Application and verification of ECMWF products 2014

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1. Summary of major highlights

The major event is the start of an operational analysis for chemical species made by the MOCAGE-VALENTINA system since March 2015.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 *Statistical adaptation*

Millions of local forecasts of weather parameters are produced daily through statistical adaptation of NWP output. Main methods are multiple linear regression (MLR) and linear discriminant analysis (DA). MOS (model output statistics) is generally preferred to PP (perfect prognosis). Kalman filter (KF) is applied when relevant. The production is described in Table 1.

Note the new production of grid point total cloud cover forecast based on a statistical adaptation using satellite data as predictand.

Deterministic model T1279

Parameter	Method	Domain	Nbr of Sites	Steps
Tri-hourly 2m Temperature	MLR (MOS) +KF	France	2781	+3h to +180h by 3h
Daily extremes 2m temperature	MLR (MOS) +KF	France	2781	D to D+6
10m Wind Speed	MLR (MOS)	France	861	+6h to +180h by 3h
10m Wind Direction	MLR (MOS)	France	822	+6h to +180h by 3h
Total Cloud Cover	MLR (MOS)/LDA	France	164/152	+12h to +180h by 3h
Total Cloud Cover	LDA	France	GRID 0.5x0.5	0h to +156h by 3h
Tri-hourly 2m relative Humidty	MLR (MOS) +KF	France	1269	+6h to +180h by 3h
Daily extremes 2m rel. Humidity	MLR (MOS) +KF	France	1269	D to D+6
Tri-hourly 2m Temperature	MLR (MOS) +KF	World	7128	+1h to +180h by 1h
Daily extremes 2m temperature	MLR (MOS) +KF	World	7128	D to D+6
Mixed ARPEGE+IFS	MLR (MOS) +KF	France	2781	+3h to +102h by 3h
Mixed ARPEGE+IFS	MLR (MOS) +KF	World	4367	+1h to +102h by 1h

Table 1 : Statistical adaptations for the deterministic high resolution model

EPS

Statistical adaptation is applied to individual ensemble runs (Table 2). Methods are the same as for the deterministic model output but pseudo-PP (statistical equations computed during the first 24 hours then applied to the other corresponding steps) is preferred to MOS. VAREPS is used and Météo-France provides local forecast (temperatures) up to 14 days.

EPS Ensemble mean and individual members

Parameter	Method	Domain	Nbr of Sites	Steps
Tri-hourly 2m Temperature	MLR (pPP) +KF	France	2761	+3h to +360h by 3h
Daily extremes 2m temperature	MLR (pPP) +KF	France	2761	D to D+14
10m Wind Speed	MLR	France	792	+6h to +240h by 3h +246 to +360 by 6h
Tri-hourly 2m relative Humidty	MLR (pPP) +KF	France	1146	0h to +240h by 3h
Daily extremes 2m rel. Humidity	MLR (pPP) +KF	France	1146	D to D+10
Tri-hourly 2m Temperature	MLR (pPP) +KF	World	3338	+0h to +360h by 3h (by 1h for ensemble mean)
Daily extremes 2m temperature	MLR (pPP) +KF	World	3338	D to D+14

Table 2 : Statistical adaptations for the EPS

EPS Distribution

Calibration is applied to the EPS distribution in order to optimize reliability. Operationally, a calibration based on rank diagrams is used for 10m wind speed and total precipitations.

Monthly forecast

Statistical models are also applied to the monthly forecasts up to 32 days (Table 3). These locally corrected forecasts allow to couple electricity consumption models.

Parameter	Method	Domain	Nbr of Sites	Steps
Tri-hourly 2m Temperature	MLR (pPP)	France	1056	+0h to +768h by 3h
Daily extremes 2m temperature	MLR (pPP)	France	1056	D to D+31
Tri-hourly 2m Temperature	MLR (pPP)	World	7128	+0h to +768h by 3h
Daily extremes 2m temperature	MLR (pPP)	World	7128	D to D+31

Table 3 : Statistical adaptations for the monthly forecasts

2.1.2 Physical adaptation

The first physical adaptation is performed by the limited area model (LAM) ALADIN which operates over western Europe (Figure 1). This model performs a dynamical adaptation of the IFS forecasts using a higher horizontal resolution of 7.5 km. The orography and the physiographic data of this ALADIN version are taken from a new database since 02/07/2013 like all the LAM operational at Météo-France. Objective scores have been computed for the surface parameters against the measurements of French surface stations and compared to the IFS forecasts.

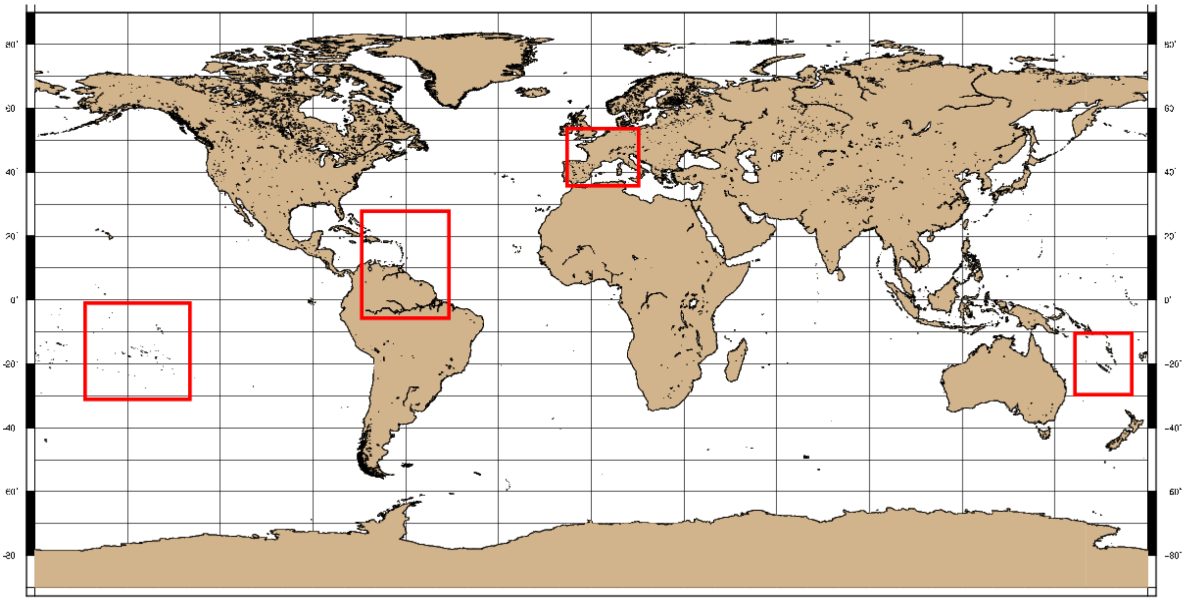

Fig. 1 Geographical extension of the ALADIN models coupled to IFS

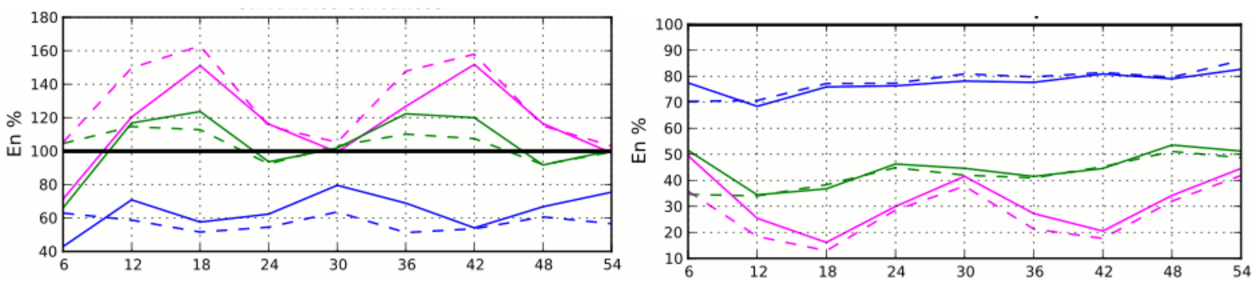

Fig. 2 Frequency bias (left) and miss ratio (right) for three thresholds 0.2mm/6h (pink) 2mm/6h (green) and 10mm/6h (blue) 6 hours precipitation forecasts performed by the ALADIN-ECMWF (full lines) and IFS (dotted lines). The scores are computed against the French rain gauge network for the year 2014 and are displayed in function of the lead time.

During the 6 first hours of forecast, ALADIN-ECMWF underestimates all thresholds of accumulated rain (Figure 2); the local adaptation by ALADIN-ECMWF of the IFS analysis and the difference between both physical packages reduce the number of forecasted rains and false alarms (not shown) for ALADIN-ECMWF but this underestimation increases the number of ALADIN-ECMWF's misses.

After 12 hours of forecast, better frequency biases are provided by ALADIN-ECMWF for the rain/no rain threshold even if light rains are over-forecasted by both models. This overestimation leads to a reduction of misses and false alarms for nearly all terms of ALADIN-ECMWF forecasts. For the second threshold 2mm/6h, differences between the two models are small and IFS bias approaches the perfect score while ALADIN-ECMWF persists in overestimation of convective events, more frequent during the afternoon.

Finally, heavy rains are underestimated and misses rise to more than 70% for both models. IFS false alarms for 10mm/6h rains are high but better than the LAM model (not shown).

Temperature at 2m AGL shows a different behaviour for IFS and for the French LAM during daytime and a common overestimation is found during the night in summer. The best RMSE of the wind at 10 m AGL is provided by IFS for all lead times and the improvement is around 3 %. For the relative humidity at 2m AGL in 2014, IFS was too dry for most of the lead times except for 6 pm while ALADIN-ECMWF was too wet most of the time (not shown).

Three LAM ALADIN are operated by Météo-France to provide high-resolution forecasts for tropical area including French overseas territories (Figure 1). Their horizontal resolution is equal to 8 km. A 3DVAR assimilation scheme has been implemented for these three LAM with 6 hours temporal windows. Two daily runs are performed at 0 and 12 UTC taking their boundary conditions in the IFS runs starting 6 hours before. The maximum lead time is 54 hours. The surface conditions are computed by a specific surface analysis similar to the one used by the French global model ARPEGE since September 2011. A major increase of the number of satellite data became operational the 02/07/2013 with the assimilation of IASI B, CRIS, OCEANSAT and ATMS. The LAM forecasts are compared with the IFS forecasts for surface parameters.

According to the diurnal variation of convection, better rain forecast scores are reached by IFS and ALADIN-ECMWF in the afternoon (local time) for both areas NOUVELLE-CALEDONIE and ANTILLES-GUYANE, but misses and false alarms are more numerous in these tropical regions than in Europe; differences between the two models are also larger than in Europe and present during the whole simulation. For the rain/no rain threshold, IFS gets better scores than the LAM but for the heavy rain threshold, both models show difficulties to simulate strong convective events (not shown). 2m AGL temperature is underestimated and relative humidity overestimated with better RMSE during the night when temperature decreases and humidity grows.

The temporal series of the RMSE for the wind at 10 m AGL (Figure 3) present a stronger improvement over the NOUVELLE CALEDONIE area than over the ANTILLES-GUYANE area. This difference is likely related to the mountainous characteristics of the domains which increase the advantage due to the higher resolution of ALADIN. The improvement oscillates between 10 and 25 % for the NOUVELLE CALEDONIE area and -5 to 5 % for the ANTILLES-GUYANE area depending on the lead time.

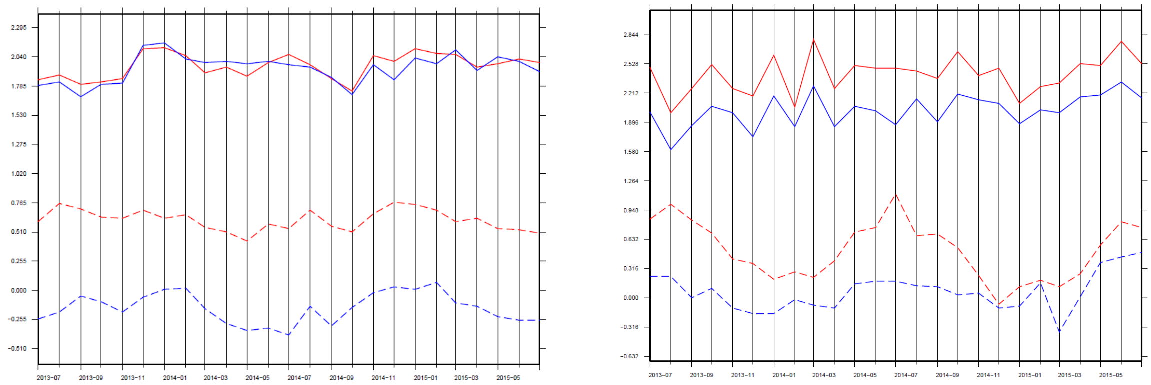

Fig. 3 Temporal series of the RMSE (full lines) and bias (dotted lines) for the wind at 10m AGL in m/s forecasted at 36 hours by ALADIN ANTILLES-GUYANE (blue lines) and IFS (red lines) on the left panel. The reference is provided by the surface stations included in the LAM domain and the errors are monthly averages. The same comparison is presented for the ALADIN CALEDONIE on the right panel at 36 hours.

The wind fields of the deterministic ECMWF-IFS system provide the forcing of the operational wave model MFWAM. The model MFWAM is based on the ECWAM code, but uses a different physical package related to the dissipation by wave breaking and the damping of the swell induced by the air-friction at the sea surface. A global version and a regional (European coasts) version centered on Europe have a horizontal grid meshes of 0.5° and 0.1°, respectively.

The global model MFWAM and other operational wave models are compared with buoys data in the framework of JCOMM intercomparison project. Figure 4 shows that in terms of normalized scatter index of significant wave height the wave model MFWAM is among the best analysis during 2014 and beginning of 2015. The regional model MFWAM-EURAT for the European coasts gives a good slope (1.01) of significant wave height in comparison with the altimeters data and a small normalized scatter index of 11.3 % during the last winter season, as illustrated in Figure 5.

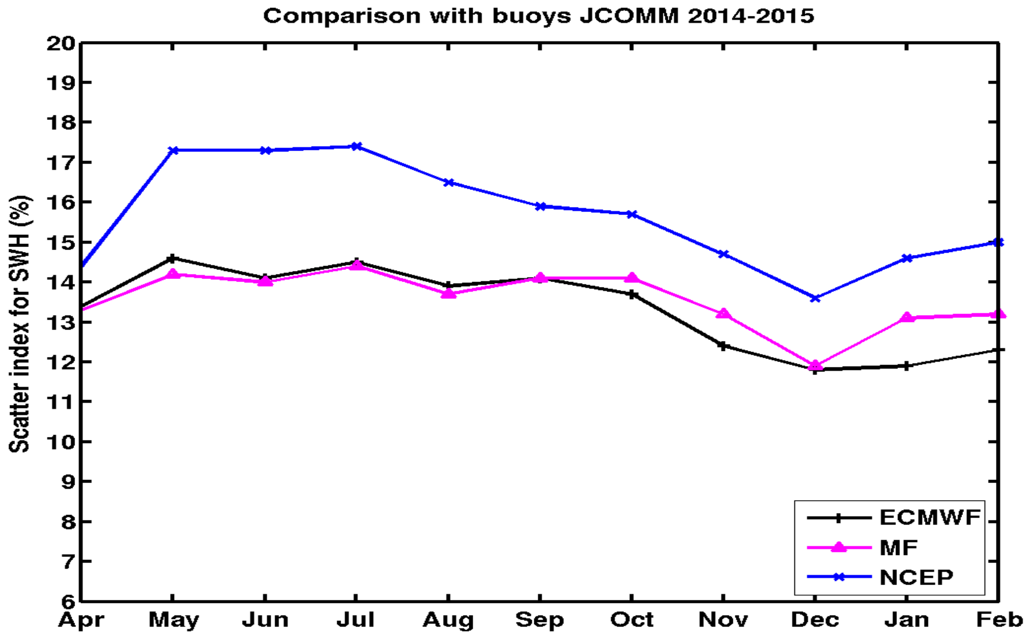

Fig. 4 Variation of normalized scatter index of significant wave height from the global wave models in comparison with buoys data (JCOMM intercomparison) from April 2014 to February 2015. Black plus, purple triangles and blue cross stand for ECMWF, Météo-France (MFWAM) and NOAA operational wave forecasting system, respectively.

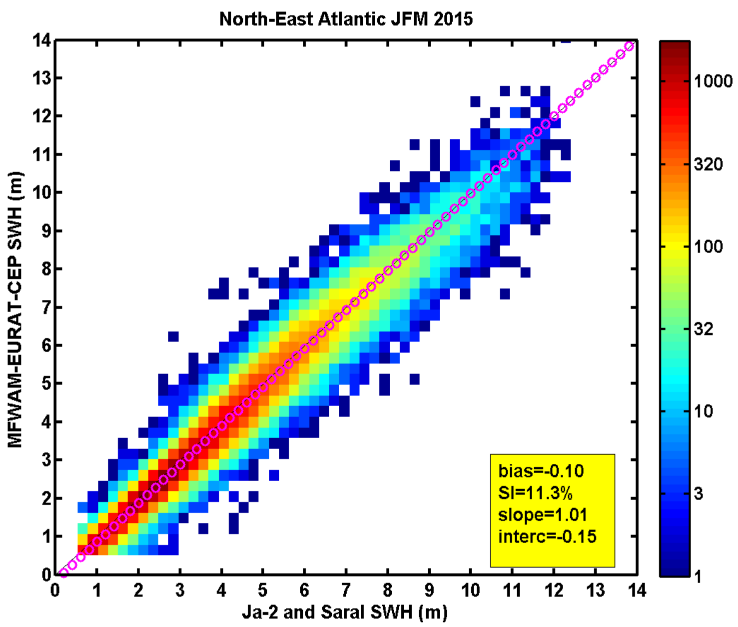

Fig. 5 Scatter plot of significant wave heights from the regional wave model MFWAM-EURAT driven by ECMWF winds (10 km grid size) and the altimeters Jason-2 and Saral/Altika during the winter season 2015 (January, February and March).

The MOCAGE chemistry transport model of Météo-France is operated daily, to provide air quality forecasts and analysis, in contribution to the MACC-II regional ensemble AQ[1] service.

The two chains (analysis and forecasts) are operated independently: due to the timing constraints of ensemble forecasts delivery (before 7 UTC for the first 48h of forecasts), on one hand, and to the late availability of surface observations on the other hand, the AQ analysis results cannot provide initial values for the AQ forecasts.

Since July 2014, the forecast system has been running on the Météo-France operational supercomputer BULL system which is 24hours/day monitored. Figure 6 summarizes the forecast operational production chains. Details are given in the next paragraphs.

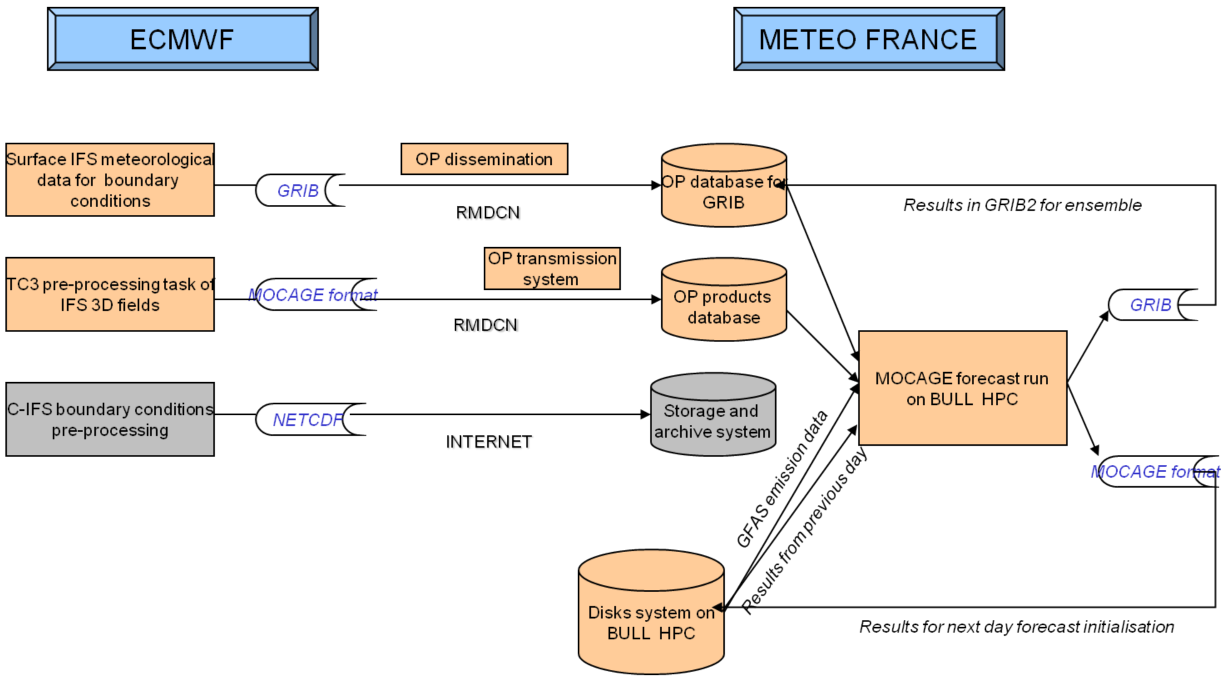

Fig 6 Schematic data-flow of the MOCAGE forecast chain. The parts in orange have a fully operational status. Others are pre-operational and underway of full operationalization

The following data are used by the forecast system:

- Meteorological initial forcings

As soon as the 12 UTC IFS meteorological forecasts are produced, a time critical task is triggered at ECMWF to pre-process 3D fields data (interpolation on the MACC domain, on MOCAGE vertical levels and conversion to suitable format for the MOCAGE model). The result files are transferred, by ECPDS, directly to Météo France’s operational transmission system, and then automatically stored in an operational products database (BDPE).

1 AQ : Air Quality

Meanwhile, surface data from IFS forecasts are disseminated directly to the operational GRIB database at Météo France (BDAP).

- Chemical boundary conditions

Chemical boundary conditions from IFS-MOZART (to be replaced soon by C-IFS) are pre-processed at ECMWF into NETCDF files, then transferred to the storage and archiving system at Météo-France. The operationalization of this chain has been delayed to 2016 and will be based on a process similar to that in place for the 3D meteorological fields.

- Aerosol boundary conditions

The aerosol boundary conditions are taken from MOCAGE global model outputs which provide more detailed aerosols than the current version of the aerosol module in IFS.

- GFAS fires emission daily products

These data are retrieved from MARS, at ECMWF, and pre-processed into NETCDF files, then transferred to the storage and archiving system at Météo-France. The operationalization of this chain has neen delayed to the last semester 2016 and will be based on a process similar to that in place for the 3D meteorological fields.

- Finally, initialisation fields from the forecast of the previous day are used, directly from the HPC disk system, where they are produced.

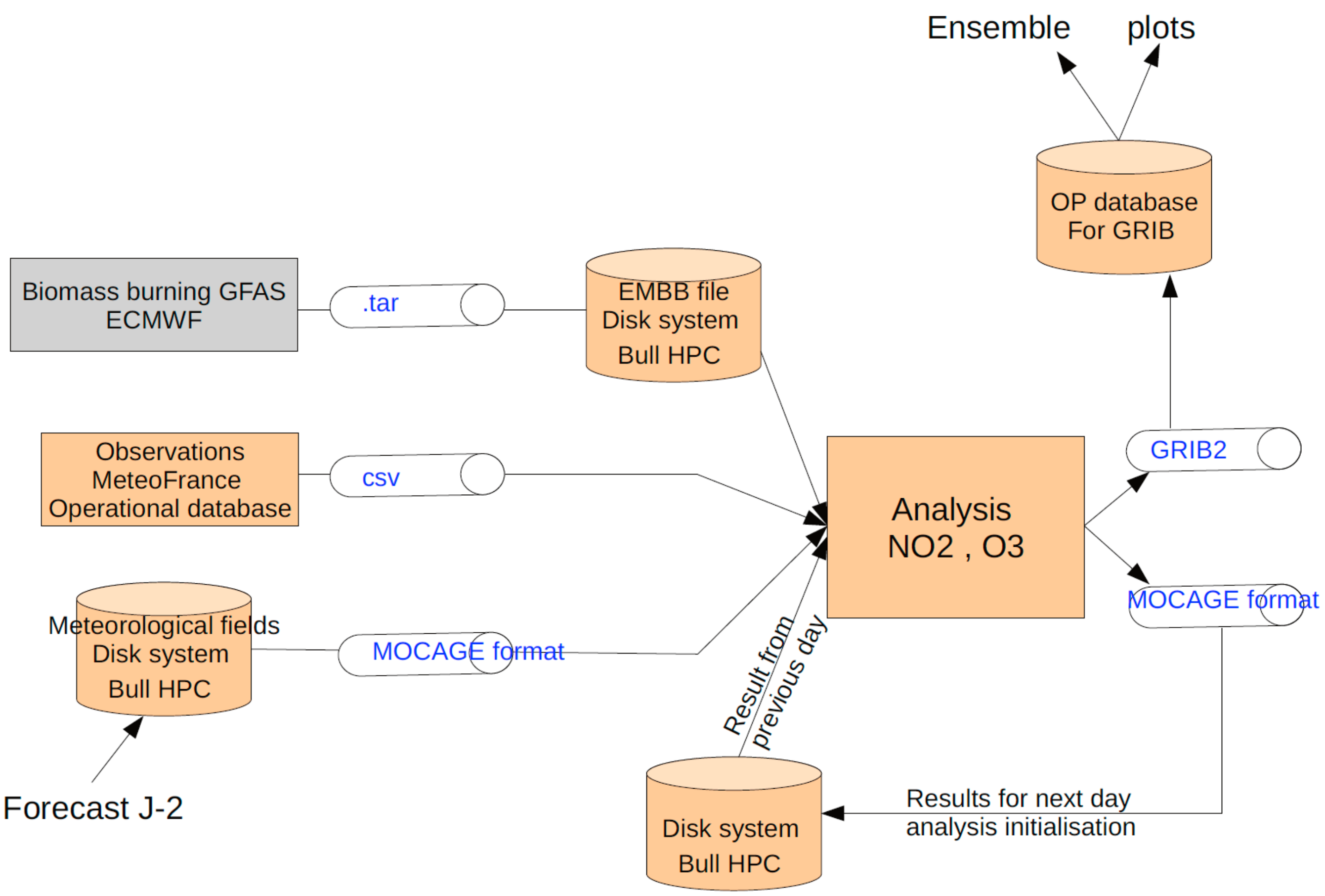

Fig 7 Schematic data-flow of the Mocage-Valentina analysis chain. The parts in orange have an operational status, and the parts in grey are daily routine operations in a R&D environment (pre-operational).

The MOCAGE-VALENTINA analysis chain has been operational since March 2015, although some parts of it still have a pre-operational status (Figure 7). Observations are from the csv file distributed from the operational system. Meteorological forcing files are extracted from ECMWF, using the same procedure as for the Mocage forecast. GFAS products are extracted from ECMWF. Note that the MOCAGE forecast can be run even if the GFAS and/or chemical boundary conditions are not available in time. All these data are stored in the R&D archiving system of Météo-France, and the analysis runs on the R&D HPC at Météo-France. Storage and simulations on these systems are mostly secured and reliable, except that they are not monitored 7/7 24/24. The grib2 files that are produced by the analysis run (resolution 0.1°x0.1°, surface only) are stored in the Météo-France operational database, thus feeding in the operational chain for ensemble processing.

2.1.3 Derived fields

Derived fields from Ensemble Prediction System are used by the forecasters from metropolitan and overseas centres. Ensemble mean and pre-calculated probabilities are available on the Synergie workstation. More elaborated products like strike-probabilities, percentiles, EFI are used via the ECMWF web sites (institutional web site and eccharts) or internal web sites.

Probabilities for specific thresholds are also calculated and available for the forecasters for marine models, for example significant wave height of at least 3 m or 9 m.

2.2 Use of products

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

3.1.2 ECMWF model output compared to other NWP models

3.1.3 Post-processed products

3.1.4 End products delivered to users

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

<u>Monthly forecast verification</u>

The monthly forecasts of 2m-temperature anomalies have been assessed by the forecasters since November 2004. For every week, the marks vary from A to D with the following meaning :
A : good localisation and intensity of the anomaly,
B : slight differences (localisation and/or intensity) between observed and forecast anomaly,
C : anomaly forecasted but not observed (false alarm) or (more frequently) anomaly observed but not forecasted (miss),
D : observed anomaly opposite to the forecasted anomaly.

The next figure (Figure 8) shows the evolution of the proportion of every mark for the ten years period from 2005 to 2014.

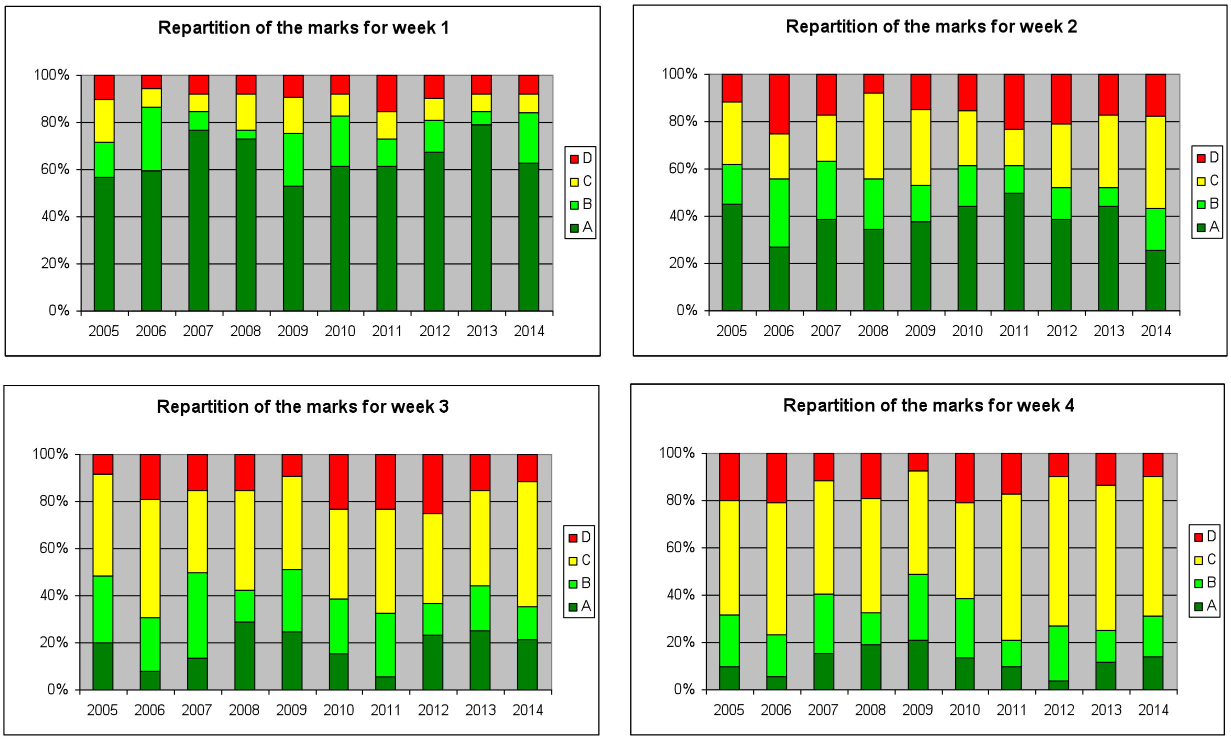

Fig. 8 Proportions of subjective notations for the forecast of the anomalies over France monthly temperature at 2m, from 2005 to 2014.

The forecast quality is good for week 1 (around 80%).

For week 2 the proportion of good forecast (A+B marks) is above 50% except for year 2014. This is mainly due to the important number of C marks (39%), which often correspond to misses where there is no signal in the forecast and an observed anomaly.

For the same reason, the proportion of good forecasts for week 3 and 4 is less than 50%. If we select the cases with signal in the forecast, the proportion of good forecasts becomes 58% for week 3 and 52% for week 4.

The repartition of the marks varies from year to year, but there is no clear tendancy over the 2005-2014 period. However there is a possible decrease in the proportion of wrong forecasts (D marks) for week 4.

3.2.2 Synoptic studies

4. References to relevant publications