Multi-Instrument Retrievals: Applications and New Synergies

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Can we derive LWC profiles from MWRs ?

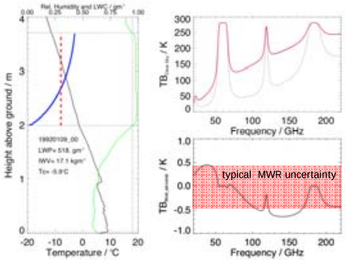


Fig. 1: *Left: Modified adiabatic (blue) and constant (red) liquid water content (LWC) profiles with the same liquid water path (LWP). Right: Effect of cloud on TB (top right) and TB differences caused by the different vertical LWC distributions (bottom right).*

- Measurements from a single instrument often contain insufficient information on the "desired" atmospheric parameter.
- E.g. Microwave Radiometer (MWR) shows no significant sensitivity to the vertical LWC distribution.

In this case add complementary cloud radar measurement

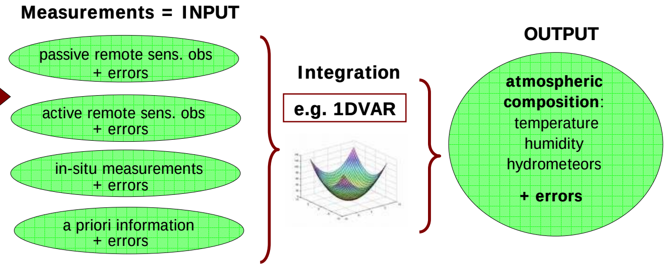
Tab. 1: *Degrees of Freedom (DoF) for signal for LWC from MWR alone using a 1DVAR approach.*

rel. LWC error vs. frequency comb.	30%	70%
22-31 GHz	0.95	1.02
22-31 + 90/150 GHz	1.45	1.85

Note: *DoF for signal for LWC decreases rapidly as LWP decreases. Above example is for LWP > 500 g/m²*

Method for combining measurements

1DVar approach: Integrated Profiling Technique (IPT)



Summary

- IPT (1DVar retrieval approach) applied to AMF-COPS dataset to retrieve temperature, humidity and LWC profiles from a combined a suite of sensors.
- IPT results and errors are used to estimate SW/LW fluxes and their corresponding errors.
- AERI retrievals of clear-sky temperature and humidity profiles outperform microwave retrievals.
- In low-LWP conditions, retrieved temperature and humdity profiles are accurate from the combination of MWR and AERI observations; retrievals of cloud microphysics also show promising results.

Application to COPS Data

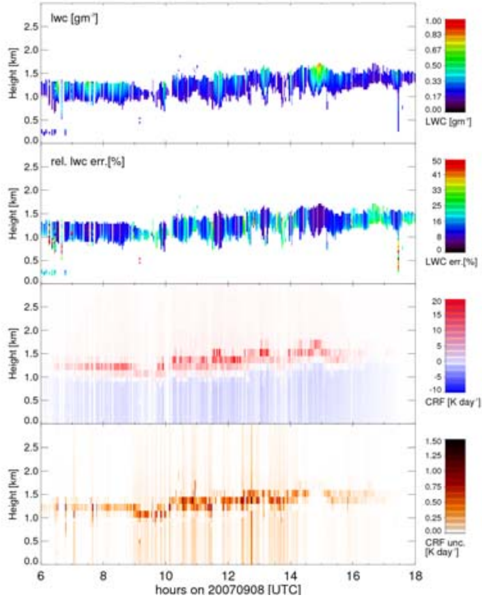


Fig. 2: *IPT LWC profiles and corresponding relative errors (top two) and from these profiles calculated CRF and the IPT-propagated errors (bottom two) on September 08, 2007*

- IPT applied to **9 month AMF-COPS data set** using MWR-profiler HATPRO (Univ. of Cologne), cloud radar (AMF), Cloudnet target classification and radiosondes (AMF) as a priori for temperature, humidity and pressure.
- IPT output coupled to a NWP 1D-radiative transfer model (COSMO – GRAALS) to calculate **SW cloud radiative forcing** (CRF).
- IPT error estimates (T, q, LWC) are propagated to SW CRF error.
- Future: Hemispheric (scanning microwave observations) will be used to assess 3D-effects; comparison of COSMO-GRAALS to the radiative transfer model RRTMG of the AER, Inc.

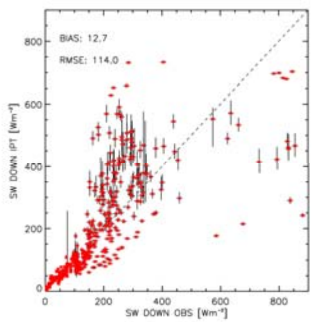


Fig. 3: *Measured SW down flux vs. calculated from IPT profiles at the Schwarzwald AMF site for time series shown in Fig. 2, temporal averaging 60-90 s.*

"New" Synergies – Microwave & Infrared

- During **clear sky cases** and low humidities AERI measurements provide ~**3x more independent retrievable layers** of temperature and humidity than zenith-viewing microwave measurements. AERI retrievals are on the order of **35-45 %** more accurate than MWR retrievals.
- Elevation scanning microwave measurements double the number of independent retrievable temperature layers.
- Combination of both measurements into one retrieval only adds to retrieval accuracy in tropical climates.

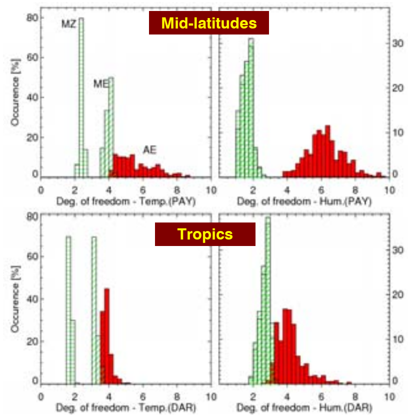


Fig. 4*: DoF for signal for temperature (left) and humidity (right) profiles for low (top) and high (bottom) humidity values for zenith looking MWR (MZ), elevation scanning MWR (ME) and infrared (AE) measurements.*

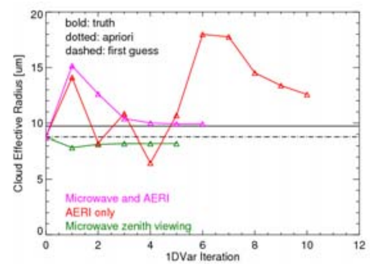


Fig. 5: *Cloudy case study: 1DVar retrieval convergence of effective radius for only microwave zenith viewing, single AERI and combined (Microwave + AERI) configurations.*

- Passive microwave (e.g. HATPRO) and infrared (e.g. AERI) sensors are both sensitive to temperature profile (O_2 and CO_2 emission lines, respectively), humidity profile (H_2O emission lines), and cloud microphysics ("windows").
- Simulation of a **cloudy case study** with LWP: 50 gm^{-2}, effective radius: 10 µm, optical Depth: 7.8

➔ AERI loses sensitivity to humidity due to saturation effects.

➔ combined MWR/AERI retrieval shows best results in retrieving effective radius.

➔ combined MWR/AERI retrieval expected to be most beneficial in LWP range 30-60 gm^{-2}.

Benefit of combining both spectral regions becomes apparent in low-LWP cases

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