Combined SPARC Data Requirements/SPIN
mid-term review meeting
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Water Vapour ECV Review

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The Task

The contractor **shall** perform a review of the requirements as specified in *Systematic Observation Requirements for Satellite-Based Products for Climate – GCOS 107* on stratospheric temperature and water vapour ECVs (e.g. are they realistic and can they be measured by current satellite instrumentation?, are the needs of the climate modelling community adequately addressed?) and generate a new User Requirements Document for these two ECV parameters. The contractor **shall** as well describe all needed data for geophysical validation and the planned validation approach in a dedicated report (Product Validation Plan).

Guiding thoughts

- Different users of water vapour data products have different needs. This has been largely ignored in measurement requirements detailed in existing documents. We considered data needs for:
  - Detection and attribution of trends
  - Process studies
  - Use in Numerical Weather Prediction (NWP)
  - Use in satellite calibration/validation
- Measurement requirements change with location and season.
- Changes in observation schedules affect measurement requirements.
- Involvement of SPARC temperature trends and water vapour activities.

Terminology

There is a need for consistency in measurement uncertainty terminology across all SPIN work packages. The default should be the International Bureau of Weights and Measures (BIPM) in the *Guide to the Expression of Uncertainty in Measurement.*

- *True value:* Value consistent with the definition of a given particular quantity that would be obtained by a perfect measurement.
- *Measurement accuracy:* Closeness of the agreement between the result of a measurement and a true value of the measurand.
- *Measurement uncertainty:* Characterizes the dispersion of the values that could reasonably be attributed to the measurand.
- *Measurement error:* The result of a measurement minus a true value of the measurand.

Terminology (continued)

- *Random error:* Result of a measurement minus the mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions. Use this term rather than ‘precision’.
- *Systematic error:* The mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions minus a true value of the measurand. Preferred over the term ‘accuracy’ since it denotes more clearly that the deviation is systematically in one direction.
- *Stability:* Stability refers to the consistency of random errors and systematic errors with time.

Envisaged uses and measurement requirements

- Climate change detection and attribution
  - Long-term stability
  - Accuracy of altitude registration
  - Minimized orbital drift
- Satellite calibration/validation
  - Small systematic and random errors
  - High vertical and horizontal resolution
  - High spatial coverage
- Reanalysis and numerical weather prediction (NWP)
  - Long-term stability
  - Small systematic and random errors
  - Measurements in key locations
- Atmospheric process studies
  - Reducing random errors is less critical than for other applications
  - High vertical resolution required to capture the processes in detail
  - High temporal resolution to provide measurements when needed

GCOS requirements

As detailed in GCOS-107 and later updated in GCOS-154

Variable/ parameter	Horizontal resolution	Vertical resolution	Temporal resolution	Systematic error	Stability
Tropospheric and lower-stratospheric profiles of water vapour.	25km in the troposphere & 100-200 km in the stratosphere	2km	4 hours in the tropo-sphere and daily in the stratosphere	5%	0.3% per decade
Upper-tropospheric humidity	25km	N/A	1 hour	5%	0.3% per decade

GRUAN requirements

GRUAN (GCOS Reference Upper Air Network) distinguishes between different potential uses of the water vapour measurements in defining the water vapour measurement requirements

Attribute	Trend detection		Satellite validation and radiation studies		Process studies
	Upper troposphere	Lower stratosphere	Radiance comparisons	Comparisons in retrieval space	
Vertical resolution	<1 km	<1 km	N/A	< 2km	10-100 m
Systematic error	profile: 5-10% or better	profile: 5-10% or better	column: 3% profile: 5% in lower and mid-troposphere, 10% in upper troposphere	column: 3% profile: 10% in 2 km thick layers	profile: 10%
Random error	up to 50%	<10%	many comparisons: 10-20% individual comparison: ≤5%		<10-25%
Stability	N/A	N/A	N/A	N/A	N/A
Temporal resolution	<1 hour	no data	high as possible		1 minute

Still some work to be done

WMO/CEOS Rolling Review of Requirements

This database is available at http://www.wmo-sat.info/oscar/

Layer	Application Area	Horizontal resolution	Vertical resolution	Temporal resolution	Random error
Lower stratosphere	Climate	Goal: 50km Min: 200km	Goal: 2km Min: 3km	Goal: 3h Min: 6h	Goal: 2% Min: 20%
	Atmospheric chemistry	Goal: 50km Min: 500km	Goal: 1km Min: 5km	Goal: 12h Min: 3d	Goal: 5% Min: 20%
	Global climate modelling	Goal: 50km Min: 250km	Not listed	Goal: 3h Min: 12h	Goal: 5% Min: 20%
	SPARC	Goal: 50km Min: 500km	Goal: 500m Min: 2km	Goal: 6h Min: 3d	Goal: 2% Min: 5%
Upper stratosphere	Climate	Goal: 50km Min: 200km	Goal: 2km Min: 5km	Goal: 3h Min: 6h	Goal: 2% Min: 20%
	Atmospheric chemistry	Goal: 50km Min: 500km	Goal: 1km Min: 5km	Goal: 12h Min: 3d	Goal: 5% Min: 20%
	Global modelling	Goal: 50km Min: 250km	Not listed	Goal: 3h Min: 12h	Goal: 5% Min: 20%
	SPARC	Goal: 50km Min: 500km	Goal: 500m Min: 2km	Goal: 6h Min: 3d	Goal: 2% Min: 5%

Database does not list values for stability

Currently achievable measurement attributes

- Radiosonde measurements of water vapour in the upper troposphere and stratosphere are not considered reliable.
- Useful measurements from limb viewing research satellites, frost point hygrometers, and perhaps from Raman lidars.
- For thermal emission sounders, vertical resolution is 3-4 km → inadequate to meet the requirements described above.
- Higher vertical resolution (1 km) from solar occultation → meets GCOS requirements but not NWP-related requirements of GRUAN or WMO.
- Solar occultation does not provide global coverage. Horizontal resolution is generally around 300 km due to horizontal smearing in the limb.
- Measurement uncertainty is generally around 10-15%, of which perhaps 5% is systematic error → borderline in terms of requirements.
- Long-term stability not assured → generally not a requirement of research satellites. No accepted 'gold standard' for water vapour measurements in the upper troposphere and stratosphere.

Requirements rationale and traceability

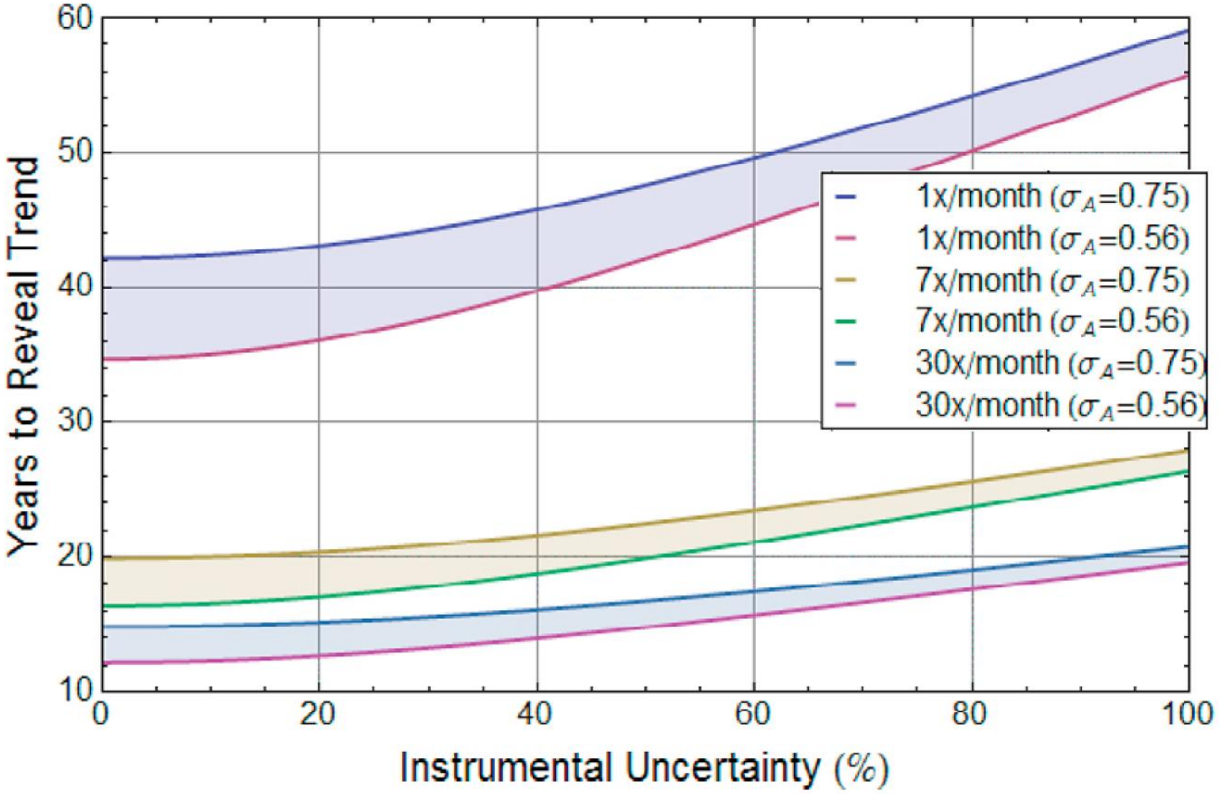
- Almost all assessments of measurement requirements for water vapour trend detection have been for the troposphere e.g.
  - Boers, R. and van Meijgaard, E., What are the demands on an observational program to detect trends in upper tropospheric water vapor anticipated in the 21st century?, GRL, 36, L19806, doi:19810.11029/12009GL040044,

Sampling, assuming a noisy measurement	Percentage of time that a statistically significant trend was detected			Maximum difference between true trend and detected trend [in percentage difference from the true trend]		
Sampling / Time period	Every 15 days	Every 8 days	Every 4 days	Every 15 days	Every 8 days	Every 4 days
2008 – 2033	19	37	55	>100	>100	70
2008 – 2038	39	63	85	>100	96	40
2008 – 2043	62	84	94	76	55	37
2008 – 2048	76	95	100	75	50	31
2008 – 2053	92	100	100	59	42	27
2008 – 2058	99	100	100	50	32	20

- Assumed 10% random error on each measurement.
- Analysis only at 300 hPa and at a single station (Cabauw).
- 30 years required to detect a trend in a perfect climate record.

Requirements rationale and traceability

Whiteman, D.N.; Vermeesch, K.C.; Oman, L.D. and Weatherhead, E.C., The relative importance of random error and observation frequency in detecting trends in upper tropospheric water vapor, JGR , 116, D21118, doi:21110.21029/22011JD016610, 2011



- Analysis at 200 hPa.
- No measurement uncertainty assumed.
- Due to high natural variability in water vapour, time to detect trends relatively insensitive to instrumental random uncertainty. More important to increase the frequency → Raman lidar

Future Work

- Measurement requirement analyses for stratospheric water vapour, similar to those done for tropospheric water vapour need to be done. But:
  - Are the reanalyses sufficient reliable to determine the temporal auto-correlation in the water vapour time series (S-RIP)?
  - Are the projected trends in stratospheric water vapour from chemistry-climate models sufficiently reliable (CCMI)?