PREFACE

The first edition of the Guide on the Global Observing System was initiated by the sixth session of the WMO Commission for Basic Systems, held in Belgrade in March/April 1974, and completed in 1977 by a study group under the leadership of Dr T. Mohr (Federal Republic of Germany). At its eighth session in February 1983 the Commission noted that, with the publication of the Manual on the Global Observing System comprising Annex V to the Technical Regulations and containing all regulatory material pertaining to the Global Observing System, it had become necessary to revise and extend the Guide. It therefore requested its Working Group on the Global Observing System to prepare a draft of a new version of the Guide for submission to the ninth session of the Commission.

The bulk of the drafting was carried out by individual members of a study group set up for the purpose, namely, Mr Y. Shavit, chairman (Israel), Mr O. Bremnes (Norway), Mr O. A. Gorodetski (USSR), Mr J. Ilko (Czechoslovakia), Mr G. Müller (Switzerland), Mr H. Veit (German Democratic Republic), and Mr F. Zbar (USA). Mr J. Hussey (USA), the working group's Rapporteur on Advanced Satellite Remote Sensing, prepared Part IV on the Space-based Subsystem, while a few sections as well as the final compilation and editing were completed by the Secretariat. Although the work was carried out mainly by correspondence, three meetings of the study group were held in November 1983, November 1984 and December 1986. Initial drafts of two chapters were reviewed by the fourth session of the working group in December 1984 and the final draft by correspondence in mid-1987. The resulting new version of the Guide was reviewed, and with a number of amendments approved by the ninth session of the Commission in January/February 1988.

The main purpose of this Guide is to provide users with general information on observational practices and procedures supplementing that already contained in the Manual on the Global Observing System, the current Plan and Implementation Programme for the World Weather Watch and other relevant WMO publications. It is not intended to be a detailed information manual for the use of observers but to form a basis for the preparation of instructions by each Meteorological Service to meet its own particular needs.

Finally, I should like to take this opportunity of placing on record, on behalf of the World Meteorological Organization, my gratitude to all those who contributed to the present publication.

(G.O.P. Obasi)
Secretary-General

WORLD METEOROLOGICAL ORGANIZATION

GUIDE

ON THE

GLOBAL OBSERVING SYSTEM

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NOTE

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the World Meteorological Organization concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

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INTRODUCTION

General

One of the principal purposes of the World Meteorological Organization, as laid down in the Convention, is to facilitate world-wide co-operation in the establishment of networks of stations for the making of meteorological observations or other geophysical observations related to meteorology, and to promote the establishment and maintenance of meteorological centres charged with the provision of meteorological services. Another purpose of the Organization is to promote standardization of meteorological observations and to ensure the uniform publication of observations and statistics. With a view to ensuring the required standardization of practices and procedures in meteorology, the World Meteorological Congress has adopted, from time to time, Technical Regulations which lay down the meteorological practices and procedures to be followed by the Member countries of the Organization. These Technical Regulations include manuals on various aspects of the Organization's activities and are supplemented by a number of Guides which describe in more detail the practices, procedures and specifications which Members are invited to follow in establishing and conducting their arrangements for compliance with the Technical Regulations and in otherwise developing meteorological services in their respective countries. The present Guide deals with the organization and implementation of the Global Observing System which is one of the three essential elements of the World Weather Watch, the basic Programme of WMO.

The World Weather Watch (WWW)

The purpose of the WWW is to provide meteorological and related geophysical and environmental information to all Members of WMO in support of their services to users in real-time and non-real-time operations. WWW primarily provides Members with observational data and processed products for meteorological forecasting and warning and research purposes but also supports other WMO activities and relevant programmes of other international organizations in conformity with WMO policies.

The WWW comprises three essential elements, each of which functions on three levels: global, regional and national:

- The Global Observing System (GOS), consisting of facilities and arrangements for making measurements and observations at stations on land, at sea, and from aircraft, meteorological satellites and other platforms;

- The Global Data-processing System (GDPS), consisting of meteorological centres with arrangements for the processing of observational data and preparation of analyses and forecast products (real-time users) and for the storage and retrieval of data and processed products (non-real-time users);

- The Global Telecommunication System (GTS), consisting of telecommunication facilities and arrangements necessary for the rapid and reliable collection and distribution of the required observational data and processed products.

Further specifications and details of the functions and organization of the three essential elements (also referred to as components) of the WWW are given in Volume I of the respective Manuals on the GOS, GDPS and GTS which are annexes to the Technical Regulations.

Purposes of the Guide on the Global Observing System

The main purpose of the Guide is to provide practical information on the development, organization, implementation and operation of the GOS in order to enhance both the participation of individual Members in the System and the benefits they may obtain from it. The Guide explains and describes the practices, procedures and specifications of the GOS and is aimed at assisting the technical and administrative staff of national Meteorological Services responsible for the networks of observing stations to prepare national instructions for observers.

The Guide supplements the regulatory material on observational matters contained in the Technical Regulations and the Manual on the GOS and, for ease of reference, follows approximately the same structure as the Manual. The Guide also complements the Guide to Meteorological Instruments and Methods of Observation while the Guide on the Global Data-processing System is used in turn to complement the Guide on the GOS.

A list of publications which are related to and may be used in conjunction with the Guide on the GOS is given below.

- The WMO Technical Regulations (WMO-No. 49);
- Manual on the Global Observing System (WMO-No. 544);
- Manual on the Global Telecommunication System (WMO-No. 386);
- Manual on the Global Data-processing System (WMO-No. 485);
- Manual on codes (WMO-No. 306);
- Information on meteorological satellite programmes operated by Members and organizations (WMO-No. 411);
- Guide to meteorological instruments and methods of observation (WMO-No. 8);
- Guide on the Global Data-processing System (WMO-No. 305);
- Guide to marine meteorological services (WMO-No. 471);
- Guide to hydrological practices (WMO-No. 168);
- Guide to climatological practices (WMO-No. 100);
- Guide to agricultural meteorological practices (WMO-No. 134);
- Guide to aeronautical meteorological practices (in preparation);
- International cloud atlas (WMO-No. 407);

- Guidelines for the education and training of personnel in meteorology and operational hydrology (WMO-No.258);

- The World Weather Watch Programme 1988-1997, Second WMO Long-term Plan, Part II, Vol. 1 (WMO-No. 691).

PART I

PURPOSE, SCOPE, AND ORGANIZATION OF THE GLOBAL OBSERVING SYSTEM

P A R T I

PURPOSE, SCOPE AND ORGANIZATION OF THE GLOBAL OBSERVING SYSTEM

1.1 PURPOSE OF THE GLOBAL OBSERVING SYSTEM

The Global Observing System is a co-ordinated system of methods, techniques and facilities, the main purpose of which is to provide, in a cost-effective way, meteorological and related environmental and geophysical observations from all parts of the globe as are required for the real-time preparation of weather analyses and forecasts, including warnings. The GOS also provides observational data for research purposes and, as agreed by the Organization, in support of other WMO programmes or relevant programmes of other international organizations.

1.2 SCOPE OF AND REQUIREMENTS FOR THE GLOBAL OBSERVING SYSTEM

The requirements to be met by the GOS are defined by Members of the Organization through the regional associations and technical commissions and formulated in the various WMO Programmes. Essentially, the GOS must provide the basic data needed for the services rendered by the national Meteorological Services or other organizations in contributing to public safety, socio-economic well-being and development in their respective countries. These services fall into three main categories: (a) weather forecasts (including reports on current weather, warnings of hazardous weather phenomena and predictions of weather on varying time-scales up to one month and sometimes beyond); (b) climate information and advice in the application of meteorological data and knowledge; and (c) hydrological services including flood warnings.

Within these three main categories there is a variety of specialized services and applications of meteorology which require different types of meteorological observations and measurements on varying scales. These include short-, medium- and long-range weather forecasting; the provision of severe weather warnings for the occurrence of such phenomena as tropical cyclones, polar lows, hail storms, floods and heavy snowfalls; services to aviation, shipping and agriculture and for other diverse areas such as energy production, environmental protection, the construction industry and tourism. In general, the requirements to be met by the GOS for each of these areas are established by the WMO Technical Commissions for Basic Systems, Climatology, Atmospheric Sciences, Hydrology, Aeronautical Meteorology, Agricultural Meteorology and Marine Meteorology.

A number of international programmes also use WWW facilities and those of the GOS in particular, and have their own special requirements. These include: the World Climate Research Programme of WMO and the International Council of Scientific Unions, the World Area Forecast System for support to aviation, the Global Environmental Monitoring System of UNEP, and the joint IOC/WMO Integrated Global Ocean Services System.

1.3 ORGANIZATION AND IMPLEMENTATION OF THE GLOBAL OBSERVING SYSTEM

In order to meet these requirements the GOS is designed as a composite system divided into surface-based and space-based (satellite) subsystems. The former (discussed in detail in Part III of the Guide) comprises the regional basic synoptic networks (RBSN) as well as other networks of land, sea and airborne stations; it also includes agricultural meteorological stations, climatological stations and special stations. The space-based subsystem (see Part IV) is composed of near-polar-orbiting and geostationary meteorological satellites and has a ground segment (for data reception and processing) as well as a space segment.

The composite system provides observational information which falls broadly into two categories:

(a) Quantitative information, derived directly or indirectly from instrument measurements; and

(b) Qualitative (descriptive) information.

Examples of quantitative information, which specify the physical state of the atmosphere, are measurements of atmospheric pressure, humidity, air temperature and wind velocity, while qualitative or descriptive information includes such observations as the amount and type of clouds and types of precipitation.

The specific requirements for the various types of information and data are addressed in Part II.

With respect to the implementation of the GOS, the guiding principle is that all activities and facilities connected with the establishment and operation of the System on the territories of individual countries are the responsibility of the countries themselves and should be met to the extent possible from national resources. Where this is not possible, assistance may be provided by UNDP, through other multilateral or bilateral assistance programmes or by the WMO Voluntary Co-operation Programme.

Implementation of the GOS outside the territories of individual countries (e.g. outer space, the oceans and the Antarctic) is based on the principle of voluntary participation of countries that desire and are able to contribute by providing facilities and services either individually or jointly from their national resources or through collective financing.

The GOS is a flexible and continuously evolving system with a choice and mix of observing elements which may be adjusted to take full advantage of new technology or to meet new requirements. As a general principle, however, the evolution of the system should be based on proven techniques and should represent the best mix of observing elements which

- Satisfies to the maximum extent the agreed-upon data requirements in respect of accuracy, frequency and spatial resolution;

- Is operationally and technically feasible;

- Meets the cost-efficiency requirements of Members.

Throughout the GOS, standardized quality-control procedures are applied (see Part VI of the Guide) to all observing system elements in order to ensure high quality and compatible data with known error structures.

Certain levels of redundancy are required for quality assurance purposes and to provide some insurance against catastrophic failure in any single component or element; multi-purpose elements or stations are encouraged in order to comply with cost-efficiency requirements.

PART II

REQUIREMENTS FOR OBSERVATIONAL DATA

P A R T II

REQUIREMENTS FOR OBSERVATIONAL DATA

2.1 GENERAL

Weather prediction can best be made on the basis of precise meteorological analyses. Such analyses are made on the basis of highly reliable observational data which are received at analysis centres, in time, from a sufficiently dense network of observations. However, requirements concerning the accuracy of observational data, the frequency of observations and the density of the network of observations are dependent upon the different scales of meteorological phenomena to be analysed. As is well known, various meteorological phenomena in different scales co-exist in the atmosphere. For example, one cell of a thunderstorm is only several kilometres in horizontal scale and has a lifetime of several hours while a tropical cyclone is about 1 000 kilometres in horizontal scale and has a lifetime of 10 days or more; many thunderstorms cells appear and disappear during the life cycle of a tropical cyclone. Therefore, the frequency and spacing of observations should be adequate to obtain observational data which describe temporal and spatial changes of the meteorological phenomena with sufficient resolution to meet the requirements of the users. If the spacing of observations is more than 100 km, the meteorological phenomena which have a horizontal scale of less than 100 km are not usually detectable. The classification of horizontal scales of the meteorological phenomena given in the Manual on the GOS are as follows:

(a) Small scale (less than 100 km), e.g. thunderstorms, local winds, tornadoes;

(b) Mesoscale (100-1 000 km), e.g. fronts and cloud clusters;

(c) Large scale (1 000-5 000 km), e.g. depressions and anti-cyclones;

(d) Planetary scale (more than 5 000 km), e.g. long upper-tropospheric waves.

The horizontal scales are closely related to the time-scales of the phenomena. The bigger horizontal-scale perturbations are likely to survive for a longer time period (Figure II. 1). Therefore, short-range weather forecasts require more frequent observations from a denser network over a limited area in order to detect any small-scale phenomena and their development. As the length of the forecast period increases, so does the area over which observations are required. Because of the dynamic interaction between the meteorological phenomena in different scales, it may not be possible to specify definitely the requirements for indiviual scales.

The requirements are generally divided into three categories:

(a) Global requirements which derive primarily from the need to define the initial conditions of global weather prediction models. These models deal with atmospheric motions on the large and planetary scales but may be influenced by motions on smaller scales;

(b) Regional requirements which derive from the need of two or more Members to describe in greater detail the planetary and large-scale atmospheric phenomena as well as those of meso- and smaller scales;

(c) National requirements which derive from the needs of individual countries for specialized services to end-users and from the particular climate regime.

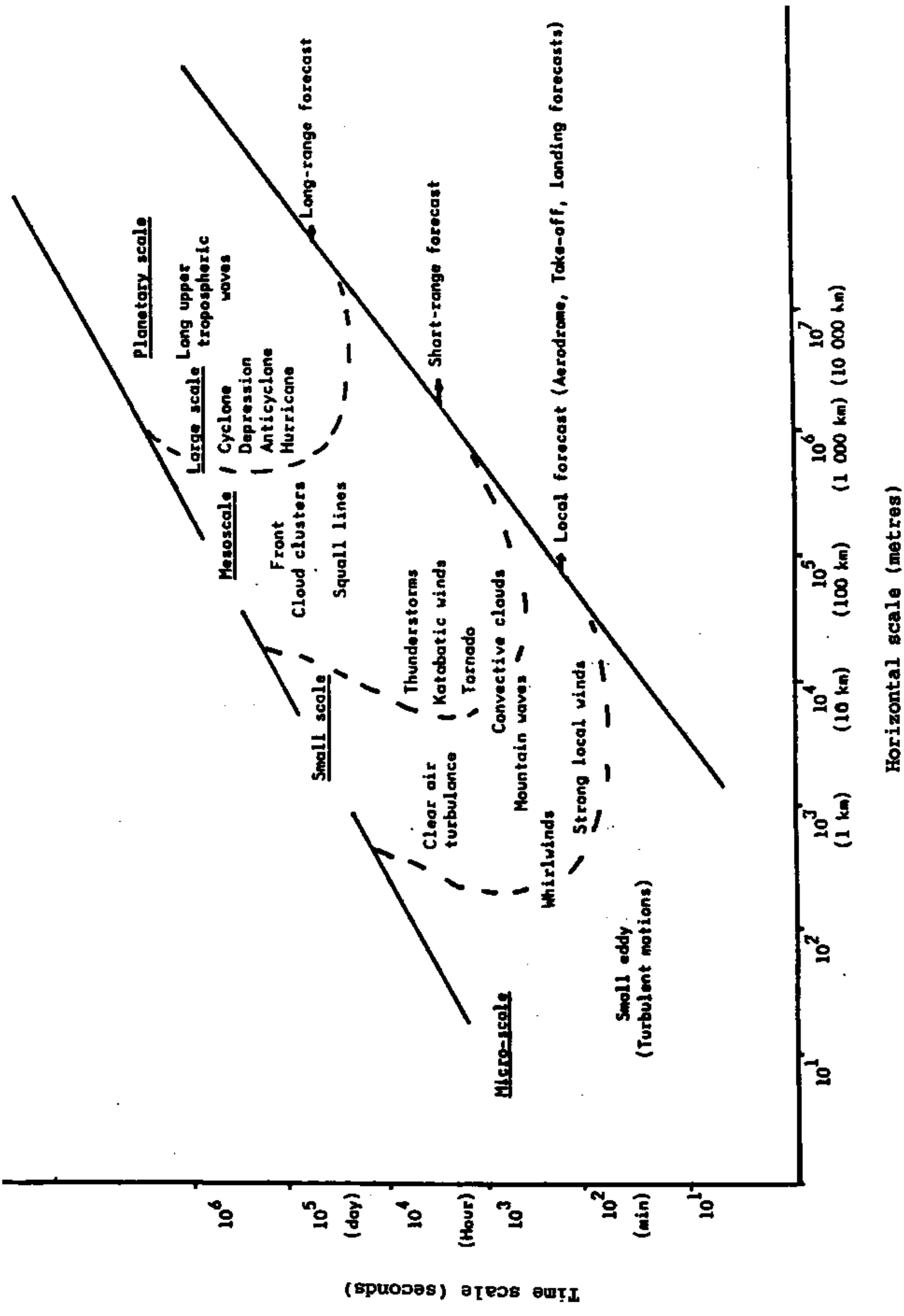

Figure II.1 – Horizontal and time scales of meteorological phenomena

2.2 GLOBAL AND REGIONAL REQUIREMENTS

2.2.1 Data requirements of GDPS

The formulation of data requirements for NWP methods for various forecasting ranges is an ongoing process based on an evolving level of experience with observing systems, on observing system experiments and network studies, and on the introduction of new data assimilation systems and NWP models. Data requirements have been established to meet the current and expected future possibilities of the GDPS.

The tables given in Attachment II.1 list the observational data which will be needed for advanced NWP systems by the year 2000. They include the needs for data assimilation and for analysis and model validation for global short- and medium-range forecasting (excluding extended-range forecasting). Requirements for regional modelling are mentioned in the explanatory text, where appropriate. The types of observing network and platforms providing data required at data-processing centres are also given in Attachment II.1. The regional observing networks are designed in accordance with data requirements of individual regions.

2.2.2 Other requirements for observational data

One of the main purposes of the GOS is to provide observational data for other WMO Programmes and for other international organizations. In particular, the Global Climate Observing System (GCOS), which is being developed as a dedicated observation system designed specifically to meet the scientific requirements for monitoring the climate and for detecting and predicting climate change, will be based largely on the GOS. However, the climate monitoring and predicting objectives will necessitate a number of improvements of the observing systems both in observational accuracy, representativeness and coverage. Reliable long-term data sets with optimal vertical resolution and homogeneous horizontal global coverage will be required. In order to meet GCOS requirements, the existing elements of the GOS should be enhanced as follows:

(a) The number of observational stations in remote areas should be increased;

(b) Long-term support should be found for a set of well-distributed high-quality upper-air stations composed of existing or new sites to provide a relatively homogeneous baseline global data network;

(c) Networks of drifting buoys making meteorological observations should be maintained and extended over data-sparse ocean areas (e.g. Indian and Southern Oceans);

(d) In order to maintain continuity in climate records, procedures should be introduced to calibrate new observing systems in the operational environment against the systems being replaced; in particular, old and new systems should be operated side-by-side for a period adequate to determine long-term relationships.

2.3 NATIONAL REQUIREMENTS

National observational data are required, in addition to general GDPS requirements, for nowcasting, very short-range weather forecasting and severe weather warnings, for interpretation of processed forecast fields into local weather parameters, for verification of the quality of issued forecasts and warnings, and for other (non-real-time) applications. The observational data required for this purpose include surface and upper-air data obtained from land stations and ships, aircraft and buoys, as well as weather radar data and satellite information (satellite-derived temperature, humidity, winds and high-resolution imagery).

National observing networks are, of course, designed by Members according to their needs individually or in agreement with other Members but in accordance with WMO regulatory and guidance material.

In designing these networks, account should be taken of the special requirements for observational data and forecast products of the end-user groups for whom the services are being provided. Much of the data requirements for these services are included in the set of global observational data requirements but individual services may often require additional data, denser networks or greater frequency of observations. An indication of the requirements for measured or observed and forecast variables for a selection of important end-user groups is given in Attachment II.2.

2.4 ACHIEVABLE PERFORMANCE OF THE GOS

The GOS will gradually evolve to address global, regional and national requirements for observational data. Many of the requirements stated here can only be met by satellite-borne observing systems. However, in most cases, a combination of satellite and in situ data will be needed to obtain adequate resolution and to ensure stability of calibration of remote sensing systems. The GOS will, therefore, continue to be composed of the surface-based and space-based subsystems. However, resource constraints require that careful judgements be made on the value of increased quality of GDPS output products weighed against the costs of additional observations. The definition of requirements and the design of the GOS are largely influenced by cost and by the ability of countries to operate GOS components and facilities. It is, therefore, important to define realistic and achievable goals for Members' efforts in respect of the composite global observing system. An estimate of the performance to be achieved by various elements of the GOS by the year 2005 related to observational requirements for the GDPS is given in Attachment II.3. It represents what are considered to be realistic and achievable goals in terms of resolution, accuracy and frequency on a global scale. In some regions, these requirements may be surpassed.

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ATTACHMENT II.1

Observational data requirements for GDPS centres for global and regional exchange

Paragraphs 1, 2, and 3 state the observations required to operate all GDPS centres at national, regional and global levels. Paragraph 4 addresses the data requirements for NWP operations only.

1. The types of observation networks and platforms providing data required at data-processing centres are as follows:

(a) All stations included in the Regional Basic Synoptic Networks;

(b) The network of supplementary stations, including automatic stations;

(c) Automatic marine stations (drifting buoy and moored buoy programmes);

(d) Mobile sea stations;

(e) All other stations making radiowind, radiosonde/radiowind and pilot balloon observations;

(f) Meteorological rocket stations;

(g) Aircraft meteorological observations;

(h) Wind profilers;

(i) Doppler and weather watch radar systems;

(j) Space-based systems producing:

- (i) Imagery (including digital imagery);
- (ii) Radiance data;
- (iii) Retrieved vertical temperature profiles;
- (iv) Cloud and water vapour motion winds;
- (v) Digital information about clouds;
- (vi) Satellite surface wind and precipitable water;
- (vii) Manual data, for example, Australian bogus surface data;
- (viii) Moisture profiles derived from satellite observations over sea areas;
- (ix) Precipitation fields from multispectral cloud radiance data;
- (x) Other meteorological and environmental products;

(k) Radiological data reporting station in case of nuclear accidents (required for GDPS centres running transport models for environmental emergency response);

(l) Rainfall radar composites;

(m) Lightning detection and location systems network.

The observational data which will be needed to obtain optimum results from NWP systems by the year 2000 are elaborated in paragraph 4 and the related three tables of this attachment.

2. The report code types which carry the data provided by the platforms listed in paragraph 1 are given below:

(a) BUFR and GRIB;

(b) TEMP – Parts A, B, C, and D;

(c) PILOT – Parts A, B, C, and D;

(d) TEMP SHIP – Parts A, B, C, and D;

(e) PILOT SHIP – Parts A, B, C, and D;

(f) TEMP MOBIL – Parts A, B, C, and D;

(g) PILOT MOBIL – Parts A, B, C, and D;

(h) COLBA;

(i) TEMP DROP;

(j) ROCOB;

(k) SYNOP;

(l) SHIP;

(m) Reports from automatic stations on land and at sea;

(n) CODAR/AIREP/AMDAR;

(o) Selected satellite data, such as cloud images, SATEM, SAREP, SARAD, SATOB;

(p) BUOY;

(q) CLIMAT, CLIMAT SHIP;

(r) CLIMAT TEMP, CLIMAT TEMP SHIP;

(s) BATHY, TESAC, TRACKOB;

(t) WAVEOB;

(u) RADOB;

(v) RADREP.

NOTES:

(1) Items (a) to (v) do not indicate priorities.

(2) BUFR can encode any of the other above data forms and many more. If BUFR is used to represent any of these data forms, in lieu of the specific alphanumeric code form, then the same data requirements apply.

3. The frequency of observational reports required is as follows:

(a) BUFR and GRIB, as available;

(b) TEMP, PILOT, TEMP SHIP, PILOT SHIP, TEMP MOBIL, PILOT MOBIL, ROCOB, COLBA and TEMP DROP, as available;

(c) SYNOP, SHIP and reports from automatic stations on land and at sea — 0000, 0300, 0600, 0900, 1200, 1500, 1800, 2100 UTC and hourly whenever possible;

(d) CODAR/AIREP/AMDAR reports, as available;

(e) Selected satellite data, such as cloud images, SATEM, SAREP, SARAD and SATOB and digital cloud data, as available;

(f) BUOY, as available;

(g) CLIMAT, CLIMAT SHIP, CLIMAT TEMP and CLIMAT TEMP SHIP — once per month;

(h) BATHY, TESAC, TRACKOB and WAVEOB, as available;

(i) RADOB and RADREP, as available.

4. Data needed for advanced NWP by the year 2000 is as follows:

General considerations

The following tables list the observational data which will be needed for advanced NWP systems by the year 2000. They include the needs for data assimilation and for analysis and model validation for global short- and medium-range forecasting (excluding long-range forecasting).

Requirements for regional modelling have also been considered. They have been mentioned in the explanatory text, where appropriate, but they have not been listed in the tables. Mesoscale modelling has not been considered.

It is most likely that data of the given specifications would benefit global NWP, if available; however, it does not mean that NWP could not be carried out without such data, as NWP models produce useful products even with the observational data set currently available. It does not mean either that data of higher specification would not be useful. On the contrary, when and where such data are produced they should be made available.

The problem of the feasibility of observing all the variables listed in these tables is not addressed. Most of the requirements stated here could only be met by satellite-borne observing systems. However, in many cases a combination of satellite and <u>in situ</u> data is needed to obtain adequate resolution and to ensure stability of calibration of remote sensing systems.

Contents of the tables

The following notes provide some explanation of how the lists were prepared and some provisos on their use:

<u>Variables</u>

Following past convention, the observational requirements for data assimilation are stated in terms of geophysical variables. This is thought to be useful since, from a user's perspective, these are the variables on which information is required. However, it is important to note that these variables are not always observed directly (satellite systems observe none of them directly, with the exception of top-of-the-atmosphere radiation and a Doppler wind lidar). Also, it is no longer true that the users need their data exclusively in the form of geophysical parameters; recent developments in data assimilation have demonstrated the potential and the benefits of using data at the engineering level (e.g. radiances, brightness temperatures).

Horizontal resolution

(a) In general (and with some oversimplification), data are useful for assimilation and validation on spatial scales which the models are attempting to represent. One hundred kilometres are given as the requirement for the variables listed in the tables. However, it is possible to benefit from higher resolution data, considering the current developments towards global models with a grid length of less than 50 km;

(b) Regional models attempt to represent spatial scales above the mesoscale. Observational data are required at a resolution of 10 km.

Vertical resolution

(a) The same rationale is applied here: global NWP models are expected to have a resolution of less than one kilometre throughout the troposphere and lower stratosphere, with considerably higher resolution in the planetary boundary layer. In the mid- and upper stratosphere, a resolution of two kilometres is likely to be sufficient. The requirements for observations should be comparable;

(b) For regional models, observations are required at a resolution of 100 m (50 m in the planetary boundary layer).

Temporal resolution

(a) Just as with spatial resolution, data will be useful for assimilation and validation on temporal scales, which the models are attempting to represent. In the past, this has not been the case; so-called "four-dimensional" assimilation systems would more appropriately be described as "intermittent three-dimensional" systems, and they have not been able to make proper use of observations more frequently than the period of the data assimilation cycle (typically six hours). However, continued progress towards truly four-dimensional data assimilation is making it possible to extract useful information from observations at higher temporal frequency. With such systems, higher temporal resolution can compensate, to some extent, for poor horizontal resolution when the atmosphere is moving. A requirement of three hours for upper-air data and one hour for surface data has been specified. However, like in the case of spatial resolution, upper-air data of higher specification (up to one hour) should also be made available (e.g. cloud motion wind data from geostationary satellites, and wind profiles from wind profilers);

(b) For regional models, both upper-air and surface data are required at a resolution of one hour.

Accuracy

The values given are intended to represent the RMS of the observation errors. The assessment of accuracy should include not only the true instrumental error but also the representativeness error (i.e. the characteristics of some observing systems, particularly in situ systems, which sample spatial and temporal scales and which are not represented by the models). For NWP applications, such effects appear as though they were observation errors.

Timeliness

In NWP, the value of data degrades with time, and it does so particularly rapidly for variables which change quickly. Operational assimilation systems are usually run with a cut-off time of about three hours for global models and one and a half hours for regional models (although data received with longer delays remain useful). Therefore, the timeliness of data delivery must take into account the advertized initiation time of any operational model that uses that data. For observations which are expected to be used for validation, and not for analysis/assimilation in near-real time, timeliness is less critical.

TABLE 1
Three-dimensional fields

	Horizontal res. (km)	Vertical res. (km)	Temporal res. (hours)	Accuracy (RMS error)	Notes
Wind (horizontal)	100	.1 up to 2 km .5 up to 16 2 up to 30	3	2 m s^{-1} in the troposphere 3 m s^{-1} in the stratosphere	(1) (2)
Temperature (T)	100	.1 up to 2 km .5 up to 16 2 up to 30	3	.5 K in the troposphere 1 K in the stratosphere	(3)
Relative humidity (RH)	100	.1 up to 2 km .5 up to tropopause	3	5 % (RH)	

NOTES:
(1) Accuracy specified as RMS vector error.
(2) Hourly wind data from geostationary satellites and from wind profilers are also required. Tropospheric horizontal and vertical resolution and accuracy can be met by a space-based Doppler wind lidar in a sun-synchronous orbit.
(3) Geopotential height can be retrieved from specified T and RH with sufficient accuracy.

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TABLE 2

Surface fields

	Horizontal res. (km)	Temporal res.	Accuracy (RMS error)	Notes
Pressure	100	1 h	0.5 hPa	
Wind	100	1 h	2 m s^{-1}	(1)
Temperature	100	1 h	1 K	
Relative humidity	100	1 h	5 %	
Accumulated precipitation	100	3 h	0.1 mm	(2)
Sea surface temperature	100	1 day	0.5 K	
Soil temperature	100	3 h	0.5 K	
Sea-ice cover	100	1 day	10 %	
Snow cover	100	1 day	10 %	
Snow equivalent-water depth	100	1 day	5 mm	
Soil moisture, 0–10 cm	100	1 day	0.02 $m^3 m^{-3}$	
Soil moisture, 10–100 cm	100	1 week	0.02 $m^3 m^{-3}$	
Percentage of vegetation	100	1 week	10 % (relative)	
Soil temperature, 20 cm	100	6 h	0.5 K	
Deep soil temperature, 100 cm	100	1 day	0.5 K	
Albedo, visible	100	1 day	1 %	
Albedo, near infrared	100	1 day	1 %	
Long-wave emissivity	100	1 day	1 %	
Ocean wave height	100	1 h	0.5 m	

NOTES:

(1) Wind at 10 metres over land. Over sea, height in the range of one to 40 metres (to be transmitted with the observation).

(2) Required principally for model validation, not time critical.

TABLE 3

Other two-dimensional fields

	Horizontal res. (km)	Temporal res.	Accuracy (RMS error)	Notes
Cloud fractional cover	100	3 h	10 %	
Cloud top height	100	3 h	0.5 km	(1)
Cloud base height	100	3 h	0.5 km	(1)
Total liquid water content	100	3 h	20 %	
TOA net short-wave radiation	100	3 h	5 W m^{-2}	(2)
TOA net long-wave radiation	100	3 h	5 W m^{-2}	(2)
Multi-purpose IR/VIS imagery	5	30 min.	–	(3)

NOTES:

(1) Accuracy higher in planetary boundary layer.

(2) Required principally for model validation; not time critical.

(3) Required to assist real-time observation monitoring and analysis/forecast validation.

ATTACHMENT II.2

Typical end-user requirements for data

End-user group	Observing elements required by Meteorological Services to satisfy end-user requirements
Agriculture and food production	
Farming (including pest control, fertilization, frost protection, seeding, harvesting)	Temperature (maximum, minimum, extremes), precipitation (amount, duration, type), dewpoint/humidity, wind speed and direction at surface to 850 hPa, cloud cover, soil temperature, evaporation, solar radiation, special phenomena
Planning of land use, (crop yields, pest and disease control, microclimatic studies, forestry operations)	Precipitation (average amounts), temperature extremes, prevailing wind direction and speed, cloud cover, special phenomena
Aviation	
Commercial or government operated (on national or international basis) and general aviation	Upper winds, temperatures and tropopause from 850 hPa to 70 hPa Significant weather en route at 400 hPa to 70 hPa Terminal and approach zone including cloud base and visibility, significant weather, surface wind and low-level wind shear, turbulence, icing
Land transport	
Road and railway conditions (maintenance and safety)	Temperature, precipitation (type and amount), wind at surface, low visibility, state of ground

End-user group	Observing elements required by Meteorological Services to satisfy end-user requirements
<u>Marine resources and shipping services</u>	
Fishing, transport, off-shore, drilling and mining Coastal engineering activities and search and rescue operations	Over-ocean and near-shore surface winds, combined sea/swell, surface visibility, ice accretion, sea ice and icebergs, precipitation, cloud cover, air temperature and humidity, sea-surface temperature and salinity, mixed layer depth, tsunamis, storm surge and critical wave heights, sea-level measurements
Marine pollution	Surface wind direction and speed, wave-swell height and direction, sea-surface current direction/ speed, ocean or bay-estuary current deviations
<u>Hydrology and water resources</u>	
Flood control, hydropower production, navigation, irrigation pollution control, municipal and industrial water supply, recreational activities	Real-time measured and forecast variables: precipitation (total amount and form), air and wet-bulb temperature, height of freezing level, wind speed and direction, cloud image indicating tropospheric wind, tropicalcyclone or hurricane movement, snow cover (water equivalent, depth, density, surface temperature, temperature profiles), net radiation, pan evaporation, evapotranspiration, water temperatures (rivers and lakes), soil moisture, frost depth, river and lake ice (thickness, type, character)
<u>Industry</u>	
Construction (office, industrial, residential, highway)	Precipitation, freezing or high temperatures, low visibility, high winds (wind chill), frozen ground depth, drying conditions

End-user group	Observing elements required by Meteorological Services to satisfy end-user requirements
<u>Environmental monitoring</u>	
Air pollution	Temperature, humidity, wind speed and direction (at surface plus profiles in lowest atmospheric levels), precipitation (amount, time of commencement and termination)
<u>Energy</u>	
Electric energy generation (load factors, supply of water, exposure of power lines)	Maximum/minimum temperature, cloud amount and general cover, precipitation amount, wind speed and direction, icing and snow, severe weather (lightning), time series of wind speed, vertical profiles of temperature and wind speed
<u>Public services, health and safety</u>	
Extra-tropics	Maximum/minimum temperature, cloudiness, wind (comfort index), humidity, precipitation type and intensity
Tropics	Maximum/minimum temperature, precipitation, thunderstorms
Special storm warnings: tropical storm	Development, track and intensity over water plus land fall (place and time) and precipitation amount, winds, waves and storm surges and tornadoes over land
Severe weather warnings: tornado, heavy thunderstorm, heavy snow, hail/rain, storm winds	Movement of tornadoes and thunderstorms, extent and intensity of heavy snow, hail and rain, storm winds

End-user group	Observing elements required by Meteorological Services to satisfy end-user requirements
<u>Public services, health and safety</u> (contd)	
Recreational services (vacation, leisure, sporting events, parades, boating)	Temperature and humidity range, cloud amount, wind direction and speed, precipitation type and occurrence, weather conditions (e.g. thunderstorms, horizontal visibility, precipitation) and wave heights, period and direction
<u>Climatology and climate services</u>	
Research, monitoring of outstanding events/climate anomalies, applications in all sectors requiring climatological information either instantaneously (over last day to last 10 days) or over longer periods, description and analysis of climate and its variations	Variables contained in CLIMAT reports for rapid global dissemination and use; all variables observed for applications and case studies at local and regional levels; all variables for climate description

ATTACHMENT II.3

Performance of elements of the GOS achievable by the year 2005

(1) Upper air observations

Meteorological variable	Observing system	Horizontal resolution	Estimated coverage	Vertical resolution	Estimated vertical range	Frequency of observation	Observational error (RMS)
Horizontal wind vector	Rawinsonde + pilot	≥ 250 km	Best over land, limited over oceans and sparsely populated areas	0.3–1.2 km	*0.1–35 km	1–4/day	1–3 m s^{-1}
	Aircraft	100 km	Limited to regular flight routes	0.1 km	Cruise level + ascent/descent	1–24/day	1–3 m s^{-1}
	Wind profiler radar	≤ 250 km	Able to improve resolution over land	0.1–1.2 km	*0.1–20 km	1–24/day	1–3 m s^{-1}
	Satellite cloud and moisture motion winds	100 km	Most useful at low latitudes, largest errors for upper cloud	0.5–4 km (depends on cloud type)	At available levels	When available, maximum possible 24/day	2–8 m s^{-1}
Temperature	Rawinsonde	≥ 250 km	Best over land, limited over oceans and sparsely populated areas	< 0.1 km	*0.1–35 km	1–4/day	0.3–1°C
	Satellite remote sensing	50 km	Global coverage, but largest errors in cloudy locations	2–8 km	0–50 km	Minimum of 4/day	1–2°C
	Surface-based remote sensing	≤ 250 km	Used to improve resolution over land	0.2–1 km	*0–6 km	1–24/day	0.5–2°C
	Aircraft	100 km	Limited to regular flight routes	< 0.1 km	Cruise level + Ascent/descent	1–24/day	0.5–1°C
Relative humidity	Rawinsonde	≥ 250 km	Best over land, limited over oceans and sparsely populated areas	< 0.1 km	**0–12 km	1–4/day	** 5 %
	Satellite remote sensing	50 km	Global coverage	2–4 km	0–12 km	Minimum of 4/day	10 %
	Surface based remote sensing + aircraft	Operational systems under development, but performance characteristics not yet available					

* Vertical range depends on equipment used.

** Vertical resolution degraded at heights above 8 km to between 0.5 and 1 km, and observation error at 10 %.

(2) Surface observations

Meteorological variable	Observing system	Horizontal resolution	Estimated coverage	Frequency of observations	Observational error (RMS)
Sea surface temperature (T)	Satellite	10 km	Global	≤ 4/day	0.5°C
	Ship	250 km	Global shipping lanes		0.5°C
	Buoy	250 km	Global		0.2°C
Surface pressure (P) Temperature (T, T_d)	Conventional land surface network and land AWS	≤ 250 km	Global	1–24/day	0.2–1 hPa (P) 0.5°C (T,T_d)
Wind vector (V)	Ship (P,T,T_d,V) Buoy (P,T,T_d,V)	≤ 250 km ≤ 250 km	Global ocean (limited coverage of T_d by moored buoy)		1–2 m s^{-1} (V)
	Satellite (V)	50 km	Global ocean	2/day	(ERS-1 specs)
	Surface-based remote sensing (V) (HF radar)	10 km	Mainly coastal regions		
Precipitation amount	Conventional land surface network and land AWS	≤ 250 km	Overland	4/day	5 %
	Weather radar	10 km	Overland	1–24/day	
	Satellite	50 km	Global	1/day	

PART III

THE SURFACE-BASED SUBSYSTEM

PART III

THE SURFACE-BASED SUBSYSTEM

3.1 GENERAL

The surface-based subsystem is divided into "main" and "other" elements. The main elements of the subsystem include the regional basic synoptic networks which produce meteorological observations at the surface (surface stations) and in the upper air (upper-air stations). All of the upper-air and a selection of the surface weather reports are used for the global exchange of data.

The detailed list of stations is established to meet the requirements laid down by the regional associations which regularly review and revise the networks taking into account any new international requirements. The regional basic synoptic networks are composed primarily of land stations, manned or automatic, but may also include certain fixed sea stations.

The main elements of the surface-based subsystem also include additional surface and upper-air synoptic stations, including in particular fixed and mobile, manned and automatic sea stations and aircraft meteorological stations, the latter generally operating at non-synoptic hours. Stations on ships and aircraft are, of course, especially important for the provision of information from data-sparse areas.

The other elements of the subsystem comprise a variety of more or less specialized observing stations and include aeronautical meteorological stations, research and special-purpose vessel stations, climatological stations, agricultural meteorological stations and special stations.

3.1.1 Design of observing networks

In an observing network:

- The location of each station should be representative of conditions in space and time;
- The station spacing and interval between observations should correspond with the desired resolution of the meteorological parameters to be measured or observed;
- The total number of stations should, for reasons of economy, be as small as possible but as large as necessary to meet the various requirements.

The various properties of the airmass should in principle be sampled at a station covering the smallest possible area, although instruments should be positioned so that they do not affect each other's measurements. In selecting sites for stations, the intention is to obtain data which are representative of a larger area. Ideally, all measurements and visual observations at all stations would be made at the same moment, i.e. at a predetermined synoptic hour. However, as this is not practical, measurements should be made within the shortest possible time.

For the purpose of achieving uniformity, the following terms are used:

- Standard time of observation
- Scheduled time of observation.

In addition to these times, there will be an "actual time of observation", i.e. the time when an observation is actually carried out at the station. This time must not deviate by more than a few minutes from the "scheduled time of observation". Wherever parameters may change considerably within the period normally required for completing an observation, arrangements should be made to obtain information on critical parameters as close as possible to the scheduled time.

The station spacing should be such as to provide sufficiently accurate values for the meteorological parameters required at any point between two stations by means of visual or numerical interpolation, taking due account of the effects of topography on the variation of parameters of interest. The same consideration applies to time series of observations obtained at the same location, which require a relatively short distance between observing sites and an accuracy of measurement higher than that to be obtained by interpolation. On the other hand, a very dense network or high frequency of observation could lead to more data than are necessary and thus to unnecessarily high cost.

Variations in space and time differ for individual meteorological elements and also depend on the topography of the area. If any information is available or can be obtained on spatial or temporal variations, it can be used to decide upon the network configuration which is necessary to provide data of the required accuracy (see The Planning of Meteorological Station Networks, Technical Note No. 111, WMO-No. 265). For certain parameters such as precipitation, a separation of 10 km between stations may be required in some areas for several purposes (e.g. very-short-period forecasting, climatology, hydrological forecasting) although, in the case of rainfall, data from more widely separated weather radars will also satisfy many requirements. For parameters such as barometric pressure and upper winds, a separation of 100 km between stations will suffice. In general, a fairly homogeneous distribution of observing stations is most suited to support numerical analyses and forecasts. However, a relatively higher station density may be necessary to support local or area forecasting (e.g. to reflect the differences between coastal and inland conditions or valley and mountain weather) whilst a lower density is likely to be sufficient in regions of low population and little topographical variation.

It is generally not practicable, within one network, to achieve an optimization of such vastly differing requirements without severely prejudicing either operational and scientific requirements or economic considerations. The solution to this problem is to establish different types of networks within the subsystem, such as the regional basic synoptic network and its selected stations for global exchange, as well as stations established on a national level and the special networks observing "other elements". For details, refer to sections 3.2 to 3.9 below covering individual types of networks and stations.

3.1.2 Planning of networks and stations

When a national Meteorological Service has difficulties in solving a problem due to a lack of observations from within its own area of responsibility, it has first to assess which data are required and from whicharea, location or height. The next step in decision-making is to determine the type of network or station most suitable to provide the required data.

If a station is to be integrated into a network, its site has to be chosen primarily from the point of view of network configuration. This can be done by adding a task to or by shifting an existing station, or by the establishment of a new station.

The basic considerations for spacing stations within an optimized station network should also be borne in mind when developing a system of station indicators with consecutive numbers or letters. It is never practicable to install all the stations required for a network at once, and some indicators should be kept in reserve to fill the remaining gaps. If no such provision is made, new stations may create increasing chaos in the system.

For the study of small-scale phenomena arrangements of a non-network type will sometimes also prove to be adequate and at the same time more economical. These may apply to agricultural meteorological observations at a single representative station, or to precipitation measurements along a more or less straight line across a mountainous barrier providing typical values for the amounts of precipitation along the windward and leeward slopes.

The process of decision-making must include cost and benefit considerations. The most suitable method of achieving the highest cost-benefit ratio is normally the co-location of stations. This can be achieved by establishing a station of another type close to an existing one, or by gradually augmenting the task of a one-parameter observing station to a multi-parameter one. This may begin with the measurement of precipitation only and end up with a round-the-clock programme of a fully equipped surface and upper-air synoptic station requiring larger facilities and additional personnel.

Before establishing a new station, and if there is a possible choice of site, the following questions will help decision-making:

(a) Is the site representative for the required meteorological data?

(b) Will the site remain representative in view of existing or anticipated construction plans, change of vegetation, etc.?

(c) Can anything be done to improve or to safeguard the representativeness (e.g. cutting down of trees, reserving rights on building and plantation limits in the vicinity)?

(d) Is the site sufficiently accessible to personnel operating the station or carrying out inspection and maintenance?

(e) Does the site provide housing and storage facilities or can they be made available if required?

(f) Are facilities such as electric power, telecommunications, running water, etc. available if required?

(g) To what extent are security measures (against lightning, flooding, theft or other interferences) required and how can they be taken?

(h) Can difficulties of posting personnel be overcome by part- or full-time automation or by locally available staff? Part-time staff from public services are especially suitable for certain work at weather stations, as the continuity is assured, even by changes in the staff.

Furthermore, it is prudent to choose land that is in public or governmental hands, for there will be less chance of having to move the station later. A long-term contract should be established with the authorities concerned or with the landowner, if necessary with the help of an estate agent. The validity of the contract should be based on the usual international standard period for climatological measurements and have a duration of at least 30 years. It should prohibit changes (e.g. the construction of buildings) near the measuring site and should include provisions for the installation and operation of instruments and other necessary equipment and of transmission and power lines, as well as a regulation governing the right of access.

There is an understandable tendency to select as station sites land which cannot otherwise be utilized and whose cost is consequently relatively low. Only in very rare circumstances will such a site correspond with meteorological requirements, which should primarily determine the suitability of a site. It must be borne in mind that, in this regard, nothing is more costly and frustrating than long records of observation which subsequently prove to be useless or even misleading. One should therefore follow the rule: "The quality standard must be as high as necessary - the cost should be as low as possible".

More specific guidance on the location of the observing site will be found under section 3.2.1.2

3.1.3 Management of manned station networks

3.1.3.1 General

The responsibility for the management of a meteorological station network, the primary task of which is the production of data of the best possible quality, rests with the Member concerned. The Member should establish an appropriate organizational unit or units within the Meteorological Service with the responsibility for the operation, maintenance and supervision of the stations, as well as for logistics, procurement, supply and repair of equipment and other material necessary for uninterrupted operation. It should function as an operational unit within the Service, be responsible for the national standards and should have an appropriate status. It will also be necessary for this unit to maintain liaison and to co-ordinate its activities with the users of the data at the national level, as well as with the supporting services (administration and finance). A continuous survey of new technological developments is required with a view to introducing improved types of instruments, equipment and techniques.

3.1.3.2 Organization of the Station Network Management Unit

The organization of the Unit should take into account the size of the network. In the case of a country with very large networks it may be necessary to have a central Unit with subcentres. The location of such subcentres will depend on the needs of the Member. Economic considerations as well as problems of a technical and logistic nature such as personnel, communications and transport facilities will need to be taken into account.

A different approach to station management may be based on the specific functions of the stations forming the network (synoptic, aviation, climatological, agrometeorological).

The Unit must have at its disposal transportation to carry out its various activities.

3.1.3.3 Administrative arrangements

The Unit should have a system of files containing all relevant and up-to-date documentation of a scientific, technical, operational and administrative nature. A gazetteer of the stations with information on geographical conditions, staff and programmes of activities should be available.

The instruments at the station play a major role in the system and particular attention should be given to maintaining appropriate records relating to the instruments in use, including an up-to-date inventory of the equipment. The technical particulars of an instrument, its movement and the periodical test certificates should be available and carefully maintained.

Current reports in respect of the functioning of a station, such as breakdowns, faults, requests for repairs, needs of supplies and other matters requiring prompt action, should be stated in brief on an "action card". From the entries on this card action should be taken according to priorities.

A register (or log-book) of repairs should be kept to identify specific problems and to provide information on the movement of instruments from a station to the repair facilities of the Unit. According to the type of instrument (mechanical, electric, electronic or mixed) and the nature of the fault, various types of workshops and laboratories may be involved.

3.1.3.4 Personnel of the Station Network Management Unit

The personnel of the Unit must be qualified and specially trained for their work. In addition to the meteorological aspects, the personnel must be sensitive to the human aspect involved both within the Service and in their contacts with voluntary observers, private institutions or other government agencies outside the Service.

An experienced Class I/II meteorologist, hydrologist or engineer specialized in observing work should be in charge of the Unit. He should also be a good administrator and an able organizer. His main responsibility will be to produce the best observational information for the users, in the most economical way.

The Unit may be divided into smaller sections as necessary, for example, when the management of the network is undertaken on a geographical or on a functional basis (see 3.1.3.2). The chief of each section should also be a meteorologist (or hydrologist or engineer) with the best possible qualifications and experience, and should be capable of direct supervision of the field work.

Depending on the size of the station network, it is indispensable to have one or more inspectors who should be members of the meteorological staff (at least Class III) with experience in the operation of observing stations.

Provision should be made for technical staff comprising station network technicians and technical assistants. The former are specially trained to cope with all technical problems and activities connected with station management, involving tasks to be performed both in the field and at the duty station. The latter should be responsible for executing the technical tasks, which involve logistics and links with the stations.

Finally, the necessary clerical staff should be available for administrative work.*

3.1.3.5 Operational tasks of the Station Network Management Unit

The operational tasks are based on the activities and the performance of individual stations. The activities of a station are set forth in the prescribed programme which must be carried out according to a routine day-to-day schedule. The Unit should issue instructions relating to the correct application of standard procedures, the operation of the instrumentation (including the execution of reliability tests) and the use of official communication, and should provide relevant tables, forms and manuals. It should also issue directives regarding relationships with local users of weather data.

The Unit should appoint an inspector responsible for the activities of a group of stations, the quality of their observations and the smooth working of the instruments. A scheme should be worked out with the users so that the incoming observational data and all relevant charts and forms from a station are routinely checked for errors and the inspector responsible for the station notified accordingly. Information about malfunctioning instruments or requests for remedial action must be evaluated by the inspector so as to enable the Unit to rectify discrepancies and to ensure that the stations are operating properly.

Periodic reports of activities from the stations should be sent to the Unit.

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* For a description of the classification of meteorological personnel and their duties, see Guidelines for Education and Training of Personnel in Meteorology and Operational Hydrology (WMO-No. 258).

The personnel of the stations must be kept informed about the organization of the national Meteorological Service and especially about the station network. This can be done through a circular letter or a printed bulletin, which would also be a medium for the dissemination of communications or messages to and from the stations. Special attention should be given to recognizing such events as anniversaries, distinguished service and retirements.

3.1.3.6 Logistics and supplies

Each type of station should have its own standards for activities, equipment, instrumentation and operational procedures; these must be in accordance with the regulations of WMO and of the Member concerned. An up-to-date inventory of instruments, office equipment and other types of material at the station should be available.

An efficient communication system must be worked out within the organization to allow the smooth transmission of messages and information, with more than one type of communication medium if possible.

The meteorological assistant in charge of the station is responsible for its principal activities and for the upkeep of the instrument site. Vegetation around the station and within its perimeter must not interfere with the operation of the instruments. Installation, repair and major maintenance work on the equipment will be the responsibility of a maintenance crew from the Station Network Management Unit.

A system for ordering forms, charts and other expendables for the stations, preferably on a half-yearly basis, should be developed and implemented. Necessary supplies should be forwarded on demand to the station by means of a reliable system, bearing in mind that most of the material is fragile; special packing providing adequate protection (boxes, cardboard, cushion, pad) should be used as needed.

3.1.3.7 Establishment of a new station

The first action following the decision to establish a station is to visit the site. All the requirements must be assessed so as to ensure that the instruments to be installed can operate unhampered. It must be ascertained whether appropriate working conditions for the observer, office accommodation, and other required facilities such as running water, electricity and communications are available.

The Unit should prepare well in advance the instruments, equipment, supplies and material required for a new station.

The task of setting up a new station is assigned to a team including an inspector, a technician and assistants. The team should be trained for the specific job to be carried out in the most efficient manner according to a detailed standard plan.

During the installation of the equipment the necessary explanations should be given to the meteorological assistant to be placed in charge of the station to enable him to assume full responsibility for its operation.

A detailed report is to be written on the new station. This should include (preferably in the form of a check-list) a description of the site and its surroundings, accompanied by a drawing and an extract from a detailed map of the area. A visibility chart should be prepared for a surface station. The report should include details about instruments, their operation, test results, tables to be used and an inventory. It is recommended that pictures taken from the four main directions be included.

The operation and performance of a newly established station should be closely monitored by the Unit. The material which arrives after the first month of operation must be carefully reviewed. Following the checking of data and evaluation of any deficiency, further visits to the station may become necessary. Thereafter, a regular standard pattern of inspections should be adopted.

3.1.3.8 Regular inspections

Regular inspections, including routine maintenance activities at automatic stations, will help to ensure the smooth functioning of a meteorological station. A detailed schedule is to be worked out by the Unit, spacing the inspections according to national practices. The inspection should follow a standardized check-list whereby information accumulated from the previous inspection, relevant station files, notification by other users and, if necessary, from special inquiries made before departure will provide additional guidance to the inspector. Comparisons of instruments at the station should be included among the items requiring the attention of the inspector (see sections 3.1.3.10 and 3.1.3.11).

The findings of regular inspections should be documented in an inspection report which can be less elaborate than the report referred to in section 3.1.3.7. Copies of the report should be circulated to the users of the observational data within the organization, the administration and others involved in the activities of the meteorological station.

3.1.3.9 Other activities of the Station Network Management Unit

The Unit, having the technical "know-how", may be of assistance to other bodies outside the national Meteorological Service if requested. Such assistance may be provided in writing or by active participation in various projects involving the performance of instruments and the application of meteorology and operational hydrology.

3.1.3.10 Procurement of instruments and equipment

The equipment used in the station network of a Member should be in accordance with the requirements of meteorological instruments as laid down in the Guide to Meteorological Instruments and Methods of Observation (WMO - No.°8), section 1.4. These requirements are:

- Reliability
- Accuracy
- Simplicity of design
- Convenience of operation and maintenance
- Strength of construction.

The instruments should be standardized and suitable for operation under prevailing climatic conditions. The standard instrument should be carefully selected, taking into account both economic and technical considerations, so as to ensure introduction of the best possible type of instrument into the system.

Instruments should be introduced only following a series of comparison tests and other checks. Comparisons of instruments should subsequently be carried out during each regular inspection of the station. Portable standard instruments used by inspectors should be checked against the relevant standards used by the Service before and after each tour of inspection.

Once a decision has been made to procure a certain type of instrument, the necessary administrative steps should be taken. Testing procedures should be instituted following the arrival of the shipment to determine if the instrument deviates in any way from the national standard, particularly in the range of the operational scale. Test certificates will be issued for each individual instrument. An instrument which falls short of the prescribed accuracy should not be introduced into the system. A separate record card will be opened for each new instrument (see section 3.1.3.3).

A minimum stock of instruments to be used must be established; the personnel in charge of procurement must make sure that it is maintained at the required level. An emergency reserve is recommended, especially for items difficult to replace. The system for keeping the spare instruments should be technically well organized.

An ordering and issuing system should be introduced within the Service. It should be applied to all instruments delivered to the organization from an outside supplier and allocated, through the Station Network Management Unit, to individual stations in the network.

Constant efforts must be made to introduce improvements in the quality, performance and price competitiveness of the various supplies. In the case of equipment, the search for improved ideas and means is very important.

For perishable items, it is important to ensure that they are stocked properly and used regularly. In the case of items such as meteorological balloons or batteries, quality tests should be made from time to time.

A computerized information system may be of great advantage in managing the equipment. In organizations where these facilities do not exist, a manual follow-up system must be implemented.

3.1.3.11 Instrument checks and maintenance

A system for checking the instruments at a station regularly should be introduced so that faults can be discovered at an early stage. The system should include regular reliability tests. If faults are discovered or suspected, the Unit should be notified immediately. Depending on the nature of the fault and the type of station, the Unit will decide whether the instrument is to be changed or a field repair carried out.

The inspector responsible for the station is to assist the Unit in keeping the instruments in the best possible working order and in carrying out periodic comparisons with the national standards. (See also sections 3.1.3.8 and 3.1.3.10.)

3.1.3.12 Co-ordination

In addition to the circulation of inspection reports within the divisions or sections concerned and the notification of discrepancies or likely errors in the observational data, close co-ordination between the various users of the observational data in other branches of the organization and the Unit should be arranged. Periodic meetings should be held to discuss and decide on any improvements or changes which may be desirable. Appropriate working arrangements within the Unit for repairs of different types (e.g. electrical, mechanical), including familiarization with new equipment, will also be necessary.

3.1.3.13 Planning and budgeting

Planning, which should be short-term (one to two years) as well as medium- and long-term (five years or more), is concerned mainly with changes and improvements in the system, priorities to be set, development and new technology. Because of financial implications, the cost-effectiveness of any new type of equipment will be an important factor to be taken into consideration. Decisions on planning may have important effects on the organizational structure for management of the station network and requirements in terms of personnel and training.

3.1.4 Management of automatic surface land station networks

3.1.4.1 General

Due to the fact that automatic meteorological land stations are normally used to augment a basic manned station network, the management of automatic station networks should, in principle, follow the same general rules and practices as for the management of manned station networks (see section 3.1.3). This is to guarantee the acquisition of an observational data set with comparable quality and accuracy, as can be achieved by a manned station network.

Complementary information on automatic stations can be found in section 3.2.1.4 as well as in the Guide to Meteorological Instruments and Methods of Observation (WMO-No. 8).

For reasons of compatibility and homogeneity of data generated by automatic stations with similar data from manned stations, the responsibility for the management of an automatic station network should rest with the same organizational unit or units within the meteorological authority responsible for the management of manned station networks. The main aim should be to implement a composite observational system of consistent quality on a global, regional and national level.

3.1.4.2 Administrative arrangements

The Station Network Management Unit should have access to all technical details of both the configuration and the sensor files for each automatic station installed in an operational network.

Experience in operational system evaluations and scientific networks studies have shown that the preparation of national operating instructions for weather stations equipped with devices for automatic data acquisition is essential for the satisfactory employment of new components such as automatic weather stations.

In view of the special position of an automatic weather station (AWS) within the flow of data from the observing site via collecting and/or coding centres to the national data-processing centre, there are many system features that must be taken into account when preparing the necessary guidance material.

Since the technology used in automatic weather stations is evolving rapidly, more emphasis should be placed on new areas of automation, e.g. in the field of data acquisition, processing and local archiving techniques for meteorological measurements. In an automated system a large number of different algorithms are used to define the quality-control routines: to evaluate with appropriate smoothing the physical quantities from the digital measurements; and to translate the resulting list of measured quantities into the WMO-code format. Standardization on an international basis remains to be achieved.

3.1.4.3 Operational tasks of the automatic station network supervising unit

The operational tasks of the network supervising unit may vary according to the type of automatic station used.

(a) Supervision of a semi-automatic station network

Analogous to the manned station network, instructions on how to apply standard procedures must be prepared, made available and strictly adhered to by the personnel in charge. The instructions should include guidance on the operation of instrumentation, as well as on preventive maintenance measures and, where feasible, may include small repairs of some automatic instrumentation or sensors done at observing sites. The unit should perform regular inspections of these stations in order to check the operation of automatic instruments or sensors.

Where appropriate, a diagnostic check of the operation could be carried out together with the data quality control at the national data-collecting centre. Information on possible malfunctioning should be transmitted as soon as possible to the maintenance experts.

(b) Supervision of a fully automatic station network

Since the technology used in automatic surface observing systems is complicated, the unit may need to consult specialists in order to address various problems in electronics, software, telecommunications and sensor-engineering. It is useful for the unit to be involved in the management of the network from the initial stages of its deployment starting from delivery, site preparation, check-out and activation. It should have access to all documentation concerning equipment, system configuration, site specification, software system and engineering services.

To ensure the reliability of sensors, data-acquisition systems and quality of data, the staff should be provided with guidance material on both manned and automatic test requirements. For remote automatic tests, equipment control procedures may include duty-checks performed on a daily schedule. Nevertheless, regular on-site instrument comparisons and inspections are needed to guarantee proper functioning of the automatic station network.

The unit should provide engineering support for the operation of the network and guidance material to the technical staff. Likely modifications, additions and site relocations of the system in the future also demand engineering support and in some cases revised versions of operational software. Operational tasks of the automatic station network supervising unit also include the organization of training courses.

3.1.4.4 Establishment of a new automatic station

(See section 3.2.1.4.4.)

3.1.4.5 Data acquisition checks, quality control and maintenance

(See section 3.2.1.4.5.)

3.2 SURFACE SYNOPTIC STATIONS

3.2.1 Organizational aspects

3.2.1.1 General

Surface synoptic stations may be on land or at sea, manned or automatic. For the purpose of the present Guide, surface synoptic stations are dealt with under three categories, namely land stations, sea stations and automatic stations.

The establishment of a network of stations, their operation in accordance with the prescribed standards, and their maintenance involve many questions of an organizational nature of varying degrees of complexity, depending on the type of station, its location, functions, instrumental equipment, communication links for the transmission of the data and requirement for trained personnel of different levels. The broad aspects of such questions, as they apply to each type of station falling under the three categories of surface synoptic station referred to above, are discussed in sections 3.2.1.2, 3.2.1.3 and 3.2.1.4 below.

3.2.1.2 Land stations*

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* The requirements for the siting of stations and instrument exposure given in this section apply to an 'ideal' situation, which should be attained where possible. It is understood that these requirements cannot always be fully met for one reason or another.

3.2.1.2.1 Siting (location) of stations

Each station making surface synoptic observations should be located at a site where the meteorological data obtained are representative of the state of the atmosphere over a large region. The dimensions of this region, or area of representativity, may range from 2 000 km^2 to 10 000 km^2 (for a plane or homogeneous relief).

The station should have a plot of land specially assigned to it. The optimum area is approximately 1 ha.

The location of the observing posts (meteorological instrument area) should be typical of the physico-geographical conditions of the surrounding area and protected from the influence of industry. It is therefore necessary to locate a meteorological instrument area in an open site far from any constructions or woods. The minimum distances from constructions and groups of trees should be greater than 10 times and 20 times their heights respectively. The site should also be farther than 100 m from bodies of water, except where coastal measurements are required.

3.2.1.2.2 Meteorological observing area

The meteorological observing area is where most of the instruments and devices are situated. The observing area should preferably be no smaller than 25 m x 25 m where there are many installations, but in cases where there are relatively few installations (as in Figure III.1) the area may be considerably smaller. The sides of the observing area should be oriented north-south and east-west. An adequate north-south dimension is very important for measurements which can be strongly influenced by shadow (e.g. radiation, sunshine duration, temperature gradients just below and above the gound).

The instruments and equipment should be set out in a definite order, in several rows or lines. In the northern hemisphere the sensors are arranged as follows: wind-measuring equipment on the north side, along with temperature and humidity equipment, then a row of precipitation gauges with soil temperature measurement taking place in the southern part of the observing area. Figure III.1 provides an example of the layout of an observing station in the northern hemisphere showing minimum distances between installations.

The meteorological observing area should be fenced, but not with solid fencing material; large-mesh wire netting is the most suitable while palings, picket fences, hedges, clay enclosures, etc. are unsuitable. In the Arctic, desert and certain other regions, the observing area may not need to be fenced and may simply be marked out.

The surface of the observing area must be left in its natural state (grass should be kept down to 20 cm). The area should not be walked on except along paths or tracks. Paths should not be of asphalt or concrete. In the interest of safety, the electrical voltage supplied to the equipment shall not exceed 24 or 36 volts. Installations should preferably be painted white (any other colour may be used for masts and fencing).

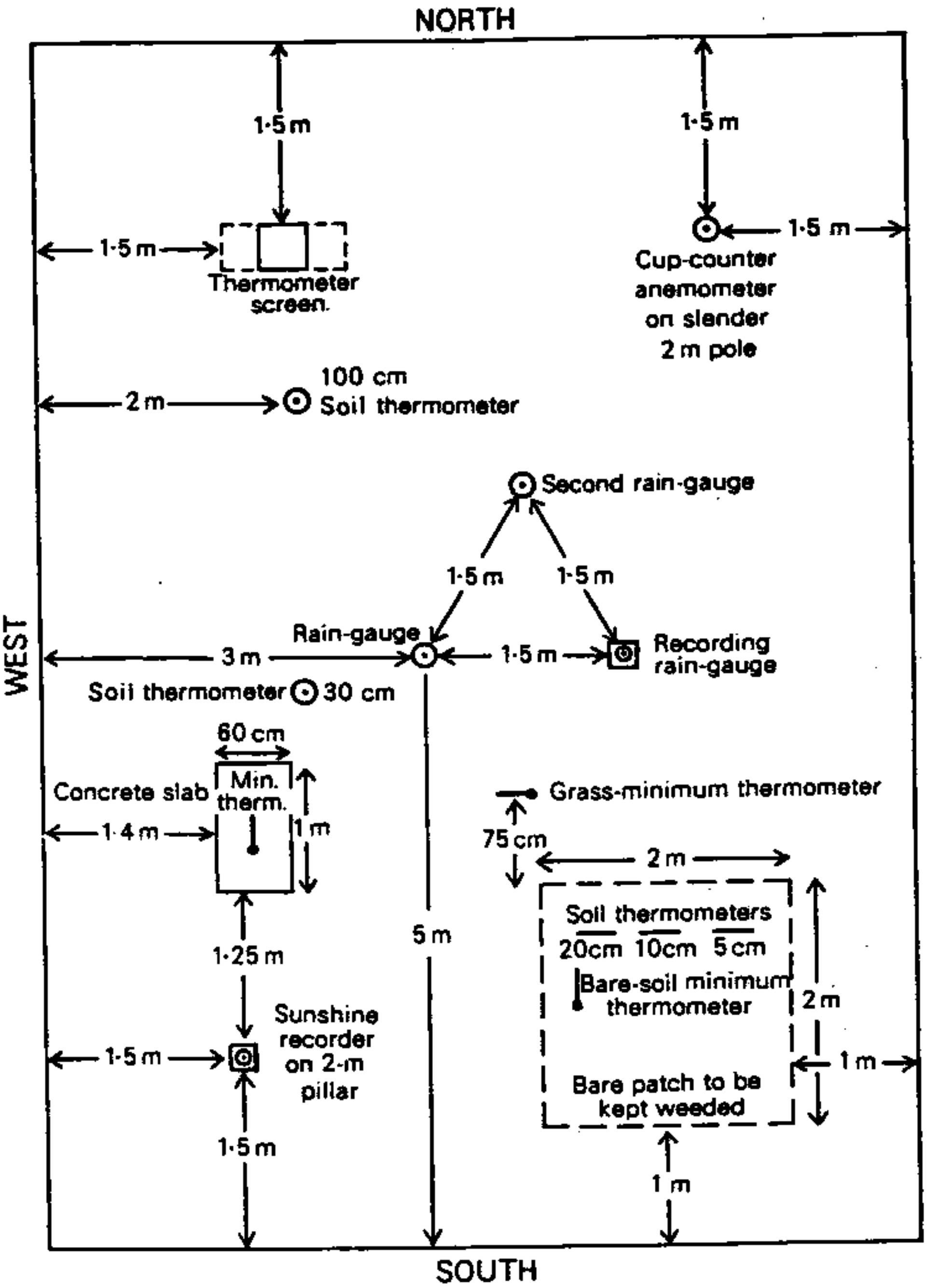

Figure III.1– Layout of an observing station in the northern hemisphere showing minimum distances between installations

(Source: UK Meteorological Office, Observer's Handbook, 4th edition, 1982)

Furthermore, it is desirable to provide special protected zones around the plots (extending about 200 m in all directions from the boundaries of the station area, if this area covers one or several hectares) which shall, where possible, be left unchanged, and whose use shall be agreed with the national Service.

Particular attention should be given to the following points in selecting the site for the measurement of precipitation:

(a) Any method of measuring precipitation should aim at obtaining a sample representative of the true amount falling over the area which the measurement is intended to represent. The choice of site, as well as the systematic measurement error, is therefore important;

(b) In choosing a site, the systematic wind field deformation above an elevated gauge orifice, as well as the effects of the site itself on the air trajectories, should be considered;

(c) For each site the average vertical angle (a) of obstacles should be estimated, and a site plan made. Sites on a slope or on the roof of a building should be avoided. The surface surrounding the precipitation gauge can be covered with short grass or gravel or shingle, but hard flat surfaces such as concrete should be avoided to prevent excessive in-splashing;

(d) In areas where there is homogeneous dense vegetation, such vegetation should be clipped regularly to keep it at the same level as the gauge orifice;

(e) Sites selected for measurement of snowfall and/or snow cover should be sheltered from the wind as much as possible. The best sites are often found in clearings within forests or orchards, among trees, in scrub or shrub forests, or where other objects act as an effective windbreak for winds from all directions.

3.2.1.2.3 Observatory premises

To ensure normal operations, each station should be provided with premises suitable for the working staff, with optimum floor space, heating and/or cooling system as required, safety and fire-fighting equipment and an emergency electricity supply.

3.2.1.2.4 Personnel of observing station

Every station must be provided with personnel whose number and functions are established in conformity with the Member's regulations and standards, and taking into account the programme of observations and other work carried out by the particular station. The work at principal land stations should preferably not be interrupted between the observation times.

A station working around the clock to collect and transmit emergency information on dangerous weather phenomena, in addition to the standard observations carried out at the eight synoptic times, usually has a staff of five. For a station that only carries out observations at the eight synoptic times and that is not continuously attended, three are sufficient.

The official titles of staff (e.g., senior technician, technician, senior observer and observer) are determined in accordance with the type and importance of the data gathered by the station, the degree of complexity of the measuring equipment used, the duties of the staff and the practice followed by the national Service.

Observers who are not full-time officials of a Meteorological Service but are designated to make the meteorological observations at any synoptic station shall be certified by the appropriate Service as having competent knowledge of observing instructions and being capable of observing meteorological elements with the accuracy required. Similarly, Meteorological Services should certify the competence of any other observers who are responsible for meteorological observations.

3.2.1.2.5 Training of station personnel

Each station should be provided with trained personnel to at least WMO Class IV level. Training of meteorological staff and other specialists for work at the station is arranged by the Member either within the country or by making use of appropriate courses abroad. In addition to the original training in the specialization, staff should undergo periodic refreesher course in order to maintain their efficiency. General and specific guidelines on personnel training are contained in relevant WMO publications.

In order to ensure reliable observations and information, it is recommended that the observing personnel be trained to the following levels:

- Chiefs of meteorological stations making standard observations (see section 3.2.2 below): intermediate specialized training (completion of a technical college or its equivalent);

- Technicians selected amongst the most experienced of the junior technicians or observers: same as above;

- Junior technicians (or observers): special training (or courses at special schools) lasting no less than six months.

NOTES: (1) It is possible for stations to have one or two observers trained on the job at the station itself (for no less than one month), preferably with subsequent training by attending courses at special training centres or by correspondence).

(2) For a description of the classification of meteorological personnel and their duties, see Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology (WMO-No. 258).

Stations should be provided with all necessary documentation, manuals, guides, other instructions and guidelines to which all staff should have access and which they should study regularly.

3.2.1.2.6 Identification of stations

A surface station included in the regional basic synoptic network shall be identified by a station index number assigned by the Member concerned in compliance with the scheme prescribed in the Manual on Codes (WMO-No.306). The general list of station index numbers together with their observing programmes and other relevant information is published by the WMO Secretariat in Volume A of WMO-No. 9. Each Member operating synoptic stations is required to send to the WMO Secretariat the necessary information for this purpose in compliance with the procedure laid down in the Manual on the GOS, Vol. I, Part III, Regulation 2.3.8.

Each Member should keep an updated list of the synoptic stations on its territory, giving the following information for each station:

- Name and geographical co-ordinates (in degrees and minutes of arc), station index number;
- Elevation in whole metres (elevation of barometer above sea level);
- Category and observation programme;
- Brief description of surrounding topography;
- Exposure of instruments, in particular height above ground of thermometers, raingauges and anemometers;
- History (date of the commencement of regular observations, transfers, interruptions in observations, changes of name and any substantial changes made to the observation programme);
- Name of supervising organization or institution;
- Datum level to which atmospheric pressure data are reduced.

3.2.1.2.7 Telecommunications

All stations shall be provided with means of telecommunication to transmit their data as fast as possible to meet the needs of both forecasting services (global, regional and national requirements) and of local users (on a permanent basis and on request). The equipment used at the stations for transmitting and receiving information may be of various kinds: telephone, telegraph, radio and others. General and specific guidelines for the collection and transmission of information are contained in the Manual on the Global Telecommunication System (WMO-No. 386).

In any case, each synoptic station whose reports are included in the list for international exchange shall be provided with such telecommunication equipment as will guarantee regular and reliable transmission of the necessary reports and other information to the established addressees of messages.