BALTRAD dual polarization hydrometeor classifier

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What is BALTRAD ?

baltrad

- Advanced weather radar network for the Baltic Sea Region
- Financed by European Union in the framework of the Baltic Sea Region programme 2007 – 2013
- BALTRAD project: 2009 – 2011
- BALTRAD+ project: 2012 - 2013
- Real time weather radar data exchange in a decentralized network.
- Visit: http://www.baltrad.eu/

One of the activities: Dual Pol. classifier

DualPol Hydrometeor Classifier

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Its components:

1. Ensure good quality and "stable" data:

special thanks to Beatrice Fradon, Meteo-France

- *Mitigate radome effects on Zdr, Φdp*
- *Zdr offset correction (currently using Zdr scans at 90º + sun calibration)*
- *Monitor φdp0 offset*
- *Monitor the quality of Zdr in light rain (20 dBZ – 22 dBZ) at close range*
- *Monitor ρhv in rain (upper 75% quantile)*

2. Computation of K_{DP}

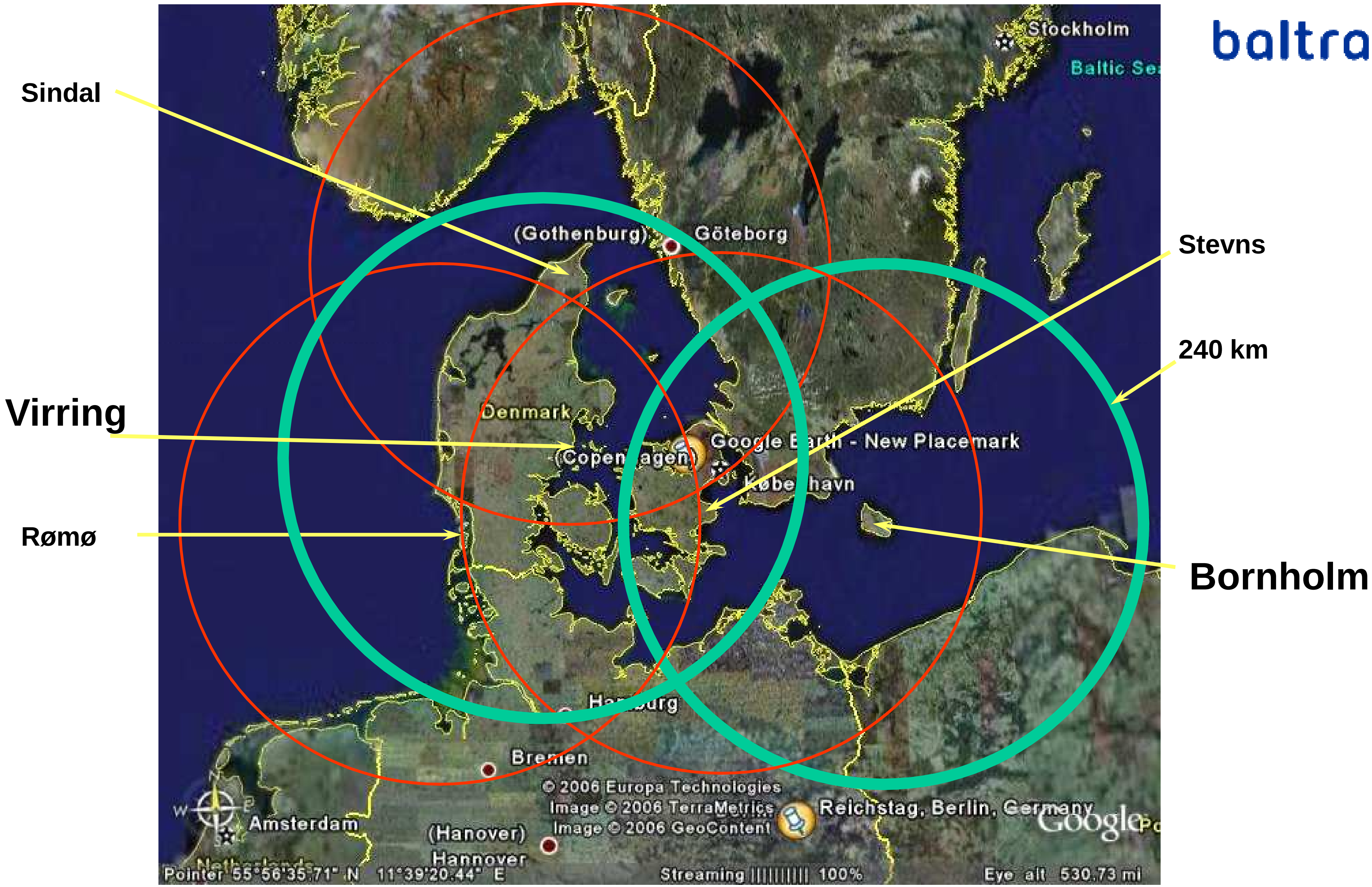
3. Correcting ZHH and ZDR for rain attenuation

4. Computation of the Melting layer (radar and NWP)

5. Fuzzy logics classification scheme:

- *Computation of the membership functions for each pre-specified radar echo class*
- *Using fuzzy rules compute the "scores" by each parameter (expert) for each pixel*
- *Weight the "scores" from each parameter*
- *Compute the total score for each class from all the parameters*
- *Final class is the one with e.g., the highest score*

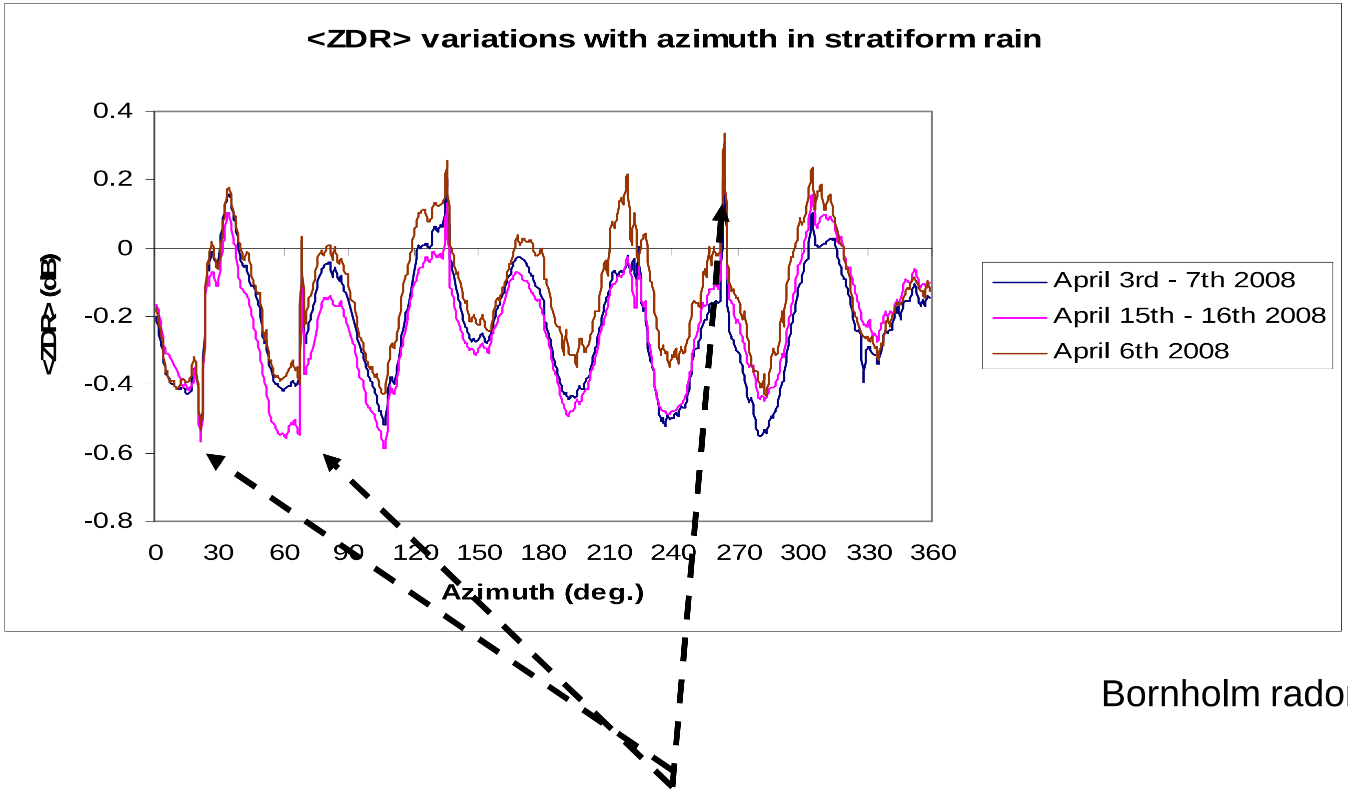
References: National Severe Storms Laboratory (NSSL), Colorado State Univ. (CSU), Meteo-France (M-F)



DMI weather radar network:
2 dualpol radars at Bornholm and Virring

Sensitivity of Zdr to radar RADOME

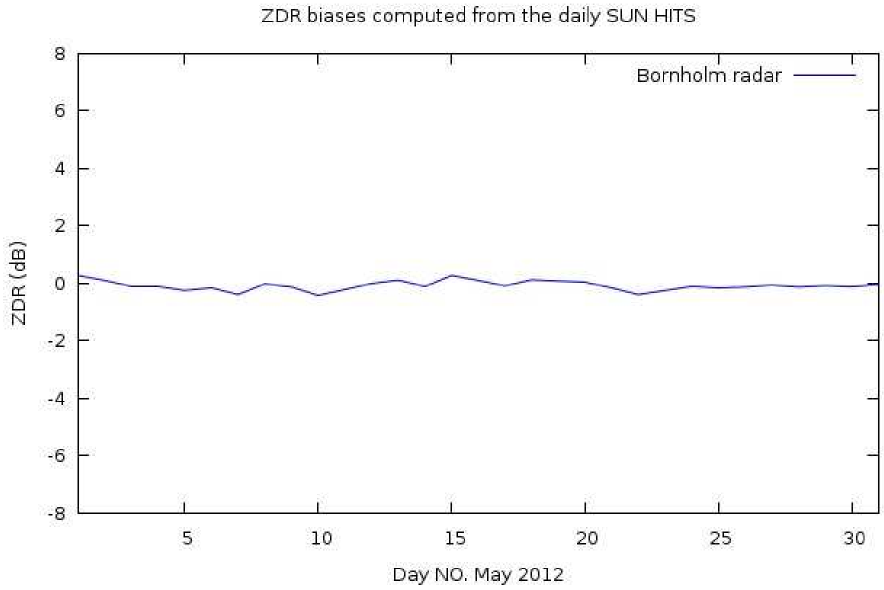
(DMI radomes: orange peel)

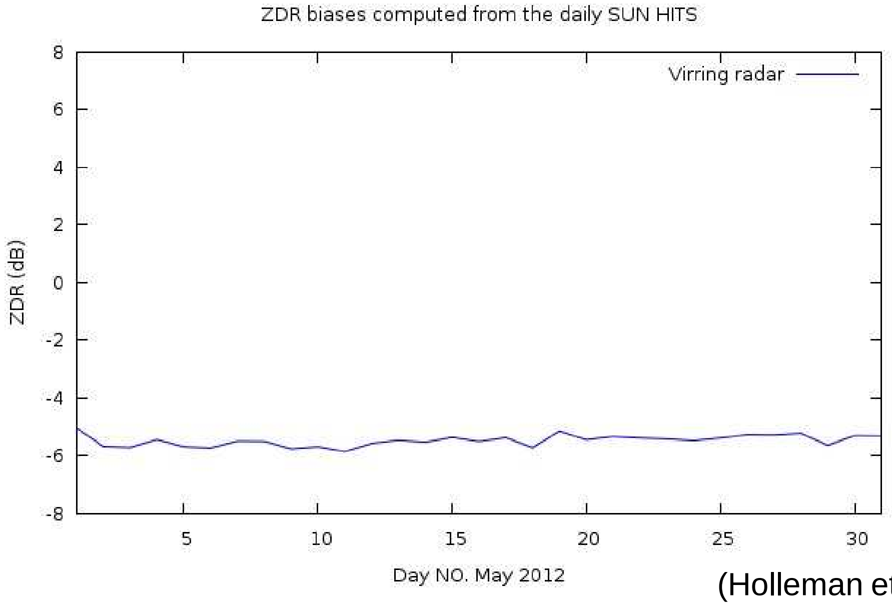


Bornholm radome with 8 panels

All elevations used: 0.5º, 0.7º, 1.0º, 1.5º, 2.4º, 4.5º, 8.5º, 10º, 13.0º, 15.0º
SNR>25 dB, ht<1200 m, range>5 km, ρhv>0.97

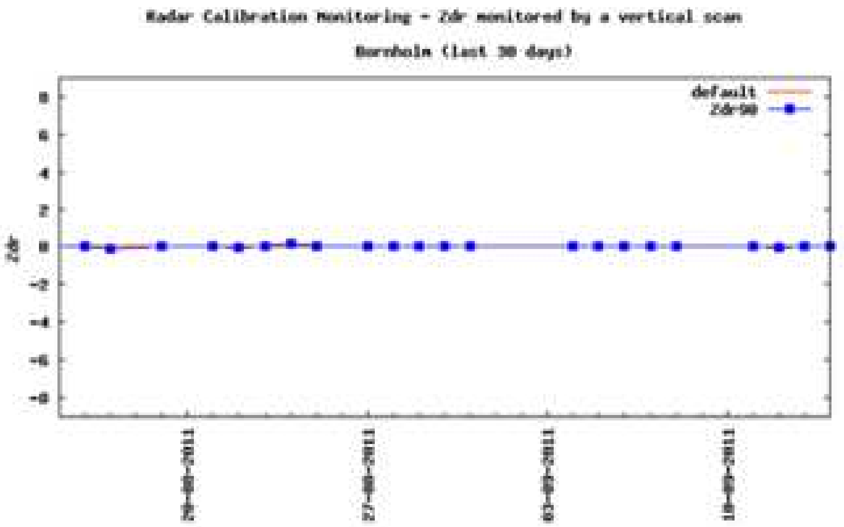
ZDR biases from daily SUN HITS



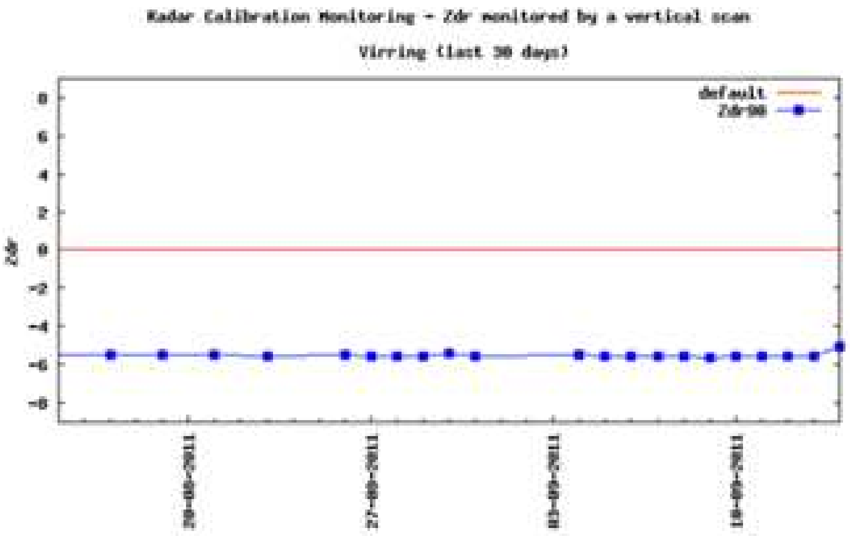


(Holleman et. al., 2010)

Diurnal potential biases in the ZDR parameter for the Bornholm and Virring radars, computed using the radar scan at 90º elevation.



Bornholm radar



Virring radar

Computation of specific differential phase K_{DP}

- K_{DP} parameter is not available from the radar processing software provided by the radar manufacturer.

- K_{DP} is computed as follows (Boumahmoud et. al, 2010):

  - The differential phase shift offset, $\Phi_{DP}(0)$, is computed dynamically for each ray from the first 5 gates containing precipitation (gate size = 0.5 km)

  - $\Phi_{DP}(0)$ is then smoothed using a median filter with a window size of 6.5km,

  - K_{DP} is then estimated by fitting a straight line on the above window.

Rain attenuation correction

Many algorithms e.g., the simplest : path integrated attenuation (PIA):

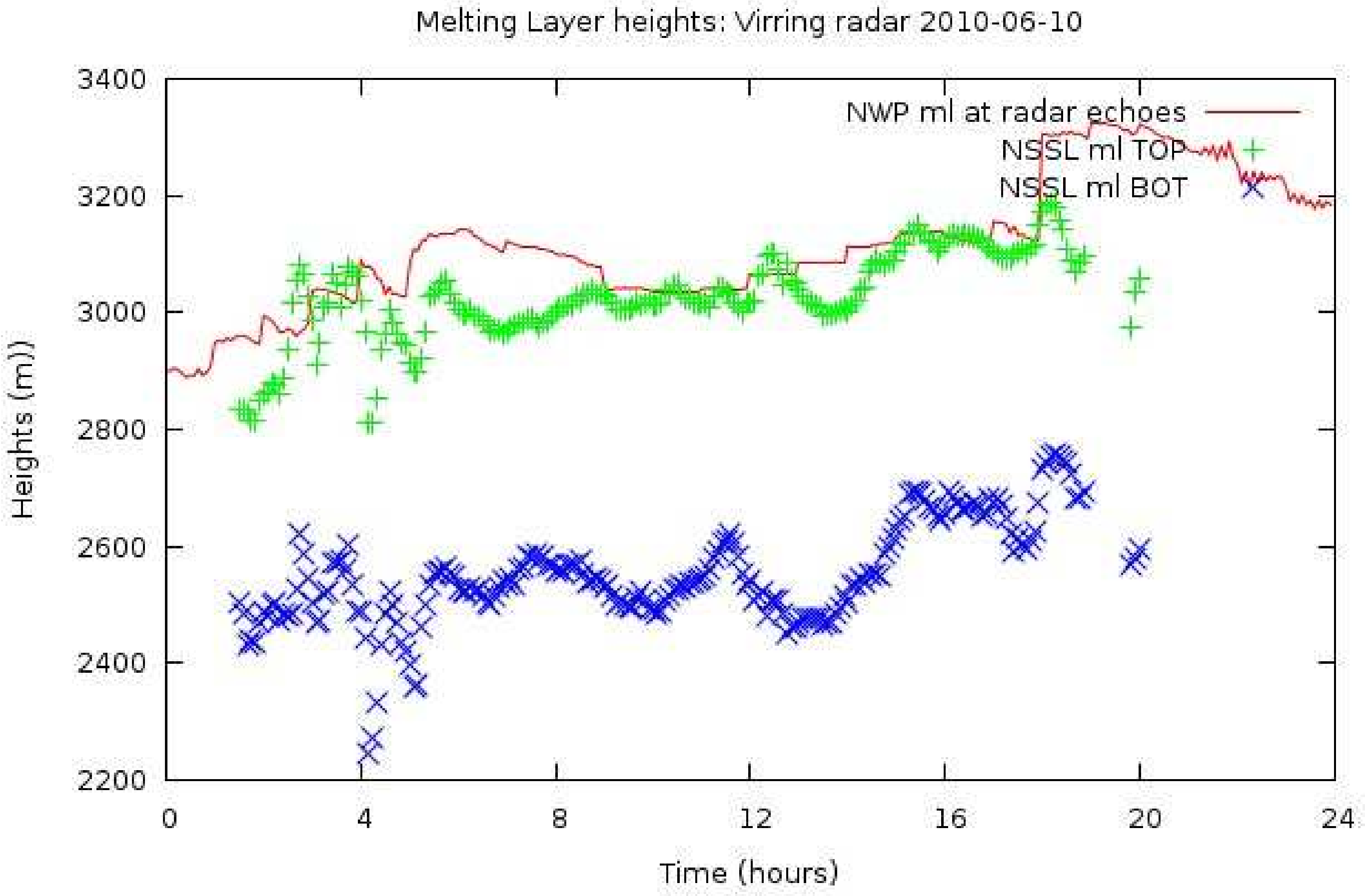
The parameters ZHH and ZDR are corrected for attenuation due to rain using the following relations:

$$ZHH\ (new)\ (r) = ZHH\ (old) + \alpha\ .\ [\Phi_{DP}(r) - \Phi_{DP}(0)]$$

$$ZDR\ (new)\ (r) = ZDR\ (old) + \beta\ .\ [\Phi_{DP}(r) - \Phi_{DP}(0)]$$

where the α and β are constants and at C-band have the values 0.08 dB/deg. and 0.03 dB/deg. , respectively (Gourley et al., 2007a).

Daily computation of the Melting layer using NSSL algorithm



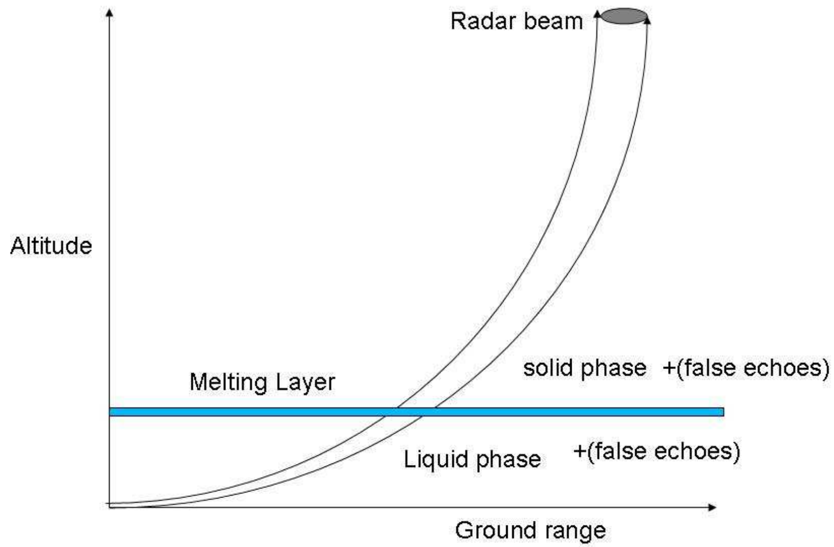
NWP melting layer: Resolution: 5 km X 5 km down sampled to 2km X 2km pixels. Forecasts made every hour.

Future use 3 km X 3 km resolution forecasts

- Performs well when volumes are full, and also when the melting layer above ~1 km
- Low elevation scans not used – cannot determine ML heights for approaching fronts at far range

Hydrometeor Classifier (using fuzzy logics)

Classify what the radar rays experience not what is observed on the ground



Pixel based fuzzy logics made simple:

Pixel of hydrometeor class j has a score Sj given by the relation

$$Sj = \frac{\sum_i w_i \cdot P_i}{\sum_i w_i}$$

where P_i and W_i are the value of the parameter i, and the associated weight, for the class j

The class that gets the highest score wins.

- Parameters used:
  - Zhh, Zdr, ρhv, Kdp, (+ texture parameters of Zhh, Zdr, Φdp),
  - HT NWP melting layer (only needed in level -2 classification – see later)

Main challenge lies in having representative membership functions

- Need to compute the membership functions for ALL the different types of echoes observed by the radar. If a particular class is not accounted for then it will be mis-classified into one of the pre-determined classes.

Current hydrometeor classes

Current version has 11 hydrometeor classes *(blue: internally in the system):*

- Ground clutter *(2)*
- Sea clutter *(2)*
- Electrical signals from external emitters that interfere with our radars + sun hits *(10)*
- Clean air echoes (CAE) such as from birds, insects *(3)*
- Light rain *(4: light drizzle, moderate drizzle, heavy drizzle, light rain)*
- Moderate rain
- Heavy rain
- Violent rain
- light snow
- Moderate to heavy snow
- Hail/rain mixture

Subsequent versions of the algorithm will also include the following classes:

- wet snow–rain mixture,
- hail,
- Graupels.

Membership functions

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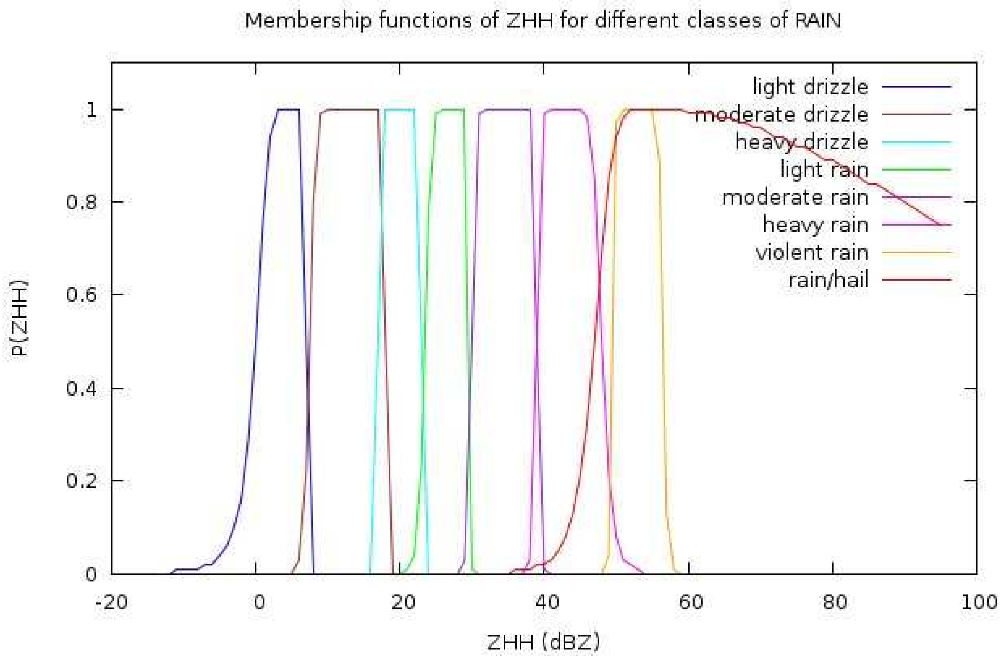
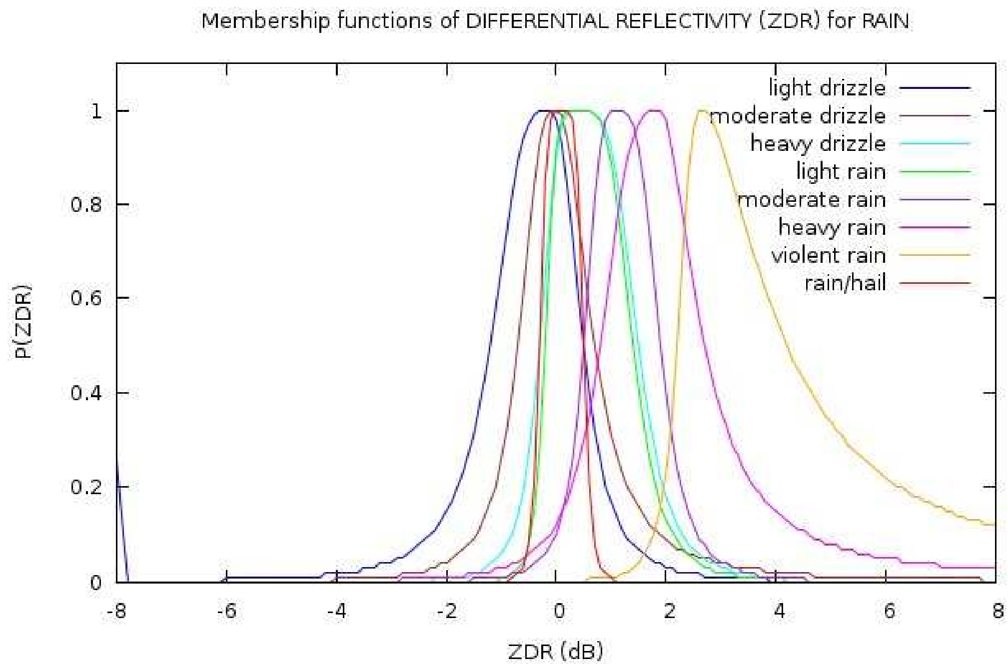
Represented by beta-Functions (Bringi & Chandrasekar, 2001)

$$beta(x,m,a,b) = 1 / [1+\{(x-c)/a]^2\}^b$$

c =centre, a=width, b=slope



ZHH



ZDR

- ZDR depends on ZHH. No relationship established as many sub categories of rain used

Some strange membership functions !

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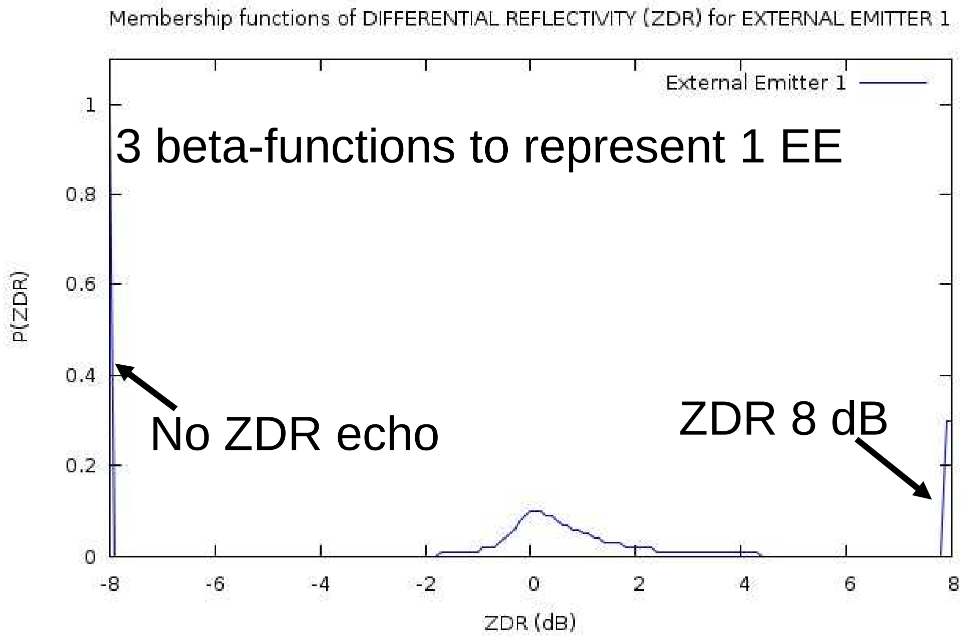
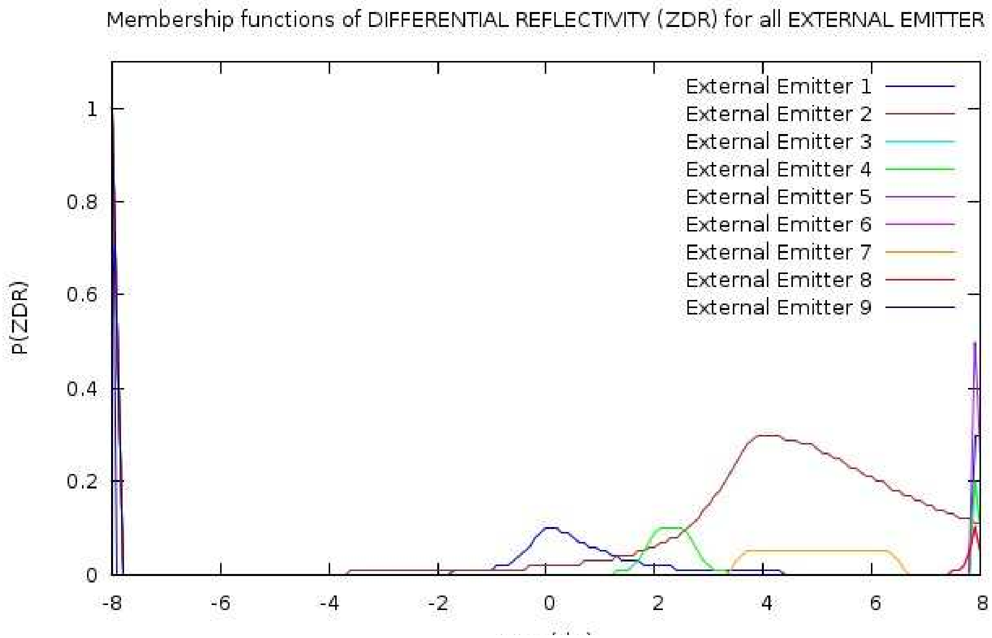
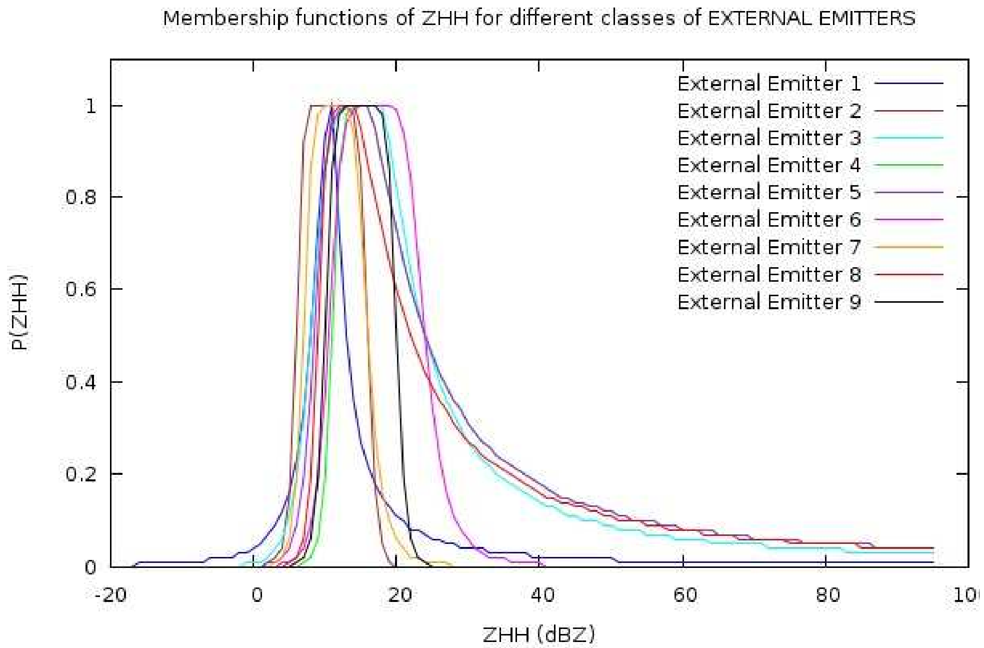
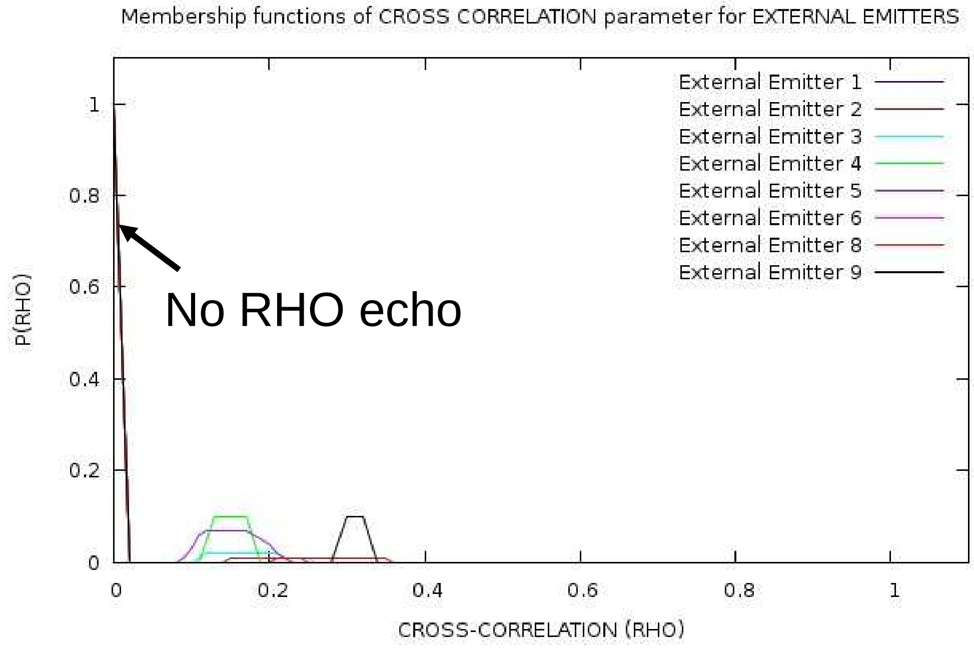


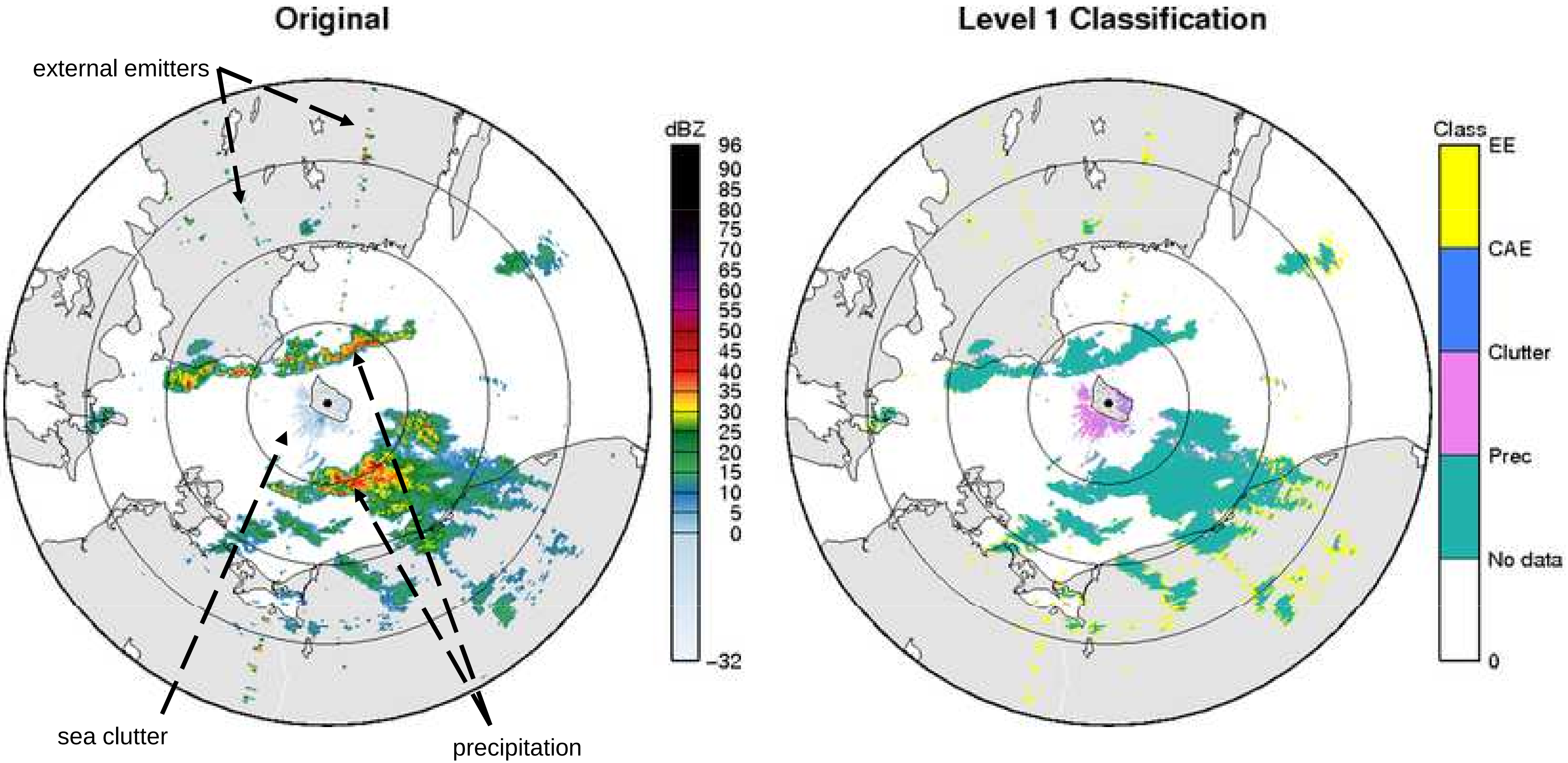






Level -1 classification

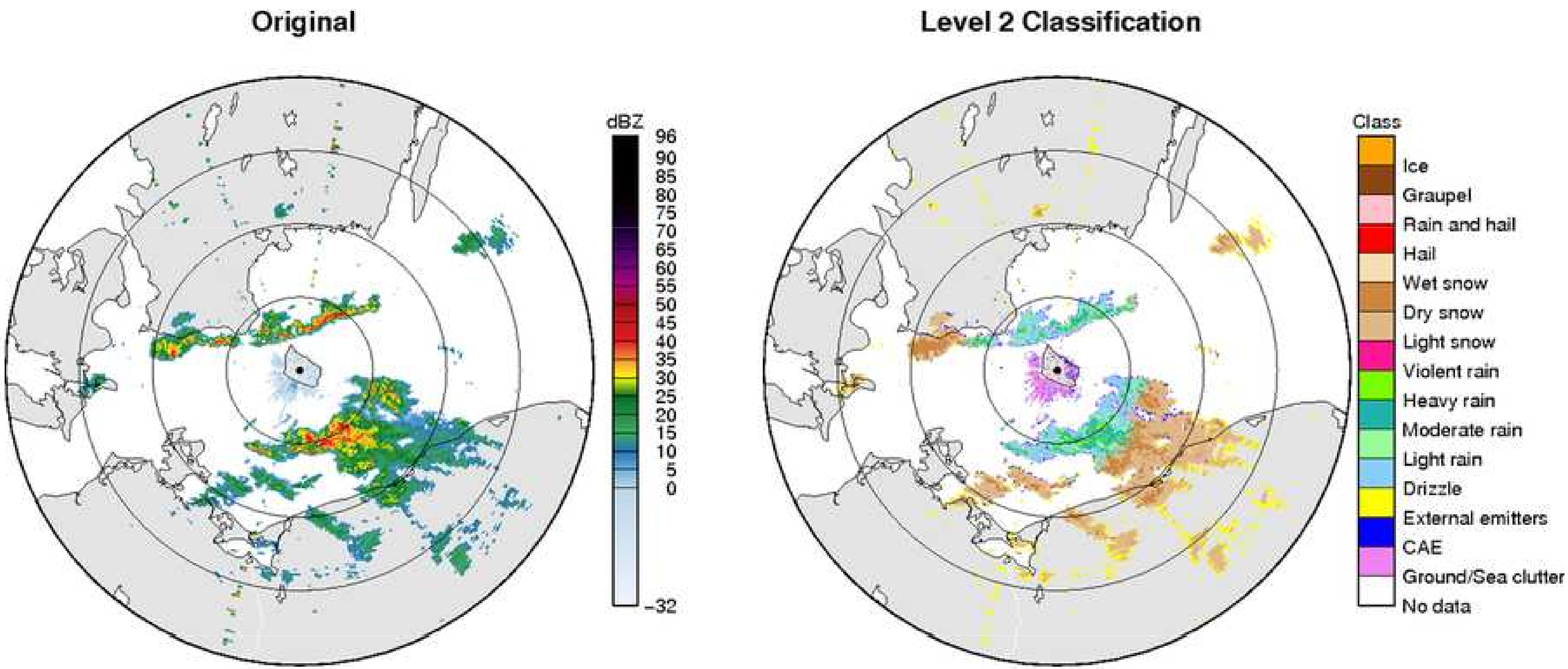
Bornholm



score for e.g., external emitters: $s_j = \frac{(1.0 \cdot Z_{HH} + 1.0 \cdot Z_{HHtex} + 0.8 \cdot Z_{DR} + 0.5 \cdot Z_{DRtex} + 0.0 \cdot \Phi_{DPtext} + 0.8 \cdot \rho_{HV})}{1.0 + 1.0 + 0.8 + 0.5 + 0.0 + 0.8}$

Level -2 classification

Bornholm

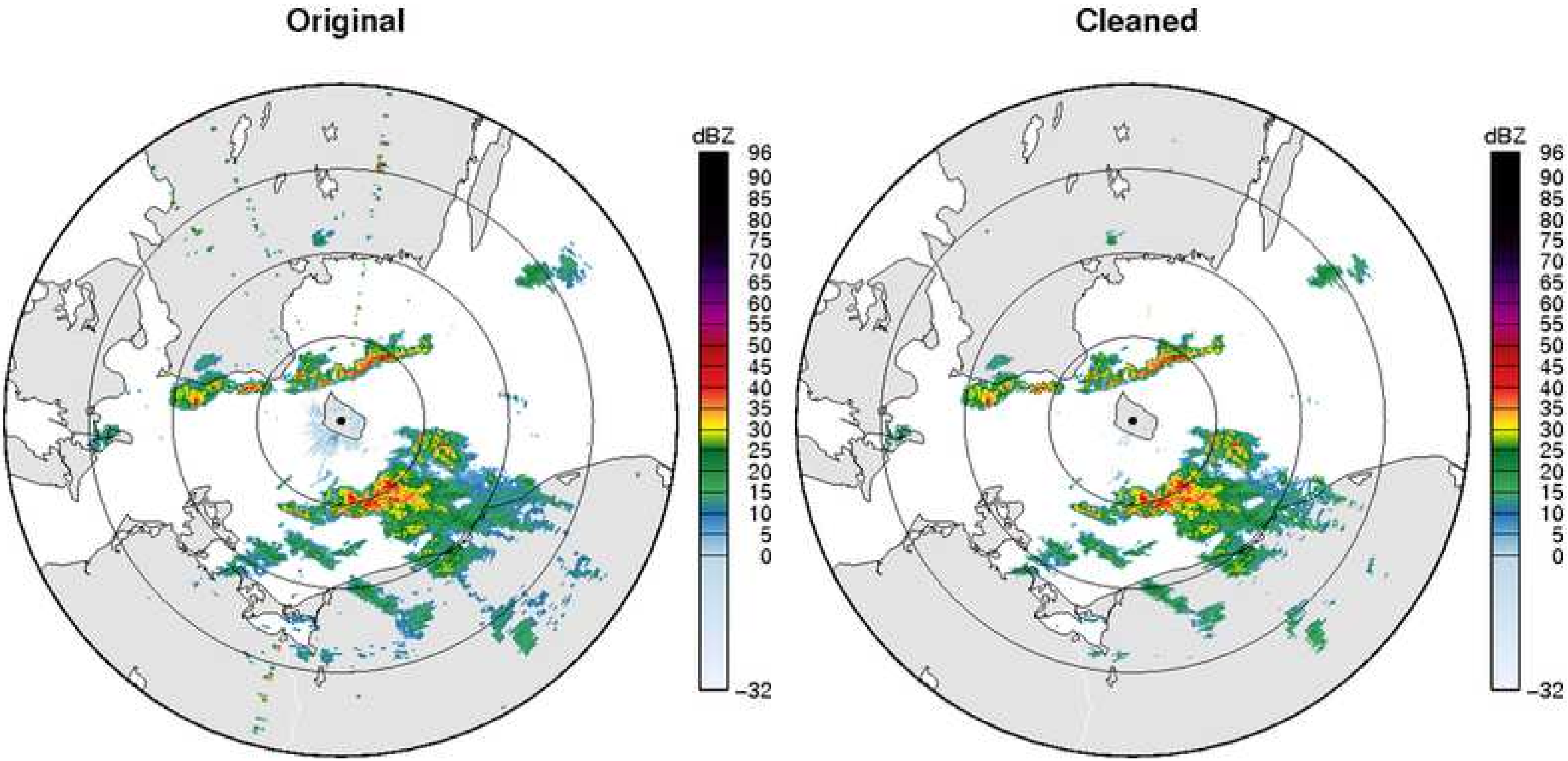


INPUT: precipitation from level 1 classification:
need NWP melting layer heights

score for e.g., drizzle $S_j = \frac{Z_{HH} \cdot H_{ML} \cdot (1.0 \cdot Z_{DR} + 0.5 \cdot \rho_{HV} + 0.4 \cdot K_{DP})}{1.0 + 0.5 + 0.4}$

"Cleaned" Product

Bornholm



Most appreciated product by DMI users

Finally

BALTRAD hydrometeor classifier:

- publicly available according to the Lesser Gnu General Public License
- HDF5 file format
- Documentation: Doxygen
- Visit: http://www.baltrad.eu/
- Caution: membership functions are derived using the data from the 2 DMI dualPol radars they will need fine tuning when used with data from other radars
- Have realistic expectations : will not get it right 100 % everytime !

Thank you for your attention

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One of the activities: Development of Dual Pol. classifier

NOTE:

Dual pol. parameters are difference between very small quantities

- Need to reduce noise in the data e.g., smooth – Zdr, ρhv, φdp, Kdp
- Noise is a special problem for Kdp – critical parameter in attenuation correction and rain estimates. smoothed over several km – smooths out peaks

- Need to correct for systematic errors e.g., radome contamination

- Accurate calibration a must.

- For reliable rain rate estimates and HMC need:
  - Zdr within 0.1 – 0.2 dB (source Illingworth, 2004).
  - Zhh within 1 dB for QPE
  - φdp within 1 deg. or better
  - ρhv => 0.98 in light to moderate rain. If this is not met then all polarimetric parameters will be affected by noise and the distinction between say rain and melting snow will be difficult. Measured values < theoretical values (OPERA report-WD-2009-1.4a).

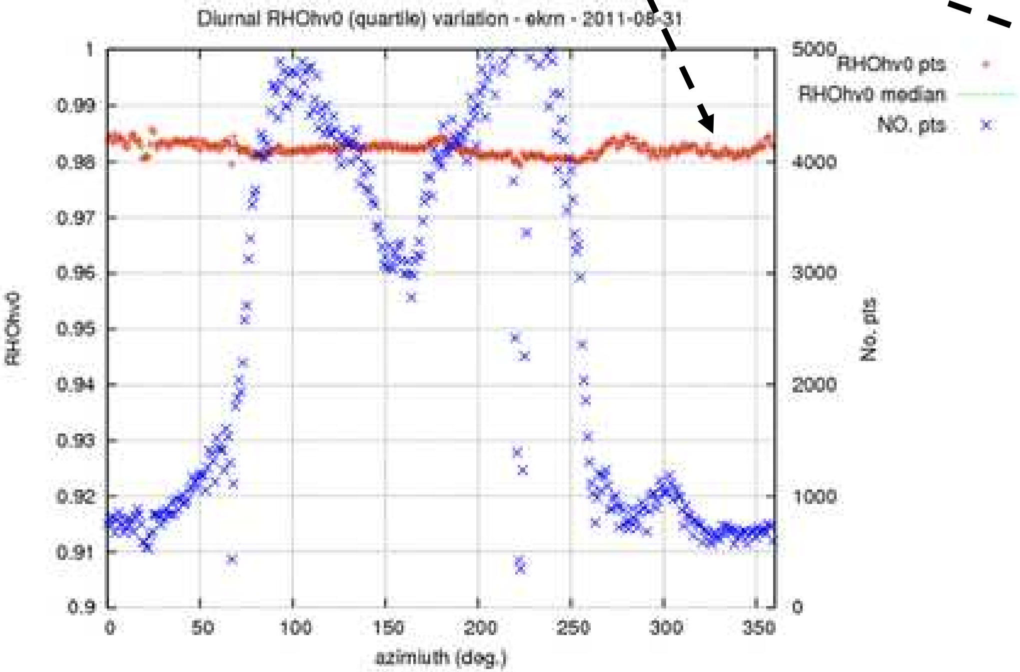
- Contamination by wind mills of secondary lobes will affect the quality of measurements made in rain by the main lobes

1. Ensure good quality data

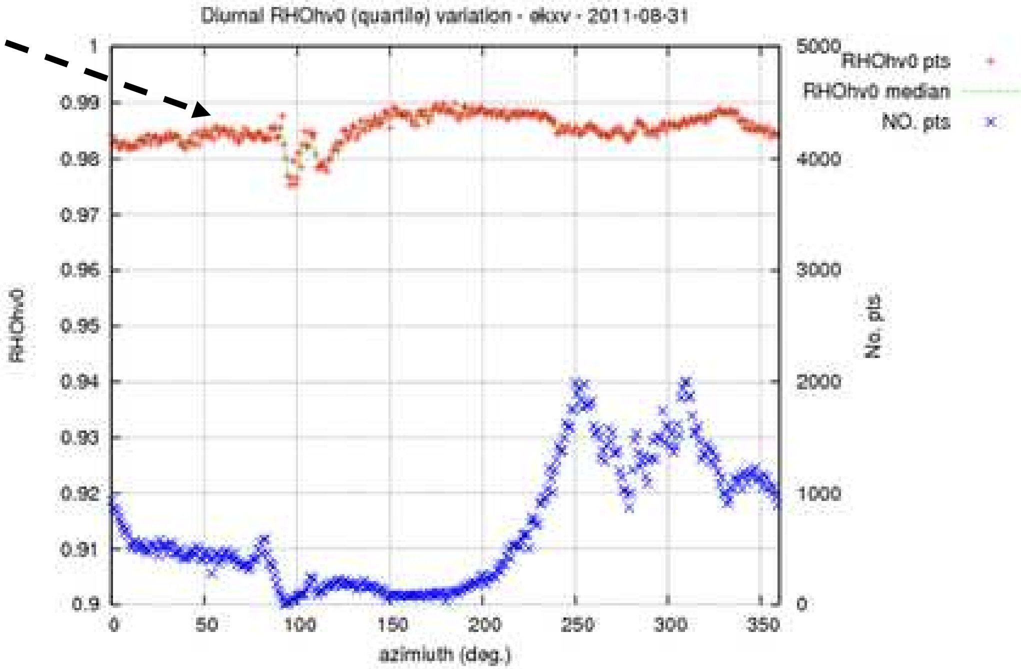
Radar data quality monitoring tools

- Special radar scans at 90º elevation is performed to compute the potential biases in ZDR
- ZDR computed from diurnal sun hits
- ZDR computed in light rain between 20 dBZ – 22 dBZ at close range
- Φdp offsets are computed
- Upper 75% quantile RHV in rain is computed.

Diurnal variations of ρHV (colour red) in rain for Bornholm and Virring radars



BORNHOLM radar



VIRRING radar

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The easy part

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