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METEOROLOGICAL AND ENVIRONMENTAL ASPECTS OF DUST STORMS IN NORTHERN MEXICO

With 6 figures and 5 tables

ERNESTO JAUREGUI

Zusammenfassung: Meteorologische und umweltwirksame Aspekte von Staubstürmen im nördlichen Mexiko

Der Beitrag untersucht Häufigkeit und Intensität von Staubereignissen in einigen der größten städtischen Gebiete im nördlichen Mexiko. Staub-erzeugende Mechanismen sind a) lebhafte Winde beim Durchzug von Fronten im Herbst und Frühling und b) turbulente abwärts wehende Strömungen der sog. trockenen Gewitterstürme während der kurzen Regenzeit. Wirkliche Staubstürme mit Sichtweiten unter 1 km machen bis zu 20% der Tage mit Staubereignissen im Untersuchungsgebiet aus. Die Staubstürme treten meistens während heißer, trockener Nachmittage auf.

Mittels des Konzepts der effektiven Temperatur wird versucht, die Umweltwirkungen während der Staubereignisse auf den menschlichen Organismus zu bewerten. Dabei zeigt sich, daß Staubstürme nicht selten verbunden sind mit effektiven Temperaturen, die deutlich über der Schwülegrenze liegen (25° ET) und bis an die Grenze der Belastbarkeit (35° ET) reichen. Die Wirkung des Hitzestresses wird noch verstärkt durch die nachteiligen Effekte der Staubpartikel für das Atmungssystem.

1. *Introduction*

Arid and semiarid regions in Northern Mexico are seasonally subject to dust events in varying degrees of intensity. Compared with other world areas of dust-raising activities such as the Sahara or the Kasakstan plains, dust events in the area under study are certainly less important. It is not infrequent, however, that dust phenomena are associated with high temperatures during late spring and summer. These environmental conditions (similar to the Sharav winds in Israel, SULMAN et al. 1975) are liable to affect the mental and physical health of the population. Apart from discomfort, they may cause depression, headaches, irritability and exacerbation of respiratory ailments.

In this paper, a description is made of the frequency of dust events in some of the largest urban areas in arid Northern Mexico. In addition, some aspects of other concurrent climatological factors such as high temperatures and low humidities are discussed and an assessment of environmental conditions during dust events is attempted.

2. *The Data*

Frequency of dusty periods was based on hourly weather observations from airport stations recording dust storms (visibility less than 1 km) or blowing dust. Climatological records (including temperature and dew point and wind) were available for 5 stations for periods varying from 2 to 11 years (see Fig. 1 for location of stations).

3. *Frequency of dust events*

As may be seen in Fig. 1 stations for which data were available are so separated that they leave large parts of the study area without data. Admittedly, it is a daring task to try to derive the frequency and dust events in a large area of Northern Mexico with such a sparse network. We shall rather concentrate on dust events at local urban scale.

Dust events that reduce visibility are coded as follows:
D : suspended dust
BD : blowing dust
TBD: thunderstorm and blowing dust
DH : dust and haze

Dust events coded as D or BD were most frequently found in the airport records and they were associated mostly with visibilities greater than 5 miles (8 km). As may be seen in Fig. 2 maximum dust frequency occurs from March to June when 1 to 3 dust events are observed in the mean (see also Table 1).

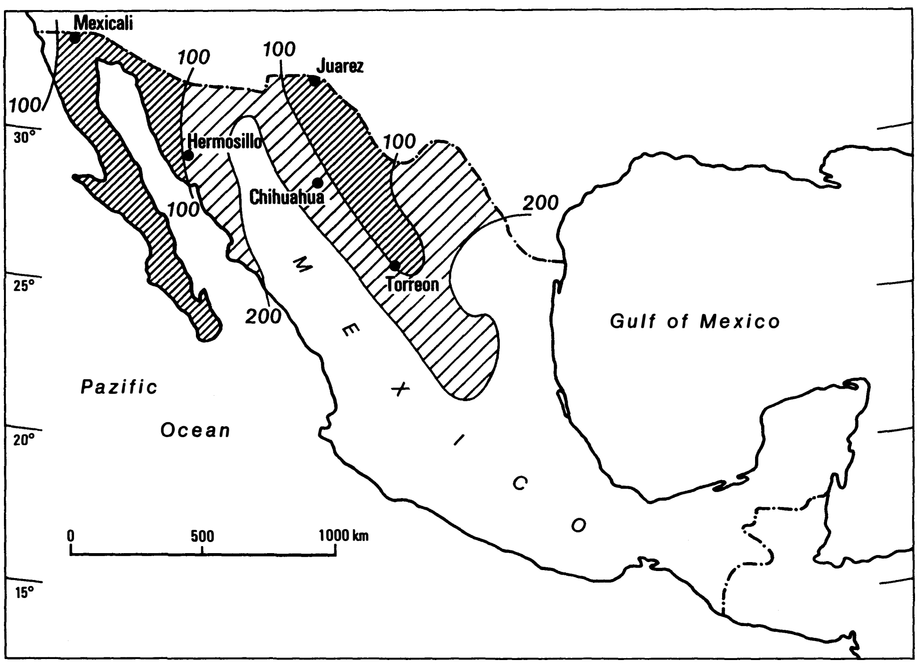

Fig. 1: Location of the stations and isohyets (mm/yr)
Lage der Stationen und Isohyeten

Tab. 1: Frequency of dust events (dust storms and blowing dust, bd) for five stations in Northern Mexico. (Periods 1955–61, 1961–70, 1971–81, 1961–62 and 1984–87 respectively)

Häufigkeit von Staubereignissen (Staubstürme und Staubwinde) für 5 Stationen im nördlichen Mexiko (Perioden 1955–61, 1961–70, 1971–81, 1961–62 bzw. 1984–87)

	J	F	M	A	M	J	J	A	S	O	N	D	YR
Mexicali	0.4	1.6	2.2	2.2	2.6	2.0	1.0	1.3	1.0	2.7	1.2	1.2	19.8
Chihuahua	0.5	0.6	2.6	1.9	1.0	0.8	0.2	0.2	0.2	0.1	0.6	0.7	9.4
Hermosillo	0.2	0.3	0.6	0.9	1.0	3.6	1.4	0.4	0.3	0.3	0.2	0.1	9.2
Torreon	1.5	3.0	6.5	3.0	4.5	2.5	5.5	3.5	2.5	3.0	1.5	1.0	38.0
Ciudad Juarez	0.3	2.6	2.6	4.9	2.5	1.8	1.2	1.6	0.9	0.3	0.3	0.3	19.3

During this period the main mechanism for dust production seems to be related to synoptic-scale frontal passages. On these occasions, the advected turbulent winds combined with convective mixing from abundant insolation in the afternoon, often lead to light/moderate dust blowing, usually from the west as may be seen from the dust wind roses for Mexicali (Fig. 3). Plowing and tillage of the highly erodible soils in the Colorado river valley (where this city is located) are perhaps responsible for the high occurrence of dust events there. At this station a second peak in frequency is observed in the fall, it is likely related again to frontal activity which brings little or no rain but dusty winds. For Chihuahua and Ciudad Juarez a marked drop in the frequency of dust events is observed during the short rainy season from July to September.

However, it is during this period when another dust-raising mechanism probably induces the most intense dust events (IDE). These are the so-called summer dry-thunderstorms (KRUMM 1954, JAUREGUI 1988). Dust is raised under these clouds by their intense downdrafts in the afternoon. These storms are linked with moist air arriving either a) from the Gulf of California, the so-called moisture surges (HALES 1972, JAUREGUI 1980) affecting the western portion of the study area (mainly Sonora and Baja California States), or b) from the Gulf of Mexico. In this latter case thunderstorm activity leading not infrequently to dust storms reaches a peak in spring and early summer (see also HOWARD and MADDOX 1988).

The preferred time of occurence for intense/moderate dust storms (visibility less than 1.6 km) is the afternoon period (when air temperature is high and

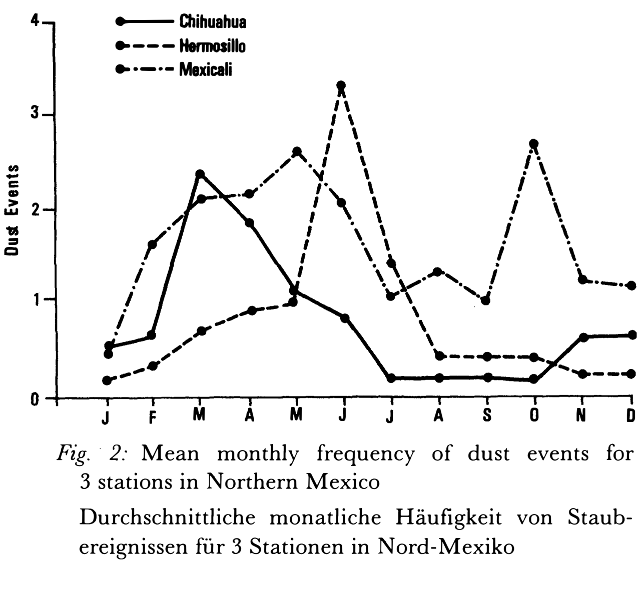

Fig. 2: Mean monthly frequency of dust events for 3 stations in Northern Mexico

Durchschnittliche monatliche Häufigkeit von Staubereignissen für 3 Stationen in Nord-Mexiko

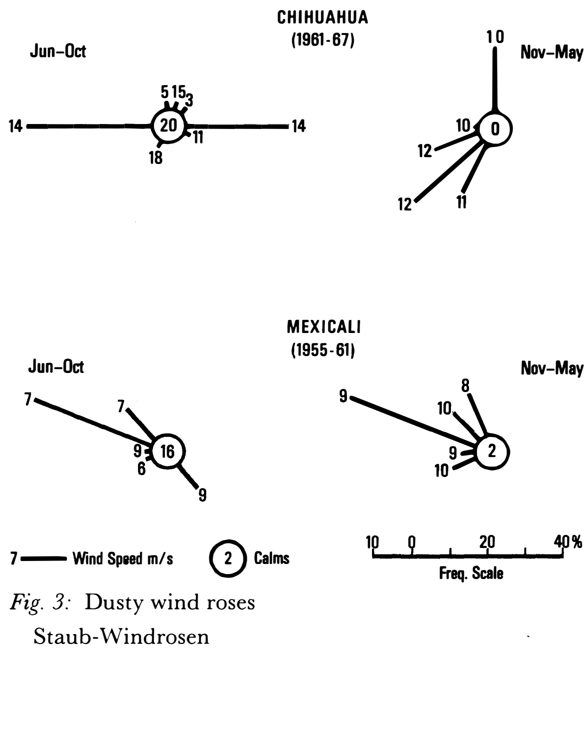

Fig. 3: Dusty wind roses

Staub-Windrosen

Tab. 2: Most frequent hours of intense dust storm (vis. less than 1.6 km) at four stations (Mexicali, Torreon, Hermosillo and Chiuhuahua). (%)

Häufigste Tageszeiten mit intensiven Staubstürmen (Sichtweite unter 1,6 km) an 4 Stationen. Angaben in Prozent

Period	Freq. (%)
12:00 - 14:30	19
15:00 - 17:30	38
18:00 - 20:00	42

humidity is low), especially at the end of the day (from 6 to 8 pm), as seen in Table 2. These intense (visibility less than 1 km) dust storms are quite frequent in Torreon and Mexicali, but are seldom observed in Hermosillo near the coast, see Table 3.

4. *Physioclimatological conditions during dust events*

By using the effective temperature (ET) concept from a psychrometric chart (ASHVE) Terjung (1968) has found the area under study to be characterized by seasonally hot and extremely hot physiological climate (H and EH). The ASHVE guide has suggested an indoor comfort zone for air temperature between 22.8 to 25°C and relative humidities of 20 to 60%. This would mean an upper limit for comfort of 22.5 ET. According to this criterium the area under study would require air conditioning from April to September/October to provide comfort, at least during the afternoon, as seen in Table 4.

For tropical man Chowdhury and Ganesan (1983) have suggested a higher value of ET (25°C) as the lower limit of thermal discomfort, based on personal experience in the hot climate of Nagpur city where temperatures of 44–46°C are often observed at the height of the summer season. Even if we adopt this suggestion, which from our own point of view seems realistic, the time requiring air conditioning in the study area would only be reduced by a month. The above mentioned heat stress conditions are aggravated by the dust-laden winds, thus adding to the already high discomfort.

Table 5 illustrates some cases of weather conditions associated with dust events that occurred in Mexicali during the summer months for the period 1955-61. During this time, the hot dust-laden air is usually above body temperature while the relative humidity is low. Also, in Table 5 it may be seen that during intense dust storms (visibility less than 1 km) the air is somewhat more humid and the winds are slightly stronger, suggesting that the mechanism responsible for dust production is of the thunderstorm outflow type.

5. *Assessment of heat stress during dust events*

Meteorological parameters such as temperature, humidity and wind, determine the human comfort in an atmospheric environment. In the case of a desert environment radiation (solar and reflected by urban surfaces) is of primary importance.

In order to give an idea of the heat stress on the human body during dust events we have used the effective temperature concept as suggested by Missenard (1955):

$$ET = T - 0.4(T-10)(1-RH)$$

where: T = Air temperature °C
RH = Relative humidity, expressed as proportion

This method does not take into account the effect of wind speed. However, for these environmental conditions (hot and dry air) the overall effect of increased wind speed on the ET would not significantly affect the results. This may be seen by inspecting the ASHVE E. T. chart.

Tab. 3: Frequency (%) of dust events by intensity for four stations, with respect of mean total number for the year

Häufigkeitsverteilung von Staubereignissen nach Intensität für 4 Stationen in %

Vis. Class (km)	Mexicali (1955-61)	Torreon (1961-62)	Chihuahua (1982-87)	Hermosillo (1971-72)
Less than 1 km	16	20	4	1
1.1- 3	14	26	31	3
3.1-16	70	54	65	96

Tab. 4: Mean effective temperatures for four stations (at 3 pm)
Durchschnittliche effektive Temperaturen an 4 Stationen (um 15 Uhr)

	J	F	M	A	M	J	J	A	S	O	N	D
Chihuahua	17	18	20	22	25	29	28	26	24	19	17	17
Hermosillo	20	22	19	25	26	31	30	30	31	26	24	22
Torreon	19	19	23	24	28	25	29	27	28	23	18	23
Mexicali	10	17	20	24	27	29	32	31	29	26	18	16

LANDSBERG (1972) mentions that skin temperature rises linearly with effective temperatures in the range from ET 25 to 40° and heart effort rises linearly to about ET 33°. Between ET 30 and 31° the body temperature begins to rise (LANDSBERG 1972). This author suggests an ET of 24° as a bounday of sultriness and 35 as the limit of tolerance.

In Table 5 it may be seen that for some of the dust events listed for Mexicali an ET of 32–35° is reached causing distress in about an hour's exposure. This condition of heat stress is aggravated by the detrimental effect of blowing dust on the respiratory system.

Fig. 4 shows on the psychrometric chart how far environmental conditions are from the comfort zone during dust events in Mexicali during summer. During this time environmental conditions as expressed by ET vary from 27 to 35°. These extreme environmental conditions occur from June to October in the region, when the mean monthly values for ET lie between 28 and 30° (Fig. 5). The climogram shows that in Hermosillo bioclimatic conditions lie in the mean near or within the comfort zone at noon from November till April. It is during this time however, especially during the second half of this period when dust events are most frequent in the area as illustrated in Fig. 2.

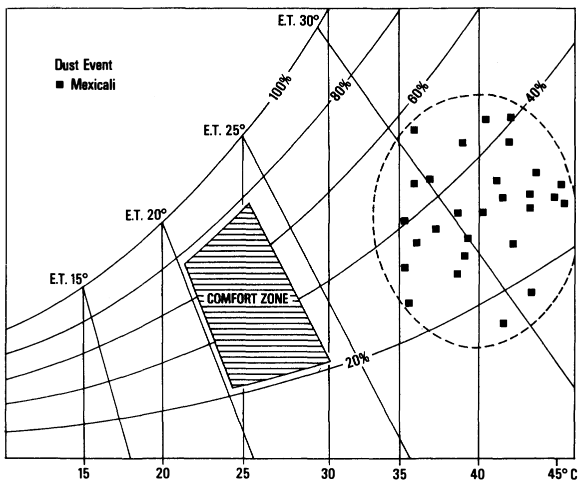

Fig. 4: Environmental conditions during dust events in Mexicali

Umweltbedingungen während Staubereignissen in Mexicali

At Hermosillo, with similar high air temperatures (above 40°C) the air is much drier (9 to 10%) during dust events and therefore, evaporating cooling there should be more effective, bringing the effective temperatures down to about 29 or 30° (Fig. 6).

Tab. 5: Cases when dust event was coincident with high temperature in Mexicali (Period 1955–61)
Kombinationen von Staubereignissen mit hohen Temperaturen in Mexicali (Periode 1955–61)

Date	Hour	Dust Event	Temp (°C)	Tdew (°C)	R. H. (%)	Wind (m/s)	Vis. (mi)	ET (°C)
13/6/56	14:30	D	45.5	22.5	26	W/10	5	35
19/6/56	14:30	BD	42.3	19.6	27	SE/10	3	33
15/7/58	18:00	D	43.5	23.0	32	W/9	5	34
25/6/60	16:00	BD	46.0	20.0	23	W/9	6	35
28/7/61	14:00	D	42.0	25.0	39	ESE/6	5	34
16/8/55	16:30	BD	36.0	26.0	57	S/15	0.5	32
28/6/56	18:30	D	35.0	17.6	36	WSW/10	0.6	29
27/6/58	19:00	BD	40.5	26.0	45	SE/13	0.0	34

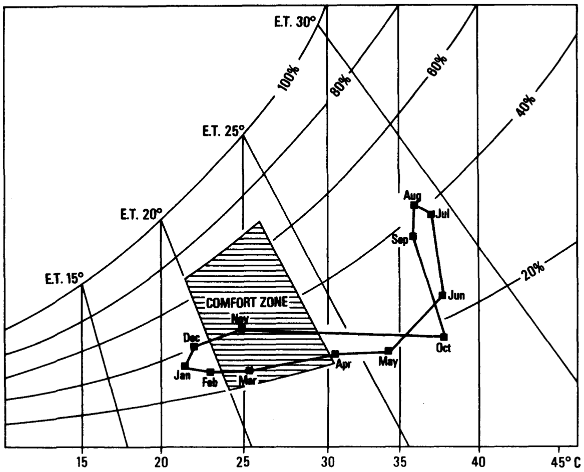

Fig. 5: Climogram for Hermosillo at 14 hrs

Klima-Diagramm für Hermosillo um 14 Uhr

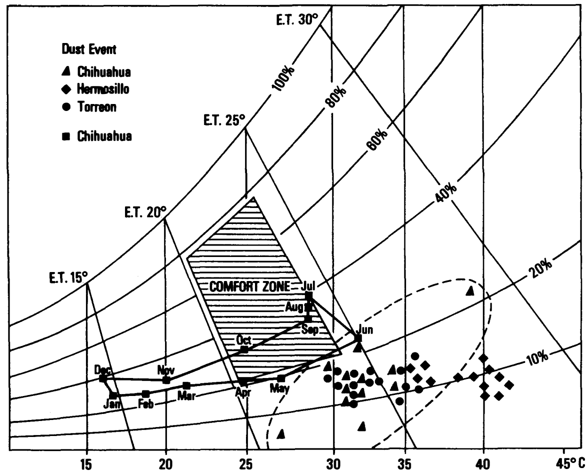

Fig. 6: Environmental conditions during dust events in Chihuahua, Hermosillo, and Torreon

Umweltbedingungen während Staubereignissen in Chihuahua, Hermosillo und Torreon

Perhaps surprisingly, in the more continental stations Chihuahua and Torreon, temperature seldom reaches the 40° mark during dust events. Since relative humidity is simultaneously very low (10–15%), environmental conditions during dusty periods are not as stressful as in Mexicali (see Fig. 6) with ET's around 24–25°.

6. *Conclusions*

The combination of both hot dry air and suspended dust in summer in Northern Mexico is not unusual and it is a rather typical feature of the climate there. The excessive heat and dust content of the air during these events are likely to affect the health of the population. Agricultural practices and the prevailing dry weather are at the origin of blowing dust days which are more frequent during the first half of the year in Northern Mexico. Suspended or blowing dust is more often observed and is probably induced by synoptic-scale winds associated with the presence of a thermal low over the region. True dust storms (visibility less than 1 km) originating from thunderstorm outflow account for less than 20% of dusty days in the study area. These environmental conditions are found to reach not infrequently beyond the limits of tolerance as assessed by the effective temperature criterion. This is especially true for Mexicali.

Acknowledgements

The author is grateful to Mr. F. Cruz, Mr. J. Arroyo, Mrs. M. L. Maya, J. Izquierdo and E. Luyando for the collection and processing of climatological data. The data were kindly provided by the airport authority (SENEAM). Thanks are due to Mr. A. Estrada for elaborating the drawings and to Ms. G. Zarraga for typing the manuscript.

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BUCHBESPRECHUNGEN

COFFEY, WILLIAM J. (Ed.): Geographical Systems and Systems of Geography. Essays in Honour of William Warntz. 211 S., 17 Abb., 22 Tab. Department of Geography, The University of Western Ontario, London/Ontario 1988

Diese Festschrift zu Ehren von W. WARNTZ, die zugleich der Erinnerung an Frau A. M. WARNTZ gewidmet ist, umfaßt dreizehn Aufsätze von Schülern und Kollegen, die sich mit geographischen Systemen im weitesten Sinne befassen. Einer historisch angelegten Einführung in den systemkonzeptionellen Denkansatz (COFFEY) folgen Analysen zur räumlichen Muster- (BUNGE) und Hierarchiebildung (PHILBRICK, MARK) sowie – ganz besonders lesenswert – zur strukturellen Evolution räumlicher Systeme (WHITE). Räumliche Interaktionsmodelle (TOBLER, POOLER, FISCH), neue Verfahren zur Matrizenrechnung (GOODCHILD und MARK) und zur Bestimmung räumlicher Transportverbindungen minimalen Kostenaufwandes werden neben geographischen Expertensystemen und den wissenschaftsbezogenen räumlichen Kontaktmustern von W. WARNTZ vorgestellt. Äußerst anregend ist die Diskussion optimaler räumlicher Verzweigungsmuster (WOLDENBERG) und deren mikrogeographische Übertragung auf das Bronchialsystem der Warmblüter.

DIETER KLAUS

BAHRENBERG, GERHARD, DEITERS, JÜRGEN, FISCHER, MANFRED M., GAEBE, WOLF, HARD, GERHARD und LÖFFLER, GÜNTER (Hrsg.): Geographie des Menschen. Dietrich Bartels zum Gedenken. X u. 573 S., zahlr. Abb. u. Tab. Bremer Beiträge zur Geographie und Raumplanung, Heft 11. Zentraldruckerei der Universität, Bremen 1987, DM 28,–

Die anzuzeigende Gedächtnisschrift ist dem 1983 früh verstorbenen DIETRICH BARTELS gewidmet, der wie kaum ein anderer die jüngere Entwicklung der deutschsprachigen Anthropogeographie geprägt hat. Auf 573 Seiten im DIN A 4-Format sind 32 Beiträge von Schülern und Freunden zu fünf Kapiteln gruppiert, die zugleich die wichtigsten Schwerpunkte des wissenschaftlichen Werks von D. BARTELS repräsentieren:

Das von G. HARD eingeleitete erste Kapitel enthält sechs Aufsätze zur „Metatheorie und Geschichte der Geographie", die sich freilich teilweise weit von der Forschungspraxis entfernen und von denen einer (von G. HARD selbst) in seiner giftigen Polemik leider „unter die Gürtellinie" zielt. Das von G. BAHRENBERG eingeleitete zweite Kapitel befaßt sich mit „Raum und Geographie" und thematisiert damit einen Grundbegriff unseres Faches, dessen wissenschaftliche Explikation und möglicherweise fachkonstituierende Funktion bis heute allerdings umstritten geblieben sind, wie nicht zuletzt die sechs hier vereinigten und teilweise divergierenden Beiträge zeigen. Das von M. M. FISCHER eingeleitete dritte Kapitel ist „Modellen und Methoden" gewidmet und enthält sieben Beiträge, die an unterschiedlichen Beispielen den fortgeschrittenen Stand der formalen Modellbildung in der Geographie demonstrieren. Das von J. DEITERS eingeleitete vierte Kapitel vereinigt sieben Aufsätze zu einigen theoretischen und empirischen Aspekten des Themenkreises „Raumordnung und Disparitätenforschung". Das von G. LÖFFLER eingeleitete abschließende Kapitel knüpft an D. BARTELS' Arbeiten zum „Satisfaktionsraum" und „Lebensraum Norddeutschland" an und enthält unter der Überschrift „Heimat und Region" sechs Beiträge zu verschiedenen Aspekten von Regionalismus und Heimatbewußtsein.

Die Herausgeber der in jeder Hinsicht „gewichtigen" Gedächtnisschrift haben auf eine umfassende Würdigung der Persönlichkeit und des Werks D. BARTELS' verzichtet; die 32 Beiträge leisten dies jedoch implizit dadurch, daß sie