

climate change initiative

→ **WATER VAPOUR**

A combined total column water vapour data record from microwave and near-infrared imager observations: new developments and results from validation and applications

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water vapour
cci

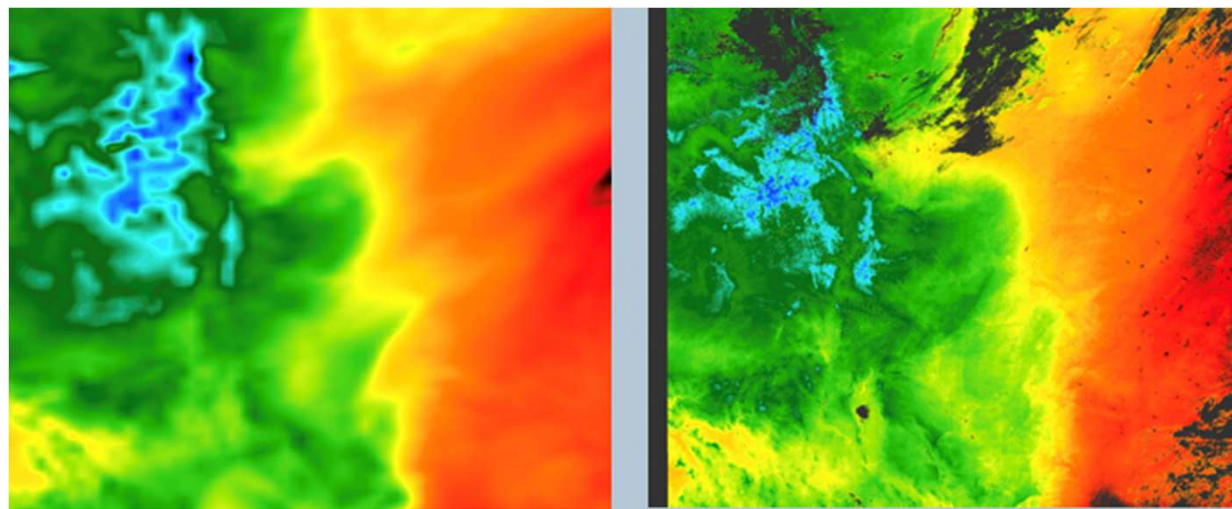
* Deutscher Wetterdienst, ** Brockmann Consult, *** Spectral Earth, ' U. Leicester / NCEO, '' U. Reading, ^o now at C3S/ECMWF



Overview



- Introduction and product overview
- New developments
- Example results from validation
- Example results from applications
- Conclusions



*Courtesy Rene Preusker & Jürgen Fischer,
see also Carbajal Henken et al. (2015, GRL)*





Introduction and product overview





A Combined TCWV data record



Total Column Water Vapour (TCWV) from microwave (ocean) and near infrared imagers (land, sea-ice, coasts).

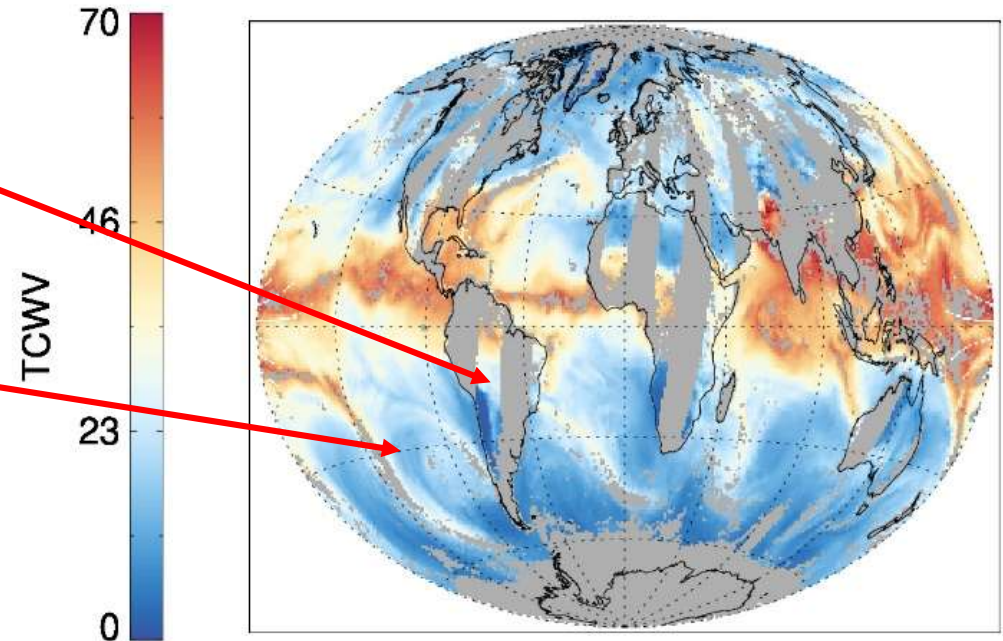
Near-infrared (NIR): high resolution (~300 m), 1-3 satellites, channels around 900 nm, **land, sea-ice and coasts**

Sampling: day, clear-sky, 10:30 and 13:30 local time
Sensors: MERIS, MODIS, OLCI*

Microwave (MW): fairly low resolution (≤ 40 km), various satellites, also in a low Earth orbit, channels around 22 GHz, **ice-free ocean**

Sampling: various local times, almost all-sky, day and night
Sensors: SSM/I, SSMIS, AMSR-E, TMI, GMI, AMSR2
From **EUMETSAT CM SAF**.

The spatial complementarity is utilized to combine both into a global TCWV water vapour product by reserving the individual characteristics + advantages.





Data record overview



Technical specifications

Dimension	Specification
Temporal resolution	Daily averages and monthly averages
Temporal coverage	July 2002 – December 2022*
Spatial coverage	Global
Spatial resolution	0.5 or 0.05 degrees

* Previous version: July 2002 – December 2017

Information layers:

- TCWV
- Standard deviation, mean retrieval uncertainty and its squared counterpart
- Quality flag based on cost function from retrievals
- Surface type flag, flags for cloud and heavy precipitation
- Number of observations, days and hours

SSM/I microwave observations hardly exceed a spatial resolution of ~ 0.5 deg. Thus, the product over ocean is oversampled to 0.05 deg while the product over land is averaged.





New developments



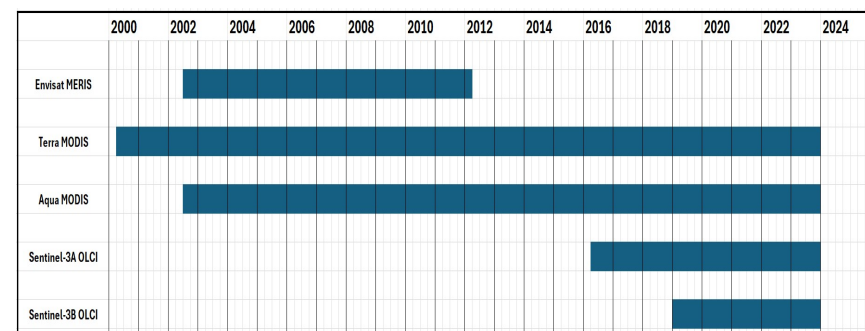
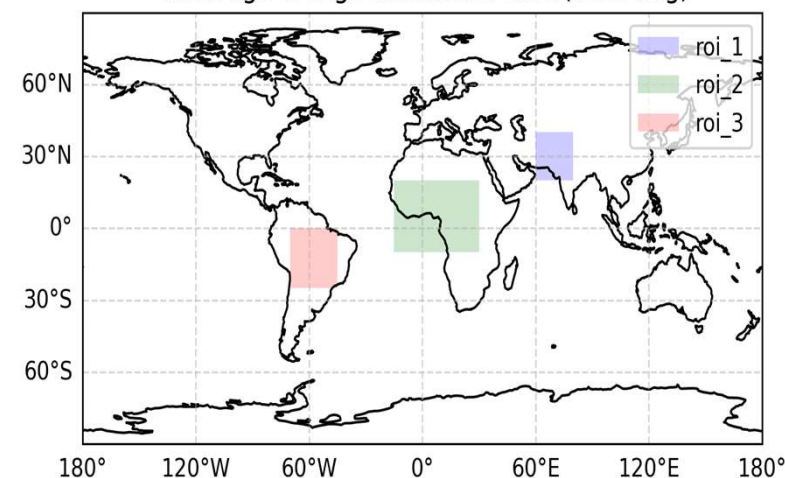


Improvements



- Extended temporal coverage (5-6 more years of data)
- New: regional high-resolution products (0.01 instead of 0.05)
- Improved sampling by adding sensors and coverage:
 - NIR: MODIS full period, MODIS Aqua and OLCI-B added
 - MW (CM SAF): GMI and AMSR2 added
- Various retrieval improvements:
 - MW (CM SAF): ESA SST_cci, updated RTTOV and 1D-Var from EUMETSAT NWP SAF,...
 - NIR: optimised RT through LUT, careful QC on sensor issues + cloud masking, efforts towards improved quality at coasts by using TIR,...

Coverage of high-resolution CDR (0.01 deg)



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European Space Agency



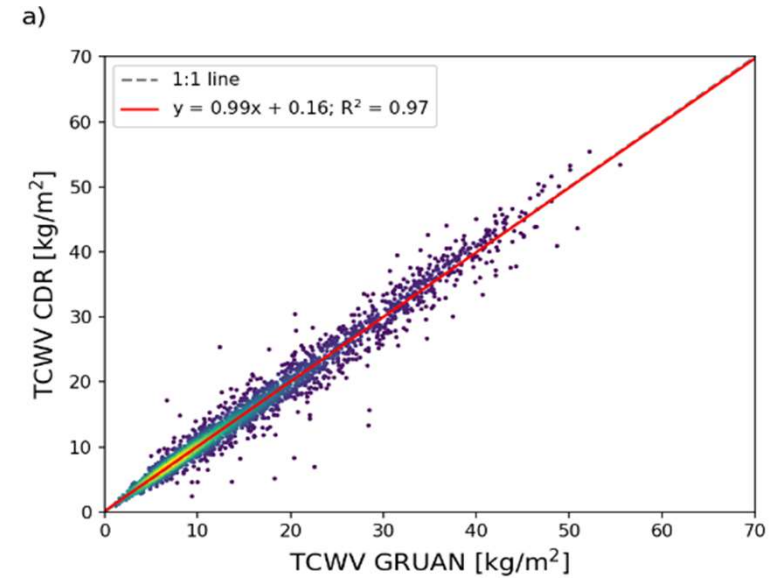
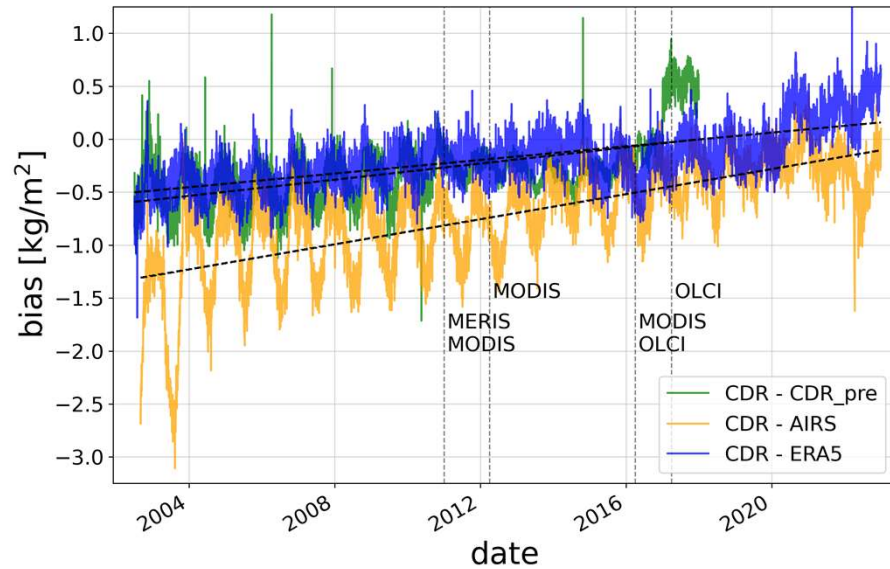
Validation

(examples only, work in progress, not yet based on final version)





Intercomparison and validation



Intercomparison of daily data to precursor, AIRS (satellite-based) and ERA5 (reanalysis)

Improved stability (note: OLCI not included yet)

Validation versus GRUAN (radiosondes)

High quality with bias=0.02 kg/m² and cRMSE=1.78 kg/m²





Consistency analysis / uncertainty validation



Starting point: hourly observations are independent (i.e., from different sensors)

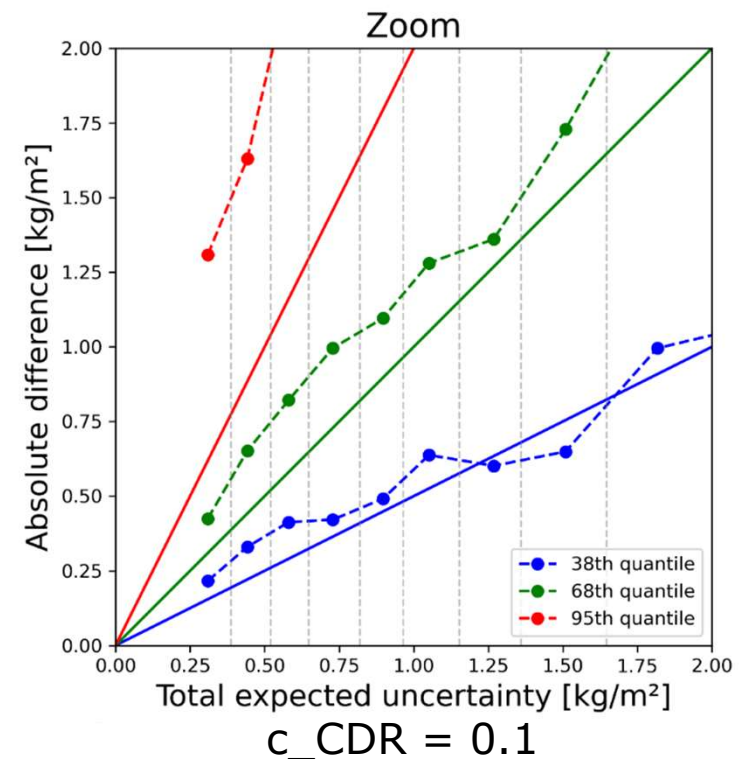
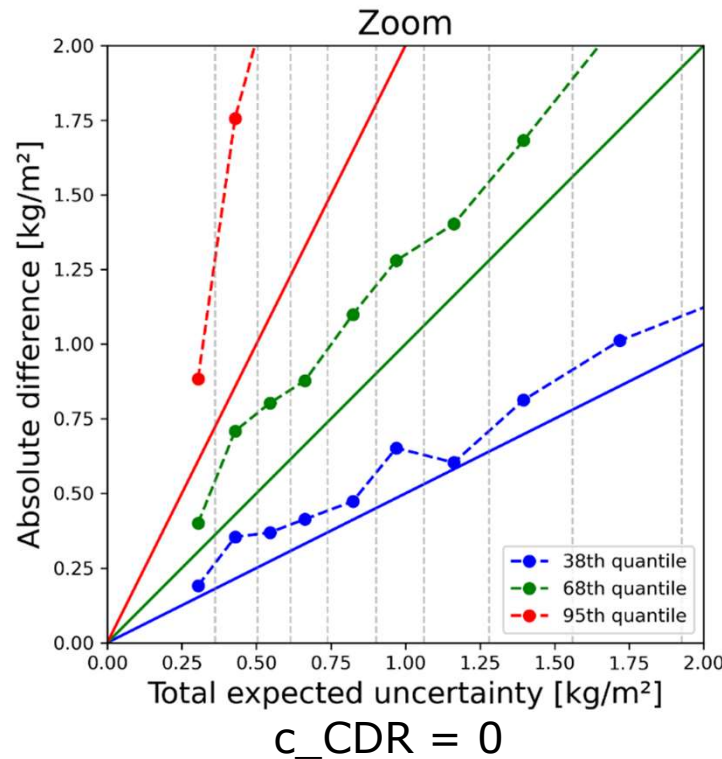
A non-zero correlation coefficient for CDR-1:

- introduces the average retrieval error into total uncertainty;
- might lead to better uncertainty estimations (compare left and right).

References:

*Immler et al. (2010, AMT),
Sayer et al. (2020, AMT),
Stengel et al. (2017, ESSD)*

TCWV from NIR (land only) and GRUAN, $n = 2301$, bins at median





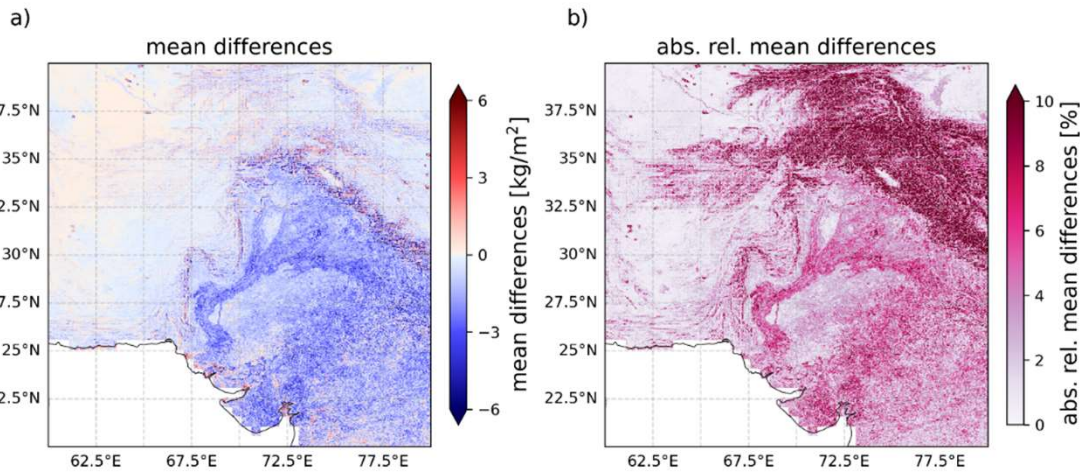
High-resolution data (monthly)



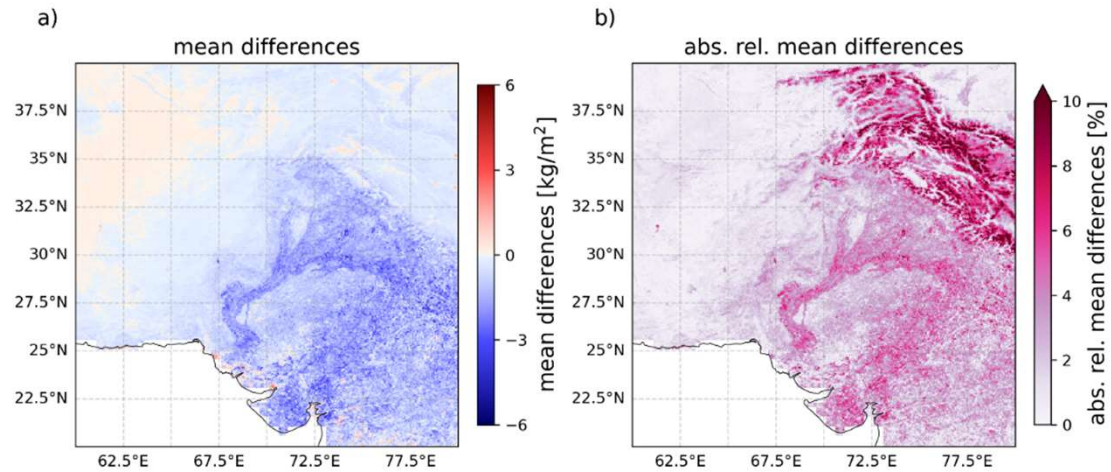
- Comparing High-resolution and standard TCWV from NIR for different spatial resolutions
 - Left: CDR-1 0.05° over-sampled to 0.01°
 - Right: CDR-high-res averaged to 0.05°

CDR_high_res - CDR1: roi_1, all_sky, all

CDR_high_res - CDR1: roi_1, all_sky, all



Grid: monthlies means, regular 0.01°, CDR1_005_standard oversampled



Grid: monthlies means, regular 0.05°, CDR_001 regridded using num_obs





Impact of including GMI and AMSR2



Three HOAPS versions:

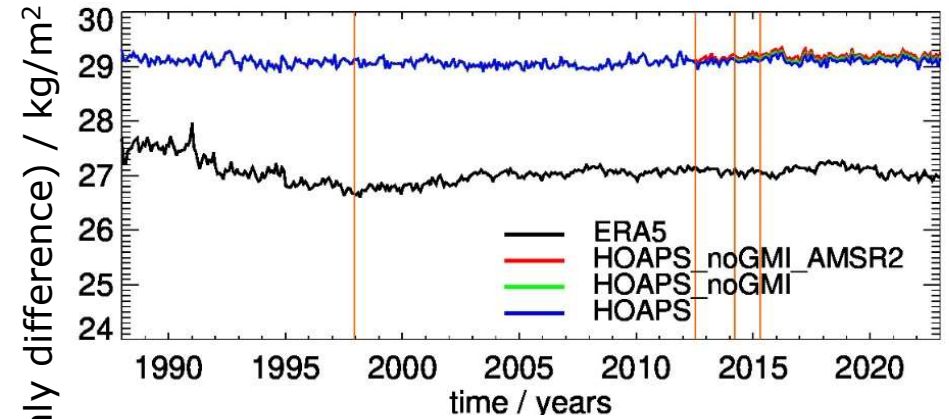
- a) All sensors
- b) GMI removed
- c) GMI and AMSR2 removed

Figure shows anomaly difference time series, shifted by mean values.

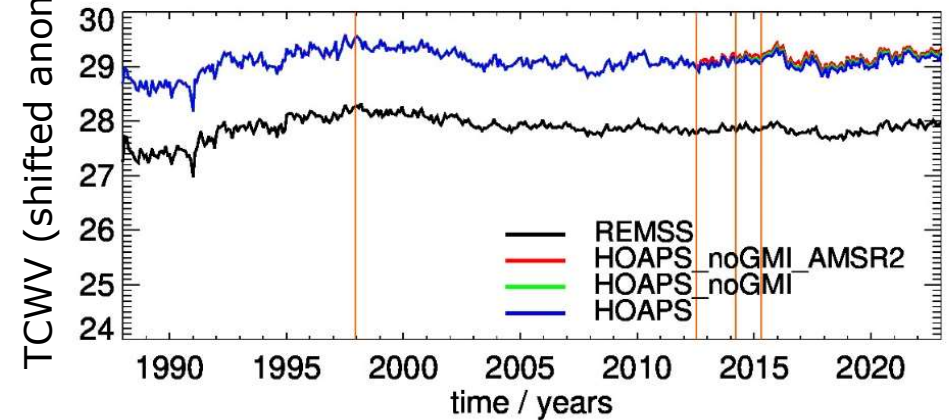
No seeming stability issues in HOAPS when GMI and AMSR2 are included!

Done in EUMETSAT CM SAF.

REMSS



ERA5



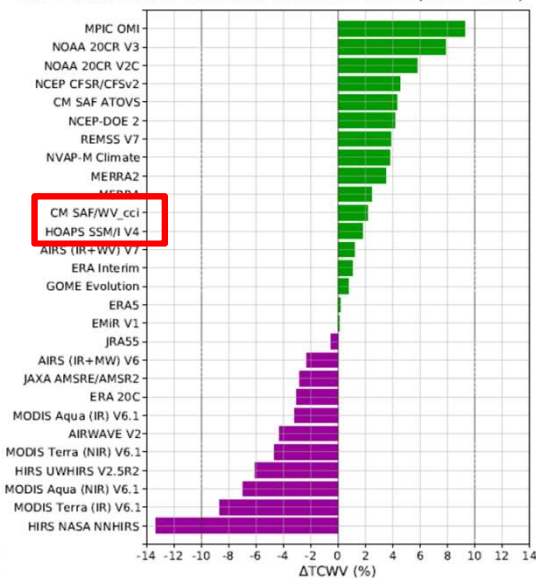


Results from G-VAP

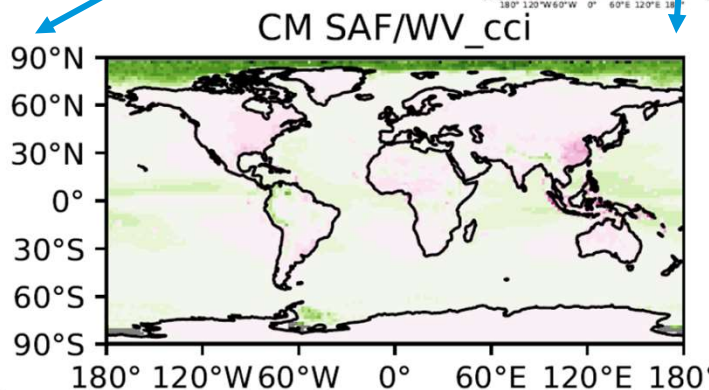
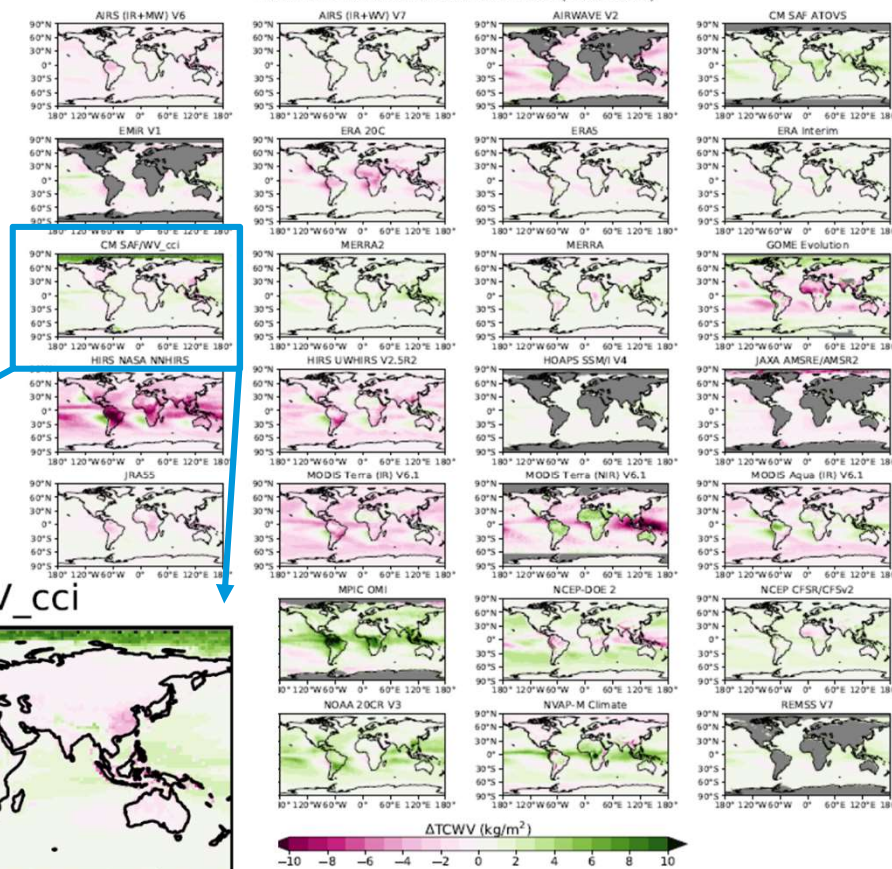


- Intercomparison results from the GEWEX Water Vapor Assessment (G-VAP, <http://gewex-vap.org/>)
- More results in Trent et al. (2024), ACP

TCWV Global Bias Relative to Ensemble Mean (2005-2009)



TCWV Bias Relative to Ensemble Mean (2005-2009)

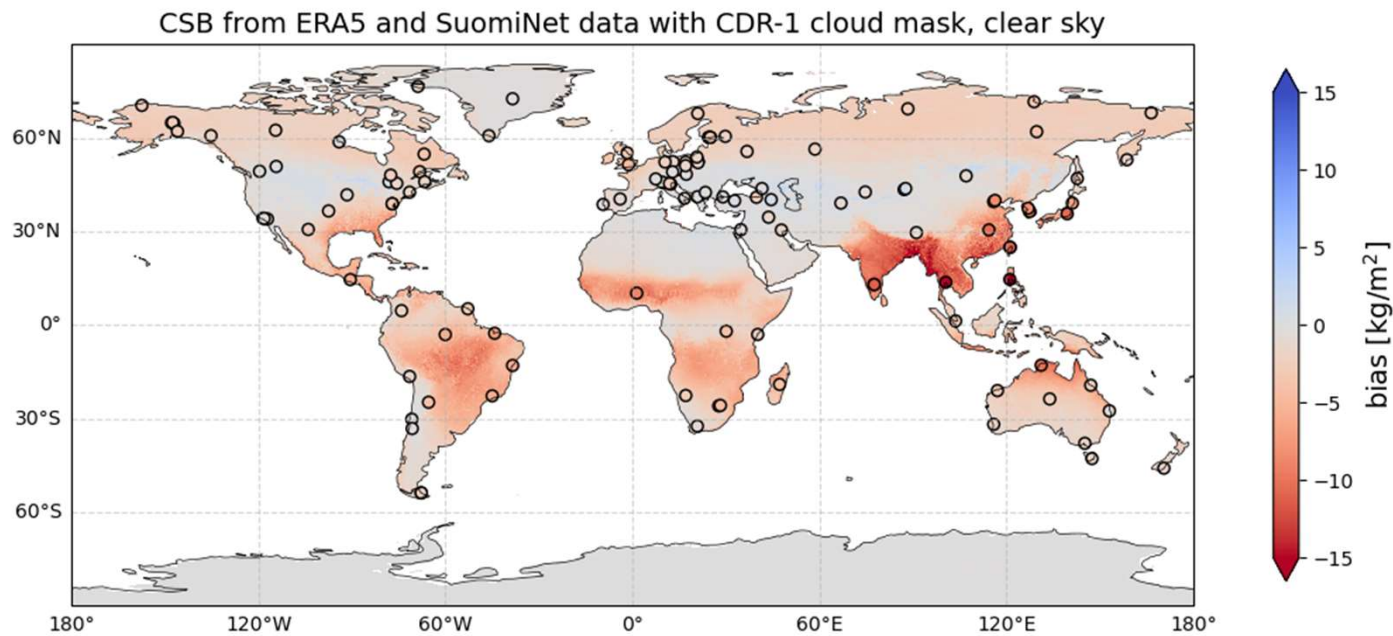




CDR1 (land): Clear-sky bias estimation



- $CSB = clear_sky_mean - all_sky_mean$
- Clear-sky bias (at "overpasses") using ERA5 and SuomiNet (circles) data
 - Same **cloud mask constructed from CDR-1** daily $\times 0.05^\circ$ applied to both datasets
- Note: Temporal coverage of ERA5 (2002 -) and SuomiNet (2005 -) different





Analysis examples





Trends and variability



Method as in the G-VAP (Schröder et al. (2016, 2019), JAOT, Rem Sens)

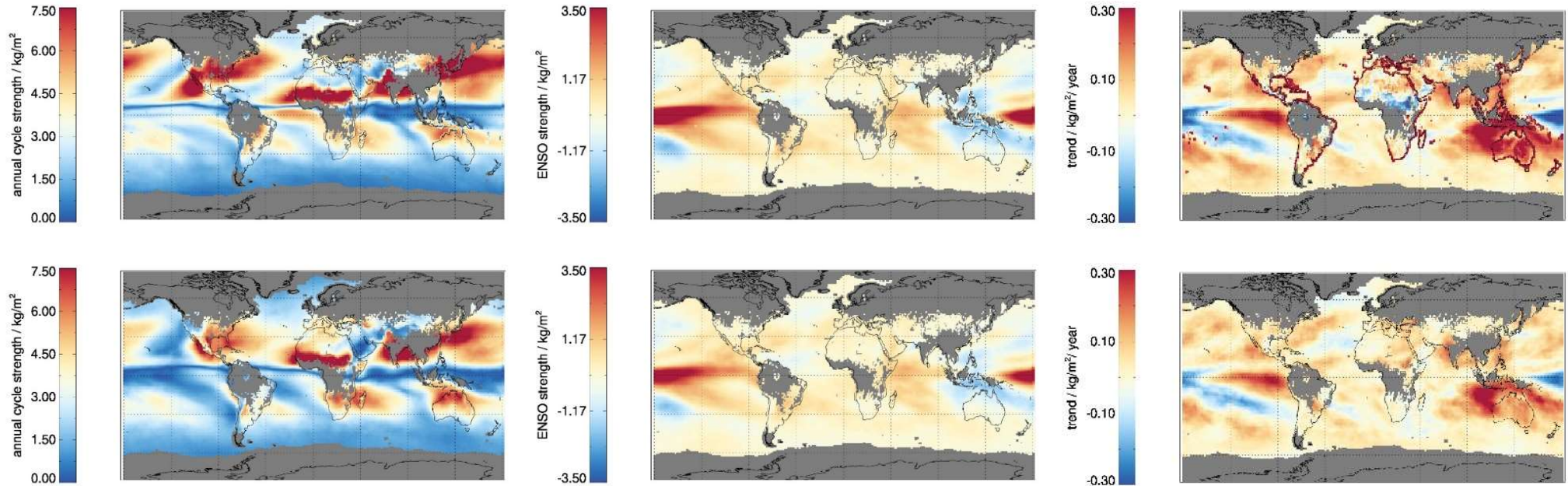
Annual cycle / kg/m^2

ENSO / kg/m^2

trend / $\text{kg/m}^2/\text{year}$

CM SAF / WV_cci

AIRS



from CAR, see <https://climate.esa.int/en/projects/water-vapour/key-documents/>



- Work in progress – expect a new version in summer 2025
- Early access possible later this year
- Careful use over inland water bodies, coasts and sea-ice.
- For climate analysis: careful analysis of transition between MODIS and OLCI pending.
- Continued excellent cooperation between agencies.

- Please let us know your comments such that we can improve the record according to your needs as much as possible.

The data is doi-referenced: 10.5676/EUM_SAF_CM/COMBI/V001
The data is freely available via EUMETSAT CM SAF (<https://wui.cmsaf.eu/>)
and ESA (<https://climate.esa.int/en/data/>).



**Thank you very
much for your
attention!**

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Analysis using TCWV

References



Analysis

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