# ECMWF Meteorological Bulletin 3.1

C O N T E N T S

# 1. Introduction

This document is intended to be a user manual for users of the ECMWF dissemination service. It outlines the real-time meteorological and oceanographic products available from the ECMWF forecasting system. FM 92 GRIB is the principle representation form for dissemination, although dissemination based on FM 47 GRID is still supported. In this manual, matters relating to GRIB code dissemination are covered first in each section, followed by those for FM 47 GRID.

This document was designed and printed at ECMWF.

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# 2. Representation and Code Forms

## 3.1 FM 92 GRIB

GRIB defintions as well as GRIB decoder can be found at http://www.ecmwf.int/products/data/software/grib_api.html

Note that ECMWF is using GRIB edition 2 for encoding its (IFS) model level fields whereas GRIB edition 1 is used for encoding all other fields (surface, pressure level, ocean surface, etc).

## 3.2 FM 94-XI Ext BUFR

BUFR definitions as well as BUFR decoder can be found at http://www.ecmwf.int/products/data/software/bufr.html.

# 3. High Resolution Atmospheric Model Products

## 4.1 Introduction

Users are referred to Meteorological Bulletin M3.2 for information on the meteorological characteristics of products, the forecast model documentation contained in Meteorological Bulletin M1.6 and analysis documentation contained in Meteorological Bulletin M1.5.

Products on latitude-longitude grids are interpolated from the spectral or (quasi regular - reduced) Gaussian grid associated with the ECMWF forecast model. Interpolation is made to a 0.125 degree latitude-longitude grid and resulting products are generated by selecting required points. Regular Gaussian grids are also available. Where appropriate, the interpolation to a latitude-longitude grid uses a land/sea mask so that an interpolated land point is assigned a value calculated using only neighbouring land grid points, and an interpolated sea point is assigned a value using only neighbouring sea grid points. For precipitation fields, the interpolation assigns a zero value if the value at the nearest grid point is zero; also any value within one per cent of the global minimum for the field is taken to be equal to zero.

Products on polar stereographic grids are interpolated from the 0.125 degree latitude-longitude interpolated fields; thus they are subject to a double interpolation error.

Rotated latitude-longitude grid point products are generated using FULLPOS post-processing package (ARPEGE/IFS, IFS Documentation, Meteorological Bulletin M1.6/7). This package generates rotated latitude-longitude grid by rotating quasi-regular (reduced) Gaussian grid using 12 point horizontal interpolation scheme. Upper-air fields (except parameter Q which is a Gaussian grid field) are first converted from spherical harmonics to quasi-regular (reduced) Gaussian grid before passing as input to the FULLPOS. Any rotation angle or resolution can be requested.

## 4.2 Products in GRIB code

### 4.2.1 Verifying times available

- analysis at 18, 00, 06 and 12 UTC
- forecasts at 3 hourly intervals from 3 to 144 hours, based on 12 UTC and 00 UTC data
- forecasts at 6 hourly intervals from 144 to 240 hours, based on 12 UTC and 00 UTC data

Parameters MN2T6, MX2T6 and 10FG6 are only available at 6-hour intervals (0 to 240 by the step of 6 hours).
Parameters MN2T3, MX2T3 and 10FG3 are only available at 3-hour intervals from T+3h to T+144.

### 4.2.2 Parameters

All of the parameters listed in table 4.2 are supported. Spectral orography field is available as the geopotential field at the model level 1 whereas grid-point orography is available as the geopotential field at the surface level (both fields can be requested as analyses fields only).

Table 4.2 High resolution Products

* denotes field accumulated since start of forecast ** denotes spectrally filtered field +Analysis only ++ Forecast only

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 3 | PT | Potential Temperature | K | 16 |
| 8 | SRO | Surface runoff | m | 16 |
| 9 | SSRO | Sub-surface runoff | m | 16 |
| 20 | PARCS | Clear sky surface photosynthetcally active radiation | J m**-2 | 16 |
| 27 | CVL | Low Vegetation Cover + | 0-1 | 8 |
| 28 | CVH | High Vegetation Cover + | 0-1 | 8 |
| 29 | TVL | Type of Low Vegetation + | - | 16 |
| 30 | TVH | Type of High Vegetation + | - | 16 |
| 31 | CI | Sea Ice Cover | 0-1 | 8 |
| 32 | ASN | Snow Albedo | 0-1 | 8 |
| 33 | RSN | Snow Density | kg m**-3 | 16 |
| 34 | SSTK | Sea Surface Temperature | K | 16 |
| 35 | ISTL1 | Ice surface temperature level1 | K | 12 |
| 36 | ISTL2 | Ice surface temperature level 2 | K | 12 |
| 37 | ISTL3 | Ice surface temperature level 3 | K | 12 |
| 38 | ISTL4 | Ice surface temperature level 4 | K | 12 |
| 39 | SWVL1 | Volumetric Soil Water layer 1 | m3m-3 | 12 |
| 40 | SWVL2 | Volumetric Soil Water layer 2 | m3m-3 | 12 |
| 41 | SWVL3 | Volumetric Soil Water layer 3 | m3m-3 | 12 |
| 42 | SWVL4 | Volumetric Soil Water layer 4 | m3m-3 | 12 |
| 43 | SLT | Soil type + | - | 16 |

Table 4.2 High resolution Products

* denotes field accumulated since start of forecast ** denotes spectrally filtered field +Analysis only ++ Forecast only

| | | | | |
|---|---|---|---|---|
| 44 | ES | Snow Evaporation | m of water | 16 |
| 45 | SMLT | Snowmelt | m of water | 16 |
| 49 | 10FG | Wind gust at 10 meters ++ | m/s | 16 |
| 50 | LSPF | Large-scale precipitation fraction | s | 16 |
| 53 | MONT | Montgomery Potential + | m**2/s**2 | 16 |
| 54 | PRES | Pressure | Pa | 16 |
| 57 | UVB | Downward UV radiation at the sfc | Wm**-2 | 12 |
| 58 | PAR | Photosynthetically active radiation at the surface | Wm**-2 | 12 |
| 59 | CAPE | Convective available potential energy | Jkg**-1 | 12 |
| 60 | PV | Potential Vorticity | m2s-1Kkg-1 | 16 |
| 66 | LAILV | Leaf area index low vegetationm | m**2/m**2 | 16 |
| 67 | LAIHV | Leaf area index high vegetation | m**2/m**2 | 16 |
| 75 | CRWC | Cloud rain water content | Kg/Kg | 16 |
| 76 | CSWC | Cloud snow water content | Kg/Kg | 16 |
| 78 | TCLW | Total column liquid water | kg m**-2 | 16 |
| 79 | TCIW | Total column ice water | kg m**-2 | 16 |
| 121 | MX2T6 | Max. temp. at 2m in the past 6hours | K | 12 |
| 122 | MN2T6 | Min. temp. at 2m in the past 6hours | K | 12 |
| 123 | 10FG6 | Wind gust at 10m in the past 6hours | m/s | 16 |
| 128 | BV | Budget Values | - | - |
| 129 | Z | Geopotential | m**2s**-2 | 16 |
| 130 | T | Temperature | K | 12 |
| 131 | WIND | Wind speed & direction | - | 20 |
| 131 | U | U-velocity | m/s | 12 |
| 132 | V | V-velocity | m/s | 12 |
| 133 | Q | Specific humidity | kg/kg | 12 |
| 134 | SP | Surface pressure | Pa | 12 |
| 135 | W | Vertical velocity | Pa/s | 16 |
| 136 | TCW | Total Column Water | kg/m**2 | 12 |
| 137 | TCWV | Total column water vapour | kg/m**2 | 12 |
| 138 | VO | Vorticity | s-1 | 16 |
| 139 | STL1 | Soil Temperature Level 1 | K | 12 |
| 139 | ST | Surface temperature | K | 12 |
| 141 | SD | Snow depth | m | 12 |
| 142 | LSP | Large scale precipitation* | m | 16 |
| 143 | CP | Convective precipitation* | m | 16 |
| 144 | SF | Snow fall* | m | 16 |
| 145 | BLD | Boundary Layer Dissipation | Wm**-2s | 12 |
| 146 | SSHF | Surface sensible heat flux ++ | Wm**-2s | 12 |
| 147 | SLHF | Surface latent heat flux ++ | Wm**-2s | 12 |
| 148 | CHNK | Charnock | - | 16 |
| 151 | MSL | Mean sea level pressure | Pa | 12 |

Table 4.2 High resolution Products

* denotes field accumulated since start of forecast ** denotes spectrally filtered field +Analysis only ++ Forecast only

| | | | | |
|---|---|---|---|---|
| 152 | LNSP | Log surface pressure | - | 12 |
| 155 | D | Divergence | s-1 | 16 |
| 156 | GH | Height (geopotential) | m | 16 |
| 156 | THK | 1000/500 hPa thickness** | m | 16 |
| 157 | R | Relative humidity | - | 8 |
| 159 | BLH | Boundary Layer Height | m | 16 |
| 160 | SDOR | Standard Deviation Orography + | - | 16 |
| 161 | ISOR | Anisotrophy Subgrid Orography + | - | 16 |
| 162 | ANOR | Angle of Subgrid Orography + | rad | 16 |
| 163 | SLOR | Slope of Subgrid Orography | - | 16 |
| 164 | TCC | Total cloud cover | (0-1) | 8 |
| 165 | 10U | 10 metre U | m/s | 12 |
| 166 | 10V | 10 metre V | m/s | 12 |
| 167 | 2T | 2 metre temperature | K | 12 |
| 168 | 2D | 2 metre dewpoint temperature | K | 12 |
| 169 | SSRD | Surface solar radiat. downwards++ | W m**-2 s | 16 |
| 170 | STL2 | Soil Temperature Level 2 | K | 12 |
| 172 | LSM | Land/sea mask + | (0,1) | 8 |
| 173 | SR | Surface Roughness + | m | 16 |
| 174 | AL | Albedo + | - | 16 |
| 175 | STRD | Surface thermal radi. downwards++ | W m**-2 s | 16 |
| 176 | SSR | Surface Solar Radiation ++ | W m**-2 s | 16 |
| 177 | STR | Surface Thermal Radiation ++ | W m**-2 s | 16 |
| 178 | TSR | Top Solar Radiation | W m**-2 s | 16 |
| 179 | TTR | Top Thermal Radiation | W m**-2 s | 16 |
| 180 | EWSS | U-stress* | Nm**-2 | 12 |
| 181 | NSSS | V-stress* | Nm**-2 | 12 |
| 182 | E | Evaporation ++ | m of water | 16 |
| 183 | STL3 | Soil Temperature Level 3 | K | 12 |
| 186 | LCC | Low cloud cover | (0-1) | 8 |
| 187 | MCC | Medium cloud cover | (0-1) | 8 |
| 188 | HCC | High cloud cover | (0-1) | 8 |
| 189 | SUND | Sunshine duration | s | 16 |
| 195 | LGWS | Latitude Gravity Wave Stress * | Nm**-2s | 16 |
| 196 | MGWS | Meridional Gravity Wave Stress * | Nm**-2s | 16 |
| 197 | GWD | Gravity Wave Dissipation * | Nm**-2s | 16 |
| 198 | SRC | Skin reservoir content | m (ofwater) | 12 |
| 201 | MX2T | Max. temp. at 2m since prev. post-processing ++ | K | 12 |
| 202 | MN2T | Min. temp. at 2m since prev. post-processing ++ | K | 12 |
| 203 | O3 | Ozone Mass Mixing Ratio | Kg/Kg | 16 |
| 205 | RO | Runoff | | |
| 206 | TCO3 | Total column Ozone | Kg/m | 16 |

Table 4.2 High resolution Products

* denotes field accumulated since start of forecast ** denotes spectrally filtered field +Analysis only ++ Forecast only

| | | | | |
|---|---|---|---|---|
| 208 | TSRC | Top Net Solar Radiation Clear Sky | J m**-2 | 16 |
| 209 | TTRU | Top Thermal Radiation Upward | J m**-2 | 16 |
| 210 | SSRC | Surface net solar radiation, clear sky | J m**-2 | 16 |
| 211 | STRC | Surface net thermal radiation, clear sky | J m**-2 | 16 |
| 212 | TISR | TOA incident solar radiation | J m**-2 | 16 |
| 213 | VIMD | Vertically integrated moisture divergence | Kg m**-2 | 16 |
| 228 | TP | Total precipitation* | m | 16 |
| 229 | IEWS | Instantaneous X surface stress | Nm**-2 | 16 |
| 230 | INSS | Instantaneous Y surface stress | Nm**-2 | 16 |
| 231 | ISHF | Instantaneous surface heat flux | Wm**-2 | 16 |
| 232 | IE | Instantaneous moisture flux | kgm**-2s**-1 | 16 |
| 234 | LSRH | Log Surface Roughness - Heat | - | 16 |
| 235 | SKT | Skin temperature | K | 12 |
| 236 | STL4 | Soil Temperature Level 4 | K | 12 |
| 238 | TSN | Temperature of snow layer | K | 12 |
| 243 | FAL | Forecast Albedo | (0-1) | 8 |
| 244 | FSR | Forecast Surface Roughness | m | 16 |
| 245 | FLSR | Forecast Log Surf. Roughness Heat | - | 16 |
| 246 | CLWC | Cloud liquid water content | Kg/Kg | 12 |
| 247 | CIWC | Cloud ice water content | Kg/Kg | 12 |
| 248 | CC | Cloud cover | 0-1 | 8 |
| 121.260 | KX | K index | K | 16 |
| 123.260 | TOTALX | Total totals index | K | 16 |
| 1.228 | CIN | Convective inhibition | J kg**-1 | 16 |
| 3.228 | ZUST | Friction velocity++ | m/s | 16 |
| 21.228 | FDIR | Total sky direct solar radiation at surface | Jm**-2 | 16 |
| 22.228 | CDIR | Clear-sky direct solar radiation at surface | Jm**-2 | 16 |
| 23.228 | CBH | Cloud base height++ | m | 16 |
| 24.228 | DEG0L | Zero degree level++ | m | 16 |
| 26.228 | MX2T3 | Max. temp. at 2m in the past 3hours | K | 12 |
| 27.228 | MN2T3 | Min. temp. at 2m in the past 3hours | K | 12 |
| 28.228 | 10FG3 | Wind gust at 10m in the past 3hours | m/s | 16 |
| 80.228 | ACO2NEE | Accumulated Carbon Dioxide Net Ecosystem Exchange | Kgm**-2 | 16 |
| 81.228 | ACO2GPP | Accumulated Carbon Dioxide Gross Primary Production | Kgm**-2 | 16 |
| 82.228 | ACO2REC | Accumulated Carbon Dioxide Eco-system Respiration | Kgm**-2 | 16 |
| 83.228 | FCO2NEE | Flux of Carbon Dioxide Net Eco-system Exchange | kgm**-2s**-1 | 16 |

Table 4.2 High resolution Products

* denotes field accumulated since start of forecast ** denotes spectrally filtered field +Analysis only ++ Forecast only

| | | | | |
|---|---|---|---|---|
| 84.228 | FCO2GPP | Flux of Carbon Dioxide Gross Primary Production | kgm**-2s**-1 | 16 |
| 85.228 | FCO2REC | Flux of Carbon Dioxide Ecosystem Respiration | kgm**-2s**-1 | 16 |
| 89.228 | TCRW | Total column rain water | kgm**-2 | 16 |
| 90.228 | TCSW | Total column snow water | kgm**-2 | 16 |
| 131.228 | U10N | Neutral wind 10m xcomponent++ | m/s | 16 |
| 132.228 | V10N | Neutral wind 10m y-component++ | m/s | 16 |
| 246.228 | 100U | 100 metre U wind component | m/s | 16 |
| 247.228 | 100V | 100 metre V wind component | m/s | 16 |

### 4.2.3 Horizontal resolution and domain

- 0.125 x 0.125 degrees latitude-longitude grid, or multiples thereof
- any spectral truncation (current model resolution is T1279)
- the Gaussian grid appropriate to the forecast model in use. The following Gaussian grid numbers are supported: 640, 400, 256, 200, 160, 128, 80, 48 and 32
- any sub-area

Additionally, as an interim measure, polar stereographic grid systems as defined in Appendix I section 2, are also supported.

### 4.2.4 Vertical resolution

Upper air parameters are available as follows:

- pressure levels: 1000, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250,

200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2, 1 hPa

- model levels: currently 91 hybrid coordinate level (model level products are encoded using GRIB edition 2)

### 4.2.5 Potential temperature and potential vorticity levels

Potential Vorticity level products, parameters PT, PRES, Z, U, V, Q and O3 (Table 4.2) are available on the level 2000 (as analysis and forecasts fields).

Potential Temperature (Isentropic) levels products (Table 4.2) are available as:

- analysis products, parameters MONT, PRES, PV, Q, VO, D and O3, on levels
 265, 275, 285, 300, 315, 330, 350, 370, 395, 430, 475, 530, 600, 700 and 850;
- forecast products, parameters PV, PRES, VO and D, on levels 300, 315, 330, 350,
 370, 395, 475, 600 and 850;

### 4.2.6 Dissemination requirements

Dissemination requirements are presented by means of the command language. Dissemination language parameters are identical to those of MARS. A description of the MARS command language is given at http://www.ecmwf.int/publications/manuals/mars/guide/index.html.

Products for dissemination are defined using the verb **DIS** followed by an appropriate selection of parameters. The available parameters are listed below.

### Identification parameters

| | | | | |
|---|---|---|---|---|
| STREAM | = | DAILY ARCHIVING | [DA] | (default) |
| DOMAIN | = | GLOBAL | [G] | (default) |
| TYPE | = | ANALYSIS | [AN] | |
| | | FORECAST | [FC] | |
| | | WEATHER PARAMETER | [WP] | |
| LEVTYPE | = | SURFACE | [SFC] | |
| | | PRESSURE LEVEL | [PL] | |
| | | MODEL LEVEL | [ML] | (GRIB only) |
| | | POTENTIAL VORTICITY | [PV] | (GRIB only) |
| | | POTENTIAL TEMPERATURE | [PT] | (GRIB only) |
| LEVELIST | = | * | | |
| | | (default 1000/850/700/500/400/300) | | |
| | | NB ALL is not permitted; | | |
| | | (See 4.2.5 for LEVTYPE=PT/PV products); | | |
| | | (1 - 91 for LEVTYPE=ML) | | |

## Target parameters

TARGET = "destination:dissemination_stream_name"
- destination is a three character destination name;
- dissemination_stream_name is a two character dissemination stream name
(the list of destinations/streams is published on:
**https://msaccess.ecmwf.int:9443/do/product/requirements/)**

## Date and time parameters

PRIORITY = 1 - 99
Indicates the transmission priority of a 'dissemination stream'.
(value 1 being the highest and value 99 being the lowest transmission priority);

TIME = * (hours)
Gives analysis 12, 18, 00, 06 or forecast base time 12, 00.

STEP = * (hours) default is 00
Gives forecast and analysis time step(s);.
For analysis value is 00.
NB ALL, is not permitted.

## Meteorological parameters

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in Table 4.2.

## Data processing parameters

RESOL = * [AV] (default 1279)

Positive integer giving the spectral triangular truncation from which products are derived, e.g. 10 indicates T10 filtered products required. May only be used with multi-level (i.e. upper air) parameters. May also be used if spectral products are required.

| | | | |
|---|---|---|---|
| FORMAT = | GRIB (default) | [GB] | For NON TYPE=ML data |
| | GRIB2 | [GB2] | For TYPE=ML data |

GAUSSIAN = REGULAR
REDUCED
OFF

Indicating Gaussian grid type. Gaussian grid resolution is given by the GRID parameter.

PROJECTION = NORTH POLAR STEREOGRAPHIC [NP]
OFF

Indicating projection type. Grid number is given by the GRID.

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined,
where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)
Both a and b must be 0.125 degrees, or multiples thereof, for latitude-longitude grids.
Note that it is possible to specify different values for a and b to generate a quasi-regular grid system with a different resolution in the West-East direction from that in the North-South direction.This feature is only valid for latitude-longitude grid.

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported: 640, 400, 256, 200, 160, 128, 80, 48 and 32.

Also, if a single positive integer is coded with,PROJECTION= NORTH POLAR STEREOGRAPHIC it is interpreted as a standard area (N3N3) number for grids from the current product catalogue.

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

AREA = */*/*/*
Output area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East;
Negative values indicate western longitudes and southern latitudes.

NB. Only supported for FORMAT=GRIB.

ROTATION = OFF to switch off rotation (default)
a/b

a = is the latitude of the southern pole of rotation
b = is the longitude of the southern pole of rotation

Both a and b (positive or negative) must be 0.125 degrees, or multiples thereof.

| | | | | |
|---|---|---|---|---|
| FRAME | = | OFF<br>n | to switch off the frame option | |

n is the number of points inward from each edge of defined area required to form a boundary product. The resulting FM 92 GRIB code will contain bits set within the appropriateate flag to indicate that sections 2 and 3 are both present.

This is only available for GRIB products.

| | | | | |
|---|---|---|---|---|
| BITMAP | = | OFF<br>“filename” | to switch off the bitmap option | |

“filename” is the name of a file containing a valid user-defined bitmap specification to build a product by selecting data from points of a latitude-longitude or a Gaussian grid.

This is only available for GRIB products.

| | | | | |
|---|---|---|---|---|
| ACCURACY | = | NORMAL<br>ARCHIVED VALUE<br>n | [N]<br>[AV] | (default) - GRIB only |

n is the number of bits per packed value. n must not be less than half of default value nor greater then 24.
[N] - Default values are listed in the Table 4.2
[AV] - Resulting field will have accuracy of the originally generated and archived field.

| | | | |
|---|---|---|---|
| PACKING | = | ARCHIVED VALUE | [AV] (default) |
| | | SIMPLE | [SIM] |
| | | SECOND ORDER | [SO] |
| | | COMPLEX | [CO] |

AV - GRIB packing as currently in use, at the moment SIMPLE for grid point data and COMPLEX for spherical harmonics data.
SIM - simple packing (both grid point and spherical harmonics data);
SO - grid point data only (substantiality reduces the size of GRIB messages);
CO - spherical harmonics data only;

| | | | | |
|---|---|---|---|---|
| PADDING | = | AUTOMATIC | [AUTO] | as currently in use (default); |
| | | NONE | | no padding; |
| | | n | [N] | |

n is the number of bytes to which multiple the binary message is padded to with NULL bytes;

The meaning of AUTO is at the moment 120 bytes for GRIB data and 8 bytes for BUFR data. Also, these are the only values supported for n at the moment.

| | | | |
|---|---|---|---|
| OPTIONS | = | NORMAL | [NORM] (default) |
| | | WMO ENVELOPE | [WMOE] |
| | | GTS PRODUCT | [WMOE] |
| | | DELAY | [DELA] |

Note:
1. WMOE is not permitted for FORMAT=GRIB;
2. DELAY causes products to be generated, but not transmitted;
DELAY products can be obtained using the repeat facility.

### 4.2.7 Command language example

The following example defines a set of products to be generated and disseminated to the destination "ECM" under the dissemination stream name "EC":

```
DIS,  TARGET=ECM:EC,STREAM=DA,EXPVER=1,DOMAIN=G,OPTI=NORM,FORM=GB,
      TIME=12/18/00/06,
      FILE=BIN,ACCU=NORN,
      TYPE=AN,LEVT=SFC,LEVE=OFF,GRID=0.125/0.125,AREA=90./-90./0./90.,
      PARA=LCC/MCC/HCC/TCC/STL1/SWL3,STEP=00
```

* This DIS requests number of surface parameters from all four analysis cycles on the $0.125^0$ by $0.125^0$ latitude-longitude grid. It also defines dissemination file format as BINARY and the packing accuracy of GRIB code to NORMAL.

```
DIS,  LEVT=PL,LEVE=1000/925/850/700/500/400/300/250/200/150/100/70/50/30/
      10,PARA=U/V/GH/T
```

* This DIS requests parameters from all four analysis cycles on the $0.125^0$ by $0.125^0$ latitude-longitude grid as the previous one but on pressure levels.

```
DIS,  ROTATION=-30.0/-10.0,AREA=14.0/-10.0/-12.0/20.0,
      BITMAP="MAP_002.DAT"
```

* This DIS requests the same parameters as the previous requirement but on rotated latitude-longitude grid. Note that resolution ($0.125^0$ by $0.125^0$) has not changed. Only the data from points selected by the bitmap defined in the file MAP_002.DAT will be disseminated.

```
DIS, TYPE=FC,TIME=12/00,LEVT=SFC,LEVE=OFF,ROTATION=OFF,BITMAP=OFF,
      GRID=1.0/1.0,AREA=90./-90./0./90.,PARA=TP/TCC/ISTL2/SWVL2,
      STEP=6/to/240/by/6
```

* This DIS defines number of surface parameters for a number of forecast time steps. Note that the ROTATION and the BITMAP parameters have been switched OFF.

```
DIS,LEVT=PL,LEVE=1000/925/850/700/500,PARA=U/V/T
```

* This DIS requests parameters from the same forecast time steps as the previous on pressure levels.

DIS, LEVT=ML,FRAME=5,
LEVE=1/to/91

* This DIS requests the same parameters as the previous requirement but on 91 model levels. Note that corresponding pressure values have to be specified when requesting model level data. Also, note that this DIS requests data in the form of rectangular "hollow boxes", where 5 points inward from each edge are requested.

DIS, LEVT=PL,PARA=GH,LEVE=500,STEP=5000,ACCU=9,FRAME=OFF,
GRID=2.5/2.5,AREA=90.0/-180.0/0.0/-90.0,
DIS,STEP=4000

* These two DIS requests define five and four days mean geopotential height fields respectively.

DIS, PARA=GH/T,LEVE=500,LEVT=PL,RESO=AV,FRAME=OFF,ACCU=12,
STEP=240

* This DIS requests two spectrally filtered spherical harmonics parameters on 500 hPa. It also requests each data value to be packed into 12 bits when coding into GRIB.

DIS, LEVT=PL,PARA=THK,LEVE=500,RESO=10,STEP=240,ACCU=NORM,
GRID=1.5/1.5,AREA=90.0/0.0/ 18.0/ 90.0

* This DIS defines temperature anomaly field.

DIS, LEVT=SFC,LEVE=OFF,GAUSSIAN=REDUCED,GRID=400,AREA=89.57/5./80./355.,
PARA=10WN/2D/2T/TP/10U/10V

* This DIS requests number surface parameters on quasi regular Gaussian grid.

## 4.3 Products in BUFR code

Products available in BUFR format are WEATHER PARAMETER products and TROPICAL CYCLONE trajectory forecast products. Data is presented in the FM 94-IX Ext. BUFR binary representation. ECMWF is using BUFR Edition 3.

WEATHER PARAMETER products have a form of time series of a specific parameter at the user defined location.

### 4.3.1 WEATHER PARAMETER products

The WEATHER PARAMETER products in the form of a time series of a specific parameter for ECMWF's high

resolution forecast (T1279), at the user defined location, are available from the ECMWF dissemination system.

WEATHER PARAMETER data is presented in the FM 94-IX Ext. BUFR (Edition 3). The forecast ranges from 0 to 240 hours by steps of 3, 6 or 12 hours (when 3 hourly product is requested, resulting values will be 3 hourly to T+144 inclusive and then 6 hourly to T+240)

The data for the WEATHER PARAMETER products is constructed from the basic model grid used for producing many of the standard dissemination fields. Where the requested location coordinates coincide with the original field grid point location, the grid point value will be taken. Otherwise, the value at the requested location will be obtained by bi-linear interpolation from the four nearest grid points in the original field.

When requesting data at a grid point location note the following:

- upper air fields are converted from spherical harmonics to 0.125/0.125 degrees latitude/longitude grid before extraction/interpolation to the requested location;

- surface fields from the operational T1279 model are represented in N640 reduced Gaussian grid;

WEATHER PARAMETER products offer users full flexibility regarding the number of parameters and locations. Any combination of these can be requested. Parameters available are listed in the Table 4.5 below.

WEATHER PARAMETER products are disseminated separately from other high resolution forecast products and have their own dissemination schedule (Table 4.11 below).

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS |
|---|---|---|---|
| 39 | SWVL1 | Volumetric Soil Water layer 1 | m**3m**-3 |
| 40 | SWVL2 | Volumetric Soil Water layer 2 | m**3m**-3 |
| 41 | SWVL3 | Volumetric Soil Water layer 3 | m**3m**-3 |
| 42 | SWVL4 | Volumetric Soil Water layer 4 | m**3m**-3 |
| 59 | CAPE | Convective available potential energy | J/K |
| 121 | MX2T6 | Max. temp. at 2m in the past 6hours | K |
| 122 | MN2T6 | Min. temp. at 2m in the past 6hours | K |
| 123 | 10FG6 | Wind gust at 10m in the past 6hours | m/s |
| 129 | Z | Geopotential | m2s-2 |
| 130 | T | Temperature | K |

* On pressure levels 1000/925/850/700/500/200; Z on surface level is orography
** WP Sunshine duration are not accumulated values but values since previous time step specified in the message
++ Takes into account time step frequency requested and generates fields accordingly

Table 4.5 WEATHER PARAMETER products

| | | | |
|---|---|---|---|
| 131 | U | U-velocity* | m/s |
| 132 | V | V-velocity* | m/s |
| 134 | SP | Surface pressure | Pa |
| 141 | SD | Snow depth | m |
| 142 | LSP | Large scale precipitation | m |
| 143 | CP | Convective precipitation | m |
| 157 | R | Relative humidity* | - |
| 228 | TP | Total Precipitation | kg/m**2 |
| 164 | TCC | Total Cloud Cover | (0-1) |
| 167 | 2T | 2 Metre Temperature | K |
| 168 | 2D | 2 Metre Dew Point Temperature | K |
| 165 | 10U | 10 Metre U Wind Component | m/s |
| 166 | 10V | 10 Metre V Wind Component | m/s |
| 144 | SF | Snow fall | m |
| 172 | LSM | Land/sea mask | (0-1) |
| 151 | MSL | Mean sea level pressure | Pa |
| 189 | SUND | Sunshine duration** | min |
| 139 | STL1 | Soil temperature level 1 | K |
| 170 | STL2 | Soil temperature level 2 | K |
| 183 | STL3 | Soil temperature level 3 | K |
| 236 | STL4 | Soil temperature level 4 | K |
| 169 | SSRD | Surface solar radiat. downwards | W/m**2 |
| 246.228 | 100U | 100 meter U wind component | m/s |
| 247.228 | 100V | 100 meter V wind component | m/s |

* On pressure levels 1000/925/850/700/500/200; Z on surface level is orography
** WP Sunshine duration are not accumulated values but values since previous time step specified in the message
++ Takes into account time step frequency requested and generates fields accordingly

Table 4.5 WEATHER PARAMETER products

### 4.3.2 WEATHER PARAMETER requirements

The following command language parameters are specific for the WEATHER PARAMETER requirements. Other DIS parameters are listed under the general requirements above.

| | | | |
|---|---|---|---|
| STREAM | = | DAILY ARCHIVING | [DA] |
| TYPE | = | WEATHER PARAMETER | [WP] |
| DOMAIN | = | GLOBAL | [G] |
| NUMBER | = | OFF | |
| FORMAT | = | BUFR | [BF] |

| | | | |
|---|---|---|---|
| LEVTYPE | = | PRESSURE LEVEL<br>SURFACE | [PL]<br>[SFC] |
| LEVELIST | = | 100/925/850/700/500/200<br>OFF | (PARAM=Z/T/U/V/R only)<br>(Surface parameters) |
| AREA | = | a/b (latitude-longitude grid)<br><br>a = latitude of location (degrees);<br>b = longitude of location (degrees); | |
| STEP | = | * (hours)<br>gives range of forecast time steps (see note above for each parameter/level availability);<br><br>240 (will result in 3 hourly values to T+144 and 6 hourly to T+240)<br>0/to/240/by/6<br>0/to/240/by/12 | |
| PARAM | = | Field name abbreviation<br>*<br>NB ALL is not permitted.<br>Available parameters are listed in the Table 4.5. | |

### 4.3.3 BUFR definition for T1279 WEATHER PARAMETER products

ECMWF's T1279 WEATHER PARAMETER products are presented in the FM 94-IX Ext. BUFR binary representation form. Products are coded into BUFR Edition 3. They contain the following:

| Table D Reference | Table B Reference | Element Name |
|---|---|---|
| | 008195 | Data Type<br>9 = Forecast |
| | 005195 | Ensemble Member Number<br>0 = T1279 data |
| 301011 | 004001<br>004002<br>004003<br>004004 | Year<br>Month<br>Day<br>Hour |

Table 4.6-1 BUFR table reference for T1279 WEATHER PARAMETER products

| | | |
|---|---|---|
| 301021 | 005001<br>006001<br><br>007004<br><br>007007 | Latitude<br>Longitude<br><br>Pressure data (Element present only for upper air parameters)<br>Height (10 m) (Element present only for 10U/10V parameter) |
| | 102nnn<br><br><br>004024 | Repeat 2 elements ‘nnn’ times (21 - 12hourly data set, 41 - 6 hourly data set or 65 - 3 hourly data set)<br><br>Time period or displacement (hours)<br>(forecast time step) |

Table 4.6-1 BUFR table reference for T1279 WEATHER PARAMETER products

| Table reference<br>List of parameters available | Element<br>Name |
|---|---|
| 012001<br>010003<br>011003<br>011004<br>020010 | Temperature<br>Geopotential<br>U-component<br>V-component<br>Cloud cover (total) |
| 013011<br>012004<br>012006<br>013233<br>012199<br>013241 | Total precipitation<br>Dry-bulb temperature at 2m<br>Dew-point temperature at 2m<br>Fraction of total precipitation in solid form (snow)<br>Maximum temperature at 2m, past 6 hours<br>Convective available potential energy |
| 012200<br>008224<br>010001<br>013230<br>013231<br>011041<br>010051<br>014034 | Minimum temperature at 2m, past 6 hours<br>Land/sea mask<br>Height of Land Surface<br>Convective precipitation<br>Large scale precipitation<br>Maximum wind speed - gust<br>Pressure reduced to mean sea level<br>Sunshine over period specified |

Table 4.6-2 BUFR table reference for T1279 WEATHER PARAMETER products

| | |
|---|---|
| 013221 | Volumetric Soil Water layer 1 |
| 013222 | Volumetric Soil Water layer 2 |
| 013223 | Volumetric Soil Water layer 3 |
| 013224 | Volumetric Soil Water layer 4 |
| 012211 | Soil temperature level 1 |
| 012212 | Soil temperature level 2 |
| 012213 | Soil temperature level 3 |
| 012214 | Soil temperature level 4 |
| 013234 | Snow depth |
| 010200 | Surface pressure |
| 013223 | Volumetric Soil Water layer 3 |
| 013224 | Volumetric Soil Water layer 4 |
| not implemented | 100 meter U velocity |
| not implemented | 100 meter V velocity |

Table 4.6-2 BUFR table reference for T1279 WEATHER PARAMETER products

Please, note that two new entries have been added to the BUFR table B:

1 008195 DATA TYPE CODE TABLE 08195

2 005195 ENSEMBLE MEMBER NUMBER NUMERIC

Users have to update their tables accordingly. Tables are also available from ECMWF.

### 4.3.4 TROPICAL CYCLONE trajectory forecast products

The ECMWF Tropical cyclone forecast products are designed to provide both high resolution and probabilistic information on movement and intensity of individual tropical cyclones. The system is vitally dependent on observations from various tropical cyclone centres around the world. In other words, the TC forecasts does not take genesis into account - TCs can however die in the process if they are not forecasted to stay strong enough.

Once observations are available, the movement of a TC is automatically tracked, both in the high resolution and the ENS forecasts. The tracking algorithm is based on extrapolation of past movement and the mid-tropospheric steering flow to obtain a first guess position. The actual position is determined by searching for MSLP and 850 hPa vorticity extremes around the first guess position. Also thickness maximum, wind speed and orography are evaluated. More details can be found in the following Tech. Memo http://www.ecmwf.int/publications/newsletters/pdf/102.pdf. Tropical cyclone products are presented in the FM 94-IX Ext. BUFR binary representation.

Tropical Cyclone products are disseminated separately from other high resolution forecast products and have their own dissemination schedule (Table 4.12 below).

### 4.3.5 TROPICAL CYCLONE trajectory forecast requirements

The following command language parameters are specific for the TROPICAL CYCLONE trajectory forecast requirements. Other parameters are listed under the general requirements above.

STREAM = DAILY ARCHIVING [DA]

TYPE = TRAJECTORY FORECAST [TF]

DOMAIN = GLOBAL [G]

FORMAT = BUFR [BF]

AREA = */*/*/*

Area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East;

Negative values indicate western longitudes and southern latitudes.

All Tropical Cyclones with the observed location within the AREA specified will be disseminated.

PARAM = TROPICAL CYCLONE [TC]

### 4.3.6 BUFR definition for TROPICAL CYCLONE trajectory forecast products

ECMWF's TROPICAL CYCLONE trajectory forecast products are presented in the FM 94-IX Ext. BUFR binary representation form. Products are coded into BUFR Edition 3. They contain the following:

| Table D Reference | Table B Reference | Element Name |
|---|---|---|
| | 001033 | Identification Of Originating/Generating Centre |
| | 001034 | Identification Of Originating/Generating Sub-Centre |
| | 001032 | Generating Application |
| | 001025 | Storm Identifier |
| | 001027 | WMO Long Storm Name |
| | 001090 | Technique For Making Up Initial Perturbations [2 = Singular vectors] |
| | 001091 | Ensemble Member Number |
| | 001092 | Type Of Ensemble Forecast |

Table 4.9 BUFR table reference for TROPICAL CYCLONE products

| | | |
|---|---|---|
| 301011 | 004001 | Year |
| | 004002 | Month |
| | 004003 | Day |
| 301012 | 004004 | Hour |
| | 004005 | Minute |
| | 008005 | Meteorological Attribute Significance |
| | | [1 = Storm Centre] |
| 301023 | 005002 | Latitude |
| | 006002 | Longitude |
| | 008005 | Meteorological Attribute Significance |
| | | [4 = Location of the storm in the perturbed analysis] |
| | | [5 = Location of the storm in the analysis] |
| 301023 | 005002 | Latitude (Coarse Accuracy) |
| | 006002 | Longitude (Coarse Accuracy) |
| | 010051 | Pressure Reduced To Mean Sea Level |
| | 008005 | Meteorological Attribute Significance |
| 301023 | 005002 | Latitude (Coarse Accuracy) |
| | 006002 | Longitude (Coarse Accuracy) |
| | 011012 | Wind Speed At 10 M |
| | 108000 | Replicate 8 distributors following delayed descriptor replication factor |
| | 031001 | Delayed Descriptor Replication Factor |
| | 008021 | Time Significance [4 = Forecast] |
| | 004024 | Time period or displacement (hours) |
| | 008005 | Meteorological Attribute Significance |
| 301023 | 005002 | [1 = Storm Centre] |
| | 006002 | Latitude (Coarse Accuracy) |
| | | Longitude (Coarse Accuracy) |
| | 010051 | Pressure Reduced To Mean Sea Level |
| | 008005 | Meteorological Attribute Significance |
| 301023 | 005002 | [Location of maximum wind] |
| | 006002 | Latitude (Coarse Accuracy) |
| | | Longitude (Coarse Accuracy) |
| | 011012 | Wind Speed At 10 M |

Table 4.9 BUFR table reference for TROPICAL CYCLONE products

## 4.4 Transmission of Products

The dissemination filename convention used for the transmission of high resolution atmospheric model products is described in **Section "Transmission of products"**. Data stream indicator for the high resolution atmospheric model products in dissemination file names is 'D'. Data stream indicator for the high resolution model Weather Parameter products in dissemination file names is 'A'.

The following is the transmission schedule for the high resolution atmospheric model products (forecast time steps not listed in the table are disseminated at regular intervals between the times shown):

| Analysis 06/12 - 12 UTC based Forecast time | Time Available | Analysis 18/00 - 00 UTC based Forecast time | Time Available |
|---|---|---|---|
| 06:00 Analysis | 17:35 | 18:00 Analysis | 5:35 |
| 12:00 Analysis | 17:40 | 00:00 Analysis | 5:40 |
| Forecast Day 1 | 17:52 | Forecast Day 1 | 5:52 |
| Forecast Day 2 | 17:59 | Forecast Day 2 | 5:59 |
| Forecast Day 3 | 18:06 | Forecast Day 3 | 6:06 |
| Forecast Day 4 | 18:13 | Forecast Day 4 | 6:13 |
| Forecast Day 5 | 18:20 | Forecast Day 5 | 6:20 |
| Forecast Day 6 | 18:27 | Forecast Day 6 | 6:27 |
| Forecast Day 7 | 18:34 | Forecast Day 7 | 6:34 |
| Forecast Day 8 | 18:41 | Forecast Day 8 | 6:41 |
| Forecast Day 9 | 18:48 | Forecast Day 9 | 6:48 |
| Forecast Day 10 | 18:55 | Forecast Day 10 | 6:55 |

Table 4.10 Dissemination schedule for the High resolution Forecast products

The operational production of the Centre's medium-range forecast has always the highest priority and its products will always be transmitted first, before any other products. Default transmission priority for these products is set to 20.

The following is the transmission schedule for the high resolution model Weather Parameter products in BUFR:

| Weather Parameter Products | Time Available |
|---|---|
| 12 UTC based | 18:55 |

Table 4.11 Dissemination schedule for the Weather Parameter Products

| | |
|---|---|
| 00 UTC based | 6:55 |

Table 4.11 Dissemination schedule for the Weather Parameter Products

The following is the transmission schedule for the high resolution model Tropical Cyclone trajectory forecast products in BUFR:

| Tropical Cyclone Products | Time Available |
|---|---|
| 12 UTC based | 18:55 |
| 00 UTC based | 6:55 |

Table 4.12 Dissemination schedule for the Tropical Cyclone trajectory forecast

# 4. Ensemble Forecast

## 4.1 Introduction

The Ensemble Forecast (ENS) has been run at ECMWF since December 1992. Initially it was run on an experimental basis as a 32 perturbed member ensemble. Forecasts were run at resolution T63, at 19 levels.

In December 1996, the operational Ensemble Forecast was changed in two ways:

i) The model on which the ENS is run, was upgraded to $T_L$159 truncation with 31 levels.
ii) The number of perturbed ensemble members was increased to 50.

In October 1999, the model on which the ENS is run, was upgraded to 40 vertical levels. A control run was also made at $T_L$159L40.

In November 2000, the model on which the ENS is run, was upgraded to TL255L40. A control run was also made at $T_L$255L40.

In September 2005, the model on which the ENS is run, was upgraded to TL399L62. The same upgrade was made to the control run.

In November 2006 ECMWF upgraded its Ensemble Forecast (ENS). In particular, the forecast range was extended to 15 days using the ENS with a resolution of T399 L62 for day 1 to day 10 (leg 1) and T255 L62 for T+246 to day 15 (leg 2). ENS also included two other constant-resolution forecasts for calibration and validation purposes ran one at T399 L62 and the other at T255 L62 for the full forecast time range day 1 to day 15.

In January 2010, the model on which the ENS is run, was upgraded to T639 for day 1 to day 10 (leg 1) and T319 for T+246 to day 15 (leg 2). The same upgrade was made to the control run.

The core of the ENS is the generation of perturbations to the initial analysis used to start the forecast. Perturbations are computed to generate 50 modified analysis, so the total number of forecasts is 51 (including a control forecast based on the unperturbed analysis). The perturbations are not generated at random (as would be the case for

example with a pure Monte Carlo technique), instead, they are a combination of 25 modes which have the largest impact on the forecast for the Northern Hemisphere in the short range (detailed information on the technique can be found in ECMWF Technical Memorandum No 188, August 1992).

On June 2012, EDA perturbations redefined using the EDA ensemble mean instead of the EDA control as the reference: Up to cycle 37r3, the EDA initial perturbations are defined as differences between perturbed EDA members and the unperturbed EDA control member. From 38r1, the EDA initial perturbations are defined as differences between perturbed EDA members and the mean of the EDA. If the distribution sampled by the EDA is symmetric, the latter method retains the shape of this distribution. In addition, the variance of the singular vector initial perturbations is increased in 38r1 in order to compensate for the reduction of spread that is due to the change of the EDA perturbations.

For full definitions of ECMWF GRIB local extensions for ENS products see http://www.ecmwf.int/products/data/software/grib_api.html

## 4.2 ENS Dissemination products in field form

A number of products are available in the field form. Products can be grouped into the following categories:

- Control, perturbed and calibration/validation forecast products
- Cluster mean and cluster representatives products
- Ensemble mean and ensemble standard deviation products
- Forecast probabilities products
- Extreme forecast index products

## 4.3 ENS Dissemination requirements

The dissemination of ENS field products is controlled in a similar manner to the dissemination of data from ECMWF's medium-range forecasting system. Dissemination requirements for ENS field products are added to the general set of dissemination requirements for each Member State - it is not necessary to update and maintain separate sets of requirements for products required from the ENS.

The rules for requesting dissemination products from ECMWF apply also to ENS field products. Member States can maintain their own dissemination requirements using web facility (https://msaccess.ecmwf.int:9443/do/product/requirements/); Also Member States may request ECMWF to make changes on their behalf. Requests for ECMWF to make changes to requirements should be addressed in writing or by computer mail from the Member State's TAC representative to the Director of Operations at ECMWF, or to the Head of the "Meteorological Application Section", who is authorised by the Director of Operations to act on his behalf with respect to such changes.

Dissemination requirements are presented by means of the command language. This language has been designed to conform, where possible, to the MARS command language.

The following command language parameters are common for all ENS requirements:

## Identification parameters

| | | | |
|---|---|---|---|
| STREAM | = | ENSEMBLE FORECAST | [EF] |

## Target parameters

| | | |
|---|---|---|
| TARGET | = | "destination:dissemination_stream_name"<br>- destination is a three character destination name;<br>- dissemination_stream_name is a two character dissemination stream name<br>(the list of destinations/streams is published on:<br>**https://msaccess.ecmwf.int:9443/do/product/requirements/)** |
| PRIORITY | = | 1 - 99<br>Indicates the transmission priority of a 'dissemination stream'.<br>(value 1 being the highest and value 99 being the lowest transmission priority); |

## Date and time parameters

TIME = 12/00
Gives products base time.

## Meteorological parameters

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in each products sub-set table.

## Data processing parameters

RESOL = * [AV] (default 639 for ENS leg 1)
(default 319 for ENS leg 2)

* Positive integer giving the spectral triangular truncation.
(e.g. 10 indicates T10 filtered products required. May only be used with multi-level (i.e. upper air) parameters. May also be used if spectral products are required.)
Operational IFS spectral resolution is:
T639 for STEP 0 to 240 (ENS leg 1)
T319 for STEP 246 to 360 (ENS leg 2)

REDUCED GAUSSIAN 160
Will result in converting original model field into reduced Gaussian grid **N160** before interpolating into requested latitude-longitude grid. Valid only when requesting latitude-longitude grids.

OFF

FORMAT = GRIB [GB] For all NON LEVT=ML data
GRIB2 [GB2] For all LEVT=ML data

GAUSSIAN = REGULAR
REDUCED
OFF

Indicating Gaussian grid type. Gaussian grid resolution is given by the GRID parameter.

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.25/0.25 (leg1) or multiples thereof; (TYPE=CF/PF/CV/EP only);
0.5/0.5 (leg2) or multiples thereof (TYPE=CF/PF/CV/EP only);

Note that it is possible to specify different values for a and b to generate a quasi-regular grid system with a different resolution in the West-East direction from that in the North-South direction. This feature is only valid for latitude-longitude grid.

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32.

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

Operational IFS Gaussian resolution is:
N320 for STEP 0 to 240 (ENS leg 1)
N160 for STEP 246 to 360 (ENS leg 2)

AREA = */*/*/*

Output area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East;

Negative values indicate western longitudes and southern latitudes.

ROTATION = OFF to switch off rotation (default)
a/b

a = is the latitude of the southern pole of rotation
b = is the longitude of the southern pole of rotation

FRAME = OFF to switch off the frame option
n

n is the number of points inward from each edge of defined area required to form a boundary product. The resulting FM 92 GRIB code will contain bits set within the appropriateate flag to indicate that sections 2 and 3 are both present.

| | | | | |
|---|---|---|---|---|
| BITMAP | = | OFF to switch off the bitmap option<br>"filename" | | |
| | | "filename" is the name of a file containing a valid user-defined bitmap specification to build a product by selecting data from points of a latitude-longitude or a Gaussian grid. | | |
| ACCURACY | = | NORMAL | [N] | (default) - GRIB only |
| | | ARCHIVED VALUE | [AV] | |
| | | n | | |
| | | n is the number of bits per packed value. n must not be less than half of default value nor greater then 24.<br>[N] - Default values are listed in the Table 4.2<br>[AV] - Resulting field will have accuracy of the originally generated and archived field. | | |
| PACKING | = | ARCHIVED VALUE | [AV] | (default) |
| | | SIMPLE | [SIM] | |
| | | SECOND ORDER | [SO] | |
| | | COMPLEX | [CO] | |
| | | AV - GRIB packing as currently in use, at the moment SIMPLE for grid point data and COMPLEX for spherical harmonics data.<br>SIM - simple packing (both grid point and spherical harmonics data);<br>SO - grid point data only (substantiality reduces the size of GRIB messages);<br>CO - spherical harmonics data only; | | |
| PADDING | = | AUTOMATIC | [AUTO | as currently in use (default); |
| | | NONE | ] | no padding; |
| | | n | [N] | |
| | | n is the number of bytes to which multiple the binary message is padded to with NULL bytes;<br><br>The meaning of AUTO is at the moment 120 bytes for GRIB data and 8 bytes for BUFR data. Also, these are the only values supported for n at the moment. | | |
| OPTIONS | = | NORMAL | [NORM] (default) | |
| | | DELAY | [DELA] | |
| | | Note:<br>DELAY causes products to be generated, but not transmitted;<br>DELAY products can be obtained using the repeat facility. | | |

## 4.4 GRIB definitions for ENS products

The set of local definitions for ENS products in GRIB edition 1 can be found at http://www.ecmwf.int/publications/manuals/d/gribapi/fm92/grib1/show/local/ and for those in GRIB edition 2 (model level data) at http://www.ecmwf.int/products/data/software/grib_api.html.

## 4.5 Control, Perturbed and Calibration/Validation forecast products

ENS forecasts are ran at T639 resolution at 62 levels up to day 10 and with grid point data being generated on reduced Gaussian grid N320. ENS forecasts are ran at T319 resolution at 62 levels from time step 246 to day 15 with grid point data being on reduced Gaussian grid N160. In addition, two calibration/validation forecasts are ran, one at T639 L62 (forecast NUMBER=1) and the other at T319 L62 (forecast NUMBER=2). Data is post-processed every 3 hours to time step 144 and 6 or 12 hourly to day 15 (depending on a parameter). Step 0 is included. Parameters available in dissemination are listed in the Table below.

Flux fields are quantities accumulated since the beginning of the forecast, e.g. all precipitation and snowfall parameters. Reducing the resolution of the model at step T+240 requires interpolation between Gaussian grids used in leg 1 (N320) and leg 2 (N160). As a consequence, noise will appear in flux fields when taking differences in time for timestep intervals starting from T+240 or spanning T+240, e.g. precipitation for the interval T+(252-240) or T+(246-234).

To limit unnecessary impact from interpolation on the consistency of the fields, users wishing to extend their applications to day 15 are advised as follows:

1. For applications requiring products starting from or spanning step T+240 users could specify the keyword GAUSSIAN = REDUCED, GRID = 160 in the dissemination request. This will provide the user with all fields on the original model grid of ENS leg 2.

2. For applications requiring products starting from or spanning step T+240 users wishing to obtain products interpolated to regular lat/lon grids are advised to have the products from leg 1 truncated to the N160 grid prior to interpolation to their choice of lat/lon grid. This can be achieved by specifying an additional key word, e.g. RESOL = REDUCED GAUSSIAN 160, GRID = 0.5/0.5 in the dissemination requests. This new feature of requesting the truncation of Gaussian grids prior to further interpolation to regular grids will also become available in MARS.

3. New applications only using data starting from step T+246 will not be affected by interpolation problems

described above.

### 4.5.1 Model levels, pressure levels and surface products

- Horizontal resolution

  - 0.25 x 0.25 degrees latitude-longitude grid, or multiples thereof (T+0 to T+240 - leg 1)
  - 0.5 x 0.5 degrees latitude-longitude grid, or multiples thereof (T+246 to T+360 - leg 2)
  - spectral truncation appropriate to the forecast model in use - T630 for leg 1 and T319 for leg2
  - the Gaussian grid appropriate to the forecast model in use. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32 (200 and 160 only for leg 1 data).
  - any sub-area

- Vertical resolution

  - pressure levels (depending on the specific parameter and the forecast time step): 1000,925,850,700,600,500,400,300,250,200,150,100,70,50,30,20,10,7,5,3,2,1 hPa;
  - model levels: currently 62 hybrid coordinate level.

- Verifying times

  - T+0 to T+144 at 3 hour intervals and T+150 to T+360 at 6 hour intervals;
  - Upper air parameters on model levels as well as parameters on 'potential temperature' level for perturbed forecast, T+0 to T+144 at 3 hour intervals and T+150 to T+168 (inclusive) at 6 hour intervals;

- Parameters

Table 5.1 Control and Perturbed forecast products

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 3 | PT | Potential Temperature | K | 16 |
| 8 | SRO | Surface runoff | m | 16 |
| 9 | SSRO | Sub-surface runoff | m | 16 |
| 31 | CI | Sea Ice Cover | 0-1 | 8 |
| 32 | ASN | Snow Albedo | 0-1 | 8 |
| 33 | RSN | Snow Density | kg m**-3 | 16 |
| 34 | SSTK | Sea Surface Temperature | K | 16 |
| 35 | ISTL1 | Ice surface temperature level1 | K | 12 |
| 36 | ISTL2 | Ice surface temperature level 2 | K | 12 |
| 37 | ISTL3 | Ice surface temperature level 3 | K | 12 |
| 38 | ISTL4 | Ice surface temperature level 4 | K | 12 |
| 39 | SWVL1 | Volumetric Soil Water layer 1 | m3m-3 | 12 |

Table 5.1 Control and Perturbed forecast products

| | | | | |
|---|---|---|---|---|
| 40 | SWVL2 | Volumetric Soil Water layer 2 | m3m-3 | 12 |
| 41 | SWVL3 | Volumetric Soil Water layer 3 | m3m-3 | 12 |
| 42 | SWVL4 | Volumetric Soil Water layer 4 | m3m-3 | 12 |
| 49 | 10FG | Wind gust at 10 meters ++ | m/s | 16 |
| 54 | PRES | Pressure | Pa | 16 |
| 59 | CAPE | Convective available potential energy | Jkg**-1 | 12 |
| 60 | PV | Potential Vorticity | m2s-1Kkg-1 | 16 |
| 75 | CRWC | Cloud rain water content | Kg/Kg | 16 |
| 76 | CSWC | Cloud snow water content | Kg/Kg | 16 |
| 78 | TCLW | Total column liquid water | kg m**-2 | 16 |
| 79 | TCIW | Total column ice water | kg m**-2 | 16 |
| 121 | MX2T6 | Max. temp. at 2m in the past 6hours | K | 12 |
| 122 | MN2T6 | Min. temp. at 2m in the past 6hours | K | 12 |
| 123 | 10FG6 | Wind gust at 10m in the past 6hours | m/s | 16 |
| 129 | Z | Geopotential | m**2s**-2 | 16 |
| 130 | T | Temperature | K | 12 |
| 131 | U | U-velocity | m/s | 12 |
| 132 | V | V-velocity | m/s | 12 |
| 133 | Q | Specific humidity | kg/kg | 12 |
| 134 | SP | Surface pressure | Pa | 12 |
| 135 | W | Vertical velocity | Pa/s | 16 |
| 136 | TCW | Total Column Water | kg/m**2 | 12 |
| 137 | TCWV | Total column water vapour | kg/m**2 | 12 |
| 138 | VO | Vorticity | s-1 | 16 |
| 139 | STL1 | Soil Temperature Level 1 | K | 12 |
| 141 | SD | Snow depth | m | 12 |
| 142 | LSP | Large scale precipitation* | m | 16 |
| 143 | CP | Convective precipitation* | m | 16 |
| 144 | SF | Snow fall* | m | 16 |
| 145 | BLD | Boundary Layer Dissipation | Wm**-2s | 12 |
| 146 | SSHF | Surface sensible heat flux ++ | Wm**-2s | 12 |
| 147 | SLHF | Surface latent heat flux ++ | Wm**-2s | 12 |
| 148 | CHNK | Charnock | - | 16 |
| 151 | MSL | Mean sea level pressure | Pa | 12 |
| 152 | LNSP | Log surface pressure | - | 12 |
| 155 | D | Divergence | s-1 | 16 |
| 156 | GH | Height (geopotential) | m | 16 |
| 156 | THK | 1000/500 hPa thickness** | m | 16 |
| 157 | R | Relative humidity | - | 8 |
| 159 | BLH | Boundary Layer Height | m | 16 |
| 164 | TCC | Total cloud cover | (0-1) | 8 |
| 165 | 10U | 10 metre U | m/s | 12 |
| 166 | 10V | 10 metre V | m/s | 12 |

Table 5.1 Control and Perturbed forecast products

| | | | | |
|---|---|---|---|---|
| 167 | 2T | 2 metre temperature | K | 12 |
| 168 | 2D | 2 metre dewpoint temperature | K | 12 |
| 169 | SSRD | Surface solar radiat. downwards++ | W m**-2 s | 16 |
| 170 | STL2 | Soil Temperature Level 2 | K | 12 |
| 172 | LSM | Land/sea mask + | (0,1) | 8 |
| 173 | SR | Surface Roughness + | m | 16 |
| 174 | AL | Albedo + | - | 16 |
| 175 | STRD | Surface thermal radi. downwards++ | W m**-2 s | 16 |
| 176 | SSR | Surface Solar Radiation ++ | W m**-2 s | 16 |
| 177 | STR | Surface Thermal Radiation ++ | W m**-2 s | 16 |
| 178 | TSR | Top Solar Radiation | W m**-2 s | 16 |
| 179 | TTR | Top Thermal Radiation | W m**-2 s | 16 |
| 180 | EWSS | U-stress* | Nm**-2 | 12 |
| 181 | NSSS | V-stress* | Nm**-2 | 12 |
| 182 | E | Evaporation ++ | m of water | 16 |
| 183 | STL3 | Soil Temperature Level 3 | K | 12 |
| 186 | LCC | Low cloud cover | (0-1) | 8 |
| 187 | MCC | Medium cloud cover | (0-1) | 8 |
| 188 | HCC | High cloud cover | (0-1) | 8 |
| 189 | SUND | Sunshine duration | s | 16 |
| 195 | LGWS | Latitude Gravity Wave Stress * | Nm**-2s | 16 |
| 196 | MGWS | Meridional Gravity Wave Stress * | Nm**-2s | 16 |
| 197 | GWD | Gravity Wave Dissipation * | Nm**-2s | 16 |
| 198 | SRC | Skin reservoir content | m (ofwater) | 12 |
| 201 | MX2T | Max. temp. at 2m since prev. post-processing ++ | K | 12 |
| 202 | MN2T | Min. temp. at 2m since prev. post-processing ++ | K | 12 |
| 205 | RO | Runoff | | |
| 228 | TP | Total precipitation* | m | 16 |
| 234 | LSRH | Log Surface Roughness - Heat | - | 16 |
| 235 | SKT | Skin temperature | K | 12 |
| 236 | STL4 | Soil Temperature Level 4 | K | 12 |
| 238 | TSN | Temperature of snow layer | K | 12 |
| 243 | FAL | Forecast Albedo | (0-1) | 8 |
| 244 | FSR | Forecast Surface Roughness | m | 16 |
| 245 | FLSR | Forecast Log Surf. Roughness Heat | - | 16 |
| 246 | CLWC | Cloud liquid water content | Kg/Kg | 12 |
| 247 | CIWC | Cloud ice water content | Kg/Kg | 12 |
| 248 | CC | Cloud cover | 0-1 | 8 |
| 1.228 | CIN | Convective inhibition | J kg**-1 | 16 |
| 21.228 | FDIR | Total sky direct solar radiation at surface | Jm**-2 | 16 |
| 22.228 | CDIR | Clear-sky direct solar radiation at surface | Jm**-2 | 16 |

Table 5.1 Control and Perturbed forecast products

| | | | | |
|---|---|---|---|---|
| 23.228 | CBH | Cloud base height++ | m | 16 |
| 24.228 | DEG0L | Zero degree level++ | m | 16 |
| 80.228 | ACO2NEE | Accumulated Carbon Dioxide Net Ecosystem Exchange | Kgm**-2 | 16 |
| 81.228 | ACO2GPP | Accumulated Carbon Dioxide Gross Primary Production | Kgm**-2 | 16 |
| 82.228 | ACO2REC | Accumulated Carbon Dioxide Ecosystem Respiration | Kgm**-2 | 16 |
| 83.228 | FCO2NEE | Flux of Carbon Dioxide Net Ecosystem Exchange | kgm**-2s**-1 | 16 |
| 84.228 | FCO2GPP | Flux of Carbon Dioxide Gross Primary Production | kgm**-2s**-1 | 16 |
| 85.228 | FCO2REC | Flux of Carbon Dioxide Ecosystem Respiration | kgm**-2s**-1 | 16 |
| 89.228 | TCRW | Total column rain water | kgm**-2 | 16 |
| 90.228 | TCSW | Total column snow water | kgm**-2 | 16 |
| 131.228 | U10N | Neutral wind 10m xcomponent++ | m/s | 16 |
| 132.228 | V10N | Neutral wind 10m y-component++ | m/s | 16 |
| 246.228 | 100U | 100 metre U wind component | m/s | 16 |
| 247.228 | 100V | 100 metre V wind component | m/s | 16 |
| 121.260 | KX | K index | K | 16 |
| 123.260 | TOTALX | Total totals index | K | 16 |

### 4.5.2 Potential temperature and potential vorticity levels

Potential Vorticity level products (Table 5.1) are available on 3 hour intervals 0-144 and 6 hour intervals 150 to 360 and on the level 2000 as:

- control, perturbed and calibration/validation forecast products, parameters PT, PRES, Z, U, V and Q;

Potential Temperature (Isentropic) level products (Table 5.1) are available on 3 hour intervals 0-144 and 6 hour intervals 150 to 168 as:

- control, perturbed and calibration/validation forecast products, parameters PV, PRES, VO and D, levels 300, 315, 320, 330, 350,370, 395, 475, 600 and 850;

### 4.5.3 Control, Perturbed and Calibration/Validation forecast requirements

The following command language parameters are specific for the control and perturbed forecast requirements. Other DIS parameters are listed under the general ENS requirements above.

| | | | | |
|---|---|---|---|---|
| TYPE | = | CONTROL FORECAST | [CF] | |
| | | PERTURBED FORECAST | [PF] | |
| | | CALIBRATION VALIDATION | [CV] | |
| DOMAIN | = | GLOBAL | [G] | (default) |
| NUMBER | = | n-ENSEMBLE NUMBER | [1-50] | (for TYPE=PF) |
| | | | off | (for TYPE=CF) |
| | | | [1-2] | (for TYPE=CV) |
| LEVTYPE | = | PRESSURE LEVEL | [PL] | |
| | | POTENTIAL VORTICITY | [PV] | |
| | | POTENTIAL TEMPERATURE] | [PT] | |

LEVELIST = * (value of pressure)
1000/850/700/500/200
NB ALL is not permitted
(See 4.4.2 for LEVTYPE=PT/PV products);
(1 - 62 for LEVTYPE=ML)

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.25/0.25 or multiples thereof (leg 1);
0.5/0.5 or multiples thereof (leg 2);

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32 (320 and 200 only for leg 1 data);

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

STEP = * (hours)
lgives forecast time step(s);
00/TO/144/BY/3
150/TO/360/by/6
(Dissemination requirements validation tool provides detailed log on the availability of each specific product)
NB ALL, is not permitted.

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in the Table 5.1.

## 4.6 Cluster Mean and Cluster Representative products

The clustering is based on the 500 hPa geopotential forecast fields. The norm used is the root mean square difference. Clustering is performed for the forecast trajectory: 120 to 168 hours with 12 hours interval.

In order to preserve synoptic continuity the membership of each cluster remains constant for the defined time period (few days): for two ENS members to belong to the same cluster, they must display a similar synoptic evolution of 500 hPa geopotential over the whole forecast trajectory. Clusters are computed within the ensemble of 51 (i.e. the 50 perturbed forecasts plus the control forecast) for one domain: 75.00N 20.00W 30.00N 40.00E and one parameter, 500 hPa geopotential.

The set of ENS clusters is described by the cluster centroids. The ENS members closest to the cluster centroids (we refer to these as the cluster representative) are used to represent the ENS clusters. In order to identify the most representative ENS member, a pattern matching algorithm, based on the minimization of the distance using the Root Mean Square metric, has been used. Clustering is performed using the K-means method. Every day the algorithm, depending on the overall spread of the ensemble, can detect up to 6 clusters. (further details are available at http://www.ecmwf.int/products/forecasts/cluster_doc/cluster_doc.html)

Extensions to the GRIB code enable cluster products to contain details of the cluster number and the numbers of the ensemble members from which a cluster was formed (an ensemble number of 0 refers to the control forecast). A full description of those extensions is available at: http://www.ecmwf.int/publications/manuals/libraries/gribex/localDefinition32.html.

The number of clusters generated varies from day to day. As described above, up to 6 clusters are produced, depending on the overall spread of the ensemble. **Note that all requested clusters will be disseminated even if they are "empty" clusters** (i.e. if the number of requested clusters is 6 and only 4 are generated on the day, clusters 5 and 6 will be disseminated as dummy constant fields of a short length).

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 129 | Z | Geopotential | m2s-2 | 16 |

Table 5.3 Cluster Mean and Cluster Standard Deviation products

- Horizontal resolution

  - 1.5 x 1.5 degrees latitude-longitude grid, or multiples thereof

- Verifying times

  - T+120 to T+168 (inclusive) at 12 hour intervals

### 4.6.1 Cluster Mean and Cluster Representative requirements

The following command language parameters are specific for the cluster mean and cluster representative requirements. Other DIS parameters are listed under the general ENS requirements above.

| | | | | |
|---|---|---|---|---|
| TYPE | = | CLUSTER MEAN<br>CLUSTER REPRESENTATIVE | | [CM]<br>[CR] |
| DOMAIN | = | European Area | [H] | (75.0 -20.0 30.0 40.0) |
| NUMBER | = | 1/2/3/4/5/6 | | |
| LEVTYPE | = | PRESSURE LEVEL | [PL] | |
| LEVELIST | = | 500 | (PARAM=Z only) | |
| GRID | = | a/b (latitude-longitude grid)<br><br>a= grid resolution (deg.) along a latitude line (i.e. East/West)<br>b= grid resolution (deg.) along a longitude line (i.e. North/South)<br>1.5/1.5 or multiples thereof; | | |
| STEP | = | * (hours)<br>lgives forecast time step(s);<br>120/132/144/156/168<br>NB ALL, is not permitted. | | |
| PARAM | = | Z<br>Field name abbreviation<br>*<br>NB ALL is not permitted.<br>Available parameters are listed in the Table 5.3. | | |

## 4.7 Ensemble Mean and Ensemble Standard Deviation products

The mean and standard deviation from the full set of 51 forecast (i.e. the 50 perturbed forecasts plus the control forecast) are computed for temperature at pressure level 850 , 500hPa and geopotential on pressure level 1000

and 500hPa and Wind speed at pressure level 850.

- Horizontal resolution

  - 0.25 x 0.25 degrees latitude-longitude grid, or multiples thereof (leg 1)
  - 0.5 x 0.5 degrees latitude-longitude grid, or multiples thereof (leg 2)
  - the Gaussian grid appropriate to the forecast model in use. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32 (320 and 200 only for ENS leg 1 data).
  - any sub-area

- Verifying times

  - T+3 to T+144 (inclusive) at 3 hour intervals and T+144 to T+360 at 6 hour intervals

### 4.7.1 Ensemble Mean and Ensemble Standard Deviation requirements

The following command language parameters are specific for the ensemble mean and ensemble standard deviation requirements. Other DIS parameters are listed under the general Monthly Forecast requirements above.

| | | | |
|---|---|---|---|
| TYPE | = | ENSEMBLE MEAN | [EM]] |
| | | ENSEMBLE STANDARD DEVIATION | [ES] |
| DOMAIN | = | GLOBAL | [G] |
| NUMBER | = | OFF | |
| LEVTYPE | = | PRESSURE LEVEL | [PL] |
| LEVELIST | = | 1000/500 | (PARAM=Z only) |
| | | 850/500 | (PARAM=T only) |
| | | 850 | (PARAM=WS only) |

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.25/0.25 or multiples thereof (ENS leg 1);
0.5/0.5 or multiples thereof (ENS leg 2);

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32 (320 and 200 only for ENS leg 1 data);

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

STEP = * (hours)
lgives forecast time step(s);
3/to/144/by/3 and 144/to/360/by/6
NB ALL, is not permitted.

PARAM = Field name abbreviation
*
NB ALL is not permitted.

## 4.8 Event Probability products

Event probability products provide the probabilities of the occurrence of weather events at each grid point. The probabilities are calculated on the basis that each ensemble member is equally likely. Available parameters are listed in the Table 5.6. Temperature anomaly is defined as the deviation from the monthly climatology values linearly interpolated to the relevant day (applied at each grid point).

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 20 | TALM2K | Temperature anomaly of at most -2 K | % | 8 |
| 21 | TAG2K | Temperature anomaly of at least 2 K | % | 8 |
| 22 | TALM8K | Temperature anomaly of at most -8 K | % | 8 |
| 23 | TALM4K | Temperature anomaly of at most -4 K | % | 8 |
| 24 | TAG4K | Temperature anomaly of at least 4 K | % | 8 |

Table 5.6 (ECMWF Local Code Table 2, parameter table, Version Number 131)

| | | | | |
|---|---|---|---|---|
| 25 | TAG8K | Temperature anomaly of at least 8 K | % | 8 |
| 60 | TPG1 | Total precipitation of at least 1 mm | % | 8 |
| 61 | TPG5 | Total precipitation of at least 5 mm | % | 8 |
| 62 | TPG10 | Total precipitation of at least 10 mm | % | 8 |
| 63 | TPG20 | Total precipitation of at least 20 mm | % | 8 |
| 64 | TPL01 | Total precipitation less than 0.1 mm | % | 8 |
| 65 | TPRL1 | Total precipitation rate less than 1 mm per day | % | 8 |
| 66 | TPRG3 | Total precipitation rate of at least 3 mm per day | % | 8 |
| 67 | TPRG5 | Total precipitation rate of at least 5 mm per day | % | 8 |
| 68 | 10SPG10 | 10 Metre wind speed of at least 10 metre per second | % | 8 |
| 69 | 10SPG15 | 10 Metre wind speed of at least 15 metre per second | % | 8 |
| 70 | 10FGG15 | 10 Metre wind gust of at least 15 metre per second | % | 8 |
| 71 | 10FGG20 | 10 Metre wind gust of at least 20 metre per second | % | 8 |
| 72 | 10FGG25 | 10 Metre wind gust of at least 25 metre per second | % | 8 |
| 73 | 2TL273 | 2 metre temperature less than 273.15 K | % | 8 |
| 89 | PTS | Probability of a tropical storm | % | 12 |
| 90 | PH | Probability of a hurricane | % | 12 |
| 91 | PTD | Probability of a tropical depression | % | 12 |

Table 5.6 (ECMWF Local Code Table 2, parameter table, Version Number 131)

Two sets of probabilities are calculated, occurrence of instantaneous weather events and occurrence of events averaged or accumulated in time.

*I) Occurrence of instantaneous weather events*

TEMPERATURE ANOMALY EVENTS (at level 850 hPa)

- Cold anomaly of at least -8K
- Cold anomaly of at least -4K
- Warm anomaly of at least 4K
- Warm anomaly of at least 8K

These temperature anomaly products are available at 12 hour intervals from T+12 to T+360 inclusive.

WIND SPEED EVENTS (at level 10m)

- At least 10m/s
- At least 15m/s

Wind speed parameters are available 12 hourly from forecast time step T+12 to T+360 inclusive.

2 METER TEMPERATURE PROBABILITY

- The probability that 2 metre temperature is less then 273.15 K.

2 meter temperature probability products are available at 12 hour intervals from T+12 to T+360 hours inclusive and for forecast step ranges 120-168, 168-240, 120-240 and 240-360 hours.

*II) Occurrence of weather events accumulated over 24 hours*

PRECIPITATION EVENTS

- At least 1 mm in 24 hours
- At least 5mm in 24 hours
- At least 10mm in 24 hours
- At least 20 mm in 24 hours

Precipitation event products are available for the following time steps ranges 24,12-36,24-48,36-60,48-72,60-84,72-96,84-108,96-120,108-132,120-144,132-156,144-168,156-180,168-192,180-204,192-216,204-228,216-240,228-252,240-264,252-276,264-288,276-300,288-312,300-324,312-336,324-348 and 336-360 hours.

WIND GUST AT 10 METERS PROBABILITY

- Max wind gust exceeding 15 m/s
- Max wind gust exceeding 20 m/s
- Max wind gust exceeding 25 m/s

Wind gust products are available for the following range of time steps 24,12-36,24-48,36-60,48-72,60-84,72-96,84-108,96-120,108-132,120-144,132-156,144-168,156-180,168-192,180-204,192-216,204-228,216-240,120-168,168-240,120-240,228-252,240-264,252-276,264-288,276-300,288-312,300-324,312-336,324-348,336-360,240-360.

*III) Occurrence of weather events accumulated over 48 hours*

PROBABILTY OF A TROPICAL STIORM
PROBABILTY OF A HURRICANE
PROBABILTY OF A TROPICAL DEPRESSION

- time step ranges are 24-72, 48-96, 72-120, 96-144, 120-168, 144-192, 168-216, 192-240, 216-264, and 240-288

*IV) Occurrence of weather events averaged or accumulated in time*

TEMPERATURE ANOMALY EVENTS (at level 850hPa)

- average temperature more than 2 degrees K below climate
- average temperature more than 2 degrees K above climate

These temperature anomaly products are available for time step ranges 120-168, 168-240, 120-240 and 240-360 hours.

MEAN PRECIPITATION RATE EVENTS

- no rain (defined as less than 0.1mm over period)
- mean precipitation rate less than 1mm/day
- mean precipitation rate greater than 3mm/day
- mean precipitation rate greater than 5mm/day

Mean precipitation rate event products are available for time step ranges 120-168, 168-240, 120-240 and 240-360 hours.

HORIZONTAL RESOLUTION:

- 0.25 x 0.25 degrees latitude-longitude grid, or multiples thereof (leg 1),

- 0.5 x 0.5 degrees latitude-longitude grid, or multiples thereof (leg 2),

- the Gaussian grid appropriate to the forecast model in use. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32 (320 and 200 only for ENS leg 1 data).

- any sub-area

NOTE: The required precision for the threshold value is achieved by scaling the units, in which the meteorological parameter itself is reported, by an appropriate power of 10 (which may be positive, negative or 0).

For example: Total precipitation, is reported in units of metres. With

D = 4 and Lower threshold = 1, the value of the lower threshold is

1 * (1 metre / 10**4) or 0.1 mm;

Data values are percentage probabilities of the indicated meteorological parameter being above the lower threshold or being below the upper threshold or lying between the upper and lower thresholds.

## Event probability requirements

The following command language parameters are specific for the control and perturbed forecast requirements. Other DIS parameters are listed under the general Monthly Forecast requirements above.

| | | | |
|---|---|---|---|
| TYPE | = EVENT PROBABILITY | | [EP] |
| DOMAIN | = GLOBAL | [G] | |
| NUMBER | = OFF | | |
| PARAM | = 2 METRE TEMPERATURE LESS THAN 273.15 K | | [2TL273] |
| | 10 METRE WIND GUST OF AT LEAST 15 METRE PER SECOND | | [10FGG15] |
| | 10 METRE WIND GUST OF AT LEAST 20 METRE PER SECOND | | [10FGG20] |
| | 10 METRE WIND GUST OF AT LEAST 25 METRE PER SECOND | | [10FGG25] |
| | 10 METRE WIND SPEED OF AT LEAST 10 METRE PER SECOND | | [10SPG10] |
| | 10 METRE WIND SPEED OF AT LEAST 15 METRE PER SECOND | | [10SPG15] |
| | TEMPERATURE ANOMALY OF AT MOST -2 K | | [TALM2K] |
| | TEMPERATURE ANOMALY OF AT LEAST 2 K | | [TAG2K] |
| | TEMPERATURE ANOMALY OF AT MOST -8 K | | [TALM8K] |
| | TEMPERATURE ANOMALY OF AT MOST -4 K | | [TALM4K] |
| | TEMPERATURE ANOMALY OF AT LEAST 4 K | | [TAG4K] |
| | TEMPERATURE ANOMALY OF AT LEAST 8 K | | [TAG8K] |
| | TOTAL PRECIPITATION OF AT LEAST 1 MM | | [TPG1] |
| | TOTAL PRECIPITATION OF AT LEAST 5 MM | | [TPG5] |
| | TOTAL PRECIPITATION OF AT LEAST 10 MM | | [TPG10] |
| | TOTAL PRECIPITATION OF AT LEAST 20 MM | | [TPG20] |
| | TOTAL PRECIPITATION LESS THAN 0.1 MM | | [TPL01] |
| | TOTAL PRECIPITATION RATE LESS THAN 1 MM PER DAY | | [TPRL1] |
| | TOTAL PRECIPITATION RATE OF AT LEAST 3 MM PER DAY | | [TPRG3] |
| | TOTAL PRECIPITATION RATE OF AT LEAST 5 MM PER DAY | | [TPRG5] |
| | PROBABILTY OF A TROPICAL STIORM | | [PTS] |
| | PROBABILTY OF A HURRICANE | | [PH] |
| | PROBABILTY OF A TROPICAL DEPRESSION | | [PTD] |

| | | | |
|---|---|---|---|
| LEVTYPE | = SURFACE<br>PRESSURE LEVEL | [SFC]<br>[PL]<br><br>PL for PARAM=TALM2K/<br>TAG2K/<br>TALM8K/TALM4K/TAG4K/<br>TAG8K only) | * |
| LEVELIST | = OFF<br>850 | *<br>(PARAM=TALM2K/TAG2K/<br>TALM8K/TALM4K/TAG4K/<br>TAG8K only) | |

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.25/0.25 or multiples thereof for ENS leg1
0.5/0.5 or multiples thereof for ENS leg 2;

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32 (320 and 200 only for ENS leg 1 data);

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

STEP = * (hours)

As described for each individual product above.

NB ALL is not permitted.

## 4.9 TUBE products

The tubing is a method designed to classify ensemble forecasts. The aim of the classification is to condense the information coming from the 51 ensemble forecasts. In the traditional clustering, ensemble forecasts are grouped into a few clusters, each cluster being represented by its mean field. In the case of the tubing, there is only one cluster, the so-called central cluster grouping those forecasts that are similar to the ensemble mean. The other

forecasts are grouped into a few tubes indicating different deviations from the ensemble mean that can be found in the ensemble. Each tube is represented by its extreme i.e. the forecast which is the most different from the ensemble mean in the direction of the tube.

How to use TUBE products?

- The central cluster mean shows the evolution which is the most likely to occur, on which can be based the most likely weather forecast. The central cluster mean field has a level of smoothing increasing with the time-step, allowing to give more details on day 3 than on day 8. This level of smoothing is day-to-day consistent for a given time-step (it depends on the internal variance of the central cluster which follows a slow seasonal trend, independent on the ensemble spread variations).

- The extremes of the tubes are not alternatives: they are extreme representatives of the tubes, almost caricatures, allowing to better visualise the different tendencies present in the ensemble, by contrast with the central cluster mean forecast. The significant tendencies, in terms of weather parameters over the area of interest for instance, can be used to describe
possible meteorological variants.

- The number of possible variants is a good indicator of the uncertainty of the high resolution
forecast based on the central cluster: if there is no significant variant the confidence is high; if there are one or two variants, the confidence is normal; if there are several variants, the confidence is low.

Reliability of TUBE products:

TUBE products are relatively reliable: the ENS is not perfect but its performance has dramatically improved since December 1996.

- The verification is not always indicated by the central cluster or one of the tubes: there is still a proportion of 10 to 20% of cases when the ensemble misses the verification.

- The verification is much more likely to be found in the central cluster than in a tube. The likelihood of the central cluster varies according to its population, but is generally grater than 50%, unless when the spread is especially large.

- The verification may be found in a tube, even if it contains only few forecasts. As a general rule a tube likelihood is around 10%, whatever its population.

For each tubing reference step (+96h, +144h, +168h, +192h, +240h), tubing products are generated over a 48-hour

sequence finishing on the reference step (e.g. +48h/+72h/+96h for the 96h tubing) allowing a sequential view of the different tendencies. (In the case of the 168h tubing, the sequence is over 96 hours from +72h to +168h.)

Tube is the central cluster mean. This forecast is not exactly the same as the ensemble mean, but generally very similar. The remaining tubes (maximum 9) are the extreme members, sorted according to decreasing distance from the central cluster. Tubes are computed based on the 500 hPa geopotential at the reference step over each of the five geographical domains Europe, NW Europe, NE Europe, SW Europe and SE Europe. The results of these computations to determine the tubing structure are then applied to 500 hPa and 1000 hPa geopotential and 850 hPa and 500 hPa temperature.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 129 | Z | Geopotential* | m2s-2 | 16 |
| 130 | T | Temperature** | K | 12 |

* On pressure levels 1000/500 ** On pressure levels 850/500

Table 5.8 TUBE products

## TUBE requirements

The following command language parameters are specific for the TUBE requirements. Other parameters are listed under the general ENS requirements above.

| | | | | |
|---|---|---|---|---|
| TYPE | = | TUBE | [TU] | |
| DOMAIN | = | General European Area | [G] | (75.0 -20.0 30.0 45.0) |
| | | North West Europe | [A] | (70.0 -27.5 40.0 10.0) |
| | | North East Europe | [B] | (72.5 0.0 50.0 45.0) |
| | | South West Europe | [C] | (57.5 -15.0 32.5 17.5) |
| | | South East Europe | [D] | (57.5 2.5 32.5 42.5) |
| NUMBER | = | OFF | | |
| LEVTYPE | = | PRESSURE LEVEL | [PL] | |
| LEVELIST | = | 1000/500 | (PARAM=Z only) | |
| | | 850/500 | (PARAM=T only) | |
| GRID | = | a/b (latitude-longitude grid) | | |
| | | a= grid resolution (deg.) along a latitude line (i.e. East/West)<br>b= grid resolution (deg.) along a longitude line (i.e. North/South)<br>1.5/1.5 or multiples thereof; | | |

| | | | |
|---|---|---|---|
| REFERENCE | = | * (hours)<br>OFF (to switch off the reference);<br><br>gives product's reference time step (for the values see definition of the parameter STEP below); | |
| STEP | = | * | (hours) |
| | | gives tube time step(s); | |
| | | 48/72/96 | for the REFERENCE=96; |
| | | 96/120/144 | for the REFERENCE=144; |
| | | 72/96/120/144/168 | for the REFERENCE=168; |
| | | 144/168/192 | for the REFERENCE=192; |
| | | 192/216/240 | for the REFERENE=240; |
| PARAM | = | Field name abbreviation<br>*<br>NB ALL is not permitted.<br>Available parameters are listed in the Table 5.3. | |

## 4.10 Extreme forecast index, Extreme forecast index control data and Shift of tails index

The Extreme Forecast Index measures how far away from the model climate distribution the ENS forecast distribution is (the ENS Control is treated as a single member distribution). It scales from -1 (all members reach unprecedented small values) to +1 (all members reach unprecedented large values). See ECMWF Tech. Memo 373 (July 2002) or QJRMS, 2003 pp3037-3058 for more details (http://www.ecmwf.int/publications/library/ecpublications/_pdf/tm373.pdf). Compared to these last two references, it should be noted that a more selective definition (order=0 or Anderson-Darling metrics) has been introduced in line with the presentation given at the Users meeting in June 2003 (see "Product Development" Slides 4 to 11 at http://www.ecmwf.int/products/forecasts/d/inspect/catalog/publications/slides/mru/2003/ec/ProductDevelopmentFLalaurette!4/".

Parameters available in dissemination are listed in the Table 5.9.1.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 144 | SFI | Snowfall index | -1 - 1 | 12 |
| 165 | 10WSI | Ten metre wind speed index | -1 - 1 | 12 |
| 167 | 2TI | 2 metre temperature index | -1 - 1 | 12 |
| 49 | 10FGI | Wind gust at 10 meters index | -1 - 1 | 12 |

Table 5.9.1 (ECMWF Local Code Table 2, parameter table, Version Number 132)

| | | | | |
|---|---|---|---|---|
| 201 | MX2TI | Maximum temperature at 2 metres index | -1 - 1 | 12 |
| 202 | MN2TI | Minimum temperature at 2 metres index | -1 - 1 | 12 |
| 216 | MAXSWHI | Maximum of significant wave height index | -1 - 1 | 12 |
| 228 | TPI | Total precipitation index | -1 - 1 | 12 |

Table 5.9.1 (ECMWF Local Code Table 2, parameter table, Version Number 132)

Time step range at which these parameters are made available differ for 00 UTC based and 12 UTC based products. For 00 UTC based products. See 4.10.1 bellow for more details. Please note that the STEP value in the form'value1-value2' represents a product for a time range 'value1 to value2' and is made available in dissemination at 'value2' time step.

On June 2012, the EFI is complemented by the new Shift of Tails (SOT) Index (based on the 90th percentile and 10th percentile for temperature parameters only) and model climate.
The SOT complements the EFI providing information about the magnitude of the potential extreme event. For more information about SOT please refer to page 8 of ECMWF Newsletter No. 107 – Spring 2006.

Horizontal resolution:

- 0.25 x 0.25 degrees latitude-longitude grid, or multiples thereof (leg 1)
- 0.5 x 0.5 degrees latitude-longitude grid, or multiples thereof (leg 2)
- the Gaussian grid appropriate to the forecast model in use. The following Gaussian grid numbers are supported: 320, 200, 160, 128, 80, 48 and 32.
- any sub-area

SOT (Shift of tails index):

The percentiles used for SOT (Shift of Tails index) are specified using the MARS "QUANTILE" key word. For the 90th percentile use QUANTILE=90:100

The 10th percentile is used for temperature parameters only, i.e QUANTILE=10:100

Steps:

24h interval: parameters: 2ti, tpi, 10swi, 10fgi, mn2ti, mx2ti, sfi, maxswhi

00UTC: 00-24, 24-48, 48-72, 72-96, 96-120, 120-144, 144-168

12UTC: 12-36, 36-60, 60-84, 84-108, 108-132, 132-156, 156-180

72h interval: parameters: 2ti, tpi, 10swi

00UTC: 00-72, 24-96, 48-120, 72-144, 96-168, 120-192, 144-216

12UTC: 12-84, 36-108, 60-132, 84-156, 108-180, 132-204, 156-228

120h interval: parameter: 2ti, tpi, 10swi

00UTC: 00-120 (only for tpi before), 24-144 (only for tpi before),48-168,72-192,96-216

12UTC: 12-132, 36-156, 60-180, 84-204, 108-228

240h interval: parameters: 2ti, tpi, 10swi

00UTC: 000-240 (only for tpi before)

12UTC: 000-240 (only for tpi before)

The following command language parameters are specific for the Extreme forecast index requirements. Other parameters are listed under the general ENS requirements above.

| | | | | |
|---|---|---|---|---|
| TYPE | = | EXTREME FORECAST INDEX | | [EFI] |
| | | EXTREME FORECAST INDEX CONTROL | | [EFIC] |
| | | SHIFT OF TAILS INDEX | | [SOT] |
| QUANTILE | = | OFF for type EFI and EFIC | 90:100 | For type = SOT |
| | | | 10:100 | For type = SOT and temperature parameters only |
| DOMAIN | = | GLOBAL | [G] | |
| NUMBER | = | OFF | | |
| PARAM | = | WIND GUST AT 10 METRES INDEX | | [10FGI] |
| | | TOTAL PRECIPITATION INDEX | | [TPI] |
| | | 10 METRE WIND SPEED INDEX | | [10WSI] |
| | | SNOWFALL INDEX | | [SFI] |
| | | MAXIMUM TEMPERATURE AT 2M ANOMALY | | [MX2TI] |
| | | MINIMUM TEMPERATURE AT 2M ANOMALY | | [MN2TI] |
| | | MAXIMUM OF SIGNIFICANT WAVE HEIGHT INDEX | | [MAXSWHI] |
| | | 2 METER MEAN TEMPERATURE INDEX | | [2TI] |
| LEVTYPE | = | SURFACE | [SFC] | |
| LEVELIST | = | OFF | | |

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.25/0.25 or multiples thereof; (leg 1)
0.5/0.5 or multiples thereof; (leg 2)

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported:320, 200, 160, 128, 80, 48 and 32.

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

STEP = * (hours)

24h Interval: parameters:
2ti,tpi,10swi,10fgi,mn2ti,mx2ti,sfi,maxswhi

00UTC:00-24,24-48,48-72,72-96,
96-120, 120-144, 144-168

12UTC: 12-36,36-60,60-84,
84-108,108-132,132-156,156-180

72h Interval: parameters: 2ti,tpi,10swi
00UTC: 00-72, 24-96, 48-120, 72-144, 96-168, 120-192, 144-216
12UTC: 12-84, 36-108, 60-132, 84-156, 108-180, 132-204, 156-228

120h interval: parameters:2ti, tpi, 10swi
00UTC: 00-120 (only for tpi before), 24-144 (only for tpi before), 48-168, 72-192, 96-216
12UTC: 12-132, 36-156, 60-180, 84-204, 108-228

240h interval: parameters 2ti, tpi, 10swi
00UTC: 000-240 (only for tpi before)
12UTC: 000-240 (only for tpi before)

NB ALL is not permitted.

## 4.11 Ensemble forecast overlap

Ensemble Forecast Overlap (EFOV) product are made available in order to address an issue that occurs at day 10 in accumulated fields of the ensemble forecast (ENS).

The issue is caused by the change in ENS horizontal resolution from higher resolution in leg 1 (0 to 240 hours) to lower resolution in leg 2 (246 to 360 hours). The change in resolution creates incorrect values for accumulations that run across day 10, i.e. those that span forecast time steps 240-246 hours.

Users of such fields are advised to request the EFOV fields through dissemination in order to resolve the problem.

The following example shows how to use the EFOV fields to obtain a correct accumulation across day 10. The example is for 48-hour total precipitation (TP) from 216 to 264 hours for one ENS member:

$$TP_{t+216\ to\ t+264} = (TP_{t+240} - TP_{t+216}) + (TP_{t+264} - TPVAR_{t+240})$$

where TPVAR is the corresponding EFOV TP field, and the subscript indicates the forecast step (hours). For time ranges that do not span day 10, the normal calculation should be used, e.g.:

$$TP_{t+72\ to\ t+120} = (TP_{t+120} - TP_{t+72})$$

for the 72 to 120 hour total precipitation, which should still be used if you do not calculate accumulations across day 10.

Horizontal resolution:

- 0.5 x 0.5 degrees latitude-longitude grid, or multiples thereof (as ENS leg 2);
- the Gaussian grid appropriate to the forecast model in use. The following Gaussian grid numbers are supported: 160, 128, 80, 48 and 32.
- any sub-area

Parameters:

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 8.230 | SROVAR | Surface runoff variable resolution | m | 16 |
| 9.230 | SSROVAR | Sub-surface runoff variable resolution | m | 16 |
| 142.230 | LSPVAR | Large scale precipitation variable resolution | m | 16 |
| 143.230 | CPVAR | Convective precipitation variable resolution | m | 16 |
| 144.230 | SFVAR | Snow fall variable resolution | m of water equivalent | 16 |

| | | | | |
|---|---|---|---|---|
| 145.230 | BLDVAR | Boundary Layer Dissipation variable resolution | Jm**-2s | 12 |
| 146.230 | SSHFVAR | Surface sensible heat flux variable resolution | Jm**-2s | 12 |
| 147.230 | SLHFVAR | Surface latent heat flux variable resolution | Jm**-2s | 12 |
| 169.230 | SSRDVAR | Surface solar radiat. downwards variable resolution | Jm**-2 s | 16 |
| 175.230 | STRDVAR | Surface thermal radi. downwards variable resolution | Jm**-2 s | 16 |
| 176.230 | SSRVAR | Surface Solar Radiation variable resolution | Jm**-2 s | 16 |
| 177.230 | STRVAR | Surface Thermal Radiation variable resolution | Jm**-2 s | 16 |
| 178.230 | TSRVAR | Top Solar Radiation variable resolution | Jm**-2 s | 16 |
| 179.230 | TTRVAR | Top Thermal Radiation variable resolution | Jm**-2 s | 16 |
| 180.230 | EWSSVAR | U-stress variable resolution | Nm**-2 | 12 |
| 181.230 | NSSSVAR | V-stress variable resolution | Nm**-2 | 12 |
| 182.230 | EVAR | Evaporation variable resolution | kgm**-2 | 16 |
| 189.230 | SUNDVAR | Sunshine duration variable resolution | s | 16 |
| 195.230 | LGWSVAR | Latitude Gravity Wave Stress variable resolution | Nm**-2s | 16 |
| 196.230 | MGWSVAR | Meridional Gravity Wave Stress variable resolution | Nm**-2s | 16 |
| 197.230 | GWDVAR | Gravity Wave Dissipation variable resolution | Jm**-2s | 16 |
| 198.230 | SRCVAR | Skin reservoir content variable resolution | Kgm**-2 | 12 |
| 205.230 | ROVAR | Runoff variable resolution | m | 16 |
| 228.230 | TPVAR | Total precipitation variable resolution | m | 16 |

Steps:

Forecast time step 240.

The following command language parameters are specific for the Ensemble Forecast Overlaprequirements. Other parameters are listed under the general ENS requirements above.

| | | | | |
|---|---|---|---|---|
| STREAM | = | ENSEMBLE FORECAST OVERLAP | [EFOV] | |
| TIME | = | 12/00<br>Gives products base time. | | |
| STEP | = | 240 (hours) | | |
| TYPE | = | CONTROL FORECAST<br>PERTURBED FORECAST | | [PF]<br>[CF] |
| NUMBER | = | n-ENSEMBLE NUMBER | [1-50]<br>off | (for TYPE=PF)<br>(for TYPE=CF) |
| GRID | = | *<br>*/*<br>AUTOMATIC [AUTO] | | |

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.5/0.5 or multiples thereof; (ENS leg 2)

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported:160, 128, 80, 48 and 32.

EOFV products are disseminated spatially from other ENS products and use data stream indication letter ‘O’ in dissemination file names:

## 4.12 Ensemble Forecast Weather Parameter products

The ENS WEATHER PARAMETER products in the form of time series of a specific parameter for a number of forecasts at the user defined location are available from the ECMWF dissemination system. Data is presented in the FM 94-IX Ext. BUFR binary representation (BUFR Edition 3 is used).

Each ENS WEATHER PARAMETER product contains 51 data subsets. Each subset represents data time series for a particular forecast: ENS control forecast and each of the 50 ENS T639 (for forecast range 0-240 hours) and T319 (for time steps 246-360 hours) perturbed forecasts. WEATHER PARAMETER forecast time steps range from 0 to 240 or 360 hours by steps of 12, 6 or 3 hours (3 hourly intervals are available up to forecast step 144

and then the values are taken 6 hourly to T+240 or T+360).

The data for the WEATHER PARAMETER products is constructed from the basic model grid used for producing many of the standard dissemination fields. Where the requested location coordinates coincide with the original field grid point location, the grid point value will be
taken. Otherwise, the value at the requested location will be obtained by bi-linear interpolation from the four nearest original field grid points.

When requesting data at grid point location note the following:

- upper air fields are converted from spherical harmonics to 0.25/0.25 (leg 1) and 0.5/0.5 (leg 2) degrees latitude/ longitude grid before extraction/interpolation to requested location;

- surface fields out of ENS T639 forecasts (control and perturbed) are represented on N320 reduced Gaussian grid whereas surface fields out of ENS T319 forecasts (ENS leg 2) are represented on N160 reduced Gaussian grid;

A number of parameters have been made available for dissemination in the form of WEATHER PARAMETER products. The system has been made fully flexible, so that any combination of parameters/levels/locations can be requested. Parameters available are listed in the Table 4.11 below.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS |
|---|---|---|---|
| 123 | 10FG6 | Wind gust at 10 meters in the past 6 hours | m/s |
| 59 | CAPE | Convective available potential energy | J/K |
| 129 | Z | Geopotential** * | m2s-2 |
| 130 | T | Temperature** | K |
| 131 | U | U-velocity** | m/s |
| 132 | V | V-velocity** | m/s |
| 142 | LSP | Large scale precipitation | m |
| 143 | CP | Convective precipitation | m |
| 157 | R | Relative humidity** | - |
| 228 | TP | Total Precipitation | kg/m**2 |
| 164 | TCC | Total Cloud Cover | (0-1) |
| 167 | 2T | 2 Metre Temperature | K |
| 168 | 2D | 2 Metre Dew Point Temperature | K |

* Orography is defined as Geopotential on level surface

** On pressure levels 1000, 850, 700, 500 and 200 hPa. See note below for time range availability

*** WP Sunshine duration are not accumulated values but values since previous time step specified in the message

++ Takes into account time step frequency requested and generates fields accordingly

Table 5.10 ENS WEATHER PARAMETER products

| | | | |
|---|---|---|---|
| 165 | 10U | 10 Metre U Wind Component | m/s |
| 166 | 10V | 10 Metre V Wind Component | m/s |
| 144 | SF | Snow fall | m |
| 121 | MX2T6 | Max. temp. at 2m in past 6 hours | K |
| 122 | MN2T6 | Min. temp. at 2m in past 6 hours | K |
| 172 | LSM | Land/sea mask | (0-1) |
| 151 | MSL | Mean sea level pressure | Pa |
| 189 | SUND | Sunshine duration*** | min |

* Orography is defined as Geopotential on level surface

** On pressure levels 1000, 850, 700, 500 and 200 hPa. See note below for time range availability

*** WP Sunshine duration are not accumulated values but values since previous time step specified in the message

++ Takes into account time step frequency requested and generates fields accordingly

Table 5.10 ENS WEATHER PARAMETER products

NOTE: WEATHER PARAMETER products are generated on either 3, 6 or 12 hour intervals (0 to 240 or 0 to 360). The following products are available only at 12 hour intervals:

- Geopotential on pressure levels 1000, 700 and 200 hPa
- Temperature on pressure levels 1000, 700 and 200 hPa
- U-velocity, V-velocity and Relative humidity on pressure levels 1000, 850, 700, 500 and 200 hPa.

ENS WEATHER PARAMETER products are disseminated separately from other ENS products and have their own dissemination schedule (Transmission Table below).

### 4.12.1 ENS Weather Parameter requirements

The following command language parameters are specific for the WEATHER PARAMETER requirements. Other parameters are listed under the general ENS requirements above.

| | | | |
|---|---|---|---|
| STREAM | = | ENSEMBLE FORECAST | [EF] |
| TYPE | = | WEATHER PARAMETER | [WP] |
| DOMAIN | = | GLOBAL | [G] |
| FORMAT | = | BUFR | [BF] |
| LEVTYPE | = | PRESSURE LEVEL<br>SURFACE | [PL]<br>[SFC] |
| LEVELIST | = | 100/850/700/500/200<br>OFF | (PARAM=Z/T/U/V/R only)<br>(Surface parameters) |

AREA = a/b (latitude-longitude grid)

a = latitude of location (degrees);
b = longitude of location (degrees);

STEP = * (hours)
gives range of forecast time steps (see note above for each parameter/level availability);

240 (will result in 3 hourly values to T+144 and 6 hourly to T+240)
0/to/240/by/6
0/to/240/by/12
360 (will result in 3 hourly values to T+144 and 6 hourly to T+360)
0/to/360/by/6
0/to/360/by/12

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in the Table 4.11.

### 4.12.2 BUFR definition for WEATHER PARAMETER products

ECMWF's ENS WEATHER PARAMETER products are presented in the FM 94-IX Ext. BUFR binary representation form. Products are coded into BUFR Edition 3. They contain the following:

| Table D Reference | Table B Reference | Element Name |
|---|---|---|
| | 008195 | Data Type |
| | 005195 | Ensemble Member Number |
| 301011 | 004001 | Year |
| | 004002 | Month |
| | 004003 | Day |
| | 004004 | Hour |
| 301021 | 005001 | Latitude |
| | 006001 | Longitude |
| | 007004 | Pressure data (Element present only for upper air parameters) |
| | 007007 | Height (10 m) (Element present only for 10U/10V parameter) |

Table 5.11 BUFR table reference for ENS WEATHER PARAMETER products

| | | |
|---|---|---|
| | 102nnn | Repeat 2 elements ‘nnn’ times<br>240 data set (21 - 12hourly data set, 41 - 6 hourly data set or 65 - 3 hourly data set)<br>360 data set (31 - 12hourly data set, 61 - 6 hourly data set or 85 - 3 hourly data set) |
| | 004024 | Time period or displacement (hours)<br>(forecast time step) |

Table 5.11 BUFR table reference for ENS WEATHER PARAMETER products

| Table reference<br>List of parameters available | Element<br>Name |
|---|---|
| 012001<br>010003<br>011003<br>011004<br>020010 | Temperature<br>Geopotential<br>U-component<br>V-component<br>Cloud cover (total) |
| 013011<br>012004<br>012006<br>013233<br>012199 | Total precipitation<br>Dry-bulb temperature at 2m<br>Dew-point temperature at 2m<br>Fraction of total precipitation in solid form (snow)<br>Maximum temperature at 2m, past 6 hours |
| 012200<br>008224<br>010001<br>013230<br>013231<br>011041<br>010051<br>014034<br>013241 | Minimum temperature at 2m, past 6 hours<br>Land/sea mask<br>Height of Land Surface<br>Convective precipitation<br>Large scale precipitation<br>Maximum wind speed - gust in past 6 hours<br>Pressure reduced to mean sea level<br>Sunshine over period specified<br>Convective available potential energy |

Table 5.11-2 BUFR table reference for ENS WEATHER PARAMETER products

Each BUFR message for ENS WEATHER PARAMETER data conforms to the above data description and contains 51 data subsets. Each subset represents data time series for a
particular forecast: ENS control forecast and each of the 50 ENS perturbed forecasts.

Please, note that two new entries have been added to the BUFR table B:

1 008195 DATA TYPE CODE TABLE 08195
2 005195 ENSEMBLE MEMBER NUMBER NUMERIC

DATA TYPE code entries (as defined in the code table 08195 and used for WEATHER PARAMETER products):

10 = Control forecast
11 = Perturbed forecast

ENSEMBLE MEMBER NUMBER values (as used for WEATHER PARAMETER products):

0 = operational T1279 forecast/ENS control forecast
n = ENS perturbed forecast (n = 1 - 50)

Users have to update their tables accordingly. Tables are also available from ECMWF.

## 4.13 TROPICAL CYCLONE trajectory forecast products

The ECMWF Tropical cyclone forecast products are designed to provide both high resolution and probabilistic information on movement and intensity of individual tropical cyclones. The system is vitally dependent on observations from various tropical cyclone centres around the world. In other words, the TC forecasts does not take genesis into account - TCs can however die in the process if they are not forecasted to stay strong enough.

Once observations are available, the movement of a TC is automatically tracked, both in the high resolution and the ENS forecasts. The tracking algorithm is based on extrapolation of past movement and the mid-tropospheric steering flow to obtain a first guess position. The actual position is determined by searching for MSLP and 850 hPa vorticity extremes around the first guess position. Also thickness maximum, wind speed and orography are evaluated. More details can be found in the following Tech. Memo http://www.ecmwf.int/publications/newsletters/pdf/102.pdf. Tropical cyclone products are presented in the FM 94-IX Ext. BUFR binary representation.

The calculations of perturbations in the Tropics

To improve the tropical- cyclone (TC) prediction in terms of the spread in the cyclone tracks and intensity a specific set of perturbations for the Tropics was introduced in the ENS (Puriet al, 2001). Tropical singular vectors are specifically designed to take in account perturbation growth due to diabatic processes.

To benefit from tropical diabatic singular vectors in TC ensemble forecasting, it is necessary to define target areas in the vicinity of TC locations. This area is defined as a 30x40 latitude-longitude degree box around all the TCs laying in the tropical strip 25S - 25N and classified at least as strong as Tropical Storm. Even though the number of TC in the tropics may vary from day to day, to limit the numerical cost a maximum number of target area is set to four merging the closest target area. Considering that weather systems originating in the Caribbean area may influence medium-range European forecast, this area (0N - 20N, 100W - 60W) is always targeted.

Tropical Cyclone products are disseminated separately from other ENS products and have their own dissemination schedule (Transmission Table below).

### 4.13.1 TROPICAL CYCLONE trajectory forecast requirements

The following command language parameters are specific for the TROPICAL CYCLONE trajectory forecast requirements. Other parameters are listed under the 4.2.6 above.

| | | |
|---|---|---|
| STREAM | = | ENSEMBLE FORECAST [EF] |
| TYPE | = | TRAJECTORY FORECAST [TF] |
| DOMAIN | = | GLOBAL [G] |
| FORMAT | = | BUFR [BF] |
| AREA | = | */*/*/* |
| | | Area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East; |
| | | Negative values indicate western longitudes and southern latitudes. |
| | | All Tropical Cyclones with the observed location within the AREA specified will be disseminated. |
| PARAM | = | TROPICAL CYCLONE [TC] |

### 4.13.2 BUFR definition for TROPICAL CYCLONE trajectory forecast products

ECMWF's TROPICAL CYCLONE trajectory forecast products are presented in the FM 94-IX Ext. BUFR binary representation form. Products are coded into BUFR Edition 3. They contain the following:

| Table D Reference | Table B Reference | Element Name |
|---|---|---|
| | 001033 | Identification Of Originating/Generating Centre |
| | 001034 | Identification Of Originating/Generating Sub-Centre |
| | 001032 | Generating Application |
| | 001025 | Storm Identifier |
| | 001027 | WMO Long Storm Name |
| | 001090 | Technique For Making Up Initial Perturbations [2 = Singular vectors] |
| | 001091 | Ensemble Member Number |
| | 001092 | Type Of Ensemble Forecast |
| 301011 | 004001 | Year |
| | 004002 | Month |
| | 004003 | Day |
| 301012 | 004004 | Hour |
| | 004005 | Minute |
| | 008005 | Meteorological Attribute Significance [1 = Storm Centre] |
| 301023 | 005002 | Latitude |
| | 006002 | Longitude |
| | 008005 | Meteorological Attribute Significance [4 = Location of the storm in the perturbed analysis] [5 = Location of the storm in the analysis] |
| 301023 | 005002 | Latitude (Coarse Accuracy) |
| | 006002 | Longitude (Coarse Accuracy) |
| | 010051 | Pressure Reduced To Mean Sea Level |
| | 008005 | Meteorological Attribute Significance |
| 301023 | 005002 | Latitude (Coarse Accuracy) |
| | 006002 | Longitude (Coarse Accuracy) |
| | 011012 | Wind Speed At 10 M |
| | 108000 | Replicate 8 descriptors following delayed descriptor replication factor |
| | 031001 | Delayed Descriptor Replication Factor |
| | 008021 | Time Significance [4 = Forecast] |
| | 004024 | Time period or displacement (hours) |

Table 5.12 BUFR table reference for TROPICAL CYCLONE products

| | | |
|---|---|---|
| 301023 | 008005<br>005002<br>006002<br><br>010051 | Meteorological Attribute Significance<br>[1 = Storm Centre]<br>Latitude (Coarse Accuracy)<br>Longitude (Coarse Accuracy)<br>Pressure Reduced To Mean Sea Level |
| 301023 | 008005<br>005002<br>006002<br><br>011012 | Meteorological Attribute Significance<br>[Location of maximum wind]<br>Latitude (Coarse Accuracy)<br>Longitude (Coarse Accuracy)<br>Wind Speed At 10 M |

Table 5.12 BUFR table reference for TROPICAL CYCLONE products

## 4.14 Transmission of ENS products

Each day the operational medium-range forecast runs first, followed as soon as possible by the ENS.

The dissemination filename convention used for the transmission of ENS products is described in **Section Transmission of Products**. Data stream indicator for the ensemble control and perturbed forecast products in dissemination file names is 'E'. Derived ENS products (other then control and perturbed ensemble forecasts) are disseminated in a dissemination file having data stream indicator 'Y'. Data stream indicator for the ENS Weather Parameter products in dissemination file names is 'B'. Ensemble Forecast Overlap (EFOV) products are disseminated using data stream indicator letter 'O'.

ENS products are prepared separately from other dissemination products. Control and perturbed forecast products are transmitted together as one file per a time step. All derived ENS data products (other then control and perturbed forecast) are disseminated in two dissemination files. One file, valid at D+10 contains products for all time step ranges T+0 to T+240 and the other file, valid at D+15 contains products for all time step ranges from T+246 to T+360. Availability of ENS products is shown in the table below. Forecast time steps not listed in the table are disseminated at regular intervals between the times shown. Default transmission priority for ENS products is set to 40.

| 12 UTC based Forecast time | Time Available | 00 UTC based Forecast time | Time Available |
|---|---|---|---|

Table 5.13 Dissemination schedule for the ENS products

| | | | |
|---|---|---|---|
| Forecast Step 0 | 19:40 | Forecast Step 0 | 7:40 |
| Forecast Day 10 | 20:20 | Forecast Day 10 | 8:20 |
| Forecast Day 15 | 20:40 | Forecast Day 15 | 8:40 |
| Derived products 0 to D+10 | 20:21 | Derived products to Day 10 | 8:21 |
| Derived products D+11-D+15 | 20:40 | Derived products D+11-D+15 | 8:40 |

Table 5.13 Dissemination schedule for the ENS products

Table 5.14 defines transmission schedule for the ENS Weather Parameter products in BUFR:

| ENS Weather Parameter products | Time Available |
|---|---|
| 12 UTC based to Day 10 | 20:20 |
| 12 UTC based to Day 15 | 20:40 |
| 00 UTC based to Day 10 | 8:20 |
| 00 UTC based to Day 15 | 8:40 |

Table 5.14 Dissemination schedule for the ENS Weather Parameter Products

Table 5.15 defines transmission schedule for the ENS Tropical Cyclone trajectory forecast products in BUFR:

| ENS Tropical Cyclone products | Time Available |
|---|---|
| 12 UTC based | 20:21 |
| 00 UTC based | 8:21 |

Table 5.15 Dissemination schedule for the ENS Tropical Cyclone trajectory forecast products

Table 5.16 defines transmission schedule for the Ensemble Forecast Overlap products

| EFOV products | Time Available |
|---|---|
| 12 UTC based | 20:21 |
| 00 UTC based | 8:21 |

Table 5.16 Dissemination schedule for the EFOV forecast products

# 5. Prediction of Ocean Waves

## 5.1 Introduction

An ECMWF Project for the Prediction of Ocean Waves was established (initially as the optional project) with the agreement of the 34th session of the ECMWF Council. Routine operational production of wave model analysis and forecasts for the global and Mediterranean areas started in July 1992. Initially a global model with a 3 degree grid was run to 10 days, and a Mediterranean model with 0.5 degree grid was run to 5 days. In July 1994. the resolution of the global wave model was increased to 1.5 degrees. In March 1995, two-dimensional wave spectra field was added to the set of fields available from the Project. In June 1998, coupled atmospheric/wave forecasting system was introduced into ECMWF operations. The resolution of the global wave model was increased to 0.5 degrees. In September 2005, the resolution of the global wave model was increased to 0.36 degrees (0.25 degrees in dissemination). In January 2010 the global wave model was increased to 0.25 degrees maintaining the same resolution for dissemination.

The change from the Mediterranean model to the new Mediterranean/Baltic model took place in June 1995 when the area covered was increased. In December 1996, the high resolution shallow water version of the global wave forecast model was introduced into ECMWF operations.

At the end of June 1998, the global wave model was dynamically coupled to the atmospheric model. Winds are passed to the wave model every coupling time step and updated information on the sea surface roughness is passed back to the atmospheric model. The products from the wave global model were the same as before, except that the GRIB format of the 2-D spectra had changed. They were archived as global fields, one per frequency and direction. The corresponding GRIB parameter was therefore changed to differentiate this new format from the old one. The analysed global spectral fields were also made available every 6 hours. 12 directions and 25 frequencies were used. Following the coupling of the high resolution forecast model with the wave model, the ensemble forecasting system was also upgraded to run with the coupled wave model. In that configuration, the wave model grid resolution was 0.5 by 0.5 degree and only the deep water physics option was used. Wave probabilistic forecasts were therefore possible. In September 2005, horizontal resolution was increased to 0.25 degrees

The Mediterranean model was modified at the end of October 1998 to cover an area that extends from the Gulf of Mexico to the Black Sea $81^0$ North/$98^0$ West/$9^0$ North/$42^0$ East and has a resolution of 0.25 by 0.25 degrees. The spatial grid was changed to a quasi-regular grid with an horizontal grid spacing of the order of 28 km. The spectral

resolution and the forecast length were kept the same as previously. Note that this new model is still referred to as the Mediterranean model when requesting the GRIB data.

In the autumn of 2000, the global wave model spectral resolution was increased to 24 directions and 30 frequencies. The frequency range is such that 2 new frequency bins are added to the low frequency part of the spectrum and 3 new bins to the high frequency limit. In March 2009 the domain of the wave model was extended from 81 degrees North to 90 degrees North.
In January 2010, the wave model spectral resolution was increased to 36 directions and 36 frequencies. The Mediterranean wave model resolution increased to 0.125 by 0.125 degrees.

## 5.2 Dissemination products

The dissemination supports products which can be represented as fields of values of single parameters over a defined area. The data are represented in FM 92 GRIB code, and the optional bitmap section of GRIB is used to designate the land-sea mask, indicating which points are present and which are missing with respect to the total area.

Data are also available in the form of rectangular “hollow boxes” to provide boundary conditions for limited area models. Such products take the form of a strip of points around the boundary of a rectangular area; the width of the strip is specified as a number of points from the boundary. Where such points are land points, they are omitted. The bitmap section of such products indicates which values are present and which are missing with respect to the total area. Member States may also specify bitmaps of required points. These are modified according to the land-sea mask to generate products containing data restricted to the points requested, provided that such points are indeed sea points. Again, the resulting GRIB products will be accompanied by bitmap sections indicating which points contain data with respect to the total area.

Data are available at any multiple of the basic grid of the generating model and for any user-defined sub-area.

A new GRIB ECMWF local Code Table 2, version 140 is used for wave model data. The parameters supported are listed in the Table 6.1 below.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/VAL. |
|---|---|---|---|---|
| 215 | UST | U-component stokes drift | m**s-1 | 16 |
| 216 | VST | V-component stokes drift | m**s-1 | 16 |

Table 6.1 (ECMWF GRIB Code table 2, version 140)

| | | | | |
|---|---|---|---|---|
| 217 | TMAX | Period corresponding to maximum individual wave height | s | 16 |
| 218 | HMAX | Maximum individual wave height | m | 16 |
| 219 | WMB | Model bathymetry | m | 16 |
| 220 | MP1 | Mean wave period based on first moment | s | 16 |
| 221 | MP2 | Mean wave period based on second moment | s | 16 |
| 222 | WDW | Wave spectral directional width | - | 16 |
| 223 | P1WW | Mean wave period based on first moment for wind waves | s | 16 |
| 224 | P2WW | Mean wave period based on second moment for wind waves | s | 16 |
| 225 | DWWW | Wave spectral directional width for wind waves | - | 16 |
| 226 | P1PS | Mean wave period based on first moment for swell | s | 16 |
| 227 | P2PS | Mean wave period based on second moment for swell | s | 16 |
| 228 | DWPS | Wave spectral directional width for swell | - | 16 |
| 229 | SWH | Significant wave height | m | 16 |
| 230 | MWD | Mean wave direction | degree | 16 |
| 231 | PP1D | Peak period 1D-spectra | s | 16 |
| 232 | MWP | Mean wave period | s | 16 |
| 233 | CDWW | Coefficient of drag with waves Significant | - | 16 |
| 234 | SHWW | Height of wind waves | m | 16 |
| 235 | MDWW | Mean direction of wind waves | degree | 16 |
| 236 | MPWW | Mean period of wind waves | s | 16 |
| 237 | SHTS | Significant height of total swell | m | 16 |
| 238 | MDTS | Mean direction of total swell | degree | 16 |
| 239 | MPTS | Mean period of total swell | s | 16 |
| 244 | MSQS | Mean Square Slope | - | 16 |
| 245 | WIND | 10 Meter Wind Speed | m/s | 16 |
| 246 | AWH | Altimeter wave height | m | 16 |
| 247 | ACWH | Altimeter corrected wave height | m | 16 |
| 248 | ARRC | Altimeter range relative correction | - | 16 |
| 251 | 2DFD | 2 Dimensional spectra | m2srad-1 | 16 |
| 252 | WSK | Wave spectral kurtosis | - | 16 |
| 253 | BFI | Benjamin-Feir index | - | 16 |
| 254 | WSP | Wave spectral peakedness | s**-1 | 16 |

Table 6.1 (ECMWF GRIB Code table 2, version 140)

The two-dimensional wave spectra field is available with the same combinations of resolution, sub-area, box boundaries, and bit-map selected points as for other wave data.

### 5.2.1 Global Wave Model products

Parameters available in dissemination are listed in the Table 6.1.

- Horizontal resolution
  - 0.25 x 0.25 degrees latitude-longitude grid, or multiples thereof
  - any sub-area

- Verifying times
  - T+0 to T+120 at 1 hour interval
  - T+123 to T+144 at 3 hour interval
  - T+150 to T+240 at 6 hour interval

The two-dimensional wave spectra field is available for 36 frequencies starting at 0.0345 Hz with 10% increments, and for 36 directions with 10 degree separation, at each point, where the first direction starts at 5 degrees (all information about the spectral discretisation is available in the grid headers)

### 5.2.2 Mediterranean/Baltic Wave Model products

Mediterranean/Baltic wave forecast model covers the area $90^0$ North/$98^0$ West/$5^0$ North/$54^0$ East. The part of the land-sea mask used by the model is plotted on the Figure 1.3. Parameters available in dissemination are listed in the Table 6.1.

- Horizontal resolution

  - 0.125 x 0.125 degrees latitude-longitude grid, or multiples thereof
  - any sub-area

- Verifying times

  - T+0 to T+120 at 1 hour interval

The two-dimensional wave spectra field is available for 36 frequencies starting at 0.04177 Hz with 10% increments, and for 36 directions with 10 degree separation, at each point, where the first direction starts at 5 degrees (all information about the spectral discretisation is available in the grid headers)

## 5.3 Dissemination requirements

The dissemination of Ocean Waves Prediction products is controlled in a similar manner as the dissemination of data from ECMWF's medium-range forecasting system. Dissemination requirements for Ocean Waves Prediction products are added to the general set of dissemination requirements for each Member State - it is not necessary to update and maintain separate sets of requirements for products required from this optional project.

The rules for requesting dissemination products from ECMWF apply also to Ocean Waves Prediction products. Member States can maintain their own dissemination requirements using web facility (https://msaccess.ecmwf.int:9443/do/product/requirements/); they also may request ECMWF to make changes on their behalf. Requests for ECMWF to make changes to dissemination requirements should be addressed in writing or by computer e-mail from the Member State's TAC representative to the Director of Operations at ECMWF, or to the Head of the “Meteorological Application Section”, who is authorised by the Director of Operations to act on his behalf with respect to such changes. Dissemination requirements are presented by mean of command language. This language has been designed to conform, where possible, to the MARS command language.

### Identification parameters

| | | | | |
|---|---|---|---|---|
| STREAM | = | WAVE | [WV] | |
| DOMAIN | = | GLOBAL | [G] | (default) |
| | | MEDITERRANEAN | [M] | |
| TYPE | = | ANALYSIS | [AN] | |
| | | FORECAST | [FC] | |
| LEVTYPE | = | SURFACE | [SFC] | |
| LEVELIST | = | OFF | | |

## Target parameters

TARGET = "destination:dissemination_stream_name"
- destination is a three character destination name;
- dissemination_stream_name is a two character dissemination stream name
(the list of destinations/streams is published on:
**https://msaccess.ecmwf.int:9443/do/product/requirements/)**

PRIORITY = 1 - 99
Indicates the transmission priority of a 'dissemination stream'.
(value 1 being the highest and value 99 being the lowest transmission priority);

## Date and time parameters

TIME = * (hours)
Gives analysis 12, 18, 00, 06 or forecast base time 12, 00.

STEP = * (hours) default is 00

Gives forecast and analysis time step(s);.
For analysis value is 00.

Global model: 0/to/120/by/1, 123/to/144/by/3 and 150/to/240/by/6

European (Mediterranean/Baltic) model: 0/to/120/by/1

## Meteorological parameters

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in Table 6.1.

## Data processing parameters

RESOL = ARCHIVED VALUE [AV]

FORMAT = GRIB [GB]

GAUSSIAN = OFF

GRID = a/b
AUTOMATIC [AUTO]

a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

Global model: 0.25/0.25 or multiples thereof

Mediterranean/European model: 0.125/0.125 or multiples thereof

AUTOMATIC - values for the parameter GRID will be defined automatically based on DOMAIN parameter values;

AREA = */*/*/*

Output area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East;

Negative values indicate western longitudes and southern latitudes.

FRAME = OFF to switch off the frame option
n

n is the number of points inward from each edge of defined area required to form a boundary product. The resulting FM 92 GRIB code will contain bits set within the appropriateate flag to indicate that sections 2 and 3 are both present.

BITMAP = OFF to switch off the bitmap option
“filename”

“filename” is the name of a file containing a valid user-defined bitmap specification to build a product by selecting data from points of a latitude-longitude or a Gaussian grid.

| | | | | |
|---|---|---|---|---|
| ACCURACY | = | NORMAL | [N] | (default) - GRIB only |
| | | ARCHIVED VALUE | [AV] | |
| | | n | | |

n is the number of bits per packed value. n must not be less than half of default value nor greater then 24.
[N] - Default values are listed in the Table 4.2
[AV] - Resulting field will have accuracy of the originally generated and archived field.

| | | | | |
|---|---|---|---|---|
| PACKING | = | ARCHIVED VALUE | [AV] | (default) |
| | | SIMPLE | [SIM] | |
| | | SECOND ORDER | [SO] | |

AV - GRIB packing as currently in use, at the moment SIMPLE for grid point data.
SIM - simple packing;
SO - grid point data only (substantiality reduces the size of GRIB messages);

| | | | | |
|---|---|---|---|---|
| PADDING | = | AUTOMATIC | [AUTO | as currently in use (default); |
| | | NONE | ] | no padding; |
| | | n | [N] | |

n is the number of bytes to which multiple the binary message is padded to with NULL bytes;

The meaning of AUTO is at the moment 120 bytes for GRIB data and 8 bytes for BUFR data. Also, these are the only values supported for n at the moment.

| | | | |
|---|---|---|---|
| OPTIONS | = | NORMAL | [NORM] (default) |
| | | DELAY | [DELA] |

Note:
DELAY causes products to be generated, but not transmitted;
DELAY products can be obtained using the repeat facility.

## 5.4 Transmission of Products

Each day the global wave model is run first, followed as soon as possible by the Mediterranean model. Products are prepared separately from each model, and are transmitted as one file per timestep per model. The dissemination filename convention used for wave data is described in the Section Transmission of Products.

Availability of Global Wave Model data is shown in the table below. Forecast time steps not listed in the table are disseminated at regular intervals between the times shown.

| Analysis 06/12 - 12 UTC based Forecast time | Time Available | Analysis 18/00 - 00 UTC based Forecast time | Time Available |
|---|---|---|---|
| Analysis 06:00 | 17:35 | Analysis 18:00 | 5:35 |
| Analysis 12:00 | 17:40 | Analysis 00:00 | 5:40 |
| Forecast Day 1 | 17:52 | Forecast Day 1 | 5:52 |
| Forecast Day 10 | 18:55 | Forecast Day 10 | 6:55 |

Availability of the European Wave Model data is shown in the table below. Forecast time steps not listed in the table are disseminated at regular intervals between the times shown.

| Analysis 06/12 - 12 UTC based Forecast time | Time Available | Analysis 18/00 - 00 UTC based Forecast time | Time Available |
|---|---|---|---|
| Analysis 06:00 | 19:20 | Analysis 18:00 | 7:20 |
| Analysis 12:00 | 19:21 | Analysis 00:00 | 7:21 |
| Forecast Day 1 | 19:23 | Forecast Day 1 | 7:23 |
| Forecast Day 5 | 19:35 | Forecast Day 5 | 7:35 |

If operations are running late, files are transmitted as produced. Operational production of the Centre's medium range forecast has higher priority than the Wave project, thus, if there should be a severe outage, it may be necessary to omit the Wave project forecasts in order to ensure delivery of the subsequent medium-range products.

Default transmission priority for the global wave model products is 30. Corresponding transmission priority value for the European Model data is 60.

# 6. Wave Ensemble Forecast

## 6.1 Introduction

In June 1998, when the ECMWF atmospheric model was coupled to the wave model, the daily wave ensemble forecast become an operational product. Alongside the high resolution forecast of wave fields on a 0.5 degrees irregular grid, a control forecast and 50 ensemble forecasts were produced daily on a regular 1.5 degrees grid. The fifty members of the ensemble are generated by perturbing the initial atmospheric conditions by means of the most unstable singular vectors. The initial wave fields are not perturbed, however. In November 2000. model grid was changed to quasi-regular 1.0 degree latitude/longitude grid. Since September 2005, alongside the high resolution forecast of wave fields on a 0.25 degrees irregular grid, a control forecast and 50 ensemble forecasts are produced daily on a regular 1.0 degrees grid. Also, in September 2005, the ENS global wave model spectral resolution was increased to 24 directions and 30 frequencies.

In November 2006 ECMWF upgraded its Ensemble Forecast (ENS). In particular, the forecast range was extended to 15 days using the ENS with a resolution of T399 L62 for day 1 to day 10 (leg 1) and T255 L62 for T+246 to day 15 (leg 2). ENS also included two other constant-resolution forecasts for calibration and validation purposes ran one at T399 L62 and the other at T255 L62 for the full forecast time range day 1 to day 15. The horizontal grid resolution of wave fields was 100Km.

In January 2010 the Ensemble Wave forecasts was upgraded to a resolution of 0.5 degrees. The horizontal grid resolution of wave fields is approximately 55Km.

## 6.2 Dissemination products

The dissemination supports products which can be represented as fields of values of single parameters over a defined area. The data are represented in FM 92 GRIB code, and the optional bitmap section of GRIB is used to designate the land-sea mask, indicating which points are present and which are missing with respect to the total area. Also, data is available in the form of rectangular “hollow boxes” to provide boundary conditions for limited area models.Member States may also specify bitmaps of required points.

Data are available at any multiple of the basic grid of the generating model and for any user defined sub-area.

A number of products are available in the field form. Products can be grouped into the following categories:

- Control, perturbed and calibration/validation forecast products
- Event probability products

## 6.3 Dissemination requirements

The dissemination of Wave ENS products is controlled in a similar manner as the dissemination of data from ECMWF's medium-range forecasting system. Dissemination requirements for Wave ENS products are added to the general set of dissemination requirements for each Member State.

The rules for requesting dissemination products from ECMWF apply also to Wave ENS products. Member States can maintain their own dissemination requirements using web facility (https://msaccess.ecmwf.int:9443/do/product/requirements/); Also Member States may request ECMWF to make changes on their behalf. Requests for ECMWF to make changes to requirements should be addressed in writing or by computer mail from the Member State's TAC representative to the Director of Operations at ECMWF, or to the Head of the “Meteorological Application Section”, who is authorised by the Director of Operations to act on his behalf with respect to such changes.

Dissemination requirements are presented by mean of command language. Dissemination language parameters are identical to those of MARS command language.

### Identification parameters

| | | | |
|---|---|---|---|
| STREAM | = | WAVE ENSEMBLE FORECAST | [WE] |
| DOMAIN | = | GLOBAL | [G] |
| TYPE | = | CONTROL FORECAST | [CF] |
| | | PERTURBED FORECAST | [PF] |
| | | CAVLIBRATION VALIDATION | [CV] |
| | | EVENT PROBABILITY | [EP] |

LEVTYPE = SURFACE [SFC]

LEVELIST = OFF

## Target parameters

TARGET = "destination:dissemination_stream_name"
- destination is a three character destination name;
- dissemination_stream_name is a two character dissemination stream name
(the list of destinations/streams is published on:
**https://msaccess.ecmwf.int:9443/do/product/requirements/)**

PRIORITY = 1 - 99
Indicates the transmission priority of a 'dissemination stream'.
(value 1 being the highest and value 99 being the lowest transmission priority);

## Date and time parameters

TIME = 12/00
Gives forecast base time;

STEP = * (hours)

Gives forecast time step(s);.

(specific for each data type - see below);

## Meteorological parameters

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in Table 7.1.

## Data processing parameters

RESOL = ARCHIVED VALUE [AV]

FORMAT = GRIB [GB]

GAUSSIAN = OFF

GRID = a/b
AUTOMATIC [AUTO]

a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.5/0.5 or multiples thereof;

AUTOMATIC - values for the parameter GRID will be defined automatically

AREA = */*/*/*

Output area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East;

Negative values indicate western longitudes and southern latitudes.

FRAME = OFF to switch off the frame option
n

n is the number of points inward from each edge of defined area required to form a boundary product. The resulting FM 92 GRIB code will contain bits set within the appropriateate flag to indicate that sections 2 and 3 are both present.

BITMAP = OFF to switch off the bitmap option
"filename"

"filename" is the name of a file containing a valid user-defined bitmap specification to build a product by selecting data from points of a latitude-longitude or a Gaussian grid.

ACCURACY = NORMAL [N] (default) - GRIB only
ARCHIVED VALUE [AV]
n

n is the number of bits per packed value. n must not be less than half of default value nor greater then 24.
[N] - Default values are listed in the Table 4.2
[AV] - Resulting field will have accuracy of the originally generated and archived field.

| | | | | |
|---|---|---|---|---|
| PACKING | = | ARCHIVED VALUE | [AV] | (default) |
| | | SIMPLE | [SIM] | |
| | | SECOND ORDER | [SO] | |

AV - GRIB packing as currently in use, at the moment SIMPLE for grid point data.
SIM - simple packing;
SO - grid point data only (substantiality reduces the size of GRIB messages);

| | | | | |
|---|---|---|---|---|
| PADDING | = | AUTOMATIC | [AUTO] | as currently in use (default); |
| | | NONE | | no padding; |
| | | n | [N] | |

n is the number of bytes to which multiple the binary message is padded to with NULL bytes;

The meaning of AUTO is at the moment 120 bytes for GRIB data and 8 bytes for BUFR data. Also, these are the only values supported for n at the moment.

| | | | |
|---|---|---|---|
| OPTIONS | = | NORMAL | [NORM] (default) |
| | | DELAY | [DELA] |

Note:
DELAY causes products to be generated, but not transmitted;
DELAY products can be obtained using the repeat facility.

## 6.4 Control, Perturbed and Calibration/Validation forecast products

A number of parameters are available for every member of the ensemble and the control forecasts. A GRIB ECMWF local Code Table 2, version 140 is used for wave ENS data. The parameters supported are listed in the Table below.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/VAL. |
|---|---|---|---|---|
| 211 | PHIAW | Normalized energy flux into waves | - | 16 |
| 212 | PHIOC | Normalized energy flux into ocean | - | 16 |
| 214 | TAUOC | Normalized stress into ocean | - | 16 |
| 215 | UST | U-component stokes drift | m**s-1 | 16 |
| 216 | VST | V-component stokes drift | m**s-1 | 16 |

Table 7.1 WAVE ENS Parameters

| | | | | |
|---|---|---|---|---|
| 217 | TMAX | Period corresponding to maximum individual wave heights | s | 16 |
| 218 | HMAX | Maximum individual wave height | m | 16 |
| 219 | WMB | Model bathymetrym | m | 16 |
| 220 | MP1 | Mean wave period based on first moment | s | 16 |
| 221 | MP2 | Mean wave period based on second moment | s | 16 |
| 222 | WDW | Wave spectral directional width | - | 16 |
| 223 | P1WW | Mean wave period based on first moment for wind waves | s | 16 |
| 224 | P2WW | Mean wave period based on second moment for wind waves | s | 16 |
| 225 | DWWW | Wave spectral directional width for wind waves | - | 16 |
| 226 | P1PS | Mean wave period based on first moment for swell | s | 16 |
| 227 | P2PS | Mean wave period based on second moment for swell | s | 16 |
| 228 | DWPS | Wave spectral directional width for swell | - | 16 |
| 229 | SWH | Significant wave height | m | 16 |
| 230 | MWD | Mean wave direction | degree | 16 |
| 231 | PP1D | Peak period 1D-spectra | s | 16 |
| 232 | MWP | Mean wave period | s | 16 |
| 233 | CDWW | Coefficient of drag with waves Significant | - | 16 |
| 234 | SHWW | Height of wind waves | m | 16 |
| 235 | MDWW | Mean direction of wind waves | degree | 16 |
| 236 | MPWW | Mean period of wind waves | s | 16 |
| 237 | SHTS | Significant height of total swell | m | 16 |
| 238 | MDTS | Mean direction of total swell | degree | 16 |
| 239 | MPTS | Mean period of total swell | s | 16 |
| 244 | MSQS | Mean Square Slope | - | 16 |
| 245 | WIND | 10 Meter Wind Speed | m/s | 16 |
| 249 | DWI | 10 metre wind direction | degree | 16 |
| 252 | WSK | Wave spectral kurtosis | - | 16 |
| 253 | BFI | Benjamin-Feir index | - | 16 |
| 254 | WSP | Wave spectral peakedness | s**-1 | 16 |
| 132216 | MAXSWHI | Maximum of significant wave height index | (-1 to 1) | 12 |

Table 7.1 WAVE ENS Parameters

The two-dimensional wave spectra field is not available as Wave ENS parameter.

- Horizontal resolution

  - 0.5 x 0.5 degrees latitude-longitude grid, or multiples thereof
  - any sub-area

- Verifying times

  - T+0 to T+144 at 3 hour intervals and T+150 to T+360 at 6 hour intervals;

### 6.4.1 Control, Perturbed and Calibration/Validation forecast requirements

The following command language parameters are specific for the control and perturbed forecast requirements. Other DIS parameters are listed under the 7.3 above.

| | | | | |
|---|---|---|---|---|
| TYPE | = | CONTROL FORECAST | [CF] | |
| | | PERTURBED FORECAST | [PF] | |
| | | CALIBRATION VALIDATION | [CV] | |
| NUMBER | = | n-ENSEMBLE NUMBER | [1-50] | (for TYPE=PF) |
| | | | off | (for TYPE=CF) |
| | | | [1-2] | (for TYPE=CV) |
| STEP | = | * (hours)<br>gives forecast time step(s);<br><br>0/to/144/by 3 and 144/to/360/by/6<br>NB ALL is not permitted. | | |
| PARAM | = | Field name abbreviation<br>*<br>NB ALL is not permitted.<br>Available parameters are listed in the Table 7.1. | | |

## 6.5 Event Probability products

Event probability products provide the probabilities of the occurrence of weather events at each grid point. The probabilities are calculated on the basis that each ensemble member is equally likely. Probability fields for wave height (with thresholds of 2,4,6,8 m) and mean period (with thresholds of 8,10,12,15 seconds) are defined in the ECMWF local table 2 version 131 (Event probabilities) and are as in Table 7.2:

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 74 | SWHG2 | Significant wave height of at least 2 m | % | 8 |
| 75 | SWHG4 | Significant wave height of at least 4 m | % | 8 |
| 76 | SWHG6 | Significant wave height of at least 6 m | % | 8 |
| 77 | SWHG8 | Significant wave height of at least 8 m | % | 8 |
| 78 | MWPG8 | Mean wave period of at least 8 s | % | 8 |
| 79 | MWPG10 | Mean wave period of at least 10 s | % | 8 |
| 80 | MWPG12 | Mean wave period of at least 12 s | % | 8 |
| 81 | MWPG15 | Mean wave period of at least 15 s | % | 8 |

Table 7.2 Wave ENS Event Probability Products

(ECMWF Local Code Table 2, parameter table, Version Number 131)

### 6.5.1 Event Probability requirements

The following command language parameters are specific for the event probability requirements. Other DIS parameters are listed under the 7.2 above.

TYPE = EVENT PROBABILITY [EP]

NUMBER = OFF

STEP = * (hours)

12/to/360/by/12 and
120-168,168-240,120-240 and 240-360

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in the Table 7.2.

## 6.6 Transmission of Products

Each day the operational medium-range forecast runs first, followed as soon as possible by the ENS.

The dissemination filename convention used for the transmission of Wave ENS products is described in **Section Transmission of Products**. Data stream indicator for the wave ensemble control and perturbed forecast products in dissemination file names is ‘W’. Products, other then control and perturbed wave ensemble forecasts are

disseminated in a dissemination file having data stream indicator 'U'.

Wave ENS products are prepared separately from other dissemination products. Control and perturbed forecast products are transmitted together as one file per a time step. All derived Wave ENS data products (other then control and perturbed forecast) are disseminated in two dissemination files. One file, valid at D+10 contains products for all time step ranges T+0 to T+240 and the other file, valid at D+15 contains products for all time step ranges from T+246 to T+360. Availability of Wave ENS products is shown in the table below. Forecast time steps not listed in the table are disseminated at regular intervals between the times shown.

| 12 UTC based Forecast time | Time Available | 00 UTC based Forecast time | Time Available |
|---|---|---|---|
| Forecast Step 0 | 19:40 | Forecast Step 0 | 7:40 |
| Forecast Day 10 | 20:20 | Forecast Day 10 | 8:20 |
| Forecast Day 15 | 20:40 | Forecast Day 15 | 8:40 |
| Derived products 0 to D+10 | 20:21 | Derived products to Day 10 | 8:21 |
| Derived products D+11-D+15 | 20:41 | Derived products D+11-D+15 | 8:41 |

Default transmission priority for Wave ENS products is 50.

# 7. Boundary Condition Optional Project

## 7.1 Introduction

At its 50th session (June 1999), the ECMWF Council approved the implementation of the Boundary Condition Optional Project (BC). The Boundary Conditions Suite was set up in June 2000. It was set up as a separate operational suite to limit the impact on the core ECMWF activities. A data cut-off time of 4 hours was used and 3D-Var analysis and forecasts ran to 90 hours at 00, 06, 12 and 18 UTC , with 3-hourly post-processing.

Dissemination of BC products is to a schedule as defined below. If there are problems for cycles 06 and 18 UTC based and dissemination data are not available six and a half hours after analysis base time, that cycle will be abondoned.

Since the 14. March 2006 Boundary Condition project has been merged with the main high resolution operational forecast suite. In the new configuration, only the 06 and 18 UTC runs are part of the BC suite. For the 00 and 12 UTC runs data are provided from the main high resolution forecast suite. This new configuration has incorporated the following changes:

- All four data assimilation cycles are based on 4D-Var, combining the boundary value forecasts with ECMWF core forecast runs for 00 and 12 UTC, and replacing the 3D-Var (FGAT) analysis cycles for 06 and 18 UTC;

- The data for 00 and 12 UTC are sent with STREAM DA instead of SCDA in the GRIB description; 06 and 18 UTC data have continued to be sent with stream SCDA in the GRIB description.

Even though the input data come from different data streams, DA and SCDA, ECMWF has continued to provide users of BC data with separate dissemination files for all four cycles 00, 06 12 and 18 UTC. Data from the 00 and 12 UTC runs requested for the BC project (specifying USE=BC in the requirements, see bellow) have continued to be delivered in dissemination files with the data stream id ’S’.

## 7.2 Dissemination products

Dissemination products are available only up to 90 hours.
Full fields for both analysis and forecast data are allowed in the dissemination system.

### 7.2.1 Verifying times available

- analysis at 18, 00, 06 and 12 UTC
- forecasts at **1 hourly** intervals from 1 to 90 hours, based on each analysis cycle

### 7.2.2 Parameters

Parameters available out of the BC Project are the same as for the main high resolution forecast (STREAM=DA).

### 7.2.3 Horizontal resolution and domain

- 0.125 x 0.125 degrees latitude-longitude grid, or multiples thereof
- any spectral truncation
- the Gaussian grid appropriate to the forecast model in use
- any sub-area

### 7.2.4 Vertical resolution

Upper air parameters are available as follows:

- pressure levels: 1000, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2, 1 hPa
- model levels: currently 91 hybrid coordinate level

## 7.3 Dissemination requirements

Dissemination requirements are presented by means of the command language. Dissemination language parameters are identical to those of MARS. Key words not listed here are as defined for main high resolution forecast.

In dissemination, for requirements requesting BC data for 00 and 12 UTC a new keyword USE=BC has been

added since 14. March 2006 to distinguish between standard dissemination for stream DA and data for the Boundary Condition Project. If BC requirements are mixed with other data streams users will have to remember to set key word USE=OFF.

## Identification parameters

| | | | |
|---|---|---|---|
| STREAM | = | SHORT CUTOFF DAILY ARCHIVE | [SCDA] |
| DOMAIN | = | GLOBAL | [G] |
| TYPE | = | ANALYSIS | [AN] |
| | | FORECAST | [FC] |
| USE | = | OFF<br>BC To indicate that DA stream products will be generated and disseminated as SCDA products - valid only for STREAM=DA,TIME=00/12 | |

## Date and time parameters

TIME = * (hours)
Gives analysis or forecast base time **12, 18, 00, 06**.

STEP = * (hours) default is 00

For TYPE=FC [STEP=1/to/90/by/1]
Gives forecast and analysis time step(s);.
For analysis value is 00.
NB ALL, is not permitted.

## Meteorological parameters

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are as listed for STREAM=DA (main high resolution forecast)

## Data processing parameters

RESOL = * [AV] (default 1279)

Positive integer giving the spectral triangular truncation.
(e.g. 10 indicates T10 filtered products required. May only be used with multi-level (i.e. upper air) parameters. May also be used if spectral products are required.)

FORMAT = GRIB [GB] For NON TYPE=ML products
GRIB2 [GB2] For TYPE=ML products

GAUSSIAN = REGULAR
REDUCED
OFF

Indicating Gaussian grid type. Gaussian grid resolution is given by the GRID parameter.

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

Both a and b must be 0.125 degrees, or multiples thereof, for latitude

longitude grids.

Note that it is possible to specify different values for a and b to generate a quasi-regular grid system with a different resolution in the West-East direction from that in the North-South direction. This feature is only valid for latitude-longitude grid.

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported: 640, 400, 256, 200, 160, 128, 80, 48 and 32.

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

AREA = */*/*/*

Output area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East;

Negative values indicate western longitudes and southern latitudes.

ROTATION = OFF to switch off rotation (default)
a/b

a = is the latitude of the southern pole of rotation
b = is the longitude of the southern pole of rotation

FRAME = OFF to switch off the frame option
n

n is the number of points inward from each edge of defined area required to form a boundary product. The resulting FM 92 GRIB code will contain bits set within the appropriateate flag to indicate that sections 2 and 3 are both present.

BITMAP = OFF to switch off the bitmap option
"filename"

"filename" is the name of a file containing a valid user-defined bitmap specification to build a product by selecting data from points of a latitude-longitude or a Gaussian grid.

| | | | | |
|---|---|---|---|---|
| ACCURACY | = | NORMAL | [N] | (default) - GRIB only |
| | | ARCHIVED VALUE | [AV] | |
| | | n | | |

n is the number of bits per packed value. n must not be less than half of default value nor greater then 24.
[N] - Default values are listed in the Table 4.2
[AV] - Resulting field will have accuracy of the originally generated and archived field.

| | | | | |
|---|---|---|---|---|
| PACKING | = | ARCHIVED VALUE | [AV] | (default) |
| | | SIMPLE | [SIM] | |
| | | SECOND ORDER | [SO] | |
| | | COMPLEX | [CO] | |

AV - GRIB packing as currently in use, at the moment SIMPLE for grid point data and COMPLEX for spherical harmonics data.
SIM - simple packing (both grid point and spherical harmonics data);
SO - grid point data only (substantiality reduces the size of GRIB messages);
CO - spherical harmonics data only;

| | | | | |
|---|---|---|---|---|
| PADDING | = | AUTOMATIC | [AUTO] | as currently in use (default); |
| | | NONE | [N] | no padding; |

The meaning of AUTO is at the moment 120 bytes for GRIB data and 8 bytes for BUFR data.

| | | | |
|---|---|---|---|
| OPTIONS | = | NORMAL | [NORM] (default) |
| | | DELAY | [DELA] |

Note:
DELAY causes products to be generated, but not transmitted;
DELAY products can be obtained using the repeat facility.

## 7.4 GRIB definitions

Dissemination products include the ECMWF local GRIB extensions so that Member States can differentiate between the forecast products by examining the stream number in the GRIB header. The 06 UTC and 18 UTC based forecasts have STREAM number set to 1026, whereas the 12 UTC and 00 UTC based forecasts have the number 1025 http://www.ecmwf.int/products/data/software/grib_api.html.

## 7.5 Transmission of Products

BC products are prepared separately from other ECMWF products and are transmitted as one file per timestep. Products are transmitted separately for each analysis/forecast cycle (four times a day). The dissemination filename convention used for the transmission of BC products is described in the Section **Transmission of Products**. Data stream indicator for the high resolution atmospheric model products in dissemination file names is '**S**'.

Availability of BC products is shown in the table below. Forecast time steps not listed in the table are disseminated at regular intervals between the times shown.

| Analysis Cycle | Analysis/Forecast time | Time Available |
|---|---|---|

| | | |
|---|---|---|
| 00:00 | Analysis | 05:40 |
| | Forecast Time Step 90 | 06:12 |
| 06:00 | Analysis | 11:40 |
| | Forecast Time Step 90 | 12:12 |
| 12:00 | Analysis | 17:40 |
| | Forecast Time Step 90 | 18:12 |
| 18:00 | Analysis | 23:40 |
| | Forecast Time Step 90 | 00:12 |

Default transmission priority for BC products is 70.

# 8. Seasonal Forecasting System 4

## 8.1 Introduction

The description of the System 4 can be found on **http://www.ecmwf.int/products/changes/system4/**

## 8.2 Seasonal forecast dissemination products

The dissemination supports products which can be represented as fields of values of a single parameter over a defined area. The data are represented in FM 92 GRIB code.

System 4 seasonal forecasts are run at TL255 resolution with 92 levels. Surface fields are post-processed every 6, 12 or 24 hours, depending on the field. Pressure level data are post-processed every 12 hours, and are only available on a limited set of pressure levels. No model level data are produced. Data are not produced at step 0, except for the land-sea mask and surface orography which are only produced at step 0. Each model integration runs for 215 days (5160 hours). An ensemble of 51 members is run (numbers 0 to 50) starting at 00 UTC on the 1st of each calendar month. Details of fields, levels and frequency of output are given below.

### 8.2.1 Pressure levels and surface products

- Horizontal resolution

  - 0.75 x 0.75 degrees latitude-longitude grid, or multiples thereof
  - any spectral truncation (default T255)
  - Gaussian grid (default N128) both regular and reduced
  - any sub-area

- Vertical resolution

  - pressure levels 1000, 925, 850, 700, 500, 400, 300, 200, 100, 50 and 10 hPa

- Verifying times

- T+0 to T+5160 (inclusive) at intervals dependent on a parameter

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 31 | CI | Sea Ice Cover + | m | 16 |
| 33 | RSN | Sea Dencity + | K | 16 |
| 34 | SSTK | Sea Surface Temperature + | K | 16 |
| 39 | SWVL1 | Volumetric Soil Water layer 1 + | m3m-3 | 12 |
| 40 | SWVL2 | Volumetric Soil Water layer 2 + | m3m-3 | 12 |
| 41 | SWVL3 | Volumetric Soil Water layer 3 + | m3m-3 | 12 |
| 42 | SWVL4 | Volumetric Soil Water layer 4 + | m3m-3 | 12 |
| 49 | 10FG | Wind gust at 10 meters ++ | m/s | 16 |
| 51 | MX2T24 | Max 2m Tem. since past 24H + | K | 12 |
| 52 | MN2T24 | Min 2m Tem. since past 24H + | K | 12 |
| 55 | MEAN2D24 | Mean 2m dewpoint since past 24H+ | K | 12 |
| 56 | MEAN2D24 | Mean 2m dewpoint since past 24H+ | K | 12 |
| 78 | TCLW | Total Column Liquid Water ** | kg m**-2 | 16 |
| 79 | TCIW | Total Column Ice Water ** | kg m**-2 | 16 |
| 129 | Z | Geopotential* | m2s-2 | 16 |
| 130 | T | Temperature ++ | K | 12 |
| 131 | U | U-velocity++ | m/s | 12 |
| 132 | V | V-velocity++ | m/s | 12 |
| 133 | Q | Specific humidity++ | kg/kg | 12 |
| 138 | VO | Vorticity++ | s-1 | 16 |
| 139 | STL1 | Soil Temperature Level 1 | K | 12 |
| 139 | ST | Surface temperature + | K | 12 |
| 141 | SD | Snow depth + | m | 12 |
| 142 | LSP | Large scale precipitation + | m | 16 |
| 143 | CP | Convective precipitation + | m | 16 |
| 144 | SF | Snow fall + | m | 16 |
| 146 | SSHF | Surface sensible heat flux + | Wm**-2s | 12 |
| 147 | SLHF | Surface latent heat flux + | Wm**-2s | 12 |
| 151 | MSL | Mean sea level pressure +++ | Pa | 12 |
| 155 | D | Divergence++ | s-1 | 16 |
| 164 | TCC | Total cloud cover +++ | (0-1) | 8 |
| 165 | 10U | 10 metre U +++ | m/s | 12 |
| 166 | 10V | 10 metre V +++ | m/s | 12 |
| 167 | 2T | 2 metre temperature +++ | K | 12 |
| 168 | 2D | 2 metre dewpoint temperature +++ | K | 12 |

* Orography field is defined as parameter Z on model level 1 and is available for STEP=0 only
+ Parameters available at 24 hour intervals
++ Parameters available at 12 hour intervals
+++ Parameters available at 6 hour intervals
** Only available for STREAM=SFMM/SMMA

Table 10.1 Seasonal Forecasting System products

| | | | | |
|---|---|---|---|---|
| 169 | SSRD | Surface solar radiat. downwards++ | W m**-2 s | 16 |
| 170 | STL2 | Soil Temperature Level 2 | K | 12 |
| 172 | LSM | Land/sea mask* | (0,1) | 8 |
| 175 | STRD | Surface thermal radi. downwards+ | W m**-2 s | 16 |
| 176 | SSR | Surface Solar Radiation + | W m**-2 s | 16 |
| 177 | STR | Surface Thermal Radiation + | W m**-2 s | 16 |
| 178 | TSR | Top Solar Radiation + | W m**-2 s | 16 |
| 179 | TTR | Top Thermal Radiation + | W m**-2 s | 16 |
| 180 | EWSS | U-stress + | Nm**-2 | 12 |
| 181 | NSSS | V-stress + | Nm**-2 | 12 |
| 182 | E | Evaporation + | m of water | 16 |
| 189 | SUND | Sunshine duration + | s | 16 |
| 201 | MX2T | Max. temp. at 2m since prev. post-processing + | K | 12 |
| 202 | MN2T | Min. temp. at 2m since prev. post-processing + | K | 12 |
| 228 | TP | Total precipitation + | m | 16 |
| 3 | PT | Potential Temperature ++ | K | 16 |
| 60 | PV | Potential Vorticity ++ | m2s-1Kkg-1 | 16 |
| 207 | 10SI | 10 metre scalar wind speed ** | m/s | 12 |

* Orography field is defined as parameter Z on model level 1 and is available for STEP=0 only
+ Parameters available at 24 hour intervals
++ Parameters available at 12 hour intervals
+++ Parameters available at 6 hour intervals
** Only available for STREAM=SFMM/SMMA

Table 10.1 Seasonal Forecasting System products

### 8.2.2 Potential temperature and potential vorticity levels

Potential Vorticity level products are available on the level 2000 as:

- parameter PT on 12 hour intervals;

Potential Temperature (Isentropic) level products are available as:

- parameter PV 12 hourly on levels 315 and 330;

## 8.3 Seasonal Forecasting System 4 dissemination requirements

The dissemination of Seasonal Forecasting System 4 products is controlled in a similar manner to the dissemination of data from ECMWF's medium-range forecasting system. Dissemination requirements for

seasonal products are added to the general set of dissemination requirements for each Member State - it is not necessary to update and maintain separate sets of requirements for products required from this project.

The rules for requesting dissemination products from ECMWF apply also to seasonal products. Member States can maintain their own dissemination requirements using the web facility (https://msaccess.ecmwf.int:9443/do/product/requirements/); Also Member States may request ECMWF to make changes on their behalf. Requests for ECMWF to make changes to requirements should be addressed in writing or by computer mail from the Member State's TAC representative to the Director of Operations at ECMWF, or to the Head of the "Meteorological Application Section", who is authorised by the Director of Operations to act on his behalf with respect to such changes.

Dissemination requirements are presented by means of the MARS command language.

## Identification parameters

| | | | | |
|---|---|---|---|---|
| STREAM | = | MULTI MODEL SEASONAL FORECAST | [MMSF] | |
| ORIGIN | = | ECMWF | [ECMWF]] | |
| DOMAIN | = | GLOBAL | [G] | |
| TYPE | = | FORECAST | [FC] | |
| SYSTEM | = | 4 | [4] | |
| METHOD | = | 1 | [1] | |
| NUMBER | = | n-ENSEMBLE NUMBER | [0-50] | (TYPE=FC) |
| LEVTYPE | = | SURFACE<br>PRESSURE LEVEL<br>POTENTIAL VORTICITY<br>POTENTIAL TEMPERATURE | [SFC]<br>[PL]<br>[PV]<br>[PT] | |
| LEVELIST | = | *<br>1000/925/850/700/500/400/300/200/100/50/10<br>NB ALL is not permitted;<br>(See 10.2.2 for LEVTYPE=PT/PV products); | | |

## Target parameters

TARGET = "destination:dissemination_stream_name"
- destination is a three character destination name;
- dissemination_stream_name is a two character dissemination stream name
(the list of destinations/streams is published on:
**https://msaccess.ecmwf.int:9443/do/product/requirements/)**

PRIORITY = 1 - 99
Indicates the transmission priority of a 'dissemination stream'.
(value 1 being the highest and value 99 being the lowest transmission priority);

## Date and time parameters

TIME = 00
Gives forecast base time.

STEP = * (hours)
6/to/5160/by/6 (+++ table 10.1)
12/to/5160/by/12 (++ table 10.1)
24/to/5160/by/24 (+ table 10.1)
Gives forecast time step(s);.
NB ALL, is not permitted.

## Meteorological parameters

PARAM = Field name abbreviation
*
NB ALL is not permitted.
Available parameters are listed in Table 10.1.

## Data processing parameters

RESOL = * [AV] (default 95)

Positive integer giving the spectral triangular truncation from which products are derived, e.g. 10 indicates T10 filtered products required. May only be used with multi-level (i.e. upper air) parameters. May also be used if spectral products are required.

FORMAT = GRIB [GB]

GAUSSIAN = REGULAR
REDUCED
OFF

Indicating Gaussian grid type. Gaussian grid resolution is given by the GRID parameter.

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

Both a and b must be 0.75 degrees, or multiples thereof, for latitude-longitude grids.

Note that it is possible to specify different values for a and b to generate a quasi-regular grid system with a different resolution in the West-East direction from that in the North-South direction. This feature is only valid for latitude-longitude grid.

128 may be coded to signify an N128 Gaussian grid.

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

AREA = */*/*/*

Output area definition. Four values (3 decimal places allowed) to provide a user-defined sub-area as North/West/South/East;

Negative values indicate western longitudes and southern latitudes.

ROTATION = OFF to switch off rotation (default)
a/b

a = is the latitude of the southern pole of rotation
b = is the longitude of the southern pole of rotation
Both a and b (positive or negative) must be 0.5 degrees, or multiples thereof.

FRAME = OFF to switch off the frame option
n

n is the number of points inward from each edge of defined area required to form a boundary product. The resulting FM 92 GRIB code will contain bits set within the appropriateate flag to indicate that sections 2 and 3 are both present.

BITMAP = OFF to switch off the bitmap option
"filename"

"filename" is the name of a file containing a valid user-defined bitmap specification to build a product by selecting data from points of a latitude-longitude or a Gaussian grid.

ACCURACY = NORMAL [N] (default) - GRIB only
ARCHIVED VALUE [AV]
n

n is the number of bits per packed value. n must not be less than half of default value nor greater then 24.
[N] - Default values are listed in the Table 4.2
[AV] - Resulting field will have accuracy of the originally generated and archived field.

PACKING = ARCHIVED VALUE [AV] (default)
SIMPLE [SIM]
SECOND ORDER [SO]
COMPLEX [CO]

AV - GRIB packing as currently in use, at the moment SIMPLE for grid point data and COMPLEX for spherical harmonics data.
SIM - simple packing (both grid point and spherical harmonics data);
SO - grid point data only (substantiality reduces the size of GRIB messages);
CO - spherical harmonics data only;

| | | | | |
|---|---|---|---|---|
| PADDING | = | AUTOMATIC | [AUTO | as currently in use (default); |
| | | NONE | ] | no padding; |
| | | n | [N] | |

n is the number of bytes to which multiple the binary message is padded to with NULL bytes;

The meaning of AUTO is at the moment 120 bytes for GRIB data and 8 bytes for BUFR data. Also, these are the only values supported for n at the moment.

| | | | |
|---|---|---|---|
| OPTIONS | = | NORMAL | [NORM] (default) |
| | | DELAY | [DELA] |

Note:
DELAY causes products to be generated, but not transmitted;
DELAY products can be obtained using the repeat facility.

## 8.4 Seasonal forecast monthly means and monthly mean anomaly dissemination products

In addition to the directly produced model output, the seasonal forecasting system produces a range of derived data which are also available for dissemination. Firstly, there are forecast monthly mean products (STREAM=MSMM). These are created for each field and each ensemble member, and are available for each of the 7 calendar months of the forecast integration. For most surface fields, monthly mean values, monthly maximum values (i.e., for each grid point the maximum value of the field output during the month), monthly minimum values and monthly standard deviations are created. All of these statistics are derived from the direct model output, i.e. the fields sampled every 6, 12 or 24 hours, and thus do not include variations on timesteps shorter than this.

As well as the monthly mean values of fields for each ensemble member (TYPE=FCMEAN), the ensemble mean (TYPE=EM) of each field is available, again for each of the 7 calendar months of the forecast.

The daily and monthly fields from the seasonal forecast model must be interpreted in the context of previous model forecasts, due to the substantial impact of model errors. If only forecast anomalies are wanted, then instead of processing the latest forecast output together
with the set of previous forecasts, it is possible to request pre-calculated monthly mean anomalies (STREAM=MMSA). These are anomalies with respect to the forecast model climate for 1987-2001, and are available as forecast monthly means for each of the 7 calendar months, both for the individual ensemble members and as an ensemble mean.

### 8.4.1 Products range

Available products are listed in the Table 10.2 bellow.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 31 | CI | Sea Ice Cover | m | 16 |
| 33 | RSN | Sea Dencity | K | 16 |
| 34 | SSTK | Sea Surface Temperature | K | 16 |
| 39 | SWVL1 | Volumetric Soil Water layer 1 | m3m-3 | 12 |
| 40 | SWVL2 | Volumetric Soil Water layer 2 | m3m-3 | 12 |
| 41 | SWVL3 | Volumetric Soil Water layer 3 | m3m-3 | 12 |
| 42 | SWVL4 | Volumetric Soil Water layer 4 | m3m-3 | 12 |
| 49 | 10FG | Wind gust at 10 meters | m/s | 16 |
| 51 | MX2T24 | Max 2m Tem. since past 24H | K | 12 |
| 52 | MN2T24 | Min 2m Tem. since past 24H | K | 12 |
| 78 | TCLW | Total Column Liquid Water | kg m**-2 | 16 |
| 79 | TCIW | Total Column Ice Water | kg m**-2 | 16 |
| 129 | Z | Geopotential | m2s-2 | 16 |
| 130 | T | Temperature | K | 12 |
| 131 | U | U-velocity | m/s | 12 |
| 132 | V | V-velocity | m/s | 12 |
| 133 | Q | Specific humidity | kg/kg | 12 |
| 137 | TCWV | Total column water vapour | kg m**-2 | 16 |
| 138 | VO | Vorticity | s-1 | 16 |
| 139 | STL1 | Soil Temperature Level 1 | K | 12 |
| 139 | ST | Surface temperature | K | 12 |
| 141 | SD | Snow depth | m | 12 |
| 142 | LSP | Large scale precipitation * | m | 16 |
| 143 | CP | Convective precipitation * | m | 16 |
| 144 | SF | Snow fall * | m | 16 |
| 146 | SSHF | Surface sensible heat flux | Wm**-2s | 12 |
| 147 | SLHF | Surface latent heat flux | Wm**-2s | 12 |
| 151 | MSL | Mean sea level pressure | Pa | 12 |
| 155 | D | Divergence | s-1 | 16 |
| 164 | TCC | Total cloud cover | (0-1) | 8 |
| 165 | 10U | 10 metre U | m/s | 12 |
| 166 | 10V | 10 metre V | m/s | 12 |
| 167 | 2T | 2 metre temperature | K | 12 |
| 168 | 2D | 2 metre dewpoint temperature | K | 12 |
| 169 | SSRD | Surface solar radiat. downwards | W m**-2 s | 16 |
| 170 | STL2 | Soil Temperature Level 2 | K | 12 |
| 175 | STRD | Surface thermal radi. downwards | W m**-2 s | 16 |

Table 10.2

* Not for TYPE=FCMIN (STREAM=MSMM);

| | | | | |
|---|---|---|---|---|
| 176 | SSR | Surface Solar Radiation | W m**-2 s | 16 |
| 177 | STR | Surface Thermal Radiation | W m**-2 s | 16 |
| 178 | TSR | Top Solar Radiation | W m**-2 s | 16 |
| 179 | TTR | Top Thermal Radiation | W m**-2 s | 16 |
| 180 | EWSS | U-stress | Nm**-2 | 12 |
| 181 | NSSS | V-stress | Nm**-2 | 12 |
| 182 | E | Evaporation | m of water | 16 |
| 183 | STL3 | Soil temperature level 3 | K | 12 |
| 186 | LCC | Low cloud cover | 0-1 | 8 |
| 189 | SUND | Sunshine duration | s | 16 |
| 3 | PT | Potential Temperature | K | 16 |
| 60 | PV | Potential Vorticity | m2s-1Kkg-1 | 16 |
| 205 | RO | Runoff | m | 16 |
| 207 | 10SI | 10 metre scalar wind speed | m/s | 12 |
| 228 | TP * | Total precipitation | m | 16 |
| 236 | STL4 | Soil temperature level 4 | K | 12 |
| 243 | FAL | Forecast albedo | 0-1 | 8 |

Table 10.2

* Not for TYPE=FCMIN (STREAM=MSMM);

- Horizontal resolution

  - 0.75 x 0.75 degrees latitude-longitude grid, or multiples thereof
  - any spectral truncation (default T255)
  - Gaussian grid (default N128) both regular and reduced
  - any sub-area

- Vertical resolution

  - pressure levels 1000, 925, 850, 700, 500, 400, 300, 200, 100, 50 and 10 hPa

- Verifying times

  - forecast month 1 to 7

Potential Vorticity level products are available on the level 2000 as parameter PT. Potential Temperature (Isentropic) level products are available as parameter PV on levels 315 and 330.

Surface fields (Table 10.2) are available for FCMONTH 1 to 7, with TYPE = FCMEAN, FCMAX, FCMIN and FCSTDEV for individual ensemble members and TYPE = EM for the ensemble. Please, note that parameters LSP, CP, SF and TP are not available for TYPE = FCMIN.

Pressure level fields (Table 10.2) are available for FCMONTH 1 to 7, with TYPE = FCMEAN for individual ensemble members and TYPE=EM for the ensemble.

### 8.4.2 Seasonal forecast monthly means and monthly mean anomaly dissemination requirements

The following command language parameters are specific for the seasonal forecast monthly mean requirements. Other DIS parameters are listed under the 10.3 above.

#### Identification parameters

| | | | |
|---|---|---|---|
| STREAM | = | MULTIMODEL SEASONAL FORECAST MEANS<br>MULTIMODEL SEASONAL FORECAST MEAN ANOMALIES | [MSMM]<br>[MMSA] |
| ORIGIN | = | ECMWF | [ECMWF]] |
| TYPE | = | FORECAST MEAN<br>FORECAST MAX<br>FORECAST MIN<br>ENSEMBLE STANDARD DEVIATION<br>ENSEMBLE MEAN | [FCMEAN]<br>[FCMAX] (only for STREAM=MSMM)<br>[FCMIN] (only for STREAM=MSMM)<br>[FCSTDEV](only for STREAM=MSMM)<br>[EM] |
| NUMBER | = | n-ENSEMBLE NUMBER<br>OFF for TYPE=EM | [0-40] |

#### Date and time parameters

| | | |
|---|---|---|
| STEP | = | OFF |
| FCMONTH | = | * (forecast month)<br>1/2/3/4/5/6/7;.<br>NB ALL, is not permitted. |

## 8.5 GRIB section 1 definition for Seasonal Forecast System 4 data

### 8.5.1 Seasonal forecast data (STREAM=MMSF)

By convention, ECMWF always uses octet 41 to define which set of local definitions follow. The set of local definitions for Seasonal forecast fields:

| Octet | Ksec1 element | Contents |
|---|---|---|
| 41<br><br>42<br><br>43 | 37<br><br>38<br><br>39 | ECMWF local GRIB use definition identifier.<br>15 = Seasonal forecast data<br>Class:<br>1 =Operations<br>Type:<br>9 = Forecast |
| 44-45<br><br>46-49 | 40<br><br>41 | Stream:<br>1090 = ECMWF ensemble seasonal forecasts<br>Version number or experiment identifier.<br>(4 ASCII characters, right justified) |
| 50-51 | 42 | Number (Ensemble forecast number: 0) |
| 56-57 | 43 | Total number of forecasts in ensemble. |
| 52-53 | 44 | System number<br>The “scientific version” number.<br>0 = RD experiment<br>1 - 65534 = operational version number<br>65535 = missing |
| 54-55 | 45 | Method number<br>Distinguishes scientifically different forecast ensembles<br>(e.g. different calibration/bias correction)<br>0 = control integration (i.e. without data assimilation)<br>1 - 65534 = operational version number |
| - | | Spare (set to zero) |

Table 10.2 GRIB section 1 definition for Seasonal Forecast products

### 8.8.2 Seasonal forecast monthly means and monthly mean anomaly dissemination data (STREAM=MSMM/MMSA)

By convention, ECMWF always uses octet 41 to define which set of local definitions follow. The set of local definitions for Seasonal forecast fields:

| Octet | Ksec1 element | Contents |
|---|---|---|
| 41<br><br>42<br><br>43 | 37<br><br>38<br><br>39 | ECMWF local GRIB use definition identifier.<br>16 = ECMWF seasonal forecast monthly mean data<br>Class:<br>1 =Operations<br>Type:<br>17 = Ensemble means<br>80 = Forecast seasonal mean<br>81 = Forecast seasonal maximum<br>82 = Forecast seasonal minimum<br>83 = Forecast seasonal standard deviation |
| 44-45<br><br><br>46-49 | 40<br><br><br>41 | Stream:<br>1221 = ECMWF seasonal forecast monthly means<br>1224 = Seasonal monthly means anomalies<br>Version number or experiment identifier.<br>(4 ASCII characters, right justified) |
| 50-51 | 42 | Number (Ensemble forecast number: 0) |
| - | 43 | Zero |
| 52-53 | 44 | System number<br>The “scientific version” number.<br>0 = RD experiment<br>1 - 65534 = operational version number<br>65535 = missing |

Table 10.3 GRIB section 1 definition for Seasonal monthly means and monthly means anomalies products

| | | |
|---|---|---|
| 54-55 | 45 | Method number<br>Distinguishes scientifically different forecast ensembles<br>(e.g. different calibration/bias correction)<br>0 = control integration (i.e. without data assimilation)<br>1 - 65534 = operational version number |
| 56-59 | 46 | Verifying month (in format YYYYMM) |
| 60 | 47 | Averaging period (e.g. 6-hour, 24-hour) |
| 61-62 | 48 | Forecast month |
| 63-80 | - | Spare (set to zero) |

Table 10.3 GRIB section 1 definition for Seasonal monthly means and monthly means anomalies products

## 8.9 Transmission of Seasonal Forecasting System products

The dissemination file name convention used for the transmission of Seasonal Forecasting system 4 products is described in **Section 12**. Data stream indicator used for these products in dissemination file names is 'L'.

Seasonal Forecasting System 4 products are prepared separately from other dissemination products, and are transmitted as one file per forecast month. Seasonal forecast products (STREAM=MMSF) which are requested using keyword STEP are also stored into these monthly dissemination files for the corresponding range of steps and are disseminated together with other seasonal products (MSMM and MMSA). Please, note that 00 UTC of the first day of the calendar month is taken as the beginning of the forecast month. Seasonal Forecasting System products are released for dissemination on the 8th of each month starting at 12 UTC. Default transmission priority for these products is 90.

| Forecast time | Time Available |
|---|---|
| Forecast Month 1-7 | 12:00 |

Table 10.4 Dissemination schedule for the Seasonal Forecasting System products

/

# 9. Ensemble Monthly Forecast

## 9.1 Introduction

ECMWF started an experimental programme of monthly forecasting (time range from 10 to 30 days) in March 2002. The monthly forecasting system is operational since October 2004. In March 2008 ECMWF has combined its Ensemble Forecast and monthly forecasting into a single system. On Monday and Thursday of each week, the 00 UTC ENS forecast is extended from 15 to 32 days at a resolution of T319 L62 with ocean coupling introduced from day 10.

### 9.1.1 Why Monthly Forecasting?

Two forecasting systems are currently operational at ECMWF: medium-range weather forecasting and seasonal forecasting. Medium-range weather forecasting produces weather forecasts out to 10 days, whereas seasonal forecasting produces forecasts out to 6 months. The two systems have different physical bases. Medium-range weather forecasting is essentially an atmospheric initial value problem. Since the time scale is too short for variations in the ocean significantly to affect the atmospheric circulation, the ECMWF medium-range weather forecasting system is based on atmospheric-only integrations. SSTs are simply persisted. Seasonal forecasting, on the other hand, is justified by the long predictability of the oceanic circulation (of the order of several months) and by the fact that the variability in tropical SSTs has a significant global impact on the atmospheric circulation. Since the oceanic circulation is a major source of predictability in the seasonal scale, the ECMWF seasonal forecasting system is based on coupled ocean-atmosphere integrations. Seasonal forecasting is also an initial value problem, but with much of the information contained in the initial state of the ocean.

The main goal of monthly forecasting is to fill the gap between these systems and produce forecasts for the time range 10 to 30 days. The time range 10 to 30 days is probably still short enough that the atmosphere retains some memory of its initial state and it may be long enough that the ocean variability has an impact on the atmospheric circulation. Therefore, the monthly forecasting system has been built as a combination of the medium-range ENS and the seasonal forecasting system. It contains features of both systems and, in particular, is based on coupled ocean-atmosphere integrations, as is the seasonal forecasting system.

An important source of predictability over Europe in the 10-30 day range is believed to originate from the Madden Julian Oscillation (MJO) (see, for instance, Ferranti et al 1990). The MJO is a 40-50 day tropical oscillation.

Several papers (see, for instance, Flateau et al, 1997) suggest that the ocean-atmosphere coupling has a significant impact upon the speed of propagation of an MJO event in the Indian Ocean and western North Pacific. The use of a coupled system may therefore help to capture some aspects of the MJO variability.

The ECMWF monthly forecasting system has two components:

- The real-time forecasting system
- The back-statistics needed to create a model climatology to calibrate the real-time forecasting system.

### 9.1.2 The real-time forecasting system

The real-time ENS/monthly forecasting system is a 51-member ensemble of 32-day integrations. The first 10 days are performed with a T639L62 resolution forced by persisted SST anomalies. After day 10, the model is coupled to the ocean model and has a resolution of T319L62. The extension of ENS to 32 days is performed every Thursday and Monday. Before January 2008, the monthly forecasting system was a separate system from ENS. The first operational real-time monthly forecast was realized on Thursday, 7 October 2004. The first operational real-time Monday monthly forecast was realized on 10 October 2011.

Atmospheric component: IFS with the same cycle as the high resolution forecast.

Oceanic component: HOPE (from Max Plank Institute for Meteorology, Hamburg) with a zonal resolution of 1.4 degrees and 29 vertical levels. The ocean has lower resolution in the extratropics, but higher meridional resolution in the equatorial region (0.3 degrees), in order to resolve ocean baroclinic waves and processes which are tightly trapped at the equator.

Coupling: OASIS (from CERFACS, France). The atmospheric fluxes of momentum, heat and fresh water are passed to the ocean every hour. In exchange, the ocean surface temperature (SST) is passed to the atmosphere.

### 9.1.3 The Back-statistics

After 10 days of coupled integrations, the model drift begins to be significant. It displays similar patterns to seasonal forecasting after 6 months of integrations, but with less amplitude. The strategy for dealing with model drift is straightforward. We initialize the ocean, atmosphere and land surface to be as close to reality as possible, and calculate the forward evolution of the system as best we can using numerical approximations of the laws of physics. No “artificial” terms are introduced to try to reduce the drift of the model and no steps are taken to remove or reduce any imbalances in the coupled model initial state: we simply couple the models together and start to integrate forward. The effect of the drift on the model calculations is estimated from previous integrations of the model in previous years (the back-statistics). The drift is removed from the model solution during the post-

processing.

An additional motivation for creating a model climatology is that after about 10 days of forecasts, the spread of the ensemble is very large (see, for instance, forecast plumes). Therefore, the probability distribution function (pdf) of the model climatology needs to be evaluated, in order to detect any significant difference between the ensemble distribution of the real-time forecast and climatology.

In the present system, the climatology (back-statistics) is a 5-member ensemble of 32-day ENS/monthly integrations, starting on the same day and month as the real time forecast for each of the past 18 years. For instance, the first starting date of the real-time forecast was 27 March 2002. The corresponding climatology is a 5-member ensemble starting on 27 March 1990, 27 March 1991,..., 27 March 2001. The 5-member ensemble is thus integrated with 18 different starting dates. This represents a total of 90 integrations and constitutes the 90-member ensemble of the back-statistics.

The back statistics are created every week and are ready 3 weeks before the real-time forecasting suite starts.

* new sea-ice treatment: before 30 June 2005, the sea-ice cover was computed from the SSTs produced by the ocean model. Since 30 June 2005, the sea-ice cover is persisted from the atmospheric initial conditions till day 10, then relaxed towards climatology. After day 30, the sea-ice cover is the climatology sea-ice cover (from ERA40).

## 9.2 Monthly forecast dissemination products

The dissemination supports products which can be represented as fields of values of a single parameter over a defined area. The data are represented in FM 92 GRIB code.

A number of products are available. Products can be grouped into the following categories:

- Raw atmospheric data
- Raw atmospheric hindcast data
- Raw wave data
- Raw wave hindcast data
- Real-time weekly means
- Hindcast weekly means
- Wave real-time weekly means
- Wave hindcast weekly means

- Anomaly weekly means

- Horizontal resolution:

  - 0.25° x 0.25° latitude-longitude grid for days 1 to 10 ( leg1)
  - 0.5° x 0.5° latitude-longitude grid for days 10 to 32 (leg 2 and leg3)
  - the Gaussian grid appropriate to the forecast model in use. The following Gaussian grid numbers are supported: 320,200 (for leg1) 160, 128, 80, 48 and 32. (for leg 2 and 3)
  - any sub-area

- Vertical resolution

  - pressure levels (depending on the specific parameter and the forecast time step): 1000,925,850,700,600,500,400,300,250,200,150,100,70,50,30,20,10,7,5,3,2,1 hPa
  - no model level data are generated;

- Verifying times for real-time data and indicts

  - Atmospheric data T+0 to T+768 (inclusive) at 6, 12 or 24 hour intervals depending on a parameter;
  - Wave data T+0 to T+768 (inclusive) on 24 hour intervals

- Verifying times for weekly means and hindcast weekly means

  - Forecast time steps ranges 96-264, 264-432, 432-600, 600-768 0-168, 168-336, 336-504 and 504-672

Monthly Forecast products are disseminated as one file per forecast day (all forecast time steps falling within a day are in the same file). Please, note that 00 hours is considered as the first hour of the day.

A four sets of dissemination files are generated by the Monthly Forecasting system each set containing the following data:

1. Real-time atmospheric data, real-time weekly means and anomaly means (data stream ENFO)
2. Hindcast atmospheric data and hindcast weekly means (data streams ENFH and EFHS)
3. Real-time wave data and real-time weekly means (data stream WAEF)
4. Hindcast wave data and hindcast weekly means (data stream ENWH)

## 9.3 Monthly forecast dissemination requirements

The dissemination of monthly forecast field products is controlled in a similar manner to the dissemination of data from ECMWF's medium-range forecasting system. Dissemination requirements for these products are added to the general set of dissemination requirements for each Member State - it is not necessary to update and maintain separate sets of requirements for products required from Monthly Forecasts.

Users have a choice to distinguish between daily and monthly ENS products on the requirement level. The language keyword "USE" will be used for this purpose. If users set USE=MONTHLY RUN MONDAY or USE=MONTHLY RUN THURSDAY in their request they will get ENS products as one dissemination file per forecast day on Mondays or/and Thursdays.

For the hindcasts, the reference date of the hindcast (date of the real-time forecast associated to the hindcast) REFDATE=YYYYMMDD is set by default in dissemination to the latest operational Monthly Forecast cycle date and does not have to be specified in the requirements. Also, for hindcast data, the only value for the parameter DATE (date on which the hindcast is based) supported in dissemination is ALL. Hindcasts are run only run on THURSDAY (00 UTC based ENS run).

The following command language parameters are common for all Monthly Forecast requirements. Language parameters not listed in this paragraph are the same as defined for STREAM=EF products.

### Identification parameters

| | | | |
|---|---|---|---|
| STREAM | = | ENSAMBLE FORECAST | [EF] |
| | | ENSAMBLE FORECAST HINDCASTS | [ENFH] |
| | | ENSEMBLE FORECAST HINDCASTS STATISTICS | [EFHS] |
| | | WAVE ENSEMBLE FORECAST | [WE] |
| | | WAVE ENSEMBLE HINCASTS | [ENWH] |
| LEVTYPE | = | SURFACE | [SFC] |
| | | PRESSURE LEVEL | [PL] |
| | | POTENTIAL VORTICITY | [PV] |
| | | POTENTIAL TEMPERATURE | [PT] |
| USE | = | OFF | OFF |
| | | MONTHLY RUN MONDAY | MM |
| | | MONTHLY RUN THURSDAY | MT |

## Date and time parameters

TIME = 00
Gives products base time.

DATE = ALL Only ALL is supported for HINDCAST.
OFF for non hindcast data
OFF for STREAM=EFHS and TYPE=EM/ES/TAEM/TAES

REFDATE = *
Reference date of the hindcast run, in dissemination set to latest operational cycle.
OFF for non hindcast data

## Data processing parameters

RESOL = * [AV] (default 639 for leg 1)
(default 319 for leg 2 and 3)

Positive integer giving the spectral triangular truncation.
(e.g. 10 indicates T10 filtered products required. May only be used with multi-level (i.e. upper air) parameters. May also be used if spectral products are required.)

GAUSSIAN = REGULAR
REDUCED
OFF

Indicating Gaussian grid type. Gaussian grid resolution is given by the GRID parameter.

GRID = *
*/*
AUTOMATIC [AUTO]

If the form a/b is used, a latitude-longitude grid is defined, where:
a= grid resolution (deg.) along a latitude line (i.e. East/West)
b= grid resolution (deg.) along a longitude line (i.e. North/South)

0.25/0.25 or multiples thereof for leg 1;
0.5/0.5 or multiples thereof for legs 2 and 3;

Note that it is possible to specify different values for a and b to generate a quasi-regular grid system with a different resolution in the West-East direction from that in the North-South direction. This feature is only valid for latitude-longitude grid.

If a single positive integer is coded, it is interpreted as Gaussian grid number for grids defined as GAUSSIAN=REDUCED or REGULAR. The following Gaussian grid numbers are supported: 320, 200 for leg 1 and 160, 128, 80, 48 and 32 for leg 2 and 3.

AUTOMATIC - values for the parameter GRID will be defined automatically based on STREAM/DOMAIN as well as RESOL/GAUSSIAN parameter values;

## 9.4 GRIB section 1 definition for Monthly Forecast data

The ECMWF local GRIB definition used for Monthly Forecast data is 30 (http://www.ecmwf.int/publications/manuals/libraries/gribex/localDefinition30.html).

## 9.5 Monthly forecast raw data

The real-time monthly forecasting system is combined Ensemble Forecast and monthly forecasting system. On Thursday and Monday of each week, the 00 UTC ENS forecast is extended from 15 to 32 days at a resolution of T319 L62 with ocean coupling introduced from day 10. The raw hindcast monthly forecasting data are a 4-member ensemble.

Parameters available in dissemination for forecast range D+0 to D+15 are as described in Ensemble Forecast section. For forecast range D+15 to D+32 available parameters are the same as for the ENS leg 2 (D+11 to D+15).

Wave model monthly forecasts are stored in the stream WAEF (1081) for the real-time forecast and in the stream ENWH (1079) for the hindcast. Parameters generated are the same.

### 9.5.1 Monthly forecast raw data requirements

Two types of data are available, the control forecast TYPE=CF and perturbed forecasts TYPE=PF.

The following command language parameters are specific for the raw data requirements. Other language parameters are listed under the 10.3 above.

| | | | |
|---|---|---|---|
| STREAM | = | ENSEMBLE FORECAST | [EF] |
| | | WAVE ENSEMBLE FORECAST | [WE] |
| TYPE | = | CONTROL FORECAST | [CF] |
| | | PERTURBED FORECAST | [**PF**] |
| NUMBER | = | 1/to/50 for TYPE=PF and STREAM=EF/WE<br>1/to/4 for TYPE=FC and STREAM=ENFH/ENWH<br>OFF for TYPE=CF | |
| LEVELIST | = | *<br>(1000/925/850/700/600/500/400/300/250/200/150/100/70/50/30/20/10/7/5/3/2/1 for STREAM=EF)<br>(1000/925/850/700/500/400/300/200/100/50/10 - for STREAM=ENFH)<br>NB ALL is not permitted;<br>(See above for LEVTYPE=PT/PV products); | |

## 9.6 Monthly Forecast Weekly Means

Monthly forecast weekly means are calculated for some atmospheric variables and stored in the stream ENFO (1035) for the real-time forecast and stream ENFH (1033) for he hindcasts. Monthly forecast weekly maximum (type FCMAX), minimum (type FCMIN) and standard deviation (type FCSTDEV) have also been calculated and archived for all surface fields.

Wave model forecast means (weekly means) are calculated and stored in the stream WAEF (1081) for the real-time forecast and stream ENWH (1079) for the hindcast.

Forecast step ranges are 0-168, 96-264, 264-432, 432-600, 600-768, 168-336, 336-504 and 504-672 hours.

Parameters available in dissemination for various data streams are listed in the tables bellow.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 1 | STRF | Stream function + | m2 s-1 | 16 |
| 2 | VPOT | Velocity potential + | m2 s-1 | 16 |
| 3 | PT | Potential Temperature + | K | 16 |
| 31 | CI | Sea Ice Cover | 0-1 | 8 |
| 33 | RSN | Snow density | kg m**-3 | 16 |
| 34 | SST | Sea Surface temperature | K | 12 |
| 39 | SWVL1 | Volumetric Soil Water layer 1 | m3m-3 | 12 |
| 40 | SWVL2 | Volumetric Soil Water layer 2 | m3m-3 | 12 |
| 41 | SWVL3 | Volumetric Soil Water layer 3 | m3m-3 | 12 |
| 42 | SWVL4 | Volumetric Soil Water layer 4 | m3m-3 | 12 |
| 49 | 10FG | Wind gust at 10 meters | m/s | 16 |
| 60 | PV | Potential Vorticity + | m2s-1Kkg-1 | 16 |
| 78 | TCLW | Total Column Liquid Water | kg m**-2 | 16 |
| 79 | TCIW | Total Column Ice Water | kg m**-2 | 16 |
| 121 | MX2T6 | Max. temp at 2m since the last 6 hours. | K | 12 |
| 122 | MN2T6 | Max. temp at 2m since the last 6 hours. | K | 12 |
| 129 | Z | Geopotential + | m2s-2 | 16 |
| 130 | T | Temperature + | K | 12 |
| 131 | U | U-velocity + | m/s | 12 |
| 132 | V | V-velocity + | m/s | 12 |
| 133 | Q | Specific humidity + | kg/kg | 12 |
| 136 | TCW | Total Column Liquid Water | kg m**-2 | 12 |
| 137 | TCWV | Total Column Water Vapour | kg m**-2 | 12 |
| 138 | VO | Vorticity + | s-1 | 16 |
| 139 | STL1 | Soil Temperature Level 1 | K | 12 |
| 141 | SD | Snow depth | m | 12 |
| 142 | LSP | Large scale precipitation * | m | 16 |
| 143 | CP | Convective precipitation * | m | 16 |
| 144 | SF | Snow fall * | m | 16 |
| 146 | SSHF | Surface sensible heat flux | Wm-2s | 12 |
| 147 | SLHF | Surface latent heat flux | Wm-2s | 12 |
| 151 | MSL | Mean sea level pressure | Pa | 12 |
| 155 | D | Divergence + | s-1 | 16 |
| 156 | GH | Height Geopotential | gpm | 12 |
| 159 | BLH | Boundary Layer Height | m | 16 |
| 164 | TCC | Total cloud cover | (0-1) | 8 |

Table 10.4 Parameter list for monthly forecast means for STREAM=ENFO and ENFH and TYPE=FCMIN, FCMAX, FCSTDEV and FCMEAN

+ FCMEAN only * Not FCMIN

| | | | | |
|---|---|---|---|---|
| 165 | 10U | 10 metre U | m/s | 12 |
| 166 | 10V | 10 metre V | m/s | 12 |
| 167 | 2T | 2 metre temperature | K | 12 |
| 168 | 2D | 2 metre dewpoint temperature | K | 12 |
| 169 | SSRD | Surface solar radiat. downwards | W m**-2 s | 16 |
| 170 | STL2 | Soil Temperature Level 2 | K | 12 |
| 175 | STRD | Surface thermal radi. downwards | W m**-2 s | 16 |
| 176 | SSR | Surface Solar Radiation | W m**-2 s | 16 |
| 177 | STR | Surface Thermal Radiation | W m**-2 s | 16 |
| 178 | TSR | Top Solar Radiation | W m**-2 s | 16 |
| 179 | TTR | Top Thermal Radiation | W m**-2 s | 16 |
| 180 | EWSS | U-stress | Nm**-2 | 12 |
| 181 | NSSS | V-stress | Nm**-2 | 12 |
| 182 | E | Evaporation | m of water | 16 |
| 189 | SUND | Sunshine duration | s | 16 |
| 201 | MX2T | Max. temp. at 2m since prev. post-processing | K | 12 |
| 202 | MN2T | Min. temp. at 2m since prev. post-processing | K | 12 |
| 207 | 10SI | 10m Wind speed iresp of direction | m/s | 12 |
| 228 | TP | Total precipitation | m | 16 |
| 229 | SWH | Significant wave height | m | 16 |
| 231 | PP1D | Peak period 1D-spectra | s | 16 |
| 232 | MWP | Mean wave period | s | 16 |
| 233 | CDWW | Coefficient of drag with waves Significant | - | 16 |
| 245 | WIND | 10 Meter Wind Speed | m/s | 16 |

Table 10.4 Parameter list for monthly forecast means for STREAM=ENFO and ENFH and TYPE=FCMIN, FCMAX, FCSTDEV and FCMEAN

\+ FCMEAN only * Not FCMIN

### 9.6.1 Monthly forecast weekly means requirements

The following command language parameters are specific for the Monthly Forecast weekly means requirements. Other parameters are listed under the 10.3 above.

Several types of data, as listed bellow, are available for weekly monthly means.

| | | | |
|---|---|---|---|
| STREAM | = | ENSEMBLE FORECAST | [EF] |
| | | WAVE ENSEMBLE FORECAST | [WE] |
| | | ENSEMBLE FORECAST HINDCASTS | [ENFH] |
| | | WAVE ENSEMBLE HINCASTS | [ENWH] |

| | | | |
|---|---|---|---|
| TYPE | = | FORECAST MAXIMUNM | [FCMAX] |
| | | FORECAST MINIMUM | [FCMIN] |
| | | FORECAST STANDARD DEVIATION | [FCSTDEV] |
| | | FOREACST MEAN | [FCMEAN] |
| NUMBER | = | 1/to/50 for STREAM=EF and WE<br>0/to/4 for STREAM=ENFH and ENWH | |
| STEP | = | 96-264,264-432,432-600,<br>600-768,<br>0-168,168-336,336-504,504-672 | |
| LEVELIST | = | *<br>(1000/925/850/700/500/400/300/200/100/50/10)<br>200 for PARAM=1/2<br>NB ALL is not permitted;<br>(See 4.2.5 for LEVTYPE=PT/PV products); | |

## 9.7 Monthly Forecast Ensemble means and standard deviation

Monthly for Ensemble means and standard deviations are generated for data stream ENFO and only for a limited number of fields, see the table below. Data types used are TYPE=EM (ensemble mean) and TYPE=ES (ensemble standard deviation).

.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 10 | WS | Wind Speed | m s**-1 | 16 |
| 129 | Z | Geopotential | m2s-2 | 16 |
| 130 | T | Temperature | K | 12 |
| 151 | MSL | Mean sea level pressure | Pa | 12 |
| 156 | GH | Geopotential Height | gpm | 12 |

Table 10.6 Parameter list for monthly weekly means for STREAM=ENFO USE=MONTHLY and TYPE=EM and ES

### 9.7.1 Monthly forecast Ensemble means and standard deviation requirements

Two types of data are available for ensemble monthly means, TYPE=EM and ES.

The following command language parameters are specific for the Monthly Forecast Ensemble means and standard deviation requirements. Other parameters are listed under the 11.3 above.

| | | | |
|---|---|---|---|
| STREAM | = | ENSEMBLE FORECAST | [EF] |
| TYPE | = | ENSEMBLE MEAN<br>ENSEMBLE STANDARD DEVIATION | [EM]<br>[ES] |
| DATE | = | ALL | |
| NUMBER | = | OFF for TYPE=EM/ES | |
| STEP | = | 3-144/3<br>150-360/6 | |
| LEVELIST | = | (1000/850/500/)<br>NB ALL is not permitted; | |

## 9.8 Time Average Ensemble mean and standard deviation

The anomalies are the difference between the real-time forecast and the model climatology. The model

climatology corresponds to the ensemble mean of the hindcast.

Monthly forecast anomalies are generated as the data stream ENFO (1035). Parameters available in dissemination are listed in the table bellow.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 1 | STRF | Stream function | m2 s-1 | 16 |
| 2 | VPOT | Velocity potential | m2 s-1 | 16 |
| 33 | RSN | Snow Density | kg m**-3 | 16 |
| 78 | TCLW | Total Column Liquid Water | kg m**-2 | 16 |
| 79 | TCIW | Total Column Ice Water | kg m**-2 | 16 |
| 121 | MX2T6 | Max. temp at 2m since the last 6 hours. | K | 12 |
| 122 | MN2T6 | Min. temp at 2m since the last 6 hours. | K | 12 |
| 129 | Z | Geopotential | m2s-2 | 16 |
| 130 | T | Temperature | K | 12 |
| 131 | U | U-velocity | m/s | 12 |
| 132 | V | V-velocity | m/s | 12 |
| 133 | Q | Specific humidity | kg kg**-1 | 12 |
| 136 | TCW | Total column water | kg m**-2 | 12 |
| 137 | TCWV | Total column water vapour | kg m**-2 | 12 |
| 139 | STL1 | Soil Temperature Level 1 | K | 12 |
| 141 | SD | Snow depth anomaly | m | 16 |
| 142 | LSP | Large-scale precipitation | m | 16 |
| 143 | CP | Convective precipitation | m | 16 |
| 144 | SF | Snow fall | m | 16 |
| 151 | MSL | Mean sea level pressure | Pa | 12 |
| 156 | GH | Geopotential height | gpm | 12 |
| 164 | TCC | Total cloud cover | (0-1) | 8 |
| 165 | 10U | 10 metre U | m/s | 12 |
| 166 | 10V | 10 metre V | m/s | 12 |
| 167 | 2T | 2 metre temperature | K | 12 |
| 168 | 2D | 2 metre dewpoint temperature | K | 12 |
| 189 | SUND | Sunshine duration | s | 16 |
| 201 | MX2T | Max. temp. at 2m since prev. post-processing | K | 12 |
| 202 | MN2T | Min. temp. at 2m since prev. post-processing | K | 12 |
| 228 | TP | Total precipitation | m | 16 |
| 171001 | STRFA | Stream function | m2 s-1 | 16 |
| 171002 | VPOT2 | Velocity potential | m2 s-1 | 16 |

Table 10.7 Parameter list for monthly weekly means for STREAM=ENFO and TYPE=TAEM and TAES

| | | | | |
|---|---|---|---|---|
| 171006 | 100UA | 100 metre U wind component | m s**-1 | 12 |
| 171007 | 100VA | 100 metre V wind component | m s**-1 | 12 |
| 171033 | RSNA | Snow Density | kg m**-3 | 16 |
| 171034 | SSTA | Sea surface temperature anomaly | K | 16 |
| 171059 | CAPEA | Convective available potential energy | J kg**-1 | 16 |
| 171078 | TCLWA | Total Column Liquid Water | kg m**-2 | 16 |
| 171079 | TCIWA | Total Column Ice Water | kg m**-2 | 16 |
| 171121 | MX2T6A | Max. temp at 2m since the last 6 hours. | K | 12 |
| 171122 | MN2T6A | Min. temp at 2m since the last 6 hours. | K | 12 |
| 171129 | ZA | Geopotential | m2s-2 | 16 |
| 171130 | TA | Temperature | K | 12 |
| 171131 | UA | U-velocity | m/s | 12 |
| 171132 | VA | V-velocity | m/s | 12 |
| 171133 | QA | Specific humidity | kg kg**-1 | 12 |
| 171136 | TCWA | Total column water | kg m**-2 | 12 |
| 171137 | TCWVA | Total column water vapour | kg m**-2 | 12 |
| 171139 | STAL1 | Soil temperature anomaly level 1 | K | 12 |
| 171141 | SDA | Snow depth anomaly | m | 16 |
| 171151 | MSLA | Mean sea level pressure | Pa | 12 |
| 171156 | GHA | Height anomaly | m | 12 |
| 171164 | TCCA | Total cloud cover anomaly | (0-1) | 8 |
| 171165 | 10UA | 10 metre U wind anomaly | m/s | 12 |
| 171166 | 10VA | 10 metre V wind anomaly | m/s | 12 |
| 171167 | 2TA | 2 metre temperature anomaly | K | 12 |
| 171168 | 2DA | 2 metre dewpoint temperature anomaly | K | 12 |
| 171201 | MX2TA | Max. temp. at 2m since prev. post-processing | K | 12 |
| 171202 | MN2TA | Min. temp. at 2m since prev. post-processing | K | 12 |
| 173144 | SFARA | Snowfall rate of accumulation | s | 16 |
| 173189 | SUNDA | Sunshine duration | s | 16 |
| 173228 | TPARA | Total precipitation | m | 16 |
| 234139 | STS | Surface temperature significance | % | 16 |
| 234151 | MSLS | Mean sea level pressure signifi-cance | % | 16 |
| 234167 | 2TS | 2 metre temperature significance | % | 16 |
| 234228 | TPS | Total precipitation significance | % | 16 |

Table 10.7 Parameter list for monthly weekly means for STREAM=ENFO and TYPE=TAEM and TAES

### 9.8.1 Time average ensemble mean and standard deviation requirements

Two types of data are available for ensemble monthly means, TYPE=TAES and TAEM.

The following command language parameters are specific for the Monthly Forecast anomaly means requirements. Other parameters are listed under the 9.3 above.

| | | | |
|---|---|---|---|
| STREAM | = | ENSEMBLE FORECAST | [EF] |
| TYPE | = | TIME AVERAGE ENSEMBLE MEAN<br>TIME AVERAGE ENSEMBLE STANDARD DEVIATION | [TAEM]<br>[TAES] |
| NUMBER | = | OFF | |
| STEP | = | 96-264,264-432,432-600,<br>600-768,<br>0-168,168-336,336-504,504-672 | |
| LEVELIST | = | OFF for TAEM<br>*<br>(1000/925/850/700/500/400/300/200/100/50/10)<br>NB ALL is not permitted; | |

## 9.9 Monthly Forecast Anomaly Probability products

Anomaly probability products show the probability that parameter's weekly means exceed the 12-years model climatology. Available parameters are listed in the Table 10.7.

| FIELD CODE | MARS ABBREV. | FIELD NAME | UNITS | NO. OF BITS/ VAL. |
|---|---|---|---|---|
| 1 | 2TAG2 | 2M Temperature anomaly of at least 2 K | % | 8 |
| 2 | 2TAG1 | 2M Temperature anomaly of at least 1 K | % | 8 |
| 3 | 2TAG0 | 2M Temperature anomaly of at least 0 K | % | 8 |
| 4 | 2TALM1 | 2M Temperature anomaly of at most -1 K | % | 8 |
| 5 | 2TALM2 | 2M Temperature anomaly of at most -2 K | % | 8 |
| 6 | TPAG20 | Total precipitation of at least 20 mm | % | 8 |
| 7 | TPAG10 | Total precipitation of at least 10 mm | % | 8 |
| 8 | TPAG0 | Total precipitation anomaly of at least 0 mm | % | 8 |
| 9 | STAG0 | Surface temperature anomaly of at least 0K | % | 8 |
| 10 | MSLAG0 | Mean sea level pressure anomaly of at least 0 Pa | % | 8 |
| 20 | TALM2K | Temperature anomaly less than -2 K | % | 8 |
| 21 | TAG2K | Temperature anomaly of at least +2 K | % | 8 |
| 22 | TALM8K | Temperature anomaly less than -8 K | % | 8 |
| 23 | TALM4K | Temperature anomaly less than -4 K | % | 8 |
| 24 | TAG4K | Temperature anomaly greater than +4 K | % | 8 |
| 25 | TAG8K | Temperature anomaly greater than +8 K | % | 8 |
| 60 | TPG1 | Total precipitation of at least 1 mm | % | 8 |
| 61 | TPG5 | Total precipitation of at least 5 mm | % | 8 |
| 62 | TPG10 | Total precipitation of at least 10 mm | % | 8 |
| 63 | TPG20 | Total precipitation of at least 20 mm | % | 8 |
| 64 | TPL01 | Total precipitation less than 0.1 mm | % | 8 |
| 65 | TPRL1 | Total precipitation rate less than 1 mm/day | % | 8 |
| 66 | TPRG3 | Total precipitation rate of at least 3 mm/ day | % | 8 |
| 67 | TPRG5 | Total precipitation rate of at least 5 mm/ day | % | 8 |
| 68 | 10SPG10 | 10 metre Wind speed of at least 10 m/s | % | 8 |
| 69 | 10SPG15 | 10 metre Wind speed of at least 15 m/s | % | 8 |
| 70 | 10FGG15 | 10 metre Wind gust of at least 15 m/s | % | 8 |
| 71 | 10FGG20 | 10 metre Wind gust of at least 20 m/s | % | 8 |
| 72 | 10FGG25 | 10 metre Wind gust of at least 25 m/s | % | 8 |
| 73 | 2TL273 | 2 metre temperature less than 273.15 K | % | 8 |

Table 10.7 (ECMWF Local Code Table 2, parameter table, Version Number 131)

Data values are percentage probabilities of the indicated meteorological parameter being above the lower threshold or being below the upper threshold or lying between the upper and lower thresholds. Monthly forecast anomaly probability products are disseminated together with other real-time Monthly forecast data.

### 9.9.1 Monthly Forecast Anomaly Probability requirements

The following command language parameters are specific for the control and perturbed forecast requirements. Other parameters are listed under the general Monthly Forecast requirements above.

| | | | |
|---|---|---|---|
| STREAM | = ENSEMBLE FORECAST | | [ENFO] |
| TYPE | = EVENT PROBABILITY | | [EP] |
| DOMAIN | = GLOBAL | [G] | |
| NUMBER | = OFF | | |
| LEVTYPE | = SURFACE | [SFC] | * |
| LEVELIST | = OFF | * | |
| STEP | = hours | | |

### 9.9.2 GRIB section 1 definition for Monthly Forecast Anomaly Probability products

The ECMWF local GRIB definition used for Monthly Forecast Anomaly Probability data is 5 (http://www.ecmwf.int/publications/manuals/libraries/gribex/localDefinition5.html ).

## 9.10 Transmission of Monthly Forecast products

The dissemination file name convention used for the transmission of Monthly Forecast products is described in **Section 12**. Four sets of dissemination files are generated, each containing data for a collection of data streams. Data stream indicators used for these products in dissemination file names are:

- ‘F’ data stream ENFO (real-time atmospheric data)
- ‘H’ data streams ENFH and ENHS (hindcast atmospheric data)
- ‘V’ data stream WAEF (real-time wave data)
- ‘Z’ data stream ENWH (hindcast wave data)

Monthly Forecast products are prepared separately from other dissemination products, and are transmitted as one file per forecast day, resulting in 33 files per a data set described above.

Monthly Forecast products which are requested using time step range (STEP=valu1-value2) are also stored in these daily dissemination files using end of the range step to determine corresponding forecast day. When determining forecast day, please note that 00 UTC of each day is taken as the first hour of that day. Real-time Monthly Forecast products are released for dissemination on Monday and Thursday, starting at 22 UTC. Hindcast Monthly Forecast products are released for dissemination on Thursdays, starting at 10 UTC. Default transmission priority for these products is 90.

| Forecast time | Time Available |
|---|---|
| Real Time Forecast | 22:00 |
| Hindcast Forecast | 10:00 |

Table 10.8 Dissemination schedule for the Monthly Forecast products

# 10. Transmission of products

## 10.1 Introduction

Dissemination data are transmitted to Member States using TCP/IP protocol. Telecommunications network and line speeds are illustrated on http://rmdcn.ecmwf.int/. Each Member State is assigned topically one normal and one temporary destination designator, and any reasonable number of dissemination streams. For each dissemination stream, a set of dissemination requirements is maintained (either by ECMWF or by the Member State - see Section 13 for details). One file containing all requested products for a dissemination stream is transmitted per a verifying time for each of the available data streams.

For GRIB data, octets between the end of one message and the beginning of the next should be ignored. Messages are separated by padding (optionally could be disabled) to multiples of 120 octets to ensure word alignment at the beginning of each message.

## 10.2 Dissemination file naming convention

The following dissemination filename convention is used for the transmission of ECMWF dissemination products:

ccSMMDDHHIImmddhhiiE where:

cc is Dissemination stream name;

S is data stream indicator:

- ‘D’ Main high resolution model products,
- ‘A’ Weather Parameter products,
- ‘P’ Global Wave Model products,
- ‘M’ Mediterranean (European) Wave Model products,
- ‘E’ Ensemble forecast products (control and perturbed forecast);
- ‘B’ Ensemble Weather Parameter products,
- ‘Y’ Ensemble derived products (other then control and perturbed forecast)
- ‘W’ Wave Ensemble products;
- ‘U’ Wave Ensemble derived products (other then control and perturbed forecast);
- ‘Q’ Boundary Condition WAVE Project products;
- ‘S’ Boundary Condition Project products;
- ‘X’ Multi-Analysis Ensemble Data products.
- ‘L’ Seasonal Forecasting System products
- ‘C’ Tropical Cyclone high resolution trajectory forecast products
- ‘T’ Tropical Cyclone ENS trajectory forecast products
- ‘F’ Monthly Forecast real time atmospheric data
- ‘H’ Monthly Forecast hindcast atmospheric data
- ‘V’ Monthly Forecast real time wave data
- ‘Z’ Monthly Forecast hindcast wave data
- ‘O’ Ensemble Forecast Overlap data

MMDDHHII is is month, day, hour and minute on which the products are based;

mmddhhii is is month, day, hour and minute on which the products are valid at;
ddhhii is set to “_____” for Seasonal Forecasting System products;
(ii is set to 01 for high resolution forecast time step zero, type=fc,step=0);

E is Experiment Version Number' (as EXPVER in MARS):

'1' All current operational products.

Should any test suite data be made available in dissemination in the future, E will represent the test suite EXPVER number which might be more than one digit.

# 11. Maintenance of Requirements

## 11.1 General

Responsibility for the approval of changes to each Member State's dissemination requirements is assigned to the Member State Technical Advisory Committee (TAC) representative and to the Director of Operations at ECMWF.

ECMWF is willing to maintain requirements on behalf of Member States and make changes when necessary. Provided two working days notice are given, changes can usually be introduced on the following Tuesday. Requests for changes must be made in writing or by computer mail; they should be signed by, or originate from, the TAC representative, and should be addressed either to the Head of the “Meteorological Application Section” or to the Director of Operations, ECMWF.

Alternatively, the TAC representative of a Member State or the person authorised by the TAC representative may maintain requirements using the web facility described below.

Note that acceptance of changes to requirements is dependent upon the total requirements of a Member State in terms of products and data volume, and the total data volume for all Member States combined remaining below given limits. These limits are enforced to prevent the requirements of any one Member State having an adverse effect on the generation of products for, and dissemination of products to, the remainder of Member States. Where interactive facilities are provided, the support software imposes these limits. The limits are reviewed and revised as the capacity to generate and disseminate products increases. Any Member State encountering difficulties arising from such limits should inform ECMWF.

## 11.2 Updating dissemination requirements

The latest releases of dissemination system provide users with the web based facility for the maintenance of dissemination requirements. Dissemination web page is located on https://msaccess.ecmwf.int:9443/do/product/

requirements/. Pages are self explanatory.

It should be noted that the support software for the web based facility has been constructed to include a number of checks, such as:

- product validity
- number of products
- product size
- total product volume

Limitations on the above, which may change from time to time, are imposed to ensure that no Member State increases its total dissemination requirements in an unreasonable way and that no Member State causes a deterioration in service to other Member States. If the updating of requirements fails for any reason, the dissemination system will continue to use the unchanged requirements previously defined.

Should Member States wish ECMWF to continue to maintain their requirements, changes to such requirements may be passed to ECMWF in the usual way, in writing or by computer mail and authorised by the Technical Advisory Committee representative.

Each Member State is allocated a three letter **"*Dissemination destination*"** and one or more **"*Dissemination streams*"**. The Dissemination Destination is used as a destination address, whereas the Dissemination Stream is used to group requirements. For dissemination purposes

- products are transmitted to the destination designated by the Dissemination Destination;
- separate files of products are generated for each Dissemination Stream belonging to each destination;
- dissemination files are given names which incorporate the Dissemination Stream name.

The Dissemination Destinations and Dissemination Streams currently in use are can be viewed on https://msaccess.ecmwf.int:9443/do/product/requirements/

The format of the requirements is defined in the Section 5.2.5 above. A combined file of all Member States' requirements is transferred from HP to FUJITSU before each analysis cycle. This means that if updating of requirements can be done any time and the change will go into first next operational analysis/forecast cycle.

# 12. Repeat Transmission

## 12.1 Introduction

The latest releases of dissemination system provide users with the web based facility for the repeat of dissemination products. Dissemination web page is located on
https://msaccess.ecmwf.int:9443/do/start. Pages are self explanatory. Number of options are available. Dissemination files can be repeated individually as well as grouped into dissemination or data streams.

# 13. Appendix I - Bitmap specifications

A user can define a GRIB product for dissemination which contains only data at selected points of a latitude-longitude grid or a Gaussian grid by defining a bitmap.

To support this extension, the following addition has been made to the command language for the definition of dissemination requirements:

BITMAP = *"filename"*

where

*"filename"* is the name of a separate file containing a valid bitmap specification.

For dissemination purposes, a bitmap specification takes the form of a set of command-like definitions containing the following:

SPEC — a stand-alone command indicating that what follows is a bitmap specification

SIZE = yy:xx — where yy indicates the number of rows,
xx indicates the number of points per row.

VALUES = OFF (default) / ON — indicates whether subsequent changes to the bitmap are with respect to a bitmap preset to OFF (i.e. 0 bits), or to ON (i.e. 1 bits)

POINTS = jj:kk — where jj indicates row number, and
kk indicates which point(s) within a row take opposite value to the preset value (VALUES).

kk can take the general form of a list of values: k1/k2/k3/../kn
where the format of a value is:

kk - depicting a single point
k1-k2 - points from k1 to k2 inclusive
0 - no points.

END a stand-alone directive terminating the specification.

The following example illustrates the use of the directives above. First the dissemination requirement:

DIS,COUNTRY=EC,TYPE=FC,LEVT=PL,LEVE=500,STEP=240,FORM=GRIB,
PARA=GH,REPR=LL,GRID=0.5/0.5,AREA=4.5/0.0/0.0/4.5,
BITMAP=”ECM_001.BITMAP”

The bitmap specification is contained in a separate file, ECM_ 001.BITMAP, in the same directory as the file containing the dissemination requirements. It contains the following:

SPEC,SIZE=10:10,VALUES=OFF,
POINTS=01:03-08/10,
03:02-04/07-09,
04:02/03/08/09,
06:0,
07:01-03/08-10,
09:01-10
END

And gives the following bitmap:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Notes:

1. Within POINTS, values for rows remain defined until new values are given. Thus, in the example above:

   - row 2 is the same as row 1;
   - row 5 is the same as row 4;
   - row 8 is the same as row 7;
   - row 10 is the same as row 9.

2. The definition of row 6 simply indicates that no points are to be switched from the preset value defined in VALUES.

3. If VALUES=ON had been coded, the values in the bitmap would all be reversed, thus:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

4. Member States may define a number of bitmaps in this way; it is suggested that, at least initially, this number be kept below about 20.

5. The same bitmap may be used for different areas, provided the areas conform with one another (i.e. have the same number of rows and columns).