Altimeter 1DVar Wet Tropospheric Correction for Sentinel-3

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Objective

- In the frame of a EUMETSAT study, the goal is to study the potential of a 1DVAR retrieval for an operational ground processing

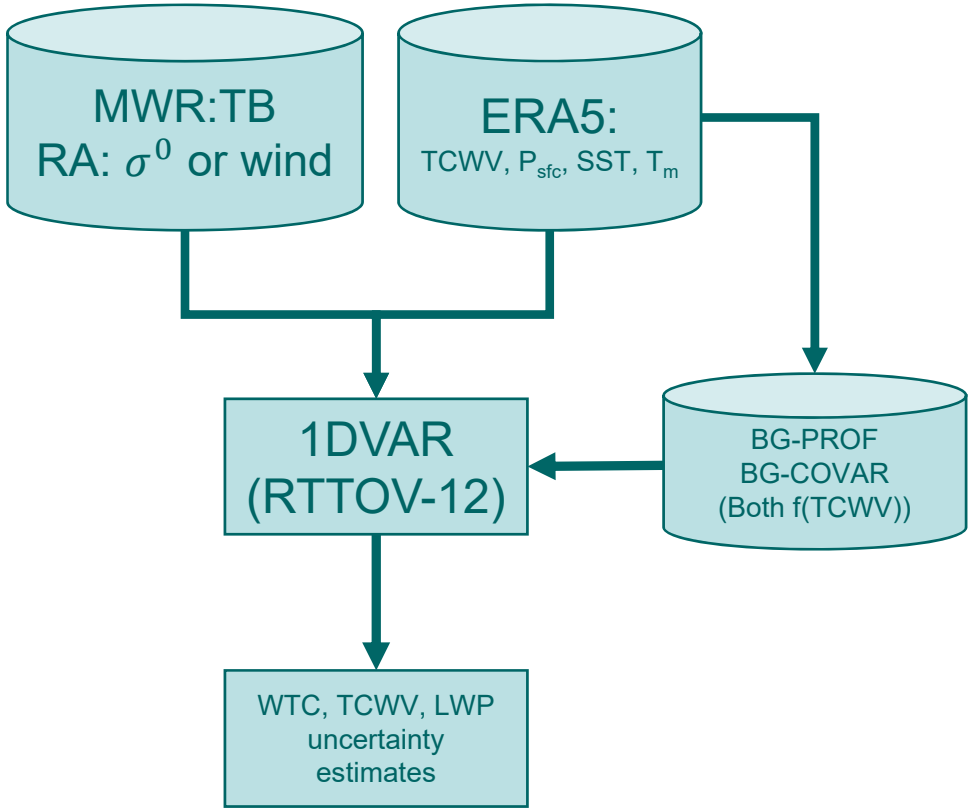
Overview

- Optimal estimation retrievals
- Retrieval implementation and heritage
- Bias-correction of S3-A MWR
- Validation of TCWV
- Validation of WTC
- Conclusions and Outlook

Optimal estimation and heritage algorithm

- Operational S3-A uses ANN (Neural Network solution) to retrieve WTC from MWR and auxiliary information (➔ "Heritage").
- Optimal estimation (1DVAR) provides advantages over heritage approach:
  - Based on robust and constantly improving tools developed by Eumetsat NWP SAF: RTTOV (radiative transfer) and 1DVAR
  - Mathematically and physically self-consistent in that it
    - Incorporates background knowledge in a Bayesian sense,
    - Provides physically self-consistent uncertainty metrics.
- Both (Heritage and 1DVAR) need careful monitoring and correction for biases in calibration.

Algorithm description



Input from S-3:

MWR TBs, σ^0

Input from NWP:

TCWV, PSFC, SST, T_m

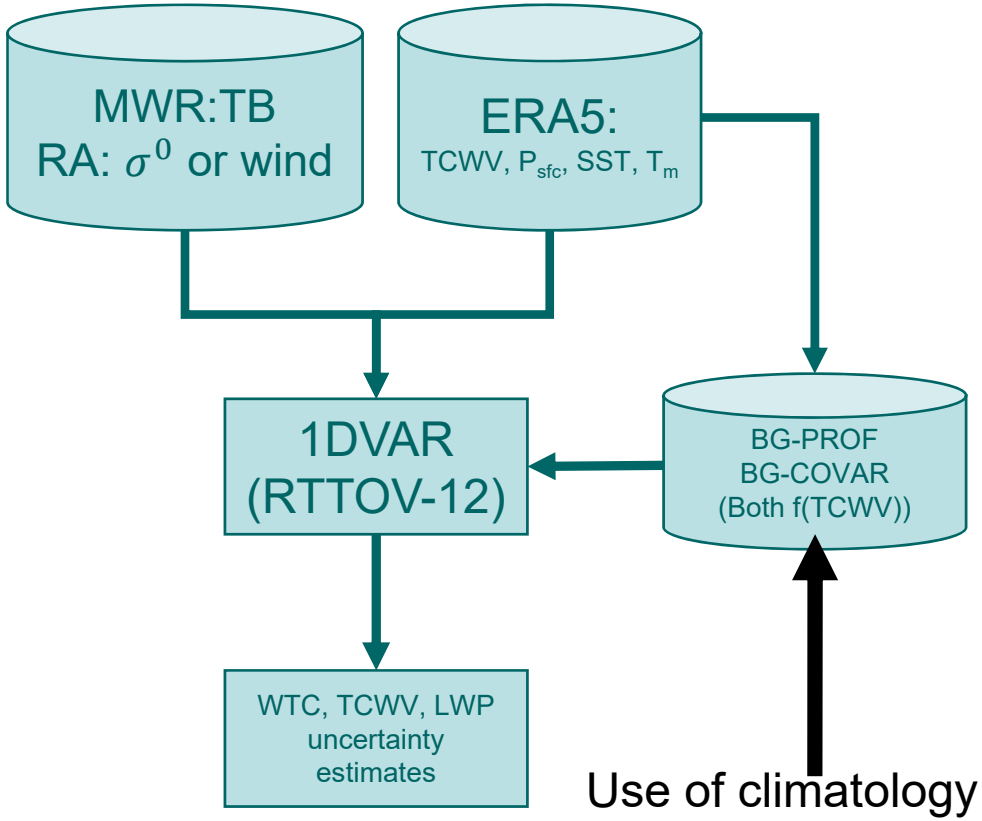
Input from NWP (static):

Background T, q profiles and background error covariance from NWP, both function of TCWV

Output:

TCWV + uncertainty
WTC + uncertainty
LWP + uncertainty

Algorithm description



Use of climatology demonstrated to provide similar performances

Input from S-3:

MWR TBs, σ^0

Input from NWP:

TCWV, PSFC, SST, TM

Input from NWP (static):

Background T, q profiles and background error covariance from NWP, both function of TCWV

Output:

TCWV + uncertainty
WTC + uncertainty
LWP + uncertainty

Datasets and Methods

- **S3-A MWR:** Use 6/15/2016 – 4/15/2017 S3-A data, ocean only, (roughly 10 million valid individual observations).
- **ATMS:** Created similar dataset from ATMS (nadir-only, 23 GHz, 31.4 GHz) for comparison. ATMS is operationally monitored by various operational weather services, so it is very well characterized in terms of calibration.
- **Retrieval:** NWP-SAF 1DVAR (V1.2) for retrieval and RTTOV-12.2 as forward model (maintained by NWP SAF, UK Met Office, EUMETSAT).
- **Background:** Collocated ERA analysis for background T/q profiles and background error covariance.
- **TCWV climatologies:** Used RSS, ERA-I, and ERA-5 climatologies to validate/compare retrieved Total Colum Water Vapor against.

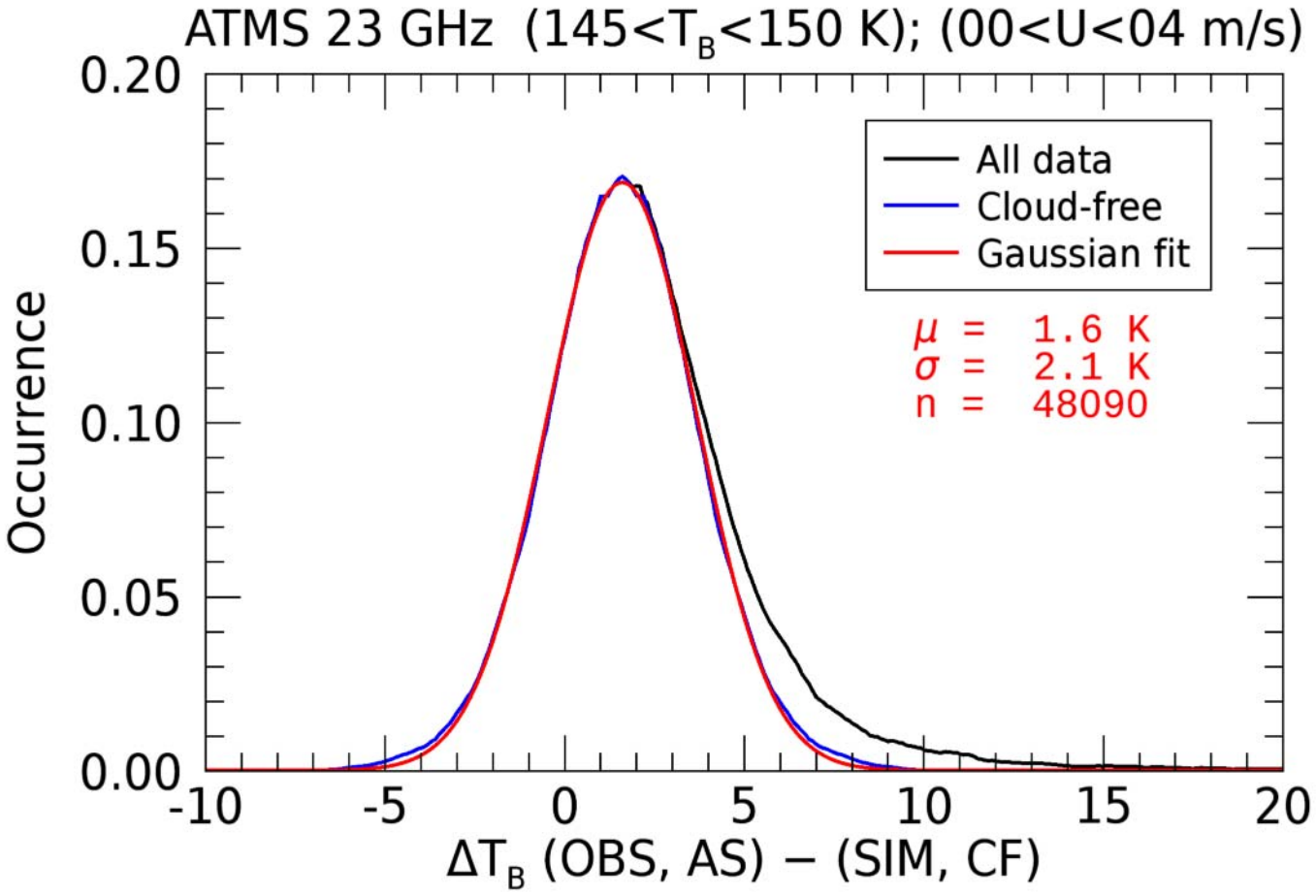
Bias correction

- 1DVAR (as ANN) makes use of RTM simulations. Bias correction account for differences between simulations and observations.

- Novel bias-correction method developed that allows to use
  - … ocean observations over range of actual TBs to derived O-B (observation TB – background TB) biases.

- Process:
  - Collocate individual observation with NWP T/q profiles.
  - Calculate cloud-free simulated TB.
  - Evaluate histograms of all-sky, observed minus cloud-free simulated TBs.
  - Stratify by wind speed and absolute TB.

Histogram of difference
Observed (all-sky) – Simulated (cloud-free)



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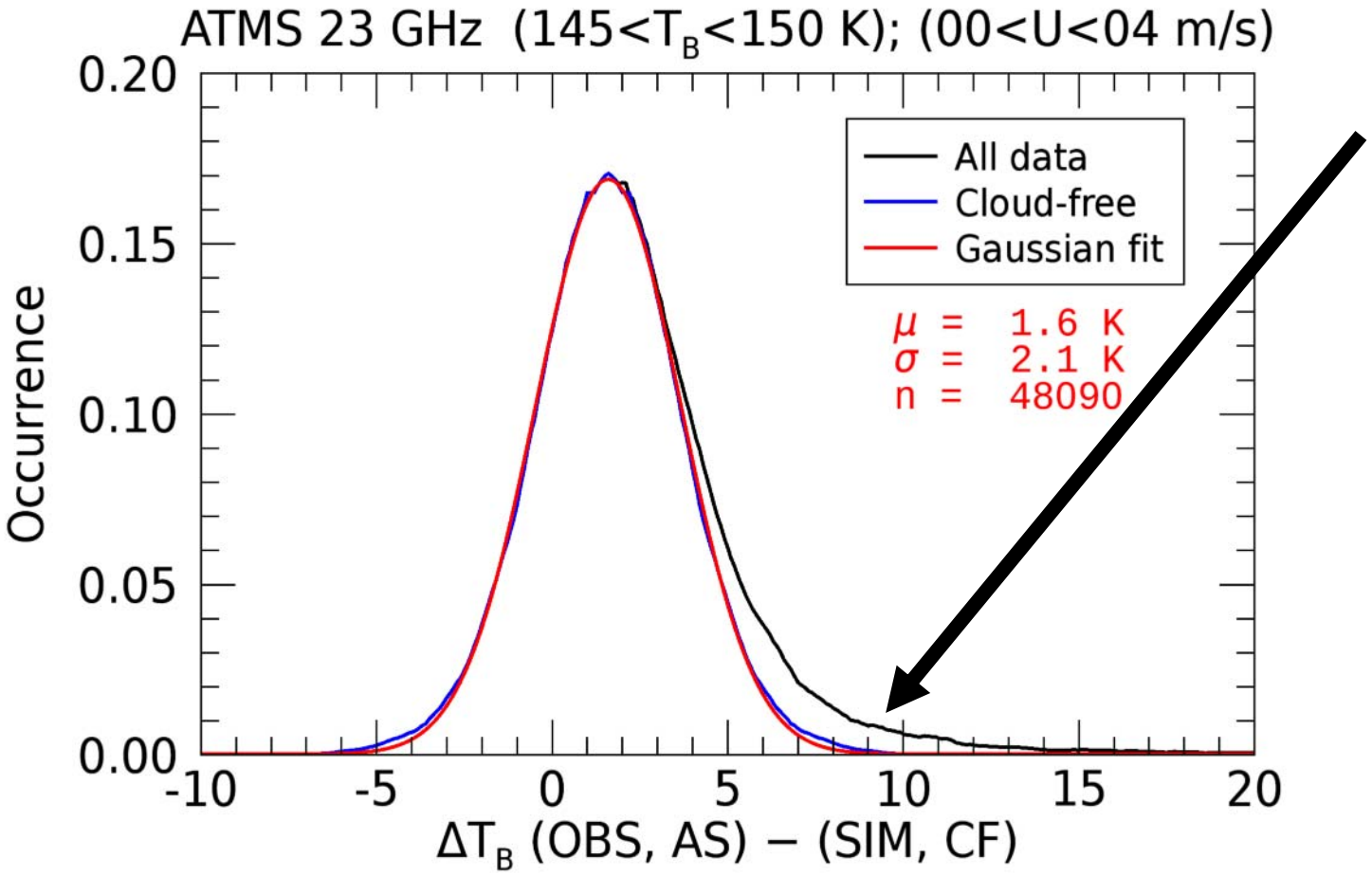
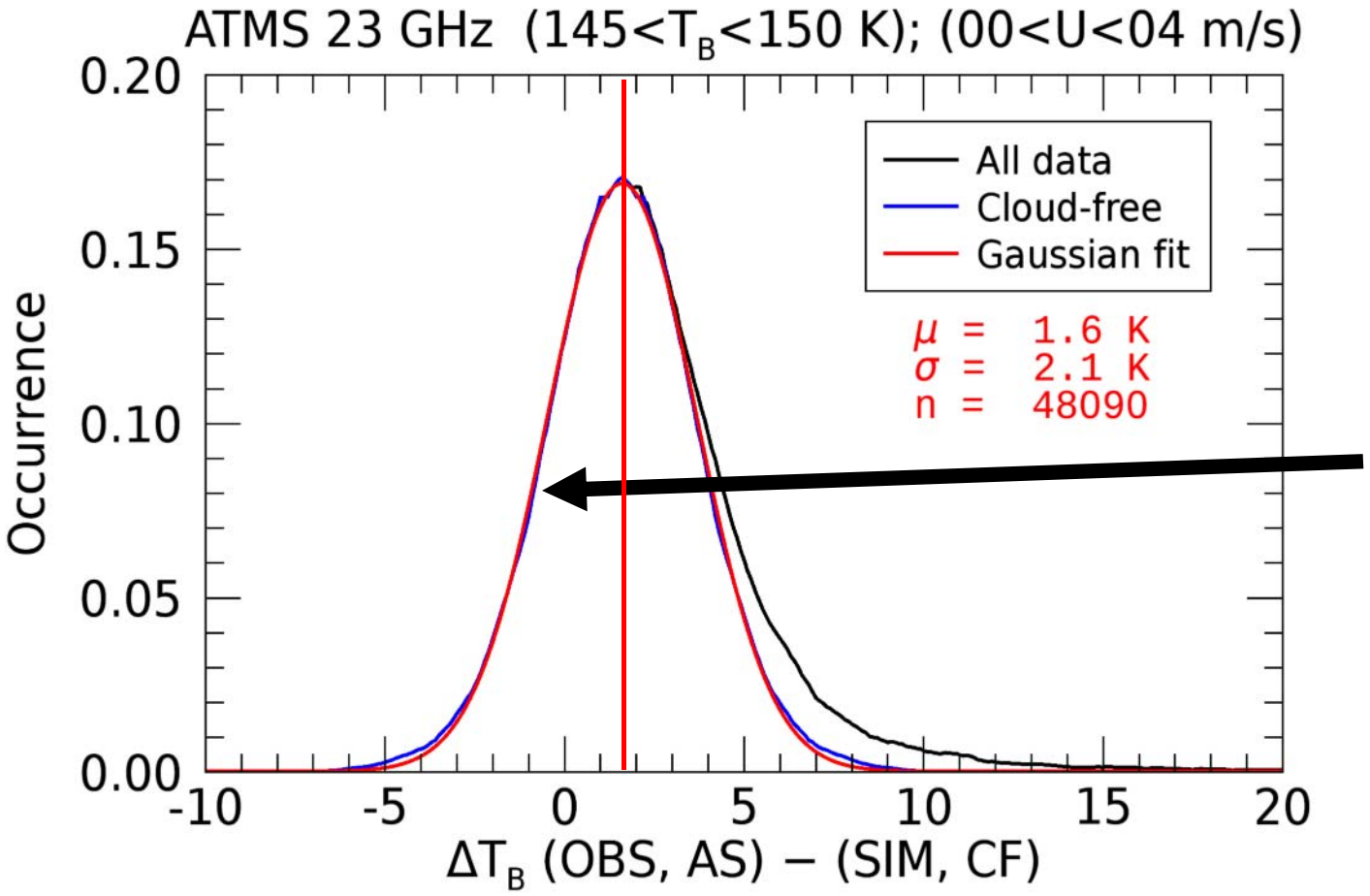


Long tail:

Cloudy observations, which are warmer than the simulated cloud-free TBs

We are not interested in those

Histogram of difference
Observed (all-sky) – Simulated (cloud-free)

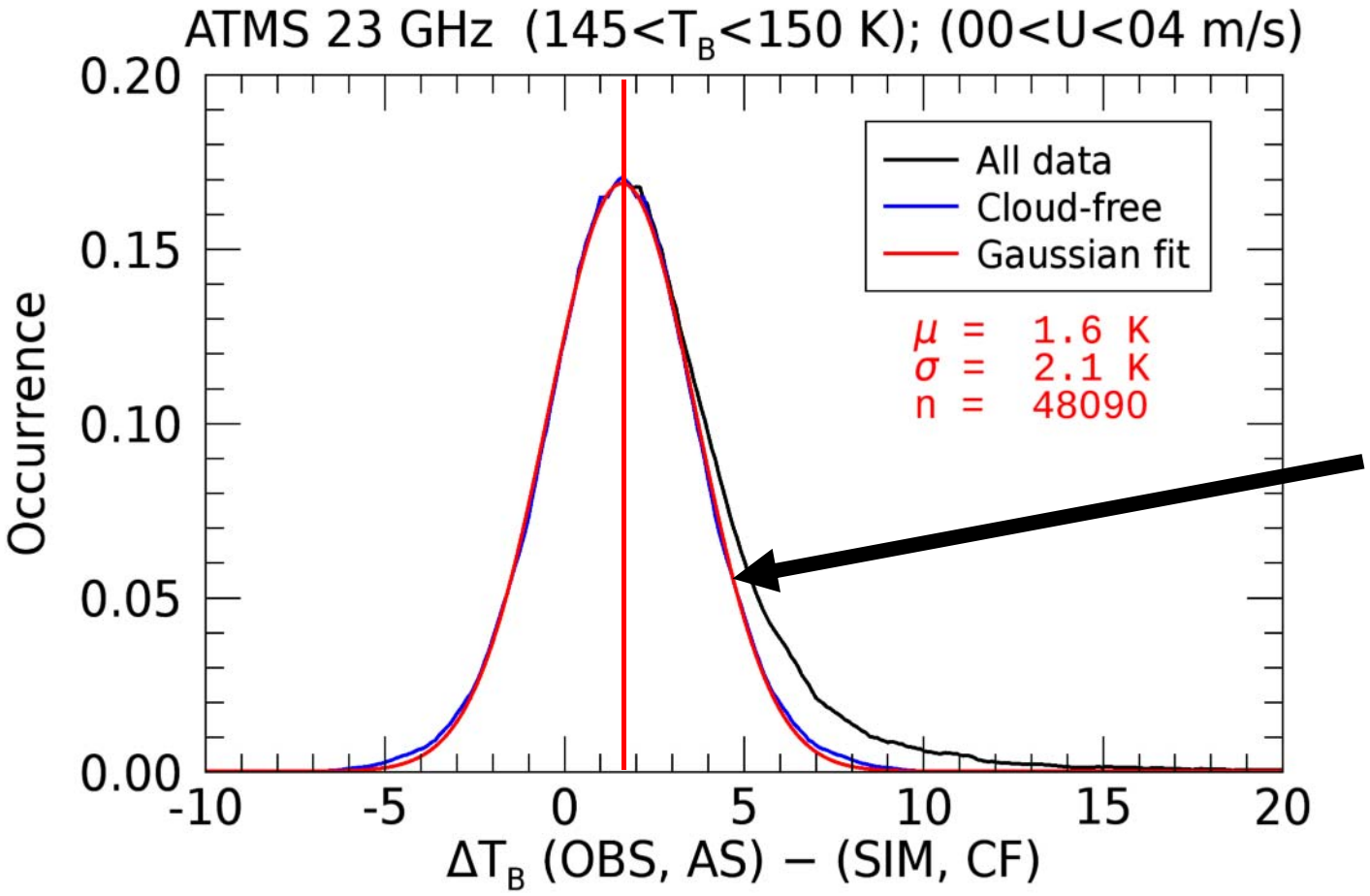


Left:

Observed TBs colder than simulated cloud-free

These are cloud-free observations, plus sensor noise and collocation uncertainty.

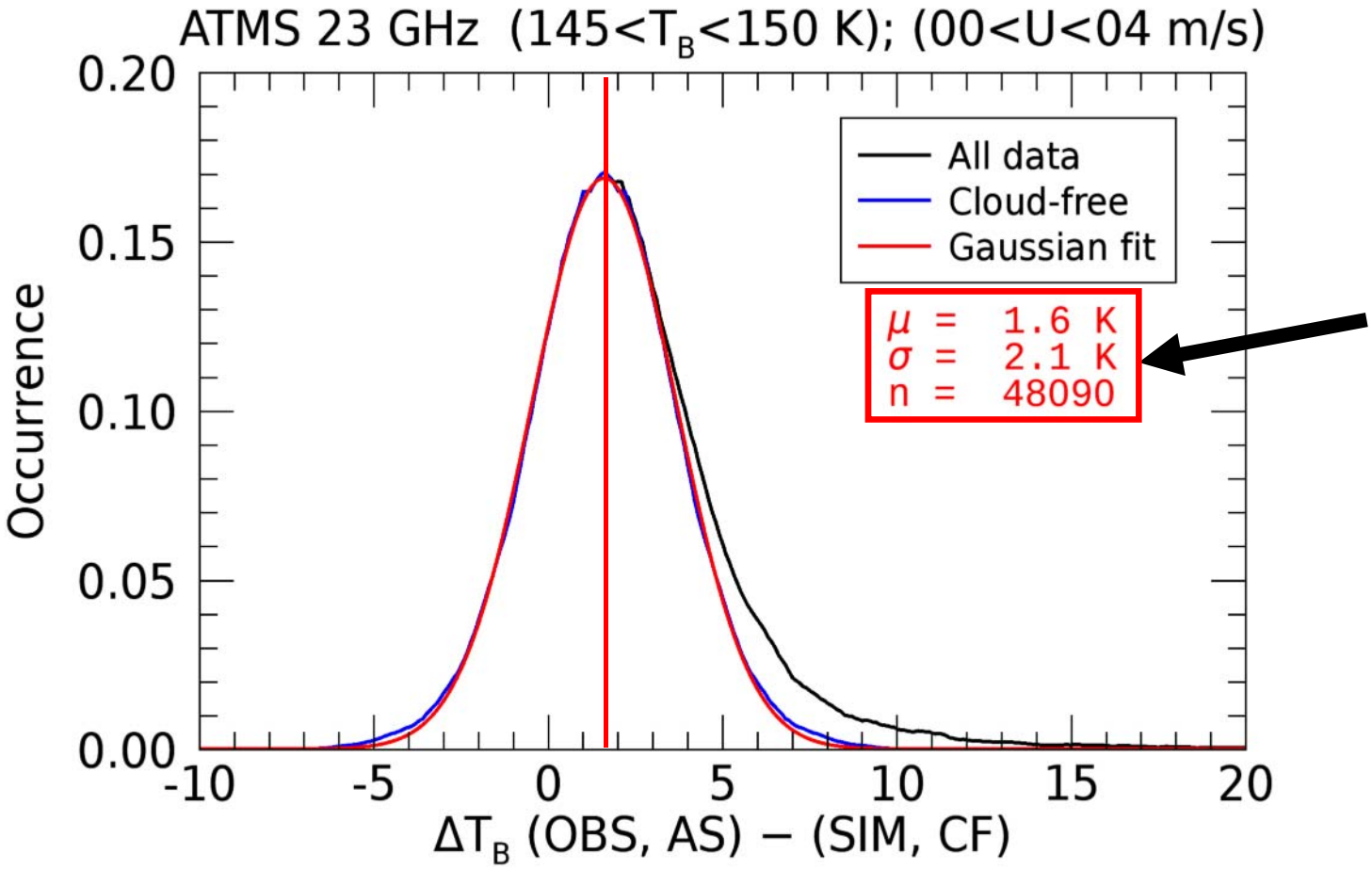
Histogram of difference
Observed (all-sky) – Simulated (cloud-free)



Red/ blue curve:

Left-side mirrored and gaussian fit

Histogram of difference
Observed (all-sky) – Simulated (cloud-free)



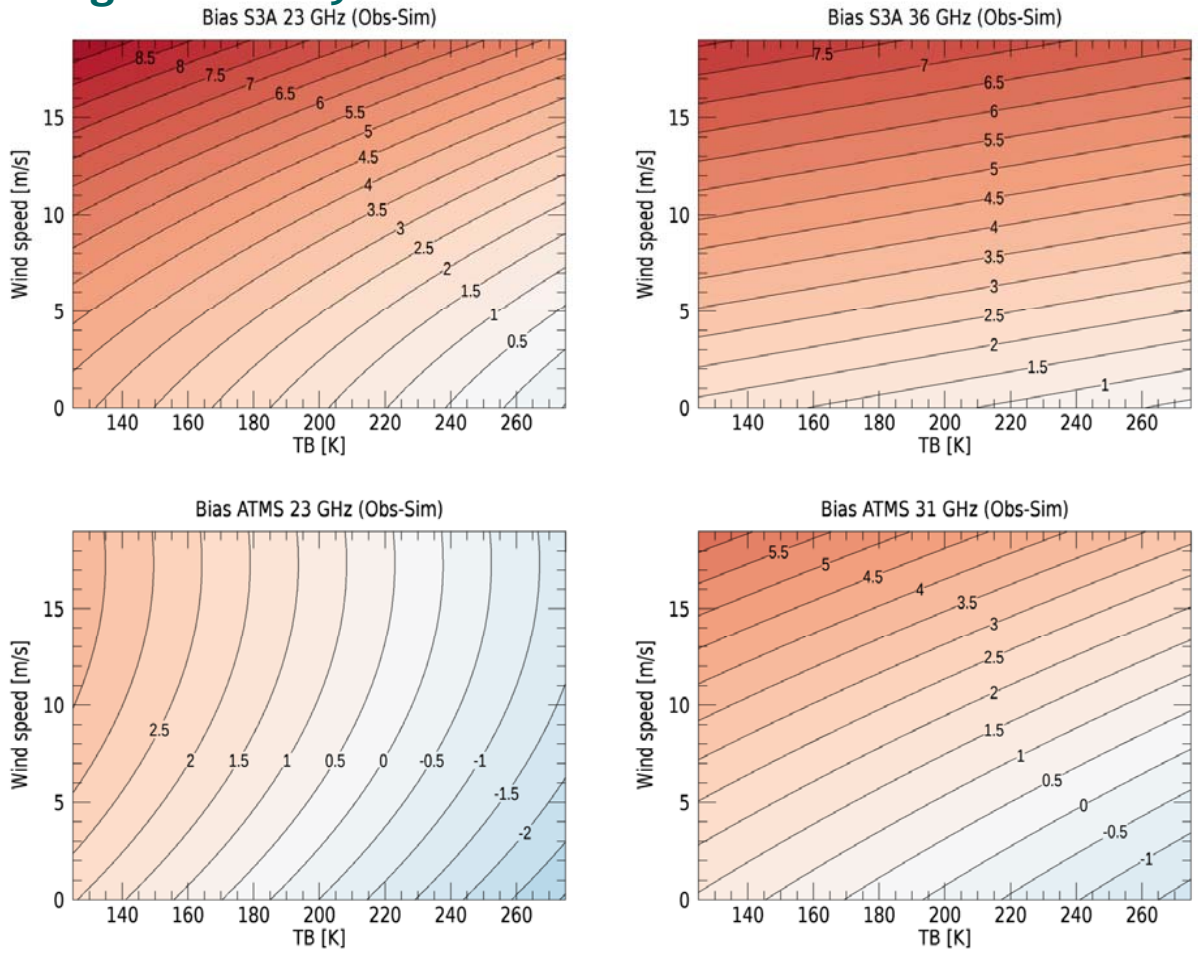
Red/ blue curve:

Parameters of Gaussian fit.

μ : is the bias

Bias correction

- Derive biases for different TBs and wind speeds.
- Fit bias against TB, wind.



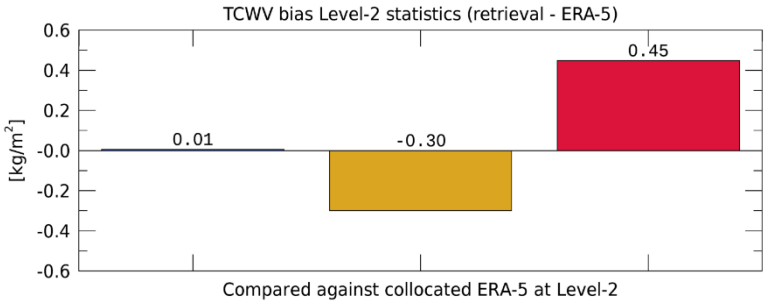
Bias correction

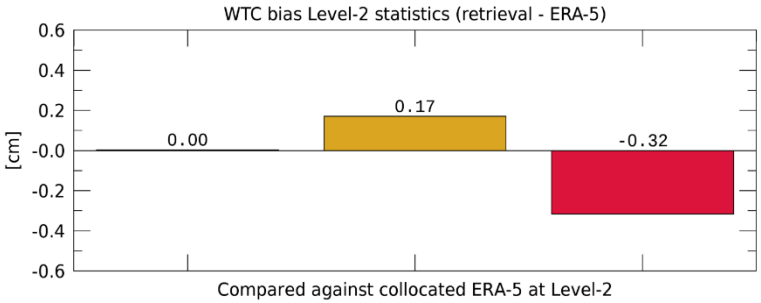
- The validation process is just starting.
- Eventually, the difference of SSH variance at xovers will be used to compare 1dVAR and SSH
- First steps provide some preliminary intel on the quality of 1DVAR compared to reference sources
  - Compare against operationally-derived (e.g. by ECMWF) biases for ATMS.
  - Evaluate results of TCWV retrieval.

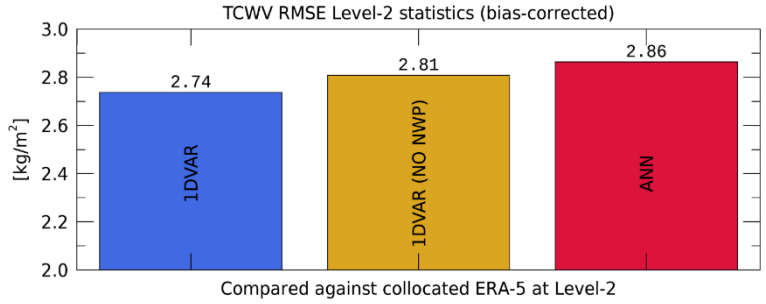
- **ATMS:** ATMS is operationally monitored by various operational weather services, so it is very well characterized in terms of calibration.

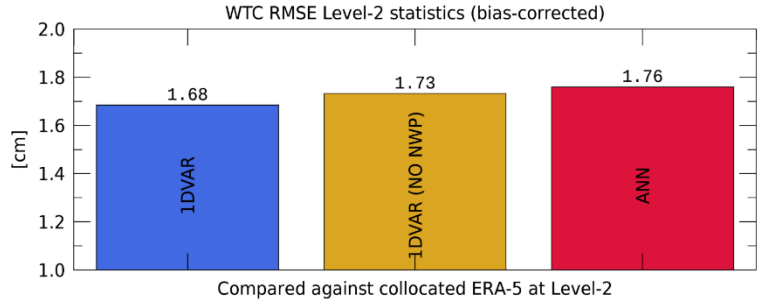
- **TCWV climatologies:** Used RSS, ERA-I, and ERA-5 climatologies to validate/compare retrieved Total Colum Water Vapor against.

TCWV and WTC retrieval and validation (from 10 million individual observations)









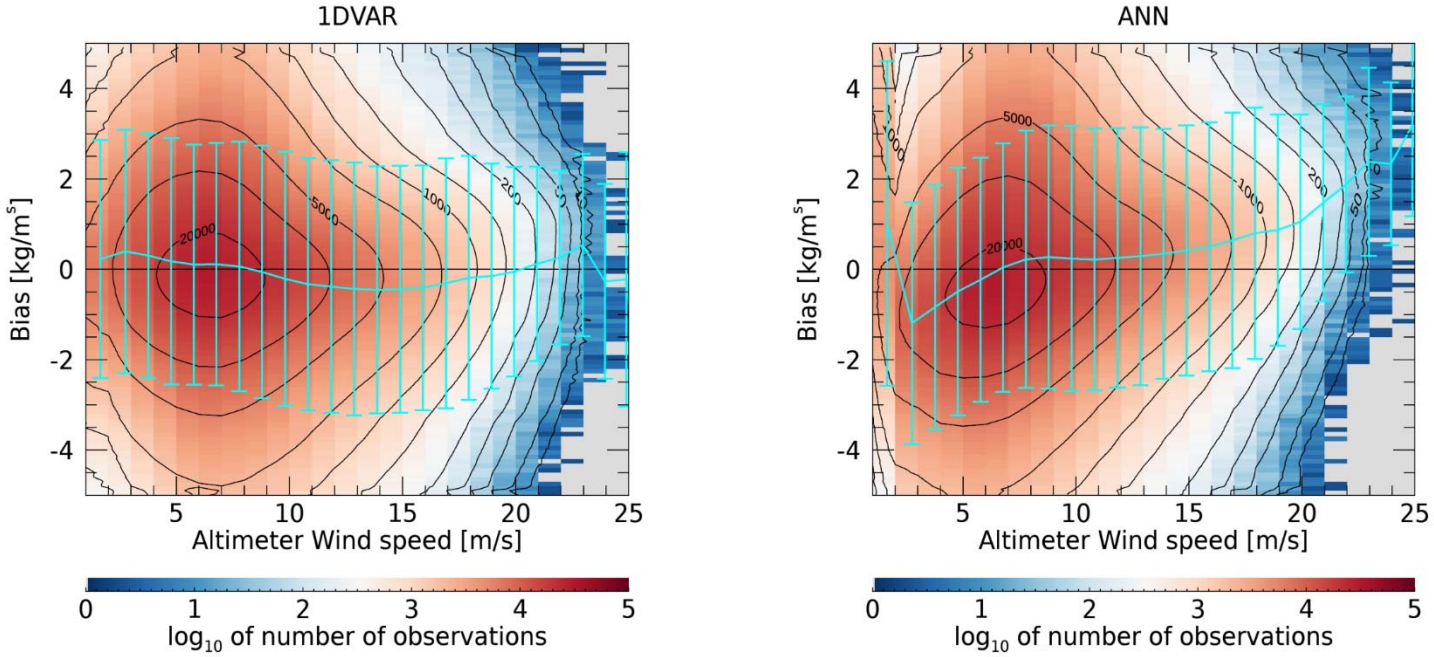
Blue: 1DVAR

Yellow: Degraded 1DVAR (without NWP surface pressure and SST)

Red: Heritage (ANN)

1DVAR agrees best with collocated ERA-5 (this does not mean it is better)

Bias as a function of wind speed



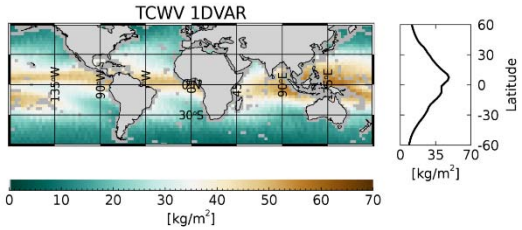
1DVAR shows weaker dependency of bias on wind speed (light blue curve shows average dependency)

TCWV retrieval and validation (against independent climatologies)

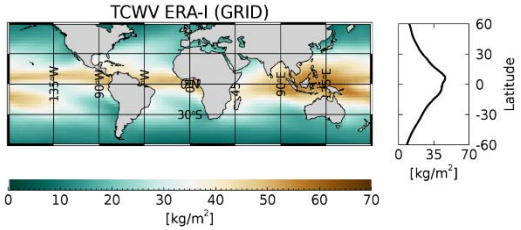
Gridded MWR

Independent climatologies

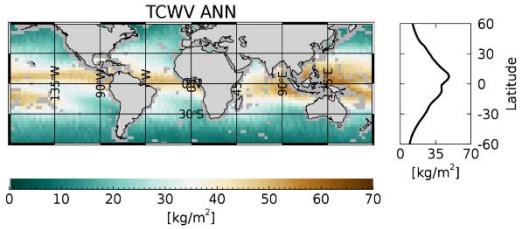
1DVAR



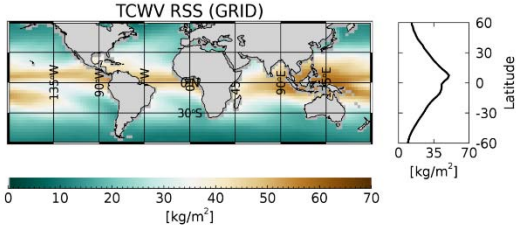
ERA-I



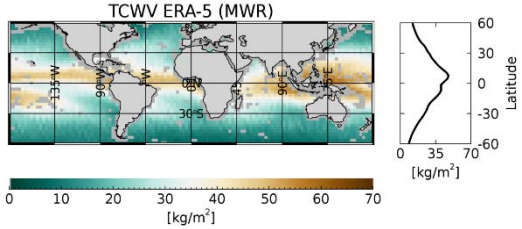
Heritage



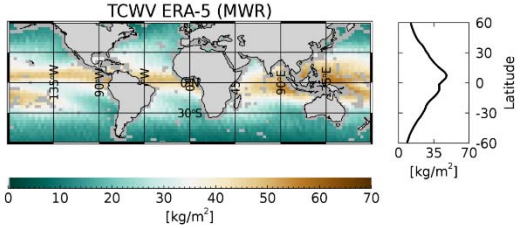
RSS



ERA-5 collocated to MWR and gridded



ERA-5



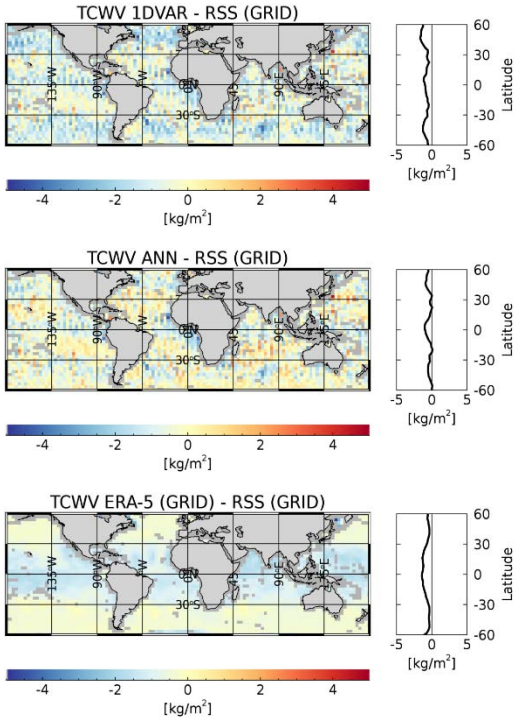
TCWV retrieval and validation (against independent climatologies)

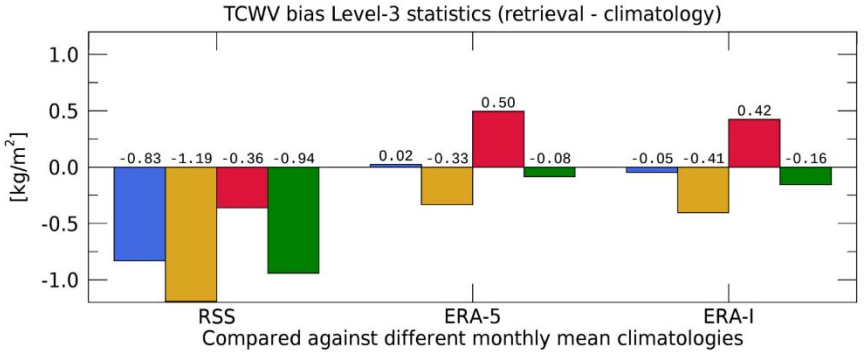
Gridded MWR - RSS

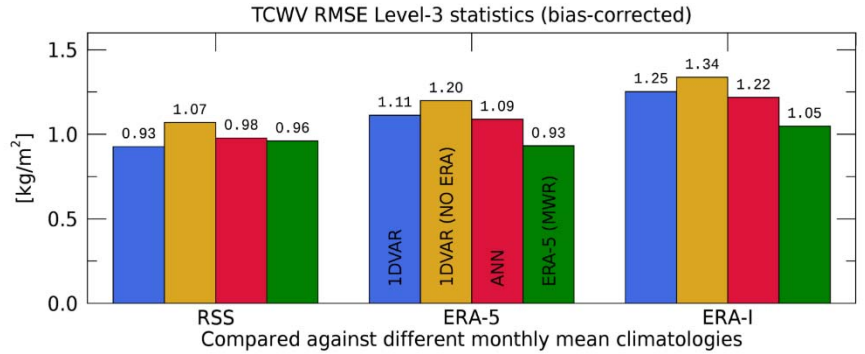
1DVAR

Heritage

ERA-5 collocated to MWR and gridded







Blue: 1DVAR
Yellow: Degraded 1DVAR (not shown on the left)
Red: Heritage (ANN)
Green: ERA-5 sample to MWR and re-gridded

Validation results

- 1DVAR provides slightly (but not necessarily significantly) better agreement with ERA-5 in terms of bias and RMSE when compared at Level-2 for TCWV.
- The same holds true for WTC at Level-2.
- Both 1DVAR and Heritage (ANN) compare well against Level-3 gridded climatologies. The differences between individual L3 climatologies are larger than the differences between the two retrievals.
- A degraded 1DVAR that does not use NWP-derived surface pressure and SST shows slightly degraded results.

Conclusions

- Proposed bias-correction method for MWR TBs allows for determination of biases caused by instrument calibration as well as forward model biases.
- Proposed use of climatology as BG
- Comparisons with climatologies show that 1DVAR retrieval provides results for TCWV and WTC on par with Heritage algorithm.
- The differences between different reference climatologies are larger than the differences between different retrievals.
- 1DVAR retrieval also provides traceable and physical uncertainty estimates alongside each retrieved parameter.