Usefulness of radar QPE for Mediterranean flash-flood ensemble forecasting

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HYdrological cycle in the Mediterranean Experiment

- **Aim**: understanding of the water cycle with emphases on intense events
- « Time-nested » observation strategy:

First HYMEX Special Observation Period (SOP):
- **North-Western Mediterranean**
- from **5 September to 6 November 2012**
- dedicated to **Heavy Precipitation Events and FF**.

- Additional observing systems deployed
- Real time meteorological and hydrological forecasting
- *e.g.* for FF: **ISBA-TOPMODEL**

![Map of Europe](image)

**ERAD 2012 -2-**
Accumulated rainfall (radar QPE) from 3 Nov. 2011 to 8 Nov. 2011

Uncertainty affects QPF even for high resolution NWP

**Accumulated rainfall (radar QPE) from 3 Nov. 2011 to 8 Nov. 2011**

**METEOROLOGICAL FORCING**

- **Precipitation**
  - AROME* QPF
  - Radar QPE

**ISBA-TOPMODEL***

*Bouilloud et al, 2010; Vincendon et al, 2010

**Observation**

- Simulation driven by radar QPE
- Forecast with deterministic QPF

**Discharges from 3 Nov. 2011 @ 00UTC to 7 Nov. 2011 @ 00UTC**

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*(Seity et al, 2011)
Assessment of high resolution QPF errors

- Climatology of differences between QPF and radar QPE
- Double penalty problem ⇒ object-oriented climatology of errors
- Objects defined according to thresholds in mm/h in the QPF and QPE fields

- PDF of **amplitude** and **location** errors
- **Structure-Amplitude-Location** method
  - measure of the QPF quality
  - no need to match objects one to one

- **S** : difference in **size, shape and gradient** of the rainy objects
- **A** : normalized difference of **averaged precipitation** values
- **L** = **L1** + **L2**
  - **L1** : global **shift** between QPE and QPF
  - **L2** : difference in relative positioning of **objects** in QPE and QPF

*(Wernli et al, 2008)*
SAL diagram

- **L component**
  - [0;0,1]
  - [0,1;0,2]
  - [0,2;0,5]
  - [0,5;1]
  - [1,2]

- **A component**
  - Too much rain in QPF
  - Too small objects and/or too large a gradient in QPF
  - Not enough rain in QPF
  - Convective rainfall observed

- **S component**
  - Too large objects and/or too small a gradient in QPF
  - Stratiform rainfall observed
  - Convective rainfall forecasted
  - Stratiform rainfall forecasted

- **False alarm**
- **Good forecast**

(Wernli et al, 2008)
Assessment of AROME QPF

- 1-h QPF vs 1-h QPE from Météo-France radar composite
- Days with significant rain from Sept. 2008 to Dec. 2011

A median value close to 0

⇒ No systematic bias

L component

- 70% of the cases with a location error < 50 km

Valuable information in AROME QPF

SAL diagram for objects with 1-h rain over 2mm
Streamflow ensembles with ISBA-TOPMODEL

Deterministic AROME

Perturbation generation*

PDF of amplitude and location errors

30 members

Single streamflow forecast

30 members streamflow ensemble

8 members streamflow ensemble

AROME Ensemble Prediction System (EPS)*

ISBA-TOPMODEL

(*Vincendon et al., 2011)

(*Vié et al., 2011)
Real time FF forecasting chain within HYMEX SOP

Daily forecast:

- $T_0 =$ Day D
- $T_0 + 36$ h
- Day D+1 à 00utc
- à 00utc

Forecasts with

ISBA-TOPMODEL driven by:

- Deterministic AROME
- AROME + Perturbation

30 members

AROME EPS

8 members

AROME + Perturbation:

RPSS ∼ 0.23

Streamflow ensembles for Gardons river:

3 nov. 2011 @ 02UTC - 4 nov. 2011 @ 04UTC

AROME EPS:

RPSS ∼ 0.35

Observation

Simulation driven by radar QPE

Interquartile range of the ensemble

Ensemble median

Forecast with deterministic QPF
Conclusions and future work

- Usefulness of radar QPE for FF forecasting
  - To document the uncertainty on QPF
  - Method of perturbation of QPF to take benefit from valuable information of AROME deterministic forecast
  - Streamflow ensemble at reduced numerical cost

- Implemented in real-time for HYMEX SOP: [http://sop.hymex.org](http://sop.hymex.org)
Bouilloud et al, 2010:

Vié et al, 2011:

Vincendon et al, 2010:

Vincendon et al, 2011:

Wernli et al, 2008:
Point-to-point assessment of QPF values

- $A$: characterizes how different are domain-averaged precipitation values

$$A = 2 \frac{R_{mod} - R_{obs}}{R_{mod} + R_{obs}}$$

*(Wernli et al, 2008)*
Point-to-point assessment of QPF values

- $L = L_1 + L_2$

- $L_1$ characterizes the global shift between QPE and QPF.
  
  $L_1 = \left| x(R_{\text{mod}}) - x(R_{\text{obs}}) \right|$

  - Barycentre of the QPE field among $D$
  - Maximal distance among $D$

- $L_2$ characterizes the spatial precipitation distribution inside the domain.
  
  $L_2 = 2 \left| r_{\text{mod}} - r_{\text{obs}} \right|$

  
  - Total number of objects
  - Barycentre of object $n$
  - Mean rainfall on object $n$

(Wernli et al, 2008)
Point-to-point assessment of QPF values

- S: characterizes the size of the rainy objects as well as the gradient

\[
V = \frac{\sum_{n=1}^{M} R_n \cdot V_n}{\sum_{n=1}^{M} R_n}
\]

\[
V_n = \frac{R_n}{R_n^{max}}
\]
Maximal rainfall on object \(n\)

\[
S = 2 \cdot \frac{V_{mod} - V_{obs}}{V_{mod} + V_{obs}}
\]

(Wernli et al, 2008)
Usefullness of radar QPE for FF forecasting?

FF simulation:

- Hydrological models dedicated to FF sensitive to rainfall (volume and spatial distribution)

⇒ Radar QPE = appropriate information

Use of radar QPE for:

- hydrological simulation
- hydrological models calibration

*Bouilloud et al, 2010; Vincendon et al, 2010
Uncertainty on FF simulations due to QPE

**Rivers:**
- Ardèche at Saint Martin (2240 km²)
- Cèze at Bagnols-sur-Cèze (1100 km²)
- Gardons at Ners (1090 km²)

Weather radars

Hydrological range (80 km)
Uncertainty on FF simulations due to QPE: November 2011 case

QPEs (mm) from 3rd nov. 2011 at 12UTC to 8 nov. 2011 at 00UTC

Discharges (m³.s⁻¹) from 3rd nov. 2011 at 12UTC to 8 nov. 2011 at 00UTC
Uncertainty on FF simulations due to QPE: November 2011 case

Several parameters

Discharges (m$^3$.s$^{-1}$) from 3rd nov. 2011 at 12UTC to 8 nov. 2011 at 00UTC

Ardèche river

Gardons river

Several radar data
Sensitivity to radar QPE time step

Temporal frequency:
- 1h
- 15 minutes
- 05 minutes

Catchments with an area < 200 km²

Cumulated frequencies of nash efficiency (Prediflood project)

Catchments with an area > 600 km²
Quantification of AROME QPF error

- PDF of amplitude and location errors for object Or and Oc
- Amplitude errors: no systematic bias
- Location errors: < 50 km in 70% of cases

(Vincendon et al., NHESS, in revision)
Quantification of AROME QPF error

- AROME hourly QPF vs Météo-France radar hourly QPE
- Significant rainy events
- Object–based climatology of AROME QPF errors:
  - Rainy objects = Or
  - Convective objects = Oc

1h-radar QPE the 01 Nov. 2008 at 20UTC
1h-AROME QPF the 01 Nov. 2008 at 20UTC (AROME run start = 01/11/2008 analyse)
Quantification of AROME QPF error

SAL, ech06h (Objets se)

SAL, ech12h (Objets se)

SAL, ech18h (Objets se)

SAL, ech24h (Objets se)

SAL, ech30h (Objets se)

ERAD 2012 -21-
Perturbation generation method

AROME déterministic forecast

N members selected

PDF of location errors

Rainfall intensity of $O_c$ $X f$

PDF of amplitude errors for $O_r$

Rainfall intensity of $O_r$ $X f_c$

PDF of amplitude errors for $O_c$

$N$ new fields

(Vincendon et al., NHESS, in revision)
Streamflow ensemble for 21-22 October 2008 event

(Vincendon et al., NHESS, in revision)

**Ardèche**

**Cèze**

**Gardons**

**Discharges simulated from:**
- 50 members of the ensemble
- deterministic AROME
- Ensemble median
- Interquartiles range

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21 October 2008  
22 October 2008
Streamflow ensemble for 01-02 November 2008 event

(Vincendon et al., *NHESS*, in revision)

- **Ardèche**
- **Cèze**
- **Gardons**

Discharges simulated from:
- 50 members of the ensemble
- Deterministic AROME
- Ensemble median

**Observed discharge**

**Interquartiles range**
Early verification

- RPSS ~ 0.35 mm/day on 24h-accumulated rainfall
  ⇒ Ensemble forecast > deterministic forecast

- Comparison to a research AROME EPS (Vié et al., 2010)
  ⇒ Close results

- Advantage of the perturbation method:
  - Reduced numerical cost
  - Lot of members
How do we simulate Mediterranean FF?

**Surface scheme resolution**

\[ \Delta x = 1\text{km} / \Delta t = 15\text{min.} \]

**ISBA-3L**

Management of water and energy at surface / atmosphere interface

\[ d_{i,t} = f(W_{I,t}) \]

\[ W'_{I,t} = f(d'_{i,t}) \]

**TOPMODEL**

Lateral water transfer within the catchments

**Routing Module**

Water transfer along slopes and rivers

**Catchments resolution**

\[ \delta x = 50\text{m} / \delta t = 1\text{h} \]

**Runoff** \( R \)

Deep drainage \( DR \)

ERAD 2012-26-
Real time FF forecasting chain within HYMEX SOP

Daily forecast:

- Spin-up period: Simulation with ISBA-TOPMODEL driven by:
  - Real time FF forecasting chain within HYMEX SOP
- Deterministic AROME

Forecasts with ISBA-TOPMODEL driven by:

- Radar QPE: RR1h
- AROME perturbated with 30 members
- AROME EPS with 8 members
- Climatology of amplitude and location errors

Usefullness of radar QPE in this framework?
- FF simulation
- QPF assessment