

Local Circulation around an Industrial Area

by F. H. Schmidt and J. H. Boer (Royal Netherlands Meteorological Institute De Bilt)

Presented at the 10th OSTIV Congress, South Cerney (England), June 1965

Abstract

The local circulation around a large heatproducing oil refinery west of Rotterdam was investigated. The horizontal wind field was determined by making observations of the horizontal wind at a height of 3 meters at twelve points around the refinery. The vertical circulation was studied by means

A few years ago the local circulation was investigated in an area west of Rotterdam, which is one of the most extensive industrial areas in the Netherlands. In this area one finds some big oil refineries amongst other industries of varying character.

The waste gases of the refineries are brought into the atmosphere with temperatures of a few hundred degrees C,

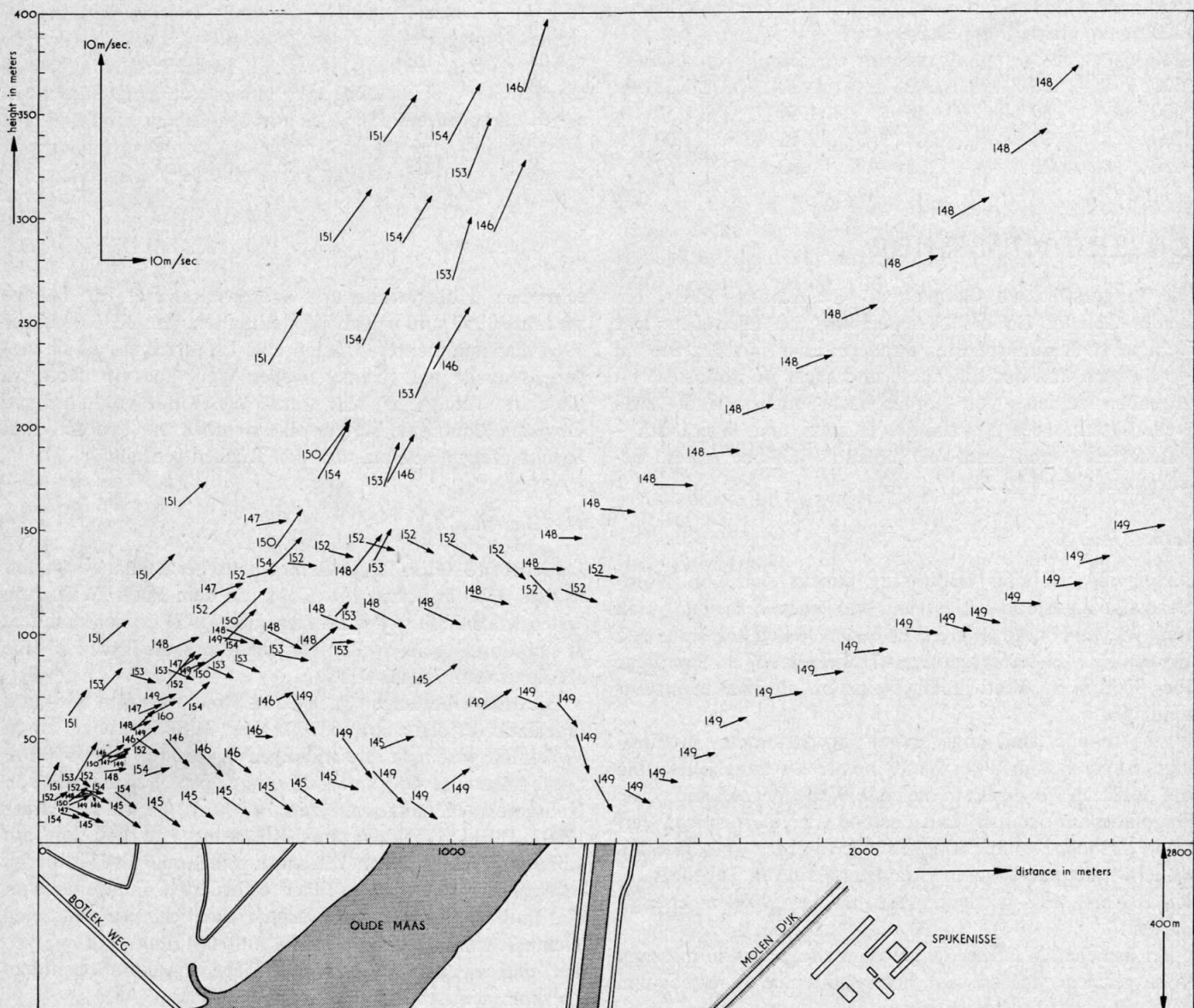


Fig. 1 - Vector difference between winds at twelve observation posts and Blankenburg, averaged for 8 cases with wind directions between 220° and 300°

of double theodolite pilot balloon observations. The vorticity and divergence fields in the layers near the ground were computed from which the vertical velocities at an altitude of 100 m could be determined. A comparison was made between the computed and measured vertical velocities. Convergence and upward motions were found above the refinery itself, whereas downward motions appeared to exist in the immediate surroundings. This shows that industrial areas create important local circulations.

which means that they have a considerable buoyancy. Nevertheless their typical smell is sometimes observed in nearby places, which suggests the presence of downdraughts. It was considered therefore to be of some importance to study the horizontal and vertical circulation in this area.

For the investigation of the horizontal circulation the horizontal wind field round the refineries was studied. The area is roughly a square with sides of 2 km. Observations of the horizontal wind were made at 12 points at a height of 3 m

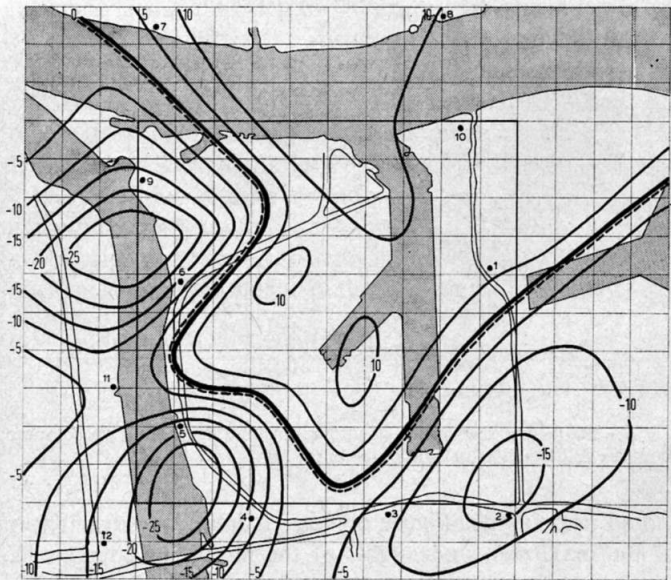


Fig. 2 - Vorticity field (10^{-4} sec^{-1}) computed from the wind vectors of fig. 1

(fig. 1) by means of a transportable wind set. The 10 minutes averages consecutively obtained at the 12 points were compared with the wind recordings made at a height of 5,5 m at a fixed station, Blankenburg, about 6 km to the west of the refinery. The vectorial difference between the wind at each observation post and the Blankenburg wind shows the influence of the industrial complex, due to heat production, friction and probably also partly to the height difference of the reference anemometer at B.

The vertical circulation was studied by means of pilot balloon observations (some 200). The balloons were very accurately weighed and had ascent velocities of 40, 60 or 150 cm/sec. They were followed by two theodolites, the base being about 400 m. Every 15 seconds an observation was made so that the path of the balloons could be determined with great precision.

Figure 1 shows the vector difference between the wind at the 12 observation posts and the undisturbed wind at B as an average of 8 situations with winds from westerly directions in August 1960. Speeds are expressed in cm/sec.

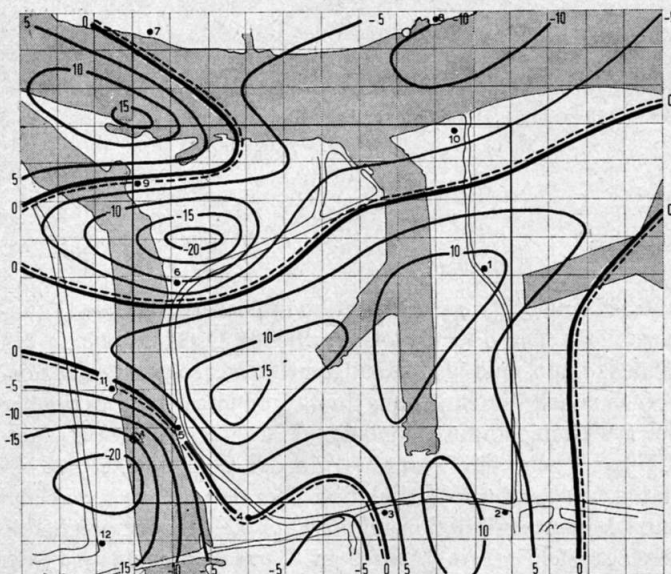


Fig. 3 - Vertical velocities of the air at 100 m in cm/sec, computed from the wind field of fig. 1

The influence of the industrial area is clear:

Firstly, almost all difference vectors show an easterly component, obviously due to the increased friction of the area.

Secondly, one obtains the impression that a cyclonic circulation exists around the westerly part of the terrain, where almost all the heat is produced.

Thirdly, a comparison of the wind vectors in the points 2, 1 and 10 on the one hand with those in 5, 6 and 9 on the other indicates that the air converges towards the centre of the area.

In order to obtain more quantitative results the vorticity and divergence fields of the difference wind have been determined.

Figure 2 shows the vorticity field expressed in 10^{-4} sec^{-1} as a unit. The positive area clearly shows the existence of a cyclonic circulation around the industrial area. It is interesting to see how the increased friction results in strong anticyclonic vorticity on the windward side of the area.

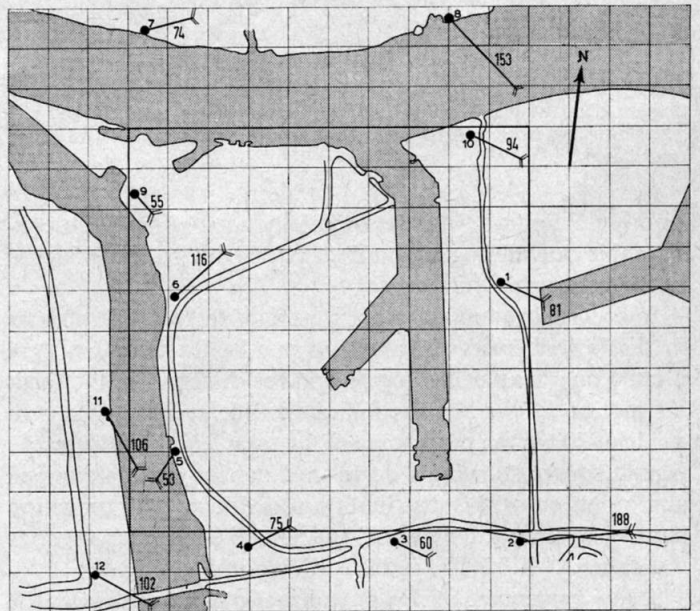


Fig. 4 - Ten consecutive pilot balloon tracks on May 10th 1961

Figure 3 demonstrates the divergence field transformed into vertical velocities at 100 m, expressed in cm/sec.

The pattern shows an upward motion above the refineries with mean velocities up to 15 cm/sec in the region of the largest production. This figure represents of course an average value taken over about 10^4 m^2 . Upward velocities in individual plumes have been much larger as will be seen from the pilot balloon observations. Downward motions are found to the west of the industrial area and over the river, to the north and northeast. Obviously the heat production gives rise to a circulation system with ascending motions in the centre and descending currents in the surroundings.

The individual vertical motions are of course much more complicated. They were investigated by means of more than 200 pilot balloon observations.

Figure 4 shows the path followed by 10 consecutive pilot balloons released within a few hours during day-time on May 10th, 1961, with an almost constant NNE-wind.

The arrows indicate the true motion of the air for each

observation, the scale of the vertical component being five times that of the horizontal one. The ascents no. 146, 151, 153 and 154 show considerable updraughts. The balloons were obviously caught by updraughts originating from one

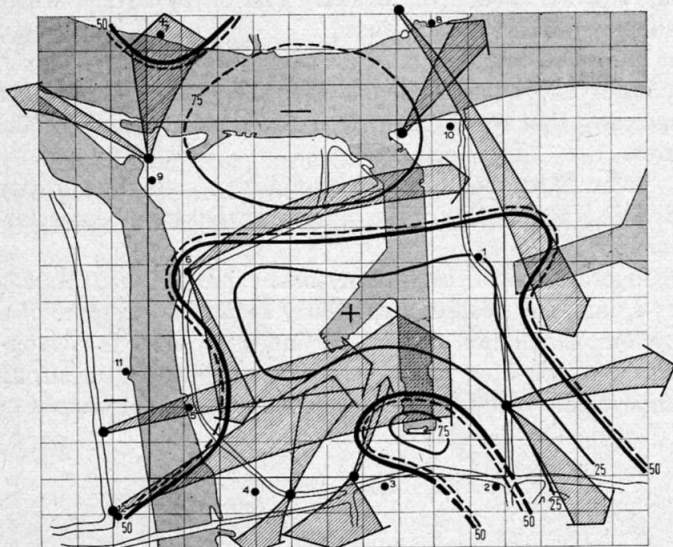


Fig. 5 - Distribution of upward and downward motions according to pilot balloon observations. Numbers indicate percentage of total track length with downward motion. Arrows give the horizontal projection of the balloon tracks used

or more chimneys, whereas especially no. 149 met with considerable downdraughts, perhaps partly due to the influence of the cold water surfaces.

In order to obtain a general picture of the vertical motions in the lowest layers all tracks up to a height of 150 m were plotted on a map of the region and the direction of the vertical motion of the air was indicated. For every square with a side of 200 m the percentage of the total length of the tracks in that square showing a downward motion was determined and a pattern of this distribution was drawn. The transition between average downward and average upward motions was taken at 50%. The result is shown in figure 5.

A low percentage of downward motions is found over the centre of the industrial area, a high percentage over the waterway to the north and in a small area in the SE. There is a good agreement with the results from the horizontal wind measurements. The broad arrows indicate the distribution of the balloon tracks over the area.

Glider pilots will be interested in the strenght of the indi-

Zusammenfassung

Westlich von Rotterdam liegt ein 4 km grosser Komplex von Ö Raffinerien (Fig. 7). Die Abgase dieser Anlage haben zuerst eine Temperatur von mehreren Hundert Grad. Trotz ihres starken Auftriebes ist ihr Geruch in der Umgebung deutlich zu spüren, was auf Abwinde hinweist. Das Zirkulationssystem wurde mittels mobiler Windstationen und Doppeltheodolit-Vermessungen von Pilotballons untersucht.

Figur 1 zeigt die Vektordifferenz der Bodenwinde zwischen einer Kontrollstation ausserhalb des Industriekomplexes (6 km westlich) und 12 Messpunkten, die das Fabrikgelände umgeben. Die Ergebnisse deuten auf Konvergenz im Zentrum

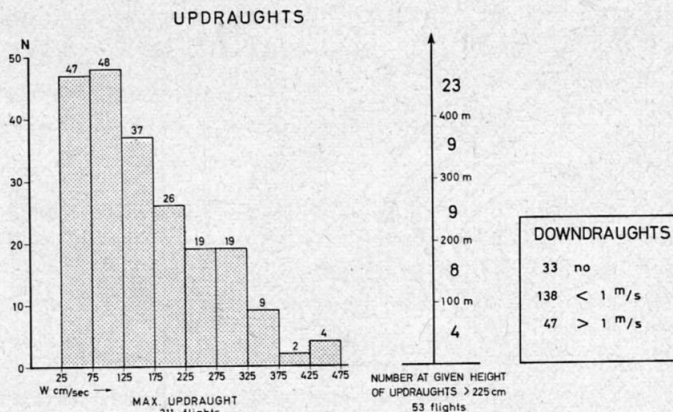


Fig. 6 - Frequency distribution of updraughts and downdraughts computed from the individual pilot balloon ascents

vidual updraughts. Figure 6 shows a frequency distribution of the maximum updraughts of the individual ascents. We see that updraughts up to values between 4 and 5 m/sec. were met, but obviously most of the balloons were not caught by the strong updraughts, which will have been rather narrow.

The heights at which the stronger updraughts were found are indicated in the centre of this picture. The majority was present above 400 m.

The downdraughts were not so strong. Only 5 out of about 200 flights showed downdraughts of about 2 m/sec.

These are the main results of measurements of an industrial thermal circulation. An example of an artificial cumulus cloud that often develops above the industrial centre is shown in figure 7.

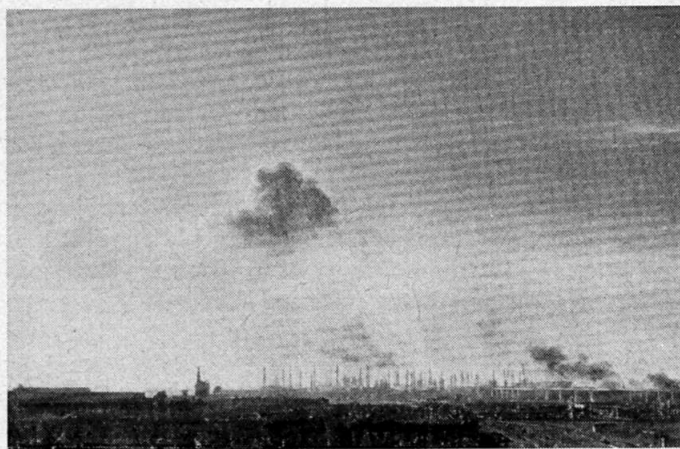


Fig. 7 - Photograph of the industrial complex crowned by a cumulus cloud

und auf eine zyklonale Zirkulation um den Westteil des Komplexes hin. Die überall vorherrschende Ostkomponente des Windes kann man als eine allgemeine Verzögerung der vorherrschenden Westströmung durch Reibung (Austausch) über der erwärmten Industrieanlage erklären.

Figur 2 zeigt das Vorticity-Feld der Bodenwinde und bestätigt die zyklonale Zirkulation über der Anlage sowie eine antizyklonale Zirkulation auf der Luvseite. Das entsprechende Divergenzfeld ist in Figur 3 in Form von Auf- und Abwinden in 100 m Höhe dargestellt. Die Geschwindigkeiten sind Mittelwerte. Dieses Feld entspricht einer Konvektions-

strömung mit Aufwinden im Zentrum und Abwinden in der Umgebung, vor allem im Westen, Norden und Nordosten.

Figur 4 zeigt wahre Luftbewegungen (Windvektoren in der Vertikalebene) entlang den Trajektorien von 10 sukzessiven Pilotballons, die innerhalb weniger Stunden am 10. Mai 1961 hochgelassen wurden. Einige Ballons zeigen starken Aufwind, Ballon Nr. 149 starken Abwind.

Die mittlere Verteilung der gemessenen Auf- und Abwinde in den unteren 150 m über dem Industriegebiet ist in Figur 5 wiedergegeben und bestätigt die Resultate der Bodenwind-

messungen (Fig. 3). Die breiten Pfeile geben die Richtung der Ballonbahnen wieder.

Von besonderem Interesse für den Segelflieger ist die Häufigkeit der gemessenen Aufwinde in der bodennahen Schicht unter 400 m (Fig. 6). Je grösser die Höhe, umso stärker die Aufwinde. Durchschnittswerte liegen bei 1 m/sec, Maximalwerte... bei 5 m/sec. Die Abwinde sind im allgemeinen schwächer.

Figur 7 zeigt eine «künstliche» Kumuluswolke, hervorgerufen durch das als Silhouette sichtbare Industriegebiet.

(Swiss Aero-Revue 5/1968)