Using a Radiosonde Trajectory Method to Calibrate the RAman Lidar for Meteorological Observations (RALMO) and determining Calibration Uncertainties

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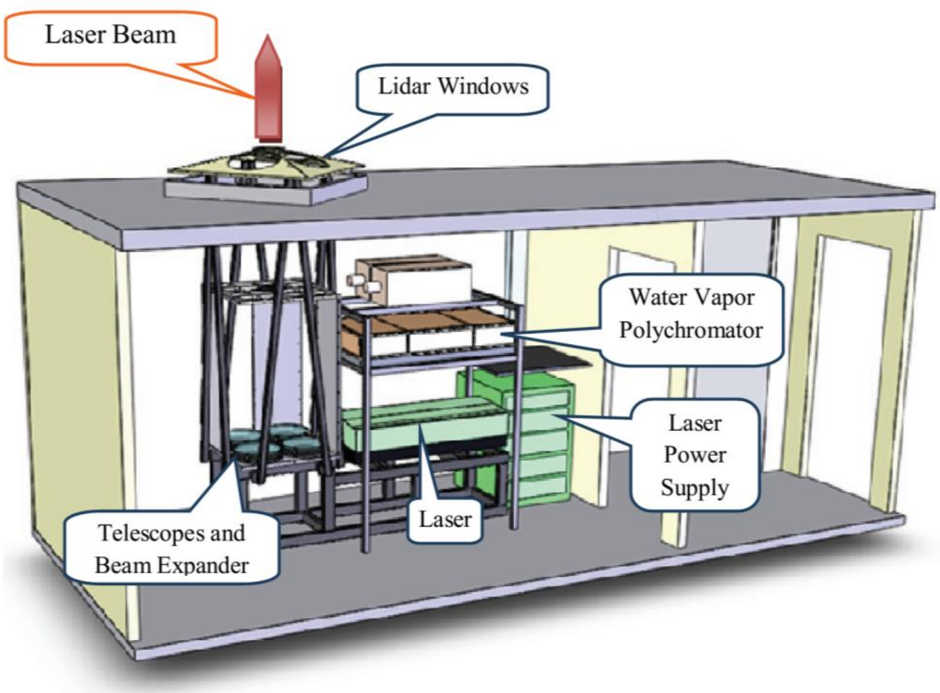
Water Vapour Trend Analysis

- Unique lidar with a huge set of water vapour data
- RALMO has 50% uptime from 2008 – 2018
- Process RALMO WV data using OEM (Sica and Haefele 2016) and validate with traditional method.
- Create a WV climatology with continuous data set.



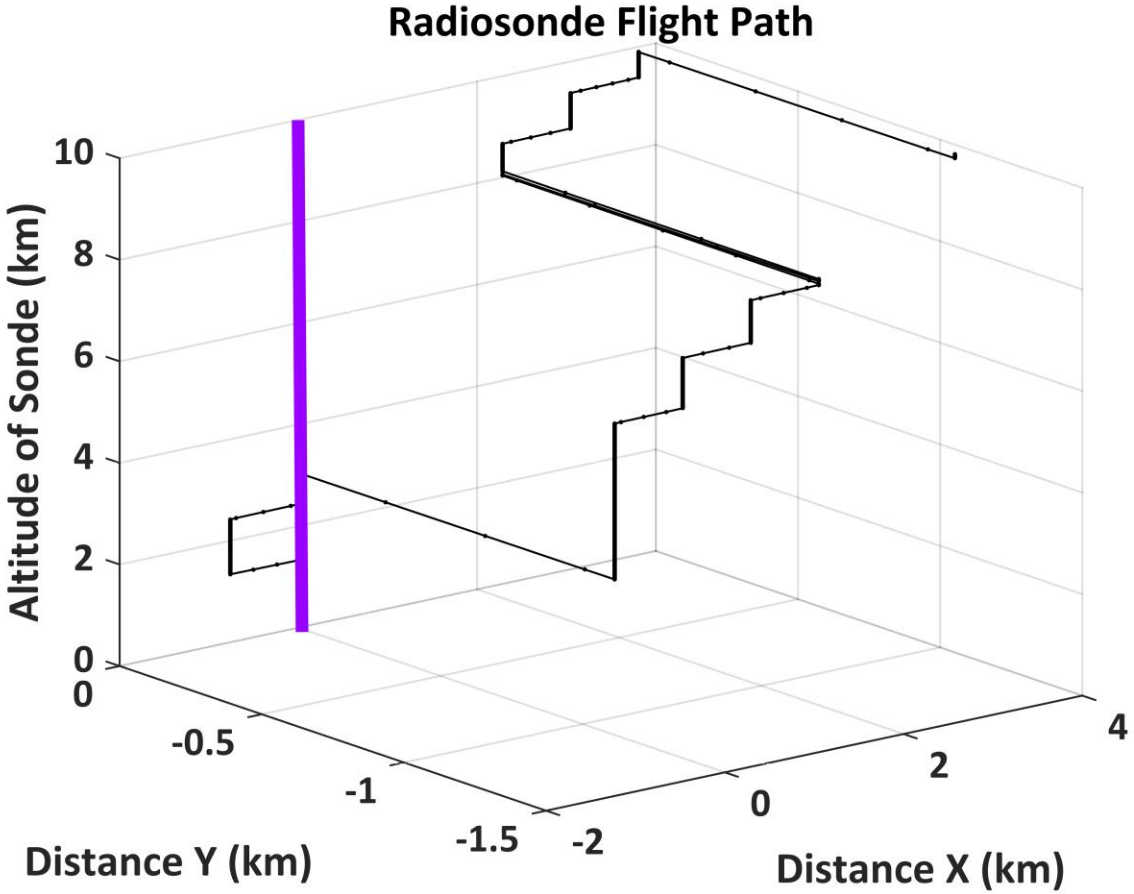
Figures provided by MeteoSwiss

Calibrating with GRUAN RS92 Vaisala Radiosondes

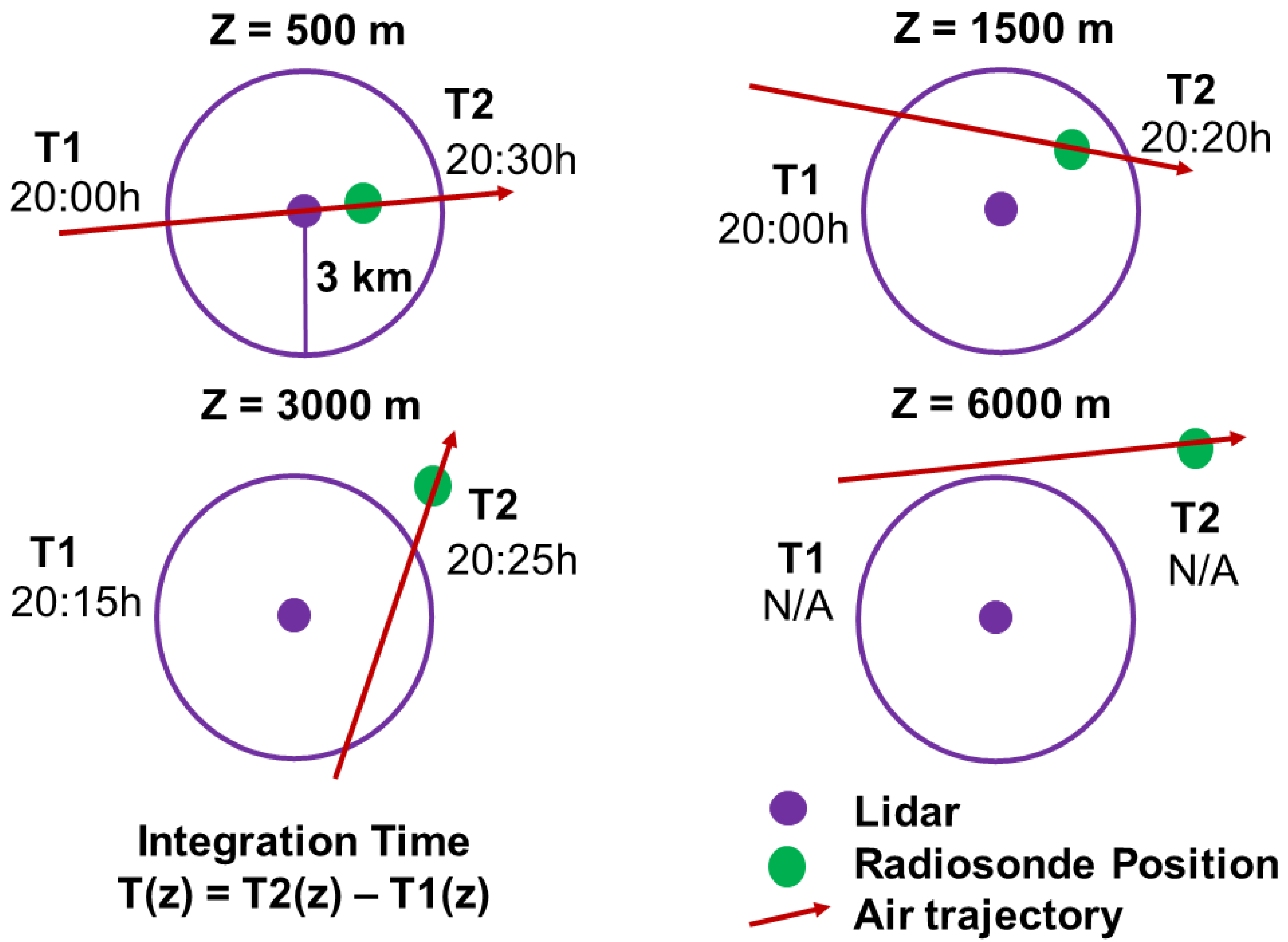
- GRUAN compatible RS92 radiosondes
  - GRUAN radiosondes are well-characterized and corrected
  - Uncertainties are reported as a function of altitude – Vaisala does not
- ~30 nighttime flights
- 2 methods:
  - Traditional : uses a standard 30 minute summation
  - Trajectory : Account for the radiosonde movement with air trajectories
  - Both methods use correlation b/w radiosonde and lidar to determine calibration ranges

The Trajectory Calibration Technique

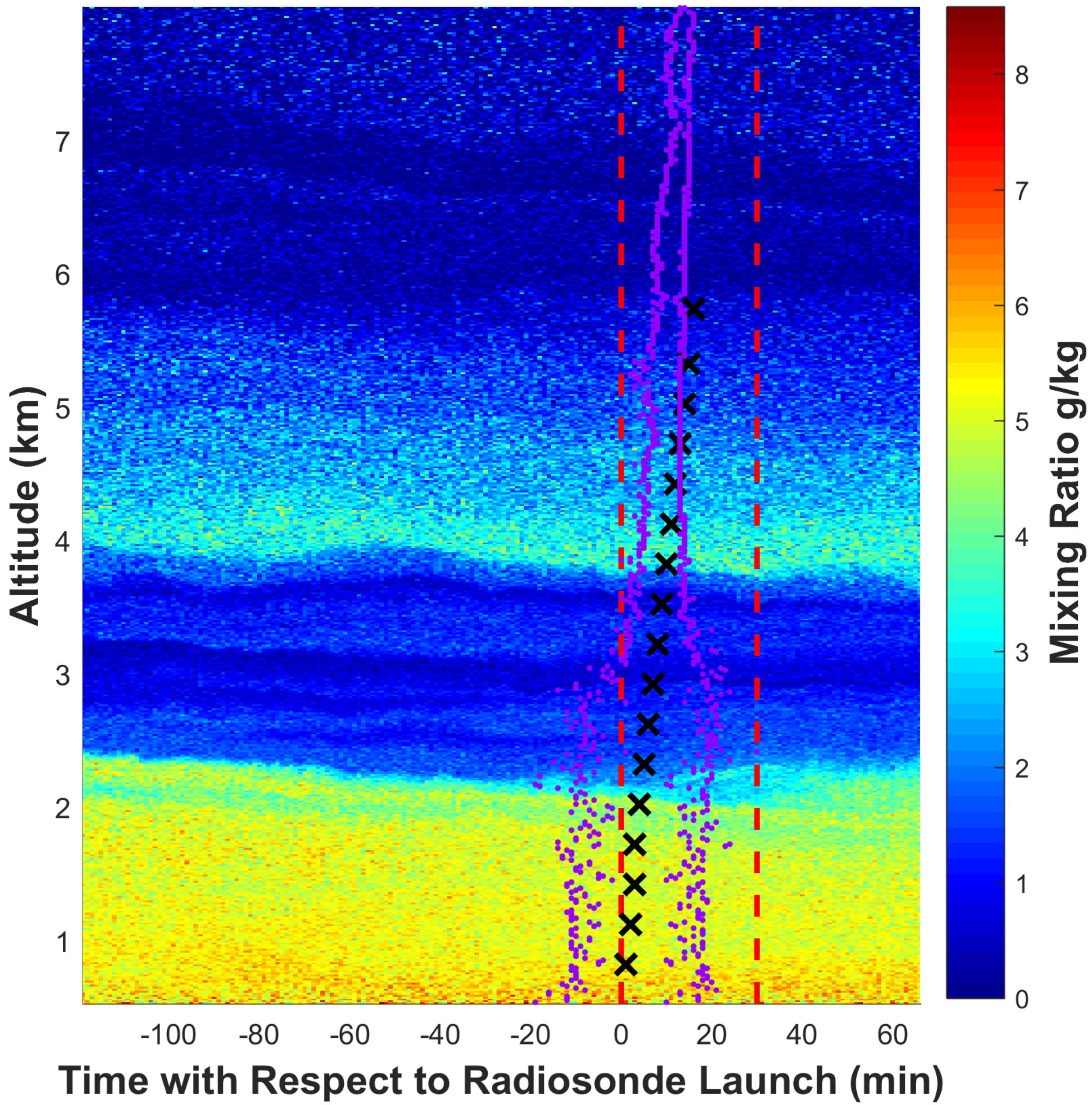
- New method will consider the radiosonde position, wind speed, and wind direction for every altitude.
- Builds on the techniques introduced in Whiteman et al. 2006, 2012 ; Dionisi et al. 2010; Leblanc et al. 2012



The Trajectory Calibration Technique

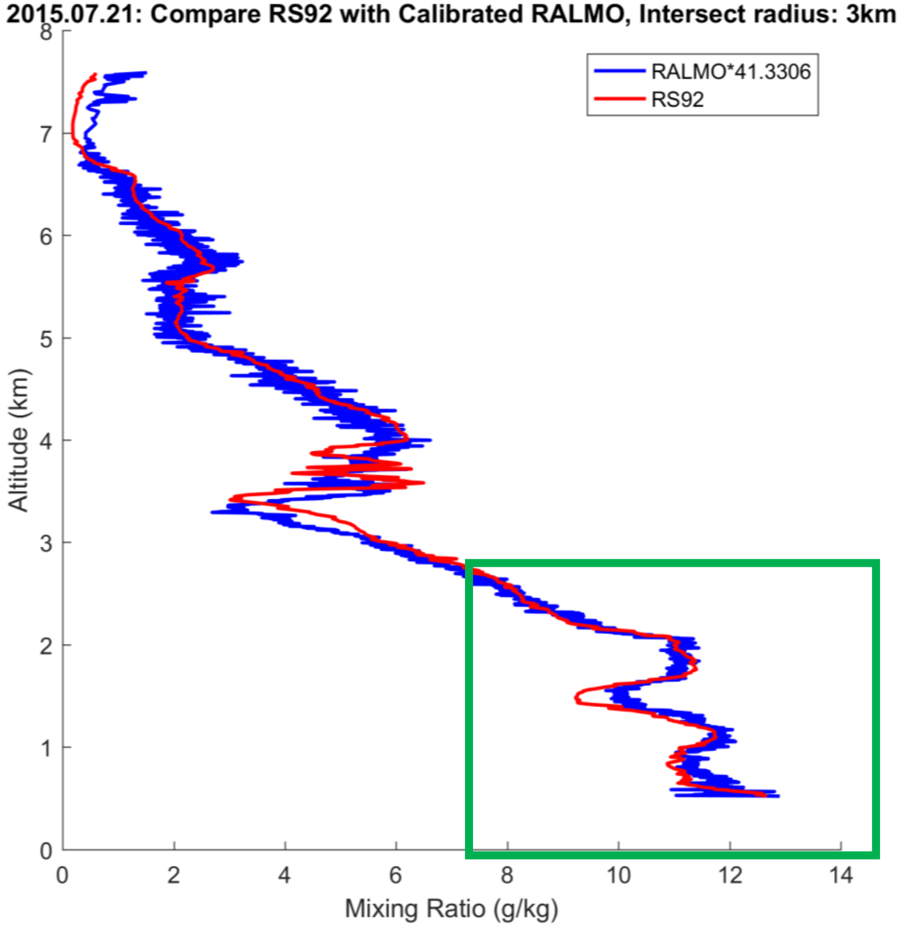


The Trajectory Calibration Method

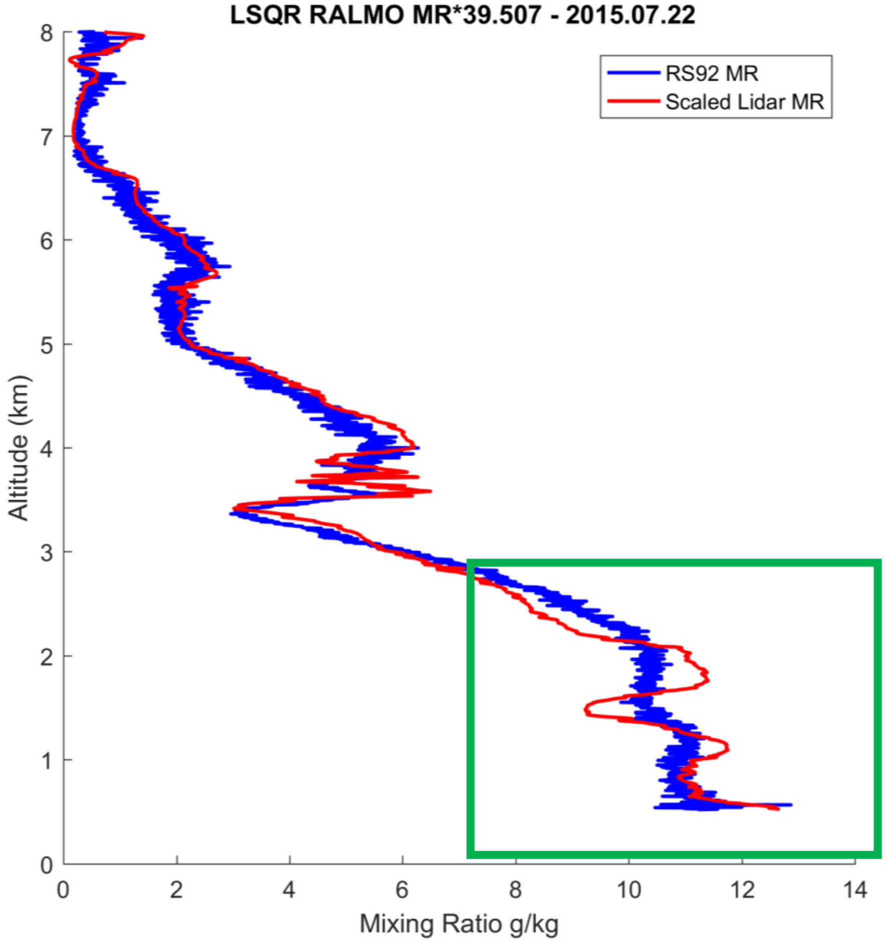


Trajectory vs Traditional

Trajectory



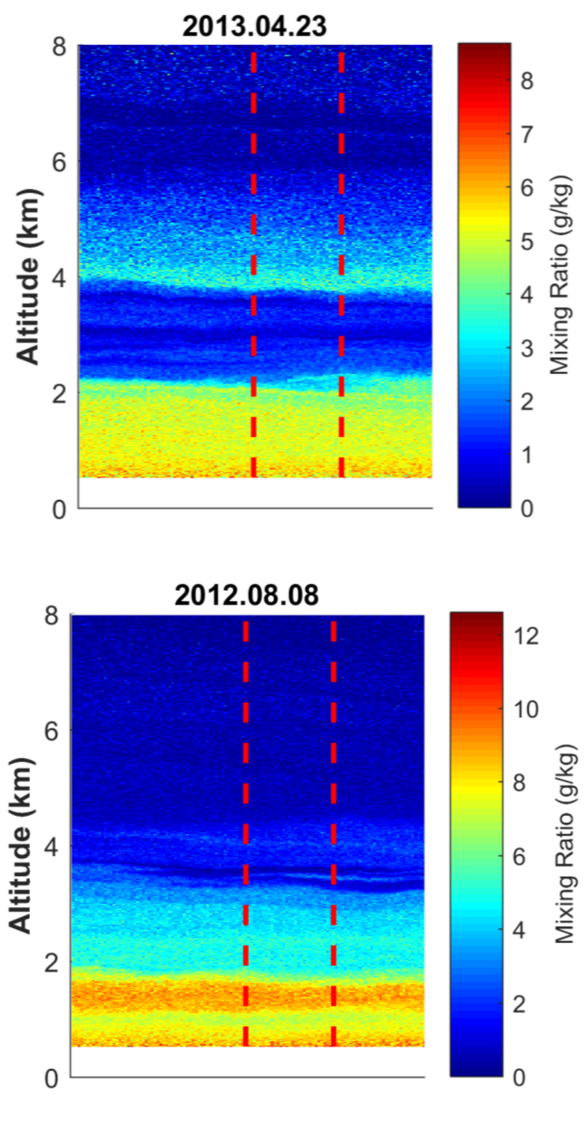
Traditional



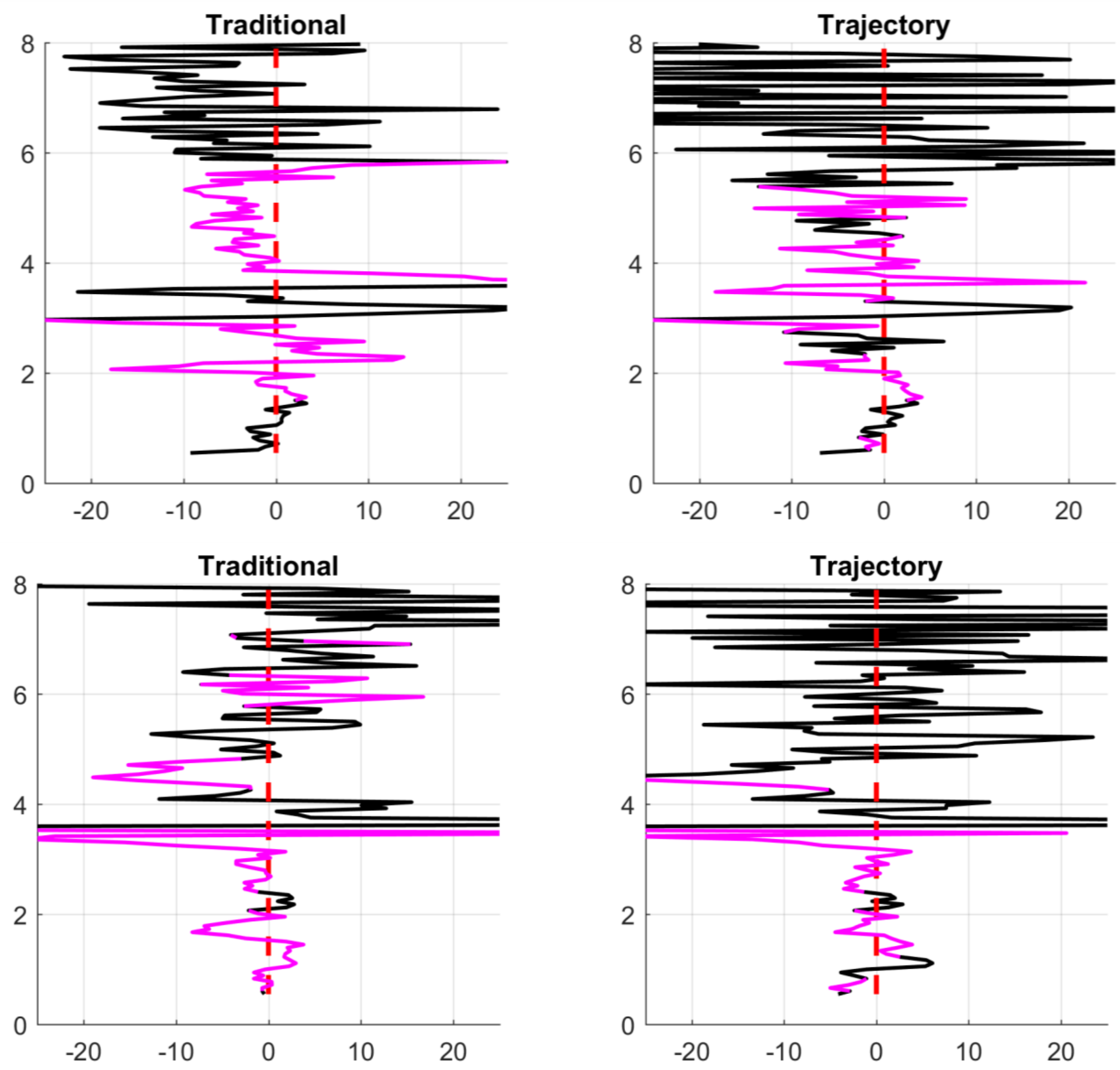
Difference between Calibration Factors is 5%
Uncertainty in the fit is on the order of 0.1%

Comparison – Homogeneous Case

Water Vapour Time Contour



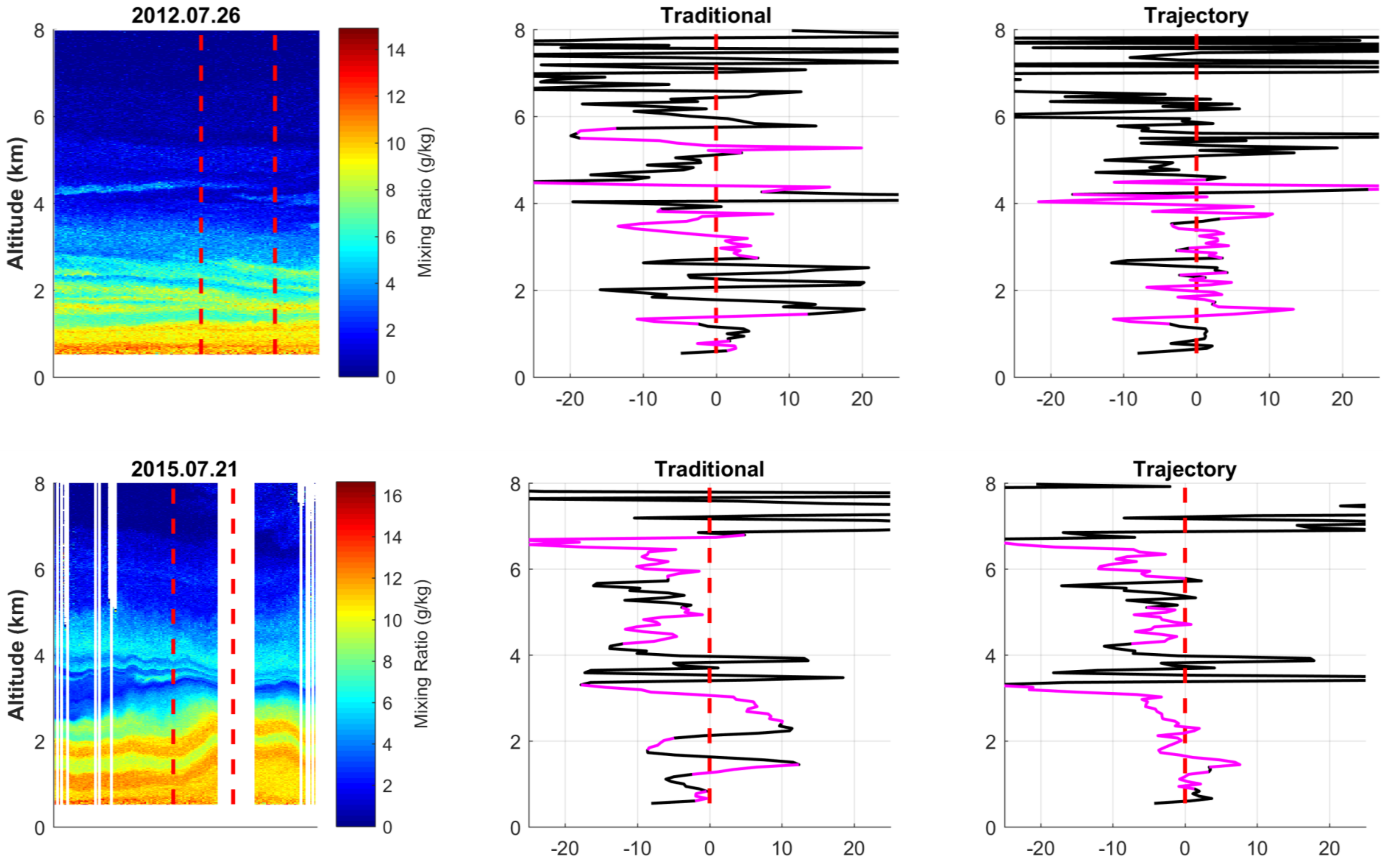
Percent Difference from Radiosonde



Comparison – Heterogeneous Case

Water Vapour Time Contour

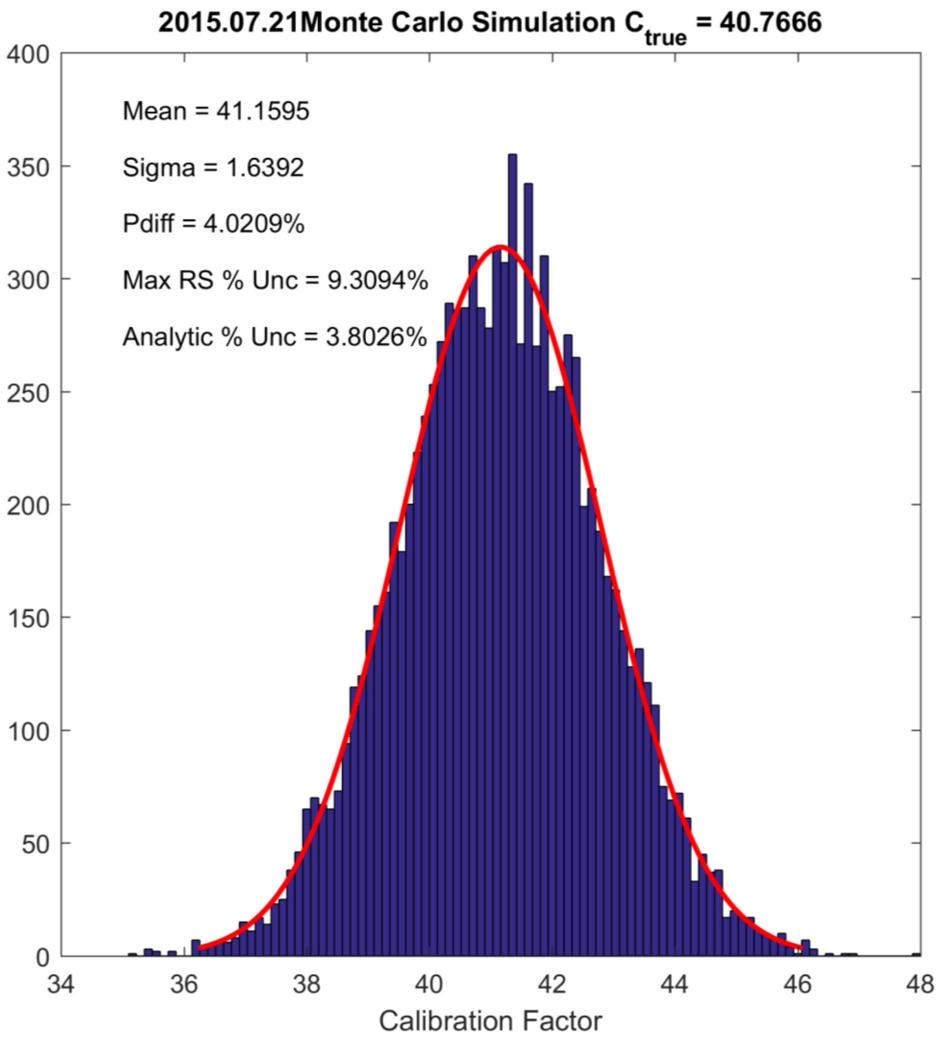
Percent Difference from Radiosonde



The Radiosonde Uncertainty Contribution

Leblanc et al 2016, Equation 2

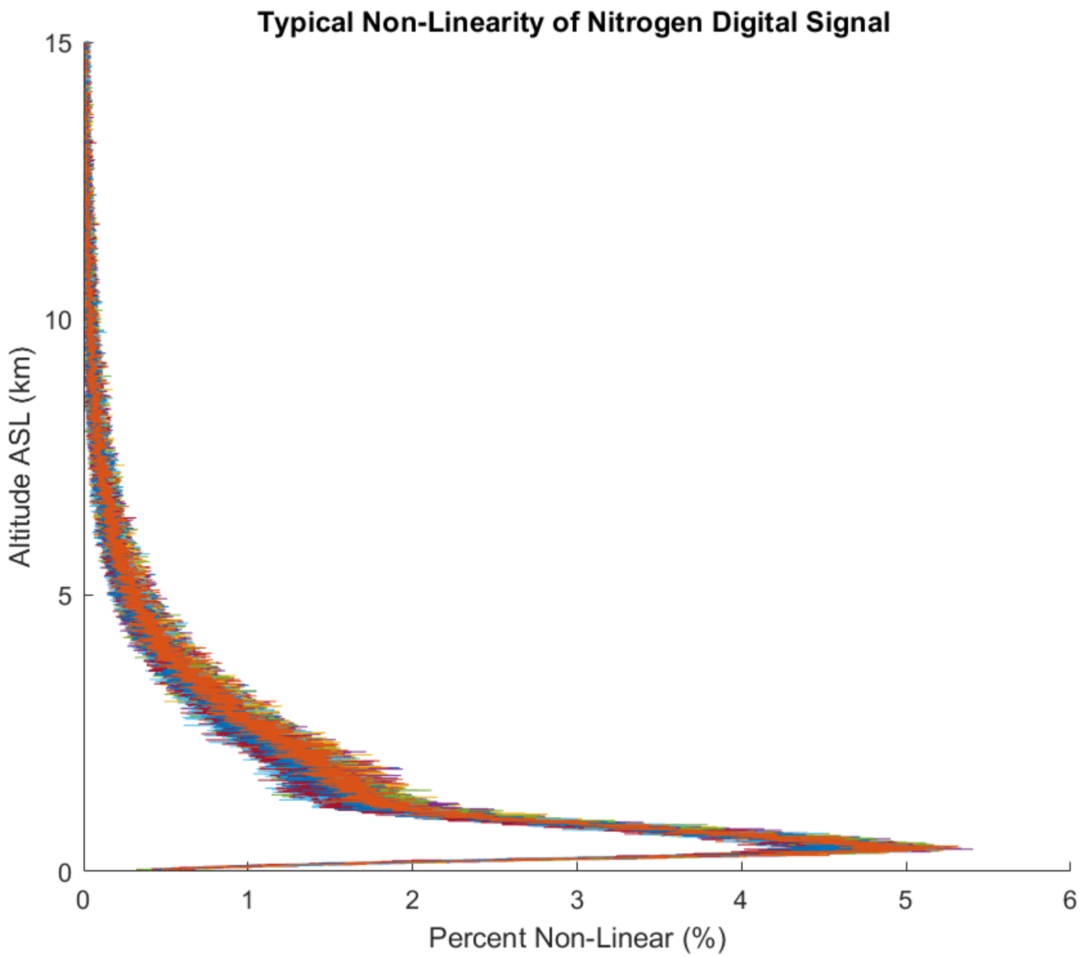
- GRUAN reports dRH(z), dP(z), dT(z) which can be propagated to Mixing Ratio Uncertainty
- Calculate uncertainty in calibration due to uncertainty in the radiosonde measurements
- Used uncertainty calculation in Leblanc NDACC papers, which is compared to a Monte Carlo Simulation
- **Average of 4% uncertainty in Calibration due to the radiosonde measurement uncertainty**



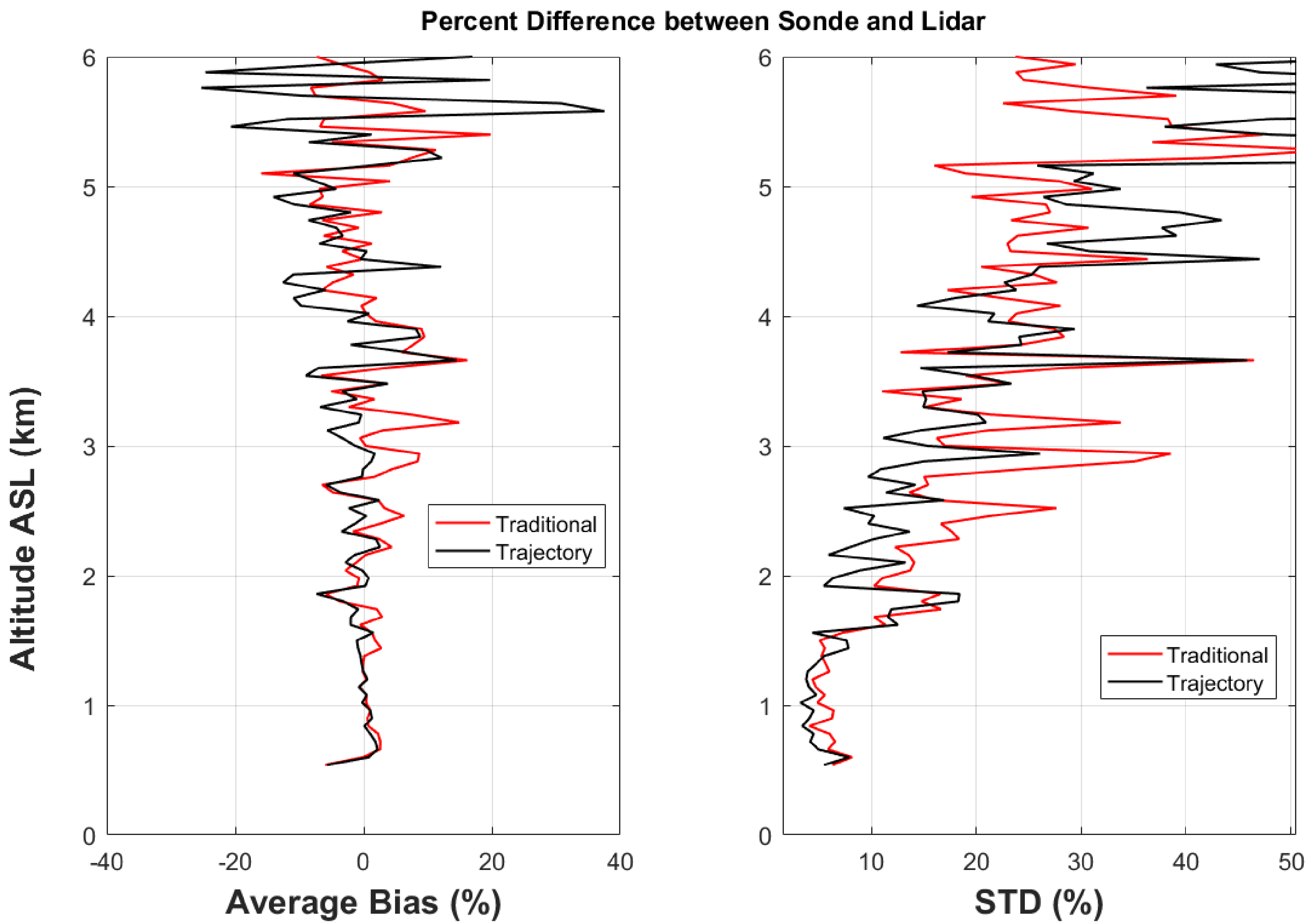
The Deadtime Uncertainty Contribution

Introduces an Average of 1% uncertainty to the Calibration

- Typical nonlinearity of 5%
- Uses the same procedure as the radiosonde calculations
- Influence on the calibration may vary depending on the nonlinearity of the signal.



Average Percent Difference from Radiosonde



Summary

- Devised a new trajectory calibration technique that considers the displacement of the radiosonde with respect to the lidar.
- The trajectory method provides the smallest fitting errors as well as the most consistent calibration values in an automatic manner.
- Using GRUAN radiosondes allows us to calculate the uncertainty of the calibration constant and quantify the radiosonde uncertainty contribution to the calibration.
- On average Trajectory C is higher by 3 %
- The calibration constant has a 5% accuracy and an RMS of 4% over the entire time series.

- Next Steps:
  - Submit Paper - "Calibrating Water Vapour Lidars with a Radiosonde Trajectory Method"
  - Fill in time series gaps with the operational radiosondes or via a fitting function.
  - Test with the OEM developed by Sica and Haefele, 2016.

Questions?

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Thank You!

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