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Estimation of Melting Layer Altitudes from Dual-Polarization Weather Radar Observations

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Introduction

Radar data algorithms, such as the estimates of surface rainfall intensity and hydrometer classification, require information about the melting layer height (MLHGT). Often MLHGT is considered constant while it is it well known that MLHGT varies in time and space.

Weather radar has the sufficient resolution to observe these variations, and the melting layer is clearly observed by the dual-polarization weather radar. Here, we present a radar based method of melting layer height estimation which is capable to map these variations, for improved performances of near-real-time applications .

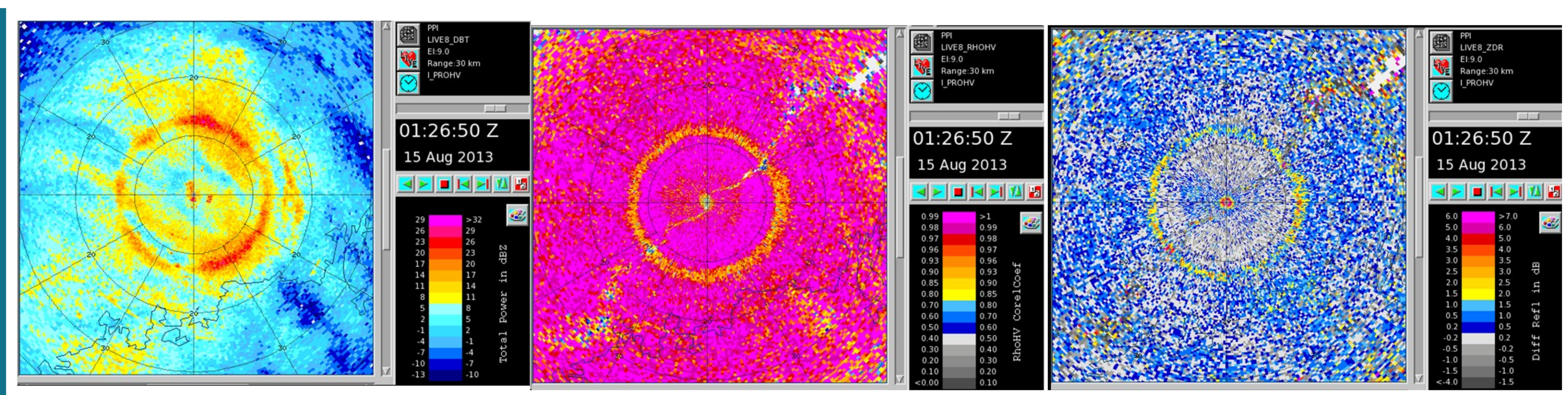


Figure 1: Characteristics of melting layer: bright band in reflectivity Z (left), reduced values in the magnitude of the co-polar correlation coefficient $|\rho_{hv}|$ (middle) and high values in differential reflectivity Z_{dr} (right) in comparison to light rain and frozen hydrometeors. The data are from a PPI scan at the elevation of 9^o, acquired by the C-band dual-polarization Doppler weather radar WRM200 at Kerava, Finland.

Bayesian inference of MLHGT from fuzzy classifications of melting snow and of not melting snow

Implementation in IRIS™/RVP900™ software

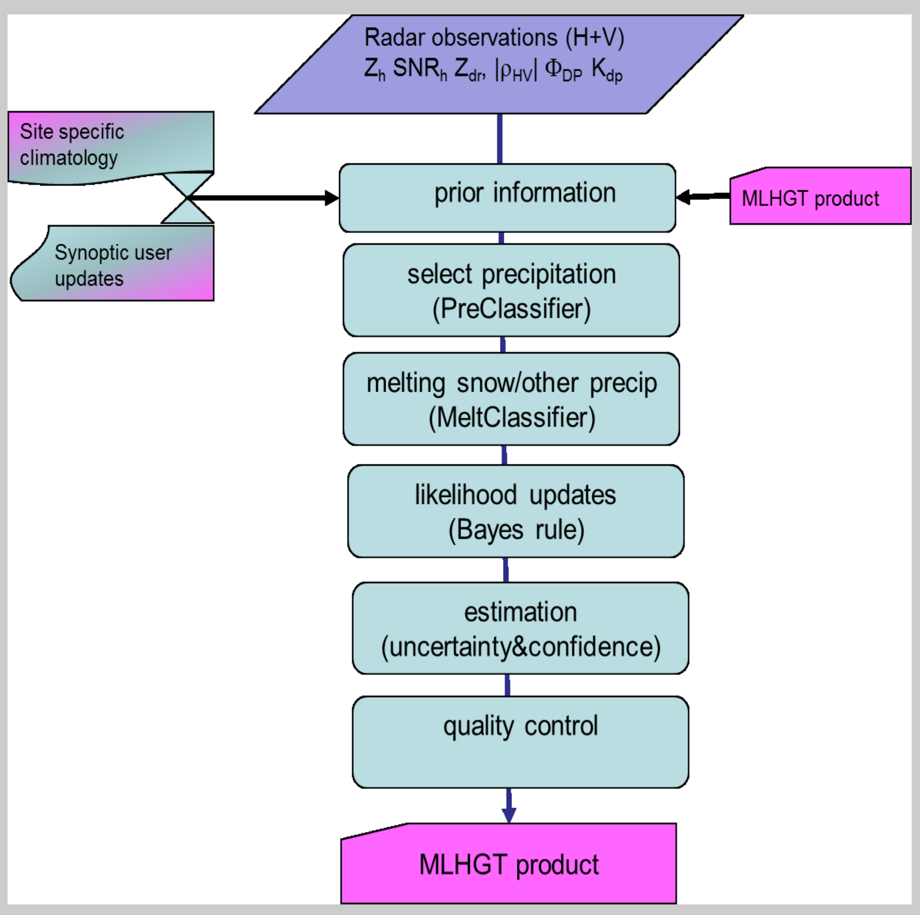
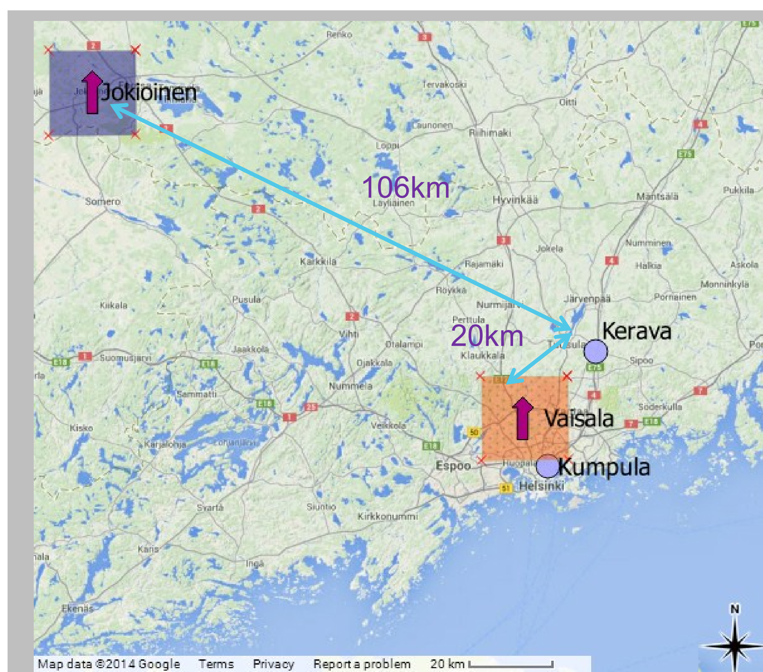


Figure 2: The flow diagram of the MLHGT procedure.

Configurable parameters of the MLHGT method:

- ***Maximum variability*** characterizes the local climatology.
- ***Correlation time*** transforms the confidences of the radar based estimates from the past to the current time.
- ***Melting layer thickness*** is a constant in local climatology.
- ***Number of azimuth sectors*** is the scale of adaptive resolution.
- ***Vertical binning*** is a technical grid parameter.
- ***Minimum radar confidence*** is a threshold for quality control.
- ***Minimum size of radar based cluster*** is a quality threshold.

Validation of the MLHGT estimates with respect to 0^oC isotherms from upper air soundings



WRM200 task settings:

- PPI scan in H+V, 2 min
- 7 elevations (0.5°, 1.5°, 2.5° 4.5°,7°, 10.5°,15°)
- Max range: 250km
- pulse width: 2 µs
- PRF 580Hz
- GMAP filtered moments

Figure 3: Sites and measurement areas of validation. Light purple circles: WRM200 radar at Kerava and WRK200 radar at Kumpula campus of University of Helsinki. Purple arrows: the sounding sites at Vaisala and the WMO site of Jokioinen.

Winter case

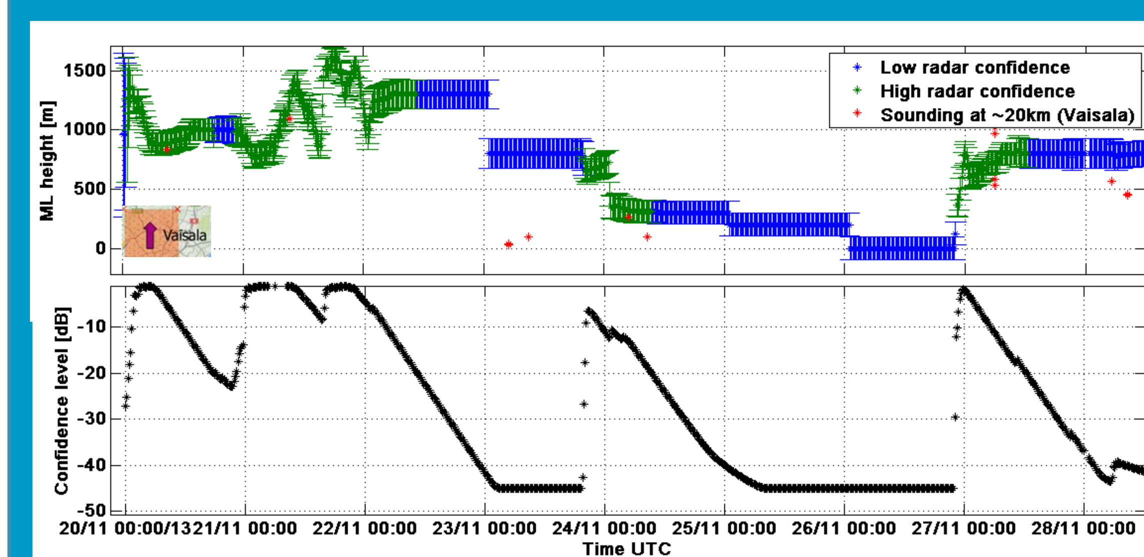


Figure 4. Top: time series of MLHGT estimates with associated one-sigma certainties in cool season from the 20th to the 28th, November 2013. The green/blue symbols indicate high/low radar confidences. The red symbols are the 0°C isotherms retrieved from temperature profiles from soundings at Vaisala. Bottom: the levels of radar confidence in the estimation.

Summer case

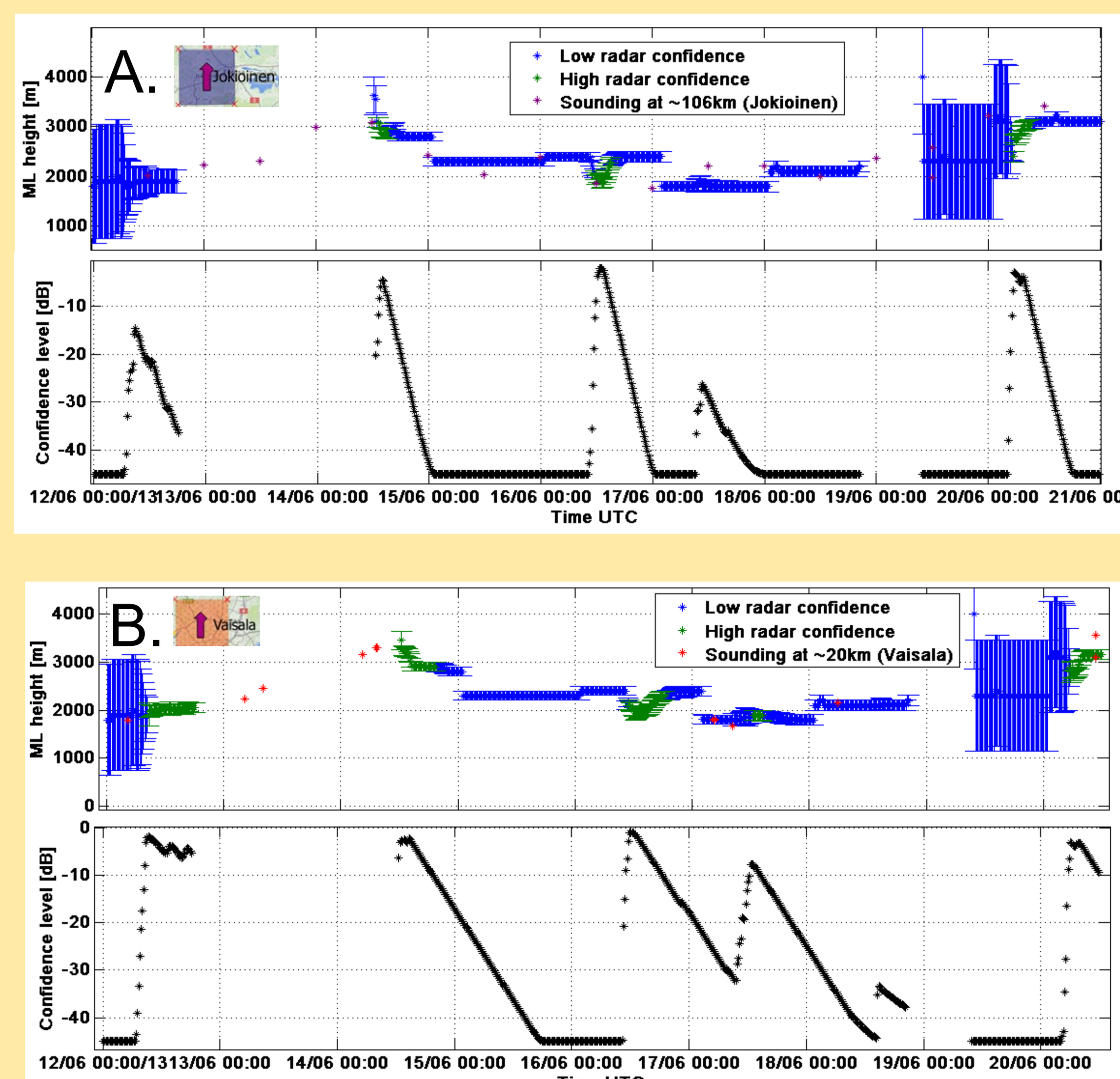


Figure 5: Time series of MLHGT estimates with associated one-sigma certainties in warm season from 12th to 20th, June 2013. The green/blue symbols indicate high/low radar confidences. Red symbols are the 0°C isotherms retrieved from the temperature profiles of upper air soundings carried in Jokioinen (A.) and at Vaisala (B.). Bottom: the levels of radar confidence in the estimation. The radar was not in operation in the interval starting from the evening June 12th and in the short interval in the evening June 19th.

Data examples

We consider evolution of a frontal system in warm season.
The radar site specific 0°C isotherms are updated daily at 01:00 UTC from the regional synoptic soundings in Jokioinen and Tallinn.

- *Maximum variability:* 4000 m centered on the site specific 0°C isotherm
- *Correlation time:* 3 hours
- *Melting layer thickness:* 500 m
- *Base spatial resolution:* 24 azimuthal sectors
- *Vertical binning:* 300 m
- *Minimum confidence:* -20 dB, in demonstration, lower estimates removed
- *Minimum cluster size:* 1

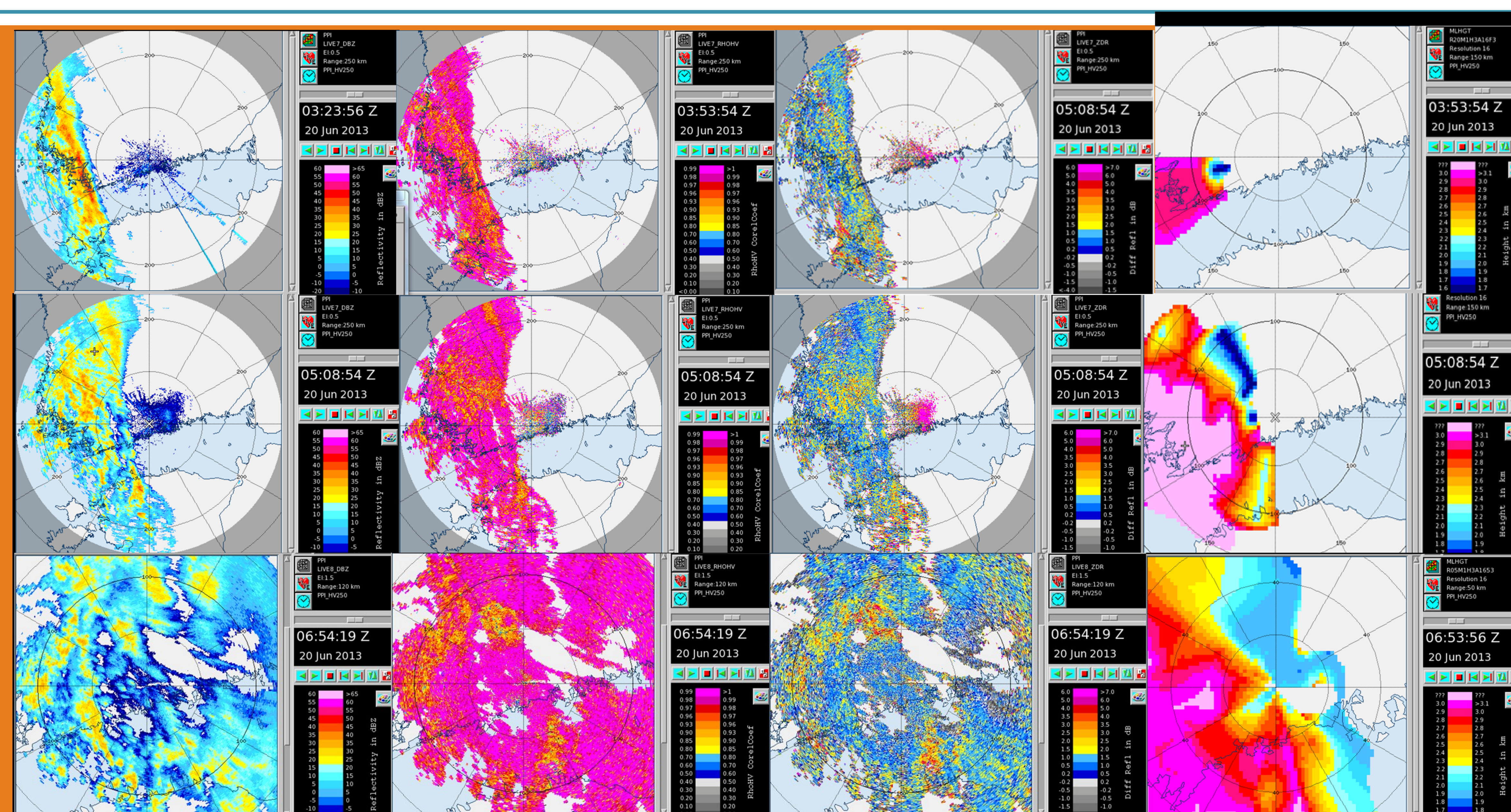


Figure 6: Frontal system of precipitation approaching from the south-west, observed by the Kerava WRM200 radar. Top: the moment when the estimates indicate first significant variability in MLHGT. Center: two hours later. Bottom: four hours later. The first column on the left is reflectivity, followed by $|\rho_{hv}|$ and Z_{dr}. In the right column, the maps of MLHGT estimates are displayed. At 05:08, the MLHGT estimates are well below 2 km towards the north-west at 170km. The echoes are likely from frozen hydrometeors while the observations at the same range towards west are likely rain below the melting layer at 3 km. At 06:54 UTC the data obtained at the elevation of 1.5 degrees display a clear ring pattern of melting layer. However, the ring pattern is tilted indicating a strong local gradient in MLHGT.

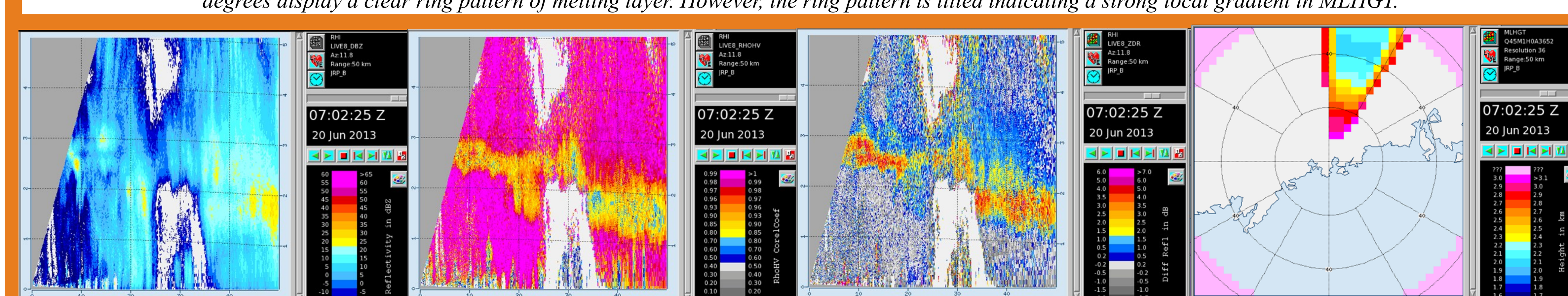


Figure 7: Same event as in Figure 6 but observations from Kumpula radar RHI scan towards the Kerava radar when the band of cold air is passing over the Helsinki region. The bright band is unambiguously seen in the RHI scan. The MLHGT estimates range from 3000 m down to 1900 m and the field indicates a general gradient in excess of 1000 m in about 50 km.

Summary

- We developed and implemented and operational configurable method for estimating melting layer altitudes in near-real-time from dual-polarization Doppler weather radar observations. PPI and RHI scans are supported.
- The method accumulates locations of precipitation recognized as melting or not melting snow in a grid of likelihoods updated for each observation in a Bayesian approach. The altitudes of the melting layer can be estimated at a high spatial and temporal resolution.
- The estimates of melting layer altitude are reported as a map in Earth coordinates in a Cartesian MLHGT product in the *IRIS*™ radar data format. The method can be scheduled to run at the radar computer, or it can be scheduled to process observations from radar networks routed to the central processing analysis facility, in near-real-time. The MLHGT results are uploaded to the *RVP900*™ signal processor and they are used as inputs and constraints to hydrometeor identification as well as in the dual-polarization corrections for rain induced attenuation.
- The MLHGT method has been evaluated in conditions of warm and cool season, with direct validation with respect to independent upper air soundings. The MLHGT estimates, the estimates of their uncertainty and of radar confidence are found to perform consistently. The remote MLHGT estimates and the 0°C isotherms derived from in-situ temperature profiles are found to agree at the level of 100 m.

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