5.3 CONTAMINATION OF THE LONG-TERM TEMPERATURE SERIES OF DE BILT (THE NETHERLANDS) BY URBAN HEAT ADVECTION

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1. INTRODUCTION

A factor that complicates the assessment of climate change and variability, is the neighborhood of (growing) cities to the locations of measuring sites. It is well known (Oke, 1974 and 1979; Landsberg, 1981) that cities develop Urban Heat Islands (UHIs). To correct long-term temperature time series for the contribution of urban warming, it is important to understand the formation of UHIs and the extent to which heat is advected to measuring sites leeward.

In contrast to the magnitude of UHIs (the temperature difference between city centers and the background rural area, $\Delta T_{u\text{-}r,}$), the extent to which urban heat is advected to measuring sites leeward is not well known. The objective of the present paper is to study the latter phenomenon for the measuring site of De Bilt. Although the magnitude of the effect is about an order of magnitude smaller than $\Delta T_{u\text{-}r}$, it is of utmost importance for the detection of climate change and variability because it may contaminate the climate signal in long-term temperature records.

2. METHODOLOGY

To examine the advection of urban heat to the measuring site at De Bilt, we studied the wind direction (*wd*) dependence of the hourly temperature differences (ΔT) between De Bilt and Soestberg for the period 1993–2000. Figure 1 shows that the measuring site in De Bilt is situated in a transition zone between urban and rural areas. The site is surrounded by three towns: De Bilt (33,000 inhabitants) extending from KNMI to the north, Utrecht (234,000 inh.) town border at 2.5 km west and Zeist (60,000 inh.) town border at 2.4 km southeast. For Utrecht, Conrads (1975) showed the presence of clearly perceptible UHI effect. Extending from the measuring site, there is a forested area in directions between NNE and SE and mainly pasture in the other directions. Our rural baseline station Soesterberg is situated at the airport just northwest of Soesterberg (6,000 inh.) within a forested area. The distance between De Bilt and Soesterberg is 7.5 km.

As an independent check of the rural nature of Soesterberg, both stations have also been compared with hourly temperature values averaged over three other rural KNMI-stations (T_{av3}): Cabauw, Deelen and Herwijnen. The distances of these stations to De Bilt range between 22 and 48 km. All five stations are situated in flat terrain.

The magnitude of urban heat advection depends on $\Delta T_{u\text{-}r}$. It is well known that $\Delta T_{u\text{-}r}$ is large during nights with cloudless skies. The magnitude of $\Delta T_{u\text{-}r}$ may also depend on the season. Therefore, we studied the ΔT-*wd* dependence as a function of: (a) season (winter, October-March, and summer, April-September); (b) day and nighttime hours (according to the times of sunrise and sunset); and (c) cloud amount (hours with few clouds have an average degree of cloud cover $\leq$ 5/8 and hours with much clouds $\geq$ 6/8). For cloudiness and wind direction the hourly values of De Bilt have been used. No threshold has been applied for wind speed.

If urban heat advection really has an effect on the De Bilt series, ΔT should be large for those directions where the measuring station at De Bilt is on the leeward of the towns (especially for Utrecht).

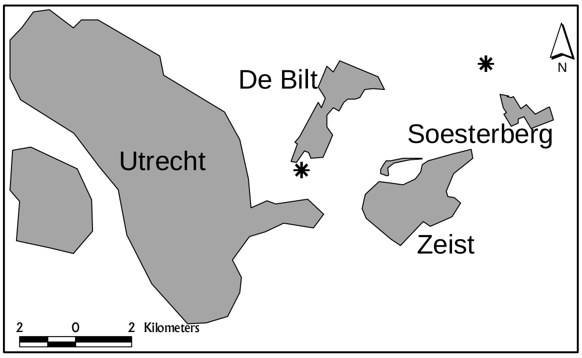

Figure 1. Situation of the measuring sites (indicated by a ∗) in the center of the Netherlands

3. RESULTS

Figure 2 presents the variation of ΔT across the year. The variations for night- and daytime hours are also shown. The figure shows a strong annual variation of ΔT with ΔT being larger in the winter half-year than in the summer half-year. Note that the annual variation in the three cases is of the same order of magnitude as the difference in ΔT for nighttime and daytime hours. The large value of ΔT for nighttime hours is in line with the suspected urban warming ef-

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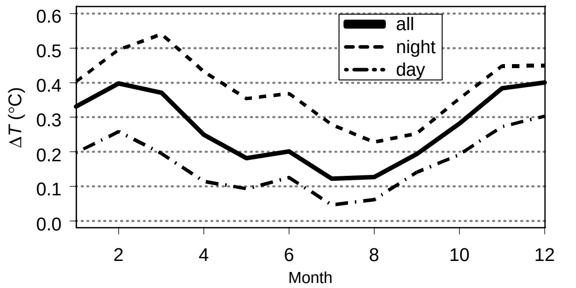

Figure 2. Annual variation of ΔT for all hours, nighttime hours and daytime hours.

fect in De Bilt. This is, however, not a proof for the existence of that effect.

Figure 3 shows the eight ΔT-*wd* panels for 10° wind direction classes. Especially at nights with few clouds, the figure shows that ΔT is much larger (~ 0.4–0.8 °C) for wind coming from the town of Utrecht (270°) and De Bilt (40°) than for the other directions. During the day these peaks are hardly noticeable. In all cases, increased cloud cover weakens the effects observed for few clouds (lower panels of Figure 3).

There are two peculiar effects in Figure 3 that deserve further attention. The first is the nighttime peak in the ΔT-*wd* dependence for SE wind directions (winter, few clouds). This peak may partly be explained by the advection of urban heat from Zeist. However, independent comparisons of De Bilt and Soesterberg with T_{av3} (not shown) revealed that this peak also partly results from the station Soesterberg that is in winter relatively cold for the considered wind direction. The second peculiarity is the minimum at SSE wind directions, especially visible in the daytime plots. Here the independent comparison revealed that the effect must be attributed to the site in De Bilt. A possible explanation is that for De Bilt for SSE wind directions the advected air has a long fetch over the pastures, while for Soesterberg there is a long fetch over a forest.

4. CONCLUSIONS

The analysis in this paper suggests that urban heat is advected to the measuring site in De Bilt. The effect is largest when $\Delta T_{u\text{-}r}$ is supposed to be the largest, namely during nights with cloudless skies. Because the urban areas around the site expanded in the past century, urban heat advection contaminates the long-term temperature series of De Bilt. Based on the present work, we estimate that this effect may have raised the annual mean temperatures by 0.1–0.2 °C in the 20th century, which is relatively large compared to the observed linear trend of about 1.0 °C in that century.

5. REFERENCES

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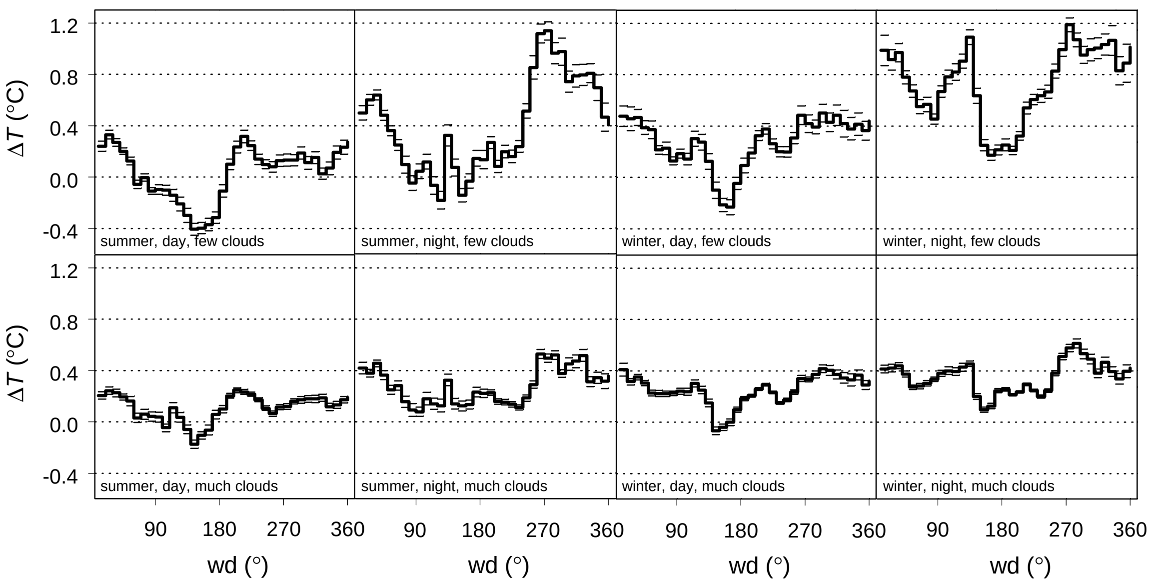

Figure 3. Dependence of ΔT on wind direction (*wd*) as a function of season, day- and nighttime hours and cloud amount. Note that the lower four panels are the same as the corresponding upper panels but with much cloud. The dashes give the 1×se-values for each 10° wind direction class. See the text for definitions.