CYCLONES THAT PRODUCE HIGH IMPACT WEATHER IN THE MEDITERRANEAN, MEDEX (Phase 1)

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Project Summary

MEDEX (Mediterranean Experiment on Cyclones that produce High Impact Weather in the Mediterranean) is designed to contribute to the better understanding and short-range forecasting of high impact weather events in the Mediterranean, mainly heavy rain and strong winds. Due to the supposed close relationship between high impact weather and cyclones, MEDEX will be focused to Mediterranean cyclones that produce high impact weather.

A dynamically oriented climatology of cyclones and high impact events is the first milestone of MEDEX. A second milestone will be the determination of sensitive areas where better initial conditions will provide a more accurate prediction of Mediterranean cyclones. The third possible milestone could be to perform impact analyses of different kinds of data in these areas. From both, recommendations about the observing systems, modelling and refined conceptual models for forecasters will arise.

The present proposal describes phase 1 of MEDEX and the work to be done in the next 3 years, providing funding sources are successfully applied for. During this phase only existing data will be used. The work will be oriented towards the aforementioned milestones, as the whole MEDEX, but, according to the Resolution on MEDEX of the Science Steering Committee for WWRP, some priority tasks will be stressed. These priority tasks deal with the identification and collection of existing data (presently not available on the GTS), the selection of cases, their numerical simulation including exploration of their sensitivity to initial conditions and about physical and dynamical hypotheses.

We also consider building and using a systematic list of cyclone events and high impact weather events as necessary and priority tasks during this phase.

Further studies, including collecting new data through field phases, are postponed to a possible Second Phase of MEDEX.

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CONTENTS

1. Background

In spite of the usually pleasant weather, the Mediterranean area is quite frequently affected by sudden events of extreme adverse weather, often producing high social impacts. The unique geography of the region, with small and steep river basins and highly populated, industrialised and tourist areas, makes the Mediterranean especially sensitive to the impact of weather phenomena, mainly in case of heavy rain.

A brief selection of events (referred to 10 years) prepared by the Munich Reinsurance Company collects 166 cases of heavy rainfall and floods and 104 cases of strong wind and storms producing serious damages. The total number of deaths is over 1,900 and the quantified economic losses are over 6,000 M Euro. These figures are certainly underestimates. For Spain alone, and only in four years (1996-99), the Programme of Natural Hazards of the Spanish Directorate of Civil Defence has accounted 155 deaths by heavy rain and flood events and 28 deaths by storms and strong winds (in front of 5 and 5 in the Munich Re. listing).

The reduction of the dramatic consequences of these extreme weather events is the ultimate motivation of the present proposal. Improving forecasts of such events is a necessary, though not sufficient, condition for the above achievement. In particular, an accurate enough forecast in the short-range would permit an on time warning to the population under risk (for self protection) as well as a proper organisation and deployment of the civil defence forces and means, to provide emergency management.

Direct NWP operational model outputs do not give yet a totally reliable guidance about extreme rainfall or wind speed in the Mediterranean area. Although examples of quite good prediction can be found, in many others values are strongly under- or overestimated and/or badly located. Improving the model behaviour or improving the added value provided by the forecasters to the model outputs are two obvious ways to improve the short-range forecasts of extreme events in the Mediterranean. Both ways require a better understanding of the mechanisms that lead to these extreme events. This better understanding would permit not only improved monitoring of the model behaviour and a refinement of the conceptual models used by the forecasters, but also the formulation of recommendations about how the observing systems could be better matched to the forecasting needs.

Although not all the extreme weather events in the Mediterranean are related to cyclones and most of the cyclones do not produce extreme weather, it is plausible to assume that Mediterranean cyclones influence most of the high impact phenomena, at least in an indirect way. Preliminary statistical results (Jansa et al., 2001) show that around 90% of the heavy rain events (in a variety of areas of the Western Mediterranean) are accompanied by the presence of a cyclone in the vicinity. Most of them in such a location that some kind of influence of the cyclone on the heavy rain generation and location can easily be inferred. According to the cited study, most of the cyclones that accompany heavy rain are not strong and deep baroclinic systems, but shallow orographic or thermal depressions.

Therefore, in order to focus the project on a tractable near term scientific objective, *the main general objective of MEDEX is stated to be the improvement of knowledge and forecasting of cyclones that produce high impact weather in the Mediterranean area.* Cyclone is understood in the most general sense of the word, that is, including shallow depressions.

There is double way to improve the knowledge on the cyclones that produce high impact weather in the Mediterranean: (a) A statistical approach to the phenomena concerned, based on a systematic collection of basic information about cyclones and high impact weather events. (b) A study in depth of a set of selected cases, with identification of the factors influencing the processes. The combination of both ways produces the deepest improvement of knowledge, because even the full identification of a mechanism is useless without its representative ness.

Such improvement of knowledge will lead to a refinement of conceptual models and by this way to an improvement of the final forecasting. Another contribution of MEDEX to the better prediction of the phenomena under consideration will come from: (a) The analysis of the behaviour and forecasting skill of the NWP models, (b) The identification of the most sensitive areas and possibly, the analysis of the impact of the observing systems.

In a first phase (the present Phase 1 of MEDEX), all the aforementioned lines of action can and will be followed using only existing and available data, including data not usually distributed by the GTS. Part of the existing and not distributed data are GTS-like data can be used both for description of the cases and checking numerical model runs and for assimilating them in the numerical models. Other not distributed data are in any case valuable for the description of the cases and/ for checking numerical experiments.

According the recommendations formulated by WWRP/SSC, all these lines of action require several priority tasks:

a. Identify the nature, availability, and usefulness of data presently not available on the GTS, and to start concentrating these data in a MEDEX database.
b. Identify a set of cases where high impact weather was poorly forecast and conduct co-ordinated, in-depth case studies that include considerations of forecast skill and societal impacts associated with both the event and the poor forecasts.
c. Conduct NWP studies to identify sensitive areas where the addition of observations would most likely lead to improved forecasts and their related benefits.
d. Conduct research to identify physical and dynamical hypotheses that might form the basis of developing improved forecast techniques for Mediterranean cyclones.

2. Research Proposal

This is the main part of the present document and describes the MEDEX research proposal. It has been organised in 3 sections, 2.1: Science basis of the proposal, 2.2: Working plan and methodology, 2.3: Societal benefits and impact assessment.

2.1 Science basis of the proposal

As mentioned before, *the main general objective of MEDEX is the improvement of knowledge and forecasting of cyclones that produce high impact weather in the Mediterranean area.*

Since the basic and practical motivation of MEDEX is to contribute to the improvement of the forecasting of the high impact weather, the above objective makes sense because the cyclones do play a determining role in this kind of events, at least in most of them, according preliminary results that are briefly summarised in this section (Jansa et al., 2001; see Fig. 1). Nevertheless our present knowledge about that and other questions regarding cyclones and high impact weather events needs more systematisation, generalisation and deepness.

2.1.1 Summary on knowledge about cyclones and high impact weather in the Mediterranean

According to our present knowledge, specific features of Mediterranean high impact weather (heavy rain and strong wind, in particular) and of Mediterranean cyclones and cyclogenesis are summarised below.

Heavy rain

The seasonal distribution of heavy rain events in the Mediterranean - with a maximum in late summer and during autumn - suggests a relevant role of the Mediterranean air-mass, whose water content is usually very large during this period of the year. The Mediterranean air-mass, that is warm and wet, especially during autumn, remains concentrated at low levels (below 2000 m), a factor that favours convective instability. In fact, convective instability can develop very easily when colder and dryer air overlies the warm and wet Mediterranean air.

Heavy rain sustained during at least a few hours is the best way to collect 100, 200 even 500 mm of precipitation. This is the kind of precipitation that quite frequently produces damage in the Mediterranean. Of course, convective instability is an important factor, but another important key is a sustained feeding current of warm and wet air from low levels, able to replace the large amount of water continuously removed by heavy rain. The other necessary ingredient is a mechanism to force air ascent, in order to reach the saturation level, destabilise the air column and release the potential or latent convective instability (Doswell, 1982).

In many Mediterranean heavy rain events, the presence of a Mediterranean low, even if not deep, organises distinct air currents, as well as internal near-surface frontal boundaries. Wherever the tip of a warm-wet current intersects a thermal-humidity boundary or an orographic feature, is the best place for the convective instability to be released. There, both the feeding and the initial ascent are guaranteed (Jansa et al., 1994, 1995, 1996, Doswell et al., 1997, 1998, Ramis et al., 1998, Romero et al., 1998, Buzzi and Foschini, 2000, Ferretti et al., 2000). Forcing of upward motion from high levels in the troposphere is another favourable factor for destabilisation and for sustaining the convection, but it is not critical in many important heavy rainfall cases (see Ramis et al., 1994, for an example). The role of the orographic ascent is actually very important in many cases (Jansa et al, 1991, Buzzi and Tartaglione, 1995, Romero et al., 1997). However the former results have to be taken with some care, because synergetic effects can may prevent simple interpretation (Stein and Alpert, 1993; Alpert et al., 1995). For example, mountains may directly induce heavy rain through orographic lifting, but also affect heavy rainfall indirectly through the formation of orographically induced cyclonic systems.

In addition, the combined effect of orographic forcing and latent heat release on the flow upstream of the orography strongly influences the precipitation amount and distribution in events of heavy orographic rain, via the modification of mesoscale cyclone structures and rainbands (Buzzi et al, 1998; Romero et al, 2000).

Not all the Mediterranean heavy rain events look the same. Although the forcing of upward motion from high levels is a favourable factor for heavy rain in general, it is not the key mechanism in many of the Mediterranean cases and it is even not relevant in some of them, as indicated above. But there are other cases in which a strong and deep upwards forcing from upper levels becomes the dominant and key factor. These cases are often related to the genesis of deep cyclones. In these cases, a vigorous large scale ascent of air is the direct mechanism to generate large stratiform cloud masses and continuous moderate rain, but it is also a very efficient way to destabilise the vertical profile, leading to convection. Therefore, it is easy to have embedded convection within a deep Mediterranean cyclone, producing occasional periods of heavy rain, within the whole rain event. Even without reaching vertical instability, symmetric instability and slantwise convection is a possible mechanism favouring heavy rain within an intense cyclone.

Strong winds

Most of the strong winds observed in the Mediterranean belong to the category of local winds, like Mistral, Tramontane, Scirocco, Ethesian, Bora, Shamsin or Sharav (see H.M.S.O., 1962, or Reiter, 1975 for a general description) and are originated by air-flow / mountain interaction, as downslope flows or due to channelling effects. (The hot winds blowing from the desert across the Libyan and Egyptian segments of flat coast (Chili, Shimum) and the strong easterlies over the Eastern Mediterranean (Saaroni et al. 1998), could constitute exceptions to the general rule).

More in detail, the Mediterranean local winds can be seen as the result of the orographic mesoscale pressure perturbation induced by the flow / mountain interaction. High and low pressure poles of the orographic disturbance (and/or the orographic pressure dipole as a whole) create local areas of strong pressure gradient that provide intense local acceleration, leading to the local wind generation (Campins et al., 1995). The onset of a local wind is, therefore, often quite abrupt. Past the narrow accelerating zone, the winds continue blowing and spreading in an inertial way, although density gradients can contribute to a more efficient wind spreading and extension (J.M. Jansa, 1960, Alpert et al. 1982). According to this mechanism, local winds are thin, only 1.5 to 2 km deep at most (J.M. Jansa, 1933, Campins et al., 1995, Alpert et al. 1998) and may remain quite independent from the general flow above the mountain crests level.

In consequence, cyclones (if shallow orographic lee depressions are included under this name) are relevant for strong local winds, at least for some Mediterranean strong local winds.

On the other hand, the not rare presence in the Mediterranean of intense cyclones of any origin is itself enough to explain some windstorms blowing within the region. Furthermore, the synergistic combination of both mechanisms, presence of intense cyclone and generation of local winds, becomes explanatory of the extreme violence of some of the strong wind events,

To connect strong winds, heavy rain and cyclogenesis it is worthy to remark that the leading edge of wind streams can act as an internal shallow front. On the other hand, associated with local wind streamers is the formation of orographically generated cyclonic and anticyclonic PV banners, characterised mainly by shear vorticity. PV banners could become an important factor in Mediterranean cyclogenesis, as mentioned below (Aëbischer and Schär, 1996, Aëbischer, 1996).

Cyclones

The formation of low level shallow depressions by orography and thermal contrasts is very frequent in the Mediterranean, owing to the complex topography of the region. This makes possible that hundreds of cyclonic disturbances can be subjectively and objectively detected in the Mediterranean every year (Campins et al., 2000; Picornell et al., 2001). Another possible consequence is the frequent formation of low level potential vorticity banners. Neither the shallow depressions nor the positive PV banners can be seen as true or deep cyclones, but they can play a role in some cases of real deep cyclogenesis.

The Mediterranean area actually presents the highest concentration of real cyclogenesis in the world (Pettersen, 1956; see Radinovic, 1987 for a general view), at least during winter. Some of the Mediterranean cyclogeneses are so active as to be considered even as "meteorological bombs" (Conte, 1986; Homar et al., 2000). Some of the Mediterranean real cyclogeneses are so fast as to be considered as “meteorological bombs” (Conte, 1986; Homar et at., 2000). Mediterranean real cyclogenesis shows a very high concentration in the Gulf of Genoa region. Nevertheless, there are other areas with quite frequent true cyclogenesis. Secondary maxima are located in the Cyprus and Aegean region (Alpert et al., 1990, Reiter 1975) and other relative maxima are situated in the Adriatic (Ivançan Picek, 1996, Flocas and Karacostas, 1994), in the Palos-Algerian sea, in the Catalonian-Balearic sea and in the gulf of Lyon (Jansa, 1986).

One popular conceptual model of cyclogenesis has been revivified by Hoskins et al. (1985). It states that cyclogenesis occurs when and where a high level PV positive anomaly overlaps a low level potential temperature or PV positive anomaly or a frontal zone. Regarding this conception three kind of evolution can be identified in the Mediterranean, that also apply for mid-latitudes cyclones in general. (a) In absence of upper level PV anomaly or when it is too far to interact with a pre-existing low level disturbance, the latter does not evolve and remains shallow, weak or moderate and nearly stationary (Genoves and Jansa, 1991): real or deep cyclogenesis does not develop. (b) In absence of any previous individual low level depression, an upper level PV anomaly will create cyclogenesis when arriving over a frontal zone, just under the maximum PV advection at high levels. Although this type of evolution is quite classical in open oceans, some Mediterranean cyclogeneses could be, at least partially of this type, comprising those cyclones generated at the quasi-permanent Mediterranean border front (Alpert and Ziv, 1989) or at some internal fronts. (c) When the upper level perturbation moves close enough over a pre-existing low level disturbance to interact with it, cyclogenesis occurs, with rapid deepening of the pre-existing perturbation. What can be seen as particular in the region is that, In this way, the high frequency of orographically induced low level disturbances may partially explain the high frequency of real cyclogenesis in the Mediterranean (Genoves and Jansa, 1991, Jansa et al., 1994).

Furthermore, the Mediterranean geographic factors add ingredients that can alter substantially the cyclogenesis mechanism itself and that are not included in the pure Hoskins' model. The orography constitutes an important active factor, in the sense that it changes quantitatively and qualitatively the development process, usually favouring or focusing the cyclogenesis (Speranza et al., 1985).

Latent heat release is usually a mechanism to sustain and intensify most of the cyclogenesis processes. The Mediterranean is no exception. The effect seems to be quite important in the Eastern Mediterranean, when a Sharav cyclone arrives there from the desert and intensifies over the sea (Alpert and Ziv, 1989). Some cases in the western Mediterranean have also the same evolution (Homar et al., 2000). Nevertheless, it is only a secondary effect in the case of the most important orographic cyclogeneses, both Alpine (Buzzi and Tibaldi, 1978, Dell'Osso and Radinovic, 1984, Speranza et al., 1985, Tibaldi et al., 1990, Stein and Alpert, 1993, Alpert et al., 1995, Buzzi, 1997) or non-Alpine (Garcia-Moya et al., 1989). There also is a special class of Mediterranean cyclones in which the main source of energy is the great amount of latent heat released in large convective cloud clusters, as in tropical cyclones or polar lows (Rasmussen and Zick, 1987). The small spatial scale of the most intense members of this class can also be provided by baroclinic instability taking place in the shallow almost saturated layer caused by direct input of vapour from the sea into the lower troposphere (Fantini and Buzzi, 1994). Enhanced baroclinic instability in saturated air (Fantini, 1995), closely influenced by latent heat release, even without vertical convection, can be another source of the Mediterranean cyclogenetic capability.

Cyclones versus high impact weather

On the base of existing studies, the following types of situation in which there is an active relationship between cyclones and high impact weather, can be identified: (a) Shallow (usually orographic) depressions, contributing to sustenance of moist inflow for localised and persistent deep convection (and heavy rain), in unstable environment. (b) Deep extensive baroclinic cyclones (usually associated with a combination of factors, including the presence of upper level PV ‘anomalies’, release of latent heat and low level effects of orography and surface heat exchanges), contributing to extensive strong winds and possible heavy rain. (c) Quasi-tropical small cyclones (mainly sustained by surface heat fluxes and by latent heat release), producing local strong winds and heavy rain. Mixed or intermediate types are also possible.

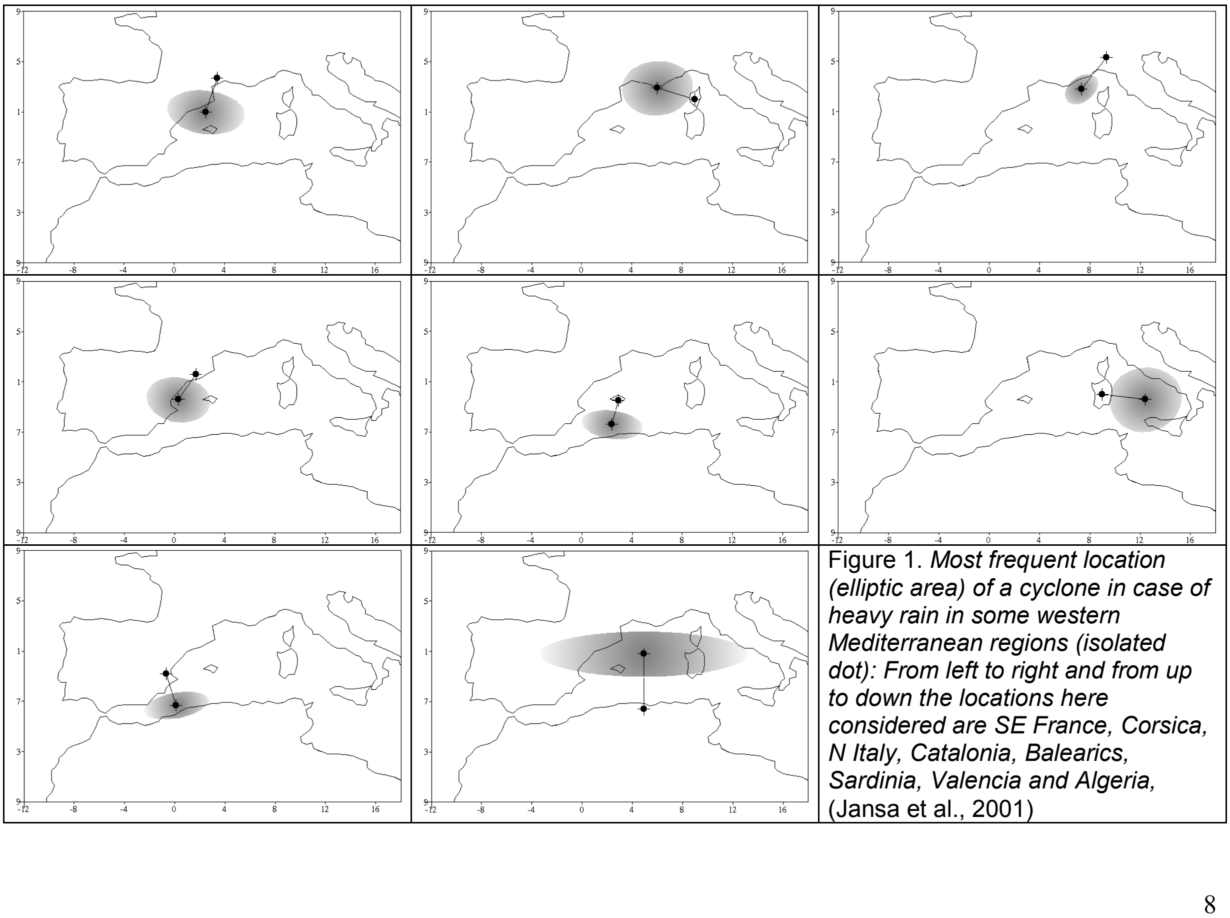


Figure 1. *Most frequent location (elliptic area) of a cyclone in case of heavy rain in some western Mediterranean regions (isolated dot): From left to right and from up to down the locations here considered are SE France, Corsica, N Italy, Catalonia, Balearics, Sardinia, Valencia and Algeria,* (Jansa et al., 2001)

Recent work (Jansa et al., 2001, see Fig. 1) has established that in most of the cases (around 90%) of heavy rain in the Western Mediterranean there is a cyclone in the vicinity. In most of these cases (around 80% of the total events of heavy rain), the location of the cyclonic centre is such that a role of the cyclone in the heavy rain generation and/or its location can easily be inferred. Concretely, the location of the heavy rain seems to be closely related with the location of the depression, specifically in the place towards where the cyclonic circulation impinges warm and wet Mediterranean air. The total number of heavy rain events here considered is more than 900 (in 5 years, 1992-96). A heavy rain event is defined here as a day with more than 60 mm/day (lowered to 30 mm/day in Algeria) of precipitation in any point of a "territorial unit" (province, department, region or island). Note that several territorial units can be affected by heavy rain in the same date: the number of events counted in that date is the number of territorial units affected, not one. Cyclones are defined here in a quite general way, including quite weak and shallow depressions, not only intense and deep systems. In fact, the average vorticity in a central area of the cyclone of 400 km of radius is 0.8×10^{-4} s^{-1}, as a mean, for all cases of simultaneity.

2.1.2 Weaknesses of the present knowledge

As described in 2.1.1, a connection between cyclones and high impact weather in the Mediterranean seems to be implicit in most of the literature on both topics, but not in a coherent, comprehensive and systematic way. The work by Jansa *et al.* (2001) is an attempt in this direction, but it is not enough general, nor complete. The geographical area covered is only a part of the Western Mediterranean. The types of cyclones that are associated with heavy rain are not identified. Only the heavy rain events are considered in that work. In other words, a dynamically oriented climatology of the cyclones that produce high impact weather events in the Mediterranean is not known enough.

In most of the cases of high impact phenomena the prediction of the weather conditions (rain, wind) is not enough accurate, even wrong. Accepting the hypothesis that in most of the cases of high impact weather the influence of some kind of cyclone exists, the inaccuracy on the forecasting of the cyclone formation and evolution would imply inaccuracy in the forecasting of the high impact weather itself. But to which extent is the inaccuracy on the forecasting of the cyclones responsible for the wrong prediction of high impact weather is another weakness in our knowledge.

The limited skill of the NWP models in anticipating the accurate formation and evolution of the Mediterranean cyclones and the associated phenomena can be due to (a) inaccuracy of the initial conditions; (b) inappropriate representation of some physical processes or erroneous interactions between them; (c) intrinsic limitations in the predictability of atmospheric flow. The details of these aspects and their relative weight in the total inaccuracy of the predictions are not known.

Most of the past literature (see above and references) has been devoted to identify relevant factors of the cyclone and high impact weather generation and evolution. But a co-ordinated and more systematic effort is necessary in this direction in order to acquire a more coherent knowledge on this aspect. This knowledge is prerequisite for the assessment of the influence of the representation of the physical processes in NWP models on the accuracy of the predictions.

The influence of the initial conditions on the accuracy of the predictions is a badly known and therefore, a very important question for the Mediterranean phenomena concerned by MEDEX. A priori, the small scale of the Mediterranean systems and the scarce density of observations in some Mediterranean and surrounding areas give relevance to this aspect.

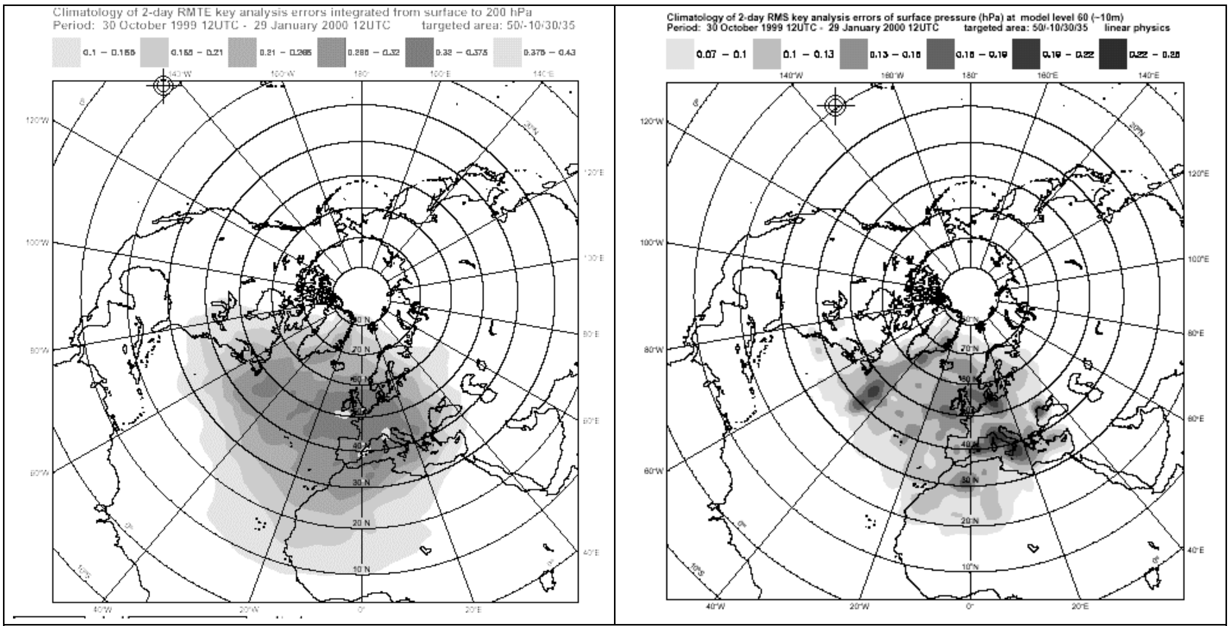


Figure 2. *EUCOS study on the climatology of sensitive areas for Southern Europe (30N-50N/10W-35E), winter, 2-day ECMWF forecasts. Left: Root Mean Total Energy (RMTE) key analysis errors integrated from surface to 200 hPa. Right: Root Mean Square (RMS) key analysis errors of surface pressure. (From* Marseille & Bouttier, 2000)

In this context, the identification of sensitive areas where better defined initial conditions would most likely lead to improved forecasts becomes an important point in which our knowledge has to improve. Although there is an EUCOS' general climatological study on sensitivity referred to Southern Europe (Marseille & Bouttier, 2000), nothing is known regarding the identification of sensitive areas for the cases of cyclones that produce high impact weather in the Mediterranean.

2.2 Working plan and methodology

From the previous paragraphs some specific objectives for MEDEX can be identified. A part of them can be considered as specific objectives for the phase 1 of MEDEX and lead to the definition of some priority tasks.

2.2.1 Specific objectives

Directed towards the general objective of MEDEX, *the improvement of knowledge and forecasting of the cyclones that produce high impact weather in the Mediterranean area*, several specific objectives can be identified for the phase 1 of the project:

(a) To implement an initial approach to a dynamically oriented climatology of the cyclones that produce high impact weather in the Mediterranean. Working in a systematic way, we want to know the type of cyclonic structures that appears related to high impact weather events of different kind, in different areas within the Mediterranean area, as well as the percentage of high impact weather events that may or may not be related to cyclones. This is a necessary step to evaluate the potential impact of the improvement of the forecasting of cyclones on the prediction of the high impact weather itself. It is also necessary to know how representative is the work done on the base of a selection of particular cases.
(b) To determine and rank the multiple geographical and meteorological factors that are acting in the generation and evolution of the different types of cyclones that produce high impact weather in the Mediterranean. The skill of NWP models to predict the Mediterranean cyclones has to be connected with the determined factors.

(c) The identification of sensitive areas where better initial conditions may likely lead to improved forecasts. In general, the inaccuracy in the initial conditions can be a source of error of the numerical prediction. It is necessary to know the areas, levels and magnitudes for which the analysis error produces most significant errors in the prediction of the cyclones. Closely connected with the former objective is an assessment of the impact of better defined initial conditions in sensitive areas.

2.2.2 Methodology

The way to achieve the aforementioned specific objectives is described in the following paragraphs.

(a) Dynamic climatology of cyclones that produce high impact weather events. It will be based on systematic information about cyclones and high impact weather events, followed by cross-referencing both types of data (cyclones and events; see below). Climatological representative ness of the results should demand the use of a long period of time (20 or 30 years), but there are practical reasons to perform first an approach using a shorter one (initially 1995-2000, further updated to the following 2-3 years). Long series should be used later to improve the representative ness of the initial results. The work will consist of the following actions:
   (1) Objective and automated detection and description of any kind of surface cyclones, based on operational objective analyses of resolution enough, to form a database of Mediterranean cyclones (1995-2000, later 1995-2003). The methodology for detection, tracking and description of surface features of the cyclones is already developed and tested in the Meteorological Centre at Palma de Mallorca of the Spanish Instituto Nacional de Meteorologia (INM/CMTIBAL), using the HIRLAM/INM operational model and covering the Western Mediterranean (Picornell et al., 2001). The methodology for describing the 3D structure of the cyclones is almost totally developed and could be tested before the end of 2001. It includes vertical extension, tilting, thermal and humidity structure, vertical stability and wind shear, etc. The extension of this work to the Eastern Mediterranean (model to be used, among other details) is still under study. Further studies based on long series of reanalyses, like ERA-40, should be used later to gain representative ness, after a work of inter-comparison of results. In fact, the foreseen resolution of ERA analyses (T163) could not be enough to detect and describe some relevant structures.
   (2) The formation of a list of high impact weather events. Regarding heavy rain and strong wind on land, the information that is available through the GTS is clearly insufficient for a systematic listing of cases of high impact weather. So, non-GTS data have to be provided by the institutions that are participating to the MEDEX project. The unavailability of these kind of data in several geographical areas in old time is one of the reasons to restrict the initial work to recent years. The calendar to be constructed is only a listing of dates in which high impact weather (that is rain or wind exceeding certain thresholds) has been observed somewhere within the inner Mediterranean area, with indication of the areas affected and the corresponding peak values.
   (3) The information contained in the database of cyclones and in the list of high impact weather events has to be cross-referenced, looking for possible connections. The results will be stratified by geographical location, kind of weather phenomenon and type of cyclone. By this way a dynamical climatology of high impact weather, in connection with cyclones, will be obtained.

(b) The studies concerning the factors that determine or influence the genesis and evolution of the cyclones that produce high impact weather will be based on a small list of selected cases. Any of the institutions that are participating in MEDEX will contribute to this work according its preferences and using the means it considers the most convenient (diagnosis tools based on observations or in objective analyses, sensitivity experiments using available models, etc.). Nevertheless, in order to avoid having a simple addition of separate and independent studies, some common aspects will be stressed:
   (1) The selection of cases will be made in agreement among the participants and working on cases, possibly affecting not only a single country will be recommended.
   (2) A database of data for verification of present weather and dynamical structures will be made available. As far as possible one or several reference analyses for each selected case will be included in the database, to make them available for the MEDEX community.

(3) Common tools for measuring the skill of the NWP models in predicting surface cyclone features will be developed. The reference analyses (if available) will be used to determine the forecasting errors on cyclonic structures.
(4) A way for the easy exchange and comparison of results of numerical model simulations and experiments will be established.
(5) The separation factor technique (Stein and Alpert, 1993; Alpert et al., 1995) will be applied in evaluating sensitivity experiments, when looking for the separate and combined effects of several factors.

(c) The identification of sensitive areas where better initial conditions may lead to improved forecasts is an important question in this phase of the MEDEX project. If possible, it is also clearly of interest to attempt to assess the impact of improving initial conditions on some cases. Such studies may be undertaken as part of selected case studies. This part of the project requires access to a sophisticated set of models, possibly also including data assimilation algorithms. The computation of sensitivities requires an adjoint code. In the case of the Mediterranean area, it is expected that diabatic processes will need to be included in the adjoint calculations, and this, in itself, is a current research topic and a challenge. The required computing and development resources are hugged and the work done on this topic depends on setting up proper funding of the project. The MEDEX project favours the case study approach rather than running sensitivities calculations blindly on all kinds of cases. The selection of cases should be the same one as in item (b). There are several ways of influencing the initial conditions once a sensitive zone has been identified. One is to add observations to a given data assimilation system (Bergot et al., 1999 among others), and another way is to modify locally the data assimilation process (Hello and Bouttier, 2001). In the present context of purely numerical experiment, it is important to have cases showing large forecast errors with one model trajectory close enough to reality so as to be used as the "true state" and source of synthetic data. Again, these are very heavy experiments that require dedicated resources that MEDEX should seek to provide The development of this item is completely under condition of successfully finding a funding source for MEDEX.

2.2.3 Priority tasks (according WWRP/SSC-3)

As already said before, WWRP/SSC (Third Session, 2000), recommended some priority tasks for MEDEX:

a. Identify the nature, availability, and usefulness of data presently not available on the GTS, and to start concentrating these data in a MEDEX database.
b. Identify a set of cases where high impact weather was poorly forecast and conduct co-ordinated, in-depth case studies that include considerations of forecast skill and societal impacts associated with both the event and the poor forecasts.
c. Conduct NWP studies to identify sensitive areas where the addition of observations would most likely lead to improved forecasts and their related benefits.
d. Conduct research to identify physical and dynamical hypotheses that might form the basis of developing improved forecast techniques for Mediterranean cyclones.

These tasks were examined with detail in the MEDEX Meeting 2001 (see *Supporting Documentation*), in connection with the general and specific objectives of MEDEX and have oriented the work done before and after this meeting. In the following, some significant details about priority tasks are exposed.

(a) Non-GTS data and MEDEX database

The first point is to identify the data needs. Different kinds of data are necessary for the different activities foreseen in the present MEDEX proposal. The corresponding data requirements are summarised in the table 1.

The kinds of data required to elaborate a dynamical climatology as described above are obvious.

Regarding the studies on factors, two aspects have to be considered. On one hand, some non-GTS data (rainfall, wind and also radar, lightening, etc.) are needed for validating the quality of the model runs, at least in a qualitative way. On the other hand, some participant institutions would like to re-make the initial analyses for experiments concerning factors, with as much additional upper air and surface data as possible. Additional data are also convenient to assess the impact of some observations or kinds of observation on the forecasting skill.

Table 1. *Data requirements for MEDEX – Phase 1*

MEDEX objective	*Type of data*	*Area*	*Details*
Dynamical climatology	**Rainfall and wind**	**Inner Mediterranean**	All peak values that overpass defined thresholds, since 1995.
	Analysed fields	**Inner Mediterranean** (at least)	4 daily at standard levels, al least since 1995.
Sensitivity to factors (validation)	**Rainfall and wind**	**Inner Mediterranean**	All data in the affected area for selected events only.
	Radar and other non-conventional	**Inner Mediterranean**	All data in the affected area for selected events only.
Impact of observations	**Upper air data**	**Outer Mediterranean** (Eastern Atlantic incl.)	All data in sensitive areas for selected events only.
	Surface data	**Outer Mediterranean** (mainly inner area)	All data in sensitive areas for selected events only.

The *inner area*, as it is mentioned in table 1, is the area in which we are considering the high impact weather events. It can be defined as the area of direct influence of the Mediterranean Sea disturbances or the area around the Mediterranean Sea that has Mediterranean climate, among other possible definitions (Fig. 3). The wider one is our initial choice.

The *outer area* would have to be as spread as necessary to cover the most sensitive areas. A first approach can be based on the EUCOS study on sensitivity (for Southern Europe) (Marseille and Bouttier, 2000), although a revision will be needed when the MEDEX study on sensitivity is achieved (Fig. 3).

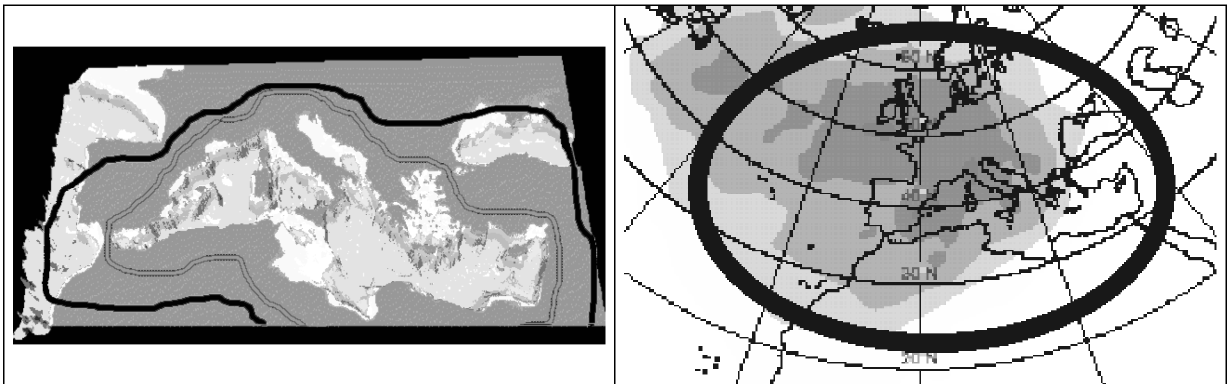


Figure. 3: *Preliminary definitions of the inner (left) and outer (right) Mediterranean areas for MEDEX.*

The second point about data is the existence and availability of the kinds of aforementioned data. To investigate on that, a questionnaire was prepared and submitted to all the participating institutions. 12 institutions (among 31) have answered the questionnaire. Note that some of the participant institutions are not concerned, because they do not acquire or store data. Table 2 summarises the results (regarding non-GTS data), that in any case have to be considered as preliminary and not complete.

An important part of the preliminary information about the existence and availability of useful non-GTS data remains unknown (there is no information about extensive areas where there are participant institutions).

Table 2.*Preliminary information about availability of ordinary non-GTS data*

Institution	*Rain. num.*	*Wind num.*	*Radar num.*	*Lightening*	*Synop num.*	*Pilot num.*	*Temp num.*
IM, Portugal	850	80	2	Yes	60		
INM, Spain	1381	76	7	Yes	191		
UB, Spain	175	50					
ONM, Algeria	29	29			40	7	1
SAR, Sardinia	49	27	1				
INM, Tunisia	96	34	1				
ARPA-FVG, Italy	39	25	1		25		
ARPA-ER, Italy	80	20	1		10		
MHS, Croatia	487		2		2		
NIMH, Bulgaria	387	95	1		8		
Cyprus MS	163	10	1	Yes			
IMS, Israel	400	120	1		120		

The results here shown mean that there will be a sufficiency of data for the dynamical climatology performance and for verification of model simulations. Regarding data for eventual reanalysis and possible studies of impact some observations, there are additional surface data over land areas, but very few or no additional, non-GTS. Also surface data at sea are rare.

There are several ways to overlap this lacks. On one hand, some of the selected events can be in coincidence with international or national field experiments, and additional data could be obtained from the corresponding databases. For instance, in the preliminary selection of events (see later), 3 of them are coincident with MAP IOPs (possible coincidences with FASTEX have not been explored yet). For future new cases, after 2001, some observations obtained in the field phases of THORPEX might be of great interest to MEDEX in case of coincident dates. THORPEX and MEDEX being RDP of the WWRP, it is highly desirable to establish a way of co-ordination.

On the other hand, some non-conventional ways of producing conventional-like surface and upper air observations do exist and could be used to obtain additional data. Figs. 4 and 5 show examples of surface winds obtained by scatterometer, from satellite, and upper air winds and soundings (AMDAR and ACAR) from aircraft.

Another possible way of obtaining upper air data should be the use of vertical profiles of wind derived from Doppler radar observation (VAD). The network of radar stations in the Mediterranean is quite important (see table 2) and most of them are Doppler radar. Nevertheless, the use these kind of data in MEDEX is not possible now, because the specific inversion algorithms or matrixes of errors for VAD-type data assimilation are not available. MEDEX cannot plan developments on this question, but if the appropriate instruments become available by any other way, VAD-type data would be used, because they are seen as very useful for our project.

Finally, although nothing is going to be developed in the MEDEX context, some new observation systems (like humidity content measurement through GPS data) and some remote sensing (radar or satellite) derived data have also to be considered as potential additional data if instruments for their assimilation become available.

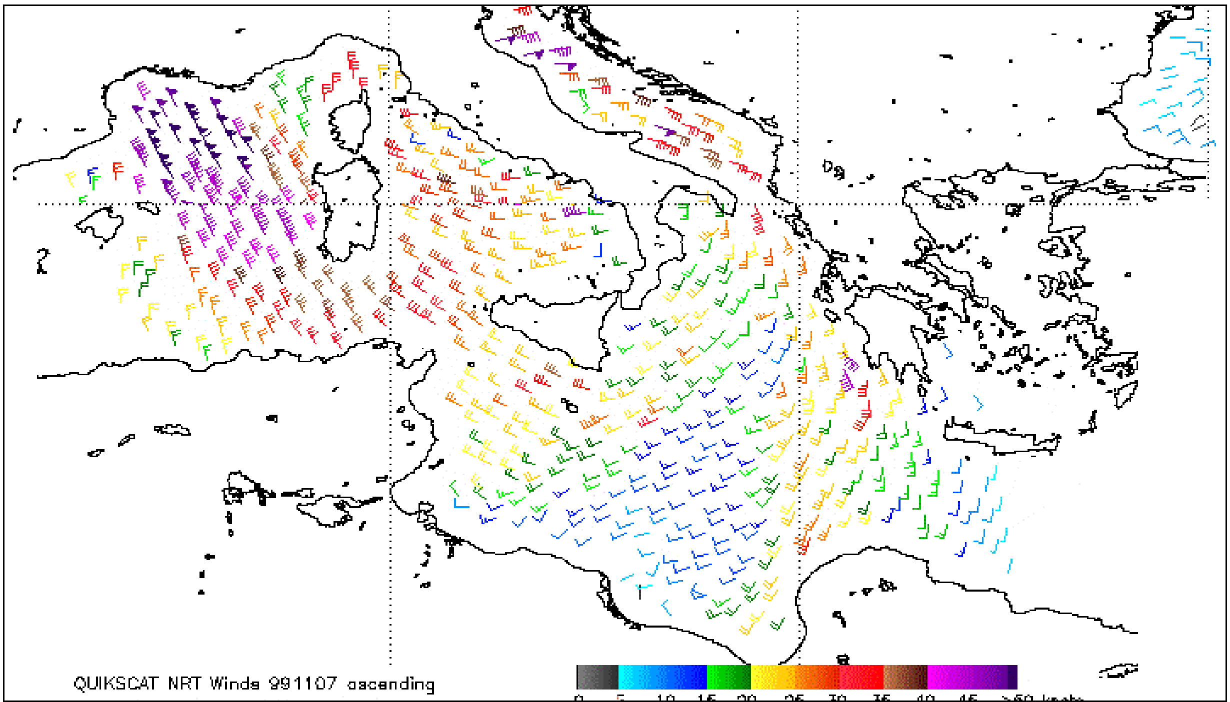
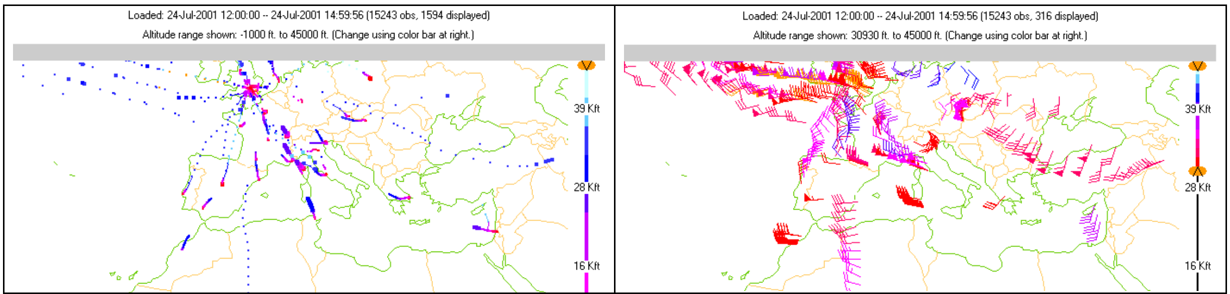


Figure 4: *Winds obtained from scatterometer, from satellite, QuikSCAT, on 07.11.1999. Elaborated by NOAA, NESDIS (Available though Internet: http://manati.wwb.noaa.gov/quikscat/)*



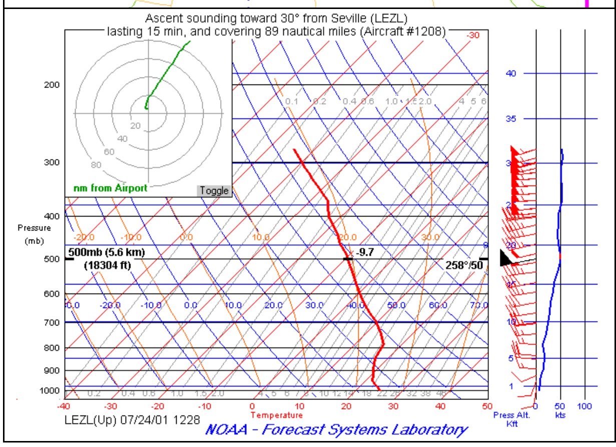


Figure 5: *3 hour sample of aircraft data (ACAR) in the Mediterranean zone, on 24.07.2001. Up left: tracks of flight, landing and taking-off. Up right: winds in the upper section. Down left: ascent sounding from Seville (Spain). Elaborated by NOAA – Forecast Systems Laboratory. (Access restricted to authorised institutions).*

The third point refers to the data storage. We have identified several kinds of useful data, observational and also model outputs, to be stored in one or several databases.

A main database on line for the first phase of MEDEX will contain the kinds of data indicated in the table 1, as provided by the participant institutions, except the series of analysed fields (that will be stored off line). As far as possible, it will also contain the specific database of cyclones (see *dynamical climatology*, 2.2.2, (a), (1)) and the complete calendar of high impact weather events (2.2.2, (a), (2)). Also, if possible, data coming from outer field experiments that are in coincidence with MEDEX selected cases, as well as non-conventional data of the types shown in fig. 4 and fig. 5 (or other). Some analyses for selected cases will also be put on line, if possible.

INM-Spain is now studying the feasibility of undertaking the establishment and maintenance of such a main database.

Model outputs from operational and experimental runs and occasional experimental re-analyses performed by the participant institutions will be stored by these institutions. A system of links will maintain all the results available on line for everybody belonging to the MEDEX community.

(b) Set of selected cases

An important part of the MEDEX activities foreseen for phase 1 are based on the selection of a common set of cases. The WWRP/SSC recommendation specifies "a set of cases where high impact weather was poorly forecast and conduct co-ordinated, in-depth case studies that include considerations of forecast skill and societal impacts associated with both the event and the poor forecasts".

The period 1995-2000 has been chosen for the selection of cases, short enough for having some guarantees of availability of useful data and long enough for catching a variety of situations. The process of selection of cases has been based on the distribution of two questionnaires among the participant institutions, the first by the end of 2000, the other on spring 2001. The questionnaires have been answered by 17 institutions, giving information about eighty events of high impact weather.

A pre-selection has been made (see table 3), using the following criteria:
(1) *Events affecting two or more contiguous countries.*
(2) *Severe impact weather events (affecting one country only).*
(3) *Additional events to ensure some degree of geographical 'balance' among countries and geographical areas left out by the previous choices.*

Although information about forecasting skill was included in the questionnaires, most of the institutions do not have a systematic and detailed information on this question. Nevertheless, some hints on this have been included in table 3.

Moreover, having in mind the availability of additional data, some preference has been given to more recent cases versus older cases.

The total number of pre-selected cases is 27 (within 1995-2000). The number per country (in spite of criterion 3) goes from 10 for Spain and 8 for Italy down to 2 for Croatia, Bulgaria, Turkey, and 1 for Cyprus. Fig. 4 corresponds to one of the pre-selected events (6-9 Nov. 1999).

Table 3. *Draft selection of events, under revision (July 2001)*

* strong impact weather cases (affecting single countries)
** cases affecting more than one country
*** cases to ensure geographical balance

Date	Country affected	Severe weather: SW = strong wind HP = heavy precipitation SN = heavy snow	Societal impacts	Alerts Warnings	Models Forecast tools Forecast quality
06-09 Oct. 1996 **	Italy (Sardinia; Emilia-Romagna) , Spain (Balears)	HP (Sardinia, Em. Rom.) SW Hurricane-like cyclone (Tirrenian). 144 mm/24h (Sardinia), 200 mm/48h.	Widespread floods, affect. 40000 people (Em. Rom.), minor floods (Sardinia)	No warning (Em. Rom.)	ECMWF, LAMBO (precip. in wrong area). BOLAM simulations sensitive to SST
14 Oct. 1996 **	Spain, Italy	HP > 100 mm/24 h (Catal.), Cyclone SE of Iber. Pen. Also Italy	Floods and damages in infrastructures. In IT (Calabria): floods, 6	No end user fc. (IT)	

		(Calabria), 112 mm/6h (Crotone)	casualties, buildings destroyed, interruption of terr. traffic, huge damages to agriculture, tourist and industrial activities		
10-12 Jan. 1997 **	Tunisia (NW), Greece (Peloponnisos)	HP 120 mm/24h (TU), 300 mm/24h (GR). Depression formed Sardinia, moved E	Severe flood (GR, NE Peloponnisus)	Generic insufficient alert (GR). Generic alert (TU)	GR: ECMWF No operat. fc. at NOA. Prelim. BOLAM success. tests TU: heavy rain fc.
21-22 Feb. 1997 ***	Israel (N, central)	HP (200 mm/48h, Galilee, Samaria)	Floods, 11 casualties, damages to agriculture	Good warnings	ECMWF, UK, MM4 Adequate but not for precip. amount
20-22 Apr. 1997 **	Algeria, Tunisia (N)	SW, HP 62 mm/24h (TU), 32 m/s (TU), deep cyclone N of Algeria, moved NE		No alert (TU)	
04-06 Nov. 1997 **	Portugal (S Alentejo), Spain, France (Med. coast, Cevennes, French Alps)	HP, SW (FR) 287 mm/24 h(?) (S Alps), 500 mm/24 h (?) (Cevennes). 150 mm/24h (SP). 80 mm/6h (PO). Wind > 35 m/s wind in FR (38 m/s in Port-Vendres).	Floods (FR, SP,PO), casualties (FR, SP), material losses. 4 casualties (PO).		
16-18 Mar. 1998 ***	Israel	SW, SN Very deep cyclone, snowfall, sand storm	Damage to agriculture, air traffic delays, road closure in Jerusalem for snow	Adequate except for snowfall	ECMWF, UK, MM5 (good for cyclone)
24-26 Mar. 1998 **	Tunisia (NE), Greece	SW, HP 30 m/s (TU), 30 m/s (Athens and west GR) 140 mm/24 h (GR, Athens). Depression over Corsica, moved E	Flood (GR) Disruption of Athens airport, electric power poles destruction	Insufficient generic alert (GR). No generic alert (TU)	GR: ECMWF. No operational fc. at NOA. TU : moderate wind fc.
21-27(?) May 1998 ***	Turkey	HP	Extensive severe flooding (151 rivers), W Black Sea area. > 17 casualties. 3000 houses ruined or evacuated. Traffic and infrastructure large damages. Agricultural and livestock huge damages. Landslides. 250 M US$ loss.		
15-18 Mar. 1999 **	Algeria, Tunisia	SW, HP 32 m/s (TU). Depression over TU		No generic alert (TU)	Strong wind fc. (TU)
23 June 1999 ***	Bulgaria	SW 24 m/s at Black sea coast, 35-40 m/s at mountain tops. Rain: 25-45 mm/24 h. Hail. Cyclone initiated over Central Med., moved E to Black	Interruption of Black sea drill.		

		Sea.			
10-11 July 1999 ***	Bulgaria	HP, SW 68 mm/6h (Montana), wind storm. Weak surface cyclone, initiated over Central Mediterranean.	Flooding and disastrous situation. 0.5 M US$ loss		ALADIN, good for precip. over 24 h, but underestimating precip. intensity
20-22 Sep. 1999 **	Italy, Portugal (NW)	HP > 160 mm/24h (PO, IT)	MAP IOP 2		
2-5 Oct. 1999 ***	Croatia	HP locally > 200 mm/12h, lightning activity	Local problems with electric power system, serious traffic interruptions, MAP IOP 5	Generic alert 1 day in advance	ALADIN/LACE, correctly fc precip. but less frontogenesis and precip
06-09 Nov. 1999 **	Greece (E contin.), Italy, Croatia, Spain (West Med., Bal. Isl.)	SW, HP severe Bora (45 m/s), strong winds West Med., strong lee cyclone, heavy precip. (GR), 70-90 mm/24h IT and strong winds (Em. Romagna). Strong lee cyclone.	Floods (GR, IT), problems with electric power system (CR), serious traffic interruptions (CR), sig. wave height ~7.5 m West. Med., risk for navigation, railway interr. (IT). Storm surge N. Adriatic (IT). MAP IOP 15	Generic alert only 1 day in advance (CR). Good sort-range and medium range warnings (West Med.), but wind and waves underestimated	BOLAM (AVN nested), good for precip. but time shift 8 h (GR). Better res. using ECMWF input for BOLAM. ALADIN/LACE (CR): problems with wind and pressure gradient intensity. Very good ECMWF med. range fc. (for West Med.)
11-14 Nov. 1999 **	Italy (Sardinia), Spain, France	HP, SW (FR) 197 mm/24h (SP), 600 mm/36 h (FR, Lezignan). 100mm/1h and 376 mm/48 h (Sardinia). Continue havy precip. And windstorm in S FR.	Serious floods, casualties (Sardinia). Severe flood, 30 casualties (FR), 1000 M Euros loss (FR)	Warning only 12 h before peak (IT)	ARPEGE, ALADIN (good in real time) Meso-NH simulations performed. ECMWF undestim. precip., BOLAM better (IT)
23-27 May 2000 **	Algeria, Tunisia (central)	HP, SW 131 mm/24h (AL, Tiaret), 105 mm/6h (TU, Sfax), 16 m/s max wind (AL). Moderate cyclone moving E north of the Saharan Atlas and Tunisia	Floods, cattle damages (>700 sheeps killed), several regions stricken AL). Interruption of traffic in Sfax town (TU)	No generic alert (TU)	Not predicted (TU)
10 Jun. 2000 *	Spain (Catalunya)	HP, SW > 200 mm/12 h, 240 mm/6h at Montserrat (Catalunya) cyclone E of Iberian Pen.	240 mm/6h, flood, 4 casualties in Catal., landslides, buildings and roads affected, very heavy material losses	Good short range warning, but unsatisfact. very short range warning	HIRLAM, acceptable fc. of precip. and wind at large scale, but deficient fine scale model. fc.
8-10 Sept. 2000 *	Italy (Calabria)	HR 360 mm/24 h,	Flood, 13 casualties, destroyed buildings, interruption of roads, large damages to agriculture, tourist and industrial activities	No end user fc.	
19-20 Sept. 2000 *	France (Montpellier, Cevennes, Marseille)	SW, HP Tornado (Montpellier) 197 mm/24h, 159 mm/3h (Marseille)	5 casualties, material losses, serious traffic interruption		
14-16 Oct. 2000	Italy	HP	Extensive floods		

*			>600 mm/48 Cyclone moving N over the west Med.	(Piemonte, Valle d'Aosta), many casualties, large damages to infrastructures		
21-26 Oct. *	2000	Spain (Catal., SE of Aragon, N Valencian comm.)	HP 600 mm/48h > 300 mm/24 h (S. Catalunya) Upper level cutoff cyclone, surface cyclone Se of Iberian Peninsula	Serious flash floods, 8 casualties in Catal. and other parts of Spain, landslides. Buildings and roads affected. Very important damages and losses.	Good short and very short range warnings.	HIRLAM Good large scale fc., under prediction of precip.
05-06 Nov. **	2000	Italy, France	SW (IT, FR), HP (IT, FR) 150 mm/24h (Monte Carlo). Very strong S winds near coasts	Floods. 7.5 m swell (FR coast), material losses		
27-29 Nov. ***	2000	Cyprus	SW, HP >150 mm Severe thunderstorms, hail	Local floods, damages		
21-22 Dec. **	2000	Portugal, Spain (Catalunya)	SW, HP > 90 mm (PO)	Floods. Trees fallen and traffic problems (PO)		
25-31 Dec. **	2000	Tunisia, Spain (Catalunya), Italy (Sardinia)	SW 41 m/s (Tabarka, TU), 39 m/s (Bizerte, TU), 50 m/s max speed (Kasserine, TU). Very strong winds > 35 m/s (SP), 35 m/s and 7 days of rain (IT), 3 cyclones, one deep cyclone	In Sardinia: local floods, intense wind and rough sea problems. Avalanches in Pyrenees (8 casualties). Buildings damaged (TU).	In Sardinia: good wind fc, fair 1 day fc of precip, but bad medium range fc, cyclone fc partly good. In Spain: good short range warning. In Tunisia: generic alert 72 h in advance.	BOLAM (better), ECMWF (IT). Strong winds predicted well in advance (TU)
9 May ***	2001	Turkey (SE)	HP 432 mm/24 h	Floods, casualties, 15 houses destroyed, 750 buildings damaged	Heavy rain warning issued	

The set of selected cases is the base of work for case studies and for identification of sensitive areas (according the *Working plan and methodology*, 2.2.2, (b) and (c)). As said in 2.2.2, (b), the case studies will include considerations on forecast skill.

The process of selection of cases is near to be closed regarding the period 1995-2000. A continuous updating for the following years will be kept alive.

(c) Identification of the most sensitive areas

We are not interested on climatology of sensitive areas elaborated from all the errors of all the predictions. We are interested in the identification of the areas where the initial conditions produce larger errors. Depending on the funding plan, as explained in 222c, sensitivities will then be computed for a small subset of MEDEX selected cases.

The most sensitive areas, levels and magnitudes are not the same for the different kind of phenomena, at different places and for different prediction ranges. For example, figure 6 might give hypothesis about the most sensitive areas and levels for the very short- and short-range predictions of heavy rain in Valencia (eastern Spain). It is supposed that heavy rain in this place is connected with the presence of a low-level cyclone to the SE (see 2.1.1 and fig. 1). This cyclone, at its time, can form in connection with an upper air trough towards the SW. In any case, this is only a hypothesis that has to be verified or corrected. If these hypotheses result to be more or less correct, in case of heavy rain forecasting in Valencia the most sensitive areas would be shifted with respect to the climatology (fig. 6).

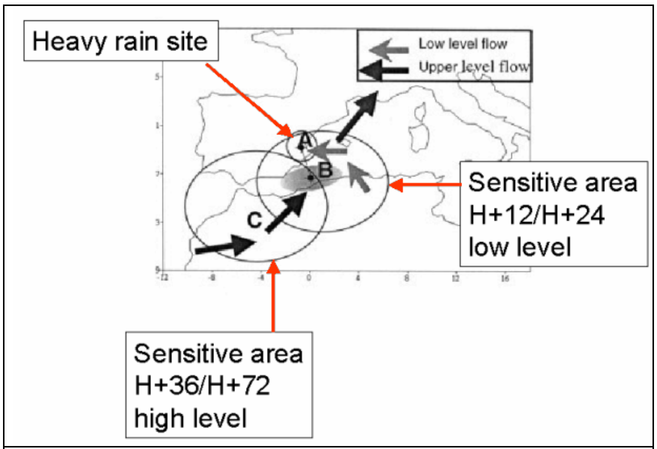


Figure 6. *Hypothesis about sensitivity (see text)*

There are groups in MEDEX that are in a position to perform this task, Météo-France in particular. These institutions may provide the computing resources needed and some know-how. However, the actual work required a proper funding of the MEDEX project.

(c) Physical and dynamical hypothesis to improve the forecast

The case studies will be oriented to identify and rank the physical and dynamical processes that are relevant for the kind of events concerned with MEDEX.

What is known until now is that the processes that lead to the generation and evolution of cyclones that produce high impact weather in the Mediterranean are a combination of passive and active factors. In principle, the weight of the different factors playing a role (orography, upper level potential vorticity, thermal advection and baroclinicity, heat release and heat fluxes, etc.) may be very different in different kinds of evolution. Diagnostic studies and numerical experiments on sensitivity to factors about the selected cases will be performed to review and construct scientific hypotheses for the different kinds of evolution. A method for weighting the factors and evaluating the synergetic effects is the factor separation technique (Stein & Alpert, 1993; Alpert et al., 1995).

It is commonly accepted that one of the crucial elements for a correct prediction of extreme phenomena in the region is the quality of the initial analyses. In consequence, the effect of the initial conditions, as well as the separate impact of the different kinds of observations, have to be parallel to the study of the impact of the physical factors.

Initially, every participating institution will use the analyses (as well as the NWP models) usually available to each one. But making available a set of common analyses, for diagnosis and validation and as reference initial conditions for the experimental model runs is highly desirable.

2.2.4 Time schedule and performance indicators

Table 4 summarises the time schedule for some of the best-defined MEDEX activities. Some of the activities listed in table 1 (in bold) have to lead to specific deliverable products and the end of the corresponding scheduled period of execution. This provides main indicators of the execution of the project. Yearly, brief reports on the state of every one of these and the other planned activities can also constitute complementary performance indicators. For example, state and content of the database, listing of studies on factors performed by the participant institutions, etc.

Table 4. *Time schedule.*

2001-1st S	2001-2nd S	2002-1st S	2002-2nd S	2003-1st S	2003-2nd S	2004-1st S	2004-2nd S
Selection of cases 1995-2000							
	Updating selection of cases (2001-2003)						
		Establishment of the MEDEX database					
		Collection of ordinary and additional data in the database					
		Western Mediterranean cyclone database 1995-2002		**Eastern Mediterranean cyclone database 1995-2002**			
			Calendar of high impact weather events 1995-2002		**Dynamic climatology of cyclones vs. high impact weather 1995-2002**		
	Diagnosis studies and sensitive experiments concerning factors (selected cases)						
			Identification of sensitive areas for selected cases				
MEDEX Meeting 2001		*MEDEX Meeting 2002*		*MEDEX Meeting 2003*		*MEDEX Meeting 2004*	**Final report for MEDEX phase 1**
			Planning a possible second phase for MEDEX				

2.3 Societal benefits and impact assessment

In principle, any forecasting accuracy improvement for the cyclones that produce high impact weather has to produce an improvement of the forecasting of the high impact phenomena themselves. This, in turn, induces increased confidence within the institutions that are responsible for civil defence and marine safety and of the population to the forecasts and warnings concerning high impact weather. The ultimate goal, then, is enhanced protection of human lives and property and a reduction of the negative societal impacts.

Apart from the improvement in the forecasting, the better knowledge of the forecasting skills, the degree of confidence and predictability of the weather phenomena concerned by the project themselves produce benefits for the end users.

2.3.1 Involvement of end users

Two level of end users can be distinguished: (a) the meteorological services of the Mediterranean area (national or regional), which are responsible for the issue of meteorological warnings concerning extreme weather events, and (b) the institutions that are responsible for the civil and marine safety, hydrological services, etc. Any improvement in the objective (models) and subjective (predictors) forecasting of high impact weather events will produce better warnings and benefit the meteorological services. Improved meteorological warnings, at its time, will benefit the hydrological warnings and the efficiency of advises and prevention actions and deployments.

Figure 7. *A segment of a PC screen, showing the diffusion through Internet of the meteorological warnings issued by the Spanish Instituto Nacional de Meteorologia. The warning system includes observed and short-range forecasted (12-48 h) extreme phenomena.*

Regarding the first type of end users, most of the national weather services and some regional meteorological services in Italy (Sardinia, Emilia-Romagna, Friuli-Venezia-Giulia, Trentino) have signed their adhesion to MEDEX and are acting as fully participant institutions in the project. The national weather services that are involved in MEDEX are Portugal, Spain, France, Switzerland, Italy, Croatia, Bulgaria, Turkey, Cyprus, Israel, Egypt, Tunisia, Algeria and Morocco. Some of them are also hydrological services. On the other hand, other participant institutions in the project – US Navy, UK Met. Office – have operational meteorological interests in the Mediterranean.

Regarding the second type of end users (responsible institutions for safety, hydrological services), there is an open invitation to participate in MEDEX, at least as advisory institutions. Up to now, the Spanish authorities on Civil Defence and Marine Safety has signed an adhesion to MEDEX. CIMA (Centro di Ricerca in Monitoraggio Ambientale), Genova, Italy, is not only a research institution, but it has responsibilities in societal impact questions. In any case, more non-meteorological end users have to be involved in MEDEX. Efforts will be made in this direction by the present participant institutions.

2.3.2 How the research is expected to impact on society

There are several levels of response to this question. The meteorological problems concerned by MEDEX are certainly the cause of serious societal negative impacts. MEDEX has to produce direct improvement of the knowledge on several aspects of these meteorological problems. The improved knowledge has to be transferred to the modellers and to the forecasters, in order to obtain better modelling and better final forecasts and warnings. In parallel, the results of MEDEX has also to be transferred to the organisms that are responsible for the implementation and exploitation of the meteorological observing systems. Note that in the European region there is a specific programme, EUCOS – EUMETNET Composite Observing System -, promoted by the Network of European Meteorological Services (EUMETNET), which objective is the co-ordination of an improvement of the observing systems. MEDEX plans to maintain a close contact with EUCOS. Any derived optimisation of the observing systems, thinking on the phenomena concerned by MEDEX, will benefit the quality of the predictions. Finally, the forecasting skills, the better knowledge on forecasting skills, the improvement of these skills have to be transmitted to the decision makers, who could take more efficient actions to reduce the impacts of the extreme weather phenomena.

Each of the aforementioned steps is quite general, not exclusive of MEDEX and not easy to be taken. The connection between research and operational teams, for an efficient transmission of useful findings from the first to the later is always a difficult question. But this is – apparently, at least – a strong point for MEDEX. As said before, many of the participating institutions in MEDEX are meteorological services, in which both research and operational branches will co-operate in MEDEX. Pure research institutions, besides having a tradition in exchanging results with operational units, in MEDEX they will be always in contact with meteorological services. For example, the University of Tel Aviv has agreed a joint participation into MEDEX with the Israel Meteorological Service. Finally, the connection between meteorological and non-meteorological end users in the frame of MEDEX, already existing, but not fully developed, has to be enlarged and become closer.

2.3.3 How societal impacts are incorporated into MEDEX?

The institutions responsible for civil defence and marine safety need to have quantitative information about (a) the impacts that are of concern to MEDEX (susceptible reduction as a result of the program), (b) the possible reduction of those impacts. To do so, the scientific team of MEDEX will collaborate with the institutions that are responsible for civil defence and marine safety, insurance companies, hydrologists, etc., as far as possible.

In parallel to the elaboration of a calendar of cases, as described before, also the impact associated with each of them have to be indicated in more detail. The experience with the process of selection of cases has demonstrated that this is not easy, because this kind of information is not systematically available to the meteorological services and research institutions, but an effort will be requested. From there, the sharing of societal impacts between different kinds of situation will be established (as far as possible). This is a necessary step to estimate the potential effect of the project in the impact reduction.

The following step for the estimation of the potential effect of the project in the impact reduction is the measurement of the improvement of the quality of the final forecasting of extreme events. We have distinguished two steps to do that. First, specific tools for measuring the skill of the models in forecasting the (dynamical) cyclonic structures have to be developed. Second, some of the sensitive experiments foreseen in MEDEX have to be oriented to evaluate the influence of the error in forecasting the cyclones into the error in forecasting the extreme weather itself (see Jansa et al., 2000, as an example).

An indirect way to achieve these objectives is the inter-comparison of model outputs, with different models. The measurement of the quality of a possible probabilistic prediction based on the ensemble forecasting with multiple models is a promising challenge that MEDEX could try to consider, taking profit of the co-ordination of work between multiple institutions. Also the added value of the forecaster, when using refined conceptual models has to be evaluated.

Finally, hydrologists, insurance companies and end users like the institutions responsible for civil defence and marine safety will be consulted in order to establish the degree of the impact reduction that could be obtained when using the improved forecasting.

3. Scientific Management

The scientific management of MEDEX includes the following elements: (a) The leading and the advisory groups, (b) the participating institutions, (c) the MEDEX permanent centre.

3.1 Leading and Advisory groups

- A MEDEX Science Steering Committee (MSSC) will lead the project planning and execution. Its present composition is as follows: Arbogast (Meteo-France), Alpert (Tel Aviv University, Israel), Buzzi (ISAO – Bologna - /CNR, Italy), Doyle (Naval Research Laboratory, US Navy), Hoinka (DLR, Germany), Jansa (INM, Spain), Kotroni (Nat. Obs. of Athens, Greece), Ramis (Balearic Islands University, Spain), Richard (Lab. d'Aerology, Toulouse Univ., France) and Speranza (DSTN-PCM and Camerino Univ., Italy). The SSC is committed to meet at least once a year. The co-ordinator of MSSC will be elected in ordinary meeting, being A. Jansa the present co-ordinator.

- A Project Advisory Group is composed of representatives (focal points) of most of the national meteorological services in the Mediterranean, as well as of some regional meteorological services, other scientific meteorological institutions, main units of national meteorological services and end users, like civil protection services, insurance companies and so on. The present listing of members of the MEDEX Advisory Group is included in the *Supporting documentation.*

3.2 Participating institutions

At present (July 2001) the following institutions have adhered the project in quality of proposer, participating and advisory institutions:

INSTITUTIONS PARTICIPATING TO MEDEX

Proposer institutions
Instituto Nacional de Meteorología (INM), Spain
ISAO, CNR, Italy
Israel Meteorological Service (IMS) (jointly with Tel Aviv University)
Tel Aviv University, Israel (jointly with Israel Meteorological Service)

Participating institutions
ARPA-Servizio Meteorologico Regionale dell'Emilia-Romagna, Italy
ARPA Friuli-Venezia Giulia, Osservatorio Meteorologico Regionale, Italy
Atmospheric Physics Group, Dpt. of Physics, Univ. of Ferrara, Italy
Centro de Información e Tecnoloxía Ambiental (Galician Government – Xunta de Galicia), jointly with University of Santiago de Compostela, Spain
Centro di Ricerca in Monitoraggio Ambientale (CIMA), Italy
Cyprus Meteorological Service
Department of Astronomy and Meteorology, University of Barcelona, Spain
Dipartimento Servizi Tecnizi Nazionali, Presidencia Consiglio Ministri (DSTN, PCM), Italy
Direction de la Météorologie Nationale (DMN), Morocco
Egyptian Meteorological Authority
Euro-Mediterranean Centre on Insular Coastal Dynamics (ICoD), University of Malta
Institut National de la Météorologie, Tunisia
Météo-France
Meteorological and Hydrological Service, Croatia
Meteorological Institute - IM, Portugal
Meteorological Office, U.K.
Meteo-Swiss / Meteo-Svizzera
Meteotrentino, Provincia Autonoma di Trento, Istituto Agrario di S. Michele, Italy
National Institute of Meteorology and Hydrology (NIMH), Bulgarian Academy of Sciences
National Observatory of Athens, Greece
Office National de la Météorologie, Algeria
Servizio Agrometeorologico Regionale della Sardegna, Italy
Turkish Meteorological Service
Ufficio Generale per la Meteorologia, Centro Nazionale di Meteorologia e Climatologia Aeronautica, Italy
Universitat de les Illes Balears (UIB), Spain
U.S. Navy - Naval Research Laboratory, USA

Collaborator and advisory institutions
Dirección General de la Marina Mercante (*Marine Safety*), Spain
Dirección General de Protección Civil (*Civil Defence*), Spain

The adhesion has been expressed through a written document, signed by a representative authority of the corresponding institution. These documents are available on the MEDEX Internet site (http://www.inm.es/MEDEX → participating institutions).

3.3 MEDEX centre

Regarding particular activities, mainly those related to the climatological study (see 2.2.1, (a), and 2.2.2, (a)), a permanent-working centre is required. The Meteorological Centre at Palma of the Spanish INM (CMTIBAL/INM) will undertake this role for both the Western and the Eastern Mediterranean. In any case, these activities have to be made in close contact and with the support of the participant institutions.

In principle the *permanent MEDEX centre* (CMTIBAL/INM) will also act as the responsible organism for the establishment, maintenance and exploitation of the MEDEX database (2.2.3, (a)). Nevertheless the final decision about this point is conditioned by the result of the study of feasibility before mentioned (see 2.2.3, (a)).

The permanent MEDEX centre will maintain the connection and information between the participating institutions. The maintenance of a proper Internet site, already established http://www.inm.es/MEDEX, is a key instrument for doing that.

3.4 Financial aspects

Due to the fact that MEDEX is not a financed project; there are not formal contracts between the participating institutions and WMO. This means that, in spite of the existence of commitment documents for all the participating institutions, the institutional participation in MEDEX has always a voluntary character. This is in fact a potential factor of risk for the management of MEDEX.

Nevertheless, the institutions that are participating in MEDEX are exploring possible sources of financing some relevant MEDEX-related activities. In principle, the most plausible way could be the achievement of an optional project on MEDEX of the European Network of Meteorological Services (EUMETNET). An optional project of EUMETNET is financed by a group of members (meteorological services) that adhere to the project. The EUMETNET project on MEDEX would be mostly oriented towards the best implementation and operation of the MEDEX database and to the performance of specific studies on sensitivity. INM-Spain could undertake the role of responsible member for such a project, although there are other possibilities, because other several members of EUMETNET, the national meteorological services of France, Italy, Portugal, Switzerland and the United Kingdom, are also participant institutions in MEDEX.

Concerning the studies of sensitivity foreseen in MEDEX, an alternative or complementary source of indirect financing could be the assumption of some of these studies by EUCOS (EUMETNET Composite Observing System programme), in its planning of scientific work. The support of EUMETNET to this assumption is seen as plausible, taking into account that several of the members of EUMETNET are also participating in MEDEX.

In any case, INM-Spain guarantees the implementation and operation of the permanent MEDEX centre, undertaking the activities related to the climatological studies, as described above. Regarding the establishment, maintenance and exploitation of the MEDEX database, the final decision is conditioned by the result of the study of feasibility under preparation, as said above.

4. Forecast Demonstration Projects

Forecast Demonstration Projects are not planned at the present stage of development of MEDEX, but they are not discarded in a next future.

Acknowledgements

Apart from those that are proposing institutions, several other institutions have expressed support to MEDEX and manifested a certain degree of involvement. See *Participating institutions* in 3.2.

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Supporting Documentation

- CV of the main proposers
- Memberships of the MEDEX Advisory Group (focal points and contacts)
- Minutes of the MEDEX Meeting 2001
- Listing of cases provided by the participant institutions