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TWO APPROACHES TO METEOROLOGICAL DATA SUPPLYING FOR POLLUTION TRANSFER MODELING

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ABSTRACT

Technological aspects of preparing the input data for transboundary pollution transport models used in the two Meteorological Synthesizing Centers (MSC-West, Oslo and MSC-East Moscow) are analyzed. Problems concerning the development of methods that provide meteorological data for this kind of models are considered. The present state of the problem is analyzed. The input data sets of the basic meteorological elements (precipitation and wind) for the central months of the 1992 seasons are compared.

Palabras clave: preparación de datos meteorológicos, transporte interfronterizo de contaminantes

RESUMEN

Se analizan aspectos técnicos en el proceso de la preparación de los datos de entrada para los modelos de transporte interfronterizo de contaminantes que se usan en dos Centros de Síntesis Meteorológica (CSM-Oeste, Oslo y CSM-Este Moscú). Se consideran varios problemas relativos al desarrollo de los métodos para abastecer dichos modelos con datos meteorológicos. Se analiza el estado presente del problema. Se comparan los conjuntos de los datos de entrada de los elementos meteorológicos básicos (precipitación y viento) para los meses centrales de las estaciones de 1992.

INTRODUCTION

The monitoring of air pollution is an urgent problem of the environmental protection. The international EMEP (Co-operative Program for Monitoring and Evaluation of the Long Transmission of Air Pollutant in Europe) implemented within the framework of the Convention on Long-Range Transboundary Air pollution (1979) deals with the observation and estimation of the long-range pollutant dispersion in Europe. At the present time, the Meteorological Synthesizing Center West (MSC-W) in Oslo and the Meteorological Synthesizing Center East (MSC-E) in Moscow develop operational models of the long-range and large-scale pollution transport in the atmosphere. For more than 10 years these centers perform regular monitoring of the transboundary pollution transport by air flows over Europe using emission data and meteorological information, and applying numerical schemes to calculate the trace transport, transformation and deposition (Pressman *et al.* 1985, Galperin *et al.* 1995, Simpson *et al.*

1992). Many pollutants like sulfur and nitrogen compounds are transported for hundreds and thousands of kilometers from the places where they were emitted into the atmosphere. The processes of the small-scale turbulent diffusion dry deposition and pollutant washout can affect the transboundary transport considerably. The intensity of these processes depends on a concrete atmosphere state, that is, on its stratification, downward or upward airflow, horizontal transport by air streams, and precipitation. Since the pollution concentration variability substantially depends on the variability of meteorological parameters (Skiba and Parra-Guevara 2000, Parra-Guevara and Skiba 2000), high-quality meteorological information is required for the successful modeling of the pollution transport and for plotting realistic distribution maps of the fall-out concentration.

In this paper the results of the analysis of input data used in the models of both Centers (MSC-E and MSC-W) are shown and consider some methods of preparing the meteorological data for this kind of models. It is also analyzed the present state of the problem and demonstrate main characteristics of the precipitation and wind for central months of the four seasons in 1992.

SHORT REVIEW OF THE CURRENT STATUS OF THE PROBLEM

As a rule, the modeling of the transport and deposition of different materials in the atmosphere is divided into two parts: the modeling of the three-dimensional atmospheric circulation and the modeling of chemical reactions of different materials (hereinafter, the MET- and CHEM- models, respectively). In order to solve the first problem it is necessary to prepare the required meteorological information using different methods. An optimum set of meteorological variables for the CHEM-models is determined by taking into account the following three conditions:

- The CHEM-models as a rule use Eulerian scheme and require data at points of a regular grid.
- The CHEM-models should be provided with information for the areas where no regular meteorological observations are available (for instance over the oceans, mountains or deserts)
- The CHEM-models include parameters that cannot be measured directly (for instance -vertical velocities or surface flows of heat and vapor.

Presently there are two radically different approaches to the diagnosis of the lower layer atmosphere conditions (SDA). The first approach consists in the development of a hydrodynamic atmospheric model that uses a detailed information on the characteristics of the underlying surface and exactly the same spatial structure as the CHEM-model has. This approach is used by the MSC-WEST (Oslo). The second possible way is to use an output diagnosis of measurements and first guess fields from the large-scale forecast model and transformation of these into a spatial structure of the CHEM-models. On this way, different kinds of the "downscaling" procedures are used (for instance, the dynamic or statistical downscaling) for each parameter. Such approach was used in the diagnostic system of the conditions at lower layers of the atmosphere (SDA) of the MSC–E (Moscow). The SDA is described in detail in the reports by Frolov *et al.* (1997a,b,c) and Rubinstein *et al.* (1997). These reports also give a brief review of the methods used to prepare meteorological information in MSC-E and MSC-W.

To determine the way of the future SDA development, one should analyze the present status of the systems at both centers. The relevant information is collected in **tables I-IV**. First of all, it is considered the simplest question of the technical equipment of the meteorological centers. **Table I** shows that the technical (computational) capabilities of both centers are comparable and sufficient for introducing a modern technology. **Table II** indicates that the CHEM-models of the MSC-E use less meteorological information, than the corresponding models of the MSC-W. In **table III,** characteristics of the objective analysis used at both centers are demonstrated. Apparently, these characteristics are very similar. The analysis of the Norwegian Meteorological Institute is characterized by a higher vertical resolution, but the Hydrometcentre of Russia assimilates the greater number of measurements (in particular, satellite data). Till 1994, the meteorological information for the MSC-E numerical model of the transboundary transport had been prepared by Shapiro's (1985) method. The fields of horizontal wind speed components and air temperature at 850 and 1000 hPa isobaric surfaces were being calculated each 6 hours on the basis of meteorological and aerological observation data and the simple quasi-geostrophic equation. Precipitation analysis was carried out only for the regions with dense network of meteorological stations. Since the calculation domain of the MSC-E CHEM-model covers the entire extra tropical Northern Hemisphere, and a multi-layer transport model (**Table IV**) improves representation of chemical processes occurring when liquid phase is available, it becomes necessary to develop a more accurate system for the process-

TABLE I. TECHNICAL EQUIPMENT INSTALLED AT THE TWO METEOROLOGICAL CENTRES

MSC-W (Oslo)	MSC-E (Moscow)
CRAY - Y MP 42 processors Unicos – 9	CRAY-Y MP 8 processors Unicos –9

TABLE II. METEOROLOGICAL INPUT FOR MSC– W AND MSC-E

Parameters	MSC -W	MSC – E
Area, Grids	Hirlam region	Stereo 150x150, 50x50 (fig1)
Horizontal wind components	All model –surfaces(20) and 10 m.,	1000,925,850,700 gPa, 10m
Vertical wind components	All model surfaces (21)	850,700
Cumulus cloud cover balls	1 level	
Cumulus and large – scale cover balls	4 levels all surfaces(20)	Ball
Rate of precipitation	All surfaces ground level	Ground level
Cloud liquid water	All surfaces	
Specific humidity	All surfaces (20)	
Temperature	All surfaces (20)	1000,925,850,700gPa,
Air pressure	Ground level	Sea level
Turbulent heat flux	Ground level	
Turbulent latent heat flux		
Turbulent stress	Ground level	
Height of model σ - lev.	All surfaces	
Ground wetness		

ing of meteorological data. The system should reconstruct the three-dimensional structure of the atmospheric circulation, including vertical velocity, precipitation and cloud fields, involving all the observation data available (e.g. ship, satellite and aircraft observations). The SDA is implemented for the extra tropical part of the Northern Hemisphere (see **Fig.1**) in the polar stereographic projection. Inside the domain A (resolution is 150 x 150 km) it was selected a region B (resolution is 50 x 50 km) extending mostly over Europe and north Atlantic. The SDA of Hydrometcentre of Russia assimilates surface data on meteorological variables (observations at surface meteorological stations). These include instrumental measurements of temperature, pressure, humidity, wind speed and direction, precipitation amount and visual observations like cloudiness, precipitation type, meteorological events (thunderstorm, fog, squall, etc.). The routine model forecasts are issued daily with 12 GMT as initial time. Cloud cover for each model layer is calculated using the diagnostic scheme by Geleyn (1979) from the prognostic data on the air humidity and temperature, surface pressure and surface air temperature. In calculating the low-level cloudiness, a random overlap of cloudy layers separated by cloud-free layers, and maximal overlap of neighboring cloudy layers are assumed.

COMPARISON RESULTS

For the purpose of the comparison and analysis, the following meteorological data sets were considered:

1. A six-hour analyses of the precipitation and wind components at the 850 hPa surface obtained with the method by Shapiro (1985) for the EMEP-region (**Fig. 1**) at the, 150×150 km grid points in the polar stereographic projection for 1992 (set I).
2. Six-hour forecasts of the precipitation and wind components at the "sigma" surface that approximate the level 850 hPa given with 12-level model by Norwegian System for the area which is slightly greater than

TABLE III. COMPARISON OF ANALYSIS SYSTEMS CHARACTERISTICS

	System used by the Norwegian Center	System used by the Russian Center
Type of analysis system	3-dimensional multivariate statistical interpolation	Quasy-3 dimensional multivariate optimal interpolation
Parameters	Surface pressure, Heopotenial, Wind components, relative humidity, sea surface temperature, ice coverage	Surface pressure, Heopotenial, Wind components, relative humidity, sea surface temperature
Levels	1000, 996, 983, 955, 909, 846, 789, 681, 589, 498, 406, 324, 250, 185, 125, 75, 25 hPa	1000, 925, 850, 700, 500, 400, 300, 200, 100, 50, 30, 20 hPa
Assimilation data	Temp, Pilot, Synop, Ship, Buoy, Airep	Temp, Pilot, Synop, Ship, Buoy, Airep,Satem,Satob
Cut off time	2h45min	3h
First guess	6 hour forecast	6 hour forecast

TABLE IV. COMPARISON OF FORECAST SYSTEMS CHARACTERISTICS

	System used by the Norwegian Center	System used by the Russian Center
Independent variables	Lat.-long, hybrid p-Sigma,t	Lat.-long, Sigma,t
Dependent variables	T, u, v, q, ps	T, u, v, q, ps
Integration domain	130-100 points, 31 ver. Lev.	North Hemisphere
Grid length	0.1 (22 km)	T40 (250km)
Time integration	Leapfrog semi-implicit(dt=5)	Leapfrog semi-implicit(dt=5)
Physical parameterisations	1. Large scale condensation 2. Kuo convection 3. Vertical diffusion- boundary eddy fluxes 4. Radiation 5. Surface processes	1. Large scale condensation 2. Kuo convection 3. Vertical diffusion- boundary eddy fluxes 4. Radiation 5. Surface processes

domain B (**Fig. 1**) and at 50 x 50 km resolution for 1992, (set II).
3. Global monthly precipitation data prepared using the method described in Human (1995) for 1992 (set III).
4. Global monthly precipitation and wind data at the 850 hPa surface from the NCAR/NCEP reanalysis (Kalnay *et al.* 1996) (set IV).

The evolution of monthly mean values in the continental part of the domain B (**Fig. 1**) (40-70N and 10W-60E) was analyzed. The choice of the year 1992 for the comparison is explained by the fact that it was the only

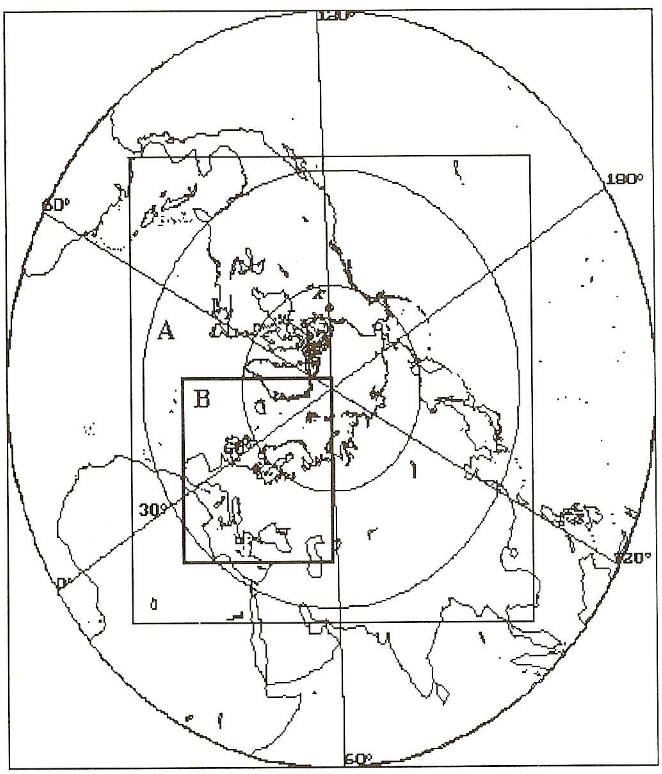

Fig. 1. The SDA of MSC - E domains; for domain "A" information is prepared for the grid with 150 x 150 km; for domain "B" (EMEP-area) it is for the 50 x 50 km

year with Norwegian System output data in our disposal. **Figure 2** shows monthly mean precipitation maps for sets I, II, III, IV in January, April, July and October 1992, and **figure 3** demonstrates temporal variations of continental precipitation (mm/day) in January, April, July and October 1992 for sets I and II. A comparison of these plots indicates that temporal variations in the first and last ten-day periods of each month are very close to each other, while the variations during the central ten days in the set I are negligible. The differences can be explained by the different amounts of information available for the analysis.

Since in the method by Shapiro (1985) the main priority is given to data from the land network, the set I was compared with the set III. The precipitation analysis results obtained for the set II are compared with those obtained for the set IV, since both sets were obtained by modeling. As it is seen from the comparison of the maps in **figure 2**, over the ocean, the precipitation of the set II is closer to that of the sets III and IV. However over the land, the precipitation of the set II is closer to that of the set I. Generally, the structure of the monthly mean precipitation and its main features in the sets I and II are satisfactory. In contrast with the other data, there is a certain systematic underestimate of the maximum precipitation values in set II, primarily over continents. For instance, one can see from set IV that in January 1992, the precipitation values of about 5-6 mm/day cover the whole central Europe, while the maximum precipitation values in the set II are just about 3-4 mm/day and observed over smaller areas. Results of the comparison for other months show similar features. Moreover, these differences over the land in spring and autumn are even greater.

Figure 4 shows the vectors of monthly mean winds for January, April, July and October 1992 in sets I, II and IV whose intensity and direction over the Atlantic Ocean, Scandinavia and Eurasia almost coincide for all the sets. The distinctions are observed only in January and just in the western part of the Mediterranean. For

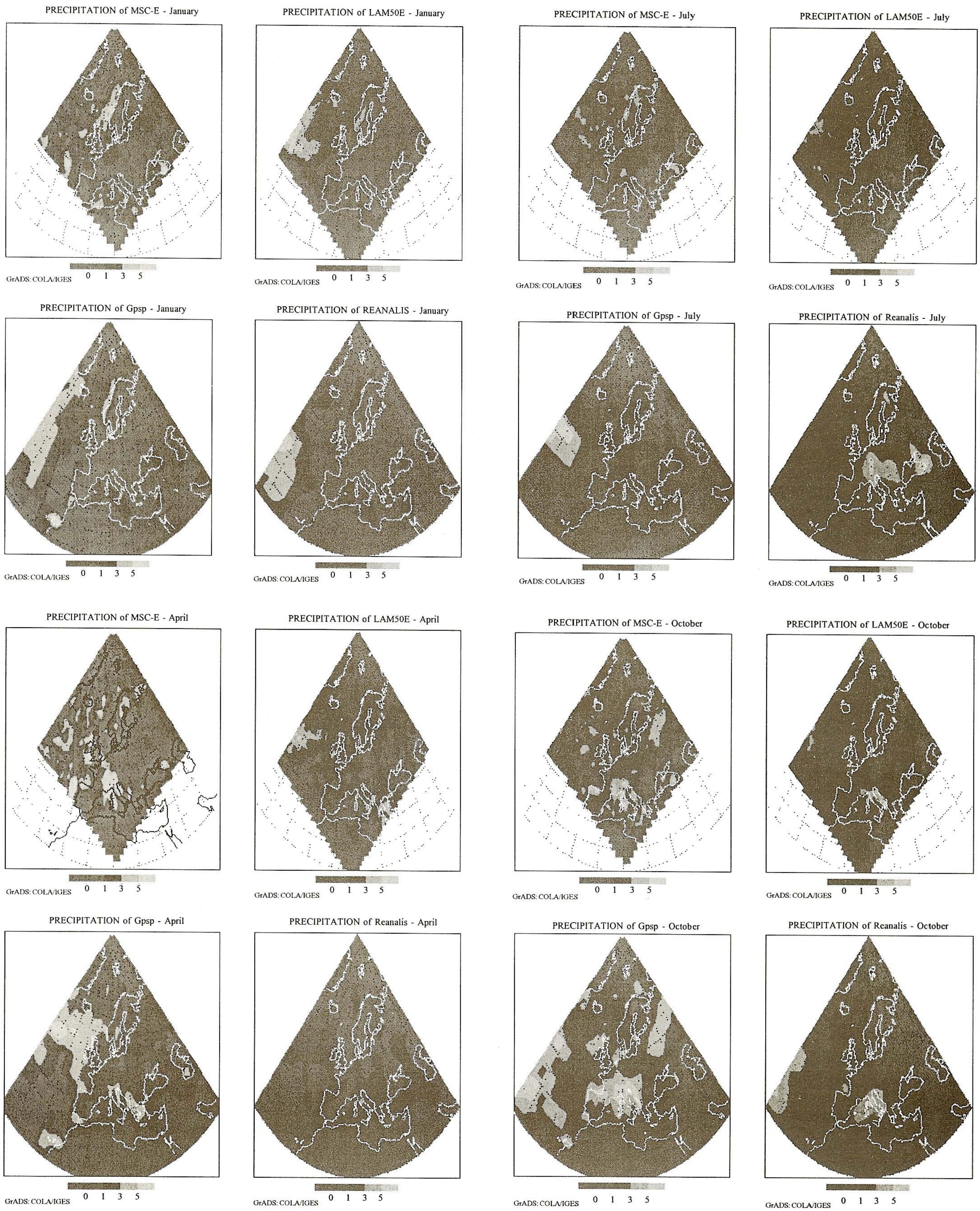

Fig. 2. Monthly mean precipitation [mm/day] maps for January, April, July and October 1992; Sets I (upper-left), II (lower-left), III (upper-right), IV (lower- right)

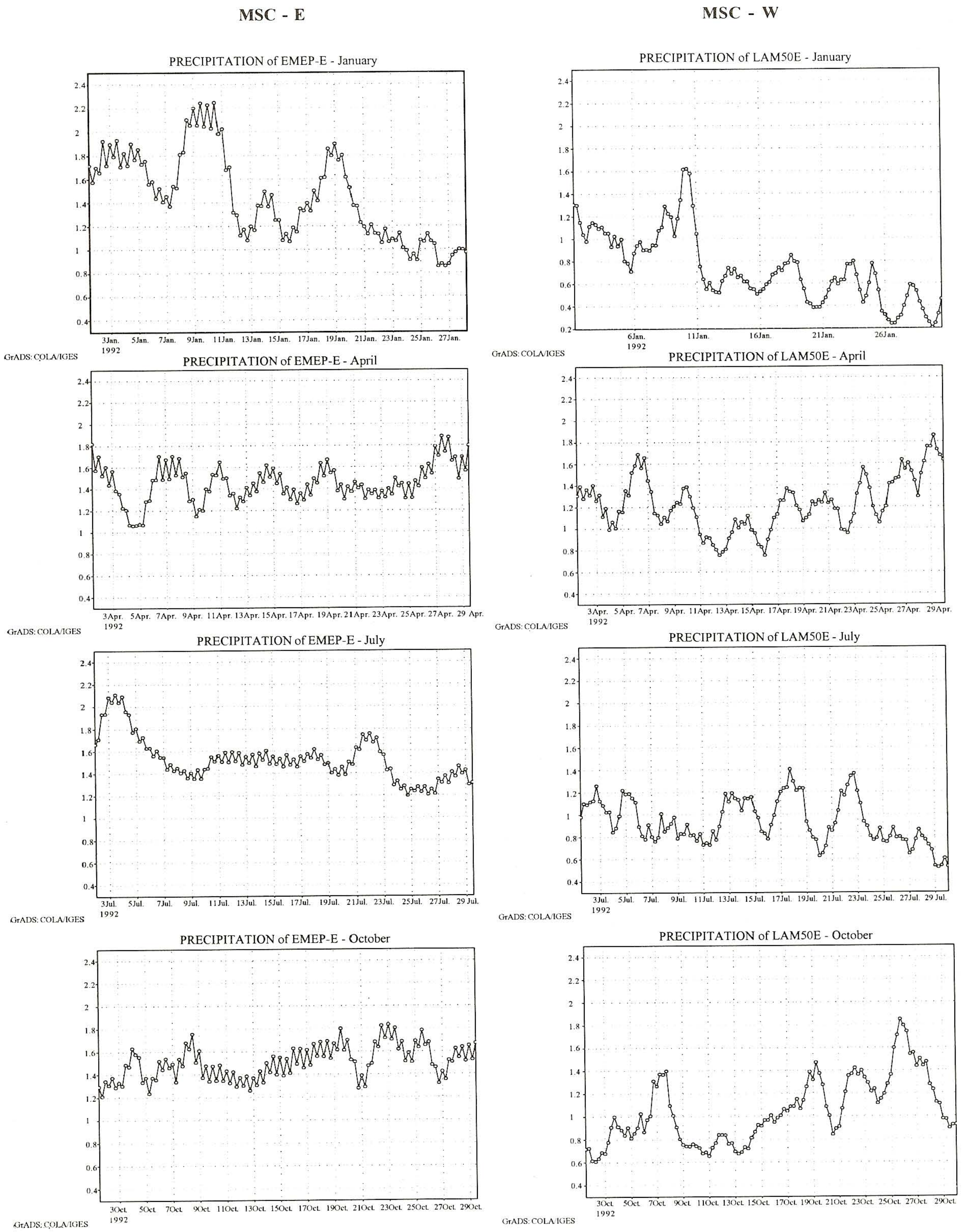

Fig. 3. Temporal variations of precipitation [mm/day] average over area 40-70 n, 10 El- 60 w. For January, April, July and October of 1992

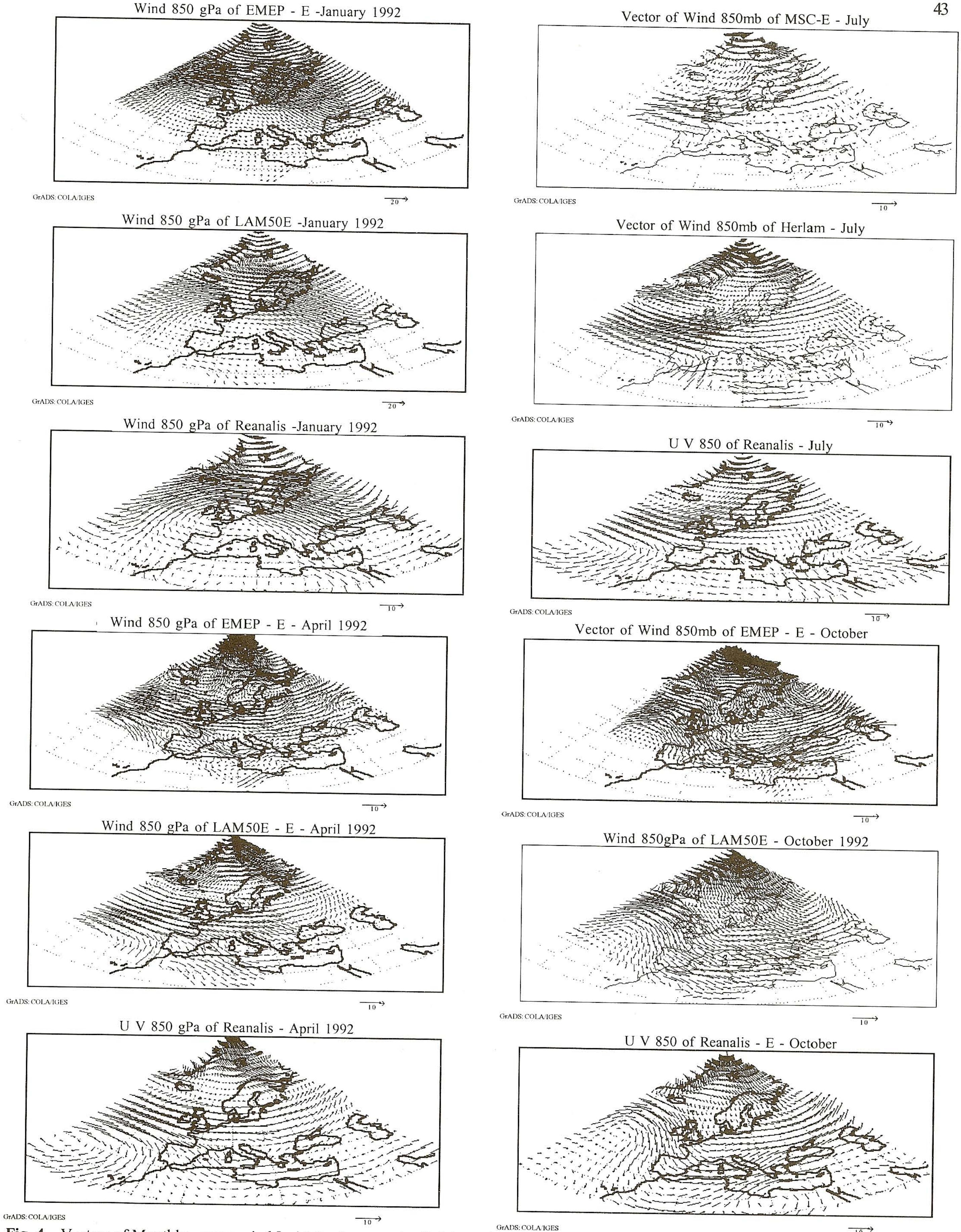

Fig. 4. Vectors of Monthly –mean wind [m/s] for January, April, July and October 1992 at 850 gPa. Sets I (upper), II (middle), IV (lower)

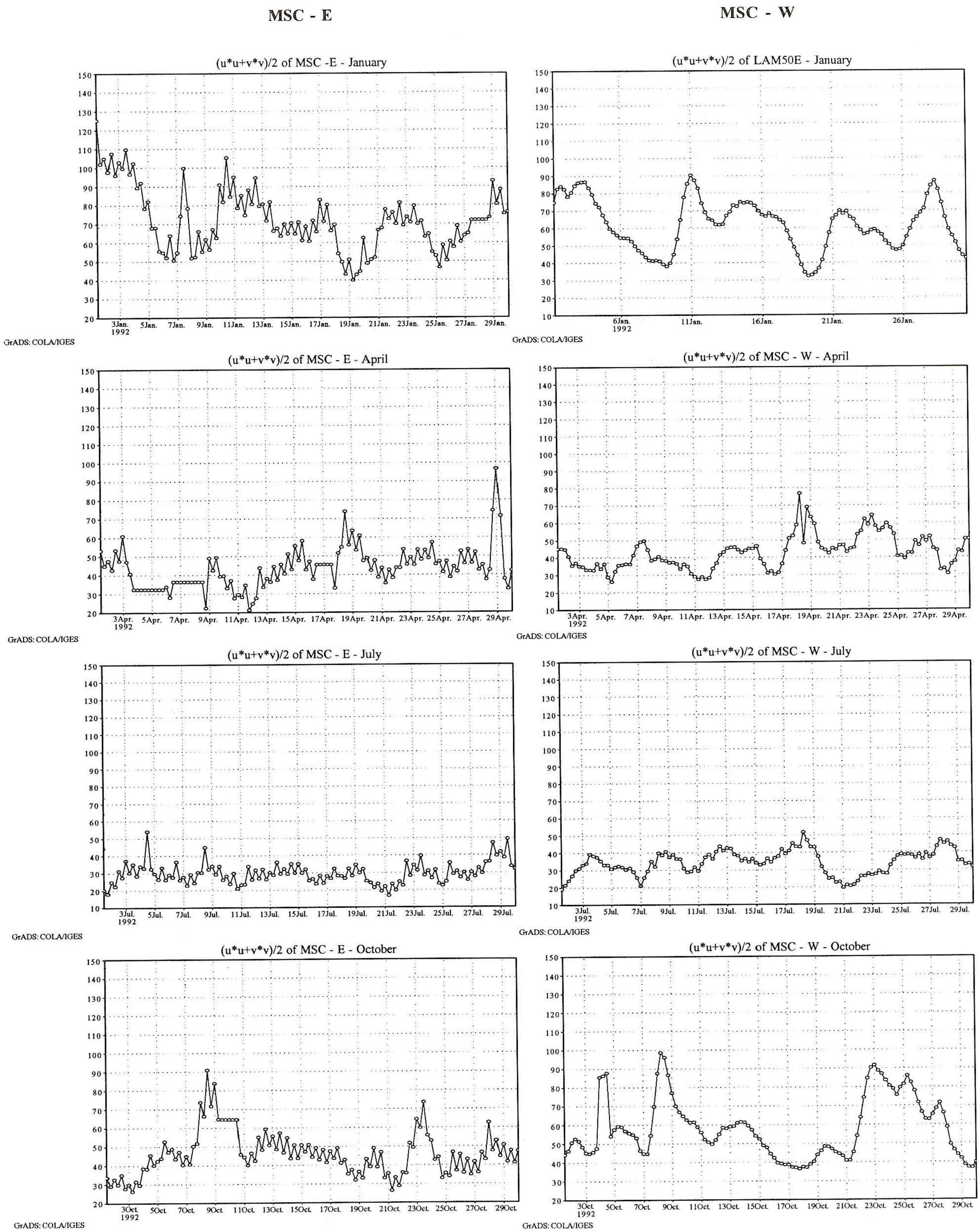

Fig. 5. Temporal variations of energy [m/s**2] analogue (Vx*Vx+Vy*Vy)/2, average over area 40-70 n, 10 El- 60 w. For January (upper row), April (second row), July (third row) and October (low row) 1992

the other months, the field structures are generally similar, with no drastic difference in the wind intensity. As a rule, the main differences are observed near the borders of the domain B (**Fig. 1**).

Figure 5 shows time variations of the kinetic energy averaged over the continental part of the EMEP domain in January, April, July and October of 1992, calculated with the data from sets I and II. These quantities reflect the circulation intensity within each month. It is obvious that the values have similar magnitude and are well correlated. Like in the case of the precipitation, there is a certain dependence of the energy on the availability of information and observations. Howevwer, this dependence is apparently weaker. It should be noted that for the other months, the patterns are nearly the same.

CONCLUSIONS

The results of two approach es to processing the meteorological information used for the pollution transport simulations were described. The first method is based on the analysis of observed data, while the second one - on the forecast results obtained with a hydrodynamic model. On the basis of a comparison of the precipitation and 850 hPa wind data analyses for 1992 the following results were obtained:

- Over the land, the amount and structure of the precipitation in set I (Meteorological Synthesizing Center-East (Moscow) are closer to those in set III, than to those in set II (Meteorological Synthesizing Center-West (Oslo)). However over the ocean, the results are as a rule inverse.
- The first method of the data preparation needs further correction, due to its strong dependence on the amount of observational information received.
- The method of calculating the precipitation by the Norwegian Meteorological Institute should be corrected because comparison with the results of MSC-W, Global Precipitation Climate Project (GPCP) (Huffman 1997), and National Center for Atmospheric Research/National Center of Environmental Prediction (NCAR/NCEP) Reanalysis data (Kalnay *et al.*, 177 1996), shows a systematic underestimation of the precipitation over continents in.
- Results of the analysis of the atmospheric circulation obtained by Shapiro's (1985) method, and results of forecast models and NCAR/NCEP Reanalysis do not indicate much difference.

In conclusion it should be mentioned that this study has a preliminary character, since a serious investigation of the data sets in recent years is required.

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