WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS
OPAG ON INTEGRATED OBSERVING SYSTEMS

EXPERT TEAM ON
OBSERVATIONAL DATA REQUIREMENTS AND
REDESIGN OF THE GLOBAL OBSERVING SYSTEM

Seventh Session
Geneva, Switzerland, 12-16 July 2004

Distr.: RESTRICTED

CBS/OPAG-IOS/
ODRRGOS-7/Doc. 7.4(1)

(30.VI.2004)

ITEM: 7.4

Original: ENGLISH

TOWARDS AN ADAPTIVE OBSERVING SYSTEM

(*Submitted by the Secretariat)*

Summary and Purpose of Document

This document, prepared by the consultant for WMO, discusses the concept of an adaptive observing system, and proposes a possible approach to implementing such a system

ACTION PROPOSED

The meeting is invited to review this document and to take into account information presented when developing the implementation plan for the Evolution of the GOS.

TOWARDS AN ADAPTIVE OBSERVING SYSTEM

by Claude Pastre, consultant for WMO[1]

March 2004

Introduction and definition of concepts

Our modern societies have become both more sensitive and less tolerant to the hazards of the environment. There is a distinct tendency from citizen all over the world to consider as an absolute necessity the availability of efficient risk management systems, including prevention, preparedness of authorities, information, early warning, etc. In recognition of this trend, the 6th WMO Long Term Plan identifies as one of the strategic goals the need for better prediction of severe weather events and for improved warning systems.

High impact weather events such as tropical cyclones trajectories, big winter storms, critically heavy rainfall, etc. prove difficult to predict. There are a number of scientific and technical reasons for this situation, among which the uncertainties in the knowledge of the initial state of the atmosphere is recognised as a prominent one. A very active research in the past decade on the way Numerical Weather Prediction models handle the analysis errors has shown that there is no spatial homogeneity in the size and growth rate of errors: for each weather situation there are different areas of particular sensitivity to errors in the initial state. This implies that meteorological observations will have a variable value for NWP depending on the time and place where they are performed. The analysis would be better if observations could be made on a particular day at the locations were the day's forecast is more sensitive errors in the analysis.

The 6th WMO Long Term Plan identifies as another strategic goal the "improvement of the effectiveness, efficiency and flexibility of the practices of WMO". The improvement of the design and operations of the Global Observing System has to be a major contributor to this goal. An optimised observing system adapted in flexible ways to meteorological circumstances could provide more value (information content) for the same expenditure.

Consequently, for both better performance and better efficiency, the 6th Long Term Plan states as part of the implementation activities that "on a regional basis, observing networks that are adaptable to changing requirements should be developed".

The term "adaptive observation" appeared in the context of what is called "observation targeting", i.e., a technique to predict the areas where specific observations will be particularly useful on a given day and to target specific observing systems on these areas. Adaptive observation is often used a synonym for observation targeting, but it can be used in a more general sense: adaptation serves an optimisation process and the optimisation criteria may be enlarged to include economic considerations such as minimising running expenditure of costly observing systems (e.g. radiosondes or AMDAR). This makes adaptive observation of interest to all NMHSs, even if they are not in a position to implement expensive dedicated observation targeting systems such as research aircraft.

Also, the tools developed for the purpose of observation targeting can be used for climatological studies of sensitivity to errors in the initial state. These studies in turn can contribute to improvement of the design of the GOS (e.g. to decide where the implementation of a specific observing system or station will be most cost-effective). Figure 1 illustrates this process. It shows a result from a climatological study of sensitivity by ECMWF that was used inter alia to plan the EUCOS/ASAP deployment programme for the period 2004-2006.

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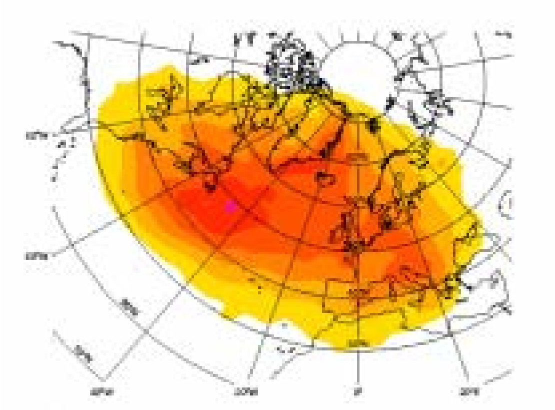
[1] This report presents the personal opinions of its author. It does not commit in anyway the WMO or its Secretariat.

It is important to note that adaptive observation must be handled at regional or sub-regional level. To define the areas of sensitivity one looks for the impact of the errors on a limited geographic region (e.g. the West Coast of Northern America). The sensitive areas are themselves limited in size having typical dimensions of a few thousands of kilometres. Consequently the operation of an adaptive observing system cannot be a global issue. There are however larger scale implications, which require a global perspective to be taken in the WMO framework.

Figure 1 : climatology of 2-day RMTE key analysis errors
Period 30 Oct 1999 -12UTC to 29 Jan 2000 -12UTC / Target 68/-10/45/35



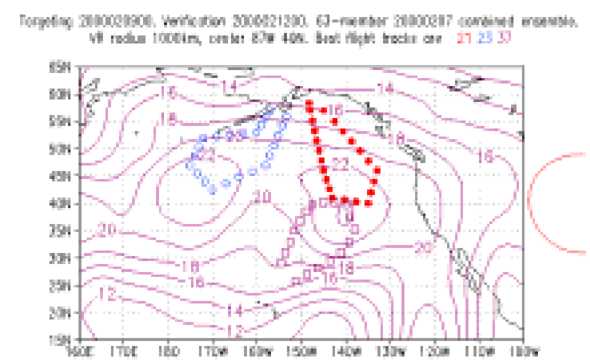
One may also note that it is now recognised that targeting of observations must also take into account the characteristics of the numerical assimilation system that is going to use them. This introduces some complications in regions such as Europe where several NWP systems work in parallel. This should not be taken as a discouraging element, but as an issue to be addressed as part of the design of the adaptive observation programmes.

Relevant past experience and assets

A number of favourable circumstances make possible the development of an operational concept for adaptive observation. There is an active research community on the subject. There is also a wealth of experience acquired in large research experiments and in convincing operational or pre-operational implementations.

The half-century old Hurricane Surveillance Program of NOAA is actually an adaptive observation programme even if it is does not make use of the new observation targeting techniques, in the sense that it performs measurements with dedicated aircraft in and around identified threatening cyclones to improve the forecast of their evolution and track. The first experiment of modern techniques for targeting observation was made during FASTEX in 1997 addressing the forecast of winter storms in the Northern Atlantic. Its results were sufficiently positive to convince NOAA to implement the Winter Storm Reconnaissance Program. This programme has run since 1999. Its objective is to improve the forecast of winter storms for the Western Seaboard of North America and of cold outbreaks in the Northeast by improving the numerical analysis over the North Pacific. It makes use of dedicated aircraft equipped for dropsonde launch, based in Alaska and Hawaii. Figure 2 gives an example of a chart displaying the aircraft trajectories selected for the sensitivity pattern of a specific day.

Figure 2 : example of targeting for the WSR program (from NOAA/NCEP/EMC)



Adaptive observation is a major element of the THORPEX research programme run under the auspices of WMO/WWRP. Research is needed in particular to improve the efficiency of sensitivity area selection and of the assimilation of targeted observations. These methods are however mature enough to be tested in pre-operational implementation. This was the purpose of the THORPEX NA-TReC 2003 (THORPEX North-Atlantic Regional Campaign) conducted by NOAA and EUMETNET with the support of ECMWF and operational European NMHSs. The most efficient future development of adaptive observation will be achieved through a tight working relationship between research and operational implementation.

A list of basic references on FASTEX, WSR and THORPEX is provided at the end of this document for the interested readers.

Technological assets are also available to perform adaptive observation. The GOES and METEOSAT satellites have a rapid-scan capability, which permits more frequent observation of fast developing weather. GOES also has a targeting capability for its sounding instrument. The technology to launch dropsondes from aircraft is mature and has been extensively used on dedicated research aircraft. This tool is certainly the most powerful one to provide targeted observations as demonstrated in FASTEX, WSR, and NA-TreC. It is unfortunately very costly to maintain and run dedicated aircraft. Imaginative collective arrangements will have to be sought by most countries to make a wider operational use of such aircraft. Promising development of less expensive targeting observing systems (driftsonde, drone aircraft, rocketsonde) is ongoing in the THORPEX context. The success of these developments will be crucial for the implementation of widespread observation targeting.

Finally, the list of available assets includes the tools and operational practices developed by EUMETNET/EUCOS to optimise the data collection from AMDAR, ASAP and radiosonde stations. These have been through a comprehensive and successful pre-operational test during the Autumn 2003 NA-TreC.

Proposed objectives for the WMO

The following objectives are proposed for the WMO as concerns adaptive observation:

- **To contribute to the improvement on a regional basis of the short-range forecast of high-impact weather through regional programmes of adaptive observation, including targeting of additional observations.**
- **To apply the study of the sensitivity of forecast to errors in the initial conditions to the optimal design and to the operation of observing systems with a view to improve their efficiency to cost ratio.**

Some of the regional programmes for adaptive observation will work on daily adaptation (e.g., winter storms or cyclone tracks). Other will find interest in seasonal adaptation provided adaptation is found to be beneficial either in terms of forecast quality or cost savings when applied to a seasonal phenomenon (e.g. monsoon).

A regional programme will target high-impact weather specific to the region and will need clear identification of objective, methods and needed resources. In particular, a mechanism for operational decisions will have to be implemented for the selection of sensitive areas and the decision on an increased observational programme once a risky episode is emerging. A systematic evaluation of the impact of actions taken will also be necessary. All these characteristics imply an international project management structure. Such structures have been used successfully in large international research experiments such as GARP/FGGE, FASTEX, THORPEX/NA-TreC, etc. They are not however a very common practice in international management of operational meteorological observing systems (one notable exception is EUMETNET/EUCOS). The careful definition and implementation of these project management structures at regional or sub-regional level will be critical for the success of adaptive observation programmes.

Optimisation studies should look for possible cost savings in the operation of the regional observing systems in weather situations where no specific meteorological risk is foreseen. On a daily basis this could be worthwhile for systems with significant running expenditure as AMDAR or radiosondes. For instance, should all radiosounding stations operate with the same programme everyday or could the number of radiosondes launched at some stations be reduced on days where the quality of the forecast does not depend significantly on data at that location on that day (e.g. from two to one sonde during the day)? Such savings would provide resources that would on the contrary permit to increase the number of sondes launched on critical days (e.g., from two to four sondes during a day). This sort of optimisation process could most probably also be applied at seasonal time scales where significantly different seasonal weather patterns may require different geographic distributions of observation density.

A strong symbiotic relationship with research and development activities on the subject will be needed as the operational possibilities will develop in parallel to R&D results and vice-versa, as is systematically the case for matters linked to numerical weather prediction. The capabilities for observation targeting techniques need to be extended and demonstrated for other phenomena than the winter storms to which they have been applied so far. Research on observation targeting should be encouraged to address the issues of hurricane track forecast, Mediterranean cyclonic storms, heavy regional rainfall events, onset of monsoon, seasonal observing system adaptation. Studies and experiments on the optimisation of the efficiency of the in-situ observing systems and networks will also be needed.

It may be useful at this point to introduce some notes of caution. Targeting additional information with dedicated systems such as dropsondes from aircraft in specific areas on specific days may be considered a marginal change to the Global Observing System, unlikely to have large-scale detrimental effects. The situation may be different when programmes for regional adaptive observation will try to optimise (or minimise) the running cost of systems like radiosounding networks or AMDAR, because this may mean decreasing in some areas the density of observations below their “normal” value. In these circumstances a number of precautions should be taken:

- a network should not be operated below a minimum spatial density to be defined through long duration OSEs. This means for instance that a process to reduce the operating cost is likely to prove not feasible where the GOS is too thin already,
- adaptive observation is exclusively serving the needs of NWP for short or short/medium range prediction. The other applications must not be neglected. In particular the observing programme of GCOS stations should be carefully respected.
- modifications to the GOS in one area may impact further downstream. This is unlikely to be a major difficulty for well designed and well conducted adaptative observation operations. At the minimum, specific studies (OSEs) of downstream impact should be conducted as part of the programme design as well as monitoring of downstream impact during the course of the programme.

Proposed approach

It is suggested that the first step should be for CBS to analyse the issue, develop a strategy and guidance to ensure that the regional implementation of adaptive observation will be coherent with the GOS design at the service of all applications. CBS should take advantage of the knowledge available from the R&D community. An important source for such knowledge will be found in THORPEX. The operational entities most active in THORPEX such as the NMSs of US, UK, France as well as ECMWF and EUMETNET/EUCOS will contribute actively to the necessary linking between research and operations. A close working relationship of CBS with THORPEX will be essential to ensure that coherence is maintained between CBS plans and the THORPEX Implementation Plan. This could be ensured through an ad-hoc joint working group.

The next step should then be taken at the level of Regional Associations with a view to elaborate the regional approach applicable to the phenomena of interest to the Region (tropical cyclones/hurricanes, winter storms, Mediterranean sea cyclones, monsoon, etc.) taking into account the status of the regional observing system. The Regional Association should first conduct a preliminary analysis to identify the potential for adaptive observation in the region and its feasibility. A positive result of this analysis would then lead to an operational implementation.

A regional workshop of experts should be tasked with this preliminary analysis to establish requirements and feasibility. The workshop would benefit from CBS guidance and should involve scientific experts, in particular from THORPEX and its Regional Committees.

The following is proposed as sketch guidelines for the workshop:

- to check requirements :

  The existence in the region of characteristic atmospheric circulations (patterns) with potentially different observation requirements should be ascertained. These might correspond to high impact weather events, in which case the requirement will be to improve forecast quality, possibly using specific systems to add targeted observations for selected cases. Or they might correspond to “standard” weather situations in which case the objective will be to optimise the running cost of the observing system, for instance to decrease the cost without degrading the accuracy of the forecast.

- to check the technical feasibility :

  Several elements are necessary to conduct a programme of adaptive observation. An access is needed to an NWP system that would provide on a regular basis the operational output necessary for identification of sensitive areas. This output might come from a global, regional, national or specialised centre. Such products are not widely available today and are relatively expensive in terms of computing power. One may expect however that they will become routine production for all major NWP centres in a relatively near future. Another necessary element is of course the existence of routine observation networks and systems able to respond in due time to operational management requests for data acquisition changes. his means response times well below one day in the case of short term forecast. The more sophisticated adaptive observation approach, involving observation targeting on a daily basis requires the availability of systems capable of delivering observations on request in void areas. At present, apart from geostationary satellites, only dedicated manned aircraft can be considered able to provide this function on an operational basis.

- to check the institutional feasibility:

  Members participating to the adaptive observation programme will have to agree a collective operational management of their observation systems on a regional or sub-regional basis. This requires a light but well defined project structure with clearly identified objectives and responsibilities. For instance, in EUMETNET/EUCOS, the members delegate the management responsibility to one of themselves, setting clearly defined limits to the delegated authority. The availability of the necessary resources should also be verified. The required operational resources may be relatively modest if only existing systems are used. In this case the main cost will be with the NWP production, plus the staff – a small number – to actually manage the process. The programme cost may become high if additional systems such as dedicated aircraft are to be used. In this case innovative institutional mechanisms will be needed to collect resources from several members and possibly involve partners who could share expensive equipment. Such might be the case for instance of military air forces: these own suitable aircraft and have to fly them anyway if only for training purposes.

The feasibility study produced by the workshop would be used by the Regional Association to decide the next steps. In case of a positive decision, the first of these next steps would likely be the establishment of a small project team to prepare a detailed project definition.

In parallel to this move towards an operational implementation, it will be most important for the WMO Members to continue their active support of THORPEX and as far as possible increase it in line with Resolution 3.3/1 of Congress-XIV. Continuing R&D is needed on many subjects, inter alia on the methods to select locations to be observed, on the applicability of these methods to cases other than those of mid-latitude winter storms for which they have been developed, on the methods to assimilate the observations (adaptive assimilation) and the necessary links between the adaptive observation and the assimilation system(s) that make(s) use of it.

It would also be helpful to have more effort dedicated to the development of systems less expensive than manned aircraft to procure targeted in-situ information, such as drifting balloons carrying dropsondes (e.g. the driftsonde system) or all-weather unmanned aircraft carrying dropsondes that could be developed from existing military drones.

The above considerations will perhaps make the road towards a fully adaptive observing system look long and arduous, but the expected benefits in terms of improvement of the forecast of high impact weather events and better cost efficiency of the observing system deserve a strong collective commitment to this strategic objective.

References

Joly, A. et al., 1999: Overview of the field phase of the Fronts and Atlantic Storm-Track Experiment (FASTEX) project. *Quart. J. Roy. Meteor. Soc*., 125, 3131-3164.

Szunyogh, I. et al., 2002: Propagation of the Effect of Targeted Observations: The 2000 Winter Storm Reconnaissance Program. *Mon. Wea. Rev*., 130, 1144-1165.

Shapiro, M.A., A.J. Thorpe, 2003: THORPEX International Science Plan, Version 2. *Access through* http://www.wmo.ch/web/arep/wwrp/THORPEX/THORPEX.htm

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