LRTAP 10/75

TRANSBORDER TRANSPORT OF AIR POLLUTANTS

BY

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KJELLER 25TH APRIL, 1975

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ABSTRACT

A simple trajectory model is used in order to estimate how the emission of SO_2 in one country influences the level of background pollution in each of the participating countries. The calculations include also the influences due to emission within countries not participating in the LRTAP PROJECT.

The transport budget depends on the choice of wind when computing the trajectories. Model estimates are therefore presented for calculations based on various winds between the surface layer and the 850 mb level.

INTRODUCTION

At the Gausdal meeting, in 1973, a short report was presented on an extremely simple back trajectory model. The emissions were divided in two categories: local emissions being less than 300 km away, and distant emissions being farther away. Neither wet nor dry deposition were considered to take place during the transport. The amplitudes of distant sources were therefore exaggerated incomparison to local sources, and consequently, only correlations were published. But the mean "weights" have some interest as a reference for the budget calculations presented in this report and in a preliminary report to the Steering Committee meeting in Paris 1974.

Fig. B1 shows that, on days with precipitation, the mean weights of distant sources are high over the continent and southern parts of the Nordic countries. The maximum in south-eastern Norway should be noticed. Fig. B2 shows the corresponding weights due to local emissions. The values

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are very low in Norway and in northern parts of the Nordic countries. High values should exist near the main emission sources.

For days without precipitation, the isolines are located more west to east, with a maximum over the continent, cf. Fig. B3. The local weights on Fig. B4 have a distribution similar to the one derived for days with precipitation.

A few correlations between scavenging of SO_4 (H^+) and precipitation times distant emission along a trajectory are given in Fig. B5. The correlations are in general best for wet deposition of H^+. Rather high values are found over Denmark and southeastern Norway in the two winters of 1972/73 and 1973/74.

The scavenging of SO_4 and H^+ depends on precipitation intensity, as demonstrated by the correlations of Fig. B6. The next figure, B7, shows that the concentrations of SO_4 and H^+ are well correlated in Norway, but not so well over the Continent.

CORRELATIONS BETWEEN POLLUTION AND NATIONAL EMISSIONS OF SO_2 -

Figs. 8 and 9, in the September 1974 report, indicated that the choice of transport wind would be a significant decision for the budget studies. Fig. B8 and B9 show the correlations between the scavenging of SO_4 and H^+ at N 01 and the estimated national SO_2 emission times the precipitation at N 01. The 850 mb trajectory estimates are well correlated to the emissions from the SSE-SW sector, while the surface trajectory estimates show high correlations in the ESE-S sector. This result is in agreement with climatological studies

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of the typical wind directions giving significant precipitation in southeastern Norway.

From Fig. B10, it may be concluded that high SO_2 concentrations ar DK 5 are associated with winds from the sector between SE and SW. A similar conclusion can be drawn by looking at the SO_2 correlations for NL 1, confer Fig. B11.

BUDGET STUDIES OF SO_2 BASED ON FOUR VARIANTS OF TRANSPORT WIND -

The selected value of $ko + k_1 = 2\ 10^{-5} s^{-1}$ is not an optimal choice. In this preliminary study, no difference was made between the decay of SO_2 whether it was precipitation or not. But, the authors consider the following sample budgets as indicators of the results to be expected in the more complete study which is to be carried out this autumn.

The budgets for station D 2 (Fig. B12), is interesting, as D 2 lies near the border to the countries outside the LRTAP project. It may be observed that all trajectory estimates give means close to the observed value. More than half of the computed SO_2 pollution is comming from the DPC region, consisting of the three countries DDR, Poland and Czechoslovakia. Between 31 and 42 per cent is comming from BRD itself. Only a few per cent is comming from each of the countries further to the west.

The budgets for NL 1 (Fig. B13) show that, according to the computations, between 52 and 73 per cent of the pollution is comming from BRD and Netherlands itself. But significant quantities are also comming from Belgium, DPC (see above) and U.K. The observed mean is close to the 850 mb estimate.

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The SO_2 budgets for UK 1 (Fig. B 14), show that most of the SO_2 is comming from domestic sources, the remainder comes from the countries across the Channel. The 850 mb mean agrees with the observed SO_2 mean.

The Finnish station of SF 3 lies also close to countries outside the LRTAP project. According to Fig. B 15, more than 50 per cent is due to domestic emissions, and another 30 to 40 per cent is comming from USSR sources. The 850 mb and "Clarke" trajectories indicate that there is also some influence due to SO_2 emissions in Sweden and DPC countries. All estimated means are much lower that the observed mean.

The budgets for S 4, see Fig. B 16, show that between 53 and 86 per cent arises from local sources. The remainder is comming from the countries around the North Sea, DPC region and USSR. The estimated means agree well with the observed mean.

According to Figure B 17, between 5 and 18 per cent of the average SO_2 at N01 come from domestic emissions. Around 10 per cent is coming from Sweden and about 20 per cent from each of U.K. and Denmark (if the surface trajectory estimates are neglected). Between 5 and 20 per cent is comming from DPC and another 10 per cent from BRD. The contributions from France, Belgium and Netherlands are each between 2 and 5 per cent. The computed means are all underestimates.

SO_4 on filter budgets have also been computed. This investigation was carried out before the studies by Jensen et al. (1975)*, and the choice of constants gave poor mean estimates. New computations will take place in the near future.

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* A summer Episode, Decay of SO_2 on Days with Precipitation and Preliminary Budget Studies (LRTAP 11/75) -

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Time budgets have also been prepared and Fig. B18 presents the budgets for N 01. 48 hours back trajectories are too short for low level winds, as can be seen from the hours spent over France or USSR.

The choice of decay constants are important for the SO_2 budgets. Fig. B 19 shows the budgets for the 48 hours back trajectories based on 850 mb and "Ekman" winds using $ko + k_1 = 10^{-5}s^{-1}$. The latter value is half the value used when comparing the budgets of Fig. B17. A slower decay reduces the impact of nearby sources and tends to increase the influence of remote sources.

SOME CONCLUDING REMARKS

During the past month, the trajecteory computations have been speeded up by replacing FORTRAN 4 codes by ASSEMBLY codes. It seems now possible to make budget calculations for as much as 500 selected points within the region considered by the LRTAP Project. If a consensus may be reached on the choice of deposition and conversion rates (a few sets only), budgets may be computed for the following quantities: SO_2, SO_4 (on filter), precipitated SO_4 and precipitated strong acid.

850 mb wind fields will be available for the whole period since July 1st, 1972. It is also possible to analyse a low level wind, either the "Ekman" wind or the surface wind. If this is done, budget calculations may possibly be carried out separately for high emissions and low emissions. It is then assumed that the high emission can be assessed with a reasonable precision.

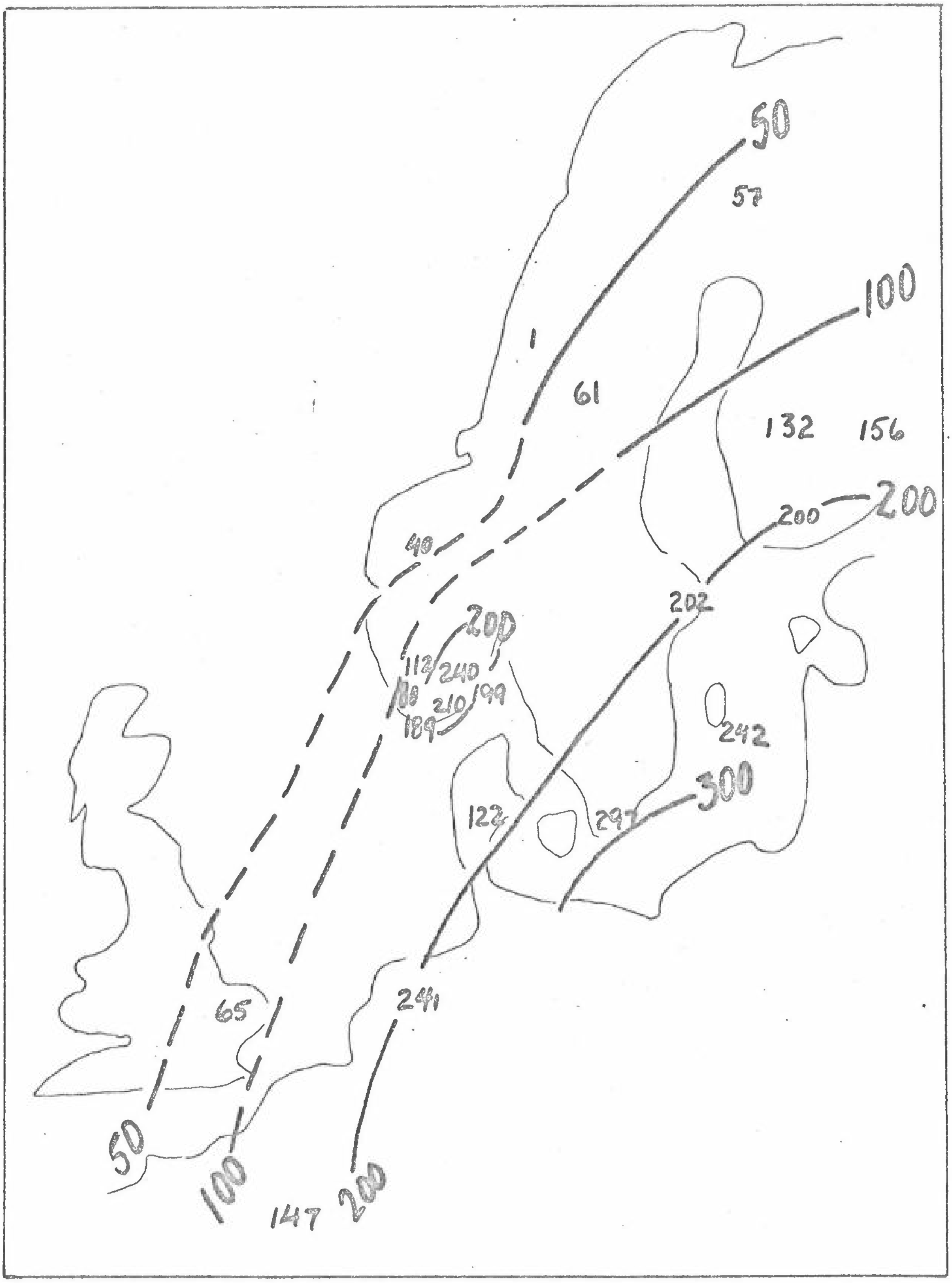

FIG. B1 NOV 72 - FEBR 73

MEAN WEIGHT OF DISTANT SOURCES
WHEN PRECIPITATION. 48 HOURS 850 MB
BACK TRAJECTORIES

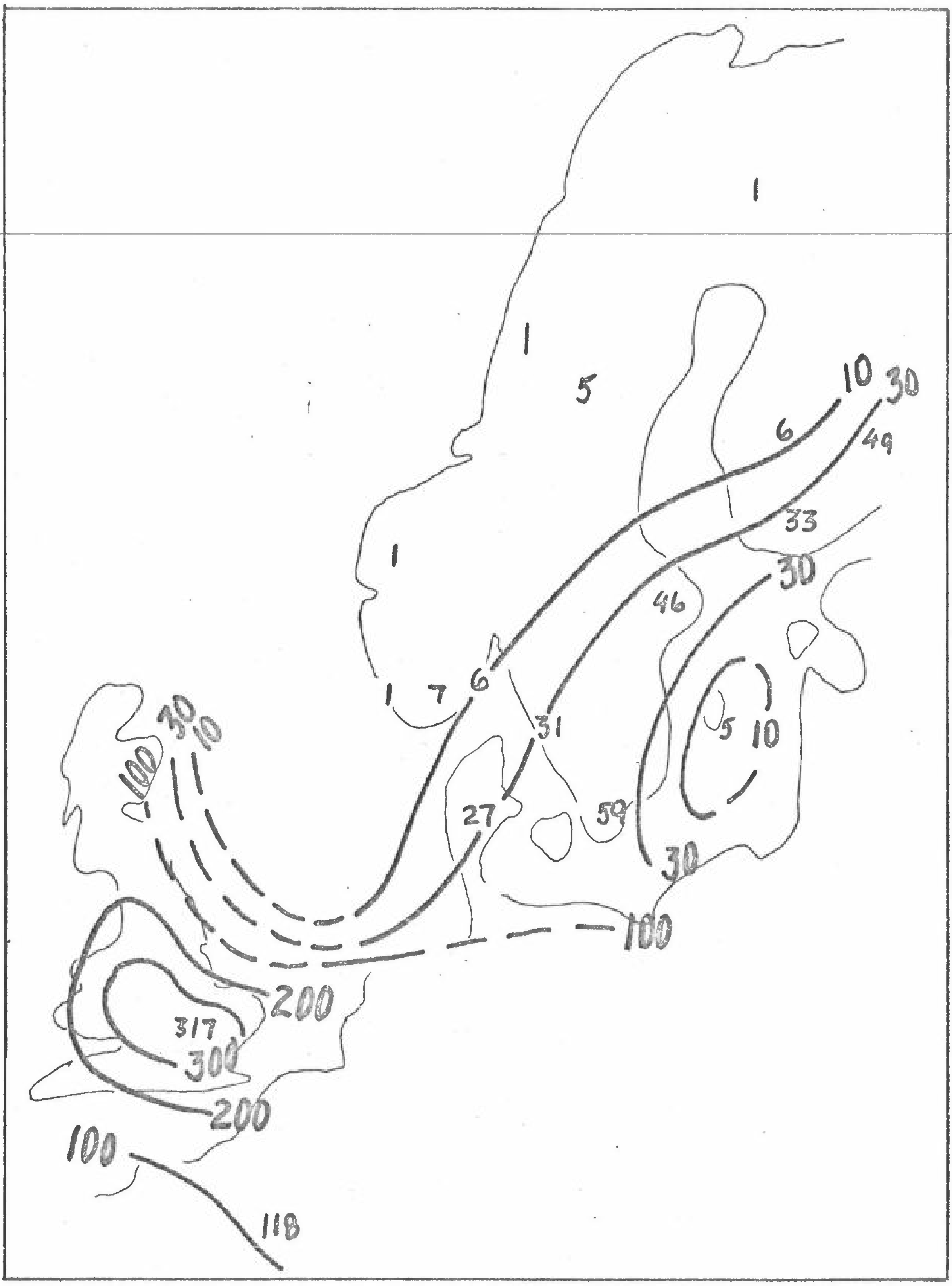

FIG. B2 NOV 72 - FEBR 73

MEAN WEIGHT OF LOCAL SOURCES WHEN
PRECIPITATION. 48 HOURS 850 MB
BACK TRAJECTORIES

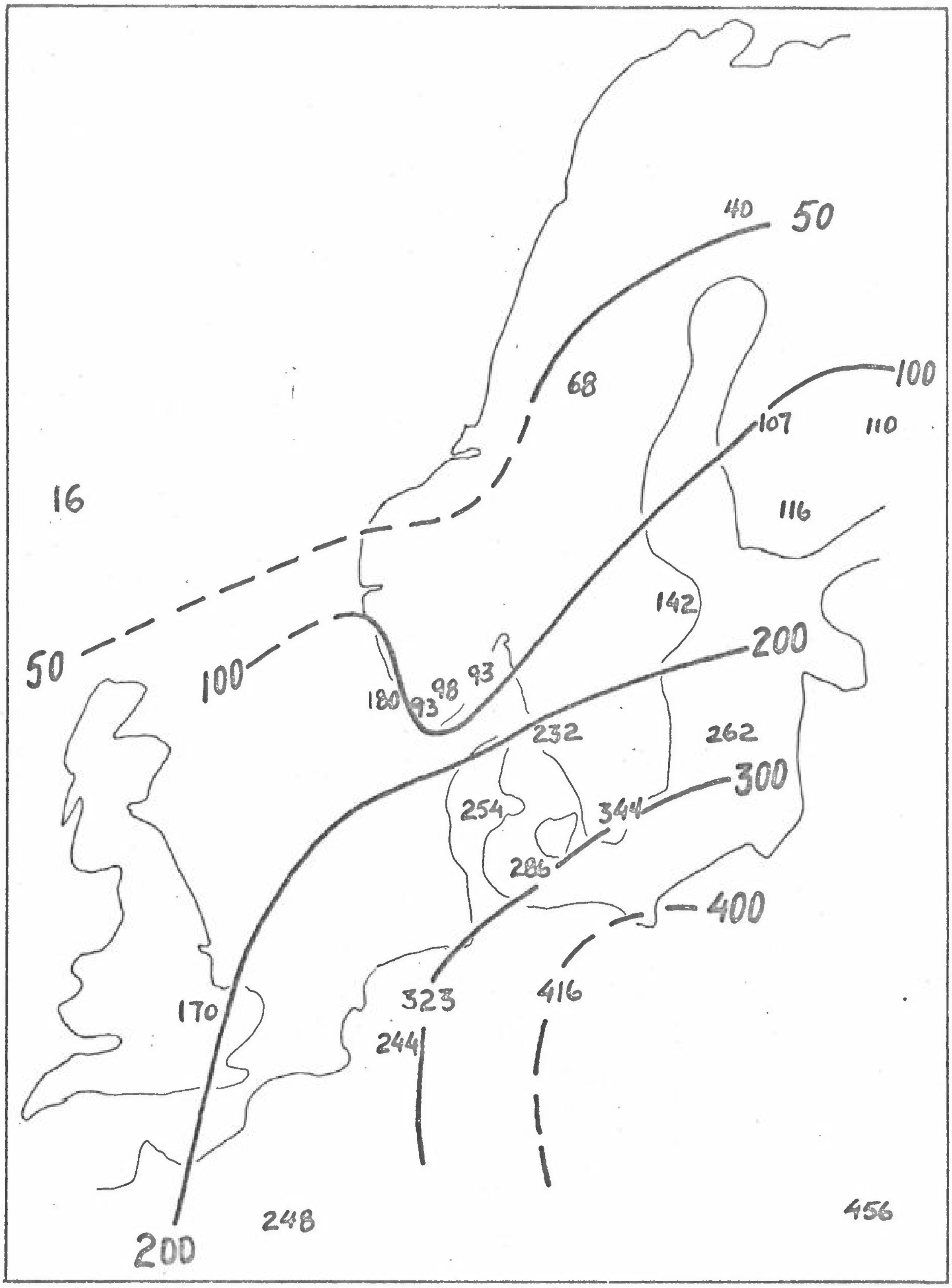

FIG. B3 NOV 72 - FEBR 73

MEAN WEIGHT OF DISTANT SOURCES
WHEN NO PRECIPITATION. 48 HOURS
850 MB BACK TRAJECTORIES

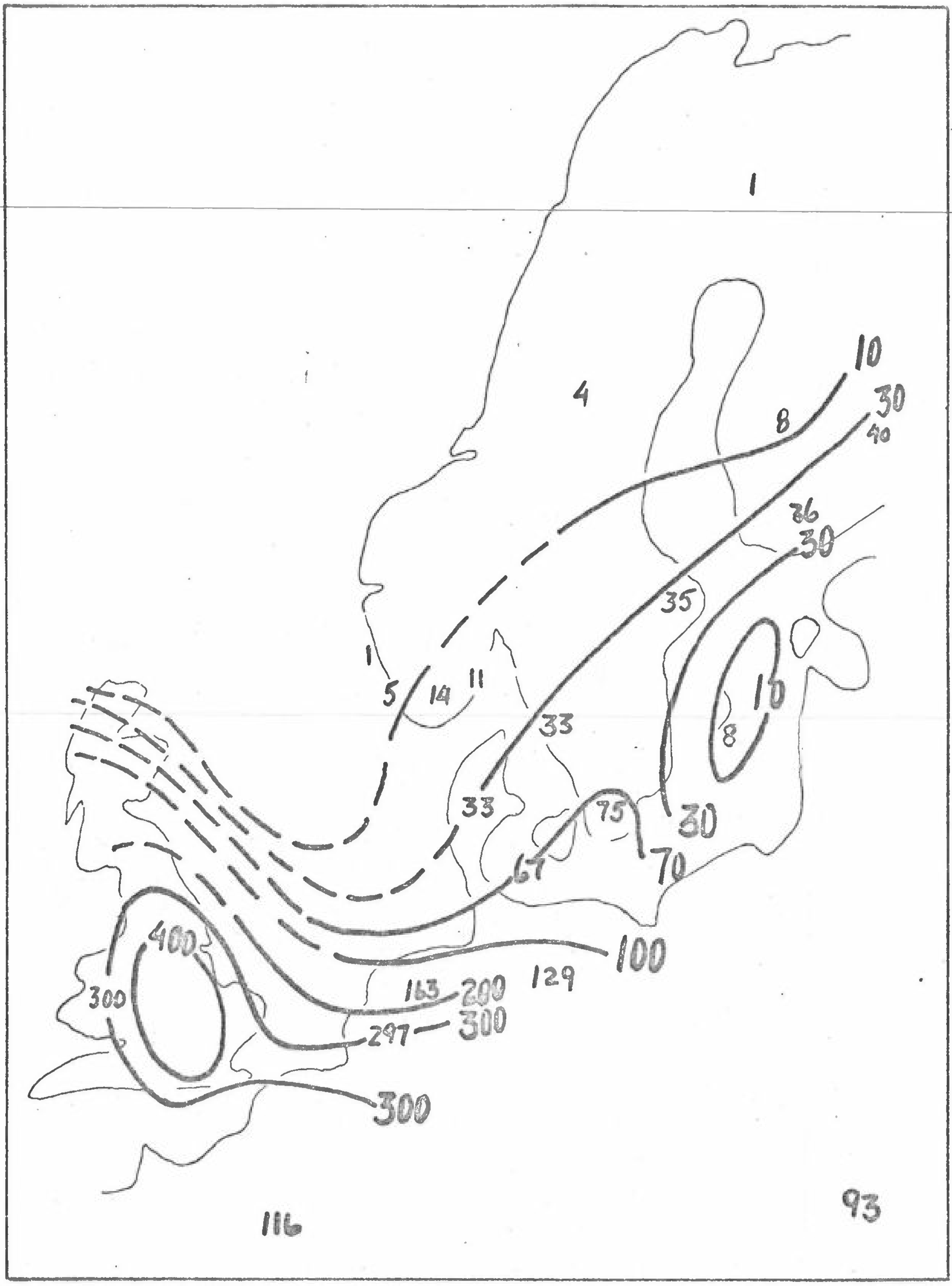

FIG. B4 NOV 72 - FEBR 73

MEAN WEIGHT OF LOCAL SOURCES
WHEN NO PRECIPITATION. 48 HOURS
850 MB BACK TRAJECTORIES

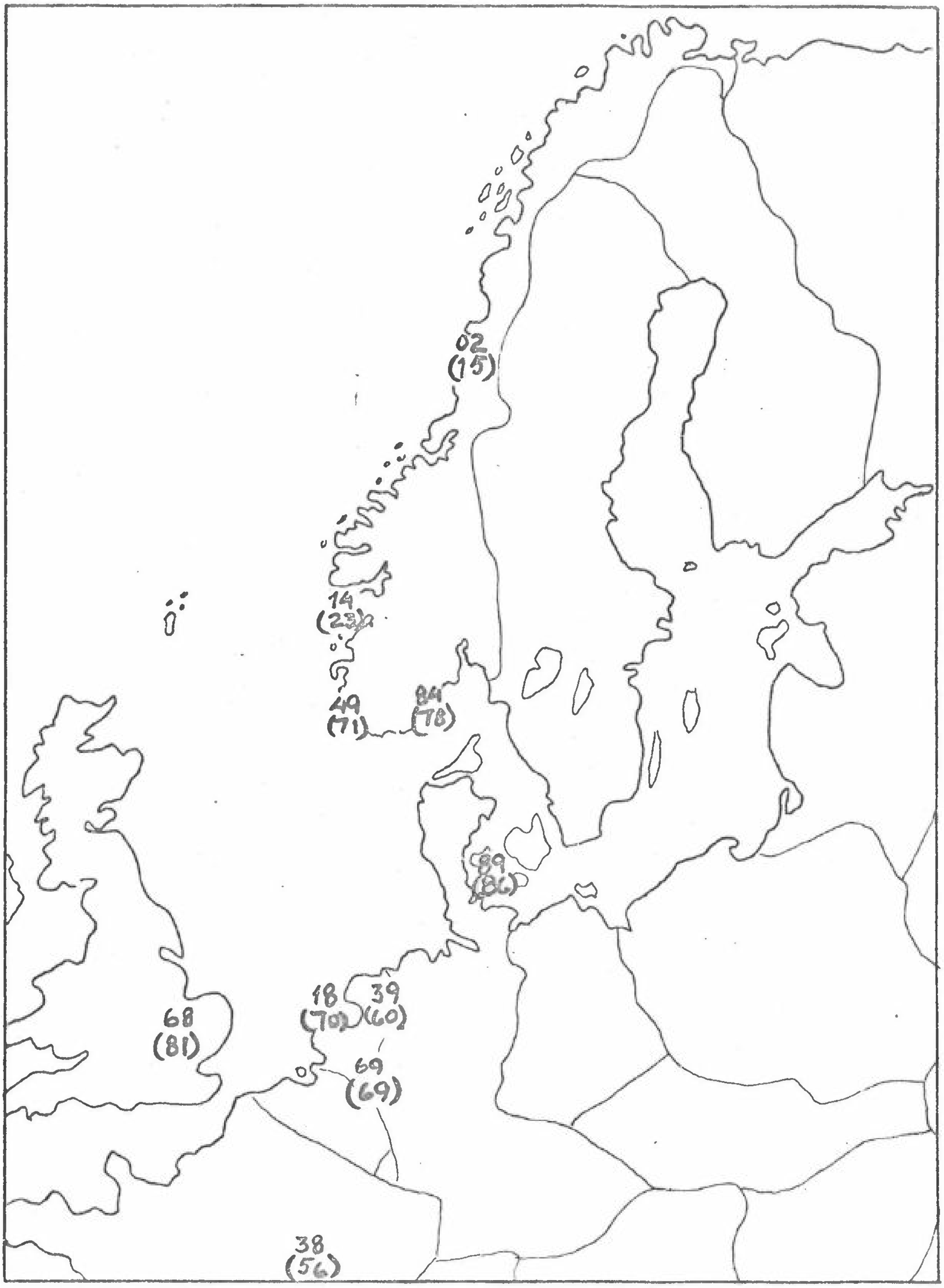

FIG. B5 TWO WINTERS, CORR. COEFFICIENTS BETWEEN WET DEP. OF SO_4 AND WET DEP. OF ΣQ_i DISTANT. THE CORRESP. CORR. FOR WET DEP. OF H^+ IS GIVEN IN BRACKETS (850 MB TRAJECTORIES)

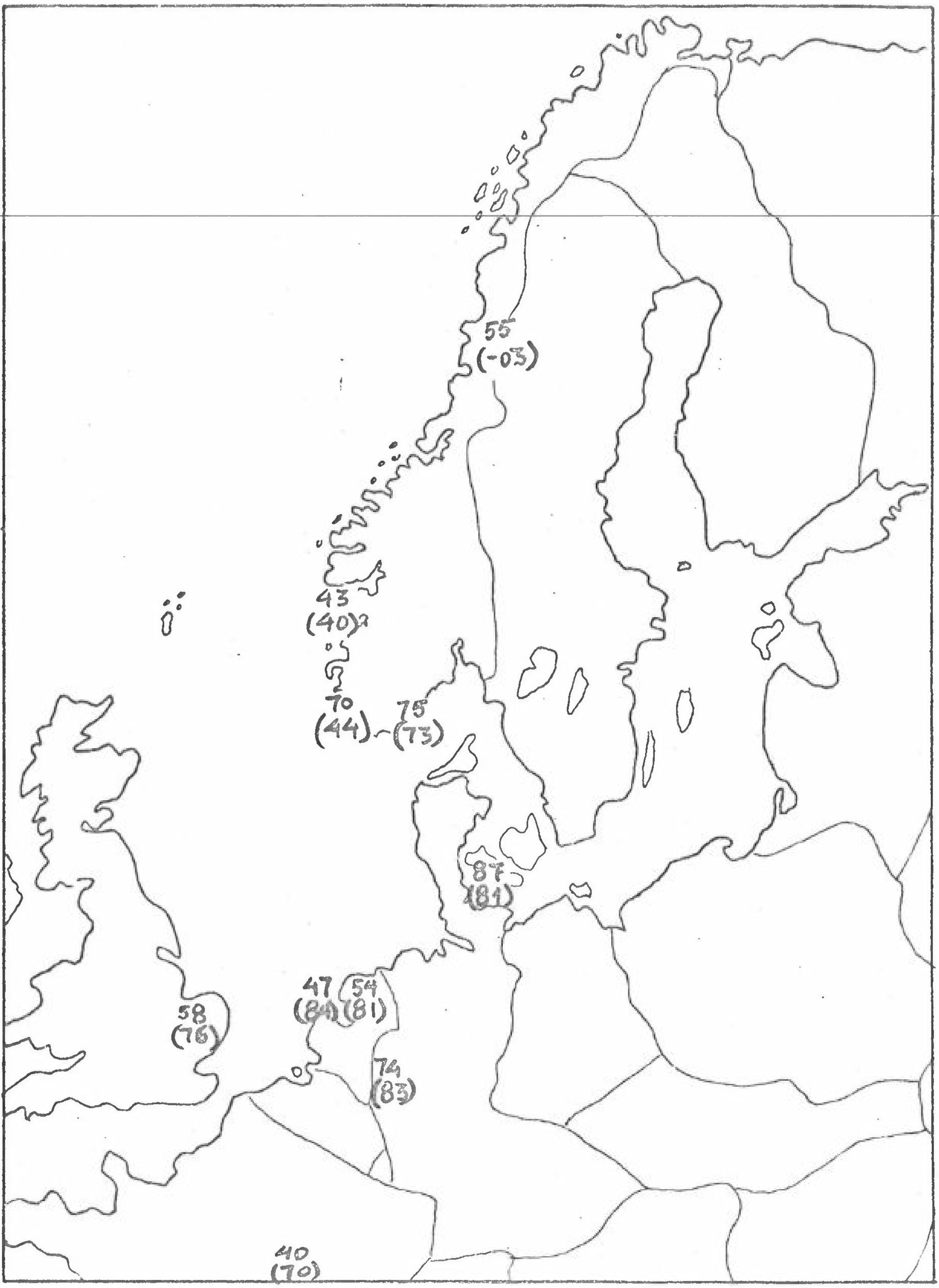

FIG. B6 TWO WINTERS
CORRELATIONS BETWEEN WET
DEPOSITION OF SO_4 (H^+) AND
PRECIPITATION, USING 850 MB
BACK TRAJECTORIES

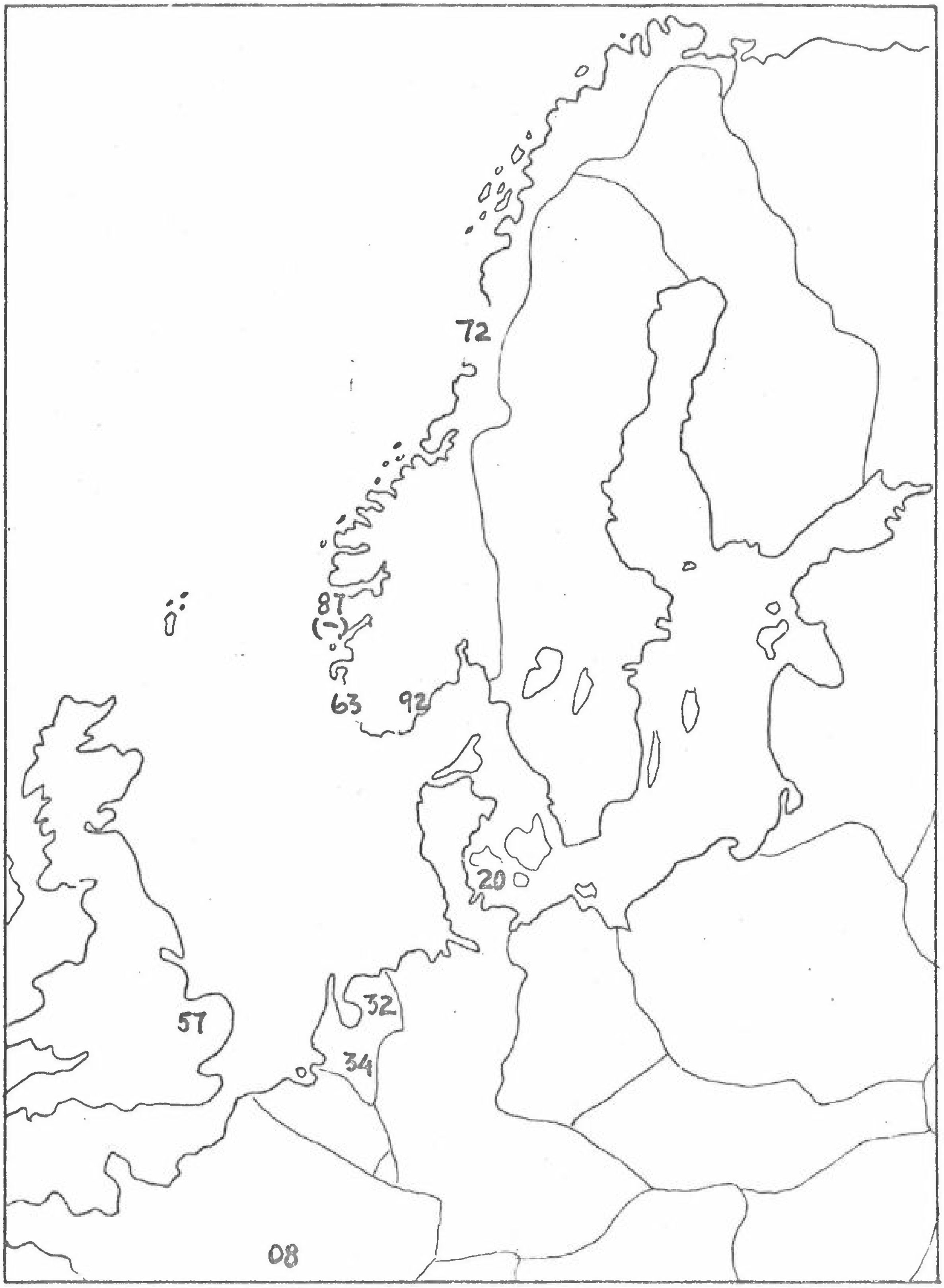

FIG. B7 TWO WINTERS
CORRELATIONS BETWEEN H^+ AND SO_4

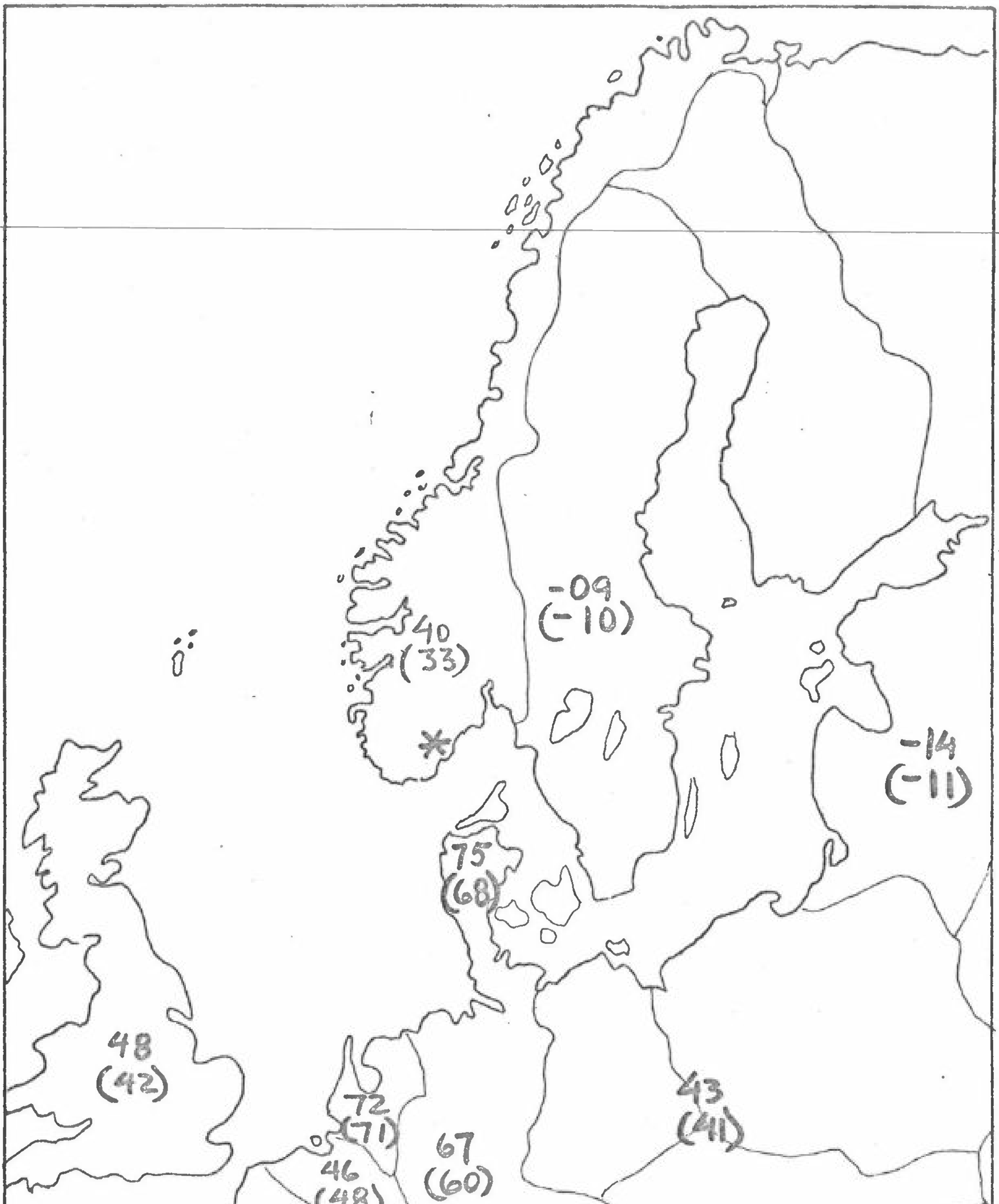

FIG. B8 DEC 73 - FEBR 74

CORRELATIONS BETWEEN SCAVENGING OF
SO_4 (H^+) ATN NO1 (*) OF SO_2
(USING 48 HOURS 850 MB BACK
TRAJECTORIES AND $k_0+k_1= 10^{-5}s^{-1}$)

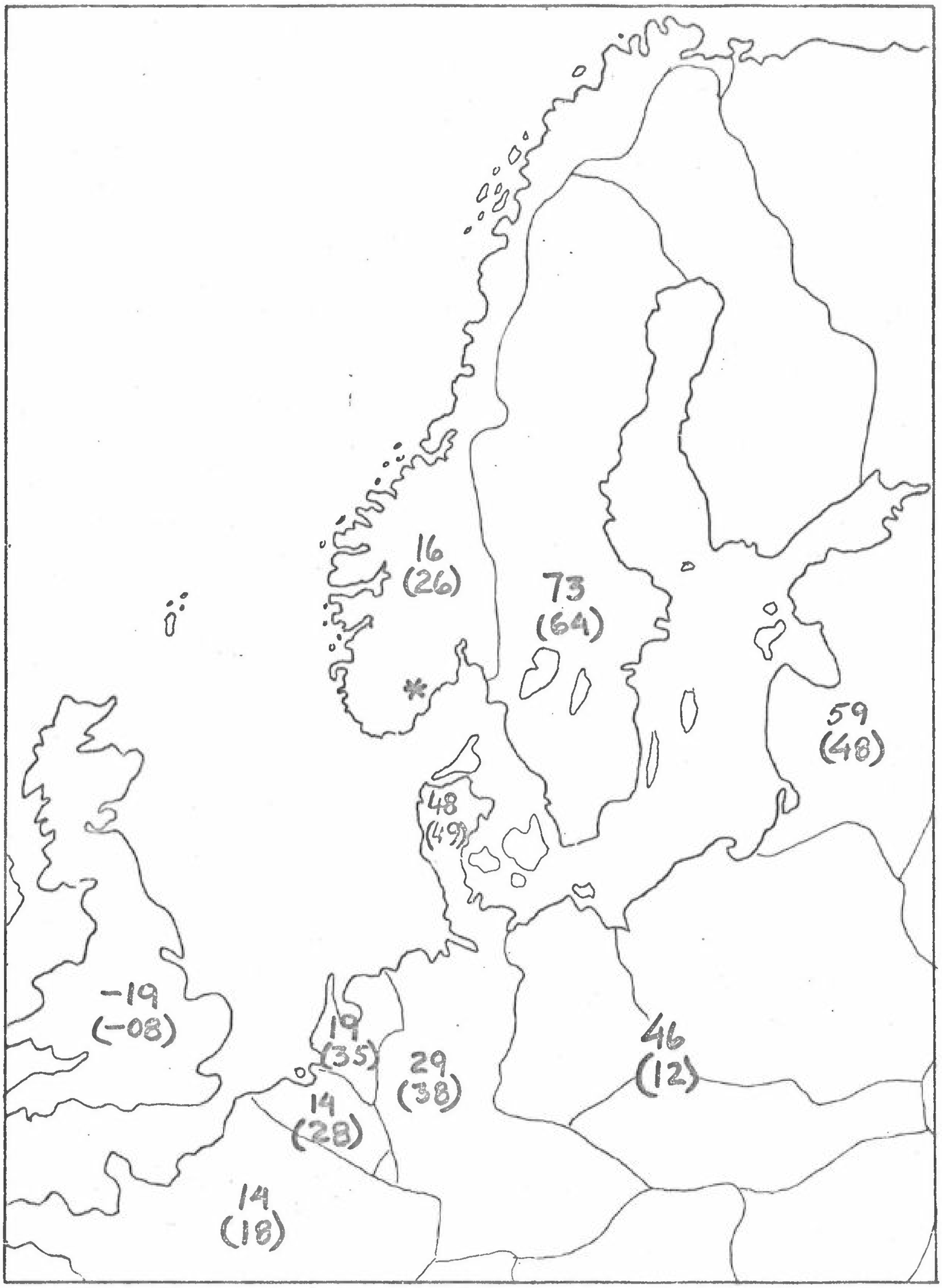

FIG. B9 DEC 73 - FEBR 74

CORRELATIONS BETWEEN SCAVENGING OF SO_4 (H^+) AT NO1 (*) AND CALCULATED CONTRIBUTIONS FROM NATIONAL EMISSIONS OF SO_2 (USING 96 HOURS SURFACE BACK TRAJECTORIES AND $k_0+k_1= 10^{-5}s^{-1}$)

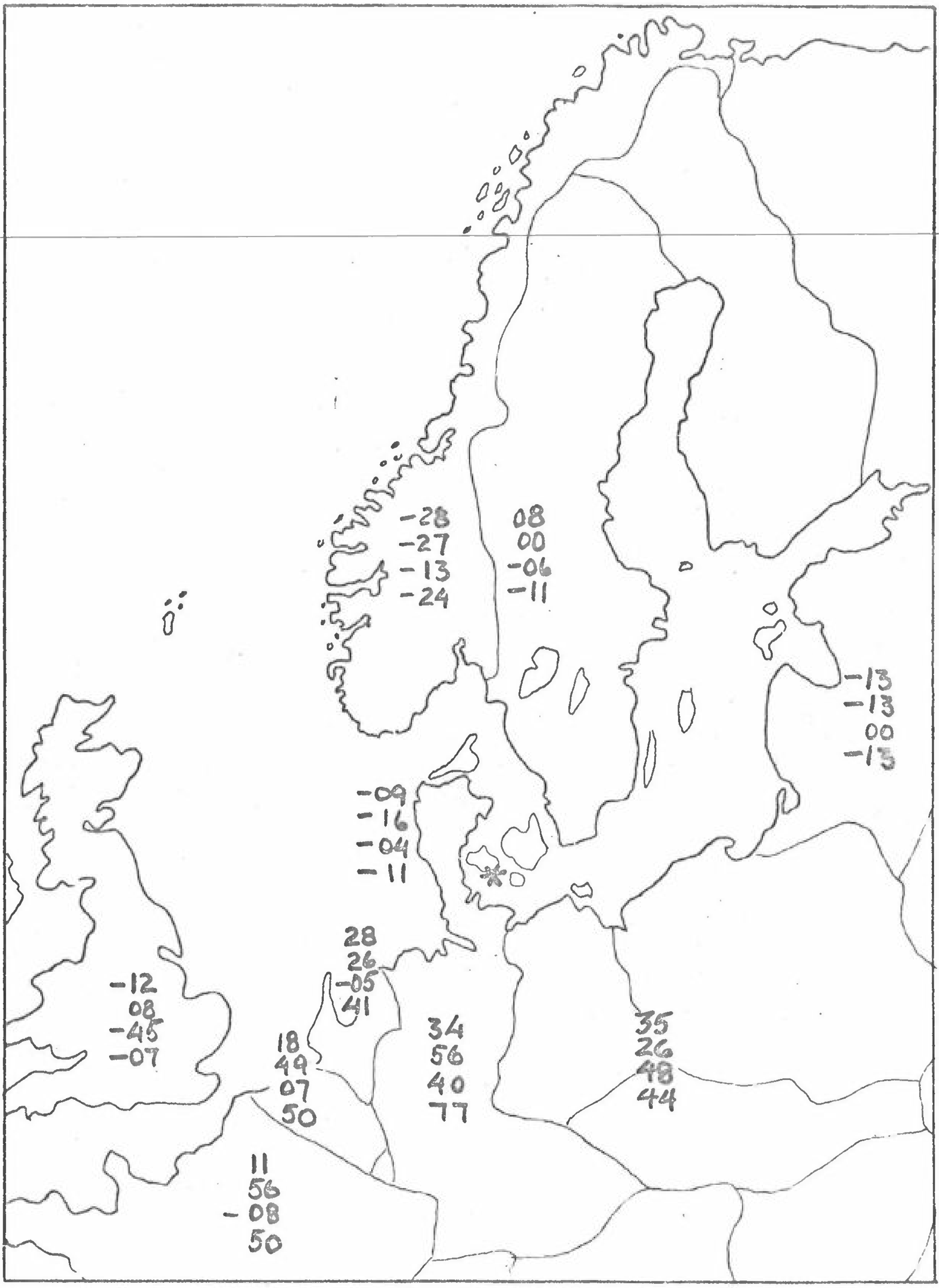

FIG. B10 DES 73 - FEBR 74

CORRELATIONS BETWEEN OBSERVED SO_2 AT DK5
AND ESTIMATES OF NATIONAL SO_2 EMISSIONS
USING $k_0 + k_1 = 10^{-5} s^{-1}$ AND

96 HOURS SURFACE BACK TRAJECTORIES, NO PRECIP. (UPPER ONE)
48 " 850 MB " " "
96 " SURFACE " " PRECIP.
48 " 850 MB " " "

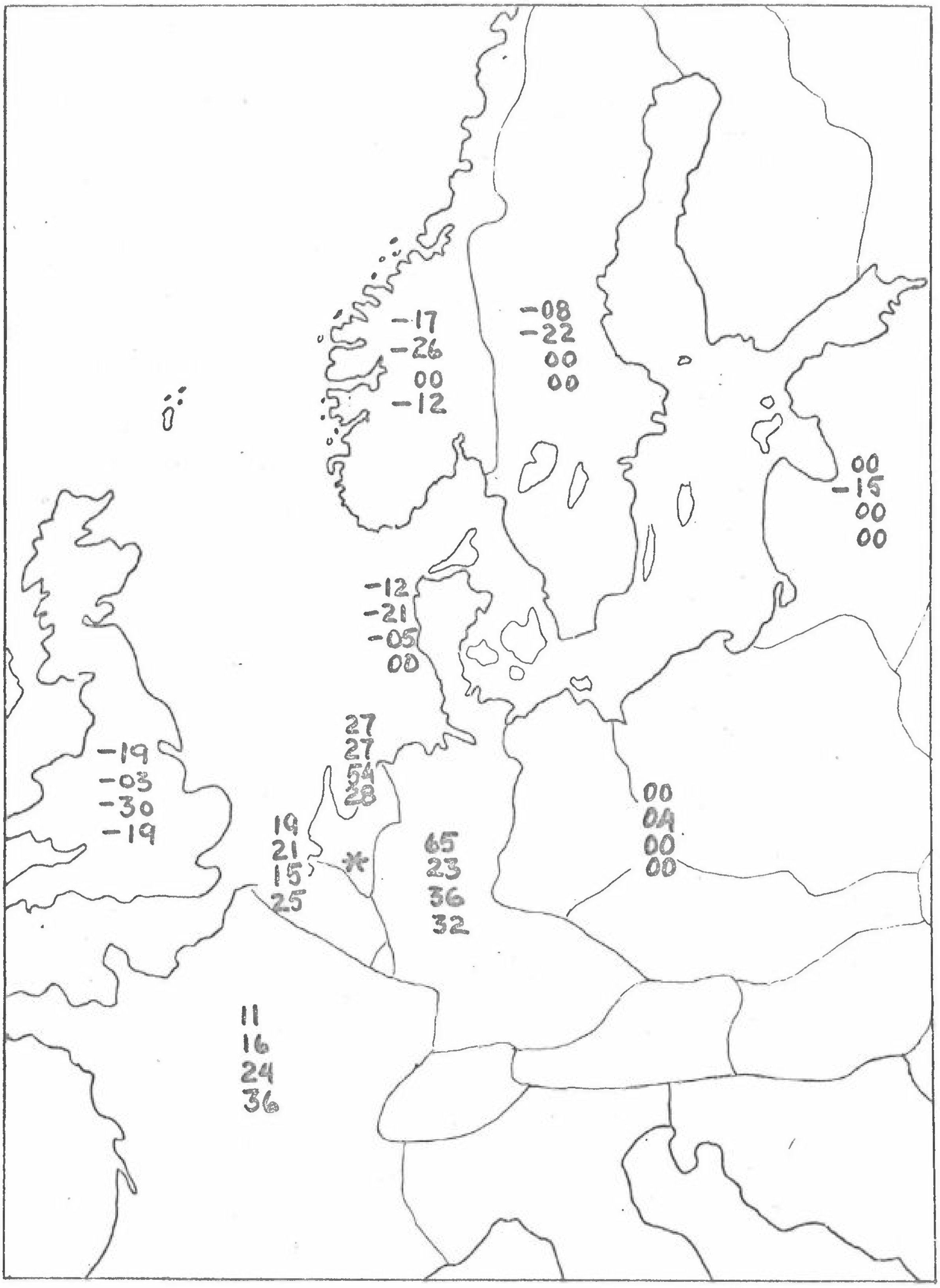

FIG. B11 DEC 73 - FEBR 74

CORRELATIONS BETWEEN OBSERVED SO_2 at NL 1
AND ESTIMATES OF NATIONAL SO_2 EMISSIONS
USING $k_o + k_1 = 10^{-5} s^{-1}$ AND
96 HOURS SURFACE BACK TRAJECTORIES, NO PRECIP. (UPPER ONE)
48 " 850 MB " " "
96 " SURFACE " " PRECIP.
48 " 850 MB " " "

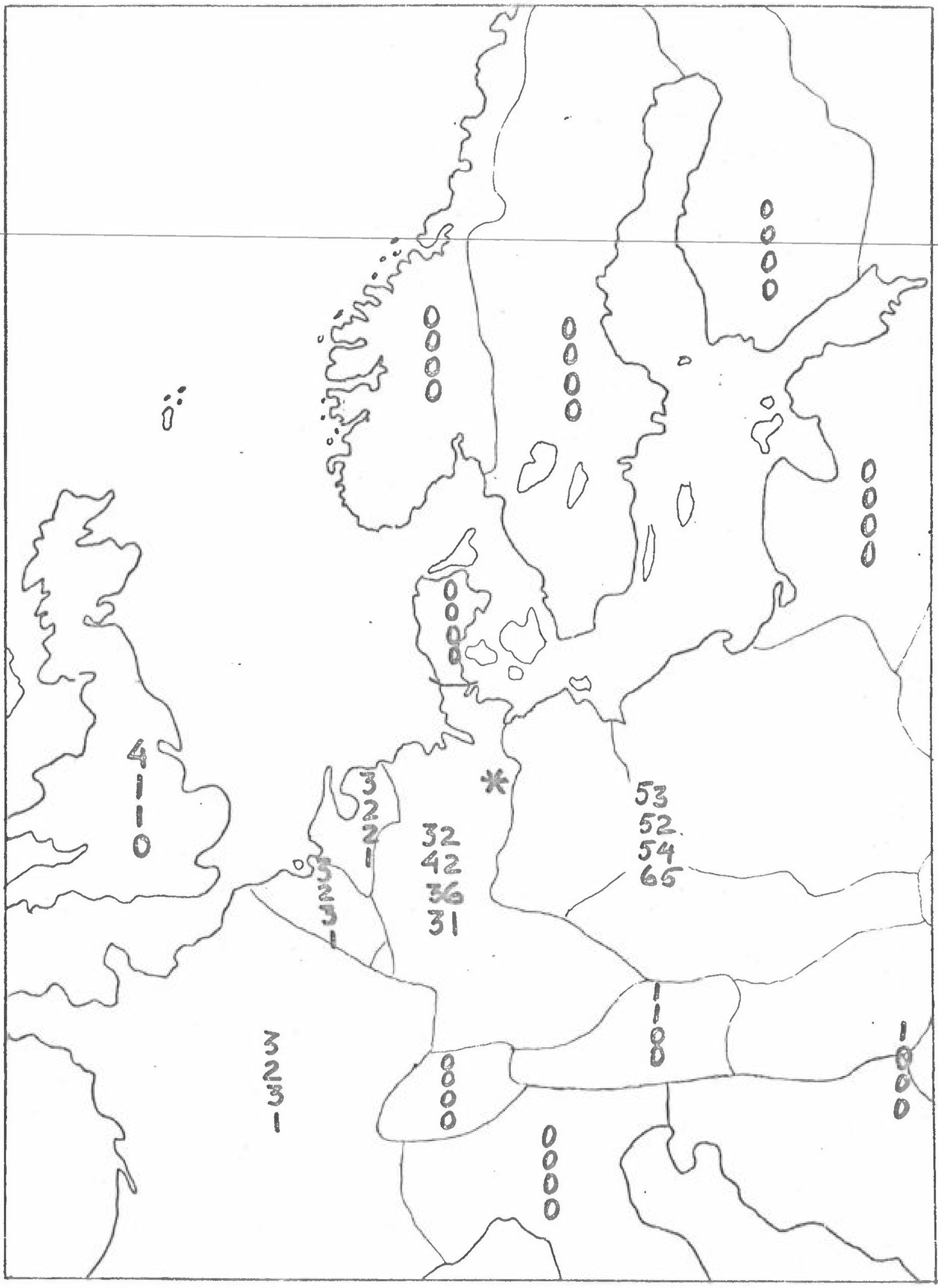

FIG. 12 DEC 73 - MARCH 74, SO_2 BUDGETS (%) FOR D 2 USING $k_0+k_1= 2.10^{-5}s^{-1}$

BACK TRAJECTORY ESTIMATES USING
850 MB WINDS, MEAN 38,2 (UPPER VALUE)
"EKMAN" " " 37,9
"CLARKE" " " 38,5
SURFACE " " 43,6

OBSERVED MEAN IS 38,0 ($\mu g/m^3$)

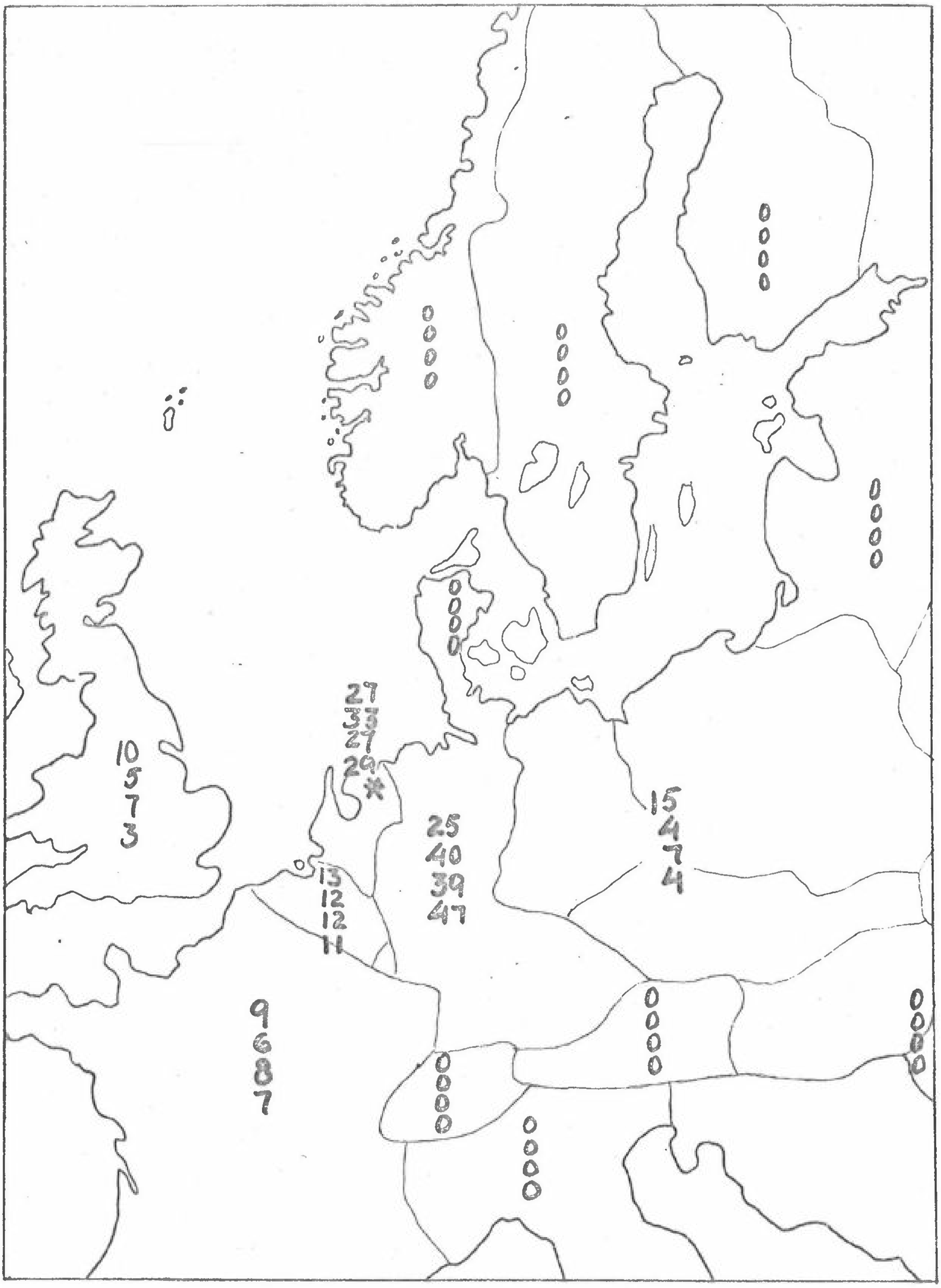

FIG. B13 DEC 73 - MARCH 74, SO_2 BUDGETS (%) FOR NL 2 USING $k_0+k_1= 2 \cdot 10^{-5} s^{-1}$

BACK TRAJECTORY ESTIMATES USING
850 MB WINDS, MEAN 27,7 (UPPER VALUE)
"EKMAN" " " 36,2
"CLARKE" " 35,9
SURFACE " " 39,5

OBSERVED MEAN IS 24,1 (μg/m^3)

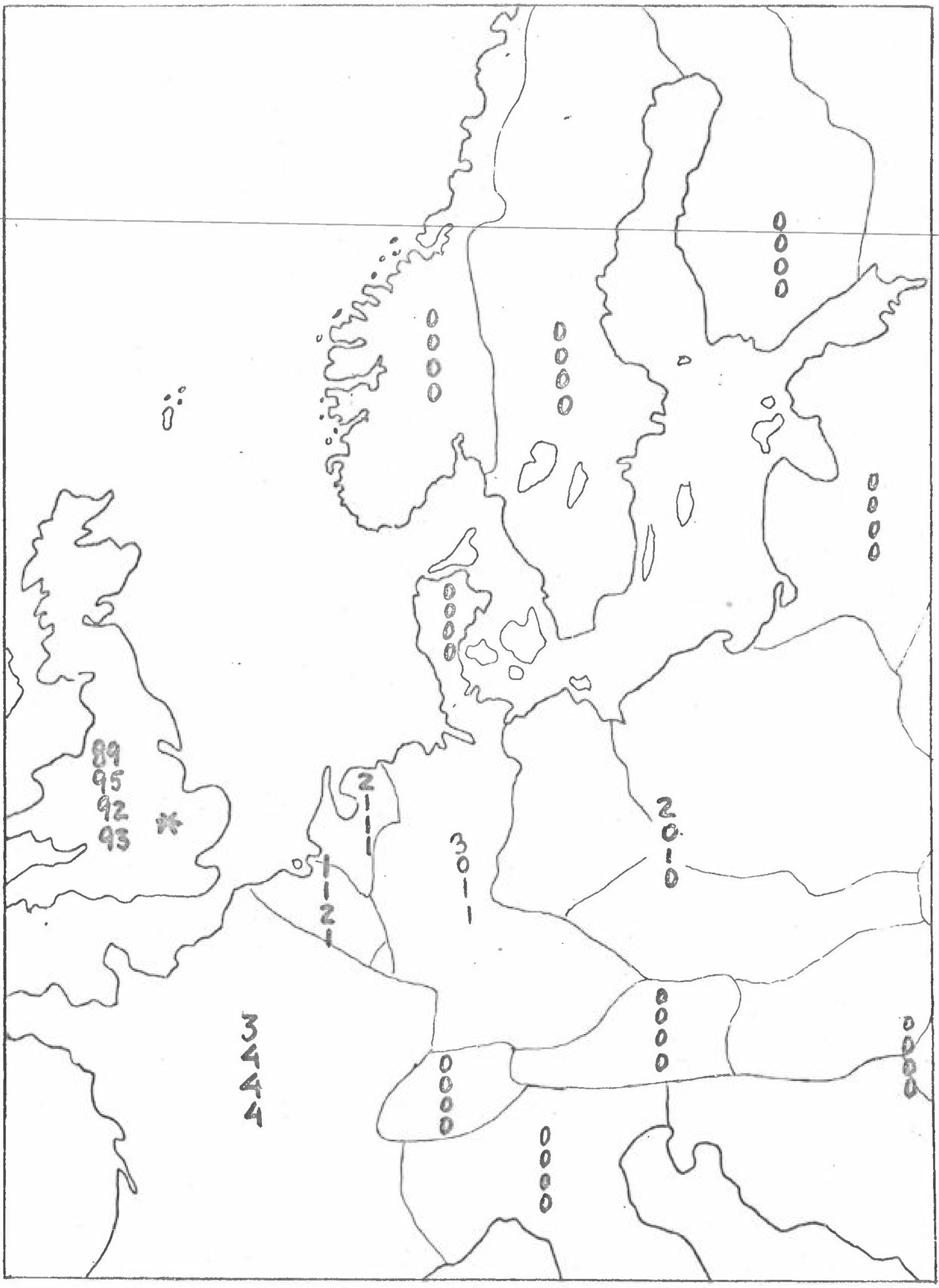

FIG. B14 DEC 73 - MARCH 74, SO_2 BUDGETS (%)
FOR UK 1 USING $k_0+k_1= 2\cdot 10^{-5}s^{-1}$

BACK TRAJECTORY ESTIMATES USING
850 MB WINDS, MEAN 27,7 (UPPER VALUE)
"EKMAN" " " 42,7
"CLARKE" " " 38,3
SURFACE " " 43,8

OBSERVED MEAN IS 29,0 $(\mu g/m^3)$

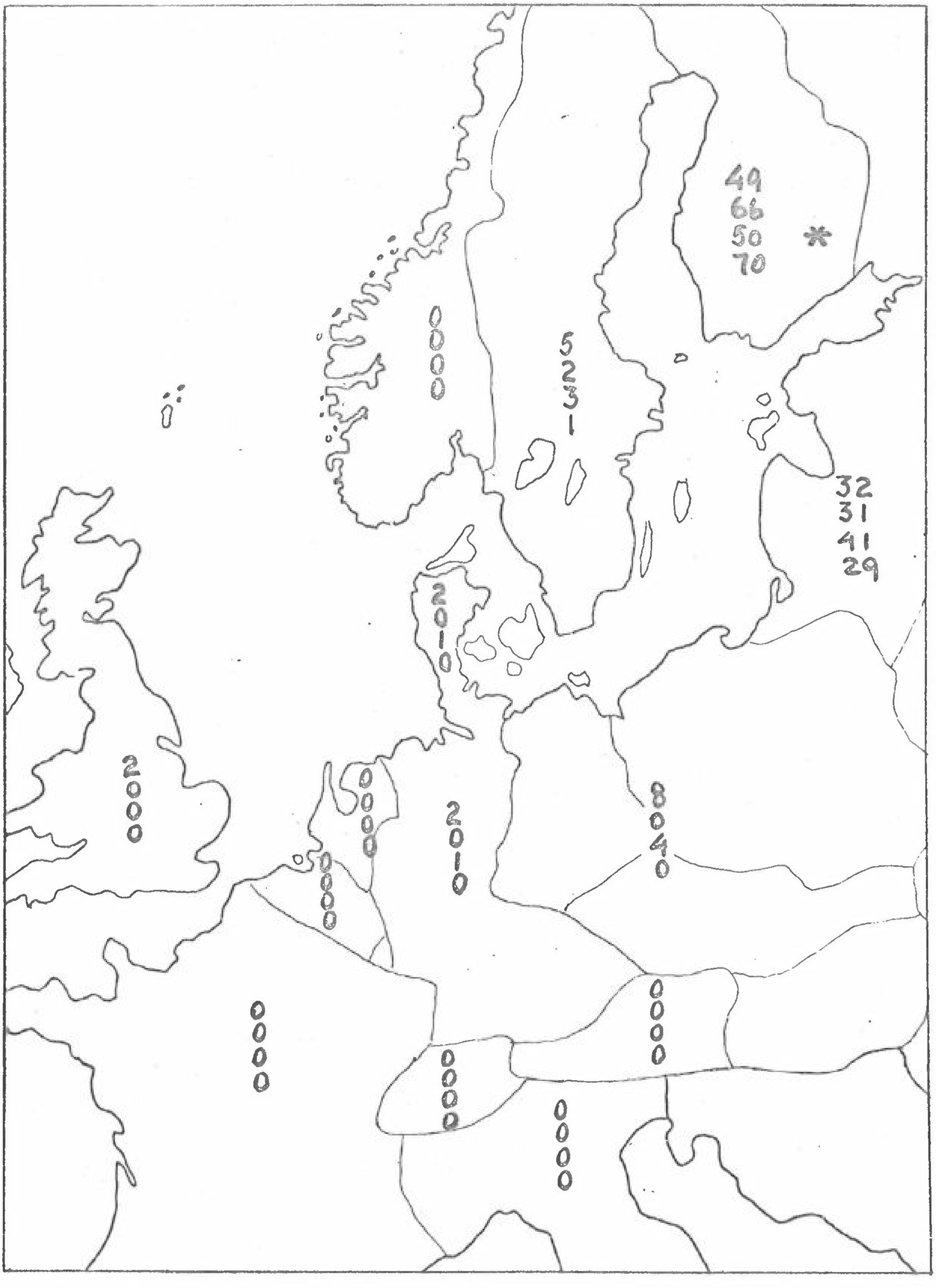

FIG. B15 DEC 73 - MARCH 74, SO_2 BUDGETS (%)
FOR SF 3 USING $k_0+k_1= 2\cdot10^{-5}s^{-1}$

BACK TRAJECTORY ESTIMATES USING
850 MB WINDS, MEAN 5,9 (UPPER VALUE)
"EKMAN" " " 6,5
"CLARKE" " " 7,2
SURFACE " " 7,2
OBSERVED MEAN IS 16,1 (μg/m³)

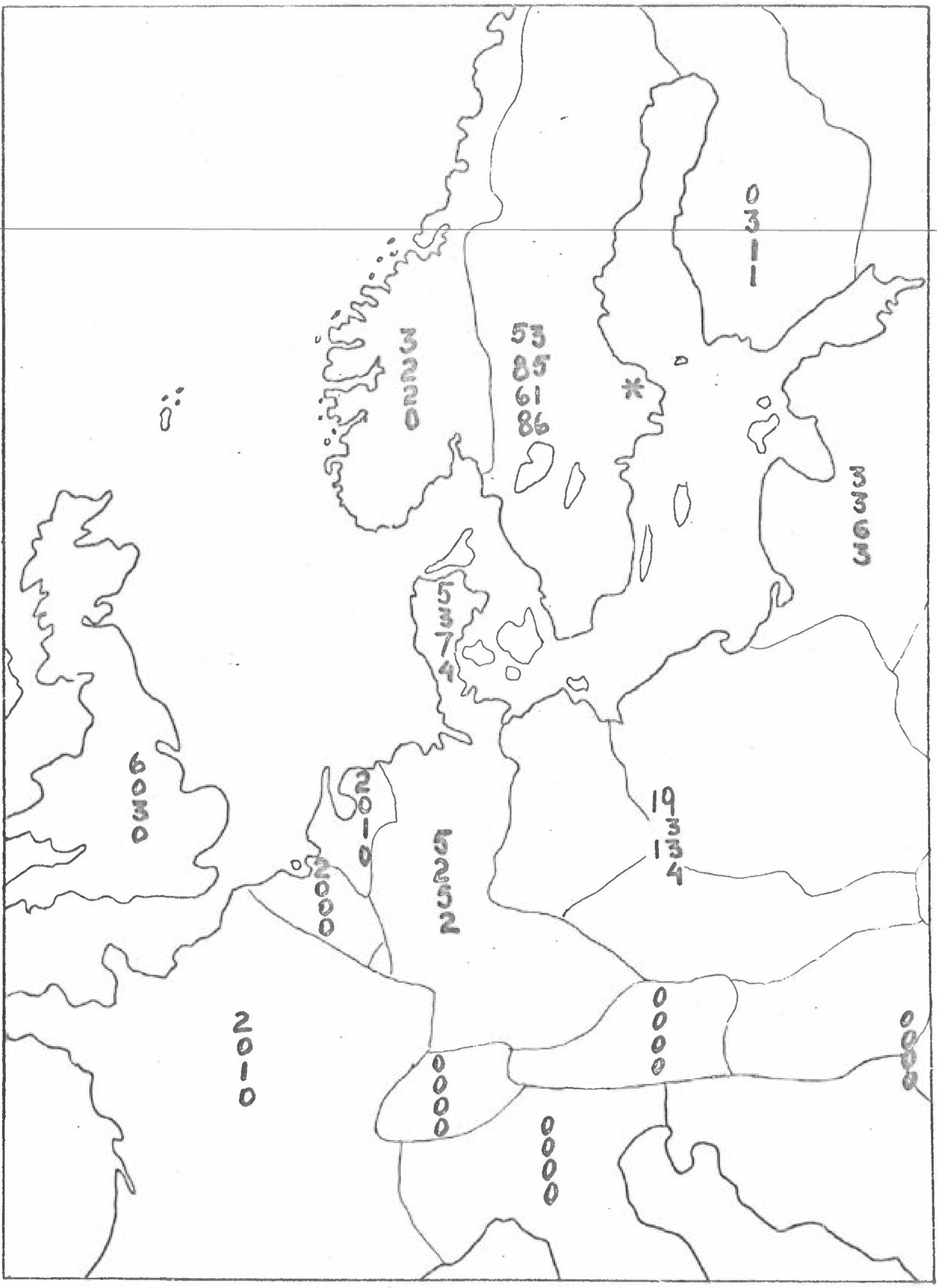

FIG. B16 DEC 73 - MARCH 74, SO_2 BUDGETS (%)
FOR S 4 USING $k_0+k_1= 2.10^{-5}s^{-1}$

BACK TRAJECTORY ESTIMATES USING
850 MB WINDS, MEANS 6,2 (UPPER VALUE)
"EKMAN" " " 5,8
"CLARKE" " " 6,6
SURFACE " " 6,5
OBSERVED MEAN IS 5,5 ($\mu g/m^3$)

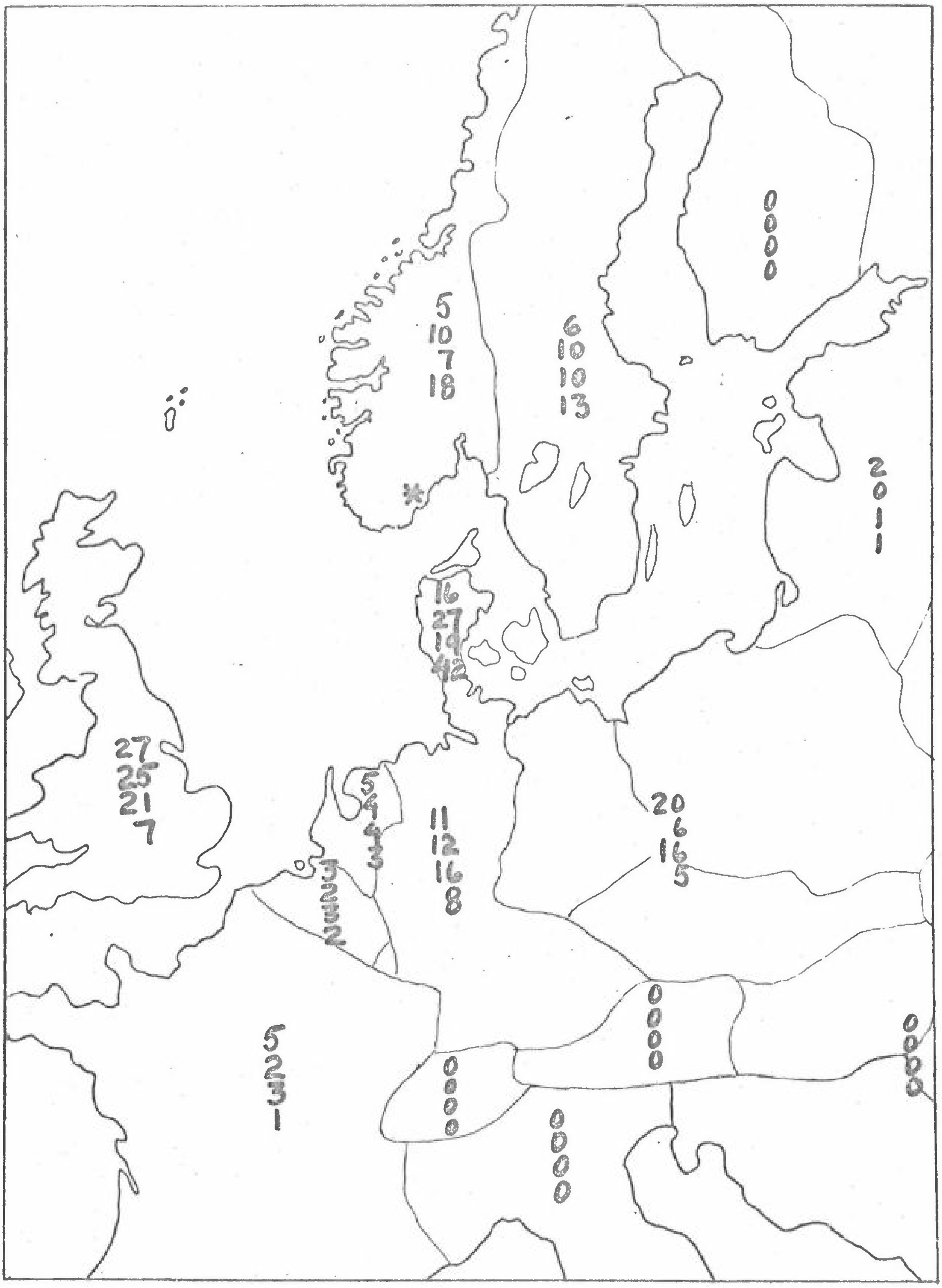

FIG. B17 DEC 73 - MARCH 74, SO_2 BUDGETS (%) FOR NO1 USING $k_0+k_1 = 2.10^{-5}s^{-1}$

BACK TRAJECTORY ESTIMATES USING
850 MB WINDS, MEAN 6,4 (UPPER VALUE)
"EKMAN" " " 5,2
"CLARKE"" " 6,6
SURFACE " " 4,1
OBSERVED MEAN IS 9.0 ($\mu g/m^3$)

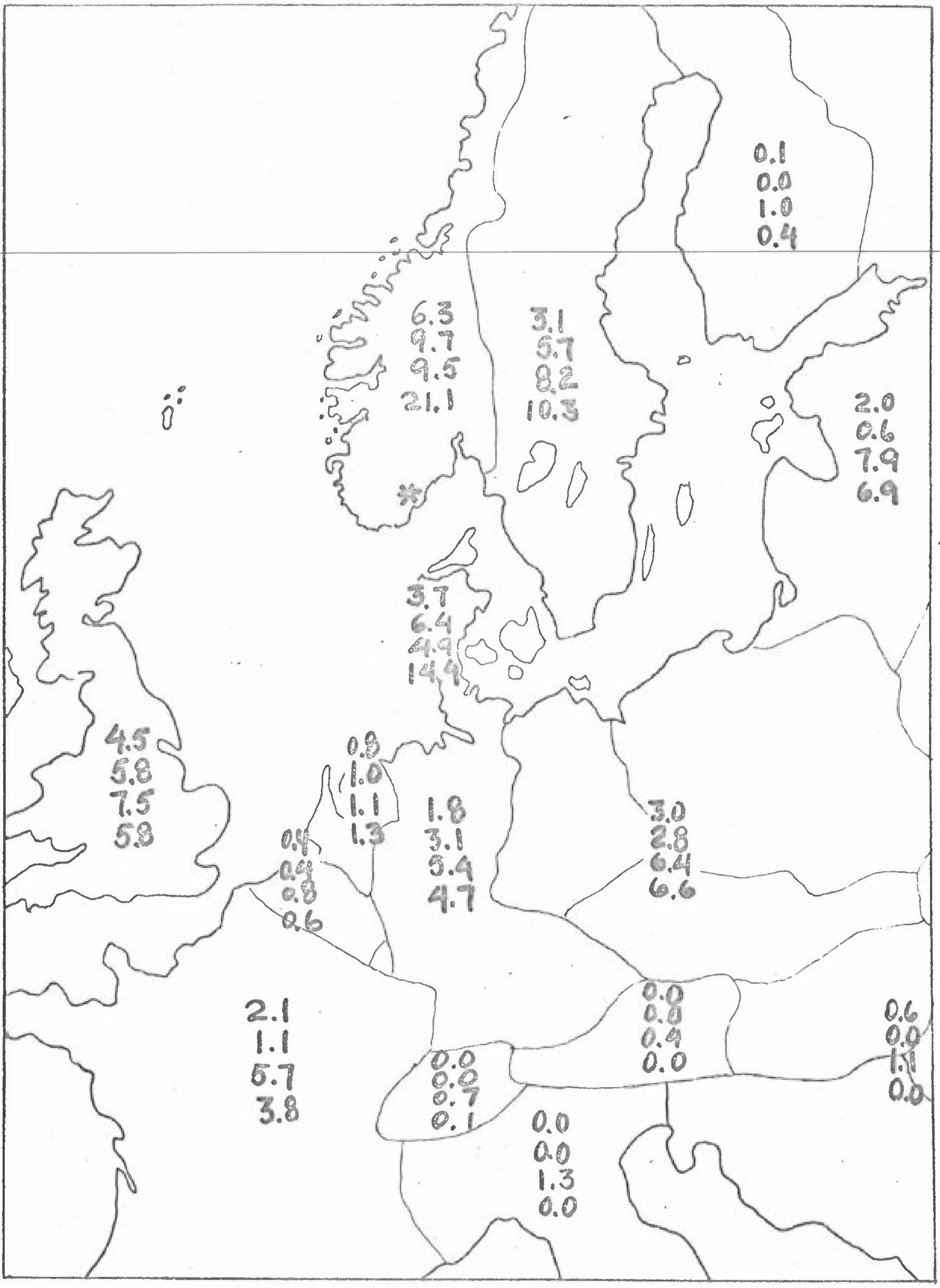

FIG B18 DEC 73 - MARCH 74

AVERAGE NUMBER OF HOURS
SPENT IN EACH COUNTRY
(OR GROUP OF COUNTRIES)
FOR BACK TRAJECTORIES AT NO1
UPPER VALUE REFERS TO 48 HOURS BACK 850 MB TRAJECTORIES
NEXT " " 48 " " "EKMAN" "
THIRD " " 96 " " "CLARKE" "
LOWER " " 96 " " SURFACE

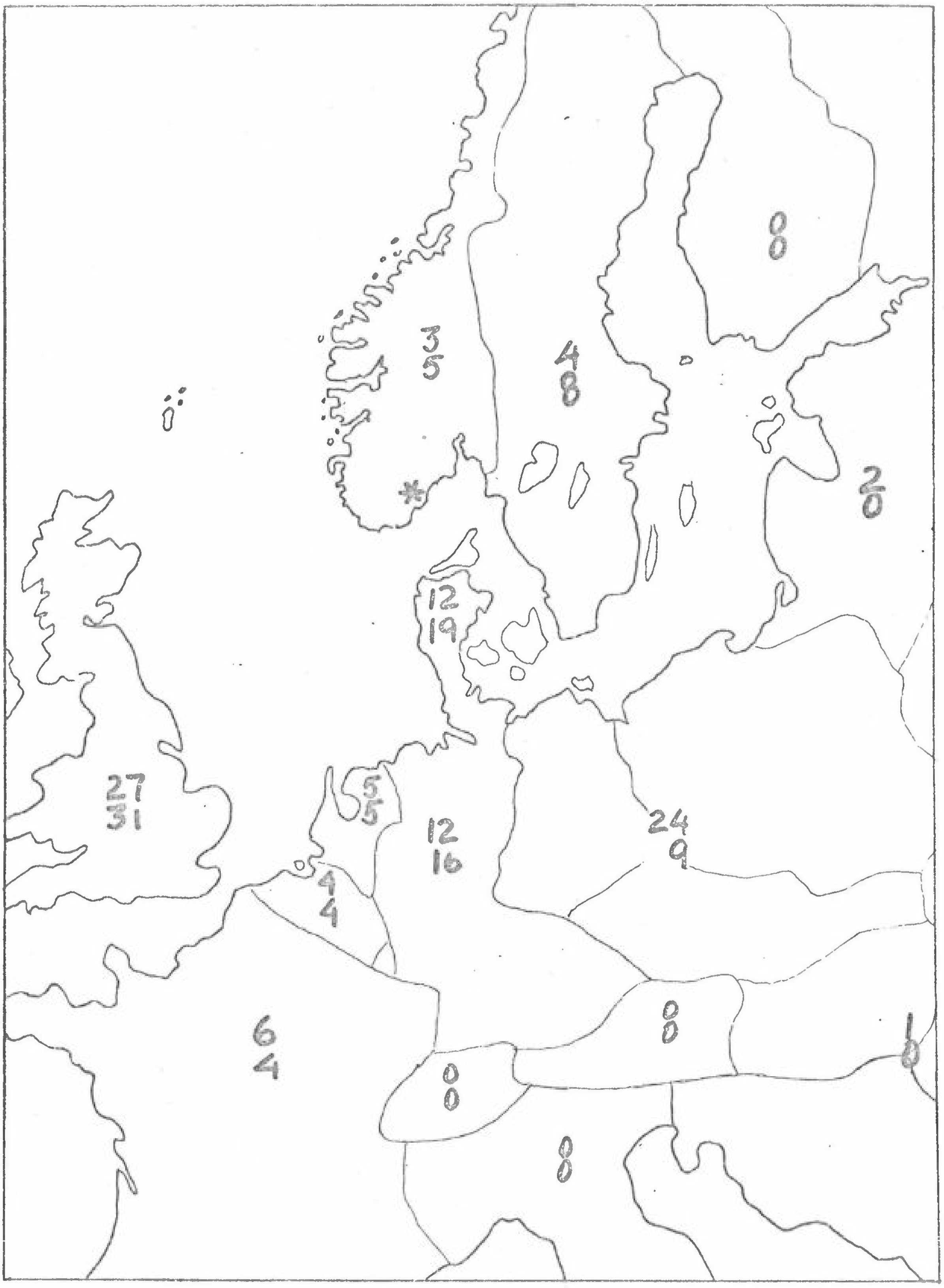

FIG. B19 DEC 73 - MARCH 74, SO$_2$ BUDGETS (%) FOR NO1 USING $k_0+k_1= 10^{-5}s^{-1}$

BACK TRAJECTORY ESTIMATES USING
850 MB WINDS, MEAN 13,2 (UPPER VALUE)
"EKMAN" " " 12,7

OBSERVED MEAN IS 9,0 (μg/m³)