LTRAP 11/75

A SUMMER EPISODE, DECAY OF SO_2 ON DAYS WITH PRECIPITATION AND PRELIMINARY BUDGET STUDIES

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In the following, some results from recent data evaluations are given.

INTRODUCTION

The selection of examples should not be taken as an indication of CCU priorities, but as interesting cases from the scientific point of view, and as illustrations of some of the problems involved in estimating export/import budgets for various areas. Figure 8-11 in particular do not represent conclusions from the CCU.

EPISODE STUDIES

Most of the episodes discussed earlier occured in winter, fall and spring. During August 26th, southerly winds prevailed over the North Sea and Skagerrak according to the 850 mb back trajectories of Figure 1.

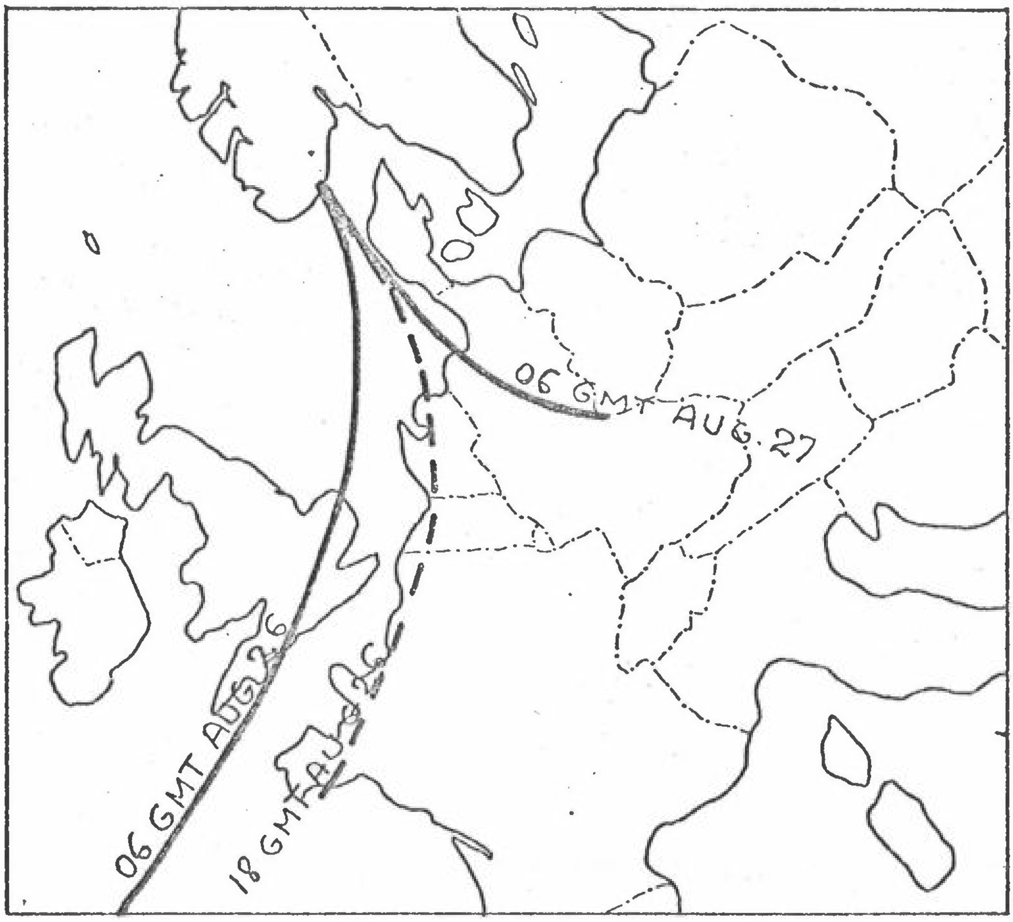

Figure 1

A frontal zone was lying along southern Norway, and vertical displacements in connection with the front and the topography released convective instability. Heavy thunderstorm acitivity occurred along the slopes and the top of the mountain range. The 24 hours rainfall figures are given in Figure 2. We notice one maximum zone along the steep mountain slopes of western Norway. The other maximum zone lies along the divide. The rainfall is modest near the coast of southeastern Norway, and the precipitation distribution deviates much from the patterns which are typical for the winter season. The acidity was high with pH less than 4.0 along the divide, cf. Figure 3. The corresponding scavenging of strong acid is shown in Figure 4. Values of 3 milliequivalences per m^2 are found along the most elevated part of southern Norway. Another maximum is found on the west coast. The wet deposition of sulphate is given on Figure 5. The major maximum lies again along the divide, but a secondary maximum is indicated along the west coast.

This episode was predicted, and the NILU aircraft was scheduled to take samples of a continental "plume" which was predicted to reach Norway late on August 26th. The aircraft measurements were carried out near noon, and are encircled on Figures 6 and 7. The routine calculations of SO_2 and SO_4 (on filters) are reproduced in Figures 6 and 7. The model used is the one-layer Lagrangian model of Eliassen and Saltbones. The sharp gradients along the western coast of Sweden are verified by the aircraft data, but the sulphate concentrations are somewhat overestimated.

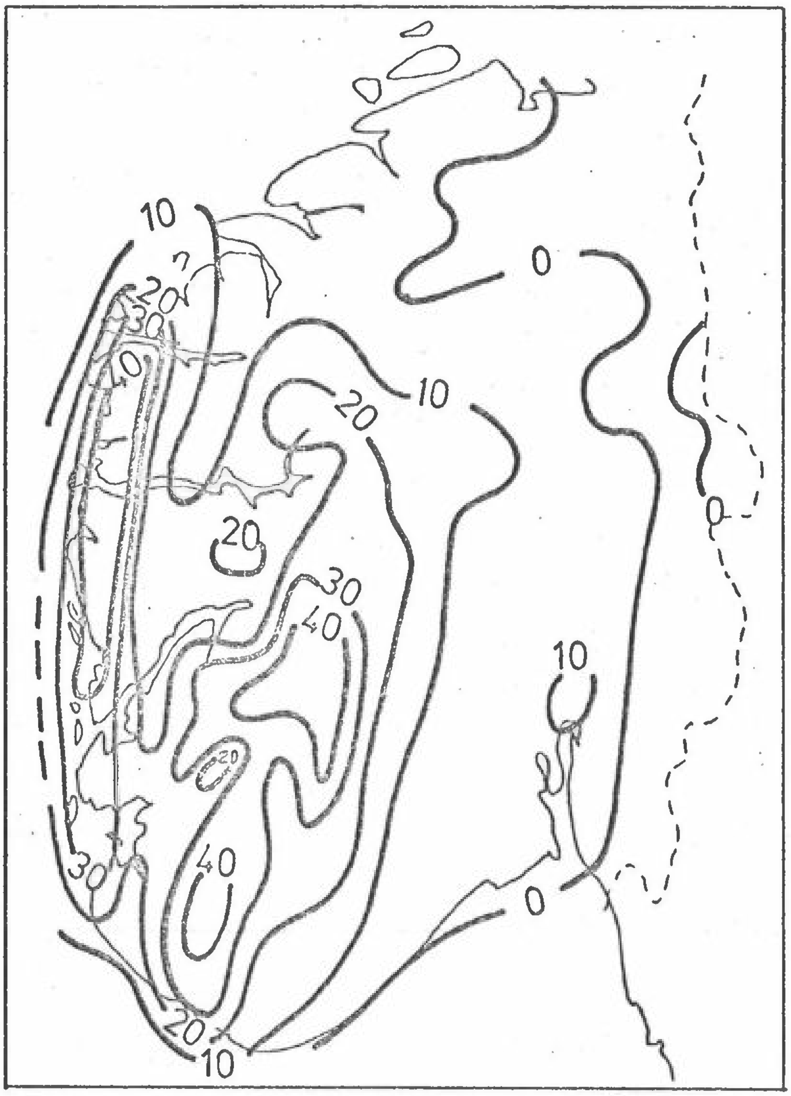

Figure 2: 24 hours rainfall (mm) in Southern Norway during August 26th - 27th 1974.

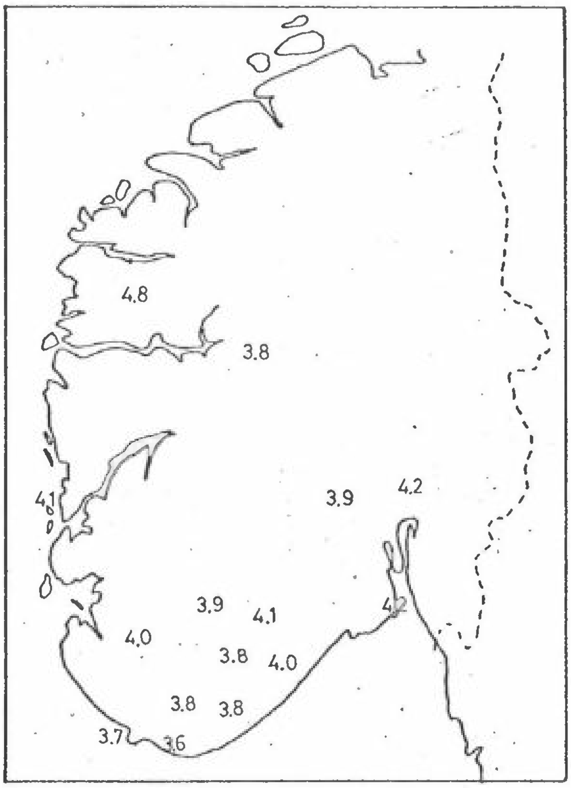

Figure 3:

Acidity of rainfall (pH) on August 26th - 27th 1974.

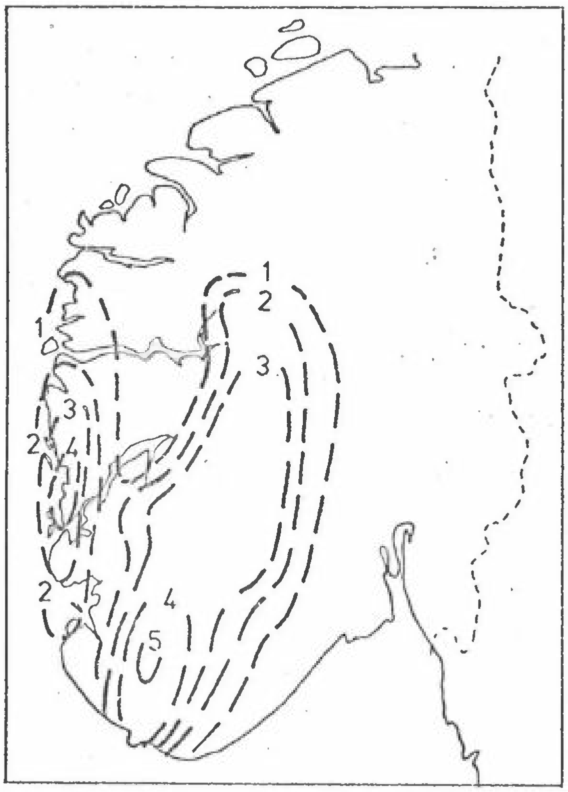

Figure 4:

Wet deposition of H^+ as meq/m^2 during August 26th - 27th 1974

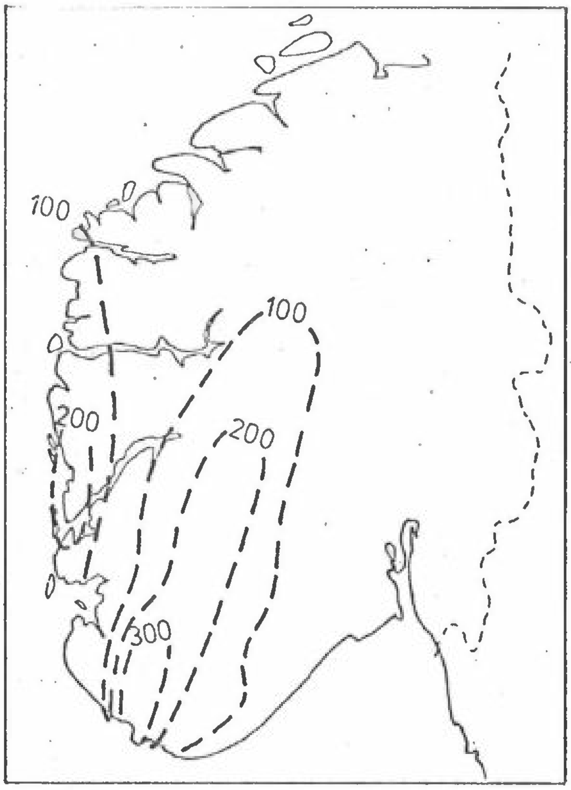

Figure 5:

Wet deposition of SO_4 as mg/m^2 during August 26th - 27th 1974

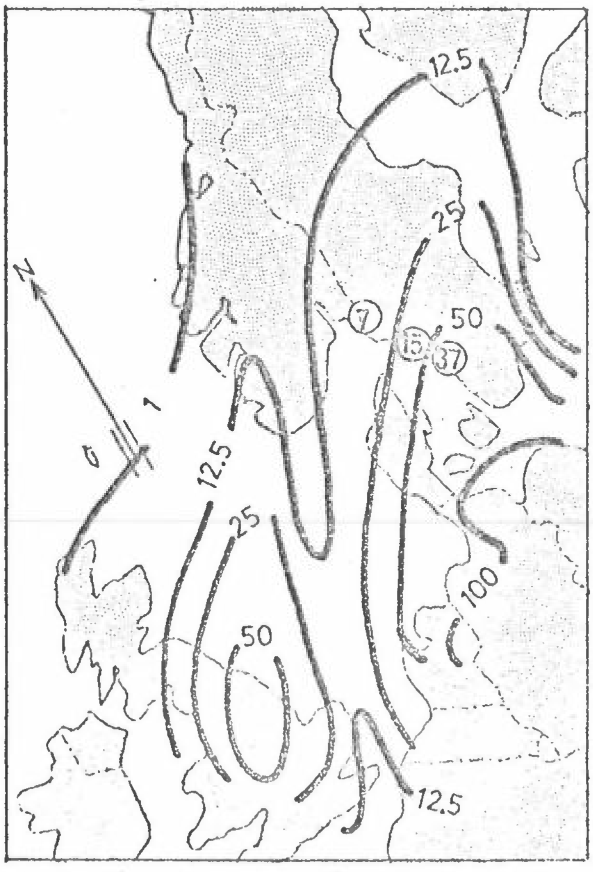

Figure 6:

Model estimates of the SO_2 concentrations at 12 GMT on August 26th 1974. Aircraft measurements are encircled.

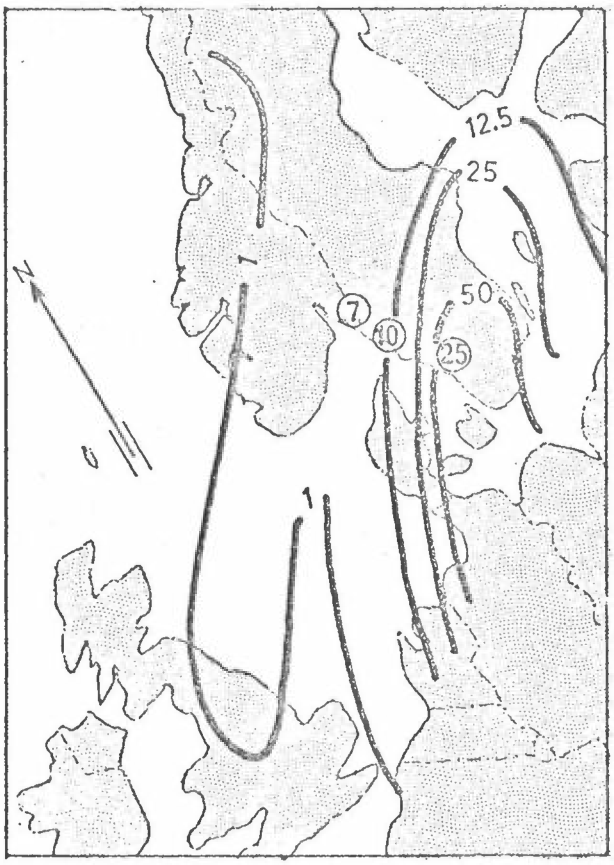

Figure 7: Model estimates of the SO_4 concentrations at 12 GMT on August 26th 1974. Aircraft measurements are encircled.

TRAJECTORIES STUDIES

Decay rate for SO_2 on days with precipitation

Some pilot investigations have been carried out in order to find a reasonable range for the decay rate of SO_2 on days with precipitation at a station. As the air parcel moves in time steps along the trajectory, its SO_2 concentration is computed by the formula:

$$(1) \quad \sum_{i=1}^{n} \frac{Q_i \, \Delta t}{h} \; e^{-k(n-i)\Delta t}$$

Δt is the time increment and h the mixing height (put equal to 1000 m in the preliminary studies). "Q_i" is the input of SO_2 per unit time. Using data from the past two winters, the decay constant "k" varied between certain bounds. The table below gives a comparison between the averages of observed and computed SO_2 concentrations. We notice that the best mean values are obtained for $k = 3 \times 10^{-5} s^{-1}$. Precipitation does not normally last for the whole day. It is therefore likely that a higher decay rate would have been found if the time resolution had been better.

Stations	Averages of computed SO_2 concentrations				Average of observed SO_2
	k=0	$k=3 \times 10^{-6} s^{-1}$	$k=10^{-5} s^{-1}$	$k=3 \times 10^{-5} s^{-1}$	
DK 5	37.4	31.5	22.0	10.8	7.3
F 01	42.7	38.2	29.6	18.9	17.5
NL 1	54.9	50.7	40.7	27.6	20.2
NL 2	41.8	36.9	28.4	16.2	14.2
N 01	32.1	24.5	13.5	3.4	7.1
UK 1	39.2	36.3	30.2	21.0	33.1

Table 1: Tabulation of computed SO_2 averages for days with precipitation during the past two winters.

The next table shows the correlation coefficients between the observed wet deposition and precipitation multiplied by daily SO_2 estimates.

Stations	k=0		$k=3 \times 10^{-6} s^{-1}$		$k=10^{-5} s^{-1}$		$k=3 \times 10^{-5} s^{-1}$	
DK 5	0.89	(0.86)	0.90	(0.86)	0.91	(0.85)	0.91	(0.80)
F 01	0.38	(0.56)	0.39	(0.58)	0.44	(0.64)	0.49	(0.74)
NL 1	0.69	(0.69)	0.69	(0.70)	0.70	(0.72)	0.69	(0.73)
NL 2	0.39	(0.66)	0.42	(0.68)	0.47	(0.71)	0.52	(0.72)
N 01	0.84	(0.78)	0.84	(0.78)	0.84	(0.78)	0.80	(0.74)
UK 1	0.68	(0.81)	0.68	(0.82)	0.69	(0.83)	0.69	(0.82)

Table 2: Tabulation of correlation coefficients between observed wet depostion of SO_4 (H^+) and precipitation times daily SO_2 estimates.

Here again, there is a slight preference for the values based on $k = 3 \times 10^{-5}\ s^{-1}$.

BUDGET STUDIES

Using the trajectory model (1) described above, various preliminary budget studies have been carried out during the second part of 1974. Table 2 shows that there is a reasonable correspondence between observed scavenging of SO_4 and the estimated deposition of SO_2 using the trajectory model. All model calculations were based on the old emission map which has too high emissions for the Netherlands and U.K. The trajectory evaluations are all based on $k = 10^{-5} s^{-1}$. The results below are therefore rather uncertain at the moment, but they give some features that might be of interest.

Figure 8 shows the estimated contributions from different countries to the scavenging of SO_4 at N 01, using trajectories based on surface winds. 49% are coming from Scandinavian sources, and only 4% from the United Kingdom sources.

Figure 9 shows quite a different picture for the estimated contributions when 850 mb trajectories are used. Now only 13% is from Scandinavian sources, and 41% is coming from the United Kingdom. The real transport should be based on the wind distribution between emission height (from the surface to a few hundred meters), and the top of the mixing layer (500 m - 2000 m). Appendix 3 (to the Progress Report submitted to the Steering Group in September 1974) gives some of the efforts made and planned in order to derive a "best" transport model.

Figure 10 shows the estimated national contributions to the total concentration of SO_2. This estimate is based on 850 mb trajectories and looks quite similar to the estimate of Figure 9.

As a final illustration, we have picked the station A 1 (Figure 11). According to the estimates, this station gets 50% of its pollution from countries outside the LRTAP Project.

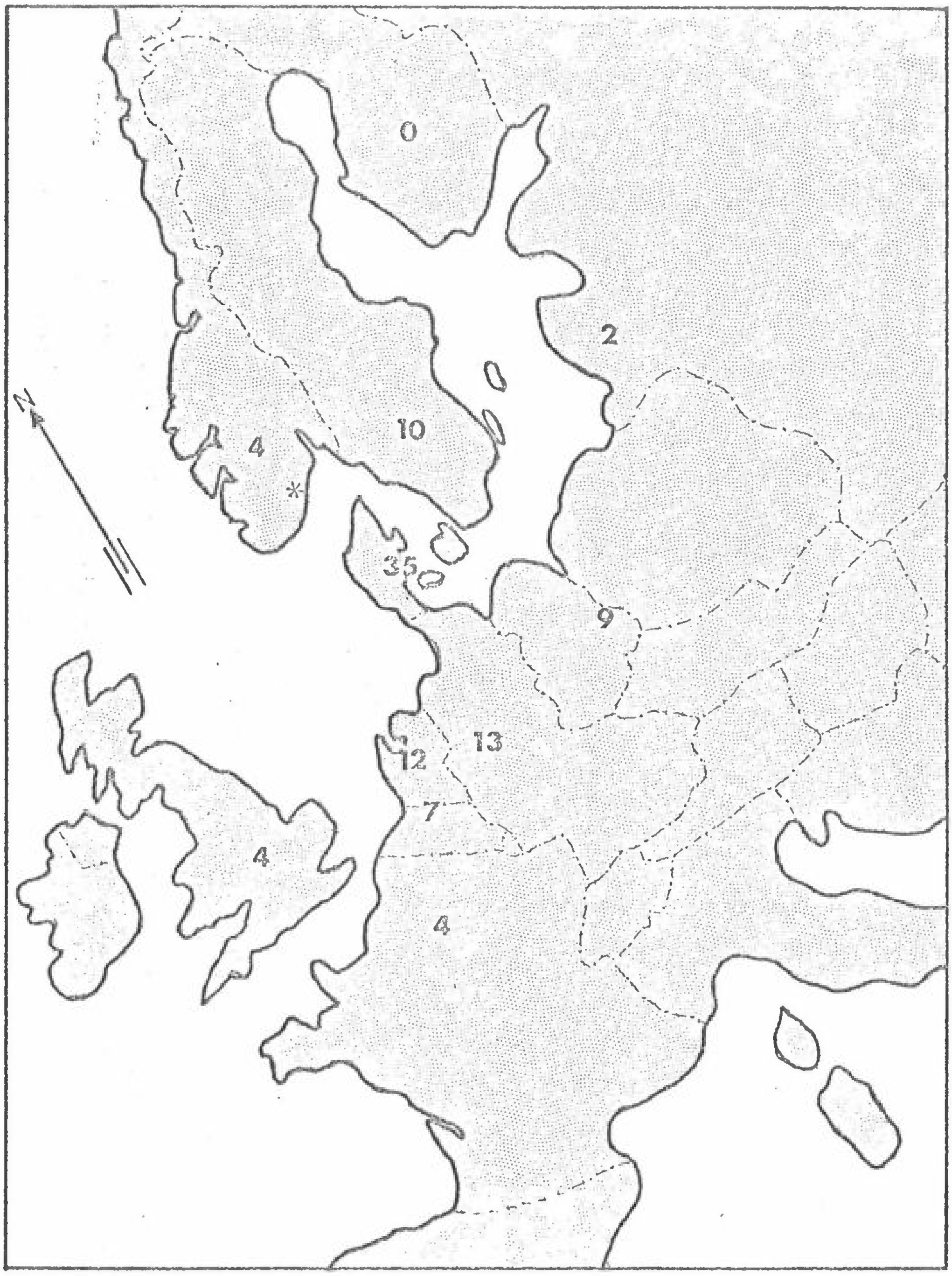

Figure 8: December 1973 - February 1974.
Calculated contributions of national emissions to the total scavenging of SO_4 at N 01 (*).
Surface back trajectories.

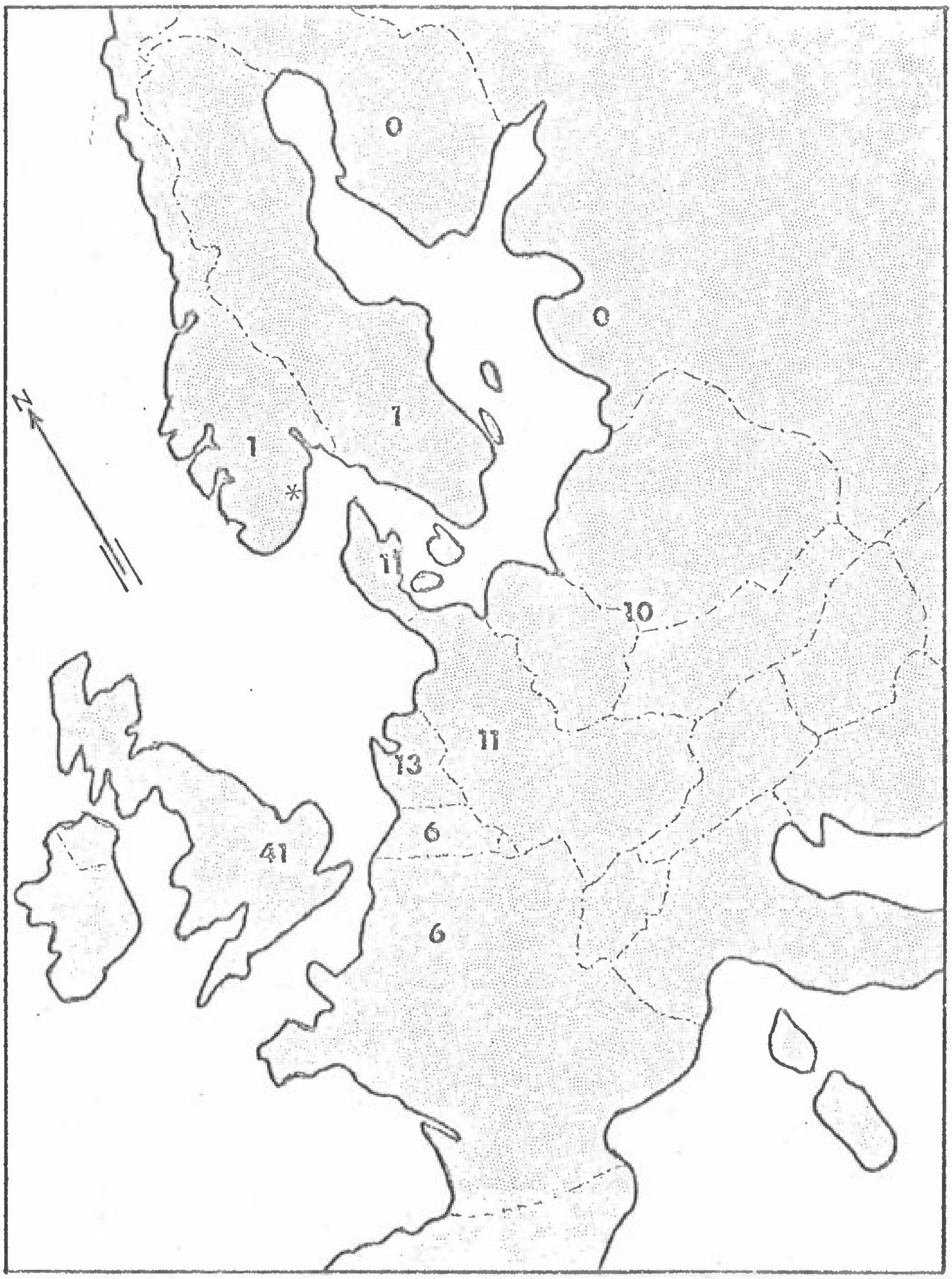

Figure 9: December 1973 - February 1974.
Calculated contributions of national emissions to the total scavenging of SO_4 at N 01 (*).
850 mb back trajectories.

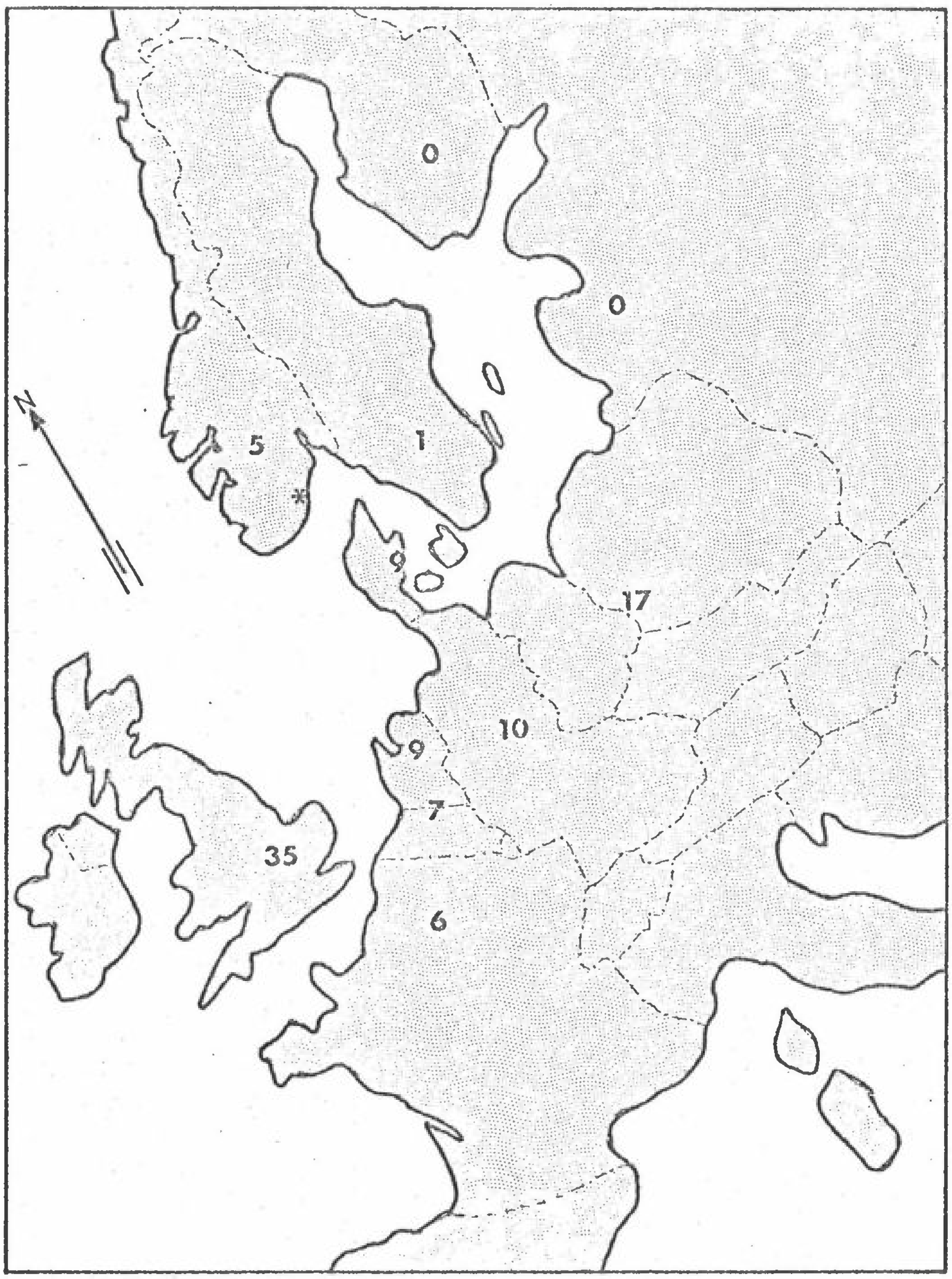

Figure 10: Two winters.
Calculated contributions of national emissions to the level of SO_2 pollution on days with precipitation at N 01 (*).
850 mb back trajectories.

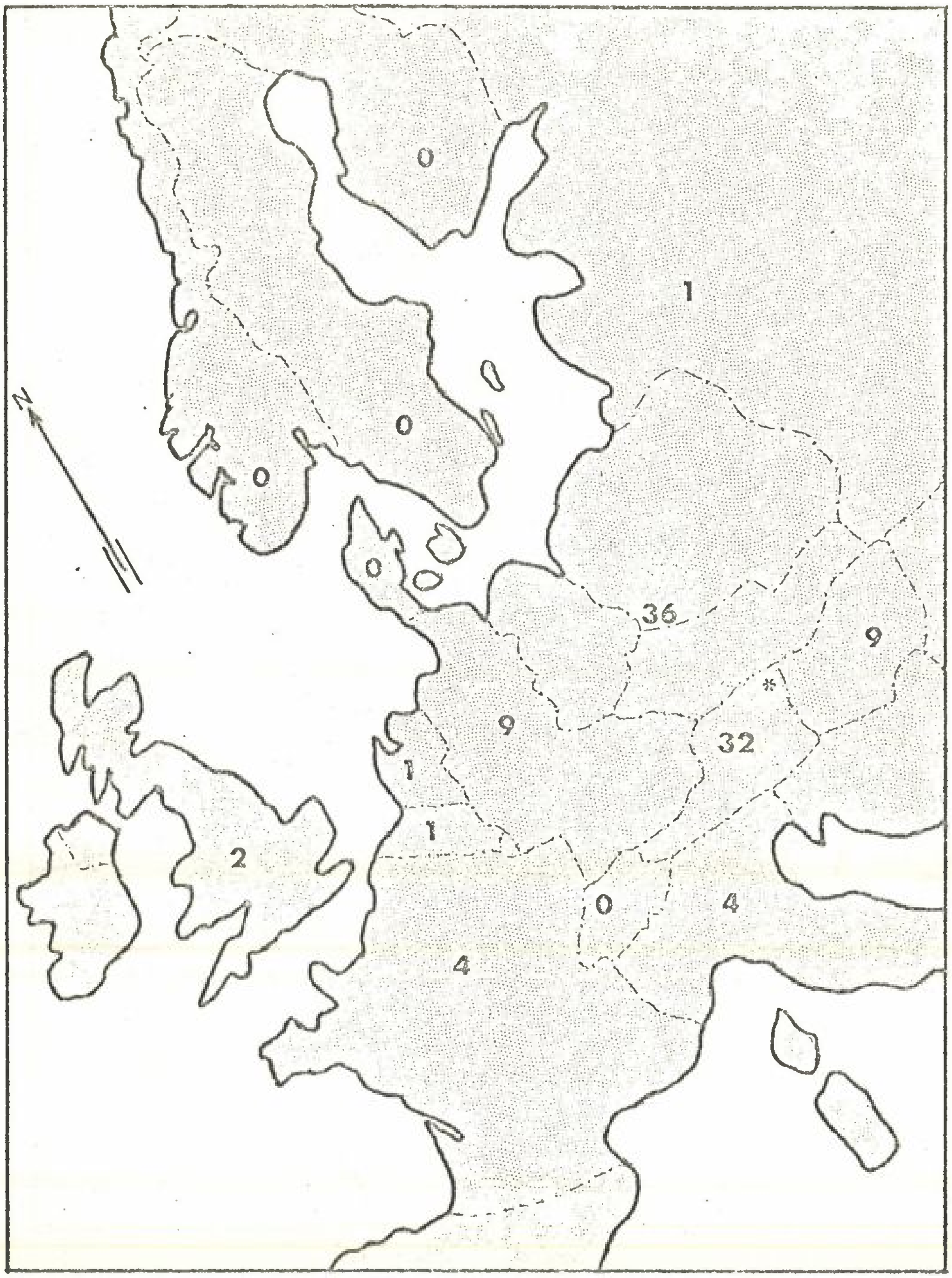

Figure 11 : November 1972/February 1973.
Calculated contributions of national emissions to the level of SO_2 pollution at A 1 (*).
850 mb back trajectories.