Total Column Water Vapour from the Split-Window Bands for EarthCARE MSI and its Possible Applications

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Why include TCWV as parameter retrieved from MSI?

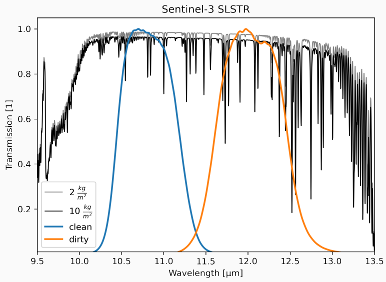
- water vapour (WV) is the key ingredient in cloud formation and weather: humidity-aerosol-cloud interactions
- WV absorbs across a wide range of wavelengths and plays crucial role in the radiation budget
- a warmer/hotter atmosphere can hold more WV: more extreme precipitation and positive feedback in radiative forcing

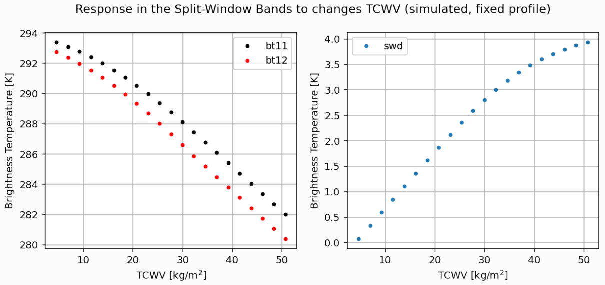
… and MSI features a band sensitive to moisture at 12 μm relative to 11 μm!

Physical Background

Why can we "see" WV in the thermal-infrared (TIR)?

- water vapour more effiently absorbing at 12 µm: colder signal in the "dirty" band
- split-window difference (swd) correlates with total column water vapour content (TCWV)





[1]simulated with RTTOV v12, Saunders, R. et al. 2018, *Geosci. Model Dev.*

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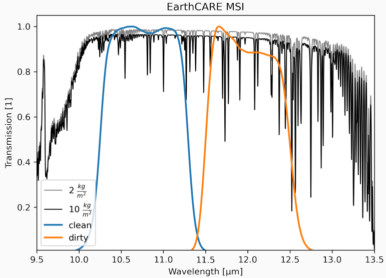

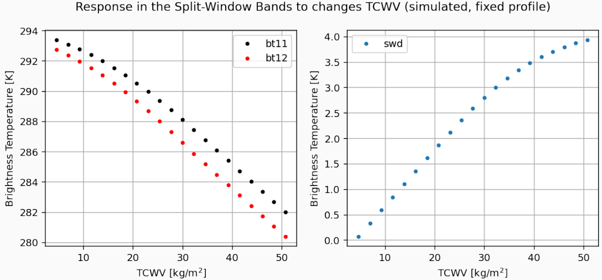

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Algorithm Description

Impact on observations in the split window

Three main influence factors (for clear-sky cases!) over land surfaces:

1. atmospheric temperature and humidity profile
2. surface emissivity
3. surface temperature

We use the CAMEL emissivity atlas included in RTTOV to approximate the emissivity. Profiles are taken from numerical weather prediction. Thus, with RTTOV we can create a forward function:

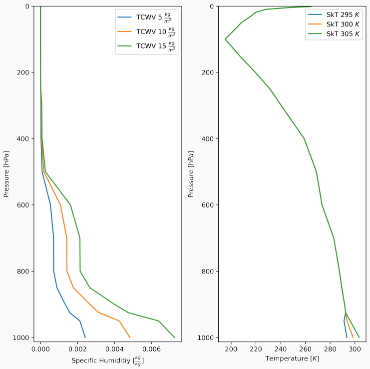
$$F(TCWV, T_{skin}) \rightarrow (BT_{clean}, BT_{clean} - BT_{dirty})$$

Adjustment of atmospheric profiles

- TCWV scales the full humidity profile
- T_{Skin} scales the layer temperature closest to surface pressure

$$q(i_1) = q(i_0) \cdot \frac{tcwv(i_1)}{\int_{p_{surf}}^{0} q(i_0)} \tag{1}$$

$$t_{bottom}(i_1) = t_{skin}(i_1) - (t_{skin}(i_0) - t_{p_{surf}}(i_0)) \tag{2}$$



The TIR TCWV Algorithm

Short Description:

- **forward model**: simulates $BT_{clean}, BT_{clean} - BT_{dirty}$ from TCW, T_{skin}
- **inverse model**: optimal estimation[1] (Rodgers 2000) $\Rightarrow$ iterative change of $TCWV$ and T_{skin}
- prior knowledge/first guess of profiles is based on ERA5 forecasts
- additional info (e.g. wind speed) also from ERA5 forecasts

Algorithm has been applied on

Meteosat Second Generation - Spinning Enhanced Visible and Infrared Imager (MSG-SEVIRI)[1]

and

Sentinel 3 - Sea and Land Surface Temperature Radiometer (S3 SLSTR)

$\rightarrow$ flexible retrieval framework which can be adapted for EarthCARE MSI

[1] El Kassar et al. 2021, *Atmos.*

Caveats of the TIR TCWV Algorithm

Less sensitivity to...

- humidity concentrated at the very lowest level
- significant humidity amounts above 500 hPa
- very low surface temperatures
- thick boundary layers with no vertical temperature gradient

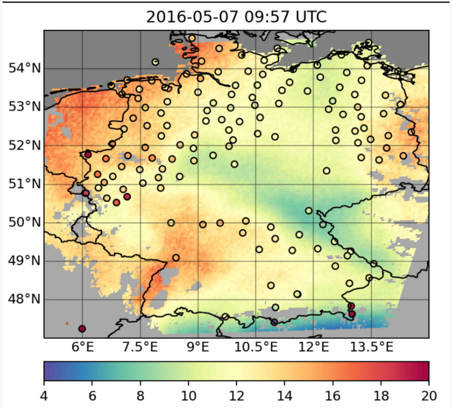
... if the sensitivity is much lower, the NWP first guess is not altered!

However, over thin cirrus the algorithm overestimates the water vapour content: good cloud mask necessary!

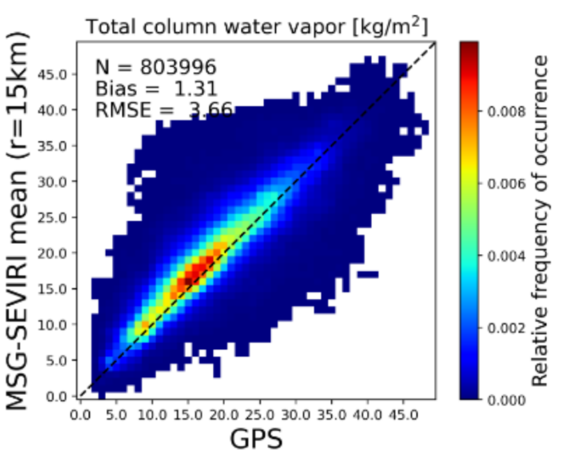
$\Rightarrow$ **the algorithm is more of an update/sharpening of first guess atmospheric profiles (from 0.25° to 0.5 km !)**

Exemplary Results of TIR TCWV

MSG SEVIRI TCWIV: Validation over Germany for 3 Years, mostly land surfaces:



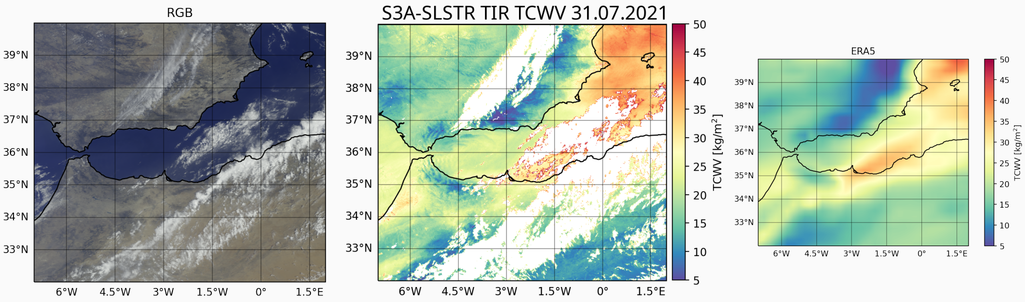
TCWV in $\frac{kg}{m^2}$ and GNSS TCWV on top[1,2]



3 years worth of matchups: slight wet bias

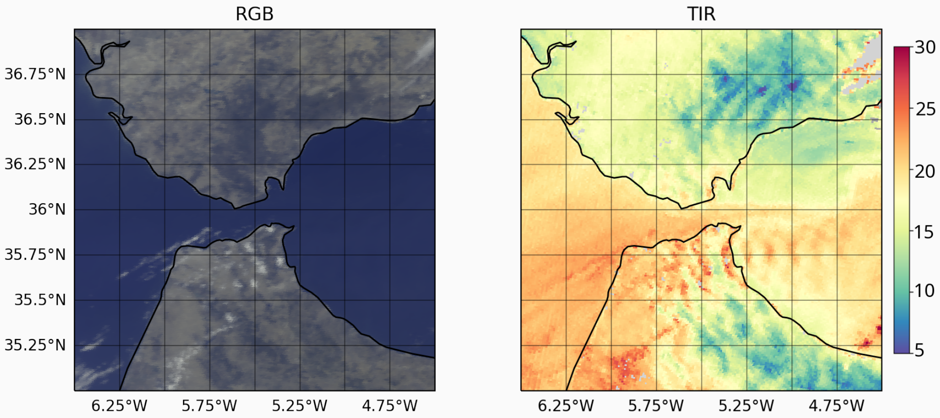
[1] El Kassar et al. 2021, *Atmos.*
[1] Gendt et al. 2004, *J. Meteorol. Soc. Japan*

Sentinel 3 SLSTR TCWV at 1km resolution



- TIR TCWV provides more detail on atmsopheric moisture content
- sensitive enough to reveal lee waves over the Meditteranean
- cloud mask is needed to filter erroneously high values

Sentinel 3 SLSTR TCWV at 1km resolution: zoom in



⇒ at 1 km resolution small scale TCWV patterns revealed! Cannot wait for MSI's 0.5 km

Applications...

- TCWV prior to cloud formation $\rightarrow$ aerosols?
- inflow of low level humidity into clouds $\rightarrow$ change in cloud microphysics?
- surrounding TCWV around dissipating clouds
- ...

Summary and Outlook

Summary/Conclusions

- a TIR TCWV product could well complement the EarthCARE (MSI) products
- a reasonable accuracy and precision can be achieved using the split window alone
- fine details in TCWV fields can be revealed
- low sensitivity to TCWV under specific conditions → in this case just use NWP

Outlook

- global validation study of the algorithm S3 SLSTR