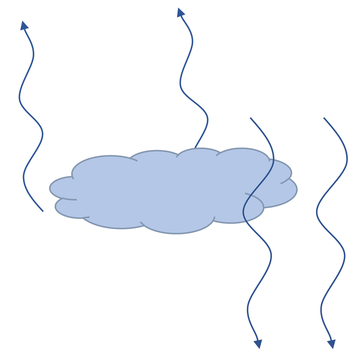
A virtual network of ground-based microwave radiometers for monitoring of atmospheric stability and its potential impact in synergy with hyperspectral satellite observations.

Maria Toporov[1], U. Löhnert[1]

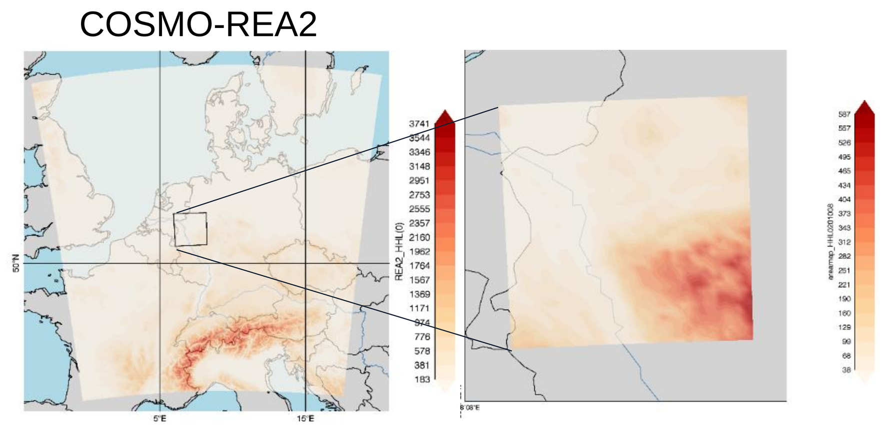
[1] *Institute of Geophysics and Meteorology, University of Cologne*

1. Motivation



- Atmospheric state close to the surface is provided by surface sensor networks. Various satellite instruments sample the upper troposphere. However, the accuracy of satellite observations in the lowest layer is limited by clouds and varying surface emissivity.
- Atmospheric Boundary Layer: Only sporadic information from radiosondes or aircraft observations → **observational gap in the ABL→** need for additional ground-based remote-sensing observations.
- **Microwave Radiometer MWR**: provides atmospheric temperature and humidity profiles under almost all-weather conditions (except heavy precipitation).
- **Meteosat Third Generation Infrared Sounder (MTG-IRS)**: will deliver profiles of atmospheric water vapor and temperature with high temporal (30 min. over Europe) and horizontal resolution (4km in nadir). Clouds are a limiting factor.
- *Toporov et al. 2020* have shown the benefit of the synergy of satellite and ground-based observations for retrieval of atmospheric stability indices such as CAPE, Lifted Index, Fog threat etc. especially under cloudy conditions.
- In this study we focus on the retrieval of CAPE fields using hyperspectral satellite and ground-based observations and show the potential of a network of ground-based MWR in synergy with future IRS observations.

2. Simulation of satellite and ground-based measurements



- ***Reanalysis COSMO-REA2*** *was used to simulate satellite and ground-based observations. Domain size is 150*150km with horizontal resolution 4km. May-September 2009-2010.*

- Ground-based MWR: RTTOV-gb (*de Angelis, 2016*). 14 channels (7 channels 22-32GHz→ water vapor, 7 channels 51-58GHz→ temperature).

- Geostationary satellite IRS: RTTOV-v12. 1113 channels between 700 and 2000cm^{-1}. Principal component Analysis applied to simulated spectra → 50 first PC's used as input for training of NN.

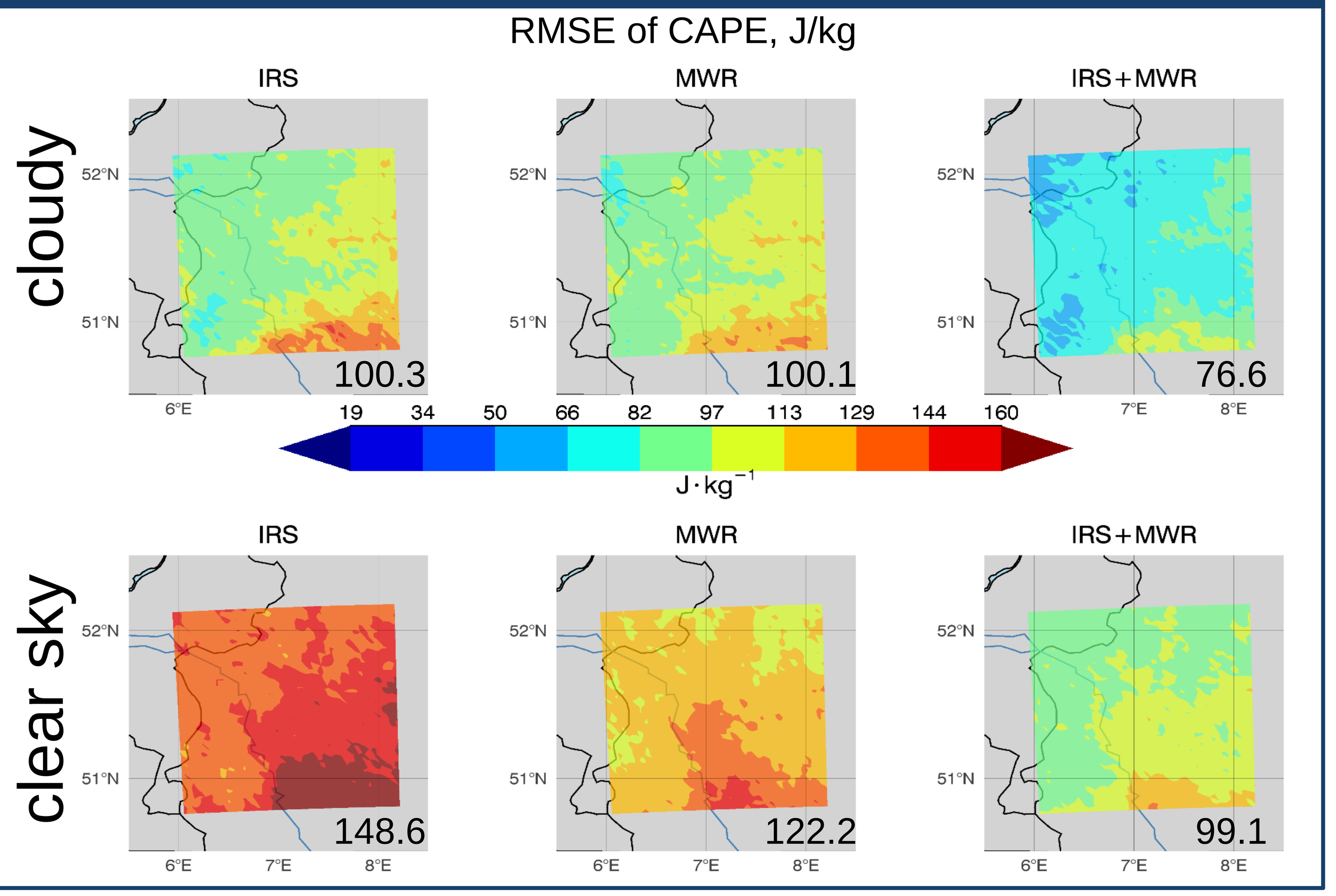
3. Neural Network Retrieval of CAPE

Most unstable CAPE

CAPE= $R_d \int_{p(mu)}^{p(TOA)} (T_v(\text{parcel}) - T_v) d\ln p$

NN were trained with simulated observations (IRS, MWR or synergistic IRS+MWR) as input, and CAPE as target.

Performance of the NN retrieval:
***RMSE of CAPE** retrieved from simulated IRS, MWR and combined IRS+MWR observations. Results separated into clear sky and cloudy cases.*
(Retrieval applied in each gridpoint of the domain).

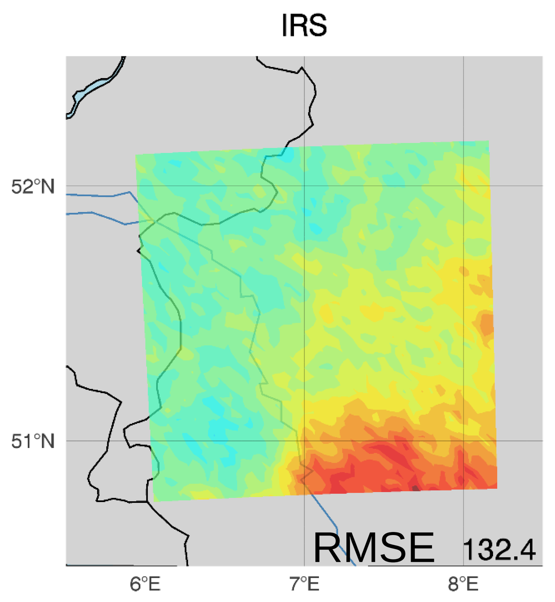


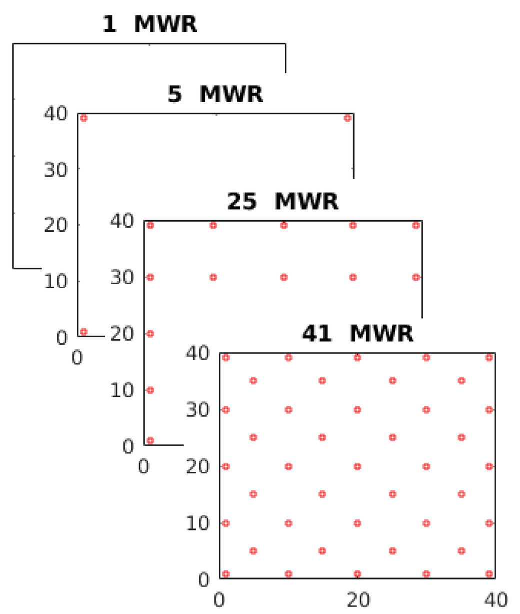
4. Method: Optimal interpolation

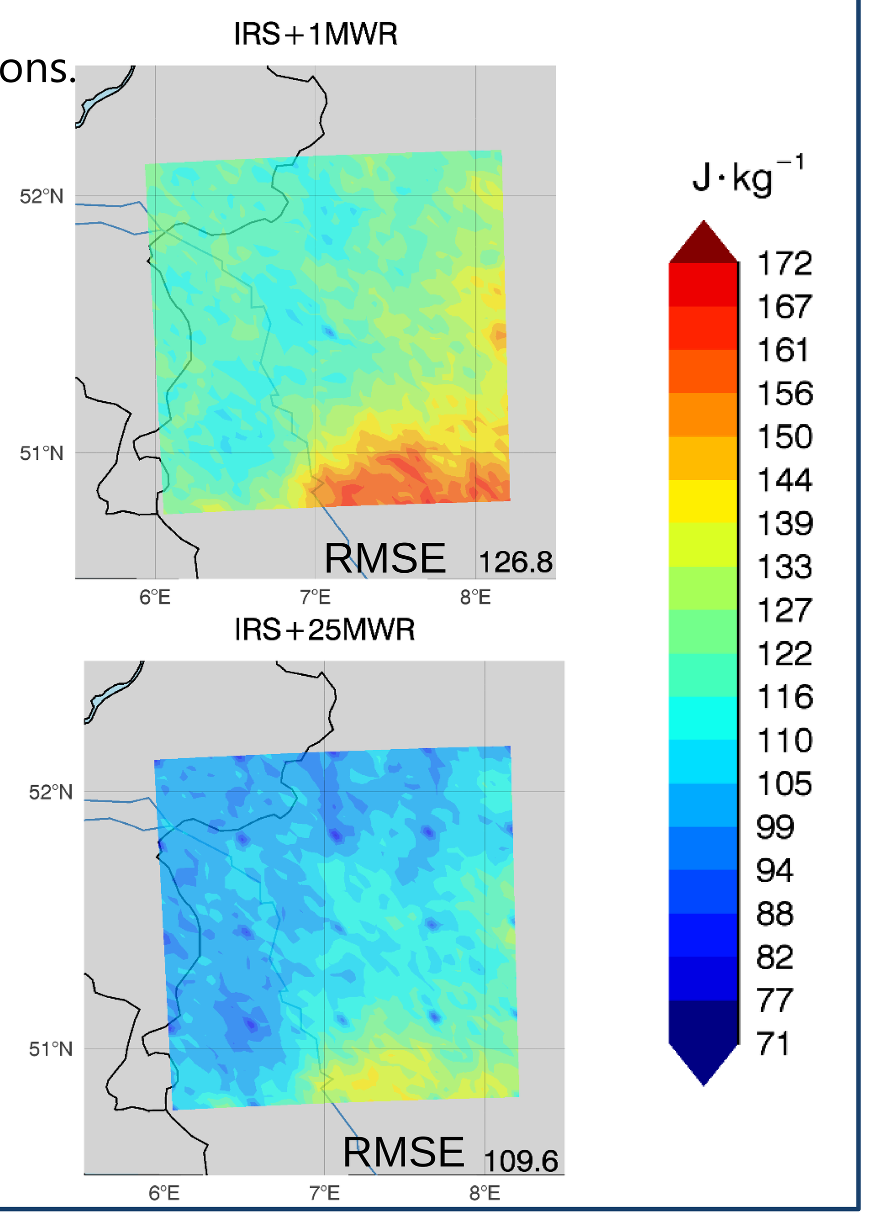
- **How to combine fields of CAPE retrieved form IRS observations and single/network CAPE values retrieved from MWR?**

→ ***Optimal interpolation*** between CAPE fields retrieved from IRS (resolution 4km) and from MWR-network observations (varying number of MWR).

→ Reduction of uncertainty due to additional ground-based observations.







X_b: CAPE from IRS + Y: CAPE from MWR

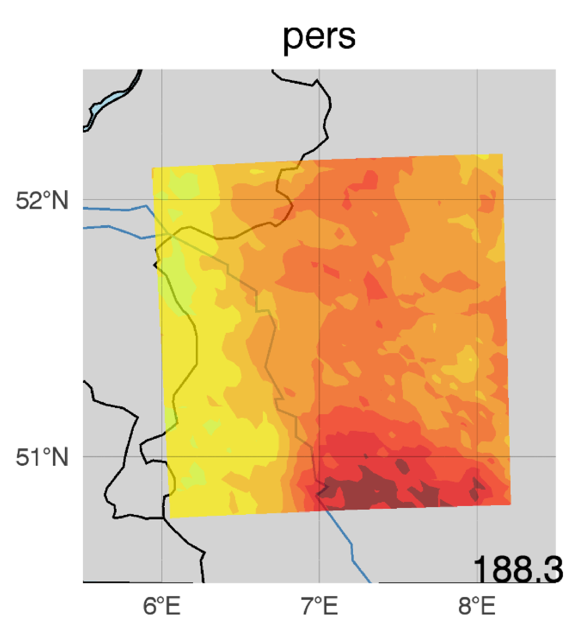
$$\boldsymbol{X_a} = X_b + W(Y - H(X_b))$$
$$W = BH^T(HBH^T + R)^{-1}$$

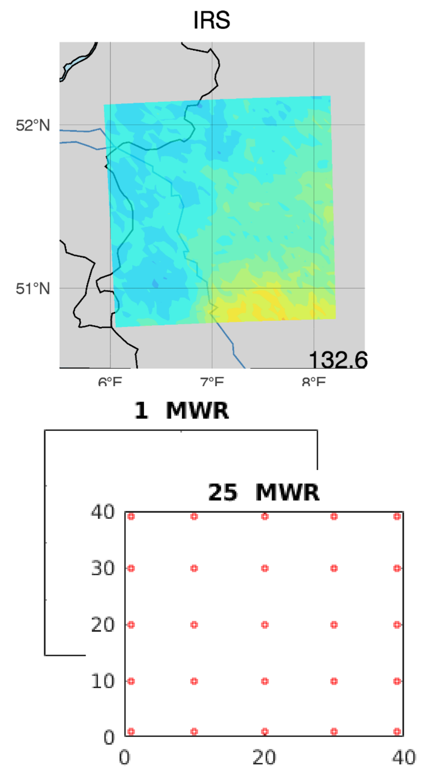
B: error covariance of IRS retrieval

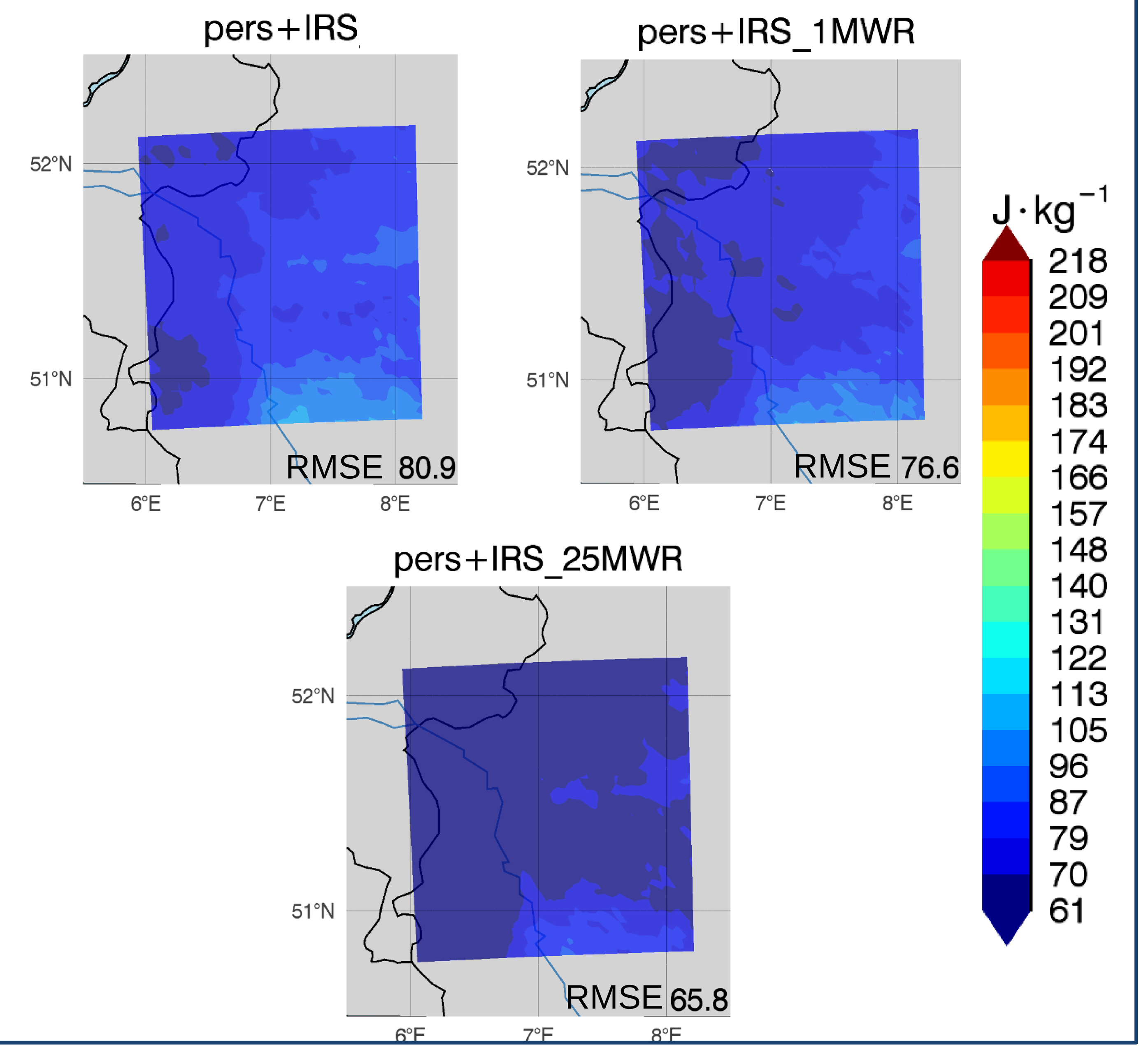
R: error covariance of MWR retrieval

4. Updating the background (persistence)

- **Assumption of persistence of CAPE fields for 6 hours**
- Assimilation (Optimal Interpolation) of CAPE fields retrieved from IRS and combined IRS+MWRnetwork.







X_b: persistence + Y: CAPE from IRS/MWR

$$\boldsymbol{X_a} = X_b + W(Y - H(X_b))$$
$$W = BH^T(HBH^T + R)^{-1}$$

B: covariance of CAPE (from Reanalysis)

R: error covariance of IRS/MWR retrieval

5. Outlook

- **Observing System Simulation Experiment**:
- Nature Run→ ICAN-LES for the same domain.
- Simulation of ground based MWR and DIAL measurements.
- Assimilation of synthetic MWR/DIAL observations into a convective-scale numerical weather prediction (NWP) model.
- Impact of different network configurations (i.e. instrument spatial density, type and accuracy of the instruments) on the accuracy of atmospheric analyses and short-term forecast.

References:

Toporov, M., & Löhnert, U. (2020). Synergy of Satellite- and Ground-Based Observations for Continuous Monitoring of Atmospheric Stability, Liquid Water Path, and Integrated Water Vapor: Theoretical Evaluations Using Reanalysis and Neural Networks, Journal of Applied Meteorology and Climatology, 59(7), 1153-1170.

De Angelis, F., Cimini, D., Hocking, J., Martinet, P., and Kneifel, S.: RTTOV-gb - adapting the fast radiative transfer model RTTOV for the assimilation of ground-based microwave radiometer observations, Geosci. Model Dev. 9. doi:10.5194/gmd-9-2721-2016, 2016.

Acknowledgments:

This work was supported by the German Weather Service within the Extramural Research Programme (2015EMF-09)

 mtoporo1@uni-koeln.de