Technical Report on the Global Data Processing System

Météo-France 2002 status

1. SUMMARY OF HIGHLIGHTS

. use of ATOVS raw radiances from NOAA satellites
. new dissemination system (RETIM2000) using DVB standard technique.

2. HARDWARE USED

- Information commutators on GTS are the TRANSMET computers (2 Sun Entreprise 3000, operating with OS Unix and RDBMS Oracle).
- the management of the forecasting system (control of the data in input of NWP models, postprocessing, production of charts with the NWP output) is made on a HP N4000 computer running Oracle RDBMS, US-Navy originating NEONS meteorological data management system, and PV-WAVE graphical software; one HP D370 is used as file server, one HP C180 workstation is devoted to the system monitoring, which is based on DCE. The whole system (production machine + file server + monitoring workstation), called DIAPASON, is doubled for backup.
- NWP operational models are running on a FUJITSU VPP5000 (31 processors, 21 with 8 Gbytes memory each, the others with 4Gbytes memory each)
- Dissemination of forecast and observation products (from GTS included), in particular to the french weather stations, is made through satellite communication (RETIM2000 system).

3. USE OF DATA AND PRODUCTS FROM GTS

Average number of messages, by day:

AIREP	AMDAR	BATHY	BUOY	PILOT	SATEM	SATOB	SHIP	SYNOP	TEMP	TEMPSHIP
3000	16000	40	11000	1000	25000	450000	5300	53000	1250	18

ACARS	ATOVS120	Quikscat	ERSURA	ERSUWA	ERSUWI	PROFILER-US	PROFILER-EU	GEOWIND	SSMI
100000	120000	25000	850	1600	0	750	1000	12000	46000

GRID from BRACKNELL : 658
GRID from WASHINGTON : 525
GRIB aero 1.25 from BRACKNELL : 5605
GRIB 2.5 from BRACKNELL : 15916
GRIB ECMWF : 984
Fac-simile products:
- aeronautical charts from Bracknell 590 and ECMWF 110 (T4 code)
- Cifax charts on RETIM1, T4 on RETIM3

4. DATA INPUT SYSTEM

Automated.

5. QUALITY CONTROL SYSTEM

GTS data are controlled at several levels:
- transmission
- syntaxic coherence

- rudimentary control of likelihood: e.g. a sea level pressure value must be above 880 hPa and below 1080 hPa
- data control by comparison to adjacent (in time and/or space) data, or to different types of data at the same location: e.g. Td T is checked; In the same manner, a sudden slope breaking of in a temperature profile from a radiosonde far from the tropopause leads to the invalidation of the data.

Data to be reemitted on GTS are not modified.

6. MONITORING OF THE OBSERVATION SYSTEM

All the observations that are used by the NWP system (SYNOP, SHIP, BUOY, SATOB, ATOVS, TEMP, PILOT, AIREP, AMDAR, ACARS) are controlled by comparison to the analyses and first guesses of the ARPEGE assimilation cycle: statistics are produced every month and summarized in a monthly bulletin.

7. FORECAST SYSTEM

The operational forecast system at Météo-France is based on two different numerical applications of the same code ARPEGE-IFS and an additional code to build the limited area model ALADIN.

The ARPEGE-IFS library has been developed jointly by Météo-France and ECMWF (ARPEGE being the usual name in Toulouse and IFS the one used in Reading):

ECMWF model for medium range forecasts (4-7 days)

a variable mesh version run in Toulouse for short range predictions (1-4 days)

The ALADIN library has been developed jointly by Météo-France and the national meteorological or hydrometeorological services of the following countries: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Hungary, Moldova, Morocco, Poland, Portugal, Romania, Slovakia, Slovenia, Tunisia.

7.1. Schedule of the Forecast System

The operational forecast system at Météo-France is based on ARPEGE/ALADIN, using the following rules :

. an assimilation (long cut-off) analysis is performed before each short cut-off analysis.

. the product's availability is :

initialysed analysis (P0)	cut-off+30'
ARPEGE forecast	20' every 24H range
ALADIN-France	ARPEGE+10'

Stretched configuration

HH	0000 UTC	0600 UTC	1200 UTC	1800 UTC
long cut-off	0810 UTC	1250 UTC	2010 UTC	0050 UTC
short cut-off	1H50	3H	1H50	3H
ARPEGE range	96H	42H	72H	30H
End of ARPEGE	0340 UTC	1010 UTC	1520 UTC	2200 UTC
ALADIN range	48H	42H	36H	30H
end of ALADIN	0310 UTC	1020UTC	2300 UTC	2210UTC

7.2. Medium range (4-10 days) forecast system

As mentioned above, it is the operational T511 IFS model of ECMWF and T255 Ensemble Prediction System for 4-5day and 6-7day forecast bulletins.

7.3. Short range forecast system

<u>The ARPEGE system(0-96 hours)</u>

ARPEGE-IFS is a common Météo-France / ECMWF development. ARPEGE is the french name (Action de Recherche Petite Echelle Grande Echelle) while IFS is the name used at Reading (Integrated Forecast System). It is a tunable system based on a global spectral model which can be used for several applications: data assimilation, short-range prediction, medium-range prediction, climate research, predictability studies.

ARPEGE-IFS uses Schmidt's transformation leading to variable mesh configurations, having a pole of maximum resolution and a resolution varying continuously from that pole to the antipode (Courtier and Geleyn 1988). T being the nominal truncation and C the "stretching factor", the local resolution of the model is T x C over the pole, and T / C at the antipode.

The present version is T298 C3.5 having its pole in France (46.5N,2.6E), leading to a horizontal resolution of the linear grid of 19 km over France and 230km over New Zealand.

The number of vertical levels is 41, with an increased density in the low atmosphere. The first level is at 1 hPa, and the lowest one at 18m above the ground.

Assimilation, objective analysis and initialization

The assimilation runs with a 6 hour cycle. The objective analysis is performed with a multi-incremental 4D variational scheme : i.e. the departure obs-guess is computed at full resolution (T298C3.5) whereas the analyzed structures are produced at "low" resolution, in 2 loops T107C1, T161C1. It is therefore assumed that the small scales (not analyzed) are forced by the (analyzed) large scales in the subsequent forecast.
The analysis works in vorticity, unbalanced divergence/ temperature/surface pressure and specific humidity on model levels.

assimilated data:	SYNOP, SHIP, BUOY, BATHY, TEMP, TEMPSHIP and PILOT (part A, B, C and D), AIREP, AMDAR, ACARS, SATOB, ATOVS with observation time in [H-3h,H+3h]
assimilation cycle:	6 hour cycle.
analysis method:	Multivariate four dimensional variational analysis
analysed variables:	Wind, temperature and specific humidity on model levels, plus surface pressure.
first guess:	A 6-hour forecast of ARPEGE. By default a 12, 18 or 24-hour forecast.
cover:	Global cover.
horizontal resolution:	T107, T161 linear grids
vertical resolution:	The analysis is done on the model levels (see below): 41 levels (hybrid vertical co-ordinate) from 18m up to 1 hPa.
initialization:	weak DFI constraint in the variational cost function and incremental digital filter initialization (ie filtering analysis increments fields) using a Dolph-Chebishev filter with a stop-band edge period of 5h .
surface:	-analysis of superficial and mean soil temperature (resp moisture) from forecast errors on 2m temperature (resp. relative humidity) - small relaxation towards climatology for snow and mean soil temperature and moisture

Model

basis equations:	Primitive equation system
independant variables:	Both components of the horizontal wind, temperature, specific humidity and surface pressure.
dependant variables:	Vertical velocity and density
numerical technique:	Spectral 2TL semi-lagrangian model and temporal discretization using semi-implicit scheme
integration domain:	The whole earth (global model).
orography, gravity wave drag:	The orography of this model is computed on the T298 C3.5 Gaussian grid (300x600 points) from GLOB95 30"+US NAVY 10' + NOAA 5' data using a variational technique that strongly reduces the noise associated to Gibbs waves (see Bouteloup, 1995). The gravity wave drag takes in account some anisotropy, blocking and mid-tropospheric effects.

horizontal diffusion:	Implicit in spectral space and incorporating an orography dependent correction for temperature
vertical diffusion:	Scheme linked to PBL (see next point)
planetary boundary layer:	ECMWF method (Louis et al. 1981) with several enhancements in the stable case
resolution, time step:	This version of the ARPEGE model has a triangular linear grid type truncation T298 with a stretching factor C3.5. It has 41 vertical levels from 18m up to 1hPa, using the hybrid (s,p) co-ordinate from Simmons and Burridge (1981). The time step is 830.770 seconds.
earth surface:	Fixed analyzed sea surface temperature and amount of sea -ice. An improved version of the ISBA (Interaction Soil Biosphere Atmosphere) scheme is used, including an explicit parameterization of soil freezing. Six prognostic variables are handled by ISBA: surface temperature, mean soil temperature, interception water content (water on the leaves), superficial soil water content (first centimeter), total liquid soil water content, total frozen soil water content. A very simple parameterization of snow cover is added. Soil characteristics (texture, depth) are point-dependent. Vegetation characteristics are point- and month-dependent.
radiation:	Highly simplified scheme (inspired from Ritter and Geleyn 1992) called at every time-step in every grid-point. Solar terms, cooling-to-space and exchange-with-surface terms for the thermal range are computed exactly but with one single spectral interval, exchange-between-layers thermal terms are further approximated by a "no-overestimation" simplification of the saturation process.
convection:	Mass-flux scheme (Bougeault 1985) enhanced with (i) the Gregory-Kershaw treatment of momentum transport by cumulus, (ii) a treatment of the moist adiabatic computation consistent with "i", (iii) a downdraft parameterisation, (iv) vertically variable entrainment and detrainment rates, (v) a parameterisation of the selective effect of entrainment leading to a warmer upper part of the single cloud ascent.
humidity:	Specific humidity is the variable: no storage of condensate; evaporation of falling rain; treatment of the ice-phase.

ALADIN (0-48hours)

ALADIN is a limited area version of ARPEGE-IFS. This implies that:
- ALADIN is spectral (like ARPEGE-IFS)
- As spectral-LAM it works on a biperiodic domain and uses bi-Fourier horizontal transforms
- Its physics and ARPEGE's one are identical
- It gets initial and lateral boundary conditions from ARPEGE

Up to now ALADIN is run in pure dynamical adaptation mode, i.e. without own data assimilation. The operational version is semi-lagrangian (usual time step 415.385.s), with elliptic linear grid type truncation E149x149 on Lambert projection domain (54°95N/33°66N,-11°18W/19°64E), leading to an equivalent finite difference resolution of roughly 9km.

The vertical resolution is 41 levels, the same as operational ARPEGE ones. The digital filter initialization uses a Dolph-Chebishev filter with a stop-band edge period of 3h and a backward-forward scheme.

NWP Products

The above described numerical models feed a analysis and forecast database, having following characteristics:
different horizontal domains for different horizontal resolution (from the global domain with a 2.5° and 1.5° mesh to the "France" domain with a 0.1° mesh)
vertical levels are the standard pressure levels
independence, from the creating model, of the format of the database products.

The meteorological fields stored in this database are:
- at all levels: geopotential, temperature, humidity, wind (including vertical velocity)
- at screen level: pressure, temperature, humidity, heat and radiation fluxes, snow and water content
- at sea surface level: reduced pressure
- some data at particular levels: 500 hPa absolute vorticity, high medium and low cloudness, iso 0° and iso -10°, tropopause etc...

ARPEGE produces boundary conditions for the ALADIN applications run by LACE in Pragues, in Morocco, Romania and Bulgaria, Poland, Portugal, while ALADIN-France provides boundary conditions for ALADIN-Belgique.

Operational use of NWP products

On screen (especially SYNERGIE workstation and Meteotel-PC software) or on paper, hundreds of charts...

7.4. Specialized forecasts

7.4.1 Local weather elements

Millions of local forecasts of weather parameters are produced daily through statistical adaptation of NWP output. Main methods are multiple linear regression (MLR) and discriminant analysis (DA). MOS (model output statistics) is preferred to PP (perfect prognosis).
Kalman filter (KF) is applied when relevant. Ensemble distributions are calibrated before computing probabilities.

- 2m temperature: MLR+KF
  ARPEGE model, France: 1182 stations. +3h to +96h (resp 42h, 72h and 30h) by 3h from 00UTC (resp.06 UTC, 12 UTC and 18UTC) + daily extremes.
  ECMWF model, France: 207 stations. +12h to +240h by 3h from 12UTC + daily extremes.
  ECMWF model, world: 2226 stations. +6h to +120h by 3h + daily extremes.
- 2m temperature: MLR applied to individual runs, KF applied to ensemble mean.
  ECMWF EPS, France: 207 stations. Daily extremes day+1 to day+8.
- 2m temperature, probabilities: MLR applied to individual runs, ensemble calibration.
  ECMWF EPS, France: 1153 stations. Daily extremes day+1 to day+8.
- 2m humidity: MLR+KF
  ARPEGE model, France: 990 stations. +3h to +96h (resp 42h, 72h and 30h) by 3h from 00UTC (resp.06 UTC,12 UTC and 18UTC).
- Dew point temperature: from temperature and humidity products
  ARPEGE model, France: 982 stations. +3h to +96h (resp 42h, 72h and 30h) by 3h from 00UTC (resp.06 UTC,12 UTC and 18UTC).
- Total cloud cover: MLR+KF
  ARPEGE model, France: 139 stations. +3h to +96h (+72h) by 3h from 00UTC (12UTC).

ECMWF model, France: 139 stations. +12h to +240h by 3h from 12UTC.

- Total cloud cover, categories (0-2, 3-4, 5-6, 7-8): DA

ARPEGE model, France: 142 stations. +3h to +96h (resp 42, 72 and 30h) by 3h from 00UTC (resp.06 UTC, 12 UTC and 18UTC).

- 10m wind speed: MLR

ARPEGE model, France: 645 stations. +3h to +96h (+72h) by 3h from 00UTC (12UTC).
ECMWF model, world: 1947 stations. +6h to +120h by 6h from 12UTC.

- 10m wind speed, probabilities: MLR applied to individual runs, ensemble calibration.

ECMWF EPS, France: 213 stations. +24h to +240h by 24h from 12UTC.

- Deterministic forecast and probabilities fo visibility (threshold 800, 1000, 1500, 3000 and 5000m): DA

ARPEGE model, France: 16 stations. +18H from 12UTC.

- Deterministic forecast and probabilities fo gust (threshold 28 to 78kt by 5kt): DA

ARPEGE model, France: 373 stations. 3h to +96h (resp 42h, 72h and 30h) by 3h from 00UTC (resp.06 UTC,12 UTC and 18UTC).

- 24h precipitations, probabilities: ensemble calibration.

ECMWF EPS, France: 776 stations. day+1 to day+8 from 12UTC.

7.4.2 Marine forecasts

Wave hindcast and forecasting system

Three models run operationally in France for determining the sea conditions:

A global wave model , computing the waves over all the oceans up to 72 hour forecast, from the wind outputs of large scale fields derived from the two global atmospheric models ARPEGE and ARPEGE/Tropiques.

Type:	coupled discrete deep water
Integration domain:	Global
Grid:	regular grid; resolution: 1°
Frequency resolution:	12 frequency components, logarithmically spaced from 0.04 Hz to 0.3 Hz
Direction resolution:	18 equally-spaced direction components
Integration scheme:	time step = 900s
Boundary forcing:	winds at 10m level from ARPEGE, updated every 6 hours
Surface classification:	sea ice deduced from ARPEGE SST
Assimilation:	4 analysis/day using significant wave heights from ERS2 altimeter

A regional model, forecasting the waves up 48 hours with 3 hour step, over the European Seas (Atlantic, Mediterrean , Baltic, North Sea, Black sea, ...) , from the wind outputs of small scale fields derived from ARPEGE.

Type:	Coupled discrete shallow water
Domain:	European Seas
Grid:	regular grid; resolution: 0°25
Frequency resolution:	12 frequency components, logarithmically spaced from 0.04 Hz to 0.3 Hz
Direction resolution:	18 equally-spaced direction components
Timestep:	300s
Boundary forcing:	winds at 10m level from ARPEGE, updated every 3 hours.

A coastal model, forecasting the waves up 48 hours with 3 hour step, over the French contiental shelf, from the wind outputs of small scale fields derived from ALADIN.

Type:	Coupled discrete shallow water
Domain:	French Seas (Metropolitan France only)
Grid:	regular grid; resolution: 0°1
Frequency resolution:	12 frequency components, logarithmically spaced from 0.04 Hz to 0.3 Hz

Direction resolution:	18 equally-spaced direction components
Timestep:	150s
Boundary forcing:	winds at 10m level from ALADIN, updated every 3 hours.

These models are available on 00UTC, 06UTC, 12UTC and 18UTC runs, except for VAG/TROPIC, available only on 00UTC.

Operational simulations of the oceanic circulation in tropical Atlantic

The oceanic primitive equation model OPA7, developed by CNRS/LODYC, has been run operationally every month, using all the surface fluxes produced by the operational ARPEGE model. Its main characteristics are 17 horizontal levels in z coordinate with a realistic bathymetry, and a 1/3 degree horizontal resolution. Systematics comparisons have been performed with bathythermic observations sent through the GTS, and against sea surface temperatures from ERS data (ATSR).

Storm surge model

A depth-averaged, numerical storm-surge model has been developed and configured to provide storm-surges forecasts along coastlines of France. Two versions of this model, one for overseas territories to forecast tropical cyclones storm surges and one for metropolitan French coastline.

Overseas domain: Atmospheric fields are inferred from an analytical-empirical cyclone model which require only cyclone position, intensity and size. The model has been operated since 1994 in the French Antilles, 1995 in New Caledonia, 1997 in the French Polynesia and 1998 in La Reunion. The model can be used in two different ways. In real-time mode as a tropical cyclone is approaching an island or in climatological mode: a cyclone climatology is used to prepare a data base of pre-computed surges. Due to the low accuracy of tropical cyclone trajectory forecasts, the second mode seems to be, at present time, the best way to use the model.
The grid mesh is fixed for each domain and varies from 150 m to 1850 m.

Metropolitan domain: Atmospheric fields are taken from atmospheric numerical models: IFS (ECMWF), ARPEGE and ALADIN (Météo-France). The system has been operated since October 1999 for the Channel and Bay of Biscay, March 2002 for the Mediterranean Sea and November 2002 for the North Sea.
48 hours forecast are produced on a 5’ grid mesh.

Drift model (oil spills, containers, Search & Rescue)

Météo-France is in charge of spill drift predictions within the spill response plan POLMAR-MER in case of a threat for the French coastline. At an international level, Météo-France can intervene within the Marine Pollution Emergency Response Support System (MPERSS) for the high seas. Météo-France is Area Meteorological Co-ordinator for METAREA II and III west, and supporting service for METAREA I, III east, VII B and VIII C.
Météo-France developed a drift model named MOTHY (Modèle Océanique de Transport d’HYdrocarbures). MOTHY is an integrated system that includes hydrodynamic coastal ocean modelling (2D+1D) and atmospheric forcing from ARPEGE or IFS models. The hydrodynamic coastal ocean is linked to an oil spill model, where oil slick is considered as a distribution of independent droplets. These droplets move with shear current, turbulent diffusion and buoyancy. The system has been operated since 1994 and can be used for oil spills or drifting objects. New developments, exercises and training are jointly conducted with CEDRE (Centre de documentation de recherche et d’expérimentations sur les pollutions accidentelles des eaux). MOTHY correctly predicted the drift of the oil during Erika (December 1999) and Prestige (2002-2003) in the Bay of Biscay.
The domain is global with a better accuracy on specific areas, including French seas.
Forecasts are produced up to 5 days on fixed grid from 150 m to 9 km.

7.4.3 Pollutant transport and dispersion forecast

After the Chernobyl catastrophe on April 26th 1986, the French meteorological service, METEO-FRANCE, has developed a powerful model to forecast the movement of radioactive clouds at long distance range. Meteorological central service of METEO-FRANCE in Toulouse (SCEM) has been designated as a regional specialized meteorological centre (RSMC) with activity specialization on the provision of atmospheric transport model products for environmental emergency response. This provision can be related, but not restricted, to nuclear accident, or radiological emergencies, and plumes of volcanic ashes for ICCA.

For environmental emergency responses we now use two models based on the use of the NWP fields that are stored in our database, from ARPEGE and from ECMWF's model:

- calculation of trajectory forecast for neutrally buoyant air parcels,
- full transport/dispersion model (Atmospheric DIspersion Eulerian Model ,french acronym: **MEDIA**).

These models proved highly successful in the ATMES experiment (Atmospheric Transport Model Evaluation Study) for the international comparison of pollutant transport/dispersion models of the Chernobyl case and is used regularly in the framework of experiments within the CEA/IPSN (Nuclear Safety Institute) and the EDF (Electricity National Board) for French nuclear sites. In these cases the source of the release is well known and allows a simulation, the results of which depend only on observed and forecast meteorological conditions.

The operational organization of Météo-France, for facing such pollution accidents, is based on a special crisis meteorological cell (CMC) that studies the evolution of weather/pollution conditions and provides the delegated authorities of a requesting country with information about pollutant transport containing in particular the standard set of products as defined during the International Workshop held in Montreal. This cell can of course be activated at any time (day or night) and is placed under authority of the director of central service of operations.

7.4.4 Tropical cyclones forecast model

A specific version of ARPEGE, called ARPEGE-Tropiques, has been implemented for more detailed forecasts over tropical areas, and sent to the SYNERGIE software in French oversea regional centers.
The ARPEGE-Tropiques model is the same as the metropolitan one, but with a uniform truncature T358L41 for the forecast (time step 1800s) , and T107C1L41 for the 4DVAR analysis. Sea surface pressure bogus data , produced by forecasters in La Réunion center are incorporated in the assimilation to get a more precise location of cyclones. These bogus data are transmitted on the GTS in BUFR.
The models are running once a day based on 00UTC, up to 72 h , with a 3.50 hour cut-off.

Uniform configuration

HH	0000 UTC	0600 UTC	1200 UTC	1800 UTC
long cut-off	0955 UTC	2145 UTC	2210 UTC	0200 UTC
short cut-off	3H50			
ARPEGE range	72H			

7.6. Long range forecasts (3 months)

A specific version of ARPEGE model , called ARPEGE-Climat is used 9 times a month to run 120 to 129 days forecasts, starting from ECMWF assimilation. The SST forecast is based on an auto regresssive statistical scheme on grid points, which is run once on the first day of the series. The seasonal forecasting system is using mainly the same ARPEGE software as the short range forecast model, except the following points:

resolution, time step: This version of the ARPEGE model has a triangular truncature T63 without stretching. The collocation grid has 128x64 points with a reduction near the poles; it has 31 vertical levels like IFS model during ERA-15 (ECMWF reanalysis). The time step is 1800 seconds.

radiation: Fouquart Morcrette scheme (1995)

clouds, vertical diffusion,

stratified precipitations: Ricard Royer statistical scheme (1993).

8. Verification of Forecasts

Scores of the operational ARPEGE model:

Against analyses

	24 hours			72 hours			
	NH	SH	TR		NH	SH	TR
Z500 RMSE	13.2	20.2			36.4	49.0	
W250 RMSEV	5.4	6.0	5.4		11.7	12.8	8.8
W850 RMSEV			2.8				4.2

NH : Northern Hemisphere SH : Southern Hemisphere TR : Tropics

Against observations

24 hours

	NA	EU	AS	AU/NZ	TR	NH	SH
Z500 RMSE	14.5	14.1	15.0	15.2	11.2	15.4	20.2
W250 RMSEV	7.4	6.9	7.1	7.6	6.3	7.0	8.1
W850 RMSEV	4.5	4.6	4.8	4.8	4.6	4.8	5.5

72 hours

	NA	EU	AS	AU/NZ	TR	NH	SH
Z500 RMSE	36.4	32.9	32.7	30.1	14.1	37.3	40.1
W250 RMSEV	13.7	12.6	11.7	12.0	8.7	12.8	13.1
W850 RMSEV	6.6	6.3	6.7	6.3	5.4	6.7	7.0

NA : North America EU : Europe AS : Asia AU/NZ : Australia / New Zealand
NH : Northern Hemisphere SH : Southern Hemisphere TR : Tropics

Recall:
Météo-France draws up a quarterly bulletin of "verification of the numerical products used for meteorological forecasting" (in French) which can be obtained by writing to:

Météo-France
DPrévi/COMPAS
42, av. Coriolis
F-31057 TOULOUSE Cedex 1
FRANCE

9. Future Plans

For more details, see the Commission of Sciences / Progress Report on Numerical Weather Prediction.

- enhanced configuration of the supercomputer Fujitsu VPP5000 with 124 processors
- further increase of models resolution
- improved use of some existing observing systems (TEMP) and satellite data (winds, HIRS, AIRS)

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