Thermodynamic profiles from the SSEC Portable Atmospheric Research Center (SPARC) Atmospheric Emitted Radiance Interferometer (AERI) during the CHEESEHEAD campaign

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1. Introduction

The SSEC Portable Atmospheric Research Center (SPARC, Wagner et al. 2019) was deployed at the WLEF-TV tall tower site (45.94554, -90.27312) for the duration of CHEESEHEAD. Among the instruments deployed aboard SPARC is the Atmospheric Emitted Radiance Interferometer (Knuteson et al. 2004a, 2004b), from which high temporal resolution atmospheric profiles can be retrieved through a physical retrieval. Data have been processed into temperature and water vapor mixing ratio profiles with a temporal resolution of 5 min and are output onto a vertical grid with spacing that decreases approximately exponentially with height. The data cover the period from 2 July through 11 September 2019. On 12 September 2019, the SPARC AERI suffered a catastrophic failure possibly associated with an uncompensated power surge. No retrievals are available from that date onward through the conclusion of the experiment.

2. Instrument Description

AERI is a ground-based infrared spectroradiometer that passively measures downwelling spectra in the near and thermal infrared bands. The spectral resolution of the AERI spectra is better than one cm^{-1} while the temporal resolution is approximately 30 s. Spectral observations are taken continuously except during precipitation at which time an automated hatch closes to protect the instrument optics. Each spectral observation is calibrated against two onboard blackbodies, a hot blackbody at 333 K and an additional blackbody at the ambient temperature; these blackbodies have calibrations that are themselves traceable to NIST. As a result, the observed radiances are accurate to within 1% of the ambient radiance.

The AERI was physically located within the SPARC trailer with a hatch open to the sky. Radiance observations were taken on a 30 s cycle; in that time, the AERI scan mirror views each blackbody in addition to the sky view. In case of precipitation, the hatch automatically closes to protect the optics; as precipitation is a strong emitter of infrared radiation the data at those times would be of little use for atmospheric remote sensing purposes anyway.

3. Data Collection and Processing

Since the downwelling spectrum is a function of the atmospheric state, including the vertical structure of temperature and the distribution of water vapor, it is possible to invert that relationship and determine the structure of the atmosphere that produced the observed spectrum. The files included in this datastream have been processed with version 2.11 of the AERI Optimal Estimation (AERIoe, Turner and Löhnert 2014, Turner and Blumberg 2018) retrieval algorithm, a Gauss-Newton optimal estimation retrieval (Rogers 2000). The forward model used by the retrieval is LBLRTM (Clough et al. 2005) version 12.1.

Several datastreams are ingested by the retrieval in order to better characterize the environment. Surface temperature and moisture observations were obtained from the SPARC surface meteorology station; these sensors were located 1.5 m above the ground and approximately 5 m away from the AERI. Cloud base heights were obtained from SPARC's Doppler Lidar, which was in vertical stare mode throughout the experiment; backscatter values above 1.5 m^{-1} sr^{-1} were assumed to represent scattering from cloud droplets. Since the information content in the infrared spectrum decreases with increasing height away from the radiometer, profiles of temperature and water vapor from the Rapid Refresh (RAP, Benjamin et al. 2016) numerical weather prediction model are ingested by the retrieval to represent the atmospheric state above 4 km.

Optimal estimation retrievals require the use of an a priori climatology which helps ground the retrieval to physically possible states. The a priori for the thermodynamic retrievals was obtained by average several years of summertime thermodynamic profiles from the Chanhassen, MN (suburban Twin Cities) National Weather Service radiosonde. While the Green Bay, WI, radiosonde is closer to the WLEF tower site (230 km to Green Bay vs. 280 to Chanhassen), the Chanhassen site was assumed to be more representative of the conditions over the CHEESEHEAD domain due to Green Bay's proximity to Lake Michigan.

While the radiance data from the radiometer are available at 30 s resolution, these data can be considerably noisy. Therefore, the data are first passed through a principal component analysis noise filter, which reconstructs the radiance using a limited number of principal components to capture the signal. The filtered radiances are then averaged over 5 min intervals to further reduce noise. As a result, the retrieved profiles are available at 5 min temporal resolution. If one requires the data at a finer temporal resolution than that, contact Tim Wagner at tim.wagner@ssec.wisc.edu to request that a specific case be processed at a finer resolution.

4. Data Format

The retrievals are stored in netCDF files, with one file per day starting at 0000 UTC (7 PM CDT). The system automatically resets itself at 0000 UTC, so there is an expected gap

of ~5 min at the start of every retrieval file. Data are named according to the following convention:
wlef05aerioe1turnC1.c0.YYYYMMDD.hhmmss.cdf

where YYYYMMDD is the date of the file and hhmmss is the time of the first valid retrieval in that file.

The metadata included within every netCDF file contains a brief description of the data; however, here are some of the variables of greatest interest to CHEESEHEAD researchers. Many more can be found within the files themselves.

Time and height variables

base_time:	time at the start of the file, in UNIX epoch [s]
time_offset:	seconds since the start of the file [s]
hours:	time since 0000 UTC [hr]
height:	height above the instrument [km AGL]

Retrieved Variables

temperature:	retrieved ambient air temperature [^{o}C]
waterVapor:	retrieved water vapor mixing ratio [g kg^{-1}]
lwp:	cloud liquid water path [g m^{-2}]
lReff:	liquid droplet effective radius [µm]

Note: All of the retrieved variables also have a corresponding sigma_X variable (e. g. sigma_temperature) which records the one-sigma uncertainty in the retrieved variable. While trace gases do appear as retrieved variables in the netCDF file, their concentration in the retrieval was fixed in order to improve convergence of the thermodynamic profiles, under the assumption that better trace gas observations were available from instruments dedicated to that purpose.

Housekeeping Variables

hatchOpen:	flag indicating if the observation hatch was open (1) or closed (0)
cbh:	cloud base height from the Doppler lidar [km AGL]

Derived Variables

pressure:	pressure of the observations [hPa]
theta:	potential temperature [K]
thetae:	equivalent potential temperature [K]
rh:	relative humidity [%]
dewPoint:	dew point temperature [^{o}C]

Data Quality

qc_flag:	Data quality flag. Non-zero values imply issues with the retrieval, such as the hatch was closed (1), the retrieval did not converge (2), or the difference between the calculated and observed spectrum was too large (3). A flag of 0 implies that the data are acceptable.

5. Data Remarks

Due to the influence of the a priori and the RAP profiles, retrievals produce data up to 17 km. However, nearly all of the information content in the AERI spectrum is found at altitudes below 3 km. If the cloud base is below that height, the AERI only provides information up to cloud based. Data above those heights are less reliable since they are not coming from the AERI-observed radiances and may be as representative of the atmospheric state as those coming from lower altitudes.

6. References

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