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CLIMATE AND TOPOGRAPHY IN RELATION TO AERO-ALLERGENS AT DAVOS AND LONDON

By

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INTRODUCTION

The climate of Davos differs from that of London and clearly the topographical features of a small town in the Alps differ widely from those of a great urban area. The purpose of this paper is to discuss the manner in which these differences affect the allergen content of the atmosphere.

CLIMATE

Temperature determines when the season occurs, its length, and during a period of years the severity of a particular season for patients with allergic sensitivity to fungal spores and pollens. In temperate climates where winter temperatures are too low for the growth of higher green plants, the values of "Accumulated Temperature" above a base temperature of 5.5° (42° F), the minimum temperature at which plant development is sustained, has been of use to the ecologist. (Accumulated temperature denotes the combined amount and duration of the excess or deficit of air temperature above or below a base temperature. It is expressed in units of day-degrees so that amounts for individual days may be added together). It has been found (Davies, in preparation) that the earlier development of high concentrations of grass pollen in the air over London, as compared with Liverpool and in Glasgow

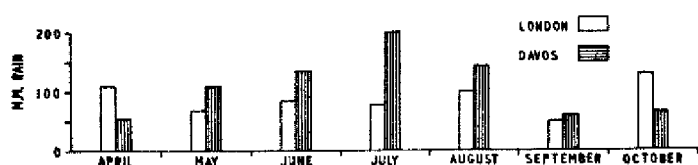
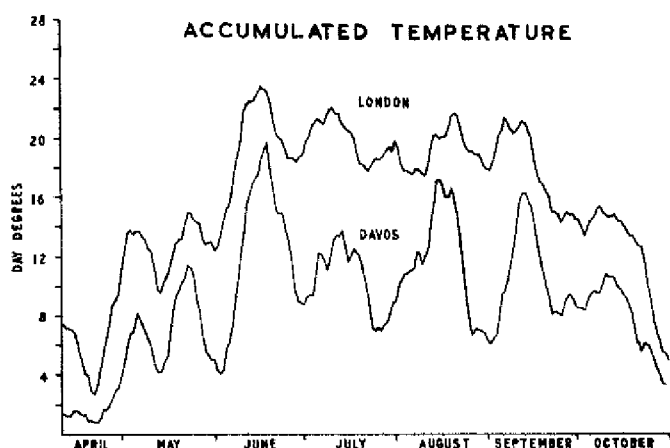


Fig. 1.

Accumulated temperature in day-degrees above 5.5° (42° F) presented as a 10 day continuous mean. Rainfall as monthly values in mm.

respectively is associated with more rapidly rising values of accumulated temperature. In London, basidiospores are most abundant in the air in the late summer and autumn. Peak concentrations of basidiospores in 1962 and 1963, occurred earlier in the year at Glasgow than at Liverpool and London respectively, and this was associated with an earlier fall in the values of accumulated temperature in the NW (Liverpool) and NNW of Britain (Glasgow) when compared with London.

Comparative values of accumulated temperature in day-degrees above 5.5° (42° F) for 1966 at Davos and London are

given in Fig. 1. Weather records for Davos were taken from *Wetter Bericht Der Schweizerischen Zentralstalt Zurich* Volume 87; those for London (Kew) from the Air Ministry, Meteorological Office Records. The data are presented as 10 day continuous means so that the effect of small changes in weather are smoothed out, and the peaks due to spells of high or low temperature have their values reduced. From late April until the end of June, the curves follow each other closely, values of accumulated temperature at Davos rising about 8 days later than in London. During the warm spells warmer weather occurred in London, but during the cold periods the temperature dropped proportionately more in Davos than in London. July was a much colder month in Davos than in London and this must be associated with the high rainfall (Fig. 1). During a cool period in late August and early September, it was very much colder in Davos and the drop in total spore concentrations at Davos reported by *Davies* (1969) may be correlated with it.

Maximum concentrations of grass pollen and total fungal spores occurred earlier in the season in London than they did at Davos (*Davies* 1969) and this must be associated with the earlier rise and sustained higher values of accumulated temperature. Maximum concentrations of basidiospores occurred earlier at Davos than in London, and this must be correlated with the earlier fall in the values of accumulated temperature and an earlier onset of autumn and increased atmospheric humidities.

Rain. Although slime-spores and ascospores are disseminated into the air during rain, prolonged rain washes the air free from particulate matter and by wetting the surfaces of vegetation temporarily inhibits spore dissemination. Very heavy rain washes pollens and even the anthers which bear them to the ground.

Monthly values of rainfall at Davos and London in 1966 are given in Fig. 1. Apart from April and October when more rain fell in London than at Davos, Davos was the wetter and in July received two and a half times as much rain as London.

Katabatic wind, Temperature-inversion and Convection. In the high Alps, katabatic wind—the flow of cold air off the ice down into the valley produces temperature-inversions. The effect of temperature-inversions in preventing the ascent of spore clouds at different altitudes has been demonstrated by sampling from aircraft (*Heise & Heise 1949, Fulton 1966*). In London in the summer time, when there are surface inversions, breakdown usually occurs by 09.00 hours but in valleys this varies with such features as the slope of the floor, steepness of the sides, and aspect with respect to the sun. The shorter the period between surface-inversion breakdown and its re-establishment in the valley, the shorter is the diurnal time interval during which allergens of local origin become airborne. After sunset, the cold air flowing into the valley enhances the settlement of airborne particles. Even at low altitudes, *Lawrence (1969)* reports that valleys develop atmospheric stability at night because they are sheltered from the wind.

The spores of such fungi as *Sporobolomyces*, *Tilletiopsis* and the Hymenomycetes (Basidiomycetes with gills) are sampled in highest concentrations in the early hours of the morning (*Hirst 1953, Gregory & Hirst 1957, Hamilton 1959, Adams 1964*). *Ingold (1967)* concluded that spore discharge in these fungi was related to atmospheric humidity which is also highest in the early hours of the morning. The climatological features of a valley are such that nocturnally produced spores will tend to accumulate, and compared with similar spore sources on an open plain attain higher atmospheric concentrations. After dawn, as the valley begins to get warmer or a wind change occurs, the dilution of the nocturnal spore cloud commences. During the day, the heating of the valley floor to a higher temperature than the surrounding mountain tops produces convection and rapidly rising air currents. Consequently, the spore clouds which develop in a valley during the day, in which are included the pollens, *Cladosporium* and *Alternaria*, will have a more rapid convective ascent and be diluted more rapidly than those from a comparable source on a plain.

TOPOGRAPHY

The assemblage of spores trapped from urban atmospheres in Britain by *Richards* (1956), *Hamilton* (1959), *Davies*, *Denny & Newton* (1963) and *Adams* (1964) are similar in composition to those recorded at rural sites by *Richards* (1956), *Hirst* (1953), *Gregory & Hirst* (1957) and *Hamilton* (1959). Clearly, the spore clouds flowing over British cities are mainly of an exogenous origin, from such sources as crops, pastures and woodlands outside. In the U.S.A. the fact that ragweed eradication programmes in the cities (*Chicago*, *Durham* 1955, *New York City*, *Walzer & Siegel* 1956, *Cohart & Kandle* 1959 a and b) neither reduced the amounts of pollen trapped nor the incidence of ragweed pollinosis shows most of the pollen is produced outside and windborne to the city. On the other hand, from the reports of *Richards* (1956) and *Ambler & Vernon* (1951) who trapped more *Penicillium* in urban than rural areas, and *Davies et al.* (1963) who reported the parks of Central London to be an important source of *Cladosporium*, it is evident that there are not unimportant sources of allergens in the city.

TABLE 1

Mean Concentrations of Cladosporium Spores between 13.00 and 14.00 Hours on 7 Days in June and July 1962 (data from Davies et al., 1963).

Site	Spores/m ²
Park (Kensington Gardens)	49,300
Roof top (Height 25 m.	
St. Mary's Hospital, Paddington)	5,239
Street (1.5 m. above carriageway level, Praed Street, Paddington)	766

Effect of Buildings and Open Spaces in Cities. On seven days in June and July 1962, *Davies et al.* (1963) investigated the mid-day concentrations of *Cladosporium* at three London sites within 1 km. (Table 1). In 1963, simultaneous air sampling was undertaken at the same three sites on nine afternoons in July, four in August and four in September, and in addition

the *Cladosporium* concentrations in a semi-basement room in the Wright-Fleming Institute were determined (Davies unpublished). During the period of the observations the window of the room was kept closed and the door which was locked shut during sampling was opened only to insert and remove apparatus. The results are given in Table 2.

TABLE 2

Mean Concentrations of Cladosporium Spores at four London Sites. Samples taken between 13.00 and 17.30 Hours on 9 days in July, and 4 in August and September. (Davies, unpublished).

Site	Spores/m ³
Park (Kensington Gardens)	3,330
Roof top (St. Mary's)	905
Street (Praed Street)	373
Indoors (semi-basement room, Wright-Fleming Institute)	230

Clearly the concentrations in which a particular allergen occurs can vary widely within the city. Webster (1956) and Hudson & Webster (1958) report *Cladosporium* predominates in the primary flora colonising moribund grass tissue. Davies *et al.* (1963) considered the 5 sq. Km. of grassland in the parks of Central London was a significant source of atmospheric *Cladosporium* because in Liverpool where there was no comparable area of grassland near the trapping site, airborne *Cladosporium* concentrations in June and July were only half that of London. The fact that the mean *Cladosporium* concentrations at the three outdoor sites in 1962 were higher than those obtained in 1963 (Tables 1 and 2) is partly because on two of the seven days when samples were taken in 1962, the grass was being mown in the park. In 1963 the grass was not cut on any of the days when sampling was undertaken, the weather was cooler and the mean figures given include values for August and September when as a result of seasonal factors the concentrations are lower.

From the 1963 data (Table 2) it may be seen that the

average roof top concentration of *Cladosporium* was 27 per cent of that in the park, and the indoor and street concentrations were 7 per cent and 11 per cent respectively. Street concentrations appear to resemble those of a room with open windows, and among the buildings away from the parks and gardens there is a degree of protection for patients with allergies to *Cladosporium*, and other spores and pollens. Davies (1964) concluded there was a discontinuity in spore concentration bordering upon the general level of the roof tops in the city. Winds are deflected over the roof tops and large particles such as pollen grains passing into the relatively still air between the buildings will tend to settle quickly to the ground. On hot sunny days street level temperatures 1°C higher than in the air streams above the 25 m high roof top have been observed, and convection and turbulence will tend to inhibit the settlement of small spores into the city.

Sampling above the general level of the buildings in an area gives a generalised representation of the spore clouds flowing over the city, and it should be noted that in a densely built-up area, the patient near an open window above the general level of the buildings is exposed to higher concentrations of pollens and spores than occur at street level.

Land utilisation, and orographic and valley shelter in relation to inhalant allergy. The spores of *Cladosporium*, *Alternaria*, *Ustilago* and ascospores such as *Leptosphaeria*, which are abundantly produced on cereal crops (Last 1955), were recorded in lower concentrations at Davos than in London (Davies 1969). London lies in a very shallow basin, cereal crops are grown only 12 Km. from the trapping site and the whole area is exposed to winds which scour the principal crop growing areas of Great Britain. Davos, by contrast, lies in a valley at an altitude of 1,560 m and is bounded by mountains over 3,000 m high. The valley is too wet and cold for cereals and although small areas are devoted to cereals in the Rhine valley some 25 Km. away to the N.W., the principal crop growing regions of Switzerland are over 75 Km. distant to the NNW on the other side of the Alps.

Pady & Kelly (1954), in trans-Atlantic flights at an altitude of 3,000 m in summer time, found fungal spore and pollen concentrations as high as 200/m³ and 25/m³ respectively. *Hirst, Stedman & Hogg* (1967) recorded fungal spore concentrations in hundreds/m³ at a height of 3,000 m over the English Channel. *Hirst & Hurst* (1967) report concentrations decrease with height until spores become undetectable at heights ranging from 2,000 to 6,000 m and that the ceiling to which spores rise by convection is unknown. The maximum height to which spores ascend over mountains may be greater than that recorded by sampling from aircraft, since wind blowing on a mountain face produces turbulence and surface currents may carry spore clouds to higher levels.

The highest mean daily concentration of *Ustilago* recorded in London between 1961 and 1967 was 7,200 spores/m³, and was obtained when the wind was from E. Anglia, an important cereal growing region. In Davos, the fact that a maximum concentration of 2,140 *Ustilago* spores was recorded suggests that at times, with a high temperature lapse rate and convective ascent over the plains, spore clouds may be carried over the Alps. Although *Cladosporium* concentrations reached over 3,000 spores/m³ on six days in Davos, spore production from local sources prohibits the use of this genus as an indicator of spore transport into the valley.

The high concentrations of basidiospores recorded at Davos are associated with the coniferous forest (*Davies* 1969) and clearly Davos has an air-spore of its own which reflects the ecology of the valley. It is sheltered from spore clouds originating on the plains by the high mountains which form an orographic barrier but as evidenced by the data on *Ustilago* the shelter is not complete, and spore clouds may be borne into the area.

The relief of asthma in the Alps is only partly related to height, the sanatoria and resorts are situated not on the mountain tops but in the valleys. *Lawrence* (1962) in a study of air pollution in a rural hilly area with a surrounding land height of about 370 m, concluded "some degree of protection from

sulphur dioxide pollution may be obtained by small orographic irregularities in the immediate environs—in addition to some protection from major orographic barriers”. In a comparative survey into the prevalence of asthma in the Rhondda Fach and the coastal plain of Glamorgan, *Williams & Higgins* (1959) found a lower incidence of asthma in the valley (mean altitude 200 m). The lower prevalence of asthma in the valley was statistically significant only in females. In the valley population, however, because of a high incidence of miners’ pneumoconiosis, miners who comprised the bulk of the male population were excluded from the survey. Ecologically, in the grassed slopes of the Rhondda valleys *Nardus stricta* Linn. predominates and this grass produces very little pollen. These valleys are almost devoid of woodland and the surrounding mountain tops have a characteristic heath and moorland vegetation. By comparison the coastal plain of Glamorgan is an area with much cultivated pasture, some cereals and woodland, and it is clearly a richer source of aero-allergens. Furthermore, the axes of the Rhondda valleys run NNW/SSE tangentially to the S.W. prevailing winds. The spore clouds collected by winds blowing over the plain region are deflected up the sides of the mountains and are then blown over their tops, and shelter is obtained in the steep-sided valleys. On warm days with clear skies, when the air is unstable, *Hirst & Hurst* (1967) report the gravitational settling of spores of all sizes is insignificant compared with convective ascent. On such days, when spore concentrations are high over the plain, the settlement of allergens into valleys is minimal and locally generated spore clouds are rapidly diluted and carried away by the enclosed masses of rising warm air. *Lawrence* (1962) reports protection by orographic barriers may be due partly to increased orographic rainfall and the resulting atmospheric washing. The Rhondda Fach receives about twice the precipitation on the vale of Glamorgan.

Although no survey has been undertaken into the prevalence of asthma in different regions of Britain, hay fever is less frequently diagnosed in Wales and the N.W. than it is in

E. and S.E. England Morbidity Statistics for General Practises (1962). Moreover, preparations affecting allergic reactions are less frequently prescribed in the Northern, East and West Ridings, Wales and N. Western regions of England and Wales than they are in the other regions (Table 3), (Min. Hlth. Rep. Publ. Hlth. & Med. Sub: No. 110—1964).

TABLE 3
Preparations Affecting Allergic Reactions as a Percentage of the Prescriptions in each Area.

Group A		Group B	
Southern	2.8*	E. and W. Ridings	1.9
Eastern	2.8*	Northern	2.0
London and		Wales	2.1
S. Eastern	2.7	N. Western	2.2
Midland	2.6		
S. Western	2.5		
N. Midland	2.3		

$$t = 5.192. \quad P = \gg 0.001.$$

Group A: Regions predominantly areas of cereal growing, and mixed crops with some stock raising.

* Most important cereal growing areas of Britain.

Group B: Regions with large areas of mountain and moorland, grass heath and rough pasture. Some leys and medium quality farmland in the low lying areas.

Prescriptions data from—Ministry of Health Rep. No. 110. Recent Prescribing Trends. London. H.M.S.O. (1964).

The Wales, Northern, N. Western and E. and W. Ridings regions of England and Wales are ecologically similar and characterised by much mountainous and upland areas with grass heath and moorland types of vegetation. By contrast in the other regions of England and Wales there is very little mountain and moorland, and the land is mainly devoted to arable farming or mixed crops with some stock raising. As a consequence these areas are a greater source of seasonal allergens. Also, because of the W. and S.W. prevailing winds, spore

clouds over the E. and S.E. regions of England will tend to be denser because of wind collection from the more westerly areas.

In the Wales region, approximately a third of the population lives in the Glamorgan and Monmouthshire valleys, all of which are ecologically similar to that surveyed by *Williams & Higgins* (1959)*. In the E. and W. Ridings region, 87.5 per cent of the population lives in the W. Riding and about 50 per cent in densely urbanised areas from Sheffield and Rotherham in the South to Halifax and Leeds in the North which, with respect to prevailing winds, lie in the lee of the Pennine Chain. The low percentage of prescriptions for allergies in the E. and W. Riding (Table 3) must partly reflect the density of urbanisation, and in part be due to the Pennine Chain. The vegetation of the Pennines is not an important source of allergens but the mountains present a barrier which upwardly deflects the spore clouds collected by the prevailing winds from the crops of the Central and Cheshire plains. This results in a reduced pollen and spore rain into the area of the W. Riding immediately to the E of the mountains. The effects of ecology and shelter from prevailing winds in the S. Wales valleys have been discussed.

From the evidence available, as a consequence of topographical and ecological factors, some areas of Great Britain appear to present less severe conditions for patients with seasonal allergies than others. The relief of asthma in the Alps, and the respite from steroid therapy which is obtained can be invaluable, especially for the severely asthmatic child. The possibilities of a British alternative in a steep-sided valley

* Ecological observations are based on personal knowledge of the areas and Land Classification, Great Britain, Ordnance Survey, Director General, Southampton 1944. Population estimates in different areas calculated from Registrar General's Annual Estimates of the population of England and Wales 1968, and Administrative County, County and Municipal Boroughs, Urban and Rural Districts and Civic Parishes, England and Wales, Diagrams, Ordnance Survey, Director General, Chessington, Surrey. 1949.

with an appropriate ecology seems worthy of investigation. A detailed survey into the prevalence of seasonal asthma in relation to topography and land usage in various regions of Great Britain is desirable.

SUMMARY

1. The effects of temperature and rainfall in relation to the seasonal occurrence of spore allergens in the air at Davos and London are considered.

2. The manner in which climatological factors such as katabatic wind, temperature inversions, atmospheric stability and convection, affect the spore content of the air in valleys as distinct from that over plains are discussed.

3. Evidence of spore transport into cities and the results of simultaneous spore-sampling above the roof tops, between the buildings, indoors, and above a wide open grassed area in a city are described.

4. The relationship between land utilisation, the incidence of asthma in two communities reported by *Williams & Higgins* (1959) and the percentages of drugs affecting allergic reactions which are prescribed in the different regions of England and Wales (Min. Hlth. Rep. Publ. Hlth. & Med. Subj. No. 110—1964) are noted.

5. Valley and orographic shelter in the lee of mountains are discussed and it is concluded that the relief of asthma in the Alps is only partly related to height; the high mountains act as barriers and Alpine valleys are sheltered from the clouds of spore allergens developed over the plains.

6. It is suggested that regional change leading to a transient relief from summer asthma of allergic origin may be obtained in Great Britain. A steep-sided valley running tangential to the prevailing winds, in a mountainous area which is ecologically dominated by a grass that produces little pollen, such as *Nardus stricta*, is recommended as worthy of investigation.

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