Certification of Upper Air Sounding System to Support NASA Launch Operations

Frank Leahy (frank.b.leahy@nasa.gov)
NASA Marshall Space Flight Center, Natural Environments Branch

AMS 25th Conference on Aviation, Range, and Aerospace Meteorology
January 15, 2025

Introduction

- The legacy sounding system at the Eastern Range is being replaced with the Vaisala MW51 sounding system
  - Legacy system: Lockheed Martin/Sippican (LMS6)
- The MW51 must be certified to support any NASA mission operations
- Official testing currently underway at the Eastern Range
  - Comparison flights between LMS6 and MW51 completed in August 2024
  - 30 Dual MW51 + single LMS6 simultaneous releases
- MSFC Natural Environments has analyzed test data and assessed against certification criteria

NASA MSFC Certification

- Quantification of the MW51 system ”accuracy” was done by comparisons to LMS6
- Simultaneous releases from August 2024 were used to determine temperature, relative humidity, and wind accuracy
- Dual MW51 flights were used to determine Effective Vertical Resolution (EVR) and system precision/error
  - EVR is wavelength boundary between signal and noise dominated wind data
- Propose additional test to assess altitude error
  - Can be done by attaching sonde to post at a known height, and tracking the altitude drift over ~1 hr

NASA MSFC Certification Criteria

- Criteria based on legacy system certification and capabilities, specifications from Artemis Program Requirements Document (PRD), and vehicle design environments

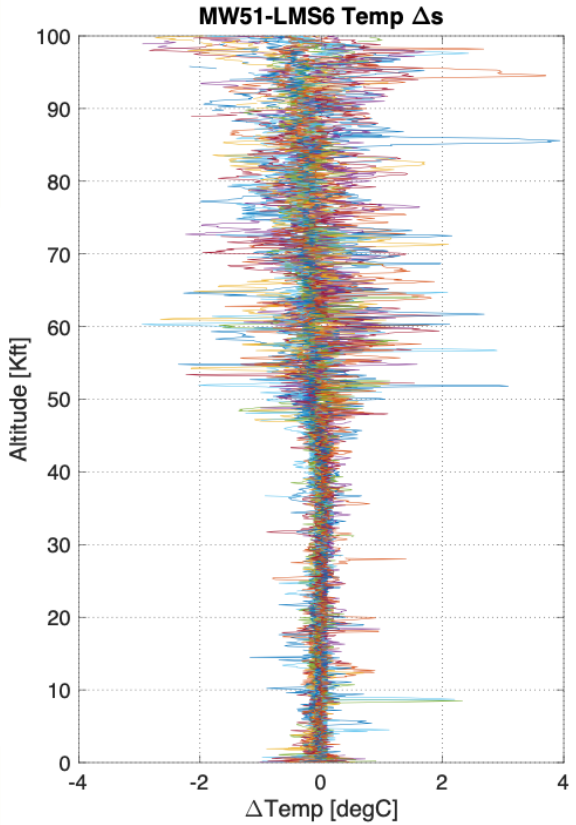
Requirement	Criteria	Rationale
Temperature	0.2°C RMS	LMS6 capability/PRD spec
Relative Humidity	5% RMS to -60°C	LMS6 capability/PRD spec
Wind Accuracy	1.5 m/s component RMS	LMS6 capability/PRD spec
Altitude Range	Near surface to 70 Kft	Day of Launch operational need (nice to have: 100 Kft)
Altitude Error	5 m RMS	PRD spec
Effective Vertical Resolution (Wind)	700 m	Based on maximum wavelength of gust analyses during SLS design (PRD spec: 350 m)

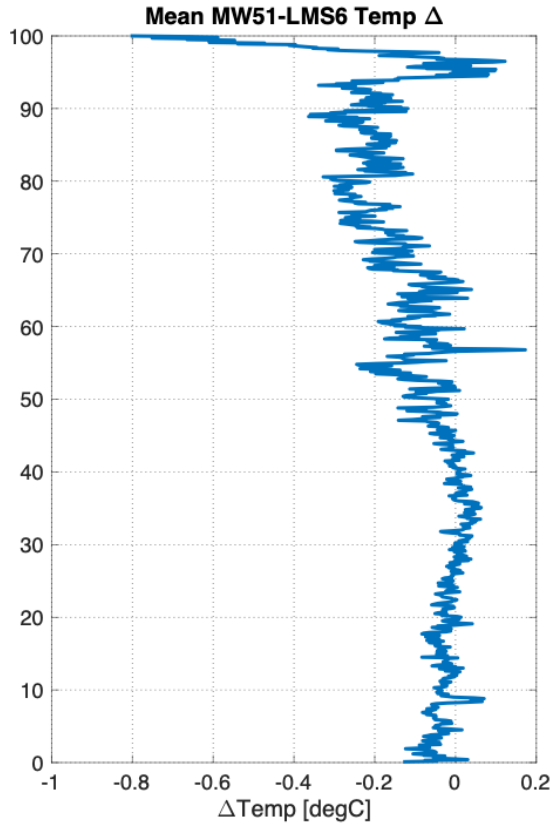
Results: MW51-LMS6 Temperature

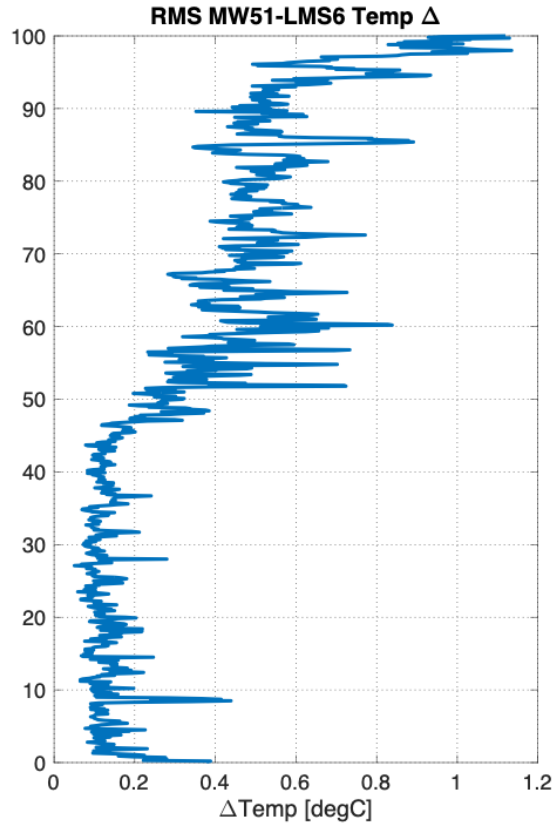
Results show an MW51 cold bias compared to LMS6 above ~40 Kft.

Increase in uncertainty with altitude is a known characteristic of the RS41 sonde per Vaisala. (see Figure 2.5 of Vaisala white paper, Ref. 1).

NWS chamber testing (Refs. 2 & 3) give 0.24°C and 0.09°C RMS for the LM and Vaisala sondes, respectively.





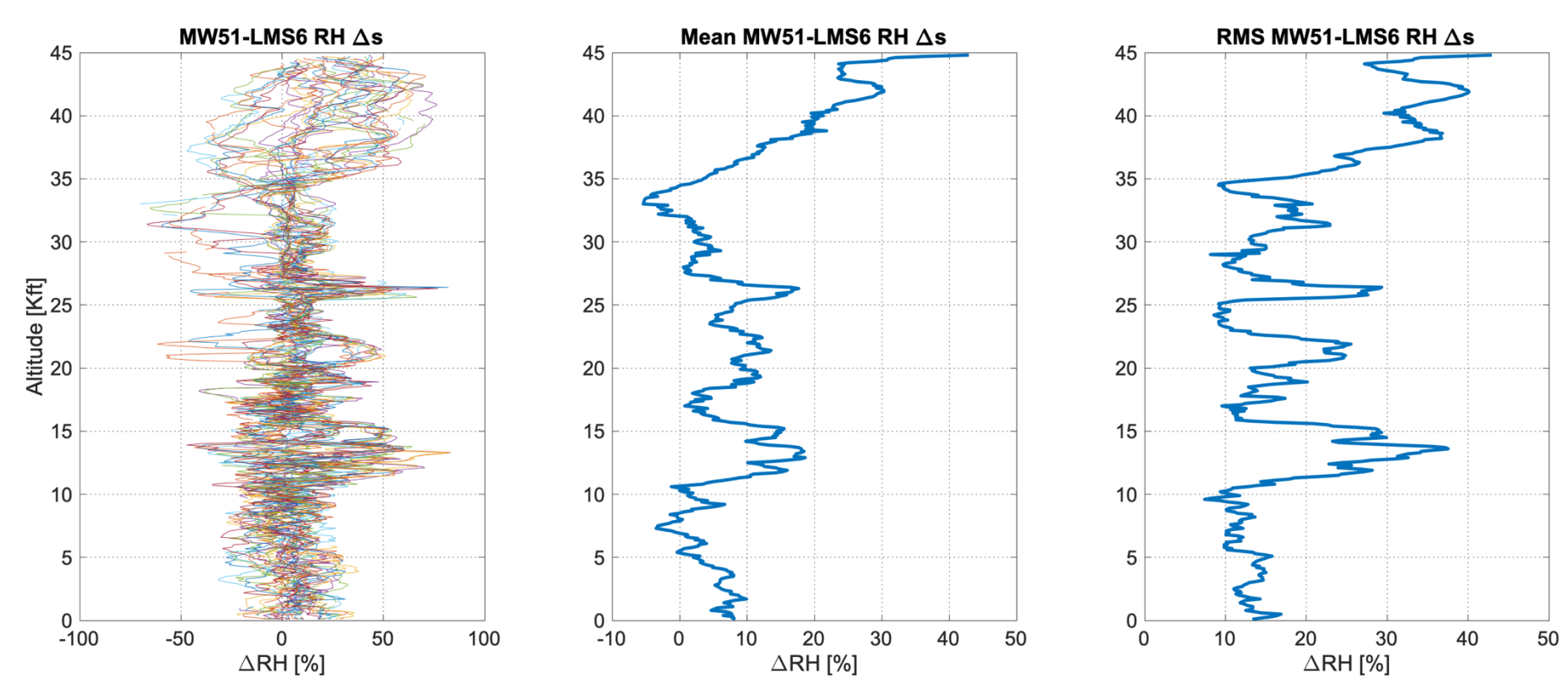


Results: MW51-LMS6 RH

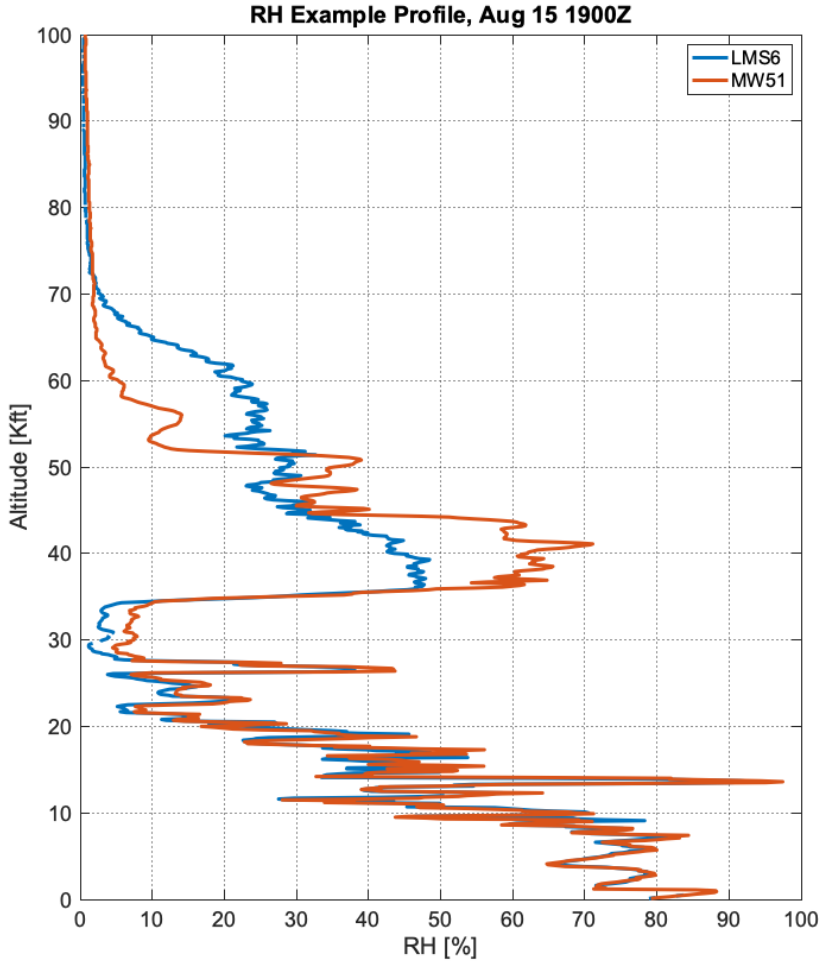
Results show an MW51 moist bias at the majority of altitudes.

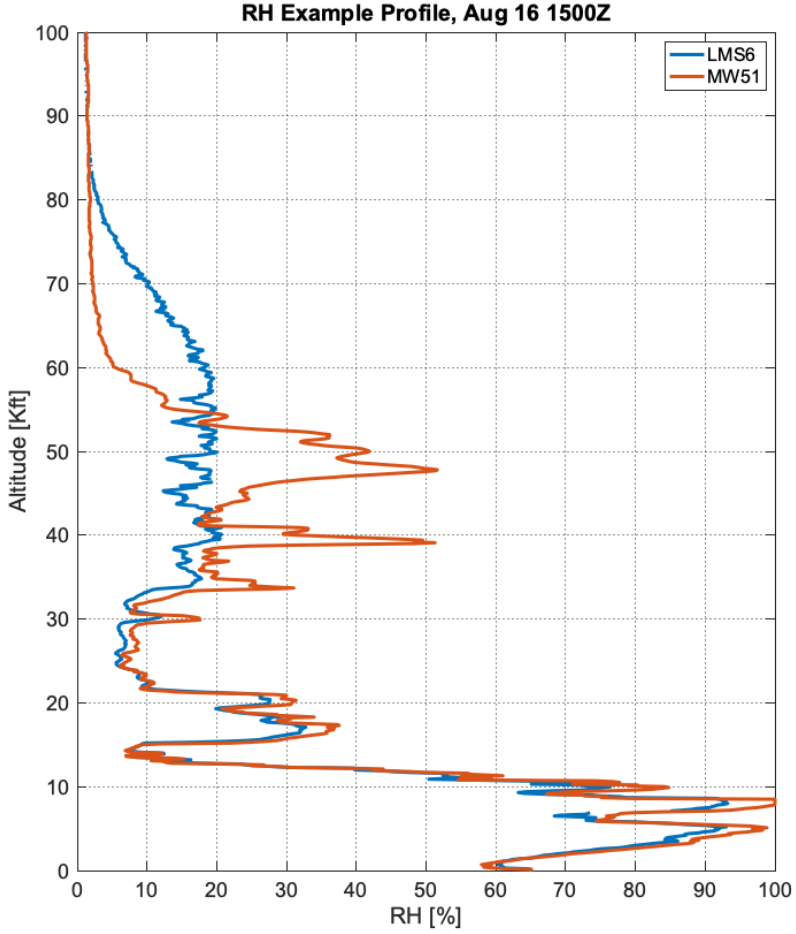
NWS chamber testing (Refs. 2 & 3) give 2.76% and 0.72% errors for the LM and Vaisala sondes, respectively.

NWS comparisons to a reference standard (frost point hygrometer, 3 flights) show LMS6 dry bias of 5% or greater. MW51 biases are generally less than 5%.



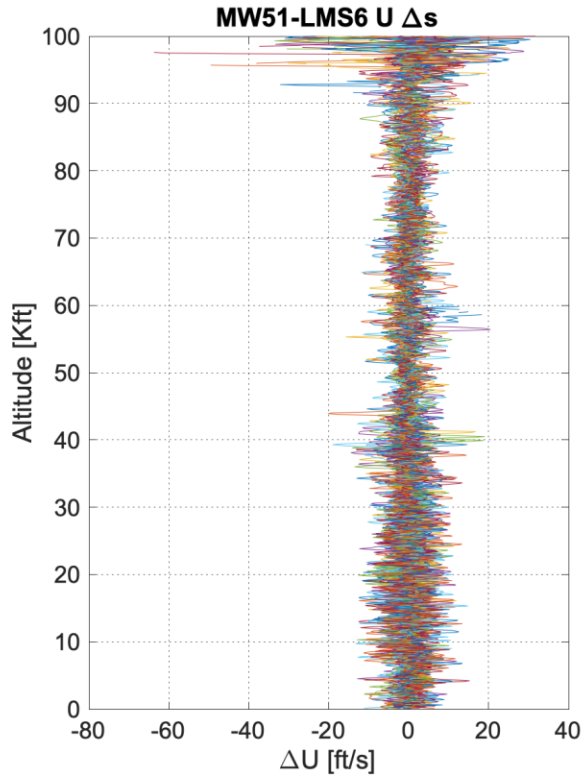
Results: RH Comparison Examples

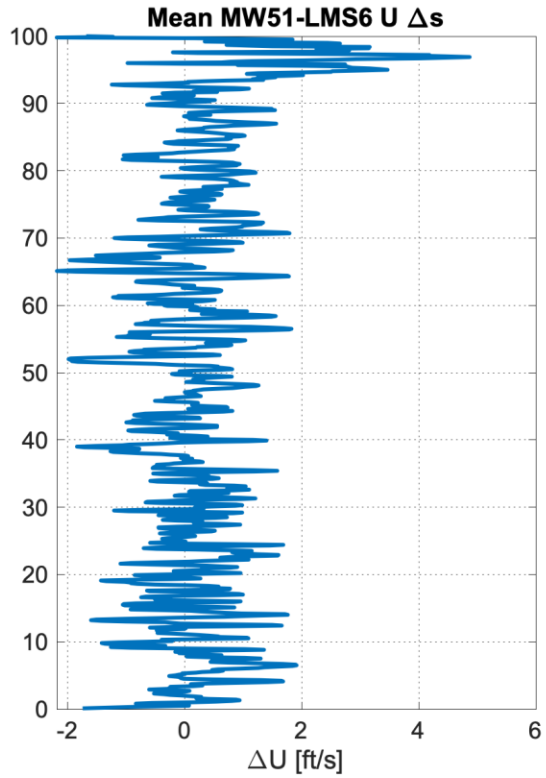


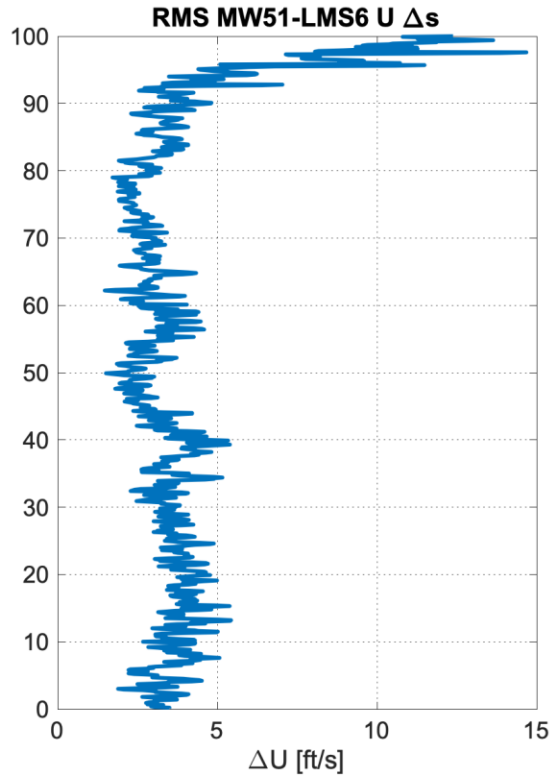


Profile comparisons show dry bias of LMS6 compared to MW51

Results: MW51-LMS6 U Wind

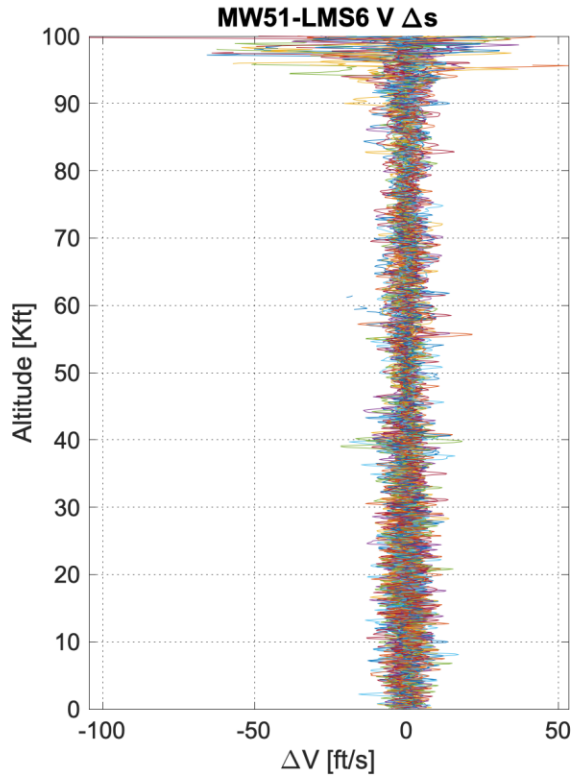


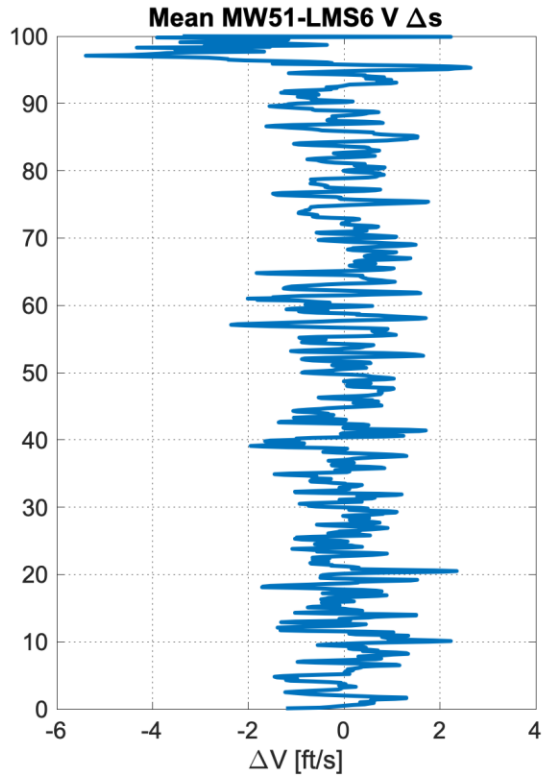


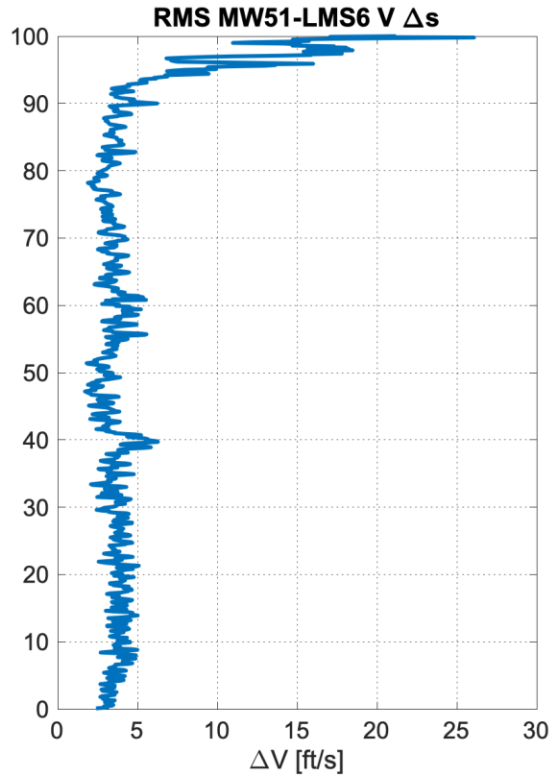


No bias noted in LMS6/MW51 U wind comparisons.
RMS values are below 5 fps up to ~90 Kft.

Results: MW51-LMS6 V Wind

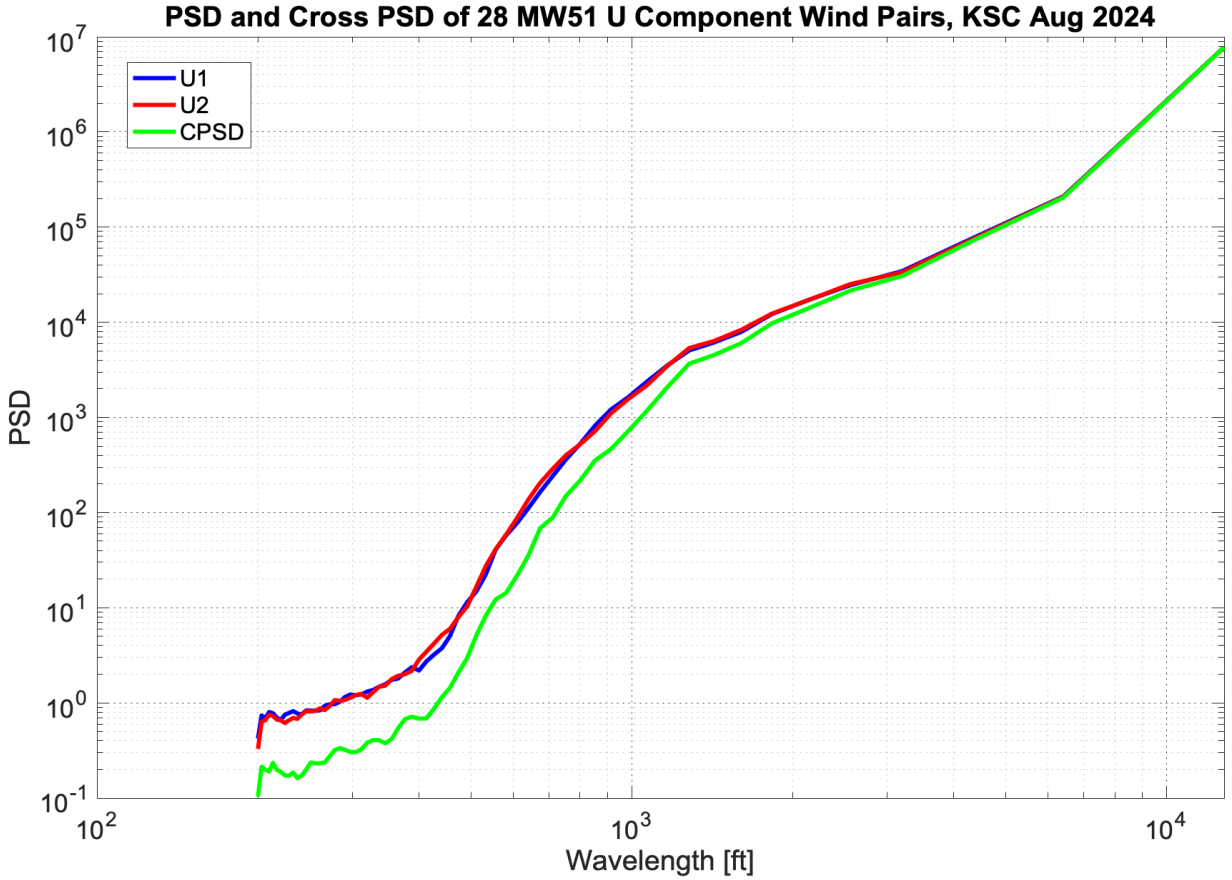


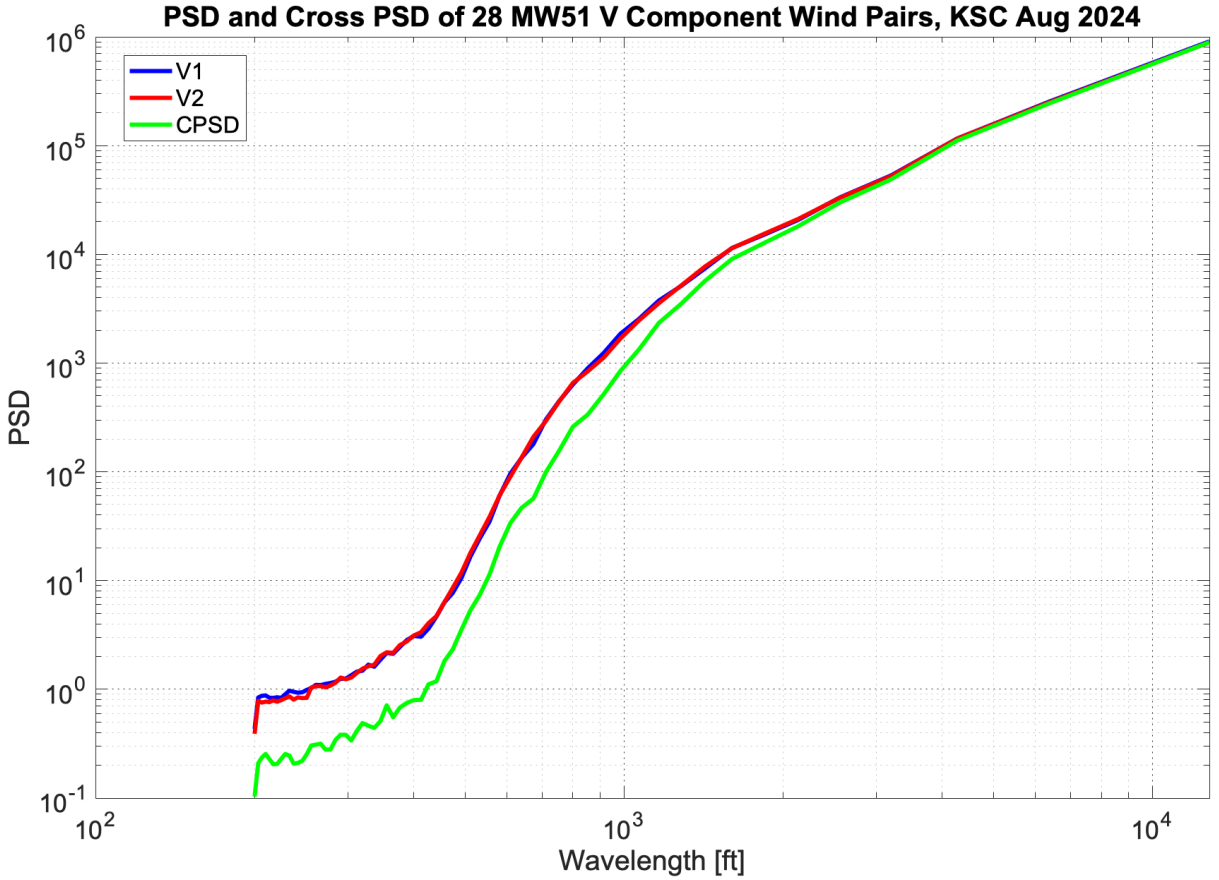




No bias noted in LMS6/MW51 V wind comparisons.
RMS values are below 5 fps up to ~90 Kft.

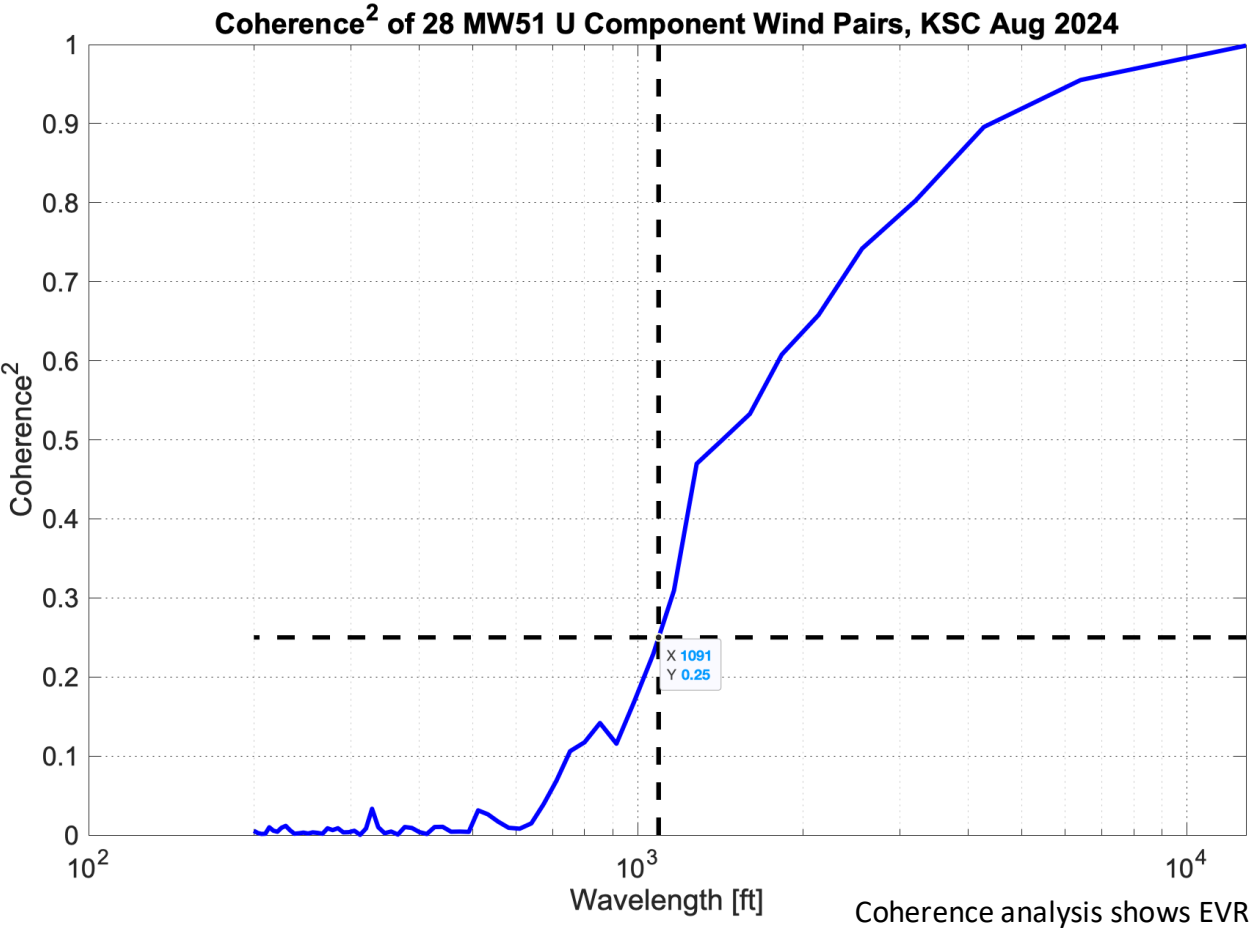
Results: MW51 Wind PSDs

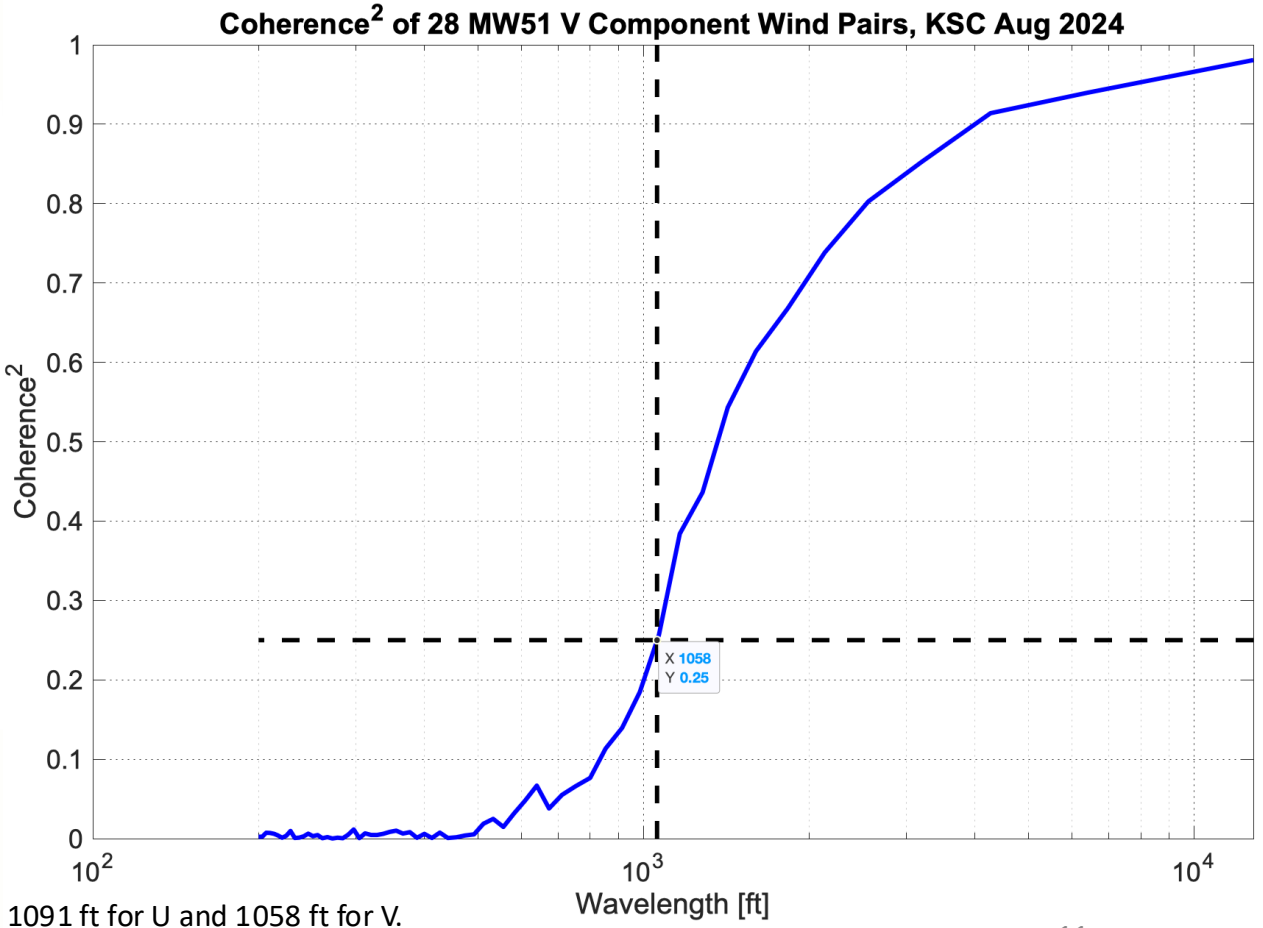




Dual MW51 wind component PSDs are similar,
with PSD fall offs between 1000 and 2000 ft

Results: MW51 Wind Coherence





Coherence analysis shows EVR is 1091 ft for U and 1058 ft for V.
These EVRs are comparable or better than the LMS6.

Summary

Temperature:
- MW51 does not meet cert criteria
- Repeatability of MW51 is comparable to LMS6/MW51 differences
- NWS chamber tests show slightly more error in LMS6 temperature

RH:
- MW51 does not meet cert criteria
- NWS chamber tests and comparison flights to reference standard show dry bias for LMS6
- Therefore, the LMS6 is not a good standard to test against

Requirement	Criteria		MW51 – LMS6 Mean	MW51 – LMS6 RMS	MW51 – MW51 Mean	MW51 – MW51 RMS
Temperature	0.2°C RMS		-0.09°C	0.40°C	0.00°C	0.40°C
Relative Humidity	5% RMS to -60°C		8.66%	21.21%	-0.06%	3.22%
Wind Accuracy	4.92 ft/s (1.5 m/s) component RMS	U	0.22 ft/s	3.98 ft/s	-0.03 ft/s	2.55 ft/s
		V	-0.07 ft/s	4.83 ft/s	-0.08 ft/s	2.83 ft/s
Altitude Range	Near surface to 70 Kft (nice to have: 100Kft)		58 of 60 MW51 reached 70 Kft (97%) 56 of 60 MW51 reached 100 Kft (93%)			
Altitude Error	5 m RMS		TBD			
Effective Vertical Resolution (Wind)	2297 ft (700 m) (PRD spec:1148ft, 350 m)		U: 1091 ft (333 m) V: 1058 ft (322 m)			

Wind:
- Wind components meet cert criteria
- EVR is within cert criteria

Forward work:
- Request Eastern Range to perform tests to evaluate MW51 height errors

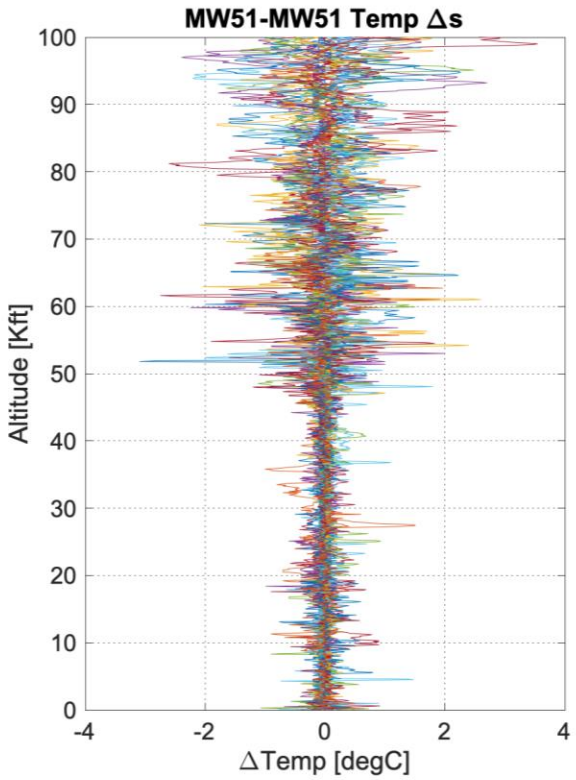
References

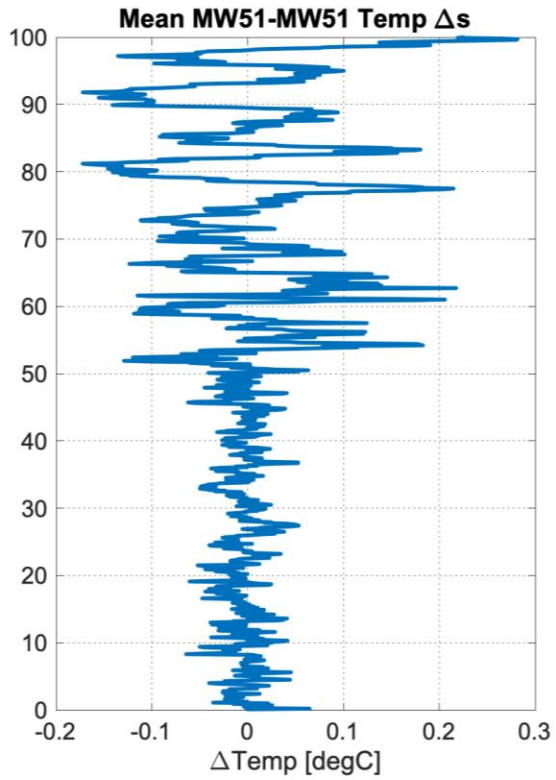
- 1) Vaisala, Vaisala Radisonde RS41 Measurement Performance, White Paper, 2013. Ref. B211356EN-A.
- 2) Radiosonde Frequency Migration Project (RFMP) Manual Radiosonde Observing System (MROS) Evaluation Report, Lockheed Martin/Sippican, January 2020, TR-003.00-UA-2019Rn_RFMP_MROS_Phase 4_LMS
- 3) Radiosonde Frequency Migration Project (RFMP) Manual Radiosonde Observing System (MROS) Evaluation Report, Vaisala, January 2020, TR-005.00-UA-2019Rn_RFMP_MROS_Phase 4_Vaisala

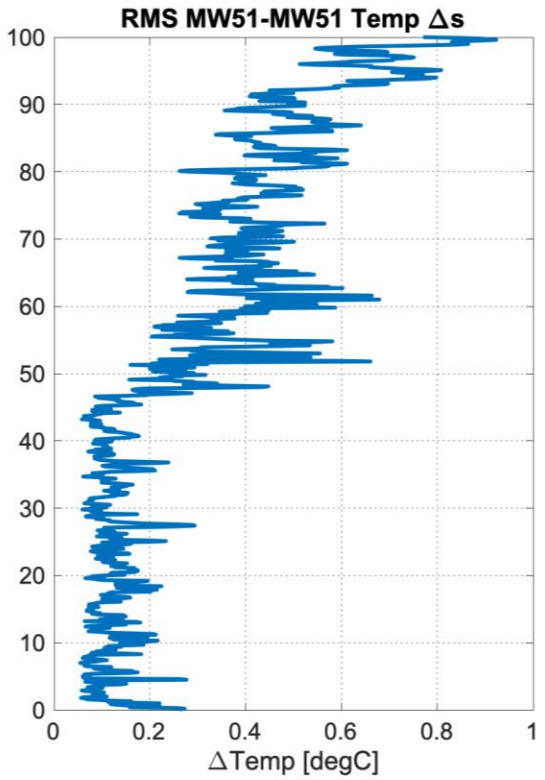


Backup

Results: MW51-MW51 Temperature

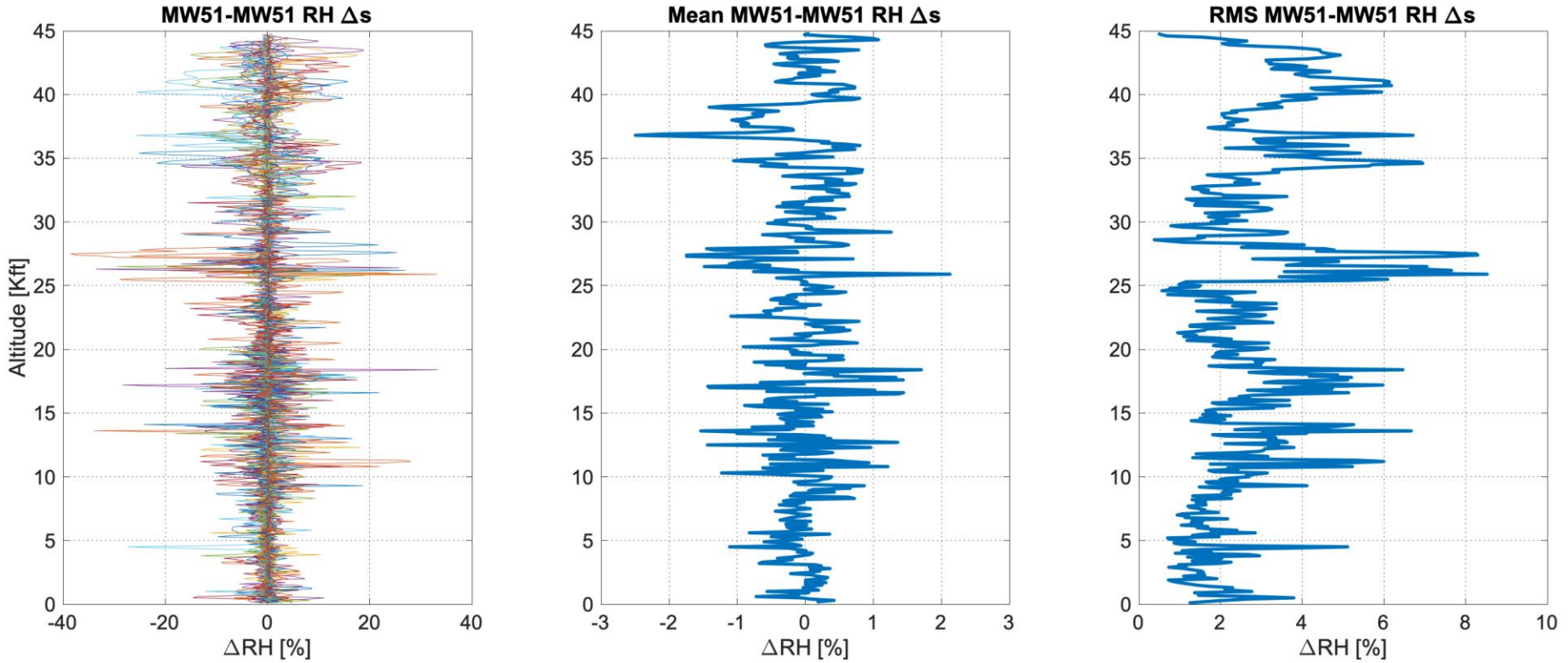






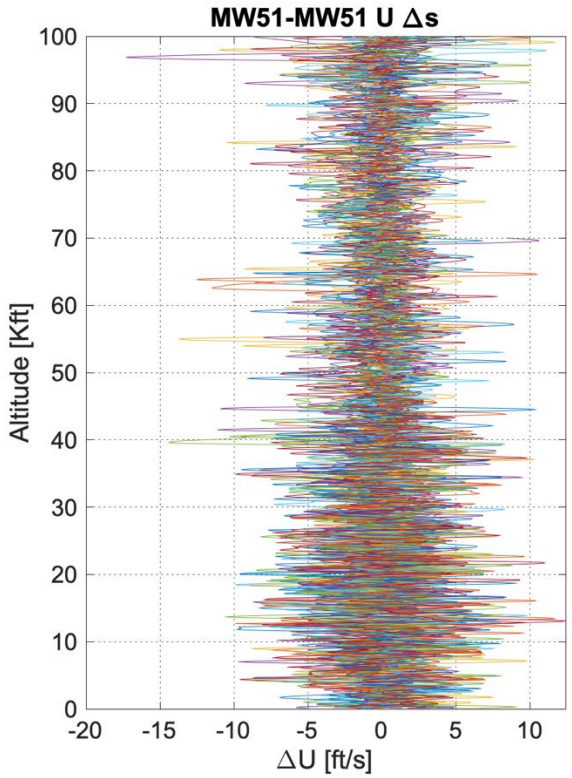
Increase in uncertainty with altitude is a known characteristic of the RS41 sonde per Vaisala. (see Figure 2.5 of Vaisala white paper, Ref. 2)

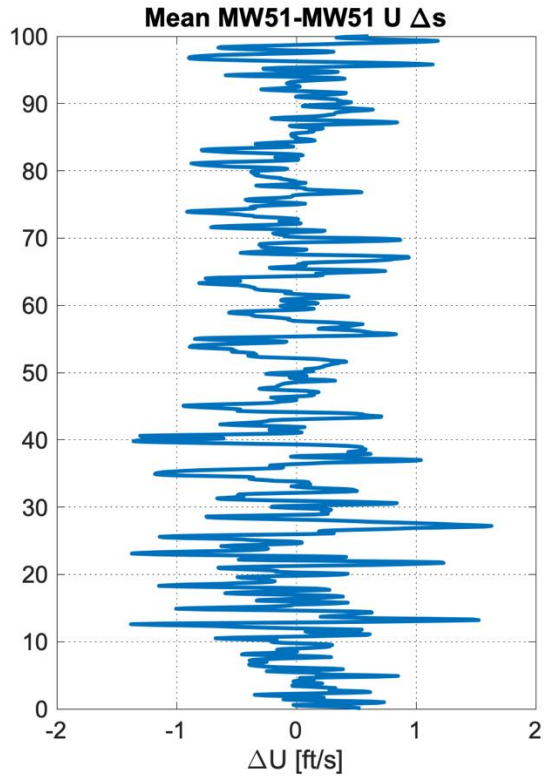
Results: MW51-MW51 RH

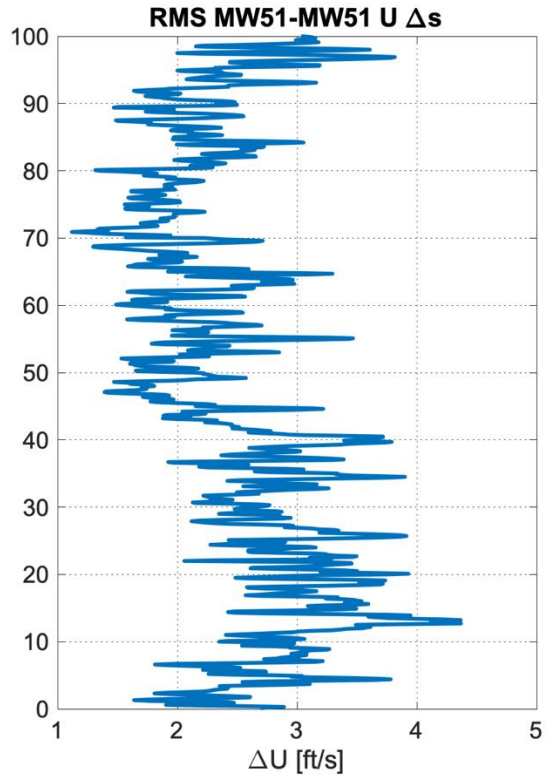


Dual MW51 comparisons show consistent RH measurements

Results: MW51-MW51 U Wind

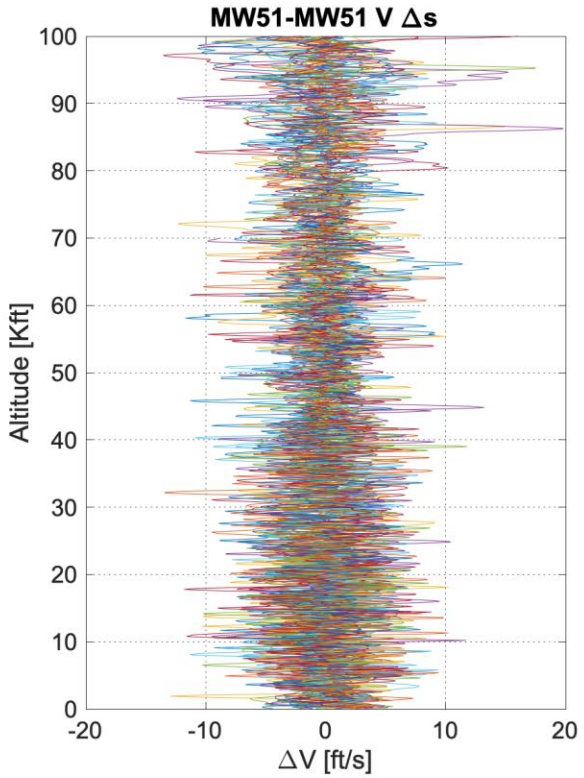


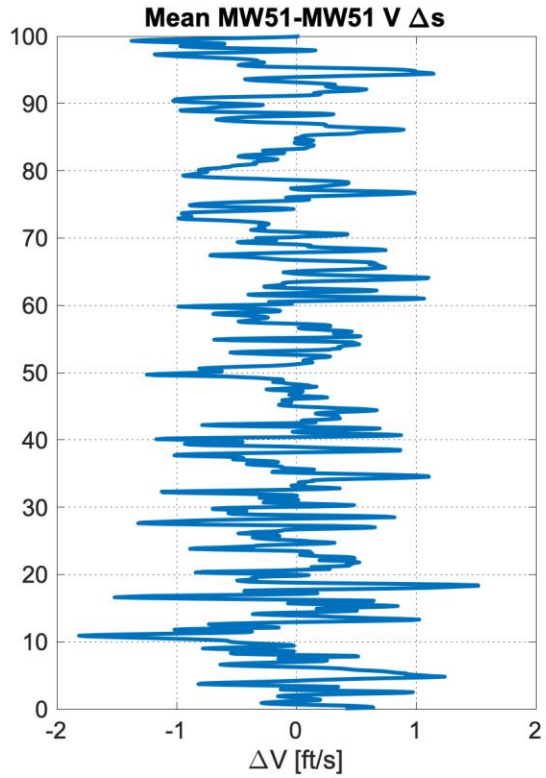


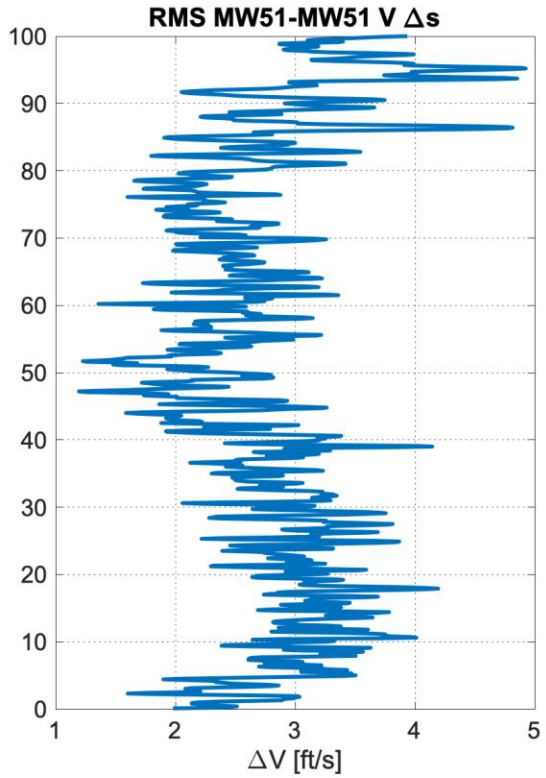


RMS values from dual MW51 comparisons are slightly less than with LMS6 comparisons

Results: MW51-MW51 V Wind







RMS values from dual MW51 comparisons are slightly less than with LMS6 comparisons