MARS – Introduction and basic concepts

Computer User Training Course 2017

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User Support

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Contents

Meteorological Archival and *Retrieval* System

- **Meteorological data (GRIB: fields, BUFR, ODB: observations)**
- **Large amount of data (size of archive & number of fields)**
- **Operational & Research environment**
- **Batch & interactive modes**
- **Large number of users with different requirements:**

  large datasets rarely ↔ few fields very often
- **Heterogeneous environment**

Introduction – MARS components

- **Client/Server architecture**
- **Clients: workstations, supercomputers**
- **Servers: supercomputers, dedicated servers**
- **Several databases**
- **Tape library**

Introduction – Some figures

- **144 PiB of data in ~ 320 billion ($3.2 \cdot 10^9$) meteorological fields in 16 million files**
- **~ 600 GiB of metadata**
- **$200 \cdot 10^6$ fields added daily (180 TiB)**
- **1000 active users/day executing ~ 1.5 million requests/day**
- **~ 100 TB retrieved daily**
- **Operational forecast since 1985**
- **Analysis, forecast and observations since 1900 (ERA-20C)**

Terminology – Forecast lead times

- Medium-range

  the high-resolution and the ensemble forecasts of weather, at the space and time-scales represented by the relevant model, up to 10 and 15 days ahead, respectively, and the associated uncertainty

- Extended-range (monthly)

  ensembles of individual forecasts and post-processed products of average conditions (e.g. weekly averages) up to 46 days ahead, and the associated uncertainty

- Long-range (SEAS)

  ensembles of individual forecasts and post-processed products of average conditions (e.g. monthly averages) up to 13 months ahead, and the associated uncertainty

Terminology – … more

- Re-forecast

  forecasts run for past decades necessary to estimate the model climate and the level of skill and to generate some of the operational products

- IFS

  `Integrated Forecasting System`, *the system* used at ECMWF

www.ecmwf.int/en/faq/what-naming-convention-ecmwf-real-time-products

www.ecmwf.int/en/forecasts/documentation-and-support

Meteorological content – Operational Analyses

- **4DVAR (T_{CO}1279 / 9 km outer loop, T_L255/319/399 inner loops, input to HRES)**
  - **At synoptic hours 00, 06, 12 and 18 UTC**
  - **Surface**
  - **Model levels (137)**
  - **Pressure levels (25)**
  - **Isentropic levels (15 PT, 1 PV)**

- **EDA (T_{CO}639 / 18 km outer loop, T_L191 inner loops, input to ENS)**
  - **At synoptic hours 00, 06, 12 and 18 UTC**
  - **26 members**
  - **Surface**
  - **Model levels (137)**
  - **Pressure levels (25)**
  - **Isentropic levels (16 PT, 1 PV)**

Meteorological content – HRES

- **Atmospheric Forecast (10 day forecast based on 00/12 UTC Analysis) at $T_{CO}1279$ (~9 km)**
  - **Surface**
  - **Model levels (137)**
  - **Pressure levels (25)**
  - **Isentropic levels (16 PT, 1 PV)**
  - **1 hourly steps from 0 to 90,**
    3 hourly from 93 to 144 and
    6 hourly from 150 to 240 hours

Meteorological content – ENS / ENS extended

- **Medium-range forecasts to 15 days, 91 Levels**
- **26 member Ensemble of Data Assimilations (EDA, stream elda)**
- **1 control forecast (as HRES but with lower resolution)**
- **50 different forecasts with Initial Condition Perturbations**
- **ENS Extended: 00 UTC FC extended Mondays & Thursdays to day 46**
- **20 years of 11 member ensemble of re-forecasts**

	#FC	ENS Day 0 - 15	ENS Extended Day 16 - 46
ENS-CF	1	$T_{co}639$ (~18km)	$T_{co}319$ (~36km)
ENS-PF	50	$T_{co}639$ (~18km)	$T_{co}319$ (~36km)

www.ecmwf.int/en/forecasts/documentation-and-support/extended-range-forecasts

Meteorological content – ENS products

Derived probability products

- Empirical distribution
- Ensemble mean
- Ensemble standard deviation
- Event probability
- Extreme forecast index
- Extreme forecast index control
- Probability boundaries
- Probability distribution
- Shift of tails
- Time-averaged ensemble mean
- Time-averaged ensemble standard deviation

Clustered products

- Cluster means
- Cluster representatives

Derived forecasts products

- Forecast maximum
- Forecast mean
- Forecast minimum
- Forecast standard deviation

Trajectories

- Trajectory forecast

Meteorological content – Ocean-Wave component (global)

Configuration	Forecast/ Analysis	Members	Horizontal resolution	Number of directions	Number of frequencies
HRES-SAW	Analysis + forecast 0–10 days	1	11 km	36	36
HRES-WAM	Analysis + forecast 0–10 days	1	14 km	36	36
ENS-WAM	Forecast 0–15 days	51	28 km	24	30
ENS-WAM extended	Forecast 16–46 days	51	55 km	12	25
SEAS-WAM	Forecast 0–7/13 months	51	111 km	12	25

Meteorological content – Boundary-Condition Programme (BC)

HRES forecast (Short cut-off forecast T_{CO}1279L137 at 06/18)

- Analysis (4DVAR)
- Forecast (to 90 hours) in hourly steps
- 00/12 UTC AN/FC is taken from HRES

Additional ENS at 06/18 UTC available since 8 July 2015

- 3-hourly steps out to forecast range 144 hours

Real-time data only available for participating MS

Meteorological content – Seasonal System 4

SEAS – atmosphere-ocean coupled model (51 members)

- **Global forecasts from 00 UTC to 7 months: (once a month)**
  - **atmosphere: ~75 km resolution, 91 levels (T255 L91)**
  - **ocean: NEMO – ORCA1 grid (~1˚x1˚ with equatorial refinement), 42 levels**
- **In February, May, August and November, 15 of the 51members are extended to 13 months**
- **Re-forecasts: 15 members (0-13m) covering 30 years (1981-2010)**
- **Part of the EUROSIP system, with UK Met Office, Météo France and NCEP**
- **Availability of products: 12:00 on the 8th of each month**

http://www.ecmwf.int/en/forecasts/documentation-and-support/long-range

Meteorological content – Monthly Means

Averaged over each calendar month

- **Atmosphere / Wave**
  - **Analysis**
- **Surface / pressure levels**
- **Simulated satellite data**

Meteorological content – Special datasets (1/2)

Projects

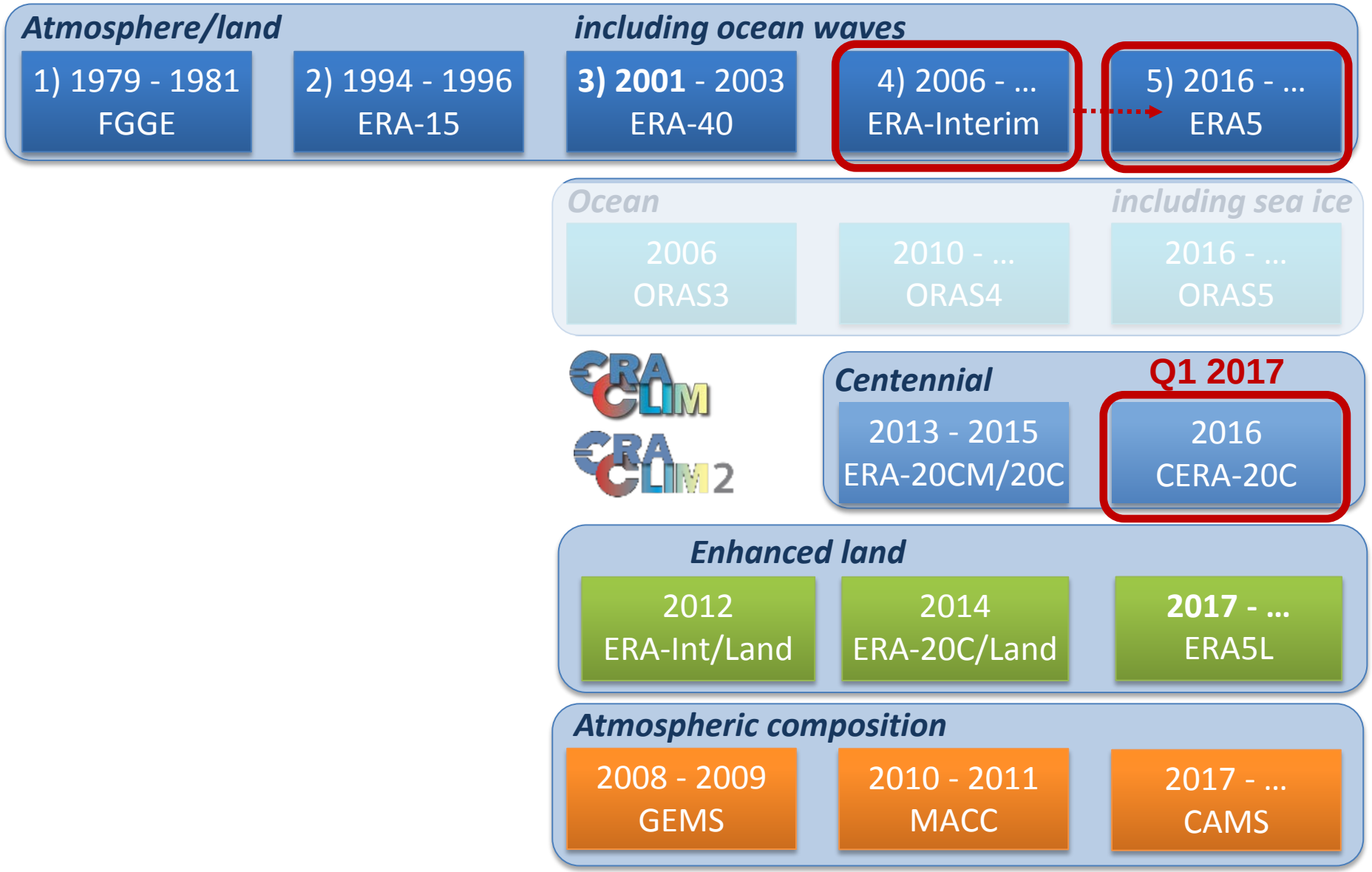
- **DEMETER: Multimodel Ensemble for seasonal to Interannual prediction**
- **Data targeting system**
- **ENSEMBLES**
- **EURO4M**
- **MACC**
- **PROVOST**
- **ECSN-Hyretics**
- **…**

https://software.ecmwf.int/wiki/display/UDOC/MARS+content#MARScontent-Specialdatasets

Meteorological content – Special datasets (2/2)

- **IFS Research experiments**
  - **ECMWF**
  - **Member States**
- **Member States' Projects**
  - **COSMO-LEPS**
  - **Aladin-LEAF**
  - **…**

Reanalyses produced at ECMWF



Meteorological content – Reanalysis datasets

www.ecmwf.int/en/research/climate-reanalysis/browse-reanalysis-datasets

ECMWF — About | Forecasts | Computing | Research | Learning | Log in | Search site | Go

Browse reanalysis datasets

- Research homepage
- Data Assimilation
- Modelling and prediction
- Climate reanalysis
  - **Reanalysis datasets**
  - ERA-Interim
  - ERA-Interim/Land
  - ERA-20C
  - ERA-20CM
  - CERA-20C
  - Coupled Earth-system reanalysis
  - Reanalysis for climate monitoring
  - Ocean reanalysis
- Projects
- Publications
- Special projects

Dataset	Archive	Time period	Atmosphere	Atmospheric composition	Ocean waves	Ocean sub-surface	Land surface	Sea Ice	Observation Feedback Archive
ERA-Interim	Download	1979-present	✓		✓		✓		Expected soon...
ERA-Interim/Land	Download	1979-2010					✓		
CERA-20C	Download	1901-2010	✓		✓	✓	✓	✓	✓
ERA-20CM	Download	1900-2010	✓		✓		✓		
ERA-20C	Download	1900-2010	✓		✓		✓		✓
ERA-20CL	Expected soon...	1900-2010					✓		
ERA-40	Download	1957-2002	✓		✓		✓		
ERA-15	Download	1979-1993	✓				✓		
ORAS4	Download	1958-2015				✓			
ORAP5	Download	1979-2013				✓		✓	
ORAS5	Expected soon...					✓		✓	

ATLAS AND PICTURE GALLERY

An atlas of key atmospheric variables was produced for ERA-40 and there is picture gallery for ERA-15

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ERA5 test dataset

Climate reanalysis

Secure | https://climate.copernicus.eu/climate-reanalysis

Copernicus Europe's eyes on Earth — Climate Change Service — Contact us — Search

About C3S | NEWS & MEDIA | EVENTS | TENDERS | PRODUCTS | SERVICES | HELP & SUPPORT

Climate reanalysis

home » products

- AVERAGE SURFACE AIR TEMPERATURE MONTHLY MAPS
- CLIMATE REANALYSIS
- SEASONAL FORECASTS

Daily mean temperature for January 2016 from ERA5 (Celsius)

NEWS

26 Jan 2017
Copernicus at the 4th International Conference on Energy & Meteorology (ICEM)

12 Jan 2017
Principal Climate Scientist – an exciting new job opportunity at C3S

13 Dec 2016
#OpenDataHack @ECMWF - explore creative uses of open data

06 Dec 2016
Report Reassesses Variations in Global Warming

28 Nov 2016
Copernicus at Wissenswerte

More News

ERA5 Climate Reanalysis Data

Reanalysis is a key contribution to the implementation of the EU-funded Copernicus Climate Change Service (C3S) delivered by the European Centre for Medium-Range Weather Forecasts (ECMWF). Reanalysis data are used for monitoring climate

https://climate.copernicus.eu/climate-reanalysis

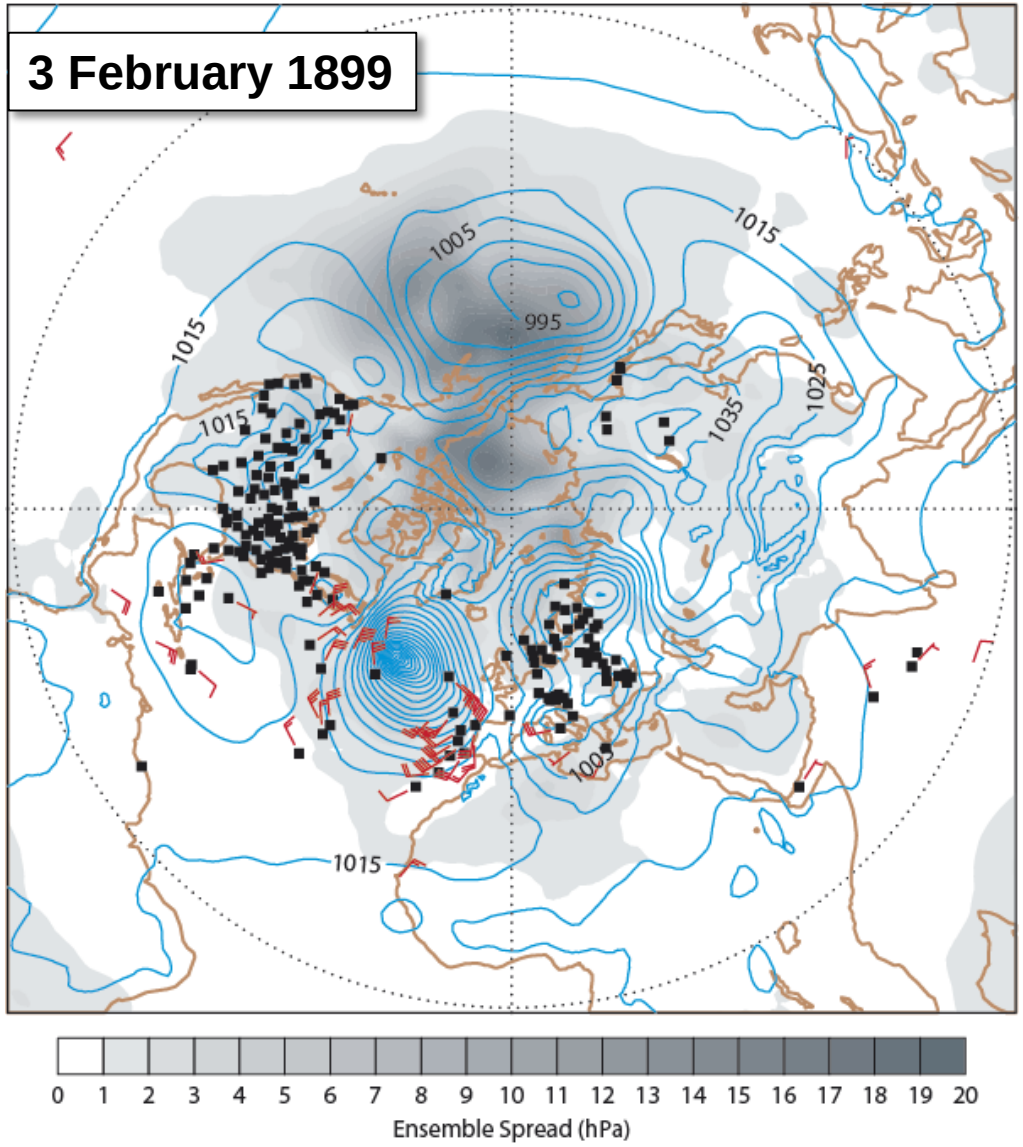
Meteorological content – ERA-Interim

- **38 years (1/1979 – 12/2016) of validated ERA-Interim analysis products are available**
- **Continued in near real-time (with ~2 months delay)**
- **Uses IFS Cycle 31r2, and 12h-4DVar**
- **Resolution:**
  - **Horizontal: T255, N128 (~0.7º)**
  - **Vertical: 60 ML, 37 PL, 16 PT, PV=±2**
- **Analyses at 00/06/12/18, Forecasts at 00/12 to 240 h**
- **Subset of products also publicly available on the ECMWF Data Server at full resolution**
- **Will be superseded by ERA5 in 2017/2018**

ERA5: the ERA-Interim replacement

	ERA-Interim	ERA5
Period	1979 - present	Initially 1979 – present, later addition 1950-1978
Start of production	August 2006	2016
Assimilation system	2006, 4D-Var	2016 ECMWF model cycle, 4D-Var
Model input (radiation and surface)	As in operations, *(inconsistent sea surface temperature)*	***Appropriate for climate***, e.g., evolution greenhouse gases, volcanic eruptions, sea surface temperature and sea ice
Spatial resolution	79 km globally 60 levels to 10 Pa	***31 km globally*** 137 levels to 1 Pa
Uncertainty estimate	-	Based on a 10-member ***4D-Var ensemble*** at 62 km
Land Component	79km	9km
Output frequency	6-hourly Analysis fields	***Hourly*** (three-hourly for the ensemble), ***Extended list of parameters ~ 5 Peta Byte***
Extra Observations	Mostly ERA-40, GTS	Various ***reprocessed CDRs***, ***latest instruments***
Variational Bias correction	Satellite radiances	Also ozone, aircraft, surface pressure

ERA-20C: A terrific storm at sea



TERRIFIC STORMS AT SEA

Steamships from All Quarters Report Extremely Rough Voyages.

ALL MORE OR LESS BATTERED

Vessels Sighted in Distress and Abandoned — Blinding Snow and Waves Like Mountains.

All the steamers that came in yesterday were coated with ice from the tops of the masts down to the water line, and all had passed through storms of blinding snow and mountainous waves. The British steamer Ethelgonda, from Bristol and Swansea, which left the latter port on Jan. 19, ran into a gale of hurricane force, and seas swept her decks repeatedly. So fierce was the wind that the boat drifted before the gales and was barely able to keep steerage way. She anchored outside the bar late Sunday afternoon. The cable parted and she lost her anchor, together with 100 fathoms of chain. Then the great snowstorm drove her 150 miles off the shore. She succeeded in getting back late on Tuesday night.

The French liner La Bretagne, from Havre, came in a little before noon yesterday, with 58 cabin and 225 steerage passen-

The New York Times
Published: February 16, 1899
Copyright © The New York Times

Meteorological content – TIGGE

- THORPEX Interactive Grand Global Ensemble
- Global ensemble forecasts to around 14 days generated routinely at different centres around the world

  ECMWF, JMA (Japan), Met Office (UK), CMA (China), NCEP (USA), MSC (Canada), Météo-France (France), BOM (Australia), CPTEC (Brazil), KMA (Korea)

- Data archived in GRIB 2
- TIGGE-LAM data since 1/1/2013

http://tigge.ecmwf.int

Meteorological content – S2S

- Sub-seasonal to seasonal prediction
- Joint WWRP/THORPEX-WCRP research project established to improve forecast skill and understanding on the sub-seasonal (up) to seasonal time scale, and promote its uptake by operational centres and exploitation by the applications community
- Following the TIGGE approach
- Provides real-time + reforecasts
- Contains data from 11 centres

https://software.ecmwf.int/wiki/display/S2S/Home

Meteorological content – Observations & Feedback

- **Observations**
  - **Surface data**
  - **Vertical soundings**
  - **Upper-air data**
  - **Satellite**
- **Analysis Input**
- **ODB feedback (superseded Analysis Feedback)**
- **MONDB feedback**

Meteorological content – Data formats

WMO formats

- **Fields in GRIB (GRid In Binary), ECMWF local extensions**
  - **Spherical Harmonics (upper-air fields, $T_{CO}1279$)**
  - **Gaussian Grid (surface fields, O1280)**
  - **Latitude/Longitude (wave and ocean products)**

- **Observations in BUFR (Binary Universal Form Representation)**
  - **Instrument specific**

ECMWF/IFS format

- **ODB (Observational Data Base)**
  - **Observation feedback**

MARS – ODB

- **In the IFS observations are handled by ODB**
- **ODB is a**
  - **Hierarchical in-core database with a data definition and query language: ODB/SQL**
  - **A data format**
  - **. . .**
- **ODB Observation Feedback (ofb) data is archived in MARS**
  - **Improve the representation of feedback data in MARS meta data**
  - **Introduce SQL capabilities to request feedback data**
- **To improve the handling of observations, ODB will be further integrated into ECMWF systems**
- **ODB can be handled by Metview, see**

software.ecmwf.int/wiki/display/METV/Tutorials

MARS – future development

- Content
  - YOPP
  - CERA-20C consolidation
  - CERA SAT
  - UERRA (Uncertainties in Ensembles of Regional Re-Analysis)
  - JRA-55
  - Copernicus datasets (ERA5, Multi-model Seasonal predictions, Regional Reanalyses, …)

- Architecture
  - ecCodes
  - New interpolation package
  - Alignment with new Product Generation

MARS language

Mechanism to *name* fields

Request syntax:

```
verb,
   keyword1    = value1,
   …           = value2,
   keywordN    = valueN
```

- **verb: action to be taken (e.g. retrieve, list, read)**
- **keyword: a known MARS variable, e.g. type or date**
- **value: value assigned to the keyword, e.g. Analysis or temperature**

MARS language

- **verb and keyword=value separated by commas, but last one**
- **Spaces and tab characters are ignored**
- ***, ! and # comment until end-of-line**
- **Directives are not case sensitive**
- **Values: predefined names, numeric values or strings (filenames)**
- **Abbreviations: enough letters to uniquely identify keyword or value**
- **Acronyms: usually initial letters of names**
- **/ is used as list separator → specify pathnames in quotes**

MARS language – Retrieve request

```
retrieve,                                   action
    class    = od,                            identification
    stream   = oper,
    expver   = 1,

    date     = -3,                           date & time related
    time     = 12,

    type     = analysis,                     data related
    levtype  = model levels,
    levelist = 1/to/137,
    param    = temperature,

    grid     = 2.5/2.5,                      post-processing

    target   = “analysis”                    storage
```

MARS language – Identification of archive

class	**ECMWF classification (od, rd, e4, …)**
stream	**originating forecasting system or (oper, wave, enfo, seas, …)**
expver	**version of the experiment (01 operational, 11, aaaa)**
domain	**area covered by the data (Global, Mediterranean, …)**
origin	**originating centre of the data (kwbc, egrr, …)**
system	**seasonal forecast operational system (1, 2, 3)**
method	**to specify how the seasonal forecast is produced, e.g. in System 2, method=0 for runs without ocean assimilation (0, 1, …, 3)**

MARS language - Date & time

time	**base time or observation time (00, 06, 09:30, …)**
date	**base date of the model (-1, 20010225, …)**
step	**forecast time-step [hours] from base time (12, 24, 240, …)**
reference	**reference forecast time step for EPS tube (96,…)**
refdate	**date of real-time forecast associated to re-forecast/hindcast (stream=mnfh)**
hdate	**base date of a re-forecast/hindcast (stream=enfh)**
range	**observations: period in minutes from base time (360,…)** **ocean fields: extension of the time series/average**
fcmonth	**month from seasonal forecast base date (1, 6, …)**
fcperiod	**period, in days, for an averaged field (26-32)**

MARS language – Fields

type	**type of field (an, fc, …)**
levtype	**type of level (pl, ml, sfc, pt, pv)**
levelist	**levels for the specified levtype (off if levtype=sfc)**
param	**meteorological parameter (t, temperature, 130, 30.128)**
number	**ensemble member (1, 2, …)**
channel	**brightness temperature frequency band**
diagnostic, iteration	**sensitivity forecast products**
frequency, direction	**2-d wave spectra products**
product, section, latitude, longitude	**ocean products**

MARS language – Observations & images

type	**type of observations or images (ob, fb, ai, af, im)**
obstype	**observation subtype (s, air) or image channel**
ident	**WMO observation station number or satellite identifier**
duplicates	**whether duplicated observations are to be kept or not**
block	**WMO block number for observation**
time	**analysis time (types ai, af) or observations time (types ob, fb, im)**
range	**denotes the period, in minutes, starting from time**

MARS language – ODB

type	Type of ODB information, ofb (ODB Feedback), mfb (MONDB Feedback), oai (ODB Analysis Input)
reportype	classification to index ODB data (16020)
obsgroup	Grouping of report types (optional)
type	Type of ODB information, ofb (ODB Feedback), mfb (MONDB Feedback), oai (ODB Analysis Input)
time	time represents the analysis time (ODB column antime)
filter	SQL filter query ("select lat,lon,obsvalue where varno=39“)

ODB Governance database: http://apps.ecmwf.int/odbgov/

MARS language – Storage

target	**UNIX pathname where retrieved data is stored**
source	**UNIX pathname from where to read data**
fieldset	**temporary storage; can be considered a MARS variable**

Unix pathnames (using /) have to be enclosed in quotes, e.g.

```
target = "/scratch/ms/gb/uid/analysis"
```

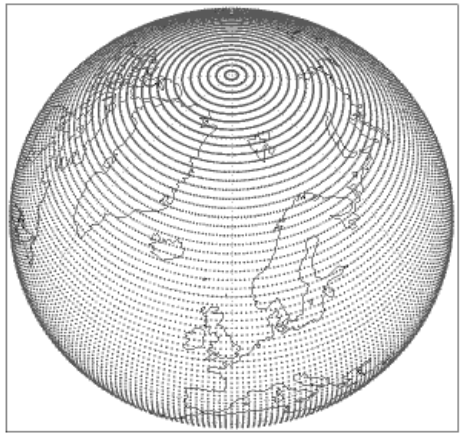
MARS language - Post-processing (1/2)

grid output grid mesh

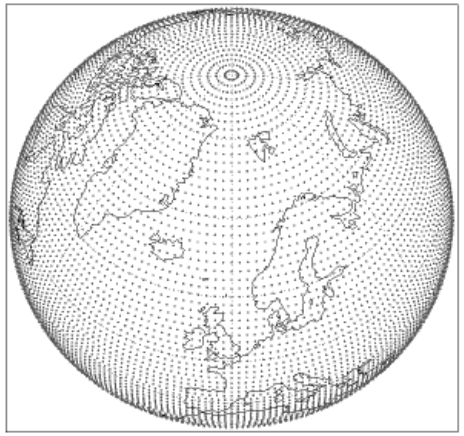
- Latitude/longitude increments in degrees (2.5/2.5)
- Type and resolution of Gaussian grid, e.g.
  - grid = F320 – full (or regular) Gaussian grid
  - grid = N320 – ECMWF original reduced Gaussian grid (only selected resolutions supported)
  - grid = O320 – ECMWF octahedral (reduced) Gaussian grid

All above with 320 latitude lines between the pole and equator

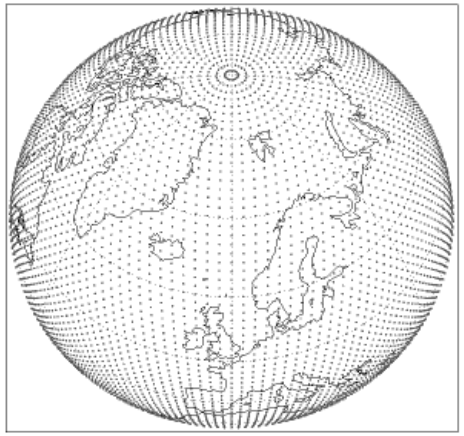
F80 regular (or full)



N80 original reduced



O80 octahedral reduced



MARS language - Post-processing (2/2)

area	**desired sub-area in degrees (north/west/south/east)**
frame	**number of grid points from sub area inwards (5)**
resol	**triangular truncation (319, auto, av)**
rotation	**lat/lon of South Pole**
accuracy	**number of bits per data value in GRIB (16)**
style	**specify post-processing style (dissemination)**

MARS language – Execution control

expect	**number of expected fields (1000, any, …)**
database	**where to look for the data**
use	**hint about frequency of use (infrequent)**

MARS language – Values

- **Single value, predefined names, numbers, mnemonics**

  param = temperature

- **List of values, separated by /**

  step = 12/24/48

- **Range of values, using keywords: to, / and by**

  date = 20020101/to/20020131

  step = 24/to/240/by/24

MARS language – Values

- **Expected number of fields is computed by multiplying number of values after expansion of ranges**

  date = 20020101/to/20020131 **31 fields**

- **Certain keywords accept all as valid value**

  levelist = all

- **Most keywords accept off as valid value**

  levtype = surface,

  levelist = off

- **Not all possible combinations keyword = value name an archived field**

Request examples – Interim Reanalysis

Retrieval of snow depth from the ERA-Interim archive for December 2007, for all analysis base times. It retrieves 124 fields.

```
retrieve,
      class     = ei,
      stream    = oper,
      expver    = 1,
      date      = 20071201/to/20071231,
      time      = 00/06/12/18,
      type      = an,
      levtype   = sfc,
      param     = sd,
      target    = "era-int.200712.sd"
```

Request examples - Ensemble forecast

Retrieval of surface temperature and 10-m wind components (U and V), 20 first members of the EPS for 2nd Jan 2001 for time steps 12, 36 and 60. It retrieves 180 fields.

```
retrieve,
        class   = od,
        stream  = enfo,
        expver  = 1,
        date    = 20010102,
        time    = 12,
        step    = 12/36/60,
        type    = pf,
        levtype = sfc,
        param   = st/10u/10v,
        number  = 1/to/20,
        target  = “perturbed.sfc”
```

Request examples – Operational analysis

Retrieval of sea surface temperature for first 10 days of May 2002, all synoptic times. It retrieves 40 fields.

```
retrieve,
        class   = od,
        stream  = oper,
        expver  = 1,
        date    = 20020501/to/20020510,
        time    = 00/06/12/18,
        type    = an,
        levtype = sfc,
        param   = sea surface temperature,
        target  = “sst”
```

Request examples – ODB observation feedback

Retrieval of 2mt observation feedback from conventional data for 12 UTC analysis run on 1 February 2015.

```
retrieve,
    class    = od,
    stream   = oper,
    expver   = 1,
    date     = 20150201,
    time     = 12,
    type     = ofb,
    obsgroup = conv,
    filter   = “select lat,lon,obsvalue where varno=39”,
    target   = “2mt.odb”
```

Retrieving data – Calling MARS in a script

- **directives from input stream**

```
mars <<EOF
retrieve,
  type   = an,
  date   = -1,
  target = “$SCRATCH/my_an”
EOF
```

- **directives from file**

```
cat > my_request <<EOF
retrieve,
  type   = an,
  date   = -1,
  target = “$SCRATCH/my_an”
EOF
mars my_request
```

MARS Practical

Point your browser to

software.ecmwf.int/wiki/display/UDOC/MARS+example+requests

or on software.ecmwf.int navigate to

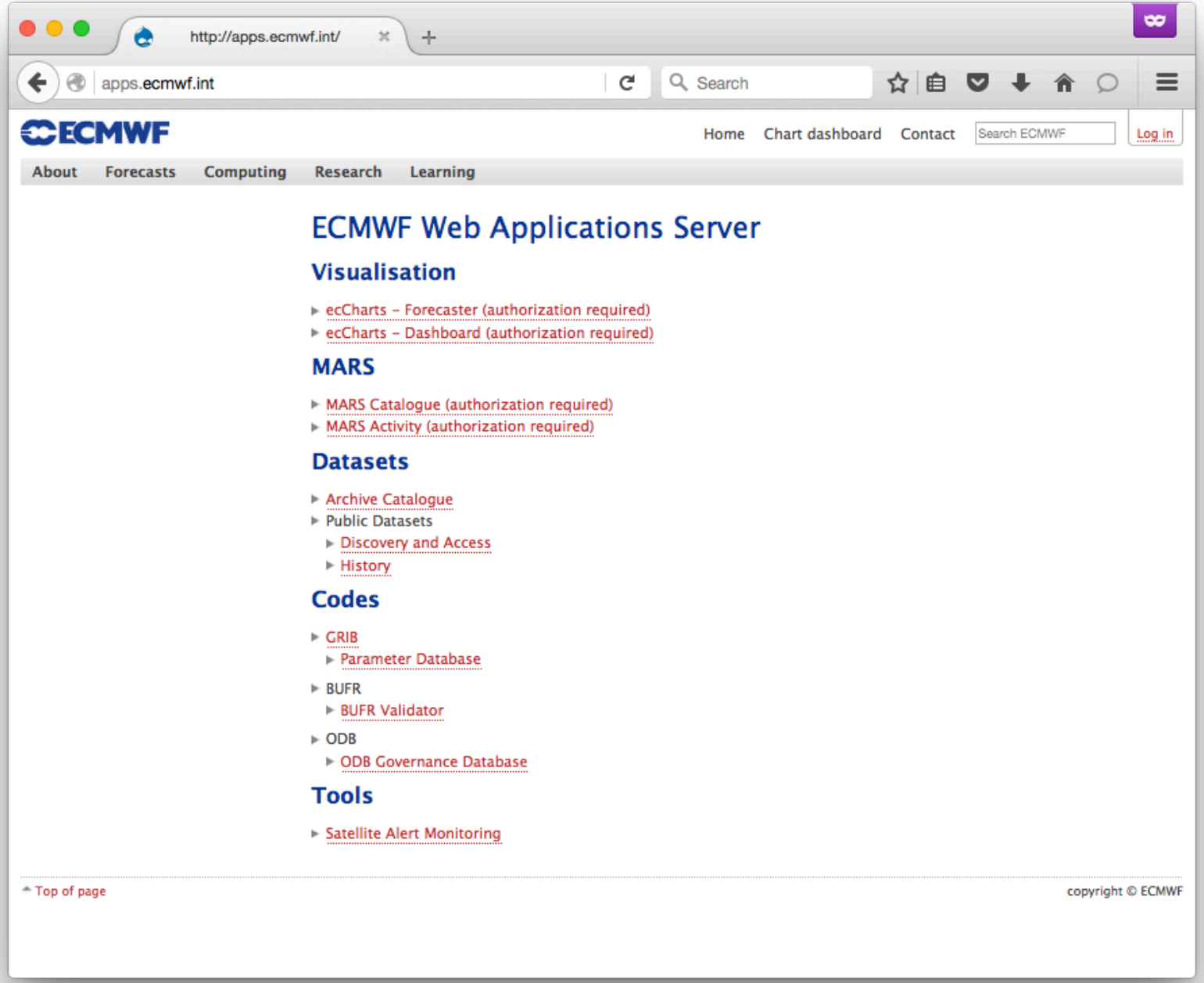
User Documentation > MARS user documentation > MARS example requests

and follow the instructions

Retrieving data – Hints

- **Default values: minimize their use**
- **No semantic check (only syntax is checked)**
- **MARS messages**
  - **INFO** **request execution and report**
  - **WARNING** **unusual aspect of execution**
  - **ERROR** **system or data errors**
  - **FATAL** **terminates execution**

apps.ecmwf.int



MARS Catalogue – apps.ecmwf.int/mars-catalogue/

Web interface to entire archive content

- Content browsing of *every* field in the archive
  - more up to date than static content documentation
- URL based on MARS requests (can be edited & bookmarked)
- Real-time (dynamic access to metadata)
- Create MARS requests (without checking availability)
- Check availability of data
- Retrieval in GRIB and NetCDF for few fields

MARS activity – apps.ecmwf.int/mars-activity/

Server activity / MARS queue

- **Show system activity**
- **Monitor your requests**
- **Learn how the queuing system works**
  - **Reason for queued requests**

Parameter database - apps.ecmwf.int/codes/grib/

GRIB table based view

- Links to IFS documentation
- Links to comprehensive list of class, stream and type

https://software.ecmwf.int/wiki/display/GRIB/Documentation

Retrieving data – Helpers

Some useful tools

- **`grib_ls, grib_dump`, …**
- Metview examiners
  - **`metview -e <grib|bufr|netcdf|odb> <file>`**
- CDO - Climate Data Operators
  - See https://code.zmaw.de/projects/cdo

Retrieving data – Conversion to NetCDF

GRIB API tool **`grib_to_netcdf`**

- To convert a GRIB file to NetCDF format
- GRIB must be a regular lat/lon grid or a regular Gaussian grid
  - i.e. the key "typeOfGrid" should be "regular_ll" or "regular_gg"
- Example

```
> grib_to_netcdf -o output.nc input.grib1
```

See https://software.ecmwf.int/wiki/display/GRIB/grib_to_netcdf

MARS Architecture

- **Client/Server**
- **Protocol: MARS request**
- **Clients, C program + GRIB API + libemos library (Interpolation)**
  - Supercomputers
  - Workstations and Servers
  - Applications like Metview (local / at ECMWF)
  - WebMARS
  - Data Server
  - Web API

MARS Architecture – Servers

- **Reports Database (RDB), on-line observations (for Operations only)**
- **Fields Database (FDB)**
  - **Data produced by most recent cycles or experiments**
  - **Very fast access (on-line data)**
  - **Suitable for model input**
- **ODB server, on-line ODB on supercomputers**
- **Main Archives (multiple servers)**
  - **Dedicated Linux servers / clustered architecture**
  - **Terabytes of disk space**
  - **Tape management SW: HPSS**
  - **Oracle (Sun) SL8500 Automated Tape Libraries**

MARS Architecture - Request execution

1) **Check syntax (MARS language and request syntax)**
2) **Print request to be processed**
3) **Query all Supercomputer's FDB**
4) **Query main archives (if data not in FDB)**
5) **Transfer data**
6) **Post-processing while transferring (if needed)**
7) **Report on result**

Request execution (1/3)

```
MARS - INFO - **
MARS - INFO - **

PPDIR is /ppdir/data/rs60005
mars - INFO   - 20090225.102926 - Welcome to MARS
retrieve,
   class    = od,
   type     = an,
   expver   = 1,
   date     = -7,
   time     = 00/to/18/by/6,
   param    = t,
   levtype  = model level,
   levelist =  1/to/91,
   area     = E,
   grid     = 2.5/2.5,
   target   = "t.ll"

mars - INFO   - 20090225.102942 - Processing request 1
mars - WARN   - 20090225.102942 - Area not compatible with grid
mars - WARN   - 20090225.102942 - Area changed from 73.5/-27/33/45 to 75/-27.5/32.5/45
```

Request execution (2/3)

```
RETRIEVE,
    CLASS      = OD,
    TYPE       = AN,
    STREAM     = DA,
    EXPVER     = 0001,
    REPRES     = SH,
    LEVTYPE    = ML,
    LEVELIST   = 1/2/3/4/5/6/7/8/9/10/11/12/13/14/15/16/17/18/19/20/21/22/23/
24/25/26/27/28/29/30/31/32/33/34/35/36/37/38/39/40/41/42/43/44/45/46/47/48/49/5
0/51/52/53/54/55/56/57/58/59/60/61/62/63/64/65/66/67/68/69/70/71/72/73/74/75/76
/77/78/79/80/81/82/83/84/85/86/87/88/89/90/91,
    PARAM       = 130,
    DATE       = 20090218,
    TIME       = 0000/0600/1200/1800,
    STEP       = 00,
    DOMAIN     = G,
    TARGET     = "t.ll",
    RESOL      = AUTO,
    AREA       = 75/-27.5/32.5/45,
    GRID       = 2.5/2.5,
    PROCESS    = LOCAL
```

Request execution (3/3)

```
mars - INFO   - 20090225.102942 - Requesting 364 fields
819480 FDB; INFO;   DB$_    Fields DataBase 4.2
mars - INFO   - 20090225.102942 - Calling mars on 'marsod', callback on 61767
mars - INFO   - 20090225.104347 - Mars client is on ecgate.ecmwf.int (136.156.240.111) 61767
mars - INFO   - 20090225.104347 - Mars server is on hdr16.ecmwf.int (136.156.228.176) 57793
mars - INFO   - 20090225.104347 - Server task is 526 [marsod]
mars - INFO   - 20090225.104347 - Request cost: 364 fields, 445.507 Mbytes online [marsod]
mars - INFO   - 20090225.104347 - Transferring 467148136 bytes
mars - WARN   - 20090225.104348 - INTFB: Resolution automatically set to   63
mars - INFO   - 20090225.104423 - 364 fields retrieved from 'marsod'
mars - INFO   - 20090225.104423 - 364 fields have been interpolated on 'ecgate'
mars - INFO   - 20090225.104423 - Request time:  wall: 14 min 42 sec  cpu: 12 sec
mars - INFO   - 20090225.104423 - Read from network: 445.51 Mbyte(s) in 24 sec  [18.43 Mbyte/sec]
mars - INFO   - 20090225.104423 - Processing in marsod: wall: 14 min 6 sec
mars - INFO   - 20090225.104423 - Visiting marsod: wall: 14 min 42 sec
mars - INFO   - 20090225.104423 - Post-processing: wall: 11 sec cpu: 9 sec
mars - INFO   - 20090225.104423 - Memory used: 13.48 Mbyte(s)
mars - INFO   - 20090225.104423 - No errors reported
```

Retrieving data

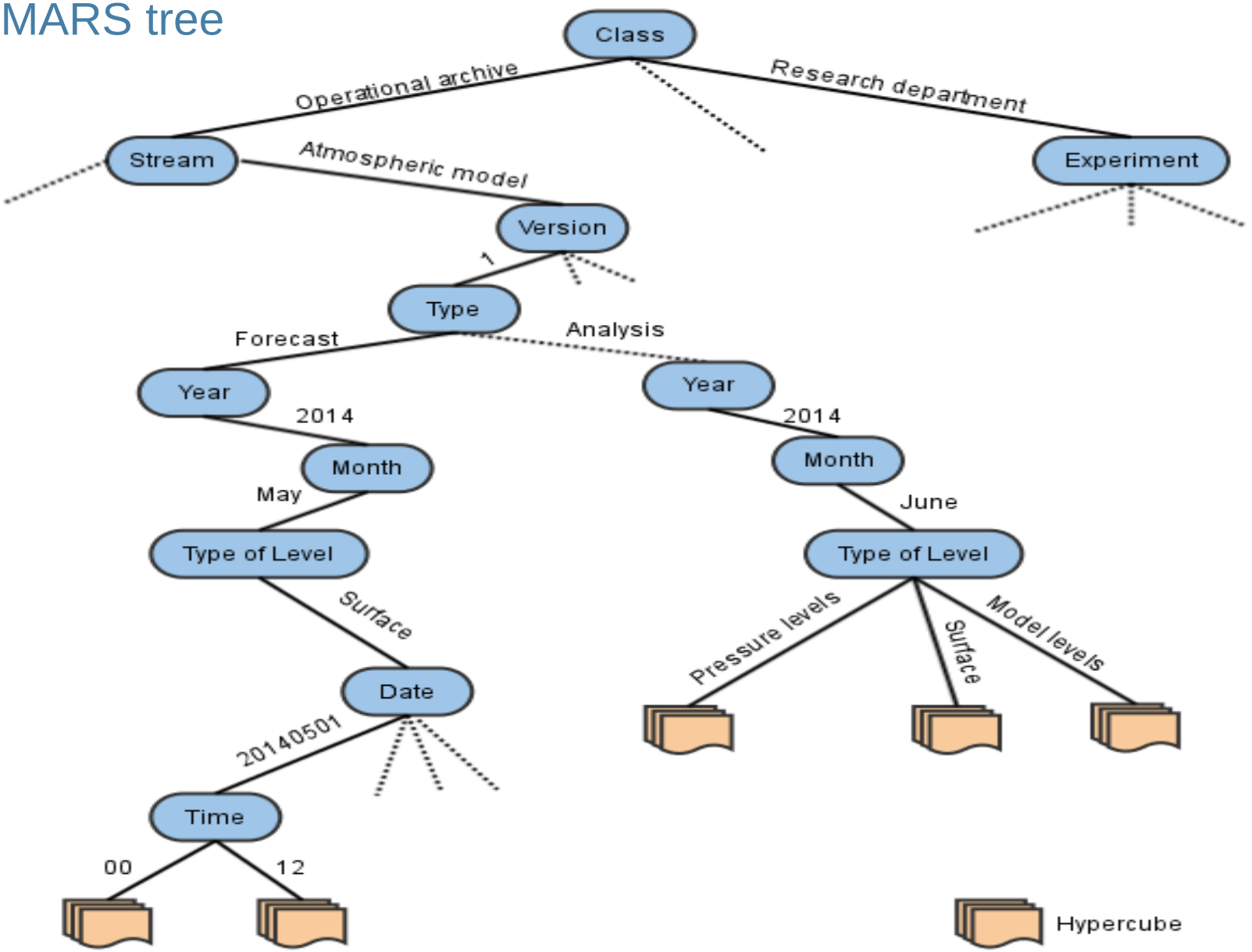
Request scheduling

- Queuing system
  Priorities: user, request age, request cost (number of tapes and fields)

Data collocation

- MARS tree
- Archive objects (for OD data)
  - 1 file per month of AN (1 level type, all times, levels, params)
  - 1 file per forecast (1 level type, all steps, levels, params)
  - 1 file per EPS (1 level type, all steps, members, levels, params)
  - 1 file per month of ERA Interim FC (1 level type, all levels, times, steps, params)

Retrieving data - MARS tree



Retrieving data - Post-processing

- **Conversions**
  - **SH ⟶ SH (reduced truncation), GG, LL**
  - **GG (reduced) ⟶ GG (lower resolution or regular), LL**
  - **LL ⟶ LL (lower resolution)**
- **Sub-area extractions (GG, LL, waves), reduces data volume**
- **Derived fields (e.g. U and V from vorticity and divergence)**
- **Rotation**

Retrieving data - Post-processing

Truncation before interpolation, reduces necessary resources

Grid increment	Truncation
2.5 ≤ Δ	T63
1.5 ≤ Δ < 2.5	T106
0.6 ≤ Δ < 1.5	T213
0.4 ≤ Δ < 0.6	T319
0.3 ≤ Δ < 0.4	T511
0.15 ≤ Δ < 0.3	T799
0.09 ≤ Δ < 0.15	T1279
0.0 ≤ Δ < 0.09	T2047

Retrieving data – Efficiency

- **Explore data in archive catalogue - collocation**
- **Estimate amount of data (list command)**
  - **Number of fields (up to tens of thousands / request)**
  - **Data size (up to several Gigabytes / request)**
- **Check computing resources: quota, CPU time, …**
- **Use local target disk (e.g. $SCRATCH for MS users)**
- **Retrieve as much data from the same tape as possible**
- **Reduce number of tapes involved (better scheduling)**
- **Avoid constantly accessing the same tape**
- **Do not create unnecessary sub-archives**

Retrieving data – Data access

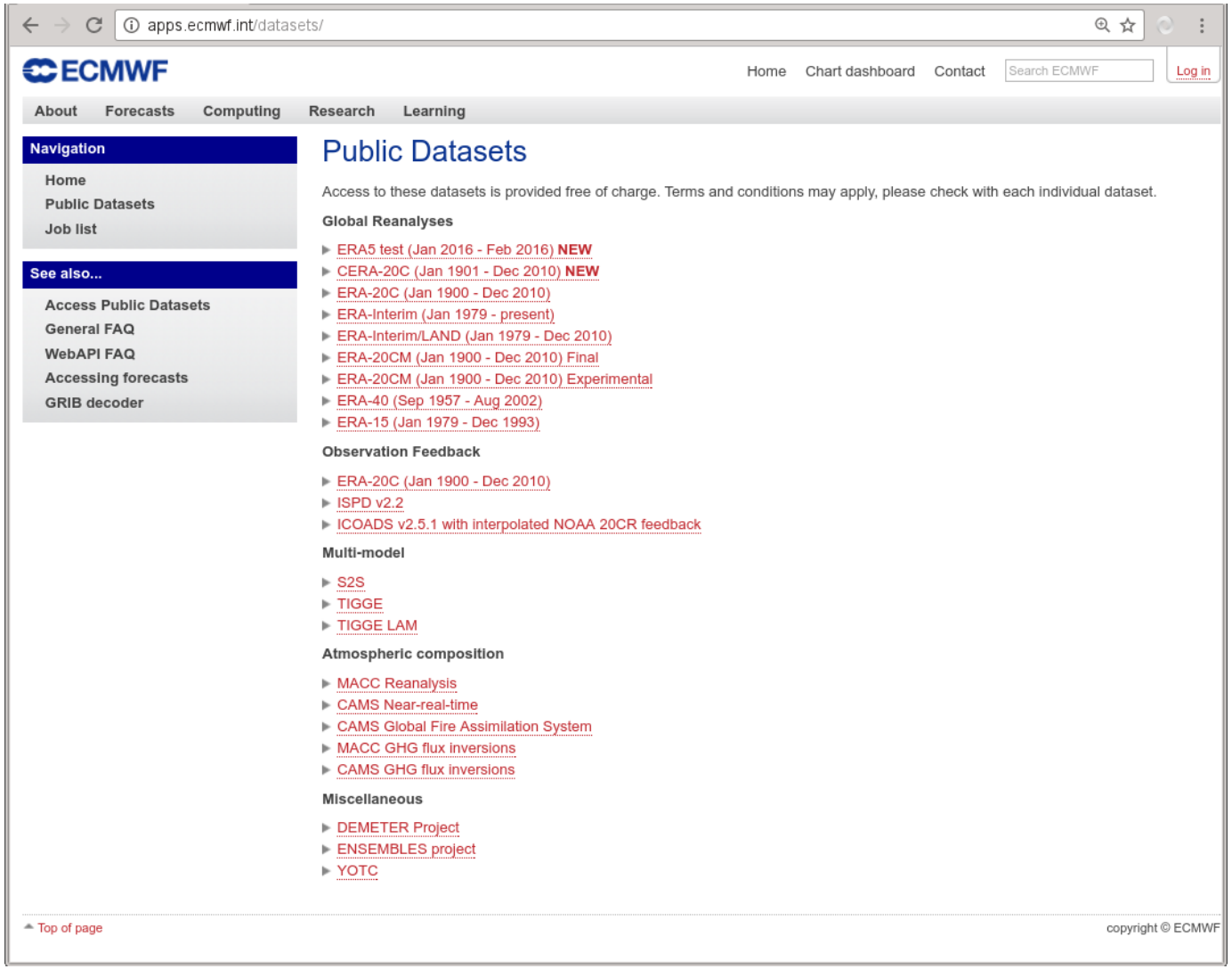
- Archived data
  - Available to all registered users
- Current (valid) data, i.e. data for which the value of

$$(\text{DATE} + \text{TIME} + \text{STEP}) + 24 \text{ hours} \geq \text{current date/time}$$

  - Needs special registration
  - Contact your Computing Representative
- Boundary Conditions Project & COSMO-LEPS
  - Restricted to participating MS / individual users
- Restrictions for Observations, TIGGE, EUROSIP…
- Data is available according to dissemination schedule, see
  - www.ecmwf.int/en/forecasts/documentation-and-support/data-delivery/dissemination-schedule
- For time-critical retrievals, use time-critical framework (option 1)

Public Datasets – http://apps.ecmwf.int/datasets/

- **Public distribution of data (licensing depends on datasets)**
  - **Self-registration**
- **Based on ecCharts framework**



Web API

- To access MARS and ECMWF Public Datasets in batch
  - Delivers data directly to the users' machine
- Alternative to retrieve – transfer jobs on ecgate
- Requirements
  - Computer or Web User ID
  - client library, e.g. python
  - API key

See https://software.ecmwf.int/wiki/display/WEBAPI/Access+MARS

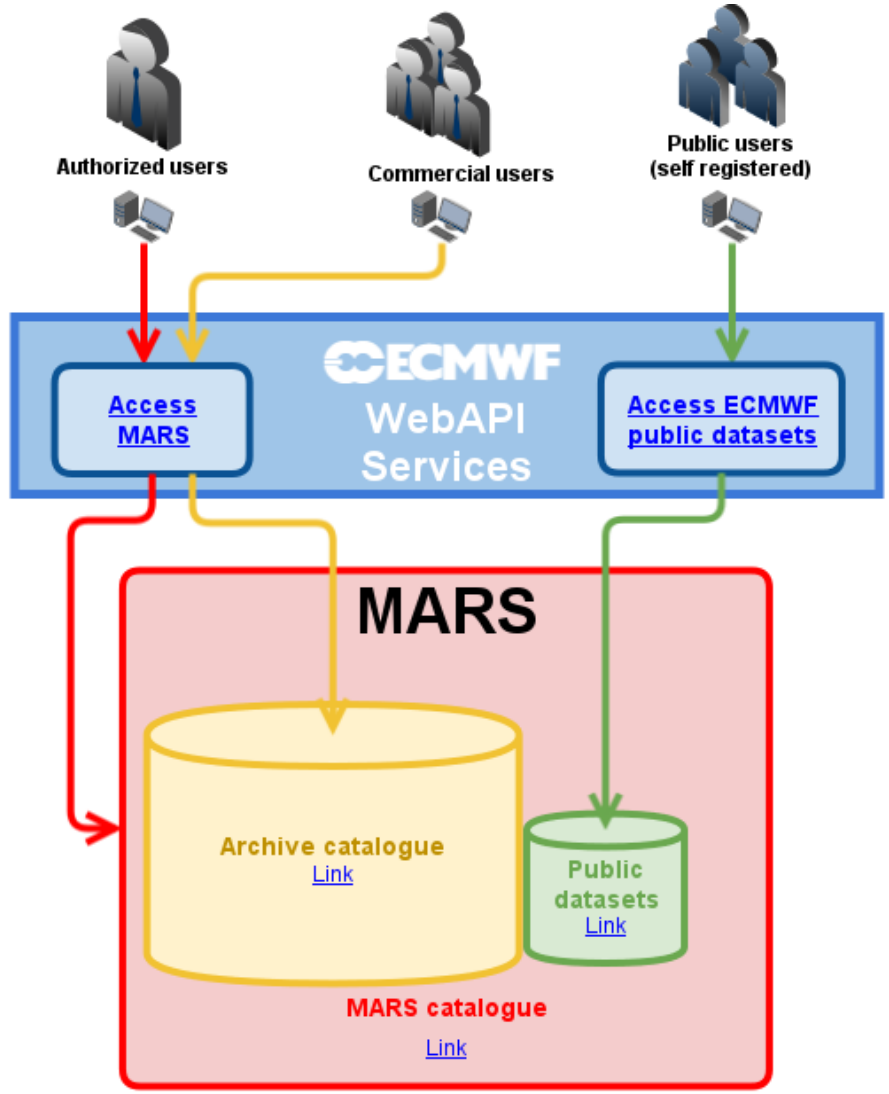
Web API

The Web API is a thin client

- Does not use GRIB API nor any interpolation library
  - therefore any functionality requiring decoding of fields (e.g. compute, read, write, multi-target) is not supported
- Only one request per MARS call is recommended
- Provides access to the Archives

Data Server – Web API

Who	Data discovery	Access method
Public user	Public Datasets	Access ECMWF Public Datasets
Commercial user	Archive catalogue	Access MARS
Authorized user	MARS catalogue	Access MARS



https://software.ecmwf.int/wiki/display/WEBAPI/ECMWF+Web+API+Home

Web API Python example

```
#!/usr/bin/env python
from ecmwfapi import ECMWFService

server = ECMWFService("mars")
server.execute(
        {
        "class": "od",
        "date": "20160101",
        "expver": "1",
        "levtype": "sfc",
        "param": "167.128",
        "step": "0/to/240/by/12",
        "stream": "oper",
        "time": "00",
        "type": "fc"
        },
        "target.grib")
```

Examples for retrieving large datasets efficiently:

https://software.ecmwf.int/wiki/display/WEBAPI/Retrieval+efficiency

Additional resources

- MARS documentation
  software.ecmwf.int/wiki/display/UDOC/MARS+user+documentation
- Web Applications
  apps.ecmwf.int/mars-catalogue/
  apps.ecmwf.int/mars-activity/
- FAQ
  http://www.ecmwf.int/search/faqs
- ECMWF real-time datasets
  www.ecmwf.int/en/forecasts/datasets
- IFS Documentation
  www.ecmwf.int/en/forecasts/documentation-and-support/changes-ecmwf-model/ifs-documentation
- ecCodes Documentation
  software.ecmwf.int/wiki/display/ECC