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THE COLLECTION AND PROCESSING OF FIELD DATA

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PROBLEMS OF MICROMETEOROLOGICAL MEASUREMENTS

(On Degree of Control in Out-of-Doors Experiments)

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CONTENTS

"Das wichtigste Resultat des Forschens ist...
in der Mannigfaltigkeit die Einheit zu erkennen,
von dem Individuellen alles zu umfassen...
die Einzel pruefend zu sondieren,
und doch nicht ihrer Masse zu unterliegen.

Alexander von Humboldt, KOSMOS,1848
(1769 - 1859)

THE MOST SIGNIFICANT CHALLENGE OF RESEARCH IS...

TO RECOGNIZE ONENESS IN MULTIPLICITY,

TO GRASP COMPREHENSIVELY ALL INDIVIDUAL CONSTITUENTS...

AND TO ANALYZE CRITICALLY THE DETAILS,

BUT WITHOUT BEING OVERWHELMED BY THEIR QUANTITY.

I. INTRODUCTION

In contrast to conditions in the laboratory, research in the out-of-doors is strongly affected by the variability of natural conditions. This establishes a handicap for research in micrometeorology, in addition to other, more obvious special problems of measurement which result from the complexity of instrumentation, e. g., sensor exposure, sampling and recording techniques, automatic data handling. Although the latter problems are certainly highly important, they represent a more technical challenge, and will be properly dealt with by other authorities. Instead, we will discuss here possibilities and approaches which promise to help overcome the lack of control. Thus, the main purpose of my presentation is to show ways to increase the efficiency of micrometeorological field work more by strategic than by tactical means. Thoughts of this nature are important because experimental studies are still necessary to improve our general knowledge and understanding of the natural aerodynamic processes which occur in the lower atmosphere. Basically, these processes are differential parts of a complex integral phenomenon which we call the general circulation of the atmosphere. We need to know more about the dependence of these atmospheric processes on the physical nature of the lower boundary conditions, and, specifically, how the variable input of solar energy (which occurs mainly at the lower boundary) is utilized by atmospheric systems of different scales.

II. TYPICAL MICROMETEOROLOGICAL FIELD EXPERIMENTS

A. Design of the Experiment and Collection of Data

The basic processes of interest concern the exchanges of energy, momentum, and mass away from or towards the soil/air (or water/air, or snow/air) interface. In biological problems, we are interested in the same transfers towards and away from the skin, or the outer surface of organic units or complexes. It is normally assumed that improved understanding of these processes must be built on concepts which utilize the fine structure of the atmospheric medium in connection with time-integrated quantities, rather than the latter alone. However, recent theoretical developments - Lettau (1, 2) - suggest that the relationship between fluctuating quantities and the mean profile structure is more capable of rationalization in an Eulerian system of measurements than has been assumed previously.

New lines of attack will, in general, require the development of radically new types of instrumentation. The danger here is that the measuring difficulties can become so great that the major effort and time of the research worker has to be devoted to the mastering of gadgetry and technique. Only a small portion of the time can be devoted to the actual experiment in the field and even less, finally, to the analysis of the results.

Furthermore, indiscriminate indulgence in extensive field tests results in the accumulation of overwhelming volumes of data but little significant advance in our basic understanding of micrometeorological factors. This can be particularly true when insufficient information on the ambient conditions and the basic processes of energy and momentum exchange at the surface is collected with the special data.

B. Surface-Roughness Modification

A first series of controlled wind-profile experiments were conducted by Kutzbach (18) on the ice of Lake Mendota, near the campus of the University of Wisconsin, at Madison. This lake has a surface area of about 40 km^2, and is closed solidly every winter between about December and April. Smooth surface fetches of several kilometers are thus available. The aerodynamic surface roughness of the ice is low, $z_0 = 0.01$ cm, and was modified by distributing about 500 commercial bushel baskets in preselected arrays on a limited area. The individual obstacles have a height, h^*, of 30 cm, with diameters of 42 cm at the open end and 37 cm at the closed end; in lateral view, the "silhouette area," s, equals 0.12 m^2. The baskets were used to produce roughness-fields of up to 50 m upwind extent, measured from a micrometeorological wind mast. Control of area-density of obstacles was one of the major features of the experiments. The "specific area" (S) per individual obstacle, ranged from about 50 to 0.4 m^2, the lower figure being close to the densest packing possible. Each experiment consisted of a sequence of six to ten 10-min. mean wind profiles, extending over a 2 to 3-hr period. Weather conditions were chosen such that moderate to strong, steady winds could be expected for several hours, and slightly diabatic conditions were permitted.

Figure 4 illustrates the degree to which modification of the wind profile was achieved during one experimental period, in the early afternoon of 24 February 1961. Note again, that more anemometer levels were used than is customary for conventional micrometeorological observations. Eleven anemometers of the Thornthwaite-type were located between 10 and 370 cm.

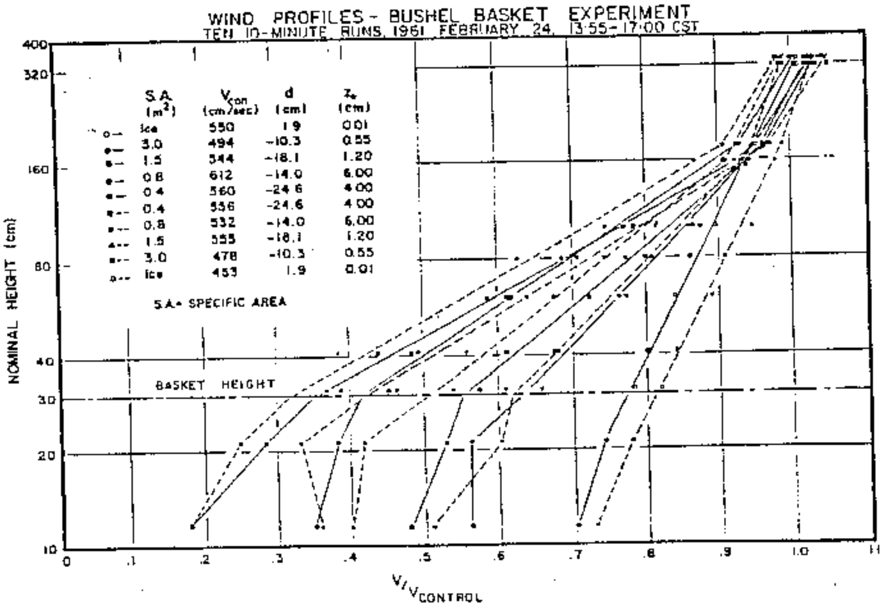


Figure 4. Wind profile experiment on the ice of Lake Mendota, 24 February 1961. The controlled parameter was the specific area per obstacle (bushel basket).

Kutzbach's relationship may be simplified to yield

$$z_0 \approx 0.5\ h^*\ s/S \qquad [6]$$

Clearly, aerodynamic roughness is a function of obstacle density as well as obstacle height. The earlier expressions (exclusively between z_0 and h^*) of Kung and others seem to be valid only for optimum area-density of obstacle distributions as studied by Kutzbach.

Several different versions of wind profile modification experiments were carried out in other winters on the ice of Lake Mendota. A brief discussion follows of two experiments reported by Stearns and Lettau (21). In the first, an array of 228 small trees were used, mostly from left-overs at a commercial Christmas-tree lot. Each tree was trimmed to an overall height of 175 cm, with an average crown diameter of about 80 cm, and distributed over a circular area, the trees being frozen into the ice. With the aid of moving masts and control masts, changes of vertical profile structure along the downwind fetch were measured with such detail that mass and momentum budgets could be analyzed. Figure 5 illustrates the result. The experiment demonstrates convincingly the role of vertical motion for the momentum budget near surface-roughness discontinuities. It is interesting to see that only a relatively small portion of the momentum deficit over the trees is caused by irreversible losses accompanying the increase of boundary stress. The major loss is of a reversible nature, due to upward displacement of mean streamlines, with horizontal momentum being returned downwards in the lee of the obstacle field.

The second experiment reported by Stearns and Lettau (21) aimed at simultaneous control of surface roughness and Richardson number. 420 of Kutzbach's bushel baskets were used, 210 of which were painted white and the other 210 black. A specific area of 2 m^2 per obstacle was selected for an experiment in which black and white bushel baskets formed adjacent roughness fields of 21 m crosswind and 20 m downwind. The albedo values were 0.15 for the black and 0.65 for the white obstacles, while that of the aged snow on the ice was around 0.52. With sunshine in March, the effective solar heating of the black field was estimated to be 0.07 ly/min., and that of the white field 0.03 ly/min., i.e., a differential heating rate of 0.04 ly/min.

Figure 6 illustrates wind profile observations and the result of analysis to compute mean vertical velocity from mass continuity. One sees that velocity defects and updrafts are more pronounced for the black than for the white field. Observations of temperature distributions suggested that the Richardson numbers between black and white fields (in the 40-to-80 cm layer) varied only from about -0.005 to +0.005. Nevertheless, the momentum budget in Figure 7 appears to demonstrate the effect of surface heating.

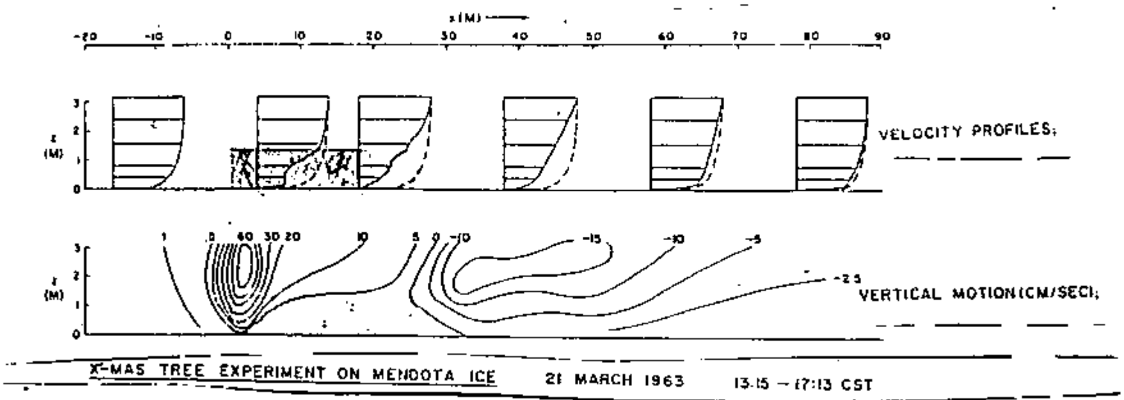


Figure 5. Roughness modificationexperiment on lake ice using an artifical stand [from x= 0 to 20 m] of conifer trees. -Facetiously,referred to as X-mas tree or, "Arctic Timberline Replica" experiment

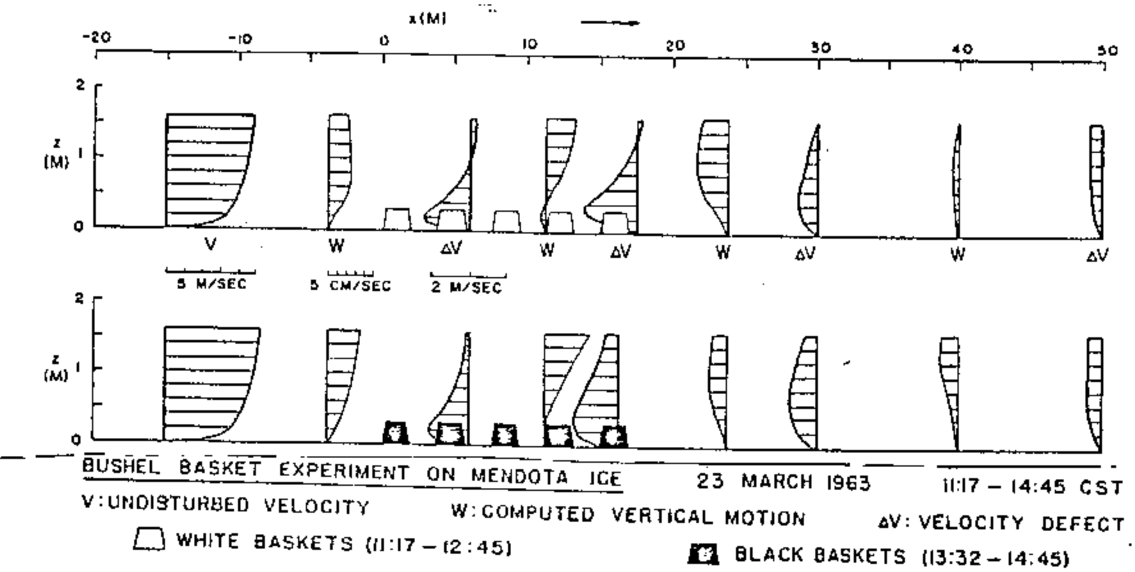


Figure 6. Roughness modification experiment on lake-ice, with partial control of Richardson numbers, using fields of black and white bushel baskets. Illustrated are profiles of velocity defect and computed mean vertical motion.

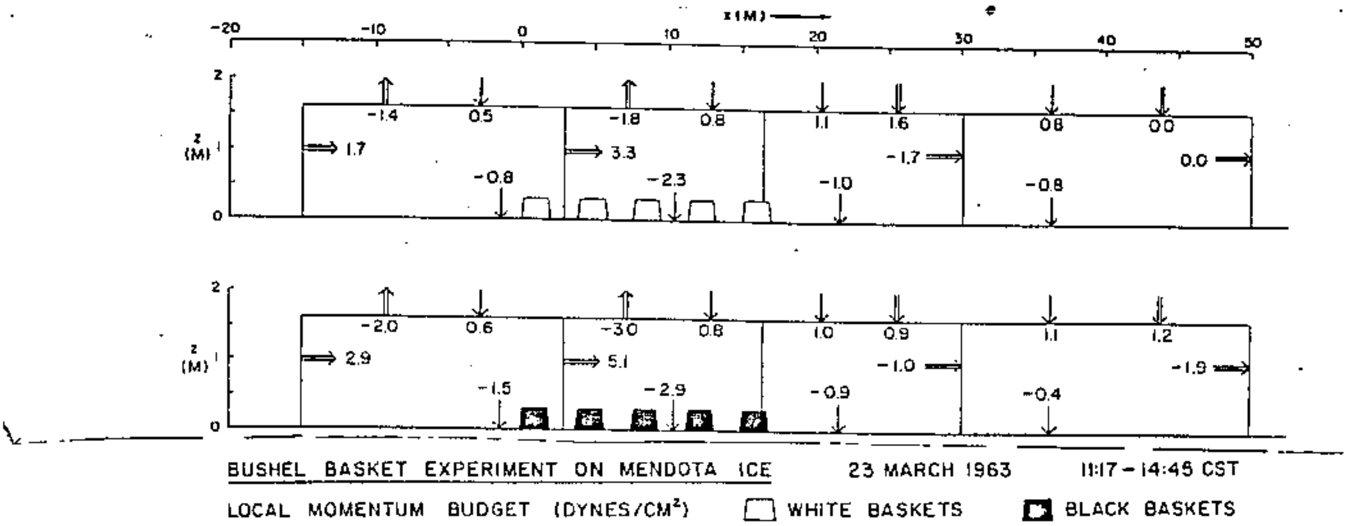
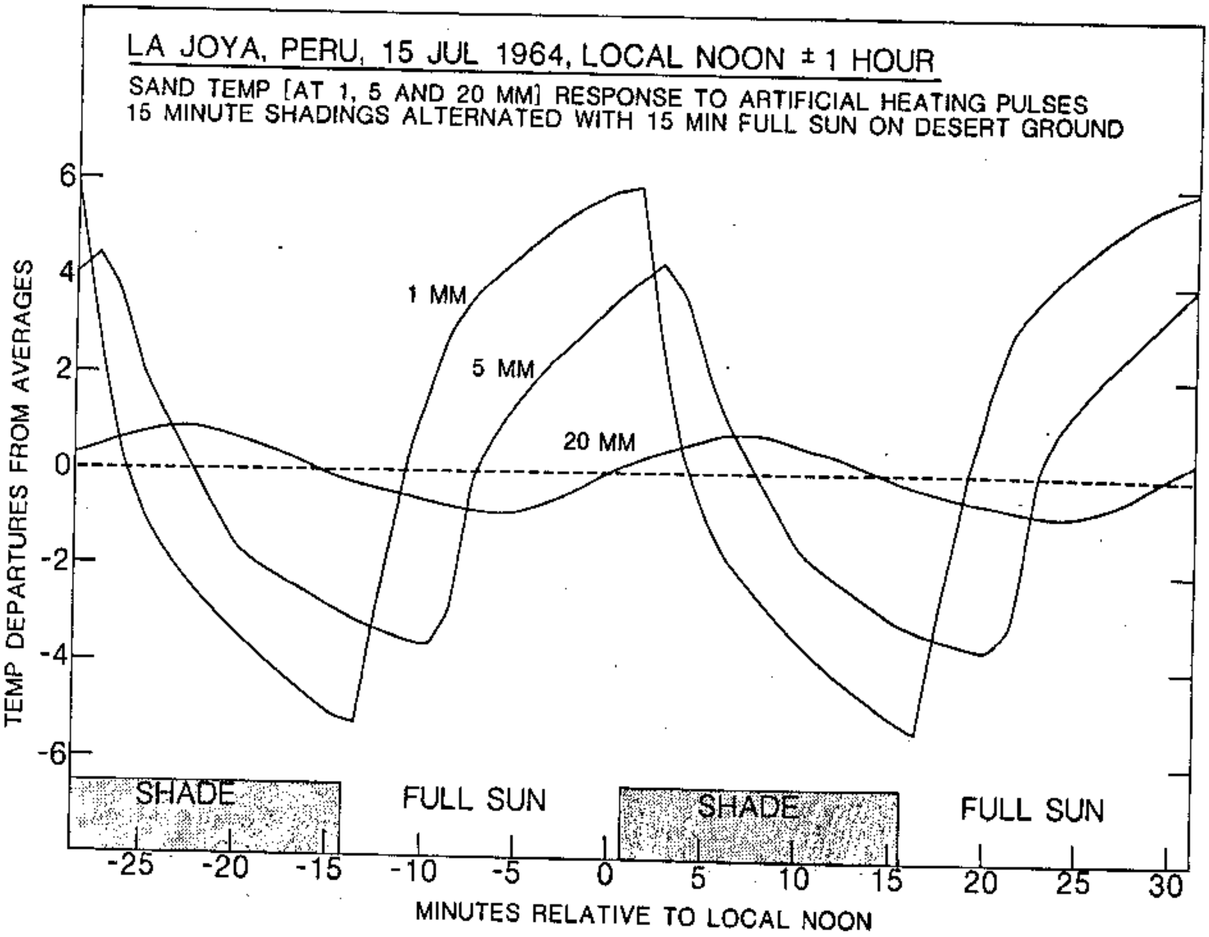


Figure 7: Roughness modification experiment on lake-ice, with partial control of Richardson numbers, using fields of black and white bushel baskets. Illustrated are local budgets of horizontal momentum. See Figure 5 for explanation of numbers (dynes cm^{-2}) written beside arrows.


LA JOYA, PERU, 15 JUL 1964, LOCAL NOON ± 1 HOUR
SAND TEMP [AT 1, 5 AND 20 MM] RESPONSE TO ARTIFICIAL HEATING PULSES
15 MINUTE SHADINGS ALTERNATED WITH 15 MIN FULL SUN ON DESERT GROUND
TEMP DEPARTURES FROM AVERAGES
6
4
2
0
-2
-4
-6
1 MM
5 MM
20 MM
SHADE
FULL SUN
SHADE
FULL SUN
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
MINUTES RELATIVE TO LOCAL NOON

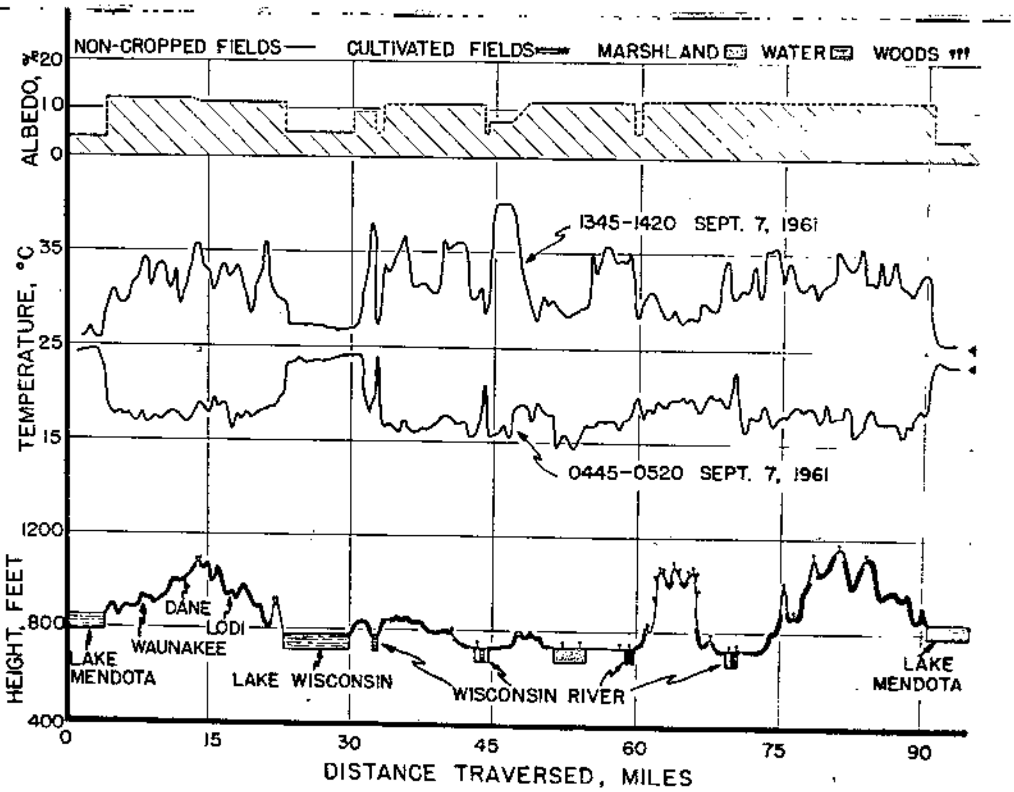


Fig. 6. Airborne measurements of surface temperature in Southern Wisconsin on September 7, 1961, in the early morning and early afternoon.

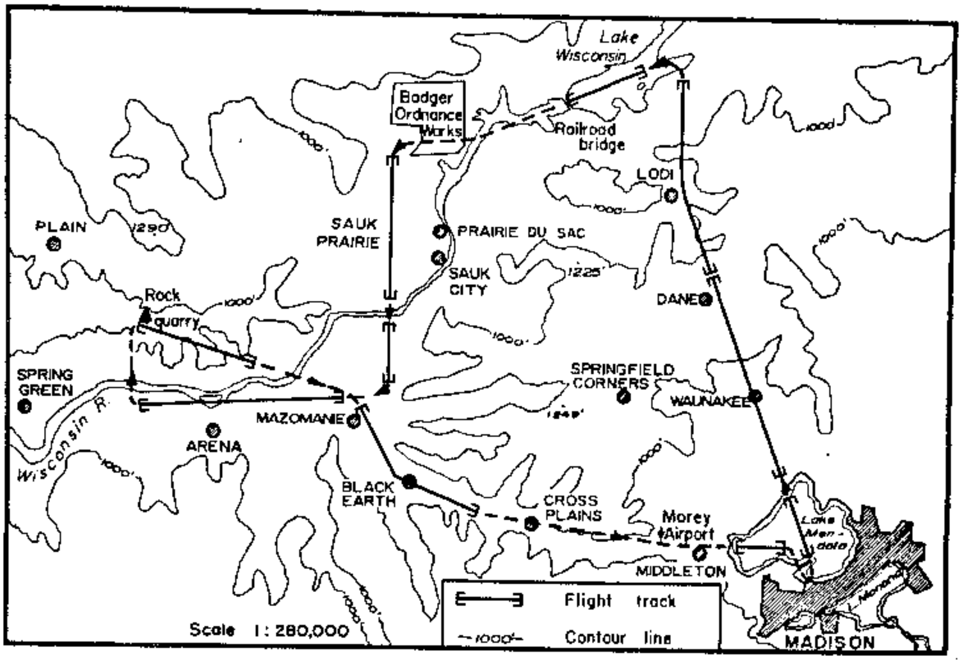


Fig. 5. Flight path used for bolometric surface temperature measurements in Southern Wisconsin. The same track was used by Bauer and Dutton (1960) for albedo studies.

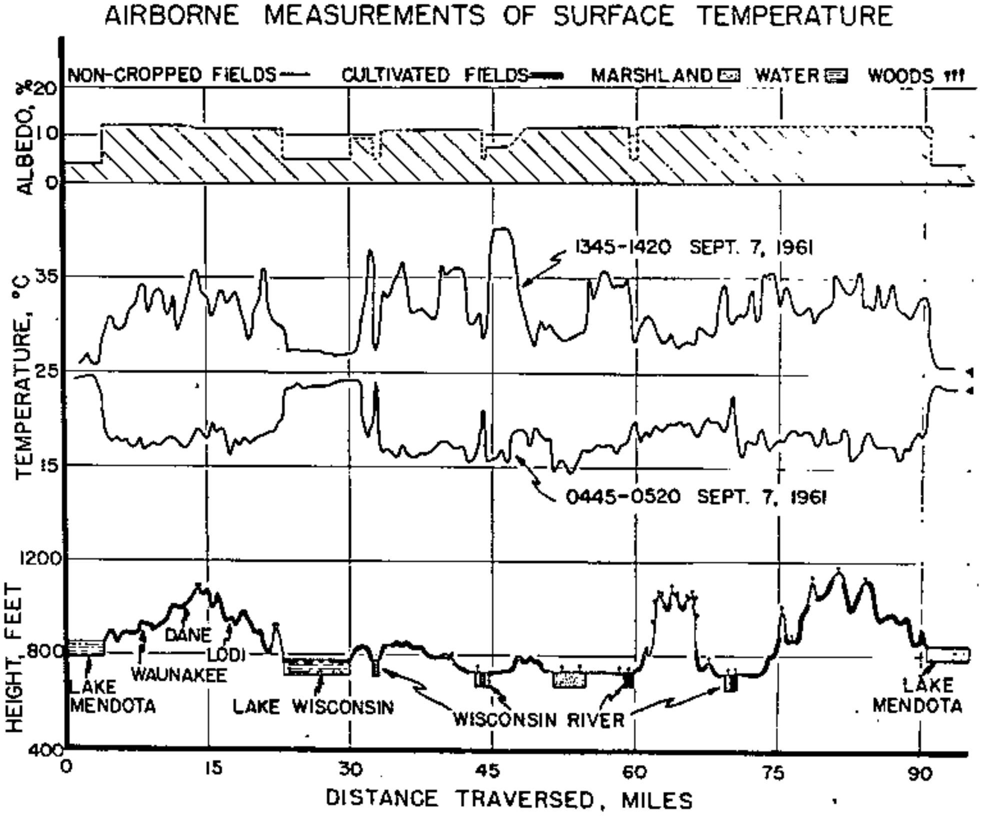
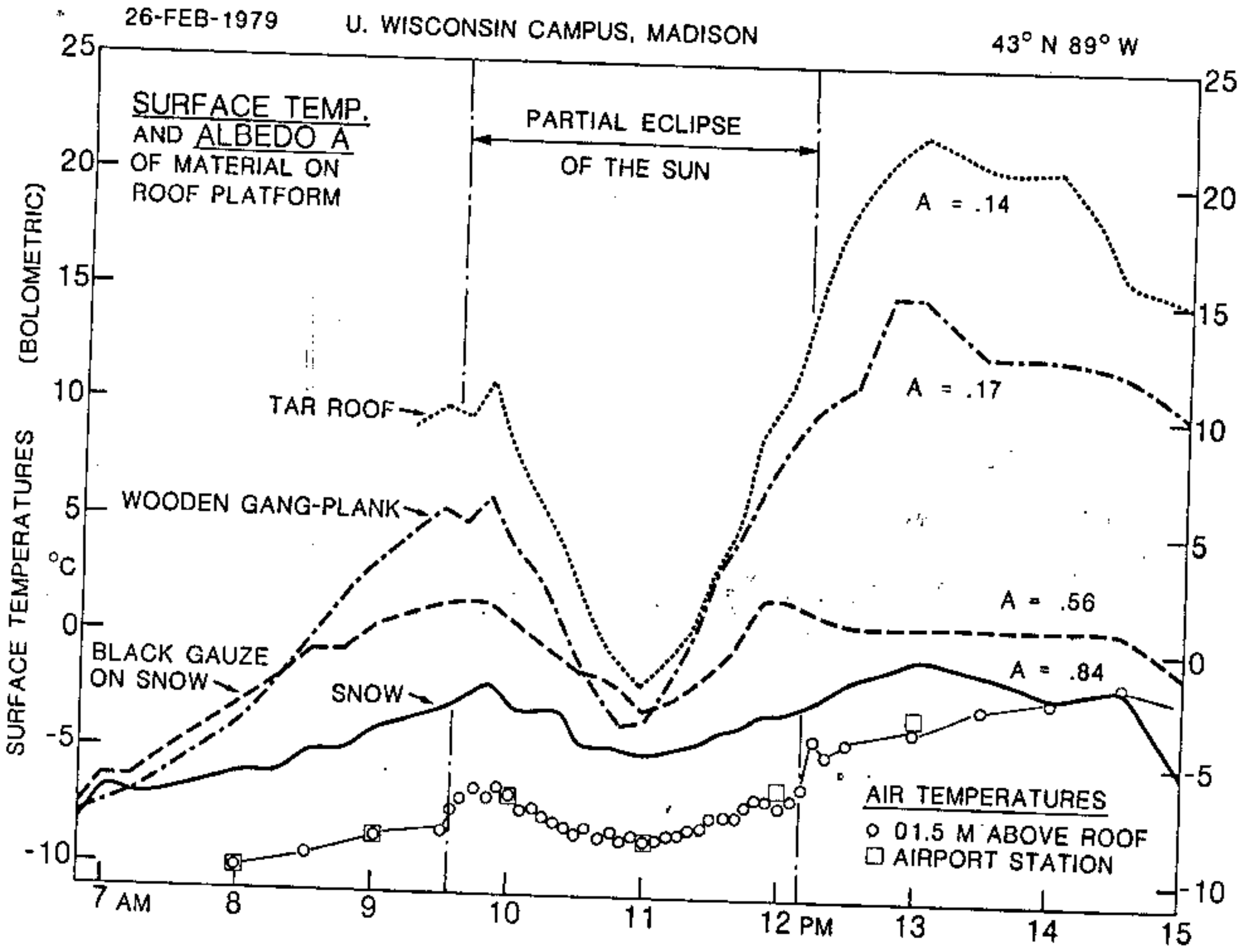


Fig. 6. Airborne measurements of surface temperature in Southern Wisconsin on September 7, 1961, in the early morning and early afternoon.


26-FEB-1979
U. WISCONSIN CAMPUS, MADISON
43° N 89° W
SURFACE TEMP.
AND ALBEDO A
OF MATERIAL ON
ROOF PLATFORM
PARTIAL ECLIPSE
OF THE SUN
(BOLOMETRIC)
SURFACE TEMPERATURES
°C
TAR ROOF
WOODEN GANG-PLANK
BLACK GAUZE
ON SNOW
SNOW
A = .14
A = .17
A = .56
A = .84
AIR TEMPERATURES
○ 01.5 M ABOVE ROOF
☐ AIRPORT STATION
25
20
15
10
5
0
-5
-10
7 AM
8
9
10
11
12 PM
13
14
15

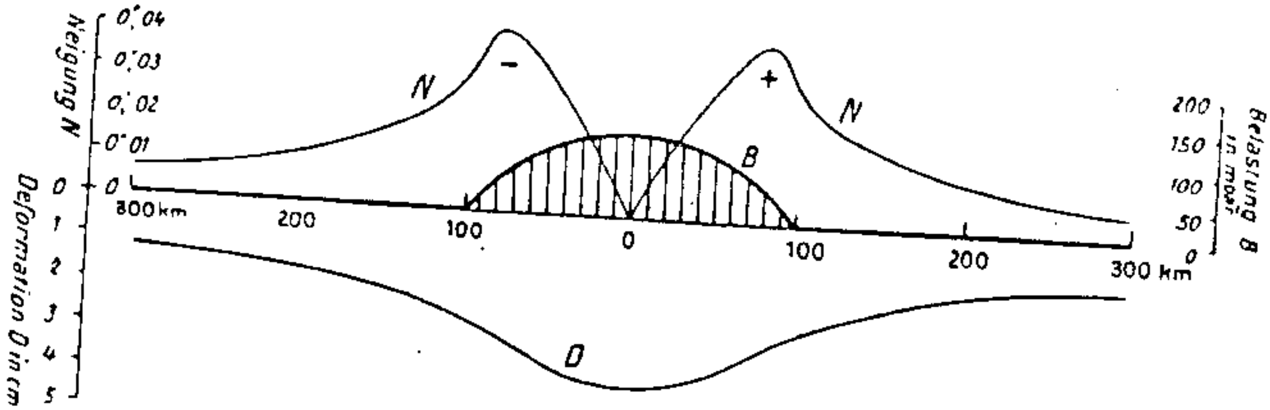


Fig. 10. B = Ausgeglichener Verlauf der Erdkrustenbelastung infolge der mittleren Schneehöhenverteilung im Winter über den Alpen (nach STEINHAUSER); D = durch die Belastung hervorgerufene vertikale Deformation der Erdkruste (nach STEINHAUSER); N = damit verbundene Neigung der Erdkruste in ihrem Verlauf quer zum Alpenzug.

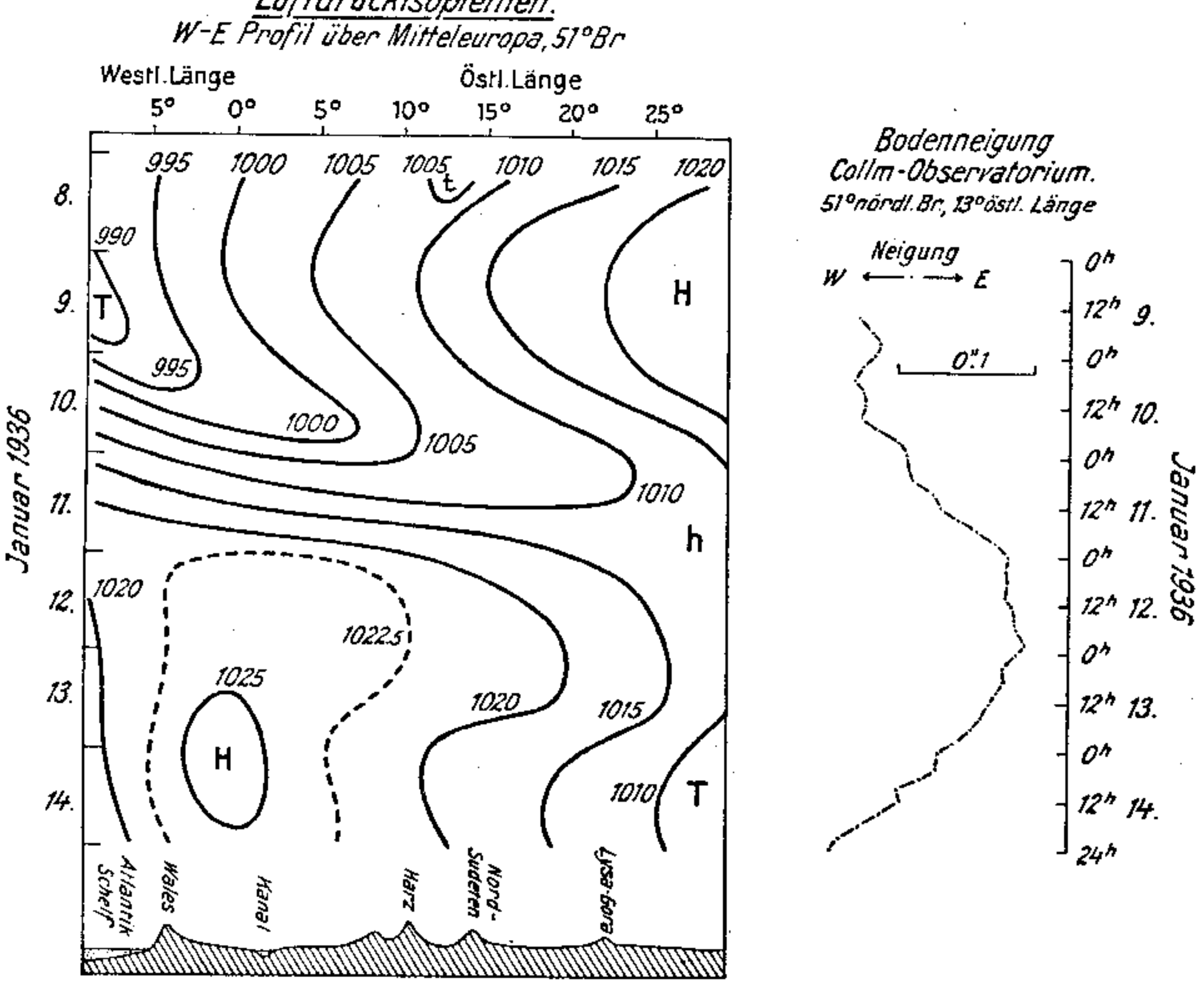
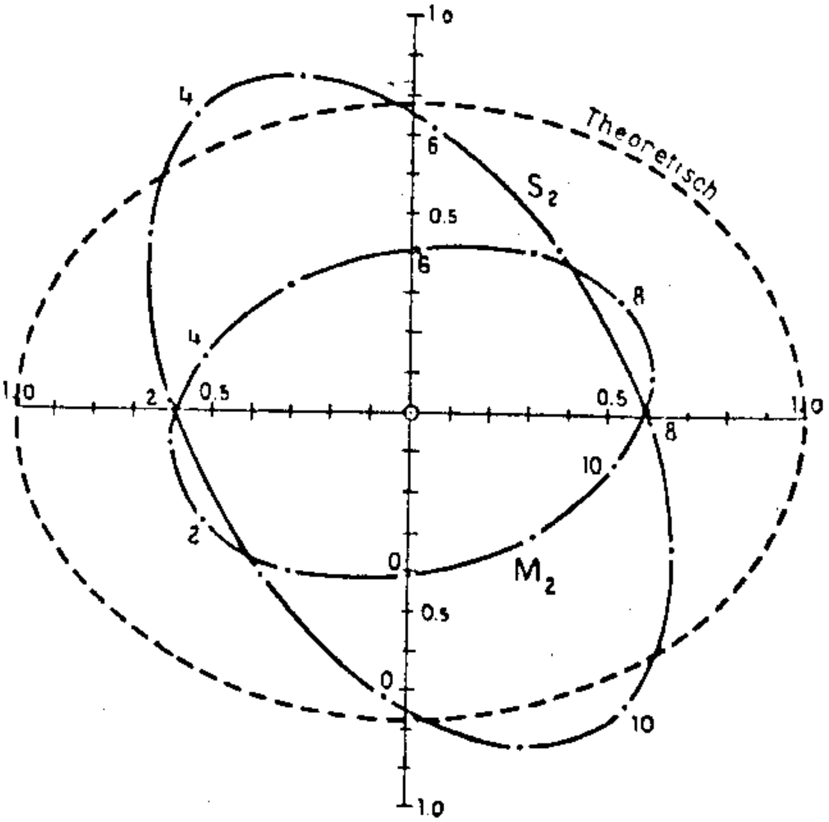


Abb. 9.

Langperiodische Schwankungen der Lotlinie, die wahrscheinlich mit Luftdruckbeeinflussungen zusammenhängen.

Fig. 8.

Theoretische Lotbewegung bei starrer Erde in 51° nördl. Breite. Die von SCHWEYDAR im 5jährigen Mittel beobachtete S_2- und M_2-Bewegung ist relativ zum theoretischen Verlauf eingetragen.



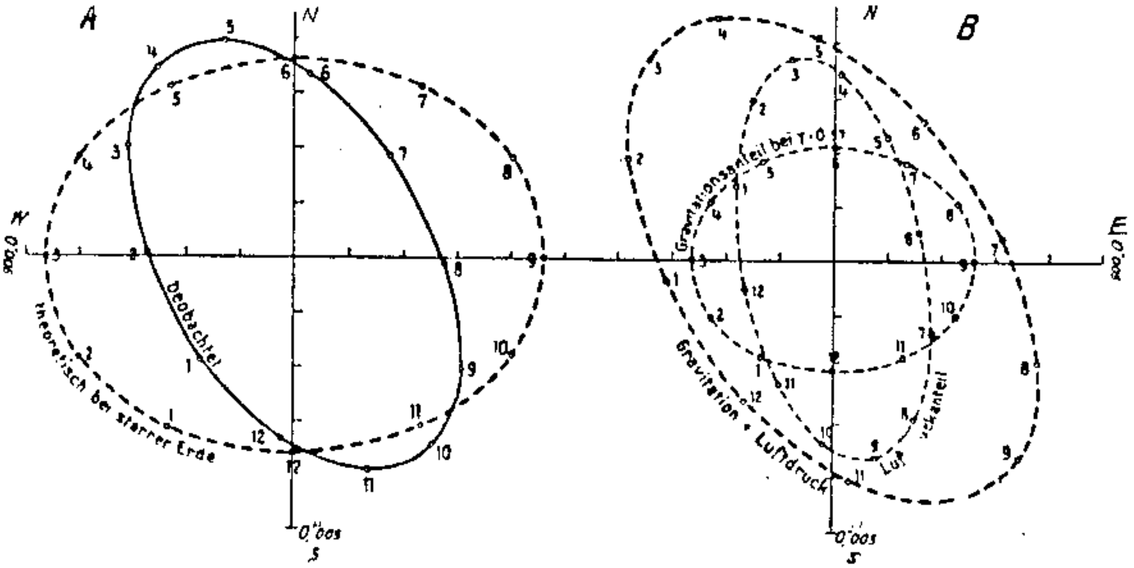
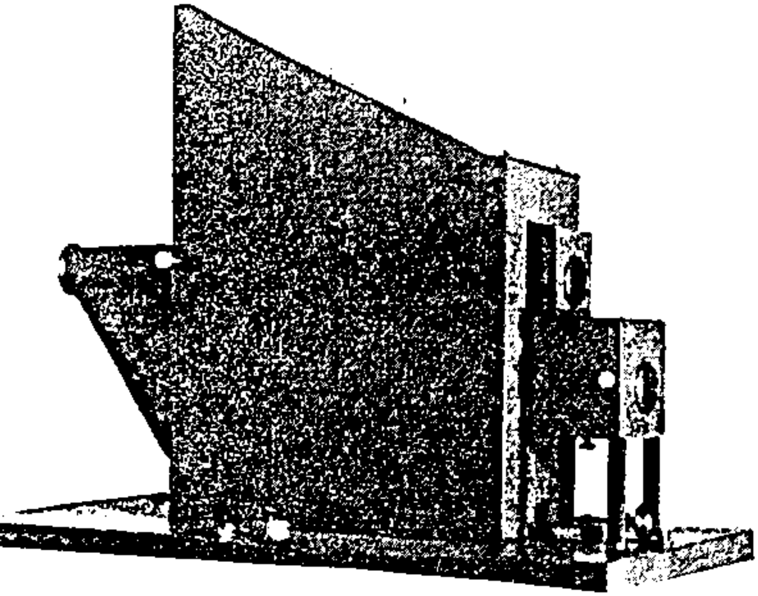


Fig. 9. Gezeitenschwankung des Lotes, halbtägige Sonnenwelle. A. Nach 5jährigen Beobachtungen SCHWEYDARS in Freiberg i. Sa. B. Versuch der Synthese der beobachteten S_2-Lotschwankung aus Gravitationsanteil (mit $\gamma = 0.57$ wie bei M_2) und aus Luftdruckanteil (mittels des von Horizontaldoppelpendelbeobachtungen hergeleiteten Luftdruckkoeffizienten $\beta' = 0.00396''$ pro mm/Hg und der doppelten täglichen Barometerschwankung).



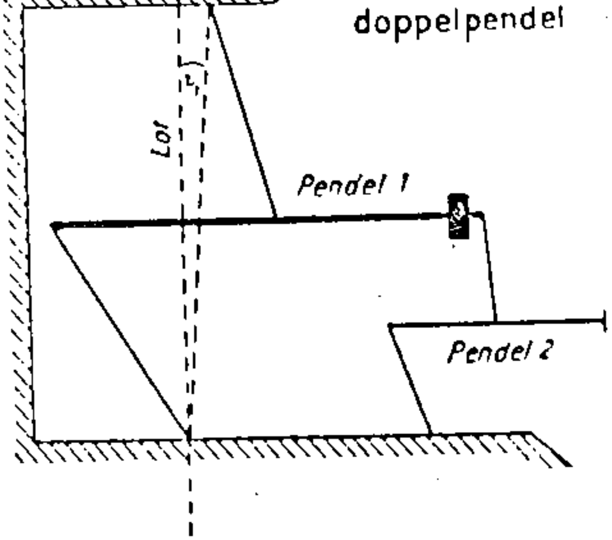


Fig. 1. Schema des Horizontaldoppelpendels (von der Seite gesehen).

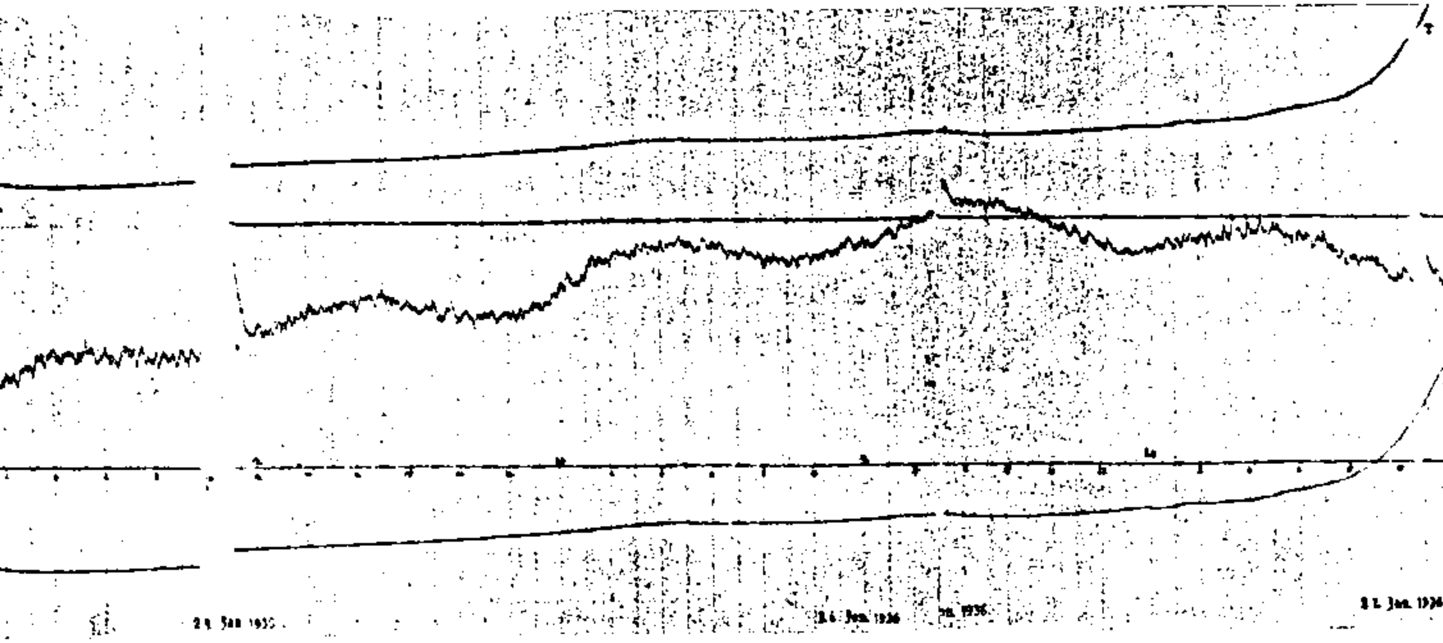


Abb. 7.
Registrierkurve vom 25. bis 27. Januar 1936 mit Gezeitenschwankungen des Lotes (Ost—West-Komponente).