Water Vapour Climate Change Initiative (WV_cci) - CCI+ Phase 1

Data Access Requirement Document (DARD)

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Authors **:** Marc Schröder (DWD), Michaela Hegglin (U. Reading), Ulrike Falk (DWD), Hélène Brogniez (UVSQ-CNRS-IPSL), Jürgen Fischer (SE), Daan Hubert (BIRA-IASB), Alexandra Laeng (KIT), Richard Siddans (RAL), Christopher Sioris (EC), Gabriele Stiller (KIT), Tim Trent (U. Leicester), Kaley Walker (U. Toronto), Olaf Danne (BC), Hao Ye (U. Reading)

Document Change Log

Issue/ Revision	Date	Comment
1.0	11 December 2018	First official version
1.2	21 October 2019	Internal revision
2.0	12 November 2019	Second version, submitted to ESA for review
3.0	19 February 2021	Third version, submitted to ESA for review
3.1	24 March 2021	Updates according to review comments
3.2	27 July 2021	Final updates prior to final meeting

TABLE OF CONTENTS

INDEX OF FIGURES

1. INTRODUCTION

This Data Access Requirements Document (DARD) details the satellite and auxiliary data required for the generation of the WV_cci data products (sections 2 and 3). It also specifies the satellite-based, *in situ* and ground-based data used for comparison and validation (sections 4 and 6). Required reanalysis and model data are described in section 5 and are mainly used during climate analysis. An overview of the dataset and its technical specifications are given, and the data sources, key references and potentially associated costs are stated.

2. SATELLITE DATA FOR PRODUCTION

2.1 CDR-1 and CDR-2: TCWV

2.1.1 TCWV from MERIS, MODIS and OLCI

The TCWV climatology over land is based on day-time, cloud-free satellite observations from the sensors MERIS, MODIS TERRA and OLCI. The TCWV processing uses L1b data as provided by ESA and NASA. L1b data are top of atmosphere radiance (OLCI and MERIS) or reflectance (MODIS). For MERIS and OLCI reduced resolution (RR) data (1.2 x 1.0 km^2) are used. For MODIS, the spatial resolution is approximately the same. The project uses data from MODIS onboard the TERRA satellite.

Overview	
Name	L1b data from MERIS, MODIS, OLCI
Variable(s)	radiances (MERIS, OLCI), reflectances (MODIS)
Version	3rd reprocessing (MERIS), collection 6.1 (MODIS); 1st reprocessing (OLCI)
doi	MODIS: http://dx.doi.org/10.5067/MODIS/MOD021KM.006
Technical specifications	
Temporal resolution	Sensor resolution, orbit periods ~100 minutes
Temporal coverage	July 2002 – March 2012 (MERIS), December 1999 - present (MODIS), April 2016 - present (OLCI) Considered periods: MERIS (2002-2012), MODIS (2011-2017), OLCI (2016-2017)
Spatial resolution, number of stations	Reduced resolution – 1.2 x 1.0 km^2 (MERIS, OLCI), 1 km (MODIS)
Spatial coverage	Global
Vertical resolution	n/a
Uncertainties available?	not per pixel, only overall estimates per sensor and spectral bands
Access details and utilization	
Access via	MERIS, OLCI: available at Calvalus MODIS: http://data.ceda.ac.uk/neodc/modis/data

Last download	01-2021 (BC)
Application	Input to CDR-1 and CDR-2
Costs	None
References	
MERIS: https://earth.esa.int/web/sppa/mission-performance/esa-missions/envisat/meris/products-and-algorithms/products-information **OLCI**: https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-3-olci/level-1/products-description **MODIS**: https://modis.gsfc.nasa.gov/data/dataprod/mod02.php	

2.1.2 TCWV from CM SAF HOAPS

The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite data record (HOAPS) is a completely satellite-based climatology of TCWV and various other parameters over the global ice-free oceans. HOAPS was originally developed at the Max-Planck-Institute for Meteorology and the University of Hamburg. It has been transferred into the operational environment of CM SAF and since version 3.1 CM SAF is generating the HOAPS products. All variables are derived from recalibrated and intercalibrated measurements from SSM/I and SSMIS passive microwave radiometers and intercalibrated AMSR-E and TMI measurements, Also, SST from AVHRR measurements is used as input. TCWV is retrieved during day and night and in clear-sky and cloudy-sky conditions. A reliable retrieval is not possible in presence of strong scattering, i.e. in presence of strong rain events. All currently available CM SAF HOAPS products have global coverage, i.e. within ±180° longitude and ±80° latitude, at 0.5° spatial resolution and are provided as monthly means and 6-hourly composites.

It was agreed between the project team and ESA and approved by the CM SAF Steering Group that CDR-2 will be released by CM SAF. The processing of the HOAPS data will be carried out by CM SAF.

Overview	
Name	TCWV from the Hamburg Ocean Atmosphere Parameters and Fluxes from Satellites data (HOAPS) provided by CM SAF

Variable(s)	TCWV
Version	dedicated processing using the HOAPS version 4 retrieval
doi	n/a
Technical specifications	
Temporal resolution	daily and monthly means
Temporal coverage	July 2002 – December 2017
Spatial resolution, number of stations	0.5°, 0.05° (oversampled)
Spatial coverage	Global ice-free ocean
Vertical resolution	n/a
Uncertainties available?	standard deviation, standard retrieval uncertainty from 1D-Var as tcwv_err (average) and tcwv_ran (average of squared retrieval uncertainty)
Access details and utilization	
Access via	DWD/CM SAF
Last download	12- 2020 (DWD)
Application	Input to CDR-2
Costs	None
References	
Andersson, A., Fennig, K., Klepp, C., Bakan, S., Graßl, H., and Schulz, J., 2010: The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data? HOAPS-3, Earth Syst. Sci. Data, 2, 215-234. Andersson, A., Klepp, C., Fennig, K., Bakan, S., Graßl, H. and Schulz, J., 2011: Evaluation of HOAPS-3 ocean surface freshwater flux components, Journal of Applied Meteorology and Climatology, 50, 379-398. Kinzel, J., K. Fennig, M. Schröder, A. Andersson, K. Bumke, R. Hollmann, 2016: Decomposition of Random Errors Inherent to HOAPS-3.2 Near-Surface Humidity Estimates Using Multiple Triple Collocation Analysis. J. Atm. Oceanic Tech., 1455-1471, 33 (7). Liman J, Schröder M, Fennig K, Andersson A, Hollmann R. Uncertainty characterization of HOAPS 3.3 latent heat-flux-related parameters. Atmospheric Measurement Techniques. 2018 Mar 29;11(3):1793-815. Schröder, M., Jonas, M., Lindau, R., Schulz, J., and Fennig, K., 2013: The CM SAF SSM/I-based total column water vapour climate data record: methods and evaluation against re-analyses and satellite. Atmos. Meas. Tech., 6, 765-775. **Website:** https://www.cmsaf.eu/	

2.2 CDR-3: stratospheric humidity profiles

2.2.1 WAVAS-II

WAVAS-II activity was initiated by Cornelius Schiller and Thomas Peter; it stemmed from a SPARC workshop in Karlsruhe in 2007 and became a project to assess the differences between the multitude of satellite water vapour measurements that currently exist.

This international activity provided a quality assessment of upper tropospheric to lower mesospheric satellite data records since the early 1990s: absolute validation against ground-truth instruments (as far as possible); inter-instrument biases, depending on altitude, location, and season; assessed the representation of temporal variations on various scales; identified and quantified instrumental drifts. The period of focus was 2000–2016, following-on from WAVAS-I that covered data up to 2000. For instruments that were active prior to 2000, all years of the data record were included in WAVAS-II. If several data records from one instrument are available, all are assessed. Generally, the most recent version only is taken into account. The original datasets can be downloaded from the different data producers' webpages. The databank of satellite vertical profiles of the water vapour, which have participated in SPARC WAVAS assessment, are available also in a harmonised format. This dataset is called WAVAS_SAHAR and is accessible via the KIT website: https://bwdatadiss.kit.edu/dataset/192 .

Overview	
Name	Vertically resolved profiles water vapour profiles from all limb-viewing satellite instruments participating in WAVAS II exercise: ACE-FTS, ACE-MAESTRO, GOMOS, HALOE, HIRDLS, ILAS-II, MIPAS, Aura-MLS, POAM, SAGE, SCIAMACHY, SMILES, SMR, SOFIE / WAVAS_SAHAR
Variable(s)	Vertical profiles of water vapour
Version	V2
Doi	10.5445/IR/1000098908
Technical specifications	

Temporal resolution	From two profiles per day for the occultation instruments, up to 1000 profiles per day for dense samplers
Temporal coverage	July 1991 – December 2018
Spatial resolution	Varies among datasets, depending on the viewing geometry
Spatial coverage	From selected latitude range (ex SOFIE: 50-70 degrees N) up to pole-to-pole coverage (MIPAS, MLS)
Vertical resolution	1.5 – 6 km depending on instrument and altitude range, see Figure 2-1 (below) for details (WAVAS_SAHAR: 1 km)
Uncertainties available?	Yes for all datasets
Spatio-temporal distribution	

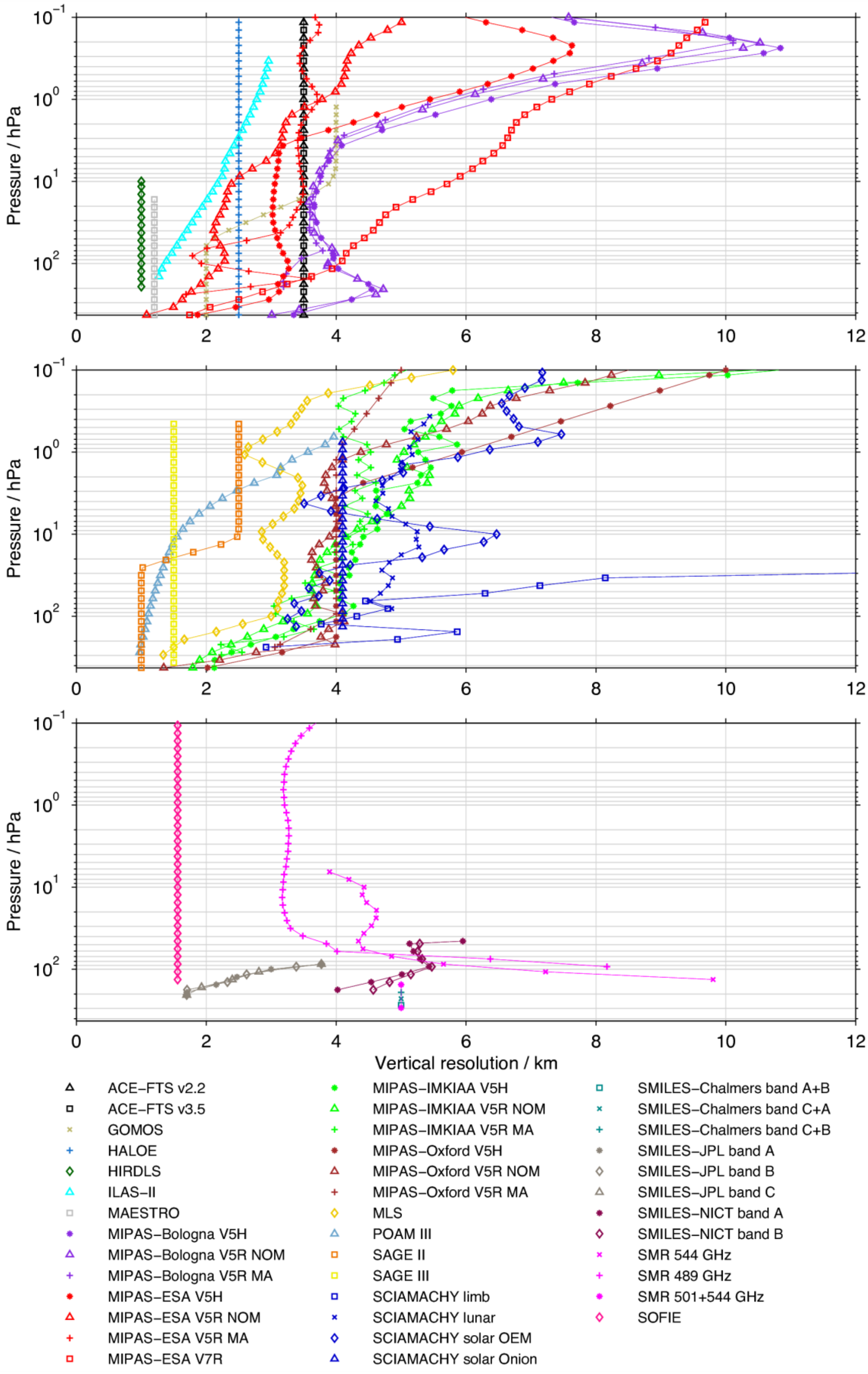

Figure 2-1: Vertical resolution of the WAVAS-II datasets. Courtesy: G. Stiller and K. Walker. From “WAVAS-II Report, chapter 2” (their Figure 1.5).

Access details and utilization	
Access via	ACE-FTS: https://databace.scisat.ca/level2/ (registration required) ACE-MAESTRO: https://databace.scisat.ca/level2/mae_water/ GOMOS: on demand from Jean-Loup.Bertaux@aerov.jussieu.fr or Laurent.Blanot@acri-st.fr HALOE: http://haloe.gats-inc.com/download/index.php HIRDLS: http://acdisc.gsfc.nasa.gov/data/s4pa/Aura_HIRDLS_Level2/ ILAS-II: on demand from sugita@nies.go.jp or ilas-data@nies.go.jp MIPAS Bologna: http://www.isac.cnr.it/~rss/mipas2d.htm contact bianca.m.dinelli@isac.cnr.it or massimo.carlotti@unibo.it for password MIPAS ESA: https://earth.esa.int/web/guest/data-access/ MIPAS KIT: http://www.imk-asf.kit.edu/english/308.php MIPAS Oxford: https://catalogue.ceda.ac.uk/uuid/48bb74ee7cf579712c04be88f3bd5e67 MLS: https://disc.gsfc.nasa.gov/datasets?page=1&keywords=AURA%20MLS POAM III: https://eosweb.larc.nasa.gov/project/poam3/poam3_table, now at https://asdc.larc.nasa.gov/project/POAM/POAM3_1 SAGE II: https://eosweb.larc.nasa.gov/project/sage2/sage2_table, now at https://asdc.larc.nasa.gov/project/POAM/POAM3_1 SAGE III : https://eosweb.larc.nasa.gov/project/sage3/sage3_table , now at https://asdc.larc.nasa.gov/project/SAGE%20III-M3M SCIAMACHY limb: on demand from weigel@iup.physik.uni-bremen.de SCIAMACHY lunar: on demand from faiza@iup.physik.uni-bremen.de SCIAMACHY solar occultation oem: on demand from klaus.bramstedt@uni-bremen.de SCIAMACHY solar occultation onion peeling: on demand from noel@iup.physik.uni-bremen.de SMILES Chalmers: on demand from patrick.eriksson@chalmers.se SMILES jpl: http://mls.jpl.nasa.gov/data/smiles.php

	SMILES NICT: on demand from ykasai@nict.go.jp and sagawa@cc.kyoto-su.ac.jp SMR: https://earth.esa.int/web/guest/missions/3rd-party-missions/current-missions/odin SOFIE: ftp://ftp.gats-inc.com/sofie/ WAVAS-SAHAR: https://bwdatadiss.kit.edu/dataset/192
Last download	05-2020 (UoR)
Application	Input to CDR-3 and CDR-4
Costs	None

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F. Khosrawi, S. Lossow, G. P. Stiller, K. H. Rosenlof, J. Urban, J. P. Burrows, R. P. Damadeo, P. Eriksson, M. García-Comas, J. C. Gille, Y. Kasai, M. Kiefer, G. E. Nedoluha, S. Noël, P. Raspollini, W. G. Read, A. Rozanov, C. E. Sioris, K. A. Walker, and K. Weigel: "The SPARC water vapour assessment II: comparison of stratospheric and lower mesospheric water vapour time series observed from satellites", Atmos. Meas. Tech., 11, 4435-4463, https://doi.org/10.5194/amt-11-4435-2018, 2018

S. Lossow, F. Khosrawi, G. E. Nedoluha, F. Azam, K. Bramstedt, J. P. Burrows, B. M. Dinelli, P. Eriksson, P. J. Espy, M. García-Comas, J. C. Gille, M. Kiefer, S. Noël, P. Raspollini, W. G. Read, K. H. Rosenlof, A. Rozanov, C. E. Sioris, G. P. Stiller, K. A. Walker, and K. Weigel: "The SPARC water vapour assessment II: comparison of annual, semi-annual and quasi-biennial variations in stratospheric and lower mesospheric water vapour observed from satellites", Atmos. Meas. Tech., 10, 1111-1137, https://doi.org/10.5194/amt-10-1111-2017, 2017

S. Lossow, F. Khosrawi, M. Kiefer, K. A. Walker, J.-L. Bertaux, L. Blanot, J. M. Russell, E. E. Remsberg, J. C. Gille, T. Sugita, C. E. Sioris, B. M. Dinelli, E. Papandrea, P. Raspollini, M. García-Comas, G. P. Stiller, T. von Clarmann, A. Dudhia, W. G. Read, G. E. Nedoluha, R. P. Damadeo, J. M. Zawodny, K. Weigel, A. Rozanov, F. Azam, K. Bramstedt, S. Noël, J. P. Burrows, H. Sagawa, Y. Kasai, J. Urban, P. Eriksson, D. P. Murtagh, M. E. Hervig, C. Högberg, D. F. Hurst, and K. H. Rosenlof: "The SPARC water vapour assessment II: Profile-to-profile comparisons of stratospheric and lower mesospheric water vapour data sets obtained from satellites", submitted to AMT in October 2018

G. E. Nedoluha, M. Kiefer, S. Lossow, R. M. Gomez, N. Kämpfer, M. Lainer, P. Forkman, O. M. Christensen, J. Jin Oh, P. Hartogh, J. Anderson, K. Bramstedt, B. M. Dinelli, M. Garcia-Comas, M. Hervig, D. Murtagh, P. Raspollini, W. G. Read, K. Rosenlof, G. P. Stiller, and K. A. Walker; "The SPARC water vapor assessment II: intercomparison of satellite and ground-based microwave measurements", Atmos. Chem. Phys., 17, 14543-14558, 2017

2.2.2 WV profiles from ACE-FTS

Water vapour is one of the 50+ species measured by the ACE-FTS. Profiles are retrieved over the altitude range from 5 to 101 km, using 54 microwindows spanning the spectral range from 937 to 2993 cm^{-1} and include CO_2, O_3, N_2O, CH_4, COF_2, and various isotopologues as interfering species. The ACE-FTS solar occultation measurements provide global latitude cover over the period of three months (approximately seasonally).

Overview	
Name	ACE-FTS
Variable(s)	WV profile
Version	V3.5/3.6
Doi	Not yet available
Technical specifications	
Temporal resolution	Up to 30 occultations per day
Temporal coverage	February 2004 – October 2020 (updated subsequently)
Spatial resolution, number of stations	n/a
Spatial coverage	~82°N – ~82°S
Vertical resolution	~3-4 km (based on instrument field-of-view); vertical sampling 1.5-6 km (depending on orbit beta angle)
Uncertainties available?	Fitting errors available for each profile but no error budget
Access details and utilization	
Access via	https://ace.uwaterloo.ca/data.php (registration required)
Last download	04- 2020 (UoR)
Application	Input to CDR-3
Costs	None
References	
Bernath, P.F. et al., 2005: Atmospheric Chemistry Experiment (ACE): Mission Overview, Geophys. Res. Lett., 32, L15S01.	

Boone, C. D., Nassar, R., Walker, K. A., Rochon, Y., McLeod, S.D., Rinsland, C.P., and Bernath, P. F., 2005: Retrievals for the atmospheric chemistry experiment fourier-transform spectrometer, Appl. Opt. 44, 7218–31

Boone, C.D., Walker, K.A., Bernath, P. F., 2013: Version 3 retrievals for the Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS), the Atmospheric Chemistry Experiment, ACE at 10: a solar occultation anthology, Hampton, Virginia, USA, A. Deepak Publishing, 103–27.

Sheese, P. E., Walker, K. A., Boone, C. D., Bernath, P. F., Froidevaux, L., Funke, B., Raspollini, R., and von Clarmann, T.: 2017, ACE-FTS ozone, water vapour, nitrous oxide, nitric acid, and carbon monoxide profile comparisons with MIPAS and MLS, J. Quant. Spectrosc. Rad. Transfer, 186, 63-80.

2.2.3 WV profiles from ACE-MAESTRO

Water vapour is one of the species measured by the ACE-MAESTRO. It also provides profiles of O_3, aerosol extinction and, up until 2010, NO_2). Retrievals are performed using features in the 940 nm spectral region. The profiles have a variable retrieval upper altitude limit of about 20 km, which depends on the observed water vapour optical depth and a lower limit of about 4 km, which is determined by the orbital beta angle and the cloud top level. The ACE-MAESTRO solar occultation measurements provide global latitude cover over the period of three months (approximately seasonally).

Overview	
Name	ACE-MAESTRO
Variable(s)	WV profile
Version	V31
Doi	N/A
Technical specifications	
Temporal resolution	Up to 30 occultations per day
Temporal coverage	February 2004 – January 2020 (updated subsequently)
Spatial resolution, number of stations	n/a
Spatial coverage	~82°N – ~82°S
Vertical resolution	~1.2 km (based on instrument field-of-view); vertical sampling 0.4 km at 5 km increasing to 1.2 km at 23 km

Uncertainties available?	Fitting errors available for each profile; error budget estimate provided in Sioris et al. (2010).
Access details and utilization	
Access via	https://ace.uwaterloo.ca/data.php (registration required)
Last download	01-2020 (UoR)
Application	Input to CDR-3
Costs	None
References	

McElroy, C.T., C. R. Nowlan, J. R. Drummond, P. F. Bernath, D. V. Barton, D. G. Dufour, C. Midwinter, R. B. Hall, A. Ogyu, A. Ullberg, D. I. Wardle, J. Kar, J. Zou, F. Nichitiu, C. D. Boone, K. A. Walker, and N. Rowlands, 2007: The ACE-MAESTRO instrument on SCISAT: description, performance, and preliminary results, Appl. Opt., 46, 4341–4356.

Sioris, C. E., J. Zou, C. T. McElroy, C. A. McLinden, and H. Vömel, 2010: High vertical resolution water vapour profiles in the upper troposphere and lower stratosphere retrieved from MAESTRO solar occultation spectra, Adv. Space Res., 46, 642–650.

Carleer, M. R., C. D. Boone, K. A. Walker, P. F. Bernath, K. Strong, R. J. Sica, C. E. Randall, H. Vömel, J. Kar, M. Höpfner, M. Milz, T. von Clarmann, R. Kivi, J. Valverde-Canossa, C. E. Sioris, M. R. M. Izawa, E. Dupuy, C. T. McElroy, J. R. Drummond, C. R. Nowlan, J. Zou, F. Nichitiu, S. Lossow, J. Urban, D. Murtagh, and D. G. Dufour, 2008: Validation of water vapour profiles from the Atmospheric Chemistry Experiment (ACE), Atmos. Chem. Phys. Disc., 8, 4499–4559.

Sioris, C. E., J. Zou, D. A. Plummer, C. D. Boone, C. T. McElroy, P. E. Sheese, O. Moeini, and P. F. Bernath, 2016: Upper tropospheric water vapour variability at high latitudes – Part 1: Influence of the annular modes, Atmos. Chem. Phys., 16, 3265–3278.

2.2.4 WV profiles from Aura-MLS

The water vapour product from the Aura Microwave Limb Sounder (MLS) consists of vertical profiles based on retrievals from 190 GHz (~1.58 mm) spectral region. The water vapour profile processing will use Level 2 data from the NASA Jet Propulsion Laboratory (JPL). The available profiles are on pressure levels from 316 hPa to 0.002 hPa. The horizontal orbit tracks have a spacing of 1.5°.

Overview	
Name	Aura-MLS

Variable(s)	WV profile
Version	V005
Doi	n/a
Technical specifications	
Temporal resolution	~3500 profiles per day
Temporal coverage	August 2004 – December 2019 (updated subsequently)
Spatial resolution, number of stations	n/a
Spatial coverage	~82°N – ~82°S
Vertical resolution	On a pressure grid with 6 pressure levels per decade change in pressure. In the range of 1.3 – 3.6 km from 316 – 0.22 hPa
Uncertainties available?	Yes, available
Access details and utilization	
Access via	https://disc.gsfc.nasa.gov
Last download	02-2021 (UoR)
Application	Input to CDR-3
Costs	None
References	
Read, W. G., Lambert, A., Bacmeister, J., Cofield, R. E., Chris- tensen, L. E., Cuddy, D. T., Daffer, W. H., Drouin, B. J., Fetzer, E., Froidevaux, L., Fuller, R., Herman, R., Jarnot, R. F., Jiang, J. H., Jiang, Y. B., Kelly, K., Knosp, B. W., Ko- valenko, L. J., Livesey, N. J., Liu, H.-C., Manney, G. L., Pick- ett, H. M., Pumphrey, H. C., Rosenlof, K. H., Sabounchi, X., Santee, M. L., Schwartz, M. J., Snyder, W. V., Stek, P. C., Su, H., Takacs, L. L., Thurstans, R. P., Vömel, H., Wagner, P. A., Waters, J. W., Webster, C. R., Weinstock, E. M., and Wu, D. L., 2007: Aura Microwave Limb Sounder upper tropospheric and lower stratospheric H2O and relative humidity with re- spect to ice validation, J. Geophys. Res.-Atmos., 112, D24S35, https://doi.org/10.1029/2007JD008752. Lambert, A., Read, W. G., Livesey, N. J., Santee, M. L., Manney, G. L., Froidevaux, L., Wu, D. L., Schwartz, M. J., Pumphrey, H. C., Jimenez, C., Nedoluha, G. E., Cofield, R. E., Cuddy, D. T., Daffer, W. H., Drouin, B. J., Fuller, R. A., Jarnot, R. F., Knosp, B. W., Pickett, H. M., Perun, V. S., Snyder, W. V., Stek, P. C., Thurstans, R. P., Wagner, P. A., Waters, J. W., Jucks, K. W., Toon, G. C., Stachnik, R. A., Bernath, P. F., Boone, C. D., Walker, K. A., Urban, J., Murtagh, D., Elkins, J. W., and Atlas, E., 2007: Validation of the Aura Microwave Limb Sounder middle atmosphere water vapor and nitrous oxide measurements, J. Geophys. Res.-Atmos., 112, D24S36, https://doi.org/10.1029/2007JD008724.	

Livesey, N. J., Read, W. G., Wagner, P. A., Froidevaux, L., Lambert, A., Manney, G. L., Millán-Valle, L. F., Pumphrey, H. C., Santee, M. L., Schwartz, M. J., Wang, S., Fuller, R. A., Jarnot, R. F., Knosp, B. W., and Martinez, E., 2017: Earth Observing System (EOS) Aura Microwave Limb Sounder (MLS), Version 4.2x Level 2 data quality and description document, Tech. Rep. JPL D-33509, Tech. Rep. version 4.2x-3.1, NASA Jet Propulsion Laboratory.

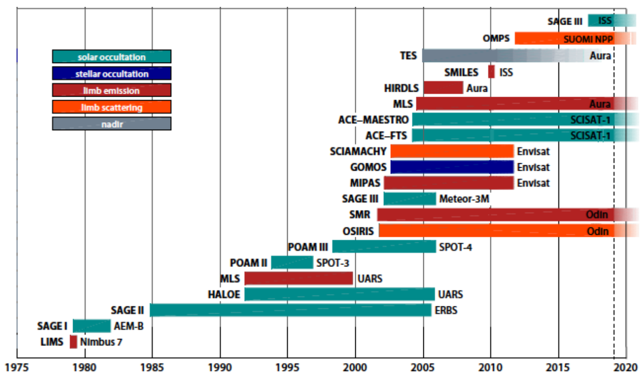
Hurst, D., Read, W. G., Vömel, H., Selkirk, H. B., Rosenlof, K. H., Davis, S. M., Hall, E. G., Jordan, A. F., and Oltmans, S. J., 2016: Recent divergences in stratospheric water vapor measurements by frost point hygrometers and the Aura Microwave Limb Sounder, Atmos. Meas. Tech., 9, 4447–4457, 2016.

2.2.5 WV monthly zonal mean climatologies from the SPARC Data Initiative

The SPARC Data Initiative performed the first comprehensive assessment of currently available stratospheric composition measurements obtained from an international suite of space-based satellite instruments. The initiative's main objectives were (1) to assess the state of data availability, (2) to compile vertically resolved, monthly zonal mean trace gas and aerosol climatologies, and (3) to perform a detailed inter-comparison of these climatologies, summarising useful information and highlighting differences between data sets. The activity compared satellite products of 26 different trace gas constituents (including water vapour, see Hegglin et al., 2013), and also aerosol.

Zonal monthly mean time series of each trace gas species in VMR and aerosol (as extinction ratio) have been calculated for each instrument on the SPARC Data Initiative climatology grid, using 5º latitude bins (with mid-points at 87.5ºS, 82.5ºS, 77.5ºS,..., 87.5ºN) and 28 pressure levels (300, 250, 200, 170, 150, 130, 115, 100, 90, 80, 70, 50, 30, 20, 15, 10, 7, 5, 3, 2, 1.5, 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1 hPa). To this end, profile data have been carefully screened before binning and a hybrid log–linear interpolation in the vertical has been performed. For instruments that provide data on an altitude grid, a conversion from altitude to pressure levels is performed using retrieved temperature/pressure profiles or meteorological analyses (ECMWF, GEOS-5, or NCEP). Similarly, this information is used to convert retrieved number densities into VMR, where needed. Along with the monthly zonal mean value, the standard deviation and the number of averaged data values are given for each grid point.

Overview	
Name	SPARC Data Initiative L3 zonal monthly mean climatologies
Variable(s)	Zonal monthly mean water vapour volume mixing ratios
Version	v1.0
Doi	doi:10.5281/zenodo.4265393

Technical specifications	
Temporal resolution	Monthly
Temporal coverage	The temporal coverage can be found in the following figure depicting all available limb sounders for context (including also those that do not offer H_2O measurements). 
Spatial resolution, number of stations	SPARC Data Initiative latitude grid: 5º latitude bins (with mid-points at 87.5ºS, 82.5ºS, 77.5ºS,..., 87.5ºN)
Spatial coverage	Zonal mean
Vertical resolution	SPARC Data Initiative pressure grid: 300, 250, 200, 170, 150, 130, 115, 100, 90, 80, 70, 50, 30, 20, 15, 10, 7, 5, 3, 2, 1.5, 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1 hPa
Uncertainties available?	RMS available / also via WAVAS-II
Access details and utilisation	
Access via	Instrument PIs
Last download	01- 2021 (UoR)
Application	Input to CDR-3
Costs	N/A
References	

Hegglin, Michaela I., Tegtmeier, Susann, Anderson, John, Bourassa, Adam E., Brohede, Samuel, Degenstein, Doug, … Weigel, Katja. (2020). SPARC Data Initiative monthly zonal mean composition measurements from stratospheric limb sounders (1978-2018) (Version p01) [Data set]. Earth System Science Data (ESSD). Zenodo. http://doi.org/10.5281/zenodo.4265393.

Hegglin, M. I., Tegtmeier, S., Anderson, J., Bourassa, A. E., Brohede, S., Degenstein, D., Froidevaux, L., Funke, B., Gille, J., Kasai, Y., Kyrölä, E., Lumpe, J., Murtagh, D., Neu, J.

L., Pérot, K., Remsberg, E., Rozanov, A., Toohey, M., Urban, J., von Clarmann, T., Walker, K. A., Wang, H.-J., Arosio, C., Damadeo, R., Fuller, R., Lingenfelser, G., McLinden, C., Pendlebury, D., Roth, C., Ryan, N. J., Sioris, C., Smith, L., and Weigel, K.: 2021: Overview and update of the SPARC Data Initiative: Comparison of stratospheric composition measurements from satellite limb sounders, Earth Syst. Sci. Data, 13, 1855–1903, doi: 10.5194/essd-13-1855-2021.

Hegglin, M.I., S. Tegtmeier, J. Anderson, L. Froidevaux, R. Fuller, B. Funke, A. Jones, G. Lingenfelser, J. Lumpe, D. Pendlebury, E. Remsberg, A. Rozanov, M. Toohey, J. Urban, T. von Clarmann, K. A. Walker, R. Wang and K. Weigel, 2013: SPARC Data Initiative: Comparison of water vapor climatologies from international satellite limb sounders. J. Geopyhs. Res., 118 (20), pp. 11,824-11,846, doi: 10.1002/jgrd.50752.

Hegglin, M.I., D. A. Plummer, T. G. Shepherd, J. F. Scinocca, J. Anderson, L. Froidevaux, B. Funke, D. Hurst, A. Rozanov, J. Urban, T. von Clarmann, K. A. Walker, H. J. Wang, S. Tegtmeier, and K. Weigel, 2014: Vertical structure of stratospheric water vapour trends derived from merged satellite data. Nature Geoscience, 7 (10), pp. 768-776. ISSN 1752-0894 doi: 10.1038/ngeo2236

SPARC, 2017: The SPARC Data Initiative: Assessment of stratospheric trace gas and aerosol climatologies from satellite limb sounders. By M. I. Hegglin and S. Tegtmeier (eds.), SPARC Report No. 8, WCRP-5/2017, available at www.sparc-climate.org/publications/sparc-reports/sparc-report-no8.

2.3 CDR-4: humidity profiles in the UTLS

2.3.1 IMS products from RAL

The IMS scheme employs optimal estimation to jointly retrieve water vapour, temperature and ozone profiles surface spectral emissivity and cloud parameters from Metop IASI, MHS and AMSU. This development was originally commissioned by EUMETSAT to extend its operational IASI optimal estimation scheme in three key respects:

1. Addition of the microwave sounders' measurements
2. Co-retrieval of surface spectral emissivity
3. Co-retrieval of two effective cloud parameters.

Those three extensions were found to improve agreement with ECMWF analyses of lower tropospheric water vapour and to reduce the sensitivity to small amounts of cloud contamination, significantly improving the coverage of useful data.

The IMS scheme was subsequently developed through work within the UK NCEO. The scheme now uses a weak prior constraint, based on zonal mean climatology. It is in practice therefore independent of ECMWF analyses or re-analyses. The IMS scheme uses the RTTOV (v10) radiative transfer model to simulate brightness temperature observations of the IASI and microwave sounders. Temperature, humidity and ozone profiles are represented in terms of the PCs of the covariance of departures from their climatological zonal means. The coefficients of 28 PCs are retrieved for the atmospheric temperature profile, 18 for the water vapour profile and 10 for the ozone profile. Surface spectral emissivity is represented in terms of 20 PCs of its global variation derived from the RTTOV infra-red and microwave atlases. The state vector also includes elements for surface temperature, cloud-top height and cloud fraction.

Via NCEO, the IMS scheme has been applied to process the complete IASI Metop A mission from 2007 to 2016. This Version-1 dataset was made available in Year-1 to the WV_cci project. This data is now archived at CEDA.

Overview	
Name	IMS retrievals provided by RAL
Variable(s)	Water vapour mixing ratio profiles, together with temperature, ozone, surface emissivity and cloud parameters
Version	Algorithm 2.1 (1st release)
Doi	http://dx.doi.org/10.5285/489e9b2a0abd43a491d5afdd0d97c1a4
Technical specifications	
Temporal resolution	L2 data at sampling times of Metop-A; I.e. 2 overpasses per day corresponding to 9:30 (descending node) and 21:30 (ascending) local equator crossing time.
Temporal coverage	July 2007 – December 2016
Spatial resolution, number of stations	12 km footprints, sampled ~every 25 km at nadir.
Spatial coverage	Global
Vertical resolution	1–2 km through troposphere, degrading in upper troposphere; little sensitivity in stratosphere
Uncertainties available?	Yes
Access details and utilisation	
Access via	http://www.ceda.ac.uk/
Last download	11-2020 (UoR)
Application	Input to CDR-4

Costs	None
References	
R. Siddans, D. Gerber, B. Bell, Optimal Estimation Method retrievals with IASI, AMSU and MHS measurements. Final Report, EUM/CO/13/46000001252/THH, 2015 Siddans, R., J. Walker, B. Latter, B. Kerridge, F. Gerber, D. Knappett, (2018): RAL Infrared Microwave Sounder (IMS) temperature, water vapour, ozone and surface spectral emissivity. Centre for Environmental Data Analysis, date of citation. doi:10.5285/489e9b2a0abd43a491d5afdd0d97c1a4. **Website:** http://dx.doi.org/10.5285/489e9b2a0abd43a491d5afdd0d97c1a4	

2.3.2 WV profiles from ACE-FTS

See section 2.2.2.

2.3.3 WV profiles from ACE-MAESTRO

See section 2.2.3.

2.3.4 WV profiles from AURA-MLS

See section 2.2.4.

2.3.5 WV profiles from MIPAS

See section 2.2.1.

3. AUXILIARY AND OTHER DATA FOR PRODUCTION

3.1 CDR-1 and CDR-2

The TCWV algorithm takes auxiliary data to constrain the retrieval process. These data are ECMWF analysis data, which are part of the OLCI L1b data files:

- surface pressure
- surface temperature
- total column water vapour (first guess over land, prior over ocean)
- 10 m wind speed (for coast).

All parameters are used directly in the retrieval to constrain the forward operator in the retrieval. The reprocessed MERIS Level 1b data (3rd reprocessing) is in the same format as OLCI and contains the auxiliary data. For MODIS we use ECMWF analysis data, interpolated in time and space. The ERA5 is available from the C3S climate data store (see section 5.2).

3.2 CDR-3

For the production of the L3 limb zonal monthly mean stratospheric CDR-3, the water vapour fields from a chemistry–climate model simulation nudged to observed meteorology was used as transfer function between satellite limb sounder datasets (see Hegglin et al., 2013). The model identified to provide such fields is the Canadian Middle Atmosphere Model (CMAM; ECCC, Canada) (see Morgenstern et al., 2017).

Access to this datasets is guaranteed via the website of the IGAC/SPARC Chemistry–Climate Model Initiative (http://blogs.reading.ac.uk/ccmi/badc-data-access/).

3.3 CDR-4

For the production of the L3 vertically resolved water vapour CDR-4 in the UTLS, MERRA-2 and/or ERA5 temperature fields were needed in order to derive tropopause height as a reference coordinate system.

Data access for ECMWF ERA5 is obtained via:
https://apps.ecmwf.int/data-catalogues/era5/?class=ea

and for MERRA-2 via:
https://disc.gsfc.nasa.gov/datasets?keywords=%22MERRA-2%22&page=1&source=Models%2FAnalyses%20MERRA-2

4. SATELLITE DATA FOR COMPARISON

Within WV_cci, satellite data are used for comparisons in round robins, during validation, and for climate analysis. These project internal application areas are indicated as well below.

4.1 GOME Evolution Climate

The GOME Evolution Climate product was generated within the ESA GOME Evolution project. The product combines GOME, SCIAMACHY and GOME-2 observations to provide a global product of TCWV.

Overview	
Name	GOME Evolution Climate
Variable(s)	TCWV
Latest version	V2.2
Doi	https://doi.org/10.1594/WDCC/GOME-EVL_water_vapor_clim_v2.2
Technical specifications	
Temporal resolution	Monthly
Temporal coverage	July 1995 – December 2015
Spatial resolution, number of stations	1°
Spatial coverage	Global
Vertical resolution	n/a
Uncertainties available?	Standard deviation
Access details and utilization	
Access via	Doi
Last download	March 2021 (DWD)
Application	Comparison
Costs	None
References	

Beirle, S., Lampel, J., Wang, Y., Mies, K., Dörner, S., Grossi, M., Loyola, D., Dehn, A., Danielczok, A., Schröder, M., and Wagner, T.: The ESA GOME-Evolution “Climate” water vapor product: a homogenized time series of H2O columns from GOME, SCIAMACHY, and GOME-2, Earth Syst. Sci. Data, 10, 449-468, https://doi.org/10.5194/essd-10-449-2018, 2018.

4.2 GOZCARDS (NASA)

The Global OZone Chemistry And Related trace gas Data records for the Stratosphere includes vertically resolved water vapour data from a subset of the limb profiling satellite instruments operating since the 1990s. The primary GOZCARDS products are zonal-mean monthly-mean time series of mixing ratios of water vapour, ozone and several other species on pressure levels (6–12 levels per decade from 147 to 0.01 hPa). GOZCARDS is a merged data product, homogenised to account for inter-satellite biases and to minimise artificial jumps in the record.

Overview	
Name	GOZCARDS
Variable(s)	H_2O, O_3, T, HCl, HNO_3, N_2O
Latest version	V2.20 (O_3) and V1.01 (others)
doi	10.5067/MEASURES/GOZCARDS/DATA3003
Technical specifications	
Temporal resolution	Monthly
Temporal coverage	1991 – present
Spatial resolution, number of stations	10° zonal mean
Spatial coverage	Global
Vertical resolution	6–12 levels per pressure decade, between 147 and 0.01 hPa (~3 km)
Uncertainties available?	Yes
Access details and utilization	
Access via	https://gozcards.jpl.nasa.gov/info.php

Last download	02-2021 (BIRA)
Application	Comparison
Costs	None
References	
Froidevaux, L., Anderson, J., Wang, H.-J., Fuller, R. A., Schwartz, M. J., Santee, M. L., Livesey, N. J., Pumphrey, H. C., Bernath, P. F., Russell III, J. M., and McCormick, M. P.: Global OZone Chemistry And Related trace gas Data records for the Stratosphere (GOZCARDS): methodology and sample results with a focus on HCl, H2O, and O3, Atmos. Chem. Phys., 15, 10471-10507, https://doi.org/10.5194/acp-15-10471-2015, 2015.	

4.3 IASI - water vapour profiles and TCWV (EUMETSAT)

The IASI is a key instrument and main payload on-board the current generation of Metop satellites. With the primary purpose of providing vertical information on temperature and humidity for NWP, the operational and performance continuity will allow for IASI to be exploited in future climate-related studies. The current version 6 release of EUMETSATs L2 product (v6.3) contains information on atmospheric temperature, humidity and ozone. Surface estimates of skin temperature and emissivity are also included along cloud properties. The inclusion of averaging kernel output from the operational processor is included from version 6 onwards.

Overview	
Name	IASIL2TWT
Variable(s)	T, q, Ts, O_3, emissivity & cloud
Latest version	V6 (30/09/2014 onwards)
doi	n/a
Technical specifications	
Temporal resolution	Twice daily
Temporal coverage	19 October 2006 – present
Spatial resolution, number of stations	~12 km nadir
Spatial coverage	Global
Vertical resolution	~2 km H_2O, ~1 km Temperatrure

Uncertainties available?	Yes
Access details and utilisation	
Access via	EUMETSAT Data Centre
Last download	2018-11 (UoL)
Application	Comparison
Costs	None
References	
August, T., Klaes, D., Schlüssel, P., Hultberg, T., Crapeau, M., Arriaga, A., O'Carroll, A., Coppens, D., Munro, R. and Calbet, X., 2012. IASI on Metop-A: Operational Level 2 retrievals after five years in orbit. Journal of Quantitative Spectroscopy and Radiative Transfer, 113(11), pp.1340-1371. Hilton, F., Armante, R., August, T., Barnet, C., Bouchard, A., Camy-Peyret, C., Capelle, V., Clarisse, L., Clerbaux, C., Coheur, P.F. and Collard, A., 2012. Hyperspectral Earth observation from IASI: Five years of accomplishments. bulletin of the american meteorological Society, 93(3), pp.347-370. **Website:** https://navigator.eumetsat.int/product/EO:EUM:DAT:METOP:IASIL2TWT	

4.4 SWOOSH (NOAA)

The Stratospheric Water and Ozone Satellite Homogenized database includes vertically resolved ozone and water vapour data from a subset of the limb-profiling satellite instruments operating since the 1980s. The primary SWOOSH products are zonal-mean monthly-mean time series of water vapour and ozone mixing ratio on pressure levels (12 levels per decade from 316 to 1 hPa). The SWOOSH pressure level products are provided on several independent zonal-mean grids, and additional products include two coarse 3-D griddings as well as a zonal-mean isentropic product. SWOOSH includes both individual satellite source data as well as a merged data product. A key aspect of the merged product is that the source records are homogenised to account for inter-satellite biases and to minimise artificial jumps in the record.

Overview	
Name	SWOOSH

Variable(s)	H_2O, O_3
Latest version	V2.6
Doi	10.7289/V5TD9VBX
Technical specifications	
Temporal resolution	Monthly
Temporal coverage	October 1986 – present
Spatial resolution, number of stations	Zonal mean: 2.5°, 5° and 10°, Gridded mean: 10° lat x 30° lon, and 5° lat x 20° lon.
Spatial coverage	Global
Vertical resolution	6–12 levels per pressure decade, between 316 and 1 hPa (~3 km)
Uncertainties available?	Yes
Access details and utilization	
Access via	http://www.esrl.noaa.gov/csd/swoosh
Last download	02-2021 (BIRA, UoR)
Application	Comparison
Costs	None
References	
Davis, S. M., Rosenlof, K. H., Hassler, B., Hurst, D. F., Read, W. G., Vömel, H., Selkirk, H., Fujiwara, M., and Damadeo, R.: The Stratospheric Water and Ozone Satellite Homogenized (SWOOSH) database: a long-term database for climate studies, Earth Syst. Sci. Data, 8, 461-490, https://doi.org/10.5194/essd-8-461-2016, 2016.	

4.5 AIRS/AMSU (NASA)

The AIRS and AMSU on-bound NASA's Aqua satellite provides 3D measurements of temperature and water vapour through the atmospheric column. The AIRS/AMSU data includes level 2 and level 3 data products, contains information on profiles of atmospheric temperature, water vapour, and ozone as well as TCWV, surface skin temperature and emissivity. Recently version 7 was made available publicly, but comparisons between 6 and 7 on level 3 data show differences. Also, version 7 does not contain uncertainty information in level 3 data. Version 6 will be used for intercomparisons in WV_cci at DWD.

Overview	
Name	AIRX2RET
Variable(s)	T, q, O_3, emissivity & cloud
Latest version	V7.0
doi	10.5067/URTYDAGTM548
Technical specifications	
Temporal resolution	6 minutes
Temporal coverage	2002-08-31 – present
Spatial resolution, number of stations	50 km
Spatial coverage	Global
Vertical resolution	14 levels between 1100 hPa and 50 hPa (H_2O, useable up to upper troposphere), 28 levels between 1100 hPa and 0.1 hPa (temperatrure)
Uncertainties available?	Yes
Access details and utilisation	
Access via	NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC)
Last download	12-2020 (UoR)
Application	Comparison
Costs	None
References	
B. H. Kahn et al. (2014), The Atmospheric Infrared Sounder version 6 cloud products, doi:10.5194/acp-14-399-2014, https://www.atmos-chem-phys.net/14/399/2014/acp-14-399-2014.html B. H. Kahn et al. (2014), The Atmospheric Infrared Sounder version 6 cloud products, doi:10.5194/acp-14-399-2014, https://www.atmos-chem-phys.net/14/399/2014/acp-14-399-2014.html Joel Susskind, John, M. Blaisdell, and Lena Iredell (2014), Improved methodology for surface and atmospheric soundings, error estimates, and quality control procedures: the	

atmospheric infrared sounder science team version 6 retrieval algorithm, J. Appl. Rem. Sens, 1, doi:10.1117/1.JRS.8.084994

Patrick Boylan, Junhong Wang, Stephen A. Cohn, Erik Fetzer, Eric S. Maddy, and Sung Wong (2015), Validation of AIRS version 6 temperature profiles and surface-based inversions over Antarctica using Concordiasi dropsonde data, Journal of Geophysical Research, 3, doi:10.1002/2014JD022551

L.N. Boisvert, D.L. Wu, T. Vihma, J.Susskind (2015), Verificaton of air surface humidity differences from AIRS and ERA Interim in support of turbulent flux estimation in the Arctic, doi:10.1002/2014JD02166

Jacola Roman, Robert Knuteson, Thomas August, Tim Hultberg, Steve Ackerman, and Hank Revercomb (2016), A global assessment of NASA AIRS v6 and EUMETSAT IASI v6 precipitable water vapor using ground based GPS SuomiNet stations, Journal of Geophysical Research, 15, doi:10.1002/2016JD024806

Adam B. Milstein, William J. Blackwell (2015), Neural network temperature and moisture retrieval algorithm validation for AIRS/AMSU and CrIS/ATMS, Journal of Geophysical Research, 4, doi:10.1002/2015JD024008

Journal Editors (May), Special Issue, Validation of Atmospheric Infrared Sounder Observations, J. Geophys, Res. Atmospheres, 9, doi:10.1029/2005/JD007020

Joel Susskind, Christopher D. Barnet, and John M. Blaisdell (2003), Retrieval of Atmospheric and Surface Parameters From AIRS/AMSU/HSB Data in the Presence of Clouds, IEEE Transactions on Geoscience and Remote Sensing, 2, doi:10.1109/TGRS.2002.808236

Website: https://disc.gsfc.nasa.gov/datasets/AIRX2RET_7.0/summary

Overview	
Name	AIRS3STM
Variable(s)	T, q, O_3, emissivity & cloud, TCWV
Latest version	V7.0
doi	10.5067/ KUC55JEVO1SR
Technical specifications	
Temporal resolution	Monthly
Temporal coverage	2002-09-01 to 2016-10-02
Spatial resolution, number of stations	1° x 1°
Spatial coverage	Global
Vertical resolution	14 levels between 1100 hPa and 50 hPa (H_2O, useable up to upper troposphere),

	28 levels between 1100 hPa and 0.1 hPa (temperatrure)
Uncertainties available?	Yes
Access details and utilisation	
Access via	NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC)
Last download	01-2021 (UoR), 12-2020 (DWD)
Application	Comparison
Costs	None
References	
Joel Susskind, John, M. Blaisdell, and Lena Iredell (2014), Improved methodology for surface and atmospheric soundings, error estimates, and quality control procedures: the atmospheric infrared sounder science team version-6 retrieval algorithm, J. Appl. Rem. Sens., 1, doi:10.1117/1.JRS.8.084994 B.H. Kahn, et.al. (2014), The Atmospheric Infrared Sounder Version 6 Cloud Products, Atmospheric Chemistry and Physics, 1, doi:10.5194/acp-14-399-2014 **Website:** https://disc.gsfc.nasa.gov/datasets/AIRX3STM_7.0/summary	

4.6 Merged Microwave (REMSS)

Remote Sensing System has produced a TCWV monthly mean time series product for global ice-free ocean on a 1°-grid from microwave imager radiometer data including, among others, SSM/I, SSMIS, AMSR-E and WindSat (Mears et al., 2018).

Overview	
Name	tpw_v07r01
Variable(s)	TCWV
Latest version	V7.0
doi	N/A
Technical specifications	
Temporal resolution	Monthly
Temporal coverage	1988-01 to 2020-03

Spatial resolution, number of stations	1° x 1°
Spatial coverage	Global ice-free ocean
Vertical resolution	Total column
Uncertainties available?	Yes
Access details and utilisation	
Access via	http://www.remss.com/measurements/atmospheric-water-vapor.html
Last download	05-2020 (DWD)
Application	Comparison
Costs	None
References	
Mears, C. A., Smith, D. K., Ricciardulli, L., Wang, J., Huelsing, H., & Wentz, F. J. (2018). Construction and uncertainty estimation of a satellite-derived total precipitable water data record over the world's oceans. Earth and Space Science, 5(5), 197-210.	

5. REANALYSIS, CLIMATE MODEL AND OTHER DATA FOR COMPARISON

WV_cci utilises the ERA5 reanalysis for comparison in validation context, to estimate the clear-sky bias and for climate analysis. Climate model output is used for climate analysis only. These project internal application areas are indicated below.

5.1 CMIP6

The objective of CMIP is to better understand past, present and future climate changes arising from natural, unforced variability or in response to changes in radiative forcing in a multi-model context. This understanding includes assessments of model performances during the historical period.

Overview	
Name	Coupled Model Intercomparison Project (CMIP) 6
Variable(s)	3D: specific humidity, temperature, vertical velocity
Latest version	The CMIP-6 models that will provide the relevant fields at the right resolution. At least: IPSL-CM, MPI, UKMO
doi	n/a
Technical specifications	
Temporal resolution	Daily (if possible), monthly
Temporal coverage	• Baseline DECK simulations (AMIP: 1979-2014) • Historical simulations (1850–2014)
Spatial resolution, number of stations	Model-dependent, 0.5°x0.5° and 0.25°x0.25° resolutions
Spatial coverage	Global
Vertical resolution	Model-dependent
Uncertainties available?	Via ensemble simulations
Access details and utilisation	
Access via	Earth System Grid Federation nodes From the IPSL-France portal: https://esgf-node.ipsl.upmc.fr/projects/cmip6-ipsl/

Last download	10-2020 (UVSQ)
Application	Climate analysis and evaluation of climate models.
Costs	None
References	
Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E.: Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, Geosci. Model Dev., 9, 1937-1958, doi:10.5194/gmd-9-1937-2016, 2016. **Webpage**: https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6	

5.2 ERA5

ERA5 is the fifth generation of ECMWF atmospheric reanalyses of the global climate. Currently, ERA5 covers the full 1950–present day period. The datasets are provided at a much higher resolution than the previous ERA-Interim reanalyses, with hourly fields and a horizontal resolution of 31 km over 137 vertical levels reaching up to 0.01 hPa (6-hourly, 79 km horizontal grid and 60 levels up to 0.1 hPa for ERA-Interim).

A major advance is the availability of uncertainty estimates computed from a 10-member ensemble of data assimilation at a reduced 63-km resolution.

Overview	
Name	ECMWF Re-Analysis 5
Variable(s)	2D: TCWV, total cloud cover (TCC), total column rain-water (TCRW), total precipitation (TP), total column cloud liquid water (TCLW) Land-sea mask, surface pressure, 10-m U wind component, 10-m V wind component, Low cloud cover, Medium cloud cover, High cloud cover 3D: VRWV, Temperature, Vertical velocity, Fraction of cloud cover
Latest version	n/a
doi	n/a
Technical specifications	
Temporal resolution	hourly, 8x daily, monthly
Temporal coverage	1 January 2002 – 31 December 2012;

	1 January 2000 – present
Spatial resolution, number of stations	0.25° x 0.25° (HRES: high resolution) 0.5° x 0.5° (EDA: reduced resolution ten members ensemble)
Spatial coverage	Global
Vertical resolution	37 pressure levels
Uncertainties available?	yes, only for the EDA dataset (resolution: 3-hourly)
Access details and utilisation	
Access via	Copernicus CDS, https://cds.climate.copernicus.eu/
Last download	05-2019 (UoR)
Application	Comparison, estimation of clear-sky bias and climate analysis.
Costs	None
References	
Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), date of citation. https://cds.climate.copernicus.eu/cdsapp#!/home **Webpage:** https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era5	

5.3 MERRA-2

MERRA-2 is the version 2 Earth system reanalyses of the global climate from NASA GMAO. Currently MERRA-2 product provides data beginning in 1980. The datasets are produced to replace the original MERRA dataset with an advanced assimilation system including modern hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets.

Overview	
Name	Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2)
Variable(s)	3D: VRWV, temperature
Latest version	n/a

doi	n/a
Technical specifications	
Temporal resolution	Hourly, Daily, Monthly
Temporal coverage	1 January 1980 – present
Spatial resolution, number of stations	0.5° x 0.625°
Spatial coverage	Global
Vertical resolution	42/72 pressure levels
Uncertainties available?	Yes
Access details and utilisation	
Access via	NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) https://disc.gsfc.nasa.gov/datasets
Last download	01-2021 (UoR)
Application	Comparison
Costs	None
References	
MERRA-2 Overview: The Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2), Ronald Gelaro, et al., 2017, J. Clim., doi: 10.1175/JCLI-D-16-0758.1 https://disc.sci.gsfc.nasa.gov/datasets?keywords=%22MERRA-2%22&page=1&source=Models%2FAnalyses%20MERRA-2	

6. GROUND-BASED, *IN SITU* AND OTHER DATA FOR VALIDATION

Within WV_cci, ground-based and *in situ* data are used in round robins and during validation. These project internal application areas are indicated below.

6.1 ARSA

The ARSA database is produced at ARA/ABC(t)/LMD, Paris, France. ARSA is mainly based on radiosonde observations that have successfully completed extensive qualitative and quantitative tests: the required minimal information being to have measured points from surface up to 30 hPa for temperature profiles and from surface to 300 hPa for water vapour profiles. Moreover, in order to give a continuous description of the atmospheric state from the surface to the top of the atmosphere (~0.002hPa), these radiosonde observations have been extended above their highest measured point with ERA-Interim data (temperature, water vapour and ozone up to 0.1 hPa) and then with SciSat ACE FTS level2 data (from 0.1h Pa to the top the atmosphere: 0.0026 hPa). Radiosonde reports are extracted from the ECMWF archive. They come from 1472 globally distributed stations and are combined with surface and other auxiliary observations. The current ARSA database starts in January 1979, and is extended onwards, on a monthly basis. It is available upon request at LMD (adapted from Scott et al., 2015, available at http://gewex-vap.org/wp-content/uploads/2016/11/QUASAR_LMD_CMSAF_GVAP_v1-0_for_release.pdf).

Overview	
Name	Analyzed RadioSoundings Archive (ARSA)
Variable(s)	Profiles of specific humidity and temperature
Latest version	V2.7
doi	Not available
Technical specifications	
Temporal resolution	variable
Temporal coverage	January 1979 – July 2018 (updated subsequently)
Spatial resolution, number of stations	~1400 stations
Spatial coverage	Globally distributed stations

Vertical resolution	43 levels
Uncertainties available?	no
Access details and utilisation	
Access via	http://ara.abct.lmd.polytechnique.fr/index.php?page=arsa-database
Last download	07-2020 (DWD)
Application	Comparison
Costs	None
References	
Website: http://ara.abct.lmd.polytechnique.fr/index.php?page=arsa	

6.2 GRUAN

The GRUAN data record currently contains characterised upper atmosphere soundings from Vaisala RS92 radiosondes, with the newer RS41 soundings not yet available to this project. All sounding profiles are reported on a 2 second vertical grid from the surface up into the UTLS. At present GRUAN comprises 30 stations, with 12 having been certified by GRUAN. Once fully established, GRUAN will likely encompass 30–40 stations globally. Certified GRUAN sites not only undergo an annual review, but are also subject to periodic complete auditing of their measurement programs to ensure all sites continue to meet GRUAN practice standards. Validation of tropospheric water vapour CDR products with GRUAN allows for more comprehensive studies compared to operational radiosonde networks due to the inclusion of uncertainty estimates..

Overview	
Name	GCOS Reference Upper-Air Network (GRUAN)
Variable(s)	Temperature, relative humidity, pressure, wind speed, longitude, latitude
Latest version	v2
doi	https://dx.doi.org/10.5676/GRUAN/RS92-GDP.2

Technical specifications	
Temporal resolution	Twice daily
Temporal coverage	2005-06-08 to present (not consistent across all sites, see below)
Spatial resolution, number of stations	12
Spatial coverage	Global, sparse coverage (see below)
Vertical resolution	2 second vertical grid
Uncertainties available?	Yes
Access details and utilisation	
Access via	doi
Last download	2018-11 (UoL), 05-2020 (DWD)
Application	Comparison, validation, and bias-correction
Costs	None
Spatio-temporal distribution	

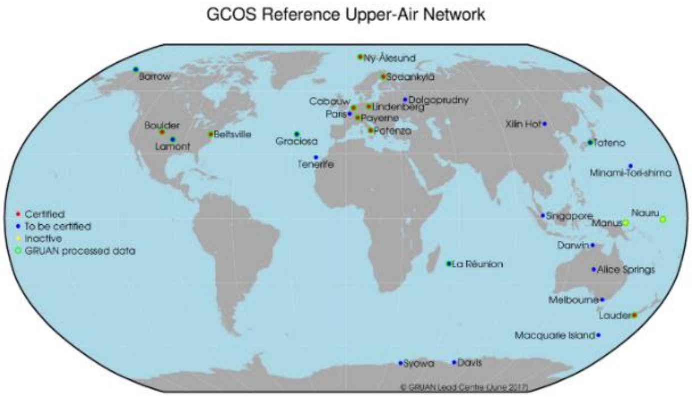


Figure 6-1: Location of GRUAN sites (source: https://www.gruan.org/).

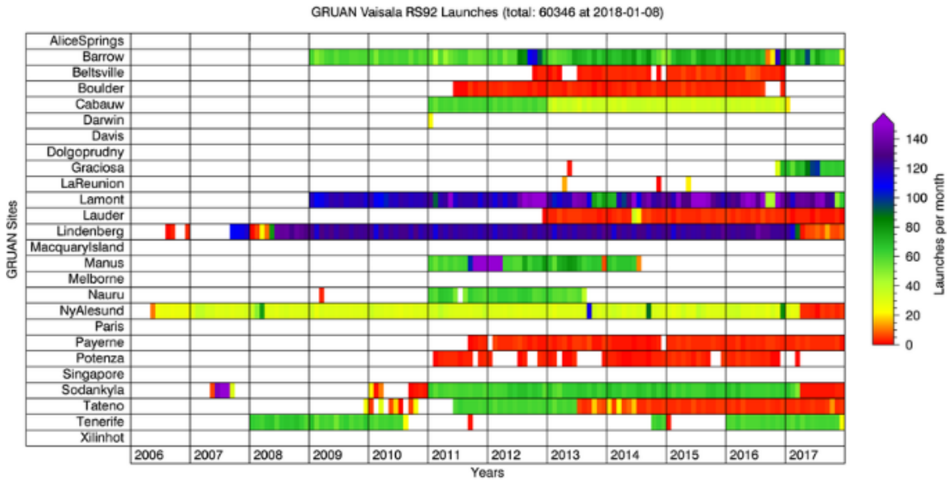


Figure 6-2: Availability of GRUAN soundings per site (source: https://www.gruan.org/).

References

Dirksen, R. J., Sommer, M., Immler, F. J., Hurst, D. F., Kivi, R., and Vömel, H.: Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde, Atmos. Meas. Tech., 7, 4463-4490, doi:10.5194/amt-7-4463-2014, 2014.

Immler, F. J., Dykema, J., Gardiner, T., Whiteman, D. N., Thorne, P. W., and Vömel, H.: Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products, Atmos. Meas. Tech., 3, 1217-1231, doi:10.5194/amt-3-1217-2010, 2010.

Thorne, P.: Guidelines on requirements for the initial development of a GRUAN data product. GRUAN Technical Note GRUAN-TN-4, v1.0 (2016-04-21)

Vömel, H., Sommer, M. and Dirksen, R.: Establishing Data Products For New Radiosondes in GRUAN. GRUAN Technical Note GRUAN-TN-1, v1.0 (2013-07-08)

Website: https://www.gruan.org/

6.3 SHADOZ

The Southern Hemisphere ADditional OZonesondes (SHADOZ) data record currently contains characterised atmospheric humidity soundings from 1998. All profiles are reported on a 10-second vertical grid from the surface up to the lower stratosphere. SHADOZ data cover 13 stations over the tropical region. Due to the limitations of radiosondes, the humidity sounding profiles are usually only suitable for use up to the upper troposphere around 300 hPa. Comparison and validation of tropospheric water vapour CDR products with SHADOZ observations allow for more humidity profiles to be included than just the frost-point hygrometer soundings.

Overview	
Name	Southern Hemisphere ADditional OZonesondes (SHADOZ)
Variable(s)	Temperature, relative humidity, pressure, longitude, latitude
Latest version	N/A
doi	N/A
Technical specifications	
Temporal resolution	Weekly to monthly
Temporal coverage	1998 to present (not consistent across all sites, see below)
Spatial resolution, number of stations	13
Spatial coverage	Global, sparse coverage
Vertical resolution	10 second vertical grid
Uncertainties available?	No
Access details and utilisation	
Access via	https://tropo.gsfc.nasa.gov/shadoz
Last download	11-2020 (UoR)
Application	Comparison, validation
Costs	None
Spatio-temporal distribution	

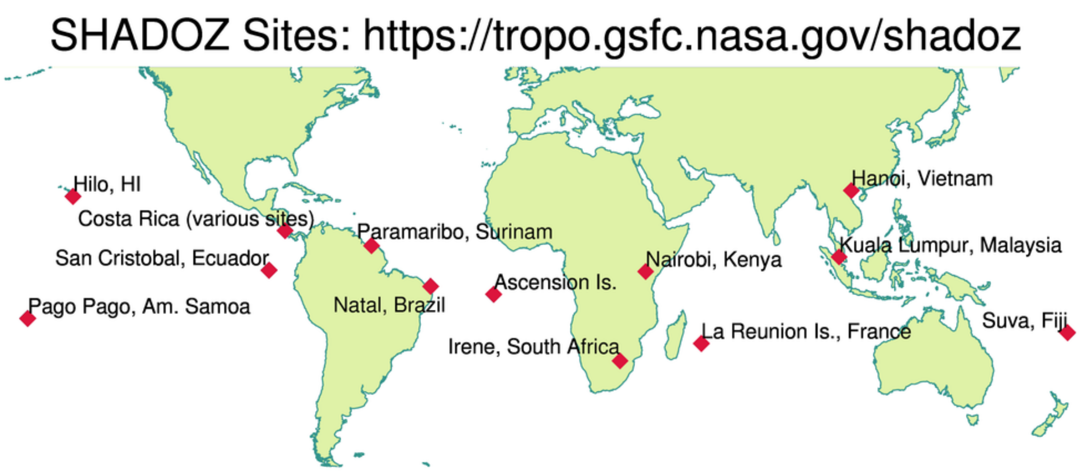


Figure 6-3: Location of SHADOZ sites (source: https://tropo.gsfc.nasa.gov/shadoz).

References

Witte, J.C., A. M. Thompson, H. G. J. Smit, etc (2017), First reprocessing of Southern Hemisphere ADditional OZonesondes (SHADOZ) profile records (1998-2015): 1. Methodology and evaluation, J. Geophys. Res. Atmos., 122, 6611-6636. https://doi.org/10.1002/2016JD026403.

Thompson, A. M., J. C. Witte, C. Sterling, et al. (2017). First reprocessing of Southern Hemisphere Additional Ozonesondes (SHADOZ) ozone profiles (1998-2016): 2. Comparisons with satellites and ground-based instruments. Journal of Geophysical Research: Atmospheres, 122, 13,000-13,025. https://doi.org/10.1002/2017JD027406.

Witte, J. C., Thompson, A. M., Smit, H. G. J., Vömel, H., Posny, F., & Stübi, R. (2018). First reprocessing of Southern Hemisphere ADditional OZonesondes profile records: 3. Uncertainty in ozone profile and total column. Journal of Geophysical Research: Atmospheres, 123, 3243-3268. https://doi.org/10.1002/2017JD027791.

Sterling, C. W., B. J. Johnson, S. J., Oltmans, H. G. J. Smit, A., Jordan, P. D., Cullis, E. G., Hall, A. M., Thompson, and J. C. Witte (2017). Homogenizing and Estimating the Uncertainty in NOAA's Long Term Vertical Ozone Profile Records Measured with the Electrochemical Concentration Cell Ozonesonde, Atmos. Meas. Tech. https://doi.org/10.5194/amt-2017-397.

Website: https://tropo.gsfc.nasa.gov/shadoz

6.4 Balloon-borne Hygrometer profiles

In situ instrumental observations of water vapour profiles are carried out with the balloon-borne hygrometers with two datasets available for use: the cryogenic frost point hygrometer (CFH) and the National Oceanic and Atmospheric Administration (NOAA) frost point hygrometer (FPH) datasets. All profiles are vertically averaged every 0.25

km from surface to 30 km based on combined ascent and descent data. The whole balloon-borne hyrometer data include sounding profiles from 27 stations globally from 1991 to 2016.

Overview	
Name	Balloon-borne Hygrometer profiles
Variable(s)	Temperature, water vapour, relative humidity, pressure, wind speed, longitude, latitude
Type	Ground-based balloon-borne in-situ observation
Technical specifications	
Temporal resolution	Variable (daily to monthly)
Temporal coverage	19912016 (not consistent across all sites)
Spatial resolution, number of stations	27
Spatial coverage	Global, sparse coverage
Vertical resolution	250 m
Uncertainties available?	No
Access details and utilisation	
Access via	Contact PIs (Dale.Hurst@noaa.gov and holger.voemel@ucar.edu) and also alexandra.laeng@kit.edu
Last download	03-2019 (UoR)
Application	Comparison, validation, and bias-correction
Costs	None
References	
Hurst, D. F., S. J. Oltmans, H. Vömel, K. H. Rosenlof, S. M. Davis, E. A. Ray, E. G. Hall, and A. F. Jordan (2011), Stratospheric water vapor trends over Boulder, Colorado: Analysis of the 30 year Boulder record, J. Geophys. Res., 116, D02306, doi:10.1029/2010JD015065. Vömel, H., D. E. David, and K. Smith (2007), Accuracy of tropospheric and stratospheric water vapor measurements by the cryogenic frost point hygrometer: Instrumental details and observations, J. Geophys. Res., 112, D08305, doi:10.1029/2006JD007224	

6.5 SPURT aircraft data

During SPURT, a project funded under the German AFO 2000 programme, measurements of a wide range of trace gases (among them water vapour) with different lifetimes and sink/source characteristics in the northern hemispheric UT and LMS were performed. A large number of *in situ* instruments were deployed on board a Learjet 35A, flying at altitudes up to 13.7 km, at times reaching to nearly 380 K potential temperature. Eight measurement campaigns (consisting of a total of 36 flights), distributed over all seasons and typically covering latitudes between 35N and 75N in the European longitude sector (10W–20E), were performed.

Name	
SPURT	
Variables	
Name(s):	H_2O mixing ratios, pressure, temperature
Type	*In situ*
Frequency	Every 5 seconds
Uncertainties available?	Yes
Temporal coverage	2001 to 2003
Description	
The SPURT aircraft campaign (Spurenstofftransport in der Tropopausenregion = trace gas transport in the tropopause region) performed measurements of a wide range of trace gases with different lifetimes and sink/source characteristics in the northern hemispheric upper troposphere (UT) and lowermost stratosphere (LMS). A large number of *in situ* instruments were deployed on board a Learjet 35A, among them a Lyman-alpha-hygrometer, FISH, to measure H_2O. The Learjet was flying at altitudes up to 13.7 km, at times reaching to nearly 380 K potential temperature. Eight measurement campaigns (consisting of a total of 36 flights), distributed over all seasons and typically covering latitudes between 35 N and 75 N in the European longitude sector (10 W–20 E), were performed.	

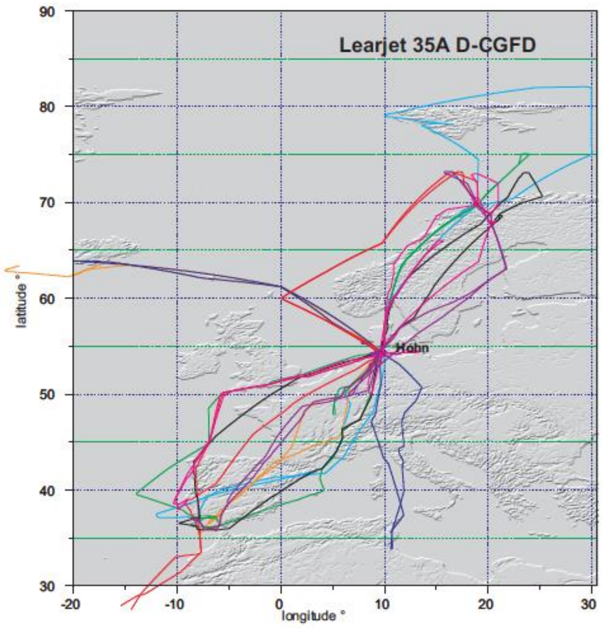


Figure 6-4: IOP flight routes during the SPURT campaign.

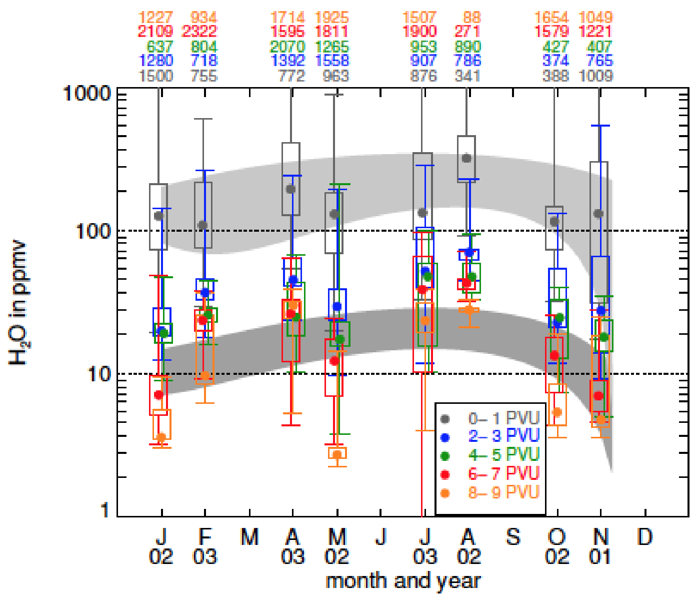


Figure 6-5: Example of FISH water vapour measurements.

Access details and utilisation	
Access via	JULIA aircraft database (contact: c.rolf@fz-juelich.de) UoR (contact: m.i.hegglin@reading.ac.uk)
Last download	08-2019 (UoR)

References

Krebsbach M., C. Schiller, D. Brunner, G. Günther, M. I. Hegglin, D. Mottaghy, M. Riese, N. Spelten, and H. Wernli, Seasonal cycles and variability of O3 and H2O in the UT/LMS during SPURT, Atmos. Chem. Phys., 6, 109-125, 2006.

Engel, A., H. Bonisch, D. Brunner, H. Fischer, H. Franke, G. Günther, C. Gurk, M. Hegglin, et al., Highly resolved observations of trace gases in the lowermost stratosphere and upper troposphere from the SPURT project: An overview, Atmos. Chem. Phys., 6, 283-301, 2006.

6.6 JULIA aircraft data

In situ aircraft observations of water vapour data, compiled in the JULIA archive, with observations during 55 field compaigns and a total of 436 flights. The dataset only includes high performance and quality checked measurements from these field compaigns. A short description of the data can be found in Kraemer et al. (2018).

Name	
JULIA	
Variables	
Name(s):	H_2O mixing ratios, pressure, temperature
Type	*In situ*
Frequency	variable (depending on research campaign)
Uncertainties available?	No.
Temporal coverage	1997-2017
Description	
An extensive dataset of water vapour and ice clouds, but also other trace substances such as ozone is sampled onboard of different research aircraft during 55 field campaigns, with a total of 436 flights. A large number of aircraft, instruments and research groups from various countries have so far contributed to the dataset, which is archived in JULIA (JÜLich In- situ Airborne Data Base) and hosted at the ForschungsZentrum Jülich, Germany (FZJ). The aircraft are for example the Russian Geophysica, the German Falcon, Learjet, HALO and AWI-Polar5&6, the British BAe-146 and the US Global Hawk and WB-57. Only high performance and quality checked measurements, covering the same measuring range, are included in JULIA.	

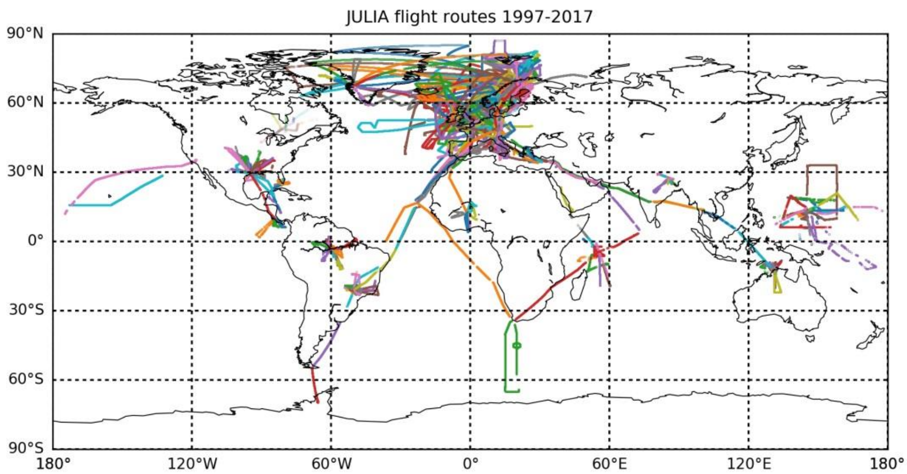


Figure 6-6: Aircraft tracks from JULIA data in the period of 1997 and 2017. The colour represents each flight.

Access details and utilisation	
Access via	JULIA aircraft database (contact: c.rolf@fz-juelich.de)
Last download	08-2019 (UoR)

References

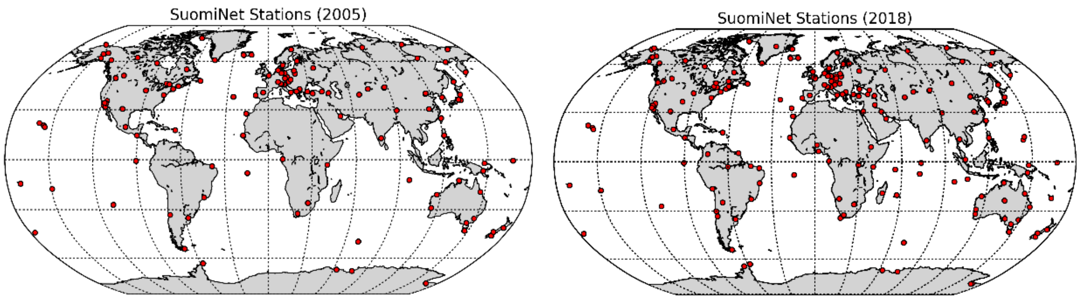
Kraemer, M., Rolf, C., Spelten, N., and Riese, M., The JÜLich In-situ Airborne Data Base JULIA: Water Vapour, Clouds & other Trace Substances in the UT/LS, abstract #A51O-2404, American Geophysical Union, Fall Meeting 2018, 2018.

6.7 SuomiNet

The SuomiNet data archive is a collection of GPS TCWV measurements from 150 global sites. A key advantage of SuomiNet is that observations are reported every 30 minutes allowing for collocations with tight time and spatial constraints. Due to the nature of GPS measurements, there is also no dependence of inter-calibration between the different sites (Alber et al., 1997). An additional strength of *in situ* GPS measurements is that not only are they accurate to within 1 kg/m^2 (Ware et al., 2000), SuomiNet provides uncertainty estimates for each TCWV measurement.

For the validation of the CCI CDR TCWV products SuomiNet is ideal due to its accuracy and sampling characteristics. With sites located on islands it also offers the opportunity to assess CDR product performance over smaller land masses in comparison to continental regions. Therefore, studies can vary from regional to global scales. It is noted that individual stations do not all cover the full period of interest and during first utilisation inhomogeneities in format and quality were observed.

Overview	
Name	SuomiNet
Variable(s)	TCWV, TZD, surface RH, Tair and pressure
Latest version	N/A
doi	N/A
Technical specifications	
Temporal resolution	Every 30 minutes
Temporal coverage	2005-01-01- to present
Spatial resolution, number of stations	Up to 150
Spatial coverage	Global, sparse coverage (see below)
Vertical resolution	N/A
Uncertainties available?	Yes
Access details and utilisation	
Access via	https://www.suominet.ucar.edu/data.html
Last download	11-2018 (UoL), 05-2020 (DWD)
Application	Validation
Costs	None
Spatio-temporal distribution	



References
Alber, C., R. Ware, C. Rocken and F. Solheim, GPS surveying with 1 mm precision using corrections for atmospheric slant path delay, Geophysical Research Letters, Vol. 24, No. 15, pp 1859-1862, August 1997. Ware, R.H., Fulker, D.W., Stein, S.A., Anderson, D.N., Avery, S.K., Clark, R.D., Droegemeier, K.K., Kuettner, J.P., Minster, J.B. and Sorooshian, S., 2000. SuomiNet: A real–time national GPS network for atmospheric research and education. Bulletin of the American Meteorological Society, 81(4), pp.677-694. Website: www.suominet.ucar.edu

6.8 ARM microwave radiometer measurements

The ARM program (*Atmospheric Radiation Measurement Climate Research Facility* of the US Department of Energy) operates a network of ground-based microwave radiometers (MWR). These measurements offer ground truth data with a very high accuracy (<0.6 kg/m^2) (Turner et al. 2007). Data and retrievals from these instruments have been available to the scientific community for almost 25 years. Three ARM sites are operated continuously (‘Southern Great Planes’ in Oklahoma, ‘Eastern North Atlantic’ on Azores island and ‘North Slope Alaska’). The key advantages of ARM MWR are the high accuracy and that observations are reported every few seconds. This allows for precise collocations with tight time and spatial constraints and further for an estimation of the temporal representativity. Additionally, it provides liquid water estimates and therewith an additional source for the constrainment to cloud-free situations of NIR satellite measurements. The drawback is the low global coverage.

Overview	
Name	ARM MWR
Variable(s)	TCWV, LWP

Latest version	N/A
doi	N/A
Technical specifications	
Temporal resolution	Every 30 seconds
Temporal coverage	1996-01-01 to present
Spatial resolution, number of stations	Up to 150, currently 3
Spatial coverage	Few locations globally
Vertical resolution	N/A
Uncertainties available?	Yes
Access details and utilisation	
Access via	https://www.archive.arm.gov/discovery
Last download	10-2019 (SE)
Application	Validation
Costs	None
Spatio-temporal distribution	
3 sites are available: - Southern Great Planes in Oklahoma, - Eastern North Atlantic on Azores island - North Slope Alaska	
References	
Turner, D. D. (2007), Improved ground-based liquid water path retrievals using a combined infrared and microwave approach, J. Geophys. Res.,112, D15204, doi:10.1029/2007JD008530	

7. OTHER DATA RECORDS

7.1 LST from ESA CCI

Within the ESA LST_cci project (https://climate.esa.int/en/projects/land-surface-temperature/) a global land-based LST product was generated using MODIS TERRA and AQUA observations. The MODIS based LST data record was downloaded in January 2021. The LST product will be used jointly with the SST product from ESA CCI and TAS from EUSTACE to assess compliance with theoretical expectation.

Overview	
Name	ESACCI-LST-L3C-LST-MODIS
Variable(s)	LST
Latest version	fv1.0
doi	
Technical specifications	
Temporal resolution	Monthly
Temporal coverage	2002-07 to 2018-12
Spatial resolution, number of stations	0.05° x 0.05°
Spatial coverage	Global
Vertical resolution	n/a
Uncertainties available?	Standard deviation, different uncertainties
Access details and utilisation	
Access via	http://gws-access.jasmin.ac.uk/public/esacci_lst/TERRA_MODIS_L3C/ regridded files via: http://surftemp.net/regridding/index.html
Last download	01-2021 (DWD)
Application	Assess compliance with theoretical expectations
Costs	None
References	

7.2 EUSTACE surface air temperature

Within the EU Horizon 2020-funded EUSTACE project, daily near surface air temperature on a global grid of 2° x 2° was derived from satellite observations of surface skin temperature.

Overview	
Name	EUSTACE_monthly_TAS
Variable(s)	TAS
Latest version	V1.0
doi	10.5285/468abcf18372425791a31d15a41348d9
Technical specifications	
Temporal resolution	Monthly
Temporal coverage	1979-01-01 to 2015-12-01
Spatial resolution, number of stations	2° x 2° (resampled by T. Trent to 0.5° x 0.5°)
Spatial coverage	Global
Vertical resolution	n/a
Uncertainties available?	Standard deviation
Access details and utilisation	
Access via	Natural Environment Research Council's Data Repository for Atmospheric Science and Earth Observation (CEDA) https://catalogue.ceda.ac.uk/uuid/468abcf18372425791a31d15a41348d9
Last download	01-2021 (DWD)
Application	Trend analysis, assess compliance with theoretical expectations
Costs	None
References	
Rayner, N. A., Auchmann, R., Bessembinder, J., Brönnimann, S., Brugnara, Y., Capponi, F., Carrea, L., Dodd, EMA., Ghent, D., Good, E.,Hoyer, JL., Kennedy, JJ., Kent, EC., Kilick, RE., van der Linden, P., Lindgren, F., Madsen, KS., Merchant, CJ., Mitchelson, JR., Morice, CP., Nielsen-Englist, P., Ortiz, PF., Remedios, JJ., van der Schrier,G., Squintu, AA., Stephens, A., Thorne, PW., Tonboe, RT., Trent, T., Veal, KL., Waterfall, AM.,Winfield, K., Winn, J. & Woolway, R. I. (2020). The EUSTACE project: delivering global, daily	

information on surface air temperature. Bulletin of the American Meteorological Society, 101(11), E1924-E1947.

Website: https://www.eustaceproject.org/

7.3 SST from ESA CCI

Within the ESA SST_cci a global ocean-based SST product was generated (Merchant et al., 2019; Merchant and Embury, 2020). The ESA SST_cci data record (version 2.1) was downloaded from http://surftemp.net/regridding/index.html in November 2020. The data record covers the period until December 2016 and was downloaded at 0.5° resolution. The SST product will be used jointly with the LST product from ESA CCI and the TAS data record from EUSTACE to assess compliance with theoretical expectation.

Overview	
Name	ESACCI-L4_GHRSST-OSTIA-GLOB
Variable(s)	SST
Latest version	v2.1
doi	doi:10.5285/62c0f97b1eac4e0197a674870afe1ee6
Technical specifications	
Temporal resolution	daily & monthly
Temporal coverage	2000-01 to 2016-02
Spatial resolution, number of stations	0.5° x 0.5° and 0.05° x 0.05°
Spatial coverage	Global
Vertical resolution	n/a
Uncertainties available?	yes
Access details and utilisation	
Access via	http://data.ceda.ac.uk/neodc/esacci/sst/data/CDR_v2/Analysis/L4/v2.1/
Last download	01-2021 (DWD)
Application	Assess compliance with theoretical expectations

Costs	None
References	

Merchant, C.J., Embury, O., Bulgin, C.E., Block, T., Corlett, G.K., Fiedler, E., Good, S.A., Mittaz, J., Rayner, N.A., Berry, D., Eastwood, S., Taylor, M., Tsushima, Y., Waterfall, A., Wilson, R. and Donlon, C. (2019), Satellite-based time-series of sea-surface temperature since 1981 for climate applications. Scientific Data 6, 223, doi:10.1038/s41597-019-0236-x

Merchant, C. J. and Embury, O. (2020) Adjusting for desert-dust-related biases in a climate data record of sea surface temperature. Remote Sensing, 12 (16). 2554. ISSN 2072-4292 doi: https://doi.org/10.3390/rs12162554

8. CONCLUSIONS

The satellite and auxiliary data required for the generation of the WV_cci data products are specified, together with the satellite- and ground-based data needed for the validation and with reanalysis and model output needed for climate analysis. Details on data sources, procurement and expected costs are also stated.

APPENDIX 1: REFERENCES

Morgenstern, O., Michaela I. Hegglin, Eugene Rozanov, et al.. Geosci. Model Dev., 10, 639-671, https://doi.org/10.5194/gmd-10-639-2017, 2017

Other references are included in the data record specific tables.

APPENDIX 2: GLOSSARY

This appendix explains all utilised abbreviations of this document.

Term	Definition
ABC(t)	Atmosphere Biosphere Climate (teledetection)
ACE-FTS	Atmospheric Chemistry Experiment Fourier Transform Spectrometer
ACE-MAESTRO	Atmospheric Chemistry Experiment Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AMSU	Advanced Microwave Sounding Unit
ARA	Atmospheric Radiation Analysis
ARSA	Analyzed RadioSoundings Archive
AVHRR	Advanced Very High Resolution Radiometer
BC	Brockmann Consult
CARIBIC	Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container
CCI	Climate Change Initiative
CDR	Climate Data Records
CDS	Copernicus Climate Data Store
CEDA	Centre for Environmental Data Analysis
CM SAF	EUMETSAT Satellite Application Facility on Climate Monitoring
CMAM	Canadian Middle Atmosphere Model
CMIP	Coupled Model intercomparison Project
CMUG	Climate Modelling User Group
CRG	Climate Research Group
DLR	Deutschen Zentrums für Luft- und Raumfahrt
DWD	Deutscher Wetterdienst (German MetService)
ECCC	Environment and Climate Change Canada
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
EDA	ERA5 - reduced resolution ten member ensemble
EMiR	ERS/Envisat MWR Recalibration and Water Vapour Thematic Data Record Generation
ERA5	ECMWF Re-Analysis 5
ERA-Interim	ECMWF Re-Analysis Interim

Term	Definition
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GCOS	Global Climate Observing System
GEOS-5	Goddard Earth Observing System Model, Version 5
GMI	Global Precipitation Microwave Imager
GNSS	Global Navigation Satellite System
GOMOS	Global Ozone Monitoring by Occultation of Stars
GOZCARDS	Global OZone Chemistry And Related trace gas Data records for the Stratosphere
GPS	Global Positioning System
GRUAN	GCOS Reference Upper-Air Network
HALOE	Halogen Occultation Experiment
HIRDLS	High Resolution Dynamics Limb Sounder
HOAPS	Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data
IAGOS	In-service Aircraft for a Global Observing System
IASI	Infrared Atmospheric Sounder Interferometer
ILAS-II	Improved Limb Atmospheric Spectrometer-II
IMS	Infrared Microwave Sounding
IPSL-CM	Institut Pierre Simon Laplace Climate Model
LMD	Laboratoire Météorologie Dynamique
LMS	Lowermost stratosphere
LST	Land Surface Temperature
LWP	Vertically integrated liquid water
MERIS	Medium Resolution Imaging Spectrometer Instrument
MERRA-2	Modern-Era Retrospective analysis for Research and Applications, Version 2
MHS	Microwave Humidity Sounder
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MLS	Microwave Limb Sounder
MODIS	Moderate Resolution Imaging Spectrometer
MOZAIC	Measurement of OZone by Airbus In-service airCraft
MPI	Max-Planck Institute
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research

Term	Definition
NCEO	National Centre for Earth Observation
NCEP	National Centers for Atmospheric Prediction
NOAA	National Oceanic & Atmospheric Administration
NWP	Numerical Weather Prediction
OLCI	Ocean and Land Colour Instrument
PCs	Principle components
POAM	Polar Ozone and Aerosol Measurement
PSD	Product Specification Document
RAL	Rutherford Appleton Laboratory
RMS	Root mean square
RR	Reduced resolution
RTTOV	Radiative Transfer for TOVS
SAGE	Stratospheric Aerosol and Gas Experiment
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SCISAT	Scientific Satellite
SE	Spectral Earth
SMILES	Solar wind Magnetosphere Ionosphere Link Explorer
SMR	Software Modification Report
SOFIE	Solar Occultation For Ice Experiment
SPARC	Stratosphere-troposphere Processes And their Role in Climate
SPURT	Spurenstofftransport in der Tropopausenregion, trace gas transport in the tropopause region
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder
SST	Sea Surface Temperature
SuomiNet	Global ground based GPS network (named after Verner Suomi)
SWOOSH	Stratospheric Water and OzOne Satellite Homogenized data set
TBD	To be determined
TCWV	Total Column Water Vapour
TMI	Tropical Rainfall Measuring Mission's Microwave Imager
UKMO	United Kingdom Meteorological Office
UoL	University of Leicester
UoR	University of Reading

Term	**Definition**
URD	User Requirements Document
UT	Upper troposphere
UTLS	Upper Troposphere and Lower Stratosphere
VMR	Volume mixing ratio
WACCM	Whole Atmosphere Community Climate Model
WAVAS-I	Water Vapour Assessment
WAVAS-II	Water Vapour Assessment 2
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
WV	Water Vapour
WV_cci	Water Vapour climate change initiative

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