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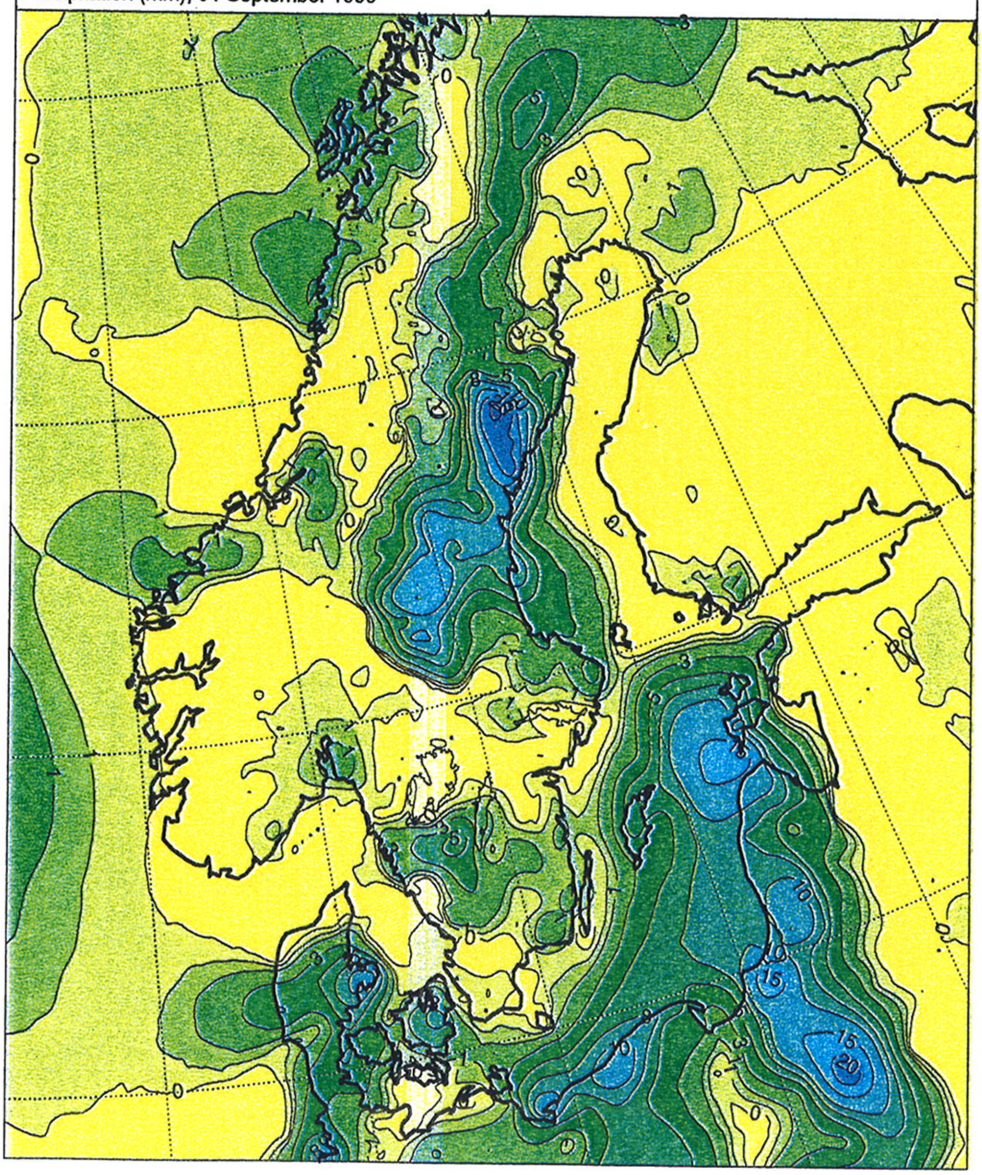
Climate Applications based on High Resolution Datasets produced by the MESAN System

D. Foltescu and V.L.Foltescu

Precipitation (mm), 01 September 1999



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Climate Applications based on High Resolution Datasets produced by the MESAN System

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PROJECT CONTRACTORS

NORDKLIM/NORDMET on behalf of the National meteorological services in Finland (FMI), Iceland (VI), Norway (DNMI) and Sweden (SMHI)

SUMMARY

This report is prepared under Task 2 in the Nordic NORDKLIM project: Nordic Co-Operation Within Climate Activities. The NORDKLIM project is a part of the formalised collaboration between the NORDic METerological institutes, NORDMET.

A MESoscale ANalysis system (MESAN) for meteorological and climatological variables has been in operation at SMHI since october 1997. Multivariate observational data synoptic stations, automatic weather stations, satellites and weather radars are integrated into the mesoscale analysis scheme. In addition to observational data, MESAN uses weather forecast fields from HIRLAM as a "first guess" initial field.

This report presents some of MESAN's climatological products; i.e. daily and monthly temperature, cloudiness and precipitation. The methods used for interpolation of the multisource data are discussed shortly. As example of application of MESAN, the Swedish Crop Growth Monitoring System is presented briefly.

SIGNATURES

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Foreword

This report is prepared under task 2 in the Nordic NORDKLIM project: *Nordic Co-Operation Within Climate Activities.* The NORDKLIM project is a part of the formalised collaboration between the NORDic METerological institutes, NORDMET.

The main objectives of NORDKLIM are:
1). Strengthening the Nordic climate competence for coping with increased national and international competition
2). Improving the cost-efficiency of the Nordic meteorological services **(*i.e. by* improving procedures for standardized quality control & more rational production of standard climate statistics)**
3). Coordinating joint Nordic activities on climate analyses and studies on long-term climate variations

The NORDKLIM project has two main tasks:
1. Climate data (Network design, Quality control, Operational precipitation correction, long-term datasets)
2. Climate Applications (Time series analysis, use of GIS within climate applications, mesoscale climatological analysis). A detailed decription of the project is given by Førland et al., 1998.

NORDKLIM is coordinated by an Advisory Committee, headed by an Activity Manager. Each of the main tasks is headed by a Task manager.

The Advisory Committee in NORDKLIM is presently consisting of:

Bengt Dahlström, SMHI
Eirik J. Førland, DNMI **(Activity Manager)**
Raino Heino, FMI
Trausti Jónsson, VI
Lillian Wester Andersen, DMI

The present NORDKLIM Task Managers are: **Task 1**: Pauli Rissanen (FMI), **Task 2**: Ole Einar Tveito (DNMI)

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Climate Applications Based on High Resolution Datasets Produced by the MESAN System

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1. Introduction

Recent developments of mesoscale analysis systems employed in meteorology result in higher spatial resolution and better accuracy. The analysis can be performed in real time, consequently allowing a timely access to its products, i.e. gridded information on a variety of meteorological variables. A reanalysis with such systems, performed after gathering information from the climatic stations may be regarded as a possible approach to obtain gridded fields of climatological variables.

A MESoscale ANalysis system (MESAN) (Häggmark et al., 1999) for meteorological and climatological variables has been in operation at the Swedish Meteorological and Hydrological Institute (SMHI) since October 1997. MESAN provides science and consumers of weather information with objective, spatially continuous fields of seventeen variables. The employed method of spatial interpolation is the optimal interpolation (OI) technique, also called statistical interpolation (Gandin 1963, 1970 and Daley, 1991).

Multivariate observational data from synoptic stations, automatic stations, satellites and weather radars are integrated into the mesoscale analysis scheme. In optimal interpolation, observations are used together with a background field i.e., the *first guess field.* Thus, in addition to observational data, MESAN uses weather forecast fields from a HIgh-Resolution Limited Area Model (HIRLAM) (Källen et al., 1996) as "first guess" initial fields. If HIRLAM information is missing, horizontally-smoothed previous analyses are used instead.

In an international context there are several mesoscale analysis systems in use. Two examples of such systems are the British Nimrod (Golding,

1998) and the American Local Analysis and Prediction System (LAPS) reviewed by Albers et al. (1996).

This report presents some of MESAN's climatological products, namely daily and monthly temperature, cloudiness and precipitation. The methods used for interpolation of the multisource data are discussed shortly. Results from another application of MESAN further exemplify the applicability: The recently developed Swedish Crop Growth Monitoring System (SCGMS) (Foltescu, 1999) is presented briefly.

2. Overview of the MESAN system

The inputs to MESAN consist in:

1) Observational data furnished by:
- synoptic stations
- automatic stations of SMHI and the Swedish Road Authority (VviS)
- climatic stations
- weather radars
- satellites (NOAA, METEOSAT)

2) Initial (first guess) fields supplied by HIRLAM

The direct output from MESAN i.e., the result of real-time analysis, consists in spatially continuous fields of seventeen meteorological variables.

When 24-hour data reported monthly by climatic stations is available, a delayed (off-line) analysis is performed. This analysis is regarded as an approach to obtaining gridded fields of climatological variables.

2.1. Real-time meteorological analysis

The MESAN system has originally been designed to produce gridded fields of variables relevant in meteorology (Häggmark et al., 1997, 1999). The real-time analysis is conducted for integration times of one hour to three hours at a spatial resolution of 0.2°×0.2°. The analysis is thereby performed on a 22-km rotated latitude-longitude grid (102×116). The geographical extent for the MESAN analysis is Scandinavia and the entire drainage basin of the Baltic Sea.

In the real-time application multisource surface observations including stations and remote sensing imagery (radar and satellites) are input into the system along with initial fields from HIRLAM.

The output from the real-time analysis consists in gridded fields of the following variables: pressure, temperature, minimum temperature, maximum temperature, virtual temperature, visibility, gust, u-wind, v-wind, relative humidity, total cloud cover, amount of low clouds, frequency of observed significant clouds, significant cloud base, significant cloud top, accumulated precipitation, accumulated new snow.

2.2. Delayed meteorological/climatological analysis

SMHI has a relatively dense network of climatological stations, which provide daily precipitation and daily mean temperature, both reported on a monthly basis.

In order to make analysis of climatological variables, the MESAN system has been adapted accordingly. The analysis is performed on a 203×231-grid of 11-km resolution, having the same geographical extent as the "real-time" grid. The time resolution is three hours and extends further to one month, depending on the integration/averaging time of the variable in question. The time of the analysis is delayed with about one month from the real-time analysis due to awaiting reports of observations from the network of climatic stations.

The same variables as analysed in real-time (see above), supplemented by daily and monthly temperature and precipitation are subjected to the delayed meteorological/climatological analysis, also called and hereafter referred to as "re-analysis".

2.3. Optimal interpolation

The optimal interpolation (OI) technique has been widely used in meteorological applications and will not be dealt with in detail here. OI is presented in e.g. Daley (1991). The interpolation is based on the minimum-mean-squared-error of the analysis.

A key aspect of the OI technique is the use of so-called autocorrelation functions that provide important information on how the variable being interpolated is correlated in space. In the development of MESAN major effort has been devoted to model these functions using a large body of historical data. The interpolation is employing the derived fixed autocorrelation functions together with first guess fields from HIRLAM.

The following chapters give a short description of some important aspects of the analysis of three significant variables for climatology: temperature, cloudiness and precipitation.

A quality control is performed before submission to OI in MESAN. Thereby can large or systematic errors be identified and eliminated.

2.4. The temperature analysis scheme

The observation systems involved in the temperature analysis consist in: synoptic (SYNOP) stations, automatic stations and climatic stations. The vertical profile of temperature is retrieved from HIRLAM and used for interpolation of the first guess to the analysis grid.

The autocorrelation functions are not isotropic. They are corrected with respect to the difference in elevation of the stations and also taking account of the land–sea fraction. The corrections are empirical linear functions.

2.5. The cloud analysis scheme

The observation systems involved in the cloud analysis consist in: SYNOP-stations, METAR (airport data), automatic stations and satellites. The polar NOAA satellite is used together with the SCANDIA classification scheme (Karlsson, 1996). The geostationary METEOSAT is used as well. The NOAA satellite provides high spatial resolution and extensive spectral information but coarse temporal resolution. METEOSAT provides high temporal resolution instead. Observations within +/- one hour from the analysis time are being considered.

In addition to the cloudiness reporting stations, the difference between the temperature at the 2-m level and the brightness temperature (which is the effective black body radiation temperature retrieved from satellites) is used as an indicator for the presence/absence of clouds. This is supplemented by HIRLAM information on stratification, relating it to the chance of encountering clouds for well-defined stability criteria.

2.6. The precipitation analysis scheme

Observational data from SYNOP- and climatic stations as well as weather radars are assimilated into MESAN.

Precipitation can be highly variable, both temporally and spatially. The autocorrelation functions vary with accumulation time (3h, 12h, 24h), and are steepest for the 3h-analysis. Orrographic effects on precipitation (such as topographic enhancement and enhancement by coastal convergence) are indirectly taken into account. If the wind direction is known, a statistical model is used to create a field with standard deviations of precipitation. The model is based on a climatological regression analysis in which: 1) the frequency of wind directions multiplied by the upslope gradient of topography, 2) the component of the roughness length perpendicular to wind direction and 3) latitude are used as predictors. The result is a field that shows the climate of the current weather situation. If the wind direction is not known, the climatological field of the standard deviations is used. Both observations and the first guess field are normalised with respect to the standard deviation, and the interpolation is performed in the normalised variable. The normalisation is inverted at the end of the analysis. Isotropic analysis in the normalised variable is possible due to the fact that the annual precipitation, normalised by the standard deviations of the daily precipitation, is nearly constant, independent on station.

3. Applications of the MESAN re-analysis

A number of applications of the MESAN re-analysis products can be identified: climatology, agrometeorology, dispersion modelling, hydrological modelling, etc. The following two chapters give examples of possible applications in climatology and agrometeorology.

3.1. Climatological maps

Climatological maps of three main climatological variables (temperature, total cloud cover and precipitation) on a daily and a monthly scale have been produced with MESAN and a related graphics package, MetGraf (developed at SMHI). Figures 1 to 6 show examples of the above gridded variables taken from September 1999.

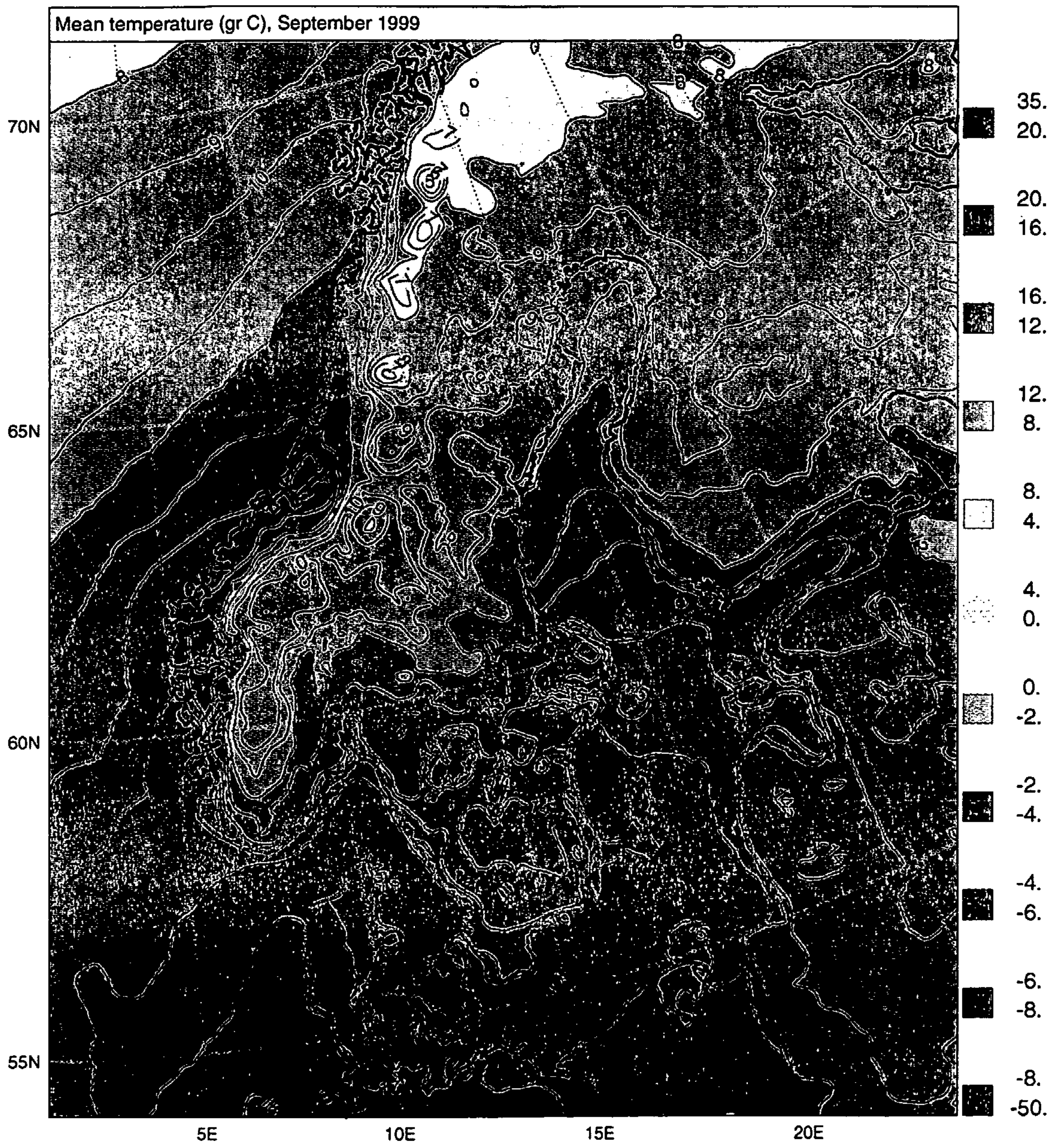

Figure 1. Monthly mean temperature (September 1999) analysed with MESAN.

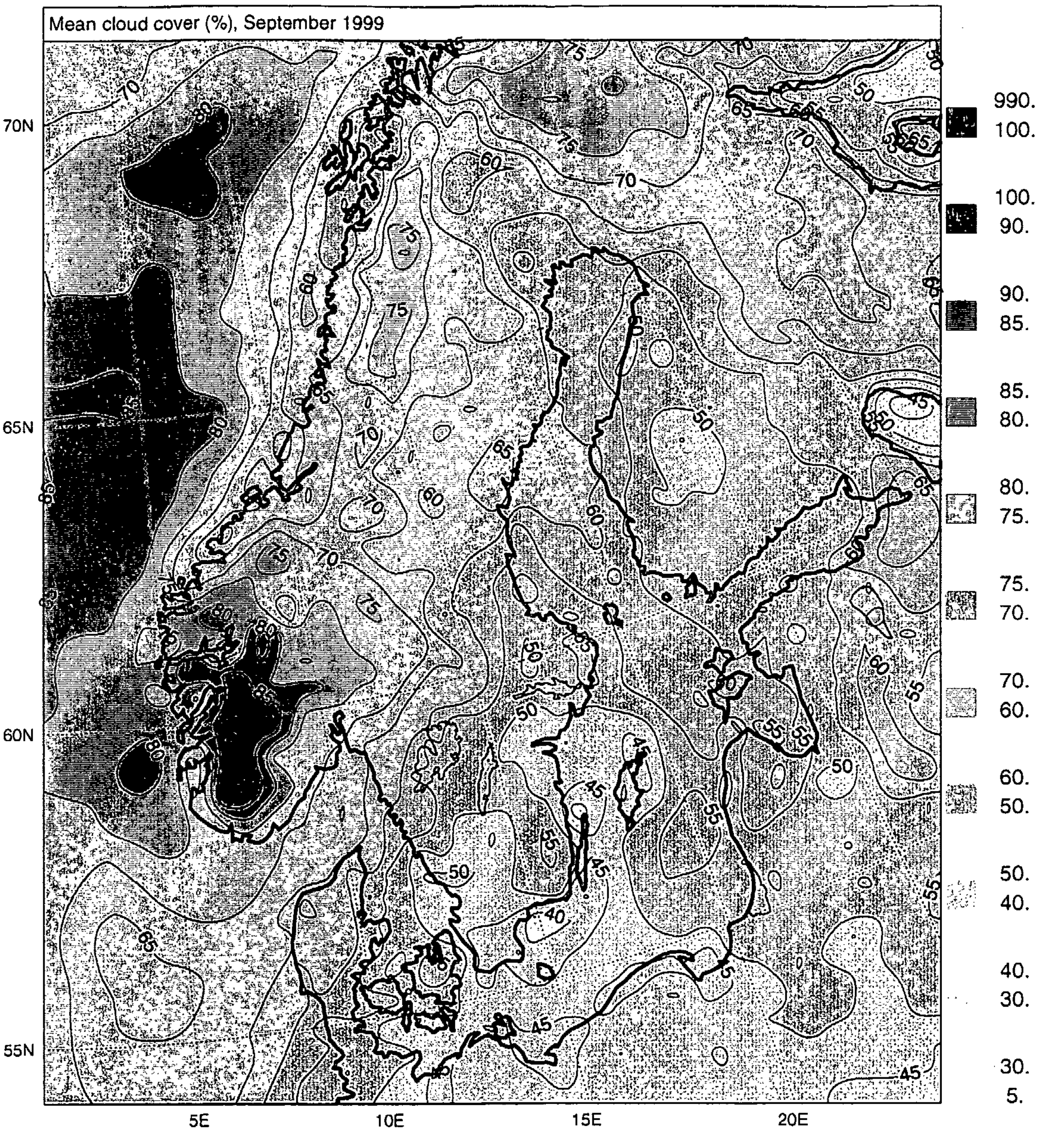

Figure 2. Monthly mean cloudiness (September 1999) analysed with MESAN.

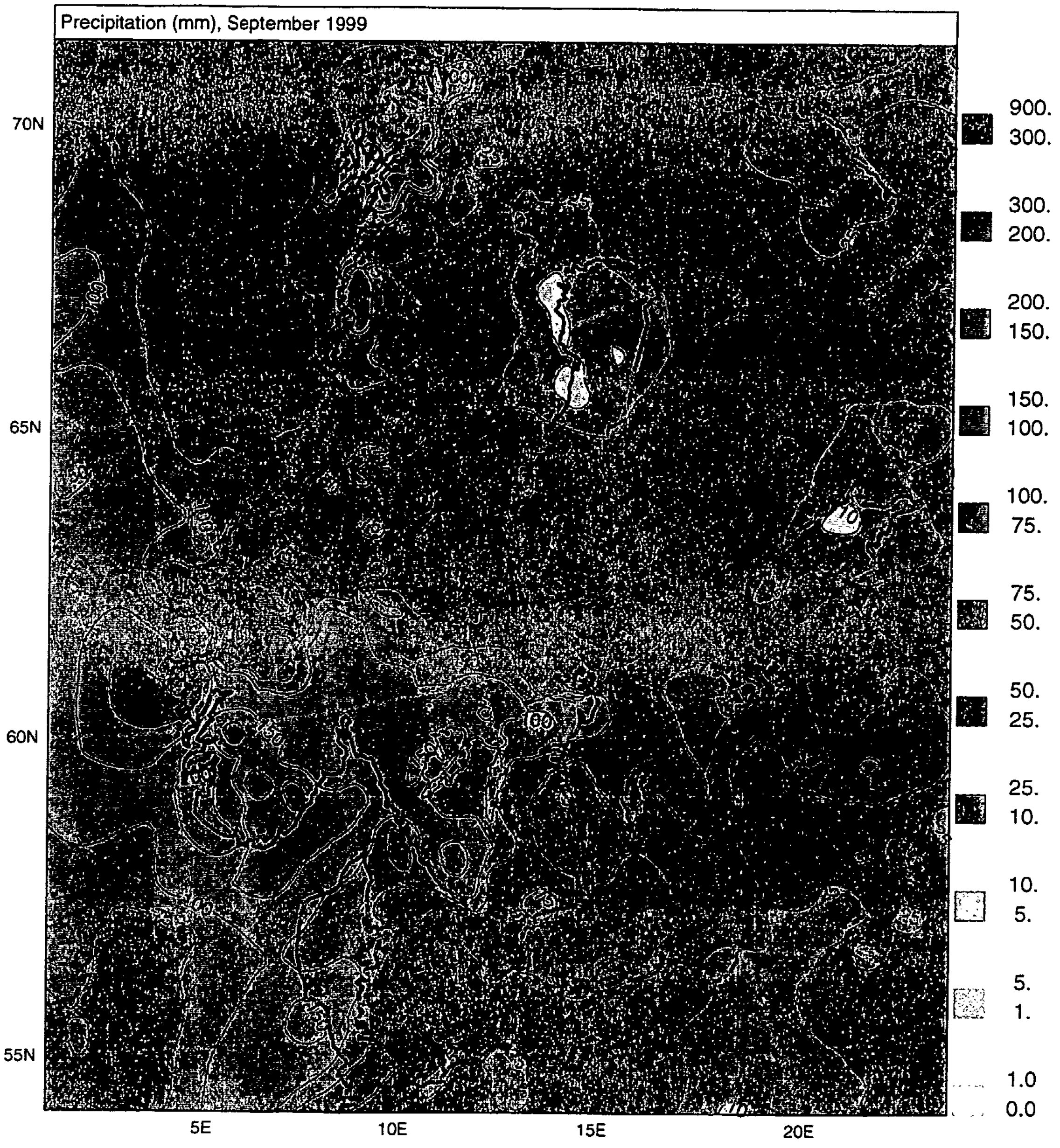

Figure 3. Monthly precipitation (September 1999) analysed with MESAN.

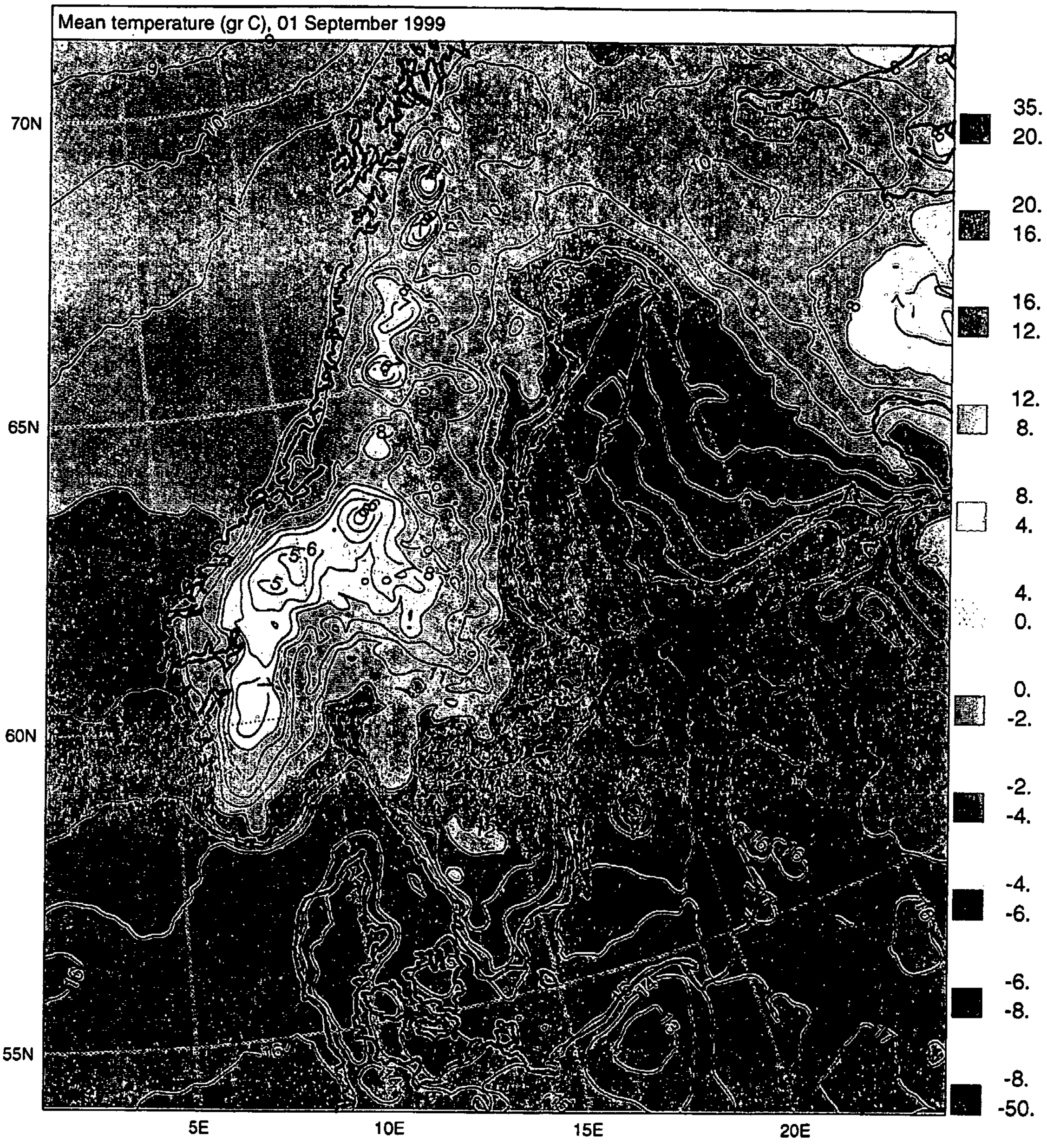

Figure 4. Daily mean temperature (01 September 1999) analysed with MESAN.

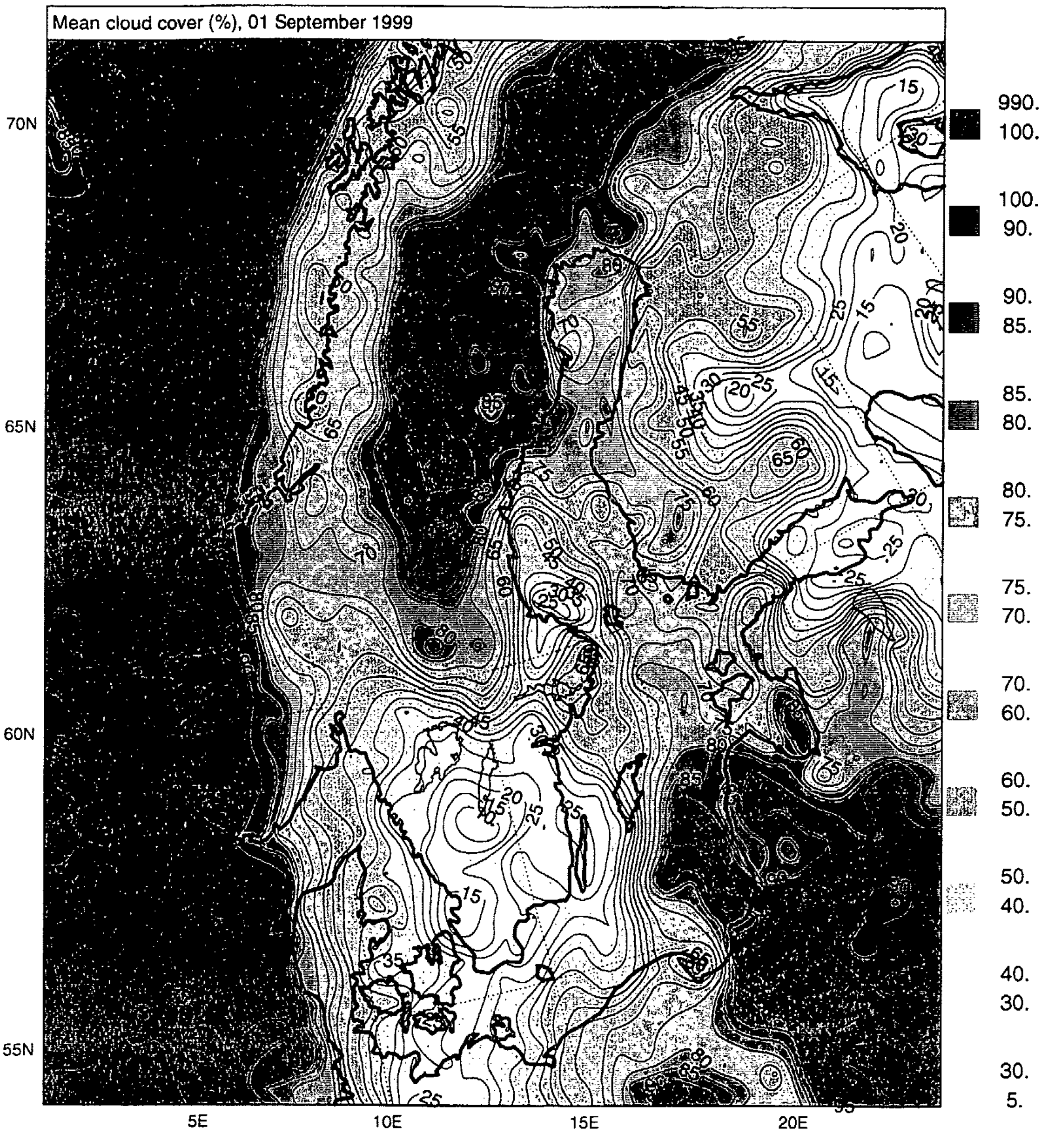

Figure 5. Daily mean cloudiness (01 September 1999) analysed with MESAN.

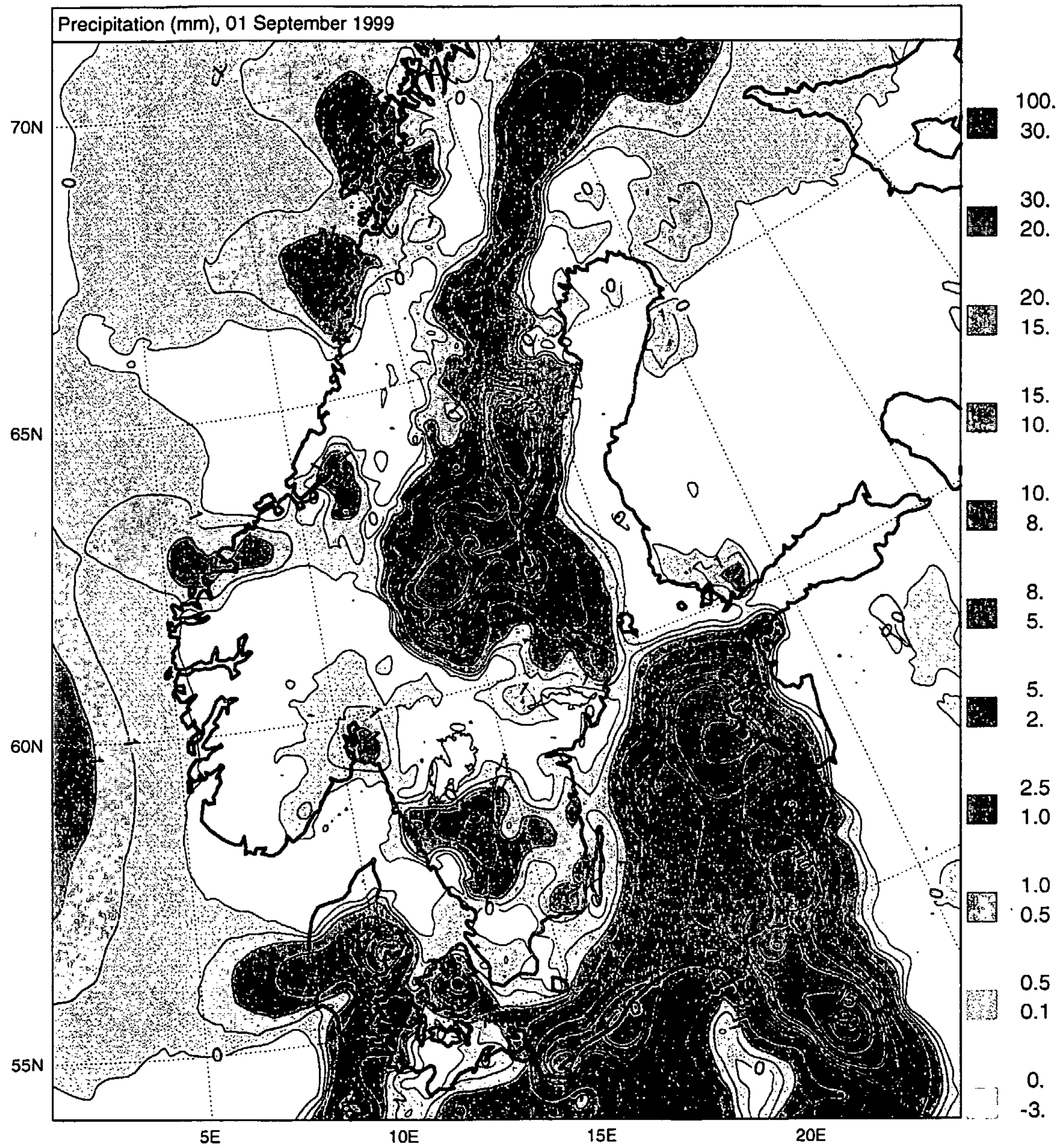

Figure 6. Daily precipitation (01 September 1999) analysed with MESAN.

A comparison between observations and fields containing gridded climatological information (including MESAN-fields) was made by Foltescu and Häggmark (1998). In the study attention was devoted to precipitation and to the comparison of observations with the cross-validated values in the grids. The difference between point observations and the spatially averaged information (defined as discrepancy) was explicitly calculated and presented for confidence intervals of one standard deviation (implying 68% confidence). As an example, the relative discrepancy for monthly precipitation varied between ±19% and ±27% (based on the years 1994 to 1997). The later figure was obtained for the summer season.

The same study (Foltescu and Häggmark, 1998) showed that the mean absolute discrepancy between gridded monthly temperatures (corrected to the station heights) and monthly means of temperature observations was of the order of 0.2°C in winter and less than 0.1°C in summer.

A validation study of the MESAN-cloudiness with independent station data is ongoing at SMHI (K.-G. Karlsson, personal communication).

3.2. The Swedish Crop Growth Monitoring System

A prediction system for regional crop growth in Sweden was recently set-up and validated at SMHI (Foltescu, 1999). The system includes a state-of-the-art crop growth model, WOFOST (WOrld FOod STudies) and inputs of daily meteorological variables from MESAN.

Two counties in Sweden are subject to the investigation so far, Skåne and Skaraborg, both of large importance for Swedish crop production. The simulated crops are spring barley, spring rape, oats and winter wheat. The investigated period is 1985-1998.

The model simulates biomass accumulation in combination with phenological development, on the basis of underlying processes, such as photosynthesis and respiration, and how these processes are being influenced by environmental and soil conditions. It simulates the crop growth of annual field crops, allowing quantitative estimation of the potential for crop growth under specified soil and weather conditions.

Making use of gridded fields from a system like MESAN is expected to increase the accuracy of the crop yield calculations in Sweden. The values in the gridded fields are more realistically used for crop growth simulations. The values no longer represent point data. They describe the average conditions prevalent in the grid cells during the time step.

4. Conclusions and prospects

Owing to the objectiveness and versatile application of the mesoscale analysis concept one can expect increased attention to MESAN-like systems in the future. Objective "gridding" of climatological information is one important application. Various types of models such as agrometeorological and transport and chemistry models are also being served by consistent and accurate gridded data.

It is feasible to think of a mesoscale analysis scheme performed at a larger scale such as the European. A pan-European mesoscale analysis system would improve and enhance much of the operational climate related work in Europe (Dahlström, 1999).

Another interesting prospect is an analysis backwards in time, based on observational data from synoptic and climatic stations accompanied by other initial fields (such as the Re-Analysis fields produced at the European Centre of Medium-range Weather Forecasts (ECMWF)). Such an analysis can go back to 1979 (as in the case of ECMWF Re-Analysis) or as long back as initial fields have been archived. The MESAN system has been modified for such purpose and tests show its well behaviour (Foltescu, internal communication).

5. References

Albers S. C., McGinley J. A., Birkenheuer D. L. and Smart J. R. (1996) *The local analysis prediction system (LAPS): Analysis of clouds, precipitation and temperature, Weather and Forecasting* **11**, 273-287.

Dahlström, B. (1999), private communication.

Daley R. (1991), *Atmospheric Data Analysis*, Cambridge University Press. ISBN 0-521-38215-7.

Foltescu V. L. and Häggmark L. (1998), *Jämförelse mellan observationer och fält med griddad klimatologisk information, SMHI-Meteorologi* nr. **90**, SMHI, Norrköping, Sweden. ISSN 0283-7730.

Foltescu V. L. (1999), *Prediction of crop yield in Sweden based on mesoscale meteorological analysis*, Accepted for publication in *Meteorol. Appl.*

Gandin L. S. (1963), *Objective analysis of meteorological fields.* Gidrometeorologischeskoe Izdatel'stvo, Leningrad, 1960. Translated from Russian into English, Israel Programme for Scientific Translations, Jerusalem.

Gandin L. S. (1970), *The planning of meteorological station networks*, WMO **265**, T.P. 149, Technical Note No. 111.

Golding B. W. (1998), *Nimrod: A system for generating automated very short range forecasts*, *Meteorol. Appl.* **5**, 1-16.

Häggmark L., Ivarsson K-I. Gollvik S., Olofsson P-O. (1999), *MESAN, An Operational Mesoscale Analysis System*, *Tellus*, in press.

Häggmark L., Ivarsson K-I. and Olofsson P-O. (1997) *MESAN Mesoskalig analys, RMK* **75** *Report* (in Swedish). SMHI, 60176 Norrköping, Sweden.

Karlsson K-G. (1996), *Validation of model cloudiness using satellite-estimated cloud climatologies*, *Tellus* **48A**, 767-785.

Källen E. (1996), *Hirlam Documentation Manual*, system 2.5, (available from SMHI, Norrköping, Sweden).