State-of-the-art Total Column Water Vapour Retrievals for Improved Characterization of Pre-convective Environments

J. R. El Kassar[1], C. Carbajal Henken[1], R. Preusker[1]

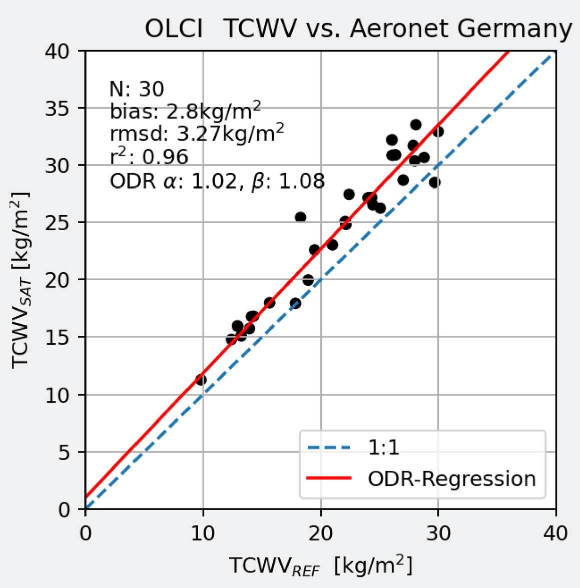
[1]Institute of Meteorology, Freie Universität Berlin, Germany - **Contact**: jan.elkassar@met.fu-berlin.de

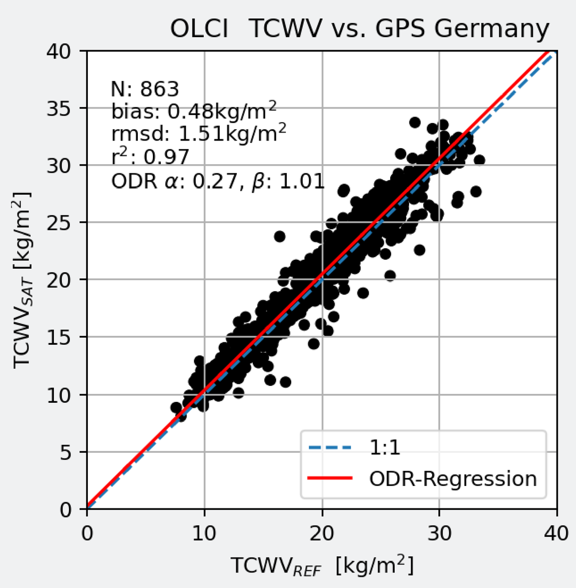
Abstract

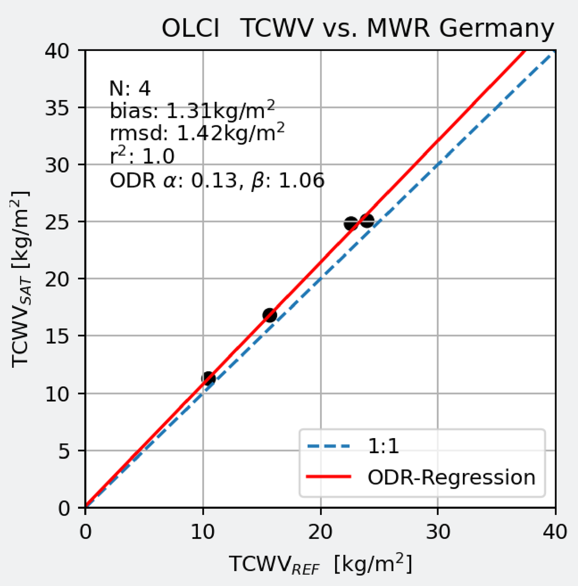
We present our progress on a two-band near-infrared (NIR) total column water vapour (TCWV) retrieval for the Flexible Combined Imager (FCI) onboard the new geostationary satellite Meteosat Third Generation (MTG). Here, we showcase first results processed from two similar bands on the Ocean and Land Colour Imager (OLCI) and a first validation against reference stations in Germany which show a good performance. Within the RealPEP project (Trömel et al. 2021) we aim to improve nowcasting of heavy precipitation in Germany. Spatial and temporal metrics of TCWV observations are used to characterize the clear-sky state of atmospheric humidity prior to the formation of convective precipitation. These may help in finding predictors for the formation of convective precipitation before the onset of cloud formation.

Validation over Germany

We collected TCWV observations from the Aerosol Robotic Network (AERONET,Holben et al. 2006), Global Positioning System stations (GPS,Gendt et al. 2004) and Microwave Radiometer stations (MWR,Löhnert and Crewell 2003).







- processed TCWV for 1st to 8th of July 2018 over Germany.
- 7x7 TCWV pixels around a given station was averaged and matched with a 15 minute average of the reference at the time of satellite overpass
- good performance over land surfaces

TCWV Algorithm Description

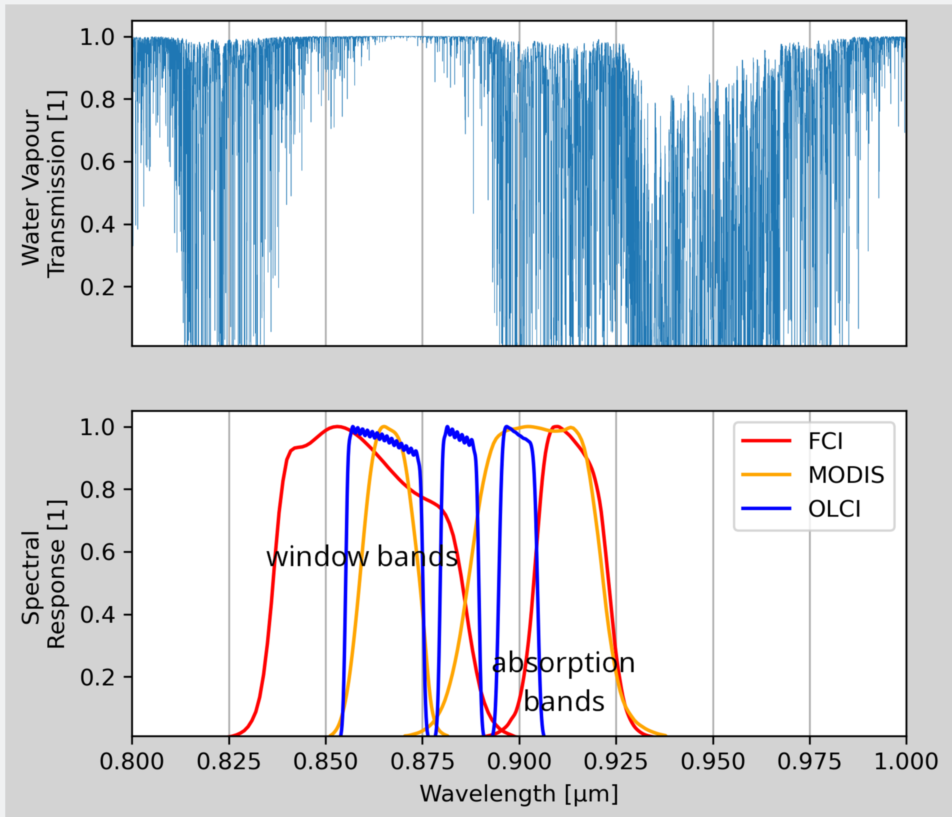


Fig. 1: Top: total WV transmittance spectrum for the region of the window and $\rho\sigma\tau$. Bottom: spectral response functions for sensors with bands suitable for TCWV retrieval from the NIR.

- WV exhibits a strong absorption feature between 0.89 to 0.98 µm ($\rho\sigma\tau$)
- the ratio of a window band to a band in the stronger absorption correlates with the amount of WV along the path of a photon (sun → surface → sensor)
- we can approximate WV transmittance with $log(\frac{R_{ABSORPTION}}{R_{WINDOW}})$, given an identical surface reflectance at both wavelengths
- however, spectral surface reflectance is **not** identical at these bands and their relationship changes (i.e. over grass, forest, water, sand, ...)
- from matrix operator model radiative transfer simulations (Hollstein and Fischer 2012) we can create a "forward model" which calculate a signal, given specific atmospheric, surface and geometric conditions

Example over Spain: 18th of August 2022, 10:00 UTC

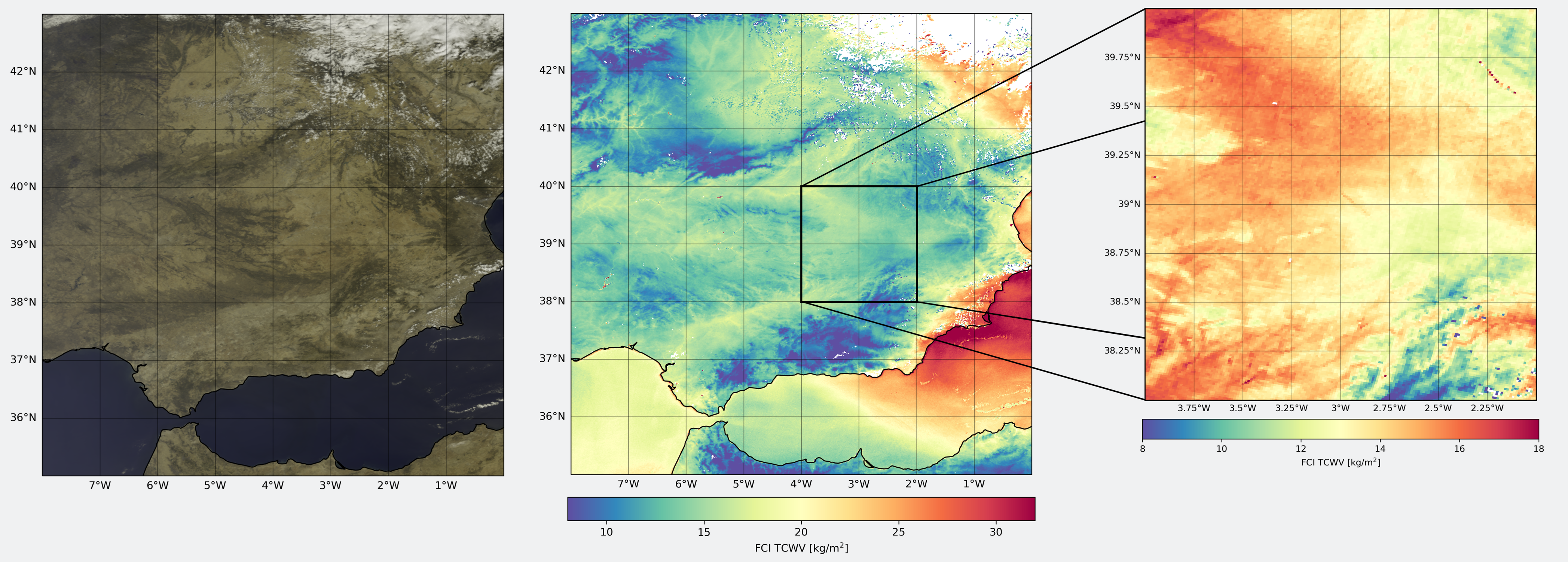


Fig. 2: From left to right: OLCI RGB over Spain, corresponding OLCI-TCWV and a zoom into the scene. Small-scale features at synoptic scale are clearly visible.

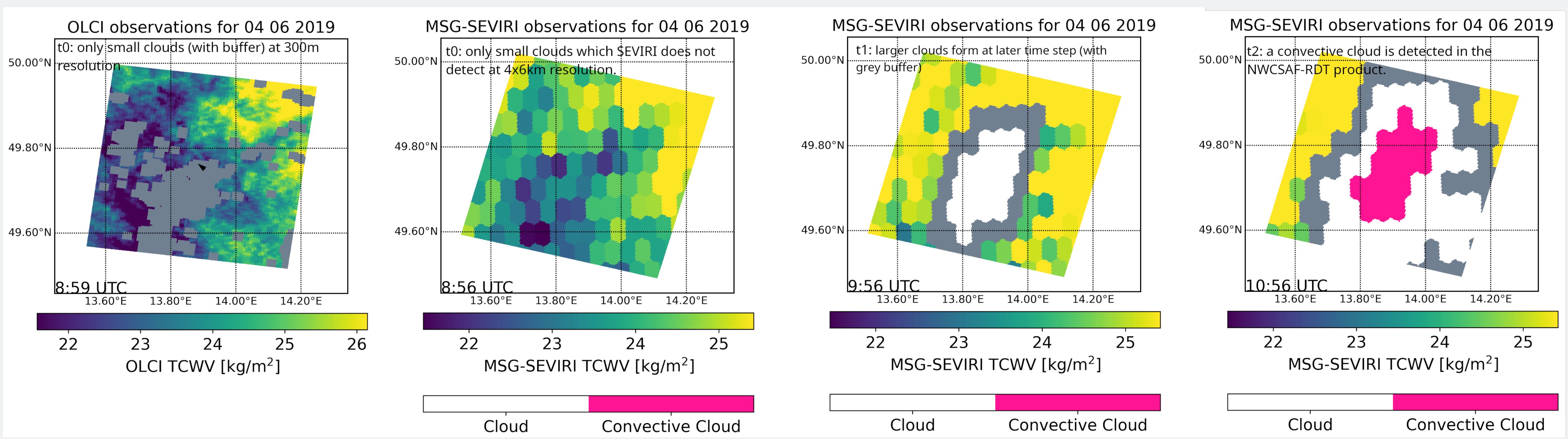
Above, an example scene of TCWV retrieved from OLCI measurements. With 1.2 by 1.2 km resolution, the reduced resolution product of OLCI provides a comparable resolution over Spain as MTG-FCI will soon deliver. The 0.3 km by 0.3 km is a still far superior resolution for details and disturbances in the water vapour field. However, FCI will provide images every 2.5 to 10 minutes, in contrast to the daily images of polar-orbiting imagers.

Application: improved characterization of pre-convective environments

As a stand-in for future MTG-FCI TCWV products we use high-spatial resolution OLCI TCWV (Preusker et al. 2021) in the morning and TCWV (El Kassar et al. 2021) product retrieved from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) lateron. We use the rapid developing thunderstorm (RDT, Autonès and Claudon 2022) NWCSAF product as proxy for convective clouds.

On the right, an exemplary development of clear-sky development of a convective cloud is shown. At the beginning (t0) we start with no or small clouds. OLCI provides information on the TCWV and its small-scale variability at t0. SEVIRI gives temporal updates of the TCWV and the cloud detection. At t1, SEVIRI detects larger clouds and at t2 these are first classified as RDT.

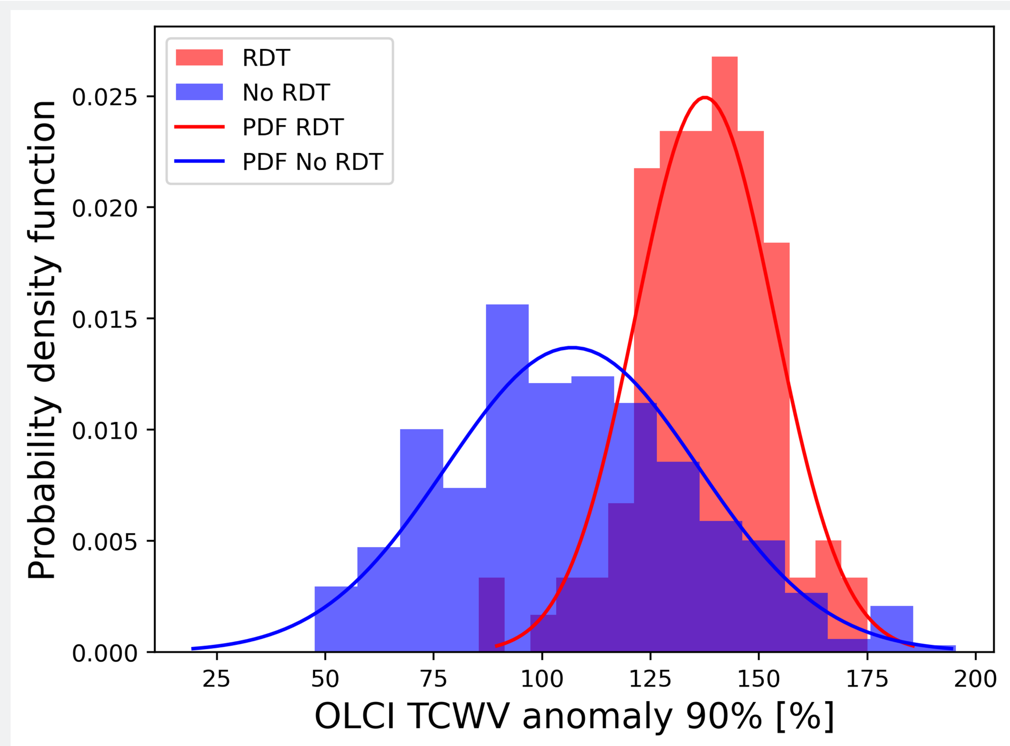
To investigate the predictive potential of clear-sky TCWV distributions for improved nowcasting of convective initiation, we employ a naive Bayesian approach.



This means that from the $Probability_{t_x}(TCWV_{high}|RDT)$ we can infer the $Probability_{t_x}(RDT|TCWV_{high})$ and update it with each time step with new information on TCWV. Under the assumption that features are conditionally independent, we can apply the chain rule of conditional probabilities for these parameters:

- (relative) amount/anomaly of TCWV
- TCWV spatial information
- TCWV temporal information

The figure on the right shows that in cases where some pixels within a given space exceeded the 90th percentile anomaly, the probability of a cloud marked as RDT is higher than for cases where the 90th percentile is not exceeded, indicating predictive power for TCWV anomalies. This is only one of many possible predictors derived from the high spatial and temporal resolution clear-sky TCWV fields FCI will provide and is still work in progress.



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