AVAILABILITY AND QUALITY OF OBSERVATIONAL DATA

H. Böttger
European Centre for Medium-Range Weather Forecasts
Reading, U.K.

1. INTRODUCTION

Numerical weather prediction has seen some spectacular developments over the last 10 years. Forecasts of all parameters and on all scales have improved. Using the anomaly correlation of the mid-tropospheric height field as a measure of skill then the range of predictive skill for operational forecasting systems has been extended to 6 to 7 days in the Northern Hemisphere, 5 to six days in the Southern Hemisphere and 2-3 days in the Tropics, depending to some extent on the season and the region. Improvements of the forecast models, the analysis schemes including better use of more data, have been supported by enhanced and more powerful computer systems.

Today global models operate with grid lengths of approximately one degree compared with three to four degrees 10 years ago. The vertical resolution has increased simultaneously, with some models using up to 20 levels for the vertical description. The parametrization of physical processes has become far more sophisticated, including a comprehensive description of boundary layer fluxes, turbulent exchange in the free atmosphere, radiation and the hydrological cycle. All these physical processes are vitally important for medium-range and extended range forecasting and deficiencies in the parametrization may have a detrimental effect on the forecast and will lead to significant systematic errors.

It is expected, and experimentation is well advanced, that a further increase in model resolution and an even better description of physical processes will be implemented at several centres over the next years. Plans at ECMWF are to operate a model with 31 vertical levels and a 50 km equivalent grid spacing within two years' time. Such models require, in order to perform at their level of capability, data which match the resolution and support the physical parametrization. Satellite data are expected to fulfil many of these requirements. They provide the global 3-dimensional profiles to the mass, wind and moisture fields complementing the essential but inhomogeneously distributed conventional observations. Essential lower boundary information is required for the current operational models. It is expected that advanced remote sensing techniques and processing methods will provide global information on snow coverage, depth and moisture content, soil moisture, surface temperatures, soil temperature and vegetation coverage and type.

However, as it is presented elsewhere in these proceedings, the satellite sounding and wind data have their deficiencies, which mean that the conventional observational network of radiosonde and synoptic surface stations still provide the backbone of the global observing system.

This paper gives an overview of the trends in data availability and highlights by means of some example how data deficiencies will have an impact on the analysis and forecast system. The emphasis in this paper will be on the conventional data while the satellite data are dealt with in contributions by G. Kelly in these Proceedings. The final chapter provides an outlook on data from new observing systems for numerical weather prediction.

2. THE ECMWF DATA MONITORING SYSTEM

In order to manifest the deficiencies in the availability and quality of the observations, ECMWF undertakes regular data monitoring of all observations types. The system was first described by F. Delsol (1984) and has since been developed further. The main components are

(i) real-time monitoring
(ii) monthly statistics and summaries
(iii) long-term trends in the performances.

While most of the real-time monitoring tools have been in operational use at ECMWF for several years, new tools were developed to assess the long-term trend of data availability and quality at individual stations and to display the results in geographical maps to facilitate a cross-reference between stations. Although the ECMWF monitoring is general and is applicable to any data type, it is acknowledged that the global radiosonde network is of primary importance not only for numerical weather analysis, but also for the calibration of other observing systems providing data from the free atmosphere such as the satellite sounding measurements.

The ECMWF monitoring system is based on the feedback on data quality from the data assimilation system (Hollingsworth et al., 1986) and has previously been documented by Radford (1987).

3. LONG-TERM TRENDS IN DATA AVAILABILITY

While the number of conventional observations, which are available from the Global Observing System of the WMO, actually decreased after the very active FGGE period, there are indications that the actual number of observations exchanged over the GTS has begun to increase again. Table 1 summarises for the years 1981, 1985 and 1989 the number of reports received at ECMWF for the main synoptic hour 12 UTC within a data window of ± 3 hours for off-time data which is the operational practice for the use of observations in the ECMWF data assimilation. The striking fact is the large increase in the number of reports from drifting buoys. In 1981 the after FGGE minimum had been reached and since then many new buoys have been deployed and are regularly renewed. However, it should also be noted that the number of SYNOP, TEMP and PILOT reports has increased by approximately 10%, which has mainly been achieved by improved data exchange mechanisms. Similarly, the increase in observations from ships and aircrafts reflects the higher number of observations injected onto the GTS rather than an increase in observing platforms. Data producers and distributors are becoming more and more aware of the global data requirements. The only way to meet these requirements at least partially is to ensure the timely and complete data exchange from the existing observation system.

Table 1 Number of global observations received at ECMWF for 1200 UTC with a data window of ± 3 hours

	1981	1985	1989
SYNOP	6,000	6,000	6,800
SHIP	800	1,050	1,200
DRIBU	120	200	350
TEMP	600	600	650
PILOT	200	220	225
AIREP	350	800	1,600

Unfortunately, there is evidence from recent WMO monitoring statistics presented in Tables 2 and 3 that in some WMO regions the positive trend in data availability is stagnant or even reversed. In particular the availability of TEMP and SYNOP data from Region I, Africa, has been reduced from 1987 to 1988. It should, however, be acknowledged that in particular in Africa the lack of resources, such as consumables, poses great difficulties for some countries to fulfil their announced observing schedule.

According to the WMO Second Long-Term Plan observations are required at a horizontal resolution of 100 km to obtain optimum results from global models by the late 1990s. In the same plan the basic set of the global observational data requirements which generally can be met by the GOS specifies the horizontal resolution as 250 km both for in situ and

Table 2 (Source: WMO, Geneva)

Average number of TEMP reports included in the global exchange list available each day at MTN centres

Monitoring period	Region I	II	III	IV	V	VI	Total
October 1986	48	526	18	270	84	258	1204
October 1987	63	513	32	269	89	248	1214
October 1988	58	523	33	264	102	265	1245

Percentage number of TEMP reports included in the global exchange list available at MTN centres out of the number of TEMP reports expected

Monitoring period	Region I	II	III	IV	V	VI	Total
October 1986	43%	85%	34%	91%	72%	92%	82%
October 1987	57%	85%	50%	91%	76%	90%	82%
October 1988	52%	85%	51%	85%	81%	91%	81%

Table 3 (Source: WMO, Geneva)

RESULTS OF THE ANNUAL GLOBAL MONITORING OF THE OPERATION OF THE WWW
Average number of SYNOP reports included in the global exchange list available each day at MTN centres

Monitoring period	Region I	II	III	IV	V	VI	Total
October 1986	1091	2424	730	1114	875	1030	7264
October 1987	1102	2461	750	1135	844	1021	7313
October 1988	886	2370	737	1129	874	1010	7006

Percentage number of SYNOP reports included in the global exchange list available at MTN centres out of the number of SYNOP reports expected

Monitoring period	Region I	II	III	IV	V	VI	Total
October 1986	54%	80%	70%	80%	77%	94%	76%
October 1987	57%	82%	72%	83%	75%	93%	77%
October 1988	45%	79%	70%	82%	78%	93%	73%

remotely sensed data. For comparison, Fig. 1 shows the global monthly averaged data coverage for July 1989 based on conventional data only. The symbols indicate the lack of observations in 5 x 5 degree boxes, falling below 30 observations per month at any level in the vertical column, thus ignoring the GOS requirements for sufficient resolution in the vertical.

Satellite sounding and wind data will, of course, provide the observation with the appropriate global coverage. Table 4 gives the historical and projected global data points from polar orbiting satellites. Such observations incorporated into Fig. 1 would leave no gap in any of the boxes. However, as studied recently by Pailleux et al. (1989) the quality of the satellite data does not meet the requirements of the present data assimilation system. Therefore they have to be excluded, in particular, in areas which are vitally important for meteorological developments such as in the jet stream area.

Table 4 Satellite Data for Numerical Weather Forecasting

	Horizontal spacing	Observation points	Data Volume
NOAA TIROS-N Series (NOAA-10 and 11)			
1980	500 km soundings	4,000	1 Mbyte
1985	250 km soundings	18,000	2.5 Mbyte
1989	80 km soundings and cleared radiances	160,000	20 Mbyte
1990/91	30 km raw radiances	1,500,000	180 Mbyte
DSMP Series (F-8 and 9)			
1988	175 km soundings	18,000	2.5 Mbyte

4. IMPACT OF BAD DATA ON THE ANALYSIS

One of the key issues for successful medium-range weather forecasting is the availability of good quality global data sets. Data deficiencies will have an impact on the analysis and the ensuing forecast (Pailleux, 1987, Böttger, 1987). The ECMWF monitoring system was set up to identify problems with the data and errors in real-time to eliminate such data before entering the analysis system. Examples are the time continuity checks on ship tracks or on

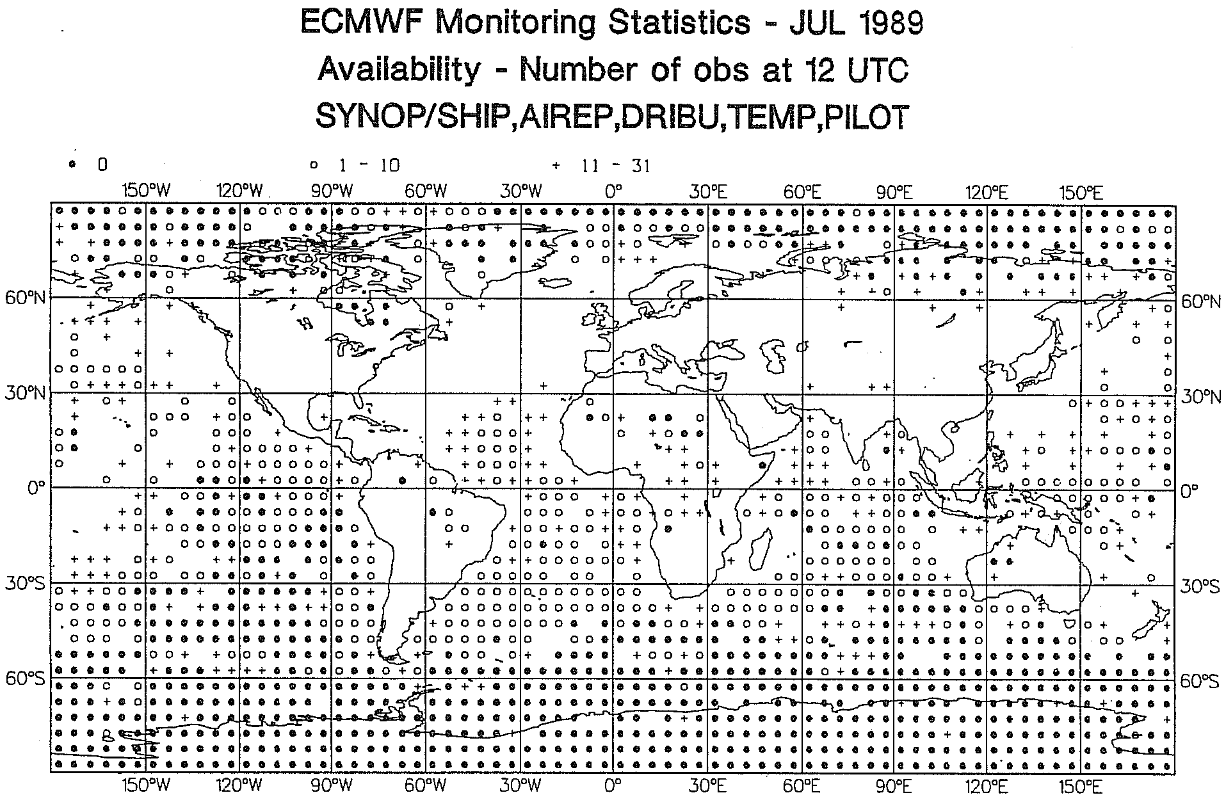

Fig. 1 Availability of conventional meteorological observations excluding satellite data in 5 x 5 degree boxes; white areas indicate a minimum of 30 observations at 12 UTC ± 3 hours in July 1989. The symbols indicate the lack of data according to the legend.

the recent history of surface pressure reports from ships and their departures from the first-guess. Isolated ships tend to have a significant impact on the analysis which, in case of an erroneous observation, is most undesirable.

Since the loss of most of the Ocean Weather Ships the Automatic Shipborne Aerological Programme (ASAP) has provided TEMPSHIP observations which, in the early stages, were a major cause of concern because of transmission errors coding problems and other deficiencies such as incomplete bulletin transmission. Although many of these deficiencies have since been removed, some problems still remain and need to be detected if at all possible. Two examples should be given:

(i) incomplete or erroneous call signs make time continuity or other error check very difficult or impossible. Re-transmission of a bulletin with different call signs generates two independent TEMPSHIP observations;

(ii) re-transmission of identical reports with new dates will definitely generate erroneous analysis input unless trapped by real-time monitoring.

Figs. 2a and b show how erroneous marine surface observations, surface wind in this case, will have a detrimental effect on the analysis. The case was documented by A. Rubli in ECMWF Newsletter No. 47, September 1989, p. 14-16:

"As a part of the national US-TOGA project, NOAA's Pacific Marine Environmental Laboratory (PMEL) operates a set of moored buoys (type ATLAS) in the tropical Pacific. The data are disseminated on the GTS and the wind observations used by the ECMWF data assimilation system.

In Figs. 2a and 2b the first-guess respectively the analysis field (wind arrows) are plotted together with the corresponding ATLAS reports (wind flags). The first-guess predicts a uniform easterly wind field. The analysis adjusts the first-guess field in order to bring it as much as possible in accordance with the reported westerly winds. The easterly flow is not turned in a westerly, but the impact of the bad data causes weakening of the wind field and the uniform easterly tradewind flow is therefore disturbed in the area of the buoys.

The problem was brought to the attention of PMEL and NMC Washington where the observations are inserted onto the GTS. It had been detected independently in the US. The wind observations were temporarily excluded from the ECMWF analysis and, at a later stage, also the transmission on the GTS was suspended."

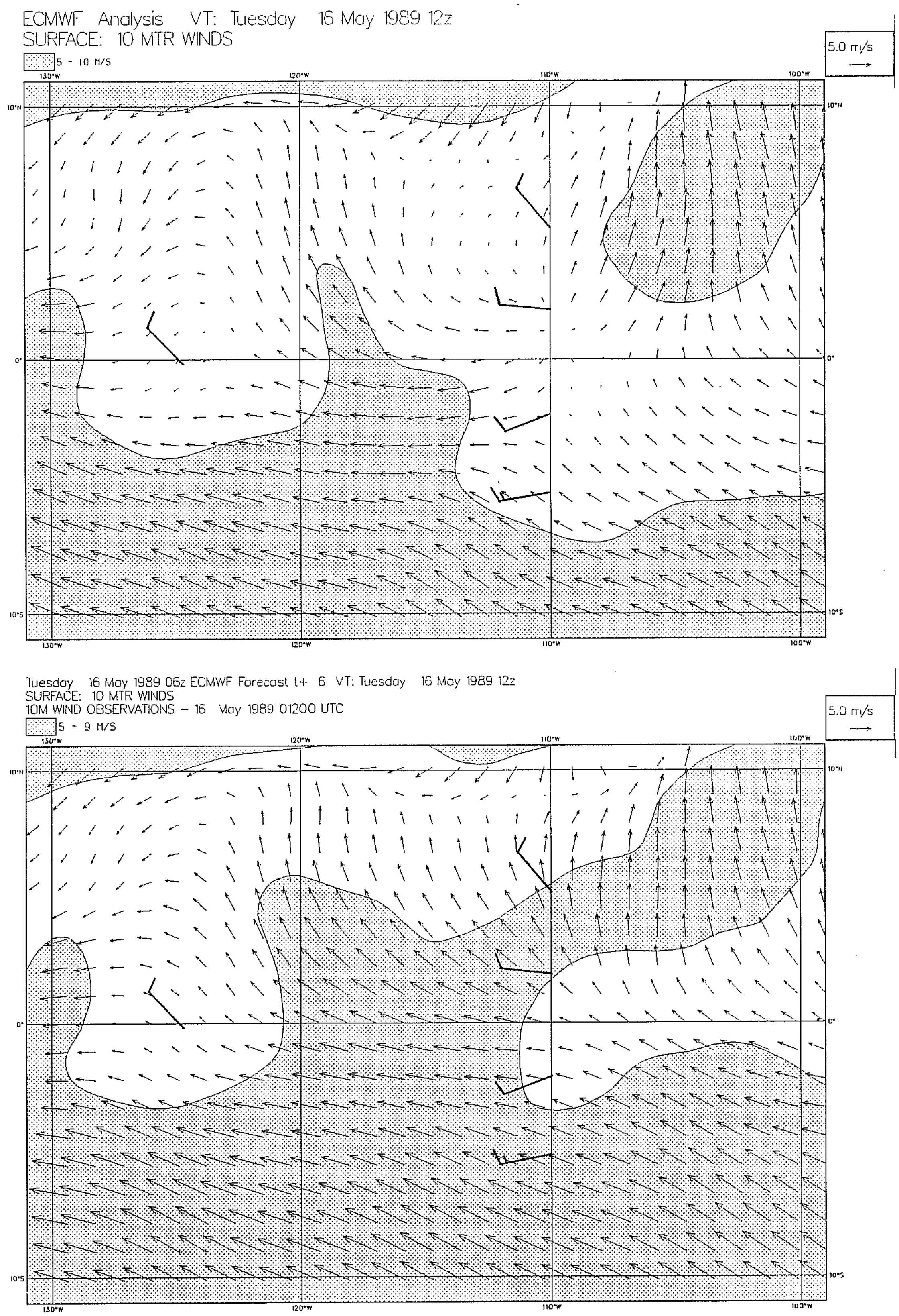

Fig. 2 First-guess and analysis of the 10m wind field (wind arrows) on 16 May 1989, 12 UTC, plotted together with the corresponding reports from the ATLAS buoys (wind flags)

The mean analysis increment field for the surface wind in June 1989 over the central Pacific confirms that the erroneous observations along the Equator had a negative impact on the analysis which is reflected in the mean increments coinciding with the position of the ATLAS moorings.

5. FUTURE DATA REQUIREMENTS

For numerical analysis and forecast systems to perform at the highest levels, they require initial and verification data which match both the resolution of the model and the parametrised physical processes. With the expected increases in the resolution of global models and the increasing sensitivity to the lower boundary conditions, a wealth of observational data is required for global exchange which is either not included in the present specification of requirements for global data exchange within the World Weather Watch of the WMO or has not even become available as it is based on new technology such as atmospheric profilers or instrumentation on satellites. The following requirements can be foreseen:

1000 hPa Mean AN–FG Increment (m/s) at 0 UTC
Between 1/6/89 and 30/6/89

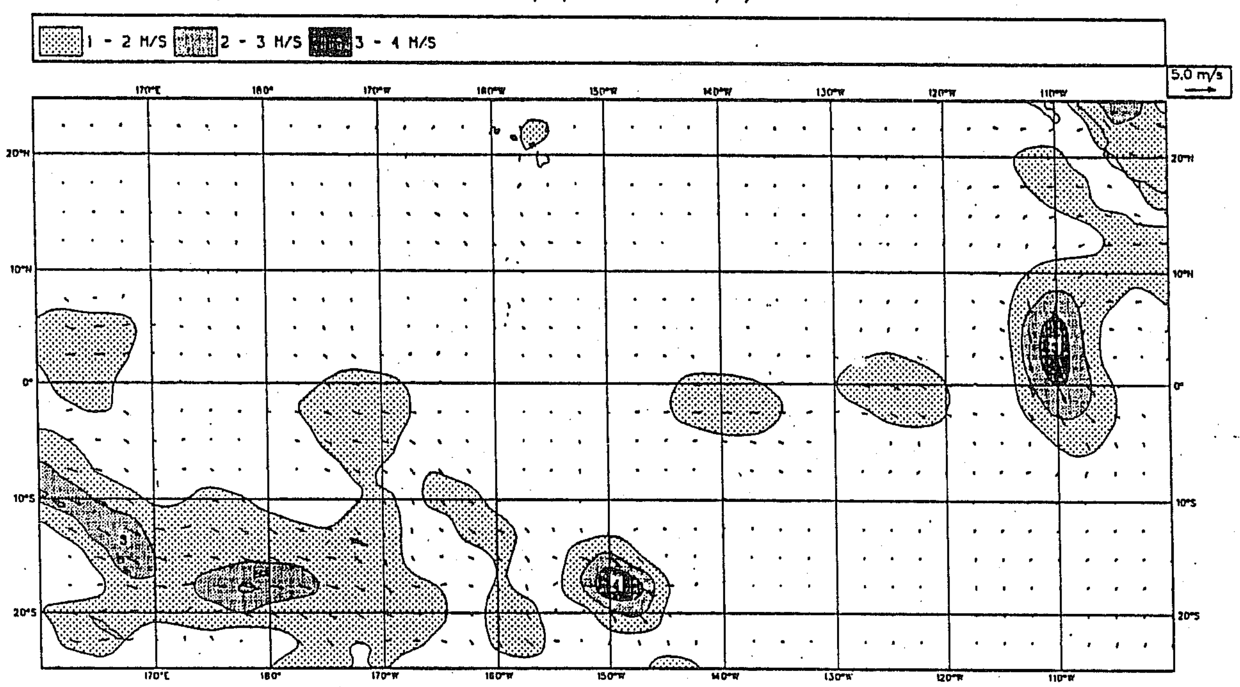

Fig. 3 Mean analysis increments for June 1989 at 00 UTC of the 1000 hPa wind field.

(i) Conventional data types

All observations from the surface and the free atmosphere, such as SYNOP, DRIBU, TEMP, PILOT, AIREP should be exchanged globally. Modern data assimilation systems can, to an increasing extent, utilise a-synoptic data either directly in the assimilation or for quality control purposes. Even synoptic systems which are on scales relevant for global analysis require observations at hourly intervals, if obtainable. For example, hourly SYNOP and profiler data are expected to lead to a significant improvement towards capturing explosive cyclogenesis in the analyses.

(ii) Satellite data

Meteorological data volumes will in future be dominated by remotely sensed data from satellites. In 1989 sounding and cloud cleared radiance data became available for operational forecasting from the polar orbiting satellites of the NOAA series. Initially the capacity of the telecommunication links will allow the transmission of the cloud cleared radiance data at only 80 to 120 km spacing, but during 1990 the reception of the raw radiance data at full resolution (30 to 45 km spacing) is anticipated in Europe. Environmental data, primarily water vapour, liquid water and rainfall rates derived from microwave instruments (SSM/I) on polar orbiting DMSP satellites, will also be received in real-time through special telecommunications arrangements with NOAA and the United Kingdom Meteorological Office. Wind related observations in the troposphere will be obtained from the geostationary satellites. Altimeter measurements from GEOSAT and scatterometer data from ERS-1 will provide surface wind information.

These data will be augmented during the period 1990-93, exploiting the opportunities presented by the potential increase in data availability resulting from the advanced microwave sounding unit AMSU on the NOAA-KLM series, additional VAS data from the GOES series and the launch of Earth Resource Satellites such as ERS-1, MOS-2 and the selected carrier for the American scatterometer NSCAT.

References

Böttger, H., 1987: Forecasts of locking and cyclone developments - operational results during winter 1986/87. ECMWF Seminar, Proceedings 1987, Vol. II, pp. 317-328.

Delsol, F., 1984: Monitoring the availability and quality of incoming GTS observations at ECMWF. ECMWF workshop on the use and quality control of meteorological observations, 1984.

Hollingsworth, A., Shaw, D.B., Lönnberg, P., Illari, L., Arpe, K., and Simmons, A.J., 1986: Monitoring of observation and analysis quality by a data assimilation system. Mon. Wea. Rev. (114) 861-879.

Pailleux, J., 1987: The impact of satellite data on global numerical weather prediction. NATO ASI Series C, Vol. 201, Remote Sensing Applications in Meteorology and Climatology (R.A. Vaughan ed.), pp. 173-188.

Pailleux, J., Kelly, G., Andersson, E., Hollingsworth, A., Lönnberg, P., Zhang, Z. and Flobert, J.F. 1989: Research and operational developments related to the use of satellite data in the ECMWF assimilation system, ECMWF Technical Memorandum No. 159, 1989.

Radford, A., 1987: Data monitoring at ECMWF. ECMWF workshop on meteorological operational systems, 1987.