Some results of turbidity networks[1]

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ABSTRACT

Turbidity networks to obtain daily values of haze attenuation from measurements of solar radiation, mostly by means of sun photometers, were established in 1961 in the USA by the National Center for Air Pollution Control, Cincinnati, Ohio, and in Western Europe from 1963 to 1967 by the author. The course of turbidity in the two networks during interesting periods is presented. Discussion of synoptic variations of turbidity is rather difficult, when referring to periods of rapid change of air masses, but consistency over large parts of the network is often observed during periods of quiet, sunny weather. Other data show that industrial activity over Central Europe is resulting in a daily increase of vertical optical thickness $\tau_D \approx 0.02$, while $\tau_D = 0.23$ in the average. Thus, the often observed high values of turbidity ($\tau_D \approx 1.1$) must normally have other causes and may, in the climate of North America and Europe, be related mostly to cloud physics.

Introduction

Up to now, measurements of direct solar radiation have hardly been used for synoptic investigation of air turbidity. Some local studies of the relationship between turbidity and air masses had been made, from which only mean variations of turbidity in continental areas or in a global sense can be derived. However, synoptic studies of haze attenuation were hardly possible, mainly because of the sparsity of measuring stations which is dictated by the laborious pyrheliometric method.

However, more adequate turbidity networks were organized a few years ago using sun photometers (Volz, 1959, 1969) with which measurement and evaluation is very simple. Apart from statistical investigations of the turbidity data sampled in the same time period, our main intention in establishing these networks was to make case studies of turbidity during the transport of air masses across a continent, hopefully to detect the influence of washout and production of natural and anthropogenic aerosols which make the turbidity variations very complex and difficult to evaluate even if weather and cloud conditions are favorable.

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Turbidity networks

The first turbidity network was established in 1961 by the U. S. Weather Bureau Research Station (later National Center for Air Pollution Control), Cincinnati, Ohio, and daily values of turbidity of initially 20 and later 40 stations have been reported. Beginning in April 1963, a network was also started in Central Europe by the author (at that time with the Astronomical Institute of Tübingen, Aussenstelle Weissenau). About 12 pyrheliometric stations made their data also available, and from 1965 to 1967, mostly due to the kind cooperation of the Central Weather Services, more than 30 stations sent us the data obtained with sun photometers. Lists of daily values of the turbidity coefficient B (for definition see caption of Fig. 1) were distributed. Generally, daily minimum values of B were reported—and used in this study—to minimize the effects of local conditions like morning haze.

Turbidity synoptics

Eastern USA. First we present in Fig. 1 turbidity data of the eastern part of the USA from April to June 1962, seperated into northern, central and southern regions. The location of stations is shown in Fig. 2 Turbidity is varying from $B = 0.025$ to extremes of 0.8 which

7

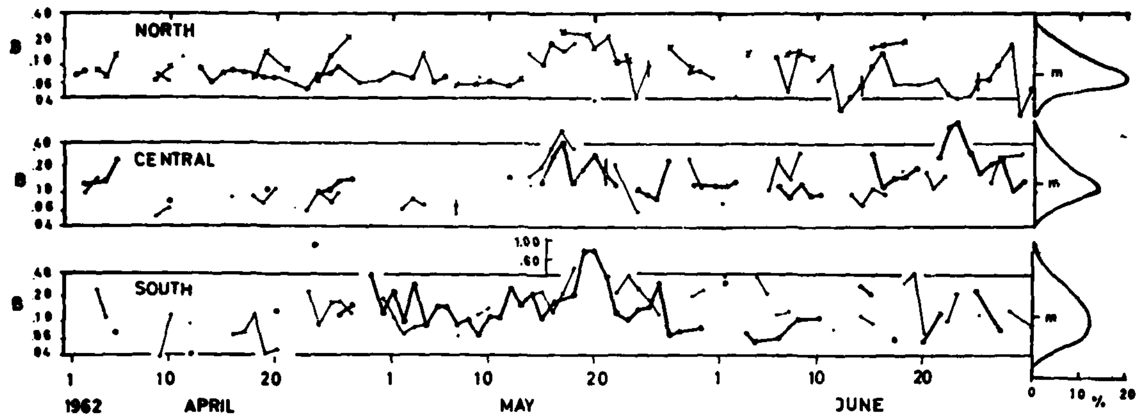


Fig. 1. Turbidity in the northern, central, and southern section of eastern USA, April to June 1962. North: ● = mean of 2 or 3 of the stations Ann Arbor, Michigan; Green Bay, Wisc., and St. Cloud, Minn.; · = only one station reporting; × = Blue Hill Observatory, Boston, Mass. Central: ● = Sterling, Va. (near Washington, D.C.); · = Cincinnati, Ohio. South: ● = New Orleans, Louisiana; · = Oak Ridge, Tenn. On the right side: smoothed frequency distribution (percent per 0.1 log B), and median value (m).

The turbidity coefficient B is the decadic attenuation coefficient by haze at λ500 nm in vertical direction. $B = 0.434 \cdot \tau_D \approx 1.07\beta$ (τ_D = optical thickness by dust, β = Ångström turbidity coefficient). In the particle radius range from 0.1 to 1 μm, the particle number above the observer is approximately 10^9 B (cm^{-2}), and the particle mass is $\approx 5 \cdot 10^{-5}$ B (g/cm^{-2}).

correspond to visibility ranges of only about 2 km. The cyclonic character of circulation in April (see 700 mb charts in Fig. 3) results in sparse measurements, and turbidity is relatively low. The average (logarithmic mean) of the turbidity in this 3 month period is about 0.08 in the northern region (40 to 45° N), and nearly twice as large in the southern regions (30 to 40° N). In each region, turbidity shows some similarity of trend. Especially interesting is a period of high turbidity around May 17 in the northern and central region which arrived a few days later in the south. It was related to an unusual heat wave and drought east of the Rocky Mountains.

Europe. The measurements from July 10 to August 12, 1963 in a European region of similar extent are condensed in Fig. 4. They give an impression of the complexity of turbidity variations and of the difficulties of synoptic evalua-

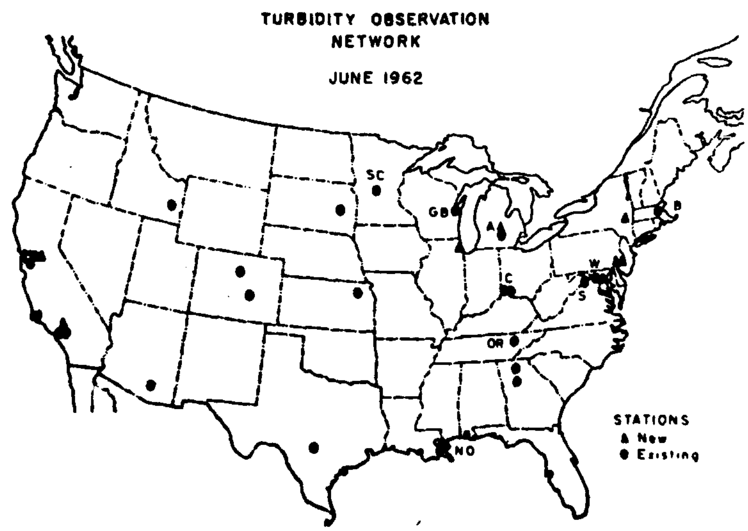


Fig. 2. Stations of the US turbidity network by 1962.

tion. First, we will discuss the central part of Fig. 4 since it is the most impressive. It comprises mainly stations of southern Germany, from a hilly location near Bonn to the Swiss border. For clarity, the usually very similar results of nearby stations were averaged logarithmically. Included are values from Vienna and Zagreb, 250 km south of Vienna. According to the average transport of air at 850 mb as obtained from construction of trajectories (Fig. 5), the time scale of all stations has been adjusted for 9° E as indicated in Fig. 4 in the brackets behind the name of the stations.

In July, southern Germany was under the influence of the Azores high and flooded by earm, humid subtropical air masses. Following moderate turbidity around July 10, rather low turbidity was observed a few days later. In the predominantly continental-tropical air of a Central European high pressure system, turbidity reached a high level by July 20. On July 24, clearer air entered from the SW. In the first days of August, southern Germany came into a frontal zone with unsteady and cool weather. Passage of the trough on August 10 brought very clear air. Even the time adjusted data of Vienna and Zagreb, and partly of Athens, followed these variations. It is interesting to note that the course of vertical turbidity B_V as derived from noon and afternoon values of the observed visibility range V (km) of different stations of southern Germany by assuming a constant dust scale height H_D of 1.5 km ($B_V = 2H_D/V$) agrees generally well with the measured solar data. On the other hand, computation of H_D from simultaneous values of B and V of a few stations resulted usually in a wide scatter of H_D from 0.5 to 3 km.

In the upper part of Fig. 4, the turbidity measured at stations located at the latitude of nothern Germany are shown. The July data of the northern section, which was generally in cyclonic flow, agree for most of the period to a much smaller degree than in the central section. By July 23, a wave of turbid air arrived from southern Germany. High turbidity was also observed in the first days of August when the region was under the influence of a high over northeastern Europe. Again, the course of B_V from visibility data of coastal stations near Hamburg shows some similarity with the course of B. The course of the sparse data from southern Europe (southern France and northern Portugal) as presented in the lower part of Fig. 4 also shows little resemblance with the data from southern Germany. The high July turbidity of southern Germany seems not to have passed this region. It probably came from the Atlantic passing southern France around July 18. Since no solar data are available for this period and region, this assumption will have to be investigated from visibility data.

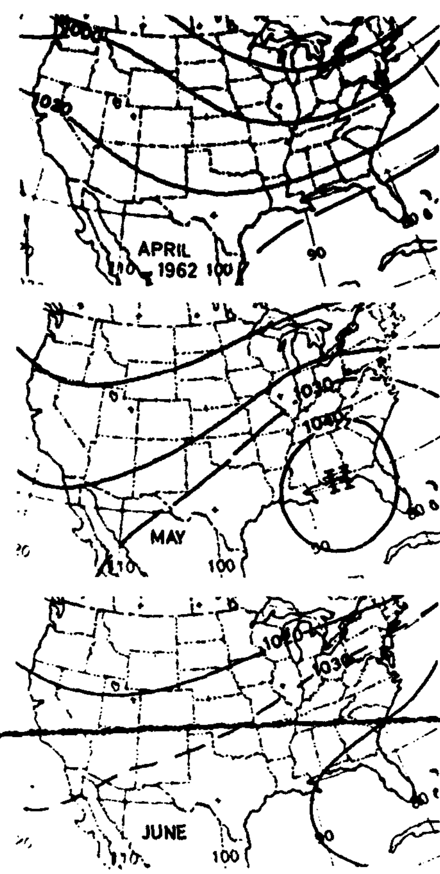


Fig. 3. Mean 700 mb contours (height in feet), April to June 1962. In May: unusual heat wave east of Rocky Mountains, drought in southern US, large swamp forest fires in Florida.

The weather development seems too fast in the above examples to show clearly the influence of aerosol steadily produced in industrial parts of Central Europe. More appropriate are turbidity data (Fig. 6) from March 14 to 27, 1953 during a long high pressure situation with very weak winds (Volz, 1957). From the generally similar increase of turbidity in this period, which was temporarily enhanced at Mainz and Brussels, we derive the production of industrial

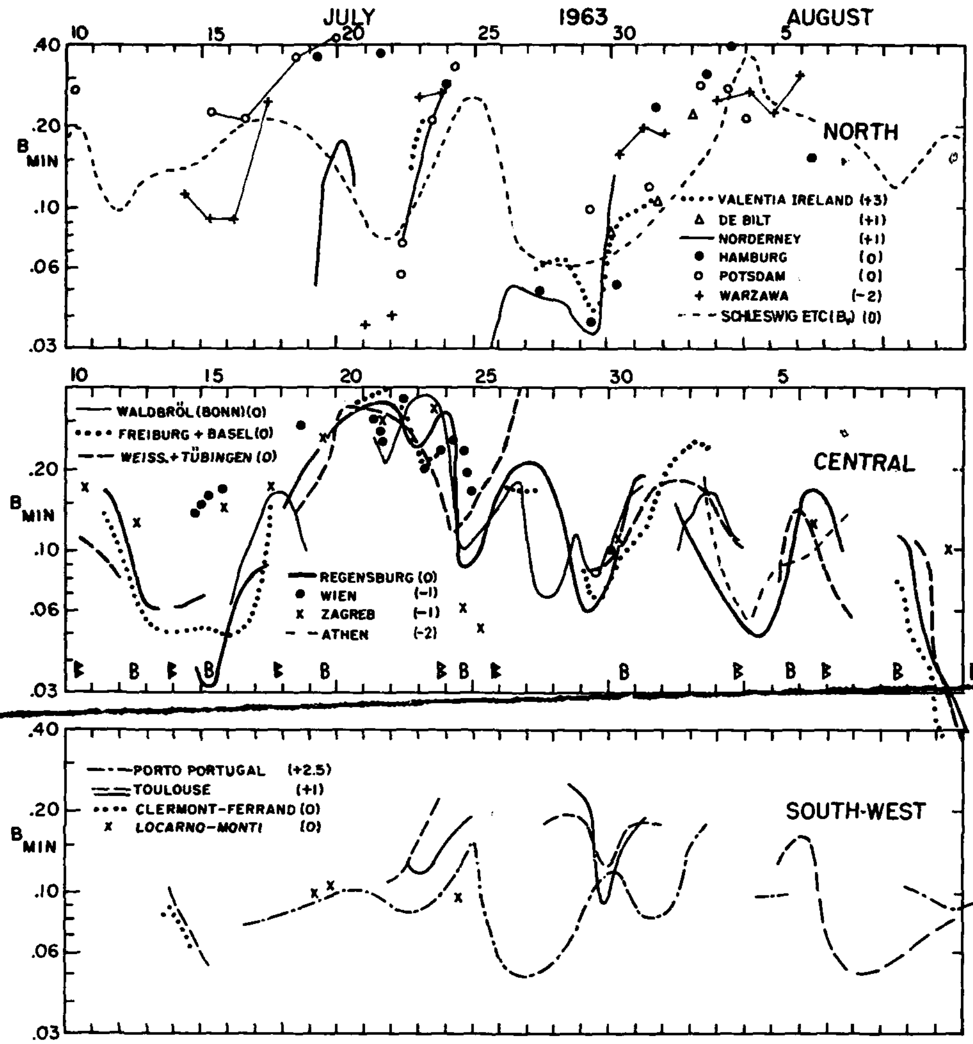
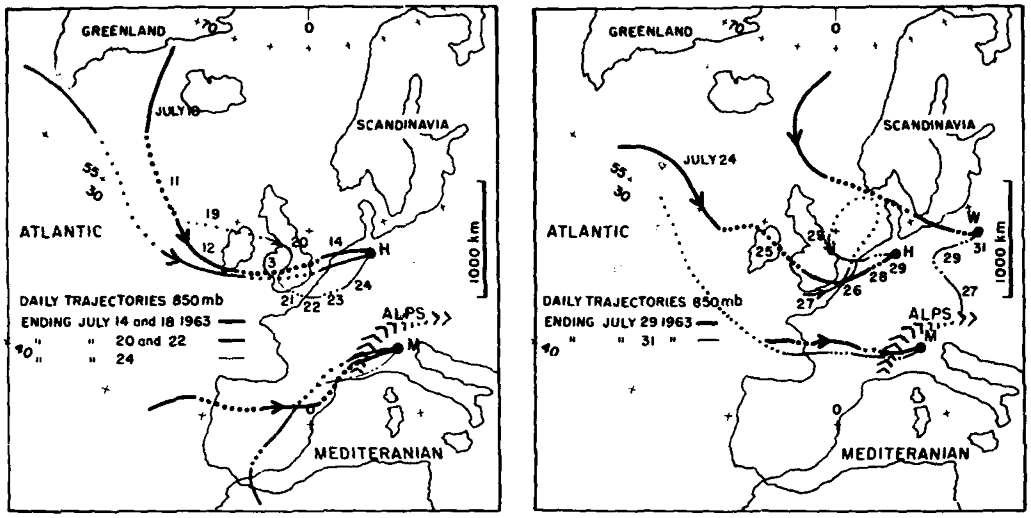


Fig. 4. Turbidity in the northern, central, and southwestern part of Central Europe, July 10 to August 12, 1963. Dashed curve in upper part. logarithmic averaged values of B_V (assuming $H_D = 1.5$ km) of the highest visibility range reported at 0900, 1200, or 1500 GMZ at Schleswig, Husum, Helgoland, and List. At bottom of central section: passage of fronts at Zurich.

turbidity of $dB/dt \approx 0.01$ day^{-1}, or a mass production of about 5 mg m^{-2}/day^{-1}. Under consideration of the population density, similar values have been derived by comparing solar radiation measurements up- and downwind of big cities. These values show that the turbidity peaks in Fig. 4 were hardly of such nature, which suggests the conclusion that the haze had been advected. Most likely the haziness was left to remain as extended cloud masses evaporated after the cloud droplets had, during condensation of the water vapor, trapped large amounts of gas traces. Further attempts should be made to trace the history of such events more closely.

It is hoped that the evaluation of the large body of data of the European turbidity network will be forthcoming. The increased area and density of the network from 1965 to 1967 will certainely result in synoptic cases as interesting as the one presented in Fig. 4.



a *b*

Fig. 5. 850 mb trajectories. H = Hamburg, M = Milano, W = Warzawa.

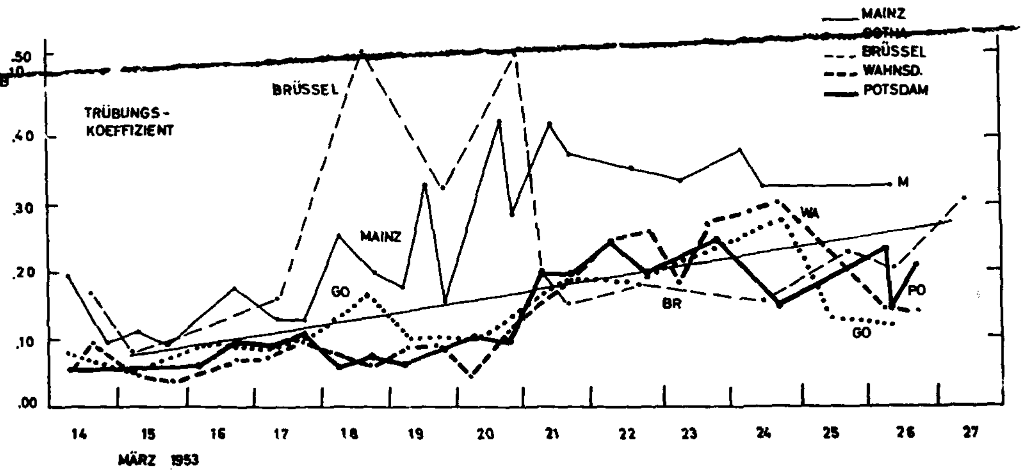


Fig. 6. Turbidity increase in central Europe, probably due to manmade pollution, in a period of weak circulation.

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НЕКОТОРЫЕ РЕЗУЛЬТАТЫ СЕТЕВЫХ НАБЛЮДЕНИЙ МУТНОСТИ

Для получения ежедневных значений ослабления в дымке по измерениям солнечной радиации в 1961 г. в США Национальным центром контроля за загрязнением воздуха (Цинциннати, Огайо) и в Западной Европе автором с 1963 по 1967 г. были организованы сетевые наблюдения мутности, в основном, с помощью солнечных фотометров. Для той и другой сети наблюдений представлен ход мутности в течение характерных периодов. Рассмотрение синоптических вариаций мутности довольно затруднительно, когда речь идет о быстром изменении воздушных масс; во время же спокойной, солнечной погоды часто наблюдается постоянство хода по большим площадям сети наблюдений. Измерения показывают, что дневное увеличение вертикальной оптической плотности в результате промышленной активности над Центральной Европой равно τ_D—0,02, тогда как в среднем τ_D—0,23. Таким образом, часто наблюдаемые высокие значения мутности (τ_D—1,1) должны иметь другие источники и для климата Северной Америки и Европы могут относиться, главным образом, к физике облаков.

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