Use of ensemble prediction techniques to protect sensitive areas from oil spills

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Introduction

French operational capacity in oil spill drift forecast is based on Météo-France and Cedre expertises. Drift forecasts rely on a pollutant drift model, named MOTHY (Modèle Océanique de Transport d'HYdrocarbures).

France has five active nuclear reactors on the seashore. Paluel is one of them (figure 1). Nuclear power plants draw cooling water directly from the sea (figure 2). If a slick spreads to their intake canals, oil could get into the cooling machinery and potentially shut down the plant. To be informed well in advance of this risk, the electricity company has set up surveillance zones around nuclear power plants and asked Météo-France to forecast the time before oil can enter the surveillance zones and associated probabilities.

Figure 1: Map of country with study area (Paluel)

Figure2: Paluel nuclear power plant and intake canal

Ensemble prediction techniques

The quality of slick drift forecasts depends primarily on the reliability of weather forecasting. The traditional method of making a weather forecast is to take the best model available and run it until it loses it's skill due to the growth of small errors in the initial conditions. An alternate method that produces forecasts with skill up to several days after the initial forecast uses what is called "ensemble forecasting". Instead of using just one model run, many runs with slightly different initial conditions are made. Due to computational cost, these runs have a lower resolution.

Discussion

We compare forecasts from one model used for day to day weather forecasting with 35 lower resolution model runs (table 1).

Model	Number of run	Resolution
ARPEGE (Action de Recherche Petite Echelle Grande Echelle)	1	0.1°
PEARP (Prévision d'Ensemble ARPege)	35	0.25°

Table 1: comparison of ARPEGE and PEARP

Figure 3 shows a 60 hours forecast. Since, PEARP atmospheric forecasts are assumed equiprobable, it is possible to associate a probability. This weather situation shows a large dispersion of forecasts.

The curves on figure 4 show the probability that oil enters the predefined areas. The forecast with ARPEGE does not enter the security zone (colored stars), while several predictions with PEARP do (red curve). The arrival times of oil in the predefined areas are highlighted in table 2.

Model	Vigilance area	Warning area	Security area
ARPEGE	25	38	Not enter
PEARP (1 run)	16	27	36
PEARP (50%)	24	40	Not reached

Table2: arrival time (hours) of oil in predefined areas

While the deterministic forecast of ARPEGE did not indicate risk for the safety zone, the ensemble forecasting PEARP shows that this risk exists and gives a probability of occurrence.

Conclusion

We have shown here how ensemble prediction techniques help to quantify forecast uncertainty and how to use them as a quantitative tool for risk assessment. Although the single deterministic prediction did not indicate a risk for the safety area, about a third of the PEARP Ensemble Prediction System's 35 members included a drift of oil into the area. Hence, users can make informed decisions based on these probabilities and their own cost/loss ratios. The potential value is then much higher than that of a forecasting system based on only a single deterministic forecast.

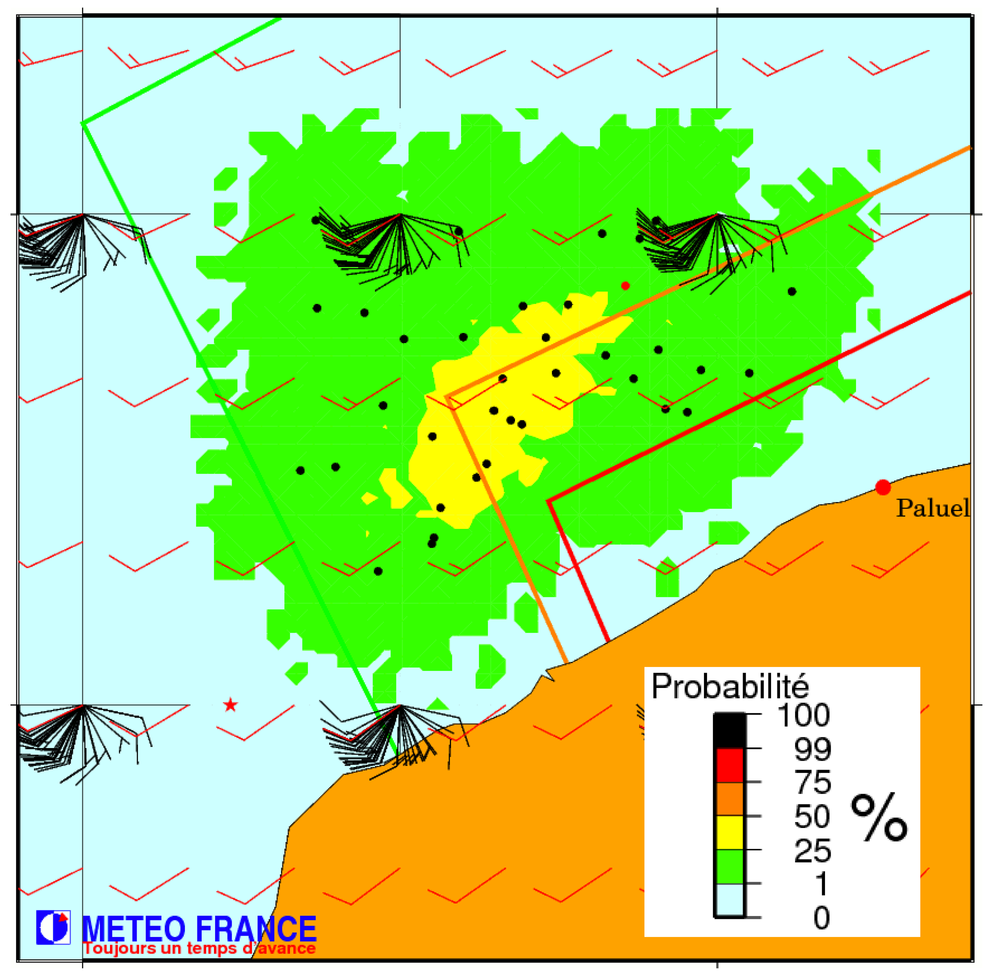

Figure 3: 60 hours oil drift forecast. Red dot locate the nuclear power plant of Paluel. Surveillance zones are in green (vigilance area), orange (warning area) and red (security area). The centroids of slicks are represented by black dots (forecast provided by PEARP). The centroid of the slick forecasted with ARPEGE is represented by a red dot. Winds in red are those of ARPEGE and those in black are the winds of PEARP. The color ranges are related to the probability of finding oil (green and yellow here).

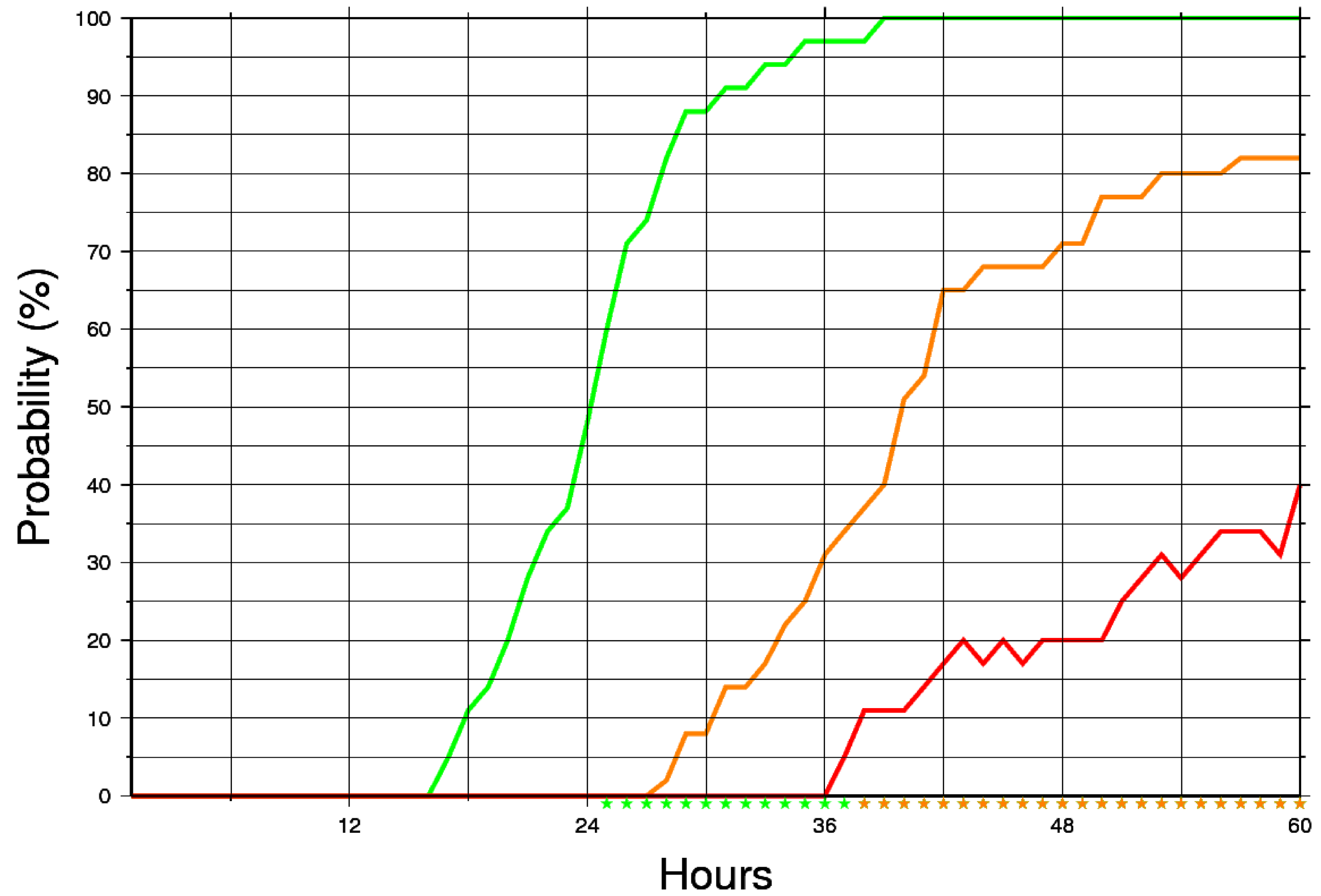

Figure 4: Probability that oil enters *the surveillance zones: green (vigilance area), orange (warning area) and red (security area): colored curves (PEARP). Colored stars, below the graph, show the arrival time of oil in the areas forecasted with the deterministic atmospheric forcing (ARPEGE).*

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