LAB_METOC
AN APPROACH TO MASTER OPERATIONS SENSITIVE TO ENVIRONMENTAL CONDITIONS ON A LAUNCH BASE

Gilles Gruez[1], Mickaël L'Haridon[1], Sophie Missonnier[1]

[1] *CT INGENIERIE, Advanced Modeling and Systems Engineering, Guyancourt, France*
gilles.gruez@ctingenierie.com

INTRODUCTION

When you consider doing an outdoor activity, you will probably ask yourself, "How will the weather affect what I want to do?".

Every day, we are all faced with the problem of carrying out activities that are weather-sensitive. There are activities as simple and ordinary as walking down the street or driving to work. There are others much more complex, such as piloting an airplane, launching a rocket or managing a wind farm.

The questioning is the same, but the stakes do not have the same importance. Without necessarily being catastrophic, the consequences of weather-sensitive human activities are frequently costly, due to the delays suffered or the objectives being partially achieved or even missed. Economic logic will then tend to reduce the consequences by anticipating unfavorable weather conditions and by reorganizing the planned activities as best as possible.

In addition, for many activities taking place in a given area, weather-sensitive operations can be manifold; they can be implemented in parallel and be carried out by different actors who must nevertheless cooperate.
In any case, it is fundamental that all the actors involved share the same knowledge of the environmental situation, called the "Environmental Situation Picture", in order to meet the requirements of safety and security, cost reduction and standardization that the globalized economy imposes.

Some will find answers on their own, thanks to their knowledge and experience. For meteorological experts, it will be a matter of analyzing and interpreting the data available to them. Our approach was to develop a decision support platform concept based on modeling and assessing the impact of weather conditions on human activities. In order to widen its scope, we have extended the notion of meteorological conditions to the Earth Sciences that characterize the Environment: Oceanography for the maritime environment and Geography for the terrestrial environment (elevation terrain, vegetation, soils and subsoils, etc.). We will thus speak of Sensitivity to Environmental Conditions.

LAB_METOC: A DECISION AID PLATFORM FOR ASSESSING THE IMPACT OF ENVIRONMENTAL CONDITIONS ON HUMAN ACTIVITIES

The concept we have developed in the LAB_METOC platform consists of implementing algorithms that model the sensitivity to environmental conditions of activities, or machines and devices used during activities.

This modeling aims to translate sensitivity into impact levels characterizing the deterioration in performance of the activity due to environmental conditions.

The impact levels are then converted into risk levels by applying thresholds that formalize a gradation of risks by intervals, from the lowest level to the highest level.

The risk levels are finally presented to the user according to a tricolor scale, green, yellow and red, respectively for the lowest level risks, the moderate risks and the strongest risks.

The decision support provided by LAB_METOC informs the user of the level of risk incurred, in a simple and direct way that does not require knowledge, reflection or interpretation.

LAB_METOC thus allows a user who is not an expert in meteorology to know at a glance the level of risk that the environmental conditions pose to the activity he plans to carry out.

If he wishes, the user can request detailed information on the causes that lead to the level of risk provided by LAB_METOC, but in any case, he is able to make the appropriate decisions regarding the possibility of carrying out his activity, being clearly aware of the level of risk he faces.

The benefits of LAB_METOC is to help the user to make operational decisions while remaining strictly focused on his job.

General principles

LAB_METOC implements a complete processing chain to provide operational decision support to users (Fig 1).

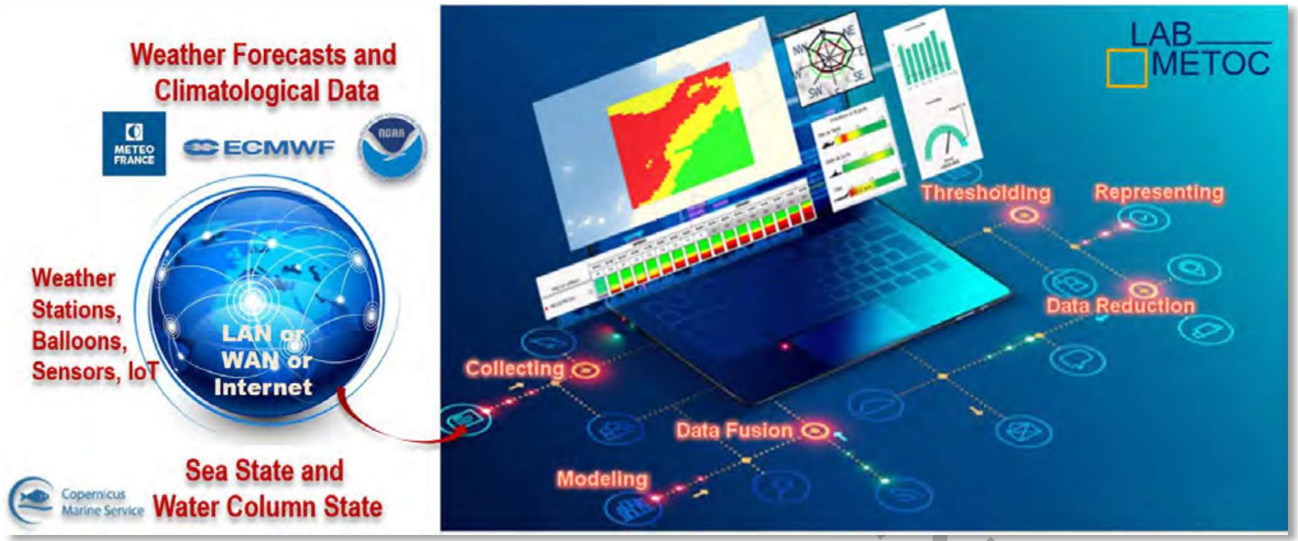

Fig 1: General principles implemented in LAB_METOC

Collecting Environmental Conditions
LAB_METOC implements a process that collects various types of environmental data:

- **Forecast data**, to anticipate the effects of environmental conditions over several days and allow activities to be reorganized if necessary. These data cover the geographical areas of interest, over the entire air column for meteorological data and over the entire water column for oceanographic data. This data are collected several times a day from forecast providers such as METEO FRANCE, ECMWF, NOAA, COPERNICUS, etc.

- **Measured or observed data**, from weather balloons and weather stations that provide accurate and reliable local information on current environmental conditions. This information is crucial as a rocket's launch time nears.

- **Climatological data**, in the form of statistics or re-analyses, which make it possible to carry out analyzes of seasonal variations in terms of impact. The objective here is to identify, for a particular place on the globe, the periods of the year favorable or on the contrary unfavorable to the realization of the activities that one wishes to carry out.

  Forecast data and measured data are evolving and ephemeral data. It is essential to refresh them regularly in order to update the picture of the Environmental Situation and the risk assessment as time goes by.

Modeling Sensitivity to Environmental Conditions
The kernel of LAB_METOC implements the modeling of the sensitivity to environmental conditions. This kernel is composed of several calculation modules implementing different modeling, merging and data reduction algorithms. LAB_METOC was designed as a scalable platform intended to host the various sensitivity models. Two modeling approaches are implemented:

1. Generic behavioral modeling.
2. Various modeling based on the simulation of physical phenomena.

These two approaches are detailed below.

Thresholding and Displaying
The purpose of thresholding is to transform a sensitivity into a level of risk. In LAB_METOC, these thresholds are adaptable and configurable in order to adapt to the particularities of the activities considered. The graphical representation, in the form of risk chronograms, impact maps or dashboards, allows the end user to understand at a glance the environmental situation and its future evolution.

Broadcasting and Sharing
In a collaborative context with multiple actors and activities carried out in parallel, the platform makes it possible to broadcast and share the Environmental Situation Picture to increase the safety and security of activities and to optimize and reduce their costs.

The MODCOMP behavioral model

MODCOMP is the behavioral model of LAB_METOC that models the sensitivity of devices and activities to environmental conditions based on expert rules. This approach is generic and configurable. It can be implemented as soon as sensitivity can be expressed in the form of rules and threshold values.

With this model, LAB_METOC can process a large number of activities, in a wide variety of fields, such as:

- Implementing of a lifting crane,
- or launching an underwater drone from a ship,
- or landing an helicopter on the deck of a ship,
- or taking into account the effects of wind chill for outdoor workers,
- or carrying out a maintenance operation in an offshore wind farm.
- Etc.

To illustrate this approach, consider the activity of implementing a surveillance drone. The person in charge of this activity is led to ask the following question:
“Can we fly a surveillance drone tomorrow, given the upcoming environmental conditions? »

However, this activity actually has two separate sub-activities: flying the drone and watching the area with the camera.

Thus, the initial question breaks down into two questions:

- Can we fly the drone safely tomorrow?
- Will the weather conditions allow the camera to provide usable images?

LAB_METOC can answer all these questions. For this, we configure in LAB_METOC the sensitivity of the drone to meteorological conditions as well as the rules to be applied for a safe use of the drone. We provide the threshold values beyond which the risk of crash becomes too high, as well as those that reduce the vision of the camera.

In this example, we express the sensitivity of the drone with respect to the following weather parameters:
Wind speed, wind gusts, precipitation intensity and distance of visibility.

On the one hand, for the flying conditions of the drone:

Wind speed	10 m/s	20 m/s	
Sensitivity	Low	Moderate	High

Gusts	15 m/s	25 m/s	
Sensitivity	Low	Moderate	High

Precipitation	Low	High	
Sensitivity	Low	Moderate	High

In addition, we also provide a weighting defining the importance of the sensitive parameters relative to each other, in order to calculate the combined impact of these parameters.

On the other hand, for the camera:

Distance of visibility	100 m/s	1000 m/s	
Sensitivity	High	Moderate	Low

From the forecast weather conditions for tomorrow, the behavioral model calculates the level of risk, low, moderate or high, associated with the drone flying conditions and the ability of the camera to provide usable images (Fig 2).

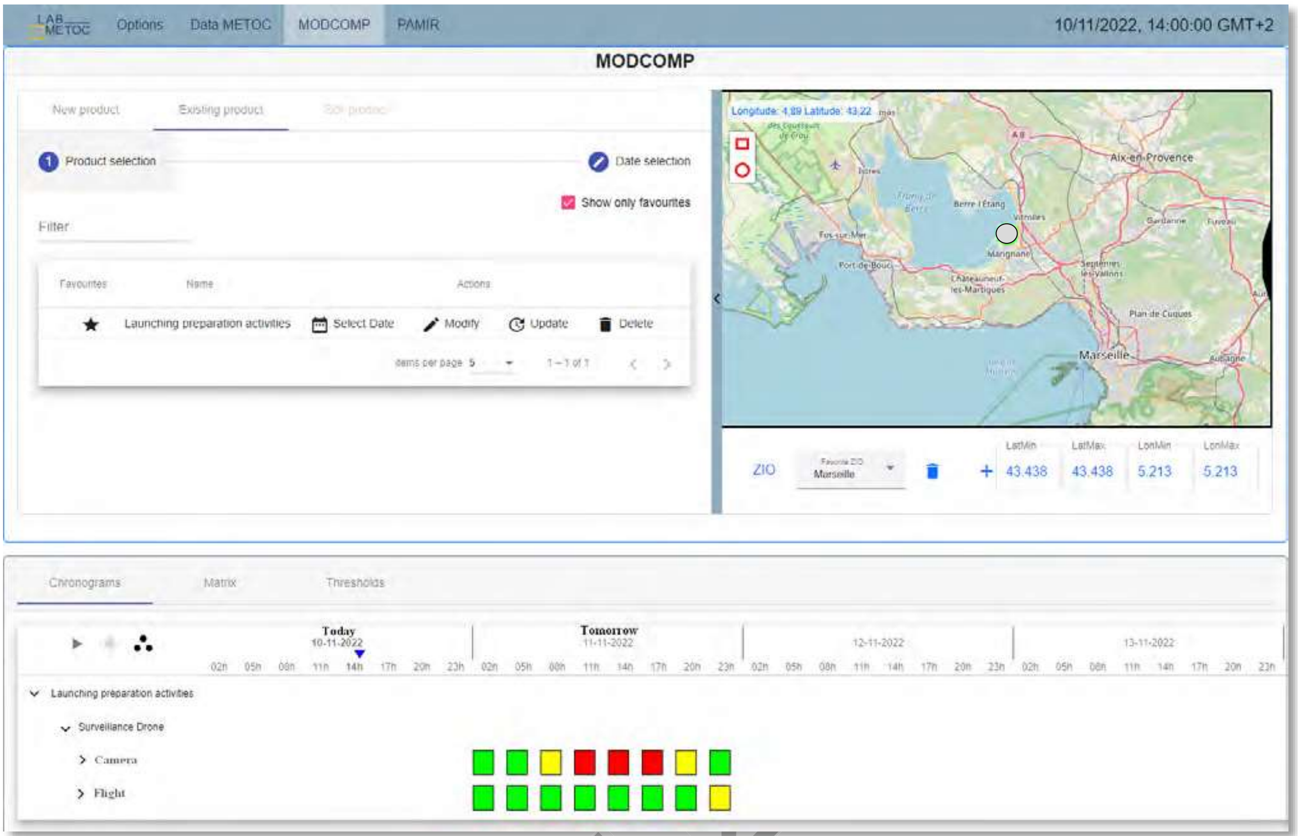

Fig 2: Risk assessment of two sub-activities calculated from a 24 hours weather forecast set every 3 hours.

Aggregating / merging of risks

Then we use weighting rules to aggregate these two risks and thus answer the user's first question about the overall risk of failure of the activity (Fig 3).

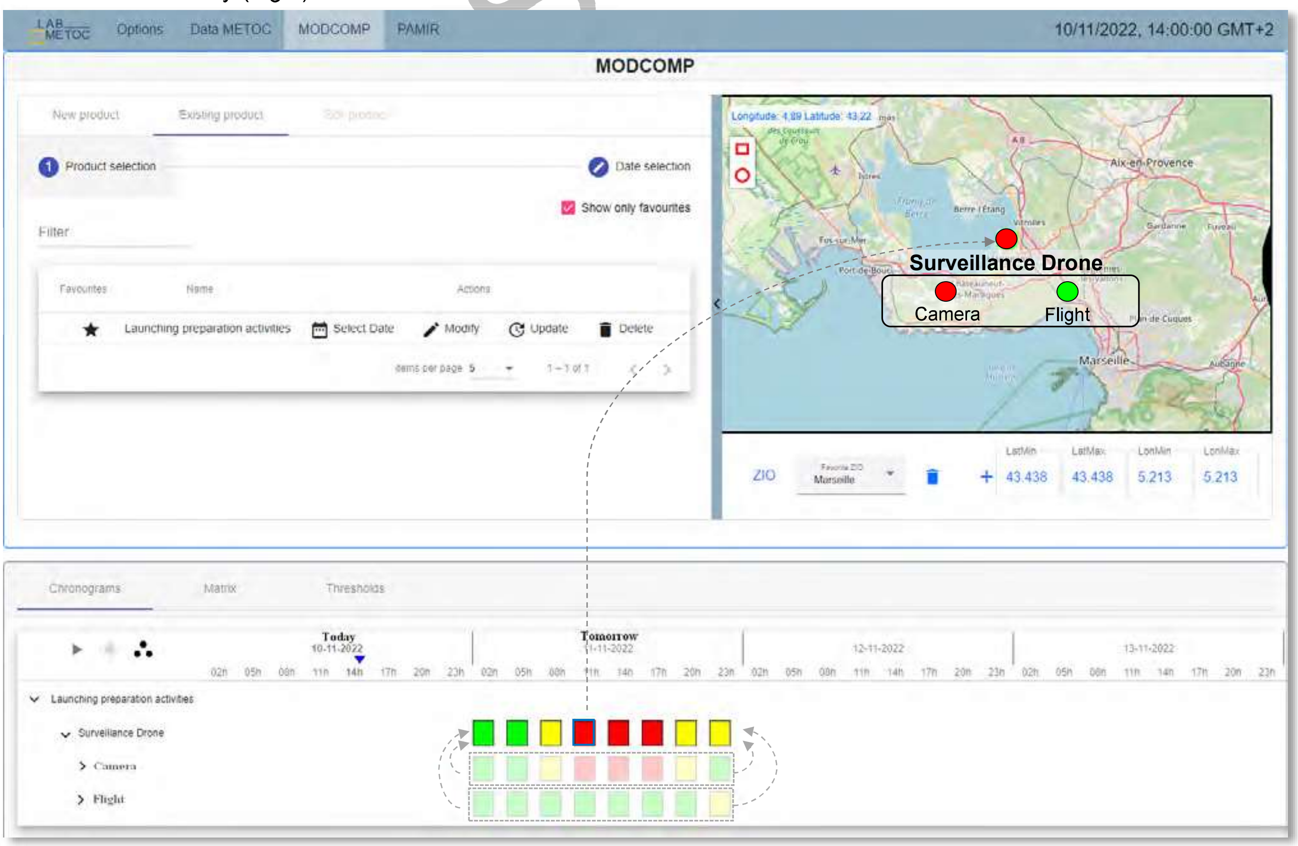

Fig 3: Aggregation of the risks of the sub-activities

Searching for favorable periods
Finally, a new question may arise if the risks are too high during the period considered.
"When will the environmental conditions be favorable enough to carry out the planned activity safely?"

To do this, you just have to provide LAB_METOC with the weather forecasts for the next few days and apply them to this modelling. The evolution of the risks will then be displayed over this period according to a chronology and will allow the user to reschedule this activity to a more favorable date (Fig 4).

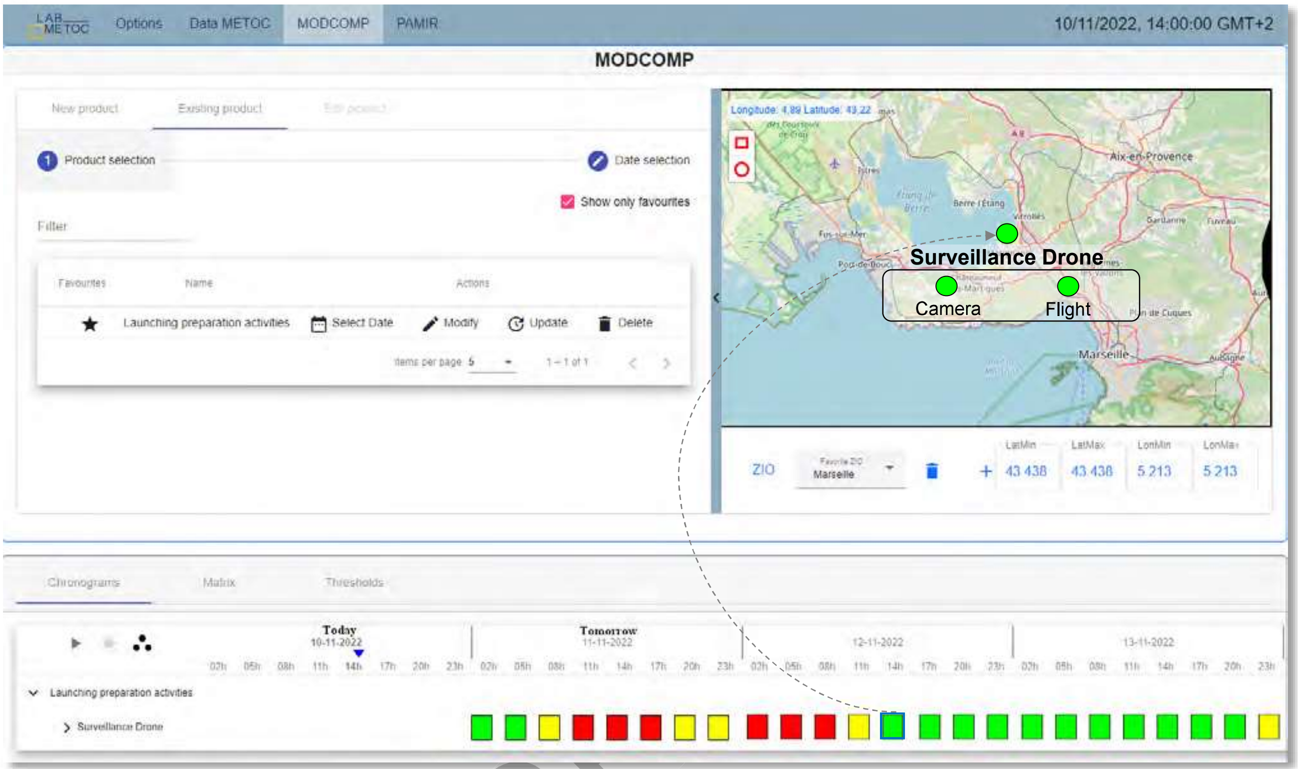

Fig 4: Identification of a favorable period for the envisaged activity

Physical models

In addition to the MODCOMP behavior model, LAB_METOC implements physical models. These types of models are used when, within an activity, a critical device or hardware deals with a physical phenomenon that can be affected by the environment where it evolves, for instance:

- The propagation of an infrared wave in the atmosphere, for infrared cameras.
- The propagation of an underwater acoustic wave, for sonars.
- The propagation of an electromagnetic wave, for radars.
- The dispersion of a polluting agent.
- Etc.

For each of these cases, models have been implemented for calculating the variation of the phenomenon, negative or positive, depending on the environmental conditions. These models deal with the physics of a phenomenon and are independent of the targeted devices. To take into account a particular device, the model is provided with the main parameters that characterize this device.
This approach is illustrated below with the PAMIR infrared propagation model.

The PAMIR infrared propagation model
We have developed the PAMIR model to assess the variations in the transmission of infrared waves as a function of the composition of the Earth's atmosphere (gas and particles).

From an operational point of view, this model makes it possible to evaluate the loss of performance of an infrared sensor due to weather conditions. Operational managers are thus informed of the periods when the infrared cameras are effective and when they are not.

The environmental conditions that affect the transmission of infrared waves and that are taken into account by PAMIR are:

- Absolute humidity in the air
- Nebulosity
- Presence and height of clouds
- Liquid and solid precipitation
- Maritime aerosols
- Terrestrial aerosols

PAMIR also takes into account the conditions of use of the infrared sensor: if, for example, it is used from a ship with a horizontal sight or if it is on board an aircraft with an oblique sight towards the ground. The environmental conditions to take into account are quite different. In the first case, only the horizontal layer of the atmosphere at sea level is taken into account. In the second case, we must consider the entire column of air between the sensor and the ground.

To illustrate the interest of this approach, let us consider an aircraft equipped with an infrared camera that takes part in a recovery mission of a launcher components.

LAB_METOC/PAMIR can answer the following operational question:
"Off the coast of French Guyana, throughout the recovery area of launcher components, where and when, in the next few hours, will the infrared camera on board the aircraft have sufficient performance to find components we are looking for? »

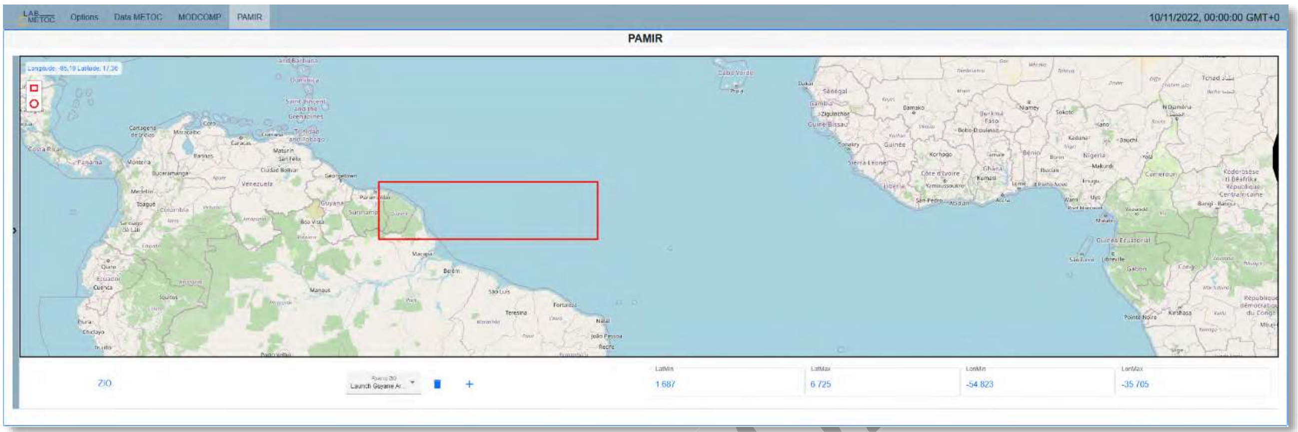

Fig 5: Recovery area of launcher components

Using a 2 days NOAA (National Oceanic and Atmospheric Administration) weather forecast, 3 hours time step, covering the weather area, PAMIR computes the IR transmittance at the selected wave length, within each weather cell provided by the forecast. If the computed transmittance is good enough, it is displayed in green, if it is too low, it is displayed in red, in between, it is yellow.

The results below show that during this period, the performance of a 4 µm wavelength sensor is good. There are very few areas in red and the areas in yellow do not prevent the sensor from providing usable images (Fig 6).

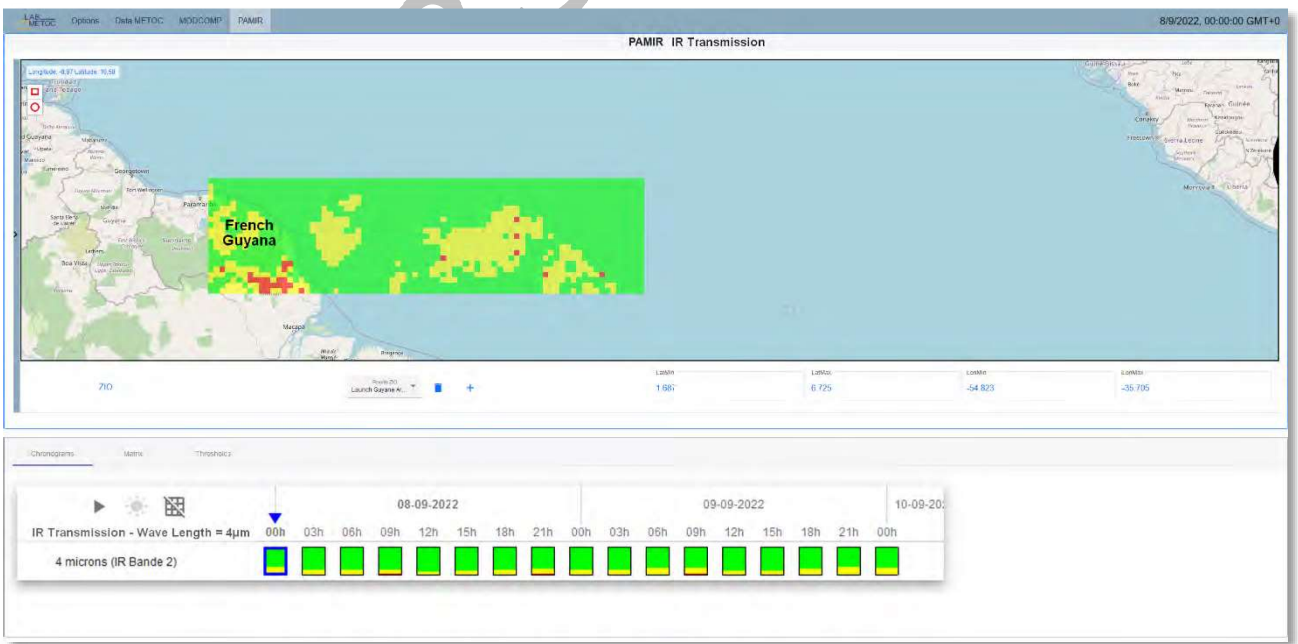

Fig 6: IR Transmission affected by environmental conditions for a 4µm IR Sensor

We made another run, using the same forecast, for a 10µm wavelength sensor. The results show that the performance of a 10µm wavelength sensor is worse, but still acceptable (Fig 7).

In any case, these results confirm that the mobilization of a patrol aircraft will be beneficial to the recovery mission scheduled for the next two days.

Additionally, they also allow us to recommend the use of a 4 µm sensor rather than a 10 µm, to increase the chance of recovery.

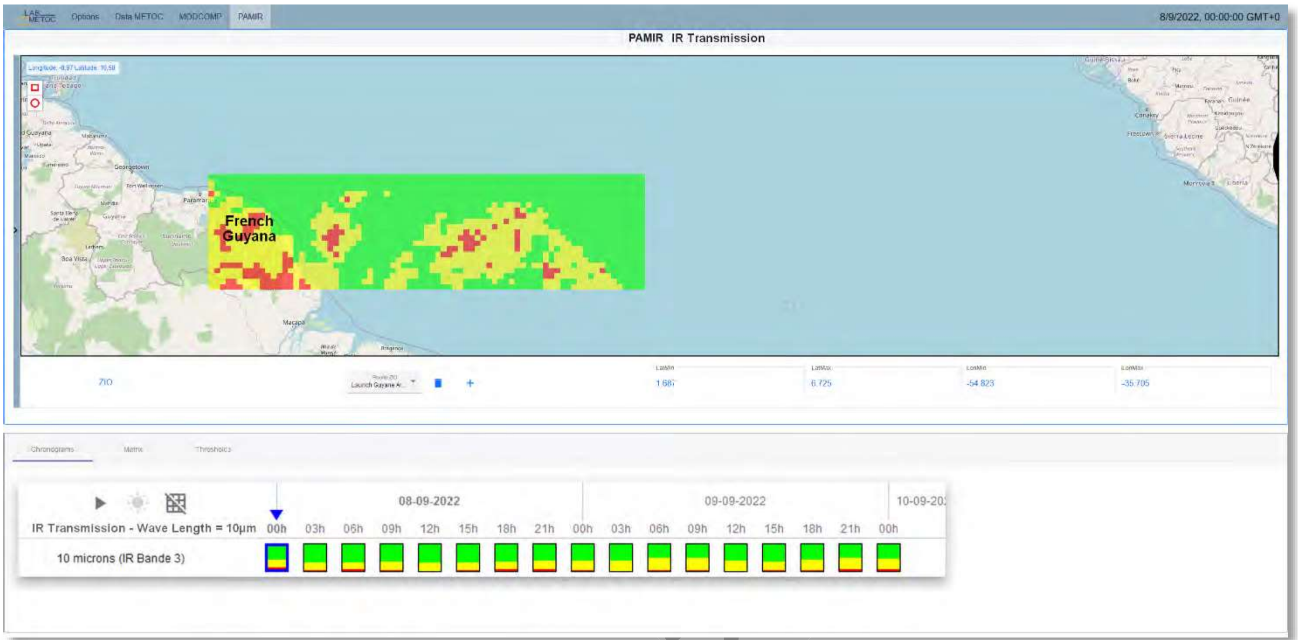

Fig 7: IR Transmission affected by environmental conditions for a 10µm IR Sensor

LAB_METOC IMPLEMENTATION FOR A SPACE BASE NEEDS

The LAB_METOC platform was initially developed and validated for the Defense sector. As part of the European SAMMBA Project, we have adapted LAB_METOC to better meet the needs of the space sector.

These adaptations focused in particular on the ease of deployment and use of LAB_METOC, in order to meet the constraints of medium and small launch bases, in which the infrastructures can be modest.

The SAMMBA project has defined a virtualized platform in which LAB_METOC has been integrated. The products and services made available by LAB_METOC are thus available to all applications capable of requesting them (Fig 8).

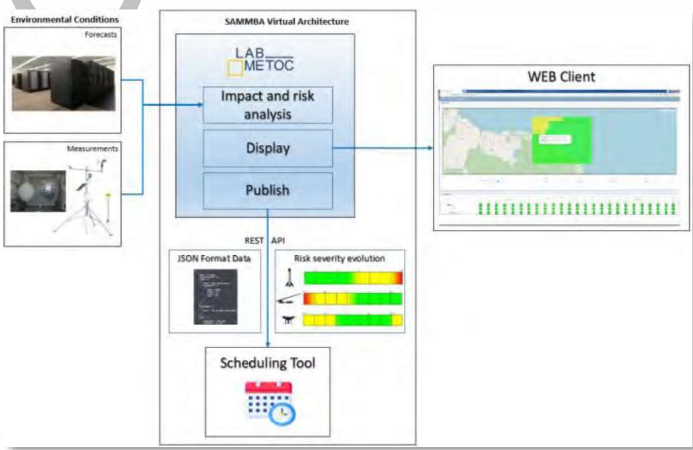

Fig 8: LAB_METOC within the SAMMBA virtual architecture

LAB_METOC offers two operating modes:

1. A production environment allows the operator to configure the modeling of all activities sensitive to environmental conditions. Then the sensitivity models are run on a recurring basis (several times a day), as the forecasts are updated. The results can be viewed and checked before being shared with the other players in the database.

2. A publishing environment, in the form of a REST API, allows any relevant application (e.g. the SAMMBA planning tool) to access risk information related to environmental conditions.

The objective of LAB_METOC is to predict the risks incurred by the various activities sensitive to environmental conditions, during all the preparation phases of a launch campaign.

This anticipation makes it possible in particular to allow the rescheduling of tasks and activities in order to optimize the duration of campaigns and reduce the occurrence of accidents on the base.

Launch Campaign Use Case

A Launch Campaign Use Case has been defined by selecting few activities occurring during a campaign. These activities are:

Activity	Sensitive to
Implementation of a surveillance drone	Wind speed Guts Precipitation Distance of visibility
Fueling	Lightning Temperature Precipitation
Launcher transport	Lightning Wind speed
Launcher Erection	Wind speed Guts
Launching (take-off and flight)	Lightning Temperature Wind speed Guts Freezing Wind shear on the column of air

Throughout the duration of the campaign, we mainly use weather forecasts, to anticipate risks several days before they occur. On the Day of Launch, we use measurements, on the ground and on the column of air column thanks to sounding balloons in order to know precisely the local conditions.

LAB_METOC produces a risk assessment for each activity and builds by aggregation the overall risk related to the campaign, over the entire duration of the campaign (Fig 9).

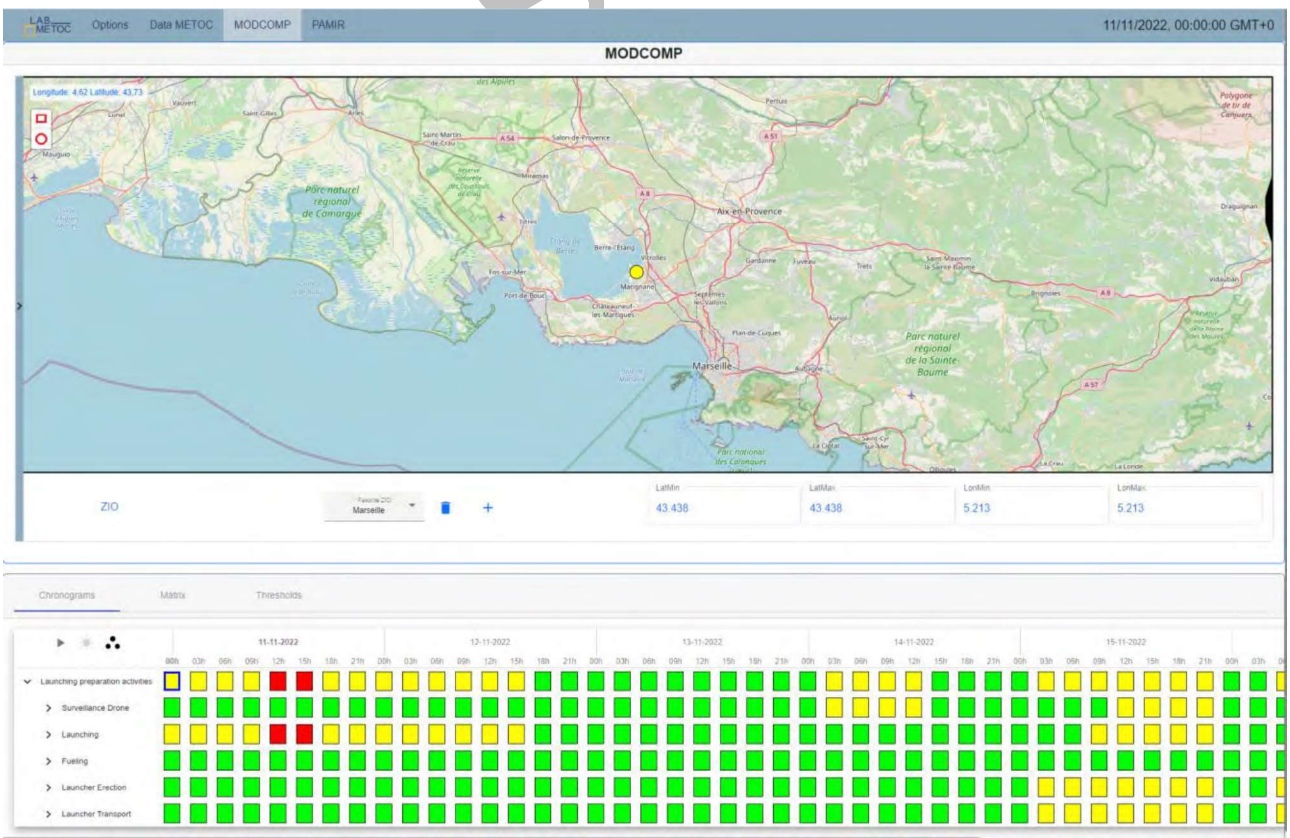

Fig 9: Risks incurred during a Launch Campaign due to environmental conditions

This information is shared with all the actors involved on the Launch Base thanks to the REST API.

A dashboard application can then display the picture of the operational situation in a concise and efficient manner (Fig. 10).

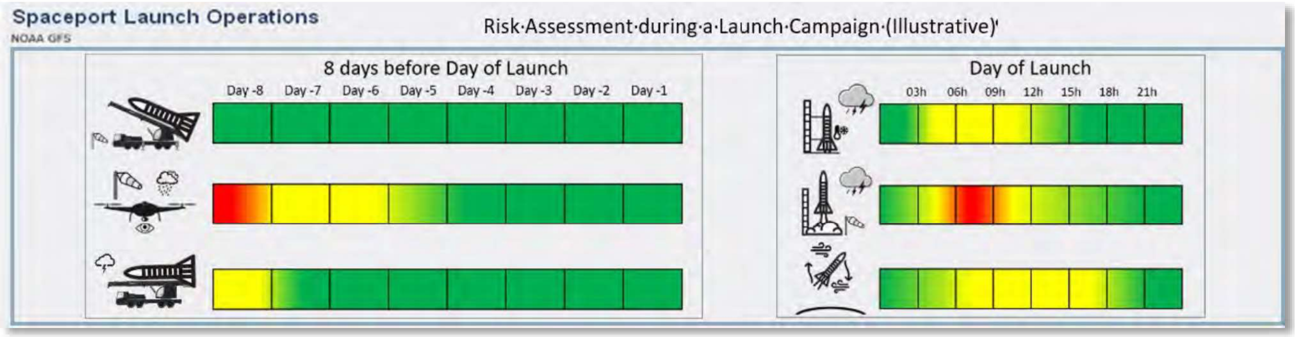

Fig 10: Picture of the Operational Situation during the last 8 days of a launch Campaign

CONCLUSION

Thanks to the H2020 SAMMBA Project, the LAB_METOC platform meets a whole range of needs specific to launch bases. We will continue this effort and increase the capabilities of LAB_METOC to make it more attractive in the space sector, in various directions:

- Take into account and anticipate the effects of space weather.
- Develop services to assist in the recovery of launcher components.
- Take into account the effects of events such as volcanic eruptions, sandstorms, wildfire, and floods.
- Extend the scope of LAB_METOC to new high altitude transport concepts.
- Participate in the ground safety of a launch base and contribute to crisis management in the event of a serious incident (explosion, fire, pollutant leak, etc.).

ACKNOWLEDGMENTS

The European Union's Horizon 2020 SAMMBA project is being implemented by a consortium of six European partners: Air Liquide Advanced Technologies (France), CT Ingénierie Paris (France), EURECAT (Technology Center of Catalonia, Spain), GTD Sistemas de Información (Spain), MT Aerospace (Germany) and SpaceTec Partners (Belgium). The project has commenced in January 2020 and will last for a total of three years.
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870451 (follow us at https://www.linkedin.com/company/sammba-h2020/ and more https://sammba.eu/)