Annual WWW Technical Progress Report on the Global Data Processing System 2001

Japan Meteorological Agency

1. Summary of highlights

(1) The mainframe computer was replaced by HITACHI SR-8000E1 with 80 nodes on 1 March 2001. The new supercomputer has a peak performance of 768 Gflops and main memory of 640 GB.

(2) The Numerical Analysis and Forecasting System (NAPS) was upgraded on 1 March 2001. The following are major changes in NAPS;

a. The vertical resolution of Global Spectral Model (GSM) was enhanced in the stratosphere to have 40 vertical levels with the model top placed at 0.4 hPa. The cumulus convection and gravity wave drag schemes of GSM were revised;

b. The global analysis with an optimal interpolation scheme was extended up to 0.4 hPa and the previous upper stratospheric analysis with a function fitting method was discontinued;

c. The vertical resolution of Regional Spectral Model (RSM) was enhanced around the tropopause to have 40 vertical levels. The prediction area of RSM was extended;

c. The spatial resolution of TYM was enhanced to have a horizontal resolution of 24 km and 25 vertical levels. The frequency of operation of TYM was increased to four times a day;

d. The operation of the Meso-Scale Model (MSM) with a horizontal resolution of 10 km was started for assisting forecasters in issuing warnings. MSM provides 18-hour forecasts four times a day within 1.5 hours from the initial time. The initial conditions for MSM are prepared by a 3-hour pre-run during which optimum interpolation analysis and physical initialization are conducted at 1-hour intervals;

e. The operation of medium-range ensemble forecasts with the T106 version of GSM was started to provide a 25-member ensemble of 9-day forecasts every day. The initial perturbations are prepared by using the Breeding of Growing Mode (BGM) method; and

f. The one-month ensemble forecast system was upgraded by enhancing the model resolution and the number of members. The system provides a 26 member ensemble once a week by extending 13 member runs from medium-range ensemble forecasts on Wednesday and Thursday using the T106 version of GSM.

(3) Assimilation of wind data from the JMA wind profiler network to the global, regional and meso-scale analyses was started on 12 June 2001. The network consists of 25 stations of 1.3 GHz wind profilers and it has been in operation since April 2001.

(4) A three-dimensional variational (3D-Var) assimilation scheme was introduced to the global analysis on 26 September 2001.

(5) The spatial resolution of the Global Wave Model was improved from 2.5 degrees to 1.25 degrees on 1 March 2001.

2. Equipment in use at the Global Data Processing System (GDPS) Center in JMA

Numerical Analysis and Prediction System (NAPS) was upgraded on March 1, 2001. Major features of the NAPS are listed in Table 1.

Table 1 Major features of NAPS

Supercomputer		HITACHI-SR8000E1/80
Total node	80	
Total performance	768 Gflops	

Total capacity of memory	640 GB	
Data transfer rate	1.2 GB/s	
Storage disk capacity	4.8 TB	
Operating system	HI-UX/MPP	

UNIX server 1		HITACHI-3500/E540PS
Total node	6	
Total performance	215SPECint95	
Total capacity of memory	12 GB	
Storage disk capacity	389 GB	
Operating system	HI-UX/WE2	

UNIX server 2		HITACHI-3500/E540PS
Total node	4	
Total performance	151SPECint95	
Total capacity of memory	8 GB	
Storage disk capacity	354 GB	
Operating system	HI-UX/WE2	

Transmitting and receiving message server		HITACHI-3500/545RM
Performance	4.8 SPECint95	
Total capacity of memory	512 MB	
Storage disk capacity	12 GB	

Automated tape library		STORAGETEK Powderhorn 9310
Total storage capacity	80 TB	

Automated DVD-RAM library 1		HITACHI DT-DVDO-02
Total storage capacity	2.5 TB	

Automated DVD-RAM library 2		HITACHI DT-DVDO-02
Total storage capacity	3.1 TB	

3. Data and Products in use from GTS

3.1 Observations

The following observation reports are used in the data assimilation:

Table 2 Number of used observation reports

SYNOP/SHIP	35500/day
TEMP-A/PILOT-A	1700/day
TEMP-B/PILOT-B	1600/day
TEMP-C/PILOT-C	1100/day
TEMP-D/PILOT-D	1000/day
AIREP/AMDAR	35500/day
BUOY	10000/day

SATOB (SST)	7500/day
SATEM-A	11000/day
SATEM-C	11000/day
SATOB (WIND)	58000/day
TOVS	82000/day
PROFILER	700/day
BATHY/TESAC	3800/month
ERS	200/day

3.2 GRIB products

Following model products are used for internal reference and monitoring.

GRIB KWBC
GRIB ECMF
GRIB AMMC

4. Data input system

Data input is fully automated with the exception of the manual input of typhoon position, size and intensity data. They are used to generate typhoon bogus data for global, regional and typhoon analyses.

5. Quality control system

Stage 1 Decoding

All the code forms of messages are checked against the WMO international code forms. When a form error is detected, some procedures are applied in order to extract as much information as possible.

Stage 2 Internal consistency check

Checks of climatological reasonability are performed for all types of data. The data enlisted as problematic data in the "black list" are rejected. Contents of the "black list" are occasionally revised based on results of non real-time quality control.

Consistency of consecutive positions is checked for reports from mobile stations such as ships, drifting buoys and aircraft. Consistency of consecutive reports and that among elements within a report are also checked for every surface station.

The vertical consistency is examined for TEMP and PILOT data using all parts of reports. The check items are:

(1) Icing of instruments;
(2) Temperature lapse rate;
(3) Hydrostatic relationship;
(4) Consistency among data at mandatory levels and those at significant levels; and
(5) Vertical wind shear.

Bias correction is applied to TEMP data which have large persistent biases from the first guess fields. Another bias correction scheme which checks consistency between the surface pressure observation and the sea surface pressure has been introduced since August 1998.

Checks of lapse rate for SATEM data are also performed using the mean virtual temperature estimated from the thickness.

Stage 3 Quality control with reference to the first guess

Gross error and spatial consistency are evaluated against the first guess in order to remove erroneous observations. The difference (D) of the observation value from the first guess value is compared with tolerance limits C_P and C_R. C_P is an acceptable limit and C_R is a rejection limit. When D is smaller than or equal to C_P, the datum is accepted for use in the objective analysis. When D is greater than C_R, it is rejected. When D is smaller than or equal to C_R and greater than C_P, the datum is further checked by interpolating the neighboring data to the location of the datum. If the difference between the datum and the interpolated value is not within a reasonable tolerance C_S, the datum is rejected.

These three tolerance limits vary according to the local atmospheric conditions which can be estimated by the first guess field. They are small if time tendency and horizontal gradient are small in the first guess field. The scheme is called "Dynamic QC" and is based on the idea that forecast errors would be small if the area is meteorologically calm and large if it is stormy.

Duplicate observation reports are frequently received through different communication lines. The most appropriate single report is chosen from these duplicate reports considering results from quality control of these reports.

All information on the quality of observational data obtained during the quality control procedure is archived in the Comprehensive Database for Assimilation (CDA). The CDA is used for non real-time quality control and global data monitoring activities.

6. Monitoring of the observing system

The non real-time quality monitoring of observations is carried out using observational data, real-time quality control information and the first guess archived in the CDA. The quality monitoring is made according to:

(1) Compilation of observational data rejected in the real-time quality monitoring;

(2) Calculation of statistics on the difference between observations and first-guess; and

(3) Statistical comparison of satellite data with collocated radiosonde data.

The above statistical information is effective in estimating systematic errors of observational data and also helpful to identify stations reporting suspect observations. If a station continuously reports suspect data for a long time, the data from the station are not used in the analysis.

The quality and availability of observational data are regularly issued as a monthly report entitled "JMA/NPD Global Data Monitoring Report". The statistics presented in the report are made according to the recommended procedures for the exchange of monitoring results by the Commission for Basic Systems (CBS). The report is sent to major Global Data Processing System (GDPS) centers as well as to the WMO Secretariat.

The RSMC Tokyo has been acting as a lead center for monitoring quality of land surface observations in Region II since March 1991. The statistical characteristics of availability and quality for sea level pressure observations of land surface stations in Region II are published in the semiannual report entitled "Report on the Quality of Surface Observations in Region II".

JMA also acts as a Principal Meteorological and Oceanographic Center (PMOC) of Data Buoy Cooperation Panel (DBCP). Quality of meteorological data for every observation element reported from ocean data buoys is monitored by time sequence maps comparing the data with the first guess field of the JMA Global Data Assimilation System. Sea surface and subsurface temperatures reported from buoys are also examined against climatic values and oceanographic analysis by JMA. Information on the buoys transmitting inferior quality data is sent to DBCP and other PMOCs over the Internet.

7. Forecasting system

JMA operationally performs four kinds of objective atmospheric analyses for the global, regional, meso-scale and typhoon forecast models. A three-dimensional variational scheme (3D-VAR) has been employed for the global and typhoon analyses since 26 September 2001. For the regional and meso-scale analyses a three-dimensional Optimal Interpolation (3D-OI) scheme is used. All analyses are made on model coordinates for surface pressure, geopotential height, vector winds, temperature and relative humidity.

Global analyses at 00UTC and 12UTC are performed twice. An early run analysis with a short cut-off time is performed to prepare initial conditions for operational forecast, and a cycle run analysis with a long cut-off time is performed to keep quality of global data assimilation system. The early run analysis is not performed at 06 and 18UTC.

The specifications of the atmospheric analysis schemes are listed in Table 3.

Daily global SST analysis and daily global snow depth analysis are described in Table 4.1 and Table 4.2.

Table 3 Specifications of operational objective analysis

Cut-off time

(global)	2.5 hours for early run analyses at 00 and 12 UTC, 12.5 hours for cycle run analyses at 00 and 12 UTC, 7.33 hours for cycle run analyses at 06 and 18 UTC.
(regional)	3 hours for analyses at 00 and 12UTC, 8.33 hours for analyses at 06 and 18 UTC,
(meso-scale)	50 minutes for analyses at 00, 06, 12 and 18 UTC
(typhoon)	2.5 hours for analyses at 00 and 12UTC, 1.5 hours for analyses at 06 and 18 UTC.

Initial Guess

(global)	6-hour forecast by GSM
(regional)	6-hour forecast by RSM
(meso-scale)	1-hour forecast by MSM
(typhoon)	6-hour forecast by GSM

Grid form, resolution and number of grids

(global)	Gaussian grid, 0.5625 degree, 640x320
(regional)	Lambert projection, 20km at 60N and 30N, 325x257, grid point (1,1) is at north-west corner and (200, 185) is at (140E, 30N)
(meso-scale)	Lambert projection, 10km at 60N and 30N, 361x289, grid point (1,1) is at north-west corner and (245, 205) is at (140E, 30N)
(typhoon)	same as global analysis

Levels

(global)	40 forecast model levels up to 0.4 hPa + surface
(regional)	40 forecast model levels up to 10 hPa + surface
(meso-scale)	40 forecast model levels up to 10 hPa + surface
(typhoon)	same as global analysis

Analysis variables

Wind, geopotential height (surface pressure), relative humidity and temperature

(Temperature is analyzed but not used as the initial condition for the regional and meso-scale model.)

Data Used

SYNOP, SHIP, BUOY, TEMP, PILOT, Wind Profiler, AIREP, SATEM, TOVS, ATOVS, SATOB, Australian PAOB and VISSR digital cloud data from the Geostationary Meteorological Satellite (GMS).

Typhoon Bogussing

For a typhoon over the western North Pacific, typhoon bogus data are generated to represent its accurate structure in the initial field of forecast models. They are made up of artificial geopotential height and wind data around a typhoon. The structure is asymmetric. At first, symmetric bogus data are generated automatically from the central pressure and 30kt/s wind speed radius of the typhoon. The asymmetric bogus data are generated by retrieving asymmetric components from the first guess field. Those bogus profiles are implanted into the first guess fields.

Initialization

Non-linear normal mode initialization with full physical processes is applied to the first five vertical modes.

Table 4.1 Specifications of SST analysis

Methodology	two-dimensional Optimal Interpolation scheme
Domain and Grids	global, 1x1 degree equal latitude-longitude grids
First guess	mean NCEP OI SST (Reynolds and Smith, 1994)
Data used	SHIP, BUOY and NOAA AVHRR SST data observed in past five days
Frequency	daily

Table 4.2 Specifications of Snow Depth analysis

Methodology	two-dimensional Optimal Interpolation scheme
Domain and Grids	global, 1x1 degree equal latitude-longitude grids
First guess	USAF/ETAC Global Snow Depth climatology (Foster and Davy, 1988)
Data used	SYNOP snow depth data observed in past one day
Frequency	daily

JMA runs the Global Spectral Model (GSM0103; T213L40) twice a day (90-hour forecasts from 00 UTC and 216-hour forecasts from 12 UTC) and the Regional Spectral Model (RSM0103; 20kmL40) twice a day as well (51-hour forecasts from 00 and 12 UTC). The Meso-Scale Model (MSM0103; 10kmL40) is run four times a day (18-hour forecasts from 00, 06, 12 and 18 UTC) to predict severe weather phenomena. The Typhoon Model (TYM0103; 24kmL25) is also run four times a day (84-hour forecasts from 00, 06, 12 and 18 UTC) when any typhoons exist or are expected to be formed in the western North Pacific. Moreover JMA carries out 9-day Ensemble Prediction System (EPS) and 1-month EPS. The basic features of the operational forecast models of JMA are summarized in Tables 6, 10 and 13.

An operational tracer transport model is run on request of national Meteorological Services in RA II or the International Atomic Energy Agency (IAEA) for RSMC support for environmental emergency response. A high-resolution regional transport model is experimentally run every day to predict volcanic gas spread.

The very short-range forecast of precipitation (VSRF) is operationally performed every hour. Details of the VSRF are described in 7.3.4.

Three ocean wave models, Global Wave Model, Japan-area Wave Model and Coastal Wave Model, are run operationally. The specifications of the models are described in Table 17.

The numerical storm surge model is run four times a day when a typhoon is approaching Japan. The specifications of the model are described in Table 18.

The Ocean Data Assimilation System (ODAS), whose specifications are described in Table 19, is operated.

ODAS in the North Pacific has been in operation since January 2001. The specifications of the model are described in Table 20.

The numerical sea ice model is run to predict sea ice distribution and thickness over the seas adjacent to Hokkaido twice a week in winter. The specifications of the model are given in Table 21.

The numerical marine pollution transport model is run in case of a marine pollution accident. The specifications of the model are described in Table 22.

7.1 System run schedule and forecast ranges

Table 5 summarizes the system job schedule of NAPS and forecast ranges. These jobs are executed in batch on the supercomputer and the UNIX server 1.

Table 5 The schedule of the NAPS operation

Time (UTC)	NAPS operation (Model forecast range)
0030 - 0120	12UTC decode, global cycle analysis
0030 - 0110	00UTC decode, meso-scale analysis
0110 - 0130	00UTC meso-scale forecast (0 - 18h)
0120 - 0210	18UTC decode, global cycle analysis
0120 - 0135	00UTC storm surge forecast (00h - 24h)
0230 - 0700	00UTC El Nino forecast, Ocean Data Assimilation
0230 - 0300	00UTC decode, global early analysis
0255 - 0320	18UTC decode, regional analysis
0300 - 0330	00UTC global forecast (00h - 90h)
0320 - 0345	00UTC decode, regional analysis
0330 - 0430	00UTC typhoon forecast (00 - 84h)
0345 - 0405	00UTC regional forecast (00h - 51h)
0405 - 0425	00UTC ocean wave forecast (00h - 90h)
0630 - 0710	06UTC decode, meso-scale analysis
0710 - 0730	06UTC meso-scale forocast (0 - 18h)
0720 - 0735	06UTC storm surge forecast (00h - 24h)
0730 - 0800	06UTC decode, typhoon analysis
0800 - 0900	06UTC typhoon forecast (00h - 84h)
1230 - 1320	00UTC decode, global cycle analysis
1230 - 1310	12UTC decode, meso-scale analysis
1310 - 1330	12UTC meso-scale forecast (0 - 18h)
1320 - 1410	06UTC decode, global cycle analysis
1320 - 1335	12UTC storm surge forecast (00h - 24h)
1430 - 1500	12UTC decode, global early analysis
1455 - 1830	12UTC medium-range ensemble forecast (0 – 216h)
1455 - 1520	06UTC decode, regional analysis
1500 - 1530	12UTC global forecast (00h - 90h)
1520 - 1545	12UTC decode, regional analysis
1530 - 1630	12UTC typhoon forecast (00 - 84h)
1545 - 1605	12UTC regional forecast (00h - 51h)
1605 - 1725	12UTC ocean wave forecast (00h - 84h)
1630 - 1715	12UTC global forecast (90h - 216h)
1715 - 1735	12UTC ocean wave forecast (90h - 216h)
1830 - 2135	12UTC one month forecast (34 days)
1830 - 1910	08UTC decode, meso-scale analysis
1910 - 1930	08UTC meso-scale forecast (0 - 18h)

1920 - 1935	18UTC storm surge forecast (00h - 24h)
1930 - 2000	18UTC decode, typhoon analysis
2000 - 2100	18UTC typhoon forecast (00h - 84h)

7.2 Medium-range forecasting system (3 - 8 days)

7.2.1 Data assimilation, objective analysis and initialization (Table 6)

A three-dimensional variational (3D-VAR) data assimilation method is employed for the analysis of the atmospheric state. In the 3D-VAR, a statistical linear balance that also includes dynamics in tropics and surface friction effects is satisfied globally. The analysis variables are relative vorticity, unbalanced divergence, unbalanced temperature, unbalanced surface pressure and natural logarithm of specific humidity. In order to save the computational efficiency, an incremental method is adopted in which the analysis increment is evaluated at the lower horizontal resolution (T106) and then it is interpolated and added to the first guess field at the original resolution (T213).

A non-linear normal mode initialization with full physical processes is applied to the first five vertical modes. The effect of the atmospheric tide is considered by adding the model tidal tendency (constant) to the specific normal modes.

7.2.2 Medium-range forecasting model

Table 6 Specifications of Global Spectral Model (GSM0103) for 9-day forecasts

Surface state	
Basic equation	Primitive equations
Independent variables	Latitude, longitude, sigma-p hybrid coordinate and time
Dependent variables	Vorticity, divergence, temperature, surface pressure, specific humidity
Numerical technique	Euler semi-implicit time integration, spherical harmonics for horizontal representation and finite difference in the vertical
Integration domain	Global
Horizontal resolution	T213 (about 0.5625 degree Gaussian grid) 640x320
Vertical levels	40 (surface to 0.4hPa)
Forecast time	90 hours from 00UTC and 216 hours from 12UTC
Forecast phenomena	Synoptic disturbances and tropical cyclones
Orography	GTOPO30 30" x 30" data-set, spectrally truncated and smoothed.
Horizontal diffusion	Linear, second-order Laplacian
Moist processes	Prognostic Arakawa-Schubert cumulus parameterization + large-scale condensation
Radiation	Shortwave radiation computed every hour Longwave radiation computed every three hours
Cloud	Prognotic cloud water, cloud cover diagnosed from moisture and cloud water
Gravity wave drag	Longwave scheme for troposphere and lower stratosphere, shortwave scheme for lower troposphere
PBL	Mellor-Yamada level-2 closure scheme and similarity theory for surface boundary layer
Land surface	Simple Biosphere Model (SiB)
Surface state	SST anomaly added to seasonally changing climatological SST.

Initial soil moisture, roughness length and albedo are climatological values. The analyzed snow depth is used for the initial value. Predicted values are used for the initial soil and canopy temperatures

7.2.3 Numerical weather prediction products for Medium-range forecast

The following model output products from GSM are disseminated through the JMA radio facsimile broadcast (JMH), GTS and RSMC Tokyo Data Serving System.

Table 7 Facsimile products for medium-range forecast

<table>
<tr><th>Content</th><th>Level (hPa)</th><th>Area (see Fig.1a)</th><th>Forecast Hours</th><th>Initial Time</th><th>Transmission Method</th></tr>
<tr><td>geopotential height, relative vorticity</td><td>500</td><td>O</td><td>96, 120, 144, 168, 192</td><td rowspan="2">12UTC</td><td>GTS</td></tr>
<tr><td>sea level pressure, rainfall amount</td><td>-</td><td>C</td><td>96, 120</td><td>radio facsimile</td></tr>
</table>

Table 8 Grid point value products (GRIB) for medium-range forecast

<table>
<tr><th>Contents</th><th>Level (hPa)</th><th>Area</th><th>Forecast Hours</th><th>Initial Time</th><th>Transmission Method</th></tr>
<tr><td>sea level pressure, rainfall amount</td><td>-</td><td rowspan="10">Global 2.5x2.5 Degree</td><td rowspan="5">96, 120</td><td rowspan="10">12UTC</td><td rowspan="10">GTS
RSMC DSS</td></tr>
<tr><td>temperature, wind</td><td>surface</td></tr>
<tr><td>geopotential height</td><td>1000</td></tr>
<tr><td>geopotential height, temperature, wind</td><td>850, 700, 500, 300, 250, 200, 100, 70, 50, 30</td></tr>
<tr><td>T-TD</td><td>850, 700</td></tr>
<tr><td>sea level pressure, rainfall amount</td><td>-</td><td rowspan="5">144, 168, 192</td></tr>
<tr><td>temperature, wind</td><td>Surface</td></tr>
<tr><td></td><td>1000</td></tr>
<tr><td>geopotential height, temperature, wind</td><td>850, 700, 500, 300, 200</td></tr>
<tr><td>T-Td</td><td>850, 700</td></tr>
</table>

7.2.4 Operational techniques for application of GSM products

Atmospheric angular momentum (AAM) functions are computed from analyzed and forecasted global wind and surface pressure data and sent to NCEP/NOAA.

7.2.5 Medium-range Ensemble Prediction System (EPS) (9-days)

The numerical weather prediction model applied for the EPS is a low-resolution version (T106) of the GSM. Thus, the dynamical framework and all physical processes are identical with those of the high-resolution GSM (T213) mentioned at 7.2.2 except for the horizontal resolution. The initial condition for the control run is prepared by interpolating the T213 analysis.

Table 9 Specifications of 9-day Ensemble Prediction System

Integration domain	Global, surface to 0.4hPa
Horizontal resolution	T106 (about 1.125 degree Gaussian grid) 320x160
Vertical levels	40 (surface to 0.4hPa)
Forecast time	216 hours from 12UTC

Ensemble size	25 members
Perturbation generator	Breeding of Growing Mode (BGM) method (12 independent breeding cycles in 12 hours period)
Perturbed area	Northern hemisphere extra-tropics (20N-90N)

7.3 Short-range forecasting system

7.3.1 Short-range forecasting system (0-51 hours)

7.3.1.1 Data assimilation, objective analysis and initialization

A multivariate three-dimensional optimum interpolation (3D-OI) scheme on model levels is employed for the analysis of geopotential height and wind. Univariate 3D-OI scheme is employed for the analysis of temperature and relative humidity.

VISSR digital cloud data from GMS are combined with ship or surface observation and they are used as proxy data to generate vertical moisture profile in the analysis.

Non-linear normal mode initialization (NNMI) with full physical processes is applied to the first five vertical modes.

Physical initialization with the use of analyzed precipitation data is executed before NNMI.

7.3.1.2 Regional Spectral Model (RSM)

Table 10 Specifications of Regional Spectral Model (RSM0103)

Basic equation	Primitive equations
Independent variables	x-y coordinate on a Lambert projection plane and sigma-p hybrid coordinate
Dependent variables	Wind components of x-y direction, virtual temperature, natural log of surface pressure and specific humidity
Numerical technique	Euler semi-implicit time integration, double Fourier for horizontal representation and finite difference in the vertical
Projection and grid size	Lambert projection, 20km at 60N and 30N
Integration domain	East Asia centering on Japan, 325 x 257 transform grid points
Vertical levels	40 (surface to 10hPa)
Forecast time	51 hours from 00, 12UTC
Forecast phenomena	Meso-beta scale disturbances
Initial	3 (9)-hour cutoff for 00, 12 (06, 18) UTC analysis with 6-hour RSM forecast as a first guess
Lateral boundary	0-51 hours forecast by GSM runs
Orography	Envelope orography. Orography is smoothed and spectrally truncated.
Horizontal diffusion	Linear, second-order Laplacian.
Moist processes	Large scale condensation + Prognostic Arakawa-Schubert convection scheme + middle level convection + shallow convection
Radiation (shortwave)	Every hour
(longwave)	Every hour
Cloudiness	Diagnosed from relative humidity, maximum overlap
Gravity wave drag	Shortwave scheme for lower troposphere is included.
PBL	Mellor-Yamada level-2 closure scheme for stable PBL, non-local scheme for unstable PBL, and similarity theory for surface boundary layer
Land surface	Ground temperature is predicted with the use of four levels in the ground. Evaporability depends on location and season.

Surface state	Observed SST (fixed during time integration) and sea ice distribution. Evaporability, roughness length, albedo are climatological values. Snow cover over Japan is analyzed every day.

7.3.1.3 Numerical weather prediction products

The following model output products from GSM are disseminated through the JMA radio facsimile broadcast (JMH), GTS and RSMC Tokyo Data Serving System. No products from RSM are disseminated through these systems.

Table 11 Facsimile products for short-range forecast

Contents	Level (hPa)	Area (see Fig.1)	Forecast Hours	Initial Time	Transmission Method
geopotential height, relative vorticity	500	A'	0	00UTC 12UTC	GTS
vertical p-velocity	700				
temprature, wind	850				
geopotential height, relative vorticity	500		24, 36		
sea level pressure, rainfall amount	-				
Temperature	500				
T-Td, vertical p-velocity	700				
temperature, wind	850				
sea level pressure, rainfall amount	-	C	24, 48, 72		
geopotential height, relative vorticity	500		48, 72		
geopotential height, temperature, T-Td	850		0		
geopotential height, temperature, T-Td	700				
geopotential height, temperature	500				
geopotential height, temperature, wind	300				
geopotential height, temperature, wind	200	Q	0		
geopotential height, temperature, wind	250		0, 24		
geopotential height, temperature, wind	500		24		
geopotential height, temperature	500	D	0	12UTC	
stream line	200	-	0, 24, 48		
stream line	850				
geopotential height, relative vorticity	500	A'	0	00UTC 12UTC	radio facsimile
vertical p-velocity	700				
temprature, wind	850				
geopotential height, relative vorticity	500		24, 36		
sea level pressure, rainfall amount	-				
Temperature	500				
T-Td, vertical p-velocity	700				
temperature, wind	850				
sea level pressure, rainfall amount	-		48, 72		
geopotential height, temperature	500	C	0		
geopotential height, temperature, T-Td	700				
geopotential height, temperature, T-Td	850				
geopotential height, relative vorticity	500		48, 72		
sea level pressure, rainfall amount	-				
vertical p-velocity	700			12UTC	
temperature, T-Td	850				
stream line	200	-	0, 24, 48		
stream line	850				

Table 12 Grid point value products (GRIB) for short-range forecast

Contents	Level (hPa)	Area	Forecast Hour	Initial Time	Transmission Method

sea level pressure	-	Global 2.5x2.5 degree	0	00UTC 12UTC	GTS RSMC DSS
temperature, wind, T-TD	Surface				
geopotential height, temperature, wind	1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10				
T-Td	1000, 850, 700, 500, 400, 300 (00UTC) 850, 700 (12UTC)				
sea level pressure, rainfall amount	-		24, 48, 72	00UTC 12UTC	
temperature, wind	Surface				
geopotential height, temperature, wind	850, 700, 500, 300, 250, 200, 100, 70, 50, 30				
T-TD	850, 700				
sea level pressure, rainfall amount	-	20S-60N 80E-160W 2.5x2.5 degree	0, 6, 12, 18, 24, 30, 36, 48, 60, 72	00UTC 12UTC	GTS RSMC DSS
temperature, wind, T-TD	Surface				
geopotential height, temperature, wind, T-TD, vertical p-velocity	850, 700				
geopotential height, temperature, wind, T-TD, relative vorticity	500				
geopotential height, temperature, wind	300, 250, 200, 150, 100				
sea level pressure, rainfall amount	-	20S-60N 80E-160W 1.25x1.25 degree	0, 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72		
temperature, wind, T-TD	Surface				
geopotential height, temperature, wind, T-TD, vertical p-velocity	925, 850, 700				
geopotential height, temperature, wind, T-TD	500, 400, 300				
geopotential height, temperature, wind	250, 200, 150, 100, 70, 50 30, 20				
relative vorticity	500				
vorticity potential, stream function	850, 200				

7.3.1.4 Operational techniques for application

The Kalman-filtering technique and the Neural-network technique are applied to grid point values predicted by RSM to derive forecast elements. The Kalman-filtering technique is used to derive probability of precipitation, three-hourly precipitation amount, surface air temperature and surface wind. The Neural-network technique is introduced to derive three-hourly weather category, minimum humidity, probability of heavy precipitation and probability of thunderstorm.

7.3.2 Short-range forecasting system (0 – 18 hours)

7.3.2.1 Data assimilation, objective analysis and initialization

Optimum interpolation scheme and nonlinear normal mode initialization with physical initialization, which are described in 7.3.1.1, are employed with 50 minutes data cut off. First guess field is derived form 3-hour pre-run, that is the hourly analysis forecast cycle of meso-scale model for each forecast. Initial and lateral boundary for pre-run is derived from RSM forecasts.

7.3.2.2 Meso-Scale Model (MSM)

The model specifications are identical to those of RSM (Table 10) except for the followings:

Table 13 Specifications of Meso-Scale Model (MSM0103)

Projection and grid size	Lambert projection, 10km at 60N and 30N
Integration domain	Japan, 369 x 289 transform grid points
Vertical levels	40 (surface to 10hPa)
Forecast time	18 hours from 00, 06, 12, 18 UTC
Forecast phenomena	severe weather
Initial	OI analysis with 50 minutes data cut off. First guess is derived from 3-hour pre-run which is the hourly cycle from 03 (09) hour forecast of RSM initialized 6 (12) hour earlier for 06, 18 (00, 12) UTC forecast.
Lateral boundary	06-24 (12-30) hour forecast by RSM initialized of 6 (12) hours earlier for 06, 18 (00, 12) UTC forecast
Orography	Mean orography. Orography is smoothed and spectrally truncated.
Surface state	Observed SST (fixed during time integration) and sea ice distribution. Evaporability, roughness length, albedo are climatological values. Snow cover over Japan is analyzed every day.

7.3.2.3 Numerical weather prediction products

No products from MSM are disseminated through JMH and GTS.

7.3.2.4 Operational techniques for application

Significant weather charts and prognostic cross section charts for domestic aviation forecast are produced 4 times a day (00, 06, 12 and 18 UTC).

7.3.3 The Hourly Wind Analysis in Lower Atmosphere

A multivariate three-dimensional optimum interpolation (3D-OI) scheme on model level is employed to analyze wind in lower atmosphere. Wind profiler data at every hour is used as an observational data, which is obtained from Wind Profiler Network and Data Acquisition System (WINDAS) by JMA, and the latest MSM forecast is used as a first guess. The analysis area is limited in and around Japan.

7.3.4 Very short-range forecasting system (0-6 hours)

7.3.4.1 Method of data processing

Using radar reflectivity factors measured with the power scattered from rain particles at 20 digitized ground-based radar sites and precipitation observations by AMeDAS (Automated Meteorological Data Acquisition System, a network of more than 1300 raingauges over Japan), one-hour precipitation data over Japan called Radar-AMeDAS precipitation are analyzed every hour with 2.5km resolution. Radar reflectivity factors are translated into rainfall intensities with a Z-R relationship and accumulated to one-hour precipitation. The analysis of precipitation at each radar is made by calibrating the accumulated radar one-hour precipitation with the raingauge observations. The Radar-AMeDAS precipitation is the composite of analyzed precipitation of all the radars. An initial field for a linear extrapolation forecast is the composite of calibrated rainfall intensities.

The linear extrapolation forecast and the precipitation forecast by the Meso-Scale Model (MSM; see 7.3.2.2) are merged into the final very-short-range precipitation forecast. The merging weight of MSM forecast is nearly zero until 3-hour forecast and gradually increased to the value determined from the relative skill of the current forecasts.

7.3.4.2 Model

Table 14 Specifications of linear extrapolation model

Forecast process	Linear extrapolation
Physical process	Topographic enhancement and dissipation
Motion vector	Motion of precipitation system is evaluated by the cross correlation method
Time step	10 minutes
Grid form	Oblique conformal secant conical projection
Resolution	5km
Number of grids	320 x 720
Initial	Calibrated radar echo intensities
Forecast time	Up to six hours from each initial time (hourly = 24 times/day)

7.3.4.3 Products

The basic products of the very short-range forecasting system are: (a) composite radar echo (echo intensity and echo top height), (b) estimated one-hour precipitation distributions and (c) one-hour precipitation forecasts up to six hours. These products are provided at about 20 minutes past the hour to support the local weather offices issuing weather warnings for heavy precipitation.

7.4 Specialized forecasts

7.4.1 Typhoon forecasting system

7.4.1.1 Objective analysis and initialization

The analysis for numerical typhoon track prediction is made using the global analysis model. After symmetric typhoon bogus data is implanted into the analysis field while asymmetric components are preserved, nonlinear normal mode initialization with full physics is applied to the first five vertical modes.

7.4.1.2 Typhoon model (TYM)

The model specifications are identical to those of RSM (Table 10) except for the followings:

Table 15 Specifications of Typhoon Model(TYM0103)

Independent variables	x-y coordinate on a Lambert (Mercator) projection plane for target typhoon north (south) of 20N and sigma-p hybrid coordinate
Projection and grid size	Lambert (Mercator) projection, 24 km at typhoon center when center of target typhoon is north (south) of 20N.
Integration domain	Center of domain is set at median of expected track of target typhoon in the western North Pacific, 271x271 transform grid points

Vertical levels	25 (Surface to 17.5hPa)
Forecast time	84 hours from 00, 06, 12, 18UTC, maximum two runs for each initial time
Forecast phenomena	Typhoons
Initial	Global analysis using 6-hour forecast by GSM as a guess field with data cut-off time of 2.5 (1.5) hours for 00, 12 (06, 18) UTC initial.
Lateral boundary	0-84 hour forecast by GSM for 00, 12 UTC initial 6-90 hour forecast by GSM initialized 6 hours earlier for 06, 18 UTC initial
PBL	Mellor-Yamada level-2 closure scheme for stable PBL, and similarity theory for surface boundary layer
Surface state	Observed SST fixed during time integration climatological evaporability, roughness length and albedo
Typhoon bogussing	Symmetric vortex generated using manually analyzed central pressure and radius of 30kt winds with gradient-wind balance assumed in the free atmosphere, Ekman-frictional inflow and compensating outflow added in PBL and in upper levels, respectively. The vortex is blended with Global Analysis in combination with asymmetric components taken from TYM's own forecasts, when available.

7.4.1.3 Numerical weather prediction products

The following products from the output of GSM and TYM are disseminated through GTS.

Table 16 Numerical weather prediction products for typhoon forecast

Contents	Level (hPa)	Area	Forecast Hours	Initial Time	Transmission Method
Center position and changes of intensity parameters from the initial time by GSM	-	Eq. - 60N 100E-180E	06, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84	00UTC 12UTC	GTS
Center position and changes of intensity parameters from the initial time by TYM	-	Eq. - 60N 100E-180E	06, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78	00UTC 06UTC 12UTC 18UTC	GTS

7.4.2 Environmental Emergency Response System

JMA is a Regional Specialized Meteorological Center (RSMC) for Environmental Emergency Response in RA II for preparation and dissemination of transport model products on exposure and surface contamination of accidentally released radioactive materials.

The transport model takes a Lagrangian method, where many tracers are released in time and space according to information on pollutant emissions, displaced due to three-dimensional advection and horizontal and vertical diffusions, dropped due to dry and wet depositions and removed due to radioactive decay. Advection, diffusion and deposition are computed from 3-hourly model-level outputs of the high resolution global numerical weather prediction (NWP) model (GSM0103/T213L40). Main products of the RSMC are trajectories, time integrated low-level concentrations and total deposition up to 72 hours.

A high resolution regional transport model is operated experimentally to predict volcanic gas spread over Japan. The concentration of SO_2 is predicted up to 36 hours every day (00UTC initial). The atmospheric state is provided by the RSM forecast 3-hourly.

7.4.3 Ocean wave forecasting system

7.4.3.1 Models

JMA operates three numerical wave models: Global Wave Model (GWM), Japan area Wave Model (JWM) and Coastal Wave Model (CWM). GWM and JWM are classified into the third generation model. CWM is a diagnostic model.

Table 17 Specifications of ocean wave prediction models

Model name	Global Wave Model	Japan-area Wave Model
Model type	spectral model (third generation)	
Spectral component	400 components (25 frequencies from 0.0375 to 0.3Hz and 16 direction)	
Grid form	equal latitude-longitude grid on spherical coordinate	
Grid size	1.25deg. ×1.25deg. (288×121)	0.5deg. ×0.5deg. (81×81)
Integration domain	Global 75N-75S, 0E-180E-1.25W	sea adjacent to Japan 55N-15N, 115E-155E
Time step	30 minutes	30 minutes
Forecast time	90 hours from 00UTC 216 hours from 12UTC	90 hours from 00,12UTC
Boundary condition	---	Global Wave Model
Initial condition	Hindcast	
Wind field	Global Spectral Model (GSM) Bogus gradient winds (for typhoons in the western North Pacific)	

Model name	Coastal Wave Model
Model type	hybrid model of significant wave method and spectral model
Spectral component	16 direction for swell
Grid form	equal latitude-longitude grid on plain
Grid size	0.1deg. ×0.1deg. (400×400)
Integration domain	coastal sea of Japan 55N-15N, 115E-155E
Time step	3 hours (Time interval, diagnostic model)
Forecast time	72 hours from 00,12UTC
Boundary condition	Japan-area Wave Model
Initial condition	(diagnostic model)
Wind field	Regional Spectral Model (RSM) with the supplement of GSM Bogus gradient winds (for typhoons in the western North Pacific)

7.4.3.2 Numerical wave prediction products

The grid point values (GPVs) of the wave models are disseminated to domestic users. The GPVs of GWM are also available in the RSMC Tokyo Data Serving System of JMA.

The model products will also be reported to the Marine Pollution Emergency Response Authority (MPEROA) within the Marine Pollution Emergency Response Support System (MPERSS).

7.4.4 Storm surge forecasting system

7.4.4.1 Model

JMA operates the numerical storm surge model and its specifications are given in Table 18.

Table 18 Specifications of numerical storm surge model

Area covered	Coastal area around Japan (122.5° - 143.1° E, 23.5° - 42.1° N)
Grid (type and resolution)	Latitudinal and longitudinal grid of one minute (1.9km × 1.5km) resolution

Model type	Numerical dynamical model
Boundary conditions (open and Coastal boundaries)	(1) Modified radiation condition at open boundaries; and (2) Zero normal flows at coastal boundaries.
Numerical procedure, time stepping	(1) Time integration: leap frog method; (2) Space differential: central difference method; and (3) Time stepping: 8 seconds.
Wind input	Grid winds as a sum of the two components: (1) gradient winds calculated by the Fujita's pressure model; and (2) moving velocity of the typhoon that is estimated by the positional difference of the typhoon centers that six hourly decided by an operational forecaster.

7.4.4.2 Numerical storm surge prediction products

Time series of predicted storm surge and predicted tidal level, and predicted highest tide for about 200 ports are disseminated to Local Meteorological Observatories, and are used for issuing storm surge advisories and warnings.

7.4.4.3 Operational techniques for application of storm surge prediction products

Considering the error of typhoon forecast track, storm surges for possible 5 tracks are predicted.

7.4.5 Ocean data assimilation system

The Ocean Data Assimilation System (ODAS) with the specifications shown in Table 19 has continued being operated.

Table 19 Specifications of Ocean Data Assimilation System

Basic equation	Primitive equations, rigid lid
Independent variables	Lat-lon coordinate and z vertical coordinate
Dependent variables	u, v, T, s (salinity, nudged to climatological value)
Numerical technique	Finite difference both in the horizontal and in the vertical
Grid size	2.5 degree (longitude) x 2.0 degree (latitude, smoothly decreasing to 0.5 degree toward the equator) grids
Vertical levels	20 levels
Integration domain	Global (from 66N to 80S, toward poles from 60N and 60S, prognostic fields are nudged to climatology)
Forcing data	Ocean currents are driven by the surface wind fields derived by operational global 4DDA, temperature in the mixed layer is nudged to the daily global SST analysis
Observational data	Sea surface and sub surface temperature
Operational runs	Two kinds of run, final run and early run, with cut-off time of 30 days and 5 days, respectively, for ocean observation data

The output of ODAS is fed to an interactive graphic tool for the analysis of tropical ocean status. Some figures based on ODAS outputs are included in the Monthly Ocean Report and in the Monthly Report on Climate System of JMA, and provided through the DDB homepage of JMA. The data are also used as the oceanic initial conditions for the JMA coupled ocean-atmosphere model.

7.4.6 Ocean Data Assimilation System in the North Pacific Ocean

7.4.6.1 Model

Ocean data assimilation system in the North Pacific has been in operation since January 2001, to represent the ocean structure such as the Kuroshio in the mid/high latitudes of the North Pacific with the following specifications.

Table 20 Specifications of ocean data assimilation system in the North Pacific Ocean

Basic equation	Primitive equations, rigid lid
Independent variables	Latitudinal and longitudinal in horizontal coordinate, z in vertical coordinate
Dependent variables	Ocean current components of latitudinal and longitudinal direction, temperature and salinity (nudged to climatology deeper than 1,000 m)
Numerical technique	Finite difference both in the horizontal and in the vertical, nudging with observational temperature, estimated temperature and salinity from sea surface height
Grid size	Variable horizontal resolution, 1/4 x 1/4 degrees adjacent to Japan between 23N and 45N west of 180E, smoothly increasing to 0.5 degree in latitude and to 1.5 degrees in longitude
Time step	10 minutes
Vertical levels	21 levels
Integration domain	North Pacific between 13N and 55N from 120E to 110W
Forcing data	Ocean currents are driven by monthly climatological wind stress
Observational data	Sea surface height, sea surface and subsurface temperature

7.4.6.2 Products of the ocean data assimilation system

The output of this system is monthly averaged and provided in a printed matter, "Monthly Ocean Report" of JMA, and on a web site, NEAR-GOOS RRTDB (http://goos.kishou.go.jp).

7.4.7 Sea ice forecasting system

7.4.7.1 Model

JMA issues information on the state of sea ice in the seas adjacent to Japan. A numerical sea ice model has been run to predict sea ice distribution and thickness in the seas adjacent to Hokkaido (mainly the southern part of the Sea of Okhotsk), twice a week in winter since December 1990 (see Table 21).

Table 21 Specification of numerical sea ice prediction model

Dynamical processes	Viscous-plastic model(MMD/JMA,1993. wind and sea water stress to sea ice, Coriolis' force, force from gradient of sea surface and internal force are considered)
Physical processes	Heat exchange between sea ice, atmosphere and sea water
Dependent variables	Concentration and thickness
Grid size and time step	12.5km and 6 hours
Integration domain	Seas around Hokkaido
Forecast time	168 hours from 00UTC twice a week
Initial	Concentration analysis derived from GMS and NOAA satellite imagery and thickness estimated by hindcast

7.4.7.2 Numerical sea ice prediction products

The grid point values (GPVs) of the numerical sea ice model are disseminated to domestic users. The sea ice conditions for the coming seven days predicted by the model are broadcast by JMH twice a week.

7.4.8 Marine pollution forecasting system

7.4.8.1 Model

JMA operates the numerical marine pollution transport model in case of a marine pollution accident. Its specifications are shown in Table 22.

Table 22 Specifications of marine pollution transport model

Area	Western North Pacific
Grid size	1 - 30km (variable)
Model type	3-dimensional parcel model
Processes	Currents caused by ocean currents, sea surface winds and ocean waves Turbulent diffusion Chemical processes(evaporation, emulsification)

7.5 Extended-range forecasting system

7.5.1 Data assimilation and Model

An extended-range ensemble prediction system is carried out as an extension of the Medium-range Ensemble Prediction System described in 7.2.5. Data assimilation, objective analysis, initialization and the model are common to those of the medium-range ensemble prediction system. For the lower boundary condition of the model, SST anomalies are fixed during the 34-day time integration. Soil moisture and snow depth are predicted by the model, although their initial states are taken from climatology.

7.5.2 Methodology

An ensemble consists of 26 members per week by extending 13 member runs of the medium-range ensemble prediction system on consecutive two days up to 34 days. Thus, initial perturbation is prepared with a combination of a breeding of growing mode (BGM) method and a lagged average forecast (LAF) method.

7.5.3 Numerical weather prediction products

A model systematic bias was estimated as an average forecast error which was calculated from hindcast experiments for years from 1984 to 1993. The bias is removed from forecast fields, and grid point values are processed to produce several forecast materials such as ensemble mean, spread, and so on.

The model output products from one-month prediction system disseminated through the GTS are shown in Table. 23.

Table. 23 Grid point value products (GRIB) for extended–range forecast

<table>
<tr><th colspan="2">Contents</th><th>Level (hPa)</th><th>Area</th><th>Initial time & Forecast Time</th></tr>
<tr><td rowspan="7">Ensemble mean value of forecast members averaged for 7 days forecast time range</td><td>Sea level pressure, rainfall amount</td><td>-</td><td rowspan="4">Global 2.5x2.5 degree</td><td rowspan="7">Initial time : 12UTC of 2 days of the week (Wednesday & Thursday)

Forecast time : 2-8, 9-15, 16-22, 23-29 days from later initial time</td></tr>
<tr><td>Temperature, T-Td, wind (u, v)</td><td>850</td></tr>
<tr><td>Geopotential height,</td><td>500,100</td></tr>
<tr><td>Wind (u, v)</td><td>200</td></tr>
<tr><td>Sea level pressure anomaly</td><td>-</td><td rowspan="7">Northern Hemi-sphere 2.5x2.5 degree</td></tr>
<tr><td>Temperature anomaly</td><td>850</td></tr>
<tr><td>Geopotential height anomaly</td><td>500,100</td></tr>
<tr><td rowspan="3">Spread (Standard deviation) among time averaged ensemble member forecasts</td><td>Sea level pressure</td><td>-</td><td rowspan="4">Forecast time : 2-8, 9-15, 16-22, 23-29, 2-15, 16-29, 2-29 days from later initial time</td></tr>
<tr><td>Temperature</td><td>850</td></tr>
<tr><td>Geopotential height</td><td>500</td></tr>
<tr><td colspan="2">large anomaly index * of geopotential height</td><td>500</td></tr>
</table>

* large anomaly index is defined as {(number of members whose anomaly is higher than 0.5xSD) – (number of members whose anomaly is lower than – 0.5xSD)}/{number of members} at each grid point, where SD is defined as observed climatological standard deviation.

7.5.4 Operational technique for an application of extended-range forecast

Objective guidance products of forecast elements such as the surface temperatures (monthly mean, weekly mean), precipitation amounts (monthly total), sunshine durations (monthly total), and snowfall amounts (monthly total) are derived by the Perfect Prognosis Method (PPM) technique. Clustering method is applied and cluster-averaged field is disseminated to local meteorological observatories.

7.6 Long-range forecasting system

JMA started the operation of a coupled ocean-atmospheric model in 1998 for the outlook of El Niño and La Niña. The specification of the coupled model is shown in Table 24. The oceanic part of the coupled model is identical to the model for ODAS described in 7.4.5. The atmospheric part of the model is a lower resolution (T42) version of the previous operational global spectral model that was used until February 1996. In August 1999, JMA started to issue the monthly ENSO outlook based on the model results for end users. JMA makes the model results available through the DDB of JMA.

Table 24 Specification of the JMA coupled model

Oceanic component	Identical to the model for ODAS	
Atmospheric component	Basic equation	Primitive equation
	Domain	Global
	Resolution	T42, 21 vertical levels
	Convection scheme	Kuo type
	Land surface processes	SiB of Sellers et al. (1986)
Coupling	Coupling interval	24 hours
	Flux adjustment	Monthly heat and momentum flux adjustment
Forecast period	18 months	
Model run interval	15 days	

8. Verification of prognostic products

Objective verification of prognostic products is operationally performed against analysis and radiosonde observations according to the WMO/CBS recommendations. Results of the monthly verification for the year of 2001 are presented in Tables 25.1 to 25.20. All the verification scores are only for the prediction from the 1200 UTC initials.

9. Plans for the future

(1) An hourly analysis system for winds in lower atmosphere using wind data from the JMA wind profiler network will be in operation in early 2002. The first guess fields are provided by MSM forecasts.
(2) A four-dimensional variational (4D-Var) assimilation scheme will be introduced to the meso-scale analysis in early 2002. The length of assimilation window is 3 hours and an incremental approach is taken with an inner-loop model with a horizontal resolution of 20 km. The radar-AMeDAS precipitation data is directly assimilated by using model physics.
(3) Assimilation of sea surface wind data from the QuikSCAT scatterometer and precipitable water data from SSM/I in the global 3D-Var system will be started early 2002.
(4) The parameterization schemes of cumulus convection, land surface processes and radiation used in GSM will be revised.
(5) A prognostic cloud water scheme will be introduced to RSM.
(6) The operation of long-range ensemble prediction with the T63 version of GSM will be started by March 2003. Four-month and eight-month prediction will be performed every month and twice a year, respectively. The initial perturbations are prepared by the singular vector method. SST will be provided by the combination of coupled model described in 7.6, persistence of anomaly and climatology.

Table 25.1 Root mean square errors of geopotential height at 500 hPa against analysis (m)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	15.8	16.3	15.1	14.9	14.2	13.6	12.8	12.9	12.9	14.2	16.0	16.6	14.6
72	37.8	42.7	38.9	36.4	34.3	32.8	29.7	31.2	31.8	36.7	37.6	40.8	35.9
120	65.5	74.1	66.4	64.4	56.7	56.0	48.8	51.0	58.2	63.8	64.7	69.5	61.6

Table 25.2 Root mean square errors of geopotential height at 500 hPa against analysis (m)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	19.6	20.3	21.3	23.5	21.7	27.1	27.2	26.9	25.1	25.9	21.6	20.5	23.4
72	48.2	49.7	50.3	57.1	53.3	65.4	62.9	65.5	55.5	54.7	48.7	44.5	54.7
120	73.7	74.8	76.3	86.4	88.2	98.2	91.9	98.4	84.4	81.9	72.6	69.6	83.0

Table 25.3 Root mean square errors of geopotential height at 500 hPa against observations (m)

North America

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	17.4	15.2	16.1	15.5	13.7	13.3	12.3	12.0	12.5	14.5	15.1	15.8	14.5
72	44.4	46.5	44.4	33.4	33.2	29.6	26.1	26.3	32.6	39.3	40.6	45.1	36.8
120	75.3	83.3	72.1	59.9	54.4	50.8	41.4	40.3	54.5	69.7	66.5	71.9	61.7
ob. num.	77	78	77	78	78	77	79	79	78	78	79	79	78.1

Table 25.4 Root mean square errors of geopotential height at 500 hPa against observations (m)

Europe

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	22.1	22.6	22.5	19.4	17.3	16.2	16.6	15.1	16.5	19.8	20.3	19.9	19.0
72	36.6	48.2	36.4	38.5	33.2	35.1	33.2	28.4	31.6	35.0	41.8	42.6	36.7
120	65.9	80.8	62.8	69.9	62.9	63.0	54.8	52.6	62.8	63.7	78.1	74.3	66.0
ob. num.	59	58	58	58	59	58	57	58	57	56	56	55	57.4

Table 25.5 Root mean square errors of geopotential height at 500 hPa against observations (m)

Asia

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	16.7	16.1	16.6	15.5	16.1	16.6	16.3	16.0	14.5	15.5	15.9	16.2	16.0
72	34.4	33.7	34.5	33.7	33.9	28.1	24.3	28.4	25.5	33.0	34.7	34.7	31.6
120	56.0	56.1	57.2	58.6	51.9	41.8	35.7	38.0	43.1	52.2	54.5	60.3	50.5
ob. num.	48	49	49	48	49	49	47	48	48	48	48	48	48.3

Table 25.6 Root mean square errors of geopotential height at 500 hPa against observations (m)

Australia / New Zealand

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	17.1	16.3	14.7	13.7	16.0	16.7	15.1	20.5	15.9	15.9	16.0	15.2	16.1
72	29.3	28.6	27.7	28.0	36.2	39.5	35.9	41.2	33.3	36.2	33.3	26.9	33.0
120	48.1	47.9	42.5	45.5	55.0	55.1	48.2	55.7	54.5	57.7	50.1	39.5	50.0
ob. num.	22	22	22	22	22	22	22	23	22	22	22	21	22.0

Table 25.7 Root mean square errors of geopotential height at 500 hPa against observations (m)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	19.3	19.1	18.7	17.5	16.5	15.6	15.6	15.7	15.5	17.6	17.9	18.4	17.3
72	41.7	46.8	42.0	38.1	36.6	34.3	31.2	32.0	33.6	39.1	41.6	44.8	38.5
120	71.9	82.2	69.6	67.9	60.6	57.5	51.1	50.8	61.8	68.6	71.6	75.0	65.7
ob. num.	241	242	243	241	243	240	239	244	241	241	241	239	241.3

Table 25.8 Root mean square errors of geopotential height at 500 hPa against observations (m)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	22.4	20.9	18.8	22.0	22.8	25.1	24.7	27.3	24.6	21.6	20.7	20.6	22.6
72	44.7	39.8	35.3	42.8	46.3	54.7	51.5	52.6	45.3	42.3	41.3	33.8	44.2
120	65.0	58.0	54.0	62.9	70.5	77.1	70.7	76.0	68.1	64.5	57.8	54.1	64.9
ob. num.	38	38	38	39	38	37	38	39	39	36	37	35	37.7

Table 25.9 Root mean square of vector wind errors at 250 hPa against analysis (m/s)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	6.7	6.4	6.4	6.3	6.2	6.2	5.9	5.9	5.8	5.6	5.6	5.7	6.1
72	11.7	12.2	11.5	11.4	11.5	11.6	11.2	11.3	11.4	11.7	11.2	11.3	11.5
120	17.0	17.3	16.7	16.8	16.8	16.4	15.3	15.8	17.0	17.5	17.0	16.9	16.7

Table 25.10 Root mean square of vector wind errors at 250 hPa against analysis (m/s)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	6.5	6.7	6.7	7.0	7.0	7.8	7.7	7.6	7.3	7.2	6.4	6.0	7.0
72	13.0	14.2	13.4	14.7	13.9	15.4	15.3	15.2	14.3	14.0	12.3	12.0	14.0
120	18.2	19.7	18.7	20.2	19.8	21.6	20.6	20.7	19.5	18.9	17.3	17.4	19.4

Table 25.11 Root mean square of vector wind errors at 250 hPa against observations (m/s)

North America

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	8.3	7.5	7.9	7.5	7.6	7.4	6.9	7.0	7.2	7.4	7.6	7.8	7.5
72	16.0	14.8	14.5	12.2	13.1	12.7	11.4	11.4	13.2	13.8	14.6	15.3	13.6
120	22.5	20.7	21.4	17.7	18.5	18.1	15.3	15.4	18.5	20.2	20.8	20.5	19.1
ob. num.	70	69	71	72	73	74	77	77	76	73	75	72	73.3

Table 25.12 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Europe

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.5	7.9	7.5	6.8	7.1	7.2	7.5	6.8	7.5	7.6	7.8	6.9	7.3
72	11.4	12.7	10.9	10.9	11.4	12.7	13.3	12.0	13.3	12.6	12.5	13.1	12.2
120	18.3	20.9	15.6	17.7	16.9	18.5	18.8	18.0	21.1	18.7	20.7	19.3	18.7
ob. num.	56	54	56	56	56	56	56	57	56	54	54	53	55.3

Table 25.13 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Asia

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.7	7.6	7.8	8.3	8.4	8.2	7.8	7.1	6.6	6.6	6.1	6.2	7.4
72	10.1	10.1	11.1	12.9	13.6	12.3	11.8	11.5	10.6	11.6	10.1	9.6	11.3
120	13.5	13.9	15.4	17.8	18.4	15.6	16.0	14.8	14.4	17.0	15.2	13.9	15.5
ob. num.	47	47	48	47	48	47	45	46	45	45	45	45	46.3

Table 25.14 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Australia / New Zealand

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.8	7.3	7.2	7.3	7.8	7.9	8.2	8.1	8.2	7.7	7.8	7.6	7.7
72	11.7	12.6	11.1	11.8	12.1	13.6	14.4	12.5	13.2	12.5	12.3	11.0	12.4
120	16.4	18.1	15.1	16.9	17.0	18.8	18.8	16.6	16.6	18.1	17.3	15.4	17.1
ob. num.	33	34	35	35	33	34	34	35	35	35	34	33	34.2

Table 25.15 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Northern Hemisphere (20-90N)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.8	7.5	7.5	7.4	7.3	7.4	7.3	7.1	7.1	7.1	7.2	7.1	7.3
72	12.9	12.8	12.1	11.9	12.4	12.6	12.3	12.0	12.8	12.6	12.7	12.9	12.5
120	18.5	18.7	17.5	17.6	17.7	17.6	16.8	16.6	19.0	18.9	19.2	18.5	18.1
ob. num.	227	225	230	230	233	231	232	236	233	227	229	223	229.7

Table 25.16 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Southern Hemisphere (20-90S)

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	8.5	7.8	8.0	8.3	8.8	9.4	9.2	9.1	9.1	8.9	8.6	8.2	8.7
72	13.2	14.0	12.5	13.6	13.7	15.8	15.8	14.6	14.2	14.0	13.6	12.5	14.0
120	17.7	19.9	17.6	19.6	19.1	21.1	20.8	19.3	18.3	19.7	18.3	17.6	19.1
ob. num.	45	45	46	46	46	45	45	46	46	45	43	42	45.0

Table 25.17 Root mean square of vector wind errors at 850 hPa against analysis (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	2.5	2.5	2.7	2.7	2.9	3.0	3.0	3.2	3.1	3.3	3.1	2.6	2.9
72	3.7	3.8	3.8	3.7	3.9	4.1	4.3	4.4	4.3	4.6	4.3	3.9	4.1
120	4.3	4.5	4.3	4.3	4.4	4.6	4.9	5.1	5.0	5.1	4.8	4.5	4.7

Table 25.18 Root mean square of vector wind errors at 250 hPa against analysis (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	5.9	6.1	5.2	5.0	5.2	5.4	5.3	5.6	5.1	6.1	5.5	5.1	5.5
72	8.7	9.2	8.0	7.7	8.1	7.9	8.1	8.3	7.7	8.4	8.1	8.1	8.2
120	10.1	11.0	9.5	9.3	9.4	9.4	9.3	9.6	8.8	9.5	9.3	9.6	9.6

Table 25.19 Root mean square of vector wind errors at 850 hPa against observations (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	4.3	4.2	4.2	4.2	4.4	4.4	4.4	4.7	4.3	4.3	4.1	4.3	4.3
72	4.6	5.1	4.6	4.4	4.6	5.0	4.9	5.2	4.7	5.0	4.8	4.8	4.8
120	5.1	5.8	5.1	4.8	4.8	5.3	5.4	5.4	5.2	5.4	5.4	5.4	5.3
ob. num.	35	36	36	35	33	32	32	31	32	32	34	34	33.5

Table 25.20 Root mean square of vector wind errors at 250 hPa against observations (m/s)

Tropic

Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
24	7.0	7.6	6.7	6.2	6.4	6.5	6.7	7.1	6.3	6.6	6.4	6.7	6.7
72	8.4	9.2	8.6	7.9	8.0	8.2	8.3	8.2	7.8	8.6	8.2	8.0	8.3
120	9.5	10.6	10.0	9.4	8.6	9.8	9.6	9.9	8.7	9.7	9.4	9.5	9.6
ob. num.	32	33	34	32	30	30	30	31	31	31	33	33	31.7