Radar-driven temperature nudging for nowcasting winter precipitation

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Introduction

➢Winter time precipitation has a strong impact on society: road closures, power outages, property damage and loss of life.

➢Discriminating between freezing rain from ice pellets, and other hydrometeors is difficult where slight variations in the atmosphere can change the phase.

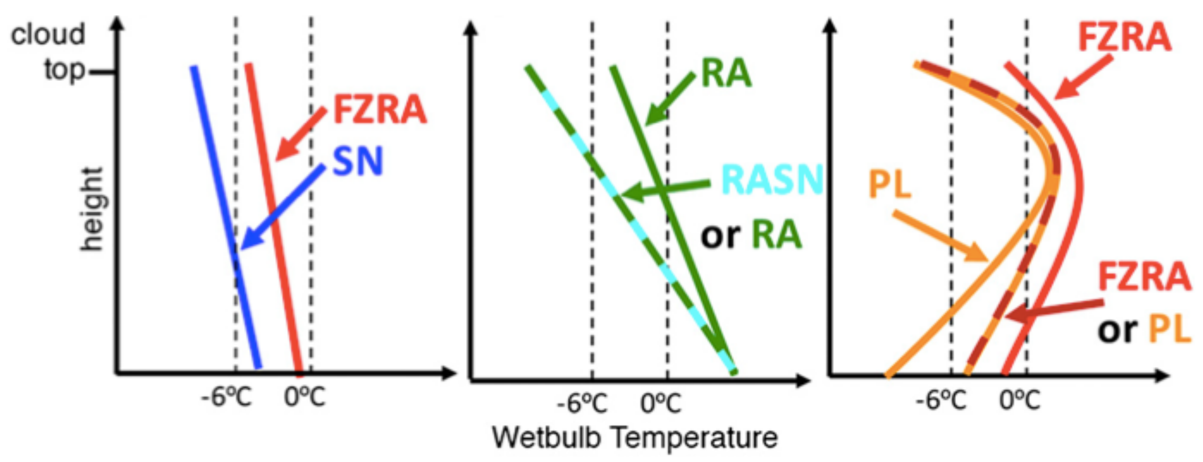


Fig. 1. Vertical wet bulb temperature profiles and the corresponding hydrometeor classification (Reeves et al. 2016). The -6°C temperature is the ice nucleation temperature for the SBC model. FZRN is freezing rain; SN is snow; RA is rain; RASN is rain and snow mixture; PL is ice pellet.

Goals

➢The implementation of a one-dimensional microphysical (SBC) model into COSMO-DE for improved winter precipitation classification and nowcasting with radar-based nudging of thermodynamic profiles

Instrumentation

➢X- and C- band Dual-polarimetric radars. C band radars are part of the operational German Weather Service network. The X band is owned/operated by University of Bonn.

➢Radiosonde data

➢Cosmo-de regional weather model

➢A 1D microphysical model, spectral bin classifier (SBC) with 6 classes based on the liquid-water fraction for hydrometeors given T and RH (Reeves et al. 2016). Inputs for the SBC model are from COSMO-de NWP model, the regional weather perdition model of the German Weather Service (DWD).

Method: Melting Layer

➢The method was adapted from a method developed by Wolfensberger et al. (2015) for RHI scans to work with Quasi-vertical profiles (QVP) of the observations.

➢QVPs of ZDR ($-1<Z_{DR}<4$), and ρ_{HV} ($.8<\rho_{HV}<1$) are normalized for each time step/vertical profile and combined as single parameter, ML.

$$ML = Z_{DR\,nor} \times (1-\varrho_{hv\,nor})$$

➢A vertical Sobel filter is run for each time step to detect gradients

➢The melting layer top (MLT) and bottom (MLB) are determined as the minimum and maximum of the gradients.

➢MLT and MLB are corrected by finding where ρ_{HV} reaches 0.97 above/below the MLT/MLB respectively (Giangrande et al 2009).

Method: Refreezing Layer

➢Refreezing layers are observable through a bump in Z_{DR}, and corresponding decrease in Z_H and ρ_{HV} (Kumjian et al 2013).

➢Refreezing layer occurs ≈ -6°C wet bulb temperature

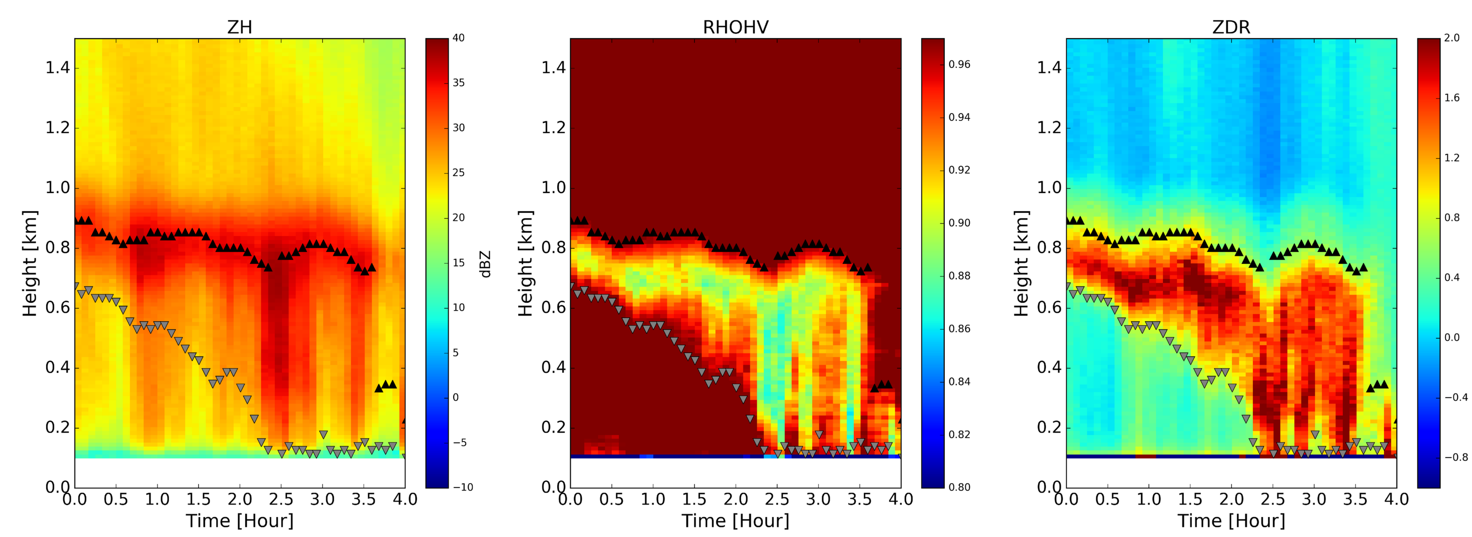
➢All observations above MLB are removed.

➢A second combined image, RL, is created from normalized ZDR, and ρ_{HV}. Zh is not applied as its decrease is less distinct as Z_{DR} bump and ρ_{HV} drop.

$$RL = Z_{DR\,nor} \cdot (1-\varrho_{HVnor})$$

➢A refreezing layer could be determined by the magnitude of the peak.

Melting Layer



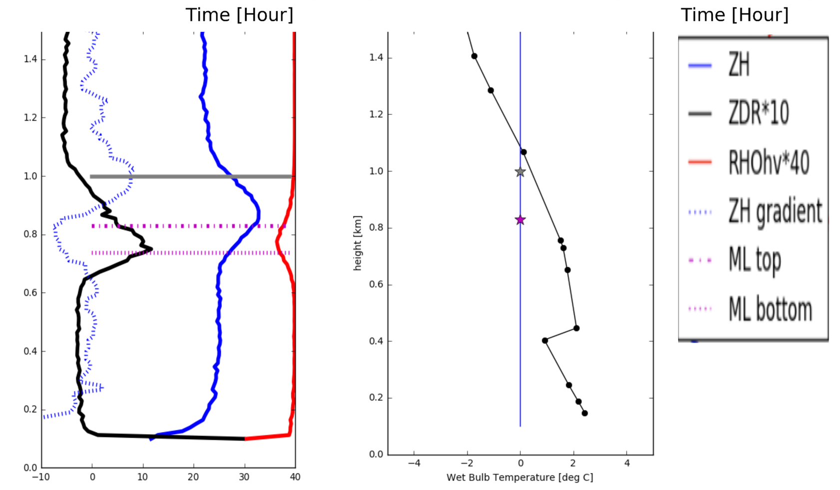


Fig. 2. QVP of Z_H, ρ_{HV}, and Z_{DR} from the X-band radar in Bonn Germany, 2017-06-10 00:00 to 04:00 UTC. Black triangles show location of MLT, and gray triangles MLB

Fig. 3. QVP of Z_H, ρ_{HV}*40, and Z_{DR}*10 and the gradient of Z_H at 00:00 UTC, the grey line is the MLT, the dashed pink line the MLB. Additionally, the TW from the Essen radiosonde The gray star it the final MLT, and the pink star is the initial MLT

Refreezing Layer

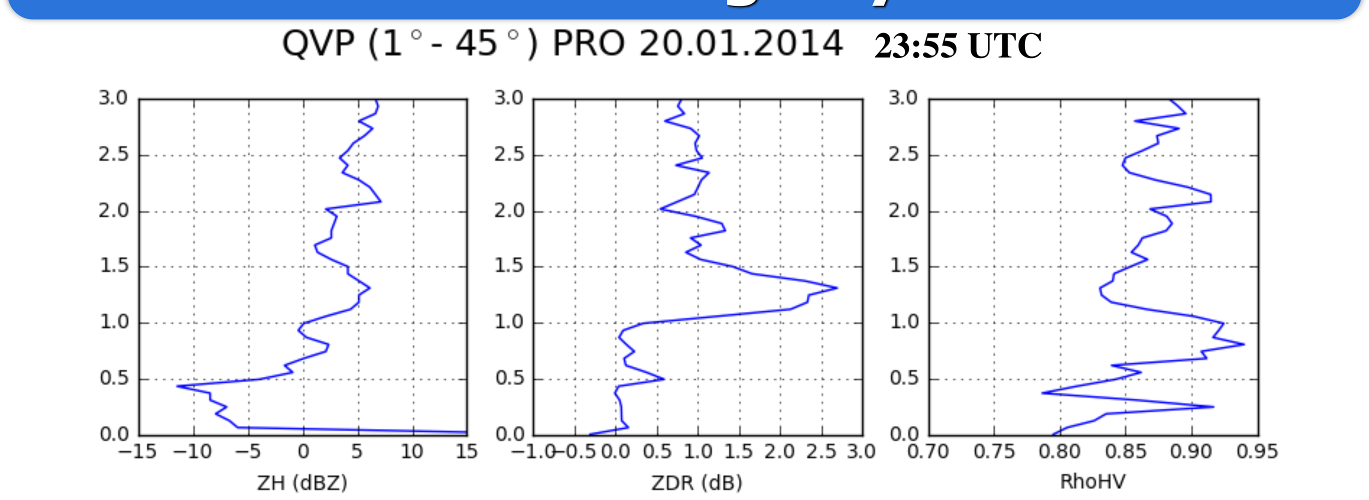


Fig. 4. QVP (azimuth: 1°– 45°) of Z_H, ρ_{HV}, and Z_{DR} from the C-band radar Prötzel, near Berlin, Germany at 2014-01-20 23:55 UTC. Ice pellets were observed at the surface and a refreezing layer can be seen at about 0.5 km above the surface.

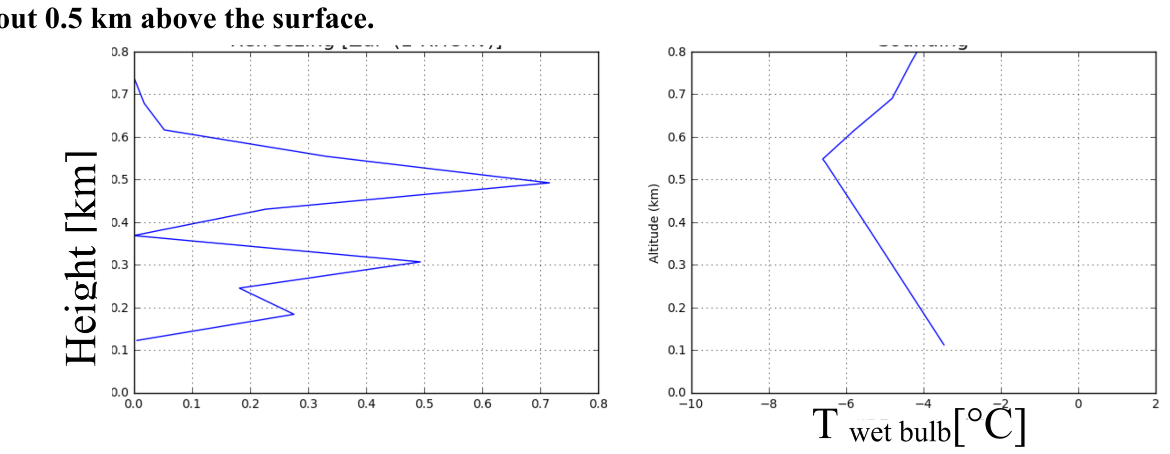


Fig. 5. Refreezing signature (left) from the Berlin QVP at 23:55UTC using the RL equation. The Maximum reaches about 0.7 (maximum of 1) at about 0.5 km. The TW temperature from the berlin radiosonde at 24:00UTC is shown (right) with the minimum temperature, below -6°C, corresponding to the maximum from RL.

Temperature nudging and surface hydrometer classification

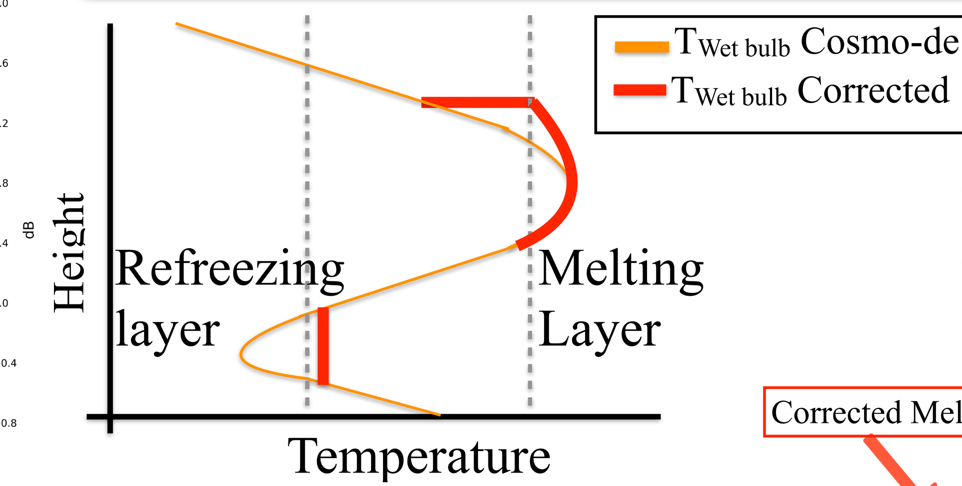
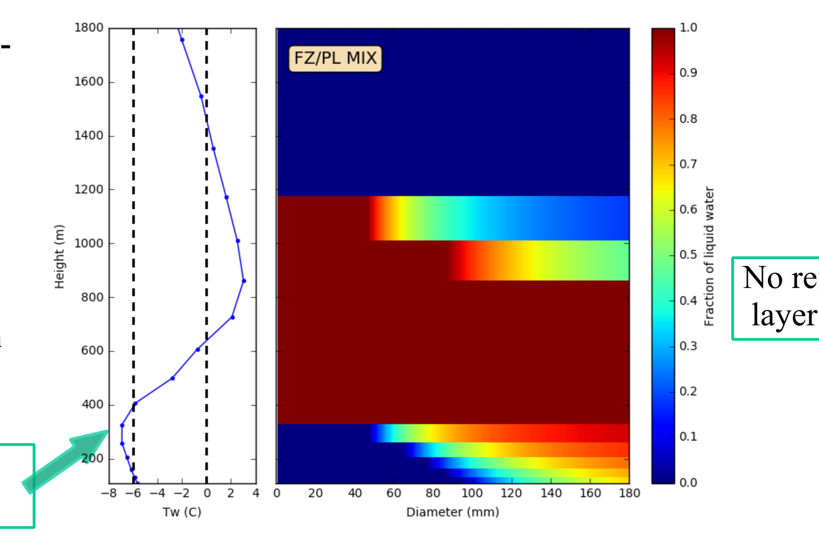


Fig. 6. Wet bulb temperature (TW) from Cosmo-de, and proposed correction using radar derived melting and refreezing layer.

Refreezing layer



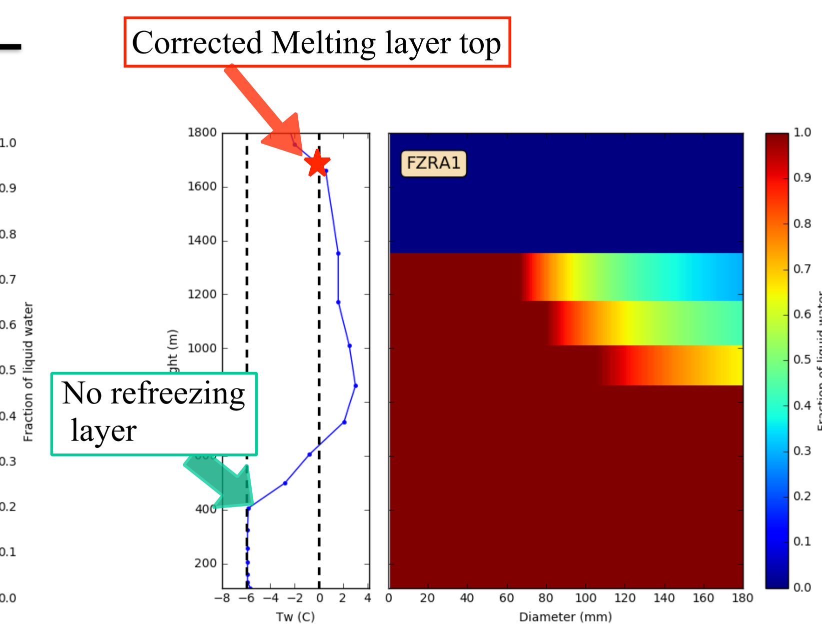


Fig. 7. Vertical profile of wet bulb temperature (left) and fraction of liquid water (right) from the SBC model at 06:00 with data from COSMO-de. The vertical lines in the T profile indicate 0°C and -6°C. Freezing rain/ice pellet mixture is predicted at the surface.

Fig. 8. Same as Fig 7, but with corrected MLT and the removal of the refreezing layer . Only Freezing rain detected predicted at the surface.

Conclusions

➢First analyses show improved surface classification results with SBC when utilizing radar derived melting and refreezing signatures.

➢Melting layer detection method developed using Quasi-vertical profiles offers alternative method to detect MLT and MLB.

➢Autonomous detection of refreezing layers is possible utilizing QVPs.

➢Sectoral QVPs allow some information on the spatial location of the ML and RL.

➢QVP melting layer detection can be used as a additional source for model data temperature corrections in regards to MLT and the presence of a RL.

➢Corrected profiles essential in distinguishing between various winter hydrometeor classes, in particular freezing rain and ice pellets.

References

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