Summary of ASTER Operations in the 1992 STORM–FEST Field Program

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1. Introduction

The NCAR ASTER (Atmosphere – Surface Turbulent Exchange Research) field facility was operated during the STORM–FEST (STORM – Fronts Experiment Systems Test) field program, February 1 to March 15, 1992, at a site 2 miles west of Sabetha, KS, in the northeast quadrant of the 50–km square boundary layer array. The principal purpose for deployment of the ASTER facility was to support the boundary layer measurement program by providing micrometeorological measurements of the turbulent fluxes of momentum, sensible heat, and water vapor. The principal investigators were Robert Grossman, University of Colorado, and Margaret LeMone, NCAR.

In addition to direct flux measurements, ASTER also provided near–surface profiles of wind, temperature, and humidity to a height of 10 m and radiation and soil measurements to complete the surface thermal energy budget. Ancillary measurements were made to intercompare the performance of three commercial sonic anemometers during winter conditions and to evaluate a solid–state capacitance humidity sensor being used for the first time on both ASTER and the PAM (Portable Automated Mesonet) surface meteorological stations during STORM–FEST.

Generic information about the ASTER field facility may be found in Businger, *et al.* (1990), Semmer and Martin (1991), or Semmer, *et al.* (1992).

2. Site

The measurement site was located 2 miles west of Sabetha, KS, in Section 3 of R. 14E, T. 2S in Nemaha County, at Longitude 95°50′35″ E, Latitude 39°54′25″ N, altitude 410 m. The topography in the immediate vicinity of the measurement site was gently rolling farmland with a maximum local relief of approximately 70′/mile from west to east and 40′/mile from north to south (see the USGS 7.5 min Sabetha, KS, quadrangle for more detail). The surrounding countryside consisted of plowed fields characterized by bare dirt furrows and short stubble, although the ASTER tower array itself was located along an east–west fenceline in the center of an 8.5 m wide strip of grass. The nearest structure was a two–story metal shed about 135 m west of the tower array, and the ASTER computer and laboratory trailers were parked on the north side of this building. The next closest structures were farm buildings located about 0.5 mile north of the array and the nearest trees were also at a distance of 0.5 mile.

3. Array

The main ASTER instrument array was mounted on six towers placed in a line from west to east along the fenceline between the northern and southern halves of Section 3, with the western–most tower about 155 m east of the western boundary of Section 3. The towers, from west to east, were a 10 m temperature/humidity profile tower, a 10 m wind profile tower, three 5 m sonic anemometer intercomparison towers, and a 10 m turbulent flux tower. The instrument booms on the temperature/humidity, wind, and flux towers pointed to the east and those on the sonic anemometer intercomparison towers pointed to the north. The radiation and soil heat flux sensors were located on the fallow cropland southwest of the temperature/humidity profile tower. The dimensions of the tower array are shown in the postscipt file ‘figure1.ps’.

The ASTER towers have a triangular cross–section 15 cm on a side. The ASTER Data Acquisition Modules (ADAMs) (marigold, cosmos and ragwort) have dimensions of 50 cm (high) x 85 cm x 85 cm and were located immediately north of the tower line as shown in figure1.ps. The ASTER power transformer was located west of the array and has dimensions of 85 cm (high) x 60 cm x 85 cm; the adjacent shelter has dimensions of 110 cm (high) x 75 cm x 95 cm. The radiation sensors were mounted on a horizontal beam at a nominal height of 2 m. There were three groups of soil sensors, each measuring soil temperature at 4 depths (1, 3, 5, 7 cm) and soil heat flux at 8 cm, which were placed at three locations corresponding to the bottom, side, and top of a furrow (denoted in the data archive as fur, int, rid).

4. Sensors

The sensors used by ASTER in STORM–FEST are shown schematically in figure2.ps and listed in Table 1. The variable names associated with the senors in figure2.ps are the mnemonics or data id's (did) used to identify the archived data variables, *e.g.* u.prop.4m and v.prop.4m. Each sensor in figure2.ps is associated with one or more system id's (sid) that are composed of an ADAM name and a channel number, *e.g.* cosmos 202. Channel numbers from 100–199 indicate an analog input channel that is usually associated with a single variable or did, and channel numbers from 200–299 indicate a serial input channel that is usually associated with a single sensor but may ingest multiple variables.

The propeller–vane wind components are in a geographic coordinate system, where u is a wind from the west and v is a wind from the south, while the sonic anemometer wind components are in an instrument–oriented coordinate system, where u is a wind along the instrument boom toward the tower and v is a wind from right to left as you face in the positive u direction. The sonic anemometer boom orientations are listed in Table 2 for conversion of the sonic wind components to geographic coordinates.

The sonic anemometers also measure the speed of sound, from which they calculate sonic (approximately virtual) temperature (tc) in °C. However the measurement of the speed of sound by the sonics is contaminated by the horizontal wind speed and only the ATI sonic temperature data is corrected (within the instrument) for this contamination.

The pyrgeometers also output dome and case temperatures in °K.

Table 1: STORM–FEST sensors and variables

Instrument	Manufacturer	Height m	Rate sec^{-1}	Variables	Units
Sonic anemometer	ATI	4, 10	10	(u,v,w).ati	m/s
	(K probe)			tc.ati	°C
PRT (fast T)	AIR	4, 10	20	t.ati	°C
UV hygrometer	CSI	4, 10	20	q_h2o.ati	gm/m^3
Sonic anemometer	ATI	4	10	(u,v,w).comp.ati	m/s
	(K probe)			tc.comp.ati	°C
Sonic anemometer	Gill	4	20	(u,v,w).comp.GILL	m/s
	(Symmetric)			tc.comp.GILL	°C
Sonic anemometer	Kaijo–Denki	4	20	(u,v,w).comp.KD	m/s
	(TR–61A)			tc.comp.KD	°C
Propeller–vane	NCAR/ RM Young	1,2,4, 7,10	1	(u,v).prop	m/s
Temperature/RH	NCAR/	1,1a,2,	1	tdry.psyc	°C
	Vaisala	4,7,10		rh.psyc	%RH
Dew Point	EG&G	1	1	(dp,t).egg	°C
Barometer	NCAR	2	1	(p1,p2,p3).baro	mb
Rain	ORG	–	1	(100,700).rain	mm/hr
Pyranometer	Eppley	2	1	psp.(in,out).rad	W/m^2
Pyrgeometer	Eppley	2	1	pyg.(in,out).rad	W/m^2
				pyg.().(dome,case)	°K
Net radiometer	Micromet	2	1	net.rad	W/m^2
Surface T	Everest	–	1	T.srfc	°C
Soil T	NCAR	1,3,5,7 cm	1	T.soil.(fur,int,rid)	°C
Heat flux plate	Micromet	8 cm	1	G(1,2,3).8cm	W/m^2

Table 2: Sonic anemometer boom orientations

Sonic anemometer	Orientation
ati.10m	91.0°
ati.4m	91.5°
comp.ati.4m	0.8°
comp.GILL.4m	2.0°
comp.KD.4m	359°

5. Operations

ASTER collected data continuously from February 1 to March 15, 1992. Detailed notes on daily ASTER field operations as well as notes on aspects of the data reduction that are unique to STORM–FEST are available in an electronic logbook at NCAR.

The major operational problem was caused by the sonic anemometers used for the turbulent flux measurements at 4 and 10 m. Two new Applied Technology (ATI) sonic anemometers were purchased for STORM–FEST, but did not arrive until February 8. Prior to that date, a similar sonic anemometer was borrowed from the manufacturer and mounted at 4 m on the flux tower. (After arrival of the new sonic anemometers, the borrowed sonic was moved to the intercomparison sub–array.) Because of a faulty connector in the new anemometers, their data were quite noisy during the experiment. The problem was reduced, but not eliminated, by the manufacturer around February 15. (ATI replaced the connectors following the field program.) The sonic anemometer data can be optionally filtered by software that compares each data point to a value predicted from the preceding data, notes those whose difference from the forecasted value exceeds a specified limit, and replaces them with the forecasted value. The replacement is noted by setting a flag variable (*e.g.* uflag.ati.10m) to 1. This data quality software has been used during the processing of the data for the STORM–FEST CDROM.

For various reasons, two of the intercomparison sonic anemometers were available for only a portion of the total operational period. The Gill or Solent sonic anemometer (loaned by the manufacturer) was operated for the entire period. The ATI intercomparison sonic (loaned by the manufacturer) was operated only after February 22 and the Kaijo–Denki (loaned by Prof. Shashi Verma of the University of Nebraska) was operated from February 4 to March 11.

In order to evaluate a new solid–state capacitance humidity sensor used on both ASTER and on the PAM (Portable Automated Mesonet) surface meteorological stations during STORM–FEST, humidity measurement intercomparisons were made at the 1 m level on the temperature/humidity tower. These involved, at various times, an EG&G

dewpoint sensor, a temperature/humidity sensor identical to those used at the other ASTER tower levels and on the PAM stations, and temperature/humidity sensors used as traveling intercomparison 'standards' during service visits to the PAM stations. The latter two types of sensor were recorded as (tdry,rh).psyc.1am.

6. Data

Daily plots have been made of a variety of parameters to provide an overview of the meteorological conditions for that day and to aid in the selection of time periods for detailed analysis. These are available on the CDROM as postscript files with the names 'aster_wx.jjj.ps', where jjj is the Julian day. Each figure consists of four panels that contain (a) temperature (4 m), humidity (4 m), pressure (2 m), and rainfall; (b) wind speed and direction (10 m); (c) net radiation, sensible heat flux, latent heat flux, and the surface soil heat flux; and (d) z/L (10 m) and u_*. The plotted data are 5 minute averages, with the exception of turbulent flux data (sensible and latent heat fluxes, z/L, and u_*) which are 20 minute averages calculated from the ATI 4 m flux data. The Monin–Obukhov stability parameter z/L has been evaluated with z set to 10 m; a line for neutral conditions ($z/L = 0$) is shown for reference.

The horizontal line at 90° on the wind direction plot denotes the east–west orientation of the line of towers. Recall that the instrument booms on the temperature/humidity, wind, and flux towers pointed to the east and those on the sonic anemometer intercomparison towers pointed to the north. Wind and flux data collected with anemometers downwind of a tower should be used with caution. Thus the flux data is suspect for winds from the west, a direction already contaminated by the nearby metal shed and the ASTER trailers.

Soil samples were collected daily or every other day, and soil moisture was measured by a gravimetric technique. These data are available in the electronic logbook and are plotted in figure3.ps, along with the rainfall rates and albedo. The percent soil moisture is defined as the difference in weight of the soil sample before and after drying, divided by the dry soil weight and multiplied by 100.

Means, variances, and covariances of the full time series data have been produced at five minute resolution and stored in Network Common Data Form (NetCDF) files. These NetCDF files contain the data in binary form, as well as supporting information about the data variables. These files are named 'stormfest.jjj.cdf', where jjj is the three digit Julian day, numbered from one on January 1; *e.g.* stormfest.033.cdf contains data for February 2, 1992.

Time (GMT) is represented in seconds since the beginning of the day. The start of day is stored in a 'base_time' variable as the number of seconds since Jan 1, 1970 00:00 GMT.

Each variable in the NetCDF file corresponds to a 5 minute statistic of the time series data. Associated with each variable is a NetCDF attribute indicating the ASTER dids, as shown in figure2.ps, which were the source of the value. The variable names correspond closely to the ASTER dids but, due to syntax restrictions, are not identical. Also associated with each NetCDF variable are a units field and the name of the NetCDF variable that contains the number of samples incorporated into the statistic.

The ZEB display software available on the STORM–FEST CDROM provides a menu driven, interactive graphical display of the ASTER NetCDF files.

NetCDF files are not ASCII character files, and therefore special software is needed to access these files. NetCDF software is licensed by the University Corporation for Atmospheric Research and is available free to the university community. Call the UCAR Finance and Administration Office, (303) 397-8571, to get a copy of the license agreement. The software is available via anonymous FTP from unidata.ucar.edu.

The unaveraged time series data for each did are stored at NCAR. Contact Tom Horst or Gordon Maclean (Internet: horst@ncar.ucar.edu, maclean@ncar.ucar.edu) to request access to the full time series data or for more information about the five–minute–averaged data provided on the CDROM.

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