Accuracy assessment of an integrated profiling technique (IPT) for temperature, humidity and liquid water content profiles

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Motivation: operational profiling by ground-based remote sensing (RS)

- NWP and climate modelers require continuous profile measurements of the atmospheric thermodynamic state for model evaluation and initialization.
- Ground-based remote sensing stations (GRSS) equipped with a **microwave profiler** (MWP), a **cloud radar** and a **lidar-ceilometer** possess the potential of continuously profiling temperature (T), humidity (q) and liquid water content (LWC).
- The IPT combines such measurements together with *a priori information* within an optimal estimation based retrieval scheme.

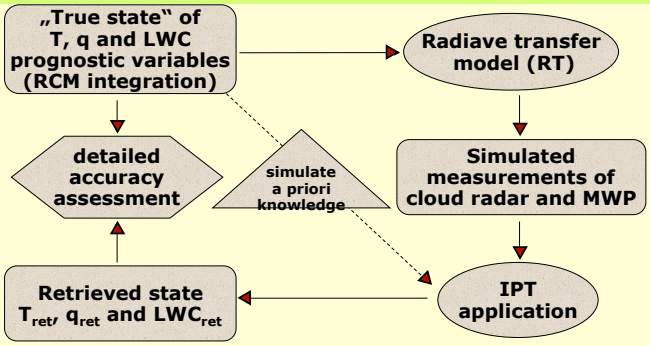
State-of-the-art microwave profiler HATPRO

Motivating questions:

- How accurate are GRSS T & q profiles w.r.t. radiosondes? How accurate are LWC profiles?
- How important is the a priori knowledge? What type of a priori is needed for optimal retrieval performance?
- Can operationally implemented GRSS complement the existing radiosonde network?
- Can GRSS replace the role of radiosondes (e.g. in remote areas)?

Suite of cloud radars at the GRSS Cabauw

Assessment test-bed: Regional climate model (RCM) used to simulate "true" state



Advantages of regional climate model test-bed: exact evaluation of all parameters (especially LWC!), no systematic errors due to microwave absorption & instrument calibration →physically consistent system

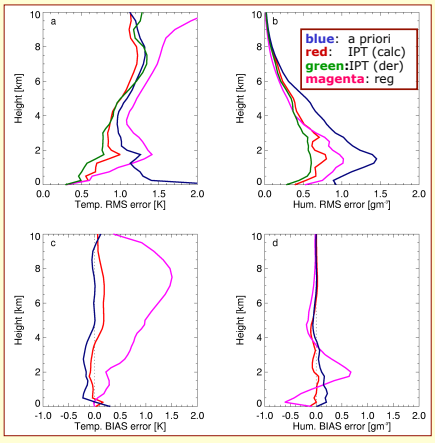
IPT accuracies: the T & q a priori consist of the latest available operational radiosonde, *launched at remote sensing site*

Description

- *IPT (der)* RMS is the theortical error given by the IPT method
- The *reg* algorithm is empirical: based on linear regression

Discussion

- blue minus red RMS lines indicate the information gain through RS, which is observed up to 4km (average: T: ~0.4K, q: ~0.4gm^{-3})
- Similarity of *IPT (calc)* and *IPT (der)* indicate satisfactory retrieval performance
- IPT outperforms *reg*



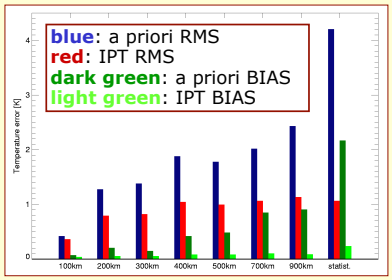
IPT accuracies: the T & q a priori consist of the latest available operational radiosonde, *launched at X km distance of remote sensing site*

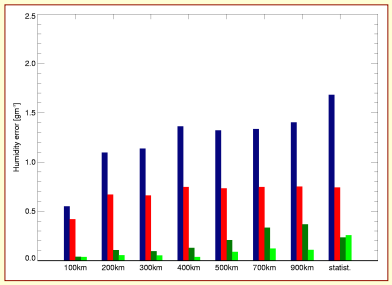
Description

- The shown results are the accuracies averaged over the lowest 4 km of the profile
- The x-axis shows the distance between RS site and radiosonde site
- blue minus red bars indicate the information gain (IG) through RS

Discussion

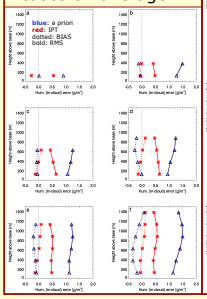
- accuracy is best at small distances, however IG is enhanced at greater distances
- For both T & q, RMS accuracies show „saturation" effect around 400km (1.0K / 0.7gm^{-3}) → as accurate as statistical a priori
- IPT can, to a certain degree, minimize BIAS errors contained in the a priori



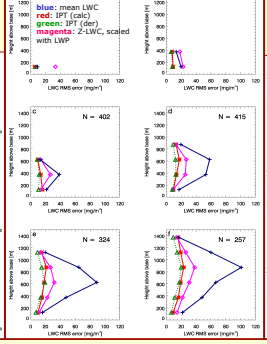


IPT accuracies: the cloudy skies → LWC, in-cloud humidity & in-cloud temperature as a function of height above cloud base

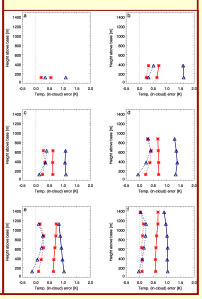
- IPT and a priori RMS & BIAS errors for in-cloud humidity
- IPT RMS behavior very satifactory (~ 0.5gm^{-3} average) due to saturation constraint
- a priori BIAS: cloudy cases contain more moisture than clear cases on average



- LWC: IPT RMS error *(calc)*, theoretical error *(der)* and RMS error of simple Z-LWC relation scaled with μwave-derived LWP; also: mean LWC profile for orientation
- On average, IPT values are 17% more accurate than scaled Z-LWC values



- IPT and a priori RMS & BIAS errors for in-cloud temperature
- IPT RMS behavior very similar (~ 0.7K on average) as in the clear & cloudy cases
- Reasons for positive BIAS (a priori & IPT) have not yet been identified



Conclusions and implications

- GRSS can provide continuous profiles of T & q with accuracies better than 1.1K, respectively 0.7gm^{-3} on average in the lowest 4km.
- The information gain through RS can be as high as 3K and 1gm^{-3}.
- IPT T & q performance can be significantly improved if operational radiosonde profiles launched within a 400km radius of the RS site are used as a priori.
- In-cloud IPT T & q performance is as accurate as outside the cloud.
- Adequately equipped GRSS allow, in contrast to radiosondes, the continuous retrieval of LWC profiles with accuracies of 30% on average.
- Once installed a GRSS can complement an existing radiosonde network by adding extra spatial *and* temporal information.
- In a dense radiosonde network (100-200km), GRSS may be able to replace existing radiosonde launch sites; overall accuracies of 0.5K and 0.5gm^{-3} seem possible.
- Need further studies to quantify possible *systematic* retrieval errors due to microwave absorption uncertainty!

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