METEO-FRANCE1999 status

1. SUMMARY OF HIGHLIGHTS

. Use NOAA14 TOVS radiances (120km data) in ARPEGE assimilation .
. New global wave model with a 1° mesh and assimilation of ERS altimeter data
. New seasonal forecast using ARPEGE-Climat model

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 T600 computer running Oracle RDBMS, US-Navy originating NEONS meteorological datamanagement 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), calledDIAPASON, is doubled for backup.
- NWP operational models are running on a FUJITSU VPP700E (26 processors with 2 Gbytes memory each)
- Dissemination of forecast and observation products (from GTS included), in particular to the french weather stations, is made through the Eutelsat communication satellite (RETIM 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
3600	13000	50	7500	1000	11000	400000	5700	43000	1200	15

ACARS/US	A_TOVS120	ERS/URA	ERS/UWA	ERS/UWI	PROFILER	SATWIND	SSMI
42000	90000	800	1000	1000	1100	12000	22000

GRID from BRACKNELL : 1500
GRID from WASHINGTON : 400
GRIB aero 1.25 from BRACKNELL : 1680
GRIB 2.5 from BRACKNELL : 3030
GRIB ECMF : 288
Fac-simile products:
- aeronautical charts from Bracknell (T4 code)
- Cifax charts on almost all links

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 thetropopause 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, TOVS120, TEMP, PILOT, AIREP, AMDAR, ACARS) are controlled by comparison to the analyses and first guesses of the ARPEGE assimilationcycle: 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 and an additional code to build the limited area model.

The ARPEGE-IFS library 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 (4-5 days)

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

The ALADIN library 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.

7.1. Schedule of the Forecast System

The operational forecast system at Météo-France is based on ARPEGE/ALADIN runs using the observed data at 00 UTC and at 12 UTC:

00 UTC data: 1h50 cut-off, ARPEGE analysis and forecast up to 96h and ALADIN up to 36h

12UTC data: 1h50 cut-off, ARPEGE analysis and forecast up to 72h and ALADIN up to 36h

assimilation cut-off

HH	0000 UTC	0600 UTC	1200 UTC	1800 UTC
extraction	1145 UTC	1215 UTC	2300 UTC	0015 UTC

availability

initialysed analysis (P0)	cut-off+30'		
ARPEGE forecast	20' every 24H range	until	96H (morning end at 0340 UTC)
		"	72H (afternoon end at 1520 UTC)
ALADIN-France	ARPEGE+10'	until	48H (morning end at 0300 UTC)
		"	36H (afternoon end at 1500 UTC)

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

As mentioned above, it is the operational T319 model of ECMWF and T159 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 truncationand 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 T199 C3.5 having its pole in France (46.5N,2.6E), leading to T696.5 over France (corresponding roughly to a horizontal resolution of 20 km) and T57 over New Zealand (corresponding roughly to a horizontal resolution of 200km).

The number of vertical levels is 31, with an increased density in the low atmosphere. The first level is at 5 hPa.

<u>Assimilation, objective analysis and initialization</u>

The assimilation runs with a 6 hour cycle, with 10h45 cutoff for 00 and 12, and 5H30 cutoff for 06 and 18. The objective analysis is performed with an incremental 3D variational scheme : i.e. the departure obs-guessis computed at full resolution (T199C3.5) whereas the analyzed structures are produced at "low" resolution (T127C1.0). 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: TEMP and TEMPSHIP (part A, B, C and D), PILOT (part A, B, C and D), AIREP, AMDAR, ACARS, SATOB, TOVS120km with observation time in [H-3h,H+3h] for the analysis at H,SYNOP, SHIP, BUOY, BATHY with observation time in [H-30',H+30'].
assimilation cycle: 6 hour cycle.
analysis method: Multivariate three dimensional variational analysis
analysed variables: Wind, temperature, surface pressure and specific humidity on model levels.
first guess: A 6-hour forecast of ARPEGE. By default a 12, 18 or 24-hour forecast.
cover: Global cover.
horizontal resolution: Semi-linear grid (160 x320 points) associated with T127C1 truncation and equivalent to T105 Gaussian grid
vertical resolution: The analysis is done on the model levels (see below): 31 levels (hybrid vertical co-ordinate) from screen up to 5 hPa.
initialization: Incremental digital filter initialization (ie filtering analysis increments fields) using a Dolph-Chebishev filter with a stop-band edge period of 5h and a backward-forwardscheme.
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 leap-frog semi-implicit scheme (see
integration domain: The whole earth (global model).
orography, gravity wave drag: The orography of this model is computed on the T199 C3.5 Gauss grid (300x600 points) from GLOB95 30"+US NAVY 10' + NOAA 5' data using a variational technique that strongly reduces the noise associated to Gibbswaves (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)
resolution, time step: This version of the ARPEGE model has a triangular truncature T199 with a stretching factor C3.5. The resolution varies from T 696.5 over France (15 km equivalent mesh for a finite difference model) to T57 over NewZealand (200 km equivalent mesh); it has 31 vertical levels from screen up to 5hPa, using the hybrid (s,p) co-ordinate from Simmons and Burridge (1981). The time step is 900 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 prognosticvariables 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 simpleparameterization of snow cover is added. Soil characteristics (texture, depth) are point-dependent. Vegetation characteristics are point- and month-dependent.
radiation:	Hypersimplified scheme at every time step (Ritter and Geleyn 1992)
convection:	Mass flux scheme (Bougeault 1985) modified by Ivanovici and Geleyn.
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 469.566s), with elliptic truncation E95x95 on Lambert projection domain (54°95N/33°66S,-11°18W/19°64E), leading to an equivalent resolution of roughly 7.5km.

The vertical resolution is 31 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, 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

Several kinds of forecasts are made by statistical adaptation of the NWP products from the above described models:

MOS method and Kalman filter based on ARPEGE model:

2 meter-temperature over 1137 stations in France, every 3 hours from 0 to 72 hour range, plus extreme values.
cloud cover over 169 stations in France, every 3 hours from 6 to 66 hour range at 00Z, and from 0 to 54 hour range at 12Z.

MOS method based on ARPEGE model:

wind over 136 stations in France, from D+1 to D+3 every 6 hours

MOS method and Kalman filter based on ECMWF model:

cloud cover over 169 stations in France, from D+1 to D+6

Perfect-Prog method and Kalman filter based on ECMWF model:

min-max daily temperature over 169 stations in France, for D (max) to D+7 (Min). A 3 hour time step temperature forecast is then obtained by superimposition of a diurnal cycle

Temperature, cloud cover and precipitations forecast over 210 towns in the world are also performed, using spatial interpolation and a Kalman filter (temperature and cloud cover), and Perfect-Prog (temperature over Europe), every 6 hours from 12 to 108 hour range.

7.4.2 Marine forecasts

Wave hindcast and forecasting system

Two 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 ARPEGE.

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.

This models are available between 0330UTC et 0345UTC, on 00UTC run.

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 17horizontal 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 high resolution limited area storm surge model designed fro tropical cyclones is used operationnaly in Fench overseas Islands: Guadeloupe, Martinique, St Martin, St Barthelemy, French Polynesia, Réunion,Mayotte and New Caledonia Islands.

Oil drift model

Three different versions of a limited area oil drift model have been implemented:

· a 5' x 5' grid mesh one, over the METAREA II for which Météo-France is responsible under WMO Marine Pollution Emergency Response Support System (MPERSS);
· another 5' x 5' grid mesh one, including the tidal forcing, over French coastal areas;
· a 1' x 1' or less grid mesh version over French overseas Islands.

Container drift model

Same areas as above

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. Meteorologicalcentral 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 model 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 ofexperiments 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 observedand 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 ofa 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 isplaced under authority of the director of central service of operations.

7.4.4 Tropical cyclones forecast model

A specific version of ARPEGE has implemented over Indian Ocean, and sent to the SYNERGIE software in La Réunion Island/Saint Denis.

The model is the same as the previous one, but with a different pole (20S, 60E) of stretching and geometry T127C3.5L31 for the forecast (time step 1350s) , and T95C1L31 for the 3DVAR analysis.

The model is running once a day based on 00UTC, up to 96 h , with a 9 hour cut-off.
assimilation cut-off

HH	0000 UTC	0600 UTC	1200UTC	1800 UTC
extraction	0900 UTC	0445 UTC	0445 UTC	0445 UTC

7.6. Long range forecasts (3 months)

A specific version of ARPEGE model , called ARPEGE-Climat is used 3 times a month to run 125 days forecasts, starting from ARPEGE assimilation. The seasonal is using mainly the same ARPEGE software as shortrange 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; ithas 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	14.9	23.7			39.5	53.3	
W250 RMSEV	5.5	6.4	5.3		11.8	13.1	8.7
W850 RMSEV			2.8				4.5

NH : Northern Hemisphere SH : Southern Hemisphere TR : Tropics

Against observations

24 hours

	NA	EU	AS	AU/NZ	TR	NH	SH
Z500 RMSE	16.6	15.1	16.6	17.4	11	16.9	22
W250 RMSEV	7.5	7	7.5	8.5	6.7	7.3	9
W850 RMSEV	4.5	4.5	4.9	5	4.6	4.7	5.8

72 hours

	NA	EU	AS	AU/NZ	TR	NH	SH
Z500 RMSE	42.9	38.1	31.7	35	14.2	40.9	42.4
W250 RMSEV	14.3	12.8	11.4	12.8	8.7	13	13.8
W850 RMSEV	7.1	6.5	6.7	6.6	5.7	6.9	7.5

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 monitoring of the numerical products used for meteorological forecasting" (french) and a "monthly bulletin of data monitoring" (french and English). These bulletins can be obtained by writingto:

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

9. FUTURE PLANS

. use of more satellite data: ERS2 winds, SSM/I sea-ice index.
. new scheduling for operational suite with two more runs at 06 and 18 UTC
. 4DVAR assimilation
. 41 levels for ARPEGE/ALADIN models

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