Application and verification of ECMWF products 2015

METEO-FRANCE J. Stein, L. Aouf, N. Girardot, S. Guidotti, O. Mestre, M. Plu, F. Pouponneau and I. Sanchez

1. Summary of major highlights

The major event is the update in May 2016 of the MOCAGE-Valentina system used for Copernicus Atmosphere Services (CAMS 50 project), with the development and implementation into the operational suite of secondary inorganic aerosols in the model and the assimilation of PM10 surface observations.

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

<u>NWP LAM models</u> : 4 ALADIN models

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.

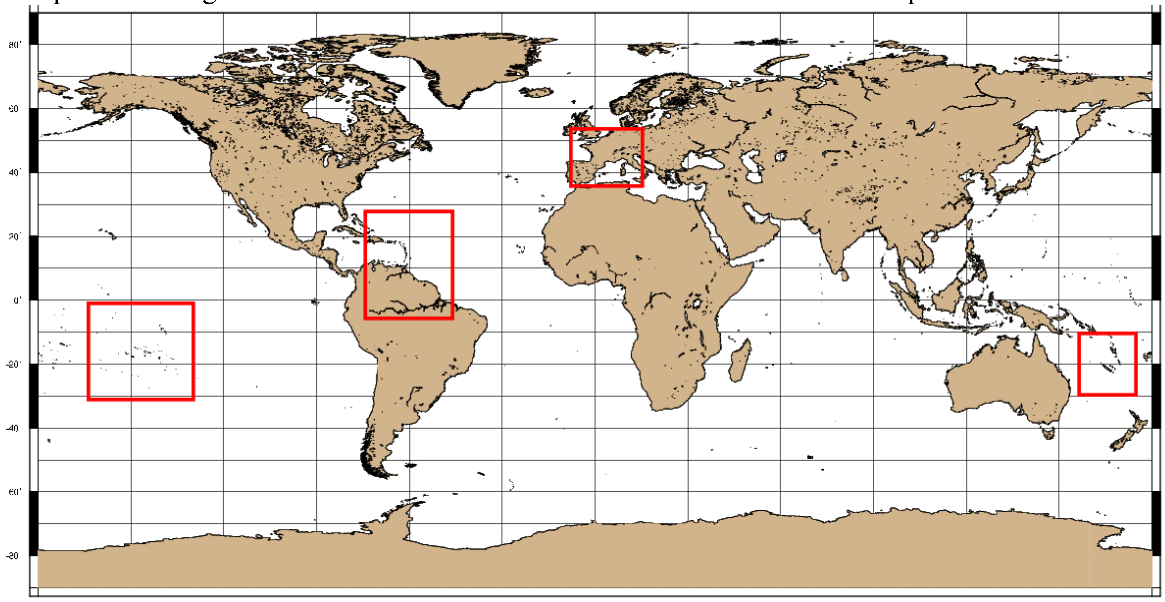

Fig. 1: Geographical extension of the ALADIN models coupled to IFS

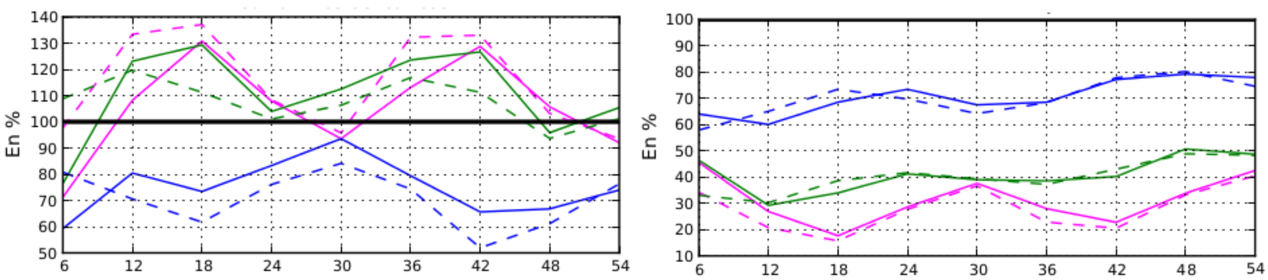

Fig. 2: Frequency bias (left) and miss ratio (right) for three thresholds 0.2mm/6h (pink) 2mm/6h (green) and 10mm/6h (blue) 6 hours precipitation forecasts performed by the ALADIN-ECMWF (full lines) and IFS (dotted lines). The scores are computed against the French rain gauge network for the year 2015 and are displayed for each six hours forecast lead time.

During the 6 first hours of forecast, all threshold of accumulated rain are underestimated by ALADIN-ECMWF; the local adaptation of the IFS analysis and the difference between the physical packages bring ALADIN-ECMWF to reduce the number of forecasted rains and so false alarms (not shown) but this underestimation increases the ALADIN-ECMWF's misses.

For light rains, 0.2mm/6h and 2mm/6h thresholds, both models present a diurnal cycle of bias with overestimation in the afternoon and better frequency biases during the night. Heavy rains are underestimated by both models, but their bias is better for ALADIN-ECMWF than for IFS. This difference produces more false alarms for ALADIN-ECMWF than IFS (not shown) but the benefit in detection if rather low.

Among the surface parameters verified but not shown, temperature at 2m AGL shows changes in IFS and ALADIN-ECMWF night scores over France during spring 2015: night overestimation of T2m AGL increased for both models and daytime biases are still negatives. The best RMSE of the wind at 10 m AGL is provided by IFS for all lead times and the improvement is around 2 %. For the relative humidity at 2m AGL, IFS was too dry for most of the ranges 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. 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 reduction of bias over the ANTILLES-GUYANE area but slight differences in RMSE between ALADIN-ECMWF and IFS and different behaviour over the NOUVELLE CALEDONIE area : wind force RMSE is reduced by ALADIN-ECMWF in 2015 but improvement in bias are weak.

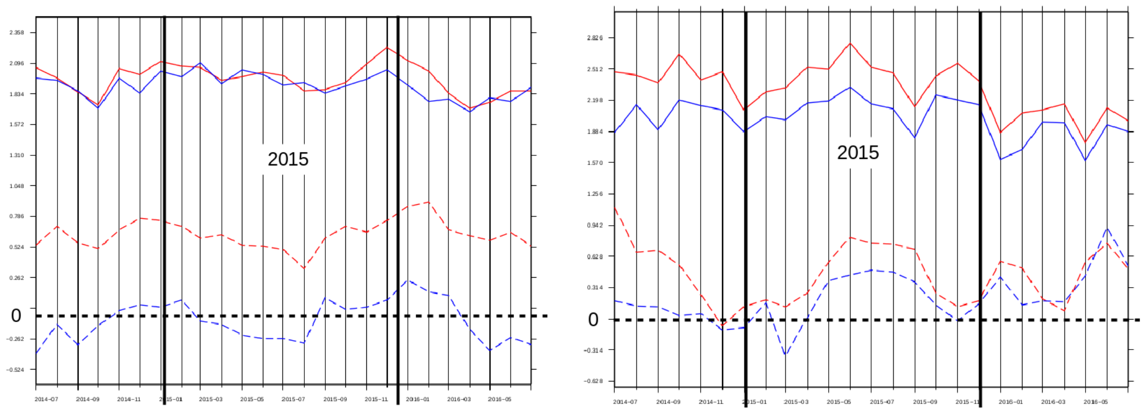

Fig. 3 Temporal series of the RMSE (full lines) and bias (dotted lines) for the wind at 10m AGL in m/s forecasted at 36 hours by ALADIN ANTILLES-GUYANE (blue lines) and IFS (red lines) on the left panel. The reference is provided by the surface stations included in the LAM domain and the errors are monthly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

<u>EMERGENCY PRODUCTIONS :</u> Pollutant transport and dispersion forecast

For the long-range dispersion forecast, Météo-France Toulouse uses two operational tools to assess impacts in case of an accidental release:

- An air mass trajectory tool computes simple lagrangian trajectories. Three neutrally buoyant particles are released in the atmosphere at a geographic location defined by the user and at three fixed vertical levels: 950, 850 and 700 hPa, corresponding to about 500, 1500 and 3000 m above sea level in standard atmosphere. The particles are only subjected to the action of the large-scale wind; no other physical or atmospheric process is taken into account. The 3-D wind field is provided by the global NWP models ARPEGE from Météo-France or IFS from ECMWF (choice of the user) sampled at 0.5° resolution and on 15 vertical pressure levels, from 1000 to 100 hPa. The tool provides a quick estimate of the expected trajectory of air parcels originating from the planetary boundary layer at the location of interest.
- a dispersion model, MOCAGE-accident, based upon the MOCAGE three-dimensional chemistry and transport model developed by Météo-France for the numerical simulation of the interactions between dynamical, physical and chemical processes in the lower stratosphere and in the troposphere (see section on air quality forecast). MOCAGE-accident is a version of MOCAGE specifically adapted for the transport and diffusion of accidental release from the regional to the global scale. Currently, only dynamical and physical processes are taken into account, excluding chemistry.

MOCAGE-accident runs in off-line mode, using Météo-France ARPEGE or ECMWF/IFS operational NWP products as dynamical forcings.
For this long-range dispersion forecast, IFS meteorological forcing over the domain needed are extracted from Meteo-France operational data bases, with fields disseminated to these databases from ECWMF, main fields used are the temperature, the humidity, and the wind related fields.

For local and regional scale dispersion forecast, Météo-France uses the system PERLE which is based on the combination of a meso-scale non hydrostatic model, which provides meteorological fields, and a lagrangian particle dispersion model (LPDM, from the Colorado State University), the formulation of which allows the description, during the first critical few hours, of the atmospheric pollutant cloud in the vicinity of a radionuclide or chemical release, without gaussian assumptions.
For the standard PERLE version, which is run over Metropolitan France in operations, the meso-scale meteorological fields considered are either AROME operational forecasts or specifically produced forecasts by the Meso-NH model (Lafore et al., 1998). In the case Meso-NH is considered, it uses two nested grids for emergency response, with a first domain covering 240km*240km area (4-km resolution) and a second domain covering 60km*60km area (1-km resolution), and two-way interactions between them; the initial and boundary conditions of the larger domain are defined by ARPEGE. In 2011, a "global" version of PERLE has been developed and can be used for any limited area domain over the globe, by considering IFS fields for both initial and boundary conditions of Meso-NH.

For this local and regional scale dispersion forecast, IFS meteorological forcing over the domain needed are extracted from ECWMF for temperature, humidity, and wind fields.

CAMS

The MOCAGE chemistry transport model of Météo-France is operated daily, to provide air quality forecasts and analysis, in contribution to the CAMS[1] regional ensemble AQ[2] service (Marécal et al, 2015).

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.

[1] Copernicus Atmosphere Services
[2] AQ : Air Quality

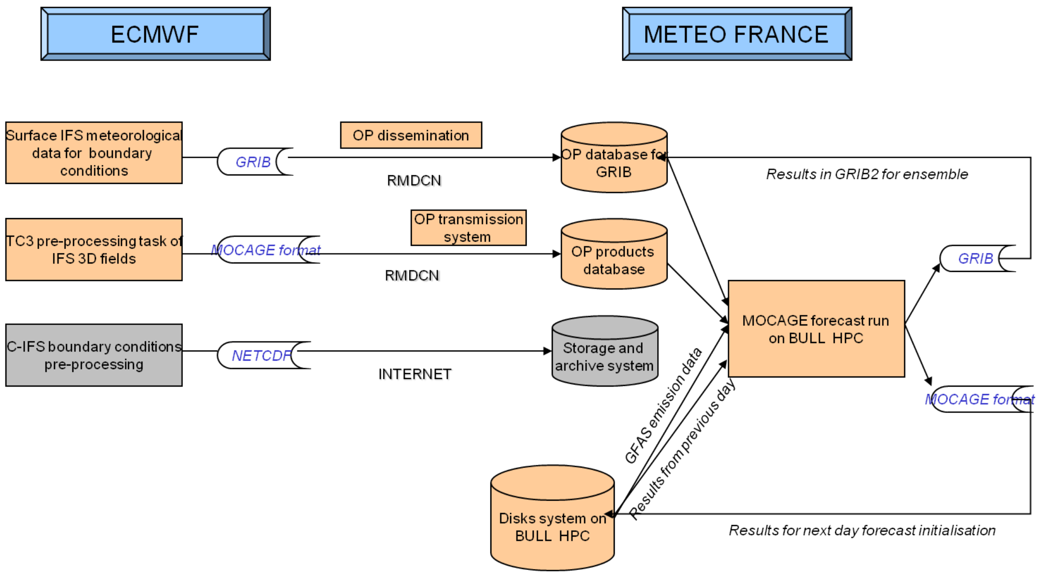

Fig 4**:** Schematic data-flow of the MOCAGE forecast chain.

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 CAMS 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).

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

Before end of 2016, the 00 UTC IFS meteorological forecasts will be added to this dissemination, by using the same system. The CAMS MOCAGE analyses will be forced by this 00 UTC IFS meteorological forecasts .

- Chemical boundary conditions

Chemical boundary conditions from 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 will be further studied before the end of 2016, it 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. As this chain is not yet fully operational, there is currently no plan to operationalize this chain. The MOCAGE forecasting and analyses chains can however run without these fields.

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

WAVE models

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. Both global and regional models MFWAM are assimilating the altimeters wave data (Jason-2, Saral/Altika and Cryosat-2).

The global model MFWAM is among the best wave forecasting system regarding to monthly intercomparison of JCOMM. Figure 5 shows the histogram of monthly normalized scatter index of significant wave height during the 12-hours of forecast. This indicates a scatter index of significant wave height in average of 10% during last year and the beginning of 2016. Further the tendency year by year is to a decrease of the scatter index. The regional model MFWAM-EURAT for the European coasts gives a good slope (1.06) of significant wave height in comparison with Brittany and Biscay buoys and a small normalized scatter index of 9.9 % during the last winter season, as illustrated in Figure 6.

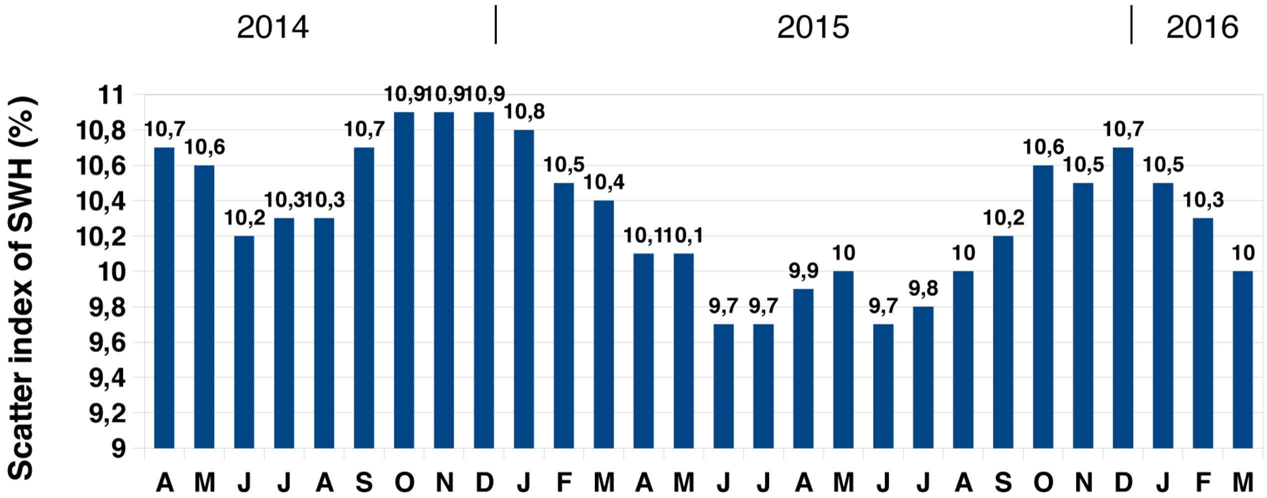

Fig. 5: Histogram over 2 years of monthly normalized scatter index of significant wave height of the global model MFWAM driven by ECMWF winds in comparison with altimeters data (Jason-2 and Saral) during the 12-hour of forecast.

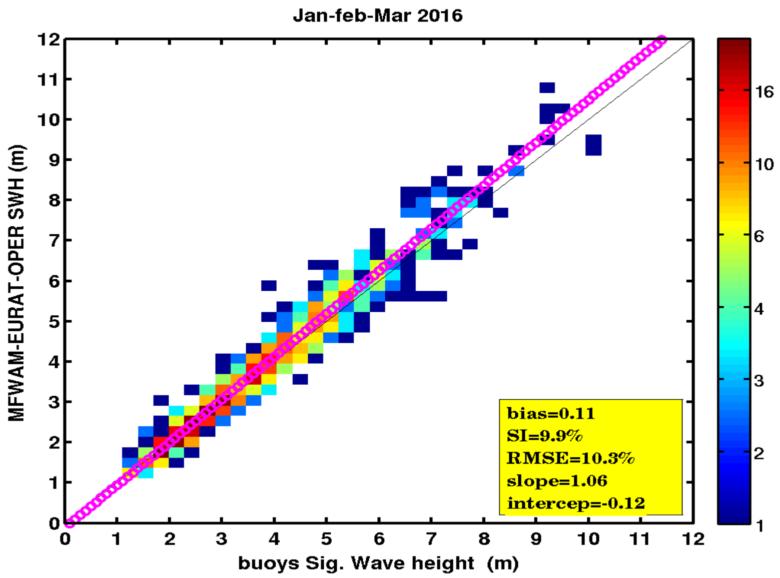

Fig. 6: Scatter plot of analysis from regional wave model MFWAM-EURAT driven by ECMWF winds (10 km grid size) and the Brittany and Biscay buoys significant wave heights during the winter season 2016 (January, February and March).

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)

Monthly forecast verification

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 7) shows the evolution of the proportion of every mark for the eleven years period from 2005 to 2015.

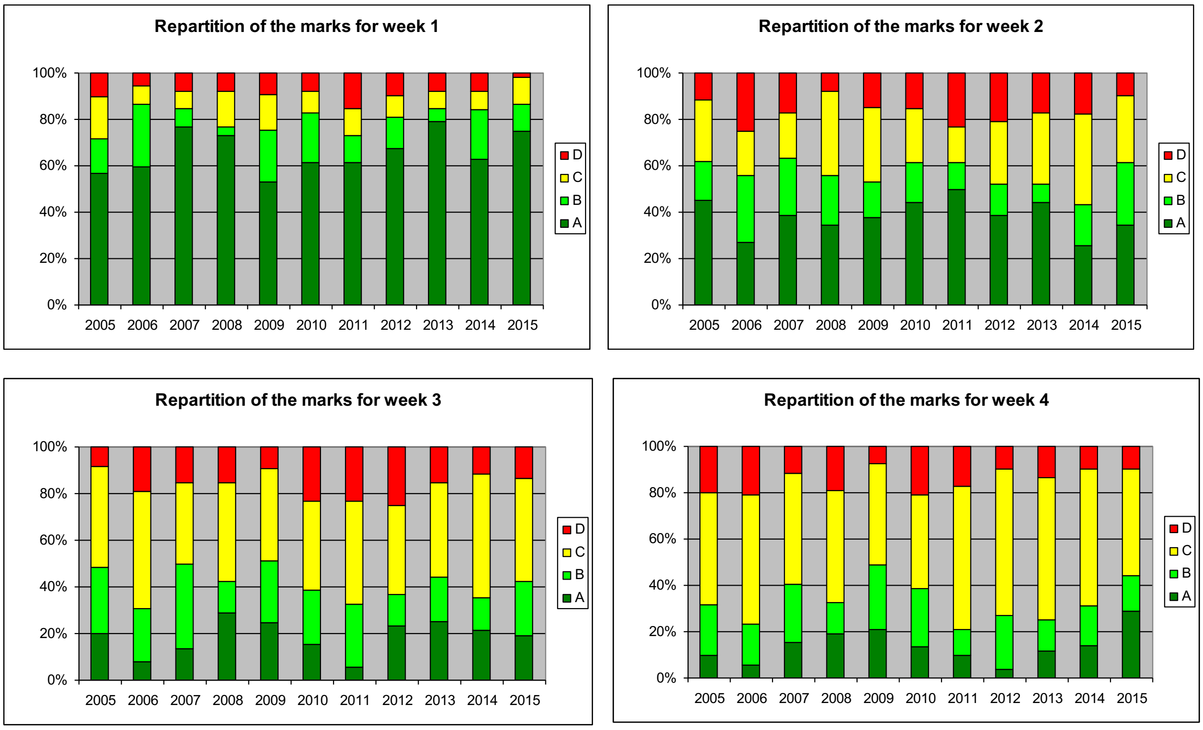

Fig. 8: Proportions of subjective verification for the forecast of the anomalies over France of monthly temperature at 2m, from 2005 to 2015.

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 2005-2015 period. However there is a possible decrease in the proportion of wrong forecasts (D marks) for week 4.
We can also stress that 2015 is one of the best years (regarding proportion of A+B marks), especially for week 2 and 4. The period from end November to end December, with strong warm anomalies, has been very well anticipated, up to week 4.

3.2.2 Synoptic studies

4. References to relevant publications