Radar-based products for nowcasting in France

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Météo-France

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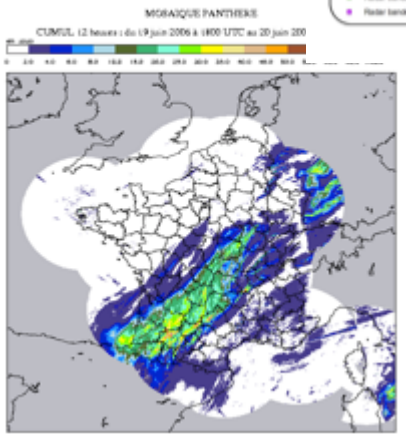
Introduction – French weather radars network

- The French radar **composite** image is processed with 26 conventional radars. The radar network has the following characteristics
  - Radar mostly in C band (some of them in S-band or X-band),
  - 1km / 5 mn

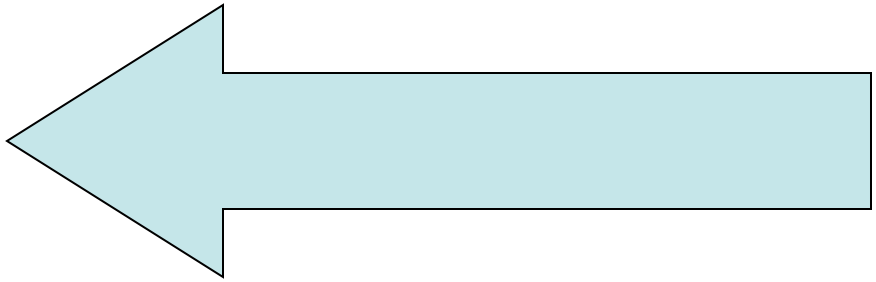
- QPE is available every 5 minutes
  - calibrated with rain gauge



- Note: some radars in overseas territories

Outlines

1. **Heavy-Rainfall warning service**



2. Rainfall 1h-nowcasting

3. Convection 1h-nowcasting

Context

- After serious floods in the southeast of France on June 15th, 2010, it appeared necessary to provide a warning service in case of localized exceptional rainfall.
- **The aim is to supply an institutional decision-making service to mayors, in a fully automatic mode, for the activation of floods management procedures**

Heavy precipitation risk (1/2)

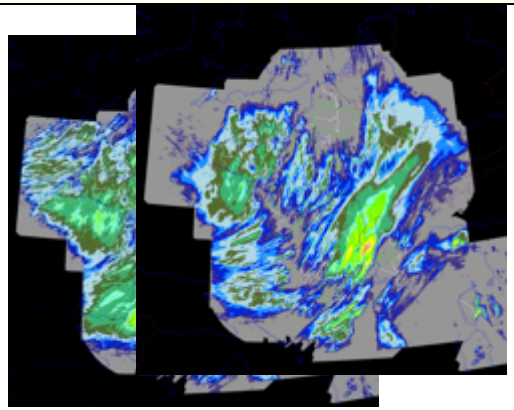
- The **APIC**[1] **service** has been developed and implemented in 2011.

- It first uses the rainfall part of the hydrological AIGA production system, which proceeds in two steps:
  - **accumulated rainfall estimation** for the last **1h, 2h, 3h, 4h, 6h, 12h and 24h** periods, with 5 min rain accumulation radar composite images of the French network;
  - evaluation whether the observed precipitations are exceptional, using a **return-period statistics** dataset established by IRSTEA[2].

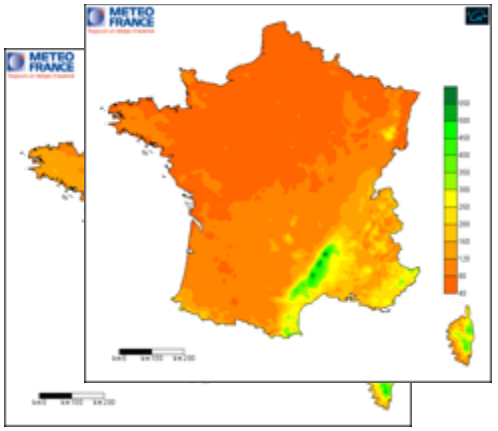
- Finally, a **spatial aggregation** is processed over each French metropolitan commune[3], possibly leading to warnings for two severity levels: ≪ heavy ≫ or ≪ very heavy ≫ rain.

1. *APIC: Avertissement Pluies Intenses à l'échelle des Communes, i.e. Heavy Rain Commune-wide Warning*
2. *Commune: smallest french territorial administrative division, like municipality*
3. *IRSTEA: Institut national de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture*

Heavy precipitation risk (2/2)

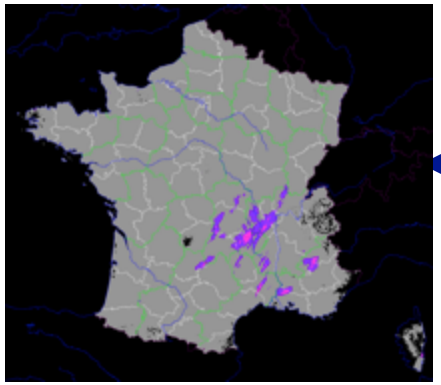


1h, 2h … 24h rain accumulation radar images



Return period statistics

Each diagnosis is compared with a climatology of rare events



1km² diagnosis of exceptional heavy rain for each period + Synthesis diagnosis

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Warnings broadcast

- When an exceptional rainfall is newly diagnosed, or in case of rainfall intensifying, a warning is sent to the subscribers by **phone vocal messages, SMS or e-mails**.

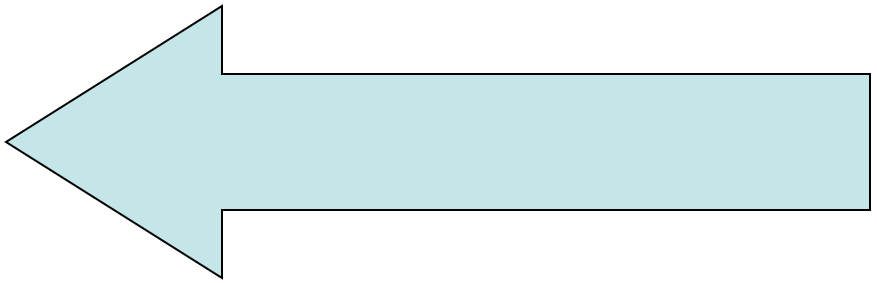
- In order to indicate service interruptions, specific e-mails are also sent. It occurs when radar data are missing or present insufficient quality.

- A **web site** provides an overall vision of the situation via a map indicating at any time current warnings, periods of unavailability and areas where service is not open.

Outlines

1. Heavy-Rainfall warning service

2. Rainfall 1h-nowcasting



3. Convection 1h-nowcasting

The 2PIR method
General principle

The core of the method : two main processes

Comparison of an observed radar image with a previous one

→ identification of cells displacement

→ diagnosis of a motion field

Extrapolation, applying the motion field to the observed radar image

→ forecasted images

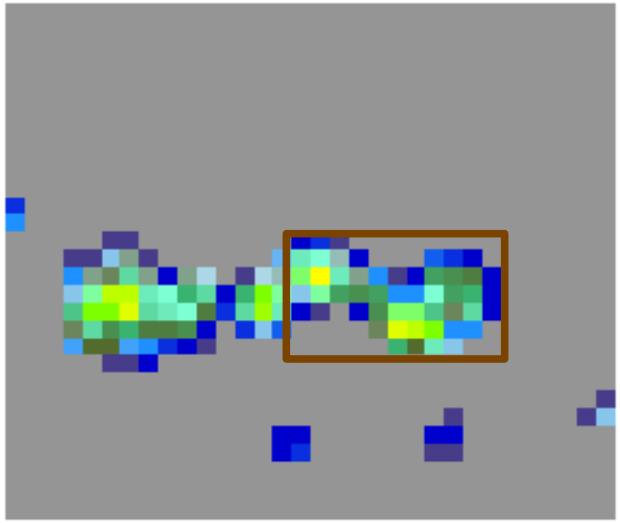
An essential refinement

Statistical quality index attached to each pixel, used at each step of the 2PIR method.

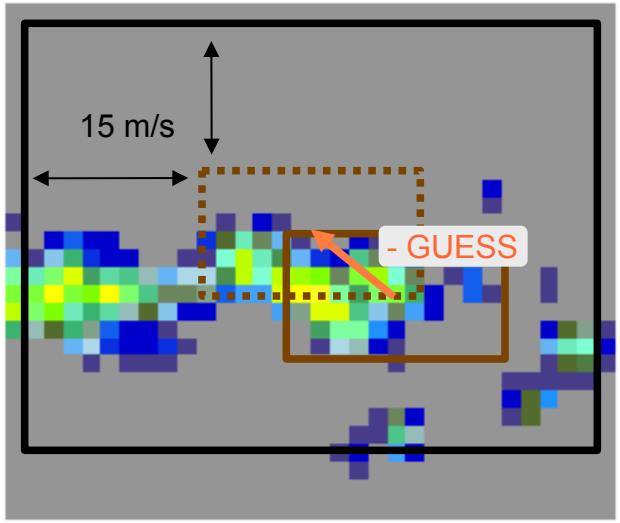
Before the extrapolation of an observed image, a substitution of "wrong pixels" is operated using prior-forecasted values ("filling")

The 2PIR method
Motion field diagnosis

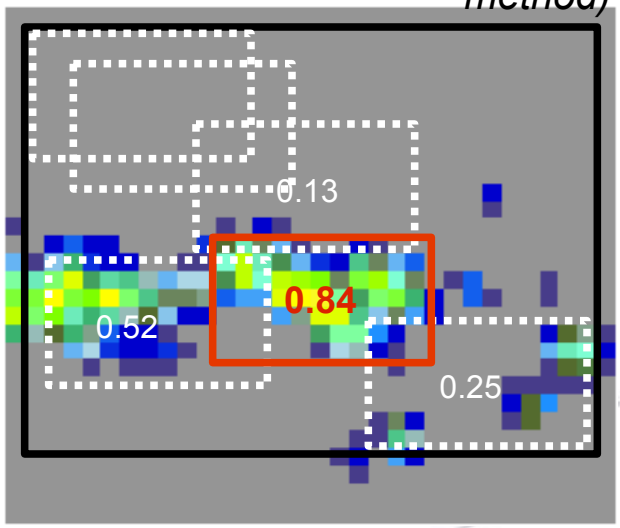
Area detection – Slot "t"



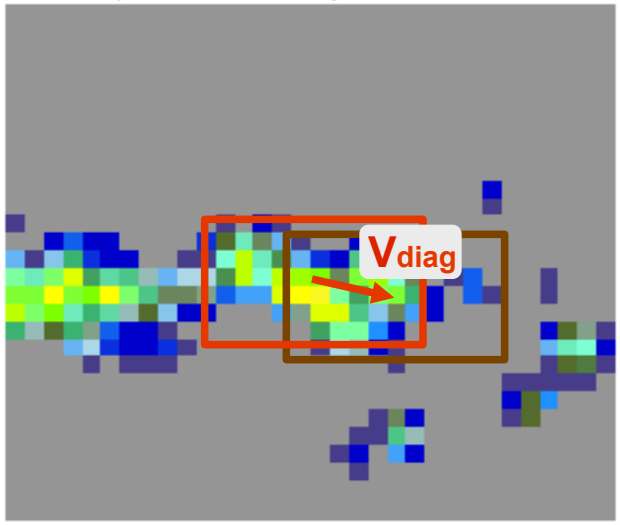
Research area – Slot "t-10 min"



Matching-Area Research (Correlation method)



Diagnosis of displacement



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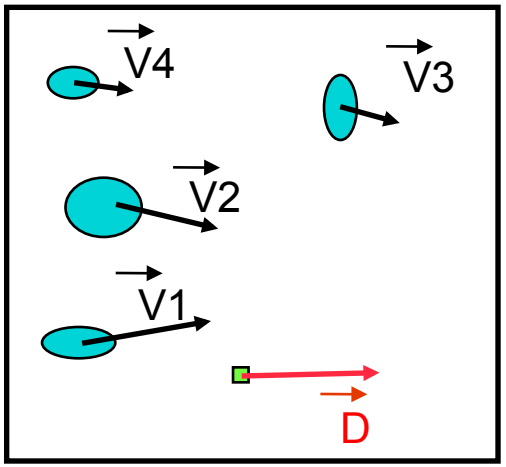
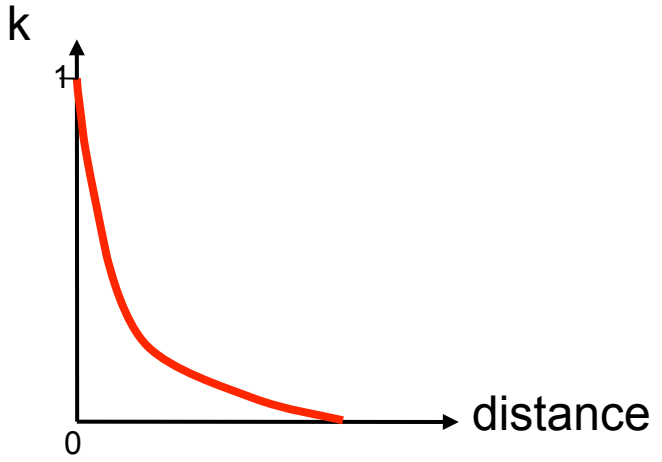
The 2PIR method
Motion field diagnosis

3- Steps identification/estimation of displacement are repeated with different threshold values

4- Interpolation of all the cells displacement (vectors) to compute a gridded motion field :

- ***interpolation operating a (sort of) Cressman filter***
- ***each vector is weighted with the distance between the considered pixel and the attachment point of the vector***



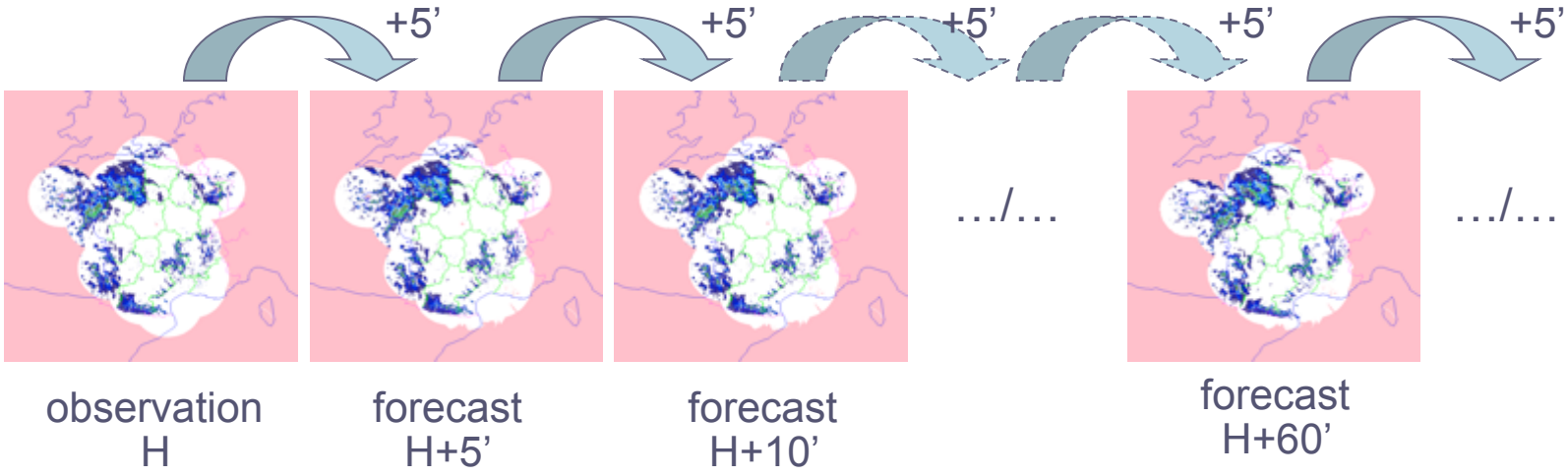


$$\vec{D} = k_1\vec{V1} + k_2\vec{V2} + k_3\vec{V3} + k_4\vec{V4} + \ldots + k_n\vec{Vn}$$

The 2PIR method
Extrapolation

Multi-linear method :

successive 5 min advections with the same motion field

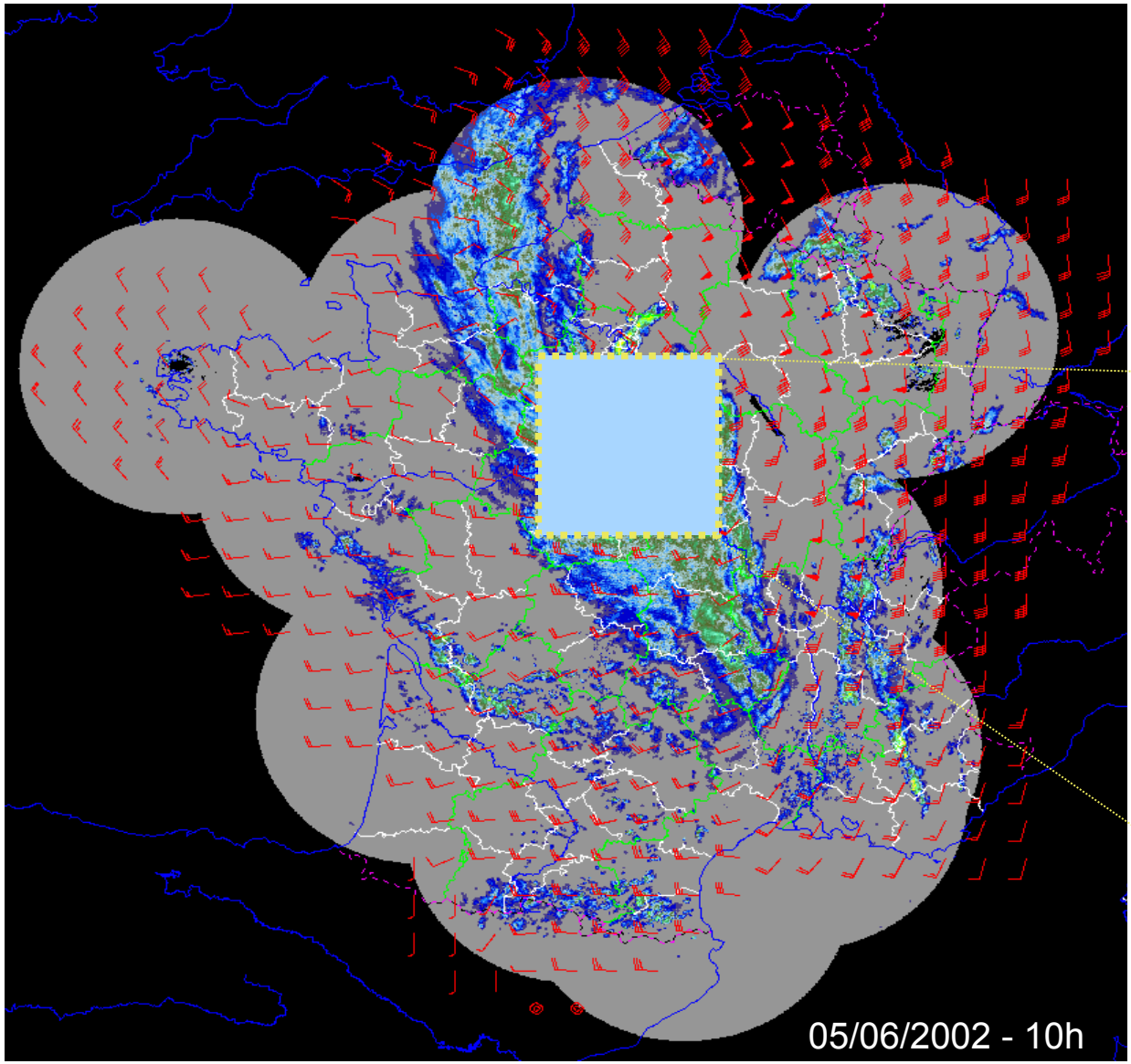


Motion is “attached” to the grid

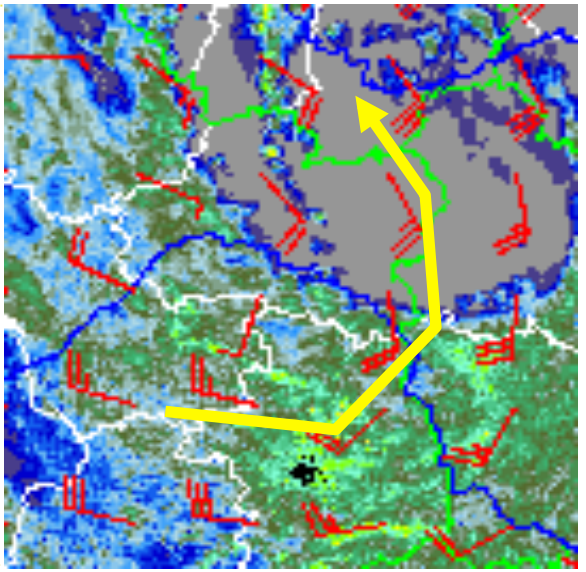
→ echoes follow the stream

→ good depiction of the rotation movements

The 2PIR method
Extrapolation



Example of rotation movement



2PIR limitations

Intrinsic in radar measurement :

- ***incomplete recognition of ground and sea clutters***
- ***clear sky echoes***
- ***attenuation due to precipitations***
- ***Orographic mask, anthropic mask (buildings, etc.)***

Due to compositing of local radar images :

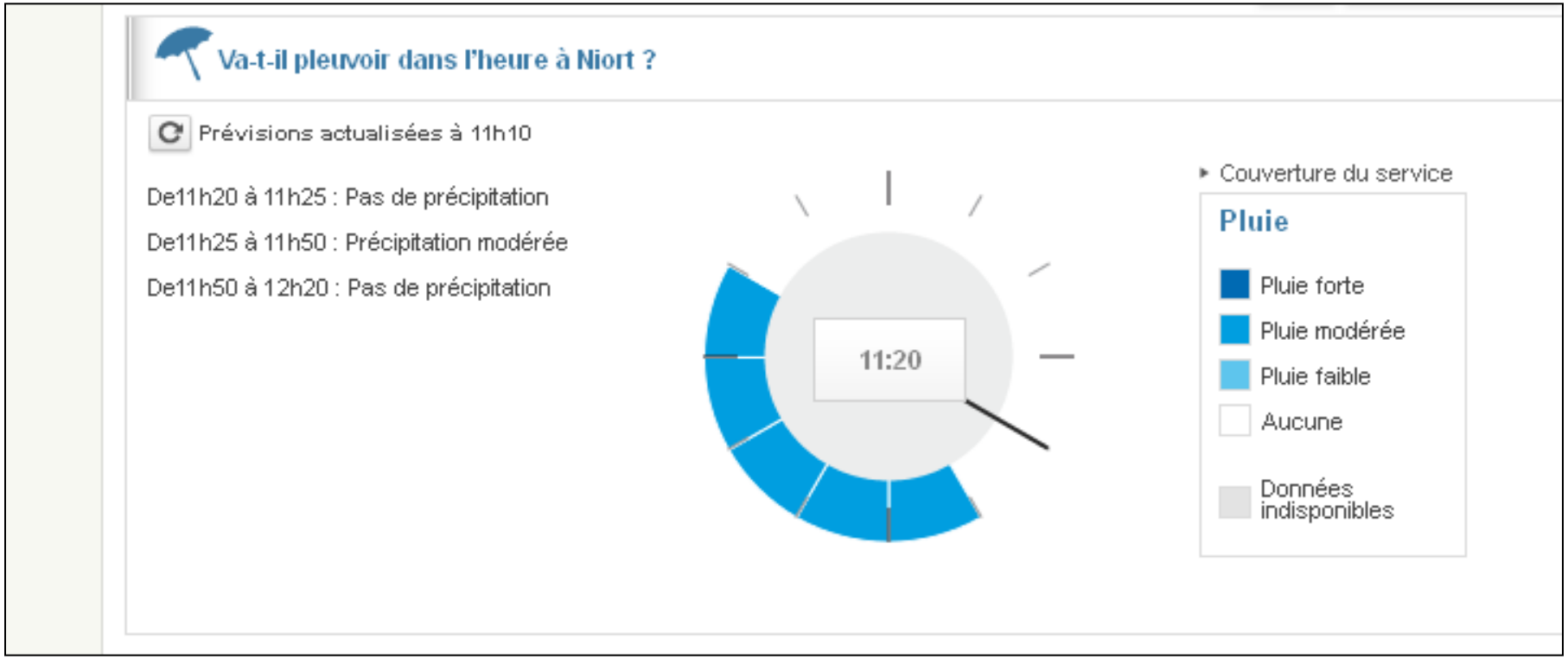
- ***heterogeneity of radar measurements***

Induced by the 2PIR method :

- *Needs a guess, or a spin-up of 30 to 60 min*
- *Orography effects are not managed (blocking, forcing, foehn)*
- *Only advection of previously observed cells*

But generally, it works fine !

Application on meteo.fr website
rainfall in next hour

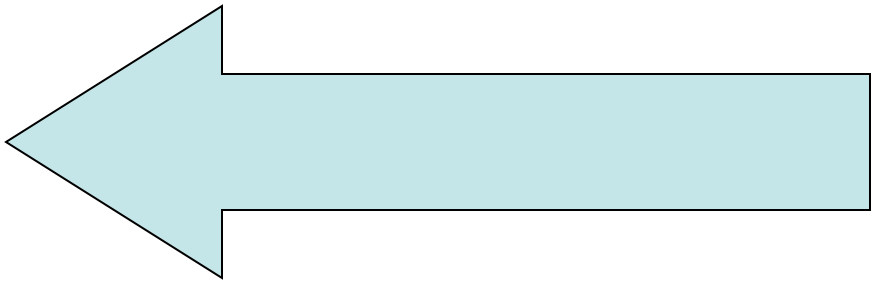


Outlines

1. Heavy-Rainfall warning service

2. Rainfall 1h-nowcasting

3. Convection 1h-nowcasting



Outlines

Convection Nowcasting Object

Significant Weather Object Oriented Nowcasting system

Introduction

- Thunderstorms
  - May cause various **damages** in many places in the world.
  - **Associated meteorological parameters** are numerous (wind, lightning, hail, rainfall).

- **Thunderstorms nowcasting is a major field development** for many meteorological services. Thunderstorms are well adapted to **object approach.**

- The **object approach makes systems tracking easier**. It helps the forecaster

- **Météo-France has developed a production chain** to detect, track and characterize thunderstorms and to warn end-users.

Significant Weather Object Oriented Nowcasting system

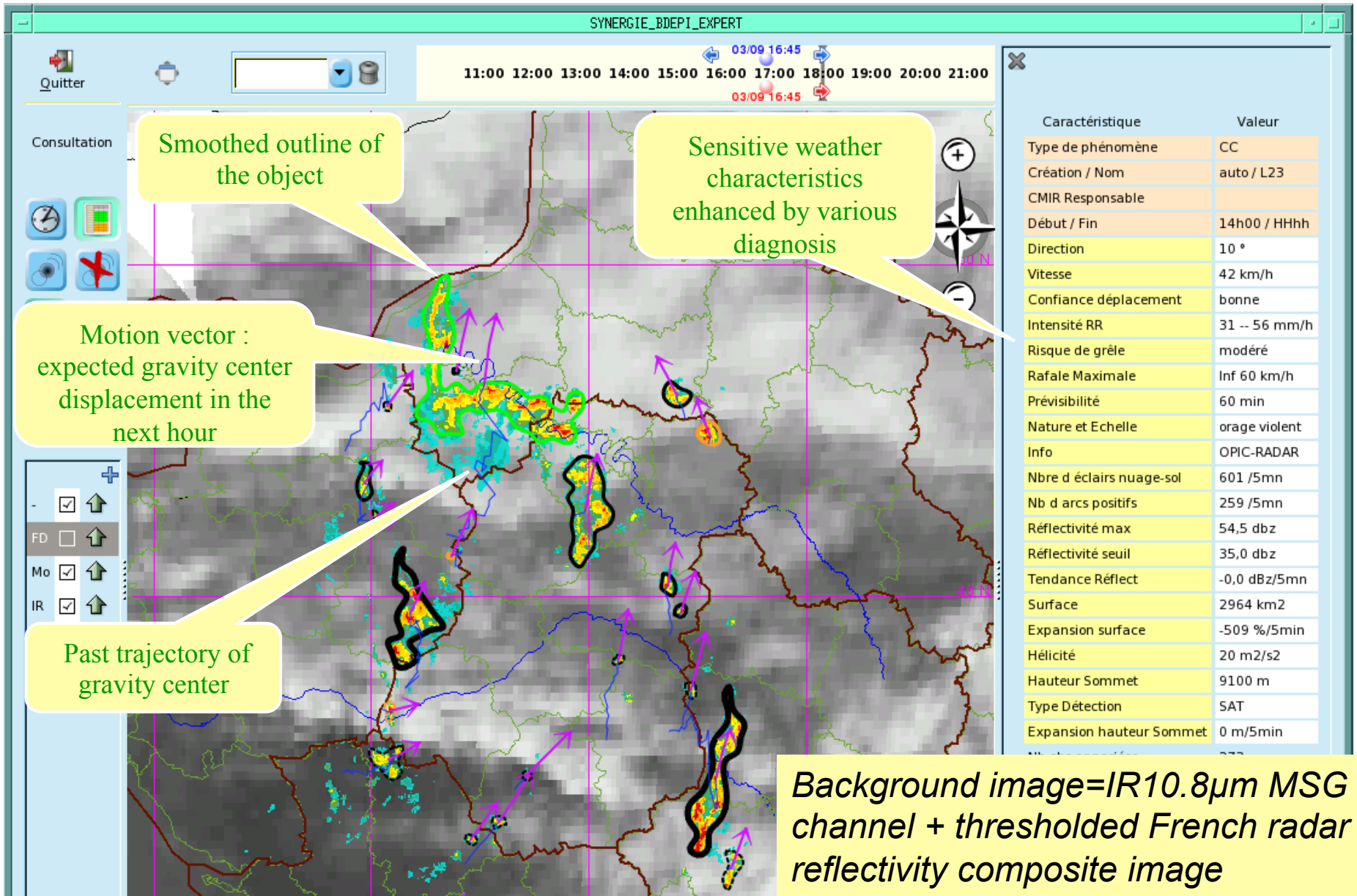
- CONO are injected into an object management system.
- Other data allow data fusion
- CONO+data fusion= SIGOONS
- Possibility to include forecaster's analysis.

- SIGOONS advantages: to make forecasters' analysis of meteorological situation easier, to merge different kinds of information

- SIGOONS challenges: to take into account different observations' features (measurement at various time resolution or geographical scale) and then to merge them

Visualization of CONO objects

with SYNERGIE (MF forecasters' workstation)

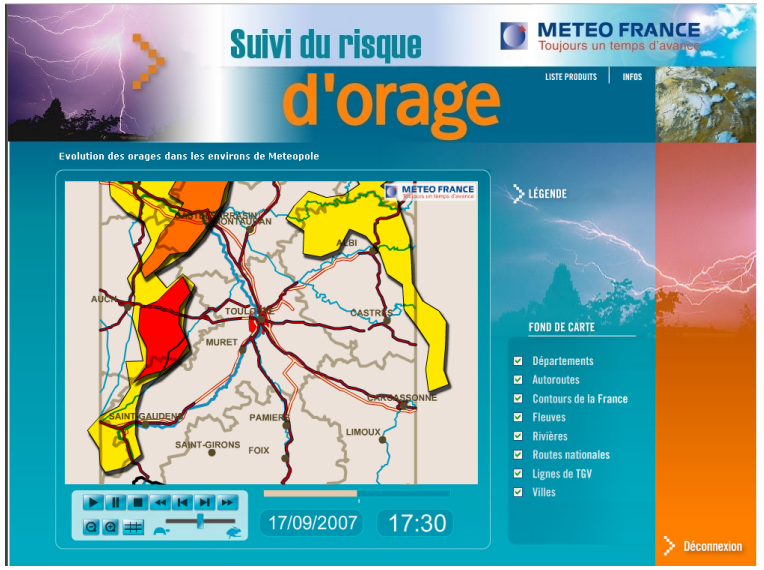


Background image=IR10.8µm MSG channel + thresholded French radar reflectivity composite image

Thunderstorm warning for end users

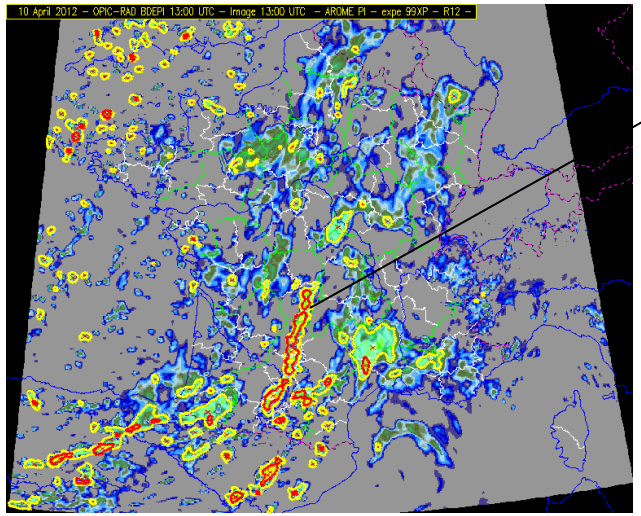
- Warning at a given place, up to one hour before the phenomena
  - End users: place, thunderstorm severity level,
  - Warning: beginning, monitoring, end.
  - Email or SMS distribution
  - Web access with graphics

- Commercialisation since 2008



Now and Future: Nowcasting and NWP

- In the past there was a clear distinction between nowcasting and numerical weather forecast
  - Nowcasting was more relying on diagnostic tools or extrapolation of current observations (and still is)
  - Forecast models were meant to predict large scale phenomena, having a weak potential for mesoscale events forecast.



Convective objects based on AROME-NWC reflectivities

April 10th, 2012, forecast loop between 13 and 18 UTC

A nowcasting suite AROME-NWC should be put into operation in 2016, with radar data assimilation and a rapidly updated cycle. Short term convection forecast is expected to be improved

Questions ?

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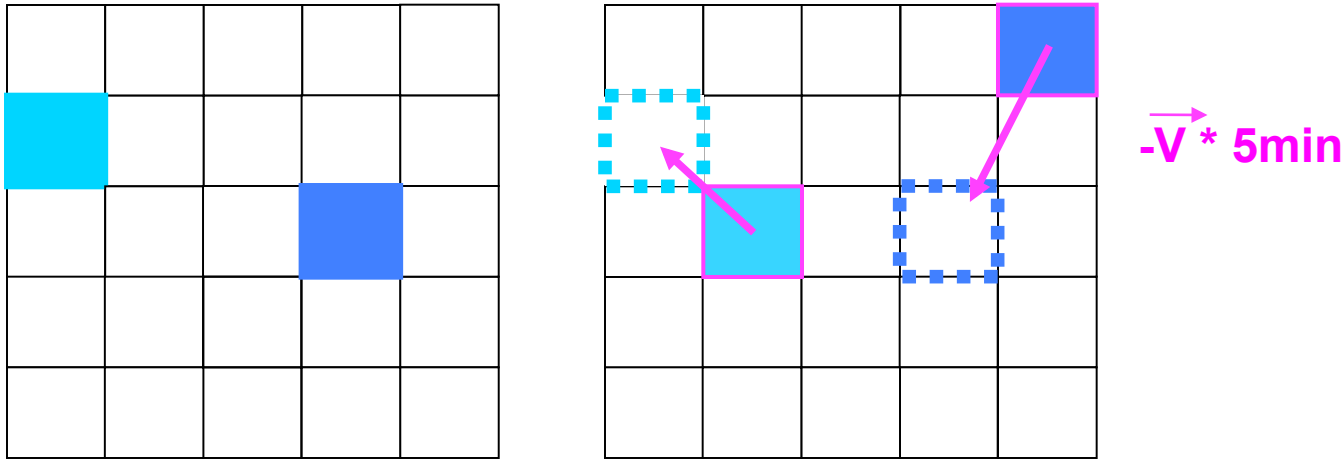
The 2PIR method
Extrapolation

To produce a 5 min advected image :

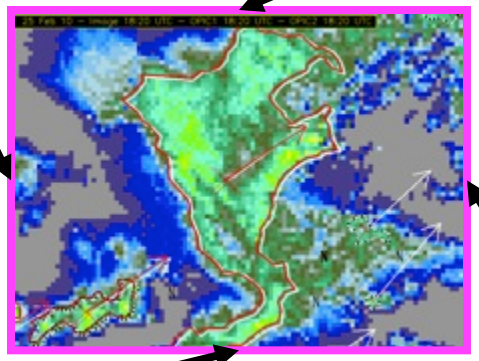
- ***each pixel is filled with the value of a pixel from the observed image***
- ***<u>backward</u> application of the motion field value at this point to determine which observed image pixel to copy. Necessary to avoid "hole" in case of divergent flow***



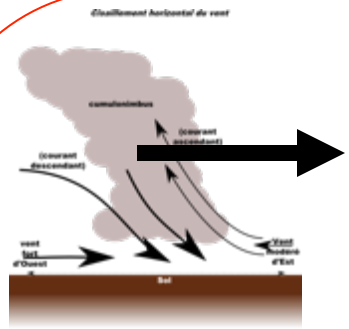
Observed image

Advected (forecasted) image

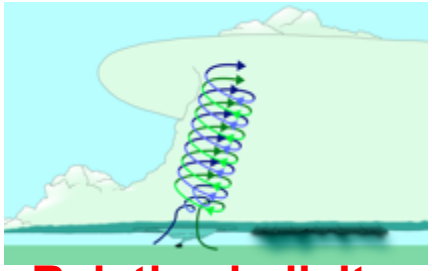
Thunderstorms characteristics - overview



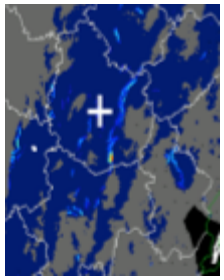
Gust estimation - overview



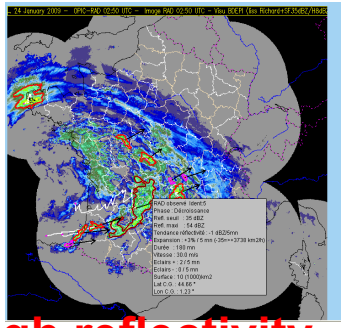
Cell Motion vector



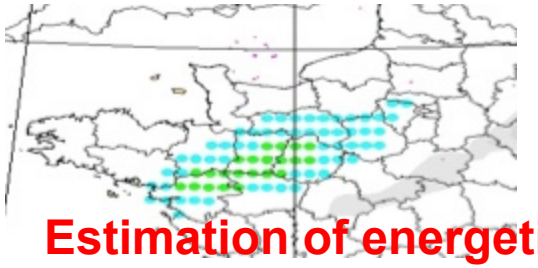
Relative helicity



Wind Shear



High reflectivity

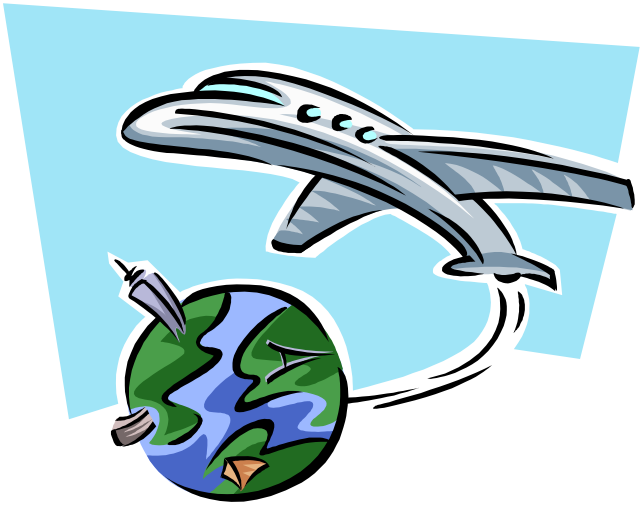


Estimation of energetic potential of density currents

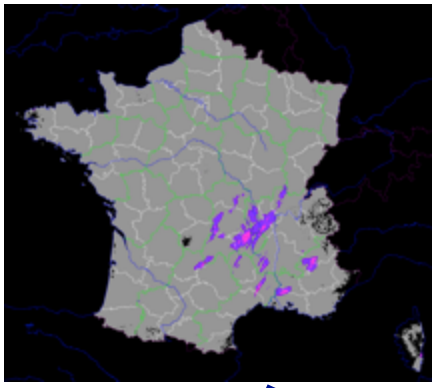
Observations

Some characteristics are introduced for specific users

- CTTH Cloud Top Temperature and **height**
  - For aeronautical users
  - A product from SAF/NWC elaborated with MSG data
  - Rule: maximum height of pixel inside the object

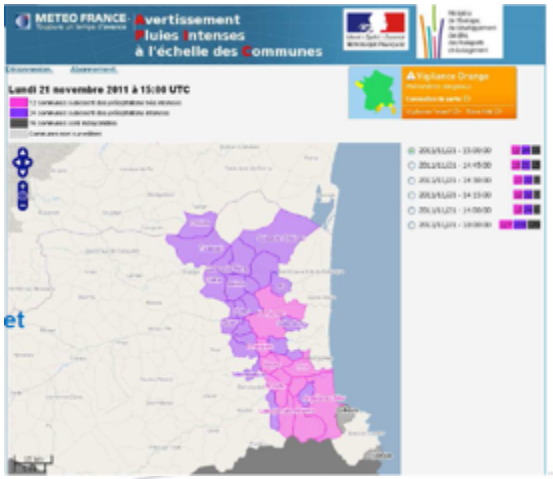


Warnings broadcast (2/2)



1km² diagnosis of exceptional heavy rain

SMS, vocal messages, email



WebSite

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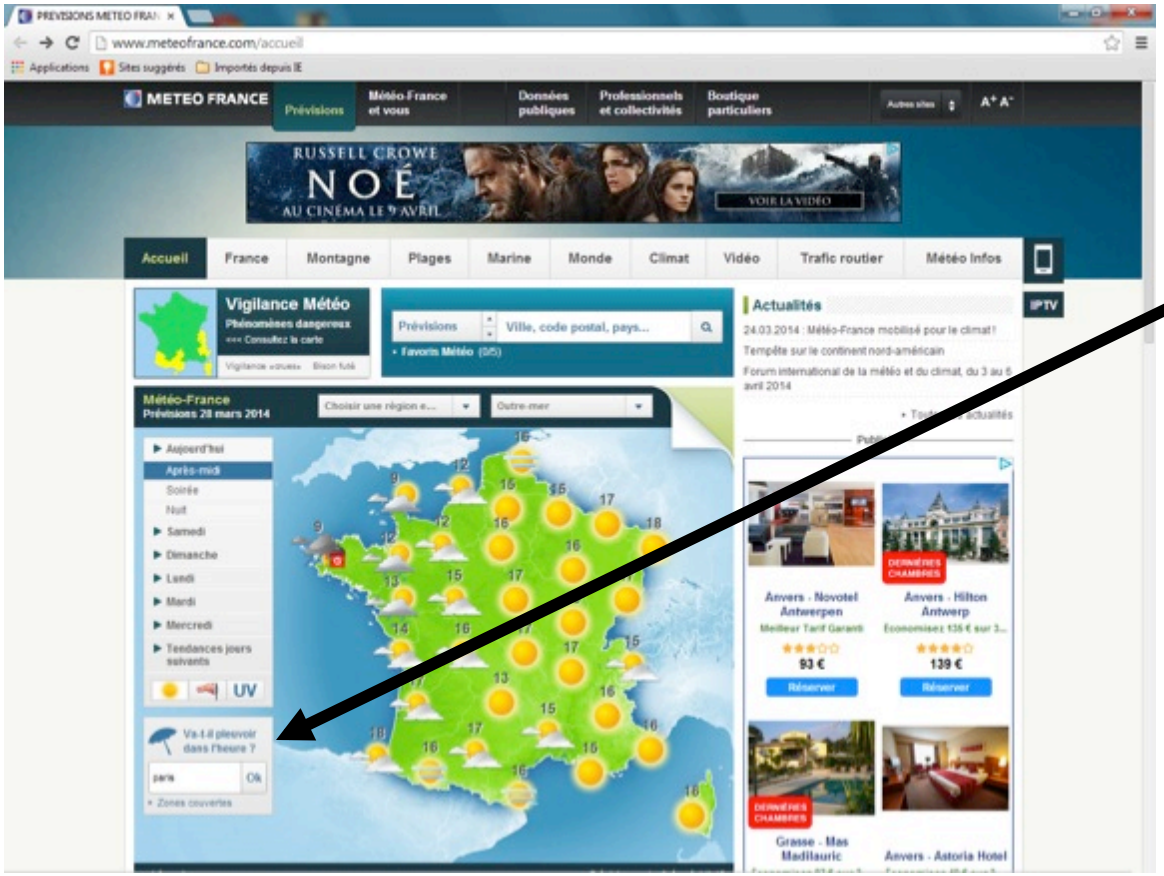
Rainfall in next hour ?



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Discussion

- The **mean quality of rainfall depth radar data** is estimated over the previous year to determine whether the service can be supplied or not for a given commune. The APIC service was opened in December 2011 for 80% of the French metropolitan communes

- The APIC service focuses exclusively on **precipitations**. It doesn't take into account hydrological effects nor ground sensibility to heavy rainfall.

- The APIC service operates on **observed** radar images. It's not forecasting production

The 2PIR method
Motion field diagnosis

1- Rainy cells identification in the observed image :

- **Thresholding**
- **Morphological filters (to get rid of isolated pixels)**
- **Identification of cells = windows containing a set of related pixels**
- **Division of the biggest cells**

2- Determination of each cell displacement using the previous image :

- **Use of a prior motion field to determine the portion of the previous image to scan**
- **Scan of this sub-image to identify, amongst the different possible positions, the one presenting the best correlation**
- **The best correlation determine the supposed past position, and so the supposed displacement of the cell**

2PIR limitations (2/2)

Induced by the 2PIR method :

- *Needs rain !*
- *Needs a guess, or a spin-up of 30 to 60 min*
- *Orography effects are not managed (blocking, forcing, foehn)*
- *Only advection of previously observed cells*

Usage dependent :

- *Well adapted for signalization needs (Roland Garros, aviation, ...)*
- *Caution for quantitative needs, particularly in convective situations*

But generally, it works fine !

Implementations

- 2PIR is carried out on different reflectivity images 1km / 5min

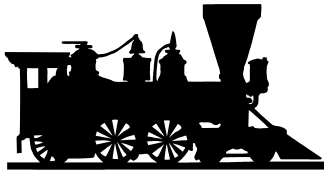
- **In mainland France**
  - National composite image including the 24 operational radars of Aramis network

- **Oversea Territories**
  - French Antilles (Caribbean Sea): radars of Martinique and Guadeloupe islands (separately)
    2014: composite image of both islands
  - French Guyana 5south America): Kourou radar (operated by the CNES)
  - Réunion Island (Indian Ocean): Colorado radar
    2014: composite image with Colorado and Piton Villers radars
  - Nouvelle Caledonie (South Pacific): Nouméa radar
    2014: composite image with Nouméa, Tiébaghi and Lifou radars

Discussion

- Efficient product in case of well-established flow with low impact of orography.

- One hour of maximum forecast range => numerous warning refreshes



- Limitation linked to Lagrangian advection
  - Constant intensity, no change of direction
  - Few non detection but some difficulty to anticipate rapid development cells
  - False alarm rate
  - Stationary phenomena difficult to capture

- Some mountainous areas not fully covered by radar network

Met. onboard

Since 2005 (*Flysafe project*) Météo-France is involved with other MET partners in the develoment of new meteorological information systems called WIMS, **Weather Information Management Systems (Wims)**, aiming at disseminating to flights observations and forecasts for cruising or approach phases. This development is present in *SESAR project* and its demonstrator *TOPMET*. Met information is integretaed in SWIM, System Wide Information Management.