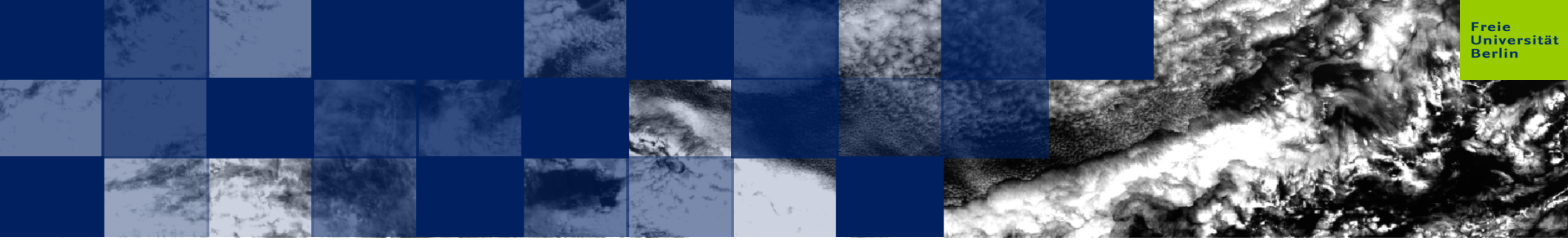


Assessment of satellite- and ground-based observed total column water vapor variabilities and their relation to convective initiation in Germany

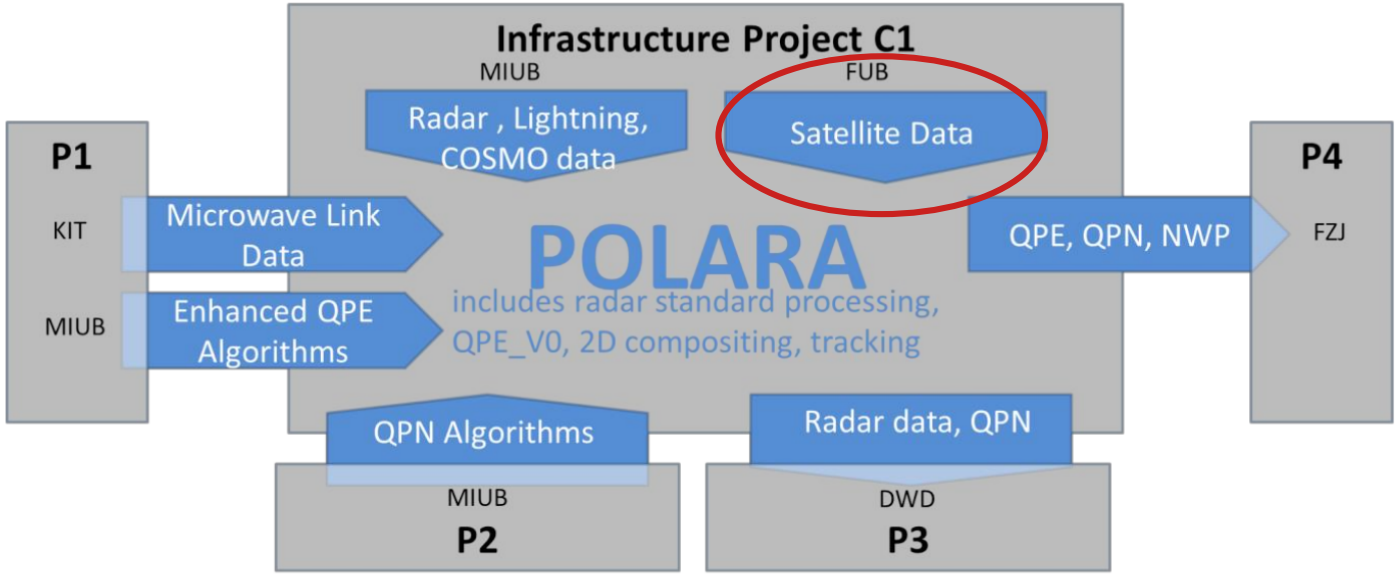
Cintia Carbajal Henken, Rene Preusker & Jürgen Fischer

Institute for Space Sciences, Freie Universität Berlin

FUB in RealPEP

Exploiting a large set of observations

regarding the evolution of the precipitation generating atmosphere



Precipitation and satellite observations

Actually, precipitation is invisible for passive satellite VIS/NIR/TIR observations, since precipitation is usually below opaque clouds!

Precipitation and satellite observations

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Novel satellite TCWV and cloud products will support the monitoring of:

- **Pre-convective environment & convective initiation**
  - High precision TCWV fields from polar-orbiting platforms (OLCI/MODIS) with spatial resolutions up to 250m
  - Temporal variability of TCWV only monitored by geostationary MSG-SEVIRI observations (15 min.), but with lower spatial resolution (4x7km^2) and precision (later MTG)

- **Convective cloud structures**, **precursors of precip and precip intensification**
  - Cloud observations from geostationary satellite MSG-SEVIRI observations

    (later MTG)

Satellite TCWV retrievals and relation to CI

Freie Universität Berlin

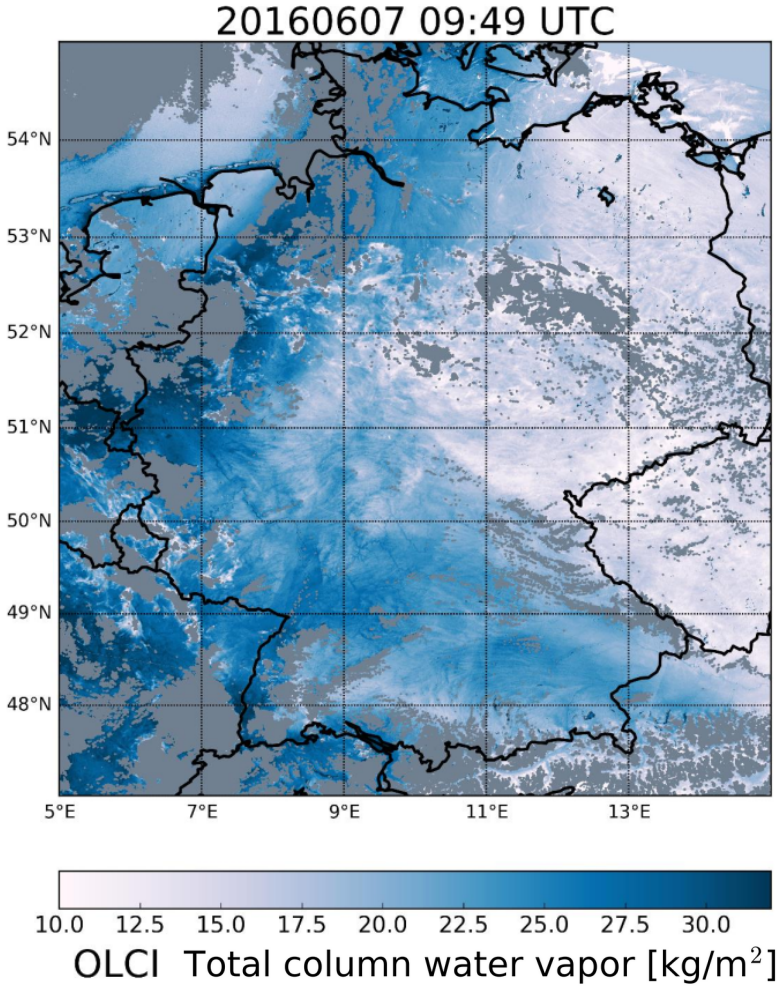
Our approach is two-fold in this project

- **Match-up of various observational datasets for statistical study on CI detection**
  - OLCI/MODIS TCWV retrieval set-up
  - Processing/collecting OLCI/MODIS TCWV, GPS TCWV, MSG-SEVIRI cloud products
  - Mimicking observational capabilities of future MTG-FCI

- **Preparations for future MTG-FCI TCWV retrievals**
  - Set-up of MSG-SEVIRI TCWV retrieval
  - RTTOV-based sensitivity studies for MTG-FCI TCWV retrievals
  - First testing with test simulation data of MTG-FCI

RealPEP

OLCI TCWV processing and validation



MODIS-Terra at 10.20 UTC

Small-scale convective structures in TCWV fields

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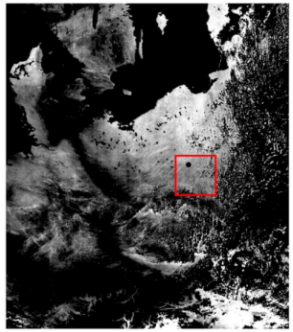
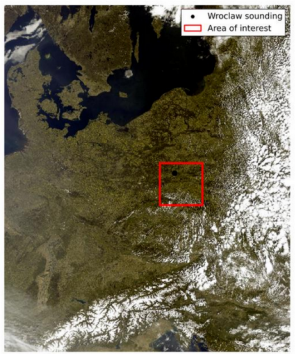
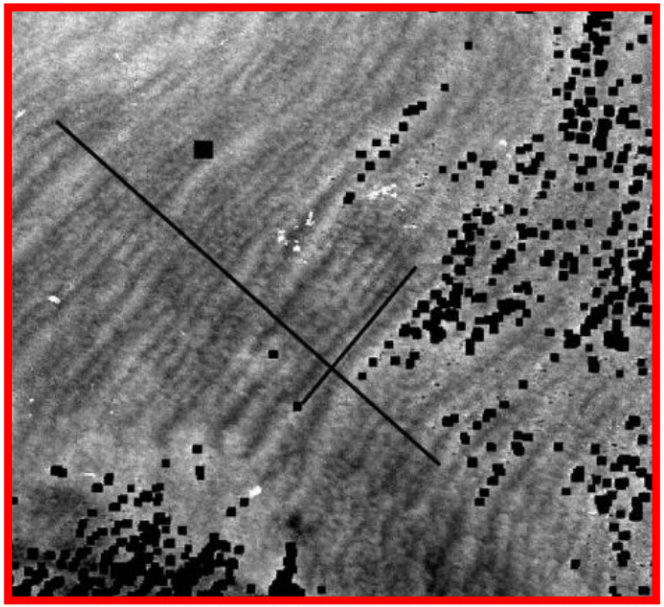
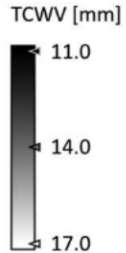
MERIS 300m high resolution TCWV
Case study of horizontal convective rolls in Central-Europe

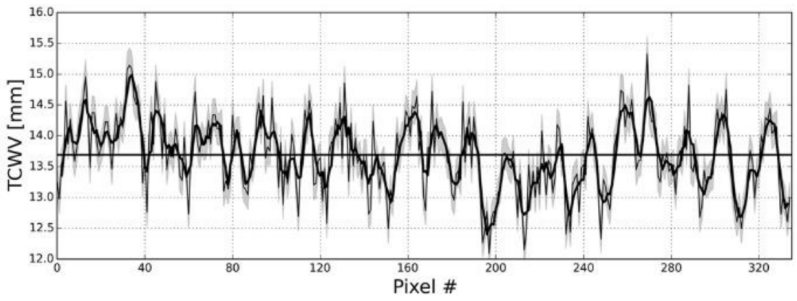




9 May 2008 at 09.42 UTC







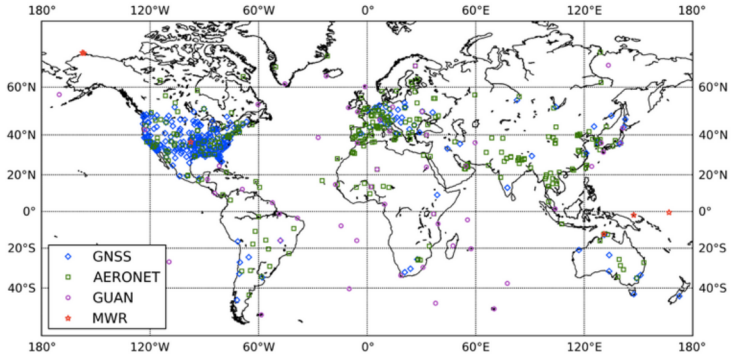
Roll wave length ~ 6.5km
Aspect ratio ~4.2

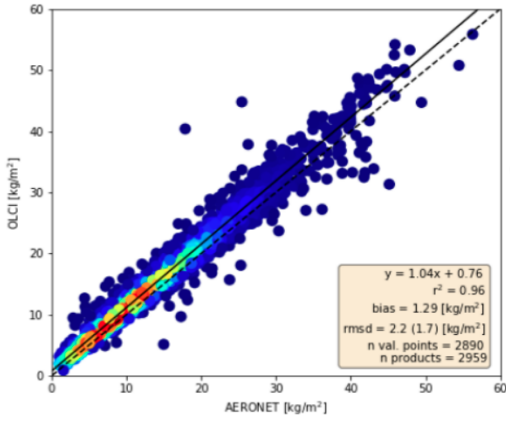
From Carbajal Henken et al. 2015

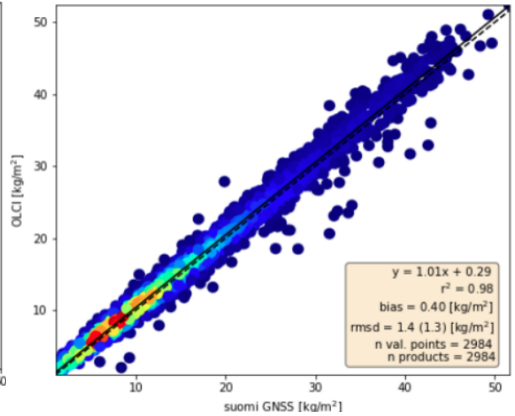
RealPEP

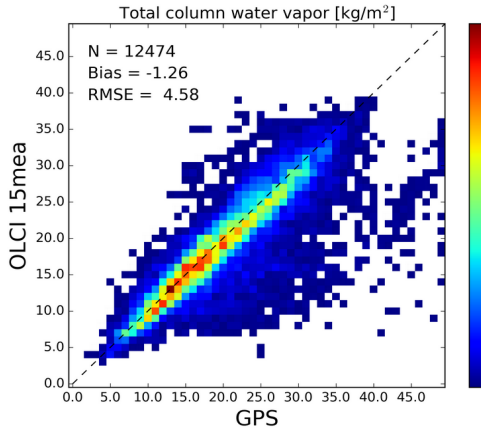
OLCI TCWV processing and validation

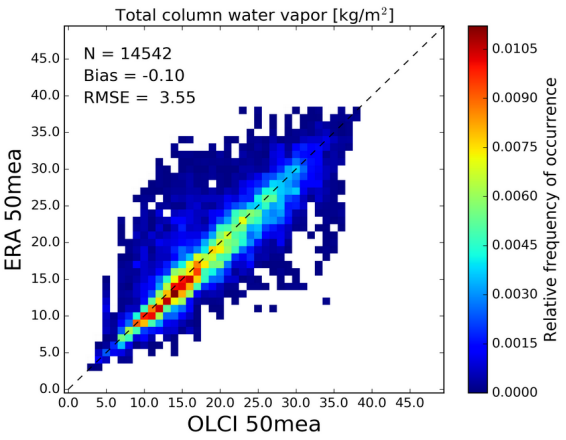
- Validation with well-established ground-based TCWV observational datasets
- Global for Nov 2017 – Oct 2018
- German domain for 2016-2018, April - Sept
- Preusker et al., in prep









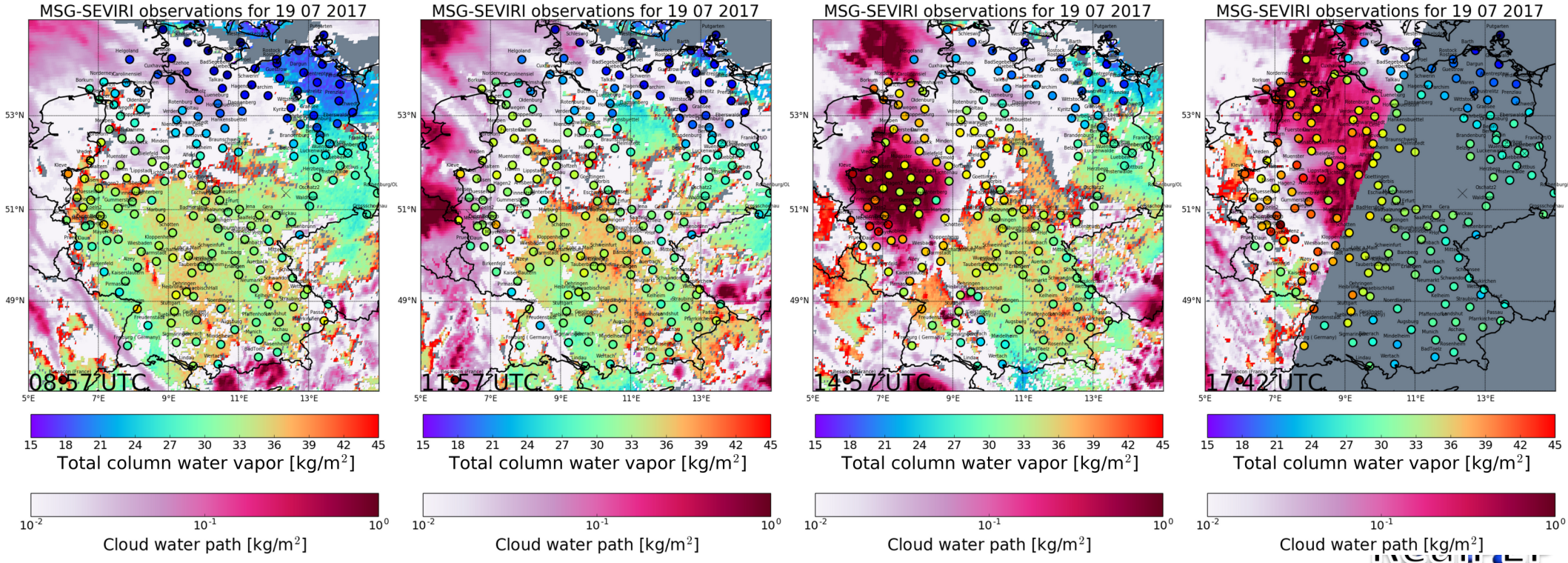


GPS and MSG-SEVIRI observations of TCWV and clouds

Freie Universität Berlin

Realpep case study day 19 July 2017

MSG-SEVIRI V1 TCWV retrievals



Circles represent GPS TCWV values at GPS stations

Towards MTG-FCI observational capabilities for CI detection

Freie Universität Berlin

Combining TCWV from OLCI and GPS and cloud products from MSG-SEVIRI

Match-up of datasets for 2016-2018, April-Sept

- Select GPS stations from network: filtered by height and height variations around station
- OLCI TCWV 2d fields around each GPS station (box with 50km radius, at least 30% cloud free pixels)
- GPS TCWV timeseries around OLCI overpass time (3h)
- MSG-SEVIRI cloud parameter 2d fields around GPS stations around OLCI overpass time (3h)

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Towards MTG-FCI observational capabilities for CI detection

Freie Universität Berlin

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- MSG-SEVIRI cloud parameter 2d fields around GPS stations around OLCI overpass time (3h)

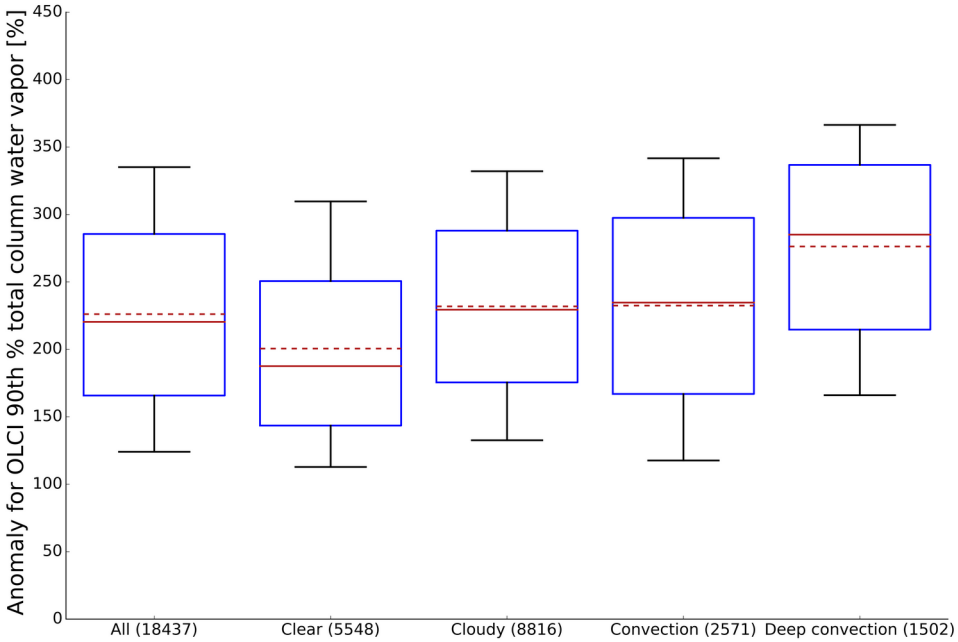
Stratification of statistical results by cloud type occurrence:

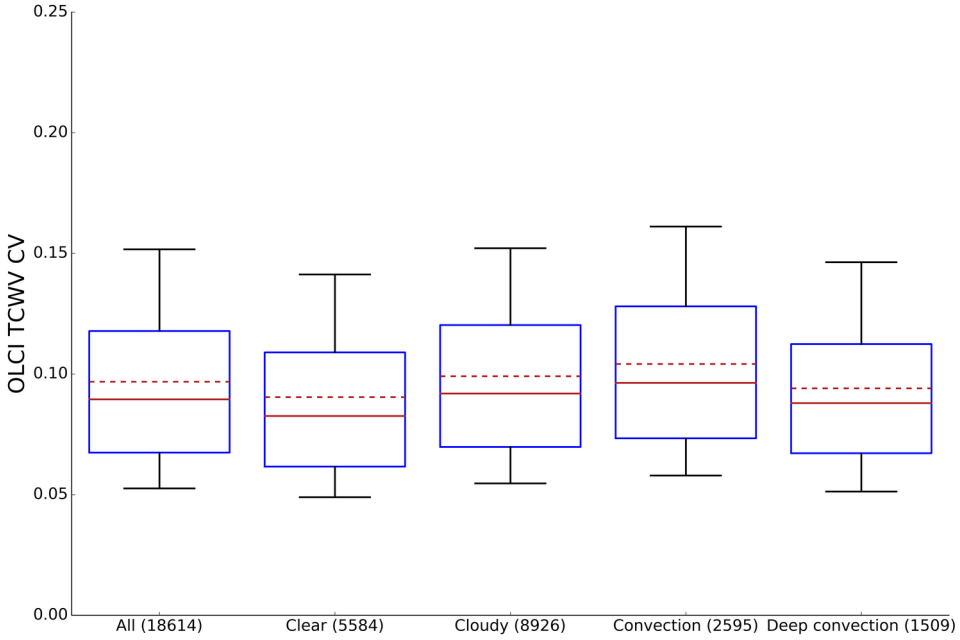
- All, Clear, Cloudy, Convection, Deep convection
- Combine thresholds for MSG-SEVIRI cloud top temperature (CTT) and cloud optical thickness (COT)
- Within 1 to 3 hours after OLCI overpass for at least 2 consecutive time steps

RealPEP

Results: OLCI TCWV spatial variability

Objective weather type classification (DWD): All

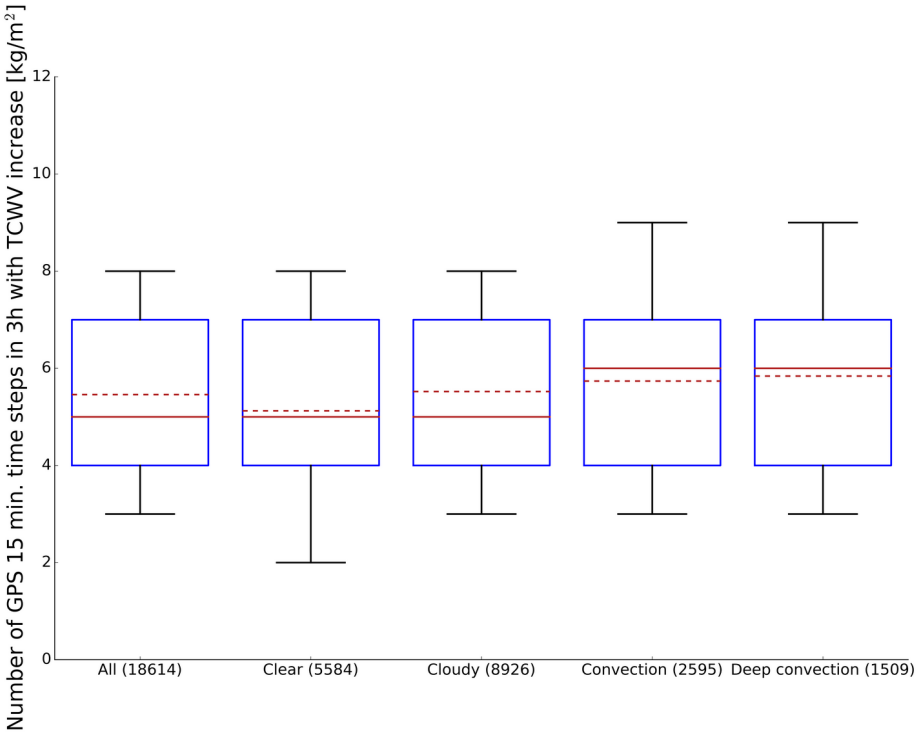


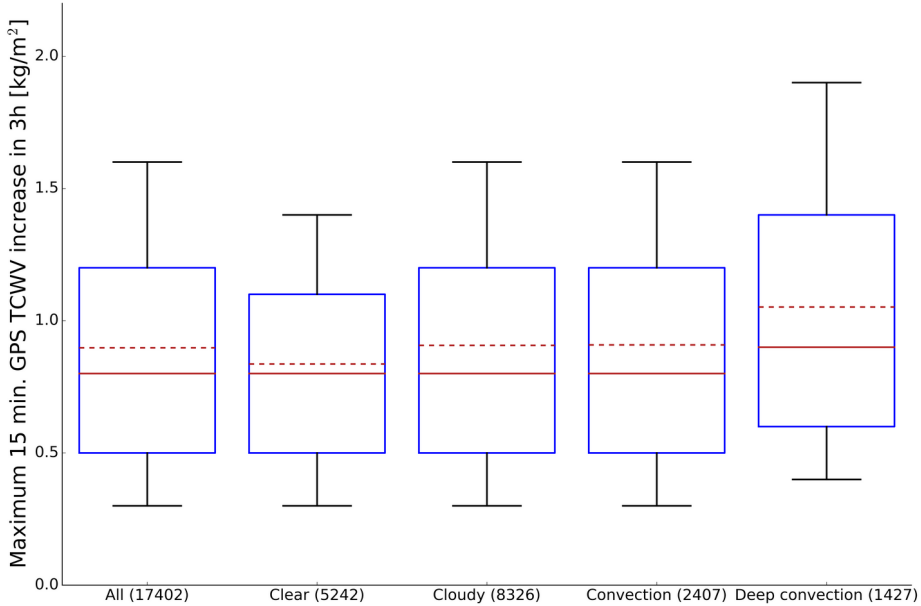


Red solid line = Median
Red dashed line = Mean
Blue box = 25 -75 percentiles
Black error bars = 10 – 90 percentiles

Results: GPS TCWV temporal variability

Objective weather type classification (DWD): All





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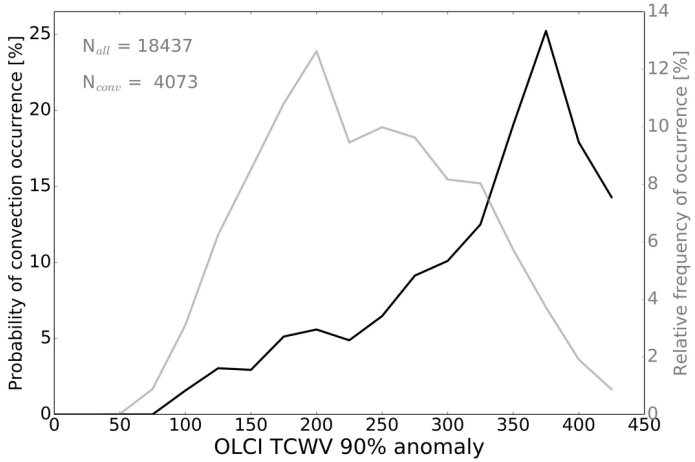

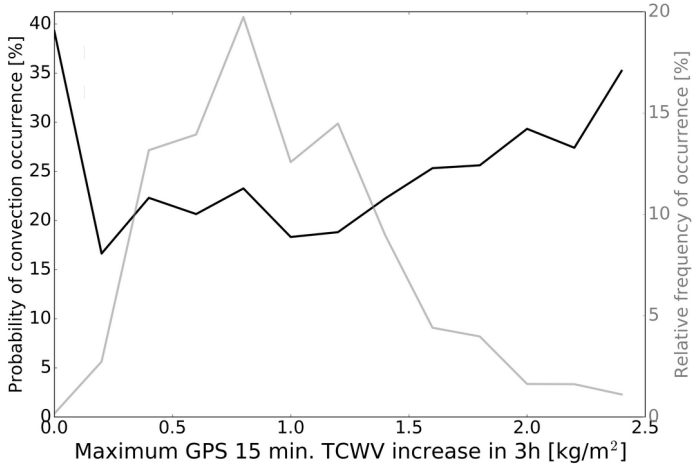

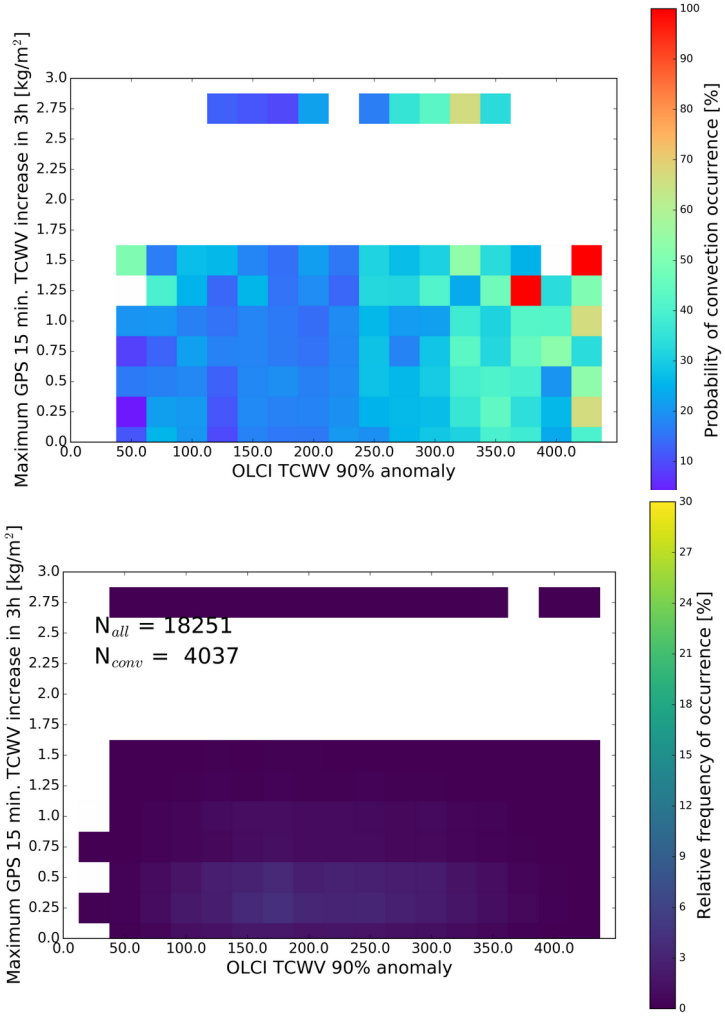

RealPEP

Results: GPS TCWV temporal variability

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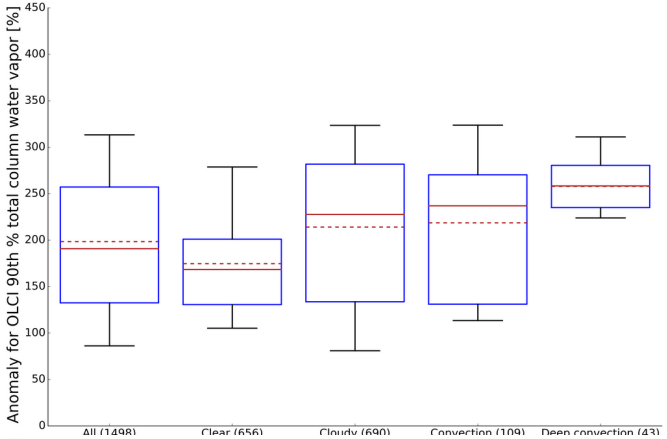
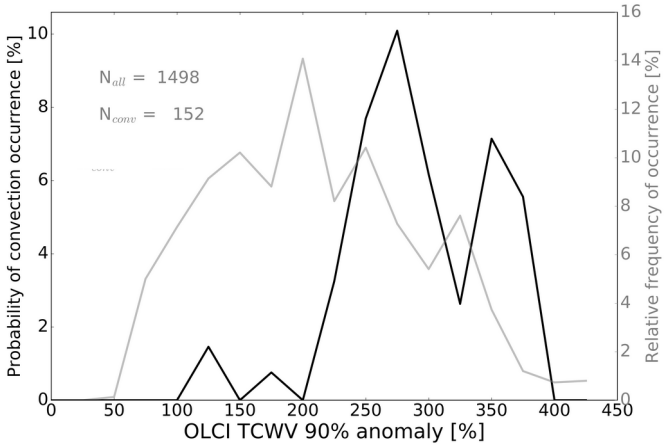
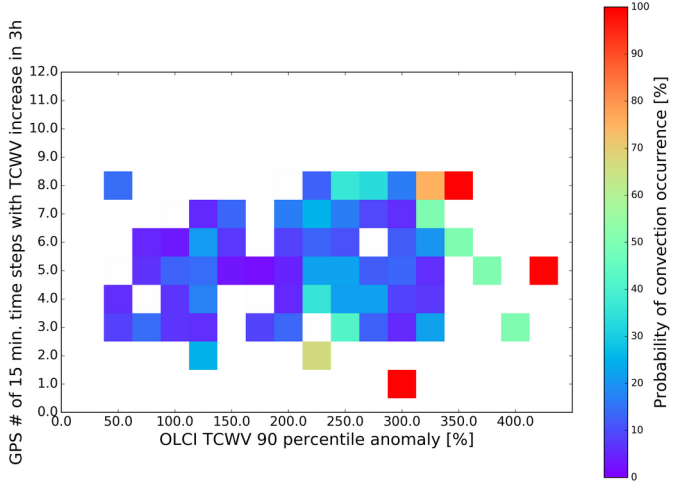
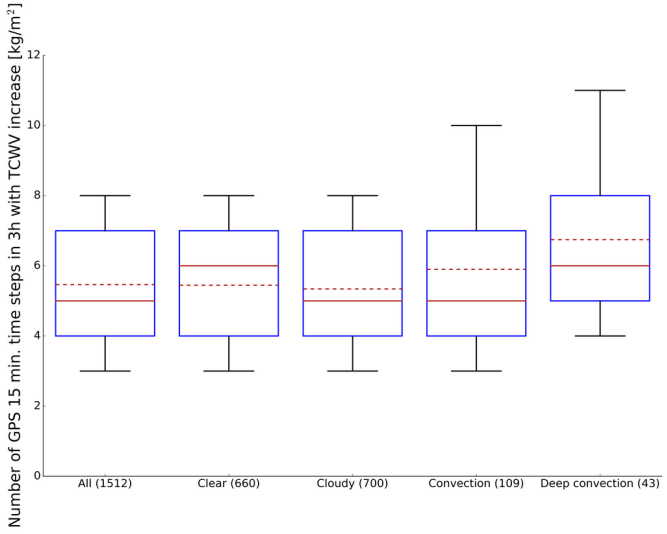
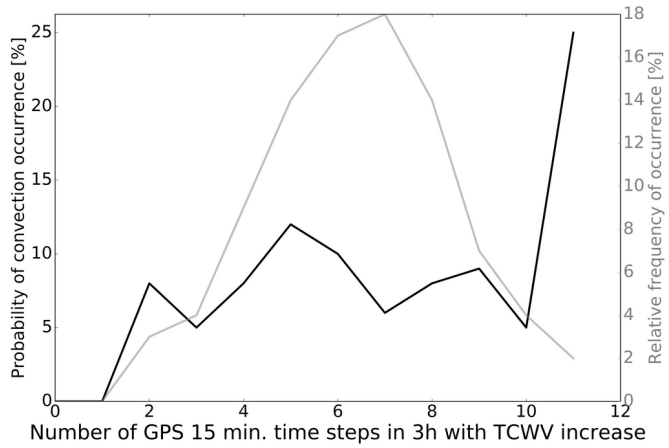
OWTC: Easterly flow, anti-cyclonic conditions near surface

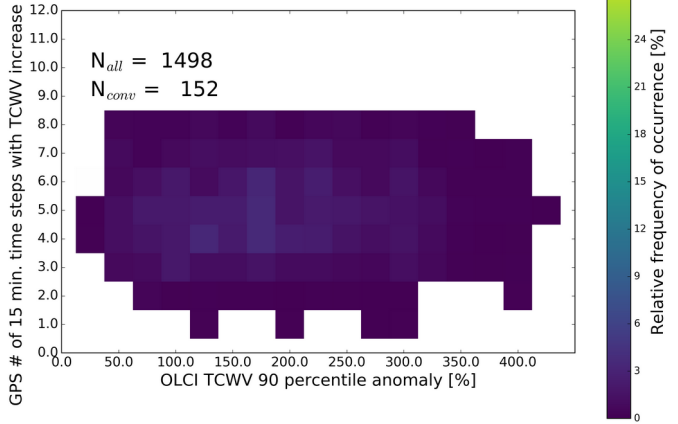








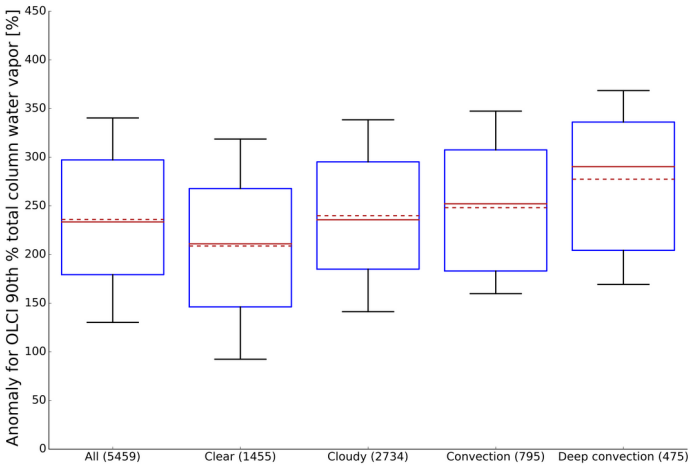


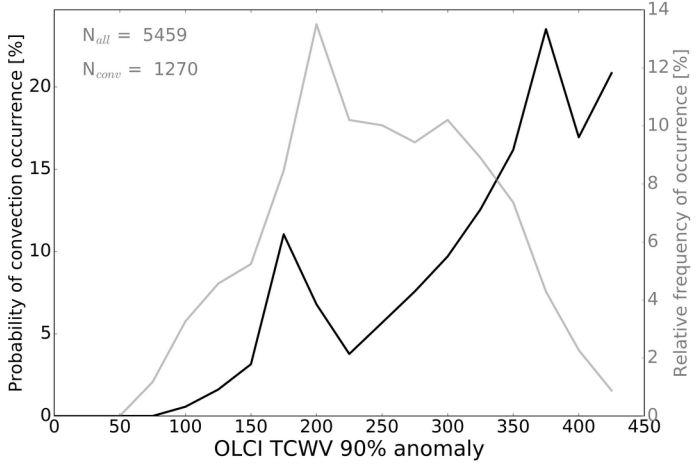


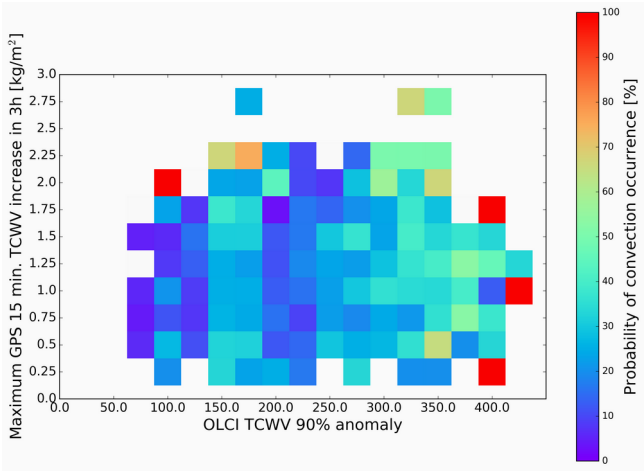
Results: GPS TCWV temporal variability

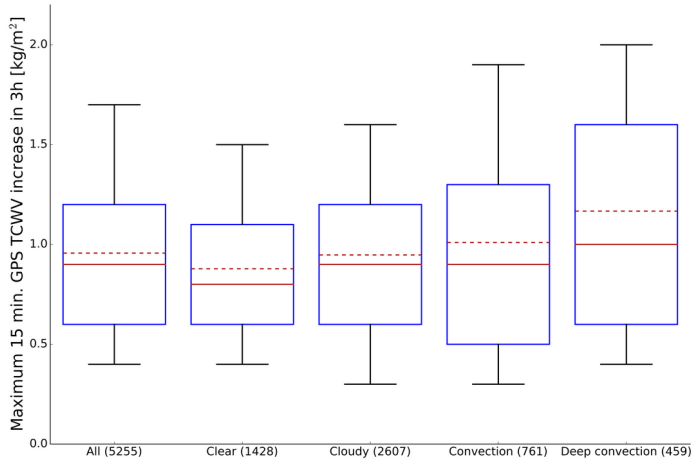
Freie Universität Berlin

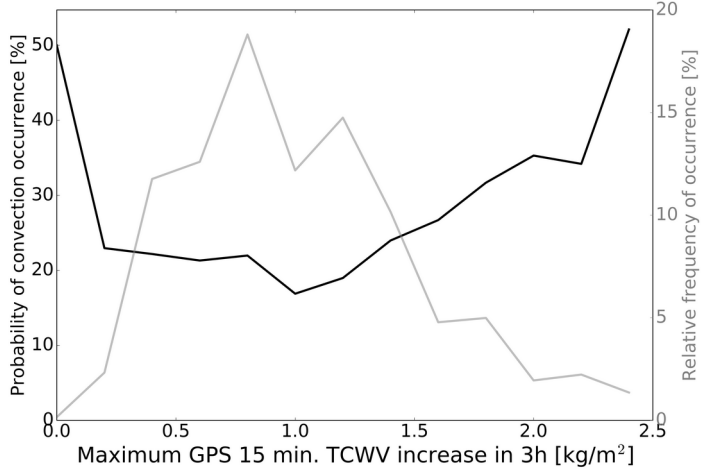
OWTC: South-westerly flow

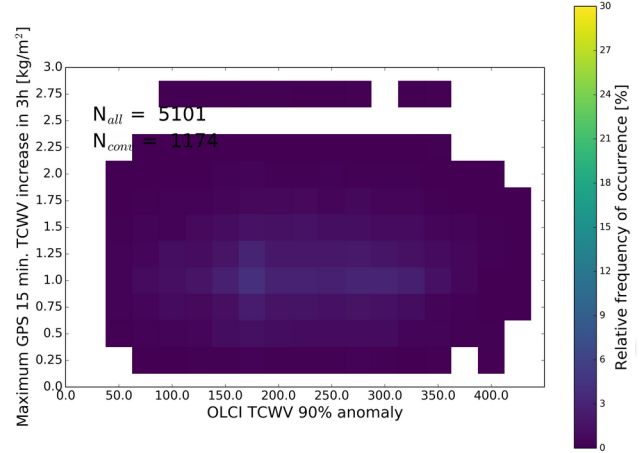




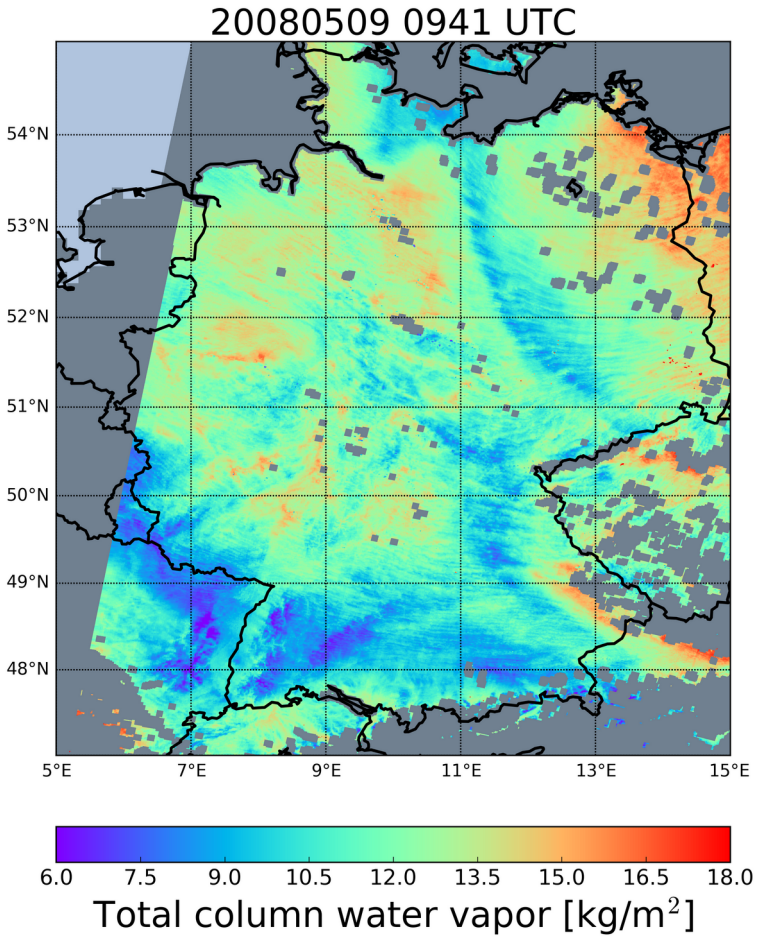




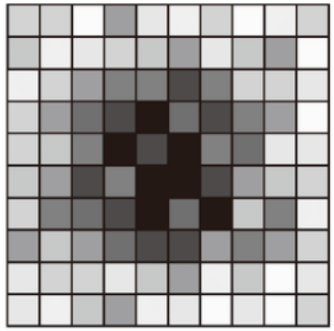




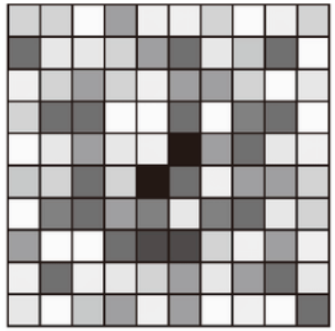
Spatial autocorrelation parameters



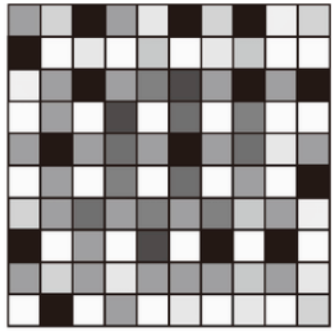
Quantify spatial autocorrelation and identify local clusters of increased TCWV or TCWV boundaries



Positive spatial autocorrelation, I > 0



No spatial autocorrelation, I = 0



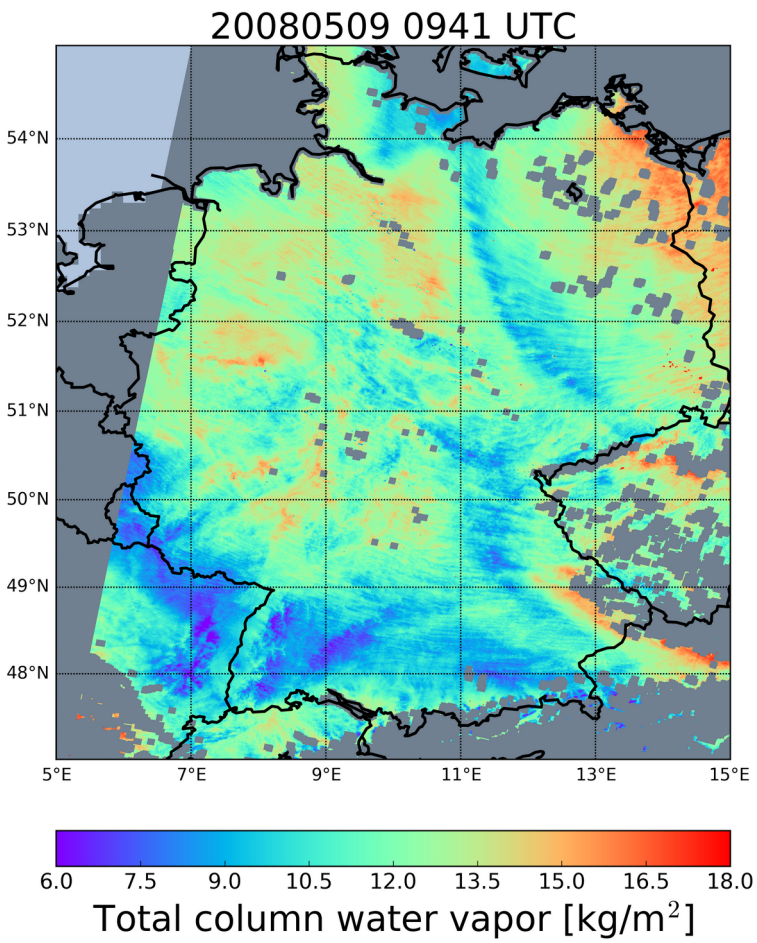
Negative spatial autocorrelation, I < 0

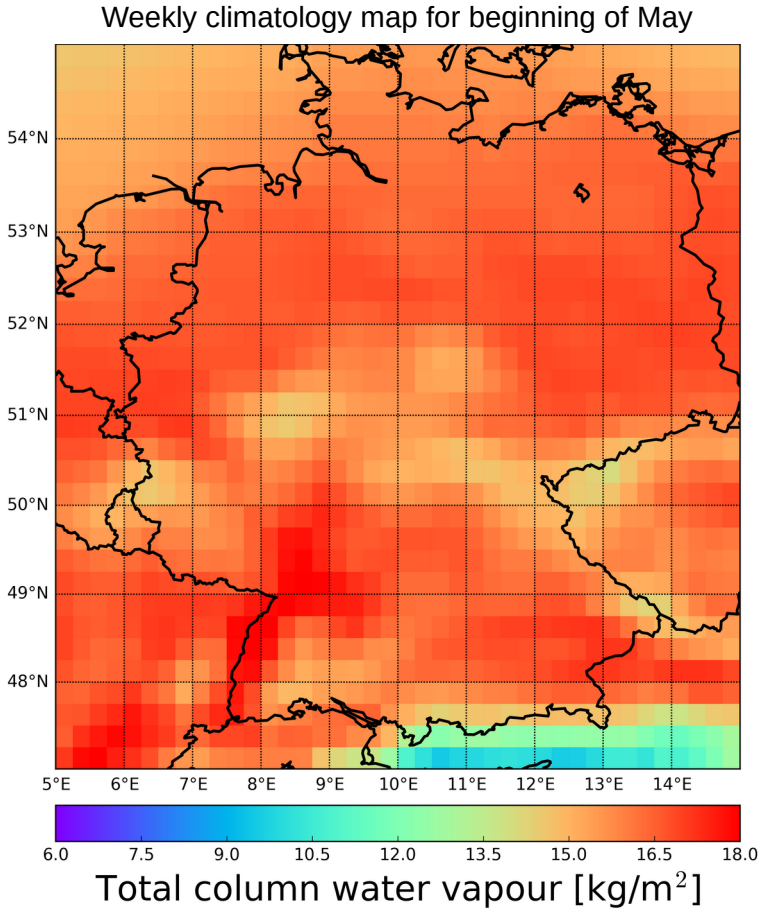
From Zhu & Liu, 2018

Local Moran's I (Anselin, 1995)

- Assess feature similarity between neighboring data points
- Spatial weights object W

Spatial autocorrelation parameters





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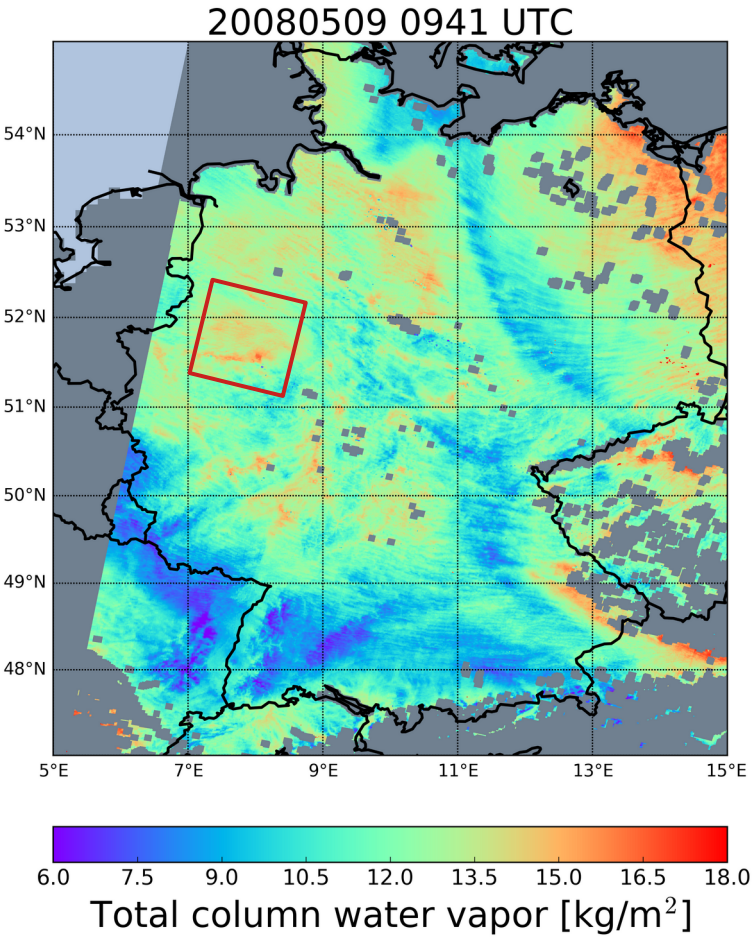

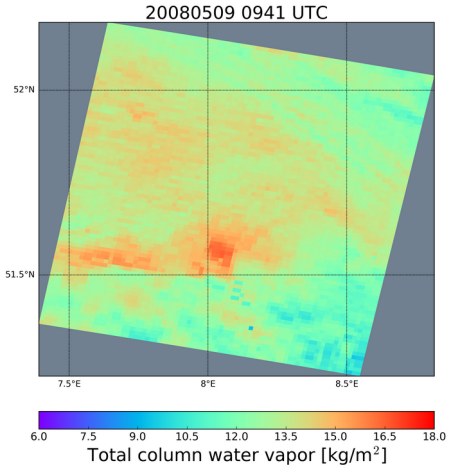

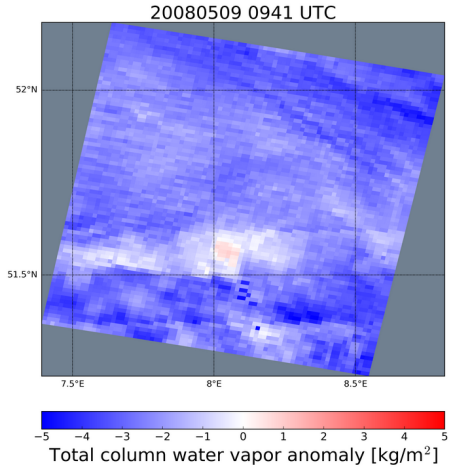

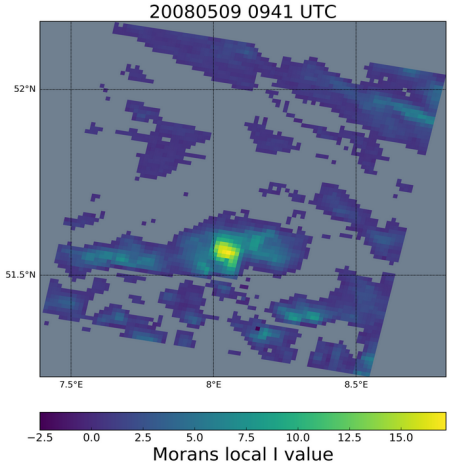

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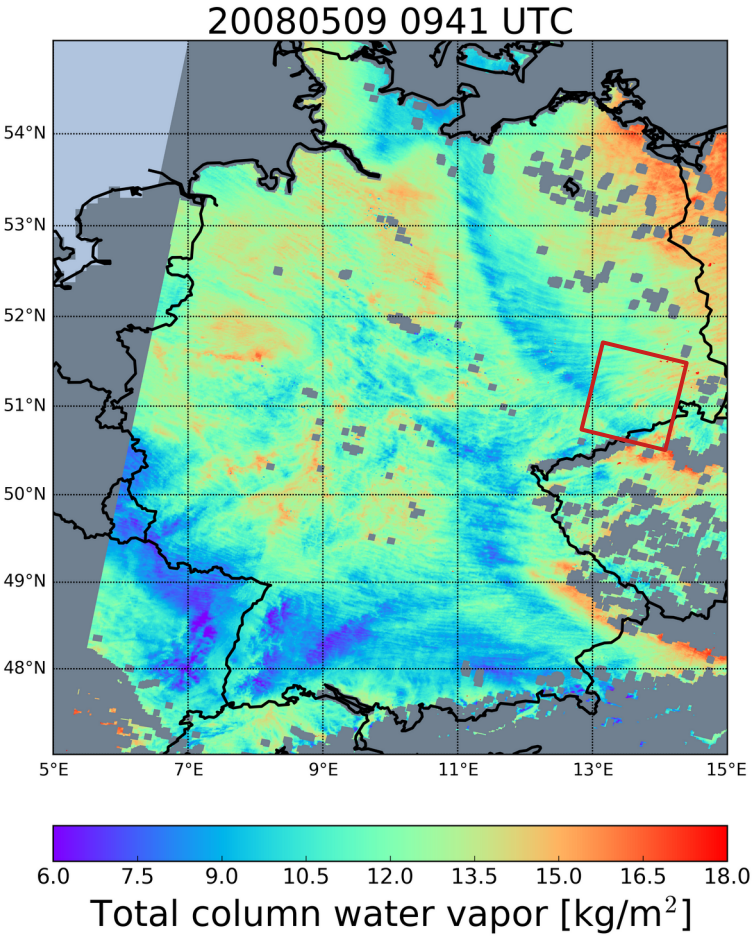

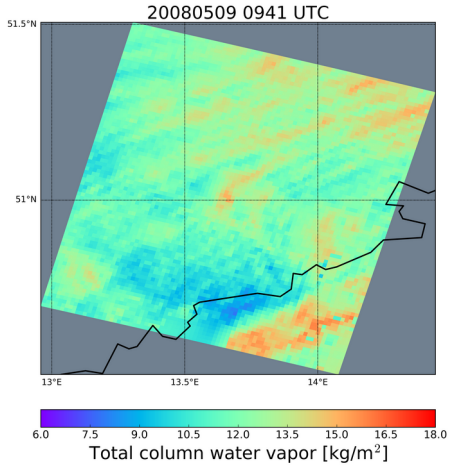

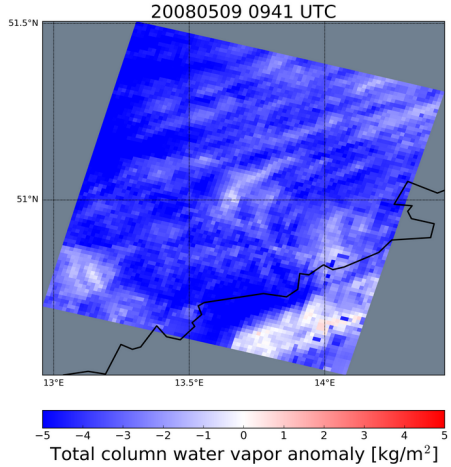

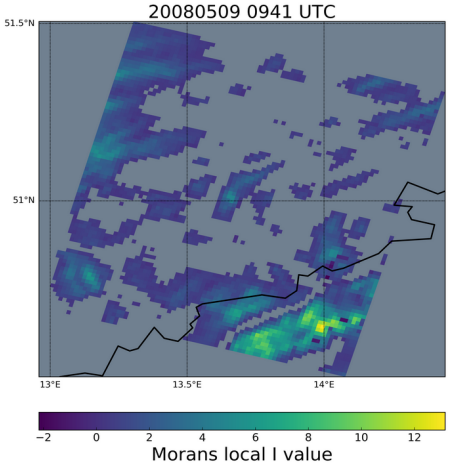

Conclusions

Our approach is two-fold in this project

- **Match-up of various observational datasets for statistical study on CI detection**
  - Finished successful set-up, processing and evaluation of OLCI/MODIS TCWV retrievals
  - Finished collection and preparation match-up of OLCI, GPS and MSG-SEVIRI satellite observations
  - Working on statistical study to assess potential of high spatial and temporal resolution TCWV fields for early CI detection (and enhanced precipitation nowcasting)

RealPEP

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- **Preparations for future MTG-FCI TCWV retrievals**
  - Finished first version of set-up of MSG-SEVIRI TCWV retrieval; low precision, problems with cloud mask
  - RTTOV-based sensitivity studies for MTG-FCI TCWV retrievals indicate potential of more accurate TCWV retrievals
  - Working on first TCWV retrievals with test simulation data of MTG-FCI

RealPEP

Outlook

Our approach is two-fold in this project

- **Match-up of various observational datasets for statistical study on CI detection**
  - Also process OLCI data for years 2019 and 2020, include observations from Sentinel-3b
  - Elaborate/refine descriptors for TCWV variability and CI detection in statistical study
  - Merge with QPN fields from Ricardo

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  - Elaborate/refine descriptors for TCWV variability and CI detection in statistical study
  - Merge with QPN fields from Ricardo

- **Preparations for future MTG-FCI TCWV retrievals**
  - Switch to CLAAS V2 MSG-SEVIRI cloud products and perform extended evaluation
  - Perform MTG-FCI TCWV retrievals for test simulation data and evaluation

Thank you!

Data (Future data)

- Geostationary satellite **MSG/SEVIRI** **(2021: MTG/FCI(,LI,IRS))**
  - Time resolution: 15 min.
  - Spatial resolution: ~ 4x7 km^2
  - Variables from SEVIRI: CF, COT, REF, CPH, CWP, CTP, CTH, CTT, (TCWV)
  - **TCWV,** (Lightning, clear sky profiles of humidity and temperature)

- Polar orbiting satellites:
  - Passive imagers **MODIS** + **MERIS/AATSR** + **OLCI/SLSTR** **(2021+ Sentinel 3 c/d, 2020 POST-EPS)**:
    - Time resolution: ~ 2 times daily (n times!)
    - Spatial resolution: ~ 1x1 km^2 (0.5kmx0.5km)
    - Variables: CF, COT, REF, CPH, CWP, CTP, CTH, CTT, TCWV
  - Active instruments **CPR** and **CALIOP** **(202X Earthcare , but difficult orbit for Polar):**
    - Time resolution: ~ 2 times daily
    - Spatial resolution: 1-d track
    - Variables: vertical profiles of clouds, cloud typing

- Ground-based observations **GNSS:**
  - Time resolution: 15 min.
  - Spatial resolution: ~400 stations in German network
  - Variable: TCWV

Objective weather type classification

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DWD weather classification for Germany and neighbouring areas (see website DWD)

- Results of the operational numerical weather analysis and forecast system (12-UTC analysis and forecasts until 7 days) of the DWD.
- 40 Classes, based on meteorological criteria:
  - wind direction (advection direction of air masses)
  - cyclonality (high- or low pressure influence)
  - humidity of the atmosphere

- **Relation to (deep) convective systems**
  - During fair weather situations in Germany, anti-cyclonic and easterly flow, local processes will have larger influence on changes of TCWV then during westerly flows where synoptic disturbances might dominate
  - Preference of humid SW flow for intense thunderstorms, which produce tornadoes and high precipitation amounts (Bissoli and Müller-Westermeier, 2005)

RealPEP

Stratification by objective weather type classification

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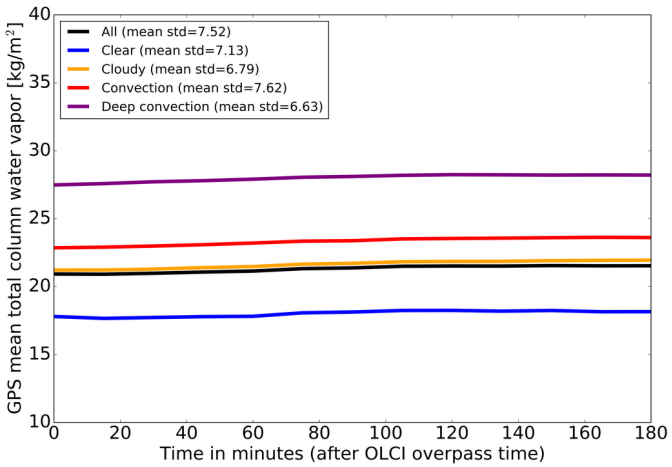
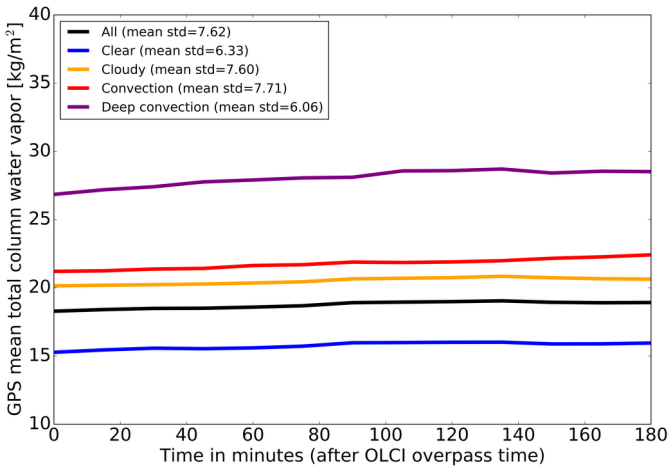
GPS TCWV temporal evolution

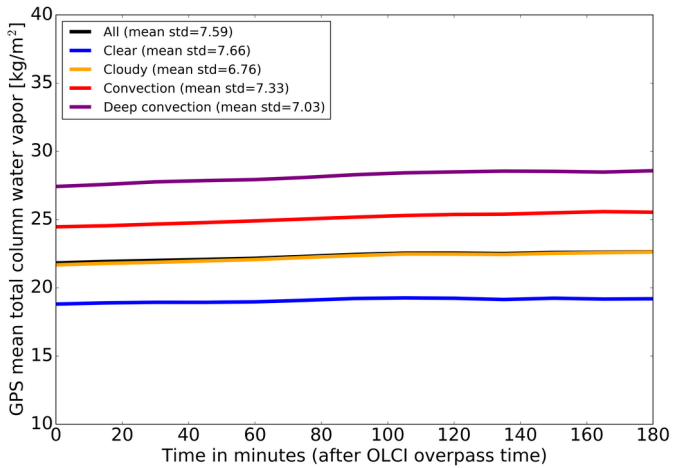
All large scale-conditions



Easterly flow with anti-cyclonic conditions near surface



South-westerly flow



RealPEP

Case study day 19 July 2017

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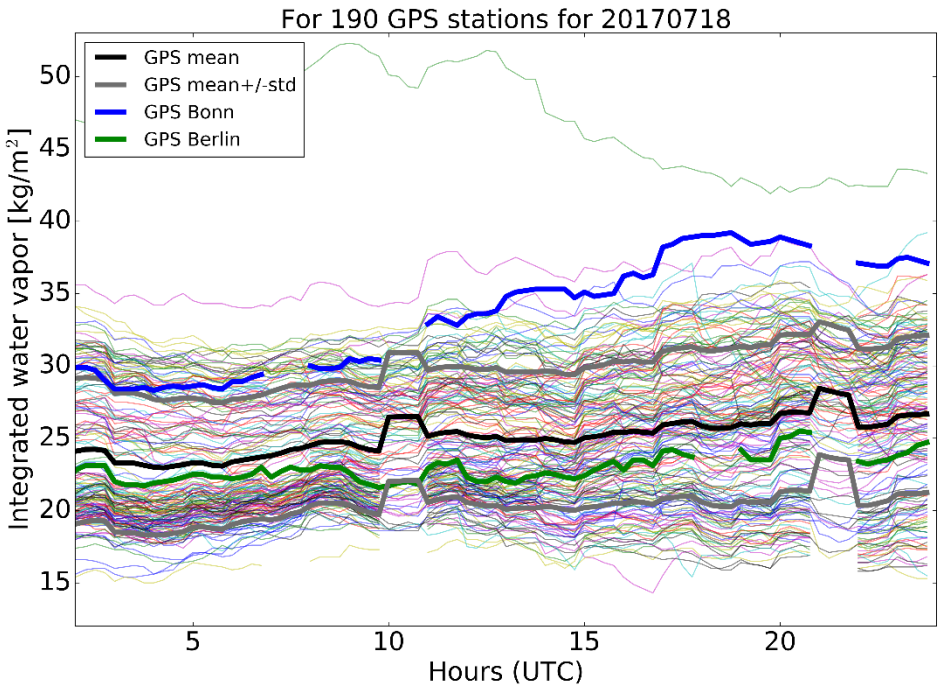
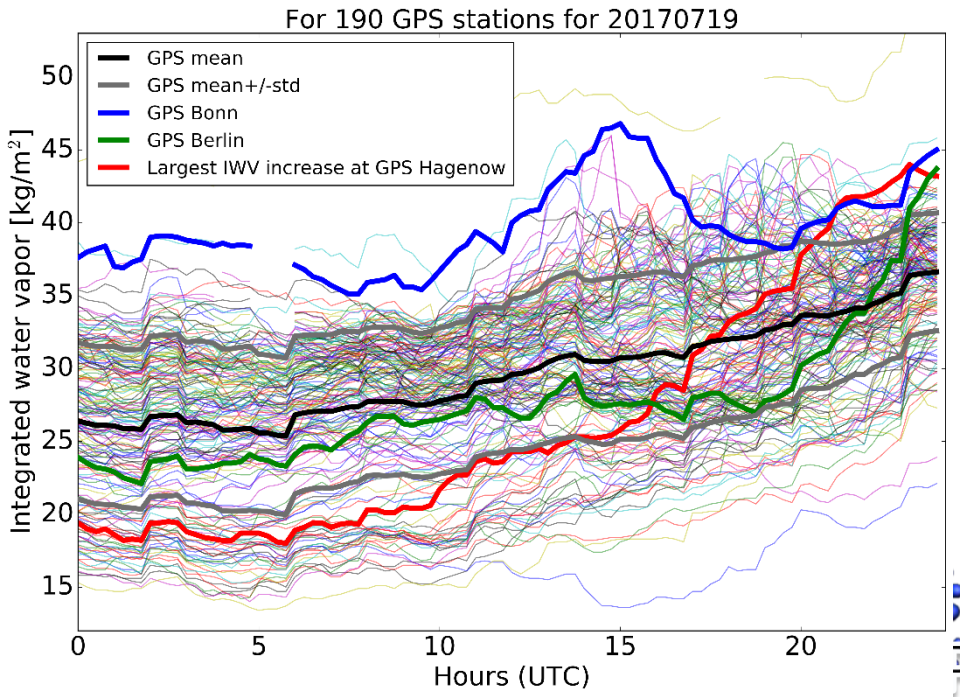
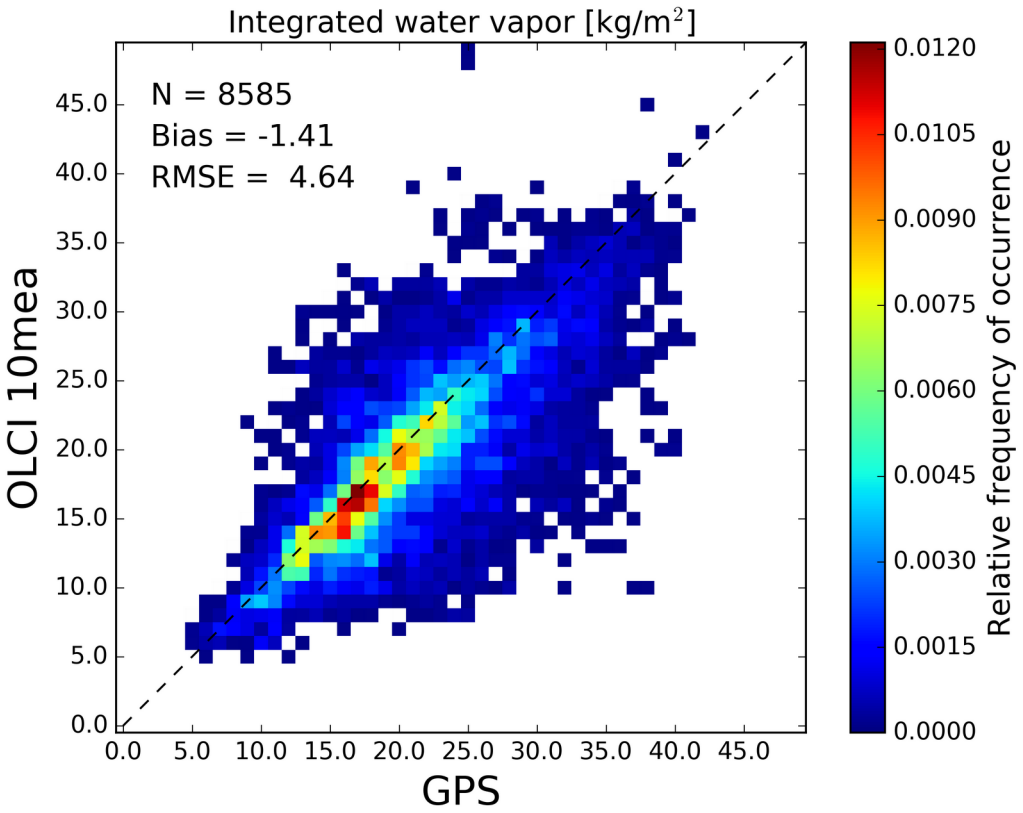
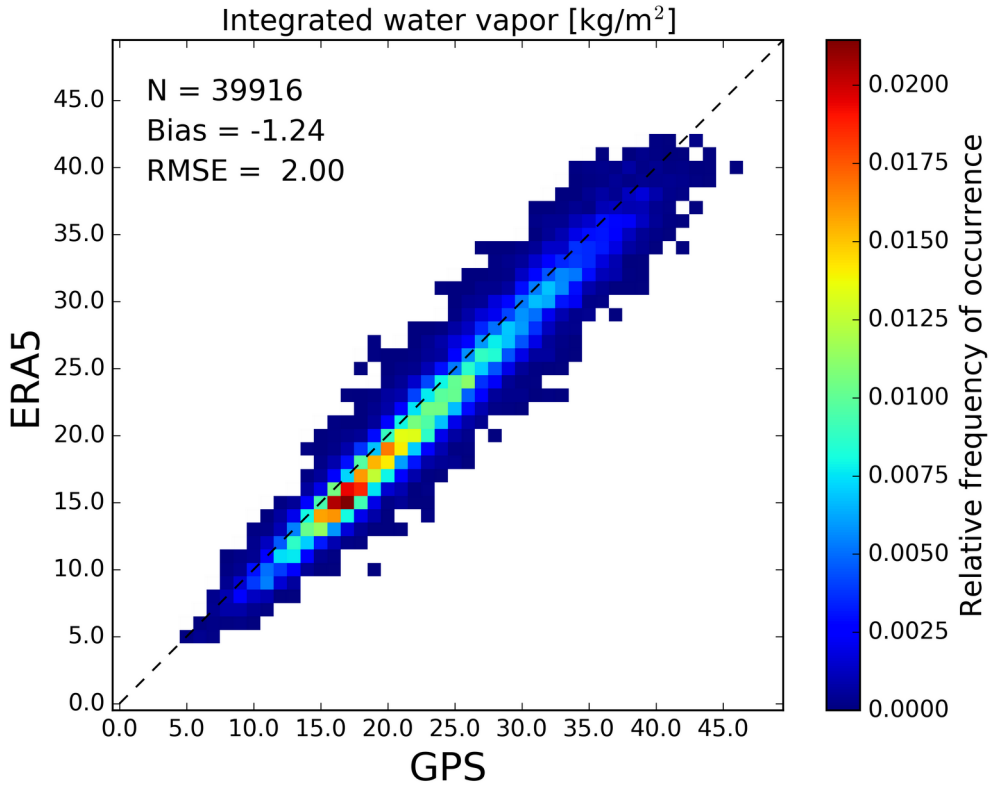
GPS TCWV temporal evolution



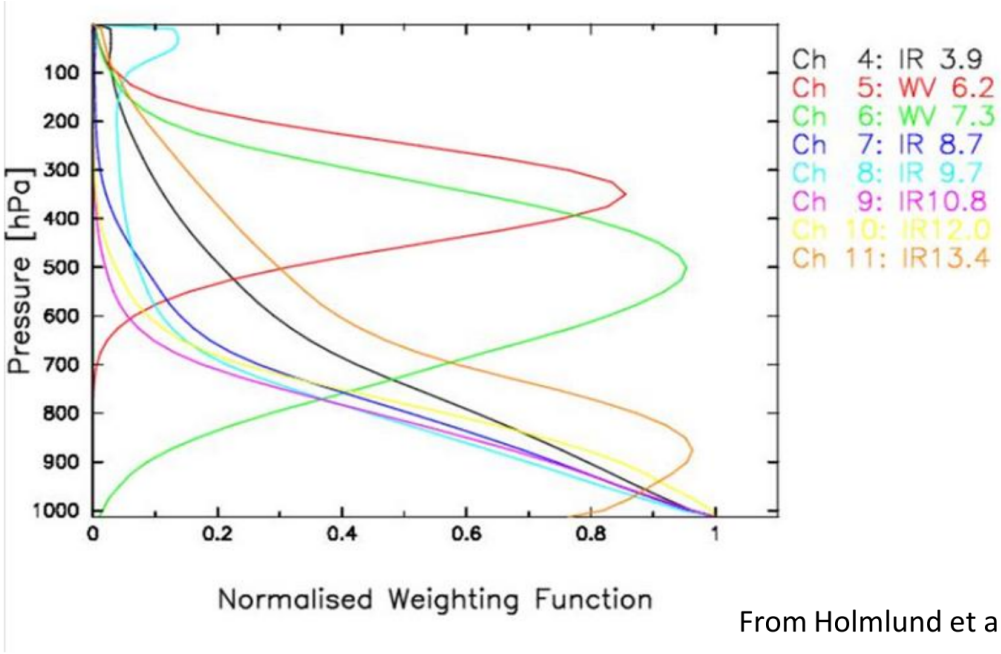


OLCI integrated water vapor

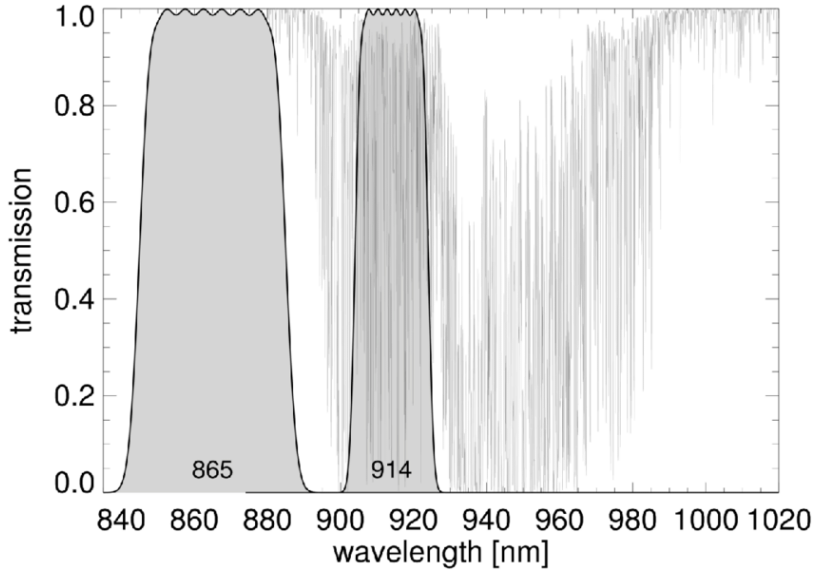




MSG-SEVIRI vs MTG-FCI



From Holmlund et al. 2004



From Diedrich et al. 2012

MSG-SEVIRI vs. MTG-FCI TCWV retrievals

MSG-SEVIRI

- 3 km spatial resolution at sub-satellite point
- 15 min temporal resolution
- Spectral channels:

Table 1. Spectral channel characteristics of SEVIRI providing central, minimum, and maximum wavelength of the channels and whether the channel is an absorption or a window channel. A concise summary of the use of the spectral channels is given in the section titled "SEVERI spectral channels."

Channel no.		Characteristics of spectral band (μm)			Main gaseous absorber or window
		λ_{cen}	λ_{min}	λ_{max}	
1	VIS0.6	0.635	0.56	0.71	Window
2	VIS0.8	0.81	0.74	0.88	Window
3	NIR1.6	1.64	1.50	1.78	Window
4	IR3.9	3.90	3.48	4.36	Window
5	WV6.2	6.25	5.35	7.15	Water vapor
6	WV7.3	7.35	6.85	7.85	Water vapor
7	IR8.7	8.70	8.30	9.10	Window
8	IR9.7	9.66	9.38	9.94	Ozone
9	IR10.8	10.80	9.80	11.80	Window
10	IR12.0	12.00	11.00	13.00	Window
11	IR13.4	13.40	12.40	14.40	Carbon dioxide
12	HRV	Broadband (about 0.4 – 1.1)			Window/water vapor

From Schmetz et al. 2002

MSG-SEVIRI vs. MTG-FCI TCWV retrievals

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MSG-SEVIRI

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12	HRV	Broadband (about 0.4 – 1.1)			Window/water vapor

From Schmetz et al. 2002

MTG-FCI

- 1 km spatial resolution at sub-satellite point for VIS/NIR channels
- 10 min temporal resolution, 2.5 min for local scale (Europe)
- Spectral channels:

Instrument information

CHANNEL	CENTRE WAVELENGTH	SPECTRAL WIDTH	SPATIAL SAMPLING DISTANCE (SSD)
VIS 0.4	0.444 µm	0.060 µm	1.0 km
VIS 0.5	0.510 µm	0.040 µm	1.0 km
VIS 0.6	0.640 µm	0.050 µm	1.0 km; 0.5 km*
VIS 0.8	0.865 µm	0.050 µm	1.0 km
VIS 0.9	0.914 µm	0.020 µm	1.0 km
NIR 1.3	1.380 µm	0.030 µm	1.0 km
NIR 1.6	1.610 µm	0.050 µm	1.0 km
NIR 2.2	2.250 µm	0.050 µm	1.0 km; 0.5 km*
IR 3.8 (TIR)	3.800 µm	0.400 µm	2.0 km; 1.0 km*
WV 6.3	6.300 µm	1.000 µm	2.0 km
WV 7.3	7.350 µm	0.500 µm	2.0 km
IR 8.7 (TIR)	8.700 µm	0.400 µm	2.0 km
IR 9.7 (O_3)	9.660 µm	0.300 µm	2.0 km
IR 10.5 (TIR)	10.500 µm	0.700 µm	2.0 km; 1.0 km*
IR 12.3 (TIR)	12.300 µm	0.500 µm	2.0 km
IR 13.3 (CO_2)	13.300 µm	0.600 µm	2.0 km

From: https://www.eumetsat.int/website/home/Satellites/FutureSatellites/MeteosatThirdGeneration/MTGDesign/index.html

MSG-SEVIRI vs. MTG-FCI TCWV retrievals

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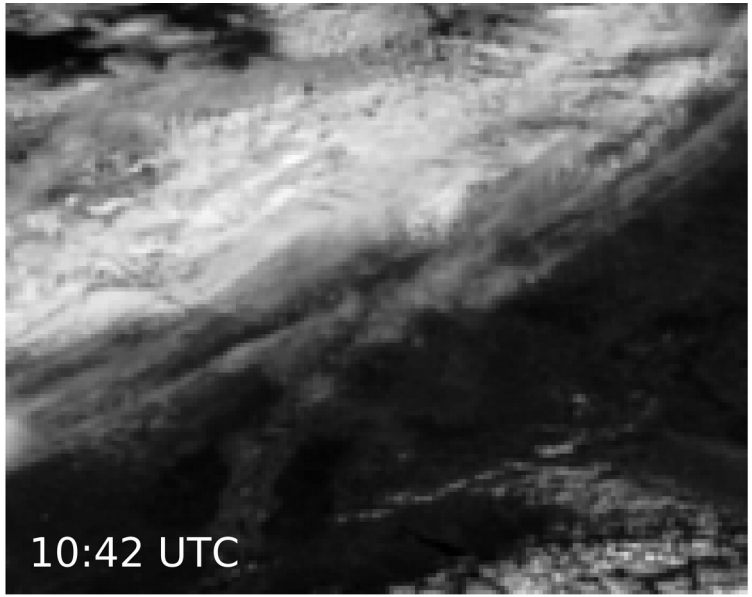
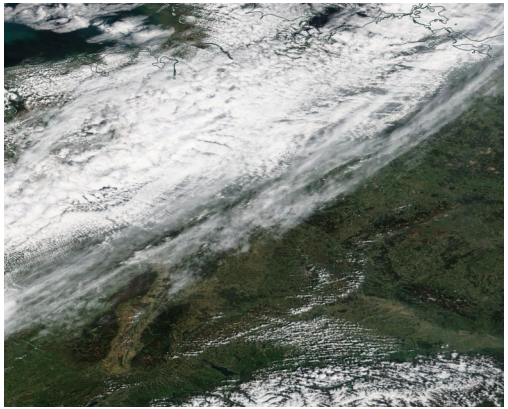
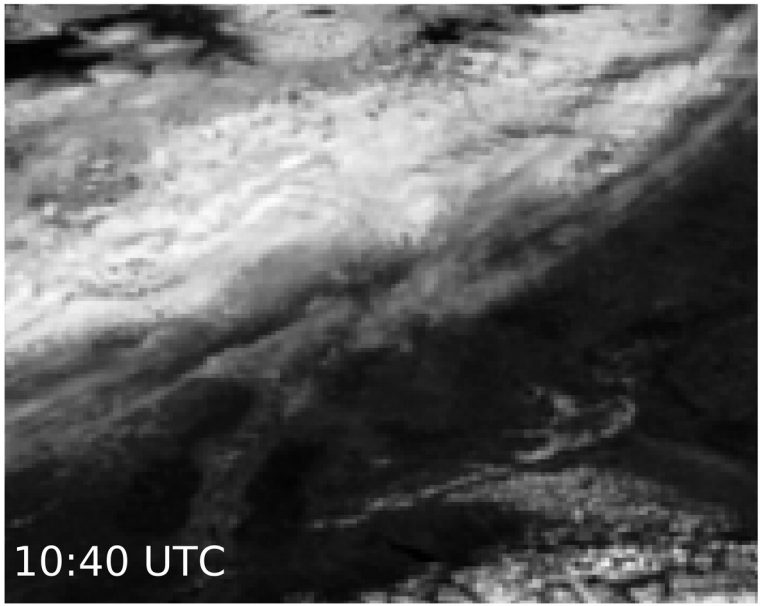
MSG-SEVIRI
VIS channel at 0.6 micron





MODIS-TERRA at 10.50 UTC

MTG-FCI
Simulated VIS channel at 0.6 micron



MSG-SEVIRI vs. MTG-FCI TCWV retrievals

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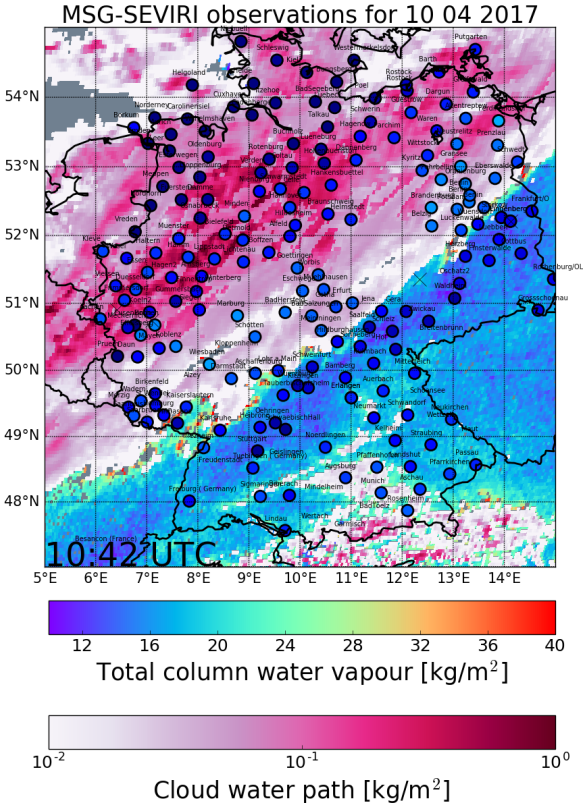
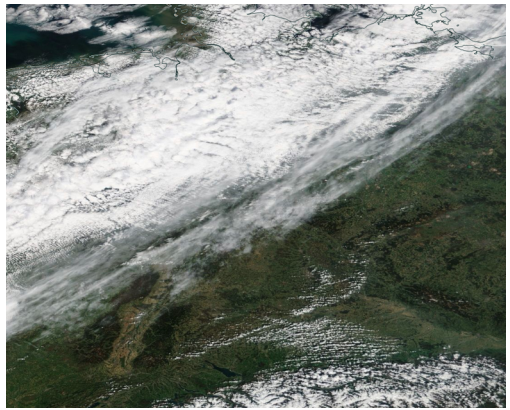
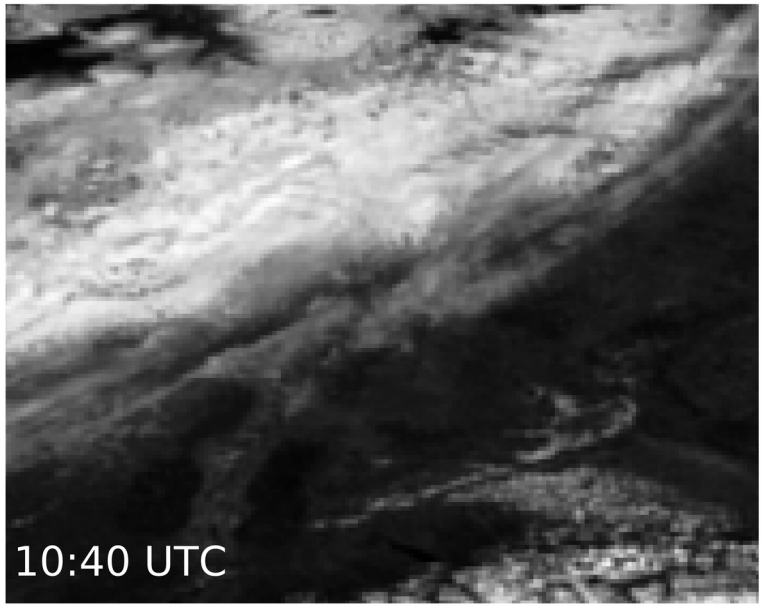
MSG-SEVIRI
VIS channel at 0.6 micron



MTG-FCI
Simulated VIS channel at 0.6 micron



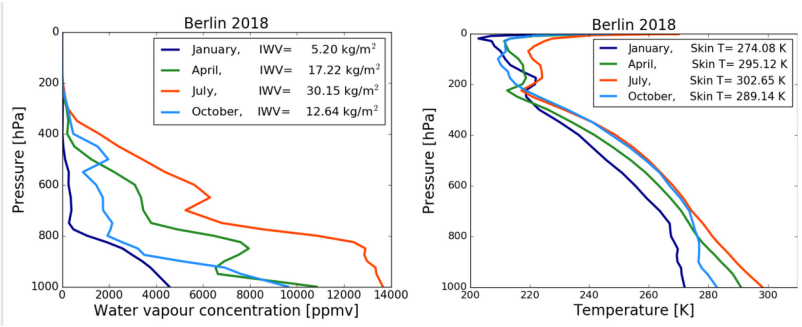
MODIS-TERRA at 10.50 UTC



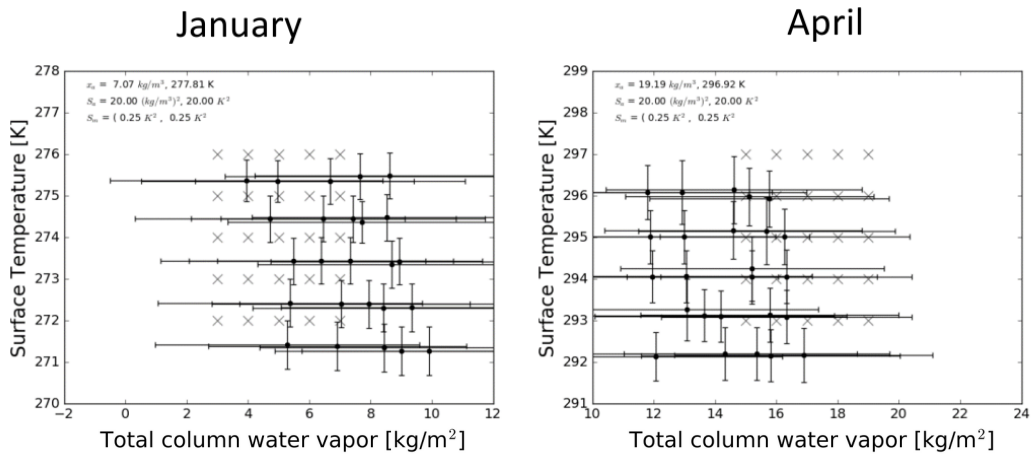
MSG-SEVIRI TCWV retrievals

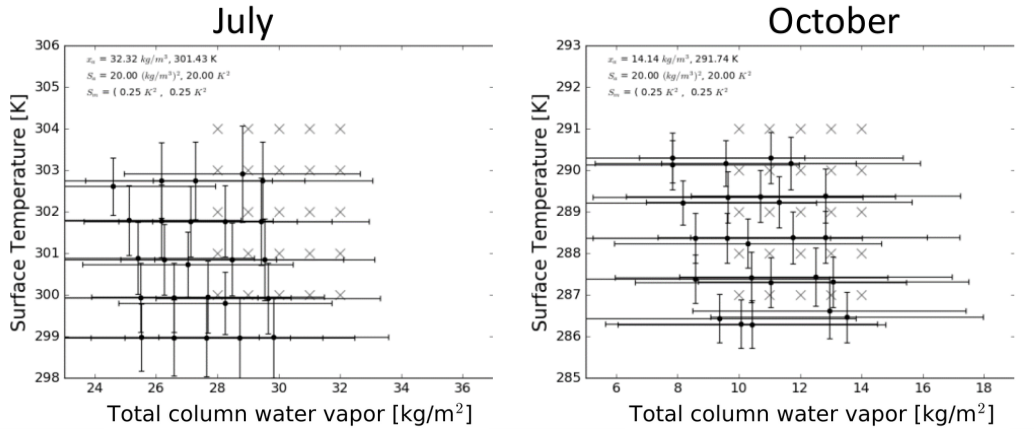
Retrieval errors & uncertainties

- Dots are ‘reality’
- Crosses are retrieved values
- Error bars are retrieval uncertainties



T and q profile shapes known from model reanalyses ERA5





MSG-SEVIRI TCWV retrievals

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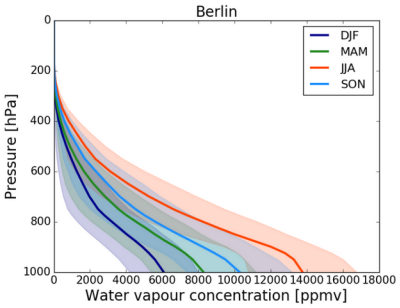
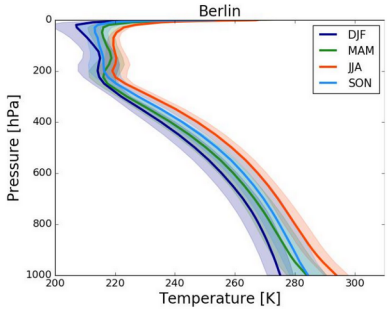
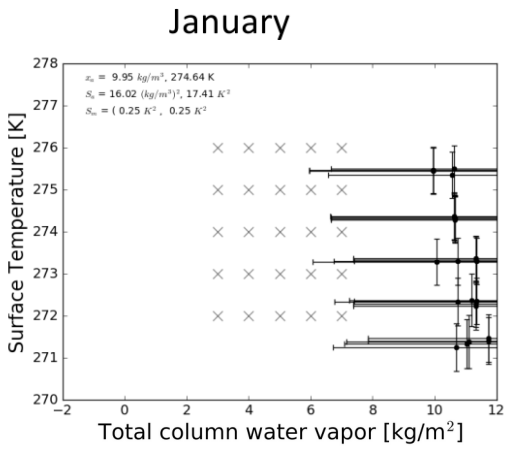
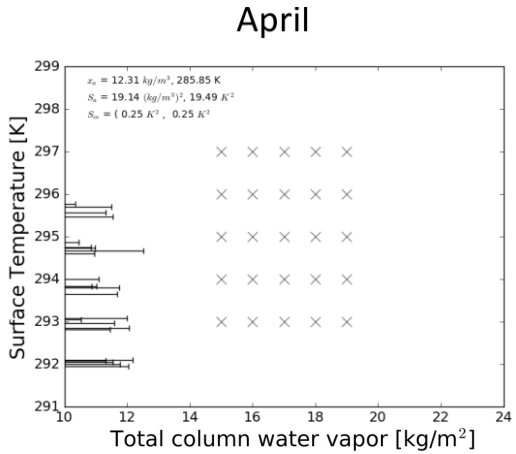
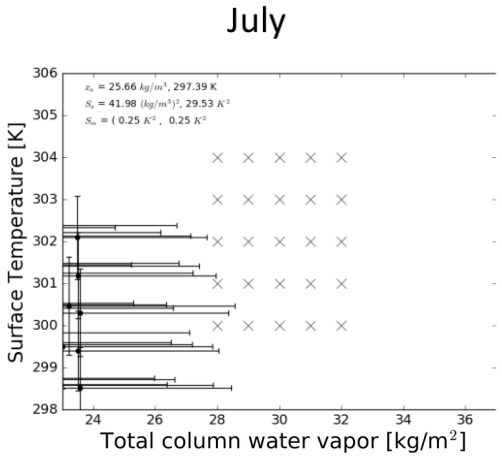


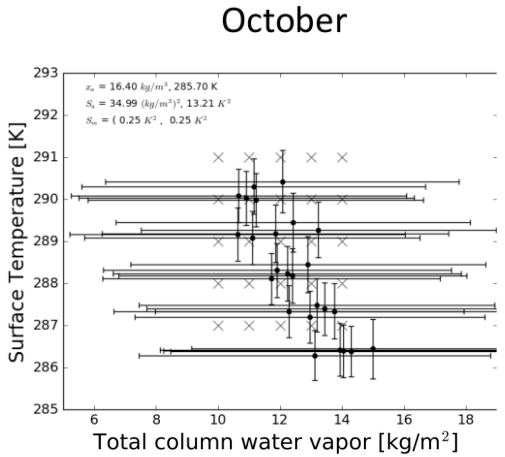


Climatological atmospheric profiles from 30 years of ERA5 data.
Mean profiles and standard deviation.









Towards MTG-FCI TCWV retrievals

Freie Universität Berlin

Retrieval errors & uncertainties

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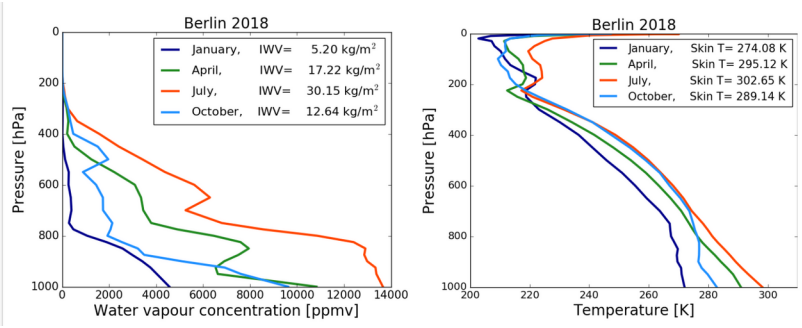

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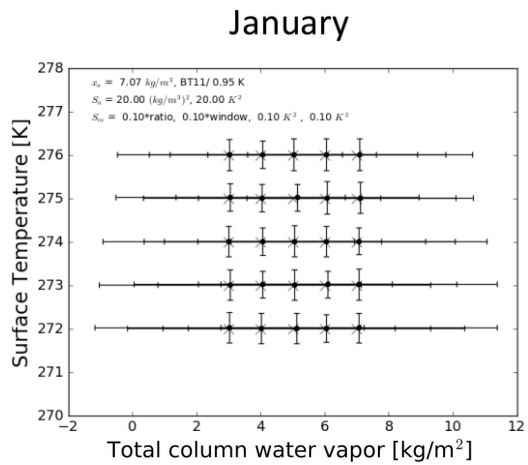

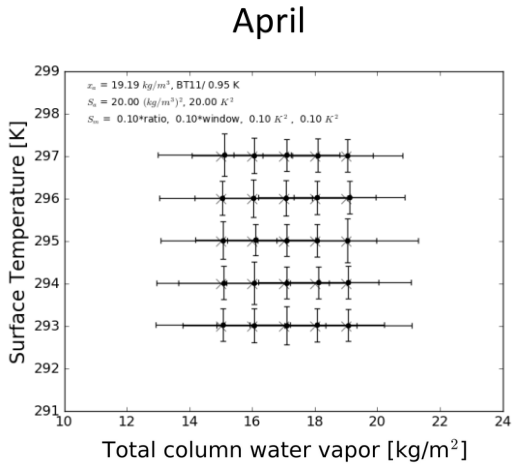

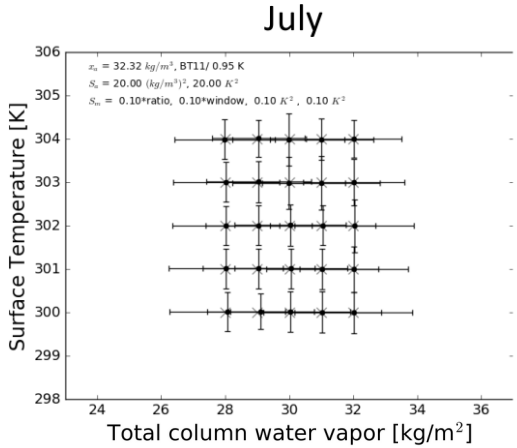

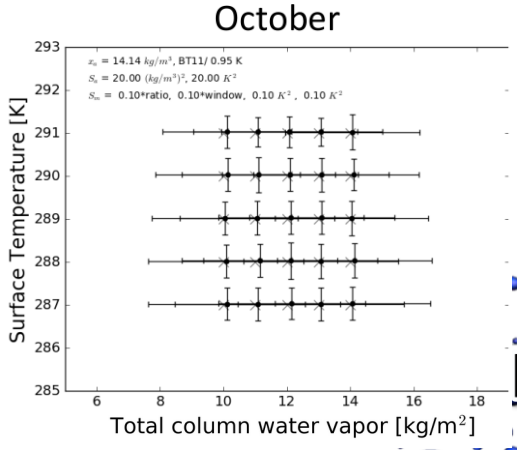

Towards MTG-FCI TCWV retrievals

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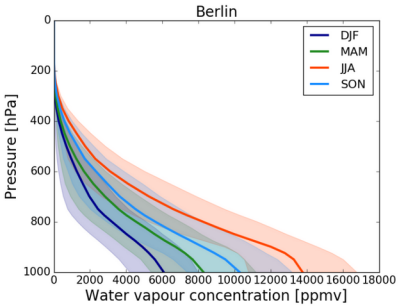

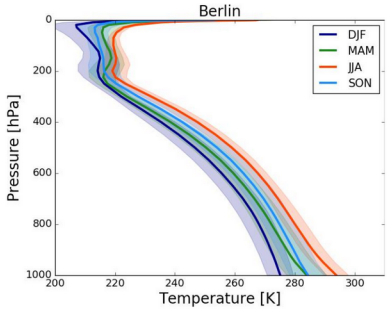

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