MEASUREMENTS OF A NETWORK OF MOBILE RADARS DURING THE EXPERIMENTAL CAMPAIGN OF THE HYDRORAD PROJECT

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What is HYDRORAD

HYDRORAD is the name of the project, co-funded by European Commission under Seventh Framework Programme, which lasted two years and three months and ended on November 2011.
HYDRORAD Project Objective

The main objective of the HYDRORAD project is the development of an innovative integrated decision support tool for weather monitoring and hydro-meteorological applications.

The integrated system tool is based on an polarimetric low cost X-band mini-radar network, an useful radar products generator and a hydro-meteorological forecasting modeling able to ingest precipitation data and mini-radar products.

See Poster session Group 2: NET 306 Picciotti et.al for more detail
Test system in Moldova campaign

The whole integrated system was tested on **Moldova Operational Field (MOF) campaign** took place during autumn 2011 in Moldova.

During the two months long of MOF campaign, three miniradar systems and the decision support tool have been successfully tested and compared against a state-of-the-art radar (X-POL) and against in situ weather station measurements (one video disdrometer, one Doppler flow meter and several rain gauges).
Mini-radar and XPol radar with disdrometer and raingauges

- 9.37 GHz H/V simultaneous transmission, Doppler, 60 kW peak power
- NCAR’s integrated acquisition cards (PIRAQ)
- 0.9° beam width, variable pulse length, 80 km typical range
- 1 and 0.3 dB noise in $Z_h$ and $Z_{dr}$ and 3° noise in $\Phi_{dp}$ (0.3 ° km$^{-1}$ in $K_{dp}$)
The basin of the Bic river in central Moldova

- 3 mini-radar R1, R2, R3
- XPol mobile radar RD (benchmark)
- 2D-video disdrometer (microphysics, radar observables)
- 6 sites along river with a pair raingauges each
- Doppler flow meter downstream (hydrological modeling)
Radar spatial (PPI) observations

- Radar reflectivity $Z_h$ at horizontal polarization
- Differential reflectivity $Z_{dr} = Z_h - Z_v$
- Differential phase shift $\Phi_{dp}$, $K_{dp} = 2d\Phi_{dp}/dr$ (3 km length)
- Co-polar correlation coefficient $\rho_{hv}$
- Two rain events: 8-9/9/11 convective, 8-9/10/11 stratiform
Radar data main processing

- Miniradar calibration using X-Pol as a reference
- Rain path attenuation correction (significant at X-band) of $Z_h$, $Z_{dr}$ and correction of backscatter effects on $\Phi_{dp}$
- Melting layer (bright band) detection and correction in the melting layer and the snow region above it (Vertical Profile of reflectivity or rainfall estimators)
- Application of polarimetric algorithms ($Z_h$, $Z_{dr}$, $K_{dp}$) for rainfall rate and rain microphysics (Drop Size Distribution parameters) estimation
Radar attenuation correction

Polarimetric relations for $D_z$, $\delta_b$, $A_h$, $A_{dp}$ from scattering simulations parameterized with Rayleigh scattering limits and polynomial approximation of Mie character of scattering

Input

$Z_{hm}$, $Z_{drm}$, $\Phi_{dpm}$

$dZ_h=a_h \Phi_{dpm}$, $dZ_{dr}=a_{dp} \Phi_{dpm}$

Correct reflectivities

$Z_h=Z_{hm}+dZ_h$

$Z_{dr}=Z_{drm}+dZ_{dr}$

Remove backscattering phase $D_z$, $\delta_b$ estimation

$\Phi_{dp} = \Phi_{dpm} - \delta_b$, $K_{dp} = d\Phi_{dp}/2dr$

Update attenuation corrections $A_h$, $A_{dp}$ estimation

$dZ_h=2|A_h|dr$, $dZ_{dr}=2|A_{dp}|dr$

| $|dZ_h| - |dZ_{hp}| \leq 0.5$ dB

| $|dZ_{dr}| - |dZ_{dp}| \leq 0.1$ dB

| $|\Phi_{dpf} - \Phi_{dpf p}| \leq 2^\circ$

NO

STOP

YES
Melting layer - Vertical profile of reflectivity

Input
PPI or RHI scan $\rho_{hv}$, $Z_h$, $P(Z_{hv}, Z_{dr}, R)$

Melting layer boundaries
$h_b: \rho_{hv} < 0.97$ (0.93)
$h_t: \rho_{hv} > 0.96$ (0.92)

Melting layer validation
max. $Z_h(h_b \leq h \leq h_t) - Z_{hb} \geq 1.5$ dB
$d = h_t - h_b \geq 150$ m
min. $\rho_{hv}(h_b \leq h \leq h_t) < 0.93$ (0.89)
in 40% of scan rays

Average height scaled VPR
$h' = (h - h_b) / d < d$, $h_b \leq h \leq h_t$
$h' = (h - h_t) + d$, $h < h_b$
Attenuation correction for $h < h_b$
$log_{10} VPR(h') = < log_{10}(P(h')/P_{hb})$

VPR correction
$VPR(h) = 1$, $h < h_b$
$VPR(h) = VPR(h')$, $h \geq h_b$
$P(h) = P(h)/VPR(h)$

YES
X-band rainfall rate estimation

- **Classic Z-R estimator:**
  \[ R = 3.36 \times 10^{-2} Z_h^{0.58} \]
  based on historic XPol and disdrometer data

- **Polarimetric estimators:**
  \[ R_{p1} = 1.305 \times 10^{-3} N_w (Z_h / N_w)^{0.58}, \quad N_w = N_w(Z_h, Z_{dr}, K_{dp}) \]
  \[ R_{p2} = 0.8106 F_R(\mu) N_w D_0^{4.67} f_R(D_0), \quad D_0 = D_0(Z_h, Z_{dr}, K_{dp}), \quad \mu = \mu(D_0) \]
  from scattering simulations (5% max. parameterization error)

- 1.5° elevation angle data was used from the radars

*N* 
\[ w, D_0, \mu \] parameters of Gamma Drop Size Distribution
Radar-raingauges comparison
Radar accumulated rainfall maps

Interpolation on a common grid with 1 km resolution
Accumulated rainfall comparison with XPol

R3 miniradar Z-R 8/9/11-9/9/11

$r=0.73$
$NB=8.5\%$
$NSE=40.3\%$

R3 miniradar Rp2 8/9/11-9/9/11

$r=0.68$
$NB=19.3\%$
$NSE=45.9\%$

R2 miniradar Z-R 8/10/11-9/10/11

$r=0.50$
$NB=-31.1\%$
$NSE=58.2\%$

R2 miniradar Rp2 8/10/11-9/10/11

$r=0.57$
$NB=1.9\%$
$NSE=67.2\%$
Conclusions-Further work

• Mini-radaras measure accurately the spatial variability of rain, and new polarimetric algorithms (attenuation correction, rain microphysics) were applied satisfactorily

• Despite their wider antenna beam, they still provide good performances within an useful range, for this type of radar, of $\approx 40-50$Km.

• They provide a reliable low cost solution for weather and flood monitoring in small scales

• More data are required to evaluate the performance

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Instruments deployed on Bic Basin

R2 Baltata 16 km far from Chisinau
Mobile radar

R3 Horesty 16 km far from Chisinau
Reflectivity images taken from MOF

A reflectivity map composite from the three radar sites
Sample Phase measurement

Differential propagation phase shift map taken from Straseni site at 60 km range (right) and range profile of the measurements along a given direction (azim. 333° clockwise from North direction and elev. 2.5 deg) As expected the $\Phi_{dp}$ increase in the rain-filled area, the corresponding average $K_{dp}$ value is about 0.5° km-1.
Accumulated rain (3h and 6 h) from Horesty site: the effect of beam blockage in south direction is quite evident.