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.

SEVENTH FRAMEWORK PROGRAMME

HIMET

C.C.I.-M.D.

RST

CYPRUS PROPLAN INDUSTRIAL ENGINEERING CONSULTANTS

ELDES Applicazioni Radar - Sistemi di Telecontrollo

SHS

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.

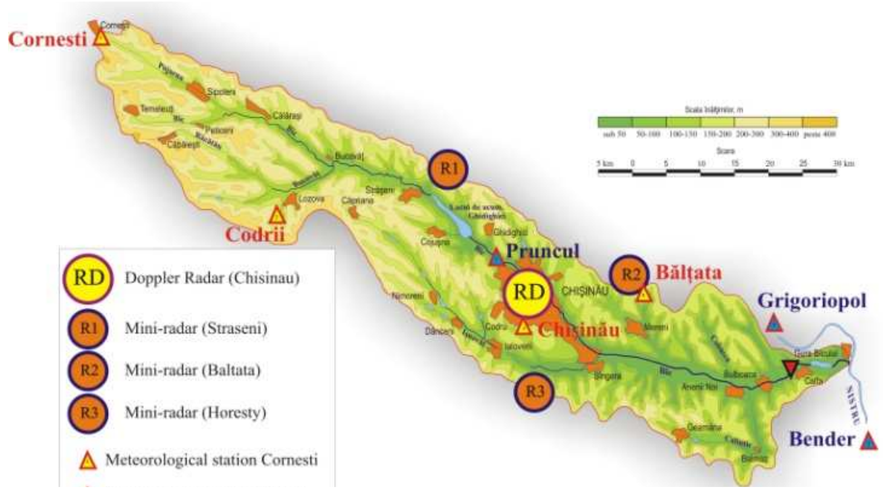
During the two months long of MOF campaign, three miniradar systems and the decision support tool have been successfully tested and compared against a state-of-the-art radar (X-POL) and against in situ weather station measurements (one video disdrometer, one Doppler flow meter and several rain gauges).

Mini-radar and XPol radar with disdrometer and raingauges

Miniradar Characteristics	
Frequency	9.41 GHz
Antenna Gain	35 dB
Antenna Type	Offset Cassegrain
Maximum Range	120 km
Beamwidth	3.0
Peak Power	25 Kw
Radome	YES
Dual Polarization	YES
Measurables	Z Z_{DR} V, Φ_{DP} ρ_{HV}

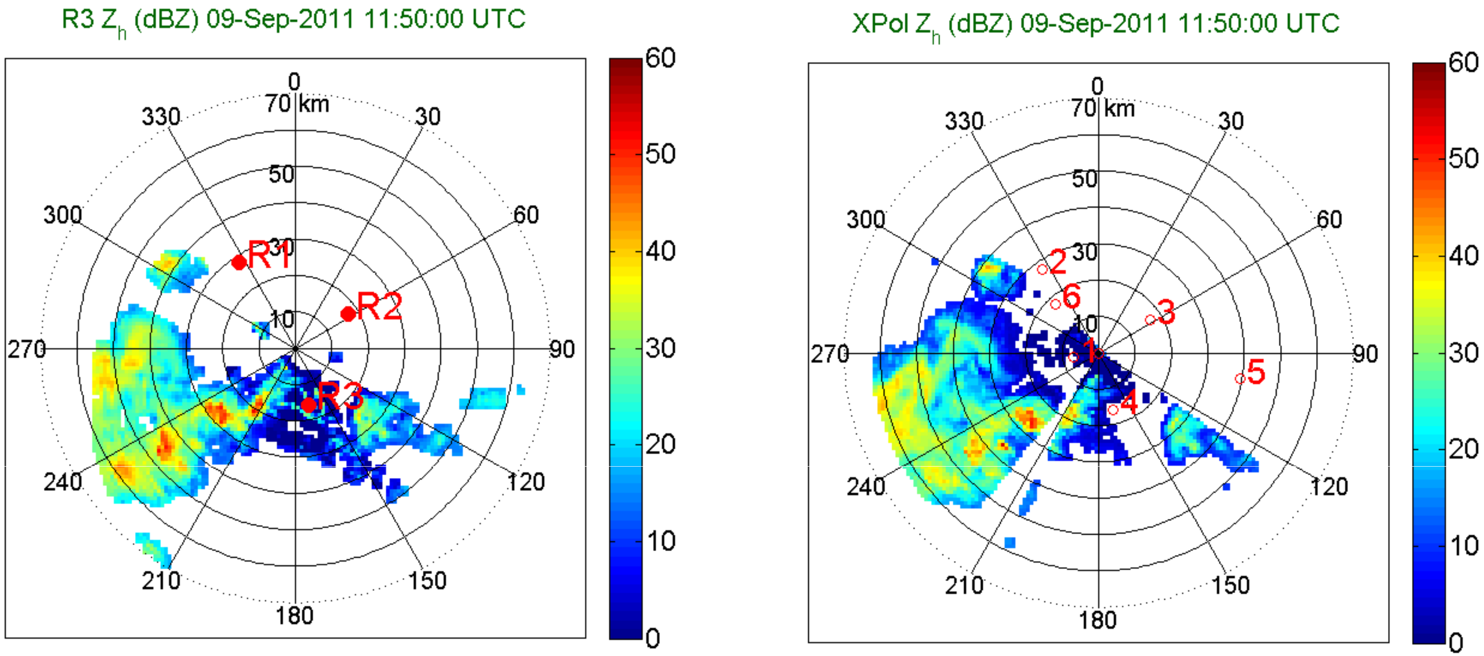
- **9.37 GHz H/V simultaneous transmission, Doppler, 60 kW peak power**
- **NCAR's integrated acquisition cards (PIRAQ)**
- **0.9^o beam width, variable pulse length, 80 km typical range**
- **1 and 0.3 dB noise in Z_h and Z_{dr} and 3^o noise in Φ_{dp} (0.3^o km^{-1} in K_{dp})**

The basin of the Bic river in central Moldova



- 3 mini-radars 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 Φ_{dp}, $K_{dp}=2d\Phi_{dp}/dr$ (3 km length)**
- **Co-polar correlation coefficient ρ_{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 Φ_{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**

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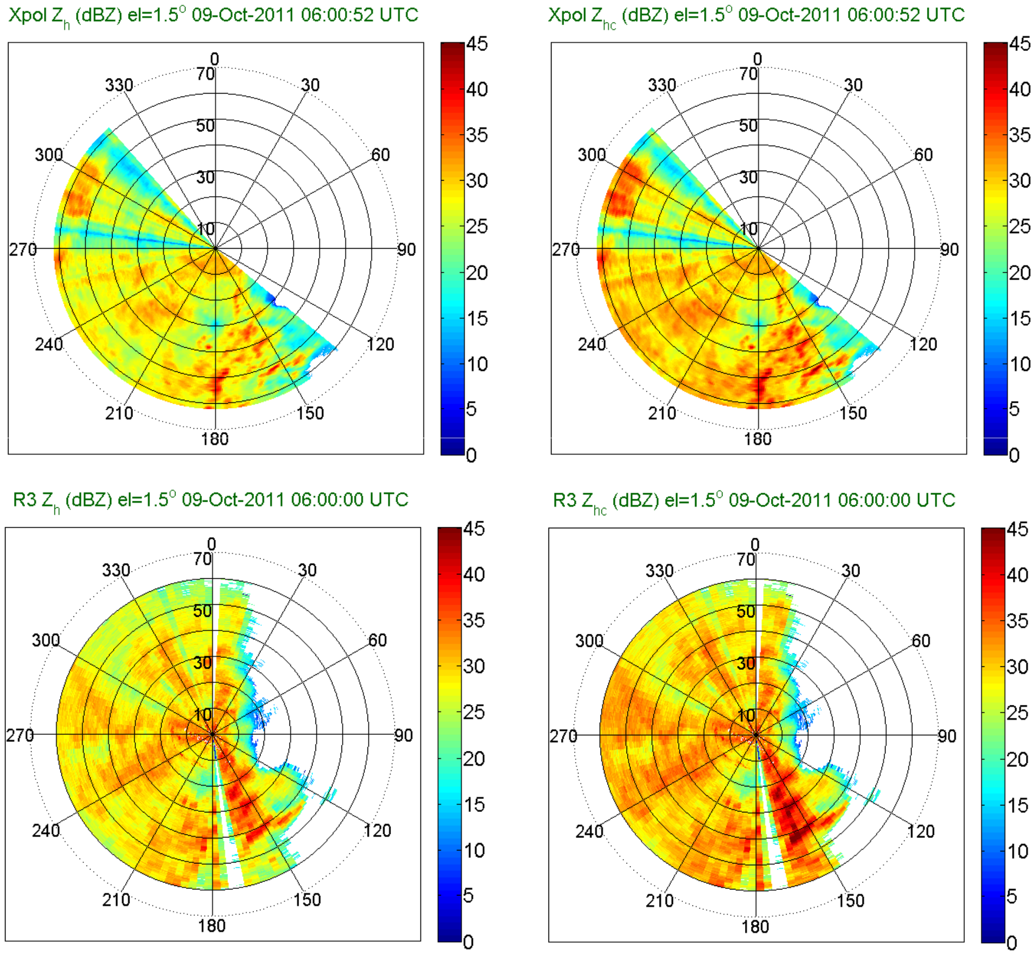
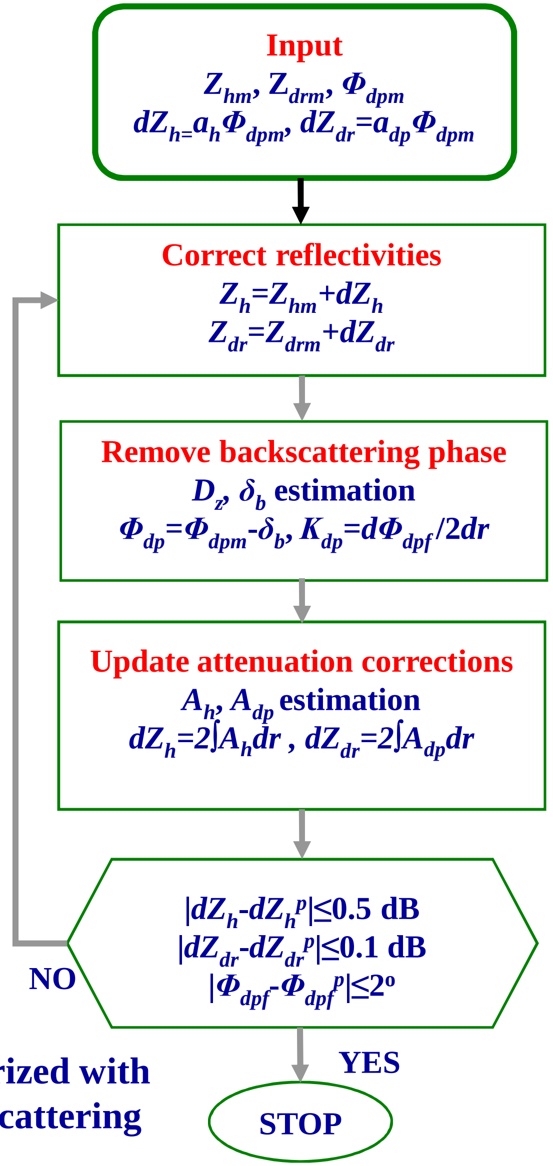
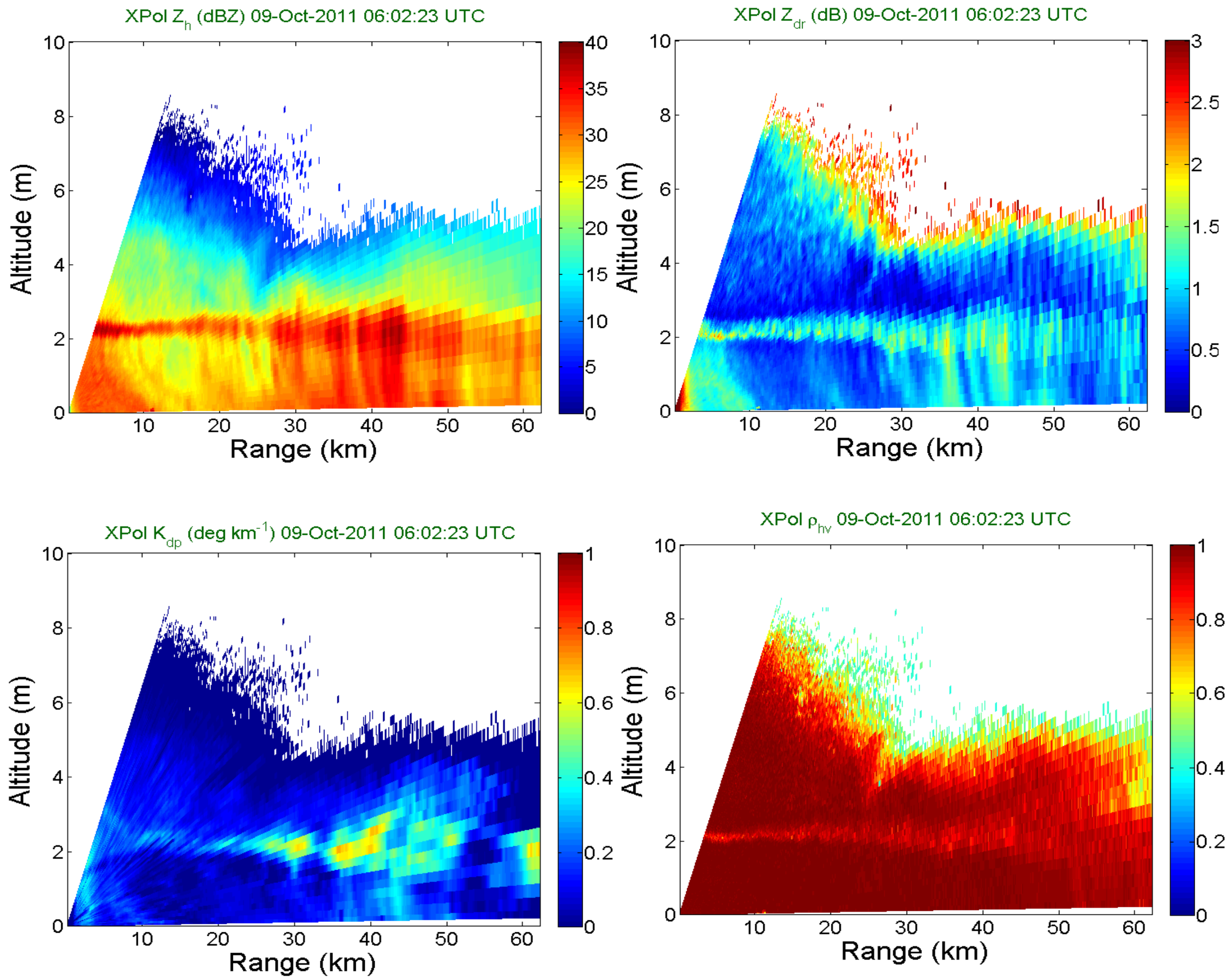
Radar attenuation correction





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

Melting layer-Vertical profile of reflectivity



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

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

YES

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

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

X-band rainfall rate estimation

- **Classic Z-R estimator:**

  $R=3.36x10^{-2}Z_h^{0.58}$

based on historic XPol and disdrometer data

- **Polarimetric estimators:**

  $R_{p1}=1.305x10^{-3}N_w(Z_h/N_w)^{0.58}$, $N_w=N_w(Z_h,Z_{dr},K_{dp})$

  $R_{p2}=0.8106F_R(\mu)N_wD_0^{4.67}f_R(D_0)$, $D_0=D_0(Z_h,Z_{dr},K_{dp})$, $\mu=\mu(D_0)$

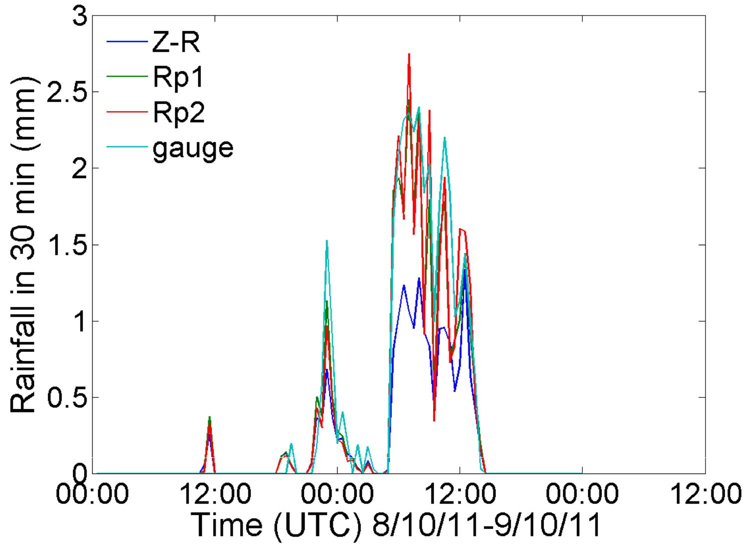
from scattering simulations (5% max. parameterization error)

N_w, D_0, μ parameters of Gamma Drop Size Distribution

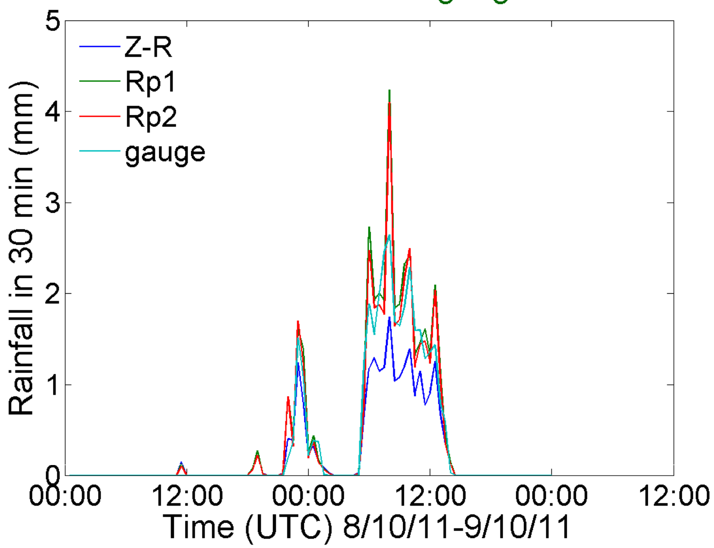
- **1.5^o elevation angle data was used from the radars**

Radar-raingauges comparison

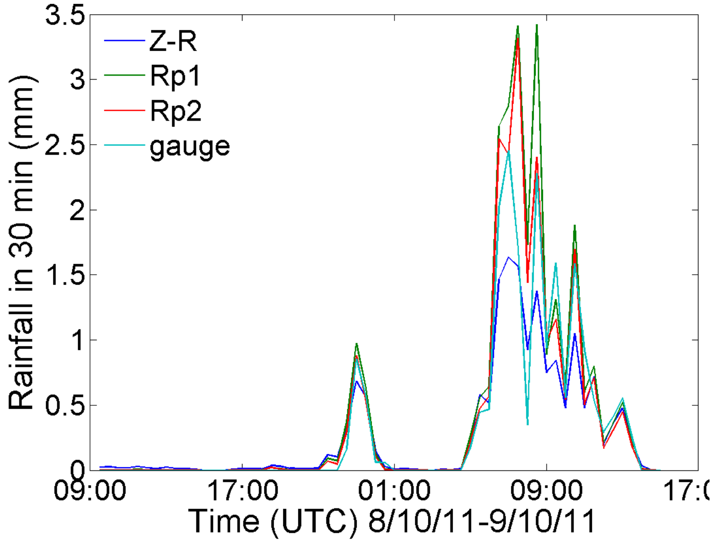
R3 miniradar-raingauge 2



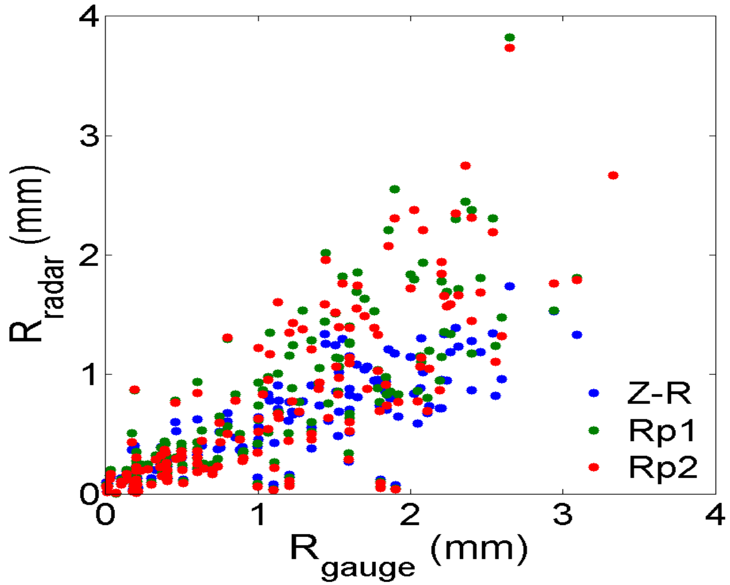
R3 miniradar-raingauge 6



XPol-raingauge 4

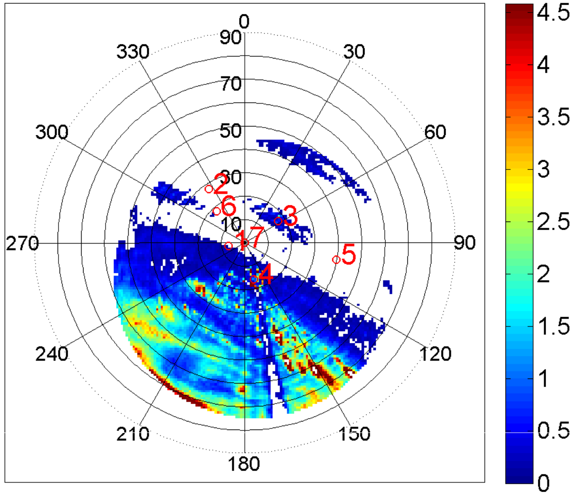


R3 miniradar-raingauges

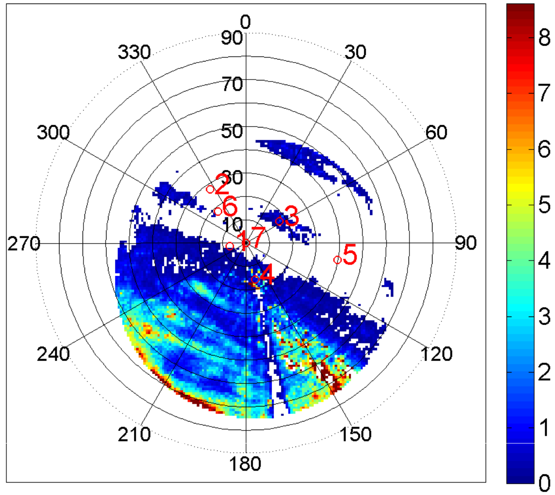


Radar accumulated rainfall maps

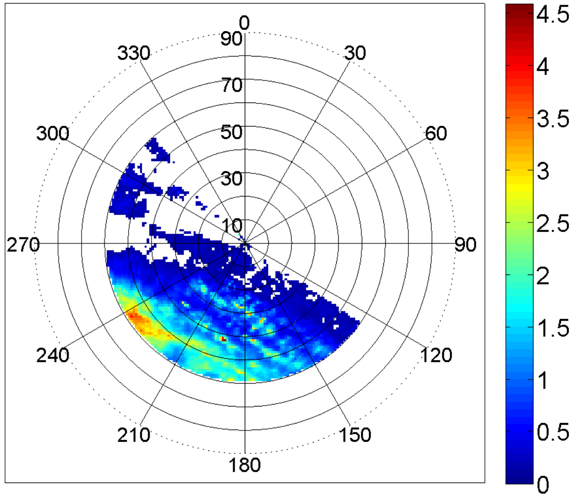
R3 accumulated rainfall Z-R (mm) 8/9/11-9/9/11



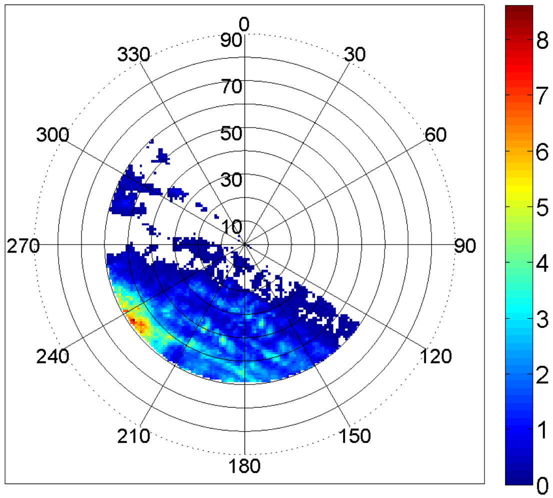
R3 accumulated rainfall Rp2 (mm) 8/9/11-9/9/11



XPol accumulated rainfall Z-R (mm) 8/9/11-9/9/11

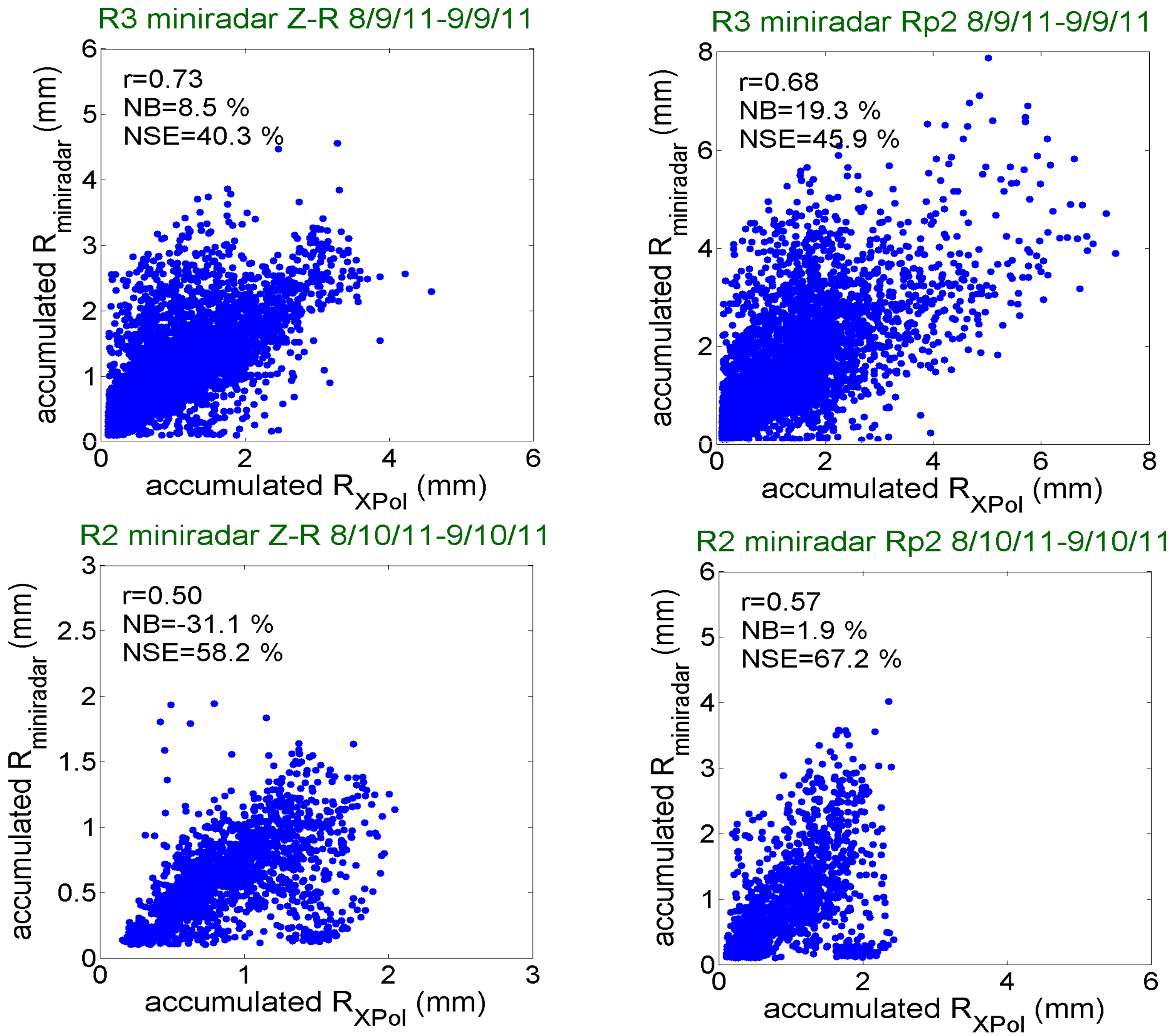


XPol accumulated rainfall Rp2 (mm) 8/9/11-9/9/11



Interpolation on a common grid with 1 km resolution

Accumulated rainfall comparison with XPol



Conclusions-Further work

- **Mini-radars 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 ≈40-50Km.**
- **They provide a reliable low cost solution for weather and flood monitoring in small scales**
- **More data are required to evaluate the performance**

ACKNOWLEDGEMENTS
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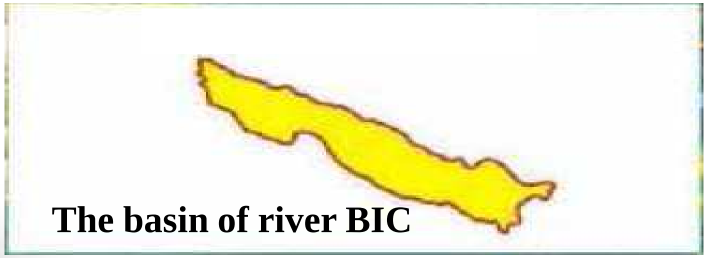
Instruments deployed on Bic Basin

R2 Baltata 16 km far from Chisinau Mobile radar

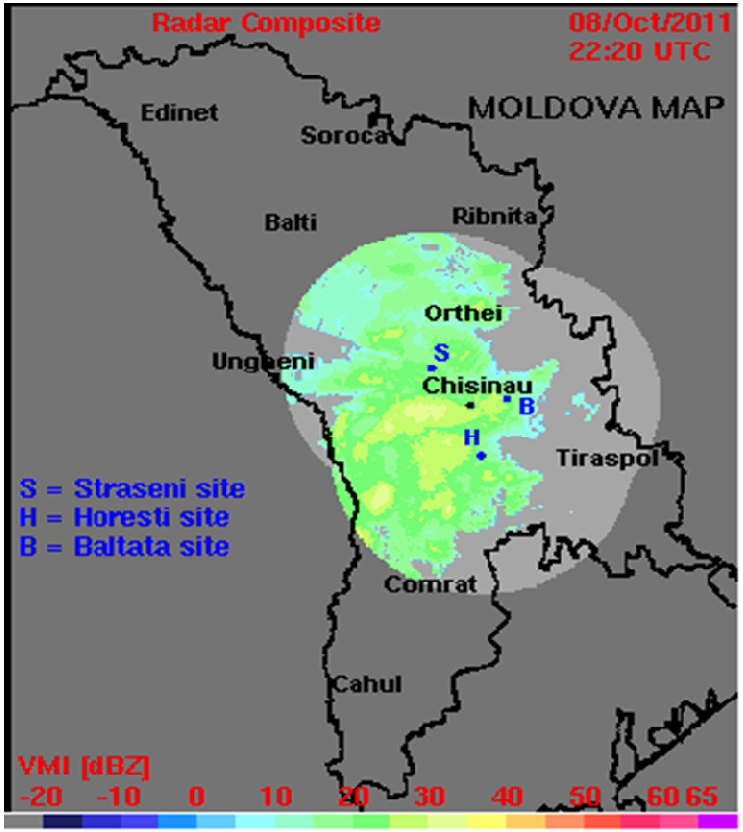


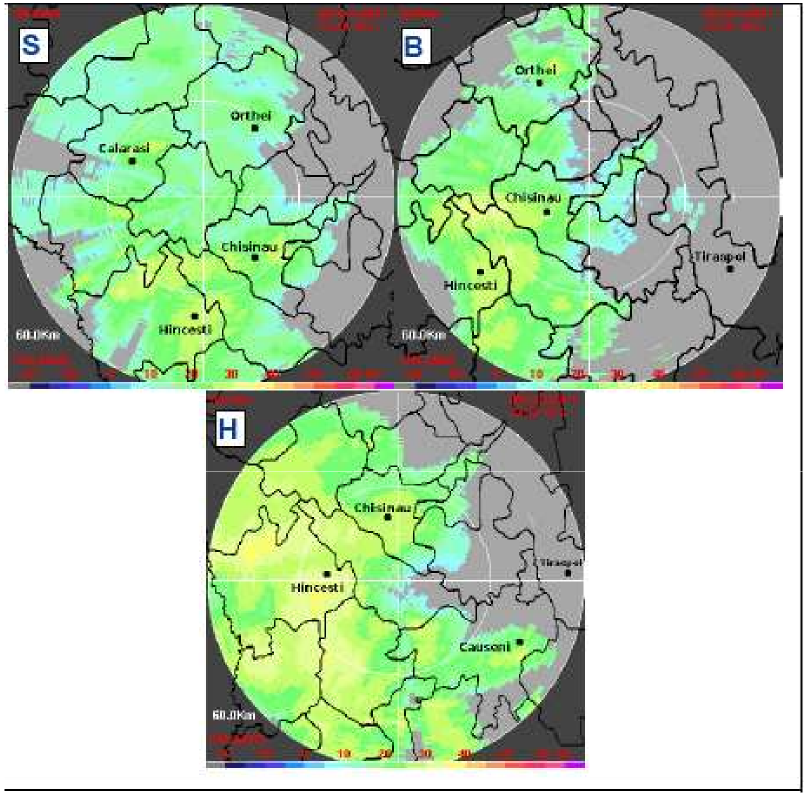
R3 Horesty 16 km far from Chisinau

D Chisinau -POL radar

...nts	[illegible]
...r	[illegible]
miniradar	[illegible]
miniradar	[illegible]
X-POL radar	[illegible]
5 Rain gauges	Co...
2D Video Disdrometer	Chisinau
Doppler flow meter	Pruncul
Stream Gauge Sensor	Calfa Village
Discharge/water quality sensor	Calfa Village

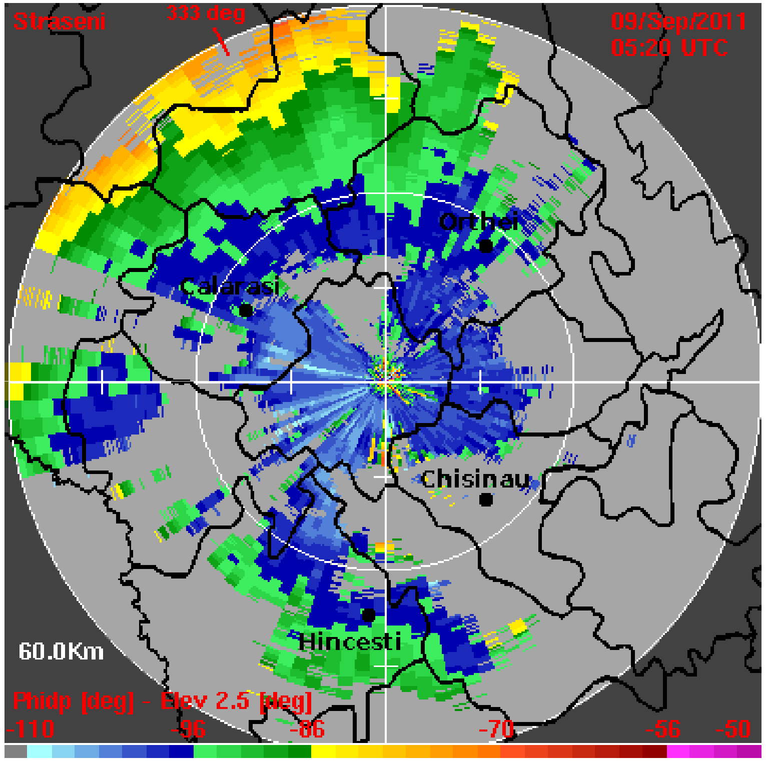
Reflectivity images taken from MOF

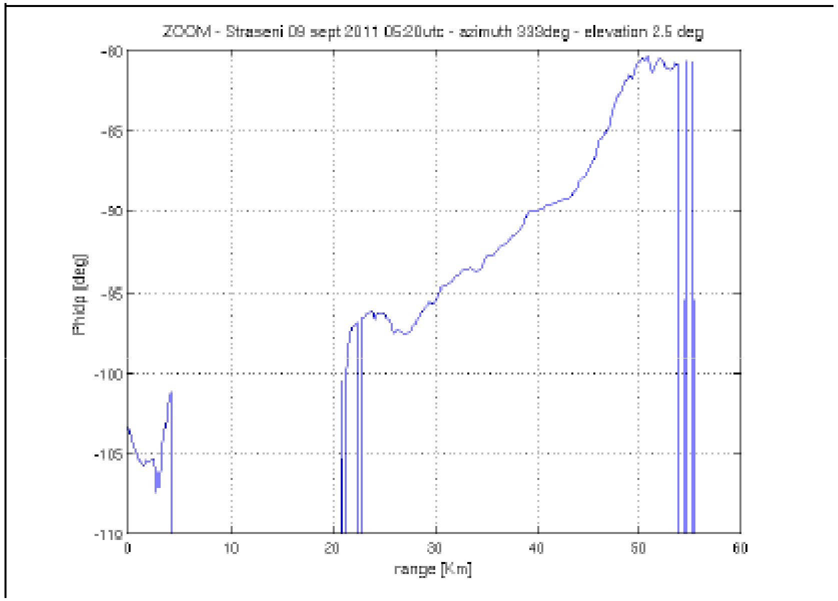




A reflectivity map composite from the three radar sites

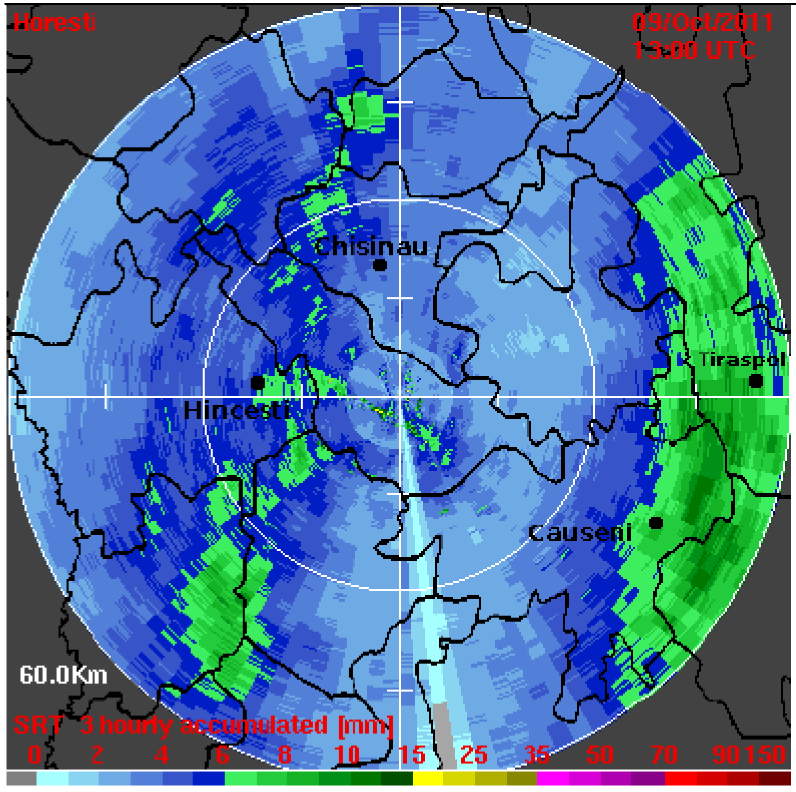
Sample Phase measurement

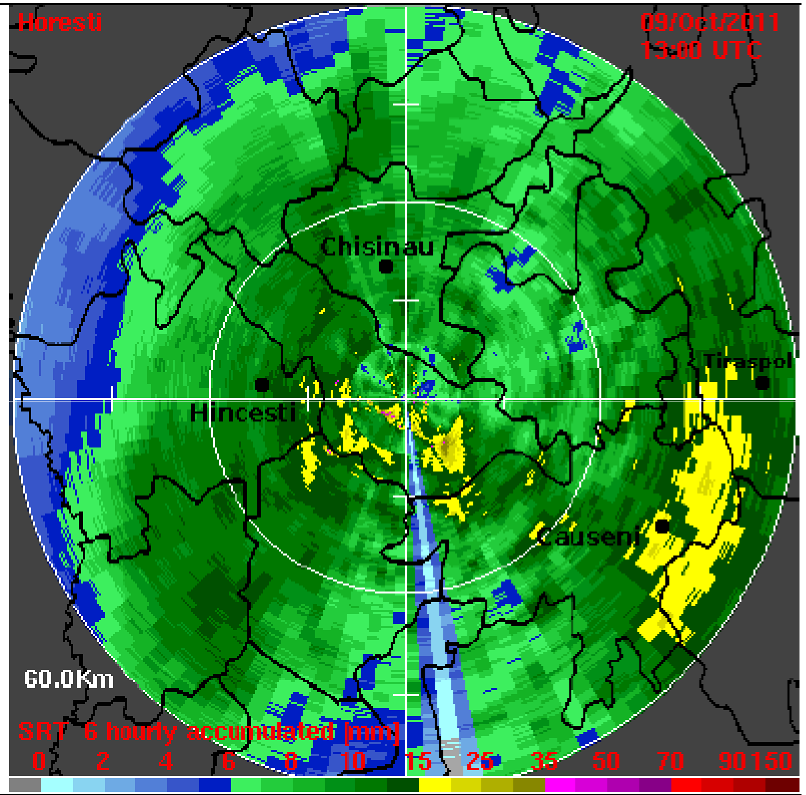




Differential propagation phase shift map taken from Straseni site at 60 km range (right) and range profile of the measurements along a given direction (azim. 333° clockwise from North direction and elev. 2.5 deg) As expected the Φdp increase in the rain-filled area, the corresponding average Kdp value is about 0.5° km-1.

Accumulated rain





Accumulated rain (3h and 6 h) from Horesty site: the effect of
The effect of beam blockage in south direction is quite evident