Surface Air Temperature in a Maritime Metropolitan Region

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ABSTRACT.—In investigations of the micrometeorology of any area, one of the basic parameters required is the spatial and temporal distribution of the surface air temperature. A mobile instrument mounted on an automobile was used for measuring temperatures within the surface mixed layer. Details are presented of a case study at Saint John, New Brunswick, in a summer period. The effects of topography, lakes, sea-breezes, and land-use characteristics are discussed.

STATISTICS for climatology of a region that are based on measurements taken at only one point fail to reflect differences in climate within the region. These differences can be especially significant in determining the scope of a tourist industry or in land-use planning on a regional and personal level.

One of the interests many people have is the distribution of surface air temperature within a region. During the summer months, some people like to stay near bodies of water where temperatures are moderated. Others prefer more radical climates where the air is drier but the temperatures vary greatly. Meteorologists are also interested in the surface isotherms, as they give an indication of the state of the atmosphere in the surface mixed layer.

A simple, mobile instrument for measuring these temperatures is described, and an example of the information that can be obtained is given for a maritime metropolitan region.

THE INSTRUMENT

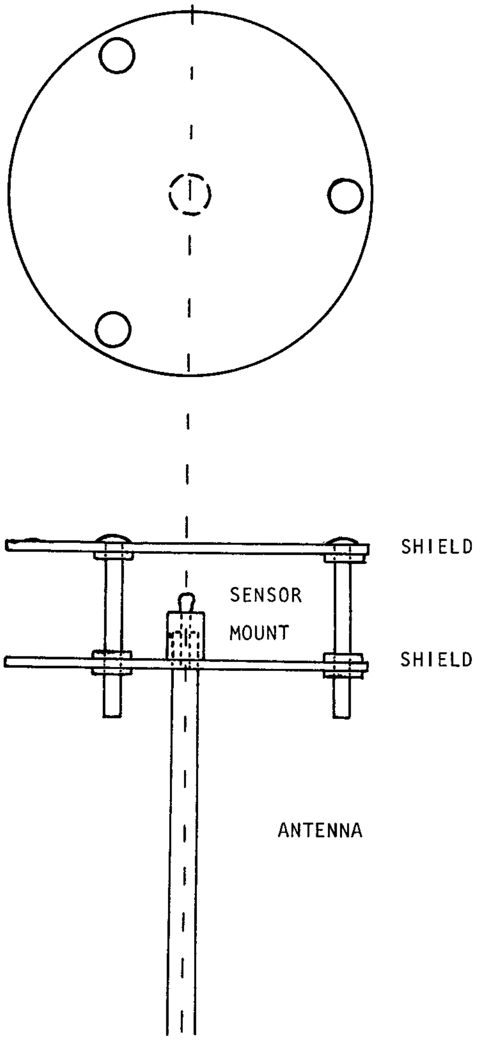
A rugged, dependable, and inexpensive direct-reading temperature system was developed for measuring the air temperature from a moving vehicle. It consists of a sensor and supporting structure (fig. 1), a simple circuit (fig. 2), and a digital voltmeter.

The sensor used is a dual thermistor made by Yellow Springs Instrument Company. These thermistors, when combined in a simple resistive network, produce a device capable of giving reproducible temperatures on a linear scale with a range of about 50°C. (The networks used in this system worked from −5°C to +45°C.)

The thermistor bead (YSI#44018) is mounted securely in a thermally insulating holder that is mounted between two circular plates about 7 cm in diameter. The separation between the plates is such that the bead is screened from the direct rays of the sun (except at low sun angles) and cannot sense the road surface on either side of the transporting vehicle. These plates, held together by three thin vertical struts, are painted shiny white on their outer surfaces and flat black on the inside surfaces. This combination serves as a fairly effective radiation shield for the sensor by blocking off direct and reflected shortwave solar radiation while permitting ample airflow past the sensor.

The bottom plate of the shield and the insulating holder attach to the top of a standard whip antenna, which is mounted on the roof rack of an auto-

Figure 1.—Sensor and supporting structure.

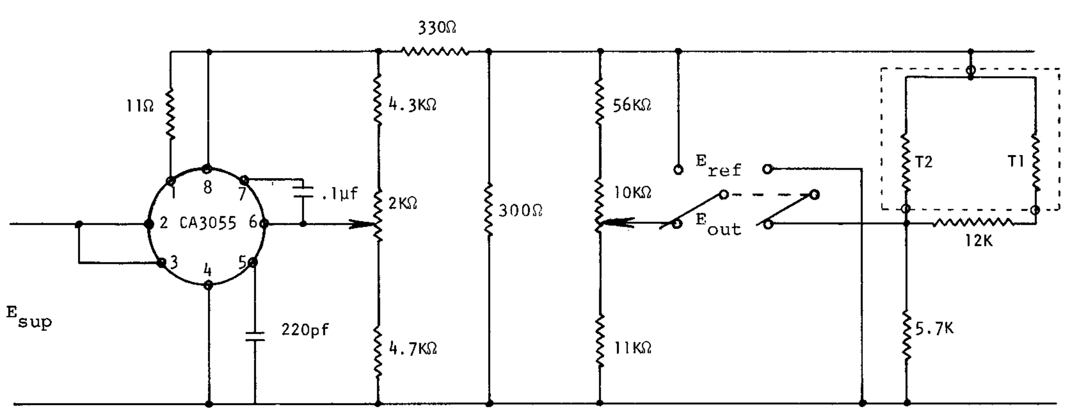


mobile. This allows the sensor to be placed several meters above the ground and at least 1 m above the roof of the transporting vehicle. Several advantages are gained by this type of mounting in that the sensor tends to be above the layer of air directly influenced by the road and thus samples in an area that represents the surroundings. The vehicle motion, which was maintained above 5 m sec^{-1} for all sampling points, produced adequate ventilation for the sensor.

Three wires lead down the mast from the sensor to the signal conditioner box inside the vehicle. This box consists of a constant voltage source generator (such as an RCA3055) working from a 9-V battery, a divider network to drop the output voltage of the regulated supply to a useful level, a zero-offset control, and the resistive network for linearizing the thermistor output. A swith is also included to permit monitoring of the regulated DC voltage, and a variable resistor control allows setting of that voltage when any drift due to system aging is detected.

The output of this box can be monitored by any DC voltmeter. A Weston Digital Voltmeter, Model 1240, was used during the field study reported in this

Figure 2.—The thermistor linearizing circuit. T1 and T2 are the sensor elements; E_{sup} is the battery supply voltage; E_{ref} is the reference voltage chosen using the thermistor's equation to yield a unit change in E_{out} for a 0.1°C change in temperature.



paper. This permitted the temperature to be read directly to 0.1°C. The absolute accuracy of the system is ±0.2°C without calibration, and the system is insensitive to air velocity above 5 m sec^{-1}.

THE FIELD PROGRAM

To investigate the spatial and temporal distribution of surface air temperature in the vicinity of Saint John, New Brunswick, Canada, two identical instruments were constructed, tested, and calibrated.

A grid was laid out on the city map, and a series of stations were identified, based on the criterion that a site selected was to be as close to the center of each grid square as possible but still on a navigable road. This produced 51 separate locations, which were divided into two courses, one on each side of the Saint John River. A continuous loop for each course was chosen, and this became the driving pattern for the two vehicles, each manned by a driver and an observer. Each course took about 1.5 hours of continuous driving to complete, and a minimum of five traverses was run each day.

The temperature at each station was obtained by averaging the readings taken during a 10-second interval centered at the preselected site. These values were then plotted against time to obtain 51 individual daily temperature curves. From these a series of surface isotherm maps was obtained for times corresponding to concurrent vertical profiling of the atmosphere. An example of these maps, showing isotherms drawn every 0.4°C, is given in figure 3. Complete data from this study are given in McTaggart-Cowan *et al. (1974)*.

RESULTS

From these isotherm plots, a number of clearly definable meteorologically influenced events can be observed. The isotherm plot made for 1430 local time on 16 July 1974 (fig. 3) shows the typical detail that can be observed during a sunny afternoon. Temperature differences of 6°C are not uncommon in a distance of 8 km from the edge of the Bay of Fundy. These differences develop rapidly during the summer when the sky is clear.

This particular day also showed the

Figure 3.—Surface isotherms at 1430 on 16 July 1974. The city of Saint John, New Brunswick, straddles the Saint John River just at its mouth. (Map Scale: 1 cm=1780 m).

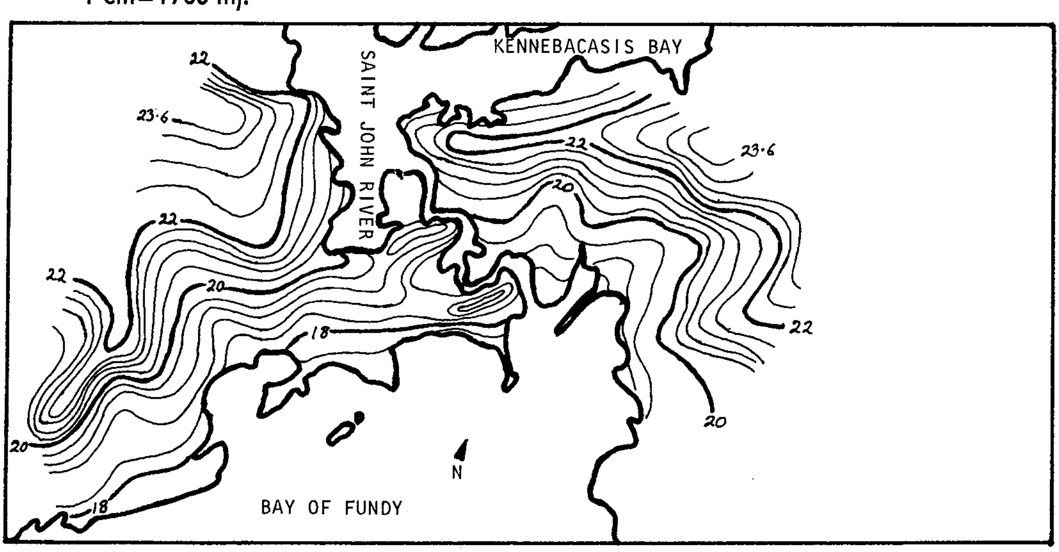
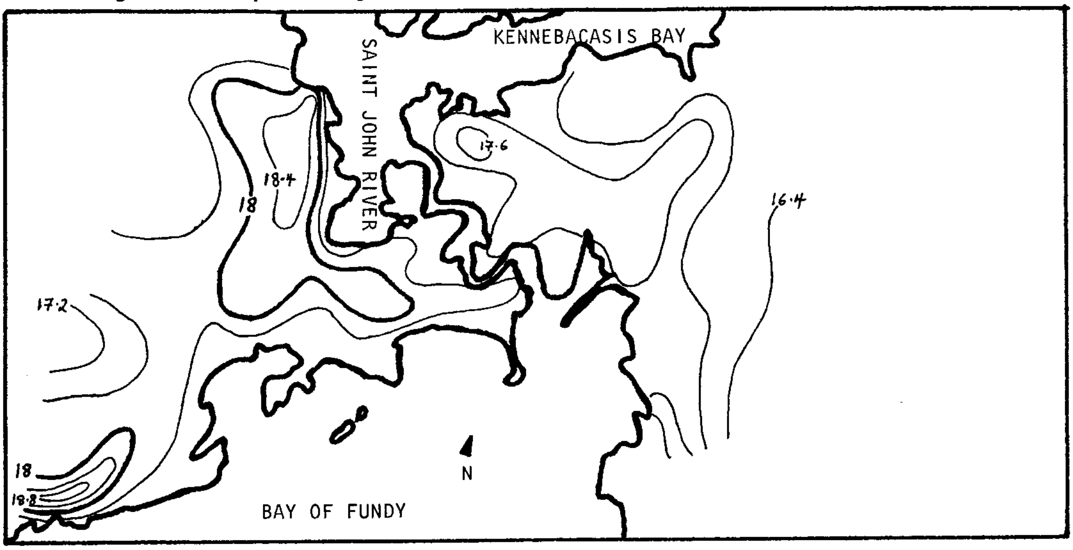


Figure 4.—Surface isotherms at 1000 on 16 July 1974, showing the effect of fog on the temperature gradient.



effect of fog. At 1000, the isotherm map (fig. 4) showed very little structure. The visibility in fog at this time was given as 6 mi, with the sky totally overcast. The sky cleared sometime after 1100, and convective-type clouds were reported by 1500, shortly after the 1430 profile. This type of cloud can be related directly to the strong heating of the surface.

The effect of the sea breeze, a characteristic event of a maritime region, can also be observed in figure 3. The bulge inland of the 20.0° and 22.0° isotherms on the right of the diagram is a result of the colder Bay of Fundy air intruding over the rapidly warming land. In the morning before this developed, the flow was light northerly, but by the afternoon the southwesterly flow of the sea breeze dominated. This resulted in the surface mixed layer temperature near the water being warmer than that further inland in the morning, but cooler later in the day. The moderation of the surface air temperatures in summer near a body of water is clearly shown.

Another example of the effect of a body of water on the surface temperature can be seen in figure 5. In the western portion, the 14.0° isotherm can be seen directly downwind of a lake. The water temperature is higher than the air temperature and, with the westerly flow that was dominant at the time, a tongue of warmer air developed on the lee side of the lake. The splitting of this warmer air flow follows the topography.

Urban versus rural temperature differences can also be demonstrated by isotherm plots. The early morning distribution of temperature on 18 July 1974 (fig. 5) shows the heart of the city with a temperature of 13.2°C, while the countryside is typically below 12°C. This feature is usually masked during clear summer days by the locally generated air flow resulting from the city's proximity to the water.

The plot for 1100 on 18 July 1974 (fig. 6) shows an example of a late-morning situation on a clear sunny day. This plot is similar in complexity to the 1430 plot on 16 July (fig. 3), but has occurred more than 3 hours earlier. Only the full-degree isotherms are shown, as the principal purpose of the figure is to show the effect of topography on the

Figure 5.—Surface isotherms at 0700 on 18 July 1974, showing the effect of Ludgate Lake on the surrounding temperature field and the warming caused by the city center.

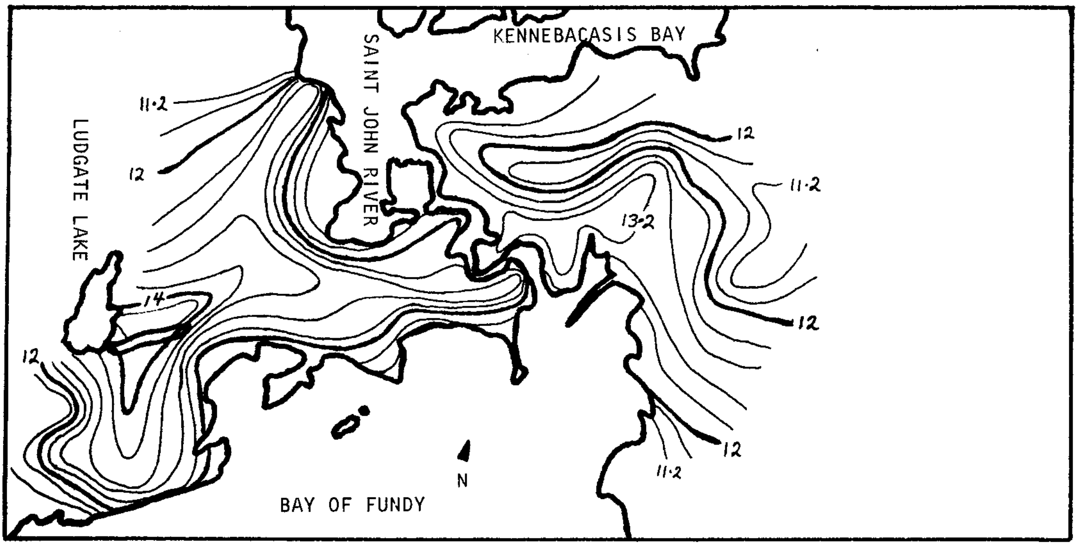
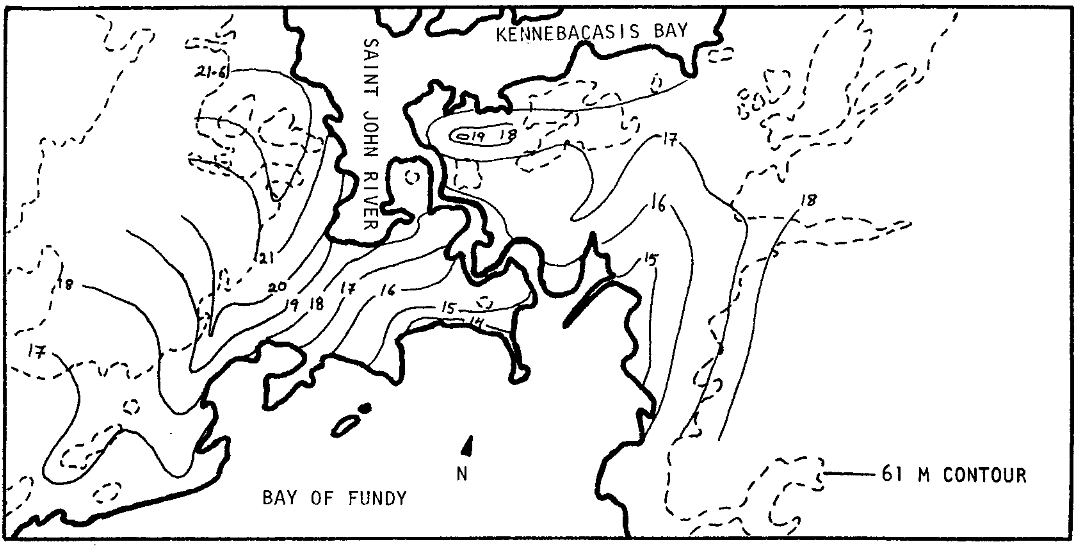


Figure 6.—Surface isotherms at 1100 on 18 July 1974, showing the effects of topography. The areas enclosed by the dashed lines (the 61-m contour) have an elevation above 61 m.



temperature distribution. The dashed lines show the 61-m contour. Two dominant hot spots can be observed, one in the upper center of the picture, and the other directly to the left of it. Each is in a valley protected from the sea breeze to the south. The inward thrust of the sea breeze can be seen to the right of the plot where it lines up reasonably well with the valley. On the west, the more complex topography tends to obscure the early effects of the sea breeze.

CONCLUSION

This technique for obtaining surface isotherms is both simple and inexpensive to operate. The results can be used to aid in land-use planning on several scales. Areas that have high summer daytime temperatures and are near water are naturals for good tourist-industry development, offering swimming and boating. Industrial development normally associated with coastal regions should be located in areas where gaseous effluent will not be carried inland to residential areas by the sea breeze on clear afternoons. Individual people can also use this type of information in a qualitative manner in choosing general areas of habitation.

REFERENCE

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