

MARS – Introduction and basic concepts

Computer User Training Course 2016

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Contents

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- **Meteorological content**
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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

- **94 PiB of data in ~ 230 billion ($2.3 \cdot 10^9$) meteorological fields in
12 million files**
- **~ 600 GiB of metadata**
- **$150 \cdot 10^6$ fields added daily (100 TB)**
- **1000 active users/day executing ~ 2 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/what-naming-convention-ecmwf-real-time-products

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

Meteorological content – Operational Analyses

- **4DVAR (T1279 / 16km, T255 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 (T399 / 50 km, T159 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 T1279L137 (16 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

- 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 perturbed initial conditions
- Truncation at day 10 from T639 (~32 km) to T319 (~64 km)
- Two additional calibration/validation runs were added
- Leg 3: 00 UTC FC extended Mondays & Thursdays to day 46

	# FC	Leg 1 day 0-10	Leg 2 day 11-15	Leg 3 day 16-46
ENS-CF	1	T639	T319	
ENS-PF	50	T639	T319	
CV-T639	1	T639		
CV-T319	1	T319		

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

Meteorological content – ENS products

- **Control forecast**
- **Calibration/Validation forecasts**
- **50 perturbed forecasts / 26 EDA members**
- **Initial condition perturbations**
- **Ensemble mean and standard deviation**
- **Extreme forecast index**
- **Event probabilities**
- **Cluster mean, cluster representatives and standard deviation**
- **Trajectories (of tropical cyclones)**

Meteorological content – Ocean-Wave component

	Forecast/ Analysis	Domain	Number of members	Horizontal resolution	Number of directions	Number of frequencies
SAW HRES	Analysis + forecast 0–10 days	Global	1	11 km	36	36
WAM HRES	Analysis + forecast 0–10 days	Global	1	28 km	36	36
WAM ENS	Forecast 0–10 days	Global	51	55 km	24	30
WAM ENS	Forecast 11–32 days	Global	51	55 km	12	25
WAM SEAS	Forecast 0–13months	Global	51	111 km	12	25

Meteorological content – Boundary-Condition Programme (BC)

HRES forecast (Short cut-off forecast T1279L137 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

MARS – IFS cycle 41r2 resolution changes

Grid resolution (km)	HRES	ENS		ENS Extended	4DVar Loops			EDA Loops			HRES-WAM	ENS-WAM		ENS-WAM Extended	HRES-SAW
		Day 0 - 10	Day 11 - 15	Day 16 - 46	1st	2nd	3rd	Outer	1st	2nd		Day 0 - 10	Day 11 - 15	Day 16 - 46	
		128										T _L 159	T _L 159		
100									T _L 191	T _L 191					
80					T _L 255	T _L 255	T _L 255								
64			T _L 319	T _L 319		T _L 319									
55												0.5°	0.5°	0.5°	
50							T _L 399	T _L 399							
36				T _{Co} 319											
32		T _L 639													
28											0.25°	0.25°	0.25°		
18		T _{Co} 639	T _{Co} 639					T _{Co} 639							
16	T _L 1279														
14											0.125°				
11															0.1°
9	T _{Co} 1279														

<https://software.ecmwf.int/wiki/display/FCST/Planned+changes+to+the+forecasting+system>

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 51 members 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**

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
 - ...

Meteorological content – Reanalysis datasets

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

ECMWF About Forecasts Computing Research Learning Carsten Maass Search site Go

Browse reanalysis datasets

- Research homepage
- Data Assimilation
- Modelling and prediction
- Climate reanalysis
 - Reanalysis datasets**
 - ERA-Interim
 - ERA-Interim/Land
 - ERA-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					✓		
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

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 (~0.7°)**
 - **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**

Meteorological content – ERA-CLIM reanalysis products

Atmospheric reanalysis for the 20th-century (1900-2010)

Using an ensemble of 10 plausible SST/sea-ice evolutions

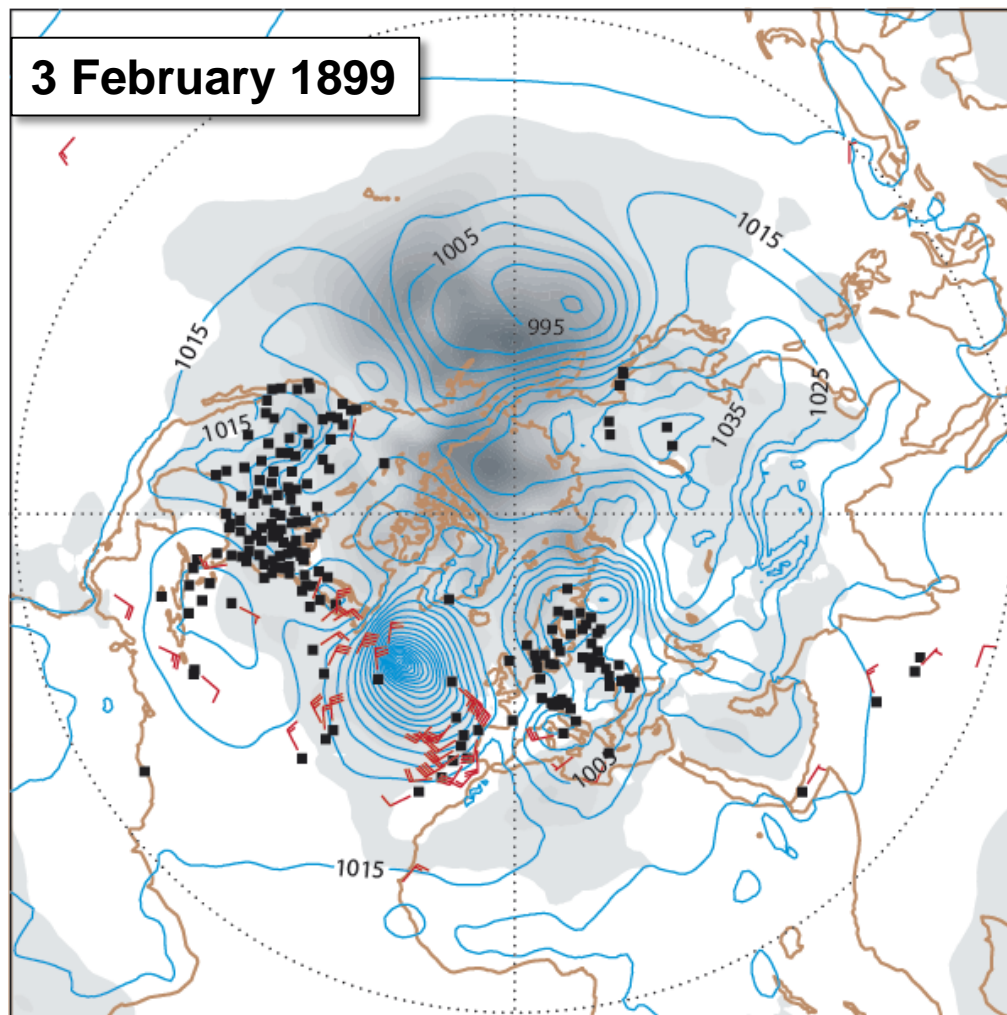
Assimilating observations of surface pressure and marine wind

125/25 km global resolution, 91 vertical model levels

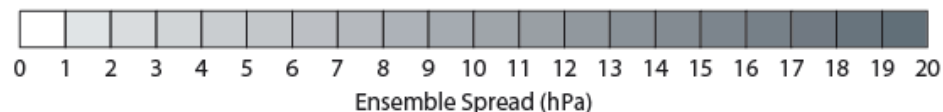
ERA-20CM	Ensemble of model integrations <i>(mainly monthly products)</i>	IFS Cy38r1 + CMIP5 data + HadISST v2.1
ERA-20C	Assimilation of surface observations <i>(3-hourly products)</i>	+ ICOADS v2.5.1 + ISPD v3.2.6 <i>(incl. ERA-CLIM)</i>
ERA-20CL	High-resolution land surface <i>(25km global)</i>	+ CHTESSEL

*Final ERA-20C/M/L datasets (~200 Tb) are becoming available at
<http://apps.ecmwf.int/datasets>*

ERA-20C: A terrific storm at sea



3 February 1899



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 snow-storm 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-

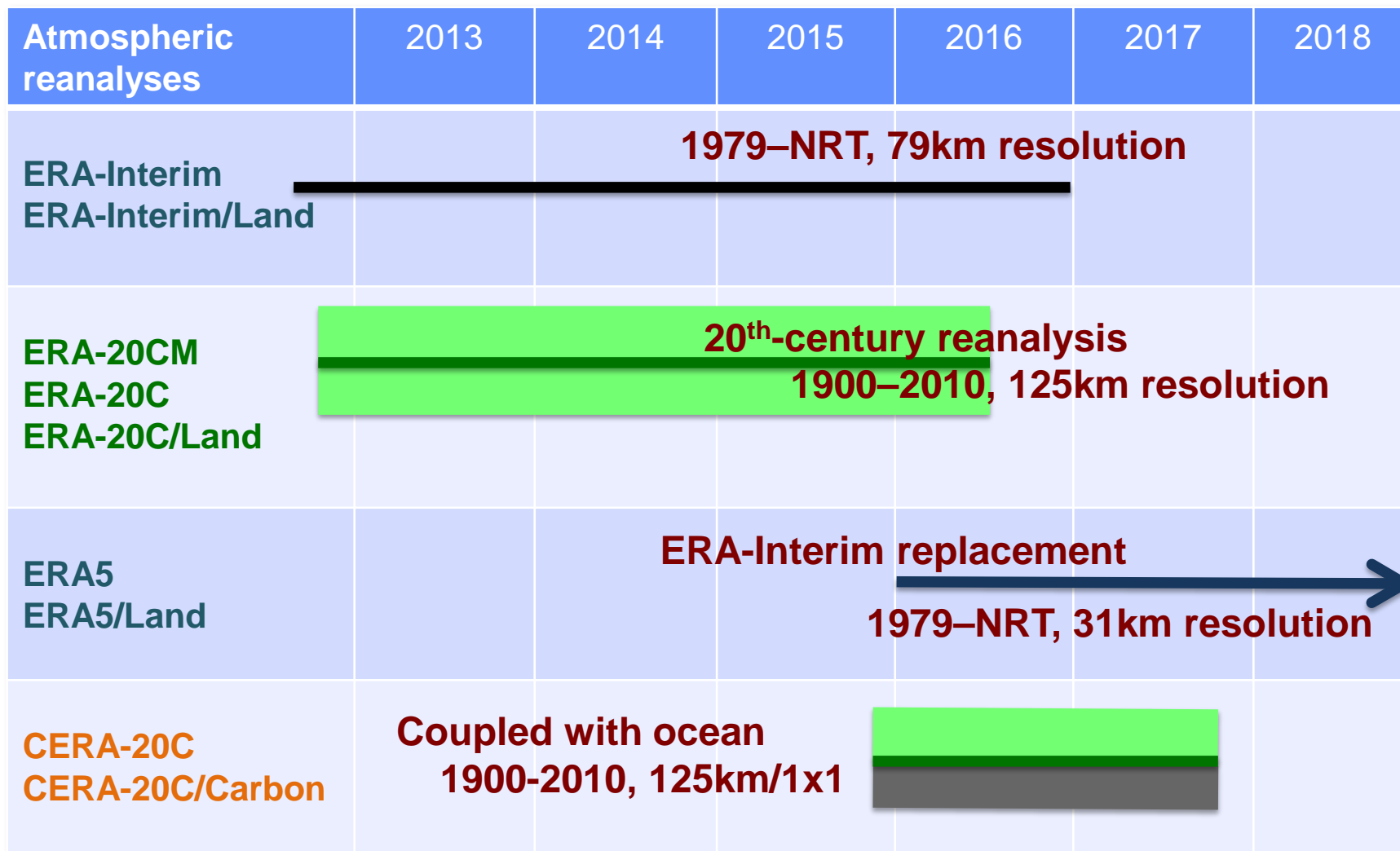
The New York Times

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

Meteorological content – Next ERA-Interim

	ERA-Interim	ERA5
Start of production	August 2006 IFS Cy31r2	January 2016 IFS Cy41r2
Model input	As in operations (<i>inconsistent SST</i>)	Appropriate for climate (CMIP5, HadISST.2)
Spatial resolution	79 km global 60 levels to 10 Pa	31 km global 137 levels to 1 Pa
Time period	1979 - present	1979 - present
Dissemination	Monthly	Monthly for ERA5; daily for ERA5T
Observations	Mostly ERA-40, GTS	Various reprocessed CDRs
Radiative transfer	RTTOV7	RTTOV11
Analysis method	4D-Var 1D+4DVar rain	10-member ensemble 4D-Var (EDA) All-sky MW
Variational bias corrections	Satellite radiances	Also ozone, aircraft, surface pressure

Meteorological content – Reanalysis outlook



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
- So far data from 9 centres, a further 2 interested

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

Meteorological content – Observations & Feedback

- **Observations**

- **Surface data**
- **Vertical soundings**
- **Upper-air data**
- **Satellite**

- **Feedback**

- **Analysis Input**

- **Analysis Feedback (superseded by ODB feedback)**

Meteorological content – Data formats

WMO formats

- **Fields in GRIB (GRid In Binary), ECMWF local extensions**
 - Spherical Harmonics (upper-air fields, T1279)
 - Gaussian Grid (surface fields, N640)
 - 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
 - Simulated satellite images (global on Gaussian grid)
 - ERA-CLIM2 (CERA-20C)
 - UERRA (Uncertainties in Ensembles of Regional Re-Analysis)
 - JRA-55
 - Copernicus datasets (ERA5, Multi-model Seasonal predictions, Regional Reanalyses, ...)
- Architecture
 - 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

<code>retrieve,</code>		
<code>class</code>	<code>= od,</code>	action
<code>stream</code>	<code>= oper,</code>	identification
<code>expver</code>	<code>= 1,</code>	
<code>date</code>	<code>= -3,</code>	date & time related
<code>time</code>	<code>= 12,</code>	
<code>type</code>	<code>= analysis,</code>	data related
<code>levtype</code>	<code>= model levels,</code>	
<code>levelist</code>	<code>= 1/to/137,</code>	
<code>param</code>	<code>= temperature,</code>	
<code>grid</code>	<code>= 2.5/2.5,</code>	post-processing
<code>target</code>	<code>= "analysis"</code>	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)
reporttype	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://data-portal.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)

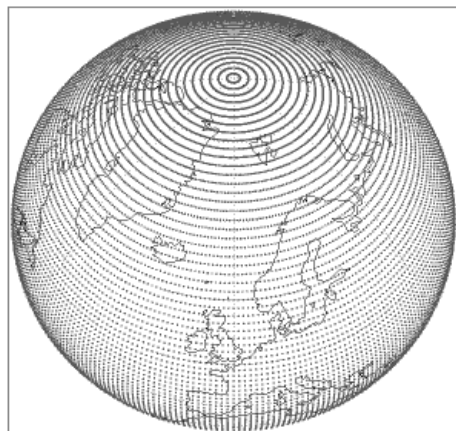
grid

output grid mesh

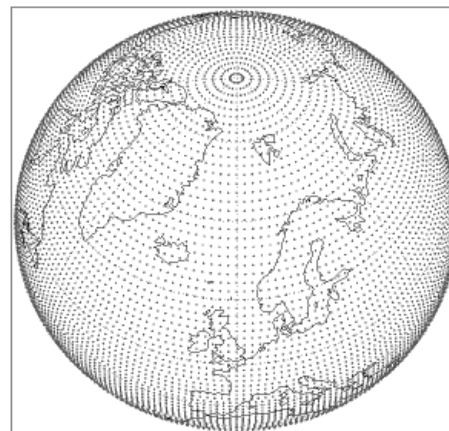
- Latitude/longitude increments in degrees (2.5/2.5)
- Type and resolution of Gaussian grid, e.g.
 - grid = F320 – full (or regular) Gaussian grid
 - grid = N320 – ECMWF original reduced Gaussian grid (only selected resolutions supported)
 - grid = O320 – ECMWF octahedral (reduced) Gaussian grid

All above with 320 latitude lines between the pole and equator

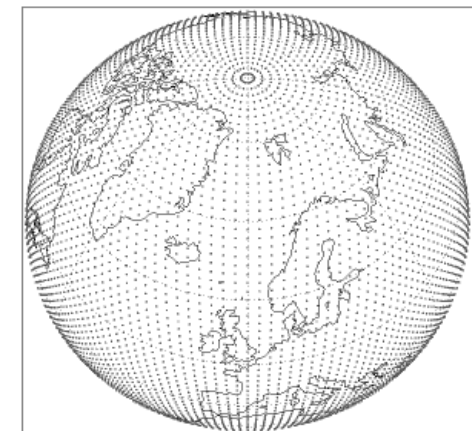
F80 regular (or full)



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

The screenshot shows a web browser window with the URL <http://apps.ecmwf.int/>. The page features the ECMWF logo and a navigation menu with links for Home, Chart dashboard, and Contact. A search bar is also present. Below the navigation, there are links for About, Forecasts, Computing, Research, and Learning. The main content area is titled "ECMWF Web Applications Server" and is organized into several sections:

- Visualisation**
 - ▶ [ecCharts - Forecaster \(authorization required\)](#)
 - ▶ [ecCharts - Dashboard \(authorization required\)](#)
- MARS**
 - ▶ [MARS Catalogue \(authorization required\)](#)
 - ▶ [MARS Activity \(authorization required\)](#)
- Datasets**
 - ▶ [Archive Catalogue](#)
 - ▶ [Public Datasets](#)
 - ▶ [Discovery and Access](#)
 - ▶ [History](#)
- Codes**
 - ▶ [GRIB](#)
 - ▶ [Parameter Database](#)
 - ▶ [BUFR](#)
 - ▶ [BUFR Validator](#)
 - ▶ [ODB](#)
 - ▶ [ODB Governance Database](#)
- Tools**
 - ▶ [Satellite Alert Monitoring](#)

At the bottom of the page, there is a "Top of page" link and a copyright notice: "copyright © ECMWF".

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**

Web-MARS – 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)
 - Remote client for Member States (security mechanism)
 - 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

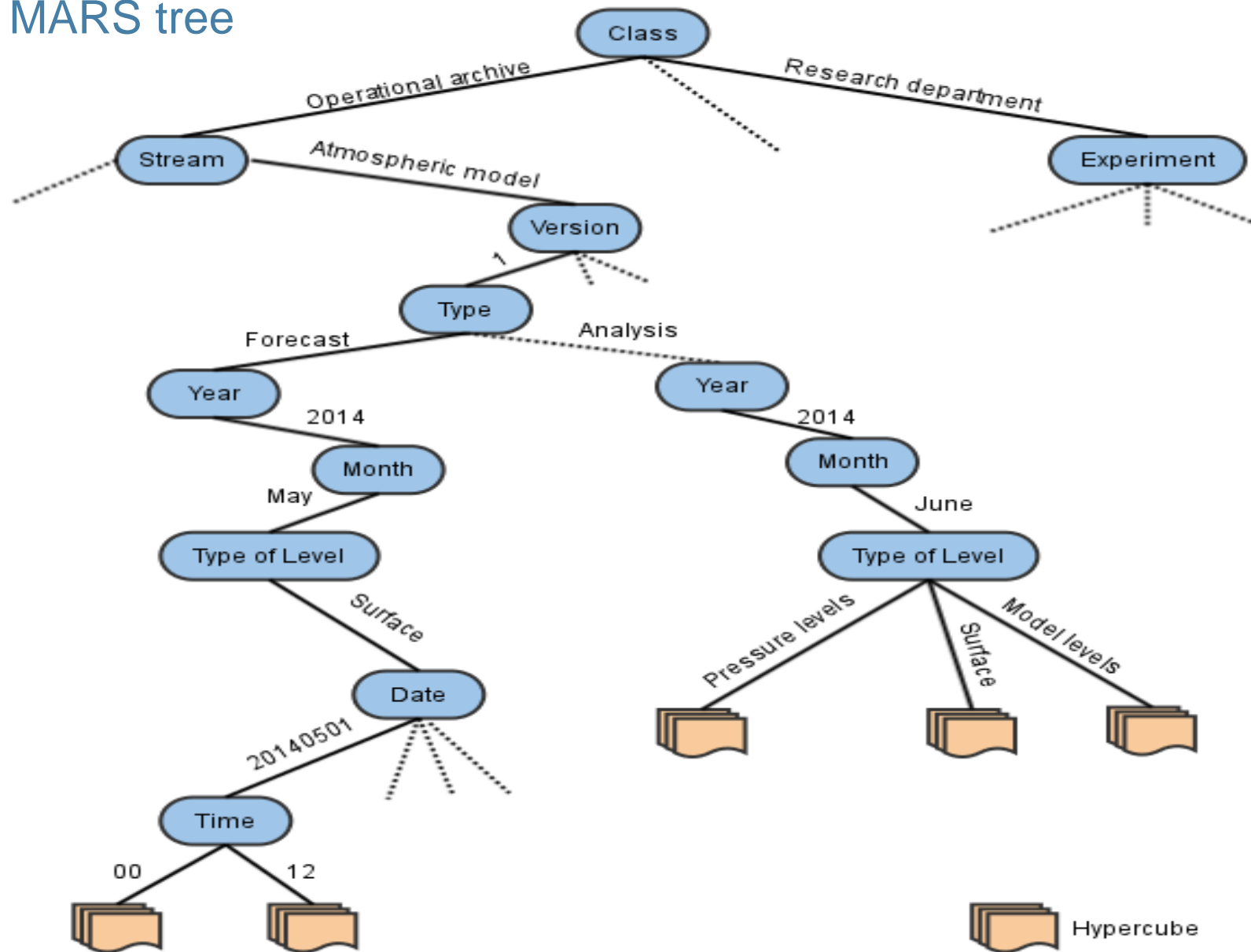
Request scheduling

- 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
$2.5 \leq \Delta$	T63
$1.5 \leq \Delta < 2.5$	T106
$0.6 \leq \Delta < 1.5$	T213
$0.4 \leq \Delta < 0.6$	T319
$0.3 \leq \Delta < 0.4$	T511
$0.15 \leq \Delta < 0.3$	T799
$0.09 \leq \Delta < 0.15$	T1279
$0.0 \leq \Delta < 0.09$	T2047

Retrieving data – Efficiency

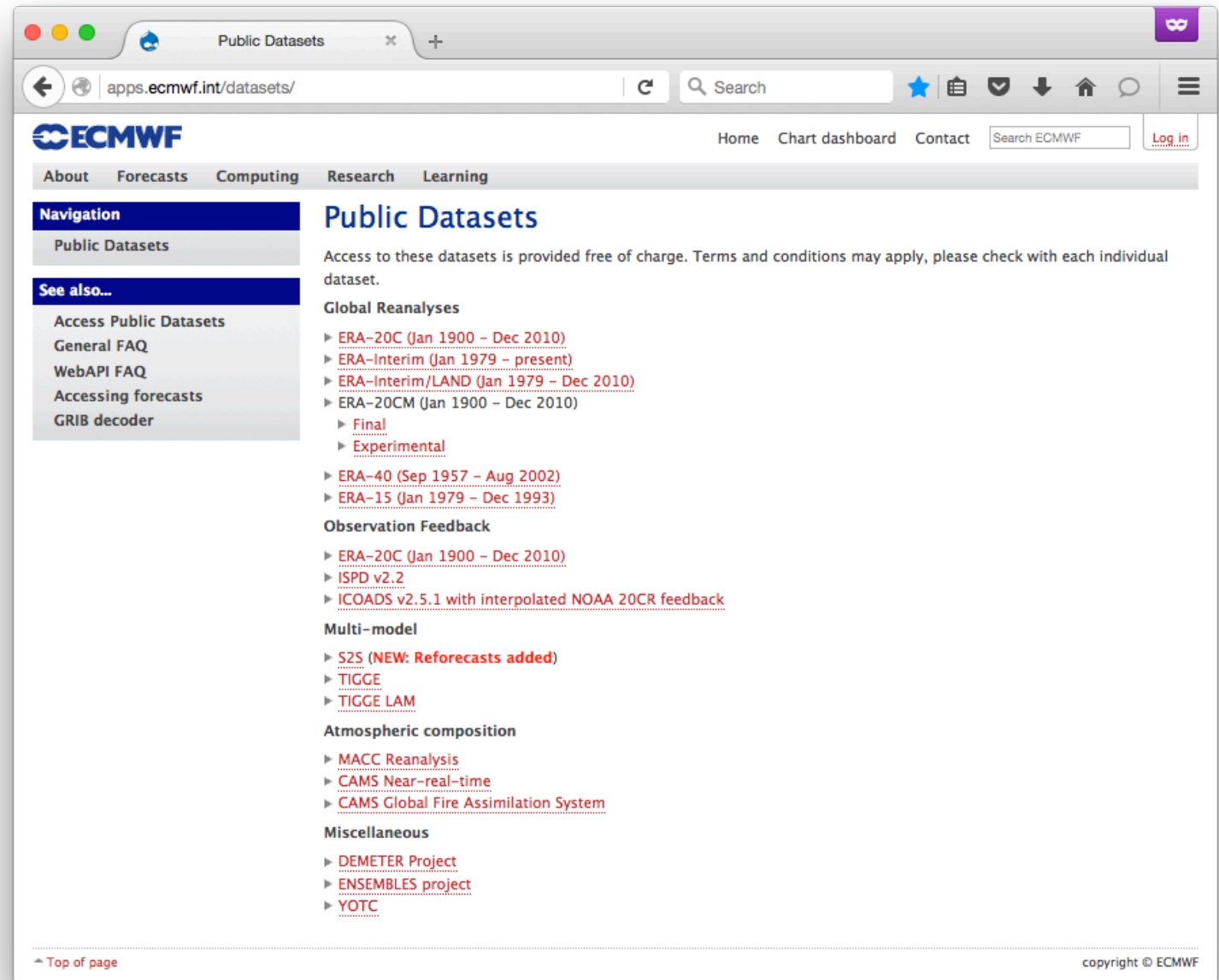
- **Use local disk (\$SCRATCH)**
- **Estimate amount of data (list command)**
 - Number of fields (up to tens of thousands / request)
 - Data size (up to several Gigabytes / request)
- **Check computer resources: quota, CPU time, ...**
- **Reduce number of tapes involved (better scheduling)**
- **Retrieve as much data from the same tape as possible**
- **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)

Data Server – <http://apps.ecmwf.int/datasets/>

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



The screenshot shows a web browser window displaying the ECMWF Public Datasets page. The browser's address bar shows the URL apps.ecmwf.int/datasets/. The page features the ECMWF logo and a navigation menu with links for Home, Chart dashboard, and Contact. A search bar is also present. The main content area is titled "Public Datasets" and includes a sub-header: "Access to these datasets is provided free of charge. Terms and conditions may apply, please check with each individual dataset." Below this, there are several sections of data products, each with a list of links:

- Global Reanalyses**
 - ▶ [ERA-20C \(Jan 1900 – Dec 2010\)](#)
 - ▶ [ERA-Interim \(Jan 1979 – present\)](#)
 - ▶ [ERA-Interim/LAND \(Jan 1979 – Dec 2010\)](#)
 - ▶ [ERA-20CM \(Jan 1900 – Dec 2010\)](#)
 - ▶ [Final](#)
 - ▶ [Experimental](#)
 - ▶ [ERA-40 \(Sep 1957 – Aug 2002\)](#)
 - ▶ [ERA-15 \(Jan 1979 – Dec 1993\)](#)
- Observation Feedback**
 - ▶ [ERA-20C \(Jan 1900 – Dec 2010\)](#)
 - ▶ [ISPD v2.2](#)
 - ▶ [ICOADS v2.5.1 with interpolated NOAA 20CR feedback](#)
- Multi-model**
 - ▶ [S2S \(NEW: Reforecasts added\)](#)
 - ▶ [TIGGE](#)
 - ▶ [TIGGE LAM](#)
- Atmospheric composition**
 - ▶ [MACC Reanalysis](#)
 - ▶ [CAMS Near-real-time](#)
 - ▶ [CAMS Global Fire Assimilation System](#)
- Miscellaneous**
 - ▶ [DEMETER Project](#)
 - ▶ [ENSEMBLES project](#)
 - ▶ [YOTC](#)

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Web API

- To access MARS and ECMWF Public Datasets in batch
 - Delivers data directly to the users' machine
- To replace local MARS clients
- 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>

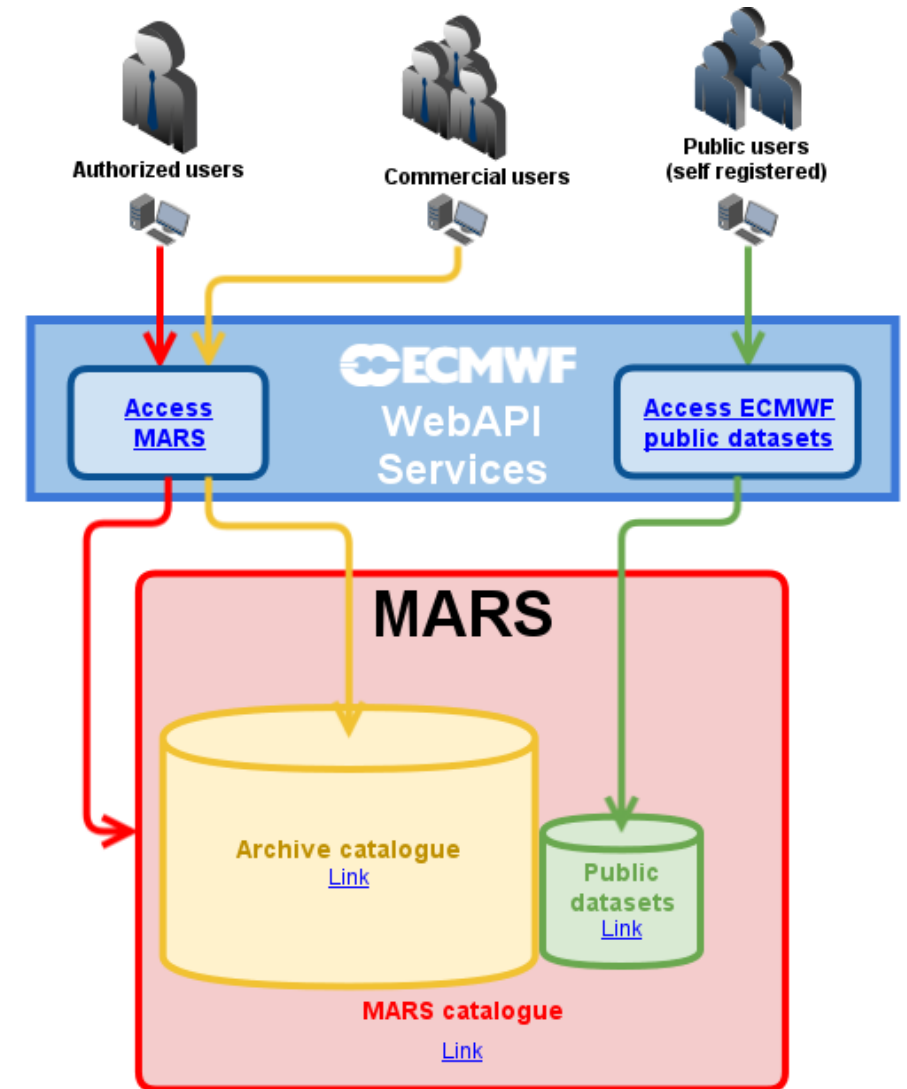
Web API

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-MARS
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
- GRIB API Documentation
software.ecmwf.int/wiki/display/GRIB/Home