AN OUTLINE OF THE NEXT METEOROLOGICAL OPERATIONAL SYSTEM AT JMA

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1. INTRODUCTION

At Japan Meteorological Agency (JMA), two systems have been separately operated for communication and data processing. One is the Central Automated Data Editing and Switching System (C-ADESS), which was installed in 1981, and the other is the Numerical Weather Prediction System, which was equipped in 1982. A new system which efficiently integrates both communication and data processing was planned in order to improve accuracy of the numerical weather prediction (NWP) and to enhance various kinds of functions for meteorological services at JMA. The new system, named the Computer System for Meteorological Services (COSMETS), is now replacing the old ones, and it will be completed in February 1988.

2. GENERAL FUNCTIONS OF THE SYSTEM

The World Weather Watch (WWW) plan, which has been recommended by the World Weather Organization (WMO), consists of three basic components, i.e., the Global Observing System (GOS), the Global Telecommunication System (GTS) and the Global Data Processing System (GDPS). The COSMETS relays meteorological messages through GTS lines as a Regional Telecommunication Hub (RTH) in GTS, and it has data processing functions as a Regional Meteorological Centre (RMC) in GDPS.

The COSMETS has functions as a Regional Area Forecast Centre (RAFC). The RAFC, which is jointly promoted by WMO and the International Civil Aviation Organization (ICAO), provides areal forecasts over a part of the globe. The COSMETS will soon operate as a Regional / Specialized Meteorological Centre (RSMC). The RSMC supplies information of typhoons for members of the Typhoon Committee in the Region II. The COSMETS also has functions as the National Meteorological Centre (NMC) of Japan.

2.1 Global perspectives relevant to the WWW plan

The system is linked with Washington, Melbourne, Beijing and New Delhi through GTS Main Telecommunication Networks (MTNs), which are shown in Fig.1. The system is also linked with Khabarovsk, Seoul, Hong Kong, Bangkok, Manila and Honolulu with regional or inter-regional circuits. Ship data are gathered by the International Maritime Satellite (INMARSAT).

The Tokyo RTH exchanges not only observations or grid coded data but also digital facsimile data with Washington, Melbourne and Beijing. Communication lines to these centres are divided into two logical lines in which conventional data and digital facsimile data are separately exchanged. For the exchange of digital facsimile data, the Aeronautical Chart Exchange System (ACXS) has already installed at JMA. The ACXS is connected with the COSMETS through a 9600 bps (bits per second) communication line.

The Tokyo RTH broadcasts JMH analog facsimile for regional and maritime services, JMJ analog facsimile for aviation services, JMG radio for sub-regional services and JMC radio for maritime services. Connections with GTS lines and broadcastings are schematically shown in Fig.2.

For regional, aeronautical and maritime services, the NWP is performed over a regional domain and over the globe. Almost all facsimile data and grid coded data are automatically made in the process of the NWP.

2.2 Domestic perspectives

Surface data, upper-air data and digital radar echo data are sent through six local communication centres, which are located at district meteorological observatories in Sapporo, Sendai, Tokyo, Osaka, Fukuoka and Okinawa. Ship data near the coast of Japan are sent through TELEX lines. Automated surface observations are collected by the Automated Meteorological Data Acquisition System (AMeDAS). Cloud tracking wind data, cloud amount grid data derived from the Geostationary Meteorological Satellite (GMS) and remote observations through a data collection platform (DCP) on the GMS are transmitted by the Meteorological Satellite Centre (MSC). Domestic communication links are shown in Fig.3.

For domestic services, the NWP of short range is performed over a domestic domain. Some data on very short range phenomena such as precipitations are processed into now-casting products, which are delivered for Local Meteorological Observatories and for primary users as well as the NWP

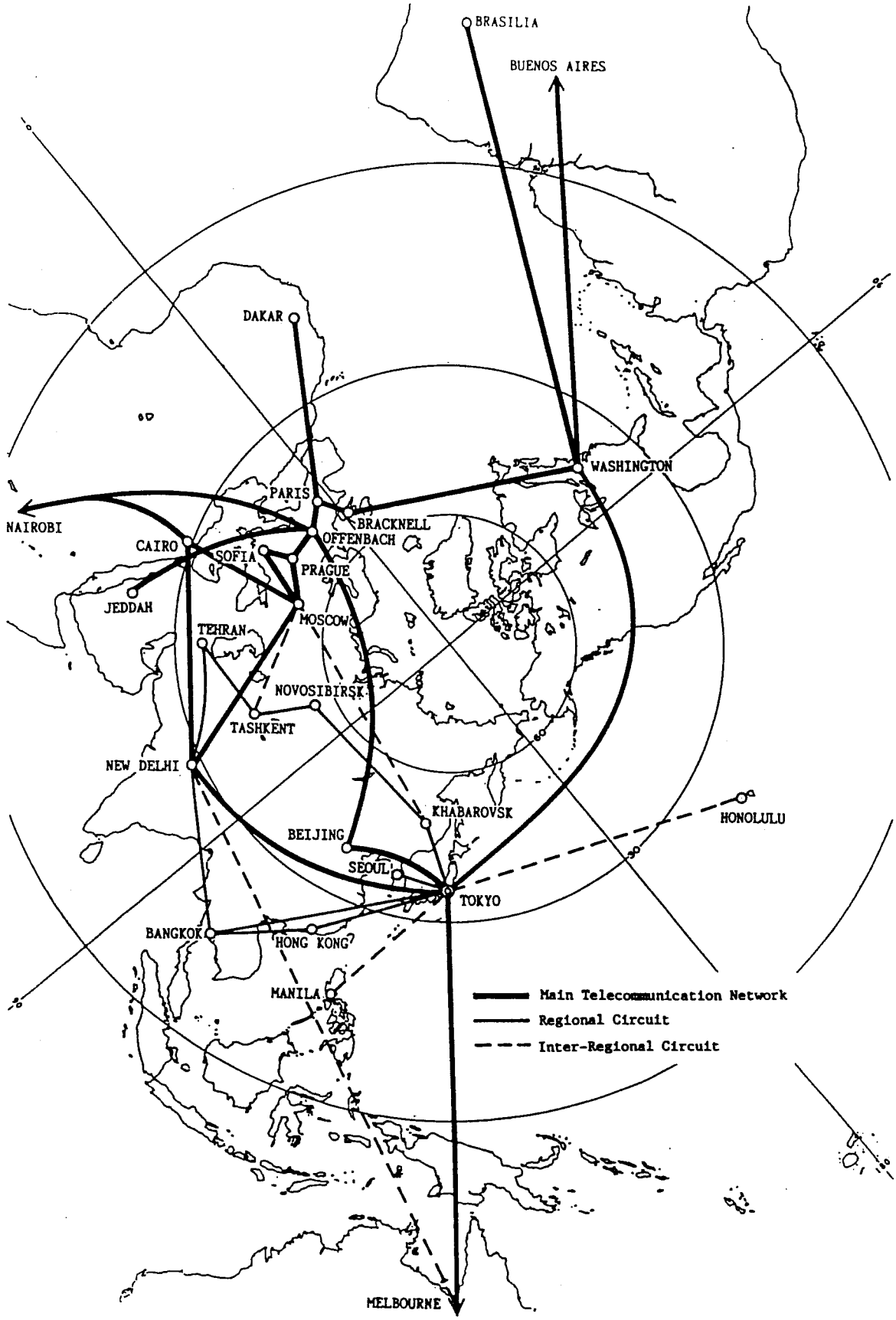

Fig. 1 Global Telecommunication System (GTS)

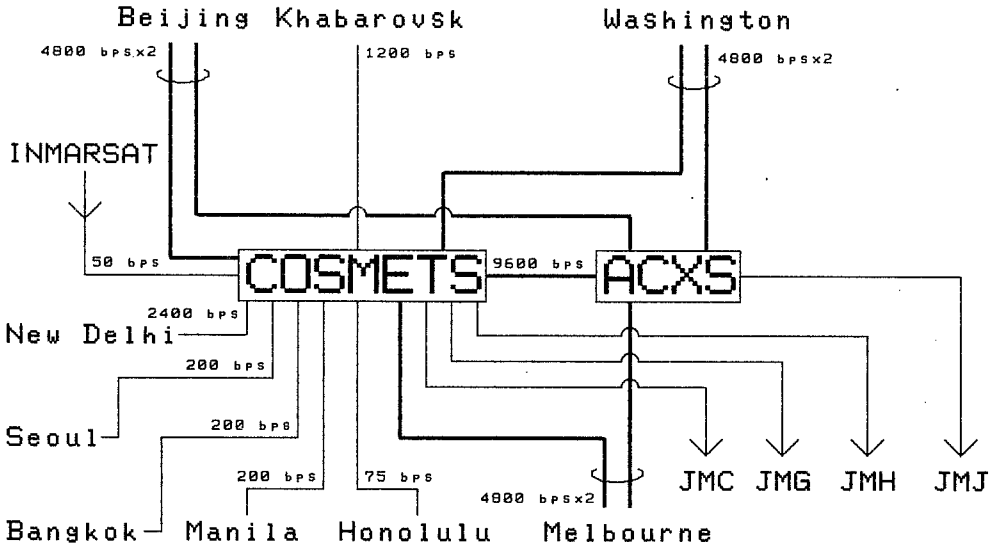

Fig. 2 Connections with GTS lines and broadcastings

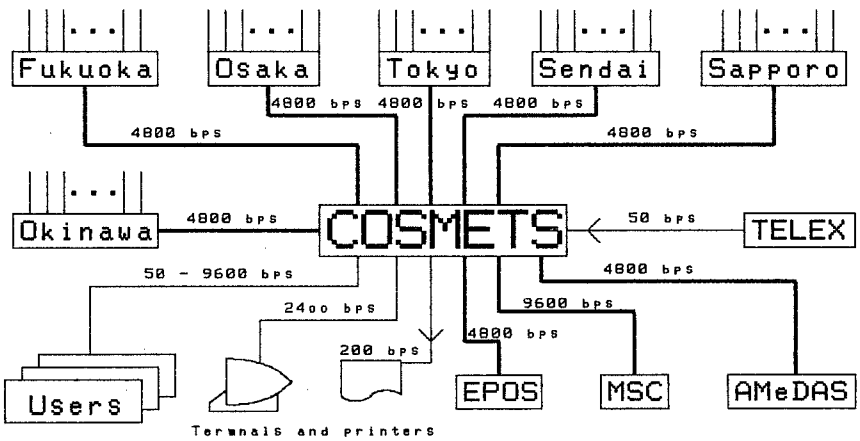

Fig. 3 Domestic communication links

products of short and medium range weather forecast. The system furnishes graphic displays and laser-beam printers in the National Forecasting Centre (NFC) for monitoring the now-casting products and the NWP products.
The system also has functions as a computation centre at JMA. Peripheral equipments are located at an open I/O room, where users in the JMA headquarters can use the COSMETS by themselves.

3. GENERAL STRUCTURE OF THE SYSTEM

3.1 Distributed processing architecture

In order to realize the functions mentioned in the previous section, we take a strategy of distributed processing architecture to ensure reliability, convertibility and flexibility. Roughly speaking, the system consists of two subsystems, i.e., a communication subsystem including communication control units and communication processing units, and a data processing subsystem including a general purpose processing unit and a high-speed operation unit. General structure of the system is illustrated in Fig. 4.

The communication control units consist of two sets of dual systems in which two units of mini-computers NEC MS-190 receive meteorological messages simultaneously so that they may not lose them. Both dual systems take charge of different communication lines. Main function of the communication control units is to absorb various kinds of communication protocols and transmission codes listed in Table 1. Planned traffic of communication lines is about 200 MB/day in all. The communication control units receive meteorological messages from communication lines, and store them in duplicated magnetic disks, and then transfer them to the communication processing units. Meteorological messages to be sent to communication lines are transferred from the communication processing units. Thus, the communication control units work as communication buffers for the communication processing units. The communication control units are connected with the communication processing units through general serial interface adapters. Another function of the communication control units is to control the configuration of both the communication control units and the communication processing units.

The communication processing units consist of two units of medium-sized computers ACOS S-850, which compose a standby redundant system. One of the

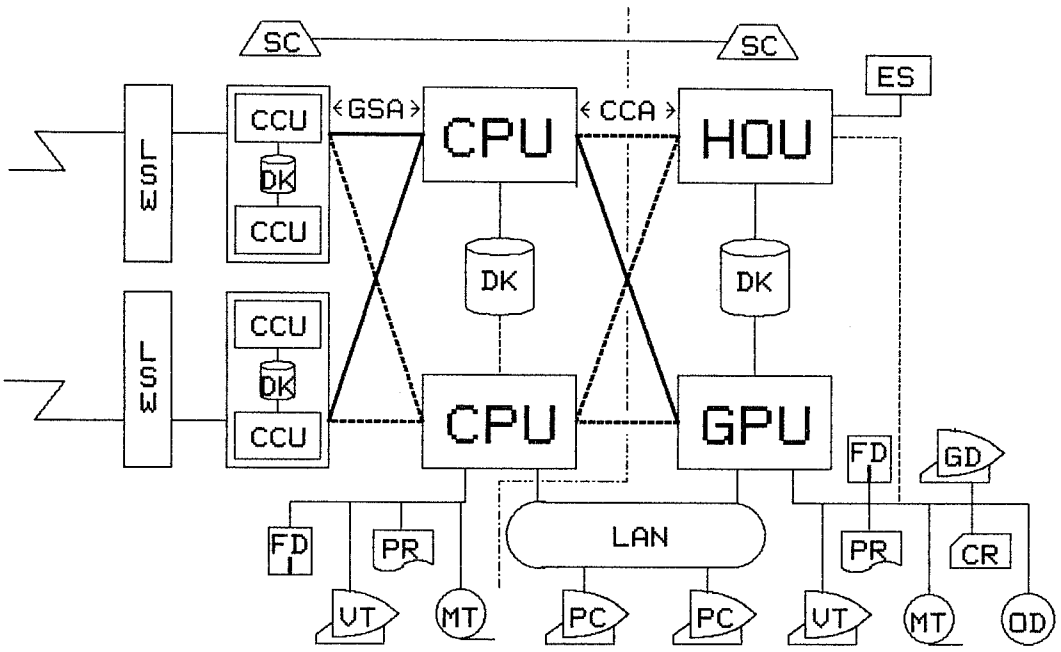

Fig. 4 General structure of the system

Abbreviations			
CCU	Communication control unit	SC	System console
CPU	Communication processing unit	ES	Extended storages
GPU	General purpose processing unit	MT	Magnatic tape units
HOU	High-speed operation unit	OD	Optical disk unit
LSW	Line switches	FD	Floppy disk units
LAN	Local area network	PR	Printers
GSA	General serial interface adapters	CR	Card readers
CCA	Channel-to-channel adapters	VT	Video terminals
DK	Magnatic disk units	GD	Graphic displays
PC	Personal computers		

Protocols	Codes	Speeds (bps)	Lines
X.25	No.5	4800	Washington
X.25-LAPB	No.5	4800	Melbourne, Beijing
X.25-JMA	JIS	4800/9600	Sapporo, Sendai, Tokyo, Osaka, Fukuoka, Okinawa, MSC, ACXS, EPOS
WMO-hardware Sync.	No.5	1200(75)	Khabarovsk
WMO-software Sync.	No.5	2400(75)	New Delhi
P/S Sync.	JIS	4800	AMeDAS
Basic Sync.	JIS	2400	operating terminals
Basic Async.	JIS	200	printers
Free Async.	JIS	200	printers
Free Async.	No.5	200	Manila, Hong Kong, AFTAX
Free Async.	No.2	200/75/50	Seoul, Bangkok, Honolulu, INMARSAT
Free Async.	TELEX	50	TELEX
Free Async.	JMA6	50	JMC

Table 1 Communication protocols and transmission codes

The X.25, the X.25-LAPB and the X.25-JMA protocol use the High Level Data Link Control (HDLC) procedure. The X.25-LAPB protocol defines only a data link layer, while the X.25 protocol defines both a data link layer and a packet layer. The X.25-JMA protocol defines a logical channel for the exclusive exchange in the networks of JMA. The WMO-hardware and the WMO-software protocol use a 75 bps backward channel for error checking. These protocols will be replaced by the X.25-LAPB protocol in future. The P/S (Polling/ Selecting) protocol is a kind of the basic protocol.

The JIS (Japan Industry Standard) code is an extension of the CCITT (International Telegraph and Telephone Consultive Committee) No.5 code. The JMA6 code is a 6 bit code of the old JMA standard.

communication processing units (the online unit) receives meteorological messages from communication control units, and it identifies kinds of messages by the heading, and then it stores them in duplicated magnetic disks. If relays of messages is necessary, their pointers are set on the output queues of certain communication lines. According to requests by the communication control units, the online unit sends meteorological messages from the top of the output queues. The online units has other realtime functions, e.g., editing meteorological messages, expanding coded digital facsimile (CDF) data, plotting weather charts and taking check point informations prepared for a possible system failure. Here, the standards of CDF data will be unified as compatible as the ISO (International Organization for Stadardization) G3 (Group 3) standards in near future. As a matter of fact, the COSMETS can exchange binary data with other centres which can exchange them either.
The other communication processing unit (the offline unit) is on standby for a possible system failure in the online unit, while it is usually used for the development of communication processing and for other jobs. The offline unit is connected with a local area network (LAN) through a distributed information processing unit. Personal computers which are connected with the LAN can use time sharing system (TSS) services of the offline unit.

The general purpose processing unit is a large-sized computer HITAC M-680H, which composes a loosely coupled multi-processor (LCMP) system with the high-speed operation unit. Here, the LCMP system means sharing magnetic disks and not sharing main storages. In the general purpose processing unit, various kinds of jobs in the computation centre are executed according to their priorities. Meteorological messages are decoded once an hour for the NWP and for the now-casting. Output data of the NWP are processed into digital facsimile data, grid coded data and application products for aviation and maritime services. Other jobs in the general processing unit include now-casting, meteorological data handling, oceanographic operations, seismologic operations, administrative processing and so on.
The TSS services of the general purpose processing unit can be used by terminals directly through channels or by personal computers through the LAN. The general purpose processing unit controls the input and output of jobs as a global processor of the LCMP system, and it is connected with peripheral equipments, which are listed in Table 2. As the COSMETS is a

multi-vendor system by some reasons, the communication processing units ACOS S-850 and the general purpose processing unit HITAC M-680H cannot share magnetic disks, and they are connected with channel-to-channel adapters, through which meteorological messages are mutually transferred.

In this system, the high-speed operation unit HITAC S-810 is newly introduced for the exclusive use of the NWP. The high-speed operation unit is a highly pipelined single vector processor. It is mainly used for the objective analyses and for the forecast models of the NWP. Summary of the objective analyses and the forecast models, which will be operated in March 1988, are listed in Table 3. The high-speed operation unit is compatible with the general purpose processing unit except vector operations, and the high-speed operation unit can take over the functions of the general purpose processing unit in case of a system failure or in case of a regular maintenance. Indispensable equipments and important data files in the COSMETS are duplicated in order to raise reliability of the system.

	Communication subsystem	Data processing subsystem			
Units	Computer room	Computer room	Open I/O room	NFC	Other rooms
Magnetic tape units	7	4	4		
Floppy disk units	2		1		
Optical disk unit		1			
Card readers		1	1		
Line printers		2	1		
Laser-beam printers	2	2	2	2	1
Electrostatic plotters		2			
Graphic displays		2		2	2
Terminals	14	9	12	2	18

Table 2 Peripheral equipments of the system

Domain		Globe	Asia and West Pacific Ocean	around Japan
Objective analyses	Method	3-dimensional O/I	3-dimensional O/I	3-dimensional O/I
	Horizontal grid	Latitude-Longitude	Stereographic projection	Stereographic projection
	Grid distance	1.875° ×1.875°	150km (60° N)	80km (60° N)
	Grid size	192× 97	88× 78	68× 68
	Vertical Coordinate	Pressure	Pressure	Pressure
	Vertical levels	15	16	16
	Guess field	Global forecast	Global forecast	Asian forecast
Forecast models	Horizontal scheme	Spectral method	Spectral method	Spectral method
	Bases	Spherical harmonics	Double Fourier series	Double Fourier series
	wave number truncation	Triangular 63	83 × 70	62 × 62
	Grid size	192× 96	129× 109	97× 97
	Grid distance	———	75km (60° N)	40km (60° N)
	Vertical coordinate	σ	σ	σ
	Vertical levels	16	16	19
	Forecast period	3 days (00UTC) 8 days (12UTC)	2 days	1 day
	Lateral boundary	———	Global forecast	Asian forecast

Table 3 Summary of the objective analyses and the forecast models

The local area network (LAN) is newly introduced in order to enhance connections between computers existing in the JMA headquarters and to utilize personal computers as terminals for TSS services. The LAN consists of a optical fibre loop, a loop service node and nine field service nodes. The loop service node and the field service nodes are connected with computers and personal computers with interfaces of communication lines. The general purpose processing unit is connected with the loop service node through a communication control processor. The Earthquake Phenomena Observation System (EPOS) is connected with one of the field nodes for the exchange of earthquake telemetric data as if a 48 kbps HDLC communication line were connected with the general purpose processing unit. Forty three personal computers are connected with field service nodes by the protocol X.28, which defines functions of packet assembly deassembly (PAD) for standard non-packet terminals.

3.2 Performance of the system

The performance of the communication control units and the performance of the communication processing units are listed in Table 4. Here, each communication processing unit has another 8 MB of disk cache storages besides main storages. The specifications are based on the assumption that the peak traffic of input messages is about 10 kB/s for each communication control unit. The operating system (OS) of the communication processing units is ACOS-6/MVX, in which a transaction management subsystem controls application programs mainly described in COBOL for communication processing.

The performance of the general purpose processing unit and the performance of the high-speed operation unit are listed in Table 5. The general purpose processing unit installs an integrated array processor (IAP) in order to accelerate simple vector operations. The operating system of the general purpose processing unit is HITAC VOS3/ES1, which supports extended addressing of 31 bits as well as 24 bits. In the input/output subsystem of the OS for the LCMP configuration, a global processor controls input devices and printers. The OS of the general purpose processing unit supports compilers for FORTRAN77, COBOL and PL/I, while most application programs are described in FORTRAN77. The general purpose processing unit equips an optical disk unit in order to store large volumes of data. It also equips laser-beam printers, electrostatic plotters and graphic displays. Laser-beam printers are used for printing documents and small-sized graphic

Communication control units NEC MS-190		instruction rate	4 MIPS
		main storage capacity	8 MB/unit
		total I/O bus transfer rate	7.4 MB/s
	Magnetic disks	total capacity	1.3 GB
		volume capacity	167 MB
		track capacity	16,384 B
		data transfer rate	1.2 MB/s
		mean seek time	20 ms
		mean rotational delay	8.6 ms
Communication processing units ACOS S-850		instruction rate	8 MIPS
		main storage capacity	16 MB/unit
		cache storage capacity	64 kB/unit
		total channel transfer rate	30 MB/s
	Magnetic disks	total capacity	7.6 GB
		volume capacity	635 MB
		track capacity	19,069 B
		data transfer rate	1.2 MB/s
		mean seek time	20 ms
		mean rotational delay	8.3 ms
General serial interface adapters		transfer rate	6.3 Mbit/s
		maximum frame length	4,089 B
Channel-to-channel adapters		total transfer rate	1 MB/s
		maximum block length	32,000 B

Table 4 Performance of the communication control units and the communication processing units

General purpose processing unit HITAC M-680H		instruction rate	30 MIPS *
		main storage capacity	32 MB
		working storage capacity	1 MB
		cache storage capacity	256 kB
		total channel transfer rate	72 MB/s
	Magnetic disks	total capacity	35 GB
		volume capacity	1.3 GB
		track capacity	47,476 B
		data transfer rate	3 MB/s
		mean seek time	17 ms
		mean rotational delay	8.3 ms
High-speed operation unit HITAC S-810		peak operation rate	630 MFLOPS
		main storage capacity	64 MB
		cache storage capacity	256 kB
		vector registers	256 W× 32
		vector masking registers	256 W× 8
		total channel transfer rate	72 MB/s
	Extended storages	total capacity	512 MB
		data transfer rate	1 GB/s

Table 5 Performance of the general purpose processing unit and the high-speed operation unit

* To be estimated.

charts, while electrostatic plotters are used for printing large-sized charts. Graphic displays are used for man-machine interactive systems such as drawing fronts in significant weather charts. Graphic software is systematized into two ways. One is a common graphic package which is mainly used for creating digital facsimile data in the NWP, and the other is translators by which graphic commands of some devices are translated into those of other devices.

The high-speed operation unit has a scalar processor and a vector processor which can be simultaneously executed. The performance of the scalar processor is equivalent to that of the general purpose processing unit. The vector processor has 32 vector registers, 8 pipelines of floating operations and 8 pipelines of vector loading. It has also 8 vector masking registers and a pipeline of masking operation. By these devices, conditional vectors, logical vectors, indirect index vectors and sparse vectors are efficiently calculated. The high-speed operation unit is operated in real storage mode when vector operations are used. Besides the main storages, it has extended storages for temporary files in order to shorten I/O times. The operating system of the high-speed operation unit is HITAC VOS3/HAP/ES, which is compatible with that of the general purpose processing unit except vector operations. Vector operations are automatically generated by the FORTRAN77 compiler without using any special function calls in source codes.

The output data of the NWP are managed in a hierarchical way. The output data of daily operations are stored in duplicated magnetic disks, and they can be copied by open users through a data management program, i.e., the Grid Point Value Copy (GPVC), which is devised to avoid interference between operational jobs and users. Some of these data are stored in other magnetic disks for a certain period as shared data at JMA. Optical disks are used for long-term preservation of the NWP data.
It is planned to construct a meteorological database on a trial base. Also, it is planned to circulate electronic mails within the meteorological networks of JMA in order to exchange documents between users. The standardization of the electronic mails includes database inquiries and remote batch jobs.

4. OPERATIONAL ASPECTS

4.1 System monitoring and configuration control

The communication subsystem and the data processing subsystem are independently controlled by operators, while system consoles of the both subsystems monitor the condition of the whole system.

The system console of the communication subsystem monitors the condition of hardware in the communication subsystem, the condition of communication lines, numbers of output queues of communication lines and failures of communication programs. It signals operators by buzzers and lamps in case of system failures. Operators of the communication subsystem use supervisory terminals and operating terminals for operating the subsystem.

The system console of the data processing subsystem monitors the condition of hardware in the data processing subsystem and failures of special jobs such as the now-casting. It signals operators by buzzers and lamps in case of system failures. Operators of the data processing subsystem use the system console of the data processing subsystem and TSS terminals for operating the subsystem.

4.2 Numerical Weather Prediction

The operational NWP is performed over a domestic domain and over a regional domain and over the globe twice a day, respectively. The operational NWP is divided into dozens of jobs for efficient parallel processing and for flexible re-execution. Orderly execution of the NWP is scheduled by a function of scheduling related jobs in the OS. A function of centralized control of the NWP is visualized on a TSS terminal by the Job-net Operating and Monitoring System (JOMS), which makes it easy to cope with various kinds of errors.

4.3 Open batch system and centralized resource control

Open users can submit their jobs in the open I/O room or through terminals in their offices. After the completion of their jobs, they can take out their results in the open I/O room. They can use an open M/T system for copying data sets between magnetic tapes and magnetic disks.

Several jobs can be executed in parallel by the general purpose processing unit. The allotment of resources between batch jobs and TSS terminals are determined according to the priorities of jobs and the characteristics of jobs by a function of centralized resource control in the OS.

5. CONCLUDING REMARKS

The COSMETS would have the following advantages to the activities of JMA.

(1) A supercomputer HITAC S-810 is equipped for the exclusive use of the NWP. Much faster processing speed of the supercomputer than that of the predecessor HITAC M-200H will enable forecasts of more extended range, and it would bring about more accurate forecasts.

(2) A communication subsystem and a data processing subsystem are connected with channel-to-channel adapters, and various kinds of messages including binary data, digital facsimile data and electronic mails can be exchanged with communication lines. That would help efficient exchange of messages, and it would encourage effective distributed processing in global and domestic networks.

(3) Functions of data managements are enhanced, and volumes of magnetic disks are increased. That would promote utilization of observational data and the NWP data for meteorological services.

(4) A local area network is prepared for connecting computers and personal computers at JMA. That would help efficient operations, and it would offer advanced environment for research and development.

It is expected that the COSMETS will flexibly evolve in response to the progress of meteorology and the development of computer technology in future.