The ERA-40 Archive Plan

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The ERA-40 Archive Plan

1. Introduction

The primary objectives of ERA-40 are:

(i) to produce and promote use of a comprehensive set of global analyses describing the state of the atmosphere and land and ocean-wave conditions from mid-1957 to 2001;

(ii) to foster European and international research by making the observations, the analyses and the study reports widely available.

An essential element of this is the production of an archive of data. This is necessary both to support the re-analysis itself and to support the subsequent use of the observations, the analyses and the diagnostic information produced by the analysis process. It is important that this archive:

- preserves all primary data;
- serves the needs of the production system for the re-analysis;
- serves the needs of users, both those with direct access to the archive and those supported by data services.

ERA-40 will generate supported data sets, archived using ECMWF's Meteorological Archive and Retrieval System (MARS). Data to be retained will be generated during production wherever possible. The supported data will comprise:

- observations;
- analysis and forecast fields from the assimilating atmospheric model at full resolution;
- analysis and forecast fields from the atmospheric model evaluated at standard pressure levels;
- analysis and forecast fields from the atmospheric model evaluated on isentropic and PV=±2 surfaces;
- analysis and forecast fields from the atmospheric model evaluated on a regular 2.5^ox2.5^o latitude/longitude grid;
- analysis and forecast fields from the coupled ocean-wave model on its regular 1.5^ox1.5^o latitude/longitude grid;
- monthly-means, variances and covariances;
- a time-series data set for a limited selection of fields;
- feedback from the data assimilation for each observation supplied to it;
- selected diagnostic and derived data.

Additional data will be generated as part of the evaluation phase of the project. Subject to satisfactory assessment of their quality and general utility, and of the feasibility of providing support, some of these data may be included later within the supported archive.

The atmospheric model used for ERA-40 has the following resolution:

- 60 levels in the vertical;
- T159 spherical-harmonic representation for basic dynamical fields;
- a reduced Gaussian grid with approximately uniform 125km spacing for surface and other grid-point fields.

Details of the way basic fields from this model are post-processed to produce the output fields are given in the documentation of the ECMWF forecasting system (the code of which has been developed jointly with Météo-France.) Reference should be made in particular to Chapter 2: *FULL-POS post-processing and interpolation*, of Part VI: *Technical and computational procedures*. The atmospheric model is coupled to an ocean-wave model which resolves 25 wave frequencies and 12 wave directions at the nodes of its 1.5^o grid.

The archived ERA-40 data will be made available directly through MARS to users from ECMWF and from ECMWF Member States with access to the ECMWF computer system. Arrangements may be made at a national level within a Members State to supply data to users within that state who do not have direct access to MARS. The National Center for Atmospheric Research (NCAR), a partner in the ERA-40 project, may distribute data to UCAR members and to non-UCAR research and educational institutions in the USA for scientific, research and educational uses. ERA-40 products will be available generally from ECMWF Data Services, subject to the rules of data distribution adopted by the Council of ECMWF. Provision of observational data will also be subject to any restrictions imposed by the original suppliers of the data.

Data can be supplied on a range of grids. Users of Data Services will, however, have to meet the handling costs incurred in satisfying their data requests. Fields will be archived on the standard 2.5^o grid as well as in their fundamental model form (T159 spherical harmonic or corresponding reduced Gaussian grid) in order to reduce handling costs (and retrieval times) for users for whom the 2.5^o resolution is adequate. Data will normally be archived as complete sets of fields for one analysis time, but selected fields will also be saved in the form of time series, again with the aim of reducing data retrieval times and handling costs. Consideration will be given to the production and supply of other subsets of the data during the course of the project, including the provision of basic data on CD-ROMs or DVDs, or through the Internet.

The Project Plan for ERA-40 identifies a priority production stream analysing data from 1987 onwards, with a second stream running from mid-1957 onwards. Data will be made available immediately to project partners who will participate in monitoring and initial validation activities. Data will be released to general users once sufficient validation has been satisfactorily completed for each full year of re-analysis. This is expected to be within three months of the completion of production for that year. It is envisaged that general release of data will begin in Autumn 2000, and continue regularly for a little over two years until a complete record for the period from mid-1957 to 2001 is available in late 2002.

It is planned to update this document from time to time so that it evolves from its initial status as an Archive Plan to its final status as an Archive Specification.

2. Archive of observations

The observational data for use in ERA-40 include both data from the operational ECMWF archives and data supplied to ECMWF by external institutions for use in re-analysis. For each stream of externally supplied data, files have been stored containing the data as received, with only minor representation changes to eliminate machine-dependent features such as Cray blocking. It is thus possible to go back to the data in their different original formats should this be needed. The complexity of these ascii/binary formats vary, and for older observations decoding has often involved the solving of observation-specific problems. The data have been converted to the FM94 BUFR representation for supply to the assimilation system and storage in MARS. Data in BUFR form will be made generally available where possible.

The input data streams are specified in Table 2.1 for the period covered by the first production stream of ERA-40, 1987-2001. The table will be completed later to include all data streams for the period since 1957. Data marked as having public availability will be disseminated subject to the rules of data distribution adopted by the Council of ECMWF. Data marked as having restricted availability have been provided to ECMWF under restrictions as to their use or supply to third parties, and thus cannot be made widely available.

TABLE 2.1 OBSERVATION STREAMS FOR USE IN THE FIRST PHASE OF PRODUCTION, 1987-2001

Data supplier	Data type	Period	Availability
ECMWF	All non-satellite types	1979-2001	Public[1]
ECMWF, NCAR, LMD, NASA	TOVS and ATOVS level 1b/1c radiances	1978-2001	Public
ECMWF	Satellite cloud motion winds	1979-2001	Public
ECMWF	ERS	1991-2001	Restricted
Remote Sensing Systems	SSM/I	1987-1998	Restricted
ECMWF	SSM/I	1997-2001	Public
NCEP	Operational data - Surface, upper air, aircraft and cloud-motion winds	1979-1994	To be confirmed
NCAR	COADS - SHIP and buoy Snow data from former USSR Automatic Antarctic stations from University of Wisconsin	1950-1999 1966-1990 1980-1998	To be confirmed
US Navy	Surface and upper air	1985-1996	To be confirmed
Japan Meteorological Agency	Radiosonde, Pilot, Aircraft Radiosonde, Pilot, Aircraft GMS Cloud Motion Winds	1975-1978 1980-1997 1980-1993	Restricted Restricted To be confirmed
Atmospheric Environment Service, Canada	Canadian snow depths	1946-1995	To be confirmed
British Antarctic Survey	Antarctic Surface Data	1947-1999	To be confirmed
Australian Bureau of Meteorology	Synthetic surface pressures (PAOBS)	1979-1993	To be confirmed
Australian Bureau of Meteorology National Climate Centre	Australian Antarctic data - Radiosonde, SHIP, SYNOP	1947-1999	Restricted
Woods Hole Institute for Oceanography	Subduction buoys	1991-1993	To be confirmed
Pacific Marine Environmental Laboratory	TAO-buoy array	1993-1995	To be confirmed

TABLE 2.1 OBSERVATION STREAMS FOR USE IN THE FIRST PHASE OF PRODUCTION, 1987-2001

Data supplier	Data type	Period	Availability
???	TOGA COARE - Dropsondes - Base Dropsondes - Radiosondes	1992-1993	To be confirmed
NASA	TOMS total ozone	1978-2001	To be confirmed
NASA, NOAA, ECMWF	SBUV ozone profile	1978-2001	To be confirmed

1. With minor exceptions

Many observations appear in more than one of the input data streams. The merging of the multiple data streams and elimination of duplicate observations will be carried out before the analysis step using in-house “ODB” database software. An additional archive will be generated comprising all observations actually provided to the ERA-40 data assimilation system. Complete sets of such observations will be stored for each six-hour assimilation period. Time series of observations of selected types may also be generated.

Externally produced analyses of sea-surface temperature and sea-ice fraction will be used in ERA-40. These will be preserved in their original form, as well as in the processed model forms specified below in Section 3.4.

3. Analysis and forecast fields

3.1 Generation of results

The re-analysis production plan is for:

- four analyses per day, for 00, 06, 12, and 18 UTC;
- two forecasts per day to 6 hours ahead, from 06 and 18 UTC;
- two forecasts per day to 36 hours ahead, from 00 and 12 UTC;
- one ten-day forecast every day from 12 UTC.

Analysis and 6-hour forecast data will be retained within the archives in full. Forecast data will also be produced for the 3-hour range for each analysis cycle, and also for 9, 12, 15, 18, 21, 24, 30 and 36 hours ahead from 00 and 12UTC. It will not be feasible to retain complete sets of data from all forecast ranges within the archives in the long term. Forecast data will be retained at a minimum to ensure complete sets of fields are available at three-hourly frequency from either analyses or forecasts. The selection of data to be retained for each forecast range will be determined depending on the results of the validation studies and user requirements. Only a limited number of fields will be archived from the ten-day forecasts. Fields from the atmospheric model will be archived either at their full T159 spectral resolution or on the corresponding Gaussian grid of the model, depending on their basic representation in the model. Fields will in most cases also be derived and saved on the regular 2.5^{o} latitude/longitude grid.

Basic T159 spherical-harmonic fields will be truncated to T63 before the 2.5^o grid values are computed. Fields from the coupled ocean-wave model will be saved on its regular 1.5^o latitude/longitude grid.

The T159 model's reduced Gaussian grid is symmetric about the equator, with a north-south separation which is close to uniform in latitude, with a spacing of about 1.121^o. There are 80 points aligned along the Greenwich Meridian from equator to pole. The number of points in the east-west varies with latitude, with uniform grid spacing along a particular line of latitude. The spacing is 1.125^o in the tropics. The grid is specified (for the Northern Hemisphere) in Table 3.1, which gives for each row the latitude (accurate to two decimal points) and the number of points in the east-west.

TABLE 3.1 THE GAUSSIAN GRID

Row no.	Lat.	Points	Row no.	Lat.	Points	Row no.	Lat.	Points	Row no.	Lat.	Points
1	89.14	18	2	88.03	25	3	86.91	36	4	85.79	40
5	84.67	45	6	83.55	54	7	82.43	60	8	81.31	64
9	80.19	72	10	79.06	72	11	77.94	80	12	76.82	90
13	75.70	96	14	74.58	100	15	73.46	108	16	72.34	120
17	71.21	120	18	70.09	128	19	68.97	135	20	67.85	144
21	66.73	144	22	65.61	150	23	64.49	160	24	63.36	160
25	62.24	180	26	61.12	180	27	60.00	180	28	58.88	192
29	57.76	192	30	56.64	200	31	55.51	200	32	54.39	216
33	53.27	216	34	52.15	216	35	51.03	225	36	49.91	225
37	48.78	240	38	47.66	240	39	46.54	240	40	45.42	256
41	44.30	256	42	43.18	256	43	42.06	256	44	40.93	288
45	39.81	288	46	38.69	288	47	37.57	288	48	36.45	288
49	35.33	288	50	34.21	288	51	33.08	288	52	31.96	288
53	30.84	300	54	29.72	300	55	28.60	300	56	27.48	300
57	26.36	320	58	25.23	320	59	24.11	320	60	22.99	320
61	21.87	320	62	20.75	320	63	19.63	320	64	18.50	320
65	17.38	320	66	16.26	320	67	15.14	320	68	14.02	320
69	12.90	320	70	11.78	320	71	10.65	320	72	9.53	320
73	8.41	320	74	7.29	320	75	6.17	320	76	5.05	320
77	3.93	320	78	2.80	320	79	1.68	320	80	0.56	320

The WMO representation form FM92 GRIB is used to represent all analysis and forecast fields. In general, ERA GRIB data are coded using ECMWF's local version of GRIB code table 2 (version number 128 for atmosphere products, 140 for wave products), which gives parameter names and units. An additional local version of GRIB code table 2 (version 160) is used for some monthly and climatological parameters. Local version 160 was devised for ERA use, and enables variances and covariances to be represented.

3.2 Upper air parameters on model and pressure levels

Upper-air data will be saved at each of the 60 “full” model levels and at 23 pressure levels, except where stated otherwise. Model “half-level” pressures $p_{k-1/2}$ are defined by

$$p_{k-1/2} = A_{k-1/2} + B_{k-1/2}\ p_s$$

where p_s is surface pressure and k=1,2,3,...61. The pressures of the “full” model levels, p_k, are defined by

$$p_k = \frac{1}{2}(p_{k-1/2} + p_{k+1/2})$$

Precise values for the $A_{k-1/2}$ and $B_{k-1/2}$ should be read from Section 2, the Grid Description Section, of a GRIB file for model-level data. Values accurate to five significant figures are given in Table 3.2, together with half and full level pressures for a surface pressure of 1013.25hPa. The corresponding heights, z_k, of the full levels are also shown, assuming a uniform scale height of 7km for pressure. For this scale height the model level spacing is precisely 1.5km in the middle stratosphere. The 23 pressure levels to which the model-level fields are interpolated are also specified in Table 3.2.

TABLE 3.2 MODEL AND PRESSURE LEVELS

Model Levels						Pressure levels (hPa)
k	$A_{k-1/2}$ (hPa)	$B_{k-1/2}$	$p_{k-1/2}$ (hPa)	p_k (hPa)	z_k (km)	
1	0.00	0.00000	0.00	0.10	64.56	
2	0.20	0.00000	0.20	0.29	57.06	
3	0.38	0.00000	0.38	0.51	53.16	
4	0.64	0.00000	0.64	0.80	50.04	
5	0.96	0.00000	0.96	1.15	47.46	1
6	1.34	0.00000	1.34	1.58	45.27	
7	1.81	0.00000	1.81	2.08	43.33	2
8	2.35	0.00000	2.35	2.67	41.58	3
9	2.98	0.00000	2.98	3.36	39.96	
10	3.74	0.00000	3.74	4.19	38.41	
11	4.65	0.00000	4.65	5.20	36.90	5
12	5.76	0.00000	5.76	6.44	35.40	7

TABLE 3.2 MODEL AND PRESSURE LEVELS

Model Levels						Pressure levels (hPa)
k	$A_{k-1/2}$ (hPa)	$B_{k-1/2}$	$p_{k-1/2}$ (hPa)	p_k (hPa)	z_k (km)	
13	7.13	0.00000	7.13	7.98	33.90	
14	8.84	0.00000	8.84	9.89	32.40	10
15	10.95	0.00000	10.95	12.26	30.90	
16	13.56	0.00000	13.56	15.19	29.40	
17	16.81	0.00000	16.81	18.81	27.90	20
18	20.82	0.00000	20.82	23.31	26.40	
19	25.80	0.00000	25.80	28.88	24.90	30
20	31.96	0.00000	31.96	35.78	23.40	
21	39.60	0.00000	39.60	44.33	21.90	
22	49.07	0.00000	49.07	54.62	20.44	50
23	60.18	0.00000	60.18	66.62	19.05	70
24	73.07	0.00000	73.07	80.40	17.74	
25	87.65	0.00008	87.73	95.98	16.50	100
26	103.76	0.00046	104.23	113.42	15.33	
27	120.77	0.00182	122.61	132.76	14.23	
28	137.75	0.00508	142.90	154.00	13.19	150
29	153.80	0.01114	165.09	177.12	12.21	
30	168.19	0.02068	189.15	202.09	11.29	200
31	180.45	0.03412	215.03	228.84	10.42	
32	190.28	0.05169	242.65	257.36	9.59	250
33	197.55	0.07353	272.06	287.64	8.81	300
34	202.22	0.09967	303.22	319.63	8.08	
35	204.30	0.13002	336.04	353.23	7.38	
36	203.84	0.16438	370.41	388.27	6.71	400
37	200.97	0.20248	406.13	424.57	6.09	
38	195.84	0.24393	443.01	461.90	5.50	
39	188.65	0.28832	480.79	500.00	4.94	500
40	179.61	0.33515	519.21	538.591	4.42	
41	168.99	0.38389	557.97	577.38	3.94	

TABLE 3.2 MODEL AND PRESSURE LEVELS

Model Levels						Pressure levels (hPa)
k	$A_{k-1/2}$ (hPa)	$B_{k-1/2}$	$p_{k-1/2}$ (hPa)	p_k (hPa)	z_k (km)	
42	157.06	0.43396	596.78	616.04	3.48	600
43	144.11	0.48477	635.31	654.27	3.06	
44	130.43	0.53571	673.24	691.75	2.67	700
45	116.33	0.58617	710.26	728.16	2.31	
46	102.10	0.63555	746.06	763.20	1.98	775
47	88.02	0.68327	780.35	796.59	1.68	
48	74.38	0.72879	812.83	828.05	1.41	
49	61.44	0.77160	843.26	857.34	1.17	850
50	49.42	0.81125	871.42	884.27	0.95	
51	38.51	0.84737	897.11	908.65	0.76	
52	28.88	0.87966	920.19	930.37	0.60	925
53	20.64	0.90788	940.55	949.35	0.46	
54	13.86	0.93194	958.15	965.57	0.34	
55	8.55	0.95182	972.99	979.06	0.24	
56	4.67	0.96765	985.14	989.95	0.16	
57	2.10	0.97966	994.75	998.39	0.10	1000
58	0.66	0.98827	1002.02	1004.64	0.06	
59	0.07	0.99402	1007.26	1009.06	0.03	
60	0.00	0.99763	1010.85	1012.05	0.01	
61	0.00	1.00000	1013.25			

Table 3.3 gives details of the "upper air" parameters. These include surface geopotential and the logarithm of surface pressure. Although not strictly upper air parameters, these are produced in spherical-harmonic form along with the model level data. Surface pressure is needed to compute the distribution of pressure on the model surfaces as indicated above. The table indicates which parameters will be stored at model levels and which will be stored at pressure levels. The various horizontal representations are indicated by **sh** (spherical harmonics), **gg** (Gaussian grid), and **2.5°** (2.5^{o} latitude/longitude grid). Except where indicated, parameters will be available from both analyses and forecasts. **Code** refers to the parameter reference number in GRIB code table 2, version 128.

TABLE 3.3 - UPPER AIR PARAMETERS ON MODEL AND PRESSURE LEVELS

Parameter	Model levels		Pressure levels			Code	Units
	sh	gg	gg	sh	2.5°		
surface geopotential[1]	X					129	$m^2\ s^{-2}$
geopotential				X	X	129	$m^2\ s^{-2}$
temperature	X			X	X	130	K
eastward wind component					X	131	$m\ s^{-1}$
northward wind component					X	132	$m\ s^{-1}$
specific humidity		X			X	133	kg/kg
vertical velocity	X			X	X	135	$Pa\ s^{-1}$
vorticity	X			X		138	s^{-1}
log surface pressure (Pa)	X					152	
divergence	X			X		155	s^{-1}
relative humidity				X	X	157	%
ozone mass mixing ratio		X			X	203	kg/kg
cloud liquid water content[2]		X				246	kg/kg
cloud ice water content[2]		X				247	kg/kg
cloud cover[2]		X				248	(0-1)
potential vorticity			X		X	60	$m^2\ s^{-1}\ K\ kg^{-1}$

1. analysis only

2. forecast only

3.3 Upper air parameters on isentropic and PV=±2 surfaces

Fields will also be interpolated to fifteen isentropic surfaces.The potential temperatures of these surfaces are specified in Table 3.4, which also shows corresponding pressures and heights for a 250K dry isothermal atmosphere.

TABLE 3.4 - ISENTROPIC LEVELS AND CORRESPONDING PRESSURES AND HEIGHTS

θ (K)	p (hPa)	z (km)
265	815	1.5
275	716	2.4

TABLE 3.4 - ISENTROPIC LEVELS AND CORRESPONDING PRESSURES AND HEIGHTS

θ (K)	p (hPa)	z (km)
285	632	3.4
300	528	4.7
315	445	5.9
330	378	7.1
350	308	8.6
370	254	10.0
395	202	11.7
430	150	13.9
475	106	16.4
530	72	19.2
600	47	22.4
700	27	26.4
850	14	31.3

Table 3.5 shows the parameters and horizontal representations of the fields to be archived on the isentropic surfaces.

TABLE 3.5 - PRODUCTS ON ISENTROPIC SURFACES

Parameter	gg	sh	2.5^{o}	Code	Units
potential vorticity	X		X	60	$m^2\ s^{-1}\ K\ kg^{-1}$
Montgomery potential		X	X	53	$m^2\ s^{-2}$
eastward wind component			X	131	$m\ s^{-1}$
northward wind component			X	132	$m\ s^{-1}$
vorticity		X		138	s^{-1}
divergence		X		155	s^{-1}
specific humidity	X		X	133	kg/kg
ozone mass mixing ratio	X		X	203	kg/kg
pressure		X	X	54	Pa

Montgomery potential is defined as $\phi + c_{pd}\theta(p/p_0)^{\kappa_d}$, where ϕ and p are respectively the geopotential and the pressure of the constant-θ surface, c_{pd} is the specific heat of dry air at constant pressure and

$\kappa_d = R_d / c_{pd}$, where R_d is the gas constant of dry air. Note, however, that θ is defined by $\theta = T(p/p_0)^{-\kappa}$, with κ defined for a moist atmosphere: $\kappa = R/c_p$, where $R = R_d(1 + (R_v/R_d - 1)q)$ and $c_p = c_{pd}(1 + (c_{pv}/c_{pd} - 1)q)$, with q the specific humidity, and R_v and c_{pv} respectively the gas constant and specific heat at constant pressure of water vapour. The effect of moisture is included also in the calculation of ϕ, as described in the documentation of the model.

Fields will also be produced on a "PV=±2" surface on which the potential vorticity takes the value 2PVU in the northern hemisphere and -2PVU in the southern hemisphere (1PVU=$10^{-6}m^2s^{-1}Kkg^{-1}$), provided such a surface can be found searching downwards from the model level close to 96hPa. Values at this model level are used where the search is unsuccessful.

Table 3.6 shows the parameters to be archived on the PV=±2 surface. All fields will saved on the model's Gaussian grid and on the regular 2.5^o latitude/longitude grid.

TABLE 3.6 - PRODUCTS ON THE PV=±2 SURFACE

Parameter	Code	Units
potential temperature	3	K
geopotential	129	$m^2\ s^{-2}$
eastward wind component	131	$m\ s^{-1}$
northward wind component	132	$m\ s^{-1}$
specific humidity	133	kg/kg
ozone mass mixing ratio	203	kg/kg
pressure	54	Pa

3.4 Surface and single-level parameters

A variety of surface and single level parameters will be saved on the model's Gaussian grid, and on the 2.5^o latitude/longitude grid. The list of these differs according to whether they are produced by the analysis (**An**), or the forecast (**Fc**), and is given in Table 3.7 below. Forecast fields marked as *(accum.)* represent accumulated values, i.e. values integrated in time over the range of the forecast.

TABLE 3.7 - SURFACE AND SINGLE LEVEL PARAMETERS

Parameter	An	Fc	Code	Units
sea surface temperature	X		34	K
sea ice fraction (1 = full ice, 0 = no ice)	X		31	
surface geopotential	X		129	$m^2\ s^{-2}$

TABLE 3.7 - SURFACE AND SINGLE LEVEL PARAMETERS

Parameter	An	Fc	Code	Units
total column water	X	X	136	kg m^{-2}
total column water vapour	X	X	137	kg m^{-2}
soil temperature level 1	X	X	139	K
soil temperature level 2	X	X	170	K
soil temperature level 3	X	X	183	K
soil temperature level 4	X	X	236	K
soil moisture level 1 (volumetric)	X	X	39	m^3/m^3
soil moisture level 2 (volumetric)	X	X	40	m^3/m^3
soil moisture level 3 (volumetric)	X	X	41	m^3/m^3
soil moisture level 4 (volumetric)	X	X	42	m^3/m^3
snow depth	X	X	141	m of water equivalent
large-scale precipitation *(accum.)*		X	142	m of water
convective precipitation *(accum.)*		X	143	m of water
snowfall *(accum.)*		X	144	m of water equivalent
boundary layer dissipation *(accum.)*		X	145	W m^{-2} s
surface sensible heat flux *(accum.)*		X	146	W m^{-2} s
surface latent heat flux *(accum.)*		X	147	W m^{-2} s
Charnock parameter	X	X	148	
mean sea level pressure	X	X	151	Pa
standard deviation of orography	X		160	m
anisotropy of orography	X		161	
angle of sub-grid scale orography	X		162	
slope of sub-grid scale orography	X		163	
total cloud cover	X	X	164	(0-1)
10 metre eastward wind component	X	X	165	m s^{-1}
10 metre northward wind component	X	X	166	m s^{-1}
2 metre temperature	X	X	167	K
2 metre dewpoint	X	X	168	K
downward surface solar radiation *(accum.)*		X	169	W m^{-2} s

TABLE 3.7 - SURFACE AND SINGLE LEVEL PARAMETERS

Parameter	An	Fc	Code	Units
land/sea mask	X		172	(0,1)
surface roughness	X		173	m
albedo (climate)	X		174	
downward surface thermal radiation *(accum.)*		X	175	W m^{-2} s
surface solar radiation *(accum.)*		X	176	W m^{-2} s
surface thermal radiation *(accum.)*		X	177	W m^{-2} s
top solar radiation *(accum.)*		X	178	W m^{-2} s
top thermal radiation *(accum.)*		X	179	W m^{-2} s
eastward component of turbulent stress *(accum.)*		X	180	N m^{-2} s
northward component of turbulent stress *(accum.)*		X	181	N m^{-2} s
evaporation *(accum.)*		X	182	m of water
low cloud cover	X	X	186	(0-1)
medium cloud cover	X	X	187	(0-1)
high cloud cover	X	X	188	(0-1)
latitudinal component of gravity wave stress *(accum.)*		X	195	N m^{-2} s
meridional component of gravity wave stress *(accum.)*		X	196	N m^{-2} s
gravity wave dissipation *(accum.)*		X	197	W m^{-2} s
skin reservoir content	X	X	198	m of water
maximum 2m temperature since last post-processing step		X	201	K
minimum 2m temperature since last post-processing step		X	202	K
runoff *(accum.)*		X	205	m of water
total column ozone	X	X	206	kg m^{-2}
instantaneous eastward component of turbulent stress		X	229	N m^{-2}
instantaneous northward component of turbulent stress		X	230	N m^{-2}
instantaneous surface heat flux		X	231	W m^{-2}
instantaneous moisture flux (evaporation)		X	232	kg m^{-2} s
log. surface roughness length (m) for heat	X		234	
skin temperature	X	X	235	K

TABLE 3.7 - SURFACE AND SINGLE LEVEL PARAMETERS

Parameter	An	Fc	Code	Units
convective snowfall *(accum.)*		X	239	m of water equivalent
large-scale snowfall *(accum.)*		X	240	m of water equivalent
forecast albedo		X	243	
forecast surface roughness		X	244	m
forecast log. surface roughness length (m) for heat		X	245	
low vegetation cover	X		27	(0-1)
high vegetation cover	X		28	(0-1)
low vegetation type (table index)	X		29	index
high vegetation type (table index)	X		30	index
snow temperature	X	X	238	K
snow albedo	X	X	32	
snow density	X	X	33	kg
sea ice temperature layer 1	X	X	35	K
sea ice temperature layer 2	X	X	36	K
sea ice temperature layer 3	X	X	37	K
sea ice temperature layer 4	X	X	38	K
boundary layer height		X	159	m
sunshine duration since last post-processing step		X	189	s
wind gusts at 10 m		X	49	ms^{-1}
large-scale precipitation fraction *(accum.)*		X	50	s
top solar radiation clear sky *(accum.)*		X	208	$W\ m^{-2}\ s$
top thermal radiation clear sky *(accum.)*		X	209	$W\ m^{-2}\ s$
surface solar radiation clear sky *(accum.)*		X	210	$W\ m^{-2}\ s$
surface thermal radiation clear sky *(accum.)*		X	211	$W\ m^{-2}\ s$
snow evaporation *(accum.)*		X	44	m
snow melt *(accum.)*		X	45	m

3.5 Additional vertical integrals for energy, mass, water and ozone budgets

The standard model post-processing produces the surface and single-level fields given in Table 3.7. A number of additional "single-level" fields of vertical integrals relating to the budgets of mass, water, ozone and energy will be derived from the instantaneous post-processed model-level data and archived on the model's Gaussian grid and on the standard 2.5^{o} latitude/longitude grid. They are listed in Table 3.8. Further details are given in Annex 1.

It is planned also to compute divergences of the fluxes. Table 3.8 will be amended to reflect this in due course.

TABLE 3.8 - VERTICAL INTEGRALS FOR BUDGETS

Parameter	Definition	Code[1]	Units
mass	$\frac{1}{g}\int_0^1 \frac{\partial p}{\partial \eta} d\eta$	97	kg m^{-2}
kinetic energy	$\frac{1}{g}\int_0^1 \frac{1}{2}(\underset{\sim}{v} \cdot \underset{\sim}{v})\frac{\partial p}{\partial \eta} d\eta$	93	J m^{-2}
thermal energy	$\frac{1}{g}\int_0^1 c_p T\frac{\partial p}{\partial \eta} d\eta$	94	J m^{-2}
eastward kinetic energy flux	$\frac{1}{g}\int_0^1 u\frac{1}{2}(\underset{\sim}{v} \cdot \underset{\sim}{v})\frac{\partial p}{\partial \eta} d\eta$	81	W m^{-1}
northward kinetic energy flux	$\frac{1}{g}\int_0^1 v\frac{1}{2}(\underset{\sim}{v} \cdot \underset{\sim}{v})\frac{\partial p}{\partial \eta} d\eta$	82	W m^{-1}
eastward geopotential flux	$\frac{1}{g}\int_0^1 u\phi\frac{\partial p}{\partial \eta} d\eta$	83	W m^{-1}
northward geopotential flux	$\frac{1}{g}\int_0^1 v\phi\frac{\partial p}{\partial \eta} d\eta$	84	W m^{-1}
eastward heat flux	$\frac{1}{g}\int_0^1 uc_p T\frac{\partial p}{\partial \eta} d\eta$	85	W m^{-1}
northward heat flux	$\frac{1}{g}\int_0^1 vc_p T\frac{\partial p}{\partial \eta} d\eta$	86	W m^{-1}
eastward mass flux	$\frac{1}{g}\int_0^1 u\frac{\partial p}{\partial \eta} d\eta$	87	kg m^{-1} s^{-1}

TABLE 3.8 - VERTICAL INTEGRALS FOR BUDGETS

Parameter	Definition	Code[1]	Units
northward mass flux	$\frac{1}{g}\int_0^1 v\frac{\partial p}{\partial\eta}d\eta$	88	kg m^{-1} s^{-1}
eastward water-vapour flux	$\frac{1}{g}\int_0^1 uq\frac{\partial p}{\partial\eta}d\eta$	91[2]	kg m^{-1} s^{-1}
northward water-vapour flux	$\frac{1}{g}\int_0^1 vq\frac{\partial p}{\partial\eta}d\eta$	92[2]	kg m^{-1} s^{-1}
eastward ozone flux	$\frac{1}{g}\int_0^1 uO_3\frac{\partial p}{\partial\eta}d\eta$	89	kg m^{-1} s^{-1}
northward ozone flux	$\frac{1}{g}\int_0^1 vO_3\frac{\partial p}{\partial\eta}d\eta$	90	kg m^{-1} s^{-1}
energy conversion	$-\frac{1}{g}\int_0^1 \frac{RT\omega}{p}\frac{\partial p}{\partial\eta}d\eta$	95	W m^{-2}

1. GRIB code table 2 version 160 except where marked

2. GRIB code table 2 version 128

3.6 Ocean-wave data

A set of ocean-wave products will be generated by the wave analysis and coupled wave-model forecasts. They will be archived together with fields of gridded data from the altimeters on the ERS-1 and ERS-2 satellites. The fields to be archived are listed in Table 3.9. **Code** refers to the parameter reference number in GRIB table 2, ECMWF local version 140. Data will be stored on the wave model's 1.5^{o} latitude/longitude grid.

TABLE 3.9 WAVE DATA - ANALYSIS, FORECASTS AND GRIDDED ERS ALTIMETER FIELDS

Parameter	Code	Units
significant wave height	229	m
mean wave direction	230	degrees
peak period of 1d spectra	231	s
mean wave period	232	s
coefficient of drag with waves	233	

TABLE 3.9 WAVE DATA - ANALYSIS, FORECASTS AND GRIDDED ERS ALTIMETER FIELDS

Parameter	Code	Units
significant height of wind waves	234	m
mean direction of wind waves	235	degrees
mean period of wind waves	236	s
significant height of primary swell	237	m
mean direction of primary swell	238	degrees
mean period of primary swell	239	s
mean square slope of waves	244	
components of the 2D wave spectra	250	m^2 s $radians^{-1}$
mean wave period from 1st moment	220	s
mean wave period from 2nd moment	221	s
wave spectral directional width	222	-
mean wave period from 1st moment of wind waves	223	s
mean wave period from 2nd moment of wind waves	224	s
wave spectral directional width of wind waves	225	-
mean wave period from 1st moment of swell	226	s
mean wave period from 2nd moment of swell	227	s
wave spectral directional width of swell	228	-
10m wind speed modified by wave model	245	m s^{-1}
gridded ERS altimeter wave height[1]	246	m
gridded corrected ERS altimeter wave height[1]	247	m
gridded ERS altimeter range relative correction[1]	248	-

1. Available from late 1991 onwards

3.7 Additional fields accumulated from the physical parametrizations

The data described in the following subsections will be accumulated over the first three- and six-hour intervals of the forecasts carried out four times per day.

3.7.1 Parameters to support chemical-transport modelling

Table 3.10 indicates the fields produced for use in chemical-transport modelling and other trajectory studies.

TABLE 3.10 - PARAMETERS TO SUPPORT CHEMICAL TRANSPORT MODELLING (ACCUMULATED)

Parameter	Surfaces	Code[1]	Units
updraught mass flux	model half levels	104	kg m^{-2}
downdraught mass flux	model half levels	105	kg m^{-2}
updraught detrainment rate	model full levels	106	s m^{-1}
downdraught detrainment rate	model full levels	107	s m^{-1}
total precipitation profile	model half levels	108	kg m^{-2}
turbulent diffusion coefficient for heat	model half levels	109	m^2

1. GRIB code table 2 version 128

3.7.2 Radiative tendencies

Tendencies from cloudy and clear-sky radiation will be accumulated. The parameters indicated in Table 3.11 will be saved at full model levels.

TABLE 3.11 - PARAMETERS TO VALIDATE CLEAR SKY RADIATION (ACCUMULATED)

Parameter	Code[1]	Units
Short wave radiative tendency	100	K
Long wave radiative tendency	101	K
Clear sky short wave radiative tendency	102	K
Clear sky long wave radiative tendency	103	K

1. GRIB code table 2 version 128

3.7.3 Net tendencies from parametrized processes

Net tendencies from parametrized processes will be accumulated for full model levels, as listed in Table 3.12.

TABLE 3.12 - NET TENDENCIES (ACCUMULATED)

Parameter	Code[1]	Units
u tendency	112	$m\ s^{-1}$
v tendency	113	$m\ s^{-1}$
T tendency	110	K
q tendency	111	kg/kg

1. GRIB code table 2 version 128

4. Monthly-means, variances and covariances

Monthly means of the analysed and forecast fields listed in section 3 above will be computed for each synoptic hour (00, 06, 12, and 18 UTC) and archived during production of the re-analyses. Averages of the 00, 06, 12, and 18 UTC values will also be produced.

A set of transient variances and covariances will be produced, with respect to the means for each of the four synoptic hours and for the daily average. Fields will be archived on both the Gaussian and 2.5^{o} grids. Parameters are specified in Table 4.1. Here the overbar denotes the relevant monthly mean, and x' denotes the deviation of field x from $\bar{x}$. ϕ denotes geopotential, u the eastward velocity component, v the northward velocity component, ω the pressure-coordinate vertical velocity, T temperature, q specific humidity, r relative humidity and O_3 ozone.

At the end of production, averages over the full period of the re-analysis will be computed for each calendar month and added to the archive.

TABLE 4.1 VARIANCES AND CO-VARIANCES

Parameter	Model levels	Pressure levels	Code[1]	Units
$\overline{\phi'\phi'}$		X	206	$m^4\ s^{-4}$
$\overline{\phi'T'}$		X	207	$m^2\ K\ s^{-2}$
$\overline{T'T'}$	X	X	208	K^2
$\overline{\phi'q'}$		X	209	$m^2\ s^{-2}$
$\overline{T'q'}$	X	X	210	K

TABLE 4.1 VARIANCES AND CO-VARIANCES

Parameter	Model levels	Pressure levels	Code[1]	Units
$\overline{q'q'}$	X	X	211	
$\overline{u'\phi'}$		X	212	m^3 s^{-3}
$\overline{u'T'}$	X	X	213	m s^{-1} K
$\overline{u'q'}$	X	X	214	m s^{-1}
$\overline{u'u'}$	X	X	215	m^2 s^{-2}
$\overline{v'\phi'}$		X	216	m^3 s^{-3}
$\overline{v'T'}$	X	X	217	m s^{-1} K
$\overline{v'q'}$	X	X	218	m s^{-1}
$\overline{u'v'}$	X	X	219	m^2 s^{-2}
$\overline{v'v'}$	X	X	220	m^2 s^{-2}
$\overline{\omega'\phi'}$		X	221	m^2 Pa s^{-3}
$\overline{\omega'T'}$	X	X	222	Pa s^{-1} K
$\overline{\omega'q'}$	X	X	223	Pa s^{-1}
$\overline{\omega'u'}$	X	X	224	m Pa s^{-2}
$\overline{\omega'v'}$	X	X	225	m Pa s^{-2}
$\overline{\omega'\omega'}$	X	X	226	Pa^2 s^{-2}
$\overline{p_s'p_s'}$	X		227	Pa^2
$\overline{u'O_3'}$	X	X	25	m s^{-1}
$\overline{v'O_3'}$	X	X	26	m s^{-1}
$\overline{\omega'O_3'}$	X	X	27	Pa s^{-1}
$\overline{O_3'O_3'}$	X	X	28	
$\overline{r'r'}$		X	29	

1. GRIB code table 2 version 160

5. Time series of selected fields

Data for a subset of parameters and levels will be archived in time-series form in addition to being archived as part of the comprehensive set of parameters and levels saved for each analysis or forecast time. The selection is specified in Table 5.1. It has been chosen in particular to facilitate:

- generation of quick-look graphical products;
- use of atmospheric and land-surface products in seasonal forecasting studies;
- use of ocean-wave products in maritime studies.

Sets of fields will be archived at six-hourly time intervals. These will be based on analysis or background-forecast values for all fields with the possible exception of precipitation, for which the optimal forecast range will be chosen based on the spin-up characteristics of the short-range forecasts.

Table 5.1 also indicates the representation of the fields to be archived. **sh** denotes the T159 spherical-harmonic representation and **mg** denotes the model-grid representation specified earlier (Gaussian Grid for products from the atmospheric model and latitude/longitude for ocean-wave products). **2.5^{o}** denotes the standard 2.5^{o} latitude/longitude grid. In most cases data will be archived in two representations. Separate time series will be generated for each representation, and for each parameter and level.

TABLE 5.1 - FIELDS TO BE ARCHIVED AS TIME SERIES

Parameter and level	Representation			Code	Units
	sh	mg	2.5^{o}		
500hPa geopotential	X		X	129	$m^2 s^{-2}$
200hPa geopotential	X		X	129	$m^2 s^{-2}$
850 hPa temperature	X		X	130	K
850hPa eastward wind component			X	131	$m s^{-1}$
200hPa eastward wind component			X	131	$m s^{-1}$
850hPa northward wind component			X	132	$m s^{-1}$
200hPa northward wind component			X	132	$m s^{-1}$
925hPa specific humidity		X	X	133	kg/kg
850hPa vorticity	X			138	s^{-1}
200hPa vorticity	X			138	s^{-1}
850hPa divergence	X			155	s^{-1}
200hPa divergence	X			155	s^{-1}
potential vorticity on θ=330K surface		X	X	60	$m^2 s^{-1} K kg^{-1}$
eastward wind component on θ=330K			X	131	$m s^{-1}$

TABLE 5.1 - FIELDS TO BE ARCHIVED AS TIME SERIES

Parameter and level	Representation			Code	Units
	sh	mg	2.5^{o}		
northward wind component on θ=330K			X	132	m s^{-1}
vorticity on θ=330K	X			138	s^{-1}
divergence on θ=330K	X			155	s^{-1}
pressure on θ=330K	X		X	54	Pa
potential temperature on PV=±2 surface		X	X	3	K
eastward wind component on PV= 2		X	X	131	m s^{-1}
northward wind component on PV= 2		X	X	132	m s^{-1}
pressure on PV= 2		X	X	54	Pa
mean sea level pressure		X	X	151	Pa
total column water vapour		X	X	137	kg m^{-2}
eastward water-vapour flux		X	X	92	kg m^{-1} s^{-1}
northward water-vapour flux		X	X	93	kg m^{-1} s^{-1}
soil[1] temperature level 1		X	X	139	K
sea-ice fraction		X	X	31	(0-1)
soil moisture level 1		X	X	39	m^3/m^3
soil moisture level 2		X	X	40	m^3/m^3
soil moisture level 3		X	X	41	m^3/m^3
soil moisture level 4		X	X	42	m^3/m^3
snow depth		X	X	141	m of water equivalent
large-scale precipitation		X	X	142	m of water
convective precipitation		X	X	143	m of water
surface sensible heat flux		X	X	146	W m^{-2}
total cloud cover		X	X	164	(0-1)
10 metre eastward wind component		X	X	165	ms^{-1}
10 metre northward wind component		X	X	166	ms^{-1}
2 metre temperature		X	X	167	K
2 metre dewpoint		X	X	168	K

TABLE 5.1 - FIELDS TO BE ARCHIVED AS TIME SERIES

Parameter and level	Representation			Code	Units
	sh	mg	2.5^{o}		
downward surface solar radiation		X	X	169	W m^{-2}
surface solar radiation		X	X	176	W m^{-2}
surface thermal radiation		X	X	177	W m^{-2}
top solar radiation		X	X	178	W m^{-2}
top thermal radiation		X	X	179	W m^{-2}
evaporation		X	X	182	m of water
maximum 2m temperature over last six hours		X	X	201	K
minimum 2m temperature over last six hours		X	X	202	K
total column ozone		X	X	206	kg m^{-2}
boundary layer height		X	X	159	m
wind gusts at 10 metres		X	X	49	ms^{-1}
significant wave height		X		229	m
mean wave direction		X		230	degrees
mean wave period		X		232	s

1. At non-land points this field contains sea-surface temperature, the top-layer ice temperature or a mixture of the two, depending on the sea-ice fraction.

6. Observation feedback

The ERA-40 data assimilation system will produce a range of BUFR-encoded feedback data relating to each observation presented to it. The feedback data include in particular the departures of background and analysis values from the observation. They also include information relating to the use of the observation by the system, for example the flags set by climatological and background screening checks and information fed back by the variational quality control. They thus provide a wealth of information concerning the characteristics of the data assimilation and observing systems. Their technical specification is given in the documentation of the observation-processing component of the data assimilation system.

The BUFR feedback data will be stored in MARS. Data will be organised into sets for each six-hour analysis period, with one set for all conventional observations, and one set for each type of satellite data.

7. Zonal-mean and grid-point diagnostics

The assimilating model has the capability to produce diagnostic output for specified individual grid-points and for averages over specified areas and along complete lines of latitude. These “DDH” (Diagnostics sur Domaines Horizontaux) data include tendencies from individual components of the physical parametrizations.

Sets of DDH diagnostics will be archived for ERA-40 forecasts. Due to their model-specific nature and non-standard format it is not planned that they be “supported data” in the sense that they be made available as part of the general data service to the user community at large. Consideration will be given to supporting subsets of the data depending on basic validation results, user demand and the availability of resources.

The data to be archived will be:

- a set of zonal-mean diagnostics;
- a set of 27 point and 30 area-mean diagnostics, defined especially to cover major field-experiment sites and river basins. An illustration of the locations of points and areas is presented in Figure 7.1, and precise specifications are given in Table 7.1.

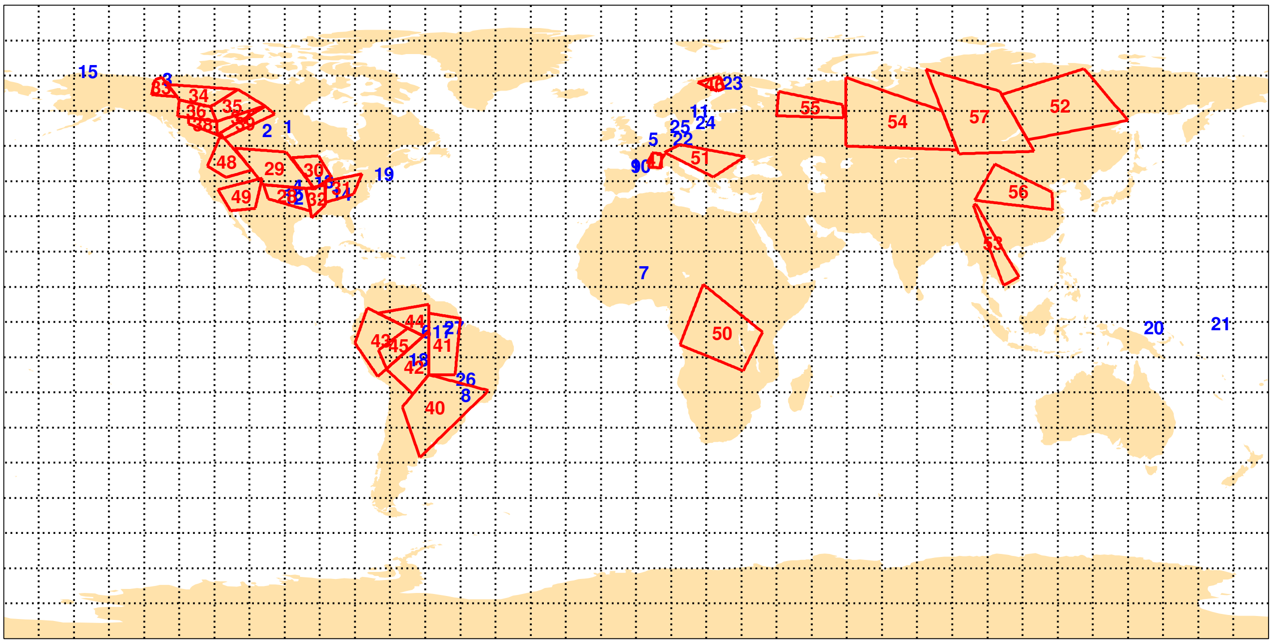

Figure 7.1 Points and areas for which detailed local (“DDH”) diagnostics will be produced.

TABLE 7.1 POINTS AND AREAS FOR THE DDH DIAGNOSTICS

	Description	Point (P) / Area (A)	Location (Lon,Lat)
1	BOREAS NSA	P	261.50, 55.90
2	BOREAS SSA-OBS	P	255.00, 54.00
3	MAGS: Tundra/forest	P	226.50, 68.75
4	FIFE	P	263.47, 39.05
5	CABAUW	P	5.60, 51.94
6	ARME	P	300.05, -2.50
7	SEBEX	P	2.50, 13.50
8	South-east Brazil: Sugar Cane	P	311.93, -21.10
9	HAPEX/MOBILHY	P	359.90, 44.00
10	Toulouse (MUREX)	P	1.50, 44.20
11	NOPEX	P	17.29, 60.50
12	Little Washita (T. Meyers)	P	262.02, 34.96
13	Illinois (T.Meyers); also SURFRAD Bondville	P	271.71, 40.02
14	Oak Ridge (T.Meyers); also SURFRAD Bondville	P	275.71, 35.96
15	ARM Barrow (Alaska)	P	204.00, 71.00
16	ARM Southern Great Plains	P	262.70, 36.37
17	LBA: NASA ecology tower (undisturbed forest)	P	305. 00, -2.86
18	LBA wet: Rondonia	P	298.10, -10.80
19	Harvard deciduous forest (S. Wofsky)	P	287.83, 42.53
20	ARM Tropics (Manus)	P	147.42, -2.06
21	ARM Tropics (Nauru Island)	P	166.92, -0.53
22	LITFASS (Germany)	P	14.06, 52.18
23	Sodankylä, Finland	P	26.65, 67.37
24	Gotland Island	P	19.50, 57.00
25	RISO (Roskilde)	P	12.10, 55.65
26	Brasilia: Cerrado	P	312.12, -15.95
27	Caxiuma: Forest site	P	308.55, -1.75
28	MISSISSIPPI:Red-Arkansas	A	254.00, 39.00 / 266. 00, 37.90 267.40, 31.50 / 255.30, 35.00
29	MISSISSIPPI:Missouri	A	245.70, 49.40 / 260.40, 48.30 268.50, 37.80 / 254.00, 39.00

TABLE 7.1 POINTS AND AREAS FOR THE DDH DIAGNOSTICS

	Description	Point (P) / Area (A)	Location (Lon,Lat)
30	MISSISSIPPI:Upper Mississippi	A	262.00, 46.70 / 269.60, 47.20 273.30, 41.20 / 268.50, 37.80
31	MISSISSIPPI:Ohio	A	271.70, 40.00 / 282.00, 42.10 279.60, 36.30 / 271.60, 34.00
32	MISSISSIPPI: Lower Mississippi/Tennessee	A	271.40, 38.90 / 271.60, 33.30 267.70, 29.60 / 266.00, 37.90
33	MACKENZIE: Peel River Basin + Mackenzie Delta	A	223.10, 68.90 / 225.10, 69.50 229.40, 64.00 / 222.10, 64.60
34	MACKENZIE: Great Bear Lake sub-basin	A	226.70, 67.50 / 246.70, 66.10 238.90, 61.20 / 230.00, 63.10
35	MACKENZIE: Great Slave Lake sub-basin	A	246.70, 66.10 / 254.40, 61.40 240.60, 57.00 / 238.90, 61.20
36	MACKENZIE: Liard River basin	A	230.00, 63.10 / 238.90, 61.20 240.60, 57.00 / 229.50, 58.50
37	MACKENZIE: Peace River basin east	A	254.40, 61.40 / 254.50, 61.30 240.80, 53.20 / 240.60, 57.00
38	MACKENZIE: Peace River basin west	A	232.70, 58.10 / 240.60, 57.00 240.80, 53.20 / 232.70, 56.30
39	MACKENZIE: Athabasca River basin	A	254.50, 61.30 / 257.20, 59.10 242.50, 52.10 / 240.80, 53.20
40	Cuenca de la Plata	A	293.50, -24.17 / 301.00, -15.00 318.00, -19.50 / 298.50, -38.50
41	Amazon River: sub-basin 1	A	301.00, 2.50 / 310.00, 1.00 308.50, -15.00 / 301.00, -15.00
42	Amazon River: sub-basin 2	A	288.88, -13.40 / 301.00, -2.67 301.00, -15.00 / 296.50, -20.50
43	Amazon River: sub-basin 3	A	283.50, 4.00 / 299.50, -4.00 286.50, -15.50 / 280.00, -6.00
44	Amazon River: sub-basin 4	A	286.60, 2.50 / 301.00, 5.00 301.00, -2.67 / 299.50, -4.00
45	Amazon River: sub-basin 5	A	286.70, -8.00 / 295.00, -1.80 299.50, -4.00 / 288.98, -13.32
46	Torne River basin	A	17.50, 68.10 / 23.80, 69.80 25.10, 66.40 / 23.10, 65.60
47	Rhone River basin	A	4.60, 48.10 / 7.20, 47.80 7.30, 43.80 / 3.60, 44.00
48	Columbia River basin	A	241.90, 53.30 / 250.70, 43.20 243.30, 41.10 / 238.00, 44.30
49	Colorado River basin	A	241.00, 37.60 / 253.60, 40.90 251.60, 32.30 / 244.60, 31.60

TABLE 7.1 POINTS AND AREAS FOR THE DDH DIAGNOSTICS

	Description	Point (P) / Area (A)	Location (Lon,Lat)
50	Congo River basin	A	12.50, -6.50 / 19.10, 10.70 36.00, -2.90 / 30.50, -13.90
51	Danube River basin	A	8.10, 48.20 / 12.50, 50.40 31.00, 47.00 / 22.00, 41.20
52	Lena River basin	A	104.00, 64.60 / 127.50, 72.00 140.00, 57.30, 111.50, 51.80
53	Mekong River basin	A	96.00, 33.10 / 96.70, 33.50 109.00, 12.80 / 104.60, 10.40
54	Ob River basin	A	59.70, 50.00 / 59.70, 69.50 87.10, 60.00 / 91.50, 48.90
55	Severnaya River basin	A	40.00, 58.60 / 40.60, 65.50 58.80, 61.80 / 59.10, 58.00
56	Yellow River basin	A	96.40, 34.60 / 102.10, 44.90 118.40, 36.90 / 118.60, 31.90
57	Yenisei River basin	A	82.50, 71.80 / 103.50, 65.60 113.30, 48.50, 91.90, 47.80

8. ECMWF/ISLSCP-II dataset

Plans are being developed with NASA to support Initiative II of the International Satellite Land Surface Climatology Project by providing near surface atmospheric and surface data from ERA40 covering the years 1988 to 1998. ISLSCP-II is an initiative to collect data for use in research on land-surface processes. Relevant ERA-40 data will be evaluated on the standard 1^{o} ISLSCP grid using interpolation suitable for land products. NASA will produce a CD-ROM and provide other data services for this particular set of products. Further details will be provided in due course.

Annex 1: Vertical integrals for energy, mass, water and ozone budgets

The continuous, adiabatic, frictionless form of the model's primitive equations may be manipulated to give the following equations, in standard notation:

Kinetic energy:

$$\frac{\partial}{\partial t}\left(E\frac{\partial p}{\partial \eta}\right) = -\nabla\cdot\left(\underset{\sim}{v}E\frac{\partial p}{\partial \eta}\right) - \nabla\cdot\left(\underset{\sim}{v}(\phi-\phi_s)\frac{\partial p}{\partial \eta}\right) - \frac{\partial}{\partial \eta}\left(\dot{\eta}E\frac{\partial p}{\partial \eta}\right) + \frac{\partial}{\partial \eta}\left((\phi-\phi_s)\int_0^{\eta}\nabla\cdot\left(\underset{\sim}{v}\frac{\partial p}{\partial \eta}\right)d\eta\right)$$
$$- \frac{RT\omega}{p}\frac{\partial p}{\partial \eta} - \underset{\sim}{v}\frac{\partial p}{\partial \eta}\cdot\nabla\phi_s \quad \text{(A.1.1)}$$

$$E = \frac{1}{2}(\underset{\sim}{v}\cdot\underset{\sim}{v})$$

Potential+Internal energy:

$$\frac{\partial}{\partial t}\left((c_pT+\phi_s)\frac{\partial p}{\partial \eta}\right) = -\nabla\cdot\left(\underset{\sim}{v}(c_pT+\phi_s)\frac{\partial p}{\partial \eta}\right) - \frac{\partial}{\partial \eta}\left(\dot{\eta}(c_pT+\phi_s)\frac{\partial p}{\partial \eta}\right) + \frac{RT\omega}{p}\frac{\partial p}{\partial \eta} + \underset{\sim}{v}\frac{\partial p}{\partial \eta}\cdot\nabla\phi_s \quad \text{(A.1.2)}$$

Mass:

$$\frac{\partial}{\partial t}\left(\frac{\partial p}{\partial \eta}\right) = -\nabla\cdot\left(\underset{\sim}{v}\frac{\partial p}{\partial \eta}\right) - \frac{\partial}{\partial \eta}\left(\dot{\eta}\frac{\partial p}{\partial \eta}\right) \quad \text{(A.1.3)}$$

Water vapour:

$$\frac{\partial}{\partial t}\left(q\frac{\partial p}{\partial \eta}\right) = -\nabla\cdot\left(\underset{\sim}{v}q\frac{\partial p}{\partial \eta}\right) - \frac{\partial}{\partial \eta}\left(\dot{\eta}q\frac{\partial p}{\partial \eta}\right) \quad \text{(A.1.4)}$$

Ozone:

$$\frac{\partial}{\partial t}\left(O_3\frac{\partial p}{\partial \eta}\right) = -\nabla\cdot\left(\underset{\sim}{v}O_3\frac{\partial p}{\partial \eta}\right) - \frac{\partial}{\partial \eta}\left(\dot{\eta}O_3\frac{\partial p}{\partial \eta}\right) \quad \text{(A.1.5)}$$

The notation is as in Simmons and Burridge(1981, *Mon. Wea. Rev.*, **109**, 758-766). The gas constant, R, and specific heat at constant pressure, c_p, vary with specific humidity, q:

$$R = R_d\left(1+\left(\frac{R_v}{R_d}-1\right)q\right) \quad \text{(A.1.6)}$$

$$c_p = c_{pd}\left(1+\left(\frac{c_{pv}}{c_{pd}}-1\right)q\right) \quad \text{(A.1.7)}$$

where subscripts d and v denote values for dry air and water vapour respectively.

It should be noted that $(c_p T + \phi_s)\frac{\partial p}{\partial \eta}$ should strictly be interpreted in terms of potential+internal energy only when vertically integrated:

$$\int_0^1 (c_v T + \phi)\frac{\partial p}{\partial \eta} d\eta = \int_0^1 (c_p T + \phi - RT)\frac{\partial p}{\partial \eta} d\eta = \int_0^1 \left(c_p T \frac{\partial p}{\partial \eta} + \frac{\partial}{\partial \eta}(p\phi)\right) d\eta = \int_0^1 (c_p T + \phi_s)\frac{\partial p}{\partial \eta} d\eta \quad \text{(A.1.8)}$$

Integrating the energy, mass, water vapour and ozone equations in the vertical, they may be written symbolically as:

$$\frac{\partial}{\partial t} KE = -(\nabla \cdot \underset{\sim}{F}_{KE}) - (\nabla \cdot \underset{\sim}{F}_{\phi - \phi_S}) + C_1 + C_2 \quad \text{(A.1.9)}$$

$$\frac{\partial}{\partial t} PIE = -(\nabla \cdot \underset{\sim}{F}_{PIE}) - C_1 - C_2 \quad \text{(A.1.10)}$$

$$\frac{\partial}{\partial t} Mass = -(\nabla \cdot \underset{\sim}{F}_M) \quad \text{(A.1.11)}$$

$$\frac{\partial}{\partial t} TCWV = -(\nabla \cdot \underset{\sim}{F}_q) \quad \text{(A.1.12)}$$

$$\frac{\partial}{\partial t} TCO = -(\nabla \cdot \underset{\sim}{F}_{O_3}) \quad \text{(A.1.13)}$$

The vertically integrated variables are:

$$KE = \frac{1}{g}\int_0^1 \frac{1}{2}(\underset{\sim}{v} \cdot \underset{\sim}{v})\frac{\partial p}{\partial \eta} d\eta \quad \text{(A.1.14)}$$

$$PIE = \frac{1}{g}\int_0^1 (c_p T + \phi_s)\frac{\partial p}{\partial \eta} d\eta = CPT + \phi_s Mass \quad \text{(A.1.15)}$$

$$CPT = \frac{1}{g}\int_0^1 c_p T \frac{\partial p}{\partial \eta} d\eta \quad \text{(A.1.16)}$$

$$Mass = \frac{1}{g}\int_0^1 \frac{\partial p}{\partial \eta} d\eta = \frac{p_s}{g} \quad \text{(A.1.17)}$$

$$TCWV = \frac{1}{g}\int_0^1 q \frac{\partial p}{\partial \eta} d\eta \quad \text{(A.1.18)}$$

$$TCO = \frac{1}{g}\int_0^1 O_3 \frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.19)}$$

The fluxes are:

$$\underset{\sim}{F}_{KE} = \frac{1}{g}\int_0^1 \underset{\sim}{v}\frac{1}{2}(\underset{\sim}{v}\cdot\underset{\sim}{v})\frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.20)}$$

$$\underset{\sim}{F}_{\phi-\phi_S} = \frac{1}{g}\int_0^1 \underset{\sim}{v}(\phi-\phi_s)\frac{\partial p}{\partial \eta} d\eta = \underset{\sim}{F}_{\phi} - \underset{\sim}{F}_{\phi_S} \qquad \text{(A.1.21)}$$

$$\underset{\sim}{F}_{\phi} = \frac{1}{g}\int_0^1 \underset{\sim}{v}\phi\frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.22)}$$

$$\underset{\sim}{F}_{\phi_S} = \frac{1}{g}\int_0^1 \underset{\sim}{v}\phi_s\frac{\partial p}{\partial \eta} d\eta = \phi_s\underset{\sim}{F}_M \qquad \text{(A.1.23)}$$

$$\underset{\sim}{F}_{PIE} = \frac{1}{g}\int_0^1 \underset{\sim}{v}(c_pT+\phi_s)\frac{\partial p}{\partial \eta} d\eta = \underset{\sim}{F}_{CPT} + \phi_s\underset{\sim}{F}_M \qquad \text{(A.1.24)}$$

$$\underset{\sim}{F}_{CPT} = \frac{1}{g}\int_0^1 \underset{\sim}{v}c_pT\frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.25)}$$

$$\underset{\sim}{F}_{M} = \frac{1}{g}\int_0^1 \underset{\sim}{v}\frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.26)}$$

$$\underset{\sim}{F}_{q} = \frac{1}{g}\int_0^1 \underset{\sim}{v}q\frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.27)}$$

$$\underset{\sim}{F}_{O_3} = \frac{1}{g}\int_0^1 \underset{\sim}{v}O_3\frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.28)}$$

and the energy conversions are:

$$C_1 = -\frac{1}{g}\int_0^1 \frac{RT\omega}{p}\frac{\partial p}{\partial \eta} d\eta \qquad \text{(A.1.29)}$$

$$C_2 = -\frac{1}{g}\int_0^1 \left(\underset{\sim}{v}\frac{\partial p}{\partial \eta}\cdot\nabla\phi_s\right) d\eta = -\underset{\sim}{F}_M\cdot\nabla\phi_s \qquad \text{(A.1.30)}$$

The two energy equations can also be written:

$$\frac{\partial}{\partial t}KE = -(\nabla \cdot \underset{\sim}{F}_{KE}) - (\nabla \cdot \underset{\sim}{F}_{\phi}) + C_1 + C_3 \qquad \text{(A.1.31)}$$

$$\frac{\partial}{\partial t}PIE = -(\nabla \cdot \underset{\sim}{F}_{CPT}) - C_1 - C_3 \qquad \text{(A.1.32)}$$

where

$$C_3 = -\nabla \cdot \underset{\sim}{F}_{\phi_s} \qquad \text{(A.1.33)}$$

The standard post-processing already produces (see Table 3.7) the net mass of water vapour (total column water vapour, $TCWV$ above) and ozone (total column ozone, TCO above) in kg/m^2 for each grid point. Also available is surface geopotential, ϕ_s, enabling the component $\phi_s Mass$ of PIE to be simply computed if $Mass$ is known. Note that ϕ_s is a fixed field, so the calculation of $\phi_s Mass$ can be done on monthly means if required.

In addition to these fields, analysis and selected forecast values of the following will be archived:

- KE, CPT and $Mass$
- $\underset{\sim}{F}_{KE}$, $\underset{\sim}{F}_{\phi}$, $\underset{\sim}{F}_{CPT}$, $\underset{\sim}{F}_{M}$, $\underset{\sim}{F}_{q}$ and $\underset{\sim}{F}_{O_3}$
- C_1

These are most directly appropriate for use of the energy equation in the form given by equations (A.1.31) and (A.1.32). The flux $\underset{\sim}{F}_{\phi_s}$ can be simply calculated as $\phi_s \underset{\sim}{F}_M$, and the conversion term C_3 is given by the convergence of this flux. The vertical integral, $\frac{1}{g}\int_0^1 e\frac{\partial p}{\partial \eta}d\eta$, of a quantity e that is defined by its analyzed or forecast values e_k at the 60 full model levels is evaluated as $\frac{1}{g}\sum_{k=1}^{60} e_k\left(p_{k+\frac{1}{2}} - p_{k-\frac{1}{2}}\right)$.

If the alternative form of the energy equations given by (A.1.9) and (A.1.10) is preferred, the fluxes $\underset{\sim}{F}_{\phi-\phi_s}$ and $\underset{\sim}{F}_{PIE}$ can be computed simply by subtracting $\phi_s \underset{\sim}{F}_M$ from $\underset{\sim}{F}_{\phi}$ and adding it to $\underset{\sim}{F}_{CPT}$.The conversion term C_2 is given by:

$$C_2 = -\underset{\sim}{F}_M \cdot \nabla\phi_s = -\nabla \cdot \underset{\sim}{F}_{\phi_s} + \phi_s \nabla \cdot \underset{\sim}{F}_M = C_3 + \phi_s \nabla \cdot \underset{\sim}{F}_M \qquad \text{(A.1.34)}$$

All RHS terms in the budget equations (A.1.9)-(A.1.13) (or (A.1.31), (A.1.32), (A.1.11), (A.1.12) and (A.1.13)) can thus be computed in terms of the supplied integrals, applying a divergence operator and simple multiplications where needed. These operations can be carried out either on the instantaneous values or on their monthly means.