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Objective analysis of precipitation observations during the Chernobyl episode

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Summary

For the international model evaluation study ATMES, precipitation observations from the 25th of April to the 10th of May 1986 are analysed.

The measurements that are used are in most cases observations of precipitation accumulated over 12 hours and sometimes over 6 hours. At KNMI an algorithm is developed that estimates precipitation amounts at a synoptic station accumulated over 3 hours based on these observations. Synoptic codes are used to interpolate the precipitation measurements in time. The values thus obtained are interpolated to a grid using a Cressman(2,3) optimal interpolation scheme for a grid of approximately 65 * 65 kilometers. For ATMES, precipitation amounts on a grid, accumulated over 6 hours, are generated.

1. Introduction

For the Atmospheric Transport Model Evaluation Study (ATMES,1) precipitation data on a regular grid for the Chernobyl episode are needed. An area from 10 degrees west to 40 degrees east and from 35 degrees north to 70 degrees north is covered (area A : see(1)).

Accumulated precipitation amounts over 6 hours are required. We estimate the amount on a gridpoint, as a representative value for the whole grid cell.

The precipitation amount on synoptical stations is often measured every 12 hours only (at 06 GMT and 18 GMT) or at the most every 6 hours. More frequently information is available on the weather conditions of the last 6 hours (at main hours: 00 06 12 and 18 GMT) or the last three hours (at intermediate hours: 03 09 15 and 21 GMT).

During previous studies at KNMI an algorithm is developed to estimate the accumulated precipitation over 3 hours on a grid with a griddistance of 1 degree longitude and 1/2 degree latitude. The Cressman interpolation scheme(2) to convert these data to a grid, is tuned to obtain a good reproduction of the observed precipitation amounts at the coordinates of the synoptic stations. Tuning of the Cressman scheme is done by variation of the number of scans, the interpolation radii and the guessfield error.

For the present application in ATMES the standard procedure is used to derive the 3 hourly fields. Consequently two fields are added to obtain the six hourly fields , as needed for the model evaluation study.

The flow and processing of the data are summarized in figure 1.

2. Extraction of the synoptical data

2.1 Observation of precipitation amount

In Europe most synoptical stations record the amount of precipitation accumulated over twelve hours at 06 GMT and 18 GMT (approximately 1000 stations in area A of ATMES). Some stations record the accumulated precipitation over six hours at 00 GMT and 12 GMT as well (approximately 600 stations). Both kinds of observations are used in the present analysis scheme.

2.2 Weather codes (4)

Code RRR is the amount of precipitation, which can easily be converted to millimeters. t_R Is the number of periods of 6 hours. However when no precipitation has occurred, t_R is encoded as 0. Apart from this problem this code is not always reliable. When it is not 1 or 2, it is put to 1 (at 00 and 12 GMT) or to 2 (at 18 and 06 GMT), assuming that the amount is accumulated over 6 hours or over 12 hours respectively. Weather codes W_1 and W_2 describe the weaather occurred during the past 3 or 6 hours.

In this case W_1 and W_2 are used to determine whether there has been some precipitation at all in the 3 hours before the intermediate hours, or 6 hours before the main hours.

2.3 Consistency and encoding errors

When the amount of precipitation is more than 100 millimeters per 6 hours, this is considered an encoding error. An amount between 40 mm and 100 mm is only considered correct when there has been a heavy shower or a thunderstorm , i.e. when W_1 is 8 or 9. In this case the amount is put to 40mm in six hours or 80mm in twelve hours, considering it unlikely that a heavy shower is representative for a whole gridcell. Observations with encoding errors are rejected.

3. Time Interpolation

Interpolation to accumulated precipitation over 6 hours is the first step to calculate amounts of accumulated precipitation over 3 hours per station using the past weather codes W_1 and W_2. First we try to get as many 6 hourly values as possible on 00 06 12 and 18 GMT.

Observations of three times in a row (I, II and III) are needed to interpolate the 6-hourly observations. To describe the algorithm, some abbreviations are useful:

T	00, 06, 12 or 18 hours (one of the main hours)
RRI	The amount of precipitation measured 6 hours before T
RRII	The amount of precipitation measured at time T
RRIII	The amount of precipitation measured 6 hours after T
WI	Weightfactor for the observation at 6 hours before T
WII	Weightfactor for the observation at the time to be calculated
WIII	Weightfactor for the observation at 6 hours after T
RVII	Accumulated amount of precipitation over 6 hours to be calculated.

To estimate missing data we add weightfactors based on the W_1 and W_2 code. First we derive a weightfactor on a station at a time according to table 1.

If W_1 or W_2 is greater than 5, then the period is considered wet. Otherwise it is considered dry.

Table 1 : weightfactor W derived from W_1 and W_2 (W is assigned to WI, WII or WIII)

W_1	W_2	W	
>5	>5	2	(both 3-h. periods are wet)
>5	<=5	1	(at least one 3-h. period is wet)
<=5	<=5	0	(whole 6-h. period is dry)
missing	missing	1	(at least one 3-h. period is wet)

3.1 Estimation of accumulated precipitation over 6 hours

- If RRII is a six hourly amount , then RVII = RRII
- If RRII is a 12 hourly amount, then the previous amount must be subtracted from this:
  RVII = RRII - RRI .

When data are missing, they are estimated as follows:

- If WII is 0 , it means no precipitation :
  RVII=0 .
- When we have a 12 hourly amount, but not the previous 6 hourly amount, then RRII is divided in two parts according to:
  RVII = WII/(WI+WII) * RRII .

When RRII is missing, we can derive a value from precipitation amounts and weightfactors of the observation 6 hours earlier and 6 hours later.

- When RRII is missing but RRIII is available as a 12 hourly amount, then :

  RVII=WII/(WIII+WII)*RRIII .
- When RRII is missing but RRI and RRIII are available as 6 hourly amounts, we are able to interpolate :

  RVII=WII/(WI+WIII)*(RRI+RRIII) .

  (if WI+WIII equals 0, the observation is rejected.)
- If only RRI is available, we calculate :

  RVII=WII/WI*RRI .

  (if WI equals 0, the observation is rejected.)
- If only RRIII is available and it is a 6 hourly amount, we calculate:

  RVII=WII/WIII*RRIII .

  (if WIII equals 0, the observation is rejected.)

3.2 Estimation of accumulated precipitation amount in two 3-hour parts

As for the 6-hourly estimation, W_1 and W_2 can be interpreted as wet or dry. However, W_1 and W_2 not always refer to the same timerange. On the main hours (00,06,12 and 18 GMT) they refer to a six hour period. On the intermediate hours (03,09,15 and 21 GMT), they refer to 3 hours. However, bearing in mind that W_1 is not allowed to be less than W_2, we can yield some result. We have to look at combinations of three and six hourly codes. The precipitation amount accumulated over six hours is divided into two precipitation amounts accumulated over three hours according to table 2 . Wp is the weightfactor.

Table 2 Dividing 6 hour accumulated precipitation amount in two three hour parts.

3 hours code		six hours code		Wp (weightfactor)	
W_1	W_2	W_1	W_2	first	second
<5	<5	<5	<5	0	0
<5	<5	>=5	<5	0	1
<5	<5	>=5	>=5	0	1
>=5	<5	>=5	<5	7/12	5/12
>=5	<5	>=5	>=5	1/3	2/3
>=5	>=5	>=5	>=5	7/12	5/12
>=5	>=5	>=5	<5	2/3	1/3

N.B. When W_1 and W_2 are not available, the observation is rejected.

The pseudo-observation RRV, defined as the estimated precipitation accumulated over 3 hours, is calculated by RRV=Wp*RVII.

4. Spatial Interpolation

To obtain values on a regular grid we use a successive correction method(2,3). The analysed precipitation amount after the n^{th} scan on a gridpoint is calculated as:

$$A_n = A_{n-1} + \frac{\sum_k \left[a_g * a_c * a_k * \left(RRV_k - A_{n-1} \right) \right]}{\sum_k \left[a_c * a_k \right]} ,$$

where A_{n-1} is the value of the guessfield on the gridpoint and RRV_k is the pseudo observation on station k.

The distance from observation to gridpoint is accounted for by a weighfactor a_k

$$a_k = \frac{1}{\left(1 + \left(r/R_n \right)^2 \right)} ,$$

where r is the distance from the gridpoint to the observation and R_n is the interpolation radius of scan n. First we interpolate with a large interpolation radius R1 = 1*R, in which R is the grid spacing, to produce values in observation void areas. A second scan is done with a radius R_2 of .25*R to obtain a better resolution in observation dense areas. Only observations closer to a gridpoint then $3*R_n$ are allowed to contribute, thus the treshold for a_k is 0.1.

The influence of the coast line is accounted for by using a land-sea index m. For a coastal point m is put to 1; for a sea point m is put to 2 and for a land point m is put to 0. We define the coastal weightfactor as:

$$a_c = \frac{1}{\left(1 + \left(m_{obs} - m_{grid} \right)^2 \right)} ,$$

where m_{grid} is the index of the gridpoint, and m_{obs} is the index of the gridcell in which the observation is located.

The relative influence of an observation compared to the guessfield is accounted for by a weightfactor a_g:

$$a_g = \frac{1}{\left(1 + \left(f_o/f_g \right)^2 \right)} .$$

where f_o is the observation error, put to 1mm in this study, and f_g is the guessfield error. For the first scan f_g is put to 4mm . For the second scan, the guessfield error is:

$$f_g = \sqrt{\frac{\sum_k \left(a_k * a_c * a_g\right) * f_0^2}{\sum_k \left(a_k * a_c\right)}}$$

The first-guess field for precipitation A_0 is put to 0.0 at every gridpoint. Every gridpoint of the first-guess field for precipitation (A_0) is put to 0.0.

This scheme causes a problem: a small amount of precipitation occurs in too many gridpoints. By putting precipitation values that are less then 0.3 mm to 0 mm, we obtain a better distinction between wet areas and dry areas.

5. Results

For ATMES two fields containing precipitation amounts accumulated over 3 hours are added to obtain precipitation amounts accumulated over 6 hours. Figures 2 till 5 show some results.

It is tried to generate rain fields that are good estimates for both the temporal and spatial distribution. However precipitation in mesoscale models is in many cases a sub-grid phenomenon in space and in time. The spatial interpolation radius and the cut-off value are chosen to make a good reproduction of the wet/dry patterns determined by a subjective analyses of the precipitation observations. The introduction of a cut-off value caused a bias towards zero of the precipitation amount of approximately 15%. Above sea the precipitation field is not reliable because of lack of precipitation data .

For 15 synoptical stations in the Netherlands the total amount of precipitation over the whole period is compared to the total analysed amount on the nearest gridpoint. The analysed amount is 22 % lower. On the average precipitation is equally devided between the first 6 hours and the second 6 hours of a 12 hour period. It is expected that the 6 hour resolution produced by this scheme is a better estimate then simply assuming equal precipitation amounts in each 6 hours.

References

1. ATMES Evaluation Team 1989: ATMES technical specification document. ISPRA.
2. Cats,G.J private communication KNMI 1989
3. Cressman G.P. 1959: An operational objective analysis system. Monthly Wea. Rev. , 87, 367-381.
4. FM.12.VII SYNOP (WMO code conventions, update January 1982)

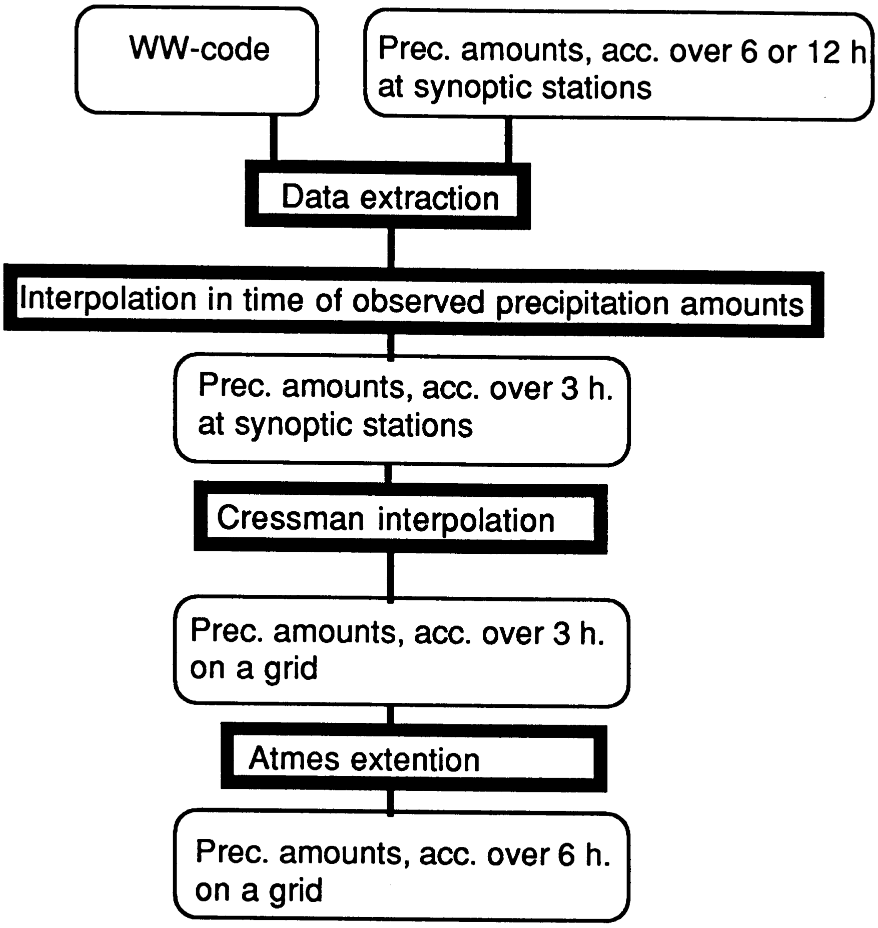
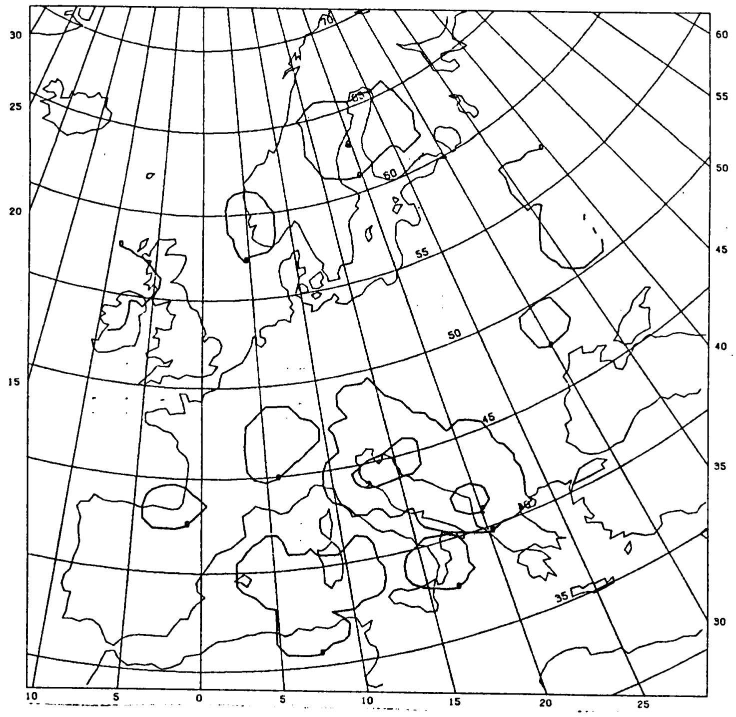


Figure 1: Precipitation analyses; flow and processing of synoptical data



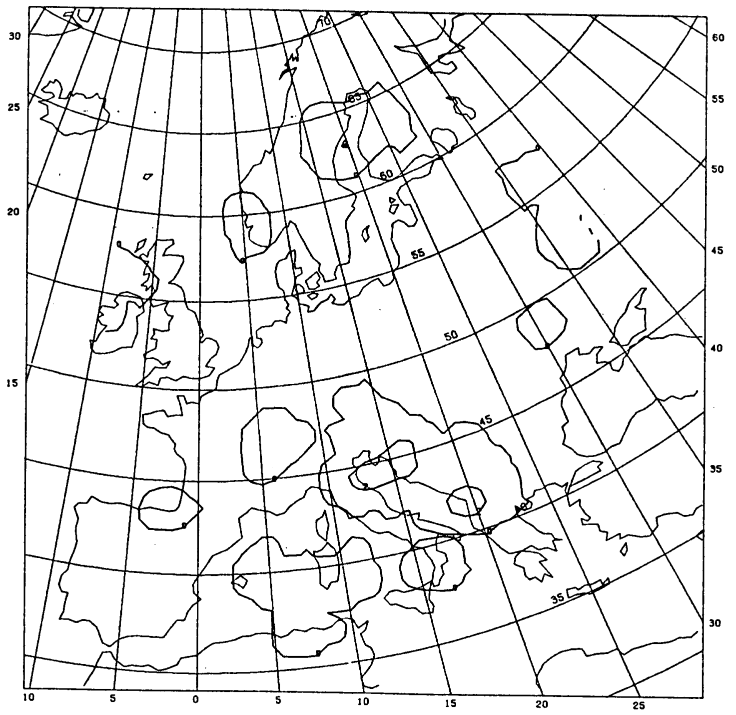


Figure 2: Precipitation accumulated over three hours at 9 GMT (above) and 12 GMT(below) at April 29, 1986

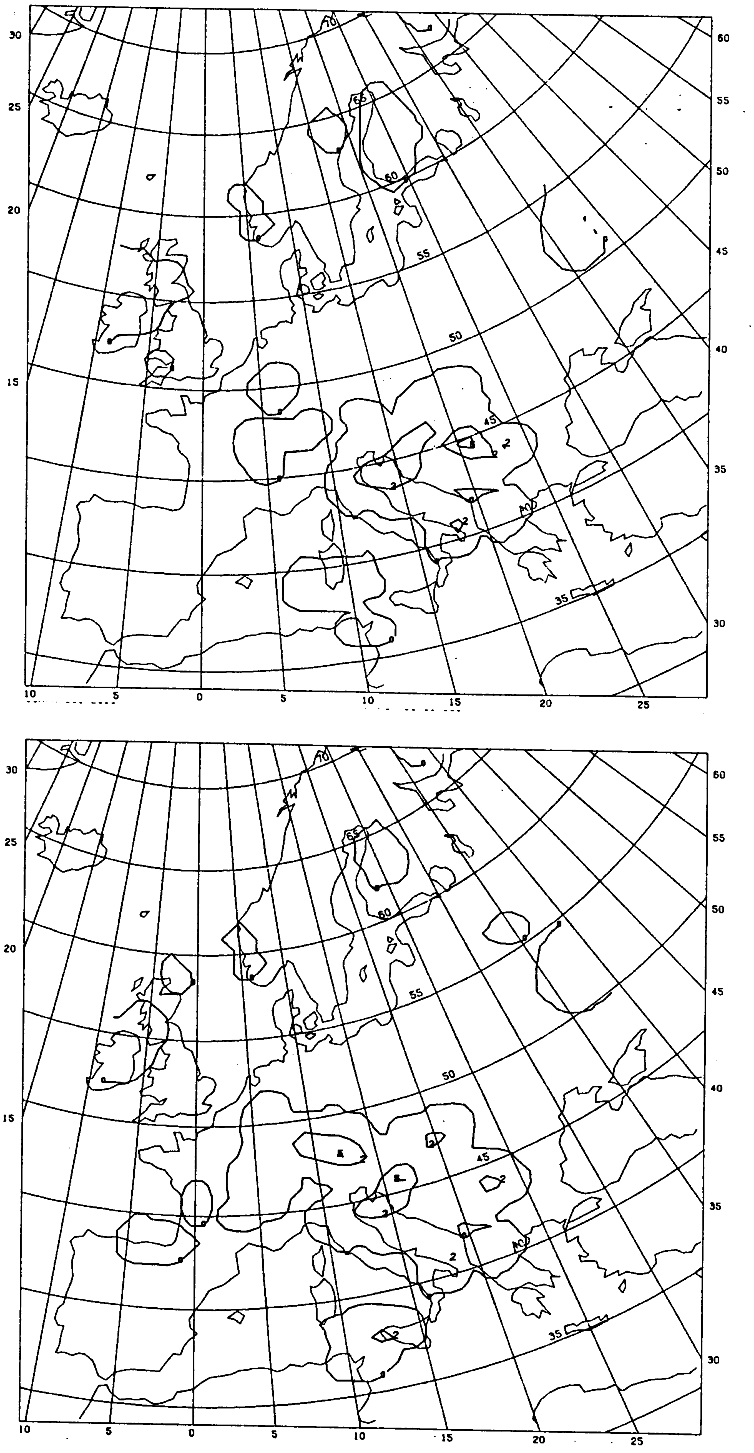


Figure 3: Precipitation accumulated over three hours at 15 GMT (above) and 18 GMT(below) at April 29, 1986

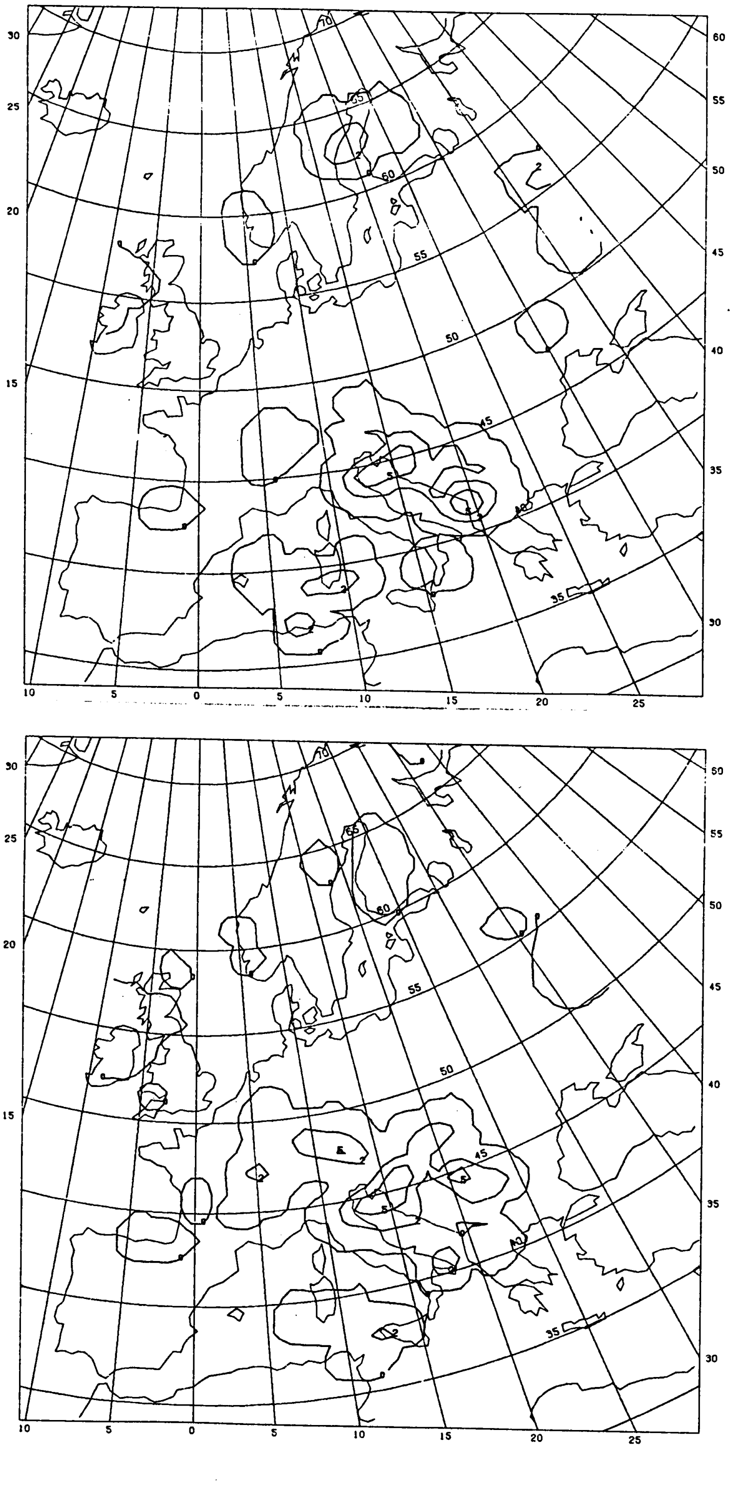


Figure 4: **Precipitation accumulated over six hours at 12 GMT (above) and 18 GMT(below) at April 29, 1986**

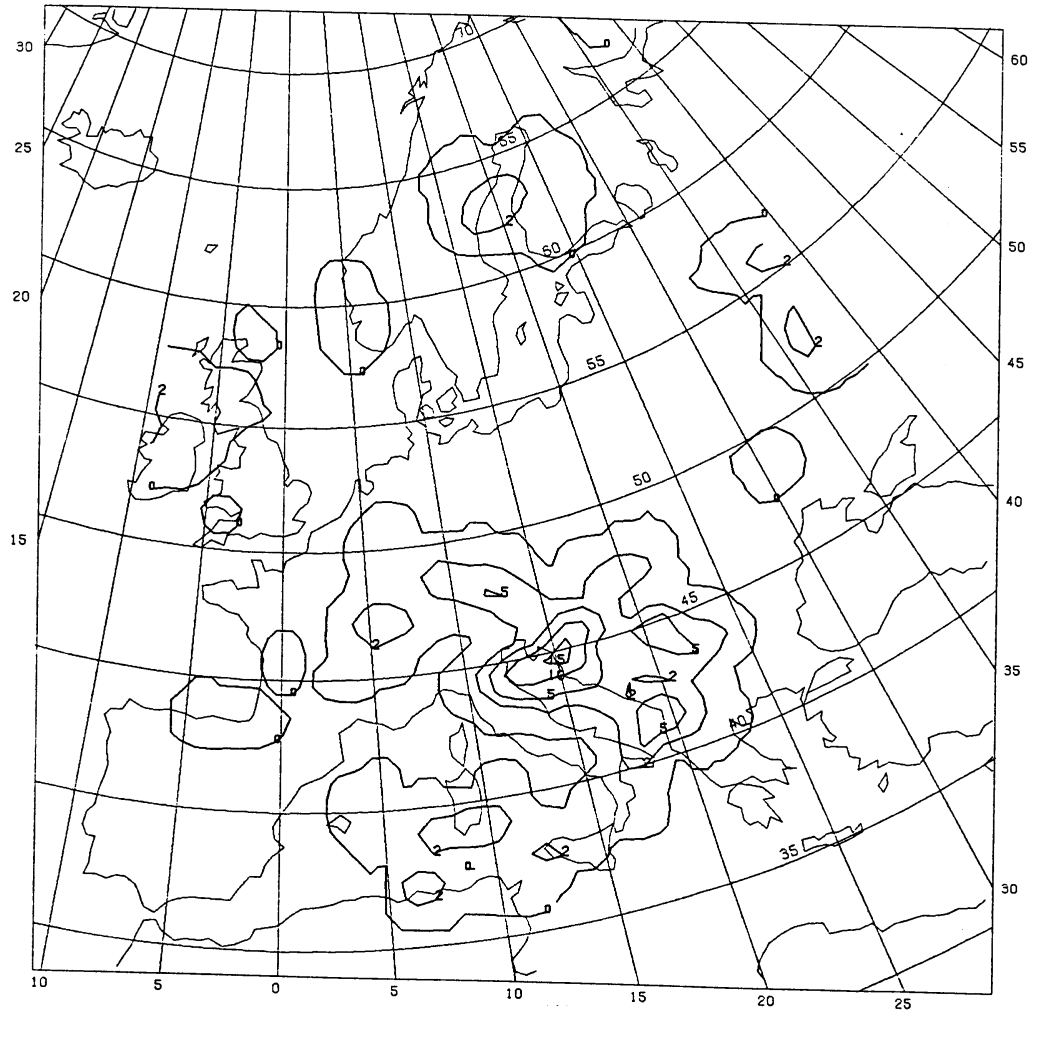


Figure 5: Precipitation accumulated over twelve hours at 18 GMT at April 29, 1986