STATISTICAL POST PROCESSING
IN THE ITALIAN METEOROLOGICAL SERVICE

C. FINIZIO
CENTRO NAZIONALE DI METEOROLOGIA E CLIMATOLOGIA
AERONAUTICA, ROMA, ITALY

1. INTRODUCTION

In the recent past, the main efforts of meteorologists have been devoted to building up a global network of conventional and non conventional meteorological observations, complex telecommunication systems, data quality checks, data analysis methods and numerical models of the atmosphere.

On the other hand, until few years ago, the final phases, consisting of predicting the weather, was left completely to forecasters. Although considerable help has been given by the impressive amount of derived products from numerical models (vorticity, vertical velocities, precipitation, etc.) it must be acknowledged that forecasters still have problems in producing accurate weather forecasts in real time for large regions and varying periods.

Usually the interpretation of meteorological maps by forecasters involves using some general criteria:

- Correlations among different parameters which are revelant for a specific meteorological situation.
- "Local" experiences (comparable to a "data bank") to which, more or less consciously, meteorologists refer.
- Knowledge of physical processes linked to particular characteristics of different regions.

There are evident limits to the above criteria:

- The meteorological experiences may cover a limited period.
- Varying "kind" of experiences (successful or unsuccessful forecasts may have a large influence when issuing the next forecast).
- Difficulties in transferring the knowledge acquired. This is an essential element for an operational service that is based upon the continuity, reliability and homogeneity of its products. Human skill, no matter what efforts are made, changes from person to person. Therefore, although the educational basis may be the same, personal interpretations may vary substantially and this leads to

noticeable differences (positive and negative) both in quality and homogeneity.

- Insufficient development of interpretation techniques when compared to the efforts devoted to improving observations, telecommunications, analysis and numerical models. In fact how much information can be considered by the forecasters within the short time available before issuing a weather prediction? Undoubtedly only a very limited amount of NWP products, mainly in their graphical form, can be examined. Such a quantity, much reduced in comparison to the potential output of models, may be insufficient and result in a lack of the 3-dimensional view necessary for a better understanding of the general situation.

Obviously there are undeniable benefits in the subjective interpretation because of the originality, flexibility and personal skill of the human element. Certainly the quality of weather prediction might be greatly improved if forecasters could spend a longer period of time studying the meteorological situation in its global complexity by considering all the maps relevant for such a purpose. However, we need to be realistic. A Met Service has to fulfil an operational schedule that becomes more pressing as the specialised use of the meteorological information increases. Presently this is the most critical point of our entire procedure. In fact meteorological information becomes increasingly more useful to the user when he is able to react in connection with his problems and particular area of interest. Therefore qualitative information, however valid it can be from a meteorological point of view, can run the risk of not having a worth consistent with the effort which has been necessary to produce it.

Therefore the need to post-process NWP products to give as many quantitative results as possible is universally acknowledged. In the near future, whatever increase in computer power and model resolution occurs, it will not be possible to predict all the different scales which are responsible for the evolution of the weather because there were still too many uncertainties in the physical interpretation of small scale events. Furthermore, these uncertainties are emphasized by observational and/or computational problems. On the other hand, it is well known that the weather may vary substantially on a space scale of a few kilometres, depending upon the orographic characteristics of the area. Therefore, it may be foreseen that models, independently by their complexity, will give more detailed meteorological fields, but will not be able to furnish "directly" user-oriented products.

Consequently, in the last decade, several Met Services developed various techniques for the post-processing of NWP products with the final aim of disseminating more specific and quantitative information to the potential users.

2. POST-PROCESSING DEVELOPED IN THE ITALIAN METEOROLOGICAL SERVICE

2.1 Statistical approach

Since the early 1970's, studies of post-processing methods were carried out at the Italian Met Service.

The first approach (PALMIERI and FINIZIO 1976) was dynamical; the main field of application being attempts to forecast the wind field over the sea, particularly in the Adriatic, in order to predict the high tides in Venice. The method used a kind of "dynamical balance" between predicted fields on the synoptic scale and local effects due to such factors as the presence of mountains (e.g. Appenines and Dynaric Alps) and land-sea contrasts.

In the second part of the 1970's, it was apparent that eventually numerical forecast products would become available from ECMWF. Therefore, it was decided that our reliable archive of data should be used to carry out studies into the post-processing of NWP products to give local forecasts of "real" weather parameters.

The aim was the development of an automatic system of local weather forecasts that could give "straightforward" predictions for all the potential users. It was desirable that the approach should have a good scientific and theoretical basis, and should meet the operational requirement of finalizing our meteorological products to satisfy the needs of the users. With this in mind a statistical method has been chosen. Within this approach, two different lines of attack have been followed: one giving the general weather type characteristics of a specific site (COZZI and LA VALLE 1979); the other oriented towards optimizing the forecast of various meteorological parameters (CONTE, DE SIMONE and FINIZIO 1979 and 1980). The first method is very similar to the traditional synoptic approach because it links, in a probabilistic way, local weather type to the predicted general circulation pattern. Furthermore, the output of this method is mainly addressed to meteorologists. Therefore, it was decided to implement the second method which has the goal of optimizing the local forecast site by site for each parameter.

With hindsight it must be said that this choice has been full of positive surprises for the operational meteorologists themselves who, when examining specific results, ought sometimes to review some of their evaluation criteria.

2.2 Perfect Prog or MOS?

In the second part of the 1970's, the choice between the perfect prog and the MOS method was trival because there was no data base suitable for MOS since in 1975 the operational quasi-geostrophic model was replaced by the present five level primitive equation model.

Later on this choice has become definitive since:

- it allows substantial changes (or even complete replacement) to the operational prediction model without ceasing or temporary degrading the objective products;
- it can be applied to different models (Italy, USA, ECMWF); this gives the possibility of an immediate comparison and a continuous updating of forecasts as soon as different NWP products become available on the telecommunication lines.

2.3 Predictands

The following parameters have been selected as predictands:

- total cloud cover,
- middle and low level cloudiness,
- cloud ceiling,
- visibility,
- wind,
- relative humidity;

along with the following at the main synoptic hours (00 and 12 GMT);

- probability of precipitation,
- probability of thunderstorm if precipitation occurs,
- quantity of precipitation if no thunderstorm is detected in the periods 06-18 GMT and 18-06 GMT;

and finally the daily parameters

- maximum and minimum temperature,
- sunshine,
- maximum wind.

For all the predictands, excluding the thunderstorm and precipitation probability, the statistical stepwise multiple linear regression method has been adopted.

A particular form of discriminant analysis has been applied for thunderstorm and precipitation probability (ECMWF Seminars (1978) and WMO Symposium (Nice - 1980).

2.4 Predictors

The predictors have been retrieved from a 15 years archive of TEMPS from the Italian stations along with some computed parameters. Taking into account the real availability, characteristics and performances of models (Italy, USA, ECMWF) used in the operational stage, the following parameters have been chosen:

- geopotential
- wind (intensity and components)
- temperature
- humidity

at the levels 1000, 850, 700, 500 and 300 mb.

All the above parameters at four Italian stations (Milano, Roma, Cagliari, Brindisi) have been tested as potential predictors in order to avoid possible interpolation problems in the vertical at a specific site. Therefore, the statistical method has been left free to choose the best spatial distribution of predictors for each predictand at a particular site.

In addition, the following predictors have been computed:

- wind shear in the layers below 500 mb,
- static stability in the layers below 500 mb,
- geostrophic vorticity at 850 and 700 mb.

Finally some climatic parameters (10 - day means of maximum and minimum temperature and of sunshine) have also been considered as predictors.

2.5 Sample stratification and selections

In order to take into account the local annual and daily climatic behaviour, the sample was initially divided in four subsets:

- cold semester 00 GMT (from October to March),
- cold semester 12 GMT (from October to March),
- warm semester 00 GMT (from April to September),
- warm semester 12 GMT (from April to September),

The relationships between predictors and predictands have been computed for each of the periods.

Finally, in order to take into account the characteristics and reliability of the different models used in the operational stage, the following four selections have been performed for each subset:

- all the predictors,
- all the predictors without the parameters at 1000 mb,
- all the predictors without the humidity,
- all the predictors without the parameters at 1000 mb and the humidity.

The choice of these subsets is governed by the frequent operational unreliability of the 1000 mb and humidity forecasts.

2.6 Operational products at the Italian Meteorological Centre (CNMCA)

Presently, local objective forecasts are produced operationally for 62 sites and the daily schedule is as follows:

05 GMT : 12-24-36-48 hrs forecasts from products of the CNMCA operational model based on 00 GMT data;

06 GMT : 12-24-36-48-60-84 hrs forecasts (12 hrs shifted) from ECMWF products based on data collected until 21 GMT on the day before;

08 GMT : 12-24-36-48 hrs forecasts from products of the NMC operational model based on 00 GMT data;

17 GMT : 12-24-36-48 hrs forecasts from products of the CNMCA model based on 12 GMT data;

20 GMT : 12-24-36-48 hrs forecasts from products of the NMC model base on 12 GMT data.

An example of these products can be seen in Table 1. The predictions are displayed on VDU screen for forecasters in two forms. In a complete form (as the one showed in Table 1) which gives forecasts for a specific time; the alternative display shows the evolution in time of all the parameters for a specific site (Table 2). These forecasts are also plotted on two maps covering the Italian region in order to stress the main phenomena (cloud cover, precipitation, thunderstorms) (Table 3) and the thermal state (Table 4).

These forecasts are sent by telex to all the peripheral meteorological offices and they have completely replaced the previous traditional weather report.

The same forecasts, conveniently organized in blocks and retrieved by direct access to the computer or by transmission on real-time, are used (together with some other information) by several external organizations such as SIP (Telephone), Civil Protection, ENEL (National Electric Agency), Ferrovie dello Stato (Railway),

* C N M C A *

GUIDA DINAMICO-STATISTICA ALLE PREVISIONI LOCALI DEL 17/ 8/1982 ORE 00 GMT

3 PREVISIONE DI 84 ORE

LOCALITA'	NT	NB	HB	VIS	V	VX	UR	PP	QP	PT	TMA	IN
8 PASSO RESIA	5	4	8	+50	8	22	60	40	7	10	16	**
20 BOLZANO	5	3	13	+50	2	13	60	30	5	40	26	6
36 AVIANO	5	4	12	+50	3	13	60	20	12	60	27	**
40 TARVISIO	5	5	11	+50	3	14	65	40	10	20	21	**
52 PIAN ROSA'	6	4	2	+50	11	33	***	0	0	0	3	6
59 TORINO	4	2	11	+50	3	11	60	20	4	50	26	8
64 NOVARA	4	3	10	+50	3	12	60	0	0	0	26	**
80 MILANO	3	2	9	+50	4	14	60	30	8	50	27	7
84 PIACENZA	5	3	9	+50	5	16	65	30	6	60	26	**
88 BRESCIA	4	2	11	+50	5	15	65	20	4	40	26	**
90 VERONA	4	3	12	+50	5	16	65	30	10	30	27	**
94 VICENZA	4	3	13	+50	3	14	60	20	14	40	27	**
99 TREVISO	4	3	12	+50	2	12	60	20	8	30	27	**
105 VENEZIA	4	3	12	+50	6	17	65	20	**	40	27	7
110 TRIESTE	5	3	13	+50	5	20	60	20	7	30	26	7
120 GENOVA	5	2	9	+50	7	18	65	30	11	50	27	9
134 MONTE CIMONE	5	4	2	+50	8	34	85	30	5	50	12	7
140 BOLOGNA	5	3	12	+50	5	16	65	20	8	0	27	8
148 CERVIA	4	3	8	+50	5	16	70	50	**	***	27	**
149 RIMINI	4	3	10	+50	7	16	70	20	**	40	27	**
153 CAPO MELE	4	3	8	+50	10	23	70	20	**	***	27	9
158 PISA	4	3	9	+50	7	17	60	20	6	30	27	8
170 FIRENZE	5	3	10	+50	4	15	55	20	9	20	29	**
172 AREZZO	6	4	9	+50	5	15	60	0	0	0	27	**
181 PERUGIA	5	3	11	+50	4	14	60	30	**	60	28	**
191 ANCONA	4	3	11	+50	8	18	75	50	**	40	27	**
200 PIANOSA	3	2	10	+50	8	22	70	0	0	0	26	10
206 GROSSETO	4	2	9	+50	7	16	60	0	0	0	29	**
219 MON. TERMINILLO	6	5	3	+50	10	**	85	30	10	40	14	7
230 PESCARA	4	3	11	+50	6	14	70	20	**	50	28	7
239 ROMA CIAMPINO	5	4	8	+50	6	17	60	0	0	0	29	9

LOCALITA'	NT	NB	HB	VIS	V	VX	UR	PP	QP	PT	TMA	IN
242 ROMA FIUMICINO	3	2	6	+50	8	17	65	20	**	***	28	**
243 LATINA	4	3	8	+50	7	18	60	20	3	20	29	**
252 CAMPOBASSO	4	4	9	+50	7	22	60	30	8	0	24	**
253 GRAZZANISE	4	3	11	+50	8	18	65	20	**	***	29	**
261 FOGGIA	4	3	8	+50	9	22	45	0	0	0	31	8
263 TREVICO	4	3	4	+50	12	30	70	20	**	30	21	**
270 BARI	3	3	7	+50	7	16	60	20	**	40	28	**
280 PONZA	3	3	9	+50	6	19	75	0	0	0	27	**
289 NAPOLI	4	3	7	+50	8	18	70	20	**	40	28	8
300 POTENZA	4	3	7	+50	8	21	55	20	5	20	22	**
310 CAPO PALINURO	3	3	8	+50	5	16	70	20	**	50	28	9
312 GIOIA DEL COLLE	4	3	7	+50	5	16	45	20	**	50	29	**
320 BRINDISI	3	3	7	+50	9	16	65	0	0	0	28	9
325 GINOSA MARINA	3	2	10	+50	9	16	70	0	0	0	29	**
332 LECCE	4	3	8	+50	7	19	55	20	**	***	30	**
344 MONTE SCURO	4	3	1	+50	8	21	75	20	9	40	18	**
350 CROTONE	3	2	11	+50	9	20	55	0	0	0	29	10
360 LEUCA	3	3	7	+50	6	17	70	0	0	0	28	**
400 USTICA	3	3	7	+50	10	26	75	0	0	0	27	10
405 PALERMO	3	2	9	+50	10	19	75	0	0	0	28	**
422 REGGIO CALABRIA	2	2	16	+50	11	20	60	0	0	0	30	**
429 TRAPANI	3	2	9	+50	13	21	65	0	0	0	29	10
450 ENNA	3	2	7	+50	7	**	***	0	0	0	24	**
453 GELA	2	0	0	+50	12	21	85	0	0	0	26	10
460 CATANIA	3	2	12	+50	11	20	55	0	0	0	32	**
470 PANTELLERIA	3	3	6	+50	10	19	75	0	0	0	27	10
520 ALGHERO	3	2	11	+50	11	21	60	0	0	0	28	10
531 OLBIA	3	3	9	+50	11	22	55	0	0	0	31	10
539 CAPO FRASCA	3	2	11	+50	10	18	75	0	0	0	27	**
550 CAPO BELLAVISTA	3	2	10	+50	7	19	65	0	0	0	28	**
560 CAGLIARI	3	2	9	+50	10	28	55	0	0	0	30	10

Table 1.

Table 2.

A E R O N A U T I C A   M I L I T A R E   - C.N.M.C.A. -
PREVISIONI DEL TEMPO SU   R O M A (CIAMPINO)

G I O R N O	MARTEDI	MARTEDI	MERCOLEDI	MERCOLEDI	GIOVEDI
O R A	02	14	02	14	14
NUVOLOSITA'-OTTAVI	0	4	0	3	4
VISIBILITA'-METRI	> 5000	> 5000	> 5000	> 5000	> 5000
VENTO -NODI	1	9	0	15	14
VENTO MAX -NODI**		20		30	28
UMIDITA'RELATIVA %	80	50	80	45	50
PROB.PRECIPIT.* %	0	0	0	0	0
PROB.TEMPORALE* %	0	0	0	0	0
TEMPERAT.MIN. ***	18 C	---	17 C	---	---
TEMPERAT.MAX. **	---	32 C	---	34 C	32 C

N O T E:
* NELL'INTORNO DI PIU' O MENO 6 ORE DELL'ORA INDICATA;
** NELL'INTORNO DI PIU' O MENO 12 ORE DELL'ORA INDICATA;
*** NELLE 24 ORE SUCCESSIVE ALL'ORA INDICATA.

================> PER PROSEGUIRE PREMERE IL TASTO "ENTER" (==========

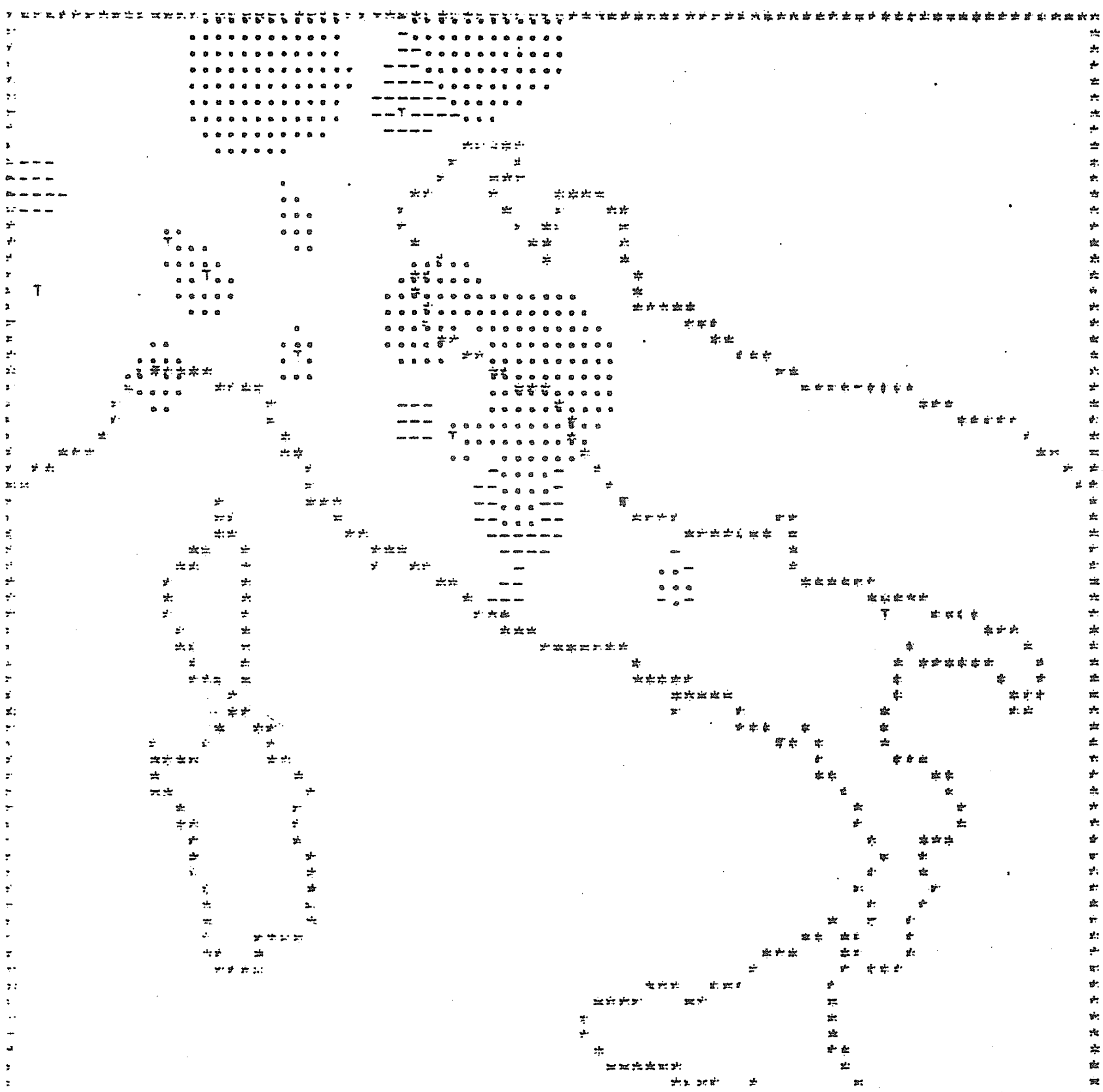
A E R O N A U T I C A   M I L I T A R E   - C.N.M.C.A. -
PREVISIONI DEL TEMPO SU   M I L A N O

G I O R N O	MARTEDI	MARTEDI	MERCOLEDI	MERCOLEDI	GIOVEDI
O R A	02	14	02	14	14
NUVOLOSITA'-OTTAVI	2	4	2	7	5
VISIBILITA'-METRI	> 5000	> 5000	> 5000	> 5000	> 5000
VENTO -NODI	1	3	2	6	5
VENTO MAX -NODI**		13		22	18
UMIDITA'RELATIVA %	85	65	80	70	60
PROB.PRECIPIT.* %	0	30	0	50	40
PROB.TEMPORALE* %	0	21	0	45	28
TEMPERAT.MIN. ***	18 C	---	18 C	---	---
TEMPERAT.MAX. **	---	30 C	---	30 C	26 C

N O T E:
* NELL'INTORNO DI PIU' O MENO 6 ORE DELL'ORA INDICATA;
** NELL'INTORNO DI PIU' O MENO 12 ORE DELL'ORA INDICATA;
*** NELLE 24 ORE SUCCESSIVE ALL'ORA INDICATA.

================> PER PROSEGUIRE PREMERE IL TASTO "ENTER" (==========

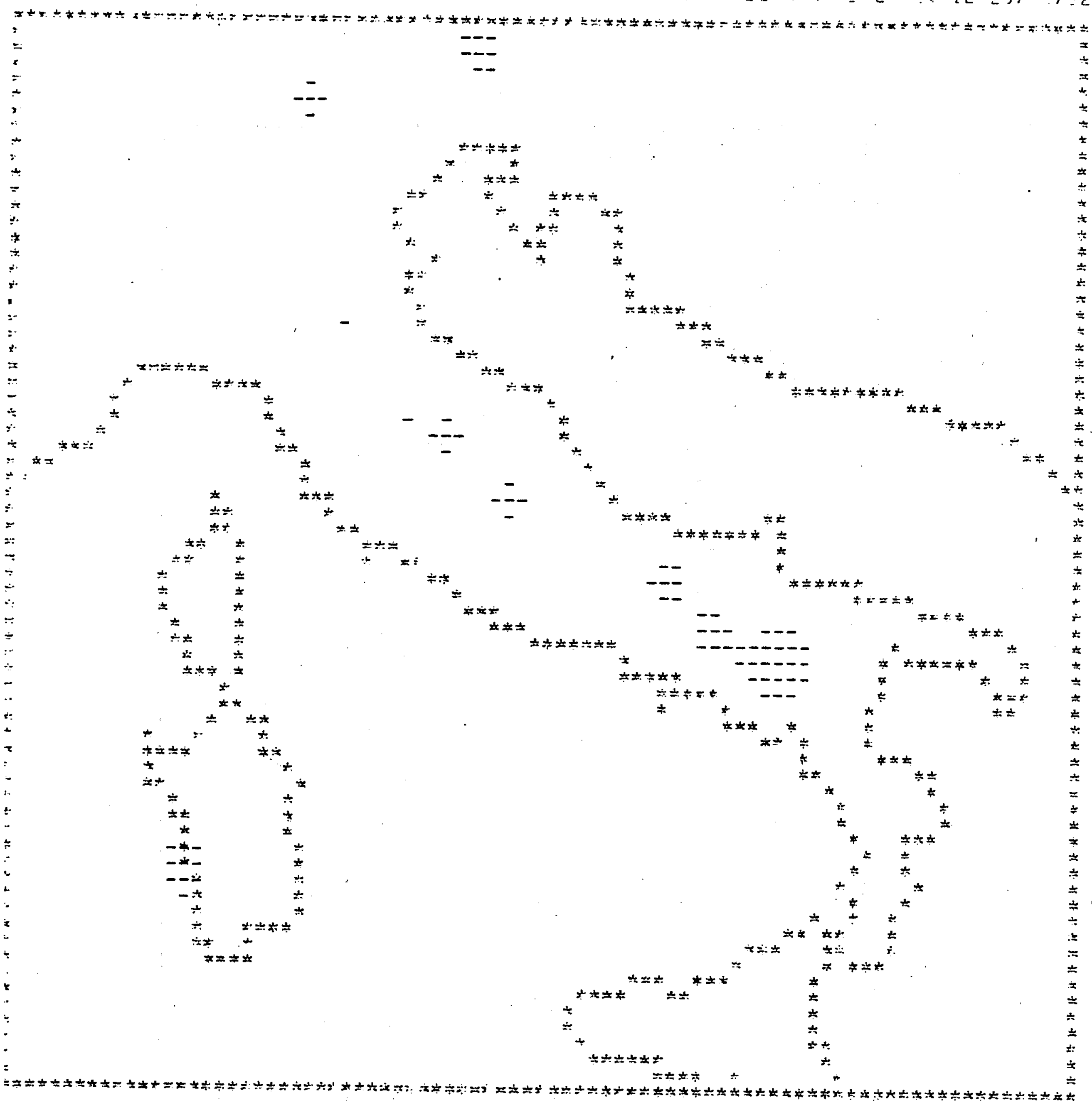
MAPPA PRECIPITAZIONI A 84 ORE PER IL 20/ 9/82/12Z



BLANK	CIELO SERENO O POCO NUVOLOSO	T	POSSIB. DI TEMPORALI
-----	CIELO PARZIALMENTE NUVOLOSO O COPERTO	TTT	
.....	PROBAB. DI PIOGGIA TRA IL 25 E IL 55 PER CENTO	TTT	TEMPORALI MOLTO PROBABIL
/////	PROBAB. MAGGIORE DEL 55 PER CENTO	TTT	

Table 3.

SCARTO DELLE TEMPERATURE MASSIME DALLA MEDIA DECADALE A 84 ORE PER IL 20/ 8/82/12Z



+++++	DIFFERENZA DALLA MEDIA DECADALE MAGGIORE DI 4 GRADI
•••••	DIFFERENZA DALLA MEDIA DECADALE TRA 2 E 4 GRADI
BLANK	DIFFERENZA DALLA MEDIA DECADALE TRA -2 E 2 GRADI
-----	DIFFERENZA DALLA MEDIA DECADALE TRA -2 E -4 GRADI
/////	DIFFERENZA DALLA MEDIA DECADALE MINORE DI -4 GRADI

Table 4.

C.N.M.C.A.

TEMPO PREVISTO SULL'ITALIA FINO ALLE ORE 18.00 DEL 20/ 8

LOCALITA'	CIELO	FENOMENO	VENTO	TMAX(C)
PASSO RESIA	PARZIALMENTE NUVOLOSO	POSSIBILITA' DI PIOVASCHI	MODERATO	16
BOLZANO	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	CALMA	26
AVIANO	PARZIALMENTE NUVOLOSO	CON TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	DEBOLE	27
TARVISIO	PARZIALMENTE NUVOLOSO	POSSIBILITA' DI PIOVASCHI	DEBOLE	21
PIAN ROSA'	PARZIALMENTE NUVOLOSO	NIL	FORTE	3
TORINO	POCO NUVOLOSO	NIL	DEBOLE	26
NOVARA	POCO NUVOLOSO	NIL	DEBOLE	26
MILANO	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	DEBOLE	27
PIACENZA	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	MODERATO	26
BRESCIA	POCO NUVOLOSO	NIL	MODERATO	26
VERONA	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	MODERATO	27
VICENZA	POCO NUVOLOSO	NIL	DEBOLE	27
TREVISO	POCO NUVOLOSO	NIL	CALMA	27
VENEZIA	POCO NUVOLOSO	NIL	MODERATO	27
TRIESTE	POCO NUVOLOSO	NIL	MODERATO	26
GENOVA	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	MODERATO	27
MONTE CIMONE	PARZIALMENTE NUVOLOSO	POSSIBILITA' DI BREVI PIOGGE E TEMPORALI	MODERATO	12
BOLOGNA	POCO NUVOLOSO	NIL	MODERATO	27
CERVIA	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	MODERATO	27
RIMINI	POCO NUVOLOSO	NIL	MODERATO	27
CAPO MELE	POCO NUVOLOSO	NIL	MODERATO	27
PISA	POCO NUVOLOSO	NIL	MODERATO	27
FIRENZE	POCO NUVOLOSO	NIL	DEBOLE	29
AREZZO	PARZIALMENTE NUVOLOSO	NIL	MODERATO	27
PERUGIA	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	DEBOLE	28
ANCONA	NUVOLOSITA' SCARSA CON	TEMPORANEA INTENSIFICAZIONE E POSSIBILITA' DI PIOVASCHI	MODERATO	27
PIANOSA	SERENO	NIL	MODERATO	26
GROSSETO	POCO NUVOLOSO	NIL	MODERATO	29
MON. TERMINILLO	PARZIALMENTE NUVOLOSO	POSSIBILITA' DI PIOVASCHI	MODERATO	14
PESCARA	POCO NUVOLOSO	NIL	MODERATO	28
ROMA CIAMPINO	PARZIALMENTE NUVOLOSO	NIL	MODERATO	29
ROMA FIUMICINO	SERENO	NIL	MODERATO	28
LATINA	POCO NUVOLOSO	NIL	MODERATO	29
CAMPO BASSO	PARZIALMENTE NUVOLOSO	POSSIBILITA' DI PIOVASCHI	MODERATO	24
GRAZZANISE	POCO NUVOLOSO	NIL	MODERATO	29
FOGGIA	POCO NUVOLOSO	NIL	MODERATO	31
TREVICO	POCO NUVOLOSO	NIL	FORTE	21
BARI	SERENO	NIL	MODERATO	28
PONZA	SERENO	NIL	MODERATO	27
NAPOLI	POCO NUVOLOSO	NIL	MODERATO	28
POTENZA	POCO NUVOLOSO	NIL	MODERATO	22
CAPO PALINURO	SERENO	NIL	MODERATO	28
GIOIA DEL COLLE	POCO NUVOLOSO	NIL	MODERATO	29
BRINDISI	SERENO	NIL	MODERATO	28
GINOSA MARINA	SERENO	NIL	MODERATO	29
LECCE	POCO NUVOLOSO	NIL	MODERATO	30
MONTE SCURO	POCO NUVOLOSO	NIL	MODERATO	18
CROTONE	SERENO	NIL	MODERATO	29
LEUCA	SERENO	NIL	MODERATO	28
USTICA	SERENO	NIL	MODERATO	27
PALERMO	SERENO	NIL	MODERATO	28
REGGIO CALABRIA	SERENO	NIL	FORTE	30
TRAPANI	SERENO	NIL	FORTE	29
ENNA	SERENO	NIL	MODERATO	24
CATANIA	SERENO	NIL	FORTE	26
GELA	SERENO	NIL	FORTE	32
PANTELLERIA	SERENO	NIL	MODERATO	27
ALGHERO	SERENO	NIL	FORTE	28
OLBIA	SERENO	NIL	FORTE	31
CAPO FRASCA	SERENO	NIL	MODERATO	27
CAPO BELLAVISTA	SERENO	NIL	MODERATO	28
CAGLIARI	SERENO	NIL	MODERATO	30

Table 5.

Agriculture, SNAM (Distribution of gas), ENEA (National Agency for Alternative Energies), Press Agencies and many others.

Also an objective translation of these forecasts into a worded forecast, which stresses the most relevant phenomena, has been arranged for some of these users (Table 5).

3. TESTS OF THE RESULTS

3.1 Stability

The method was checked in both dependent and independent samples by carrying out the following experiments for Milano Linate (CONTE, FINIZIO and DE SIMONE 1980):

- The relationship between predictands and predictors and the control indices were computed using the complete data set.
- The sample was divided in three subsets. The same computations were then carried out on pairs of subsets to give three potentially different relationships.
- The total and partial control indices were compared.
- Each of the relationships between predictands and predictors computed from the three different subsets, was applied alternatively to the third independent external subset in order to compute control indices on data outside of the sample.

These intercomparisons have revealed an overall stability of the results both inside and outside of the sample. Obviously that is due both to the quantity of observations considered in the sample and to their substantial intercorrelation (many data have been rejected for internal inconsistency leading to events randomly distributed in time).

3.2 Performances of the method

In order to show the specific characteristics of the method, the distribution of errors will be considered for the selection without the parameters at 1000 mb.

a. Total cloud cover

The absolute error distribution for the cold semester at 12 GMT (with and without humidity) for ROMA Fiumicino is presented in Fig. 1. It is evident that the forecast is degraded when the humidity is not taken into account; the number of completely correct cases is reduced from 26% to 21% and the events with an absolute

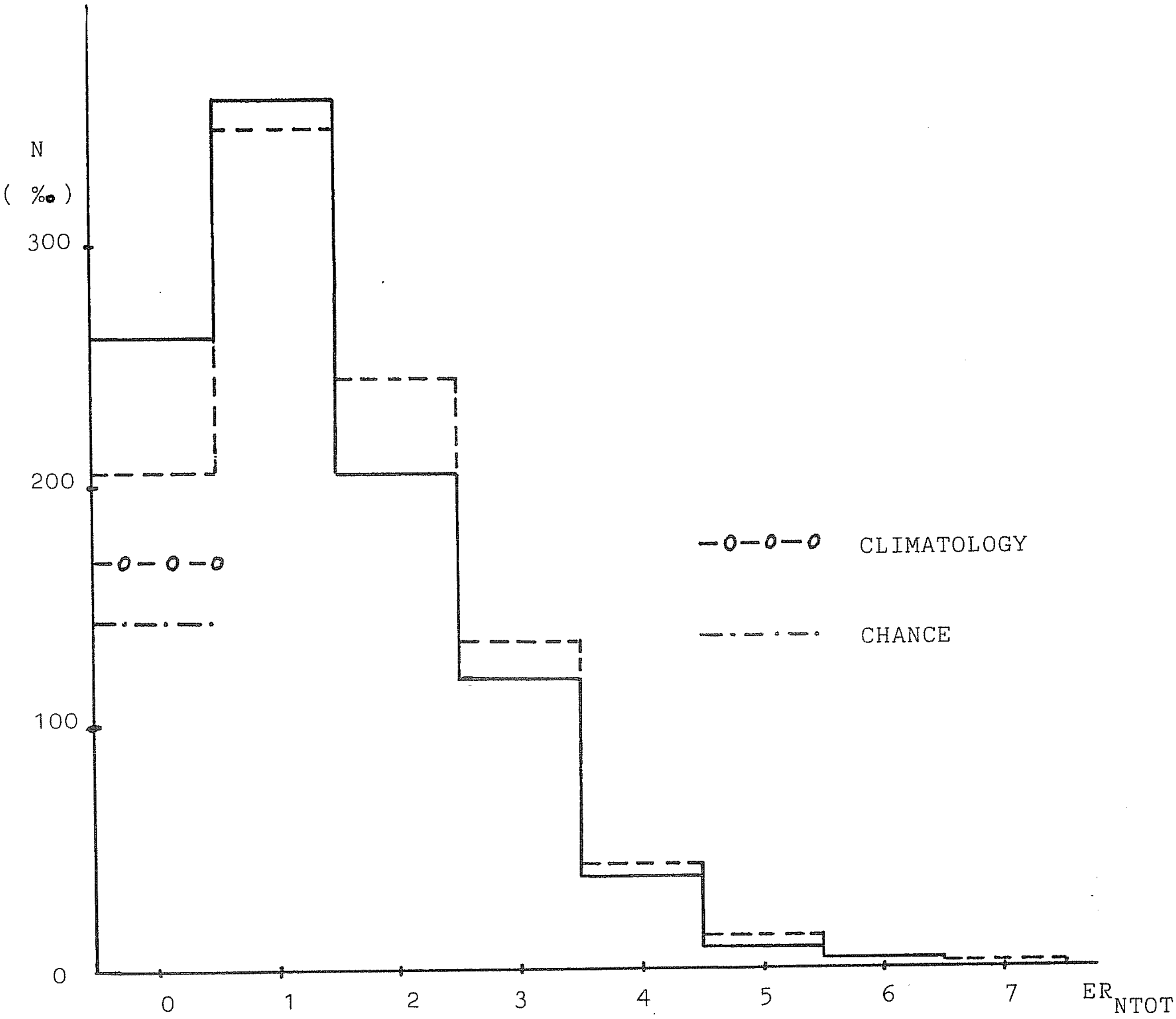


Fig. 1 Total cloud cover - Number of cases (N in ‰) as a function of absolute errors in octas (—— with humidity; ---- without humidity) - ROMA Fiumicino, cold semester 12GMT.

error less than or equal to 2 octas drops from 83% to 81%. However, the comparison with climatology and chance is always favourable since using these methods would produce only 17% and 14% correct forecasts. In order to emphasize the characteristics of the model results (bias, etc.) summaries of contingency tables for the cold semester at 00 GMT are shown in Figs. 2 and 3. These show two different evaluations with respect to the verifying and predicted cases. In Fig. 2, for each class of the actual value of cloudiness in octas, the model result in term of mean and standard deviation is shown. However, in Fig. 3 reality, represented as above by its mean and standard deviation, is presented for each class of the predicted value. It is evident that there is a bias in the method since the extreme cases of clear and overcast sky are smoothed. Such a bias is reduced when the reply of the reality is evaluated against predictions of the model. However, in this case, there is a greater dispersion of the results of reality against the model prediction for the intermediate classes in comparison with the model response to real cases of broken cloudiness (3 to 5 octas).

b. Maximum and minimum temperatures

The relative humidity field in the 850-500 mb layer is relevant for predicting the surface temperature parameters. The reason the moisture has a large effect in the evolution of the temperature during the day and the night is because it is highly correlated to cloudiness and generally representative of a specific air mass. Due to the large variability in the temperature parameters, the gain of the model in respect to climatology or chance is substantial. Fig. 4 shows the distribution of the absolute errors of T min for ROMA Fiumicino. A summary of the contingency tables for T min in the cold semester is also shown (Figs. 5 and 6). In this case the bias is very much reduced and is concentrated in the extreme cases because meteorological parameters are continuous and fluctuate over a wide interval.

c. Precipitation

In the following, the forecast of precipitation probability will be considered. As a test site NAPOLI Capodichino has been selected. Really, contrary to what might first be expected, this town (among the largest cities) is characterized by a relatively high precipitation frequency during the cold semester. In the period from October to March in the hours between 06-18 GMT, it rains on almost 30% of the days.

In order to emphasize the intrinsic performance of the method, model output in cases of rain or no rain (normalized to 1000) is shown in Fig. 7. It is evident that a constant climate forecast would be correct on a very large number of cases; however, this information does not give any useful indication of what is actually going to happen. Instead the model results improve as the two classes become more distinct - that is as the area common to the two curves becomes smaller.

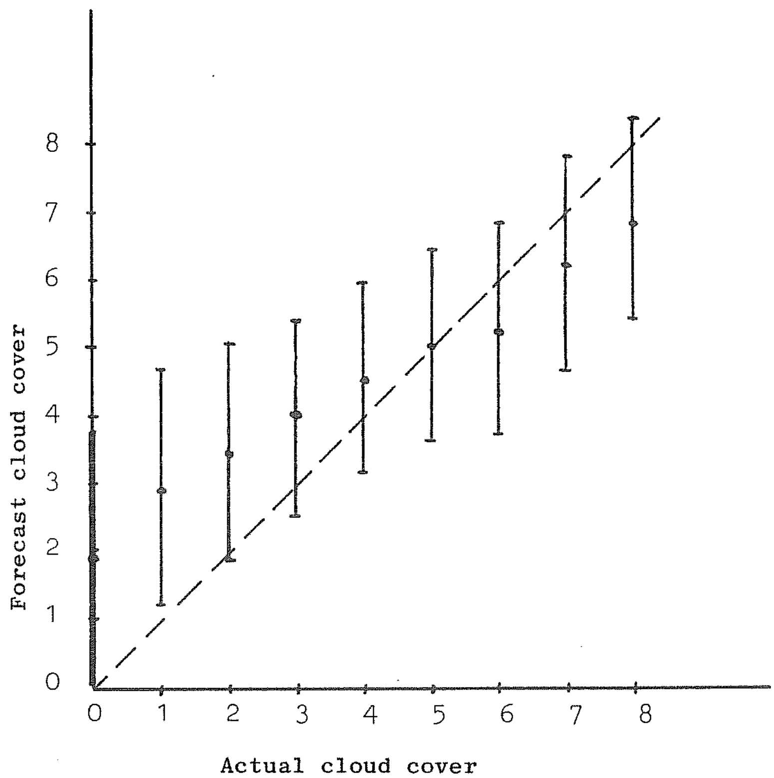


Fig. 2 Distribution of forecast cloud cover as a function of actual cloud cover - ROMA Fiumicino, cold semester 00GMT.

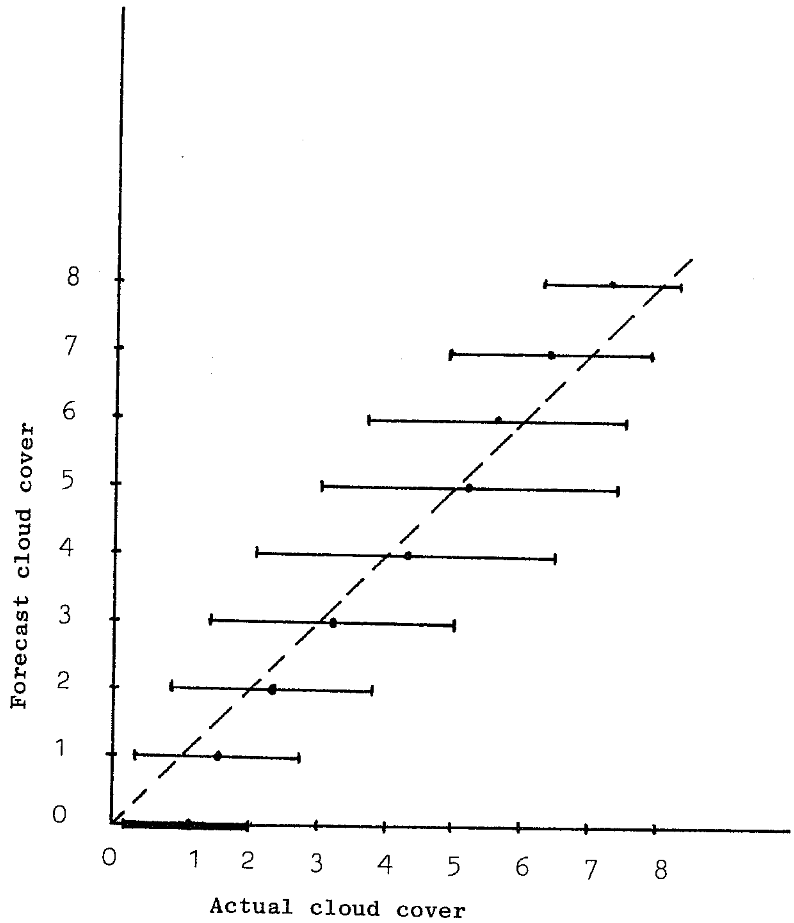
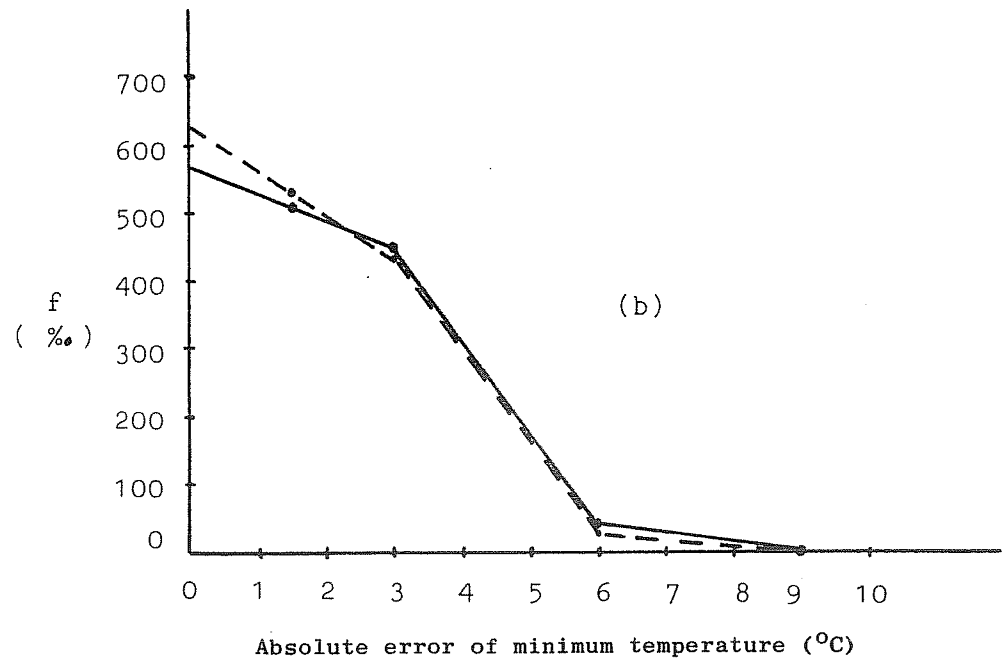


Fig. 3 Distribution of actual total cloud cover as a function of forecast cover - ROMA Fiumicino, cold semester 00GMT.



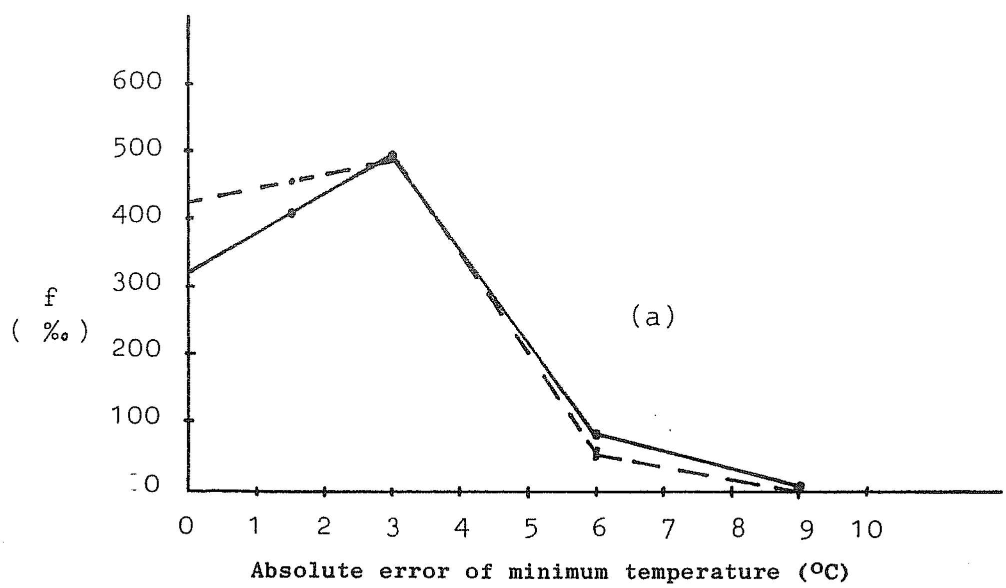


Fig. 4 Distribution of absolute errors of minimum temperature -
(a) cold semester (b) warm semester
(——) without humidity (----) with humidity ROMA Fiumicino

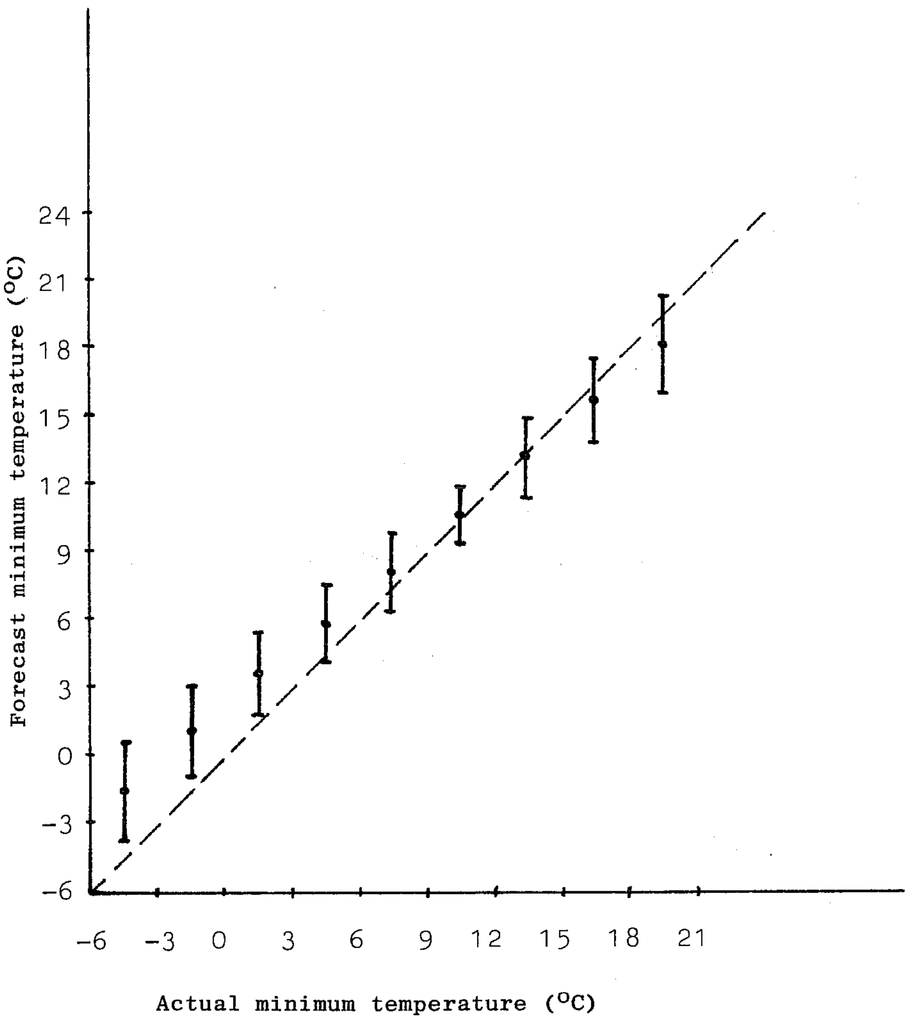


Fig. 5 Distribution of forecast minimum temperature as a function of actual minimum temperature - ROMA Fiumicino, cold semester.

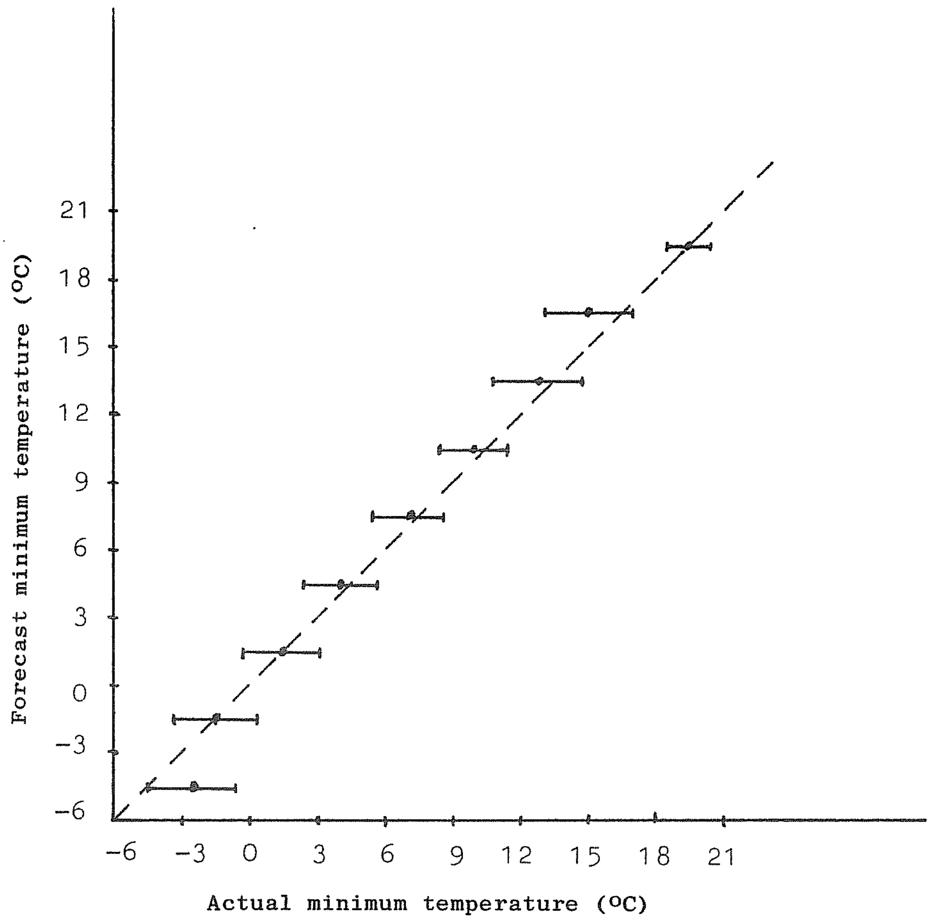


Fig. 6 **Distribution of actual minimum temperature as a function of forecast minimum temperature - ROMA Fiumicino, cold semester.**

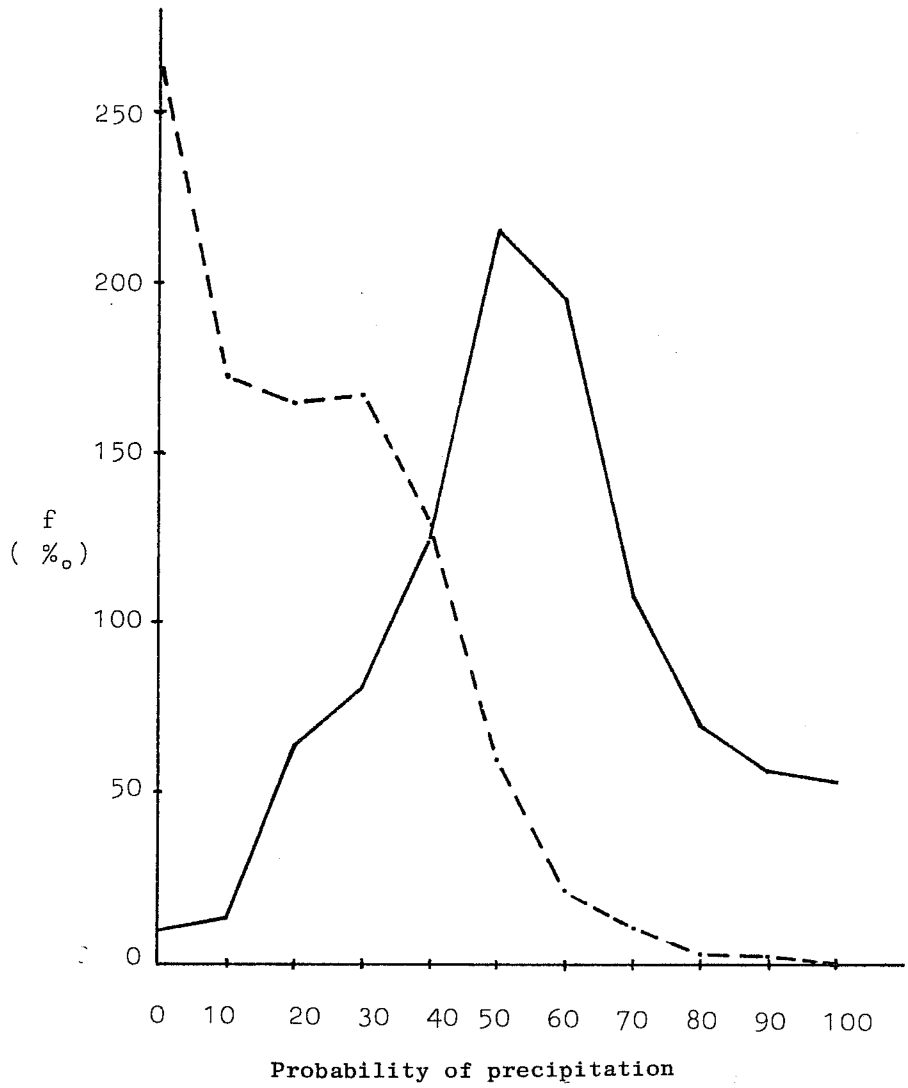


Fig. 7 Frequency of cases of rain (——) and no rain (----) as a function of the predicted probability of precipitation by statistical model - Number of cases of rain = number of cases of no rain = 1000 - NAPOLI Capodichino, cold semester 06-18GMT

Furthermore, these probabilistic results can be used in very different ways according to the particular problem of the user. As a very crude example, the most simple option of forecasting rain when f (rain) > f (no rain) and no rain when the opposite holds. In this case the common area can be divided in two parts. The area on the left represents the cases that are wrong when no rain is predicted while the area on the right represents the cases which are wrong when rain is forecast. The results for NAPOLI Capodichino in the cold semester are shown below:

Predicted rain cases

correct forecast 704
wrong forecast 99

Predicted no rain cases

correct forecast 901
wrong forecast 296

The total percentage of correct forecasts is 80.3%. It is important to remember that these results have been obtained by normalizing to the same frequency events of rain and no rain.

Taking into account the real climatic distribution, the model results are shown in Fig. 8. Assuming, as before, that there is a policy of forecasting rain when f (rain) > f (no rain) and no rain when the opposite is true, then out of 1000 cases there are

636 correct no rain forecast
199 correct rain forecasts

giving a total percentage of 85.5%.

Considering separately rain and no rain cases, we find that cases of no rain are correctly predicted in 90% of cases whereas the corresponding figure for rain cases is 67%. However, this is a very simple evaluation obtained by considering only a very small amount of all the possible information.

3.3 Operational tests

Here we will discuss only the tests of the objective local predictions based on the NWP products of the ECMWF.

Using the daily analysis from August 1979, we initially made a synoptic evaluation of the ECMWF products. As a consequence of this, the following defects were apperant in the examined area (Fig.9):

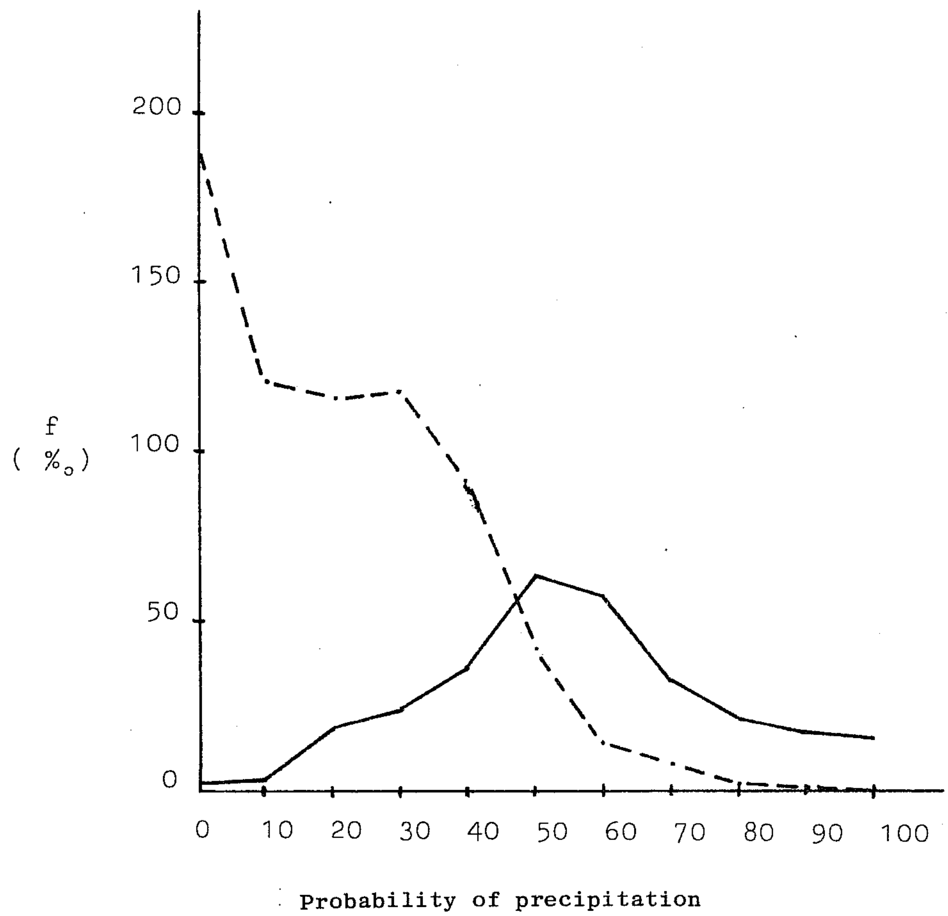


Fig. 8 Frequency of cases of rain (——) and no rain (----) as a function of the predicted probability of precipitation by statistical model
Number of cases of rain = 296
Number of cases of no rain = 704
NAPOLI Capodichino, cold semester 06-18 GMT

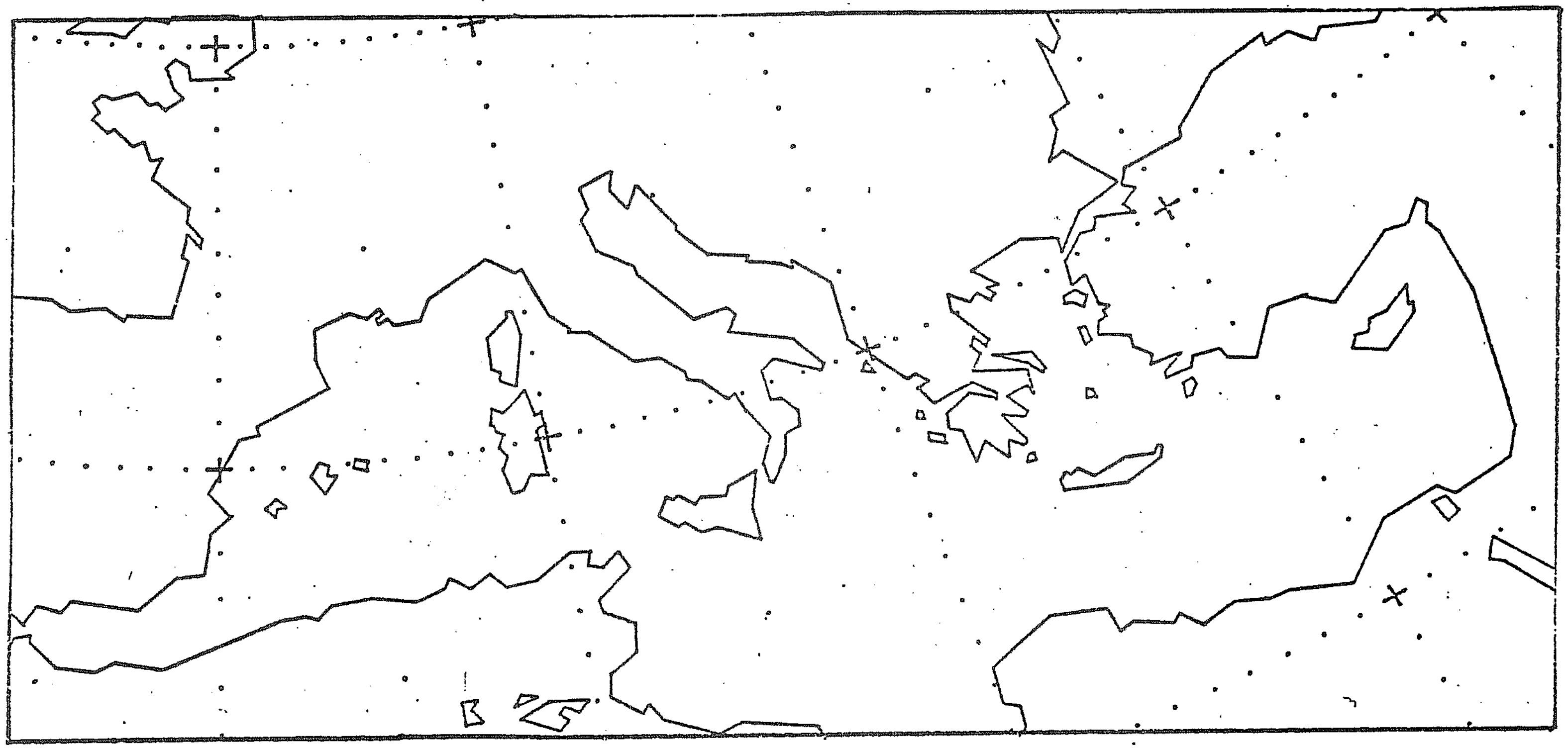


Fig. 9 Area for synoptic evaluation of the ECMWF products.

- a systematic southerly shifting in time of the zonal flow;
- a tendency for there to be an excessive deepening of the geopotential at 500 mb;
- during zonal situations, the movement of the weather patterns seems to be slightly too rapid;
- often the weather pattern at the surface appears to be too much in phase with the corresponding pattern at 500 mb.

On the basis of these findings and some preliminary numerical tests of the post-processing of the ECMWF products, we have choosen to work, from the operational point of view, with the selection of predictors which excludes the data at 1000 mb and the humidity. The reason is that our statistical model is based on the perfect prog method and so it is highly dependent on the quality of these fields, and so it is important that the less reliable products from ECMWF are not included.

We made numerical tests of all our products from October 1981 to March 1982 (cold semester), and here we will show some results for total cloud cover, temperature and precipitation.

The RMSE for D+1 to D+4 at 12GMT of total cloud cover at ROMA Fiumicino is shown in Fig. 10; the RMSE of persistence is also shown. At day D+4, the increase in the error is due mainly to some cases where the forecast is completely wrong (error of 6 to 7 octas), and these are associated with situations where there is a poor precition in the low layers by the model. For this parameter it is worth stressing that extreme cases (clear or overcast) are predicted by means of the ECMWF products much more frequently than with our own or the USA production; hence the bias is similar to that with actual data.

As far as the temperature is concerned, we have found some interesting results. For the sites in central and southern Italy, there is practically no bias in the prediction of maximum temperature, and the main characteristic of the prediction is that the RMSE increases in time (Fig. 11).

However, for the sites in northern Italy (and in particular these in the western Po valley) for this period, we had a negative mean error significantly different from zero; this was due to very poor basic forecasts. For example Fig. 12 shows the distribution of the error of the D+3 and D+4 prediction of maximum temperature at MILANO Linate.

In this area the defects found in the synoptic evaluation may be important. The systematic southerly shifting in time of the zonal flow, the excessive deepenings at 500 mb, the excessive speed of the perturbation in the zonal flow and the inadequate representation of the mechanism of the cyclogenesis in the lee of the Alps are all possible reasons of a negative systematic error in the temperature over nothern Italy.

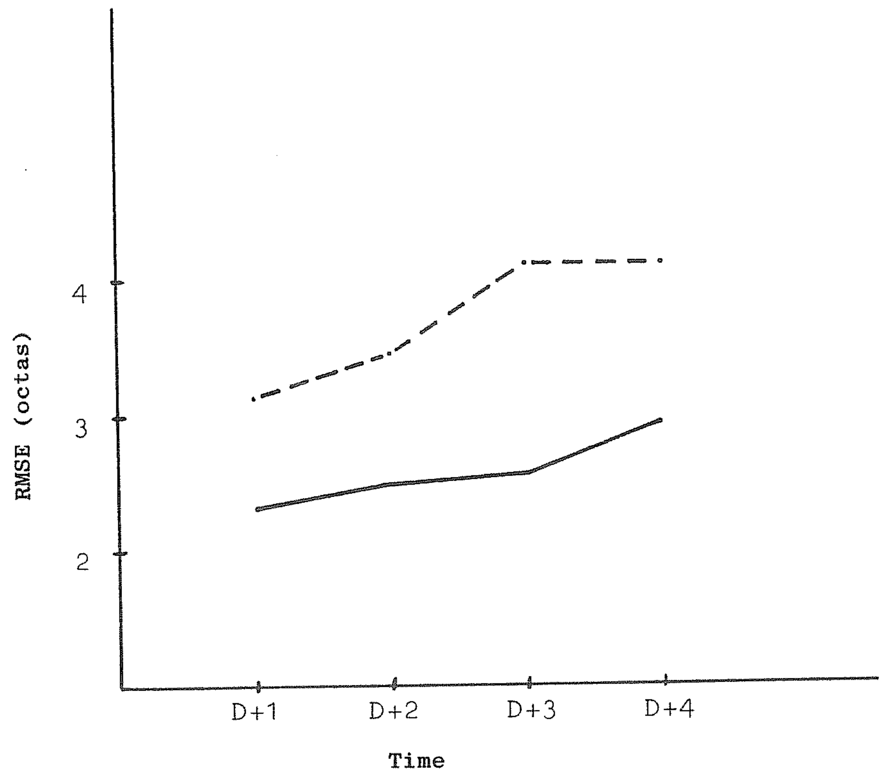


Fig. 10 Total cloud cover : root mean square error (——) post-processed model forecast (----) persistence. ROMA Fiumicino, cold semester 12GMT.

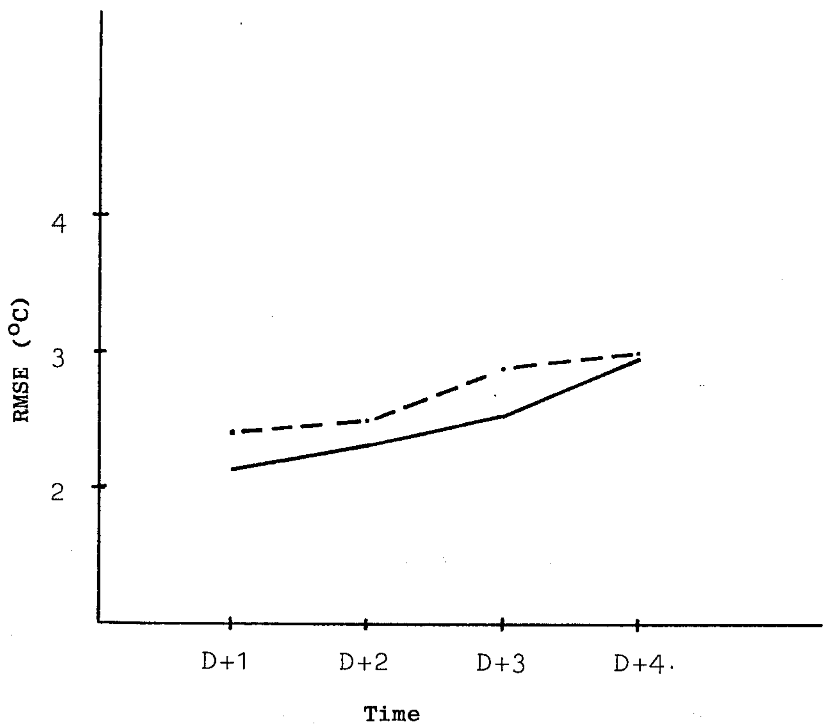


Fig. 11 Maximum temperature : root mean square error (——) post-processed model forecast (----) persistence. ROMA Fiumicino, cold semester.

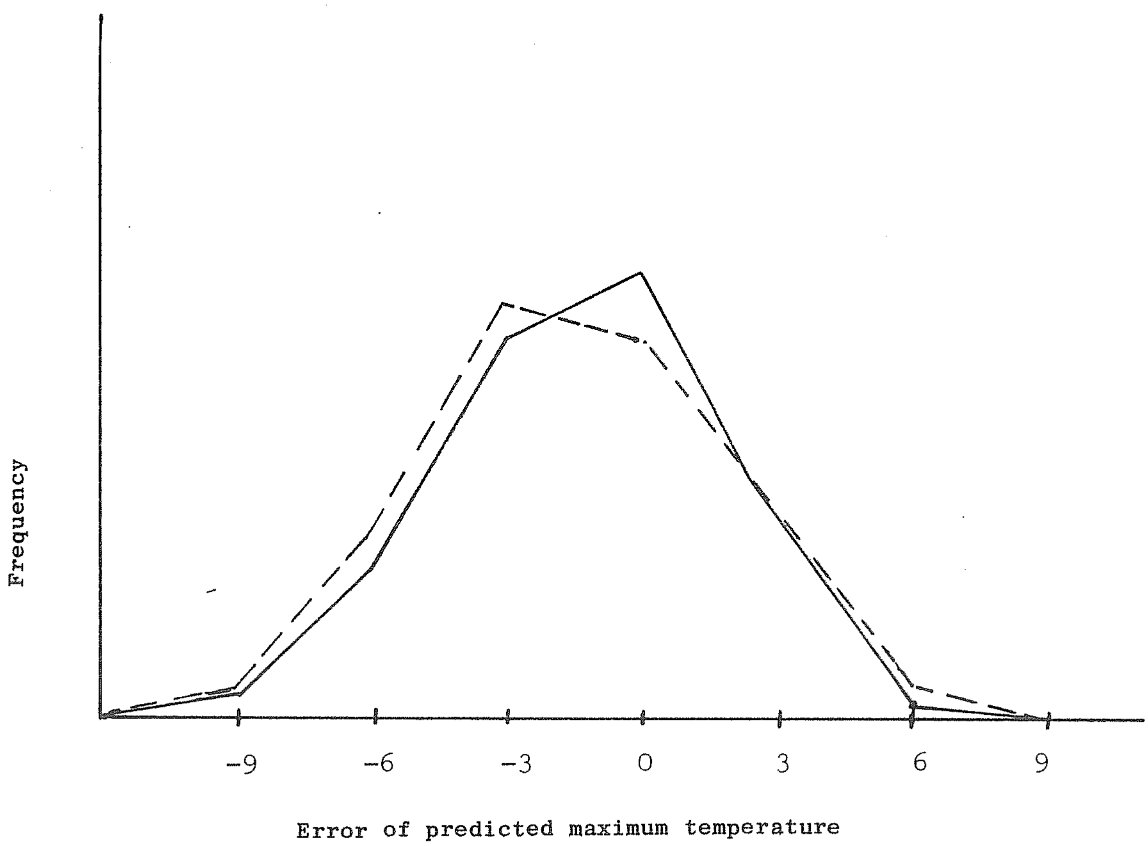


Fig. 12 Distribution of errors of the predicted maximum temperature (——) D+3, (----) D+4. MILANO Linate, cold semester.

Certainly the test is limited to only one semester, but this is probably not a chance defect since the findings are supported by synoptic evaluations and partially confirmed by the numerical tests of the ECMWF products.

In order to test the precipitation forecasts for the last cold semester in Italy, it was necessary to amalgamate the results from all the sites due to lack of rain.

Fig. 13 shows the behaviour of the RMSE of this parameter with time (the actual possible values are 1 or 0, depending upon if there is rain or not).

It is important to stress the gain with respect to the persistence, and the decay of the quality of the RMSE from D+3 to D+4. Nevertheless, in order to assess the reliability of this parameter, it is necessary to have a larger number of cases of rain available.

4. FUTURE PLANS

In the last two years experiments have been carried out with other statistical techniques (non linear regression, principal components), etc., but the results have been of a similar quality to those of the operational model.

Therefore in the future we intend to develop the model mainly in the two fields: the data base of predictors and the time resolution of the stratification of the sample.

As far as the data base of predictors is concerned, we intend to include some TEMPS of non-Italian stations (such as Malta, Athens, Belgrado, Payerne and Marsiglia) in order to have a better coverage in the Italian region.

With regard to the time resolution of the stratification of the sample, it must be stressed that it is sometimes possible to have problems in the transition months from one semester to the other. Therefore we are still working with a time resolution of one month using as a data base periods of three months overlapped of two months each to other.

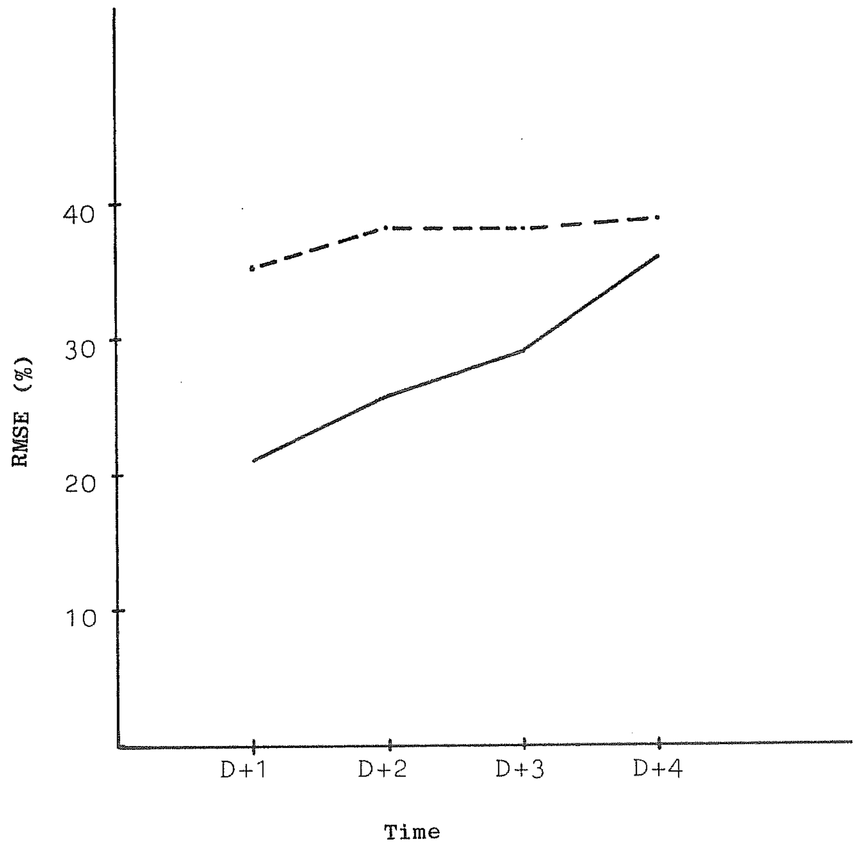


Fig. 13 Probability of precipitation : root mean square error (——) post-processed model forecast (----) persistence

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