# Removal of artificial echoes and coordinate transformation of aircraft radar measurements in the Arctic


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## Introduction

The **Mi**crowave **R**adar/radiometer for **A**rctic **C**louds (**MiRAC**) has been flown on the **Polar 5** aircraft during the **ACLOUD** campaign to characterize Arctic clouds in May and June 2017.

To the best of our knowledge it is the first time that a **F**requency-**M**odulated **C**ontinuous **W**ave (**FMCW**) radar is used for down-looking cloud observations. The inclination is 25° with respect to nadir.

***Fig. 1:*** *MiRAC mounted in the belly pod between the wings below Polar 5. During flight Mirac's inclination is 25° with respect to nadir view.*

## MiRAC

**MiRAC performs active (radar reflectivity Z, Doppler velocity $v_D$) and passive (brightness temperature $T_B$) measurements:**

- The **Z**-profile is influenced by the strong surface reflection and radar processor artifacts. The artifacts near the surface likely occur due to the special measurement technique (FMCW-Radar), which includes two Fourier transforms (Küchler et al., 2017). The radar calibration was also thoroughly checked.
- The use of $\mathbf{v_D}$ is difficult due to aircraft motion and unknown total wind velocity.
- $\mathbf{T_B}$ will be used to retrieve the **L**iquid **W**ater **P**ath **LWP** and **I**ntegrated **W**ater **V**apor **IWV**.

**FMCW-Radar**: 94 GHz (25°)

**Radiometer**: 89 GHz (25°), 6 x 183, 240, 340 GHz (nadir)

## Removal of artificial echoes

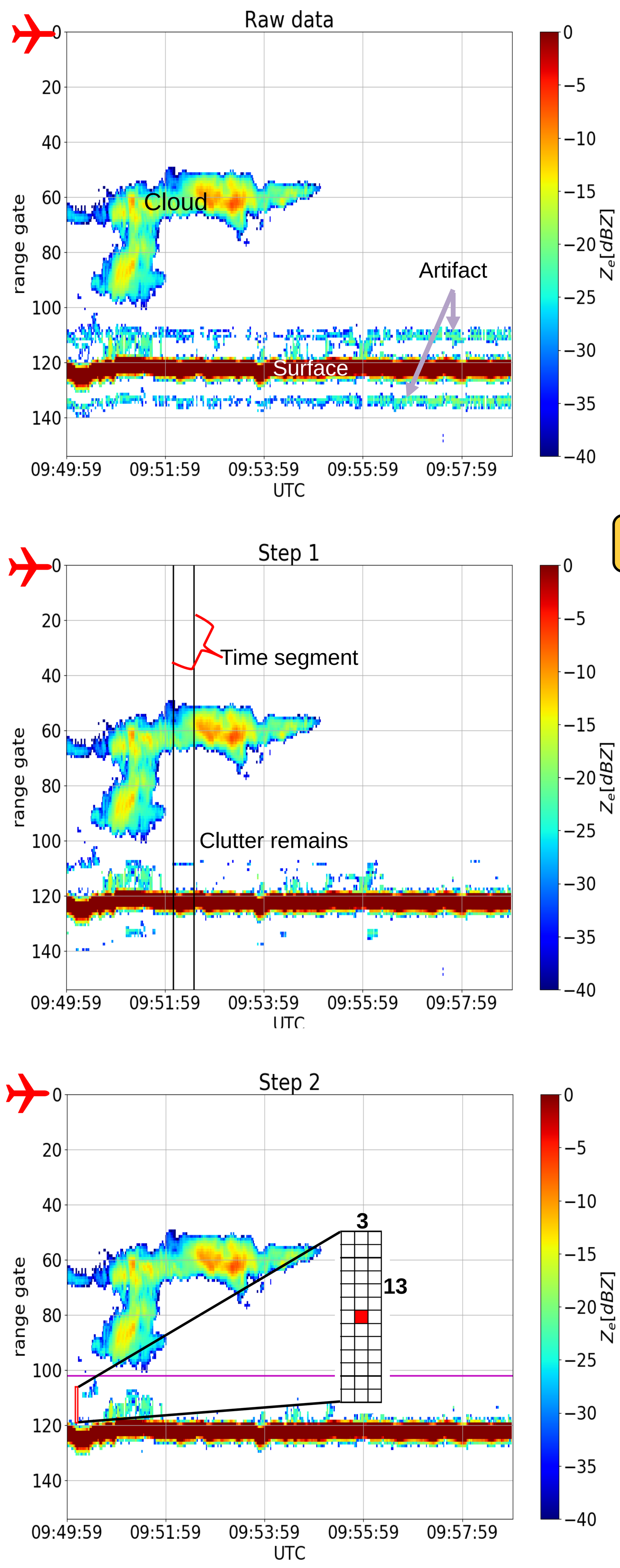
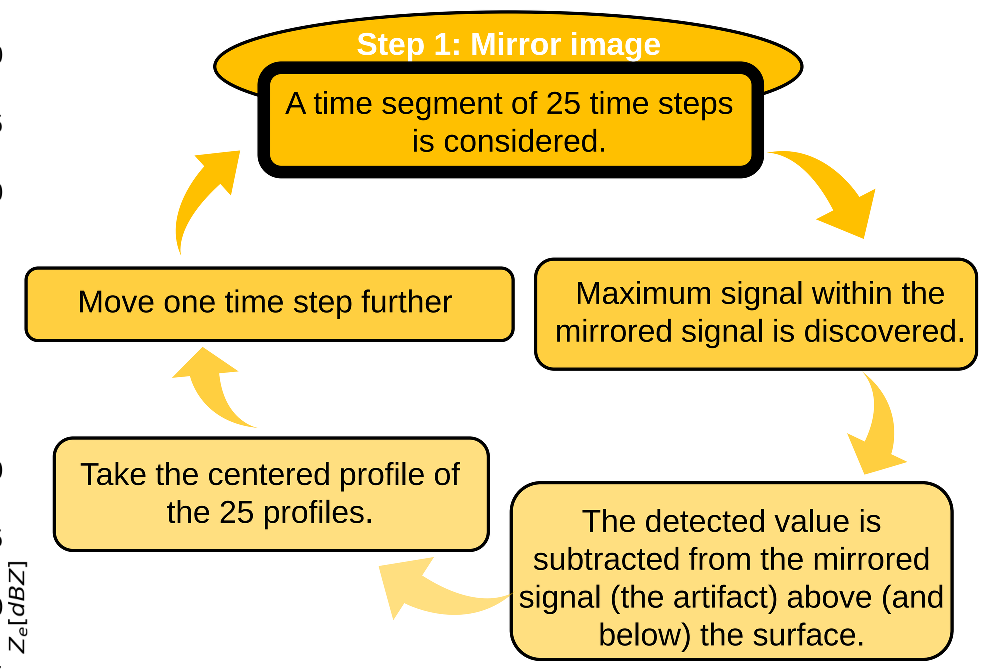



***Fig. 2:*** *Radar reflectivity May 25, 2017, flight 5, Top: raw data, Center: Step 1 mirror image bottom: Step 2 filter below magenta line*

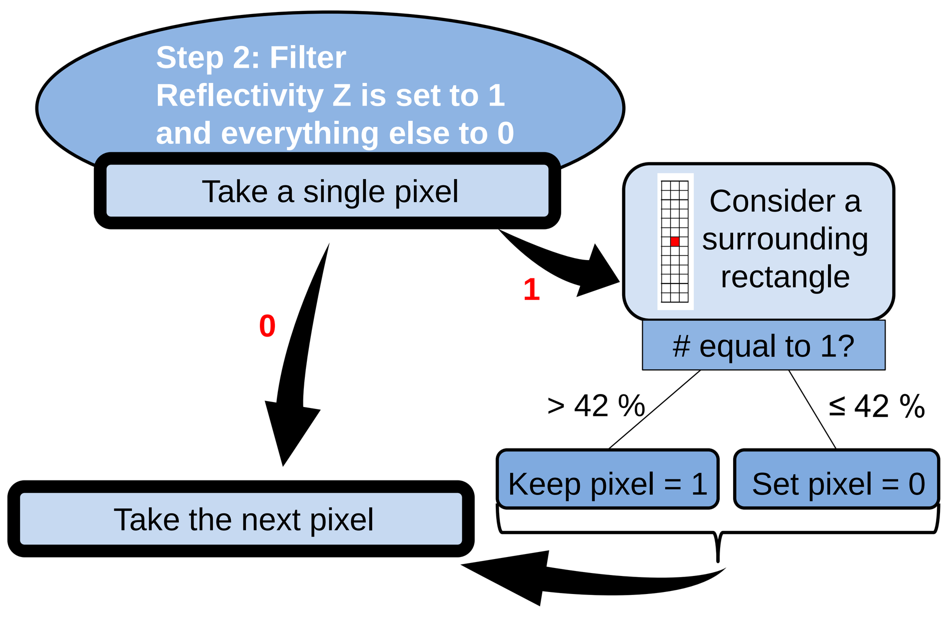
The raw data of Z consist of range gates with a length of 18 to 27 m as a function of distance from the aircraft.

I. Strong Surface echo leaks into range gates further away from the surface:




A threshold is used to exclude reflectivities below the sensitivity level. Another threshold is used to exclude radar processor artifacts (not shown).

II. Speckle filter removes noisy signals:




## Coordinate transformations

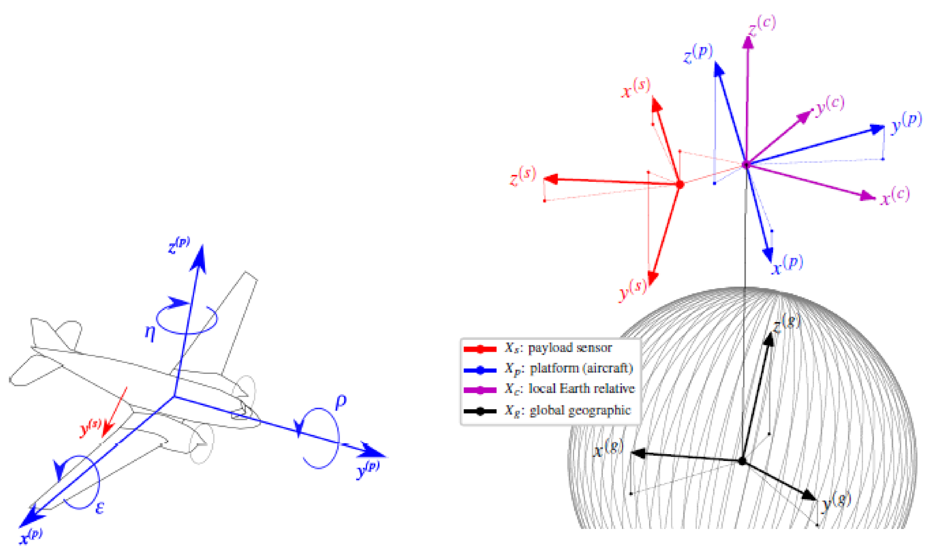


***Fig. 3:*** *Sensor-relative, platform-relative, local Earth relative, global geographic coordinate system*

1. A calibration provides the exact position and attitude of the sensor within the aircraft.
2. The data are transformed from the sensor-relative coordinate system via the platform- and local Earth relative coordinate system to the global geographic coordinate system.
3. The data are mapped onto a constant vertical grid.

## Resulting profiles and Ny-Ålesund overflight

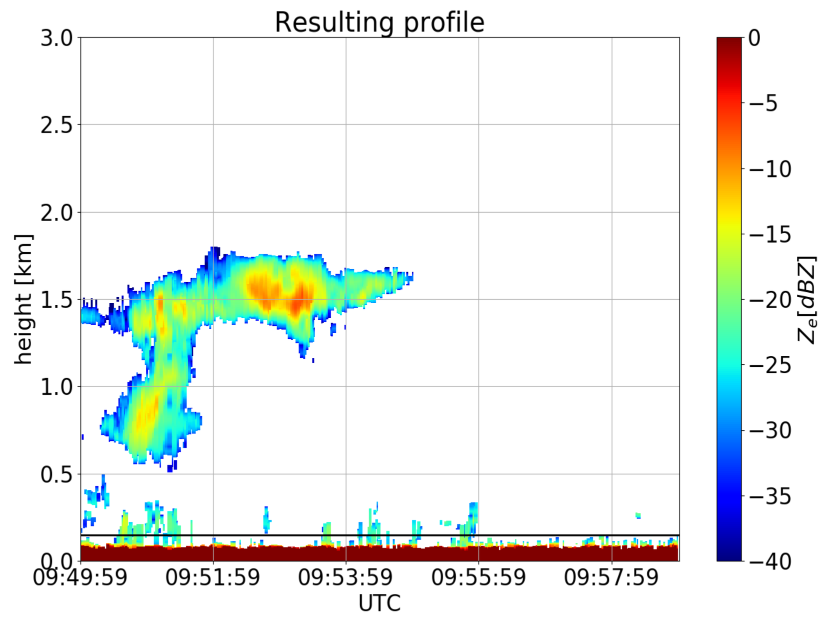



***Fig. 4:*** *Radar reflectivity May 25, 2017, corrected and transformed coordinates: Step 1 & 2, coordinate transformation and remapping,* ***black line:*** *150 m*

**Surface influence:**
For cloud analyses a height above 150 m is recommended. Everything below 150 m is considered to be strongly influenced by the surface. This will be indicated by a flag.

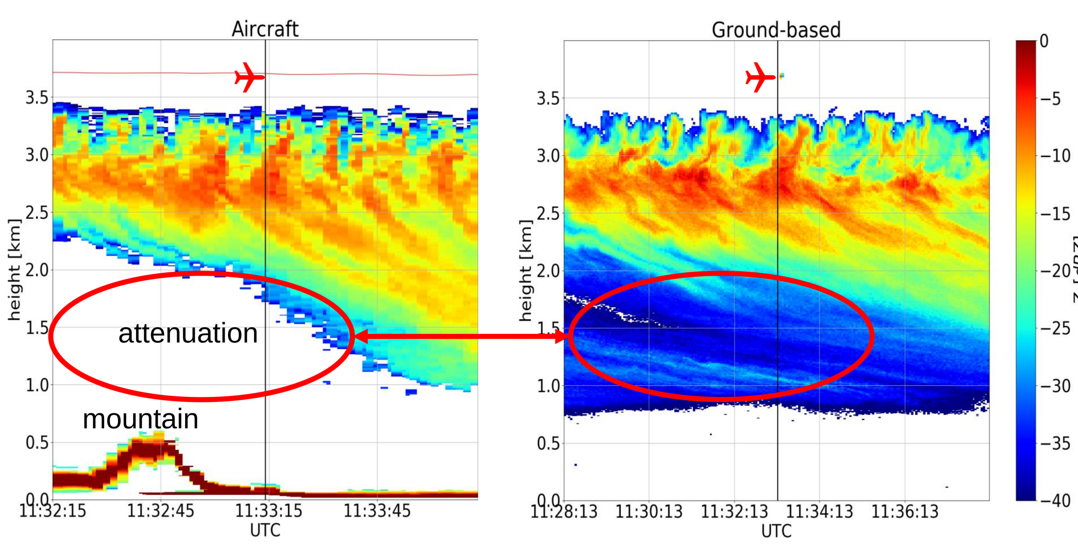



***Fig. 5:*** *Flight over Ny-Ålesund (left), Ground-based JOYRAD-94 (right).* ***Black line*** *indicates overflight. Flight 22, 2017/06/23*

**Comparison MiRAC and JOYRAD-94:**
Measurements can differ strongly due to

1. The different perspective from above or below the cloud (attenuation).
2. The perspective of MiRAC inclined by 25°.
3. The surrounding wind conditions.

## Outlook

- In total measurements of 77.5 h are available. About 40.5 h (~ 52 %) are straight and horizontally oriented.
- The next step is to analyze the changes due to the correction process and to include quality flags to assign uncertainty levels of the measurements.
- The surface reflectivity will also be used to distinguish between land, ice and ocean.

**Following milestones:**

1. Upload corrected radar reflectivity into the database PANGAEA.
2. Develop LWP rerieval algorithm from $T_B$.
3. Derive cloud and precipitation properties.


***Reference:***
*N. Kuechler, S. Kneifel, U. Loehnert, P. Kollias, H. Czekala, and T. Rose. A W-Band Radar/Radiometer System for Accurate and Continuous Monitoring of Clouds and Precipitation. Journal of Atmospheric and Oceanic Technology, 34:23752392, 2017. doi:10.1175/JTECH-D-17-0019.1.*