in the central portion of the area.) Atlantic Ocean and Long Island Sound surface water temperatures in the 20 to 22 °C range provided a 6 to 10 °C differential to the afternoon maximum temperatures of 28-30 °C forecast within 15 km of the coast. This temperature differential drove sea-breeze circulations during the day.

Figure 5 shows the surface observations six hours later. Sea breeze circulations have been established on the south shores of Long Island and Connecticut but has not penetrated very far inland on Long Island; there were insufficient surface observations available to determine the penetration into Connecticut.

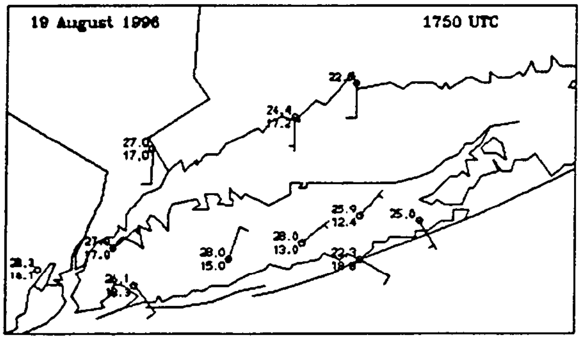

Figure 5. Same as Figure 4 except at one hour after noon

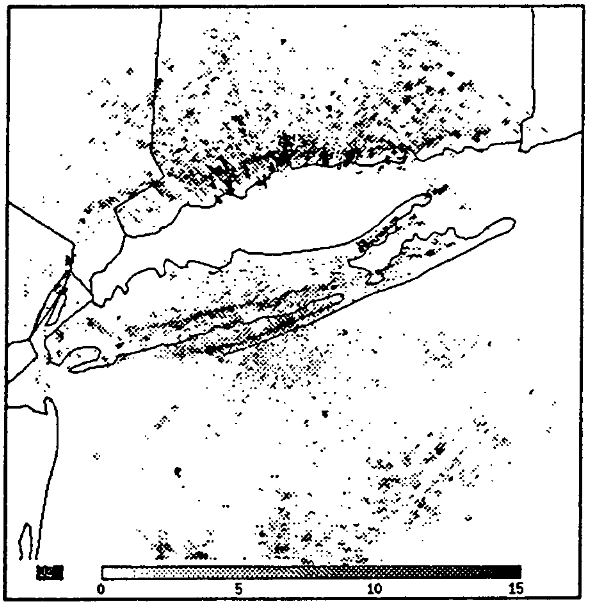

Figure 6. Reflectivity from OKX WSR-88D, CAPPI of 500 m; sampled during the 10 minute period ending 1759 UTC on 19 August 1996.

Figure 6 is a CAPPI display at 500 m of the reflectivity measured by the WSR-88D OKX radar; the volume scan was done during the 10 minutes ending at 1759 UTC. An apparent sea breeze front is located over the south shore of Long Island; about 5 km inland. Another sea breeze front is located in Connecticut just inland of the shore of Long Island Sound indicating that the sea breeze has not advanced much beyond the coast.

A RAMS simulation was run using conditions similar to that discussed above except that it was initialized from the 1100 UTC sounding made at the OKX station, used observed sea surface temperatures and the appropriate solar cycle. Figure 7 shows the near surface winds at 1800 UTC. One can see that the limited sea breeze penetration on the south shores of Long Island and Connecticut is well represented; however the advance in the vicinity of La Guardia airport (LGA) is over estimated; this may be due to the fact that this simulation does not take into account urban roughness effects.

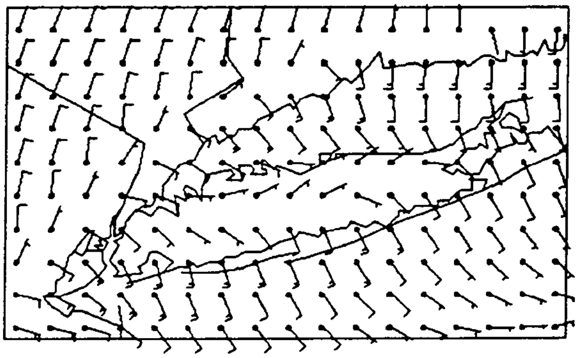

Figure 7. Winds from a RAMS simulation an hour after local noon (1800 UTC) run with initial conditions taken from 1200 UTC sounding at OKX on 19 August 1996

4. CONCLUDING REMARKS

The geographical configuration of the New York City region induces a variety of sea breeze regimes — only two of which are discussed above. The WSR-88D is becoming an important diagnostic tool that augmented by modeling, can enhance understanding and improve forecasts.

Acknowledgments

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