DET NORSKE METEOROLOGISKE INSTITUTT

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Meteorological input data

for the EMEP/MSC-W air pollution models.

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Preface and acknowledgements.

This note was prepared for the twenty fourth session of the Steering Body to EMEP (Co-operative programme for monitoring and evaluation of the long range transmission of air pollutants in Europe).

It presents an overview on the meteorological database, the data availability and the historical use of meteorological data at the MSC-W (**M**eteorological **S**ynthesizing **C**entre – **W**est) of EMEP. The dedicated meteorological model, PARLAM-PS has been used to produce meteorological input data for the year 1998 and 1997. Improvements in the PARLAM-PS model, used to produce meteorological data for 1998, are presented in this note together with model experiments based on these improvements.

The calculations are made possible through access to a CRAY T3E computer at the Norwegian University of Science and Technology (NTNU) in Trondheim. We are especially grateful to Dag Bjørge, Jan Erik Haugen and Anstein Foss for their help and support with the PARLAM-PS model, and Dr. Leonor Tarrason for valuable discussions.

CONTENTS

1. Introduction.

Meteorological data are key input parameters to air pollution models, which determine to a great extent the limitations and possibilities of the computing schemes introduced in these models. It is essential to have good knowledge on the weakness and strengths of the meteorological input data before setting up or introducing new equations for air pollution modelling.

Thanks to the very close cooperation with the numerical weather prediction group here at the Research Department at the Norwegian Meteorological Institute (**DNMI**), it has been possible to develop specially dedicated versions of the **NWP** (**N**umerical **W**eather **P**rediction) models that produce operational meteorological data for use in air pollution modelling. Our systematic verification and application of the meteorological data has, on the other hand, contributed to improvements in the NWP-models.

EMEP/MSC-Ws close collaboration with the NWP-modellers naturally benefits from the development work going on in this field, with steady evaluations and improvements. The main advantages of using a special dedicated version of NWP models are:

- The possibility of identifying output fields not available otherwise.
  For example: Air pollution models require 3D precipitation fields, while only the surface precipitation rates are stored and verified for weather forecasting purposes.
- The possibility of using the same map projection and spatial grid definition, both in the vertical and in the horizontal, as used in air pollution models. This is important to avoid interpolations of meteorological data, which can give problems with mass conservation (Trenberth (1991)).
- The possibility of sharing parametrizations, to secure initial consistency between meteorological and pollution dispersion models.
  For example, surface exchange processes like dry deposition and turbulent exchange would benefit by the use of similar parametrizations and physiographic and land-use data.

A number of studies on the effect of meteorological data resolution and parameterization (e.g. Brandt et al. (1998), Nasstrom and Pace (1988)) emphasize the importance of adequate meteorological input for long-transport modelling. In this note we document the validation of 3D precipitation fields for use in EMEP/MSC-W Eulerian models and analyse the consequences for the parametrization of wet deposition. The type of NWP models used at EMEP/MSC-W has changed over time. We acknowledge that the changes in NWP input models may sometimes have been confusing for EMEP users. In this note we provide an overview of the use of NWP models and on the meteorological data available at EMEP/MSC-W, with the hope that it may be useful and clarifying.

2. Use of meteorological data at MSC-W.

Since the end of the seventies, calculations on transboundary air pollution at European scale have been carried out at DNMI as host centre for EMEP/MSC-W. Since then, there has been an enormous development in computer capacities, making it possible to develop air pollution models taking into account complex chemistry, transport and removal processes.

First phase (1977-1985): *Using meteorological data based on observations:*

Initially, starting as an OECD programme on Long Range Transport of Air Pollutants (OECD, 1977; Eliassen ,1978), only observed meteorological data was used for calculating the transport and deposition of sulphur. Observed meteorological data were interpolated to the EMEP-grid, and then used for calculations. In this very early stage, only wind-field and precipitation data were used. The mixing heights and deposition velocities were assumed constant values.

In 1979, calculations with the EMEP sulphur model were initiated (Eliassen and Saltbones , 1983) and the OECD model was improved by including a variable mixing height and aerodynamic resistance in the dry deposition calculation, still using only observed meteorological fields.

Second phase (1986-1998): *Combining 2-dimensional meteorological data from NWP-models and observations.*

In the 1980s as the computer capacities and numerical model development increased, meteorological data from a numerical weather prediction (NWP) model became available at DNMI. In 1986 meteorological data for 1985 was produced, based on output from the **LAM150** (**L**imited **A**rea **M**odel with 150km spatial resolution) developed at DNMI by Grønås and Hellevik (1982), Grønås and Midtbø (1986) and Nordeng (1986). In 1986 and 1987, trajectories were calculated to a selection of measurement points. In this period the nitrogen components was included in the EMEP Lagrangian model for acidifying components (Hov *et.al.*(1988); Eliassen *et.al.* (1988)). The first complete set of source–receptor matrices for sulphur and nitrogen components was produced in 1988 for the year of 1985 (Eliassen *et.al.* 1988). Later on the EMEP Lagrangian photochemical model was developed by Simpson and Hov (1990), Simpson (1992).

In 1991, a NWP model called **LAM50E** (Limited Area Model for **E**urope) took over the routine runs at DNMI. This model was based on the same principles as LAM150, except for the spatial resolution that was increased to a 50km by 50km grid. Two-dimensional meteorological data for the EMEP 150 km. grid was then stored on a regular basis. The full three-dimensional LAM50E data with 50km by 50km grid-resolution was stored on magnetic tapes, but those data are in general not easy accessible now, and the data sets are incomplete. In addition of meteorological output from LAM150 and LAM50E, the EMEP Lagrangian air-pollution models also used analysed observations of the mixing height and precipitation over land.

In this period the EMEP-grid consisted of 39 times 37 grid squares of 150 by 150 km^2, the innermost area in fig. 2.1.

Figure 2.1 : Meteorological data domains.

The smaller light domain was used in the period 1985-1996 by the DNMI LAM system, used for EMEP **Lagrangian** models. The grid resolution was 150km by 150 km (39x37 grid cells)

The larger area is the PARLAM-PS domain used for 1997 meteorological data and onward. Those data are used as input to the EMEP Eulerian models. Polar stereographic grid projection with 50x50km grid resolution (170x133 grid cells).
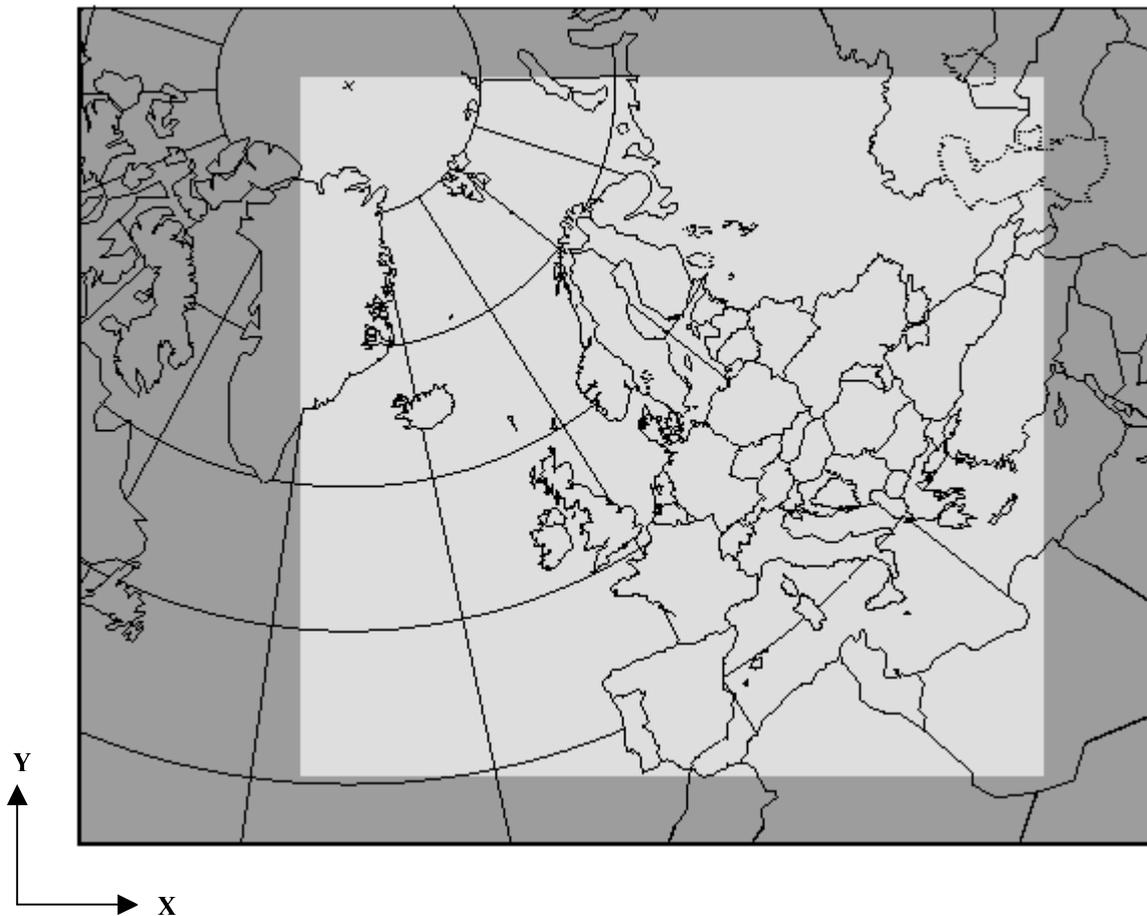
Third phase (1999 – onwards): *Three-dimensional meteorological data from NWP-models:*

As the EMEP models evolved from Lagrangian to Eulerian, demands for meteorological data changed and the need for three-dimensional meteorological input data became evident.

In the early develop stage of the Eulerian dispersion model, 3D input fields from the LAM50E model were used (Berge 1993, Jonson and Berge 1995, Jonson, Jakobsen and Berge 1997). When the first complete sets of receiver-emitter matrices were produced experimentally by the Eulerian Acid deposition model in 1997 (Jakobsen *et.al.* 1997), the meteorological data for 1992 from the LAM50E model were used.

In 1996, DNMI ended the work and further development of the LAM system, and introduced **HIRLAM** (**HI**gh **R**esolution **L**imited **A**rea **M**odel) for use in operative weather forecasting (Källen,1996). The HIRLAM forecasting system is a Nordic, Dutch, French, Irish and Spanish co-operation on short-range numerical weather prediction. At DNMI, a parallel version of the HIRLAM code, **PARLAM** was developed (Bjørge and Skålin, 1995). In 1996 the HIRLAM and PARLAM systems could not be used in air pollution models because the EMEP model domain was not fully covered. Therefore a special version of the HIRLAM model, called **EUROLAM** (The HIRLAM model covering whole Europe) was developed. Meteorological data from EUROLAM was first calculated for the year 1986. Differences between EUROLAM and LAM50E were presented by Tsyro(1999). Unfortunately the EUROLAM model did not use the same grid specifications as the EMEP air pollution models, and interpolation of the meteorological fields from the EUROLAM spherical (latidute-longitude) grid system to the EMEP polar-stereographic grid system was necessary. Interpolation was needed both in the horizontal plane and in the vertical, since EUROLAM used a hybrid pressure-sigma co-coordinate in 31 layers, while the EMEP/MSC-W air pollution models use a vertical co-ordinate of 20 sigma layers. Interpolation of meteorological fields could give rise to mass conservation errors (Trendberth, K.E. 1991). Therefore the meteorological **data produced from the EUROLAM system were never used for routine EMEP runs** in producing transboundary air pollution estimates.

Work was then initiated to develop a new dedicated version of the PARLAM weather forecast model that uses the same grid-system both in the horizontal and in the vertical, as the Eulerian air pollution models at MSC-W. This new dedicated model is called **PARLAM-PS (PAR**alell

Limited Area Model with Polar-Stereographic map-projection). Meteorological data from PARLAM-PS, and their use in air pollution models was presented for the first time in the 1999 EMEP/MSC-W reports, for calculations for the year 1997 (Olendrzynski (1999), Tarrason and Schaug (1999)). The PARLAM-PS domain was extended compared with the old LAM50E domain, so the whole Mediterranean sea, Cyprus and Turkey was now included in the calculation domain (see the whole area shown in fig 2.1). In Table 2.1 a overview on the meteorological models used by the MSC-W through time, and their main properties are shown. See Tables 3.1 and 3.2 for the actual meteorological data stored

Table 2.1:
Properties of the models used for processing EMEP meteorological input data

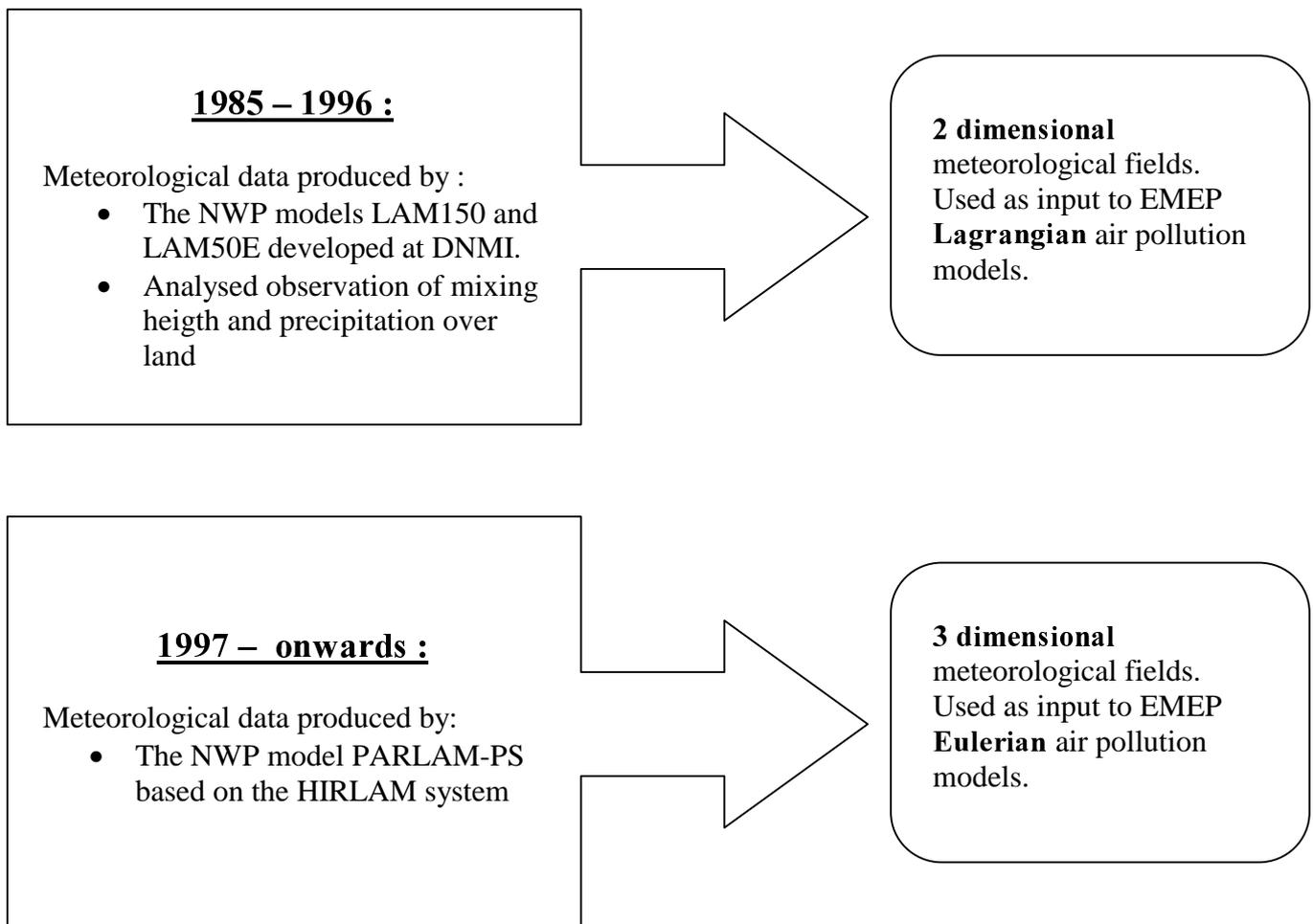| Model Name	Data coverage	Meteorological data used for air pollution models	PROPERTIES	
			Vertical co-ordinate and resolution	Map-projection and horizontal grid properties
LAM150 2-dim. data stored	1985, 1987-apr 1991	Lagrangian 2D models	10 vertical sigma-layers	Polar-stereographic map projection covering EMEP 150km grid with 39 x 37 grid squares.
LAM50E* 2-dim data stored.	1986, may 1991- 1996	Lagrangian 2D models	20 vertical sigma-layers	Polar-stereographic map projection covering EMEP 50km grid with 39 x 37 grid squares. All meteo data interpolated from 50km resolution to 150km resolution.
EUROLAM ** (Hirlam) 3-dim. data stored.	1996 - 1998	Only experimental use in Lagrangian 2D models and Eulerian 3D models	31 vertical layers (10 within the boundary layer). Hybrid pressure - sigma vertical coordinate (eta)	Spherical (latitude - longitude) grid 1/6 x1/6 degrees.. Cover a larger domain, output data are extended to cover Cyprus, Turkey and the Mediterranean Sea (45 x 37 grid squares in the EMEP 150km grid)
PARLAM-PS (Hirlam) 3-dim data stored.	1997 - 1998 *	Eulerian 3D models	20 vertical sigma-layers	Polar-stereographic map projection. Extended EMEPgrid.

* LAM50E; Three dimensional data was also stored and used during the period of testing and development of the Eulerian dispersion model for the year 1996.

** EUROLAM only for experimental use. **The model was never used for operative EMEP runs** because derived problems with mass conservations due to interpolation of meteorological fields.

3. The meteorological database.

Meteorological data have been systematically stored at EMEP/MSC-W since 1985. Up to 1996 two-dimensional data was prepared and stored on a regular basis for the EMEP Lagrangian models in the smallest and original EMEP domain (see fig.2.1). From 1997 and onwards, three-dimensional meteorological data has been stored for use in the EMEP Eulerian models in the extended EMEP domain (fig.2.1).

Figure 3.1 : Data available in the meteorological data-base :

1985 – 1996 :

Meteorological data produced by :
- The NWP models LAM150 and LAM50E developed at DNMI.
- Analysed observation of mixing heigth and precipitation over land

2 dimensional meteorological fields. Used as input to EMEP **Lagrangian** air pollution models.

1997 – onwards :

Meteorological data produced by:
- The NWP model PARLAM-PS based on the HIRLAM system

3 dimensional meteorological fields. Used as input to EMEP **Eulerian** air pollution models.

3.1 Meteorological data stored from the LAM150 and LAM50E models.

Table 3.1 shows the full set of meteorological data stored for the period 1985-1996 with 6-hourly resolution. The data stored from the LAM models are 6 hour prognoses for most fields, except for the precipitation where the 6 to 8 hour prognostic values have been used to minimize the spin-up problem. Over land, however, observed precipitation using Cressmann analysis has been utilized. The cloud cover were generated as an average using 3 and 6 hour prognostic values and cloud levels in 3 vertical layers (the 300 , 500 and 850 mb surfaces).

Table 3.1 :
Fields and properties for 1985 – 1996 stored 6-hourly meteorological data .
The Numerical Weather Prognose model used are LAM150 or LAM50E.

		Fields	Purpose
FIELDS FROM NWP models (LAM150 or LAM50E) : 6 hour prog.		**A) Mixed layer data $\sigma = 0.925$ (z ≈550)**	
		Horizontal Wind fields (u,v)	Horizontal transport
		Temperature (T925)	Chemical reaction rates
		Relative Humidity (Rh)	Ammonium nitrate equilibrium, Surface resistance
		B) Ground level data	
		Precipitation, used over sea (PRnwp)	Wet deposition
		Surface Stress (τ)	Aerodynamic Resistance
		Surface flux of sensible heat (Hd)	
		Temperature at 2 m	
		c) OTHER	
		Vertical wind speed (w) at $\sigma = 0.850$ (z ≈1100)	mass exchange between the free troposphere.
		Cloud cover (CL)	Photolysis rate
		Cumulus clod cover (CLB)	cloud ventilation
ANALYSED OBSERVATIONS		Precipitation (PRobs) , 6-hourly	Wet deposition, surface wetness
		Mixing Height from temperature soundings, every 24 hour.	Initial dilution of emissions.

3.2 Meteorological data stored from the PARLAM-PS model.

After the introduction of the PARLAM-PS model, a rather extensive amount of meteorological data has been stored. Although the Eulerian dispersion models use only a fraction of the meteorological data stored. An overview is provided in Table 3.2.

3 hourly time resolution.

New data sets are produced every 6 hour, and from those the 9 and 12 hour prognostic values are used, generating a meteorological data set with **3 hourly time resolution**. Most of the fields are not processed any more after written out by the PARLAM-PS system, except for the precipitation field. Since the stored precipitation value in the 12 hour prognostic field is the accumulated precipitation during the whole forecasting period (0-12), we calculate a 3 hourly accumulated precipitation by taking the difference between 12 and 9, and the difference between 9 and 6 prognostic values. For example, 3 hour precipitation at 9 and 12 UTC was derived from the 12 hour forecast generated at 00 UTC as follows:

$$Pr\_acc_{3h}(\text{ at } 9 \text{ UTC }) = Pr\_acc(00+9) - Pr\_acc(00+6)$$
$$Pr\_acc_{3h}(\text{ at } 12 \text{ UTC }) = Pr\_acc(00+12) - Pr\_acc(00+9)$$

Consistency of cloud cover and cloud water content with precipitation fields.

In the HIRLAM model used in weather forecasting, cloud cover and cloud water content are instantaneous values, while the precipitation are accumulated values. This difference in time resolution gives rise to inconsistencies between the fields. To avoid such inconsistencies, output from PARLAM-PS model are now averaged cloud cover and cloud water content, over the same 3 hour period as precipitation. This averaging is done inside the PARLAM-PS code.

The boundary relaxation zone.

Meteorological fields are affected by prescribed boundary values. The influence of boundaries is parametrerized in NWP models by use of a boundary relaxation zone. In this relaxation zone the meteorological data are adjusted towards the exterior boundary value according to this formula (Davies (1976); Kållberg and Gibson (1977); Davies (1983)) :

$$F = \alpha \cdot Fext + (1-\alpha) \cdot Fint$$

Where Fext is the exterior value, and Fint is the interior value of a meteorological field, and α varies between 0 on the inner boundary to 1 at the outer boundary.

In the PARLAM-PS model this zone cover the 8 grid-squares close to each outer border, in this zone the data are forced toward boundary values. This may cause strange and artificial data in this zone.
To avoid unphysical meteorological data in the Eulerian models, the meteorological data domain should cover a larger area than the Eulerian model domain with at least 8 grid squares more in each direction. However the Eulerian model uses the same domain as the PARLAM-PS, which gives rise to artificial values near the boundaries.

The Canary Islands and Africa are inside this relaxation zone, and therefore the Eulerian model cannot be trusted to calculate reasonable depositions and concentrations maps over these areas.

Common parametrizations and use of the same physiographic data in the Eulerian model and the PARLAM-PS model.

The meteorological models are not using the same physiographic data as the EMEP air-pollution models. This give rise to inconsistencies of meteorological values important for the turbulent transport (ex. turbulent surface stress and the friction velocity) in the surface layer when used in the air-pollution models. (Jakobsen (1996)). This can be improved by using the same physiographic data in the PARLAM-PS model and the Eulerian air pollution models.

Table 3.2 :

1997 – onwards. Meteorological data stored. Parameters and their use in air pollution models. Parameters in **bold** letters are input to the Eulerian dispersion model. The NWP model used are PARLAM-PS.

ID	Unit	Fields	Purpose
Fields at 11 pressure levels, time levels : 0 +6 +12			
Z	1	m	Geopotential Height	
θ	18	°K	Potemtial Temperature	
U	2	m/s	Wind component in x-direction	
V	3	m/s	Wind component in y-direction	
RH	18	%	Relative Humidity	
Fields at 20 σ – layers, time levels +6 +9 +12			
U	**2**	**m/s**	**Wind component in x-direction**	
V	**3**	**m/s**	**Wind component in y-direction**	
q	**9**	**kg/kg**	**Specific Humidity**	**Chemical reactions**
$\bullet$ σ	**11**	**1/s**	**Vertical Wind Velocity in σ - coordinate**	
θ	**18**	**°K**	**Potential Temperature**	**Chemical reactions**
CW	**22**	**kg/kg**	**Cloud liquid water**	**Wet removal**
CU	26	%	Cumulus Cloud Cover	
CL	**39**	**%**	**Cloud Cover**	**Wet removal, Photo dissociation.**
PRlev	**23**	**mm**	**Precipitation**	**Wet removal**
SURFACE fields time levels 0 +3 +6 +9 +12			
Ps	**8**	**hPa**	**Surface Pressure**	
mslp	**58**	**hPa**	**Mean Sea Level Pressure**	
PRsurf	17	mm	Total precipitation	
PRs	19	mm	Stratiform Precipitation	
PRc	20	mm	Convective Precipitation	
CW	22	kg/kg	Cloud Liquid Water (integrated)	
	25	%	Total Cloud Cover	
Tsoil	29	°K	Temperature below ground	
T0	30	°K	Temperature in air at 0m height	
T2	**31**	**°K**	**Temperature in air at 2m height**	**Dry Deposition**
Rh2	32	%	Relative Humidity at 2 m. height	
U10	33	m/s	Wind component in x-direction at 10m height	
V10	34	m/s	Wind component in y-direction at 10m height	
	35	Kj/m^2	Accumulated global radiation	
SH	**36**	**W/m^2**	**Surface Flux of Sensible Heat**	
LH	**37**	**W/m^2**	**Surface flux of latent Heat**	
τ	**38**	**N/m^2**	**Surface Stress**	
	66	mm	Snow (precipitation)	
	83	m	Surface Roughness	
	85	m	Soil water content	
	86	m	Deep soil water content	
	21	hPa/s	Tendency dPs/dt	
	87	W/m^2	Short wave radiation flux	
Special output in 4 pressure levels (300,500,800,1000), time levels 0 +3 +6 +9 +12			
	39	%	Cloud cover	
Climatologically surface parameters and special parameters, time level 0.			
	101	m	Topography	
	103	°K	Sea surface temperature	
	181	%	Fraction of land	
	182	m	Climatologically roughness	
	183	°K	Climatologically deep soil temperature	
	184	%	Albedo	
	186	m	Climatologically deep soil water	
	196	%	Fraction of ice	

4. The precipitation fields from PARLAM-PS.

For the year 1997, PARLAM-PS meteorological fields were first presented and used for operative EMEP runs with the new EMEP Eulerian acid deposition model.

As seen in Table 3.2, precipitation amounts are stored in 4 different fields:

- The total 3-dimensional precipitation, accumulated from model top to the actual model level, **PRlev**.

- The total surface precipitation, **PRsurf**

- The part of surface precipitation generated in stratiform clouds, **PRs**

- The part of surface precipitation generated in convective clouds, **PRc**.

Results of the verification of *surface* precipitation fields (PRsurf) presented in Tsyro and Støren (1999) showed that the predicted PARLAM-PS surface precipitation compared reasonably well with observations at a number of European stations. This surface precipitation field, PRsurf, is also routinely used and verified by weather forecasters. While the 3D precipitation field, PRlev, is an special output from the PARLAM-PS model, only used for air pollution modelling purposes. The first verification of *total 3D* precipitation amounts was reported in Olendrzynski (1999), showing a systematic underestimation of *total 3D* precipitation amounts (PRlev at surface) compared to observed precipitation data at the EMEP monitoring network. Consequently, a further verification process was initiated in order to explain the considerable underestimation of PARLAM-PS *total 3D* precipitation data.

Investigation of the internal consistency between the precipitation fields showed that the *total 3D* precipitation amount in the lowest model layer, PRlev(20), was underestimated compared to the surface precipitation, PRsurf (those fields should be equal). It appeared that only the stratiform part of the precipitation rates had been stored as PRlev in 1997, and not the total as it should have been. This has now been corrected for the 1998 meteorological data, used for calculations with the Eulerian model reported this year. The correction of the meteorological data for 1997, and subsequent rerun of the Eulerian dispersion model will be carried out later this year.

For wet scavenging processes not only the precipitation amounts are of importance, but also the occurrence or not of precipitation (ref. the *hit frequency* defined later). The efficiency of wet removal is determined to a great extent by the probability of encounting precipitation, the so-called *"dry Lagrangian way"* (Rodhe and Grandell (1981)). Quite often, both stratiform and convective precipitation occur in the same precipitation event. If there is enough stratiform precipitation to remove the pollution, the error done by not taking the convective precipitation into account is minimized. This is believed to be the reason why verification of air concentrations, depositions and concentrations in precipitation in Olendrzynski (1999) showed reasonable results, although the precipitation was underestimated.

To confirm this view a sensitivity test was made with the EMEP Eulerian model for transport of primarily particulate matter (PM2.5) for the month of September 1997. September was selected as a month with quite frequent convective precipitation events, therefore errors in wet depositions and air concentrations are expected to be relatively large compared to errors for e.q. winter months or the year as total. For PM2.5, in-cloud nucleation scavenging efficiency of 0.6 was assumed, and the sub-cloud precipitation scavenging efficiency was 0.1 (Tsyro and Erdman, 2000). These scavenging efficiencies are of the same order of magnitude as for the secondary inorganic aerosols in the Eulerian Acid Deposition model. It was found that the wet deposition underestimation of PM2.5 was on average 18%, even though the precipitation amount was 50% underestimated. The effect on PM2.5 air concentrations appeared to be less significant (fig 4.9). Even smaller underestimation is expected for secondary inorganic aerosols (sulphate, nitrate and ammonium) due to their higher solubility. For soluble gases, which are very efficiently scavenged, both in-cloud and sub-cloud, it is believed that the effect of the underestimation in precipitation amount will be further reduced, as long as the occurrence of precipitation events is predicted correctly.

Since the convective precipitation was missing in the 1997 fields, the precipitation underestimation was largest over warm sea areas, like the Mediterranean Sea where yearly precipitation amounts were underestimated by about 70% or more. (Fig 4.3) In central Europe, however, the underestimation was about 50%, decreasing northward to 10-20% underestimation in the yearly precipitation amount.

Figures 4.4, 4.6 and 4.8 show the hit frequency in percent for the whole 1997, January 1997 and July 1997 respectively. The "hit frequency" (HF) quantifies the number of cases when convective precipitation is concurrent with stratiform precipitation and it is defined as:

$$HF = \frac{(\ Number\ of\ termins\ (PRlev(20)>0\ and\ PRsurf>0)}{Number\ of\ termins\ \ PRsurf>0}$$

The hit frequency is a measure to compare the modelled probability of being removed by precipitation when using the underestimated 1997 precipitation fields.

From figure 4.4 we can see that in central Europe the hit frequency for the year 1997 are most frequent 80% or more.

Looking at the seasonal variation, Figure 4.5 shows that in January 1997 the underestimation of precipitation over Europe was less than 10%, because wintertime precipitation rates are dominated by stratiform precipitation over land. On the other hand, over the relatively warm sea the underestimation was large, and it was most extreme over the Mediterranean sea with an underestimation of 90%. However, the precipitation-hit percent, Figure 4.6, was quite good over Europe with values larger than 95%. In Spain, Italy, Greece and Balkan the hit percent decreases due to the nearby warm sea areas but also for those countries the hit percent was mostly above 85 %. In July 1997, the conclusions are somewhat different. Figure 4.7 shows that the 1997 underestimation in precipitation amounts is about 40-50% in southern Europe, and smaller when going northward down to 20% underestimation. The hit percent over Europe is about 60 – 70 %.

From this we can conclude that the underestimation of 1997 modelled precipitation amounts is smallest during wintertime, when concentrations reaches their highest levels. Since the hit percent (HF) is very high over land during winter, the wet deposition calculated by the Eulerian Acid Deposition model is not highly affected by the underestimation of precipitation amounts. The largest impact in wet deposition calculations occurs during summer in Southern Europe, where convective precipitation is important and the concurrence with stratiform precipitation takes place only in 60-70% of the cases with precipitation.

Figure 4.1 : Total accumulated surface precipitation for 1997, *PRsurf*

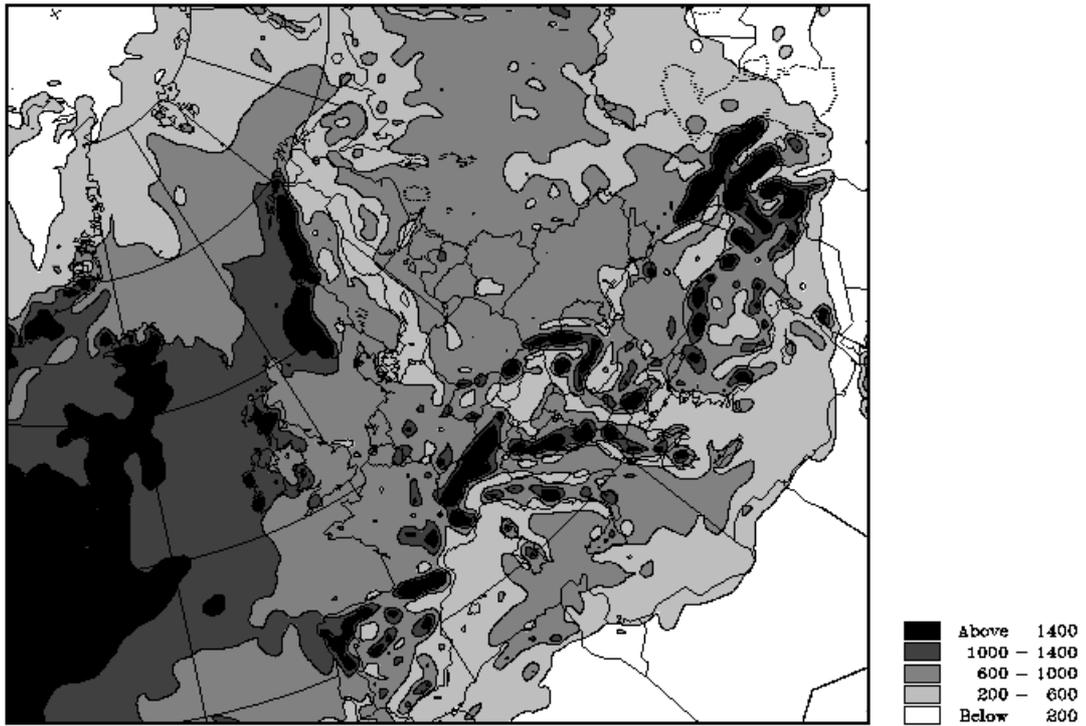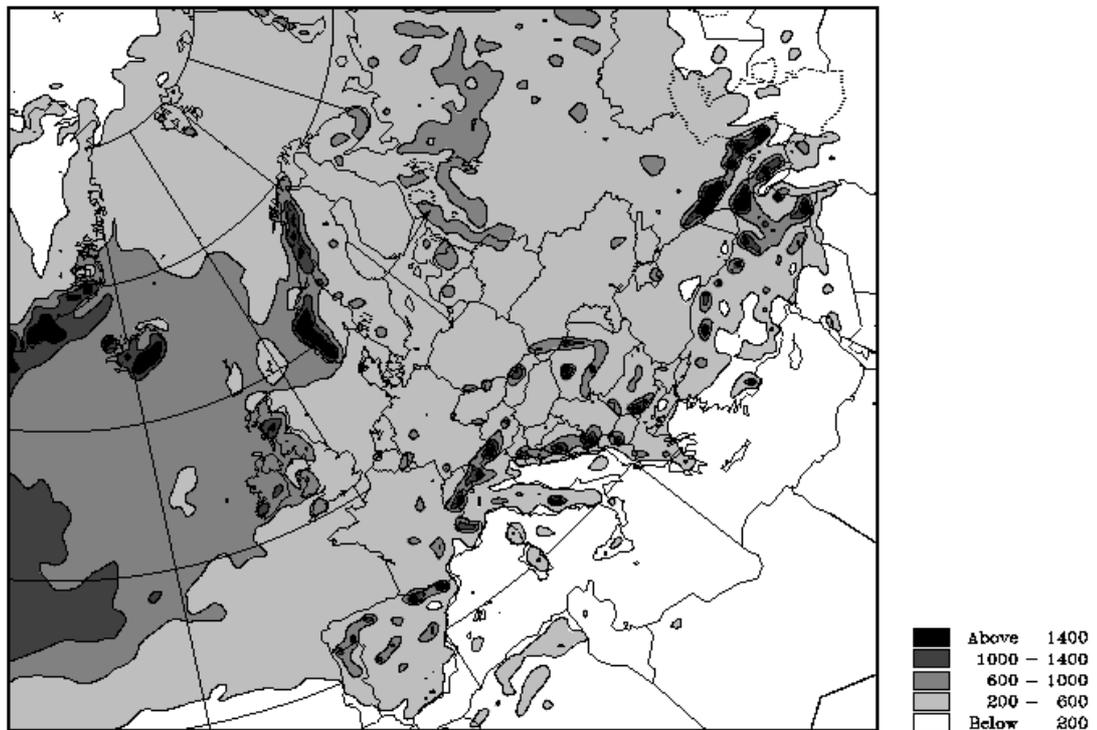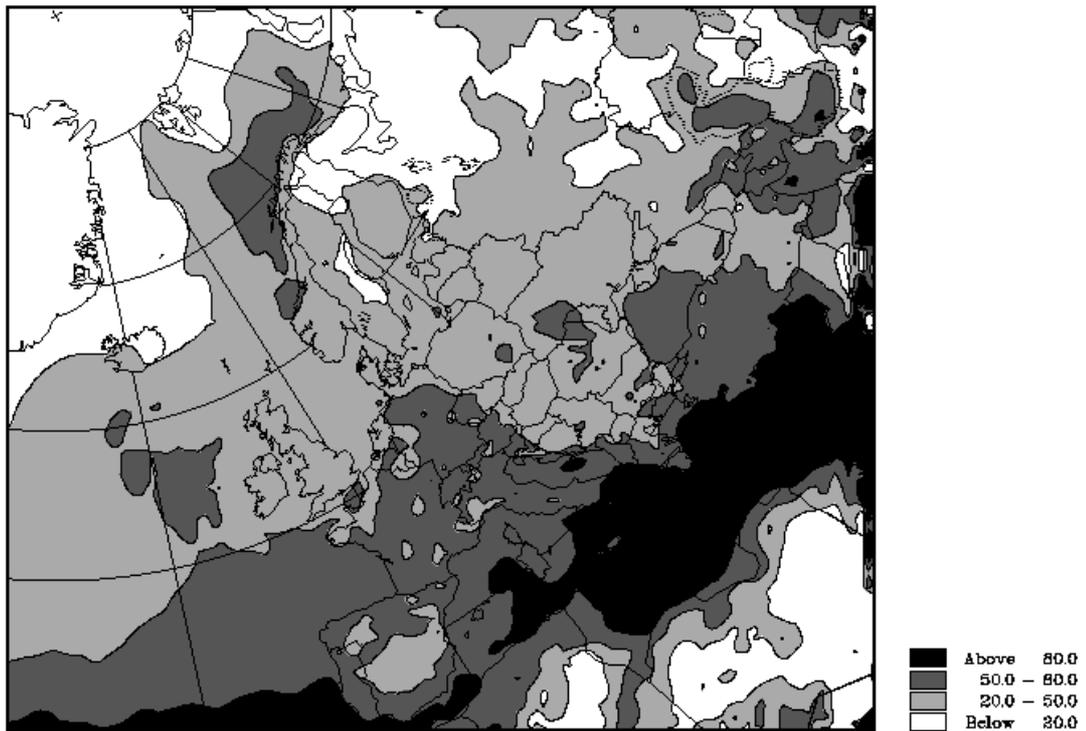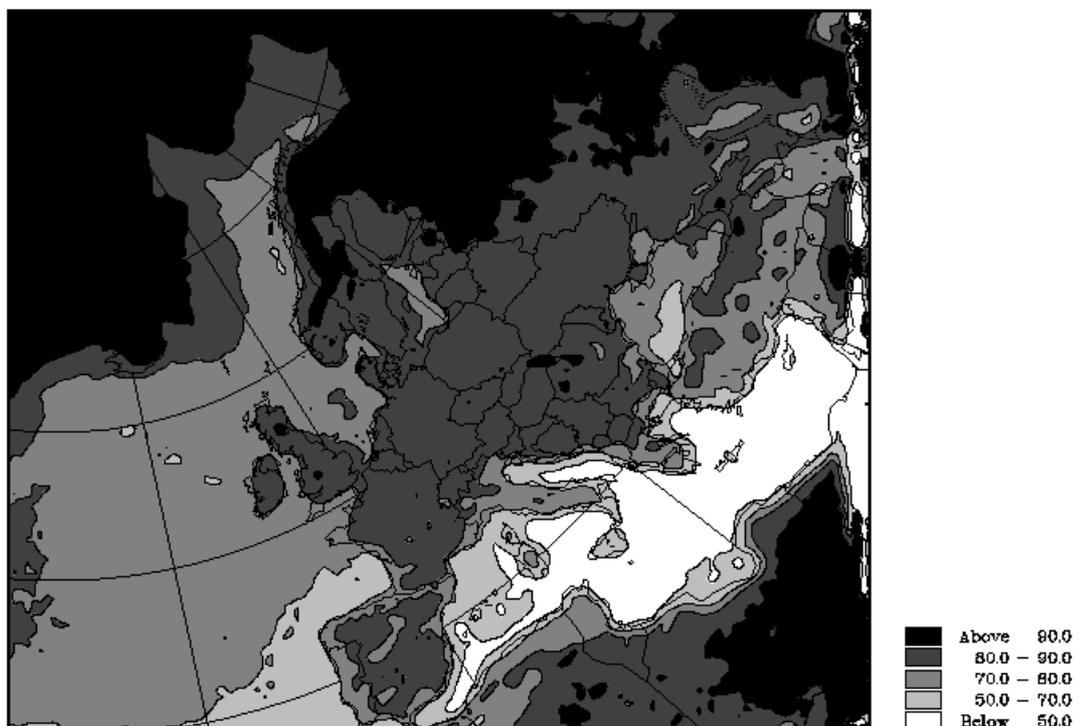|	
■	Above 1400
	1000 — 1400
	600 — 1000
	200 — 600
□	Below 200

Figure 4.2: 3-dimensional precipitation at the lowest model layer for 1997. PRlev(20).

■	Above 1400
	1000 — 1400
	600 — 1000
	200 — 600
□	Below 200

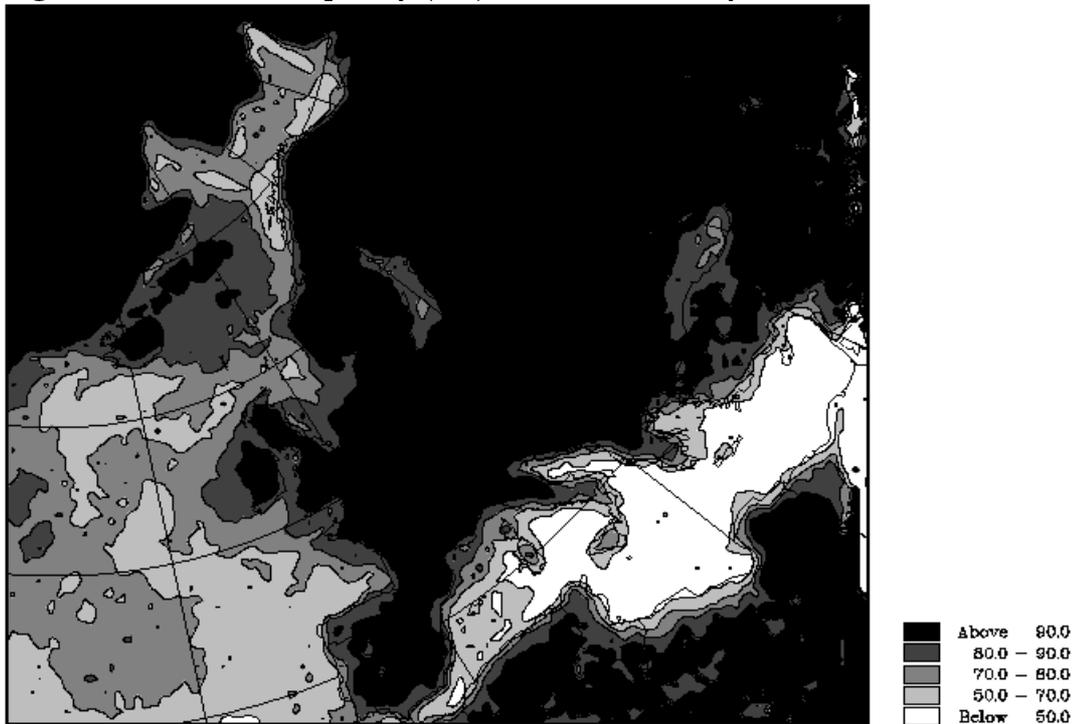**Figure 4.3 The relative underestimation of precipitation in % for 1997.**

Figure 4.4. The hit frequency (HF) in % for 1997.

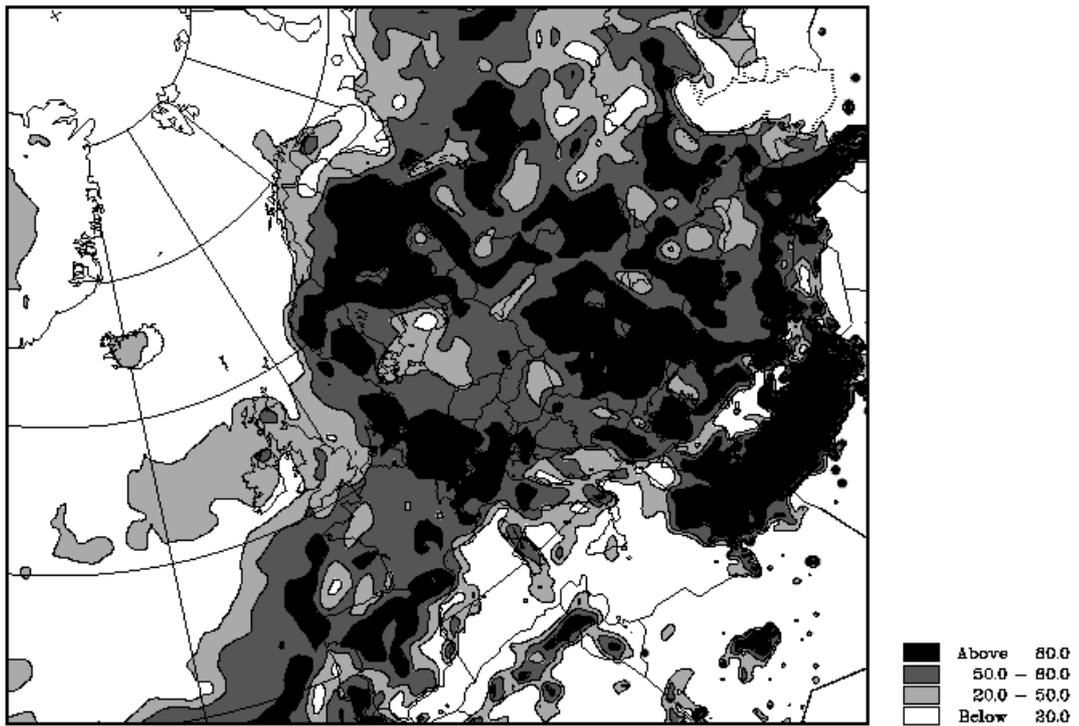**Figure 4.5 The relative underestimation of precipitation in % for January 1997.**
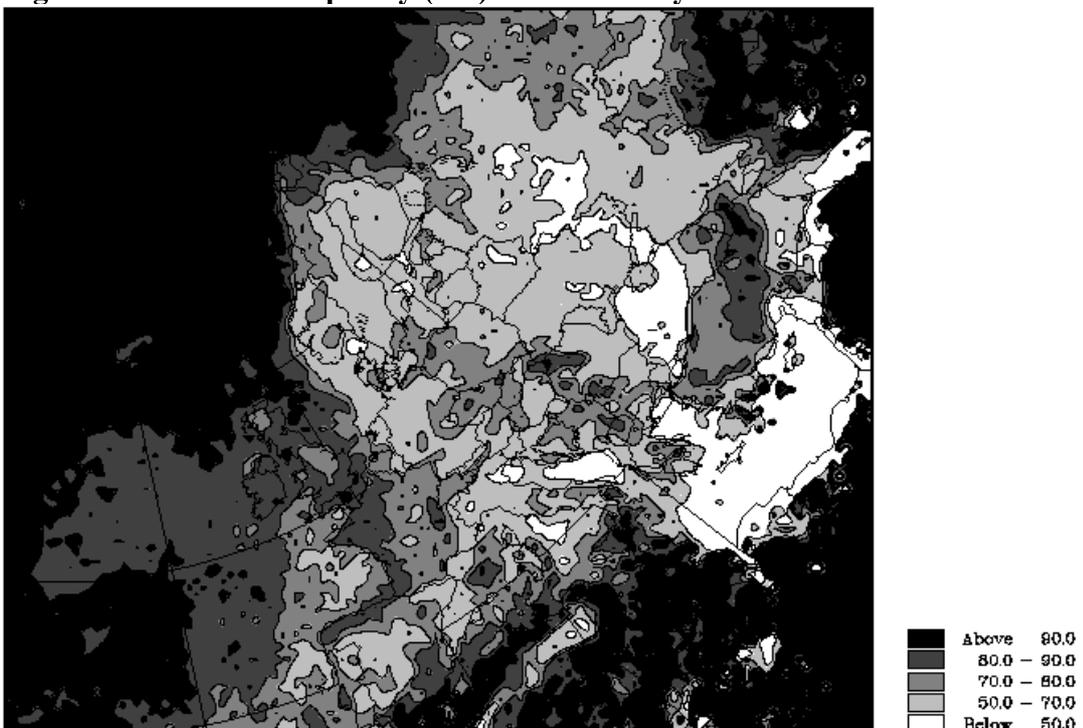

Above   80.0
50.0 — 80.0
20.0 — 50.0
Below   20.0
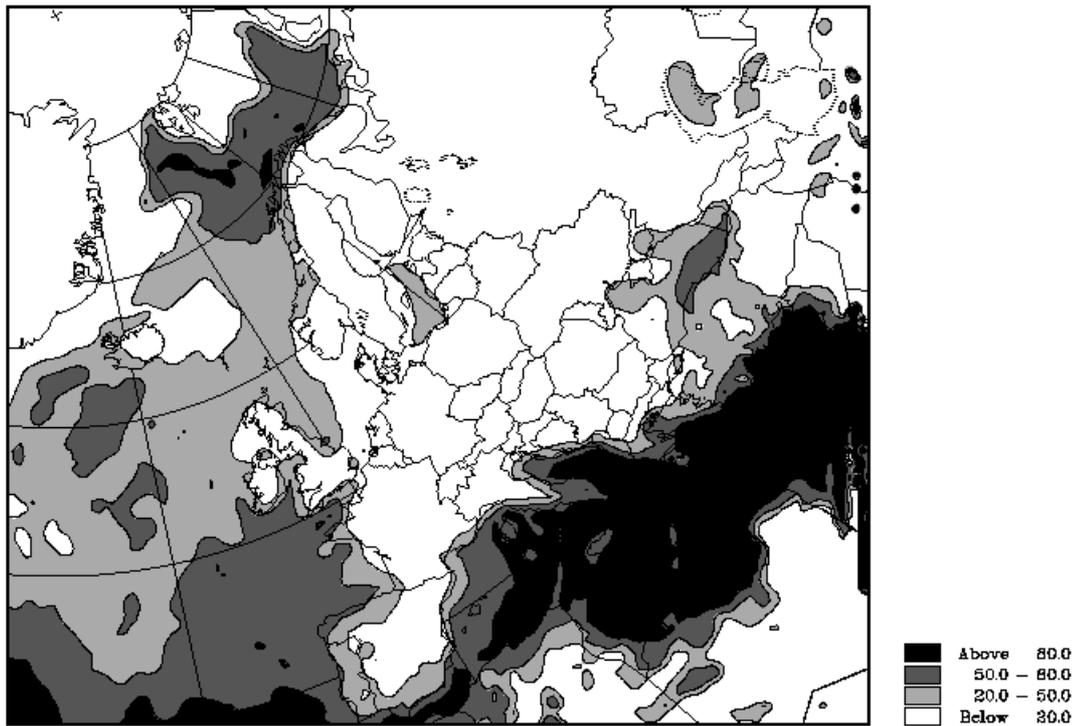
Figure 4.6 : The hit frequency (HF) in % for January 1997

Above   90.0
80.0 — 90.0
70.0 — 80.0
50.0 — 70.0
Below   50.0

Figure 4.7 : The relative underestimation of precipitation in % for July 1997.

Above   80.0
50.0 — 80.0
20.0 — 50.0
Below   20.0

Figure 4.8 : The hit frequency (HF) in % for July 1997

Above   90.0
80.0 — 90.0
70.0 — 80.0
50.0 — 70.0
Below   50.0

Figure 4.9 : Spatial distribution of the relative error in air concentrations of PM2.5

1997 09 30 12 +12

1000 [1 - PM2.5$_B$ / PM2.5]

> 0.5000

0.2000 - 0.5000

0.1000 - 0.2000

< 0.1000
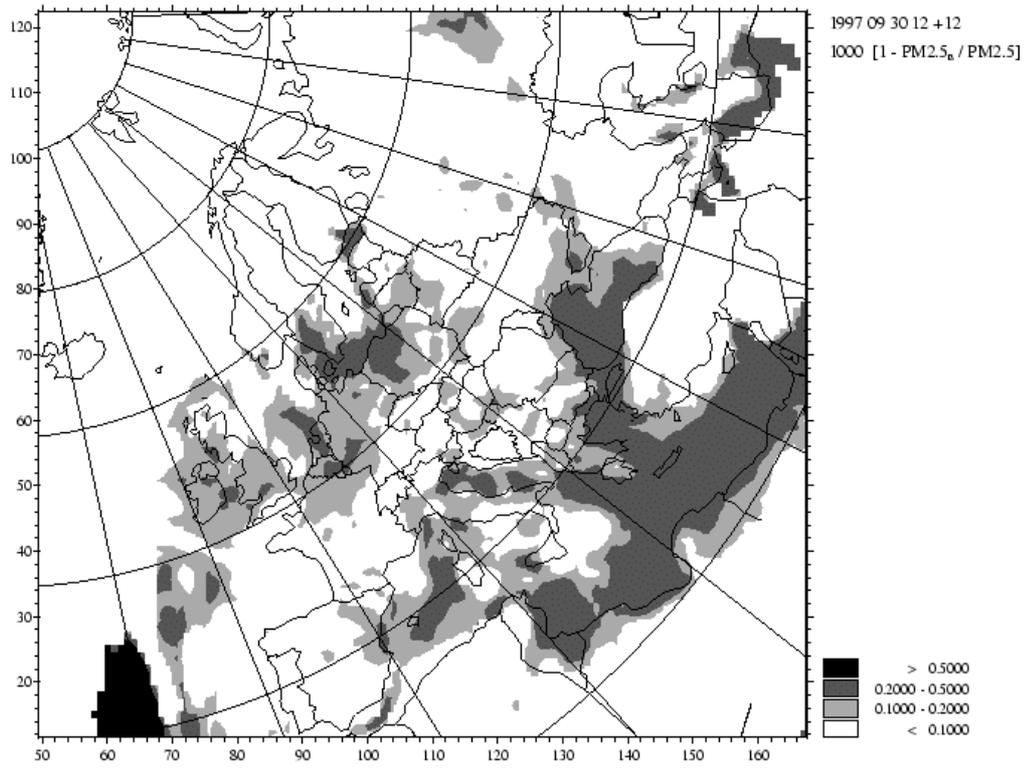
5. Summary and recommendations.

This year, for the first time, 3D precipitation fields have been analysed. The verification process reported here was initiated to explain the observed considerable underestimation of PARLAM-PS *total 3D* precipitation data for 1997 reported by Oldendrzynski (1999).

Investigations showed that only the stratiform part of the precipitation had been stored in the PARLAM-PS 3D precipitation fields. Unfortunately these data have been used in the EMEP Eulerian Acid Deposition model for the year of 1997. However, verification of air concentrations and wet depositions of several acidifying components did not show large discrepancies between observed and calculated values (Olendrzynski (1999)) even though the precipitation amounts was underestimated about 50% on a yearly basis. This rather good verification can be explained by the importance for the final results of the correct prediction of precipitation events. The investigation showed that the concurrence between the underestimated precipitation events and the correct precipitation events were as high as 80% during the whole 1997. With seasonal variation of wintertime values as high as 90% or more over Europe. The summertime values showed a larger variation between north and south because of the lager convective activity in summer, but even tough the values were as high as 60-70% over Europe.

For the next year, we intend to continue with systematic analysis of meteorological fields, among others a common parametrization of physiographic data in NWP models and the EMEP air pollution models needs to be investigated further.

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