NBS REPORT

5588

Climatic Charts of the Surface Refractivity for Germany

by

B. R. Bean and A. M. Ozanich

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
BOULDER LABORATORIES
Boulder, Colorado

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
8380-40-8881	July 9, 1958	5588

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SUMMARY

In recent years there has been an increased utilization of meteorological information for the prediction of radio field strengths at frequencies of 50 Mc. and above. Various studies have used radiosonde measurements to describe the effect of elevated superrefractive layers[1/], the gross gradient in the first kilometer of the earth's atmosphere[2, 3/], and, more recently, it has been shown that the long term mean value of the radio transmission loss may be represented as a linear function of the surface value of the radio refractivity as derived from surface weather observations[4, 5, 6, 7/]. The refractivity, N, is given by[8/]:

$$N = (n - 1)\, 10^6 = \frac{77.6}{T}\left[P_s + \frac{4810\, e_s\, RH}{T}\right]$$

where P_s is the station pressure in millibars, RH is the percent of the saturation vapor pressure, e_s, in millibars at the absolute temperature, T, in degrees Kelvin, and n is the refractive index.

The data used in the present study were obtained from the Kopenhagener Schluessel deck of the punched card library of the National Weather Records Center, U. S. Weather Bureau. The location of the weather stations used in this study are shown on Fig. 1, and are specified in more detail in Table I. The choice of stations was made so as to give detailed geographic coverage for the arbitrarily chosen two year period

Table I

German Weather Stations

Call Letters	Code Number	Station Name	Elev. in feet	Latitude	Longitude
GSS	00791	Grosser Falkenstein	4291	49°-05'N	013°-17'E
TRR	40049	Trier Petrisberg	265	49°-45'N	006°-40'E
TVM	40130	Travemuende	1	53°-58'N	010°-52'E
QKB	40170	Quakenbrueck	23	52°-40'N	007°-56'E
PLB	40210	Perleberg Wittenberge	31	53°-04'N	011°-49'E
ATK	40240	Altkarbe	35	52°-51'N	15°-40'E
KBN	40247	Konigsberg/Neumark	50	52°-53'N	14°-25'E
GFD	40284	Greifswald	4	54°-06'N	13°-26'E
LAC	40379	Lachen-Speyerdorf	120	49°-20'N	008°-12'E
FSB	40400	Flensburg	42	54°-46'N	009°-22'E
BKM	40401	Borkun	12	53°-36'N	006°-42'E
HAM	40403	Hamburg	18	53°-38'N	10°-00'E
AAC	40407	Aachen	205	50°-47'N	006°-06'E
FFM	40412	Frankfurt am Main	111	50°-03'N	008°-36'E
FTB	40419	Fichtelberg	1213	50°-26'N	12°-57'E
GBS	40420	Gruenberg Silesia	148	51°-55'N	15°-30'E
WSS	40423	Wasserkuppe	926	50°-30'N	009°-56'E
FWS	40427	Feldberg, Schwartz Wald	1493	47°-52'N	008°-01'E
BLN	40440	Berlin	56	52°-29'N	13°-26'E
HEL	40465	Helgoland	50	54°-11'N	007°-53'E
CLH	40558	Crailsheim	422	49°-08'N	10°-03'E
HLN	40622	Halle Nietleben	79	51°-29'N	11°-56'E
GTT	40631	Gottingen	154	51°-33'N	009°-54'E
NHB	40636	Nordhausen Bleicherode	180	51°-29'N	10°-47'E
GOT	40645	Gotha	300	50°-58'N	10°-45'E
SHD	40653	Steinheid	840	50°-28'N	11°-05'E
RBO	40733	Regensberg Obertraubling	330	48°-59'N	21°-12'E
MMM	40775	Memmingen	630	47°-59'N	10°-14'E
BAD	40781	Bad Aibling	486	47°-53'N	11°-59'E
GLZ	40936	Goerlitz	237	51°-09'N	14°-57'E
PRG	52010	Prag Kbely	928	50°-07'N	14°-32'E
PIZ	52666	Pilsen	1168	49°-44'N	13°-21'E
POZ	55552	Poznan	325	52°-25'N	16°-50'E

1940-1941. The refractivity was calculated for each observation and then averaged for each time of observation and each month of the two year period; this average is designated $\bar{N}_o$. For example, mean values were obtained for the hour of 0800 during the month of June. The refractivity was then presented in terms of a reduced-to-sea level value, N_o:

$$\bar{N}_o = \bar{N}_s \exp \{0.032218\, h_s\}$$

where N_s is the value of the refractivity at the station and h_s is the elevation of the station in thousands of feet above sea level. The advantages of removing the altitude dependence of N_s by the use of N_o are discussed in a recent study of the world wide variation of N[9].

Normally the refractivity is calculated by inserting the station pressure, temperature and humidity into the expression for N_s. The Kopenhagener Schluessel observations, however, are in terms of station temperature and humidity but reduced-to-sea level pressure, P_o, rather than station pressure, P_s. The station pressure was obtained by utilizing a pressure-height dependence derived from the U.S. Standard Atmosphere:

$$P_s = P_o \exp \{-0.037405\, h_s\}$$

where h is in thousands of feet. This now yields the expression for N_o:

$$N_o = \left\{ \frac{77.6\, P_o \exp(-0.037405\, h_s)}{T} + \frac{3.733 \times 10^5\, e_s\, RH}{T^2} \right\} \exp \left\{0.032218\, h_s\right\}$$

This latter expression was then used to obtain the reduced-to-sea level value of N_o from the basic meteorological data.

The average annual and diurnal cycles of N_o for eight of the German weather stations were selected to display the range of climatic conditions for the country and are given on Figs. 2 through 9. A consideration of the annual and diurnal cycles of all eight of the sample stations reveals a somewhat uniform annual range of 17 to 24 N units of the monthly mean values while the average diurnal cycles, even for the summer months, are but a few N units. These rather small annual and diurnal ranges indicate that the climate of all of Germany, refractivity wise, tends to reflect the maritime influence of the North Atlantic. This tendency towards a maritime climate is further illustrated by Table II where it is seen that the German annual and diurnal cycles are most comparable with the west coast U.S. stations of Tatoosh Island and Oakland. This one might expect since the absence of coastal mountain ranges in Western Europe permits the inland flow of maritime air to a greater extent than over the west coast of North America. It is interesting to note that the east coast U.S. stations have significantly greater seasonal and diurnal ranges than the German stations, which would lead one to expect smaller seasonal variations of transmission loss in Germany than in the United States. An informal examination of radio transmission loss data recorded in Germany and kindly lent to the authors by Dr. J. Grosskopf of the Fernmeldetechnisches Zentralamt der Deutschen Bundespost indicates that the annual cycle of VHF transmission loss is indeed smaller than is generally observed in the United States. Values of the maximum annual range of monthly means are given on Fig. 10. The maximum annual ranges shown on Fig. 10 are generally in excess of the 17 to 24 N unit annual range previously noted from Figs. 2 - 9 since the maximum annual ranges were determined as the difference between the maximum and minimum values of $\overline{N}_o$ occurring throughout the year. Maximum diurnal ranges of $\overline{N}_o$ are given for the months of February and August in Figs. 11 - 12. There is a noticeable trend for the diurnal ranges to increase with increasing distance from the ocean.

Table II

Comparison of Annual and Diurnal Ranges of $\bar{N}_o$ in Germany and in the United States

Station	Annual Range at 0200 in N units	August Diurnal Range in N units
Germany:		
Helgoland	25	1 - 2
Steinheid	23	2
Quakenbrueck	27	4
Berlin	24	10
Trier	26	8
Frankfurt am Main	26	10
Grosser Falkenstein	20	1
Feldsberg, Schwartz Wald	19	3
United States:		
Tatoosh Island	19	1
Oakland	14	7
Denver	23	20
Joliet	41	10
San Antonio	44	38
Washington	48	15

Values of the individual maximum and minimum observed values of N_o were obtained for the hours of 0200, 0800, 1400 and 1900 during the months of February, May, August and November. Contour maps of these maximum and minimum N_o values, as well as the mean of all the observations, were derived for the above indicated hours and months. These maps, Figs. 13 - 60, were checked for consistency of contouring by placing a grid of 72 points over the finished maps, reading the value of N_o indicated by the contours at the grid point and then comparing the contour-derived diurnal and seasonal cycles with the corresponding cycles of nearby weather stations. This procedure permitted the maintenance of an estimated 1 or 2 N units variation in contouring, depending upon the parameter being contoured.

It is sometimes desirable for radio systems planning to know the individual values of the maximum and minimum N_o and the times at which they occur. The minimum values of N_o can be used [5] to estimate the power requirements of the system. Further, the maximum strength of high undesired field strengths that would cause disruption of the desired service may be estimated from the maximum value of N_o. The individual maximum values are given on Fig. 61, the hour of occurrence on Fig. 62 and the month of occurrence on Fig. 63. Similar values for the individual minimum observations are given on Figs. 64, 65, and 66.

The times of occurrence of the maximum value of N_o are during the summer months of June to September with a decided tendency towards occurrence in the early afternoon. This afternoon maximum observation of N_o is in the opposite sense of the diurnal trend of the mean values which, on the average, shows a minimum during the early afternoon. A close examination of the meteorological observations for the day when the maximum N_o occurred reveals a most interesting singularity. On these occasions the air was nearly saturated throughout the day with the result that when the air reached its temperature maximum in the early afternoon it also reached an absolute humidity maximum with a resultant maximum in N_o. It must be noted that this is not a common diurnal pattern, occurring less than 10% of the days during the summer months.

In appraising the climatic charts given above, it is noted that the maps of mean N_o are more self-consistent than the maximum or minimum maps since these latter maps will frequently represent local meteorological singularities or errors in observation. The addition of more data to the stations used would possibly result in more uniform maps but it seems unlikely that the general trends would be changed. The addition of stations in France, however, would modify the contouring for West Germany with perhaps slight changes in contour detail.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to G. E. Richmond and B. J. Weddle for their aid in many aspects of this work.

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GERMAN
WEATHER STATIONS
FSB
HEL
TVM
GFD
BKM
HAM
PLB
KBN
ATK
QKB
BLN
POZ
GBS
GTT
NHB
HLN
AAC
GLZ
GOT
WSS
SHD
FTB
FFM
TRR
PRG
PIZ
LAC
CLH
RBO
GSS
FSW
MMM
BAD
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 1

SEASONAL AND DIURNAL CYCLES OF N_0

HELGOLAND

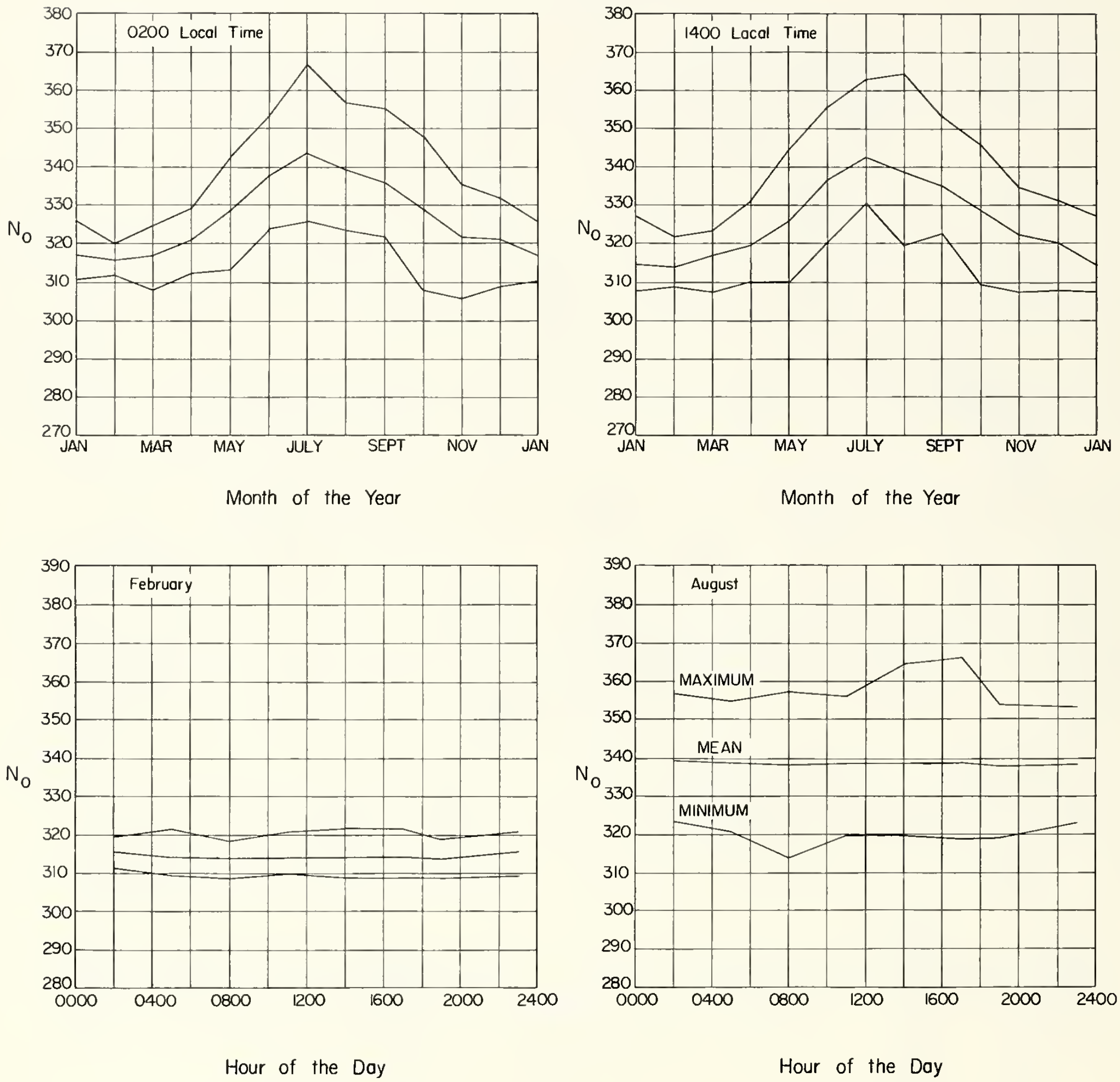


Figure 2

SEASONAL AND DIURNAL CYCLES OF N_0

QUAKENBRUECK

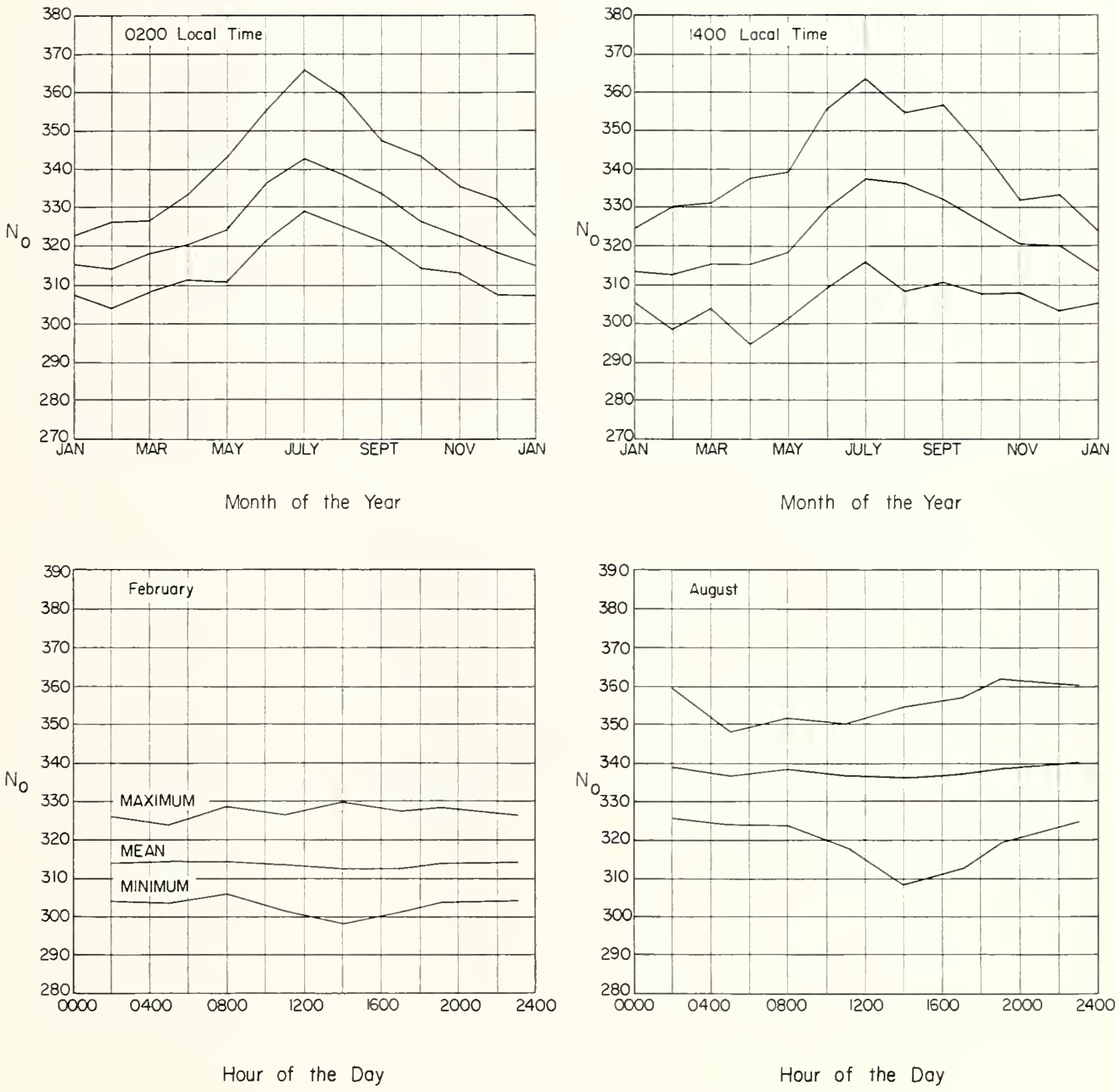


Figure 3

SEASONAL AND DIURNAL CYCLES OF N_0

TRIER

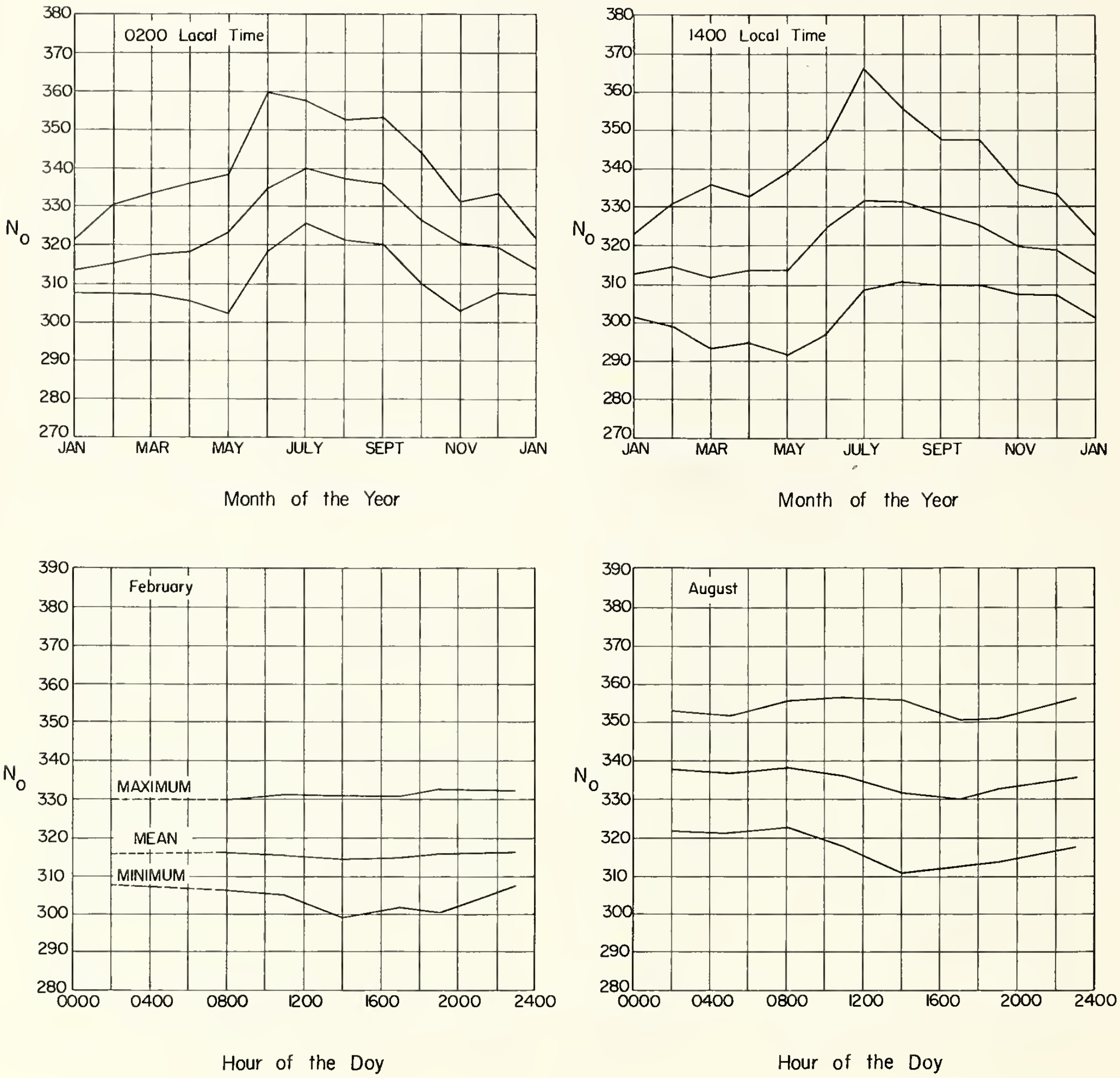


Figure 4

SEASONAL AND DIURNAL CYCLES OF N_0

FELDBERG SCHWARTZ WALD

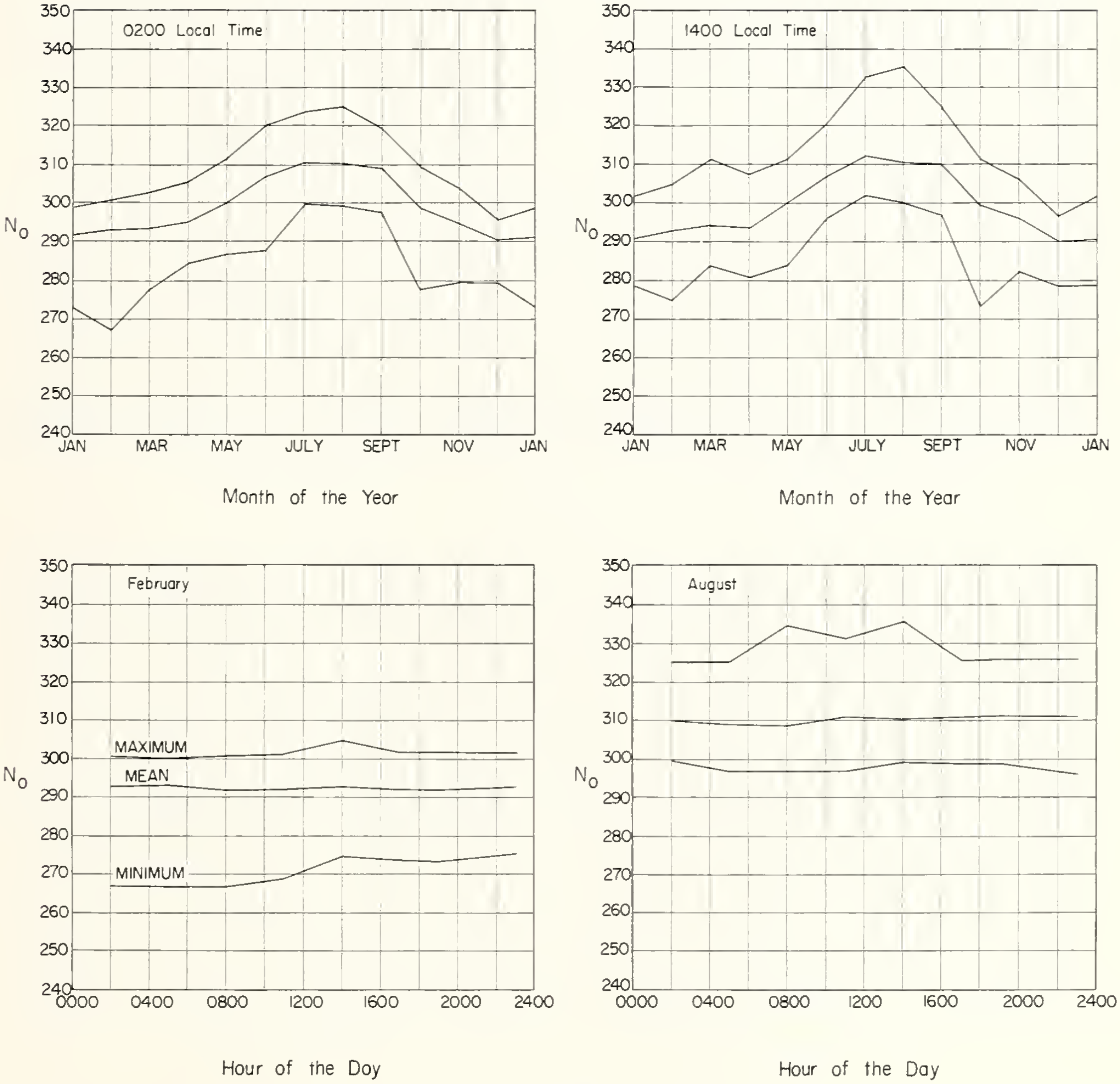


Figure 5

SEASONAL AND DIURNAL CYCLES OF N_0

FRANKFORT ON MAIN

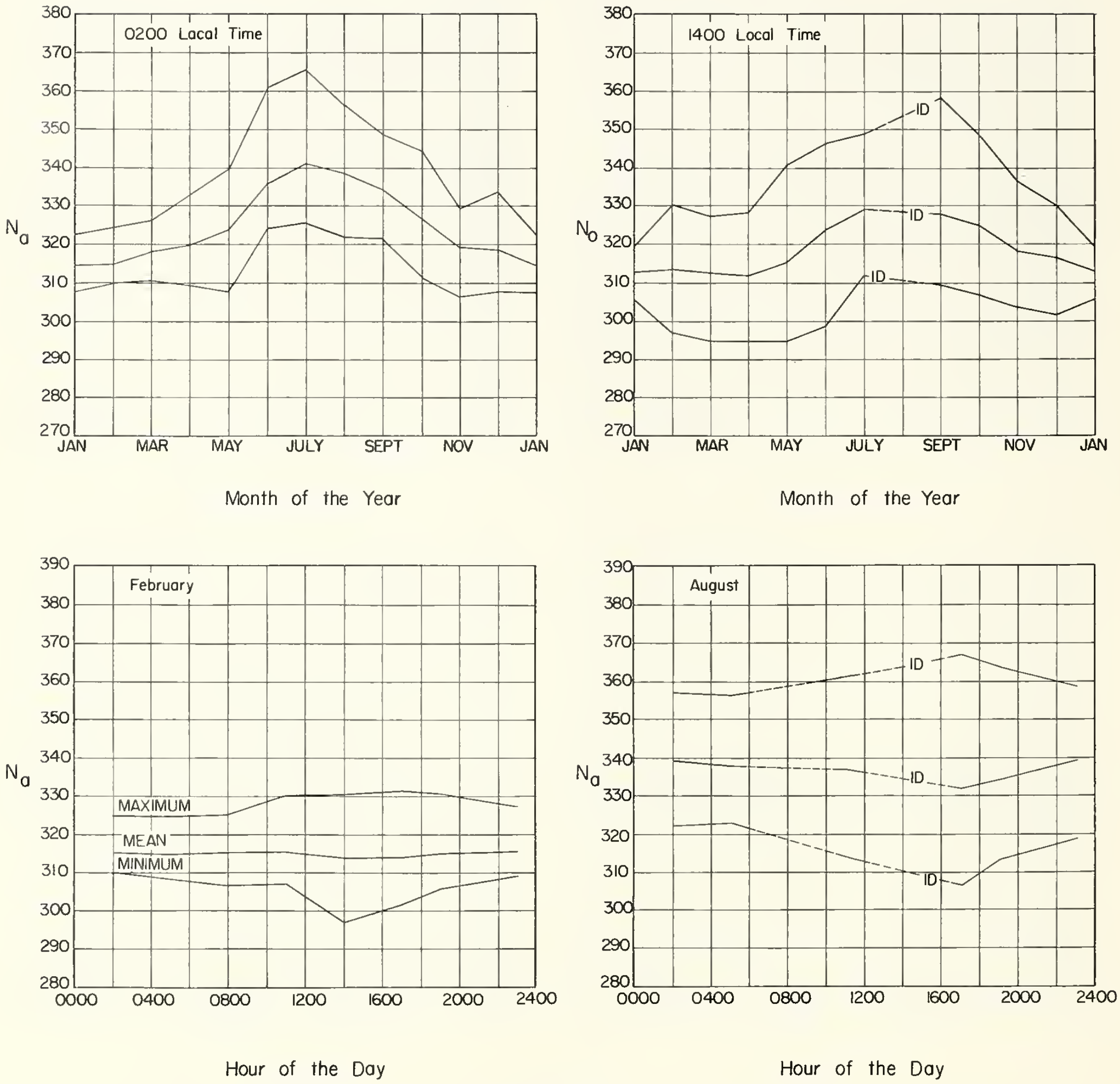


Figure 6

SEASONAL AND DIURNAL CYCLES OF N_0

BERLIN

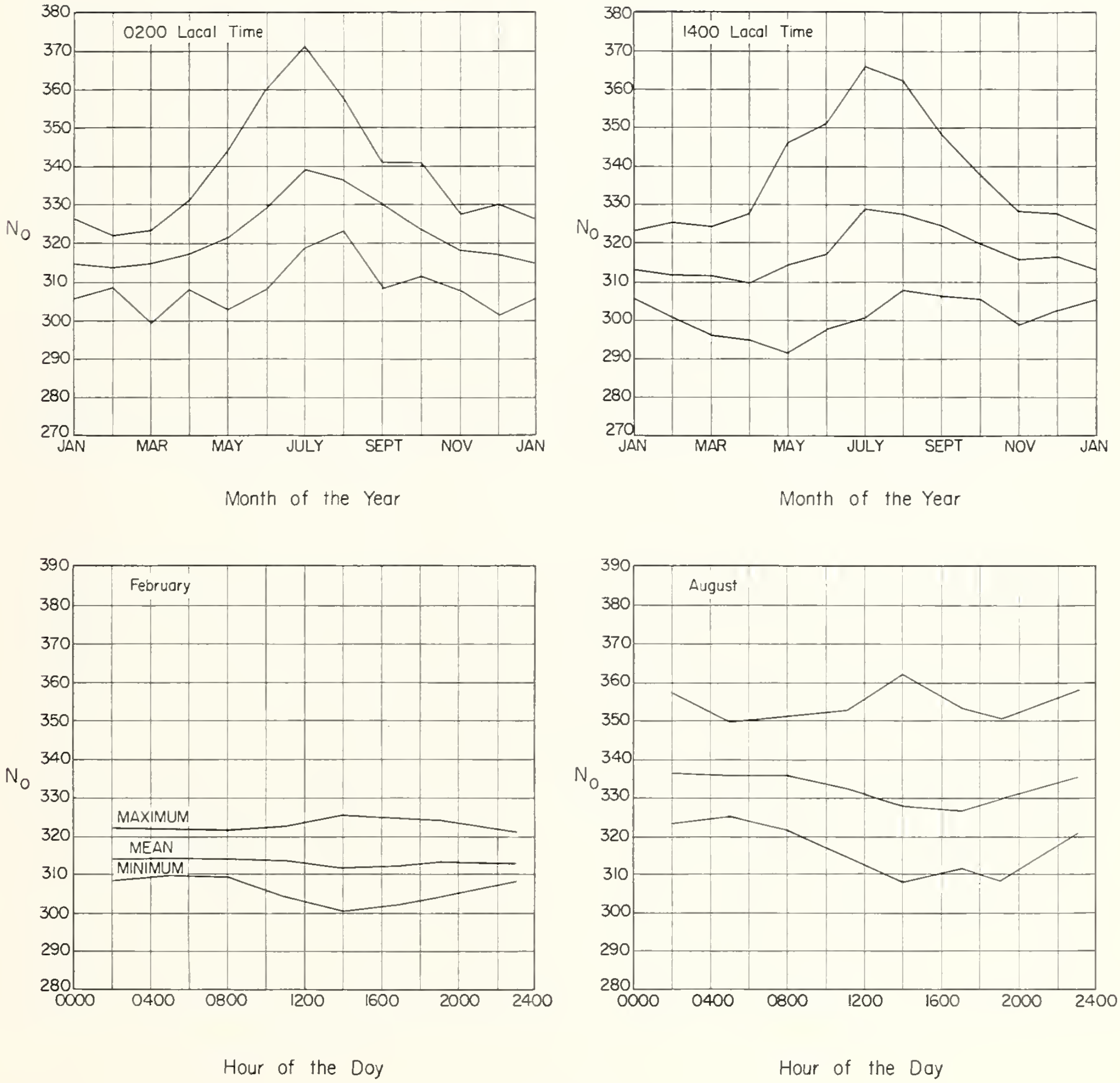
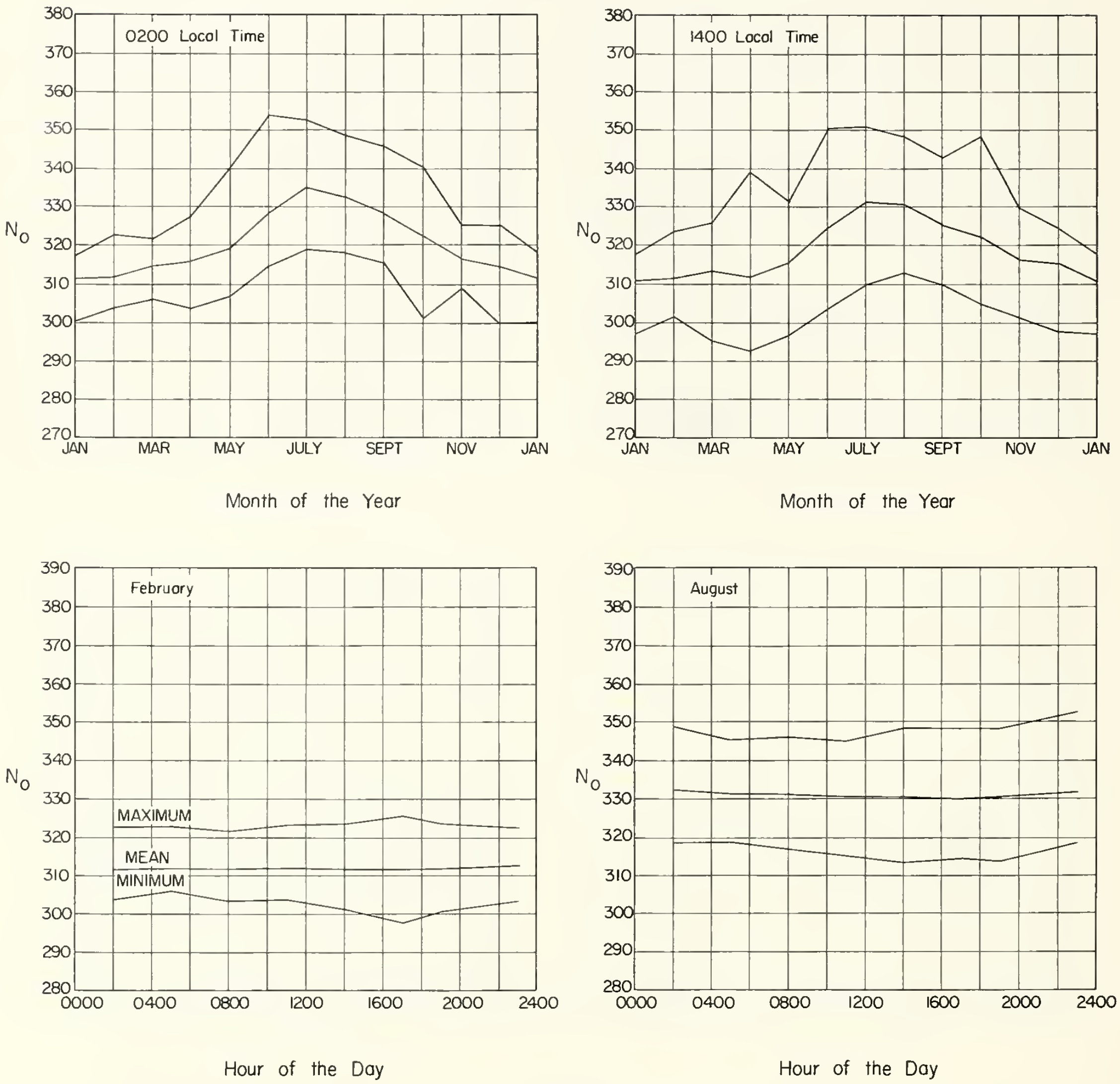


Figure 7

SEASONAL AND DIURNAL CYCLES OF N_0

STEINHEID



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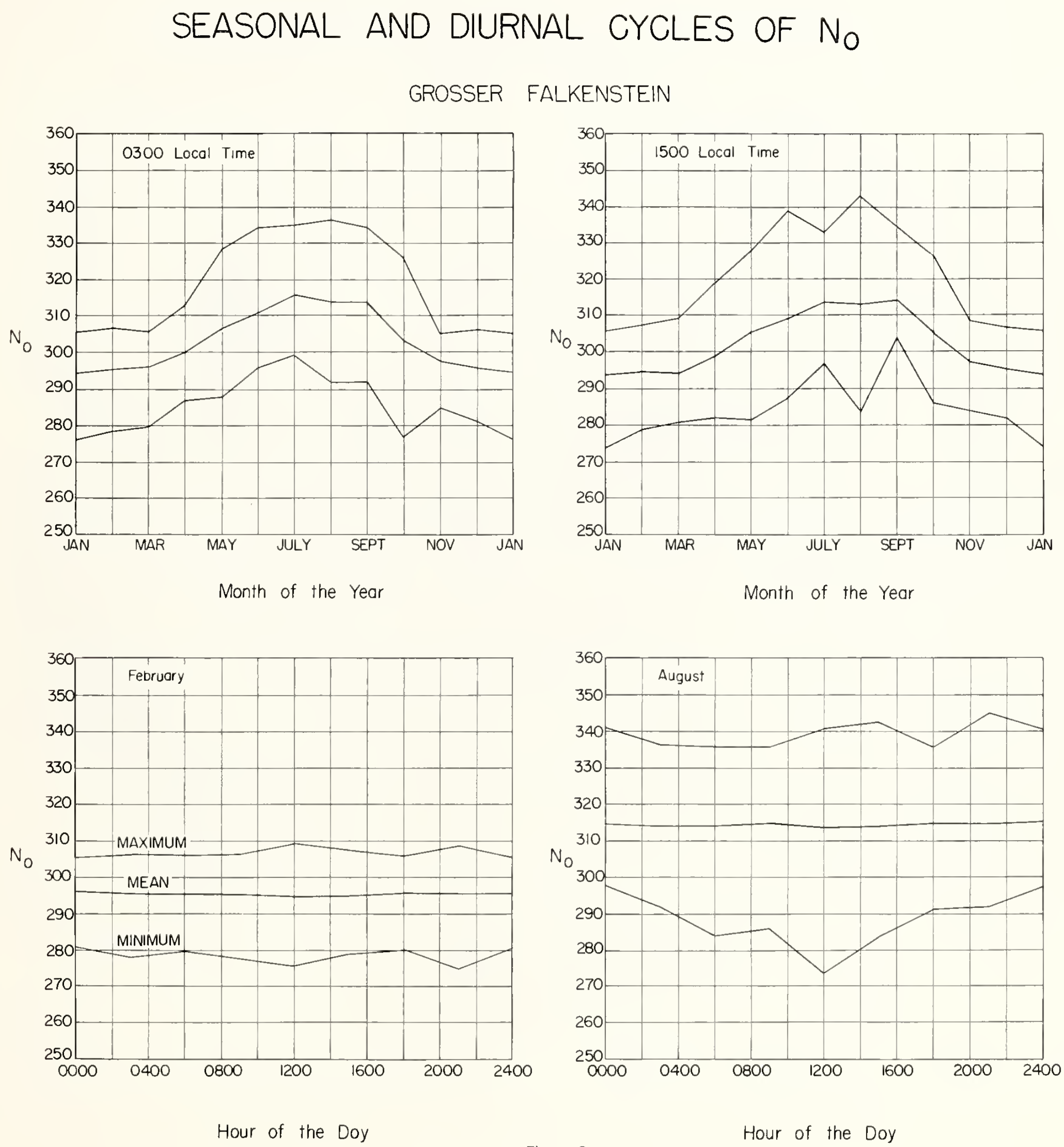


SEASONAL AND DIURNAL CYCLES OF N_O
GROSSER FALKENSTEIN
0300 Local Time
1500 Local Time
February
August
MAXIMUM
MEAN
MINIMUM
N_O
360
350
340
330
320
310
300
290
280
270
260
250
JAN
MAR
MAY
JULY
SEPT
NOV
JAN
Month of the Year
0000
0400
0800
1200
1600
2000
2400
Hour of the Day

Figure 9

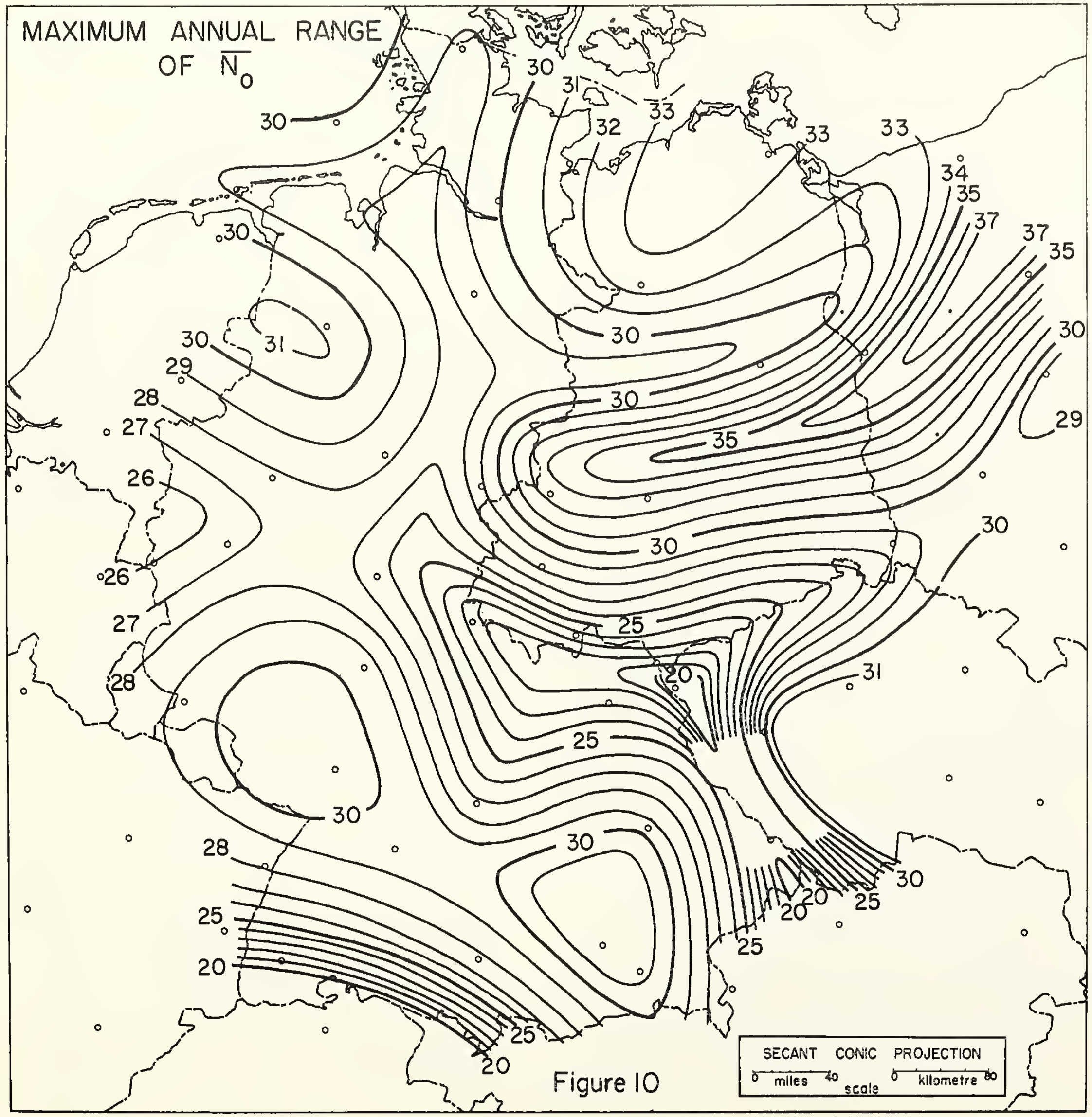

MAXIMUM ANNUAL RANGE
OF $\overline{N}_0$
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 10

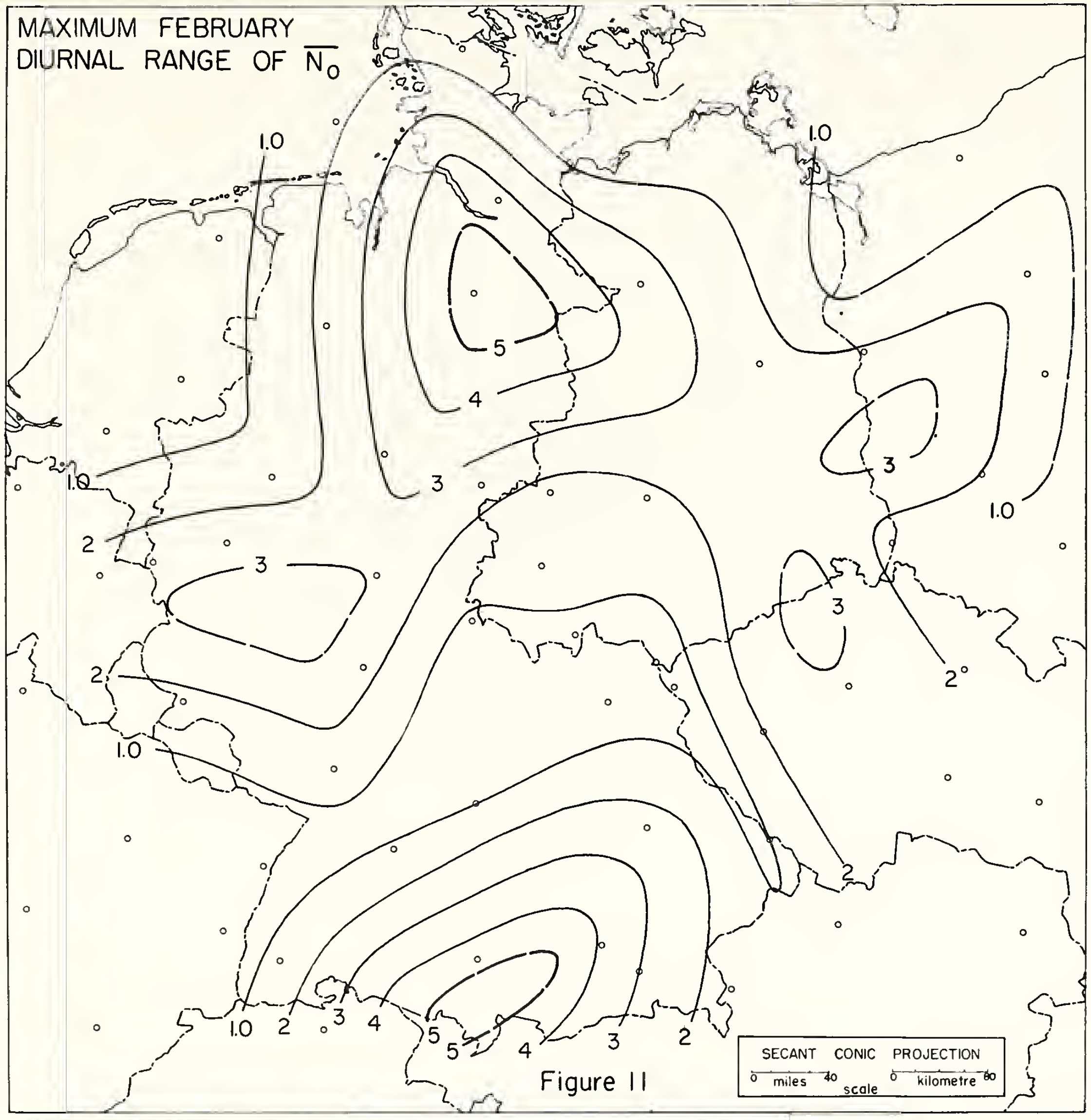

MAXIMUM FEBRUARY
DIURNAL RANGE OF $\overline{N_0}$
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 11

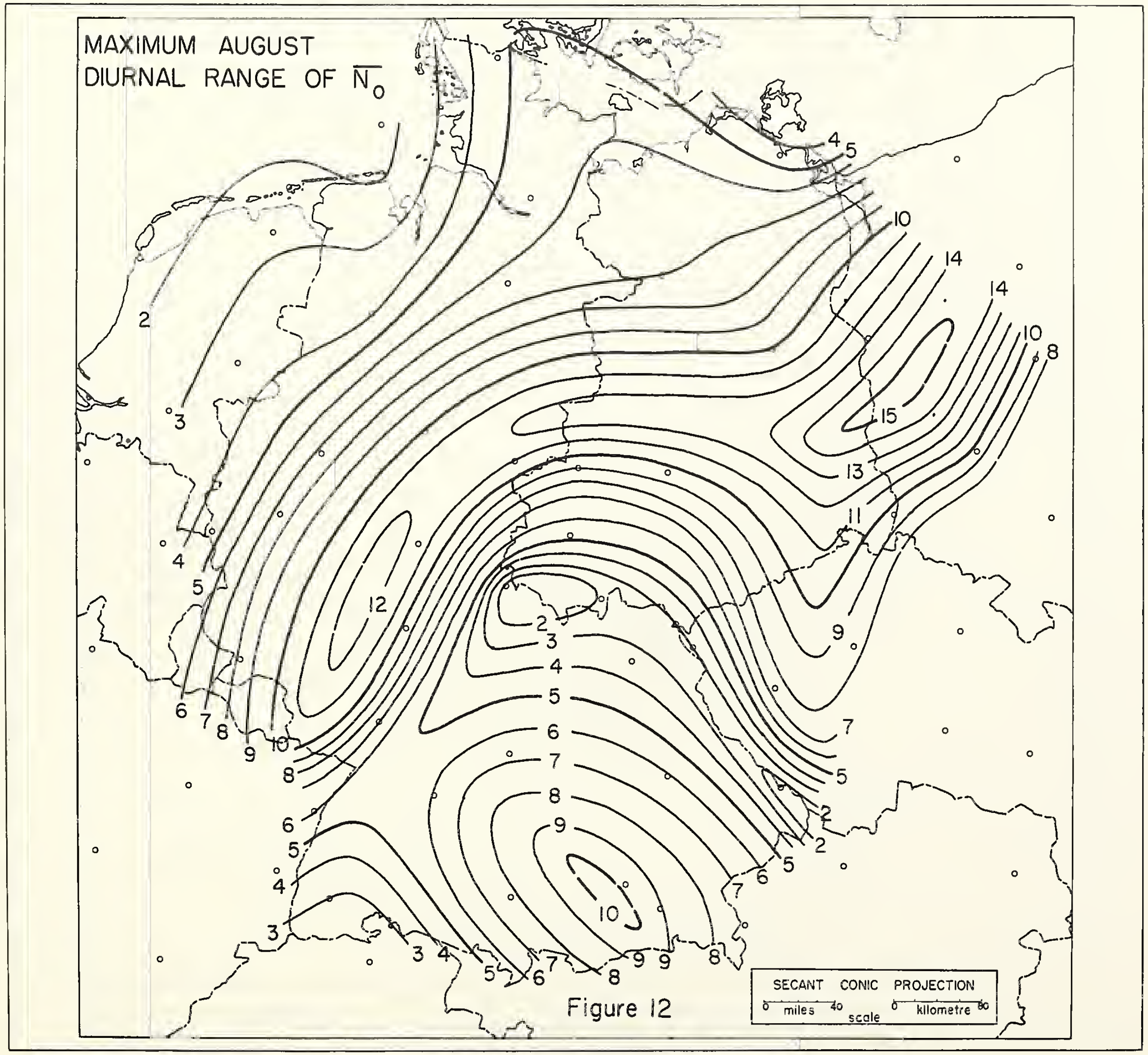

MAXIMUM AUGUST
DIURNAL RANGE OF $\overline{N_0}$
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 12

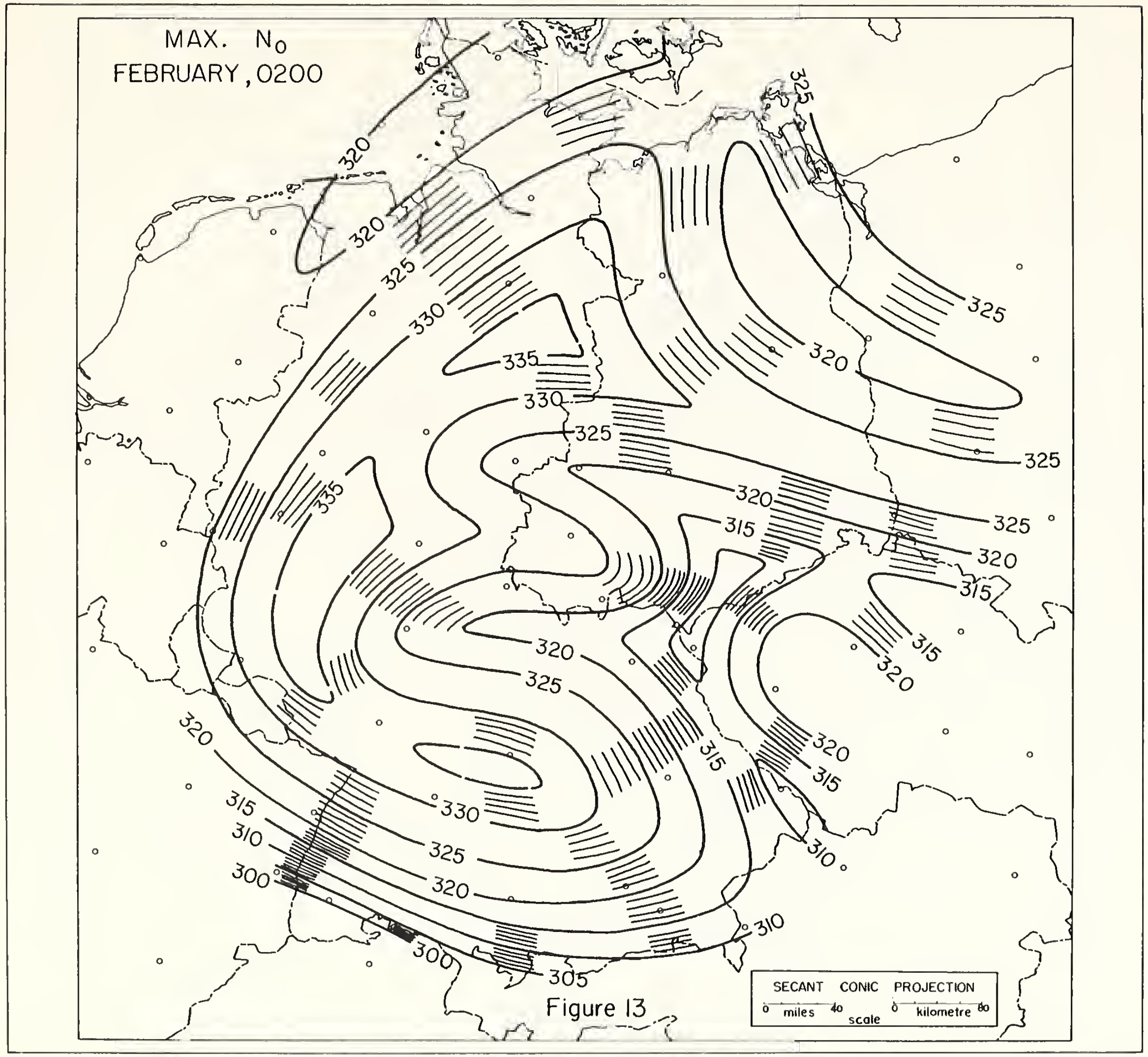

MAX. N_0
FEBRUARY, 0200
320
325
330
335
315
310
305
300
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 13

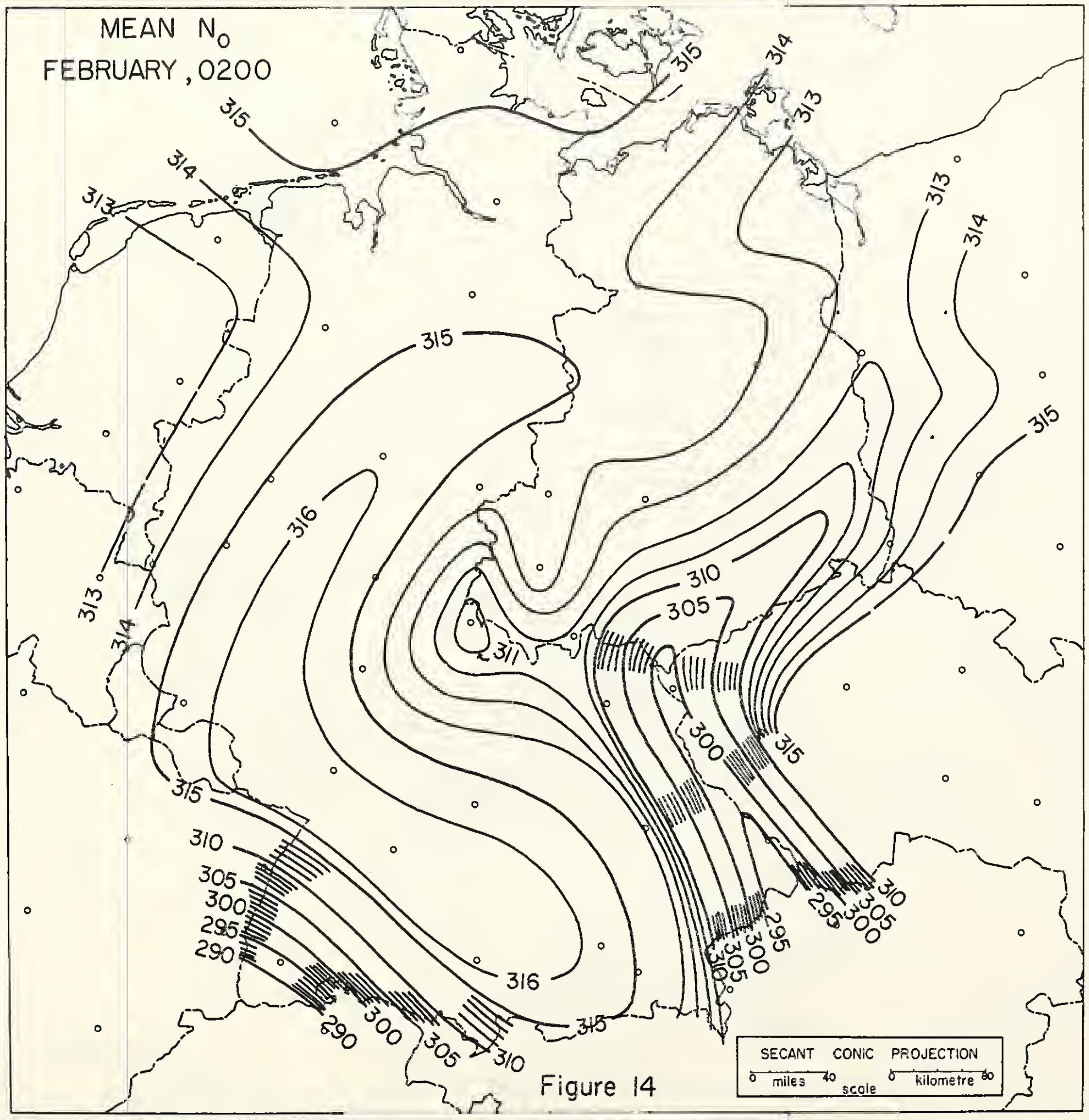

MEAN N_0
FEBRUARY, 0200
315
314
313
316
311
310
305
300
295
290
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 14

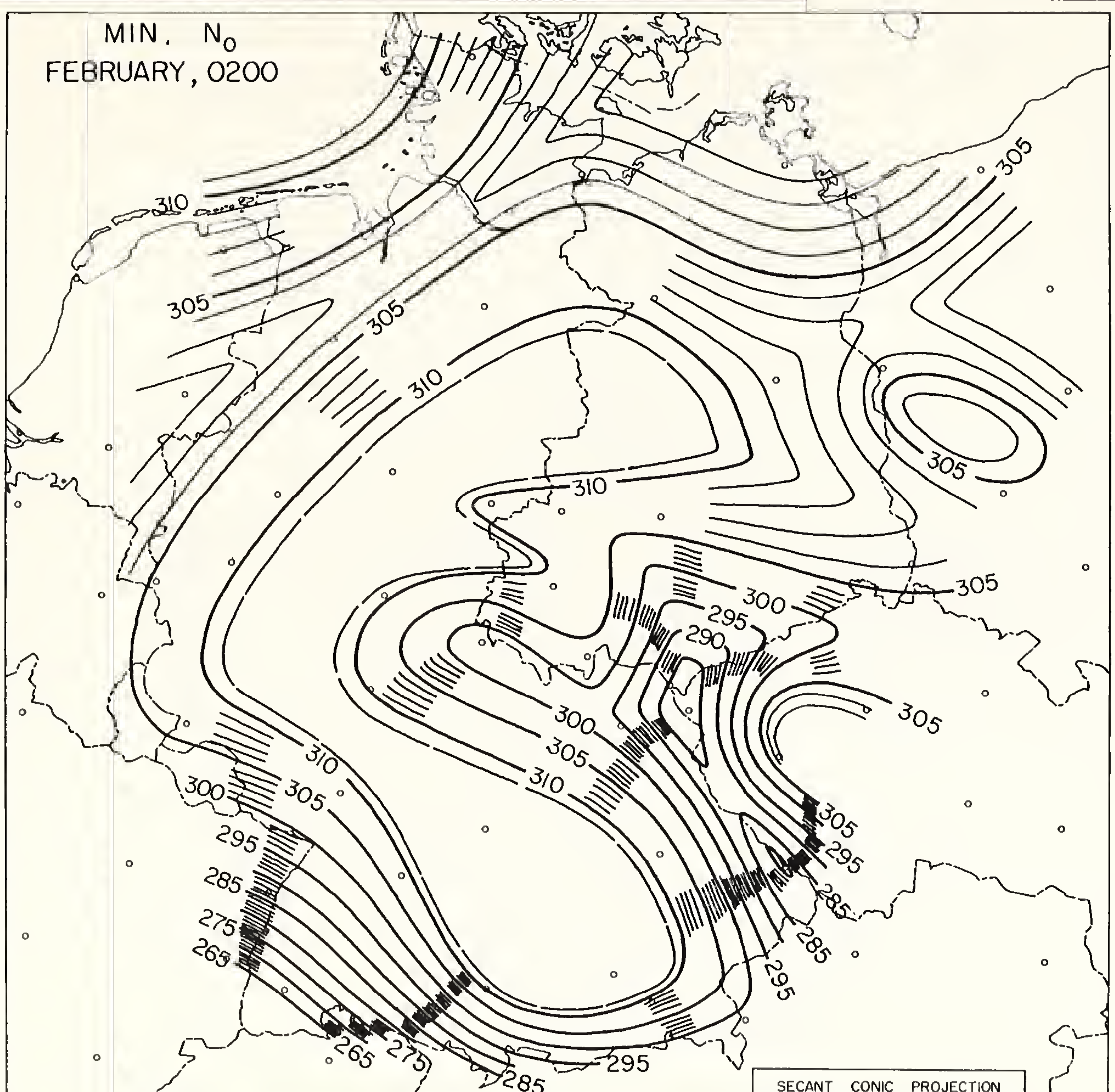
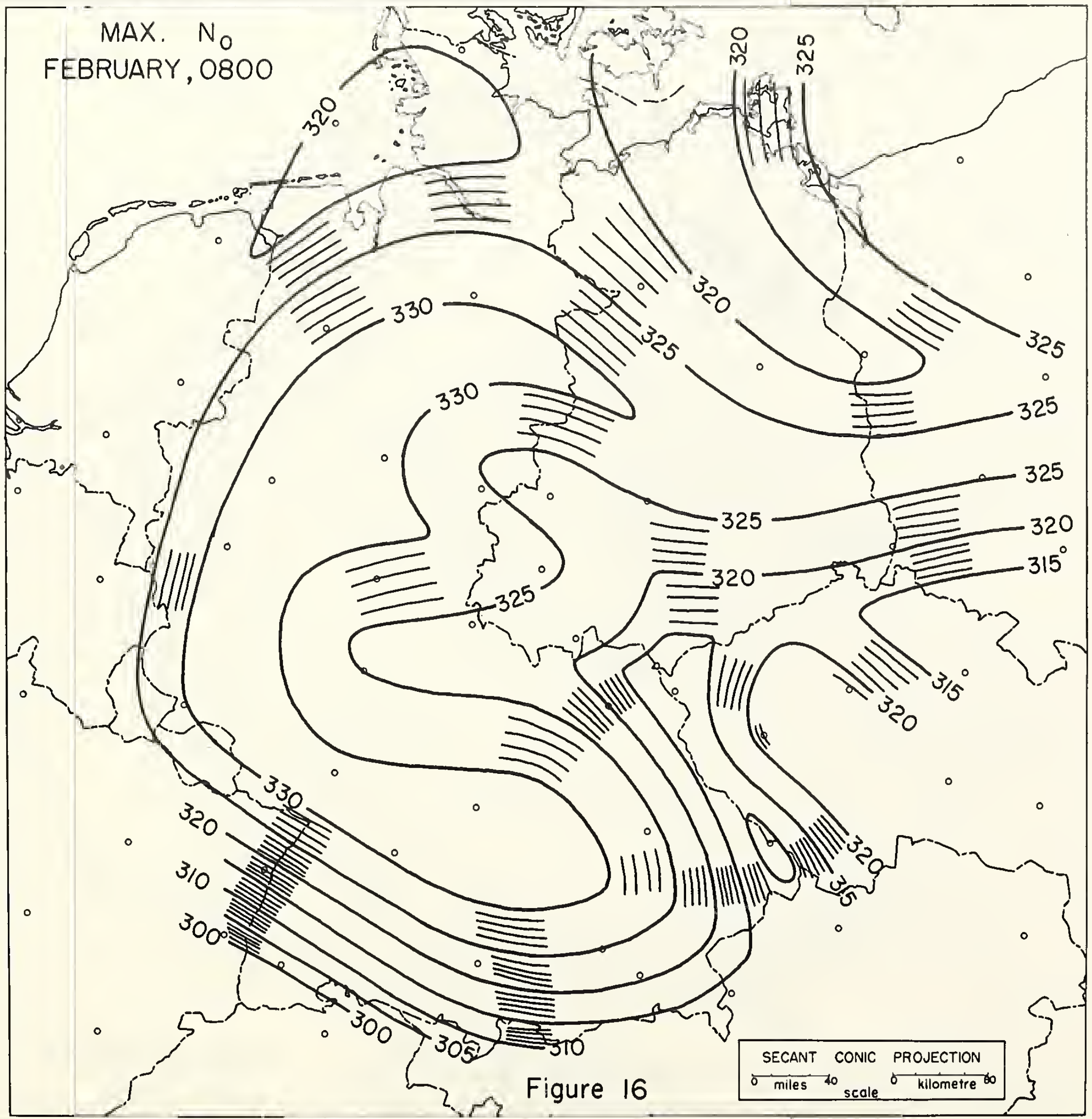

MIN. N_0
FEBRUARY, 0200
310
305
305
310
310
305
300
295
290
300
305
310
305
310
300
305
295
285
275
265
265
275
285
295
295
285
285
295
305
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 15



MAX. N_0
FEBRUARY, 0800
320
325
330
310
305
300
315
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 16

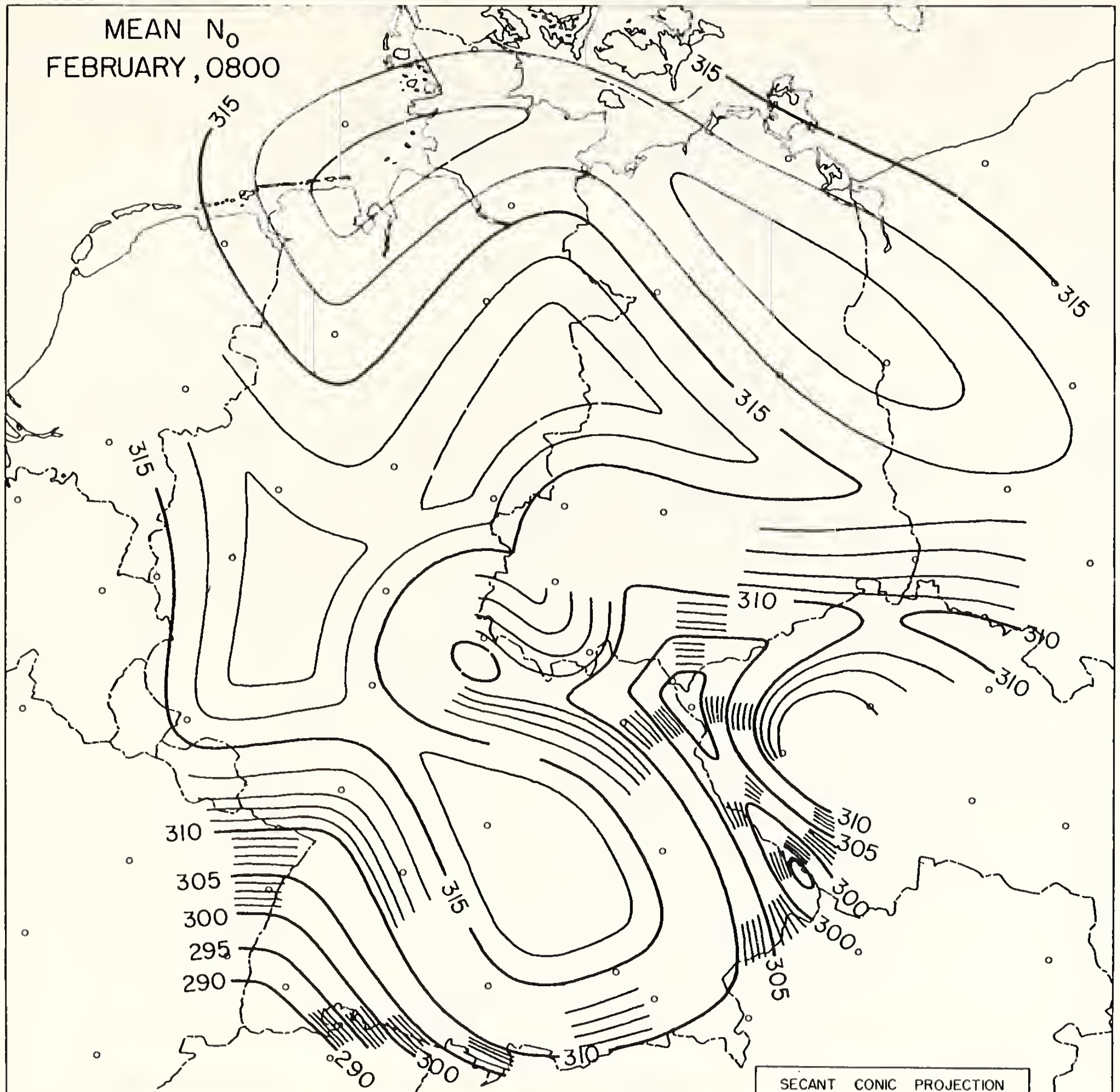
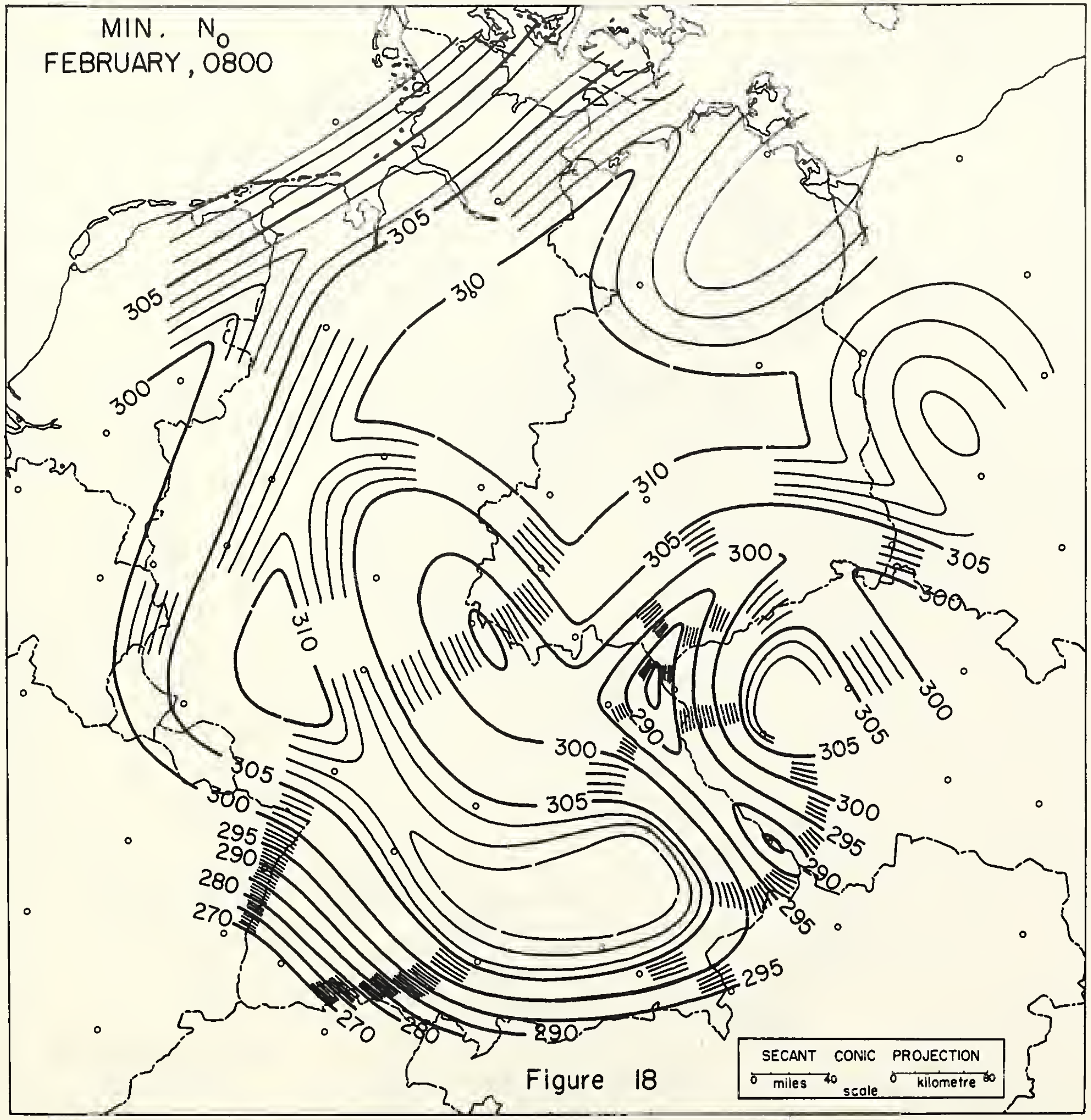

MEAN N_0
FEBRUARY, 0800
315
310
305
300
295
290
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 17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FEBRUARY, 0800
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 18

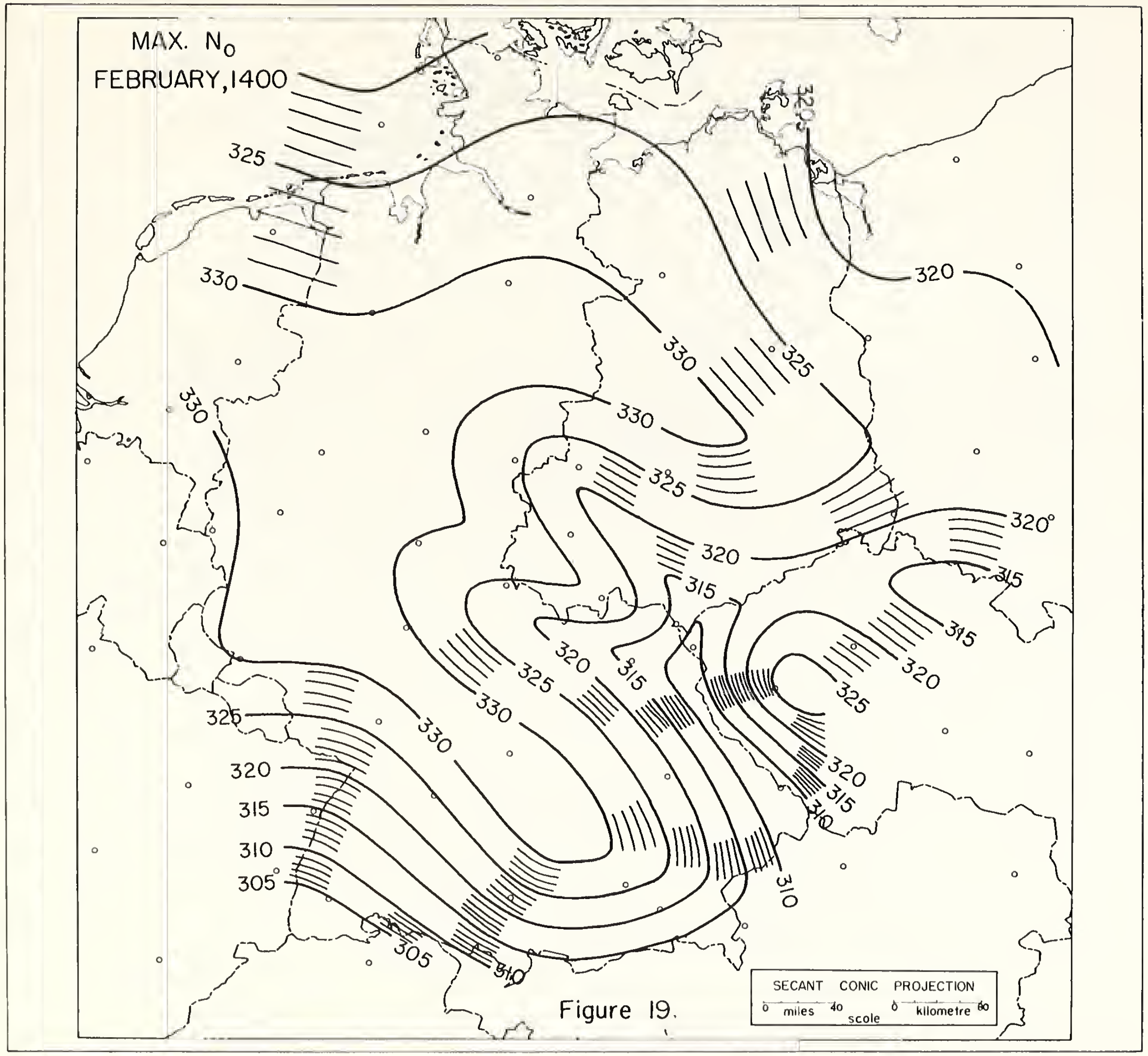
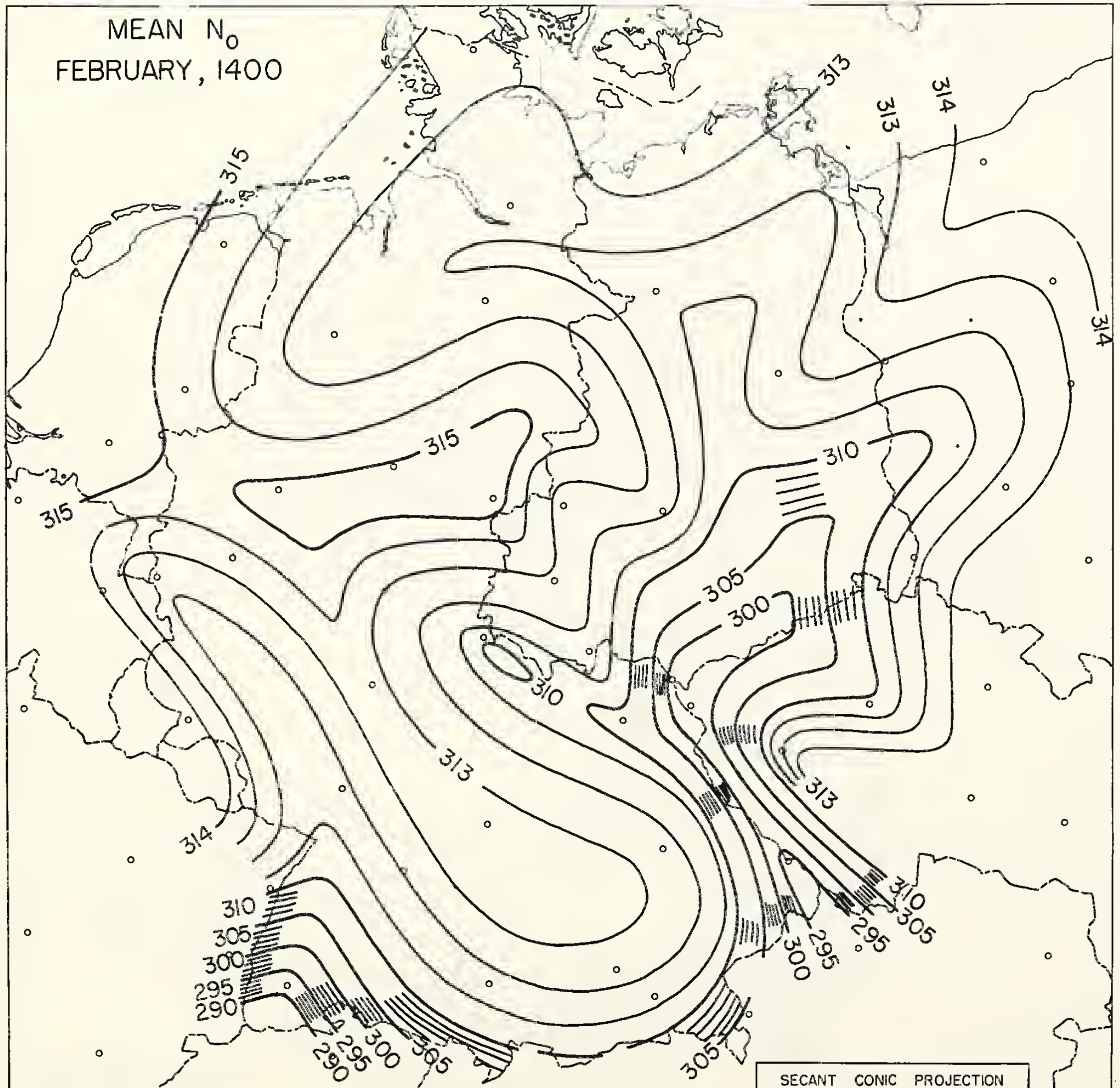

MAX. N_o
FEBRUARY, 1400
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 19.



MEAN N_0
FEBRUARY, 1400
315
315
315
314
314
314
313
313
313
313
313
310
310
310
305
300
305
300
295
290
305
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290
310
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295
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295
305
305
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 20

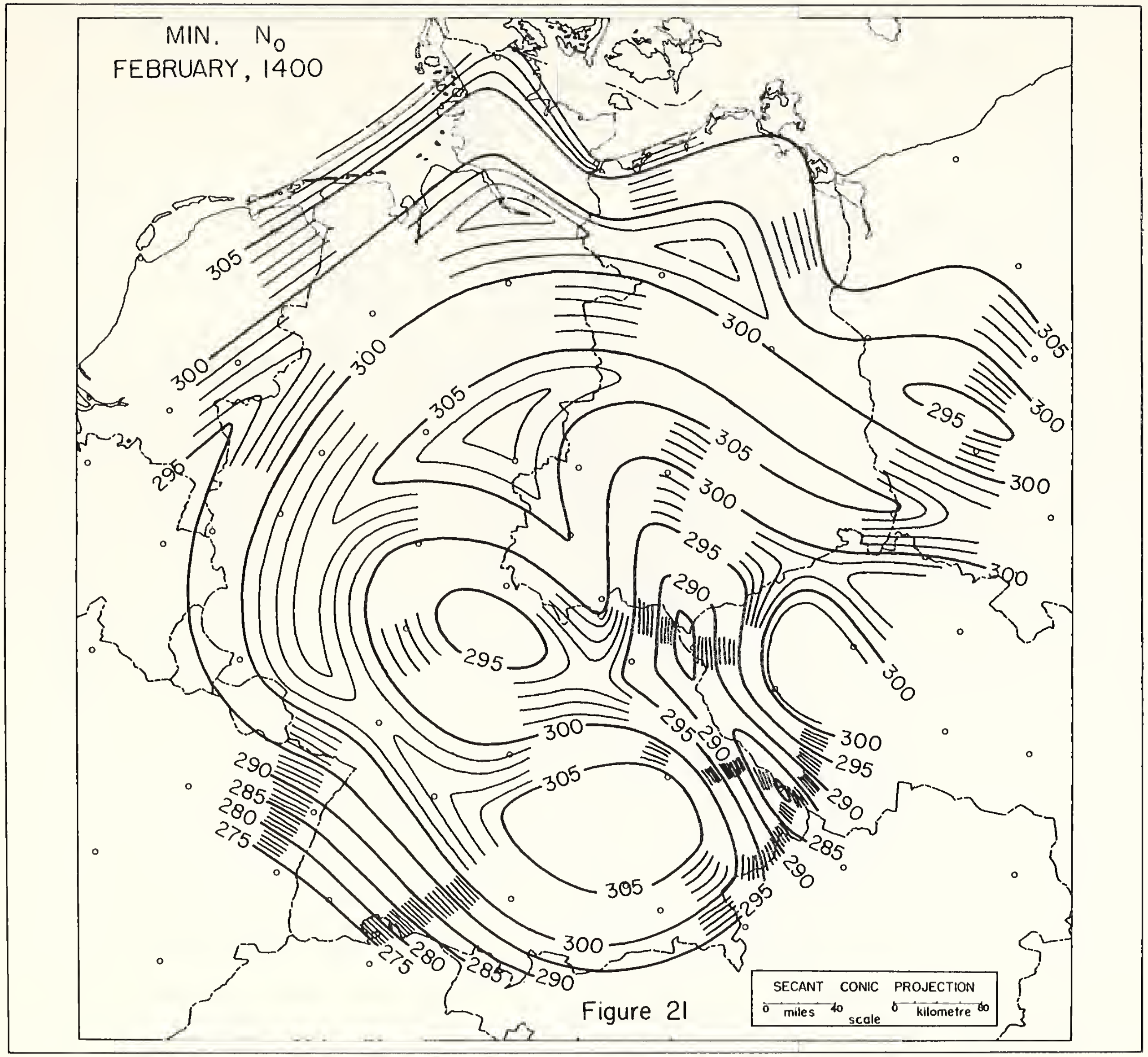
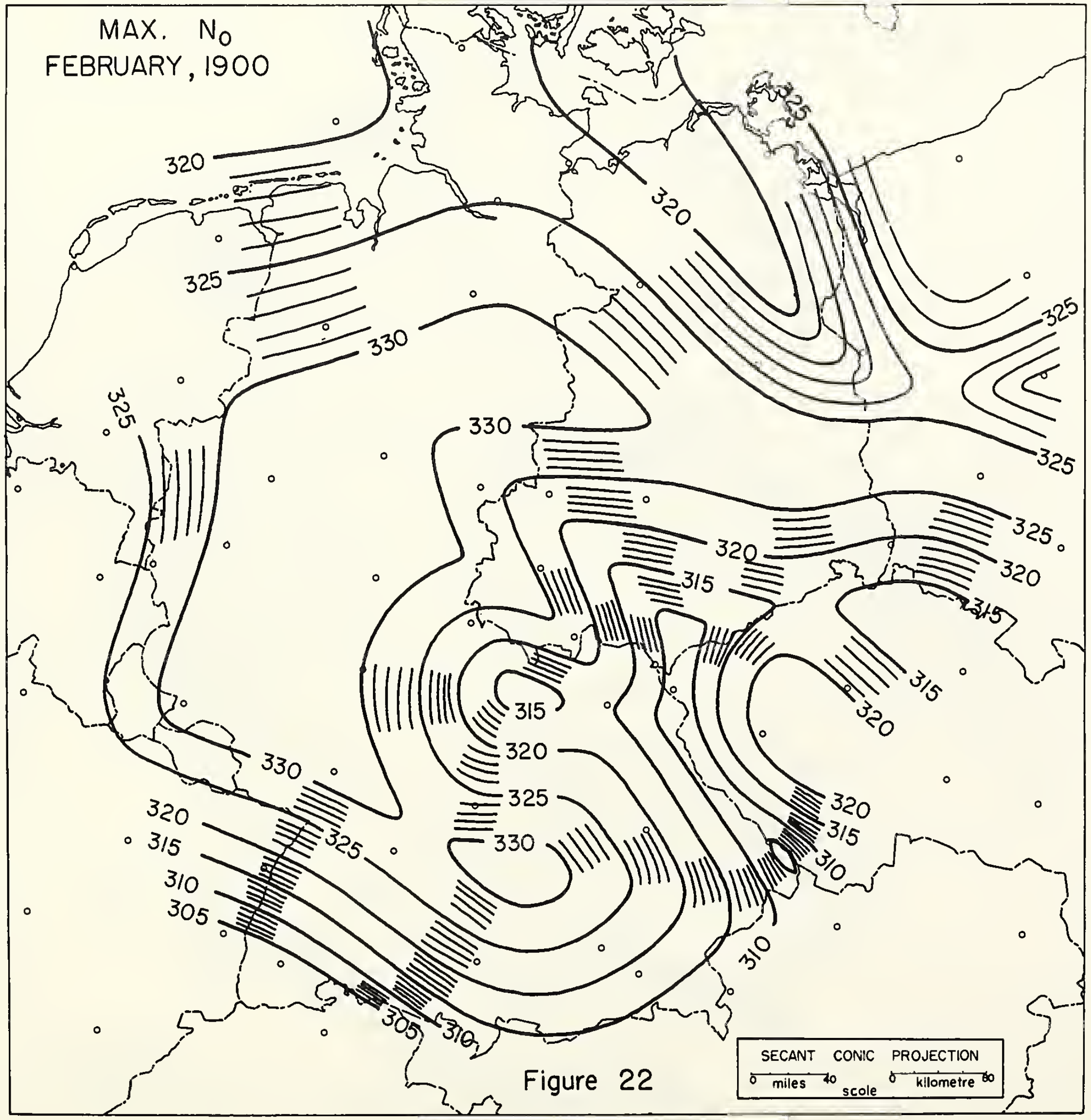

MIN. N_0
FEBRUARY, 1400
305
300
295
290
285
280
275
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 21


MAX. N_0
FEBRUARY, 1900
320
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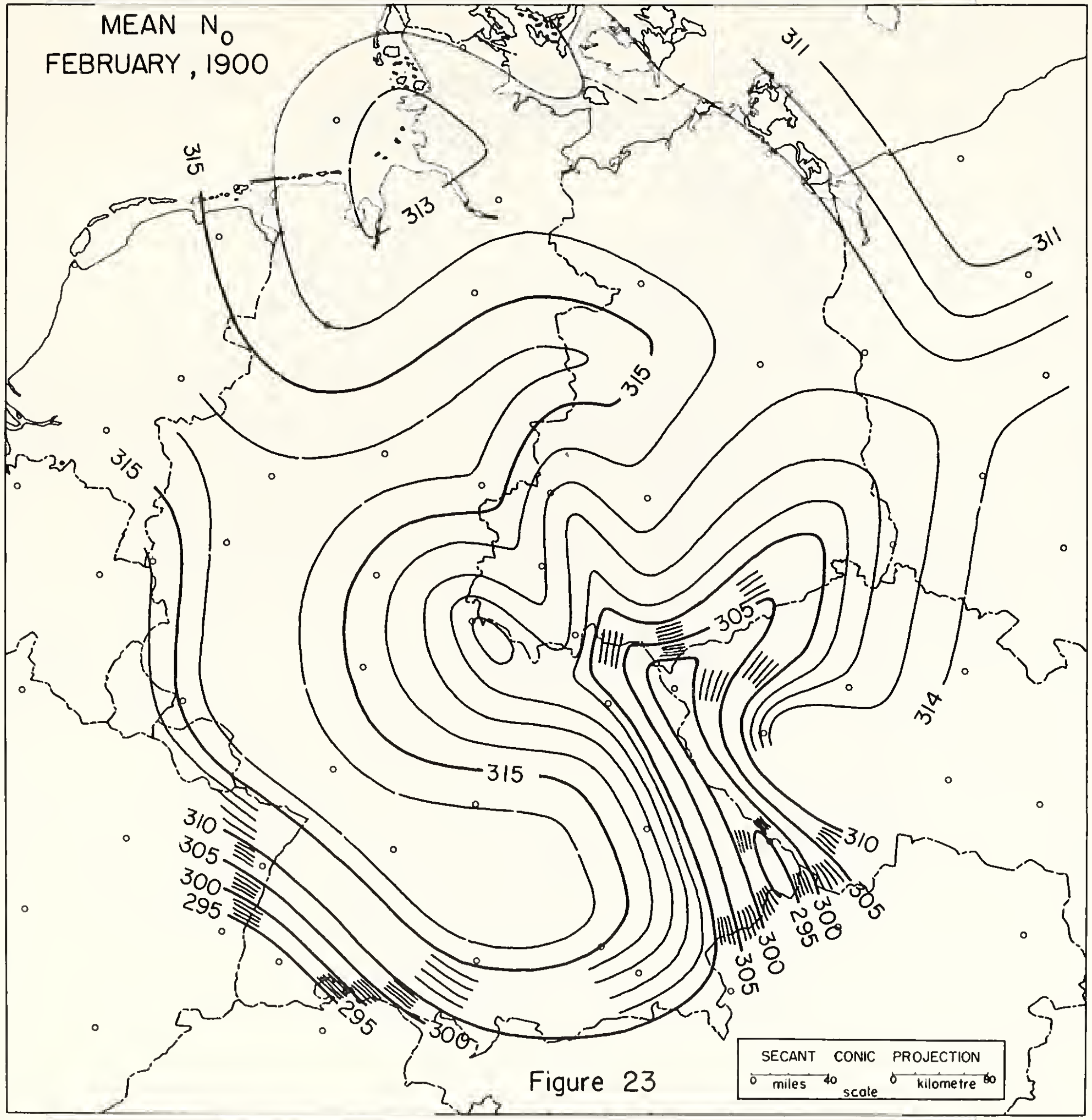
330
315
310
305
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 22


MEAN N_0
FEBRUARY, 1900
311
311
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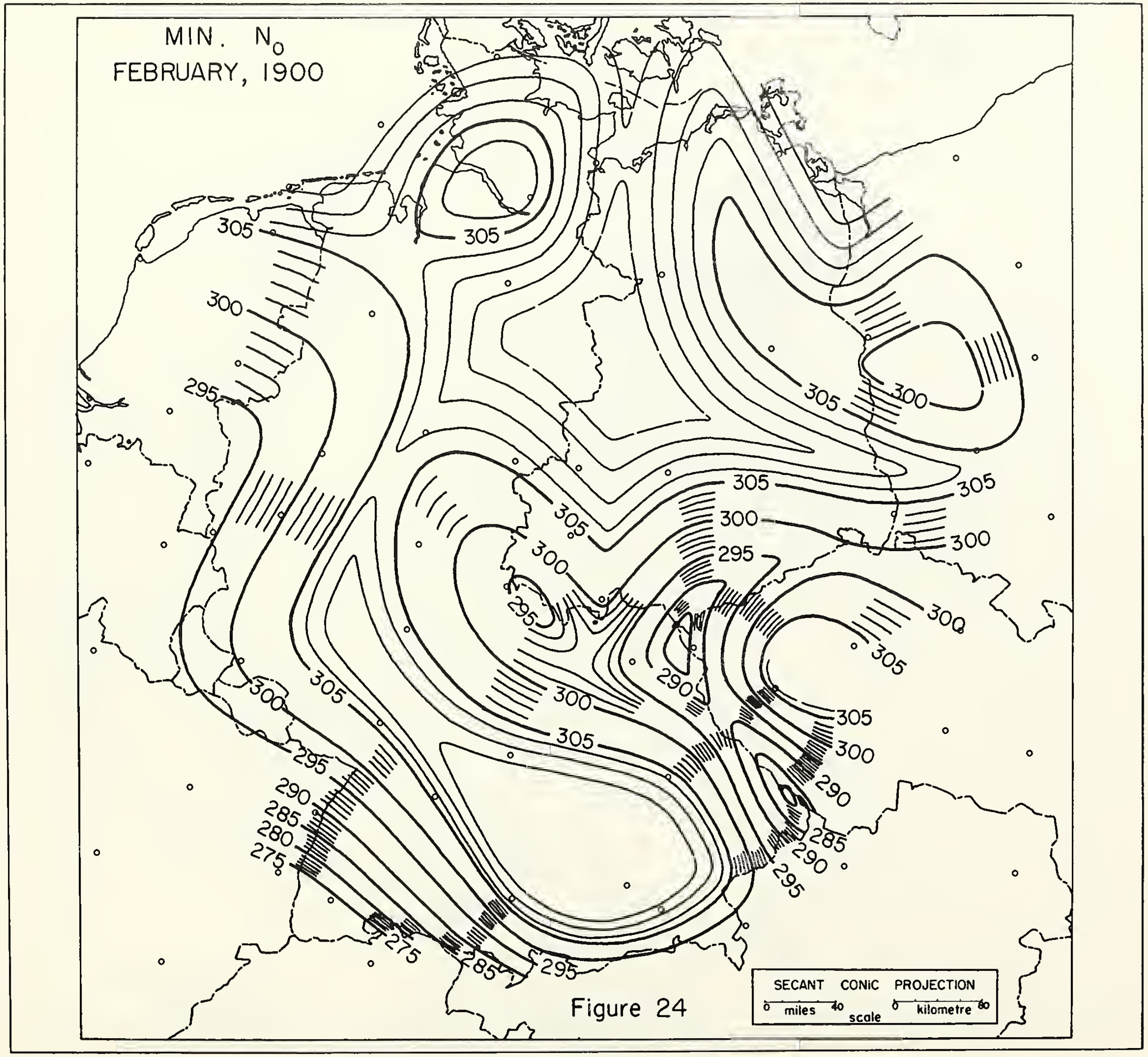
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 23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SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80
305
300
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290
285
280
275

Figure 24

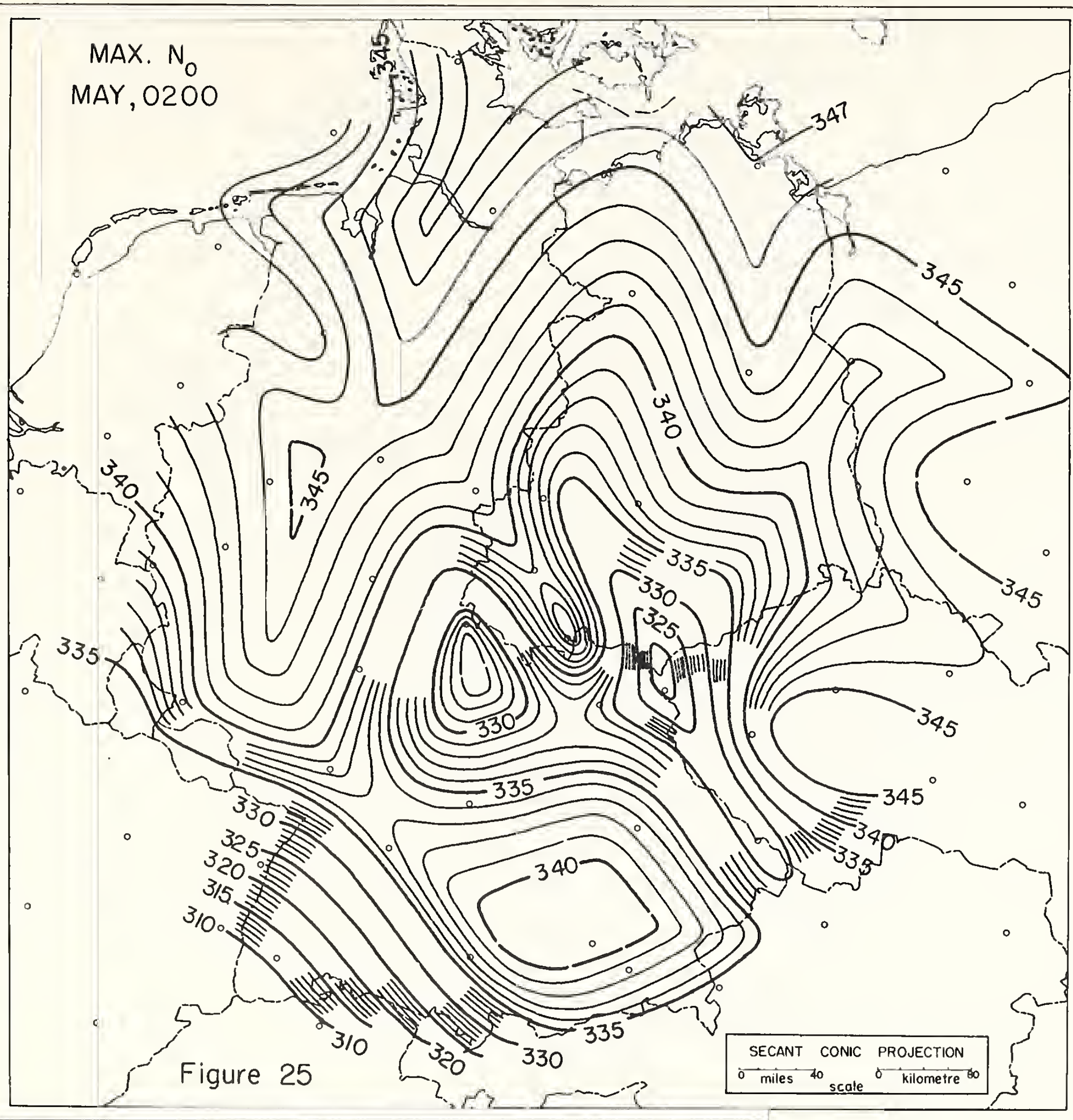
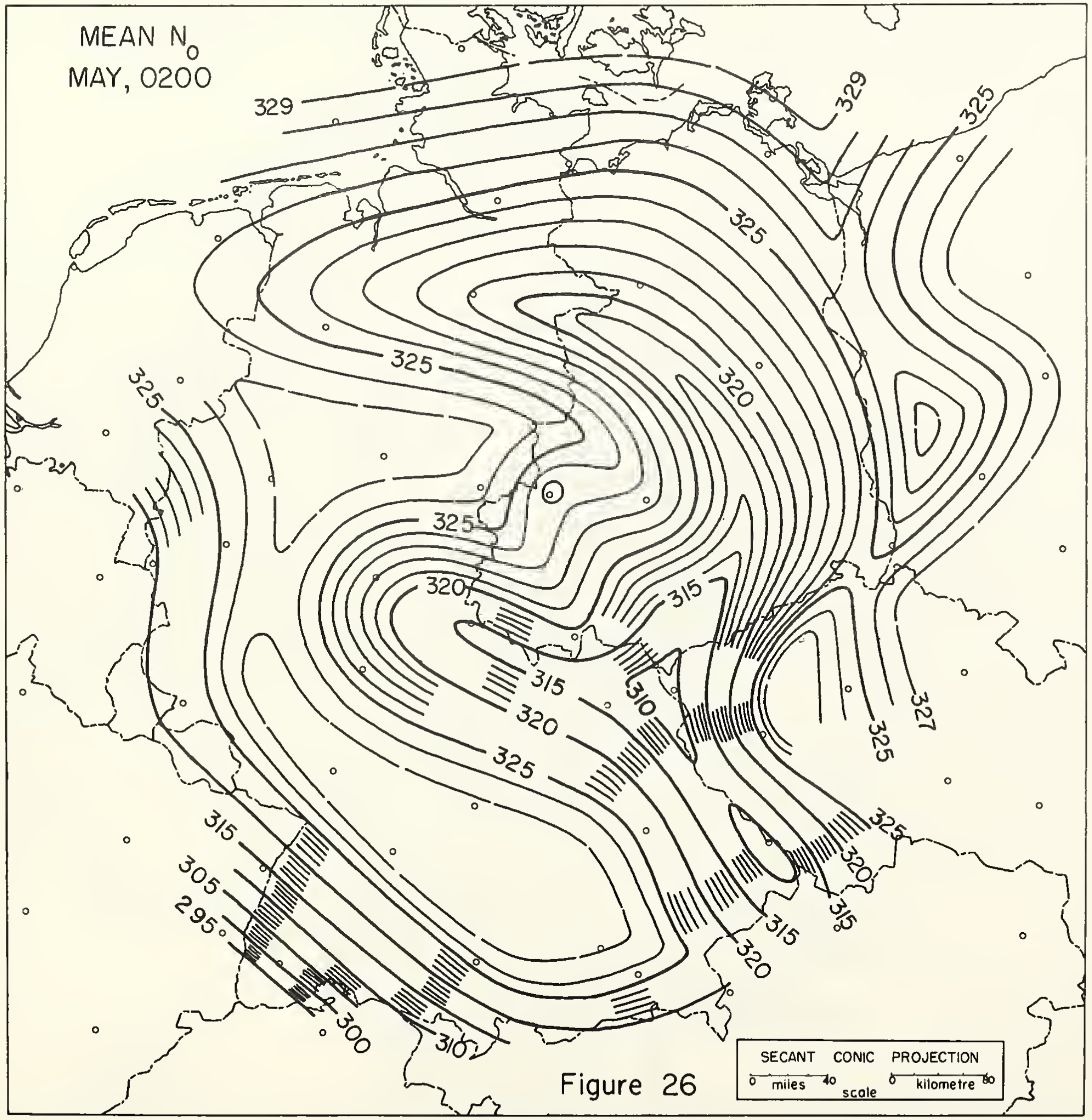
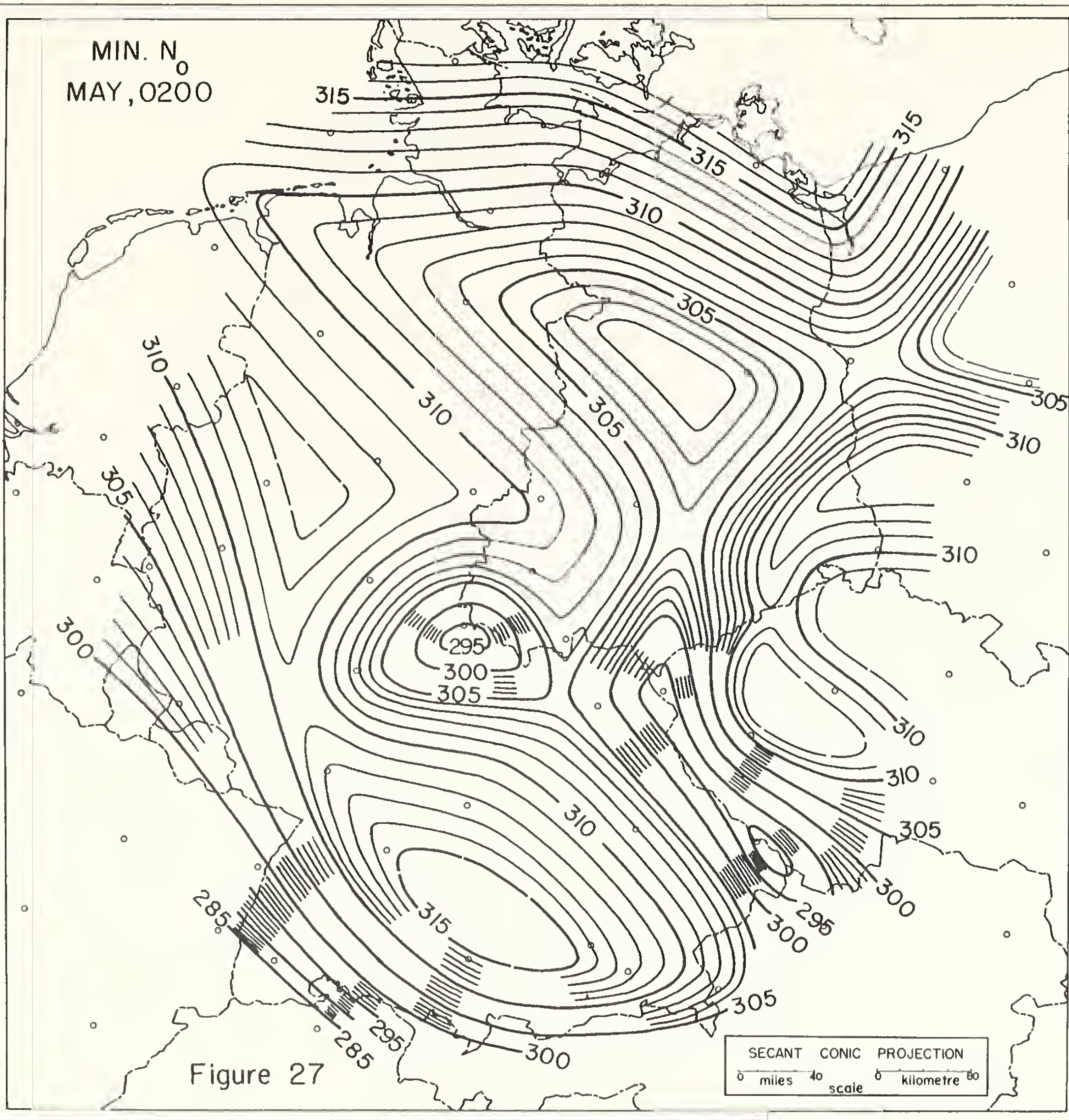

MAX. N_0
MAY, 0200
345
347
340
335
330
325
320
315
310
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 25



MEAN N_0
MAY, 0200
329
325
320
315
310
305
300
295
327
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 26



MIN. N_0
MAY, 0200
315
315
315
310
305
305
310
310
305
310
310
305
300
295
300
305
310
310
310
305
300
295
300
315
310
305
300
285
295
285
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 27

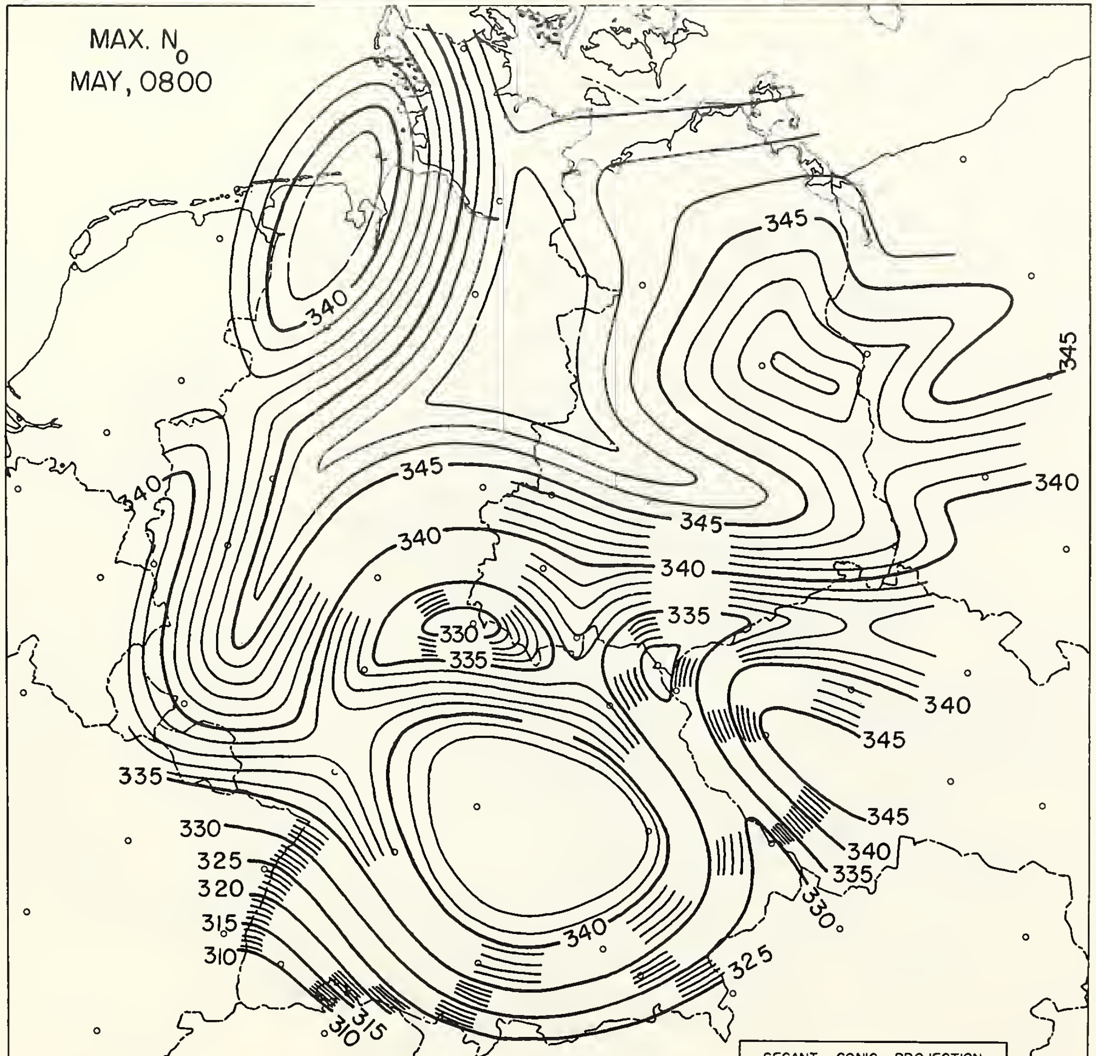

MAX. N_0
MAY, 0800
345
340
345
340
345
340
335
330
335
340
345
340
345
345
340
335
330
325
340
335
330
325
320
315
310
315
310
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 60

Figure 28

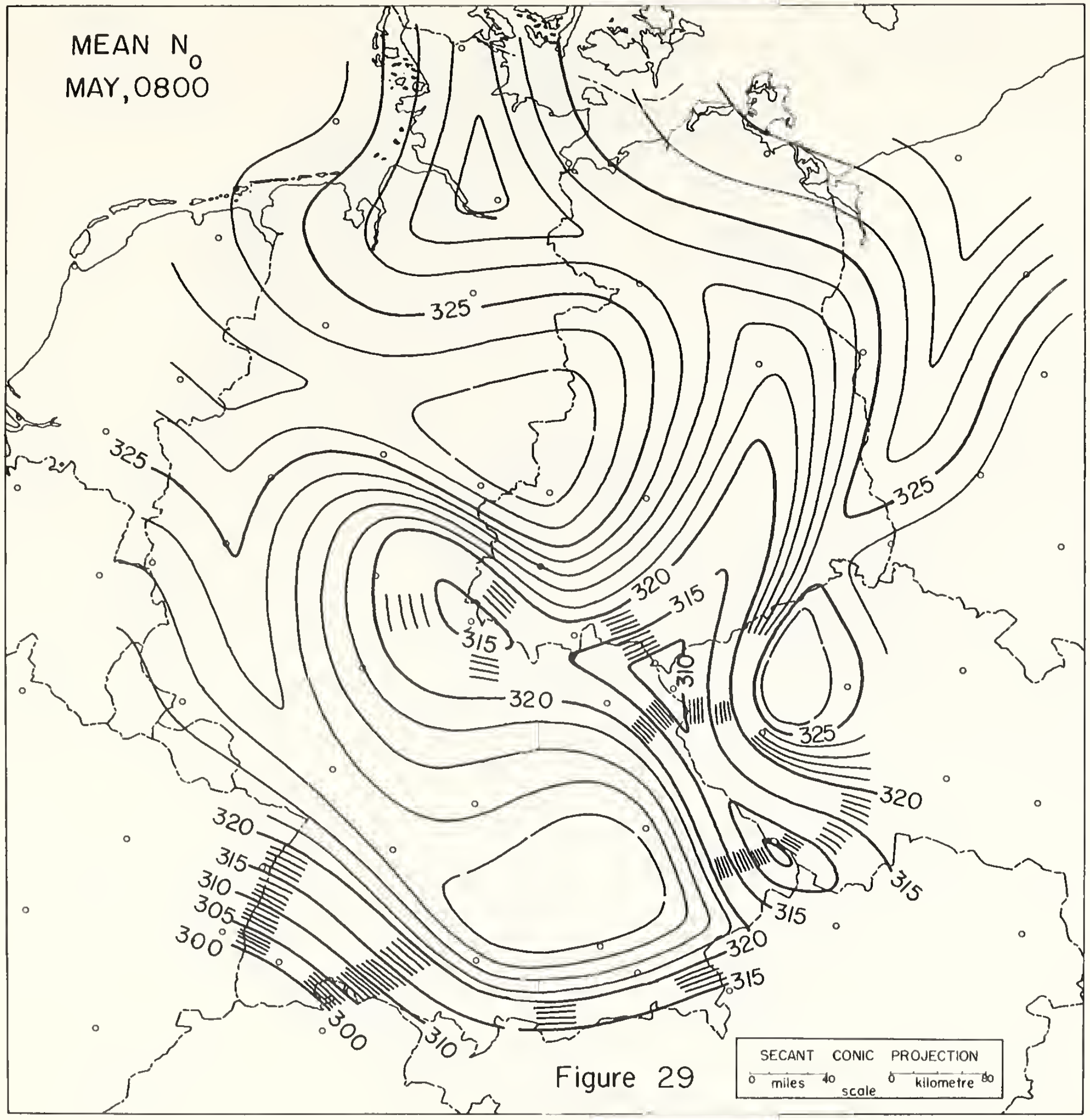

MEAN N_0
MAY, 0800
325
325
325
320
315
315
310
320
325
320
315
320
315
310
305
300
300
310
315
320
315
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 29

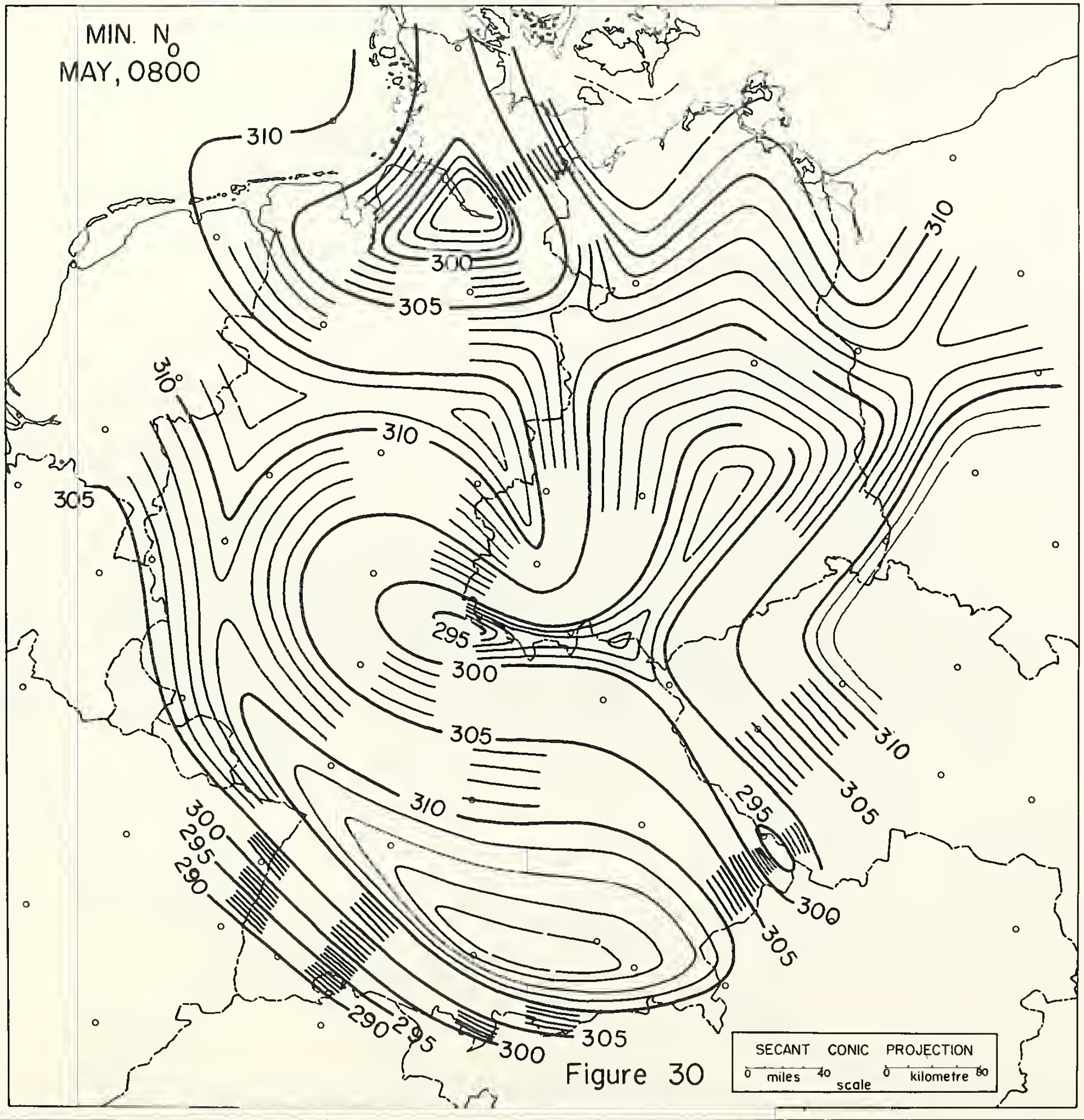

MIN. N0
MAY, 0800
310
305
300
295
290
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 30

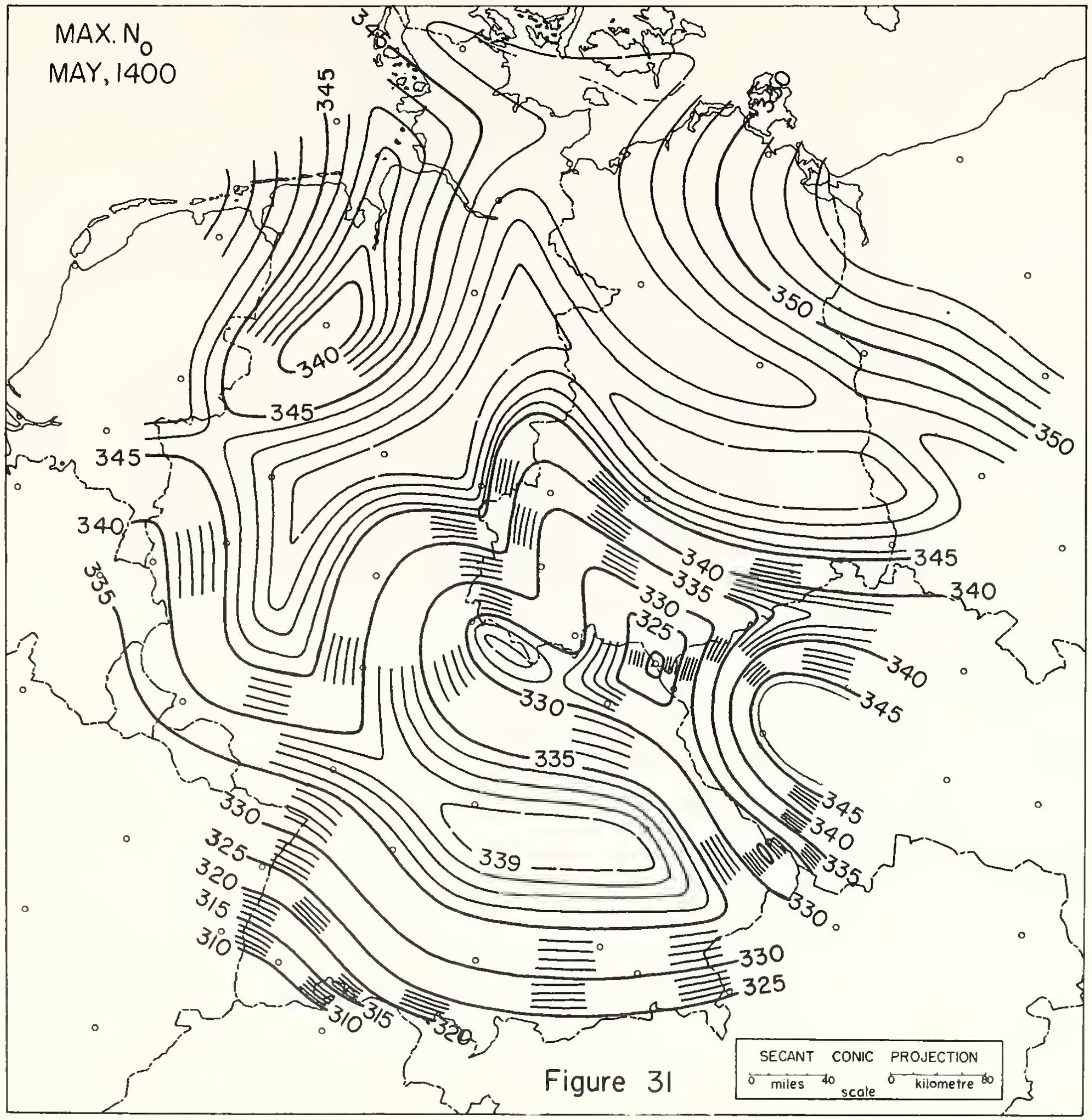
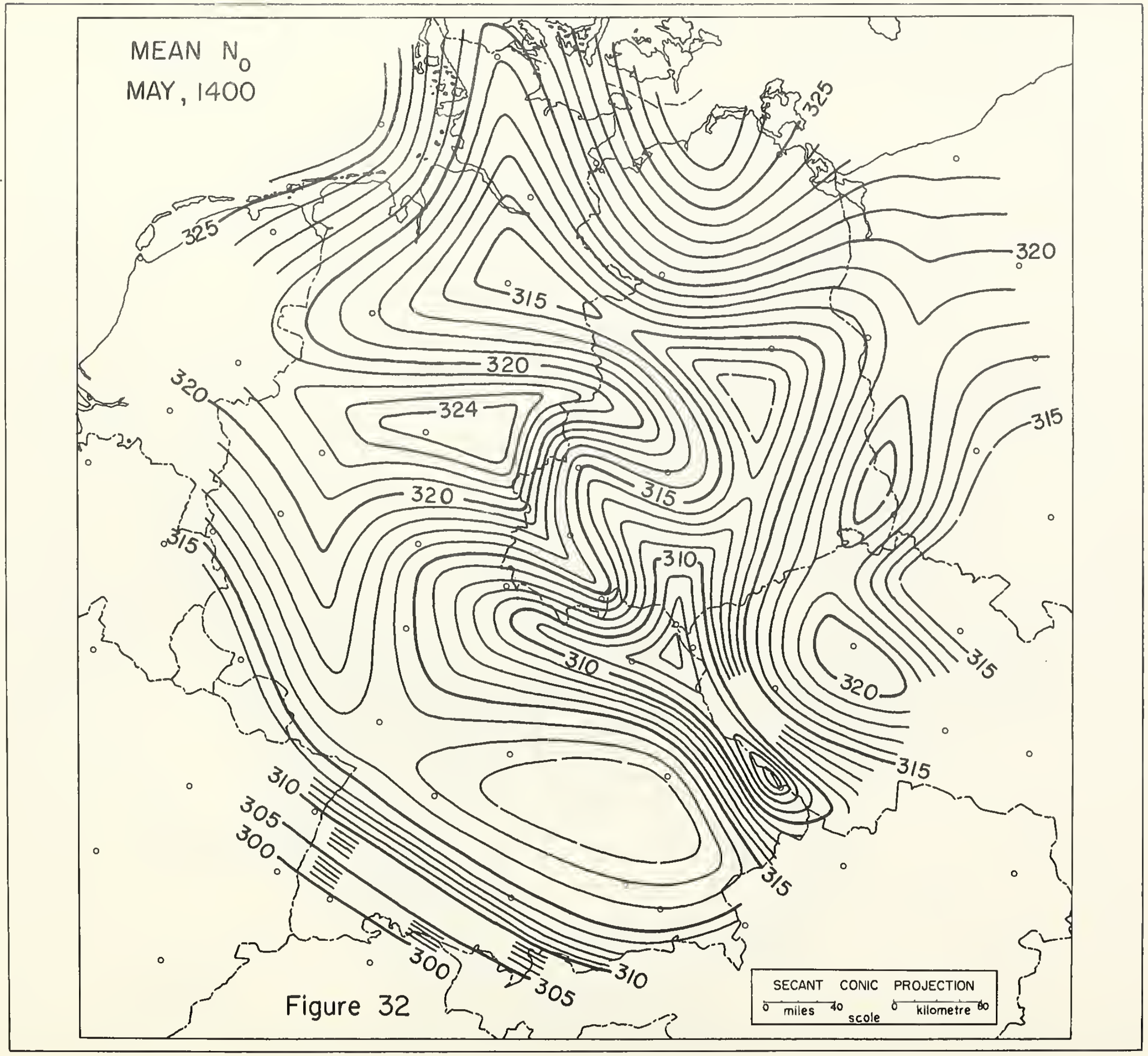

MAX. N_0
MAY, 1400
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80
350
345
340
335
330
325
320
315
310
339

Figure 31



MEAN N_0
MAY, 1400
325
320
315
324
310
305
300
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 32

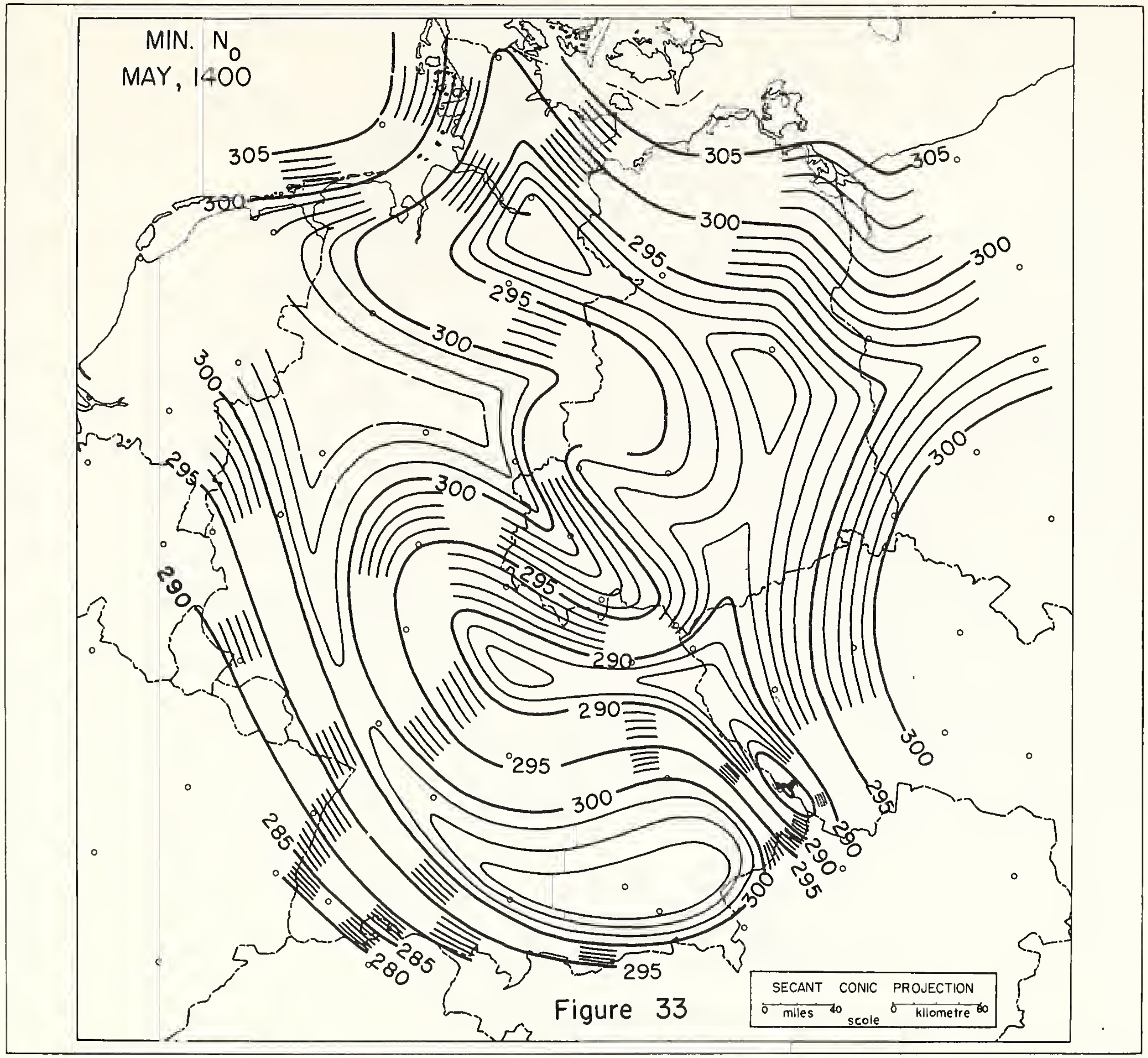

MIN. N_0
MAY, 1400
305
300
295
290
285
280
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 33

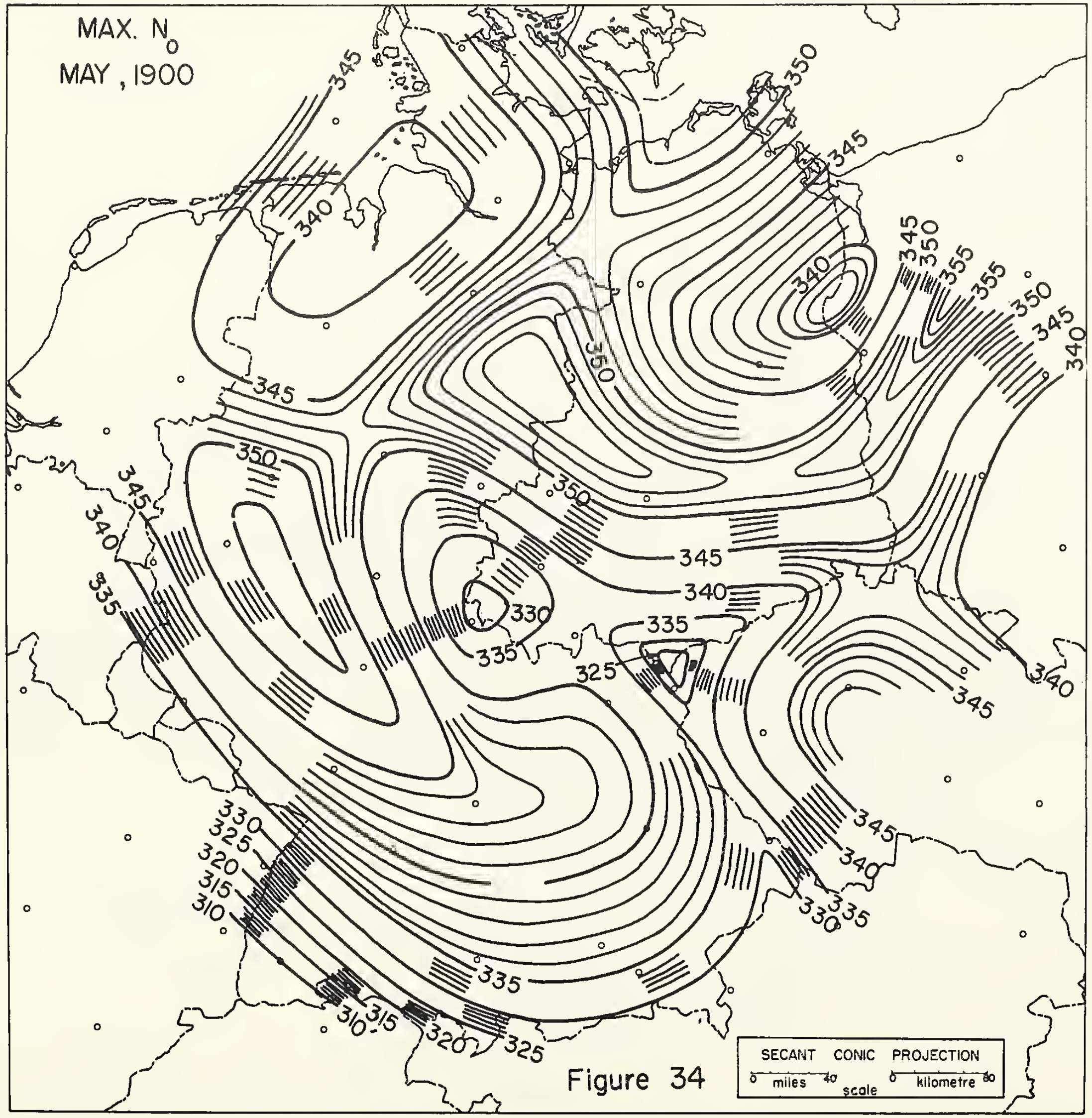

MAX. N_0
MAY, 1900
345
340
350
345
340
345
350
355
355
350
345
340
345
350
350
350
345
340
335
330
335
325
345
340
335
340
345
345
340
335
330
330
325
320
315
310
335
310
315
320
325
SECANT CONIC PROJECTION
miles
scale
kilometre

Figure 34

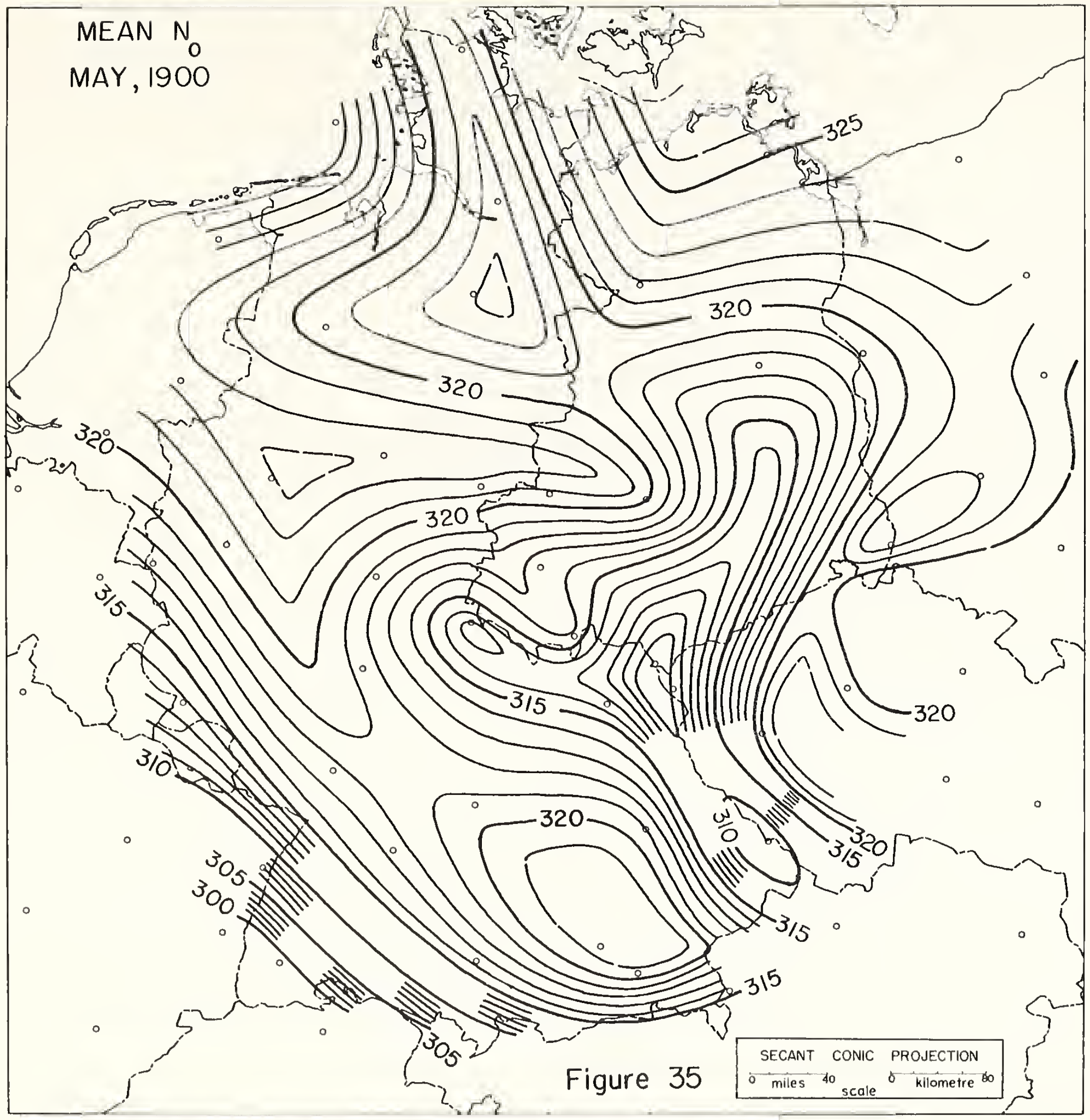

MEAN N_0
MAY, 1900
325
320
320
320
320
320
315
315
310
320
310
315
320
315
315
315
305
300
305
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 35

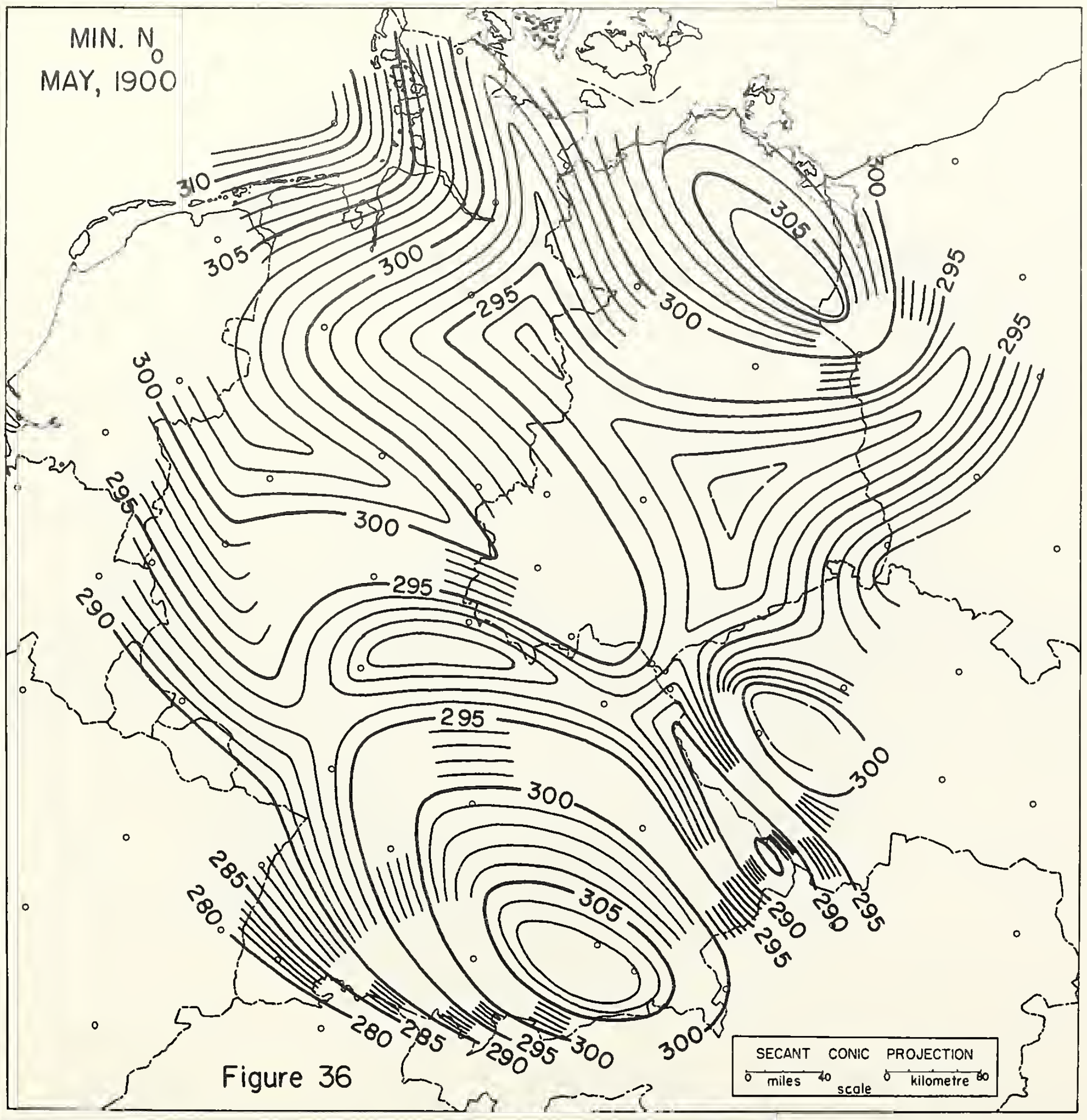
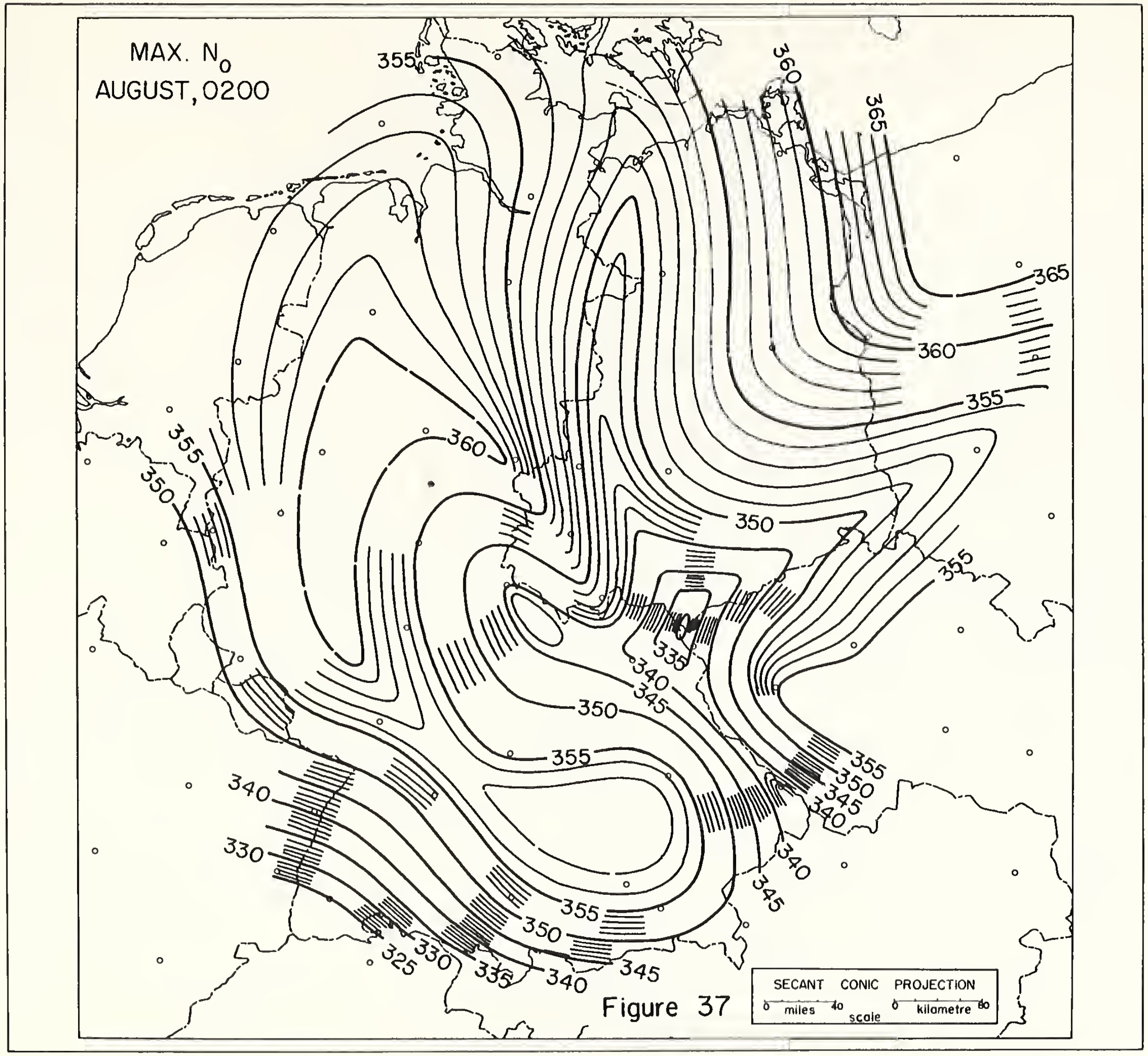

MIN. N_0
MAY, 1900
310
305
300
295
290
285
280
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 36


MAX. N_0
AUGUST, 0200
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80
Figure 37

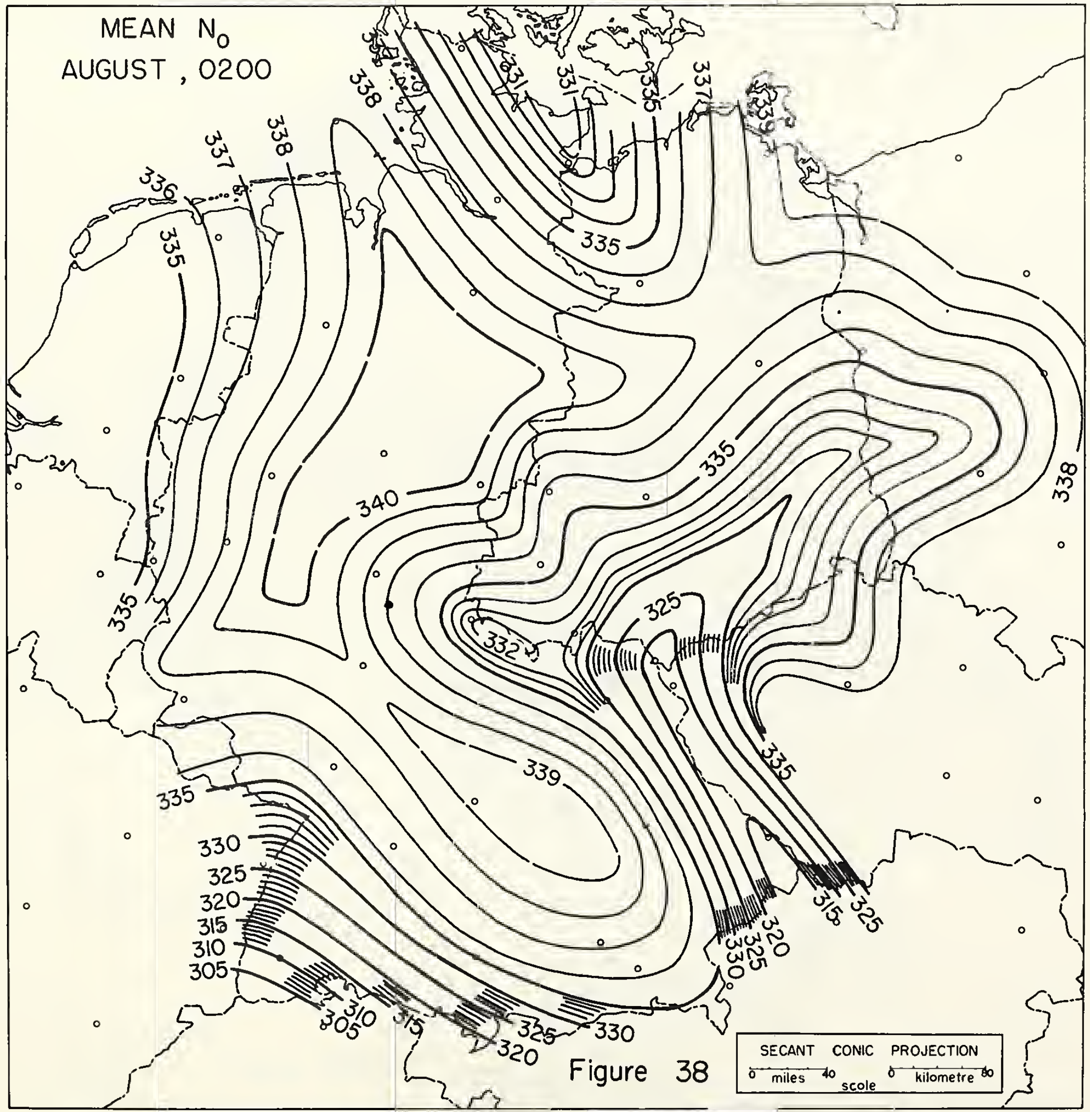
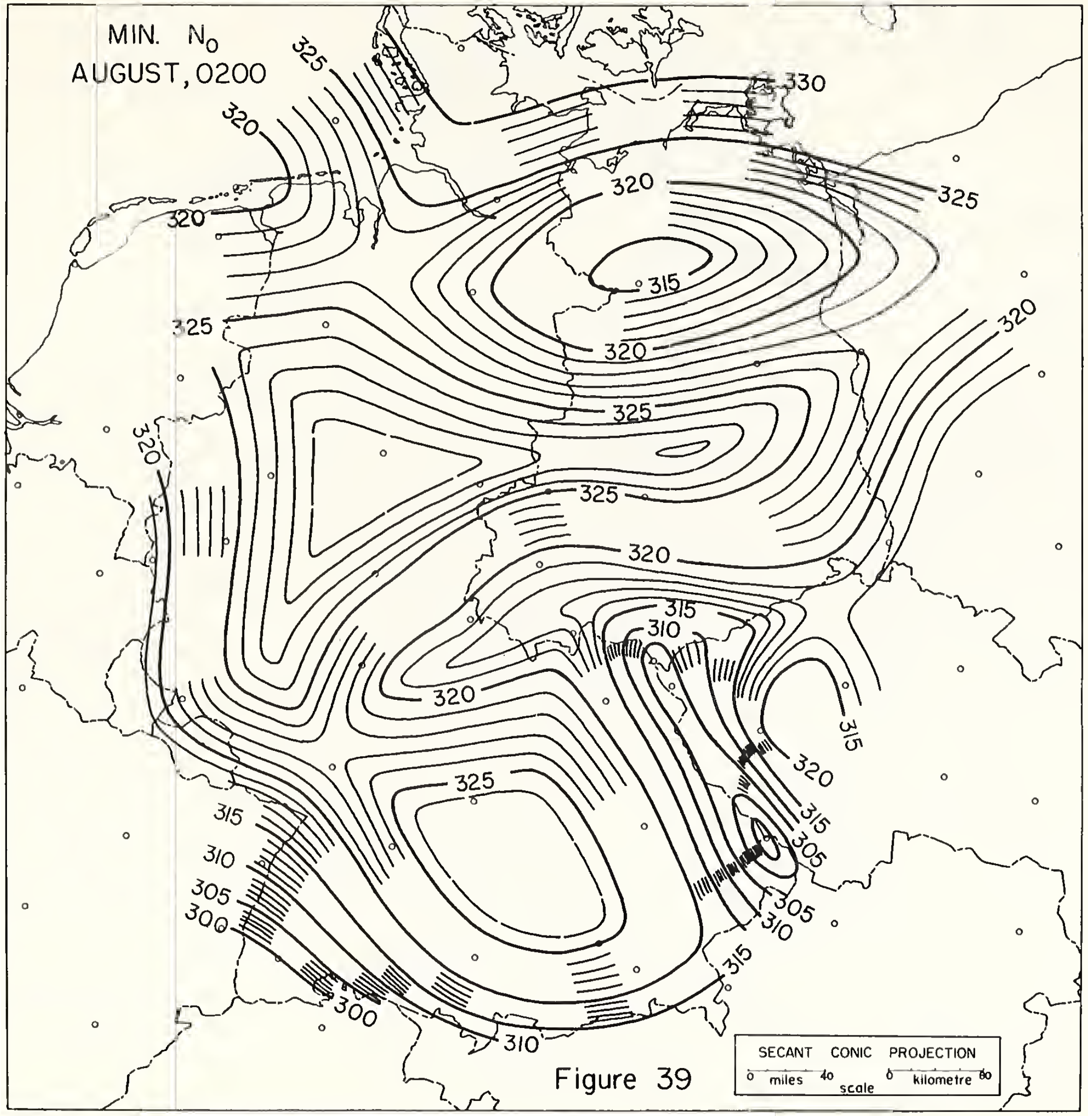

MEAN N_0
AUGUST , 0200
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80
335
336
337
338
340
339
332
325
330
320
315
310
305
331
337
339

Figure 38


MIN. N_0
AUGUST, 0200
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80
330
325
320
315
310
305
300
Figure 39

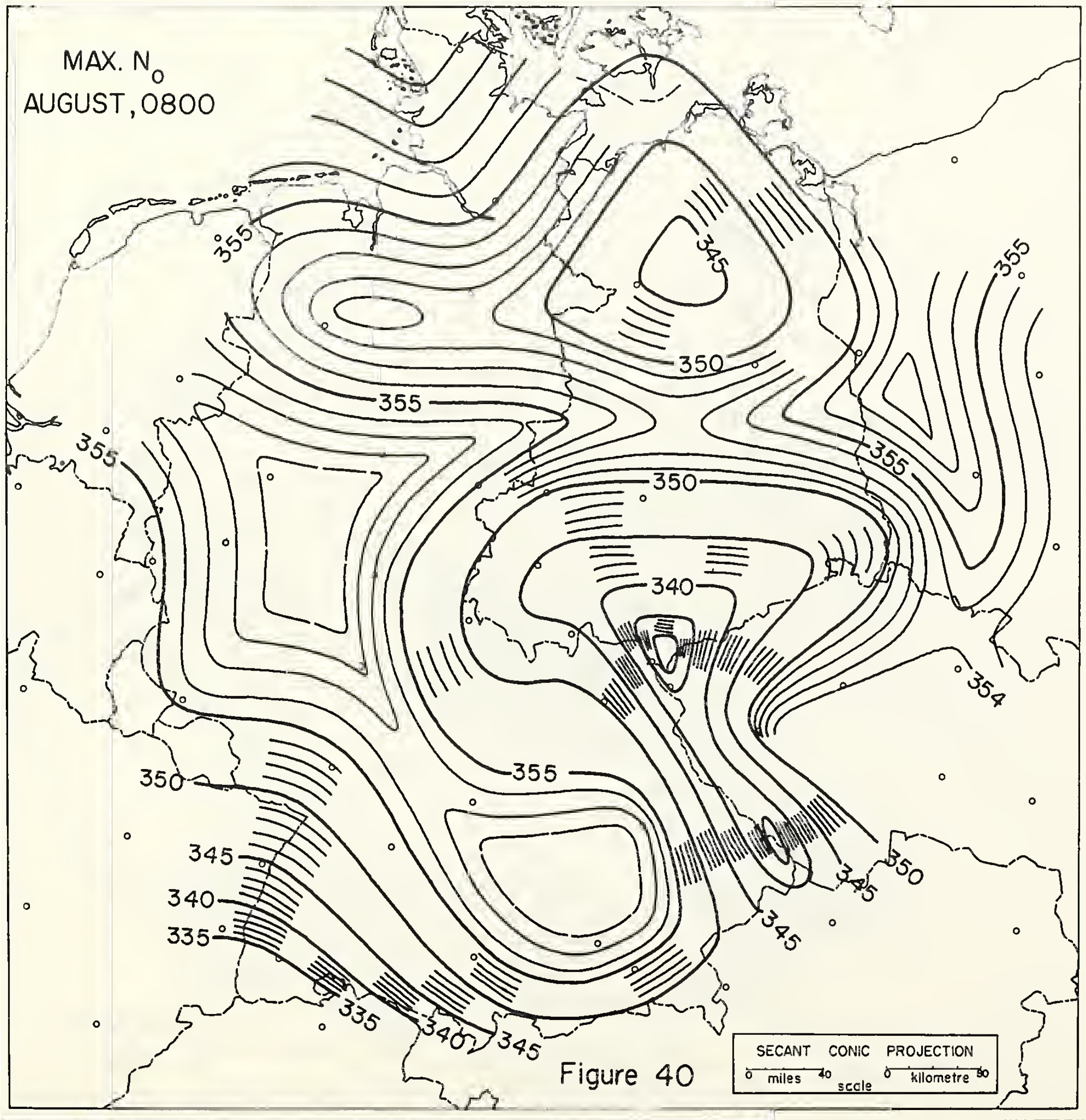

MAX. N_o
AUGUST, 0800
355
355
355
345
350
355
350
355
340
354
355
350
345
340
335
335
340
345
350
345
345
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 40

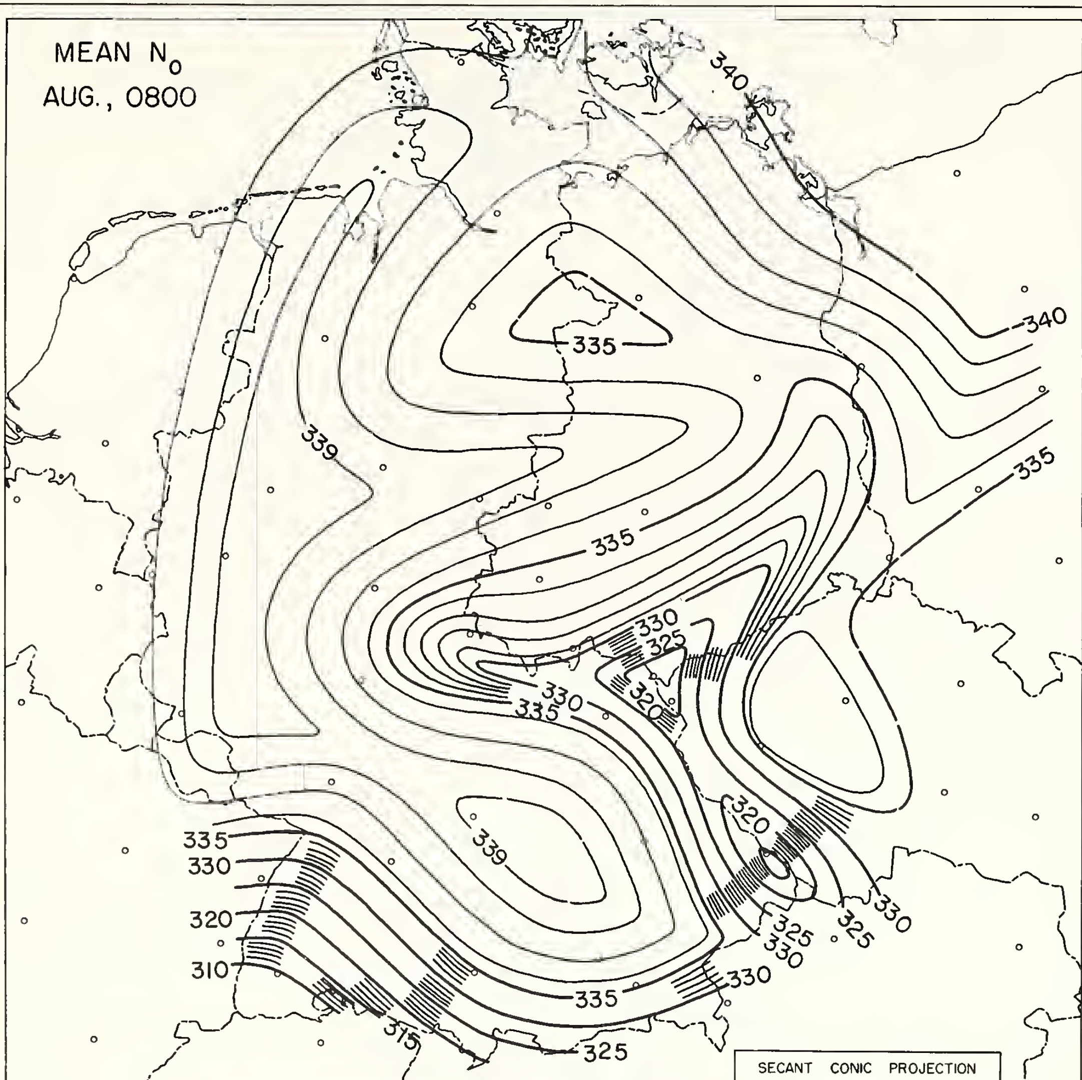

MEAN N_0
AUG., 0800
340
340
335
335
335
339
330
325
320
330
335
335
330
320
339
320
310
315
325
335
330
330
325
325
330
330
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 41

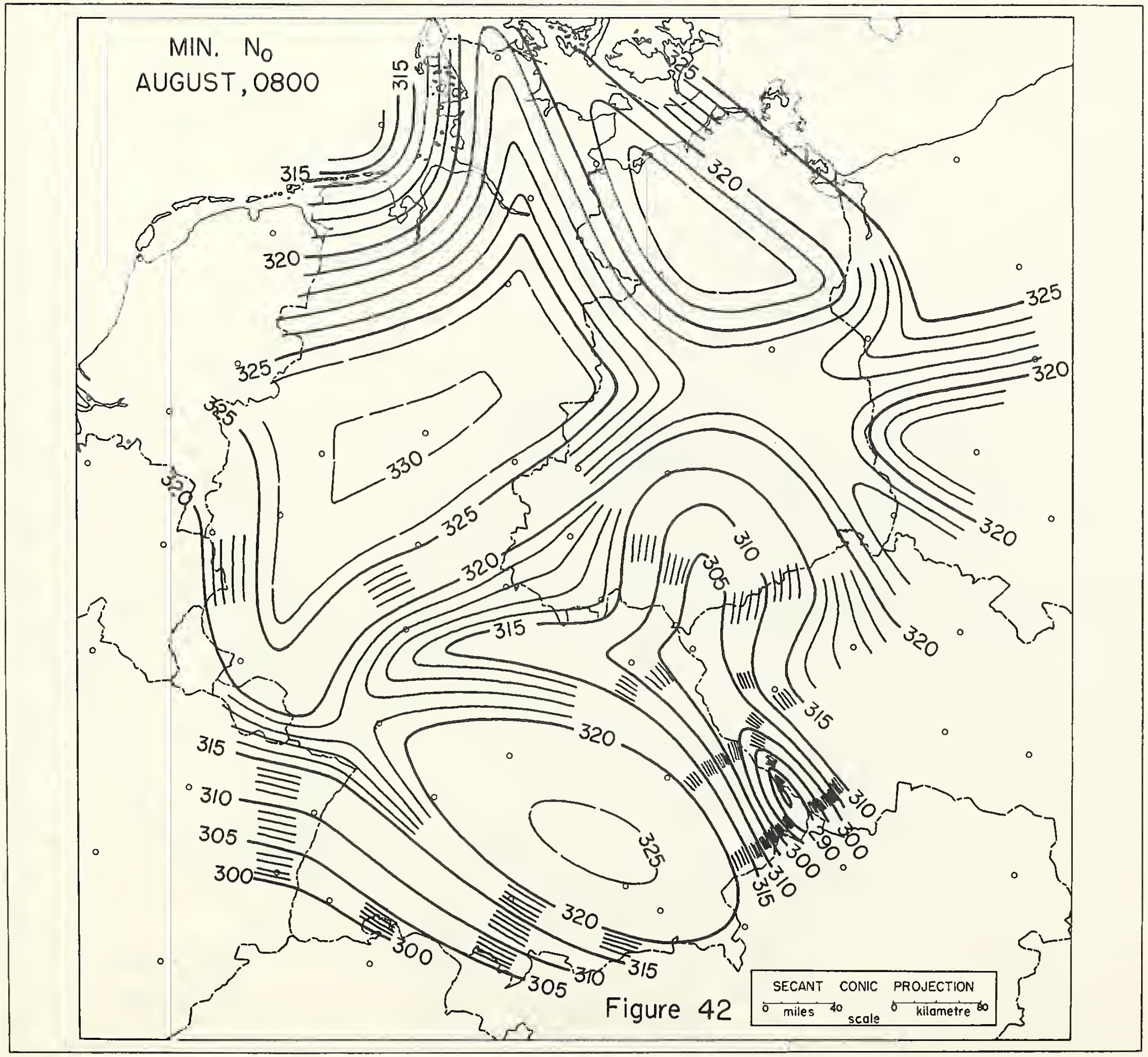

MIN. N_0
AUGUST, 0800
330
325
320
315
310
305
300
290
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilametre 80

Figure 42

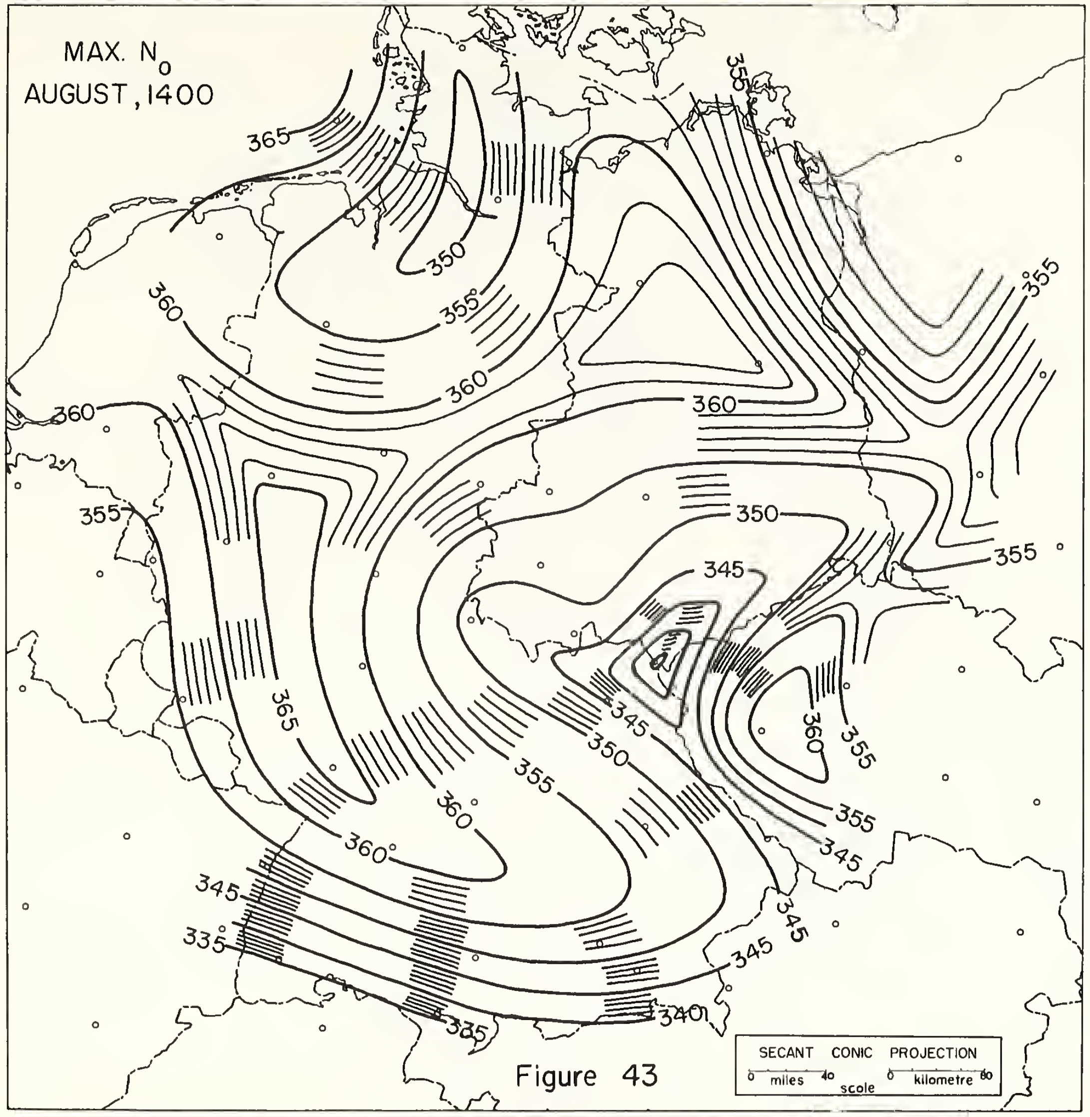

MAX. N_0
AUGUST, 1400
365
350
355
360
345
340
335
SECANT CONIC PROJECTION
miles
scale
kilometre

Figure 43

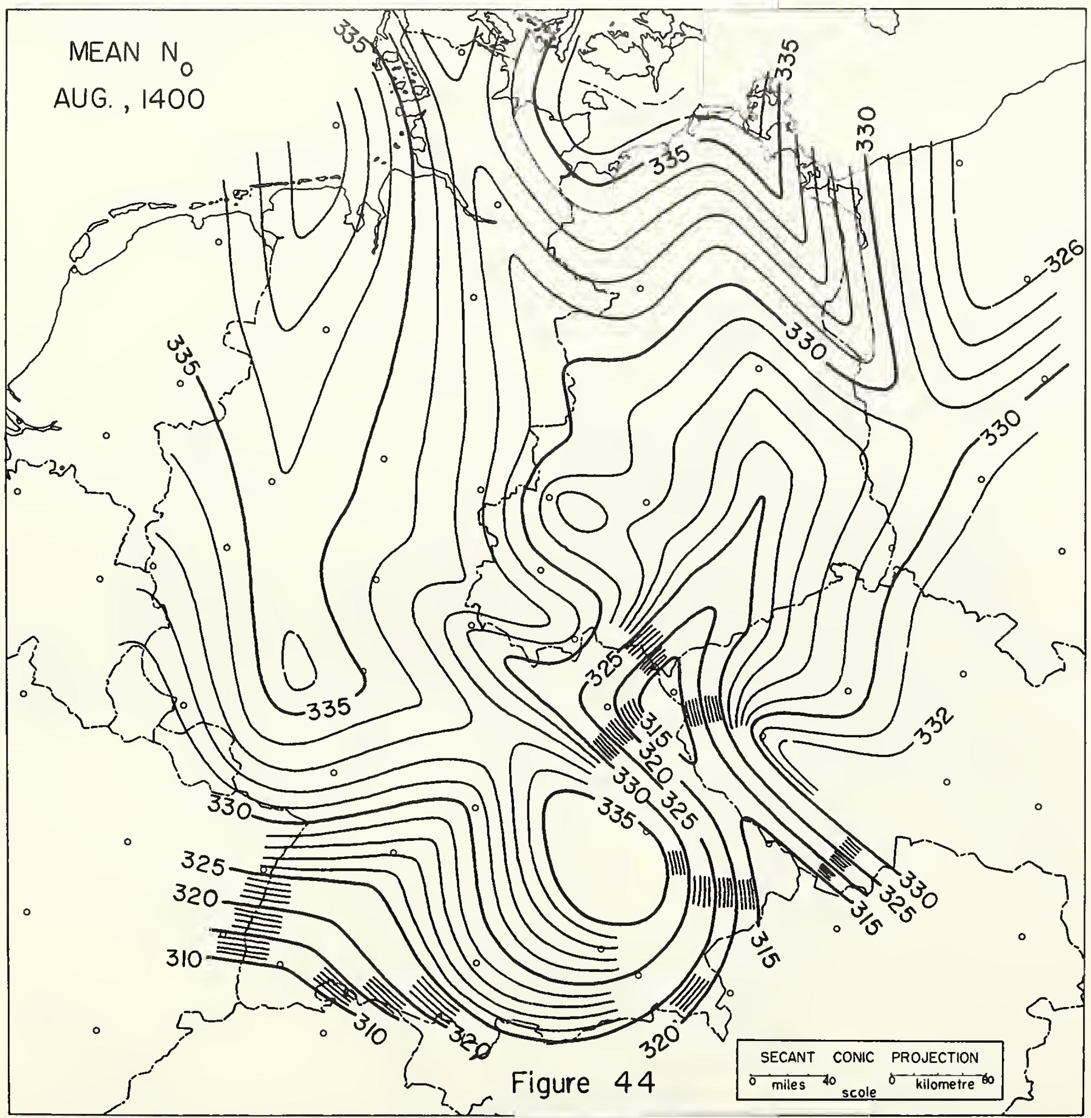

MEAN N_o
AUG., 1400
335
335
330
326
330
330
335
335
332
325
315
320
330
325
335
330
325
320
310
315
315
325
330
310
320
320
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 60

Figure 44

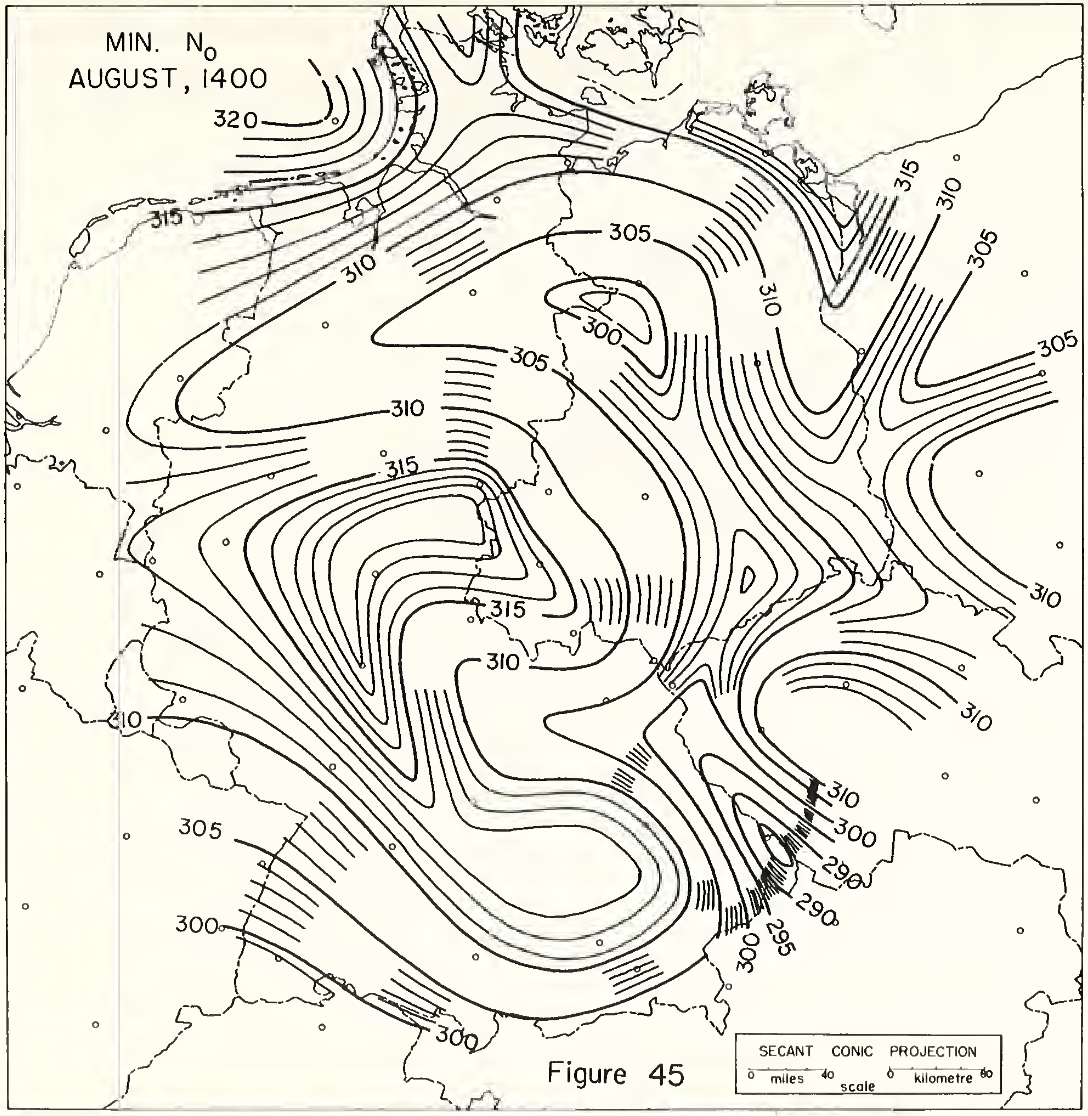

MIN. N_0
AUGUST, 1400
320
315
310
305
300
290
295
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 60

Figure 45

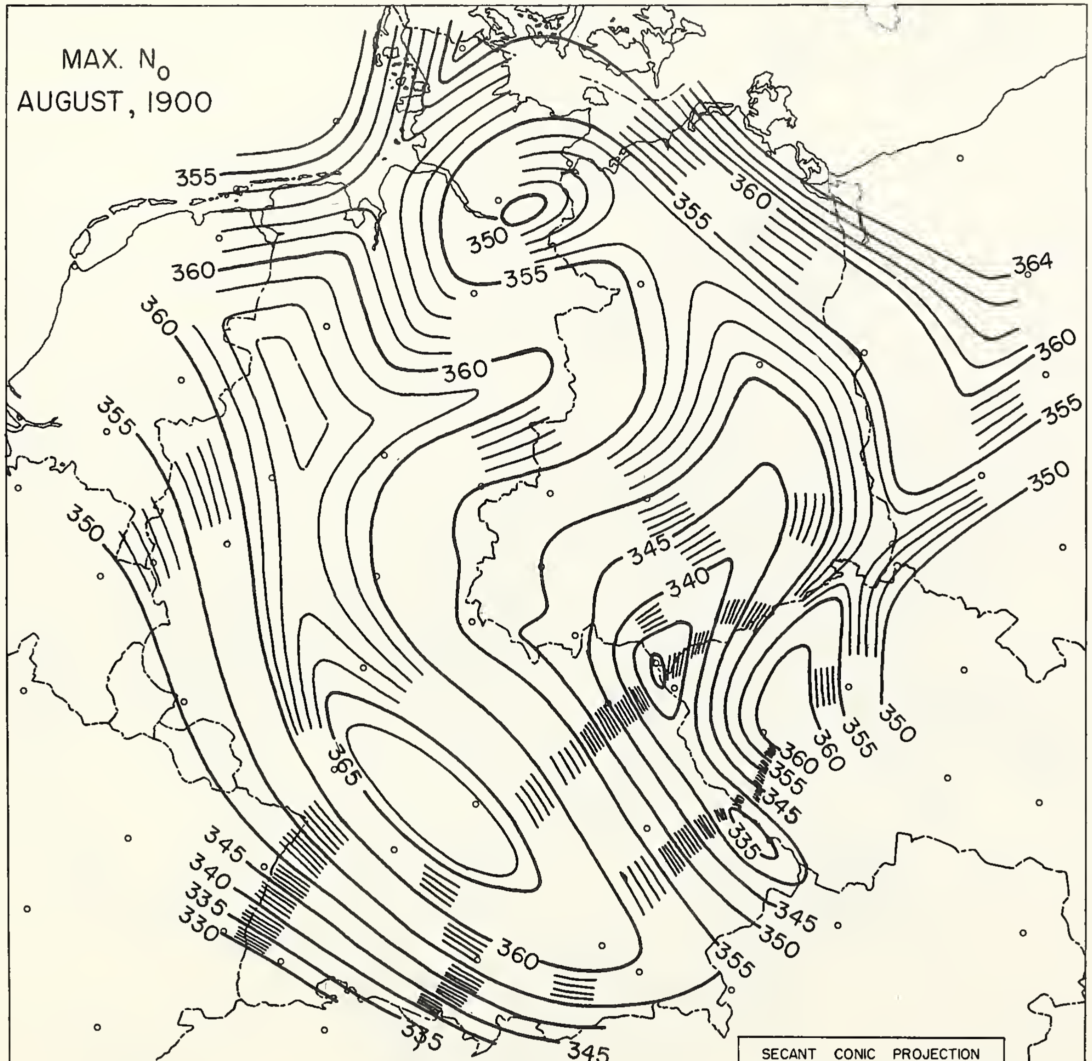

MAX. N_0
AUGUST, 1900
355
360
360
355
350
350
355
360
355
360
364
360
355
350
345
340
365
360
355
350
360
355
345
335
345
350
355
345
340
335
330
360
335
345
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 46

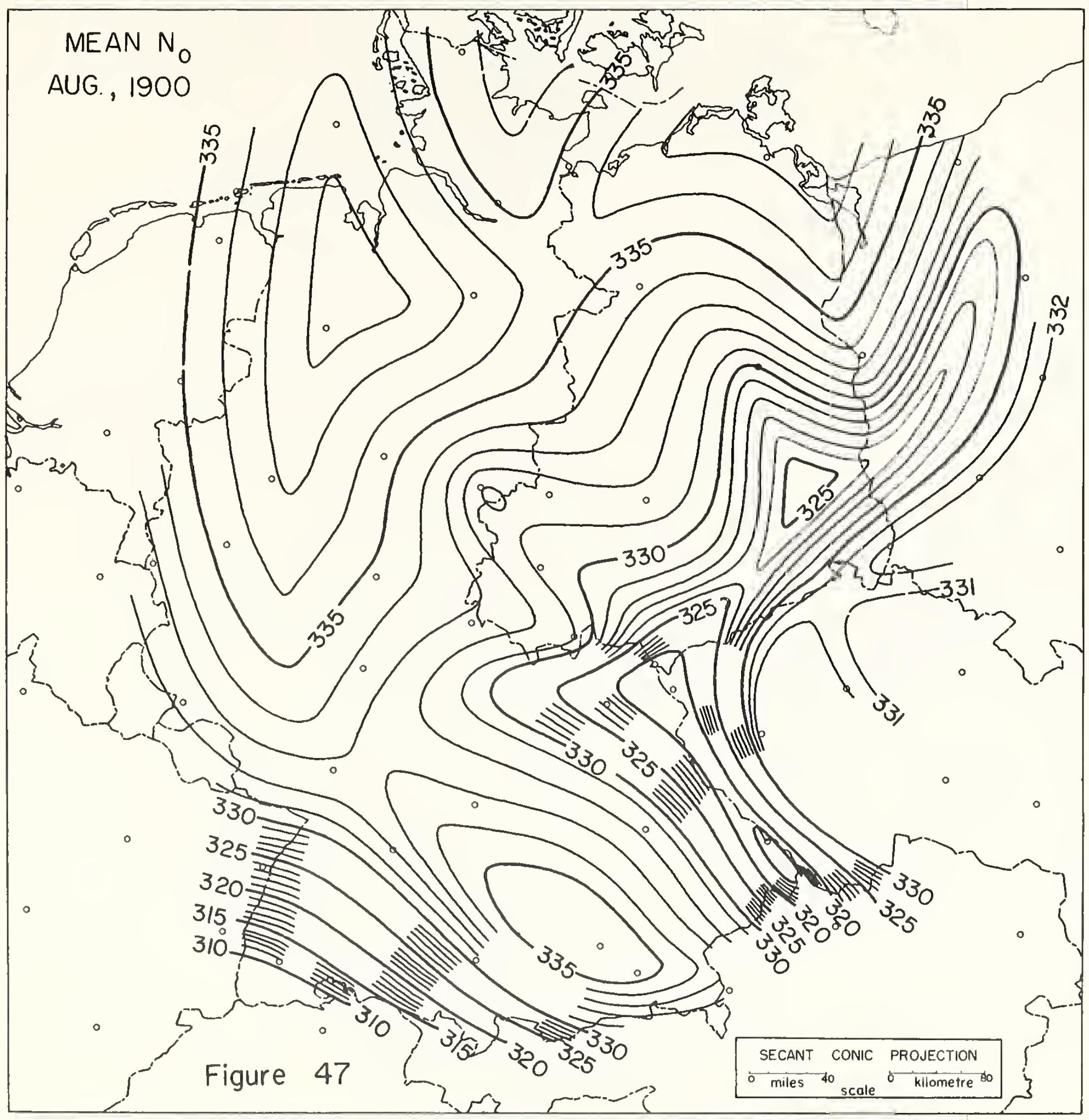
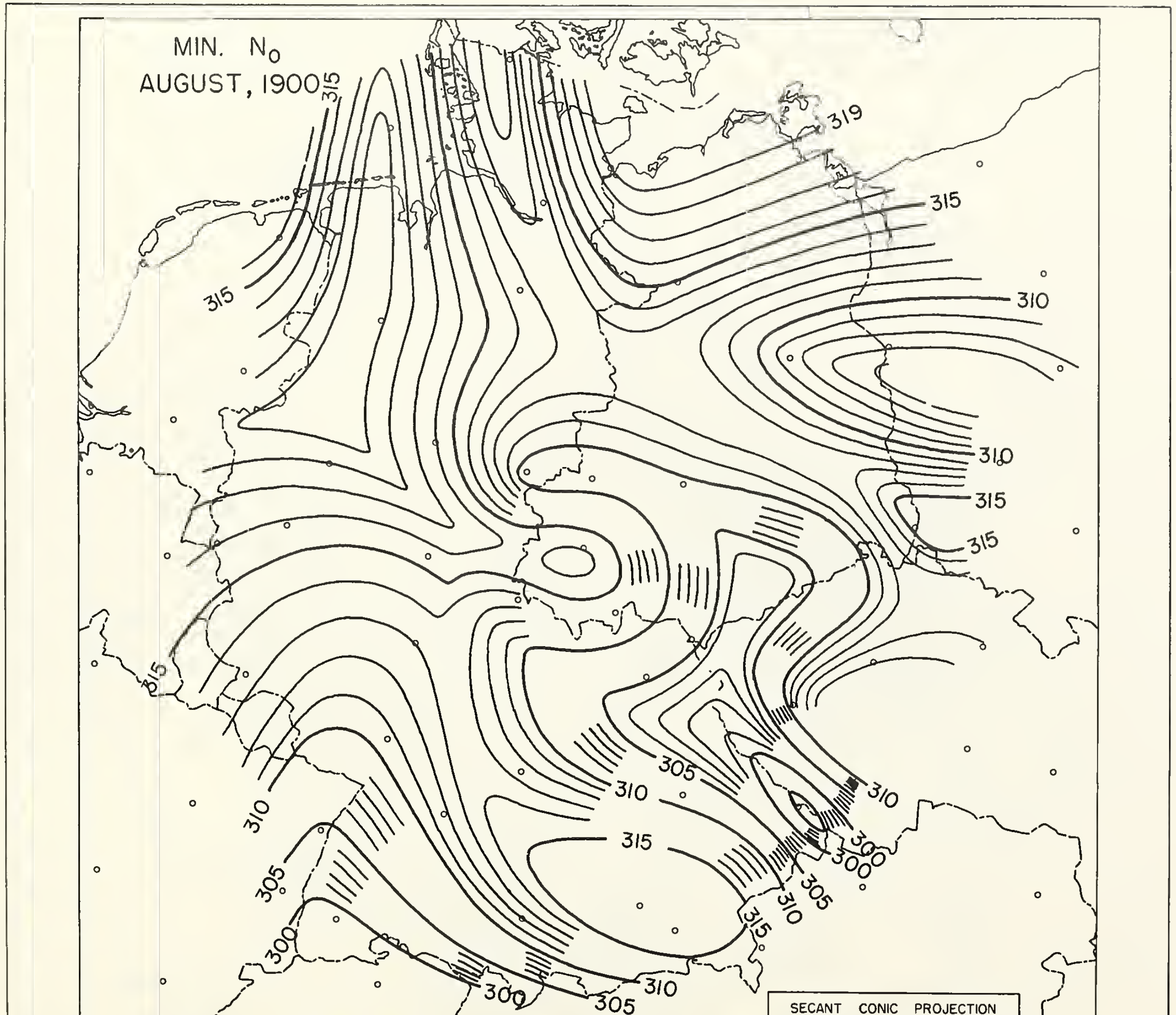

MEAN N_0
AUG., 1900
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 47



MIN. N_0
AUGUST, 1900
319
315
310
305
300
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 48

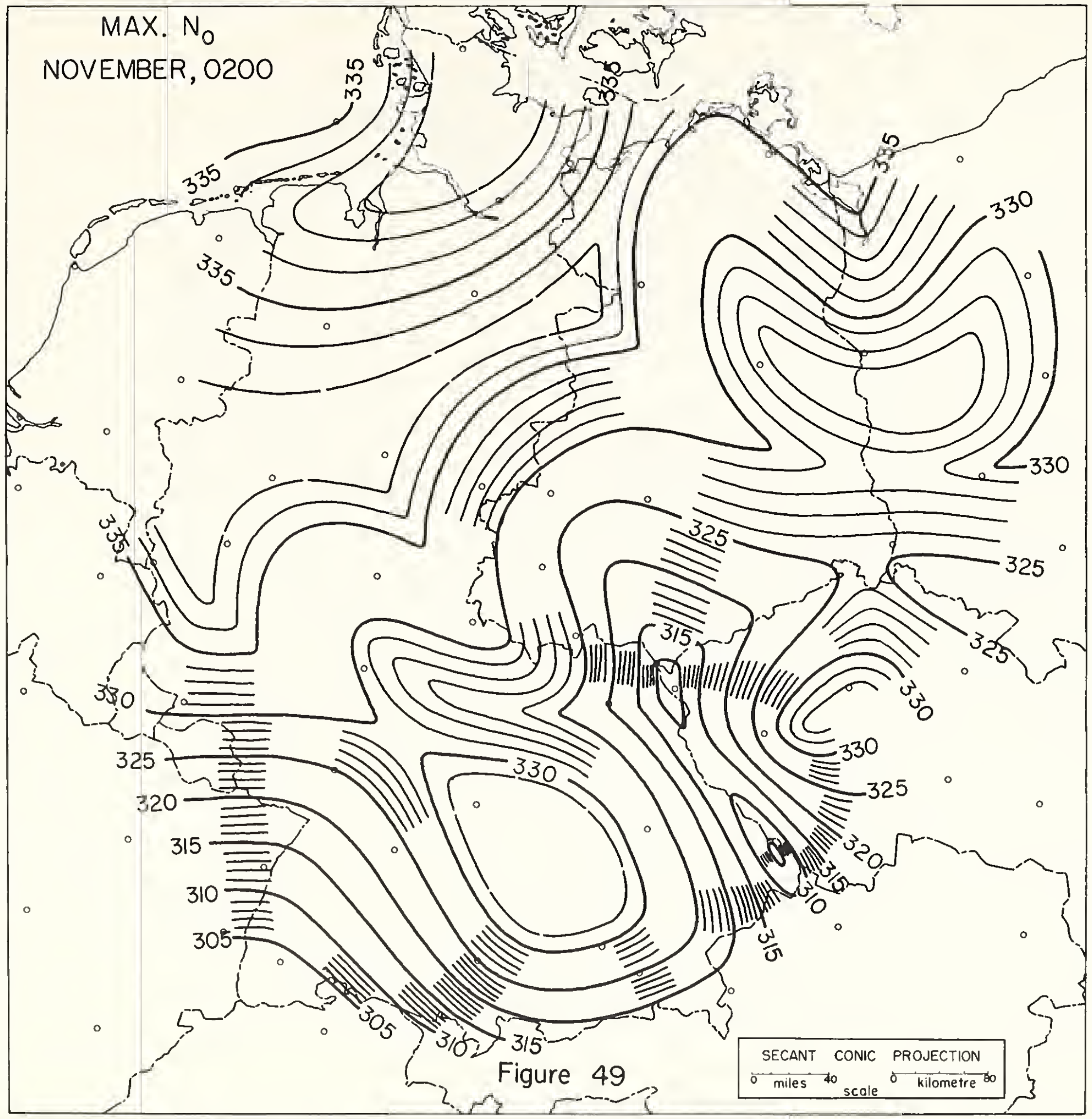

MAX. N_0
NOVEMBER, 0200
335
330
325
320
315
310
305
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 49

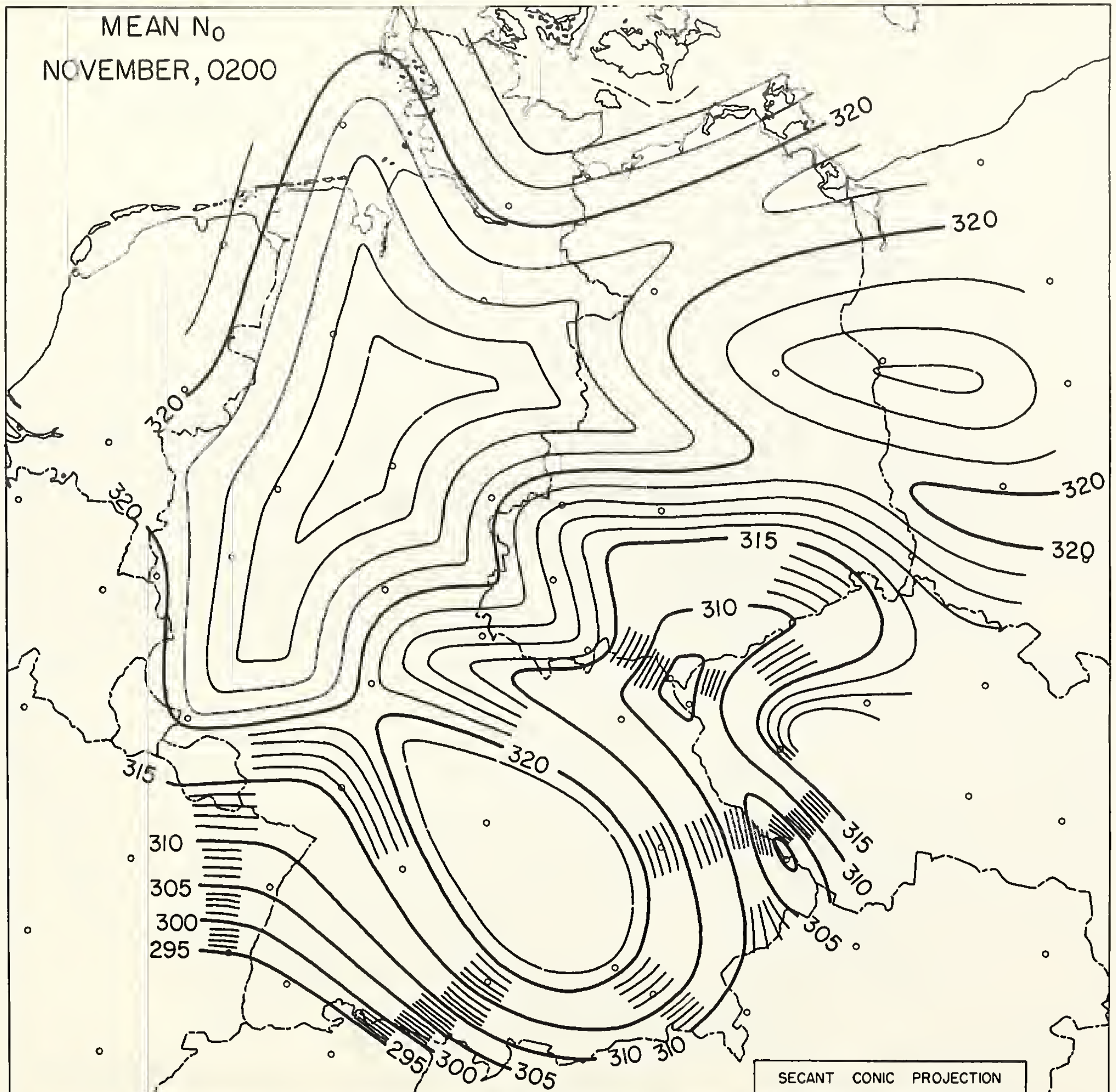

MEAN N_0
NOVEMBER, 0200
320
320
320
320
320
320
320
315
310
320
315
310
305
300
295
315
310
305
295
300
305
310
310
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 50

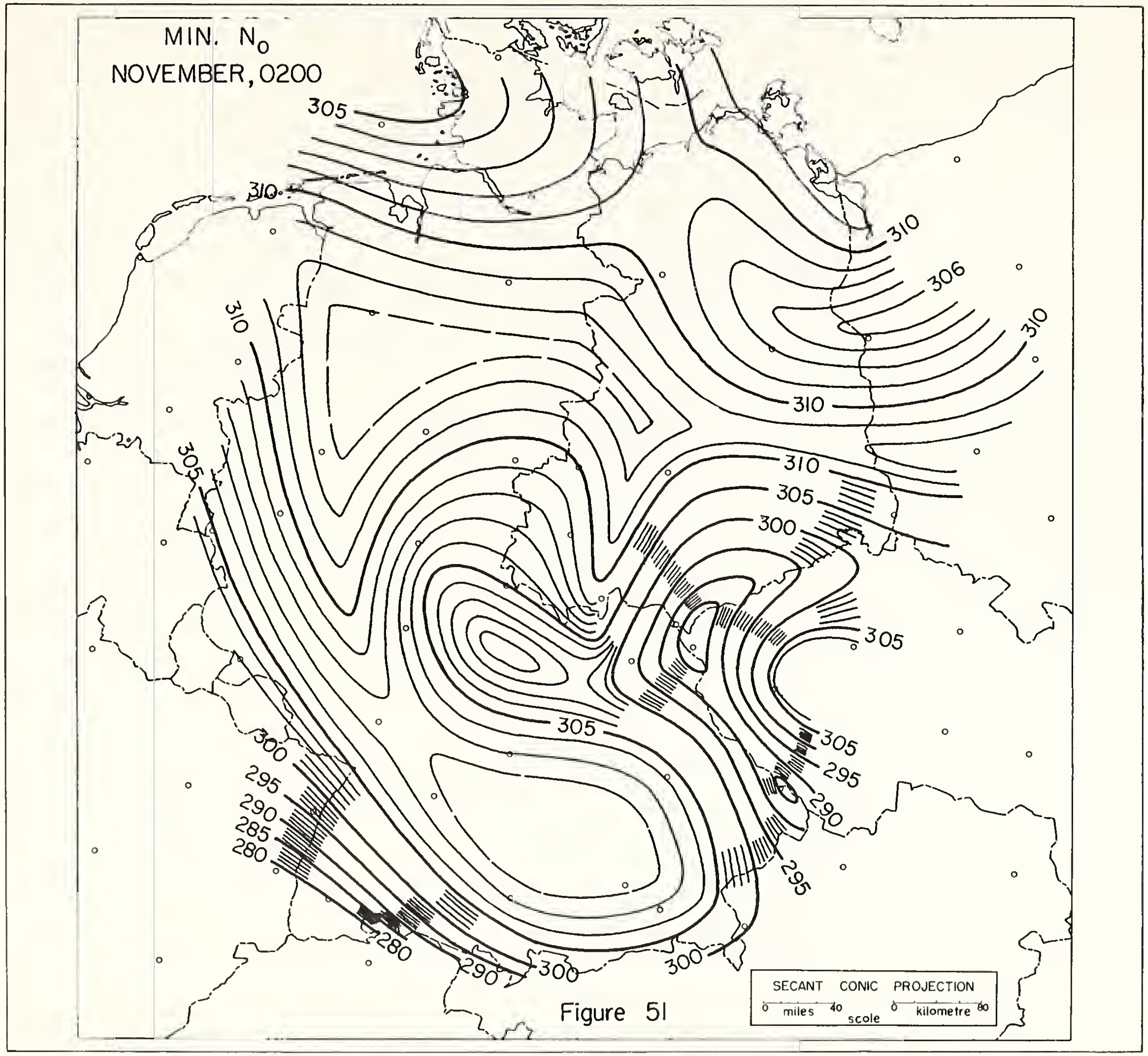
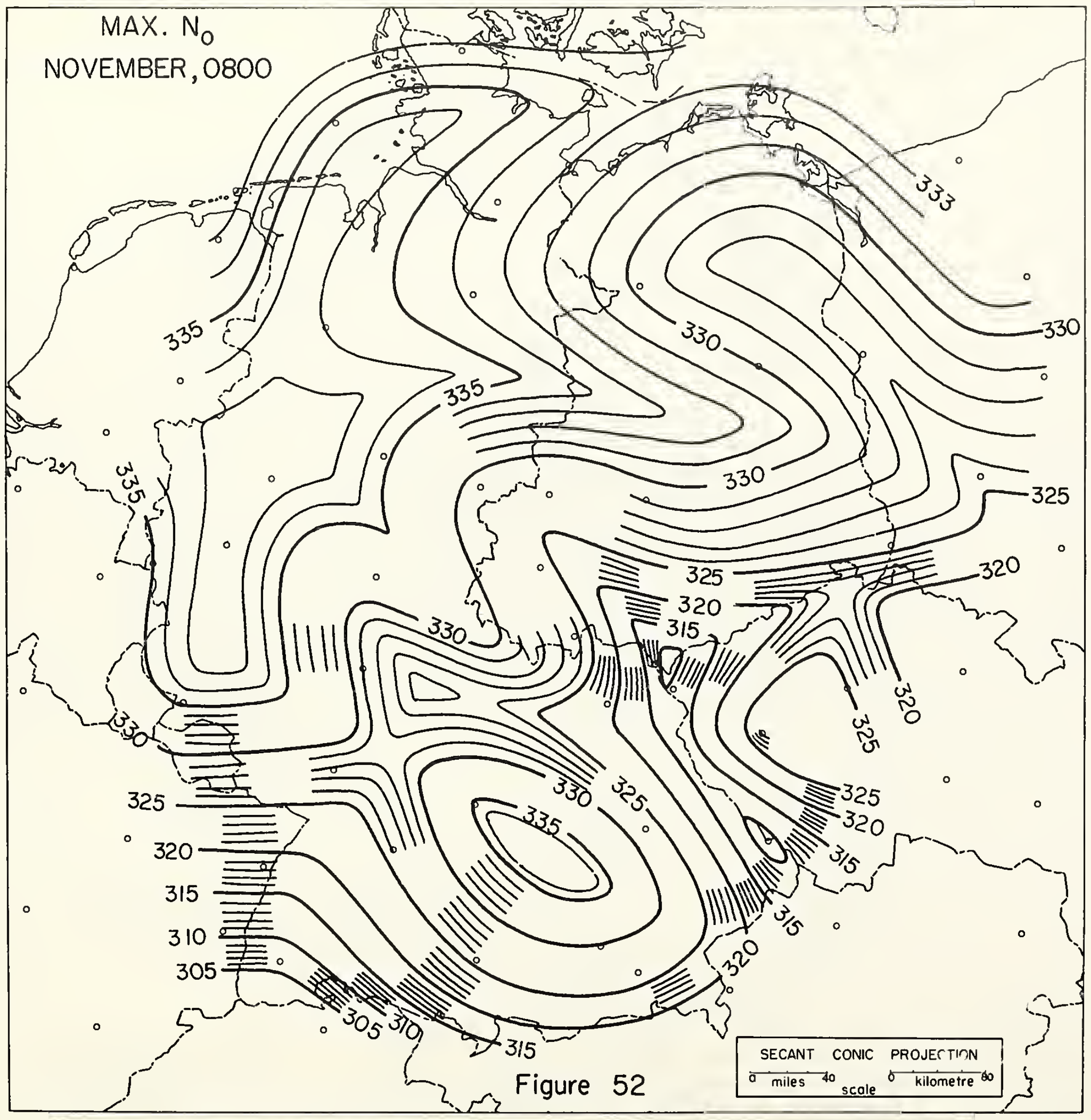

MIN. N_0
NOVEMBER, 0200
305
310
306
310
310
310
305
300
310
305
305
305
295
290
295
300
295
290
285
280
280
290
300
300
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 51


MAX. N_0
NOVEMBER, 0800
333
330
325
320
315
310
305
335
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 60
Figure 52

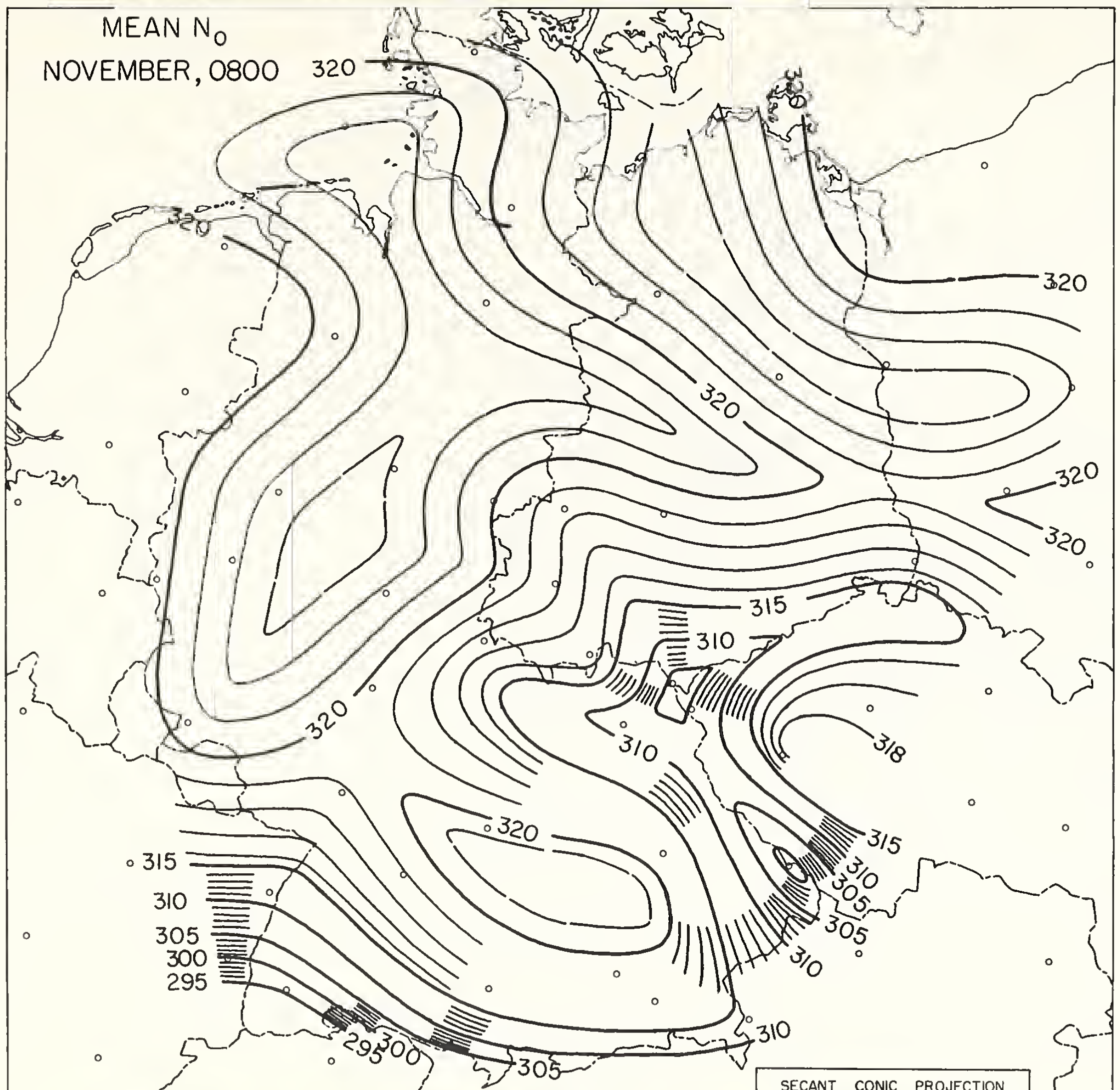

MEAN N_0
NOVEMBER, 0800
320
318
315
310
305
300
295
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 53

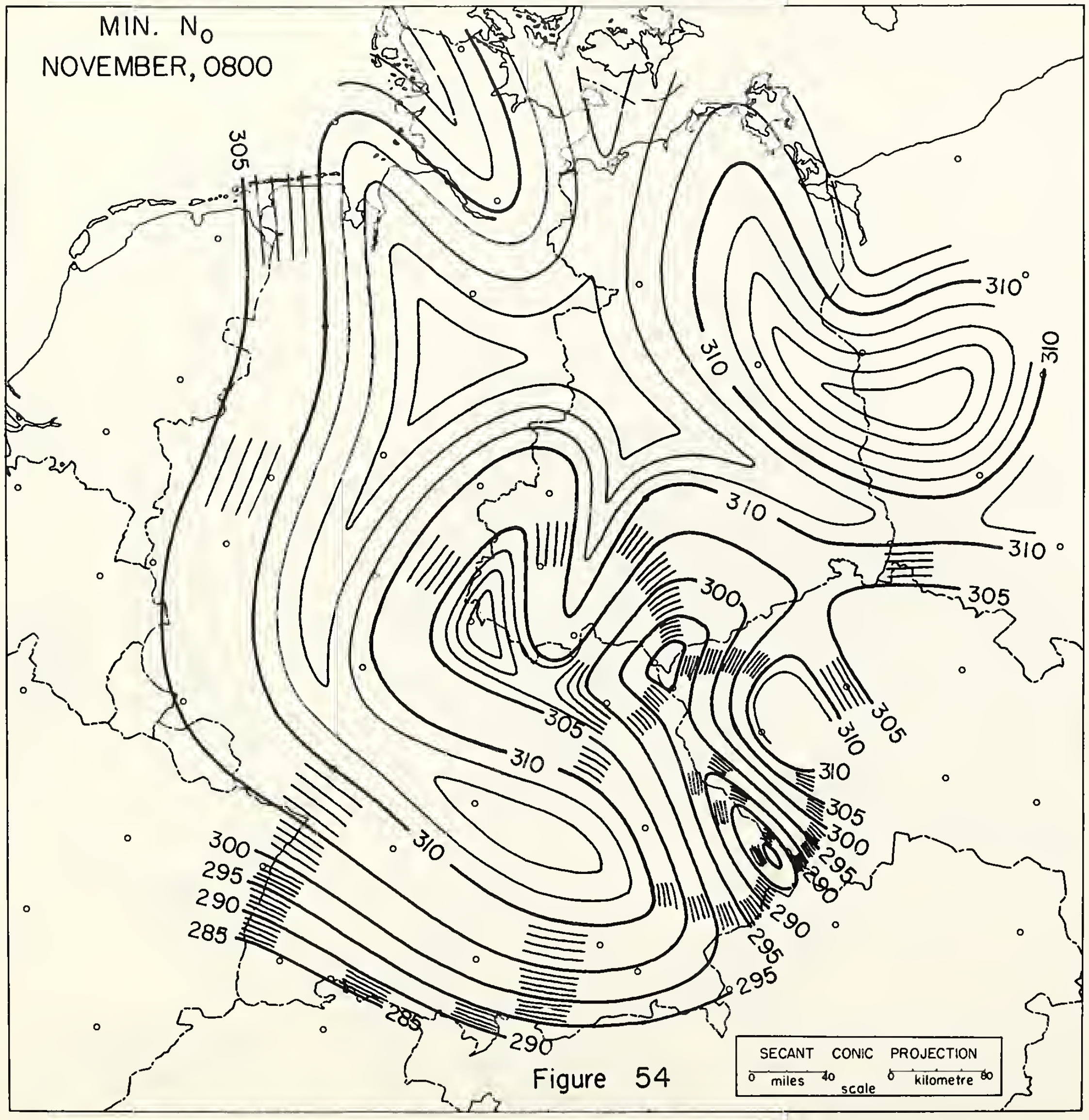

MIN. N_0
NOVEMBER, 0800
305
310
305
300
295
290
285
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 54

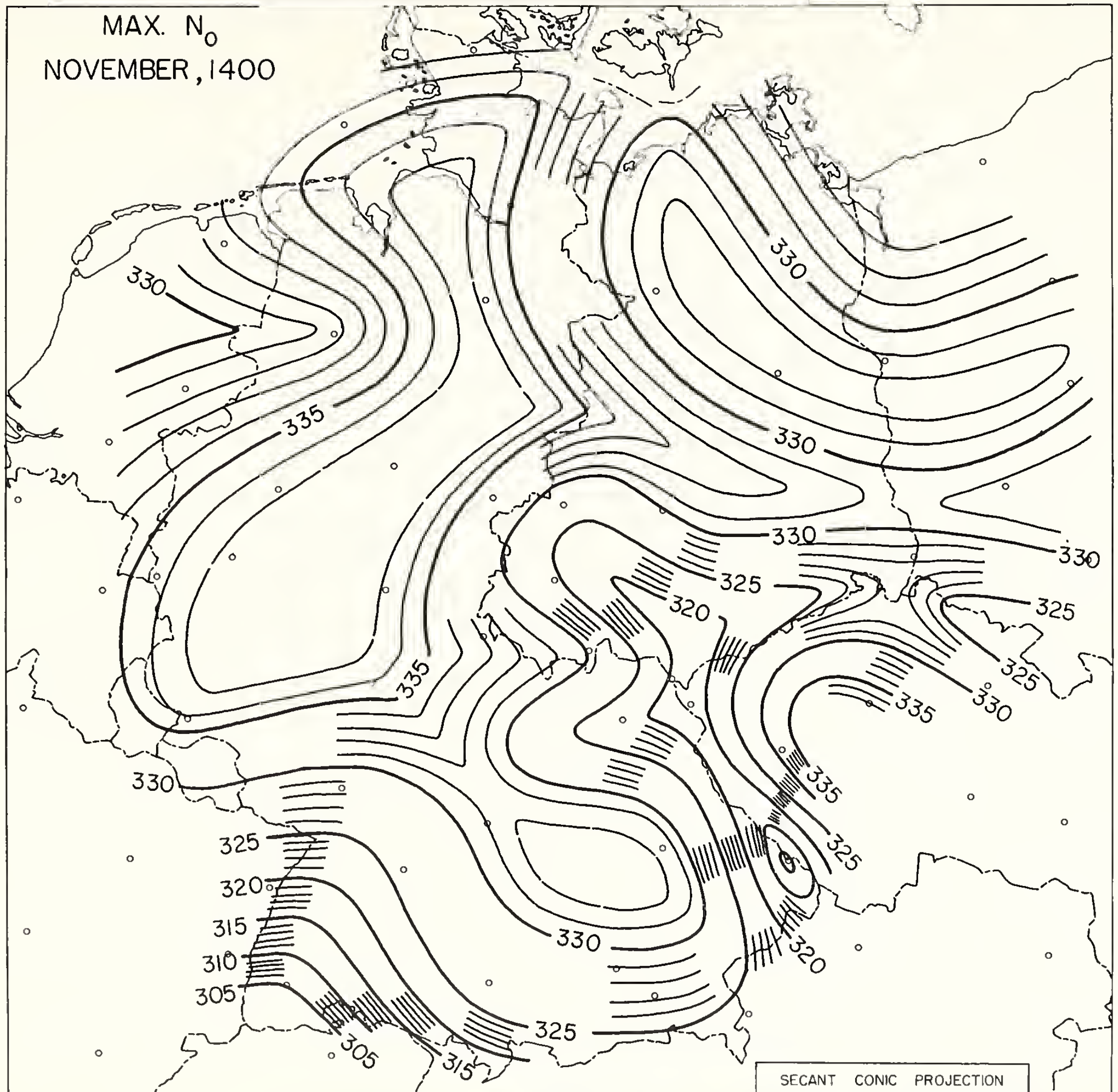

MAX. N_0
NOVEMBER, 1400
330
335
330
330
330
325
325
320
325
325
330
335
335
335
325
320
330
330
325
320
315
310
305
305
315
325
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 55

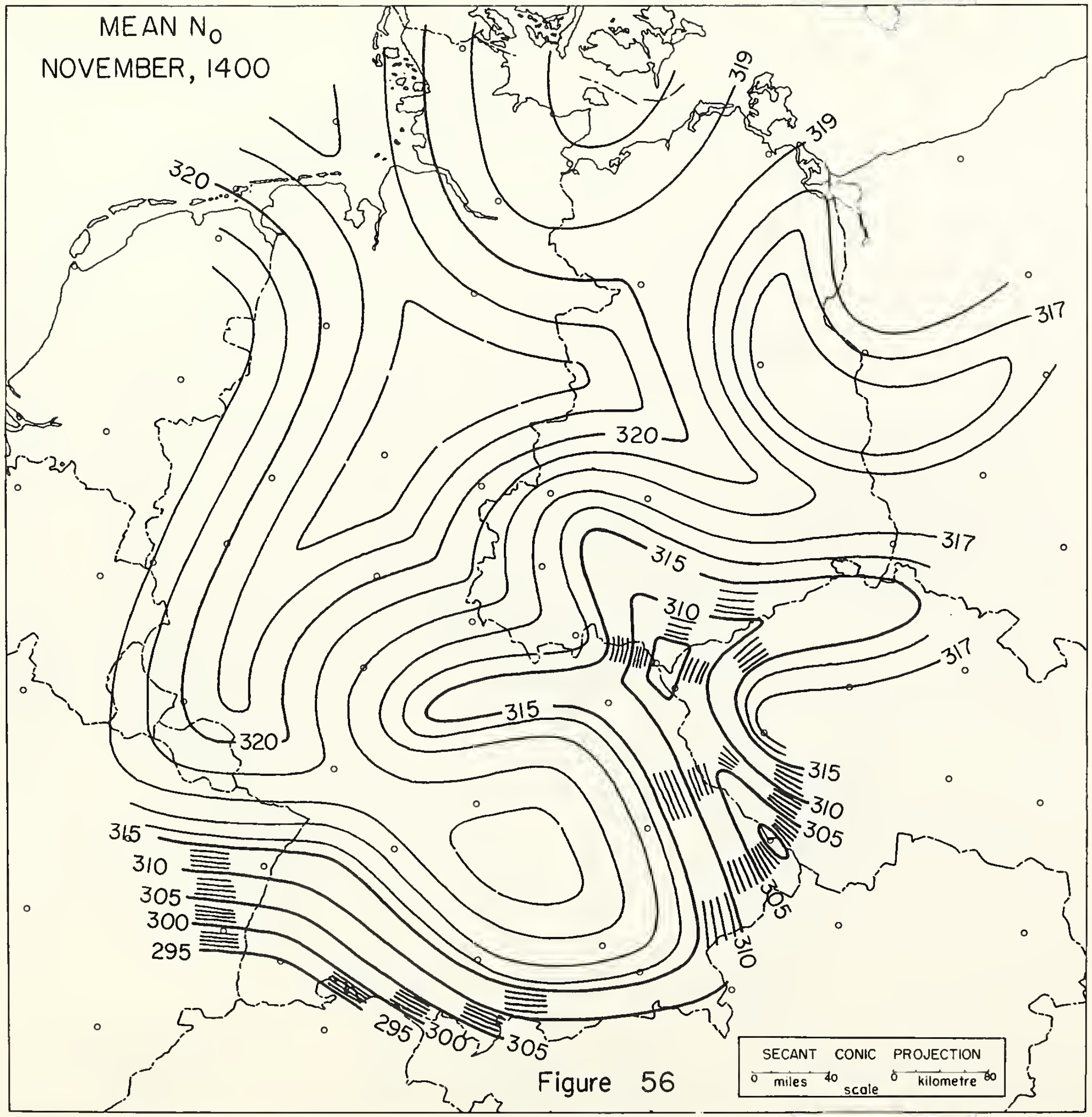

MEAN N_0
NOVEMBER, 1400
320
319
319
317
317
317
320
320
315
310
315
315
310
305
305
310
315
310
305
300
295
295
300
305
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 56

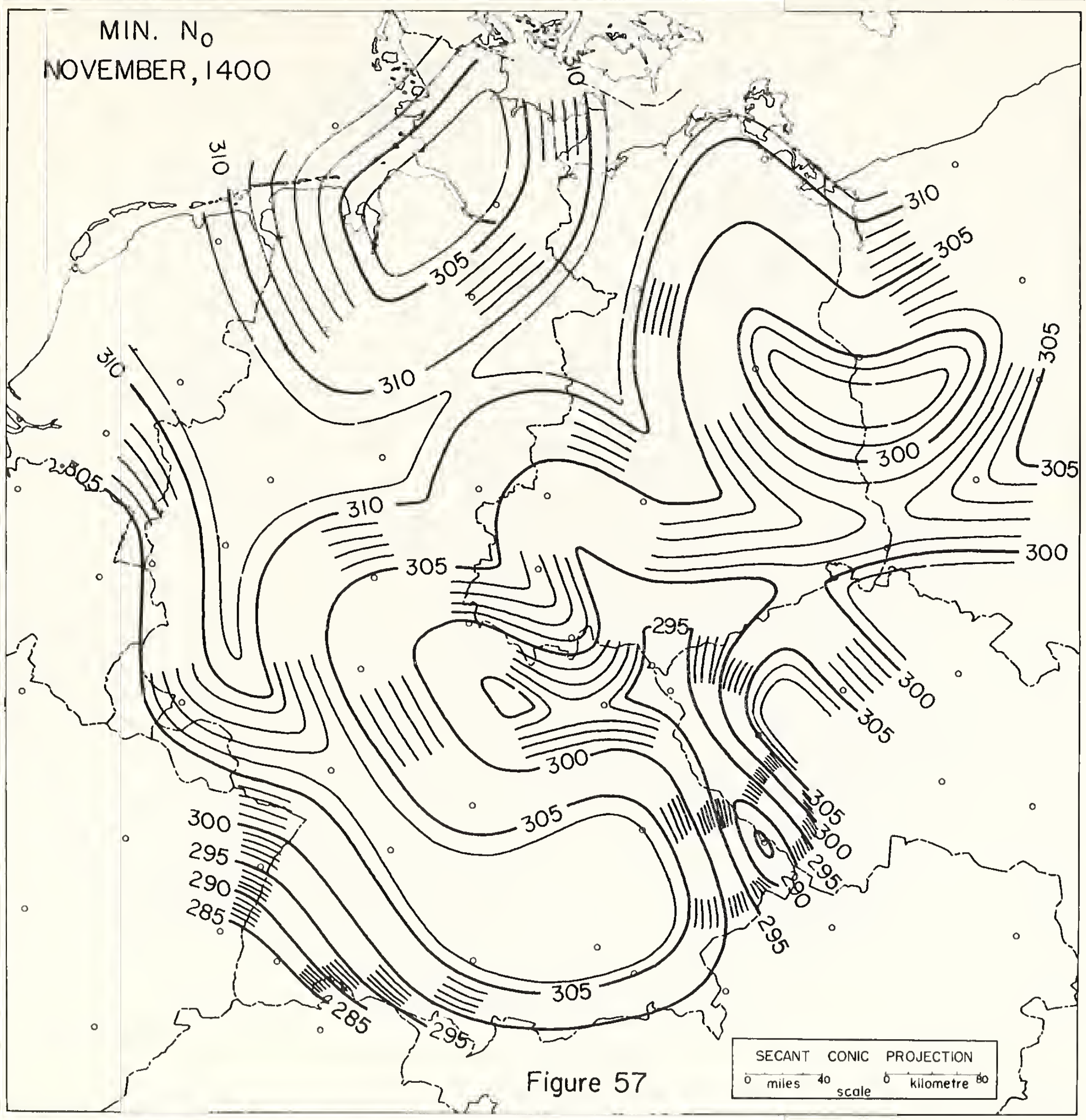
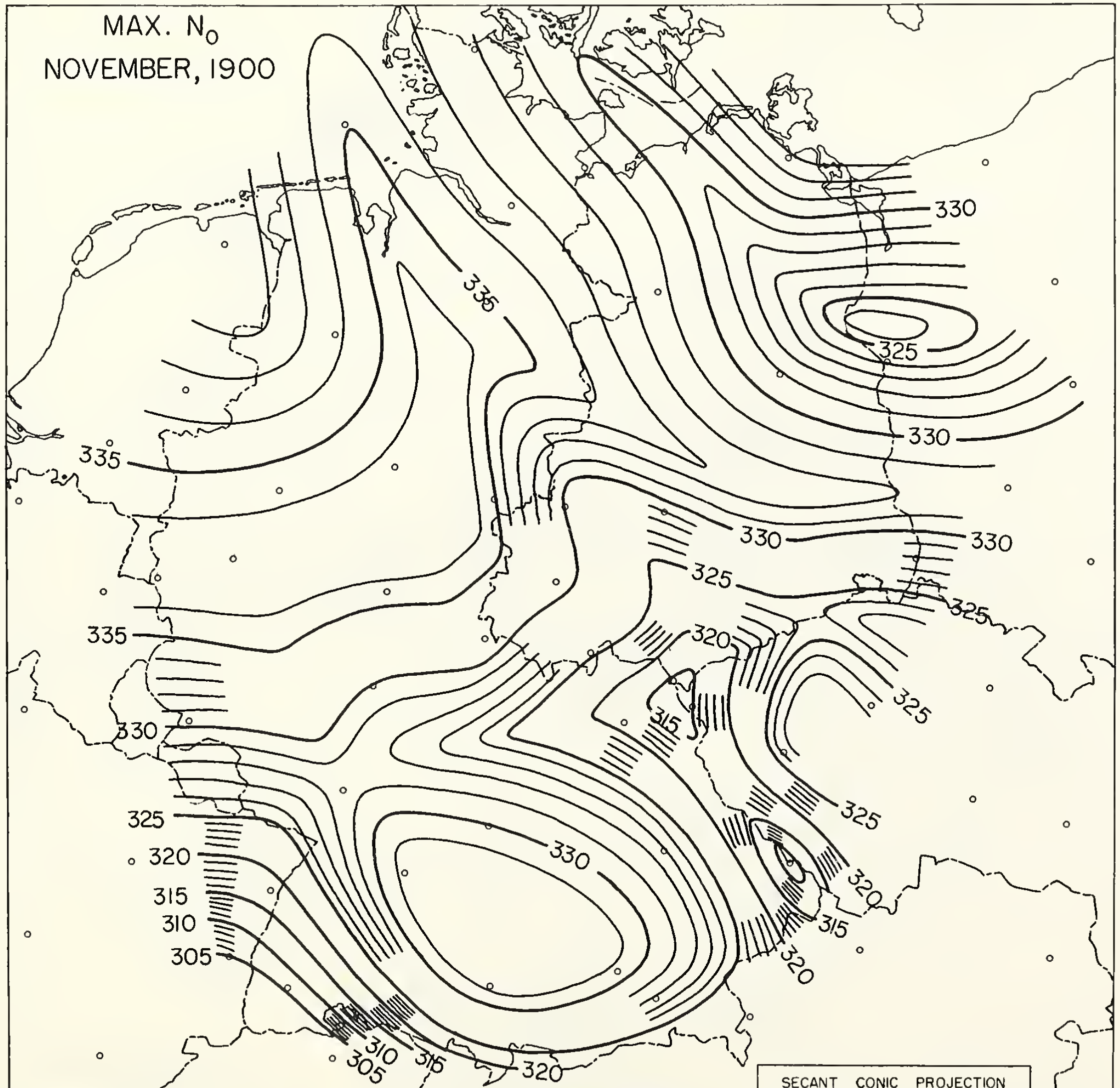

MIN. N_0
NOVEMBER, 1400
310
305
300
295
290
285
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 57



MAX. N_0
NOVEMBER, 1900
330
325
330
330
330
325
325
320
315
320
325
325
335
335
335
330
325
320
315
310
305
330
310
305
315
320
320
315
320
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 58

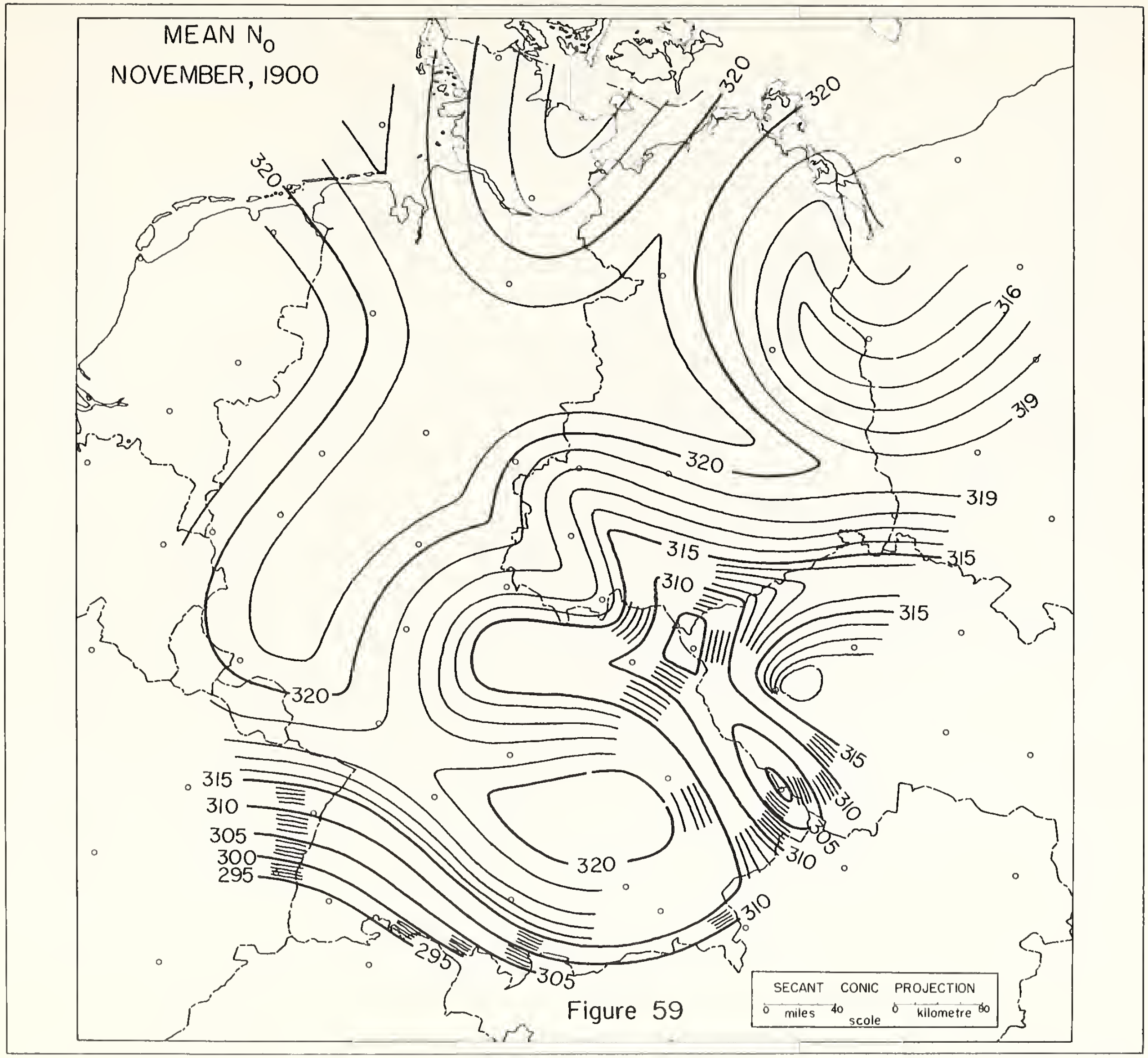

MEAN N_0
NOVEMBER, 1900
320
316
319
315
310
305
300
295
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 60

Figure 59

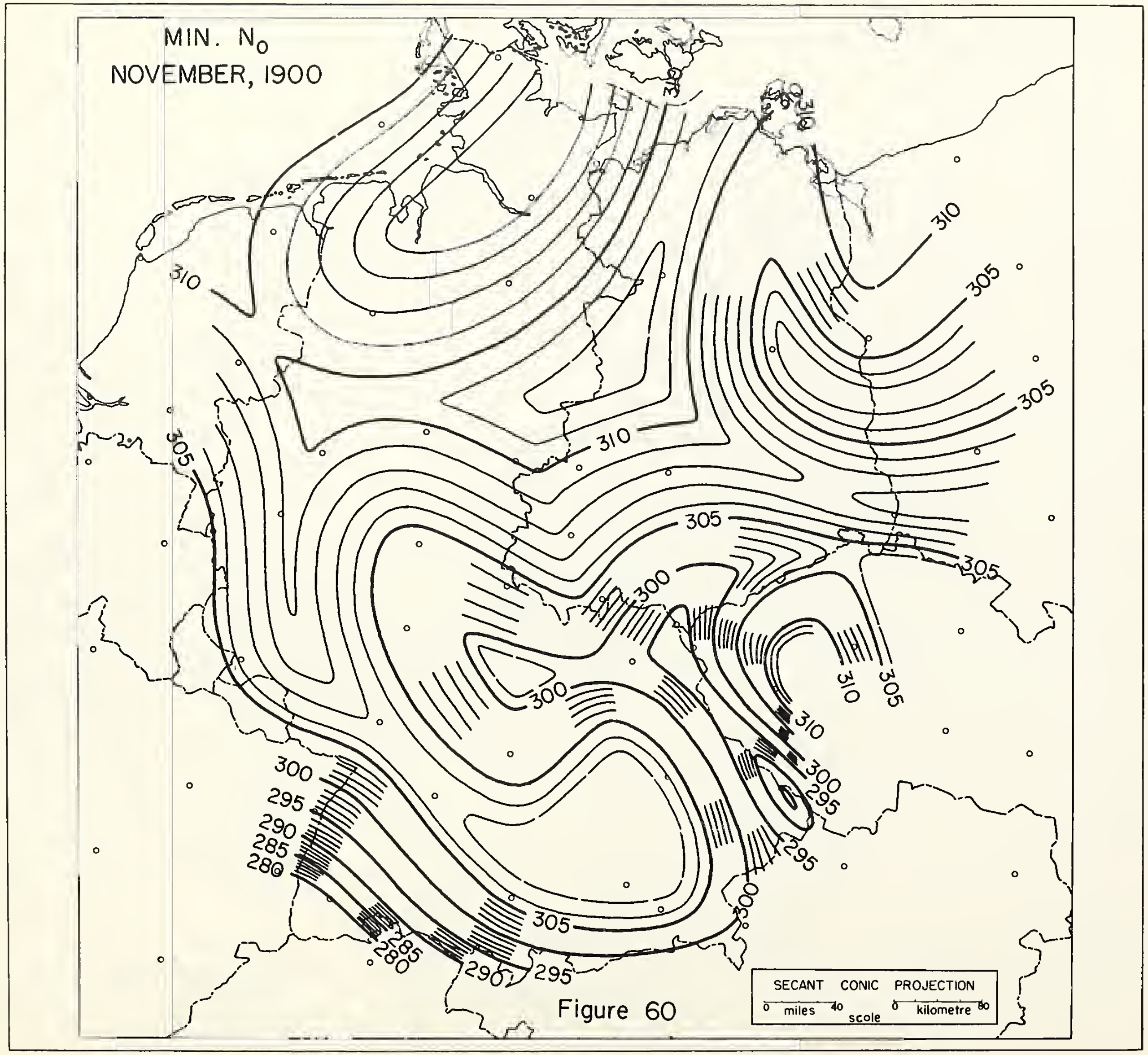

MIN. N_0
NOVEMBER, 1900
310
305
300
295
290
285
280
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 60

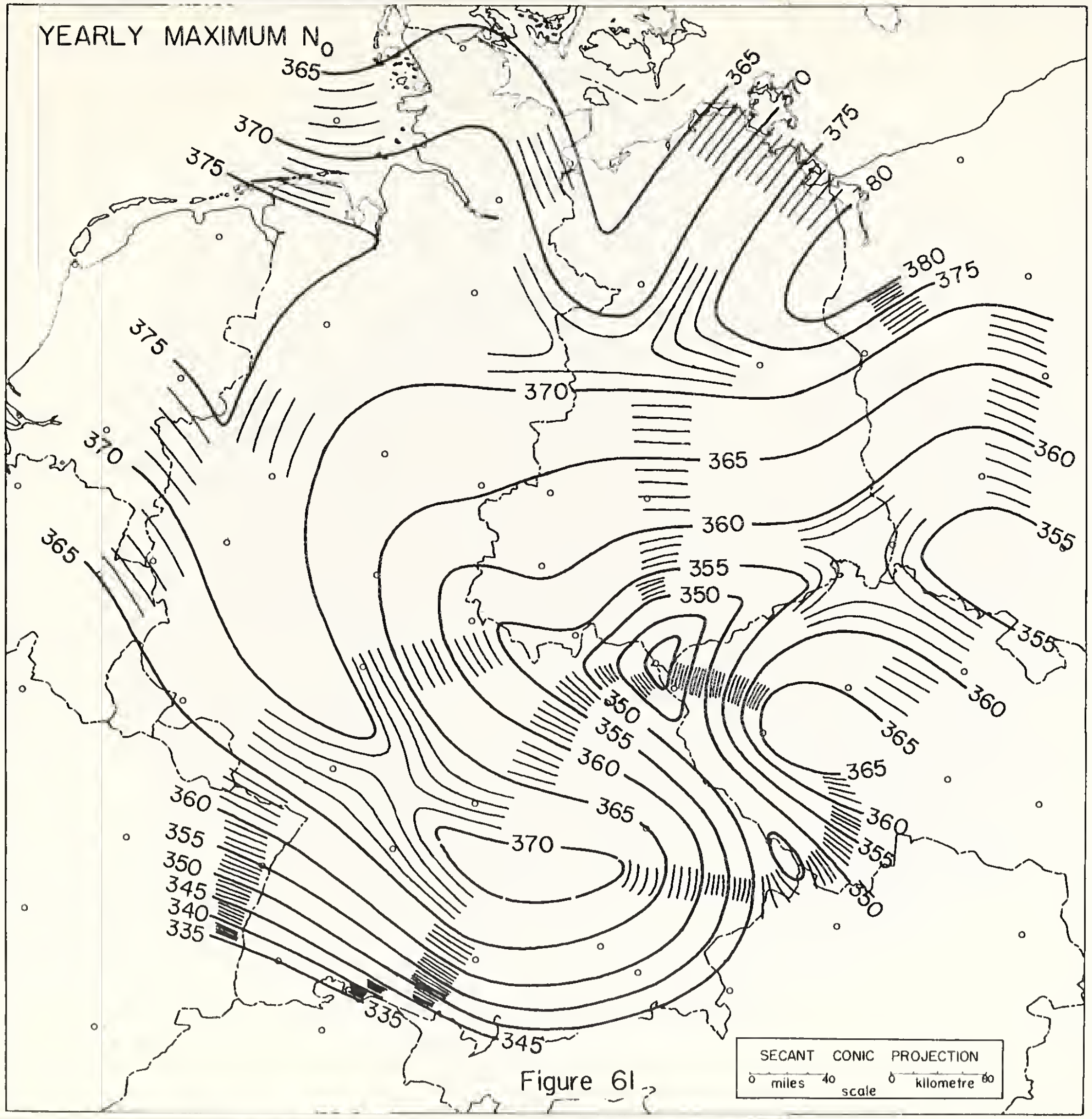

YEARLY MAXIMUM N_0
365
370
375
380
360
355
350
345
340
335
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 61

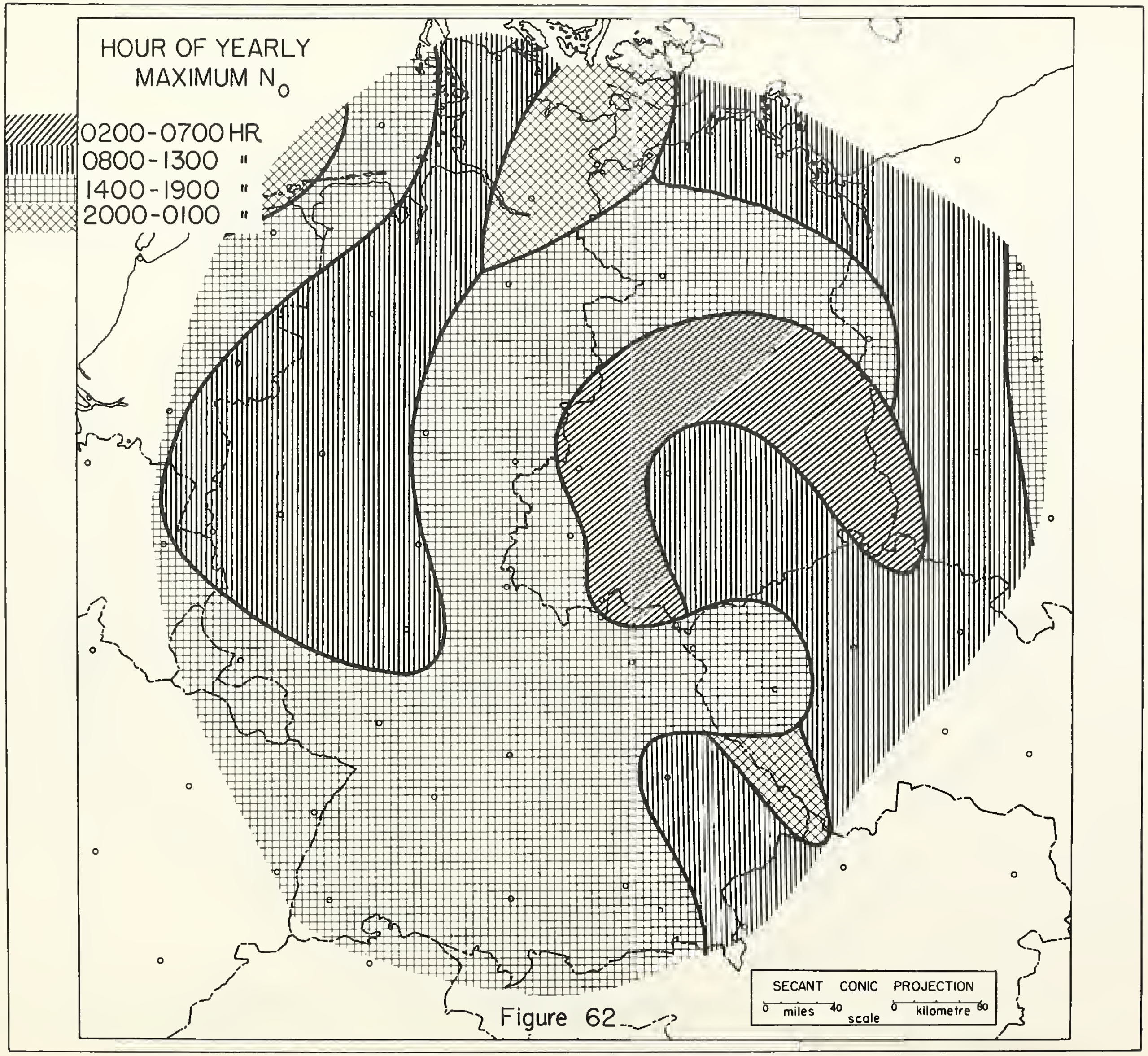

HOUR OF YEARLY
MAXIMUM N_0
0200-0700 HR
0800-1300 "
1400-1900 "
2000-0100 "
SECANT CONIC PROJECTION
0 miles 40 scale 0 kilometre 80

Figure 62

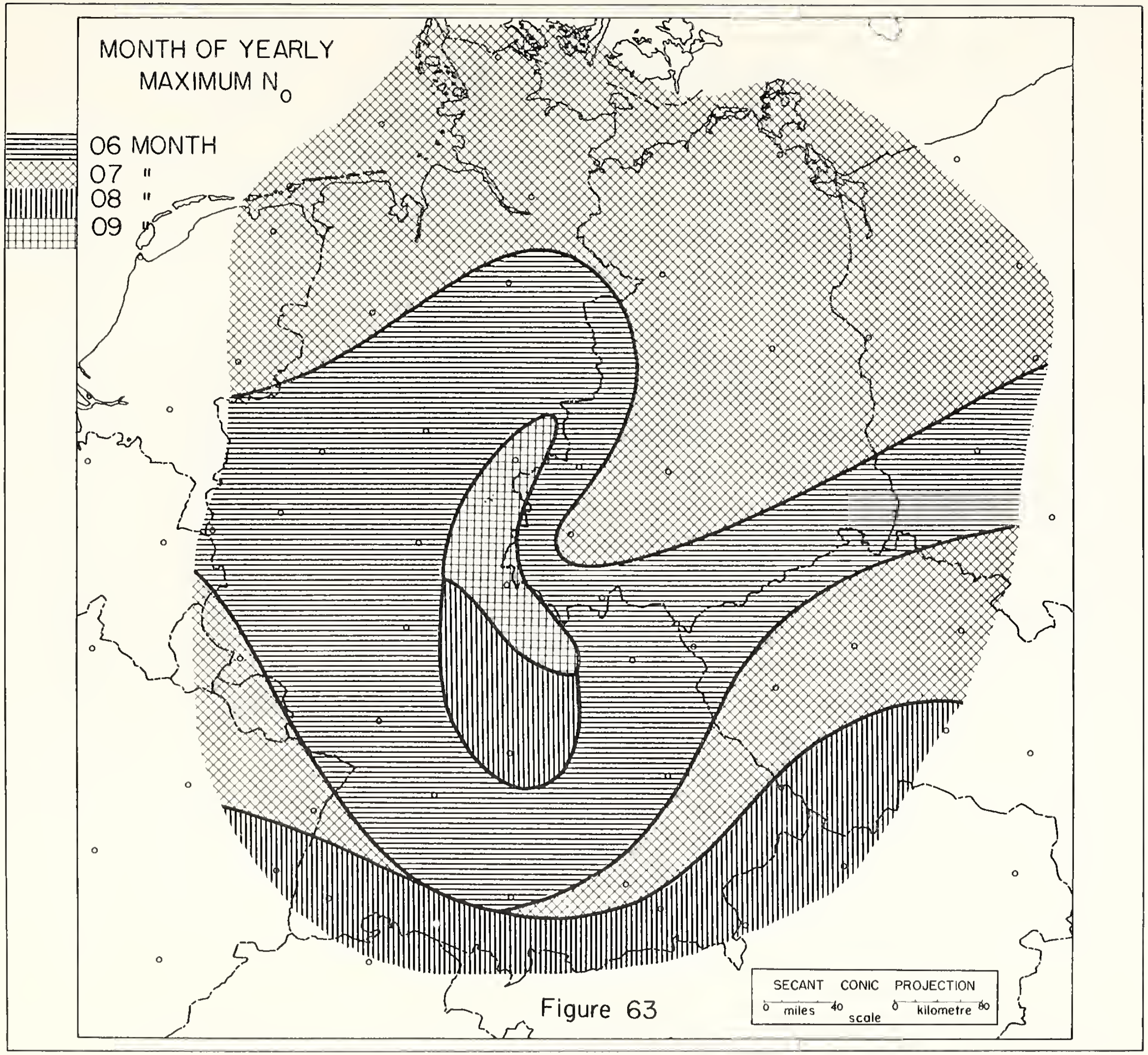

MONTH OF YEARLY
MAXIMUM N_0
06 MONTH
07 "
08 "
09 "
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 63

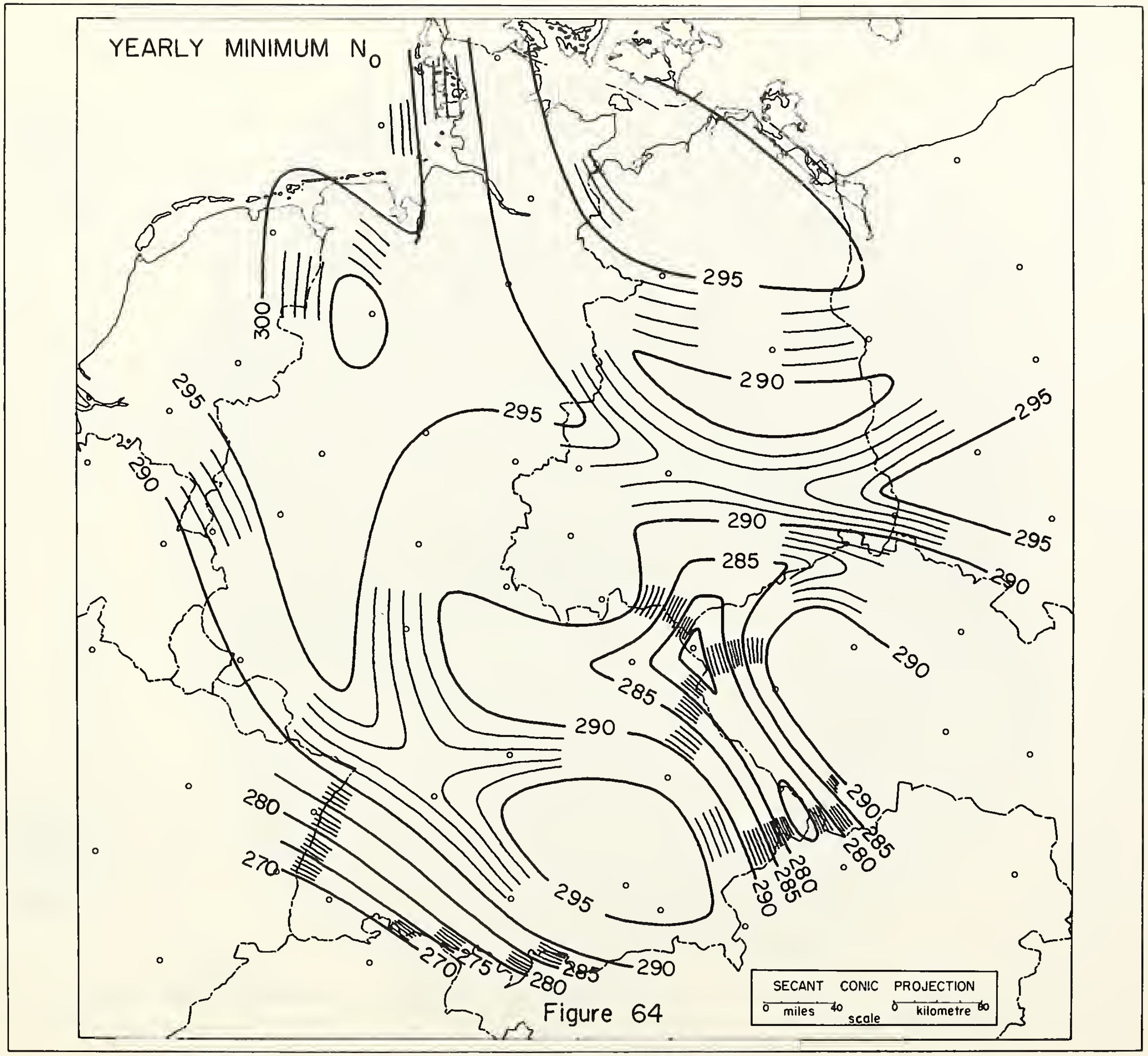

YEARLY MINIMUM N_0
SECANT CONIC PROJECTION
miles
scale
kilometre

Figure 64

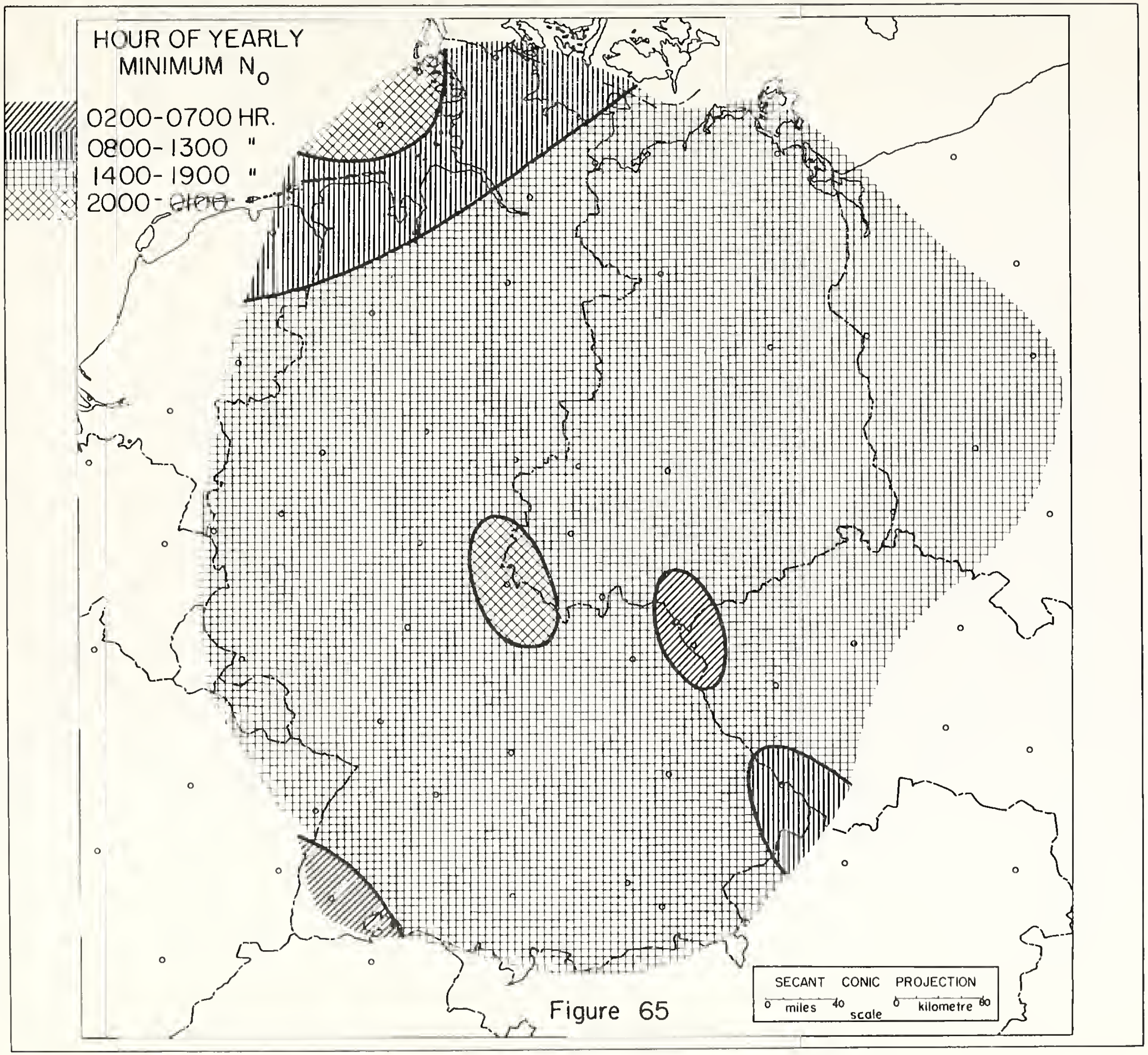

HOUR OF YEARLY
MINIMUM N_0
0200-0700 HR.
0800-1300 "
1400-1900 "
2000-0100
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 60

Figure 65

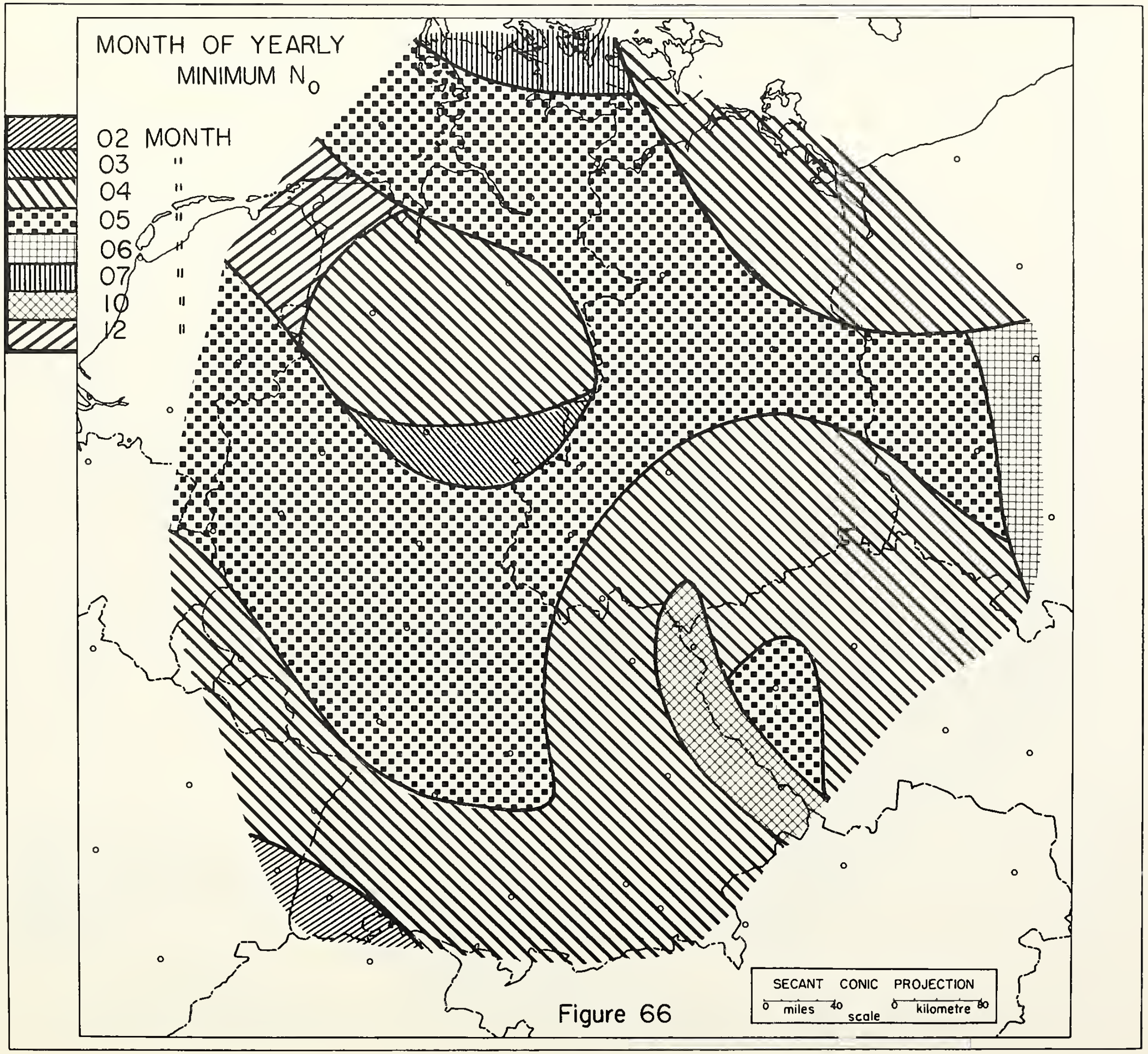

MONTH OF YEARLY
MINIMUM N_0
02 MONTH
03 "
04 "
05 "
06 "
07 "
10 "
12 "
SECANT CONIC PROJECTION
0 miles 40
scale
0 kilometre 80

Figure 66

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of the scientific program of the National Bureau of Standards at laboratory centers in Washington, D. C., and Boulder, Colorado, is given in the following outline:

Washington, D.C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Application Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

Boulder, Colorado
BOULDER LABORATORIES
F. W. Brown, *Director*

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere. Ionosphere. Regular Propagation Services. Sun-Earth Relationships. VLF Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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