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Atmospheric Emitted Radiance Interferometer (AERI) Instrument Handbook

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March 2025

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Acronyms and Abbreviations

ABB	Ambient Blackbody
AERI	Atmospheric Emitted Radiance Interferometer
AERI QC	AERI quality control algorithm, part of AERI ARMORY
AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
AWR	AWARE AMF2 deployment
DQR	ARM Data Quality Report
ER-AERI	Extended range Atmospheric Emitted Radiance Interferometer
FTS	Fourier Transform Spectrometer
FTSW	GUI for AERI operating system
GUI	Graphical user interface
HBB	Hot blackbody
M-AERI	Marine-AERI
NIST	National Institute of Standards and Technology
NSA	North Slope of Alaska
OLI	Oliktok Point AMF3 deployment
QC	Quality Control
RU	Radiance Unit
SGP	Southern Great Plains
SSEC	Space Science and Engineering Center
TROPoe	Tropospheric Optimal Estimation Retrieval
TWP	Tropical Western Pacific
UTC	Universal Time Coordinates
VAP	Value-added product
VM	Virtual Machine

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1.0 Instrument Description

The Atmospheric Emitted Radiance Interferometer (AERI) measures the downwelling infrared radiance from the Earth's atmosphere. The observations have broad spectral content, and sufficient spectral resolution to discriminate among gaseous emitters (e.g., carbon dioxide, water vapor) and suspended matter (e.g., aerosols, water droplets, ice crystals). These remote sensing observations can be used to obtain vertical profiles of tropospheric temperature and water vapor, as well as measurements of trace gases (e.g., ozone, carbon monoxide, methane) and downwelling infrared spectral signatures of clouds and aerosols.

1.1 Technical Specifications

Optical

The AERI is a passive remote sounding instrument, employing a Fourier transform spectrometer operating in the spectral range 3.3–19.2 µm (520–3020 cm^{-1}) at an unapodized resolution of 0.5 cm^{-1} (max optical path difference of 1 cm). The extended range AERIs (ER-AERI) deployed in dry regions (e.g., the Arctic and Antarctic: NSA, OLI, AWR sites) have a spectral range of 3.3–25.0 µm (400–3020 cm^{-1}) that allow measurements in the far-infrared region. Two detectors are used, an HgCdTe and an InSb, cooled to cryogenic temperatures with a Stirling cycle cooler, to cover these spectral ranges. The instrument has a zenith angular field-of-view of 46 mrad full angle.

Radiometric

The AERI absolute radiometric accuracy is designed to be better than 1% of the radiance of a blackbody at surface ambient temperature. This level of absolute accuracy is important for long-term trending applications as well as for products derived from AERI radiances. The radiometric accuracy is ensured by regular calibration views of two accurately characterized and calibrated blackbodies: the Hot Blackbody (HBB) is temperature controlled to 333 K; the Ambient Blackbody (ABB) passively follows ambient temperature. A scene mirror is programmed to view a sequence of eight sky views and two calibration blackbody views. The AERI sky and blackbody views are averaged over a 17 second interval. The sequence repeats continuously thought the day. Exceptions to this scan sequence are AERIs operating in slow-sample mode prior to 2010, and the Marine-AERI which often has custom scan sequences due to its limb-scanning capability.

Ancillary Measurements

Ancillary measurements of temperature, pressure, relative humidity, rain/sun sensors are also monitored to obtain a complete picture of the measurement conditions. These observations, however, are primarily for diagnostic use, so ARM MET sensors nearby should be used for calibrated measurements.

Physical Installation

The instrument is typically mounted in a thru-wall configuration, with the front-end outside, and the back-end in a temperature controlled indoor environment (see Figures 1 and 2). A protective enclosure protects the instrument front-end against sun, rain, snow, wind, sand, etc. A hatch, actuated by the precipitation sensors, is closed to protect the scene mirror and front-end optics during precipitation. The AERI does not acquire sky data during precipitation events. Manual opening or closing of the hatch is possible with a manual switch on the back-end. The hatch can also be commanded closed with a software script. The AERI hatch automatically closes in case power is cut to the instrument.

Software

The AERI operating system is fully autonomous, and the instrument can operate unattended. The AERI software system performs all data calibration in real-time. The AERI software performs a series of quality control (QC) checks in real-time with problem conditions indicated real-time in the FTSW display window, as well as stored with the data. A separate higher level quality control algorithm, AERI QC, is available as a mentor product and part of the AERI ARMORY software package, with more detailed and customizable QC metrics.

The AERI operating system typically runs on virtual machines (VMs) at each site, that can be accessed remotely by site technicians and the mentor team. Typically, 30 days of raw data are stored on the VM. An automatic script deletes the oldest datafiles to make disk space for newer data.

Reference

Knuteson et al. 2004a & b are the primary reference for the AERI instrument, containing detailed technical specifications.

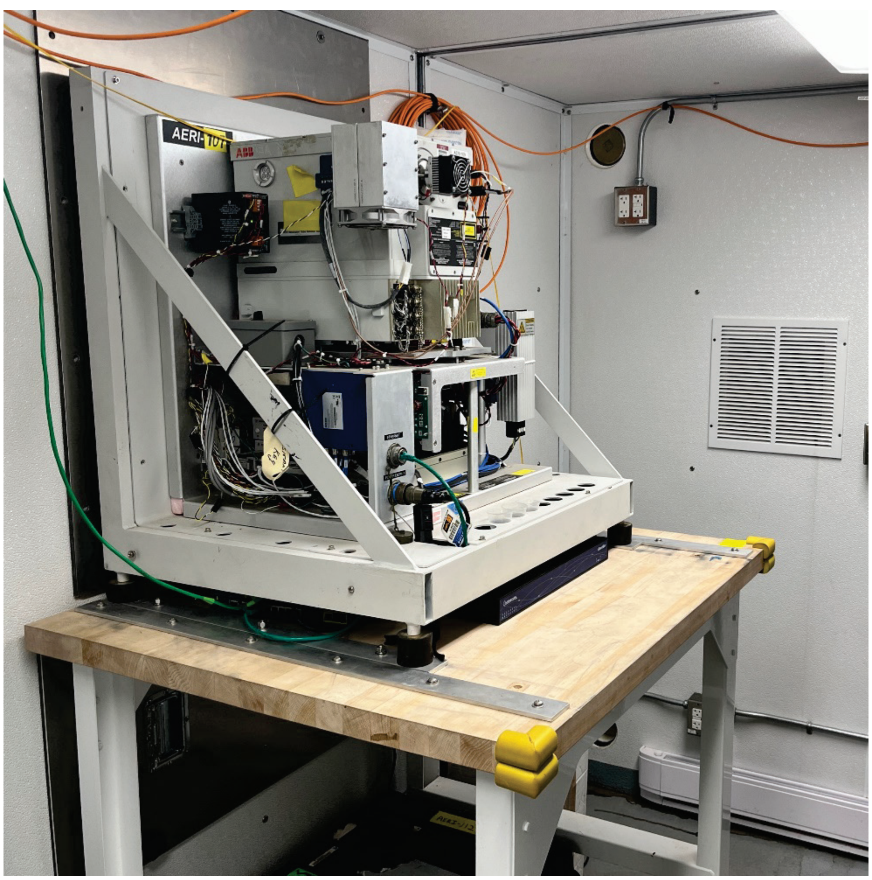

Figure 1. AERI back-end, in sea container in thru-wall configuration.

Figure 2. AERI front-end at BNF M1 site (left). Protective enclosure removed, showing blackbodies, sky aperture, and fan (right).

1.1.1 Primary Measurements

The primary measurement from the AERI instrument is calibrated spectral radiance, measured in Radiance Units (RU = mW m^{-2} sr^{-1} $(cm^{-1})^{-1}$), with a radiometric calibration absolute accuracy of <1% of the ambient blackbody radiance.

Furthermore, measurements of spectral blackbody radiance, blackbody temperature, front-end ambient temperature and hatch status are used in radiometric calibration, as well as the generation of primary quality control parameters (standard deviation, responsivity, noise-equivalent radiance).

1.1.2 Secondary Measurements

Secondary measurements from the AERI provide auxiliary information for real-time monitoring, quality control, and stand-alone data analysis. These measurements include:

- Ambient air temperature
- Ambient pressure
- Ambient humidity
- Instrument housekeeping data

These measurements are not rigorously calibrated. Data from ARM MET sensors should be used for scientific analysis, whenever available.

1.2 Instrument / Measurement Theory

The AERI is a Fourier transform interferometer (FTS). It is a Michelson interferometer design, with cube corners mounted on a voice-coil actuated wishbone structure. Broadband downwelling radiation enters the instrument aperture, it is split into two beams using a beamsplitter, then recombined, then an aft-optic system focuses the beam onto two broadband single pixel thermal detectors cooled to cryogenic temperatures. The path difference between the two beams in the interferometer is continuously varied, with a max optical path difference of 1 cm. The raw measurement is a time series of the light intensity recorded at the detectors, as a function of optical path difference over the course of one full interferometer scan from -1 to +1 cm; this is known as an interferogram (see Figure 3).

In order to sample the interferogram at evenly spaced intervals, a HeNe metrology laser is also sent through the interferometer. Since the laser is effectively monochromatic, the resulting interferogram will be effectively sinusoidal, and the periodic sinusoidal signal registered by the laser detector can be used to trigger sampling for the thermal detectors.

The signal from the detectors is sent through pre-amplifiers, then digitized using analog-to-digital converters.

The recorded, digitized and coadded interferogram (intensity as function of distance) is inverted using a Fourier transform, which results in a raw spectrum (intensity as function of 1/distance, or wavenumber) (see Figure 4).

The raw spectrum is converted into a calibrated spectrum using the calibration equation (Revercomb et al. 1988), which uses the two blackbody calibration targets with traceable temperatures and emissivity as a reference. A series of corrections are applied to take into account various instrument effects (Knuteson et al. 2004b), resulting in an absolutely calibrated spectrum (see Figure 5).

The instrument back-end optical system is uncooled and operates at ambient temperature, except for the thermal detectors, which are sensitive to all thermal radiation, including that of the instrument itself. In order to ensure that changes in the instrument temperature do not induce errors, radiometric calibration is performed at a high duty cycle, with views of the blackbodies every 3 minutes in standard rapid sample mode. As long as the ambient temperature for the instrument back-end changes slowly with respect to the (3-minute) calibration cycle, the instrument will be immune from such error.

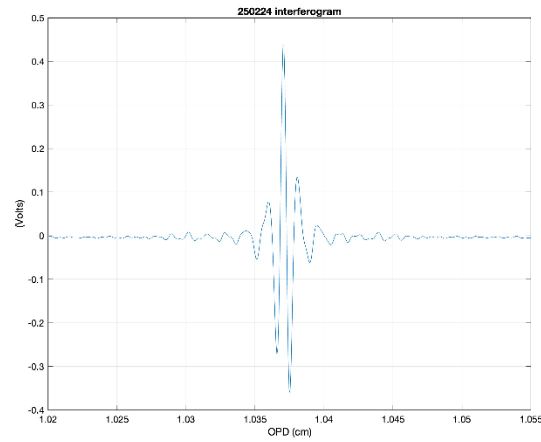

Figure 3. Interferogram centerburst measured by the AERI.

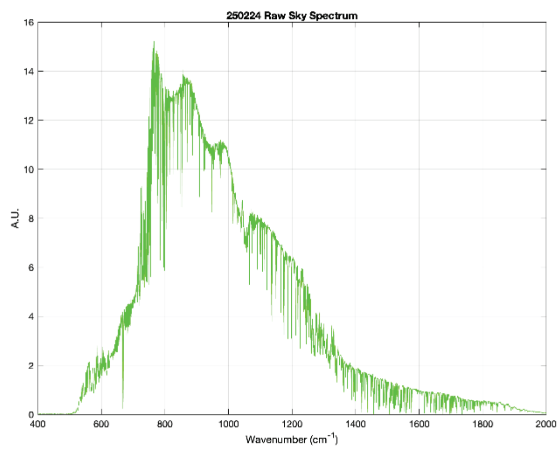

Figure 4. Raw spectrum measured by the AERI.

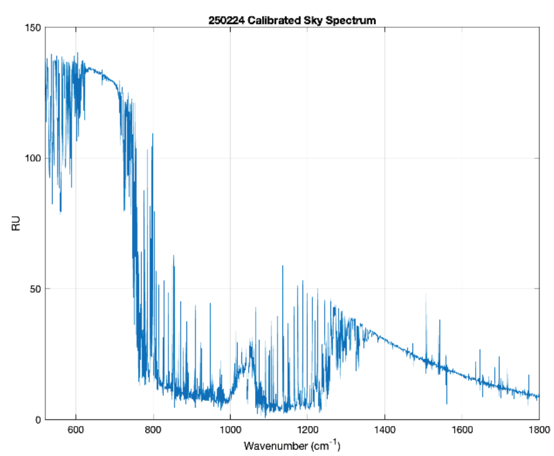

Figure 5. AERI calibrated sky spectrum, from the BNF M1 site.

2.0 Data

2.1 Data Description

The following primary AERI datafiles are archived:

- **ch1** & **ch2** files (e.g., *sgpaerich1C1.b1*) contain the observed zenith sky spectral radiances in the variable *mean_rad*, indexed by wavenumber *wnum*. Channel 1 has radiances between 520–1800 cm^{-1}; channel 2 has radiances between 1800–3020 cm^{-1}. Basic housekeeping parameters are also included. For the M-AERI instrument only, the variable *all_mean_rad* contains spectral radiances for all scenes, including limb and zenith views; this is indexed by the parameter *sceneMirrorAngle* indicating the elevation angle measured from nadir (e.g., horizon = 90°, zenith = 180°).
- **ch1nf1turn & ch2nf1turn** (e.g., sgpaerich1nf1turnC1.c1) contain the observed spectral radiances as above, but with uncorrelated random error filtered out.
- **engineer** files (e.g., *sgpaeriengineerC1.b1*) contain all housekeeping data, as well as basic radiance data averaged over certain microwindows corresponding to various vertical levels in the atmosphere (e.g., surface layer, elevated layer, atmospheric window).
- **summary** files (e.g., *sgpaerisummaryC1.b1*) contain housekeeping data, microwindow radiances, as well as derived quantities related to the instrument noise performance (e.g., responsivity, noise-equivalent radiance).

A thermodynamic profiling algorithm, **TROPoe** (formerly AERIoe), can be run on the AERI data to retrieve profiles of temperature and water vapor, as well as other atmospheric parameters. The TROPoe retrievals are available as a value-added product on the ARM Archive for various sites (e.g., *sgptropoeM1.c1*). Contact the mentor if the TROPoe retrievals are not available for a specific dataset of interest.

The AERIPROF retrieval was in use at the time the AERI instrument was first developed, however it has been discontinued. AERIPROF has been superseded by TROPoe.

2.2 Data Quality and Uncertainty

The main uncertainty parameters for AERI data are as follows:

- Radiometric calibration absolute accuracy: <1% of ambient blackbody radiance
- Repeatability: <0.2% of ambient blackbody radiance
- Noise (RMS responsivity for 2 min. blackbody view)
  - AERI: <0.2 RU for 670–1400 cm^{-1} †
  - <0.015 RU for 2000–2600 cm^{-1} †
  - ER-AERI: <0.4 RU for 420–1400 cm^{-1} †
  - <0.015 RU for 2000–2600 cm^{-1} †

† except 667 cm^{-1} and 2300–2400 cm^{-1}, where CO_2 in the instrument reduces responsivity

Quality control of AERI data is essential for reliable scientific analysis.

At the highest level, ARM Data Quality Reports (DQRs) indicate time periods longer than 24 hours where AERI data may be suspect, incorrect or missing.

Basic quality control can be performed by the user by considering the following parameters:

- Hatch Open – This parameter indicates the hatch position. Only when Hatch Open = 1 is valid atmospheric data collected.
- LW HBB NEN – This is the noise-equivalent radiance of the hot blackbody at 1000 cm^{-1}. This measures longwave detector noise. High values indicate degraded data.
- SW HBB NEN – This is the noise-equivalent radiance of the hot blackbody at 2500 cm^{-1}. This measures shortwave detector noise. High values indicate degraded data.
- LW Responsivity – This indicates the sensitivity of the longwave channel and detector. Low values indicate degraded data.
- SW Responsivity – This indicates the sensitivity of the shortwave channel and detector. Low values indicate degraded data.

A mentor data product, AERI QC, has been developed that algorithmically calculates data quality flags and checks for about 20 different quality control tests, including the above. AERI QC is available through the AERI ARMORY set of software tools. AERI QC uses raw AERI data, which must be obtained either directly from the instrument, or as a special request from the ARM Archive. Contact the mentor team for more information about AERI QC.

2.3 Examples of Data

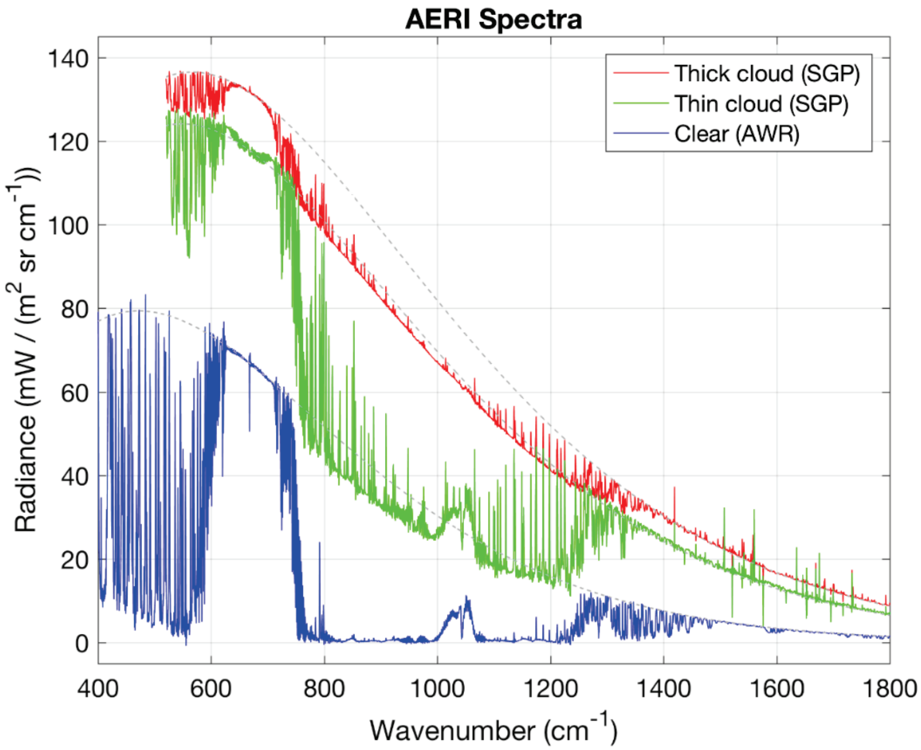

Figure 6. AERI channel 1 spectra for thick could (red), thin cloud (green), and clear sky (blue) conditions obtained at the SGP (standard range) and AWR (extended range) ARM sites.

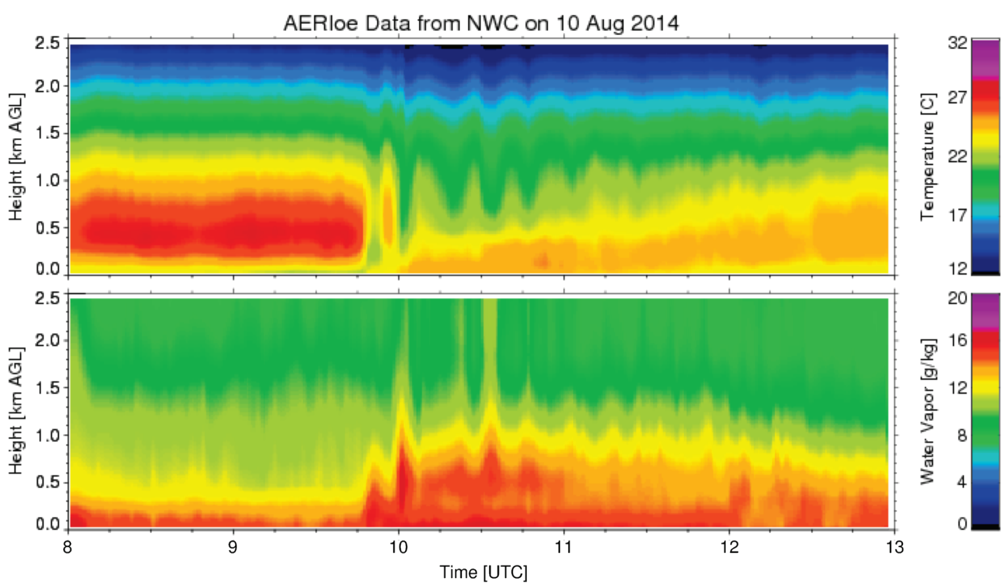

Figure 7. Time-height cross sections of temperature and water vapor concentration over the course of 5 hours showing a nocturnal boundary layer with an elevated bore at Norman, Oklahoma, retrieved from AERI data using the TROPoe algorithm.

3.0 Historical Background

The AERI was designed by the University of Wisconsin Space Science and Engineering Center (UW SSEC) for the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility in the 1990s. The AERI instrument played an essential role in the success of the ARM program by providing an accurate reference in tropical, mid-latitude continental, and arctic atmospheres for the validation of infrared radiative transfer models used in global circulation models. AERI instruments have since been deployed worldwide.

Long-term AERI data records are available at the DOE ARM fixed sites at the Southern Great Plains (SGP, 1995–present), the North Slope of Alaska (NSA, 1998–present), the Tropical Western Pacific (TWP, 1998–2014) and Eastern North Atlantic (ENA, 2016–present). The AERIs in the ARM Mobile Facilities (AMF) have been deployed for field campaigns throughout the world. The AMF-2 contains a Marine-AERI that is capable of shipboard deployment and can also measure sea surface emissivity and skin temperature.

The AERI technology has been licensed by the University of Wisconsin to the commercial company ABB Inc., who is currently responsible for the manufacture of the hardware and installation of the operating software. UW continues to provide calibration blackbodies, the software kernel, and oversees calibration and certification for all AERI instruments.

Three different versions of AERI instrument have been deployed at ARM sites.

- Version 1 (V1) was the original operational prototype AERI deployed at the SGP site. The instrument was built by the University of Wisconsin. Instrument unit number *01* operated between 1995–2014.
- Version 2 (V2) was the production model AERI built by the University of Wisconsin. It operated between 1997–2010, and also between 2015–2022 at the SGP site. Instrument unit numbers *00* through *08* (except *01*).
- Version 4 (V4) is the current commercially available model of AERI, available from the vendor ABB Inc. It has operated from 2010–present. Instrument unit numbers between *105* and *127*.

The radiometric uncertainties are uniform and constant across all versions of AERI. In general, AERI data can be used interchangeably independent of the instrument and instrument version. In practice, some properties (e.g., instrument noise) may vary as different instruments and instrument versions have been deployed at given sites. The instrument unit number is provided in the parameter *instrumentUnitNumber*, and can be used to identify instrument changes.

4.0 Maintenance Plan

AERI Knowledge Base

All mentor documentation about AERI maintenance and troubleshooting is provided online at the AERI Knowledge Base: https://www.ssec.wisc.edu/aeri/kb/

Daily Maintenance

- Physical inspection of the instrument
- Software inspection, confirming Ingest is operational, and housekeeping parameters in FTSW window are nominal
- Refer to AERI daily preventative maintenance procedure

Monthly Maintenance

- Replace outside air filter
- Replace desiccant as needed
- Inspect / clean / replace scene mirror as needed
- Clean rain sensors as needed

Yearly Maintenance

- Replace inside air HEPA filter
- Replace laser as needed. Typical lifetime ~2 years. Usually done by the mentor team.
- Replace Stirling cooler as needed. Typical lifetime ~5 years. This is done by the mentor team.

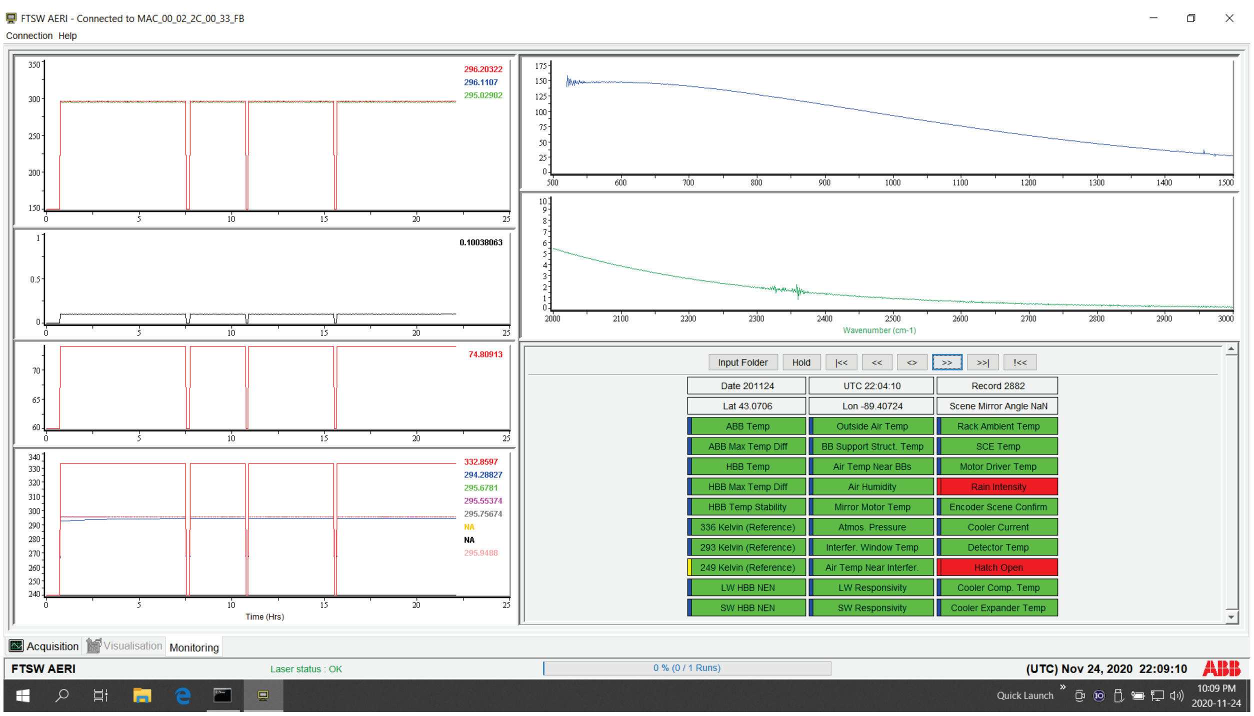

Figure 8. FTSW window, showing real-time housekeeping time series, ch1 & ch2 spectra, and housekeeping acceptable limits. The red boxes indicate that the rain sensor has been activated and the hatch is closed.

5.0 Calibration Plan

Operational Calibration

The AERI is configured to view the two calibration targets (ABB, HBB) once every 3 minutes in standard rapid sample mode. Older instruments, and the M-AERI may have a different calibration sequence.

Calibration Validation (3rd blackbody test)

A 3rd blackbody calibration validation is typically performed once a year at fixed sites, and at the start and end of all mobile deployments. It is also performed before and after any major instrument configuration change. The 3rd blackbody test confirms that the instrument calibration has not changed, and remains traceable to the original instrument certification, which itself is traceable to NIST standards. This test involves places a 3rd blackbody of known temperature in the instrument sky view to evaluate the overall instrument radiometric uncertainty.

Resistance Validation

The resistance validation evaluates the accuracy of blackbody temperature measurement, by testing the multimeter and full electronics measurement path at the blackbody connector point. This is done by measuring the resistance of a set of ultra-stable resistors. The resistance validation is typically done before and after a multimeter swap, or if the built-in Fixed Resistor values show a secular drift.

Multimeter Calibration

The multimeter (Agilent, Keysight, Keithley) should be re-calibrated by the vendor typically every 1–2 years, or if the Fixed Resistor values show a secular drift. In practice this is done by swapping out an old multimeter with a newly calibrated one, in order to minimize downtime. Resistance validation and calibration validation should be performed before and after a multimeter swap.

Blackbody Thermistor Calibration

Each blackbody should be re-calibrated at the University of Wisconsin blackbody calibration facility typically every 3–5 years to obtain new thermistor calibration coefficients and confirm that the old ones have not drifted. In practice this is done by swapping out an old pair of blackbodies with a new pair, in order to minimize downtime. Calibration validation should be performed before and after the blackbody swap.

6.0 User Notes and Known Issues

The instrument is subject to recurring single event upsets, in particular the Version 4 systems. Performing quality control, as outlined in section 2.2, is imperative for scientific analysis.

7.0 Frequently Asked Questions

AERI Knowledge Base

The AERI Knowledge Base contains a vast repository of information about various aspects of AERI installation, operation and software.

https://www.ssec.wisc.edu/aeri/kb/

AERI Laser

The AERI uses a 632.8 nm, 1 mW red HeNe metrology laser as part of the reference interferometer. The laser is used to trigger the detector sampling electronics. The AERI instrument is considered Class 1, with no laser radiation transmitted outside of the instrument under normal operating conditions.

Are AERI data taken at night?

Yes, the AERI instrument operates continuously 24 hours a day, observing thermal infrared radiance from the atmosphere both day and night.

Can AERI data be taken during precipitation?

No. The rain sensors trigger the hatch to close during precipitation events (rain, snow, etc.), in order to protect the instrument optics. The instrument continues to operate normally with the hatch closed, but the instrument “sky” views are actually looking at the inside of the closed hatch, which looks similar to ambient temperature blackbody spectrum. It is important to remove these data from datasets for scientific analysis using the Hatch Open flag (see section 2.2).

Are thermodynamic retrievals (temperature and water vapor profiles) available from the AERI?

Yes, thermodynamic retrievals are available from AERI data using the TROPoe algorithm. This is a value-added product that can be found in the ARM Archive for various sites (e.g., *sgptropoeM1.c1*). Processing is ongoing to run TROPoe for all historical AERI data. Contact the mentor if the TROPoe retrievals are not available for a specific dataset of interest.

8.0 Citable References

Primary Instrument Reference

Knuteson, R.O., H.E. Revercomb, F.A. Best, N.C. Ciganovich, R.G. Dedecker, T.P. Dirkx, S.C. Ellington, W.F. Feltz, R.K. Garcia, H.B. Howell, W.L. Smith, J.F. Short, and D.C. Tobin. 2004. “Atmospheric Emitted Radiance Interferometer. Part I: Instrument Design.” *Journal of Atmospheric and Oceanic Technology* 21:1763-1776.

Knuteson, R.O. , H.E. Revercomb, F.A. Best, N.C. Ciganovich, R.G. Dedecker, T.P. Dirkx, S.C. Ellington, W.F. Feltz, R.K. Garcia, H.B. Howell, W.L. Smith, J.F. Short, and D.C. Tobin. 2004. "Atmospheric Emitted Radiance Interferometer. Part II: Instrument Performance." *Journal of Atmospheric and Oceanic Technology* 21:1777-1789.

General

Revercomb, H.E., H. Buijs, H.B. Howell, D.D. LaPorte, W.L. Smith, and L.A. Sromovsky. 1988. "Radiometric Calibration of IR Fourier Transform Spectrometers: Solution to a Problem with the High-Resolution Interferometer Sounder." *Applied Optics* 27(15):3210-3218.

Brown, P.D. , S.A. Clough, N.E. Miller, T.R. Shippert, D.R. Turner, R.O. Knuteson, H.E. Revercomb, and W.L. Smith. 1995. "Initial Analyses of Surface Spectral Radiance Between Observations and Line-by-Line Calculations." Proceedings of the Fifth Atmospheric Radiation Measurement (ARM) Science Team Meeting. March 19-23, pp. 29-32.

M-AERI Instrument

Minnett, P.J., R.O. Knuteson, F.A. Best, B.J. Osborne, J.A. Hanafin, and O.B. Brown. 2001. "The Marine-Atmospheric Emitted Radiance Interferometer: A High-Accuracy, Seagoing Infrared Spectroradiometer." *Journal of Atmospheric and Oceanic Technology* 18:994-1013.

Thermodynamic Retrievals with TROPoe

Turner, D. D., and U. Löhnert. 2014. Information content and uncertainties in thermodynamic profiles and liquid cloud properties retrieved from the ground-based Atmospheric Emitted Radiance Interferometer (AERI). *Journal of Applied Meteorology and Climatology* 53, 752–771.

Turner, D. D. and W. G. Blumberg, 2018. Improvements to the AERIoe Thermodynamic Profile Retrieval Algorithm. *IEEE J-STARS*, 12, 1339–1354, https://doi.org/10.1109/JSTARS.2018.2874968

Turner D. D. and U Löhnert. 2021. Ground-based temperature and humidity profiling: combining active and passive remote sensors. *Atmospheric Measurement Techniques* 14, 3033–3048, https://doi.org/10.5194/amt-14-3033-2021

Long-term Trend Detection

Feldman, D. R., W. D. Collins, S. C. Biraud, M. D. Risser, D. D. Turner, P. J. Gero, J. Tadic, D. Helmig, S. Xie, E. J. Mlawer, T. J. Shippert, M. S. Torn .2018. Observationally derived rise in methane surface forcing mediated by water vapour trends, *Nature Geoscience* 11, 238–243.

Feldman, D. R., W. D. Collins, P. J. Gero, M. S. Torn, E. J. Mlawer, T. R. Shippert. 2015. Observational determination of surface radiative forcing by CO2from 2000 to 2010, *Nature* 519, 339–343.

Gero, P. J., D. D. Turner. 2011. "Long-Term Trends in Downwelling Spectral Infrared Radiance over the U.S. Southern Great Plains." *Journal of Climate* 24, 4831-4843, https://doi.org/10.1175/2011JCLI4210.1

Liu, L., Y. Huang, J. R. Gyakum, D. D. Turner, P. J. Gero. 2022. Trends in downwelling longwave radiance over the Southern Great Plains. Journal of Geophysical Research, 127, e2021JD035949, https://doi.org/10.1029/2021JD035949

Liu L., Y. Huang, J. R. Gyakum. 2025. Clouds reduce downwelling longwave radiation over land in a warming climate. *Nature* 637, 868–874, https://doi.org/10.1038/s41586-024-08323-x

Turner, D. D., P. J. Gero. 2011. "Downwelling 10 µm radiance temperature climatology for the Atmospheric Radiation Measurement Southern Great Plains site." *Journal of Geophysical Research* 116, D08212, https://doi.org/10.1029/2010JD015135

Atmospheric Profiling with AERIPROF

Feltz, W.F., H.B. Howell, R.O. Knuteson, H.M. Woolf, and H E. Revercomb. 2003. "Near Continuous Profiling of Temperature, Moisture, and Atmospheric Stability Using the Atmospheric Emitted Radiance Interferometer (AERI)." *Journal of Applied Meteorology* 42:584-597.

Feltz, W.F., and J.R. Mecikalski. 2002. "Monitoring High Temporal Resolution Convective Stability Indices Using the Ground-Based Atmospheric Emitted Radiance Interferometer (AERI) During the 3 May 1999 Oklahoma/Kansas Tornado Outbreak." *Weather Forecasting* 17:445-455.

Feltz, W.F., W.L. Smith, R.O. Knuteson, H.E. Revercomb, H.M. Woolf, and H.B. Howell. 1998. "Meteorological Applications of Temperature and Water Vapor Retrievals from the Ground-Based Atmospheric Emitted Radiance Interferometer (AERI)." *Journal of Applied Meteorology* 37:857-875.

He, Hui, W.W. McMillan, R.O. Knuteson, and W.F. Feltz. 2001. "Tropospheric Carbon Monoxide Column Density Retrieval During the Pre-Launch MOPITT Validation Exercise." *Atmospheric Environment* 35:509-514.

Smith, W.L, W.F. Feltz, R.O. Knuteson, H.E. Revercomb, H.B. Howell, and H.M. Woolf. 1999. "The Retrieval of Planetary Boundary Layer Structure Using Ground-Based Infrared Spectral Radiance Measurements." *Journal of Atmospheric and Oceanic Technology* 16:323-333.

Smith, W.L., H.E. Revercomb, H.B. Howell, H.M. Woolf, R.O. Knuteson, R.G. Dedecker, M.J. Lynch, E.R. Westwater, R.G. Strauch, K.P. Morton, B. Stankov, M.J. Falls, J. Jordan, M. Jacobsen, W.F. Daberdt, R. McBeth, G. Albright, C. Paneitz, G. Wright, P.T. May, and M.T. Decker. 1990. "GAPEX: A Ground-Based Atmospheric Profiling Experiment." *Bulletin of the American Meteorological Society* 71(3).

Turner, D.D., W.F. Feltz, and R.A. Ferrare. 2000. "Continuous Water Profiles from Operational Ground-Based Active and Passive Remote Sensors." *Bulletin of the American Meteorological Society* 81:1301-1317.

Cloud Retrieval

Collard, A.D., S.A. Ackerman, W.L. Smith, X. Ma, H.E. Revercomb, R.O. Knuteson, and S.-C. Lee. 1995. "Cirrus Cloud Properties Derived from High Spectral Resolution Infrared Spectrometry during FIRE II. Part III: Ground-Based HIS Results." *Journal of the Atmospheric Sciences* 52:4264-4275.

DeSlover, D.H., W.L. Smith, P.K. Piironen, and E.W. Eloranta. "A Methodology for Measuring Cirrus Cloud Visible-to-Infrared Spectral Optical Depth Ratios." *Journal of Atmospheric and Oceanic Technology* 16:251-262.

Turner, D. D. 2005. Arctic Mixed-Phase Cloud Properties from AERI Lidar Observations: Algorithm and Results from SHEBA. *Journal of Applied Meteorology and Climatology* 44, 427–444, https://doi.org/10.1175/JAM2208.1.

Turner, D.D., S.A. Ackerman, B.A. Baum, H.E. Revercomb, and P. Yang. 2003. "Cloud Phase Determination Using Ground-Based AERI Observations at SHEBA." *Journal of Applied Meteorology* 42:701-715.

IR Modeling

Tobin, D.C., and coauthors. "Downwelling Spectral Radiance Observations at the SHEBA Ice Station: Water Vapor Continuum Measurements from 17 to 26 um." *Journal of Geophysical Research* 104:2081-2092.

Turner, D. D., and Coauthors. 2004. The QME AERI LBLRTM: A Closure Experiment for Downwelling High Spectral Resolution Infrared Radiance. *Journal of Atmospheric Sciences* 61, 2657–2675, https://doi.org/10.1175/JAS3300.1.

Oceanic / Land Surface Remote Sensing

Kearns, E.J., J.A. Hanafin, R.H. Evans, P.J. Minnett, and O.B. Brown. 2000. "An Independent Assessment of Pathfinder AVHRR Sea Surface Temperature Accuracy Using the Marine Atmosphere Emitted Radiance Interferometer (MAERI)." *Bulletin of the American Meteorological Society* 81:1525-1536.

McKeown, W., F. Bretherton, H.L. Huang, W.L. Smith, and H.E. Revercomb. 1995. "Sounding the Skin of Water: Sensing Air-Water-Interface Temperature-Gradients with Interferometry." *Journal of Atmospheric and Oceanic Technology* 12:1313-1327.

Smith, W.L., R.O. Knuteson, H.E. Revercomb, W. Feltz, H.B. Howell, W.P. Menzel, N. Nalli, O. Brown, J. Brown, P. Minnett, and W. McKeown. 1996. "Observations of the Infrared Radiative Properties of the Ocean - Implications for the Measurement of Sea Surface Temperature via Satellite Remote Sensing." *Bulletin of the American Meteorological Society*.

9.0 Version History

Date Released/Version #	DOI	Changes
March 2025	10.5439/1253918	Handbook using the new format

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