MEDIUM-RANGE FORECASTING: APPLICATIONS

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Summary: The use and application of ECMWF products in Italy are presented. In particular the synoptic evaluation methods and the objective interpretation carried out at the National Meteorological Centre of the Italian Meteorological Service are discussed. Finally the most significant applications developed by other italian Agencies are analyzed.

1. INTRODUCTION

In the Italian Meteorological Service the development and the operational activities in the NWP are concentrated in the short term models, until 48 hours, with and without the updating of the lateral boundary conditions. For the medium range forecasting, although there are available an autonomous development and an experimental operational method based on teleconnections and on a rationalization of the synoptic analogues, the main part of the operational production is based on the interpretation of the products disseminated by ECMWF.
The activity carried out in this specific sector at the National Meteorological Centre is here analyzed, with particular attention to the evaluation of these products and to their objective interpretation in terms of local weather, useful, together with the direct model output, to the forecaster responsible of medium range forecasting.
All these products are disseminated in the national field from NMC to the various Agencies and Istitutes, which deal with meteo-dependent activities. Most of these Agencies use directly these products as guidance for the planning and the management of the activities; some Institutes, taking into account specific local problems, have developed autonomous methods of interpretation of ECMWF products. Some of the most interesting studies carried out in this sector will be presented.

2. SYNOPTIC EVALUATION AND USE OF ECMWF PRODUCTS AT THE ITALIAN METEOROLOGICAL SERVICE

2.1 Synoptic evaluation

2.1.1 General remarks

Taking into account the experimental project in the forecast skill predictability carried out by the ECMWF during the winter 88-89, the reliability of ECMWF medium range forecast

fields over Europe has been deeply checked at the NMC of Rome for the period 1 december 1988 - 28 february 1989.
Only geopotential fields at 500 hpa with verifying times 72, 120, 168 hrs have been considered in this study.
RMS and ACC are given to Member States by ECMWF in order to perform an "a posteriori" process of comparison between the objective values computed and predicted and the subjective evaluations carried out by Member States. An "a posteriori" subjective evaluation method has been deviced by the operational branch of the National Meteorological Centre.
In order to give an objective and operationally useful evaluation of 500 hpa forecast fields, it is necessary an "a posteriori" comparison between a forecast field and the corresponding analysis on the same area at the same verifying time.
The following five independent synoptic parameters have been considered:
a1 - phase shift related to synoptic configuration over the european area (mainly Western Europe);
a2 - mean error of geopotential over the european area;
a3 - phase shift related to synoptic configuration over Italy;
a4 - mean error of geopotential over the italian area;
a5 - subjective evaluation of the curvature error over the italian area.
Each a(i) parameter is represented by an integer value ranging from -2 to +2, according to

phase shift	+180	+90	0	-90	-180
a1 (a3)	+2	+1	0	-1	-2
m.e.(m) of gp.	+120	+60	0	-60	-120
a2 (a4)	+2	+1	0	-1	-2
curv. error	++	+	0	-	--
a5	+2	+1	0	-1	-2

Therefore a set of five numbers is given for the evaluation of each map.
Each synoptic parameter has been studied in order to know its time distribution and to give an operational estimate of systematic errors of forecast fields. The results are summarized in the table 1.

hrs	mnt	a1	a2	a3	a4	a5
72	dec	same	same	same	pessim	same
	jan	same	same	same	pessim	same
	feb	same	pessim	same	pessim	same
120	dec	delay	pessim	delay	pessim	same
	jan	advance	same	same	optim	same
	feb	same	pessim	advance	same	same
168	dec	advance	indiff	advance	pessim	pessim
	jan	advance	pessim	delay	pessim	pessim
	feb	advance	pessim	delay	indiff	indiff

Tab. 1 : Subjective comparison between predicted and actual maps

It is possible to stress the following characteristics:
- a certain trend to accelerate the movement of large synoptic systems (european area);
- pessimistic evaluation of the geopotential either on the european area and the italian area;
- the χ^2 test of each a(i) parameter has shown a non negligeable casual (random) component especially at the 168 hrs, that has to be taken into account in the operational use.

2.1.2 Subjective Reliability Index (SRI)

The quality of the predicted maps has been defined as SRI (Subjective Reliability Index). It is a linear combination of a(i) parameters on the european and the italian area:

$$SRI = \sum_i |a(i)| \qquad i=1 \text{ to } 5$$

The range of SRI is 0 to 10. The best predicted map has SRI=0; the worst has SRI=10.
The threshold value of SRI, beyond which the forecast field is considered to be useless from a synoptical point of view, has been observed to have a value between 4 and 5.
The SRI behavior on the three months at time 72, 120 and 168 hrs is shown in the table 2.

hrs		72			120			168		
month		D	J	F	D	J	F	D	J	F
	0	45	50	57	5	15	19	0	0	5
	1	58	73	74	5	31	41	0	5	5
	2	73	86	85	14	36	44	3	10	13
S	3	79	85	88	33	45	58	10	13	35
	4	93	85	92	43	52	70	21	13	52
R	5	100	89	96	75	75	91	47	25	56
	6		92	100	82	88	90	52	47	72
I	7		100		95	95	95	62	70	76
	8				100	100	95	81	70	92
	9						95	83	83	89
	10						100	100	100	100

Tab. 2 - Subjective reliability (%) as a function of SRI for different months (dec, jan, feb) and terms (72, 120 and 168 hrs)

The cumulated reliability changes to every value of SRI and, if the threshold value is established, it is possible to find the corresponding value of the cumulated subjective reliability for each month. For example December had a subjective reliability equal to 93% at 72 hrs, equal to 43% at 120 hrs anf equal to 21% at 168 hrs.

2.1.3 Comparison between SRI and RMS & ACC

In order to detect any possible correlation in respect to predicted and actual RMS and ACC, these data, directly provided by ECMWF, have been divided into contiguous classes and, for each class, experimental frequency of SRI values has been computed, with the condition that the threshold value of SRI for an useful map were SRI = 4. From this point of view the results are summarized in the table 3.

----	72 hrs		120 hrs		168 hrs	
----	ACC	%	ACC	%	ACC	%
A	95 - 100	100	90 - 99	89	80 - 100	65
N	90 - 95	94	80 - 90	73	60 - 80	43
A	≤ 90	78	≤ 80	29	≤ 60	12
F	95 - 100	100	90 - 95	100	> 80	29
O	90 - 95	90	80 - 90	71	60 - 80	20
R	≤ 90	80	≤ 80	38	≤ 60	36
----	RMS	%	RMS	%	RMS	%
A	< 40	100	< 70	78	< 100	52
N	40 - 60	91	70 - 90	44	100 - 120	40
A	60 - 80	76	≥ 90	27	≥ 120	25
F	< 40	97	< 70	46	< 100	28
O	40 - 60	93	70 - 80	55	100 - 120	32
R	60 - 80	100	80 - 93	60	≥ 120	25

Tab. 3 - Frequency of useful synoptic maps for different classes of ACC & RMS, actual and predicted

At 72 hrs all the maps (100%) with predicted ACC values in the interval 95-100 have been useful from the synoptic point of view (SRI less or equal 4); those with predicted ACC in the interval 90-95 have been synoptically useful at the 90% and finally those with predicted ACC less than 90 have been useful at the 80%.
It is possible to observe the same behaviour at 72 hrs for the actual RMS. For the predicted RMS values there is a discrepancy in the behaviour of the frequency of the maps useful from the synoptic point of view, for the class 60-80, but this problem could be enhanced due to the small number of cases (only 5) in this class.
Similar considerations could be made for the 120 hrs. The reliability improves with the increase of the actual and predicted ACC and with the fall of actual RMS. Only for the predicted RMS there is an opposite behaviour, and this fact, connected with an equal discrepancy at 72 hrs, stress some problem in the use of predicted RMS values in "a priori" evaluation of the predicted fields. In any case it is evident at 120 hrs the rapid decreasing of the reliability, from the

third class of ACC and from the second class of RMS; so it is confirmed the more useful information of ACC respect to RMS in our area.
Finally at 168 hrs the actual values of ACC & RMS mantain some correspondence with the synoptic evaluation, particularly ACC, although at levels not very high; no information instead is present in the predicted values of ACC & RMS.

2.2 ARGO : THE OBJECTIVE INTERPRETATION OF ECMWF PRODUCTS AT THE ITALIAN NATIONAL METEOROLOGICAL CENTRE

2.2.1 General remarks

Obviously there are undeniable benefits in the subjective synoptic interpretation of the NWP products, due to the originality, flexibility and personal skill of the human element. And 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 this is particularly true for short and very short range forecasts, taking into account that in this case the forecaster has a certain amount of informations, coming from radar and satellites, not (or not yet completely) considered in the NWP. On the countrary in case of medium range forecasting the guidance of the NWP must be very strong, so that, in addition to direct NWP output, it is important to made available to the forecasters also an objective interpretation of NWP fields in terms of local weather. In this way the basic material is complete enough to give forecasters a reliable guidance for determining the type of weather at the base of the worded medium range forecasting.
In Italy these studies led to build up the automatic system for local forecasts named AFRODITE. The present operational system is a development of AFRODITE. The new system, called ARGO, takes its name from the mytological one hundred eyes giant.
In order to improve the quality of the predictions two factors were introduced. The historical series of aerological observations of Malta was added to the AFRODITE data set giving 25% increase of information. Redundancy in the rough data set has been reduced by a condensation technique (EOF) that retains 90% of the aerological observation properties.
As far as predictors, in order to improve both forecasts quality and quantity, the original observations have been manipulated to define the actual 57 predictands set.

2.2.2 Predictors

The choice of the PPM method in the Italian Meteorological Service has been finalized at the beginning of the eighties since:

- it allows substantial changes (or even complete replacement) of the operational prediction model without ceasing or temporary degrading the objective products;
- it can be applied to different models (Italy, ECMWF, UK, USA, ..); this fact 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.

On the other hand, given this choice, it is important to take into account that the quality of operational products decreases respect to the quality obtained during the development, due to the error of the NWP fields. So, in order to take into account the characteristics and the reliability of the various fields , different selections have been developed. At the end of this preliminary study it has been decided to do make no use of the 1000 hpa and the relative humidity, due to the fact that these are very important as actual fields, but they are characterized by a frequent low operational reliability, especially on a medium range.

With these basic choices, the original predictors of the system ARGO are the tropospheric dynamic and thermodynamical variables measured by 5 observatories: Milano, Roma, Brindisi, Cagliari e Malta.

The basic pressure levels employed are 850, 700, 500, 300 hpa. For each level 4 physical quantities have been considered: temperature, geopotential height, zonal and meridional wind. Therefore troposphere at each synoptic hour over Italy has been described by 80 physical variables:

5 observatories (MI, RO, CA, BR, MA) *
4 levels (850, 700, 500, 300) *
4 variables (T , Z , U , V)

These can be represented in a 80 dimensions euclidean space R80. Each point of R80 is associated with a physical state of the troposphere. If in R80 we introduce a cartesian coordinate system, every meteorological situation over Italy can be identified by a vector X = (x1,x2,...,x80). The vector X describes a domain (X) in a variety V of the atmospheric phase space volume in R80.

Since the aerological observations are not mutually independent, the coordinate system is not orthogonal and the number of the effective components is less than 80. If we introduce, in the variety V described by X, an orthogonal cartesian system with 20 dimensions we observe that 90% of the X variance is explained by the vector Z = (z1,z2,..z20).

The transformation matrix A = (aij) (i=1,80; j=1,20) of the coordinate system has been computed by a modifiied version of the technique known as principal component analysis. So, using the EOF so obtained, the physical properties of the free atmosphere over Italy are described by a 20 components vector in the domain (Z) for each synoptic hour.

Finally clustering of the observations, according to which month they belong to, is also carried out to obtain a fine description of seasonal fluctuations. So we have obtained 12 reference systems in 12 domains of the transformed variables Z, where it is possible to describe the aerological properties.

2.2.3 Predictands

Experiences carried out with the AFRODITE system have shown that to choose as predictand the istantaneous value of a meteorological parameter , synchronous with the recorded predictors, makes often forecasts poorly representative of the reality. On the other hand the same predictors, upper air observations during the study phase and the NWP products in the operations, doesn't have an istantaneous value but they are representative of a situation in a certain time period. Therefore the ARGO predictands have been defined in a more meaningful way.
So the list of the actual predictands and their main features are the following:

at 00, 06, 12 and 18 GMT

NTO - cloud coverage (6 hrs average)
NBM - low level cloud coverage (6 hrs average)
HBN - ceiling (6 hrs average)
URL - relative humidity (6 hrs average)
VIS - horizontal visibility (6 hrs minimum)
PBF - wind probability (6 hrs probability $V \geq 5$ kts)
FFF - wind intensity (6 hrs maximum)
DIR - wind direction (6 hrs ....)
PBR - probability of rain (6 hrs centered)
PBT - probability of thunderstorm (6 hrs centered)

at 00 and 12 GMT

PBR - probability of rain (12 hrs centered)
PBT - probability of thunderstorm (12 hrs centered)
QPM - quantity of precipitation (12 hrs centered)

daily

TMX - daily maximum temperature
TMN - daily minimum temperature
INS - sunshine
FMA - daily maximum wind
PBF - wind probability (daily probability $V \geq 10$ kts)
DIR - direction of the daily maximum wind

2.2.4 Multivariate correlation analysis

Once predictors Z and predictands y have been defined, the shape of the function F is to be determined, in order to achieve the best approximation of the predictands.
If we call $\tilde{y} = F(Z)$ the estimate of the predictand y, the linear function F is computed which fulfills the least square condition for every couple y, $\tilde{y}$, by the multiple regression method. Z predictors belonging to a time interval, containing the predictand, are emploied in the regression with the purpose of taking into account the temporal variability of the atmosphere, the complete formula of the regression is

$$\tilde{y}(t^*) = F(Z(t1), Z(t2)) \qquad t1 \leq t^* \leq t2 \; , \; t2-t1=12 \text{ hours}$$

Having in mind the seasonal variation, both aerological and surface data were clustered according to the month they belonged to. This fact was possible due to the lenght of the sample (16 years).
Time variation inside the months are identified by means of two trigonometric functions SIN(2 D) and COS(2 D) where D is the Julian day.

2.2.5 Operational products

Presently local objective forecasts are produced operationally for 150 sites. The production based on the ECMWF products is available at 04 GMT of the day D (D+1 for ECMWF) in the morning and contains 16 predictions from 00 GMT of the day D+1 (D+2 for ECMWF) until 18 GMT of the day D+4 (D+5 for ECMWF), one for each synoptic hour (00, 06, 12, 18).
The map of the network is shown in fig. 1. The fig. 2 shows a meteorological map predicted in which the international simbology for the weather phenomena is used. An example of the forecast on a single site is given in the table 4.

	D1				D2				D3				D4			
	00	06	12	18	00	06	12	18	00	06	12	18	00	06	12	18
NTO	2	2	0	0	0	0	2	2	0	2	4	4	4	4	6	5
NBM	0	0	0	0	0	0	0	0	0	0	3	3	2	3	4	4
HNB	-	-	-	-	-	-	-	-	-	-	5	6	12	5	5	6
URL	80	85	45	75	85	90	55	75	90	90	65	85	90	90	60	80
PBR	0	0	0	0	0	0	0	0	0	0	30	30	20	30	60	50
PBT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	20
PBR	0		0		0		0		0		40		40		70	
PBT	0		0		0		0		0		0		0		40	
QPM	0		0		0		0		0		4		3		8	
VIS	43	38	43	50	35	26	41	50	39	30	42	49	43	40	50	50
FFF	0	0	0	0	0	0	0	0	0	0	0	5	5	6	7	7
DIR	-	-	-	-	-	-	-	-	-	-	-	22	20	20	33	32
FMA		0(≤10)				0				0			15 from 32			
TMN		2				2				5				6		
TMX				16				18				18				16
INS		7				8				6				3		

Tab. 4 - Example of the ARGO forecast on a single site

2.2.5 Operational verifications

It is interesting to examine the operational performances of local weather forecasts in the last five years. The parameters, analyzed here, are rain (y/n) and temperature.
The evaluation of the local rain forecasts has been made also defining some classes of quality, corresponding to different number of correct forecasts:

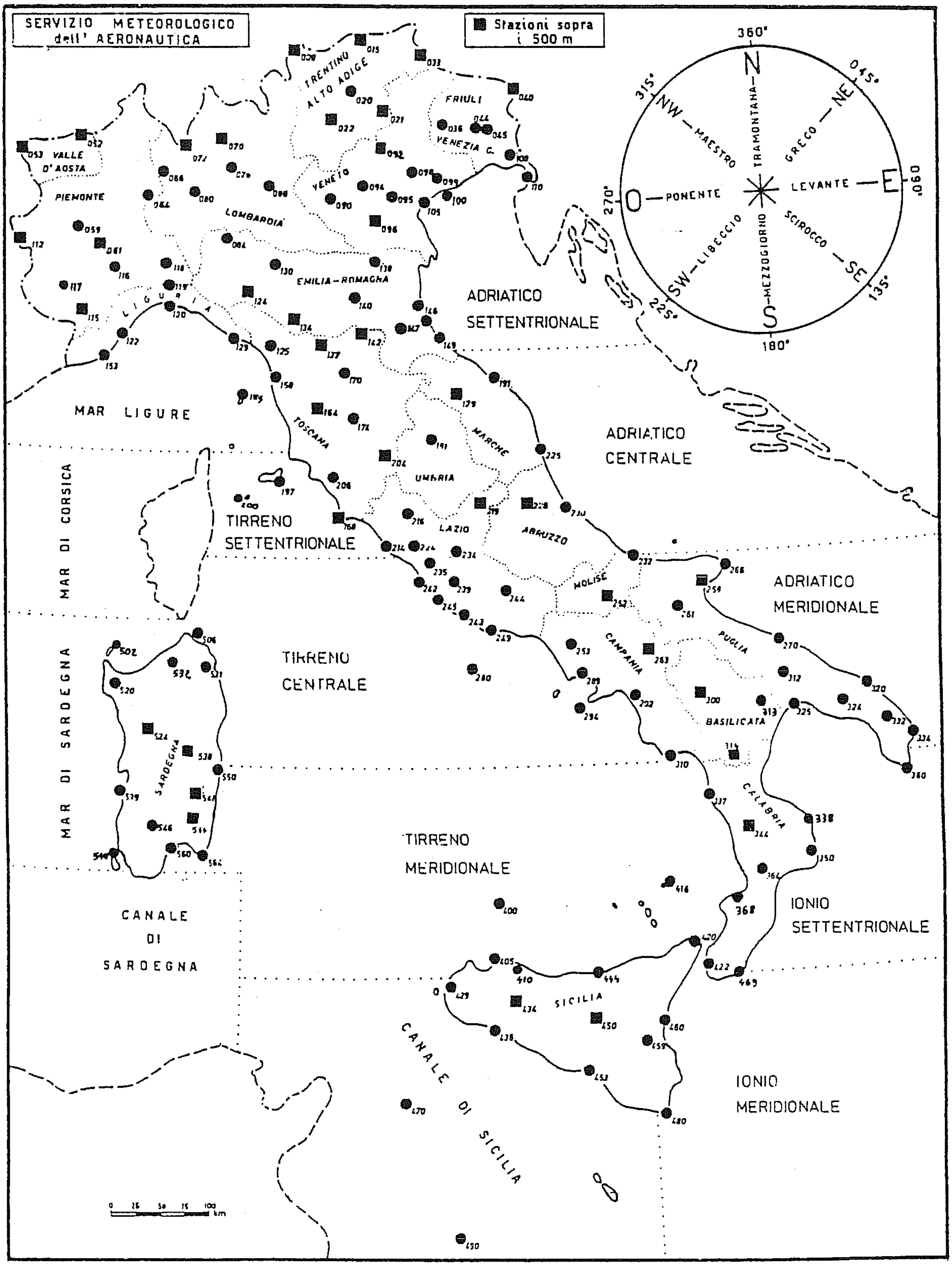

Fig. 1 – Network of ARGO.

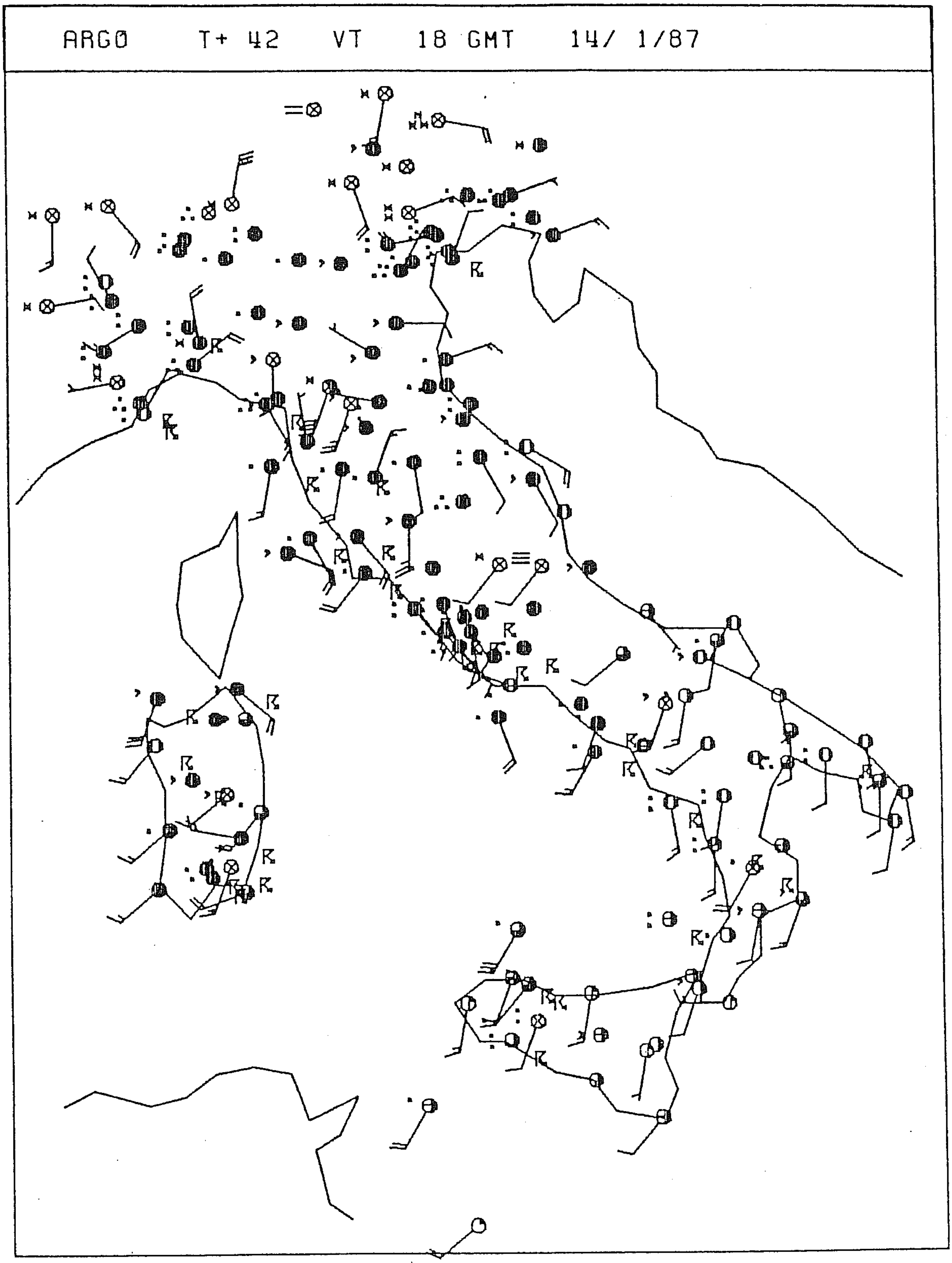

Fig. 2 - Meteorological map predicted by ARGO.

worse	-	correct forecasts on the 15% of the sites
bad	-	correct forecasts on the 35% of the sites
par.usef.	-	correct forecasts on the 55% of the sites
good	-	correct forecasts on the 75% of the sites
excellent	-	correct forecasts on the 95% of the sites

The results of these verifications are published on the ECMWF Report on the Verification of ECMWF Products in Member States. If we consider here the number (referred to a total of 100 cases) of predictions good and excellent we obtain the data contained in the table 5.

day \ winter	84/85 mod	84/85 per	85/86 mod	85/86 per	86/87 mod	86/87 per	87/88 mod	87/88 per	88/89 mod	88/89 per
D2	69	59	76	45	76	63	76	61	83	78
D5	48	50	58	32	69	46	71	54	80	78

Tab. 5 - Number of rain predictions good and excellent

The Gilbert and Heidke scores are also presented in table 6.

day	winter	84/85 mod	84/85 per	85/86 mod	85/86 per	86/87 mod	86/87 per	87/88 mod	87/88 per	88/89 mod	88/89 per
D2	Gilbert	17	9	19	8	20	12	22	9	15	6
D2	Heidke	39	21	47	20	48	27	50	22	31	13
D5	Gilbert	10	3	13	1	13	3	14	4	11	2
D5	Heidke	24	11	32	4	31	8	32	9	24	4

Tab.6 - Gilbert and Heidke scores for rain predictions

As far as the temperatures, the various ME and MAE are regularly published on the ECMWF Reports. It is interesting to show here the evaluation carried out in a way similar to the method used for rain.
If we consider the number (referred to a total of 100 cases) of predictions of temperature good and excellent (with MAE$\leq$2), we obtain the data contained in the table 7.

day \ winter	84/85 mod	84/85 per	85/86 mod	85/86 per	86/87 mod	86/87 per	87/88 mod	87/88 per	88/89 mod	88/89 per
D2	68	60	74	60	81	68	83	69	68	61
D5	51	48	64	48	75	52	77	53	64	57
Climat.	48		66		61		64		57	

Tab. 7 - Number of predictions of temperature with MAE $\leq$ 2

It is interesting to point out two particular aspects of the results of these operational verifications.
First of all there is a general positive trend in the quality of forecasts. But this trend is more evident for D5 than for D2. Certainly the evolution of these figures will be asymptotic and the difference between D2 and D5 means that in the last years the absolute improvement in the NWP for D5 has been greater than the improvement for D2. And probably there are yet greater possibilities of gain.
The second interesting aspect is represented by the figures referred to the winter 88/89. It has been a very unusual winter for Italy with an exceptional lack of rain. Although the number of rain forecasts good and excellent increases respect to the previous years, the improvement respect to the persistence method decreases markedly (83 versus 78 in the winter 88/89 and 76 versus 61 in the winter 87/88). This fact is evident in the Gilbert and Heidke scores, which have an evident worsening in the last winter. The same problems are present for the temperature and the number of predictions good and excellent (MAE $\leq$ 2) decrease markedly in the winter 88/89. Probably there are two concurrent reasons for this fact. The first, but certainly not the most important, is the behaviour of the ECMWF model. Although the quality, as we will discuss also in the following paragraph, has been generally good, it is well known that it is in a phase of no major improvement. The second reason, certainly the most important, is the particular meteorological scenario of this winter. The statistical objective interpretations perform better if the meteorological situations are well represented in the data sample on which the development is based. They have experienced problems in case of persistent occurrence of anomalous situations. Probably the same reason is responsible of the low scores in the winter 84/85 for temperature predictions. This winter was in fact characterized by an unusually intense and persistent cold outbreak in Central Europe and in Italy.
On the base of the experience of the last winter an interactive procedure has been deviced in order to correct from a subjective point of view the regional response of the statistical interpretation in cases of evident and longlasting objective weather phenomena misinterpretation.

3. APPLICATION OF ECMWF PRODUCTS IN ITALY

3.1 General remarks

In Italy there are many Agencies and Istitutions, governmental or not, which have an Agreement with the Italian Meteorological Service in order to receive in real time, by medium or low speed line, all the meteorological information necessary for the planning and the management of meteo-dependent actvities.
Among all the products made available to these Agencies, also the local weather forecasts of ARGO and the requested ECMWF products are furnished for medium range forecasting.

Most of these Institutions use directly all this information for their purposes, without any other processing. In the eighties the utility of this information has been very high. It is sufficient to point out three important cases of assistance to the Governmental Agency of Civil Protection:

- Few days after the earthquake in Irpinia, cold outbreaks and snow affected that region adding serious problems to the dramatic circumstances. The change in the meteorological situation was announced from the Italian Met Service to the Civil Protection 3-4 days in advance.
- During january 1985 the meteorological situation in Italy was characterized by an unusual cold outbreak and in the final part of the period the northern Italy, in particular the western Po Valley, was interested by extended and intense snowfalls. During all the period, with some record in low temperatures, particular assistance was furnished from the Italian Met Service, on the base of the post-processed products of the ECMWF fields.
- Finally this last winter in Italy has been characterized by an anomalous lack of precipitation, with serious problems in particular for agricolture. To manage this emergency an "Interministerial Permanent Observatory of the Drough" was created and in this Institution the medium range forecasting furnished by the Met Service were very useful and appreciated (... also if negative for a long period!), and in particular the main change in the meteorological scenario over Central Europe and the mediterranean area, responsible of the interruption of this drough in Italy, was well foreseen 4-5 days in advance.

On the other hand it is well known that not all the meteorological aspects can be treated from a National Met Service. There are many meteo-dependent activities for which a tuned information, related to specific local problems, is necessary. That is the reason why some of these Agencies has developed autonomous methods of interpretation of ECMWF products. Some of the most interesting studies in this sector are presented here.

3.2 Use of ECMWF products by the Methane National Society

The Methane National Society (SNAM) is the public company entitled of distributing natural gas (Methane Gas) in Italy. It provides 20% of the gross national energy budget.

To manage and plan uses of a very large amount of gas, weather forecasts and very accurate software are needed. SNAM merges such information through the system CASSANDRA (Computer Aided Sales Series Nullifying Daily Residuals Autocorrelation).

This system provides the distribution of the gas toward almost 5000 users (2000 public companies, 3000 industrial and thermoelectric users) by means of complex teleoperations. In order to satisfy sudden requests of gas during the winter months (e.g. during the exceptional cold outbreak of january 1985) the methane gas is stored very deeply under the earth surface during the summer period. The italian network of gas pipelines, which run across the country, reaches a lenght of 2000 km and a volume of one hundred of cubic meters. This network is monitored by 300 observing stations, properly located, in order to acquire in real time the knowledge of the data needed for estimating the situation of the requests and the possibility of meeting them by the offer. However the amount of the demand is strongly dependent on the meteorological situation. It is estimated, for example, that during particular environmental conditions over Northern Italy methane consumption can have variations up to 10% causing a large impact on the general distribution of the gas. Therefore reliable weather predictions are essential in order to foresee plans for the distribution of the gas. For that reason from 1983 there is an Agreement with the Italian Meteorological Service in order to receive in real time the necessary meteorological information.

The operational schedule of activities can be briefly described. Before 9.30 a.m. L.T. all the informations are retrieved by the observing network. The following data are checked in the operational room:

- previous day consumption estimated by a special software analysing the retrieved data;
- temperatures predicted by ARGO;
- final consumption results by thermoelectric users.

These data form the information needed as input by the CASSANDRA system which performs the prediction of the possible demand for the next 4-5 days. This system consider the following components:

- the trend, represented by a linear function, which takes into account the long term variations in the demand;
- the thermal components, described as a multilinear regression of the temperatures over some italian sites found statistically significant for this problem;
- the periodic component of the demand expressed by a synusoidal function and its first four harmonic components;
- the stocastic component of ARIMA type.

The tables 8 and 9 show an example of final results as they are presented on the VDUs of the operational room.

The final output of the CASSANDRA system was very useful for the D+3 forecast during the winter 84-85, due to the peak of consumptions in January 1985 and the corresponding good performance of the forecast.

Weather forecasts from NMC of Rome
issued at 04 a.m. 02/01/1985

daily average temperature

	TO	MI	BS	VE	BO	FI	RO
02/01/85	-1.5	-1.7	-2.5	0.7	0.6	1.7	2.9
03/01/85	-2.5	-3.0	-2.5	-0.5	-1.5	1.0	3.5
04/01/85	-4.5	-3.0	-4.0	-2.5	-3.0	-1.5	2.5
05/01/85	-4.5	-3.0	-3.5	-1.5	-3.5	0.5	3.5
06/01/85	-2.5	-3.0	-3.0	-1.5	-5.0	-0.5	3.5
07/01/85	-3.0	-4.0	-3.5	-3.0	-6.0	-1.5	3.0

Tab. 8- Example of weather forecasts for CASSANDRA

CASSANDRA sales forecasts (million of cubic meters) issued at 09.30 a.m. 02/01/85			
	pred. sale	confidence interval (90%) min.sale	 max.sale
02/01/85	119.8	115.8	123.8
03/01/85	125.5	120.5	130.5
04/01/85	131.2	125.7	136.8
05/01/85	125.4	119.5	131.4
06/01/85	119.0	112.6	125.4
07/01/85	133.9	127.5	140.3

Tab. 9 - Example of output of the CASSANDRA system

3.3 Use of ECMWF products by the Regional Meteorological Service in Emilia-Romagna

The Agency of Research and Development in Agricolture (ERSA) of the italian region Emilia-Romagna has an Agreement with the Italian Meteorological Service for a cooperation in operations and research in meteorology, in particular in agrometeorological problems. In this framework there is a link between the National Meteorological Centre in Rome and the Regional Met Service (SMR) of this region. Besides the other data, products and informations, daily in the first hours of the morning the products of ARGO and a selection of ECMWF products received in Rome are available in Bologna. So here it is possible to use the ECMWF products, directly with a synoptic interpretation of the maps and indirectly by means of the predictions of ARGO for the national stations in Emilia-Romagna.

On the other hand the SMR has developed a regional observational network and has collected hystorical rainfall data in 44 stations, a number very high of stations compared with the 10 stations of the national network. For this reason the SMR has developed an objective method of medium range forecasting of precipitation for the region as a whole and for all these stations, based on a particular post processing of the ECMWF products.

Fig. 3 shows the location of the stations, the orographic features and the border of the ER region.

The potential predictors are ECMWF fields of geopotential, zonal and meridional components of the wind vector, relative humidity and vertical wind speed at nine standard pressure levels. From these fields other fields were derived (temperature, geostrophic vorticity, specific humidity and vertical water vapour flux).

Rainfall data were available for the period from 1960 to 1984, so that ECMWF fields were limited to the period from 1981 to 1984. From a monthly Empirical Orthogonal Functions Analysis a long precipitation "winter period" has been identified from october to april and a "summer period" from may to september excluding july, which is peculiar from the

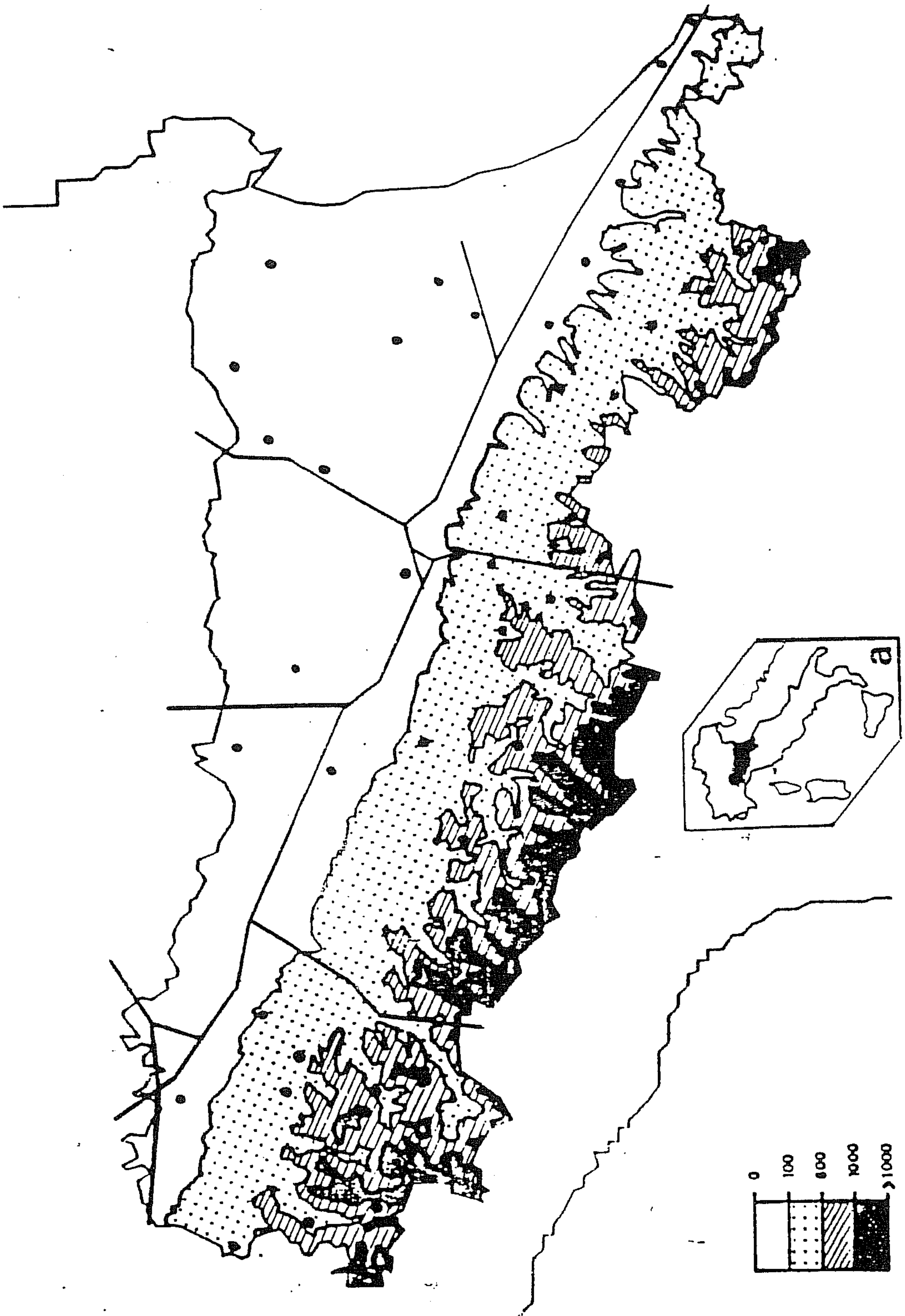

Fig. 3 – Emilia-Romagna region, wih the location of the stations and the orographic features.

precipitation point of view. So precipitation data and corresponding ECMWF analyses, from 1981 to 1984, have been grouped in a winter data set of 781 days and in a summer data set of 488 days.
The relative importance of the predictors with respect to the precipitation field has been studied computing the correlations between the principal components of the rainfall data and the 52 upper air fields. After choosing the most correlated fields, a study in the framework of the analogue method has been performed. This study consisted in selecting from the analysis archive some weather patterns similar to the pattern of the reference day, and predicting the precipitation on the basis of the precipitation that had occurred on those days in the past.
An objective evaluation of the analogy was made by computing simultaneously the ACC and standardized RMS parameters. The best results have been obtained coupling 500 hpa geopotential and 700 hpa vertical water vapour flux fields to define the analogy. In defining the analogy 500 hpa height is considered relative to the whole area while 700 hpa vertical water vapour flux only relative to a smaller region covering northern Italy. These area have been defined on the basis of correlation maps between grid point analyses of each parameter and precipitation. Finally the forecast of the yes/no precipitation event is performed on the basis of what occurred in the 15 selected past "similar" situations and taking into account the climatology of rainy days in the region.
A preliminary evaluation of the score of the method has been obtained by simulation of the forecasting for each day of the hystorical archive separately for winter and summer periods.
The quality of the forecast is expressed in terms of the Rousseau Index IR. For the rain forecasting over the region as a whole, the results normalized to a total of 100 situations are the following:

winter

analogue method

		forecast yes	forecast no
actual	yes	22	9
	no	7	62

IR = 64%

persistence method

		forecast yes	forecast no
actual	yes	17	14
	no	14	55

IR = 37%

summer

analogue method

		forecast yes	forecast no
actual	yes	29	9
	no	9	53

IR = 62%

persistence method

		forecast yes	forecast no
actual	yes	21	17
	no	17	45

IR = 39%

In order to provide a more detailed local information forecasts were performed, as already said, also over each of the 44 stations for the same data set. An evaluation of these forecasts was made defining some classes of quality, corresponding to different numbers of correct forecasts, in accordance with the following scheme:

quality of forecast	NFC : number of correct forecasts on 44 stations
very poor	NFC ≤ 20%
poor	20% ≤ NFC ≤ 40%
partly useful	40% ≤ NFC ≤ 60%
good	60% ≤ NFC ≤ 80%
very good	80% ≤ NFC ≤100%

The results referred to a total of 100 have been the following:

WINTER	very poor	poor	par. usef.	good	very good
analogue method	3	6	7	15	69
persistency	7	10	11	16	56

SUMMER	very poor	poor	par. usef.	good	very good
analogue method	2	7	15	14	62
persistency	5	11	19	17	48

The general improvement obtained with the analogue method compared with the persistence method appears evident, both for the forecasting over the region as a whole and for the local forecasting over the 44 stations.
This method is operational from october 1988, but, taking into account the particular winter 88-89 in Italy, characterized from an anomalous lack of rain, the control test on the first operational winter is not meaningful, and this summer is not yet finished. In any case the experts of the SMR are shure that the score obtained in the development with the perfect prog does not change very much in the operations at least up to 48 hrs, because the mean RMS between the reference days and the selected analogues is greater (in the area here considered) than the mean RMS between the analyses and the relative 48 forecasts.

3.4 Use of ECMWF products by the Italian National Electricity Agency

The Thermal and Nuclear Research Centre (CRTN) of the Italian National Electricity Agency (ENEL) has developed an operational program of application of meteorological medium range information (ARGO and synoptic maps from ECMWF) into electric energy management. On the other hand now this CRTN is developing a research program of objective interpretation of ECMWF products in the particular field of precipitation over the Alps, where the most important basins in Italy are located. On the Alps the meteorological events are drastically related to the orography and in northern Italy many hydroelectric plants receive water from snowfields, glaciers and directly from rainfall. In many situations an objective forecast, three or four days in advance, can be very useful.

For this purpose studies have been started on the possibility to use directly ECMWF products as predictors of precipitation patterns over the Alps.

Some recent works attempted to verify the rainfall forecasts directly produced by the ECMWF model or by ARGO, but the results were not satisfactory for the Alps; the models due to the difficulties of the representation of the orography and ARGO due to the very low resolution of the national stations in this area. Therefore it was decided to implement the statistical post processing approach using the fields from ECMWF as predictors.

A first scheme of objective forecast over the Central Alps was performed with the following features:

- september to may period;
- six area clusters ;
- three classes of 24-hrs amount of precipitation;
- v-component of wind at 850 and 700 hpa as best predictors.

Skill scores computed on the base of the analysis fields have been quite satisfactory (tab. 10) and at present ECMWF forecasts are collected to verify the feasibility of an operational suite for the rain forecasting over all the Alps.

cluster	pred	lev	threshold	Rousseau Index
1	v	850	3.5	0.59
2	v	850	3.1	0.56
3	v	850	2.9	0.61
4	v	700	2.8	0.51
5	v	700	3.0	0.58
6	v	850	4.0	0.56

Tab. 10 - For each cluster: predictor, level, threshold and Rousseau index

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