# 9A.2 Real-time multiple-Doppler wind fields from RHYTMME and ARAMIS radars with implications for data assimilation within AROME for southeast France

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## 1. INTRODUCTION

France possesses one of the most dense radar networks in the world, with many of the radars having dual-polarization capability. This combination allows for a great deal of potential research and development. A few possibilities include precipitation estimation, real-time, multiple-Doppler syntheses, model verification of hydrometeor type, and data assimilation of reflectivity, radial velocity, and three-dimensional wind fields.

The main radar network, ARAMIS (Application RAdar à la Météorologie Infra-Synoptique), consists of a combination of 24 S- and C-band radars. Ten of these radars use dual-polarization techniques. Together, over 90% of the country is covered by the ARAMIS network. However, gaps in the network exist, particularly in complex terrain, where the risk of high-precipitation events and potential flash-flooding warrant the need for an expanded network of radars.

The RHYTMME (Risques HYdrométéorologiques en Territoires de Montagnes et MEditerranéens) project was developed to mitigate these gaps in coverage, and to improve the ability to forecast and study localized, high-risk precipitation events (RHYTMME, 2011). Eventually, a total of four X-band, dual-polarization radars will be deployed within the Alpine region of southeast France. In the future, the possibility exists to expand this network to other mountainous regions such as the Pyrenees. At present, two new X-band radars are currently operational: Mt. Vial and Mt. Maurel, providing coverage for the maritime French Alps.

The goal of this research is to combine the ARAMIS and RHYTMME radar networks to compute real-time, multiple-Doppler syntheses in regions that were previously inaccessible, to better understand how topography effects high-risk precipitation events. Currently, reflectivity, hydrometeor type, and multiple-Doppler analyses are being compared to model output for accuracy assessment. However, data from the three-dimensional wind syntheses will eventually be assimilated into the AROME (Applications of Research to Operations at MEsoscale) high-resolution, non-hydrostatic, mesoscale model to test the ability of multiple-Doppler wind fields to improve model forecasts.

## 2. RADAR NETWORKS

The ARAMIS radar network (Fig. 1), while covering an extensive portion of France, contains gaps in regions that are particularly important, specifically, southeastern France, north of the

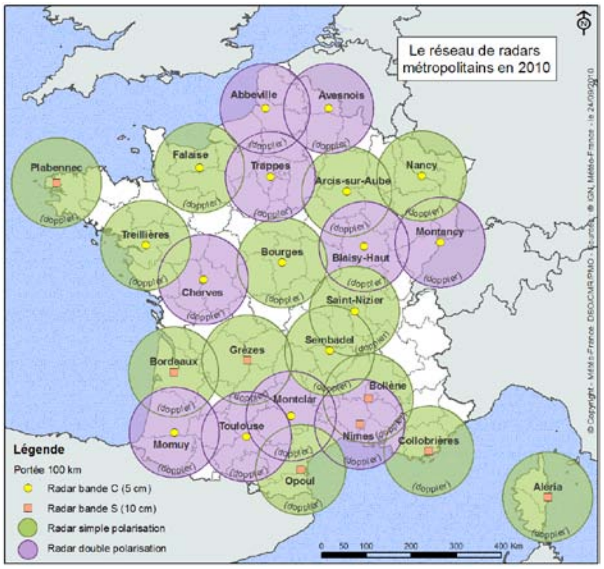

*FIG. 1 – Map of the French ARAMIS radar network. Green coverage represents radars with single polarization, while purple coverage shows radar coverage with dual polarization.*

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ARAMIS radar of Collobrieres. The highly populated Provence and Côte d'Azur regions spanning the length of the southeastern Mediterranean coast of France, are notably susceptible to flash flooding. The RHYTMME project and associated radars north of these regions are key not only to providing better advanced warning for severe weather, but also to providing an opportunity to study the dynamics of high-risk, convective events.

In its final implementation, the RHYTMME radar network in southeastern France (Fig. 2) will consist of three X-band radars: Mt. Maurel, Mt. Colombis (2012), and Vars (2013), in addition to the pre-existing Mt. Vial radar, owned by CNRS and operated by NOVIMET. Along with the ARAMIS network, these radars will provide coverage for the watershed origin of all southeastern France.

With the installation and operation of the Mt. Vial radar, maps were produced to show the difference between theoretical (ground clutter impact not included) multiple-Doppler coverage before and after the introduction of the Mt. Vial radar.

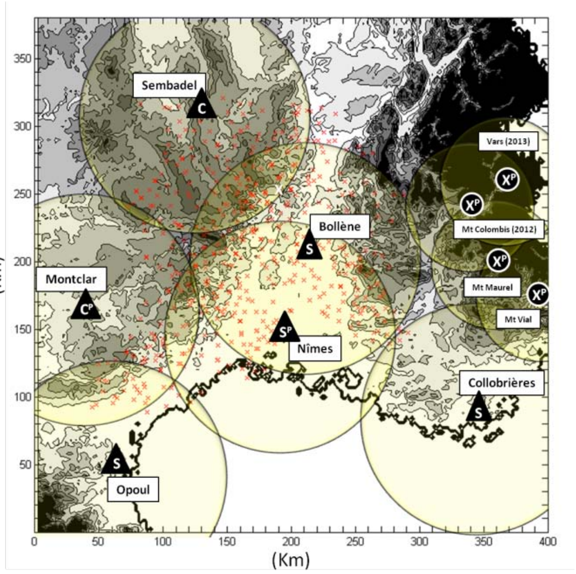


*FIG. 2 – Regional relief map of southeastern France showing the existing ARAMIS radars and coverage with current and future RHYTMME radars. Triangles and circles represent radar locations with the letters inside corresponding to the band of the radar.*

At 2.5 km ASL, with only the ARAMIS radars for southeast France (Fig. 3), multiple-Doppler coverage is limited along the extreme southeastern French coastline and into the Mediterranean Sea. With the addition of Mt. Vial, dual-Doppler coverage at 2.5 km ASL is possible over a greatly enhanced portion of these regions (Fig.4)

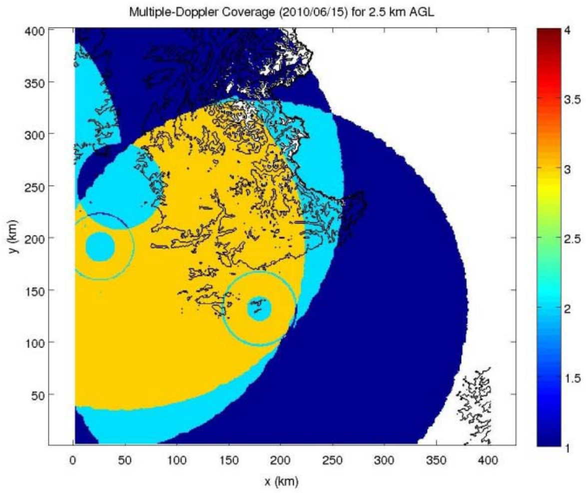


*FIG. 3 – Multiple-Doppler coverage map for ARAMIS radars Collobrieres, Nimes, and Bollene for southeast France. The number of radars covering a given region are indicated by the colorbar Terrain is contoured in black.*

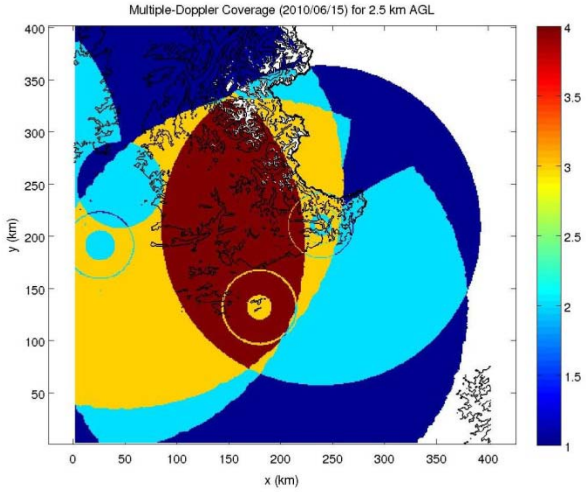


*FIG. 4 – Identical to Figure 3 with the addition of the Mt. Vial radar.*

To provide an idea of how the ARAMIS and Mt. Vial radars operate and are combined for multiple-Doppler synthesis, Table 1 is provided, detailing the scanning strategy, PRF and Nyquist velocities. The radars utilize dual- and triple-PRF capabilities to increase the Nyquist velocity, limiting the amount of velocity aliasing that is produced.

| | **Angles (°)** | **PRF (Hz)** | **Nyquist** |
|---|---|---|---|
| **ARAMIS** | Average: (0.5, 1, 1.5, 2, 4, 6) | Triple PRF: 379, 325, and 303 | 60 $ms^{-1}$ |
| **Mt. Vial** | 0.4, 1.2, 2.4, 4.0, 17, 30, 60 | Dual PRF: 800 and 1000 | 24 $ms^{-1}$ |

Table 1 – Scanning strategies for ARAMIS and Mt. Vial radars.

## 3. PRELIMINARY SYNTHESIS RESULTS

During the afternoon of June 15th, 2010, parts of southeast France received nearly 20 cm of rain within six hours, causing localized, flash-flooding. This torrential rain event was caused by the combination of a strong synoptic low pressure system and mesoscale, orographically-induced convection. This case provides a perfect opportunity to assess the impact RHYTMME radars can have on the retrieval of multiple-Doppler wind fields where ARAMIS radars lack coverage.

At 1500 UTC, a large region of precipitation moved from south to north directly overhead of the Nimes, Bollene, and Collobrieres ARAMIS radars. A 3D wind retrieval was conducted for this time using the operational version of the MUSCAT multiple-Doppler synthesis program (Bousquet et al., 2008). At 2.5 km ASL (Fig. 5), the impact of the Alps on the wind flow is revealed as southerly winds are deflected toward the west. However, east of the Collobrieres radar (extreme southeastern part of the multiple-Doppler synthesis), no wind vectors are retrieved due to a lack of coverage. The same wind synthesis was conducted using data from Mt. Vial to compare the value the RHYTMME radars can provide for this particular event.

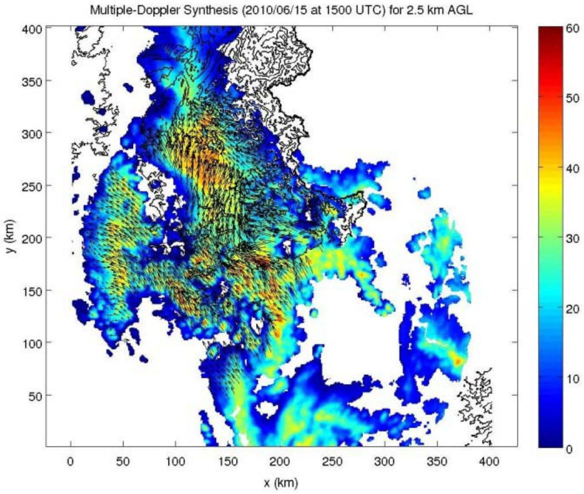


*FIG. - 5. Multiple-Doppler wind retrieval with reflectivity at 2.5 km ASL for 1500 UTC on June 15th, 2010. Topography is shown using black contours. Wind vectors are displayed in black where at least dual-Doppler retrieval is possible. The domain is identical to that in Figures 3 and 4.*

With the addition of the Mt. Vial radar (Fig. 6), a substantial region of dual- and multiple-Doppler derived wind vectors are added to the synthesis east of a north-south line through the Collobrieres ARAMIS radar. This additional data makes retrieval of wind field vectors over the Cote d'Azur region and Mediterranean Sea possible.

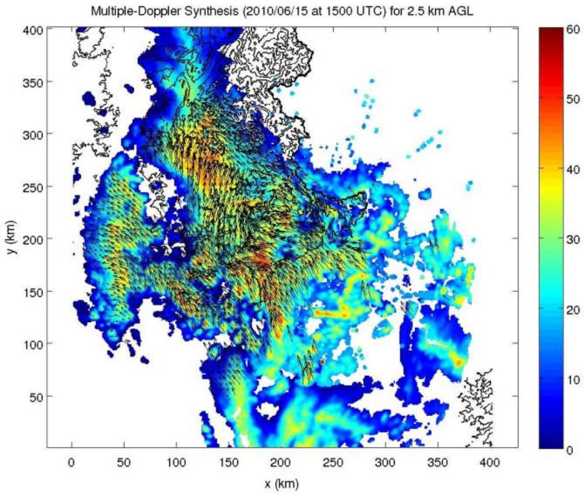
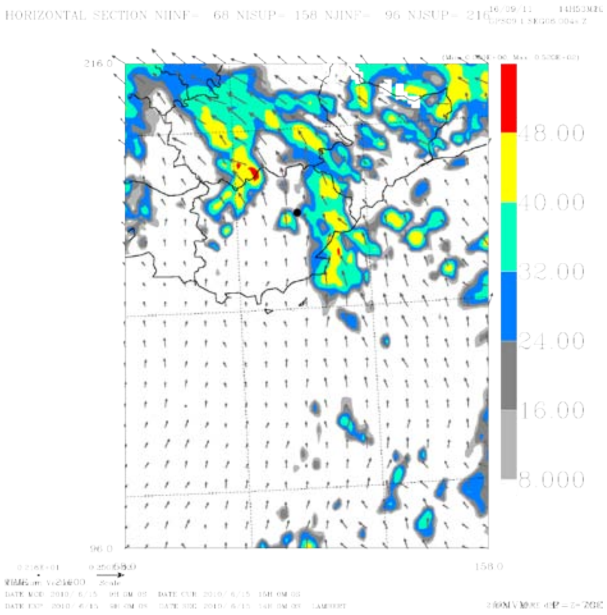


*FIG. - 6. Identical to Figure 5, except with the addition of Mt. Vial data (reflectivity and derived wind vectors).*

## 4. RECENT MODEL RESULTS

Simulations have been conducted at Meteo-France to model the June 15th, 2010 extreme rainfall event in southeast France. In particular, the Meso-NH (non-hydrostatic) research model (Lafore et al., 1998) and the operational AROME-WMED model (Seity et al., 2010) were used. Initialization for these simulations included the radial velocity from the ARAMIS radars in the region analyzed.

a)



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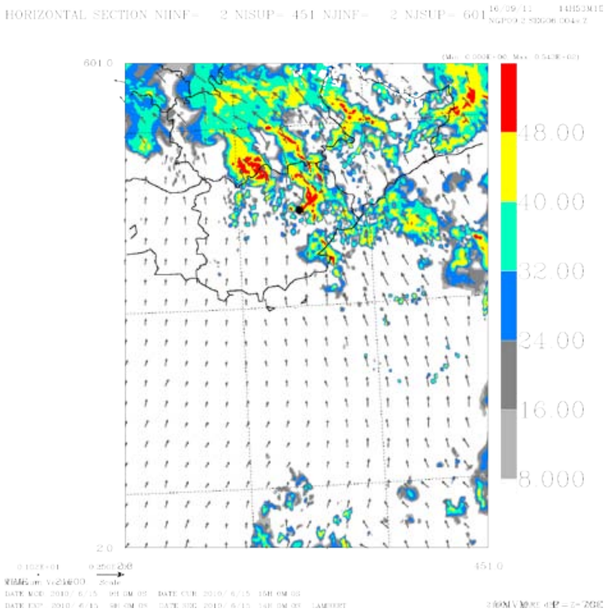

*FIG. – 7. a) 2.5 km horizontal resolution Meso-NH simulation of the June 15th, 2010 case at 1500 UTC for 2.5 km ASL, b) Identical to a) but with 500 m horizontal resolution. Two-dimensional wind vectors are shown in black with rain-rate in color. Images used with permission from Emilie Bresson.*

Simulations using Meso-NH (Emilie Bresson, 2011, personal communication), initialized at 0900 UTC, focused on comparing the impact of horizontal resolution (2.5 km versus 500 m) on the accuracy of the forecast. Comparison of Meso-NH simulation results at 2.5 km ASL (Fig. 7a,b) to the multiple-Doppler retrievals shows a potential improvement in both the wind field and reflectivity/rainfall-rate with increased horizontal resolution. Operational, non-hydrostatic AROME-WMED simulations of the June 15th, 2010 case were conducted at 2.5 km horizontal resolution (Mathieu Nuret, 2011, personal communication), in anticipation of the HyMeX (Hydrological cycle in the Mediterranean Experiment) field project that will take place in the western Mediterranean region beginning in 2012 (HyMeX, 2011). This convective, mesoscale event is of particular interest, given its proximity to the HyMeX domain, in order to assess forecast accuracy potential.

The simulation results at 1500 UTC, also initialized at 0900 UTC, show promising similarities to the multiple-Doppler syntheses (Fig. 8). Reflectivity location is fairly well matched, while breadth is slightly less than in the syntheses. In addition, the wind field matches very well, with the minor exception of the region near and north of Nice, showing south-easterly winds, while in the syntheses, the winds are more easterly. These

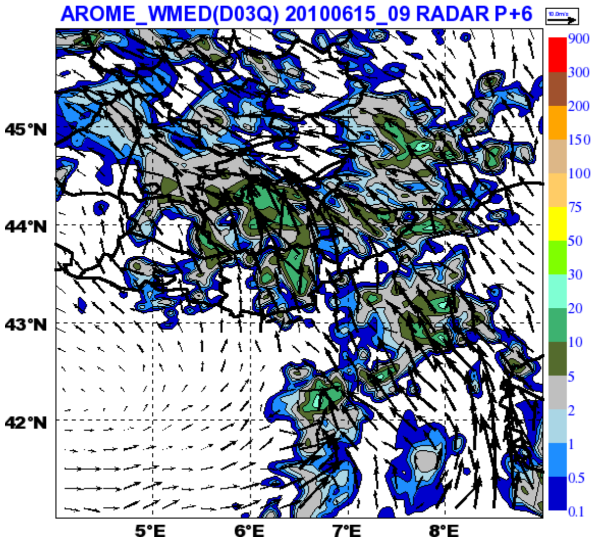

*FIG. – 8. 2.5 km horizontal resolution AROME-WMED simulation of the June 15th, 2010 case at 1500 UTC for 2.5 km ASL. Two-dimensional wind vectors are shown in black with rainfall-rate in color. Image used with permission from Mathieu Nuret.*

discrepancies are also evident in the Meso-NH simulations, However, overall, the results are extremely promising.

Aside from the simulation initialized at 0900 UTC, a second model run starting at 0600 UTC was conducted to compare sensitivity to the initialization time period (Mathieu Nuret, 2011, personal communication). Results from these two simulations are shown in Figure 9. The simulation initialized at 0900 UTC correlates better with the location of heavy precipitation as seen by the measurements from rain gauges, as well as in the multiple-Doppler syntheses. Reasons for the increase in error from the simulation initialized at 0600 UTC could be quite varied, potentially depending on the amount and quality of available data included in the initialization.

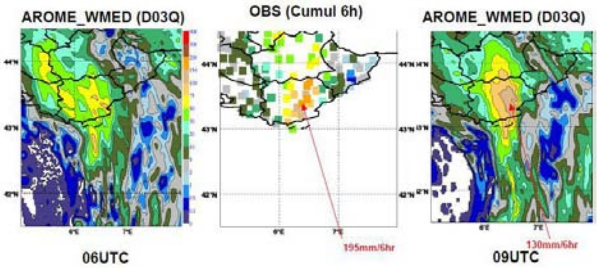

*FIG. – 9. Plots of 6-hour AROME-WMED accumulated precipitation ending at 1500 UTC from two separate 2.5 km horizontal resolution simulations (initialization at 0600 UTC, left, and 0900 UTC, right) for June 15th, 2010. Rain gauge observations for the 6-hour period ending at 1500 UTC are shown in the middle.*

## 5. FUTURE WORK

The availability of 3D wind syntheses for initialization within the operational AROME-WMED model provides an intriguing potential to investigate their impact on model accuracy. In anticipation of this possibility, an automated, real-time analysis algorithm was created to produce multiple-Doppler syntheses such as those shown above. Radar polarimetric parameters are used to enable automated data editing and removal of ground clutter, clear air, and second trip echoes. Multiple-Doppler syntheses are then conducted from 0.5 km ASL to 13 km ASL using the MUSCAT synthesis program.

Simulations using the AROME-WMED model will first be conducted with the assimilation of 2D winds for the June 15th, 2010 event to assess any improvement in accuracy these extra data may provide. In addition, other cases may be investigated, given the real-time availability of multiple-Doppler syntheses, particularly within southeast France for the upcoming HyMeX field campaign.

## 6. REFERENCES

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