19. Assessment of Satellite Measurements of Upper Tropospheric Water Vapor

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Introduction

A general assessment of water vapor measurements, both from remote and in situ sensors was undertaken within the Stratosphere-troposphere Processes and their Role in Climate (SPARC) core project of the World Climate Research Program (WCRP) prior to 2000. This activity known as the Water Vapor Assessment (WAVAS) published a report in 2000 [1]. Since then, there have been a significant increase in satellite missions, ground based instruments, balloon launches of frostpoint hygrometers and improved operational radiosonde hygrometers. Therefore a reassessment of these new resources is needed, now referred as the SPARC WAVAS-II assessment. This paper amongst several in an ACP/AMT/ESSD special issue focuses on the upper troposphere.

Data Sets

The table below gives the list of satellite based instruments used this assessment.

Data Set	Version	Period	Meas. Type	Lat. Coverage	Vert Range
AIRS Aqua	V6	Jul 2002—present	IR Thermal Emission	90S–90N	p $\geq$ 200 hPa
ACE-FTS	V3.5	Aug 2003—present	IR solar Occultation	90S–90N	p $\leq$ 500 hPa/CT[a]
GOMOS	V6	Mar 2002–Apr 2012	NIR Stellar Occultation	90S–90N	p $\leq$ 300 hPa
HALOE	v19	Sep 1991–Nov 2005	IR solar Occultation	80S–80N	p $\leq$ 300 hPa
HIRDLS	V7	Jan 2005–Apr 2008	IR Thermal Emission	65S–82N	p $\leq$ 200 hPa
MAESTRO	V27,28,29,30	May 2004–present	NIR Solar Occultation	86S–87N	p $\leq$ 500 hPa/CT[a]
MIPAS Bologna	V5H	Jul 2002–Mar 2004	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MIPAS Bologna	V5R NOM	Jan 2005–Apr 2012	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MIPAS ESA	V5H	Jul 2002–Mar 2004	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MIPAS ESA	V5R NOM	Jan 2005–Apr 2012	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MIPAS IMK	V5H	Jul 2002–Mar 2004	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MIPAS IMK	V5R NOM	Jan 2005–Apr 2012	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MIPAS Oxford	V5H	Jul 2002–Mar 2004	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MIPAS Oxford	V5R NOM	Jan 2005–Apr 2012	IR Thermal Emission	90S–90N	p $\leq$ 300 hPa
MLS Aura	V4.2	Jul 2004–present	mm Thermal Emission	82S–82N	p $\leq$ 316 hPa
MLS UARS	V490	Sep 1991–Jun 2008	mm Thermal Emission	80S–34N, 34S–80N	464–147 hPa
POAM-III	V4	Mar 1998–Dec 2005	NIR Solar Occultation	88S–63S, 55N–71N	p $\leq$ CT[a]
SAGE-II	V7	Oct 1984–Aug 2005	NIR Solar Occultation	70S–70N	p $\leq$ CT[a]
SAGE-III	V4	Dec 2001–Mar 2006	NIR Solar Occultation	50S–80N	p $\leq$ CT[a]
SCIAMACHY	V3	Mar 2002–Apr 2012	UV limb solar backscatter	85S–85N	p $\leq$ 300 hPa
SMILES NICT	V1	Sep 2009–Apr2010	smm Thermal Emission	40S–65N, 65S–40N	200–100 hPa
SMILES JPL	V2	Sep 2009–Apr2010	smm Thermal Emission	40S–65N, 65S–40N	215–83 hPa
SMILES Chalmers	V3	Sep 2009–Apr2010	smm Thermal Emission	40S–65N, 65S–40N	280–200 hPa
SMR-Odin	UT	Feb 2001–present	smm Thermal Emission	83S–83N	p $\leq$ 300 hPa
TES	V6	Jul 2004–present	IR Thermal Emission	82S–82N	p > 200 hPa

a Cloud top

In addition, we compare with balloon frost point hygrometers and corrected Vaisala-RS92 radiosondes. Six frostpoint sites are considered that have a long time series of repeated launches. The chosen sites are Boulder, USA (1980 to present), Lauder, New Zealand. (2004 to present), Hilo, USA (2010 to present), Heredia, Costa Rica (2005-present), Lindenberg, Germany. (2006 to present), and Sodankylä, Finland (2002 to present). The Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) launches high quality radiosondes for climate research. Here we use water vapor observations from the Vaisala-RS92 radiosondes, which have been processed by GRUAN to remove all known biases and to correct for all known effects inlfuencing water vapor measurements [2]. For the corrected Vaisala-RS92 radiosonde set we use data from Barrow, USA (2009 to present), Boulder, USA (2011 to present), Cabauw, Netherlands (2011 to present), Lauder, New Zealand. (2012 to present), Lindenberg, Germany. (2005 to present), Ny-Ålesund, Norway (2006 to present), Southern Great Plains, USA (2009 to present), and Sodankylä, Finland (2007 to present).

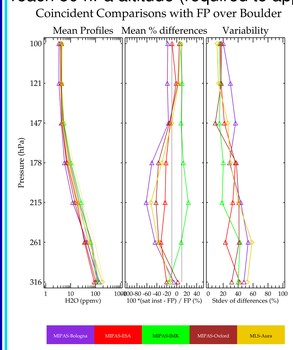
Comparison Methods

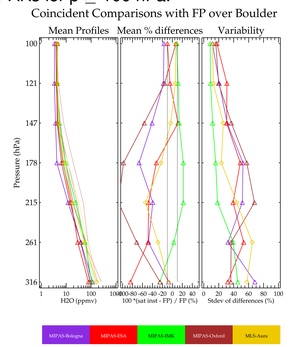
- Coincidences with frostpoint and Vaisala-RS92 sondes.
- Time series.
- Gridded maps.

Shown are some figures that will appear in an article titled "The SPARC Water Vapor Aseesment II: Assessment of satellite measuremets of Upper Tropospheric Water Vapor" to appear in a special issue of Atmospheric Measurement Techniques dedicated to the SPARC WCRP water vapor measurement assessment project.

Frost Point Coincidences

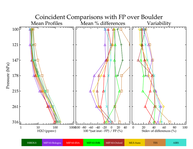
Summaries of Boulder frostpoint coincident comparisons with some satellite datasets. Left is without applying averaging kernels (AK) and the right includes the averaging kernels. Averaging kernels are not available for all datasets and generally have fewer coincidences because some frostpoint balloons fail to reach 50 hPa altitude (required to apply AKs for p $\geq$ 100 hPa.

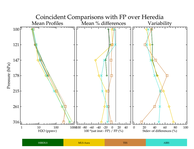


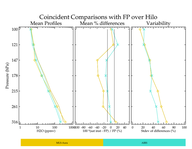


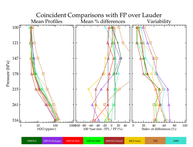
The impact of including the AK is not clearly helpful, reduces the number of coincidences and they are not available for many datasets. Therefore comparisons here did not consider them.

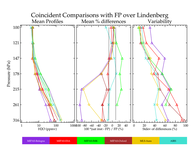
Summaries for other sites and datasets / No AK

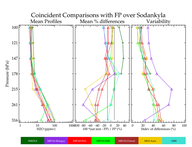




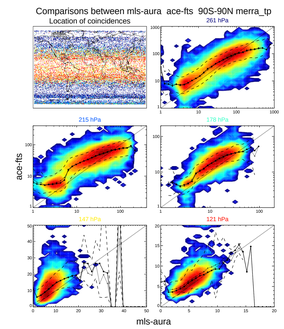


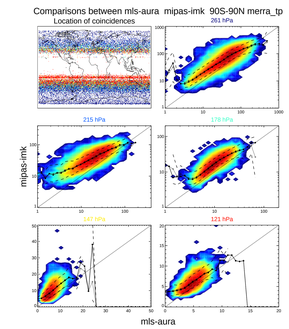




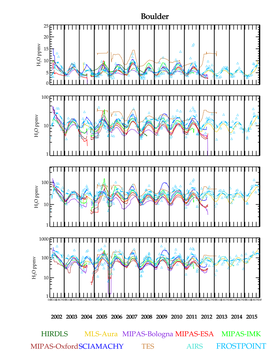


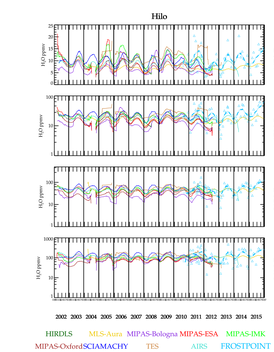
Satellite dataset Coincidences





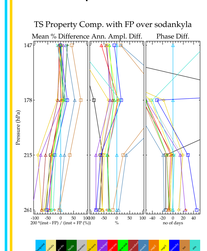
Satellite dataset time series

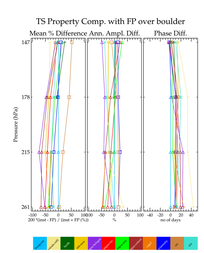


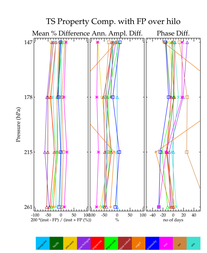


Reconstructed Time Series Comparison Summary

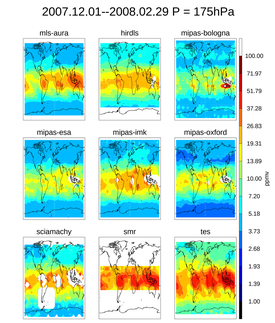
The multiyear mean, amplitude, and phase are fitted to the dataset time series and compared to that fitted to the frostpoint.

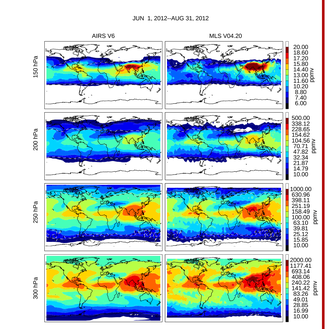




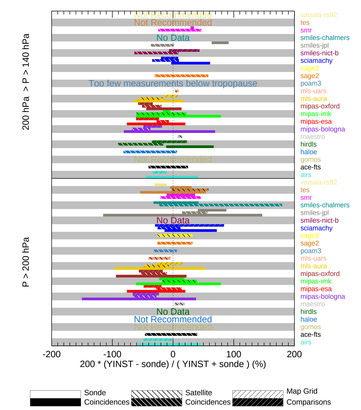


Gridded Map Comparison





Summary of Comparisons



The x-axis is the bias relative to frostpoint except for MAESTRO (relative to ACE-FTS) and MLS-UARS (relative to SAGE-II). The width of the bar represents a spread of biases based on location and concentration amounts.

Acknowledgements

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